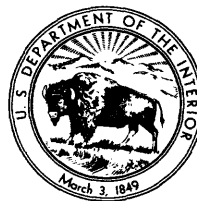WATER-QUALITY INVESTIGATIONS OF

THE JORDAN RIVER, SALT LAKE COUNTY,

UTAH, 1980-82

By Doyle W. Stephens

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 84-4298

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SALT LAKE COUNTY DIVISION OF FLOOD CONTROL

AND WATER QUALITY

Salt Lake City, Utah

1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

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GLOSSARY

Chemical-oxygen demand (COD).-- The total quantity of oxygen required to oxidize the chemical and biological material in a sample. The procedure involves refluxing the samples with a strong acid-dichromate solution.

Chlorophyll a and b.--The photosynthesizing pigments found in algae and other plants which effect the conversion of light energy to chemical energy.

Coefficient of variation (Cv).--The standard deviation of a number set expressed as a percentage of the mean of that number set.

Correlation coefficient.--A measure of the similarity of linear relationship between two variables. Values range from minus 1.0 to plus 1.0. Values of almost plus 1.0 show a correlation with a positive slope, and values of almost minus 1.0 show a correlation with a negative slope.

Dissolved-organic carbon (DOC).--The amount of organic carbon passing through a 0.45-micrometer silver filter. Determined by combustion to carbon dioxide with quantification by infrared spectrometry.

Five-day biochemical-oxygen demand (BOD_5).--The quantity of oxygen used to degrade the carbonaceous-organic matter in a sample at 20° Celsius in a 5-day period.

Indicator bacteria.--Bacterial types that normally are nonpathogenic but do indicate the possibility of fecal contamination.

Jackson turbidity unit (JTU).--A measure of the ratio of the light transmitted through water in a straight line to the intensity of the incident light.

K_2.--Reaeration coefficient calculated to log e.

Nephelometric turbidity unit (NTU).--A measure of the ratio of intensity of light scattered at right angles by the suspended matter to the intensity of the incident light. Nephelometric turbidity units approximate Jackson Turbidity Units.

Priority pollutants.--Any of a group of 129 compounds and elements from 65 pollutant classes which have been identified by the U.S. Environmental Protection Agency and currently have recommended quality criteria for concentrations in water.

R-square.--Coefficient of determination. This is calculated as the square of the correlation coefficient and when multiplied by 100 represents the percent variation of the dependent variable, which is explained by the regression equation. It is a "best-fit" test for the population scatter about a curve.

Suspended-organic carbon (SOC).--The quantity of organic carbon filtered from a sample by a 0.45-micrometer silver filter. Determined as for DOC.

Ultimate biochemical-oxygen demand (BOD_u).--The total quantity of oxygen required to degrade the carbonaceous organic matter in a sample at 20° Celsius.

CONVERSION FACTORS AND RELATED INFORMATION

Values in this report are given mostly in inch-pound units. Conversion factors to metric units are listed below:

Multiply	By	To obtain
cubic foot per second	0.02832	cubic meter per second
cubic foot per second per mile	0.0176	cubic meter per second per kilometer
foot	0.3048	meter
foot per mile	0.1894	meter per kilometer
inch	2.54	centimeter
mile	1.609	kilometer
pound	0.4536	kilogram
square mile	2.59	square kilometer
acre-foot	1,233	cubic meter

Chemical concentration and water temperature are given only in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (ug/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter of water). One thousand micrograms per liter is equivalent to 1 mg/L. For concentrations less than 7,000 mg/L, the numerical value is about the same as for concentrations in parts per million.

Water temperature is given in degrees Celsius ($^\circ$C), which can be converted to degrees Fahrenheit ($^\circ$F) by the following equation:
$$^\circ F = 1.8(^\circ C) + 32$$

WATER-QUALITY INVESTIGATIONS OF THE JORDAN RIVER,

SALT LAKE COUNTY, UTAH, 1980-82

By Doyle W. Stephens

ABSTRACT

Water-quality studies were made on the Jordan River, Salt Lake County, Utah, from 1980-82 to investigate specific problems involving dissolved oxygen, toxic substances, sanitary quality, and turbidity. The studies were coincident with an investigation of the affects of urban runoff on surface-water quallity in Salt Lake County.

The combination of large organic loads, small discharge, and slight reaeration rates resulted in dissolved-oxygen concentrations in the Jordan River downstream from 5800 South Street during April-September which frequently did not meet State intended use standards. The dissolved oxygen typically decreased from about 8 milligrams per liter at the Jordan Narrows to less than 5 milligrams per liter at 500 North Street. Accompanying this decrease was an increase in chemical-oxygen demand of about 23 percent and in biochemical-oxygen demands of 90 percent. An estimated load of 6 million pounds of oxygen-demanding substances was discharged to the Jordan River annually from point sources north of 9000 South Street. Wastewater-treatment plants contributed 77 percent of these substances, nonstorm base flows from the major tributaries to the river contributed 22 percent, and storm flows contributed less than 1 percent. Most of the organic substances were discharged to the reaches characterized by the smallest reaeration rates. A diversion to the Surplus Canal removed 67 percent of the oxygen-demanding substances in the river.

Several toxic substances, primarily trace metals, were detected in the Jordan River and its major tributaries. Nearly 78 percent of the water samples analyzed for total mercury exceeded the State intended-use standard of 0.05 microgram per liter. Concentrations of five other toxic substances exceeded the standards occasionally: ammonia (18 percent of the samples); cadmium (9 percent); copper (9 percent); lead (2 percent); and zinc (6 percent). The concentrations of trace elements found in bottom sediments increased markedly at 5800 South Street and persisted downstream to 500 North Street. The pesticides DDT, DDD, DDE, dieldrin, methoxychlor, and 2,4-D were detected in bottom materials, but most were at concentrations less than 15 micrograms per kilogram. Bottom samples from the Jordan Narrows contained PCB concentrations as great as 320 micrograms per kilogram. Samples were collected from three conduits during a storm on October 29, 1981, and analysed for priority pollutants as designated by the U.S. Environmental Protection Agency. Trace metals were identified as common contaminants, but only 2 of the 113 organic pollutants (chloroform and phenol) were detected.

The concentrations of bacteria in the Jordan River often exceeded the State sanitary standards for total coliform bacteria (5,000 colonies per 100 milliliters) and for fecal coliforms (2,000 colonies per 100 milliliters). Concentrations of three indicator bacteria (total coliform, fecal coliform, and fecal streptococcal) generally increased in a downstream direction. Contamination from animal waste was indicated in 92 percent of the samples

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from the Jordan Narrows, but this decreased to about 50 percent of the samples at downstream sites. Contamination from human waste was not found at the Jordan Narrows or 9000 South Street, but it increased to 20 percent of the samples at 1700 South Street. Storm runoff from urban areas contributed large concentrations of indicator bacteria to the river, with fecal contamination from animal wastes indicated in about 72 percent of the samples.

The primary sources of turbidity in the Jordan River are Utah Lake and discharges from the wastewater-treatment plants. Relatively large values of turbidity were measured at the Jordan Narrows, with a mean of 88 Nephelometric turbidity units during June-October and a mean of 43 Nephelometric turbidity units during November-May. The means at other sites for same periods were 27 and 32 Nephelometric turbidity units. Correlation coefficients ranging from 0.71-0.83 indicated that significant relationships existed between turbidity and suspended-organic carbon during June-October at each of five sites. A smaller but statistically significant correlation of 0.46 occurred between turbidity and suspended-sediment concentration during November-May when data for all five sites were combined.

INTRODUCTION

The selection of Salt Lake County, Utah, as a study area in the U.S. Geological Survey's Nationwide Urban Runoff Program in 1979 provided an excellent opportunity to assess the effects of urban runoff on the Jordan River as the principal receiving stream in the county. Cooperative agreements were established between the Geological Survey and the Salt Lake County Division of Flood Control and Water Quality to: (1) Monitor the storm and nonstorm urban runoff in the Salt Lake Valley, for the purpose of characterizing its quantity and quality, and (2) investigate specific water-quality problems in the Jordan River. Letters were sent to local, State, and other Federal agencies requesting their advice about priorities needed for water-quality research on the Jordan River. Based on responses to that inquiry, the following problems were selected: dissolved oxygen, toxic substances, sanitary quality, and turbidity.

Successful planning for river-basin development requires identification of specific flow and water-quality problems and quantification of data relating to these problems. Previous river-quality assessments by the U.S. Geological Survey on the Willamette River, Oregon, the Chattahoochee River, Georgia, and the Yampa River, Colorado, identified an intensive, synoptic approach as the best procedure for such quantification. By contrast, routine monitoring and surveillance sampling by the Geological Survey on the Jordan River during 1974-79 provided an indication of general water-quality trends but lacked the specific data necessary to define the quantitative nature of recognized water-quality problems. Several of the U.S. Environmental Protection Agency studies completed under Section 208 of the Clean Water Act obtained data from problem-oriented sampling, but most of those studies were too short to provide meaningful conclusions. Data from previous work were combined with information gained from short, problem-oriented studies conducted from 1980 to 1982 to provide the broadest insight to the four study problems.

The approach to each of these water-quality problems differed slightly, and each study is described in one of the following reports: dissolved oxygen

(Stephens, 1984); toxic substances (Thompson, 1984a); sanitary quality (Thompson, 1984b); and turbidity (Weigel, 1984). Hydrologic data collected during the overall investigation appear in Pyper and others (1981) and McCormack and others (1983), and some historical data were reported by the U.S. Geological Survey (1982, and earlier volumes). The interpretive analysis of the effects of urban runoff on surface-water quality in Salt Lake Valley appears in Christensen and others (1984).

The objectives of the water-quality investigations of the Jordan River were to define the four problems and to quantify the data relating to these problems. This report summarizes the results of the four studies.

Topography and General Hydrology

The Jordan River originates as outflow from Utah Lake and flows north approximately 55 miles before it is diverted into marshlands south of the Great Salt Lake. The lake serves as the terminal receiving body for the Jordan Hydrologic Accounting Unit, a drainage basin of 3,825 square miles in the Great Basin Region (U.S. Geological Survey, 1974). Two-thirds of the river miles are within Salt Lake County, the area of this study.

The Jordan River enters Salt Lake County at the Jordan Narrows, a gap in the Traverse Mountains, 10 miles downstream from Utah Lake (fig. 1). The altitude decreases from 4,470 feet at the Jordan Narrows to about 4,200 feet at Farmington Bay. The mean gradient of the Jordan River through Salt Lake County is 6 feet per mile; although the gradient from the Jordan Narrows to 4200 South Street is 11 feet per mile and from 4200 South Street to the river mouth only 1.9 feet per mile. Salt Lake County includes a dense urban area commonly known as the Salt Lake Valley, which is bordered by mountains on three sides. The Wasatch Range to the east rises to more than 11,000 feet, the Oquirrh Mountains on the west rise to more than 9,000 feet, and the Traverse Mountains on the south rise to more than 6,000 feet.

The population of Salt Lake County in July 1981 was estimated to be 641,000 (Marvin Levy, Utah State Health Department, Bureau of Statistical Services, oral commun., 1982), which is 42 percent of the total population of the State. The Jordan River is the primary receiving water for most of this urban area, including seven municipal wastewater-treatment plants in Salt Lake County and one in Davis County to the north.

The seven major tributaries to the Jordan River in Salt Lake County originate in the Wasatch Range. Little Cottonwood Creek flows into the Jordan River at about 4900 South Street, Big Cottonwood Creek enters at about 4200 South Street, and Mill Creek enters at 3000 South Street. Parleys, Emigration, and Red Butte Creeks all are diverted to a storm conduit which discharges into the Jordan River near 1300 South Street. City Creek is diverted into a storm conduit which discharges into the Jordan River at North Temple Street. Streams on the west side of the Jordan River typically are intercepted by canals or cease flowing before reaching the river.

During the irrigation season, large quantities of water are diverted from the Jordan River at or near the Jordan Narrows and channeled northward through seven major canals. The canals east of the river terminate in smaller canals and exchange water with streams that drain the Wasatch Range. Return flows

Figure 1.—Monitoring sites on and major inflow sources to the Jordan River in Salt Lake County, Utah.

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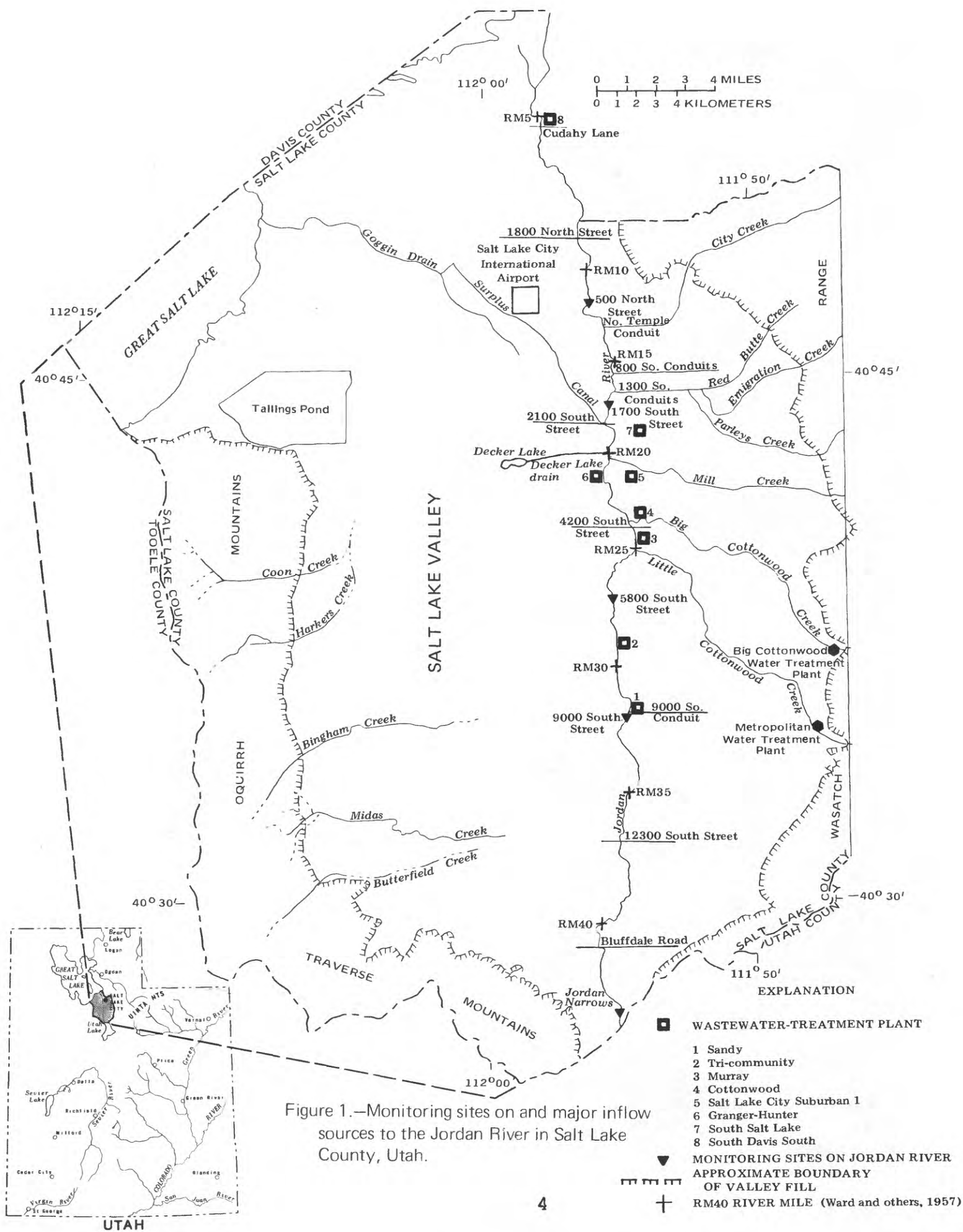
from canals west of the river typically reach the Jordan River less directly as nonpoint-source runoff. The only major diversion north of 9000 South Street is at 2100 South Street to the Surplus Canal, which is a flood-control structure that allows excess water to pass directly to Great Salt Lake.

Large quantities of ground water enter the upstream part of the Jordan River. Ward and others (1957, p. 4) reported an average gain of 7.6 cubic feet per second per river mile during November 1957 between the Jordan Narrows and 6400 South Street. The average gain from 6400 South Street to 3300 South Street was 6.7 cubic feet per second per mile. No gain was measured north of 3300 South Street. Data reported by Hydroscience, Inc. (1976, p. 23) indicate a mean summertime gain of 3 cubic feet per second per mile from 9400 South to 5800 South Streets and 6.3 cubic feet per second per mile from 5800 South to 2100 South Streets.

Precipitation

The climate ranges from semiarid in parts of Salt Lake Valley to humid in areas of the Wasatch Range. The precipitation during 1981 near the Salt Lake International Airport was 16.59 inches (National Oceanic and Atmospheric Administration, 1981, p. 4). This was 0.69 inch greater than the 93-year mean reported for Salt Lake City by Hely and others (1971, p. 16). Precipitation in the low areas of the valley generally is slight and infrequent during the growing season; thus, most crops are dependent on irrigation.

Data Collection

Five sites were selected on the Jordan River for continuous-streamflow recording and water-quality monitoring during 1980-82 (fig. 1). Two of the sites, 1700 South Street (U.S. Geological Survey station no. 10171000) and 5800 South Street (station 10167300) have been water-quality-monitoring stations since 1974, although continuous discharge was measured at 5800 South Street only since 1980. Streamflow at 500 North Street (station 10172550) has been monitored since 1975, at 9000 South Street (station 10167230) since 1979, and at Jordan Narrows (station 10161001) since 1937.

Water samples were collected monthly from December 1980 through August 1982. Additional samples of the Jordan River and inflowing streams and conduits were collected during storms, as part of the Salt Lake County project, and during special synoptic-sampling studies.

DISSOLVED OXYGEN

Dissolved-oxygen depletion in the Jordan River has been a recognized problem for many years. Small concentrations of oxygen have resulted in decreased fish populations and little recreational use of the river, and it also has adversely affected the esthetic appeal of the river, which is the largest in Salt Lake County. Dissolved-oxygen concentrations in the river typically are near saturation as the water enters the Salt Lake Valley at the Jordan Narrows. As the water flows north through the valley, it receives secondary-treated effluent from eight municipal wastewater-treatment plants, storm runoff from urban areas, and numerous nonpoint-source discharges.

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The study of the dissolved-oxygen regime in the Jordan River was designed to:

(1) Determine historical trends in dissolved-oxygen concentrations and concentrations of oxygen-demanding substances;

(2) Measure reaeration rates and time-of-travel during low flow through Salt Lake Valley;

(3) Determine the effects of oxygen production and consumption by algal on the Jordan River north of 5800 South Street; and

(4) Calculate loads of oxygen-demanding substances discharged by storm runoff and wastewater-treatment plants.

Data collection and analysis were concentrated between 9000 South and 500 North Streets where most of the dissolved-oxygen problems occur. Data were collected from December 1980 through August 1982, with storm-runoff data collected through September 1981. High water conditions existed in the river during almost the entire period of data collection, with the annual discharge at 2100 South Street being 18 to 40 percent greater than the average for the preceding 10 years.

Few data are available for dissolved-oxygen concentrations in the Jordan River prior to the popularization of the polarographic-oxygen probe in the 1970's. Gaufin (1958, p. 5-8) measured dissolved-oxygen concentrations of 0 to 15.3 milligrams per liter at 17 sites, and he concluded that north of 4800 South Street (river mile 25.2) the river was so polluted that the fish population was limited to carp. An intensive survey by the U.S. Environmental Protection Agency (1972, p. 18) reported the average dissolved-oxygen concentrations in the river south of 3300 South Street (river mile 21.5) during August and September equaled or exceeded the State limits of 5.5 milligrams per liter for a warm-water fishery and 6 milligrams per liter for a cold-water fishery. North of 2100 South Street, the dissolved-oxygen concentrations in the river failed to meet the State standards for either type of fishery. Comparison of data collected from 1976-79 with data from 1979-81 indicated that small dissolved-oxygen concentrations were a problem in the Jordan River from the Jordan Narrows to North Temple Street during both periods, with no significant changes in dissolved-oxygen concentrations noted between data sets (Gunnell and others, 1982, p. 6, 62).

Trends in Dissolved-Oxygen Concentration and Oxygen Demands

Comparison of synoptic measurements of dissolved-oxygen concentrations made during the late summer from 1957-82 illustrates the progressive decrease in dissolved-oxygen concentrations as the river flows north from the Jordan Narrows (fig. 2). The few data available indicate the greatest decrease in dissolved-oxygen concentrations during 1972, 1981, and 1982 as compared to 1957 and 1975. Comparison of a larger data set available for the Jordan River at 1700 South Street indicates a general decrease in mean dissolved-oxygen concentrations from 1974-82 for samples collected from April to September (fig. 3). A similar decrease also was noted for dissolved-oxygen concentrations at 5800 South Street from 1974-82, and the percent saturation of oxygen decreased correspondingly at both sites during the same time period.
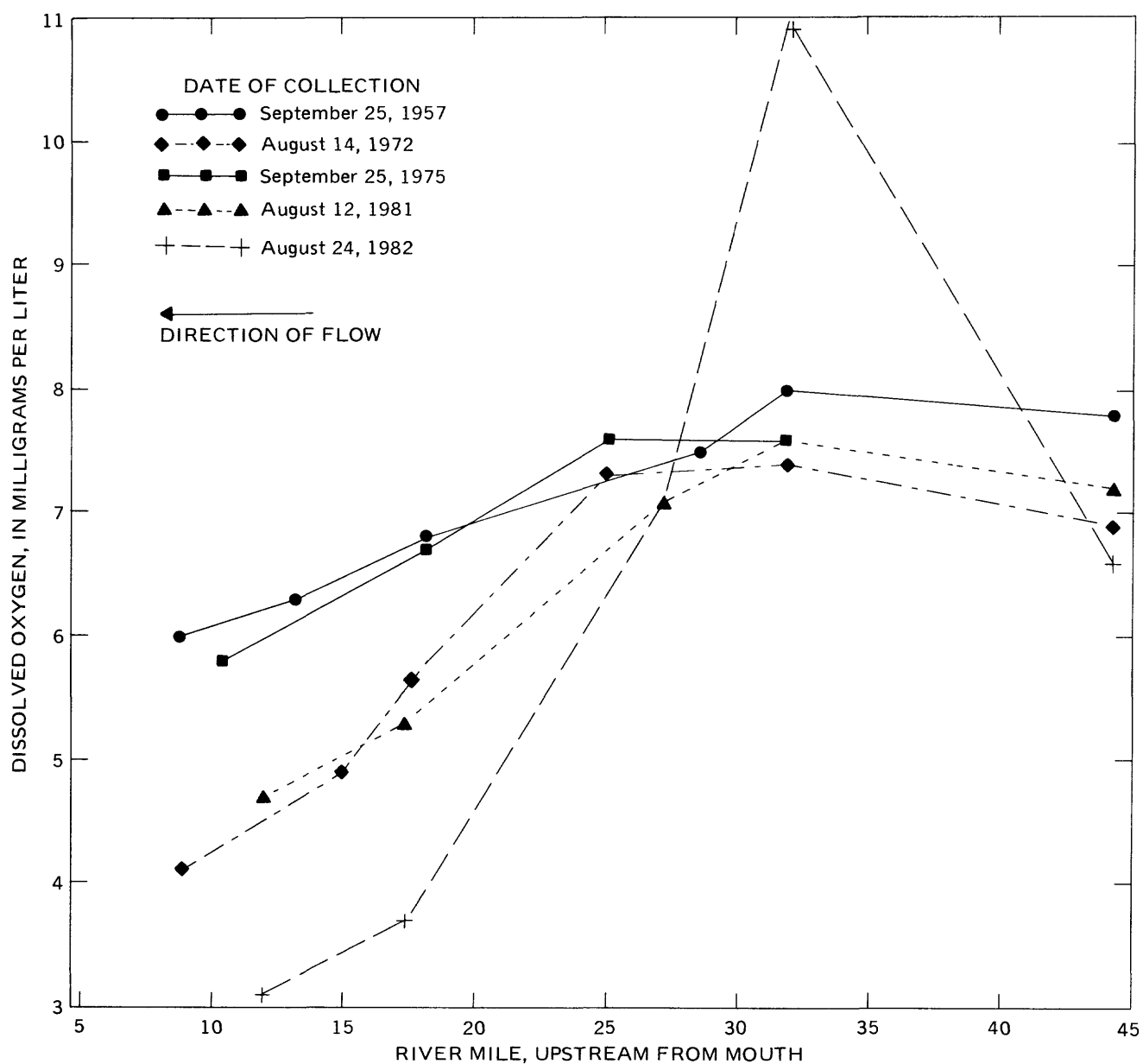
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Figure 2.—Variation in dissolved-oxygen concentrations with river mile during low-flow conditions from 1957 to 1982. From Stephens (1984).
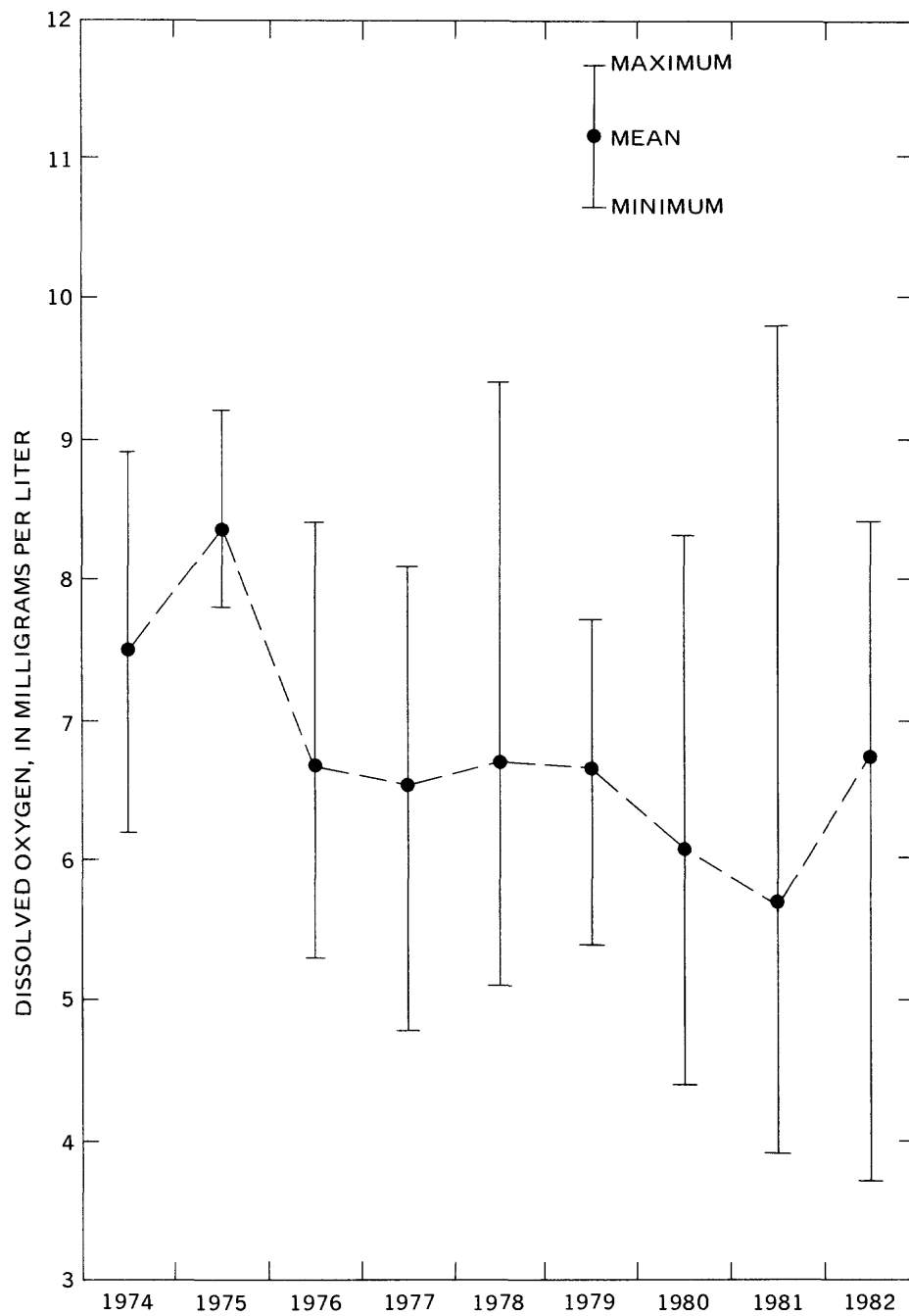
Figure 3.—Variation in dissolved-oxygen concentrations during daytime at 1700 South Street, April-September 1974-82. From Stephens (1984).

Data collected during October-March at 1700 South Street indicated a 16-percent decrease in mean dissolved-oxygen concentrations from 1974-77, a 16-percent increase from 1977-80, and a 10-percent decrease during 1981.

The decrease in dissolved-oxygen concentrations downstream of 5800 South Street was accompanied by increases in oxygen-demanding substances as measured by chemical-oxygen demand (COD) and biochemical-oxygen demand (BOD). The mean COD increased 23 percent between 5800 South Street and 500 North Street. The mean 5-day BOD (BOD_5) increased from 7 milligrams per liter at 5800 South Street to 12 milligrams per liter at 1700 South Street then decreased to 7 milligrams per liter at 500 North Street. The winter mean BOD_5 increased from 9 to 17 milligrams per liter between 5800 South and 500 North Streets. The mean BOD_5 increased 90 percent between the Jordan Narrows and 500 North Street.

Dissolved-oxygen concentrations and percent saturation were consistently greater at all sites during the winter. That was due to the increased solubility of oxygen at lower temperatures and the reduced satisfaction of oxygen demands in the river at lower temperatures. Dissolved-organic carbon (DOC) and BOD were noticeably greater during in the winter because the oxygen demands required to stabilize the organic substances were not exerted in the river at low temperatures. The effects of small oxygen concentrations and large organic loads on the Jordan River may be summarized by the frequency of noncompliance with State intended-use standards (Utah Department of Social Services, Division of Health, 1978, p. 8). About 50 percent of all dissolved-oxygen measurements made during 1981-82 at or downstream of 5800 South Street and from 60-90 percent of all BOD_5 measurements failed to comply with the standards (table 1).

Multiple-regression analysis was used to identify specific independent variables that affected the dissolved-oxygen concentrations at each site. Water temperature was a significant variable that was inversely related in several equations, reflecting the inverse relationship of solubility and temperature. Discharge was positively correlated with dissolved-oxygen concentrations which represents association of larger reaeration rates with increased discharge and the dilution of oxygen-demanding substances by increased streamflow. The regression analysis indicated that part of the summertime BOD at the Jordan Narrows was due to the respiration and decay of phytoplankton transported from Utah Lake.

Reaeration Rates and Time-of-Travel

Reaeration is the principal process by which oxygen is transported into the water. The rate of reaeration is dependent on the temperature, depth, and turbulence of the water and the concentration of other dissolved substances. Measurements of reaeration rates in the Jordan River were made during periods of low flow in September and October 1981 and 1982 using the modified tracer-gas method of Rathbun (1979). Rhodamine-WT dye was used to establish dispersion characteristics and to provide information on time-of-travel for various reaches of the river. The general trend for the reaeration rate (K_2, in dimensionless units per day) was to decrease with distance downstream and decreasing channel slope. The channel of the Jordan River has a marked change in slope near river mile 24, near the confluence with Big Cottonwood Creek

Table 1.--Frequency of noncompliance with water-quality standards for intended use, 1981-82 (Utah Department of Social Services, Division of Health, 1978, p. 8

Dissolved oxygen: Standards are 6 milligrams per liter for the Jordan Narrows and 9000 South and 5800 South Streets, and 5.5 milligrams per liter for the other sites.

Five-day biochemical-oxygen demans: Standard is 5 mg/L at all sites.

Noncompliance frequency: Percentage of total number of measurements.

Site	Dissolved oxygen		5-day biochemical-oxygen demand	
	Total number of measurements	Noncompliance frequency	Total number of measurements	Noncompliance frequency
Jordan Narrows	29	3	27	44
9000 South Street	32	0	23	39
5800 South Street	51	10	26	58
1700 South Street	61	46	23	87
500 North Street	62	52	25	92

(fig. 4). Upstream from this point, the reaeration rate averaged 9.5 per day, with a travel time of 10.5 hours to flow 11.6 miles from 12300 South Street. Discharge in this reach ranged from 84 to 203 cubic feet per second. Between 4800 South and 1800 North Streets, the reaeration rate averaged only 1.8 per day, with a travel time of 15.4 hours to traverse the 16.4-mile reach.

Effects of Algal Populations

Suspended algae (phytoplankton) and attached algae (periphyton) produce oxygen as a by-product of photosynthetic activity during daylight. They consume oxygen through respiration at all times, but more noticeably at night. Phytoplankton populations are quite large in Utah Lake, and much of this algal material is present in the Jordan River, particularly at the Jordan Narrows. Phytoplankton chlorophyll a, the major photosynthetic pigment, decreased from a summer mean concentration of 35 milligrams per liter at the Jordan Narrows to about 10 milligrams per liter at 500 North Street. Diel (24-hour) production of oxygen was monitored at several sites from 5800 South to 500 North Streets during July and September 1981 and January 1982 but no net gain was detected in dissolved-oxygen concentrations in the river due to algal photosynthesis. An oxygen demand ranging from 11 to 22 milligrams per liter was measured on July 28, 1981, in this reach. Net gains in dissolved oxygen due to photosynthesis south of 9000 South Street are indicated by the data assembled by Gaufin (1958), U.S. Environmental Protection Agency (1972, p. 14), and Hydroscience, Inc. (1976, p. 47). Application of diel-curve analysis to data collected by Gaufin (1958, p. 50-54) and the U.S. Environmental Protection Agency (1972, p. 62) indicated no net gains of oxygen during a 24-hour period at any site where measurements were made north of Fairfield Road, which is 5 miles south of the Jordan Narrows.

Effects of Storm Runoff and Wastewater-Treatment Plants

Mean concentrations of BOD_5, ultimate BOD (BOD_u), COD, and organic carbon were slightly greater in storm samples than in nonstorm samples collected from the Jordan River. Statistical evaluation of these differences using Student's t-test (95-percent confidence level) indicated that only the concentrations of dissolved- and suspended-organic carbon (DOC and SOC) were significantly greater. When analyzed on a site basis, all sites except 500 North Street showed decreases in dissolved-oxygen concentrations during storms; but not all differences were statistically significant. Analysis of the data for 500 North Street indicated that an increase in dissolved-oxygen concentrations occurs during storms due to an increase in oxygenated water that enters the river upstream through storm conduits at 1300 South and North Temple Streets.

Considerable quantities of oxygen-demanding substances were discharged to the Jordan River annually in storm runoff. The quantities of these substances from point sources, based on inflow during 10 major rain-storms during 1981 are summarized in table 2. More than 80 percent of the BOD entered the river downstream from Big Cottonwood Creek (river mile 24) in the reach that has the smallest reaeration rate and the least assimilation capacity for oxygen-demanding substances.

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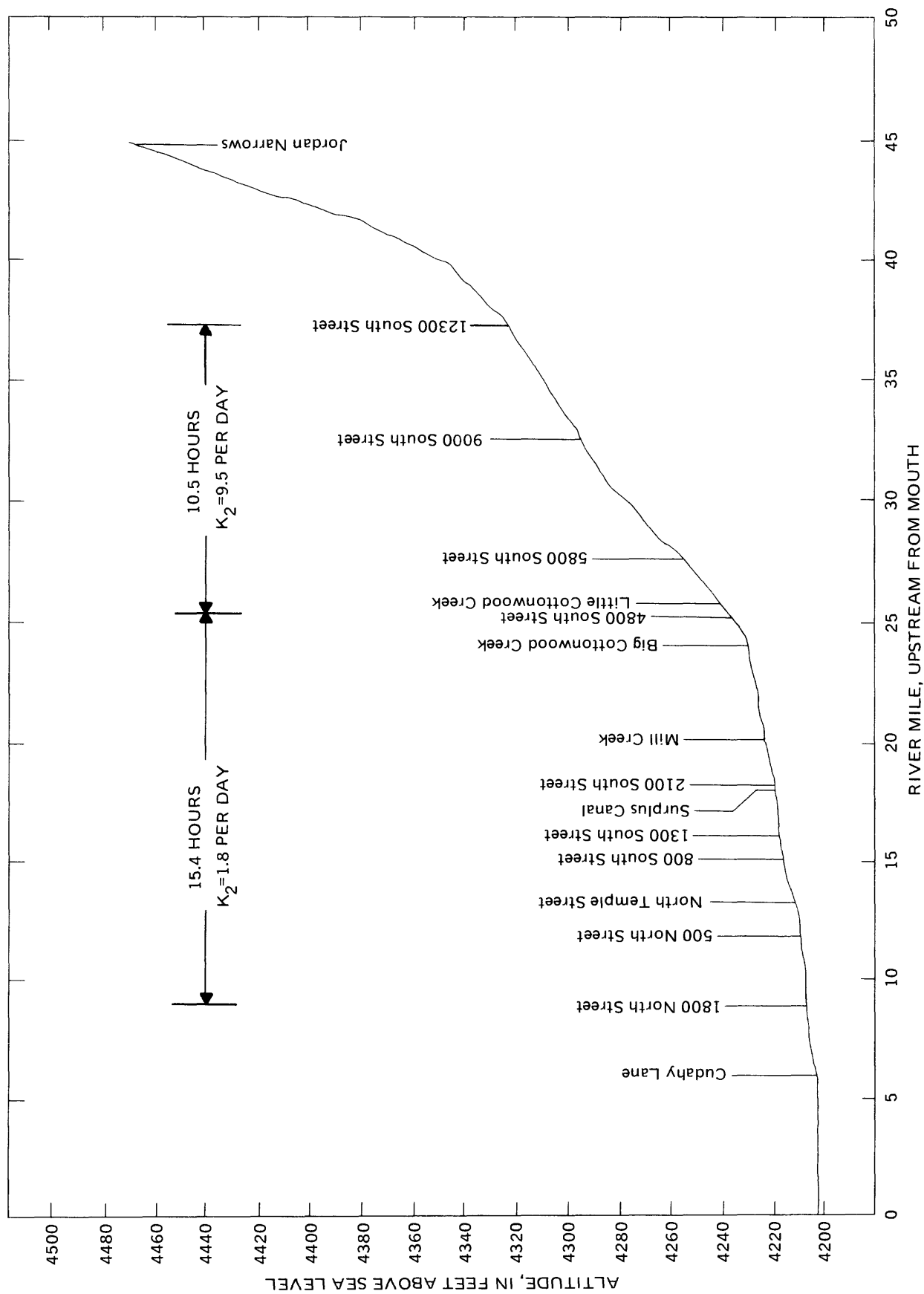
Figure 4.—Profile of the river channel with selected reference points, travel times, and reaeration rates (K_2). Modified from Stephens (1984).

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Table 2.--Estimated total loads for annual-storm runoff from the major tributaries and storm conduits during 10 storms in 1981, in pounds of oxygen-demanding substances

5-day biochemical-oxygen demand: Values in parentheses represent that part of the load contributed by wastewater-treatment plants discharging to the 2100 South Conduit and Big Cottonwood Creek.

Site	5-day biochemical-oxygen demand	Ultimate biochemical-oxygen demand	Chemical oxygen demand	Dissolved-organic carbon	Suspended-organic carbon
North Temple Conduit	2,500	4,800	22,300	2,200	1,000
800 South Conduit	1,800	3,600	13,700	1,100	1,100
1300 South Conduit	5,500	11,300	44,900	12,200	3,800
2100 South Conduit	3,400 (1,700)	7,300	15,600	2,600	600
Mill Creek	8,000	16,500	64,000	13,500	3,600
Big Cottonwood Creek	27,200 (23,000)	47,600	68,200	16,000	5,900
Little Cottonwood Creek	6,800	15,700	51,000	27,900	2,000
9000 South Conduit	2,300	3,600	21,100	7,000	19,300
Totals	557,500 (24,700)	110,400	300,800	82,500	37,300

Of the seven wastewater-treatment plants in Salt Lake County that discharge directly or indirectly to the Jordan River only the South Salt Lake plant is not hydraulically overloaded (Gunnell and others, 1982, p. 61). The mean daily load of BOD_5 discharged from the seven plants in 1981 was calculated as nearly 13,000 pounds, with 85 percent of this load entering the river downstream of river mile 25, where reaeration rates are decreased. The projected annual load of BOD_5 from the seven wastewater-treatment plants during 1981 was 4.7 million pounds. The study was confined to Salt Lake County, therefore, loads were not calculated for the South Davis South wastewater-treatment plant.

A total annual BOD_5 load of 6 million pounds was calculated as the sum of the major point sources that discharged to the Jordan River during 1981 (fig. 5). The wastewater-treatment plants contributed 77 percent of this load, nonstorm baseflows from the major tributaries contributed 22 percent, and storm runoff contributed less than 1 percent. The storm-runoff load was based on 10 major storms and it could be a conservative estimate. Doubling the stormflow load however, would make little relative change in the total load from point-sources that enters the Jordan River.

The travel time of about 1 day between 9000 South and 500 North Streets resulted in only a part of the total-oxygen demand being actually satisfied in the river. Not all the oxygen-demanding substances are in the dissolved phase, and some particle aggregation and sedimentation produces the dark organic silts found in much of the river bottom. The accumulation of these oxygen-demanding sediments has long-term effects on the oxygen regime in the river.

The diversion to the Surplus Canal at 2100 South Street also decreases the total load of oxygen-demanding substances in the river. During the 1981 water year (October 1, 1980 to September 30, 1981), the total diversion to the Surplus Canal was 309,800 acre-feet, which was 72 percent of the flow in the Jordan River upstream from the diversion. Ninety percent of the total BOD_5 load was discharged to the river from point sources between 9000 South and 2100 South Streets. Therefore, the Surplus Canal diverted about 4 million pounds of BOD_5 load from the river during 1981. The load in the Jordan River between 2100 South and 500 North Streets, therefore, was reduced to about 2 million pounds.

The increase in population in Salt Lake County is expected to result in the production of even greater loads of oxygen-demanding substances, which will further decrease the oxygen concentrations in the Jordan River. Without additional wastewater-treatment plants and improvements in the existing plants, considerable impairment of the Jordan River oxygen regime likely will occur.
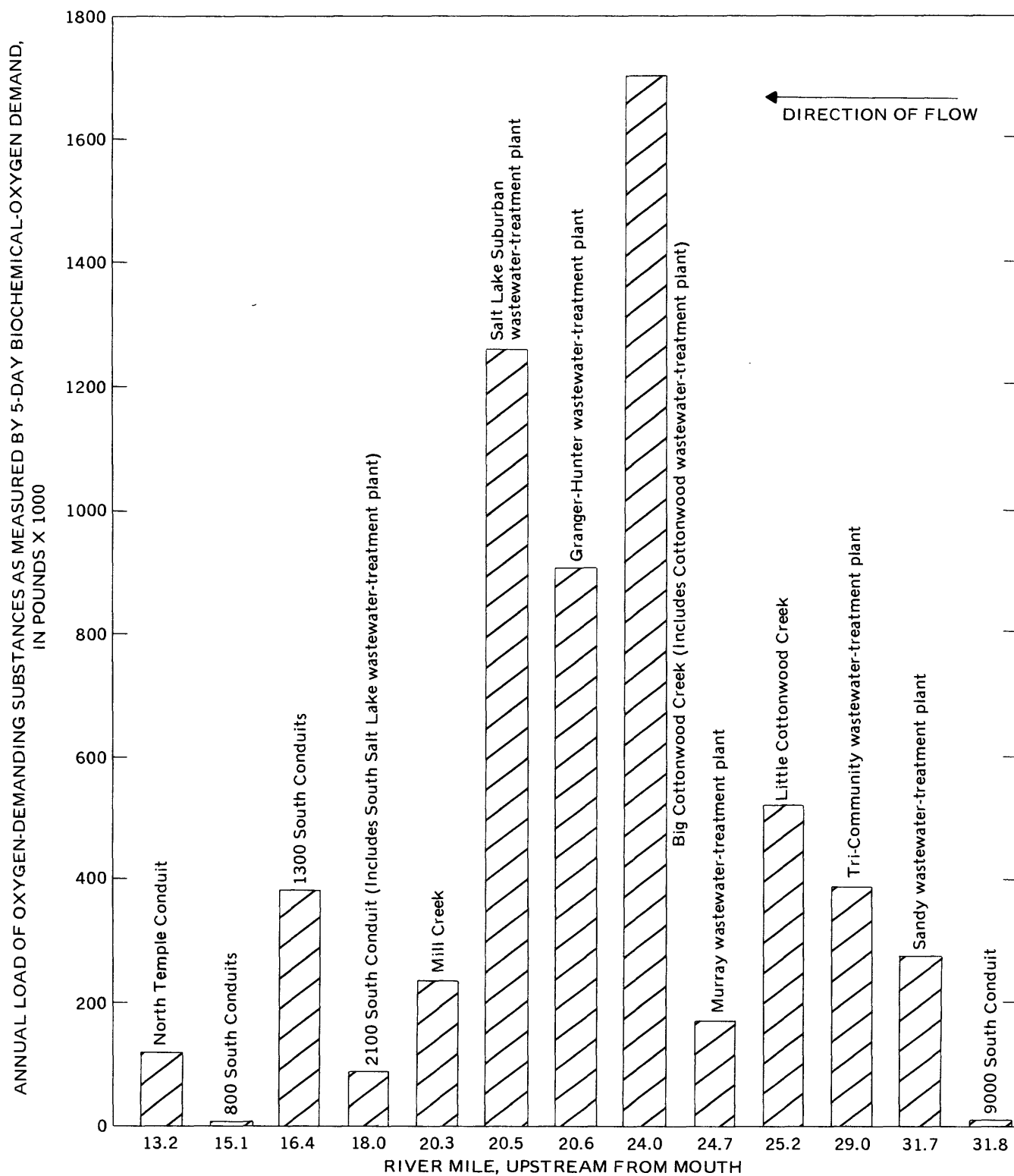
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Figure 5.– Total annual loads of oxygen-demanding substances, as measured by 5-day biochemical-oxygen demand discharged during 1981 from point sources. From Stephens (1984).

TOXIC SUBSTANCES

The concern with toxic substances in water stems from an increased public awareness of the carcinogenic, mutagenic, and chronic effects of exposure to water-born elements and compounds. The identification of 129 elements and compounds as priority pollutants and the 1976 court settlement requiring the U.S. Environmental Protection Agency to establish water-quality criteria for them (Keith and Telliard, 1979) demonstrated the diverse nature of toxic substances that are transported in water.

The study of toxic substances in the Jordan River was designed to:

(1) Identify toxic substances that exceed State intended-use standards in the Jordan River and major tributaries;

(2) Measure differences between the dissolved phase and the suspended phase of selected toxic substances;

(3) Determine selected pesticide concentrations in the Jordan River and major tributaries;

(4) Determine concentrations of selected toxic substances in bottom materials of the Jordan River and major tributaries;

(5) Identify toxic substances that may be transported to the Jordan River as a result of storm runoff from urban areas.

The five primary monitoring sites along the Jordan River used in this study were: (1) Jordan Narrows; (2) 9000 South Street; (3) 5800 South Street; (4) 1700 South Street; and (5) 500 North Street (fig. 1). Sampling also was done at three major tributary inflows to the Jordan River: Little Cottonwood, Big Cottonwood, and Mill Creeks. Storm runoff from urban areas was sampled at the following major storm drains to the river: 1300 South, north and south conduit; 800 South conduits, north, middle, and south conduit; and North Temple conduit.

No comprehensive studies have dealt specifically with toxic substances in the Jordan River. Several general studies have reported concentrations of the more common toxic substances such as ammonia (Hydroscience, Inc., 1976; Way, 1977), pesticides (Coburn, 1972; Salt Lake County Soil Conservation District, 1981), and common trace metals (U.S. Environmental Protection Agency, 1972; Salt Lake County Soil Conservation District, 1981).

Identification and Distribution of Toxic Substances

About one-half of the substances for which State intended-use standards have been established were not detected in concentrations that exceeded the standard during 1981-82. Among these, analyses for arsenic (16 samples), boron (27), chromium (131), endrin (27), lindane (6), phenol (25), selenium (38), silver (38), and toxaphene (6) indicated that these substances did not appear to constitute a hazard in the Jordan River or its three major tributaries. State standards have not been established for many other substances which are known to be toxic.

Reconnaissance during this study identified several toxic substances (table 3) which were present in the Jordan River and the three major tributaries at concentrations exceeding the State standards.

Ammonia, which is a natural degradation product of nitrogenous-organic matter, is toxic to fish and creates an oxygen demand in the water. The State standard of 20 micrograms per liter of ammonia (as nitrogen) is based on the presence of the un-ionized form, NH_3, which is the most toxic. Ionization of ammonia in water is dependent on temperature and pH—as the temperature or pH increases, the degree of ionization decreases. In warm, alkaline waters a greater proportion of a given concentration of dissolved ammonia will be present in the toxic, un-ionized form than in cooler, less alkaline water. Eighteen percent of the samples from the Jordan River and its major tributaries that were analyzed for ammonia had concentrations in excess of the State standard. Most of the problem concentrations of ammonia are just downstream from the wastewater-treatment plants.

Cadmium exceeded State standards in 9 percent of the samples from the Jordan River and its principal tributaries. Eighty-six percent of the samples that were collected in the storm conduits during storms, however, exceeded a concentration that is similar to State standards (table 4). Most of the storm conduits discharge to the river downstream of 2100 South Street, but most of the samples that exceeded the State cadmium standard were collected at 9000 South Street.

Cyanide, and iron typically are present in concentrations that do not exceed the State standards in the Jordan River, its major tributaries, and conduits that discharge to the river (tables 3 and 4). Copper concentrations in excess of the State standard were detected in only 9 percent of the river and tributary samples but were common in storm runoff in the conduits. A similar relationship was determined for lead, which exceeded State standards in only 2 percent of the river and tributary samples but exceeded them in 83 percent of the storm-runoff samples.

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Table 3.--Occurrence of constituents that exceeded State intended-use

standards in the Jordan River and three major tributaries

Constituent	Total number of samples	Number of samples in which State standards were exceeded	Mean of concentrations that exceeded State standards (micrograms per liter)
Ammonia, dissolved	85	15	NA[1]
Cadmium, dissolved	228	20	3.1
Copper, dissolved	228	20	15.4
Cyanide, dissolved	45	1	-
Iron, dissolved	213	1	-
Lead, dissolved	213	4	64.5
Mercury, total	138	107	.17
Zinc, dissolved	220	13	103

[1] Not applicable. Concentrations of un-ionized ammonia that exceeded

State standards are determined by calculation using known values for

temperature, pH, and ammonia concentration.

Table 4.—Frequency of occurrence of constituents that exceeded selected concentrations in samples from conduits

Number of samples.—A dash (--) indicates that no sample exceeded the selected concentrations
First line-- Total number of samples that exceeded selected concentrations
Second line--Number of above samples collected during storm runoff
Third line--Total number of samples

	Cadmium, dis- solved	Chromium, dis- solved	Copper, dis- solved	Cyanide, total	Iron, dis- solved	Lead, dis- solved	Mercury, total	Zinc, dis- solved
Selected concen- tration (micro- grams per liter)[1]	[1]12	100	10	5	1,000	50	0.05	50
Conduit			Number of Samples					
9000 South	[2]6	—	9	--	--	3	12	14
	5	—	6	—	—	2	9	13
	27	10	27	1	27	27	14	24
2100 South	--	--	14	1	—	1	7	5
	—	—	9	0	—	1	4	5
	18	7	18	1	17	18	7	17
1300 South South Conduit	--	--	5	--	--	--	7	5
	--	--	5	—	—	—	3	4
	19	8	17	1	19	18	8	19
1300 South North Conduit	--	—	3	--	—	1	7	1
	--	--	2	--	--	1	4	1
	20	8	19	1	19	19	8	19
800 South South Conduit	—	--	3	--	--	--	4	4
	--	—	3	--	—	—	4	2
	20	6	20	1	20	20	6	20
800 South Middle Conduit	—	—	4	--	—	—	8	8
	--	--	3	--	--	—	6	5
	19	9	18	1	18	19	9	18
800 South North Conduit	—	1	5	1	1	1	8	7
	—	0	5	1	1	1	6	7
	21	9	21	1	20	21	9	20
North Temple	1	--	3	—	--	—	8	1
	1	--	2	--	--	--	6	1
	18	9	18	1	18	18	9	18

[1] Selected concentrations are similar to State standards; however, State standards do not apply in these conduits.

[2] A concentration of 1.2 micrograms per liter of cadmium was used at the 9000 South Street conduit to agree with the State 3A standard for the Jordan River near 9000 South Street.

Concentrations of total mercury exceeded the State standards in 78 percent of the samples from the Jordan River and its three principal tributaries. Eighty-seven percent of the samples collected from storm conduits exceeded a total-mercury concentration of 0.05 microgram per liter. This represents a conservative estimate of the problem because the analytical detection limit for total mercury is 0.1 microgram per liter whereas the standard is 0.05 microgram per liter.

Dissolved-zinc concentrations occasionally did not meet the standards in the Jordan River and tributary samples, but concentrations in excess of 50 micrograms per liter were observed in 84 percent of all storm samples from the storm drains.

Transport of Trace Elements

Standards for toxic substances may be given in the dissolved, total, or total-recoverable phase. The U.S. Environmental Protection Agency (1976) presents standards for trace elements in either the total or total-recoverable phase. Standards established by the State of Utah are primarily for dissolved constituents (Utah Department of Social Services, 1978, appendix A). More than 90 percent of the arsenic, selenium, and silver, and more than 70 percent of the barium and mercury transported in the Jordan River during 1980-81 was in the dissolved phase. Ninety-eight percent of the iron was transported in the suspended phase.

Mean daily discharges were determined for nonstorm periods and total loads of 13 trace elements were calculated at each of the five monitoring sites. The mean load for each constituent was then determined as the average of the loads at the five sites. The mean load of iron for all sites was 110 pounds per day, with boron at about 31 pounds per day, zinc at 8 pounds per day, and lead at about 5 pounds per day. Loads of other trace elements were less than 5 pounds per day.

Toxic-Organic Substances in the Water

Water samples collected during August 1981-82 from the five sites on the Jordan River and from Little Cottonwood, Big Cottonwood, and Mill Creeks were analyzed for the following 19 pesticides and total polychlorinated biphenyls (PCB):

Aldrin	Chlordane	DDD
DDE	DDT	Dieldrin
Endosulfan	Endrin	Heptachlor
Heptachlor epoxide	Lindane	Mirex
Napthalenes, polychlorinated	PCB	Silvex
Perthane	2,4-D	2,4-DP
Toxaphene		
2,4,5-T		

The only pesticides detected in water from the Jordan River were DDE at a concentration of 0.01 microgram per liter at the 1700 South Street site, 2,4-D at 0.02 microgram per liter at the Jordan Narrows, and silvex at 0.01 microgram per liter at the 1700 South and 500 North Street sites. Silvex was

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detected at 0.02 microgram per liter at Big Cottonwood Creek at the Jordan River, and 2,4-D at 0.06 microgram per liter at Little Cottonwood and Big Cottonwood Creeks at the Jordan River.

Water samples collected during nonstorm periods during June and August 1982 were analysed for 27 of the 31 volatile organic compounds identified by the U.S. Environmental Protection Agency as a subcategory of priority pollutants (Keith and Telliard, 1979, p. 418). Tetrachloroethylene was detected at 500 North Street in concentrations of 5 and 1 micrograms per liter during both sampling periods. No other volatile organic compounds were detected.

Toxic Substances in Bottom Materials

The accumulation of 11 trace elements in bottom sediments was investigated at five sites on the Jordan River and in the three principal tributaries. Mean concentrations of the trace elements were smaller at the Jordan Narrows and 9000 South Street than at the three downstream river sites or in the tributaries (table 5). Concentrations of arsenic, cadmium, chromium, copper, lead, mercury, and zinc increased substantially at 5800 South Street, and the larger concentrations persisted downstream. Mean concentrations of arsenic, cadmium, and chromium in the bottom materials generally were twice as large at the three downstream sites as at the Jordan Narrows and 9000 South Street. Mean concentrations of copper and zinc were six times greater, and lead was eight times greater at the three downstream sites. Concentrations of beryllium, selenium, and silver were near detection limits and never exceeded 3 micrograms per gram. Analyses for cobalt were made only on one sample from each of the five sites, and concentrations ranged from less than 5 to 30 micrograms per gram.

Concentrations of most of the trace metals in the sediments in the three principal tributaries were similar to concentrations in the sediment of the Jordan River at the three downstream sites (table 5). Concentrations of zinc were about 50 percent greater, however, and concentrations of copper were about 23 percent less in the tributaries.

Analyses were made for 17 pesticides and (PCB) in bottom materials from five sites on the Jordan River and from the mouths of the three principal tributaries. Only 9 of the possible 18 compounds were detected at least once in any of the samples. The compound most frequently detected was PCB, in the bottom materials. Sampling on two dates detected concentrations of PCB (320 and 230 micrograms per kilogram) at the Jordan Narrows. Concentrations of PCB in the bottom materials at the downstream sites did not exceed 50 micrograms per kilogram.

Chlorinated-hydrocarbon pesticides and their degradation products such as DDT, DDD, DDE, dieldrin, and methoxychlor were detected in the bottom materials at most sites downstream of the Jordan Narrows. Concentrations of these compounds generally did not exceed 15 micrograms per kilogram. A sample of bottom material from Big Cottonwood Creek at the Jordan River, however, contained a 2,4-D concentration of 320 micrograms per kilogram.

Table 5.--Mean concentrations of selected trace elements in bottom materials in the Jordan River and three tributaries

Location	Trace elements (micrograms per gram)						
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Zinc
Jordan River							
Jordan Narrows and 9000 South Street	6.0	1.0	2.5	10.0	25.0	0.03	32.5
5800 South, 1700 South, and 500 North Streets	13.0	2.0	5.5	64.5	192.5	.05	186.9
Tributaries							
Little Cottonwood, Big Cottonwood, and Mill Creeks	15.0	2.0	7.3	49.7	191.4	.04	282.9

Priority Pollutants in Storm Runoff

The possible occurrence of the 129 priority pollutants (except dioxin and asbestos) in urban-storm runoff was investigated during a storm on October 29, 1981. Samples were collected from conduits discharging to the Jordan River at 1300 South, 800 South, and North Temple Streets. Only 2 of the 113 organic pollutants analyzed for were detected in the sampling. Chloroform, at 12 micrograms per liter, was found in the 800 South Street middle conduit; and phenol, at 10 to 30 micrograms per liter, was detected in all conduits except the 800 South Street middle conduit. Analyses for cyanide, phenol, and 13 trace metals, all of which are included in the priority pollutants, showed large concentrations of lead and zinc in samples from most of the storm conduits. The mean concentrations for the six conduits was 194 micrograms per liter for lead and 152 micrograms per liter for zinc. These concentrations are 4 and 3 times, respectively, the limits of State standards for the Jordan River.

Analyses were made for an additional 13 trace metals, which are not classified as priority pollutants. Concentrations of these metals typically were less than 150 micrograms per liter. Exceptions were total aluminum, with a mean concentration of 4,633 micrograms per liter for the six conduits; total iron, 4,420 micrograms per liter; and total strontium, 257 micrograms per liter. The large concentrations of these metals probably indicate large quantities of soil particles in the storm runoff. Nearly 90 percent of the strontium concentrations was present in the dissolved phase.

SANITARY QUALITY

The study of the sanitary quality of the Jordan River was designed to:

1. Determine the extent of sanitary (bacteriological) contamination.
   A. Identify contaminated stream reaches.
   B. Identify probable sources of contamination.

2. Determine trends of sanitary quality in the river.

3. Determine effects of storm runoff from urban areas on the sanitary quality of the river.

Data used in this study were collected by the U.S. Geological Survey and the Salt Lake City-County Health Department. The data collected by the Geological Survey were published in Pyper and others (1981) and McCormack and others (1983). The data collected by the Salt Lake City-County Health Department are available primarily as unpublished laboratory analyses.

Due to the difficulty of isolating and identifying pathogenic organisms from water, the appearance of common nonpathogens typically is used as an indicator of sanitary quality. Historically, the total coliform group has been used as an indicator; but recently, fecal coliform and fecal streptococci bacteria have been used more generally as they are more specific indicators of sources of contamination. Ratios of concentrations of fecal streptococci to fecal coliform bacteria are used to distinguish between human and non-human sources of contamination.

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All bacterial studies of the Jordan River since the early 1970's have concluded that coliform densities increase downstream from the Jordan Narrows (U.S. Environmental Protection Agency, 1972; Templeton, Linke, Alsup, and Engineering-Science, Inc., 1974; Salt Lake County Water Quality and Water Pollution Control, 1978). Concentrations of total coliforms downstream from 9000 South Street were always greater during the irrigation season (Salt Lake County Soil Conservation District, 1981), and agricultural sources were believed to be responsible for 1,000 organisms per 100 milliliters of the total bacterial concentrations detected (Hydroscience, Inc., 1976). Six of the seven wastewater-treatment plants in Salt Lake County are hydraulically overloaded (Gunnell and others, 1982, p. 61), which results in decreased treatment efficiency and increased bacterial concentrations. The plants were estimated to contribute 1,000 to 6,000 total coliforms per 100 milliliters of the measured concentrations in the downstream reaches of the Jordan River by Hydroscience, Inc., (1976). Nonstorm runoff from the conduits upstream from 2100 South Street was responsible for as much as 15,000 total coliforms per 100 milliliters of the total concentrations in the river (Hydroscience, Inc., 1976).

Distribution of Bacterial Contamination

The 1980-82 study of sanitary conditions in the Jordan River found that concentrations of indicator bacteria increased markedly as the river flowed north through Salt Lake County (figs. 6-8). Great variability typically is observed in most biological data, and such variability was a dominant factor in all the sanitary data analyzed for this study. The coefficient of variation for the bacterial data collected from the Jordan River ranged from 130 to 350 percent. Mean concentrations of coliform bacteria in the river at the Jordan Narrows were fairly large, ranging from 82 colonies per 100 milliliters for fecal coliforms to 7,320 for total coliforms. The greatest increase in the coliform groups was downstream of 9000 South Street. Fecal streptococcal bacteria showed only a gradual increase from a mean of about 1,500 colonies per 100 milliliters at the Jordan Narrows to about 2,900 colonies per 100 milliliters at 1700 South Street. Within the 5-mile reach from 1700 South to 500 North Streets, the mean increased to more than 11,000 colonies per 100 milliliters, primarily due to inflow from the conduits at 1300 South, 800 South, and North Temple Streets.

The Jordan River in Salt Lake County is classified as 2-B (Utah Department of Social Services, 1978, p. 45), which establishes standards protecting the water for boating, water skiing, and similar uses, excluding bathing. Bacterial standards for this class include a maximum 30-day geometric mean of 5,000 total coliform colonies per 100 milliliters and a maximum of 2,000 fecal coliform colonies per 100 milliliters. Although these are geometric means, they are useful as relative indicators of unacceptable limits for individual samples. The frequency with which coliform samples exceeded the State standard increased downstream of 9000 South Street (fig. 9). Nearly 75 percent of the samples for total coliform and 45 percent of those for fecal coliform samples collected at 500 North Street exceeded the State standards. There are no standards for fecal streptococcal bacteria, but the ratio of concentrations of fecal coliform to fecal streptococcal bacteria can be used as an indicator of sources for the bacteria (American Public Health Association and others, 1980, p. 819). Ratios greater than 4.1 are typical of pollution derived from human wastes; and ratios less than 0.7 are indicators of nonhuman sources, such as domestic animals.
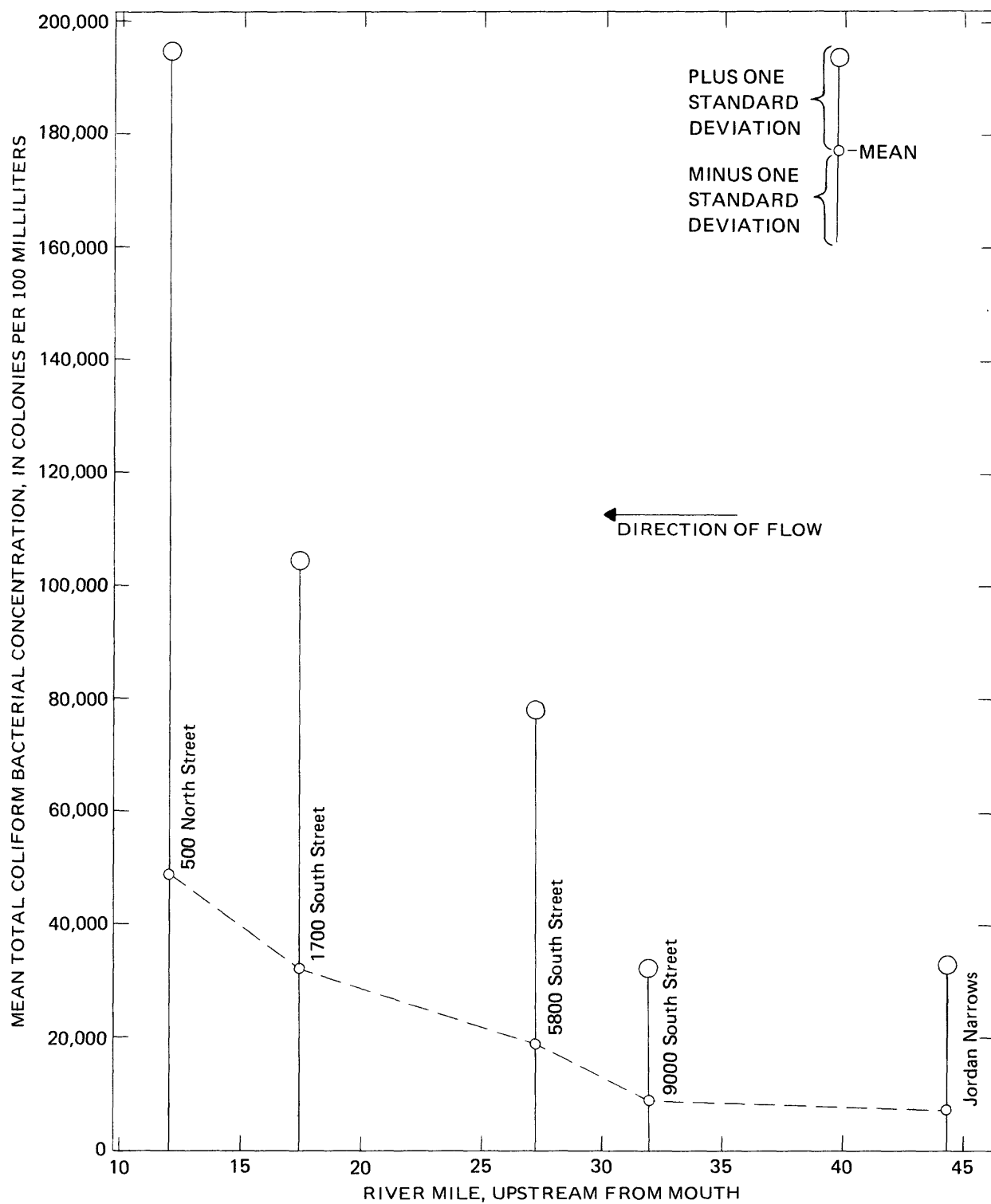
Figure 6.—Mean concentration and one standard deviation for total coliform bacteria at five sampling sites. From Thompson (1984b).
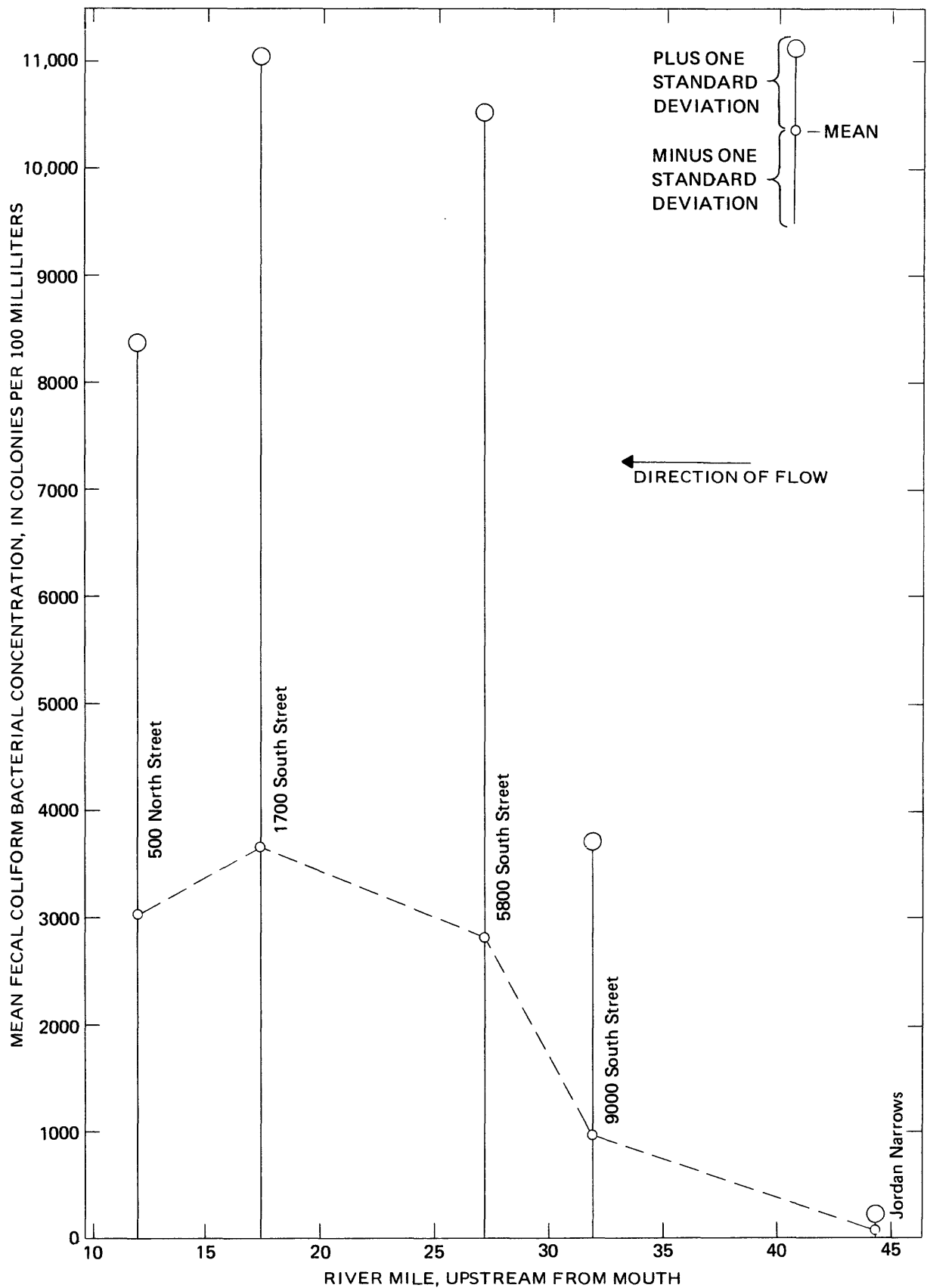
Figure 7.—Mean concentration and one standard deviation for fecal coliform bacteria at five sampling sites. From Thompson (1984b).
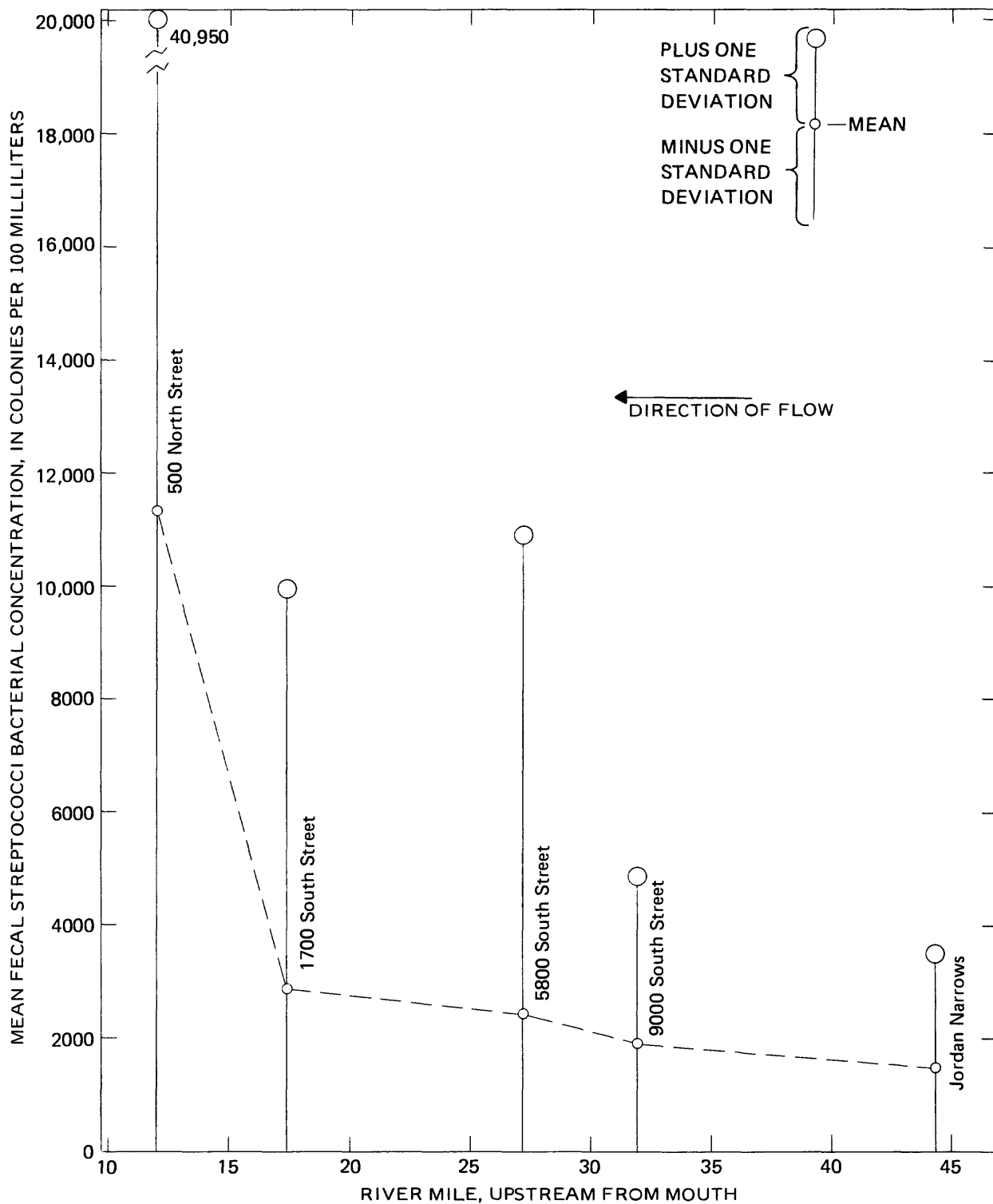
Figure 8.—Mean concentration and one standard deviation for fecal streptococcal bacteria at five sampling sites on the Jordan River. From Thompson (1984b).
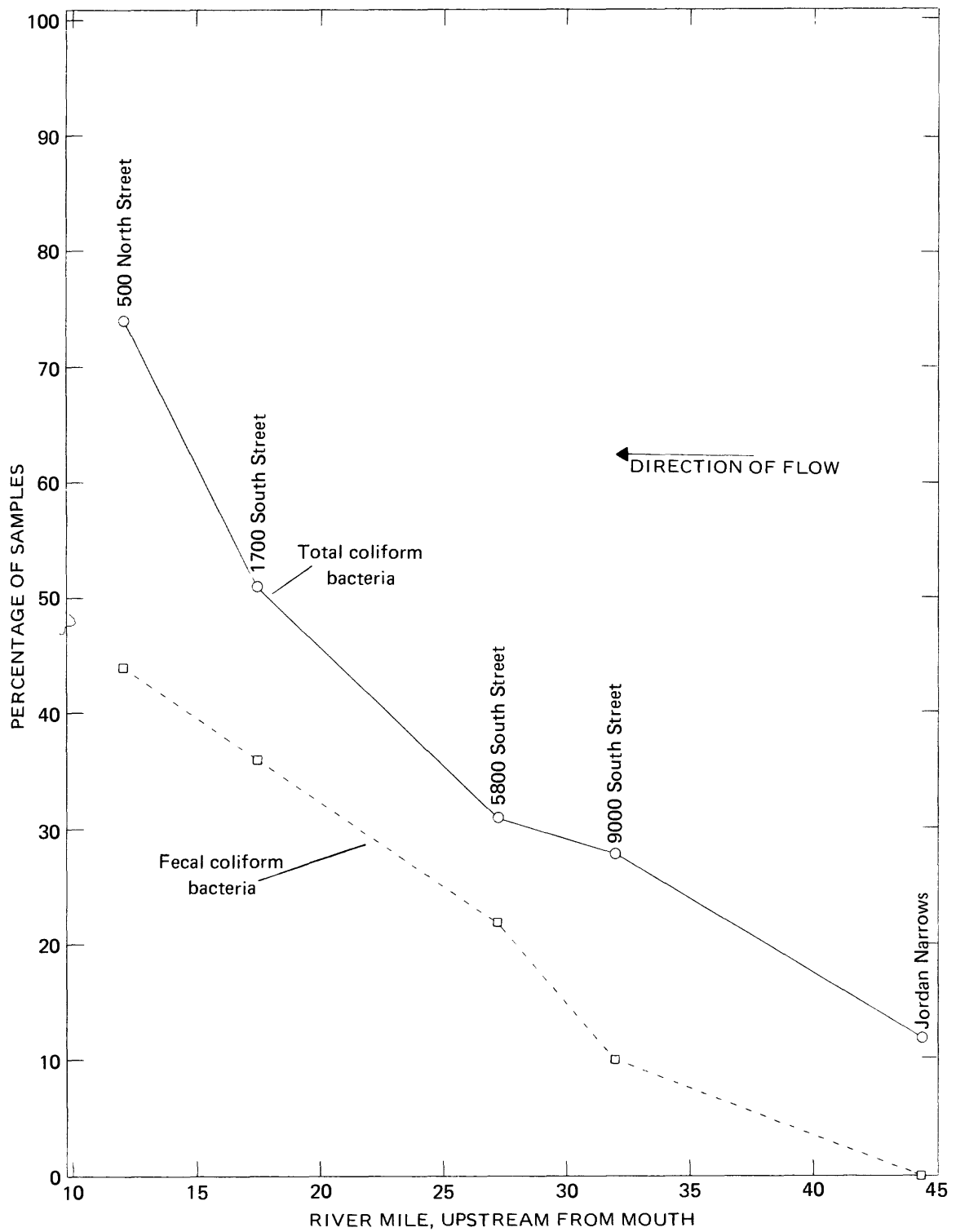
Figure 9.—Percentage of samples in which concentration of total and fecal coliform bacteria were greater than the sanitary standards at five sampling sites. From Thompson (1984b).

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Ninety-two percent of the samples collected at the Jordan Narrows had ratios of concentrations of fecal coliform to fecal streptococcal bacteria that were less than 0.7 (fig. 10). This decreased to about 50 percent at 5800 South Street and sites downstream (fig. 10). The percent of samples with ratios indicative of human wastes (greater than 4.1) increased from 0 at the Jordan Narrows and 9000 South Street to 20 percent at 1700 South, then decreased to less than 10 percent at 500 North Street. The increase corresponds closely with the distribution of seven wastewater-treatment plants in the reach from 9000 South and 1700 South Streets. The ratio is useful only where the travel time from the source is less than 24 hours. Under low-flow conditions in the Jordan River, travel times in this reach are considerably less than 1 day; therefore, this ratio should provide a valid indicator of contamination.

Sources of Bacterial Contamination

The Jordan River as it enters Salt Lake Valley at the Jordan Narrows, contains significant concentrations of total coliform and fecal coliform bacteria. The most probable source of this contamination is Utah Lake. A report by Environmental Dynamics, Inc., (1975) listed mean total coliform concentrations collected at seven sites in Utah Lake during 1968-70. The maximum mean, total coliform concentration in 1970 was 6,439 colonies per 100 milliliters at a site near the northeast shore.

Wastewater-Treatment Plants

The seven wastewater-treatment plants that discharge secondary effluent to the Jordan River in Salt Lake County were a major source of sanitary contamination (table 6). Mean total coliform concentrations ranged from 5,790 to 125,500 MPN (most probable number) per 100 milliliters and mean fecal concentrations ranged from 37 to 62,850 MPN per 100 milliliters. The maximum concentrations of both total and fecal coliforms reached 240,000 MPN per 100 milliliters. The data showed considerable variability, with the coefficient of variation typically greater than 100 percent.

Tributary Streams

Mean concentrations of total coliform bacteria in Little Cottonwood, Big Cottonwood, and Mill Creeks during nonstorm periods were all significantly less than the concentrations in the Jordan River near the confluence with these creeks. Big Cottonwood Creek had the greatest mean with 8,940 colonies per 100 milliliters, which was greater than the State 2-B sanitary standard of 5,000 colonies per 100 milliliters. Means for Little Cottonwood and Mill Creeks were 2,490 and 2,030 colonies per 100 milliliters. Two of 11 samples exceeded the standard for Little Cottonwood Creek, 3 of 11 samples exceeded the standard for Big Cottonwood Creek, and none of the samples from Mill Creek exceeded the standard.
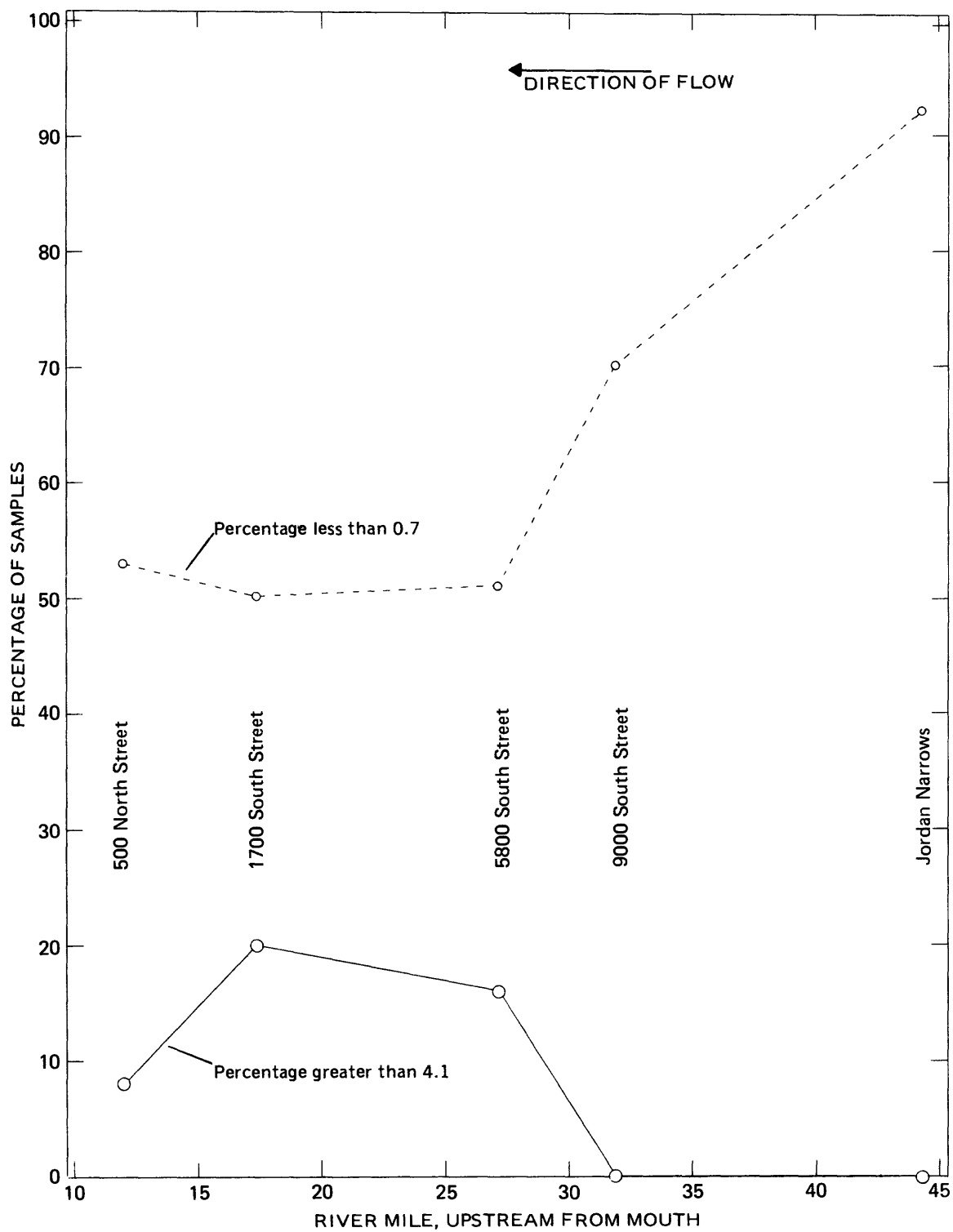
Figure 10.—Percentage of samples where ratio between concentration of fecal coliform and fecal streptococcal bacteria was greater than 4.1 and less than 0.7. From Thompson (1984b).

Table 6.—Summary of coliform concentrations discharged by wastewater-treatment plants in Salt Lake County for the period September 1980 to October 1982

Wastewater-treatment plant	Sandy	Tri-Community	Murray	Cottonwood	Granger-Hunter	Salt Lake City Suburban 1	South Salt Lake
River mile	31.7	29.0	24.7	24.0	20.6	20.5	18.0
TOTAL COLIFORM							
Number of samples	16	19	18	19	19	19	17
Mean (colonies per 100 millilters)	31,040	125,500	5,790	104,430	71,010	64,390	6,230
Coefficient of variation (percent)	263	91	196	114	150	115	139
FECAL COLIFORM							
Number of samples	14	19	17	19	18	19	17
Mean (colonies per 100 milliliters)	200	16,300	37	62,850	22,310	3,310	2,230
Coefficient of variation (percent)	207	334	161	159	256	321	278

Mean fecal coliform concentrations were 660 colonies per 100 milliliters for Little Cottonwood Creek, 2,670 for Big Cottonwood Creek, and 700 for Mill Creek. The frequency of samples that exceeded the fecal coliform standard of 2,000 colonies was zero for Little Cottonwood Creek, 1 of 6 for Mill Creek, and 4 of 8 for Big Cottonwood Creek. The ratio of concentrations of fecal coliform to fecal streptococcal bacteria generally was between 0.7 and 4.4 for all three creeks, indicating that the bacteria were from mixed human and nonhuman sources.

Storm samples collected from Little Cottonwood Creek had significantly greater mean concentrations of fecal coliform and fecal streptococcal bacteria than nonstorm samples (table 7). Means of the three bacterial types were significantly greater in storm samples collected from Mill Creek than in nonstorm samples.

Trends in Sanitary Quality

Considerable data for bacterial concentrations since 1974 are available for sites at 5800 South and 1700 South Streets. Data collected before and after July 1980 were grouped as "recent" and "historical" data to determine if bacterial concentrations had increased. A group comparison t-test at the 95-percent confidence level indicated no significant differences between the two periods at 5800 South Street. A possible explanation for the lack of differences was the great variability of the data. At 1700 South Street, concentrations of fecal coliform and fecal streptococcal bacteria were significantly greater in samples collected after July 1980. A siginificant positive correlation was found at this site between concentrations of fecal coliform bacteria and time, with a correlation coefficient of 0.5. The increase with time and the variability in data are shown in figure 11. The mean concentration of fecal streptoccal bacteria at 1700 South Street for 1974-82 was 1,610 colonies per 100 milliliters and for 1980-82, it was 2,870 colonies per 100 milliliters.

Effects of Storm-Water Discharges

Runoff discharged to the Jordan River in the conduits contained large concentrations of indicator bacteria (fig. 12). Large concentrations of total coliform bacteria in storm runoff generally are due to native soil coliform bacteria, which are washed off soil particles by overland flow (Mallard, 1980, p. 5). Large concentrations of the other indicator bacteria were due to animal sources. The median ratios of concentrations of fecal coliform to fecal streptococcal bacteria from the tributaries and conduits generally were less than 0.7. Additionally, 72 percent of the 130 bacterial samples of storm runoff from urban areas had a ratio less than 0.7. This indicates that nonhuman fecal waste was the major type of fecal contamination in storm runoff from urban areas discharged to the Jordan River. Ratios greater than 4.1, which indicate human contamination, were determined only in 11 percent of the samples.

Table 7.--Comparison of mean bacterial concentrations for nonstorm and
  storm samples collected near the mouths of Little Cottonwood and
  Mill Creeks
                      [concentrations in colonies per 100 milliliters]

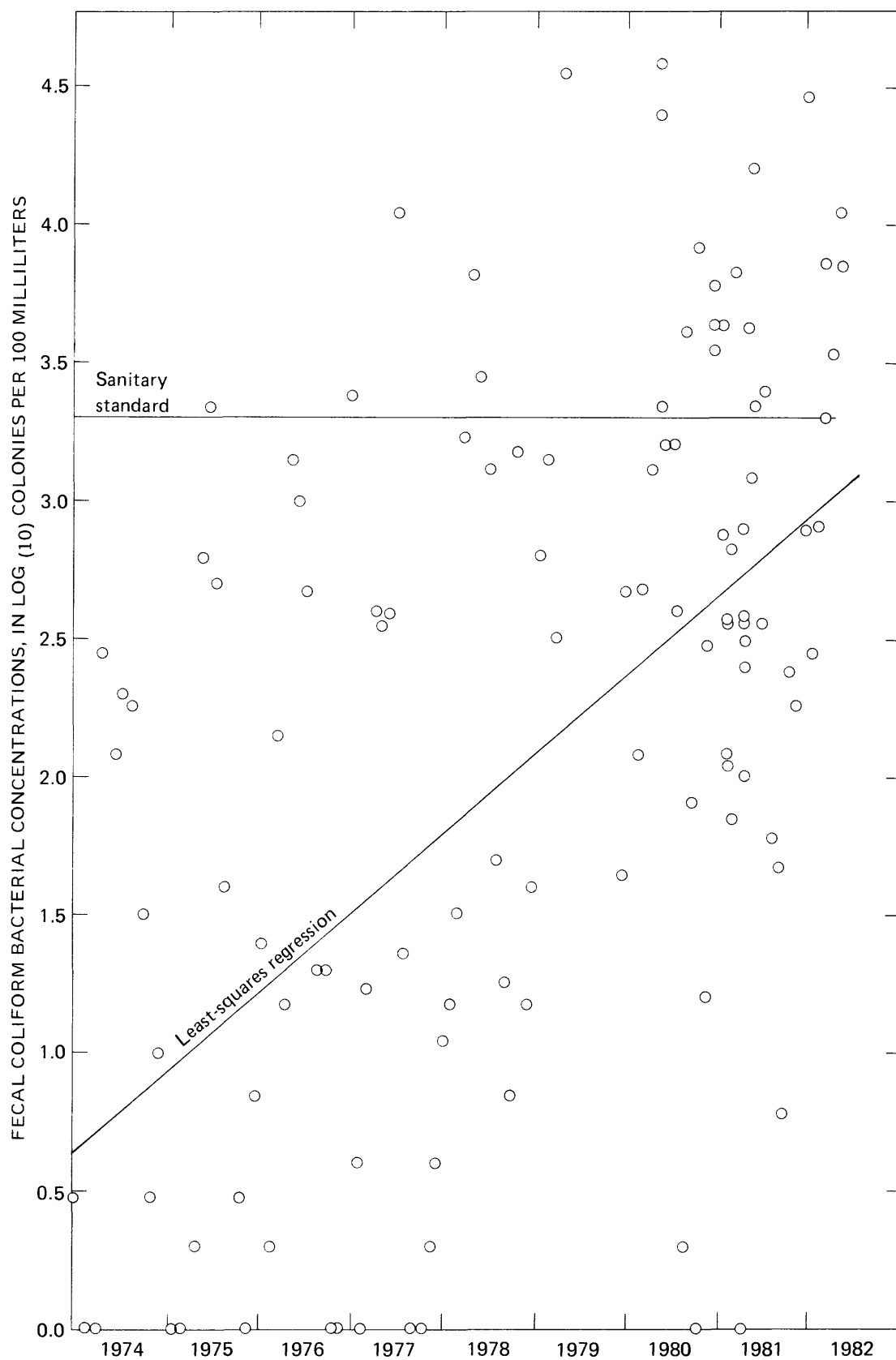|	Samples	Total coliform bacteria	Fecal coliform bacteria	Fecal streptococcal bacteria
Little Cottonwood Creek				
Nonstorm	7 to 11	2,490	660	620
Storm	8 to 11	2,670	1,300	11,880
Mill Creek				
Nonstorm	6 to 11	2,030	700	820
Storm	8 to 12	4,620	1,710	8,450

Figure 11.—Increase in fecal coliform bacterial concentrations with time and comparison
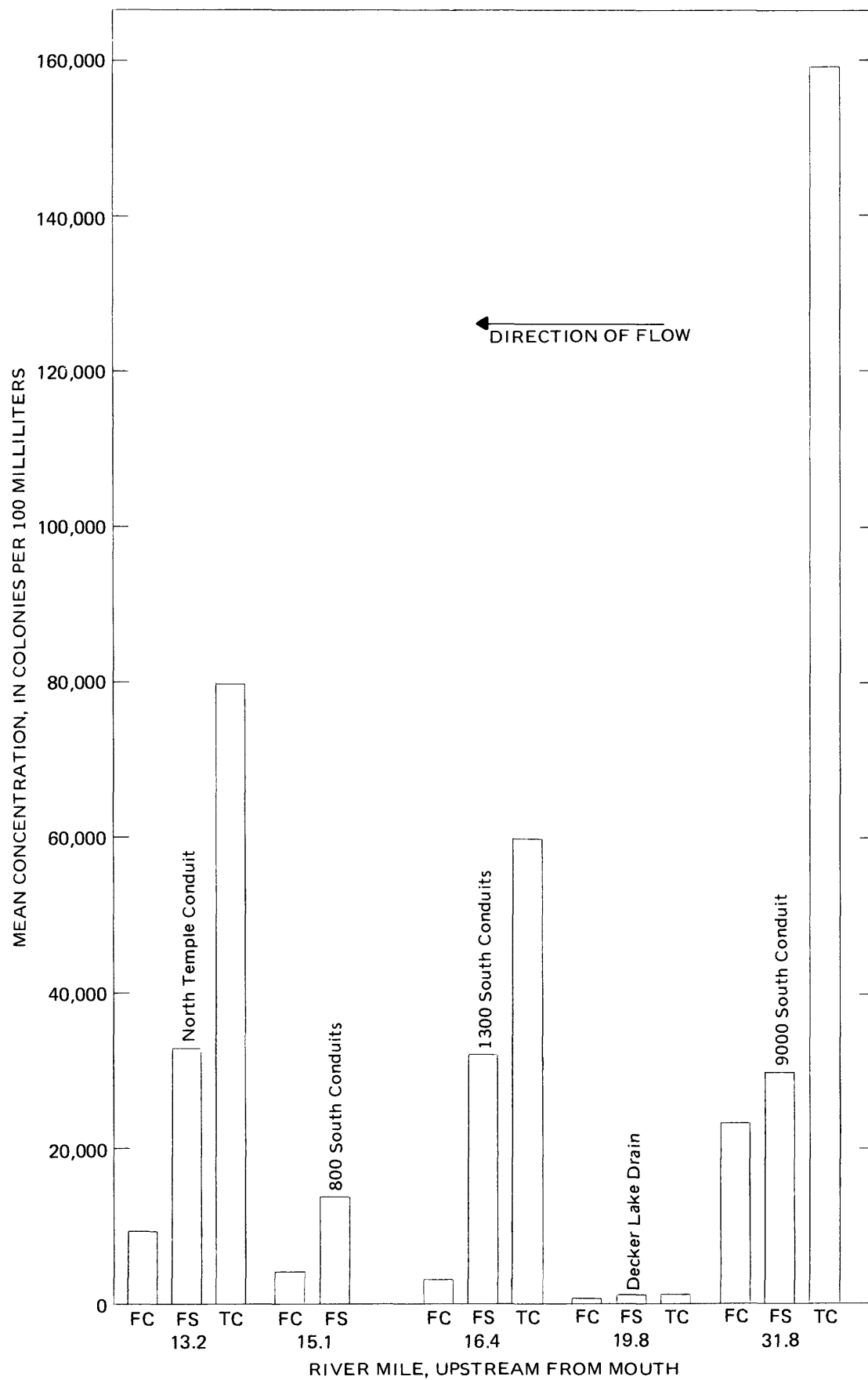with the sanitary standard at 1700 South Street. From Thompson (1984b).

Figure 12.—Mean concentrations of fecal coliform bacteria (FC), fecal streptococcal bacteria (FS), and total coliform bacteria (TC) in conduits. From Thompson (1984b).

Large bacterial concentrations in storm runoff resulted in an increase of the concentration of some bacterial types in the Jordan River during storms (table 8). The mean concentrations of total coliform bacteria varied, but they generally were greater during nonstorm periods; whereas, the mean concentrations of fecal coliform bacteria were greater at all sites during storms. Concentrations of fecal streptococcal bacteria were greater during storms at all sites except the Jordan Narrows. Statistical verification of the differences between nonstorm and storm data was difficult due to the variability within the data sets.

TURBIDITY

Excessive turbidity in a river is not desirable because it detracts from the esthetic appearance, it interferes with sprinkler-irrigation systems, and it can adversely affect the fishery potential. The study of turbidity in the Jordan River, was designed to:

1. Measure the turbidity and concentrations of suspended sediment in the Jordan River from the Jordan Narrows to 500 North Street.

2. Identify the specific components and sources of the turbidity.

3. Describe possible remedial measures to decrease the turbidity.

Few previous studies of water quality of the Jordan River have dealt specifically with turbidity, although it was generally recognized as a problem (U.S. Environmental Protection Agency, 1972, p. 35; Salt Lake County Water Quality and Water Pollution Control, 1978, Sec. II, p. 22; Gunnell and others, 1982, p. 62). Considerable water-quality data, including turbidity, have been collected by the U.S. Geological Survey since 1974 at gaging stations at 5800 South and 1700 South Streets. More specific data on the causes and distribution of turbidity were collected at five sites on the Jordan River from January 1981 through August 1982. Samples were collected monthly and analyzed for turbidity, suspended sediment, and organic carbon. The samples collected during the summer were analyzed for phytoplankton chlorophyll to assess the effect of suspended algae on turbidity.

Variation in Turbidity

Relatively large values of turbidity were measured at the Jordan Narrows, with a mean of 88 Nephelometric turbidity units (NTU) during June-October as contrasted to and a mean of 43 NTU during November-May. The combined mean for all other sites was nearly identical for June to October (27 NTU) and November to May (32 NTU). The generally synchronous pattern of variability of turbidity at all sites except the Jordan Narrows is indicated in figure 13. The latter site also had the greatest variability in turbidity, ranging from 10 to almost 150 NTU.

Table 8.—Mean concentrations of indicator bacteria in nonstorm and storm
    samples at five sampling sites
                [concentrations in colonies per 100 milliliters]

| Site	Total coliform bacteria	Fecal coliform bacteria	Fecal streptococcal bacteria
Jordan Narrows			
Nonstorm	7,320	82	1,480
Storm	2,090	140	1,120
9000 South State			
Nonstorm	9,110	970	1,890
Storm	8,210	1,140	4,010
5800 South Street			
Nonstorm	19,120	2,820	2,410
Storm	7,100	3,080	9,980
1700 South Street			
Nonstorm	32,070	3,660	2,870
Storm	40,120	8,670	5,040
500 North Street			
Nonstorm	48,970	3,030	11,320
Storm	36,590	3,920	25,500
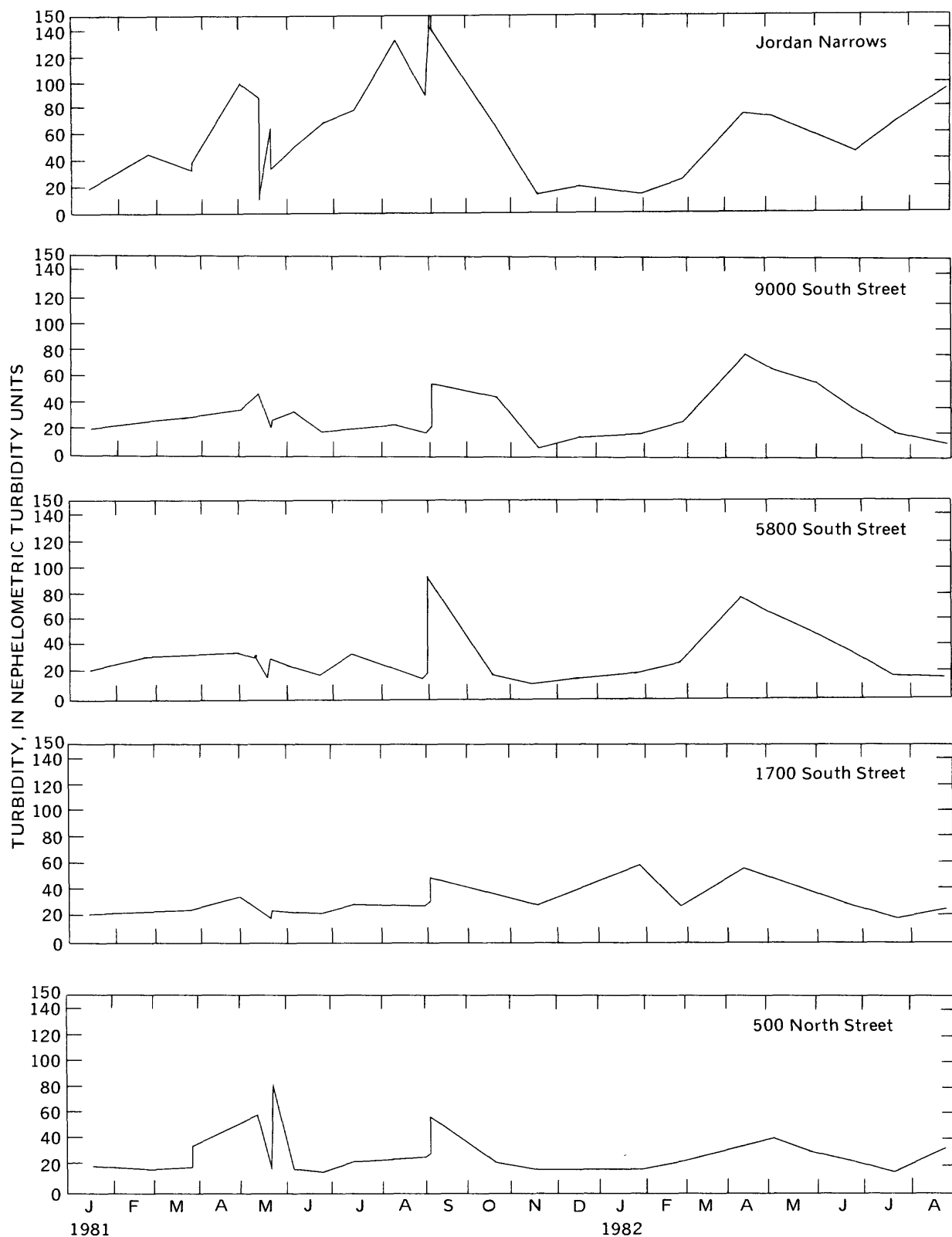
Figure 13.—Variations in turbidity at five sampling sites, January 1981 to August 1982. From Weigel (1984).

Variation in the Components of Turbidity

Mean concentrations of suspended sediment did not vary significantly among sites or between the November-May and June-October periods, but the daily variation among sites occasionally was large. The means for the entire study period ranged from 169 milligrams per liter at 500 North Street to 193 milligrams per liter at the Jordan Narrows (table 9). No seasonal trend was observed but the mean concentration appeared to decrease from the Jordan Narrows to 500 North Street during June to October.

The mean concentration of suspended-organic carbon was larger at all sites during June to October. During that period, the concentrations of SOC always were largest at the Jordan Narrows, averaging nearly twice the concentrations at some downstream sites. The large concentrations of SOC coincided with large concentrations of phytoplankton chlorophyll a, which averaged 42 micrograms per liter at the Jordan Narrows and decreased downstream to 9.2 micrograms per liter at 500 North Street. Phytoplankton samples collected during a bloom on August 24, 1982, contained a maximum of 99,000 cells per milliliter at the Jordan Narrows, with a minimum of 23,000 cells per milliliter at downstream stations. Blue-green algae constituded 84 to 98 percent of the total cell count.

Correlation of Turbidity With Related Parameters and Control of Turbidity

Correlation analysis was used to identify relationships between turbidity and concentrations of suspended sediment and SOC in the Jordan River during different periods of the year (table 10). Significant correlations (correlation coefficient greater than 0.70) were obtained between turbidity and the concentration of suspended sediment during June to October and November to May at the Jordan Narrows. Samples collected during June to October had significant correlations between turbidity and SOC at all sites. Significant correlations were observed between suspended-organic carbon and turbidity during November to May only at 1700 South Street. Correlations between turbidity and concentrations of suspended sediment were more variable at all sites. There were significant correlations during June to October between turbidity and the concentration of suspended sediment at the three upstream sites: Jordan Narrows and 9000 South and 5800 South Streets. When all sites were combined and the overall relationships evaluated, turbidity correlated significantly with SOC during June to October.

Concentrations of suspended sediment did not correlate well with turbidity at 1700 South Street, but SOC correlated significantly at all times. The addition of organic matter to a clay suspension has been shown to result in precipitation of an organic-clay complex (van Olphen, 1977, p. 71). This mechanism may have operated upstream from 1700 South Street, resulting in a decrease in turbidity due to the precipitation of inorganic solids by organic material contributed by the wastewater-treatment plants. The decrease in turbidity due to removal of inorganic-suspended sediment was accompanied by an increase in turbidity due to suspended-organic sediment. Analysis of a small amount of particle-size data indicated a considerable decrease in clay-size particles between 5800 South and 1700 South Streets, which tends to support this mechanism.

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Table 9.—Variations in the means for turbidity and for suspended-sediment suspended-organic carbon, and chlorophyll concentrations

[NTU, Nephelometer Turbidity Units; mg/L, milligrams per liter; ug/L, micrograms per liter]

Location	Turbidity		Suspended-sediment concentration		Suspended-organic carbon (as C) Concentration		Chlorophyll a and b concentration		
	Number of samples	Mean (NTU)	Number of samples	Mean (mg/L)	Number of samples	Mean (mg/L)	Number of samples	Mean (ug/L) a	b
Entire study period (January 1981–August 1982)									
Jordan Narrows	27	61	19	193	24	2.3	—	—	—
9000 South Street	26	30	19	189	20	1.4	—	—	—
5800 South Street	25	30	21	174	20	1.7	—	—	—
1700 South Street	22	29	17	181	20	2.0	—	—	—
500 North Street	25	29	19	169	21	1.9	—	—	—
June–October									
Jordan Narrows	11	88	10	228	11	3.5	9	42	1.2
9000 South Street	11	27	10	199	10	1.6	9	17	1.4
5800 South Street	11	27	11	170	11	2.0	9	19	1.3
1700 South Street	10	27	10	191	9	2.3	8	11	.46
500 North Street	10	26	10	153	10	2.1	7	9.2	.31
November–May									
Jordan Narrows	16	43	9	154	13	1.2	—	—	—
9000 South Street	15	32	9	179	10	1.3	—	—	—
5800 South Street	14	32	10	179	9	1.4	—	—	—
1700 South Street	12	31	6	166	11	1.8	—	—	—
500 North Street	15	32	9	187	11	1.7	—	—	—

Table 10.—Correlation coefficients between turbidity and two components of suspended sediment

Location	Suspended-sediment concentration		Suspended-organic carbon (as C)	
	Number of samples	Correlation coefficient	Number of samples	Correlation coefficient
Entire study period (January 1981–August 1982)				
Jordan Narrows	19	0.86	24	0.69
9000 South Street	19	[1] .44	20	.53
5800 South Street	21	.61	20	.57
1700 South Street	17	.63	20	.63
500 North Street	19	.53	21	[1] .37
Combined sites	95	.54	105	.60
June–October				
Jordan Narrows	10	0.92	11	0.71
9000 South Street	10	.67	10	.81
5800 South Street	11	.78	11	.81
1700 South Street	10	[1] .60	9	.83
500 North Street	10	[1] .49	10	.81
Combined sites	51	.59	51	.75
November–May				
Jordan Narrows	9	0.77	13	[1] 0.06
9000 South Street	9	[1] .35	10	[1] .45
5800 South Street	10	[1] .30	9	[1] .42
1700 South Street	7	[1] .74	11	.74
500 North Street	9	[1] .54	11	[1] .27
Combined sites	44	.46	54	[1] .23

[1] Correlation coefficient less than the 95-percent-confidence level.

Particle-size analyses indicated that at least 67 percent of the suspended sediment in water samples collected from November to May at the Jordan Narrows consisted of clay-size particles. Utah Lake is turbid, and precipitated calcite has been suggested as the likely cause (Fuhriman and others, 1981, p. 59). This indicates that clay-size particles entering the river from Utah Lake, were responsible for much of the turbidity at the Jordan Narrows during this time.

The decrease of turbidity in Utah Lake could decrease turbidity in the Jordan River upstream from 5800 South Street. Control of algal growth in Utah Lake and Jordan River could decrease the turbidity during June through October in the river. A decrease in the quantity of organic material discharged from the wastewater-treatment plants into the Jordan River could decrease the turbidity in the river downstream from 5800 South Street. Further studies specifically to identify sources of turbidity in the Jordan River would benefit from additional particle-size and phytoplankton analyses. Studies of turbidity and suspended sediment in tributary streams and canals possibly could identify additional sources of turbidity.

SUMMARY AND CONCLUSIONS

The results of an intensive study of the Jordan River from 1980-82 indicated that severe water-quality problems exist which may interfere with productive use of the river. Concentrations of dissolved oxygen, which were less than 5.5 milligrams per liter, were common during April-September downstream of 5800 South Street. These small concentrations were due to increases in organic materials contributed by discharges from wastewater-treatment plants, tributary streams, and storm conduits. Most of the oxygen-demanding substabces enter the river in the reaches that have the smallest reaeration rates and consequently the smallest assimilatory capacity.

Toxic substances were a major pollution problem in the Jordan River. Most of the problem substances identified in the river were trace metals. Total mercury concentrations exceeded the State's standard of 0.05 microgram per liter in about 75 percent of all samples. Large concentrations of cadmium, copper, lead, and zinc, were an occasional problem, but less than 10 percent of all samples exceeded the recommended use standards. Concentrations of ammonia that are toxic to fish were present in 18 percent of all samples; and these concentrations likely were due to discharges from wastewater-treatment plants. Pesticides and organic compounds identified as priority pollutants did not appear to be a serious problem in the Jordan River. Concentrations of pesticides such as DDD, DDE, DDT, dieldrin, and methoxychlor, which were commonly used in previous years, have been detected in bottom sediments. Only DDE, Silvex, and 2,4-D were found dissolved in the river water, and they typically were at concentrations less than 0.1 microgram per liter. Chloroform and phenol occasionally were detected in water entering the river from conduits.

A serious sanitary problem existed in the Jordan River, as indicated by the presence of large numbers of indicator bacteria. Bacterial concentrations generally increased as the river flowed northward. Contamination from animals appeared in 92 percent of the samples from the Jordan Narrows but decreased to 50 percent downstream. Contamination from humans was rare at the Jordan

Narrows but increased to 10-20 percent of the samples downstream. The numerous conduits contributed large numbers of indicator bacteria to the river and contamination from animal wastes was present in nearly 75 percent of all samples obtained from the conduits. Data collected before and after July 1980 indicate that the bacterial contamination of the river at 1700 South Street has increased. With the increasing population in the Salt Lake Valley and its effect on already overloaded wastewater-treatment plants, this trend is likely to continue.

Turbidity gives the Jordan River a murky appearance, which is objectionable to most river users. Turbidity is the most visible pollutant in the Jordan River, although it is the least hazardous of the contaminants. Much of the turbidity was due to clay-size particles in suspension that enter the river at Utah Lake and to suspended-organic materials discharged from wastewater-treatment plants. During June to October, turbidity was due primarily to suspended-organic matter, whereas, during November to May, inorganic-suspended sediment (possibly calcite) was the likely cause.

The establishment of the Jordan River Parkway and the construction of numerous foot bridges, jogging paths, and equestrian trails indicate a committment to recreational and esthetic enjoyment of the river. Population increase in the area will increase the loads of contaminants discharged to the river as well as increase the recreational demands on its resources. If provisions are not made to minimize the effect of the increased population, continued degradation of the river could occur.

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