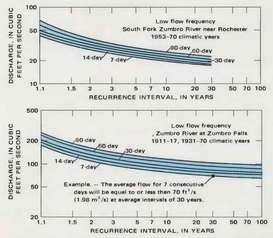
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

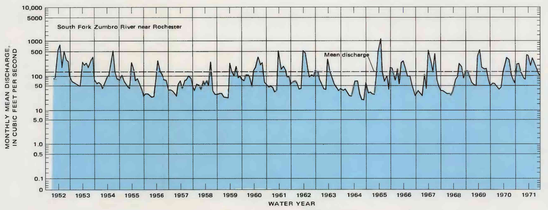
PREPARED IN COOPERATION WITH THE
MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS, SOILS, AND MINERALS

HYDROLOGIC INVESTIGATIONS
ATLAS HA-543 (SHEET 3 OF 3)



LOW FLOWS ARE DERIVED LARGELY FROM THE GROUND-WATER SYSTEM, THUS, LOW-FLOW FREQUENCY CURVES REFLECT GEOHYDROLOGIC CONDITIONS AND INDICATE CONTRIBUTIONS TO STREAMFLOW FROM GROUND-WATER SOURCES.—*The flatness of the low-flow frequency curves for the Zumbro River indicates the existence of a large ground-water reservoir whose discharge sustains low flow.*

These curves are prerequisites for any study involving water supply during periods of critically low flow, in those situations where the construction of storage facilities is not contemplated.



FLUCTUATIONS IN STREAMFLOW ARE CAUSED BY VARIATIONS IN BOTH PRECIPITATION AND TEMPERATURE.—*The highest flows usually result from seasonal snowmelt in the spring. Lowest flows occur either during extended periods of subfreezing weather or during periods of deficient rainfall in the late summer and early fall. The highest monthly mean discharge for the period of record for the South Fork Zumbro River near Rochester was 1,860 ft³/s (52.9 m³/s) in the 1965 water year, and the lowest was 20.8 ft³/s (0.59 m³/s) in the 1961 water year.*

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 is necessary for the evaluation of surface-water resources.

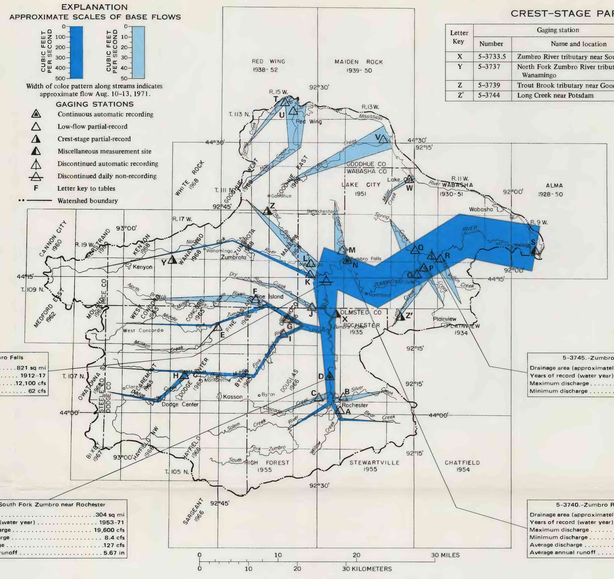
DISCHARGES DURING BASE FLOW PERIOD

Letter Key	Gaging Station		CFs
	Number	Name and Location	
A	5-3729.3	Bear Creek at Rochester	38.4
B	-3729.7	Silver Creek at Rochester	4.85
C	-3729.9	Cascade Creek at Rochester	3.69
D	-3730	South Fork Zumbro River near Rochester	*95.0
E	-3731	Milliken Creek near Concord	1.09
F	-3731.3	North Branch Middle Fork Zumbro River at Pine Island	8.35
G	-3731.5	Middle Fork Zumbro River near Oronoco	32.6
H	-3732	Dodge Center Creek near Dodge Center	3.84
I	-3732.9	South Branch Middle Fork Zumbro River near Oronoco	26.8
J	-3734	Dry Run Creek near Oronoco	4.38
K	-3738.5	North Fork Zumbro River at Mazeppa	37.2
L	-3739.5	Trout Brook near Mazeppa	12.7
M	-3739.95	Cold Creek at Zumbro Falls	11.0
N	-3740	Zumbro River at Zumbro Falls	*335
O	-3744.2	Long Creek near Millville	7.16
P	-3744.5	Middle Creek near Thielman	4.58
Q	-3744.8	Spring Creek near West Albany	11.4
R	-3745.2	West Indian Creek at Thielman	8.75
S	---	Zumbro River at Kellogg	440
T	-3552.6	Spring Creek near Red Wing	4.92
U	-3552.8	Hay Creek at Red Wing	19.3
V	-3553.5	Wells Creek near Frontenac	21.8
W	-3553.6	Miller Creek near Lake City	2.58

*Average for period Aug. 10–13, 1971

CREST-STAGE PARTIAL-RECORD STATIONS

Letter Key	Gaging station		Drainage area (square miles)	Years of record (water years)	Discharge (cfs)	
	Number	Name and location			Maximum	Minimum
X	5-3733.5	Zumbro River tributary near South Troy	0.16	1962–71	84	No flow
Y	5-3737	North Fork Zumbro River tributary near Wanamingo	9.36	1960–71	1,120	No flow
Z	5-3739	Trout Brook tributary near Goodhue	.41	1960–71	592	No flow
Z′	5-3744	Long Creek near Potsdam	4.46	1966–71	408	No flow



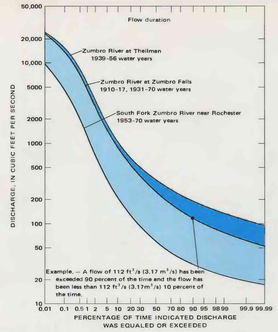
5-3735.–Zumbro River near Zumbro Falls
Drainage area ..... 821 sq mi
Years of record (water year) 1912-17
Maximum discharge ..... 12,100 cfs
Minimum discharge ..... 62 cfs

5-3745.–Zumbro River at Thielman
Drainage area (approximately) ..... 1,320 sq mi
Years of record (water year) 1939-56
Maximum discharge ..... 33,000 cfs
Minimum discharge ..... 75 cfs

5-3730.–South Fork Zumbro near Rochester
Drainage area ..... 304 sq mi
Years of record (water year) 1953-71
Maximum discharge ..... 19,600 cfs
Minimum discharge ..... 8.4 cfs
Average discharge ..... 127 cfs
Average annual runoff ..... 5.67 in

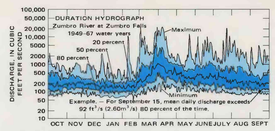
5-3740.–Zumbro River at Zumbro Falls
Drainage area (approximately) ..... 1,130 sq mi
Years of record (water year) 1930-71
Maximum discharge ..... 35,900 cfs
Minimum discharge ..... 27 cfs
Average discharge ..... 488 cfs
Average annual runoff ..... 5.86 in

THE FLOW DIAGRAM SHOWS THE DISTRIBUTION OF STREAMFLOW IN THE WATERSHED DURING THE BASE FLOW PERIOD AUGUST 10-13, 1971.—*Ground water was the major source of streamflow during a base flow investigation August 10–13, 1971. A series of discharge measurements was made to determine the distribution of surface-water resources in the watershed within the given time interval. There had been no measurable precipitation for 10 days prior to this period. Although there were some scattered local showers on August 10 and 11, because of dry antecedent conditions runoff did not increase, and the measured streamflow represents base-flow yields from the basin. The measured tributary inflow amounted to 58 percent of the total increase in flow observed between the gage on the South Fork Zumbro River near Rochester and the gage on the Zumbro River at Zumbro Falls. This indicated that almost half the total flow (46 percent) could be attributed to direct ground-water inflow along the main stem of the South Fork Zumbro River. The average ground-water inflow amounted to 1.3 ft³/s/mi of channel (0.76 m³/s/km) between the gages.*

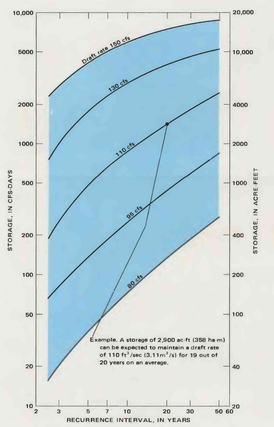


FLOW-DURATION CURVES OF STREAMS IN THE WATERSHED PROVIDE A CONVENIENT MEANS FOR RELATING STREAMFLOW TO BASIN CHARACTERISTICS.—*Flow-duration curves are used for investigating problems dealing with power development, water supply, and dilution and disposal of sewage or industrial wastes. The moderate slopes of the curves, especially at their low ends, indicate a large ground-water reservoir, which tends to equalize streamflow.*

Duration curves may also be used to estimate the percentage of time a specified discharge will be equaled or exceeded. By subtracting percentages shown on the graph from 100 percent, the percentage of time that flow may be equal to or less than a specified amount may also be estimated.

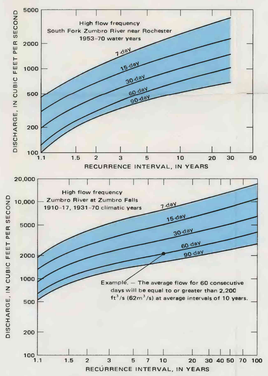


THE VARIATION OF DAILY MEAN DISCHARGE FOR EACH DAY AND THE SEASONAL VARIATION OF DAILY MEAN DISCHARGE FOR A 19-YEAR PERIOD IS SHOWN BY THE DAILY DURATION HYDROGRAPH.—*For the Zumbro River the smallest monthly range and the most uniform daily mean discharge usually occurs in January, whereas the greatest range usually occurs in March. The lowest flows usually occur in the winter and the highest during the spring ice breakup. The lowest observed flow, 47 ft³/s (1.33 m³/s), occurred on February 16, 1961 and the highest, 23,600 ft³/s (668 m³/s), occurred on March 29, 1962.*

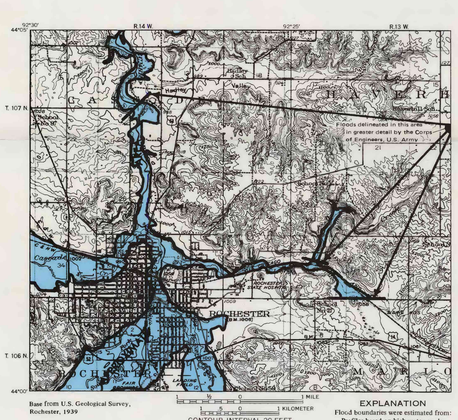


THE APPROXIMATE RESERVOIR STORAGE REQUIRED TO MAINTAIN SPECIFIED DRAFT RATES FOR VARIOUS RECURRENCE INTERVALS IS SHOWN BY THE CURVES.—*Streamflow can be increased during periods of low flow by release of reservoir water stored during periods of high flow. The curves were computed from streamflow records of the Zumbro River at Zumbro Falls for 1930–65.*

The storage requirements were not adjusted for reservoir losses through evaporation or seepage because these would vary with surface area and geologic setting at reservoir sites. Average annual evaporation in the area is about 2.3 ft³/s/mi² (0.002 m³/s/km²) of water surface (35 inches (11.3 cm)), computed from data published by the U.S. Department of Commerce (1959).

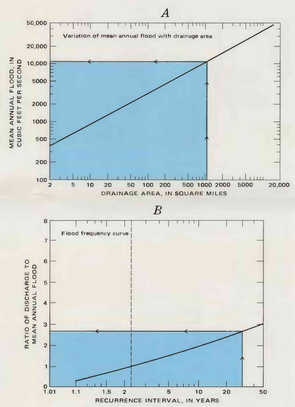


HIGH FLOWS OF LONG DURATION RESULT FROM SNOWMELT, AUGMENTED AT TIMES BY SPRING RAINS, AND ARE INFLUENCED BY BASIN SHAPE, SIZE, AND TOPOGRAPHY; HOWEVER, HIGH FLOWS OF SHORT DURATION MAY OCCUR AT ANY TIME AS A RESULT OF INTENSE STORMS.—*High-flow frequency curves are a necessary tool in the design of flood-control storage and associated channel improvements. They show for various durations the average interval, in years, between exceedances of a specified average discharge.*



FLOOD-PRONE AREAS AT ROCHESTER, MINNESOTA.—*This map shows areas that may be occasionally flooded. It provides no information on frequency, depth, duration, and other details of flooding.*

Flood-hazard reports provide the detailed flood information that is needed for economic studies, for formulating zoning regulations, and for setting design criteria to minimize future flood losses. Such detailed information may be obtained from the U.S. Army, Corps of Engineers or the U.S. Geological Survey.



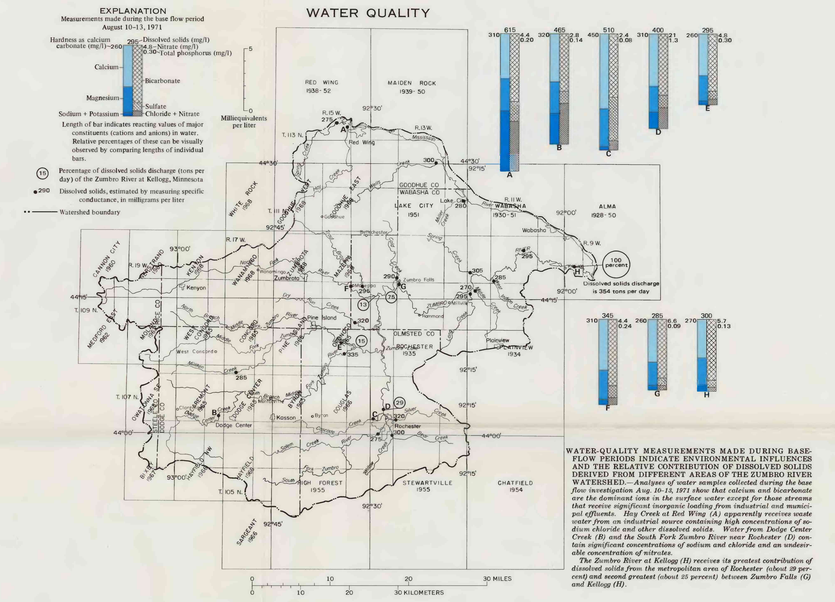
MAGNITUDE AND FREQUENCY OF FLOODS IN THE ZUMBRO RIVER WATERSHED.—*The magnitude and frequency of floods are related to drainage area and can be predicted from approximate curves developed from stream-flow records. Curves "A" and "B" refer to streams such as those within the Zumbro watershed and are not applicable to the main stem of the Mississippi River.*

Example: Find the magnitude of the peak discharge having a 20-year recurrence interval for the Zumbro River at Zumbro Falls. The drainage area at this site is 1,130 sq mi (2927 km²).

1. *Relation curve "A" shows that for a drainage area of 1,130 sq mi (2927 km²) the peak discharge for the mean annual flood is 11,100 ft³/s (314 m³/s).*
2. *Relation curve "B" shows that the ratio of a 20-year peak to that of the mean annual flood is 2.70.*
3. *Therefore, the magnitude of a flood peak that has a 20-year recurrence interval is 11,100 X 2.70, or 30,000 ft³/s (849 m³/s).*

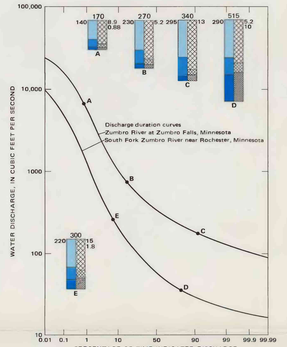
The recurrence interval of a flood peak of a specified magnitude at this same site can also be found by reversed procedure.

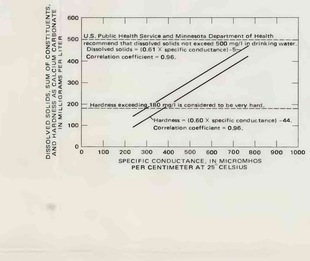
WATER QUALITY



WATER-QUALITY MEASUREMENTS MADE DURING BASE-FLOW PERIODS INDICATE ENVIRONMENTAL INFLUENCES AND THE RELATIVE CONTRIBUTION OF DISSOLVED SOLIDS DERIVED FROM DIFFERENT AREAS OF THE ZUMBRO RIVER WATERSHED.—*Analyses of water samples collected during the base flow investigation Aug. 10–13, 1971 show that calcium and bicarbonate are the dominant ions in the surface water except for those streams that receive significant inorganic loading from industrial and municipal effluents. Hay Creek at Red Wing (A) apparently receives waste water from an industrial source containing high concentrations of sodium chloride and other dissolved solids. Water from Dodge Center Creek (B) and the South Fork Zumbro River near Rochester (D) contain significant concentrations of sodium and chloride and an undesirable concentration of nitrates.*

The Zumbro River at Kellogg (H) receives its greatest contribution of dissolved solids from the metropolitan area of Rochester (about 19 percent) and second greatest (about 15 percent) between Zumbro Falls (G) and Kellogg (H).





WATER IN THE ZUMBRO RIVER CONTAINS VARIABLE CONCENTRATIONS OF DISSOLVED CONSTITUENTS, WHICH ARE PARTLY CONTROLLED BY VOLUME OF WATER AND WASTE DISPOSAL.—*The dominant ions (calcium, magnesium, and bicarbonate) and dissolved solids are reduced (see C-A) by dilution during periods of high water discharge in the Zumbro River at Zumbro Falls. Similarly, in the South Fork Zumbro River near Rochester, dominant ions, dissolved solids, and those ions that are increased by waste disposal (sodium, chloride, and nitrates) are all reduced (see D-E) by dilution at high water discharge.*

For investigations that require immediate results, dissolved solids and hardness may be estimated by measuring specific conductance and applying the measured values to the graph or to the linear relation expressed with the graph.

EXPLANATION

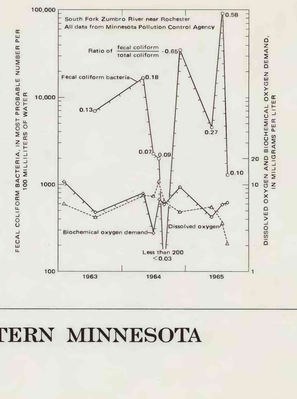
Symbolic expression of relation between dissolved oxygen DO (mg/l) and biochemical oxygen demand, 5-day 20° C, BOD (mg/l) at points on streams in the Zumbro River watershed. Measurements made during the base flow period, August 10–13, 1971.

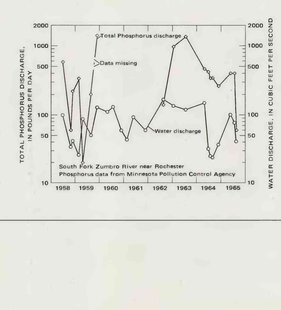
BOD less than 3 — Insignificant pollution
DO greater than BOD — Stabilization can occur without aeration

BOD in range 3–10 — Moderate pollution
DO equal to BOD — Stabilization will consume all oxygen unless aeration occurs

BOD greater than 10 — Dangerous pollution
DO less than BOD — Stabilization infers anaerobic decay unless aeration occurs

Fecal coliform bacteria population (number per 100 milliliters of water)
1 Less than 400
2 400–1000
3 Greater than 1000
Sampling site
Watershed boundary





MEASUREMENTS OF WATER QUALITY AND BACTERIA DURING BASE FLOW INDICATE LOCATIONS WHERE STREAMS RECEIVE SUFFICIENT ORGANIC LOADING TO LOWER DISSOLVED OXYGEN LEVELS. HISTORICAL MEASUREMENTS SHOW THAT ADEQUATE NUTRIENTS FOR PLANT AND BACTERIAL GROWTH OCCUR AT ROCHESTER.—*Dissolved oxygen and biochemical oxygen demand measurements made in the afternoon indicate that dissolved oxygen concentrations were reduced from 6.4 to 7.6 mg/l below the Rochester waste-treatment plant on the South Fork Zumbro River and from 9.7 to 7.2 mg/l in Hay Creek near Red Wing. The number of fecal coliform bacteria is generally less than the maximum allowable for recreation (100 per 100 ml water) recommended by the Federal Water Pollution Control Administration (1965). However, this number is exceeded in tributaries draining housing developments and farm lands near Rochester, Mazeppa, and Frontenac. Fecal coliform populations in the South Fork Zumbro River near Rochester during 1963–65 generally exceeded the recommended maximum. Fecal coliform percentage (ratio) of total coliform is largest when the contribution of fecal coliform from municipal waste-treatment plants is greatest. Nonfecal growth is accelerated in the carbon enriched (B.O.D. range 8.8–11 mg/l) waste waters.*

Patterns of phosphorus discharge for stream samples do not correlate with those of water discharge during the years of parallel data. This suggests that municipal waste discharge is the principal control on phosphorus discharge at Rochester.

WATER RESOURCES OF THE ZUMBRO RIVER WATERSHED, SOUTHEASTERN MINNESOTA

By
H. W. Anderson, Jr., D. F. Farrell, W. L. Broussard, and M. F. Hult

1975

Interior—Geological Survey, Reston, Va.—1975