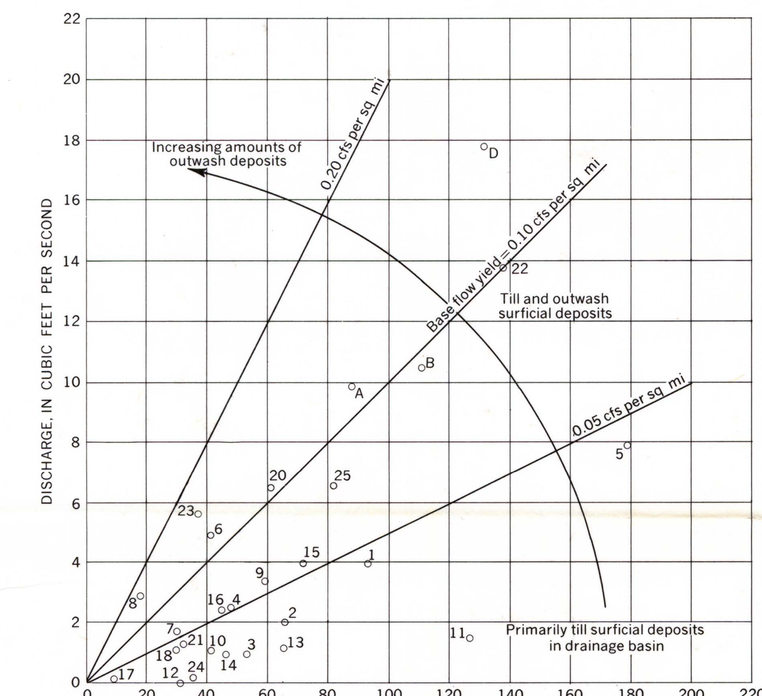
PREPARED IN COOPERATION WITH THE
MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS, SOILS, AND MINERALS

SURFACE WATER

SITE DATA FOR FLOW DIAGRAM

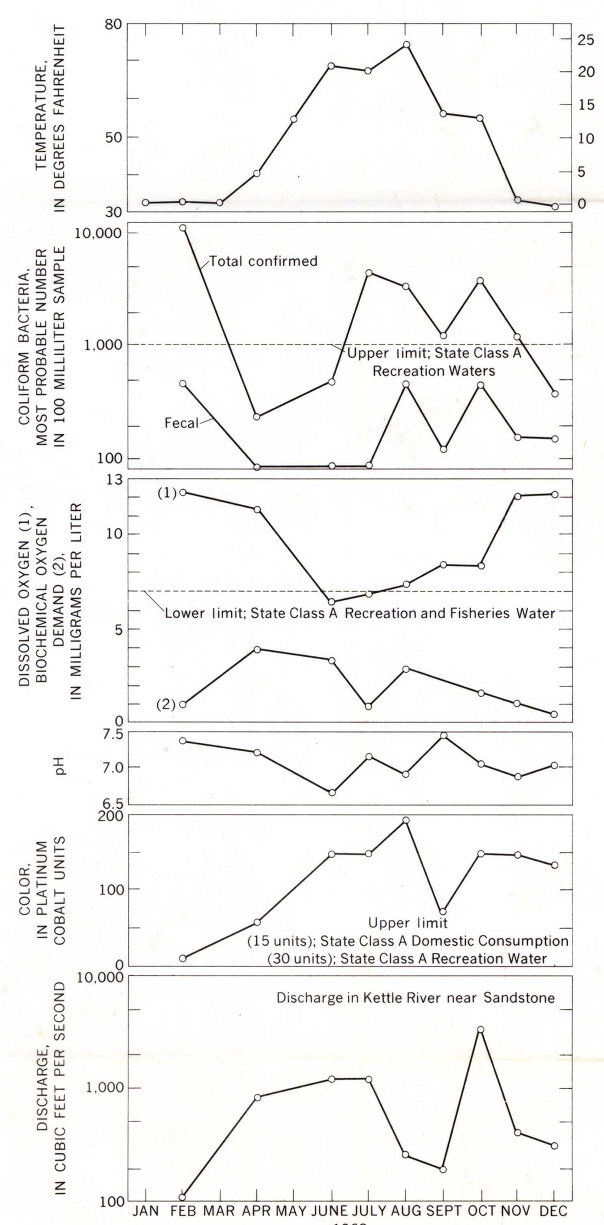
Letter or number key	Partial record or miscellaneous discharge measurement site	Drainage area (sq mi)	Discharge measured during base-flow period Sept 5–7, 1967 (cfs)	Yield cfs per sq mi	7-day minimum discharge, 10-year recurrence interval (cfs)
A	Crooked Creek near Hinckley	88	9.95	0.113	6
B	Sand Creek near Hinckley	111	10.5	.095	7
C	Kettle River near Sturgeon Lake	308	4.91	.016	3
D	Moose River at Sturgeon Lake	132	17.8	.135	11
E	Kettle River near Sandstone	820	—	—	65
1	Upper Tamarack River at Markville	93	3.94	.042	—
2	Lower Tamarack River near Duxburg	66	1.99	.030	—
3	McDermott Creek near Duxburg	53	0.99	.019	—
4	Hay Creek near Markville	48	2.58	.054	—
5	Lower Tamarack River near Markville	179	7.93	.044	—
6	Sand Creek near Sandstone	42	4.89	.116	—
7	Little Sand Creek near Hinckley	30	1.71	.057	—
8	Clover Creek near Hinckley	18	2.90	.161	—
9	Bear Creek near Hinckley	59	3.39	.057	—
10	West Branch River near Kettle River	41	1.07	.026	—
11	Kettle River near Kettle River	127	1.51	.012	—
12	Dead Moose River near Kettle River	31	dry	.000	—
13	Split Rock River near Kettle River	65	1.16	.018	—
14	Birch Creek near Sturgeon Lake	46	0.97	.021	—
15	Moose River at Barnum	72	3.96	.055	—
16	Willow River near Kerrick	45	2.64	.059	—
17	Hay Creek near Kerrick	9.5	0.13	.014	—
18	Little Willow River near Bruno	30	1.08	.036	—
19	Willow River at Willow River	147	17.5	.119	—
20	Pine River near Rutledge	62	6.50	.105	—
21	Bremen Creek near Rutledge	32	1.23	.038	—
22	Pine River at Rutledge	138	13.8	.100	—
23	North Br. Grindstone River near Hinckley	37	5.65	.153	—
24	South Br. Grindstone River near Hinckley	35	0.23	.007	—
25	Grindstone River near Hinckley	82	6.59	.080	—
26	Kettle River near Hinckley	1000	124	.124	—



BASE-FLOW YIELDS ARE RELATED TO THE TYPE OF SURFICIAL DEPOSITS IN THE DRAINAGE BASIN

During the low-flow period, September 5–7, 1967, base-flow yields were generally less than 0.05 cfs per square mile from those drainage basins whose surficial deposits are primarily till. Yields exceeding 0.05 cfs per square mile were from basins having surficial deposits consisting of till and outwash. The basins containing more extensive outwash areas generally had a correspondingly higher base-flow yield.

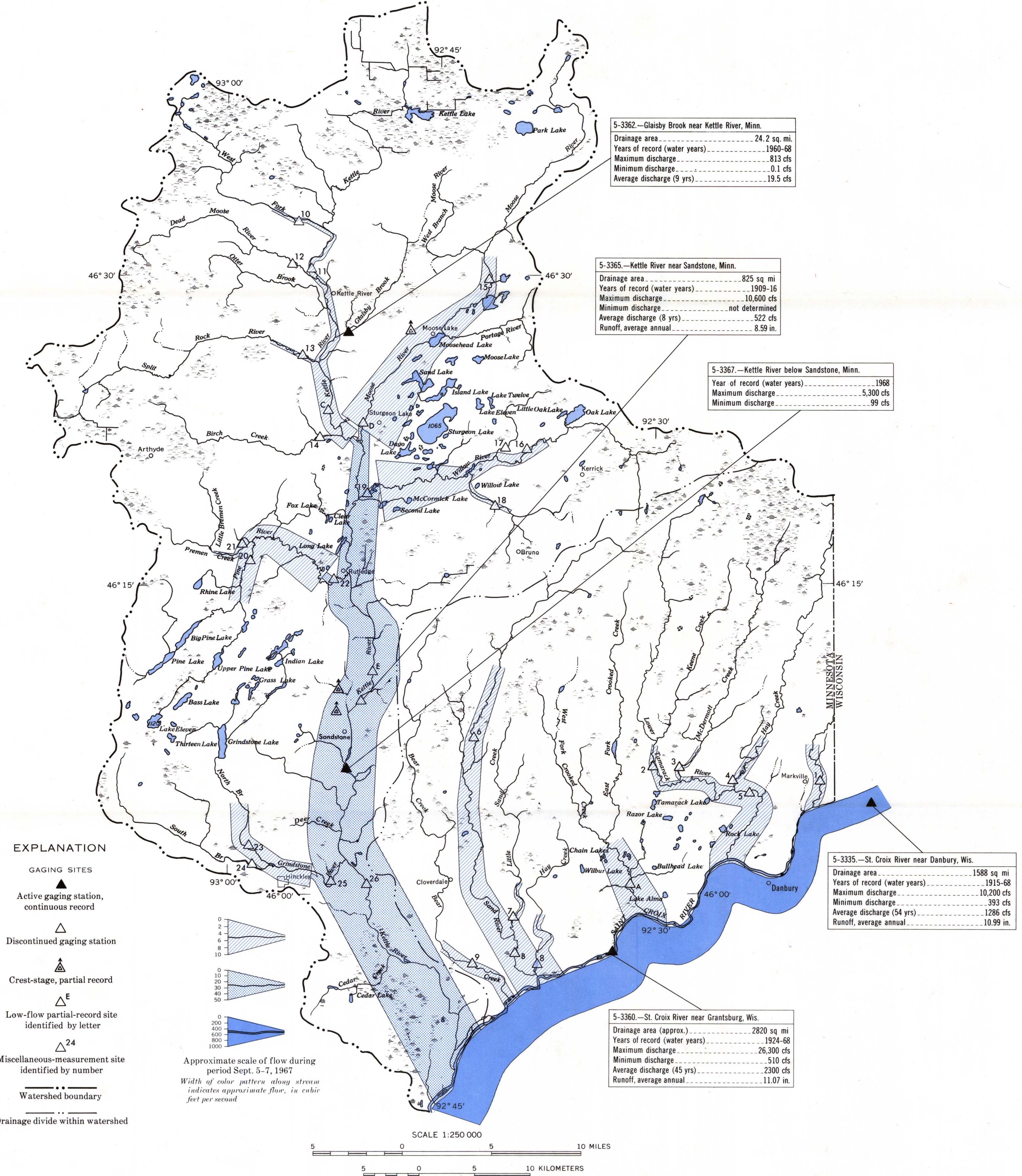
The largest yield in the watershed was on the mainstem of the Kettle River from Sturgeon Lake to Sandstone. Excluding contributions of major tributaries, there was a flow increase of 53 cfs in this reach from 99 square miles of intervening area. This high yield of 0.54 cfs per square mile is attributed to two factors: (1) the large outwash area located in the upper two-thirds of this reach, and (2) the entrenchment of the Kettle River into the water-bearing sandstones of the Hinckley formation. See section D-D′ on Sheet 3.



SAMPLES COLLECTED BY MINNESOTA POLLUTION CONTROL AGENCY FROM KETTLE RIVER 4.5 MILES EAST OF HINCKLEY

MONTHLY VARIATION OF POLLUTION PARAMETERS, COLOR, ACIDITY, AND TEMPERATURE, ARE RELATED TO SEASON, ENVIRONMENTAL CONDITIONS, AND DISCHARGE.

Color in water from the Kettle River increases during periods of high discharge because heavy rainfall flushes decaying organic matter from swamps. The pH shows an indirect relation to color because decaying organic matter releases carbon dioxide to the water making it less alkaline or slightly acid. Dissolved oxygen and biochemical oxygen demand concentrations are generally inversely related because organic color creates a demand for oxygen. A small amount of sewage effluent, and the decaying organic matter which imparts color, create a biochemical oxygen demand which brings the dissolved oxygen concentrations to the lower limits of State Class A requirements during the months when other stresses such as temperature and photosynthetic activity adversely affect dissolved oxygen levels. Total coliform bacteria concentrations generally exceed recommended limits during summer months. Fecal coliform concentrations serve as a positive indication of fecal contamination by warm-blooded animals.

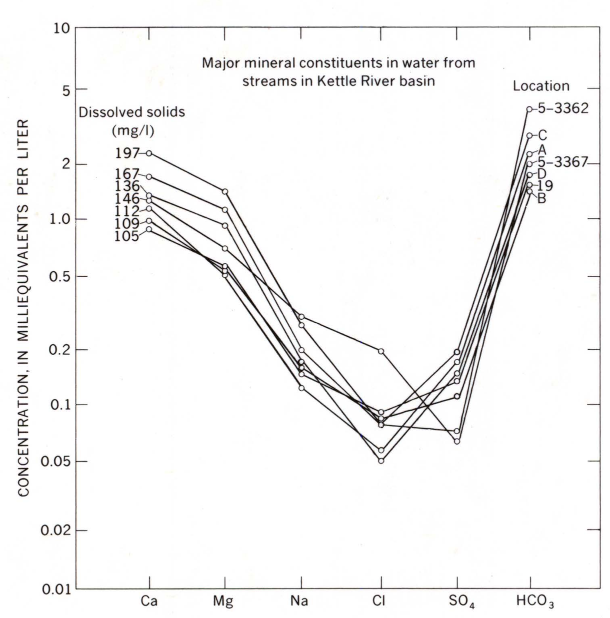


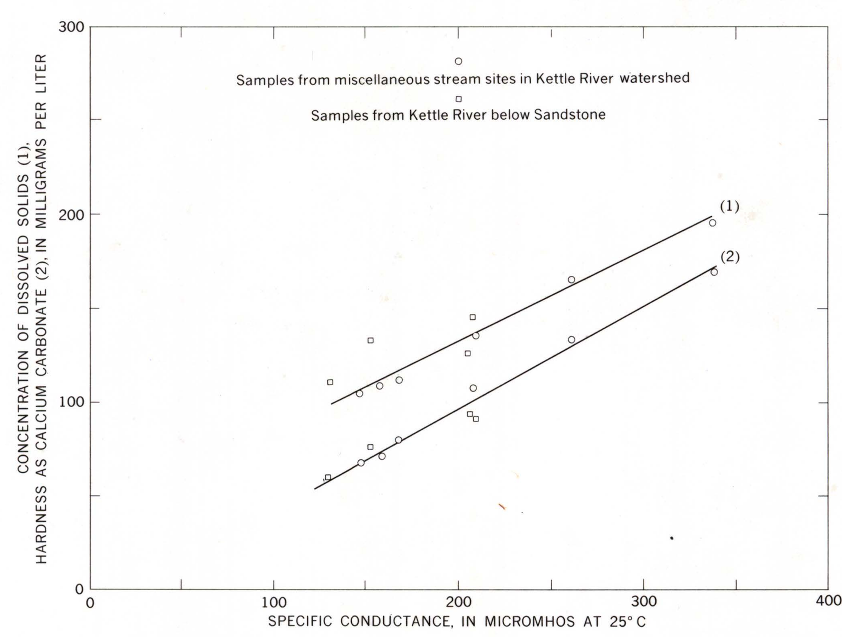
THE FLOW DIAGRAM SHOWS THE DISTRIBUTION OF STREAMFLOW IN THE WATERSHED DURING THE LOW-FLOW PERIOD, SEPTEMBER 5–7, 1967

A series of discharge measurements was made during September 5–7, 1967, to determine the distribution of the surface-water resources in the watershed within the given time interval. There was no measurable precipitation for 10 days prior to this investigation so the stream-flow measured was primarily ground-water discharge and represents base-flow yields from these basins.

The flows indicate in the diagram for the Kettle River basin and the direct tributaries to the St. Croix River will occur as annual minimum 7-day flows at intervals averaging about 1.5 years. At low-flow partial record sites A–E, the annual minimum 7-day flows will be approximately two-thirds of the discharge shown at intervals averaging 10 years in length.

More than 70 percent of the annual minimum monthly mean discharges recorded at gaging stations in the St. Croix River basin occur late in the winter. The annual minimum monthly mean discharges occurring outside the winter period are usually for the months of August or September and result from prolonged drought conditions.





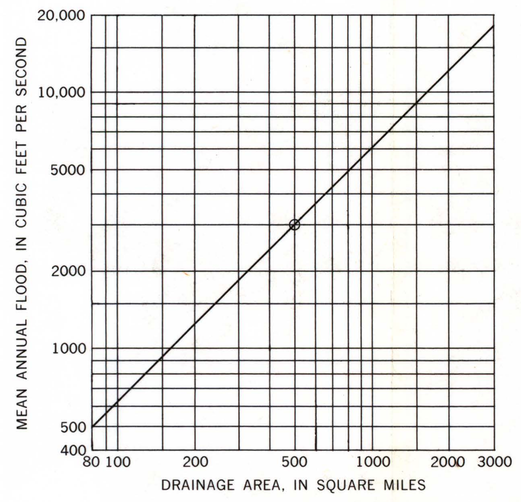
CHEMICAL ANALYSES
(RESULTS IN MILLIGRAMS PER LITER EXCEPT AS INDICATED)

Source	Date collected	Discharge (cfs)	Silica	Iron	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Fluoride	Nitrate	Boron	Dissolved solids (residue)	Hardness as $CaCO_3$	Manganese	Color (platinum cobalt units)	Phosphate (ortho)	Lab. pH
Crooked Creek near Hinckley (A)	Sept 7, 1967	10.0	14	0.16	25	11	3.7	1.0	126	6.8	1.7	0.1	0.2	0.02	136	108	0.01	12	0.03	8.0
Sand Creek near Hinckley (B)	Sept 7, 1967	10.5	14	.49	17	6.4	3.4	.9	82	6.2	3.1	.1	.2	.02	105	69	.06	11	.02	7.8
Glaisby Brook near Kettle River (5-3362)	Sept 5, 1967	0.3	15	.04	42	16	6.0	.9	220	3.5	2.8	.1	.2	.01	197	171	.05	4	.02	7.9
Kettle River near Sturgeon Lake (C)	Sept 6, 1967	4.9	4.0	.06	32	13	4.4	1.5	162	8.8	2.7	.2	.4	.02	167	133	.04	38	.02	8.1
Moose River at Sturgeon Lake (D)	Sept 6, 1967	17.8	9.8	.08	22	6.1	2.8	1.0	95	7.8	2.0	.1	.2	.01	112	80	.05	17	.02	8.0
Willow River at Willow River (19)	Sept 6, 1967	17.5	11	.30	19	6.1	3.6	.9	90	5.2	3.0	.1	.1	.01	109	72	.07	10	.01	7.7
Kettle River below Sandstone (5-3367)	Sept 7, 1967	108	12	.43	24	8.5	6.9	1.2	110	5.8	8.0	.1	.2	.02	125	95	.13	14	.03	
	Sept 25, 1967	102	13	.44	24	8.1	7.0	1.4	113	3.0	6.6	.1	.1	.03	146	93	.12	4	.13	7.6
	June 21, 1968	3,030	8.4	.80	20	6.8	2.5	2.0	86	7.7	1.5	.3	1.4	.04	133	77	.17	100		7.9
	Oct 3, 1968	445	11	1.3	16	5.3	3.0	1.8	65	7.7	3.0	.2	1.1	.04	112	61	.11	100	.15	7.4
Recommended upper limits: State Class A Domestic Consumption Water				0.30						250	250	0.15	45		500		0.05	15		

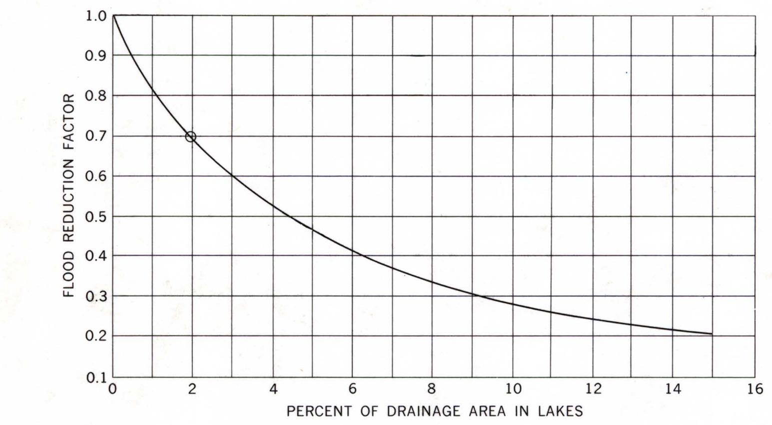
WATER FROM STREAMS IN THE KETTLE RIVER WATERSHED CONTAINS MINERALS TAKEN INTO SOLUTION PRINCIPALLY FROM GLACIAL DRIFT

Dissolved solids and individual constituents show only minor variations as the discharge of the Kettle River changes. Iron and manganese concentrations at site 5-3367 are generally higher than at other stream sites because the Kettle River in this reach receives inflow from sandstone aquifers containing higher concentrations of reduced iron and manganese.

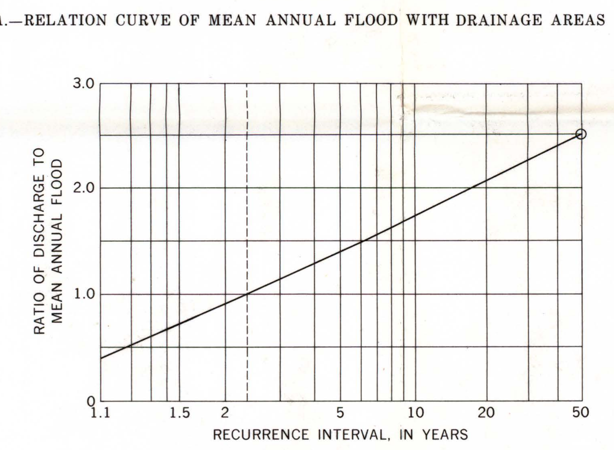
The level of dissolved solids (105–197 mg/l) in stream water of this basin is characteristic of minerals in solution from a calcium-magnesium carbonate environment. Major mineral constituents in water from these streams are calcium, magnesium, bicarbonate, and small varying concentrations of other constituents. Dissolved solids and hardness concentrations approximate a linear relationship to specific conductance.



A.—RELATION CURVE OF MEAN ANNUAL FLOOD WITH DRAINAGE AREAS



B.—FLOOD REDUCTION CURVE



C.—FLOOD FREQUENCY CURVE FOR KETTLE RIVER BASIN

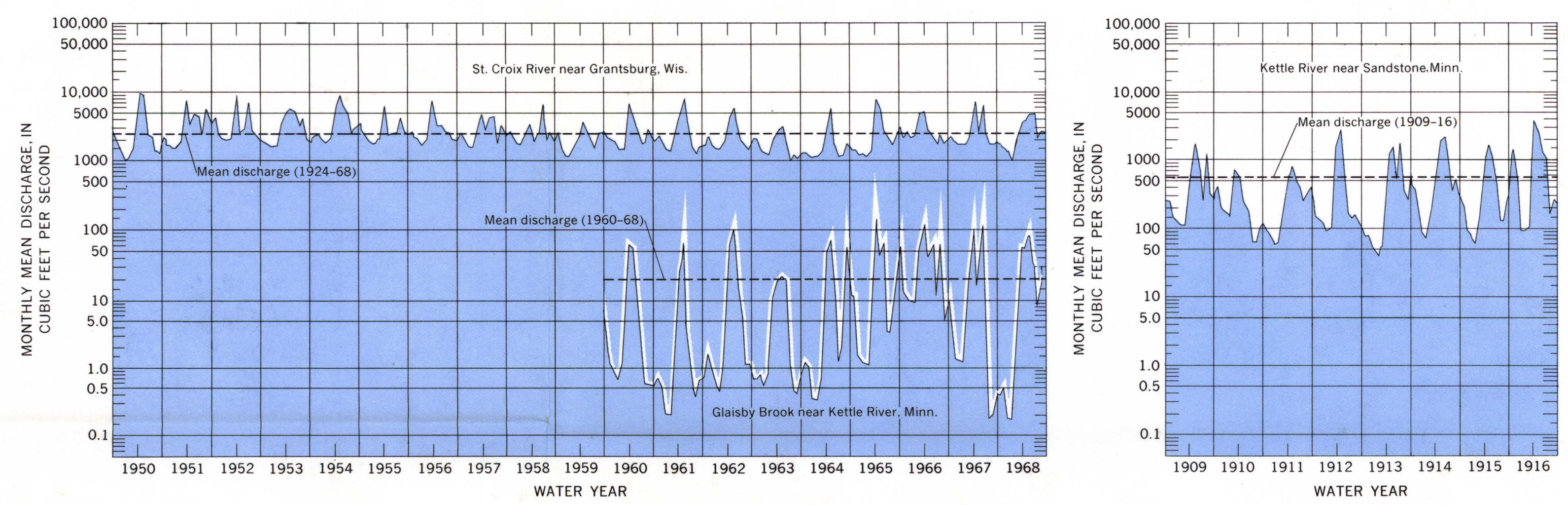
THE MAGNITUDE AND FREQUENCY OF FLOODS CAN BE DETERMINED BY USE OF RELATION CURVE A, FLOOD-REDUCTION CURVE B, AND FLOOD-FREQUENCY CURVE C

Example.—Find the magnitude of a flood having a 5-year recurrence interval at a site having a 500 square mile drainage area of which 2.0 percent is lakes.

1. *From curve in diagram A, the mean annual flood for 500 sq mi drainage area is 3,000 cfs.*
2. *From curve in diagram B, when 2.0 percent of the drainage area is lakes, the mean annual flood is reduced by a factor of 0.69. The adjusted mean annual flood becomes 0.69 x 3,000 cfs = 2,070 cfs.*
3. *From frequency curve in diagram C, the ratio of a flood having a 50-year recurrence interval to the mean annual flood is 2.5.*
4. *The magnitude of the 50-year flood is the mean annual flood times the ratio or 2,070 cfs x 2.5 = 5,180 cfs.*

The recurrence interval of a flood of a selected magnitude can be found by reversing this procedure.

Curves are from Patterson and Gamble (1968).

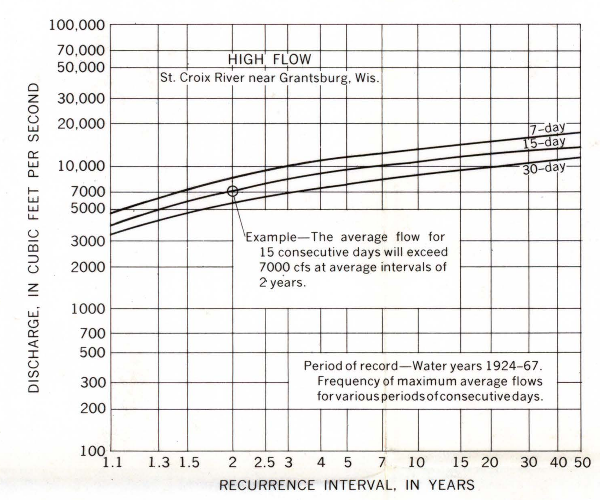


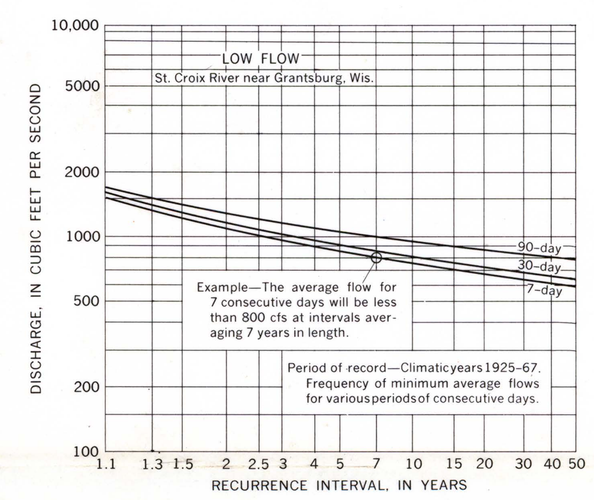
VARIATION IN MONTHLY MEAN DISCHARGE IS SHOWN BY THE HYDROGRAPHS

The hydrograph for St. Croix River near Grantsburg, Wis. does not include the first 26 years of record at this gaging station. The period selected does include the maximum monthly mean discharge of 9,774 cfs that occurred in May 1950, but not the minimum monthly that occurred in August 1934 when the discharge averaged 616 cfs.

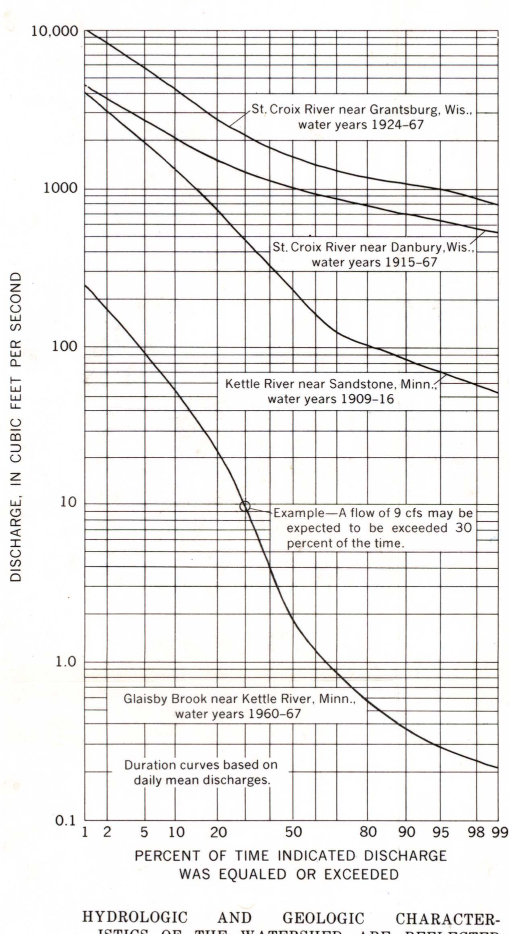
In contrast to the stable flow of the St. Croix River is the erratic flow in Glaisby Brook near Kettle River. The drainage area at this site is small so the large variation in flow is to be expected. Surficial deposits in this basin are predominantly till but include some outwash in the lower part of the basin.

The streamflow record for the Kettle River near Sandstone is for the period 1909–16. Long-term records on nearby streams indicate flow for this 8-year period was about 10 percent less than the long-term averages.





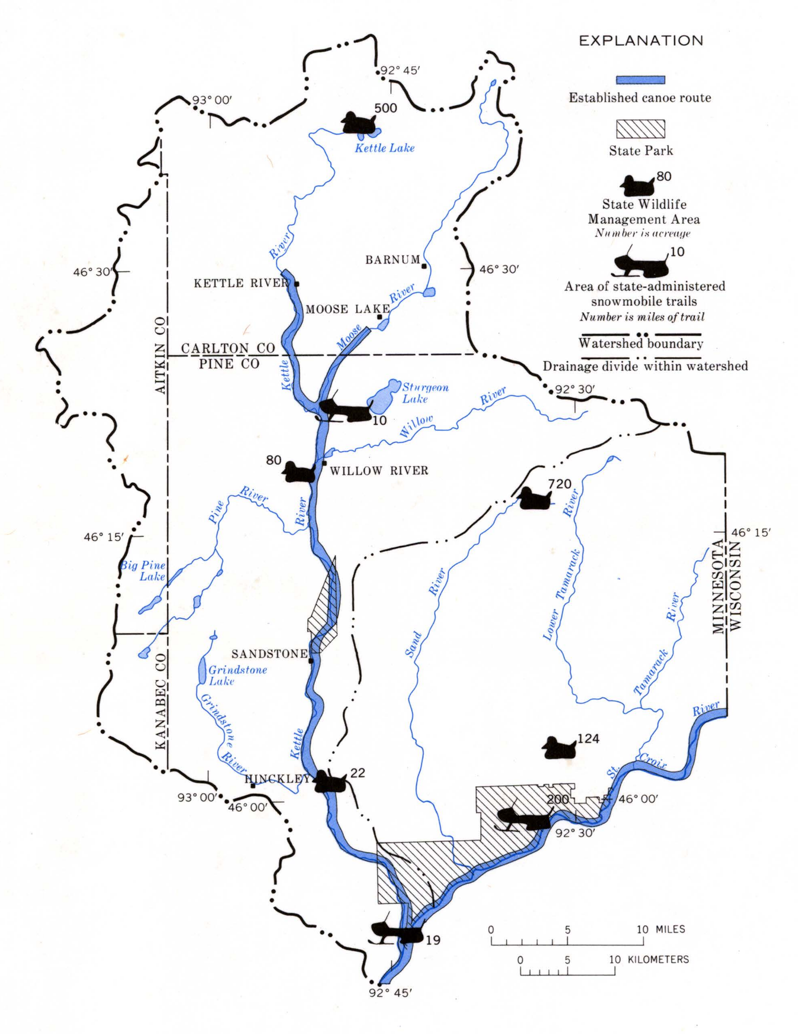
THE STABLE FLOW OF THE ST. CROIX RIVER IS ILLUSTRATED BY THE LOW-FLOW AND HIGH-FLOW FREQUENCY CURVES FOR THE ST. CROIX RIVER NEAR GRANTSBURG, WISCONSIN



HYDROLOGIC AND GEOLOGIC CHARACTERISTICS OF THE WATERSHED ARE REFLECTED IN THE SHAPE OF THE FLOW-DURATION CURVES.

—Surface runoff from till of low permeability in the Kettle River drainage basin is affected by storage in lakes, swamps, and areas having little topographic relief. This storage effect is reflected in the moderate slope of the upper part of the duration curve for the Kettle River near Sandstone. The relatively flat slope of the lower part of the curve represents base flow during extended periods of no rainfall and through the winter months.

The rather large variation in flow shown in the duration curve for Glaisby Brook near Kettle River is typical for smaller drainage basins. Low flows at this site are maintained by discharge from a small outwash area in the basin. Nearby basins of similar size containing no outwash areas would probably be dry during parts of most years (Site 12).



LARGE FORESTED AREAS AND NUMEROUS STREAMS IN THE KETTLE RIVER WATERSHED OFFER GOOD RECREATIONAL OPPORTUNITIES.

—Two State parks provide areas for public camping, boating, snowmobiling, and other outdoor activities. Several wildlife management areas maintained by the state contribute toward wildlife conservation.

Canoeists on the St. Croix, Kettle, and Moose Rivers may encounter conditions varying from easy in some reaches to extremely difficult in others. The St. Croix River shown above was designated as part of the National Wild and Scenic Rivers System, assuring its preservation for future recreational use.

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WATER RESOURCES OF THE KETTLE RIVER WATERSHED, EAST-CENTRAL MINNESOTA

By
J. O. Helgesen, G. F. Lindholm, W. L. Broussard, and D. W. Ericson
1973