DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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

HYDROLOGIC INVESTIGATIONS
ATLAS HA-582 (SHEET 1 OF 2)

TOPOGRAPHY, DRAINAGE, WATER USE

THE LAKE SUPERIOR WATERSHED IS MOSTLY A HIGHLAND, GENERALLY 1,200 FEET (366 METERS) TO 2,000 FEET (610 METERS) ABOVE MEAN SEA LEVEL. IT EXTENDS FROM DULUTH TO THE CANADIAN BORDER—*from 90°00′ to 92°00′ west longitude and from 46°45′ to 48°00′ north latitude. It is 152 mi (244 km) at Eagle Mountain, about 12 mi (19 km) northeast of Grand Marais, and 60 ft (184 m), the normal level of Lake Superior. Total relief is nearly 2,700 ft (818 m). The North Shore area (Duluth to the Canadian border) has a southeastward slope that is especially precipitous adjacent to Lake Superior.*

The Lake Superior watershed in the United States comprises a series of 17 southeastward-flowing stream drainages averaging 28 mi (36 km) in length, with an average gradient from headwaters to mouth of about 57 ft/mi (10.8 m/km). The streams are deeply entrenched and characterized by swift flows, many rapids and waterfalls, and especially steep gradients in the lower 3 to 5 mi (4.8 to 8.0 km) before entering Lake Superior.

The Pigeon River drains the extreme northern part of the watershed and forms the international border between the United States and Canada. More than half of the area of the Lake Superior watershed is drained by the Pigeon River.

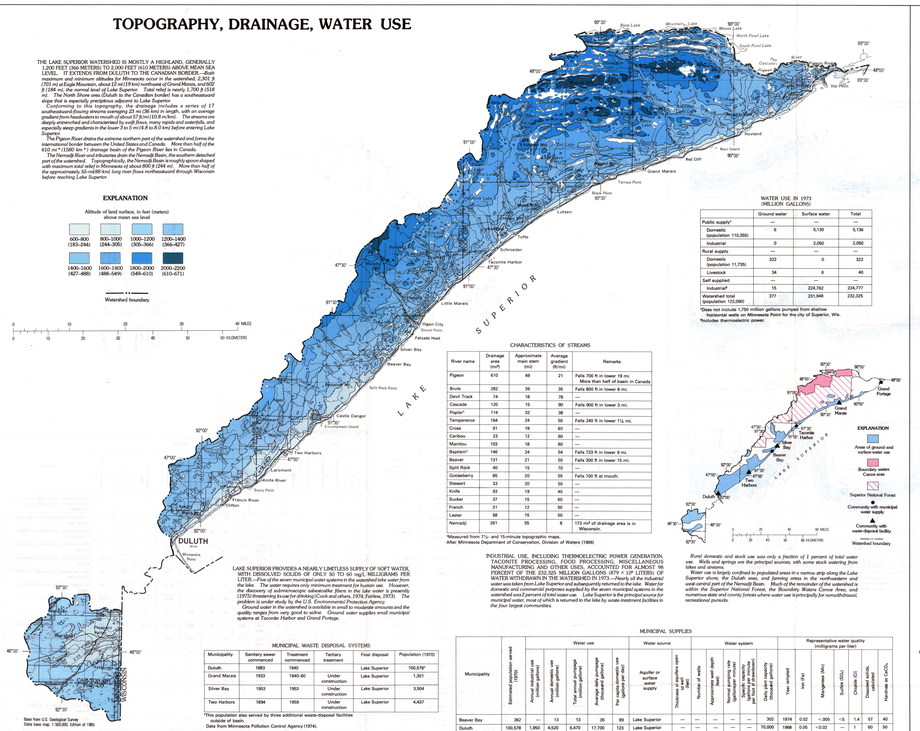
The Nemadji River and tributaries drain the Nemadji Basin, the southern detached part of the watershed. Topographically, the Nemadji Basin is roughly spoon-shaped with maximum total relief in Minnesota of about 800 ft (244 m). More than half of the approximately 55-mi (88-km) long river flows northeastward through Wisconsin before reaching Lake Superior.

EXPLANATION

Altitude of land surface, in feet (meters) above mean sea level

600–800 (183–244) · 800–1000 (244–305) · 1000–1200 (305–366) · 1200–1400 (366–427) · 1400–1600 (427–488) · 1600–1800 (488–549) · 1800–2000 (549–610) · 2000–2200 (610–671)

Watershed boundary



LAKE SUPERIOR PROVIDES A NEARLY LIMITLESS SUPPLY OF SOFT WATER, WITH DISSOLVED SOLIDS ON ONLY 50 TO 60 mg/L MILLIGRAMS PER LITER.—*Five of the seven municipal water systems in the watershed take water from the lake. The water requires only minimum treatment for human use. However, the discovery of submicroscopic asbestiform fibers in the lake water is presently (1975) the subject of intensive study by the U.S. Environmental Protection Agency. The problem is under study by the U.S. Environmental Protection Agency.*

Ground water in the watershed is available in small to moderate amounts and the quality ranges from very good to saline. Ground water supplies small municipal systems at Taconite Harbor and Grand Portage.

See text U.S. Geological Survey
Data base map, 1:500,000, Edition of 1965

MUNICIPAL WASTE DISPOSAL SYSTEMS

Municipality	Sanitary sewer commenced	Treatment commenced	Tertiary treatment	Final disposal	Population (1970)
Duluth	1883	1940	—	Lake Superior	100,578*
Grand Marais	1933	1940–60	Under construction	Lake Superior	1,301
Silver Bay	1953	1953	Under construction	Lake Superior	3,504
Two Harbors	1894	1959	Under construction	Lake Superior	4,437

*This population also served by three additional waste-disposal facilities outside of basin.
Data from Minnesota Pollution Control Agency (1974).

LAKE SUPERIOR WATER QUALITY AT MUNICIPAL INTAKE CITY OF DULUTH

Date	Temperature (°C)			Sulfate (mg/L)			Chloride (mg/L)			Dissolved solids residue (mg/L)			Hardness as $CaCO_3$ (mg/L)		
	Range	Mean	Number of samples	Range	Median	Number of samples	Range	Median	Number of samples	Range	Median	Number of samples	Range	Median	Number of samples
Jan. to Dec. 1967[1]	1.1–16.7	5.9	49	2–4	3	49	46–65	56	49	—	—	—	42–45	44	49
Aug. 1968 to Sept. 1973	0–16.0	4.9	250	1.30–6.70	3.68	206	0.01–3.30	1.36	205	—	—	—	43.00–45.00	44.56	206

[1]Information from Water and Gas Department City of Duluth, Minn (1975).

WATER USE IN 1973 (MILLION GALLONS)

	Ground water	Surface water	Total
Public supply[1]	—	—	—
Domestic (population 110,356)	6	5,130	5,136
Industrial	0	2,050	2,050
Rural supply	—	—	—
Domestic (population 11,735)	322	0	322
Livestock	34	6	40
Self supplied:			
Industrial[2]	15	224,762	224,777
Withdrawal total (population 122,091)	377	231,948	232,325

[1]Does not include 1,750 million gallons pumped from shallow horizontal wells on Minnesota Point for the city of Superior, Wis.
[2]Includes thermoelectric power.

CHARACTERISTICS OF STREAMS

River name	Drainage area (mi²)	Approximate main stem (mi)	Average gradient (ft/mi)	Remarks
Pigeon	610	49	21	Falls 790 ft in lower 19 mi. More than half of basin in Canada
Brule	282	39	35	Falls 800 ft in lower 3 mi.
Devil Track	74	18	78	—
Cascade	120	15	90	Falls 900 ft in lower 3 mi.
Poplar[1]	114	32	38	—
Temperance	164	24	50	Falls 240 ft in lower 1¼ mi.
Cross	91	19	60	—
Caribou	23	12	60	—
Manitou	103	18	80	—
Baptism[1]	146	24	54	Falls 733 ft in lower 9 mi.
Beaver	131	21	50	Falls 300 ft in lower 10 mi.
Split Rock	40	15	70	—
Gooseberry	85	20	55	Falls 100 ft at mouth.
Stewart	33	20	50	—
Knife	93	19	40	—
Sucker	37	15	60	—
French	31	12	50	—
Lester	58	15	50	—
Nemadji	261	55	8	173 mi² of drainage area is in Wisconsin.

*Measured from 7½- and 15-minute topographic maps.
After Minnesota Department of Conservation, Division of Waters (1968)

INDUSTRIAL USE, INCLUDING THERMOELECTRIC POWER GENERATION, TACONITE PROCESSING, FOOD PROCESSING, MISCELLANEOUS MANUFACTURING AND OTHER USES, ACCOUNTED FOR ALMOST 98 PERCENT OF THE 232,325 MILLION GALLONS (879 × 10⁶ LITERS) OF WATER WITHDRAWN IN THE WATERSHED IN 1973.—*Nearly all the industrial water was withdrawn from surface sources and returned to streams in the basin. Most of the remainder of the water used in domestic and commercial premises supplied by the seven municipal systems in the watershed was 2 percent of total water use. Lake Superior is the principal source for municipal water, most of which is returned to the lake by waste-treatment facilities in the four largest communities.*

Rural domestic and stock use was only a fraction of 1 percent of total water use. Wells and springs are the principal sources, with some stock watering from lakes and streams.

Water use is largely confined to populated areas in a narrow strip along the Lake Superior shore, the Duluth area, and farming areas in the northeastern and southeastern parts of the Nemadji Basin. Much of the remainder of the watershed is within the Superior National Forest, the Boundary Waters Canoe Area, and numerous state and county forests where water use is principally for nonwithdrawal, recreational pursuits.

MUNICIPAL SUPPLIES

Municipality	Estimated population served (1970)	Average annual withdrawal (mgd)	Annual industrial use (mgd)	Annual domestic use (million gallons)	Total annual precipitation (inches)	Annual average precipitation (inches)	Per capita domestic use (gallons per day)	Water use: Source	Water use: Type of treatment	Water use: Number of wells	Water use: Approximate well depth (ft)	Water use: Yearly pumping rate (million gallons per year)	Water use: Specific capacity (gallons per minute per foot of drawdown)	Water use: Ultra-pure water for industrial use	Water use: Water pumped	Water supply quality (milligrams per liter): Year	Fe	Manganese (Mn)	Sulfate (SO_4)	Chloride (Cl)	Dissolved solids, residue on evap.	Hardness as $CaCO_3$
Beaver Bay	362	—	13	13	36	99	—	Lake Superior	—	—	—	—	—	302	1974	0.02	<.005	<.5	1.4	57	40
Duluth (includes Proctor)	100,578	1,800	4,520	6,470	17,730	123	—	Lake Superior	—	—	—	—	—	70,000	1968	0.05	<0.02	—	1	60	—
Grand Marais	1,200	—	53	53	145	121	—	Lake Superior	—	—	—	—	—	403	1973	.08	<.01	<.5	2	57	42
Grand Portage	174	—	4.0	4.0	11	63	—	State and graywacke	15	2	155	12	0.5	36	—	—	—	—	—	—	—
Silver Bay	3,504	—	243	243	666	190	—	Lake Superior	—	—	—	—	—	2,000	1974	.15	.08	<.5	2	51	40
Two Harbors	4,437	100	301	401	1,000	198	—	Lake Superior	—	—	—	—	—	3,600	1972	.06	.03	—	2	—	57
Taconite Harbor	100	—	2.1	2.1	5.8	58	—	North Shore Volcanic Group	488	2	502	22	0.8	154	1974	.07	.02	.07	15	—	95
Total	110,355	2,050	5,136.1	*7,186.1	18,583.8	840															

*Does not include 1,750 million gallons pumped from shallow horizontal wells on Minnesota Point for the city of Superior, Wis.

GEOLOGY AND GROUND WATER

EXPLANATION

QUATERNARY
- Glacial drift — pGM

PREDIMBRIAN X
- Animikie Group: Hinckley Sandstone and Fond du Lac Formation[1] — *Predominantly quartzose and arkosic sandstone and interbedded shale* — pEH

PREDIMBRIAN Y
- Keweenawan Supergroup: Volcanic rocks, undivided — pEv
  - Duluth Complex — pEd
  - Mafic intrusive rocks — pEm
  - *Includes basalt, andesite, and minor felsite; contains interbeds of conglomerate and sandstone*
  - *Multiple intrusions of gabbroic anorthosite, troctolite, gabbro, anorthosite, and felsic rocks*
- North Shore Volcanic Group — pEn
  - *Includes lava ranging in composition from olivine basalt to latite and local rhyolite; contains interbeds of conglomerate and related clastic rocks*
- Slate and graywacke — pEg
  - *Includes Rove Formation and Thompson Formation[1]. Thompson Formation includes Logan tonalite rocks of middle Keweenawan age*

PRECAMBRIAN

Contact — *Dashed where approximately located; queried where doubtful*

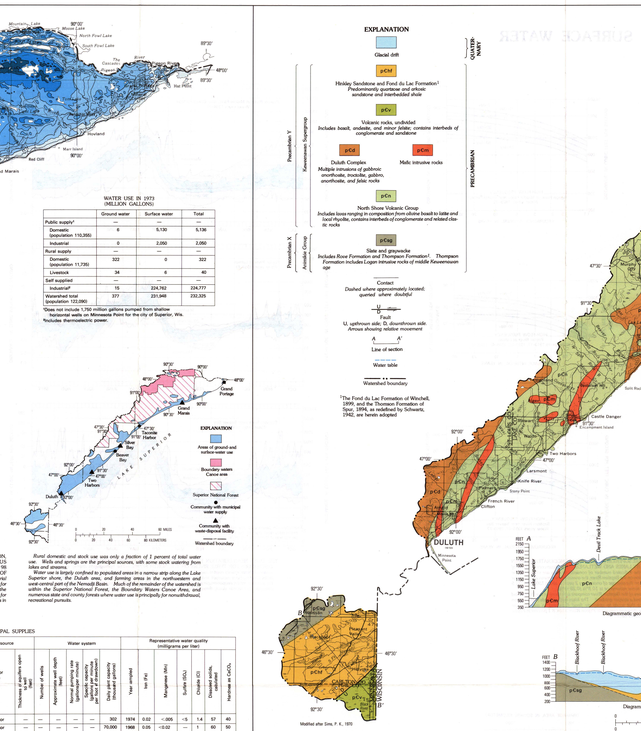
Fault — U, upthrown side; D, downthrown side. *Arrows showing relative movement*

Line of section

Water table

Watershed boundary

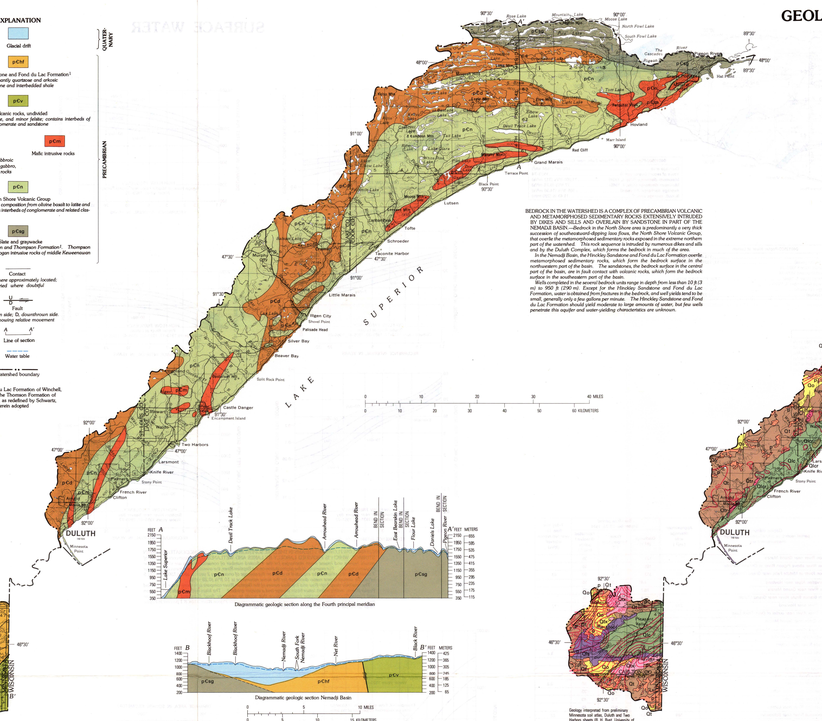
[1]The Fond du Lac Formation of Winchell, 1899, and the Thomson Formation of Spur, 1894, as redefined by Schwartz, 1942, are herein adopted



BEDROCK IN THE WATERSHED IS A COMPLEX OF PRECAMBRIAN VOLCANIC AND METAMORPHOSED SEDIMENTARY ROCKS EXTENSIVELY INTRUDED BY DIKES AND SILLS AND OVERLAIN BY SANDSTONE IN PART OF THE NEMADJI BASIN.—*Bedrock in the North Shore area is predominantly a very thick succession of southeastward-dipping lava flows, the North Shore Volcanic Group, and a smaller volume of intrusive rocks of the Duluth Complex underlies a narrow zone in part of the watershed. This rock sequence is intruded by numerous dikes and sills and by the Duluth Complex, which forms the bedrock in much of the area.*

In the Nemadji Basin, the Hinckley Sandstone and Fond du Lac Formation overlie metamorphosed sedimentary rocks, which form the bedrock surface in the southeastern part of the basin. The Hinckley Sandstone and Fond du Lac Formation, part of the basin, are in fault contact with volcanic rocks, which form the bedrock surface in the southeastern part of the basin.

Wells completed in the several bedrock units range in depth from less than 50 ft (15 m) to 950 ft (290 m). Except for the Hinckley Sandstone and Fond du Lac Formation, which yield moderate to large amounts of water, but few wells penetrate this aquifer and water-yielding characteristics are unknown.

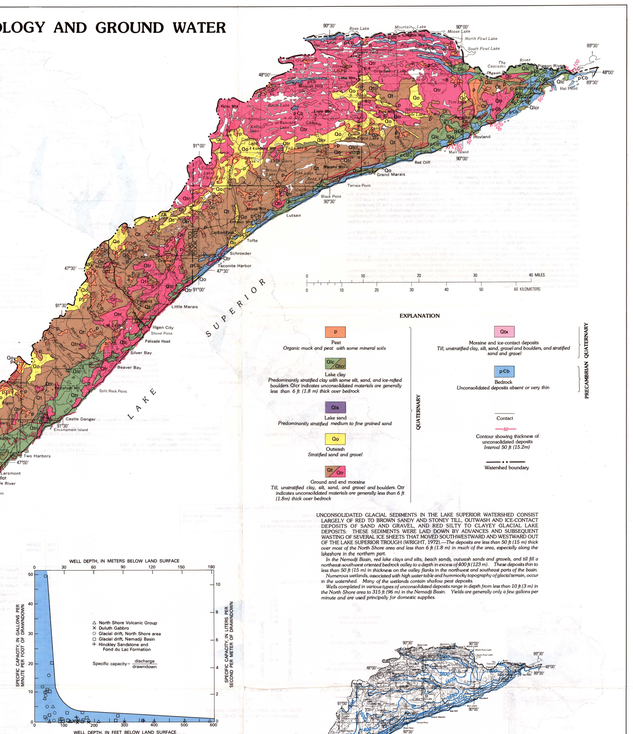


SPECIFIC CAPACITIES THROUGHOUT THE WATERSHED ARE GREATEST IN WELLS LESS THAN 100 FEET (30 METERS) DEEP.—*The glacial drift and the upper part of the bedrock are more permeable and consequently yield larger quantities of water to wells than the deep bedrock.*

EXPLANATION

Line of equal water-table altitude
Interval 200 feet North Shore area, 100 feet Nemadji Basin. Datum is mean sea level

Watershed boundary



REGIONAL GROUND-WATER MOVEMENT IN THE NEMADJI BASIN IS DOWNWARD AT THE DIVIDES AND UPWARD IN THE AREA OF THE RIVERS.—*Ground-water recharge is through glacial drift into the Hinckley Sandstone and Fond du Lac Formation, dikes and graywackes, and lava flows. Ground-water discharge from the bedrock units moves upward through the glacial drift to streams and springs.*

The stream above the generalized direction of ground-water movement denotes areas of ground-water recharge; upward, denotes areas of discharge.

EXPLANATION

QUATERNARY
- Glacial drift — pGM

PRECAMBRIAN
- Hinckley Sandstone and Fond du Lac Formation — pEH
- Volcanic rocks, undivided — pEv
- Slate and graywacke — pEg

Contact — *Dashed where approximately located; queried where doubtful*

Fault

Showing relative movement

Water table

Line of equal hydraulic potential
Interval is 50 ft; datum is mean sea level

Point of known hydraulic potential
Number is potentiometric head in feet above mean sea level

Direction of ground-water movement

VERTICAL EXAGGERATION 183

GROUND-WATER QUALITY

REPRESENTATIVE CHEMICAL ANALYSES

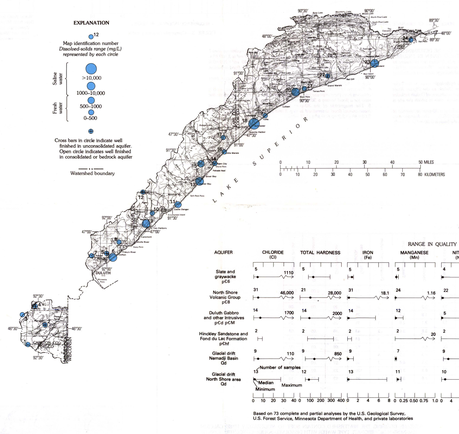
Map no.	Geologic unit	Date sampled	Color (Pt-Co units)	Dissolved solids residue (mg/L)	Dissolved silica (SiO_2) (mg/L)	Dissolved iron (Fe) (mg/L)	Dissolved manganese (Mn) (mg/L)	Total hardness as $CaCO_3$ (mg/L)	Total noncarbonate hardness (mg/L)	Dissolved calcium (Ca) (mg/L)	Dissolved magnesium (Mg) (mg/L)	Dissolved sodium (Na) (mg/L)	Dissolved potassium (K) (mg/L)	Total bicarbonate as $CaCO_3$ (mg/L)	Total carbonate as $CaCO_3$ (mg/L)	Total magnesium as Mg (mg/L)	Dissolved sulfate (SO_4) (mg/L)
	Pine County																
1	Hinckley and Fond du Lac Formations	12-21-74	5	164	7.7	149	0	4.4	13	0.7	00.6	0.00	19	6.2	33	2.4	73
	Carlton County																
2	Lake clays	3-19-75	3	341	8.1	125	0	110	37	.6	.9	.00	29	11	78	3.7	120
3	Slate and graywacke	12-12-74	3	252	8.0	284	0	.8	5.1	.7	.2	.00	38	29	18	1.7	210
4	Lake sands	12-12-74	3	101	7.7	79	0	1.0	13	.1	3.0	.00	20	5.8	2.5	.5	74
	St. Louis County																
5	Lake clays	3-20-75	3	253	7.8	254	0	9.1	15	.3	2.2	.00	33	24	29	1.9	180
6	North Shore Volcanic Group	—	<10,000	8.5	—	1,400	19	—	—	—	—	360	—	—	520	800	1.5
7	Duluth Gabbro	3-20-75	3	152	7.9	138	0	1.8	13	.6	2.5	.00	28	6.5	.14	1.1	110
8	North Shore Volcanic Group	3-21-75	3	161	8.2	152	0	.9	14	1.4	.4	.00	8.3	2.3	49	.8	30
	Lake County																
9	North Shore Volcanic Group	3-21-75	3	1,230	9.7	12	25	540	170	.1	.15	.00	130	.4	320	1.5	330
10	North Shore Volcanic Group	3-20-75	5	134	7.8	130	0	2.5	9.5	.3	.2	.01	28	.16	6.9	.8	10
11	North Shore Volcanic Group	5-14-57	0	363	8.1	—	10	370	210	1.2	.0	.00	70	1.0	270	1.6	178
12	Glacial deposits	3-22-75	5	156	8.1	—	1.6	11	.4	.1	.00	.30	13	.4.1	140	.25	50
13	Duluth Gabbro	—	1	>2,000	7.3	37	0	1,390	83	2.2	—	—	170	—	760	—	430
14	North Shore Volcanic Group	3-26-75	5	353	7.7	259	0	.47	.28	.4	.8	.01	.33	3.6	95	1.1	97
15	North Shore Volcanic Group	4-16-75	5	850	9.7	48	31	47	7.7	1.6	.00	100	9.0	250	.8	250	25
16	North Shore Volcanic Group	3-26-75	0	324	8.0	167	0	100	14	1.2	.4	.00	45	18	49	1.7	190
17	Duluth Gabbro	3-7-71	—	65	—	79	—	.2.1	7.8	<.1	<.1	<4.4	—	8.0	7.8	<1.1	65
	Cook County																
18	North Shore Volcanic Group	6-12-63	—	>10,000	—	29	—	46,000	71	—	—	—	11,200	—	17,000	28,000	1.4
19	North Shore Volcanic Group	4-19-75	2	214	8.3	47	18	.71	9.8	2.9	.6	.00	11	.0	.56	.4	27
20	North Shore Volcanic Group	6-10-65	—	1,260	—	32	—	700	64	2.3	<4.4	—	136	.0	343	—	340
21	North Shore Volcanic Group	3-26-75	5	95	8.0	64	—	4.9	11	1.8	.0	.01	.9.4	.0	.29	.3	8
22	Glacial deposits	3-26-75	5	129	7.9	125	0	.8	8.3	1.6	.2	.02	.25	12	5.8	1.0	110
23	North Shore Volcanic Group	4-17-75	2	2,400	7.5	18	0	1,400	61	1.0	8.8	.00	610	8.9	300	1.0	1,600
24	State and graywacke	3-26-75	35	422	8.1	214	0	.34	130	1.1	.4	.00	61	.34	34	3.1	290

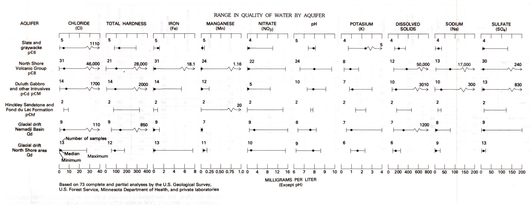
QUALITY OF GROUND WATER IN THE LAKE SUPERIOR WATERSHED IS HIGHLY VARIABLE, RANGING FROM GOOD TO SALINE IN THE BEDROCK AQUIFERS, BUT IS MORE CONSISTENT AND GENERALLY GOOD IN GLACIAL AQUIFERS.—*The numerous and irregular interfine zones of the North Shore Volcanic Group and the fractured basaltic conductivity of other volcanic rocks create a large number of independent artesian flow systems in the bedrock aquifers. In places, low hydraulic conductivity and a tendency for disruptive entrapment lead to a long residence time of water in the rock and a consequent buildup of dissolved materials in the water. Variable flow rates through the bedrock aquifers are dependent on the local recharge environment and reliability of such materials, cause large differences in water quality.*

Dissolved-solids concentrations in water from the bedrock ranges from 65 to 2,400 mg/L (milligrams per liter) and generally increase southeastward. Sodium, sulfate, with calcium replacing sodium in areas of calcium-rich rocks. Dominant ions in the less-mineralized ground water are calcium, magnesium, bicarbonate, and carbonate. High sodium and chloride in water from well 2, finished in glacial drift at the top of the Hinckley Sandstone and Fond du Lac Formation, indicates that saline water from the lower part of the sandstone where the aquifer is confined by glacial lake clays.

Owing to the fact that glacial aquifers are more shallow and permeable than the bedrock aquifers and are composed of rock material of generally low solubility, they contain water of good quality, with dissolved-solids concentrations generally less than 500 mg/L and dominant ions of calcium, magnesium, bicarbonate. The lowest dissolved-solids concentrations occur in the southern North Shore area and the central Nemadji Basin where lake deposits provide a source for calcium and bicarbonate.

Fluoride concentration in ground water in the watershed is generally below the recommended maximum of 1.4 mg/L (U.S. Public Health Service, 1962, p. 9). In some small areas, however, especially in the North Shore Volcanic Group, these limits are exceeded. High fluoride is generally accompanied by high boron, which complicates with the fluoride ion.

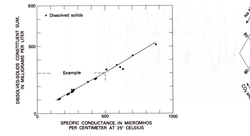




Based on 73 complete and partial analyses by the U.S. Geological Survey, U.S. Forest Service, Minnesota Department of Health, and private laboratories

WATER OF GOOD QUALITY IS AVAILABLE FROM EACH OF THE SIX PRINCIPAL AQUIFERS IN THE WATERSHED, AS SHOWN BY RANGE AND MEDIAN VALUES OF CHEMICAL CONSTITUENTS.—*Chemical constituents in water from each of the aquifers are generally within limits recommended for drinking water by the U.S. Public Health Service (1962). However, high values, especially of hardness, chloride, sulfate, and sulfate, indicate saline water is present in parts of each bedrock aquifer and in glacial drift in the Nemadji Basin. The saline water in the drift is in the area of lacustrine silts and is probably discharged from the underlying Hinckley Sandstone and Fond du Lac Formation.*

Locally, iron and manganese can be a problem in each of the aquifers, but concentrations are generally below the 0.3 and 0.05 mg/L limit, respectively. Nutrient enrichment is locally evident. Nitrate is low in each of the aquifers and, except for possible local contamination, is not a problem.



DISSOLVED-SOLIDS CONCENTRATIONS IN GROUND WATER CAN BE ESTIMATED WITH REASONABLE ACCURACY FROM SPECIFIC CONDUCTANCE, WHERE IT IS LESS THAN 1,000 MICROMHOS PER CENTIMETER AT 25 DEGREES CELSIUS.—*The curve defines the specific conductance of the sum of the constituents in solution. Example: Specific conductance of 500 µmho corresponds on the curve to 300 mg/L dissolved solids. The dissolved-solids and specific conductance relationship becomes nonlinear because of high sodium and chloride where values of specific conductance are over 1,000 µmho.*

Sodium, potassium, and bicarbonate are the dominant ions, hardness also can be correlated to specific conductance. Plum and dotted plots, respectively, which are present in much of the ground water of the watershed, greatly increases specific conductance and dissolved-solids concentrations without significantly changing hardness. Thus, specific conductance above 1,000 µmho cannot be used as a reliable indication of hardness in the watershed.

A PIPER PLOT OF 24 REPRESENTATIVE CHEMICAL ANALYSES ILLUSTRATES THE HETEROGENEITY OF GROUND WATER IN THE WATERSHED AND INDICATES CALCIUM MAGNESIUM BICARBONATE AND SODIUM CHLORIDE SULFATE WATER AS THE DOMINANT TYPES.

SUMMARY AND CONCLUSIONS

RELATIVE ADEQUACY OF WATER SOURCES

Purpose	Consideration	Surface water: Lake Superior	Surface water: Baptism, Poplar, Pigeon, and Brule Rivers	Surface water: Nemadji River and major tributaries	Surface water: Other major streams	Surface water: Large inland lakes	Surface water: Small inland lakes and minor streams	Ground water: Unconsolidated aquifers: Buried sand and gravel	Ground water: Unconsolidated aquifers: North Shore Volcanic Group	Ground water: Unconsolidated aquifers: Duluth Gabbro and other intrusives	Ground water: State and graywacke	Ground water: Hinckley Sandstone and Fond du Lac Formation
Municipal or industrial supply	For a moderate supply of adequate quality, indicate needs or use	Abundant quantity	Adequate flow in lower reaches	Adequate flow except near headwaters	Adequate flow except near headwaters	Adequate quality	Adequate quality	Good quality. Rapid recharge from precipitation	Available over a large area of North Shore Volcanic Group	Adequate quality	Adequate quality may be available	Adequate quality may be available
	Quantity: Minimum available surface water supply of 1.5 ft³/s (0.03 m³/s) or wells yielding 250 gal/min (16 L/s)	Minimum treatment required	Adequate quality	Adequate quality	Adequate quality	Adequate quality	Adequate quality	Shallow wells and water table	Shallow water levels			
		Excellent quality		Treatment required	Treatment required	Treatment required	Inadequate quality	Many deposits too thin to yield adequate supply	Variable quality ranging from alkaline to acid. Difficult to obtain supply	Generally inadequate supply	Generally inadequate supply	Requires deep wells in much of area
	Quality: Dissolved-solids concentration less than 5,000 mg/L	Asbestiform particles in water may prove to be a health hazard	Color commonly high	Color commonly high	Color commonly high	Color commonly high	Quality may be inadequate	Treatment required. Iron and manganese may be necessary				
Rural, domestic, and stock supply	For an adequate farm supply, needs are:	Abundant quantity	Adequate flow	Adequate flow except near headwaters	Adequate flow	Suitable for stock use	Suitable for stock use	Many deposits too thin or impermeable to yield adequate supply	Variable quality ranging from alkaline to acid. Difficult to obtain supply	Generally adequate supply	Adequate supply	Adequate supply
	Quantity: Minimum of 3 gal/min (0.3 L/s)	Excellent quality	Adequate quality	Adequate quality	Adequate quality	Adequate quality	Adequate quality	Treatment required for domestic use		Adequate quality	Adequate quality	Adequate quality
	Quality: Dissolved-solids concentration less than 1,000 mg/L	Treatment required for domestic use	Available only to riparian lands	Available only to riparian lands	Available only to riparian lands	Available only to riparian lands	Available only to riparian lands	Treatment required for domestic use	Difficult to obtain supply	Difficult to obtain supply	Adequate supply	Requires deep wells in much of area
		Color commonly high	Color commonly high	Color commonly high	Color commonly high	Color commonly high	Quality may be inadequate	Color commonly high				
Irrigation supply	For an average farm, needs are:	Abundant quantity	Adequate flow in lower reaches	Adequate flow except near headwaters	Adequate flow except near headwaters	Adequate quality	Adequate quality	Adequate quality	Adequate quality	Adequate quality	Adequate quality	Adequate quality
	Quantity: Minimum available surface water supply of 1 ft³/s (0.03 m³/s) during growing season, or wells yielding 250 gal/min (16 L/s)	Excellent quality	Adequate quality	Adequate quality	Adequate quality	Adequate quality	Adequate quality	Adequate quality				Adequate quality may be available with property constructed well
	Quality: Suitability of water supply for irrigation as indicated by classification of Wilcox (1955)	Available only to riparian lands	Available only to riparian lands	Restricted to riparian lands which have little potential for irrigation in lower two-thirds of river	Restricted to riparian lands	Restricted to riparian lands	Restricted to riparian lands	Generally inadequate supply	Generally inadequate supply	Generally inadequate supply	Generally inadequate supply	Deep wells required in much of area
Fish and wildlife habitat	Adequate depth and quality of water for fish in lakes and streams	Adequate depth. Excellent quality	Adequate depth. Excellent fisheries	Adequate depth in upper parts. Adequate wildlife habitat in upper watersheds	Adequate depth. Adequate wildlife habitat in adjacent wetlands	Adequate depth. Adequate wildlife habitat in adjacent wetlands	Adequate depth. Adequate wildlife habitat in adjacent wetlands	Adequate quality	Adequate quality	Adequate quality	Adequate quality	Adequate quality
	Adequate cover needed for life habitat is provided by:	Excellent aesthetic values	Excellent fisheries. Excellent wildlife habitat along banks and in adjacent wetlands					Depth may be inadequate				
	Wetlands—rates or portholes surrounded by marsh areas	Poor wildlife cover		Large suspended sediment load in lower two-thirds of river								
	Streams—marsh and woodland along banks											
Recreation	Adequate access to lakes and streams	Excellent aesthetic values	Excellent aesthetic values	Good aesthetic values		Excellent aesthetic values	Excellent aesthetic values	Adequate quality	Adequate quality	Adequate quality	Adequate quality	Adequate quality
	Availability of areas suitable for hunting, fishing, and other water sports	Excellent fishing. Excellent boating. Adequate public access		Excellent fisheries in places		Good fisheries in places	Good fisheries in places	Adequate quality	Good fisheries	Adequate quality		
	Favorable resorts, lake cottages, and campgrounds	Few small boat harbors. Treacherous boating during storms	Limited access	Limited access. Limited resorts and campgrounds		Limited access	Limited access	Limited access	Limited access	Limited access		
	Esthetic values and absence of pollution							Flow and depth may be inadequate				

EXPLANATION

Adequate quality — Desirable features above line
Limited access — Undesirable features below line
Inadequate quality

Good · Fair · Poor

Colors indicate overall adequacy of water as evaluated for specific uses

CONCLUSIONS

1. Bedrock in the watershed is a complex of Precambrian volcanic and metamorphosed sedimentary rock extensively intruded by dikes and sills and overlain in part of the Nemadji Basin by sandstone. The overlying glacial drift is as much as 500 ft (152 m) thick and averages about 100 ft (30 m) in thickness in a buried b