STREAMFLOW AND WATER-QUALITY CONDITIONS, WILSONS CREEK AND JAMES RIVER, SPRINGFIELD AREA, MISSOURI

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GEOLOGICAL SURVEY

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CONVERSION FACTORS

For use of those readers who may prefer to use the International System of Units (SI) rather than inch-pound units, the conversion factors for the terms used in this report are listed below.

Multiply inch-pound units	By	To obtain SI units
foot	0.3048	meter
foot per mile	0.1896	meter per kilometer
cubic foot per second	0.02832	cubic meter per second
mile	1.609	kilometer
square mile	2.590	square kilometer
gallon	3.785	liter

To convert temperature in °C (degrees Celsius) to °F (degrees Fahrenheit), multiply by 1.8 and add 32.

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level." NGVD of 1929 is referred to as sea level in this report.

STREAMFLOW AND WATER-QUALITY CONDITIONS,

WILSONS CREEK AND JAMES RIVER, SPRINGFIELD AREA, MISSOURI

By Wayne R. Berkas

ABSTRACT

A network of water-quality-monitoring stations was established upstream and downstream from the Southwest Wastewater-Treatment Plant on Wilsons Creek to monitor the effects of sewage effluent on water quality. Data indicate that 82 percent of the time the flow in Wilsons Creek upstream from the wastewater-treatment plant is less than the effluent discharged from the plant. On October 15, 1977, an advanced wastewater-treatment facility was put into operation. Of the four water-quality indicators measured at the monitoring stations (specific conductance, dissolved oxygen, pH, and water temperature), only dissolved oxygen showed improvement downstream from the plant. During urban runoff, the specific conductance momentarily increased and dissolved-oxygen concentration momentarily decreased in Wilsons Creek upstream from the plant. Urban runoff was found to have no long-term effects on specific conductance and dissolved oxygen downstream from the plant before or after the addition of the advanced wastewater-treatment facility. Data collected monthly from the James River showed that the dissolved-oxygen concentrations and the total nitrite plus nitrate nitrogen concentrations increased, whereas the dissolved-manganese concentrations decreased after the advanced wastewater-treatment facility became operational.

INTRODUCTION

Wilsons Creek (fig. 1), in Greene and Christian Counties of southwestern Missouri, drains an area of approximately 84 square miles. The northern one-fourth of the basin is within the city limits of Springfield, Mo. Wilsons Creek flows into the James River, which also drains part of southern Springfield. The drainage basins of both streams are in the Springfield Plateau, which is underlain by rocks of Mississippian age.

Effluent from the Southwest Wastewater-Treatment Plant, which services part of Springfield, is discharged into Wilsons Creek. This effluent and materials that have been washed into Wilsons Creek by urban runoff have created water-quality problems. Various landowners and users of Wilsons Creek and the James River have complained of odor problems and fish kills.

The Federal Water Pollution Control Administration (FWPCA) [now the U.S. Environmental Protection Agency] studied this problem and presented their findings and recommendations in a report (Federal Water Pollution Control Administration, 1969). The results of the study showed that water-quality changes in Wilsons Creek and the James River were caused by a combination of urban runoff and sewage effluent. The FWPCA report recommended that the Southwest Wastewater-Treatment Plant construct a detention dam on Wilsons Creek upstream from the plant that would delay and decrease the peak flows from the urban area. The FWPCA report indicated that this dam would cause the materials washed from the urban areas to become diluted and less hazardous downstream from the plant; however, the detention dam was not constructed. The report also recommended that an advanced wastewater-treatment facility be added to the Southwest Wastewater-Treatment Plant. During September 1970, a sewage lagoon was installed at the plant and used until the advanced wastewater-treatment facility became operational on October 15, 1977.

Currently (1981), the Springfield Southwest Wastewater-Treatment Plant is designed to provide primary treatment; two-stage activated sludge treatment, consisting of pure oxygen-activated sludge; secondary settling; air nitrification; and final settling. Advanced treatment consists of final effluent filtration and disinfection with ozone. The plant is designed to process an average flow of 46.5 cubic feet per second (30 million gallons per day), and maximum flow of 65.1 cubic feet per second (42 million gallons per day). Flow-equalization basins with a capacity of 42 million gallons are provided to accommodate excessive flows during rainfall.

This report describes how the water quality in Wilsons Creek and the James River is affected by urban runoff and sewage effluent. Data are presented for before and after the advanced wastewater-treatment facility was added to the Southwest Wastewater-Treatment Plant.

METHODS OF STUDY

Water-quality-monitoring stations were installed to provide data upstream and downstream from the wastewater-treatment plant on Wilsons Creek and upstream and downstream from Wilsons Creek on the James River (fig. 1) to determine the effects of urban runoff and wastewater-treatment plant effluent on Wilsons Creek and the James River.

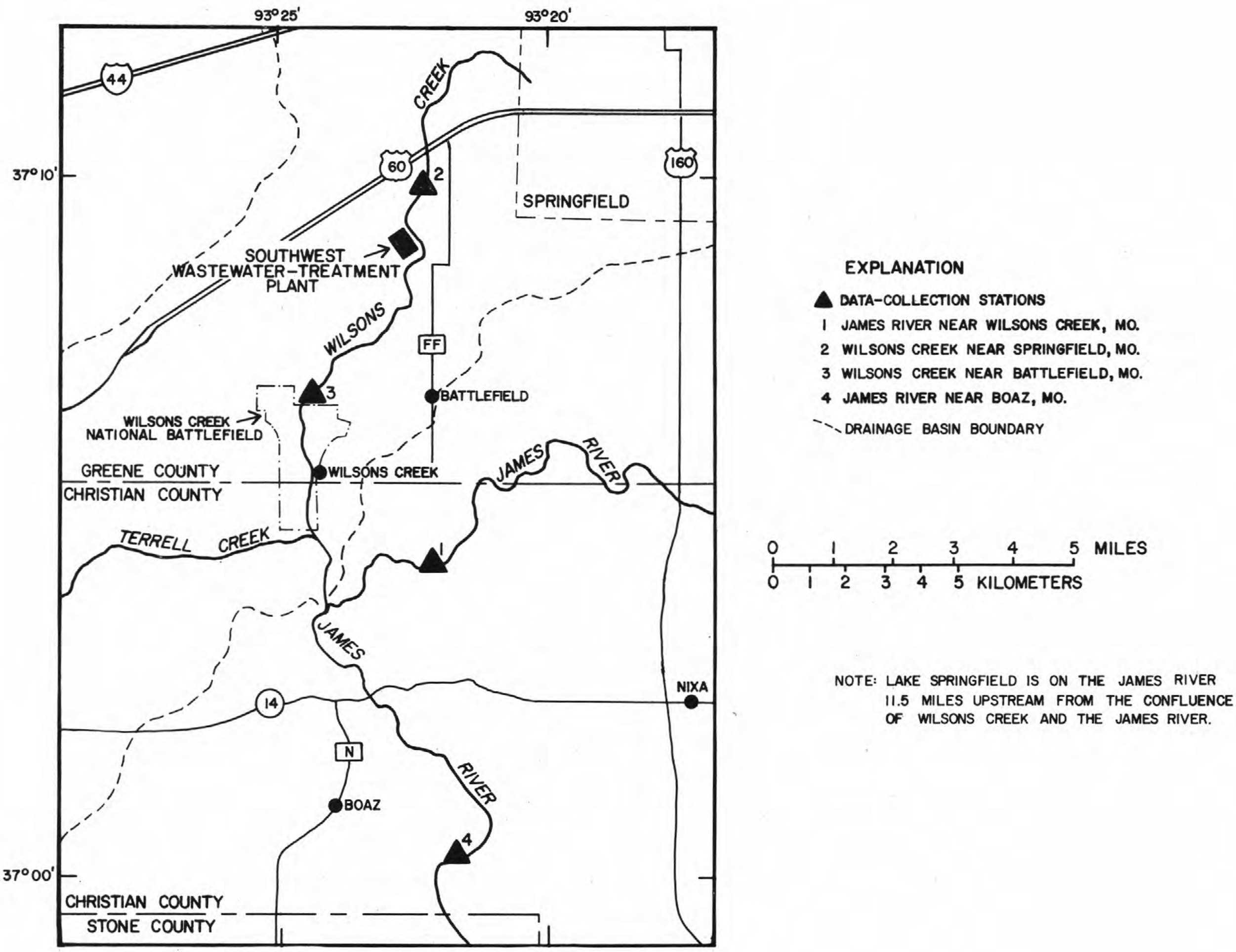

Figure 1.--Location of data-collection stations on Wilsons Creek and the James River.

Continuous records of water discharge, water temperature, specific conductance, pH, and dissolved-oxygen concentration were collected at Wilsons Creek near Springfield (fig. 1, station 2) upstream from the wastewater-treatment plant; Wilsons Creek near Battlefield (station 3) downstream from the wastewater-treatment plant; and James River near Boaz (station 4) downstream from the confluence of Wilsons Creek and the James River. In addition, water samples were collected at approximately monthly intervals from the James River near Wilsons Creek (station 1) and the James River near Boaz to determine physical characteristics, common inorganic constituents, major nutrients, and bacteria. All these data are published annually by the U.S. Geological Survey (1973-80).

Various statistical tests were used to analyze streamflow and water-quality data. Flow duration and flow frequency were determined to characterize flow conditions in the area. Statistical analyses were made on water-quality parameters collected before and after the completion of the advanced wastewater-treatment system to determine if there were significant differences.

The water-quality data were analyzed using a t-test to determine if the mean values of the parameters were significantly different for the two time periods. The procedure required that the two groups of data have equal variances. The means for the two groups of data are determined not to be significantly different if the sample variances are equal and sample means are not significantly different (Lentner, 1975).

SURFACE-WATER CHARACTERISTICS

Factors Affecting Streamflow

Wilsons Creek and the James River drain approximately one-half of the city of Springfield. The city is in the headwaters of Wilsons Creek basin, occupying approximately one-fourth of the total Wilsons Creek basin. The terrain in the drainage divide areas is gently rolling and ranges in elevation from 1,200 to 1,300 feet above sea level. Along the creeks and rivers, the relief is moderate. The average slope of Wilsons Creek is 17.4 feet per mile, and the average slope of the James River is 7.3 feet per mile. The Springfield Plateau is underlain by carbonate rocks of Mississippian age and sinkholes and springs are common. Within the corporate limits of Springfield, 195 sinkholes have been identified--more than three per square mile (Hayes, 1977). These sinkholes are major drains for storm runoff in the city of Springfield (Crawford, Murphy, and Tilly, Consulting Engineers, 1963).

The carbonate or karst topography has an effect on streamflow, especially low-flow conditions. Sinkholes throughout the area channel flow into natural underground conduits such as cracks, tunnels, and caves developed in the carbonate rocks. These conduits also intersect streambeds and cause the streams to gain or lose large amounts of water within a short distance, depending on the relationship of ground-water elevations to streambed elevation. Seepage-run data for Wilsons Creek show that it is not a losing stream downstream from the Southwest Wastewater-Treatment Plant (Emmett and others, 1978).

Springfield occupies a small part of the James River basin, thus urban runoff has little effect on streamflow or water quality in the James River. Lake Springfield is 11.5 miles upstream from the confluence of Wilsons Creek and the James River and affects flow in the James River downstream from the lake, particularly during low flow. The purpose of the reservoir is to provide water for cooling at the Springfield power plant. Discharge from the reservoir follows no specified schedule, although the operators try to maintain flow in the James River.

Flow Variability, Magnitude, and Frequency

The records from three streamflow-gaging stations (fig. 1, stations 2, 3, and 4) were analyzed for variability in flow with time. For the period of record common to these stations (October 1972 through September 1979), calendar year 1978 had a yearly volume of flow closest to the mean yearly volume of flow. The hydrograph for each station for 1978 (figs. 2, 3, and 4) gives an example of the variability expected for an average year and shows that the stations having the smallest drainage area have the greatest flow variability. Low flow of Wilsons Creek near Springfield has much greater variability than at the other two stations (figs. 2, 3, and 4) because the wastewater-treatment plant augments the flow at Wilsons Creek near Battlefield, and Lake Springfield partly regulates the low flow of the James River near Boaz.

Low-Flow Characteristics

The volume of flow in a stream largely determines the dilution capabilities of the stream. Thus it is useful to know the percentage of time that streamflow does not exceed a given value to understand how the effluent will affect the water quality in the streams. The percentage of time that daily discharges are less than specific values is shown in figures 5, 6, and 7. Streamflow in Wilsons Creek near Springfield is less than 10 cubic feet per second approximately 50 percent of the time (fig. 5). The average daily sewage effluent discharged from the wastewater-treatment plant from July 1980 to February 1981 was 33 cubic feet per second (M. Trotter, Southwest Wastewater-Treatment Plant, oral commun., 1981).

The discharge in Wilsons Creek increases between Wilsons Creek near Springfield and the outflow from the Southwest Wastewater-Treatment Plant, but this increase is minor in relation to the total flow. Eighty-two percent of the time the flow in Wilsons Creek near Springfield is less than the average sewage-effluent discharge.

Duration of low flows can sometimes be misleading because it does not indicate how long a period low flow is maintained in a stream. For this reason, frequency of recurrence of the 7-day average low flow for the three continuous-record, streamflow-gaging stations is shown in table 1. The values for the 2- and 5-year recurrence intervals were calculated following the guidelines described by Riggs (1972).

High-Flow Characteristics

Recurrence intervals of floods can be computed from peak-flow data measured at long-term streamflow-gaging stations when the basin characteristics and flow characteristics are not significantly affected by man. In the Wilsons Creek basin, the period of record is relatively short and urbanization and effluent from the Southwest Wastewater-Treatment Plant have changed the flow characteristics at all the stations. Estimates of recurrence intervals have been made in two ways: (1) Using regional equations of flood magnitude and frequency, and (2) using log-Pearson Type III fitting of flood peaks during the period of record (table 2).

Estimates of peak flow for various recurrence intervals were made from equations developed by Hauth (1974). These equations are used to estimate a peak flow for selected recurrence intervals. The peak flow for each recurrence interval was plotted on log-probability paper and a line was fitted to the data. The peak flows for each year were compared to this line and an estimated recurrence interval obtained. These estimated recurrence intervals are given in table 2.

Annual peak flows also were analyzed using log-Pearson Type III methods as outlined by the U.S. Water Resources Council (1977). Estimates of recurrence intervals for the yearly peak flows were made from these distributions and are given in table 2. Because of the short period of record, estimates of flows for recurrence intervals greater than 10 years were not made.

Recurrence intervals shown in table 2 need to be used with caution because floodflows are: (1) Decreased by the many sinkholes in the area, which divert surface runoff; and (2) increased because of urbanization in each basin. The degree that one compensates for the other is unknown. Additional data and study are needed to determine these factors.

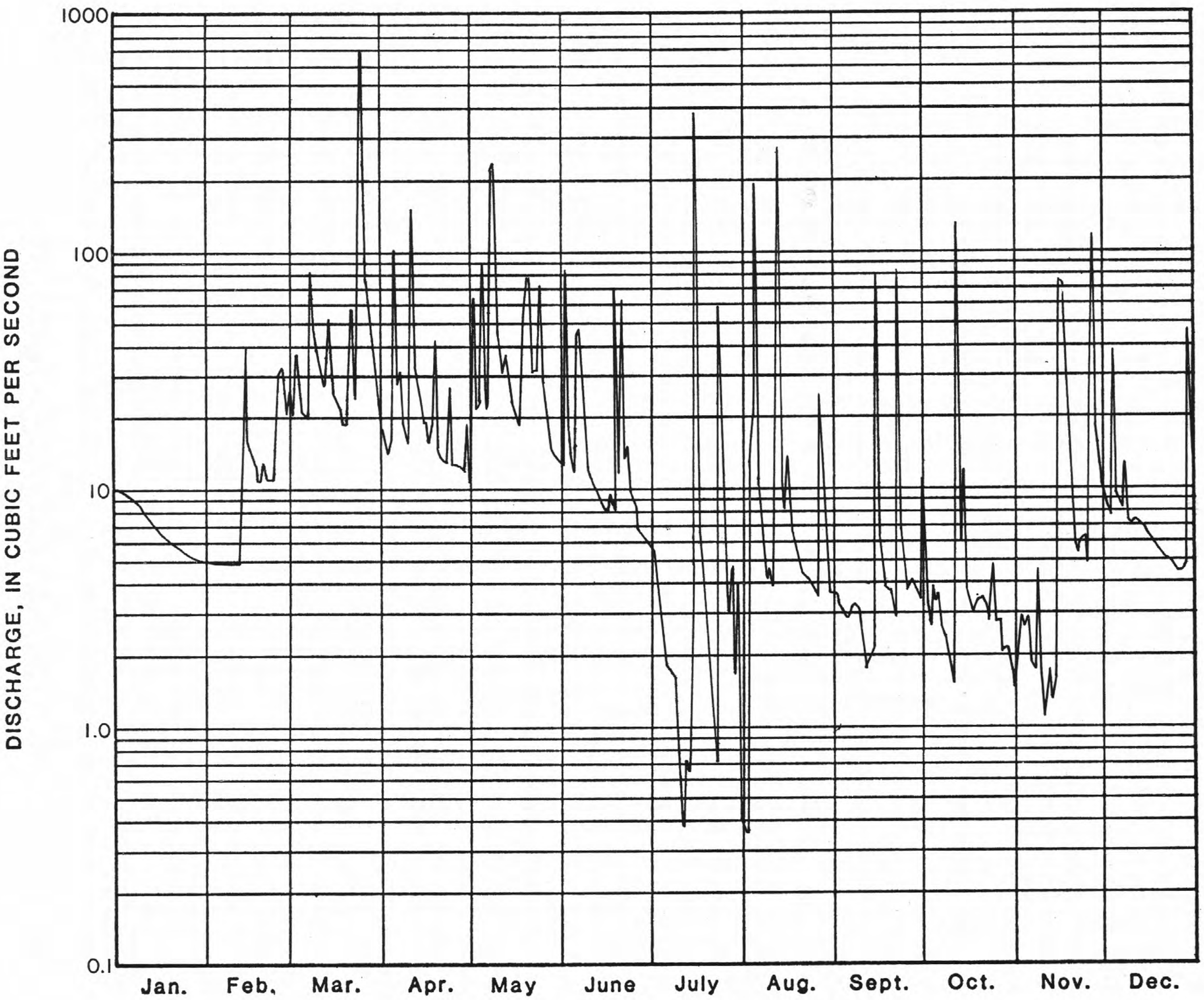

Figure 2.--Daily discharge for 1978, Wilsons Creek near Springfield (fig. 1, station 2).

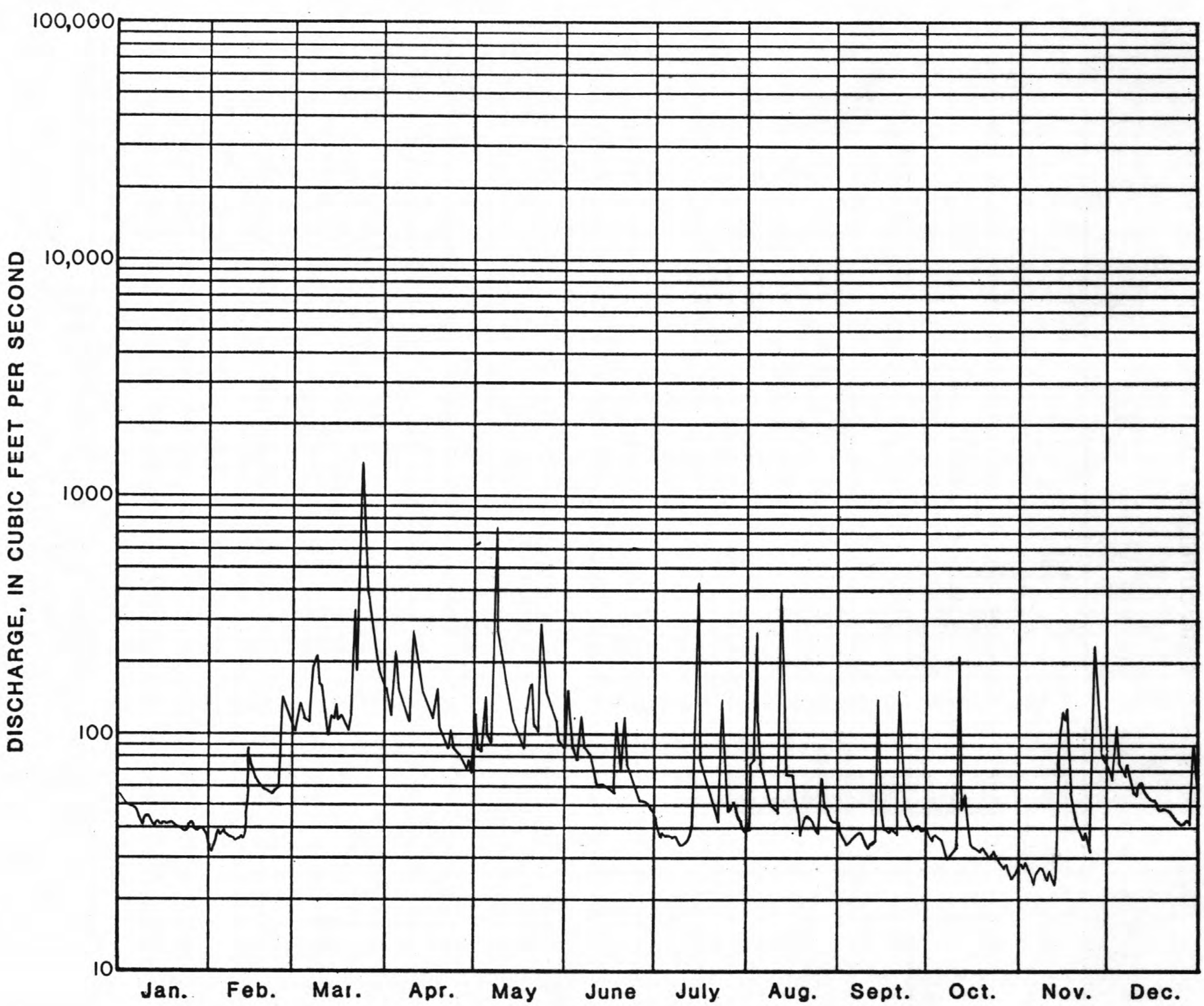

Figure 3.--Daily discharge for 1978, Wilsons Creek near Battlefield (fig. 1, station 3).

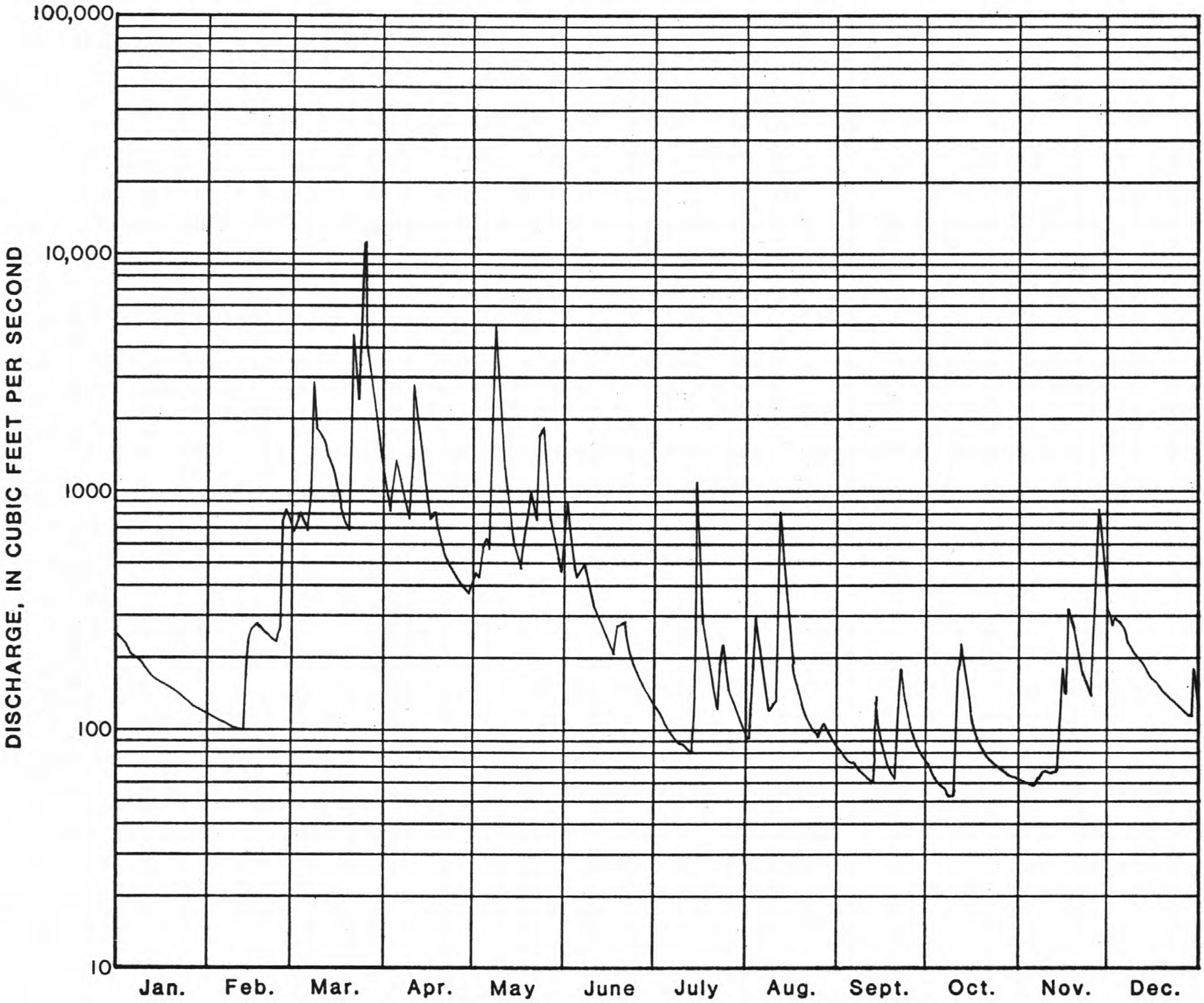

Figure 4.--Daily discharge for 1978, James River near Boaz (fig. 1, station 4).

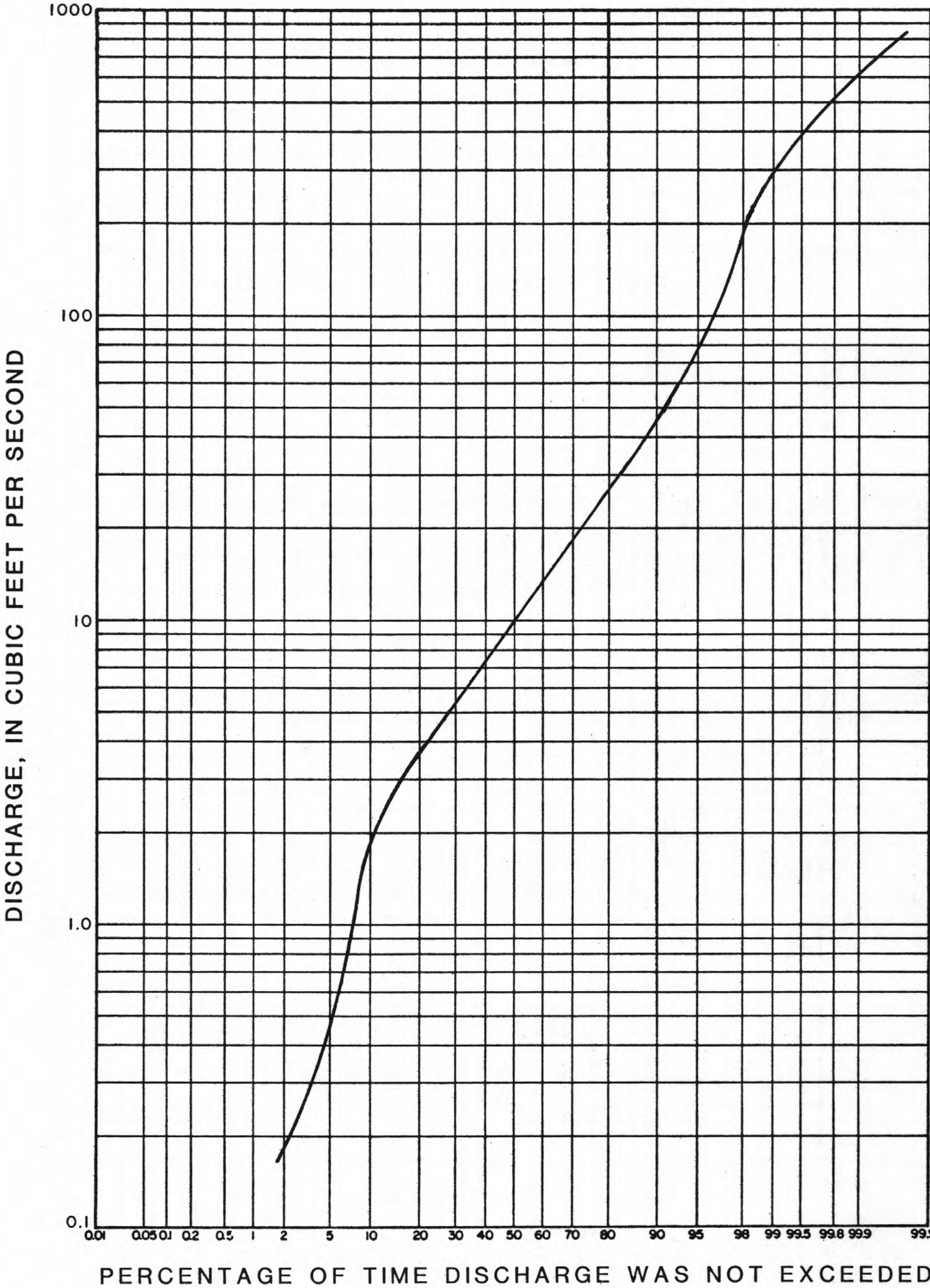

Figure. 5.--Discharge duration curve for Wilsons Creek near Springfield.

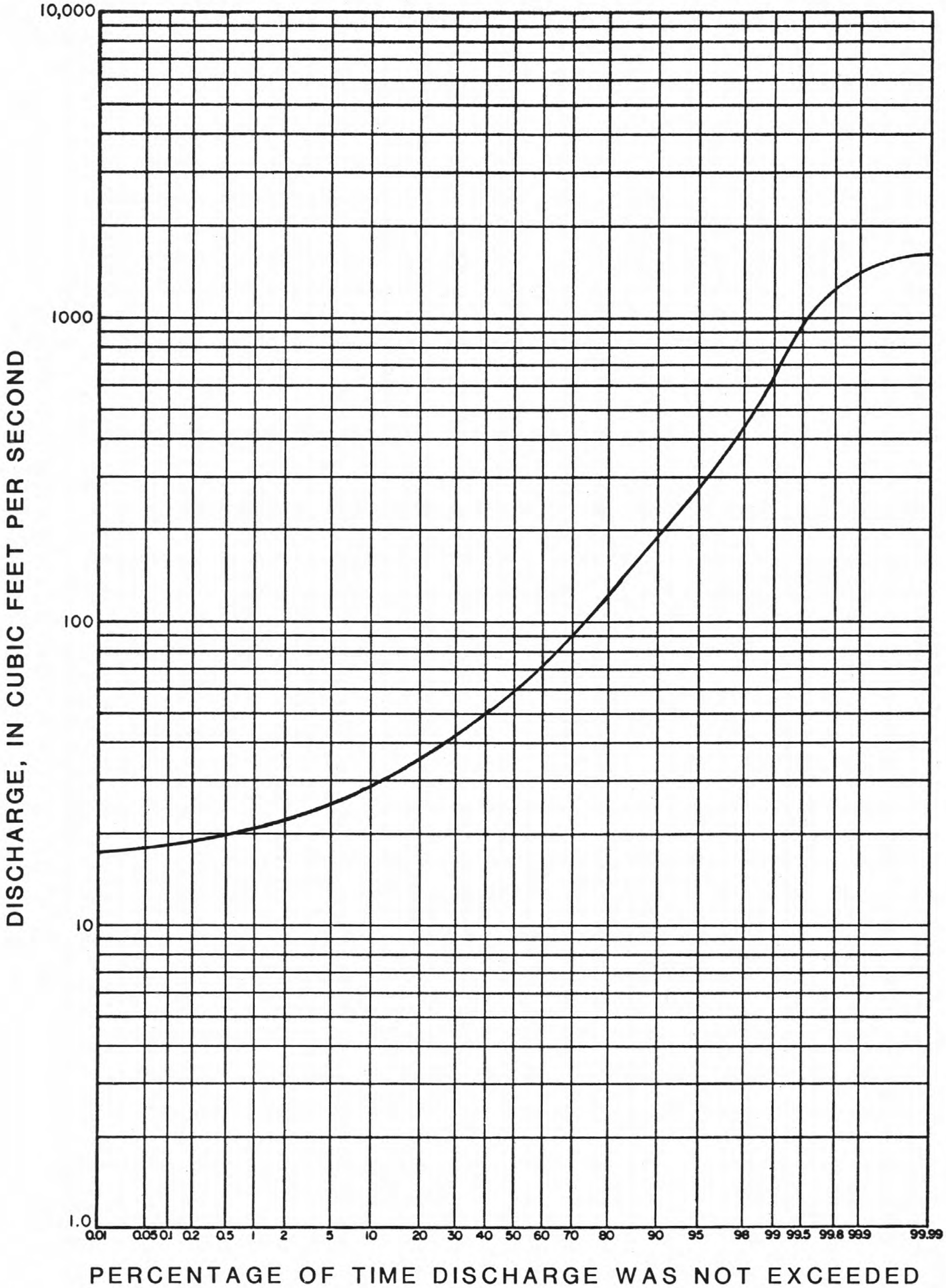

Figure 6.--Discharge duration curve for Wilsons Creek near Battlefield.

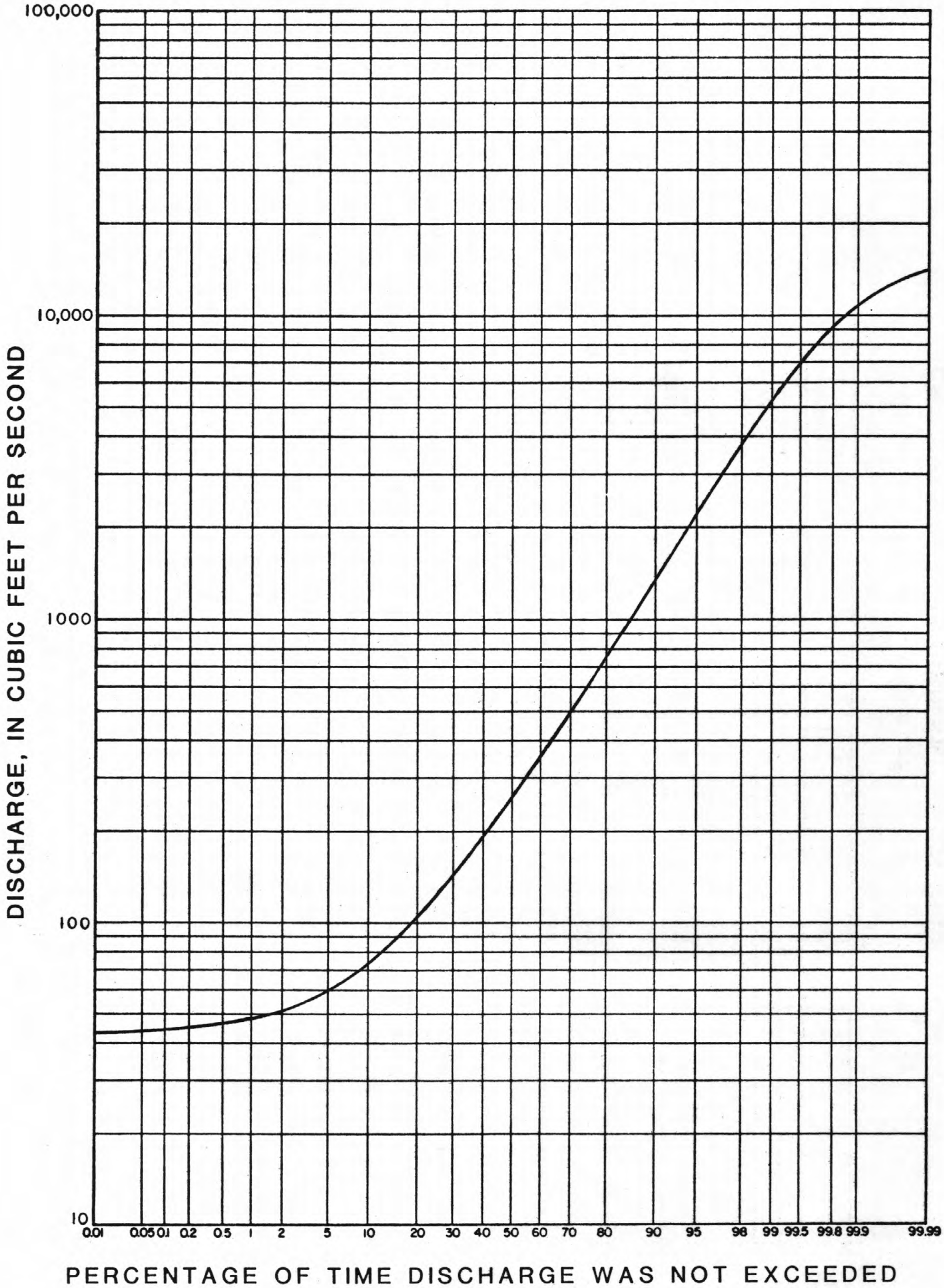

Figure 7.--Discharge duration curve for the James River near Boaz.

Table 1.--Estimates of lowest 7-day average flow for given recurrence intervals at three continuous-record, streamflow-gaging stations

Station no. (fig. 1)	Station name	Period of record used in analysis	7-day average flow, in cubic feet per second, for indicated recurrence interval, in years: 2	5
2	Wilsons Creek near Springfield	April 1974-March 1978	0.6	0.2
3	Wilsons Creek near Battlefield[1]	April 1969-March 1970 April 1974-March 1978	27.0	23.0
4	James River near Boaz[1]	April 1974-March 1979	62.0	51.0

[1]Augmented by flow from Southwest Wastewater-Treatment Plant. Although low flows were augmented by gradually increasing amounts of effluent from Southwest Wastewater-Treatment Plant, the pattern was consistent enough for limited frequency estimates.

Table 2.--Yearly peak flows and estimated recurrence intervals for three continuous-record, streamflow-gaging stations

Station no. (fig. 1)	Station name	Period of record used in analysis	Drainage area, in square miles	Water year	Peak flow, in cubic feet per second	Estimated recurrence interval, in years[1]	Estimated recurrence interval, in years[2]
2-------	Wilsons Creek near Springfield	October 1972-September 1979	31.4	1973	2,840	2	2
				1974	2,510	2	---
				1975	2,720	2	---
				1976	2,680	2	---
				1977	3,320	3	6
				1978	2,170	---	---
				1979	3,480	3	10
3-------	Wilsons Creek near Battlefield	March 1968-September 1970	55.0	1969	2,390	---	---
				1970	2,420	---	---
		October 1972-September 1979		1973	3,860	2	3
				1974	2,820	---	---
				1975	2,490	---	---
				1976	2,130	---	---
				1977	4,830	3	7
				1978	2,010	---	---
				1979	7,240	9	>10
4-------	James River near Boaz	October 1972-September 1979	462	1973	31,400	>10	>10
				1974	16,900	4	---
				1975	11,500	2	---
				1976	9,800	---	---
				1977	23,000	8	3
				1978	15,900	3	---
				1979	24,200	9	4

[1]Based on regional relationships for rural areas (Hauth, 1974).

[2]Based on log-Pearson Type III fitting.

Water-Quality Characteristics

Factors Affecting Water Quality

The quality of water in a stream is affected by flow conditions, ground-water seepage, climate, and land use. Flow volume characterizes the diluting ability of the stream. If water containing excessive constituent concentrations is introduced into a stream that has a large flow, the water quality of the receiving stream may not change significantly due to dilution. Similarly, the change in the stream's water quality caused by ground-water inflow depends on the quality and volume of ground water entering the stream. Climatic conditions affect biochemical reactions occurring in the stream, and these in turn affect some water-quality parameters such as dissolved oxygen. Land use determines, in part, the type of material that enters a stream by overland flow.

Effects of Sewage Effluent

Sewage effluent contains large concentrations of biodegradable materials, nutrients, and inorganic compounds which are added through municipal use of the water. Wastewater-treatment facilities attempt to remove the biodegradable materials and nutrients, but usually the sewage effluent has larger concentrations of inorganic and biodegradable materials than before the water is used.

On October 15, 1977, an advanced wastewater-treatment facility, which uses an ozonation process, became operational at the Southwest Wastewater-Treatment Plant. The ozonation process treats the effluent with ozone to disinfect the sewage. As the ozone (O_3) breaks down, it forms oxygen (O_2) that oxidizes the organic material in the sewage. Ozonation produces effluent with less biochemical oxygen demand and more dissolved oxygen. Analyses made of water-quality samples collected on April 6, 1977 (before the addition of the advanced wastewater-treatment system), showed the effluent had a biochemical oxygen demand of 77 milligrams per liter and dissolved-oxygen concentration of 5.8 milligrams per liter; analyses of samples collected on April 8, 1981 (after the addition of the advanced wastewater-treatment system), showed the effluent had a biochemical oxygen demand of 4 milligrams per liter and dissolved-oxygen concentration more than 20 milligrams per liter (Burks, Jim, Southwest Wastewater-Treatment Plant, 1981, written commun.).

Before the addition of the advanced wastewater-treatment facility, the sewage effluent caused a decrease in dissolved-oxygen concentration in Wilsons Creek near Battlefield (fig. 8). By the time the effluent reached the James River near Boaz, the dissolved-oxygen concentration had increased.

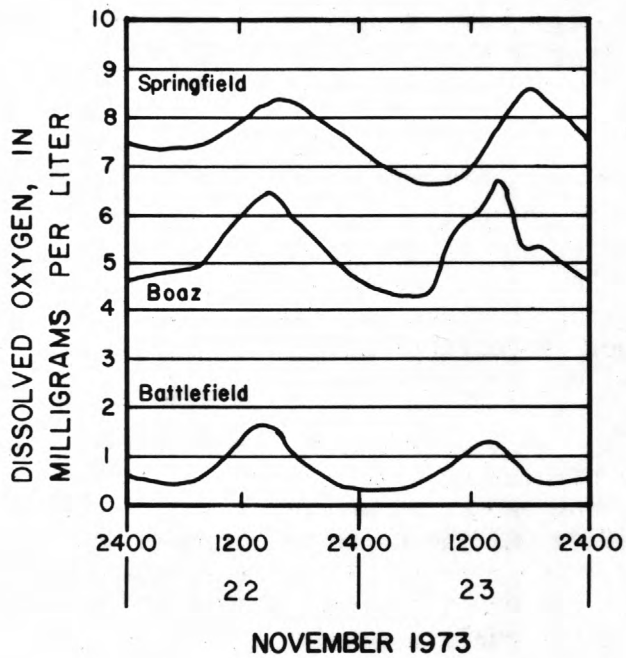

Figure 8.--Dissolved-oxygen concentrations for Wilsons Creek near Springfield, Wilsons Creek near Battlefield, and the James River near Boaz, before addition of the advanced wastewater-treatment facility (fig. 1, stations 2, 3, and 4).

Oxidation of biodegradable material by organisms causes a decrease in the dissolved-oxygen concentration of the water. The dissolved-oxygen is replenished by reareation and photosynthesis. During daylight hours, photosynthetic activity produces enough oxygen to more than compensate for the metabolic use of oxygen by microorganisms, resulting in an increase in dissolved-oxygen concentration. When daylight ends, photosynthesis ends; but the metabolic reduction of oxygen continues and the dissolved-oxygen concentration decreases.

Before the advanced wastewater-treatment facility became operational, the dissolved-oxygen concentration of the James River near Boaz varied diurnally from 0.0 to 6.0 milligrams per liter, as shown in figure 9. Approximately two-thirds of the flow of the James River near Boaz comes from Wilsons Creek, thus decreasing the diluting characteristics of the James River. Dissolved-oxygen concentration was about zero in the James River because the biodegradable material in the sewage effluent was not totally oxidized in Wilsons Creek.

Dissolved-oxygen concentrations after addition of the advanced wastewater-treatment facility, show an increase for Wilsons Creek near Battlefield (fig. 10). The increase is due to the smaller biochemical oxygen demand of the effluent.

Data collected after the advanced wastewater-treatment system was operational show that the dissolved-oxygen concentration in Wilsons Creek near Battlefield was larger than in Wilsons Creek near Springfield and in the James River near Boaz. An example of this is shown in figure 11. The ozonization process almost eliminates the biodegradable material and produces an effluent that is supersaturated with dissolved oxygen. Part of the excess dissolved oxygen is used to oxidize the remaining oxidizable material and the rest is released to the atmosphere until equilibrium between the atmosphere and the water is attained. The dissolved-oxygen concentration in the James River near Boaz is less than that in Wilsons Creek near Battlefield; this may be due to oxidation of materials, reareation, or both.

The specific conductance, pH, and water temperature of the sewage effluent are not changed by the ozonation process. Therefore these parameters at the water-quality-monitoring stations should not change with the operation of the advanced wastewater-treatment facility; the data indicate this to be true. Statistical procedures cannot be used for the data before 1978 because the record is too fragmentary.

The sewage effluent caused the specific conductance in Wilsons Creek near Battlefield to increase because of the increased amount of inorganic compounds (fig. 12).

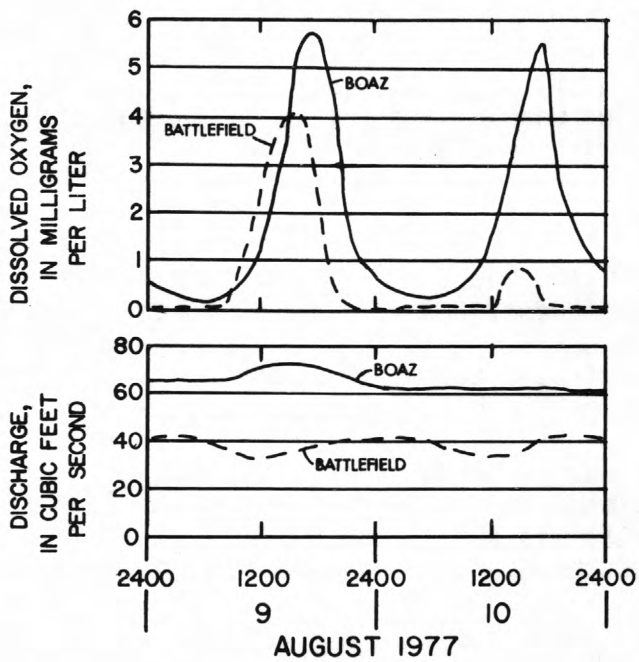

Figure 9.--Dissolved-oxygen concentrations and discharge for Wilsons Creek near Battlefield and the James River near Boaz, before addition of the advanced wastewater-treatment facility (fig. 1, stations 3 and 4).

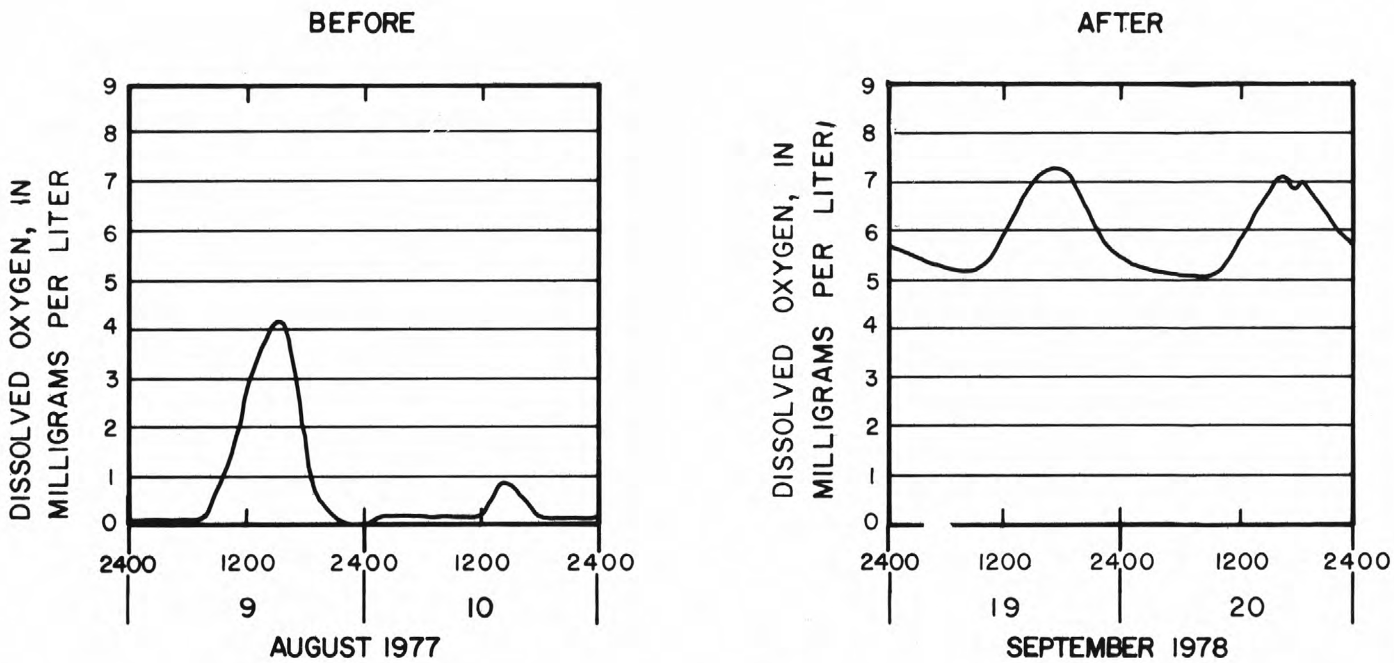

Figure 10.--Dissolved-oxygen concentration for Wilsons Creek near Battlefield before and after addition of the advanced wastewater-treatment facility (fig. 1, station 3).

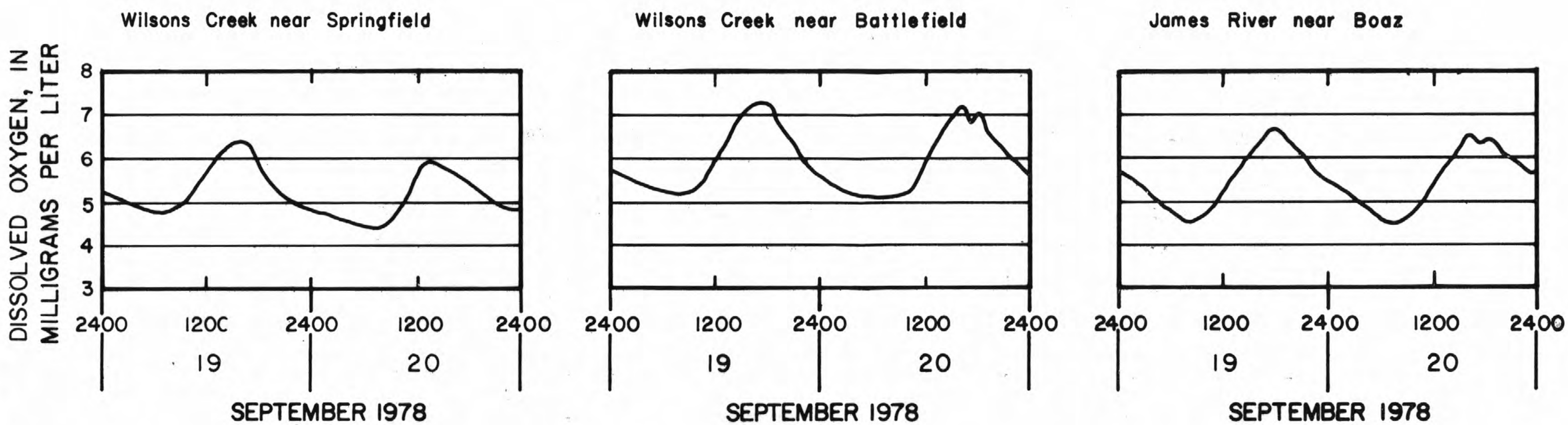

Figure 11.--Dissolved-oxygen concentration for Wilsons Creek near Springfield, Wilsons Creek near Battlefield, and the James River near Boaz, after addtiion of the advanced wastewater-treatment facility (fig. 1, stations 2, 3, and 4).

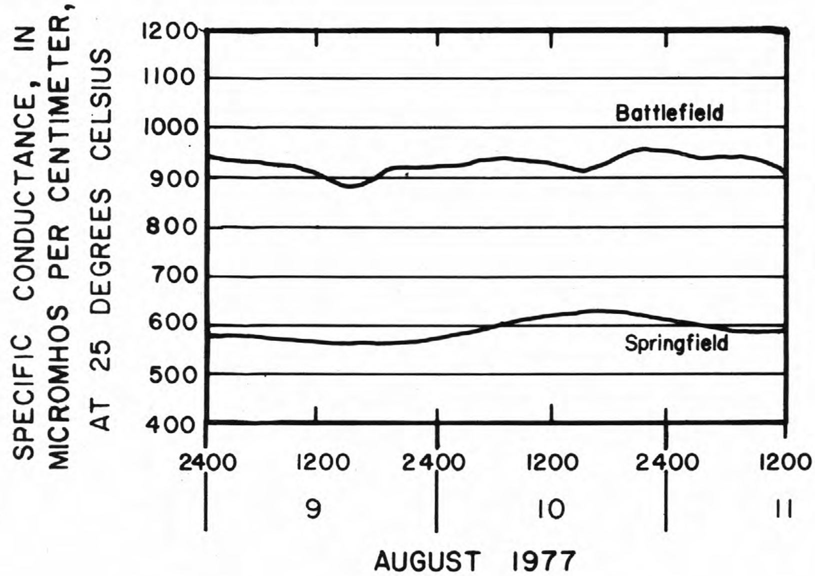

Figure 12.--Specific-conductance values for Wilsons Creek near Springfield, and Wilsons Creek near Battlefield (fig. 1, stations 2 and 3).

During cold-weather periods, the sewage effluent increases the water temperature in Wilsons Creek downstream from the wastewater-treatment plant (fig. 13). The effluent has traveled below ground to the wastewater-treatment plant, thus the colder climate has not had a chance to cool the effluent.

The effluent tends to maintain a pH of 7.4 in Wilsons Creek near Battlefield, whereas the pH in Wilsons Creek at Springfield may be larger (fig. 14). The difference in pH between the two stations is due to the pH of the sewage effluent. The sewage-treatment process tends to maintain a pH of approximately 7.4 in the effluent, and because the volume of effluent discharged into Wilsons Creek usually is greater than the flow in Wilsons Creek, the pH downstream from the wastewater-treatment plant will tend toward 7.4.

Effects of Urban Runoff

The effects of urban runoff on specific conductance and dissolved-oxygen concentrations for Wilsons Creek near Springfield (fig. 1, station 2) and Wilsons Creek near Battlefield (fig. 1, station 3) before the addition of the advanced wastewater-treatment facility are shown in figure 15.

Before the February 12, 1977 storm, specific conductance was about 800 micromhos per centimeter near Springfield, and 1,250 micromhos per centimeter near Battlefield. The larger values reflect the effect of the effluent discharge. A significant increase in specific conductance occurred momentarily at both stations as the discharge increased due to the runoff from the storm. At Springfield the increase was caused by readily ionizable material washing into the stream. At Battlefield the increase was partly due to ionizable material washing into the stream, and partly due to resuspension of sewage sludge. As runoff continued to increase, specific conductance decreased because of dilution and quickly reached a minimum of less than 600 micromhos per centimeter near Springfield and less than 800 micromhos per centimeter near Battlefield.

Dissolved-oxygen concentrations were about 10 milligrams per liter near Springfield and 2 milligrams per liter near Battlefield before the February 12, 1977 storm (fig. 15). The smaller concentration near Battlefield was caused by the effluent discharge. During initial runoff, water with minimal dissolved-oxygen concentration enters the stream. Dissolved-oxygen concentrations decreased to 7 milligrams per liter near Springfield and increased slightly as the runoff contained greater amounts of dissolved oxygen. Near Battlefield, the dissolved-oxygen concentration decreased to almost zero during the initial flushing period, but quickly recovered to concentrations similar to those upstream from the wastewater-treatment plant as flow increased.

The decrease to almost zero probably was due to resuspension of sludge that had accumulated on the streambed from the wastewater-treatment plant.

The changes in specific conductance and dissolved-oxygen concentration at Wilsons Creek near Battlefield had little relation to whether the runoff was from an urban area or a natural area. The changes that occurred were a result of resuspension of sludge from the streambed, and dilution.

Effects of urban runoff on specific conductance and dissolved-oxygen concentrations at the two Wilsons Creek stations for the August 20-21, 1978 storm, after the addition of the advanced wastewater-treatment facility, are shown in figure 16. The peak flows at the two stations were about twice as large for this storm as for the February 12, 1977 storm. This resulted in greater dilution and hence smaller minimum specific conductance. The minimum dissolved-oxygen concentration for the 1978 storm was 5.5 milligrams per liter near Battlefield compared to almost zero for the 1977 storm. The increase probably resulted from the absence of sludge accumulation on the streambed after the addition of the advanced wastewater-treatment facility.

Effects of the Wastewater-Treatment Plant on Water Quality in the James River

Data collected from the James River upstream and downstream from the confluence with Wilsons Creek (fig. 1, stations 1 and 4) were analyzed statistically to determine how the addition of the advanced wastewater-treatment facility affected the water quality in the James River. The data were divided into two periods; before the addition (September 1970 to September 1977), and after the addition (October 1977 to September 1979). T-tests were used to determine if the mean values for a number of parameters were significantly different for the two periods. Univariate statistics (mean, standard deviation, and so forth) were used to show magnitude of change.

The Statistical Analysis System (SAS)[1] programs TTEST (computes the t statistics), MEANS (univariate descriptive statistics), and FREQ (frequency table) [Helwig and Council, 1979], were used to analyze the data. The TTEST program also tests for equality of the variances.

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[1]The use of brand names in this report is for identification only and does not imply endorsement by the U.S. Geological Survey.

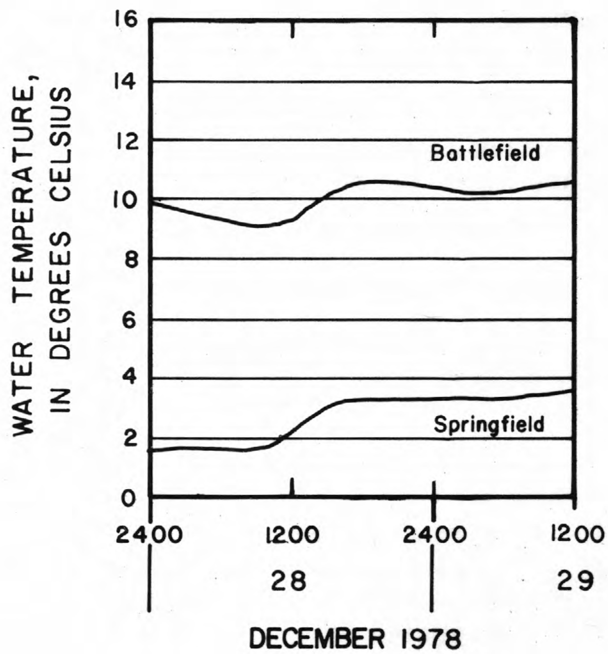

Figure 13.--Water temperatures during winter for Wilsons Creek near Springfield, and Wilsons Creek near Battlefield (fig. 1, stations 2 and 3).

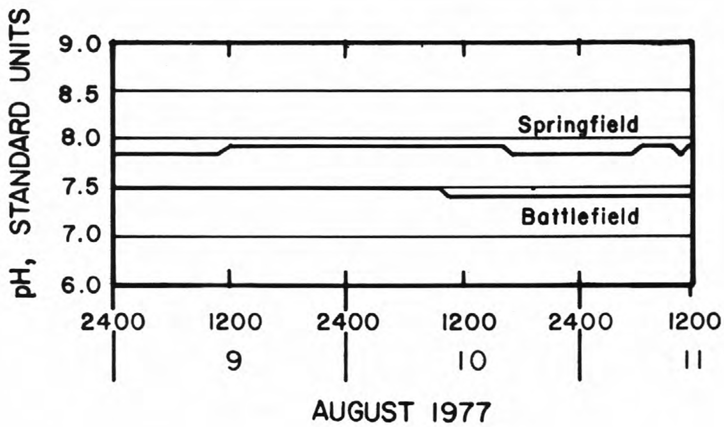

Figure 14.--pH values for Wilsons Creek near Springfield, and Wilsons Creek near Battlefield (fig. 1, station 2 and 3).

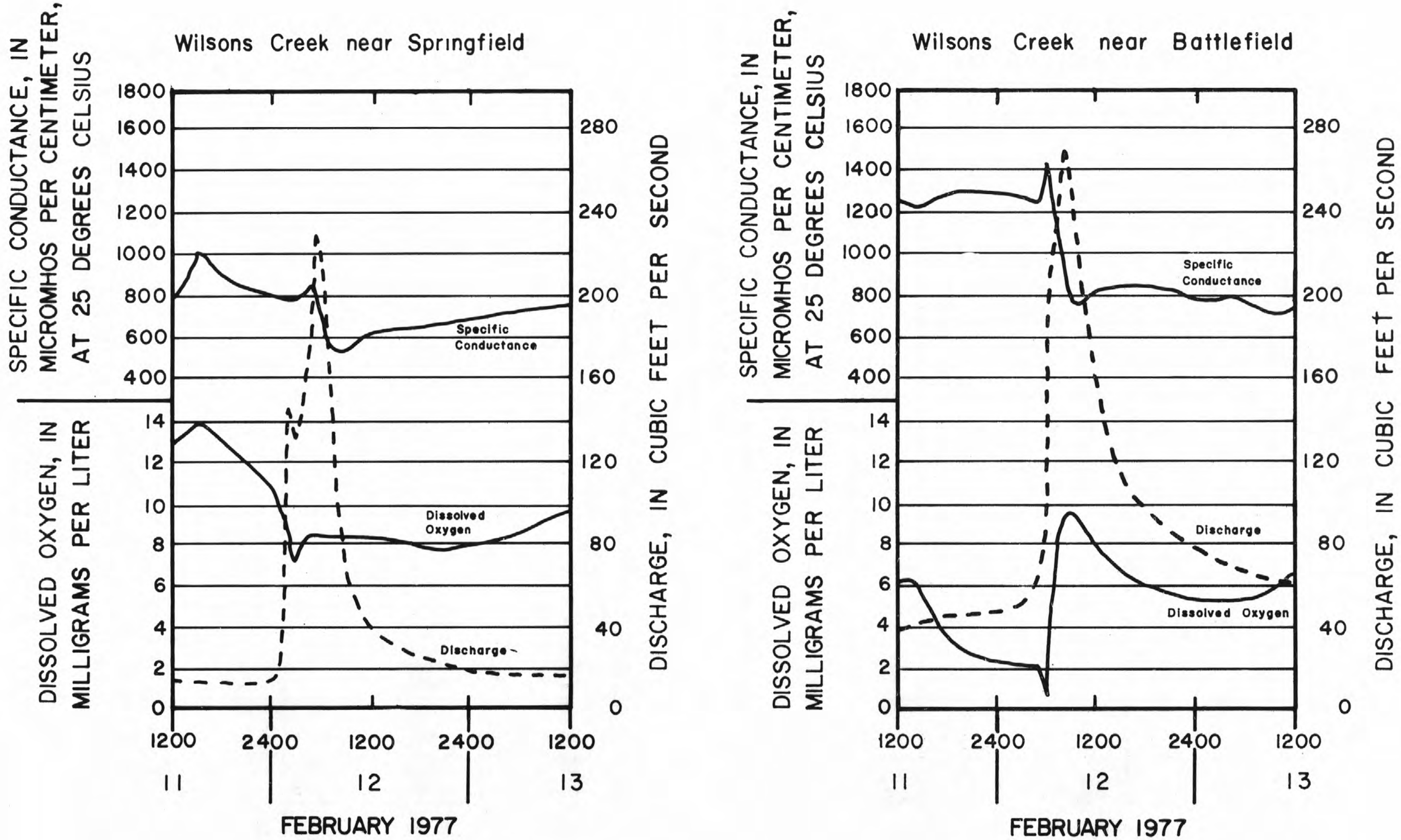

Figure 15.--Specific-conductance values and dissolved-oxygen concentrations for Wilsons Creek near Springfield, and Wilsons Creek near Battlefield during urban runoff, before addition of the advanced wastewater-treatment facility (fig. 1, stations 2 and 3).

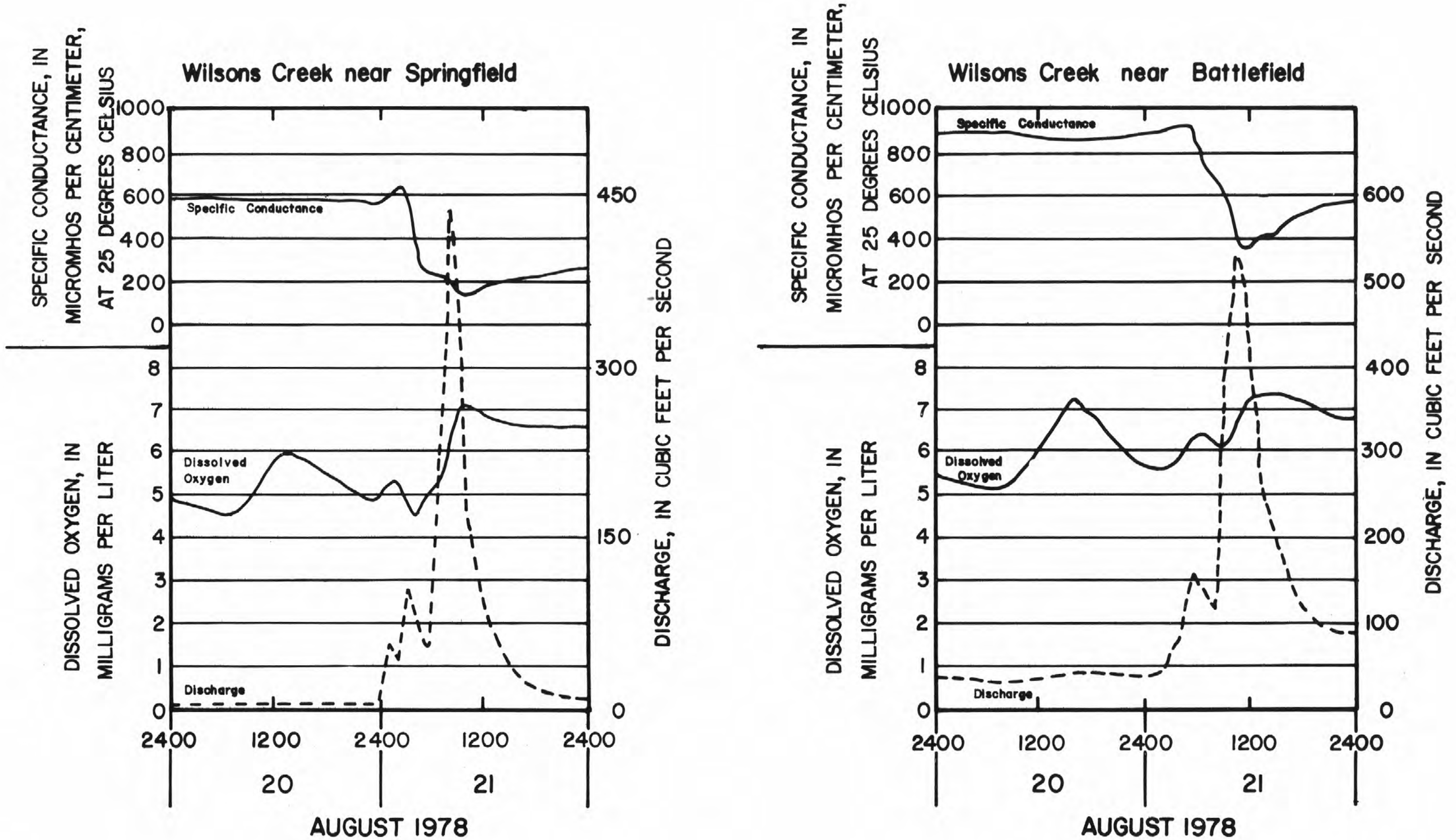

Figure 16.--Specific-conductance values and dissolved-oxygen Concentrations for Wilsons Creek near Springfield, and Wilsons Creek near Battlefield during urban runoff, after addition of the advanced wastewater-treatment facility (fig. 1, stations 2 and 3).

Fourteen water-quality parameters measured at the two stations (stations 1 and 4) were statistically analyzed. Samples were collected before (period 1) and after (period 2) the addition of the advanced wastewater-treatment facility. The univariate statistics for the 14 parameters for each station and time period are given in tables 3 and 4. Four t-tests were made on 12 parameters to determine if the mean concentrations were significantly different at the 0.05 probability level between: (1) Stations 1 and 4 for period 1, (2) stations 1 and 4 for period 2, (3) periods 1 and 2 for station 1, and (4) periods 1 and 2 for station 4. The results are summarized in table 5.

Results of the t-tests may be used to determine those parameters for which mean concentrations have changed. The parameters that may be affected by the addition of the advanced wastewater-treatment facility will show a change at station 4 when compared between time periods. The new wastewater-treatment facility definitely affected those parameters that also did not show a change at station 1 when compared between time periods. Dissolved oxygen, dissolved manganese, and total nitrite plus nitrate nitrogen are the only parameters that show a significant change at station 4 when compared between time periods. Dissolved oxygen and dissolved manganese did not show a significant change at station 1 when compared between time periods.

The average dissolved-oxygen concentration increased from 6.7 to 8.5 milligrams per liter in the James River near Boaz, after the addition of the advanced wastewater-treatment facility. The t-test showed that the average concentration did not change in James River near Wilsons Creek for the same time periods. This indicates that the new wastewater-treatment facility has caused an increase in the dissolved-oxygen concentration in the James River. The t-test also showed no change in average dissolved-oxygen concentration between the two stations after the addition of the wastewater-treatment facility. The dissolved-oxygen concentration in the James River is no longer altered by the sewage effluent from the Southwest Wastewater-Treatment Plant.

The average dissolved-manganese concentration decreased from 57.5 to 22.9 micrograms per liter in the James River near Boaz, after the addition of the advanced wastewater-treatment facility. The t-test also showed that the average concentration did not change in the James River near Wilsons Creek for the same time period. This indicates that the new wastewater-treatment facility has caused a decrease in dissolved manganese. The t-tests show that the average dissolved-manganese concentration did not change between the two stations after the addition to the wastewater-treatment plant, indicating that manganese concentrations in the James River are not natural concentrations. The smaller dissolved-oxygen concentrations in the river before the improvement to the wastewater-treatment plant probably allowed greater amounts of manganese to become dissolved in the water.

Therefore, the dissolved-manganese concentrations in the James River are no longer altered by the sewage effluent from the Southwest Wastewater-Treatment Plant.

The average total nitrite plus nitrate nitrogen concentrations increased from 1.77 to 3.09 milligrams per liter in the James River near Boaz after the addition of the advanced wastewater-treatment facility. The average concentration also increased from 1.07 to 1.63 milligrams per liter in the James River near Wilsons Creek for the same time periods. The magnitude of change was much greater at Boaz, indicating that the new wastewater-treatment facility increased the total nitrite plus nitrate nitrogen concentration in the James River. The organic and ammonia nitrogen in the sewage effluent are oxidized, as a result of ozonation, to form nitrate nitrogen.

Table 3.--Statistical summary of water-quality parameters for James River near Wilsons Creek for September 1970 to September 1977, and October 1977 to October 1979

[Results reported in milligrams per liter, except as indicated. °C=degrees Celsius; ft^3/s=cubic feet per second; µmho/cm at 25 °C=micromhos per centimeter at 25°C; µg/L-micrograms per liter; col/100 mL=colonies per 100 milliliter]

Parameter	Mean	Standard deviation	Median	Range	Number of samples
			September 1970 to September 1977		
Water temperature (°C)	16.1	6.7	17.0	0.5 - 27.0	107
Discharge, instantaneous (ft^3/s)	305	391	158	11.9 - 2,200	106
Specific conductance (µmho/cm at 25°C)	334	37.6	340	162 - 418	107
pH (standard units)	----	----	7.9	7.2 - 8.2	107
Dissolved oxygen (DO)	8.67	1.75	8.6	5.0 - 13.3	107
Chemical oxygen demand (COD)	7.37	9.34	5.0	0.0 - 68.0	85
Alkalinity as $CaCO_3$	145	17.5	144	72 - 171	100
Bicarbonate (HCO_3)	176	21.3	176	88.0 - 210	100
Total nitrite plus nitrate nitrogen (N)	1.07	0.486	1.0	0.0 - 2.1	52
Total phosphorus (P)	0.056	0.080	.04	0.0 - 0.5	85
Dissolved iron (µg/L as Fe)	21.4	21.0	20	0.0 - 130	61

Table 3.--Statistical summary of water-quality parameters for James River near Wilsons Creek for September 1970 to September 1977, and October 1977 to October 1979--continued

Parameter	Mean	Standard deviation	Median	Range	Number of samples
Dissolved manganese (Mn)	18.0	22.5	10	0.0 - 140	62
Dissolved solids (residue at 180°C)	192	26.1	195	107 - 241	84
Fecal coliform bacteria (col/100 mL)	758	1,950	---	---------	13
			October 1977 to October 1979		
Water temperature (°C)	15.2	7.8	15.0	2.5 - 28.0	23
Discharge, instantaneous (ft^3/s)	299	326	157	24 - 1,050	23
Specific conductance (μmho/cm at 25°C)	344	50.8	350	230 - 425	23
pH (standard units)	---	-----	7.7	7.5 - 8.2	23
Dissolved oxygen (DO)	8.57	1.90	8.0	6.0 - 12.6	23
Chemical oxygen demand (COD)	7.91	6.08	7.0	1.0 - 23.0	20
Alkalinity as $CaCO_3$	148	22.7	154	92.0 - 174	23
Bicarbonate (HCO_3)	180	27.5	188	112 - 212	23
Total nitrite plus nitrate nitrogen (N)	1.63	1.18	1.3	0.5 - 6.5	22

Table 3.--Statistical summary of water-quality parameters for James River near Wilsons Creek for September 1970 to September 1977, and October 1977 to October 1979--continued

Parameter	Mean	Standard deviation	Median	Range	Number of samples
Total phosphorus (P)	0.106	0.082	0.08	0.020 - 0.390	21
Dissolved iron (μg/L as Fe)	36.1	33.8	23.0	5.0 - 140	15
Dissolved manganese (μg/L as Mn)	15.6	8.99	10	5.0 - 30.0	15
Dissolved solids (residue at 180°C)	202	14.6	205	174 - 214	6
Fecal coliform bacteria (col/100 mL)	897	1,970	----	----------	23

Table 4.--Statistical summary of water-quality parameters for James River near Boaz for September 1970 to September 1977, and October 1977 to October 1978

[Results reported in milligrams per liter, except as indicated. °C=degrees Celsius; ft^3/s=cubic feet per second; µmho/cm at 25°C=micromhos per centimeter at 25°C; µg/L=micrograms per liter; col/100 mL=colonies per 100 milliliter]

Parameter	Mean	Standard deviation	Median	Range	Number of samples
Water temperature (°C)	15.5	6.87	16.0	0.5 - 29.0	107
Discharge instantaneous (ft^3/s)	475	692	257	49.0 - 5,000	107
Specific conductance (µmho/cm at 25°C)	448	114	410	234 - 810	107
pH (standard units)	---	---	7.7	7.2 - 8.4	107
Dissolved oxygen (DO)	6.65	2.49	6.9	1.0 - 13.2	107
Chemical oxygen demand (COD)	13.6	10.5	11.0	0.0 - 56.0	85
Alkalinity as $CaCO_3$	165	24.1	154	89.0 - 230	101
Bicarbonate (HCO_3)	201	29.5	200	108 - 280	101
Total nitrite plus nitrate nitrogen (N)	1.77	0.860	1.8	0.0 - 3.7	52
Dissolved iron (µg/L as Fe)	29.7	24.0	20	0.0 - 130	61
Dissolved manganese (µg/L as Mn)	57.5	48.1	40	0.0 - 210	60

Table 4.--Statisitcal summary of water-quality parameters for James River near Boaz for September 1970 to September 1977, and October 1977 to October 1979--continued

Parameter	Mean	Standard deviation	Median	Range	Number of samples
Dissolved solids (residue at 180°C)	269	81.3	244	140 - 648	85
Fecal coliform bacteria (col/100 mL)	1,790	3,750	---	--------	23
Total phosphorus (P)	1.22	0.951	0.88	0.15 - 4.3	85
		October 1977 to October 1979			
Water temperature (°C)	14.7	7.7	15.0	1.0 - 27.0	23
Discharge instantaneous (ft^3/s)	481	497	260	68.0 - 1,950	23
Specific conductance (μmho/cm at 25°C)	445	94.2	460	285 - 620	23
pH (standard units)	----	-----	7.7	7.4 - 8.3	23
Dissolved oxygen (DO)	8.51	2.58	7.8	4.2 - 14.6	23
Chemical oxygen demand (COD)	14.9	14.3	12.0	1.0 - 59.0	22
Alkalinity as $CaCO_3$	158	20.8	161	95.0 - 187	23
Bicarbonate (HCO_3)	193	25.4	196	116 - 228	23
Total nitrite plus nitrate nitrogen (N)	3.09	1.65	2.5	0.10 - 6.50	22
Total phosphorus (P)	1.34	1.85	0.69	0.16 - 8.00	21

Table 4.--Statistical summary of water-quality parameters for James River near Boaz for September 1970 to September 1977, and October 1977 to October 1979--continued

Parameter	Mean	Standard deviation	Median	Range	Number of samples
Dissolved iron (μg/L as Fe)	28.9	16.9	26.0	6.0 - 60.0	15
Dissolved manganese (μg/L as Mn)	22.9	11.7	20.0	3.0 - 50.0	15
Dissolved solids (residue at 180°C)	280	46.3	279	200 - 341	6
Fecal coliform bacteria (col/100 mL)	3,900	5,750	----	----------	12

Table 5.--Results of t-tests comparing mean concentrations for 12 water-quality parameters at the 0.05 probability level

[SD=significantly different; NSD=not significantly different]

	MEANS COMPARED			
	Period 1	Period 2	Station 1	Station 4
Water-quality parameter	Station 1 versus station 4	Station 1 versus station 4	Period 1 versus period 2	Period 1 versus period 2
Water temperature------------	NSD	NSD	NSD	NSD
Specific conductance---------	SD	SD	NSD	NSD
Dissolved oxygen-------------	SD	NSD	NSD	SD
Chemical oxygen demand-------	SD	SD	NSD	NSD
Alkalinity as $CaCO_3$----------	SD	NSD	NSD	NSD
Bicarbonate------------------	SD	NSD	NSD	NSD
Total nitrite plus----------- nitrate nitrogen	SD	SD	SD	SD
Total phosphorus-------------	SD	SD	SD	NSD
Dissolved iron---------------	NSD	NSD	NSD	NSD
Dissolved manganese----------	SD	NSD	NSD	SD
Dissolved solids-------------	SD	SD	NSD	NSD
Fecal coliform bacteria------	SD	SD	NSD	NSD

SUMMARY AND CONCLUSIONS

A network of water-quality-monitoring stations was established upstream and downstream from the Southwest Wastewater-Treatment Plant on Wilsons Creek to monitor the effects of sewage effluent on water quality. Discharge data from these stations were used to characterize flow conditions in Wilsons Creek and James River. Hydrographs for an average year for each station shows the variability in flow (fig. 2, 3, and 4). Frequency analyses were made of the discharge data, and estimates of low- and high-flow frequencies were made. Data indicate that 82 percent of the time the flow in Wilsons Creek near Springfield, upstream from the Southwest Wastewater-Treatment Plant, is less than the effluent discharged from the plant.

On October 15, 1977, an advanced wastewater-treatment facility became operational at the wastewater-treatment plant. Data from the water-quality-monitoring stations were compared to determine if the advanced wastewater treatment process caused changes in water quality in Wilsons Creek downstream from the plant. Of the four water-quality indicators measured (specific conductance, dissolved oxygen, pH, and water temperature) only dissolved oxygen showed improvement downstream from the Southwest Wastewater-Treatment Plant.

The water-quality-monitoring stations also were used to determine how urban runoff affected water quality in Wilsons Creek. When urban runoff occurred, specific conductance increased momentarily and dissolved-oxygen concentration decreased momentarily in Wilsons Creek upstream from the wastewater-treatment plant. Downstream from the wastewater-treatment plant, specific conductance also increased momentarily and dissolved-oxygen concentration also decreased momentarily; these changes were attributed to the resuspension of sewage sludge. After the advanced wastewater-treatment facility became operational, sludge on the streambed disappeared and specific conductance and dissolved-oxygen concentration no longer showed momentary changes during runoff.

Data collected monthly from the James River were analyzed using t-tests to aid in determining if the advanced wastewater-treatment process was responsible for water-quality changes in the James River. Data indicate that the dissolved-oxygen concentrations and the total nitrite plus nitrate nitrogen concentrations increased, whereas dissolved-manganese concentrations decreased in the James River after the advanced wastewater-treatment facility became operational.

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