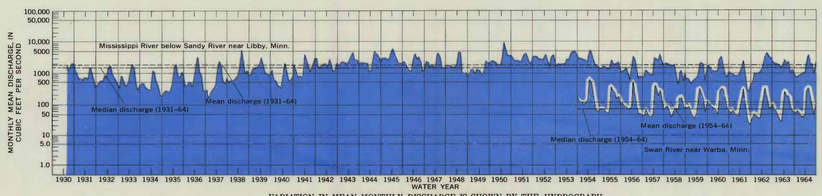
PREPARED IN COOPERATION WITH
THE MINNESOTA DEPARTMENT OF CONSERVATION
DIVISION OF WATERS, SOILS AND MINERALS

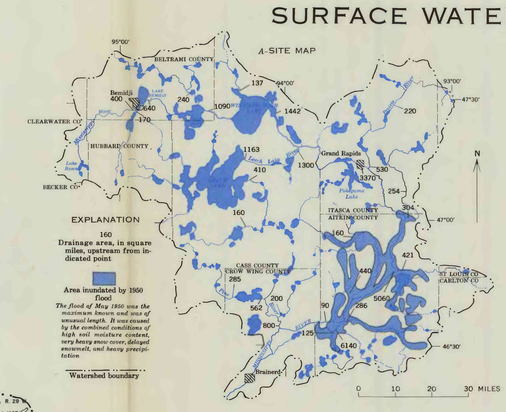


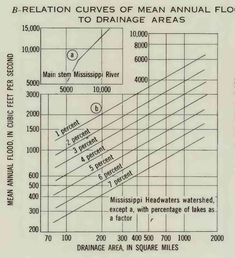
# SURFACE WATER

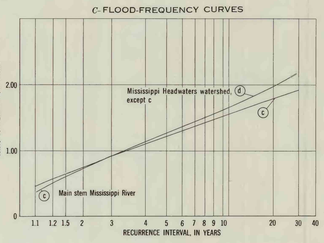



VARIATION IN MEAN MONTHLY DISCHARGE IS SHOWN BY THE HYDROGRAPH

*Although approximately 70 percent of the drainage area of the gaging station, Mississippi River below Sandy River near Libby, is affected by four of the Mississippi River headwater reservoirs, the hydrograph reveals the severity of the drought during the 1930's and the year to year changes in runoff. The Swan River near Warba is affected by discharge from the iron-mining industry but not by reservoir operation. Record high runoff throughout the watershed occurred during the flood of May 1950*




Example—

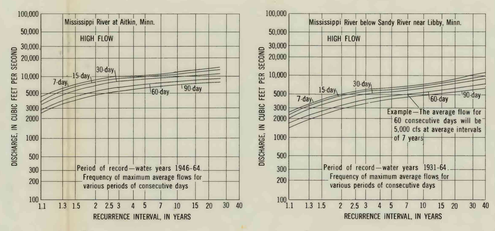
Find the recurrence interval of a flood of 1,500 cfs at a site on a tributary of the Mississippi River of 380 sq. miles drainage area of which 5 percent is lakes

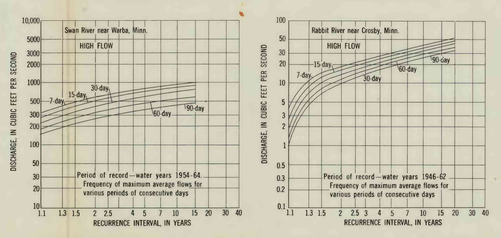
1. The 5 percent "a" curve in diagram (B) shows that for a drainage area of 380 sq. miles the mean annual flood is 1,000 cfs
2. The ratio of the 1,500 cfs flood to the mean annual flood of 1,000 cfs is 1,500/1,000 or 1.5
3. Entering diagram (C) with a ratio of 1.5, the flood-frequency curve "d" shows that the 1,500 cfs flood will occur on an average once every 7 years

The magnitude of a flood at a specified recurrence interval at this same site can also be found by reversed procedure

THE RECURRENCE INTERVAL OF A FLOOD OF SELECTED MAGNITUDE, OR THE MAGNITUDE OF A FLOOD AT A SPECIFIED RECURRENCE INTERVAL CAN BE DETERMINED BY USE OF DRAINAGE AREA (MAP A, FOR SELECTED SITES), RELATION CURVES (B), AND FLOOD-FREQUENCY CURVES (C)

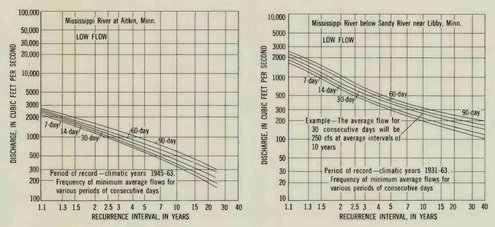
*Relation curve "a" is unreliable below 3,000 square miles and group "b" curves are unreliable at sites below reservoirs because of regulation of peak discharge. The magnitude of floods is affected by the area of lakes in the drainage basin. Although most of the floods from large drainage areas are from snowmelt, those from small drainage areas result from heavy local thunderstorm rainfall*

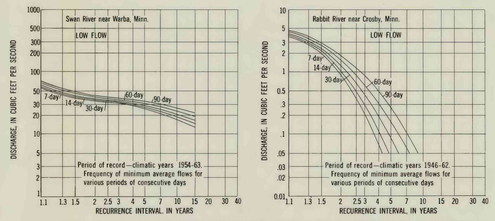


NOST OF THE MAXIMUM FLOWS ON THE MISSISSIPPI RIVER MAIN STEM AND MAJOR TRIBUTARIES ARE FROM SNOWMELT, AUGMENTED AT TIMES BY RAINFALL AND ARE INFLUENCED BY BASIN SHAPE, SIZE, AND TOPOGRAPHY

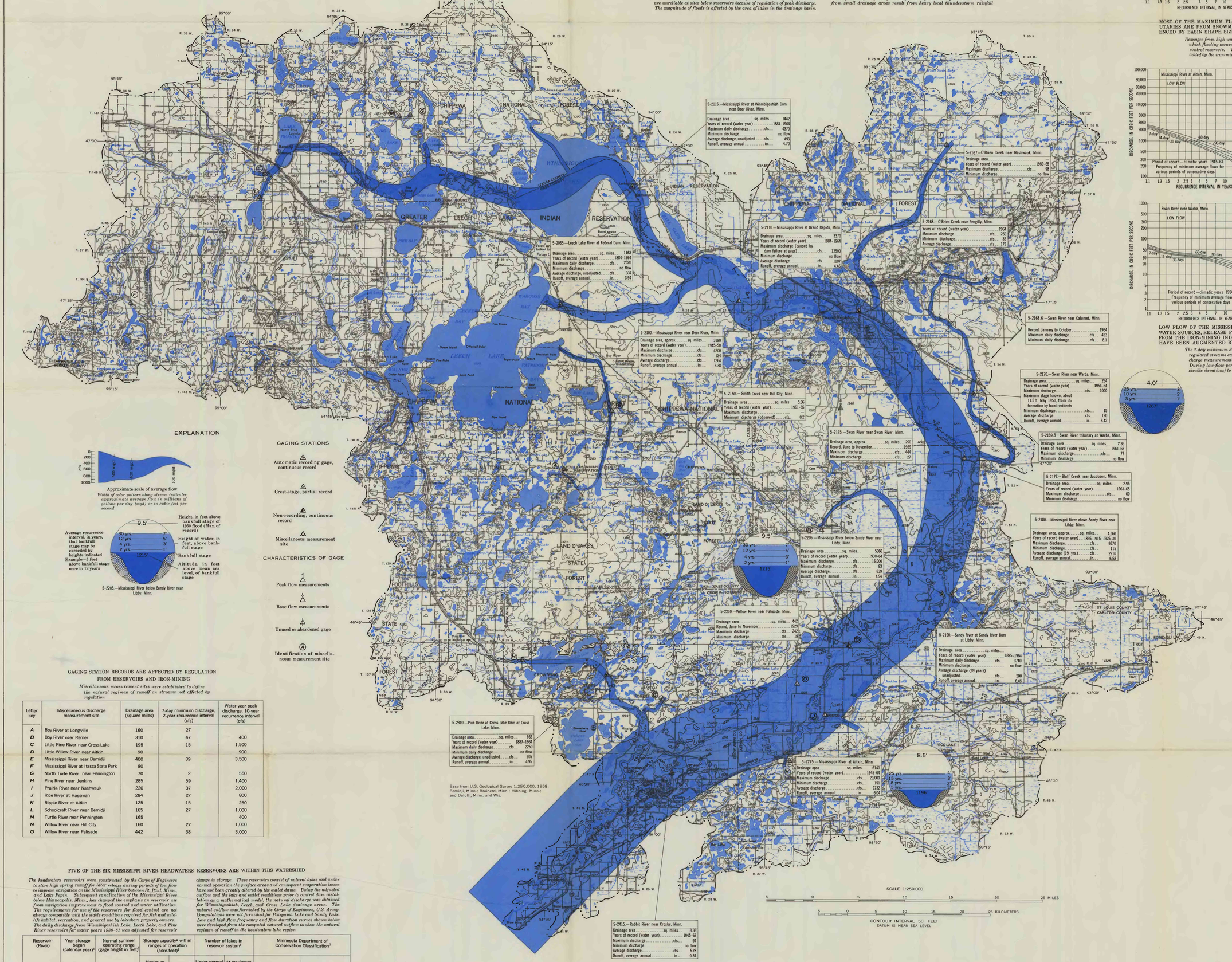
*Damages from high water are affected by the height, duration, frequency, and season in which flooding occurs. These four factors are also considerations in the design of a flood control reservoir. There is some regulation from power plants, reservoirs, and water added by the iron-mining industry*



LOW FLOW OF THE MISSISSIPPI RIVER NEAR LIBBY AND AT AITKIN IS FROM GROUND-WATER SOURCES, RELEASE FROM RESERVOIR STORAGE, AND DISCHARGE OF WASTE WATER FROM THE IRON-MINING INDUSTRY WHILE LOW FLOWS OF THE SWAN AND RABBIT RIVERS HAVE BEEN AUGMENTED BY DISCHARGE FROM THE IRON-MINING INDUSTRY

*The 7-day minimum discharges recurring every 2 years on the average for sites on unregulated streams can be compared by referring to the tables listing miscellaneous discharge measurement sites.*
*During low-flow periods the headwaters reservoirs are operated (within limits of desirable elevations) to provide minimum prescribed flows downstream*




Base from U.S. Geological Survey 1:250,000, 1958: Bemidji, Minn.; Brainerd, Minn.; Hibbing, Minn.; and Duluth, Minn. and Wis.

EXPLANATION



Approximate scale of average flow

*Width of color pattern along stream indicates approximate average flow in millions of gallons per day (mgd) or in cubic feet per second*



5-2205.—Mississippi River below Sandy River near Libby, Minn.

Average recurrence interval, in years, that bankfull stage may be exceeded by heights indicated
Example—5 feet above bankfull stage once in 12 years
Height, in feet above bankfull stage of 1950 flood (Max. of record)
Height of water, in feet, above bankfull stage
Bankfull stage
Altitude, in feet above mean sea level, of bankfull stage

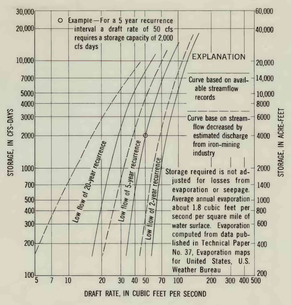
GAGING STATIONS

- Automatic recording gage, continuous record
- Crest-stage, partial record
- Non-recording, continuous record
- Miscellaneous measurement site

CHARACTERISTICS OF GAGE

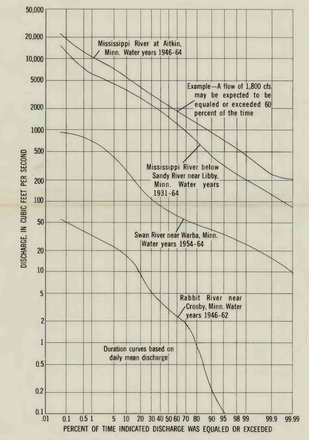
- Peak flow measurements
- Base flow measurements
- Unused or abandoned gage
- Identification of miscellaneous measurement site






DRAFT-STORAGE-FREQUENCY CURVES FOR SWAN RIVER NEAR WARBA SHOW THE APPROXIMATE STORAGE THAT WOULD BE NECESSARY TO MAINTAIN SPECIFIED FLOWS FOR VARIOUS LOW-FLOW RECURRENCE INTERVALS

*Available streamflow records at Warba include pumpage from ground-water sources used in the iron-mining industry and the two curves for each recurrence interval show the range of storage required between existing streamflow and estimated streamflow with no discharge from the mining operations. Water stored in reservoirs during high flows can be released to augment low flows*




THE EFFECT OF STORAGE IN LAKES, SWAMPS, AND GLACIAL DEPOSITS IS SHOWN BY THE FLAT SLOPE OF THE FLOW DURATION CURVES FOR THE MISSISSIPPI AND SWAN RIVERS

*The continuing flat slope at the lower end of the Mississippi River curves is caused by release of headwaters reservoir storage, whereas waste water from the iron-mining industry flattens the lower end of the Swan River curve. Although there is some regulation of the Rabbit River flow by Clinker Lake and pumpage from iron mining, the duration curve is typical for streams of a small drainage area*

GAGING STATION RECORDS ARE AFFECTED BY REGULATION FROM RESERVOIRS AND IRON-MINING

*Miscellaneous measurement sites were established to define the natural regimen of runoff on streams not affected by regulation*

| Letter key | Miscellaneous discharge measurement site | Drainage area (square miles) | 7-day minimum discharge, 2-year recurrence interval (cfs) | Water year peak discharge, 10-year recurrence interval (cfs) |
|---|---|---|---|---|
| A | Boy River at Longville | 160 | 27 | |
| B | Boy River near Remer | 310 | 47 | 400 |
| C | Little Pine River near Cross Lake | 195 | 15 | 1,500 |
| D | Little Willow River near Aitkin | 90 | | 900 |
| E | Mississippi River near Bemidji | 400 | 39 | 3,500 |
| F | Mississippi River at Itasca State Park | 80 | | |
| G | North Turtle River near Pennington | 70 | 2 | 550 |
| H | Pine River near Jenkins | 285 | 59 | 1,400 |
| I | Prairie River near Nashwauk | 220 | 37 | 2,000 |
| J | Rice River at Hassman | 284 | 27 | 800 |
| K | Ripple River at Aitkin | 125 | 15 | 250 |
| L | Schoolcraft River near Bemidji | 165 | 27 | 1,000 |
| M | Turtle River near Pennington | 165 | | 400 |
| N | Willow River near Hill City | 160 | 27 | 1,000 |
| O | Willow River near Palisade | 442 | 38 | 3,000 |

FIVE OF THE SIX MISSISSIPPI RIVER HEADWATERS RESERVOIRS ARE WITHIN THIS WATERSHED

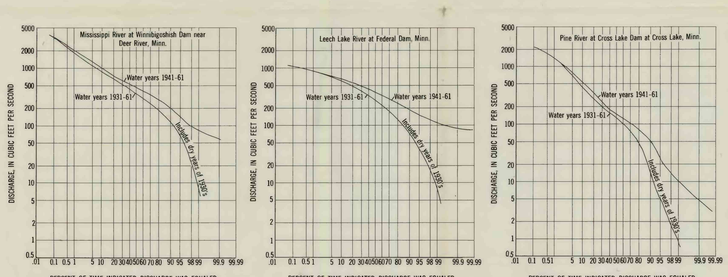
*The headwaters reservoirs were constructed by the Corps of Engineers to store high spring runoff for later release during periods of low flow to improve navigation on the Mississippi River between St. Paul, Minn., and Lake Pepin. Subsequent canalization of the Mississippi River below Minneapolis, Minn., has changed the emphasis on reservoir use from navigation improvement to flood control and water utilization. The requirements for use of the reservoirs for flood control are not always compatible with the stable conditions required for fish and wildlife habitat, recreation, and general use by lakeshore property owners. The daily discharge from Winnibigoshish Lake, Leech Lake, and Pine River reservoirs for water years 1930–61 was adjusted for reservoir change in storage. These reservoirs consist of natural lakes and under normal operation the surface areas and consequent evaporation losses have not been greatly altered by the outlet dams. Using the adjusted outflow and the lake and outlet conditions prior to control dam installation as a mathematical model, the natural discharge was obtained for Winnibigoshish, Leech, and Cross Lake drainage areas. The natural outflow was furnished by the Corps of Engineers, U.S. Army. Computations were not furnished for Pokegama Lake and Sandy Lake. Low and high flow frequency and flow duration curves shown below were developed from the computed natural outflow to show the natural regimen of runoff in the headwaters lake region*

| Reservoir (River) | Year storage began (calendar year)[1] | Normal summer operating range (gage height in feet) | Storage capacity* within ranges of operation (acre-feet)[1] | | Number of lakes in reservoir system[1] | | Minnesota Department of Conservation Classification[2] | |
|---|---|---|---|---|---|---|---|---|
| | | | Maximum allowable | Normal | Under normal operating stages | At maximum operating stage | Chemical | Fish |
| Winnibigoshish (Mississippi) | 1884 | 10.0–10.5 | 653,570 | 416,270 | 16 | 30 | Hardwater lake | Walleyes, northern pike, panfish, some muskellunge |
| Leech Lake (Leech Lake) | 1884 | 1.8–2.2 | 689,780 | 356,570 | 8 | 14 | Hardwater lake | Walleyes, northern pike, panfish, some muskellunge. |
| Pokegama Lake (Mississippi) | 1884 | 8.75–9.25 | 81,720 | 53,150 | 10 | 18 | Hardwater lake | Walleyes, northern pike, panfish. |
| Sandy River (Sandy) | 1893 | 8.75–9.25 | 73,330 | 37,550 | 5 | 7 | Hardwater lake, bordering soft water. | Walleyes, northern pike, crappie, panfish. |
| Pine River (Pine) | 1886 | 12.75–13.25 | 118,710 | 53,280 | 12 | 13 | Hardwater lake | Northern pike, panfish, some walleyes |

[1] Data obtained from the Corps of Engineers, U.S. Army.
[2] Data obtained from Minnesota Department of Conservation.
* Does not include "dead" storage–storage below minimum allowable stage.

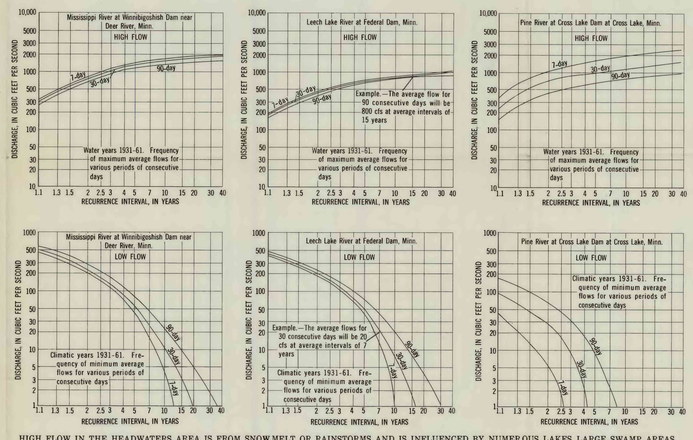
THE AVERAGE FLOW DIAGRAM SHOWS THE THEORETICAL MAXIMUM QUANTITY OF WATER IN THE STREAM THAT COULD BE DEVELOPED FOR A WATER SUPPLY

*Natural streamflow is variable and provision for a constant supply requires storage of high flow. Water losses in transmission and lack of suitable reservoir sites prevent utilization of the average streamflow. Flow of the Mississippi River and some tributaries in the watershed are regulated by power plants and five headwaters reservoirs. The large ground-water reservoirs, surface-water reservoirs, and many lakes and swamps, have some effect in reducing peak flows and increasing low flows. Evaporation loss, lack of storage capacity, and economic considerations limit the use of the five headwaters reservoirs. Water from the iron-mining industry is discharged into the Mississippi, Prairie, Swan and Rabbit Rivers. Medium and high flows diverted from the Mississippi River into the Aitkin diversion channel reduce flood stages above Pine Knoll. Extreme floods are not affected by the diversion*




THE EFFECT OF STORAGE IN LAKES, SWAMPS, AND GLACIAL DEPOSITS IN THE HEADWATERS AREA IS SHOWN BY THE FLAT SLOPES OF THE FLOW DURATION CURVES

*Pine River has less natural storage than Leech Lake River and Mississippi River above Winnibigoshish Dam. The sources of base flow were affected severely and depleted during the extreme dry years of the 1930's*




HIGH FLOW IN THE HEADWATERS AREA IS FROM SNOWMELT OR RAINSTORMS AND IS INFLUENCED BY NUMEROUS LAKES, LARGE SWAMP AREAS, AND FLAT TERRAIN WHILE LOW FLOW IS LARGELY FROM LAKE STORAGE AND GROUND-WATER SOURCES

*Although prolonged high water is characteristic of the watershed, peak runoff per square mile is low. Good yields are generally sustained throughout the year. During dry periods, evaporation from the many lakes exceeds the runoff*

THE SELECTED LARGE LAKES, SMALL LAKES, AND MANY STREAMS IN THE WATERSHED ARE AN IMPORTANT ALL-SEASON RECREATIONAL RESOURCE

*They are relatively stable because of good ground-water contribution and provide for hunting, fishing, water sports, and general vacation uses. Ice fishing is a major winter sport and has extended the recreational use of lakes to the winter months. Although little consumptive use is made of surface water, it is potentially a valuable source for water supply. The natural lakes forming the headwaters reservoirs are listed in the reservoir table*

| Name of lake | Surface area (acres) | Length of shoreline (miles) | Depth, in feet | | Outlet control | Composition of lake bottom | Type of shoreline | Fish and game classification |
|---|---|---|---|---|---|---|---|---|
| | | | Maximum | Median or average | | | | |
| Ball Club | 3,940 | 15 | 85 | 37 | Natural | About half sand and half muck | Mostly sand, some muck | Good northern pike, some walleyes |
| Bemidji | 6,760 | 14 | 80 | 29 | Natural, power dam 6 miles below causes some regulation | About half sand and half clay | Mostly sand, some rubble | Game fish |
| Boy | 3,140 | 21 | 45 | about 12 | Natural | Mostly muck, some sand and clay | Mostly muck and bog, some sand | Game fish |
| Cass (main body) | 15,710 | 39 | 120 | 25 | Dam | Sand and clay | Steep sand and boulders | Game fish |
| Cass (Pike Bay) | 4,640 | 10 | 75 | 25 | | | Steep sand and boulders | Waterfowl, fur animals, game fish |
| Deer | 4,160 | | 121 | | Dam | | Mostly sand, some muck | Walleye lake |
| Itasca | 1,180 | 14 | 40 | 14 | Natural | Sand, muck, some gravel | | Game fish |
| Pelican | 6,810 | 23 | 102 | 22 | Dam on diversion channel to Ossawinamakee Lake | Muck, sand and gravel | Sand | Walleyes, northern pike, bass, panfish |
| Big Rice | 2,830 | 10 | 3 | 2 | Dam | Muck and sandy muck | Marsh | Waterfowl nesting and resting area, fish spawning area, muskrat |
| Swan | 2,330 | 18 | 65 | | Natural | Sand and ooze over sand | Sand | Walleyes, northern pike, panfish |
| Ten Mile | 5,150 | | 208 | | Natural channel to Birch Lake | Weedy bays, sand and gravel shoals | Sand, gravel, rubble | Walleyes, northern pike, bass, excellent panfish |
| Woman | 4,070 | | 60 | | Dam on outlet of Girl Lake | | Over half sand and gravel, rest muck | Walleyes, northern pike, bass, panfish |

Data obtained from Minnesota Department of Conservation.

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1968—W67286

# WATER RESOURCES OF THE MISSISSIPPI HEADWATERS WATERSHED, NORTH-CENTRAL MINNESOTA

By
E. L. Oakes and L. E. Bidwell

1968