WATER QUALITY ANALYSES OF THE RECREATIONAL WATERS OF SABINO AND BEAR CREEKS

by

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STATEMENT BY AUTHOR

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ABSTRACT

Sabino Canyon Recreation Area has received over 600,000 visitors per year. Sabino and Bear Creeks flow through the area creating a diverse habitat for vegetation and wildlife, and a unique desert setting for water-based recreation. Proximity to the city of Tucson places constant user pressure on the water resources and prime concern in a water-based recreation area is water quality.

An intensive study of existing water quality status of Sabino and Bear Creeks was conducted because the quality of water in Sabino and Bear Creeks was unknown. This study examines bacterial, chemical, and physical parameters. Data were collected twice a week on Sundays and Wednesdays for a year.

Results of the study indicate there were: (1) no major chemical problems, (2) highest turbidity values occurred during the warm weather months, and (3) high concentrations of fecal coliform in the bottom sediment and periodically in overlying water indicate major sources of fecal contamination have access into Sabino Creek.

This study provides the United States Forest Service with baseline water quality data and a benchmark from which to continue an efficient water quality monitoring program.

CHAPTER 1

INTRODUCTION

The Santa Catalina Mountains, which are part of the Coronado National Forest, are located immediately adjacent to the metropolitan area of Tucson, Arizona (Figure 1). Composed of four major life zones, the Catalina Mountains offer the visitor the enjoyment of a natural resource that encomapsses five vegetation types. Vegetation types range from desert shrub at 2,000 feet, with 11 inches of precipitation annually to mixed conifer at 9,000 feet, with annual precipitation accumulation to 30 inches or more (Natural Resource Recreation, 1973). Within the Santa Catalina Mountains, numerous recreation areas, which include day-use areas, overnight-use areas, and second home areas receive over two million visitors per year with most of the visitation concentrated on weekends and holidays (United States Forest Service, 1975).

Sabino Canyon Recreation Area, a major recreation complex within the Catalina range (Figure 1), experiences a large portion of the visitor use and has in the past drawn over 600,000 visitors per year. Sabino and Bear Creeks flow through the recreation area creating a diverse habitat for vegetation and wildlife, and a unique desert setting for water-based recreation activities. Stream side picnicking, wading the stream, and swimming in the deeper pools are the main activities pursued by the visitor.

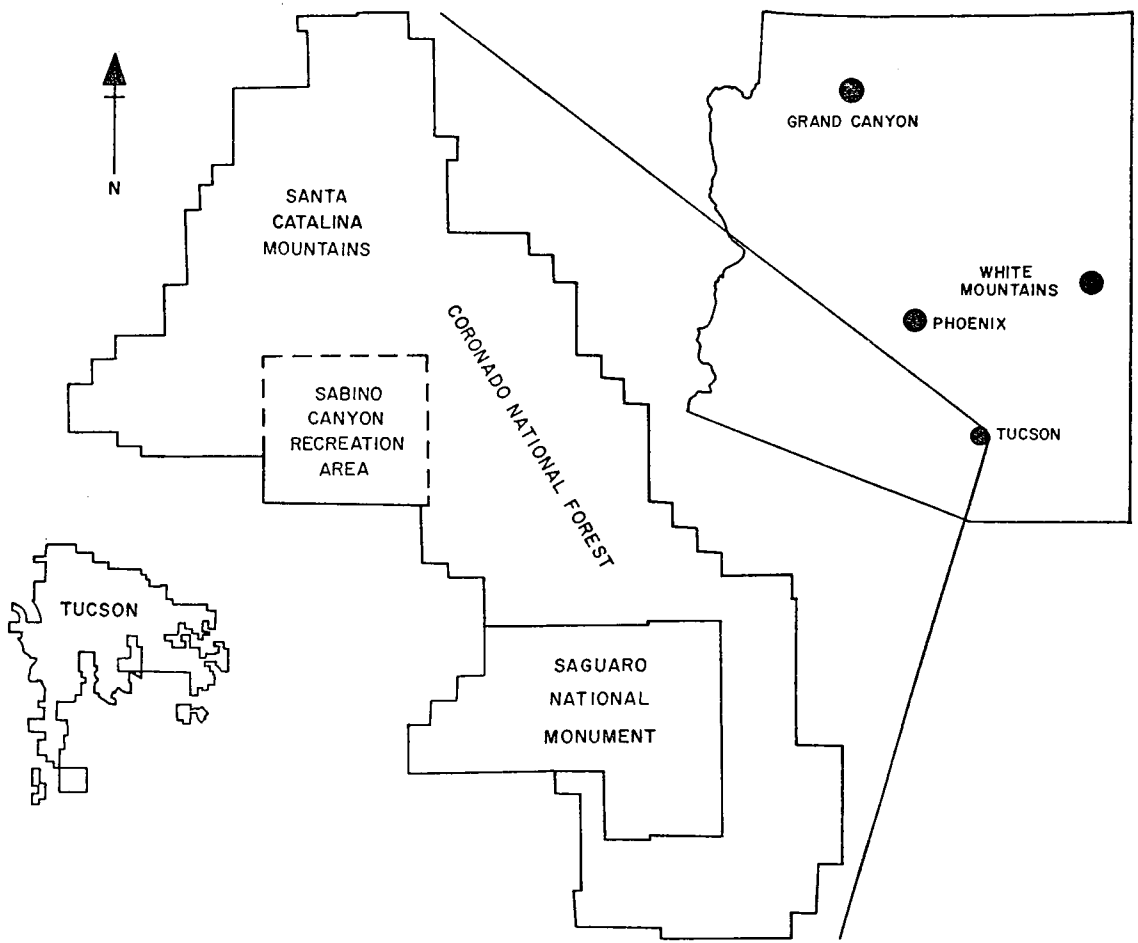

Figure 1. Regional location of Sabino Canyon Recreation Area within the Coronado National Forest.

Sabino Canyon Highway provides primary access into the recreation area, which is 12 miles from downtown Tucson. From the southern edge of the Forest boundary, the road penetrates four miles into Sabino Canyon and loop roads provide access within the recreation area. A well developed trail system furnishes back country routes from any section of the Catalina Mountains (Figure 2).

Sabino Canyon Recreation Area is the lower portion of two canyons, Sabino and Bear. Sabino Creek drains a watershed of 35.5 square miles and Bear Creek drains a watershed of 16.3 square miles (Figure 2). Both streams are fed by natural springs and snow melt; stream flow can be described by intermittent perennial with no flow at times during the summer months. Flash flooding within steep canyon walls occurs during the rainy season (July through September) depositing fine sand, gravel, and rock debris within natural and man-made barriers; wider areas of the stream where movement of the stormwater slows, receive a considerable deposition as well.

Nine miles upstream from Sabino Canyon Recreation Area at the headwaters of Sabino Creek are located the small community of Summerhaven, six United States Forest Service (USFS) second home areas, and USFS Marshall Gulch picnic area. At the headwaters of Bear Creek are Bear Canyon and General Hitchcock picnic areas and Willow Canyon second home area (Figure 2).

Sewage facilities for Summerhaven consist of a holding tank-chlorinator system with effluent piped directly into Sabino Creek. Of the 240 homes in Summerhaven, 26 are known to be hooked into the chlorinator system with an unknown number of illegal connections (Adams and

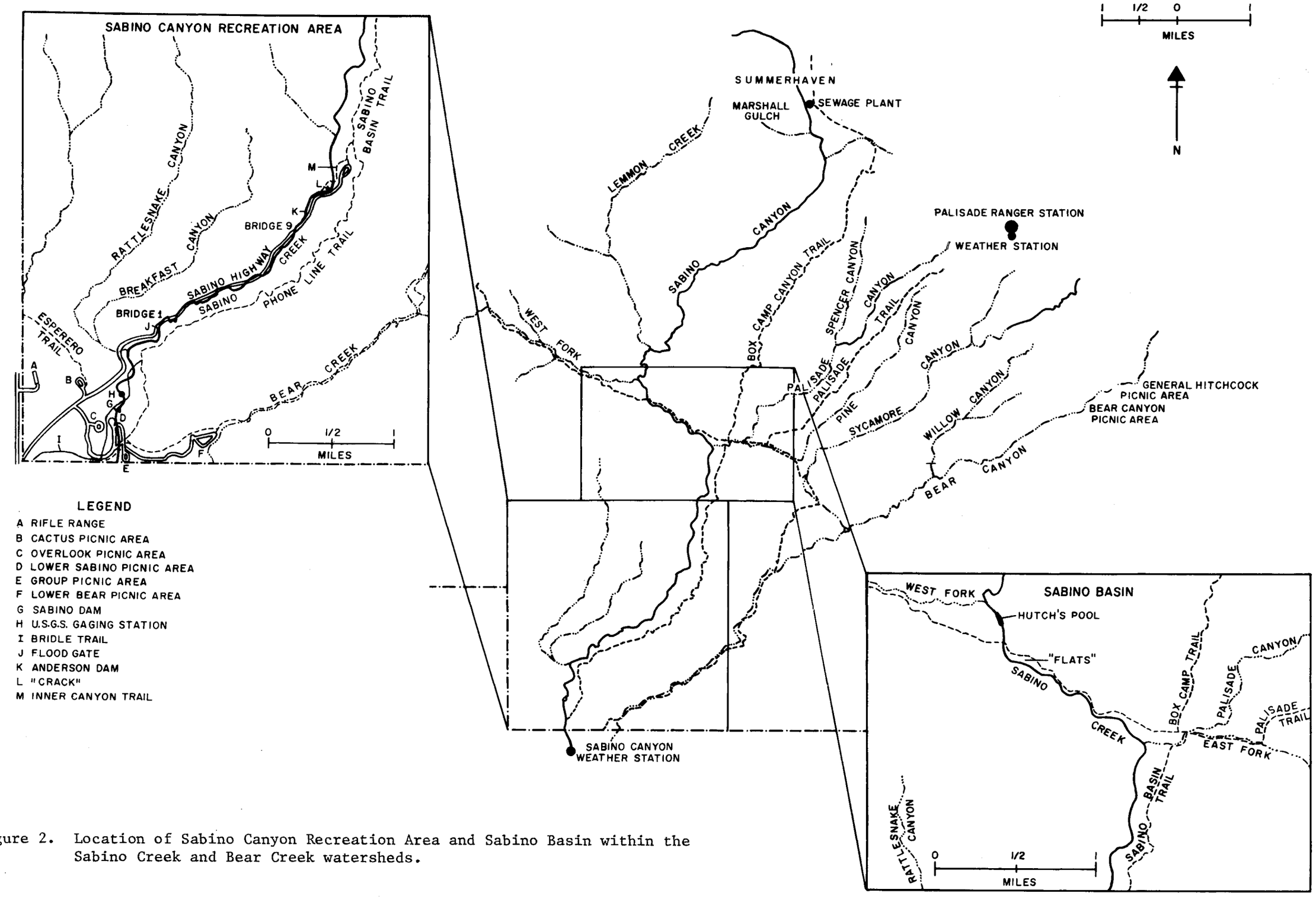

Figure 2. Location of Sabino Canyon Recreation Area and Sabino Basin within the Sabino Creek and Bear Creek watersheds.

Geiser, 1970). Failure of the Summerhaven chlorinator system has resulted in the periodic closure of Marshall Gulch picnic area. Unsanitary conditions at the headwaters of Sabino and Bear Creeks have been a focal point of concern but these unsanitary conditions at the headwaters may also cause unknown problems downstream in Sabino Canyon Recreation Area.

Statement of the Problem

Natural, free flowing, surface water has all but disappeared in Southern Arizona. Historical records indicate that numerous vibrant perennial streams once existed in this area, but their fragile balance with nature has been altered. Sabino and Bear Creeks are among the last streams in the Southern Arizona desert region. Because surface water is limited in the Southwest, a hike through Sabino and Bear Canyons presents the visitor unordinary contact with the desert riparian community near a unique desert commodity, WATER.

Colonel C. C. Smith (1930, p. 9) writing about life in Tucson during the 1880's, states "Sabino Canyon was considered to be a little remote for visiting by the town's people." Today, Sabino Canyon Recreation Area is a playground primarily for the people of Tucson; proximity to the city places constant user pressure on the water-based recreation area. The Santa Catalina Ranger District Multiple Use Plan (1969) indicates that Sabino Canyon Recreation Area has received more use than any other recreation area of comparable size in the region. As competition for water-based recreational experiences increases in Arizona, visitor use of Sabino Canyon Recreation Area can be expected to grow accordingly.

Impact of the visitor use on Sabino Canyon Recreation Area has not previously been assessed. In order to ascertain the impact of visitor use on the recreational experience within a recreation area, input from carrying capacity indicators is needed. Recreational carrying capacity is the function of the biological carrying capacity, the physical carrying capacity, and the sociological carrying capacity of the area (Lucas, 1964; Wagar, 1964). With respect to biological carrying capacity indicators, prime concern in a water-based recreation area is water quality. An intensive study of existing water quality status of Sabino and Bear Creeks has not been conducted. Because the quality of water in Sabino and Bear Creeks is unknown, this study investigated such questions as: (1) What are the physical, chemical, and bacterial characteristics of the streams?, and (2) What are the relationships between time of day, day of week, season of year, and water quality parameters?

Objectives of the Study

The objectives of this study are:

(1) To develop a water quality reconnaisance of Sabino and Bear Creeks for the purpose of assessing the present water quality status.

(2) To establish a benchmark for future water quality analyses of Sabino and Bear Creeks, and a prelude to water quality research of desert recreational streams.

(3) To identify significant trends in water quality parameters throughout the study area.

(4) To evaluate changes in bacteria parameters by stratifying sample collection based on time, day, and location.

(5) To provide management alternatives for Sabino Canyon Recreation Area which will aid in the solution of observed water quality problems.

Specific Processes of the Study

For the purpose of this study, water quality will be determined by measuring the concentrations of bacteria as fecal coliform and fecal streptococcus; chemical concentrations of copper, nitrate-nitrogen, orthophosphate, and pH; and physical characteristics as turbidity, water and air temperature, and rate of flow. The specific processes to meet the objectives of this study are:

(1) To establish sampling stations that will represent and evaluate water quality trends through the water course for the purpose of continued monitoring (Kittrell, 1969).

(2) To establish a water quality sampling schedule that permits collection, transport, and laboratory processing consistent with the eight hour bacterial count reliability limit (American Water Works Association, 1971).

(3) To perform bacterial analyses of surface water using the membrane filter (MF) technique testing for fecal coliform and fecal streptococcus concentrations (Millipore Corporation, 1973).

(4) To perform bacterial analyses of bottom sediment using the Most Probable Number (MPN) technique testing for fecal coliform concentrations (American Water Works Association, 1971).

(5) To measure chemical concentrations and turbidity using the Hach Chemical Company technique based on Standard Methods for the

Examination of Water and Waste Water (American Water Works Association, 1971) and measuring air and water temperatures by standard field procedures (Kittrell, 1969).

(6) To obtain climactic data, rate of flow data, and visitor use data from the National Oceanic and Atmospheric Administration, the United States Geological Survey, and the United States Forest Service, respectively.

(7) To perform statistical analyses for differences in parameters tested.

(8) To form management alternatives to help solve observed water quality problems.

Delimitations

Research by this team, headed by Drs. Brickler and Phillips of The University of Arizona, is concerned with the water quality of Sabino and Bear Creeks on a total watershed basis. This study investigated the lower portions of Sabino and Bear Creeks and is part of ongoing water quality research by Drs. Brickler and Phillips for the United States Forest Service.

Data collection for this study began June, 1974, and terminated June, 1975. During May and June, 1974, field reconnaissance was conducted so that on-site procedures would be established; also laboratory methods were perfected during this period.

Management policy regarding the use of personal motorized vehicles within the recreation area varied during the sampling year. Due to construction of a sanitation system, personal motorized vehicles were

prohibited in the recreation area through August, 1974. Prior to the 1973-1974 construction period, personal motorized vehicles were permitted on all roads within the recreation area. After August, 1974, personal motorized vehicles were permitted on all roads up to the floodgate (see Figure 2) during weekdays and to Cactus picnic area on weekends. Data obtained during this study are discussed under the considerations of the visitor use policy.

Visitor use data were collected in the form of car counts. A preliminary assessment between visitor use and water quality parameters was made, but the intent of this study was to provide the Forest Service with baseline water quality data not to define or collect specific data on the type and number of recreation users within the sampling area.

Flow data were obtained from the U.S.G.S. gauging stations on Sabino and Bear Creeks (see Figure 2). Both stations were terminated on October 1, 1974; flow data from June, 1974 through September, 1974, and a ten-year mean flow was used in the analyses of data.

All data analyses in this study were conducted through the use of computer programs in the Statistical Package for the Social Sciences (Nie, Bent and Hull, 1970; Nie et al, 1975), and through programs developed by the National Educational Resources, Inc. (1972).

CHAPTER 2

REVIEW OF RELATED LITERATURE

Traditionally early man had settled near water to sustain his life and raise his standard of living. Waterways have offered man an inexpensive source of transportation, potable water, and a means of waste disposal. As the development of transportation, wells, and sewage treatment facilities increased, the traditional need to settle near waterways decreased and the social need to use waterways has increased. Within the American society, increasing free time, mobility, and money have led to the expansion of outdoor recreation participation (Clawson and Knetsch, 1966). Furthermore, Clawson and Knetsch (1966) point out that attendance at National Parks has increased a hundred times since 1920, and a participation at water-based recreation areas has grown at an even faster rate.

Water-based recreation plays an important part in the total recreation experience. Approximately two-thirds of all public administered recreation areas contain or are adjacent to water bodies, but growing pressures on the water resource, which include recreation, are a hindrance to the future use of lakes and rivers for water-based recreation (Bureau of Outdoor Recreation, 1973). Outdoor recreation can offer each person personal enrichment, but perpetual personal enrichment through outdoor recreation will depend on the quality of the recreation environment. Water-based recreation depends on an abundance of water of good quality; but at the same time water-based activity can be detrimental to the

quality of water (Carlson, 1971). In order to protect man-made and natural water bodies from increasing degradation, political leaders have enacted several water quality laws.

As discussed by Bennett (1970), the Water Pollution Control Act of 1956 (PL 660) and an amendment to that law in 1961 (PL 87-88) provided pollution abatement programs and also money for research and training for private agencies, institutions, and individuals. The Water Quality Control Act of 1965 (PL 89-234) encouraged each state to develop water quality standards, and in 1966, the Clean Water Restoration Act (PL 89-753) introduced the watershed or drainage basin concept of pollution control.

In the Southwest where water is a scarce resource, and particularly in Arizona with its extremely high rate of population growth, each source of available water is pressured extensively by all potential users, including recreationists (Brickler and Lehman, 1972). Effects of this pressure on the water resource need to be monitored and documented in order that management agencies may plan accordingly.

Multiple Use and Water Quality

Inefficient or unwise management of watershed areas is a luxury the country cannot afford and a dominant factor in determining how to manage watershed areas is water quality (Rademacher, 1968). Single use verses multiple use of water bodies and watersheds regarding water quality has been discussed in the literature.

Dambach (1956) and Riehl (1956) expound opposite opinions on multiple use of water supply reservoirs. Dambach (1956) argues in support of recreation on public water supplies because of the short supply

of water-based recreation in populated areas, and multiple use of reservoirs provides more benefits than costs to the public. Contrary to endorsing multiple use on public water supplies, Riehl (1956) provides two good arguments against water-based recreation on water supply reservoirs: (1) the decrease in water quality and the increase in cost to provide potable water; (2) proper recreational use levels are harder to maintain than prohibiting recreation on water supply reservoirs. Both authors present views regarding multiple use, but the management of reservoirs and other water bodies for water-based recreation should be determined by water quality research (Rademacher, 1968).

Intensive water quality studies regarding water-based recreation are limited. Several studies (Little, 1963; Rosebery, 1964; Indiana Water Quality Recreational Project, 1966) indicated that recreation use of reservoirs and corresponding watersheds was not detected at intake towers for potable water supplies, but the studies did find higher indicator organisms in areas of concentrated recreational activity. Two additional studies found higher indicator organisms during recreational use periods. Kavalekas and Lynch (1965) demonstrated a decrease in indicator organisms when recreation use (fishing) was prohibited from two Massachusetts reservoirs. Comparing two Connecticut reservoirs with similar watersheds, Minkus (1965) found significantly higher coliform counts in the reservoir with heavy recreation use than in the one closed to recreation.

Misapplication of septic tank-drainfield systems on watersheds and waterfronts can lead to intolerable conditions with respect to aesthetics and public health aspects of water used for recreation (Hall and

Sproul, 1971). Worms and Brickler (1967) investigated Lake of Egypt, near Marion, Illinois; found high bacterial densities in surface and stratified water samples near cabins and permanent homes using sand box filters or septic tank-tile fields.

In addition to human influence on the water resource, Kunkle and Meiman (1967) documented the impact of domestic livestock on the water quality of mountain watersheds. Kunkle and Meiman (1967) observed higher coliform, fecal coliform, and fecal streptococcus concentrations on the grazed area than on the ungrazed. Stuart et al. (1971) found four to six times the coliform counts on a Montana watershed closed to recreation than an adjacent watershed open to recreation. The authors postulated that the large wild animal population was responsible for the increase in bacteria counts.

Human enteric pathogens have been detected in warm-blooded wildlife and domestic animal feces (Clark et al., 1962; Fair and Morrison, 1967). Animals may become infected by human pathogens or act as natural carriers of human disease (Geldreich, 1972). Janssen and Meyers (1968) suggest that freshwater fish may also act as natural carriers by acquiring pathogenic organisms through feeding in contaminated water and defacating these organisms in clean water.

Effects of swimming on water quality have been studied under controlled conditions by two research teams. Robinton and Mood (1966) found that bathers while swimming contribute both fecal and eye-ear-throat-nose type bacteria to the water. Hanes and Fossa (1970) demonstrated that swimmers can increase chemical and bacterial indicators of bathing water quality.

Stevenson (1953) conducted epidemiological studies on Lake Michigan at Chicago, Illinois, the Ohio River at Dayton, Kentucky, and Long Island Sound at New Rochelle, New York, to determine natural bathing water quality and the effect upon the health of swimmers. The author found some correlation between high coliform concentrations and swimmer illness. Epidemiological studies and laboratory studies, concerning the health of water-based recreation users, were the initial steps toward the development of recreational water quality standards.

Water Quality Indicators

Questions arise regarding which indicator organisms or chemicals should be used to determine the quality of recreational waters. Each State was encouraged by the Water Quality Control Act of 1965 (PL 89-234) to develop water quality standards. Total coliform bacteria was proposed and used by all States as the standard of acceptability for recreational waters (Mechalas et al., 1972). Coliform concentrations per 100 ml in one State could exceed by greater than fifty times the allowable coliform limit in another State. Researchers (Robinton and Mood, 1966; Foster, Hanes and Sabin, 1971) point out that water-based recreation standards are so variable due to the fact the standards were based on little epidemiological data and evolved by the modificatin of drinking water standard.

Total coliform have been questioned (Geldreich, Kenner, and Kabler, 1964) as an indicator because of aftergrowth and nonwarm-blooded sources of the bacteria. Both of these characteristics make total coliform of limited use for recreation water quality standards (Mechalas

et al., 1972). Indicators, such as total coliform, of possible enteric disease have also been questioned (Foster et al., 1971) because the majority of swimming related health complaints are eye, ear, and nose problems rather than gastrointestinal.

Hoadly (1968) suggested that Pseudomanas aeroginosa be used as the indicator organisms for recreational waters because of an association with ear infections. Fecal streptococcus as an indicator was proposed by Mallman and Seligman (1950) because of a relationship between streptococcus concentrations and bathing activity. In contrast, Foster et al. (1971) found that coliform, streptococcus, and Pseudomanas aeroginosa densities varied independently of swimming activity. Their study suggests that bacterial limits be considered only a guide requiring additional investigation based on epidemiological data for a particular area.

Other indicator systems have been proposed (Gallagher and Spino, 1968) which include pathogenic bacteria. Geldreich (1970) suggests that the occurrence and density of pathogens in polluted water and in animal feces are highly variable. Thus, microbiological monitoring of water using waterborne pathogens would require a variety of complex, time consuming, and often insensitive procedures.

Fecal coliform bacteria, a subgroup of the total coliform population, have a direct correlation with fecal contamination from warmblooded animals (Geldreich, 1966; American Water Works Association, 1971; Mahloch, 1974). Geldreich (1970, p. 114) states "measurements of stream pollution must be based on the detection of fecal contamination from all warmblooded animals. For this is the natural link to the occurrence of pathogenic microorganisms in polluted water." Fecal coliform bacteria

should be used as a baseline indicator system for evaluating the suitability of recreational waters (Geldreich, 1970). Research by Smith and Twedt (1971) supports the use of fecal coliform due to the isolation of Salmonella when fecal coliform levels per 100 ml were between 100 and 200 organisms. Reconfirmation of earlier work, Smith, Twedt and Flanigan (1973) found fecal coliform beneficial as an indicator of recreation water quality.

Primary contact standard for water-based recreaton areas is "fecal coliform content -- shall not exceed a geometric mean of 200/100 ml, nor shall more than 10 percent of total samples during any 30-day period exceed 400/100 ml" (Federal Water Pollution Control Administration, 1968, p. 30).

The fecal coliform standard adheres to research findings and field investigations (Geldreich, 1970; Smith and Twedt, 1971; Van Donsel and Geldreich, 1971; Smith et al., 1973).

In addition to fecal coliform, the fecal streptoccocus group merits consideration in water quality criteria because the occurrence of fecal streptoccocus concentrations in water indicates fecal pollution; an absence suggests little or no warm-blooded animal contamination (Geldreich and Kenner, 1969). Developing a fecal coliform to fecal streptococcus ratio is a valuable tool to determine the source of contamination (Geldreich and Kenner, 1969). The authors warn that the use of this relationship for natural streams would be valid only during the initial 24-hour travel downstream from the point of pollution discharge into the receiving stream.

Besides quantifying bacteria in surface water, fecal coliform in bottom sediments need to be investigated. Hendricks (1971a) and Van Donsel and Geldreich (1971) found greater concentrations of fecal coliform in bottom sediments than in the surface water. Hendricks (1971a) observed higher recovery rates of Salmonella in stream bottom sediments than in surface water. Fecal coliform in bottom sediments were 100 to 1,000 times higher than in surface water; survival of fecal coliform in the bottom sediment closely parallels survival of Salmonella (Van Donsel and Geldreich, 1971).

Bottom sediment-water interface is not a static system. Consequently, the recirculation of older pollutants into bathing areas poses new problems in water quality, which must be considered potentially hazardous to swimmers (Van Donsel and Geldreich, 1971). Hendricks (1971b) states that bacterial bottom sediment samples should be included in water quality monitoring programs.

In addition to biological indicators, chemical indicators have been applied to recreational water quality research. Monitoring of chemical constituents in recreation waters is important to the resource manager because of eutrophication, which is an enrichment of water bodies by nutrients (Mackenthun, 1968). Eutrophication can cause an increase in algae and weed nuisances. Large, visible, floating masses of algae can ruin the aesthetic enjoyment of the water resource (Hall and Sproul, 1971).

Mackenthun and Ingram (1964) state that "present knowledge indicates that the fertilizing elements, nitrogen and phosphorus, are most responsible for eutrophication." Due to the complex nature of biological

activity, the importance of nitrogen and phosphorus in eutrophication has been oversimplified (Weaver, 1969). Other factors do influence the growth of algae and aquatic plants, but Ferguson (1968) states that if phosphorus or nitrogen were not available, algae would not grow.

In natural waters, nitrogen and phosphorus are the nutrients most likely to be found in limited amounts (Keeney, 1972). Various forms of these nutrients are found in generous amounts of sewage and sewage effluents; soluble nitrogen and phosphorus forms are readily available so discharge to natural waters can stimulate growth of algae and aquatic plants in excess of natural occurrences (Committee Report -- American Water Works Association, 1970).

Interpretation of biological and chemical indicators requires knowledge of the aquatic environment from which the data was collected. Kittrell (1969, p. 6) in his book concerning water quality studies of streams, states:

> A streams physical characteristics greatly influence its reaction to pollution and its natural purification. An understanding of the nature of these influences is important to the intelligent planning and execution of stream studies. Important physical factors include temperature, turbidity, depth, velocity, turbulance, slope, changes in direction and in cross sections, and nature of the bottom.

CHAPTER 3

METHODS

Discussion in Chapter 3 consists of a description of the study site, the field procedures, and laboratory procedures. The study site description section explains the legal account, the vegetation type, the soil type, the man-made resources, the recreational activities, and the sample station location; the field procedures section includes (1) the frequency, day, and time of sample collection, (2) the collection and transportation technique, and (3) the parameters obtained at each station. Laboratory procedures section describes the process that was used to measure each parameter.

Study Site Description

Recreation waters sampled in this study are found in Sabino Basin and Sabino Canyon Recreation Area. Sabino Basin (see Figure 2), a low use area, is the middle section in the Sabino watershed. Access into Sabino Basin is by trail. Sabino Canyon Recreation Area, located on the southern edge of the Sabino and Bear watersheds, is divided into three distinct sections: (1) Upper Sabino, (2) Lower Sabino, and (3) Lower Bear. Each section represents a varied degree of intensive recreational use. Upper Sabino is a walk-in area with recreational pressure decreasing from the parking area (see Figure 2). Lower Sabino and Lower Bear are high use areas with pleasure driving, horseback riding,

picnicking, and in-water activities as the major forms of recreational activity.

Sabino Basin

Sabino Basin (Section 22, 23, and 26, T. 12S., R. 15E) lies five miles downstream from the sewage facilities for Summerhaven and four miles upstream from the end point of Sabino Canyon road (see Figure 2). Elevation of Sabino Basin ranges from 3800 feet to 4000 feet with a moderate topography. Vegetation of this area is a mixture of desert shrub, desert grassland and oak-woodland types. Among the plant species are Saguaro (Carnegiea gigantea), Emory oak (Quercus emoryi), Alligator Juniper (Juniperus deppeana), Silverleaf Oak (Q. hypoleucoides), Arizona Cypress (Cupressus arizonica), Sotol (Dasylirion wheeleri), Bluestem (Andropogon sp.), Manzanita (Arcotostaphylos pungens), Grama (Bouteloua sp.), and Bear grass (Nolina sp.). Desert shrub vegetation is found mainly on areas with a southern aspect; oak-woodland vegetation is found on areas with a northern aspect or near the stream bottom.

Soils within the research area are in the Ardisols order which are low in organic matter and dry more than six months of the year (Brady, 1974). Soil types in Sabino Basin include Alluvial and the Barkerville-Faraway Association. Oak-woodland vegetation is connected with the Barkerville-Faraway soils which are found in areas of 20 to 30 percent slope; alluvial soils are found in areas with slopes of 5 to 20 percent. Barkerville-Faraway soils have a moderate to high erosion potential (United States Forest Service, 1975).

Recreational activities pursued in Sabino Basin are backpacking, camping, horseback riding, fishing, and swimming; no developed campsites or waste disposal facilities are provided. Hutch's Pool, the "Flats" on Sabino Creek, and the confluence of Palisade Creek and the East Fork of Sabino Creek are favorite camping areas (Figure 3). Livestock grazing is not permitted in Sabino Basin.

U.S.G.S. maps of Sabino Canyon, on-site investigation, and user data patterns were utilized to determine the location of water sample stations. Sample stations by design rather than random point or grid plot were employed to form a water quality monitoring system. In small streams with vertical and lateral mixing, only a single sample at mid-point of the stream is necessary (Kittrell, 1969). Due to the usual depth of Sabino and Bear Creeks, samples were obtained just below water surface. Sample stations for this investigation were constituted under these considerations.

Seven sample stations were selected for Sabino Basin (Figure 3). Sample stations include:

Station SB1 Inflow to Hutch's Pool.

Station SB2 Mid-point at Hutch's Pool.

Station SB3 Outflow from Hutch's Pool.

Station SB4 First major pool below Hutch's Pool.

Station SB5 Inflow to the "Flats."

Station SB6 Outflow from the "Flats."

Station SB7 Confluence of Palisade Creek and the East Fork of Sabino Creek.

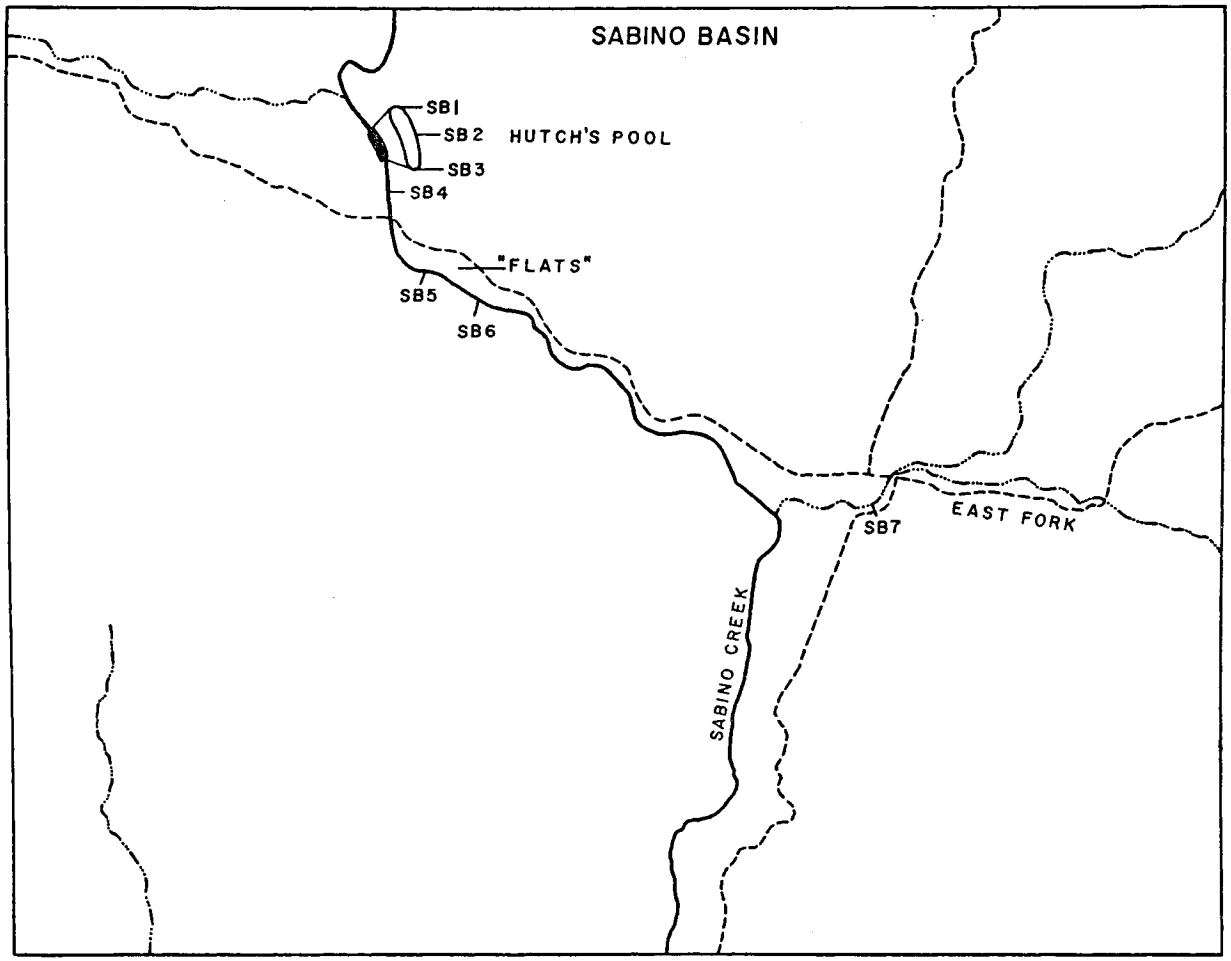

Figure 3. Location of sample stations on Sabino Creek within Sabino Basin.

Upper Sabino

Upper Sabino is located directly downstream from Sabino Basin in Sections 2 and 3, T. 13S., R. 15E., and Section 35, T. 12S., R. 15E. (see Figure 2). Elevations range from 2800 feet to over 5000 feet. Most of the topography is greater than 15 percent slope with gentle sloping land concentrated along the stream bottom. Along the stream bank, the riparian vegetation typically consists of Cottonwood (Populus fremontii), Sycamore (Plantanus wrightii), Walnut (Juglans major), Willow (Salix taxifolia), and Ash (Fraxinus velutina), Bermuda grass (Cynodon dactylon), a domestic garden grass, has invaded disturbed areas replacing the natural bunch grasses as Deer grass (Muhlenbergia rigens) and Bull grass (Muhlenbergia emerslyi). Vegetation in higher elevations away from the stream bottom consists of the Sonoran desert shrub species including Creosote bush (Larrea divericata), Palo verde (Cercidium microphyllum), Cholla (Opuntia spinosior), and Saguaro (Carnegiea gigantea).

Soil patterns within Upper Sabino are made up of Alluvial soils, the Cellar-Rockland Association, and the Lampshire-Rockland Association (United States Forest Service, 1975). Deep (40 to 60 inches), old alluvial soils are found in areas near the stream bottom with slopes of zero to ten percent. Mixed residual and old alluvial soils are found in areas with slopes of 5 to 20 percent; the Cellar-Rockland and the Lampshire-Rockland Associations are found in areas with slope greater than 20 percent. Cellar-Rockland and Lampshire-Rockland Associations consist of cobble stones and gravel; due to the steep topography of Upper Sabino, these soils have a great potential for erosion hazard (United States Forest Service, 1975).

Recent construction of a sanitation system has provided Upper Sabino with sealed vault rest rooms. Transportation within Upper Sabino is limited to hiking, bicycling, and horseback riding with horses restricted to bridle trails in all sections of Sabino Canyon Recreation Area. Nine one-lane bridges constructed in the 1930's provide easy access across Sabino Creek except during extensive flooding. Developed picnic sites are situated throughout Upper Sabino; overnight use is prohibited in all sections of Sabino Canyon Recreation Area. Overnight users passing through the recreation area must leave motorized vehicles outside the forest boundary.

Fifteen water sample stations were established in Upper Sabino (Figure 4). Sample stations include:

Station 1: Located at the first major pool on the inner-canyon trail approximately one-half mile upstream from the Sabino Canyon road trail head.

Station 2: Located at the first major pool in the inner-canyon trail approximately one-half mile downstream from the Sabino Canyon road trail head.

Station 3: Large pool approximately 100 yards downstream from Station 2.

Station 4: Inflow to the "Crack" which is the deepest pool in the Sabino Canyon Recreation Area.

Station 5: Outflow from the "Crack."

Station 6: Located at Anderson Dam.

Station 7: Located at Bridge 9.

Station 8: Located at Bridge 8.

Station 9: Located at Bridge 7.

Station 10: Located at Bridge 6.

Station 11: Located at Bridge 5.

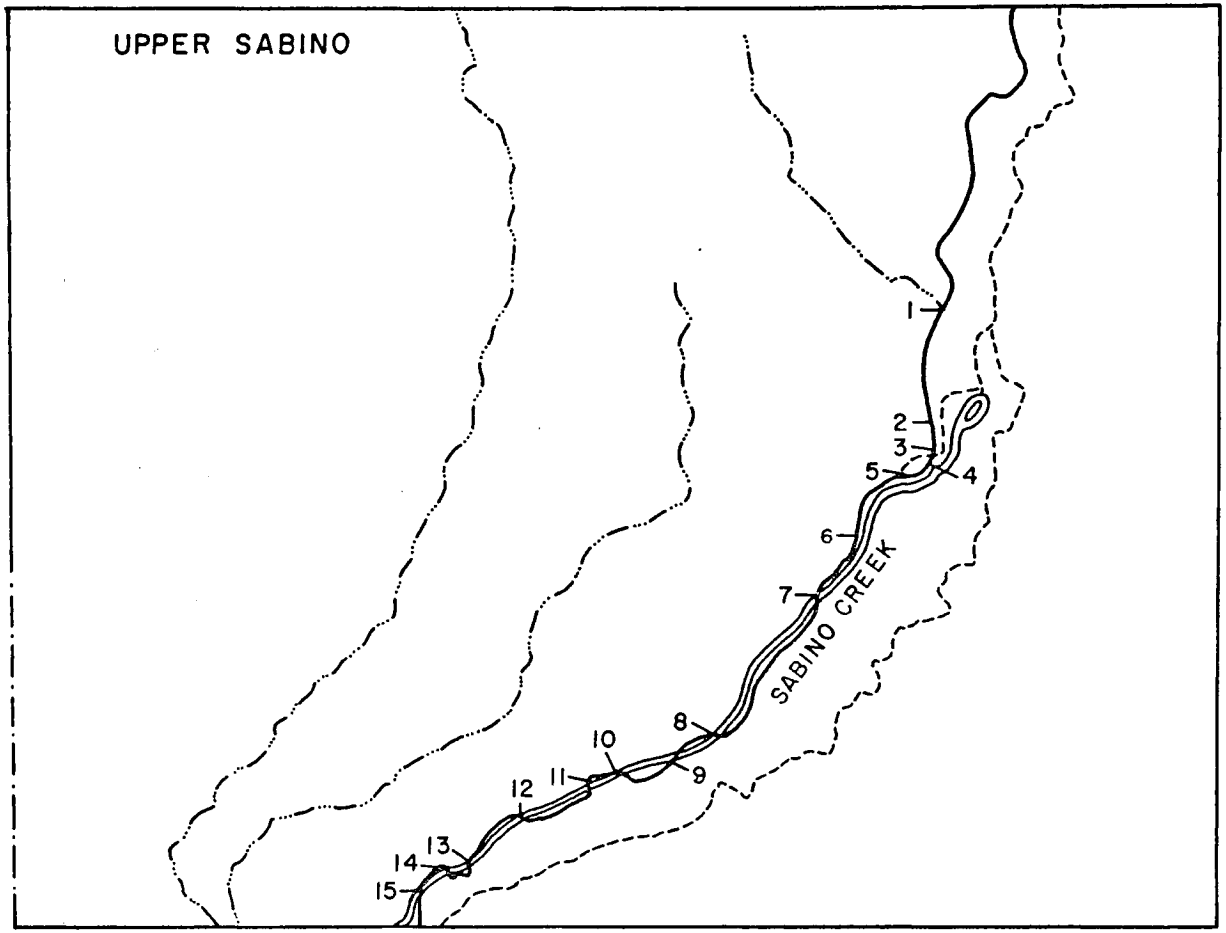

Figure 4. Location of sample stations in Upper Sabino on Sabino Creek.

Station 12: Located at Bridge 4.

Station 13: Located at Bridge 3.

Station 14: Located at Bridge 2.

Station 15: Located at Bridge 1.

Lower Sabino and Lower Bear

Lower Sabino and Lower Bear are located on the southern boundary of the recreation area (Sections 9 and 10, T. 13S., R. 24E.), and are in the Catalina foothills with elevations ranging from 2800 feet to 3600 feet. Similar riparian vegetation exists in Lower Sabino and Lower Bear as in Upper Sabino with the exclusion of Sycamore (Plantanus wrightii) and Walnut (Juglans major).

Construction of a sanitation system has provided the area with modern flush toilet waste disposal system. Both single unit and group picnic sites are available. All forms of transportation are permitted on the roads in Lower Sabino and Lower Bear. Chapter 1 explains visitor use policy for these sections.

Eight water sample stations were located in Lower Sabino and Lower Bear: six stations on Sabino Creek and two on Bear Creek (Figure 5). Sample stations include:

Station 16: Located one-fourth mile south of the "Floodgate" at a footbridge.

Station 17: Located below the confluence of Rattlesnake and Breakfast Canyons with Sabino Creek. Washes draining both canyons did not flow during sample periods.

Station 18: Located at the U.S.G.S. gauging station.

Station 19: Located at the inflow to Sabino Lake.

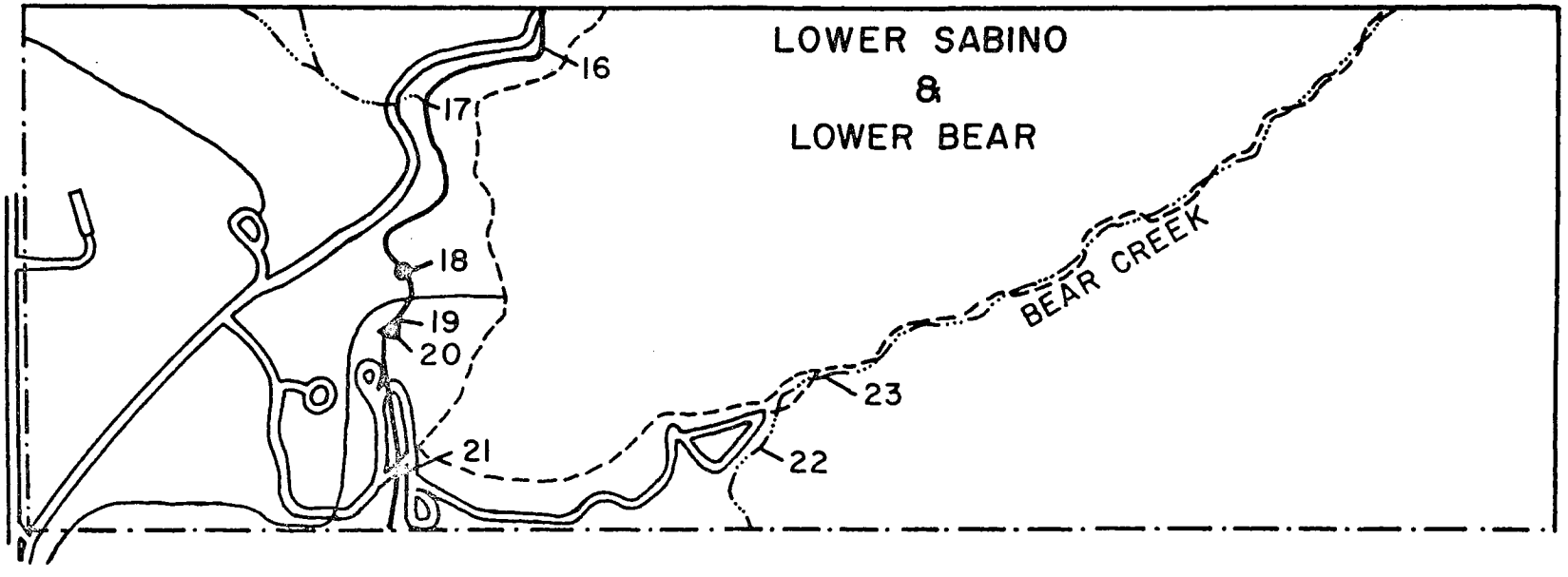

Figure 5. Location of sample stations in Lower Sabino and Lower Bear on Sabino and Bear Creeks.

Station 20: Located at the midpoint on the Sabino Lake Dam.

Station 21: Downstream of Sabino Lake Dam at the southern bridge which crosses Sabino Creek.

Station 22: On Bear Creek located adjacent to the rest room on the east side of Lower Bear Picnic Area.

Station 23: On Bear Creek located at the first foot bridge on the Seven Falls trail.

Field Procedures

Water sample collection programs were developed for Sabino Canyon Recreation Area and Sabino Basin based on the eight hour bacterial reliability limit as suggested by the American Water Works Association (1971). In Sabino Canyon Recreation Area water samples were collected twice a week on Sunday and Wednesday. Sunday-Wednesday sample collection program provided, each week, a sample of relative high and low visitor use periods during the sampling year. Time of sample collection varied each week utilizing three rotating sample periods: 8 a.m., 12 noon, and 4 p.m. Rotating time periods were used to determine the relationships between water quality parameters and time of day. Sabino Basin was sampled once a month. Due to the length of field time required to collect samples and the frequency of sample collection, all samples were collected in the morning.

Water samples were obtained with sterile plastic (Whirl-pak, 18 ounce size) bags. For stream samples, a slow scooping technique into the flow (Kittrell, 1969) was employed. One Whirl-pak was used for the bacteria parameters and a second used for chemical and physical parameters. Samples were collected in the following manner. At each station the pull tab from a premarked Whirl-pak was removed and the bag opened

aseptically using the wire frame. Forcing the bag just below the surface with a sweeping motion, a sample was obtained. After filling, a portion of the water was poured from the bag to facilitate closure and provide air space for subsequent shaking in the laboratory. By spinning the sample over the wire frame several times and twisting the wire frame together, the bag was sealed. Both ends of the wire frame were dog-eared to prevent puncture and contamination of the sample. All samples were placed on ice and transported to the laboratory.

Fecal coliform bacteria concentrations were determined for all sample stations. Fecal streptococcus, chemical parameters, and turbidity were determined at representative sites along Sabino and Bear Creeks. Stations 6, 20, and 22 duplicated sampling points previously established by U.S.F.S. personnel in an infrequent sampling programs. Table 1 lists the sample station number with the parameters collected at each station.

In addition to surface water samples, bottom sediment and stir samples at selected stations were added during the last seven months of the study. Van Donsel and Geldreich (1971) suggest that bottom sediments may be a concentrated and stable index of water quality, particularly where there is great variability in the bacterial quality of the water. Collection of chemical and physical data was reduced to permit the collection of bottom sediment data. Bottom sediment samples were collected five to six times per month during the last seven months of the study. Chemical and turbidity data were collected during the remaining three sample periods per month.

Thin deposits of stream bottom materials overlying large rock sheets and lengthy distances traveled by foot to reach sampling stations

Table 1. Sample stations and the corresponding water quality parameters.[a]

Water quality parameters	Sample Station Number																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Fecal coliform	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Water temperature	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fecal streptococcus	X				X	X										X				X		X	
Copper	X					X														X		X	
PO_4	X					X														X		X	
NO_3-N	X					X														X		X	
Turbidity	X					X														X		X	
pH	X					X														X		X	
Air temperature	X																						
Bottom sediment	X					X													X				

a. X indicates parameter collection.

discouraged the use of a core sampling instrument as outlined by Van Donsel and Geldreich (1971). Using sterile beakers to collect a sediment sample proved unsatisfactory. On the rocky bottom the glass beakers were easily chipped or broken; wading into the water would have been required to obtain sediment from the center of the stream, which might have affected sampling results. A telescoping pole with a ring on the end (golf-ball retriever) was employed to collect sediment samples permitting access to all stream bottom points. Collection ring and the lower end of the pole were disinfected with ethyl alcohol; aseptically a Whirl-pak (18 ounce size) was placed over the ring and attached to the pole with the wire frame of the bag. More than 100 ml of sediment was collected randomly by obtaining ten scoops of sediment across the stream. Previous work suggested that a minimum of ten areas be sampled within a site to reduce variation in bacteria data (Van Donsel and Geldreich, 1971). Surface waters were sampled before each bottom sediment and stir sample. Bottom sediments were collected by introducing the sample ring into the stream bed forcing sediment through the ring into the Whirl-pak. The upper two inches of bottom material were sampled to avoid diluting the sample with low count sediment (Van Donsel and Geldreich, 1971). Bottom sediment samples were collected at Stations 1, 6, 19, and SB3.

Following the collection of surface and bottom sediment samples, a stir sample was collected in the same manner as a surface sample after bottom sediments were mixed into the overlying water, causing a sediment cloud through brisk stirring of the bottom with the extension pole. For logistic purposes, the initial stir sample station (19) was changed to Station 6.

Water temperatures were measured at all stations with a standard centigrade thermometer. In all cases the thermometer bulb was submerged below the water surface during temperature readings (Kittrell, 1969). Prior to taking water temperatures, air temperatures were obtained at Station 1 and SB 1. All temperatures were recorded in a field log and transferred to the laboratory log.

Laboratory Procedures

Laboratory facilities for the study were provided by the Sanitation Engineering Laboratory, Civil Engineering Department, at The University of Arizona. Sabino Canyon Recreation Area was 45 minutes by truck from the laboratory. Upon return from the field, bottom sediment samples were transferred aseptically from the sample bag to a sterile graduated cylinder to settle and be measured. While the sediment was settling, surface water samples were processed for incubation; samples remained on ice until processing. Chemical samples were left on ice and processed immediately following bacterial procedures. Enumeration of fecal coliform and fecal streptococcus in water samples was performed using a membrane filter (MF) technique, developed by the Millipore Corporation (1973) and described in Standard Methods (American Water Works Association, 1971). Bottom sediments and stir samples were enumerated for fecal coliform using the Most Probable Number (MPN) method (American Water Works Association, 1971).

Fecal coliform bacteria (MF) were cultured on M-FC broth and incubated in a water bath at 44.5 $\pm$ 2°C for 24 hours. Fecal streptococcus bacteria (MF) were cultures on M-Enterococcus Agar and incubated

in a dry incubator for 48 hours at 35 $\pm$ .5°C. Incubated cultures were counted for indicator organisms using a 10X disecting microscope and recorded in a laboratory log.

Using a method by Van Donsel and Geldreich (1971) to enumerate fecal coliform in bottom sediments, samples were transferred into a sterile graduated cylinder and allowed to settle, then the volume of sediment and supernatant were measured. A one to one dilution of sediment and sterile buffered distilled water was made with the supernatant as a portion of the diluent. Transferring the sediment and water to a wide mouth bottle, the mixture was shaken vigorously. Ten, one, one-tenth, and one-hundredth ml were the usual dilutions tested. Fecal coliform (MPN) were cultured in the following manner. Lauryl Tryptose broth fermentation (presumptive test for coliform group) tubes were inoculated with the selected dilutions. Brilliant Green Lactose Bile broth fermentation tubes and EC Medium fermentation tubes were inoculated with positive (production of gas within 48 $\pm$ 3 hours) presumptive tubes. Positive (production of gas within 48 $\pm$ 3 hours) Brilliant Green tubes indicated a confirmed coliform group test and positive (production of gas within 24 $\pm$ 2 hours) EC Medium tubes indicate a confirmed fecal coliform test. Computing fecal coliform densities through MPN technique followed the procedures established by the American Water Works Association (1971).

Chemical and turbidity determination were based on colorimetry as the analytical method used in order to keep data consistent with previously collected data by U.S.F.S. personnel. A Hach DR-EL engineer's laboratory was used in the study. Procedures for obtaining the nitrate-nitrogen, ortho-phosphate, copper and turbidity data followed those

outlined in Hach Chemical Corporation's Methods Manual (1971). A Beckman glass electrode meter was used for the determination of pH.

Official weather stations at Palisade Ranger Station and Sabino Canyon (see Figure 2) were the source of precipitation and temperature (minimum and maximum) data for this study. Stream flow data were obtained from the United States Geological Survey.

CHAPTER 4

DATA PRESENTATION

Climatic, physical, chemical, biological, and visitor use data are introduced in this chapter to provide an overview of the 1974-1975 research results. Climatic data as air temperature, are presented as mean monthly minimum and maximum values. Precipitation data are expressed as total monthly values and also as daily values for the months of July, August, and September. Physical factors which are water temperature, turbidity, and stream flow are presented as mean monthly values. Chemical data and visitor use data as car counts are displayed in mean monthly values. Biological data are the focal point of this study. Fecal coliform and fecal streptococcus data for surface water and fecal coliform data for bottom sediment are presented in detail. Effects of climate, physical and chemical factors on the biological data are examined.

Climatic Factors

Air Temperature

Seasonal fluctuations of climatic factors establish a framework work from which other data, specifically bacteria indicators, may be analyzed. Minimum and maximum air temperatures were recorded at the Sabino Canyon Weather Station (see Figure 2). Figure 6 is a comparative graph of the minimum and maximum air temperatures; mean temperatures varied

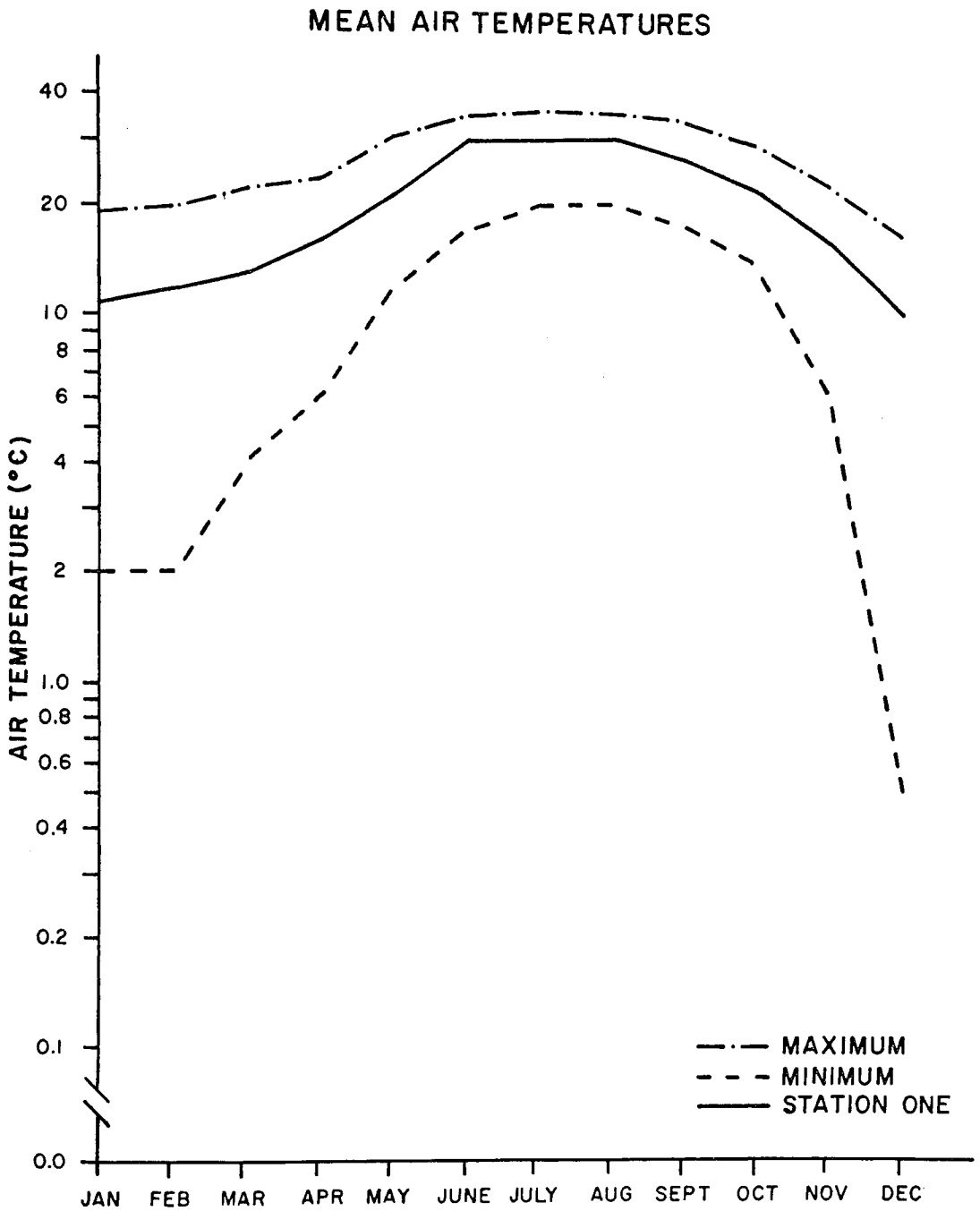

Figure 6. Mean air temperature recorded from July, 1974 through June, 1975.

from 40° in June to 0.5°C in December. Daily temperatures dictate recreational use, especially body-water contact activities. Mean air temperature collected during field procedures (Figure 6) is reflective of the mean maximum air temperature recorded at Sabino Canyon Weather Station.

Precipitation

Sabino and Bear Canyons usually receive precipitation during two seasons which are December through February and July through September. Figure 7 delineates on a monthly basis the total precipitation data recorded at Sabino Canyon and Palisade Weather Stations; the greatest total monthly events were recorded during September (7.5 inches of rain) at Palisade Weather Station and during July (3.1 inches of rain) at Sabino Canyon Weather Station. Snowfall was recorded at Palisade Weather Station from October to April. Geldreich et al. (1968) suggest that storm water surface runoff is a potential source of intermitten fecal contamination to bathing areas. Kunkle and Meiman (1967) found a flushing of bacteria from a watershed into a receiving stream after rain stroms. Summer rain events are most important to the flushing of bacteria because the summer events are local and intense rainstorms are more likely to produce surface runoff. Daily rainfall events for both stations from July through September are presented in Figures 8 to 10. During July and September both stations recorded at least 14 events; Palisade Weather Station had seven events during the summer that were greater than 0.8 inches and Sabino Canyon Weather Station had one event greater than 0.8 inches.

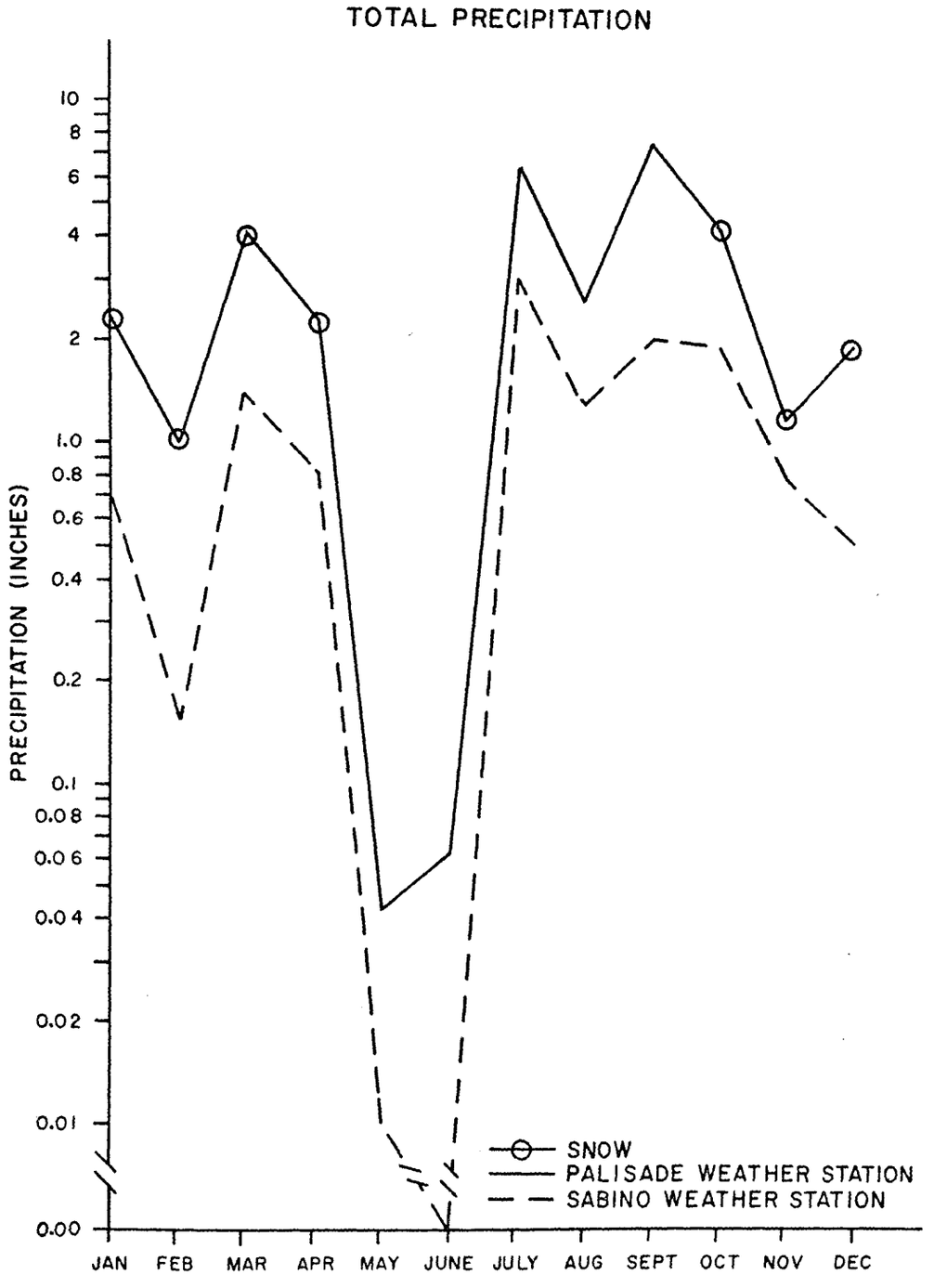

Figure 7. Total monthly precipitation recorded from July, 1974 through June, 1975.

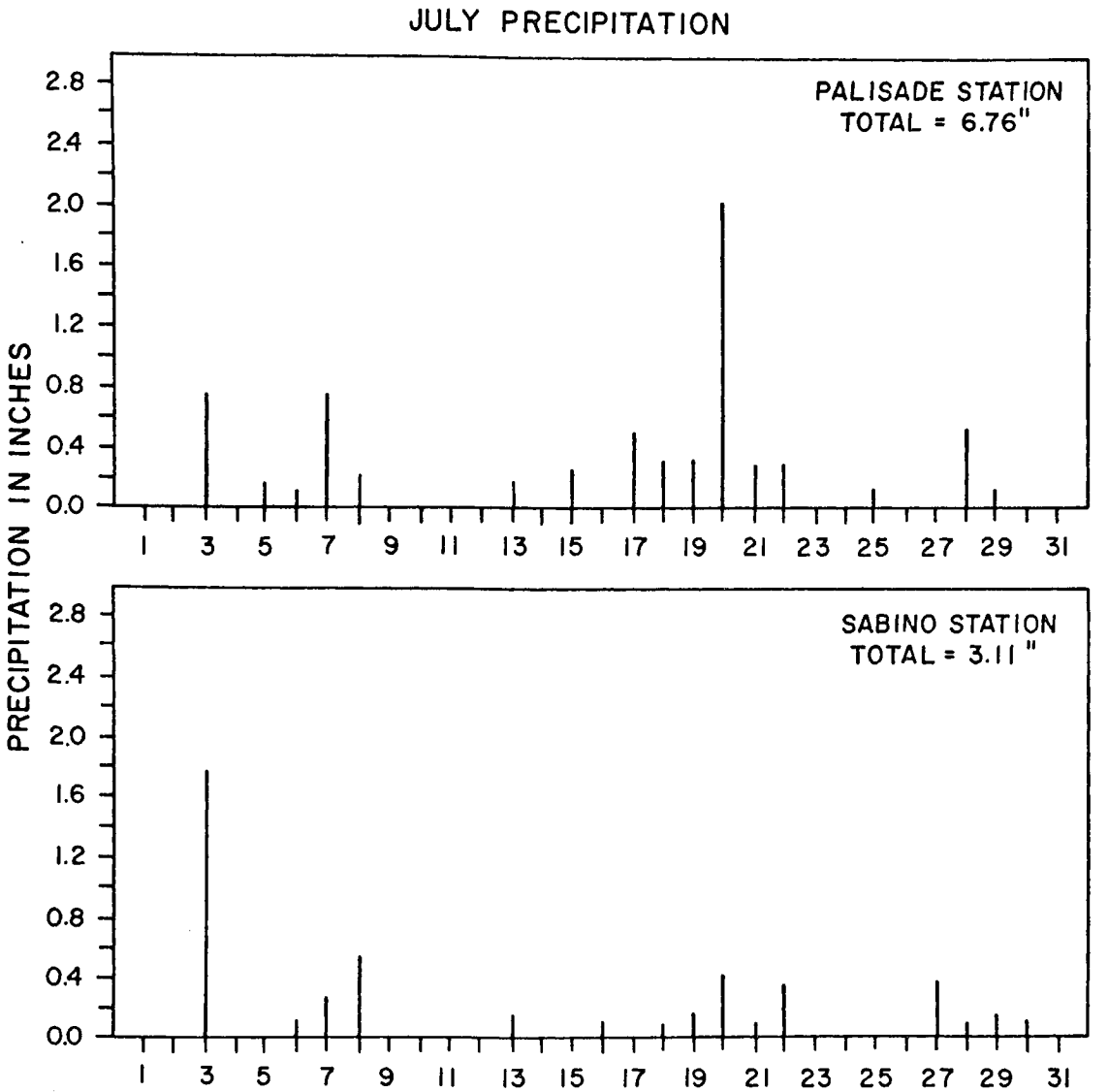

Figure 8. Daily precipitation recorded during July, 1974.

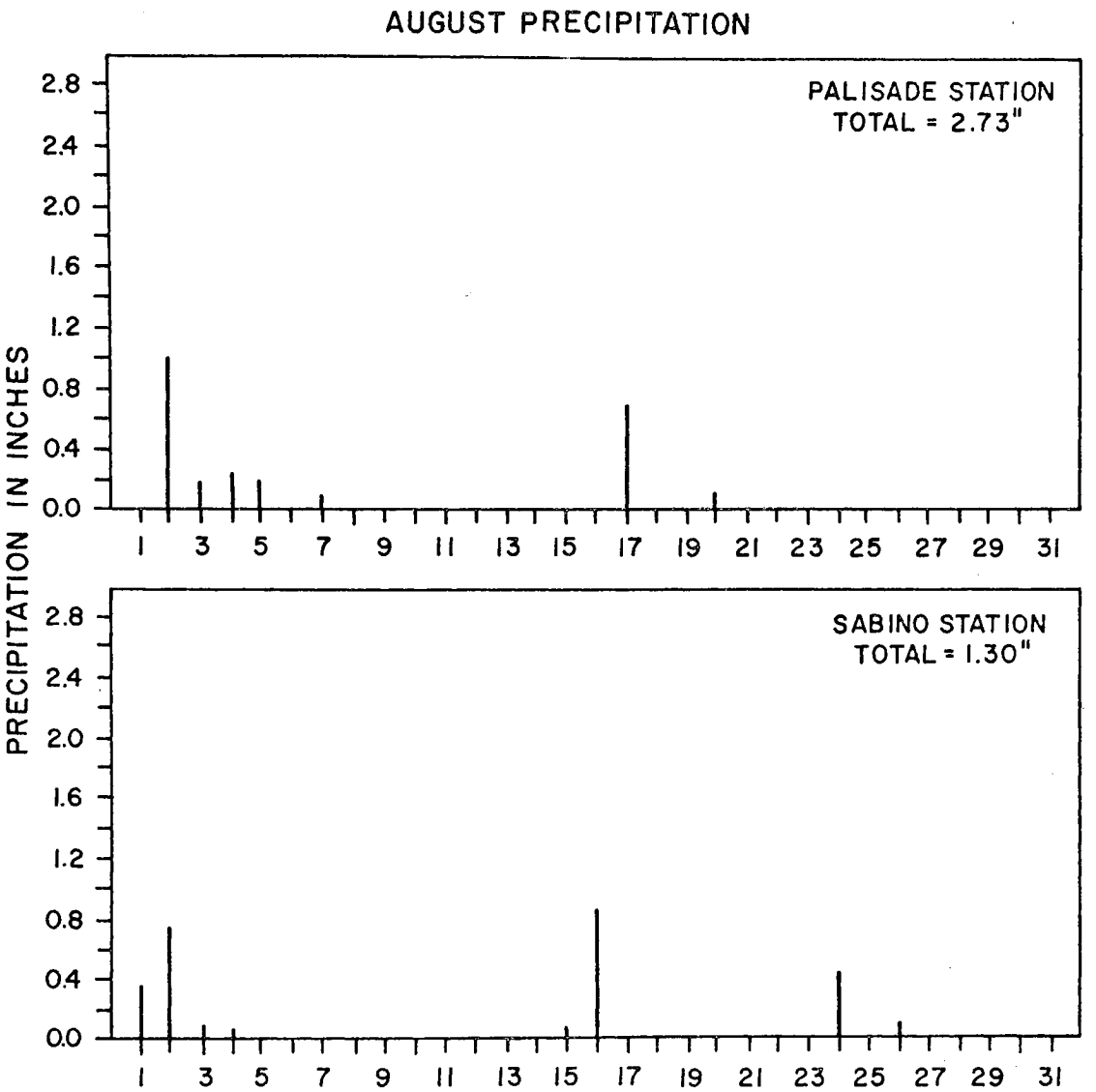

Figure 9. Daily precipitation recorded during August, 1974.

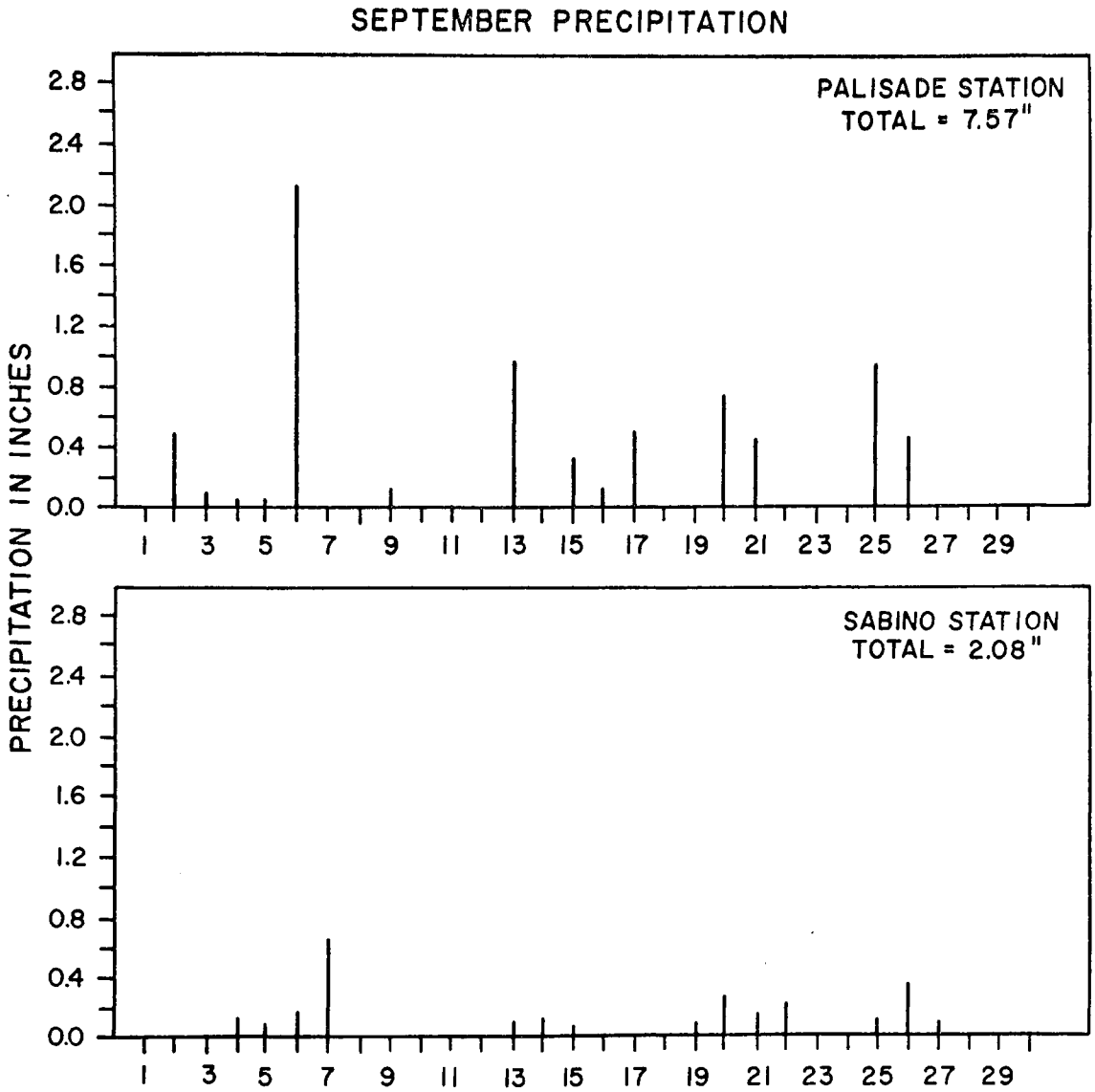

Figure 10. Daily precipitation recorded during September, 1974.

Physical Factors

Water Temperature

Water temperature was measured after the collection of each surface water sample. Survival rate of the bacterial indicators is in part determined by the environmental influences of the water temperature. Ballentine and Kittrell (1968) found prolonged survival of indicator organisms during the winter due to water temperature. Mean monthly water temperatures for Sabino Canyon Recreation Area are presented in Figure 11 and for Sabino Basin in Figure 12. Mean water temperatures for Bear Creek except for September were higher than Sabino Creek. Data for Sabino Creek ranged from 8° to 25°C and for Bear Creek from 9° to 30°C. Data for Sabino Basin are slightly lower than Sabino Creek due to the morning sample period and change in elevation. Mechalas et al. (1972) state that at water temperatures from 16° to 30°C, humans can function in water without temperature stress for a long period of time.

Turbidity Values

For the purpose of this study, turbidity was measured as the intensity of light transmitted through a water sample (Hach Chemical Corporation, 1971). Figure 13 presents the mean turbidity values for Sabino Creek (Stations 1, 6, and 20) and Bear Creek (Station 22). Mean turbidity values for Sabino Basin are presented in Figure 12. Mechalas et al. (1972) relate that mean monthly turbidity values for warm water streams in Arizona should not exceed 50 JTU. High turbidity reduces the aesthetic value of the water resource, and can reduce the performance of the membrane filter technique by blocking the filter thus preventing

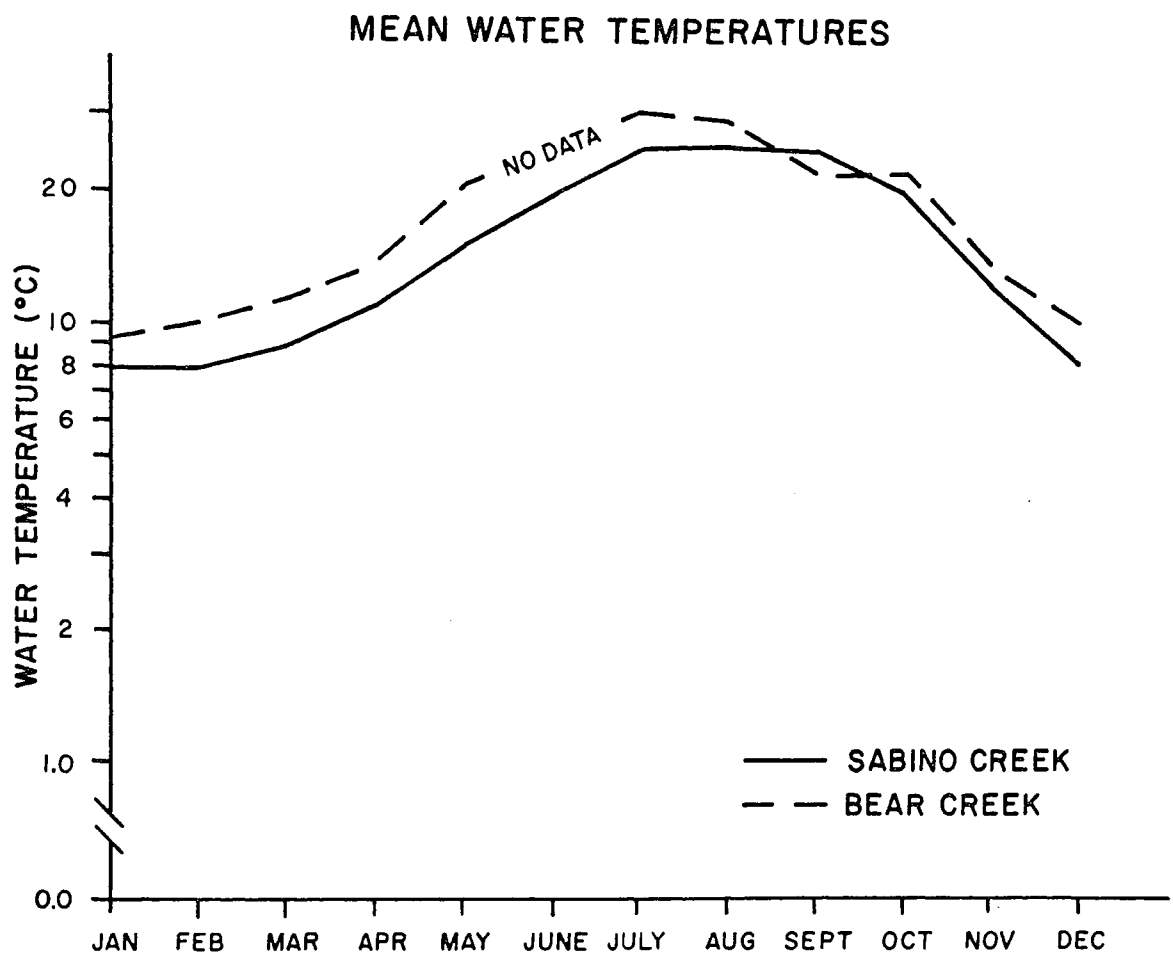

Figure 11. Mean monthly water temperature for Sabino Creek and Bear Creek from July, 1974 through June, 1975.

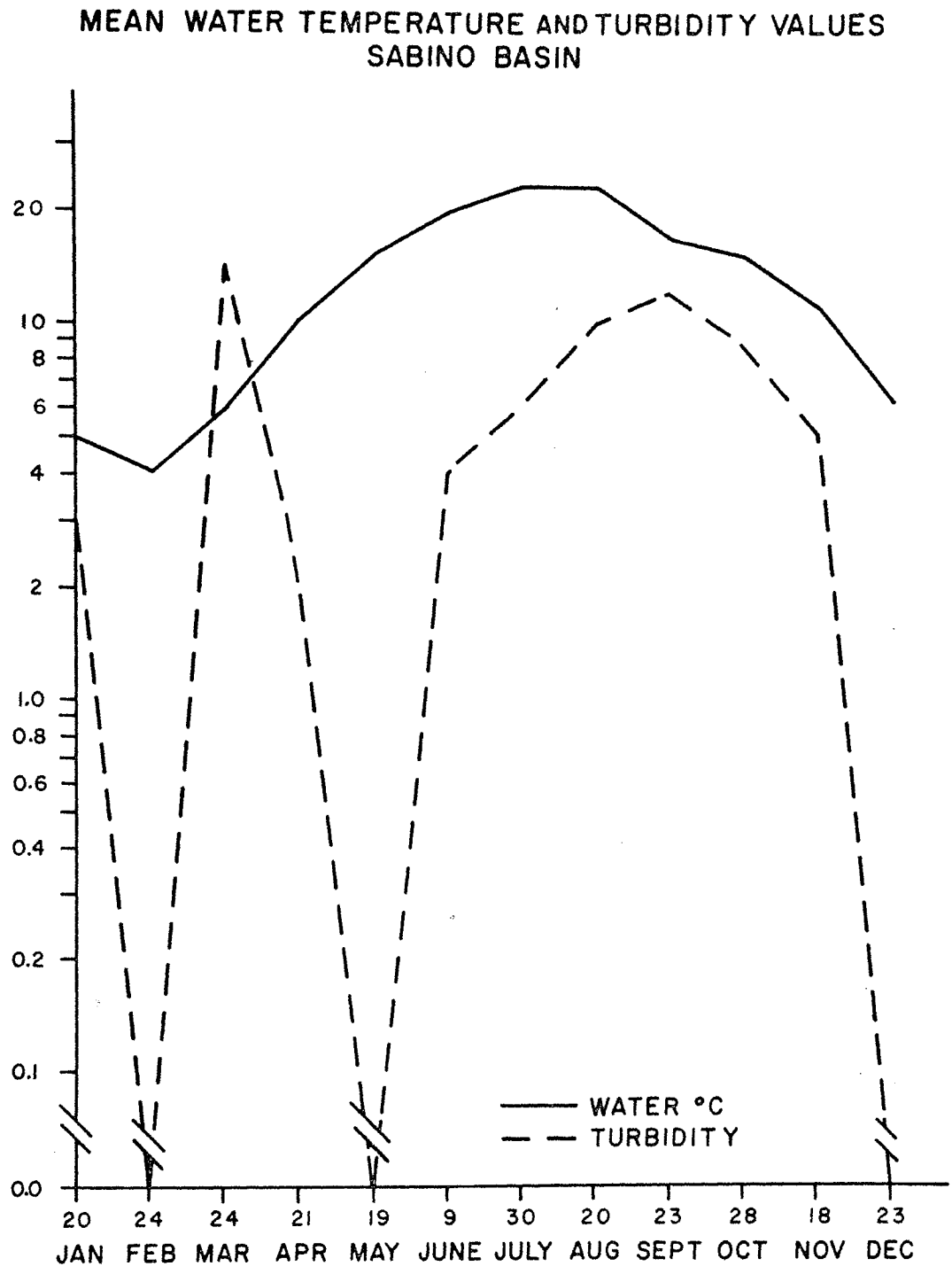

Figure 12. Mean water temperatures and turbidity values for Sabino Basin from July, 1974 through June, 1975.

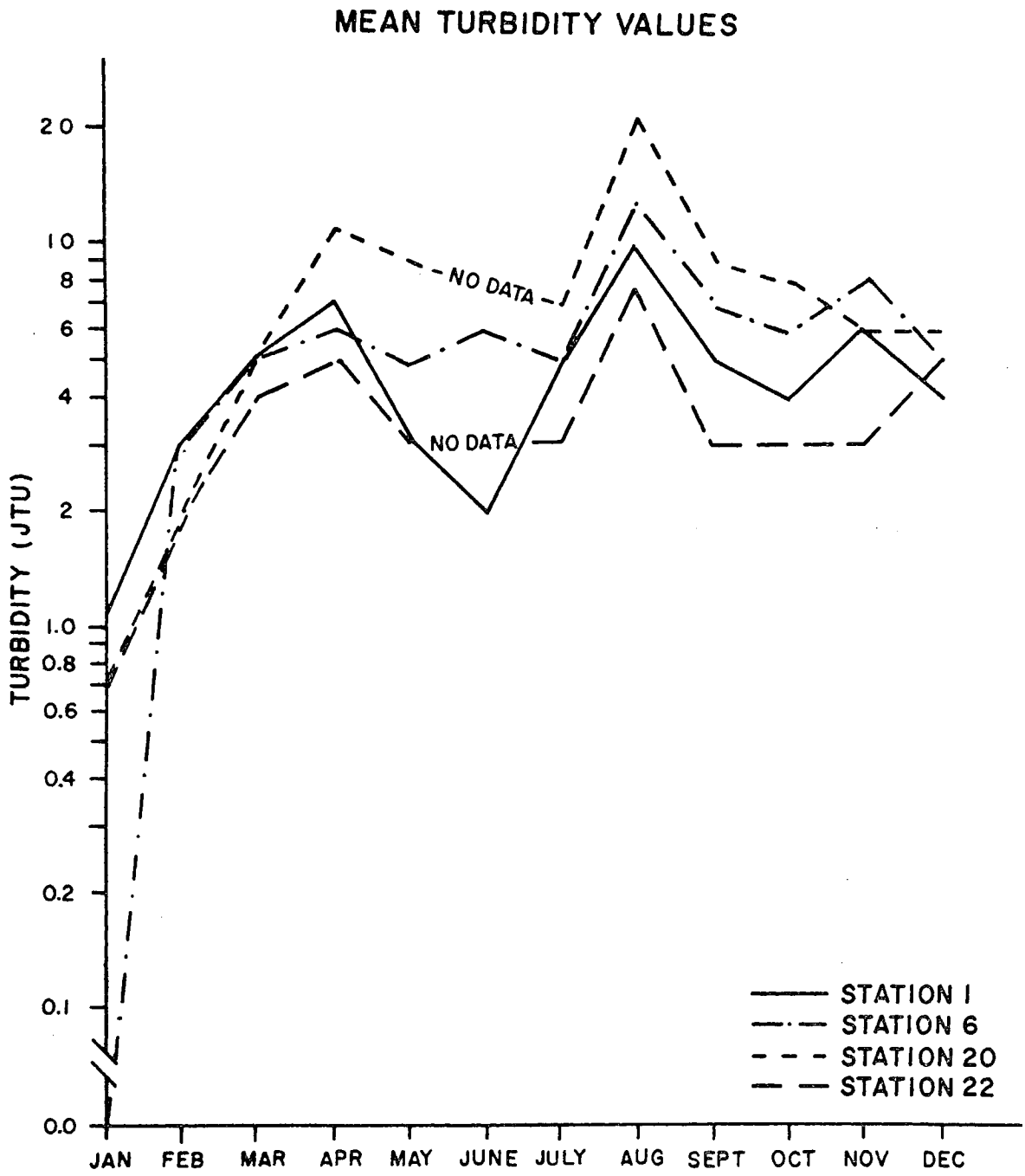

Figure 13. Mean turbidity values for Sabino Canyon Recreation Area from July, 1974 through June, 1975.

bacteria growth. Mean turbidity values for Sabino Creek ranged from zero to 22 JTU; Bear Creek values ranged from zero to 8 JTU. In Sabino Basin, mean turbidity values ranged from zero to 14 JTU.

Stream Flow

As described in the Delimitations, flow data were collected from June to September. Flow data during this period ranged from zero in both creeks to 25 CFS in Sabino Creek and 12 CFS in Bear Creek. Mean stream flow data for June through September, and the ten year mean flow data for both creeks are presented in Figures 14 and 15.

Flow rate was above 10 CFS from October, 1974, through April, 1975, determined from observation of Sabino Creek by the research team. During May, 1975, the flow rate began to decrease; Sabino Creek stopped flowing on the last sample day in June, 1975. Precipitation records (see Figure 7) indicate that flow rates were average during the study because the monthly precipitation events except for August were average.

Incomplete flow records prevent direct comparison of bacteria data with rate of flow. To obtain a general framework of the seasonal flow cycles, the ten year mean flow data were presented.

Chemical Factors

Chemical data for Sabino Creek were determined at Stations 1, 6, and 20. Statistical analyses showed no significant differences in chemical data between stations on Sabino Creek, so data are presented as the mean of the stations. Chemical data for Bear Creek were obtained at

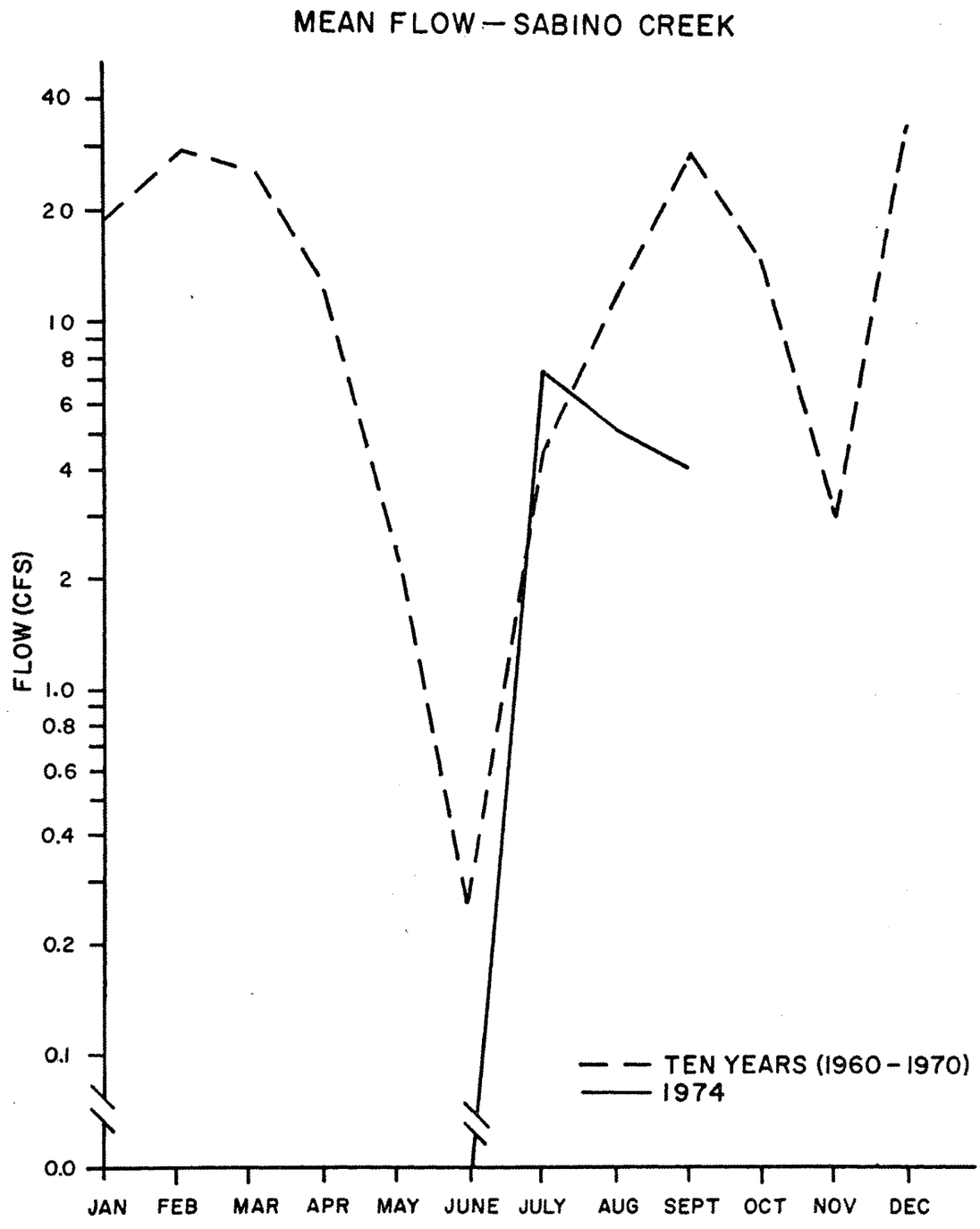

Figure 14. Mean flow for Sabino Creek.

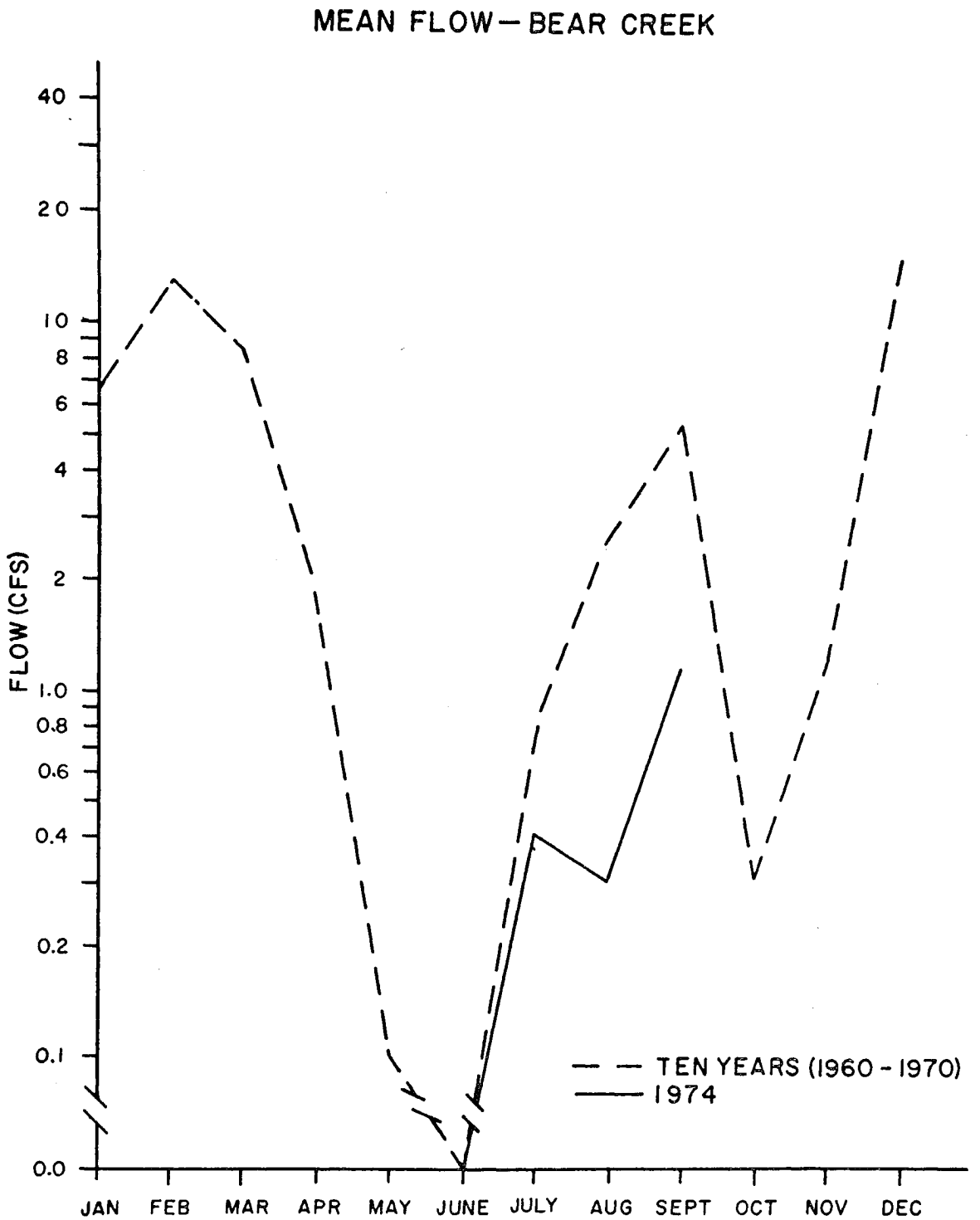

Figure 15. Mean flow for Bear Creek.

Station 22 and for Sabino Basin at Stations SB1, SB2, and SB3. Data for Sabino Basin are presented as mean values of the three stations.

Copper

Copper is a common metal in the Santa Catalina range. Shipe and Fields (1954) state that 1 mg/l of copper in water supplies can inhibit or reduce the growth of coliform organisms when the membrane filter technique is employed. Data show that copper values in all sample areas were significantly below the 1 mg/l level. Copper data are presented in Figures 16, 17, and 18.

Nitrate-nitrogen

Algae and other aquatic plant life utilize inorganic nitrogen compounds as an initial source of nitrogen in the synthesis of complex molecules for growth. In stream water the inorganic compounds of nitrogen are found in small quantities, usually less than 3 mg/l; natural sources of nitrogen are from soil runoff, precipitation on the water surface, fixation of atmospheric nitrogen, and the decomposition of bottom material (Committee Report -- American Water Works Association, 1970). Agricultural runoff and sewage effluents can introduce large quantities of inorganic nitrogen into water bodies. Inorganic nitrogen compounds in streams under aerobic conditions are rapidly oxidized by nitrifying bacteria to the nitrate form so nitrates can serve as fertilizing agents in streams. If the levels of nitrate-nitrogen are below 0.3 mg/l, excessive growth of plants and algae can be avoided (Muller, 1953, cited in Mackenthun, 1969). Mean nitrate-nitrogen data are presented in Figures 16, 17, and 18. In both Sabino Basin and Bear Creek, mean data

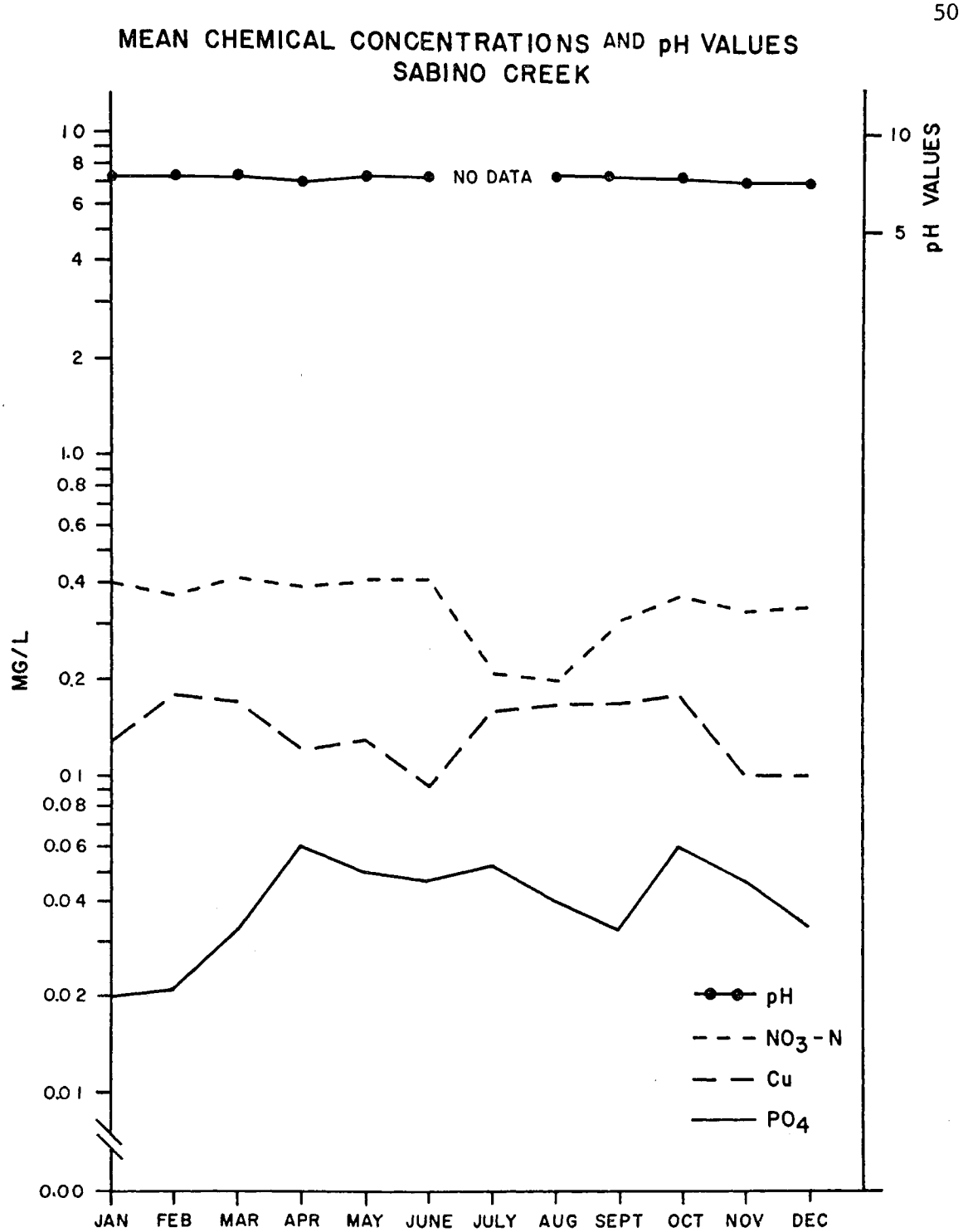

Figure 16. Mean chemical data for Sabino Creek from July, 1974 through June, 1975.

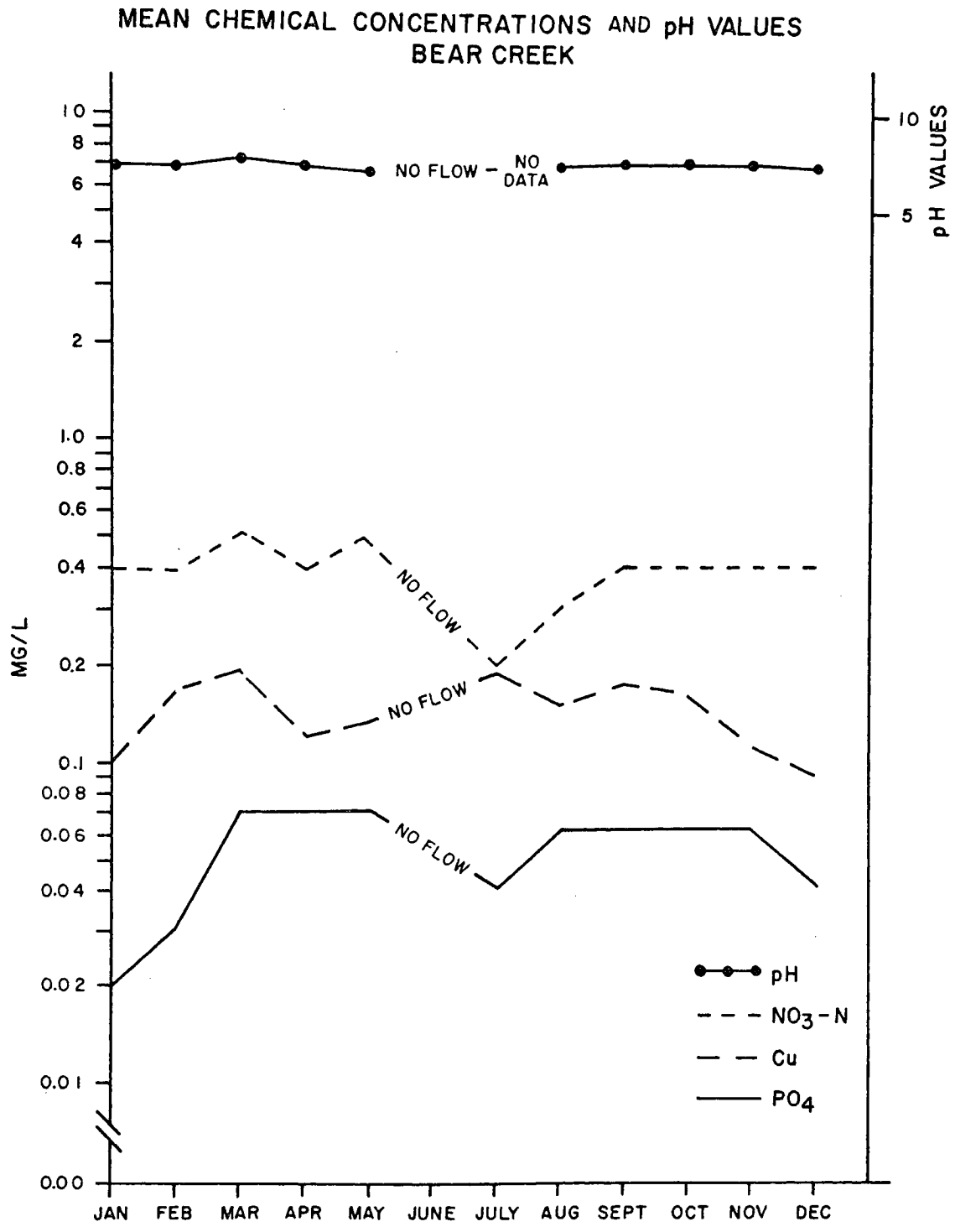

Figure 17. Mean chemical data for Bear Creek from July, 1974 through June, 1975.

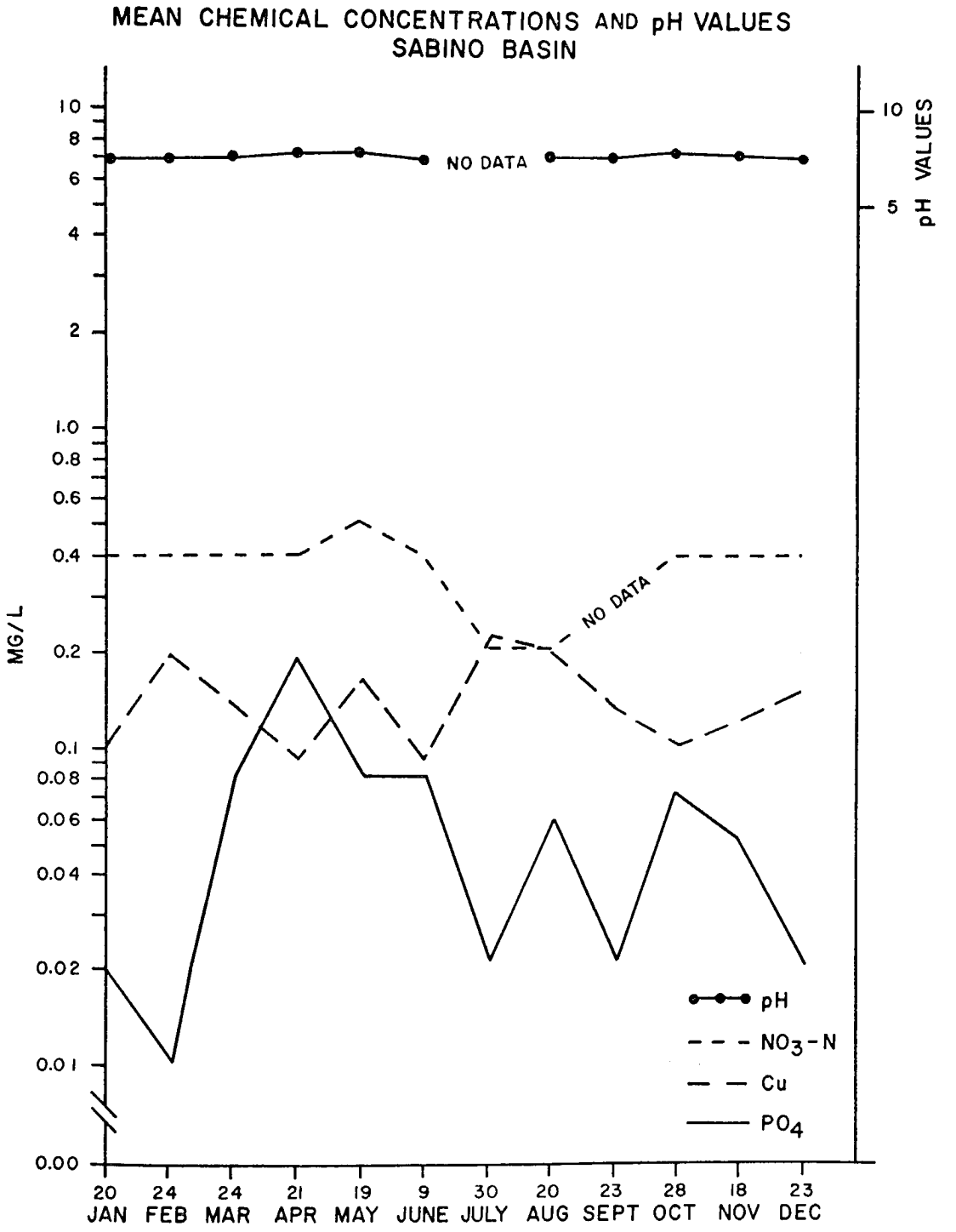

Figure 18. Mean chemical data for Sabino Basin from July, 1974 through June, 1975.

ranged from 0.2 to 0.5 mg/l and mean data for Sabino Creek ranged from 0.2 to 0.4 mg/l. Data from the three areas followed the same seasonal pattern with high values recorded during the winter months and lower values occurring during July and August. On-site observations noted excessive aquatic plant growth during June, July, and August.

Orthophosphate

In addition to nitrogen, phosphorus is another basic element for growth found in limited supply in natural waters. Hutchinson (1957) summarized phosphorus data of natural waters; phosphorus values ranged from 0.01 to 0.04 mg/l P. Natural and polluted rivers in the United States have phosphorus concentrations which range from approximately 0.01 to 1.0 mg/l P (Mackenthun, 1968). Inorganic orthophosphate and complex phosphate compounds are found in aqueous solutions. Of the total phosphorus in sewage effluents, 70 to 90 percent is in the orthphosphate[1] form (Committee report -- American Water Works Association, 1970). In flowing streams, to prevent excessive aquatic growth total phosphorus should not exceed 0.1 mg/l P (Mackenthun, 1969).

Mean orthophosphate data for Sabino Creek (see Figure 16) ranged from 0.02 to 0.06 mg/l and for Bear Creek (see Figure 17) orthophosphate data ranged from 0.02 to 0.07 mg/l. In Sabino Basin mean orthophosphate had a larger range from 0.0 to 0.19 mg/l. Unlike nitrate-nitrogen data, no apparent seasonal trend was detected from the orthophosphate data.

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1. Orthophosphate (PO_4 ≡ mg/l) = 3 X phosphorus (mg/l P).

pH

pH is the expression of the hydrogen-ion activity which is an indicator of the relative intensity of the acid or alkaline condition of a water system (Sawyer and McCarty, 1967). Most natural waters have pH values which lie between 6 and 9 (Stumm and Morgan, 1970). Figures 16, 17, and 18 present pH data which show that pH values for the study were neutral.

Biological Factors

The focal point of this study was the enumeration of fecal coliform and fecal streptococcus bacteria to assess the present condition with regard to fecal contamination of Sabino Basin and Sabino Canyon Recreation Area. Bacteria data for Sabino Basin were obtained from 164 bacterial culture plates. An equal number of fecal coliform and fecal streptococcus cultures were examined. Data for Sabino Canyon Recreation Area were obtained from 2,904 bacterial culture plates; 69 percent of the plates were fecal coliform and 31 percent were fecal streptococcus.

Substantiation of bacterial analysis procedures and results were obtained through separate analyses of the cultures taken from the study site. Non-members of the research team from the Department of Microbiology, The University of Arizona, confirmed the proper employment of investigation technique. M-FC broth is selective for the fecal coliform group which appear as rough, dark blue colonies. M-Enterococcus agar is selective for the fecal streptococcus group which appear as pink and dark red colonies. Selective medias do not always prevent the growth of exotic bacteria. Exotic colonies cultured on M-FC broth during this

study were Enterobacter aerogenes, Enterbacter sp., Pseudomonas sp., and Salmonella sp.; exotic colonies, including the insignificant species Streptococcus faecalis var liquifaciens were not observed on the M-Enterococcus culture plates.

Surface Water

Primary indicator of recent fecal contamination by warm-blooded animals is fecal coliform (Geldreich, 1966). Support for the fecal coliform data can be obtained from the fecal streptococcus group. In surface water, fecal streptococcus concentrations indicate warm-blooded fecal contamination; water without fecal streptococcus concentrations indicates little or no fecal contamination from warm-blooded animals (Geldreich, 1970).

Bacteria data were obtained from Sabino Basin on a monthly basis. Data indicate the condition of the stream at the time of sampling and were not intended to show specific trends. General surface water bacterial characteristics of Sabino Basin are presented in Figure 19. Mean fecal coliform data for the seven Sabino Basin sample stations ranged from zero/100 to 40/100 ml and mean fecal streptococcus data ranged from 6/100 to 200/100 ml.

Mean fecal coliform and streptococcus data for Sabino Creek within Sabino Canyon Recreation Area are presented in Figure 20. Mean monthly fecal coliform data ranged from less than 1/100 in December to 100/100 ml in September. Mean monthly fecal streptococcus data ranged from 25/100 in December to 300/100 ml in both July and September. Mean monthly bacteria data by sample station are presented in Appendix A.

Figure 19. Mean bacteria data for Sabino Basin from July, 1974 through June, 1975.

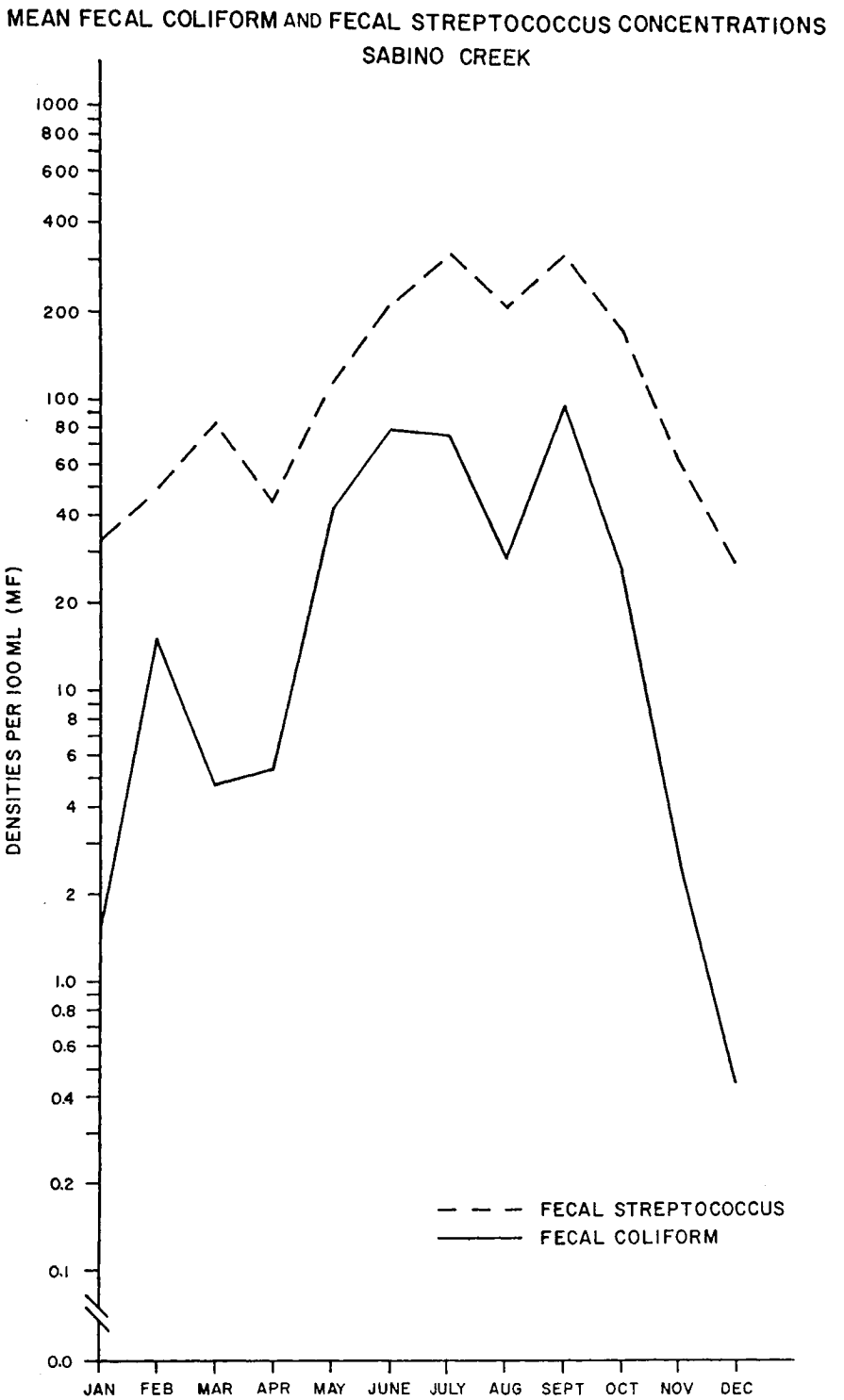

Figure 20. Mean bacteria data for Sabino Creek from July, 1974 through June, 1975.

For comparison and statistical analyses of fecal coliform data, sample stations were grouped into three sample locations (S-1, S-2, and S-3) on the basis of proximity and similarity of the site, and by the natural geographic divisions within the canyon. S-1 and S-2 represent the stations in Upper Sabino and S-3 represents the stations in Lower Sabino. Figure 21 presents sample stations divided into the three blocks and presents the mean yearly fecal coliform data per station. Mean fecal coliform values per sample station on a yearly basis are less than 50/100 ml. In order to detect differences in fecal coliform data between sample locations, data are combined in the three locations and presented on a mean monthly basis (Figure 22). Mean data (S-1) ranged from zero/100 to less than 70/100 ml with high values recorded during July and September. For S-2, mean data ranged from zero/100 in December to 90/100 ml in September and mean data (S-3) ranged from 1/100 to less than 250/100 ml. High fecal coliform values were detected during July and September.

Fecal streptococcus data were collected at Sample Stations 1, 5, and 6 (S-1) and 16 and 20 (S-3); mean data are presented in Figure 23. Mean fecal streptococcus data (S-1) ranged from 14/100 to less than 500/100 ml and mean data (S-3) ranged from 300/100 to 600/100 ml. Mean monthly fecal streptococcus data by sample station are presented in Appendix A.

Bear Creek was sampled at two locations for fecal coliform and one location for fecal streptococcus. Fecal coliform data responded the same seasonally but with different intensity (Figures 24 and 25). Bear Creek (Station 22) near the parking lot had mean fecal coliform that ranged from less than 1.0/100 in February to 90/100 ml in September,

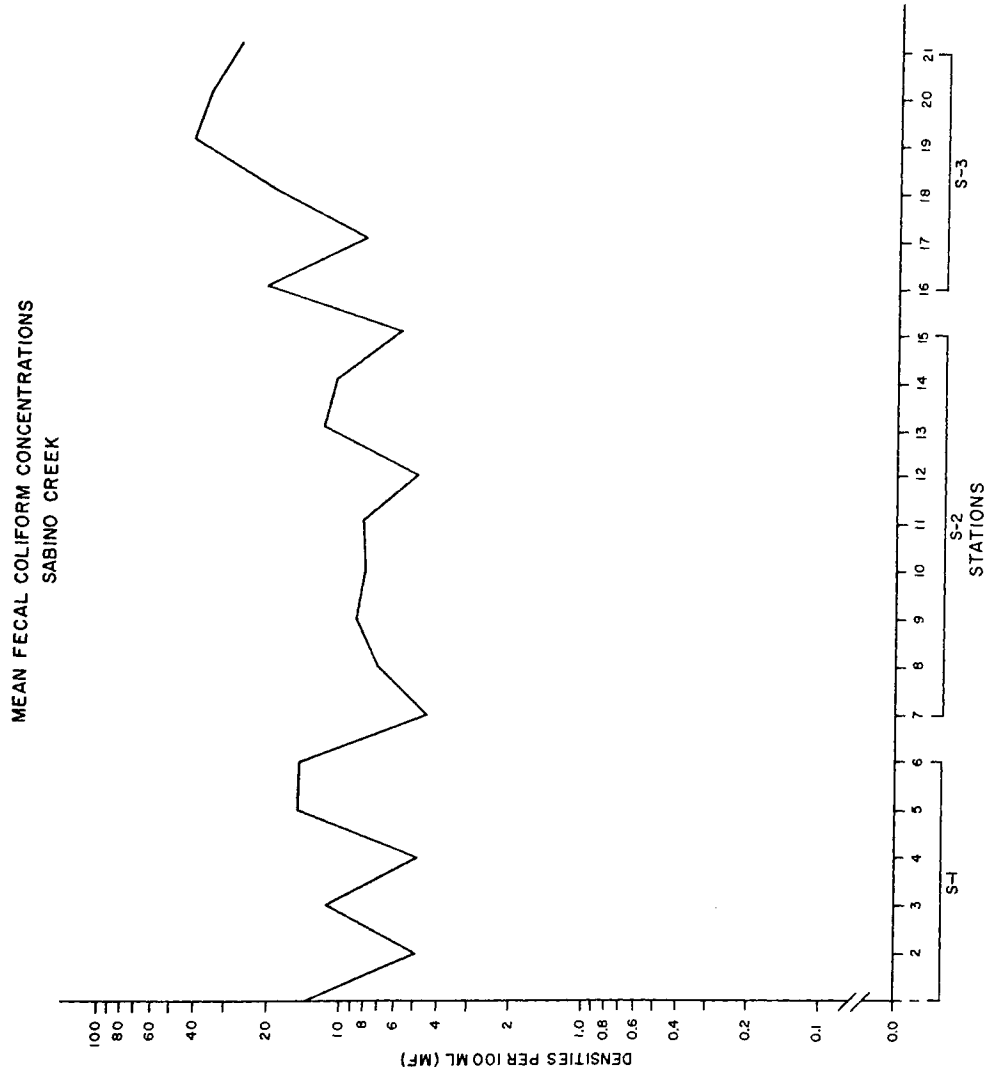

Figure 21. Mean fecal coliform data by sample station for the sample year.

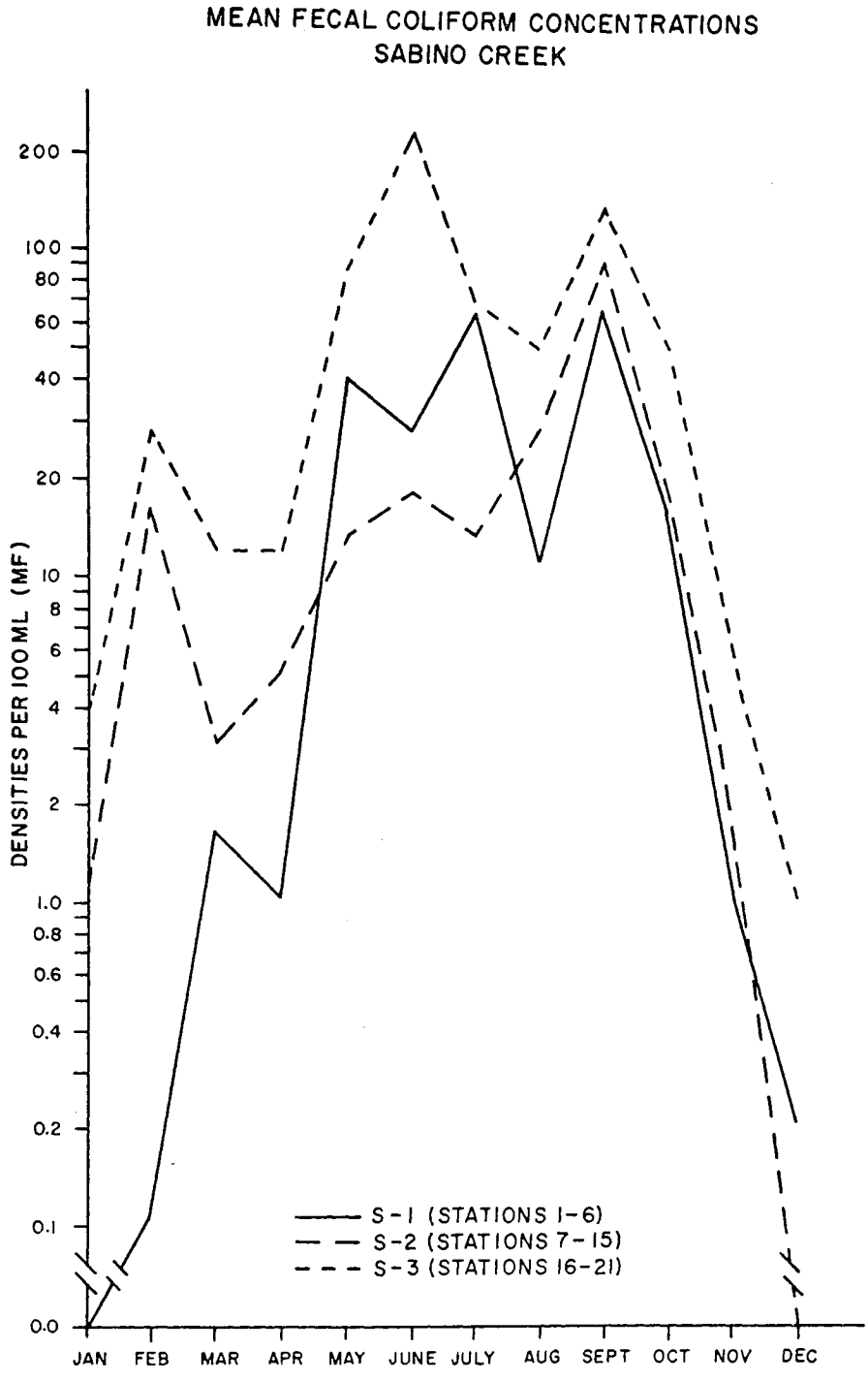

Figure 22. Mean fecal coliform data by sample location (S-1, S-2, and S-3) from July, 1974 through June, 1975.

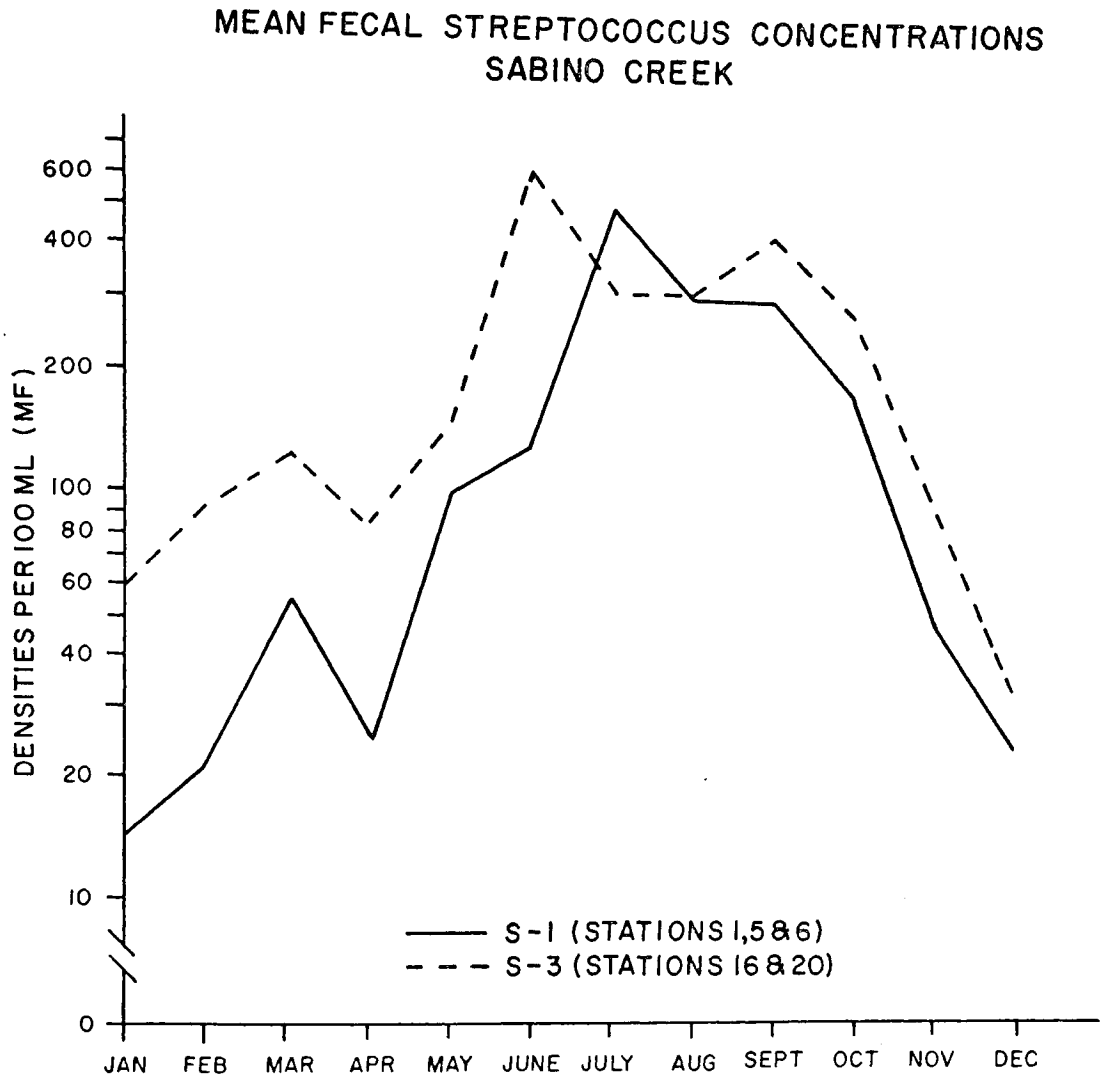

Figure 23. Mean fecal streptococcus data by sample location (S-1 and S-3) from July, 1974 through June, 1975.

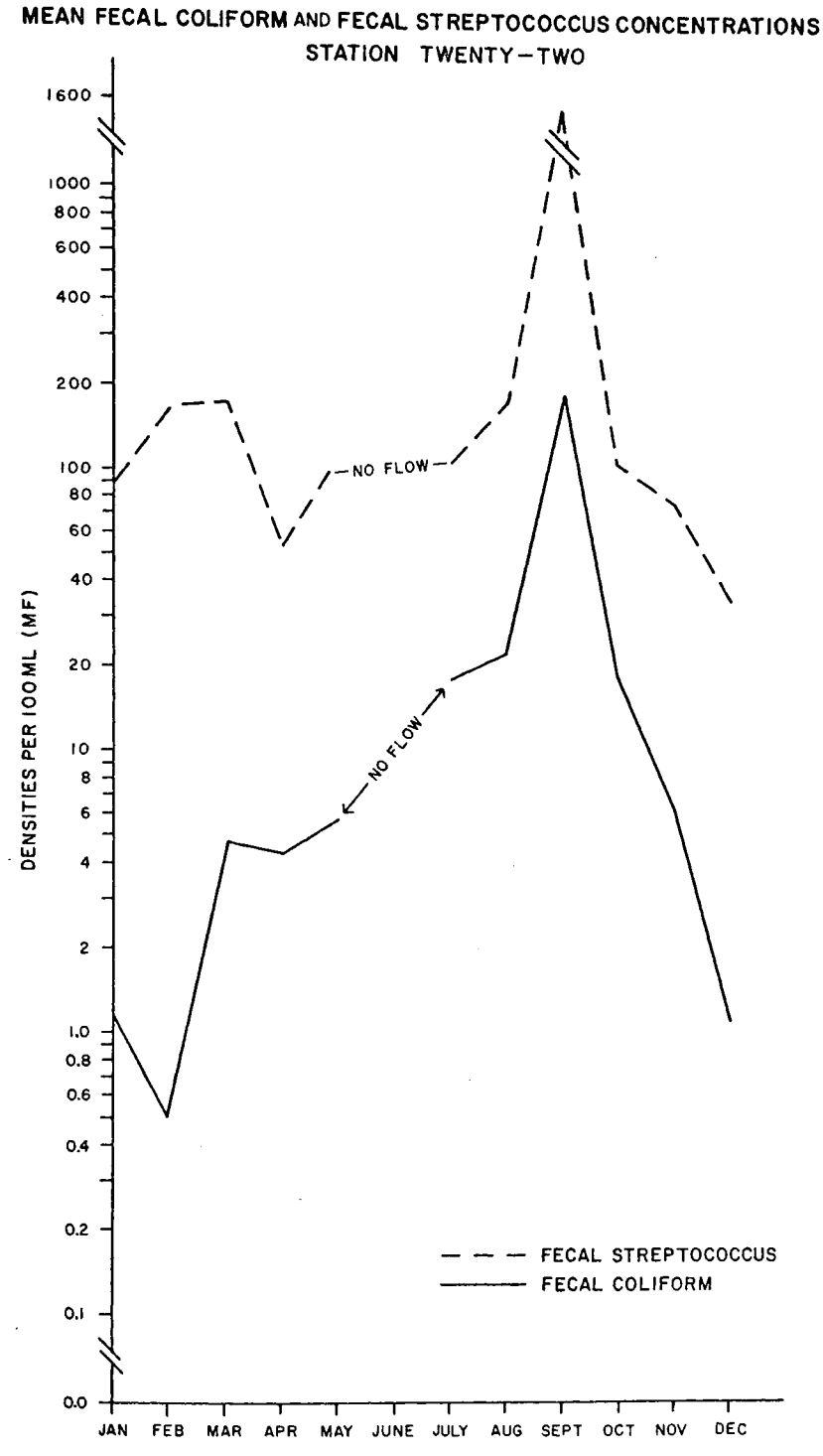

Figure 24. Mean fecal coliform and fecal streptococcus data for Station 22 on Bear Creek from July, 1974 through June, 1975.

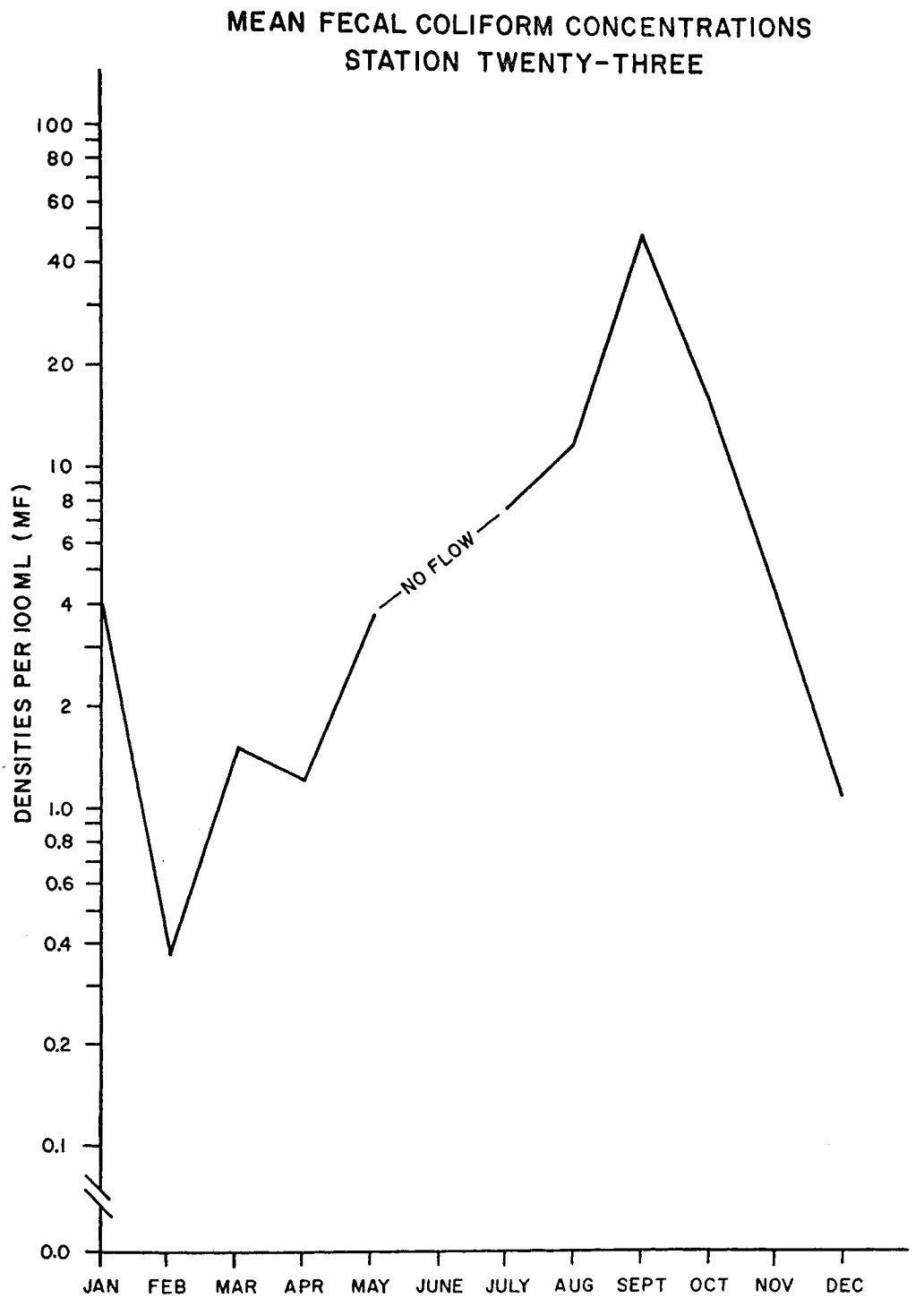

Figure 25. Mean fecal coliform data for Station 22 on Bear Creek from July, 1974 through June, 1975.

whereas mean fecal coliform data one-half mile upstream from the parking lot (Station 23) ranged from less than 1.0/100 in February to 500/100 ml in September.

Mean fecal streptococcus data for Bear Creek (Station 22) ranged from 30/100 in December to greater than 1500/100 ml in September.

Time sampling of Sabino Creek surface water on two warm weather holidays (Labor Day, 1974 and Memorial Day, 1975) was conducted to determine the relationship between the highest visitor use days and fecal coliform counts on Sabino Creek. Five water samples were collected at Stations 6 and 19 on Labor Day and Station 19 on Memorial Day from morning to mid-afternoon.

Labor Day, 1974 was the first time in a year that visitors were allowed to drive into Sabino Canyon. Cars were allowed up to Station 14 (see Figure 1). Station 6 was sampled on Labor Day; mass penetration by the recreational users up the canyon was anticipated by the research team because of easier access to Upper Sabino Canyon. Users on Labor Day moved toward Station 6; the area was crowed by midday.

Due to traffic problems created on Labor Day, car access on Memorial Day was limited to Station 19 and Cactus Picnic area (see Figure 2). On Memorial Day, Station 19 received intensive use from the start of the day.

Data show (Figure 26) increasing fecal coliform counts in Sabino Creek from morning to mid-afternoon on Labor Day (Station 6) and Memorial Day (Station 19). Fecal coliform values ranged from 4/100 to 40/100 ml in the morning to 600/100 ml in mid-afternoon. On Labor Day, fecal coliform values at Station 19 did not increase but remained near 200/100 ml

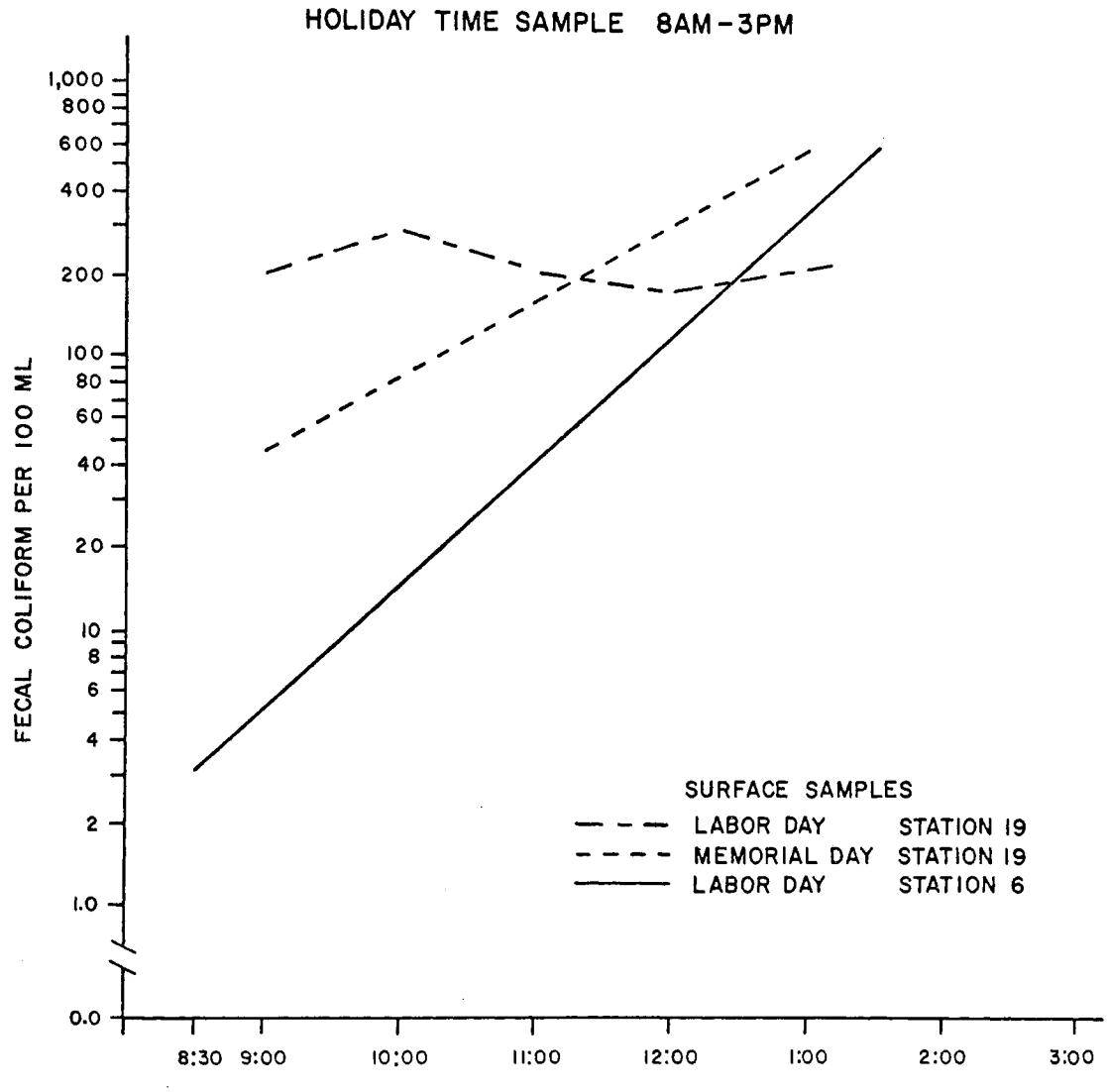

Figure 26. Holiday time sample for fecal coliform at selected sample stations.

through the sampling day which may be due to the lower than normal uses previously noted.

Increase in fecal coliform concentrations in surface water may be a result of corresponding increase of recreation activity in water and subsequent stirring of bottom sediment.

Bottom Sediment

Figure 27 demonstrates the difference of mean fecal coliform bacteria in bottom sediments and surface water; data show larger concentrations of fecal coliform in the bottom sediment. Mean monthly concentrations of fecal coliform in the bottom sediment ranged from 150/100 to 4500/100 ml. Six of the seven mean monthly fecal coliform values exceed 200/100 ml; five exceed 800/100 ml and three exceed 1000/100 ml. Surface water mean fecal coliform values, corresponding to bottom sediment samples, range from less than 10/100 to 120/100 ml. Daily mean fecal coliform values (Figure 28) of bottom sediment and surface water (38 sample periods) show consistently higher concentrations of fecal coliform in bottom sediment than in surface water at the three bottom sediment sampling stations (Stations 1, 6, and 18). Mean fecal coliform concentration in bottom sediment range from 20/100 to 8000/100 ml within the seven month period. Twenty-seven of 38 mean fecal coliform values exceed 200/100 ml; 15 values exceed 1000/100 ml. Mean fecal coliform concentrations of surface water range from zero/100 to 490/100 ml. Only one mean fecal coliform value exceeds 200/100 ml. Bottom sediment data and corresponding surface water data for the three sample stations (1, 6, and 19) are presented in Appendix B.

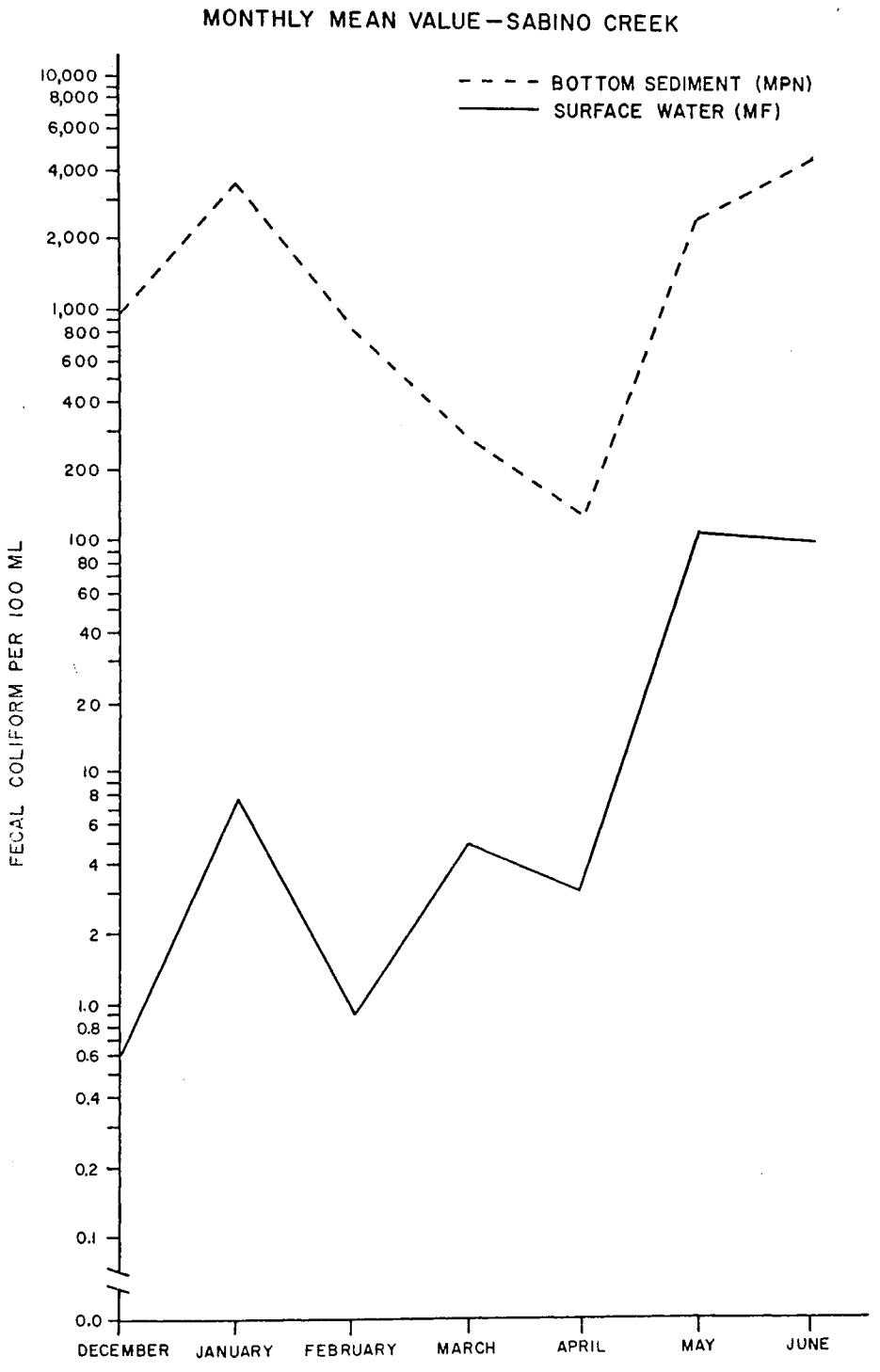

Figure 27. Monthly mean fecal coliform data for Sabino Creek bottom sediment and corresponding surface water samples.

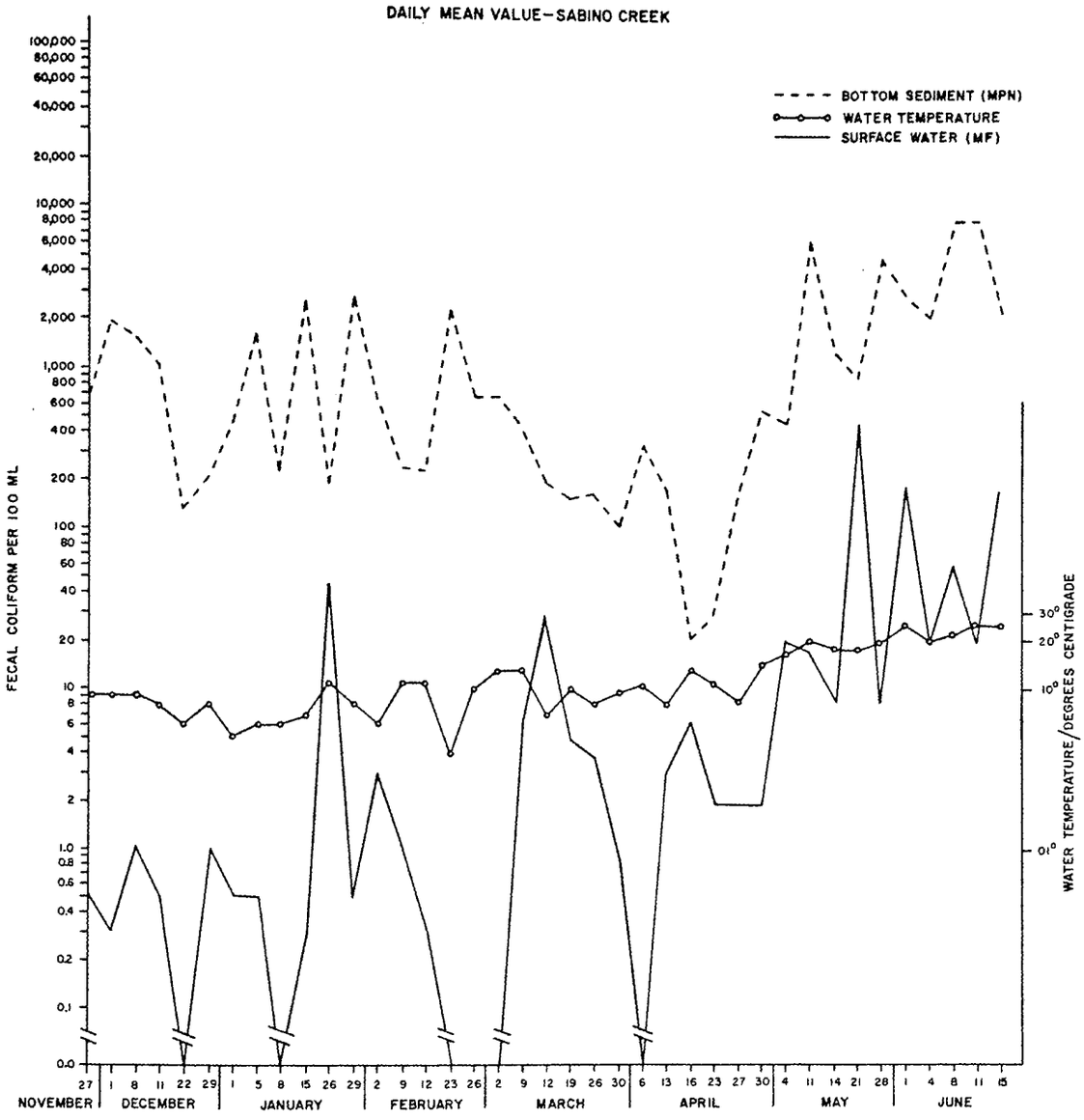

Figure 28. Daily mean fecal coliform data for Sabino Creek of bottom sediment and corresponding surface water samples.

Bottom sediment data were also obtained at Hutch's Pool within Sabino Basin. Data of seven samples (Figure 29) show that in the bottom sediment fecal coliform range from 80/100 to 16,000/100 ml and surface water fecal coliform range from zero/100 to 36/100 ml.

Stir Samples

Stir samples were collected after bottom sediments were mixed into the overlying water in order to casually test whether the disturbance of bottom sediment could significantly increase the concentration of fecal coliform in surface water. Stir sample data (Figure 30) show that in 37 of 38 sampling periods, stir sample fecal coliform concentrations exceed surface samples. Some stir samples exceed 200/100 ml. High surface water fecal coliform count on May 21 represents direct introduction of fecal matter into the water just prior to sampling.

Visitor Use

Sabino Canyon Recreation Area was closed to personal motorized vehicles on October 1, 1973, due to construction of a sanitation system. On September 2, 1974, personal motorized vehicles were again permitted into the recreation area. Table 2 is a list of monthly car counts from September, 1974 through June, 1975. More than 10,000 cars per month were recorded with over 32,000 cars counted during January. Motorized vehicles were limited to lower Sabino and Lower Bear so both of these areas received intensive vehicular traffic pressure throughout the sampling year, especially on weekends and holidays. More than 2,400 vehicles on Labor Day and 1,000 vehicles on Memorial Day entered Sabino Canyon Recreation Area; a weekend in January over 3,000 cars were counted.

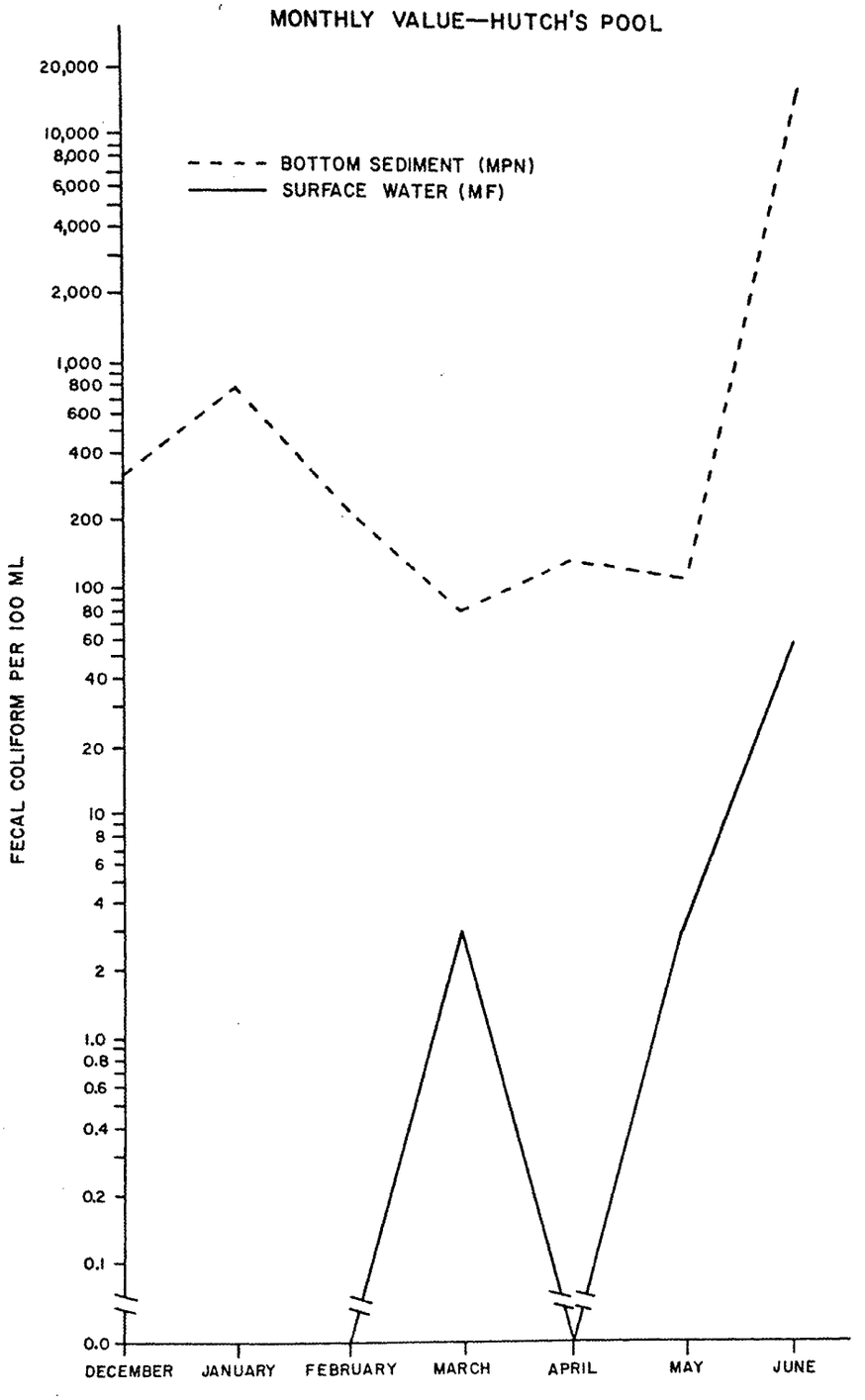

Figure 29. Fecal coliform data for Sabino Basin of bottom sediment and corresponding surface water samples.

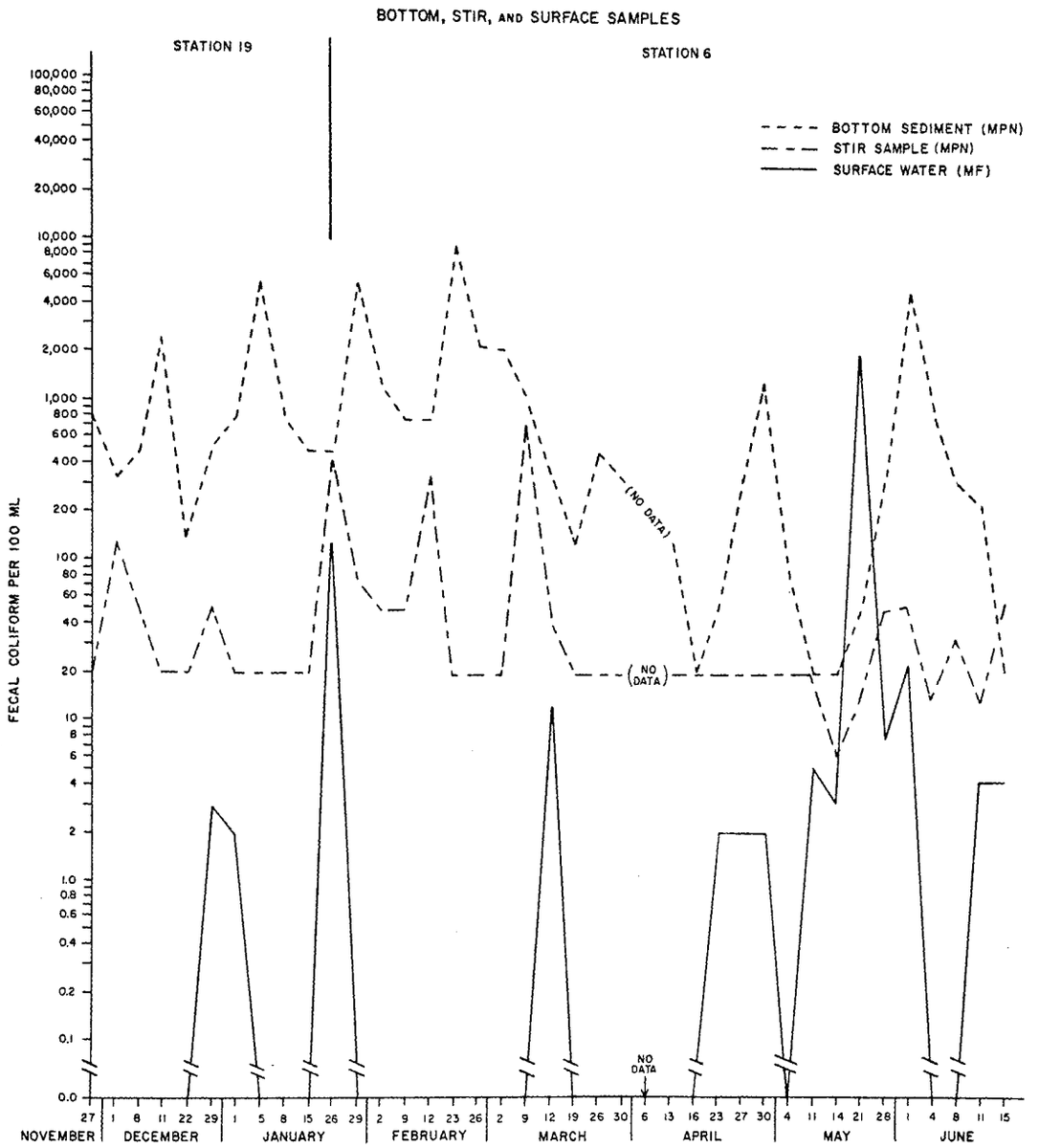

Figure 30. Stir sample fecal coliform data with corresponding bottom sediment and surface water samples.

Table 2. Number of vehicles that entered Sabino Canyon Recreation Area on a monthly basis from September, 1974 through June, 1975.[a]

Month	Number of Vehicles
September	11,582
October	13,277
November	11,759
December	22,977
January	32,823
February	19,930
March	20,718
April	18,725
May	18,153
June	11,022
Ten Month Total	181,066
724,264 people[b]	

a. Sabino Canyon Recreation Area was closed to cars from Ocrober 1, 1973 to September 1, 1974.

b. The total number of people is determined from an average figure of four persons per vehicle.

CHAPTER 5

RESULTS AND DISCUSSION

Results discussed in this chapter represent significant differences among sample populations. Graphical comparison, analysis of variance, and Student's t-test were employed to detect differences in water quality data. Differences in mean fecal coliform data due to treatments of time, day, and location were determined through a three-way analysis of variance. Significant differences in fecal coliform data were used to determine which treatments produced higher fecal coliform counts. Significant differences between the other water quality parameters were based on Student's t-test. Significant difference for analysis of variance and Student's t-test was set at the five percent level.

Statistical Results

Analysis of Variance

Steel and Torrie (1960, p. 281) state "the valid application of tests of significance in the analysis of variance requires that the scale of measurement should be one for which the linear additive model holds." With biological data such as bacteria counts, which exhibit a wide range of positive integers, a logarithmic transformation of the data conforms to the linear additive model. For data with values from zero to 10, log (x+1) must be used (Steel and Torrie, 1960).

Fecal coliform data for the analysis of variance was transformed as follows: log (fecal coliform + 1). Results of the analysis of variance are presented as the transformed data because Steel and Torrie (1960) warn that changing analysis of variance results back to the original scale of measurement is not proper.

This experiment was designed so that each of the 18 sub-populations would be sampled within a three week period. Analysis of variance was determined on each three week period. Through the course of this study, 17 three week periods were obtained. Results of the analysis of variance are focused on nine of the three week periods which were determined to be biologically important through graphical analyses (see Figures 20-22).

Time of Sample. As explained in Chapter 3, times of sampling were 8 a.m., 12 noon, and 4 p.m. Based on the analysis of variance, seven of the nine three week periods were significant with time as well as treatment. Results are presented in Table 3. For the significant F-values, the least significant difference was used to determine the important factor among the three mean values. Analysis of variance indicates that five of the seven three week periods had significantly larger mean fecal coliform concentrations with 4 p.m. as the sample time period. Although 8 a.m. and 12 noon time periods had some significantly high mean values, most were co-significant with the 4 p.m. time period. Wildlife early morning watering or intensive recreation may account for high mean values at 8 a.m. and 12 noon. Accumulation of in-water and associated land-based recreation use through the day would account for the high mean values at the 4 p.m. sample period.

Table 3. Results of the analysis of variance with mean (log [fecal coliform + 1]) fecal coliform concentrations as determined by the treatment time for nine three-week sample periods.[a]

Three Week Sample Period	F-value / Significance	08 AM	12 NOON	04 PM
07/03/74 to 07/21/74	3.38 / .047	2.12	1.09	1.46
07/24/74 to 08/11/74	13.96 / .001	1.03	1.36	1.40
08/14/74 to 09/01/74	2.29 / .105	1.11	0.97	1.11
09/04/74 to 09/22/74	8.51 / .001	1.85	1.32	1.69
09/25/74 to 10/13/74	26.65 / .001	1.79	1.39	1.30
10/16/74 to 11/03/74	37.66 / .001	1.02	0.67	1.17
04/23/75 to 05/11/75	24.18 / .001	0.20	0.56	0.83
05/14/75 to 06/01/75	7.48 / .001	0.54	0.87	1.05
06/04/75 to 06/22/75	0.03 / .999	0.94	0.94	1.09

a. Underlined mean values are significant by the Least Significant Difference Test.

Day of Sample. Two sample days (Sunday and Wednesday) represent the relative high and low recreation use within Sabino Canyon Recreation Area. Based on the analysis of variance, six of the nine three week periods were significant with day as the treatment. Results are presented in Table 4. Analyses show that mean fecal coliform data were significantly higher on Sunday than on Wednesday. On weekends and holidays, USFS personnel would have to close recreation area to cars by midday to reduce recreation pressure but this problem did not occur on weekdays. Analyses of fecal coliform data reflect the visitor use pattern for Sunday and Wednesday.

Location of Sample. As discussed in Chapter 4, the twenty-one sample stations were grouped into three sample locations. Based on the analysis of variance, eight of the nine three week periods had significantly larger mean fecal coliform concentrations with location as the treatment. Results are presented in Table 5. For the significant F-values, the least significant difference was used to determine the important value among the three values. Analyses show that mean fecal coliform data were significantly higher at sample location S-3, which is Lower Sabino. Higher mean fecal coliform samples from Lower Sabino than Upper Sabino can be explained in three ways: (1) Upper Sabino was closed to cars while Lower Sabino was surrounded by parking for cars, thus visitors had easy access to Lower Sabino; (2) Lower Sabino is an attractive swimming area due to the beach effect created by Sabino Lake Dam; (3) Accumulation of upstream fecal contamination would flow into Lower Sabino from Upper Sabino.

Table 4. Results of the analysis of variance with mean (log [fecal coliform + 1]) fecal coliform concentrations as determined by the treatment day for nine three-week sample periods.[a]

Three Week Sample Period	F-value / Significance	Sunday	Wednesday
07/03/74 to 07/21/74	0.43 / .999	1.41	1.71
07/24/74 to 08/11/74	7.21 / .008	1.37	1.17
08/14/74 to 09/01/74	4.56 / .033	1.15	0.98
09/04/74 to 09/22/74	15.19 / .001	1.80	1.43
09/25/74 to 10/13/74	77.08 / .001	1.76	1.23
10/16/74 to 11/03/74	119.58 / .001	0.69	1.22
04/23/75 to 05/11/75	10.65 / .001	0.64	0.42
04/14/75 to 06/01/75	3.36 / .066	0.92	0.72
06/04/75 to 06/22/75	0.72 / .999	1.09	0.89

a. Underlined mean values are significant by the analysis of variance.

Table 5. Results of the analysis of variance with mean (log [fecal coliform + 1]) fecal coliform concentrations as determined by the treatment location for nine three-week sample periods.

Three Week Sample Period	F-value / Significance	S-1	S-2	S-3
07/03/74 to 07/21/74	0.64 / .999	1.40	no data	1.72
07/24/74 to 08/11/74	15.15 / .001	1.02	1.26	1.51
08/14/74 to 09/01/74	26.87 / .001	0.89	0.75	1.54
09/04/74 to 09/22/74	9.38 / .001	1.41	1.50	1.94
09/25/74 to 10/13/74	7.57 / .001	1.34	1.48	1.66
10/16/74 to 11/03/74	21.49 / .001	0.84	0.83	1.19
04/23/75 to 05/11/75	83.63 / .001	0.21	0.22	1.17
05/14/75 to 06/01/75	39.58 / .001	0.44	0.51	1.52
06/04/75 to 06/22/75	29.11 / .001	0.41	0.87	1.69

a. Underlined mean values are significant by the Least Significant Difference Test.

Student's t-test

Student's t-test was calculated to determine differences between sample populations on Sabino Creek and between sample populations on Sabino and Bear Creeks.

Turbidity Values. As presented in Figure 13, turbidity values recorded from the four points on Sabino and Bear Creeks were not similar. Results of t-test on turbidity data are presented in Table 6. Stations 1 and 22 had similar mean turbidity values and both of these stations had mean turbidity values significantly lower than Station 20. Mean turbidity values for Station 22 were also significantly lower than Station 6.

Chemical Factors. Figures 16 and 17 show that chemical data were different on Sabino and Bear Creeks. Results of t-test on chemical factors are presented in Table 7. Stations 1 and 6 on Sabino Creek had significantly lower nitrate-nitrogen concentrations than Station 22 on Bear Creek; Station 22 also had a significantly higher concentration of ortho-phosphate than Station 1.

Biological Factors. Mean fecal streptococcus concentrations for the six sample stations on Sabino and Bear Creeks were similar through the sampling year. Student's t-test did not show significant differences in data among the sample locations.

Differences in mean fecal coliform concentrations were presented in the analysis of variance section. Analyses of fecal coliform data between Sabino and Bear Creeks were based on the t-test. Results are presented in Table 8. Results of the analysis of variance and Student's t-test show that Lower Sabino had significantly higher fecal coliform concentrations than Lower Bear and both sections of Upper Sabino.

Table 6. Student's t-test results indicating significant differences between turbidity values on Sabino and Bear Creeks.

Variable	Groups	No. of Cases	Mean JTU	Standard Deviation	t Value	Degrees of Freedom	Significance Level
Turbidity Values	Station 1	51	5.0	5.2	2.85[a]	65	2.00
	Station 20	44	9.5	9.3			
	Station 6	50	6.7	5.4	2.99[a]	80	2.01
	Station 22	42	3.8	3.6			
	Station 20	44	9.5	9.3	3.77	56	2.01
	Station 22	42	3.8	3.6			

a. Separate variance estimate of t.

Table 7. Student's t-test results indicating significant differences between chemical concentrations for Sabino Creek and Bear Creek.

Variable	Groups	No. of Cases	Mean mg/l	Standard Deviation	t value	Degrees of Freedom	Significance Level
PO_4	Station 1	50	0.04	0.02	-2.18	88	2.00
	Station 22	40	0.06	0.03			
NO_3-N	Station 1	51	0.32	0.11	-2.24	89	2.00
	Station 22	40	0.38	0.13			
	Station 6	49	0.31	0.10	-2.59	87	2.00
	Station 22	40	0.38	0.13			

Table 8. Student's t-test results indicating significant differences between fecal coliform concentrations for Sabino Creek (S-1) and Bear Creek.

Variable	Groups	No. of Cases	Mean #/100ml	Standard Deviation	t value	Degrees of Freedom	Significance Level
Fecal	Bear Creek	163	10.6	46.9	5.00[a]	713	1.96
	Lower Sabino (S-1)	561	53.9	185.6			

a. Separate variance estimate of t.

Discussion

Research in the field situation presents the study team with external variables such as climatic factors which must be examined in the discussion of water quality data. Results of statistical tests and seasonal trends in the water quality data are discussed with the external variables.

Climatic and Physical Factors

Temperature. Air and water temperature followed normal seasonal trends. Survival rate of the bacterial indicators is in part determined by the environmental influences of temperature. Ballentine and Kittrell (1968) found prolonged survival on land and in water of the indicator organisms with decreasing temperatures. Interpretation of bacterial data with temperature data would indicate that little recent warm-blooded fecal contamination was introduced within the study area during cold weather months. Conversely, during the warm weather months with reduced bacterial survival, data show that recent warm-blooded fecal contamination was introduced into the study area. Lower bacteria counts during the winter months would tend to exclude wildlife populations as the sole source of fecal contamination because bacteria concentrations were not the same through the sample year.

Identification of the sources of warm-blooded fecal contamination was not within the scope of this study. A list of possible warm-blooded sources for the study area would include: (1) man, through body-water contact and associated recreational activities on the immediate

watershed, (2) animal populations as wildlife and domestic animals, (3) sewage treatment facilities at the headwaters of both creeks.

Precipitation. Flushing of fecal contamination from the watershed by rain events as reported by Kunkle and Meiman (1967) was not observed during this study. Student's t-test of fecal coliform and fecal streptococcus data did not show significant differences in bacteria data collected on days without rain events and those collected the day of a rain event or the day after a rain event. Sampling periods for this study did not coincide with rain events; consequently the flushing effect was not measured during the research period.

Turbidity. Turbidity data show that selected sample stations (see Figure 13) had greater turbid conditions in April and August. During April increasing runoff from snow-melt would introduce sediment into the system. During August, a low precipitation month, the streams had the highest mean turbidity values. In-water recreational activities occurred with greater frequency during warm weather months because air and water temperatures were within comfortable limits. Raising of bottom sediments by in-water recreational activity was the most probable source of the turbid conditions in August. Stream areas near man-made structures (Stations 6 and 20) which trap large sediment deposits, were more susceptible to have turbid water than natural stream areas such as Stations 1 and 22. During the summer months the lowest mean concentration of fecal coliform occurred in August (see Figure 22). Turbid water during this period may have caused the lower bacteria counts. Using the membrane filter (MF) technique to enumerate fecal coliform during severe periods of turbid water may hinder bacteria growth because of particulate

matter blocking filter pores. Fecal coliform concentrations during this turbid period may not accurately reflect stream conditions.

Chemical Factors

Copper and pH. Copper concentrations were all well below the 1.0 mg/l limit when using the membrane filter technique for the enumeration of fecal coliform and fecal streptococcus bacteria. Average pH during the study was 7.1 which is a favorable condition for biological growth of concern in this research.

Nitrate-nitrogen and Orthophosphate. Although excessive algae growth was observed at times in back eddy areas, nutrient levels as measured in this study indicated an oligotrophic system.

Biological Factors

Surface water. Fecal coliform data from the warm weather months indicate that all areas of Sabino Canyon Recreation Area received some recent warm-blooded animal contamination. Statistical procedures show that Lower Sabino had the greatest amount of fecal contamination. Fecal streptococcus data indicate that there was a source of fecal contamination through the sampling year.

The primary water quality standard is presented in Chapter 2. Comparison of fecal coliform data with recreational water standards should be undertaken only if a minimum number of samples are examined (Foster et al., 1971). Federal Water Pollution Control Administration (Environmental Protection Agency) suggests that a minimum of five samples per 30 day period should be required when applying recreational water quality standards (Millipore Corporation, 1973). Due to the Sunday-Wednesday

sample program, five samples that could possibly exceed the water quality standard would not be found in a thirty day period. Only during the Labor Day sample period was the standard exceeded by five samples within a thirty day period; at Station 19 (see Figure 26) five fecal coliform samples were collected that exceeded a geometric mean of 200/100 ml. The analysis of variance show that data collected on Sunday would be higher than on Wednesday. For this reason only half of the data collected for the study would generally be expected to exceed the water quality standard.

The water quality standard also includes a provision that 10 percent of samples collected within a 30 day period should not exceed 400 fecal coliform/100 ml. Bacteria samples were collected eight to nine times per month; hence one sample per month represents greater than 10 percent of the samples collected at each station within a thirty day period. With respect to the water quality standard, Bear Creek exceeded the fecal coliform level of 400/100 ml once during the sampling year. Table 9 presents for Sabino Creek and Bear Creek the number of fecal coliform samples that exceeded the upper limit of the water quality standard. Sabino Creek exceeded the standard 21 times. The reader is reminded that the primary water quality standard for recreation areas could potentially have been exceeded more than 22 times on Sabino and Bear Creeks if the sampling program had been concentrated on weekends and holidays.

Bottom Sediment. Analyses of bottom sediment suggest that the bottom material acts as a bacteria trap in which large amounts of fecal coliform bacteria were found. Large concentrations of fecal coliform

Table 9. Number of fecal coliform samples on a monthly basis that exceeded 400/100 ml.

Sample Station	Month											
	01	02	03	04	05	06	07	08	09	10	11	12
01	0	0	0	0	0	0	1	0	0	0	0	0
02	0	0	0	0	0	0	0	0	0	0	0	0
03	0	0	0	0	0	0	1	0	0	0	0	0
04	0	0	0	0	0	0	0	0	0	0	0	0
05	0	0	0	0	0	0	1	0	0	0	0	0
06	0	0	0	0	1	0	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0	1	0	0	0
09	0	0	0	0	0	0	0	0	1	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	1	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	1	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	1	0	0	0	0	0	0
19	0	0	0	0	0	3	0	0	2	0	0	0
20	0	0	0	0	2	1	0	0	0	0	0	0
21	0	1	0	0	1	1	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	1	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

were present in the bottom sediment even during the cold weather months. Testing of the bottom sediment stir sample concept was not part of the purpose of the overall research project, but the data are interesting. Data from stir samples show that minimal disturbance of the bottom sediment can cause recirculation or redistribution of older pollutants with significant influence on overlying water. In Figure 28, an increase in mean water temperatures show a corresponding increase in fecal coliform concentrations in surface water as water temperatures exceed 15°C which is sufficiently warm for body contact, apparently resulting in the disturbance of bottom sediment. Data suggest that bottom sediments are an intermediate source of warm-blooded animal contamination within Sabino Canyon Recreation Area.

Bacteria Data for Sabino Basin

Determination of statistical differences in data between Sabino Basin and Sabino Canyon Recreation Area was not undertaken because the two areas were not sampled with the same schedule. Sabino Basin was sampled in order to obtain basic information on the influence of the upper watershed on Sabino Canyon Recreation Ara. Water quality data from Sabino Basin show the same relative values as those recorded within Sabino Canyon Recreation Area. No attempt was made to compare data of Sabino Basin with the recreation water quality standards because this area was sampled once a month. Data (see Figure 19) indicate a source of warm-blooded animal contamination during warm weather months. Recreation users of Sabino Basin should treat the water before drinking.

Bottom sediment data collected at Hutch's Pool (see Figure 29) on a monthly basis, show high concentrations of fecal coliform bacteria in bottom material. Speculation on bottom sediment data from Hutch's Pool, a low use back country area, would indicate that other sources besides recreation users are contributing to the bacteria population in the sediment. The primary treatment of sewage at the headwaters of Sabino Creek may be ultimately responsible for the fecal coliform counts in the sediment along Sabino Creek.

Visitor Use

USFS visitor use data (car counts) indicate that during the cold weather months visitor use was the highest for the sampling year. When visitor use was the lowest, fecal coliform levels were the highest because in-water activities were the major form of recreation during the warm weather months. Temperatures (air and water) and visitor use play an important part in the determination of the recreation use impact on the water resources. Quantitative data on recreational activity especially water-based must be obtained in conjunction with water quality parameters before the impact of recreation use on the water resource can be determined.

CHAPTER 6

CONCLUSIONS AND MANAGEMENT ALTERNATIVES

This study provides the United States Forest Service with baseline water quality research of Sabino and Bear Creeks. Results from this intensive sample program form a benchmark from which a continued water quality sampling program can efficiently examine the natural water resources within Sabino Canyon Recreation Area. Conclusions concerning water quality trends associated with chemical, turbidity, and biological factors are presented in separate sub-sections. Management alternatives are examined in two categories: (1) water quality monitoring program for Sabino Canyon Recreation Area, and (2) management suggestions to reduce sources of water pollution.

Water Quality Trends

Chemical Trends

Chemical conditions of the streams were determined at three representative sampling stations on Sabino Creek and one station on Bear Creek. Sabino and Bear Creeks were sampled a minimum of three times per month for chemical analyses. Sabino Basin was sampled once a month with chemical data being obtained at three sample locations within the Basin.

Mean nitrate-nitrogen data of Sabino Creek ranged from 0.2 to 0.4 mg/l. In both Bear Creek and Sabino Basin, mean data ranged from

0.2 to 0.5 mg/1. Mean orthophosphate data for Sabino Creek ranged from 0.02 to 0.06 mg/1 and for Bear Creek mean orthophosphate data ranged from 0.02 to 0.07 mg/1. In Sabino Basin mean orthophosphate data ranged from 0.01 to 0.19 mg/1. Nitrate-nitrogen concentrations of the study area are low compared to values found in other stream studies (Committee Report -- American Water Works Association, 1970). Orthophosphate values for Sabino and Bear Creeks were within the range of values found in most natural (Hutchinson, 1957) streams.

No major chemical pollution problems were identified during the study period. Although some excessive algae growth was observed, the primary source of nutrients within the recreation area was most likely the decomposition of the riparian vegetation debris. Dry periods occurring in the streams quickly destroyed any excess algae growth; aesthetic problems due to algae are minor.

Turbidity Trends

Turbidity analyses were performed concurrently with the same sampling schedule as developed for chemical investigation. Mean turbidity values for Sabino Creek ranged from zero to 22 JTU; Bear Creek mean turbidity values ranged from zero to 8 JTU. Sabino Basin mean turbidity values ranged from zero to 14 JTU. Standards established in the State of Arizona for turbidity measurement for warm water streams are 50 JTU (Mechalas et al., 1972). No single turbidity measurement exceeded 50 JTU; mean values were well below the State Turbidity standard.

Highest turbidity values occurred during the warm weather months, the period of greatest in-water recreational activity. Turbidity problems

arose due to the man-made and natural constraints of Sabino Creek. Shallow flowing water over the silt-laden bottom in some areas amplifies turbidity problems created from minimal disturbance of in-water recreational activity.

Intensive use and construction sites in some areas adjacent to the stream denuded the natural vegetation. Erosion occurring along these disturbed areas is high, especially bordering the steep stream banks paralleling the road above Anderson Dam, the "Crack," and in the local area above Sabino Lake Dam. Stream sections near man-made structures, as dams and bridges, that trap large sediment deposits, become more susceptible to turbid conditions than natural stream areas.

Bacteria Trends

Surface Water Bacteria. Fecal coliform concentrations were sampled from 21 locations on Sabino Creek and two locations on Bear Creek; five points on Sabino Creek and one on Bear Creek were sampled for fecal streptococcus organisms. Bacteria parameters for Sabino and Bear Creeks were collected twice weekly (Sunday-Wednesday) for twelve months with rotating time periods of 8 a.m., 12 noon, and 4 p.m. throughout the year.

Data show that Sabino and Bear Creeks receive varying degrees of fecal contamination, and bacterial concentrations are at times in excess of State and Federal primary contact recreation water quality standards. High use periods such as Sunday and Holiday afternoons show highest fecal coliform concentrations that in many cases exceed the primary contact recreation standard.

Mean monthly fecal coliform concentrations for Sabino Creek ranged from less than 1/100 to 100/100 ml; fecal streptococcus data ranged from a mean monthly value of 25/100 to 300/100 ml. Fecal coliform and fecal streptococcus mean monthly values for Bear Creek ranged from less than 1/100 to 70/100 ml and from 30/100 to greater than 1500/100 ml respectively.

An important characteristic of the mean representation of fecal coliform data required notation. Although the mean fecal coliform counts appear low over all with regard to primary contact recreation water quality standards, these data do not reflect the high fecal coliform concentrations on specific occasions. One objective of this study was to provide the USFS with broad based information and data regarding stream conditions under varied situations. Had the collection of data been focused solely on the high use periods, the mean fecal coliform values would have been considerably higher.

Fecal coliform counts showed significant relationships between day, time, and location of sample collection. Analysis of variance tests showed fecal coliform concentrations to be significantly higher on Sunday than on Wednesday, significantly higher at 4 p.m. than at 8 a.m. or 12 noon, and significantly higher in the Lower Sabino segment of the four mile reach of Sabino Creek.

Bottom Sediment Bacteria. Enumeration of fecal coliform concentrations in bottom sediment was added to this study during the last seven months of the sample program. For comparative purposes the sample procedure included the collection of surface water sample followed by a bottom sediment sample. The bottom sediment sampling program for Sabino

Creek occurred three times per month at three representative sample locations.

Mean monthly concentrations of fecal coliform in bottom sediment ranged from 150/100 to 4500/100 ml. Surface water mean fecal coliform values, collected in conjunction with bottom sediment samples, ranged from less than 10/100 to 120/100 ml.

On a monthly basis, one bottom sediment sample was processed from Sabino Basin. Seven Sabino Basin bottom sediment samples showed fecal coliform values ranging from 80/100 to 16,000/100 ml; corresponding surface water fecal coliform data ranged from zero/100 to 36/100 ml.

Following surface water and bottom sediment sample collection, a stir sample (mixture of surface water and bottom sediment) was immediately collected at one specific location on Sabino Creek. Data show that stir sample fecal coliform concentrations exceeded corresponding surface water counts 37 of 38 times; five stir samples exceeded 200 fecal coliform/ 100 ml.

Bottom sediment analyses indicate that the disturbance of sediment in Sabino Creek, especially in areas near man-made structures having high sediment deposition such as Anderson Dam, the bridges and Sabino Lake Dam, have the potential of releasing fecal coliform bacteria into the overlying water exceeding the primary contact recreation water quality standard. Consequently, a study of surface waters alone may not accurately reflect overall existing or potential condition of the stream. A program determining water quality conditions should include both surface water and bottom sediment analyses.

In conclusion, high concentrations of fecal coliform in the bottom sediment and periodically in overlying water indicate major sources of fecal contamination have access into Sabino Creek. An apparent association of intensive in-water recreational use with significantly higher fecal coliform concentrations demonstrates the need to: (1) limit the number of visitors to Sabino Canyon Recreation Area during the warm weather months, and (2) determine the sources of fecal contamination in surface water and the bottom sediment. The Forest Service must consider the natural constraints of Sabino and Bear Creeks and recognize potential water quality problems when planning recreation user patterns and facility development within Sabino Canyon Recreation Area.

Major Conclusions

(1) No major chemical pollution problems were identified during the study period.

(2) No single turbidity measurement exceeded the State turbidity standard. Highest turbidity values occurred during the warm weather months, the period of greatest in-water recreational activity.

(3) Fecal coliform concentrations were significantly higher on Sunday than on Wednesday, significantly higher at 4 p.m. than at 8 a.m. or 12 noon, and significantly higher in the Lower Sabino segment of the four mile reach of Sabino Creek. High use periods as Sunday and Holiday afternoons show highest fecal coliform concentrations that in many cases exceed the primary contact recreation standard.

(4) Bottom sediment analyses indicate that the disturbance of sediment in Sabino Creek has the potential of releasing fecal coliform bacteria into overlying water exceeding the primary contact recreation water quality standard.

(5) Intensive in-water recreation activity requires that the water resource of Sabino and Bear Creeks be managed as primary contact waters.

Management Alternatives

Water Quality Monitoring Program

The following recommendations are presented as guidelines for the monitoring of the natural water resources in Sabino Canyon Recreation Area:

(1) Water resources within the recreation area should be sampled during the period of the year between April and October with a minimum of five surface water samples per month.

Data show that fecal coliform concentrations are highest during April through October, the months with frequent in-water recreational activity. The USFS Directional Amendment No. 12, in the Forest Service Manual (FSM) 2542.2, requires the sampling of developed water based recreation areas under USFS control for fecal coliform when in-water recreation activity occurs. The Federal Water Pollution Control Administration (EPA) suggests that a minimum of five samples per 30 day period should be required when applying recreational water quality standards (Millipore, 1973).

Should a sampling day be disrupted by turbid conditions of the stream precluding the MF technique, the Most Probable Number (MPN) technique should be used so that a minimum of five individual fecal coliform sampling periods are compared to the water quality standard.

(2) The water sample collection program should be focused on weekends and holidays during the late afternoon time period.

One important goal of the USFS water quality monitoring program should be to collect bacteria data when counts are expected to be the highest, so that Sabino Creek can be accurately compared to the primary contact standard. Analysis of variance demonstrated that Sunday (weekend) fecal coliform samples were significantly higher than Wednesday (weekday) and 4 p.m. fecal coliform values were significantly higher than 8 a.m. or 12 noon.

(3) Under the present visitor use policy, the water quality monitoring program should be concentrated in Lower Sabino; select sites in Upper Sabino should be sampled as well as to maintain an overall perspective.

Lower Sabino receives intensive pressure from recreation use due to the lake/beach effect of Sabino Dam and the ease of access. Fecal coliform data collected from Lower Sabino were significantly higher than data from Lower Bear or Upper Sabino.

Popular locations such as Anderson Dam and the "Crack" should be sampled on a regular basis. Sample sites in Upper Sabino would serve as a control for comparative purposes if the visitor use policy is changed.

(4) Bottom sediment fecal coliform analyses should be continued in a regular scheduled water quality monitoring program.

Bottom sediments are an intermediate source of fecal contamination. Combination of bottom sediment and surface water samples will assist in the determination of the bacterial condition of Sabino and Bear Creeks.

(5) Anderson Dam should be reconstructed into a broad-crest weir so that flow rates can be measured during the sample period.

Due to the construction design of Anderson Dam, only a small investment would be necessary to calibrate the structure into a stream gauging station. A recording gauge would not be necessary if USFS personnel would make scheduled readings on a daily basis.

Flow records would help determine the characteristics of the hydrograph at the time of bacteria sampling thus aiding in the analyses of bacteria data.

(6) The ultimate source of fecal coliform in the bottom sediment must be documented.

Research grants from the Eisenhower Consortium or National Science Foundation may be necessary in order to fulfill this objective. Cooperative efforts should be developed with a research agency as The University of Arizona to formulate research plans for future studies.

Source of Contamination

The following management suggestions are presented as broad precautionary measures to reduce all controllable sources of contamination:

(1) Public transportation should not be allowed beyond the Floodgate during the months of April to October.

In-water activity is a major form of recreation pursued during the warm weather months. Motorized public access into Upper Sabino could add a large potential source of fecal contamination to Sabino Creek. The stirring of bottom sediment and the subsequent release of bacteria in the upper sections of Sabino Canyon Recreation Area could have a compound effect downstream in Lower Sabino where high counts were observed during this study.

(2) Limit the number of visitors permitted into Sabino Canyon Recreation Area on a daily basis during the warm weather months.

The purpose of this study was not to make a correlation between fecal coliform counts and visitor use, however, hourly sample do show that fecal coliform counts exceeded 200/100 ml and car counts exceeded 1000 cars per day. Speculating on the data, less than 1000 cars should be permitted into Sabino Canyon Recreation Area when in-water recreation activity occurs.

A goal of the USFS water quality monitoring program should include visitor use data collection as total number of visitors with activities pursued and concentration patterns identified. Time sample fecal coliform data plus sound visitor use data will further aid the USFS in defining the optimum number of people that the water resource can accommodate on a daily basis.

(3) Pets should be restricted from all sections of Sabino Canyon Recreation Area.

A large number of dogs were observed on all sampling days; dog feces were prevalent at stream side and on all trails especially Bear

Canyon Trail. Pets within this water-based recreation area are not in the best interest of the public enjoyment of the resource.

(4) Access to the Phone Line Trail should be changed so that horse travel does not cross Sabino Creek above Sabino Lake Dam.

Present access to the Phone Line Trail corsses Sabino Creek in two areas above Sabino Lake Dam. Direct defacation in the water by horses was not observed by this research team but horse feces floating in the water and trapped on the dam were observed. Horse feces in primary contact recreation water are not in the best interest of the in-water recreation user.

(5) Educate the visiting public that disposable diapers, bottles, and cans are not part of the stream ecosystem.

On-site interpretive programs and the use of public media such as newspaper, radio and television discussing the dangerous effects of fecal matter, broken glass, and rusty cans in the stream would help reduce the incidences of trash in Sabino Creek.

(6) Restroom facilities must be maintained to the highest standards.

The sealed vault type restrooms in Upper Sabino need extra care, such as deodorizers to reduce odor. This policy will insure that visitors will use the facilities provided and not various stream side locations.

APPENDIX A

TWENTY-TWO GRAPHS OF THE MEAN MONTHLY BACTERIA CONCENTRATIONS BY SAMPLE STATION

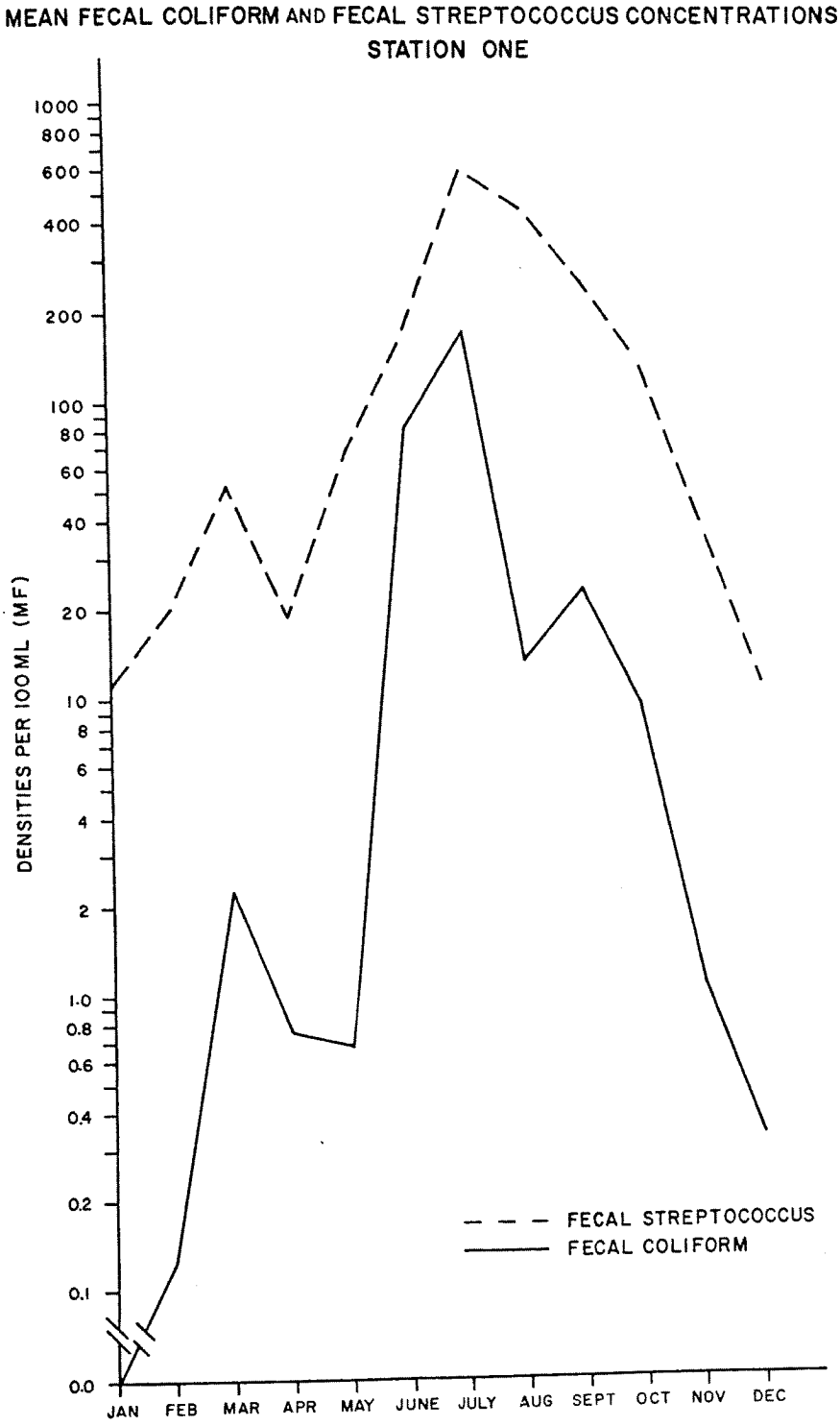

Figure A-1. Mean fecal coliform and fecal streptococcus concentrations for Station 1 from July, 1974 through June, 1975.

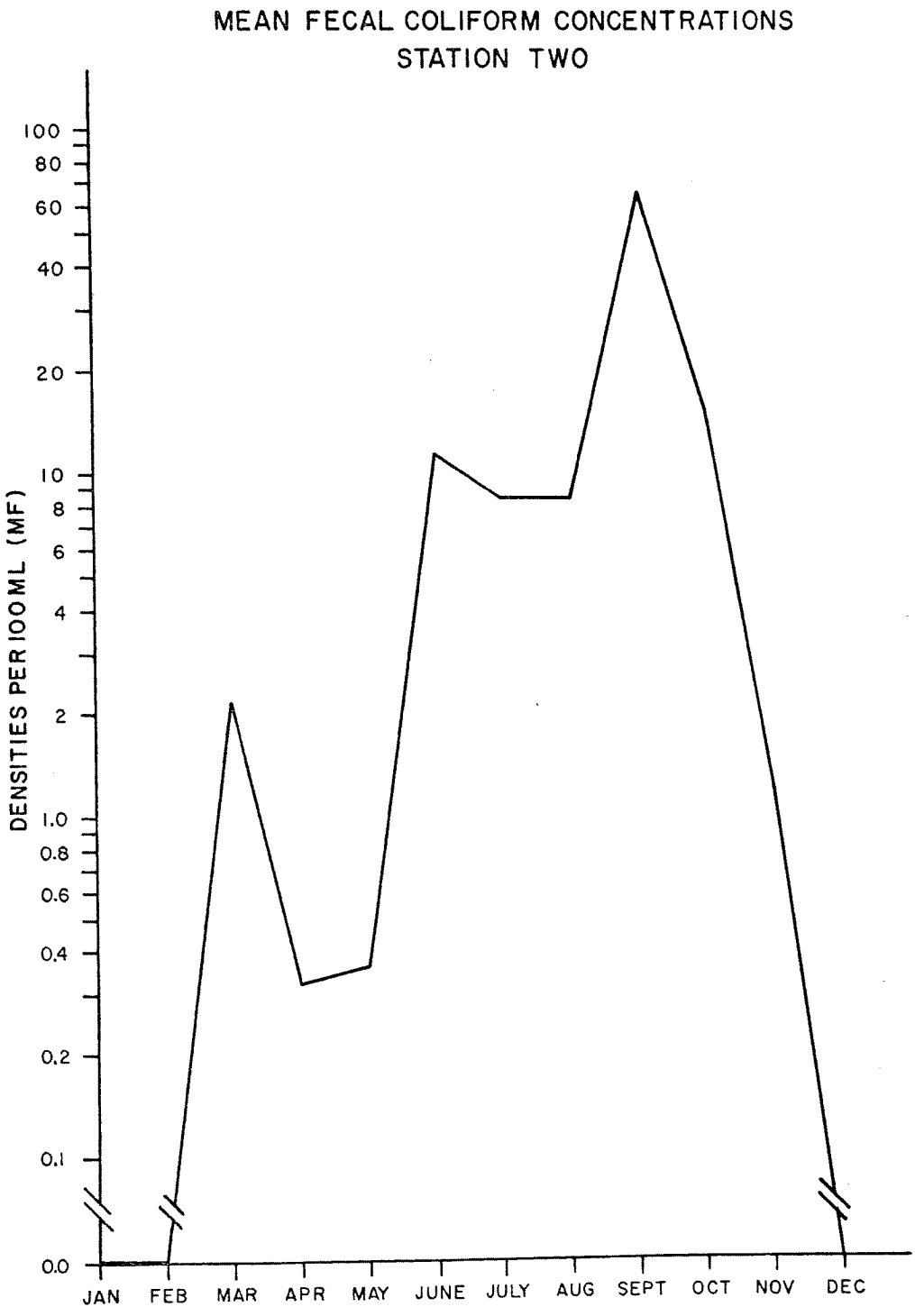

Figure A-2. Mean fecal coliform concentrations for Station 2 from July, 1974 through June, 1975.

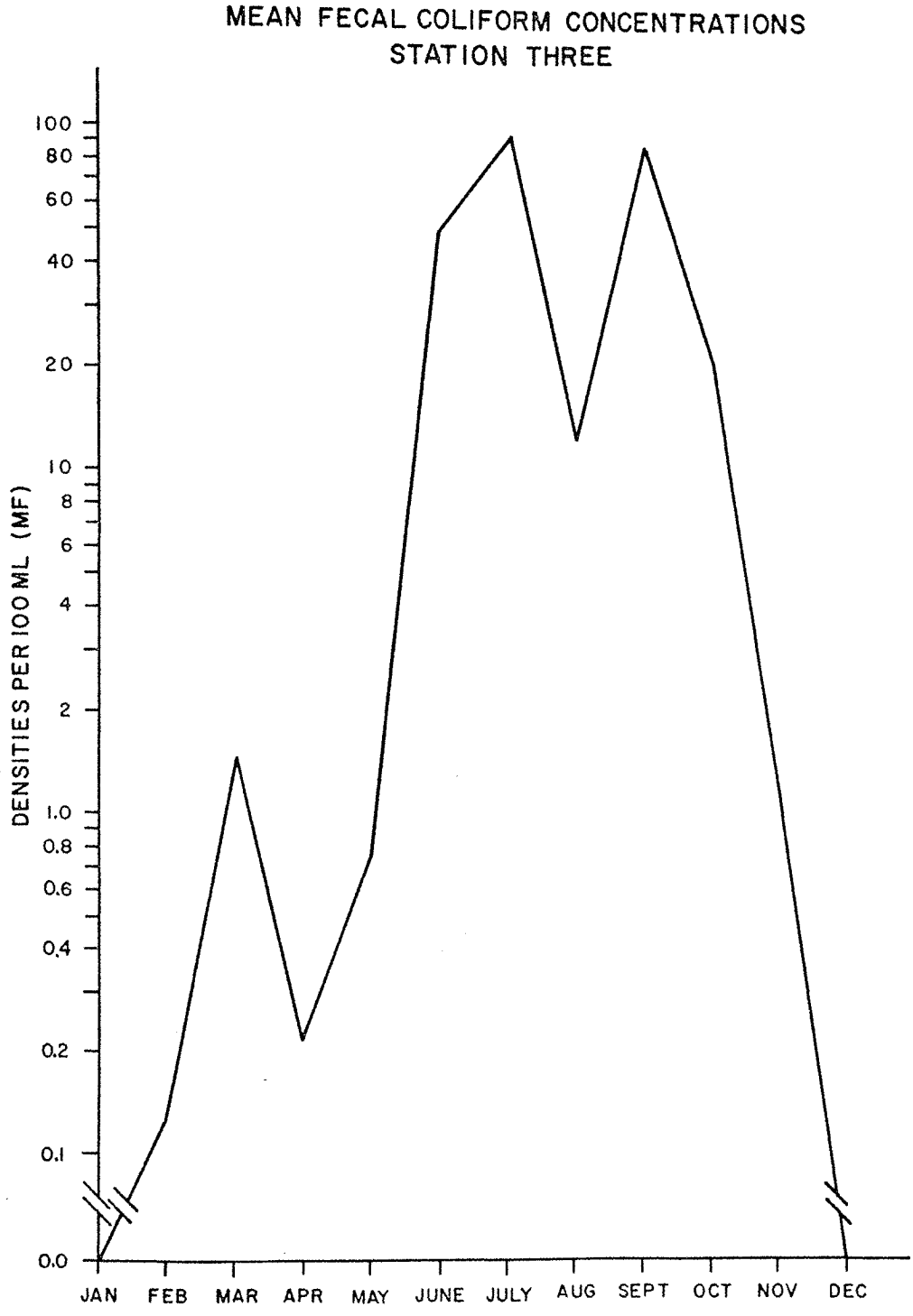

Figure A-3. Mean fecal coliform concentrations for Station 3 from July, 1974 through June, 1975.

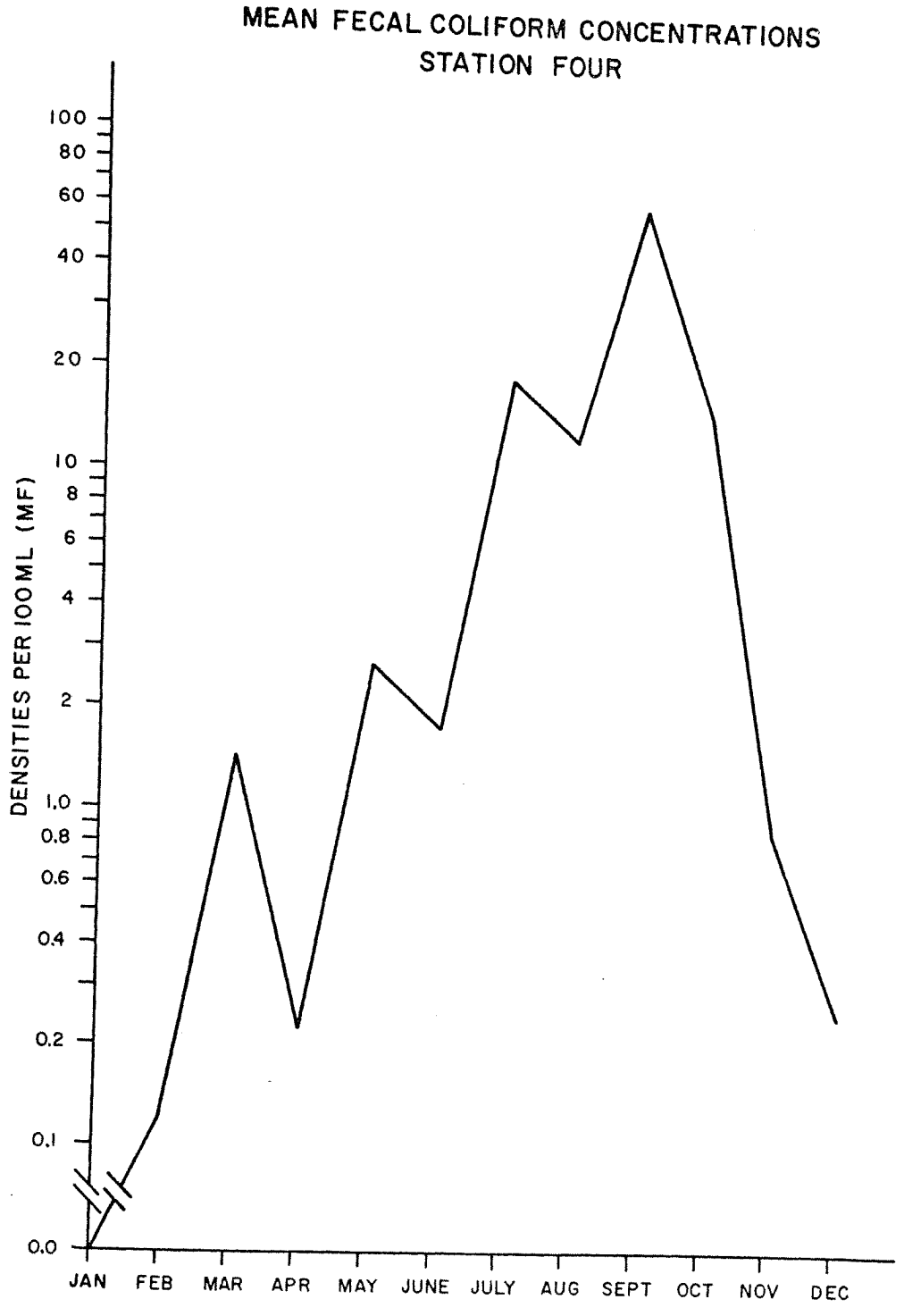

Figure A-4. Mean fecal coliform concentrations for Station 4 from July, 1974 through June, 1975.

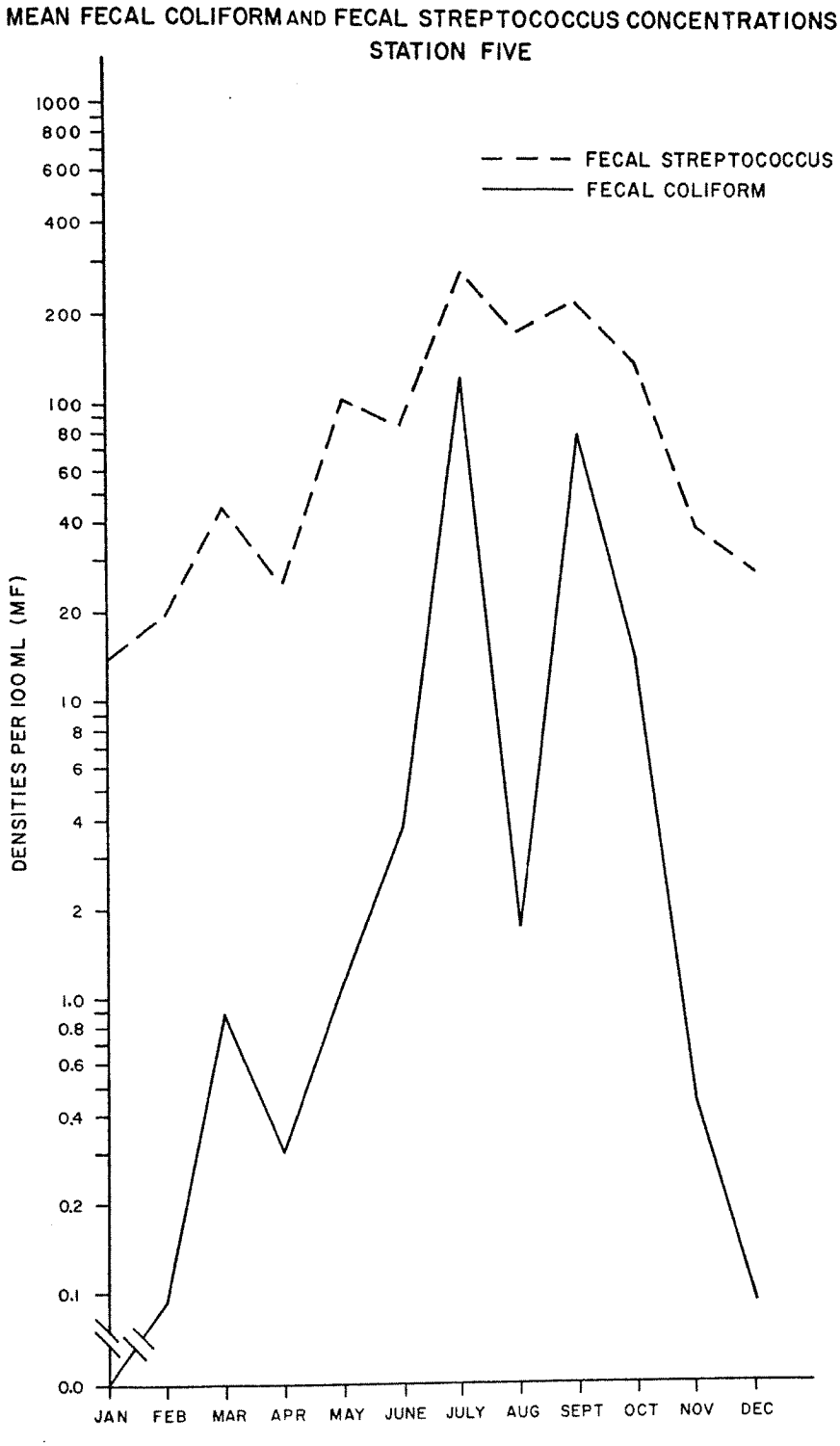

Figure A-5. Mean fecal coliform and fecal streptococcus concentrations for Station 5 from July, 1974 through June, 1975.

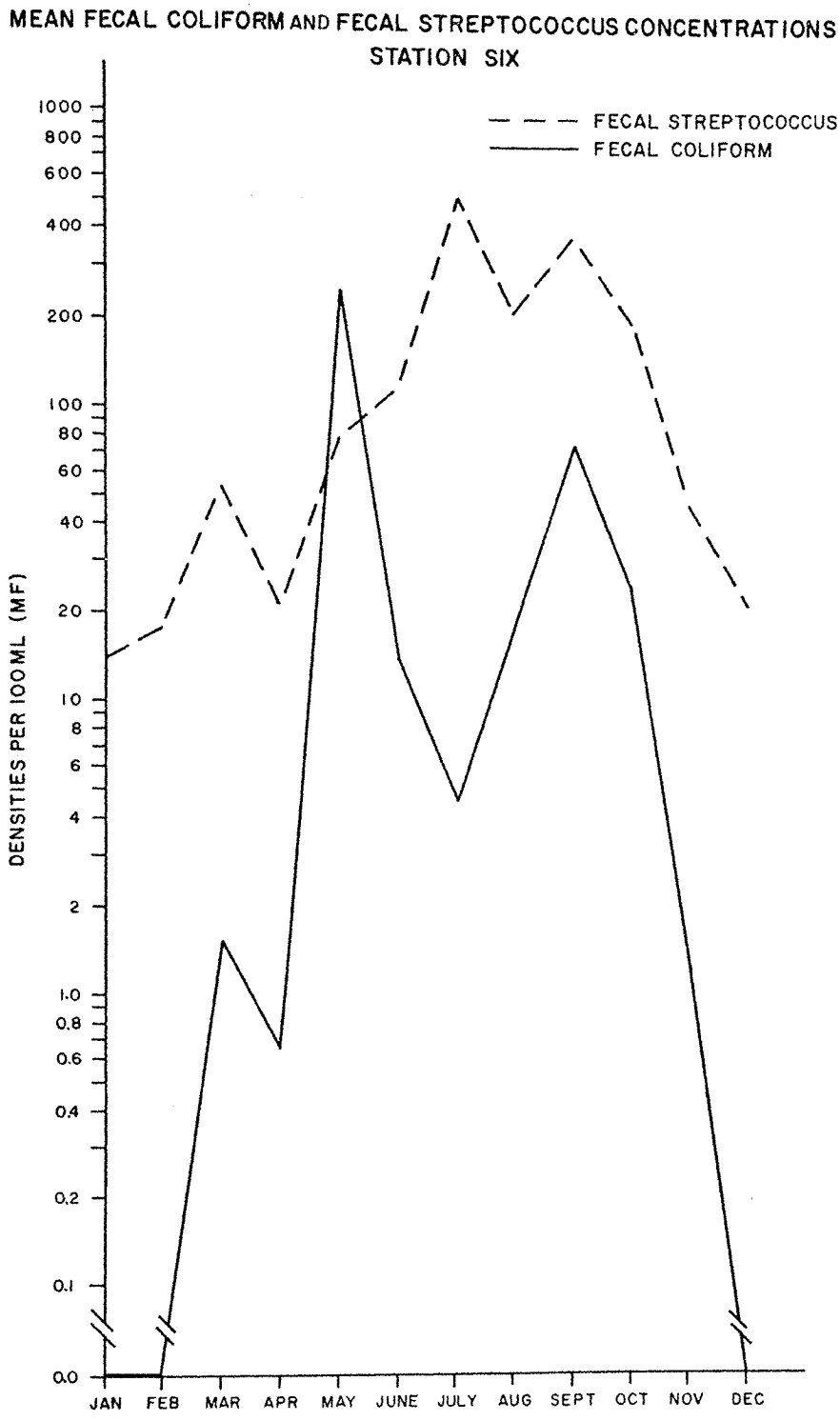

Figure A-6. Mean fecal coliform and fecal streptococcus concentrations for Station 6 from July, 1974 through June, 1975.

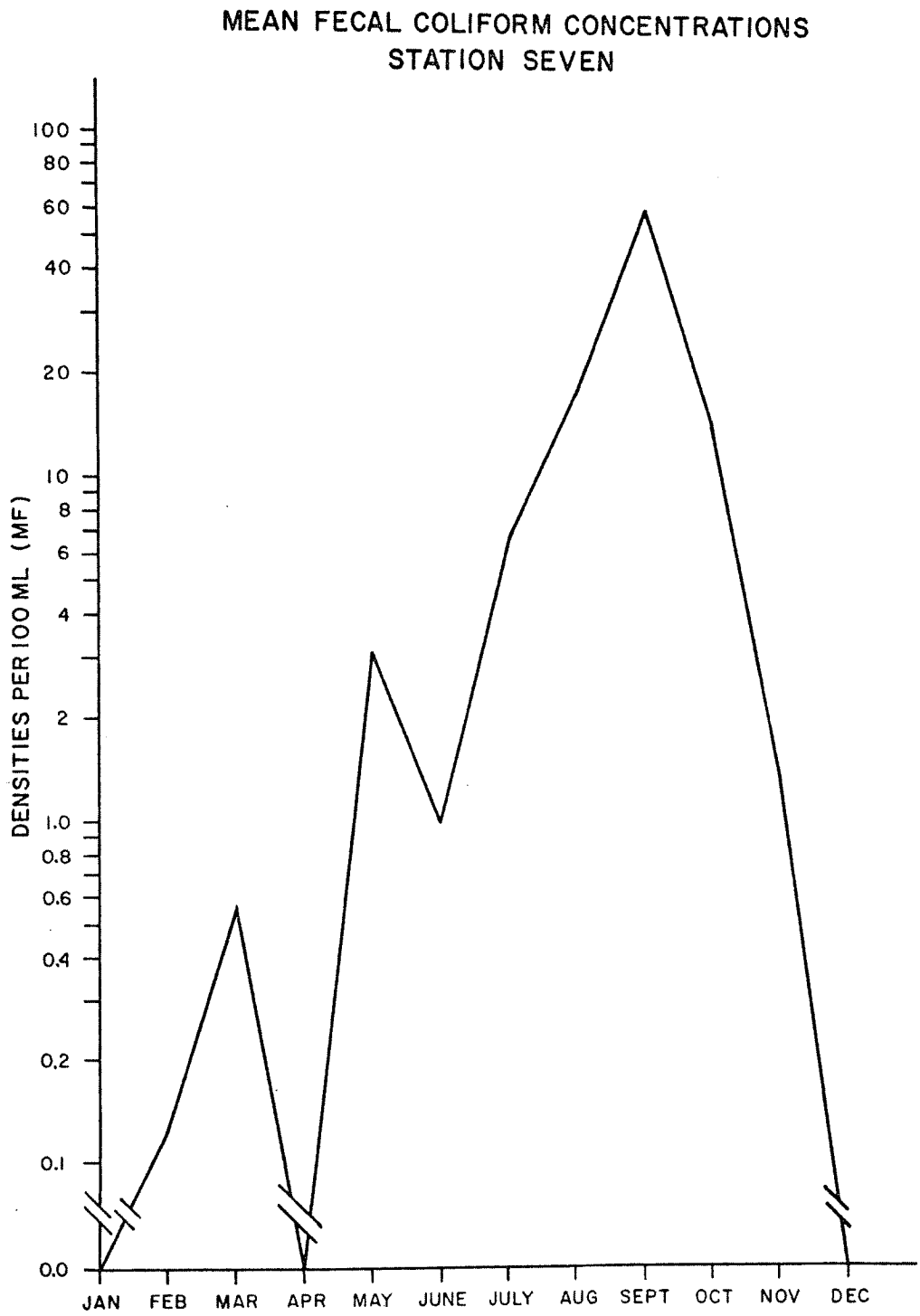

Figure A-7. Mean fecal coliform concentrations for Station 7 from July, 1974 through June, 1975.

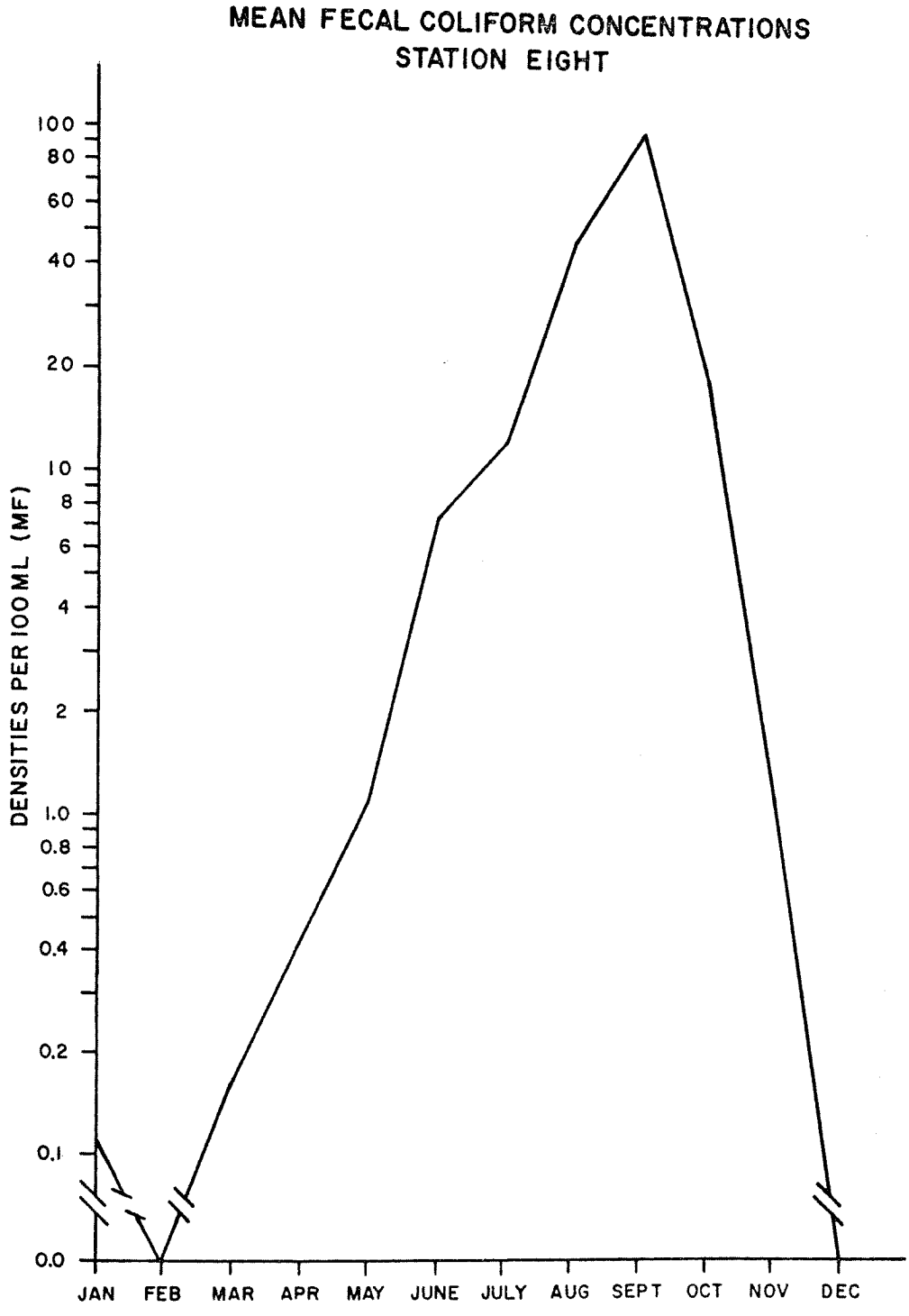

Figure A-8. Mean fecal coliform concentrations for Station 8 from July, 1974 through June, 1975.

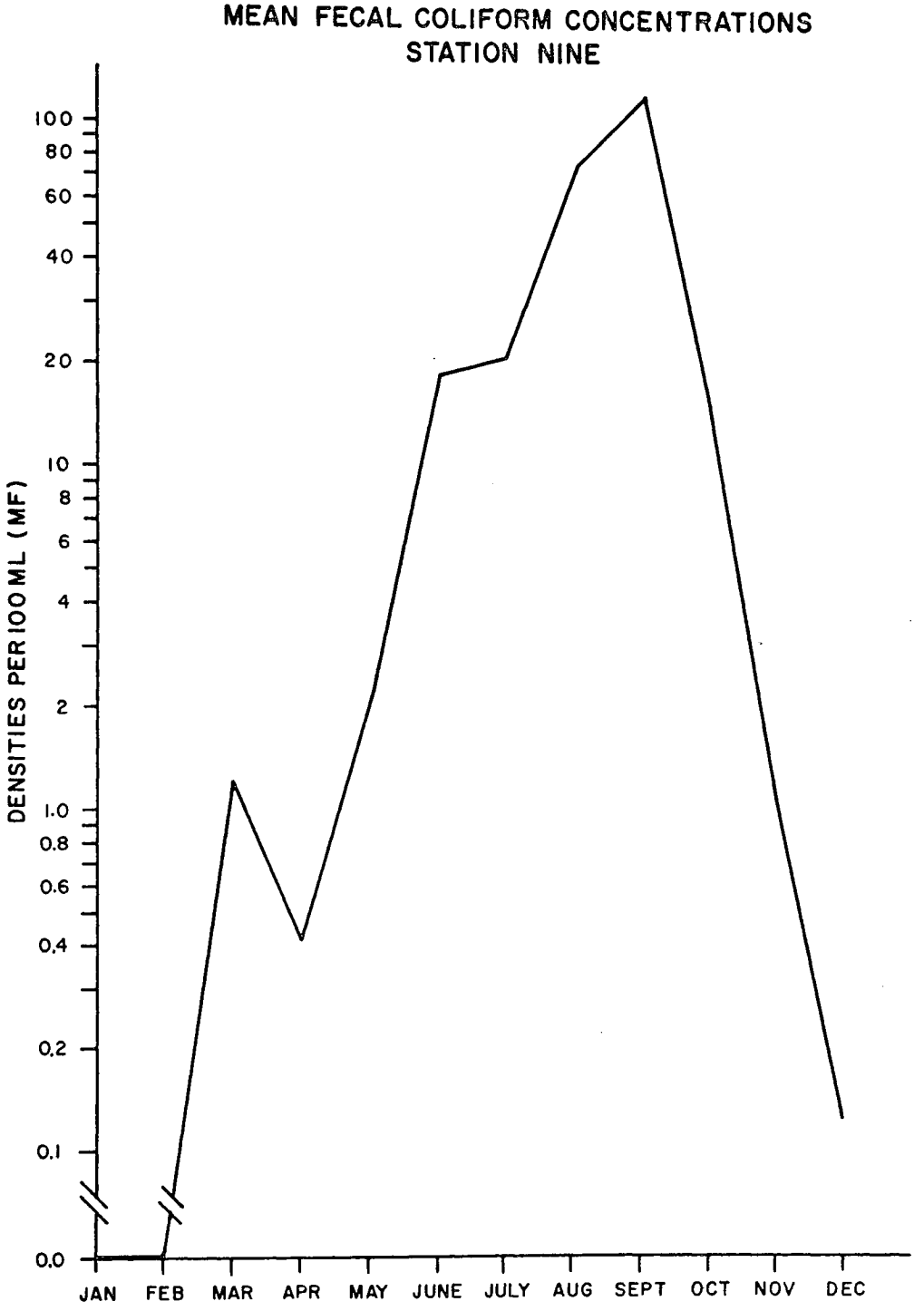

Figure A-9. Mean fecal coliform concentrations for Station 9 from July, 1974 through June, 1975.

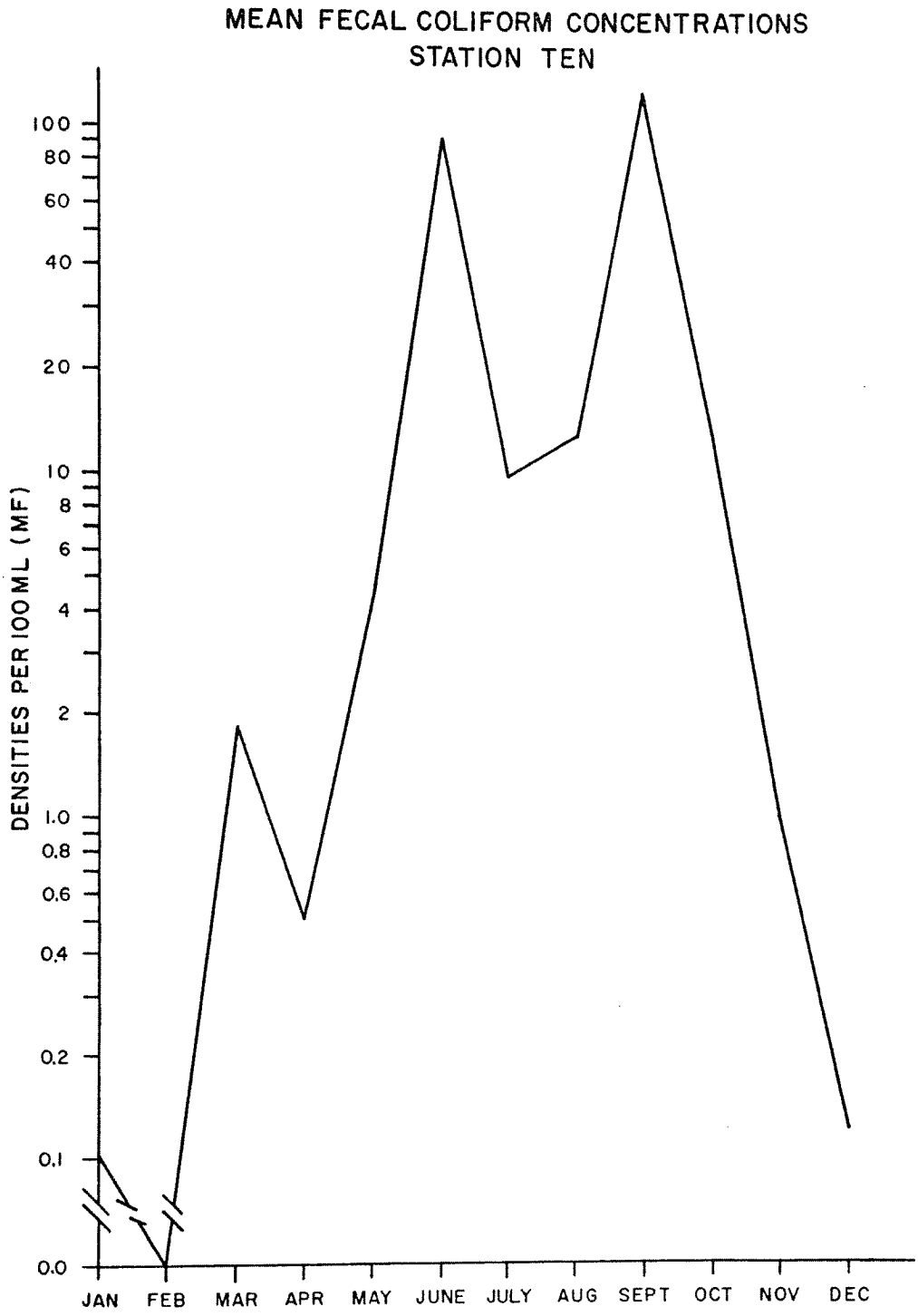

Figure A-10. Mean fecal coliform concentrations for Station 10 from July, 1974 through June, 1975.

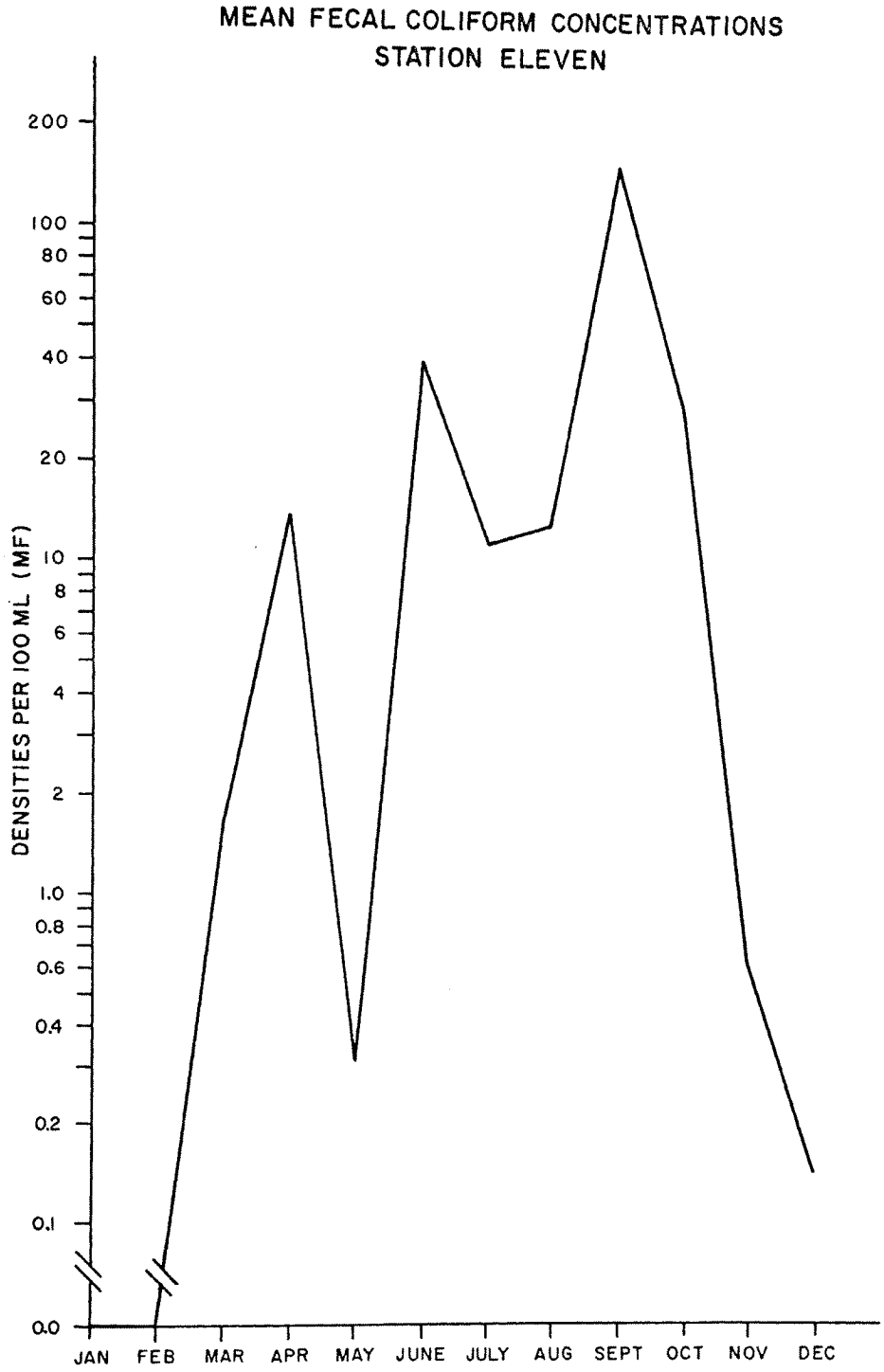

Figure A-11. Mean fecal coliform concentrations for Station 11 from July, 1974 through June, 1975.

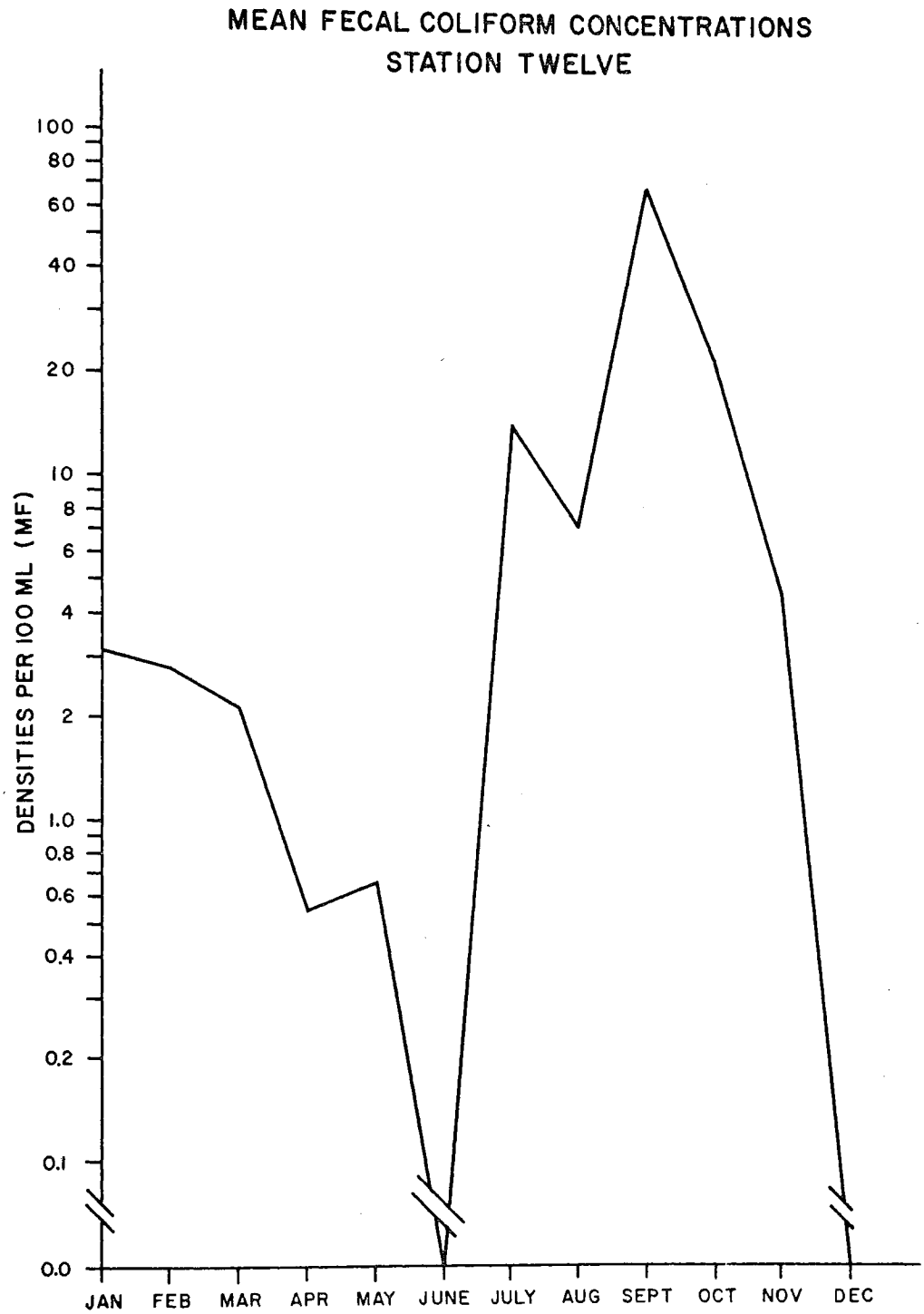

Figure A-12. Mean fecal coliform concentrations for Station 12 from July, 1974 through June, 1975.

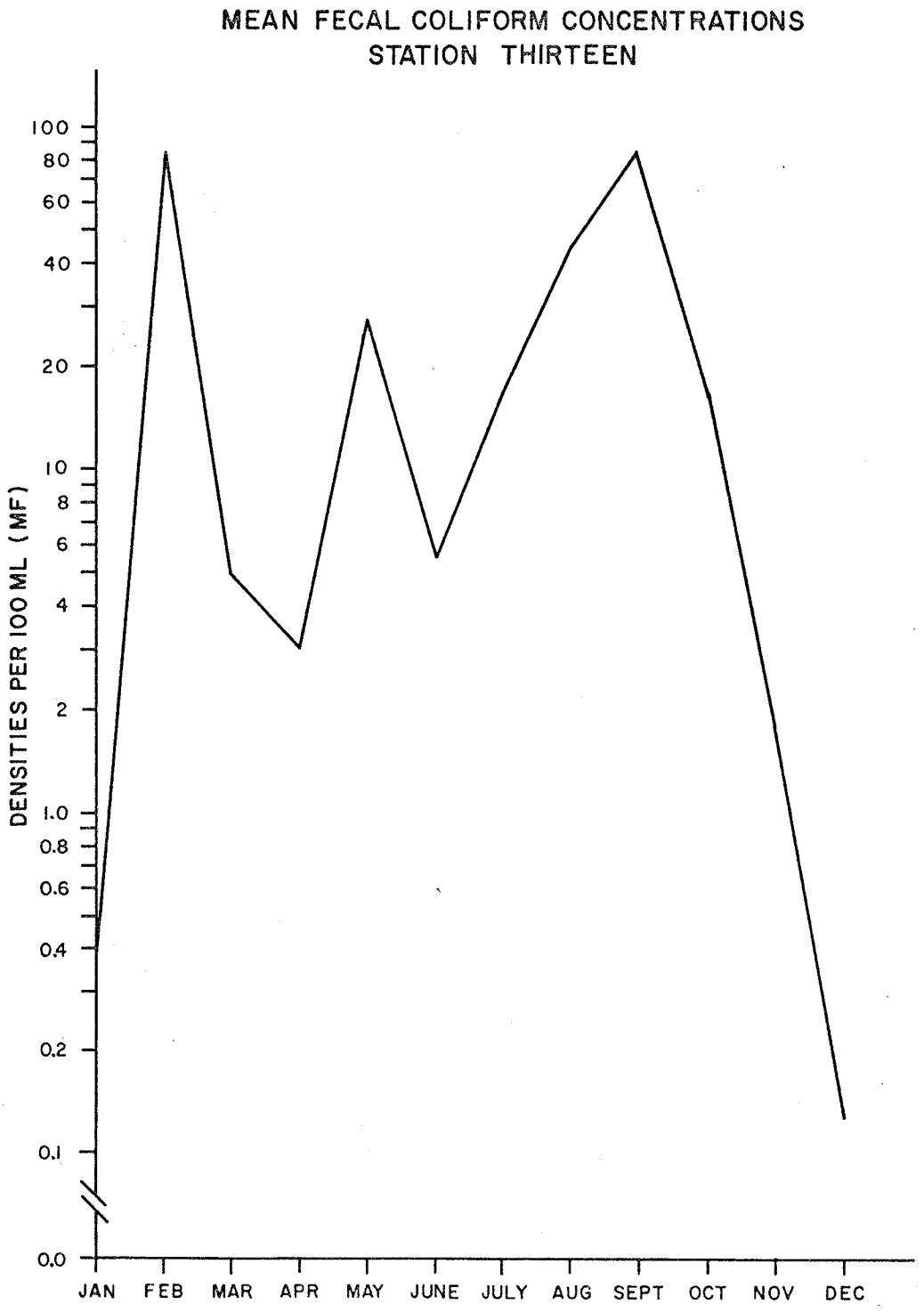

Figure A-13. Mean fecal coliform concentrations for Station 13 from July, 1974 through June, 1975.

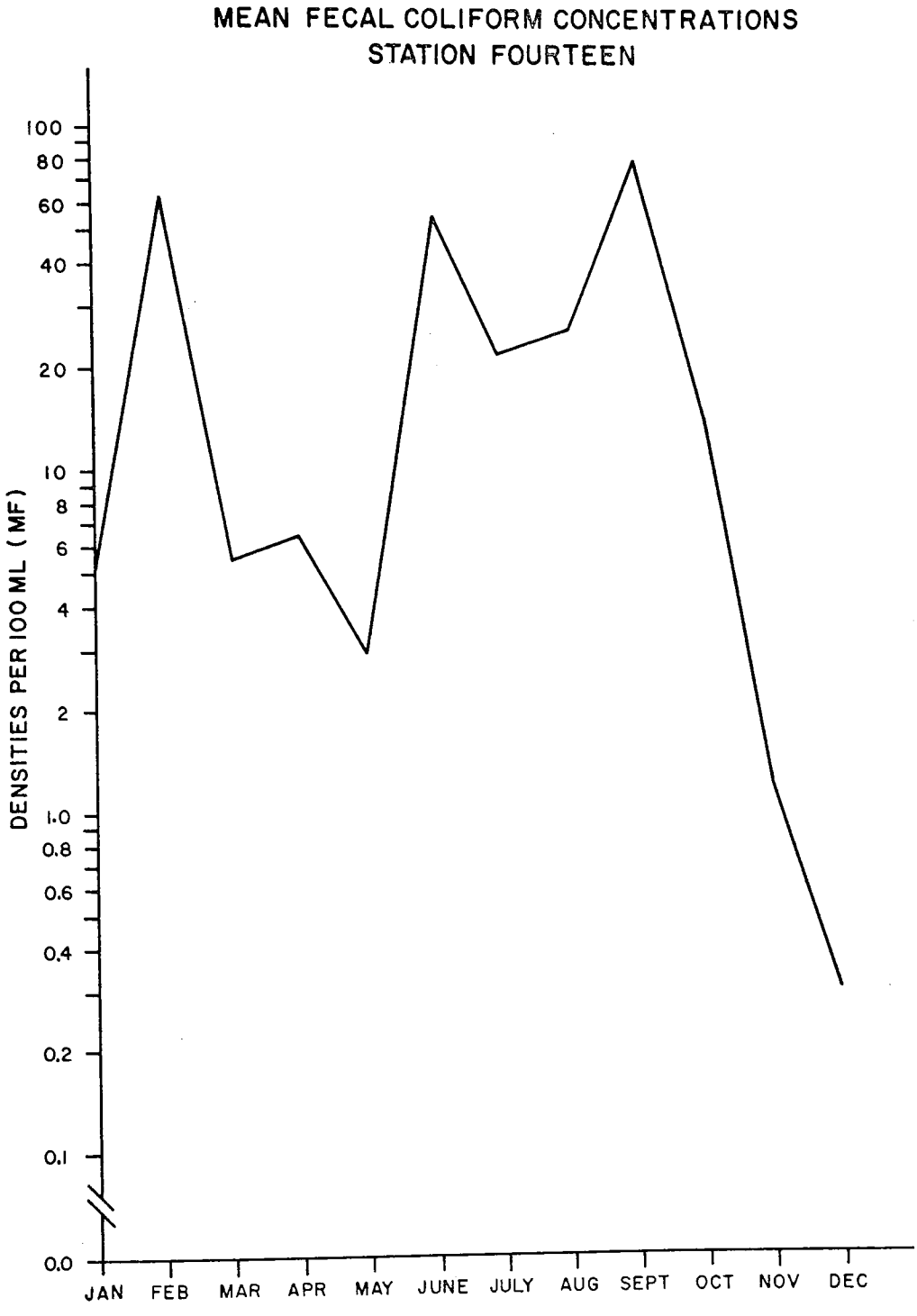

Figure A-14. Mean fecal coliform concentrations for Station 14 from July, 1974 through June, 1975.

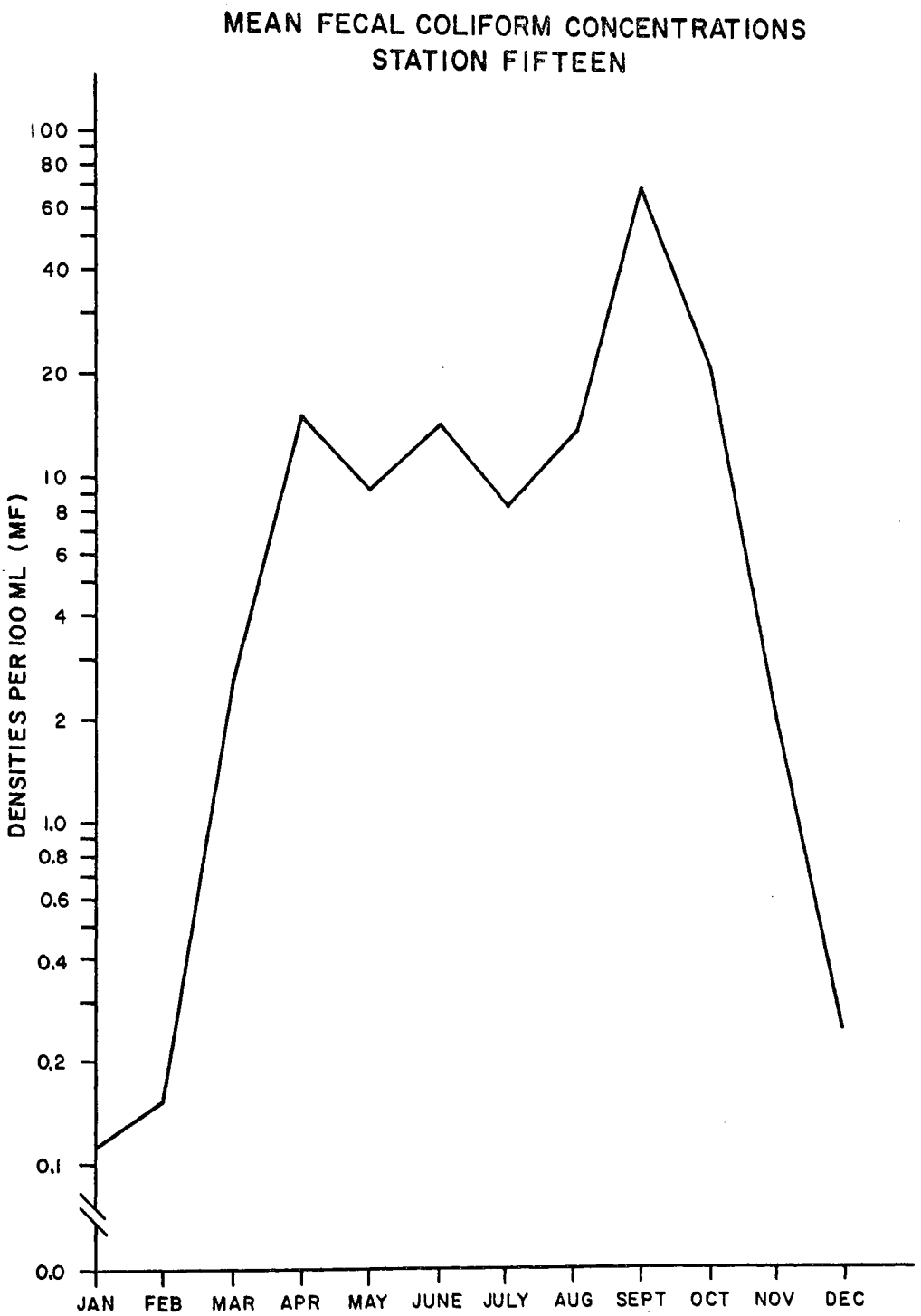

Figure A-15. Mean fecal coliform concentrations for Station 15 from July, 1974 through June, 1975.

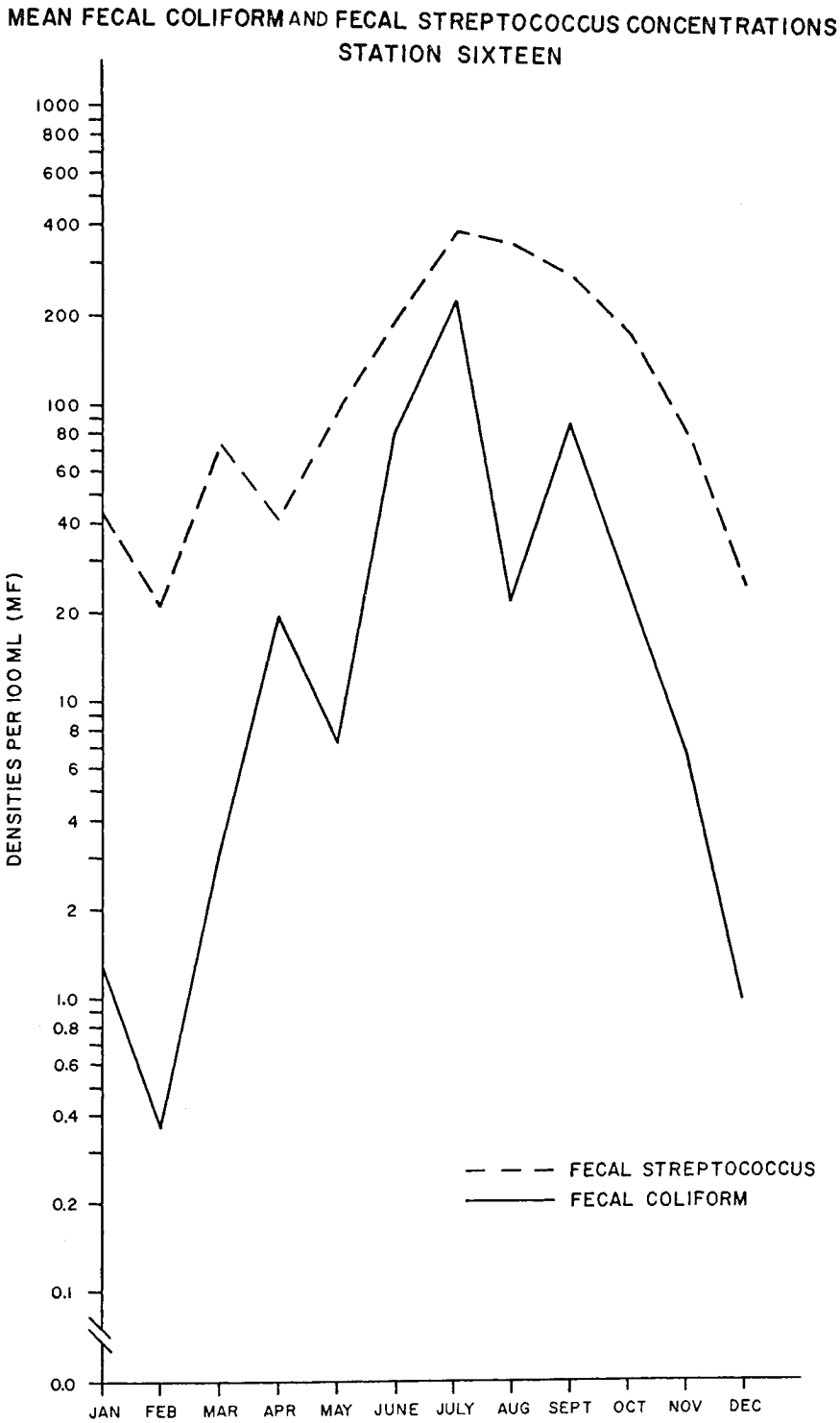

Figure A-16. Mean fecal coliform and fecal streptococcus concentrations for Station 16 from July, 1974 through June, 1975.

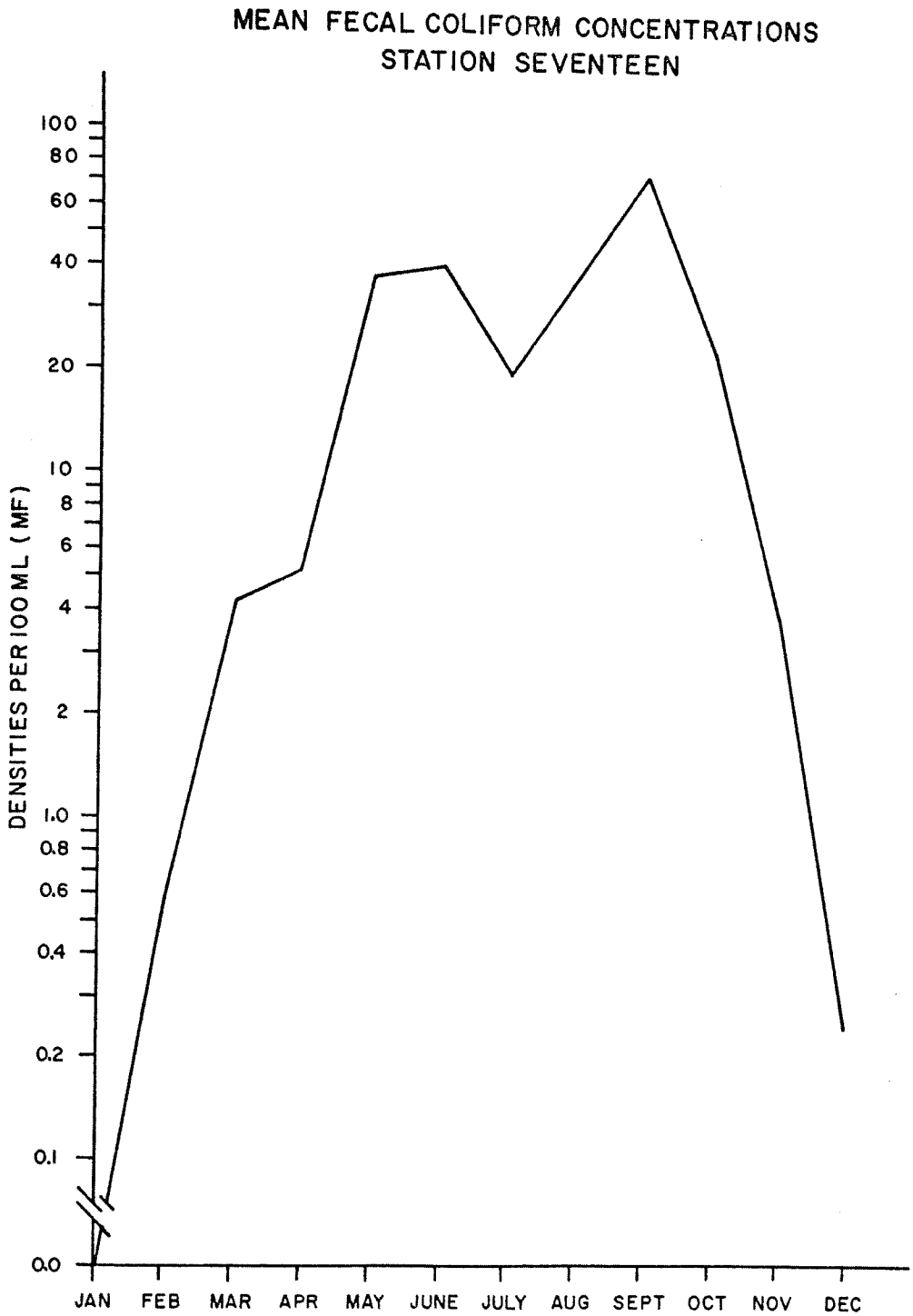

Figure A-17. Mean fecal coliform concentrations for Station 17 from July, 1974 through June, 1975.

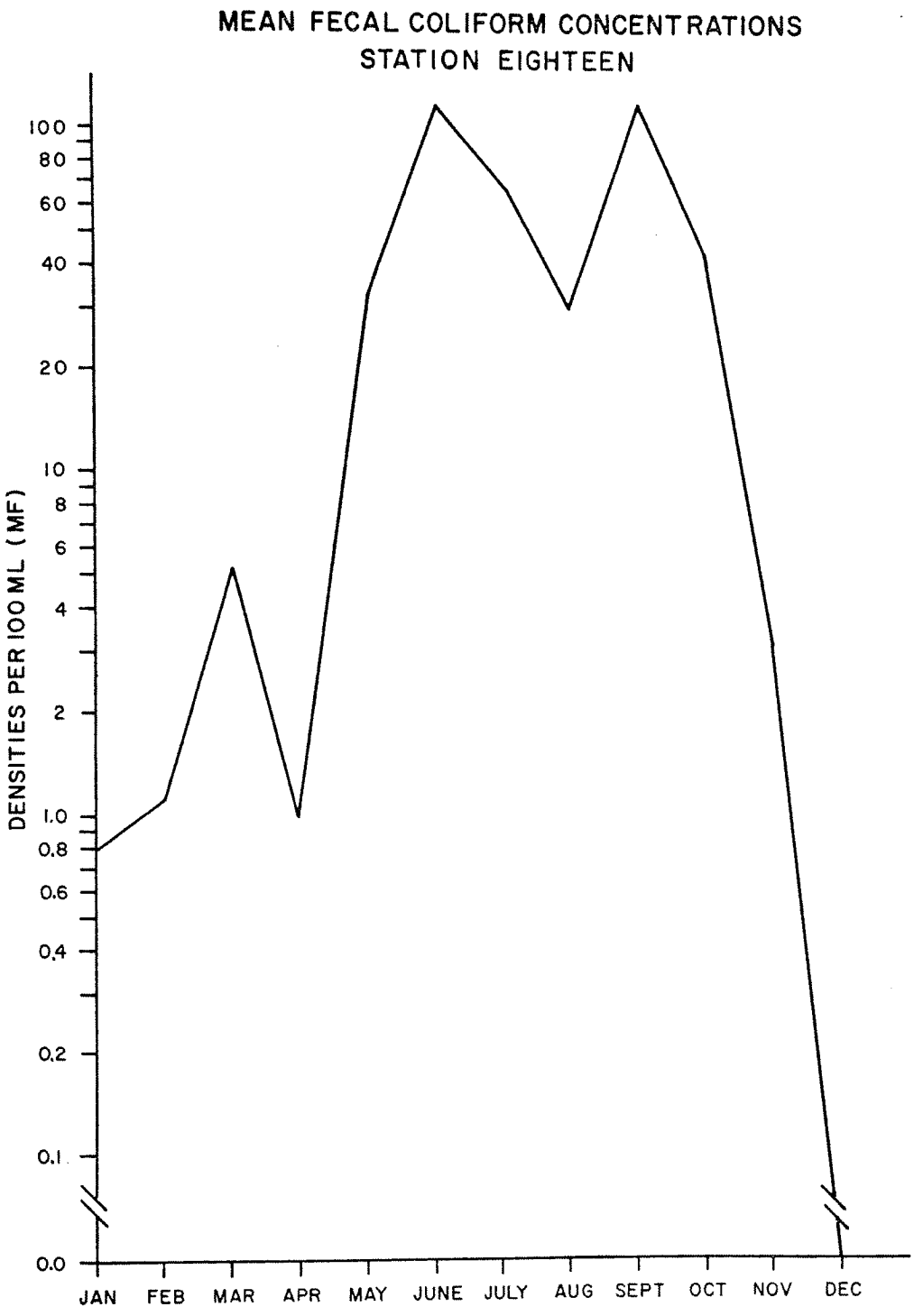

Figure A-18. Mean fecal coliform concentrations for Station 18 from July, 1974 through June, 1975.

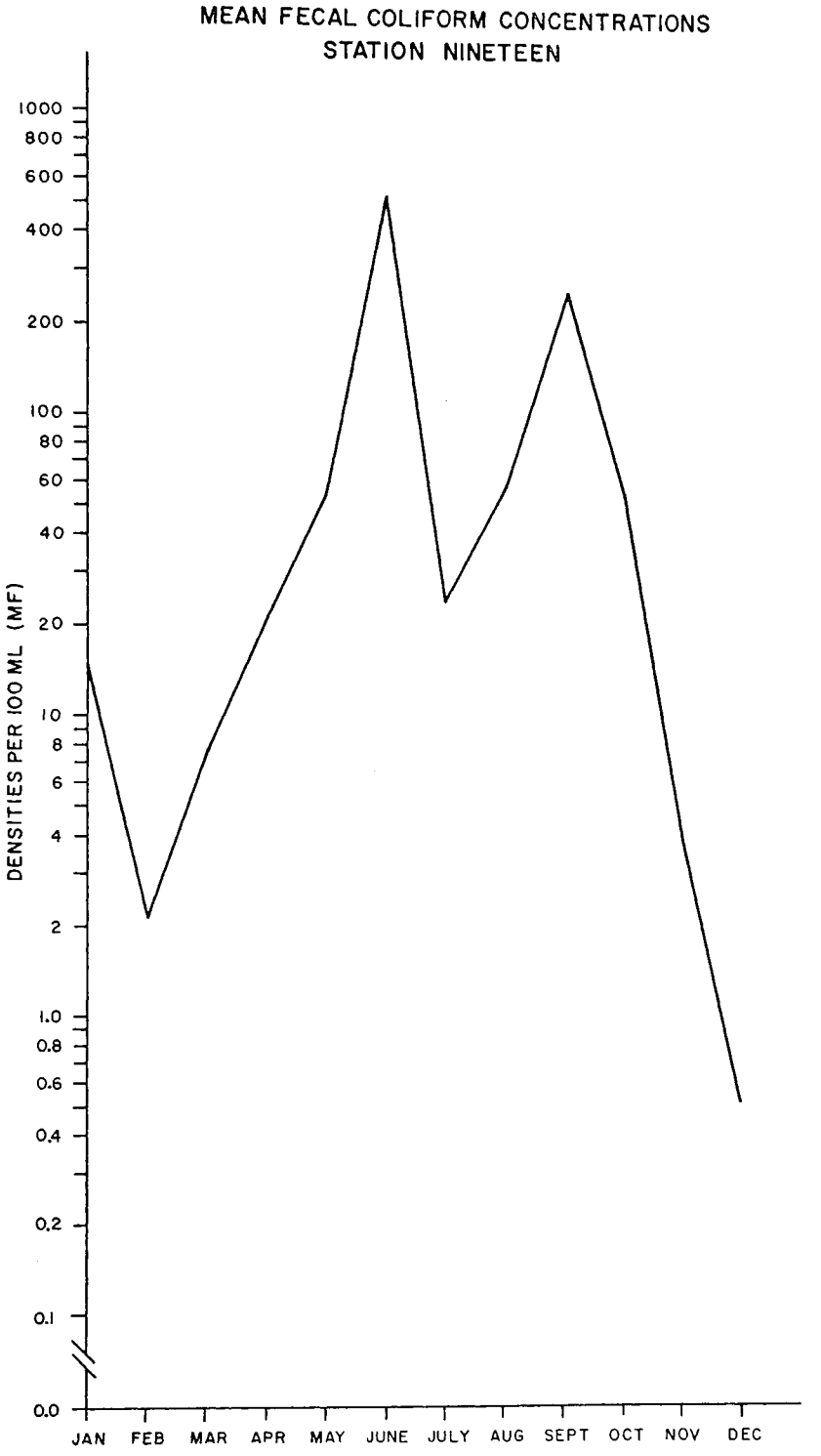

Figure A-19. Mean fecal coliform concentrations for Station 19 from July, 1974 through June, 1975.

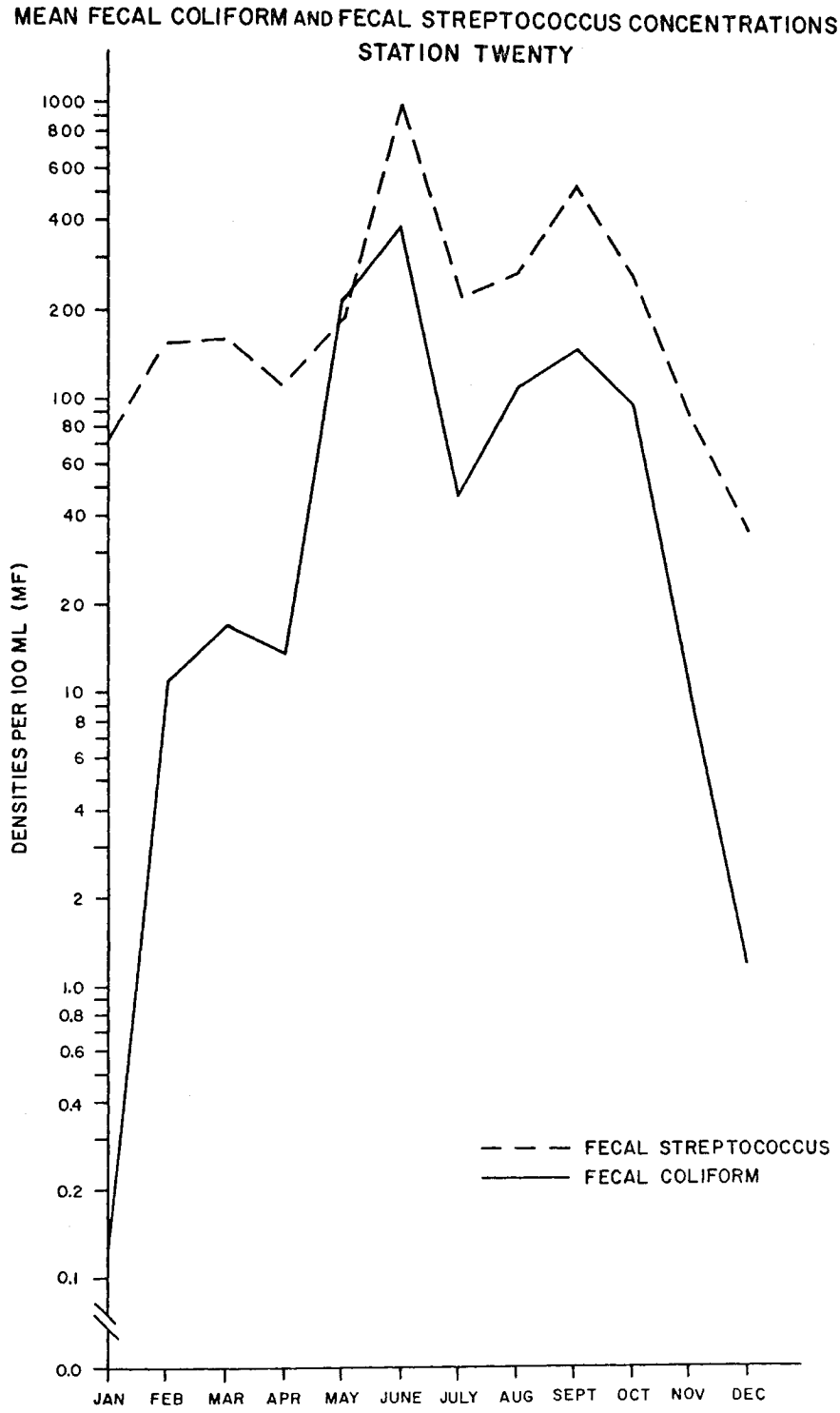

Figure A-20. Mean fecal coliform and fecal streptococcus concentrations for Station 20 from July, 1974 through June, 1975.

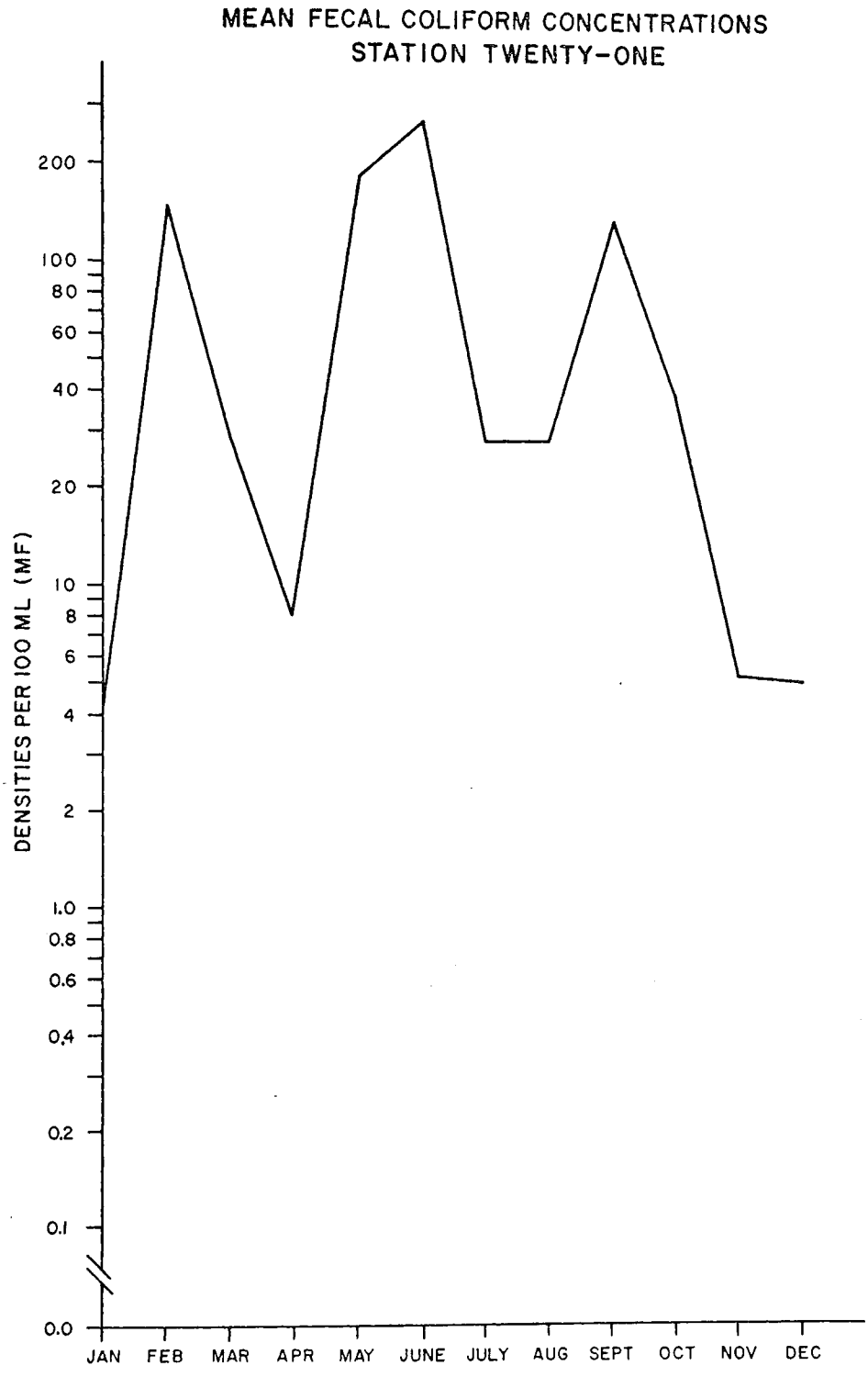

Figure A-21. Mean fecal coliform concentrations for Station 21 from July, 1974 through June, 1975.

APPENDIX B

THREE GRAPHS OF BOTTOM SEDIMENT FECAL COLIFORM CONCENTRATIONS WITH CORRESPONDING SURFACE WATER FECAL COLIFORM CONCENTRATIONS

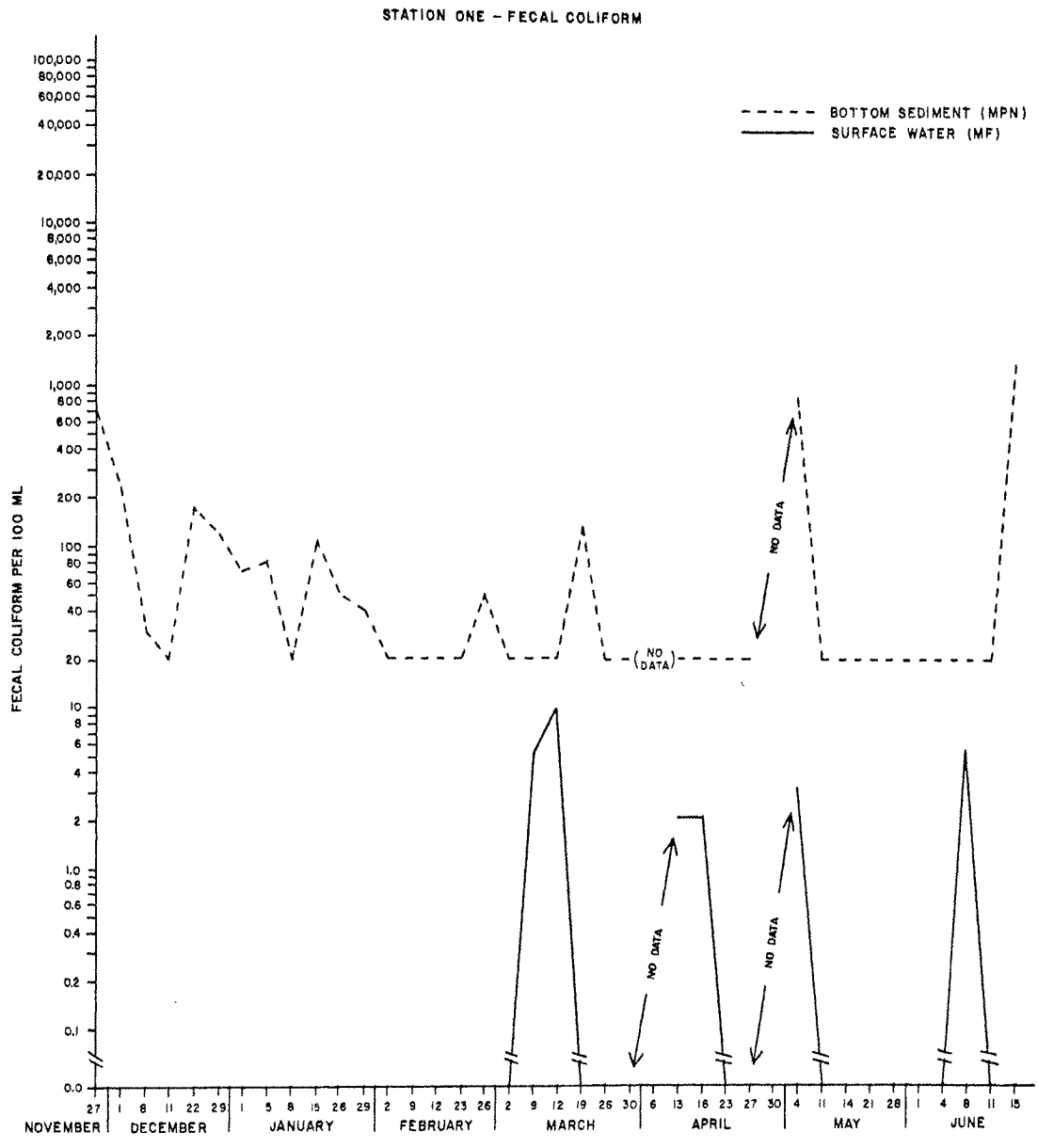

Figure B-1. Fecal coliform concentrations in bottom sediment and corresponding surface water from Station 1.

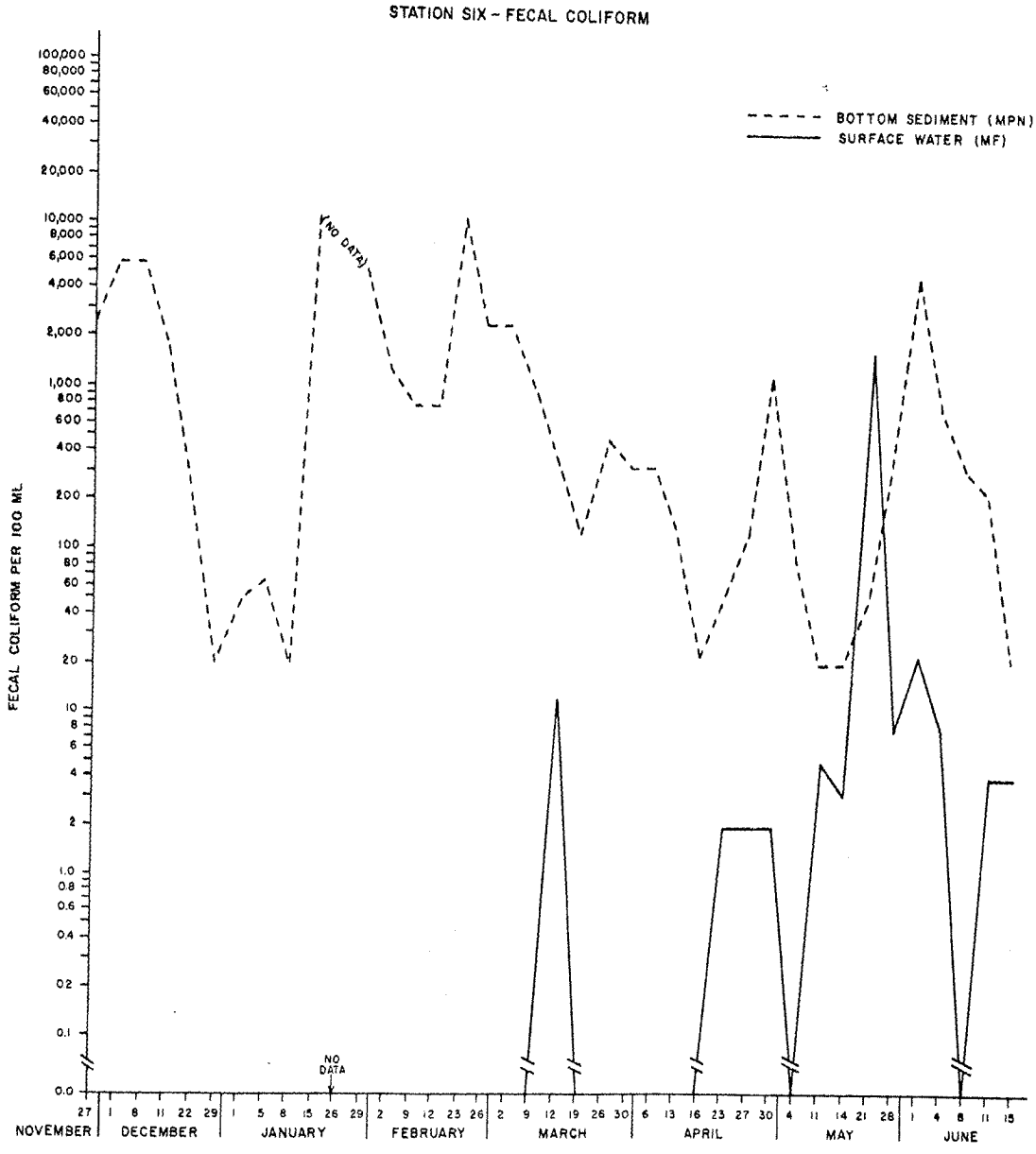

Figure B-2. Fecal coliform concentrations in bottom sediment and corresponding surface water for Station 6.

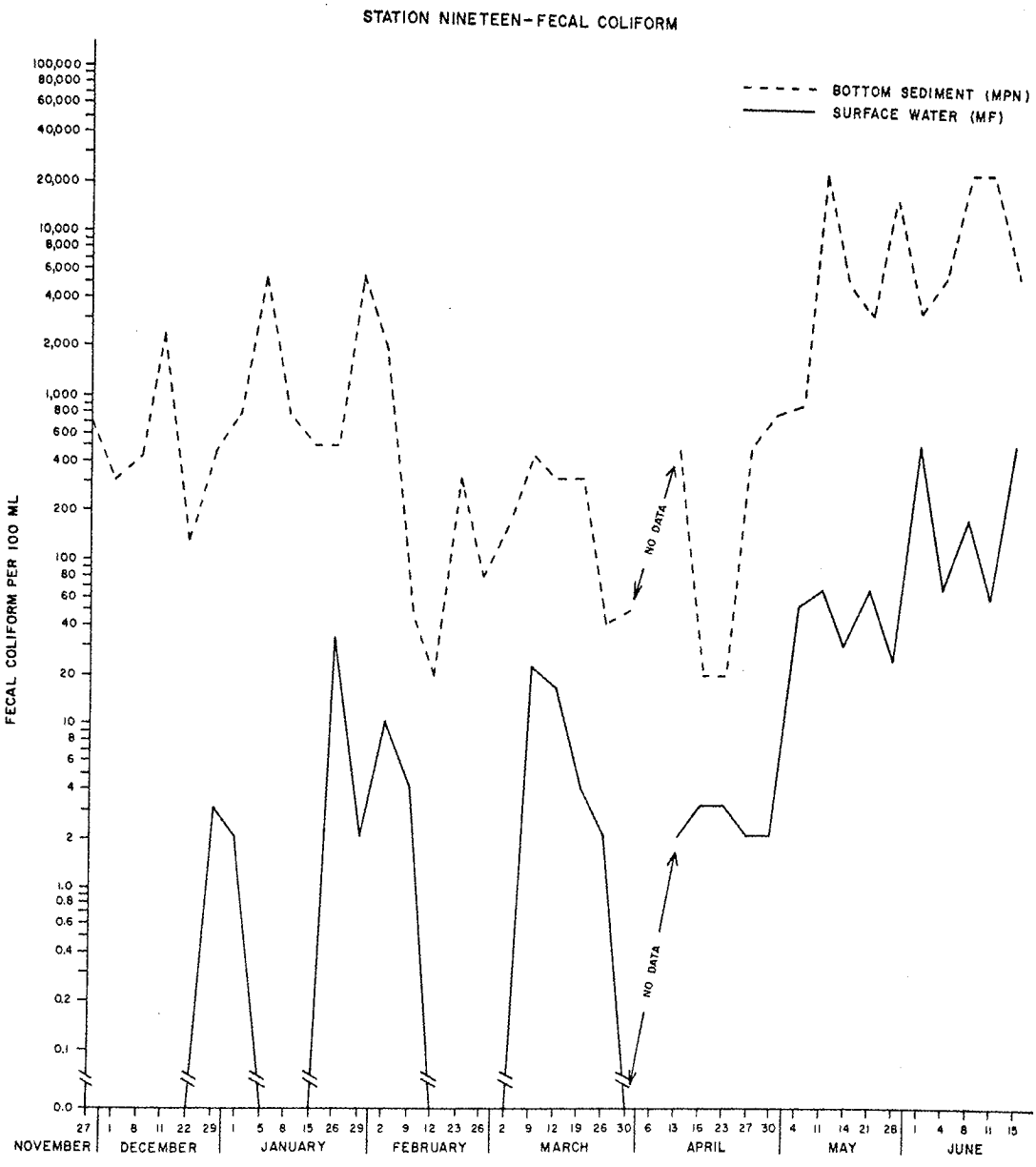

Figure B-3. Fecal coliform concentrations in bottom sediment and corresponding surface water for Station 19.

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