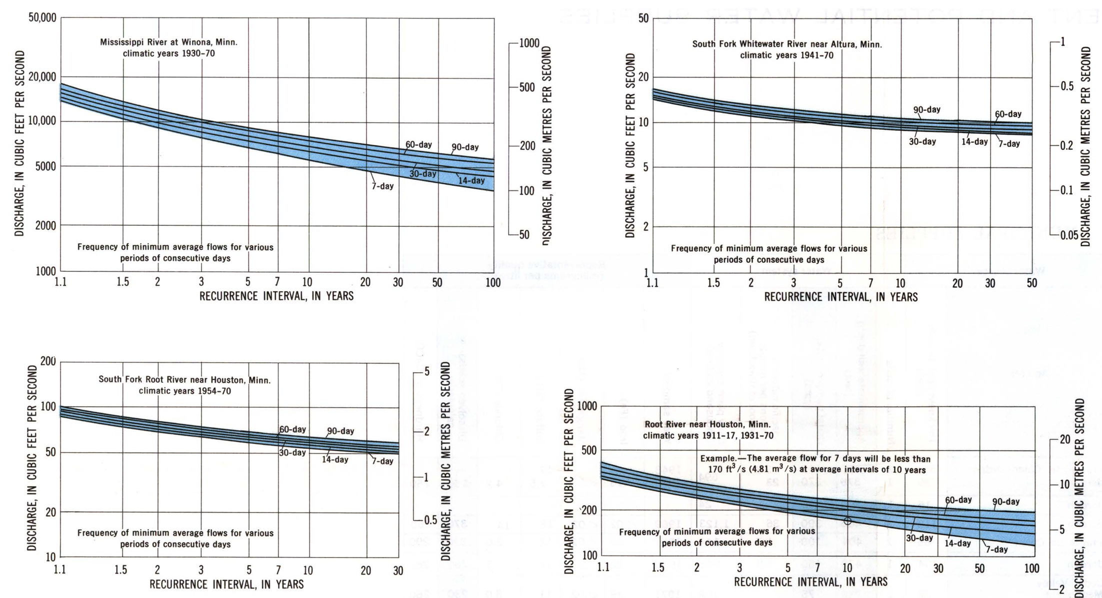
SURFACE WATER

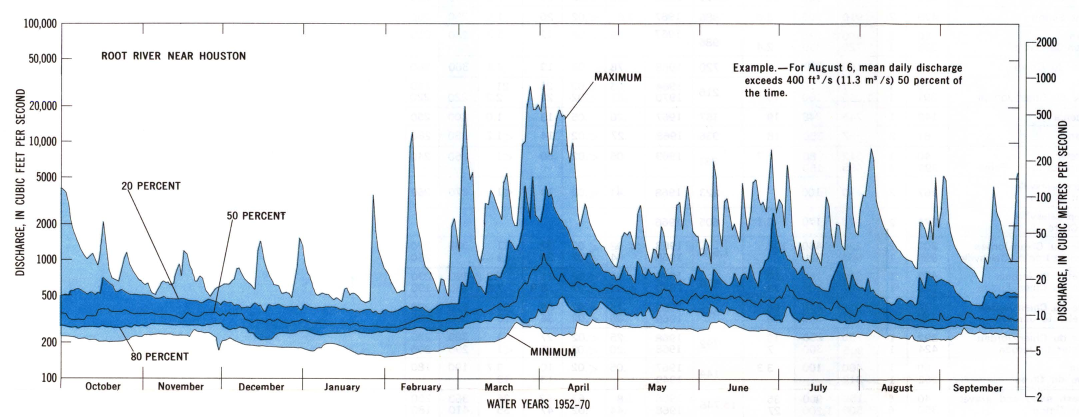
Variations of streamflow affect the suitability and quantity of water available for various uses. Consideration of magnitude, frequency and time of occurrence, effects of streamflow upon quality, and the duration of streamflow variations are necessary for the evaluation of surface-water resources.

LOW-FLOW FREQUENCY CURVES



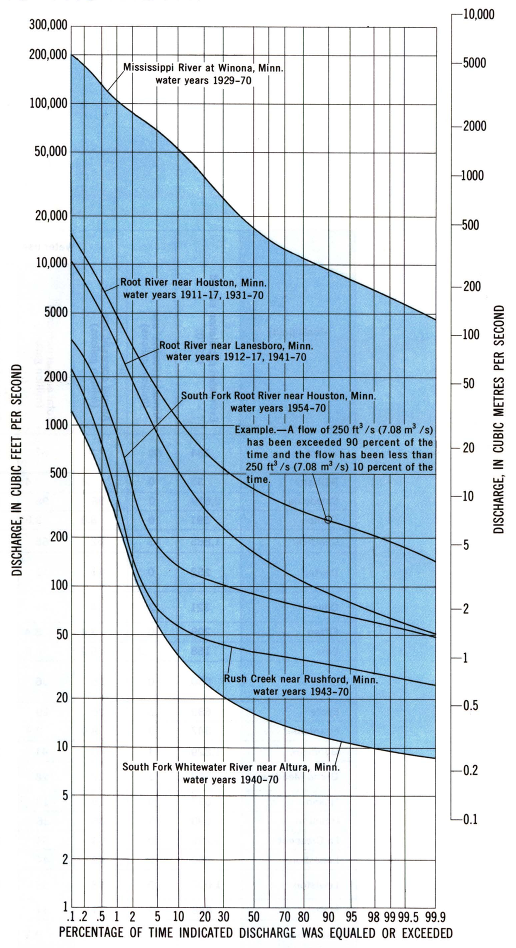
KNOWLEDGE OF LOW STREAMFLOW AND ITS FREQUENCY OF OCCURRENCE IS A NECESSITY IN THE ECONOMIC DESIGN OF WATER SUPPLY, POLLUTION ABATEMENT, AND RECREATIONAL DEVELOPMENT PROJECTS

The slope of the frequency curve is a function of basin storage. A flatter slope depicts a slower release of stored water than a steeper slope. The relatively flat slopes of the above curves are indicative of large ground-water storage in the watershed because most low flows of streams are derived largely from ground water.

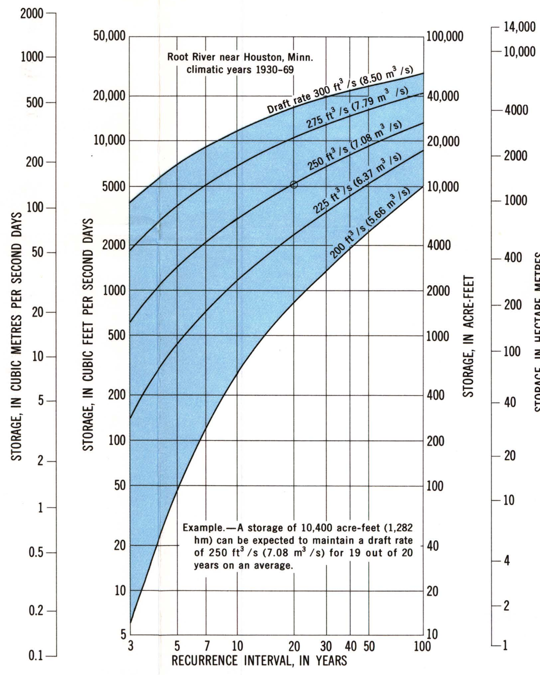


THE VARIATION OF MEAN DAILY DISCHARGE AND THE SEASONAL VARIATION OF MEAN DAILY DISCHARGE FOR A 19-YEAR PERIOD ARE SHOWN BY THE DAILY DURATION HYDROGRAPH

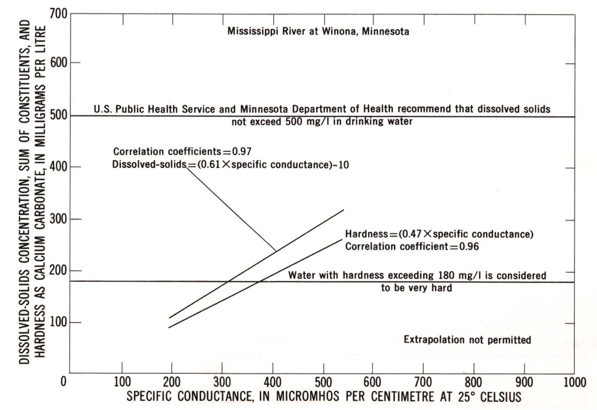
The smallest range occurs in November and the greatest range during March and April. The lowest flows usually occur in winter and the highest during spring breakup. The lowest mean daily flow was 150 ft³/s (4.25 m³/s) on February 1, and the highest mean daily flow was 31,000 ft³/s (878 m³/s) on April 2.



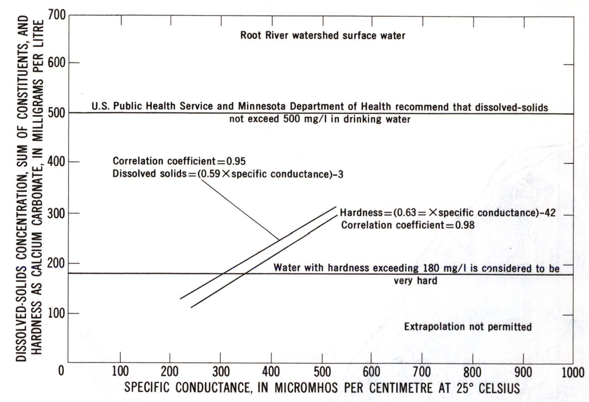
FLOW-DURATION CURVES IN THE ROOT RIVER WATERSHED MAY BE USED TO ESTIMATE STREAMFLOW AND BASIN CHARACTERISTICS.—*The curve for the Mississippi River at Winona has a fairly flat slope throughout, denoting the presence of water storage in stream channels and in aquifers, which tends to equalize the flow. Root River and its tributaries have fairly steep slopes in their high ranges, indicating little or no storage, whereas their medium and low ranges are relatively flat, indicating a good ground-water supply to the streams. Duration curves may be used to estimate the percentage of time a specified discharge will be equaled or exceeded in the future. By simple subtraction, the percentage of time that flow may be equal to or less than a specified amount may also be estimated.*



THE APPROXIMATE STORAGE REQUIRED TO MAINTAIN SPECIFIED DRAFT RATES FOR VARIOUS RECURRENCE INTERVALS IS SHOWN BY THE CURVES.—*Storage-draft relations can be used by water managers and professional planners concerned with seeking new or additional sources of surface-water supply for municipal and industrial uses or appraising potential water supply for regional growth and development. Storage required is not adjusted for losses from evaporation or seepage. Average annual evaporation is 2.4 (ft³/s) /mi² [0.026 (m³/s) /km²] of water surface, or 32 inches (812 mm), computed from data published by the U.S. Weather Bureau (1959).*

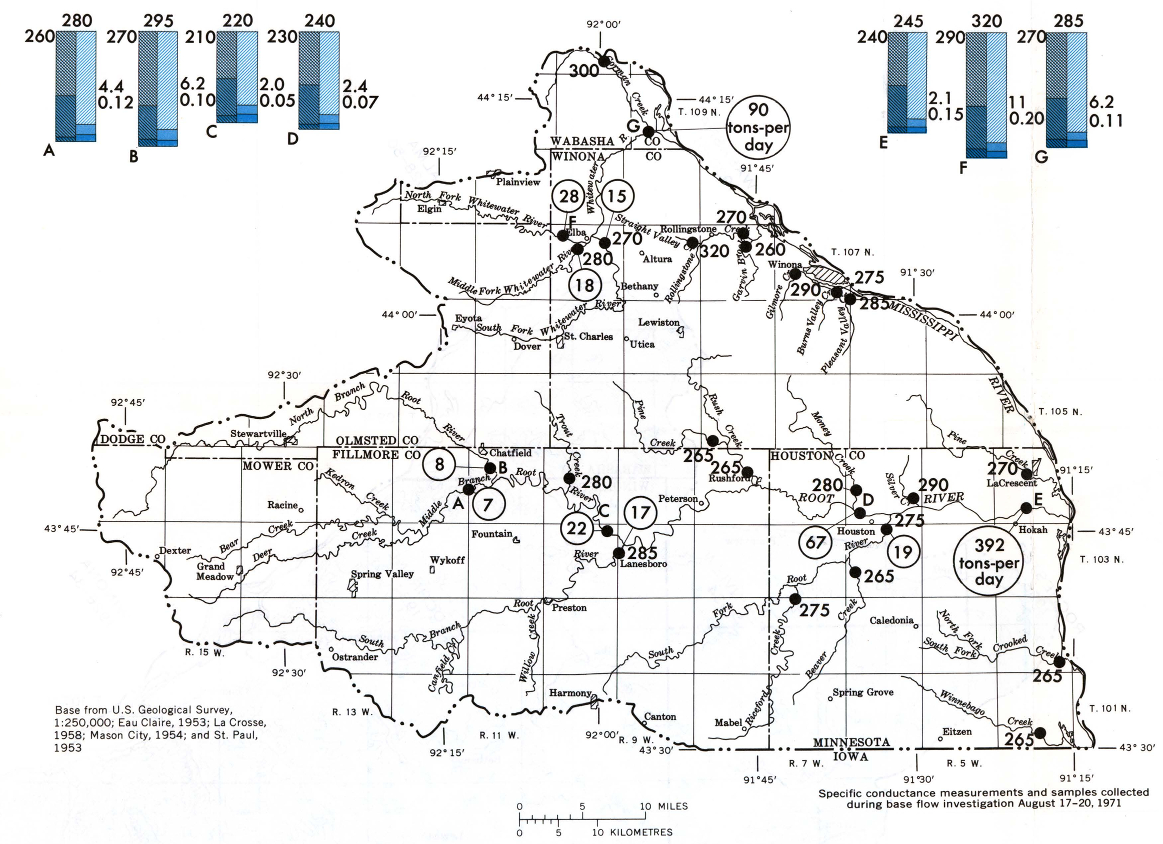


DISSOLVED-SOLIDS CONCENTRATION AND HARDNESS MAY BE ESTIMATED BY APPLYING VALUES OF SPECIFIC CONDUCTANCE TO THE ABOVE GRAPH OR LINEAR EQUATIONS.—*Water from the Mississippi River at Winona having a specific conductance of 500 micromhos has a dissolved-solids concentration of about 300 mg/l and a hardness (as calcium carbonate) of about 250 mg/l.*



ESTIMATES OF DISSOLVED-SOLIDS CONCENTRATION AND HARDNESS MAY BE MADE BY MEASURING AND APPLYING VALUES OF SPECIFIC CONDUCTANCE TO THE GRAPHS OR LINEAR RELATIONS EXPRESSED ABOVE THE GRAPHS.—*The graphed relationships apply only to streams within the Root River watershed and not to the Mississippi River. Mississippi River relationships are found on the graph for Mississippi River at Winona. Water having a specific conductance of 500 micromhos would contain about 300 mg/l dissolved solids and about 280 mg/l hardness as calcium carbonate.*

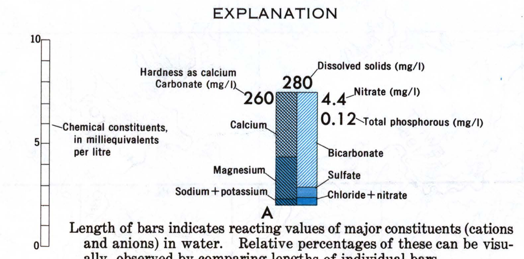
WATER QUALITY



Base from U.S. Geological Survey, 1:250,000; Eau Claire, 1953; La Crosse, 1958; Mason City, 1954; and St. Paul, 1953

Specific conductance measurements and samples collected during base flow investigation August 17-20, 1971

EXPLANATION



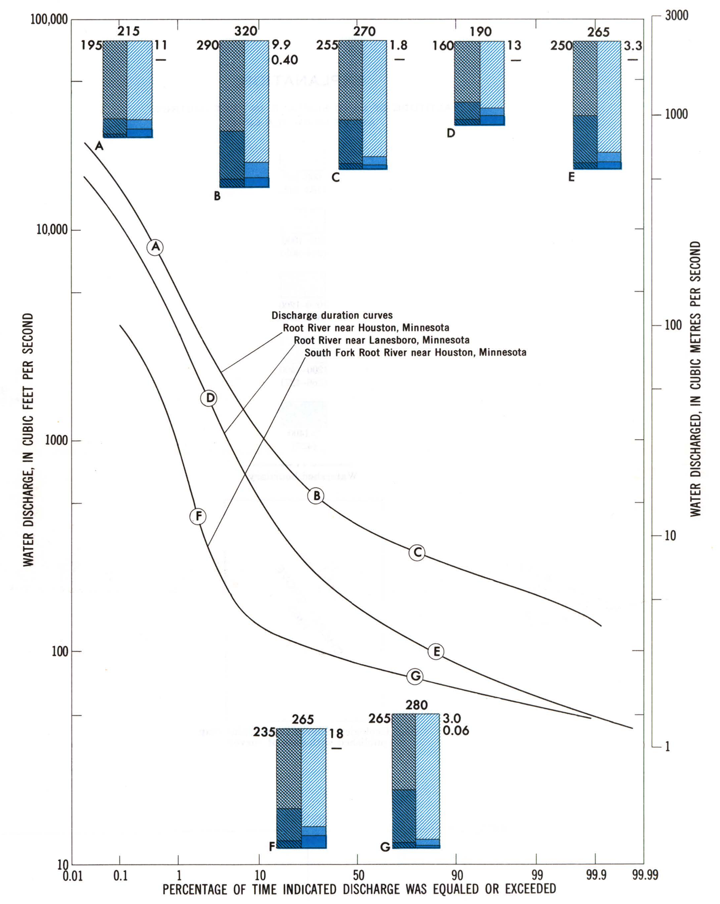
Length of bars indicates reacting values of major constituents (cations and anions) in water. Relative percentages of these can be visually observed by comparing lengths of individual bars

(19) Percentage of dissolved-solids discharge (tons per day) of the Root River at Hokah, Minnesota, or the Whitewater River near Weaver, Minnesota

275 ● Dissolved-solids concentration, estimated from specific conductance measurements

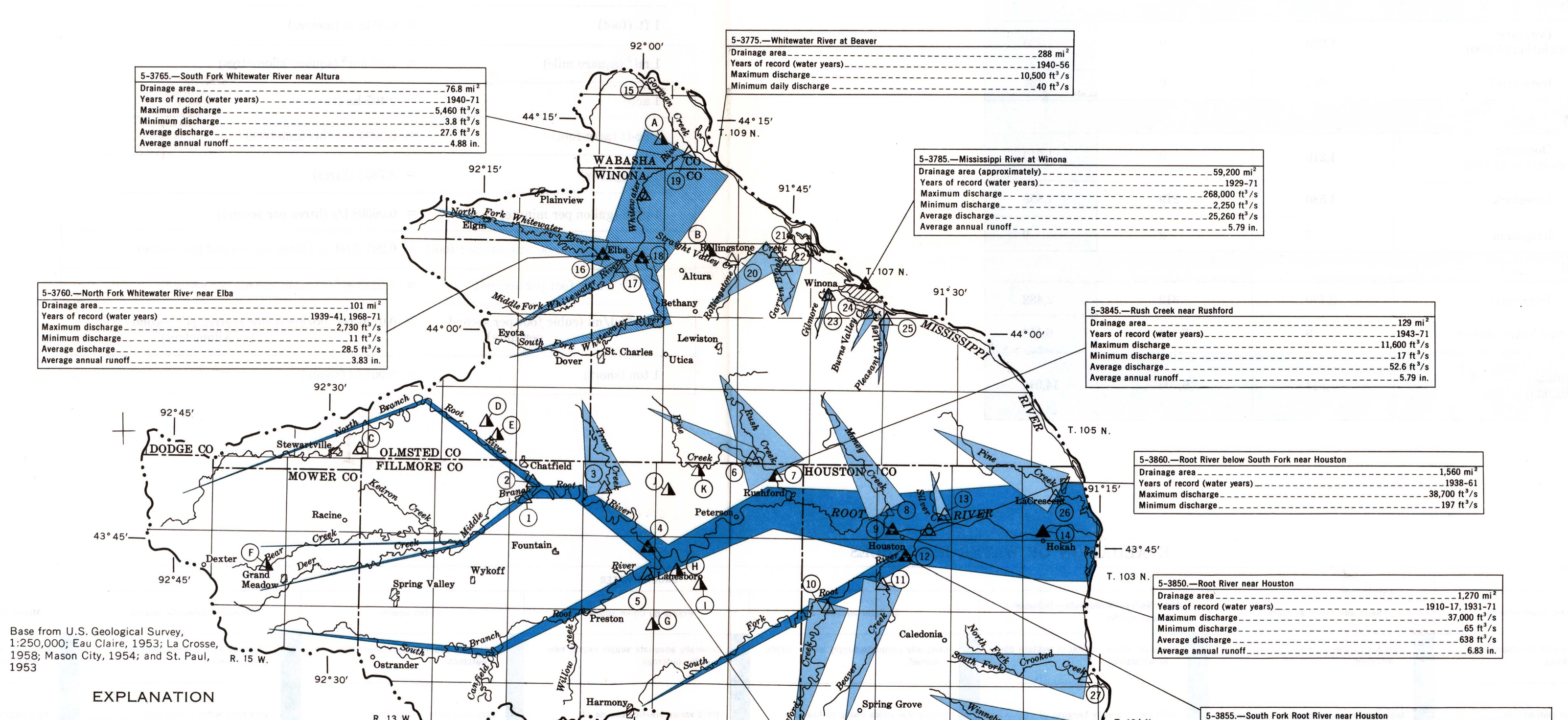
WATER IN STREAMS IN THE ROOT RIVER WATERSHED HAS SUITABLE QUALITY FOR MANY USES; ITS MAJOR DISADVANTAGE FOR DOMESTIC USE IS EXCESSIVE HARDNESS.—*The dominant ions in stream water are calcium, magnesium, and bicarbonate derived from the solution of limestone and dolomite. Measurements made at base flow indicate that water entering tributaries from carbonate bedrock generally contains more dissolved solids (A, B, F, and estimates) than water entering the main stems (C, D, E, G) of the Root and Whitewater Rivers through alluvial sands.*

The North Fork Whitewater River and the headwaters of Root River (above C) contribute the greatest percentage of dissolved solids to the main stem of their respective rivers.



WATER DISCHARGE AND GEOLOGY ARE THE MAJOR CONTROLS OF DISSOLVED MINERALS IN THE ROOT RIVER AND SOUTH FORK ROOT RIVER.—*Decreased concentrations indicating dilution of dissolved solids, calcium, magnesium, and bicarbonate are shown for three locations during high-flow periods (A, D, F). Nitrate concentrations increase at high flow because of runoff from farmlands. Dissolved-solids concentrations decrease (B-C) in the Root River near Houston as flow decreases, because a large percentage of the water percolates through alluvial sand beds deficient in soluble minerals.*

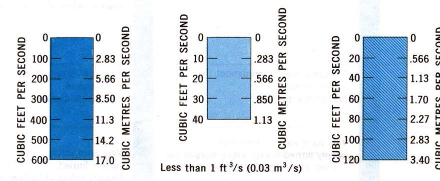
BASE-FLOW MAP



Base from U.S. Geological Survey, 1:250,000; Eau Claire, 1953; La Crosse, 1958; Mason City, 1954; and St. Paul, 1953

EXPLANATION

APPROXIMATE SCALES OF BASE FLOW



Width of color pattern along streams indicates approximate flow Aug. 17-20, 1971

GAGING STATIONS

- Continuous automatic recording
- Daily nonrecording
- Crest-stage partial-record
- Low-flow partial-record
- Miscellaneous measurement site
- Discontinued automatic recording
- Letter or number key to tables

CREST-STAGE PARTIAL-RECORD STATIONS

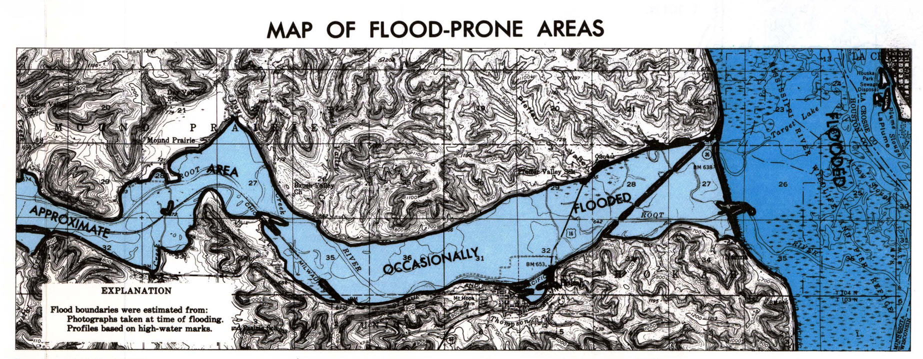
DISCHARGES DURING BASE-FLOW PERIOD

THE FLOW DIAGRAM SHOWS THE DISTRIBUTION OF STREAMFLOW IN THE WATERSHED DURING THE BASE-FLOW PERIOD AUGUST 17-20, 1971

Ground water was the major source of streamflow during the base-flow investigation. A series of discharge measurements was made to determine the distribution of surface-water resources in the watershed within the given period. There was no precipitation the first 10 days of August. On August 11, 15, and 19, there were some local scattered showers; however, owing to the antecedent conditions no increase in runoff occurred, and the streamflow as measured represents base-flow yields in the watershed. The average discharge of Root River near Houston during the period was 405 ft³/s (11.5 m³/s), which is 48 percent on the flow-duration curve. This high base flow was caused by excessive precipitation during the previous fall and spring recharge period. Ground-water storage and base streamflow remained high during the latter part of the 1971 water year.

This base flow distribution pattern would change during extended dry periods.

FLOODS

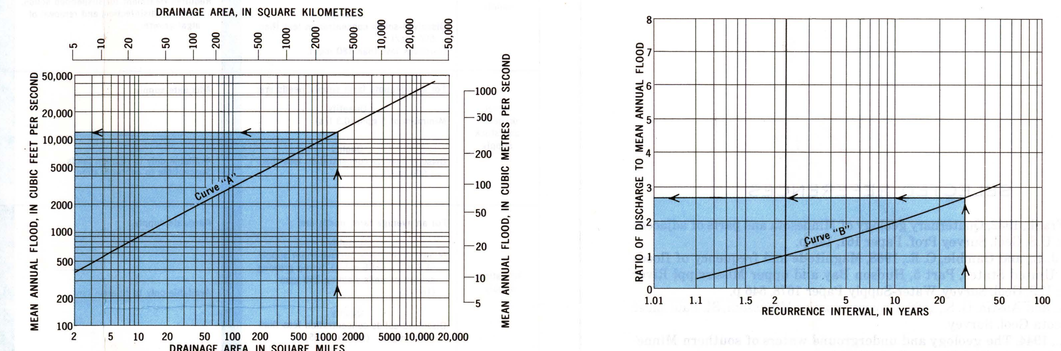


Base from U.S. Geological Survey, 1956

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

FLOOD-PRONE AREAS AT THE MOUTH OF THE ROOT RIVER

This map indicates areas that may be occasionally flooded, but provides no information on the frequency, depth, duration, and other details of flooding. Flood-hazard reports provide the detailed flood information needed for formulating zoning regulations and for setting design criteria to minimize future flood losses. Such detailed information may be available from the U.S. Army, Corps of Engineers or the U.S. Geological Survey.



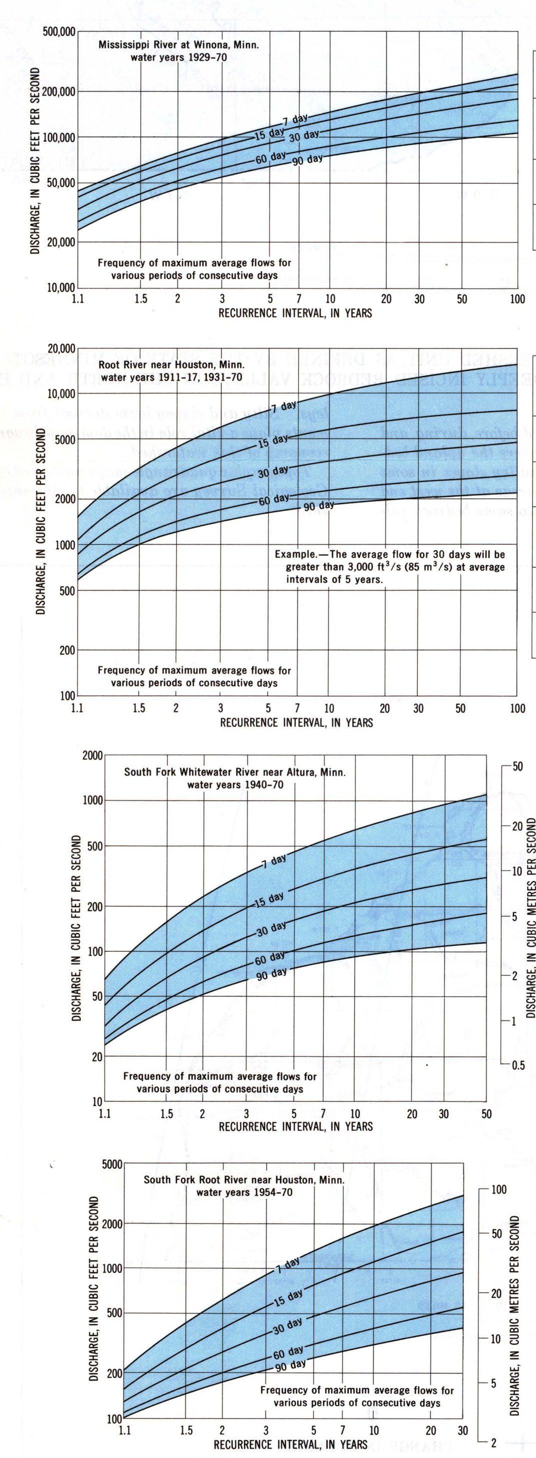
MAGNITUDE AND FREQUENCY OF FLOODS ARE RELATED TO DRAINAGE AREA AND CAN BE DETERMINED FROM THE ABOVE RELATION CURVES (PATTERSON AND GAMBLE, 1968). CURVES "A" AND "B" REFER TO STREAMS WITHIN THE WATERSHED AND ARE NOT APPLICABLE TO THE MAIN STEM OF THE MISSISSIPPI RIVER

Example.—Find the magnitude of a flood that has a 30-year recurrence interval for Root River near Houston. The drainage area at this site is 1,270 mi² (3,289 km²).

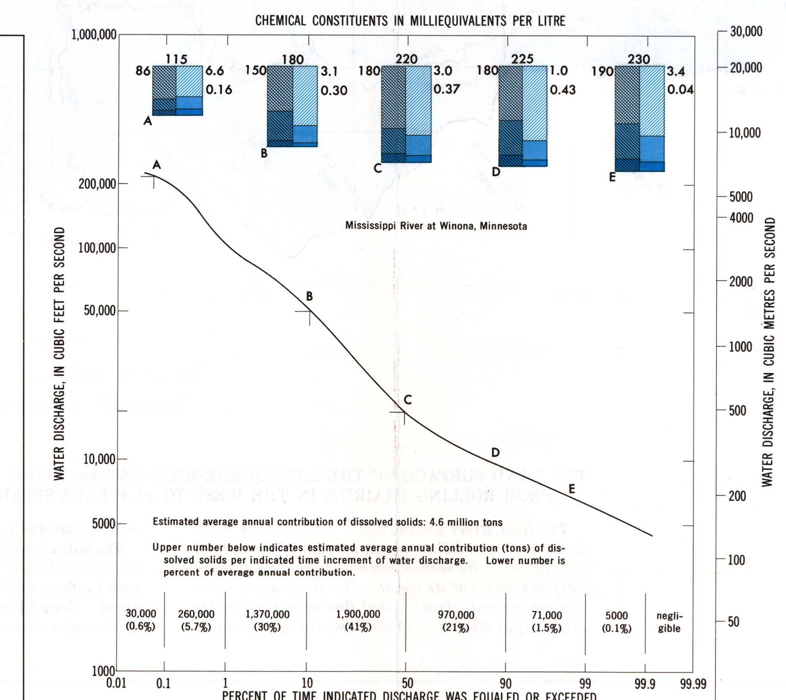
1. *Relation curve "A" shows that for a drainage area of 1,270 mi² (3,289 km²) the discharge for the mean annual flood is 11,700 ft³/s (331 m³/s).*
2. *Relation curve "B" shows that for a 30-year recurrence interval the ratio of discharge to the mean annual flood is 2.70.*
3. *Therefore, the magnitude of a flood that has a 30-year recurrence interval is 11,700×2.70 or 31,600 ft³/s (895 m³/s).*

The recurrence interval of a flood at a specified magnitude at this same site can also be found by reversed procedure.

HIGH-FLOW FREQUENCY CURVES

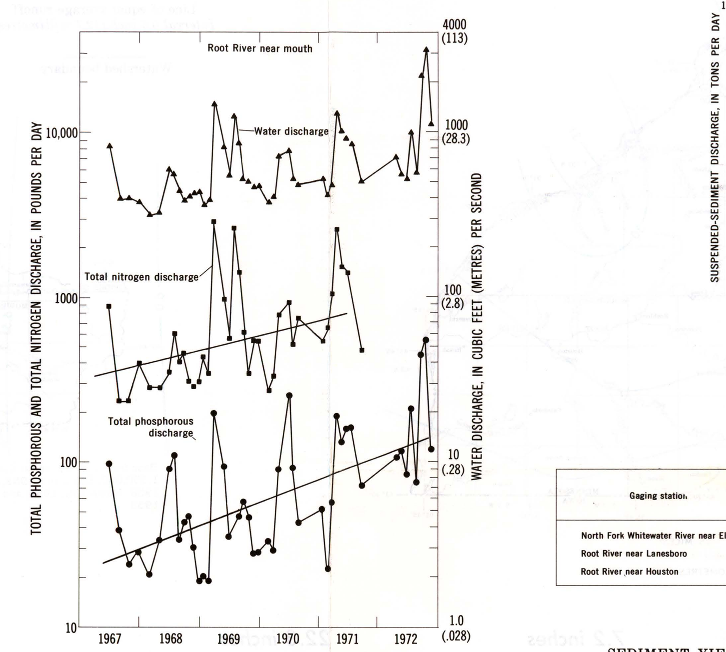


HIGH FLOWS ARE FROM SNOWMELT AUGMENTED AT TIMES BY RAINFALL AND ARE INFLUENCED BY BASIN SHAPE, SIZE, AND TOPOGRAPHY.—*However, high flows of short duration may occur at any time as a result of intense storms. Damages from high flows are related to the height, duration, frequency, and season in which flooding occurs. These factors are considered in the design of flood-control reservoirs, and the high-flow frequency curves are useful in solving problems of reservoir design and operation.*

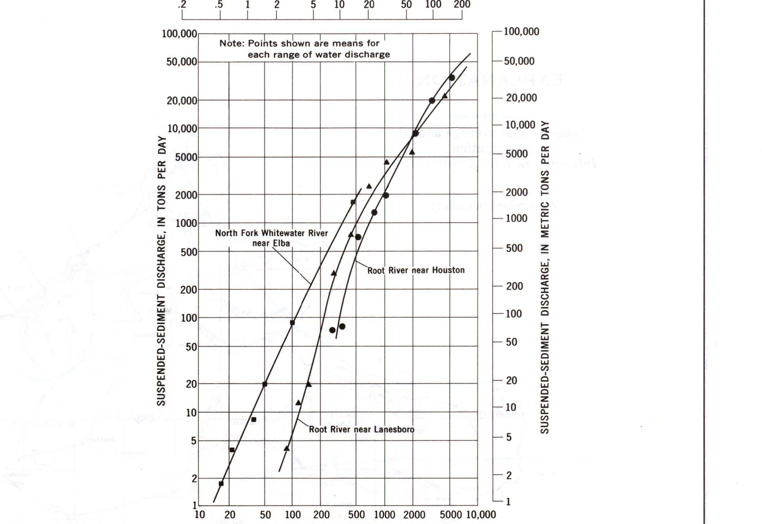


DISSOLVED-SOLIDS CONCENTRATION IN THE MISSISSIPPI RIVER AT WINONA IS AMONG THE LOWEST IN THE STATE. THE ESTIMATED ANNUAL CONTRIBUTION OF DISSOLVED SOLIDS, IN TONS, AT GIVEN WATER DISCHARGE INTERVALS IS SHOWN ON THE GRAPH.—*Dissolved-solids concentrations of about 115 mg/l (A on graph) occur at water discharges greater than 200,000 ft³/s (5660 m³/s). The decrease of water discharge to about 20,000 ft³/s (566 m³/s) is accompanied by an increase of dissolved-solids concentration to about 220 mg/l (C on graph), and this concentration remains about the same throughout the lower range of water discharges. Dominant ions in this water are calcium, magnesium, and bicarbonate.*

Even though contributions of dissolved solids are greatest at water discharges above 200,000 ft³/s (5660 m³/s), the large part of the annual average dissolved-solids discharge (41 percent) occurs in the discharge range from 20,000 to 50,000 ft³/s (566 to 1415 m³/s).



TOTAL NITROGEN CONTRIBUTION TO THE ROOT RIVER ABOVE THE MOUTH IS ABOUT 10 TIMES THE CONTRIBUTION OF TOTAL PHOSPHORUS.—*Mobility of the nitrate ion and the larger proportion of nitrogen in farm fertilizers may in part account for these differences. Larger contributions of both nutrients occur at periods of overland runoff. (The inclined lines on the graph indicate increased contributions with time.)*



Gaging station	Drainage area mi²	Mean suspended-sediment discharge (tons day⁻¹)	Estimated annual sediment yield (tons mi⁻² yr⁻¹)	Expected suspended-sediment concentrations (mg/l): During low flow	During storm runoff
North Fork Whitewater River near Elba	101	22	80	15-50	100-2000
Root River near Lanesboro	615	880	520	50-200	1000-10,000
Root River near Houston	1270	1800	520	50-200	1000-10,000

SEDIMENT YIELD OF THE NORTH FORK WHITEWATER RIVER BASIN ABOVE ELBA IS ONLY ONE-SIXTH OF THE SEDIMENT YIELD IN THE ROOT RIVER.—*Although soils in both river basins have similar erosion characteristics, more extensive farming in the Root River basin may account for the difference in sediment yield. The curves on the graph are based on periodic measurements made throughout the 1968 to 1971 water years. Sediment concentrations in the Root River are higher, particularly during periods of high flow, than in the North Fork Whitewater River.*

WATER RESOURCES OF THE ROOT RIVER WATERSHED, SOUTHEASTERN MINNESOTA

By
W. L. Broussard, D. F. Farrell, H. W. Anderson, Jr., and P. E. Felsheim

1975