SANITARY QUALITY OF THE JORDAN RIVER

IN SALT LAKE COUNTY, UTAH

By Kendall R. Thompson

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CONVERSION FACTORS

For readers who prefer to use metric units, conversion factors for inch-pound units used in this report are listed below:

Multiply inch-pound units	By	To obtain metric units
foot	0.3048	meter
foot per mile	0.1894	meter per kilometer
inch	25.40	millimeter
mile	1.609	kilometer

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By Kendall R. Thompson

ABSTRACT

This investigation of the sanitary quality of the Jordan River in Salt Lake County, Utah was conducted from July 1980 to October 1982. Indicator bacteria (total coliform, fecal coliform, and fecal streptococci) rather than specific pathogens were used to establish the sanitary quality of the river.

A serious sanitary problem was identified in the Jordan River during the investigation. Concentrations of total coliform bacteria commonly exceeded 5,000 colonies per 100 milliliters and concentrations of fecal coliform bacteria commonly exceeded 2,000 colonies per 100 milliliters in the downstream reaches of the river. At times these concentrations were greatly exceeded. The most conspicuous aspect of the bacteriological data is its extreme variability. Seven wastewater-treatment plants, seven major tributaries, numerous storm conduits, irrigation-return flow, and other sources all contribute to the dynamic system that determines the sanitary quality of the river. Because of this variability, the sanitary quality of the river cannot be predicted at any one time.

In general, concentrations of all three indicator bacteria increased in a downstream direction. The ratio of fecal coliform to fecal streptococci concentration indicated contamination from animal waste was present in 92 percent of the samples from the upstream sampling site at Jordan Narrows and decreased to about 50 percent of the samples at downstream sampling sites. No contamination from human waste was found at two upstream sampling sites but such contamination was found in 20 percent of the samples downstream at the sampling site at 1700 South Street.

Regression analysis of 9 years of data collected at the sampling site at 1700 South Street showed a significant positive correlation between both fecal coliform and fecal streptococci bacteria concentrations versus time. Concentrations of fecal coliform and fecal streptococci bacteria have both been increasing in the river at 1700 South Street since 1974.

Storm runoff from urban areas contributed large concentrations of indicator bacteria to the Jordan River. Fecal contamination from animal waste was indicated in 72 percent of the samples of storm runoff from urban areas. Fecal contamination from human waste was indicated in 11 percent of the samples of storm runoff from urban areas.

INTRODUCTION

During July 1980-October 1982, the U.S. Geological Survey in cooperation with the Salt Lake County Division of Flood Control and Water Quality conducted a study of the quality of the Jordan River. To initiate the study, a letter was sent to 39 other Federal, State, and local agencies stating proposed study plans and priorities, and requesting input from those agencies; this was to assure coordination of the work with that of other agencies. As a result of responses from 14 agencies, the study focused on the following four subjects: sanitary quality, toxic substances, dissolved oxygen, and turbidity. This report describes sanitary quality. Three other reports will be prepared for each of the other subjects, and all subjects will be summarized in a fifth report.

Purpose and Scope

The objectives of the study described in this report were to:

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

B. Determine trends of sanitary quality in the river.

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

The study was limited only to the reach of the Jordan River located in Salt Lake County.

Methods

Data for this report were collected by the U.S. Geological Survey and the Salt Lake City-County Health Department. The inclusion of data from both agencies created a more complete data base for the study.

Methods used by the U.S. Geological Survey are outlined in Greeson and others (1977). The only deviation from the methods of Greeson and others was the collection of depth-integrated samples using a methanol-disinfected sampler and sterile container. Doyle Stephens (U.S. Geological Survey, written commun., Dec. 29, 1980) determined depth-integrated sampling best fit the needs of this study. The membrane-filter technique was used to determine concentrations of total coliform, fecal coliform, and fecal streptococci bacteria.

Methods used by the Salt Lake City-County Health Department are outlined in American Public Health Association and others (1980). The membrane-filter technique was used for all samples collected from the Jordan River and tributary streams during this study. The multiple-tube fermentation technique was used for all samples collected from wastewater-treatment plants during this study.

"It is customary to report results of the coliform test by the multiple-tube fermentation procedure as a Most Probable Number (MPN) index. This is merely an index of the number of coliform bacteria that, more probably than any other number, would give results shown by the laboratory examination. It is not an actual enumeration of coliform bacteria. By contrast direct plating methods such as the membrane filter procedure permit a direct count of coliform colonies. In both procedures coliform density is reported conventionally as the MPN or membrane filter count per 100 mL. Either procedure is a valuable tool for appraising the sanitary quality of water and the effectiveness of treatment processes" (American Public Health Association and others, 1980, p. 747).

It is customary to report bacterial counts that fall outside of specified limits as nonideal. The large variability of bacteriological concentrations from samples obtained from the Jordan River resulted in a large quantity of data being classified as nonideal. The main objective of this study was to determine the extent of sanitary contamination in the river and not to determine violations of State or other water-quality standards; nonideal data were included in the data base and used for statistical analyses. It should be noted that the concentrations and statistics derived from these data represent the best estimated values and are not exact enumerations. Bacteria concentrations in this report are reported in colonies or MPN per 100 milliliters.

State Water-Quality Standards

Although it was not an objective of this study to determine violations of State sanitary standards, the comparison of bacteriological data with State sanitary standards is useful as a relative measure of the general sanitary quality of the Jordan River and its tributaries. The entire reach of the Jordan River in the study area and part of Big Cottonwood Creek from its mouth upstream to the wastewater-treatment plant are use-classified "2B"-protected for boating, water skiing, and similar uses excluding bathing (swimming). (See State of Utah Department of Social Services, Division of Health, 1978, p. 5 and appendices A and B.) Numerical standards for "2B" bacteriological concentrations (30-day geometric mean) are a maximium of 5,000 colonies of total coliform bacteria per 100 milliliters and a maximum of 2,000 colonies of fecal coliform bacteria per 100 milliliters. Throughout this report a maximum concentration of 5,000 colonies of total coliform bacteria per 100 milliliters and a maximum concentration of 2,000 colonies of fecal coliform bacteria per 100 milliliters will be referred to as the "sanitary standards" and will be used as a measure of sanitary quality and not a violation of State water-quality standards. This measure of sanitary quality may be used to describe conditions in a particular stream reach where the State sanitary standards may or may not apply.

Previous Studies

The U.S Environmental Protection Agency (1972) conducted a study of the Jordan River during June-August 1972. The second part of that study consisted of an intensive evaluation of water quality and biological activity throughout the entire length of the Jordan River. The study indicated that total coliform bacteria densities increase in a downstream direction from Bluffdale Road about 2 miles north of Jordan Narrows. Sources of bacteria described include irrigation-return flows, wastewater-treatment-plant discharges, and storm drains.

A report prepared by Templeton, Linke, and Alsup and Engineering-Service, Inc. (1974) concluded that total coliform bacteria densities in the river exceeded the sanitary standard of 5,000 colonies per 100 milliliters from 7800 South Street downstream to the mouth of the Jordan River.

Environmental Dynamics, Inc. (1975) made an environmental evaluation of the Utah Lake-Jordan River basin for the National Commission on Water Quality. The primary objective of the evaluation was to assist the National Commission on Water Quality in the preparation of: (1) A description of the historical and present water quality and quantity conditions within the Utah Lake-Jordan River basin, (2) a projection of the future water quality and quantity for the basin, and (3) an assessment of the biological, ecological, and environmental impacts associated with attainment of goals set forth in the Federal Water Pollution Control Act Amendments of 1972.

Hydroscience, Inc. (1976) prepared a report for the Salt Lake County Council of Governments 208 study in December 1976 that describes the effects on water quality of point and nonpoint loads to the Jordan River. The report concluded that agricultural loads contribute 1,000 colonies of total coliform bacteria per 100 milliliters to the total bacteria concentrations measured in the Jordan River. wastewater-treatment plants contribute about 1,000-6,000 colonies per 100 milliliters to the total coliform concentrations in the downstream reaches of the Jordan River. The dry-weather discharge of storm drains downstream from the Surplus Canal account for about 15,000 colonies per 100 milliliters to the total coliform bacteria measured in the downstream reaches of the Jordan River.

Hydroscience, Inc. (1977a) prepared another report for the Salt Lake County Council of Governments 208 study in February 1977. In that report, projections are given for baseline conditions in 1995, east-side urbanization, improvement of irrigation efficiency, low-flow conditions, storm-water runoff, and water quality of a proposed reservoir. Those projections were made using the mathematical model, STREM2.

Hydroscience, Inc. (1977b) also prepared a report for the Salt Lake County Council of Governments 208 study in March 1977 describing water quality in Jordan River tributaries. The report concluded that at least a part of the valley segments of each of the principal tributary streams (Red Butte, Emigration, Mill, Big Cottonwood, and Little Cottonwood Creeks) contain total coliform bacteria in excess of the State water-quality standards for primary water-contact recreation and secondary water-contact recreation.

The Area-Wide Water Quality Management Plan (208) prepared by Salt Lake County Water Quality and Water Pollution Control (October 1978) provides some data on total coliform and fecal coliform bacteria concentrations in the Jordan River and includes projections of future water quality of the river.

A report prepared by the Salt Lake County Soil Conservation District (1981) describes a 4.9-mile reach of the Jordan River and its contiguous watershed between 9000 and 12300 South Streets. The report concluded that in this reach of the Jordan River total coliform bacteria concentrations were consistently greater during the irrigation season than during the pre-irrigation and post-irrigation seasons.

Hydrologic Setting

The Jordan River originates as outflow from Utah Lake and flows north approximately 55 miles before it empties into Farmington Bay adjacent to the Great Salt Lake, which has no outlet and is very saline. Two-thirds of the Jordan River basin is contained within Salt Lake County. The river enters Salt Lake County and Salt Lake Valley at the Jordan Narrows, a gap in the Traverse Mountains, 10 miles downstream from Utah Lake (fig. 1). Flow in the river is controlled by river gates or by pumping directly from Utah Lake. Altitude along the river decreases from 4,470 feet at the Jordan Narrows to about 4,200 feet at Farmington Bay. The mean gradient of the Jordan River in Salt Lake Valley is 6 feet per mile, although the gradient from the Jordan Narrows to 4200 South Street Street is 11 feet per mile, and from 4200 South Street to the river mouth the gradient is only 1.9 feet per mile. Salt Lake County includes a densely populated urban area that is bordered by mountains on three sides (fig. 1). 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 was estimated to be 641,000 as of July 1981 (Marvin Levy, Utah State Health Department, Bureau of Statistical Services, oral commun., 1982), which is about 42 percent of Utah's 1981 population. The Jordan River is the primary receiving water for the majority of this urban area, including seven municipal wastewater-treatment plants within Salt Lake County.

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

During the summer months large quantities of water are diverted from the river at or near the Jordan Narrows and channeled northward through seven major irrigation canals. The major canals east of the river terminate in smaller canals and interchange water with streams draining the Wasatch Range. Return flows to the Jordan River usually are through streams or storm conduits. Return flows from canals west of the river typically reach the Jordan River less directly through nonpoint-source runoff. The only major diversion north of 9000 South Street is the Surplus Canal at 2100 South Street, which is used principally for flood control allowing excess water to pass directly to Great Salt Lake.

Climate ranges from semiarid in parts of Salt Lake Valley to alpine in areas of the Wasatch Range. Precipitation during 1981 near the Salt Lake

International Airport was 16.59 inches, which was 1.42 inches greater than the 53-year average at this site (National Oceanic and Atmospheric Administration, 1981). Precipitation in the valley area is generally light and infrequent during the summer months. Most agricultural crops within the valley are irrigated.

SANITARY QUALITY OF THE JORDAN RIVER

Several diseases can be transmitted by water that has been contaminated by human sewage. Typhoid, cholera, hepatitis, and dysentery can be transmitted in unsanitary water. The sanitary quality of water is, therefore, important to whoever may come in contact with it. It is very difficult to isolate individual pathogens to indicate the sanitary quality of water. A better method has been developed using indicator bacteria that correlate with the number of pathogens in a water sample. Total coliform, fecal coliform, and fecal streptococci are indicator bacteria that were used in this study of the sanitary quality of the Jordan River. "Experience has established the significance of coliform group density as a criterion of the degree of pollution and thus of the sanitary quality of the sample" (American Public Health Association and others, 1980, p. 747). Fecal streptococci bacteria are useful in determining the source of fecal contamination. "In combination with fecal coliform data, data on fecal streptococci may provide more specific information about pollution sources because certain fecal streptococci are host specific" (American Public Health Association and others, 1980, p. 818).

The sanitary quality of the Jordan River is affected by numerous factors as it flows through the Salt Lake Valley. Several diversions remove water from the river for irrigation and flood control thus decreasing the river's capacity for assimilation and dilution of wastes. The river also receives inflow from seven major tributaries, seven wastewater-treatment plants, numerous storm conduits, the ground-water system, irrigation-return flow, and other sources. All of these factors contribute to the dynamic system that determines the sanitary quality of the Jordan River.

The most conspicuous aspect of the bacteriological data is its extreme variability (table 1). Because of this variability, data analysis was restricted to those sampling sites where 20 or more samples had been collected. Bacterial concentrations are compared extensively in this report by using mean concentration values. Bacterial data from the Jordan River, being extremely variable, tend to skew mean concentration values. Median bacterial concentrations are included in several tables in this report as a comparison. The median concentrations tend to be smaller than mean concentrations but both follow the same general trends.

Mean total coliform bacteria concentrations in the Jordan River increased in a downstream direction (fig. 2). Variability (as measured by the standard deviation) also increased in a downstream direction. The coefficient of variation (table 1) is the ratio of the standard deviation to the mean expressed as a percent and is a dimensionless measure of variability.

All sampling sites represented in figure 2 are plotted according to the river mile at which they are located. The numbering system for river miles

Table 1.—Summary of bacteriological data at five sampling sites on the Jordan River

[Concentrations in colonies per 100 milliliters.]

Sampling site	Jordan Narrows	9000 South Street	5800 South Street	1700 South Street	500 North Street
River mile	44.3	31.9	27.2	17.4	12
Date	10/80-8/82	8/80-10/82	7/80-7/82	7/80-9/82	8/80-8/82
			Total coliform bacteria		
Number of samples	25	35	32	43	34
Mean	7,320	9,110	19,120	32,070	48,970
Median	200	1,000	2,000	6,000	8,600
Minimum	10	30	120	410	520
Maximum	120,000	118,000	320,000	340,000	850,000
Standard deviation	24,930	22,600	58,400	72,070	145,300
Coefficient of variation	341	248	305	225	297
			Fecal coliform bacteria		
Number of samples	29	38	41	55	39
Mean	82	970	2,820	3,660	3,030
Median	48	220	300	750	1,300
Minimum	1	1	1	1	1
Maximum	500	16,000	40,000	38,000	30,000
Standard deviation	110	2,730	7,680	7,360	5,330
Coefficient of variation	130	280	272	201	176
			Fecal streptococci bacteria		
Number of samples	27	33	39	55	41
Mean	1,480	1,890	2,410	2,870	11,320
Median	760	950	500	780	1,500
Minimum	10	42	26	2	100
Maximum	8,000	13,000	53,000	43,000	130,000
Standard deviation	1,990	2,940	8,450	7,000	29,630
Coefficient of variation	134	155	350	244	262

begins at the mouth of the river and increases upstream (Ward and others, 1957). Sampling sites and their corresponding river-mile location are listed below:

Sampling site (fig. 1)	River mile
Jordan River at Jordan Narrows	44.3
Jordan River at 9000 South Street	31.9
Jordan River at 5800 South Street	27.2
Jordan River at 1700 South Street	17.4
Jordan River at 500 North Street	12.0

The mean total coliform bacteria concentration at the Jordan Narrows was 7,320 colonies per 100 milliliters with a standard deviation of 24,930 colonies per 100 milliliters. The mean concentration at 500 North Street was 48,970 colonies per 100 milliliters with a standard deviation of 145,300 colonies per 100 milliliters. The mean total coliform bacteria concentrations at all sites exceeded the sanitary standard as defined on page 9. The percent of samples in which total coliform bacteria concentrations exceeded the sanitary standard also increased in a downstream direction (fig. 3). Although the mean concentration of total coliform bacteria exceeded the sanitary standard at the Jordan Narrows, only 3 of the 25 samples had concentrations that actually exceeded the sanitary standard. The large concentrations of these three samples caused the elevated mean value. One sample had a concentration 24 times greater than the sanitary standard. Of the 34 samples collected at 500 North Street, 25 (74 percent) had concentrations that exceeded the sanitary standard. The maximum total coliform concentration at 500 North Street was 170 times greater than the sanitary standard. It is apparent that the percent of samples in which total coliform bacteria concentrations exceeded the sanitary standard not only increase in a downstream direction, but at times, total coliform bacteria concentrations in the river greatly exceeded the sanitary standard at all sites.

Fecal coliform bacteria concentrations also generally increased in a downstream direction (fig. 4) as did variability (standard deviation). Both the mean concentration and the standard deviation decreased slightly at 500 North Street. The mean fecal coliform bacteria concentration was 82 colonies per 100 milliliters at the Jordan Narrows, 970 at 9000 South Street, 2,820 at 5800 South Street, 3,660 at 1700 South Street and 3,030 at 500 North Street. Mean concentrations exceeded the sanitary standard at three of these five sites. Samples with concentrations that exceeded the sanitary standard increased downstream from none at the Jordan Narrows to 44 percent at 500 North Street (fig. 3). Maximum concentrations greatly exceeded the sanitary standard at 9000 South Street and all sampling sites downstream from 9000 South Street. At 5800 South Street, the maximum concentration was 20 times greater than the sanitary standard and at 1700 South Street the maximum concentration was 19 times greater than the sanitary standard. Fecal coliform bacteria concentrations not only increased in a downstream direction, but at times greatly exceeded the sanitary standard at all sites.

Fecal streptococci bacteria follow the same general trend shown by total and fecal coliform bacteria; concentrations increase in a downstream direction (fig. 5). Mean concentrations increased from 1,480 colonies per 100 milliliters at the Jordan Narrows to 2,870 colonies per 100 milliliters at 1700 South Street. Mean concentration increased considerably downstream from 1700 South Street to 11,320 colonies per 100 milliliters at 500 North Street. No sanitary standard exists for fecal streptococci bacteria; however, the fecal coliform-fecal streptococci ratio is useful. The normal habitat of both fecal coliform and fecal streptococci bacteria is the intestinal tract of man and other animals. The existence of these organisms in water is evidence of fecal pollution. "A ratio greater than 4.1 is considered indicative of pollution derived from domestic wastes composed of human excrement whereas ratios less than 0.7 suggest that pollution was due to nonhuman sources. Ratios between 0.7 and 4.4 usually indicate wastes of mixed human and animal sources" (American Public Health Association and others, 1980, p. 819). Contamination from animal wastes (ratio less than 0.7) decreased from 92 percent of the samples at the Jordan Narrows to about 50 percent of the samples at 5800 South, 1700 South, and 500 North Streets. The median ratio at all sampling sites was less than 0.7. Contamination from human wastes (ratio greater than 4.1) increased from none of the samples at the Jordan Narrows and 9000 South Street to 20 percent of the samples at 1700 South Street then decreased to 8 percent of the samples at 500 North Street (fig. 6).

This ratio neets to be interpreted with discretion. The survival of these organisms is limited in a "hostile" environment like a river. "Points downstream, where travel time from pollution sources exceeds 24 hr, will provide erroneous ratios. . ." (American Public Health Association and others, 1980, p. 819). Time-of-travel studies in the fall of 1981 and 1982 showed it took approximately 23 hours for water to travel from 12300 South Street to 500 North Street during low-flow conditions in the Jordan River (Doyle Stephens, U.S. Geological Survey, oral commun., 1983). "Even if used correctly, the FC:FS ratio should not be regarded as a 'magic number,' especially for samples that contain water from a mixture of nonpoint sources. For example, if most of the contamination in a sample were from nonhuman sources, a small amount of human sewage might not be sufficient to shift the overall ratio upward enough to cause concern. As a result, the presence of human pathogens in the human sewage would be masked by the indicator ratio characteristic of animal waste, and a real danger would go undetected" (Mallard, 1980, p. 4).

General Sources of 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, the origin of the Jordan River. 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 300 feet from the northeast shore of the lake. Several sources of contamination also may exist along the 10-mile reach of the Jordan River between Utah Lake and the Jordan Narrows.

Downstream from the Jordan Narrows concentrations of all three indicator bacteria increase. Major contributors to the contamination problem are the effluents from seven wastewater-treatment plants in the study area. Concentrations of indicator bacteria in the effluents of these wastewater-treatment plants is extremely variable (table 2). Mean concentrations of total and fecal coliform bacteria are plotted in figure 7. All concentrations are plotted using the approximate river mile at which the effluent is discharged into the river. Wastewater-treatment plants and the approximate river mile at which each discharges effluent into the river are listed below:

Wastewater-treatment plant (fig. 1)	River mile
Sandy	31.7
Tri-community	29.0
Murray	24.7
Cottonwood	24.0
Granger-Hunter	20.5
Salt Lake City Surburban 1	20.6
South Salt Lake	18.0

The plots shown in figure 7 and the statistics given in table 2 show the extreme variability. Total coliform bacteria concentrations ranged from 7 to 240,000 MPN per 100 milliliters. Fecal coliform bacteria concentrations ranged from 0 to 240,000 MPN per 100 milliliters. At any time any one of the seven wastewater-treatment plants may or may not be discharging fecal contamination into the river. With the highly variable degree of contamination that is possible because of the discharge of any one (or more) of the wastewater-treatment plants it is not possible to predict the sanitary quality of the river at any time.

The three major tributaries that are not diverted into conduits (Big Cottonwood, Little Cottonwood, and Mill Creeks) were sampled for indicator bacteria near their confluences with the Jordan River (table 3). Mean total coliform bacteria concentrations in these tributaries were all significantly smaller than the mean total coliform bacteria concentration in the Jordan River near the confluence. Nevertheless those tributaries do contribute to the total bacteria in the Jordan River.

Total coliform bacteria concentrations exceeded the sanitary standard in 2 of 11 samples from Little Cottonwood Creek and 3 of 11 samples from Big Cottonwood Creek. Big Cottonwood Creek had the largest mean total coliform bacteria concentration of 8,940 colonies per 100 milliliters and also the maximum concentration of 30,000 colonies per 100 milliliters which was six times greater than the sanitary standard. None of the samples from Mill Creek exceeded the sanitary standard.

Table 2.—Summary of bacteriological data for effluent from seven wastewater-treatment plants

[Concentrations in MPN per 100 milliliters]

Wastewater-treatment plant	Sandy	Tri-Community	Murray	Cottonwood	Granger-Hunter	Salt Lake City Suburban No. 1	South Salt Lake
River Mile	**31.7**	**29.0**	**24.7**	**24.0**	**20.6**	**20.5**	**18.0**
Date	**9/80-9/82**	**9/80-10/82**	**9/80-10/82**	**9/80-10/82**	**9/80-10/82**	**9/80-10/82**	**9/80-10/82**
				Total coliform bacteria			
Number of samples	16	19	18	19	19	19	17
Mean	31,040	125,500	5,790	104,430	71,010	64,390	6,230
Median	460	110,000	2,400	24,000	1,100	46,000	4,600
Minimum	23	2,400	93	23	7	750	43
Maximum	240,000	240,000	46,000	240,000	240,000	240,000	24,000
Standard deviation	81,610	114,080	11,360	118,900	106,700	73,790	8,690
Coefficient of variation	263	91	196	114	150	115	139
				Fecal coliform bacteria			
Number of samples	14	19	17	19	18	19	17
Mean	200	16,300	37	62,850	22,310	3,310	2,230
Median	23	1,100	23	240	90	240	240
Minimum	0	23	0	4	0	23	0
Maximum	1,100	240,000	240	240,000	240,000	46,000	24,000
Standard deviation	400	54,380	60	99,900	57,030	10,630	6,190
Coefficient of variation	207	334	161	159	256	321	278

Table 3.--Summary of bacteriological data for three tributary streams

[Concentrations in colonies per 100 milliliters.]

Tributary	Little Cottonwood Creek	Big Cottonwood Creek	Mill Creek
River mile at confluence with Jordan River	25.2	24.0	20.3
Date	6/80-9/82	6/80-9/82	6/80-9/82
	Total coliform bacteria		
Number of samples	11	11	11
Mean	2,490	8,940	2,030
Median	1,900	4,000	1,700
Minimum	100	500	200
Maximum	7,500	30,000	4,600
Standard deviation	2,450	11,270	1,650
Coefficient of variation	98	126	81
	Fecal coliform bacteria		
Number of samples	8	8	6
Mean	660	2,670	700
Median	600	3,000	600
Minimum	100	100	80
Maximum	1,560	10,500	2,500
Standard deviation	430	3,410	920
Coefficient of variation	65	128	131
	Fecal streptococci bacteria		
Number of samples	7	7	7
Mean	620	850	820
Median	620	600	430
Minimum	100	100	20
Maximum	1,000	1,750	3,000
Standard deviation	320	580	1,090
Coefficient of variation	52	68	133

The mean fecal coliform bacteria concentration from Big Cottonwood Creek was slightly smaller than the mean concentration in the Jordan River near their confluence, and the mean fecal coliform bacteria concentrations from Little Cottonwood Creek and Mill Creek were significantly smaller than the mean concentration in the Jordan River. Fecal coliform bacteria concentrations exceeded tne sanitary standard in none of the samples from Little Cottonwood Creek, one of six samples from Mill Creek and four of eight samples from Big Cottonwood Creek. The maximum concentration measured at Big Cottonwood Creek was about five times greater than the sanitary standard.

Mean fecal streptococci bacteria concentrations were significantly smaller in Big Cottonwood, Little Cottonwood, and Mill Creeks than the mean concentration in the Jordan River near their confluence. Values of the fecal coliform-fecal streptococci bacteria ratio were generally between 0.7 and 4.4 indicating a mixed contamination source. One ratio was greater than 4.4 in samples from Mill and Big Cottonwood Creeks and one ratio was less than 0.7 in samples from Little Cottonwood and Mill Creeks.

A study conducted during 1979-80 by the Salt Lake County Soil Conservation District (1981) found significantly larger total coliform and fecal coliform bacteria concentrations during the irrigation season. This indicates that irrigation-return flow may contribute some fecal material and probably large numbers of bacteria of nonfecal origin. The study also found that livestock contributed large quantities of fecal material to a tributary in the study area.

Diel Study

Intensive sampling at four sites on the Jordan River (5800 South, 1700 South, 700 South, and 500 North Streets) was conducted July 28-29, 1981 to determine if diel (24-hour) fluctuations or trends could be detected. No diel fluctuations at any of the four sites were found. Bacteria concentrations at individual sites appeared randomly distributed throughout the period except at 5800 South Street. A definite decreasing trend was evident at 5800 South Street although only three samples were collected. Total coliform bacteria concentrations decreased from 47,000, to 13,000, to 3,300 colonies per 100 milliliters indicating that a slug of contaminated water had passed the site. Fecal streptococci bacteria also decreased at this site with concentrations decreasing from 4,500, to 1,400, to 860 colonies per 100 milliliters.

Mean total coliform bacteria concentrations decreased in a downstream direction during the diel study. Normally, concentrations increased as the river flowed downstream. This decrease probably was due to the slug of contaminated water that passed 5800 South Street being diluted as it progressed downstream.

At all sites collectively, 11 of the 30 samples exceeded the sanitary standard for total coliform bacteria and 3 of the 30 samples exceeded the sanitary standard for fecal coliform bacteria. The predominant source of contamination, as indicated by the fecal coliform-fecal streptococci bacteria ratio, was animal waste with 21 of the 30 samples having a ratio less than 0.7. Human waste was indicated in 4 of the 30 samples.

Long-Term Trends

Long-term bacteriological data are available at two sites in the study area. Data have been collected since February 1974 at 5800 South Street and since January 1974 at 1700 South Street.

Regression analysis was used to determine if bacteria concentrations have been increasing or decreasing with time. The mean total coliform bacteria concentration at 5800 South Street was 11,380 colonies per 100 milliliters for data from all 9 years of data collection and 19,120 colonies per 100 milliliters for data collected only during this investigation; however, no correlation was found between total coliform bacteria concentration and time (correlation coefficient r = 0.06). A "T" test (one tailed, 95-percent confidence level) confirmed that there is no statistical difference between the two means. The difference probably is caused by the large variability of the data. The median concentration was 2,000 colonies per 100 milliliters for both time periods. A plot of all total coliform bacteria data collected at 5800 South Street versus time is shown in figure 8. A line representing the sanitary standard for total coliform bacteria also is shown to indicate the number of samples with concentrations more or less than this sanitary standard. The maximum total coliform bacteria concentration recorded during the 9 years of data collection at 5800 South Street was 320,000 colonies per 100 milliliters, which is 64 times greater than the sanitary standard (table 4). This sample was collected June 6, 1981. Total coliform bacteria data at 1700 South Street was discontinuous and could not be used in regression analysis. The mean total coliform bacteria concentration at 1700 South Street was 28,730 colonies per 100 milliliters, almost six times the sanitary standard. However, the majority of total coliform bacteria data at 1700 South Street was collected during this investigation and only is representative of recent conditions.

No correlation was found between fecal coliform bacteria concentrations and time at 5800 South Street (correlation coefficient r = 0.03). The mean fecal coliform bacteria concentration for 9 years of data at this site was 2,290 colonies per 100 milliliters, which is only slightly less than the mean of 2,820 colonies per 100 milliliters obtained from data collected during this investigation. The maximum fecal coliform bacteria concentration recorded during the 9 years of data collection at 5800 South Street was 62,000 colonies per 100 milliliters, which is 31 times greater than the sanitary standard. This sample was collected February 1, 1977. A plot of all fecal coliform bacteria data collected at 5800 South Street versus time is shown in figure 9. A line representing the sanitary standard for fecal coliform bacteria is shown to indicate the number of samples with concentrations more or less than the sanitary standard.

A significant positive correlation (95-percent confidence level using the F statistic) was found between fecal coliform bacteria concentrations and time at 1700 South Street (correlation coefficient r = 0.50). Fecal coliform bacteria concentrations have been increasing at 1700 South Street since 1974 as shown by the least squares regression line plotted in figure 10. A "T" test (one tailed, 95-percent confidence level) confirmed that the mean

Table 4.--Summary of bacteriological data at two long-term sampling sites

[Concentrations in colonies per 100 milliliters.]

Sampling site	Jordan River at 5800 South Street		Jordan River at 1700 South Street	
River mile	27.2		17.4	
Date	2/74-8/82	7/80-8/82	1/74-9/82	7/80-8/82
	Total coliform bacteria			
Number of samples	162	32	50	43
Mean	11,380	19,120	28,730	32,070
Median	2,000	2,000	6,000	6,000
Minimum	1	120	68	410
Maximum	320,000	320,000	340,000	340,000
Standard deviation	31,520	58,400	67,310	72,070
Coefficient of variation	277	305	234	225
	Fecal coliform bacteria			
Number of samples	174	41	120	55
Mean	2,290	2,820	2,300	3,660
Median	150	330	300	750
Minimum	1	1	1	1
Maximum	62,000	40,000	38,000	38,000
Standard deviation	7,970	7,690	6,120	7,360
Coefficient of variation	347	272	266	201
	Fecal streptococci bacteria			
Number of samples	53	39	122	55
Mean	1,850	2,410	1,610	2,870
Median	340	580	340	780
Minimum	24	26	1	2
Maximum	53,000	53,000	43,000	43,000
Standard deviation	7,290	8,450	4,980	7,000
Coefficient of variation	395	350	310	244

concentration increased. The mean fecal coliform bacteria concentration at 1700 South Street for all 9 years of data collection was 2,300 colonies per 100 milliliters. The mean concentration during this investigation had increased to 3,660 colonies per 100 milliliters. A plot of all fecal coliform bacteria data at 1700 South Street versus time is shown in figure 10. The fecal coliform sanitary standard is plotted as a reference. According to the data in figure 10, the mean fecal coliform bacteria concentration has almost increased to the sanitary standard at 1700 South Street.

Fecal streptococci bacteria data at 5800 South Street were discontinuous and could not be used in regression analysis. The mean fecal streptococci bacteria concentration for 9 years of data collection at 5800 South Street was 1,850 colonies per 100 milliliters. The mean concentration for samples collected during this investigation was 2,410 colonies per 100 milliliters.

A significant positive correlation (95-percent confidence level using the F statistic) was found between fecal streptococci bacteria versus time at 1700 South Street (correlation coefficient r = 0.59). Fecal streptococci bacteria concentrations have been increasing at 1700 South Street since 1974 as shown by the least-squares regression line plotted in figure 11. A "T" test (one tailed, 95-percent confidence level) confirmed that the mean concentration increased. The mean fecal streptococci bacteria concentration at 1700 South Street for 9 years of data collection was 1,610 colonies per 100 milliliters. The mean concentration during this investigation increased to 2,870 colonies per 100 milliliters.

Storm Runoff from Urban Areas

The Jordan River flows through part of the most densely populated area of Utah and receives the majority of runoff from this urban area. The sanitary quality of runoff from a densely populated urban area can have a detrimental effect on the receiving waters. The sanitary quality of storm runoff was sampled at five storm drains and two tributaries immediately upstream from their confluence with the Jordan River (table 5). The Jordan River also was sampled during the storm runoff (table 6).

The mean total coliform bacteria concentration in Little Cottonwood Creek from storm samples was not significantly different from the mean concentration from nonstorm samples. However, mean total coliform, fecal coliform, and fecal streptococci bacteria concentrations from Mill Creek all were significantly larger in storm samples than they were in nonstorm samples. The mean fecal streptococci bacteria concentration from storm samples in Mill Creek of 8,450 colonies per 100 milliliters was 10 times larger than the mean nonstorm concentration.

Storm drains contributed large concentrations of bacteria during rainstorm runoff. The Decker Lake drain, however, was an exception. Storm runoff from Decker Lake may be retained for sufficient time to decrease bacteria concentrations. Mean total coliform bacteria concentrations in the other storm drains were large ranging from 59,750 to 159,000 colonies per 100 milliliters. The maximum total coliform bacteria concentration measured of 780,000 colonies per 100 milliters was from the 9000 South Street storm drain.

Table 5.–Summary of bacteriological data for storm samples from two tributaries and five storm drains

[Concentrations in colonies per 100 milliliters.]

Source	9000 South Street storm drain	Little Cottonwood Creek at mouth	Mill Creek near mouth	Decker Lake drain	1300 South Street storm drain	800 South Street storm drain	North Temple Street storm drain
River mile	**31.8**	**25.2**	**20.3**	**19.8**	**16.4**	**15.1**	**13.2**
Date	**8/80-9/81**	**8/80-9/81**	**8/80-9/81**	**8/80-5/81**	**8/80-5/81**	**8/80-5/81**	**8/80-9/81**
			Total coliform bacteria				
Number of samples	6	8	8	5	4	1	3
Mean	159,000	2,670	4,620	1,230	59,750	150,000	79,700
Median	78,000	2,400	5,200	600	27,000	–	80,000
Minimum	820	10	460	60	22,000	–	9,000
Maximum	780,000	8,000	8,000	3,100	100,000	–	150,000
Standard deviation	306,400	3,450	3,480	1,280	41,000	–	70,500
Coefficient of variation	193	129	75	104	68	–	88
			Fecal coliform bacteria				
Number of samples	8	11	12	9	16	19	13
Mean	23,200	1,300	1,710	730	3,240	4,200	9,330
Median	12,000	270	440	400	1,600	1,000	4,100
Minimum	280	154	1	1	1	1	1
Maximum	141,000	7,400	7,000	4,000	21,000	21,000	46,000
Standard deviation	48,080	2,200	2,150	1,280	5,210	6,590	14,410
Coefficient of variation	207	169	126	176	161	157	154
			Fecal streptococci bacteria				
Number of samples	8	10	11	9	17	19	13
Mean	29,760	11,880	8,450	1,280	32,100	13,770	32,990
Median	15,000	7,000	3,400	100	15,000	6,900	17,000
Minimum	1,500	10	20	1	300	1	500
Maximum	88,000	74,000	41,000	8,400	216,000	120,000	100,000
Standard deviation	30,890	22,180	12,370	2,740	53,700	29,340	38,800
Coefficient of variation	104	187	146	214	167	213	118

Table 6.—Summary of bacteriological data for storm samples from the Jordan River at five sampling sites

[Concentrations in colonies per 100 milliliters.]

Sampling site	Jordan Narrows	9000 South Street	5800 South Street	1700 South Street	500 North Street
River mile	44.3	31.9	27.2	17.4	12
Date	10/80-9/81	8/80-9/81	8/80-5/81	8/80-5/81	8/80-5/81
Total coliform bacteria					
Number of samples	8	5	5	6	6
Mean	2,090	8,210	7,100	40,120	36,590
Median	380	7,000	2,800	6,000	20,000
Minimum	10	30	420	2,400	520
Maximum	12,900	20,000	25,000	200,000	110,000
Standard deviation	4,410	8,070	10,120	78,700	41,830
Coefficient of variation	211	98	142	196	114
Fecal coliform bacteria					
Number of samples	9	7	7	9	9
Mean	140	1,140	3,080	8,670	3,920
Median	75	820	570	3,500	2,600
Minimum	1	1	1	110	1
Maximum	500	3,000	16,000	38,000	12,000
Standard deviation	170	1,180	5,790	13,500	4,150
Coefficient of variation	120	104	188	156	106
Fecal streptococci bacteria					
Number of samples	8	7	6	9	12
Mean	1,120	4,010	9,980	5,040	25,550
Median	730	2,000	1,200	2,000	6,500
Minimum	10	50	200	300	100
Maximum	4,700	13,000	53,000	24,000	130,000
Standard deviation	1,540	4,550	21,100	7,730	44,860
Coefficient of variation	137	113	212	153	176

Mallard (1980, p. 5) reported that most total coliform bacteria in storm water are native soil organisms that are washed off soil particles by water running over the land surface. Mean total coliform, fecal coliform, and fecal streptococci bacteria concentrations at all of the storm drains sampled are shown in figure 12. The river mile that corresponds to each storm drain is shown below:

Storm drain (fig. 1)	River mile
9000 South Street	31.8
Decker Lake	19.8
1300 South Street	16.4
800 South Street	15.1
North Temple Street	13.2

Mean fecal coliform bacteria concentrations also were large ranging from 3,240 colonies per 100 milliliters at the 1300 South Street storm drain to 23,200 colonies per 100 milliliters at the 9000 South Street storm drain. The maximum fecal coliform bacteria concentration of 141,000 colonies per 100 milliliters was from the 9000 South Street storm drain.

Large concentrations of fecal streptococci bacteria were measured in all the storm drains except the Decker Lake drain. Mean fecal streptococci bacteria concentrations ranged from 13,770 colonies per 100 milliliters at the 800 South Street storm drain to 32,990 colonies per 100 milliliters at the North Temple Street storm drain. The maximum fecal streptococci bacteria concentration of 216,000 colonies per 100 milliliters was from the 1300 South Street storm drain.

Although travel time from contamination sources was not determined for storm samples the fecal coliform-fecal streptococci bacteria ratio may be useful if used with discretion. The median fecal coliform-fecal streptococci bacteria ratios at the storm drains and in storm samples from tributary streams were all less than 0.70 except at the Decker Lake drain, which had a median ratio of 0.72. In addition 72 percent or 93 of the 130 samples of storm runoff from urban areas had a ratio less than 0.70. This indicates nonhuman fecal waste is the major type of fecal contamination in storm runoff from urban areas. The fecal material of dogs, cats, and other animals is most likely responsible for this contamination. Fecal contamination from human wastes was indicated in 11 percent or 14 of the 130 samples of storm runoff from urban areas.

Because the Jordan River is the receiving waters for the majority of the storm runoff from urban areas, indicator bacteria were measured at the five sampling sites on the Jordan River during storm runoff (table 6). Mean total coliform bacteria concentrations ranged from 2,090 to 40,120 colonies per 100 milliliters. Mean total coliform bacteria concentrations increased rapidly between 5800 South and 1700 South Streets (fig. 13). The maximum total coliform bacteria concentration measured during storm runoff of 200,000 colonies per 100 milliliters (table 6) was at 1700 South Street. This concentration was 40 times greater than the sanitary standard.

Mean fecal coliform bacteria concentrations from the Jordan River ranged from 140 colonies per 100 milliliters at the Jordan Narrows to 8,670 colonies per 100 milliliters at 1700 South Street. The maximum fecal coliform bacteria concentration measured of 38,000 colonies per 100 milliliters was at 1700 South Street. Mean fecal coliform bacteria concentrations in the Jordan River increased in a downstream direction to 1700 South Street then decreased at 500 North Street (fig. 13).

Mean fecal streptococci bacteria concentrations in the Jordan River ranged from 1,120 colonies per 100 milliliters at the Jordan Narrows to 25,550 at 500 North Street. Mean fecal streptococci bacteria concentrations increased rapidly between 1700 South and 500 North Streets (fig. 13). The maximum fecal streptococci bacteria concentration measured in the Jordan River during storm runoff of 130,000 colonies per 100 milliliters was at 500 North Street.

SUMMARY AND CONCLUSIONS

Data collected from July 1980 through October 1982 showed a serious sanitary problem in the Jordan River. Concentrations of total coliform bacteria commonly exceeded 5,000 colonies per 100 milliliters and concentrations of fecal coliform bacteria commonly exceeded 2,000 colonies per 100 milliliters in the downstream reaches of the river. At times these concentrations were greatly exceeded. The most conspicuous aspect of the bacteriological data is its extreme variability. Seven wastewater-treatment plants, seven major tributaries, numerous storm drains, irrigation-return flow, and other sources all contribute to the dynamic system that determines the sanitary quality of the Jordan River. Because of this variability, the sanitary quality of the river cannot be predicted at any one time.

In general, concentrations of all three indicator bacteria in the Jordan River increased in a downstream direction. The predominant type of fecal contamination in the river as indicated by the fecal coliform-fecal streptococci bacteria ratio is animal waste. Contamination from animal waste was indicated in 92 percent of the samples from the Jordan Narrows and decreased to about 50 percent of the samples at 5800 South, 1700 South, and 500 North Streets. Contamination from human waste as indicated by the fecal coliform-fecal streptococci bacteria ratio was indicated in none of the samples at the Jordan Narrows and at 9000 South Street but increased to about 20 percent of the samples at 1700 South Street. Human sewage in many of the samples may be camouflaged by large concentrations of fecal streptococci bacteria.

Wastewater-treatment plants, at times, contribute significant concentrations of indicator bacteria to the Jordan River. Bacteria concentrations in effluent from the wastewater-treatment plants are extremely variable. The variable bacteria concentrations in the plant effluents is at least partly responsible for the highly variable concentrations of bacteria measured in the Jordan River.

Mean total coliform bacteria concentrations from three major tributaries (Big Cottonwood, Little Cottonwood, and Mill Creeks) were all significantly smaller than the mean concentration in the Jordan River near their confluence. The mean fecal coliform bacteria concentrations from both Little Cottonwood and Mill Creeks also were significantly smaller than that of the Jordan River near their confluence, and the mean fecal coliform bacteria concentration from Big Cottonwood Creek was slightly smaller than that of the Jordan River. In addition, fecal coliform bacteria in 50 percent of the samples from Big Cottonwood Creek exceeded 2,000 colonies per 100 milliliters.

Mean fecal streptococci bacteria concentrations were significantly smaller in Big Cottonwood, Little Cottonwood, and Mill Creeks than the mean fecal streptococci bacteria concentration in the Jordan River near their confluence. Values of the fecal coliform-fecal streptococci bacteria ratio from the majority of samples from Big Cottonwood and Mill Creeks indicated a mixed contamination source.

A diel study (24-hour sampling) on the Jordan River during July 28-29, 1981 failed to show any diel fluctuations in bacteria; however, an apparent slug of contaminated water was detected as it progressed downstream during the study.

Regression analysis of 9 years of data collected at 1700 South Street showed a significant positive correlation between both fecal coliform and fecal streptococci bacteria concentrations versus time. Concentrations of fecal coliform and fecal streptococci bacteria have both been increasing in the river at 1700 South Street since 1974.

Storm drains in the urban area of Salt Lake County contributed large concentrations of bacteria during storm runoff. The only exception was storm water from Decker Lake. Bacteria concentrations in samples from the Decker Lake storm drain were considerably smaller than concentrations in the other storm drains. Storm runoff may have been retained in Decker Lake for sufficient time to decrease bacteria concentrations. Mean total coliform bacteria concentrations in storm drains (excluding Decker Lake) ranged from 59,750 to 159,000 colonies per 100 milliliters, and mean fecal coliform bacteria concentrations ranged from 3,240 to 23,200 colonies per 100 milliliters. Mean fecal streptococci bacteria concentrations from storm drains (excluding Decker Lake) ranged from 13,770 to 32,990 colonies per 100 milliliters.

Mean total coliform, fecal coliform, and fecal streptococci bacteria concentrations from Mill Creek were all significantly larger in storm samples than in nonstorm samples. The mean fecal streptococci bacteria concentration from storm samples in Mill Creek was 10 times larger than the mean concentration from nonstorm samples. The mean total coliform bacteria concentration in Little Cottonwood Creek from storm samples was not significantly different from nonstorm samples.

Fecal contamination from animal waste as indicated by the fecal coliform-fecal streptococci bacteria ratio was shown in 72 percent of the samples from storm runoff. Fecal contamination from human waste was indicated in 11 percent of the samples from storm runoff.

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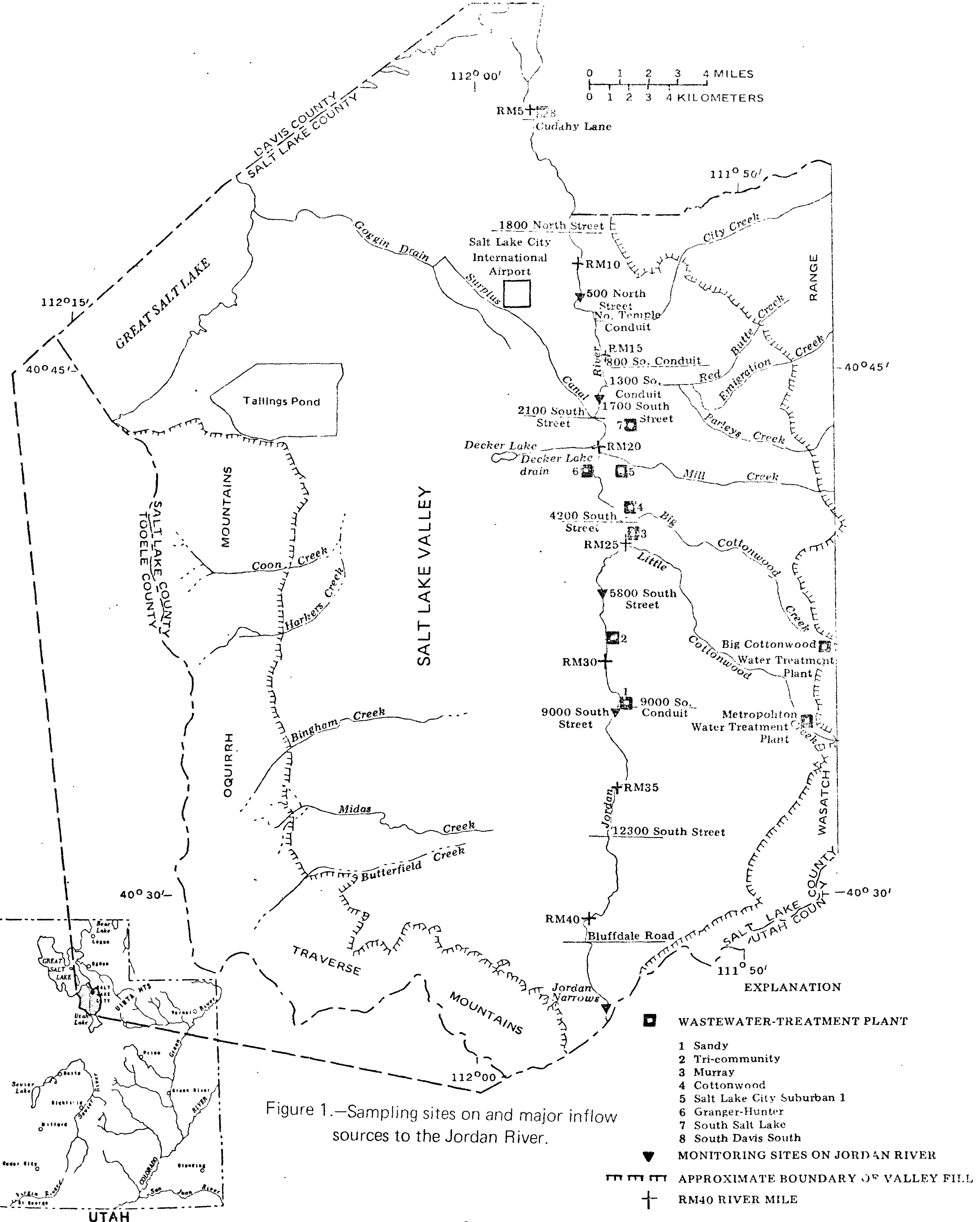

Figure 1.—Sampling sites on and major inflow sources to the Jordan River.

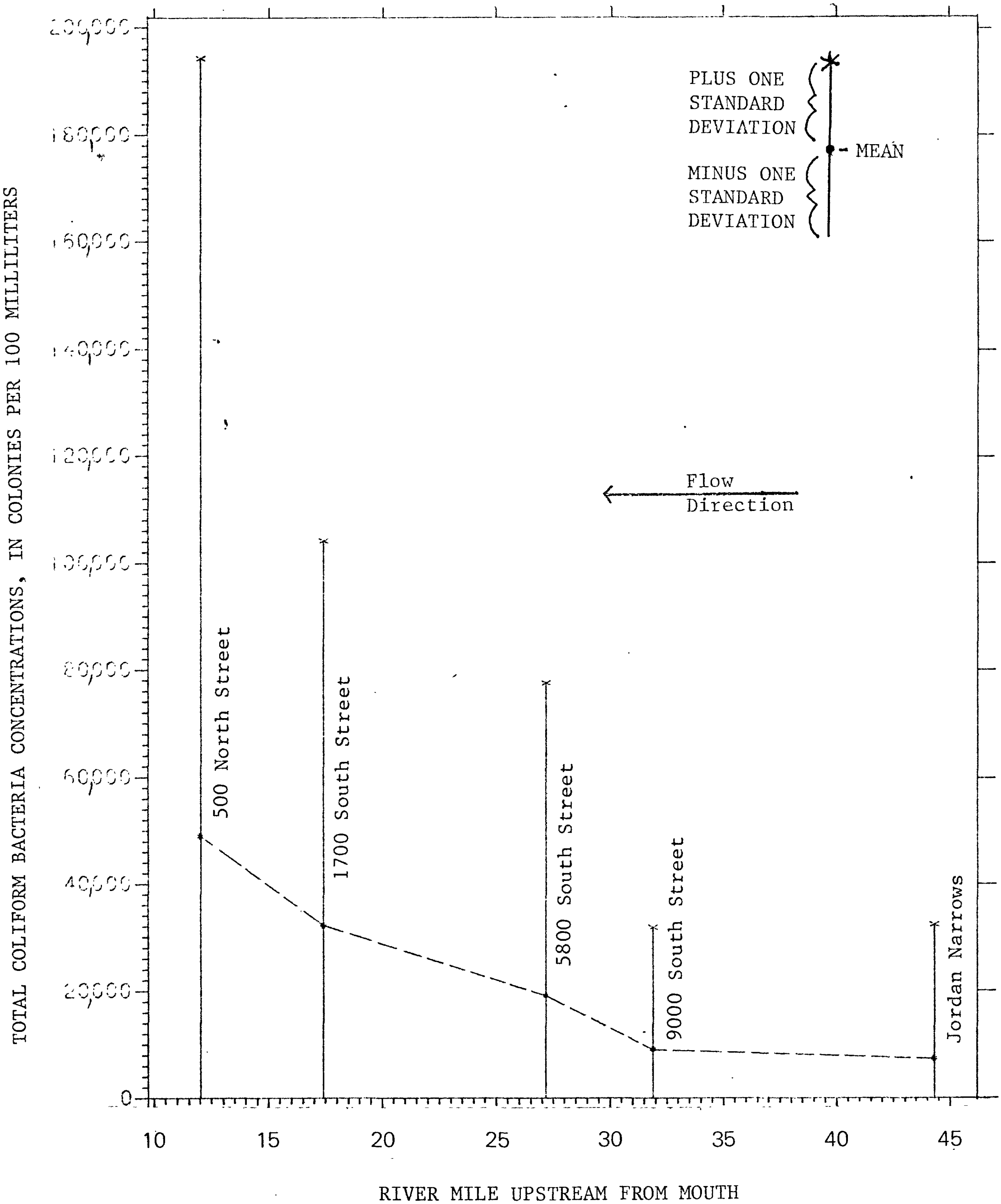

Figure 2.- Mean concentrations and one standard deviation for total coliform bacteria at five sampling sites on the Jordan River.

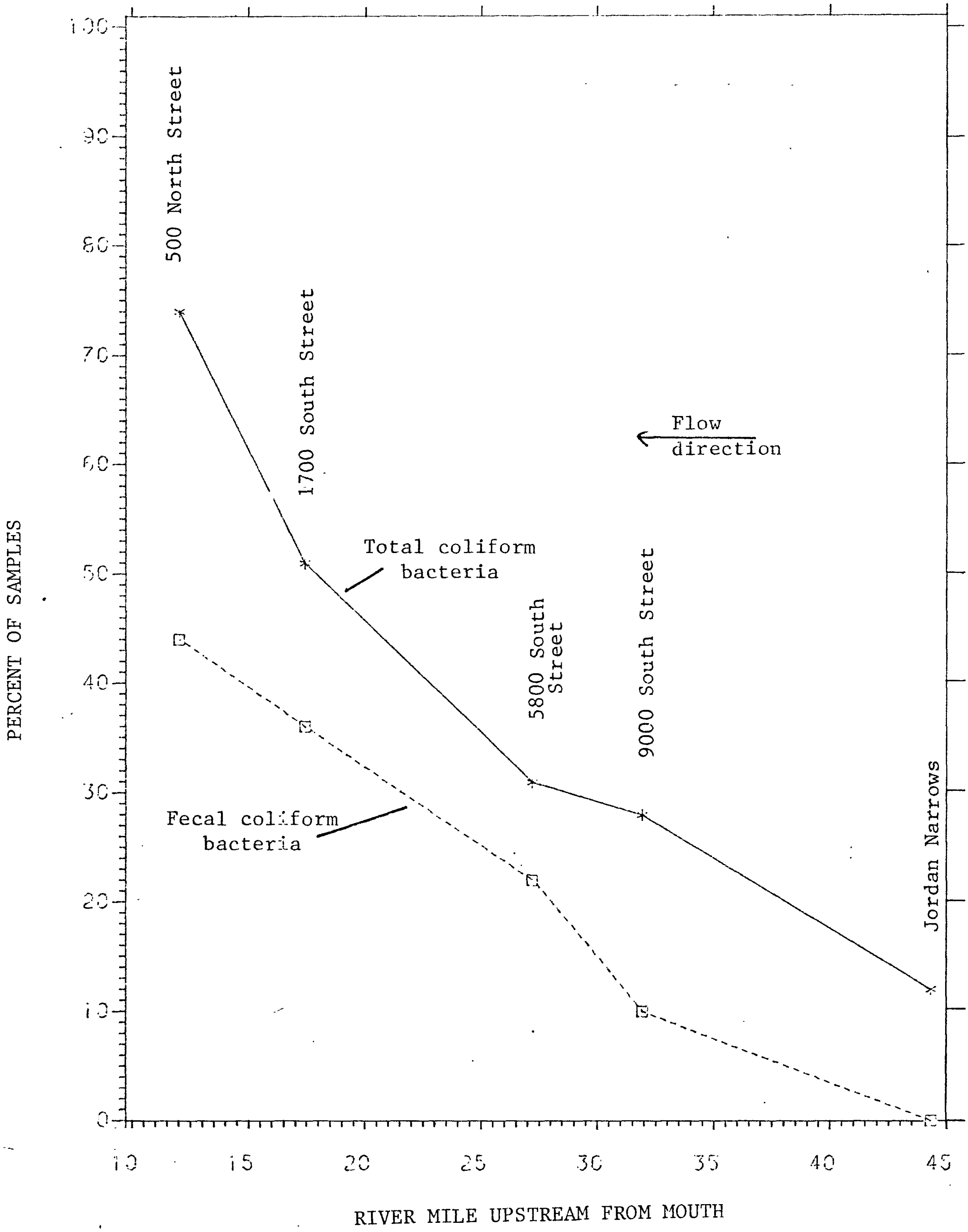

Figure 3.- Percent of samples in which total and fecal coliform bacteria concentrations were greater than the sanitary standards at five sampling sites on the Jordan River.

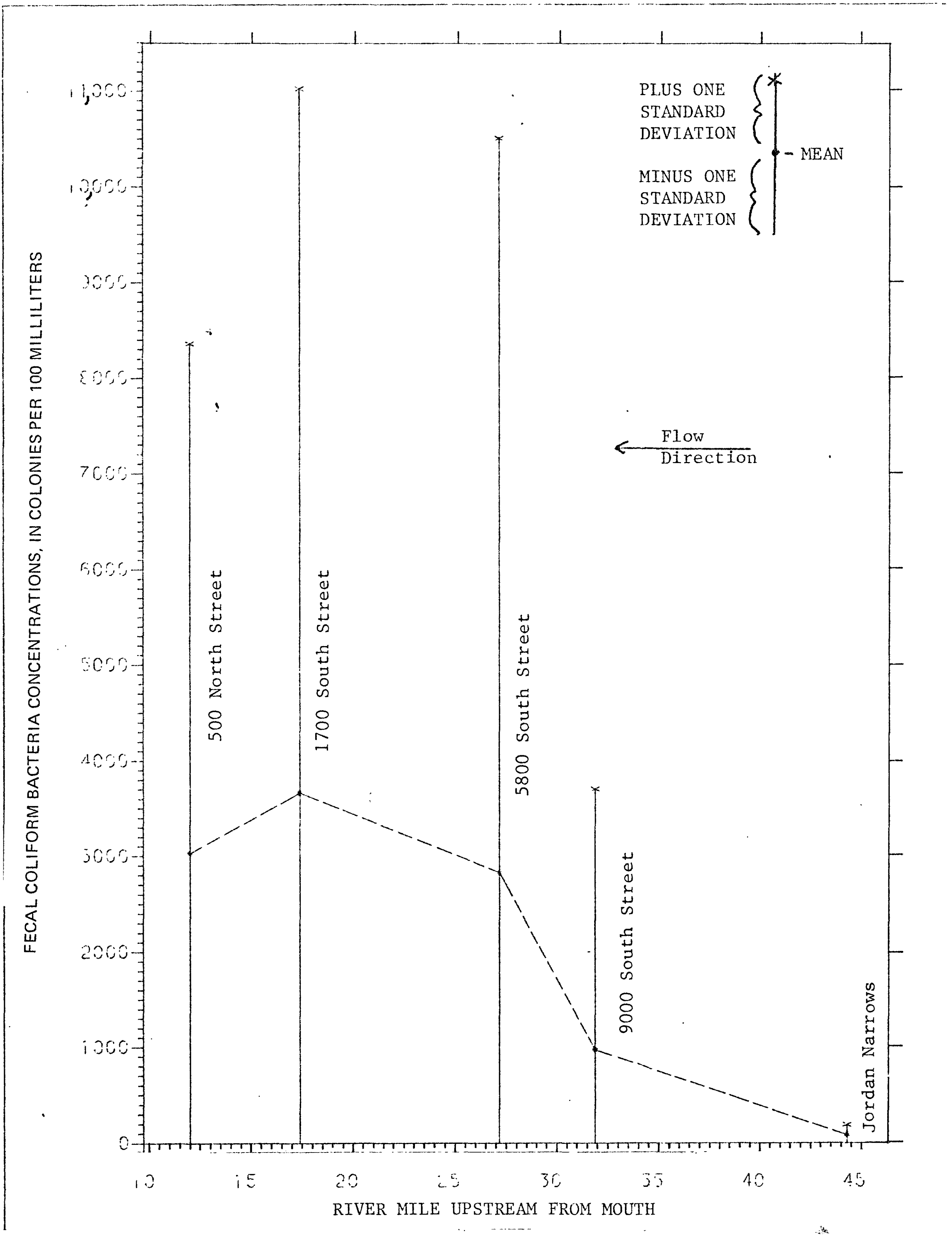

Figure 4.- Mean concentration and one standard deviation for fecal coliform bacteria at five sampling sites on the Jordan River.

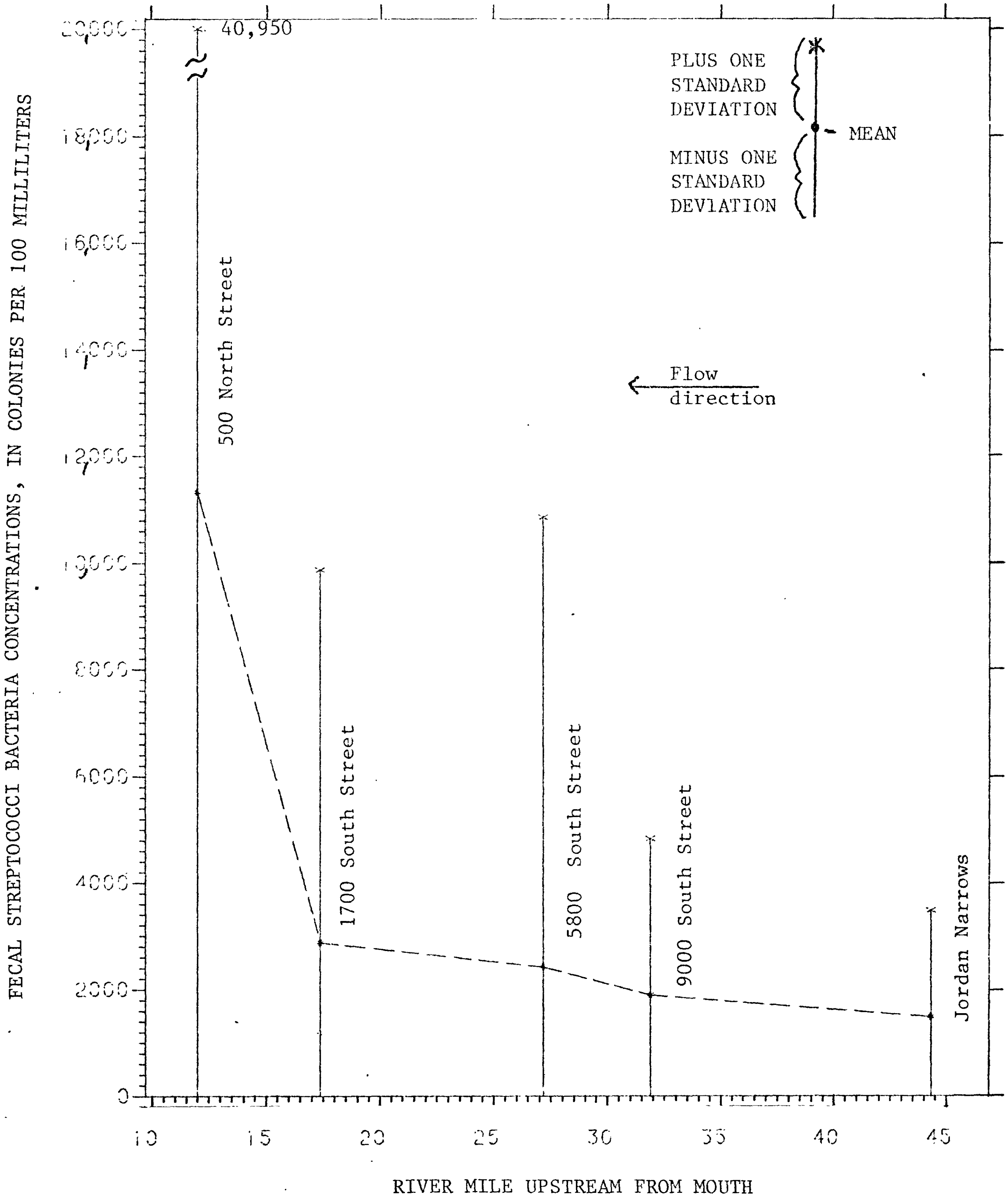

Figure 5.- Mean concentration and one standard deviation for fecal streptococci bacteria at five sampling sites on the Jordan River.

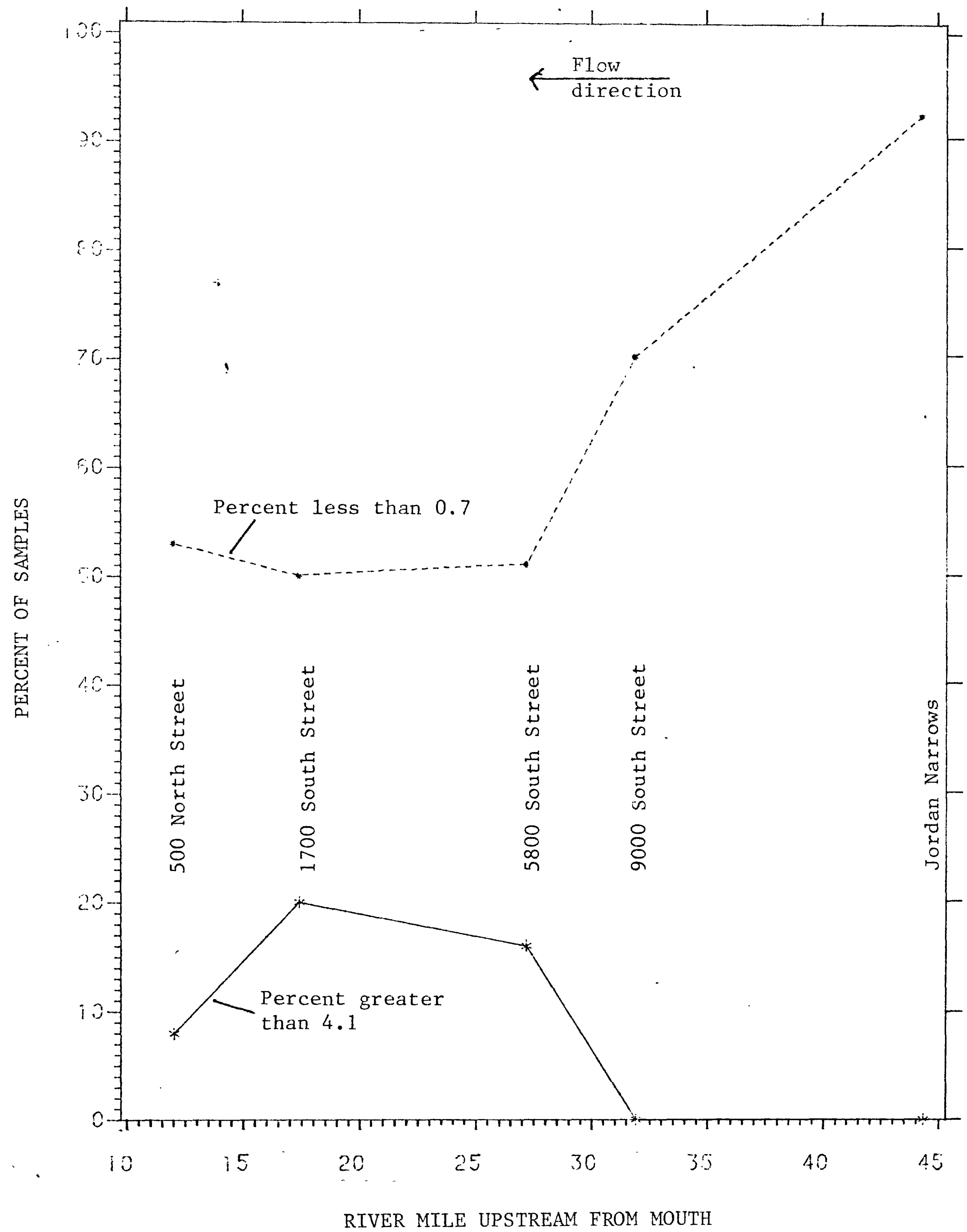

Figure 6.- Percent of samples where ratio between fecal coliform and fecal streptococci bacteria was greater than 4.1 and less than 0.7.

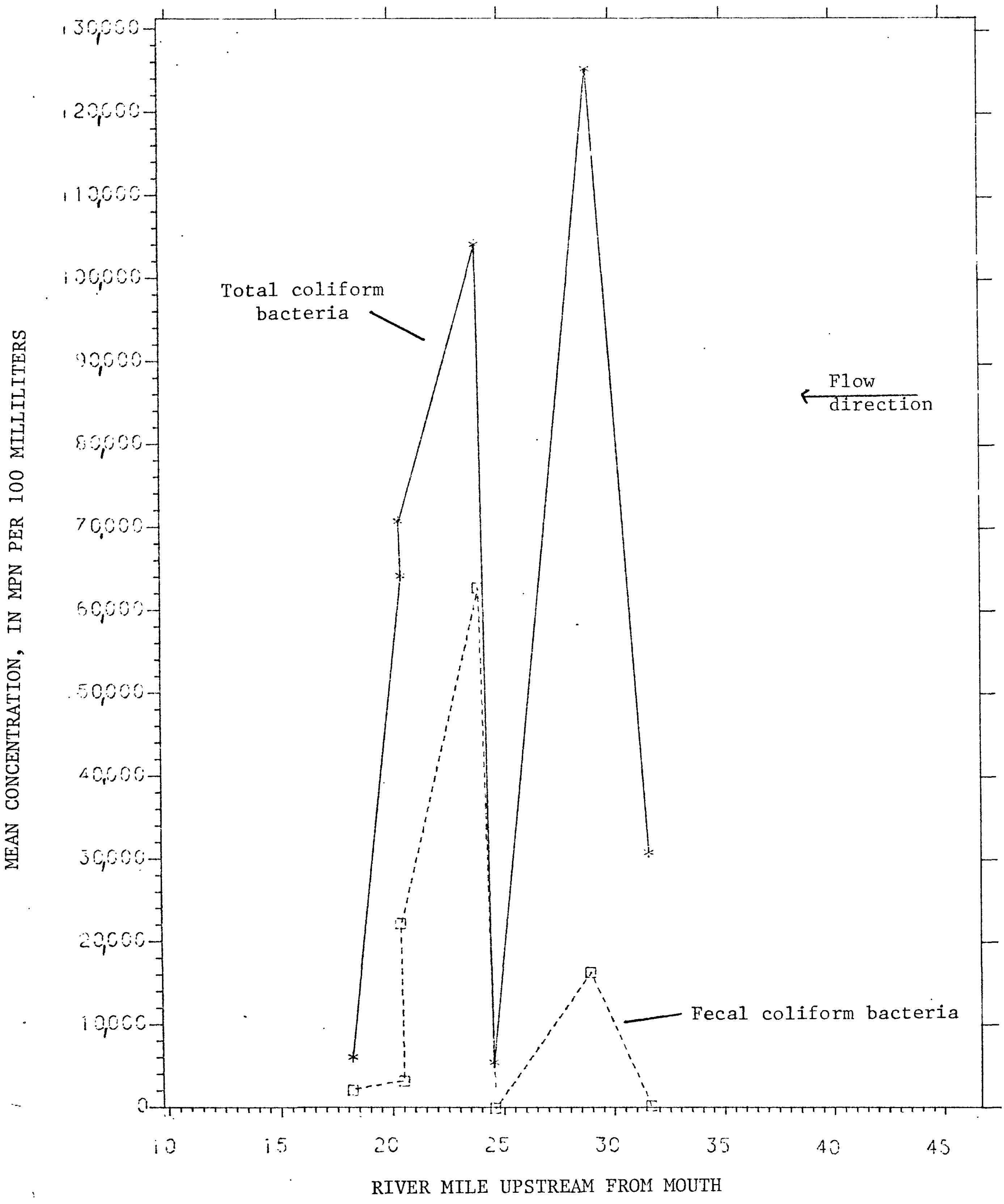

Figure 7.—Mean total coliform and fecal coliform bacteria concentrations in effluent from wastewater-treatment plants discharging to the Jordan River.

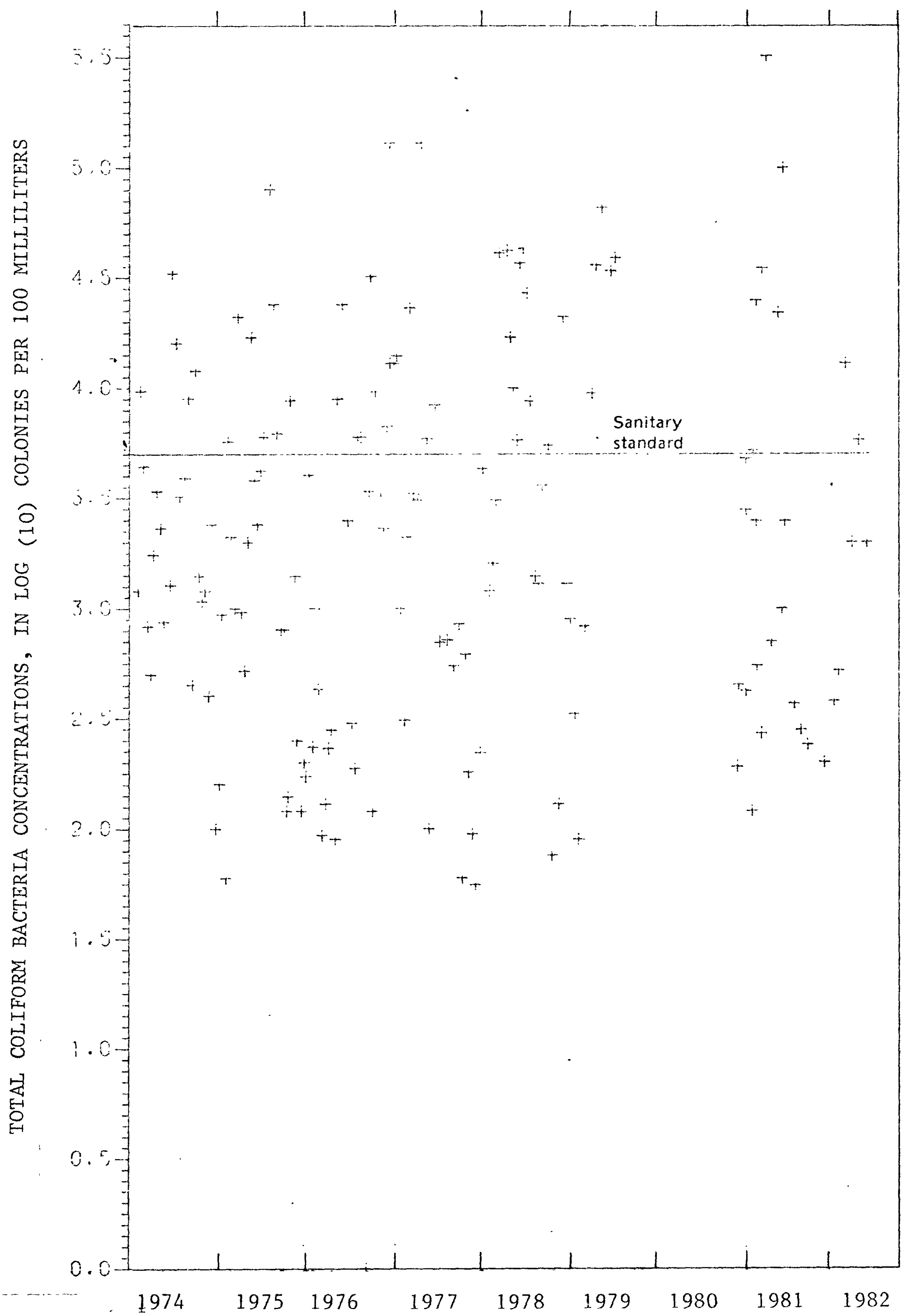

Figure 8.- Total coliform bacteria distribution compared to the sanitary standard (as $\log_{10}$ 5,000) at 5800 South Street.

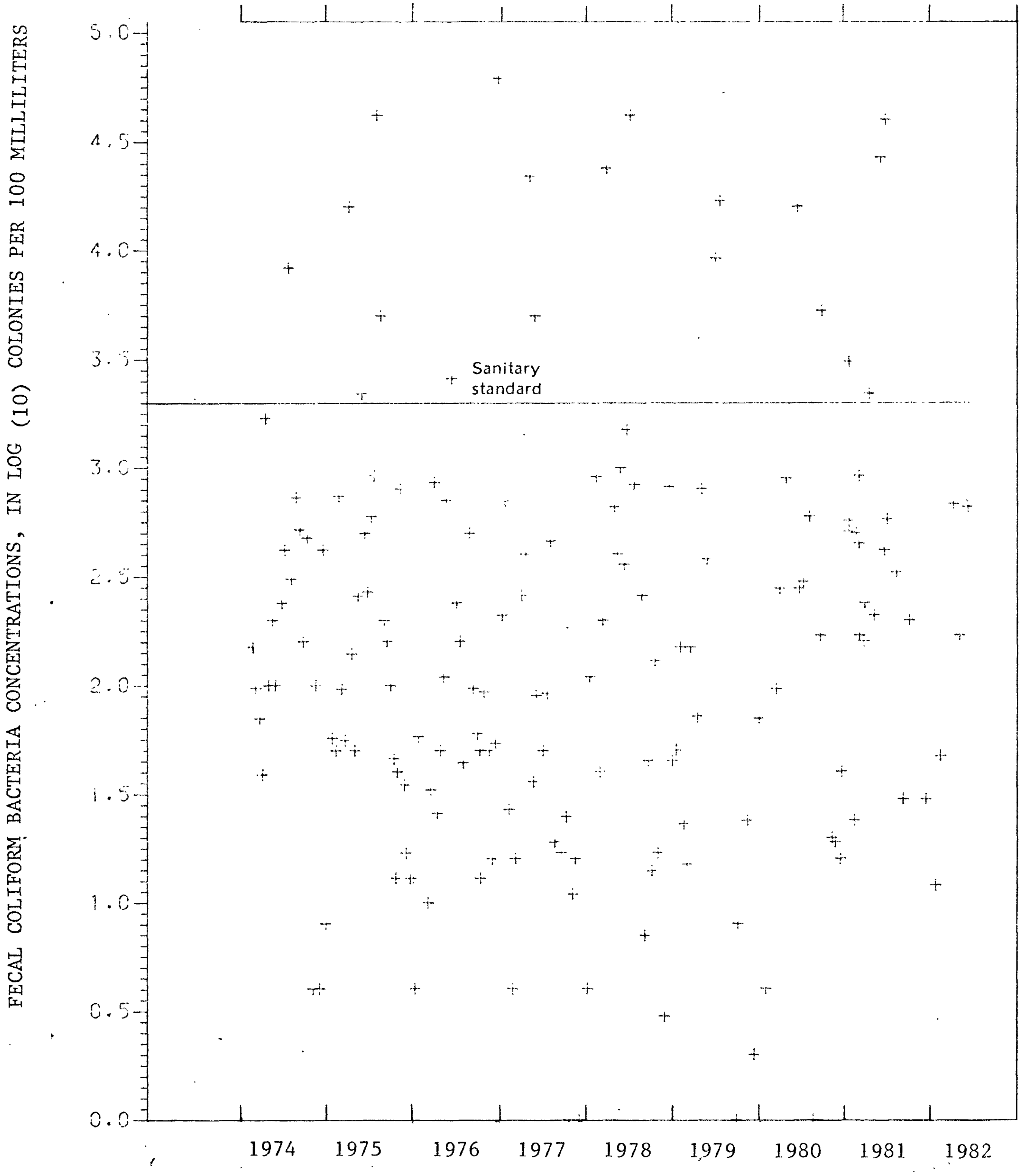

Figure 9.- Fecal coliform bacteria distribution compared to the sanitary standard (as $\log_{10}$ 2,000) at 5800 South Street.

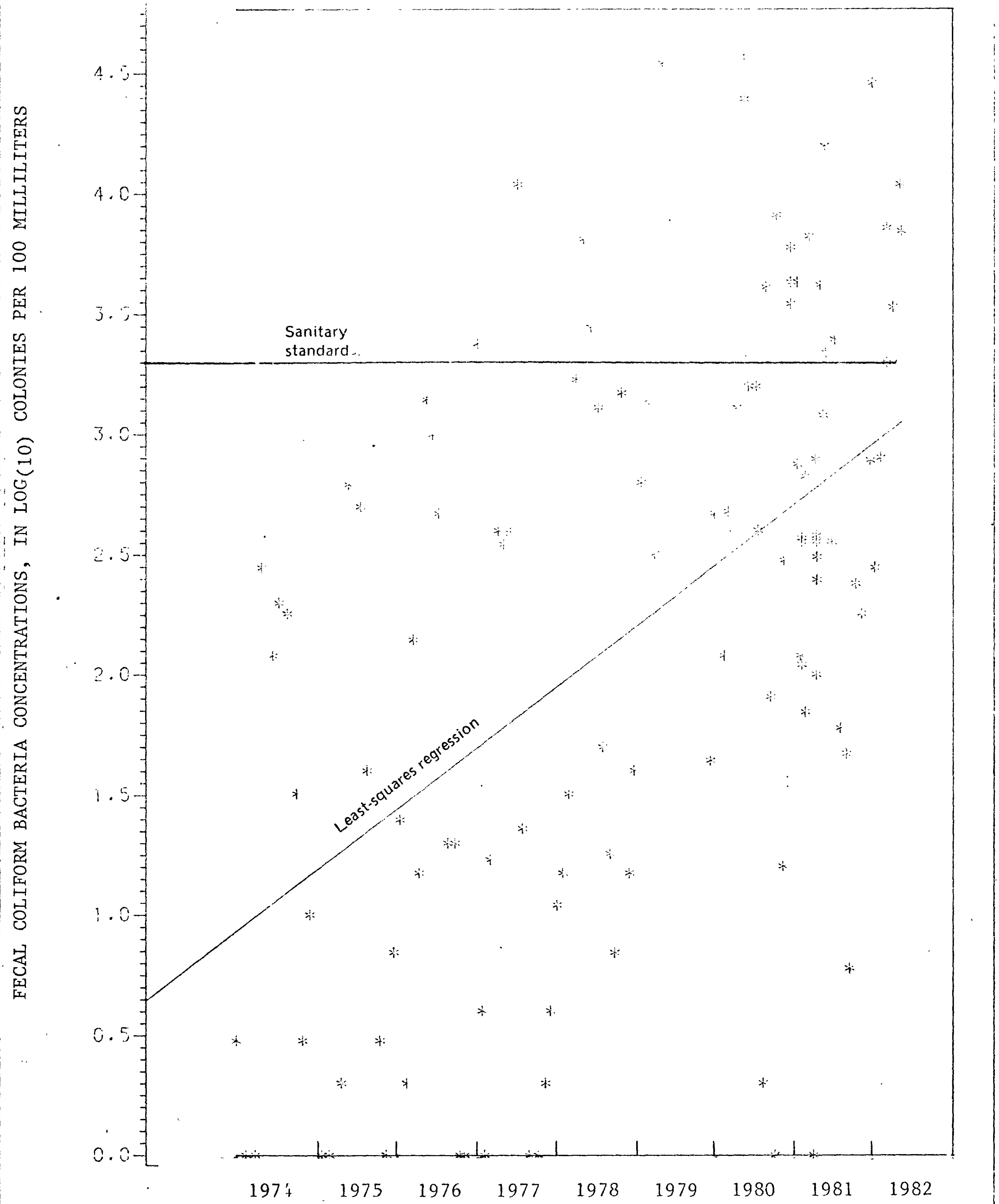

Figure 10.—Increase in fecal coliform bacteria concentrations with time and the sanitary standard at 1700 South Street.

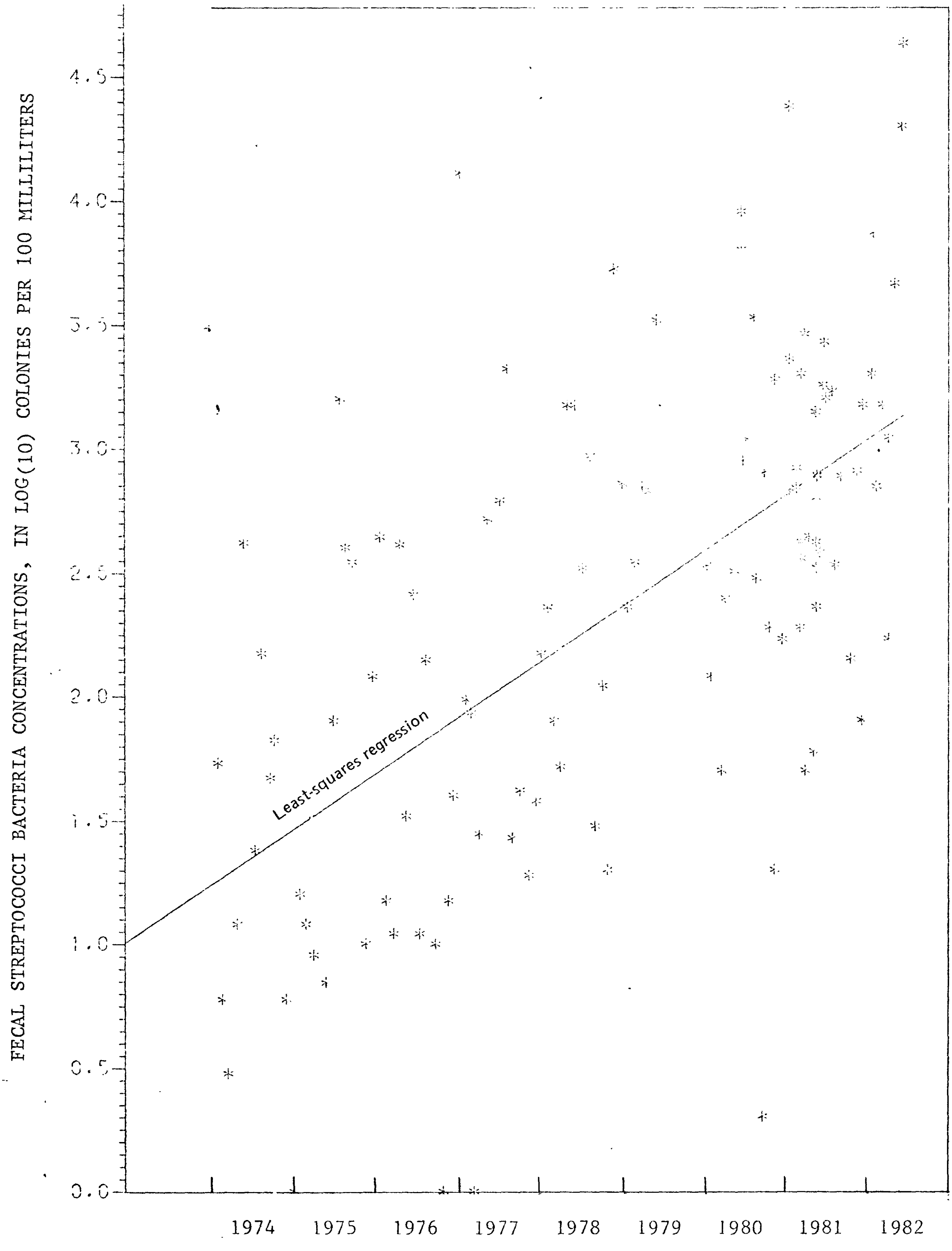

Figure 11.- Increase in fecal streptococci bacteria concentrations with time at 1700 South Street.

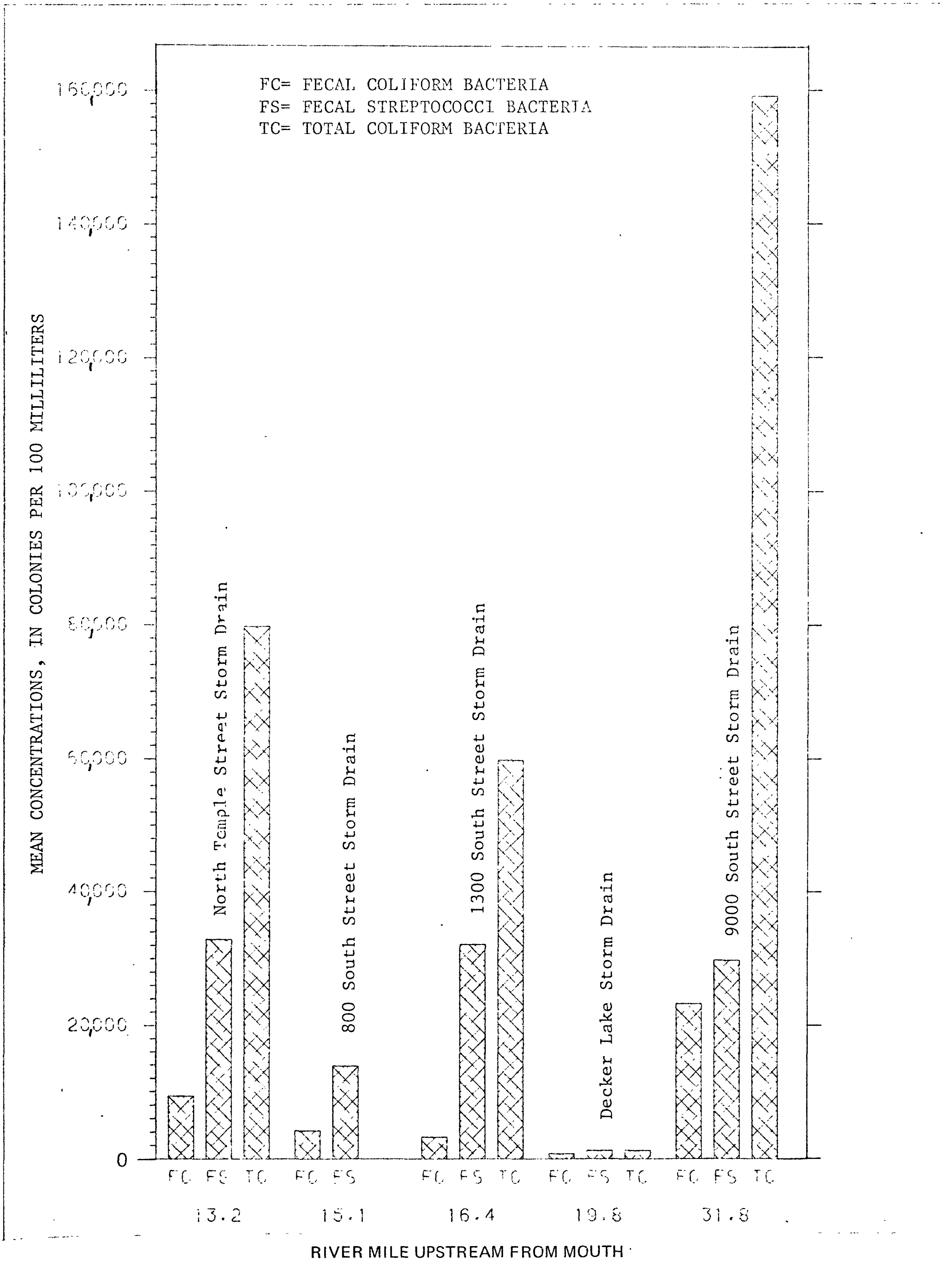

Figure 12.—Mean fecal coliform, fecal streptococci, and total coliform bacteria concentrations from storm drains.

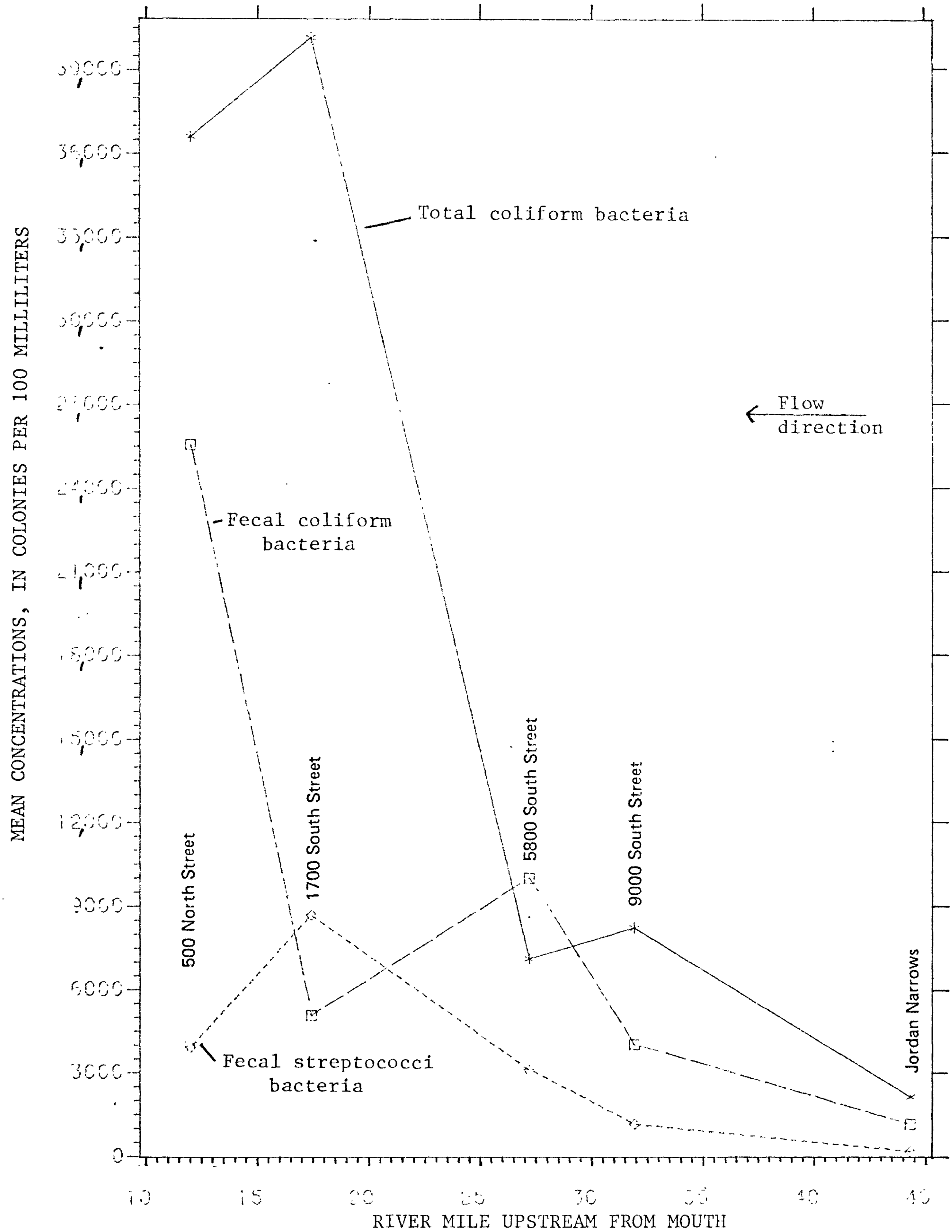

Figure 13.—Variation in total coliform, fecal coliform, and fecal streptococci bacteria concentrations in storm-runoff samples from the Jordan River at five sampling sites.