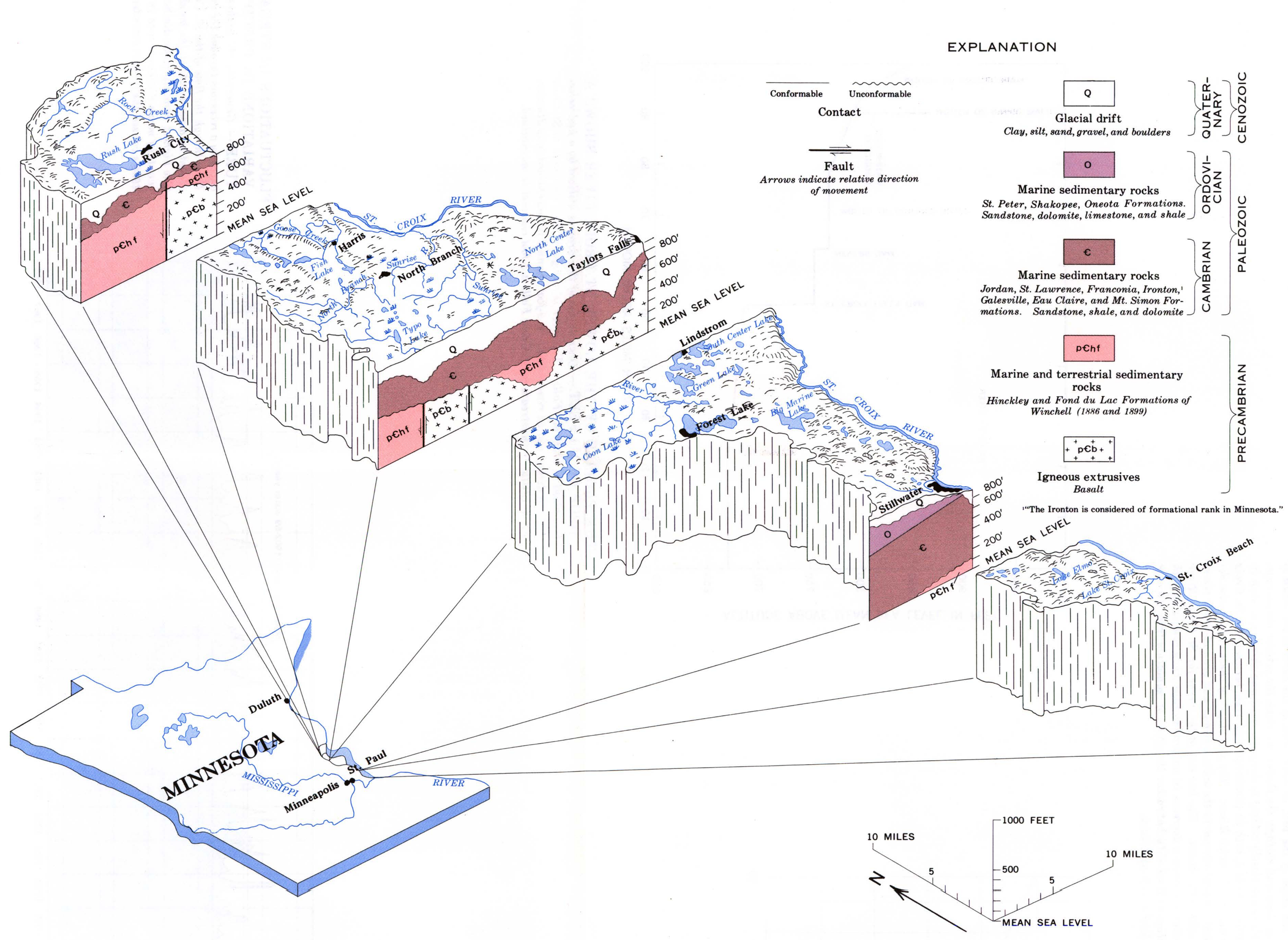
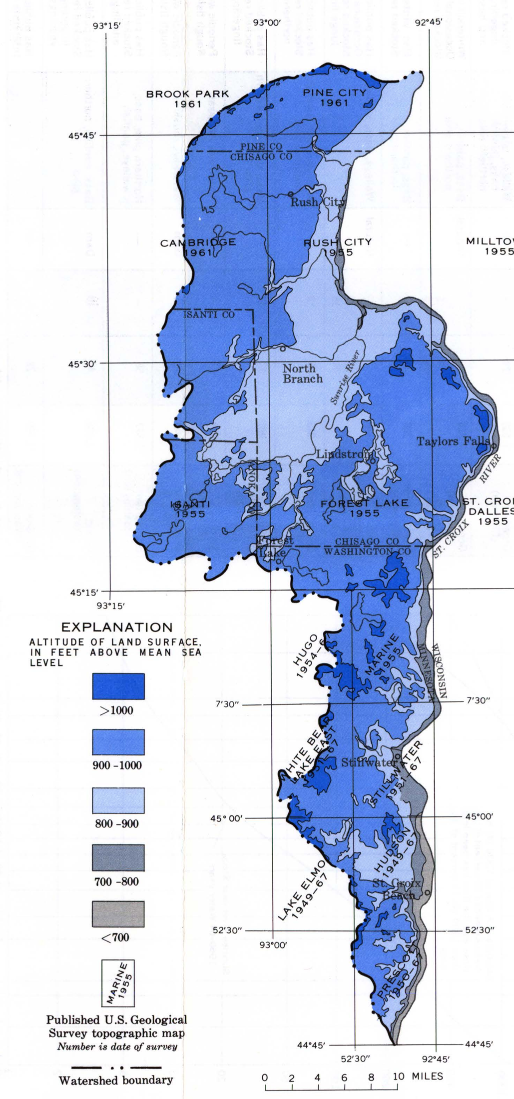
PREPARED IN COOPERATION WITH
THE MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS, SOILS, AND MINERALS

INTRODUCTION





THE LOWER ST. CROIX RIVER WATERSHED IS AN ELONGATE AREA OF ABOUT 930 SQUARE MILES BOUNDED ON THE EAST BY THE ST. CROIX RIVER.

The St. Croix River forms the Minnesota-Wisconsin boundary along the eastern side of the watershed. Additional drainage to the St. Croix River includes areas of about 2,590 square miles upstream in Minnesota and about 4,540 square miles in Wisconsin. At the southern tip of the watershed, the St. Croix joins the Mississippi River.

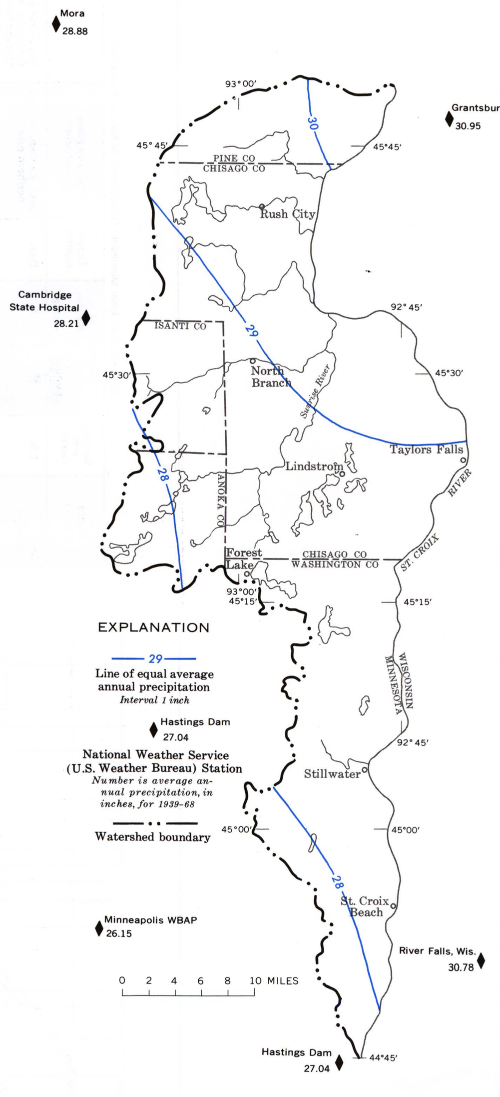
Because part of the St. Croix River is deeply entrenched, topography in the watershed ranges from relatively rugged in highly dissected areas near the river to nearly flat in the west-central area. Topographic maps, as indexed above, are available for the entire watershed from the U.S. Geological Survey.

In the southern third of the watershed and along the St. Croix River, many outcrops of Ordovician, Cambrian, and Precambrian bedrock occur. The remainder of the watershed is covered by glacial deposits whose maximum thickness is about 400 feet.

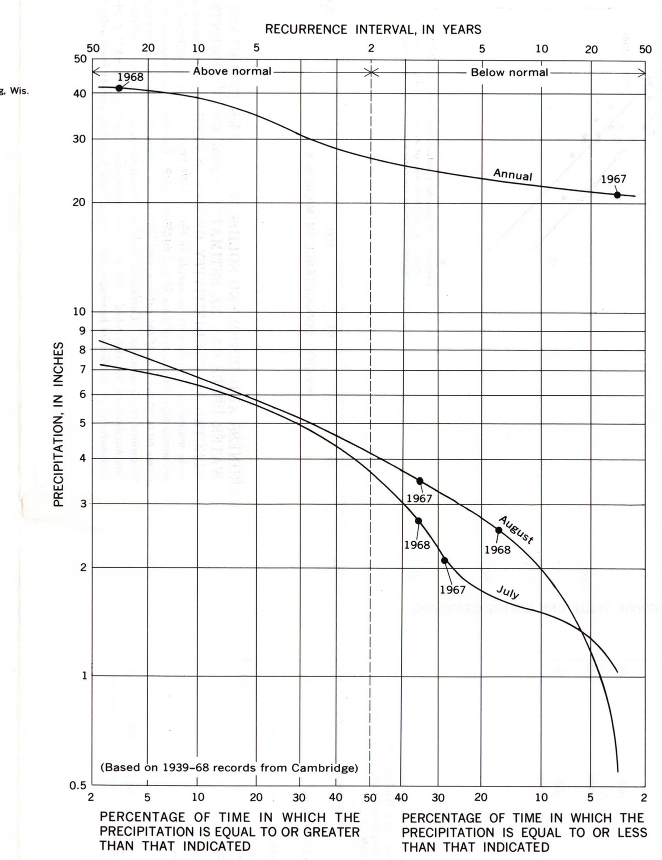
Much of the original forest cover, primarily hardwoods, has been removed; the largest concentrations remaining are along the St. Croix River and in the west-central area.

The proximity of the watershed to the expanding Minneapolis-St. Paul metropolitan area emphasizes the importance of defining water resources essential for future growth.

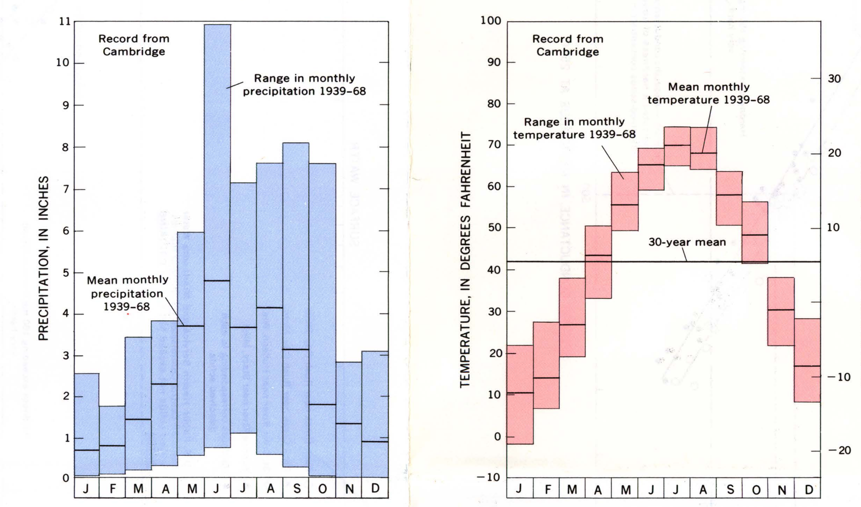
CLIMATE AND WATER BUDGET



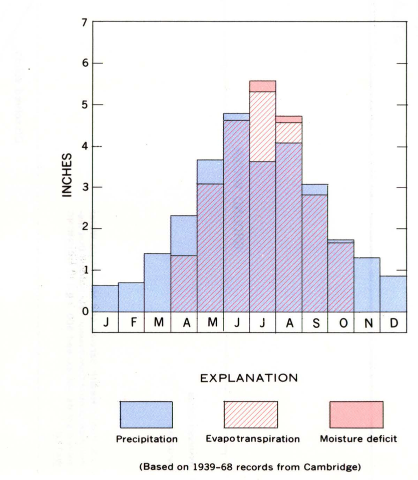
AVERAGE ANNUAL PRECIPITATION, DETERMINED FROM 1939-68 CLIMATOLOGICAL DATA, VARIES CONSIDERABLY ACROSS THE WATERSHED.— *Although no long-term weather stations are in the watershed, data from Cambridge State Hospital, 4 miles west of the watershed boundary, is assumed to be representative and is used for further climatological considerations.*



FREQUENCY ANALYSIS OF PRECIPITATION REVEALS WIDE ANNUAL AND MONTHLY VARIATIONS.— *Low and high annual precipitation extremes occurred in 1967 and 1968, respectively. Even though the total precipitation was high in 1968, it was below normal during July and August. This fact illustrates the importance of considering precipitation distribution as well as total amount.*



VARIATIONS IN MONTHLY MEAN PRECIPITATION AND TEMPERATURE ATTEST TO THE CLIMATIC EXTREMES IN THE WATERSHED.— *Although the greatest amount of precipitation falls during the May-September growing season, the wide range in monthly precipitation during this period indicates the uncertainty of adequate moisture for plant growth.*



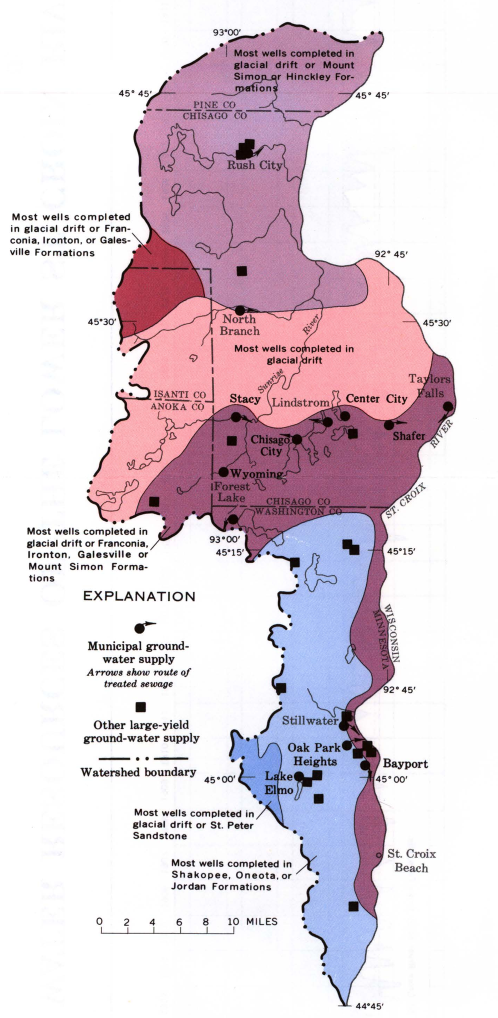
MOISTURE DEFICITS FOR OPTIMUM PLANT GROWTH OCCUR MOST COMMONLY IN JULY AND AUGUST.— *During these months, when temperatures are highest, and plant moisture demands are greatest, evapotranspiration often exceeds precipitation.*

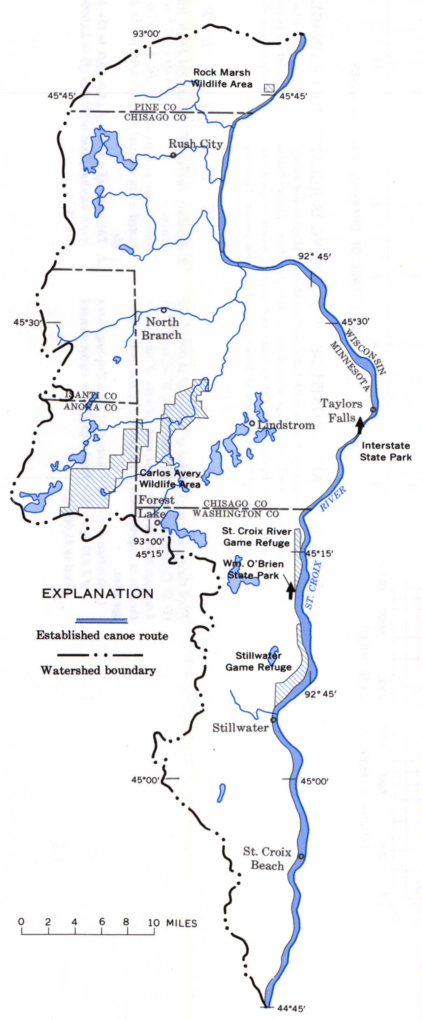
Annual evapotranspiration from the watershed as determined by the method of Thornthwaite and Mather (1957) is 23.4 inches. This quantity compares favorably with the 21.7 inches as determined in the water-budget equation below.

THE AVERAGE ANNUAL WATER BUDGET FOR THE WATERSHED INDICATES THAT PRECIPITATION IS LARGELY OFFSET BY EVAPOTRANSPIRATION LOSSES.— *Runoff for the watershed was determined from records for the Sunrise River basin and from gaging stations in adjacent watersheds. Net underflow and change in storage are unknown; over a long period of time they are assumed to be zero. Data for the period 1939-68 suggest the following average annual hydrologic equation for the watershed:*

PRECIPITATION	=	EVAPOTRANSPIRATION	+	RUNOFF	±	CHANGE IN STORAGE AND NET UNDERFLOW
28.2 inches *(measured)*	=	**21.7 inches** *(remainder)*	+	**6.5 inches** *(measured)*	±	**0** *(assumed)*

WATER USE





VIRTUALLY ALL WATER USED IN THE WATERSHED IS GROUND WATER OBTAINED FROM AQUIFERS IN GLACIAL DRIFT OR CAMBRIAN AND ORDOVICIAN SEDIMENTARY ROCKS.— *Because of the areal distribution of different bedrock units, wells can be grouped according to source of water as illustrated above. Wells in bedrock are generally completed in progressively older aquifers from south to north across the watershed. In the northern half of the watershed, many small-yield wells obtain water from the glacial drift which is generally thicker in that area.*

Ground-water withdrawal in 1967 by municipalities and other selected large users in the watershed was about 1.2 billion gallons. This is a minimum quantity, as data available are not all inclusive. About 60 percent of this amount was for municipal use. Data pertaining to selected large-yield wells are presented in the table at right.

Most communities having a municipal water supply also have secondary sewage-treatment facilities. Exceptions are Stillwater which uses a primary treatment plant and Center City, Lake Elmo, and Wyoming which have no sewage-treatment facilities (Minnesota Pollution Control Agency, 1970).

SUITABLE PHYSICAL FEATURES AND ITS PROXIMITY TO A METROPOLITAN AREA MAKE THE LOWER ST. CROIX RIVER WATERSHED POPULAR FOR WATER-BASED RECREATION.— *The St. Croix River, along the entire eastern boundary of the watershed, is an established canoe route and, above Taylors Falls, is part of the National Wild and Scenic Rivers System. The river and numerous lakes provide excellent swimming, fishing, and boating opportunities. Wildlife management areas and game refuges provide suitable habitat for waterfowl and other wildlife. Recreational pressures in the watershed are increasing rapidly as population increases.*

DATA FOR SELECTED LARGE-YIELD WELLS

Municipality or other user (1970 population)	¼ section	Section	Township	Range	Year completed	Well diameter (inches)	Well depth (feet)	Primary aquifer(s) (Abbreviations for bedrock aquifers: S-O = Shakopee-Oneota, J = Jordan, F-I-G = Franconia-Ironton-Galesville, and MS-H-Fdl = Mount Simon-Hinckley-Fond du Lac)	Well construction	Static water level (feet below land surface)	Test pumping rate (gpm)	Drawdown (ft)	Period of testing (hrs)	Specific capacity (gpm per ft of drawdown)	1967 withdrawal (millions of gallons)	Year analyzed	Total hardness as Ca CO₃ (mg/l)	Iron (mg/l)	Manganese (mg/l)	Dissolved Solids (residue) (mg/l)
Bayport (2,987)	NE	10	29	20	1946	20	310	J	Open hole 173-310	102	1440	60	8	24	80.8	1967	230	0.28	0.09	—
	NW	11	29	20	1952	8	296	J	Open hole 129-296	25	580	6	6	97		1957	240	0.24	0.07	—
	NE	11	29	20	1964	24	399	J, F-I-G	Open hole 136-399	13	1800	37	—	49		1967	230	0.29	0.02	—
Center City (326)	NW	35	34	20	1965	36	629	F-I-G, MS-H-Fdl	Open hole 233-629	85	650	25	6.5	26	7.6	1967	220	0.34	0.09	—
Chisago City (1,868)	SW	6	33	20	1936	8	401	F-I-G	Open hole 217-401	46	150	30	6	5.0	—	1968	130	0.37	0.09	160
	SW	6	33	20	1950	12	401	F-I-G	Open hole 232-401	46	220	34	—	6.5		—	—	—	—	—
	NE	5	33	20	1962	12	602	MS-H-Fdl	Open hole 320-602	36	930	42	—	22		1968	110	0.07	0.08	140
Forest Lake (3,207)	NE	8	32	21	1931	16	678	J, F-I-G, MS-H-Fdl	Open hole 142-678	20	—	—	—	—	77.6	1968	310	1.5	0.02	390
	NW	8	32	21	1950	16	404	F-I-G	Open hole 150-404	20	450	30	—	15		1968	350	1.6	0.02	400
	SE	5	32	21	1965	16	630	F-I-G, MS-H-Fdl	Open hole 310-630	86	710	47	9.5	15		1968	340	1.5	0.02	390
Lake Elmo (4,032)	SW	13	29	21	1962	20	809	J, F-I-G, MS-H-Fdl	Open hole 280-809	96	800	43	—	19	15.8	1968	200	0.02	0.03	220
Lindstrom (1,260)	NE	33	34	20	—	6	300	—	—	50	100	—	—	—	—	—	—	—	—	—
	[illegible]	[illegible]	34	20	—	8	615	MS-H-Fdl	Open hole 507-615	46	420	76	3	5.5		1968	100	0.02	0.09	140
North Branch (1,106)	NW	21	35	21	1947	12	762	MS-H-Fdl	Open hole 263-762	31	350	6	9	58	39.7	1968	250	0.72	0.04	310
Oak Park Heights (1,238)	NE	4	29	20	—	8	204	S-O, J	—	75	—	—	—	—	3.5	—	—	—	—	—
	NW	4	29	20	1967	16	310	J	Open hole 230-310	140	1510	26	40	58	—	1968	190	0.15	0.02	250
Rush City (1,130)	NE	21	37	21	1931	6	98	—	—	22	150	13	—	12	—	—	—	—	—	—
	NE	21	37	21	1957	8	96	MS-H-Fdl	Open hole 78-96	13	260	15	18	17		1968	380	0.86	0.08	660
	SE	16	37	21	1954	12	104	Glacial sand and gravel	Screened 88-104	19	500	43	21	12	32.0	1968	320	0.05	0.24	390
Shafer (149)	SW	32	34	19	1967	8	550	MS-H-Fdl	Open hole 360-550	95	415	70	12	5.9	—	1968	140	0.22	0.02	150
Stacy (278)	NE	32	34	21	1967	8	495	MS-H-Fdl	Open hole 352-495	12	300	18	—	17	—	1967	210	0.93	0.02	270
Stillwater (10,191)	SE	28	30	20	1889	8	321	F-I-G	—	Flowing	1250	—	—	—	469.3	—	—	—	—	—
	NW	28	30	20	1925	12	787	F-I-G, MS-H-Fdl	Open hole 176-787	146	800	30	—	27		—	—	—	—	—
	NW	28	30	20	1956	24	763	F-I-G, MS-H-Fdl	Open hole 176-763	138	1110	54	—	21		1969	210	0.11	0.04	260
	SE	29	30	20	1963	24	220	J	Open hole 155-220	66	1500	58	120	26		—	—	—	—	—
	NE	33	30	20	1967	24	271	J	Open hole 200-271	160	500	30	—	17		1969	200	0.13	0.02	230
Taylors Falls (587)	NE	25	34	19	1942	6	172	—	—	106	120	35	—	3.4	16.7	1968	220	0.02	0.02	260
	NW	25	34	19	1955	8	246	—	—	113	55	33	—	1.7		—	—	—	—	—
	SW	26	34	19	[illegible]	[illegible]	[illegible]	—	Open hole	98	500	102	—	4.9		1968	270	0.02	0.04	320
Wyoming (695)	NE	20	33	21	1965	15	650	MS-H-Fdl	Open hole 339-650	26	1300	124	24	10	19.6	1971	190	0.53	0.08	220
Industry	NW	3	27	20	1964	8	430	—	—	—	200	—	—	—	15.8	—	—	—	—	—
Do	NW	2	29	20	1965	12	664	MS-H-Fdl	Open hole 557-664	5	600	89	24	6.7	11.5	1969	137	4.0	0.13	181
	NW	2	29	20	1965	12	663	MS-H-Fdl	Open hole 570-663	3	610	63	24	9.7						
Do	NW	2	29	20	1965	14	506	F-I-G, MS-H-Fdl	Open hole 157-506	12	1000	22	36	46	39.7					
Do	SW	13	29	21	—	17	150	Glacial sand and gravel	Screened 106-[illegible]	12	250	40	—	6.2	1.1					
Do	NE	28	30	20	—	14	[illegible]	—	—	40	900	10	—	90	Approx. 25					
Do	SW	10	30	21	—	12	[illegible]	—	—	30	—	—	—	—	56.6					
Do	NW	14	32	20	1944	16	301	J	Open hole 206-301	108	155	21	—	7.4	—					
Do	NW	6	33	21	1964	6	[illegible]	MS-H-Fdl	Open hole 225-[illegible]	24	150	39	14	3.8	—					
Do	NW	4	35	21	1966	10	475	MS-H-Fdl	Open hole 250-475	48	120	150	10	[illegible]	—					
Do	NE	21	37	21	1967	6	104	—	—	25	250	39	—	6.4	13.1					
Do	NE	21	37	21	—	4	104	MS-H-Fdl	—	17	210	50	—	4.2	14.1					
Do	NE	21	37	21	—	8	[illegible]	MS-H-Fdl	Screened 55-64	27	475	29	—	16	3.1					
Institution	SE	3	29	20	—	6	[illegible]	F-I-G, MS-H-Fdl	Screened 126-[illegible]	63	800	—	—	—	135.4					
	SE	3	29	20	1961	16	740	F-I-G, MS-H-Fdl	Open hole 340-740	78	1000	61	9	16						
Do	SW	14	32	20	1965	8	344	J	Open hole 203-344	153	70	3	8	23	—					
Do	NW	2	33	20	—	6	309	F-I-G	Open hole 193-309	91	105	19	6	5.5	—					
	NW	2	33	20	1965	4	386	—	Open hole 276-386	81	100	19	—	7.9						
Irrigator	NW	17	29	20	—	12	293	—	—	—	650	—	—	—	31.6					
Do	NE	26	29	21	1960	16	320	J	—	48	780	147	28	5.3	0.1					
	NW	25	29	21	1961	12	285	J	—	23	350	193	25	1.8	16.1					
	NE	25	29	21	1963	10	255	J	—	18	800	139	6	5.8	25.7					
Do	NW	30	32	20	1967	12	260	S-O, J	Open hole 142-260	60	750	28	7	27	5.7					
Do	SE	32	33	22	1950	12	380	MS-H-Fdl	Open hole 280-380	20	250	37	3	7.6	8.7					
	SE	32	33	22	1957	10	236	Glacial sand and gravel	Screened 213-236	25	520	14	6	37	5.3					

SUMMARY AND CONCLUSIONS

RELATIVE ADEQUACY OF WATER SOURCES

PURPOSE	CONSIDERATIONS	SURFACE WATER: St. Croix River	SURFACE WATER: Large lakes	SURFACE WATER: Small lakes and minor streams	GROUND WATER[1]: Surficial outwash[2]	GROUND WATER[1]: Undifferentiated drift[3]	GROUND WATER[1]: St. Peter Sandstone	GROUND WATER[1]: Shakopee and Oneota Formations	GROUND WATER[1]: Jordan Sandstone	GROUND WATER[1]: Franconia, Ironton, and Galesville Formations	GROUND WATER[1]: Mount Simon, Hinckley, and Fond du Lac Formations
Municipal and industrial supply	For a moderate supply, principal needs are: Quantity: Minimum available surface water supply of 1 cfs or wells yielding 250 gpm. Quality: Dissolved-solids content less than 500 mg/l. Hardness less than 180 mg/l.	Adequate supply / Location favorable for only a few communities. Treatment necessary for municipal use.	Adequate supply from most. Good areal distribution / Treatment necessary for municipal use	Many adequate with development of storage facilities. Good areal distribution / Treatment necessary for municipal use	Adequate quantity where saturated thickness is sufficient. Rapid recharge from precipitation. Generally good quality. Inexpensive to develop relative to other sources. / General fine texture of sand necessitates proper screening. Easily polluted. Treatment of hardness and iron may be necessary.	Buried sand or gravel may yield adequate supply. Wells may be open to more than one aquifer. Generally good quality / Aquifer extent generally small. Recharge may be slow. Treatment for hardness and iron may be necessary. May be costly to develop	May yield adequate quantity. Good quality / Small areal extent	May yield adequate supply using several wells. Good quality / Difficult to predict water-yielding capability because of uncertainty of intersecting fractures and solution cavities. Relatively small areal extent. May be easily polluted	Adequate quantity. Good quality	May yield adequate quantity. Good quality / Fine texture of Franconia Formations may limit its productivity.	Commonly yields adequate quantity. Good quality. Thickness of sandstone enhances possibility of obtaining large yield. / Hinckley Formation discontinuous, hard to predict water-yielding capability. May require wells several hundred feet deep. Fond du Lac Formation contributes little water to wells because of fine texture.
Rural domestic and stock supply	For an adequate farm supply needs are: Quantity: Minimum of 5 gpm. Quality: Dissolved-solids content less than 1,000 mg/l.	Adequate supply / Available only to riparian lands. Treatment necessary for domestic use	Adequate supply / Available only to riparian lands. Treatment necessary for domestic use	Adequate for stock / Available only to riparian lands. Treatment necessary for domestic use	Adequate quantity and quality. Inexpensive to develop relative to other sources. / General fine texture of sand necessitates proper screening. Easily polluted. Treatment for hardness and iron may be necessary for domestic use.	Commonly adequate quantity. Generally good quality. Large areas of thick drift enhance probability of encountering permeable zone yielding at least a domestic supply. / Treatment for hardness and iron may be necessary for domestic use.	Commonly adequate quantity. Good quality / Small areal extent	Generally adequate quantity and quality. / Relatively small areal extent. May be easily polluted	Adequate quantity. Good quality	Generally adequate quantity and quality. / Depth of well required may be prohibitive in parts of watershed.	Adequate quantity and quality / Depth of well required may be prohibitive in parts of watershed.
Irrigation supply	For an average farm needs are: Quantity: Minimum available surface-water supply of 2 cfs during growing season or wells yielding 250 gpm. Quality: Suitability of water quality for irrigation as indicated by classification of U.S. Dept. of Agriculture.	Adequate supply / Available only to riparian lands	Adequate supply / Available only to riparian lands	Many are adequate for small acreage / Available only to riparian lands	Adequate quantity where saturated thickness is sufficient. Rapid recharge from precipitation. Good quality. Inexpensive to develop relative to other water sources. / General fine texture of sand necessitates proper screening.	Buried sand or gravel may yield adequate supply. Wells may be open to more than one aquifer. Good quality. / Aquifer extent generally small. Recharge may be slow. May be costly to develop	May yield adequate quantity. Good quality / Small areal extent	May yield adequate supply using several wells. Good quality / Difficult to predict water-yielding capability because of uncertainty of intersecting fractures and solution cavities. Relatively small areal extent	Adequate quantity. Good quality	May yield adequate quantity. Good quality / Fine texture of Franconia Formations may limit its productivity.	Commonly yields adequate quantity. Good quality. Thickness of sandstone enhances possibility of obtaining large yield. / Hinckley Formation discontinuous, hard to predict water-yielding capability. May require wells several hundred feet deep.
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: Wetlands—lakes or potholes surrounded by marsh areas. Streams—marsh and woodland along banks.	Excellent migratory waterfowl resting and feeding areas. Excellent wildlife habitat along banks. Excellent for fish / Occasional high water	Excellent migratory waterfowl resting and feeding areas. Excellent wildlife habitat along banks. Excellent for fish	Good migratory waterfowl resting and feeding areas. Excellent habitat along shores and banks. Wide areal distribution / Low water stage during droughts							
Recreation	Adequate access to lakes and streams. Availability of areas suitable for hunting, fishing, and other water sports. Available resorts, lake cottages and campgrounds. Esthetic values and absence of pollution.	Public access at many sites. Suitable for hunting, fishing, and water sports. Favorable location with respect to municipalities. Esthetic values generally good / Occasional high water	Public access at many sites. Suitable for hunting, fishing, and water sports. Favorable location with respect to municipalities. Lakeshore resorts and residences	Public access at many sites. Many suitable for hunting, fishing and water sports. Wide areal distribution / Occasional high water. Low water stage during droughts							

[1] The Platteville, Glenwood and St. Lawrence Formations, Eau Claire Sandstone, and basalt are relatively poor water sources and usually occur in association with one or more of the better aquifers included herein.
[2] Includes gray-brown and red outwash where not separated by till.
[3] Includes gray and red undifferentiated drift.

EXPLANATION

Buried sand or gravel may yield adequate supply
Wells may be open to more than one aquifer
Generally good quality
} Desirable features above line

Aquifer extent generally small
Recharge may be slow
Treatment for hardness and iron may be necessary
May be costly to develop
} Undesirable features below line

Good — Fair — Poor

Color indicates overall adequacy of water source as evaluated for specific purposes

CONCLUSIONS

1. Based on climatological data for 1939-68, average annual precipitation in the Lower St. Croix Watershed is about 28 inches. Of that amount, about 22 inches is removed by evaporation and transpiration. The average annual runoff is about 6 inches.
2. The St. Croix River is a major control on ground-water movement in the watershed. Movement is generally east toward the river even where the bedrock dips westward.
3. Virtually all large water users in the watershed obtain water supplies from bedrock aquifers. Withdrawals in 1967 exceeded 1.2 billion gallons.
4. The most productive bedrock aquifers are: Jordan Sandstone; Franconia, Ironton, and Galesville Formations; and Mount Simon, Hinckley, and Fond du Lac Formations. Each is generally capable of yielding several hundred gallons per minute to wells. The common practice of completing a well open to several bedrock units generally satisfies even very large water-supply needs.
5. Water-yielding capability of glacial drift varies widely because of the random occurrence of sand and gravel contained therein. Thickness of the drift commonly ranges from 0-200 feet and exceeds 400 feet in some bedrock valleys. The thickest sections may include substantial amounts of productive sand and gravel.
6. Some of the surficial outwash in the west-central part of the watershed is theoretically capable of yielding 500-1,000 gpm to wells. Because of the generally low hydraulic conductivity of this outwash, its water-yielding capability is largely dependent on saturated thickness.
7. The predominance of calcium magnesium bicarbonate waters results from the widespread occurrence of calcium-magnesium carbonate minerals throughout the watershed.
8. Ground water in the watershed is generally very hard, greater than 180 mg/l (milligrams per liter). Water from any of the formations may be high in iron, exceeding the recommended limits of 0.3 mg/l for drinking water.
9. Water quality in bedrock is generally similar to that of the overlying drift. An exception is in the southern part of the watershed where water from carbonate aquifers is commonly higher in dissolved solids than water from the overlying drift.
10. The lower St. Croix River, its tributaries, and many lakes, provide an abundance of water of good quality which is suitable for most industrial, municipal, and agricultural uses.
11. Surface water provides excellent year-round recreational facilities and habitat for fish and wildlife.
12. Flooding is not a major problem in the basin. Most flood damage is confined to the vicinity of Lake St. Croix.
13. Streamflow is sustained during dry periods by the large amount of natural storage, both on the surface and in the ground.

ACKNOWLEDGMENTS

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By
G. F. Lindholm, J. O. Helgesen, W. L. Broussard, and D. F. Farrell

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