PREPARED IN COOPERATION WITH
THE MINNESOTA DEPARTMENT OF IRON RANGE
RESOURCES AND REHABILITATION

ANALYSIS OF GROUND-WATER RESOURCES

INTRODUCTION

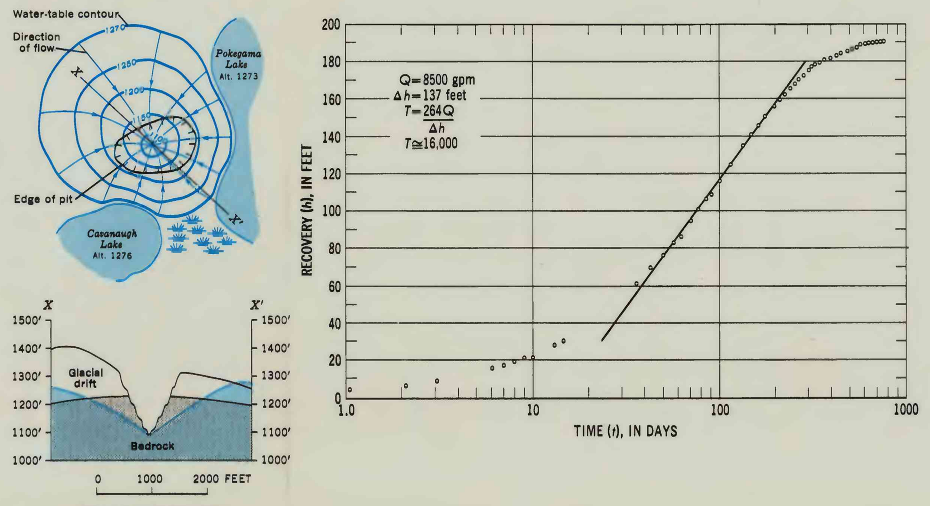
A buried outwash aquifer in the vicinity of the village of Grand Rapids is the major source of ground water for municipal and industrial use. Northwest of Cohasset, in the valley of the Mississippi River, a similar aquifer probably occurs. These aquifers are not indicated on the geologic map (sheet 1). The extent of these aquifers was determined by deep test drilling and other well logs. They are shown on the geologic sections (sheet 1) as buried outwash.

Regional ground-water movement through glacial drift is toward the Mississippi and Prairie Rivers. Local movement is toward local surface-water bodies where ground water maintains uniform lake levels and streamflow. Recharge to ground water is by infiltration of precipitation.

Average annual recharge to ground water in the area is 5.7 inches of water (25.6 inches of precipitation minus 19.9 inches of evapotranspiration). Recharge by vertical infiltration of 5.7 inches directly over the 108 square-mile area of the buried-outwash aquifer near Grand Rapids is 1040 mgy (million gallons per year). Estimated pumpage from this aquifer (Oakes and Bidwell, 1968) is 283 mgy, or 28 percent of annual calculated recharge. As ground water is moving toward the buried-outwash aquifer from an area far greater than the area of the aquifer, the quantity of actual recharge is considerably greater than the calculated amount.

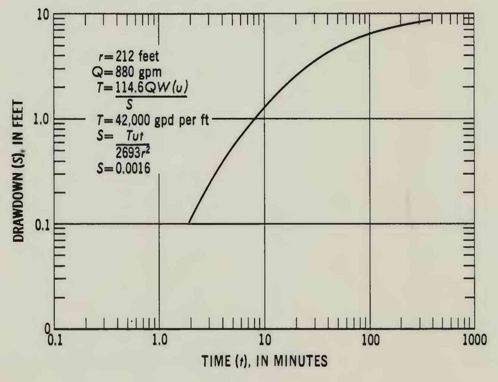
Increased ground-water pumpage from the buried-outwash aquifer should lower the artesian head in the aquifer and induce a greater rate of ground-water movement to the aquifer. Thus, increased pumpage could "salvage" water that would ordinarily leave the area as ground-water contribution to streamflow.

Water quality from each ground-water source is similar. Ground water is generally hard (100–200 mg/1 (milligrams per liter) hardness as $CaCO_3$) to very hard (over 200 mg/1 hardness). Iron and manganese are frequently higher than the maximum recommended limits (0.3 mg/1 for iron, and 0.05 mg/1 for manganese). Total dissolved solids content are within permissible limits for most ground-water use. After treatment for hardness, iron, and manganese removal, ground water in the Grand Rapids area may be used for most municipal and industrial purposes.



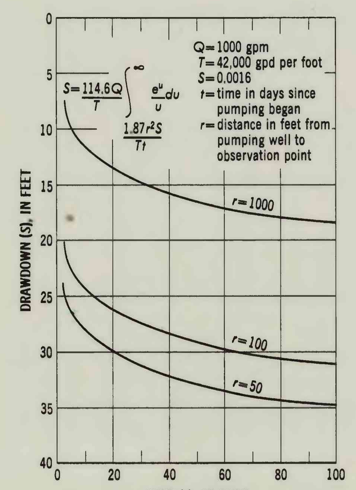
WATER-LEVEL RECOVERY IN A MINE PIT RESEMBLES THAT OF A LARGE DIAMETER WELL

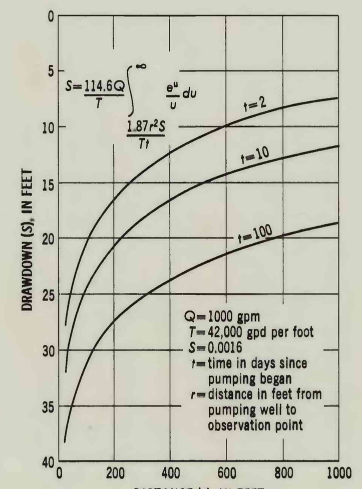
Consideration of this pit as a large diameter well is based on two assumptions: That interception structures present most overland runoff from flowing into the pit; and that the 25 inches of annual precipitation added to the pit are equaled by the 25 inches of annual evaporation lost from the water surface in the pit (Meyer, 1942). Analysis of the flow net shown at left above gives a transmissibility value of about 16,000 gallons per day per foot for the metasedimentary bedrock. This is also the figure obtained from the graph of water-level recovery. Transmissibilities within metasedimentary bedrock (iron-formation and slate) are much lower than those within permeable glacial drift. However, these formations are significant sources of ground water.



AT WELL 3 (55.25.17dbb3) THE COEFFICIENT OF TRANSMISSIBILITY OF BURIED OUTWASH IS 42,000 GALLONS PER DAY PER FOOT.—

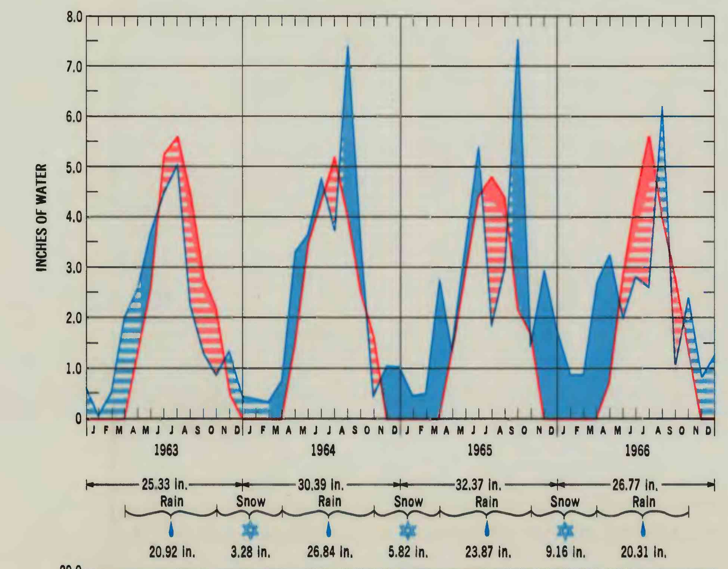
This figure was determined from a 5-hour pumping test. Test results were obtained by comparing the above time-drawdown curve (not adjusted for boundaries) with a non-steady state, non-leaky, artesian type curve (Walton, 1962).





THE EFFECTS OF PUMPING A WELL AT A GIVEN RATE MAY BE PREDICTED

The above time-drawdown and distance-drawdown curves (not adjusted for boundaries) assume well 55.25.17dbb3 is pumped at a rate of 1000 gpm (gallons per minute). Where these similar aquifer characteristics exist, similar wells will have similar characteristics. Wells should be spaced so that the drawdown of one does not significantly affect the drawdown of the other.



EXPLANATION

Precipitation

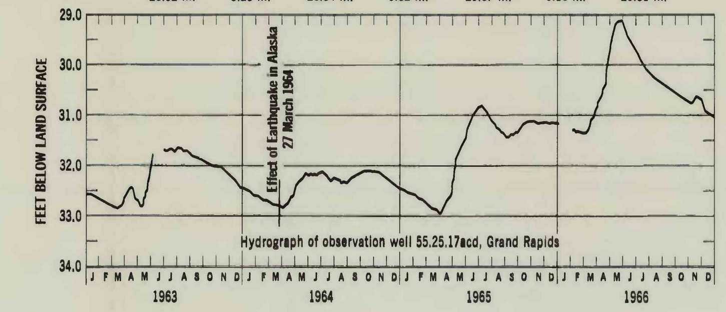
Potential evapotranspiration

Soil-moisture recharge — *Precipitation during this time is replenishing soil moisture. In the case of unmelted snow, this moisture is available for soil recharge after thawing occurs*

Moisture surplus — *Precipitation during this time is in excess of soil needs. Some infiltrates to ground-water storage, some directly runs off to streams. If the moisture occurs as snow, infiltration or direct runoff will not occur until the spring thaw*

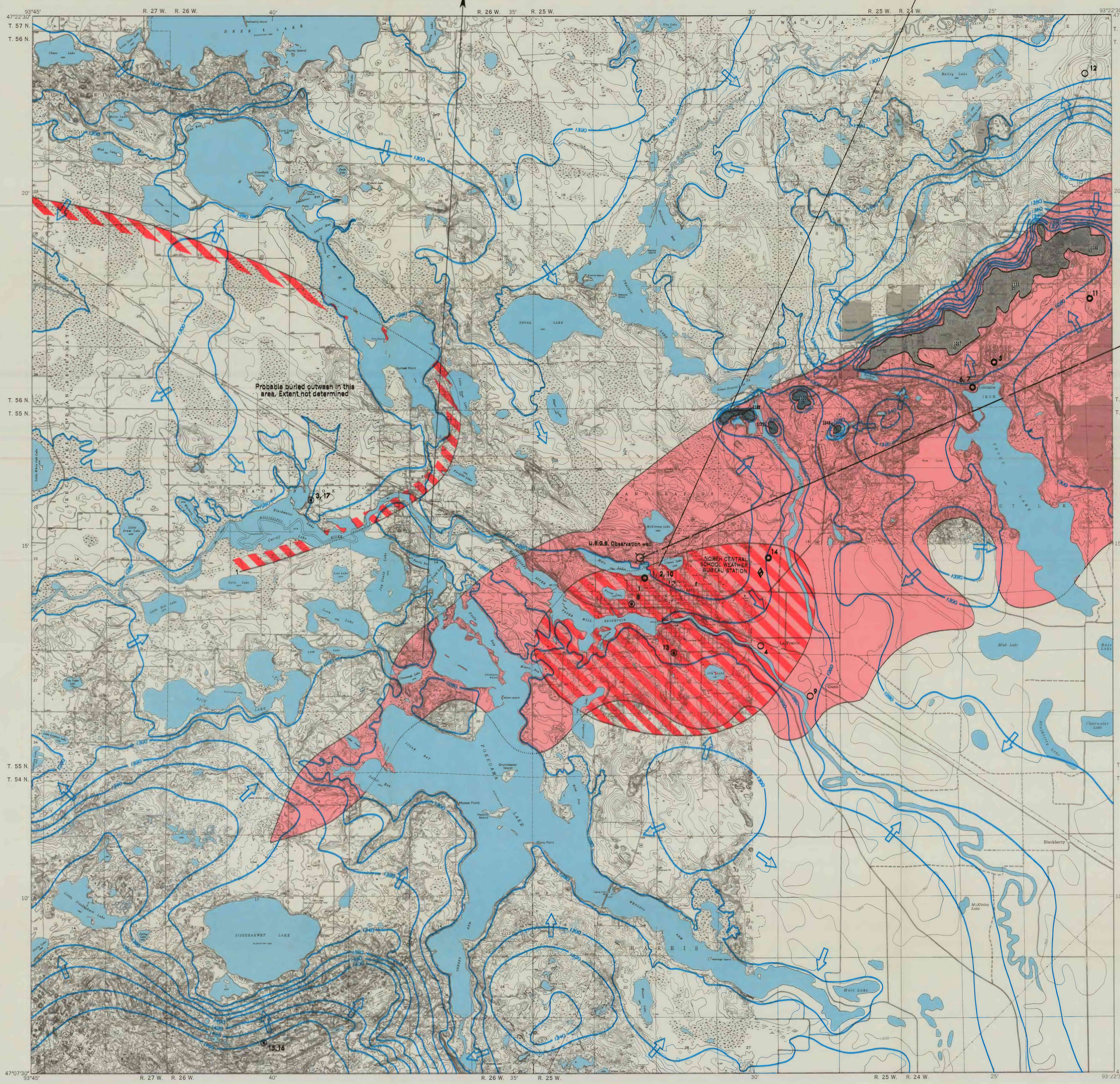
Soil-moisture utilization — *During this period, moisture in soil storage and precipitation that falls are used for plant growth*

Moisture deficit — *During this period of moisture utilization, potential evapotranspiration is greater than actual evapotranspiration. This does not necessarily imply "drought" conditions, but means that plants can use more moisture than is actually available*



PRECIPITATION, EVAPOTRANSPIRATION, AND GROUND-WATER LEVELS ARE COMPARED ABOVE

The evapotranspiration figure is based on the method of Thornthwaite and Mather (1957) using meteorological data recorded at the U.S. Weather Bureau station, North Central School, Grand Rapids. The comparison shows the importance of snowfall to the annual restoration of ground-water levels. Although the bulk of annual precipitation falls during the summer months, most of this is used as soil moisture and is lost by evapotranspiration. Mean annual precipitation for Grand Rapids (58-year record) is 25.58 inches with 5.14 inches as snow. The upward trend in ground-water levels in 1965 and 1966 are, for the most part, due to higher than normal snowfall. Ground-water recharge by infiltration of snowmelt in the spring restores levels in wells and lakes and ground-water discharge supplies base flow to streams during the summer months.



Base from U.S. Geological Survey, 1:24,000 Bovey, 1952, Cohasset East, 1953, Cohasset West, 1953, Grand Rapids, 1953, Sissebakwet Lake, 1953 and Hibbing, 1954, 1:250,000

APPROXIMATE MEAN DECLINATION, 1970

SCALE 1:48 000

CONTOUR INTERVALS 10 AND 50 FEET
DATUM IS MEAN SEA LEVEL

EXPLANATION

Buried-outwash aquifer
Depth of burial, 50 to 115 feet below land surface

Precambrian metasedimentary-bedrock aquifer (Biwabik Iron-Formation and Virginia Argillite)
Depth of burial, 300 feet or less below land surface

1400
Piezometric contour
Shows altitude of piezometric surface in glacial drift. Contour interval, 50 feet. Datum is mean sea level

Mine pit presently being dewatered
Number is water-level altitude at point of pumping

Direction of ground-water movement

Wells
Public supply — Industrial or commercial — Domestic
Number next to well symbol is same as listing in tables of water quality or properties of wells

A BURIED OUTWASH AQUIFER NEAR GRAND RAPIDS IS THE MAJOR SOURCE OF GROUND WATER FOR MUNICIPAL AND INDUSTRIAL USE

In addition, a buried outwash aquifer of undetermined extent may exist several miles west of Grand Rapids. Locally metasedimentary bedrock (Virginia Argillite and Biwabik Iron-Formation) is also an important source of ground water

PHYSICAL PROPERTIES OF SELECTED WELLS

Map number	U.S.G.S. field number	Ownership and use of water	Diameter (inches)	Depth (feet)	Finish	Yield (gpm)	Specific Capacity of Wells: Gallons per min per ft of drawdown	Pumping rate (gpm)	Pumping time (hours)	Aquifer
11	56.24.27bcc	Municipal—Public supply	12	280	Open hole	100	2.0	100	Unknown	170 ft of well open to upper members of Biwabik Iron-Formation
5	56.24.32bda	Municipal—Public supply	16	88	40 ft screen	743	35.4	743	9.0	Glacial sand and sandy gravel at a depth of 39–91 ft.
6	56.24.32cab1	Municipal—Public supply	24	107	28 ft screen	—	--	--	--	Glacial sand and gravel (thickness unknown).
7	56.24.32cab2		16	120	17 ft screen	1022	53.8	1022	10.0	Glacial sand and gravel at a depth of 77–121 ft.
1	55.25.17dbb1	Municipal—Public supply	12	168	30 ft screen	1200	17.5	1000	12.0	Buried outwash sand and gravel at a depth of 80–178 ft.
10	55.25.17dbb2		16	573	Open hole	500	2.8	500	24.0	375 ft of well open to Virginia Argillite and Biwabik Iron-Formation.
2	55.25.17dbb3		12	176	60 ft screen	956	10.4	956	8.0	Buried outwash sand and gravel at a depth of 113–179 ft.
15	54.26.29cca1	Private—Ski lodge and artificial snow making	8	97	30 ft screen	150	25.0	150	Unknown	Layered ice-contact gravel and clay at a depth of 6–97 ft.
16	54.26.29cca2		8	110	16 ft screen	150	7.5	150	Unknown	Layered ice-contact gravel and clay at a depth of 6–110 ft.
13	55.25.28bab	Private—Commercial laundry	6	63	4 ft screen	33.3	30.3	33.3	Unknown	Glacial sand at a depth of 38–63 ft.
3	55.26.9bdc2	Private—Industrial boiler feed makeup	10	194	3–10 ft screens	350	44.7	350	3.0	Buried outwash sand and gravel at a depth of 83–194 ft.
17	55.26.9bdc3		10	186	3–10 ft screens	350	41.0	350	3.0	Buried outwash sand and gravel at a depth of 64–178 and 178–186 ft.
14	55.25.15adc	Public—Agricultural experimental station	8	150	Screen	65	3.9	65	7.5	Buried outwash sand and gravel at a depth of 141–150 ft.

SELECTED CHEMICAL ANALYSES OF GROUND WATER

Map number	U.S.G.S. field number	Well Depth (ft.)	Aquifer	Silica (SiO_2)*	Iron (Fe)*	Manganese (Mn)*	Calcium (Ca)*	Magnesium (Mg)*	Sodium (Na)*	Potassium (K)*	Bicarbonate (HCO_3)*	Carbonate (CO_3)*	Sulfate (SO_4)*	Chloride (Cl)*	Fluoride (F)*	Nitrate (NO_3)*	Boron (B)*	Dissolved Solids*	Hardness as $CaCO_3$*	Noncarbonate hardness*	Alkalinity as $CaCO_3$*	Specific conductance (µ mhos at 25°C)	pH	Color (units)	Turbidity as SiO_2	Temperature (°C)	Date of collection	Analysis by:
1	55.25.17dbb1	168	Buried outwash	16	1.50	0.25	54	14	4.5	—	240	—	3.8	1.0	0.15	—	—	—	191	—	196	—	7.4	13	3	—	31 Aug. 1954	Permutit Co.
2	55.25.17dbb3	176	Buried outwash	18	1.90	.22	57	12	5.0	2.2	235	0	5.8	3.8	.20	0.1	0	279	191	0	193	373	7.6	5	—	—	30 Sept. 1965	U.S.G.S. Lab.
3	55.26.9bdc2	195	Buried outwash	26	.48	.29	78	24	18.0	3.6	395	0	12.0	1.5	.30	.2	0.10	358	294	0	324	594	8.2	3	—	—	23 Aug. 1965	U.S.G.S. Lab.
4	55.25.22dcd	42	Sand and gravel	25	.55	.25	50	7	—	—	195	0	35.0	3.3	.45	.1	—	—	155	0	160	350	7.7	—	—	—	1 Dec. 1964	U.S.G.S Field Kit
5	56.24.32bda	88	Sand and gravel	20	5.20	.51	72	24	6.8	2.8	259	0	68.0	3.5	.20	.6	.06	336	277	65	212	532	7.2	0	30	48	26 Sept. 1957	U.S.G.S. Lab.
6	56.24.32cab1	107	Sand and gravel	—	.62	.34	—	—	—	—	195	0	55.0	5.0	.18	—	—	—	220	60	160	—	7.8	—	—	—	19 Mar. 1953	Minn.-Dept. Health
7	56.24.32cab2	120	Sand and gravel	18	.30	.48	58	16	7.5	3.1	214	0	42.0	4.0	.20	.5	.08	258	210	35	175	424	7.4	0	1	49	26 Sept. 1957	U.S.G.S. Lab.
8	55.25.20aac	237	Virginia Argillite	24	< .02	< .02	46	23	8.5	5.5	280	0	<5.0	1.1	.23	<4.4	—	280	210	0	230	320	7.4	—	—	—	20 Aug. 1965	Minn.-Dept. Health
9	55.25.26dbc	275	Virginia Argillite	11	< .01	0	10	1	—	—	207	24	6.0	318.0	1.15	.1	—	—	30	0	210	1350	8.8	—	—	—	1 Apr. 1967	U.S.G.S Field Kit
10	55.25.17dbb2	573	Virginia Argillite and Biwabik Iron-Formation	14	.65	0	54	19	7.5	5.8	271	0	6.1	0.5	.10	1.2	—	224	213	0	222	413	7.8	3	—	46	22 Sept. 1954	U.S.G.S. Lab.
11	56.24.27bcc	280	Biwabik Iron-Formation	14	.30	.05	74	20	11.0	2.9	333	0	16.0	1.0	.20	1.0	.06	296	268	0	273	523	7.8	0	0.8	43	26 Sept. 1957	U.S.G.S. Lab.
12	56.24.4daa	124	Granite	36	5.10	<.10	96	29	—	—	415	24	5.0	5.0	.30	.9	—	—	360	0	380	690	7.4	—	—	—	24 Apr. 1967	U.S.G.S Field Kit

*Columns marked * are printed under the spanning head *MILLIGRAMS PER LITER.

*One milligram per liter (mg/1) is equivalent to one part per million (ppm). Milligrams per liter ÷ 17.1 equals grains per gallon.

EVALUATION OF GROUND-WATER RESOURCES

	Rural domestic, stock, or resort supply	Municipal or industrial supply
Aquifer	Needs for an adequate supply are: Quantity 1. About 5 gpm or more. Quality 1. Total dissolved-solids content less than 1000 mg/1	Needs for an adequate supply are: Quantity 1. 900 gpm or more. Quality 1. Total dissolved solids content less than 500 mg/1 2. Iron content less than 0.3 mg/1 3. Hardness less than 180 mg/1
Sand	Wide distribution, particularly in low-lying inhabited areas. Suitable quality. May be too fine for proper well development. Saturated thickness may be insufficient to supply needed yield	Suitable dissolved-solids content. Inadequate yield. High iron content. High hardness
Ice-contact sand and gravel	Adequate yield. Suitable quality. Distribution limited to moraines and ice-contact areas	A pumping test at well 54.26.29acc obtained a transmissibility value of 82,000 gpd /ft. Suitable dissolved-solids content. Limited distribution. Adequate yields not known (in spite of pumping test). High iron content. High hardness
Buried outwash	Adequate yield. Suitable quality. Limited distribution. May require drilling to at least 150 ft	Adequate yield. Suitable dissolved-solids content. Limited distribution. High iron content. High hardness
Precambrian metasedimentary bedrock (Biwabik Iron-Formation and Virginia Argillite)	Adequate yield. Suitable quality. Limited distribution. May require very deep drilling	Adequate yields produced from mine pits. Suitable dissolved-solids content. Limited distribution. Adequate yields from individual wells not known. High iron. High hardness
Granite	Suitable quality. Adequate yield if well is sufficiently deep. Limited distribution. May require very deep drilling. Used when nothing better is available	Suitable dissolved-solids content. Limited distribution. Inadequate yield. High iron content. High hardness

EXPLANATION

Advantages
Adequate yield
Suitable quality

Disadvantages
Limited distribution
May require very deep drilling

Overall evaluation for needs indicated
Good
Fair
Poor

ACKNOWLEDGMENTS

This report was made possible through the kind cooperation of home owners, well drillers, and municipal and mining company officials. Particular thanks are given the Grand Rapids American Legion Post for furnishing an observation well site, and to the Minnesota Department of Conservation, Division of Forestry, for supplying office space from 1961 to 1965.

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GEOLOGY AND GROUND-WATER RESOURCES OF THE GRAND RAPIDS AREA, NORTH CENTRAL MINNESOTA

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1970