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A BIOLOGICAL SURVEY AND FISHERY MANAGEMENT PLAN FOR THE STREAMS OF THE LAKE SUPERIOR NORTH SHORE WATERSHED

LLOYD L. SMITH, JR.
and
JOHN B. MOYLE

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A CONTRIBUTION FROM THE
MINNESOTA FISHERIES RESEARCH LABORATORY

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1944

STATE OF MINNESOTA

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A BIOLOGICAL SURVEY AND FISHERY MANAGEMENT PLAN FOR THE STREAMS OF THE LAKE SUPERIOR NORTH SHORE WATERSHED

INTRODUCTION

The streams of the North Shore of Lake Superior comprise a natural fish management unit of 2,400 square miles. Increased stream use, change of natural conditions on the watershed, and poor fishing returns have made the need for a complete and thorough fisheries management program apparent.

Until 1900 the area was largely covered with a mixed stand of hardwoods and conifers in which white pine, red pine, jack pine, birch, and poplar were most conspicuous. Heavy utilization of forest trees and the fires which followed lumbering denuded large areas and contributed to the deterioration of the trout streams. The burning out of headwater bogs, with consequent loss of cool water sources, made streams more intermittent in their flow and the water temperatures less favorable to trout. Increased floods scoured the bottom and accelerated erosion. Although there has been some rehabilitation of the watershed in recent years, many changes have occurred in the streams which can be corrected only by artificial means.

Increased use of the area by tourists and fishermen during the past 20 years has been an important factor in the creation of present problems. Whereas in the early days the few anglers were able to report their catch in boatloads, the present army of fishermen must work hard to fill their creels. Greater accessibility through road development and use of the automobile is largely responsible for the added load. The old Highway No. 1, going from Duluth to Little Marais and later to Grand Marais and Pigeon River, was open to automobile transportation as far as Little Marais in 1915 and shortly thereafter to the Canadian border. This highway, although poor and not serving large areas of the trout stream basins, permitted many fishermen to get at the streams. In 1923 the present Highway No. 61 was improved to Little Marais. Later, the improved section was extended beyond Grand Marais. From 1933 to 1940 extensive road and trail developments were made throughout the area by the U. S.

Table 1. Annual average 24-hour traffic on Highway No. 61, from 1925 to 1941[1]

LOCATION OF COUNT	ANNUAL AVERAGE 24-HOUR TRAFFIC						
	1925	1928	1931	1934	1937	1940	1941
Clifton (French River)	556	1,117	1,206	1,083	1,457	1,677	1,618
3 miles N.E. of Two Harbors	...	609	672	607	796	869	872
N. E. of Ilgen City	...	...	...	272	328	407	344
At Tofte	233	531	328	...	...	...	...
At Pigeon River Bridge	87	206	299	136	...	...	...

[1]The total traffic for any of the years at the points listed above may be estimated by multiplying the annual average 24-hour traffic figure given above by 365. The traffic on this section of Highway No. 61 along the north shore of Lake Superior is predominately passenger car, particularly northerly of Two Harbors. (Data supplied by Minnesota Department of Highways.)

Forest Service, Emergency Conservation Works, and other conservation agencies. Although no information is available on the increased use of streams resulting from the road development, traffic counts on Highway No. 61 from 1925 to 1941 show a large increase in the number of people entering the area during this period (Table 1). The majority of people using these road systems do so largely for recreational purposes so it may be assumed that increased traffic would be roughly correlated with increased fishing load.

Successful fisheries management must be based on sound biological principles, complete habitat information, and economically feasible procedure. Most successful results will be obtained when large, naturally delimited areas, such as complete watersheds, are handled as units and individual waters are considered only as component parts. In recognition of this fact the Minnesota Department of Conservation authorized the Bureau of Fisheries Research to gather the required field data and prepare the fisheries program which is contained herein. The first field party started work on the project in the summer of 1940 and the final observations on the study were made during the summer of 1942.

Previous Investigations

Except for brief references in early geological papers, no extensive consideration was given to any North Shore stream until the "Water Resources Investigation of Minnesota" compiled by the State Drainage Commission (1911-1912) was published. This comprehensive report, which covered the whole state, examined the North Shore streams only from the standpoint of water power resources. Because many streams were too small for consideration and many of those covered were too intermittent to warrant careful analysis, the report gives little information of value for fisheries management.

Shortly after Dr. Thaddeus Surber took over the direction of Minnesota fish propagation in the early 1920's, it was found necessary to make a reconnaissance of North Shore streams to provide a basis for more efficient stocking. Surber (1922) and Surber (1924) presented an extensive report which covered the principal streams from the Knife to the Devil Track River. Until the present investigation was completed these data were used as a guide by the state propagation units. While the conditions reported by Dr. Surber have changed considerably on many streams, this early work is particularly valuable at the present time for the evaluation of current trends.

During 1932 a series of reports on potential water power developments was prepared by the U. S. Army Engineers Corps for presentation to the Seventy-second and Seventy-third Congresses (U. S. War Dept., 1932-1933). These papers provide an accurate analysis of the lower parts of the watersheds, the stream channels, and flow data for the principal rivers. They are based partly on original observations and partly on data prepared by other agencies.

During the developmental work carried on by the Civilian Conservation Corps, U. S. Forest Service, and other federal agencies, a certain amount of stream investigational work was done. These efforts consisted mostly of physiographic surveys and temperature data with little critical biological information. None of the data collected has been published or summarized except as it is included in the present report.

Of the surveys and investigations made over the North Shore area only the Surber report is of any considerable value in the preparation of management plans and, as has been pointed out, this report is now inadequate.

The Organization of the Stream Survey and the Methods Employed

The survey crews which worked on this project consisted of four biologists working under a party leader.[1] They examined the streams, using automobile transportation where possible, but in all cases walking the length of the channel. No permanent field headquarters were established and all work was directed from the Bureau of Fisheries Research Laboratory in St. Paul. In 1940 the streams from Duluth to Little Marais were worked and in 1941 the remainder of the shore was covered. During 1942 one crew which was working principally on the St. Louis system made a series of checks to pick up data previously omitted.

[1]Stream survey personnel: 1940 — John B. Moyle, party leader; Walter A. Kenyon, Hugo Saari, Harvey Gunderson. 1941 — Walter A. Kenyon, party leader; E. J. Karolyi, Hugo Saari, L. L. Bissinger. 1942 — Walter A. Kenyon, party leader; Ralph O. Cooper, Arthur J. Cronquist, Ray C. Anderson.

Stream survey methods were adapted from those recommended by Davis (1938). Alterations were made to adjust them to local conditions and to facilitate the compilation of data in the laboratory. Field determinations of dissolved oxygen, pH, total alkalinity, and carbon dioxide were made at the field stations but detailed mineral analyses were run in the laboratory. Similarly, analyses of bottom fauna, plankton, and aquatic plants were made in the laboratory. Field crews gave special attention to factors concerned with stream improvement. The tentative recommendations for management made by the fieldmen were checked in the laboratory after completion of all analyses. Specific laboratory procedures are described in the sections dealing with chemistry, bottom fauna, plankton, plants, and fishes.

THE NORTH SHORE WATERSHED

The North Shore watershed of Lake Superior lies in portions of St. Louis, Lake, and Cook counties (Fig. 1). It covers approximately 2,400 square miles (Table 2) and extends 15 to 25 miles back from the lake shore. Twenty-eight major streams and a number of small or intermittent creeks discharging directly into the lake drain this narrow area. The watershed is rugged with numerous large rock outcrops and deep valleys. It slopes so rapidly toward the lake that some of the streams descend 1,300 feet from their sources to the level of discharge. The majority of the streams have precipitous falls and rugged cataracts in their lower courses.

Because the terrain is steep and water retention on the watersheds is poor, the streams are very erratic in their flow (Table 2). There are few large springs and the water is derived mostly from lakes and swamp drainage. Before large fires destroyed the forests and the muskegs, there was a more continuous source of cool water than now exists. At the present time the majority of the streams are dependent upon a more or less regular precipitation throughout the season. The mean annual precipitation, averaged for Two Harbors, Grand Marais, and Duluth, is 26.3 inches, somewhat less than that recorded for South Shore stations particularly east of the Keweenaw Peninsula.[2]

[2]U. S. Weather Bureau Climatological Reports.

Table 2. Watersheds, stream mileage, and altitudes of individual streams in North Shore watershed

	Area drainage basin—Sq. mi.	Total length stream channel—Mi.	Approx. altitude of source[2]	Av. Flow[1] C.F.S.	Max. Flow C.F.S.	Min. C.F.S.
McCarthy Creek	20					
Lester River	58	43.40	1400			
Talmadge Creek	19	6.25				
French River	31	18.65	1400			
Sucker River	37	33.40	1500			
Knife River	90	94.15	1600			
Stewart River	33	34.50	1600			
Silver Creek	20	16.50	1300			
Encampment River	18	17.50	1400			
Gooseberry River	97	86.70	1700	60	1,273	2.00
Split Rock River	40	44.40	1700			
Beaver River	135	143.60	1700	110	2,120	2.00
Baptism River	132	125.75	1850	121	1,600	4.00
Manitou River	103	82.60	1800	65	498	4.00
Caribou River	23	40.13	1500-2000			
Two Island River	22	21.30	1500-2000			
Cross River	91	54.90	1500-2000			
Temperance River	180	98.55	1850	150	2,500	6.00
Onion	23	13.91	1500			
Poplar	151	65.8	1800	93	1,250	11.00
Spruce Creek	15	6.63				
Cascade	93	78.55	1900	82	583	2.00
Devil Track	85	51.15	1920	66	505	2.00
Durfee Creek	10	4.00				
Kimball Creek	24	12.45	1500			
Kadunce Creek	18	10.00	1500			
Arrowhead (Brule)	290	120.80	1850	248	2,600	11.00
Flute Reed	15	20.40	1000-1500			
Reservation	20	16.10	1700			
Hollow Rock Creek	15	10.76				
Portage	11	5.00				
Pigeon River (System)	235 (610)	44.96		443	7,050	30.00
Duluth Area	70					
Minor Drainage	192	7.48				
Total	2,416	1,430.27				

[1]Average, maximum, and minimum flow is taken from War Department records.
[2]Feet above sea level.

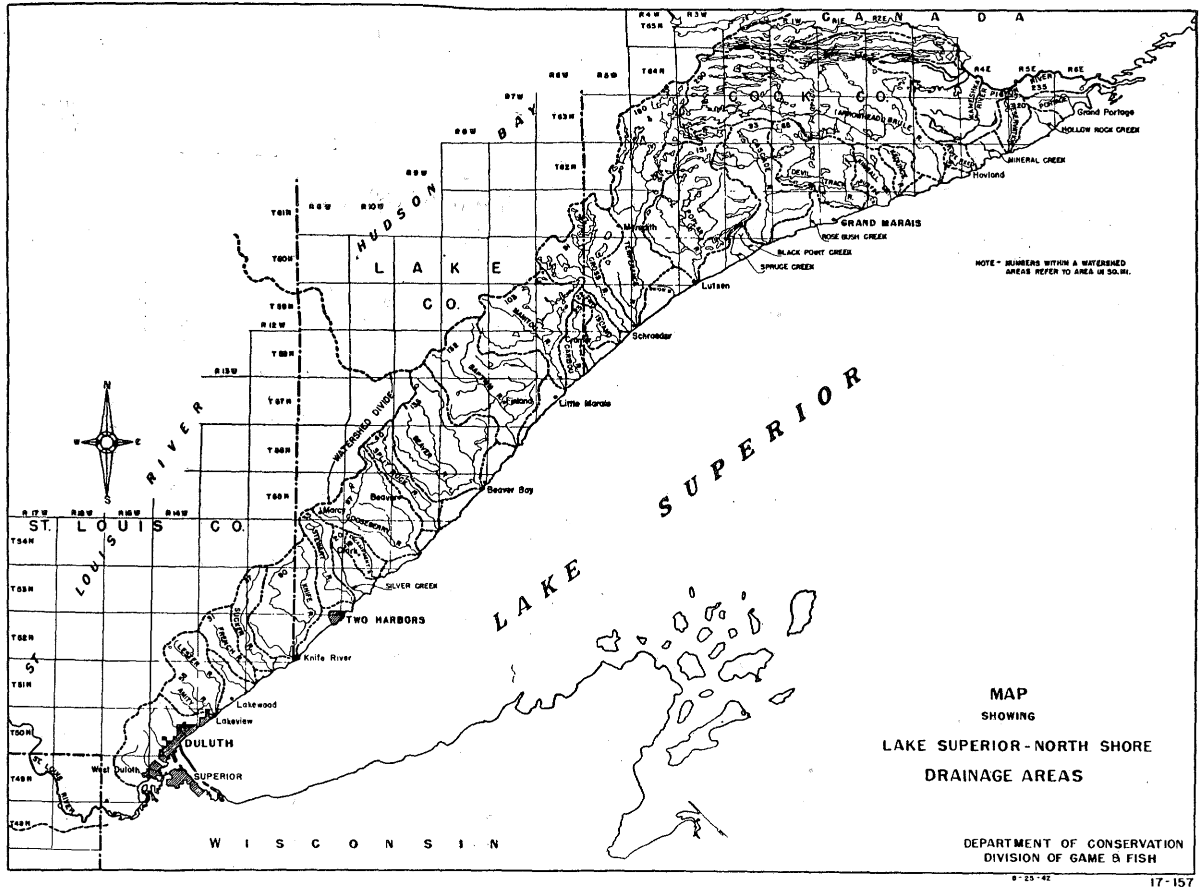

CANADA
COOK CO.
LAKE CO.
ST. LOUIS CO.
WISCONSIN
LAKE SUPERIOR
HUDSON BAY
WATERSHED DIVIDE
ST. LOUIS RIVER
GRAND MARAIS
Grand Portage
HOLLOW ROCK CREEK
MINERAL CREEK
Hovland
ROSE BUSH CREEK
BLACK POINT CREEK
SPRUCE CREEK
Lutsen
Schroeder
Little Marais
Finland
Beaver Bay
SILVER CREEK
TWO HARBORS
Knife River
Lakewood
Lakeview
DULUTH
West Duluth
SUPERIOR
NOTE - NUMBERS WITHIN A WATERSHED AREAS REFER TO AREA IN SQ. MI.
MAP
SHOWING
LAKE SUPERIOR - NORTH SHORE
DRAINAGE AREAS
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
17-157

Figure 1

The mean annual temperature of the region is 38° to 40° F. and the growing season varies from 100 to 150 days with the last killing frost usually occurring between May 5 and May 30. This late occurrence of low temperatures has a marked effect on the spawning and abundance of certain introduced warm-water fishes and in some cases is probably a definite limiting factor. Low mean summer temperature (July, 62.6° F.) and the short growing season also limit the total productivity of the fishing waters.

The soils of the region are poor and the waters in the streams which drain them are of moderate fertility. This factor, together with the numerous floods, precipitous channels, and extreme fluctuation in waterflow (Table 2), reduces the fish-carrying capacity of the streams to a marked extent. Erratic flow characteristics have prevented extensive commercial use of any of the streams except for transportation of timber.

The Geology and Topography of the Minnesota North Shore as Related to Fisheries Management

A successful fisheries management program for the streams of the North Shore of Lake Superior must take into account the geology and topography of the area. These streams flow over crystalline and metamorphic rocks that are the roots of ancient Proterozoic mountains. On these rock formations are deposited glacial and lacustrine soils of late Pleistocene age. The ancient rock formations and the younger deposits associated with the last great continental ice sheet combine to give portions of the North Shore a semi-mountainous topography. As a result, the streams that drain this area have many of the characteristics of rivers of younger and less eroded mountainous regions.

Pre-Pleistocene Geology

Minnesota's North Shore lies along the southern edge of the great expanse of crystalline and metamorphic rocks known as the Canadian Shield (Fig. 2). These rocks, either exposed or mantled with Pleistocene glacial and lacustrine deposits, underlie all of the North Shore streams. They are of late Proterozoic age, perhaps a billion years old (Schuchert and Dunbar, 1933), and fall into two major groups: the Animikie, represented by the

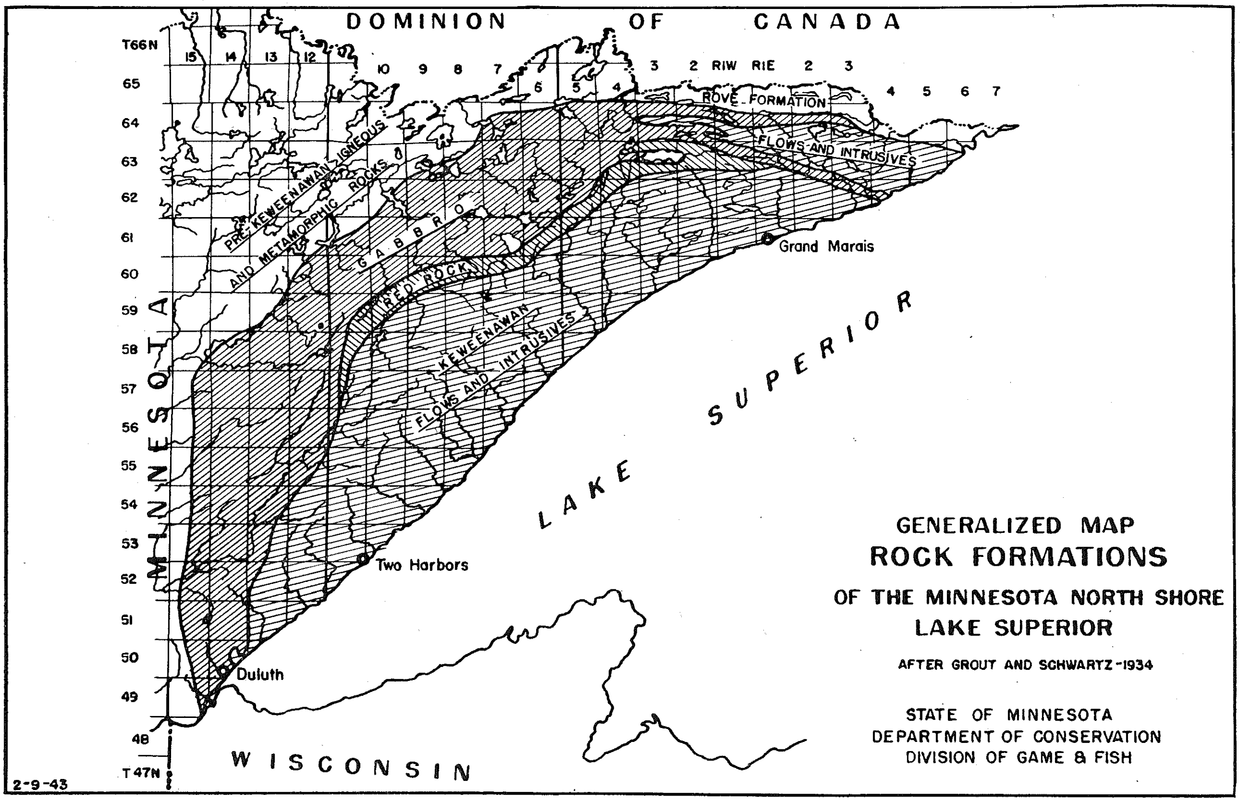

DOMINION OF CANADA
GENERALIZED MAP
ROCK FORMATIONS
OF THE MINNESOTA NORTH SHORE
LAKE SUPERIOR
AFTER GROUT AND SCHWARTZ-1934
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
PRE-KEWEENAWAN IGNEOUS AND METAMORPHIC ROCKS
GABBRO
RED ROCK
KEWEENAWAN FLOWS AND INTRUSIVES
ROVE FORMATION
FLOWS AND INTRUSIVES
LAKE SUPERIOR
MINNESOTA
WISCONSIN
Grand Marais
Two Harbors
Duluth
T66N
T47N
R1W R1E
2-9-43

Figure 2

Rove Formation of the Pigeon River valley, and the younger Middle Keweenawan igneous series on the remainder of the shore.[3]

The Rove Formation of the Pigeon River valley consists of graywacke and slates. These metamorphic rocks have been extensively intruded with harder diabase sills and dikes that run in a general east-west direction. The subsequent erosion of the softer graywacke and slates lying between the intrusive dikes and sills has formed valleys in which the lakes of this area lie (Grout and Schwartz, 1933). The streams likewise tend to follow this same erosion pattern.

The Middle Keweenawan igneous series, which underlies the rest of the shore, has been divided by Grout and Schwartz (1939) as follows:

- Beaver Bay complex
  - Beaver Bay and other diabases
  - Red granite facies
  - Anorthrosites, etc.
- Keweenaw Point volcanics
  - Basalt and felsite lava flows
  - Local tuffs and sediments

Basalt flows are extensively exposed near the mouths of many North Shore streams as dark colored, fine grained trap rock. The individual superimposed lava flows vary in thickness from a few inches to several feet and dip or slope gently toward Lake Superior. Concerning their origin, Schwartz (1925) states, "It is believed that they issued from fissures and spread out over the surrounding country like those of Iceland in historic time." Many gas bubbles trapped in the rock while it was still molten cause some of the flows to be softer and more vesicular than others. Stream erosion of these softer beds with the undercutting of the harder overlying flows has formed most of the falls and gorges. Less common but similar in texture to the basalt flows are those of reddish felsite.

The coarser grained igneous rocks are more in evidence back from the shore. These rocks, of which diabase and gabbro are the most common, are thought to have arisen from the same subsurface mass of molten rock or magma as the flows. Because they cooled more slowly, their component minerals crystallized to a

[3]Puckwunge conglomerate and sandstone of the Lower Keweenawan series also occur on the North Shore but are of very limited distribution.

greater degree giving the rocks a coarser texture. Gabbro, which is prominently exposed as black rock hills in the vicinity of Duluth and which forms the backbone of the highlands north of Lake Superior, is the most coarsely grained of these rocks. Diabase, a dark colored rock intermediate in texture between gabbro and the basalt flows, occurs commonly along the shore and is especially evident in the vicinity of Beaver Bay. A narrow band of red granite and related rocks (red rock) lies between the area of basalt and diabase along the shore and the extensive gabbro area of the Lake Superior highlands. The headwaters of a few of the longer streams extend into this red rock area. Outcrops of light colored anorthrosite, a rock chemically similar to gabbro, are scattered along the central portion of the shore (Grout and Schwartz, 1939). Carlton Peak is the best known of the anorthrosite knobs.

Because the underlying rock beds dip gently toward Lake Superior, the outcropping edges form rock ridges paralleling the shore. These monoclinal ridges (Van Hise and Leith, 1911) deflect the lower courses of some of the rivers and cause them to flow sluggishly at right angles to the general drainage pattern. This phenomenon is well illustrated by the Baptism, Split Rock, and Beaver rivers.

The Proterozoic rocks of the North Shore are very poor in soluble salts and permit almost no storage of water that may later be released as springs or seepage. As a result, the streams have a comparatively low dissolved mineral content and an irregular flow. In areas where bedrock is exposed on the stream bottoms there is no economically feasible type of stream improvement. These rock bottoms are poor in fish food and in many places warm the water that flows over them. Many of the falls of the lower stream stretches form impassable barriers to fish migration and preclude spawning runs of trout from Lake Superior.

Pleistocene Geology

The glacial soil lying upon the ancient Proterozoic rocks was deposited by the Lake Superior lobe of the fourth Wisconsin ice sheet (Leverett and Sardeson, 1932). Judging from the estimated age of related glacial phenomena, the ice of this last great continental glacier was probably still present in the Lake Superior basin 10,000 years ago. The Lake Superior lobe of the fourth

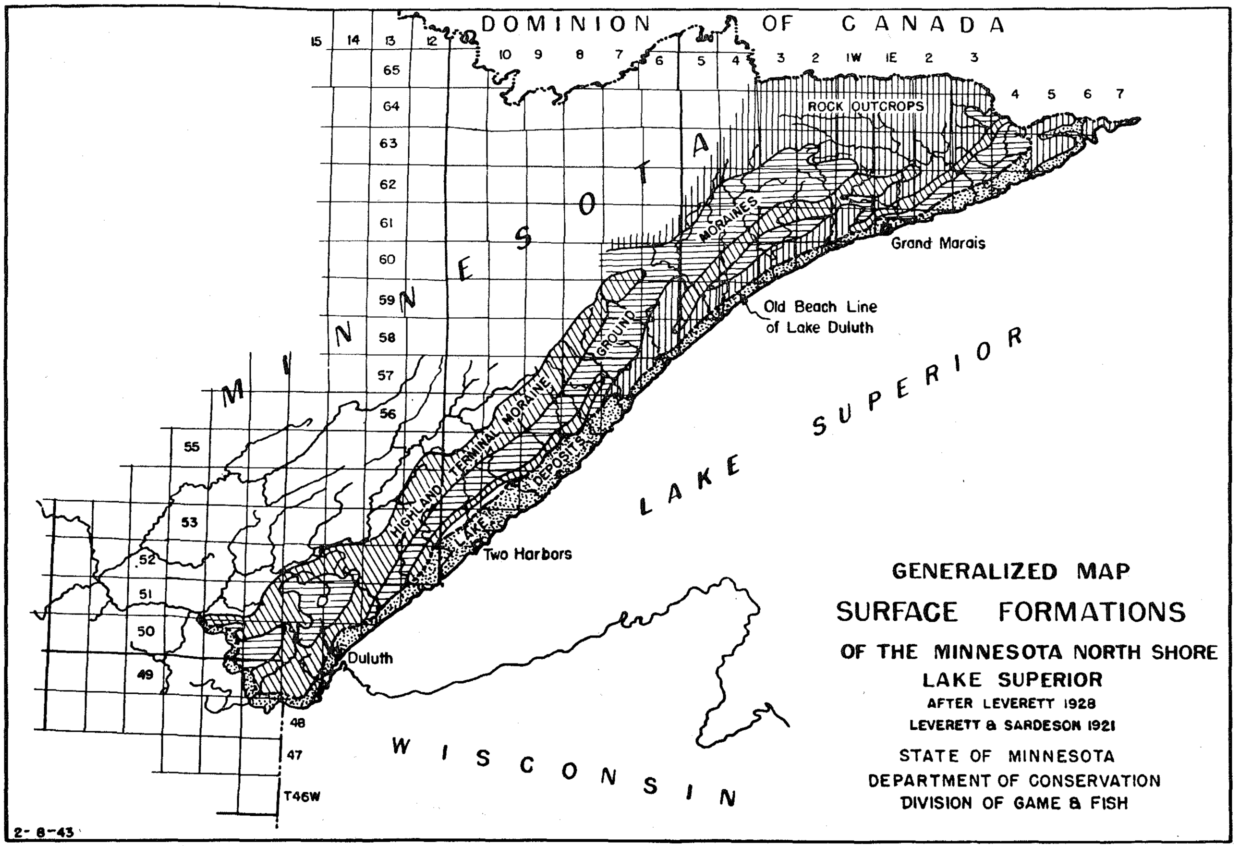

DOMINION OF CANADA
MINNESOTA
LAKE SUPERIOR
WISCONSIN
ROCK OUTCROPS
MORAINES
GROUND MORAINE
HIGHLAND TERMINAL MORAINE
LAKE DEPOSITS
Grand Marais
Old Beach Line of Lake Duluth
Two Harbors
Duluth
GENERALIZED MAP
SURFACE FORMATIONS
OF THE MINNESOTA NORTH SHORE
LAKE SUPERIOR
AFTER LEVERETT 1928
LEVERETT & SARDESON 1921
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
2-8-43
15 14 13 12 10 9 8 7 6 5 4 3 2 IW IE 2 3 4 5 6 7
65 64 63 62 61 60 59 58 57 56 55 53 52 51 50 49 48 47 T46W

Figure 3

Wisconsin ice sheet, which had its centers in the highlands of central and eastern Canada, entered the basin of Lake Superior from the northeast. After filling the Lake Superior basin the ice front advanced a few miles inland over the rocky rim of the Minnesota North Shore. Forward movement was halted by the elevation of the rocky highlands north of Lake Superior and as the climate warmed the ice began to melt. The melt water from the ice front flowed down the present Cloquet River valley, eventually finding its way into the glacial St. Croix River. Rocky glacial debris that had been incorporated in the ice mass during its forward movement was deposited as a system of stony ridges or terminal moraines paralleling the shore.

The most massive of these, the Highland moraine, was deposited along the southern portion of the shore where the rocky hinterlands are lower (Fig. 3). Leverett (1928) describes this moraine as follows:

> "From the east side of Duluth northeastward for more than 60 miles is a single massive morainic system of 4 to 6 miles in general width but in places reaching 7 to 8 miles * * *. In the vicinity of Duluth its highest points are about 1,500 feet above sea level * * * and it covers the slope toward Lake Superior to a level below 1,200 feet."

Leverett and Sardeson (1917) found that this morainic system had an elevation of about 1,700 feet near the Lake County line.

Ground moraine separates the massive Highland moraine from a similarly orientated glacial ridge that lies closer to the shore and which probably marks a later forward movement of the ice front. This narrower moraine extends from near Knife River to the vicinity of Finland and has a general elevation of about 1,200 feet. At most places it is between 1 and 3 miles wide. From the vicinity of Cramer northeastward, a narrow terminal moraine with an elevation of more than 1,500 feet extends to Brule Lake. A similar narrow moraine begins near the shore at Grand Marais and continues northeastward until it crosses the Pigeon River about 18 miles west of Grand Portage (Leverett, 1928).

The matrix of the morainic ridges is sandy while that of the more level deposits of ground moraine is largely clay (Leverett and Sardeson, 1917). Boulders of igneous rock are common in both types of soil and it is this stony material that causes the monotonous shallowness of the North Shore streams. In most places the clay and sand have washed away, leaving the stream bed paved with boulders. Because further erosion of this boulder pavement is difficult, the channel tends to widen rather than to deepen in periods of flood. Deep holes and pools which are characteristic of the best trout streams are usually lacking. The common stream improvement methods for constructing pools, such as digging logs and deflectors, are ineffective on such boulder bottoms. Rocks from which the glacial soils of the North Shore were derived are largely igneous and metamorphic in character. The soils, like their parent rocks, are relatively poor in soluble minerals. This condition is reflected in the water analyses of the streams.

Aside from lakes, the most important water storage areas on the North Shore are the peat deposits lying in depressions near the headwaters of many of the streams. The peat is usually thin, often not more than a foot deep, and in many places has been considerably damaged by forest fires.

In their lower stretches the North Shore streams flow through a strip of lake deposits that were laid down during the higher levels of the glacial precursors of Lake Superior. This strip of lacustrine deposits is about a mile wide in the vicinity of Duluth and has a maximum width of 5 miles in the Gooseberry, Knife, and Beaver river valleys. Along the upper portion of the shore it is usually less than 2 miles in width but expands to about 4 miles in the lower valleys of the Brule River and Kadunce Creek (Leverett and Sardeson, 1917). The waterlaid material varies in texture from the fine lake clays that were deposited in deep water to the coarse pebbles and cobbles of the ancient beaches.

These deposits are the result of three successively lower glacial lake stages. The earliest and highest of these, glacial Lake Duluth, has its upper beach line at an elevation of 1,135[4] feet above sea level in Duluth. Because of post glacial uplift of the North Shore, this beach and those of later glacial lake stages rise northeastward. The highest Lake Duluth beach at Schroeder has an elevation of 1,191 feet, at Grand Marais 1,250 feet, and at Hovland 1,300 feet (Leverett, 1928). Lake Duluth came into

[4]The present elevation of Lake Superior is 602 feet above sea level.

existence when the normal eastward drainage of the Great Lakes basin was blocked by glacial ice. Swollen with the melt water from the ice of the Lake Superior lobe, the water in the Lake Superior basin rose until drainage southward was established through the valley of the Brule River in Douglas County, Wisconsin. The water flowed over the present divide into the St. Croix River where it eroded such spectacular natural features as the dalles at Taylors Falls. With further melting of the glacial ice and recession of the ice front, eastward drainage began around the edge of the ice sheet. The water level receded to the Lake Algonquin stage and the St. Croix outlet was abandoned. The highest beach of this stage is at an elevation of 880 feet above sea level at Duluth, 910 feet near Knife River, and 1,042 feet at Grand Marais (Leverett, 1928). Beaches of the last glacial lake stage, the Nipissing, are combined with or below the present shore line as far north as Beaver Bay and have an altitude of 623 feet above sea level at Lutsen, 630 feet at Grand Marais, and 638 feet at Chicago Bay (Leverett, 1928). Drainage at this stage was eastward and only slightly at variance with the present Great Lakes drainage pattern.

Many stretches of the North Shore streams that lie within the strip of lacustrine deposits are not suited to trout. The laminated lake clays are easily eroded and provide a poor bottom for invertebrate fish food and the beach deposits of pebbles, cobbles, and coarse gravel are so easily shifted during periods of high water that they are usually barren of insect life. These soil characteristics, combined with the exposure of much bedrock, the widening of the stream channels, the paucity of shade, and uncertain water supply, make stream improvement and stocking of trout below the highest beach line impractical in many cases.

History of the North Shore Watershed

Timber Exploitation

The North Shore watershed is primarily a timber area and until a relatively few years ago was covered with a virgin stand of hardwoods and conifers. Before the exploitation of timber the region was an undisturbed wilderness frequented only by Indians, trappers, and traders. The first logging operations were started in 1840 when a sawmill was built near Fond-du-Lac. In the latter part of the 1850's several small mills were set up along the lake shore at Duluth, Two Harbors, and Beaver Bay. Most of the logs were taken in the immediate vicinity of the mills where timber could be floated down the streams, skidded, or dragged in by sleds. Following the Civil War several more mills were established and a brief boom in the lumber business took place. Logging was still confined to the immediate vicinity of the mills with white pine and shingle bolts being the principal output. After the panic of 1873 there was a considerable increase in the lumber industry and the first river drives were made on Midway River. By 1890 logging operations had extended as far up the shore as Castle Danger but cutting was still confined to a narrow strip within a few miles of the lake shore. During this period timber was moved to the sawmills largely by rafting it down the lake. Toward the end of the decade Duluth operations were approaching their record cut but the bulk of the timber was still coming from the South Shore in Wisconsin. Extensive cuts were made immediately east of Duluth and other big operations were scattered along the shore at various points.

In the late nineties two logging railroads were built from Duluth and the heavy logging operations, which were to deplete the North Shore area, began. Whereas the earlier cuts had been largely limited to white pine, now cedar, tamarack, and spruce were utilized extensively and the first pulpwood was taken.

Between 1900 and 1910 lumber production in Duluth and logging along the North Shore reached its peak. During this period logging railroad spurs were extended until they crisscrossed the whole watershed from Duluth to the Cross River. As a result of increased accessibility, heavy cutting was done in all the stream basins. With the removal of the heavy white pine stands, the less important species were more and more utilized. Heavy operations along the upper part of the shore began during the middle nineties when large cuts were made on the Pigeon River watershed. Extensive logging was soon done on all the watersheds from the Cross to the Pigeon River. From 1910 to 1925 logging declined as the more accessible and valuable stands were taken out. During this interval the heavy operations were limited to the upper part of the shore and small operators moved in to take the light stands and less valuable species. The last extensive logging was done in the years between 1928 and 1931 on the Cascade and Brule River watersheds and after 1936 on the Pigeon River. With the exception of these two operations, most of the logging since 1925 has been on a relatively small scale and the lumber has been cut on portable mills. Over a period of 40 years, logging operations changed from heavy cutting with extensive outfits and railroad transportation to small job logging using trucks and portable sawmills.

A study of early logging and other factors which led to the deterioration of trout streams along the North Shore indicates that the big operations were not nearly as important as low precipitation and the series of fires which burned over large parts of the trout stream basins. Since the white pine was usually not found in pure stands but in small, isolated patches scattered amongst the other forest trees, habitat conditions were not radically changed by the early logging. It was not until the later days that increased value of the poorer woods brought about clear cutting.

Fires

There were widespread fires on the North Shore in 1850 and again in 1878. Occasional fires of varying importance occurred from then until 1909. From that year until 1927 a series of destructive fires swept the North Shore from Duluth to the Cross River. In 1929 the Brule Lake fire raged over the Arrowhead and Cascade watersheds. The last serious fire on the North Shore was in 1936 when a large tract in the Pigeon River watershed was burned. These fires not only denuded the cover and removed shade from the streams but, probably more important, burned out many of the swamps and muskegs from which the streams derived their source of water. The character of the vegetation in some areas was so radically changed that the natural and artificial reforestation which has occurred only partially restores the cover. Additional area was opened up to tourists and resort development became very extensive during the twenties. Many places heretofore inaccessible came within reach of the tourist. Fire problems mounted and the process of rehabilitation was retarded.

The upper part of the North Shore watershed together with a large tract of land lying to the west were incorporated into the Superior National Forest in 1909. Two enlargements were made, the last of which was in 1935. In 1933 the Grand Portage State Forest and the Finland State Forest, one to the north and the other to the south of the federal holdings, were created. The federal and the state forest policies checked the deteriorating influences at work on the streams. After 1933 the Civilian Conservation Corps, under the auspices of the state and federal governments, made big efforts to re-forest the area, develop the streams, and improve the facilities for control of forest fires.

At the present time railroads do not extend further north than Two Harbors and all access to the territory is by automobile. It is to be anticipated that careful forest management, which will take into consideration not only the forest and agricultural uses of the land but also the recreational uses, will rehabilitate the trout streams and in many cases will improve them over their original condition.

Existing Forest and Ground Cover

The Minnesota North Shore is now largely forested with second-growth hardwoods and conifers. On the uplands, principal species are aspen, white birch, balsam poplar, jack pine, white spruce, and balsam fir. According to Juni (1879), red or Norway pine was also once common along the shore. The white pine occurred in scattered stands but was more abundant back from the lake. These two species are still present but are now unimportant components of the forest. The principal trees of the swamps are tamarack, black spruce, and white cedar. Black ash is fairly common along streams and on wet soil elsewhere.

The most common large upland shrubs are beaked hazel, mountain maple, chokecherry, and several species of juneberries. On recently burned areas the native red raspberry and the upland blueberry are abundant. The stream banks are commonly lined with tag alder (*Alnus incana*), sweet gale (*Myrica Gale*), red osier (*Cornus stolonifera*), and several species of willows. These same shrubs are abundant in swamps where they often have a dense understory of labrador tea, leatherleaf, and sphagnum moss.

The herbaceous ground cover of the upland forests is usually dominated by the large-leaved aster (*Aster macrophyllus*), wild sarsaparilla (*Aralia nudicaulis*), and the flowering raspberry (*Rubus parviflorus*). The last species is most abundant close to the shore of Lake Superior. Two other conspicuous and common herbs are the bluebell (*Mertensia lanceolata*) and the cornell or bunchberry (*Cornus canadensis*).

Mosses and lichens are everywhere common but are not now present in the great abundance recorded by Juni in 1879. The destruction of moss and lichens, along with other herbaceous vegetation and forest duff by fires, has been an important factor in increasing the rate of runoff in this area. A continuation of the present efficient fire protection will gradually alleviate this condition and allow a heavy ground cover to reestablish itself.

Detailed lists of the upland vegetation of the North Shore have been compiled by Juni (1879), Roberts (1880), and Rosendahl and Butters (1925). The nature and composition of the cut-over forests of Lake County are considered by Schantz-Hansen (1934).

Origin of Stream Names

Most, and perhaps all, of the North Shore streams originally had Chippewa names. Only one of the main streams, the Manitou River, has retained its original name unchanged. Some of the Indian names have been translated, with varying degrees of correctness, and others have been replaced with names applied by the white settlers. Most of the following information on stream names has been gained from Winchell (1920) and Culkin (1931).

Lester River was named for a pioneer and was called Busabiki zibi or Rocky-canyon River by the Chippewas. French River gains its name from a translation of Riviére des Francais, the name used by Owen in his geological report of 1852. The older Chippewa name was Angwassago zibi or Floodwood River. Sucker River is a direct translation from the Chippewa, Namebini zibi. Similarly, Knife River is a direct translation and is thought to refer to the sharp stones in the stream bed and on its banks. Stewart River is named for John Stewart who took up a claim here in 1852. Encampment River was so named in the geological report of Norwood in 1852.

On the map of Long's expedition in 1823 the Gooseberry River was shown. Although it is generally considered to be a translation from the Chippewa, there is some evidence that the river was originally named Riviére des Groseilliers after the French explorer and was later corrupted to Riviere aux Groseilles which was translated as Gooseberry River. Split Rock River is named for the rocky gorge near its mouth but its present name bears no relationship to the Chippewa Gininwabiko zibi or War-eagle-iron River. Beaver River was originally Beaver Bay River and named for the bay at its mouth. Gugijikensikay, or The-place-of-the-little-cedars, was the older Indian name of this bay. Baptism River is a corruption of the name Baptist River which appeared on Long's map in 1823. Manitou River retains its original Chippewa name meaning spirit.

Caribou River is named for the woodland caribou that according to Herrick (1892) were common in this region as late as 1884. Near the mouth of Two Island River there are two small islands, Gull and Bear, from which the stream derives its name. The Cross River gains its name from a wooden cross erected near its mouth in 1843 by Father Baraga, a French missionary, in gracious commemoration of his safe passage across Lake Superior. This name supplanted the older Indian name, Tchibaiatigo zibi, or Wood-of-the-soul River. Clark, in 1864, seeing the Kawimbash, or Deep-hollow River, facetiously named it Temperance because he observed that in contrast to most North Shore streams it had no "bar" at its mouth. Cascade River received its name from the series of waterfalls in its lower stretches.

Devil Track River is an approximate translation of the Chippewa Manidobimadagokowini zibi, or Spirits (or God)-walking-place-on-the-ice River. Durfee Creek was named for George H. Durfee, Judge of Probate Court of Cook County. This name has been corrupted to "Dufee Creek" on many recent maps. Kimball Creek was named for Charles G. Kimball, a member of Clark's geologic expedition of 1864, who drowned in Lake Superior near the mouth of this stream. Kadunce Creek is a fairly recent name for the stream earlier known as Greenwood, or Diarrhoea River. Brule River is a French translation of Chippewa Wissakode zibi or Half-burnt-wood River. As the river has had this name for over a hundred years, there seems to be no very good reason for the recent change to Arrowhead River. Reservation River forms part of the west boundary of the Pigeon River Indian Reservation. Red Sand and Cranberry Marsh River are the older Indian names for this stream. Grand Portage, or

Portage River, is named from the old Grand Portage Trail which parallels the lower stretches of this stream. Pigeon River receives its name from the now extinct passenger pigeon which, prior to 1890, frequented this region in great numbers. Its largest Minnesota tributary is the Kaweshka River. This name is a variant of the Chippewa Kameshkeg meaning swamp.

A MANAGEMENT POLICY FOR NORTH SHORE STREAMS

Past Fish Management

The North Shore streams were famous for their trout fishing as early as 1879 (Winchell, 1880). During the early years access to the fishing waters was possible only by boat, but it appears that fishing was limited to the stream estuaries below the falls. It is doubtful that trout existed above the impassable barriers until they were planted there. An interesting commentary was made by Winchell on the use of the streams and the need for fish conservation. In part, his report stated:

> "The brook-trout is an object of wanton destruction in northeastern Minnesota. This beautiful and universally admired species inhabits, in great numbers, the many small rivers flowing into Superior. These streams, in fact, have become one of the most famous fishing grounds on the continent. That they may continue so, they must be protected. Those within the State of Minnesota are visited annually by large numbers of amateur fishermen, who go in parties, and thus make most enjoyable vacation excursions. A boatman and a cook are engaged at Duluth or some other accessible point, who load into a sail-boat a store of provisions and other essentials to comfort and pleasure, and then take the excursionists to the best trout streams around the lake. One stream after another is visited. A camp is pitched beside each where it empties into the lake. Then, for several days, perhaps a week, the river banks are lined with the creeping, stealthy forms of the fishermen, throwing every temptation the ingenuity of man can devise before the eyes of the wary trout. By diligently and patiently continuing at their posts through every hour from daylight until evening, it is surprising if any fish are spared in the stream. So far as the trout are caught and saved for food within the legal fishing season, it is not proposed here to find fault with the fishermen. * * * It is a very common thing for parties to fish

Table 3. Years of first recorded fish planting in streams of the North Shore watershed

Stream	Brook Trout	Brown Trout	Rainbow Trout	Steelhead[1] Trout	Lake Trout	Smallmouth Bass
Lester River	1902	1913	1901	1905	...	...
Talmadge River	1902	1923	1926	...	...	...
French River	1900	1917	1921	1905	1905	...
Sucker River	1900	1917	1921	1906	...	...
Knife River	1906	1923	1906	1917	...	...
Stewart River	1900	1921	...	1918	...	...
Silver Creek	1906	1925	1926	1935	...	...
Gooseberry River	1906	1919	1916	...	...	...
Split Rock River	1906	1934	1917	...	...	...
Beaver R ver	1900	1920	1918	1914	...	...
Baptism River	1900	1921	1916	...	...	...
Manitou River	1912	1920	1915	...	...	...
Caribou River	1916	1924	1927	...	...	...
Two Island River	1909	1924	...	...	...	...
Cross River	1901	1920	1917	...	...	...
Temperance River	1910	1926	1928	...	...	1924
Onion River	1909	1929	1934	...	...	...
Poplar River	1902	1924	1901	...	1905	...
Spruce Creek	1923	...	...	...	...	...
Blackpoint Creek	1937	...	...	...	...	...
Cascade River	1906	1924	1918	...	...	...
Rosebush Creek	1923	...	...	...	...	...
Devil Track River	1915	1924	1929	...	...	...
Durfee Creek	1932	...	1942	...	...	...
Kimball Creek	1913	...	1926	...	...	...
Kadunce Creek	1909	...	1926	...	...	...
Arrowhead (Brule) River	1927	1928	1930	...	...	1924
Flute Reed River	1901	...	1933	...	...	...
Reservation River	1918	...	1926	...	...	...
Pigeon River	1929	...	1933	...	...	...

[1]Steelheads are a migratory form of rainbow trout which were imported from the Pacific Coast. These interbreed with other strains of rainbow so completely that differentiation is now rarely made in inland waters.

> out a stream and select only the very largest specimens for eating and salting, throwing all the rest, probably three-fourths of their whole number, back into the river. Such treatment of the fishing grounds causes much indignation among the people living in the northern part of the State, and who have a lively interest in the preservation of their fish and game. It is true we have game laws, but it is a very difficult thing to have them enforced so that all would hold a proper respect for them."

Whether a trout planting program was started to restore depleted streams or to extend the range of trout into the headwater areas is not clear. We do know, however, that plants of trout, presumably brook trout, were made as early as 1891 (Board of Game and Fish Commissioners, 1895). These fish were merely designated as "trout" and were sent to Grand Marais. The first recorded plantings of brook trout in specific streams were made by the U. S. Fish Commission in the Baptism, Beaver, French, and Sucker rivers during 1900 (Table 3). State records first show plantings in specific streams during 1908.

Exotic species made their appearance in 1901 when rainbow trout were placed in the Lester River. Steelhead trout came next, in 1905, with plantings in both the Lester and the French Rivers. The first recorded planting of brown trout on the North Shore was in Kimball Creek in 1913. One large planting of lake trout was placed in the French River and the Poplar River during 1905. It is not clear whether the initial recorded plantings of exotic species were actually the first introductions. From early reports of the Minnesota Commission of Fisheries (1889) it is evident that rainbows were raised in state hatcheries in 1887 and brown trout in 1888. It is therefore quite possible that some of these fish were placed in the streams prior to 1900.

Until 1919 all trout were planted in the fry stage. In that year the first fingerlings were introduced. There was considerable controversy over the relative merits of fingerling and fry planting but the growing body of information amassed by biologists and fish culturists soon indicated that fry planting was of little value for maintaining fish populations. With increase in the fishing load, it became evident that further alterations in stocking policies must be made. Consequently, a program of planting adult fish was initiated in 1940. Except for occasional liberation of

Table 4. Summary of the fish planted in the North Shore streams between 1900–1942

STREAM	BROOK			BROWN			RAINBOW			TOTAL		
	Fry	Fingerling	Yearling	Fry	Fingerling	Yearling	Fry	Fingerling	Yearling	Fry	Fingerling	Yearling
Lester River	814,466	228,515	...	71,100	258,805	2,670	171,200	194,090	420	1,056,766	681,410	3,090
Talmadge River	148,430	32,900	...	...	9,573	...	...	618	...	148,430	43,091	...
French River	372,855	531,513	420	89,000	317,510	1,920	34,715	134,970	220	496,570	983,993	2,560
Sucker River	562,966	774,707	...	80,482	580,843	2,560	35,146	285,608	...	678,594	1,644,158	2,560
Knife River	1,416,200	1,066,672	630	325,050	646,040	1,640	108,300	212,650	780	1,849,550	1,925,362	3,050
Stewart River	824,757	486,720	240	79,840	191,680	...	40,680	150,725	140	945,277	829,125	380
Silver Creek	338,950	295,585	1,190	2,500	9,200	...	...	81,425	...	341,450	386,210	1,190
Encampment River	162,177	58,075	...	...	9,750	...	...	875	...	162,177	68,700	...
Gooseberry River	1,006,656	614,887	1,190	116,900	166,400	...	28,000	68,150	370	1,151,556	849,437	1,560
Split Rock River	786,655	254,817	280	...	23,000	...	12,500	91,100	560	799,155	368,917	840
Beaver River	776,550	516,830	...	100,313	242,480	...	16,400	137,275	...	893,263	896,585	...
Baptism River	1,063,583	738,021	980	63,000	282,300	1,872	26,100	166,150	560	1,152,683	1,186,471	3,412
Manitou River	618,690	148,108	840	42,000	129,700	1,200	7,000	114,375	560	667,690	392,183	2,600
Caribou River	163,600	131,808	...	...	20,000	...	...	9,750	...	163,600	161,558	...
Two Island River	166,400	178,648	...	30,000	6,000	...	...	...	...	196,400	184,648	...
Cross River	470,650	294,250	...	28,472	146,420	...	8,750	52,450	...	507,872	493,120	...
Temperance River[1]	195,150	566,625	...	15,000	173,100	...	48,750	146,125	...	258,900	885,850	...
Onion River	22,750	26,775	...	...	4,000	...	...	600	...	22,750	31,375	...
Poplar River	212,100	278,780	...	89,000	201,950	600	24,350	129,850	...	325,450	610,580	600
Spruce Creek	33,000	32,515	...	...	...	...	...	...	...	33,000	32,515	...
Blackpoint Creek	...	8,000	...	...	...	...	...	...	...	...	8,000	...
Cascade River	338,567	363,345	280	...	17,700	...	10,000	42,445	...	348,567	423,490	280
Rosebush Creek	15,382	4,750	...	...	...	...	...	...	...	15,382	4,750	...
Devil Track River	443,650	578,125	1,120	9,000	72,800	...	...	37,500	...	452,650	688,425	1,120
Durfee Creek	...	27,025	...	...	...	...	...	...	...	...	27,025	...
Kimball Creek	120,700	99,250	280	...	16,875	...	...	...	...	120,700	116,125	280
Kadunce Creek	166,496	154,950	450	...	...	...	...	16,875	...	166,496	171,825	450
Arrowhead (Brule)[2]	225,166	289,450	280	...	106,150	...	...	106,730	...	225,166	502,330	280
Flute Reed River	173,400	109,400	3,200	...	...	...	...	340	...	173,400	109,740	3,200
Reservation River	47,750	105,800	...	9,000	...	...	...	...	...	56,750	105,800	...
Mineral Creek	...	33,250	...	...	...	...	...	3,125	...	...	36,375	...
Total	11,687,696	9,030,096	11,380	1,150,657	3,632,276	12,462	571,891	2,186,301	3,610	13,410,244	14,849,173	27,452

[1] 1,130 fingerling and 63 adult smallmouth bass.
[2] 1,760 fingerling and 42 adult smallmouth bass.

brood stock from the hatcheries, the first adult fish were placed in the North Shore streams in 1941.

From the beginning of recorded planting to 1942, 28,286,869 fish have been placed in the North Shore streams (Table 4). Of these, 13,410,244 have been fry, 14,849,173 have been fingerlings, and 27,452 adults. Brook trout were supplied in the greatest numbers with 20,729,172 being introduced. Brown trout were second with 4,795,395 and rainbow third with 2,762,302. Also, 2,995 smallmouth bass were planted experimentally. This large number of fish has comprised a substantial part of the output from state trout hatcheries.

A federal hatchery was placed in operation at Lester River during 1888 and presumably supplied fish for the North Shore from that date forward (Minnesota Commission of Fisheries, 1889). Fish were acquired from this source and from state hatcheries in the southern part of the state until 1920 when fish were produced in the Lake Superior Hatchery at French River (Minnesota State Game and Fish Commissioner, 1920). Seven- to nine-inch trout for recent plantings have been produced in the Root River Basin Hatchery at Lanesboro.

Timber exploitation and fires did much to spoil natural habitat conditions in the North Shore area. In order to rehabilitate the streams and increase their natural fish-carrying capacity, an improvement program was begun in the early 1930's. All this work was done by the U. S. Forest Service and the state Emergency Conservation Works, using Civilian Conservation Corps labor. Streams in the vicinity of the various camps were most heavily worked and frequently streams of little importance were developed because they were accessible. The Devil Track, Cascade, Poplar, Temperance, Baptism, and Pigeon rivers were heavily worked and several smaller streams received considerable attention. This activity was continued until 1941 by the U. S. Forest Service. The total mileage of stream channel improved by all agencies was not great and some of the structures have not proved to be permanent. In 1942 the Department of Conservation started a stream rehabilitation program with a development project on the Knife River.

Summary of Fish Management Policy

The management policy for the streams of the North Shore watershed has been based on the environmental characteristics of these waters and the recent trends in fishery biology. In the preparation of plans an attempt has been made to consider not only habitat conditions and ideal procedures but also the practical limitations imposed by accessibility and the facilities available to the fisheries managers. Since these streams are primarily suited to trout, a brief discussion of the requirements, limiting factors, and stocking procedures peculiar to these species is included with the summary of management plans. Details of stocking and stream control are presented in the individual stream sections and the stocking tables (Appendix 1).

Environmental Requirements and Fishery Procedures

TEMPERATURE.—Although various trout differ in their tolerance to temperature, they are all essentially cold-water fishes. Needham (1938) comparing the temperature tolerance of brook trout (*Salvelinus fontinalis*), the brown trout (*Salmo trutta fario*), and the rainbow trout (*Salmo gairdnerii irideus*) found that the upper limits of their ranges were 75° F., 81° F., and 83° F. respectively. Optimum stream temperatures for these three species do not exceed 66° F., 75° F., and 80° F. Temperature limitations are applicable under average conditions but gaseous content of the water, pollution, and certain physical factors may further limit or extend the range. Since temperature is the primary limiting factor in trout distribution and production (Creaser, 1930), it is essential that maximum water temperatures during the hottest season of the year be determined. To assist in these calculations, Embody (1929) prepared a comparative table of water and air conditions (Table 5).

Table 5. Relation of air and water temperatures in trout streams located in open country up to 1,000 feet elevation

Maximum air temperature, degrees Fahrenheit	80.0	82.0	84.0	86.0	88.0	90.0	92.0	94.0
Maximum water temperature, brook trout	65.0	66.5	68.0	70.0	71.5	73.0	74.0	75.0
Maximum water temperature, Brown trout / Rainbow trout	69.0	70.5	72.0	73.5	75.0	76.5	78.0	79.0

If at a given air temperature the water temperature is higher than that indicated for a particular species, it can be anticipated that the habitat will at some time be unfavorable. This table was compiled after extensive observation of New York streams with moderate cover and located at average altitudes. In applying these constants to North Shore streams, several allowances had to be made. Temperature observations on open, poorly shaded streams made in bright sunlight when air temperatures were above 80° F. are given most consideration. Final analysis took into account the period of warm weather preceding the observations and the occurrence or absence of various trout species. In determining the type of stream management, the trout species whose optimum temperature range falls close to the stream average were normally selected even though the environment might permit other species to survive.

Various factors influence stream temperatures. Cool waters from source springs or lakes may be warmed by wide, unshaded channels, by beaver ponds, and by long stretches without cool feeders. Warm source waters, on the other hand, may be cooled by heavy cover over the channel. This condition is especially true in high altitudes or northern latitudes where nights are cool and solar radiation is the principal warming influence. Cool tributary springs along the course of the stream are often sufficient to maintain satisfactory trout conditions even though other factors may be unfavorable.

CHEMICAL REQUIREMENTS.—It has been shown that carbon dioxide, hydrogen-ion concentration (pH), total alkalinity, and the quantity of dissolved salts are secondary to temperature in habitat selection by trout (Kendall and Dence, 1927; Powers, 1929; Creaser, 1930; Davis, 1926; Coker, 1925). Minnesota North Shore streams have chemical conditions falling well within the normal tolerance of trout. The chemical quality of these waters determines their productivity rather than limits the species of fish which may live successfully in them. All trout are extremely sensitive, however, to polluting agents such as heavy metal salts, oil wastes, paper mill wastes, cannery wastes, acids, etc. (Moore and Kellerman, 1905; Ellis, 1937.)

BIOLOGICAL FACTORS IN TROUT PRODUCTION.—Physical and chemical conditions may be adequate to maintain some species of trout but the presence of spiny-rayed fishes and other predators or competitors may limit trout production. It has been found that stream trout will usually not compete successfully with spiny-rayed fishes such as rock bass, smallmouth bass, and perch. Trout have been eliminated from their normal habitats on numerous occasions by the introduction or invasion of these species. While it is not clear whether this replacement is due to the predation on the trout and their young or to competition for available food supply, it rarely pays to plant trout where spiny-rayed fish abound.

The brown and rainbow trout are exotic species which have been introduced to Minnesota waters. They have entered brook trout habitats and at some places crowded out the native species, but where such replacement has taken place it has usually led to an increased total production. The desirability of this shift may be questioned where it is felt that native species should be conserved, even though the exotics give a higher return to the angler. In many streams both brown and brook trout can be maintained separately if there is a barrier between the cool headwaters and the lower, warmer waters. In such cases it is desirable to preserve the headwaters for brook trout and the lower waters for brown trout. Where there are no such barriers, brown trout will frequently predominate in sections which are equally habitable to both species. It should be pointed out, however, that in many streams brook trout and brown trout exist side by side and furnish good angling for both species.

The rainbow trout is a strong competitor which often reduces brook trout in their native habitat (Holloway and Chamberlain, 1942). It is a vigorous migrant and tends to go into deep waters of lakes and streams. If these large waters are separated from the headwater stream by impassable barriers, the rainbows will be kept to a minimum in the headwaters and will not limit the brook trout.

Several fishes which have been considered detrimental to the propagation and maintenance of the trout occur abundantly in trout waters. Most notable of these is the common sucker. This fish has been accused of digging up the redds and eating trout eggs. Careful observations indicate that this predation is very small (Greeley, 1932). While trout eggs are not infrequently found in sucker stomachs, it has been shown that these eggs were picked up as they floated down the stream after having failed to lodge in the redds. Such eggs would be lost to normal reproduction in any event. On the other hand, suckers are important forage fishes which utilize food material that contributes slightly, if at all, to the trout diets. Until strong evidence to the contrary is presented, it must be assumed that the sucker, when present in moderate numbers, is an asset rather than a liability in our trout streams.

CONDITIONS REQUIRING ARTIFICIAL STOCKING.—There are several stream conditions which require the planting of trout: (1) inadequate reproduction caused by poor spawning areas, winter destruction of redds, or floods which destroy the redds or fry; (2) extreme fishing pressure which so reduces spawning stock that insufficient eggs are laid; and (3) a fishing load which requires more fish than the natural productive capacity of the stream will furnish.

SIZE OF FISH TO BE PLANTED.—When it has been determined that stocking must be done to maintain a satisfactory yield, it is essential that proper-sized fish be used. Until shortly after 1900 most trout were planted in the fry stage or as soon after hatching as they could be conveniently and safely moved. After 1910 the stocking of fry was gradually discontinued in favor of advanced fingerling planting.

With increased fishing pressure and the gradual depletion of streams, it became apparent that further changes in stocking techniques were required. In order to maintain trout waters, especially heavily fished streams, 7- to 9-inch fish were planted. Since stock of this size is costly to raise, an extensive series of experiments was carried out by various investigators to determine whether fingerlings or "keeper trout" gave the largest return to the angler. Shetter (1939), working on Michigan streams, found that only slightly more than 1 per cent of the brook and rainbow trout fingerlings stocked were returned to the angler's creel within 3 years after planting. Surber (1940) confirmed these findings in a West Virginia stream where there was a return of only 2.4 per cent from large fingerling plantings. King (1942) and Chamberlain (1943), working in southern trout streams, found that fingerling planting was not successful in improving the angler's take. On the contrary, numerous experiments have indicated that the return from planting of catchable-sized fish varies from 19 per cent to 90 per cent, depending on the stream and the extent of the fishing load (Hoover and Johnson, 1938; Shetter and Hazzard, 1941; Smith, 1941; Gee, 1942). Under certain conditions the return may be even more favorable. Chamberlain (1943) was able to demonstrate that planting catchable-sized fish actually increased the total take from the stream. From these experiments it has been clearly demonstrated that planting of 7- to 9-inch trout is more successful than planting with fingerlings. Careful consideration of all the data at hand indicates that fingerling stocking is justified in areas where natural reproduction is inadequate but the carrying capacity is high and where inaccessibility precludes the planting of larger fish. Because this latter condition is found in only occasional instances, it is usually most economical to plant 7- to 9-inch fish.

TIME OF YEAR WHEN FISH SHOULD BE PLANTED. — Many experiments have shown that the most successful 7- to 9-inch trout plantings are made in the spring or during the actual angling season (Hoover and Johnson, 1938; Shetter and Hazzard, 1941; Smith, 1941; King, 1942; Chamberlain, 1943). In most cases where fall planting and spring planting were compared, the percentage of return to the angler's creel varied from 10 to 20 times greater from spring plantings than from fall plantings.

To test these results on Minnesota's North Shore streams, marked brook trout and brown trout were planted in the fall of 1942 and the spring of 1943 in the Knife River. A creel census was carried on during the fishing season of 1943 and a check made on all anglers and on the number of tags returned from each planting. From the total fall planting 1.9 per cent and from the total spring planting 14.1 per cent were returned during the 1943 fishing season (Smith and Smith, 1944). A higher percentage of brook trout than of brown trout was recovered from both plantings. In 1943, 2.4 per cent of the brook trout and 1.4 per cent of the brown trout planted in the fall and 19.6 per cent of the brook trout and 8.6 per cent of the browns planted in the spring were taken during the open season. The low recovery of the brown trout is probably correlated with lower fishing intensity in the area where this species was stocked. Average returns for fall and spring plantings are similar to those reported by Smith (1941) working in the Salmon Trout River on the south shore of Lake Superior. He found that 1.0 per cent of the fall planting was returned the following season while 19.6 per cent was returned from spring and seasonal planting. The returns found by Smith (1941) and by Smith and Smith (1944) are below those reported by other workers. This fact may be due, in part, to light fishing load and migration into Lake Superior as well as low survival. The factors involved in the poor over-winter survival of 7- to 9-inch fish have not been clearly established but they probably include predation, natural mortality, and inability of hatchery trout to compete favorably in a natural environment.

AREAS TO BE STOCKED.—After a survey has been made, it will be apparent that there are many trout waters in which stocking is impractical. Fish planting is unnecessary where the normal harvest by anglers is less than natural annual production of catchable fish. Where light angling is due to inaccessibility, there is little justification for attempting to improve the trout fishing. Likewise, it is not practical to recommend areas for stocking which cannot be reached by truck or by easy foot carry. Shetter and Hazzard (1941), Smith (1941), Gee (1942), and others have shown that 7- and 9-inch hatchery reared brown and brook trout migrate only a short distance before they are caught by anglers. It is, therefore, not desirable to plant large numbers in a single spot anticipating that they will move up and down stream for several miles. From actual experience it has been found that the fish tend to stay in large schools near the planting site and there fall an easy prey to the angler who acquires his limit with no effort. Such local concentrations also encourage the meat hunter and the poacher. Best results are obtained when a few fish are planted in each pool throughout the fishing area.

The final consideration in the allotment of fish is the relative importance of the trout fishery to the general fishing resources of the region. On many watersheds, particularly on certain parts of the North Shore, the lakes constitute the bulk of fishing waters. In such locations it would be a misplacement of emphasis to develop trout waters at great cost when the natural facilities for other species are present in abundance.

THE NUMBER OF FISH TO BE PLANTED.—The number of fish to be planted in each stream will depend on its carrying capacity, the success of natural reproduction, the mortality of planted fish, and the fishing load. A stream's carrying capacity will depend upon its size, the amount of food available, the number of pools, and amount of shelter. Since these factors are all variable, a sliding scale for planting must be used. Embody (1927) proposed a scheme for stocking New York streams which has proved to be

Table 6. Number of 3″ fingerlings per mile—planting table for trout streams[1]

Stream Width Feet	Pool Grade A			Pool Grade B			Pool Grade C			Stream Width Feet
	1[2]	2	3	1	2	3	1	2	3	
1	144	117	90	117	90	63	90	63	36	1
2	288	234	180	234	180	126	180	126	72	2
3	432	351	270	351	270	189	270	189	108	3
4	576	468	360	468	360	252	360	252	142	4
5	720	585	450	585	450	315	450	315	180	5
6	864	702	540	702	540	378	540	378	216	6
7	1008	819	630	819	630	441	630	441	252	7
8	1152	936	720	936	720	504	720	504	284	8
9	1296	1053	810	1053	810	567	810	567	324	9
10	1440	1170	900	1170	900	630	900	630	360	10
11	1584	1287	990	1287	990	693	990	693	396	11
12	1728	1404	1080	1404	1080	756	1080	756	432	12
13	1872	1521	1170	1521	1170	819	1170	819	468	13
14	2016	1638	1260	1638	1260	882	1260	882	504	14
15	2160	1755	1350	1755	1350	945	1350	945	540	15
16	2304	1872	1440	1872	1440	1008	1440	1008	576	16
17	2376	1930	1485	1930	1485	1039	1485	1039	594	17
18	2448	1989	1530	1989	1530	1071	1530	1071	612	18
19	2520	2047	1575	2047	1575	1102	1575	1102	630	19
20	2592	2106	1620	2106	1620	1134	1620	1134	648	20

For streams over 20 feet in width use formula $\frac{1}{2}N_1 W+8N_1=X$.
N_1 = number fingerlings for stream 1 ft. wide, W = average width.
X = number to be stocked per mile.
The above table refers to 3″ fingerlings only. To find the number of other sizes multiply the number of fish given for the stream width in question by the following factors (dependent on size).

Length inches	1″ Fry	3″ Fing.	4″ Fing.	6″ Legal	10″ Adult
Factor	12	1	0.75	0.6	0.3

[1]Embody, 1928.
[2]The figures 1, 2, 3 at the heads of columns indicate the food grade.

satisfactory as a general guide in other areas. His stocking plan is based on the assumption that half the catchable-sized fish are removed each year by anglers and that half of the 3-inch fingerlings planted fail to survive. He assumes that the percentage mortality of fishes is proportional to their size when planted. To adjust this differential mortality, a series of factors is applied to the numbers specified for 3-inch fish. The original table covered streams up to 10 feet. Embody (1928) later proposed calculations which would permit its use for any stream. Food and pool conditions, as well as size, were considered in the preparation of the table. Three food grades (1, 2, 3), based on the amount of bottom forms present, were proposed and three pool grades (A, B, C) were used to indicate the relative richness and potential carrying capacity of the stream. Embody's calculations and adjustments are presented in Table 6.

In using the Embody table as a guide for stocking the Minnesota North Shore area, large corrections had to be made for variations in the fishing load, success of natural reproduction, and the known mortality of planted 7- to 9-inch fish. Other local conditions and peculiarities exposed by the survey also modified the theoretical plan in many cases. In general, the following factors for local variation were applied to totals presented in the table. Where fishing load was heavy and natural reproduction fair, the full calculated stocking was proposed. Where load was heavy and natural reproduction good or where the fishing load was moderate and natural reproduction fair, a factor of 0.50 was applied. In streams where the load was light or moderate with good natural reproduction, a factor of 0.25 was used. All stocking recommendations have been conservative because it is felt that stocking should be a supplement to rather than a substitute for natural reproduction.

Embody specified food grades of "1", "2", and "3", on the basis of good, medium, or poor, and did not give strict delimitations on the amount of food per unit area. Hazzard (1935) revised these classifications and made them more specific by designating food grades as follows:

Grade I. Volume greater than 2 cc. (2 grams), 50 or more organisms.

Grade II. Volume from 1 to 2 cc. (1 to 2 grams), 1 to 50 organisms.

Grade III. Volume less than 1 cc. (1 gram) and/or not more than 50 organisms.

In the present report Hazzard's system is modified to omit the numbers of organisms (Davis, 1938).

Pool grades were classified by Embody as "A", "B", and "C" on the following basis:

(A) Streams showing best conditions in which pools are large, frequent, and well sheltered.

(B) Streams showing average conditions in which deep, sheltered pools are fairly numerous.

(C) Streams showing poorest conditions, pools generally shallow, without shelter.

Hazzard (1935) and Davis (1938) revised this classification to make it more specific and recommended that the actual number of pools per mile be taken into consideration in evaluating the stream.

In the present survey of the North Shore streams, the following system of pool evaluation was used:[7]

Type A—Deep pools (3 times average depth of stream) with good shelter created either by submerged logs and rocks or undercut banks; with a high production of food organisms on the bottom. This pool will usually have a silt, muck, or detritus bottom.

Type B—Shallow pools (1 to 2 times average depth of stream) with a moderate amount of shelter and food production.

Type C—Deep pools with little or no shelter, unprotected bottom and fast current.

Type D—Shallow pools with unproductive bottoms, fast current, and no shelter.

The size of the pools was designated by numbers 1, 2, 3:

No. 1—Pools larger than twice the average width of the stream.

No. 2—Pools up to twice the width of the stream.

No. 3—Pools narrower than average width of the stream.

[7]Minnesota Bureau of Fisheries Research Stream Survey Manual.

"A" grade of the Embody table includes streams in which pools are A-1, A-2, and B-1, and where pools constitute more than 60 per cent of the total stream area. The "C" grade of the table includes all pools in the C and D group. Between these two extremes falls the "B" class of Embody. The variable nature of the stream conditions, however, has made it necessary to use a flexible designation and considerable judgment on what pool grades should be applied to the stocking table.

It must be recognized, as it was by Embody, that the stocking table is not inflexible and that it can be used only as a general guide. Many of the factors which modify it are known but the incompleteness of our knowledge concerning the absolute carrying capacity of various types of streams must be admitted. In the matter of food grade we know now that the total quantity of food does not necessarily indicate that which is available to trout (Hess and Swartz, 1941; Allen, 1942). It is quite probable that the gross food grades designated in the present report will need modification as more information on this problem is made available to us.

NURSERY STREAMS.—Some streams tributary to trout areas have been closed to form permanent nursery or breeding grounds. Protection of these feeders during the time of spawning may be desirable, but whether or not year round closing can be justified is an entirely different matter. Maintenance of closed streams is based on the assumption that the trout migrate to larger waters after they reach a certain age or larger size. Available evidence does not entirely bear out this belief. Trout in small, cold feeders are frequently of advanced age even though they remain small and appear to be young fish (Hoover, 1938). Instead of going down to larger waters as anticipated, the fish remain in their native habitat and compete for the available food supply. Where migration may occur, the removal of larger fish from the nursery waters during the open fishing season reduces the number of predators that limit the production of small fish (Hazzard, 1931). Little information has been presented that shows closing of nursery streams actually results in the improvement of connected waters (Kendall and Dence, 1929). On the contrary, much desirable angling water has been removed from the active list thus putting a heavier drain on over-fished waters. It is believed that under certain conditions closing of nursery streams after August

Table 7. Summary of fish stocking plan for the rivers of the North Shore of Lake Superior exclusive of the St. Louis system and Duluth Metropolitan area

System	Total Miles	Mi. to be Stocked	Brown Trout 3-inch	Brown Trout 7-inch	Brook Trout 3-inch	Brook Trout 7-inch	Smallmouth Bass 4-inch	Total Adults	Total Fingerlings
Lester River	43.4	9.9	....	3,700	....	....	....	3,700	....
French River	18.65	9.0	....	....	....	850	....	850	....
Sucker River	33.4	5.5	1,350	450	450	225	....	675	1,800
Knife River	94.15	22.6	....	2,225	910	780	....	3,005	910
Stewart River	34.5	7.5	....	2,625	....	....	....	2,625	....
Gooseberry River	86.7	19.8	....	....	448	2,062	....	2,062	448
Split Rock River	44.4	14.8	....	628	125	310	....	938	125
Beaver River	143.6	21.2	450	2,397	....	1,200	....	3,597	450
Baptism River	125.75	31.6	....	5,400	3,150	2,290	....	7,690	3,150
Manitou River	82.6	12.0	1,400	4,300	500	575	....	4,875	1,900
Caribou River	40.13	3.7	....	....	....	1,295	....	1,295	....
Two Island River	21.3	8.0	125	125	....	1,730	....	1,855	125
Cross River	54.9	3.0	....	400	....	....	....	400	....
Temperance River	98.55	11.5	350	1,525	....	700	....	2,225	350
Onion River	13.91	1.5	....	....	....	225	....	225	....
Poplar River	65.8	7.5	800	....	....	1,350	600[1]	1,350	1,400
Spruce River	6.63	1.0	....	....	200	....	....	....	200
Cascade River	78.55	11.45	....	660	360	2,905	....	3,565	360
Devil Track River	51.15	13.5	....	2,295	782	1,395	....	3,690	783
Durfee Creek	4.0	2.5	....	....	....	125	....	125	....
Kimball Creek	12.45	3.9	....	....	....	975	....	975	....
Kadunce Creek	10.0	5.5	....	600	....	1,050	....	1,650	....
Arrowhead River	120.8	6.0	....	100	....	690	....	790	....
Flute Reed River	20.4	4.6	....	460	....	....	....	460	....
Reservation River	16.1	0.0	....	....	....	....	....	....	....
Hollow Rock Creek	10.76	1.5	....	150	....	....	....	150	....
Pigeon River	44.96	3.5	....	75	....	250	....	325	....
Total	1,377.54	245.55	4,475	28,115	6,925	20,982	600	49,097	12,001

[1]This planting is experimental; to be discontinued after 3 years if bass fishing does not develop.

15, when large fish start to run into the spawning tributaries, may be desirable to assure adequate natural reproduction. Having the streams open to fishing from the beginning of the season until August 15 would permit an increased harvest and not endanger spawning.

Stocking and Development Recommendations

MANAGEMENT POLICY. — The streams of the North Shore area are suited primarily to the production of stream trout. Those areas which cannot be managed for trout are of doubtful use for other species. It is therefore recommended that the North Shore streams be managed primarily for stream trout and, in a few selected areas, for smallmouth bass.

PLANTING RECOMMENDATIONS.—Rainbow trout tend to run downstream into Lake Superior from the tributary rivers. Since in most cases impassable barriers prevent their return to the streams, it is recommended that only brook and brown trout be planted. No additional exotic trout species and no forage fishes not already native to the area are to be introduced. No trout species are to be stocked in waters abounding with spiny-rayed fish or northern pike because competition and predation will tend to nullify the efforts to improve trout production.

The total number of fish to be planted annually in 27 streams will consist of 4,475 fingerling brown trout, 27,455 7- to 9-inch brown trout, 6,925 brook trout fingerlings, 21,642 7- to 9-inch brook trout (Table 7). In addition, 600 smallmouth bass will be planted annually for 3 years in one stream. The total number of fish to be planted each year will be 61,700. This total does not include requirements of the streams in the Duluth metropolitan area which must be managed individually in accordance with city park policies.

All 7- to 9-inch fish are to be planted in the spring or during the regular fishing season, and fall planting of this sized stock is to be strictly avoided. Fingerling fish are to be planted in September. Wherever possible, the stream quotas should be filled by two or more partial stockings during the season rather than by a single spring plant. It will be noted from examination of Table 7 and detailed stocking tables (Tables 13-39) that certain streams are omitted entirely and that a few of the well known streams are

Table 8. Recommended development on North Shore streams

System	Miles to Improve	Priority	Remarks
Lester	8.6	High	Plant trees for shade, create pools and install shelters.
French	8.4	High	Create pools and shelters.
Sucker	6.2	High	Plant trees, drain beaver ponds, create pools and install shelters.
Knife	21.6	High	Plant trees, drain beaver ponds, create pools and shelters.
Stewart	7.5	High	Plant trees, narrow channel, create pools and shelters.
Encampment	....	....	Volume of flow too unstable.
Gooseberry	20.1	High	Create pools and install shelters.
Split Rock	10.9	Medium	Create pools and install shelters.
Beaver	12.7	Medium	Create pools and install shelters.
Baptism	16.3	High	Create pools and install shelters.
Manitou	....	....	Present environmental conditions are good.
Caribou	3.0	Medium	Create few pools and install shelters.
Two Island	7.2	Medium	Drain beaver ponds, create pools and shelters.
Cross	....	....	Maintain U. S. Forest Service improvements.
Temperance	3.1	Medium	Create pools and install shelters.
Onion	....	....	Shade and pools are ample.
Poplar	1.5	Medium	Create pools and install shelters.
Spruce	....	....	Summer flow inadequate.
Cascade	1.5	Low	Plant trees, drain beaver pond, maintain U. S. Forest Service improvements.
Devil Track	....	....	Maintain U. S. Forest Service improvements.
Durfee	1.3	Low	Create pools and install shelters.
Kimball	2.8	Low	Create pools and install shelters.
Kadunce	....	....	Maintain U. S. Forest Service improvements.
Arrowhead	2.0	Low	Create pools and install shelters. Narrow channel.
Flute Reed	....	....	Maintain U. S. Forest Service improvements.
Mineral	....	....	Too small. Manage for beaver.
Reservation	....	....	Too warm for brooks. Accessible to rainbow run.
Hollow Rock	2.0	Low	Create pools and install shelters.
Grand Portage	....	....	Uncertain water supply. Lightly fished.
Pigeon	1.3	Low	Create pools and install shelters. Maintain U. S. Forest Service improvements.
Total	138.0		

stocked only lightly. In the former case the streams may furnish a small amount of fishing, but the light angling load or poor habitat conditions make planting disproportionately expensive for the return to be expected. In the latter case, natural reproduction and habitat conditions are so good that heavy planting is unnecessary.

STREAM IMPROVEMENT.—A total of 138 miles of stream is recommended for improvement (Table 8). Stream development is most essential on the western end of the shore below the Baptism River. The heavier fishing load, greater accessibility, and fewer miles of trout stream make early improvement of this area desirable. As is pointed out subsequently, the stream development program is of long-range duration and should be extended over several years. Details of stream improvement are considered in the sections on individual streams.

STREAMS OF THE NORTH SHORE WATERSHED

The following discussions include brief descriptions and management summaries for each of the North Shore streams. Detailed consideration of water chemistry, plankton, aquatic plants, fishes, and stream improvement is given in the sections dealing with these subjects and in the appendices. Stocking programs for the individual streams are contained in Tables 13-39. Following the title of each stream is the map number, the number of the table giving specific data by stations, and the number of the stocking table. The brief treatment of each stream given in this section presents the general conditions and major problems. Critical analyses and substantiation of management policies are presented elsewhere.

Lester River

(Fig. 4, Tables 13 and 40)

The Lester River drains an area of 58 square miles in Townships 50, 51, and 52 North, Ranges 13 and 14 West, St. Louis County, and the lower portion of its drainage basin is within the city limits of Duluth. Underlying the deposits of stony red glacial soil that cover most of the area are crystalline Keweenawan rocks. The basalt flows of this series are exposed here and there at the falls and rapids in the lower 6 miles of the valley and in the gorges through which both the main stream and its largest tributary, Amity Creek, flow. A 15-foot waterfall over these rocks in

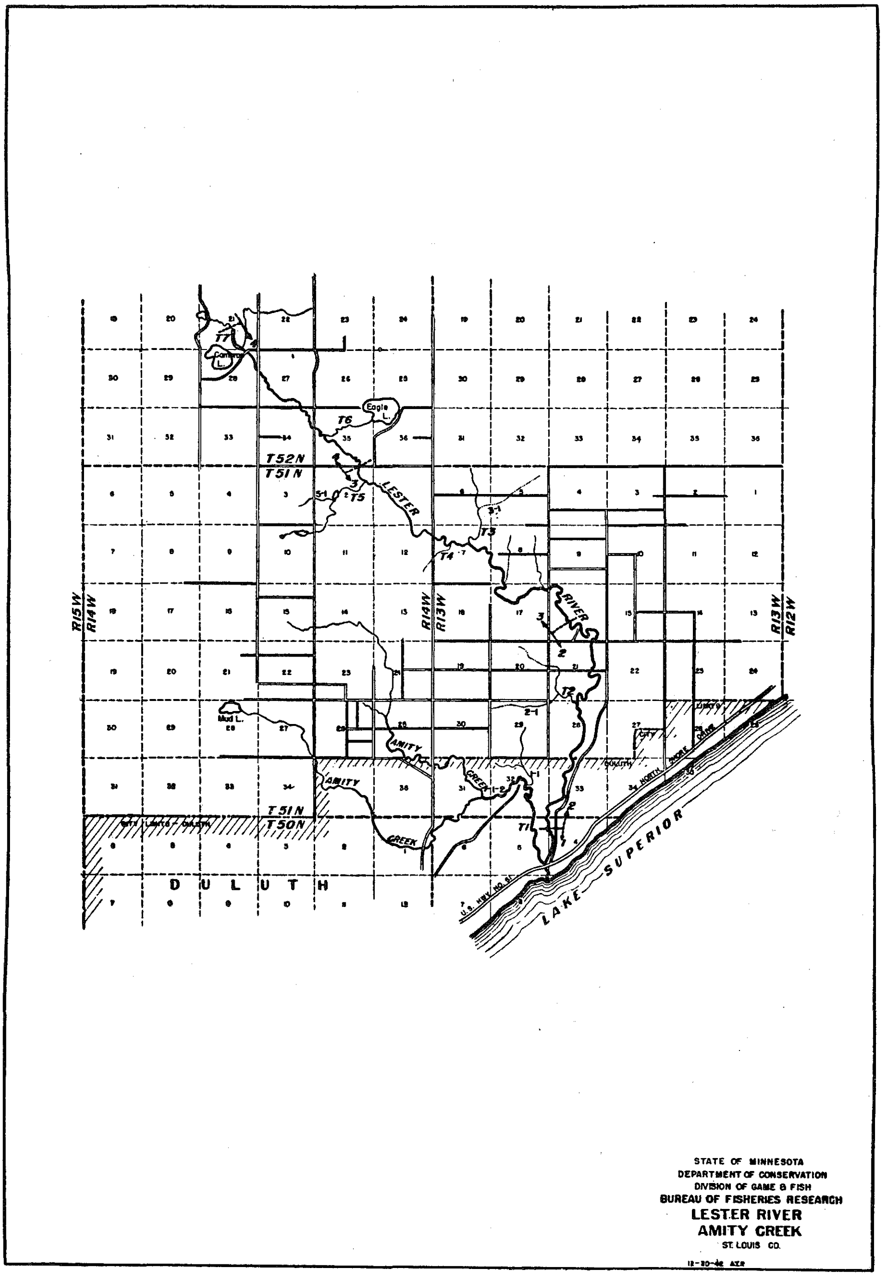

T52N
T51N
T50N
R15W
R14W
R13W
R12W
LESTER
RIVER
AMITY
CREEK
Eagle L.
Mud L.
LAKE SUPERIOR
D U L U T H
CITY LIMITS DULUTH
U.S. HWY. NO. 61
NORTH SHORE DRIVE
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
LESTER RIVER
AMITY CREEK
ST. LOUIS CO.

Figure 4

Lester Park forms a barrier to spawning runs of rainbow trout from Lake Superior.

The main stream rises in swamps and wet woods at an elevation of about 1,400 feet above sea level and, for the upper two-thirds of its course, flows at a moderate rate through second-growth aspen, birch, and conifer forests. In this portion of the drainage basin there is some farmland and wooded pasture. Seepage and runoff from glacial drift, the swamps, and forest duff form the water supply of the stream. Although the Lester River often has a torrential flow in spring, the summer volume in dry years may be less than 2 cubic feet per second near the mouth. At times there is insufficient flow to supply water for aquarium tanks of the federal fish hatchery located at its mouth. It should be pointed out, however, that there is considerable water lost by seepage through joints in exposed basalt rocks of the last few miles. In the heaviest fished sections of this stream the average width is about 15 feet. Most of the stream bottom is covered with boulders and rubble and good pools are scarce. All the tributaries were nearly dry at the time of the 1940 survey. However, Amity Creek (Trib. 1) is reported to supply trout fishing in its upper stretches during years of more abundant rainfall.

The Lester River is of moderate hardness, ranging in total alkalinity from 67.3 to 100.0 parts per million. Dissolved oxygen is adequate and the stream is well suited chemically to trout. There is a small amount of milk, barnyard, and domestic pollution in the lower rocky stretches but, as this section is too warm for trout, the elimination of pollution is a sanitary and esthetic matter.

Twenty-two species of fish were taken from this stream. Forage fish are fairly abundant, the commonest being the blacknose dace and the creek chub. Bottom fauna is light; at all stations less than 1 cubic centimeter per square foot was taken. Plankton, except in the ponded estuary at the mouth, is sparse and largely limited to diatoms. Larger aquatic plants occur infrequently, the most common species being *Potamogeton tenuifolius* and *Callitriche palustris*.

Summer water temperatures show that most of the Lester River is best suited to brown trout and that only a short headwater stretch is cool enough to be good brook trout water. In con-

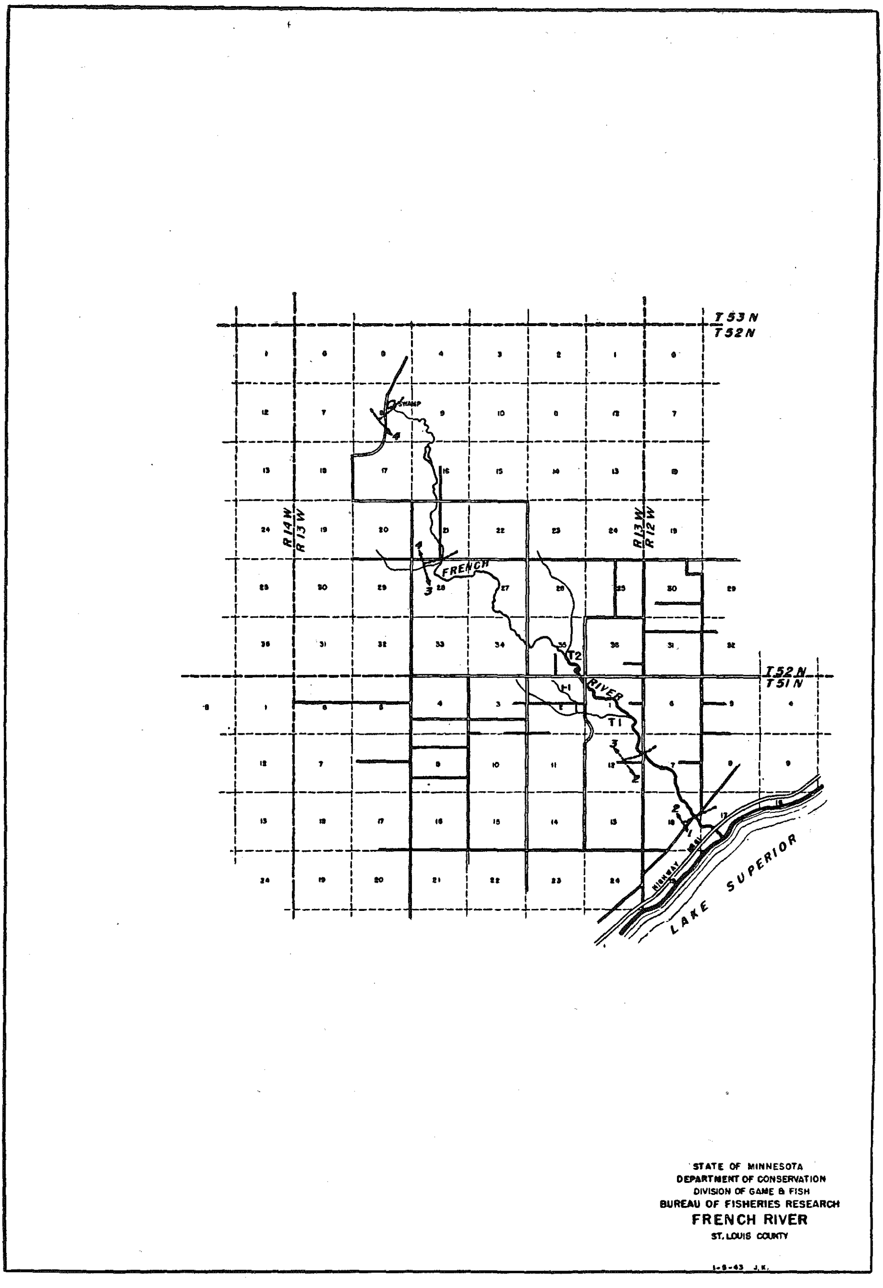

T53N
T52N
R14W
R13W
R13W
R12W
FRENCH
RIVER
T2
T1
T52N
T51N
LAKE SUPERIOR
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
FRENCH RIVER
ST. LOUIS COUNTY

Figure 5

sideration of the heavy fishing to which this stream is subjected, it is recommended that with the exception of the lower rocky portion it be stocked with 7- to 9-inch brown trout. No stocking is recommended for Amity Creek since it will have to be managed in accordance with City of Duluth Park Board policies. All other tributaries are too small to warrant stocking. The headwater brook trout area is too short to be managed separately. Rainbow trout, although they supply some spring fishing at the mouth, are not recommended because of their migratory habits. To utilize the spawning run of rainbow trout, it would be necessary either to blast out the two lower falls or to build fish ladders around them. Neither course is justified by the small benefits that might be gained.

Two types of stream improvement are recommended for the Lester River. Bank cover should be planted in Sections 27, 34, 35, Township 52 North, Range 14 West, to maintain low water temperatures where the stream flows through open meadows. Pools and shelters should be constructed in the stretch from the north boundary of Section 2, Township 51 North, Range 14 West, to the middle of Section 16, Township 51 North, Range 13 West, to provide shelter and deep water for wintering of trout. A considerable amount of cover planting has already been accomplished through the aid of local sportsmen, and other work is scheduled for the near future.

French River

(Fig. 5, Tables 14 and 41)

French River, with its four small tributaries, drains an area of 31 square miles in Townships 51 and 52 North, Ranges 12 and 13 West, St. Louis County. It is one of the smaller North Shore streams and has a total length of 12 miles. It has long been recognized as a good brook trout stream and since 1920 has been the main source of water for a Minnesota Department of Conservation fish hatchery located near its mouth. The underlying igneous rocks of its drainage basin are, for the most part, covered with stony, red glacial soil which is forested with second-growth aspen, birch, and conifers. This stream has its origin in extensive sedge-willow and leatherleaf-sphagnum swamps which contain several fairly large seep springs.

The stream drops at a comparatively gradual rate of about 50 feet per mile and flows over glacial soil for the first 9 miles.

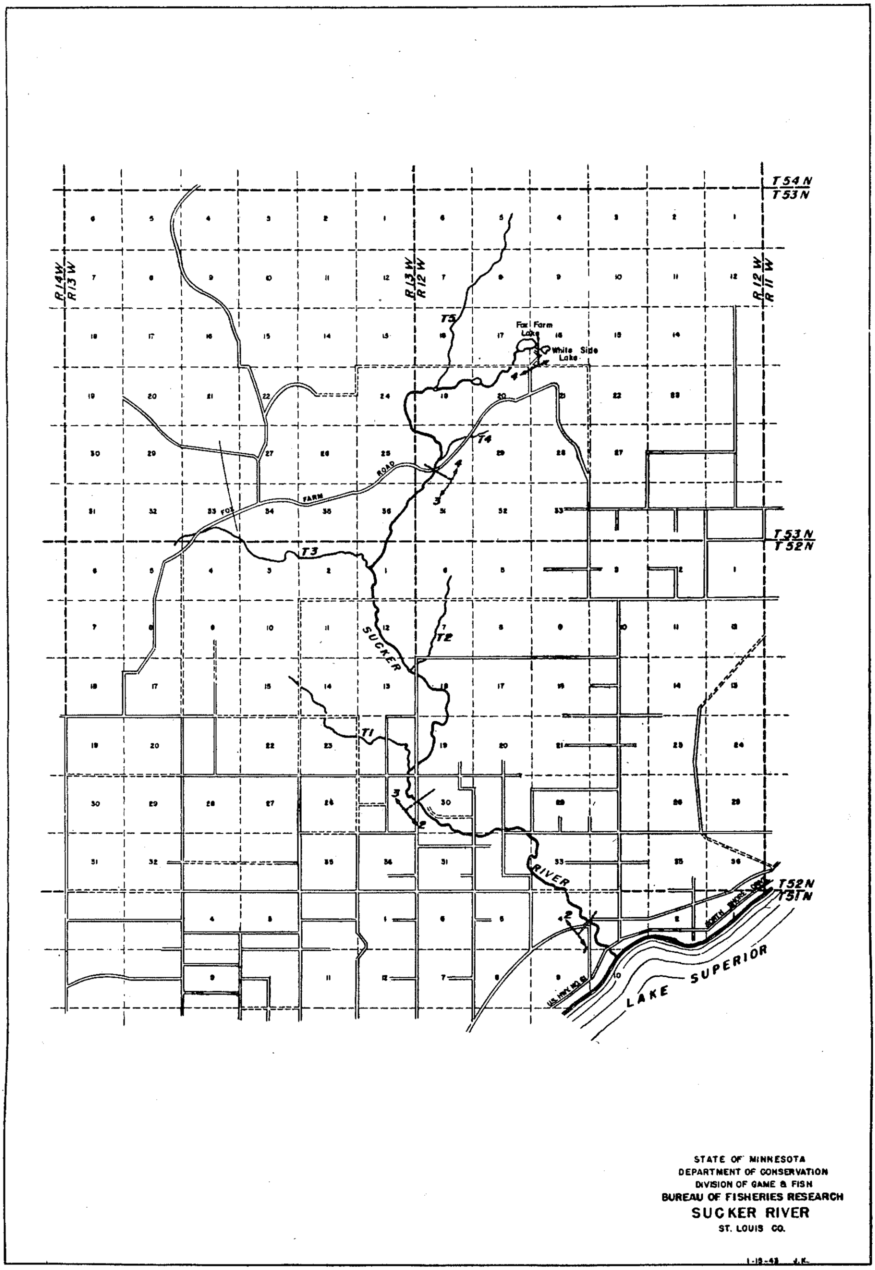

T54N
T53N
R14W
R13W
R13W
R12W
R12W
R11W
T53N
T52N
T52N
T51N
Fox Farm Lake
White Side Lake
T5
T4
T3
T2
T1
FOX FARM ROAD
SUCKER RIVER
LAKE SUPERIOR
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
SUCKER RIVER
ST. LOUIS CO.

Figure 6

Throughout this stretch it varies in width from 4 to 10 feet and has a bottom largely of boulders washed from the glacial till. Natural pools are few. In the lower 3 miles the stream falls precipitously to Lake Superior through a rocky gorge. Although there is great seasonal variation, the normal summer flow rarely exceeds 3 or 4 cubic feet per second near the mouth.

Throughout the system chemical conditions are well suited to trout. The water is moderately hard, having a total alkalinity ranging from 52.5 to 77.5 parts per million. It is slightly alkaline with most of the pH readings ranging around 7.6. Comparison of summer air and water temperatures show this stream to be best adapted to brook trout.

Fourteen species of fish including the brook trout were taken. In addition to these, brown, rainbow, and lake trout have been planted. Forage fish are present in considerable numbers. The commonest species is the blacknose dace. Bottom fauna is sparse and at most stations less than 1 cubic centimeter per square foot was taken. Plankton is scanty and aquatic plants, except for mosses on rocks, are little in evidence.

Because of the proximity of French River to the city of Duluth and because it is crossed by several good roads, it is heavily fished. Although there is considerable natural reproduction of brook trout, it is inadequate to maintain good fishing. Stocking with 7- to 9-inch brook trout is recommended.

It is recommended that occasional pools be constructed in the stretch extending from the old beachline of glacial Lake Duluth (S. 1, T. 51 N., R. 13 W.) to a mile above the Pioneer Road bridge (S. 21, T. 52 N., R. 13 W.). Such pools will increase the carrying capacity of the stream for trout by providing shelter in summer and deep water in which they can survive the winter. Planting of trees and shrubs in a few exposed areas is desirable.

Sucker River

(Fig. 6, Tables 15 and 42)

Sucker River drains an area of 37 square miles in Townships 51, 52, and 53 North, Ranges 12 and 13 West, St. Louis County. The drainage basin is underlain with Keweenawan igneous rocks which are covered with stony glacial soil above the glacial Lake Duluth beachline in Section 30, Township 52 North, Range 12

West, and below with stony, waterworked soils and lake deposited clays. There are two extensive exposures of the underlying basalt rock in the lower 5 miles, the first in Section 30, Township 52 North, Range 12 West, and the second beginning about a mile from the shore and extending to the mouth. This lower stretch is an area of cascades and waterfalls.

The Sucker River rises in the Highland Moraine at an elevation of about 1,500 feet above sea level and has two main sources, a stream flowing from Whiteside Lake and a feeder stream draining swamps and wet forests in this same area. From the junction of these two headwater streams, the Sucker River flows at a fairly rapid rate 15 miles to Lake Superior. The drainage basin is covered with a mixed second-growth forest of birch, aspen, and conifers. Some of the forest land has been cleared and is cultivated or pastured. In Sections 18 and 19, Township 52 North, Range 12 West, the stream has an average width of about 16 feet. Its bottom is largely of rubble and boulders. Below the glacial Lake Duluth beachline (S. 30, T. 52 N., R. 12 W.), the stream falls rapidly over bedrock, modified drift, and lacustrine deposits to Lake Superior. Only a small amount of water is supplied in dry periods by the lower tributaries and by seepage along the lower portion of its course. The summer flow in 1940 was found to average 4.2 cubic feet per second at the headwaters and to be only 8.7 feet per second near the mouth.

Waters of the Sucker River are harder than those found in any other North Shore stream. They range in total alkalinity from 87.5 to 95.0 parts per million. In other respects they are quite similar to the neighboring streams and entirely favorable to trout.

Twelve species of fish occur in this stream. These include brown, brook, and rainbow trout and nine species of forage fish of which the black-nose dace and the creek chub are most frequent. Bottom fauna production is low with all samples being below 1 cubic centimeter per square foot. Plankton is sparse and larger aquatic plants are of occasional occurrence. The commonest species are the red alga, *Lemanea,* in falls and rapids and *Potamogeton tenuifolius* on clay and gravel.

On the basis of water temperatures the Sucker River can be divided into two sections, the 4.5 miles of headwaters above the

Fox Farm road, which are best suited to brook trout, and the 8 miles below this point which are best suited to brown trout. Silting from clay deposits and high water temperatures make the waters below the old beachline generally unfavorable to trout.

As the Sucker River is subjected to a moderate fishing load, it is recommended that the lower mile of Sector 4 be stocked with fingerling and 7- to 9-inch brook trout and 4.5 miles of Sector 3 with fingerling brown trout and some 7- to 9-inch fish of the same species. No stocking is recommended for the precipitous stretch near the mouth.

The improvement recommended consists of pool and shelter construction with appropriate maintenance devices in those suitable portions of the main stream that lie within a mile of roads (S. 25, 13, 12, 18, 19, T. 52 N., R. 12, 13 W.). The planting of trees and shrubs as bank cover is recommended for Sections 30, 31, 36, and 1, Townships 52 and 53 North, Ranges 12 and 13 West, and also for isolated open areas elsewhere.

Knife River

(Fig. 7, Tables 16 and 43)

The Knife River drains an area of 90 square miles in Townships 52, 53, and 54 North, Ranges 11 and 12 West, St. Louis and Lake Counties. Its entire drainage basin is underlain with igneous Keweenawan rocks. Basalt flows of this series are exposed at the low falls and in the stream bed near the mouth. The outcropping edges of these rock formations determine the direction of the lower portion of the main stream and cause it to flow nearly parallel to the lakeshore. Covering the rocks which lie below the ancient beachline of glacial Lake Duluth is a strip of lake-deposited soils about 4 miles wide. This area of clay, sand, and gravel soils is relatively level and a considerable portion is farmed. Above the ancient beachline the rocks are covered with rolling hills of stony red glacial soil on which is a second-growth forest of aspen, birch, and conifers. In the depressions between the morainic hills are swamps and wet woods that are the stream's main source of water supply. The flow is augmented in the upper stretches by a considerable number of small seep springs which rise at the base of the moraines and flow for a short distance as forest rills.

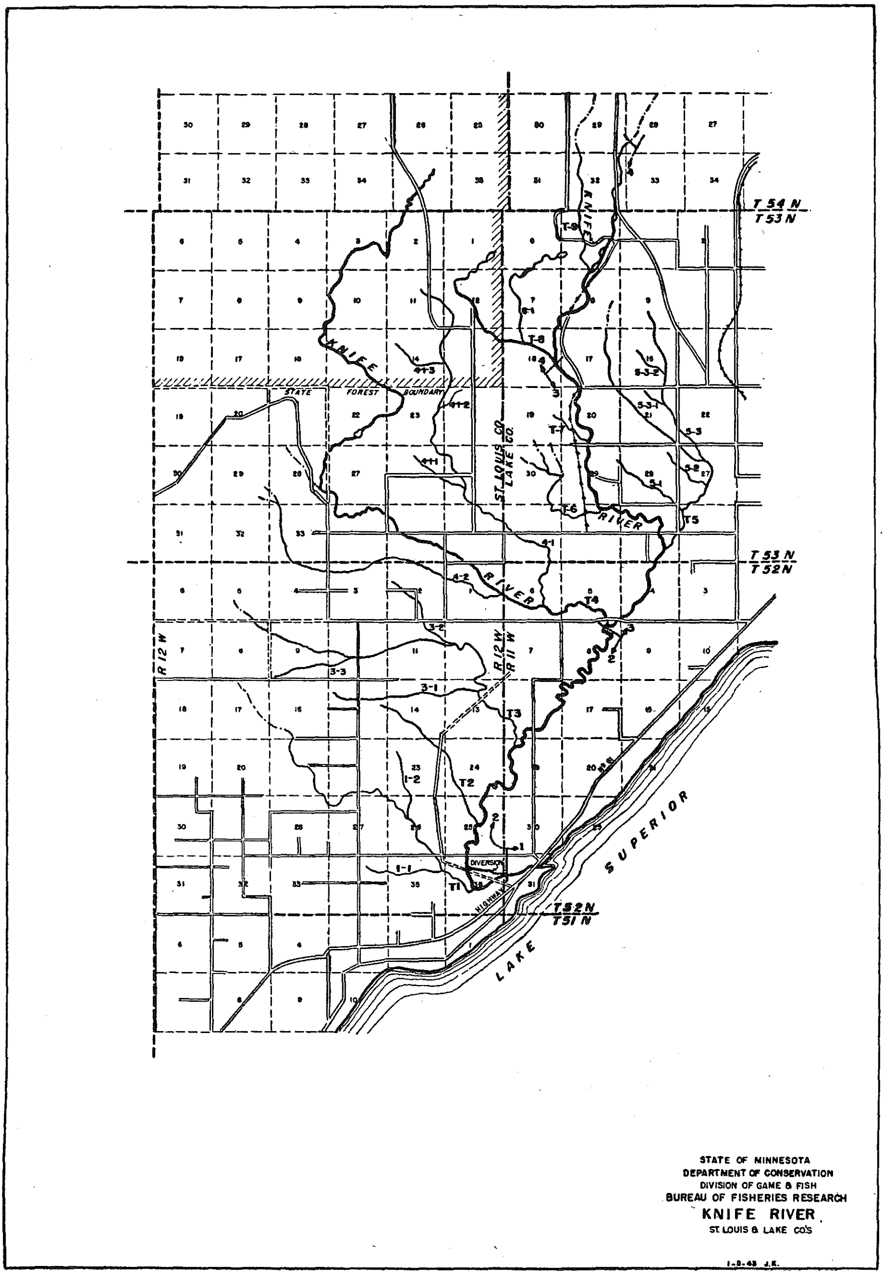

STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
KNIFE RIVER
ST LOUIS & LAKE CO'S
LAKE SUPERIOR
STATE FOREST BOUNDARY
ST LOUIS CO
LAKE CO.
T 54 N
T 53 N
T 52 N
T 51 N
R 12 W
R 11 W
DIVERSION
HIGHWAY

Figure 7

The water of the Knife River system is moderately hard, ranging in total alkalinity from 47.5 to 70.0 parts per million, and is slightly alkaline, having a median[8] pH reading of 7.5. Analyses for dissolved oxygen and other dissolved substances show that the water is chemically well suited to trout.

Thirteen species of fish including brook, brown, and rainbow trout occur in this stream. The commonest forage fish are the common sucker, the creek chub, and the blacknose dace. Bottom fauna and plankton are sparse and aquatic plants of only occasional occurrence. *Potamogeton tenuifolius* and *Callitriche palustris* are the commonest aquatic plants in the wider stretches, and the water moss (*Fontinalis gigantea*) the most frequent species in the smaller, colder streams.

The Knife River has its source in swamps in Section 28, Township 54 North, Range 11 West, and flows southward a distance of about 3 miles as a small, cold stream ranging from 4 to 6 feet in width. This portion of the stream, which is locally known as Spring Creek, is heavily shaded and has a bottom of boulders and gravel. After passing through a short stretch of beaver ponds, it is joined in Section 8, Township 53 North, Range 11 West, by a small, cold tributary (Trib. 9) that flows nearly parallel to the main stream. Below this junction the stream flows 2 miles to the mouth of McCarthy Brook (Trib. 8) in Section 18. This portion is a cold, well-shaded stream about 12 feet in width with a bottom of about 50 per cent boulders and 50 per cent sand and gravel. McCarthy Brook is a cold, well-shaded stream about 6 feet wide and similar in other characteristics to those stretches of the upper Knife River already described. These streams are well suited to brook trout, and stocking with 7- to 9-inch fish is recommended. Fingerling brook trout should also be stocked in McCarthy Brook to augment the natural reproduction.

Between the entrance of McCarthy Brook in Section 18 and the junction of the main stream with the Little Knife River (Trib. 4) in Section 8, Township 52 North, Range 11 West (Sector 3), the Knife River is a fast, well-shaded stream 20 to 25 feet wide with a bottom largely of boulders. Because it is heavily fished and tends to become too warm for brook trout, stocking with 7- to 9-inch brown trout is recommended. The tributaries entering

[8]The median pH reading is given as the best expression of the most usual concentration of hydrogen ions.

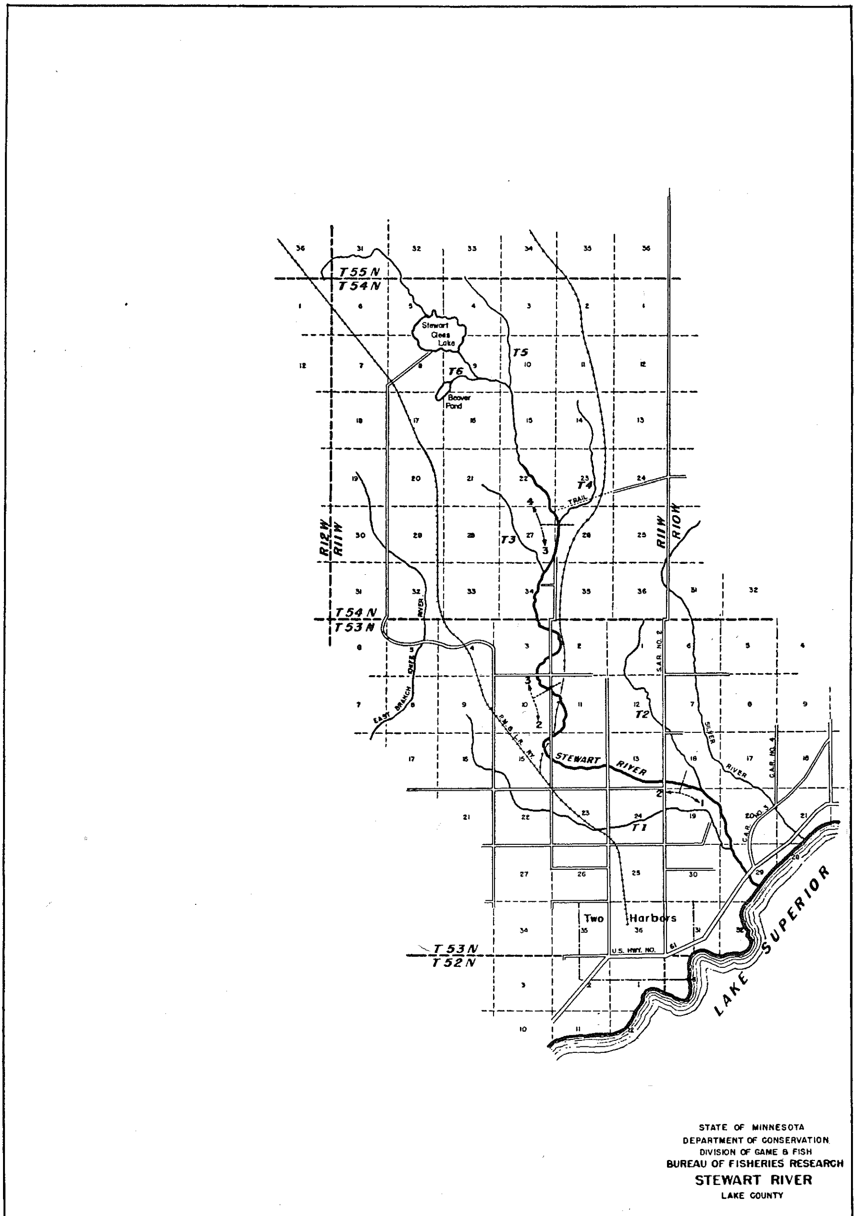

T55N
T54N
Stewart Class Lake
Beaver Pond
T5
T6
T4
T3
T2
T1
TRAIL
R12W
R11W
R11W
R10W
T54N
T53N
T53N
T52N
EAST BRANCH STEWART RIVER
STEWART RIVER
SILVER RIVER
S.A.R. NO. 2
C.A.R. NO. 4
C.A.R. NO. 3
D.M. & I.R. RY.
Two Harbors
U.S. HWY. NO. 61
LAKE SUPERIOR
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
STEWART RIVER
LAKE COUNTY

Figure 8

the main stream in this sector (Tribs. 5, 6, and 7) are too small to warrant stocking.

Below the junction of the Knife River and the Little Knife River (Sectors 1 and 2) no stocking is recommended. This stretch is wide and warm and is suited only for spring fishing of rainbow trout. The falls near the mouth are low enough to permit a spawning run of this species from Lake Superior. The tributaries below the Little Knife River (Tribs. 1, 2, and 3) all lie below the Lake Duluth beachline and flow through much farm land. They are too warm and of too inconstant flow to be trout streams.

The Little Knife River (Trib. 4) has its origin in swamps and wet woods in Section 35, Township 54 North, Range 12 West, and flows for the upper 6 miles through state forest lands where it is relatively inaccessible and little fished. Below Section 27, Township 53 North, Range 12 West, it is a well-shaded stream about 9 feet wide with a boulder bottom, and in the lower 6 miles flows through much cleared and farm land. It is subject to considerable variation in summer flow. Because fluctuations are great and the water is warm, it is recommended that the lower stretches of the Little Knife River be stocked with 7- to 9-inch brown trout. Brook trout are to be stocked only in the headwaters. The main tributary of the Little Knife River (Trib. 4-1) is a poorly shaded stream about 5 feet wide flowing mostly through cleared land. No stocking is recommended for this tributary.

Stream improvement recommended for the Knife River system is of two general types, the planting of trees and shrubs for bank cover, and the construction of pools and shelters in the better trout stretches to provide shelter and wintering places for fish. The stretches recommended for improvement are the main Knife River from Section 33, Township 53 North, Range 11 West, to the source, and McCarthy Brook in this same area. Much of the improvement work on these streams has already been completed (page 147). Stream improvement is also recommended for the Little Knife River in Sections 6, 1, 36, 35, 34, and 27, Townships 53 and 52 North, Ranges 11 and 12 West.

Stewart River

(Fig. 8, Tables 17 and 44)

The Stewart River drains an area of 33 square miles in Townships 53, 54, and 55 North, Ranges 10, 11, and 12 West. Except for a fraction of a mile in its extreme headwaters, it lies entirely in Lake County. It has a total length of 19.75 miles and enters Lake Superior a short distance northeast of Two Harbors. The six small tributaries, of which the Little Stewart River (Trib. 1) is the largest, all have inconsequential and intermittent summer flows. The main source of water for Stewart River is Stewart Lake, a shallow spring-fed lake near the headwaters.

The gently rolling country drained by the Stewart River is underlain with Keweenawan igneous rock on which are deposited glacial and lacustrine soils. These soils support a second-growth forest broken here and there by scattered farms. In the lower 2.5 miles (Sector 1) the stream flows rapidly over exposed bedrock and several low falls, and in the 7.5 miles above this stretch flows at a moderate rate over a bottom largely of rubble, gravel, and sand. The average width in this area is about 12 feet.

The water is chemically favorable to trout. It is slightly softer than that of the neighboring streams, ranging in total alkalinity from 35.0 to 67.5 parts per million. Oxygen content is high and the concentration of other dissolved substances suited to the production of trout.

In the single collection of fish taken from this stream eight species, including brook, brown, and rainbow trout, occurred. The most common forage fish are the blacknose dace, the longnose dace, the creek chub, the common sucker, and Nachtrieb's dace. Large numbers of small naturally-spawned rainbow trout were seen in the lower 2 miles. Larger aquatic plants, of which *Potamogeton tenuifolius* and *Sparganium chlorocarpum* are the most frequent, cover less than 5 per cent of the bottom. Water moss (*Fontinalis*) is fairly common in the tributaries.

Under present conditions the Stewart River is essentially a brown trout stream and should be managed and stocked as such. Because this stream is not far from Duluth and Two Harbors, stocking with 7- to 9-inch fish is recommended. It is not necessary to stock the lower 2.5 miles (Sector 1) as there is considerable reproduction of rainbow trout from the Lake Superior spawning run. No stocking is recommended above Sector 3 because the stream is relatively inaccessible and little fished.

Stream improvement is recommended for the 7.5 miles of stream extending from Section 18, Township 53 North, Range 10

West, to Section 22, Township 54 North, Range 11 West. This stretch includes all of Sectors 2 and 3 and less than a mile of the lower portion of Sector 4. The recommended improvement is of three types: the planting of trees and shrubs in the farmed and open stretches to increase the shade and thus maintain lower water temperatures in Sections 3 and 10, Township 53 North, Range 11 West; the construction of wing deflectors to concentrate the flow in a few areas of wide riffles; and the construction of shelters and pools with structures for maintaining them to provide cover and resting places for the fish. A number of beaver dams on the lower part of Sector 4 should be opened to prevent the warming of the water in the headwater area.

The Stewart River is potentially one of the best small trout streams on the North Shore and would be markedly benefited by such an improvement program. It is likely that with the completion of the recommended improvement it could be managed for brook trout.

Encampment River

The Encampment River drains an area of 18 square miles in Townships 53 and 54 North, Range 10 West, Lake County. It rises in an area of spruce swamps and flows for a distance of about 9 miles through wooded country. In the summer of 1940 this stream was nearly dry and was unsuited to trout. This condition was similar to that found by Surber in September, 1924. No stocking or improvement is recommended as this stream is of value only for spring rainbow trout fishing.

Gooseberry River

(Fig. 9, Tables 18 and 45)

The Gooseberry River drains an area of 97 square miles in Townships 54, 55, and 56 North, Ranges 9, 10, and 11 West, Lake County. In the upper portion of the drainage basin the underlying Keweenawan igneous rocks are mantled by rolling hills of stony red glacial soil and in the lower portion by a strip of waterlain soils about 5 miles wide paralleling the shore. Almost the entire drainage basin is covered with second-growth aspen, birch, and coniferous forest.

Three years of flow gauging on the stream by the United States Army Engineers, 1928-1931, show a variation near the

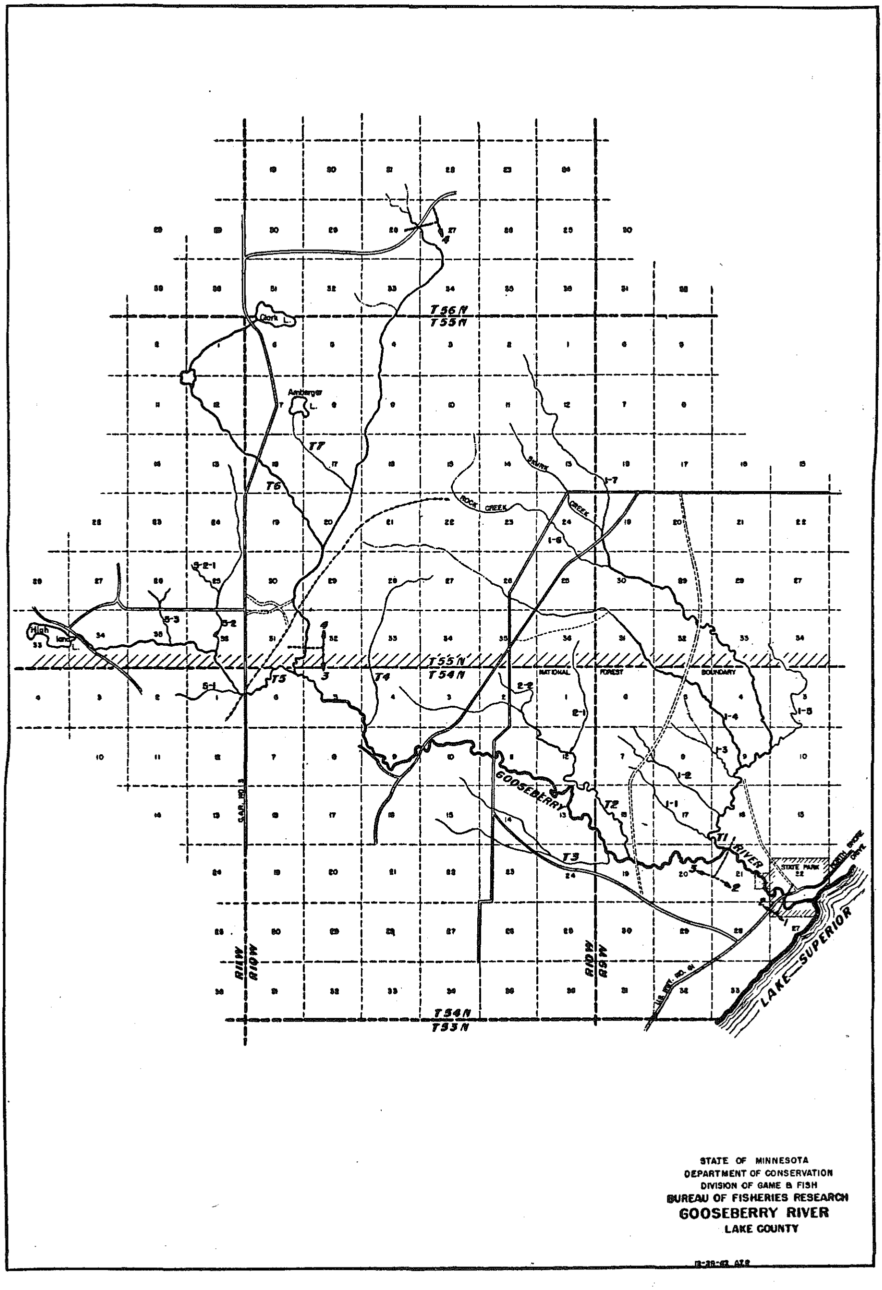

T56N
T55N
T54N
T53N
R11W
R10W
R9W
Clark L.
Amberger L.
Highland L.
ROCK CREEK
SKUNK CREEK
GOOSEBERRY
RIVER
NATIONAL FOREST BOUNDARY
STATE PARK
LAKE SUPERIOR
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
GOOSEBERRY RIVER
LAKE COUNTY

Figure 9

mouth from less than 2 to 1,270 cubic feet per second. During this period the lowest flow occurred during February and August (U. S. War Dept., 1932c). In the course of the 1940 survey the lowest flow recorded near the mouth was 7.2 cubic feet per second. It should be pointed out, however, that a considerable amount of water is lost by seepage as the stream approaches its mouth and that some of the headwater streams of this system have sufficient water for trout when the lower stretches are nearly dry.

The Gooseberry River has two main branches, the east branch (Trib. 1) and the main stream or west branch, which join in Section 21, Township 54 North, Range 9 West. Below this junction the river flows over boulder-strewn bedrock as a shallow stream about 20 feet wide. Near the lake, in Gooseberry Falls State Park, the stream plunges 100 feet in a series of three waterfalls over the exposed trap rock.

Chemically, the water of the Gooseberry River system is well suited to trout. It is moderately hard, ranging in total alkalinity from 40.0 to 70.0 parts per million, and is slightly alkaline, having a median pH reading of 7.6. Fifteen species of fish including brook, brown, and rainbow trout occur in the system. Forage fish are fairly abundant and are represented in the collections by 12 species, the commonest of which are the blacknose dace and the creek chub. Plankton is sparse and largely limited to diatoms. In the main stream the larger aquatic vegetation is confined to scattered plants of pondweed and bur-reed and the red alga, *Lemanea,* is common on rocks in rapid water. Bottom fauna volumes show this stream to be of the lowest food grade.

The east branch of the Gooseberry River rises from the junction of Rock Creek (Trib. 1-6) and Skunk Creek (headwaters of Trib. 1) in Section 30, Township 55 North, Range 9 West. These two streams have their headwaters in wooded swamps. Above their point of junction, Rock Creek is about 7 feet and Skunk Creek about 6 feet wide. At low water stages the combined flow of these tributaries continues for a mile or so when it begins gradually to seep away. At these low stages very little water reaches the main river. Rock and Skunk creeks are brook trout streams and it is recommended that they be stocked with 7- to 9-inch fish. Similarly, the east branch should be stocked for about a mile below the junction of these two feeders. Although stream improvement is less essential on these streams than on portions

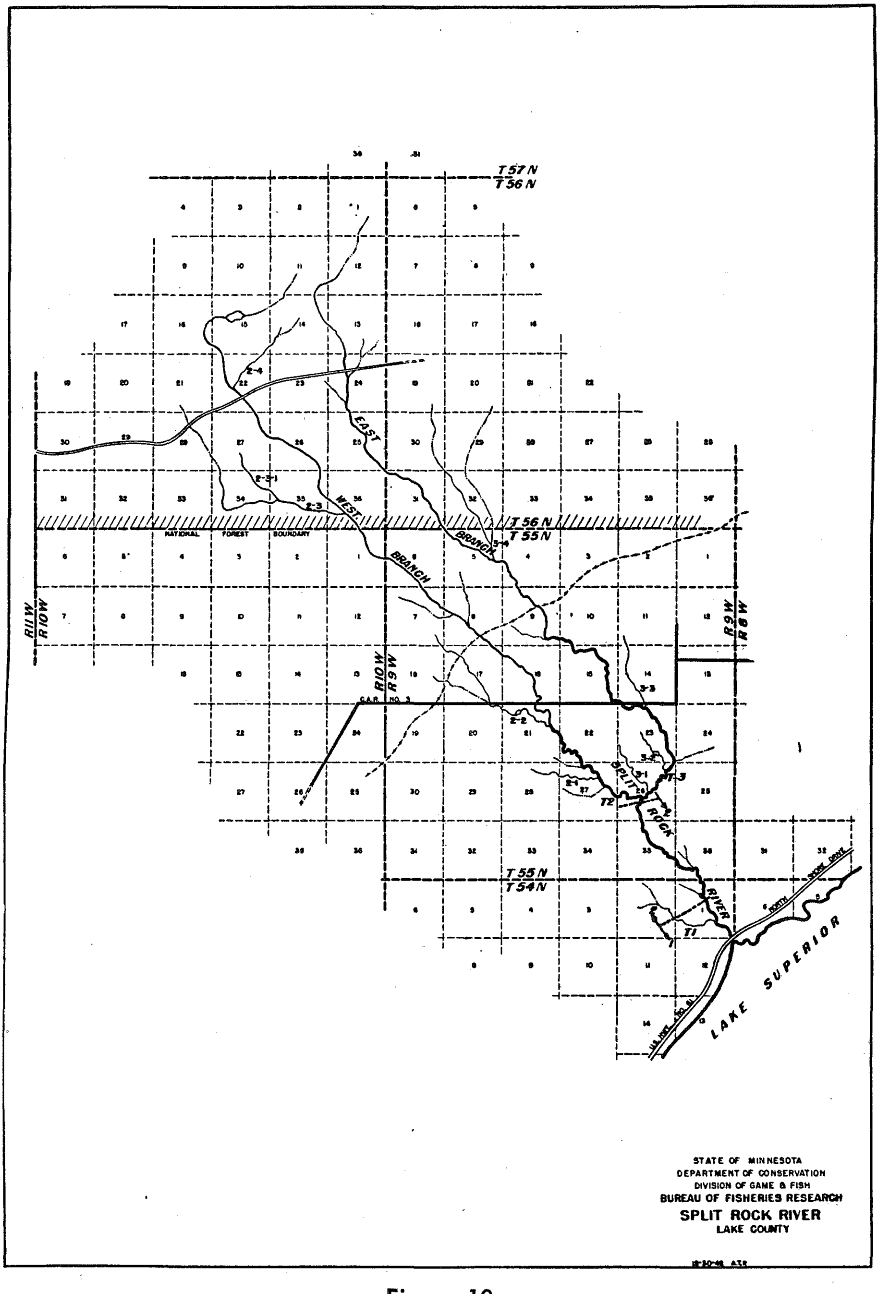

STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
SPLIT ROCK RIVER
LAKE COUNTY
EAST BRANCH
WEST BRANCH
SPLIT ROCK RIVER
LAKE SUPERIOR
T 57 N
T 56 N
T 55 N
T 54 N
R 11 W
R 10 W
R 9 W
R 8 W
NATIONAL FOREST BOUNDARY
NORTH SHORE DRIVE
U.S. HWY. NO. 61

Figure 10

of the west branch, the construction of some pools and deflectors in Sections 23, 24, 25, 13, 19, and 30, Township 55 North, Ranges 9 and 10 West, is recommended.

The main Gooseberry River, or west branch, rises at about 1,700 feet above sea level in swamps, and in its upper stretches is fed by seepage from bogs and wet woods and by the tributaries draining Clark, Amberger, and Highland Lakes. It is a cold stream and should be stocked and managed for brook trout from its junction with the east branch (Trib. 1) to about 2 miles above its junction with the tributary flowing from Highland Lake (Trib. 5). This section of the stream averages about 20 feet in width, has ample shade, and a bottom of boulders and rubble. Since this stretch is heavily fished, the stocking of 7- to 9-inch trout is recommended. The lower 2.8 miles of the Highland Lake tributary likewise should be managed for brook trout and stocked with fingerlings.

Recommended stream improvement for the main Gooseberry River consists of the construction of pools and shelters, with appropriate devices for maintaining them, in the stretch extending from the Lake Duluth beachline (S. 12, T. 54 N., R. 10 W.) to the junction of the main stream with Tributary 5 in Section 6, Township 54 North, Range 10 West. Similar improvement is recommended for the Highland Lake tributary in Sections 6, 1, and 23, Townships 54 and 55, Ranges 10 and 11 West. Above the Highland Lake tributary, light improvement is recommended in Sections 31, 32, 30, and 29, Township 55 North, Range 10 West. Shade is ample so the planting of cover trees and shrubs is not necessary.

Split Rock River

(Fig. 10, Tables 19 and 46)

The Split Rock River has an elongate drainage basin of 40 square miles in Townships 54, 55, and 56 North, Ranges 9 and 10 West, Lake County. The two main branches, the east and west, join at the fork in Section 26, Township 55 North, Range 9 West, and from this junction the main stream flows southeastward a distance of 2.4 miles to Lake Superior. About a mile below the fork the stream enters an extensive area of red slate cascades which are terminated in the middle of Section 1 by a fall over a basalt sill. In this stretch the stream falls about 400 feet before entering the wide and nearly level lower valley.

Above the fork the underlying igneous rocks are covered for the first 1.5 miles with poorly differentiated stony, water-worked soil, and above this point with stony glacial soil. The entire area supports a heavy second-growth hardwood and coniferous forest and at some places the stream banks are covered with nearly impassable alder thickets. This second-growth forest has, for the most part, developed in the last 20 years, the drainage basin having been previously logged and burned over (Surber, 1924). Above the fork the stream bed is generally covered with boulders and angular basalt blocks, most of which are less than a foot in diameter. Good pools are scarce and the stream has little variation in depth.

Both branches rise in swamps about 1,600 feet above sea level and increase in width from about 6 feet near the headwaters to about 15 feet near their junction. Despite their similar width, the west branch (Trib. 2) has nearly twice the flow of the east branch (Trib. 3), and it is reported that this latter branch was entirely dry in 1937. At present it has several beaver dams in its lower stretches. Bud Creek (Trib. 2-2) which enters the west branch about one-half mile below Highway No. 1 is the only other tributary suited to trout. In the summer of 1940 it had an average flow of 1 cubic foot per second. Flow readings covering a period of years are not available for the Split Rock River, but from those taken in 1940 it appears that at low stages this stream has a summer flow approximating that of the Gooseberry River.

The water of the Split Rock River is moderately hard, ranging in total alkalinity from 27.5 parts per million in the main stream to 82.5 parts per million in Bud Creek. It is slightly alkaline, has sufficient dissolved oxygen, and is otherwise suited chemically to trout.

Plankton is sparse and larger aquatic plants are mostly limited to mosses and liverworts on the rocks of the headwater streams. Rated on the abundance of bottom fauna, this stream is of the lowest food grade. Thirteen species of fish are known to be present in this system but forage fish are scarcer than in many of the other North Shore streams. The commonest species, the common sucker, the creek chub, and the longnose dace, are found in abundance only below the lower falls.

Although there is some brook trout fishing in the lower stretches of the two main branches, water temperatures show that both are best suited to brown trout. It is therefore recommended that they be stocked with 7- to 9-inch brown trout. Fingerling brook trout are recommended for the headwaters of both branches and 7- to 9-inch brook trout for Bud Creek. No stocking is recommended for the main stream below the junction of the two branches. There is considerable natural reproduction of brown trout in the stretch of river between the lake and the lower falls.

Shade is ample and planting of cover trees and shrubs is unnecessary. Since the stream is fairly shallow and uniform in depth, the construction of pools and shelters is recommended. Stretches to be improved are the west branch from the forks to a mile above the Alger-Smith railroad grade (S. 7, T. 55 N., R. 9 W.) and the east branch from the forks to a mile above Highway No. 1 (S. 15, T. 55 N., R. 9 W.). Similar improvement is recommended for the lower portion of Bud Creek. Some beaver control and elimination of old beaver dams may be necessary in the lower stretches of the east branch.

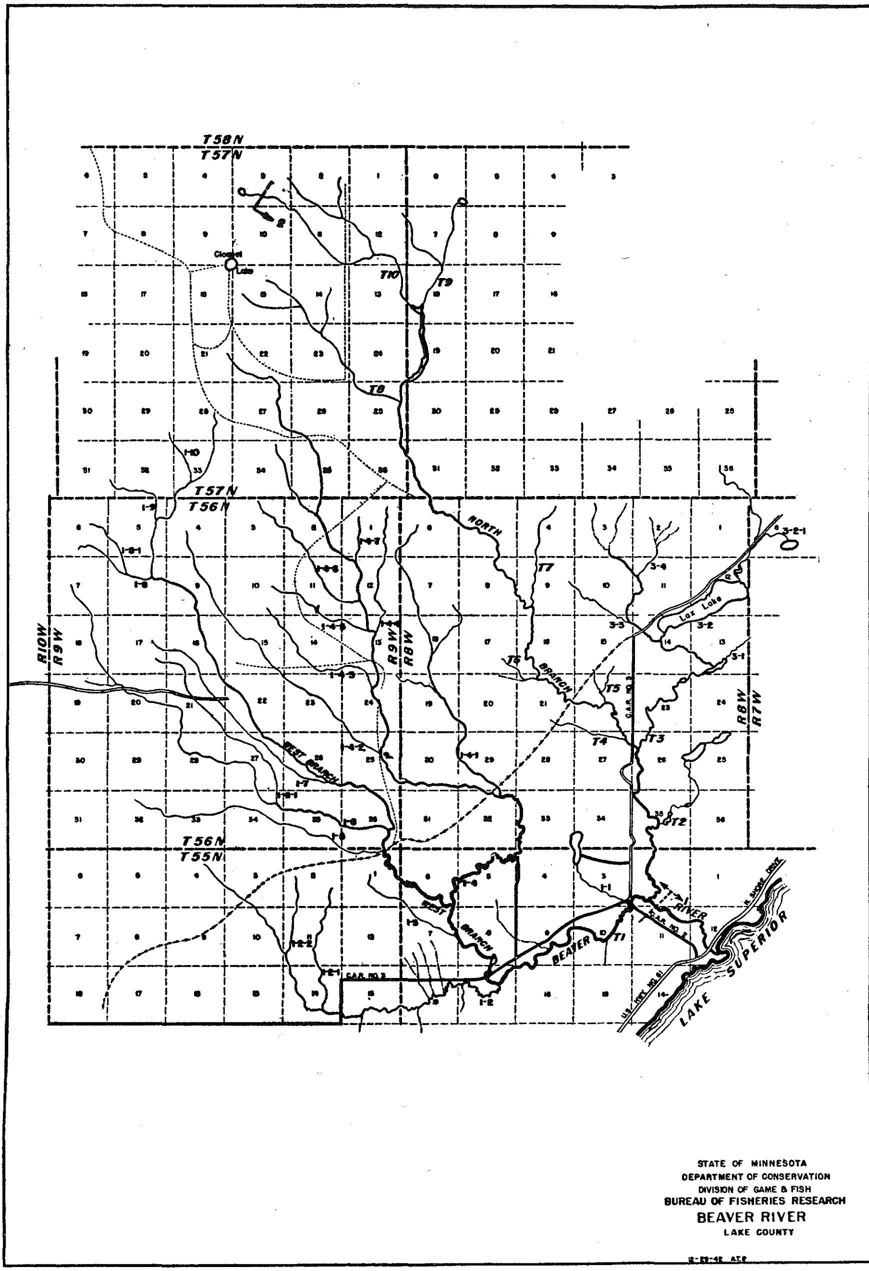
Beaver River

(Fig. 11, Tables 20 and 47)

The Beaver River has a drainage basin of 135 square miles in Townships 55, 56, and 57 North, Ranges 7, 8, and 9 West, Lake County. Its principal tributary, the west branch (Trib. 1), joins the main stream or north branch in Section 2, Township 55 North, Range 8 West, 1.6 miles above Lake Superior. Below this junction there is an area of large, quiet, gravel-bottomed pools followed by a drop of 300 feet over a series of falls.

Like most other North Shore streams, the Beaver River drains an area largely covered with deposits of stony glacial soil. In the lower portion of its drainage basin is a strip of lake-deposited sand, gravel, and clay and a considerable amount of exposed bedrock. The underlying rocks of the lower portion of the system are largely Beaver Bay diabase with scattered light colored knobs of anorthrosite (Grout and Schwartz, 1939).

Surface formations are covered with second-growth hardwood and coniferous forest which supply shade, varying from none near the mouth to 90 per cent near the headwaters. There are a few dairy and truck farms in the lower portion of the drainage basin and a resort on Lax Lake.



T58N
T57N
T56N
T55N
R10W
R9W
R8W
R7W
Lax Lake
NORTH BRANCH
WEST BRANCH
BEAVER RIVER
LAKE SUPERIOR
C.A.R. NO. 3
U.S. HWY. NO. 61
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
BEAVER RIVER
LAKE COUNTY

Figure 11

The Beaver River is subject to great variation in flow. Five years of records show a maximum flow near the mouth of 2,120 cubic feet per second and a minimum flow of about 2 cubic feet per second. It has been estimated by United States Army Engineers that "the average long-term yield of the river is about 110 cubic feet per second" (U. S. War Department, 1932b).

Waters of the Beaver River system are softer than the more southerly streams, having a range of total alkalinity varying from 20.0 to 57.5 parts per million and a median pH reading of 7.4. Summer oxygen content, while not high, is ample and the water in other respects is well suited chemically to trout.

There are 22 species of fish found in the Beaver River. Forage fish are rare in the upper fast stretches and are limited to a few muddlers (*Cottus*), blacknose dace, and creek chubs. In headwater pools the commonest species are the redsided dace, the fivespine stickleback, and Nachtrieb's dace. The ponded water near the mouth has forage fish typical of Lake Superior. Above this area in the lower and slower stretches of the main stream and west branch, the common shiner and the common sucker are fairly abundant. Although brook trout have been found in this river system since the time of settlement, and portions of it have long been stocked, only a few trout were seen during the 1940 survey and these in the vicinity of recent plantings.

Plankton is sparse and largely limited to diatoms. Larger aquatic plants are scarce and confined to a few species in the slower stretches. Mosses and liverworts are common on rocks in the smaller feeders. Bottom fauna is scarce but the crayfish (*Cambarus virilis*) is fairly abundant in the graveled-bottom pools of the lower stretches.

The main Beaver River, or north branch, rises in swamps near the Cloquet Lake fire tower in Township 57 North, Range 9 West, and flows southeastward, crossing the Alger-Smith Railroad grade in Section 21, Township 56 North, Range 8 West. At this point it is a well-shaded stream about 10 feet wide with a stony bottom. It is best suited to brown trout. This stream is subjected to moderately heavy fishing for about one-half mile above the Alger-Smith Railroad grade and below it as far as old Highway No. 1. Below Highway No. 1, Cedar Creek (Trib. 3), which is fed by Lax Lake outlet, joins the main stream. From this junction to the falls in Section 2 the stream is heavily fished, especially in spring. It is recommended that the main stream be stocked with 7- to 9-inch brown trout from one-half mile above the Alger-Smith Railroad grade to the falls in Section 2. Stream improvement consisting of pool construction is recommended from the falls in Section 35, Township 56 North, Range 8 West, to one-half mile above the Alger-Smith Railroad grade.

Cedar Creek (Trib. 3) is heavily fished from its mouth to Lax Lake. It is a stream about 12 feet wide that is best suited to brook trout. Above the Lax Lake outlet, Cedar Creek has an average width of about 8 feet and is fairly heavily fished. The construction of pools is recommended from the mouth to a mile above Highway No. 1. Seven- to 9-inch brook trout should be stocked in the entire tributary. Nicado Creek (Trib. 3-2), which is fed by Nicado Lake and enters the east end of Lax Lake, is cold enough for brook trout but had a very small flow at the time of the survey. This creek has supplied some trout fishing in the past and may be worth stocking if future observations show an increase in flow.

The west branch of the Beaver River (Trib. 1) rises in moraines in Township 57 North, Range 9 West, at an elevation of about 1,700 feet above sea level. In the upper part of its drainage area it has one major tributary, Big Thirty-nine Creek (Trib. 1-4), which enters in Section 6, Township 55 North, Range 8 West, a short distance below the upper beachline of glacial Lake Duluth. Above this junction the main stream and the tributary are similar with well shaded channels about 10 feet wide. These streams are warm and best suited to brown trout. Because in their upper stretches they flow through inaccessible swamps and alder bottoms, they are little fished and are very difficult to stock. There is some fishing on Big Thirty-nine Creek in Sections 32, 33, 4, and 5, Townships 55 and 56 North, Range 8 West. Stocking with fingerling brown trout is recommended. In the spring the lower portion of the west branch is also fished, especially near its junction with the main stream in Sections 10 and 2, Township 55 North, Range 8 West. Pool construction is desirable on Big Thirty-nine Creek in Sections 32 and 5, Townships 55 and 56 North, Range 8 West.

The southwest branch (Trib. 1-2) of the west branch is a small stream about 5 feet wide. In its lower stretches it flows through meadow and hay land and in its upper stretches through areas flooded by beaver. It supplies spring fishing in Sections 14, 13, and 18, and can be best stocked with 7- to 9-inch brown trout. No improvement is recommended.

The Beaver River system presents two special problems. Headwater streams arise in alder bottoms having a shallow deposit of peat, often less than 2 feet in thickness, and are warm from their sources. No amount of stream improvement will lower the water temperature sufficiently to make most of the streams good brook trout water. Stocking is extremely difficult in the upper stretches of both the main stream and west branch because of their inaccessibility. Numerous waterfalls prevent migration of trout from the lower stretches into these headwaters. Fishing is reported to have been better before 1923 when stocking was done near the headwaters from the now defunct Alger-Smith Railroad.

Lax, Bear, and Nicado lakes are the three most important lakes on this system. Nicado and Bear lakes once had good populations of brook trout and Lax Lake provided a wintering area for this species. Bear Lake has been spoiled for trout by the introduction of smallmouth bass and now has a stunted population of this species.

Baptism River

(Fig. 12, Tables 21 and 48)

The Baptism River and its tributaries drain 132 square miles of rough topography in Townships 56, 57, 58, and 59 North, Ranges 6, 7, 8, and 9 West, Lake County. Basalt, diabase, rhyolite, and anorthrosite are the principal igneous Keweenawan rocks underlying the drainage basin (Grout and Schwartz, 1939). Bedrock is exposed between Finland and Lake Superior and is evident elsewhere in the lower portion of the drainage basin as the steep, rock ridges paralleling the shore. These ridges determine the direction of flow of the lower tributaries. Along the lake shore the rocks are more or less covered by a narrow strip of lake deposits that extends to the first big bend of the river (S. 4, T. 56 N., R. 7 W.) and above Finland the bedrock is covered with rolling moraines.

The entire drainage area is covered with second-growth forest, largely aspen, birch, jack pine, and spruce, and the stream

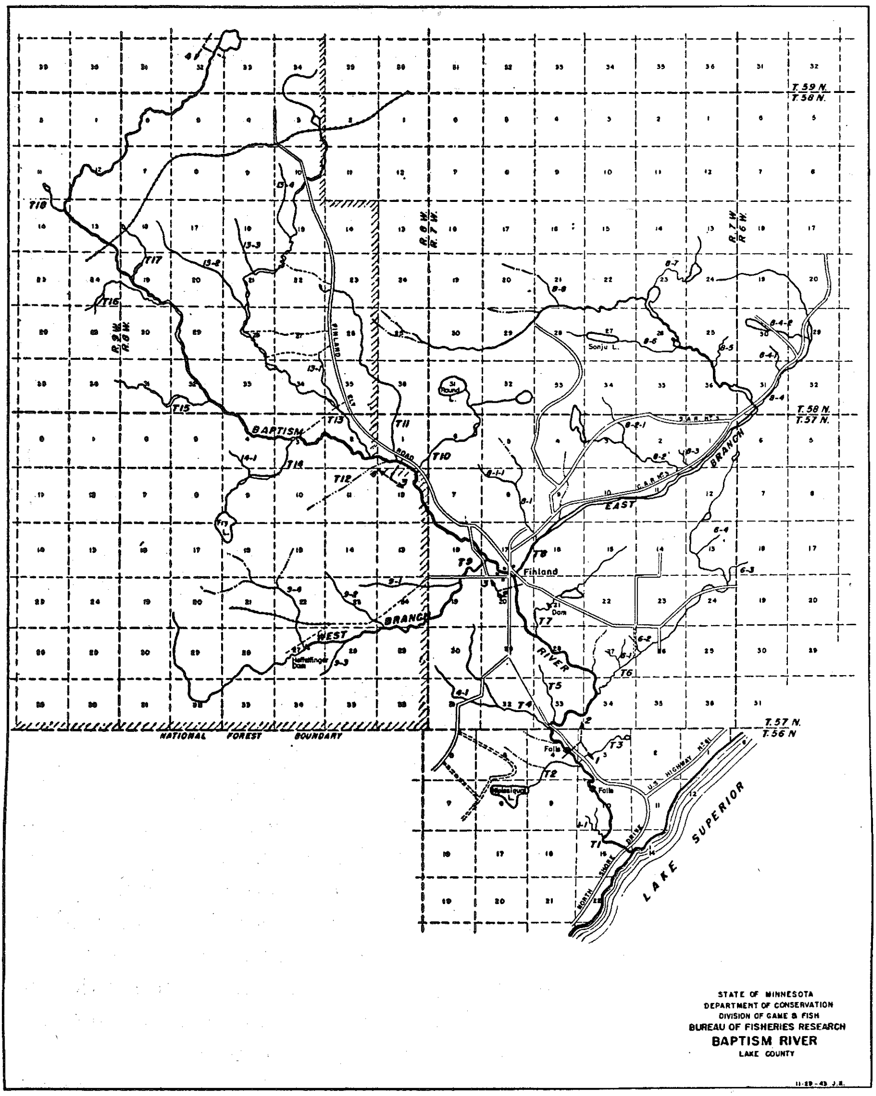

T.59 N.
T.58 N.
T.57 N.
T.56 N
R.8 W.
R.7 W.
R.7 W.
R.6 W.
R.9 W.
R.8 W.
BAPTISM
WEST
BRANCH
EAST
BRANCH
RIVER
FINLAND
ROAD
Finland
Sonju L.
Round L.
Dam
Falls
Falls
NATIONAL FOREST BOUNDARY
U.S. HIGHWAY No. 61
NORTH SHORE DRIVE
LAKE SUPERIOR
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
BAPTISM RIVER
LAKE COUNTY

Figure 12

banks are usually lined with alders and willows. Much of this forest growth has appeared since the surveys of Surber in 1922. In the lower portion of the drainage basin are scattered dairy farms. Agricultural conditions in this vicinity have been discussed in detail by Davis (1935).

The main Baptism River is joined at the town of Finland by the east (Trib. 8) and west (Trib. 9) branches. Below this junction the flow is augmented in Section 34, Township 57 North, Range 7 West, by the entrance of Sawmill Creek (Trib. 6). In the 8.9 miles below Finland the exposed stream bed varies from 20 to 80 feet in width and is thickly strewn with large boulders and angular fragments of basalt. In this distance the stream drops 733 feet (State Drainage Commission, 1911-1912) over a series of rapids and waterfalls, two of which have sheer drops of 50 and 70 feet.

The east branch of the Baptism River rises in Section 25, Township 58 North, Range 8 West, and flows in a general easterly direction through Township 58 North, Range 7 West. In its upper reaches it is a sluggish stream, flowing through swamps and having elongate pools separated by short riffles. After flowing through Lake Twenty-three in Section 23, Township 58 North, Range 7 West, the east branch runs southeastward until it enters the ponded portion below the junction with Blessner Creek (Trib. 8-4) in Section 31, Township 58 North, Range 6 West. At this point the stream reverses its direction and for the remainder of its course flows in a general southwestward direction. This lower stretch, which lies in an ancient rock valley, has comparatively little fall and at low water it is a series of elongate pools varying in width from less than 100 feet to one-quarter mile. Blessner Creek (Trib. 8-4), which lies in a continuation of this same valley, is similar to the lower east branch.

Just below its headwaters, the west branch (Trib. 9) is joined by Tributary 9-4. At the Heffelfinger farm the flow of the two streams is impounded by a small dam. The west branch, like the east branch, lies in an ancient rock valley and throughout most of its course is a slow stream with many ponded areas. In Sections 26 and 25, Township 57 North, Range 8 West, the impoundments lie in swamps and have an average width of about 50 feet and a peaty margin covered with black spruce and bog shrubs.

The main Baptism River, or north branch, has its headwaters above the General Logging Railroad in Township 58 North, Range 8 West, and is fed by swamps. It is a fast-flowing stream, draining an area of stony glacial soil, and ranges in width from about 8 feet in its upper portions to nearly 30 feet at Finland. Throughout most of its course it is well shaded by a heavy growth of alder and has a bottom composed largely of glacial boulders. Good pools are few. Sawmill Creek (Trib. 6), the lowest major tributary of the Baptism, is a small stream, at most places not over 8 feet in width. It enters the main stream in Section 34, Township 57 North, Range 7 West. It is a good brook trout stream with a gradual gradient and much gravel bottom.

The inadequacy of natural water storage areas in the headwaters of the Baptism River system is reflected in rapid runoff and variable flow. Gauge readings taken by United States Army Engineers in the years 1928-1931 (U. S. War Department, 1932a) show a discharge near the mouth varying from about 4 to 1,600 cubic feet per second, with the lowest average monthly flow in March (18.7 cubic feet per second) and the highest in May (522 cubic feet per second). The comparative flow at low summer stage of the two main branches and main stream above their junction can be judged from the following data taken on August 8, 1940:

East branch	2.0 cubic feet per second
West branch	4.2 cubic feet per second
Main stream	16.8 cubic feet per second

Some idea of summer fluctuation can be gained from a reading taken on the north branch following a rain on July 31, 1940. The volume at that time was 192.0 cubic feet per second, or more than 11 times that of 8 days later. Similar fluctuation can be noted in the United States Army data.

The water of the Baptism River is quite soft, ranging in total alkalinity from 15.0 to 37.5 parts per million, and is just about neutral, with a median summer pH reading of 6.9. Dissolved oxygen is sufficient and the water otherwise chemically suited to trout.

Plankton is sparse in the faster waters and is abundant only in ponded areas at the mouth and in the quiet stretches of the lower east branch. Bottom fauna is likewise sparse in the more rapid waters, the most frequent forms being stoneflies, caddis flies, and smaller mayflies. In the slower portions beetle and fly larvae and dragonfly nymphs are common. Larger aquatic plants are abundant in the ponded waters of the east branch, the most common species being the yellow water lily, the submerged bulrush (*Scirpus subterminalis*), and pondweeds. In these weeds there are many forage fish, especially the common shiner, the common sucker, and the fivespine stickleback. In the faster, well-shaded waters of the main stream aquatic plant growth is sparse and largely limited to mosses on rocks. The common forage fish in the more rapid waters are the blacknose dace, the creek chub, muddlers, and the common sucker. In all, 22 species of fish occur in this river system, including six species of game fish, the three common trout, perch, bluegills, and sunfish.

Summer water temperatures show that the main stream above the junction with Tributary 11 (S. 1, T. 57 N., R. 8 W.), Tributary 14, the east branch above Lake Twenty-three (S. 23, T. 58 N., R. 7 W.), Sawmill Creek (Trib. 6), Linstrom Creek (Trib. 4), Egge Creek (Trib. 8-2), and Tributaries 11 and 14-4 are suited to brook trout. Although the east branch below Lake Twenty-three becomes too warm for brook trout, it is reported that it supplies good fishing in spring. Local residents are of the opinion that there are submerged springs in this section which allow the trout to survive high water temperatures. Only brown trout are recommended for this lower portion of the east branch. The west branch is quite heavily fished in Sections 24, 25, 26, and 19, Township 57 North, Ranges 7 and 8 West, and should be managed for brown trout. The other tributaries are too warm, have too small a flow, or are too inaccessible to warrant stocking. As the Baptism River is subjected to heavy fishing, most of the recommended stocking is with 7- to 9-inch fish. Fingerlings are recommended only for the small, cold feeder streams.

Stream improvement, consisting of the construction of pools, would be desirable in the main stream from Section 18, Township 57 North, Range 7 West, to Section 10, Township 58 North, Range 8 West. This area is quite heavily fished and, with improvement, could carry a considerably larger number of trout. Similar improvement is recommended for Sawmill Creek from its mouth to Section 13, Township 57 North, Range 7 West. No improve-

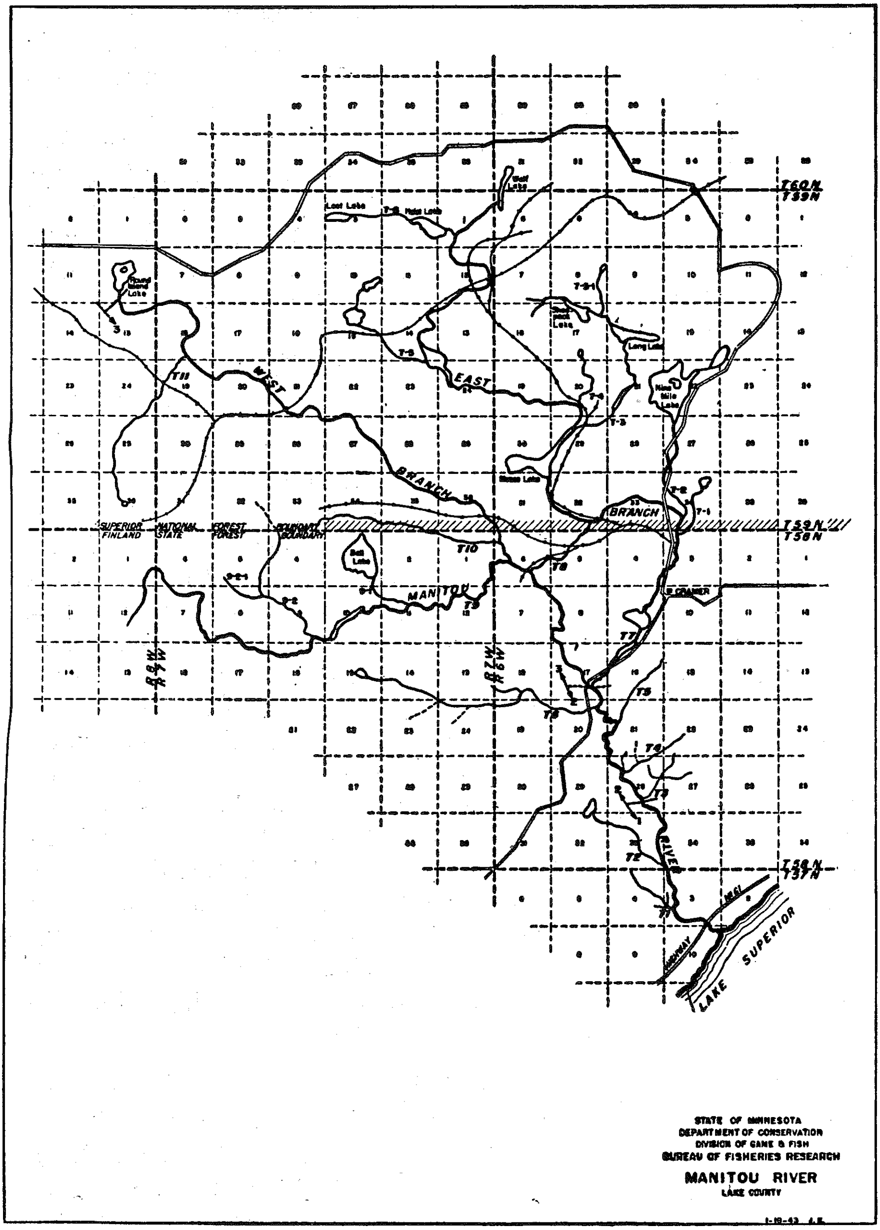

WEST
BRANCH
EAST
BRANCH
MANITOU
RIVER
LAKE SUPERIOR
SUPERIOR NATIONAL FOREST
FINLAND STATE FOREST
BOUNDARY
T60N
T59N
T58N
T57N
R8W
R7W
R7W
R6W
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
MANITOU RIVER
LAKE COUNTY

Figure 13

ment is recommended for the east or west branches or their tributaries. These streams have an abundance of pools and, in most places, are too wide for effective planting of trees and shrubs.

Manitou River

(Fig. 13, Tables 22 and 49)

The Manitou River and its tributaries drain an area of 103 square miles in Townships 57, 58, 59, and 60 North, Ranges 6, 7, and 8 West, Lake County. Crystalline Proterozoic rocks that outcrop frequently as rocky hills give the drainage basin a rugged topography. From the stream mouth to Cramer these underlying rocks are largely basalt flows, and above this point are diabase. With the exception of the extreme headwaters, these rocks are lightly covered with glacial soil. The narrow strip of lake and beach deposits paralleling the Lake Superior shoreline has little effect on the stream.

The Manitou River system differs from the Baptism River system and most of the other streams south of it in that the upper portion of its drainage basin has considerable areas of lakes and swamps which increase the water storage and decrease the rate of runoff. There are 11 small lakes with a total area of about 2 square miles that are directly connected with this system and several others that probably drain into it in times of high water. In addition to the lakes, there are an estimated 10 square miles of tamarack, spruce, cedar, and alder swamps. Even with these water storage areas there is considerable fluctuation in the flow. United States Army Engineers, in the period 1920 to 1931, found that the discharge near the mouth varied from a minimum of about 6 cubic feet per second to a maximum of 498 cubic feet per second. Judging from the daily discharge records in this period, the highest rate of flow can be expected in May and the lowest rate in February (U. S. War Department, 1932a).

The uplands of the entire drainage basin are covered with second-growth aspen, birch, jack pine, and spruce. In most places these stands are now 20 to 30 feet tall, and the general appearance of the country is in marked contrast to that found by Surber in 1922 when most of the area was covered with brush about 5 feet tall as a result of fires which followed the logging.

The extreme headwaters of the Manitou River system are in moraines approximately 2,000 feet above sea level (1,400 feet above Lake Superior). Although much of the central part of the system lies in an area of rugged topography, most of the streams have a moderate gradient with good pools and bottoms with considerable gravel. About 1.5 miles below the Finland-Cramer road, the main stream begins a precipitous descent through a preglacial rock gorge and drops to Lake Superior over a series of falls and rapids including eight major waterfalls, ranging in height from 20 to 70 feet.

The main Manitou River has two major tributaries, the south branch (Trib. 9) and the east branch (Trib. 7). Locally, the upper portion of the main stream is called the west branch. The main stream rises in Round Island Lake (S. 12, T. 59 N., R. 8 W.) and flows in a general southeasterly direction for 13 miles before it is joined by the east branch immediately below the Finland-Cramer road. Only about 4 miles of the main stream above the entrance of the east branch are readily accessible to fishermen. The south branch (Trib. 9) rises in Section 12, Township 58 North, Range 8 West, and flows 9 miles before entering the main channel in Section 6, Township 58 North, Range 6 West. Although there are some warm ponded stretches, this tributary is generally suited to brook trout. Two tributaries, including the stream flowing from Belle Lake (Trib. 9-1), feed this branch. The east branch of the Manitou River, which is locally known as Moose Creek, rises in Wolf Lake in Section 6, Township 59 North, Range 6 West, and has a meandering course through rugged country above Moose Lake. After leaving Moose Lake it flows about a mile before dividing into two branches, one of which goes westward to join the main stream and the other which continues eastward as the main east branch to the junction with Nine Mile Creek (Trib. 7-2) in Section 34, Township 59 North, Range 6 West. From this junction the east branch flows southeastward through Upper and Lower Cramer Lakes, joining the main stream just below the Finland-Cramer road. Nine Mile Creek (Trib. 7-2) has its source in Nine Mile Lake which is, in turn, fed by Echo Lake, a small, cold lake with an elevation of 1,550 feet above sea level. An unusual feature of the drainage pattern of the Manitou River system is the area about 5 miles square south of Moose Lake that is entirely surrounded by connected Manitou River tributaries.

Good water storage resulting in more unifiorm flow, abundance of good pools, ample shade, and favorable stream bottom make the Manitou River one of the best trout streams on the North Shore. The water is soft, ranging in total alkalinity from 17.5 to 37.5 parts per million, and nearly neutral, ranging in pH from 6.8 to 7.4. Dissolved oxygen and other dissolved substances are present in concentrations favorable to trout.

Compared to other North Shore streams, plankton is fairly abundant. Bottom fauna organisms are common, especially immature stages of caddis flies, mayflies, two-winged flies, and beetles. Sixteen species of fish, including the three common trout, occur in this river. In quieter waters forage fish are abundant with common shiners and common suckers being most frequent. The fivespine stickleback, Nachtrieb's dace, the creek chub, and the blacknose dace occur occasionally in the cooler, faster headwaters. Brook trout are abundant in the cooler streams and brown trout common in the warmer and wider, lower stretches. In the wide, deep pools below the Finland-Cramer road, great northern pike are frequent and perch abundant. Aquatic plants are fairly abundant especially in the pools of the central gravel-bottomed stretches. They are represented by several species of which the alpine pondweed (*Potamogeton tenuifolius*) and the green-fruited bur-reed (*Sparganium chlorocarpum*) are the most common.

The planting of 7- to 9-inch brown trout is recommended for the 3.5 miles of the main Manitou River immediately below the Finland-Cramer road and above this road in Section 17. Similar stocking is recommended for the east branch from the falls below Moose Lake to upper Cramer Lake, and in the stretch between lower Cramer Lake and the junction with the main stream. Stocking with 7- to 9-inch brook trout is recommended for the lower 2 miles of Nine Mile Creek (Trib. 7-2). Rock Cut Creek (Trib. 6) is recommended for fingerling brook trout. Other portions of the Manitou River system, such as Tributaries 9 and 10, are well suited to trout, but because of their inaccessibility and good natural spawning conditions no stocking is recommended. Most of the proposed stocking is with 7- to 9-inch fish to take care of the immediate fishing load.

Caribou River

(Fig. 14, Tables 23 and 50)

The Caribou River drains an area of about 23 square miles in Townships 58 and 59 North, Ranges 5 and 6 West, the headwaters lying in Cook and the rest in Lake County. On the diabase and basalt rocks underlying the lower part of the drainage basin is a strip of lake-deposited soil about 2 miles wide paralleling the shore. The rest of the drainage basin is covered with a mantle of stony glacial soil and with swamps. A terminal glacial moraine extends along the north bank of the stream for the upper two-thirds of its course. From its spring source in Section 18, Township 59 North, Range 5 West, the Caribou River meanders for

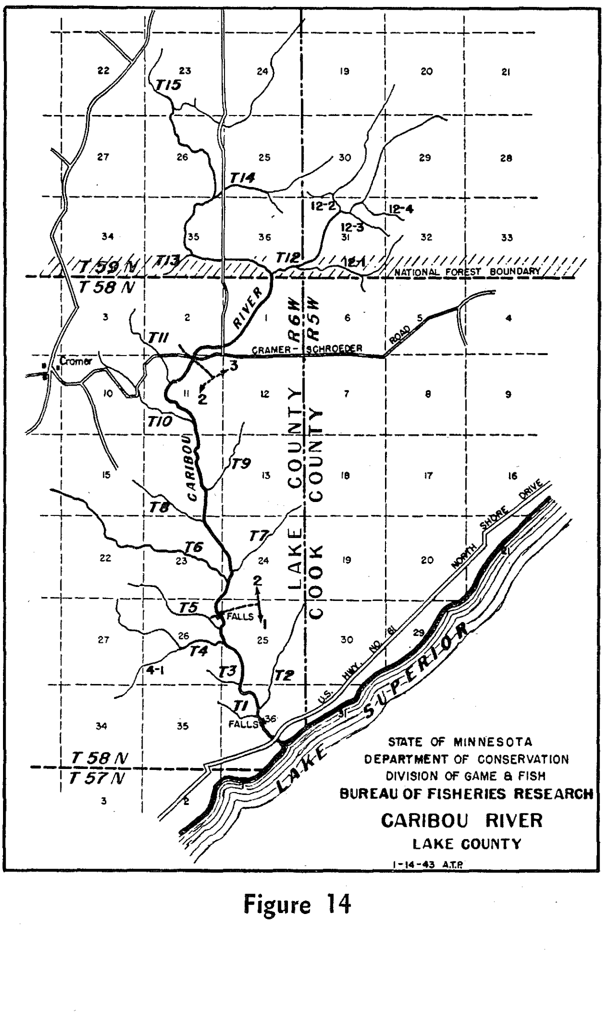


Figure 14

about 5 miles through swamps as a slow stream with a bottom predominantly of muck and detritus. It is fed by springs, seepage, and two swampy tributaries (Tribs. 13 and 14) in Section 35, Township 59 North, Range 6 West. The most important tributary (Trib. 12) also rises in swamps, and near the junction with the main river in Section 36, Township 59 North, Range 6 West, is a clear, cold stream of about 6 feet in width and 18 inches in depth.

Below the entrance of Tributary 12 the Caribou River flows southwestward to the Cramer-Schroeder road where it is a stream about 12 feet wide and 9 inches deep, moving at the fairly rapid rate of 1.5 feet per second. A water temperature of 62° F. was recorded here when the air temperature was 80° F. Below the Cramer-Schroeder road the Caribou River flows through a valley with low but quite steep sides, and in the lower portion of this valley (to Section 26) is a stream about 16 feet wide. From here to the mouth the stream drops rapidly and much bedrock is exposed. In this lower rocky stretch is a series of rapids and falls, the highest of which are 35 and 60 feet. About half a mile above its mouth the river enters a steep, narrow canyon.

The stream bottom undergoes a gradual change from source to mouth. Organic soils in the upper stretches gradually merge into gravel, the gravel into rubble and the rubble into ledge rock near the mouth. An abundance of gravel spawning areas is evidenced by the large numbers of naturally-spawned small trout occurring in this stream.

Waters of the Caribou River are quite soft, ranging in total alkalinity from 26.2 to 28.7 parts per million, and nearly neutral with a median pH reading of 7.1. It is chemically well suited to trout. Plankton is sparse and bottom fauna moderately abundant in the upper gravel- and muck-bottomed stretches. Although aquatic plants are almost lacking near the mouth, they cover 15 to 20 per cent of the bottom in headwaters. Alpine pondweed (*Potamogeton tenuifolius*) and the watermoss (*Fontinalis gigantea*) are the most common species. Only seven species of fish including brown, brook, and rainbow trout are recorded from this stream. Forage fish are scarce, the commonest species being the blacknose dace, the creek chub, and the muddler (*Cottus cognatus*).

The Caribou River is a brook trout stream. A combination of ample shade and spring water keeps the temperature within the range tolerated by this species. Stocking with 7- to 9-inch brook trout is recommended for Sectors 2 and 3. Light stream improvement to provide pools and shelter in the stretch between the Finland-Schroeder road and the lower rocky portion is recommended. Because there is much gravel for natural spawning in this stream, it is not necessary to stock the Caribou River as heavily as some other North Shore streams of similar size.

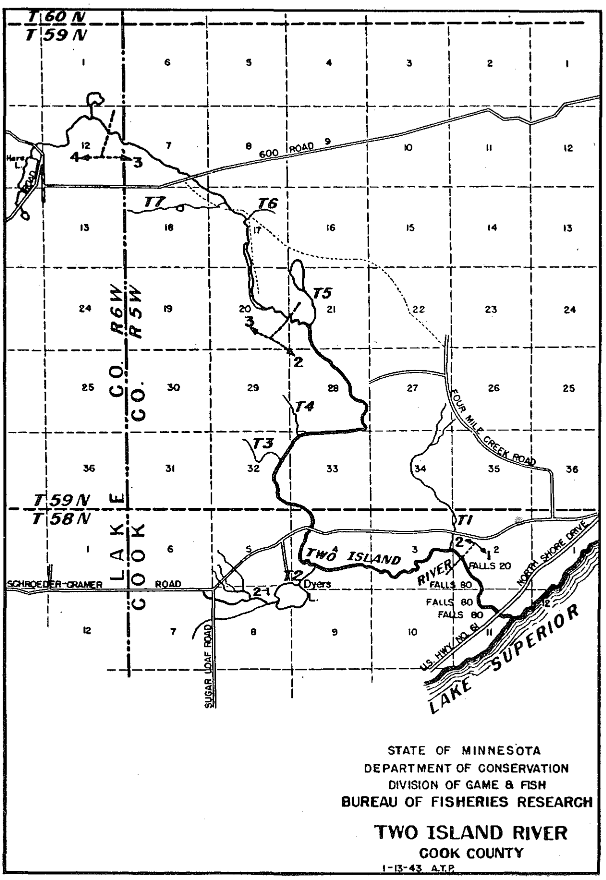


Figure 15

Two Island River

(Fig. 15, Tables 24 and 51)

The Two Island River drains an area of 30 square miles in Townships 58 and 59 North, Ranges 5 and 6 West, with the extreme headwaters lying in Lake and the rest of the system in Cook County. The drainage basin is underlain with Keweenawan rock formations. Basalt flows predominate along the shore and are exposed in the lower gorge. Above this area the underlying rocks are mostly the coarser-grained Beaver Bay diabase. The rock formations rise rapidly from the lake shore and reach the gradually sloping Lake Superior highland about a mile above the stream mouth. In this lower mile the stream falls rapidly over a series of steep rapids, cascades, and waterfalls, the three highest of which have sheer drops of about 80 feet. Inland from this steep, rocky stretch the underlying rocks are largely mantled with glacial drift and swamps. The upland soils are covered with a heavy growth of hardwood forest, and the swamps with stands of tamarack, black spruce, and tag alder. Shade along the stream is entirely ample in most places.

The Two Island River has its origin in Hare Lake in Section 11, Township 59 North, Range 6 West, and is fed in its upper stretches by seep springs and drainage from adjoining swamps. In Sections 12 and 14 it is nearly ponded and for the following 3 miles flows at a gradually increasing rate through tag alder swamps. Small swampy areas occur along the stream nearly to the Schroeder-Cramer road. Although the main direction of flow is southeast, the topography of the drainage basin is such that about 1.25 miles north of the Cramer-Schroeder road it runs directly westward for a distance of 1 mile, turns southward again and then swings eastward for nearly 2 miles. It then enters the lower rocky stretch that drops rapidly to Lake Superior.

The stream bottom of the swampy headwaters is mostly muck and detritus. Below Section 12 the gradient gradually increases and the bottom is covered with varying proportions of boulders, rubble, sand, and gravel. Basalt rocks are exposed in the lower portion of the stream. The Two Island River varies in width from about 8 feet in the non-impounded headwater areas to about 12 feet near the mouth. It is fed by eight tributaries. All but Dyer Lake outlet (Trib. 2) are too small for trout fishing. The small tributaries, especially Tributaries 1 and 9, are, how-

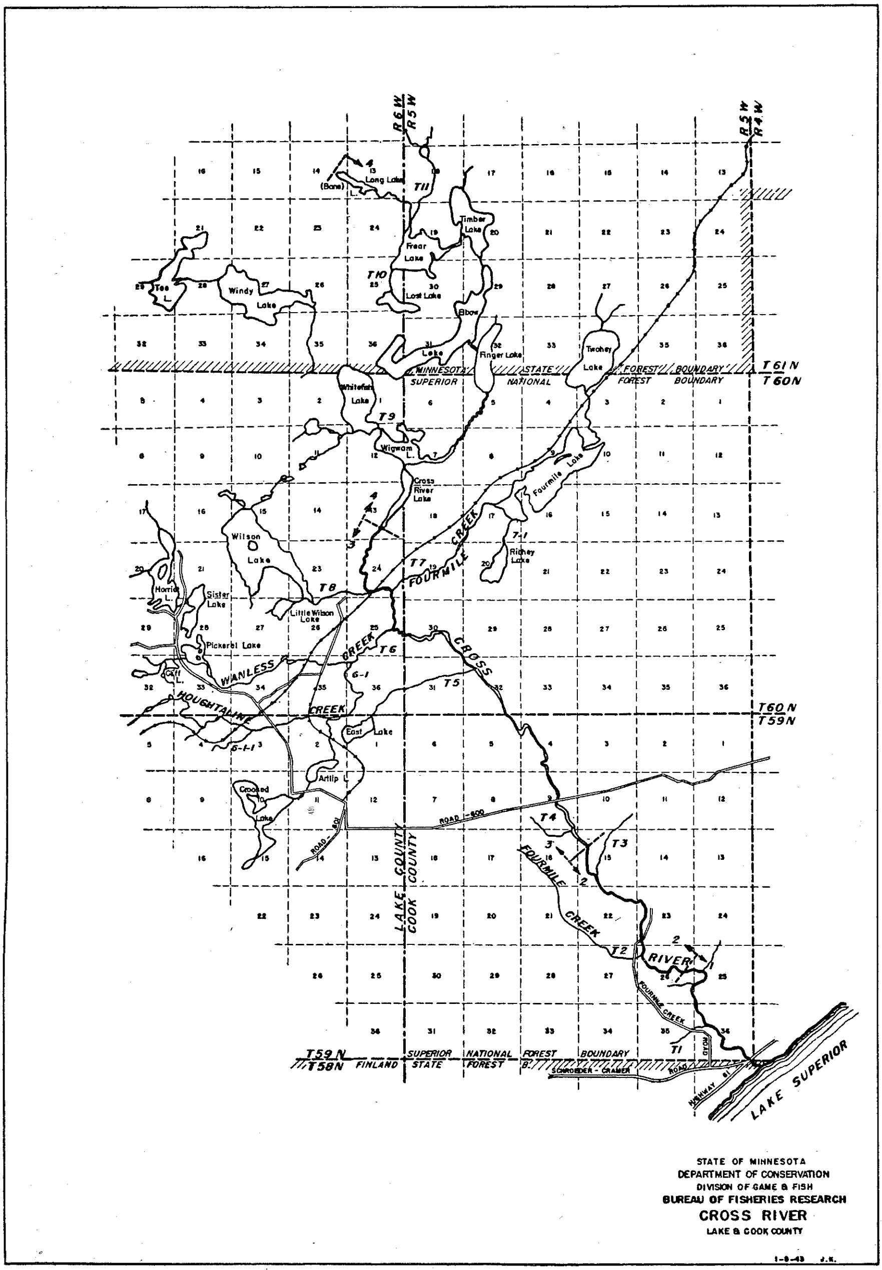

STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
CROSS RIVER
LAKE & COOK COUNTY
LAKE SUPERIOR
FOURMILE CREEK
CROSS RIVER
WANLESS CREEK
HOUGHTALINE CREEK

Figure 16

ever, of value as spawning areas for brook trout. The Dyer Lake outlet is fed by cold springs and has a water temperature seldom exceeding 45° F. It is about 6 feet wide and supplies good brook trout fishing.

The water of the Two Island River is soft, ranging in total alkalinity from 13.7 to 30.5 parts per million, has a median pH reading of 7.0, and is chemically favorable to trout. Plankton is sparse, consisting mostly of diatoms. Bottom fauna is moderately abundant. Fifteen species of fish were taken from the river. Of these, 13 were forage fish, the most common being the common sucker, Nachtrieb's dace, the blacknose dace, the common shiner, and the muddler (*Cottus cognatus*). Brook trout are abundant throughout the system and brown trout are occasionally taken. Aquatic plant growth is sparse and largely limited to bur-reed, water starwort, and mosses.

Seven- to 9-inch brook trout should be stocked in Sector 2 and Tributary 2-1 and 7- to 9-inch brown trout in Sector 3. Fingerling brown trout are recommended for Sector 4.

Light stream improvement is recommended for the main stream in Sections 21, 28, 32, 33, 3, and 4, and for that portion of Tributary 2 extending from Dyer Lake to the main stream.

Cross River

(Fig. 16, Tables 25 and 52)

The Cross River drains an area of 91 square miles in Townships 58, 59, 60, and 61 North, Range 4, 5, and 6 West, Lake and Cook Counties. Stony glacial soil covers the underlying Keweenawan rock formations throughout most of the drainage area. Basalt flows are exposed in the lower stretch of rapids and falls. White spruce, balsam, aspen, and birch are the common trees in the second-growth forest which covers the entire area, but stream banks are lined with alder and willow.

The main stream has its source in Bone Lake and flows through Frear, Timber, Elbow, Finger, Wigwam, and Cross River lakes before it begins its real existence as a stream. Below Cross River Lake it flows 3 miles as a fairly rapid stream about 15 feet in width. In this stretch it receives the three major tributaries, Wilson Lake outlet (Trib. 8), Four Mile Creek (Trib. 7), and Wanless Creek (Trib. 6). Below the entrance of Wanless

Creek the Cross River runs about 6 miles through long ponded stretches separated by short rapids. Many of the pools are 50 feet in width and have a luxuriant growth of aquatic vegetation. Shade is scant and the ponded stretches become so warm that they are suited only to northern pike and other warm-water fishes. In the northwest quarter of Section 15 the stream narrows to about 30 feet and flows rapidly over a stony bottom to the falls about a mile below the Four Mile Creek Road crossing. This stretch supplies some spring fishing for rainbow and brown trout. Between the upper falls, which are 40 feet in height, and Lake Superior the stream drops rapidly over five waterfalls which range in height from 12 to 90 feet. Except for spring fishing of rainbows near the mouth, this lower rocky portion is of little value.

All the tributaries, with the exception of Wanless Creek (Trib. 6), are either too warm or too small to warrant management for trout. Wanless Creek has its source in Pickerel Lake which is, in turn, fed by Cliff Lake and its tributaries. Below the Pickerel Lake outlet this creek flows as a well-shaded, moderately rapid stream for about 3 miles to the junction with Houghtaline Creek (Trib. 6-1). Wanless Creek averages about 5 feet in width and supplies fair fishing. About a mile of the lower portion was improved by the Civilian Conservation Corps in 1934. Below the junction with Houghtaline Creek in Section 36, Wanless Creek flows through swamps and is too warm for trout. Houghtaline Creek is a cold spring-fed stream but, because it has a very small summer flow, no improvement is recommended.

The water is similar to that of the neighboring streams and is chemically suited to trout. Besides brook trout and brown trout, 15 species of fish were taken from this river system. Of these, the blacknose dace and Nachtrieb's dace were the most common. Plankton is sparse and consists largely of diatoms and desmids but, because of the large amount of ponded water, more true plankton species occur than in most of the North Shore streams. Bottom fauna is abundant and in most places more than 2 cubic centimeters per square foot were taken. The ponded stretches support a luxuriant growth of aquatic vegetation, 16 species of larger aquatic plants being noted.

Stocking with 7- to 9-inch brown trout is recommended for Wanless Creek in Sections 34 and 35. To supply spring and early summer fishing in the main stream it is recommended that Sector 2 be lightly stocked with 7- to 9-inch brown trout. The stream improvement structures in Wanless Creek should be kept in repair. No other improvement is recommended.

Temperance River

(Fig. 17, Tables 26 and 53)

The Temperance River system with a drainage basin of 180 square miles has the second largest watershed of the Minnesota North Shore streams. This river rises in Brule Lake at an elevation of 1,851 feet and flows southward through five townships to Lake Superior. The stream descends approximately 1,250 feet between its source and mouth with about half the total fall occurring in the lower 4 miles. In the last 1.25 miles the channel drops 240 feet over a series of falls and rapids. Low divides between the Temperance and neighboring systems in the headwater regions make considerable manipulation of the waters possible. Brule Lake serves as the headwater for both the Temperance River and the Arrowhead River, and the divide between the Temperance and the Poplar rivers is so low that with a relatively small diversion the greater part of the Temperance River flow could be turned into the Poplar. This project was investigated by the U. S. Army Engineers and from an engineering standpoint was considered feasible. Since it would involve the virtual elimination of the Temperance River and was of doubtful economic value, the project was not recommended.

The watershed is underlain with conglomerate and basic igneous rock near the mouth, with diabase in most of the central region, and with Keweenawan red rock and gabbro in the headwater area. Except in a small area near the mouth, the rock formations are thickly overlain with glacial deposits. The terrain is rugged with numerous rock outcrops and morainic formations. For the most part the river valley is relatively narrow, especially toward the mouth.

The entire drainage area, although used for forest production, has been heavily logged and burned. At the present time a vigorous second-growth composed of birch, poplar, and spruce is firmly established and is rapidly reclaiming the region. Most of the water in the lower stretches of the river originates in the headwater lakes. A large tributary known as Sawbill Creek

(Trib. 12) drains Smoke, Sawbill, and Alton lakes and enters the river from the west in Section 28, Township 62 North, Range 4 West. As the river progresses downstream it is augmented by several other feeders, the most prominent of which are Plouff Creek (Trib. 10), Torgeson Creek (Trib. 8), the Blind Temperance (Trib. 4), and the Little Temperance (Trib. 2).

In its upper reaches the river flows through a series of lakes and dead waters interspersed with rapid, rubble-bottomed stretches. Below the entrance of Sawbill Creek it is a shallow stream 50 to 75 feet wide which flows over boulder and rubble bottoms with little shade and infrequent pools. In the lower portion of Township 60 and in the upper portion of Township 59 the river falls with moderate gradient over rubble and large stretches of gravel to within approximately 4 miles of the shore where a rapid descent begins. As the shore is approached, the channel narrows until the water runs in a deep, narrow canyon with vertical walls which at some points are not over 3.5 feet apart. The river empties into a small bay of Lake Superior and unlike most of the streams has no bar at the mouth.

Except in a few tributary streams, water temperatures in the Temperance River system are unfavorable to trout. Because the river flows through many lakes and wide, shallow, and unsheltered channels, the temperature may rise as high as 85° F. during August. The Little Temperance, with a cool spring source, is well shaded throughout its length and maintains temperatures well within the brook trout range. The Blind Temperance, although not typical trout water, maintains temperatures sufficiently low to provide a habitat for brown trout. Plouff Creek and Torgeson Creek which enter the main stream in Section 17, Township 61 North, Range 5 West, and Section 30, Township 61 North, Range 4 West, respectively, have constant flows of cool water that is suitable for brook trout. Tributary 11, which enters the main stream in Section 8, Township 61 North, Range 4 West, runs through swamps and over mucky bottoms, and maintains temperatures as low as 70° F. when the air temperature ranges at 90° F. or above.

The general chemical characteristics of the system as a whole are favorable for trout, and the water is moderately fertile. Total alkalinity, ranging from 17.5 to 29.5 parts per million, is somewhat lower than many other North Shore streams. The water

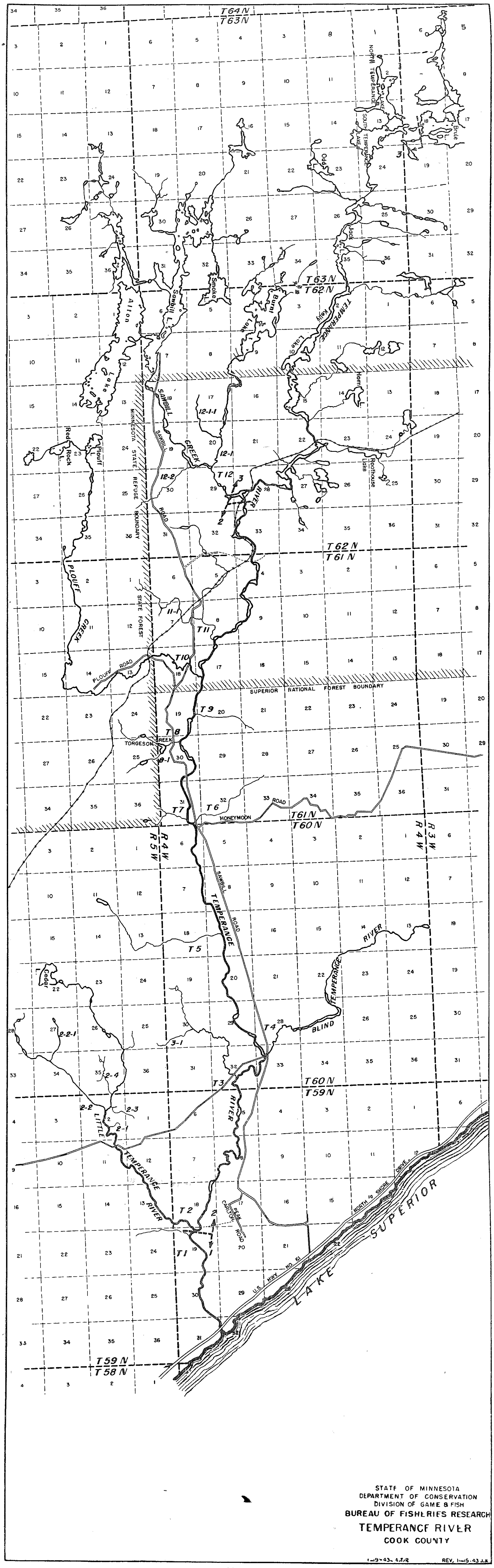

T64N
T63N
T62N
T61N
T60N
T59N
T58N
R4W
R5W
R3W
North Temperance Lake
South Temperance Lake
Brule L.
Jock L.
Kelly Lake
Burnt Lake
Smoke L.
Sawbill L.
Alton Lake
Red Rock L.
Plouf L.
Horn L.
Rodhouse Lake
Cedar L.
MINNESOTA STATE REFUGE BOUNDARY
STATE FOREST
SUPERIOR NATIONAL FOREST BOUNDARY
SAWBILL ROAD
SAWBILL CREEK
TEMPERANCE RIVER
PLOUFF CREEK
PLOUFF ROAD
TORGESON CREEK
HONEYMOON ROAD
BLIND TEMPERANCE RIVER
LITTLE TEMPERANCE RIVER
BEAR CARLTON ROAD
U.S. HWY. NO. 61
NORTH SHORE DRIVE
LAKE SUPERIOR
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
TEMPERANCE RIVER
COOK COUNTY

Figure 17

is slightly alkaline except in the tributaries lying principally within Township 61 North, Range 5 West. These streams are quite acid, with pH readings as low as 6.2.

Except in the upper stretches above the entrance of Sawbill Creek, submerged aquatic vegetation is scanty, usually covering less than 5 per cent of the stream bottom. Plankton is scarce and composed mostly of adventitious species swept off the bottom. In the upper reaches a few lake species may be found. On the other hand, insects and other aquatic invertebrate organisms are very numerous and provide a much larger quantity of fish forage than is characteristic of most North Shore streams.

Seventeen species of fish were reported from the streams of the Temperance River system. In addition to these, rainbow trout and smallmouth bass have been planted. Forage fish, especially the creek chub, common sucker, and blacknose dace, are abundant. The northern pike is common in the upper stretches of the river and according to Surber (1922) has always been abundant. An interesting feature of the fish population is the prominence of the johnny darter which is not usually taken in quantity from streams of this region.

Subsequent to Surber's investigations in 1922 smallmouth bass were planted in the main Temperance River but this species has never become an important game fish. Apparently, natural reproduction has not been successful in building up a population. Fishing throughout the main stream is poor although trout are occasionally taken below the entrance of Sawbill Creek. The only important trout fishing is in the tributary streams where suitable temperature conditions exist. Considerable warm-water fishing is done in the tributary lakes, especially Alton and Sawbill, which are relatively accessible by road.

Since the main Temperance River is of little value as a game fish habitat throughout its length, no fish management or improvement is recommended. The Little Temperance (Trib. 2) is well suited to brook trout but because pools are scarce and vegetation scanty the carrying capacity is low. It is recommended that 7- to 9-inch brook trout be planted and that stream improvement devices to create pools be installed in Sections 2, 11, 12, and 13, Township 59 North, Range 5 West. Similar brook trout stocking is recommended for Torgeson Creek (Trib 8). Light plantings of 7- to 9-inch brown trout are recommended for the Blind Temperance River (Trib. 4). Plouff Creek and Tributary 11 are recommended for the planting of 7- to 9-inch brown trout. Stream improvement on these tributaries is not justified.

Onion River

(Fig. 18, Tables 27 and 54)

The Onion River drains an area of about 10 square miles in Townships 59 and 60 North, Ranges 3 and 4 West, Cook County. Its drainage basin is underlain with Keweenawan flows and intrusives on which are deposited morainic soils in the upper portion of the system and waterlain soils over the lower 2 miles.

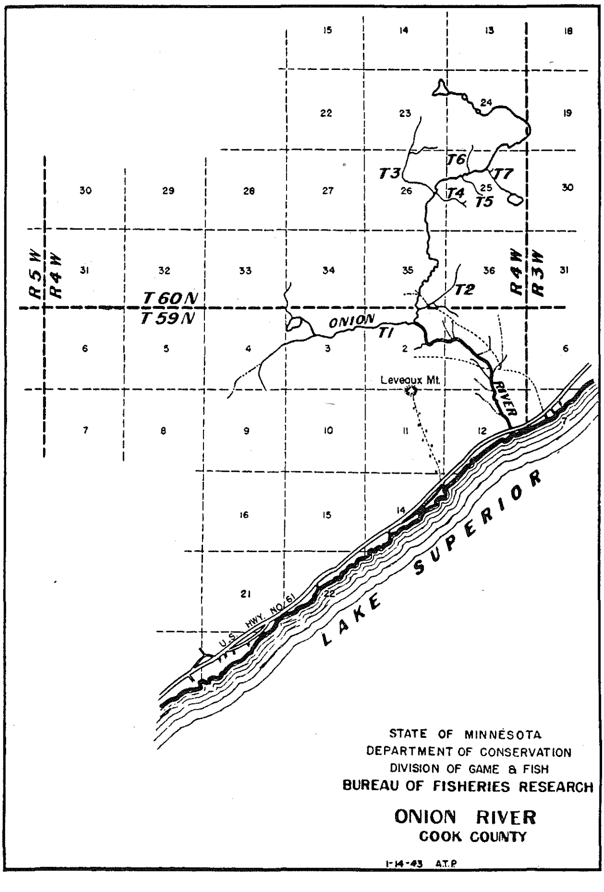


Figure 18

The entire area is covered with second-growth forest that supplies ample shade to the stream. Except for the crossing of Highway No. 61 just above the mouth, the stream is approachable only by trails.

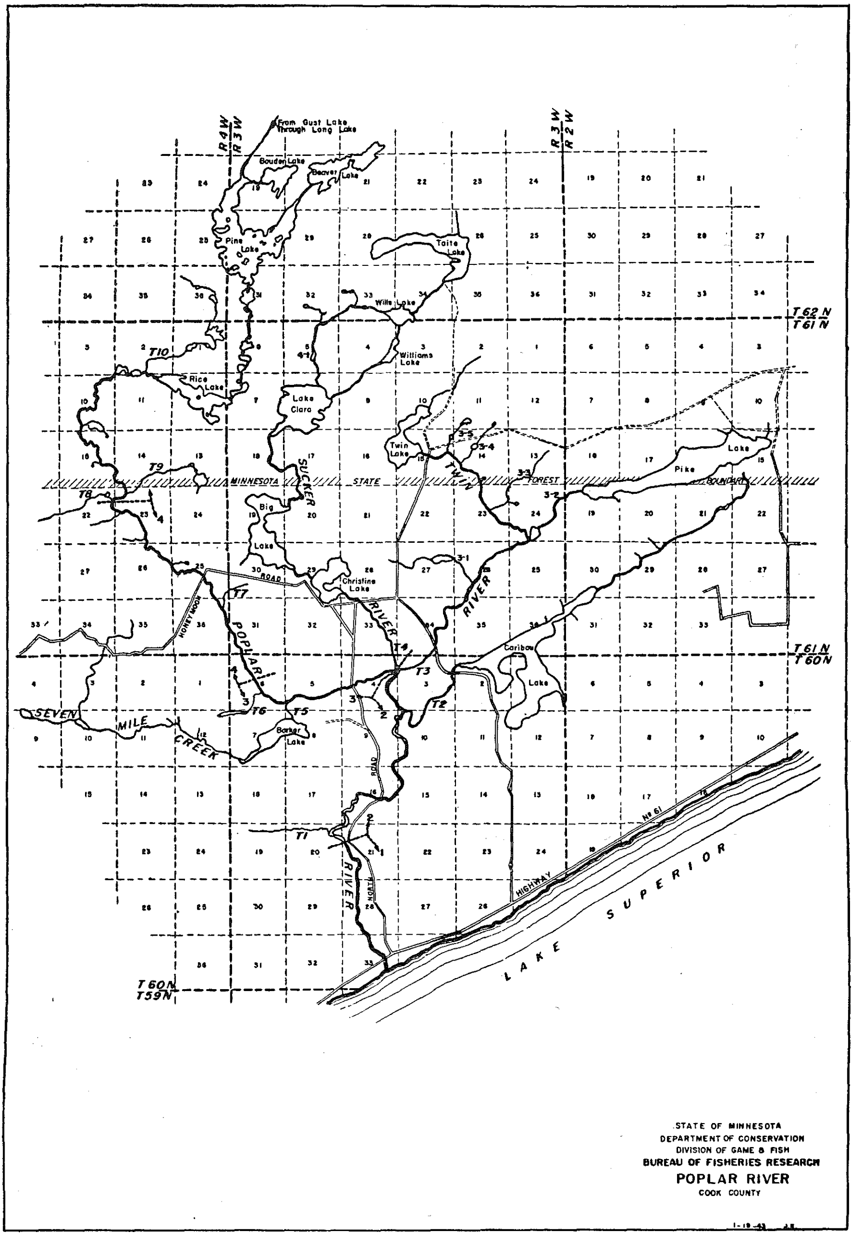
From its source, a small lake in Sections 23 and 24, Township 60 North, Range 4 West, the main stream flows southward to the junction with the west branch in Section 2, Township 59 North, Range 4 West. Its flow is augmented by small springs and seepage. This portion of the stream varies from 3 to 8 feet in width, has a considerable number of good pools, and is cool enough for brook trout. The west branch (Trib. 1) rises in Section 4, Township 59 North, Range 4 West, and is fed by a stream draining a small lake in Section 3. The lower part of the west branch flows through swamps and is largely ponded. It is too warm for trout. Another warm stretch is found on the main stream behind a beaver dam in Section 2. Below the beaver dam the stream cools rapidly and is brook trout water as far as the falls and canyon near the mouth. The stream is most heavily fished in Sections 1 and 12, Township 59 North, Range 4 West, and in Section 35, Township 60 North, Range 4 West.

It is recommended that Sections 1 and 12 of the main stream be stocked with 7- to 9-inch brook trout. Because there is a sufficient number of good pools and shade is ample, no stream improvement is advisable.

Poplar River

(Fig. 19, Tables 28 and 55)

The Poplar River system, draining 150 square miles of rugged terrain, lies principally in Cook County. Surface formations of the watershed are composed largely of heavy glacial till and moraines that overlay the characteristic rock strata of the area. The main stream rises in Gust Lake at an elevation of 1,800 feet above sea level, or 1,200 feet above Lake Superior. From its source the river flows through a series of lakes and dead waters interspersed with rapids to a high falls in Section 21, Township 60 North, Range 3 West. Below this point it drops rapidly over boulder bottoms and enters a narrow gorge near Lake Superior. In this gorge there is a series of cataracts terminating about one-third of a mile back from the lake in a 10-foot power dam. This obstruction effectively prevents any fish movement upstream.



From Gust Lake Through Long Lake
Bouden Lake
Beaver Lake
Pine Lake
Taite Lake
Wills Lake
Williams Lake
Rice Lake
Lake Clara
Twin Lake
Pike Lake
Big Lake
Christine Lake
Caribou Lake
Barker Lake
MINNESOTA STATE FOREST BOUNDARY
SUCKER
TWIN RIVER
POPLAR RIVER
HONEYMOON ROAD
SEVEN MILE CREEK
HIGHWAY No 61
LAKE SUPERIOR
R4W R3W
R3W R2W
T62N T61N
T61N T60N
T60N T59N
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
POPLAR RIVER
COOK COUNTY

Figure 19

Sucker River (Trib. 4), Twin River (Trib. 3), and Caribou Lake outlet (Trib. 2), the three principal tributaries, drain a series of lakes lying at an elevation of approximately 1,300 feet. Much of the stream bottom soil, especially in the deadwaters, is muck and silt. In the main channel these areas are interspersed with boulder, rubble, and riffles. Above the entrance of Sucker River (Trib. 4) there is much sand and gravel.

The watershed is well covered with a mixed hardwood and coniferous forest in which large poplars are very prominent. A vigorous second-growth has largely overcome the effects of forest fires and lumbering which denuded certain areas. The wide stream channel, ponded waters, and numerous swamps, however, expose large portions of the stream to direct sunlight.

Most of the water originates in the swamps, lakes, and seepage but in a few areas large, cold springs make very significant contributions to the stream. They are especially prominent in Sections 22, 23, 26, and 25, Township 61 North, Range 4 West, along the main channel. One feeder (Trib. 8) in Section 22, Township 61 North, Range 4 West, has a temperature of 43° F. and a flow of approximately 1.3 cubic feet per second. These spring-fed areas provide the only good brook trout water in the main river channel. In Section 31, Township 61 North, Range 3 West, and Section 6, Township 60 North, Range 3 West, water conditions are suitable for brown trout. The lakes and dead waters and the unsheltered condition of the channel overcome the effect of cool springs and make the greater part of the Poplar River system too warm for trout.

Chemical conditions throughout the entire drainage are within the limits tolerated by trout. The general fertility of the water is moderate and the carbonate content varies from 22.0 to 47.0 parts per million in various parts of the stream. In general, the river is alkaline with most stations ranging above pH 7.3. Warm, ponded waters and favorable chemical conditions make the Poplar River more productive of fish-food organisms than the majority of the North Shore streams. Its plankton contains the typical diatoms swept off the bottom and, in addition, many true plankton forms such as the green and blue-green algae. In the dead waters higher aquatic plants are very abundant and there are many species more typical of lakes than of streams.

Seventeen species of fish are known to occur in the Poplar River but since the lakes contain forms not reported in the recent stream survey it is probable that the total number is somewhat greater. Of the forage fish present, the common sucker, the black-nose dace, the longnose dace, the lake chub, and the muddler are prominent. The lake chub, which is characteristic of ponded water, is more aboundant here than in any other North Shore stream. Northern pike is also common in various parts of the system and probably limits the production of other fishes. The fishing load is relatively light except in the region of the Honeymoon road. Early in the season fishing is done in other parts of the system and some success is reported.

The Poplar River is limited in its capacity to carry trout and much of its water is better suited to the spiny-rayed fishes which inhabit tributary lakes. It is therefore recommended that only the limited portions of the stream previously mentioned as good trout water be managed for brook and brown trout. From Tributary 8 through Section 25, Township 61 North, Range 4 West, 7- to 9-inch brook trout should be planted. This section has been heavily improved just below the Honeymoon road, but additional improvement structures should be installed to a point a mile above the road and for approximately one-half mile below Tributary 8. In Sections 6, 5, and 4, Township 60 North, Range 3 West, limited plantings of 7- to 9-inch brown trout could be made if a heavy fishing load develops. No trout should be planted below the entrance of Sucker River. General habitat conditions in the region between Sucker River and the high falls in Section 21 are more favorable for smallmouth bass than for trout. It is therefore recommended that experimental bass plantings be made in Sections 10, 15, and 16, Township 60 North, Range 3 West. If low spring temperatures, the short growing season, or other factors make natural reproduction ineffective, attempts to create a smallmouth bass population should not be continued.

Sucker River and Twin River become too warm in summer to support trout. It is therefore recommended that no trout planting be made in these areas. While the streams have the general appearance of a good trout water and stream improvement work would normally be indicated, no development is recommended until such time as general watershed conditions result in lower water temperatures. Seven Mile Creek (Trib. 5), entering the main channel in Section 6, Township 60 North, Range 3 West, has several miles of brook trout water above Barker Lake. Its general inaccessibility justifies only limited stocking with catchable-sized brook trout in the stretches near the Honeymoon road.

Spruce Creek

(Fig. 20, Tables 29 and 56)

Spruce Creek is a small stream draining about 15 square miles in Townships 60 and 61 North, Range 2 West. From its source in Trout Lake it flows a meandering course of 5 miles to Lake Superior. The only tributary rises in Round Lake in Section 6, Township 60 North, Range 2 West, and enters the main stream

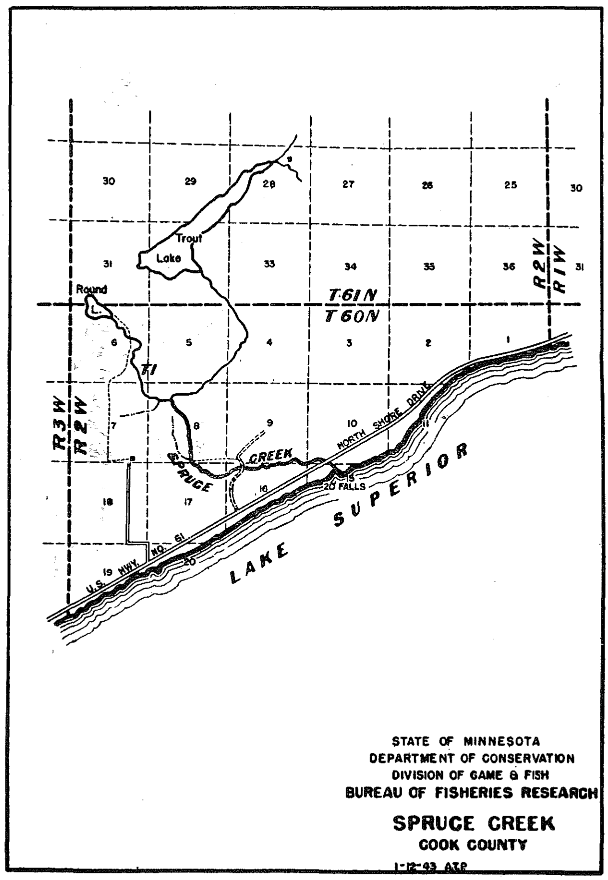
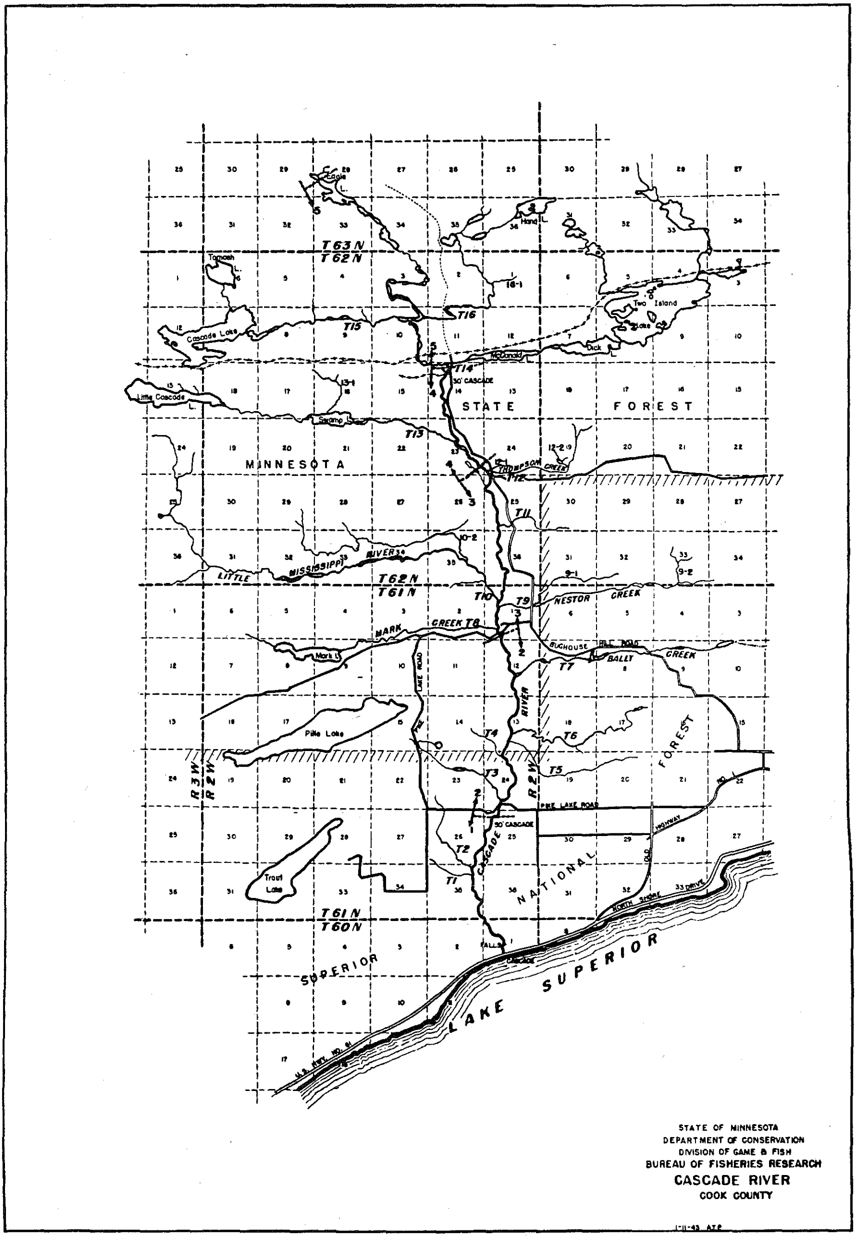


Figure 20


STATE OF MINNESOTA
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BUREAU OF FISHERIES RESEARCH
CASCADE RIVER
COOK COUNTY
MINNESOTA
STATE
FOREST
NATIONAL
FOREST
SUPERIOR
LAKE SUPERIOR
T63N
T62N
T61N
T60N
R3W
R2W
Cascade Lake
Little Cascade L.
Tomash L.
Eagle L.
Two Island Lake
Dick L.
McDonald
Swamp Lake
Mark L.
Pike Lake
Trout Lake
THOMPSON CREEK
LITTLE MISSISSIPPI RIVER
MARK CREEK
NESTOR CREEK
BALLY CREEK
CASCADE RIVER
PIKE LAKE ROAD
BUGHOUSE TRAIL ROAD
50' CASCADE
U.S. HWY. NO. 61
NORTH SHORE DRIVE
OLD HIGHWAY

Figure 21

in Section 8 of this same township. The drainage basin is well forested with birch and white spruce. There are several small beaver dams on the upper stretches of this system.

The stream is fished only from Lake Superior to the falls below Highway No. 61. Fingerling brook trout are recommended for the cold, upper portion of this stream. Because the summer flow is small, no stream improvement is recommended.

Cascade River

(Fig. 21, Tables 30 and 57)

The Cascade River system, with its 78.5 miles of stream channel, drains 93 square miles of rugged upland. At times of high water, part of the Devil Track River drainage is diverted into this system through Devil Track Lake. Eagle Lake, the source of the Cascade, and the upper portion of the stream lie at an elevation approximately 2,000 feet above sea level. Seven miles northeast of Eagle Lake is the highest point in Minnesota (2,230 feet). From the highland plateau the river drops 1,400 feet to Lake Superior over a rough stream bed characterized by many falls and rapids. In the last 3 miles the river descends 900 feet over a series of cascades from which the stream derives its name. A final plunge of 120 feet is located only a quarter of a mile from Lake Superior. The river valley is narrow and deep and is intersected by a number of lateral valleys separated from each other by high rock ridges running east and west. From these valleys the numerous tributaries of the main stream enter almost at right angles. The river rises in an area underlain with gabbro and Keweenawan red rock thinly covered with till. It then traverses a wide belt of Beaver Bay diabase and finally, near Lake Superior, cuts through mixed Proterozoic rock formations in which diabase intrusions are prominent. The red rock approaches the main river channel on the east, and several of the tributaries entering from that direction flow principally through this formation. Except in the lower stretches, the whole area is covered with a deposit of boulder till and sand.

In the reaches of the river lying above the entrance of Tributary 14 the channel is composed of a series of dead waters and slowly flowing riffles. Below the falls in Section 14, Township 62 North, Range 2 West, the river widens and drops through a series of rapids and pools to the outlet of Bally Creek (Trib. 7) in Section 12. From Bally Creek to the large cascade below the Pike Lake Road the channel remains wide and is paved mostly with boulders and ledge rock. After the river enters the gorge near Lake Superior it flows almost entirely through a narrow channel formed of ledge rock and big boulders.

The principal water supply is derived from Eagle Lake and the swamps lying in the headwater plateau. A tributary draining Cascade Lake (Trib. 5) comes in from the west and another tributary draining Two Island, Dick, and McDonald lakes (Trib. 14) comes in from the east. This combined flow of water enters the main stream above the falls in Section 14. Below the falls numerous spring tributaries and feeder creeks bring in a considerable volume of cold water. Thompson Creek (Trib. 12), Little Mississippi (Trib. 10), Nestor Creek (Trib. 9) which carries the flow from Devil Track Lake, Mark Creek (Trib. 8), Bally Creek, and two other tributaries entering in Section 13, Township 61 North, Range 2 West (Tribs. 5 and 6), are the principal feeders that influence the main stream. Thompson Creek, entering in Section 24, Township 62 North, Range 2 West, changes the warm Cascade River into a stream suitable for trout. Its continuous flow of cold, clear water is suitable for establishment of a rearing pond. The Little Mississippi flows over a silt and gravel bottom and except for occasional high temperatures is a good trout stream. Mark Creek rises in Mark Lake and flows slowly eastward, entering the main stream in Section 1. Bally Creek joins the main stream in Section 12, Township 61 North, Range 2 West. In its upper stretches it is a typical trout stream but when it reaches the beaver impoundments in Section 7 the channel broadens and the water becomes too warm for trout. The lateral tributaries in the middle portion of the stream have stretches of moderate gradient, interspersed with swamps and areas of slow current. Most of them have numerous springs that supply a more or less constant flow of water. The tributaries which enter toward the mouth of the river run through more rugged channels similar to that of the main stream.

The watershed is used entirely for forest purposes. Logging and fires denuded much of the headwater and tributary region but a good second-growth of aspen, birch, and spruce is rapidly reforesting these areas. Remnants of the virgin stands of timber that covered the greater part of the Cascade River system (Surber, 1922) still exist in the lower portion of the river valley.

Temperature conditions vary widely throughout the Cascade River system. The warm feeder lakes and many ponded areas above the falls in Section 14 create temperatures too high for trout. In the main channel water temperatures become suitable for brook trout below the entrance of Thompson Creek. This creek and several other feeders, notably Tributary 11 in Section 25, Township 62 North, Range 2 West, pour enough cold water into the main stream to permit trout survival even in the hot summer months. Below Section 1, Township 61 North, Range 2 West, several warm tributaries and the broad, open stretches of stream channel again raise the temperature to a point where it is suitable only for brown trout and where, at certain periods of the year, these cannot survive. In 1941 longnose dace, apparently killed by high temperatures, were observed where the river crosses the Pike Lake Road. Although several cool tributaries enter the stream in the vicinity of the gorge, the nature of this area and the many barriers do not favor high trout production.

The wide, boulder-studded stream bed over which the greater length of the stream flows makes maintenance of low water temperatures difficult. Stream improvement devices already installed in the middle section of the stream have helped produce better temperature conditions but the suitable trout habitat is largely created by the influence of cold tributaries.

Chemical analyses indicate that the stream is moderately fertile and capable of good fish-food production. The pH varies from 6.3 near the headwaters (Trib. 15) to 7.8 at the mouth. Throughout most of the stream the water is slightly alkaline. Like some other streams of the North Shore, total alkalinity increases considerably from the headwaters to the mouth (12.5 p.p.m. to 40.0 p.p.m.). Dissolved oxygen conditions are suitable throughout the stream and at no place did other chemical conditions appear to limit trout production.

Plankton is scarce and submerged aquatic vegetation is scanty except in dead waters. Bottom fauna is abundant especially in tributary streams. Of the 18 species of fish reported from this river, trout, creek chub, and blacknose dace are the most numerous. Surber reported large numbers of perch, some northern pike, and other warm-water species especially from the upper region of the stream. Since the waters in which these fish abound are largely ponded and do not constitute trout habitats, these species have little effect on trout production.

The Cascade River is heavily fished, accessible, and has a reputation extending over many years for trout production. Environmental conditions, although not ideal for trout in many areas, are sufficiently favorable to warrant stocking with both brook and brown trout. In the area above the falls in Section 14, Township 62 North, Range 2 West, temperatures are too high for trout and the prevalence of spiny-rayed fishes makes trout planting inadvisable. No improvement is practical in this region. From the falls to the entrance of Thompson Creek the stream is too warm to maintain trout. No improvements are recommended. Between Thompson Creek and Mark Creek the river is very accessible by road and has a habitat suitable for brook trout. It is therefore recommended that 7- to 9-inch brook trout be planted throughout this stretch. Heavy improvement work, designed largely to create pools and narrow the stream channel, was done through this area by the C.C.C. in 1935 and 1936. It is recommended that the structures be repaired and that careful observations be made to determine their effectiveness. Below Mark Creek stocking should be limited to the planting of 7- to 9-inch brown trout in Sections 12 and 13. No planting is suggested below these sections except as specified for the tributary streams.

Thompson Creek (Trib. 12) and Tributary 11 are excellent streams and should be stocked with 3-inch fingerling brook trout. Nestor Creek (Trib. 9), because of its accessibility and size, should be stocked with catchable-sized brook trout in Section 1. Mark Creek (Trib. 8), although heavily improved, has temperatures too high for either brook or brown trout. It is therefore recommended that no trout be planted in this tributary and that no further stream improvement work be done. Bally Creek (Trib. 7) is reputed to be the best tributary of the river. In its upper stretches it provides ideal trout habitat and should be planted with 7- to 9-inch brook trout. In the area of beaver impoundments in Section 7, Township 61 North, Range 1 West, and Section 12, Township 61 North, Range 2 West, temperatures rise above the optimum for either brown or brook trout. It is desirable to improve the lower section of the stream by removing the beaver dams and replanting the area to provide cover. Tributaries 2 and 3 could be planted with 3-inch fingerling brown trout to assist in the maintenance of the main stream.

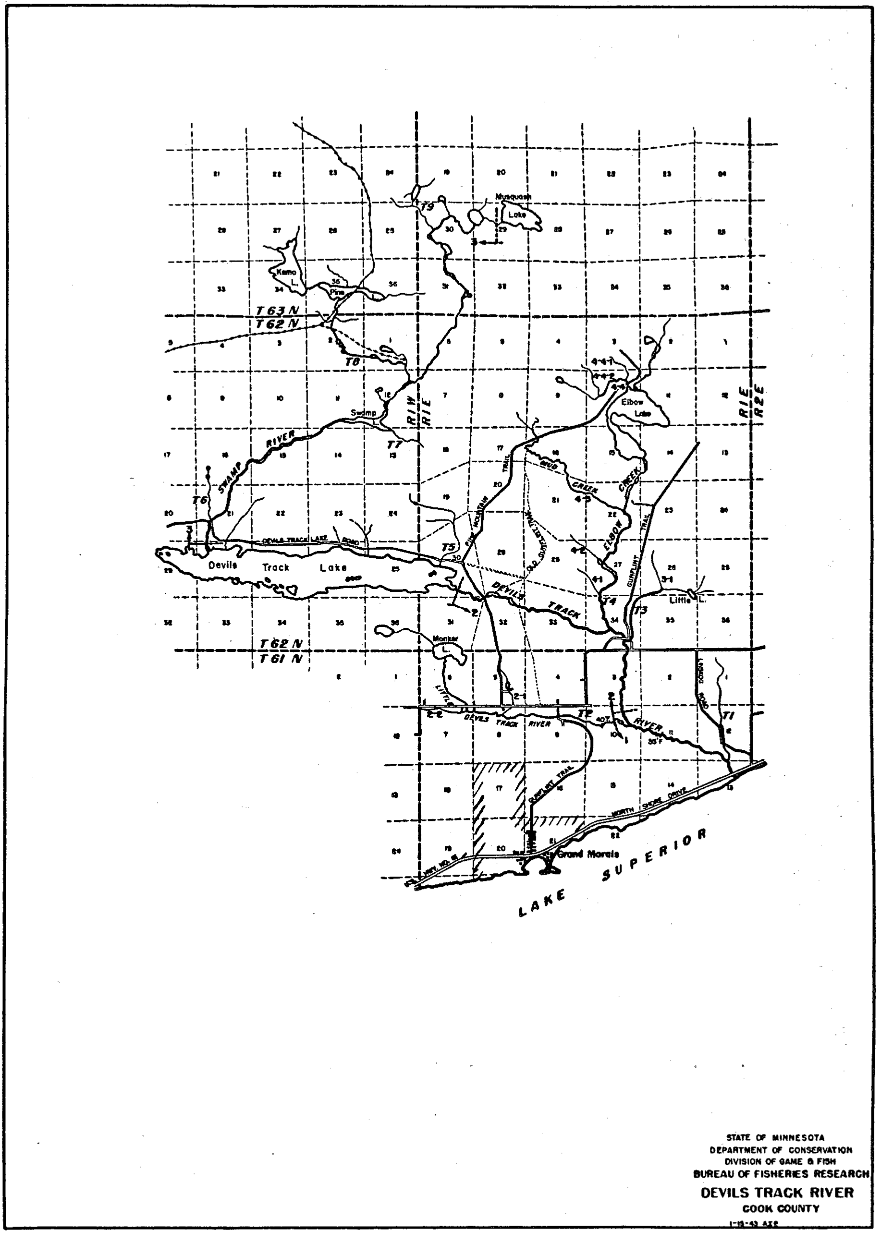
Devil Track River

(Fig. 22, Tables 31 and 58)

The Devil Track River system drains 85 square miles of upland forest and is underlain by two types of igneous rock, the Keweenawan red rock and related rhyolite flows extending back from Lake Superior as far as the north shore of Devil Track Lake and the Beaver Bay diabase lying in a narrow strip north of the red rock. Red rhyolite is conspicuous in the deep river gorge and the precipitous falls on the lower end of the river and in the smaller but similar gorge which lies about 1.5 miles below the outlet of Devil Track Lake. Except for these exposures and a few scattered outcrops, the underlying strata are largely covered by glacial boulder till.

The river rises in Round Lake (S. 30, T. 63 N., R. 1 E.) at an elevation of approximately 1,300 feet above Lake Superior (1,910 feet above sea level). It flows slowly through swamps and Swamp Lake to within 2 miles of Devil Track Lake and then starts a rapid descent over a rough boulder-strewn course containing many good pools and much artificial stream improvement work. Devil Track Lake is about three-quarters of a mile wide and 5.5 miles long and constitutes a natural reservoir for the lower part of the system. In 1911 a 7-foot logging dam was in operation at the outlet of the lake. This elevation of water level flooded much of the surrounding lowland and forced water from the Devil Track watershed over the low divide at the west end of the lake into the Cascade River system. Although the dam was later removed, this new outlet had been sufficiently cut down to permit water to flow through it at any high water stage.

The river flows sluggishly from the outlet at the east end of the lake through swamps and small impoundments to the gorge located in Sections 32 and 33, Township 62 North, Range 1 East. From this point to Lake Superior it descends rapidly at a rate of approximately 130 feet per mile. The channel in this lower region is composed of boulders and rock fragments and as the Superior



Musquash Lake
Kemo L.
Pine
T63 N
T62 N
T61 N
Swamp
SWAMP RIVER
R1W
R1E
R1E
R2E
Elbow Lake
MUD CREEK
ELBOW CREEK
Devils Track Lake
DEVILS TRACK LAKE ROAD
DEVILS TRACK
Monker L.
Little L.
DEVILS TRACK RIVER
Grand Marais
LAKE SUPERIOR
NORTH SHORE DRIVE
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
DEVILS TRACK RIVER
COOK COUNTY

Figure 22

shore is approached it plunges over a series of falls and through a rhyolite gorge. Much stream improvement work has been done in boulder areas above the Little Devil Track River. In the 1.5 miles below the lower falls the river runs smoothly through a narrow channel marked with many deep pools. The Devil Track River derives most of its volume from the headwater swamps and lakes, but numerous cold springs along its course and in its tributaries augment the supply.

The watershed is utilized principally for forest management and is covered with a dense second-growth of aspen, birch, and spruce, intermingled with remnants of the original forest. A marked improvement in general cover since Surber's (1924) observations was indicated by the present survey. There are some substantial tracts of farm land lying north of Grand Marais but the short growing season and the poor soil limits the quantity and variety of farm crops.

The river has two principal tributaries, the Little Devil Track (Trib. 2) arising in Section 36, Township 63 North, Range 1 West, and Elbow Creek (Trib. 4) arising in Elbow Lake, Sections 10 and 11, Township 62 North, Range 1 East. The Little Devil Track flows through Monker Lake and then enters a rugged valley which merges with the main Devil Track in Section 10, Township 61 North, Range 1 East. This stream has a continuous flow of spring water and is marked by excellent pools, stable bottom, and a well-shaded channel. Elbow Creek, after leaving Elbow Lake, flows through a series of small beaver impoundments and dead waters and finally over a 15-foot falls just above the entrance of Mud Creek (Trib. 4-3). At normal water stages this falls is probably impassable to trout. From this point to the main river the creek flows over a coarse boulder bottom which has been heavily improved to provide many excellent pools and a good fish habitat.

Temperature conditions vary throughout the system but except for the lakes and minor tributaries the water is adaptable to some species of trout. Above Devil Track Lake in Swamp River the many springs maintain temperatures which are well within the optimum range for brook trout. Below the lake, however, the temperature frequently exceeds optimum conditions and on one occasion a water temperature of 81° F. was reported where the river crosses the Gun Flint Trail. This high temperature is an exception and ordinarily brown trout can survive and prosper. Below the Gun Flint Trail several cold springs and Little Lake Outlet (Trib. 3) reduce the temperature. The cool spring waters of the Little Devil Track River enter the main stream between the falls and cool it to a point where the lake-run rainbows can maintain themselves in quantities. Elbow Creek has a warm source of water but the entrance of Mud Creek and numerous springs maintain a temperature condition suitable for brown trout. In Section 16, Township 62 North, Range 1 East, at the head of Mud Creek there is an excellent spring which produces water with a temperature of 44° F. There is sufficient flow to permit maintenance of limited artificial rearing facilities.

Chemical conditions of the water in the Devil Track system are nowhere a limiting factor. Analyses show that the water is moderately fertile. In most of the system the water is nearly neutral (pH 7.0) except below the entrance of the Little Devil Track where a decided alkaline condition exists (pH 7.6) and in the headwaters of Elbow Creek where the water is acid (pH 6.2). A minimum of 12.5 parts per million total alkalinity was recorded at the head of Mud Creek but the main stream varies from 24.3 at Swamp River to 37.5 at the mouth. Dissolved oxygen appears to be adequate in all sections of the stream to maintain trout.

The river contains a scanty adventitious plankton composed almost entirely of diatoms. Higher aquatic plants are not numerous except in the ponded areas. Bottom fish-food organisms are more abundant than in many of the north shore streams and consist mostly of immature aquatic insects. Of the 18 fish species which occur in the streams, 16 are native and the other 2 have been introduced as game fish. Three forage fish, the blacknose dace, the finescale dace, and the northern muddler, are abundant. The brook trout is native in the lower stretch of the river but the brown and the rainbow trout were introduced in 1924 and 1929 respectively.

Dr. Surber (1922) reported that northern pike were so abundant in Swamp River and in the Devil Track River below the outlet of the lake that trout production was seriously inhibited. During the course of the present survey, however, northern pike were not found in sufficient numbers to be considered detrimental. A survey of the Devil Track Lake itself indicated that although large numbers of northern pike and walleye pike are present, the fishing load apparently holds these species to a level where they do not seriously interfere with the stream conditions.

Temperatures and other habitat conditions in the Swamp River make it advisable to manage this stretch of stream for brook trout. Since the fishing is moderately heavy and the accessible water limited, it is recommended that 7- to 9-inch brook trout be planted in Sections 16 and 21, Township 62 North, Range 1 West. That portion of the stream between the outlet of Devil Track Lake and the entrance of Little Devil Track River is best suited to brown trout. It is therefore recommended that 7- to 9-inch brown trout be planted in Sections 33 and 34, Township 62 North, Range 1 East and in Section 3, Township 61 North, Range 1 East.

Extensive stream improvement work has been done through this area to create pools and to narrow the stream channel. While it is essential that these structures be maintained, no further work is recommended at the present time. Stream-side planting, except in a short stretch above the Gun Flint Trail, is not essential. No trout planting below the falls is recommended since the accessible areas will be maintained by natural stocking from Lake Superior.

Elbow Creek (Trib. 4) should be managed for brown trout. The upper cool stretches of Mud Creek (Trib. 4-3, S. 16, T. 62 N., R. 1 E.) should be stocked with fingerling brook trout and the lower warm water (S. 22, 27, 34, T. 62 N., R. 1 E.) with 7- to 9-inch brown trout. Extensive stream improvement has been carried on in Elbow Creek and its present effectiveness renders any additional work unnecessary.

The Little Devil Track River (Trib. 2) is accessible throughout its length and has excellent brook trout conditions. It is recommended that 3-inch brook trout be planted in Section 6, Township 62 North, Range 1 East and in Tributary 2-2. Sections 8, 9, and 10 are to be stocked with 7- to 9-inch brook trout. Since it is an excellent trout stream, no improvement work is recommended.

Durfee Creek

(Fig. 23, Tables 32 and 59)

Durfee Creek or Dufee Creek, as the name appears on some maps, is a small stream draining an area of about 6 square miles

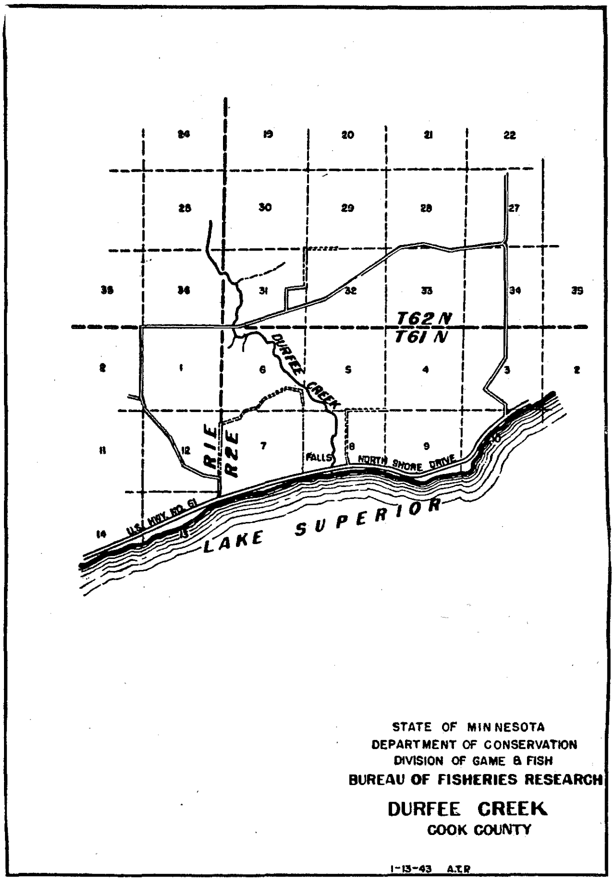


Figure 23

in Townships 61 and 62 North, Ranges 1 and 2 East, Cook County. The basalt flows underlying its drainage basin are covered with lake-deposited soil and are exposed only near the mouth where there are several low cascades about 2 feet in height. Throughout most of its course the stream has a width of 2 to 3 feet and a bottom largely of gravel and rubble. The surrounding area is forested with aspen and pincherry, and creek banks are well covered with alder and willow.

The stream is fed by small springs, seepage, and runoff. The water is cold, soft, and well suited chemically to brook trout. Plankton and aquatic plants are scarce and bottom fauna moderately abundant. No forage fish were taken during the 1941 survey. Some brook trout were caught and fishermen's trails indicate that the fishing is heavy.

It is recommended that Durfee Creek be stocked with 7- to 9-inch brook trout and that pools with appropriate deflectors be constructed in Section 6, Township 61 North, Range 2 East.

Kimball Creek

(Fig. 24, Tables 33 and 60)

Kimball Creek drains an area of about 15 square miles in Townships 61, 62, and 63 North, Range 2 East, Cook County. The drainage area is underlain with basic Keweenawan flows and

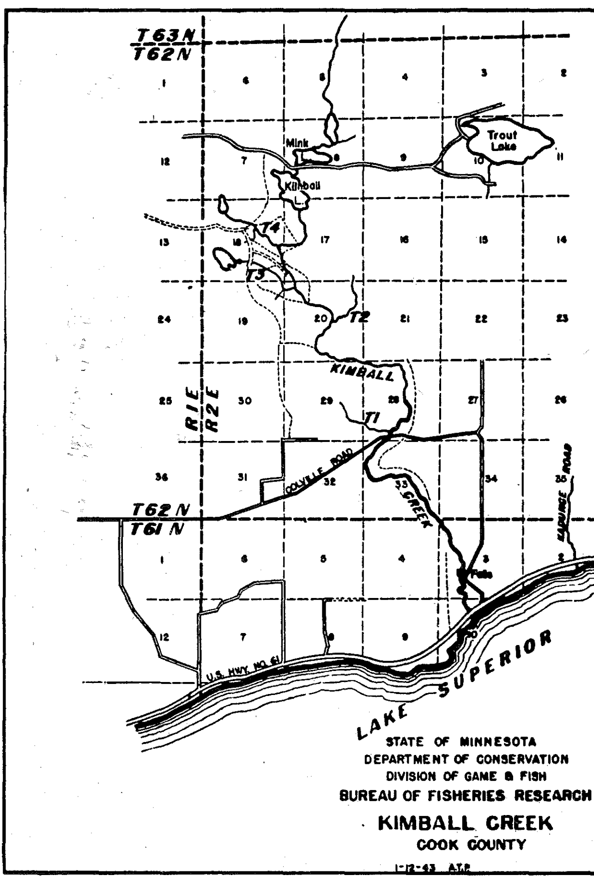


Figure 24

intrusives. These rocks in the lower half of the drainage basin are covered with stony water-worked soils and in the upper half with glacial drift. The forest cover is largely aspen, birch, and spruce and the stream banks are thickly lined with alder.

Two small lakes, Kimball and Mink in Section 8, Township 62 North, Range 2 East, are the sources of this stream. Tributaries 3 and 4 likewise rise in small lakes. The former is a slow stream about 6 feet wide near its mouth and the latter a stream about 3 feet in width. Tributaries 1 and 2 have inconsequential flows. Between the outlet of Kimball Lake and Section 29 the main stream has an average width of about 30 feet and is, in places, 2.5 feet deep. There is a beaver dam in this portion of the main stream and two small beaver dams on Tributary 4. Below this stretch of slow water the stream narrows to a width of about 12 feet and flows at a fairly rapid rate over boulder, rubble, gravel, and sand until it reaches the falls in Section 3. After passing over these falls, the highest of which is about 10 feet, the creek enters a steep-walled canyon and drops rapidly to Lake Superior.

Kimball Creek is a soft water stream, ranging in total alkalinity from 32.5 to 48.7 parts per million. Chemically, it is favorable to trout. Plankton is sparse, the bottom fauna is fairly abundant, and aquatic plants are occasional in the faster waters but fairly abundant in the upper slower stretches. Nine species of fish were taken including brook and rainbow trout, the common sucker, Nachtrieb's dace, the redbelly dace, and the longnose dace.

Since Kimball Creek is a cold stream that provides good fishing, it is recommended that it be stocked with 7- to 9-inch brook trout. Stream improvement to create and maintain pools and to provide shelter is recommended for Sections 28 and 33, Township 62 North, Range 2 East.

Kadunce Creek

(Fig. 25, Tables 34 and 61)

Kadunce Creek drains an area of about 15 square miles in Townships 61 and 62 North, Range 2 East, Cook County. The lower portion of the drainage basin is underlain with rhyolite flows and the upper portion with diabase. These rocks are for the most part covered with lake-deposited soils. The stream bottom

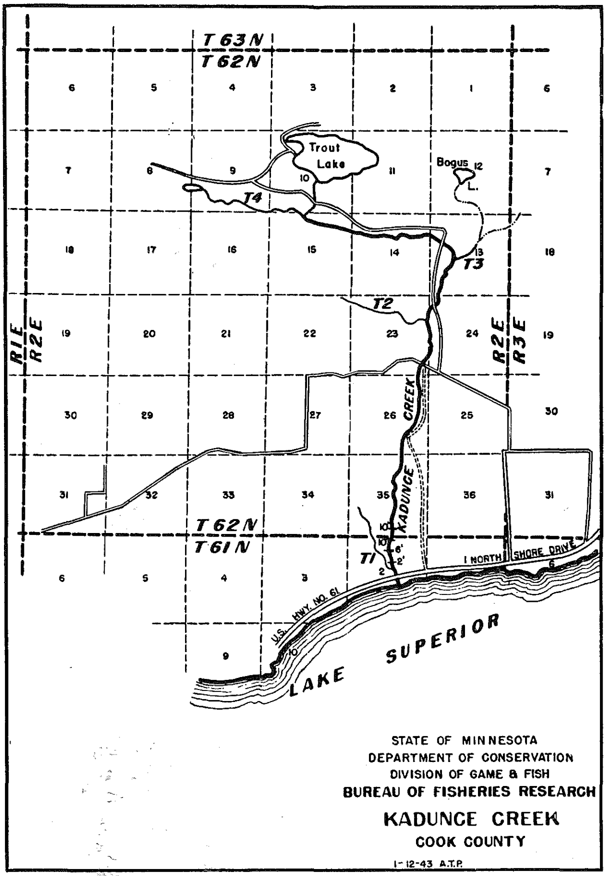


Figure 25

above Section 26 is mostly clay and sand, and from this point to the rocky gorge at the mouth the bottom is largely boulder, rubble, and gravel. About a mile above the mouth the stream enters an area of exposed bedrock and passes over a series of waterfalls, the highest of which is about 10 feet. In the lower portion of this rocky stretch the stream passes through a rhyolite canyon with nearly vertical walls as high as 80 feet. The surrounding country is covered with a second-growth forest of aspen and birch and the stream is about 35 per cent shaded with alder, black ash, cedar, and birch.

The main source of Kadunce Creek is Trout Lake, lying in Sections 10 and 11. Below the outlet of this lake the stream is about 3 feet wide and is joined in Section 15 by a small feeder (Trib. 4) which enters from the west. This tributary is a slow, small stream with two beaver dams in Section 9. Below this junction the main stream flows sluggishly eastward passing through two more beaver impoundments, one in Section 15 and one in Section 14. At the highway crossing in Section 13 it is about 8 feet wide. Between this point and the bridge in Section 23 the stream is a series of long pools with short intervening rapids. Below Section 23 Kadunce Creek falls with increasing rapidity over boulder, rubble, and gravel bottom for about 2 miles before entering the lower rocky area. The stream in this stretch has an average width of about 10 feet. About a mile in Section 26 was improved by the Civilian Conservation Corps in 1940.

The light brown water of Kadunce Creek is soft, having a total alkalinity of 27.5 parts per million, and slightly acid, having a median pH reading of 6.9. These and other chemical characteristics show the water to be well suited to trout. Plankton is sparse and aquatic plants, while nearly absent in the lower stretches, cover 10 to 20 per cent of the bottom in the upper area of the slow pools and beaver ponds. Bottom inhabiting insects are moderately abundant. Eight species of fish were taken: brook trout, rainbow trout, the common sucker, Nachtrieb's dace, the redbelly dace, the finescale dace, the fivespine stickleback, and the muddler (*Cottus cognatus*).

It is recommended that Sections 26 and 25 be stocked with 7- to 9-inch brown trout and the 3.5 miles above this stretch with 7- to 9-inch brook trout. The existing stream improvement structures in Section 26 should be kept in repair. No additional stream improvement is recommended.

Arrowhead River

(Fig. 26, Tables 35 and 62)

The Arrowhead, or Brule, River system has the largest North Shore drainage lying exclusively within the United States. Its watershed has an area of 290 square miles and is exceeded in extent only by that of the Pigeon River. The rock structures which underlie the area are largely formed of Beaver Bay diabase near the shore of Lake Superior and Keweenawan red rock in the central and upper regions. Red rock is supplanted by gabbro in the headwaters of the north Brule and by igneous and conglomerate formations in the upper portions of the Greenwood River system. Glacial till is spread thinly over the entire area. Toward the western end of the Brule system the terrain is rough and broken by a series of parallel rock ridges running in a general east-west direction. In the central and eastern parts of the watershed the terrain becomes less rugged and contains many swamps. Brule Lake, lying at an elevation of 1,249 feet above Lake Superior, serves as a headwater for both the Arrowhead

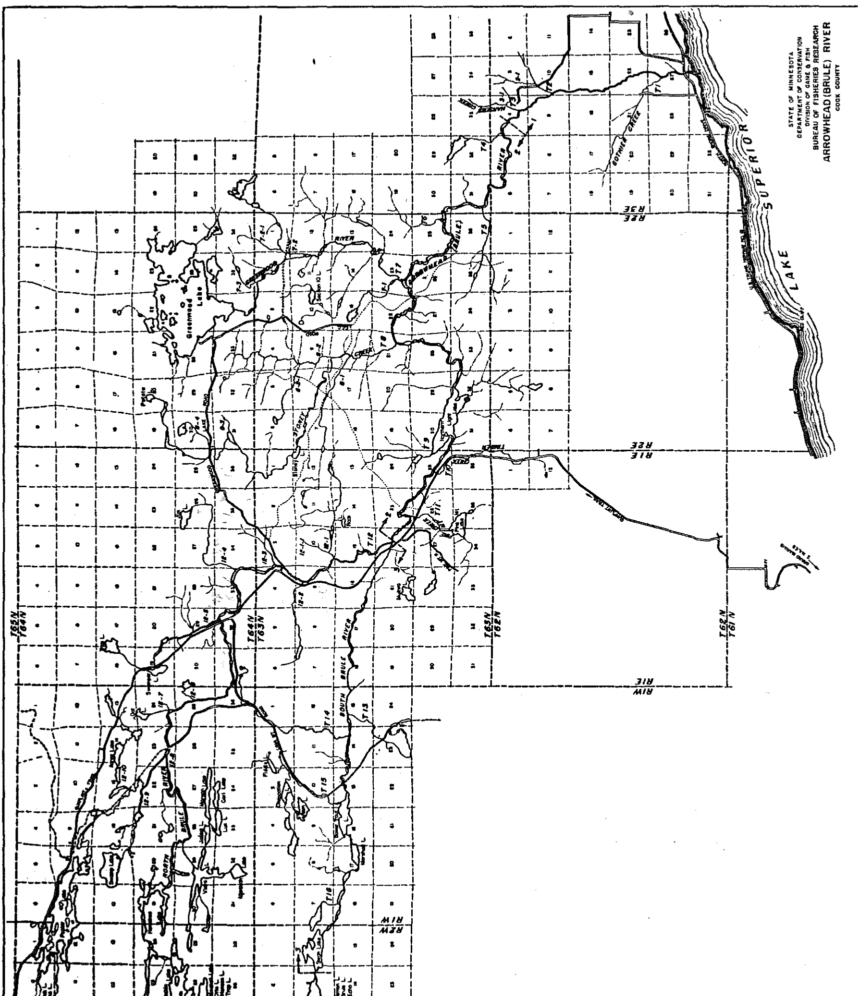


Figure 26

and Temperance systems. The Arrowhead River (South Brule) flows from the lake in a general easterly direction and traverses many lakes and dead waters interspersed with short boulder stretches until it is joined by the North Brule (Trib. 12) which rises in Poplar Lake. This tributary is equal in size to the main stream and is very similar to it in general characteristics. Below this junction the river, now doubled in volume, continues through alternate dead waters and boulder riffles to Section 4, Township 62 North, Range 3 East, where it turns south and plunges rapidly to the level of Lake Superior. In the last 8 miles there is an approximate drop of 800 feet. The channel contains a series of rapids and falls which terminate about 1.5 miles from the shore in a sheer 70-foot drop. From the base of the high falls the river runs through a deep gorge to Highway No. 61. At this point the sheer walls recede and the river runs between low banks to the lake. With the exception of the lower stretch the channels throughout the system are wide and poorly sheltered with little gradient. Silt and muck bottoms are common but in the short stretches of rapid water between pools and dead waters, large boulders fill the channel.

The watershed is used almost exclusively for timber management. Although lumbering operations and fires have removed much of the original cover a strong second growth, especially of poplar, birch, and spruce, is rapidly restoring the forest. The river has a very erratic flow which varies between 2,600 cubic feet per second and 11 cubic feet per second but averages approximately 248 cubic feet per second (U. S. War Dept., 1933a). Most of the water is derived from surface runoff but several of the tributaries are fed by seepage and springs.

In this system almost all the trout fishing is done in a few of the tributaries. Two feeders (Tribs. 2 and 3) in Sections 10 and 4, Township 62 North, Range 3 East, have supplies of cold water which make them well suited to brook trout. Although they are short and have a small flow they provide some fishing and form a reservoir of fish for the main stream. The Greenwood River (Trib. 7) which enters the Arrowhead in Section 23, Township 63 North, Range 2 East, has a number of dead waters but provides a small amount of trout habitat in the upper stretches, especially in Sections 1, 2, 11, and 12, Township 63 North, Range 2 East. In this region, however, splitting of the channel into numerous diversions materially limits the fish production. Stony Creek (Trib. 8) is an excellent brook trout stream which rises in Stony Lake and enters the main river in Section 21, Township 63 North, Range 2 East. At various points along rugged boulder channel, good springs contribute cold water and help maintain the moderate but constant flow. Since it is reported that this stream has never been stocked, its population is either native or derived from the main river. Timber Creek (Trib. 10) enters the main stream west of Northern Light Lake. The upper stretches of its channel drop rapidly over a stony course but as the river is approached the gradient decreases and the creek flows through swamps. Numerous springs help create excellent brook trout conditions. Farther to the west in Section 23, Pine Mountain Creek (Trib. 11) joins the main Arrowhead. It rises in Pine Mountain Lake and is augmented by many springs. Although small in volume and moderate in flow, its rugged channel is noted for brook trout fishing.

Temperatures throughout the river system vary considerably but only in the tributaries are conditions suitable for trout. The lake source of water and the slow, semi-impounded areas make the entire main course of the river unfavorable. Chemical conditions are within the normal range of stream trout and the water is moderately fertile. Except in some of the minor tributaries the alkalinity is moderate and the pH ranges above neutral.

The scanty plankton is marked by numerous pond and lake forms which are not commonly observed in most of the other North Shore streams. In the lower stretch of the river where the water plunges precipitously over a rugged course the only prominent plant is the red alga, *Lemanea annulata.* Throughout the ponded stretches, however, submerged aquatic plants are abundant and species numerous. Invertebrate fish-food organisms are moderately abundant especially in the rapids and boulder stretches.

The 12 species of fish which were recorded during the survey operations are probably not the only ones occurring in the stream. Two unrecorded species, the brown trout and the smallmouth bass, have been planted in the system and several others, notably *Cottus* sp. and *Eucalia* sp., are very likely present. Failure to take these forms may be due to difficulties encountered in seining operations. The northern pike (*Esox lucius*) is found throughout the ponded areas of the stream and although not present in excessive numbers is probably an effective check on other species. Trout in the tributary streams, however, do not appear to be adversely affected by this predacious fish. The principal forage fish found in the Arrowhead River system is the longnose dace. Shiners are uncommon and only one percoid, the yellow perch, has been recorded.

Since the main stream is unsuited to trout and plantings of smallmouth bass have proven unsuccessful, it is recommended that the impounded waters be managed for northern pike. No stream improvement along the main channel or in the North Brule (Trib. 12) is recommended. Tributaries 2 and 3 are to be moderately stocked with 7- to 9-inch brook trout but no channel improvement is suggested. Greenwood River (Trib. 7) should be managed for brook trout but until the stream is made more accessible by road development, stocking and improvement are not recommended. Stony Creek (Trib. 8) is to be managed for brook trout. Natural reproduction at present is adequate to maintain the supply of fish. Stream improvements to create more pools and shelters and to narrow the stream channel are recommended for Sections 16 and 21, Township 63 North, Range 2 East. Timber Creek (Trib. 10) should receive plantings of 7- to 9-inch brook trout. No stream improvement is recommended at the present time since natural conditions appear to be adequate in all except the lower stretch near the entrance of the stream into the main river channel. Here, the swampy condition makes the value of improvement questionable. Pine Mountain Creek (Trib. 11) is to be managed for brook trout and stocked annually with 7- to 9-inch fish. No channel alteration is recommended.

Flute Reed River

(Fig. 27, Tables 36 and 63)

The Flute Reed River drains about 15 square miles in Townships 62 and 63 North, Ranges 3 and 4 East, Cook County. Underlying basic Keweenawan rocks are largely covered with stony water-worked soil containing a large amount of clay and sand. Aspen, spruce, balsam, fir, and cedar are the principal species making up the forest cover, and together with willow and alder bushes provide the stream with 25 to 50 per cent shade.

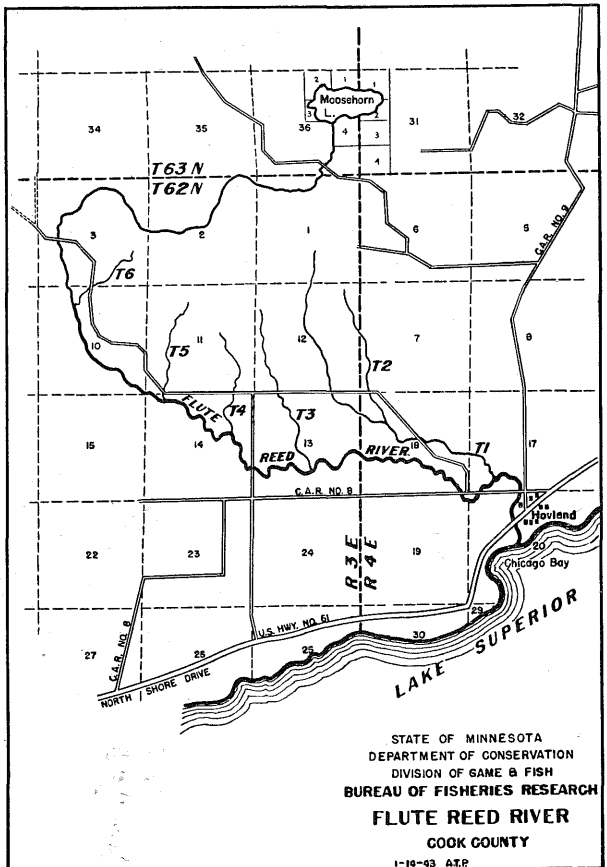


Figure 27

Moosehorn Lake, which lies in Sections 36 and 31, Township 63 North, Ranges 3 and 4 East, is the source of the Flute Reed River. After leaving the rugged topography of its headwaters the stream meanders westward, flowing sluggishly through swamps, as far as a beaver dam in Section 3, Township 62 North, Range 3 East. Below this point it runs at a fairly rapid rate and has a width of about 12 feet. Near its mouth, at the town of Hovland, the river flows over bedrock in which it has cut low falls. Between the upper swampy area and the lower region of rock outcrops the stream bed is largely boulders and rubble with occasional gravel. The tributary streams are all too small to warrant management for trout.

The soft water differs little from the neighboring streams and is favorable to trout. Bottom insects are quite abundant and plankton and aquatic plants are sparse. The only species of forage fish taken from this stream was the blacknose dace.

As this stream tends to become too warm in midsummer for brook trout it is recommended that 4.6 miles of the main stream (S. 13, 14, 10, 3, T. 62 N., R. 3 E., and S. 18, T. 62 N., R. 4 E.) be stocked with 7- to 9-inch brown trout. About a mile of improvement work was completed by the Civilian Conservation Corps in this stream in 1935. It is recommended that the improvement structures be kept in repair.

Stony Brook

Stony Brook, or Mineral Creek, is a small stream lying between the Flute Reed and Reservation rivers. It originates in Sections 28 and 32, Township 63 North, Range 4 East, and enters Lake Superior in Section 10, Township 62 North, Range 4 East. The only tributary rises in Section 34, Township 63 North, Range 4 East, and joins the main stream in Section 9 of Township 62. The stream below this junction is about 8 feet wide and flows through heavy aspen forest.

This stream is of little value and is fished only from the mouth to the falls about one-half mile above the shore. No stocking or improvement is recommended.

Reservation River

(Fig. 28, Tables 37 and 64)

The Reservation River drains an area of 20 square miles in Townships 62 and 63 North, Ranges 4 and 5 East, Cook County. With the exception of Rove slates and graywacke in the headwaters, this system is underlain mostly by diabase. The lake-deposited soils on these rocks support a mixed coniferous and hardwood forest, the principal species of which are white birch, mountain ash, pincherry, balsam, and spruce.

The river has its source in Swamp Lake. In Section 18 below its outlet there are three tributaries (Tribs. 3, 4, and 5), all of which at the time of the 1941 survey had flows of less than 0.5 cubic feet per second. Tributary 2 which joins the main stream in Section 21 is often dry in the summer. Tributary 1 which

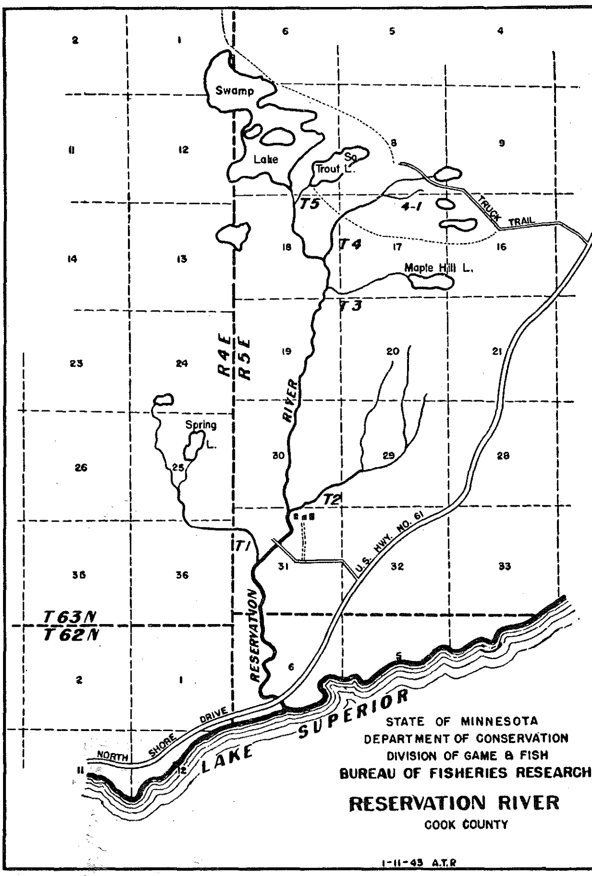


Figure 28

drains Spring Lake and another small lake in Section 24 enters in Section 31 and had a flow in the summer of 1941 of about 0.7 cubic feet per second.

Reservation River is unique among the North Shore streams in that there are no falls near the mouth. The first and only falls, located in the upper portion of Section 19 about 4.5 miles from the shore, has a height of 30 feet. Between this point and the lake the stream has an average width of about 12 feet and a bottom largely of sand, gravel, and rubble. The water is soft, having a total alkalinity of 30.0 parts per million. It has a pH of 7.0 and is otherwise well suited to trout. The only species of forage fish seen was the redbelly dace. Aquatic plants and plankton are both sparse.

No stocking is recommended as this stream becomes too warm for brook trout and is available throughout most of its length to spawning rainbows from Lake Superior. No stream improvement is recommended.

Hollow Rock Creek

(Fig. 29, Tables 38 and 65)

Hollow Rock Creek is a small stream lying entirely within Township 63 North, Range 5 East. It has a total drainage area of about 7 square miles and flows entirely over water-deposited

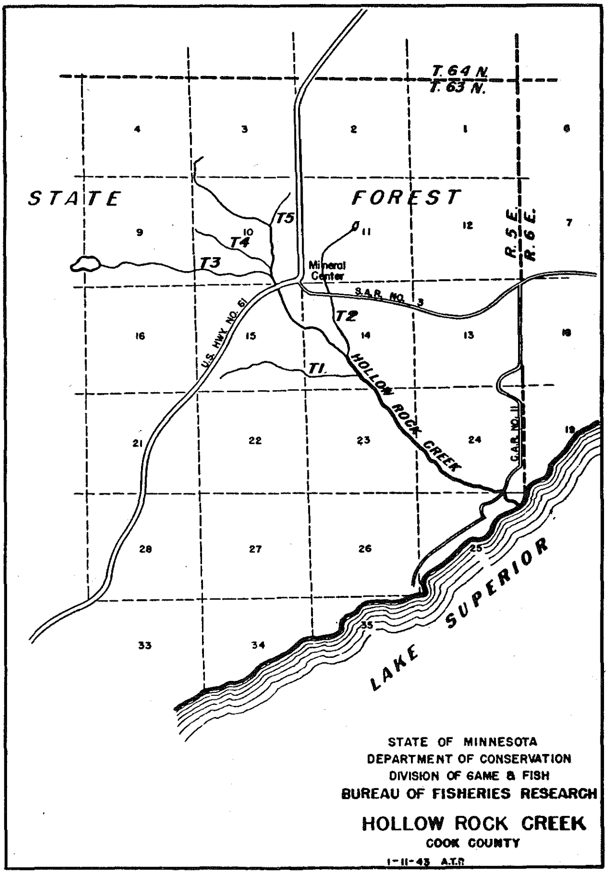


Figure 29

soils. Underlying these deposits are Keweenawan crystalline rocks. The stream has two low falls, one near Mineral Center and the other near the mouth.

Hollow Rock Creek rises in springs and swamps just north of Mineral Center and flows southeastward a distance of about 4 miles to Lake Superior. The stream varies in width from 6 to 10 feet and has a rocky bottom of rubble, gravel, sand, and clay. The banks are lined with a dense thicket of alders that shade about 50 per cent of the stream bed. Back from the creek the common forest trees are aspen, balsam poplar, balsam fir, and pincherry.

The water is soft, having a total alkalinity of 32.5 parts per million, a pH of 7.0, and other characteristics suited to trout. Aquatic vegetation is nearly absent and the only fish taken were rainbow trout.

Stocking with 7- to 9-inch brown trout and the construction of a few pools and shelters are recommended in Sections 14 and 15.

Grand Portage River

The Grand Portage River drains an area of about 8 square miles in Township 63 North, Range 5 and 6 East, that is underlain by Rove formations of graywacke and slates with associated intrusive rocks. The main stream has its source in Section 4, Township 63 North, Range 5 East, and flows eastward to Lake Superior, a distance of about 5 miles. It is accessible by roads only at Grand Portage and is paralleled by the old Grand Portage Trail in the lower portion of its course. The largest of its three tributaries drains Dutchman Lake and joins the main stream in Section 8, Township 63 North, Range 6 East. Stream banks are high and the bottoms stony with some rock outcrops. It is well shaded by aspen, birch, and scattered conifers. As the stream is little fished and has an uncertain water supply, no stocking or stream improvement is recommended.

Pigeon River Tributaries

(Fig. 30, Tables 39 and 66)

The Pigeon River which forms a portion of the boundary between the United States and Canada rises in Mountain Lake in Township 65 North, Range 2 East. and flows southeastward

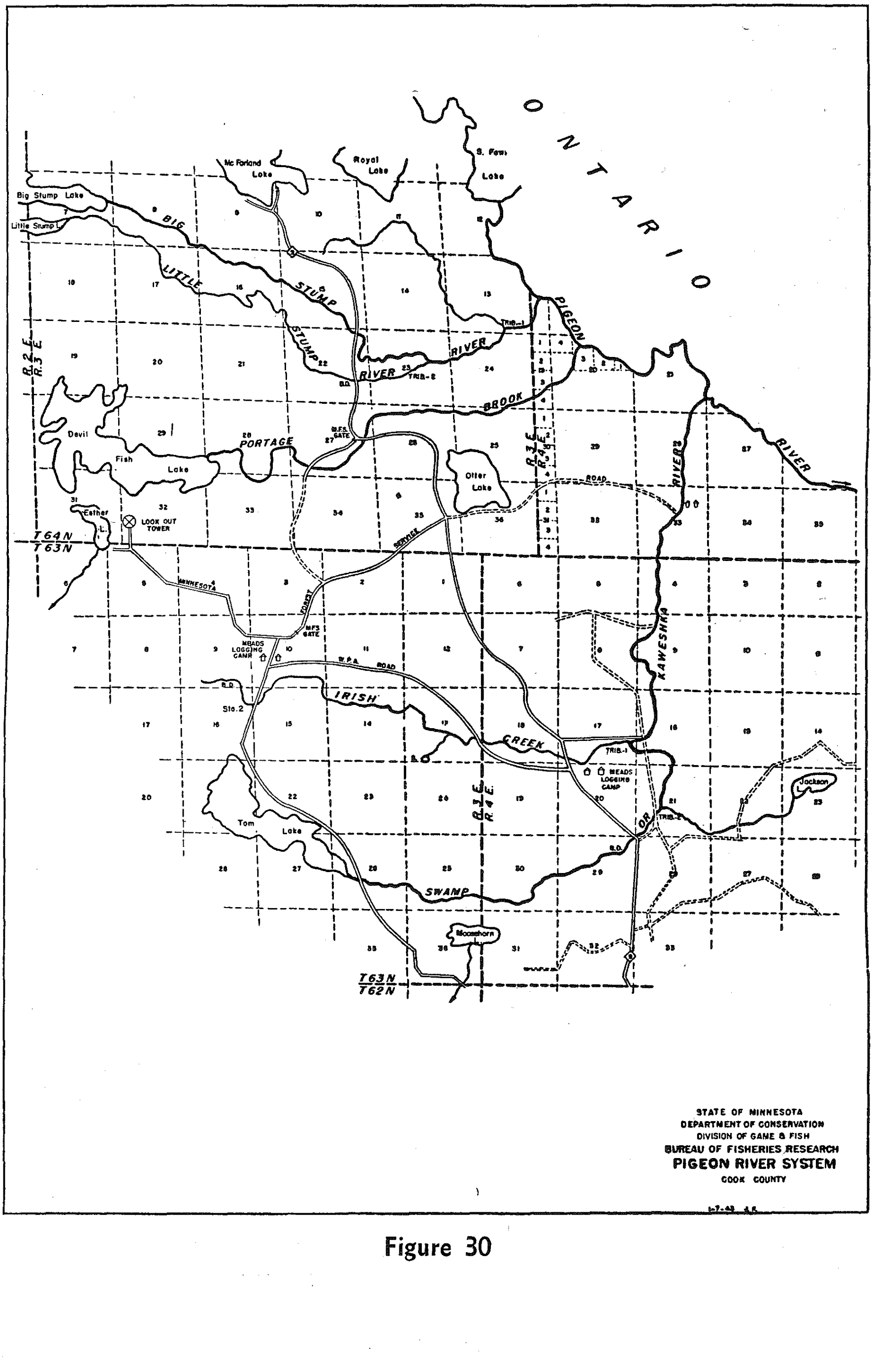

ONTARIO
Big Stump Lake
Little Stump L.
Royal Lake
Lake
BIG STUMP
LITTLE STUMP
STUMP RIVER
PIGEON RIVER
RIVER
BROOK
PORTAGE
Devil Fish Lake
Otter Lake
Esther L.
LOOK OUT TOWER
T64N
T63N
R.2E.
R.3E.
R.3E.
R.4E.
MINNESOTA
IRISH CREEK
KAWESHKA
SWAMP
Tom Lake
Moosehorn L.
Jackson
T63N
T62N
STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION
DIVISION OF GAME & FISH
BUREAU OF FISHERIES RESEARCH
PIGEON RIVER SYSTEM
COOK COUNTY

Figure 30

through Upper Lily, Lower Lily, Moose, North and South Fowl lakes. It begins its real existence as a river in Township 64 North, Range 3 East, at the outlet of South Fowl Lake. In the 30.4 miles between this point and its mouth the stream drops from an elevation of 1,436 feet above sea level to Lake Superior. Between South Fowl Lake and Partridge Falls in Section 29, Township 64 North, Range 5 East, a distance of about 10 miles, the stream has a moderate gradient of 16 feet per mile and is readily navigable by canoe. At Partridge Falls it begins a precipitous descent of nearly 20 miles to Lake Superior. This stretch is marked by rapids, rock gorges, and two major waterfalls, the Big Falls and the Middle Falls. Although the Pigeon River drains a total area of 628 square miles, the drainage areas of the Minnesota tributaries that have been considered trout waters total somewhat less than 100 square miles. This area includes the basins of the Kaweshka (Kameshkeg, Swamp, or Mission Pine) River, Big and Little Stump rivers, and Portage Brook.

The underlying rocks are largely graywacke and slates (Rove Formation). This formation has been much intruded with diabase dikes and sills running in a general east-west direction, and most of the lakes and rivers lie in valleys eroded in the softer graywacke and slates. The headwaters of some of the Minnesota tributaries lie south of the Rove Formation in the younger Keweenawan rocks. In the area considered (T. 63 and 64 N., R. 3 and 4 E.) these rocks are largely covered with glacial clay which contains considerable amounts of stone. In the depressions there are extensive swamps.

Nine years of gauging the main stream near its mouth by United States Army Engineers (1923 to 1932) showed variation in flow between 30 and 7,000 cubic feet per second, with the least flow usually occurring in February and March (U. S. War Department, 1933d).

Stump River is the first tributary entering the Pigeon River east of South Fowl Lake. This stream has two main branches, Big Stump River which rises in Big Stump Lake in Section 7, Township 64 North, Range 3 East, and Little Stump River which rises in Little Stump Lake in this same section. The two branches have parallel sluggish courses through spruce swamps and aspen forest to their junction in Section 23, Township 64 North, Range 3 East. The beds of these streams are largely clay and the summer flow of both is so small that no stocking or improvement is recommended.

Portage Brook which enters the Pigeon River in Section 20, Township 64 North, Range 4 East, is the next tributary. It has its origin in Devil Fish Lake in Section 28, Township 64 North, Range 3 East. For the first mile it flows through upland timber and black spruce swamps and then for the next 2 miles through cutover balsam fir, white spruce, and black ash forest. The remainder of its course is through virgin hardwood forest. Its bed is mostly boulder, rubble, and gravel, and its average width is 10 to 12 feet. The water is clear and soft, having a total alkalinity of 21.3 parts per million, and is slightly acid with a pH of 6.8. Because it is cold and well suited to brook trout, it should be lightly stocked with 7- to 9-inch fish in Sections 26 and 27. Stream improvement work was completed in Section 27 by the Civilian Conservation Corps in 1935. It is recommended that these improvement structures be kept in repair and that the improved section be extended to include the western half of Section 26.

Continuing eastward the Kaweshka, or Swamp River, enters the Pigeon River in Section 21, Township 64 North, Range 4 East. It has one major tributary, Irish Creek (Trib. 1), that joins it in Section 17, Township 63 North, Range 4 East. The Kaweshka River has its source in Tom Lake, a warm pike-pickerel water. Between the outlet and the junction with Irish Creek, Swamp River has an average width of about 12 feet and flows through a heavy forest of cedar, spruce, and hardwoods. An active beaver dam was observed in the northwest quarter of Section 29, and about one-fourth mile below this dam the stream becomes ponded in cedar, tamarack, and black spruce swamps. This sluggish area continues to the junction with Irish Creek. The water is soft and generally similar to that of Portage Brook. Fairly good spring trout fishing is reported from the Swamp River but in midsummer the water becomes dangerously warm. It is therefore recommended that this stream be stocked in Section 26 with a limited number of 7- to 9-inch brown trout.

Irish Creek (Trib. 1) has its source in wet woods in Section 9, Township 63 North, Range 3 East, and flows as a fairly rapid stream over gravel, boulder, and rubble until it enters a ponded stretch about one-half mile above its junction with the Kaweshka River in Section 17, Township 63 North, Range 4 East. In the lower portion of its course it runs through a shallow rock gorge. The stream is shaded with alder, cedar, and black ash and the adjoining land is covered with aspen and birch. Chemically, the water is similar to that of Swamp River and Portage Brook and is favorable to trout. This creek averages about 10 feet in width and is cold enough for brook trout but has, unfortunately, an inconstant water supply. It was almost dry in the summers of 1936 and 1939. In 1936 this stream was improved in Section 18 by the Civilian Conservation Corps. No stocking or further stream improvement is recommended.

THE FISHES OF THE STREAMS OF THE NORTH SHORE OF LAKE SUPERIOR WITH ANNOTATED LIST

During the course of the 1940 and 1941 surveys of the streams tributary to Lake Superior, 212 collections of fish were made. In addition to these which were taken with minnow seines, a few collections were obtained with traps in 1942. The 27 streams covered by these collections include all the important rivers and creeks on the North Shore. The fish fauna of these streams is made up of 36 species, three of which, the rainbow trout, the brown trout, and the smallmouth bass, are known to have been introduced (Table 9). Two others, the bluegill and the pumpkinseed, are probably not native.

Many of the North Shore streams have high falls near their mouths which prevent the migration of fish from Lake Superior into the upper parts of the river system. This fact suggests that the present fish fauna of most of these streams became established in late Pleistocene time. During this period glacial precursors of Lake Superior submerged the falls and enabled fish to migrate from the lake into the central stretches of the streams. Extensive fish migration over the morainic divide that separates the St. Louis River system from the North Shore streams seems improbable since the tadpole cat, *Schilbeodes gyrinus* (Mitchill), is a common species in many of the St. Louis River tributaries but is entirely absent from the North Shore streams.

On the basis of habitat preference, the native species fall into two general groups: (1) common Lake Superior fishes that inhabit the estuaries and the portions of the streams below the lower falls and (2) those typical trout-stream species that are

Table 9. The occurrence of fishes in the Minnesota North Shore streams—seining, planting, and authenticated records[1]

Species	Lester	French	Sucker	Knife	Stewart	Gooseberry	Split Rock	Beaver	Baptism	Manitou	Caribou	Two Island	Cross	Temperance	Onion	Poplar	Hollow Rock Creek	Cascade	Devil Track	Durfee Creek	Kimball Creek	Kadunce Creek	Arrowhead (Brule)	Flute Reed	Reservation	Spruce Creek	Pigeon	Rivers where species occurred
1. *Salmo trutta fario* Linnaeus	XP	P	RP	P	XP	XP	RP	P	P	XP	XP	XP	XP	XP	P	P	..	XP	P	..	..	..	P	..	..	..	..	19
2. *Salmo gairdnerii irideus* Gibbons	XP	P	XP	XP	XP	P	P	P	P	P	P	..	P	P	XP	XP	X	XP	XP	..	XP	XP	XP	P	XP	X	P	25
3. *Salvelinus fontinalis fontinalis* (Mitchill)	XP	XP	XP	XP	XP	XP	P	XP	P	P	XP	XP	XP	XP	XP	XP	..	XP	XP	XP	XP	XP	XP	P	P	XP	XP	26
4. *Cristivomer namaycush namaycush* (Walbaum)	..	P	..	..	..	..	..	..	..	..	..	..	..	..	..	P	..	..	..	..	..	..	..	..	..	..	..	2
5. *Catostomus commersonnii commersonnii* (Lacepede)	X	X	X	X	X	X	X	X	X	X	..	X	X	X	X	X	..	X	X	..	..	..	X	..	..	..	X	19
6. *Catostomus catostomus catostomus* (Forster)	X	X	..	..	..	..	X	..	X	..	..	..	X	X	X	X	..	X	X	..	X	X	X	..	..	X	..	14
7. *Semotilus atromaculatus atromaculatus* (Mitchill)	X	X	X	X	X	X	X	X	X	X	..	X	X	X	..	X	..	X	X	..	..	..	X	..	..	X	..	18
8. *Margariscus margarita nachtriebi* (Cox)	X	..	..	..	X	X	..	X	X	X	X	X	X	X	X	X	..	..	X	..	X	X	..	..	..	..	X	16
9. *Couesius plumbeus plumbeus* (Agassiz)	X	X	..	..	..	X	..	X	..	..	..	..	..	..	X	X	..	X	..	..	..	..	X	..	..	..	..	8
10. *Rhinichthys atratulus meleagris* Agassiz	X	X	X	X	X	X	..	X	X	X	X	X	X	X	..	X	..	X	X	..	..	..	X	..	..	X	..	18
11. *Rhinichthys cataractae cataractae* (Valenciennes)	X	X	X	..	X	X	X	X	X	X	..	..	X	X	X	X	..	X	X	..	X	..	X	X	..	..	..	18
12. *Pfrille neogaea* (Cope)	X	X	..	..	..	X	..	X	..	..	..	..	..	X	..	..	..	X	..	..	..	X	..	..	X	..	X	9
13. *Chrosomus eos* Cope	X	X	..	X	..	..	..	X	X	..	..	X	..	X	..	..	..	X	X	..	X	X	X	..	..	..	..	12
14. *Notropis atherinoides atherinoides* Rafinesque	X	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2
15. *Notropis cornutus frontalis* (Agassiz)	..	..	X	X	..	..	X	X	X	X	..	X	X	X	..	X	..	X	..	..	..	..	X	..	..	..	..	12
16. *Notropis hudsonius selene* (Jordan)	X	X	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3
17. *Notropis heterodon* (Cope)	..	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
18. *Notropis heterolepis heterolepis* Eig. and Eig.	X	..	..	..	..	..	..	..	X	..	..	X	X	X	..	X	..	X	..	..	..	..	..	..	..	..	..	7
19. *Hybognathus hankinsoni* Hubbs	..	..	..	..	..	..	..	..	X	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2
20. *Pimephales promelas promelas* Rafinesque	X	X	..	..	..	..	..	X	X	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	5
21. *Hyborhynchus notatus* (Rafinesque)	..	..	..	..	..	..	..	..	X	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2
22. *Umbra limi* (Kirtland)	X	..	..	X	..	..	..	..	..	X	..	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5
23. *Esox lucius* Linnaeus	..	..	..	..	..	X	..	..	..	X	..	..	X	X	..	X	..	..	X	..	..	..	X	..	..	..	..	7
24. *Percopsis omiscomaycus* (Walbaum)	..	..	..	..	..	X	X	X	X	..	..	..	..	..	..	X	..	..	X	..	..	..	..	..	..	..	..	6
25. *Perca flavescens* (Mitchill)	X	X	X	..	..	..	X	X	X	X	..	..	X	X	..	..	..	X	..	..	..	..	X	..	..	..	..	11
26. *Stizostedion vitreum vitreum* (Mitchill)	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	2
27. *Percina caprodes semifasciata* (De Kay)	X	..	..	..	..	X	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4
28. *Boleosoma nigrum nigrum* (Rafinesque)	X	..	..	X	..	..	..	X	X	X	..	..	X	X	..	X	..	X	..	..	..	..	..	..	..	..	..	9
29. *Poecilichthys exilis* (Girard)	X	..	..	..	..	..	..	..	..	..	..	X	X	..	..	X	..	..	X	..	..	..	..	..	..	..	..	5
30. *Micropterus dolomieu dolomieu* Lacepede	..	..	..	..	..	..	..	..	..	..	..	..	..	P	..	..	..	..	..	..	..	..	P	..	..	..	..	2

1. X—taken in the 1940-42 collections; P—planted; R—authentic report.

Table 9. (Cont'd.) The occurrence of fishes in the Minnesota North Shore streams—seining, planting, and authenticated records[1]

Species	Lester	French	Sucker	Knife	Stewart	Gooseberry	Split Rock	Beaver	Baptism	Manitou	Caribou	Two Island	Cross	Temperance	Onion	Poplar	Hollow Rock Creek	Cascade	Devil Track	Durfee Creek	Kimball Creek	Kadunce Creek	Arrowhead (Brule)	Flute Reed	Reservation	Spruce Creek	Pigeon	Rivers where species occurred
31. *Lepomis gibbosus* (Linnaeus)	. .	. .	. .	. .	. .	. .	. .	. .	x	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	1
32. *Lepomis macrochirus macrochirus* Rafinesque	. .	. .	. .	. .	. .	. .	. .	. .	x	. .	. .	. .	. .	. .	. .	. .	. .	R	. .	. .	. .	. .	. .	. .	. .	. .	. .	2
33. *Cottus bairdii bairdii* Girard	x	. .	. .	. .	. .	x	x	x	. .	x	. .	. .	x	x	. .	x	x	x	x	. .	x	. .	. .	. .	. .	. .	. .	12
34. *Cottus cognatus* Richardson	. .	x	. .	x	. .	. .	. .	x	x	x	x	x	. .	x	x	. .	. .	x	x	. .	x	x	. .	. .	. .	. .	. .	13
35. *Eucalia inconstans* (Kirtland)	x	x	x	x	x	x	x	x	x	x	x	. .	x	x	. .	. .	. .	x	x	. .	x	x	. .	. .	. .	. .	x	17
36. *Pungitius pungitius* (Linnaeus)	. .	. .	. .	. .	. .	. .	. .	x	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	1
Total number species	23	17	12	13	9	15	13	20	22	16	7	15	18	20	9	18	2	19	18	1	9	8	14	3	3	5	6	

1. x—taken in the 1940-42 collections; P—planted; R—authentic report.

more at home in the faster, colder waters above the falls. The first group includes the northern sucker, *Catostomus c. catostomus* (Forster), the lake chub, *Couesius p. plumbeus* (Agassiz), the troutperch, *Percopsis omiscomaycus* (Walbaum), the logperch, *Percina caprodes semifasciata* (De Kay), the northern spottail shiner, *Notropis hudsonius selene* (Jordan), the lake emerald shiner, *Notropis a. atherinoides* Rafinesque, and the ninespine stickleback, *Pungitius pungitius* (Linnaeus). The second group includes many common cold-water stream species of which the most abundant are the common sucker, *Catostomus c. commersonnii* (Lacépède), the creek chub, *Semotilus a. atromaculatus* (Mitchill), the blacknose dace, *Rhinichthys atratulus meleagris* Agassiz, the longnose dace, *Rhinichthys c. cataractae* (Valenciennes), Nachtrieb's dace, *Margariscus margarita nachtriebi* (Cox), the common shiner, *Notropis cornutus frontalis* (Agassiz), and the brook trout, *Salvelinus f. fontinalis* (Mitchill).

Agassiz (1850) collected fish from the Ontario portion of the Lake Superior shoreline and published the first species list. Since then the fish fauna of part or all of the Lake Superior drainage has been considered by Cox (1897), Surber (1920 and 1922), and in several papers by Hubbs and his co-workers. Hubbs and Brown (1929) compiled a species list for the Ontario shoreline. Lanman (1847) and Kohl (1860) include general accounts of the common fishes and fishing conditions in the Lake Superior region.

The following annotated list includes only those fish that have been collected from the North Shore streams or are known to have been planted in them.

Salmonidae

1. *Salmo trutta fario* Linnaeus, brown trout.—Plantings in the Lester River and Kimball Creek in 1913 marked the introduction of this European species into the North Shore streams. Since then it has been more or less extensively stocked in 21 of the streams, especially in the larger, warmer waters.

2. *Salmo gairdnerii irideus* Gibbons, rainbow trout.—This species was first introduced into North Shore streams in 1901 when the Lester and Poplar rivers were stocked. During the early years many heavy plantings of western steelhead rainbows were also made. Many later stockings, beginning with 1927, were

of an Ozark Mountain strain of rainbows. Large specimens are commonly taken from the mouths of many of the streams but upstream spawning migration of this anadromus species is prevented in most of the streams by the falls near the mouths.

3. *Salvelinus fontinalis fontinalis* (Mitchill), brook or speckled trout.—The South Shore of Lake Superior was famed for brook trout fishing as early as the 1840's (Lanman, 1847, Shiras, 1921) and in 1850 Agassiz recorded this species from the Black River in Ontario. In 1880 Winchell, speaking of the Minnesota portion of the shore, stated, "This beautiful and universally admired species inhabits, in great numbers, the many small streams flowing into Lake Superior." Myron Cooley (1894), who fished the North Shore streams prior to 1889, gives an account of brook trout fishing in the Brule, Baptism, Reservation, Split Rock, Manitou, and Knife rivers. Brook trout taken from the mouth of the Brule (Arrowhead) River and weighing 5¾ pounds were seen by Winchell. Shiras (1921) states that prior to 1890 brook trout weighing 3 to 4 pounds were common in the Lake Superior area. Lanman (1847) remarks, "You may take a boatload of them which will average 3 to 4 pounds in weight."

The question arises as to whether brook trout originally inhabited those stream stretches above the high falls that now form impassable barriers to fish migration. Thaddeus Surber, in 1922, questioned the older residents of the North Shore concerning the original distribution of brook trout and concluded that they were found at the time of settlement in the upper stretches of the Reservation River and Trout Lake, its source, and in four small lakes in the vicinity of Beaver Bay, Bear, and Nicado lakes in the Beaver River system, Nipissiquit Lake in the Baptism River system, and Tetagouche Lake, the source of the creek of that name. It should be pointed out, however, that at the time of settlement brook trout were not known to be native above high falls in the other streams nor in the many other suitable lakes of the North Shore drainage. Hubbs (1929) working on the South Shore found that brook trout did not occur as natives in waters which were separated from Lake Superior by falls impassable since late Pleistocene time.

The North Shore streams have been extensively stocked with brook trout since 1900, and it is probable that occasional plantings as early as 1891, recorded as "trout," were of this species.

4. *Cristivomer namaycush namaycush* (Walbaum), lake trout.—The lake trout occurs commonly in Lake Superior and in some of the headwater lakes of the North Shore streams. Although it is not known to occur in the streams themselves, both the French and Poplar rivers have been planted with this species.

Catostomidae

5. *Catostomus commersonnii commersonnii* (Lacépède), common sucker.—This species was taken in 87 of the 212 collections and is abundant in the lower, warmer stretches of most of the streams. Most specimens taken were in their first year.

6. *Catostomus catostomus catostomus* (Forster), northern sucker. — Fingerlings were common in the mouths of most streams. In the upper stretches it was taken commonly only in the Arrowhead (Brule) River. As this is primarily a lake species, it is probable that the adults are present in the river mouths only during spawning.

Cyprinidae

7. *Semotilus atromaculatus atromaculatus* (Mitchill), northern creek chub.—Creek chubs were taken from all the major streams except the Caribou River. Females with nearly mature eggs were found in the Knife River on June 28, 1940, and in the Lester River on July 5, 1940.

8. *Margariscus margarita nachtriebi* (Cox), Nachtrieb's dace, leatherback.—This minnow, which was originally described from Mille Lacs Lake by Cox (1896), is fairly common in the quiet water near the stream mouths and in slower stretches and backwaters upstream. It is highly prized as a bait minnow throughout northern Minnesota.

9. *Couesius plumbeus plumbeus* (Agassiz), lake chub.—This is the most abundant species in the mouths of most North Shore streams and occurs commonly in wide, slow stretches back from the shore in the Poplar, Cascade, and Arrowhead (Brule) rivers.

10. *Rhinichthys atratulus meleagris* Agassiz, blacknose dace.—The blacknose dace is the most abundant fish in the North Shore streams and occurs in practically all habitats. Numerous

gravid females taken from three streams indicate that this species spawns during the first two weeks of July.

11. *Rhinichthys cataractae cataractae* (Valenciennes), longnose dace.—This species is fairly abundant in rapid water and occasional elsewhere. It is frequently associated with the blacknose dace.

12. *Pfrille neogaea* (Cope), finescale dace.—Prior to the 1940 collections from the North Shore this species was not known in Minnesota. It is of occasional occurrence in stream mouths and in slow, boggy stretches upstream. It is often associated with the redbelly dace and Nachtrieb's dace.

13. *Chrosomus eos* Cope, northern redbelly dace.—This is often the commonest species in boggy headwater pools and backwaters where it is usually found with the fivespine stickleback. Occasional collections were taken from the stream mouths. Females with nearly mature eggs were collected from the Knife River on June 27, 1940, and from the French River on July 6, 1940.

14. *Notropis atherinoides atherinoides* Rafinesque, lake emerald shiner.—A common Lake Superior species that was taken only in the mouths and lower stretches of the Lester and Sucker rivers.

15. *Notropis cornutus frontalis* (Agassiz), common shiner. —Agassiz (1850) first described this subspecies from the Montreal River on the eastern shore of Lake Superior. On the Minnesota portion of the shore it is common in the warmer, deeper stretches of the larger streams.

16. *Notropis hudsonius selene* (Jordan), spottail shiner.—A Lake Superior species that was taken only from the slow, lower portions of the Lester, French, and Knife rivers.

17. *Notropis heterodon* (Cope), blackchin shiner.—A rare species on the North Shore that was collected only from a weedy stretch of the Two Island River.

18. *Notropis heterolepis heterolepis* Eigenmann and Eigenmann, blacknose shiner.—This inconspicuous minnow was taken from weedy portions of seven North Shore streams. It is nowhere abundant but occurs most frequently in the vicinity of lakes and behind beaver dams.

19. *Hybognathus hankinsoni* Hubbs, brassy minnow.—The brassy minnow was collected in the Two Island River in 1941 and in the Baptism River in 1942. It usually inhabits slower stretches. This minnow is reported to have been recently planted in the Baptism River from lakes in Pine County.

20. *Pimephales promelas promelas* Rafinesque, fathead minnow.—The fathead is of only occasional occurrence in stream mouths and ponded stretches.

21. *Hyborhynchus notatus* (Rafinesque), bluntnose minnow.—Like the brassy minnow, this species was taken only from the slower portions of the Baptism and Two Island rivers.

Umbridae

22. *Umbra limi* (Kirtland), mudminnow.—This species is of infrequent occurrence and was taken only from Lester, Knife, Manitou, Two Island, and Cross rivers. It is most common in slow, boggy areas.

Esocidae

23. *Esox lucius* Linnaeus, northern pike, pickerel.—Northern pike are occasional in the deeper, slow water stretches and in the vicinity of lakes. Few mature specimens were taken.

Percopsidae

24. *Percopsis omiscomaycus* (Walbaum), troutperch.—An estuary and lake species that is limited in the North Shore streams to quiet waters near the mouths.

Percidae

25. *Perca flavescens* (Mitchill), yellow perch.—Occasional in stream mouths, in deeper pools, and in the vicinity of headwater lakes.

26. *Stizostedion vitreum vitreum* (Mitchill), walleye or pike-perch.—This species, which is common in Lake Superior and has been successfully planted in some of the headwater lakes, was taken only from the mouths of the Devil Track and French rivers.

27. *Percina caprodes semifasciata* (De Kay), logperch.—Occasional in the lower stretches and mouths of the Gooseberry, Split Rock, and Beaver rivers.

28. *Boleosoma nigrum nigrum* (Rafinesque), Johnny darter.—The Johnny darter is of general but infrequent occurrence throughout the North Shore streams. It is commonest in slow waters on sand and mud bottoms.

29. *Poecilichthys exilis* (Girard), Iowa darter.—This darter was collected from five of the North Shore streams. It is often locally quite abundant but is not as generally distributed as the Johnny darter. It seems to prefer sandy bottoms and warmer water than is usually frequented by brook trout.

Centrarchidae

30. *Micropterus dolomieu dolomieu* Lacépède, smallmouth bass.—The smallmouth bass is not known to be native to the North Shore streams but has been planted in the Arrowhead (Brule) and Temperance rivers, in Bear and Lax lakes, both tributary to the Beaver River, and in Stewart Lake on the Stewart River. Although no specimens were taken in the 1940 and 1941 surveys, anglers have reported catching this species. Some of the stockings of smallmouth bass in the North Shore area have been unfortunate in that habitats suited to trout have been preempted by this locally less desirable species.

31. *Lepomis gibbosus* (Linnaeus), pumpkinseed sunfish.—A single specimen of this centrarchid was taken from the ponded weedy east branch of the Baptism River.

32. *Lepomis macrochirus macrochirus* Rafinesque, bluegill.—A few immature specimens were taken in minnow traps from the east branch of the Baptism River in the fall of 1942. Surber (1922) reports the bluegill from the Cascade River. It is possible that both this and the preceding species may have been introduced.

Cottidae

33. *Cottus bairdii bairdii* Girard, sculpin or northern muddler.—Although this and the following species of sculpin sometimes occur together, *Cottus b. bairdii* seems to be largely limited to the warmer waters. The average temperature of the water

from which 21 collections of this species were taken is 67.6° F. with a maximum of 79° F. Both this and the following species are fairly common in the North Shore streams.

34. *Cottus cognatus* Richardson, slimy sculpin or muddler. —On the North Shore this species inhabits colder water than does *Cottus b. bairdii.* The average temperature of the water from which 21 collections were taken is 60.5° F. with a maximum of 68° F. The value of this species as an indicator of potential trout waters has been pointed out by both Cooper (1939) and Hubbs and Lagler (1941).

Gasterosteidae

35. *Eucalia inconstans* (Kirtland), brook or fivespine stickleback.—This is a common species in the slower, muddy stretches and quiet eddies of most of the streams.

36. *Pungitius pungitius* (Linnaeus), ninespine stickleback. —The ninespine stickleback is at times very abundant along the North Shore. It is primarily a lake species and is represented in the stream collections by a single specimen from the mouth of the Beaver River.

THE CHEMICAL QUALITY OF THE TROUT-STREAM WATERS ON THE MINNESOTA NORTH SHORE OF LAKE SUPERIOR

Sampling and Analytical Methods

During the 1940 surveys of 10 streams on the lower portion of the Minnesota North Shore, field analyses were made for dissolved oxygen, carbon dioxide (titratable acidity), total alkalinity, and pH. At least one sample was collected from each stream for more detailed laboratory analysis. A similar procedure was followed in 1941 for the remaining streams, except that analyses for dissolved oxygen and carbon dioxide were discontinued because the upper streams are generally similar to those surveyed in 1940. Additional samples for laboratory analysis were collected from nine of the southern streams in the summer of 1942. Analyses for nitrogenous compounds were made on fresh samples, and most analyses for sulphates, chlorides, total phosphorus, total iron, and total dissolved solids several months after the collection of the samples.

All analyses except those for total phosphorus and sulphate ion were made according to procedures outlined in "Standard Methods of Water Analyses, 8th Edition" (American Public Health Association, 1936). Total phosphorus was determined by the modified Denige method of Taylor (1937). Sulphates were determined turbidimetrically using concentrated barium chloride and hydrochloric acid. The results of the mineral analyses are shown in detail in Table 10. Dissolved gas, pH, and additional total alkalinity determinations by stations are presented in Tables 40-66.

Variations in water analysis are often reflections of differences in water stage. Since the streams were very low in 1940 and high in 1942, all average analyses cited for these lower streams have been calculated by averaging the means for the two years.

General Chemical Quality of the Water

In common with most other waters of the Great Lakes drainage, the North Shore streams have a predominance of carbonate salts. Sulphates and chlorides occur only in low concentrations. In most of the samples the concentration of sulphate ion was less than 3.0 parts per million, and the concentration of chloride ion less than 2.0 parts per million. Individual total alkalinity (carbonate) readings range from 13.0 to 100.0 parts per million with the stream averages ranging from 87.7 parts per million for the Sucker River to 20.0 parts per million for the Temperance River. Classified according to Birge and Juday (1911), the waters of the North Shore streams are medium hard to hard. However, a comparison with analyses of other Minnesota rivers and lakes shows that they are among the softer waters of the state (Table 10).

On the basis of carbonate content the North Shore streams can be roughly divided into two groups, those streams south of the Beaver River, most of which have an average carbonate content between 60 and 90 parts per million, and the softer streams from the Beaver River northward, most of which have an average carbonate content of between 20 and 40 parts per million. This difference in carbonate hardness is probably the result of the more extensive deposits of glacial and lacustrine soils along the southern portion of the shore. Many of the individual streams also show a slight increase in carbonate hardness from source to mouth.

A comparison of the total alkalinity, sulphate, and chloride content with total dissolved solids shows that the North Shore river waters have a considerable amount of additional filterable suspended and dissolved material. The brown color of the water and the results of other water analyses from this region suggest that at least part of this difference is colloidal organic matter and silica.

Dissolved Gases and Hydrogen-Ion Concentration

In the summer of 1940, analyses for dissolved oxygen and carbon dioxide (titratable acidity) were made at most of the field stations on 10 of the southern streams. These analyses showed the dissolved-oxygen content of the water to range between 5.0 and 9.0 parts per million and in most places to be above 6.0 parts per million. Embody (1927) sets 4.29 parts per million of oxygen as the safe lower limit for brook trout waters and Needham (1938) 4.0 parts per million as a safe lower limit for brook, brown, and rainbow trout waters.

The individual field analyses for dissolved carbon dioxide or titratable acidity on these same streams show a range in concentration between 0.0 and 31.0 parts per million with a concentration in most places ranging between 1.0 and 7.0 parts per million. Only in a few ponded boggy headwater areas did the concentration exceed 15.0 parts per million which Embody (1936) considered to be the upper limit for trout hatchery water supplies. According to Powers (1938), it is the sudden and drastic change of carbon dioxide tension that is injurious to fish. The danger of rapid changes in carbon dioxide content and tension is at a minimum in rapidly flowing streams such as those of the North Shore in which the water is being continually mixed and in which oxygen is ample.

Field determinations of hydrogen-ion concentration or pH with LaMotte comparators show that the North Shore streams are neither markedly acid nor alkaline. Most of the pH readings are but little above or below pH 7.0, the neutral point, and all are well within the range of pH 4.0 to pH 9.5 found by Creaser

(1930) to be tolerated by trout. In general, the harder streams of the southern portion of the shore tend to be slightly alkaline (pH above 7.0), and the softer streams of the upper portion of the shore to be slightly acid (pH below 7.0).

Dissolved Iron

As the Minnesota North Shore streams lie in an area rich in iron, analyses were run on 48 samples from 15 of the upper streams to determine the iron content of the water (Table 10). The individual determinations ranged from 0.00 to 1.25 parts per million, and the stream averages from 0.05 to 0.386 parts per million. These amounts are well below 50 parts per million, the upper limit of fish toleration, as determined by Ellis (1935), and within or below the most favorable range for algal growth as found by Smith (1933). The mean total iron content for the 15 streams is 0.201 parts per million or slightly more than twice that found by Clarke (1924) for Lake Superior. Although ferric iron is abundant enough in the glacial soils of the North Shore to color them red, very little seems to be reduced to the soluble ferrous state.

Chemical Fertility

It has been shown that hard-water or alkaline trout streams are generally more productive of fish food than soft-water or acid streams (Tarzwell, 1938; Needham, 1938). Judging from the general position of the North Shore waters in the entire series of carbonate surface waters and from the nearly neutral pH readings, these streams can be considered moderately fertile. Phosphorus and nitrogen analyses of the North Shore stream waters bear out this conclusion. The average total phosphorus content of the streams ranges from 0.005 to 0.063 parts per million, with a mean for 29 streams of 0.035 parts per million. This concentration of phosphorus is similar to that shown by Juday, Birge and co-workers (1928) for Wisconsin lakes, and similar to that found by the Minnesota Department of Conservation (Table 10 and unpublished data) for waters of central Minnesota, but is more than that found for the soft waters of some other regions (Deevey and Bishop, 1941; Pearsall, 1930).

In the summer of 1942, analyses for nitrogenous compounds were run on fresh samples from nine of the lower streams. A total of 11 samples was analyzed for nitrate nitrogen and Kjeldahl nitrogen and nine of these same samples were analyzed for nitrite nitrogen. The total nitrogen content of the nine samples varied from 0.208 to 0.607 parts per million with a mean of 0.355 parts per million. A comparison of these analyses with those run by the United States Geological Survey on the other Minnesota river waters (Table 10) shows that the nitrogen content of the North Shore streams is not as high as it is in some of the harder rivers. In most cases the nitrogen content of North Shore streams is higher than that found for fish lakes in central and northern Minnesota (Table 10 and unpublished data, Minnesota Bureau of Fisheries Research).

Table 10. A comparison of average water analyses of the major Minnesota North Shore streams with analyses of some other Minnesota surface waters—expressed as parts per million[1]

	T. Alk.	SO_4	Cl	Tot. N.	T. D. S.	Tot. Fe.	Tot. P.
North Shore Rivers							
1. Pigeon River	35.6	2.4	3.0	....	....	1.08	....
2. Arrowhead River	25.9	1.5	0.8	....	76.8	.214	.045
3. Devil Track River	30.8	1.6	0.4	....	95.8	.215	.043
4. Cascade River	35.0	1.7	0.5	....	86.2	.110	.026
5. Poplar River	31.6	1.4	1.0	....	85.9	.103	.016
6. Temperance River	20.0	0.9	1.9	....	92.7	.283	.045
7. Cross River	29.3	1.4	0.6	....	80.2	.224	.017
8. Two Island River	23.7	0.6	0.2	....	89.1	.386	.018
9. Caribou River	27.0	0.7	0.9	....	106.6	.073	.015
10. Manitou River	31.8	0.4	0.8	....	90.0	....	.037
11. Baptism River	30.0	1.5	1.3	.261	91.1	....	.063
12. Beaver River	39.7	2.6	0.0	.518	109.8	....	.053
13. Split Rock River	61.2	1.9	3.2	.336	113.1	....	.041
14. Gooseberry River	63.1	1.5	0.4	....	103.2	....	.048
15. Stewart River	56.3	0.1	1.5	.342	113.5	....	.021
16. Knife River	62.0	2.5	2.3	.214	110.1	....	.044
17. Sucker River	87.7	1.1	0.0	.607	129.3	....	.044
18. French River	73.0	1.0	....	....	....	....	.044
19. Lester River	85.1	2.5	4.5	.208	169.5	....	.044
Other Minnesota Rivers							
20. St. Croix River	89.0	Trace	1.0	.2854	135.0	Trace	....
21. Upper Mississippi	151.0	Trace	.9	.5594	189.0	Trace	.055
22. Red River	202.0	38.0	6.3	.4133	346.0	Trace	....
23. Minnesota River	220.0	178.0	6.4	.5686	556.0	Trace	....
Minnesota Lakes							
24. Brule Lake	12.9	3.5	0.2	....	36.3	.05	....
25. Lake Superior	47.2	2.2	1.2	....	....	.096	....
26. Mille Lacs Lake	97.5	0.4	0.4	.709	145.7	....	.028
27. Whitefish Lake	120.0	0.0	1.4	.210	141.6	....	.030
28. Maple Lake	145.0	180.0	2.8	.844	482.0	....	.045

1— 1. Recalculated from W. A. Noyes, as cited by Clarke (1924).
2-19. Means of analyses for streams. Samples collected in the summers of 1940, 1941, and 1942. J. B. Moyle, K. L. Osterud and W. A. Kenyon, analysts, Minn. Bur. Fish. Res.
20-23. After Dole and Wesbrook (1907); nitrogen recalculated. Phosphorus for Upper Mississippi River by J. B. Moyle, 1939, Minn. Bur. Fish. Res.
24. Analysts, L. L. Smith and C. B. Reif. Sample, summer 1935. Minn. Bur. Fish. Res.
25. Recalculated from Clarke (1924).
26. Mille Lacs county, Oct. 8, 1942. J. B. Moyle, analyst, Minn. Bur. Fish Res.
27. Sept. 16, 1942, Crow Wing Co., J. B. Moyle, analyst, Minn. Bur. Fish. Res.
28. Polk County, Sept. 17, 1942. J. B. Moyle, analyst, Minn. Bur. Fish. Res.

THE PLANT AND ANIMAL PLANKTON AND THE BOTTOM-INHABITING ALGAE OF THE NORTH SHORE STREAMS

The free-floating microscopic plants and animals that make up the plankton of lakes and streams are the ultimate food supply of most aquatic animals. Algae or microscopic plants are the principal medium through which minerals and gases dissolved in the water are synthesized into organic foods. The true plankton of lakes and other impounded waters consists of free-floating microscopic plants and animals that have developed in the particular body of water in which they are found. The greenish bloom on the surface of lakes in late summer is the result of a heavy growth of such true plankton. In contrast to the true plankton of lakes the plankton of fast streams, such as those of the North Shore, is composed of free-floating microscopic organisms that have had some other source of origin than the moving waters they temporarily inhabit. In the North Shore streams the plankton is made up largely of microscopic plants and animals that have been torn loose from the bottom by the current or have been swept into the streams from headwater lakes or quiet backwaters.

During the surveys 141 collections of plankton were taken from 23 of the North Shore streams. A standard No. 25 silk bolting cloth plankton net was used to concentrate the plankton from 50 to 100 liters of water. The resulting 25 cubic centimeter samples were preserved with formaldehyde for future laboratory examination. Samples were examined and the general abundance of component species noted. Because of the origin of the plankton and the irregular flow of the streams, quantitative counts were not made. In addition to the plankton, the algae occurring in the bottom samples were examined. As there is a close relationship between the stream plankton and the bottom-inhabiting forms, data from both sources have been included.

The plankton of the North Shore streams is sparse and shows a preponderance of diatoms and desmids. These minute plants are the common components of the slippery brown film that covers submerged rocks, debris, and larger plants. As members of this film they form the food of mayfly and stonefly nymphs and other small aquatic animals that forage on the surface of submerged objects. When these minute plants are torn loose from the anchoring film they float downstream. The commonest members of this plankton are the chain diatoms *Meloseira varians* Ag., *Tabellaria fenestrata* (Lyngb.) Kuetz., and *Fragilaria capucina* Desmaz. Although desmids are generally present and are represented by 14 genera and over 50 species, the only species of common occurrence is *Closterium moniliforme* (Bory) Ehr. The varied desmid flora of the North Shore streams is similar to that of other crystalline rock areas (West, 1909; Smith, 1920; Fritsch, 1935).

In the North Shore streams true plankton is limited to the slow stretches between the lower falls and Lake Superior and to a few ponded portions back from the lake. The commonest true plankton species occurring in such situations are *Coelosphaerium Naegelianum* Unger, *Microcystis aeruginosa* Kuetz., *Dinobryon sertularia* Ehr., *Pandorina morum* Bory, *Sphaerocystis Schroeteri* Chod., and *Pediastrum duplex* Meyen.

Attached filamentous algae are common on submerged rocks and debris. Fragments of the blue-green alga, *Oscillatoria tenuis* Ag., and green algae of the genera *Oedogonium, Spirogyra,* and *Zygnema* were taken in many of the plankton samples and occurred commonly in the bottom samples. A heavy growth of *Cladophora* sp. was noted in the lower Lester River below the entrance of barnyard and milk pollution. Of the red algae, *Lemanea annulata* Kuetz. is abundant on rocks in most of the falls and rapids, and *Batrachospermum moniliforme* Roth is of frequent occurrence in cold, shaded streams. *Tuomeya fluviatilis* Harvey occurs occasionally in similar situations.

Microscopic animals are scarce. The commonest protozoa found in the collections were the testate bottom dwelling and moss inhabiting species, *Arcella vulgaris* Ehr., *Campascus cornutus* Leidy, and *Centropyxis aculeata* Stein. Rotifers occurred most frequently in samples from the quieter waters, the commonest species being *Notholca striata* (O.F.M.), *Keratella cochlearis* (Gosse), and *Monostyla lunaris* (Ehr.). Micro-crustacea were rare and largely limited to ponded stretches. *Acroperus harpae* Baird, *Bosmina longirostris* (O.F.M.), *Cyclops* sp., *Diaptomus* sp., *Alona* sp., and occasional nauplii were observed.

A distributional table of the plant and animal plankton species and of the bottom algae of the North Shore streams is given in Table 67 (Appendix I). The arrangement and definition of the algal genera is that of Smith (1933). Specific determinations of true plankton algae and desmids are in most cases based upon Smith (1920, 1924); the diatoms upon Elmore (1921) and Boyer (1927); the filamentous blue-green algae upon Tilden (1910); the protozoa upon Kudo (1939); and most of the other invertebrates upon Ward and Whipple (1918).

It will be noted from this tabulation that while most of the species are of general distribution in the area, a few of the diatoms are apparently restricted to the harder water streams south of the Caribou River. This group of diatoms includes *Eunotia major* (W. Smith) Rab., *Cocconeis pediculus* Ehr., *Diploneis elliptica* (Kuetz.) Cleve, *Gyrosigma* sp., *Amphiprora ornata* Bailey, *Epithemia turgida* (Ehr.) Kuetz., *Nitzschia sigmoidea* (Nitz.) W. Smith, *Cymatopleura elliptica* (Breb.) W. Smith, and *Cymatopleura solea* (Breb.) W. Smith. A greater variety of desmids was taken from the slower portions of the Baptism and Brule rivers than anywhere else on the shore.

THE LARGER AQUATIC PLANTS OF THE NORTH SHORE STREAMS

The Minnesota North Shore trout streams, like fast trout streams of many other localities, have a scant growth of aquatic vegetation. At most places these plants which are commonly known as weeds, mosses, reeds, and rushes cover less than 5 per cent of the predominately stony bottom. In the faster, lower stretches vegetation is often entirely absent. Weeds are abundant only in such ponded portions as the east branch of the Baptism River and in comparatively slow waters of the wide, lower stretches of some of the more easterly streams. The amount of vegetation is limited by the current, nature of the bottom, and by the mineral and organic content of the water. Since many of the streams rise in swamps the water tends to be brown from suspended organic matter. Light penetration is poor in such waters and plant growth is consequently inhibited. The growth of aquatic plants is also greatly influenced by the concentration of dissolved minerals (Moyle, 1939; McAtee, 1939). Because the waters of the North Shore streams are comparatively soft, the plants growing in them are either members of the soft-water flora or are such widely tolerant and ubiquitous species as the common cat-tail and Richardson's pondweed. Water cress, a valuable species of hard-water trout streams, is absent from the North Shore, and because of chemical deficiencies plantings of this and other hard water species are not likely to succeed.

The value of aquatic plants in trout streams has long been recognized by fishermen but has been only recently investigated in detail. The larger aquatic plants provide shelter for the fish, and food, shelter, and anchorage for the myriad of lesser aquatic animals that are directly or indirectly the food of fish. Algae and higher plants are the basic crop of lakes and streams and aquatic animals are as dependent upon them as land animals are upon grass and other upland vegetation. Rushton (1937) stated that the best British trout streams are those that support such a dense growth of aquatic plants that it is necessary to weed them. Needham (1929) shows that although fish-food production on bare stream bottoms in New York State varies from 0.5 to 176 pounds per acre, the food production in weed beds may be as great as 3,553 pounds per acre in *Chara* beds and 1,229 in beds of water cress. Tarzwell (1937) showed a similar relationship between weed beds and trout-food production in Michigan streams and demonstrated that one of the results of stream improvement was the extension of weed beds.

Fifty-seven species of aquatic and semi-aquatic plants have been recorded from the North Shore streams (Table 11). Twenty-two of these are submerged aquatic plants, such as pondweeds and water mosses, seven are rooted plants with floating leaves, such as the water lilies, and with the exception of the free-floating lesser duckweed, the rest are emergent species such as sedges and cat-tails. The most commonly occurring aquatic plants are the alpine pondweed, *Potamogeton tenuifolius* Raf., the grassy pondweed, *Potamogeton gramineus* L. var *graminifolius* Fries, the water starwort, *Callitriche palustris* L., the green-fruited bur reed, *Sparganium chlorocarpum* Rydb., and the water moss, *Fontinalis gigantea* Sulliv. On the sticks and stones in smaller feeder streams, amphibious lichens and mosses are common together with the leafy liverwort, *Chiloscyphus polyanthos* (L.) Corda.

Most of the distributional records shown in Table 11 and included in the following list are field determinations for the commoner species and laboratory determinations of those of less frequent occurrence. Specimens of most of the less common

Table 11. The occurrence of larger aquatic plants in the streams of the Minnesota North Shore of Lake Superior

Species	Lester River	French River	Sucker River	Knife River	Gooseberry River	Split Rock River	Beaver River	Baptism River	Manitou River	Caribou River	Two Island River	Cross River	Temperance River	Onion River	Poplar River	Cascade River	Devil Track River	Durfee Creek	Kimball Creek	Kadunce Creek	Brule River	Flute Reed River	Reservation River	Pigeon River Tribs.
Chara sp.	...	...	...	...	...	...	...	...	x	...	...	x	...	...	x	...	...	...	...	...	...	...	...	...
Nitella sp.	...	...	...	...	x	...	...	x	...	...	...	...	...	...	x	...	...	...	...	x	...	...	...	...
Chiloscyphus polyanthos (L.) Corda	x	x	...	x	x	...	x	...	...	x	...	x	...	x	...	...	...	x	x	...	...	x	...	...
Fontinalis gigantea Sulliv.	x	x	x	x	x	x	x	x	...	x	...	x	...	...	...	...	...	...	...	...	x	...	...	...
Fontinalis biformis Sulliv.	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...	...	...	...	...	x	...	...	...
Fontinalis novae-angliae Sulliv.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...
Isoetes Braunii Dur.	...	...	...	...	...	...	...	...	x	...	...	...	x	...	...	...	...	...	...	...	x	...	...	...
Isoetes macrospora Dur.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...	...	...	...	...
Equisetum fluviatile L.	...	x	x	x	x	x	x	x	x	...	x	...	x	...	x	...	...	...	...	...	x	...	...	...
Typha latifolia L.	...	...	...	x	...	x	...	x	x	x	...	...	...	...	x	...	...	...	...	...	...	...	...	...
Sparganium chlorocarpum Rydb.	...	...	x	...	x	x	x	...	x	...	...	...	x	...	...	...	...	...	...	...	x	...	...	...
Sparganium fluctuans (Morong) Robinson	...	...	...	...	...	...	...	x	x	...	x	...	...	...	...	x	...	...	...	...	...	...	...	...
Potamogeton amplifolius Tuckerm.	...	...	...	...	x	...	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...
Potamogeton epihydrus Raf.	...	...	...	...	...	...	...	x	...	...	x	...	x	...	...	x	x	...	...	...	x	...	...	...
Potamogeton gramineus L. var. *graminifolius* Fries	x	...	...	...	...	x	x	x	x	...	...	x	...	...	x	x	x	...	...	...	x	...	...	...
Potamogeton natans L.	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Potamogeton pusillus L.	x	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Potamogeton Richardsonii (Benn.) Rydb.	x	...	x	...	...	...	x	...	x	...	...	x	x	...	x	...	...	...	...	...	...	...	...	...
Potamogeton Spirillus Tuckerm.	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	x	...	...	...
Potamogeton tenuifolius Raf.	x	x	x	x	x	x	x	x	x	x	...	x	x	...	x	...	...	...	x	...	...	...	...	...
Potamogeton zosteriformis Fern.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...	...	...	...	...
Sagittaria latifolia Willd.	x	x	x	x	x	...	x	...	x	...	...	x	x	...	x	x	...	...	...	...	x	...	...	...
Glyceria borealis (Nash) Batcheldor	...	...	...	...	...	...	x	...	x	...	...	...	x	...	...	...	...	...	...	...	x	...	...	...
Glyceria canadensis (Michx.) Trin.	...	...	...	...	...	...	...	x	x	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...
Glyceria grandis S. Wats.	x	x	...	...	x	...	x	...	x	...	...	x	x	...	...	x	...	...	x	...	x	x	...	...
Glyceria neogaea Steud.	...	...	...	...	x	...	...	...	x	...	...	x	x	...	...	...	...	...	...	x	...	...	...	...
Glyceria striata (Lam.) Hitchc.	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Phalaris arundinacea L.	...	x	...	...	x	...	x	...	...	x	...	...	x	...	...	...	...	...	...	...	...	...	...	...
Zizania aquatica L.	...	...	...	x	...	...	...	...	...	...	...	...	x	...	...	...	...	...	...	...	x	...	...	...

Table 11. (Cont'd.) The occurrence of larger aquatic plants in the streams of the Minnesota North Shore of Lake Superior

Species	Lester River	French River	Sucker River	Knife River	Gooseberry River	Split Rock River	Beaver River	Baptism River	Manitou River	Caribou River	Two Island River	Cross River	Temperance River	Onion River	Poplar River	Cascade River	Devil Track River	Durfee Creek	Kimball Creek	Kadunce Creek	Brule River	Flute Reed River	Reservation River	Pigeon River Tribs.
Eleocharis palustris (L.) R. and S.						x					x		x											
Scirpus atrovirens Muhl.		x							x															
Scirpus subterminalis Torr.								x					x			x				x				
Lemna minor L.								x												x				
Acorus Calamus L.						x			x											x				
Calla palustris L.									x			x												
Juncus nodosus L.					x															x				
Iris versicolor L.								x	x			x												
Nuphar microphyllum (Pers.) Fern.			x						x		x		x											
Nuphar rubrodiscum Morong							x													x				
Nuphar variegatum Engelm.			x			x		x	x		x				x	x								
Nymphaea odorata Ait.								x												x				
Brasenia Schreberi Gmel.								x																
Caltha palustris L.										x			x	x		x								
Ranunculus trichophyllus Chaix.										x			x			x	x		x		x			
Chrysosplenium americanum Schwein.				x																	x			
Potentilla palustris (L.) Scop.					x	x		x			x					x			x					
Callitriche palustris L.	x	x		x			x	x	x	x	x	x	x	x	x	x	x		x		x			x
Hippuris vulgaris L.	x					x	x		x			x			x	x	x				x			
Myriophyllum alterniflorum DC.							x	x				x	x											
Myriophyllum exalbescens Fern.																	x							
Myriophyllum Farwellii Morong									x															
Sium suave Walt.								x					x		x	x	x				x			
Veronica americana Schwein.				x	x				x															
Veronica scutellata L.																								x
Utricularia intermedia Hayne	x							x													x			
Utricularia macrorhiza LeConte								x	x							x								
Bidens Beckii Torr.					x				x			x									x			

water plants have been deposited in the University of Minnesota Herbarium. The distribution records also include the 1936 collections from the Temperance and Arrowhead rivers made by Dr. C. B. Reif. Previous records of aquatic plants from this region are few. A small number of species are included in the lists of Juni (1879) and Roberts (1880).

Charophyta

1. *Chara* sp., stonewort.—Rare in ponded stretches especially near the headwaters.

2. *Nitella* sp., nitella.—Occasional in mucky-bottomed pools.

Bryophyta

3. *Chiloscyphus polyanthos* (L.) Corda, leafy liverwort.—Common on rocks and sticks in small feeder streams and rills.

4. *Fontinalis biformis* Sulliv., water moss.—Collected from the Temperance and Arrowhead rivers.

5. *Fontinalis gigantea* Sulliv., water moss.—Common on sticks and stones especially in smaller streams.

6. *Fontinalis novae-angliae* Sulliv., water moss.—Collected from the Arrowhead River in 1936.

Pteridophyta

7. *Equisetum fluviatile* L., water horsetail.—A common emergent plant in shallow water on muck or clay bottoms.

8. *Isoetes Braunii* Dur., quillwort.—Rare on sandy soil in slow water.

9. *Isoetes macrospora* Dur., quillwort.—Collected from the Devil Track River.

Spermatophyta

10. *Typha latifolia* L., common cattail.—Generally distributed throughout the North Shore but nowhere very abundant.

Sparganiaceae

11. *Sparganium chlorocarpum* Rybd., green-fruited bur reed.—The commonest emergent aquatic plant in the North Shore streams; often very abundant in slow water on mucky soil.

12. *Sparganium fluctuans* (Morong) Robinson, floating-leaved bur reed.—Occasional in slow mucky-bottomed stretches.

Potamogetonaceae

13. *Potamogeton amplifolius* Tuckerm., pondweed.—Rare in deeper pools.

14. *Potamogeton epihydrus* Raf., pondweed.—Occasional in slower streams on the upper portion of the shore.

15. *Potamogeton gramineus* L., var. *graminifolius* Fries, pondweed.—Fairly common in wider, slower streams on the upper portion of the shore.

16. *Potamogeton natans* L., pondweed.—Recorded only from the mouth of the Lester River.

17. *Potamogeton pusillus* L., pondweed.—Rare in quiet water in the Lester and Beaver rivers.

18. *Potamogeton Richardsonii* (Benn.) Rydb., pondweed. Occasional in deeper pools.

19. *Potamogeton Spirillus* Tuckerm., pondweed.—Collected only from the Cross River.

20. *Potamogeton tenuifolius* Raf., pondweed.—The commonest submerged aquatic plant in the North Shore streams and often the only species present in stretches with moderately fast current.

21. *Potamogeton zosteriformis* Fern., pondweed.—Taken only from the Devil Track River.

Alismaceae

22. *Sagittaria latifolia* Willd., arrowhead.—Generally distributed, nowhere abundant or making very robust growth.

Gramineae

23. *Glyceria borealis* (Nash) Batcheldor, northern manna grass.—Infrequent in shallow water.

24. *Glyceria canadensis* (Michx.) Trin., manna grass.—Occasional on stream margins.

25. *Glyceria grandis* S. Wats., manna grass.—Generally distributed and often fairly common in shallow water.

26. *Glyceria neogaea* Steud., manna grass.—Locally abundant in shallow water.

27. *Glyceria striata* (Lam.) Hitchc., manna grass.—Occasional on peaty stream margins.

28. *Phalaris arundinacea* L., reed canary grass.—Fairly common on wet peaty stream margins.

29. *Zizania aquatica* L., wild rice.—Rare in the streams but forming small stands in some of the headwater lakes. The wild rice of this region is the short, narrow-leaved type, var. *angustifolia* Hitchc.

Cyperaceae

30. *Carex* spp., sedges.—A considerable number of species of the genus *Carex* occur on swampy stream margins. *Carex riparia* W. Curtis and *C. retrorsa* Schwein. are among the commoner species.

31. *Eleocharis palustris* (L.) R. and S., spikerush.—The typical form was recorded from the margin of the Two Island and Temperance rivers and the var. *major* Sonder from the mouth of the Split Rock River.

32. *Scirpus atrovirens* Muhl., leafy bulrush.—Occasional on swampy stream margins.

33. *Scirpus subterminalis* Torr., submerged bulrush.—Locally abundant in ponded and slow water.

Lemnaceae

34. *Lemna minor* L., lesser duckweed.—Rare in beaver ponds on the Beaver River system.

Araceae

35. *Acorus Calamus* L., sweet flag.—Occasional in wet peaty soil.

36. *Calla palustris* L., wild calla.—A common bog form that is occasionally found on peaty stream margins.

Juncaceae

37. *Juncus nodosus* L., rush.—Noted only from the margin of the Gooseberry River near its mouth.

Iridaceae

38. *Iris versicolor* L., blue flag.—Occasional on peaty stream margins.

Nymphaeaceae

39. *Brasenia Schreberi* Gmel., water shield.—Noted only in the ponded east branch of the Baptism River.

40. *Nymphaea odorata* Ait., white waterlily.—Taken only from ponded water of the Baptism River.

41. *Nuphar variegatum* Engelm., yellow waterlily.—Occasional on muck or clay bottoms in slow or ponded water.

42. *Nuphar microphyllum* (Pers.) Fern., little yellow waterlily.—In similar situations and often with the preceding. The intermediate form, *N. rubrodiscum* Morong, is of infrequent occurrence.

Ranunculaceae

43. *Caltha palustris* L., marsh marigold.—Occasional on mucky stream margins.

44. *Ranunculus trichophyllus* Chaix, white water buttercup.—Occasional and sometimes occurring in fairly rapid water. Fruiting collections from the Arrowhead and Temperance rivers are var. *eradicatus* (Laestadius) Drew.

Saxifragaceae

45. *Chrysosplenium americanum* Schwein., golden saxifrage.—Common in spring-fed rills in the upper Knife River system.

Rosaceae

46. *Potentilla palustris* (L.) Scop., swamp five-finger.—Common in headwater bogs and occasional on peaty stream margins.

Callitrichaceae

47. *Callitriche palustris* L., water starwort.—Common in ponded and slower waters on clay or organic soils.

Haloragidaceae

48. *Hippuris vulgaris* L., mare's tail.—Common throughout in shallow water.

49. *Myriophyllum alterniflorum* DC., milfoil.—Locally abundant in slow water and especially abundant in Lax Lake in the Beaver River drainage.

50. *Myriophyllum exalbescens* Fern., common milfoil.—Rare; known only from the Devil Track River.

51. *Myriophyllum Farwellii* Morong, milfoil.—Collected from fairly fast waters on gravel bottoms in the lower Manitou River.

Umbelliferae

52. *Sium suave* Walt., water parsnip.—Occasional throughout in shallow water on peaty soil.

Scrophulariaceae

53. *Veronica americana* Schwein., brooklime.—Taken from springy places in the Manitou, Gooseberry, and Knife River systems.

54. *Veronica scutellata* L., brooklime.—Recorded only from the Pigeon River system.

Lentibulariaceae

55. *Utricularia macrorhiza* LeConte, greater bladderwort. —Rare; occurring mostly in beaver ponds.

56. *Utricularia intermedia* Hayne, bladderwort.—About as abundant and in the same situations as the preceding.

Compositae

57. *Bidens Beckii* Torr., water marigold.—Rare; in quiet waters.

THE BOTTOM FAUNA OF THE NORTH SHORE STREAMS

It is axiomatic that an adequate supply of food is necessary for any kind of life and that the number of organisms, such as fish in streams, that can be produced on any area is related to the amount of available food. Since trout are largely dependent on bottom-inhabiting invertebrate organisms, quantitative samples of this important fish food were taken on all the major rivers and tributaries. A quadrat stream bottom sampler of the type illustrated by Surber (1936) and enclosing one-ninth of a square meter (1.19 square feet) was used. In all, 202 samples were taken. All organisms retained by a No. 40 mesh soil sieve were preserved for laboratory examination. The bottom animals in the samples were identified and counted, and the total volume of organisms in each sample determined by alcohol displacement.[10]

The bottom fauna production of trout streams can be measured in two ways: the number of aquatic organisms produced per square foot, and the total volume or weight of these organisms for the same unit area. Numbers take no account of the size of the individual organisms but do show which forms are abundant enough to form the staples of the trout diet. Total volume or weight of organisms per square foot is a measure of the amount of food produced, and a series of such measurements can be used to compare a stream with other streams of known bottom fauna and trout production. It thus forms a yardstick for the measurement of trout-carrying capacity. The evaluation of streams on the basis of bottom fauna production is considered in the section dealing with stocking policy.

The variation in production of bottom fauna on specified areas throughout the year has been considered by Surber (1936), Needham (1938) and others, and the errors involved in sampling techniques by Mottley et al. (1939) and Behney (1937). In general, it can be assumed that counts and volumes of bottom fauna are working estimates comparable to those obtained from other streams by similar techniques and can be used as a relative measure of stream food productivity.

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[10]Because of labor shortages during the present war emergency, both counts and volume are available only for the nine lower streams. Volumes have been obtained for most of the stations on the upper streams.

Bottom Fauna Production of the North Shore Streams

The bottoms of the North Shore streams are predominantly boulder and large rubble. Bottoms of gravel, sand, clay, and muck are not common. Even in the stretches of exposed bedrock the channel is usually covered with a layer of boulders that have been washed from the glacial drift or with the angular fragments of the underlying formation. The average volumes of bottom organisms per unit area on various bottom soil types are:

	Number of samples	*Cubic centimeters per square foot*	*Pounds per acre*
Bedrock and boulder..	13	0.46	44.2
Boulder and rubble...	65	0.89	85.4
Gravel and sand......	8	0.09	8.6
Muck	6	0.93	89.3
Clay	4	0.24	23.0

It will be noted that the average food production for all types of bottom is less than 1 cubic centimeter per square foot and so is in food Grade 3, the poorest category (page 33). The North Shore streams show a higher average bottom fauna production than some New Hampshire streams, but are poorer than many New York, Virginia, and California streams on which similar analyses have been made (Behney, 1937; Needham, 1929, 1934; Surber, 1936; Pate, 1932, 1933). They are similar in food production to the soft-water streams of New Mexico (Tarzwell, 1938) and to those of the South (Michigan) Shore of Lake Superior (Smith, 1940).

The most productive waters on the North Shore are the wide, warm portions of such upper streams as the Cascade, Arrowhead, Devil Track, and Temperance rivers in which the bottom fauna production is usually between 1 and 2 cubic centimeters per square foot. In the colder trout waters the production is usually between 0.2 and 0.5 cubic centimeters per square foot. Even in the warmer water, bottom fauna production is not markedly high when compared to trout streams of other regions. Only two samples on the entire shore showed a volume of more than 3.0 cubic centimeters per square foot. Volumes of bottom fauna for individual stream stations are given in Tables 40-66 (Appendix I).

Composition of the North Shore Bottom Fauna

The composition of the North Shore bottom fauna by larger groups is shown in Table 12. Counts and more specific identification are included in Table 68 (Appendix I).

It will be observed from these tables that the larvae of two-winged flies (Diptera) are the most abundant forms, making up 49.1 per cent of the total number of organisms taken. An average of 52.7 dipterous larvae per square foot occurred. The great bulk of these were chironomids or bloodworms, with blackflies (*Simulium*) the next most abundant group. Present in lesser numbers were the genera *Antocha, Tipula, Atherix, Chrysops,* and *Sarcophaga.* It should be pointed out that while the numbers of dipterous larvae were high, the availability for fish food of such forms as chironomids is relatively low.

Mayfly (Ephemerida) nymphs are the second most abundant major group, making up 21.2 per cent of the total count and occurring at an average rate of 22.8 individuals per square foot. Most of the mayflies were of the small baetid and stenomenid types, the principal genera being *Neocloeon, Stenonema, Ephemerella,* and *Paraleptophlebia.* Burrowing mayflies of the genera *Ephemera* and *Ephoron* occurred in small numbers especially in the lower and quieter stream stretches.

Caddis fly larvae make up the third most abundant group, making up 18.9 per cent of the total number of organisms taken and occurring at the average rate of 20.3 individuals per square foot. The bulk of the caddis flies taken were Hydropsychids. Microcaddids (Hydroptilidae) occurred commonly and the case-building forms only occasionally.

Beetles (Coleoptera) made up 4.6 per cent of the total count and had an average occurrence of 4.9 individuals per square foot. Most of those taken were larvae of the genus *Elmis.* Other genera of occasional occurrence were *Dytiscus, Haliplus,* and *Laccophilus.*

Stoneflies (Plecoptera) were comparatively scarce in the North Shore samples, making up 2.1 per cent of the total count and occurring at the rate of 2.3 individuals per square foot. The principal genera found were *Capnia, Isoperla, Acroneuria,* and *Nemoura.*

Table 12. Average number of organisms per square foot and percentage composition of the bottom fauna of nine North Shore streams

	Lester River 11 samples		French River 10 samples		Sucker River 9 samples		Knife River 15 samples		Gooseberry River 13 samples	
	No. per sq. ft.	%[1]	No. per sq. ft.	%	No. per sq. ft.	%	No. per sq. ft.	%	No. per sq. ft.	%
Oligochaeta	1.9	1.7	2.0	1.3	3.5	3.1	1.3	1.6	3.6	3.7
Hirudinea (leeches)	0.2	0.2	0.4	0.3	0.2	0.2	0.8	1.0	0.4	0.4
Crustacea	0.0	0.0	0.4	0.3	1.1	1.0	0.1	0.1	0.0	0.0
Plecoptera (stoneflies)	0.3	0.3	2.4	1.6	0.5	0.4	0.9	1.1	4.4	4.4
Ephemerida (mayflies)	38.0	34.7	39.3	26.5	13.0	11.4	22.1	26.5	14.3	14.7
Odonata (dragonflies)	0.9	0.7	0.3	0.2	0.3	0.3	0.0	0.0	0.9	0.9
Hemiptera (water-bugs)	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Neuroptera	0.4	0.4	0.3	0.2	0.2	0.2	0.0	0.0	0.0	0.0
Trichoptera (caddis flies)	6.5	5.9	7.4	5.0	23.2	20.3	16.9	20.3	15.5	15.9
Coleoptera (beetles)	11.2	10.2	4.8	3.2	.8	.7	2.6	3.1	6.2	6.4
Diptera (two-winged flies)	48.4	44.2	87.9	59.2	67.0	58.7	39.3	47.1	52.0	53.4
Sphaeriidae (fingernail clams)	0.4	0.4	2.2	1.5	2.8	2.5	0.0	0.0	0.0	0.0
Gastropoda (snails)	0.2	0.2	0.9	0.5	1.5	1.3	0.4	0.5	0.0	0.0
Others	1.2	0.9	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Average total number per sq. ft.	109.6	....	148.1	....	114.1	....	83.3	....	97.4	....

[1]Percentage occurrence in total number of samples.

Table 12. (Cont'd). Average number of organisms per square foot and percentage composition of the bottom fauna of nine North Shore streams

	Split Rock River 10 samples		Beaver River 12 samples		Baptism River 14 samples		Manitou River 9 samples		All streams 98 samples	
	No. per sq. ft.	%	No. per sq. ft.	%	No. per sq. ft.	%	No. per sq. ft.	%	No. per sq. ft.	%
Oligochaeta	1.1	1.1	1.9	3.2	2.0	3.0	1.3	0.9	1.9	1.7
Hirudinea (leeches)	0.3	0.3	1.0	1.7	1.0	1.5	0.2	0.1	0.6	0.6
Crustacea	0.6	0.6	0.0	0.0	0.1	0.2	0.5	0.3	0.3	0.3
Plecoptera (stoneflies)	4.1	4.1	1.0	1.7	2.6	3.9	2.1	1.4	2.3	2.1
Ephemerida (mayflies)	12.6	12.4	6.2	10.7	15.1	22.7	33.9	22.5	22.8	21.2
Odonata (dragonflies)	0.5	0.5	0.4	0.7	0.1	1.5	0.1	0.7	0.4	0.4
Hemiptera (water-bugs)	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Neuroptera	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Trichoptera (caddis flies)	22.9	22.6	3.0	5.2	15.2	22.9	69.3	45.9	20.3	18.9
Coleoptera (beetles)	3.7	3.7	2.0	3.2	1.5	2.3	10.5	7.0	4.9	4.6
Diptera (two-winged flies)	54.4	43.9	42.5	73.0	28.4	42.8	32.8	21.7	52.7	49.1
Sphaeriidae (fingernail clams)	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.6	0.6
Gastropoda (snails)	0.3	0.3	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.3
Others	1.5	1.5	0.0	0.0	0.2	0.3	0.1	0.1	0.2	0.2
Average total number per sq. ft	101.2	....	58.2	....	66.3	....	150.9	....	107.4	....

The order Odonata was represented in the samples almost entirely by dragonfly nymphs. Damselflies of the genus *Chromagrion* occurred in only one sample. The principal dragonfly genera were *Ophiogomphus, Gomphus, Cordulegaster, Progomphus, Aeschna,* and *Boyeria.* Although of large individual size, the Odonata are usually rare and are an unimportant component of the North Shore bottom fauna.

The alderflies (Neuroptera) are of uncommon occurrence and are represented by the genera *Sialis* and *Chauliodes* in the Lester River and by *Sialis* elsewhere on the shore.

Invertebrates other than insects are of minor importance. Snails and fingernail clams (Sphaeriidae) are largely limited to scattered individuals in the southernmost harder streams. Of the crustaceans, scuds (*Gammarus* and *Hyalella*) occur throughout the watershed but are nowhere abundant enough to be of any great importance. The watersow bug (*Asellus*) was taken only from the Sucker River. The crayfish (*Cambarus virilis*) was taken from the Manitou and Beaver rivers and seems to be common only in the wide, lower stretches of the latter stream. Aquatic oligochaetes occur in small numbers in all the streams together with occasional terrestrial earthworms that have been washed in. Four species of leeches were taken, the commonest of which was the horse leech (*Haemopis plumbeus*). A few Planaria and nemotodes and the occasional terrestrial invertebrates, including centipedes, spiders, leafhoppers, and ants were also taken.

Factors Influencing the Production of Bottom Fauna

The most important single factor affecting the bottom fauna production of streams is the physical nature of the bottom. Rubble is the most productive type. Such a bottom is fairly stable, has an abundance of small interstices to provide shelter for bottom organisms, and presents a large surface for the growth of the microscopic plants that are the basic food of most smaller aquatic animals. Food production decreases as the particles become larger or smaller than rubble size and is poorest on bedrock and fine sand (Needham, 1938). Muck, being an organic soil, tends to be more fertile than fine-grained inorganic soils and may in some instances exceed the production on rubble.

Stream width is also a factor since the bottom fauna production tends to fall off toward the center of channels wider than 18 or 20 feet (Needham, 1934; Behney, 1937). This factor is of minor importance on the Minnesota North Shore as nearly all the good trout streams of this area are less than 18 feet in width.

It has been shown that hard waters are usually the most productive of bottom fauna (Tarzwell, 1938, and Needham, 1938). Other factors are the speed of the current and the abundance of larger aquatic plants (Needham, 1929, 1938). It is also generally recognized that the production of bottom fauna is greater in warm than in cold waters and greater in riffles than in pools of the same stream.

Food Preferences of Trout-stream Fishes

The food of trout and other fishes inhabiting trout streams is of four general types: (1) aquatic insects and other lower animals, such as leeches and aquatic oligochaetes that make up the normal bottom fauna of streams; (2) terrestrial insects and other small land animals that have fallen or been washed into streams; (3) the larger free-swimming plankton animals, such as waterfleas, and (4) vertebrates, such as fish, frogs, and salamanders.

Of these four groups the bottom fauna supplies a large proportion of fish food. Its major components, the mayflies, the caddis flies, and the two-winged flies, are the diet of stream trout and of such cyprinid forage fishes as the creek chub, the blacknose dace, and the longnose dace. Sculpins or muddlers show a similar preference. The only important exception among trout-stream fishes is the common sucker which feeds largely on plant material. Detailed analyses of the food in the stomachs of trout from regions having streams with a bottom fauna generally similar to that of the Minnesota North Shore streams show that the proportion of these insect orders in the diet may vary but that, in general, the food preference of stream-inhabiting brook, brown, and rainbow trout is mayflies and caddis flies followed by two-winged flies (Moore, et al., 1934; Needham, 1938; Pate, 1933).

Land food usually makes up an important part of the trout diet during the summer, sometimes comprising more than half of the total (Needham, 1938). It includes such typically terrestrial forms as ants, wasps, grasshoppers, leafhoppers, springtails, and earthworms, together with the adults of mayflies, stoneflies, two-winged flies, and caddis flies.

In hard-water streams, especially where water cress and other aquatic plants are abundant, scuds (*Hyalella* and *Gammarus*) may be important trout foods. However, in most rapid soft-water streams, crustacea are of little importance.

Trout, especially large trout, frequently take fish and sometimes frogs, salamanders, and crayfish. In most streams, however, these forms serve only to supplement the regular diet.

STREAM IMPROVEMENT ON THE NORTH SHORE WATERSHED[11]

Scope of Improvement Work

Stream improvement in the broad sense is the creation of optimum habitat conditions for trout, smallmouth bass, or other stream fish. Application of the many methods available to achieve this end is an attempt to simulate nature at its best. Since on the North Shore we are primarily interested in trout streams and trout production, the discussion will be limited to the methods employed to improve trout streams.

The installation of elaborate channel devices and control structures, which is popularly considered to be the only technique available for stream improvement, is in reality only one of the final stages of trout stream development. Before these devices can be effectively applied, several other vital phases of stream and watershed control must be considered. First of all, a continuous supply of pure, cold water must be available. This need may involve the opening up of springs, the elimination of headwater impoundments which unnecessarily warm the water, or in some cases may require the establishment of headwater reservoirs to insure adequate flow at times of low precipitation. The water must then be maintained at a suitable temperature throughout the area where trout are to be produced. This important objective can be obtained only through proper control of the entire watershed. Control of the watershed implies proper plant cover, elimination of sheet and gully erosion, and the provision of shade

[11]Prepared by Thomas Evans, Stream Improvement Supervisor, Division of Game and Fish.

along the stream banks. Natural and artificial pollution must be eliminated or reduced to a point where it does not interfere with the normal habitat conditions in the stream. After these ends are all accomplished, stream channel improvements, such as bank planting, revetments, dams, wing deflectors, shelters, etc., can be installed to create and maintain pools, uncover gravel beds, produce better food conditions, and improve spawning facilities.

Sometimes the elimination of impoundments caused by beaver dams is necessary to permit cool water to travel down the stream and to allow shade to develop over the channel. Various obstructions such as old logging dams and unused beaver dams which impede or eliminate upstream migration must be removed to permit access to headwater spawning areas. An improvement program that actually increases fish production and improves angling must encompass all the phases of development mentioned above.

It has been demonstrated in many parts of the United States that streams can be improved and trout production increased by suitable methods. Practical management considerations, however, eliminate many streams from a development program. Before improvement can be recommended for any trout stream, a number of conditions must be satisfied. The factors which determine the practicability of improvement work are: (1) the existing condition of the stream; (2) its potential productivity; (3) the estimated cost of improvement; (4) the intensity of existing and possible fishing load; (5) accessibility; (6) quality of other fishing water in the area; and (7) the relative cost of improvement compared to neighboring streams. These factors are all interrelated and must be considered in the final plan. For example, the existing condition and accessibility of a stream will determine the cost and the benefit which can be derived from improvement. While the actual channel work might normally require only moderate expenditures, inaccessibility may raise the cost to an unreasonable level and at the same time prevent fishermen from deriving full benefit from the work done. An accessible stream may, on the other hand, justify large expenditures because greater use can be anticipated.

The condition of the stream and the amount of good which can be obtained per unit of cost are closely allied. Present productivity of the Manitou River, for example, is at such a high level that improvement could not raise it sufficiently to justify the cost. The same amount of money required to increase production in this stream could better be spent on a stream in poor condition which has a high potential yield. In some instances the installation of channel improvements, although inexpensive, is unjustified because the stream is inherently poor. On the other hand, some streams with high production potentials which could be improved at moderate cost may be located so that the fishing load will never be heavy enough to utilize existing production. In such cases, little or no improvement would be recommended. From the foregoing considerations it is apparent that each situation must be carefully examined, and that improvement be attempted only where returns will be commensurate with the cost.

Application of Development Methods to North Shore Streams

Many North Shore streams can be improved for trout production but the geological nature of the area limits the potential yield. Since several of the primary problems discussed above are well under control in these streams, development will be less complicated than in more heavily populated regions. Although the original coniferous forest cover has been almost entirely removed from many of the watersheds, a good stand of second-growth timber has come in. Many of the streams are amply shaded by aspen, birch, and alder except in the regions of beaver ponds and old meadows. The amount of tilled land is small and is confined to the lower portion of the shore area from Duluth to Two Harbors.

Domestic or industrial pollution does not affect North Shore streams. In the lower portion of the streams, however, where they flow through the clay soils of the glacial Lake Duluth deposits, natural pollution in the form of silt may become a serious problem. The bulk of this silt originates from the stream banks, the gullies, and road ditches.

Since the watersheds are in fair condition and pollution is not a factor, most of the efforts to improve fish production will involve the installation of channel devices, bank controls, and shade. At certain seasons of the year the water flow fluctuates widely. It may become so low in winter and summer that trout cannot survive in many parts of the stream channel. This condition can be relieved by the proper installation and maintenance of pools. A second factor which limits production is unfavorably high water temperatures caused by lack of shade in meadows, in wide channels and farm lands, and by beaver impoundments and natural impoundments inherent to the water course. In many streams temperatures can be substantially lowered by the planting of trees along the banks, the reduction of impoundments, and the narrowing and deepening of wide, shallow channels. Minor improvements following pool construction and temperature reduction will include installation of shelters and the control of bank erosion.

In the North Shore streams, structures should be limited for the most part to log and boulder deflectors, log dams, boulder dams, floating covers, boom corner covers, and the revetments necessary to control the limited erosion. Deflectors can be used most effectively to create or maintain deep pools and to narrow channels and concentrate the water in areas where the stream flows over exposed boulder riffles. Boulder-log and boulder dams should be placed where a minimum amount of impoundment will result since their purpose is chiefly to create and maintain plunge-basin pools below them. In most cases where pools have been created it will be found desirable to install floating covers to provide additional shelter for the fish. In some instances, boom corner covers can be effectively used to protect eroding bends and to provide good fish shelter.

The expenditure per mile which can be justified varies with the individual stream and with the area in which it lies. After careful analysis of the North Shore streams it becomes apparent that the average expenditure per mile need not be as high as in some other areas of the state. There are several reasons why costs are to be kept low on these streams. First, the potential productivity is not extremely high. Second, the fishing load per mile is relatively light compared to trout streams in other parts of the state. In some streams the potential fishing load may be considerably greater than that which now exists. However, a shift to a heavily improved stream will probably result in decreased load in other areas. The result will then be that the load in the region as a whole will remain approximately the same. Such a shift may result in better over-all fishing if the production of the improved stream has been greatly increased. The third reason for moderate expenditures is the availability of other good fishing facilities in the area. Streams in the vicinity of good fishing lakes need not be as heavily developed as those in areas where the streams constitute the only fishing waters. The North Shore, in contrast to the southeastern counties, provides abundant lake fishing. A fourth consideration is the inaccessibility of many portions of the North Shore streams. Except in those regions which are readily accessible to roads, improvements will be light.

The final consideration which determines the effort that can be properly expended on a stream system is the actual benefit which can be accomplished per unit of cost. On the North Shore benefits will be high because water temperatures and lack of pools, the principal limiting factors, can be readily controlled.

The Knife River Project

Purpose of the Project

On the basis of the foregoing considerations and the data of the present survey, a plan of improvement for the Knife River was formulated. It was evident that this stream had a relatively high production potential, that it could be improved at reasonable cost, that it was very accessible and could be expected to carry a heavy fishing load, and that the benefits derived per unit of cost would be high.

Following the outbreak of the war this project assumed a two-fold purpose. Anticipated field activities were sharply curtailed and had to be limited to a single stream which could be used as a demonstration and a yardstick for future planning. It was felt that in order to plan and estimate costs of a long range postwar program accurately, it was necessary to test and develop standard improvement methods for Minnesota waters. Thus, this objective became the primary purpose of the project. A second purpose was to raise the carrying capacity of a heavily fished stream. As has been previously pointed out, the principal limiting factors on the Knife River are excessive water temperature, scarcity of pools, and inadequate shelter. The stream work done during the course of the project was designed to improve these conditions.

Planning and Execution of the Program

Since it is essential to insure an adequate supply of cool, pure water before channel devices are effective, it is usually desirable to start work at the headwaters and proceed downstream. In consequence, tree planting and elimination of beaver impoundments were the first operations planned for the Knife River project. Two ponds near the headwaters needed reduction and tree planting in these flowages and in three old beaver meadows which no longer held water was required.

Underplanting of aspen stands with white pine (*Pinus strobus*), white spruce (*Picea glauca*), white cedar (*Thuja occidentalis*), jack pine (*Pinus banksiana*), and red pine (*Pinus resinosa*) was outlined for all portions of the stream to provide more dense shade and to assist in snow and moisture retention. Limited erosion control work was planned along with the tree planting. Two willow revetments were laid out for the dual purpose of providing shade and preventing bank erosion at stream bends.

Plans for channel improvement included 26 deflectors and 16 dams to create additional deep pools and to eliminate exposed shallow areas where warming could occur, 12 crib dams to plug up small side channels and keep the full flow in the main channel, and 79 fish shelters.

In flowing through Township 53 North, Range 11 West, the only portion of the stream considered for the 1942 project, the stream crosses 42 small holdings of 40 acres. Thirteen of these tracts are owned by local residents, 24 by absentee owners, 3 have reverted to the state through tax forfeiture, and 1 is owned by the U. S. Forest Service. The three tax delinquent forties have recently been turned over to the state conservation department to be administered as conservation lands. Nine forties, held by an absentee owner, is the largest individual ownership on this portion of the river.

Since state funds cannot be expended on private lands unless the state has been granted a permanent easement to the property, considerable time was spent during the winter of 1941-42 determining ownerships, contacting land owners, and securing easements.

Attempts were made to secure easements on all the land surrounding the stream from the north line of Section 5, Township 53 North, Range 11 West, to the south line of Section 33, Township 53 North, Range 11 West. Of the 42 tracts which the stream crosses in this stretch, the state owned 3 and easements were secured on 23. It was therefore possible to carry on work in about 60 per cent of the stream channel. Fortunately, a large part of this land was in a single block which permitted coordinated and effective improvements.

Devices Used in Channel Developments

Many commonly used channel alteration methods were not applicable to the hard boulder bottom of the Knife River. In this stream, structures cannot be anchored to the bottom by stakes nor can the force of the water be relied upon to dig pools in the stream bed. Anchorage can be attained by setting the structures well back into the banks and by weighting the logs with heavy rock. Pools must be created by hand excavation or dynamite and must be so located that they will be maintained by the water plunging over dams or going around the end of deflectors.

Either of two basic types of dams and deflectors was used depending upon the materials available, but variations of these types were sometimes necessitated by local conditions. Where suitable material was at hand, dams and deflectors were built from boulders alone. In areas where satisfactory key boulders could not be found, log dams and log-rock crib deflectors were installed.

BOULDER DEFLECTOR (Fig. 31). — Boulder deflectors, constructed entirely of rock, were used wherever possible to narrow the channel. Channels were narrowed to hasten the water through areas where it was exposed to the sun or to force the entire stream flow through an artificially created pool.

In this type of structure it is essential that large key boulders be firmly embedded in the stream bottom.

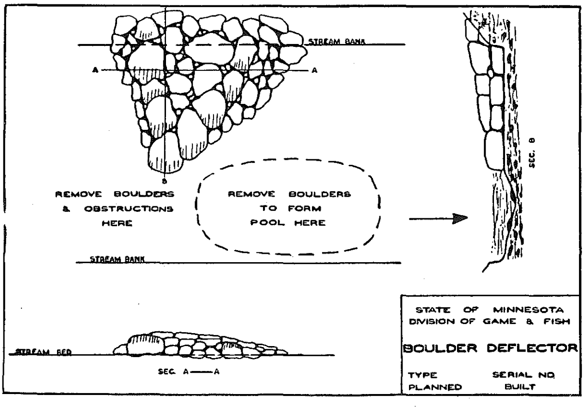

Figure 31

All other rocks are then wedged in on the upstream side of the key boulders so that the current tends to hold them in place. The upper edge of the deflector may be at right angles to the current or it may extend at an angle downstream, but the lower edge should always extend upstream from the bank. Thus, when the structure is topped by high water, the flow is turned back toward midstream and prevented from cutting the bank at the base end of the structure. Materials for the structure are taken from the stream bed where the pool is to be created and from the channel at the outer end of the deflector. Removal of obstructions from the desired channel is effective in controlling the direction of flow.

Single wing deflectors usually extend not more than halfway across the stream channel. They are constructed just high enough to be effective at low water but completely submerged by floods. Streamlining is essential since it reduces resistance to flood waters, thus increasing the permanence of the structure. A gradual slope from the upstream to the downstream edge lessens the danger of washing at the lower edge during high water and permits the water to flow over with less drag.

CRIB DEFLECTOR (Fig. 32). — The same general features of shape and contour are used in the crib deflector as in the boulder deflector. The crib deflector is used where suitable boulders are not available or where the crib will be more permanent, and is designed to accomplish the same purposes as the boulder deflector. The structure consists of mud sills buried in the stream bed parallel to the current with logs spiked to the top at right angles to the current and a downstream brace extending from the edge of the crib to the bank. Top logs are set back into the bank

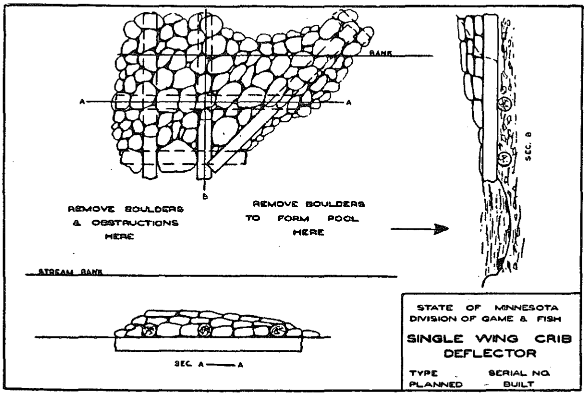

Figure 32

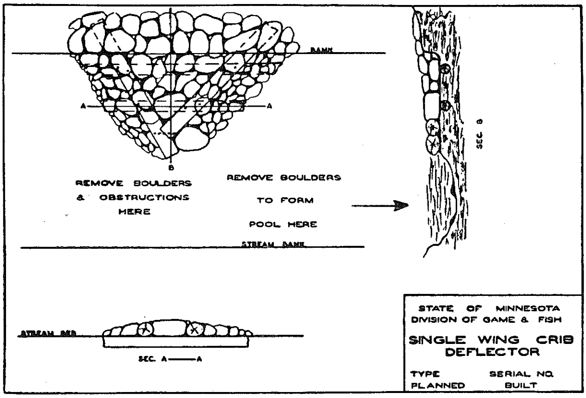

Figure 33

from 4 to 5 feet. Rock is then loaded onto the crib to hold it in place. The downstream brace prevents the outer end from being forced downstream and also throws the water back into midstream when the structure is submerged. In some locations it was found more desirable to use an "A" design rather than the standard type (Fig. 33).

Log Dams (Fig. 34).—As stated previously, dams were used principally as overfalls to maintain the pools below them. Any impoundment created was incidental and efforts were made to keep such impoundments at a minimum. In a stream with a soft bottom the water plunging over the dam digs and maintains a pool, but on the Knife River pools had to be dynamited at the foot of the dam.

In constructing single log dams the ends are set back into the banks 3 to 5 feet and weighted down with boulders. The log is set well down in the stream bed and sealed with boulders, rubble, gravel, and sand to prevent undercutting. Pole facings were sometimes required in the areas of finer bottom materials. Downstream braces add to the rigidity of the structure, prevent

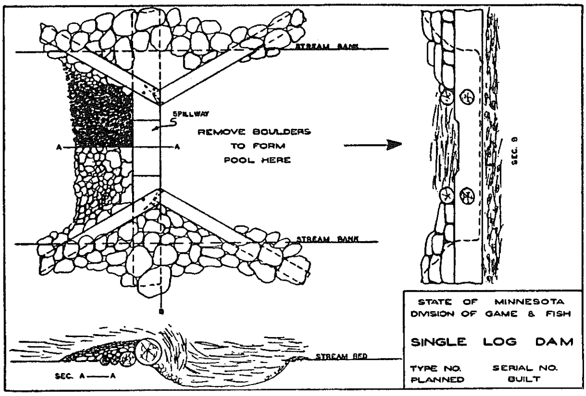

Figure 34

bank cutting, and provide excellent shelters for trout. The pool below usually extends well back under the dam log, providing good cover for fish. A spillway from one-half to one-third the width of the stream is used to maintain a good flow during low water periods.

Most dams were built with the crest from 1 to 2 feet above the original stream bed so they would be easily negotiable by trout and present little obstruction to the current during high water. Some were built with the crest almost level with the tail water. Such dams have the advantages of greater permanence, more natural appearance, and small impoundments. They may, however, prove less effective than higher dams for pool maintenance since they provide only a slight overfall.

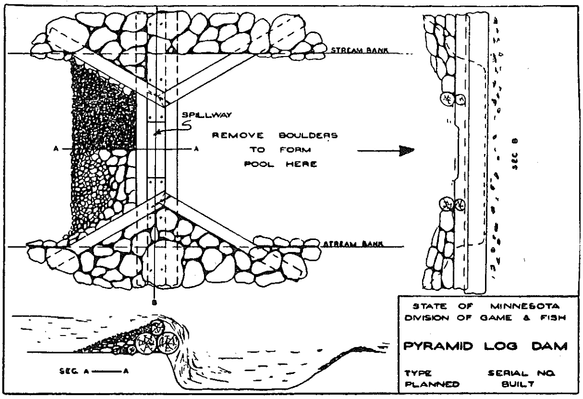

Figure 35

At some locations logs sufficiently large for single log dams were not available. In such cases double log or pyramid log dams were built. The double log dam consists of one log laid on top of another while pyramid dams (Fig. 35) are built by laying two logs together across the stream bed with a third log in the cradle formed by the bottom two. Logs are all spiked together and the joints sealed.

Boulder Dams (Fig. 36).—Boulder dams require large angular blocks of material to insure reasonably permanent construction. Since such material is scarce on the Knife River, this type of structure was little used. The dam is constructed by embedding large key boulders solidly in the stream bottom to form the spillway. Other large rocks are then keyed in between the spillway and the banks so that an arch is formed against the current. The arch is sealed with small rock and sod, followed by a sand and gravel fill on the upstream side. The ends of the dam are built higher than the center to reduce the danger of bank cutting. With this type of construction the pressure of the current tends to wedge the boulders more tightly into place.

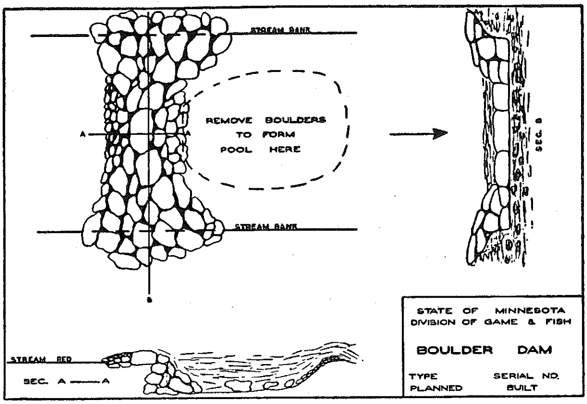

Figure 36

Diversion Dams (Fig. 37).—Diversion dams were built to block small side channels and keep all the flow in the main channel. They were constructed on the crib design with two logs laid parallel 2 to 3 feet apart across the channel to be blocked. The ends were dug back into the banks and weighted with boulders. Then the space between the logs was filled with rock, gravel, sand, and mud to provide as tight a seal as possible. Both upstream and downstream faces were streamlined with rock.

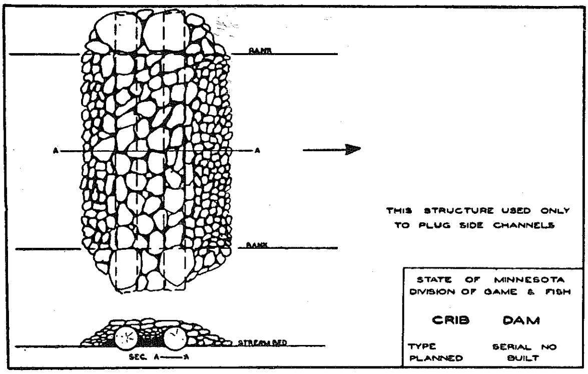

Figure 37

DIGGING LOGS (Fig. 38).—Digging logs are designed to gouge pools out of the stream bed by forcing the water to pass beneath them. They impart a downward thrust to the current causing a scouring action on the bottom. Although such devices are not adaptable on a large scale to the Knife River, one was tried in conjunction with a log jam. A bar of sand and gravel is usually built up 5 to 6 feet below the dams. By locating a digging log at this distance below the dam, it was felt the bar would be moved further downstream and the pool lengthened.

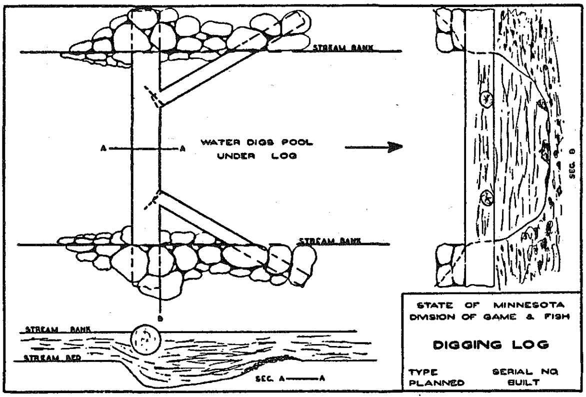

Figure 38

Design and installation is similar to that used for log dams. The log, however, is not laid on the bottom but is approximately half submerged so at normal water level the entire flow passes beneath it. The ends are set back into the banks 4 to 5 feet and weighted with heavy boulders.

FLOATING SHELTERS.—A floating shelter consists of two or three cedar logs spiked together and cabled to the bank so they float over a pool. The upstream end is pulled in against the bank behind a tree, alder bush, or boulder so the current cannot cut in between the shelter and the bank. Two anchor cables were used, one attached upstream from the shelter and the other at right angles to keep the shelter against the bank. The tail end is allowed to float free.

WILLOW MAT REVETMENT (Fig. 39).—The willow mat revetment is designed to provide temporary mechanical protection for eroding stream banks until vegetation comes in for permanent control. It consists of long willow brush laid flat on the sloped bank at right angles to the current with the butt ends in the water. Two or three rows of long poles are laid across the brush and staked in place. After the brush has been fastened down a light covering of soil is placed over it. Rock rip-rap is placed at the water line to prevent the mat from being undercut. This type of work will be used more extensively on southern Minnesota streams where it has proved effective. It was tried on this project to test its adaptability to northern streams.

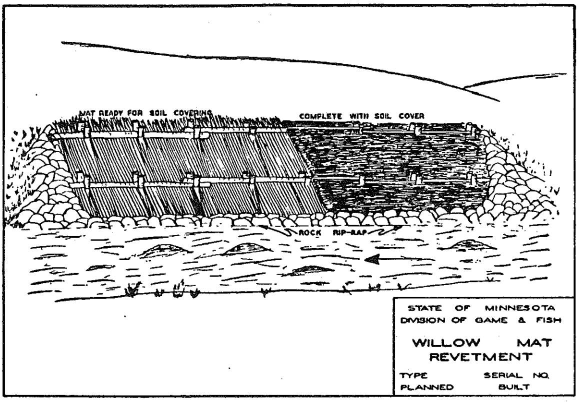

Figure 39

Willow Bulkhead Revetment (Fig. 40).—Bulkhead revetments consist of willow stakes 2 to 4 inches in diameter and 4 to 5 feet long driven into the stream bank at the water's edge in eroding bends of the stream. These stakes are driven on 18 inch centers until only 1.5 to 2 feet remain above ground. Wire or poles are then strung along the bulkheads. Willow brush is set up behind the poles and soil from the bank is worked down behind it. The brush and bulkheads will both grow, providing excellent vegetative protection for the bank and shade for the stream.

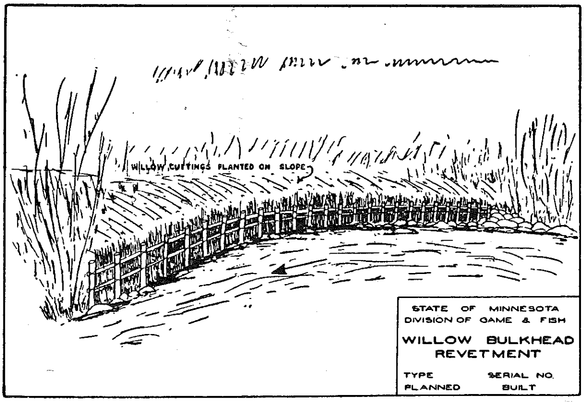

Figure 40

Execution of the Program

The war crisis necessitated a curtailment of the proposed field force. Accordingly, one crew of seven laborers and a foreman was organized. With the exception of the foreman, the entire crew lived on or near the river.

The crew started tree planting on May 4, as soon as the frost was out of the ground, and continued this activity until June 2. Because good coniferous cover was scarce along the entire stream, tree planting was much more extensive than will be required on most streams. Approximately half the entire stream mileage recommended for improvement was planted to pine, spruce, cedar, alder, and willow. Planting was restricted to a 15 to 30 foot strip on each side of the stream. Erosion control structures involving live material were begun on May 15 and in conjunction with tree planting so that they could be completed before the season's growth was too far advanced.

The first beaver pond was opened May 25 and work continued on this flowage and on other ponds until June 11. Willows and alders were planted on the pond bottom and old stream banks as soon as the water was lowered. Widening the breaches in the dams and lowering of the outlets continued intermittently all summer until the ponds were drained as completely as was feasible. Cleaning up and burning of beaver cuttings, driftwood, snags, and logging debris was delayed until the fall rains made it safe to burn. Additional tree willows were planted in the fall after the cleanup to complete the reforesting of the old flowages.

A beaver colony moved into one of the ponds after the work was first planned. Three adult and two young beavers were live-trapped from this pond and released on another stream. Three adults were also live-trapped and transplanted from a colony which moved into another meadow and rebuilt the dam.

The willow mat and some of the tree plantations were in pastures where damage from livestock was likely to occur. To forestall this possibility, fencing of these areas was begun June 6 after initial reduction of the beaver ponds had been completed. Ninety-four rods of 3-strand barbed wire fence was built around two plantations including the willow mat revetment.

Since low water temperatures prevent early season channel work, this activity was begun on June 12 with installation of boulder deflectors. Construction was carried on with slight interruptions for beaver pond work until the water became too cold in the fall. The last structure was completed October 8. Following completion of the last structure, the clean-up and burning of debris in the beaver meadows was completed.

The last job was installation of the willow bulkhead revetment which was completed October 16. A few man-days were expended during the summer on miscellaneous jobs. On rainy days the foreman and two or three men would sharpen drift pins and dress tools. When heavy rains raised the river too high for channel work the crew cultivated the tree plantations. This work reduced competition from weeds and grasses and resulted in a higher tree survival rate.

Work Completed. — Five and one-half miles of the Knife River were covered by this project. Some areas were heavily developed with tree planting and channel installations while other portions were improved through tree planting, erosion control, and elimination of the beaver ponds. Five beaver ponds and meadows were treated and a total of 20,000 conifers, 3,800 alders, and 10,000 willow cuttings were planted. Two erosion control revetments totaling 225 lineal feet were installed. Thirteen boulder deflectors, 13 crib deflectors, 12 log and 4 boulder channel dams, 12 crib diversion dams, and 79 floating shelters were installed. Some areas were in good condition as far as pools and shelter were concerned and needed only a cooler supply of water. The effect of the beaver pond elimination and tree planting is reflected on the entire length of the stream. Miscellaneous jobs included removal of one large log jam, construction of 94 rods of barbed wire fence, and hoeing tree plantations.

Cost of Development. — The total cost of the Knife River project including all pre-project planning, easement work, and mileage, as well as actual labor and supervisory costs, was $5,872.69. Five and one-half miles of stream were wholly or partially improved at a cost of $1,067.94 per mile. The cost of the project, exclusive of time and mileage for technical planning and supervision, was $4,556.19, or an average of $828.40 per mile. Since the work was new to the foreman and crew, considerably more technical supervision was given this project than will be given to future projects.

From the standpoint of initial cost, boulder deflectors were the cheapest of the four major types of channel improvement structures. An average of 44 man-hours was required to install these devices. Average total cost including labor, supervision, planning, and materials was $40.83. The crib diversion dams, at 35 man-hours each, averaged less than the boulder deflectors but installation of them was not as exacting since they are situated in side channels where they are not subject to the full force of the flood waters and ice in the spring. Among the channel devices, boulder dams were next lowest in initial cost. Average time was 58 man-hours and total cost averaged $56.38. Over a period of time, however, these structures will probably prove more costly than other types since it is difficult to build them as permanent as log dams. Crib deflectors were next in order of cost at an average of $61.98. Sixty-six man-hours were required for each. Here again the greater cost of this type of structure over the boulder deflector will probably be offset by greater permanence. Log channel dams were the most expensive to build. An average of 78 man-hours was required for these structures. The total cost averaged $84.46.

Results of the Work

The effect of the development work on fishing in the Knife River cannot yet be completely evaluated. It can be stated definitely, however, that good fishing was had in some areas immediately following completion of the work. Trout were caught from pools which had been created 2 days before in areas where previously the water was less than 6 inches deep.

Physical improvements in the stream, such as increased number of pools, increased pool depths, and lower water temperatures, have been measured. Thirty-eight new pools from 2 to 3 feet deep were created. In many cases these pools were developed in areas where the maximum depth of water for several hundred feet did not exceed 12 inches. Some pools were dug where previously there was only 2 to 3 inches of water. Many of these pools will undoubtedly be deepened by the surge of high water through them in spring. Removal of the boulders has exposed a bottom of rubble and gravel which is much more susceptible to water action.

The effect of the work on summer water temperature is reflected in the spread usually found between air and water temperatures. This spread varied from 11° F. to 24° F. in 1942. In the summer of 1940 the spread was from 2° F. to 16° F. Unfortunately, the temperature data for 1940 do not include records on days over 75° F. All records in 1940 were on June 26 and August 2 when the water temperatures varied from 50° to 60° F. Complete records were kept during 1942 on the improvement areas. The maximum water temperature of 64° F. was recorded on July 23 when the air was 82° F. Beneficial effects of beaver pond reduction are shown by the fact that on June 9 (air temperature 80° F.) no increase in water temperature occurred as the stream passed unimpeded through the drained pond in Section 8. The water entered and left this area at 60° F. Earlier in the season, at the time reduction of this pond was begun, the water temperature rose from 60° F. to 70° F. as it passed through the impoundment. The pond in Section 5 could not be eliminated as completely as the one in Section 8 with the result that some ponded water remained though the surface area was reduced by more than 50 per cent. On June 9 the stream temperature rose 1° F. in passing through this area.

The summer of 1942 was generally considered to be abnormally cool. This fact would, of course, contribute to lower stream temperatures. An inspection of daily temperature records for the past 4 years as maintained by the U. S. Forest Service Ranger Station located in Section 29, Township 53 North, Range 11 West, reveals that conditions were not as abnormal as believed. The highest temperature recorded for 1942 was 90° F. on July 12 and August 21 as compared to 92° F. in 1939, 91° F. in 1940, and 99° F. in 1941. The mean monthly temperatures for July and August for the 4 years were as follows:

1939—July, 66° F.; August, 62° F.
1940—July, 64° F.; August, 61° F.
1941—July, 67° F.; August, 61° F.
1942—July, 65° F.; August, 62° F.

There were 9 days in 1939 when the air temperature rose to 85° F. or above, 8 in 1940, 9 in 1941, and 6 in 1942. The days of 90° F. and over were 2 in 1939, 2 in 1940, 3 in 1941, and 2 in 1942.

Another physical improvement resulting from the work was an increase in the amount of gravel and rubble bottom types. Large areas of gravel and fine rubble were uncovered in the pools and in the narrow channels at the ends of the deflectors. Gravel bars have been built up behind some of the deflectors and at the lower ends of the pools. All these areas should be highly productive of food where the water is not too deep and some should prove satisfactory as spawning beds. On October 14, 1942, courtship activity of a pair of brown trout was observed on the gravel bar at the lower end of the pool below one structure.

Full productiveness of these gravel and rubble areas may not be realized for several years. Since they have been developed by normal summer flow of the stream, such areas are unstable at present. Spring floods will shift the materials about, eliminating some bars and building up new ones in other locations. Not until this procedure has been repeated several times will the gravel and rubble beds be sufficiently stable to reach full productivity.

Throughout the duration of the project it was necessary to consider the fact that improvement of the Knife River itself was not the sole objective. Various devices and improvements were installed to test and demonstrate their applicability to streams of Minnesota and especially to the rocky streams of the North Shore. Some of the installations, notably those of the erosion control type, will have greater application in other parts of the state but were used here to test their applicability to northern streams.

In general, those methods which prove to be successful on the Knife River will be applicable to other North Shore streams. Observations on this project will be extremely valuable in planning future programs on other streams of the state.

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APPENDIX I

Detailed Stocking Recommendations for North Shore Streams

Stocking tables 13 to 39 are computed for each stream on the basis of annual requirements. When the desirable procedure of planting several times during the year is employed, the totals for all planting should not exceed those specified. The areas proposed for stocking refer to map figures contained in the text and should be stocked in designated sections. Much trout water exists which is impractical to stock. For this reason the tables cannot be considered a list of waters inhabited by trout but only a guide to efficient stocking.

Detailed Stream Data by Stations

Tables 40-66 inclusive contain detailed stream data recorded by stations. The stations are listed in accordance with the sectors and tributaries on which they lie rather than serially. Temperatures are recorded as degrees Fahrenheit, and total alkalinity as equivalent parts per million of calcium carbonate. The following series of symbols is used to designate various bottom soils:

L—ledge rock
B—boulder
R—rubble
G—Gravel
S—sand
M—muck
D—detritus
C—clay

Tables 67 and 68 list the occurrence of plankton forms and the number of bottom organisms per square foot in the various streams.

Table 13. Fish planting recommendations for Lester river system (Fig. 4)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	0.9	0.0	no stocking	...	...	...	...
Sector 2	5.1	0.0	no stocking	...	...	...	...
Sector 3	6.9	6.9	total sector	brown trout	7″	500	3,400 a.
Sector 4	4.5	3.0	secs. 35, 34, 27, 28	brown trout	7″	100	300 a.
Trib. 1	9.4	0.0	no stocking	...	...	...	...
Trib. 1-1	1.1	0.0	no stocking	...	...	...	...
Trib. 1-1-1	0.5	0.0	no stocking	...	...	...	...
Trib. 1-2	6.0	0.0	no stocking	...	...	...	...
Trib. 2	1.1	0.0	no stocking	...	...	...	...
Trib. 2-1	0.9	0.0	no stocking	...	...	...	...
Trib. 3	1.3	0.0	no stocking	...	...	...	...
Trib. 3-1	0.8	0.0	no stocking	...	...	...	...
Trib. 4	0.4	0.0	no stocking	...	...	...	...
Trib. 5	1.8	0.0	no stocking	...	...	...	...
Trib. 5-1	0.6	0.0	no stocking	...	...	...	...
Trib. 6	1.0	0.0	no stocking	...	...	...	...
Trib. 7	1.1	0.0	no stocking	...	...	...	...
Total	43.4	9.9					
Brown trout	...	...	...	...	7″	...	3,700 a.

Table 14. Fish planting recommendations for French river system (Fig. 5)

Stream	Total Miles	Mi. to be Stocked	Area tc be Stocked	Species	Size	No. per Mile	Totals
Sector 1	0.25	0.00	no stocking				
Sector 2	2.00	0.00	no stocking				
Sector 3	6.50	6.50	total sector	brook trout	7″	100	650 a.
Sector 4	3.25	2.50	secs. 21, 16	brook trout	7″	75	200 a.
Trib. 1	2.40	0.00	no stocking				
Trib. 1-1	0.80	0.00	no stocking				
Trib. 2	2.00	0.00	no stocking				
Trib. 3	1.45	0.00	no stocking				
Total	18.65	9.00					
Brook trout					7″		850 a.

Table 15. Fish planting recommendations for Sucker river system (Fig. 6)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	1.00	0.0	no stocking				
Sector 2	4.00	0.0	no stocking				
Sector 3	8.00	4.5	secs. 12, 13, 18	brown trout	3″	300	1,350 f.
Sector 3			secs. 19, 24, 25	brown trout	7″	100	450 a.
Sector 4	4.50	1.0	sec. 30	brook trout	3″	450	450 f.
Sector 4			sec. 30	brook trout	7″	225	225 a.
Trib. 1	3.20	0.0	no stocking				
Trib. 2	2.00	0.0	no stocking				
Trib. 3	3.80	0.0	no stocking				
Trib. 4	3.50	0.0	no stocking				
Trib. 5	3.40	0.0	no stocking				
Total	33.4	5.5					
Brown trout					7″		450 a.
Brown trout					3″		1,350 f.
Brook trout					7″		225 a.
Brook trout					3″		450 f.

Table 16. Fish planting recommendations for Knife river system (Fig. 7)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	0.75	0.0	no stocking				
Sector 2	5.50	0.0	no stocking				
Sector 3	6.80	6.8	total sector	brown trout	7″	250	1,700 a.
Sector 4	4.50	4.5	total sector	brook trout	7″	100	450 a.
Trib. 1	5.40	0.0	no stocking				
Trib. 1-1	1.40	0.0	no stocking				
Trib. 1-2	1.30	0.0	no stocking				
Trib. 2	2.70	0.0	no stocking				
Trib. 3	6.00	0.0	no stocking				
Trib. 3-1	2.70	0.0	no stocking				
Trib. 3-2	1.60	0.0	no stocking				
Trib. 3-3	1.50	0.0	no stocking				
Trib. 4	15.80	7.0	S. 8, T. 52, R. 11 to S. 28, T. 53, R. 12	brown trout	7″	75	525 a.
Trib. 4		1.0	sec. 22 to source	brook trout	3″	250	250 f.
Trib. 4-1	6.00	0.0	no stocking				
Trib. 4-1-1	1.20	0.0	no stocking				
Trib. 4-1-2	0.60	0.0	no stocking				
Trib. 4-1-3	1.00	0.0	no stocking				
Trib. 4-2	4.70	0.0	no stocking				
Trib. 5	5.00	0.0	no stocking				
Trib. 5-1	1.50	0.0	no stocking				
Trib. 5-2	1.00	0.0	no stocking				
Trib. 5-3	2.90	0.0	no stocking				
Trib. 5-3-1	0.60	0.0	no stocking				
Trib. 5-3-2	0.80	0.0	no stocking				
Trib. 6	1.90	0.0	no stocking				
Trib. 7	0.90	0.0	no stocking				
Trib. 8	3.30	3.3	total sector	brook trout	3″	200	660 f.
					7″	100	330 a.

Table 16. Cont'd.) Fish planting recommendations for Knife river system (Fig. 7)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Trib. 8-1	4.40	0.0	no stocking				
Trib. 9	2.40	0.0	no stocking				
Total	94.15	22.6					
Brown trout					7″		2,225 a.
Brook trout					7″		780 a.
Brook trout					7″		910 f.

Table 17. Fish planting recommendations for Stewart river system (Fig. 8)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	2.50	0.0	no stocking				
Sector 2	4.00	4.0	total sector	brown trout	7″	350	1,400 a.
Sector 3	3.50	3.5	total sector	brown trout	7″	350	1,225 a.
Sector 4	6.75	0.0	no stocking				
Trib. 1	6.25	0.0	no stocking				
Trib. 2	3.90	0.0	no stocking				
Trib. 3	2.00	0.0	no stocking				
Trib. 4	2.60	0.0	no stocking				
Trib. 5	2.50	0.0	no stocking				
Trib. 6	0.50	0.0	no stocking				
Total	34.5	7.5					
Brown trout					7″		2,625 a.

Table 18. Fish planting recommendations for Gooseberry river system (Fig. 9)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	0.5	0.0	no stocking	....	....	....	....
Sector 2	1.5	0.0	no stocking	....	....	....	....
Sector 3	11.4	11.4	total sector	brook trout	7″	150	1,710 a.
Sector 4	9.0	1.0	secs. 31, 32	brook trout	7″	150	150 a.
Trib. 1	10.2	3.0	secs. 30, 19, 24, 13	brook trout	7″	44	132 a.
Trib. 1-1	1.6	0.0	no stocking	....	....	....	....
Trib. 1-2	1.5	0.0	no stocking	....	....	....	....
Trib. 1-3	0.8	0.0	no stocking	....	....	....	....
Trib. 1-4	5.8	0.0	no stocking	....	....	....	....
Trib. 1-5	2.2	0.0	no stocking	....	....	....	....
Trib. 1-6	3.3	1.6	secs. 24, 25, 30	brook trout	7″	44	70 a.
Trib. 1-7	2.4	0.0	no stocking	....	....	....	....
Trib. 2	8.0	0.0	no stocking	....	....	....	....
Trib. 2-1	2.0	0.0	no stocking	....	....	....	....
Trib. 2-2	1.2	0.0	no stocking	....	....	....	....
Trib. 3	3.4	0.0	no stocking	....	....	....	....
Trib. 3-1	2.2	0.0	no stocking	....	....	....	....
Trib. 4	3.0	0.0	no stocking	....	....	....	....
Trib. 5	3.7	2.8	secs. 36, 1, 6	brook trout	3″	160	448 f.
Trib. 5-1	1.2	0.0	no stocking	....	....	....	....
Trib. 5-2	3.3	0.0	no stocking	....	....	....	....
Trib. 5-2-1	0.8	0.0	no stocking	....	....	....	....
Trib. 5-3	0.8	0.0	no stocking	....	....	....	....
Trib. 6	5.2	0.0	no stocking	....	....	....	....
Trib. 7	1.7	0.0	no stocking	....	....	....	....
Total	86.7	19.8					
Brook trout	....	....	....	....	7″	....	2,062 a.
Brook trout	....	....	....	....	3″	....	448 f.

Table 19. Fish planting recommendations for Split Rock river system (Fig. 10)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	0.9	0.0	no stocking	...	...	...	...
Sector 2	2.5	0.0	no stocking	...	...	...	...
Trib. 1	1.0	0.0	no stocking	...	...	...	...
Trib. 2 (West Branch)	12.7	4.5	R.R. sec. 8 to junc. trib. 2	brown trout	7″	90	400 a.
Trib. 2	...	2.8	secs. 26, 27, 22	brook trout	7″	55	154 a.
Trib. 2-1	1.3	0.0	no stocking	...	...	...	...
Trib. 2-2 (Budd creek)	2.6	2.6	total trib.	brook trout	7″	60	156 a.
Trib. 2-3	2.8	0.0	no stocking	...	...	...	...
Trib. 2-3-1	1.2	0.0	no stocking	...	...	...	...
Trib. 2-4	1.5	0.0	no stocking	...	...	...	...
Trib. 3 (East Branch)	13.0	3.9	secs. 26, 23, 15	brown trout	7″	90	228 a.
Trib. 3	...	1.0	sec. 24	brook trout	3″	125	125 f.
Trib. 3-1	1.0	0.0	no stocking	...	...	...	...
Trib. 3-2	0.7	0.0	no stocking	...	...	...	...
Trib. 3-3	1.3	0.0	no stocking	...	...	...	...
Trib. 3-4	1.9	0.0	no stocking	...	...	...	...
Total	44.4	14.8					
Brown trout	...	...	...	...	7″	...	628 a.
Brook trout	...	...	...	...	7″	...	310 a.
Brook trout	...	...	...	...	3″	...	125 f.

Table 20. **Fish planting recommendations for Beaver river system** (Fig. 11)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	1.6	0.0	no stocking				
Sector 2	18.0	5.5	secs. 2, 35, 26, 27, 22, 21	brown trout	7″	190	1,045 a.
Trib. 1 (West Branch)	18.2	5.7	secs. 2, 10, 9, 8, 7	brown trout	7″	160	912 a.
Trib. 1-1	1.4	0.0	no stocking				
Trib. 1-2	7.5	3.5	secs. 17, 18, 13, 14	brown trout	7″	125	440 a.
Trib. 1-2-1	2.2	0.0	no stocking				
Trib. 1-2-2	1.5	0.0	no stocking				
Trib. 1-3	1.9	0.0	no stocking				
Trib. 1-4 (39-mile creek)	14.0	2.5	secs. 5 & 33	brown trout	3″	180	450 f.
Trib. 1-4-1 (Little 39-mile cr.)	5.4	0.0	no stocking				
Trib. 1-4-1-1	0.8	0.0	no stocking				
Trib. 1-4-1-2	1.1	0.0	no stocking				
Trib. 1-4-2	5.1	0.0	no stocking				
Trib. 1-4-3	2.5	0.0	no stocking				
Trib. 1-4-4	2.2	0.0	no stocking				
Trib. 1-4-5	2.0	0.0	no stocking				
Trib. 1-4-6	2.6	0.0	no stocking				
Trib. 1-4-7	0.6	0.0	no stocking				
Trib. 1-4-8	1.5	0.0	no stocking				
Trib. 1-5	4.5	0.0	no stocking				
Trib. 1-6	8.0	0.0	no stocking				
Trib. 1-6-1	3.5	0.0	no stocking				
Trib. 1-7	4.0	0.0	no stocking				
Trib. 1-8	1.5	0.0	no stocking				
Trib. 1-8-1	1.2	0.0	no stocking				

Table 20. (Cont'd.) Fish planting recommendations for Beaver river system (Fig. 11)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Trib. 1-9	1.3	0.0	no stocking				
Trib. 1-10	1.0	0.0	no stocking				
Trib. 2	1.6	0.0	no stocking				
Trib. 3 (Cedar creek)	6.0	4.0	secs. 26, 23, 13, 14, 15	brook trout	7″	300	1,200 a.
Trib. 3-1	0.8	0.0	no stocking				
Trib. 3-2	2.0	0.0	no stocking				
Trib. 3-3	1.0	0.0	no stocking				
Trib. 3-4	0.6	0.0	no stocking				
Trib. 4	1.4	0.0	no stocking				
Trib. 5	1.3	0.0	no stocking				
Trib. 6	0.8	0.0	no stocking				
Trib. 7	1.8	0.0	no stocking				
Trib. 8	3.2	0.0	not observed				
Trib. 8-1	0.9	0.0	not observed				
Trib. 8-2	1.0	0.0	not observed				
Trib. 9	2.1	0.0	not observed				
Trib. 9-1	1.2	0.0	not observed				
Trib. 10	2.0	0.0	not observed				
Trib. 10-1	0.8	0.0	not observed				
Total	143.6	21.2					
Brook trout					7″		1,200 a.
Brown trout					7″		2,397 a.
Brown trout					3″		450 f.

Table 21. Fish planting recommendations for Baptism river system (Fig. 12)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	3.0	0.0	no stocking	...	...	...	...
Sector 2	5.4	0.0	no stocking	...	...	...	...
Sector 3	3.5	0.0	no stocking	...	...	...	...
Sector 4	14.5	3.5	Finland junction with Trib. 2	brown trout	7″	400	1,400 a.
Sector 4	...	1.1	sec. 2	brook trout	7″	300	330 a.
Trib. 1	0.6	0.0	no stocking	...	...	...	...
Trib. 1-1	0.3	0.0	no stocking	...	...	...	...
Trib. 2	1.5	0.0	no stocking	...	...	...	...
Trib. 3	1.2	0.0	no stocking	...	...	...	...
Trib. 4 (Lindstrom creek)	3.0	3.0	total trib.	brook trout	3″	150	450 f.
Trib. 4-1	1.6	0.0	no stocking	...	...	...	...
Trib. 5	1.2	0.0	no stocking	...	...	...	...
Trib. 6 (Saw Mill creek)	7.0	5.3	secs. 34, 26, 23, 24, 13	brook trout	7″	200	1,060 a.
Trib. 6-1	0.5	0.0	no stocking	...	...	...	...
Trib. 6-1-1	1.0	0.0	no stocking	...	...	...	...
Trib. 6-2	0.5	0.0	no stocking	...	...	...	...
Trib. 6-3	1.0	0.0	no stocking	...	...	...	...
Trib. 6-4	0.6	0.0	no stocking	...	...	...	...
Trib. 7	2.8	0.0	no stocking	...	...	...	...
Trib. 8 (East Baptism)	14.0	6.0	secs. 16, 9, 10, 11, 1, 31	brown trout	7″	500	3,000 a.
Trib. 8	...	2.7	secs. 36, 21, 29	brook trout	3″	500	1,350 f.
Trib. 8-1 (Knapp's creek)	2.0	0.0	no stocking	...	...	...	...
Trib. 8-1-1	1.0	0.0	no stocking	...	...	...	...
Trib. 8-2 (Egge creek)	2.1	2.0	secs. 2 & 3	brook trout	3″	350	700 f.
Trib. 8-2-1	1.0	0.0	no stocking	...	...	...	...
Trib. 8-3	0.5	0.0	no stocking	...	...	...	...
Trib. 8-4 (Blessner creek)	1.5	0.0	no stocking	...	...	...	...
Trib. 8-5	6.0	0.0	no stocking	...	...	...	...

Table 21. (Cont'd.) Fish planting recommendations for Baptism river system (Fig. 12)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Trib. 8-6	1.1	0.0	no stocking				
Trib. 8-7	1.9	0.0	no stocking				
Trib. 8-8	0.9	0.0	no stocking				
Trib. 9	8.3	2.0	secs. 19, 24, 25	brown trout	7″	500	1,000 a.
Trib. 9-1	1.6	0.0	no stocking				
Trib. 9-2	1.4	0.0	no stocking				
Trib. 9-3	1.00	0.0	no stocking				
Trib. 9-4	1.90	0.0	no stocking				
Trib. 10 (Silver creek)	1.80	0.0	no stocking				
Trib. 10-1	1.15	0.0	no stocking				
Trib. 11	4.20	2.0	secs. 1, 36	brook trout	3″	300	600 f.
Trib. 12	3.00	0.0	no stocking				
Trib. 14	3.60	0.0	no stocking				
Trib. 13	9.00	3.0	secs. 2, 34, 35, 10	brook trout	7″	300	900 a.
Trib. 13-1	2.10	0.0	no stocking				
Trib. 13-2	2.50	0.0	no stocking				
Trib. 13-3	1.00	0.0	no stocking				
Trib. 13-4	2.00	1.0	sec. 10	brook trout	3″	50	50 f.
Trib. 15			no stocking				
Trib. 16			no stocking				
Trib. 17			no stocking				
Trib. 18			no stocking				
Total	125.75	31.6					
Brook trout					7″		2,290 a.
Brook trout					3″		3,150 f.
Brown trout					7″		5,400 a.

Table 22. Fish planting recommendations for Manitou river system (Fig. 13)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	3.5	0.0	no stocking				
Sector 2	3.5	3.5	total sector	brown trout	3″	400	1,400 f.
Sector 2			total sector	brown trout	7″	200	700 a.
Sector 3	13.0	0.9	sec. 17	brown trout	7″	1,000	900 a.
Trib. 1	1.2	0.0	no stocking				
Trib. 2	1.7	0.0	no stocking				
Trib. 3	1.1	0.0	no stocking				
Trib. 3-1	0.5	0.0	no stocking				
Trib. 3-2	0.6	0.0	no stocking				
Trib. 4	1.3	0.0	no stocking				
Trib. 5	1.4	0.0	no stocking				
Trib. 6 (Rock Cut creek)	4.5	2.0	secs. 19 & 20	brook trout	3″	250	500 f.
Trib. 6-1	0.5	0.0	no stocking				
Trib. 7 (East Branch)	15.5	0.5	sec. 17	brown trout	7″	1,000	500 a.
Trib. 7		3.5	secs. 9, 4, 3, 34, 33	brown trout	7″	630	2,200 a.
Trib. 7-1	1.0	0.0	no stocking				
Trib. 7-2 (9-Mile creek)	2.1	1.6	secs. 34 & 27	brook trout	7″	360	575 a.
Trib. 7-3	4.1	0.0	no stocking				
Trib. 7-3-1	0.9	0.0	no stocking				
Trib. 7-4	1.1	0.0	no stocking				
Trib. 7-5	2.2	0.0	no stocking				
Trib. 7-6	2.0	0.0	no stocking				
Trib. 8	1.5	0.0	no stocking				
Trib. 9	9.0	0.0	no stocking				
Trub. 9-1	1.0	0.0	no stocking				
Trib. 9-2	2.6	0.0	no stocking				

Table 22. (Cont'd.) Fish planting recommendations for Manitou river system (Fig. 13)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Trib. 9-2-1	0.6	0.0	no stocking				
Trib. 10	3.2	0.0	no stocking				
Trib. 11	3.0	0.0	no stocking				
Total	82.6	12.0					
Brown trout					7″		4,300 a.
Brown trout					3″		1,400 f.
Brook trout					7″		575 a.
Brook trout					3″		500 f.

Table 23. Fish planting recommendations for Caribou river system (Fig. 14)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	2.00	0.0	no stocking	...	...	...	...
Sector 2	3.50	2.2	secs. 11 & 14	brook trout	7″	350	770 a.
Sector 3	7.10	1.5	secs. 1& 2	brook trout	7″	350	525 a.
Trib. 1	0.60	0.0	no stocking	...	...	...	...
Trib. 2	1.50	0.0	no stocking	...	...	...	...
Trib. 3	0.50	0.0	no stocking	...	...	...	...
Trib. 4	1.60	0.0	no stocking	...	...	...	...
Trib. 4-1	1.25	0.0	no stocking	...	...	...	...
Trib. 5	1.50	0.0	no stocking	...	...	...	...
Trib. 6	2.80	0.0	no stocking	...	...	...	...
Trib. 7	1.30	0.0	no stocking	...	...	...	...
Trib. 8	1.15	0.0	no stocking	...	...	...	...
Trib. 9	1.10	0.0	no stocking	...	...	...	...
Trib. 10	1.60	0.0	no stocking	...	...	...	...
Trib. 11	1.25	0.0	no stocking	...	...	...	...
Trib. 12	3.00	0.0	no stocking	...	...	...	...
Trib. 12-1	1.60	0.0	no stocking	...	...	...	...
Trib. 12-2	2.00	0.0	no stocking	...	...	...	...
Trib. 12-2-1	0.50	0.0	no stocking	...	...	...	...
Trib. 12-2-2	0.55	0.0	no stocking	...	...	...	...
Trib. 12-3	0.40	0.0	no stocking	...	...	...	...
Trib. 13	0.50	0.0	no stocking	...	...	...	...
Trib. 14	1.60	0.0	no stocking	...	...	...	...
Trib. 14-1	0.33	0.0	no stocking	...	...	...	...
Trib. 15	0.90	0.0	no stocking	...	...	...	...
Total	40.13	3.7					
Brook trout	...	...	...	...	7″	...	1,295 a.

Table 24. Fish planting recommendations for Two Island river system (Fig. 15)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	1.25	0.0	no stocking	....	......	......	......
Sector 2	6.50	5.6	secs. 3, 4, 33, 32, 28	brook trout	7″	300	1,600 a.
Sector 3	3.60	1.0	secs. 7, 17	brown trout	7″	125	125 a.
Sector 4	1.60	0.5	sec. 12	brown trout	3″	250	125 f.
Trib. 1	2.25	0.0	no stocking	....	......	......	......
Trib. 2	1.50	0.0	no stocking	....	......	......	......
Trib. 2-1	0.90	0.9	secs. 7, 8	brook trout	7″	145	130 a.
Trib. 3	0.90	0.0	no stocking	....	......	......	......
Trib. 4	0.60	0.0	no stocking	....	......	......	......
Trib. 5	0.50	0.0	no stocking	....	......	......	......
Trib. 6	0.40	0.0	no stocking	....	......	......	......
Trib. 7	1.30	0.0	no stocking	....	......	......	......
Total	21.3	8.0					
Brook trout	......	......	....	....	7″	......	1,730 a.
Brown trout	......	......	....	....	7″	......	125 a.
Brown trout	......	......	....	....	3″	......	125 f.

Table 25. Fish planting recommendations for Cross river system (Fig. 16)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	3.00	0.0	no stocking				
Sector 2	3.30	1.0	secs. 23, 26	brown trout	7″	200	200 a.
Sector 3	8.00	0.0	no stocking				
Sector 4	9.10	0.0	no stocking				
Trib. 1	0.80	0.0	no stocking				
Trib. 2 (4-Mile creek)	3.25	0.0	no stocking				
Trib. 3	1.70	0.0	no stocking				
Trib. 4	0.70	0.0	no stocking				
Trib. 5	2.15	0.0	no stocking				
Trib. 6	4.50	2.0	secs. 34, 35	brown trout	7″	100	200 a.
Trib. 6-1	5.50	0.0	no stocking				
Trib. 6-1-1	0.50	0.0	no stocking				
Trib. 6-1-2	0.90	0.0	no stocking				
Trib. 7	6.50	0.0	no stocking				
Trib. 7-1	0.40	0.0	no stocking				
Trib. 8	1.00	0.0	no stocking				
Trib. 9	1.40	0.0	no stocking				
Trib. 10	0.50	0.0	no stocking				
Trib. 11	1.70	0.0	no stocking				
Total	54.9	3.0					
Brown trout					7″		400 a.

Table 26. Fish planting recommendations for Temperance river system (Fig. 17)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	2.50	0.0	no stocking				
Sector 2	20.10	0.0	no stocking				
Sector 3	11.50	0.0	no stocking				
Trib. 1	1.30	0.0	no stocking				
Trib. 2 (Little Temperance)	8.00	2.0	secs. 2, 11, 12	brook trout	7″	150	300 a.
Trib. 2-1	0.25	0.0	no stocking				
Trib. 2-2	3.25	0.0	no stocking				
Trib. 2-2-1	1.00	0.0	no stocking				
Trib. 2-3	0.50	0.0	no stocking				
Trib. 2-4	1.00	0.0	no stocking				
Trib. 2-5	0.50	0.0	no stocking				
Trib. 3	3.25	0.0	no stocking				
Trib. 3-1	1.00	0.0	no stocking				
Trib. 4 (Blind Temperance)	6.20	1.0	secs. 33 & 28	brown trout	7″	250	250 a.
Trib. 5	3.50	0.0	no stocking				
Trib. 6	2.10	1.0	secs. 31 & 32	brown trout	3″	350	350 f.
Trib. 7	1.25	0.0	no stocking				
Trib. 8 (Torgeson creek)	1.75	1.0	secs. 30 & 25	brook trout	7″	400	400 a.
Trib. 8-1	1.00	0.0	no stocking				
Trib. 9	1.40	0.0	no stocking				
Trib. 10 (Plouff creek)	10.0	3.0	secs. 8, 13, 14	brown trout	7″	250	750 a.
Trib. 11	4.00	2.5	secs. 8 & 5	brown trout	7″	150	375 a.
Trib. 11-1	2.30	1.0	secs. 8 & 7	brown trout	7″	150	150 a.
Trib. 12 (Saw Bill creek)	5.00	0.0	no stocking				
Trib. 12-1	3.00	0.0	no stocking				
Trib. 12-1-1	1.30	0.0	no stocking				
Trib. 12-2	1.60	0.0	no stocking				
Total	98.55	11.50					
Brook trout					7″		700 a.
Brown trout					7″		1,525 a.
Brown trout					3″		350 a.

Table 27. Fish planting recommendations for Onion river system (Fig. 18)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Main channel	6.40	1.5	secs. 1 & 12	brook trout	7″	150	225 a.
Trib. 1	2.20	0.0	no stocking				
Trib. 1-1	0.90	0.0	no stocking				
Trib. 2	0.75	0.0	no stocking				
Trib. 2-1	0.35	0.0	no stocking				
Trib. 3	0.75	0.0	no stocking				
Trib. 3-1	0.37	0.0	no stocking				
Trib. 4	1.12	0.0	no stocking				
Trib. 5	0.40	0.0	no stocking				
Trib. 6	0.36	0.0	no stocking				
Trib. 7	0.31	0.0	no stocking				
Total	13.91	1.5					
Brook trout					7″		225 a.

Table 28. Fish planting recommendations for Poplar river system (Fig. 19)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	2.60	0.0	no stocking	....	....	....	....
Sector 2	4.75	2.0	secs. 16, 15, 10	smallmouth bass	4″	300	600 f.[1]
Sector 3	2.75	0.0	no stocking	....	....	....	....
Sector 4	4.90	3.0	secs. 22, 23, 26, 25	brook trout	7″	400	1,200 a.
Sector 4	....	1.0	secs. 31 & 6	brown trout	3″	800	800 f.
Sector 5	4.30	0.0	no stocking	....	....	....	....
Trib. 1	1.50	0.0	no stocking	....	....	....	....
Trib. 2	2.25	0.0	no stocking	....	....	....	....
Trib. 3 (Twin river)	7.50	0.0	no stocking	....	....	....	....
Trib. 3-1 (Sucker river)	1.50	0.0	no stocking	....	....	....	....
Trib. 3-2	1.80	0.0	no stocking	....	....	....	....
Trib. 3-3	1.25	0.0	no stocking	....	....	....	....
Trib. 3-4	1.60	0.0	oo stocking	....	....	....	....
Trib. 3-5	1.00	0.0	no stocking	....	....	....	....
Trib. 3-6	0.80	0.0	no stocking	....	....	....	....
Trib. 4 (7-Mile creek)	6.50	1.5	secs. 3 & 34	brook trout	7″	100	150 a.
Trib. 4-1	1.25	0.0	no stocking	....	....	....	....
Trib. 5	1.25	0.0	no stocking	....	....	....	....
Trib. 6	0.80	0.0	no stocking	....	....	....	....
Trib. 7	0.60	0.0	no stocking	....	....	....	....
Trib. 8	1.60	0.0	no stocking	....	....	....	....
Total	50.5	7.5					
Brook trout	....	....	....	....	7″	....	1,350 a.
Brown trout	....	....	....	....	3″	....	800 f.
Smallmouth bass	....	....	....	....	4″	....	600 f.

[1]This planting is experimental, to be discontinued after 3 years, if bass fishing does not develop.

Table 29. Fish planting recommendations for Spruce creek system (Fig. 20)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Main channel	5.20	1.0	secs. 8 & 5	brook trout	3″	200	200 f.
Trib. 1	1.43	0.0	no stocking	....	....	....	....
Total	6.63	1.0					
Brook trout	....	....	....	....	3″	....	200 f.

Table 30. Fish planting recommendations for Cascade river system (Fig. 21)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	2.80	0.00	no stocking				
Sector 2	3.60	2.20	secs. 12 & 13	brown trout	7″	300	660 a.
Sector 3	3.00	3.00	secs. 1, 36, 25	brook trout	7″	600	1,800 a.
Sector 4	2.50	0.00	no stocking				
Sector 5	5.50	0.00	no stocking				
Trib. 1	0.80	0.00	no stocking				
Trib. 2	1.60	0.00	no stocking				
Trib. 3	2.20	0.00	no stocking				
Trib. 4	0.70	0.00	not observed				
Trib. 5	2.50	0.00	no stocking				
Trib. 6	3.50	0.00	no stocking				
Trib. 7 (Bally creek)	4.00	2.50	secs. 8 & 9	brook trout	7″	180	450 a.
Trib. 8 (Mark creek)	3.00	0.00	no stocking				
Trib. 9 (Nestor creek)	4.95	1.75	secs. 1 & 6	brook trout	7″	375	655 a.
Trib. 9-1	1.60	0.00	no stocking				
Trib. 9-2	0.70	0.00	no stocking				
Trib. 10 (Little Miss.)	8.00	0.00	no stocking				
Trib. 10-1	0.50	0.00	no stocking				
Trib. 10-2	3.90	0.00	no stocking				
Trib. 11	1.50	1.00	sec. 25	brook trout	3″	180	180 f.
Trib. 12	2.00	1.00	sec. 24	brook trout	3″	180	180 f.
Trib. 13	4.20	0.00	no stocking				
Trib. 13-1	1.00	0.00	no stocking				
Trib. 14	7.00	0.00	no stocking				
Trib. 15	2.50	0.00	no stocking				
Trib. 16	4.50	0.00	no stocking				
Trib. 16-1	0.50	0.00	no stocking				
Total	78.55	11.45					
Brook trout					7″		2,905 a.
Brook trout					3″		360 f.
Brown Trout					7″		660 a.

Table 31. Fish planting recommendations for Devil Track river system (Fig. 22)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	2.60	0.0	no stocking				
Sector 2	4.50	3.0	secs. 3, 34, 33	brown trout	7″	540	1,620 a.
Sector 3	10.75	1.6	secs. 21, 16	brook trout	7″	450	720 a.
Trib. 1	2.00	0.0	no stocking				
Trib. 2 (Little Devil track)	5.40	3.0	secs. 8, 9, 10	brook trout	7″	225	675 a.
Trib. 2		1.0	sec. 6	brook trout	3″	225	225 f.
Trib. 2-1	1.00	0.0	no stocking				
Trib. 2-2	1.25	1.0	sec. 7	brook trout	3″	180	180 f.
Trib. 3	2.40	0.0	no stocking				
Trib. 3-1	0.75	0.0	no stocking				
Trib. 4 (Elbow creek)	5.50	2.5	secs. 22, 27, 34	brown trout	7″	270	675 a.
Trib. 4-1	0.50	0.0	no stocking				
Trib. 4-2	0.80	0.0	no stocking				
Trib. 4-3 (Mud creek)	3.20	1.4	sec. 16	brook trout	3″	270	378 f.
Trib. 4-4	1.55	0.0	no stocking				
Trib. 4-4-1	0.60	0.0	no stocking				
Trib. 4-4-2	0.60	0.0	no stocking				
Trib. 5	2.00	0.0	no stocking				
Trib. 6	0.90	0.0	no stocking				
Trib. 7	0.75	0.0	no stocking				
Trib. 8	2.50	0.0	no stocking				
Trib. 9	1.30	0.0	no stocking				
Trib. 10	0.30	0.0	no stocking				
Total	51.15	13.5					
Brook trout					7″		1,395 a.
Brook trout					3″		783 f.
Brown trout					7″		2,295 a.

Table 32. Fish planting recommendations for Durfee creek system (Fig. 23)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Main channel	4.0	2.5	secs. 6, 5, 8	brook trout	7″	50	125 a.
Total	4.0	2.5			7″		125 a.

Table 33. Fish planting recommendations for Kimball creek system (Fig. 24)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Main channel	8.80	3.9	secs. 28, 33, 3	brook trout	7″	250	975 a.
Trib. 1	0.75	0.0	no stocking				
Trib. 2	1.00	0.0	no stocking				
Trib. 3	1.00	0.0	no stocking				
Trib. 4	0.90	0.0	no stocking				
Total	12.45	3.9					
Brook trout					7″		975 a.

Table 34. Fish planting recommendations for Kadunce creek system (Fig. 25)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Main channel	6.7	2.0	secs. 26, 35	brown trout	7″	300	600 a.
Main channel		3.5	secs. 13, 14, 15, 23	brook trout	7″	300	1,050 a.
Trib. 1	1.0	0.0	no stocking				
Trib. 2	0.5	0.0	no stocking				
Trib. 3	0.5	0.0	no stocking				
Trib. 4	1.3	0.0	no stocking				
Total	10.0	5.5					
Brook trout					7″		1,050 a.
Brown trout					7″		600 a.

Table 35. Fish planting recommendations for Arrowhead river system (Fig. 26)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Sector 1	5.2	0.0	no stocking				
Sector 2	14.1	0.0	no stocking				
Sector 3 (South Brule)	6.8	0.0	no stocking				
Trib. 1 (Gothier creek)	2.9	0.0	no stocking				
Trib. 2	1.9	1.0	sec. 10	brown trout	7″	50	50 a.
Trib. 2-1	1.0	0.0	no stocking				
Trib. 3 (Hanson's creek)	1.4	1.0	secs. 4, 33	brown trout	7″	50	50 a.
Trib. 3-1	0.6	0.0	no stocking				
Trib. 4	1.1	0.0	no stocking				
Trib. 5	2.1	0.0	no stocking				
Trib. 5-1	1.0	0.0	no stocking				
Trib. 6	1.5	0.0	no stocking				
Trib. 7 (Greenwood river)	6.4	0.0	no stocking				
Trib. 7-1	1.5	0.0	no stocking				
Trib. 7-2	2.6	0.0	no stocking				
Trib. 7-2-1	1.0	0.0	no stocking				
Trib. 7-3	1.4	0.0	no stocking				
Trib. 8 (Stony creek)	11.2	1.0	sec. 16	brook trout	7″	150	150 a.
Trib. 8-1	3.0	0.0	no stocking				
Trib. 8-2	3.0	0.0	no stocking				
Trib. 8-2-1	1.75	0.0	no stocking				
Trib. 9	1.45	0.0	no stocking				
Trib. 10 (Timber creek)	2.40	2.0	secs. 1, 36, 25	brook trout	7″	180	360 a.
Trib. 11 (Pine Mt. creek)	1.40	1.0	sec. 26	brook trout	7″	180	180 a.
Trib. 12	14.60	0.0	no stocking				
Trib. 12-1	2.40	0.0	no stocking				
Trib. 12-1-1	0.80	0.0	no stocking				
Trib. 12-2	2.50	0.0	no stocking				
Trib. 12-3	0.90	0.0	no stocking				

Table 35. (Cont'd.) Fish planting recommendations for Arrowhead river system (Fig. 26)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Trib. 12-4	2.60	0.0	no stocking				
Trib. 12-5	3.25	0.0	no stocking				
Trib. 12-6	0.90	0.0	no stocking				
Trib. 12-7	0.60	0.0	no stocking				
Trib. 12-8	3.50	0.0	no stocking				
Trib. 12-8-1	0.80	0.0	no stocking				
Trib. 12-9	0.75	0.0	no stocking				
Trib. 13	3.20	0.0	no stocking				
Trib. 14	4.40	0.0	no stocking				
Trib. 15	2.40	0.0	no stocking				
Trib. 16	0.50	0.0	no stocking				
Total	120.8	6.0					
Brook trout					7″		690 a.
Brown trout					7″		100 a.

Table 36. Fish planting recommendations for Flute Reed river system (Fig. 27)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Main channel	10.7	4.6	secs. 13, 14, 10, 3, 18	brown trout	7″	100	460 a.
Trib. 1	3.5	0.0	no stocking				
Trib. 1-1	1.5	0.0	no stocking				
Trib. 2	1.8	0.0	no stocking				
Trib. 3	1.1	0.0	no stocking				
Trib. 4	1.0	0.0	no stocking				
Trib. 5	0.8	0.0	no stocking				
Total	20.4	4.6					
Brown trout					7″		460 a.

Table 37. Fish planting recommendations for Reservation river system (Fig. 28)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Main channel	5.96	0.0	no stocking				
Trib. 1	2.15	0.0	no stocking				
Trib. 1-1	0.40	0.0	no stocking				
Trib. 2	2.50	0.0	no stocking				
Trib. 2-1	1.30	0.0	no stocking				
Trib. 2-2	0.60	0.0	no stocking				
Trib. 3	0.96	0.0	no stocking				
Trib. 4	1.50	0.0	no stocking				
Trib. 4-1	.43	0.0	no stocking				
Trib. 5	.30	0.0	no stocking				
Total	16.1	0.0	no stocking				

Table 38. Fish planting recommendations for Hollow Rock creek system (Fig. 29)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Main channel	5.00	1.5	secs. 15, 14	brown trout	7″	100	150 a.
Trib. 1	1.38	0.0	no stocking				
Trib. 2	1.40	0.0	no stocking				
Trib. 3	1.70	0.0	no stocking				
Trib. 4	0.90	0.0	no stocking				
Trib. 5	0.38	0.0	no stocking				
Total	10.76	1.5					
Brown trout					7″		150 a.

Table 39. Fish planting recommendations for Pigeon river system (Fig. 30)

Stream	Total Miles	Mi. to be Stocked	Area to be Stocked	Species	Size	No. per Mile	Totals
Big Stump river	6.60	0.0	no stocking				
Trib. 1	2.80	0.0	no stocking				
Trib. 2	5.70	0.0	no stocking				
Portage brook	6.00	2.5	secs. 26, 27	brook trout	7″	100	250 a.
Kaweshka river	15.00	1.0	sec. 26	brown trout	7″	75	75 a.
Trib. 1 (Irish creek)	6.16	0.0	no stocking				
Trib. 2	2.70	0.0	no stocking				
Total	44.96	3.5					
Brook trout					7″		250 a.
Brown trout					7″		75 a.

Table 40. Physical and biological data for Lester river system recorded by stations (Fig. 4)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	7- 2-40	2	¼ mile from mouth	10	3.4	.5	61.7	73.4	5.8	7.6	72.5	.22	70/30	L-G
	7- 3-40	2	falls	......	......	......	74.9	76.1	......	......	......	......	100/0	L-B
	7- 8-40	2	below dam	3	1.6	2.0	......	......	......	......	......	.57	......	L
	7- 8-40	12	above dam	8	1.4	.66	......	......	......	......	......	......	......	......
	7- 8-40	13	below falls	15	4.8	.66	......	......	......	......	......	......	......	......
Sector 2	7- 8-40	1	above falls	11.5	4.8	.9	65.3	78.8	......	......	......	......	......	......
	7- 3-40	1	s28-t51-r13	24	8.0	1.0	58.1	66.2	6.7	7.7	72.5	......	......	B
	8-20-40	1	above falls	8	3.8	.8	60.0	68.0	7.2	7.8	80.0	......	......	......
	8-20-40	1	above Lester Park	11	5.8	1.2	......	......	......	......	......	......	......	......
	7- 3-40	4	s28-t51-r13	14	5.8	.5	70.0	65.3	6.2	7.6	72.5	.26	......	......
Sector 3	7- 2-40	5	s16-t51-r13	......	......	......	64.4	73.4	6.1	7.5	75.0	.35	30/70	B-G
	8-12-40	5	s16-t51-r13	15	5.2	.4	58.0	68.0	5.3	7.6	87.5	......	......	......
	7- 5-40	6A	s7-t51-r13	30	8.7	.5	68.0	71.6	......	......	......	......	......	B-G
Sector 4	7- 5-40	6	s34, 27-t52-r14	9	......	......	......	......	......	......	......	......	......	......
	8- 2-40	6	s34, 27-t52-r14	10	3.7	.7	62.0	68.0	5.5	7.6	95.0	.32	......	......
	7- 5-40	7	s2, 35-t51-r14	8	3.7	.7	71.6	76.1	......	7.5	67.3	.66	70/30	B-G
	8-20-40	7	s2, 35-t51-r14	14	2.4	.33	66.0	75.0	5.6	7.7	95.0	.84	......	......
	7- 5-40	8	s34, 35-t52-r14	11	1.3	.19	67.1	77.9	......	7.4	92.5	.40	......	M
	8-20-40	9	s27, 28-t52-r14	9	1.0	.16	64.0	75.0	5.3	7.3	100.0	.09	......	......
	7- 5-40	10	s27, 28-t52-r14	10	1.0	.5	60.8	84.2	......	......	......	......	10/90	B-M
	7- 5-40	11	s21, 22-t52-r14	3	......	......	64.4	......	......	......	......	......	......	L-M
Trib. 5-1	7- 5-40	9A	s3, 2-t51-r14	2.5	......	......	......	......	......	......	......	......	......	......
Trib. 3	7- 3-40	7A	s6-t51-r13	......	......	......	......	......	......	......	......	.09	......	......

Table 41. Physical and biological data for French river system recorded by stations (Fig. 5)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	7- 8-40	9	s17-t51-r12	15	4.0	.5	72.5	69.8	5.6	7.8	75.0	.08	75/25	L-B
	8-22-40	9	s17-t51-r12	3	2.7	2.0	58.0	56.0	8.0	7.9	75.0	......	......	....
Sector 2	7- 8-40	7	s7-t51-r12	9	4.3	1.2	69.7	80.6	6.4	7.6	75.0	......	50/50	B-G
	8-22-40	7	s7-t51-r12	6	1.8	.75	56.0	58.0	7.4	7.8	77.5	.1	......	....
Sector 3	7- 8-40	6	s36-t52-r13	10.5	2.4	1.0	61.7	82.4	......	......	......	.5	80/20	B
	7- 6-40	3A	s34, 35-t52-r13	9	.9	.37	66.2	85.8	......	......	......	1.7	......	B-G
	8-21-40	3A	s34, 35-t52-r13	5.5	1.0	1.5	60.0	74.0	7.1	7.6	70.0	.2	......	....
Sector 4	7- 6-40	3	s21-t52-r13	6	1.2	.33	65.3	84.0	......	......	65.0	.2	70/30	B-G
	7- 6-40	2	s21-t52-r13	4	3.7	.4	66.2	77.0	3.6	6.7	65.0	2.8	......	S-G-M
	8- 2-40	2	s21-t52-r13	5	1.7	1.0	63.0	73.0	5.6	7.3	62.5	.4	......	....
	7- 6-40	1	s8, 9-t52-r13	18	ponded	......	68.0	85.8	......	6.6	52.5	.9	......	....
Trib. 1	7- 8-40	5	s3, 2-t51-r13	2.5	no flow	......	68.0	83.3	......	......	......	......	......	....

Table 42. Physical and biological data for Sucker river system recorded by stations (Fig. 6)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	7-10-40	7	s10-t52-r12	15	13.2	1.6	68.0	76.1	......	8.0	87.5	.09	80/20	L
	8-22-40	7	s10-t52-r12	10	4.0	1.0	57.0	55.0	7.8	7.9	95.0	.3	......	....
Sector 2	7-10-40	6	s29-t52-r12	19	11.1	1.25	68.0	77.0	......	......	......	......	50/50	B-S
	8-22-40	6	s29-t52-r12	14	10.0	0.6	54.0	58.0	7.6	7.7	97.5	.18	......	....
Sector 3	7- 7-40	5	s30-t52-r12	18	7.9	0.6	65.3	77.0	5.6	7.6	90.0	.18	......	R-B
	8-24-40	5	s30-t52-r12	9	4.2	1.0	52.0	57.0	7.6	7.7	97.5	.13	......	....
	7- 7-40	4	s19-t52-r12	18	8.6	0.5	73.4	80.6	......	......	......	......	75/25	R-B
	7- 9-40	3	s18-t52-r12	13.0	13.3	1.4	69.8	82.4	5.1	7.8	90.0	.3	80/20	....
	8-24-40	3	s18-t52-r12	16	8.0	0.6	52.0	57.0	7.5	7.7	97.5	.09	......	....
Sector 4	7- 9-40	1	s30-t52-r12	13.5	8.2	0.6	64.8	84.2	5.1	7.4	95.0	.3	0/100	M-C
	8-24-40	1	s30-t52-r12	8	3.2	0.6	55.0	54.0	7.0	7.6	100.0	.3	......	C
Whiteside Lake	7- 9-40	2	s16, 17-t53-r12	......	......	......	77.0	82.4	4.5	7.5	42.5	......	......	....

Table 43. Physical and biological data for Knife river system recorded by stations (Fig. 7)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	6-24-40	1	s31-t52-r11	50	47.6	1.0	61.7	68.9	6.2	7.6	52.5	.04	75/25	L-B
Sector 2	8-26-40	1A	s36-t52-r12	20	21.2	2.0	58.0	62.0	7.3	7.8	72.5			
Sector 3	8-26-40	19E	s5-t52-r11	9	4.3	1.2	56.0	63.0	7.1	7.6	67.5	.07		
	8-27-40	19J	s33-t53-r11	7	3.0	1.25	56.0	58.0	7.4	7.6	62.5			
	6-27-40	19	s20, 29-t53-r11	22	18.4	1.0	60.3	69.8	6.0	7.5	60.0	.44	80/20	B-G
	6-26-40	20	s17, 20-t53-r11	25	8.3	1.0	60.4	75.2				.35	75/25	B
	8-27-40	20I	s17-t53-r11	10	3.8	0.8	55.0	59.0	7.5	7.6	62.5			
Sector 4	6-26-40	21A	s8-t53-r11	9	3.8	0.9	59.0	75.2						
	6-26-40	21	s8-t53-r11	12	3.8	0.6	59.5	75.2	6.0	7.0	47.5		66/34	B-G
	8-27-40	22F	s5-t53-r11	5	1.0	1.0	51.0	61.0	7.0	7.3	55.0	.13		
	6-26-40	22	s5-t53-r11	6	3.6	1.5	51.8	64.4	6.0	7.2	47.5	.13	95/5	B-G
Trib. 1	6-24-40	5	s36-t52-r12	6	1.6	0.5	62.4	75.2				.38	75/25	B-G
	6-24-40	4	s35-t52-r12	12	1.8	0.25	66.4	73.8						L-C
	6-26-40	2	s26-t52-r12	7	1.5									
	6-24-40	3	s36-t52-r12	20	3.4	.42	64.4	70.4						L-B
	8-26-40	2B	s22-t52-r12	nearl	y dry									
Trib. 2	6-25-40	6	s14-t52-r12	nearl	y dry		58.2	71.6						M-C
Trib. 3	6-25-40	7	s12-t52-r12	nearl	y dry		55.4	70.4						M-C
	6-24-40	9	s10-t52-r12	20	5.6	.3	62.6	84.2	5.7	7.5	47.5		50/50	G-C-B
	8-26-40	9C	s10-t52-r12	2	.1	1.0	51.0	61.0						
Trib. 3-1	6-25-40	8	s13-t52-r12	nearl	y dry									
Trib. 4 (Little Knife river)	8-26-40	10D	s5-t52-r11	8	6.4	2.0	56.0	58.0	6.6	7.6	67.5	.04		
	6-24-40	10	s6-t52-r11	9	9.6	2.0	64.4	78.8					40/60	S-G-B
	6-24-40	17	s6-t52-r11	7.5	4.0	1.0	63.0	75.2	5.6	7.6	57.5	.18	90/10	L-G
	6-27-40	18	s1-t52-r12	14.5	3.8	1.0	60.8	75.2				.09		
	8-28-40	16M	s35-t53-r12	5	1.7	0.7	54.0	58.0	6.1	7.6	70.0	.17		
	6-27-40	16	s27-t53-r12	14	3.6	0.48	60.8	71.6	5.2	7.4	55.0		50/50	B-G
Trib. 4	6-27-40	32	s25-t54-r12	13	pon	ded	60.8	68.0	4.5	7.0	82.5		0/100	M
	8-28-40	32L	s35-t54-r12	8	2.5	.12	54.0	59.0	4.1	7.1	87.5			
Trib. 4-1	6-24-40	13	s31-t53-r11	8	3.0	0.8	61.2	82.4					80/20	L-G
	8-28-40	13N	s31-t53-r11	5	1.0	0.8	54.0	58.0	6.4	7.6	70.0			
	6-24-40	13A	s31-t53-r11	8	0.8	0.28	59.0	75.2					75/25	B-G
	6-24-40	14A	s36-t53-r12	6	1.2	0.5	60.8	71.6						
	6-24-40	14	s25-t53-r12	5	1.2	0.5	62.6	75.2					30/70	L-B-G
	6-24-40	15	s25-t53-r12	5	1.3	0.66	61.4	75.2						C-G-S
Trib. 4-2	6-24-40	12	s3-t52-r12	3	0.8	1.0	60.8	75.2					75/25	L-S-G
Trib. 5	6-25-40	31	s33-t53-r11	3	0.2	0.15	68.4	73.4					10/90	C-M
	6-27-40	27	s17-t53-r11	2	0.26	0.5	60.8	73.4						B-G
	8-27-40	27H	s17-t53-r11	1	0.1		53.0	58.0						
Trib. 5-1	6-27-40	25	s27-t53-r11	nearl	y dry									
	8-27-40	25K	s27-t53-r11	nearl	y dry									
Trib. 8 (McCarty creek)	6-27-40	33	s18-t53-r11	5.5	5.0	2.5	65.2	82.4						B-G
	6-27-40	30	s12-t53-r12	5	2.0	1.0	59.4	73.4					80/20	B-G

Table 44. Physical and biological data for Stewart river system recorded by stations (Fig. 8)

Stream	Date	Sta- tion	Location	Width Feet	Flow C.F.S.	Veloc. Ft./ Sec.	Temperature		Diss'd. O_2	pH	Total Alkal.	Food cc/ sq. ft.	Riffles Pools	Bottom Soil
							Water	Air						
Sector 1	8-10-42	1	s29-t53-r10	8	10.7	.5	68	68	9.0	7.6	57.5	......	40/60	G-R
Sector 2	8-11-42	7	s13-t53-r11	12	7.7	.8	64	59	9.7	7.4	......	......	65/35	B-R-G
	8-11-42	6	s14-t53-r11	18	7.6	.63	65	72	8.8	7.4	......	......	65/35	R-G-S
	8-11-42	5	s15-t53-r11	8	7.4	.43	63	70	8.4	7.4	......	......	65/35	R-B-G
Sector 3	8-11-42	3	s34-t54-r11	12	5.8	1.2	56	67	8.9	7.5	50.0	......	65/35	R-B-G
	8-12-42	4	s27-r54-r11	12	6.4	2.0	59	71	8.5	7.4	50.0	......	65/35	R-G-S
Sector 4	8-12-42	8	s27-t54-r11	8	4.8	1.0	65	76	......	7.4	52.5	......	......	R-S-G
Trib. 1	8-10-42	2	s19-t53-r10	4	0.9	0.8	68	68	9.0	7.6	52.5	......	......	....
Trib. 2	8-11-42	....	s12-t53-r11	......	0.2	......	58	64	......	......	......	......	......	....
Trib. 3	8-11-42	....	....	nearl	y dry	......	......	......	......	......	......	......	......	....
Trib. 4	8-12-42	9	s23-t54-r11	2	0.4	1.0	......	......	......	6.9	35.0	......	......	....

Table 45. Physical and biological data for Gooseberry river system recorded by stations (Fig. 9)

Stream	Date	Sta-tion	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	7-11-40	1	s22-t54-r9	......	pon	ded	64.4	56.3	5.8	7.6	57.5	......	0/100	G-C
	9- 5-40	1	s22-t54-r9	......	pon	ded	70.0	68.0	6.9	7.6	60.0	......	0/100	G-C
Sector 2	7-11-40	2	s21-t54-r9	18	7.2	1.0	......	......	......	......	......	......	90/10	B-L
Sector 3	7-12-40	3	s19-t54-r9	23	9.6	.66	59.0	73.4	6.3	7.6	57.5	......	80/20	L-B
	8-29-40	3	s19-t54-r9	25	8.4	.5	58.0	64.0	6.9	7.6	57.5	......	80/20	L-B
	7-16-40	4	s19-t54-r9	18	9.4	.83	62.6	71.6	6.0	7.2	60.0	......	50/50	L-B
	7-12-40	9	s9-t54-r10	18	13.5	1.25	60.8	76.1	5.1	7.5	60.0	......	25/75	L-G-C
	9- 1-40	9	s9-t54-r10	12	9.8	1.4	56.0	64.0	5.5	......	62.5	......	......	......
Sector 4	7-16-20	11	s32-t55-r10	15	4.3	0.6	63.5	84.2	5.3	7.2	60.0	......	50/50	L-B
Trib. 1 (East Branch)	7-17-40	13	s16-t52-r9	15	1.6	.12	64.4	66.2	......	......	55.0	......	50/50	......
	9- 1-40	13	s16-t52-r9	4	0.7	.33	62.0	74.0	......	7.6	60.0	......	......	......
Trib. 1-6 (Rock creek)	7-12-40	7	s24-t55-r10	8	1.3	.8	57.2	78.8	6.2	7.2	45.0	......	80/20	L-B
	8-29-40	7	s24-t55-r10	6	0.8	.3	54.0	64.0	7.1	7.5	47.5	......	......	......
Trib. 1-7 (Skunk creek)	7-12-40	8	s24-t55-r10	7	1.6	.5	68.0	76.1	......	7.4	50.0	......	80/20	L-B
	9- 1-40	8	s24-t55-r10	4	1.6	1.5	58.0	65.0	7.2	7.5	65.0	......	......	......
Trib. 1-4	7-12-40	6	s26-t55-r10	......	almos	t dry	......	......	......	......	......	......	......	......
Trib. 2	7-12-40	5	s2-t54-r10	......	almos	t dry	......	......	......	......	......	......	......	......
Trib. 5	7-16-40	10	s1, 6-t54-r10	5	0.5	.77	59.0	77.0	5.1	7.5	67.5	......	20/80	L-C
	9- 1-40	10	s1, 6-t54-r10	3	1.0	1.66	54.0	58.0	6.7	7.5	70.0	......	......	......
Trib. 5-2	7-16-40	12	s25-t55-r11	......	almos	t dry	......	......	......	......	......	......	......	......
Highland lake	7-16-40	12A	s34-t55-r11	......	......	......	75.2	79.7	......	7.6	40.0	......	......	......
Trib. 6	7-19-40	14	s6-t55-r10	1	0.1	.25	......	......	......	......	......	......	......	......

Table 46. Physical and biological data for Split Rock river system recorded by stations (Fig. 10)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	7-18-40	1	s7-t54-r8	78	pon	ded	67.2	75.2	4.9	7.3	60	.08	0/100	C-B
	9- 4-40	1	s7-t54-r8	......	......	......	72.0	70.0	6.6	7.5	57.6	.22	......	....
Sector 2	7-18-40	11	s36-t55-r9	20	casc	ades	67.4	68.8	......	......	......	......	......	L
Trib. 1 (East Branch)	7-18-40	9	s26-t55-r9	14	2.8	1.0	67.0	68.8	......	......	......	......	50/50	B
	7-19-40	5	s15-t55-r9	15	7.0	1.0	68.0	84.5	5.4	7.4	40.0	......	75/25	B-G
	9- 4-40	5	s15-t55-r9	14	3.8	.33	66.0	78.0	6.8	7.5	47.5	.08	......	....
	7-22-40	7	s9-t55-r9	12	22.4	2.0	68.0	76.0	......	......	27.5	......	90/10	B-G
	7-19-40	3	s24-t56-r10	8	3.7	2.0	60.8	82.0	......	......	......	......	50/50	B-G-M
	7-29-40	3	s24-t56-r10	......	9.6	2.5	60.8	81.5	......	......	......	......	50/50	B-G
	8-28-40	3	s24-t56-r10	6	1.38	.33	50.0	58.0	......	7.2	57.5	......	......	....
Trib. 2 (West Branch)	7-18-40	10	s26-t55-r9	15	8.8	.8	66.2	68.8	......	......	......	......	......	....
	7-22-40	8	s16-t55-r9	18	35.3	2.1	66.2	87.8	5.4	......	35.0	.22	50/50	B-G
	9- 4-40	8	s16-t55-r9	18	5.3	2.0	61.0	78.0	9.1	7.6	60.0	1.0	......	....
	7-22-40	6	s8-t55-r9	11	13.8	2.1	68.0	88.7	5.5	......	35.0	.48	90/10	B-G
	7-19-40	2	s22-t56-r10	7.5	0.6	0.55	68.0	75.2	4.4	7.0	35.0	.13	50/50	B-G
	8-28-40	2	s22-t56-r10	2	0.6	1.3	50.0	56.0	7.8	7.2	62.5	.22	......	....
Trib. 2-2 (Bud creek)	7-19-40	4	s17, 20-t55-r9	3	0.4	.7	68.0	75.0	......	......	......	.08	......	B-G
	7-22-40	4	s17, 20-t55-r9	7.5	1.6	.33	68.0	75.0	8.0	7.6	82.5	......	50/50	C-B
	9- 4-40	4	s17, 20-t55-r9	3	1.0	1.0	60.0	78.0	......	7.6	80.0	.26	......	....

Table 47. Physical and biological data for Beaver river system recorded by stations (Fig. 11)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	7-24-40	5	s12-t55-r8	75	pon	ded	73.4	67.7	5.6	7.5	30.0	......	0/100	G-B
	9- 6-40	5A	s12-t55-r8	11	6.6	1.0	66.0	72.0	5.7	7.6	40.0	......	......	......
Sector 2	7-24-40	6	s2-t55-r8	13	24.9	3.6	73.4	91.4	......	......	......	......	50/50	G-B-C
	7-23-40	2	s26, 27-t56-r8	15	24.0	1.0	79.3	91.4	4.8	7.2	20.0	.26	50/50	B-C-M
	9- 7-40	2	s27-t56-r8	10	4.7	0.5	63.0	73.0	7.0	7.2	35.0	......	50/50	B-G-C
	7-26-40	15	s21-t56-r8	12	11.5	1.2	68.0	75.7	......	......	30.0	......	25/75	L-B
Trib. 1 (West Branch)	7-24-40	4	s2-t55-r8	50	18.5	0.278	73.4	85.2	4.7	7.4	35.0	......	20/80	S-G-C
	9- 6-40	4	s2-t55-r8	40	10.6	0.2	71.0	78.0	7.7	7.6	50.0	......	......	......
	7-25-40	9	s17-t55-r8	25	26.6	2.0	69.8	77.9	5.4	7.4	37.5	......	70/30	S-B-C
	9- 6-40	9	s17-t55-r8	13	3.6	0.6	65.0	76.0	6.7	7.6	52.5	......	......	......
	7-25-40	12	s6-t55-r8	19	11.4	1.5	71.6	85.2	......	7.4	40.0	......	80/20	B-G
	7-29-40	19	s22-t56-r9	15	12.0	2.6	68.0	69.8	......	7.5	27.5	......	70/30	B-S
Trib. 1-1	7-25-40	11	s3-t55-r8	2	.3	1.0	......	......	5.0	7.8	15.0	......	......	M
T b. 1-2	7-25-40	8	s17-t55-r8	......	pon	ded	69.6	80.6	......	......	......	......	0/100	C
	7-25-40	7	s13, 14-t55-r9	7	2.8	0.5	67.8	78.8	4.6	7.4	57.5	......	50/50	C-B
	9- 6-40	7	s13, 14-t55-r9	3	0.1	0.1	64.0	80.0	5.9	7.4	60.0	......	......	......
Trib. 1-4 (Big 39 creek)	7-25-40	10	s6-t55-r8	10	5.1	1.27	77.0	85.5	......	7.5	35.0	......	80/20	B-G
	7-27-40	22	s5-t55-r8	14	3.7	0.33	66.3	78.8	......			......	35/65	M-C
	7-26-40	17	s32-t56-r8	10	8.0	2.0	67.7	71.6	......	......	......	......	75/25	B-C
	7-29-40	21	s24-t56-r9	6	3.2	1.0	73.4	82.4	......	7.4	37.5	......	75/25	B-G
Trib. 1-4-1	7-26-40	14	s29-t56-r8	25	10.0	2.0	63.5	71.6	......	7.5	40.6	......	50/50	B-G
Trib. 1-4-2	7-29-40	20	s23-t56-r9	6	1.2	0.5	63.5	82.4	......	7.3	27.5	......	75/25	M-G-B
Trib. 1-7	7-29-40	18	s22-t56-r9	8	3.8	1.2	62.6	75.2	......	......	......	......	75/25	B-G
Trib. 3 (Cedar creek)	7-24-40	3	s26-t56-r8	11	11.5	3.0	73.4	91.4	......	7.3	35.0	......	50/50	B-C-M
	7-26-40	16	s14-t56-r8	13	9.4	1.8	68.6	78.8	......	7.6	25.0	......	80/20	B-G-S
Trib. 3-3	7-23-40	1	s14-t56-r8	12	4.5	0.8	68.9	91.4	5.8	7.4	32.5	......	50/50	B-G-M
	9- 6-40	1	s12-t55-r8	11	6.6	1.0	66.	72.0	5.7	7.6	40	......	......	......
Trib. 3-3	7-26-40	13	s10-t56-r8	......	......	......	60.8	78.4	......	7.4	42.5	......	50/50	G-B-M
Trib. 3-2	7-31-40	23	s6-t56-r7	8	0.5	0.8	63.5	75.0	......	......	......	......	......	......

Table 48. Physical and biological data for Baptism river system recorded by stations (Fig. 12)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	7-31-40	1	s15-t56-r7	70	pon	ded	60.0	70.0	5.9	7.4	15.0	......	0/100	G-B
	9- 9-40	1A	s15-t56-r7	13	31.2	2.0	62.0	60.0	7.1	7.4	32.5	......	......	......
Sector 2	7-31-40	2	s33, 34-t56-r7	80	192.0	2.0	70.0	73.0	5.0	7.2	20.0	......	90/10	B-G
	9- 9-40	2	s33; 34-t56-r7	60	88.0	2.0	62.0	63.0	8.2	7.5	30.0	......	......	......
	8- 8-40	12	s20-t56-r7	40	16.8	.56	72.0	80.0	5.9	6.9	20.0	0.17	25/75	B
Sector 3	7-31-40	4	s17-t57-r7	50	135.0	4.0	68.0	79.0	5.0	7.0	17.5	......	100/0	B
	9- 9-40	4	s17-t57-r7	30	18.0	1.5	52.0	54.0	6.3	7.3	30.0	......	......	......
	8- 1-40	10	s1-t57-r8	30	56.0	3.0	62.0	70.0	6.2	7.0	15.0	......	100/0	B
Sector 4	8- 8-40	29	s2-t57-r8	18	3.3	0.25	63.0	78.0	5.0	6.8	30.0	......	60/40	B
	8- 8-40	32	s18-t57-r8	1	nearl	y dry	......	......	......	......	......	......	......	......
Trib. 4	7-31-40	5	s31-t57-r7	3	0.4	1.4	59.0	70.0	......	7.2	30.0	......	80/20	B-G
Trib. 6 (Sawmill creek)	8- 1-40	8	s26-t57-r7	5	......	......	58.0	67.0	......	......	......	......	80/20	S-C
	8- 1-40	7	s24-t57-r7	6	2.8	0.7	57.0	68.0	......	7.2	37.5	......	75/25	S-C
Trib. 7	8- 1-40	6	s21-t57-r7	3	0.6	3.1	69.0	67.0	......	6.5	22.5	......	......	G-M
Trib. 8 (East branch)	8- 2-40	12A	s20-t57-r7	40	72.0	3.0	67.2	69.8	5.9	6.9	20.0	......	40/60	B-G
	9-11-40	12A	s20-t57-r7	15	14.0	1.3	56.0	62.0	6.4	7.0	27.5	......	......	......
	8- 8-40	24	s17-t57-r7	10	2.0	0.5	74.0	78.0	......	......	......	......	25/75	B-G
	8- 2-40	15	s1-t57-r7	100	pon	ded	75.2	71.6	4.2	6.8	20.0	0.1	5/95	S-M
	9-11-40	15	s1-t57-r7	......	pon	ded	64.0	66.0	4.4	6.0	22.5	......	100/0	......
	8- 2-40	33	s31-t58-r6	34	49.0	1.2	72.0	74.0	......	7.2	15.0	......	100/0	B
	9-11-40	33	s31-t58-r6	27	17.3	0.8	57.0	64.0	6.8	7.1	25.0	......	......	......
	8- 5-40	20	s21-t58-r7	10	5.3	0.6	68.0	76.0	......	6.4	25.0	......	25/75	G-B-M
Trib. 8-1	8- 2-40	13	s17-t57-r7	5	0.3	1.5	64.0	73.0	......	7.0	22.0	......	80/20	B-G
Trib. 8-2	8- 2-40	14	s11-t57-r7	6	1.1	0.8	62.0	77.0	......	6.9	20.0	......	50/50	G-C
Trib. 8-4	8- 2-40	16	s31-t58-r6	16	pon	ded	75.2	71.6	......	......	......	......	0/100	M
Trib. 9 (West Branch)	7-31-40	3	s7-t57-r7	20	11.9	1.5	71.0	75.0	5.2	7.2	20.0	......	85/15	B
	9-11-40	3	s7-t57-r7	6	4.0	1.0	53.0	55.0	7.0	7.0	30.0	......	......	......
	8- 8-40	28	s19-t57-r7	15	4.2	0.66	80.0	80.0	......	......	27.5	......	......	B
	8- 8-40	27	s24-t57-r8	50	pon	ded	80.0	82.0	......	......	......	......	0/100	M
	8- 8-40	26	s27-t57-r8	15	0.13	.5	77.0	82.0	......	6.8	27.5	......	75/25	B
Trib. 9-1	8- 8-40	21	s19-t57-r8	0.5	......	......	66.0	81.0	......	......	......	......	......	M-S
Trib. 9-2	8- 8-40	25	s24-t57-r8	3.0	0.4	1.0	65.0	82.0	......	......	......	......	50/50	B-G
Trib. 11	8- 1-40	9	s1-t57-r8	10.0	5.2	1.0	61.0	70.0	6.0	6.9	12.5	0.1	75/25	B-G
	9- 9-40	9	s1-t57-r8	2	0.4	1.0	55.0	52.0	7.8	6.8	20.0	0.1	......	......
Trib. 14	8- 6-40	19	s28-t58-r8	18	6.0	.5	......	......	......	6.0	22.5	......	70/30	B
	8- 1-40	11	s7-t58-r8	10	8.8	1.0	65.0	67.0	4.8	6.3	15.0	......	75/25	B-G
	9- 9-40	11	s7-t58-r8	8	2.1	0.4	62.0	62.0	6.0	6.8	27.0	......	......	......
	8- 6-40	18	s3-t58-r8	15	2.9	0.14	67.2	77.0	......	......	......	......	10/90	B-S-M
Trib. 14-1	8- 8-40	30	s35-t57-r8	8	0.3	0.06	59.0	80.0	......	......	......	......	60/40	B-G
Trib. 14-2	8- 8-40	31	s18-t58-r8	1	......	......	......	......	......	......	......	......	......	G-M
Trib. 14-4	8- 6-40	17	s10-t58-r8	1.5	0.2	0.6	65.4	77.0	......	6.5	20.0	......	80/20	B-G-S

Table 49. Physical and biological data for Manitou river system recorded by stations (Fig. 13)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	8- 8-40	26	s3-t57-r6	45	......	......	......	......	......	......	......	......	80/20	L-B
Sector 2	8-14-40	20	s28-t58-r6	45	90.0	3.0	73	77	......	......	......	......	90/10	B-G
	8-10-40	19	s20-t58-r6	40	52.0	1.0	75	76	......	7.4	27.5	......	40/60	G-B
Sector 3	8-15-40	24	s17-t58-r6	40	......	......	70	77	5.8	7.4	32.5	0.08	75/25	G-B
	9-11-40	24	s17-t58-r6	40	64.1	0.8	57	62	7.6	7.4	32.5	0.13	......	......
	8-15-40	18	s17-t58-r6	24	......	......	72	78	......	......	......	......	50/50	G-B
	9-11-40	18	s17-t58-r6	9	2.96	0.1	52	60	......	......	......	......	......	......
	8-14-40	10	s7-t58-r6	......	......	......	69	79	......	7.4	35.0	......	30/70	B-G
	8-13-40	16	s6-t58-r6	15	18.0	1.6	67	80	......	7.5	37.5	......	75/25	L-B
Trib. 6	8-15-40	25	s17-t58-r6	2	0.28	1.0	65	78	5.6	7.3	30.0	0.08	50/50	G-B
Trib. 7 (East Branch)	8-14-40	17	s17-t58-r6	20	11.0	0.5	76	77	......	7.3	25.0	......	75/25	G-B
	8-15-40	23	s17-t58-r6	22	5.4	0.22	78	74	4.3	6.8	25.0	0.53	25/75	G-B
	8-15-40	22	s9-t58-r6	pon	ded	......	74	80	......	......	......	......	0/100	......
	8-15-40	21	s3-t58-r6	18	11.9	1.0	69	75	5.4	7.2	25.0	0.4	25/75	G-B
	9-11-40	21	s3-t58-r6	15	7.9	.66	58	62	6.7	7.3	22.5	0.9	......	......
	8-12-40	7	s34-t59-r6	18	16.8	1.0	72	76	5.9	7.2	25.0	0.13	40/60	B-G
	8-13-40	14	s33-t59-r6	15	......	......	75	80	......	......	......	......	50/50	B-G
	8-13-40	13	s32-t56-r6	12	10.1	0.7	70	81	......	7.1	25.0	......	25/75	G-B
	8-13-40	9	s33-t57-r6	9	5.2	1.0	72	76	......	7.2	22.5	......	60/40	G-B
	8-13-40	8	s31-t57-r6	22	52.8	0.7	76	78	......	7.1	25.0	......	40/60	B-G
Trib. 7-2 (Nine Mile creek)	8-12-40	6	s34-t59-r6	10	4.0	0.5	66	80	......	......	......	0.08	25/75	B-M
	8-12-40	5	s34-t59-r6	7	2.3	1.4	70	78	......	6.8	25.0	......	25/75	B-M
	8-12-40	4	s27-t59-r6	5	1.5	1.5	78	80	4.5	6.2	17.5	......	75/25	B-M
Trib. 8	8-14-40	12	s6-t58-r6	15	4.0	1.0	78	77	......	7.2	25.0	......	40/60	B-G
Trib. 9 (Southwest branch)	8-14-40	11	s6-t58-r6	10	2.3	0.4	65	75	......	7.0	27.5	......	40/60	B-G
	8-10-40	2	s10-t58-r7	20	4.0	0.66	76	79	......	6.8	22.5	......	100/0	B-G
	8-10-40	3	s16-t58-r7	15	......	......	68	72	......	6.8	25.0	......	5/95	G-S
Trib. 9-2	8- 9-40	1	s9-t58-r7	......	......	......	70	78	......	6.8	27.5	......	0/100	S-M

Table 50. Physical and biological data for Caribou river system recorded by stations (Fig. 14)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	6-17-41	1	s36-t58-r6	18	16.5	0.86	56	78	......	7.3	28.7	.22	80/20	R-G
		1	....	9	10.6	4.0	50	58	......	......	......	......	......	R-G
Sector 2	6-18-41	2	s14-t58-r6	16	25.3	3.0	66	85	......	......	28.7	......	70/30	R-G
	6-18-41	3	s2-t58-r6	12	10.8	1.5	62	80	......	7.0	27.5	......	70/30	....
		3	....	8	3.2	1.3	50	58	......	......	......	......	......	R-G
Sector 3	6-21-41	4	s35-t59-r6	14	10.1	1.8	69	81	......	7.2	26.2	......	60/40	R-M
Trib. 12	6-21-41	5	s26-t59-r6	6	2.5	0.35	59	82	......	6.8	23.7	......	60/40	R-M

Table 51. Physical and biological data for Two Island river system recorded by stations (Fig. 15)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	6-23-41	1	s11-t58-r5	12	5.2	1.3	61	64	......	7.5	26.2	......	80/20	B-G
	9- 3-41	1	s11-t58-r5	10	11.25	5.0	58	63	......	......	......	......	......	....
Sector 2	6-24-41	3	s3-t58-r5	10	8.8	2.2	66	74	......	7.1	25.5	......	50/50	R-G
	6-24-41	4	s4-t58-r5	10	5.2	1.3	66	64	......	7.0	25.0	......	50/50	G'
	9- 3-41	4	s4-t58-r5	......	......	......	58	72	......	......	......	......	......	....
	6-25-41	8	s28-t59-r5	6	2.9	1.8	67	79	......	7.3	25.0	......	70/30	S-G
Sector 3	6-27-41	10	s7-t59-r5	6	1.4	0.9	74	88	......	6.8	28.7	......	60/40	R-G
	9- 4-41	10	s7-t59-r5	4	2.1	2.0	61	69	......	......	......	......	......	....
	6-27-41	10A	s20-t59-r5	6	1.6	1.0	74	76	......	......	......	......	......	....
Sector 4	....	11	s11-t59-r6	8	pon	ded	82	90	......	6.6	16.2	......	0/100	S-M
	....	12	s14-t59-r6	2	0.1	1.0	84	84	......	......	......	......	......	....
Trib. 1	9- 3-41	2	s2-t58-r5	4.0	1.06	2.0	......	......	......	......	......	......	......	....
	6-24-41	2	s2-t58-r5	2.0	.12	0.97	51	74	......	7.2	27.5	......	......	S-G
Trib. 2	6-24-41	5	s4-t58-r5	5.0	2.0	0.83	80	76	......	7.0	18.7	......	50/50	....
	6-24-41	6	s8-t58-r5	6.0	2.7	1.0	54	64	......	7.0	30.5	......	50/50	....
Trib. 2-1	6-24-41	7	s7-t58-r5	1.5	0.3	0.54	45	69	......	......	......	......	......	S-D
	....	7	s7-t58-r5	......	......	......	......	......	......	......	......	......	......	....
Trib. 5	6-25-41	9	s21-t59-r5	2.0	0.53	1.0	74	84	......	6.5	13.7	......	70/30	....

Table 52. Physical and biological data for Cross river system recorded by stations (Fig. 16)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	6-30-41	1	s36-t59-r5w	20	46.4	2.9	67.0	57.0	......	7.6	27.75	.87	100/0	L-B
Sector 2	7- 1-41	2	s26-t59-r5w	30	48.0	3.0	68.0	63.0	......	7.3	25.0	1.0	75/25	B-R-G
	7- 1-41	3	s23-t59-r5w	30	44.4	2.8	62.0	70.0	......	7.2	27.5	1.3	75/25	B-R-G
Sector 3	7- 1-41	5	s9-t59-r5w	35	34.0	0.8	62.0	64.0	......	7.2	25.0	1.5	50/50	R-G
	7- 1-41	9	s24-t60-r6w	15	13.8	2.3	71.0	75.0	......	7.4	22.5	12.7	60/40	B-R-G
	7-10-41	10	s24-t60-r6w	20	12.9	3.0	74.0	74.0	......	7.4	23.0	......	75/25	M-R-G
Trib. 1	6-30-41	......	s36-t59-r5w	dry	......	......	......	......	......	......	......	......	......	......
Trib. 2	6-30-41	4	s37-t59-r5w	3	0.6	1.0	65.0	86.0	......	7.1	27.5	4.0	60/40	B-R-G
Trib. 6 (Wanless creek)	7- 1-41	9A	s25-t60-r6w	30	18.0	0.33	72.0	75.0	......	......	......	......	0/100	......
	7- 8-41	7	s35-t60-r6w	5	1.9	0.7	68.0	72.0	......	7.5	42.5	2.7	70/30	R-G-S..
	7- 9-41	7A	s35-t60-r6w	......	......	......	69.0	82.0	......	......	......	......	......	......
	7- 8-41	8	s33-t60-r6w	3.5	1.1	1.1	73.0	75.0	......	......	......	......	......	......
Trib. 6A (Houghtaline creek)	7- 8-41	6A	s36-t60-r6w	3	.8	1.0	58.0	70.0	......	7.0	28.75	......	60/40	B-G-S
	7-10-41	6	s3-t59-r6w	10	3.2	0.5	70.0	79.0	......	......	......	......	......	B-R-G

Table 53. Physical and biological data for Temperance river system recorded by stations (Fig. 17)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature		Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
							Water	Air						
Sector 1	7- 9-41	1	s32-t59-r4w	25	75.0	2.5	63.0	57.0	......	7.4	20.0	1.6	80/20	L-B-R
	8-28-41	1	s32-t59-r4w	30	115.0	3.0	52.0	59.0	......	......	......	......	......	......
Sector 2	7-15-41	6	s18-t59-r4w	35	93.3	3.3	67.0	72.0	......	7.2	20.5	1.0	90/10	B-R
	7- 9-41	2	s33-t60-r4w	60	133.3	2.8	72.0	81.0	......	7.3	18.25	1.9	80/20	R-B-S
	7-16-41	2A	s33-t60-r4w	......	......	......	67.5	70.0	......	......	......	1.9	......	......
	7-15-41	5	s30-t61-r4w	70	111.7	1.5	70.0	70.0	......	7.3	17.5	......	65/35	B-R
	9- 5-41	5	s30-t61-r4w	50	40.0	1.0	62.0	66.0	......	......	......	......	......	......
	7-15-41	14	s4-t61-r4w	30	68.8	1.6	76.0	90.0	......	7.1	15.0	0.5	60/40	B-R
Trib. 1	8-28-41	......	s25-t59-r4w	......	0.4	......	......	......	......	......	......	......	......	......
Trib. 2 (Little Temperance river)	7-15-41	7	s18-t59-r4w	8	6.4	2.0	66.0	69.0	......	......	......	0.5	60/40	R-B-G
	7-15-41	4	s11-t59-r5w	6	3.6	3.0	56.0	68.0	......	7.3	28.8	0.3	60/40	R-B-G
	9- 4-41	4	s11-t59-r5w	15	8.0	1.3	58.0	71.0	......	......	......	......	......	......
Trib. 3	7- 9-41	3	s32-t60-r4w	5	4.0	2.0	64.0	81.0	......	7.3	36.25	2.0	70/30	B-M-G
	9- 4-41	3	s32-t60-r4w	5	3.3	2.0	61.0	71.0	......	......	......	......	......	......
Trib. 4 (Blind Temperance river)	7-16-41	8	s33-t60-r4w	15	6.0	0.4	62.0	70.0	......	7.3	29.5	......	60/40	R-G-B
	9- 5-41	8	s33-t60-4rw	12	14.4	2.0	60.0	68.0	......	......	......	......	......	......
Trib. 6	7-16-41	9	s31-t61-r4w	4	0.33	0.6	60.0	72.0	......	7.2	27.5	5.4	65/35	R-G-B
Trib. 8	7-16-41	10	s30-t61-r4w	8	10.6	1.66	68.0	72.0	......	6.6	15.0	......	60/40	B-S-R
Trib. 10 (Plouff creek)	7-17-41	11	s18-t61-r4w	10	36.4	3.0	61.0	64.0	......	6.5	13.0	......	70/30	B-S-D
	9- 5-41	11	s18-t61-r4w	12	16.6	1.6	60.0	63.0	......	......	......	......	......	......
	7-17-41	11A	s14-t61-r5w	15	15.0	0.5	62.0	75.0	......	......	......	......	......	......
Trib. 11	7-22-41	15	s5-t61-r4w	4	2.5	0.9	70.0	92.0	......	7.1	27.5	......	20/80	R-D-M
	9- 5-41	15	s5-t61-r4w	4	3.0	1.0	56.0	63.0	......	......	......	......	......	......
Trib. 11-1	7-17-41	12	s7-t61-r4w	15	5.7	0.34	61.0	68.0	......	6.2	18.0	......	......	M-B-R
Trib. 12 (Sawbill creek)	7-15-41	13	s18-t62-r4W	10	9.0	1.3	68.0	68.0	......	7.0	13.75	2.8	40/60	B-S-M
Trib. 12-2	7-15-41	13A	s30-t62-r4w	3	1.8	1.0	61.0	68.0	......	......	......	......	......	......

Table 54. Physical and biological data for Onion river system recorded by stations (Fig. 18)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Onion river	7-24-41	1	s12-t59-r3w	10	1.1	2.3	64.0	84.0	......	7.2	33.75	.75	60/40	L-B-R
	7-24-41	3	s2-t59-r3w	25	pon	ded	84.0	84.0	......	......	......	......	0/100	......
	7-24-41	2	s35-t58-r4w	8	1.2	.55	69.0	84.0	......	7.3	33.0	.02	30/70	G-S

Table 55. Physical and biological data for Poplar river system recorded by stations (Fig. 19)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	7-25-41	1	s3-t60-r3w	35	42.0	2.0	78	74	......	7.5	28.0	2.08	55/45	B-R
Sector 2	7-25-41	2	s16-t60-r3w	32	76.8	2.0	79.5	80	......	7.3	30.2	......	60/40	R-G
	7-26-41	3	s21-t60-r3w	100	pon	ded	78	78	......	7.6	28.7	......	0/100	R-G
Sector 3	7-28-41	4	s4-t60-r3w	20	24.0	2.0	76	77	......	7.4	27.5	......	40/60	R-G-S
	9- 6-41	4	s4-t60-r3w	18	21.6	1.3	56	58	......	......	......	......	......	......
Sector 4	7-28-41	5	s25-t61-r4w	20	23.8	2.0	76	88	......	7.4	35.0	2.0	60/40	R-G-S
	9- 6-41	5	s25-t61-r4w	12	19.2	3.0	54	58	......	......	......	......	......	......
	7-28-41	5C	s22-t61-r4w	10	16.0	2.0	67	80	......	7.4	32.0	......	......	......
	7-28-41	5D	s14-t61-r4w	18	9.6	1.3	78	82	......	......	......	......	......	......
Trib. 2	7-29-41	10	s3-t61-r4w	12	11.0	1.2	80	83	......	6.9	27.5	1.5	80/20	R-S
	9- 6-41	10	s3-t61-r4w	8	8.8	.8	58	58	......	......	......	......	......	......
Trib. 3 (Twin river)	7-29-41	9	s10-t61-r3w	2	0.13	1.0	76	83	......	......	......	......	60/40	R
	7-29-41	8	s15-t61-r3w	12	2.4	0.5	84	81	......	7.2	22.5	......	60/40	G
	7-29-41	11	s34-t61-r4w	8	7.3	2.0	74	80	......	7.5	47.7	.75	60/40	R-G
	9- 8-41	11	s34-t61-r4w	......	......	......	......	......	......	......	......	......	......	......
Trib. 4 (Sucker river)	9- 6-41	7	s34-t61-r4w	8	10.6	2.0	......	58	......	......	......	......	......	......
	7-29-41	7	s33-t61-r3w	10	7.3	1.25	82	82	......	7.3	25.0	......	80/20	R-G
Trib. 5 (Seven Mile creek)	7-29-41	6	s34-t61-r4w	......	2.6	0.1	64	79	......	7.0	41.2	......	......	R-G-S

Table 56. Physical and biological data for Spruce creek system recorded by stations (Fig. 20)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature		Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
							Water	Air						
Spruce creek	8-13-41	1	s15-t60-r2w	6	.8	2.0	72.0	73.0	.....	7.6	37.5	.....	65/35	L-B-R
	8-13-41	2	s8-t60-r2w	4	.35	0.66	73.0	60.0	.....	7.2	37.5	.....	50/50	B-R-M
	8-13-41	4	s5-t60-r2w	3	.78	1.7	73.0	64.0	.....	7.4	37.5	.....	50/50	B-R-M
Trib. 1	8-13-41	3	s9-t60-r2w	1.5	.2	1.0	73.0	61.0	.....	7.2	40.0	.....	50/50	B-R

Table 57. Physical and biological data for Cascade river system recorded by stations (Fig. 21)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature		Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
							Water	Air						
Sector 1	8- 5-41	1	s1-t60-r2w	20	20.0	2.5	68.0	78.0	.....	7.8	40.0	0.6	35/65	L-B
Sector 2	8- 5-41	2	s24-t61-r2w	30	12.0	0.5	78.0	78.0	.....	7.5	37.75	0.7	75/25	B-R-G
	9- 8-41	2	s24-t61-r2w	25	53.3	1.3	52.0	58.0	.....	.....	.....	.....	.....	.....
	8- 5-41	3	s1-t61-r2w	30	11.8	0.5	72.0	74.0	.....	7.4	33.75	1.4	60/40	B-R-G
Sector 3	8- 8-41	12	s1-t61-r2w	35	13.8	1.5	71.0	77.0	.....	7.2	34.25	.....	50/50	R-G-B
	8- 7-41	9	s24-t62-r2w	35	5.9	0.2	66.0	72.0	.....	7.2	17.5	.....	60/40	R-G-B
	9- 8-41	9	s24-t62-r2w	20	12.00	0.4	.....	.....	.....	.....	.....	.....	.....	.....
Sector 4	8-11-41	14	s13-t62-r2w	3	2.4	1.0	76.0	76.0	.....	6.3	23.8	.....	0/100	M-D
	9- 9-41	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sector 5	8-11-41	16	s3, 10-t62-r2w	100	pon	ded	84.0	84.0	.....	.....	.....	.....	.....	.....
Trib. 3	8- 5-41	2B	s24-t61-r2w	1	0.1	1.0	60.0	73.0	.....	.....	.....	.....	.....	.....
Trib. 4	8- 5-41	2A	s24-t61-r2w	2	0.3	1.0	56.0	78.0	.....	.....	.....	.....	.....	.....
Trib. 7 (Bally creek)	8- 6-41	5	s7-t61-r1w	100	pon	ded	80.0	75.0	.....	7.1	31.0	.....	0/100	M-R
	8- 6-41	4	s8-t61-r1w	4	0.8	1.0	65.0	75.0	.....	7.0	33.75	.....	20/80	M-G-B
	9- 9-41	4	s8-t61-r1w	8	0.9	0.3	.....	.....	.....	.....	.....	.....	.....	.....
Trib. 8 (Mark creek)	8- 8-41	11	s1-t61-r2w	6	1.6	1.3	78.0	77.0	.....	7.2	46.75	0.9	25/75	M-D-S
Trib. 9 (Nestor creek)	8- 7-41	6	s1-t61-r2w	12	1.2	0.25	67.0	74.0	.....	7.2	60.0	1.4	40/60	M-G-R
	9- 9-41	6	s1-t61-r2w	10	2.5	2.8	.....	.....	.....	.....	.....	.....	.....	.....
Trib. 10 (Little Miss. R.)	8- 8-41	10	s1-t61-r2w	3	3.9	2.2	69.0	78.0	.....	6.8	41.5	.....	50/50	G-S-R
Trib. 11	8- 7-41	7	s25-t62-r2w	2	0.6	2.0	61.0	74.0	.....	6.8	35.0	.....	.....	.....
Trib. 12 (Thompson creek)	8- 7-41	8	s24-t62-r2w	1.5	0.4	0.5	47.0	72.0	.....	7.2	44.0	.....	.....	.....
	9- 8-41	8	s24-t62-r2w	3.0	0.6	1.0	.....	.....	.....	.....	.....	.....	.....	.....
Trib. 12-1	8- 7-41	.....	s24-t62-r2w	.....	0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....
Trib. 14	8-11-41	13	s13-t62-r2w	8	1.9	1.9	76.0	78.0	.....	6.8	12.5	.....	.....	.....
	9- 8-41	13	s13-t62-r2w	7	2.8	1.0	.....	.....	.....	.....	.....	.....	.....	.....
Trib. 15	8-11-41	17	s10-t62-r2w	1	0.1	1.0	78.0	82.0	.....	.....	.....	.....	.....	.....
Trib. 16	8-11-41	15	s11-t62-r2w	5.5	0.1	1.0	81.0	84.0	.....	.....	.....	.....	.....	.....

Table 58. Physical and biological data for Devil Track river system recorded by stations (Fig. 22)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	8-14-41	1	s13-t61-r1e	15	6.0	2.0	66.0	71.0	......	7.6	37.5	1.58	60/40	R-B-G
	9-10-41	1	s13-t61-r1e	15	20.0	2.5	51.0	51.0	......	......	......	......	......	......
	8-14-41	1B	s12-t61-r1e	16	7.3	0.9	......	......	......	......	......	......	......	......
Sector 2	8-14-41	3	s34-t62-r1e	12	4.8	1.0	69.0	70.0	......	7.2	25.0	......	65/35	B-R-G
	8-15-41	6	s34-t62-r1e	6	1.8	1.5	66.0	76.0	......	7.0	26.3	......	60/40	B-R-G
	9-10-41	6	s34-t62-r1e	9	6.8	1.9	52.0	51.0	......	......	......	......	......	......
	8-19-41	11	s32-t62-r1e	18	5.3	1.3	71.0	64.0	......	7.6	18.8	......	60/40	G-R-B
	9- 9-41	11	s32-t62-r1e	20	5.5	0.7	53.0	55.0	......	......	......	......	......	......
Sector 3	8-18-41	8	s33-t62-r1w	20	11.0	0.5	61.5	67.0	......	7.0	24.3	......	......	G-R-B
	9- 9-41	8	s33-t62-r1w	12	8.1	0.8	52.0	54.0	......	......	......	......	......	......
Trib. 1	8-14-41	1A	s13-t61-r1e	1	0.2	3.0	59.0	69.0	......	7.0	46.3	......	......	......
Trib. 2 (Little Devil Track river)	8-19-41	12	s9-t61-r1e	4	0.6	1.2	58.0	66.0	......	7.4	47.5	......	35/65	M-B-R
	9-10-41	12	s9-t61-r1e	9	7.1	0.9	51.0	56.0	......	......	......	......	......	......
	8-19-41	13	s8-t61-r1e	6	0.8	1.0	57.0	68.0	......	7.8	47.5	......	45/55	R-G-B
	8-19-41	14	s7-t61-r1e	4	0.3	1.0	58.0	68.0	......	7.0	26.3	......	......	......
Trib. 2-1	8-19-41	......	s8-t61-r1e	......	0.1	......	58.0	68.0	......	......	......	......	......	......
Trib. 2-2	8-19-41	15	s7-t61-r1e	2	0.1	1.0	59.0	68.0	......	6.8	47.5	......	......	......
Trib. 3	8-14-41	2	s34-t62-r1e	0.8	0.2	2.0	65.0	75.0	......	7.0	31.3	......	55/45	M-R-S
	9-10-41	2	s34-t62-r1e	3.0	2.4	1.0	50.0	51.0	......	......	......	......	......	......
Trib. 4 (Elbow creek)	8-15-41	7	s34-t62-r1e	6	1.7	2.0	69.0	70.0	......	7.0	27.5	2.24	40/60	B-R-G
	9-10-41	7	s34-t62-r1e	16	8.5	1.3	50.0	51.0	......	......	......	......	......	......
Trib. 4-1	8-15-41	......	s27, 34-t62-r1e	3	0.3	4.0	......	......	......	......	......	......	......	......
Trib. 4-2	8-15-41	......	s27-t62-r1e	......	pon	ded	68.0	70.0	......	......	......	......	......	......
Trib. 4-3	8-15-41	5	s22-t62-r1e	5	1.0	1.0	64.0	70.0	......	6.8	30.0	......	......	......
	8-17-41	10	s10-t62-r1e	4	0.3	1.0	63.0	63.0	......	6.2	22.5	......	......	B-G-D
Trib. 4-4	8-17-41	9	s16-t62-r1e	9	1.4	0.4	56.0	60.0	......	6.2	12.5	......	......	G-S
	9- 9-41	9	s16-t62-r1e	8	4.8	0.25	52.0	55.0	......	......	......	......	......	......
Trib. 6 (Swamp river)	8-18-41	......	s21-t62-r1w	......	0.5	......	......	......	......	......	......	......	......	......

Table 59. Physical and biological data for Durfee creek system recorded by stations (Fig. 23)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Durfee creek	9- 3-41	1	s8-t61-r2e	3	0.6	3.0	60.0	68.0	......	7.7	47.5	......	55/45	R-G-S
	9- 3-41	2	s6-t61-r2e	2.5	0.7	2.0	58.0	62.0	......	7.5	45.0	.56	55/45	R-G-S
	9- 3-41	3	s31-t62-r2e	2.5	0.7	2.0	56.0	59.0	......	7.5	43.75	......	55/45	R-G-S

Table 60. Physical and biological data for Kimball creek system recorded by stations (Fig. 24)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Kimball creek................	9- 4-41	1	s10-t61-r2e	12	3.0	1.25	62.0	75.0	......	7.4	47.5	......	70/30	B-R-G
	8-28-41	2	s27-t62-r2e	10	2.0	3.0	59.0	58.0	......	7.6	48.75	......	60/40	B-R-G
	8-28-41	5	s18-t62-r2e	30	0.1	0.02	53.0	58.0	......	7.0	32.5	1.8	0/100	M-D
Trib. 3....................	8-28-41	4	s18-t62-r2e	3	0.2	1.0	53.0	58.0	......	7.2	31.2	......	......	G-S
Trib. 4....................	8-28-41	3	s18-t62-r2e	7	1.4	0.5	53.0	60.0	......	6.9	36.3	......	50/50	M-R-D

Table 61. Physical and biological data for Kadunce creek system recorded by stations (Fig. 25)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Kadunce creek...............	9- 5-41	1	s2-t61-r2e	12	25.8	2.7	60.0	62.0	......	7.2	36.25	......	65/35	L-B-R
	9- 5-41	2	s23-t62-r2e	10	23.6	5.0	61.0	63.0	......	6.8	28.75	.36	10/90	C-S-M
	9- 5-41	4	s13-t62-r2e	7	8.4	3.0	61.0	61.0	......	6.8	25.0	......	50/50	B-R-M
	9- 5-41	3	s10-t62-r2e	3	1.2	3.0	63.0	61.0	......	6.9	15.0	2.6	60/40	R-G-S

Table 62. Physical and biological data for Arrowhead (Brule) river system recorded by stations (Fig. 26)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Sector 1	8-20-41	1	s27-t62-r3e	50	160	2.0	60.0	66.0	......	7.2	23.8	0.66	75/25	B-R-G
	8-20-41	2	s4-t62-r3e	60	96	2.0	71.0	73.0	......	7.8	25.0	0.70	80/20	L-B-R
Sector 3	......	13	s22-t63-r1e	20	16	0.5	64.0	63.0	......	7.2	25.0	......	60/40	G-R-S
	8-25-41	15	s15-t63-r1w	20	16	1.2	59.0	55.0	......	7.0	28.8	......	15/85	B-M-G
Trib. 1	8-20-41	5	s21-t62-r3e	3	0.2	1.0	59.0	66.0	......	7.0	32.5	......	......	......
Trib. 2	8-20-41	4	s10-t62-r3e	......	0.8	......	......	......	......	......	......	......	......	......
Trib. 3 (Hansen's creek)	8-20-41	3	s4-t62-r3e	3	0.6	1.0	64.0	73.0	......	......	......	......	......	......
Trib. 4	8-20-41	......	s10-t62-r3e	4	0.8	1.0	63.0	72.0	......	7.4	41.25	......	......	B
Trib. 7 (Greenwood river)	8-21-41	7	s2-t63-r2e	6	3.6	0.66	66.0	88.0	......	6.8	15.0	......	70/30	B-R-G
Trib. 7-2	8-21-41	9	s2-t63-r2e	2	0.1	1.0	54.0	73.0	......	......	......	......	......	......
Trib. 8 (Stoney creek)	8-21-41	6	s16-t63-r2e	8	1.6	0.5	60.0	72.0	......	7.2	30.0	......	55/45	B-R-G
	8-21-41	6B	s15-t63-r2e	8	0.4	0.08	60.0	72.0	......	......	......	......	......	......
	8-21-41	6A	s25-t64-r1e	0.5	0.1	3.0	56.0	69.0	......	......	......	......	......	......
Trib. 8-2	8-21-41	6C	s16-t63-r2e	4	0.6	0.7	62.0	72.0	......	......	......	......	......	......
Trib. 10 (Timber creek)	8-22-41	11	s25-t63-r1e	8	0.3	0.6	60.0	60.0	......	6.6	32.5	......	60/40	M-G-C
	8-22-41	10	s1-t62-r1e	3	0.2	0.25	51.0	59.0	......	7.4	35.0	......	60/40	R-B-M
Trib. 11 (Pine Mt. creek)	8-22-41	12	s26-t63-r1e	4	1.1	1.0	61.0	63.0	......	7.0	22.5	1.4	60/40	B-G-S
Trib. 12 (N. Brule river)	8-22-41	14	s4-t63-r1e	12	19.2	2.0	66.0	63.0	......	7.2	26.3	......	40/60	B-R-G
	8-25-41	18	s23-t64-r1w	22	36.3	0.7	58.0	56.0	......	6.8	16.3	......	10/90	M-S-G
Trib. 12-2	8-23-41	......	s9-t63-r1e	......	0.3	......	......	......	......	......	......	......	......	......
Trib. 12-3	8-23-41	......	s3-t63-r1e	......	dry	......	......	......	......	......	......	......	......	......
Trib. 12-5	8-25-41	19	s19-t64-r1e	2	0.8	1.0	62.0	55.0	......	7.0	23.8	......	......	......
	8-25-41	20	s19-t64-r1e	5	5.3	4.0	55.0	56.0	......	......	......	......	......	......
Trib. 13	8-22-41	16A	s13-t63-r1w	......	1.1	......	......	......	......	......	......	......	......	......
Trib. 14	8-22-41	17	s14-t63-r1w	......	0.4	......	......	......	......	......	......	......	......	......
Trib. 15	8-22-41	......	s15-t63-r1w	......	3.8	......	......	......	......	......	......	......	......	......

Table 63. Physical and biological data for Flute Reed river system recorded by stations (Fig. 27)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Flute Reed river	9- 5-41	1	s20-t62-r4e	12	19.2	3.0	56.0	63.0	......	7.3	25.0	.02	70/30	L-B-R
	9- 9-41	2	s13, 14-t62-r3e	10	12.0	3.0	52.0	55.0	......	6.7	20.0	.02	60/40	B-R-G
	9- 9-41	3	s10-t62-r3e	7	8.4	3.0	51.0	68.0	......	6.8	20.0	......	65/35	B-R-C
	9- 8-41	4	s36-t63-r3e	2	0.4	0.5	51.0	54.0	......	6 8	23.7	......	60/40	R-G-L

Table 64. Physical and biological data for Reservation river system recorded by stations (Fig. 28)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Reservation river.............	9-10-41	1	s6-t62-r5	15	flood	1.5	51	54	......	7.0	30	.33	70/30	B-R-G
	9-10-41	2	s31-t63-r5	12	flood	1.5	51	54	......	7.0	27.5	1.37	70/30	B-R-G

Table 65. Physical and biological data for Hollow Rock creek system recorded by stations (Fig. 29)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Hollow Rock creek............	9-10-41	1	s25-t63-r5e	6	4.8	1.0	52.0	60.0	......	7.0	35.0	......	55/45	L-B-R
	9-10-41	2	s15-t63-r5e	4	2.4	0.5	52.0	60.0	......	6.9	30.0	......	55/45	L-B-R

Table 66. Physical and biological data for Pigeon river tributaries recorded by stations (Fig. 30)

Stream	Date	Station	Location	Width Feet	Flow C.F.S.	Veloc. Ft./Sec.	Temperature Water	Temperature Air	Diss'd. O_2	pH	Total Alkal.	Food cc/sq. ft.	Riffles Pools	Bottom Soil
Swamp river (Kaweshka river)..	9-13-41	1	s31-t64-r4e	10	96	8.0[1]	52.0	63.0	......	6.8	35.0	......	0/100	B-R-M
	9- 9-41	2	s29-t63-r4e	6	9.6	2.0	53.0	58.0	......	7.0	28.75	......	50/50	B-R-G
	9- 9-41	3	s26-t63-r3e	8	0.5	1.0	57.0	52.0	......	6.9	17.5	......	50/50	B-R-G
Irish creek..................	9- 8-41	1	s15-t63-r3e	4	0.7	1.25	50.0	52.0	......	6.5	13.75	......	60/40	R-G
	9- 9-41	2	s13-t63-r3e	8	9.6	1.0	52.0	52.0	......	6.9	37.5	......	50/50	R-G
Portage brook................	9- 8-41	1	s27-t63-r3e	4	2.0	1.25	57.0	52.0	......	6.8	21.25	.8	60/40	B-R-G

[1]At Lock in dam. River mostly ponded above. High stage.

Table 67. The occurrence of plankton species and bottom algae in the plankton and bottom samples from Minnesota North Shore streams

	Lester River	French River	Sucker River	Gooseberry River	Split Rock River	Beaver River	Baptism River	Manitou River	Caribou River	Two Island River	Cross River	Temperance River	Onion River	Poplar River	Cascade River	Devil's Track River	Durfee Creek	Kimball Creek	Kadunce Creek	Brule River	Flute Reed River	Reservation River	Pigeon River
MYXOPHYCEAE																							
1. *Chroococcus dispersus* (V. Keissler) Lemm.				x																			
2. *Chroococcus limneticus* Lemm.				x										x								x	
3. *Aphanocapsa Grevillei* (Hass.) Rab	x																						
4. *Microcystis aeruginosa* Kuetz				x						x		x		x								x	
5. *Merismopedia punctata* Meyen				x																			
6. *Merismopedia tenuissima* Lemm.															x								
7. *Aphanothece stagnina* (Spreng.) A. Br.				x																			
8. *Coelosphaerium Naegelianum* Unger							x			x	x	x		x		x							
9. *Gomphosphaeria lacustris* Chod.											x												
10. *Xenococcus sp.*														x									
11. *Oscillatoria anguina* Bory					x																		
12. *Oscillatoria limosa* Ag															x			x					
13. *Oscillatoria princeps* Vauch.										x													
14. *Oscillatoria tenuis* Ag		x	x		x	x	x	x							x			x					
15. *Anabaena circinalis* (Kuetz.) Rab														x									
16. *Anabaena flos-aquae* (Lyng.) Breb				x																			
17. *Nostoc spp*	x			x	x					x				x	x								
18. *Aphanizomenon flos-aquae* (L.) Ralfs.														x									
19. *Tolypothrix byssoidea* (Hass.) Kirch												x											
20. *Tolypothrix penicillata* (Ag.) Thuret					x	x													x	x			
21. *Tolypothrix tenuis* Kuetz							x		x														
22. *Stigonema sp.*				x			x																
23. *Rivularia compacta* Collins								x															
24. *Gloeotrichia echinulata* (J. E. Smith) P. Richter																				x			
RHODOPHYCEAE																							
25. *Bangia atropurpurea* (Roth) Ag							x			x													
26. *Audouinella sp*	x			x			x			x					x	x							
27. *Batrachospermum moniliforme* Roth	x			x	x	x	x	x								x					x		x
28. *Lemanea annulata* Kuetz	x	x			x	x	x	x				x											
29. *Tuomeya fluviatilis* Harvey								x				x											

Table 67. (Cont'd.) The occurrence of plankton species and bottom algae in the plankton and bottom samples from Minnesota North Shore streams

	Lester River	French River	Sucker River	Gooseberry River	Split Rock River	Beaver River	Baptism River	Manitou River	Caribou River	Two Island River	Cross River	Temperance River	Onion River	Poplar River	Cascade River	Devil's Track River	Durfee Creek	Kimball Creek	Kadunce Creek	Brule River	Flute Reed River	Reservation River	Pigeon River
CHRYSOPHYCEAE																							
30. *Symura uvella* Ehr	...	...	x	x	...	...	x	x	...	...	...	...	...	x	x	...	...	...	x	x	...	...	...
31. *Uroglenopsis americana* (Calkins) Lemm	...	...	...	...	...	...	...	...	...	...	x	x	...	...	...	...	...	...	...	...	...	...	...
32. *Dinobryon sertularia* Ehr	...	...	x	...	...	...	x	x	...	x	...	...	...	...	...	...	...	...	...	x	...	...	...
BACILLARIEAE																							
33. *Meloseira crenulata* (Ehr.) Kuetz	x	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
34. *Meloseira distans* (Ehr.) Kuetz	...	...	x	...	...	...	...	x	...	x	x	...	...	...	...	...	...	...	...	...	...	...	x
35. *Meloseira varians* Ag	x	x	x	x	x	x	x	x	...	x	x	x	x	x	x	x	...	x	x	x	x	x	x
36. *Cyclotella meneghiniana* Kuetz	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
37. *Tabellaria fenestrata* (Lyng.) Kuetz	x	x	x	x	x	x	x	x	...	x	...	x	x	x	x	x	...	...	...	x	...	...	...
38. *Tabellaria flocculosa* (Roth) Kuetz	...	...	...	x	...	...	x	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
39. *Meridion circulare* (Grev.) Ag	...	...	x	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...	...	x	...	...	...
40. *Diatoma vulgare* Bory	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...	...	...	...	...
41. *Fragilaria capucina* Desmaz	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
42. *Fragilaria crotonensis* Kitton	...	x	...	x	...	x	x	...	...	x	x	x	...	x	x	x	...	...	...	...	...	...	...
43. *Synedra spp*	x	x	x	x	x	x	x	x	...	x	x	x	...	x	...	x	...	...	...	x	...	...	...
44. *Synedra ulna* (Nitz.) Ehr	...	x	x	x	...	x	x	x	x	x	x	x	x	x	x	x	...	...	...	x	x	...	...
45. *Asterionella formosa* Hass	...	x	...	x	...	...	x	...	...	x	...	x	...	...	...	...	...	...	...	...	...	...	...
46. *Eunotia major* (W. Smith) Rab	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
47. *Cocconeis pediculus* Ehr	x	x	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
48. *Navicula spp*	x	x	x	x	...	x	x	x	...	...	...	x	x	...	x	x	...	x	x	...	...	...	...
49. *Diploneis elliptica* (Kuetz) Cleve	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
50. *Pinnularia nobilis* Ehr	...	...	x	...	...	...	x	x	x	x	x	...	...	x	x	x	...	...	x	x	...	...	...
51. *Pinnularia viridis* (Nitz.) Ehr	x	x	x	x	x	x	x	x	...	x	x	x	x	x	x	x	...	x	x	x	x	x	...
52. *Stauroneis acuta* W. Sm	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...
53. *Stauroneis phoenicenteron* (Nitz.) Ehr	...	...	x	x	...	x	x	x	...	...	...	...	...	...	...	...	...	x	...	...	...	...	...
54. *Frustulia vulgaris* (Thw.) De Toni	x	x	...	...	x	...	x	x	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...
55. *Gyrosigma sp*	...	x	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
56. *Amphiprora ornata* Bailey	x	x	x	x	x	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
57. *Gomphonema spp*	...	x	...	...	...	...	x	x	...	...	...	x	x	...	x	x	...	...	x	x	...	...	...
58. *Cymbella aspera* (Ehr.) Cleve	x	x	x	x	...	x	x	x	...	...	x	x	x	...	...	...	...	...	...	...	...	...	...
59. *Cymbella cuspidata* Kuetz	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
60. *Cymbella ehrenbergii* Kuetz	...	...	x	...	...	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...

Table 67. (Cont'd.) The occurrence of plankton species and bottom algae in the plankton and bottom samples from Minnesota North Shore streams

	Lester River	French River	Sucker River	Gooseberry River	Split Rock River	Beaver River	Baptism River	Manitou River	Caribou River	Two Island River	Cross River	Temperance River	Onion River	Poplar River	Cascade River	Devil's Track River	Durfee Creek	Kimball Creek	Kadunce Creek	Brule River	Flute Reed River	Reservation River	Pigeon River
61. *Cymbella lanceolata* (Ehr.) Brun		x					x								x					x			
62. *Cymbella turgida* (Greg.) Grun		x		x		x	x	x							x								
63. *Epithemi turgida* (Ehr.) Kuetz	x	x	x	x		x	x																
64. *Nitzschia sigmoidea* (Nitz.) W. Smith	x																						
65. *Cymatopleura elliptica* (Breb.) W. Smith	x	x	x	x		x	x	x															
66. *Cymatopleura solea* (Breb.) W. Smith		x	x	x	x	x																	
67. *Surirella ovalis* Breb	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x		x	x	x	x	
68. *Surirella robusta* Ehr			x	x				x	x														
69. *Surirella saxonica* Auersw							x			x					x								
CHLOROPHYCEAE																							
70. *Gonium pectorale* Muell							x																
71. *Pandorina morum* Bory	x		x	x	x		x					x				x				x			
72. *Eudorina elegans* Ehr					x																		x
73. *Volvox aureus* Ehr															x								
74. *Volvox Weissmanniana* Powers										x						x							
75. *Palmella sp*				x																			
76. *Sphaerocystis Schroeteri* Chod					x	x	x	x		x		x		x	x	x				x			x
77. *Stylosphaeridium stipitatum* (Bachm.) Geitler & Gimesi														x		x							
78. *Ulothrix spp*	x	x			x	x	x					x		x	x		x			x			
79. *Stigeoclonium sp*		x																					
80. *Draparnaldia plumosa* (Vauch.) Ag	x																						
81. *Fridaea torrenticola* Schmidle											x												
82. *Cladophora sp*	x					x																	
83. *Rhizoclonium hieroglyphicum* (Ag.) Kuetz	x																						
84. *Oedogonium spp*	x	x		x	x		x	x			x	x		x	x	x				x			
85. *Bulbochaete sp*							x					x								x			
86. *Pediastrum Boryanum* (Turp.) Menegh				x	x	x	x					x								x			
87. *Pediastrum duplex* Meyen							x			x	x												
88. *Pediastrum duplex* Meyen var. *clathratum* (A. Br.) Lag				x				x			x	x		x		x				x			
89. *Pediastrum duplex* Meyen var. *gracillimum* W. & G. S. West						x																	
90. *Westella botryoides* (W. West) De Wildm												x		x									

Table 67. (Cont'd.) The occurrence of plankton species and bottom algae in the plankton and bottom samples from Minnesota North Shore streams

	Lester River	French River	Sucker River	Gooseberry River	Split Rock River	Beaver River	Baptism River	Manitou River	Caribou River	Two Island River	Cross River	Temperance River	Onion River	Poplar River	Casecade River	Devil's Track River	Durfee Creek	Kimball Creek	Kadunce Creek	Brule River	Flute Reed River	Reservation River	Pigeon River
91. *Dictyosphaerium pulchellum* Wood	...	...	...	...	...	...	x	...	...	...	...	x	...	...	...	x	...	...	...	...	...	...	...
92. *Dimorphococcus lunatus* A. Br	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...
93. *Kirchneriella lunaris* (Kirchner) Moebius var. *Dianae* Bohlin	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...
94. *Kirchneriella obesa* (W. West) Schmidle var. *major* (Bernard) G. M. Smith	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...
95. *Scenedesmus abundans* (Kirchner) Chod	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
96. *Scenedesmus quadricauda* (Turpin) Breb	...	...	...	x	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
97. *Mougeotia viridis* (Kuetz.) Wittr	x	x	x	x	...	x	x	x	...	...	...	x	...	...	x	x	...	...	...	x	...	...	x
98. *Zygnema spp*	x	x	x	...	x	x	x	x	...	...	...	x	...	...	...	...	...	...	...	x	...	...	...
99. *Spirogyra spp*	x	...	...	x	...	x	x	x	...	...	x	x	x	x	x	x	...	...	x	x	...	...	x
100. *Gonatozygon pilosum* Wolle	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...
101. *Closterium acerosum* (Schrank) Ehr	...	...	x	...	...	x	x	x	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...
102. *Closterium Kuetzingii* Breb	...	x	...	...	...	x	x	...	...	...	x	...	...	...	...	x	...	...	...	x	...	...	...
103. *Closterium moniliforme* (Bory) Ehr	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	...	x	...	x	x
104. *Closterium ralfsii* Breb. var. *hybridum* Rab	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
105. *Closterium subtruncatum* W. & G. S. West	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
106. *Penium minutum* (Ralfs) Cleve	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
107. *Pleurotaenium Ehrenbergii* (Breb.) DBy	...	...	...	...	x	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
108. *Pleurotaenium trabecula* (Ehr.) Naeg. var. *rectum* (Delp.) W. & G. S. West	x	...	...	...	x	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
109. *Euastrum didelta* (Turp.) Ralfs	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
110. *Euastrum gemmatum* Breb	...	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
111. *Euastrum oblongum* (Grev.) Ralfs	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
112. *Euastrum verrucosum* Ehr. var. *reductum* Nordstedt	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...
113. *Cosmarium bioculatum* Breb	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
114. *Cosmarium botrytis* (Bory) Menegh	...	...	...	...	x	x	...	...	x	...	...	...	...	...	...	...	...	...	...	x	...	...	...
115. *Cosmarium circulare* Reinsch	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	x	...	...	...	...	...	...
116. *Cosmarium reniforme* (Ralfs) Arch	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
117. *Micrasterias americana* (Ehr.) Ralfs	x	...	...	...	x	x	x	...	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...
118. *Micrasterias apiculata* (Ehr.) Menegh	...	...	...	...	...	...	...	...	...	...	x	...	...	...	...	x	...	...	...	...	...	...	...
119. *Micrasterias pinnatifida* (Kuetz.) Ralfs	...	...	...	x	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
120. *Micrasterias radiata* Hass	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...	...	...	...	...
121. *Micrasterias radiosa* Ralfs var. *ornata* Nordst	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x

Table 67. (Cont'd.) The occurrence of plankton species and bottom algae in the plankton and bottom samples from Minnesota North Shore streams

	Lester River	French River	Sucker River	Gooseberry River	Split Rock River	Beaver River	Baptism River	Manitou Rive	Caribou River	Two Island River	Cross River	Temperance River	Onion River	Poplar River	Cascade River	Devil's Track River	Durfee Creek	Kimball Creek	Kadunce Creek	Brule River	Flute Reed River	Reservation River	Pigeon River
122. *Micrasterias truncata* (Corda) Breb						x														x			
123. *Xanthidium antilopaeum* (Breb.) Kuetz. Var. *polymazum* Nordst	x						x		x				x			x			x	x			
124. *Xanthidium cristatum* Breb							x																
125. *Xanthidium subhastiferum* W. West						x	x					x								x			
126. *Xanthidium subhastiferum* W. West var. *Johnsonii* (W. & G. S. West) G. M. Smith														x		x				x			
127. *Xanthidium subhastiferum* W. West var. *Toweri* (Cushman) G. M. Smith																				x			
128. *Staurastrum anatinum* Cooke & Wills var. *curtum* G. M. Smith																				x			
129. *Staurastrum anatinum* Cooke & Wills var. *denticulatum* G. M. Smith																				x			
130. *Staurastrum artiscon* (Ehr.) Lund							x											x		x			
131. *Staurastrum breviaculeatum* G. M. Smith		x									x			x									
132. *Staurastrum cingulum* (W. & G. S. West) G. M. Smith																						x	
133. *Staurastrum curvatum* W. West														x									
134. *Staurastrum cuspidatum* Breb																			x				
135. *Staurastrum furcatum* (Ehr.) Breb							x																
136. *Staurastrum megacanthum* Lund												x											
137. *Staurastrum muticum* Breb						x																	
138. *Staurastrum ophiura* Lund							x																
139. *Staurastrum paradoxum* Meyen														x									
140. *Staurastrum pentacerum* (Wolle) G. M. Smith							x																
141. *Staurastrum psuedopelagicum* W. & G. S. West														x									
142. *Staurastrum setigerum* Cleve						x														x			
143. *Arthrodesmus Ralfsii* W. West							x													x			
144. *Spondylosium planum* (Wolle) W. & G. S. West		x		x																			
145. *Hyalotheca dissiliens* (Smith) Breb				x	x	x				x	x									x			
146. *Hyalotheca mucosa* (Dillw.) Ehr															x				x	x			
147. *Desmidium Grevillei* (Kuetz.) De Bary																					x		
148. *Desmidium Swartzii* C. A. Ag						x	x							x	x				x		x	x	
149. *Gymnozyga moniliformis* Ehr								x								x				x			

Table 67. (Cont'd.) The occurrence of plankton species and bottom algae in the plankton and bottom samples from Minnesota North Shore streams

	Lester River	French River	Sucker River	Gooseberry River	Split Rock River	Beaver River	Baptism River	Manitou River	Caribou River	Two Island River	Cross River	Temperance River	Onion River	Poplar River	Cascade River	Devil's Track River	Durfee Creek	Kimball Creek	Kadunce Creek	Brule River	Flute Reed River	Reservation River	Pigeon River
DINOPHYCEAE																							
150. *Glenodinium cinctum* Ehr	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
151. *Ceratium hirundinella* (O. F. M.) Schrank	...	...	...	x	...	...	x	...	...	x	...	x	...	...	...	...	...	...	...	...	...	...	...
PROTOZOA																							
152. *Arcella dentata* Ehr	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
153. *Arcella vulgaris* Ehr	...	x	x	...	...	x	x	x	...	...	...	...	...	...	x	x	...	...	...	...	...	...	...
154. *Difflugia oblonga* Ehr	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...
155. *Centropyxis aculeata* Stein	...	...	...	x	x	x	x	x	...	...	...	x	...	...	...	...	...	...	...	x	...	x	...
156. *Euglypha acanthophora* (Ehr.)	x	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
157. *Campascus cornutus* Leidy	x	x	x	x	x	...	...	...	...	...	x	...	...	x	x	...	...	...	...	x	...	x	...
158. *Placocystis spinosa* (Carter)	x	x	...	...	x	...	x	...	...	...	x	x	...	...	x	...	...	...	...	...	...	...	...
159. *Actinophrys sol* Ehr	x	...	...	x	...	x	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
160. *Codinella cratera* (Leidy)	...	...	...	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
ROTIFERA																							
161. *Keratella cochlearis* (Gosse)	...	...	...	x	...	...	x	...	...	...	x	...	...	x	...	...	...	...	...	x	...	x	...
162. *Cathypna sp*	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...
163. *Lecane sp*	x	...	...	x	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
164. *Limnias sp*	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
165. *Monostyla lunaris* (Ehr.)	x	x	...	...	x	x	x	...	...	...	x	...	...	x	x	x	...	x	...	...	...	...	...
166. *Notholca striata* (O. F. M.)	x	...	...	...	x	x	x	...	...	...	...	...	...	...	...	...	...	...	...	x	...	x	...
167. *Polyarthra trigla* Ehr	...	...	...	x	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	x	...
CRUSTACEA																							
168. *Acroperus harpae* Baird	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	x	...	...	...
169. *Bosmina longirostris* (O. F. M.)	...	...	...	x	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
170. *Alona sp*	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
171. *Cyclops sp*	...	...	...	x	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
172. *Diaptomus sp*	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Table 68. Average numbers per square foot of bottom fauna organisms in nine North Shore streams

	Lester R. 11 samples	French R. 10 samples	Sucker R. 9 samples	Knife R. 15 samples	Gooseberry R. 13 samples	Split Rock R. 10 samples	Beaver R. 12 samples	Baptism R. 19 samples	Manitou R. 9 samples
Planaria	0.04	0.13	0.1	...	...	0.8	0.4	...	0.1
Nematodes	0.04	...	...	...	0.04	...	...	...	...
ANNELLIDA									
Aquatic oligochaetes	1.9	1.3	3.4	1.2	3.4	0.5	1.8	2.0	1.3
Lumbricus sp	0.04	0.66	...	...	1.3	0.66	...	.07	...
Glossiphonia complanata	...	0.1	...	...	.03	...	...	.07	...
G. stagnalis	...	...	0.1	...		0.13	...	.52	...
Haemopsis grandis	...	...	...	...	...	...	.03	...	...
H. plumbeus	0.15	0.13	0.15	0.77	.4	0.18	.95	.47	0.24
Macrobdella decora	0.04	0.04	...	...	...	...	...	...	...
CRUSTACEA									
Hyalella sp	0.15	0.4	1.1	...		0.62	...	1.1	0.53
Gammarus sp	...	...	...	0.1	...	...	...	...	...
Asellus sp	...	...	.05	...	...	...	...	...	...
PLECOPTERA									
Acroneuria sp	0.24	0.58	0.44	0.27	0.1	0.44	...	.44	0.8
Capnia sp	...	1.3	0.05	0.15	2.0	0.49	.1	.7	1.3
Isoperla sp	...	...	...	0.12	2.0	...	.1	.8	0.05
Nemoura sp	...	0.04	...	...	...	1.4	...	.02	...
Pteronarcys sp	0.04	...	...	...	.03	.044	...	...	...
Others	...	0.41	...	0.27	3.7	1.6	.73	.63	1.3
EPHEMERIDA									
Baetisca sp	...	...	...	...	...	...	.7	...	...
Ephemera sp	2.2	0.18	0.05	0.1	0.13	...	...	...	...
Ephemerella sp	7.6	13.0	1.6	1.4	2.8	2.4	1.7	0.9	7.0
Ephoron sp	...	...	...	...	...	...	0.04	...	...
Heptagenia sp	...	...	...	0.03	1.5	...	1.1	1.6	...
Iron sp	1.3	0.18	0.7	0.2	...	...	...	0.4	1.5
Neocloeon sp	15.2	15.4	5.2	10.9	4.4	4.9	0.7	5.5	10.5
Paraleptophlebia sp	0.5	2.3	0.8	1.6	1.2	2.4	1.6	1.5	4.7
Stenonema sp	10.1	8.4	4.2	6.4	4.4	2.4	0.9	5.7	10.2
ODONATA									
Aeschna sp	...	0.2	...	...	0.1	...	0.18		...
Boyeria sp	0.04	...	...	...	...	...	...	...	0.1
Chromagrion sp	...	...	...	...	...	...	...	...	0.1
Cordulegaster sp	...	...	...	...	0.1	.09	...	...	...
Gomphus sp	0.15	0.27	...	0.06	0.3	0.04	1.3	.05	0.1
Ophiogomphus sp	0.69	0.1	0.25	0.03	...	0.18	0.2	.09	...
Progomphus sp	...	...	...	...	0.23	...	0.1	...	...

Table 68. (Cont'd.) Average numbers per square foot of bottom fauna organisms in nine North Shore streams

	Lester R. 11 samples	French R. 10 samples	Sucker R. 9 samples	Knife R. 15 samples	Gooseberry R. 13 samples	Split Rock R. 10 samples	Beaver R. 12 samples	Baptism R. 19 samples	Manitou R. 9 samples
HEMIPTERA									
Buenoa sp	...	...	...	...	...	...	...	.02	...
Corixa sp	...	...	0.15	0.03	...	0.04	...	...	...
Gerris sp	0.04	...	...	...	...	...	...	...	...
Terrestrial forms	...	...	...	0.03	...	0.04	...	...	...
NEUROPTERA									
Chauliodes	0.12	...	...	...	...	...	...	...	...
Sialis	0.03	0.27	0.2	...	.03	0.1	0.04	...	0.05
TRICHOPTERA									
Hydropsychidae	4.6	5.0	11.0	10.9	9.2	15.5	2.4	11.3	68.7
Hydroptilidae	1.1	1.4	11.8	4.8	5.7	6.3	1.25	3.4	0.7
Others	0.7	0.8	0.4	0.8	.37	1.1	.04	.07	.05
COLEOPTERA									
Dytiscus sp	...	...	...	.06	.08	...	...	...	...
Elmis sp	10.3	3.7	...	2.0	5.6	3.1	2.0	1.4	10.0
Haliplus sp	0.7	0.84	0.83	0.3	...	0.03	...	...	0.9
Laccophilus	...	0.04	...	0.18	0.1	0.2	...	0.02	0.24
Others	0.25	0.22	...	0.08	1.3	0.04	...	0.04	0.34
DIPTERA									
Antocha sp	0.7	1.5	3.7	0.33	2.5	1.2	...	0.4	0.73
Atherix sp	...	0.13	0.2	0.12	.03	0.04	0.07	0.1	0.19
Chironomidae	41.6	83.4	56.7	36.6	48.7	53.4	41.5	27.5	30.0
Ehrysops sp	2.4	0.1	0.05	0.2	0.06	0.4	.04	...	.05
Eriocera sp	...	0.1	...	0.06	0.07	...	.04	...	.05
Sarcophaga sp	...	...	...	...	0.03	...	...	...	...
Simulium sp	5.5	1.4	6.3	1.4	...	0.27	0.04	0.3	0.15
Tipula sp	0.08	0.53	...	0.15	0.23	0.09	0.14	0.09	...
Others	0.28	0.8	0.05	0.7	0.27	0.1	0.3	0.05	0.24
MOLLUSCA									
Musculium	0.04	...	0.34	...	...	...	...	...	0.05
Pisidium	0.25	1.5	2.5	0.03	...	...	...	0.05	...
Sphaerium	0.04	0.75	...	0.03	...	...	...	0.05	...
Ancylus	0.04	0.5	0.5	0.4	...	...	...	...	...
Goniobasis	...	0.18	...	...	...	...	...	...	0.1
Helisoma	0.12	...	0.1	...	...	0.18	...	...	...
Physella	0.04	0.28	0.9	0.11	...	0.18	...	0.07	...
Others	0.04	...	...	...	...	...	...	...	...
Average total number per square foot	109.6	148.6	114.1	83.3	97.0	102.8	57.7	65.9	153.0