DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

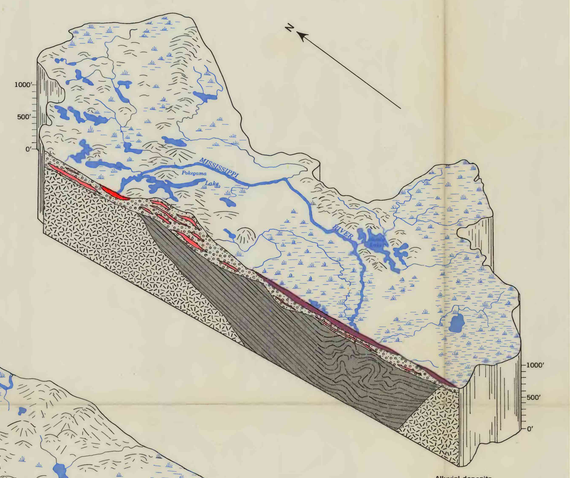
PREPARED IN COOPERATION WITH
THE MINNESOTA DEPARTMENT OF CONSERVATION
DIVISION OF WATERS, SOILS AND MINERALS

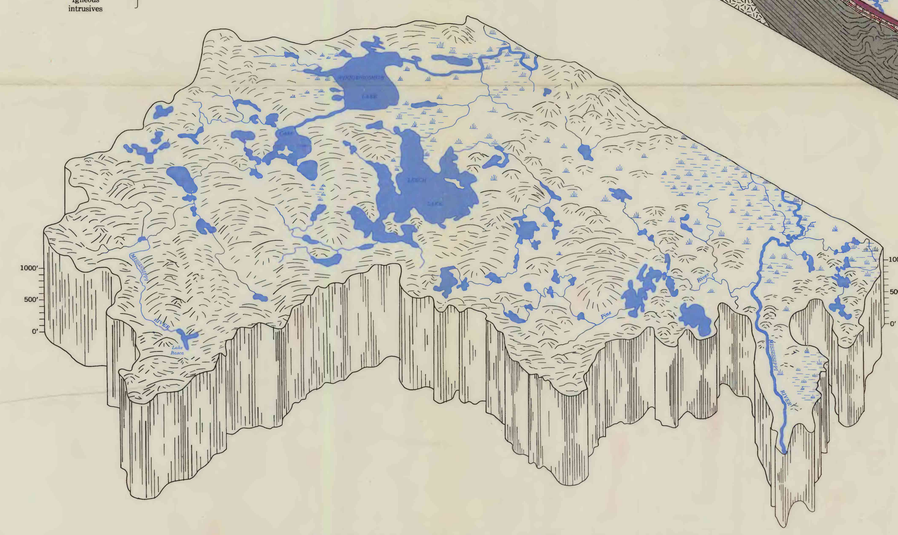
HYDROLOGIC INVESTIGATIONS
ATLAS HA-278 (SHEET 1 OF 4)

INTRODUCTION

EXPLANATION

- PLEISTOCENE
  - Outwash sand and gravel
  - Buried sand and gravel
  - Till
  - Lake deposits
- PRECAMBRIAN
  - Metasediments (slate, iron formation, and quartzite)
  - Igneous intrusives





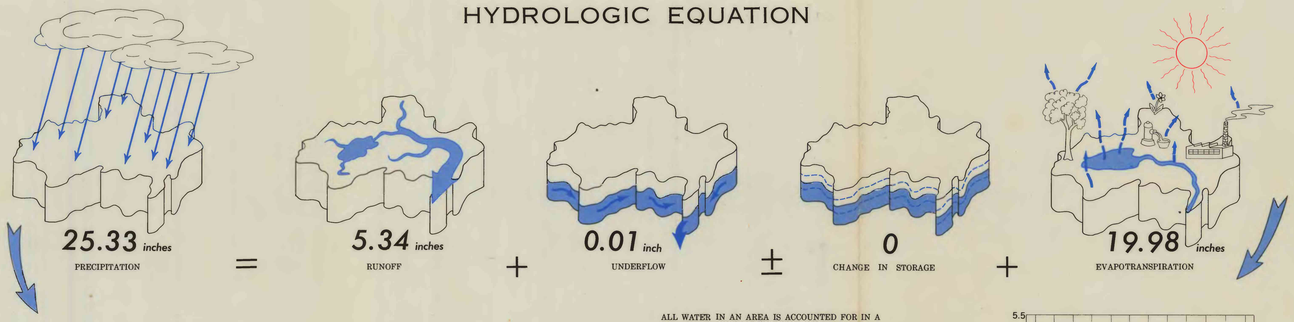
THE MISSISSIPPI HEADWATERS WATERSHED IS A 7,068 SQUARE MILE AREA IN NORTH-CENTRAL MINNESOTA WHICH INCLUDES ALL LAND DRAINED BY THE MISSISSIPPI RIVER ABOVE THE CROW WING RIVER

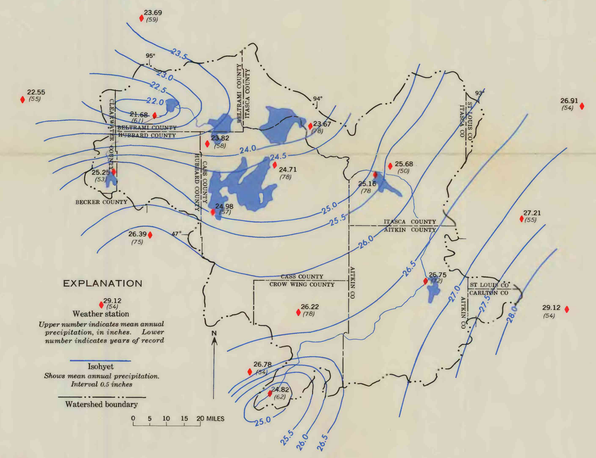
From its source in Lake Itasca, 1,460 feet above mean sea level, the Mississippi River follows a semicircular 376 mile course to where it leaves the watershed at an altitude of 1,150 feet. The origin of the river is in glacial moraine. The river flows through end moraines and rolling till plains, across an extensive outwash plain occupied by large reservoir lakes, and finally across an extensive marshy plain which is the bed of an ancient glacial lake.

Glacial deposits in the watershed include till, lenses of sand and gravel in till, outwash deposits of sand and gravel, and lake deposits of fine sand, silt, and clay. Beneath the glacial drift is an uneven surface of Precambrian bedrock. Bedrock consists of igneous intrusives and metamorphosed sedimentary formations.

Water resources in the area are abundant. Lakes and streams occupy about 8 percent of the surface of the area. Groundwater supplies are available from glacial drift and from bedrock

HYDROLOGIC EQUATION





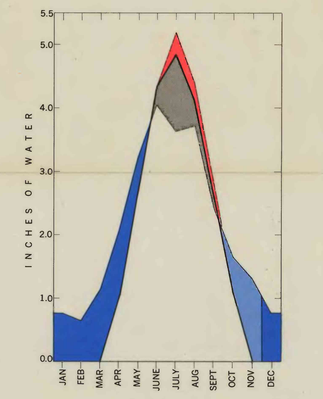
WATERSHED PRECIPITATION AVERAGES 25.33 INCHES PER YEAR
Based on climatological records from and adjacent to the watershed

ALL WATER IN AN AREA IS ACCOUNTED FOR IN A HYDROLOGIC EQUATION

The hydrologic equation states that: All water entering an area in a given period of time must either go into storage, be consumed, be exported, or flow out either on the surface or underground, during the same period. The simplest form of the equation is that all items of supply equal all items of disposal. For comparison all water quantity units are converted to average inches per year

Items of supply		
Item	Quantity in Mississippi Headwaters Basin	How determined
1. Surface inflow	none	Not applicable to Mississippi Headwaters Basin.
2. Subsurface inflow		
3. Precipitation on area	25.33 inches	Weighted average, years of record (see precipitation figure).
4. Imported water and sewage	none	Not applicable to Mississippi Headwaters Basin.
5. Decrease in surface storage	none	Assumed to equal increases on a long-term basis.
6. Decrease in soil moisture storage		
7. Decrease in ground-water storage		
Total of items of supply = 25.33 average inches per year.		

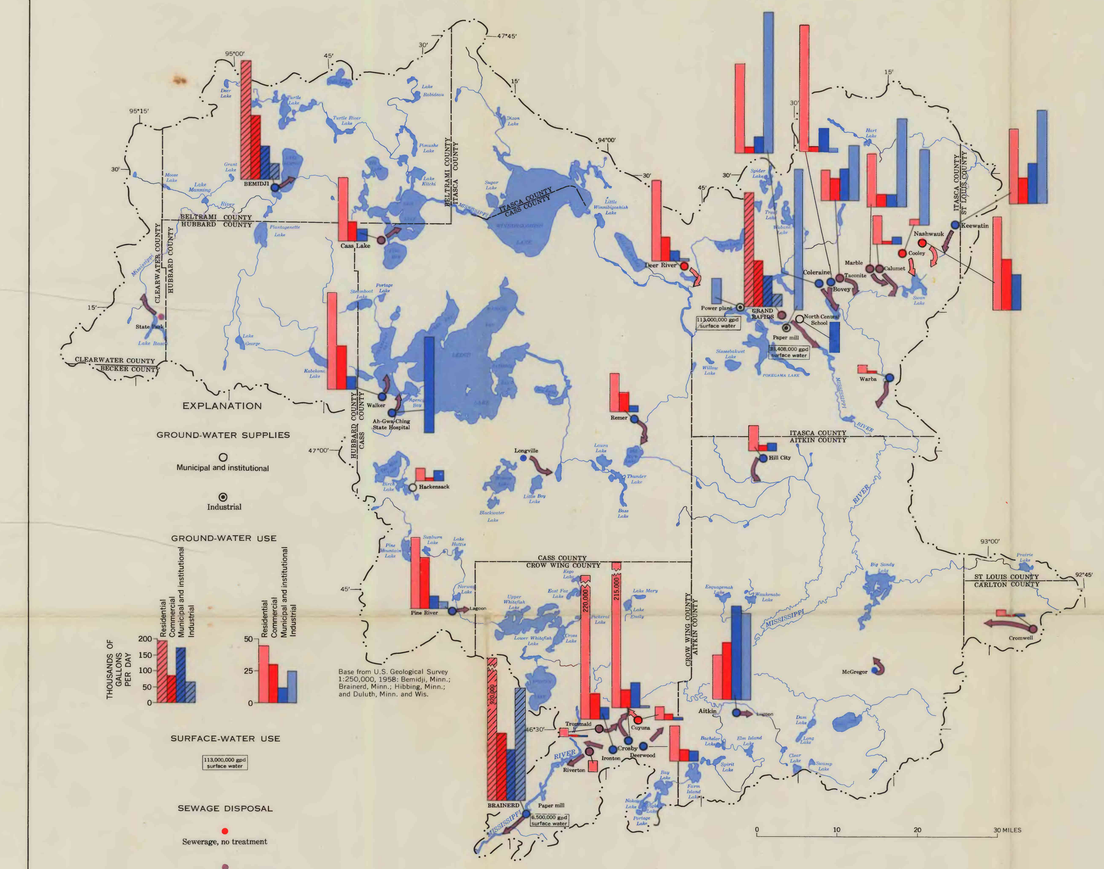
Items of disposal		
Item	Quantity in Mississippi Headwaters Basin	How determined
1. Runoff	5.34 inches	Stream gaging.
2. Underflow	0.01 inch	Estimated for Mississippi River channel at Brainerd.
3. Evapotranspiration	19.98 inches	Calculated (see diagram).
4. Exported water and sewage	none	Not applicable to Mississippi Headwaters Basin.
5. Increase in surface storage	none	Assumed to equal increases on a long-term basis.
6. Increase in soil moisture storage		
7. Increase in ground-water storage		
Total of items of disposal = 25.33 average inches per year		



EVAPOTRANSPIRATION AND PRECIPITATION ARE COMPARED IN THE ABOVE DIAGRAM

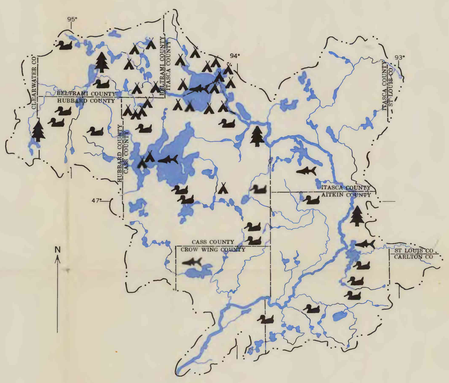
The diagram (Thornthwaite and Mather, 1957) is based on climatological records for the period 1886-1964 and shows that while the bulk of annual precipitation falls during the summer, evapotranspiration exceeds precipitation during this time. Ground-water replenishment and basin yield (outflow from the watershed) are dependent upon adequate snowfall during winter months. The diagram, a theoretical calculation, shows that for the Mississippi Headwaters watershed runoff equals 1.61 inches. Indirect measurement of streamflow gives a figure of 5.34 inches

WATER USE



MUNICIPAL WATER USE IS GREATEST NEAR THE MESABI AND CUYUNA IRON RANGES AND ADJACENT TO THE MISSISSIPPI RIVER MAIN STEM

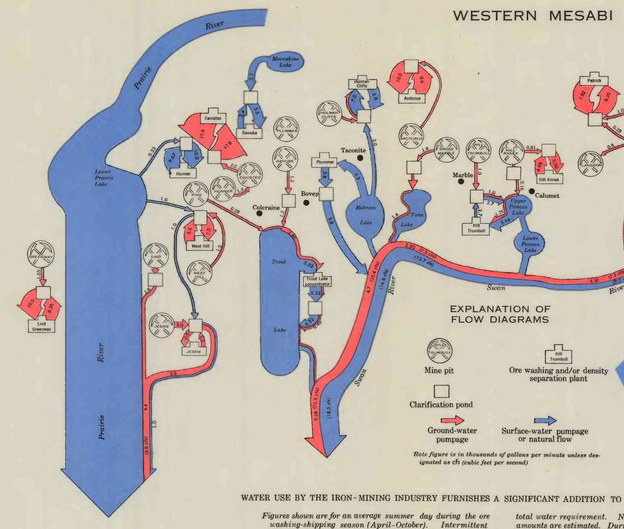
Industry is the largest user of both surface and ground water. Use figures shown are pumpage amounts. Most of this water is discharged to streamflow



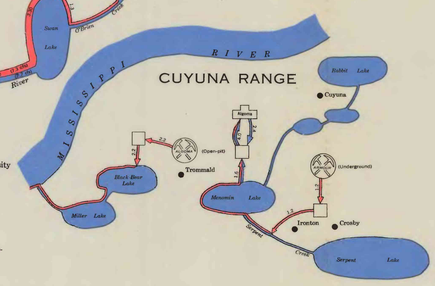
CONSERVATION AND RECREATION USE OF WATERS AND WETLANDS IS NONCONSUMPTIVE AND ECONOMICALLY BENEFICIAL TO THE AREA

Items depicted above are only a partial list of the ways in which waters and wetlands are used. Tourism and resort operation are major business enterprises in the Mississippi Headwaters area

WESTERN MESABI RANGE



CUYUNA RANGE



WATER USE BY THE IRON-MINING INDUSTRY FURNISHES A SIGNIFICANT ADDITION TO STREAMS LEAVING THE AREA

Figures shown are for an average summer day during the ore washing-shipping season (April-October). Intermittent pumping is shown as an average continuous amount. Water losses (consumptive use) in the continuous recirculation from pond, through plant, to pond, average about 20 percent of the total water requirement. Natural surface water low-flow amounts are estimated. During winter months, when ore is not being washed, additional water from pit dewatering is discharged to surface streams. Therefore, the summer direct addition to streams as shown, is a minimum

SUMMARY OF WATER USE IN MINING
(in thousands of gallons per minute)

MINE PIT OR PLANT	Use		Direct addition to surface water	
	Consumptive	Total	Summer	Winter
MESABI RANGE				
Greenway	1.65	10.00	none	1.65
Lind	none	none	1.80	1.80
Jessie	0.40	2.50	2.60	3.00
West Hill	1.50	7.00	none	1.50
Hunner	0.33	10.00	none	unknown
King	none	none	0.28	0.28
Canisteo	2.00	17.80	none	unknown
Danube	3.10	5.50	1.20	1.20
Plummer	0.70	4.50	none	none
Trout Lake concentrator	1.00	7.00	none	none
Holman-Cliffs	3.00	8.00	none	unknown
Arcturus	1.40	10.00	none	unknown
Gross marble	none	none	1.40	1.40
Hill-Trumbull	3.80	7.50	none	1.00
Hill Annex	0.81	5.50	none	1.57
Patrick	1.28	9.20	none	unknown
Kevin	none	none	0.55	1.55
Harrison	0.50	2.50	1.45	1.95
Sargent	none	none	1.00	2.50
Mesabi Chief	1.70	6.50	none	none
Section 18	none	none	0.30	0.50
Total	23.17	113.50	9.58[1]	unknown[2]
CUYUNA RANGE				
Algoma	none	none	2.20	2.20
Algoma Plant	1.60	4.00	none	none
Armour No. 2	none	none	1.20	1.20
Total	1.60	4.00	3.40	3.40

[1] 1.0 thousand gpm consumed by Trout Lake concentrator.
[2] Total is at least 19.90 thousand gpm.

SUMMARY OF WATER USE IN THE WATERSHED
(in millions of gallons per day)

User	Ground water	Surface water
Residential	3.02	none
Commercial	0.95	none
Municipal and institutional	0.85	none
Industrial		
Iron mining	110.65[1]	58.55
Other	0.64	152.95
Agricultural	0.20	none
Total	116.31	211.50

[1] Includes surface water of pit dewatering origin.

SUMMARY AND CONCLUSIONS

SUMMARY OF WATER RESOURCES

Purpose	Considerations	Surface water: Mississippi River and major tributaries	Surface water: Large lakes and reservoirs	Surface water: Small lakes and minor streams	Ground water: Moraines and till plains	Ground water: Outwash areas	Ground water: Glacial lake plains	Ground water: Precambrian metasedimentary bedrock
Municipal and industrial supply	For a moderate supply, principal needs are: Quantity 1. Minimum sustained flow of 2 cfs or 900 gpm. Quality 1. *Total dissolved-solids content less than 500 mg/l. 2. *Iron concentration less than 0.3 mg/l. 3. *Hardness less than 180 mg/l.	Adequate flow. Favorable location with respect to municipalities and industries. At low flow water is hard. Treatment necessary.	Adequate for most uses. Additional storages possible. Good surface and ground-water inflow. Limited areal distribution. High evaporation losses. Treatment necessary.	Many adequate with development of storage facilities. Wide areal distribution. At low flow water is hard. Treatment necessary.	Adequate supplies are available in most places. Suitable dissolved-solids content. Water is very hard. (>180 mg/l hardness). Iron removal treatment necessary.	Adequate supplies are available in most places. Suitable dissolved-solids content. Water is very hard. Iron removal treatment necessary.	Suitable dissolved-solids content. Buried aquifers not known to provide adequate supplies. Water is very hard. Iron removal treatment necessary.	Adequate supply where bedrock is fractured. Suitable dissolved-solids content. An adequate supply may require very deep drilling. Water is very hard. Iron removal treatment necessary.
Rural domestic, stock and resort supply	For an adequate farm or resort supply, needs are: Quantity 1. About 5 gpm or more. Quality 1. *Total dissolved solids content less than 1,000 mg/l.	Adequate flow. Suitable quality. Available only to riparian lands. Treatment necessary for domestic use.	Adequate supply. Suitable quality. Available only to riparian lands. Treatment necessary for domestic use.	Adequate for stock. Suitable quality. Available only to riparian lands. Treatment necessary for domestic use.	Adequate supply. Suitable quality.	Adequate supply. Suitable quality.	Adequate supply. Suitable quality.	Adequate supply. Suitable quality. An adequate supply may require very deep drilling.
Irrigation supply	For an average farm in watershed, needs are: Quantity 1. Minimum flow of 2 cfs during growing season or wells yielding 250 gpm or more. Quality 1. *Total dissolved solids content less than 2,000 mg/l. 2. Percent sodium less than 70 3. *Boron content less than 3 mg/l.	Adequate flow. Suitable quality. Restricted to riparian lands.	Adequate supply at present; additional storage possible. Suitable quality. Restricted to riparian lands. High evaporation losses.	Some are adequate for small acreage; additional storage possible. Suitable quality. Restricted to riparian lands. High evaporation losses.	Adequate supply. Suitable quality.	Adequate supply. Suitable quality.	Suitable quality. Buried aquifers known to provide adequate supplies are of limited extent.	Adequate supply. Suitable quality. An adequate supply may require very deep drilling.
Fish and wildlife habitat	Adequate depth and quality of water for fish in lakes and streams. Adequate cover needed for wildlife habitat is provided by: 1. Wetlands—lakes or potholes surrounded by marsh areas. 2. Streams—marsh and woodland along banks.	Excellent migratory waterfowl resting and feeding areas. Excellent wildlife habitat along banks. Adequate depths. Sustained flow maintained by lakes and reservoirs. Suitable quality. Occasional floods in lower reaches.	Excellent migratory waterfowl resting and feeding areas. Excellent for fish. Excellent wildlife habitat in marsh areas and along shores. Suitable quality. Occasional change in stage.	Good migratory waterfowl resting and feeding areas. Excellent habitat along banks. Wide areal distribution. Suitable quality. Shallow. Low water stage during droughts.	EXPLANATION Good Fair Poor Adequate flow. Favorable location with respect to municipalities and industries. At low flow water is hard. Treatment necessary. Advantages Disadvantages Overall evaluation for purpose and considerations indicated.			
Recreation	Adequate access to lakes and streams. Availability of areas suitable for hunting, fishing and other water sports. Available resorts and lake cottages. Aesthetic values: 1. Absence of odors. 2. Unsightliness. 3. Physical setting. 4. Pollution.	Public access at many sites. Suitable for fishing and hunting. Aesthetic values generally good. Favorable location with respect to municipalities. Suitable quality. Floods.	Public access at many sites. Suitable for fishing, hunting and water sports. Permanent Lakeshore resorts and residences. Favorable location with respect to municipalities Suitable quality. Floods.	Public access at many sites. Many suitable for fishing and hunting Wide areal distribution Suitable quality Floods. Shallow. Some pollution by domestic sewage.				

*Expressed as milligrams per liter (mg/l) which is essentially the same as parts per million (ppm).

GROUND WATER

The ground-water reservoir contains the largest quantity of water available within the area.
Base flow of streams and uniform lake stages are maintained in part by constant ground-water discharge.
Ground-water yields up to 500 gpm are available to wells at many places in the area.
Outwash deposits, underlying present water courses are the best source of water supply. Ground water is also available from buried glacial aquifers and from Precambrian sedimentary bedrock.
Saturated thickness of glacial drift ranges from less than 50 feet in the northeast, central, and southeast parts of the watershed to more than 500 feet in the northwest part.
Ground-water quality may indicate one or both of the following: Rapid water movement through highly permeable glacial drift; or short distance travel from recharge to discharge areas.
Hardness of ground water ranges from 68 mg per liter (moderately hard) to 700 mg per liter (very hard) and the sum of iron plus manganese ranges from 0.02 to 7.80 mg per liter. Where iron and manganese exceeds permissible limits, these constituents can be removed in order to provide municipal and industrial water supplies.
Ground-water supplies are of suitable quality for irrigation.

SURFACE WATER

The Mississippi River, major tributaries, headwaters reservoirs, and many lakes, provide an abundance of water of good quality which is suitable for most industrial, municipal, and agricultural uses.
Natural streamflow is not subject to large variations in discharge because of the storage in lakes, swamps, and glacial deposits.
All the major streams have some regulations from either powerplants, reservoirs, or discharge of waste water from the iron-mining industry.
The average annual runoff from the watershed is about 5.34 inches.
The five headwaters reservoirs are used to reduce floods in the vicinity of Aitkin and to augment low flows near the Twin Cities. Although their usefulness is limited by economic considerations, control structures are used in part to maintain uniform water levels in the reservoirs.
Evaporation of about 1.8 cubic feet per second per square mile of lake surface (27 inches) must be considered in the design of storage reservoirs and other aspects of water management.
Surface water provides excellent year-around recreational facilities and habitat for fish and wildlife.

ACKNOWLEDGMENTS

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

By
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1968

For sale by U.S. Geological Survey, price $2.00 per set