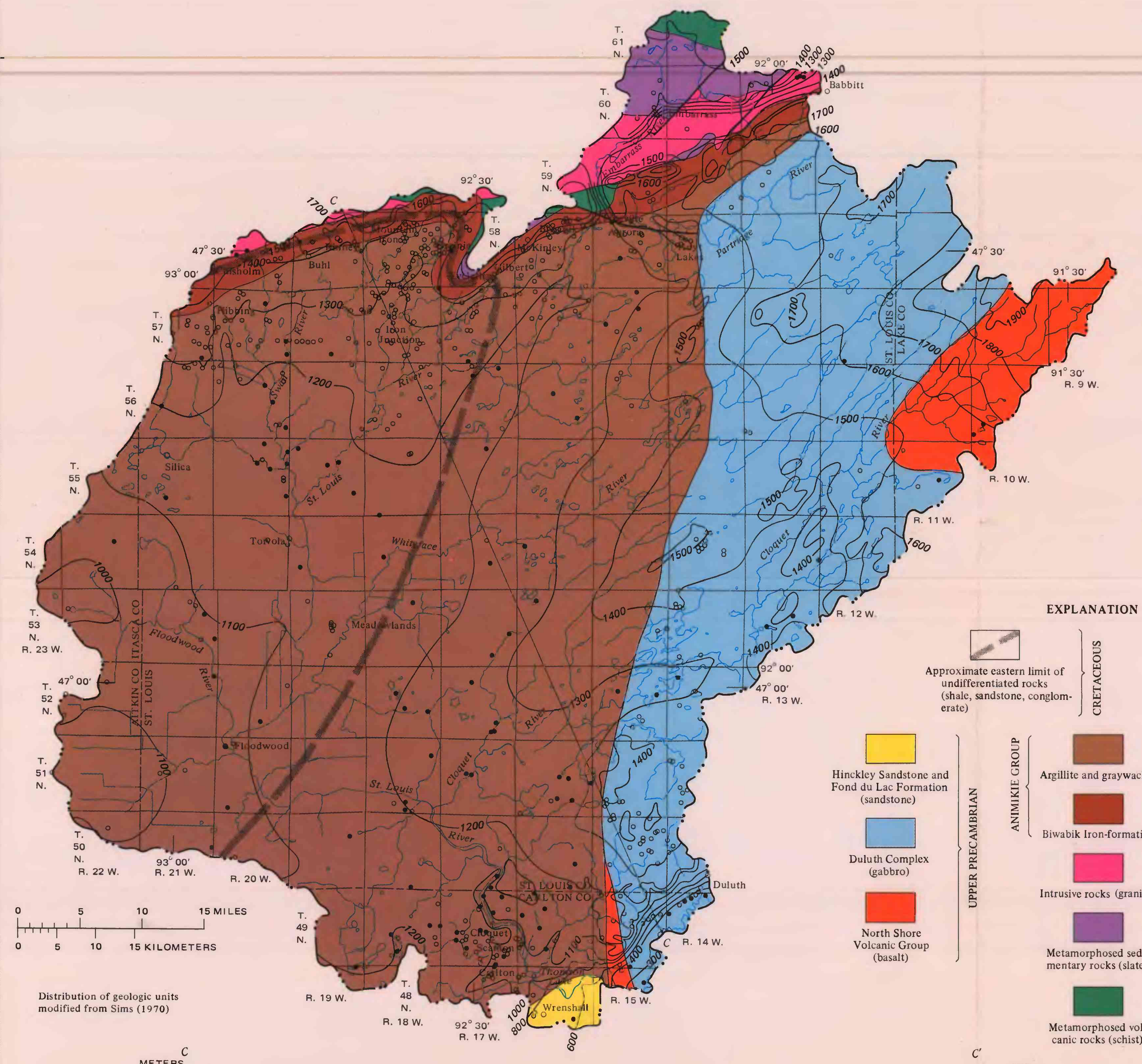
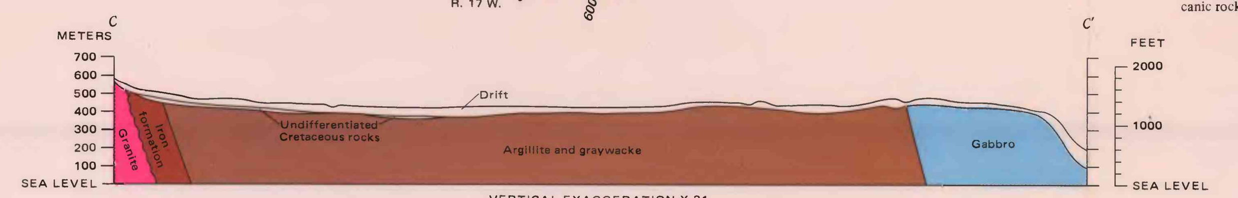
GROUND WATER





GEOLOGIC UNIT	WATER-YIELDING CHARACTERISTICS
Surficial sand and gravel	Easily developed. Yield depends on texture and thickness. Lake sands are usually fine grained, less than 20 ft (6.1 m) thick. Outwash is fine to coarse grained, up to 150 ft (46 m) thick in buried valleys. Aquifer should be protected from contamination
Till	Not usually considered an aquifer. Water-yielding capability is dependent upon predominant grain size; clayey till yields little water. Sandy till may yield minimal supply for domestic or stock purposes.
Buried sand and gravel	Occurrence difficult to predict; occurs within, or between till sheets. Aquifer delineation requires extensive test drilling. Thick drift enhances possibility of penetrating aquifers. Where of sufficient thickness, a possible source of at least a domestic supply in most parts of watershed. Large yields available in some areas (see municipal supply table, sheet 1)
Undifferentiated Cretaceous rocks	Not considered an aquifer in this watershed. Little known about unit except on Mesabi Iron Range. Largely shale. Water-bearing sandstone reported at Hibbing.
Hinckley Sandstone and Fond du Lac Formation	Untested in this watershed. May be a good source where of sufficient thickness. Sandstone is adequate for domestic or stock supply in adjacent watersheds.
Duluth Complex	Gabbro is usually massive and a poor source of water. May yield domestic or stock supply from fractures.
North Shore Volcanic Group	Little data in watershed. In Lake Superior watershed water for domestic or stock use is obtained from fractures in basalt, interflow sediments, and weathered tops of individual flows.
Animikie Group	Argillite and graywacke — fractures near top of unit may yield domestic or stock supply. Usually used in conjunction with iron formation for larger supplies. Total thickness 0-2000 ft (610 m). Biwabik Iron-formation — where fractured and leached may be adequate for municipal or industrial supplies. Untested except in vicinity of Iron Range. Thickness 0 to 800 ft (244 m).
Intrusive rocks	Granite, where fractured, may yield domestic or stock supply. Generally a poor source.
Metamorphosed sedimentary rocks	Slate, where fractured, may yield domestic or stock supply. Generally a poor source.
Metamorphosed volcanic rocks	Schist, where fractured may yield domestic or stock supply. Generally a poor source.

BEDROCK IN THE WATERSHED IS LARGELY A VARIETY OF PRECAMBRIAN VOLCANIC, METAMORPHOSED SEDIMENTARY, AND INTRUSIVE ROCKS

Outcrops are numerous near the northern boundary and in the eastern and southeastern parts of the watershed.

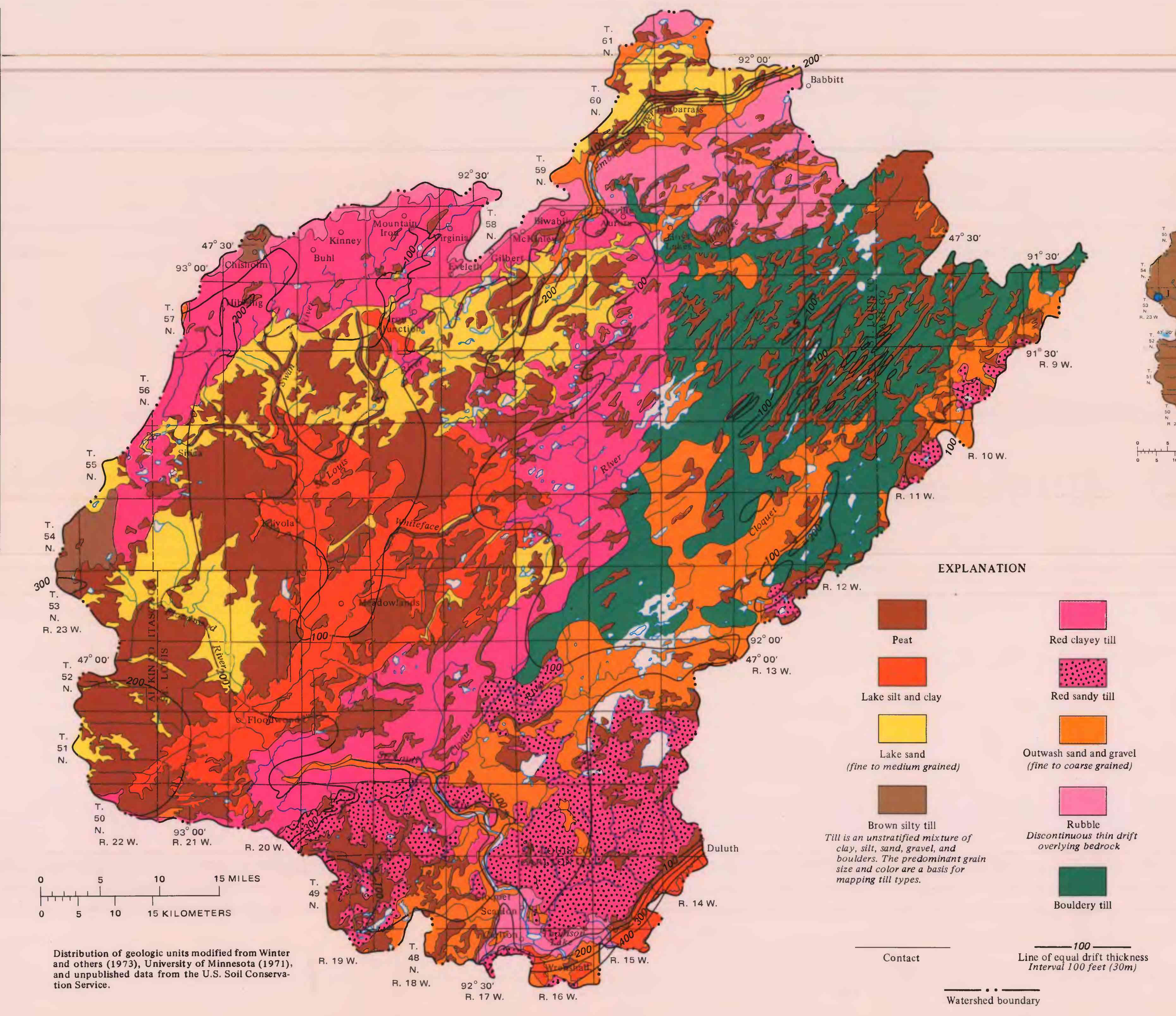
Iron ore has been mined, largely from open pits, on the Mesabi Iron Range since the turn of the century. The Duluth Complex is being explored for low-grade copper and nickel sulfides, mainly along its northern contact.

Undifferentiated rocks of Cretaceous age unconformably overlie Precambrian rocks in the western part. Cretaceous rocks are exposed in several mine pits on the Iron Range, but little is known about their occurrence elsewhere in the watershed. Cretaceous rocks are relatively unconsolidated and difficult to differentiate from basal till in drill cuttings, therefore, they are included as part of the drift in this report. Their continuity and subsurface extent is unknown, and their eastern limit may be greater than shown above.

The Mesabi Iron Range is on the south flank of the Giants Range Batholith (Sims and Viswanathan, 1972), a bedrock high that forms much of the northern watershed boundary. The high separates the northern tip of the watershed from the southern part, except for along the Embarrass River gap. The dominant feature of the bedrock surface is a southwestward plunging "nose" in the eastern half of the watershed. This "nose", together with the Giants Range high, was a primary control on ice movement and on postglacial drainage.

The low on the bedrock surface in the western half of the watershed was a control on deposition through late Pleistocene time. The area then was occupied by a glacial lake which later drained eastward through the St. Louis River (Wright, 1972).

The bedrock surface drops off abruptly into the Lake Superior basin in the extreme southeastern part of the watershed.



THE VARIETY OF GLACIAL DEPOSITS IS INDICATIVE OF A COMPLEX GLACIAL HISTORY

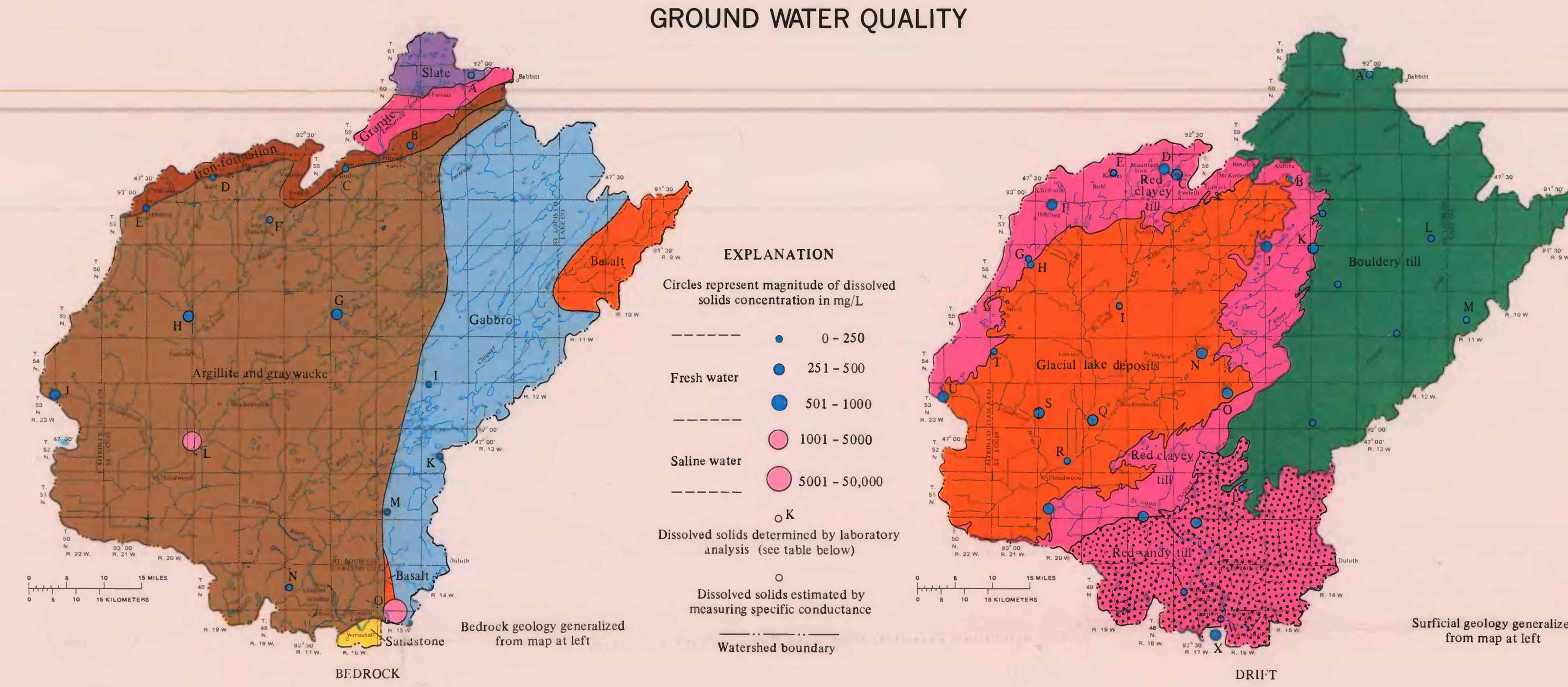
Fine-grained glacial lake deposits of sand, silt, and clay, and extensive postglacial peat deposits predominate in the western half of the watershed. The presence of drumlins (elongate hills) in the bouldery-till area is accentuated by the distribution of till and peat. Drift in the northeastern part of the watershed is generally less than 100 feet thick.

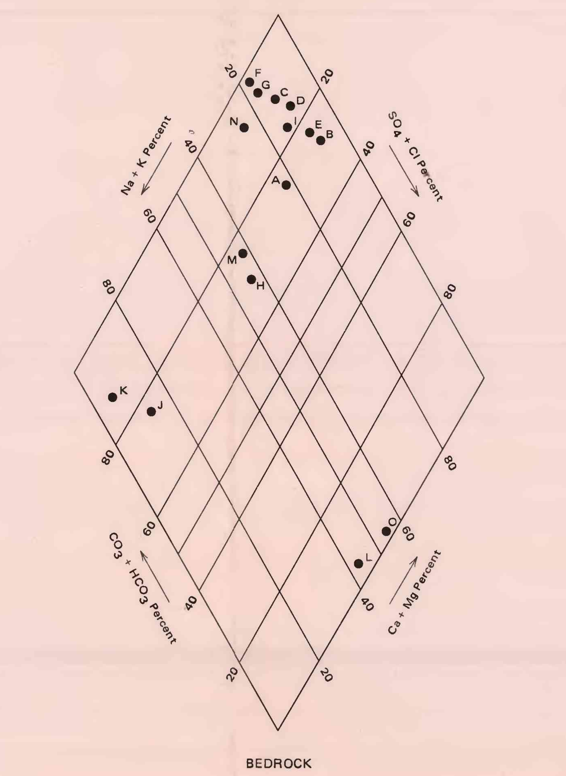
Thin drift and numerous bedrock outcrops are common features on the Iron Range. Drift is thickest in the western part of the watershed and in narrow valleys that head into or transect the Iron Range bedrock high (Winter, 1973).

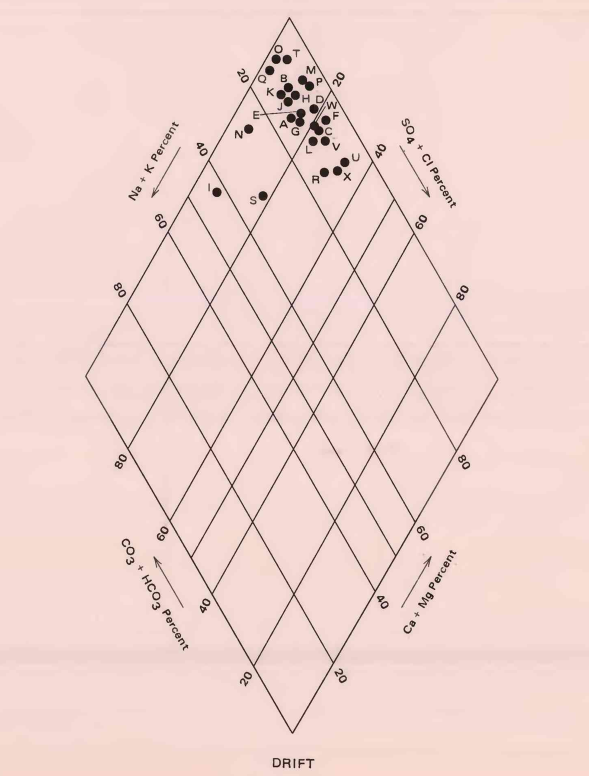
The thickest and most permeable drift deposits in the northern part of the watershed are in a buried channel south of Biwabik, where saturated surficial outwash (primarily fine to medium sand) is as much as 50 feet thick. The possibility of penetrating other sand units in the buried channel enhances the probability of obtaining water.

Surficial outwash in the southeastern and east-central parts of the watershed is typically medium to coarse sand and gravel. Test augering indicates saturated thicknesses of as much as 35 feet in the southeastern part, whereas in the east-central part, the gravel is too coarse to penetrate. Thick drift in the extreme southeastern part is largely glacial lake silts and clays. Saturated glacial-lake sands are commonly less than 10 feet thick.

GROUND WATER QUALITY





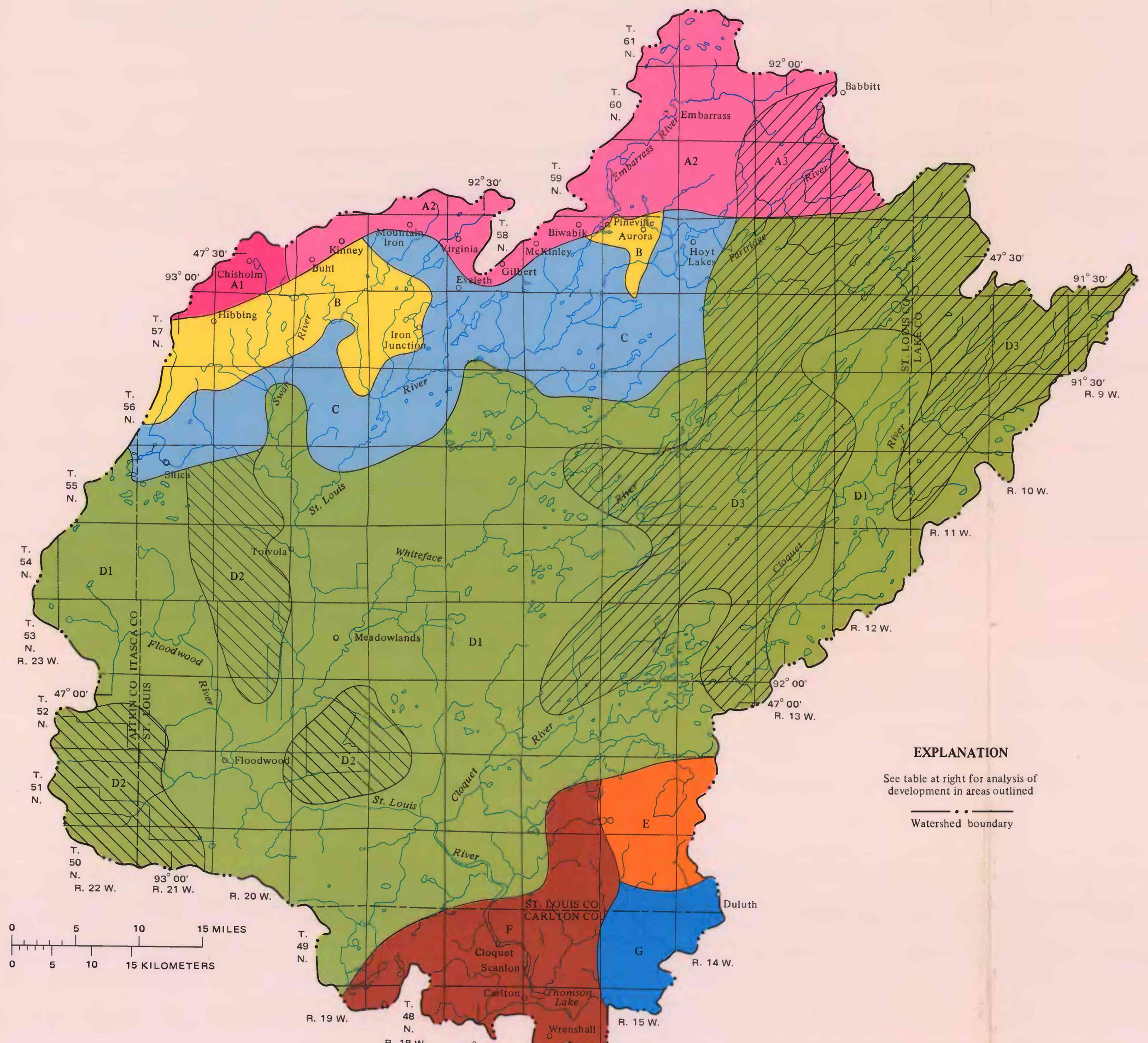


QUALITY OF GROUND WATER IN THE ST. LOUIS RIVER WATERSHED IS GENERALLY GOOD AND AMONG THE BEST IN THE STATE

Dissolved-solids concentration in water from drift and bedrock aquifers in the eastern part of the watershed (map above and tables below) is commonly less than 250 mg/L. Water in aquifers overlain by red clayey till and glacial lake deposits is higher in dissolved solids because of a high carbonate mineral content in those units.

Water in bedrock aquifers is mostly of the calcium-bicarbonate type (graph above and table below). In some areas, sodium-softened water occurs in the argillite and graywacke, and gabbro; in other areas, these aquifers contain sodium chloride type water. Water from the Biwabik Iron-formation is of good quality and suitable for most uses without softening or iron removal. It is generally lower in dissolved solids (less than 250 mg/L) than is water in the argillite and graywacke. Deep wells in the argillite and graywacke, basalt, and gabbro may yield saline water (dissolved-solids concentration greater than 1,000 mg/L), unsuitable for many uses (L and O, table at left below).

Water in all drift aquifers is of the calcium or magnesium bicarbonate type. In 24 samples analyzed, dissolved-solids concentration ranged from 86 to 468 mg/L and averaged 248 mg/L. Water from some wells finished in glacial lake deposits is esthetically unsuitable for human consumption (J and O, table at right below) owing to a high color content. Excessive chloride in water from some shallow wells (U and X) is probably a local phenomenon and may be due to leachates from highway salt or septic tanks. High nitrogen concentrations are most common in water from surficial sand aquifers that are susceptible to contamination. Hardness of water in surficial sands varies from 63 to 280 mg/L, whereas water from buried sands is typically hard, ranging from 160 to 420 mg/L. High concentrations of iron in water from drift aquifers cause problems in many places.



SOURCES OF WATER AND ANALYSIS OF DEVELOPMENT

AREA	SOURCE OF WATER (Numbers in parentheses are number of wells on record)	DEGREE OF DEVELOPMENT	Depth (ft)	Static water level (ft below land surface)	Available drawdown[1] (ft)	Yield[2] (gal/min)	Specific capacity [(gal/min)/ft of drawdown]	COMMENTS	POTENTIAL FOR ADDITIONAL DEVELOPMENT
		PRESENT DEVELOPMENT — Common well characteristics							
A1	Drift (17)	Moderate	40–70	10–15	10–30	Public supply up to 300	Up to 50 most < 10	Drift is source for city of Chisholm. Several public supplies are from Iron-formation. Domestic wells concentrated near cities.	Most of area highly disrupted by mining activities. Apart from immediate vicinity of open pits, drift and Iron-formation will support additional development.
	Bedrock (22)		100–300	40–60	100–200	Argillite up to 40 Iron-formation up to 500	Up to 10 most < 1		
A2	Drift (75)	Slight	10–175	5–40	5–85	Domestic < 10 Public supply up to 1100	– Public supply up to 40	Many drift wells are 10–30 ft deep, dug open end or sand point; many drift wells are 125–175 ft deep in buried valley, drilled and screened. Wells in bedrock completed as open hole.	Most drift less than 50 ft thick, as much as 200 ft in buried valley along Embarrass River. An excellent source. Iron-formation generally a good source for additional development. Granite a poor source.
	Bedrock (17)		100–300	30–40	100–200	Iron-formation up to 15 Granite < 5	Up to 5 most < 1		
A3	Drift	Virtually undeveloped							Potential for development comparable to A2 above except drift is commonly thinner and bedrock outcrops are numerous.
	Bedrock								
B	Drift (178)	Moderate	10–150	10–40	5–75	Domestic < 20 Public supply up to 1000	< 20 Public supply up to 50	Many drift wells are 10–30 ft deep, dug open end or sand point; many drift wells are 50–150 ft deep, drilled and screened or open end, includes city of Hibbing Wells. Wells in bedrock completed as open hole.	Most drift less than 100 ft thick, as much as 200 in buried valleys. An excellent source. Iron-formation largely untested. Argillite commonly adequate for domestic supply.
	Bedrock (15)	Slight	100–300	10–30	75–200	Argillite up to 25 Iron-formation inadequate data	No data		
C	Drift (453)	Moderate	10–100	10–40	5–100	Domestic < 10 Public supply up to 1400	< 10 Public supply up to 50	Includes large areas of surficial sand in which most drift wells are less than 20 ft deep, dug open end or sand point; many drift wells are 40–100 ft deep, drilled and screened or open end. Wells in bedrock completed as open hole.	Drift 100–200 ft thick, surficial sand usually less than 20 ft and fine-grained. Sands thickest and coarsest in eastern third. Argillite commonly adequate for domestic supply.
	Bedrock (13)	Slight	100–200	10–40	100–200	Inadequate data	–		
D1	Drift (284)	Slight	30–100	0–30 Some flow in west-central part	20–80	Domestic < 20 Public supply up to 300	< 2 Public supply up to 10	Most drift wells drilled and screened or open end. Numerous flowing wells along Floodwood River. Wells in bedrock completed as open hole.	Drift generally more than 100 ft thick. Surficial sands are fine grained in western part, coarser in eastern part. Argillite commonly adequate for domestic supply.
	Bedrock (38)	Slight	100–300	10–30	50–150	Argillite up to 60	< 1		
D2	Drift	Virtually undeveloped							Potential for development comparable to D1 above. Extensive peat-covered wetlands hinder development
	Bedrock								
D3	Drift	Virtually undeveloped							Potential for development less than D2 above because drift is less than 100 ft thick and much of area is underlain by gabbro having low water-yielding capability
	Bedrock								
E	Drift (59)	Moderate	15–80	5–25	5–60	Domestic < 25	< 10	Many drift wells are 15–35 ft deep, dug open end; many drift wells are 60–80 ft deep, drilled and screened. Wells in bedrock completed as open hole, deep drill hole serves as reservoir.	Drift in most areas less than 50 ft thick. Commonly suitable for domestic supply but inadequate for large supply. Gabbro is a generally poor but only alternate source.
	Bedrock (20)		100–700	10–30	100–200	Gabbro < 5	< 1		
F	Drift (77)	Moderate	50–125	20–50	20–80	Domestic < 20 Public supply up to 500	< 2 Public supply up to 20	Most drift wells drilled and screened or open end. Source for city of Cloquet. Wells in bedrock completed as open hole.	Drift in much of area greater than 100 ft thick. Contains considerable sand and gravel. Will support additional development. Test drilling required to locate most favorable areas. Argillite and sandstone commonly adequate for domestic supply
	Bedrock (6)	Slight	100–200	20–30	40–160	Argillite up to 50	Inadequate data		
G	Drift (17)	Moderate	100–250	50–100	40–100	Public supply up to 600	Up to 25	Proximity to Duluth results in concentrated development locally. Wells in drift drilled and screened. Wells in bedrock completed as open hole, deep drill hole serves as reservoir.	Drift generally less than 100 ft thick. Numerous bedrock outcrops. Drift contains much gravel. A good source of water. Gabbro is a generally poor source.
	Bedrock (9)		300–600	20–30	200–300	Gabbro < 10	< 1		

[1] For drift wells assumed equal to vertical distance between static water level and top perforation, for bedrock wells assumed equal to vertical distance between static water level and bottom of well.

[2] Reported yields are more indicative of user needs than of water-yielding capabilities of aquifers.

AN AREAL ANALYSIS OF PRESENT DEVELOPMENT INDICATES THE RELATIVE FAVORABILITY OF GROUND WATER AS A SOURCE OF SUPPLY

Ground water is moderately developed in the northwestern and southeastern parts of the watershed and little developed elsewhere.

Most wells are completed in drift; but, where the drift is not an aquifer, deep wells drilled into bedrock may provide a supply. The Biwabik Iron-formation along the northern watershed boundary is the most favorable bedrock aquifer; however, because of mining activities, it cannot always be considered a reliable alternative source. Locally, other bedrock units might yield an adequate amount for domestic or stock supply but often they are inadequate. Gabbro is generally the least favorable source.

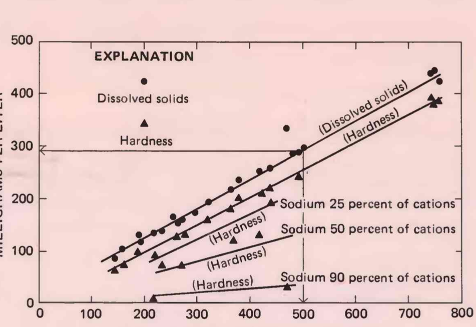
All aquifers are capable of supporting additional development. Detailed studies could locate favorable areas and determine the optimum amount of water that might be obtained.

TRACE ELEMENT ANALYSES OF WATER FROM SELECTED BEDROCK WELLS
(Total concentrations reported in micrograms per liter)

Map key	Aluminum	Barium	Chromium	Copper	Selenium	Strontium	Zinc	Formation
B	100	<100	<10	<10	0	180	400	Biwabik Iron-formation
L	300	300	<10	10	0	6300	250	Argillite and graywacke
M	300	<100	<10	30	0	700	270	Gabbro
		1000	50	1000	10		5000	Minnesota Water Pollution Control Agency domestic consumption standards (1972)

WATER FROM BEDROCK CONTAINS CONCENTRATIONS OF TRACE ELEMENTS BUT THEY DO NOT EXCEED THE DOMESTIC-CONSUMPTION STANDARDS SET BY THE STATE

Water in the gabbro, a rock known to include copper sulfide minerals, contains uncommonly high concentrations of copper. Strontium and barium are abundant in saline water in the argillite and graywacke. Zinc concentrations, not representative of natural water, occur probably because of contamination from distribution systems.



RELIABLE ESTIMATES OF DISSOLVED-SOLIDS CONCENTRATIONS IN GROUND WATER CAN BE MADE BY MEASURING SPECIFIC CONDUCTANCE

An example on the graph indicates that water having a conductivity of 500 micromhos will contain about 290 mg/L of dissolved solids. Accurate estimates of hardness cannot be made by this method because cation exchange in clay tends to soften water by sodium substituion, and the amount of clay in glacial deposits is highly variable.

CHEMICAL ANALYSES OF WATER FROM SELECTED WELLS FINISHED IN BEDROCK

Map key	Geologic unit	Date sampled	Color (platinum cobalt units)	Field pH (log units)	Dissolved solids (constituent sum) (mg/L)	Bicarbonate (mg/L)	Dissolved chloride (mg/L)	Dissolved sulfate (mg/L)	Dissolved fluoride (mg/L)	Total nitrogen as NO_3 (mg/L)	Total phosphorus as P (mg/L)	Dissolved calcium (mg/L)	Dissolved magnesium (mg/L)	Dissolved sodium (mg/L)	Dissolved potassium (mg/L)	Hardness as $CaCO_3$ (mg/L)	Total iron (mg/L)	Total manganese (mg/L)	Dissolved boron (mg/L)
A	Slate	12- 5-74	0	7.1	171	140	12	17	0.3	0.8	0.00	31	9.1	13	1.9	110	0.09	0.02	0.35
B	Iron-formation	12- 4-74	5	7.4	234	189	9	41	.3	.1	.00	43	22	5	2.3	200	.93	.09	.04
C	Iron-formation	9-21-56	3	6.4	104	94	.0	7.5	.0	.2	–	18	6.6	4.1	.9	72	.10	.00	.01
D	Iron-formation	9-27-57	0	6.8	212	214	3	22	.2	.4	–	42	19	8.2	2.0	185	.10	.02	.05
E	Iron-formation	12-27-56	2	7.4	145	128	7.5	23	.0	.2	–	26	14	4.7	1.0	124	.17	.00	.05
F	Argillite and graywacke	10-57	3	7.6	147	167	.0	.3	.6	.8	–	32	9.5	9.7	2.8	119	.37	.07	.08
G	Argillite and graywacke	11- 7-74	5	7.3	285	338	4.1	1.9	.3	1.9	.00	42	32	21	2.6	240	.33	.12	.11
H	Argillite and graywacke	11-24-74	0	7.6	252	185	5	56	.3	5.4	.00	31	12	41	5.3	130	.12	.01	.40
I	Gabbro	12-12-74	5	6.6	132	97	6	8.8	.1	1.9	.01	29	6.9	4.8	2.0	100	.60	.11	.30
J	Argillite and graywacke	11-18-74	3	8.2	331	284	48	0.4	1.4	2.4	.17	8.8	2.2	120	1.8	31	.42	.10	1
K	Gabbro	11-30-74	3	9.1	131	97	3.2	5.1	.8	.6	.03	1.7	.2	48	.7	5	.18	.01	.48
L	Argillite and graywacke	11-15-74	2	7.5	2,420	89	1,500	1.8	.9	21	.01	200	100	560	9.5	910	.11	.11	1
M	Gabbro	12-13-74	3	6.9	237	185	18	19	.3	2.9	.01	30	10	37	.7	120	.09	.00	.28
N	Argillite and graywacke	12-11-74	8	7.8	135	135	4	1.7	.4	3.5	.59	23	8.2	12	1.1	91	.21	.07	.06
O	Gabbro	1888?	–	–	33,500	–	20,560	1.6	–	–	–	6,220	129	6,020	262	16,100	21.5	–	–
Minnesota Water Pollution Control Agency domestic consumption standards (1972)					500		250	250	1.5	45							.30	.05	

CHEMICAL ANALYSES OF WATER FROM SELECTED WELLS FINISHED IN DRIFT

Map key	Geologic unit	Date sampled	Color (platinum cobalt units)	Field pH (log units)	Dissolved solids (constituent sum) (mg/L)	Bicarbonate (mg/L)	Dissolved chloride (mg/L)	Dissolved sulfate (mg/L)	Dissolved fluoride (mg/L)	Total nitrogen as NO_3 (mg/L)	Total phosphorus as P (mg/L)	Dissolved calcium (mg/L)	Dissolved magnesium (mg/L)	Dissolved sodium (mg/L)	Dissolved potassium (mg/L)	Hardness as $CaCO_3$ (mg/L)	Total iron (mg/L)	Total manganese (mg/L)	Dissolved boron (mg/L)
A	Surficial sand	12- 5-74	0	8.3	86	79	1.3	7.3	0.1	0.6	0.04	12	8.1	4.2	0.5	63	0.04	0.05	0.02
B	Surficial sand	11-30-74	0	8.1	117	121	1.0	5.4	.1	.2	.06	27	10	3.9	1.8	110	.15	.10	.04
C	Buried sand	9-26-58	–	7.2	455	400	.4	87	.2	.2	–	91	40	14	3.8	391	.06	1.7	.06
D	Buried sand	10- 6-54	–	7.5	309	283	2.5	47	.3	.1	–	64	26	6.8	2.5	266	.32	.66	.04
E	Surficial sand	9-26-57	4	6.5	133	104	.0	15	.2	.3	–	20	11	3.4	1.8	97	.94	5.5	.06
F	Buried sand	6-13-58	5	7.4	468	413	9.5	79	.2	.2	–	90	48	8.5	1.8	420	5.6	1.8	.11
G	Surficial sand	11-23-74	0	6.6	160	123	5.2	12	.1	30	.00	35	10	6.9	2	130	.17	1.3	.10
H	Lake deposits	11-23-74	0	7.5	216	219	2.2	14	.1	1.4	.04	47	16	7.1	1.9	180	.73	.42	.03
I	Lake deposits	11-14-74	8	8.0	137	148	3.4	1.1	.4	.4	.04	21	4.9	23	2.3	73	1.9	.08	.09
J	Lake deposits	12- 5-74	30	7.3	440	473	16	20	.2	1.7	.13	61	56	24	2.1	380	8.4	.55	.04
K	Buried sand	12- 3-74	9	7.8	436	523	1.3	22	.4	.5	.06	46	66	19	4.2	390	.72	.11	.09
L	Surficial sand	12- 6-74	0	7.8	153	120	2.4	22	.3	15.0	.00	33	11	5.3	2	130	.07	.01	.01
M	Surficial sand	12-10-74	3	7.3	168	152	1.8	7.6	.2	2	.11	46	9.1	4.1	.9	150	.07	.00	.02
N	Buried sand	11- 7-74	0	7.6	257	291	5.3	3.5	.6	1.2	.02	35	25	30	2.1	190	.09	.08	.16
O	Lake deposits	12- 3-74	70	7.0	296	317	1.1	2.2	.3	11	.06	64	28	9	2.7	280	17	.58	.11
P	Surficial sand	12-12-74	3	7.8	165	159	1.9	12	.4	1.1	.07	38	12	3.6	.9	140	.19	.00	.03
Q	Lake deposits	11-15-74	4	7.9	253	301	1.0	3.8	.3	.5	.05	43	27	11	1	220	.49	.12	.08
R	Surficial sand	11-15-74	2	6.3	129	85	8.6	16	.1	28	.02	26	9.5	5.9	3.1	100	.10	.00	.04
S	Buried sand	11-19-74	0	7.9	287	262	17	21	.2	2.2	.10	48	16	37	1.8	190	.42	.05	.10
T	Buried sand	11-24-74	5	7.4	193	210	1.4	5.3	.2	1.4	.01	42	14	4.9	1.4	160	.36	.29	.06
U	Lake deposits	11-16-74	3	7.2	418	324	82	15	.1	1.6	.03	100	31	6.2	1.1	380	.55	.41	.02
V	Surficial sand	1- 7-58	–	7.8	190	159	17	20	–	–	–	32	19	7	–	160	–	–	–
W	Surficial sand	4-68	–	8.2	140	124	5.1	15	.2	4.4	–	38	11	4	2	140	.79	.02	–
X	Surficial sand	4-68	–	7.7	320	244	53	23	.2	4.4	–	76	22	11	2	280	6.4	.08	–

Base from U.S. Geological Survey, Duluth, 1953, Two Harbors, 1954 and Hibbing, 1954

Interior – Geological Survey, Reston, Va. – 1979 – W77312

WATER RESOURCES OF THE ST. LOUIS RIVER WATERSHED, NORTHEASTERN MINNESOTA

By
G. F. Lindholm, D. W. Ericson, W. L. Broussard, and M. F. Hult

1979