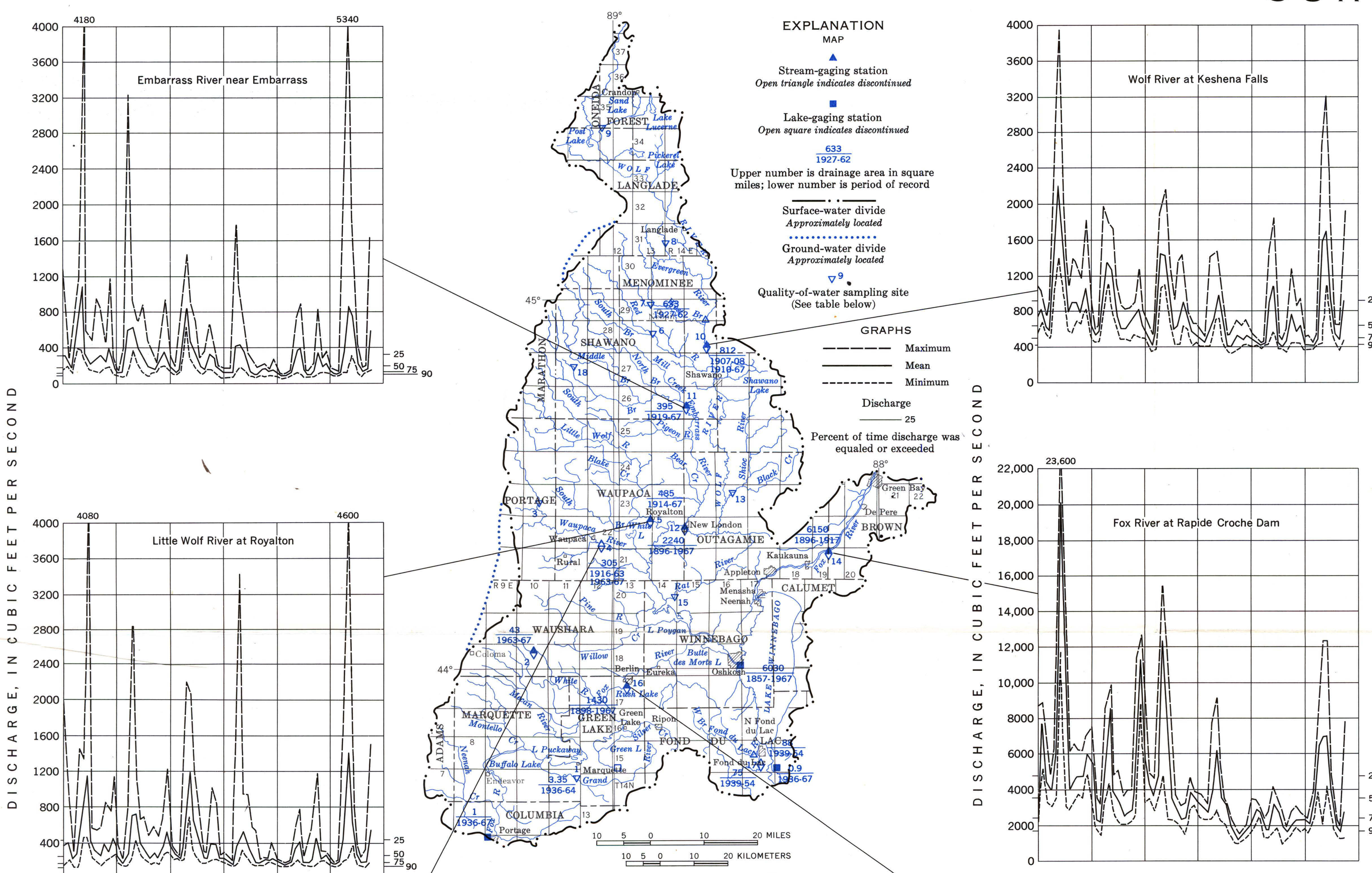
SURFACE WATER

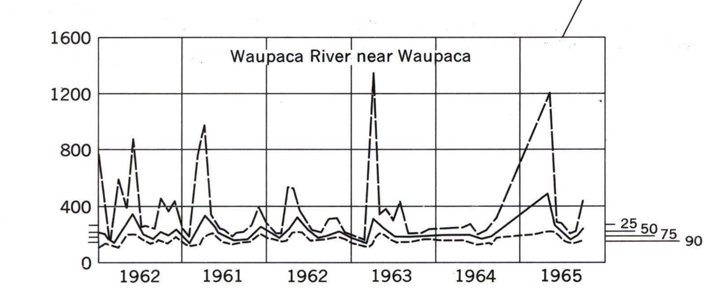


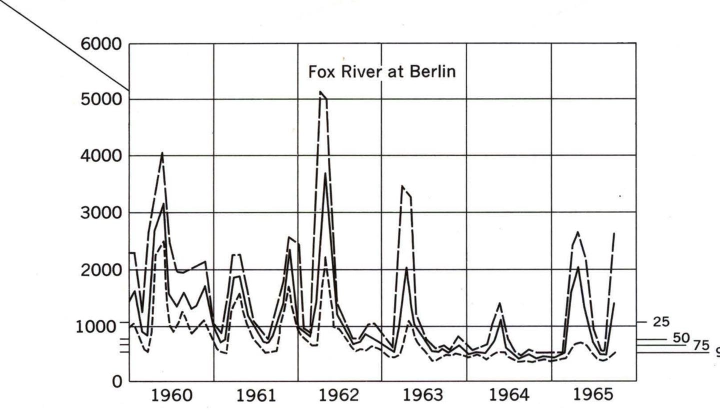
STREAM DISCHARGE

Streamflow characteristics, as determined at long-term gaging stations, chiefly depend upon the geology, topography, size, and climate of the drainage basin. Manmade changes, including dams and land use, also affect streamflow characteristics.

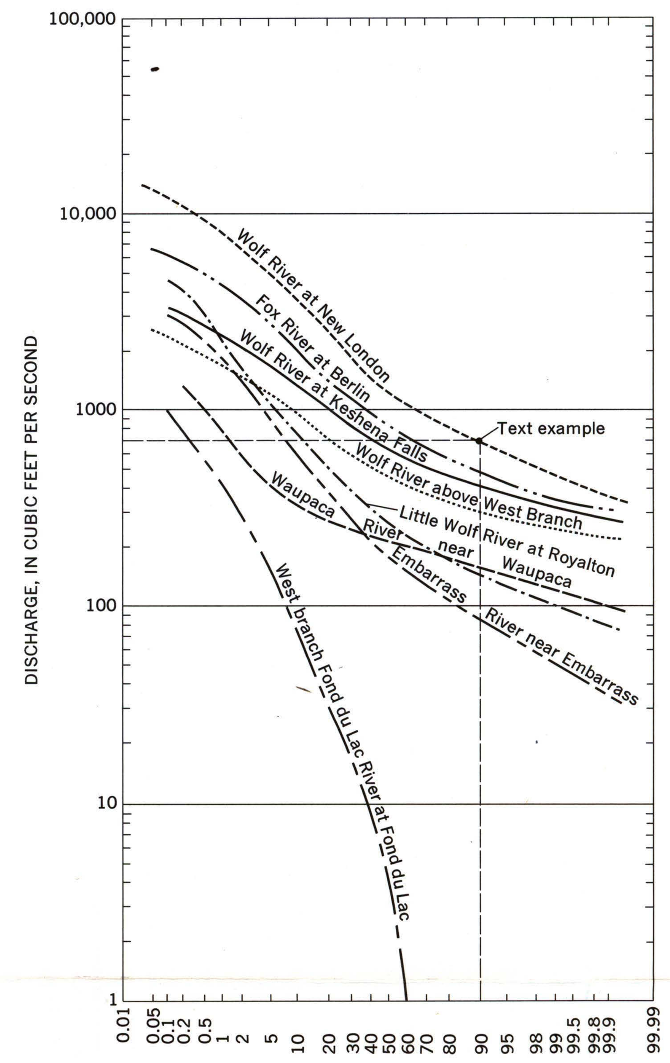
The locations of long-term streamflow gaging stations and pertinent information are shown on the accompanying illustration. Hydrographs of maximum, minimum, and mean monthly streamflow, 1960-65, at representative gaging stations summarize streamflow conditions. Flow duration, or streamflow equaled or exceeded 90, 75, 50, and 25 percent of the time for the period of record at each station, also is shown on the hydrographs.

The water yield per square mile in the permeable glacial-outwash areas in the western and northern parts of the basin is higher than those in the poorly permeable glacial-lake and ground-moraine areas in the central, eastern, and southern parts of the basin. This is especially apparent on the White River in Green Lake, Marquette, and Waushara Counties where the river above the upstream measuring site drains a glacial-outwash area. Glacial-lake deposits underlie the basin between the upstream and downstream measuring sites. The stream has a much lower yield per square mile of basin in the lake deposits than in the outwash deposits. The intermediate yields in Waupaca and Shawano Counties on the Little Wolf, Pigeon, and Embarrass Rivers probably result from the thinness of the glacial-outwash aquifer in that area.





REPRESENTATIVE DISCHARGE HYDROGRAPHS, GAGING STATIONS, AND SAMPLING SITES



FLOW DURATION OF MAJOR STREAMS

FLOW DURATION OF STREAMS

Flow-duration curves for streams at several gaging stations in the Fox-Wolf basin were drawn from streamflow records. Although many small dams and lakes are on these gaged streams, all of the reservoirs are small or are not manipulated. Therefore, the flow-duration curves generally reflect natural streamflow.

The flow-duration curves are shown on the graph above. An example taken from the graph shows the flow of the Wolf River at New London equaled or exceeded 700 cfs (cubic feet per second) 90 percent of the time.

The shape of a flow-duration curve reflects the type of geohydrology of the drainage basin above the gaging site. A curve with a steep slope denotes a highly variable stream whose flow is largely from direct runoff, whereas a curve with a flat slope reveals the presence of surface- and/or ground-water basin storage, which tends to equalize flow.

The flow-duration curves for streams in the Fox-Wolf basin, with the exception of curves for the Embarrass, Little Wolf, and Fond du Lac Rivers, are similar and relatively flat, indicating considerable basin storage. These streams generally drain thick outwash deposits. The curves for the Embarrass and Little Wolf Rivers have steeper slopes, indicating less storage in their respective subbasins. These streams drain a thin drift area in the northwestern part of the study area. The curve for the West Branch Fond du Lac River is very steep, indicating a very little basin storage. The river drains an area of thin and very clayey drift. The flow-duration curve for the West Branch Fond du Lac River probably is characteristic for streams originating in the glacial-lake and ground-moraine deposits in the southern and eastern parts of the basin.

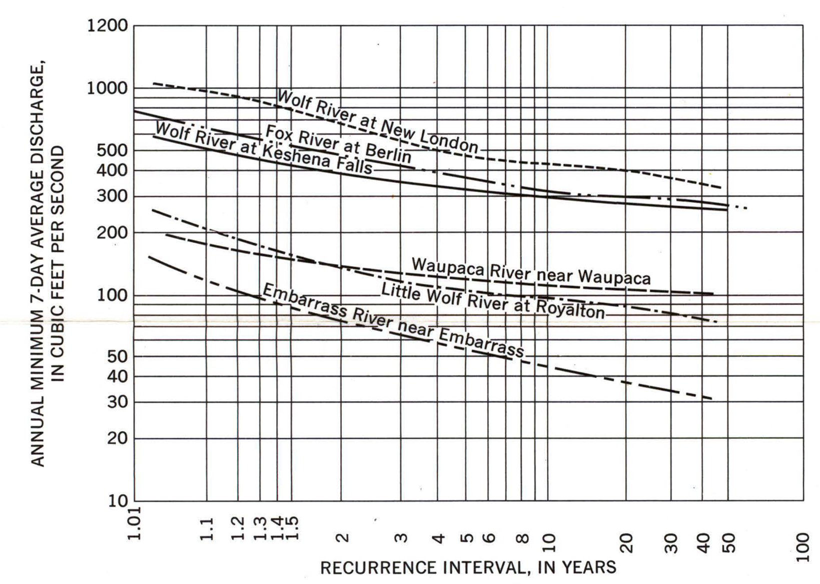
These flow-duration curves can be used to predict the probable distribution of future flows for water-power, water-supply, sewage transport, and pollution studies.

LOW FLOW OF STREAMS

Low flow of streams is predicted by analysis of past streamflow records. Although accidents of climate may occur that would reduce streamflow below minimum discharges of the past, this analysis is the best means of prediction and generally is reliable.

The recurrence interval, or the number of times a given low flow (for 7 consecutive days) is likely to occur, is shown by the graph below. This recurrence interval also is based on past records of streamflow.

Low-flow data are important for users of stream water, such as an industry that diverts water from the stream for cooling purposes. If the industry's use of water exceeds the average 7-day minimum low flow, provisions must be made to supply part of the cooling water from some other source, or from a storage reservoir. Low-flow data also are important to municipalities that discharge sewage into streams. If the discharge of the stream drops below the required amount to dilute the sewage properly, provisions must be made either to hold the sewage until higher flow, or supplement streamflow from a reservoir or wells.



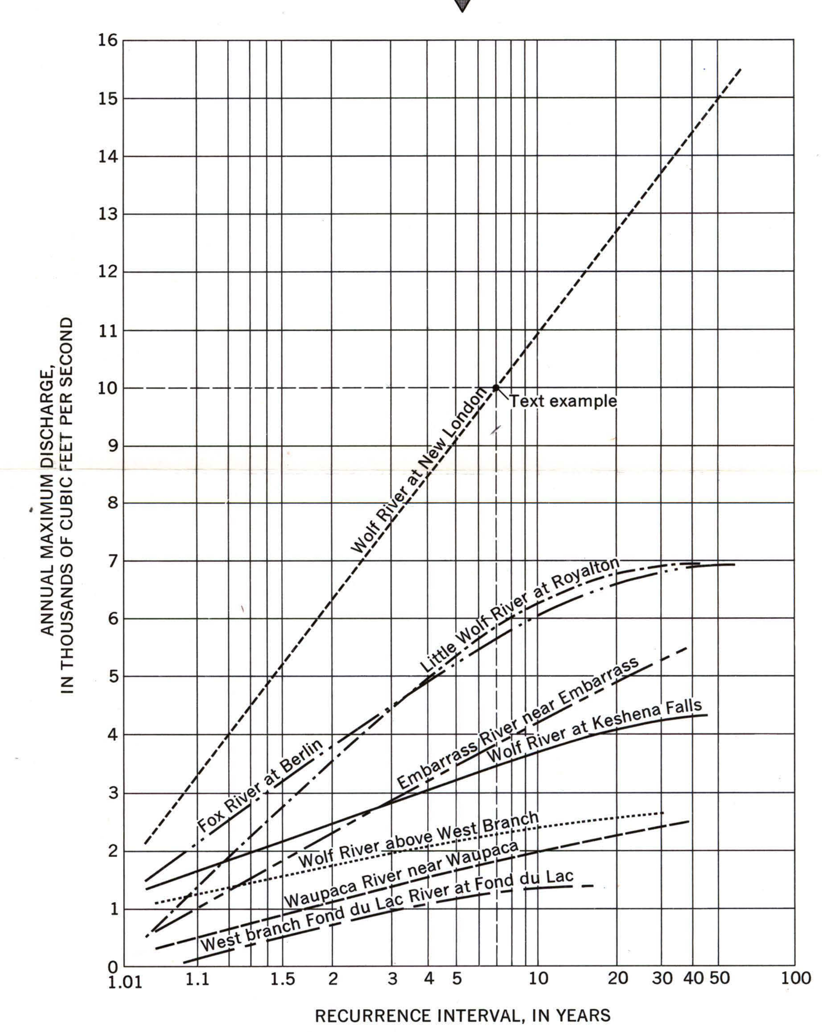
LOW-FLOW RECURRENCE OF MAJOR STREAMS

FLOODFLOW OF STREAMS

Floodflow also is predicted from analysis of past streamflow records. Floodflow predictions are necessary for bridge and dam design and for structures built on or near the flood plain of a stream.

Floodflow-recurrence curves are shown below. As an example, a flow of 10,000 cfs can be expected on the Wolf River at New London on an average of once in 7 years. A flow of 15,000 cfs can be expected once in every 50 years.

The Wolf River at New London traditionally floods during the spring thaw. The flooding tendency is reflected in the steep slope of its floodflow-frequency curve. Although there is ample ground water storage in the upper part of the Wolf basin, impermeable lake deposits provide little storage in the area south of Shawano. The steep slope of the curves for the Embarrass and Little Wolf Rivers also reflects a lack of basin storage. The low slope of the curve for the Fond du Lac River, which should flood easily because of little basin storage, probably results from the small size of its drainage basin.



FLOODFLOW RECURRENCE OF MAJOR STREAMS

QUALITY OF SURFACE WATER

Representative chemical analyses of stream water at 18 selected sites are listed on the table and are keyed to sample locations shown on the map above. The water generally is of the calcium magnesium bicarbonate type and is moderately hard. Many analyses show a relatively high concentration of iron.

Stream water is subject to rapid changes in chemical quality because of sudden large quantities of overland flow, effluents dumped into the stream by man, and other factors. The accompanying illustration shows changes of dissolved materials in the Fox River with changes in flow. The chemical data are from the Wisconsin Department of Natural Resources monitoring station at Omro. Similar changes in chemical quality occur throughout the basin.

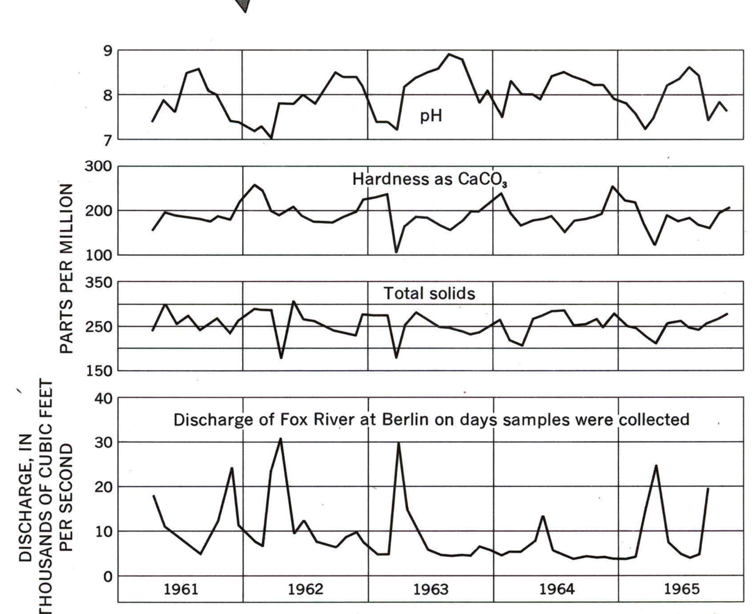
Both overland flow and ground-water discharge generally have a neutral pH of about 7, but ground water is more variable (see table, sheet 2). Stream water generally has the highest pH during the summer months because of biologic activity.

Hardness (as $CaCO_3$) and total solids in the Fox River are largely derived from ground-water discharge. Concentrations of hardness and total solids generally are least in the spring when the stream receives large quantities of overland flow from snow and icemelt. Concentrations of other dissolved minerals, largely contributed to the stream with ground-water discharge, fluctuate in a similar manner as hardness and total solids.

QUALITY OF SURFACE WATER AT SELECTED SITES

Results in parts per million except pH. Asterisk (*) indicates analysis by Wisconsin State Laboratory of Hygiene; remaining samples analyzed by the U.S. Geological Survey

Map key	Stream name and approximate location of gaging station	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids	Hardness (as $CaCO_3$)	Specific conductance (micromhos at 25°C)	pH
1	Grand River near Kingston	5/10/66	7.1	.96	.00	56	42	9.2	2.2	286	75	16.0	.2	2.1	356	390	601	7.6
2*	White River near Wautoma	3/11/66	10	.14	.05	37	20	1.8	0.6	185	6.0	2.0	.05	2.28	190	176	320	7.6
3	Tomorrow River at Amherst	5/10/66	11	.05	.00	43	22	3.7	.8	192	11	3.0	.4	5.4	208	214	353	8.6
4*	Waupaca River near Waupaca	3/11/66	9.6	.58	.05	34	16	2.1	1.7	163	10	2.9	.2	1.68	210	148	300	7.3
5*	Little Wolf River at Royalton	3/11/66	9.0	.34	.05	32	17	2.2	1.9	161	12	3.8	.25	.88	198	148	290	7.3
6*	Red River near Morgan	3/11/66	8.2	.3	.05	27	15	1.8	1.6	134	10	2.4	.2	.92	158	128	250	7.2
7*	Little W. Br. Wolf at Neopit	3/11/66	10.2	.24	.05	34	16	1.8	1.2	163	7	2	.2	1.0	178	148	290	7.4
8*	Evergreen River near White Lake	3/12/66	10.8	.08	.05	30	16	1.5	1.2	158	7	.8	.45	.4	158	140	270	7.7
9*	Swamp Cr. near Post Lake	3/12/66	8.4	.26	.05	19	9.2	1.7	.7	90	5	1.3	.05	.28	104	84	160	7.3
10*	Wolf River at Keshena Falls	3/12/66	10.2	.3	.05	27	17.2	1.8	1.1	132	7	1.7	.2	.56	154	138	230	7.4
11*	Embarrass River near Embarrass	3/11/66	6.5	.38	.05	30	14.7	2.2	2.4	144	12	3.8	.25	1.08	180	136	270	7.3
12	Wolf River at New London	3/11/66	5.0	.46	.05	22	9.1	2.1	3.0	95	14	3.8	.15	.66	130	92	200	7.2
13	Shioc River near Shiocton	5/10/66	5.2	1.2	.13	83	32	18	3.6	308	80	25	.3	1.3	436	425	659	7.7
14*	Fox River at Rapide Croche Dam	3/12/66	6.5	.38	.05	42	19.2	7.8	2.4	171	32	18.4	.25	<.24	252	184	370	7.7
15	Rat River near Winchester	5/10/66	4.2	---	--	76	38	7.4	.8	330	71	8.0	.4	1.1	412	421	607	7.6
16*	Fox River at Berlin	3/12/66	2.9	.22	.05	32	15.6	2.5	1.4	154	16	3.6	.1	.52	182	144	290	7.4
17	E. Br. Fond du Lac River near Fond du Lac	5/10/66	5.4	.29	.22	78	50	12	2.5	367	84	20	.3	3.3	457	499	724	8.2
18	S. Br. Embarrass River near Wittenberg	5/10/66	10	.29	.00	36	19	3.4	.8	190	11	4.0	.4	2.3	187	180	316	8.0

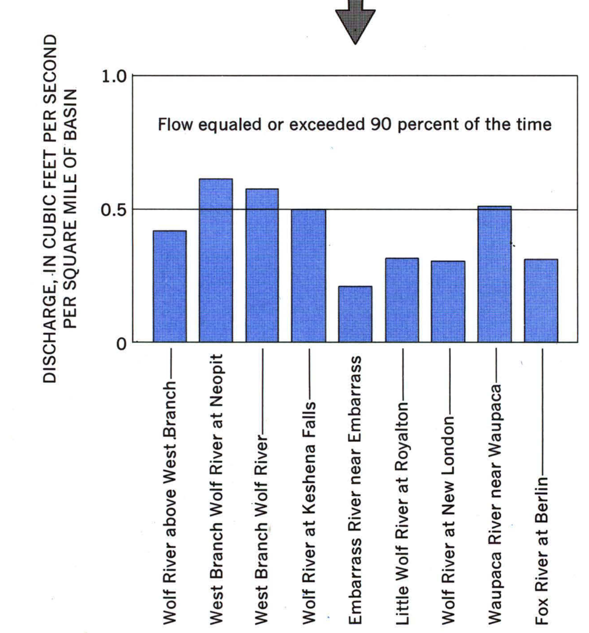


RELATIONSHIP OF STREAMFLOW AND WATER QUALITY

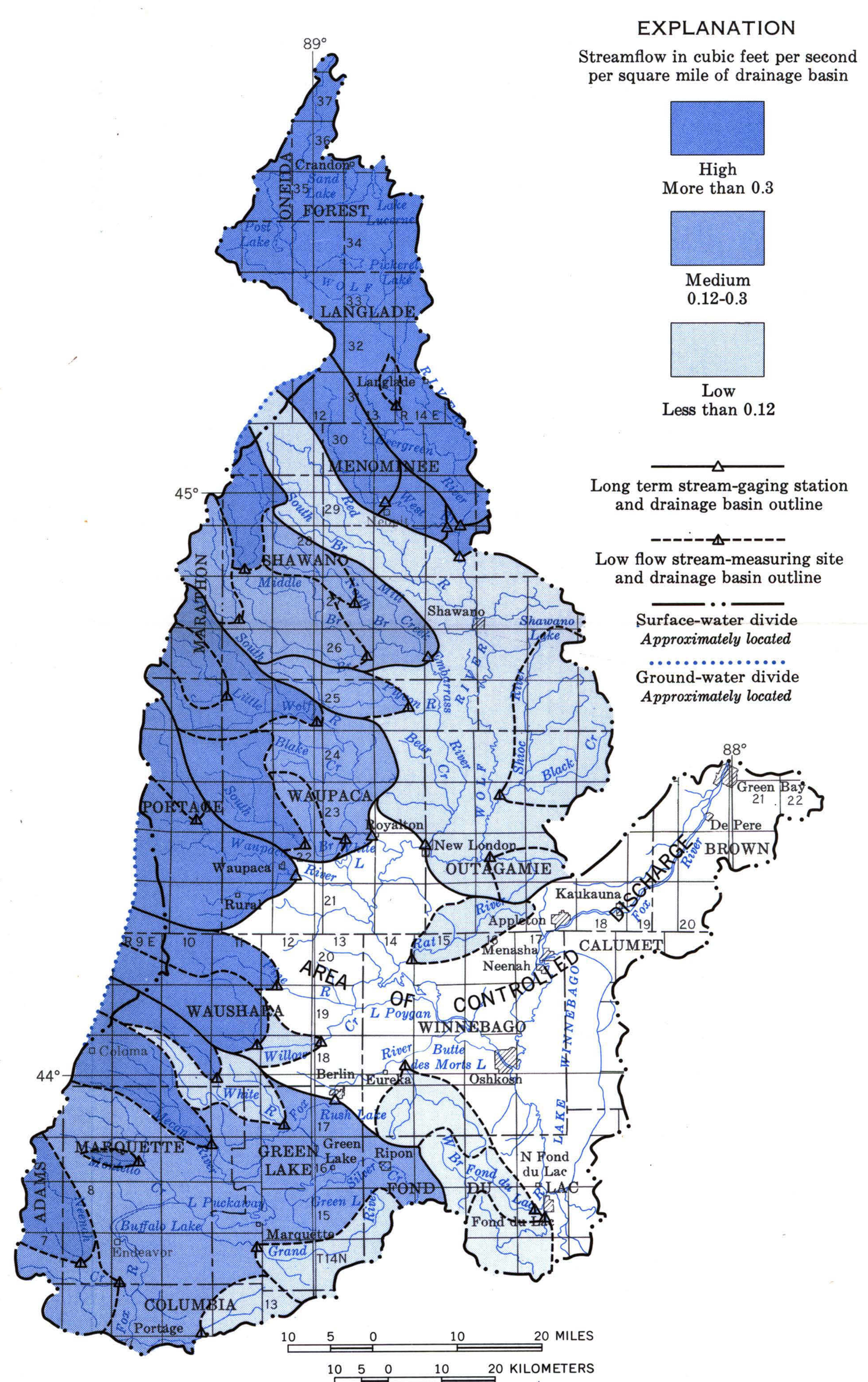
STREAM FLOW DIFFERENCES AND SIGNIFICANCES

Stream discharge per square mile in the Fox-Wolf River basin differs between subbasins and within a single subbasin because of differences in geology. Where permeable, thick, and extensive aquifers underlie the subbasin, base runoff to streams is large and the stream has a consistently high sustained flow. Floods from overland runoff are minimized because water from precipitation and snowmelt easily enters ground-water storage. Conversely, where aquifers are relatively impermeable, thin, or areally small, base runoff is low and streamflow is highly variable and diminishes greatly during the late summer. Such streams generally are subject to flash floods because most of the water from large rainstorms or sudden spring thaws flows overland, and only a small part enters ground-water storage.

Low-flow measurements of streams were made at 35 selected sites, including the principal gaging stations, in August 1965. Streamflows at the principal gaging stations were in the 80 and 90 percent range of flow duration. Many of the measurement sites were selected near the geologic contact between outwash deposits and glacial-lake deposits to determine differences in water yield per square mile in the two geologic environments. The stream measuring sites and range of yields per square mile of drainage basin are shown on the right. A graph of streamflow equaled or exceeded 90 percent of the time at the principal gaging stations shows the long-term basin water yields in the different geologic environments.



LOW FLOWS AT SELECTED STATIONS



LOW FLOW OF STREAMS

Base from U.S. Geological Survey
State base map, 1911

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1968—W68285

WATER RESOURCES OF WISCONSIN—FOX-WOLF RIVER BASIN

By
Perry G. Olcott

1968