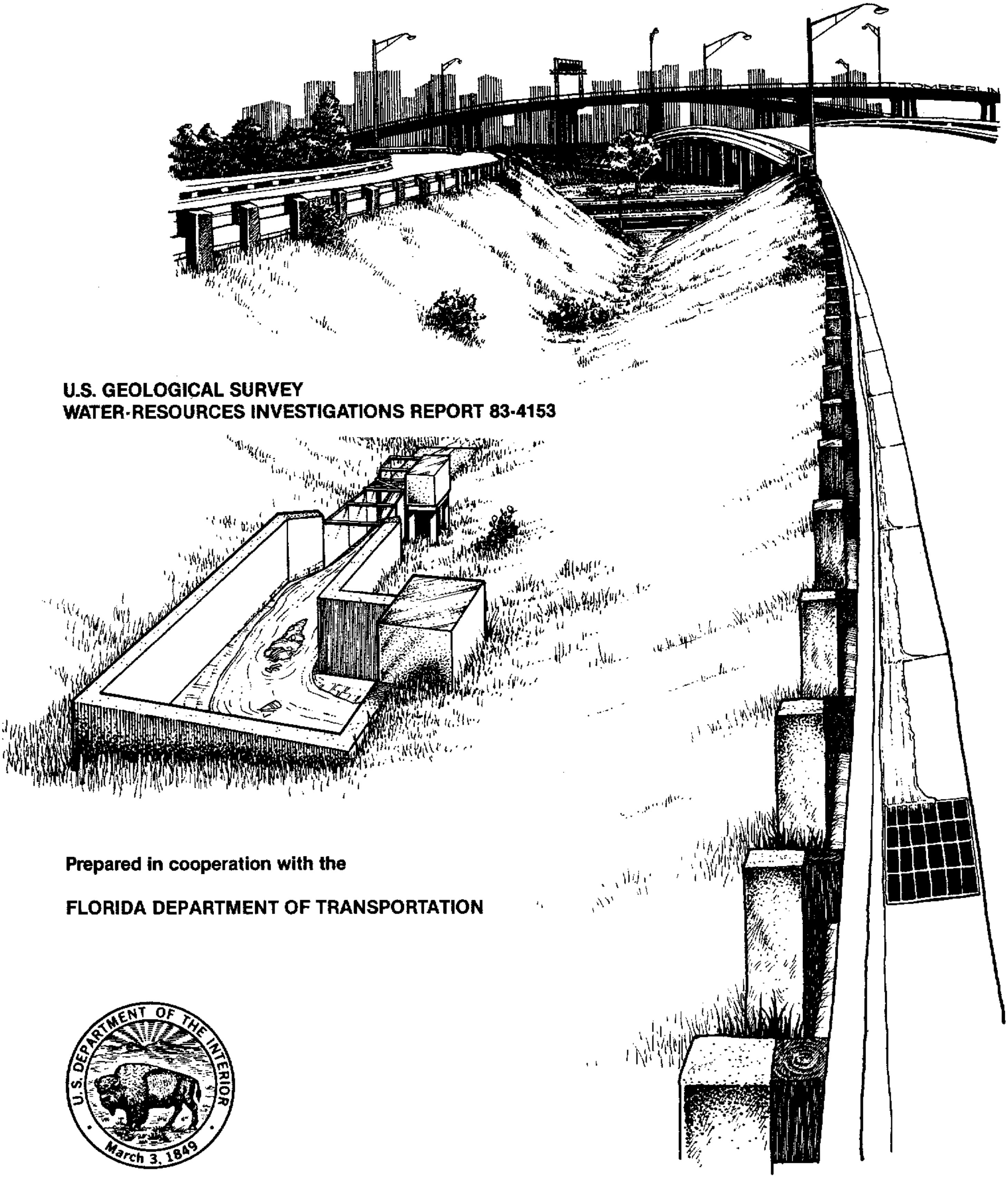
# WATER-QUALITY ASSESSMENT OF STORMWATER RUNOFF FROM A HEAVILY USED URBAN HIGHWAY BRIDGE IN MIAMI, FLORIDA



U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS REPORT 83-4153

Prepared in cooperation with the

FLORIDA DEPARTMENT OF TRANSPORTATION

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By Donald J. McKenzie and G. A. Irwin

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Tallahassee, Florida

1983

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

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[Factors for converting inch-pound units to International System of of units (SI) and abbreviation of units]

| Multiply | By | To obtain |
|---|---|---|
| inch (in) | 25.4 | millimeter (mm) |
| foot (ft) | 0.3048 | meter (m) |
| acre | 0.4047 | hectare (ha) |
| cubic foot per second ($ft^3/s$) | 0.002832 | cubic meter per second ($m^3/s$) |
| square foot ($ft^2$) | 0.09290 | square meter ($m^2$) |
| pound (lb) | 0.4536 | kilogram (kg) |
| cubic foot ($ft^3$) | 0.02832 | cubic meter ($m^3$) |
| micromho per centimeter (µmho/cm) | 1 | microsiemens (µS/cm) |

WATER-QUALITY ASSESSMENT OF STORMWATER RUNOFF FROM A

HEAVILY USED URBAN HIGHWAY BRIDGE IN

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## ABSTRACT

Runoff from a 1.43-acre bridge section of Interstate 95 in Miami, Florida, was monitored during five storms to estimate loads of selected water-quality parameters washed from this heavily traveled roadway. The monitoring was conducted periodically from November 1979 to May 1981 in cooperation with the Florida Department of Transportation for the specific purpose of quantifying the concentrations and loads of selected water-quality parameters in urban-roadway runoff which may have an adverse impact on State surface waters.

Automated instrumentation was used during each of the five storms to collect periodic samples of bridge runoff and to measure continuously the storm discharge from the bridge surface and the local rainfall. For most target parameters, 6 to 11 samples were collected for analyses during each event. Results of these analyses generally indicated that the parameter concentrations in the stormwater runoff and the parameter load magnitudes were quite variable among the five storms, although both were similar to the levels reported for numerous other roadway sites. Storm intensity influenced the rate of loading, but parameter concentration was the dominant variable controlling the overall magnitude of loading.

Although only a limited number of runoff events were sampled, the data were used to estimate the following average, discharge-weighted parameter loads per storm per acre of bridge surface: 28 pounds (total solids), 7.1 pounds (suspended solids), 12.8 pounds (total volatile solids), 4.6 pounds (suspended volatile solids), 4.7 (total organic carbon), 11 pounds (chemical oxygen demand), 0.27 pounds (total nitrogen), 0.06 pounds (total lead), and 0.03 pounds (total zinc). Results of a very limited sampling of rainfall (wetfall) suggested that perhaps 15 percent of the total solids loading and 10 percent of the suspended solids loading originated from material that was transported directly to the bridge surface by precipitation. Further, a cursory assessment suggested that the total number of antecedent dry days and traffic volume were not conspicuously related to either runoff concentrations or loads.

# INTRODUCTION

Roadways serve as depositories for a conglomerate of traffic-related litter, vehicular byproducts, and indigenous substances which may be washed directly into surface waters during stormwater runoff. This assemblage of materials is generated and deposited on highway surfaces, medians, and other contiguous areas as a result of roadway use, maintenance, and natural processes such as erosion and atmospheric fallout; these materials accumulate on roadway systems between periods of precipitation, maintenance sweeping, and wind (Gupta, Agnew, and Kobriger, 1981, p. 3). Some components of this roadway deposition, upon entering a surface-water system, may be environmentally harmful to the aquatic community or may adversely impact surface water quality with respect to other water uses.

Numerous studies, Sartor and Boyd (1972), Shaheen (1975), and Lager and others (1977) have identified various chemical and physical components of traffic-related material that may degrade the quality of streams. In a study prepared for the Federal Highway Administration, Gupta, Agnew, and Kobriger, (1981, p. 4) list eight general categories of common contaminants of roadways: (1) particulates, (2) heavy metals, (3) PCB and pesticides, (4) inorganic salts, (5) organic matter, (6) nutrients, (7) pathogenic bacteria (indicators), and (8) other asbestos, rubber, and special vehicular additives. The actual quantity and composition of deposition for a specific roadway, however, are a function of many factors such as land use, geographical locale, season, weather, traffic volume, and the composition of the highway surface.

In Florida, transportation systems are legislatively recognized as potential nonpoint sources for substances which may adversely impact the environmental quality of the State's surface waters. However, scientific data on the magnitude and distribution of these potentially detrimental substances in stormwater runoff from roadways in Florida are sparse.

The Florida Department of Transportation, along with its vast commission to construct, operate, and maintain the State's roadway system, is the primary agency responsible for the quality of runoff from these highways. Concurrent with the Department's dedication to the preservation of the environmental integrity of the State's water resources, was its cognizance of the paucity of scientific data with which to formulate sound management decisions. Recognizing the critical need for a scientific data base on the quality of runoff from highway structures in Florida, the Department initiated an investigation to selectively measure the quality of stormwater runoff from three-bridge sites having variable ADT (average daily traffic) counts. Results of two previous studies were reported separately. Irwin and Losey (1978) reported on results from a study site in north Florida (near Tallahassee) with a low traffic count (about 4,000 ADT count; Wanielista and others (1980) reported on results from a study site in central Florida (near Orlando) with a medium traffic count (about 50,000 ADT). The current study and report furnish data for an urban bridge site in south Florida with an ADT of about 70,000 for the period of study, November 1979 and March to May 1981 (René H. Tossas, Florida Department of Transportation, oral commun., 1983).

## Purpose and Scope

In 1978, the Florida Department of Transportation and the U.S. Geological Survey began a cooperative study of the quality of stormwater runoff from a heavily traveled 1.43-acre bridge section of Interstate 95 in Miami (fig. 1). The ADT count at this site was about 70,000 vehicles.

The primary purpose of the investigation was to measure both the concentrations and loads of selected water-quality parameters in runoff from the bridge surface during storms. These data, along with data from two similar studies conducted at a low-traffic site on U.S. Highway 27 near Tallahassee and medium-traffic site on Interstate 4 near Orlando, are germane to the Department of Transportation's continuing assessment of best management alternatives to prevent any possible degradation of State surface waters caused by stormwater runoff from roadways.

The scope of the study included intensive measurement and sampling of stormwater runoff during five storms between November 1979 and May 1981. This included the installation and operation of a water stage recorder and flume for the continuous measurement of runoff, a recording rain gage, and an automatic water sample collector. Samples of rain (wetfall) were collected manually. Water-quality analyses were done both in the field and in Geological Survey laboratories.

## Site Description

The highway site selected for study was the northbound bridge on Interstate 95 just north of State Road 836 in central Miami. The bridge is comprised of three asphalt traffic lanes and one emergency lane all of which slope longitudinally downward to the north to a catch basin and laterally to the east curb (fig. 2).

The calculated contributing drainage area of the bridge surface from the drainage divide to the catch-basin drain was 62,415 $ft^2$ (square feet). The study drainage was created laterally by an east-west curb distance of 45 feet and longitudinally by a crest (drainage divide) in the bridge surface which is 1,387 feet south of the catch basin. A 1,048-foot section of the bridge originating at the southern drainage divide had downdrains at intervals of 80 to 137 feet along the east curb. The final 339 feet of bridge, ending at the catch basin, had no downdrains. Stormwater on the bridge section flowed northward along the east curb and drained from the roadway either through the downdrains or the grate-covered catch basin. Consequently, the catch basin drains some of the stormwater runoff from the southern 47,160 $ft^2$ of the bridge section and virtually all the runoff from the northern 15,255 $ft^2$ of the bridge section.

The Florida Department of Transportation estimated that the ADT count at the Interstate 95 sampling site was about 70,000 vehicles per day during the general period of study. The ADT count for specific months when stormwater runoff was sampled were as follows: 73,966 (November 1979), 73,693 (March 1981), and 66,516 (May 1981).

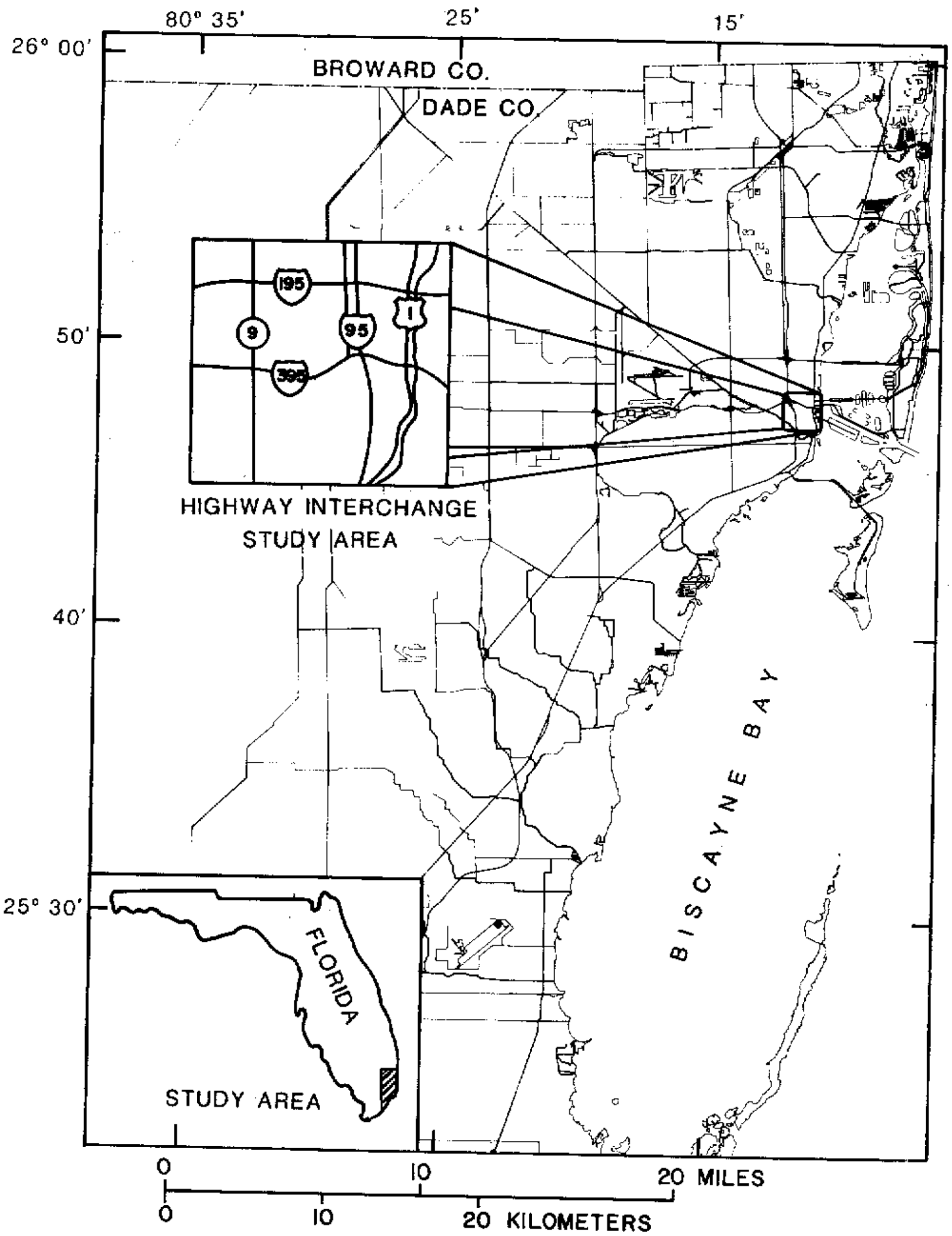


Figure 1.--Location of study area in Miami, Florida.

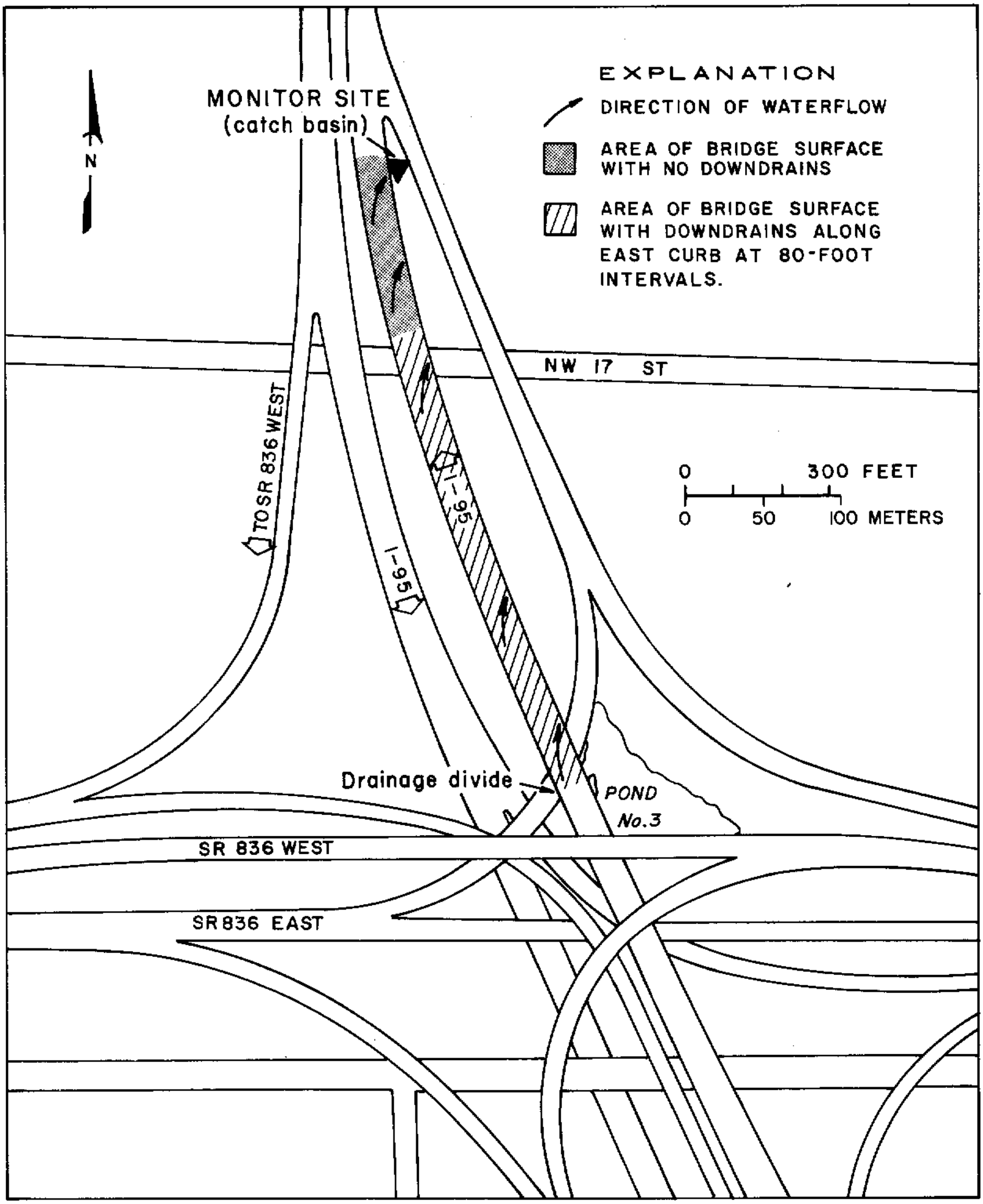


Figure 2.--Study site on Interstate 95 bridge north of State Road 836 in Miami, Florida.

## METHODS AND PROCEDURES

Five stormwater runoff events were sampled under varying conditions of rainfall, antecedent dry days, and seasons. Two runoff events were sampled during November 1979 which is a dry-season month in south Florida, and three runoff events were sampled during March and May 1981 which are wet-season months.

Samples of runoff were analyzed for dissolved solids, suspended solids, chemical oxygen demand, organic carbon, nitrogen species, phosphorus, cadmium, chromium, lead, zinc, oil and grease, and PCB.

The U.S. Geological Survey National Water Quality Laboratory-Atlanta, in Doraville, Ga., provided analyses for the trace metals and the Water Quality Service Unit, in Ocala, Fla., provided analyses for all the other physical and chemical parameters. The analytical methods that were used are described by Goerlitz and Brown (1972), Fishman and Brown (1976), and Skougstad and others (1979).

An automatic water sample collector (Manning S-4050)[1] was used to collect samples of stormwater runoff draining through the 12-inch diameter drain pipe of the catch basin (fig. 3). The sampler was connected to the drain pipe and sampling was triggered with the arrival of the first flush of stormwater runoff. After the first sampling, runoff samples were collected about 3.8 minutes (minimum time interval of control panel). The automatic sampler contained 24-polyethelene bottles of 500 mL (milliliters) capacity. The sampler was self-purging and the vacuum tubes and collection chamber were flushed with stormwater immediately prior to the next sampling.

A continuous record of the water stage and discharge of bridge runoff in the 12-inch diameter drainage pipe was made using a Thompson Parshall flume with a 12-inch throat and a Stevens type-F water-level recorder. Continuous measurement of rainfall was also made and data were recorded on the water-level strip chart so that time-synchronous rainfall and discharge data, along with the runoff analyses, could be used to estimate loads.

It should be noted that some of the stormwater was intercepted and discharged from the bridge section through 6-inch downdrains spaced at varying intervals of 80 to 137 feet along the east curb upgradient from the catch basin. Therefore, any stormwater loss through the downdrains would result in an underestimate of the total loads per storm per unit area which are presented in a later section of this report. Measurements of rainfall and runoff for individual events, excluding May 1, indicated that 7 to 83 percent of the estimated rainfall volume to the bridge surface was measured as runoff at the catch basin as follows:

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

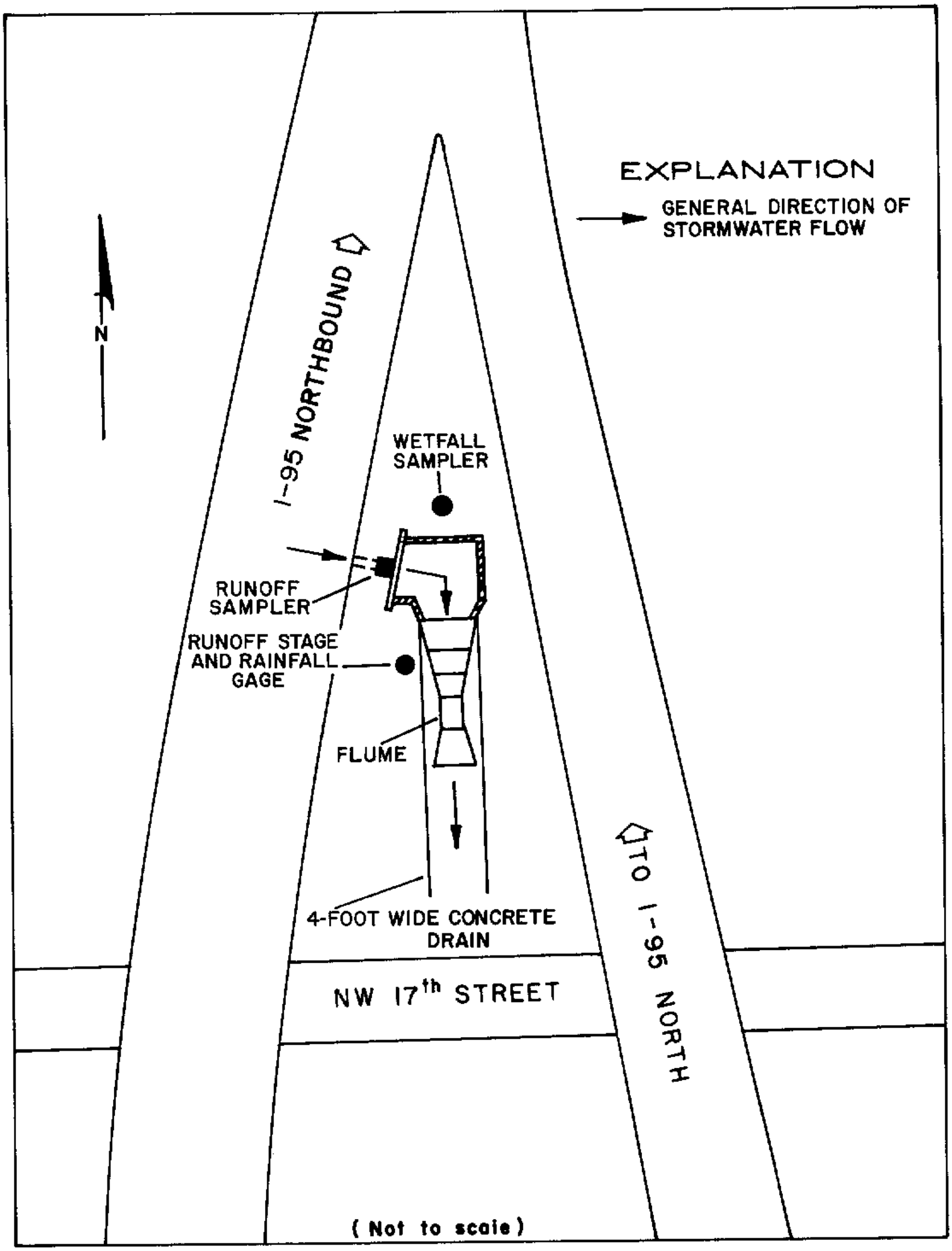


Figure 3.--Stormwater runoff site and the location of equipment used to collect water-quality and discharge data.

| Date | Rain-fall (inches) | Discharge measured (cubic feet) | Discharge calculated (cubic feet) | Percent discharge recovered |
|---|---|---|---|---|
| 11/03/79 | 0.40 | 1,720 | 2,070 | 83 |
| 11/20/79 | .55 | 1,120 | 2,850 | 39 |
| 3/23/81 | .12 | 45 | 620 | 7 |
| 5/01/81 | .08 | 1,700 | 420 | 405 |
| 5/20/81 | .65 | 2,140 | 3,370 | 64 |

However, many factors other than downdrains, such as variability in rainfall over the bridge and evaporation and splash can affect rainfall-runoff relations; and, therefore, estimates of runoff loss attributable solely to downdrains could not be made. Also, the factors that caused the anomalous relation which occurred on May 1 are not known. In broad view, however, and considering the reconnaissance nature of this experimental design, the unmeasured loss of stormflow through the downdrains does not significantly bias the use of the Interstate 95 loading data for general comparisons with stormwater loading from other high-traffic interstate bridge structures in Florida because most have similar construction.

Rainfall (wetfall) was collected using a 5-gallon polyethylene container. Although manual grab sampling excluded the dryfall contribution during periods of no rainfall, a fixed sampling device was not practicable because of vandalism to the sampling equipment.

## RESULTS

### Quality of Stormwater Runoff from Interstate 95 Bridge

A summary of water-quality analyses of stormwater runoff from the Interstate 95 study site is presented in table 1. This summary includes only those data collected at times of stormwater runoff. The analyses of the few samples collected at zero flow are not included in table 1. Individual data for each sample collected during the five storms are given in the supplementary-data section of this report beginning on page 41. For general comparison, table 1 presents selected results from two previous bridge-site studies that were conducted by the U.S. Geological Survey (U.S. Highway 27) and the University of Central Florida (Interstate 4) in cooperation with the Florida Department of Transportation.

The following results are arranged to present selected data that are at least partly indicative of most of the general categories of roadway contaminants given in Gupta, Agnew, and Kobriger (1981, p. 4).

Table 1.--Summary of water-quality analyses of stormwater runoff from a 1.43-acre bridge section of Interstate 95 collected during five storms, November 3 and 20, 1979; March 23, 1981; and May 1 and 20, 1981

[Concentrations in milligrams per liter, except as indicated]

| | Number of samples | Mean | Median | Standard deviation | Range | Selected data from two previous bridge site investigations in Florida: U.S. Highway 27[1] Mean | U.S. Highway 27[1] Range | Interstate 4[2] Mean | Interstate 4[2] Range |
|---|---|---|---|---|---|---|---|---|---|
| Specific conductance (µmhos/cm at 25°C) | 31 | 337 | 182 | 297 | 36-845 | 28 | 8-64 | | |
| Turbidity (NTU) | 11 | 19 | 20 | 2 | 14-22 | 40 | 4-100 | 33 | 12-82 |
| Solids, total residue at 105°C | 43 | 437 | 524 | 312 | 31-1,190 | | | | |
| Solids, dissolved residue at 105°C | 43 | 356 | 388 | 273 | 20-784 | | | | |
| Volatile solids, dissolved residue at 550°C | 43 | 131 | 136 | 92 | 11-327 | | | | |
| Volatile solids, suspended residue at 550°C | 32 | 64 | 48 | 60 | 5-266 | | | | |
| Suspended solids, total residue at 110°C | 43 | 81 | 42 | 85 | 7-433 | 99 | 21-278 | | |
| Chemical oxygen demand (high level) | 40 | 223 | 285 | 139 | 26-530 | 51 | 36-64 | | |
| Ammonia, total as N | 34 | .17 | .14 | .09 | .04-.50 | .04 | .00-.11 | | |
| Nitrite, total as N | 34 | .25 | .04 | .32 | .01-1.0 | .02 | .00-.03 | | |
| Nitrate, total as N | 34 | 1.4 | 1.0 | 1.1 | .06-3.2 | .07 | .04-.12 | 3.9 | 1.4-8.2 |
| Organic, total as N | 34 | 2.3 | 2.0 | 1.9 | .06-5.8 | 1.1 | .06-3.4 | | |
| Nitrogen, total as N | 34 | 4.1 | 3.2 | 3.0 | .49-8.2 | 1.2 | .12-3.5 | | |
| Phosphorus, total as P | 34 | .17 | .16 | .12 | .02-.66 | .15 | .01-.30 | .43 | .16-1.2 |
| Organic carbon, total | 44 | 77 | 86 | 55 | 3.2-205 | 6 | .0-23 | | |
| Cadmium, total recoverable[3] | 34 | ([4]) | 1 | -- | <1-8 | | | 5 | 3-9 |
| Chromium, total recoverable[3] | 32 | ([4]) | <10 | -- | <10-30 | ([4]) | <10-30 | 11 | 3-27 |
| Copper, total recoverable[3] | 35 | 54 | 40 | 50 | 7-250 | 32 | 6-210 | 52 | 32-100 |
| Lead, total recoverable[3] | 35 | 680 | 590 | 590 | 41-2,400 | 210 | 16-620 | 1,560 | 690-3,250 |
| Zinc, total recoverable[3] | 36 | 370 | 330 | 300 | 50-1,300 | 130 | 20-340 | 500 | 230-1,120 |
| Oil and grease, total | 8 | 7 | 4 | 6 | 2-16 | 1 | 0-3 | | |
| Polychlorinated biphenyls, total | 2 | | | | <.10 | | | | |

[1] Irwin and Losey (1978, table 2, p. 11).
[2] Wanielista and others (1980, Appendices C-3 and C-4, p. 139-140).
[3] Concentrations in micrograms per liter.
[4] Some concentrations were below the analytical detection limit.

## Solids

Dissolved and suspended (particulate) solids in stormwater runoff from roadways may adversely impact receiving waters. Dissolved solids may increase salinity and may be comprised of potential contaminants. Suspended solids may have a direct pollutional impact on receiving waters by reducing water clarity or by physically burying aquatic organisms. Suspended solids may also have an indirect pollutional impact by acting as a substrate on which toxic materials may be sorbed, transported, and later released into receiving waters.

The summary of results presented in table 1 shows that, on the average, the bridge runoff contained high levels of both dissolved and suspended substances. For example, the total-solids residue at 105°C for the five runoff events averaged 437 mg/L with about 75 percent of the sample concentrations in excess of 130 mg/L. The dissolved solids averaged 356 mg/L with about 75 percent of the concentrations about 70 mg/L or greater. The suspended solids residue at 110°C averaged 81 mg/L and ranged from 7 to 433 mg/L, with 75 percent of the runoff sampled having concentrations greater than about 20 mg/L. Interestingly, the average concentration of suspended solids collected at the low-traffic, U.S. Highway 27 bridge was slightly higher at 99 mg/L; however, a difference between 81 mg/L and 99 mg/L is not considered particularly significant.

Based on a cursory literature review, the concentrations of total, dissolved, and suspended solids in runoff from the bridge site on Interstate 95 were generally comparable with similar data reported for other urban-roadway environments. For example, a total- and dissolved-solids range of 194 to 8,620 mg/L and 27 to 7,340 mg/L, respectively, was reported by Colston (1974, p. 1) to represent generalized urban runoff of the Piedmont Province of the East Coast. Field and Tafuri, (1973, p. 9) reported concentrations of total solids in urban stormwater ranging from 450 to 14,600 mg/L. Loehr (1975, p. 240) reported typical suspended-solid ranges in various urban-land drainage of 84 to 2,050 mg/L (Tulsa, Okla.), 102 to 210 mg/L (Detroit, Mich.), 20 to 340 mg/L (Madison, Wis.), and 31 to 14,500 (U.S.S.R). In a study of stormwater runoff from a drainage comprised primarily of paved roadway with a traffic flow of about 20,000 vehicles per day in Broward County, Fla., Mattraw (1978, p. 257) reported respective averages of total solids (113 mg/L), dissolved solids (99 mg/L), and suspended solids (15 mg/L). Gupta, Agnew, Gruber, and Kreutzberger (1981, p. 133) reported averages of 1,147 mg/L and 261 mg/L for total and suspended solids, respectively, in stormwater runoff for 159 events at six highway sites distributed throughout the United States.

As a gross analytical measurement of the organic fractional composition of the runoff, the suspended and dissolved solids were volatilized at 550°C. Based on the average volatilization loss of 64 mg/L for the suspended-solids samples and 131 mg/L for the dissolved-solids samples, the total volatilization loss at 550°C was estimated to be about 195 mg/L. Therefore, on the average, a 195 mg/L volatilization loss from a total solids residue of 437 mg/L suggests that approximately 45 percent of the total solids in the runoff was comprised of organic material. The average concentration of

77 mg/L for organic carbon generally corroborates an estimated organic content of about 195 mg/L in as much as twice the carbon concentration, in this case 144 mg/L, is a commonly used approximation of a substance's organic content.

Colston (1974, p. 1) reported a total volatile solids range of 33 to 1,170 mg/L and a suspended volatile solids range of 5 to 970 mg/L for urban runoff in Durham, N.C. A total volatile solids range of 12-1,600 mg/L for selected urban drainage was reported by Field and Tafuri (1973, p. 9). Gupta, Agnew, Gruber, and Kreutzberger (1981, p. 133) reported concentration averages and ranges in highway runoff of 242 mg/L and 26 to 1,522 mg/L for total volatile solids and 77 mg/L and 1 to 837 mg/L for suspended volatile solids. Based on the volatile solids data reported by Gupta, Agnew, Gruber, and Kreutzberger (1981) about 21 percent of the total solids of highway runoff was comprised of organic material.

## Chemical Oxygen Demand

The level of oxygen-demanding substances in the stormwater runoff from Interstate 95 was estimated by its COD (chemical oxygen demand). Although COD has certain interpretive limitations because it does not distinguish between biologically inert and biologically oxidizable organic substances, it does provide a rather inclusive estimate of the total quantity of oxygen required to oxidize the organic component of a water sample. Thus, the COD data presented in table 1 are a relative measure of the potential oxygen demand or impact that the Interstate 95 runoff would contribute to a receiving water.

Overall, runoff from the five events contained notable levels of COD, averaging 223 mg/L and ranging 26 to 530 mg/L. The COD in runoff at Interstate 95 was usually much higher than that in runoff at the low-traffic, U.S. Highway 27 bridge in north Florida. The COD in runoff from U.S. Highway 27 ranged from only 36 to 64 mg/L, whereas approximately 75 percent of the runoff samples collected at Interstate 95 had COD concentrations in excess of 86 mg/L.

Selected literature indicated that the COD levels in runoff at the Interstate 95 site were about the same magnitude as those contained in urban drainage in other areas. Loehr (1975, p. 290), for example, reports COD ranges of 20 to 610 mg/L for Cincinnati, Ohio, 40 to 600 mg/L for Durham, N.C., and 42 to 138 mg/L for Tulsa, Okla. An average COD of 170 mg/L and range of 20 to 1,042 mg/L was reported by Colston (1974, p. 1) as representative of runoff in urban areas of the Piedmont Province of the Eastern United States. In a study of highway runoff in Broward County, Fla., Mattraw (1978, p. 257) measured an average COD of 59 mg/L. The average and range of COD in highway runoff at six sites throughout the country were 14.7 mg/L and 5 to 1,058 mg/L, respectively (Gupta, Agnew, Gruber, and Kreutzberger, 1981, p. 132).

## Nitrogen and Phosphorus

Vitale and Sprey (1974) report that commonly less than 10 percent of the nitrogen and phosphorus loads to the surface-water environment is contributed by urban runoff. However, the nutrient load in urban runoff is often environmentally significant because it may cause a process of accelerated biostimulation of receiving waters. This process is often referred to as shock loading.

The concentration of total nitrogen in the stormwater runoff from the Interstate 95 bridge averaged 4.1 mg/L and ranged from 0.49 to 8.2 mg/L. Slightly over 50 percent of the average total nitrogen was in organic form and about 30 percent was in nitrate form.

Overall, the concentrations of the individual nitrogen species in runoff from Interstate 95 were much higher than those in runoff from the low-traffic site at U.S. Highway 27. The average concentration of total nitrogen in runoff from U.S. Highway 27 was 1.2 mg/L as compared to an average of 4.1 mg/L at Interstate 95. Of the individual species, the difference in nitrate concentrations was the most notable, with an average of 1.4 mg/L at Interstate 95 and 0.07 mg/L at U.S. Highway 27. However, the nitrate concentration in runoff from the study site on Interstate 4 in the Orlando area was substantially higher than those at either Interstate 95 or U.S Highway 27. At the Interstate 4 site, the nitrate concentrations ranged from 1.4 to 8.2 mg/L and averaged 3.9 mg/L.

The average concentration (4.1 mg/L) of total nitrogen in the runoff from Interstate 95 was generally within the range of 2 to 4 mg/L which is reported to represent urban drainage on a national scale (Loehr, 1975, p. 292). Mattraw (1978, p. 1) reported an average total nitrogen of 0.96 mg/L for a Broward County roadway. Similarly, concentrations of nitrate in runoff at Interstate 95 compare generally with previously reported levels. For example, nitrate-nitrogen concentrations in urban drainage in Cincinnati, Ohio, averaged 0.53 mg/L and in drainage in Washington D.C., nitrate ranged from 0.4 to 2.0 mg/L (Loehr, 1975, p. 290). Nitrate-nitrogen concentrations averaged 0.28 mg/L in highway runoff in Broward County (Mattraw, 1978, p. 257). Gupta, Agnew, Gruber, and Kreutzberger (1981, p. 132) reported average concentrations of nitrite and nitrate (as nitrogen) in highway runoff of 0.26 mg/L ranging from <0.01 to 1.93 mg/L.

Total phosphorus averaged 0.17 mg/L and ranged from 0.02 to 0.66 mg/L in runoff from Interstate 95. Phosphorus concentrations in runoff from the low-traffic, U.S. Highway 27 and Interstate 95 were about the same magnitude, whereas the phosphorus concentration in runoff from the medium-traffic, Interstate 4 bridge in the Orlando area was somewhat higher with an average of 0.43 mg/L and a range of 0.16 to 1.2 mg/L.

Phosphorus levels in the Interstate 95 runoff were generally comparable with a general range of about 0.2 to 1 mg/L for urban drainages reported by Loehr (1975, p. 292). Gupta, Agnew, Gruber, and Kreutzberger (1981, p. 132) reported an average total phosphate of 0.79 mg/L (0.26 mg/L as P) in runoff from highways. However, urban drainage in some areas have much greater phosphorus ranges, for example: 0 to 7.3 mg/L, Cincinnati, Ohio; 0.5 to 4.0 mg/L, Washington, D.C.; and 0.15 to 2.5 mg/L, Durham, N.C. (Loehr, 1975, p. 291).

## Trace Metals

Road runoff often contains significant amounts of heavy metals, particularly zinc and lead, and depending upon their specific chemical form, many metals can have highly adverse environmental impacts on surface waters (Sartor and Boyd, 1975, p. 305). Lead is a common vehicular byproduct and is perhaps the most common trace-metal contaminant on roadway surfaces.

Results indicated that both lead and zinc were present at appreciable levels in bridge runoff from Interstate 95. Lead averaged 680 μg/L (micrograms per liter) and ranged from 41 to 2,400 μg/L; zinc averaged 370 μg/L and ranged from 50 to 1,300 μg/L.

The concentrations of lead and zinc in runoff from the Interstate 95 bridge were about three times those in runoff from the low-traffic, U.S. Highway 27 bridge. However, the average lead in runoff at Interstate 95 (680 μg/L) was notably less than that found at Interstate 4 (1,560 μg/L), but the overall ranges of zinc were generally comparable.

Copper was present in the Interstate 95 runoff in detectable concentrations, but at notably lower levels than either lead or zinc. Overall, the concentrations of copper were quite comparable among the three sites.

Only trace concentrations of cadmium and chromium were detected in runoff from the Interstate 95 bridge site with levels generally comparable among all three-bridges sites.

The concentrations of both lead and zinc in runoff from Interstate 95 were generally comparable with levels commonly present in other urban drainages. Reported ranges for lead and zinc, respectively, are: 100 to 2,860 μg/L and 90 to 4,600 μg/L (Colston, 1974, p. 1), 0 to 1,900 μg/L (lead), (Field and Tafuri, 1973, p. 9); and 100 to 1,000 μg/L and 150 to 1,100 μg/L (Alley and Ellis, 1978, p. 195). Specifically for highway runoff, Mattraw (1978, p. 257) reported an average lead and zinc of 282 μg/L and 90 μg/L, respectively; and Gupta, Agnew, Gruber, and Kreutzberger (1981, p. 132) reported an average concentration of lead of 960 mg/L and an average concentration of zinc of 410 μg/L.

## Selected Organic Compounds

Analysis for oil and grease was made on samples collected during both the May 1981 storms. Oil and grease was used as a general indicator of vehicular leakage of fuel, lubricants, hydraulic fluids, and coolants. The average concentration was 7 mg/L with a range of 2 to 16 mg/L. Oil and grease levels in runoff from U.S. Highway 27 ranged from 0 to 3 mg/L. Field and Tafuri (1973, p. 9), report that oil and grease in urban stormwater can be expected to range from 0 to 110 mg/L. The average concentration of oil and grease in samples from 159 storms at six highway bridges ranged from 1 to 20 mg/L (Gupta, Agnew, Gruber, and Kreutzberger, 1981, p. 135).

PCB (Polychlorinated biphenyls) are classed as a National Priority Pollutant and are reported by Sartor and others (1974, p. 461) to be a common substance in urban runoff. Gupta, Agnew, Gruber, and Kreutzberger (1981, p. 135) reported a geometric-mean PCB concentration of 0.33 μg/L in highway runoff. The two grab samples collected during two storms at Interstate 95, however, had concentrations less than 0.10 μg/L.

## Quality of Precipitation at the Interstate 95 Study Site

Analytical results of three precipitation (wetfall) samples collected at the Interstate 95 bridge site during early 1981 are presented in table 2. Also presented in table 2 are bulk-precipitation data collected at the low traffic, U.S. Highway 27 site in rural north Florida (Irwin and Losey, 1978, p. 17). The data for the Interstate 95 site were collected during rainfall events (wetfall) and the U.S. Highway 27 data were bulk precipitation (wetfall and dryfall) collected over a period of time; therefore, data are only generally comparable. Wetfall and bulk precipitation (wetfall and dryfall) do not normally represent equivalent analytical information because dryfall also contains measurable quantities of numerous substances.

### Solids

The total solids were variable ranging from 33 to 88 mg/L with most of the measured solids concentration present in the dissolved form. The dissolved solids ranged from 28 to 68 mg/L. The suspended solids ranged from 5 to 20 mg/L and were comparable with the general range of 12 to 13 mg/L in urban precipitation reported by Loehr (1975, p. 211). The magnitude of suspended sediment in wetfall at Interstate 95 was also virtually the same as for the bulk precipitation collected at the low-traffic, U.S. Highway 27 site.

### Chemical Oxygen Demand

The chemical oxygen demand in precipitation (wetfall) at Interstate 95 was variable with a range of 0 to 20 mg/L. This concentration interval is generally comparable to the lower part of the COD range for bulk precipitation reported in other urban areas: 9 to 16 mg/L (Loehr, 1975, p. 271); 4 to 49 mg/L (Hardee and others, 1978); and 4 to 130 mg/L (Miller and others, 1979).

### Nitrogen

Most forms of nitrogen were present in the precipitation (wetfall) at the Interstate 95 study site. Nitrate averaged 0.31 mg/L and ammonia averaged 0.28 mg/L, with nitrate and ammonia comprising, respectively, 40 and 36 percent of the total nitrogen. The total nitrogen ranged from 0.53 to 1.1 mg/L and was similar in magnitude to the 0.15 to 1.2 mg/L measured in bulk precipitation at the low traffic, U.S. Highway 27 bridge site in north Florida. Total nitrogen ranges reported for bulk precipitation in other urban areas were 0.05 to 2.6 mg/L (Hardee and others, 1978), 0.05 to 3.9 mg/L (Miller and others, 1979), and selected averages reported by Loehr (1975, p. 271) were 1.27 mg/L, 1.17 mg/L and 0.72 mg/L.

Table 2.--Results of selected analyses of samples of precipitation (wetfall) collected at the Interstate 95 study site and bulk precipitation from Highway 27 in north Florida

[Concentrations in milligrams per liter, except as indicated]

| Date: / Time: | 03/23/81 0631 | 05/01/81 1906 | 05/20/81 1836 | Average | Concentration ranges in bulk precipitation, Highway 27[1] |
|---|---|---|---|---|---|
| Specific conductance (μmho/cm) at 25°C | 24 | 18 | -- | 21 | 18-25 |
| Solids, total residue at 105°C | 88 | 33 | -- | 60 | -- |
| Solids, dissolved residue at 105°C | 68 | 28 | -- | 48 | -- |
| Solids, suspended residue at 110°C | 20 | 5 | -- | 12 | 0-16 |
| Chemical oxygen demand (high level) | 0 | 5 | 20 | 8 | -- |
| Ammonia, total as N | .16 | .43 | .25 | .28 | .02-.66 |
| Nitrite, total as N | .01 | .00 | .01 | .01 | .00-.01 |
| Nitrate, total as N | .38 | .42 | .12 | .31 | .06-.31 |
| Organic, total as N | .11 | .22 | .15 | .16 | .00-.31 |
| Nitrogen, total as N | .68 | 1.1 | .53 | .77 | .15-.12 |
| Phosphorus, total as P | .00 | .02 | .02 | .01 | .01-.05 |
| Organic carbon, total | 4.2 | 5.9 | .0 | 3.4 | .0-2.0 |
| Cadmium, total recoverable | 1 | -- | 1 | 1 | -- |
| Chromium, total recoverable | 25 | -- | -- | -- | <10 |
| Copper, total recoverable[2] | 20 | -- | 7 | 14 | 1-6 |
| Lead, total recoverable[2] | 0 | -- | 2 | 1 | 27-74 |
| Zinc, total recoverable[2] | 80 | -- | 40 | 60 | 10-30 |

[1] From Irwin and Losey, table 4, p. 17.
[2] Concentrations in micrograms per liter.

## Phosphorus

Phosphorus was present only in trace amounts in precipitation (wetfall) at the Interstate 95 bridge site and with levels about the same as those measured at the U.S. Highway 27 bridge site. Hardee and others (1978) reported a total phosphorus range of 0.0 to 0.24 mg/L in bulk precipitation collected at a roadway environment in Broward County, Fla., and Loehr (1975, p. 271) reported a generalized concentration range of 0.02 to 0.04 mg/L for urban precipitation.

## Trace Metals

Very low quantities of trace metals were present in the precipitation (wetfall) at the Interstate 95 site. Interestingly, virtually no lead was detected in the wetfall; however, the lead concentrations in bulk precipitation at the low traffic, U.S. Highway 27 bridge site in north Florida ranged from 27 to 74 µg/L. Although these data are extremely sparse, this difference in concentrations focuses on the significance of dryfall as a transport mechanism for lead. Other studies report rather high lead levels in bulk precipitation. Hardee and others (1978) reported a lead range of 9 to 310 µg/L and Miller and others (1979) reported a range of 10 to 2,400 µg/L. The data given in Hardee and others (1978) represents an urban-roadway environment in Pompano Beach, Fla., with an ADT flow of 20,000 vehicles; the data from Miller and others (1979) represent a regional shopping mall in downtown Fort Lauderdale, Fla.

# Concentrations of Selected Water-Quality Parameters as a Function of Stormwater Runoff

Plots of the concentrations of selected parameters and the corresponding instantaneous discharge at the time of each sampling for each of the stormwater runoff events are presented in the following section. The parameters were selected to portray generally the dissolved inorganic component (dissolved solids), the particulate component (suspended solids), the oxygen-demand component (chemical oxygen demand), the organic component (total organic carbon, the nutrient component (total nitrogen), and the trace-metal component (copper, zinc, and lead). The relations are plotted to illustrate both the concentration variability as a function of runoff during an individual storm event and the variability among the five storms.

## Storm of November 3, 1979

Selected data for the runoff of November 3, 1979, are presented in figure 4. This storm began with an intense rainfall that produced a peak runoff of 2.33 $ft^3/s$ in about 8 minutes with the total sampled interval of runoff spanning a duration of about 40 minutes. The total rainfall was 0.40 inch.

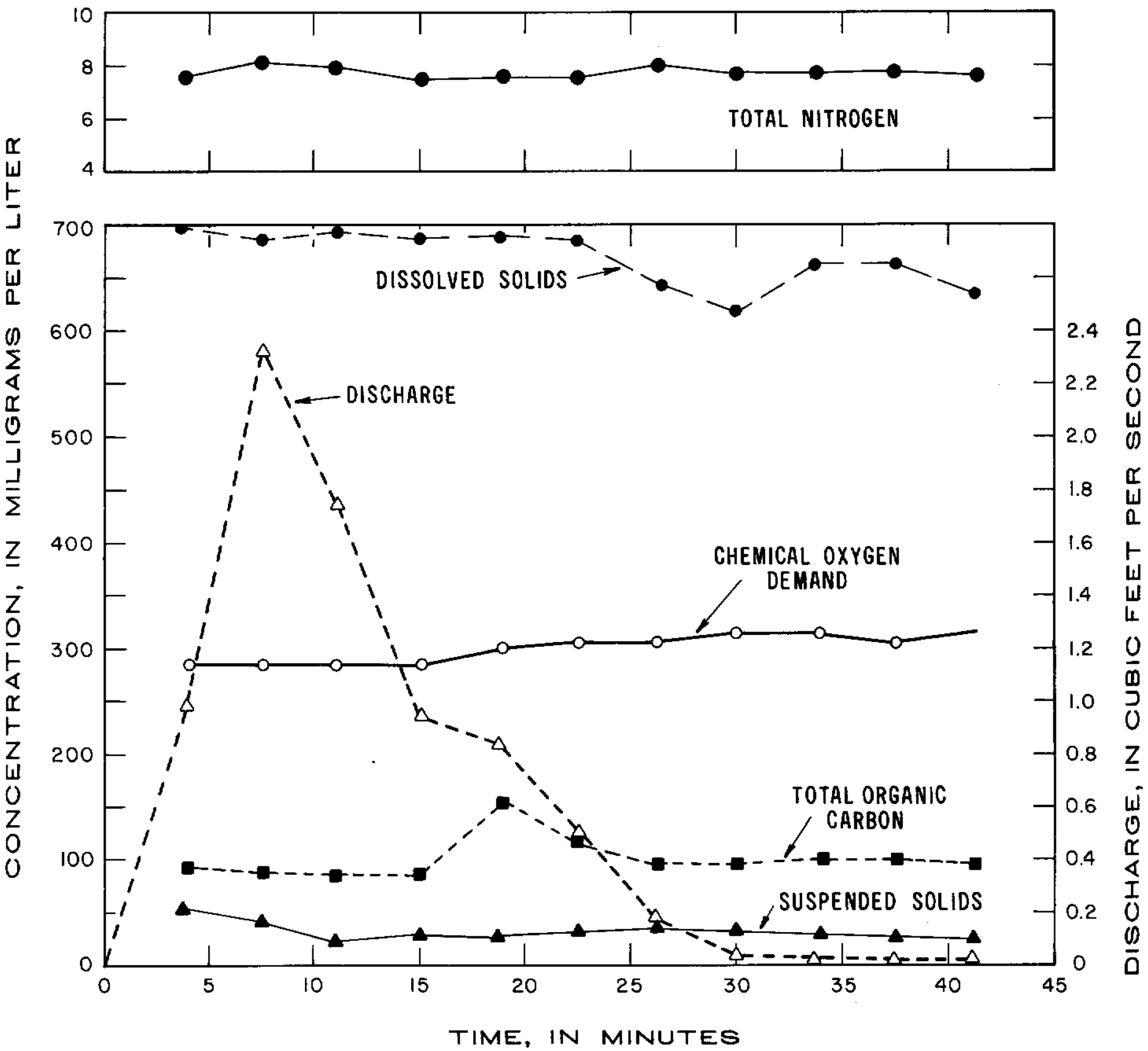


Figure 4.--Bridge runoff and selected water-quality parameters, 1030-1110 hours, November 3, 1979.

For this event, most of the parameter concentrations were not highly variable as a function of discharge. Regression analysis using discharge as the independent variable and parameter concentration as the dependent variable did, however, indicate that the direct relation between discharge and dissolved solids was significant at the 1-percent probability level. The indirect relation of the chemical oxygen demand with discharge was also significant at 1 percent. Other parameters did not indicate statistically significant variation as a function of runoff.

## Storm of November 20, 1979

Figures 5 and 6 portray selected data for the November 20, 1979, runoff. This storm also began with a sudden and intense rainfall followed by light showers for a total duration of about 32 minutes. The total rainfall for this event was 0.55 inch which produced a peak runoff of 2.48 $ft^3/s$ occurring about 4 minutes after initial rainfall.

Unlike the November 3 storm, all parameters given in figure 5 were directly related to runoff at the 1-percent probability level. Similarly, the trace metals presented in figure 6 were also significantly related to runoff.

There were notable differences in concentrations between the two November storms. That is, based on the results of t tests, the mean concentrations of dissolved solids, suspended solids, chemical oxygen demand, and total organic carbon between the two events were significantly different at the 5-percent probability level. Interestingly, the average concentrations of suspended solids, chemical oxygen demand, and total organic carbon were higher in the November 20 runoff, but the average concentration of dissolved solids was higher in the November 3 runoff.

## Storm of March 23, 1981

Figures 7 and 8 present selected data for the March 23, 1981, storm. This storm was low intensity with a total rainfall of only 0.25 inch which occurred during a 2-hour period. Of this total rainfall, approximately 0.12 inch fell during the 26-minute sampling period. The peak runoff during the sampling was 0.05 $ft^3/s$.

Concentrations generally indicated a direct relation with discharge, but none were highly significant. Most of the higher concentrations, however, did occur during initial runoff.

## Storm of May 1, 1981

Figures 9 and 10 show selected data for the May 1, 1981, storm. This storm had about the same rainfall (0.08 inch) as that of the March 23, 1981, storm, but it was more intense with a shorter duration. The May 1 storm produced two runoff peaks. The first peak (1.35 $ft^3/s$) occurred about 3 minutes after rainfall began and the second peak (2.13 $ft^3/s$)

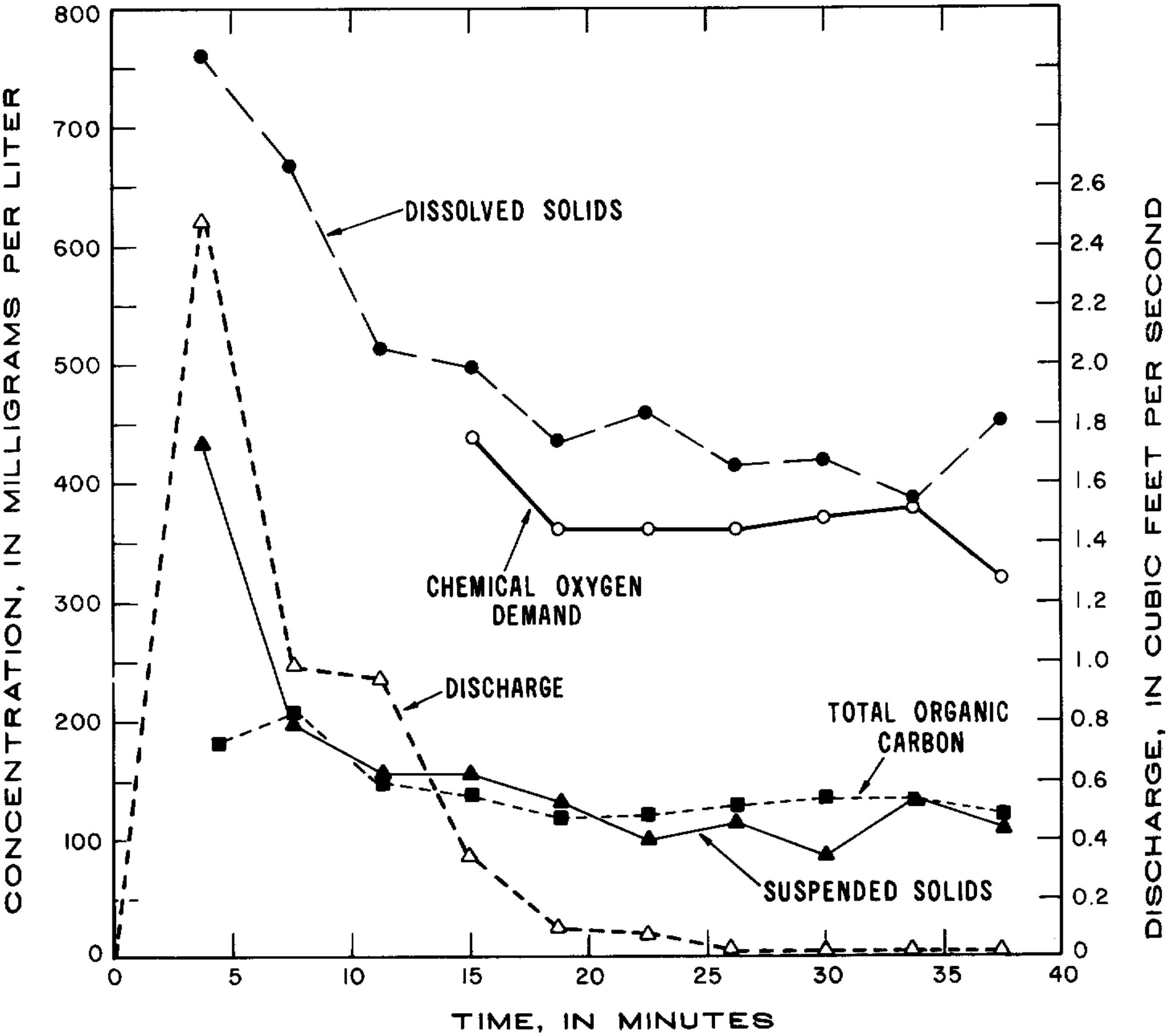


Figure 5.--Bridge runoff and selected water-quality parameters, 0830-0905 hours, November 20, 1979.

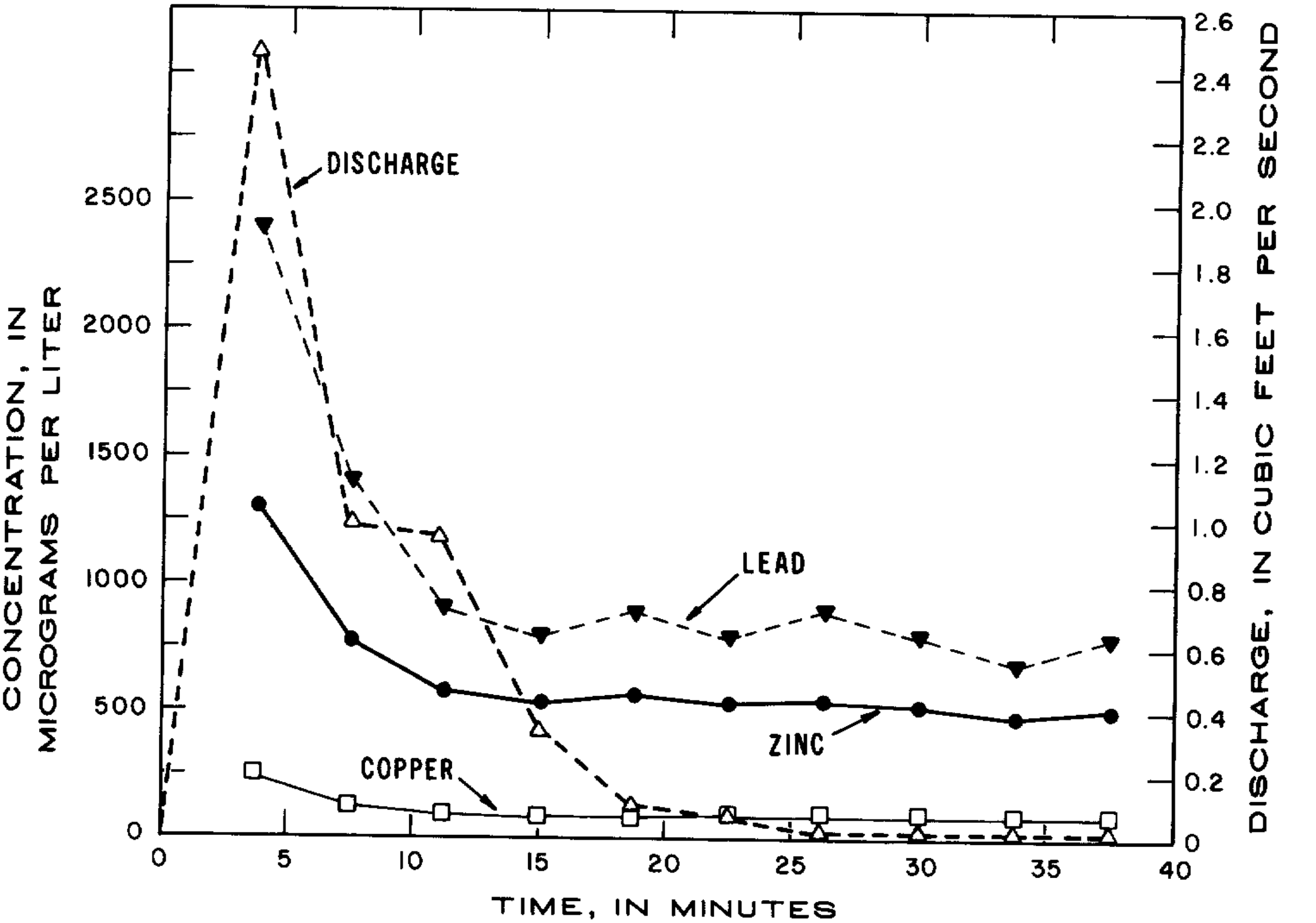


Figure 6.--Bridge runoff and selected trace metals, 0830-0905 hours, November 20, 1979.

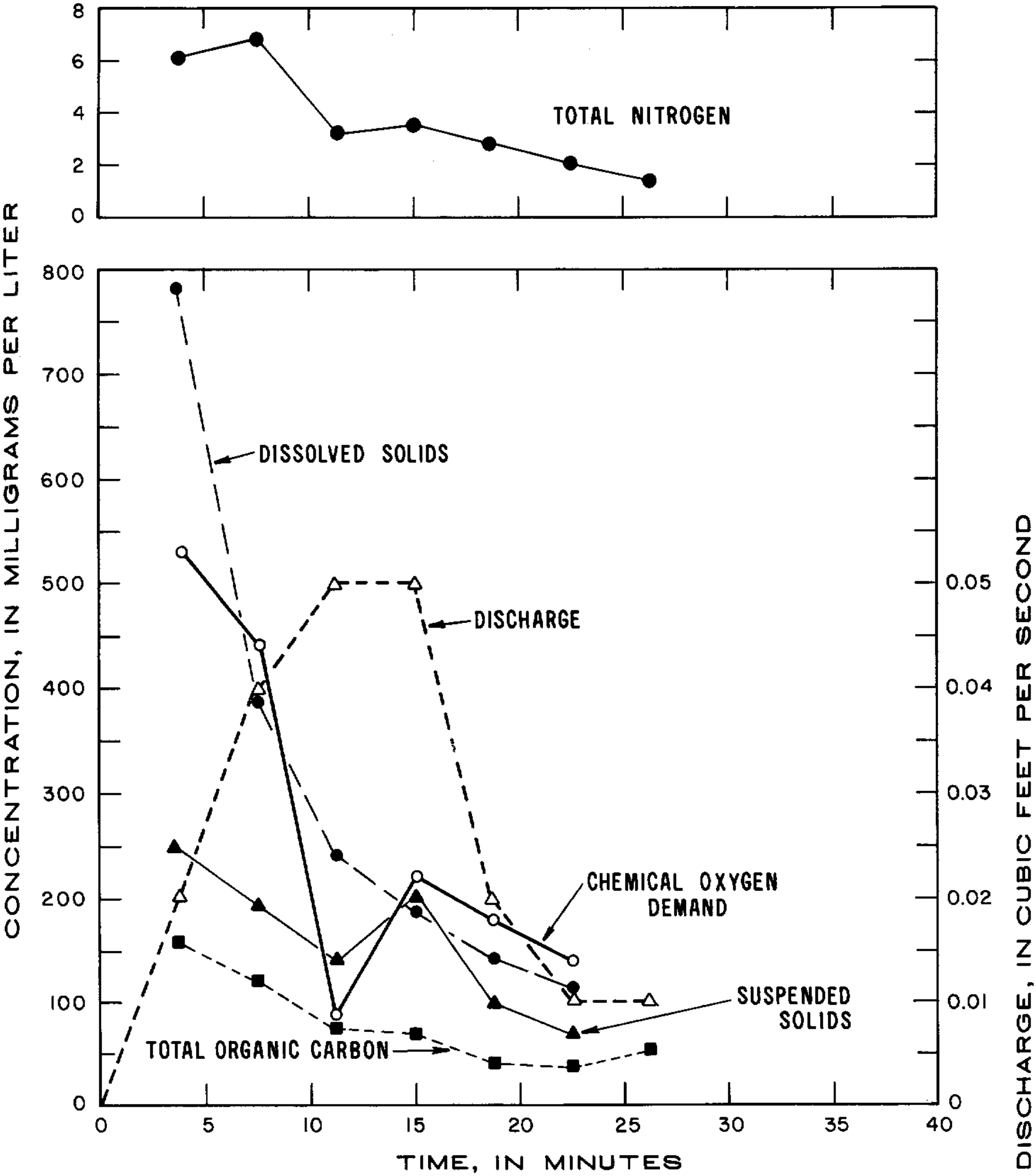


Figure 7.--Bridge runoff and selected water-quality parameters, 0604-0630 hours, March 23, 1981.

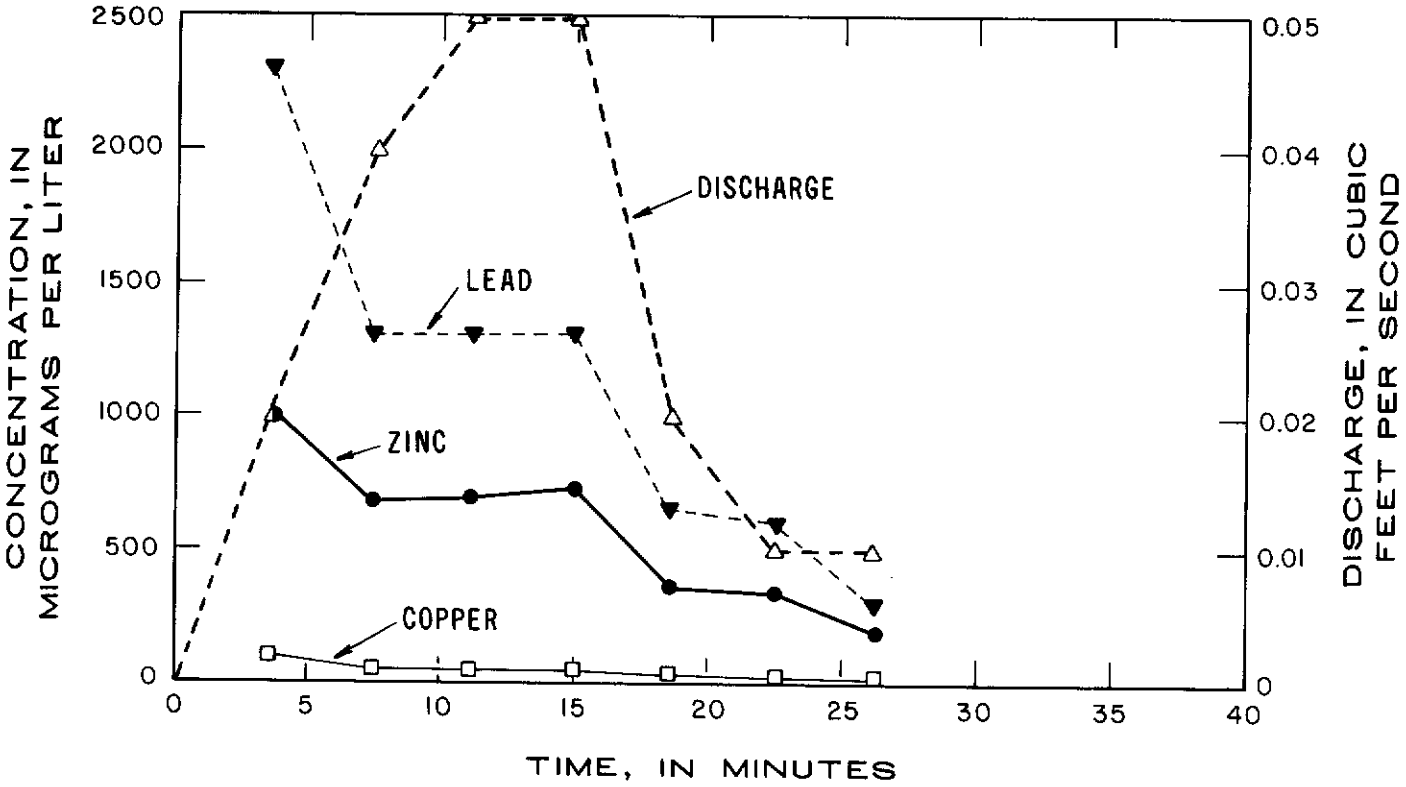


Figure 8.--Bridge runoff and selected trace elements, 0604-0630 hours, March 23, 1981.

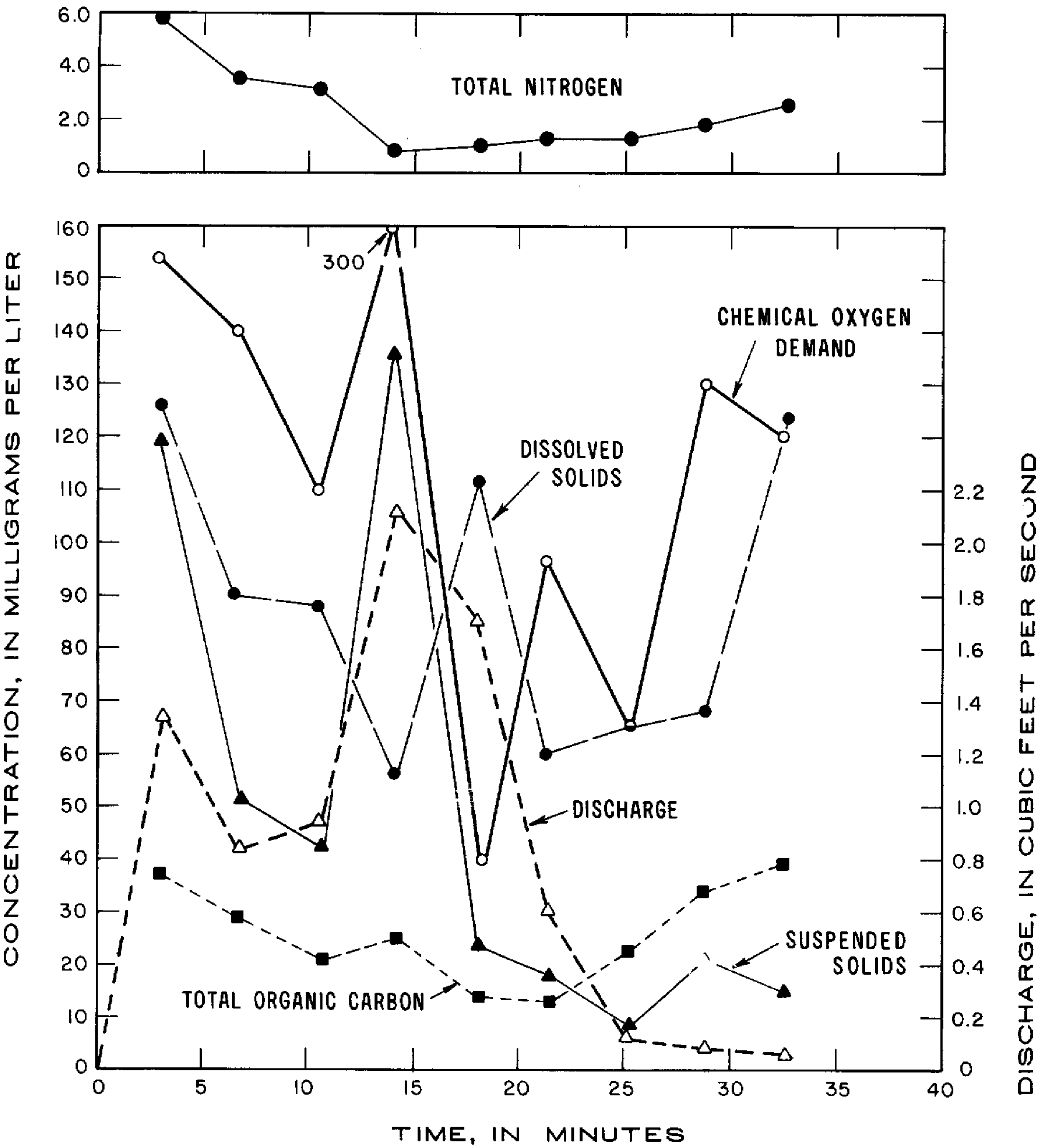


Figure 9.--Bridge runoff and selected water-quality parameters, 1833-1904 hours, May 1, 1981.

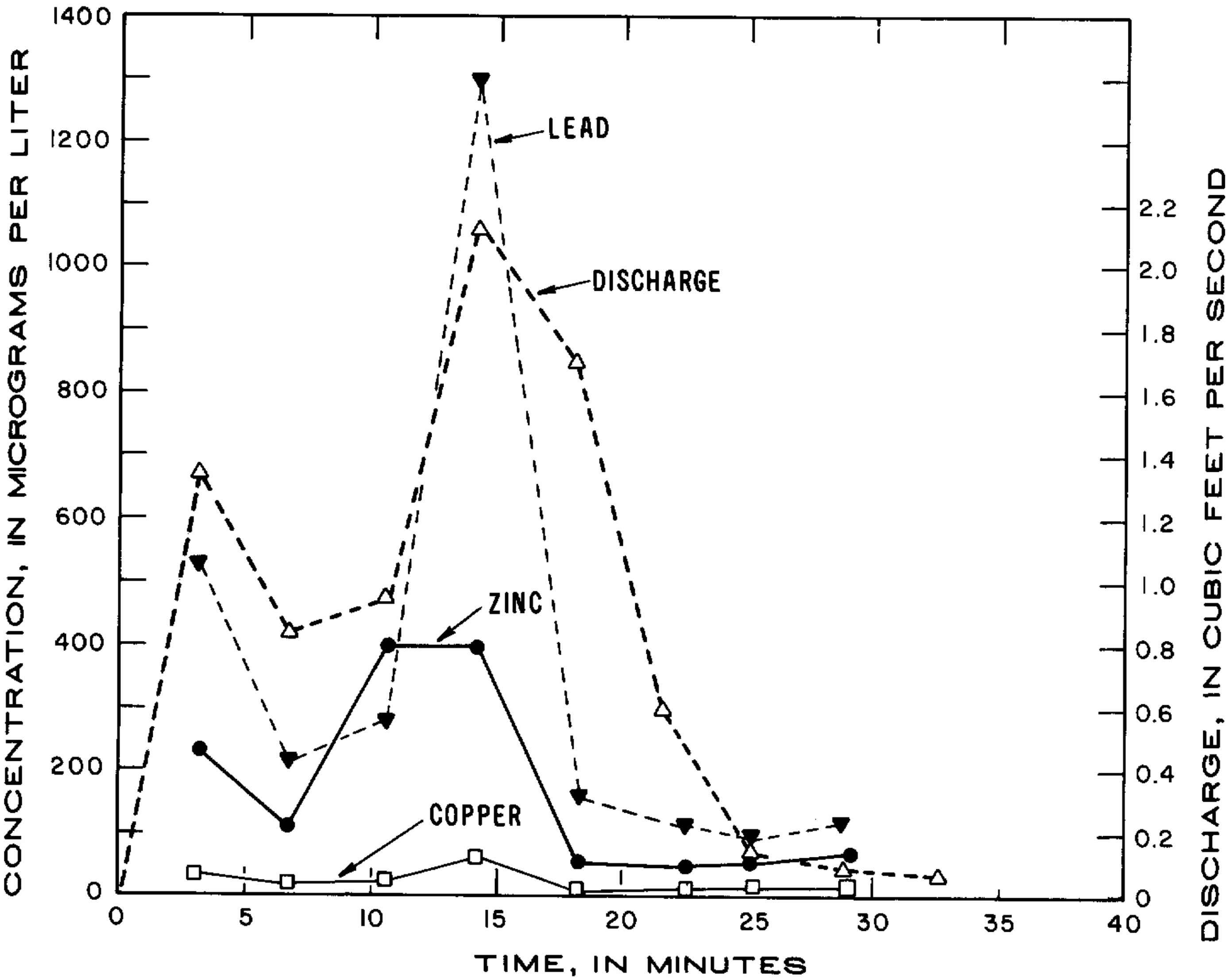


Figure 10.--Bridge runoff and selected trace elements, 1833-1904 hours, May 1, 1981.

occurred about 14 minutes after initial rainfall. (Note: the total rainfall of 0.08 inch did not correlate well with the runoff. This discrepancy is believed to be due to extreme rainfall variability at the study site and not equipment malfunction.

The concentration variation of most parameters suggested a linear relation with discharge, but only suspended solids (fig. 9) and lead (fig. 10) were significant at the 1-percent probability level. Both suspended solids and lead were directly related to runoff.

Except for suspended solids and chemical oxygen demand, t tests indicated that the mean concentrations of the parameters in the May 1 and March 23 runoff were significantly different at the 5-percent probability level. The mean concentrations for all the selected parameters shown in figures 9 and 10 were lowest in the May 1 runoff.

### Storm of May 20, 1981

Figures 11 and 12 present selected data for the May 20, 1981, storm. The total rainfall for this event was 0.65 inch which produced a sustained peak discharge of 2.48 $ft^3/s$ for a duration of about 4 minutes.

All the parameters were at their highest concentrations during the initial part of the peak runoff, then sharply decreased, followed by slight increases toward the end of the runoff. Consequently, none of the selected parameters were highly significant as a function of discharge.

Based on t tests of the concentrations of the selected parameters shown in figures 11 and 12, the concentrations of organic carbon, chemical oxygen demand, nitrogen, and dissolved solids between the May 1 and 20 runoff were significantly different at the 5-percent probability level. The lower concentrations occurred in the May 20 runoff.

## Quality of Stormwater Runoff and State Criteria

Some of the parameters monitored in the Interstate 95 runoff are regulated for Florida waters under the Rules of the Florida Department of Environmental Regulation, Chapter 17-3, Water Quality Standards, amended March 19, 1979 (Florida Department of Environmental Regulation, 1983). Therefore, as a general perspective, the concentrations of selected parameters in the Interstate 95 runoff were compared with State criteria for Class III surface waters designated for recreation, and propagation and management of fish and wildlife. (Note: This comparison is only relative; an actual evaluation of the suitability of a discharge to a receiving water must consider the "zone of mixing.")

Median concentrations of copper, lead, and zinc in runoff from Interstate 95 were 40, 560, and 330 μg/L, respectively; thus, the State criteria of 30 μg/L for copper, lead, and zinc were commonly exceeded. Cadmium levels in runoff also approximated the criterion of 0.8 to 1.2 μg/L in most samples.

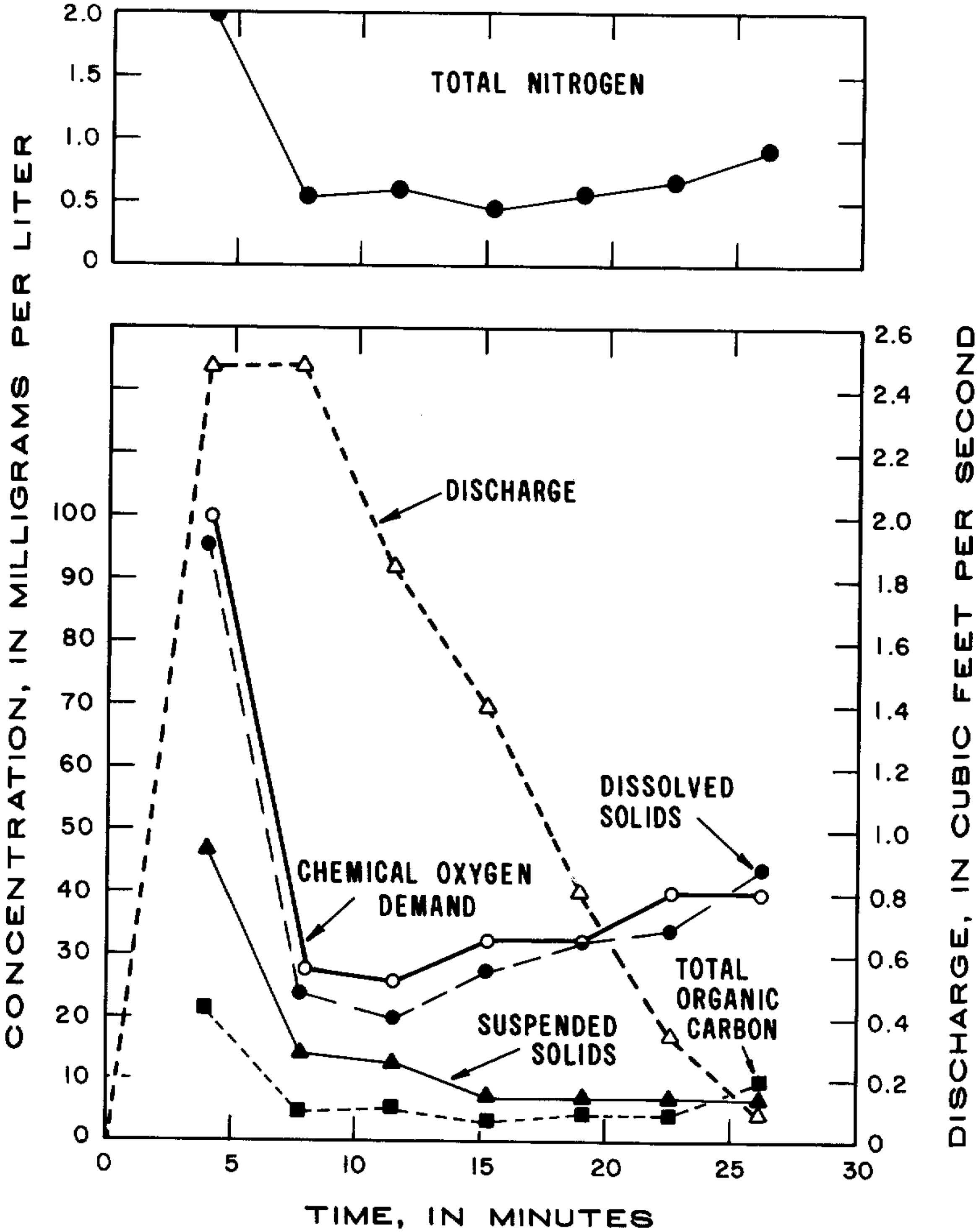


Figure 11.--Bridge runoff and selected water-quality parameters, 1812-1835 hours, May 20, 1981.

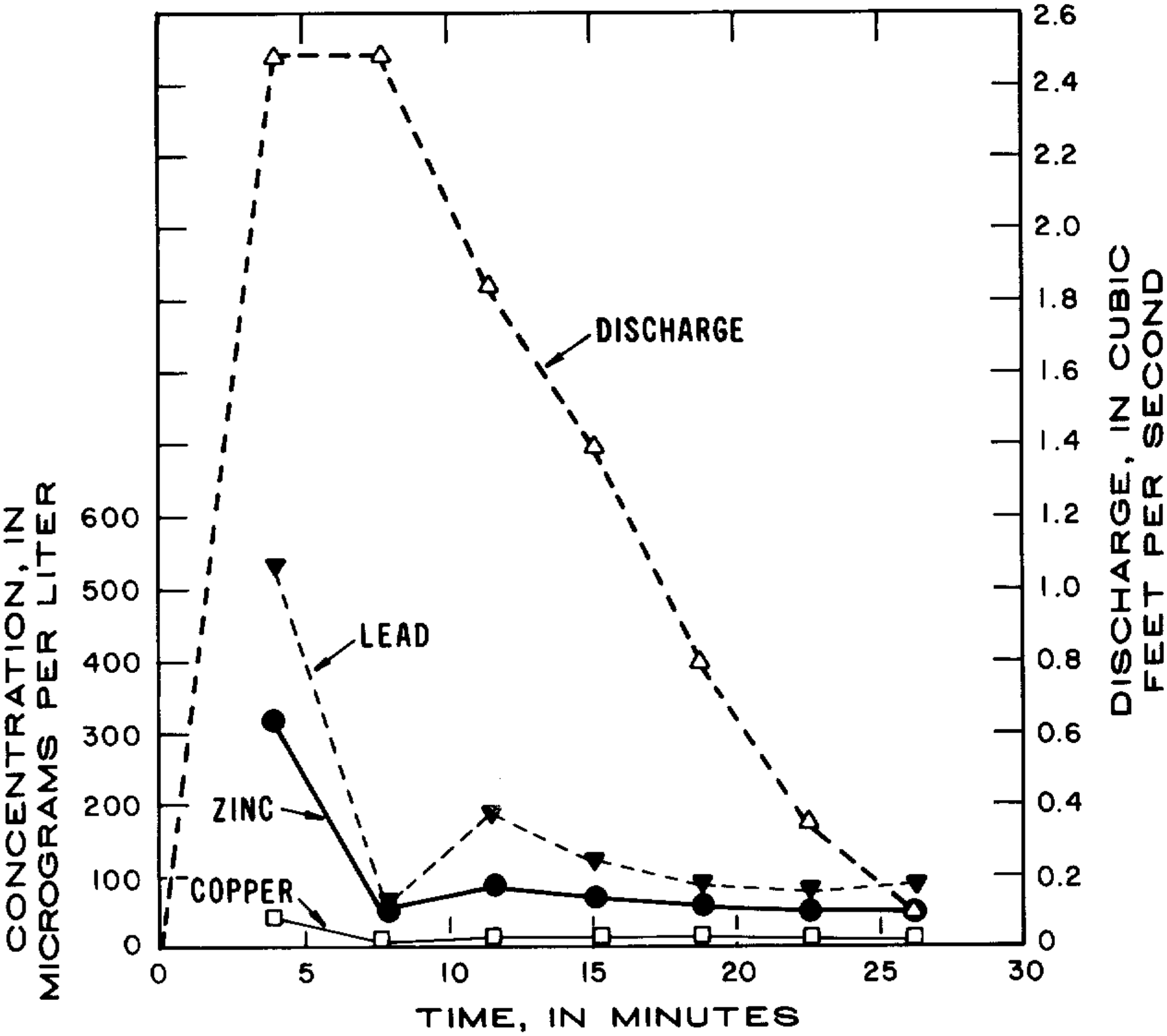


Figure 12.--Bridge runoff and selected trace metals, 1812-1835 hours, May 20, 1981.

## Loads of Selected Water-Quality Parameters

### Stormwater-Runoff Loads

Estimates of total loads for selected water-quality parameters for the five runoff events are given in table 3. The load estimates for each event were based on the parameter concentrations, the quantity of runoff, and the duration of runoff. The total load for each parameter was discharge-concentration weighted, whereby instantaneous loads were computed for 1-minute intervals throughout the runoff hydrograph. Instantaneous parameter concentrations for periods between samples were estimated by interpolation. The sum of the 1-minute loads represented the total load.

Even a cursory review of table 3 indicates that a high loading variability for most parameters existed among the runoff events. Overall, however, the magnitude of runoff loads, on the average, for both the suspended and dissolved component were quite comparable with the stormwater runoff loads from other highway drainages. For example, selected parameter loads given in table 3 were adjusted to an average, discharge-weighted load per acre of highway drainage per storm and compared with data from the six-highway sites reported in Gupta, Agnew, Gruber, and Kreutzberger (1981). (Note--Computations of total loads from Interstate 95 did not account for any loading loss from downdrains upgradient from the sampling site at the catch basin.)

At Interstate 95, the discharge-weighted total loads of total and suspended solids were estimated to average 28 and 7.1 pounds per acre per storm, respectively; Gupta, Agnew, Gruber, and Kreutzberger (1981) reported an average range of total solids load of 21 to 78 pounds per acre per storm and an average range of suspended solids load of 4.7 to 19.6 pounds per acre per event. The volatile component was also similar, with the load of total and suspended volatile solids averaging 12.8 and 4.6 pounds per acre per storm at Interstate 95. At the six sites monitored by Gupta, Agnew, Gruber, and Kreutzberger (1981, p. 57), the average total solids load ranged from 4.2 to 15.3 and the suspended volatile solids ranged from 1.1 to 6.2 pounds per acre per storm.

The runoff loads at Interstate 95 for other parameters were also similar to those monitored at the six highway sites. The following compares the average loads for Interstate 95 and the range in average loads for the six sites reported in Gupta, Agnew, Gruber, and Kreutzberger (1981, p. 66, 74, and 82):

Average pounds per storm per acre

| | Interstate 95 | Gupta, Agnew, Gruber, and Kreutzberger (1981) |
|---|---|---|
| Total organic carbon | 4.7 | 0.96-3.83 |
| Chemical oxygen demand | 11 | 3.04-12.3 |
| Total nitrogen | .27 | .13-.34 |
| Total lead | .06 | .007-.210 |
| Total zinc | .03 | .006-.05 |

Table 3.--Estimated loads, in pounds, of selected parameters in stormwater runoff from a 1.43-acre bridge section of Interstate 95 for five storms

| | 11/03/79 | 11/20/79 | 03/23/81 | 05/01/81 | 05/20/81 |
|---|---|---|---|---|---|
| Total storm runoff, in cubic feet | 1,720 | 1,120 | 45 | 1,700 | 2,140 |
| Rainfall, in inches | .40 | .55 | .12 | .08 | .65 |
| Total solids, residue at 105°C | 78.0 | 67.6 | 1.3 | 17.5 | 8.6 |
| Dissolved solids, residue at 105°C | 73.9 | 46.6 | .8 | 9.8 | 5.9 |
| Suspended solids, residue at 110°C | 3.7 | 21.1 | .5 | 8.0 | 2.7 |
| Dissolved volatile solids, residue at 550°C | 25.2 | 17.1 | .4 | 4.0 | 5.3 |
| Suspended volatile solids, residue at 550°C | -- | 14.1 | .2 | 3.3 | 1.6 |
| Chemical oxygen demand (high level) | 31.1 | -- | .7 | 17.1 | 6.4 |
| Ammonia, total as N | .018 | -- | .006 | .020 | .026 |
| Nitrite, total as N | .082 | .001 | < .001 | .002 | .002 |
| Nitrate, total as N | .266 | .007 | .004 | .088 | .062 |
| Organic nitrogen, total as N | .49 | -- | .01 | .15 | .04 |
| Nitrogen, total as N | .85 | -- | .02 | .26 | .13 |
| Phosphorus, total as P | .026 | -- | .001 | .017 | .010 |
| Organic carbon total | 10.6 | 12.2 | .25 | 2.6 | 1.2 |
| Cadmium total recoverable | -- | -- | < .001 | < .001 | < .001 |
| Chromium total recoverable | -- | .001 | < .001 | .002 | .001 |
| Copper total recoverable | -- | .013 | < .001 | .003 | .002 |
| Lead total recoverable | -- | .122 | .004 | .059 | .029 |
| Zinc total recoverable | -- | .068 | .002 | .024 | .018 |
| Oil and grease | -- | -- | -- | -- | .89 |

Although the loading at Interstate 95 was quite similar to other highway sites throughout the country, it should be noted that the Interstate 95 loading for individual parameters also indicated high variability among storms. For example, the maximum and minimum loads for selected parameters for the five events are presented below to illustrate the magnitude of variability in parameter loading among individual storms. (To more closely quantify the comparison, the loads were computed on the basis on pounds per cubic feet per acre rather than pounds per storm per acre.):

Pounds per cubic foot per acre

| | Maximum | Minimum |
|---|---|---|
| Total solids | $4.2 \times 10^{-2}$ | $0.28 \times 10^{-2}$ |
| Suspended solids | $1.3 \times 10^{-2}$ | $.09 \times 10^{-2}$ |
| Dissolved volatile solids | $1.1 \times 10^{-2}$ | $.2 \times 10^{-2}$ |
| Suspended volatile solids | $.9 \times 10^{-2}$ | $.06 \times 10^{-2}$ |
| Total organic carbon | $.8 \times 10^{-2}$ | $.04 \times 10^{-2}$ |
| Chemical oxygen demand | $1.3 \times 10^{-2}$ | $.2 \times 10^{-2}$ |
| Total nitrogen | $3.4 \times 10^{-4}$ | $.4 \times 10^{-4}$ |
| Total lead | $.7 \times 10^{-4}$ | $.2 \times 10^{-4}$ |

Overall, the total water-quality component of runoff (as estimated by total solids) varied by a magnitude of about 15 times. Total organic carbon exhibited the highest variability with a twentyfold difference between the minimum and maximum load and lead the least with a fourfold range.

## Precipitation (Wetfall) Loads

The results of the precipitation analyses given in table 2 were used to estimate, very approximately, the wetfall loading to the bridge surface. The following range in loads for selected parameters was computed on the basis of 1 inch of rainfall per acre of bridge surface:

Wetfall load in pounds per inch per acre

| | |
|---|---|
| Total solids | 7.52-19.9 |
| Suspended solids | 1.13-4.54 |
| Total nitrogen | .15-.84 |
| Total organic carbon | .94-1.31 |
| Total lead | .00-.001 |
| Total zinc | .013-.018 |

For a general perspective, the average wetfall loads to the bridge surface were compared to the average loads transported from the bridge by runoff. That is, the loads for each of the five stormwater runoff events were weighted by the rainfall (loads normalized to 1 inch of rainfall per acre) for each storm and then averaged and compared with the average load transported by rainfall (also normalized to 1 inch of rainfall per acre):

Average load in pounds per inch of rainfall per acre

| | Wetfall | Stormwater runoff | Percent wetfall-stormwater runoff |
|---|---|---|---|
| Total solids | 13.7 | 78.5 | 17 |
| Suspended solids | 2.8 | 21.8 | 13 |
| Total nitrogen | .5 | 1.0 | 50 |
| Total organic carbon | .8 | 11.9 | 7 |
| Total lead | <.001 | .18 | <1 |
| Total zinc | .016 | .08 | 20 |

These estimates suggest that, on the average, perhaps 13 to 17 percent of the runoff loads of total and suspended solids, respectively, and up to 50 percent of the total nitrogen might have been transported directly to the bridge surface by wetfall.

These estimates of wetfall load are conjectural because of limited data, because wetfall samples were not collected for every runoff event sampled, and particularily because of a somewhat unreliable correlation between rainfall and runoff. For instance, there is evidence that the rainfall measured at the gage, at least for the May 1, 1983, event, was not a good estimate of the rainfall for the entire highway drainage. The total runoff of 1,700 $ft^3$ for the May 1 event exceeds by about 300 percent the quantity of runoff likely generated by a 0.08 inch rainfall. The rainfall-runoff relations for the events of March 23, 1981, and May 20, 1981, however, seem reasonable. That is, 45 $ft^3$ of runoff is about 10 percent of the quantity likely generated from a 0.12 inch rain and 2,140 $ft^3$ is about 65 percent of the quantity potentially generated from a 0.65 inch rain.

## Factors Affecting the Variance of Parameter Loads

### Loading as a Function of Parameter Concentration

The results of this reconnaissance indicated that parameter loading was primarily controlled by the parameter concentration (the amount of material available for washoff). However, the total quantity of rainfall and subsequent runoff, along with rainfall intensity, obviously were determining factors in parameter loading for a runoff event.

The storms of November 3, 1979, and May 1, 1981, were the most notable examples of loading variability as a function of variable parameter concentration. The storm of November 3, 1979, had a total runoff of about 1,720 $ft^3$ with a peak discharge of 2.33 $ft^3/s$; the event of May 1, 1981, had a total runoff of about 1,700 $ft^3$ with a peak of 2.13 $ft^3$. However, even though the runoff volumes were similar, the November 3, 1979, runoff transported significantly higher loads of such parameters as total solids, dissolved solids, chemical oxygen demand, and total organic carbon (table 3); this is simply because parameter concentrations were higher in the November 3 runoff.

The concentration of dissolved solids in runoff ranged from 620 to 700 mg/L during the November 3, 1979, event and 60 to 126 mg/L during the May 1, 1981, event. The two events show an order of magnitude difference, in cumulative loading with the November event having a total load of 73.9 pounds and the May event 9.8 pounds. For illustrative purposes, the general circumstances of loading for the two events are portrayed using dissolved solids (fig. 13).

Perhaps not so obvious is that large differences in parameter concentrations can also mask rather sizeable differences in runoff volume. For example, the storm of November 20 had a total runoff of 1,120 $ft^3$, but it transported higher loads of most parameters than did the May 1, 1979, event which had a runoff of 1,700 $ft^3$. Again, high parameter concentrations controlled the higher loading. Similarily, the May 1 and 20, 1981, storms had respective volumes of total runoff of 1,700 and 2,140 $ft^3$, but the loads of most parameters were on the order of 30-100 percent less for May 20, 1981, event because of lower parameter concentrations.

## Loading as a Function of Time

Discounting the dominant influence of parameter concentration upon the actual total load, rainfall intensity and runoff volume do have considerable influence on the relative loading rates. To illustrate the observed variability in washoff rates, double mass curves which delineate the cumulative total loads of suspended solids (dependent variable) as a function of time (independent variable) for each of the five runoff events are presented in figure 14.

The variability in loading rates is evident, for instance, over 60 percent of the total loads of suspended solids for the events of November 20, 1979, and May 20, 1981, were transported within the initial 4-minutes (approximately) of runoff, whereas only about 15 percent of the total load of suspended solids for the event of March 23, 1981, was transported within the first 4-minutes of runoff. The March 23, 1981, storm was a low-intensity rainfall with a low-runoff which had a gradually rising discharge with a rather flat peak having a 5-minute duration occurring 10 to 15 minutes after initial runoff. Unlike the March 23 event, the runoff hydrographs for November 20, 1979, and May 20, 1981, had very sharp peaks which occurred within less than 5 minutes after initial runoff. Because of the much higher velocities, these sharp-peak flows transported the available material from the bridge much more rapidly than the low-intensity storm of March 23, 1981. Overall, however, about 90 to 100 percent of the cumulative load of

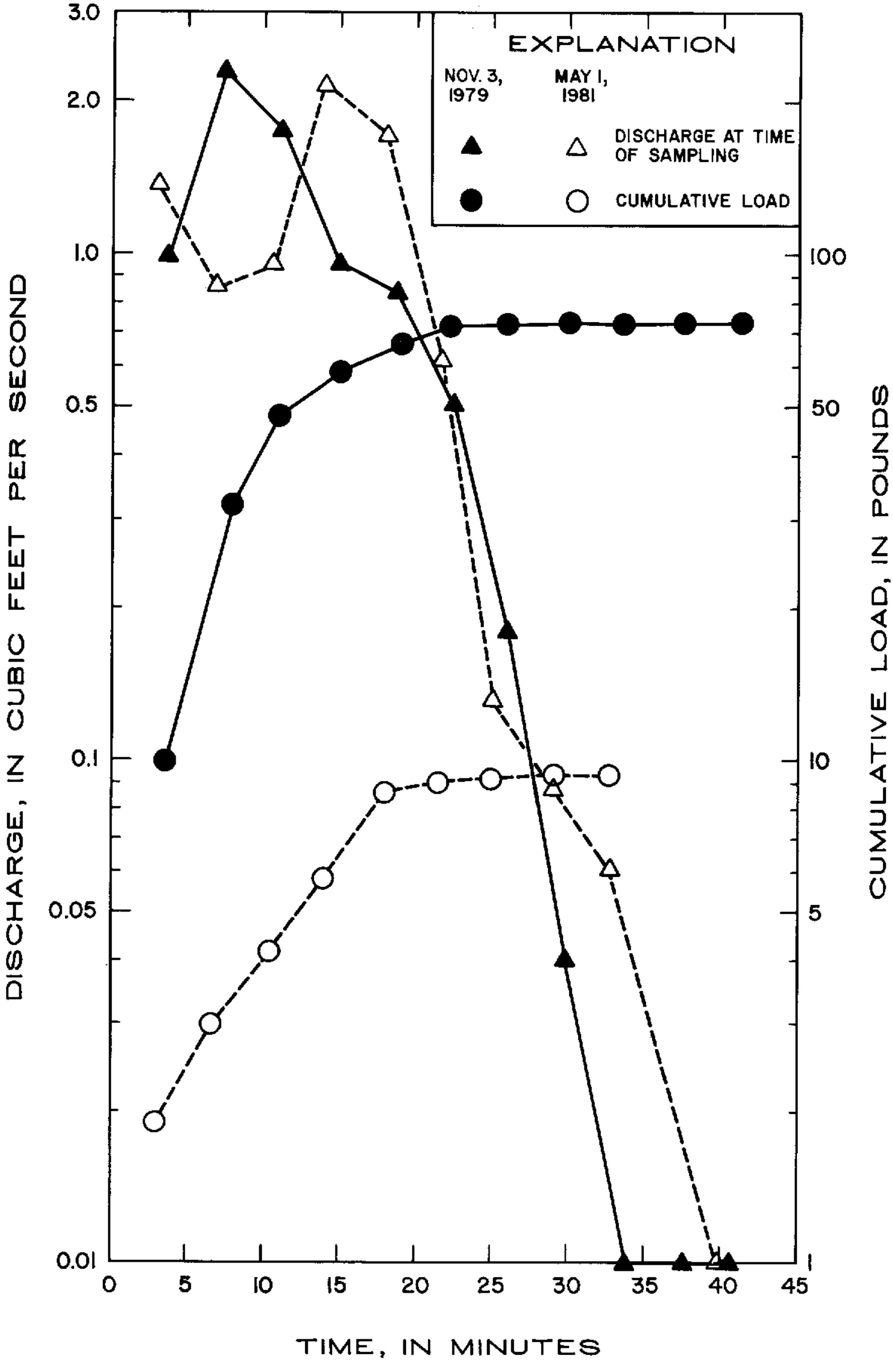


Figure 13.--Discharge and cumulative loads of dissolved solids of stormwater runoff as a function of time, November 3, 1979 and May 1, 1981.

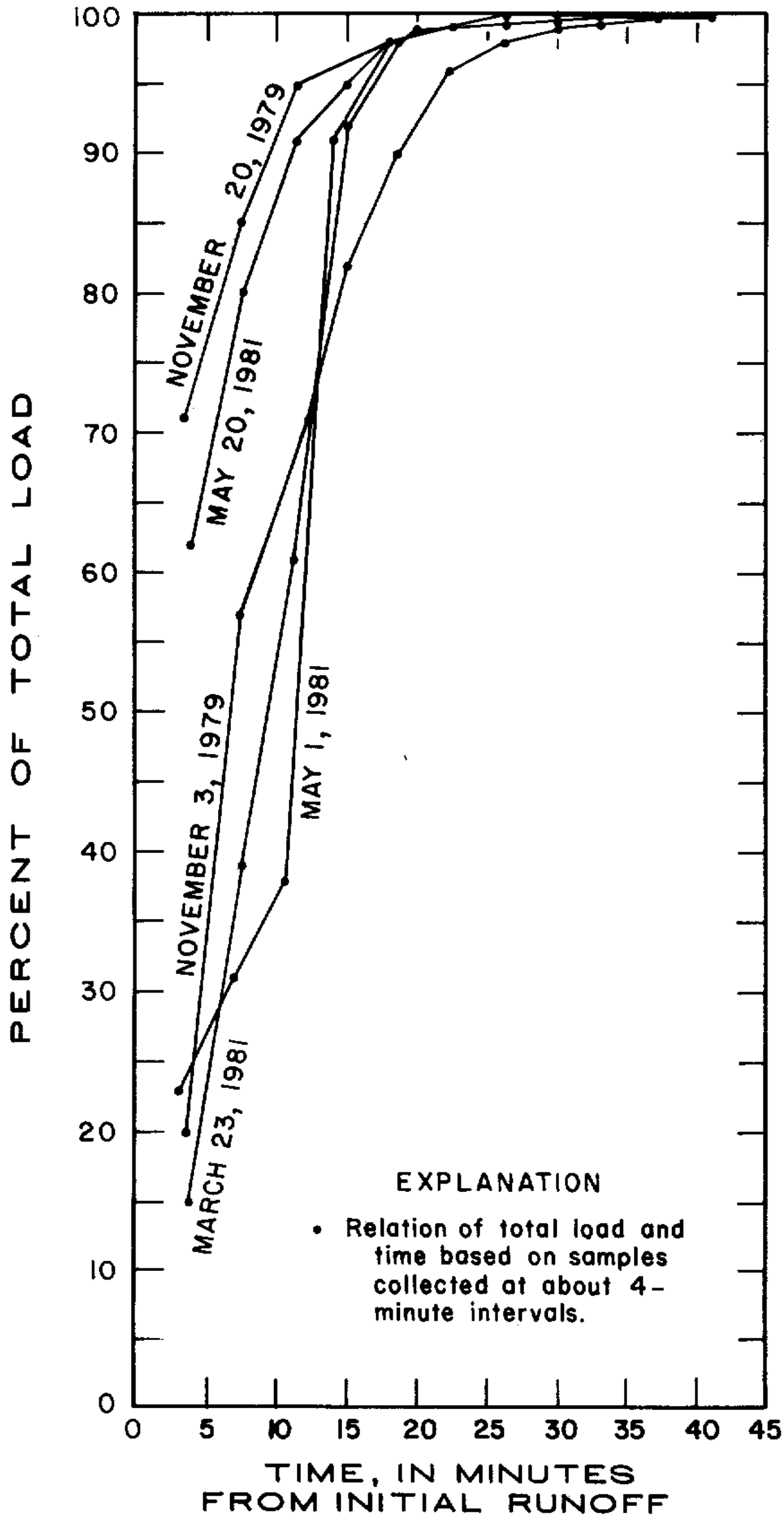


Figure 14.--Percentage of cumulative loads of suspended solids in bridge runoff as a function of time.

suspended solids for the five events were transported in about 10 to 18 minutes after initial runoff. Most other parameters indicated a similar transport sequence.

## Loading as a Function of Discharge

A double-mass relation of cumulative load as a function of stormwater discharge for the five events is shown in figure 15. These limited data indicate some variability among the events in the rates of parameter transport from the bridge surface. For example, the high-intensity runoff events of November 20, 1979, and May 20, 1981, transported approximately 70 to 80 percent of their respective suspended-solids loads in about 50 percent of their cumulative runoff. The low-intensity event of March 23, 1981, however, transported only about 55 percent of its cumulative load in 50 percent of its cumulative runoff.

On the average, however, the results of these five storm events indicated that about 90 percent of the total load of suspended solids occurred in 65 to 90 percent of the cumulative runoff. Most of the other parameters exhibited similar patterns. Further, of the three storms exceeding 0.2 inches, approximately 40 to 60 percent of both the total loads of dissolved and suspended solids were washed from the bridge during the first 0.2 inch of rainfall.

## Antecedent Factors

The quantity, intensity, and quality of rainfall are certainly significant factors affecting the magnitude of parameter loads in stormwater runoff. Antecedent activity within the roadway drainage, however, is likely the most significant influence on the amount and type of material available for transport by stormwater runoff. It is the antecedent-environmental factors such as the number of dry days, the traffic volume, atmospheric dryfall, and numerous local activities which largely control the amount of available material on the bridge surface, which consequently controls the amount available for washoff by stormwater runoff.

A quantitative assessment of the various antecedent-environmental factors which contribute to the generation of road-surface materials would have required a far more elaborate experimental design than was possible within the scope of this study. However, for very generalized purposes, the number of dry days and traffic volumes prior to each of the five storm events, along with other selected data, are summarized below:

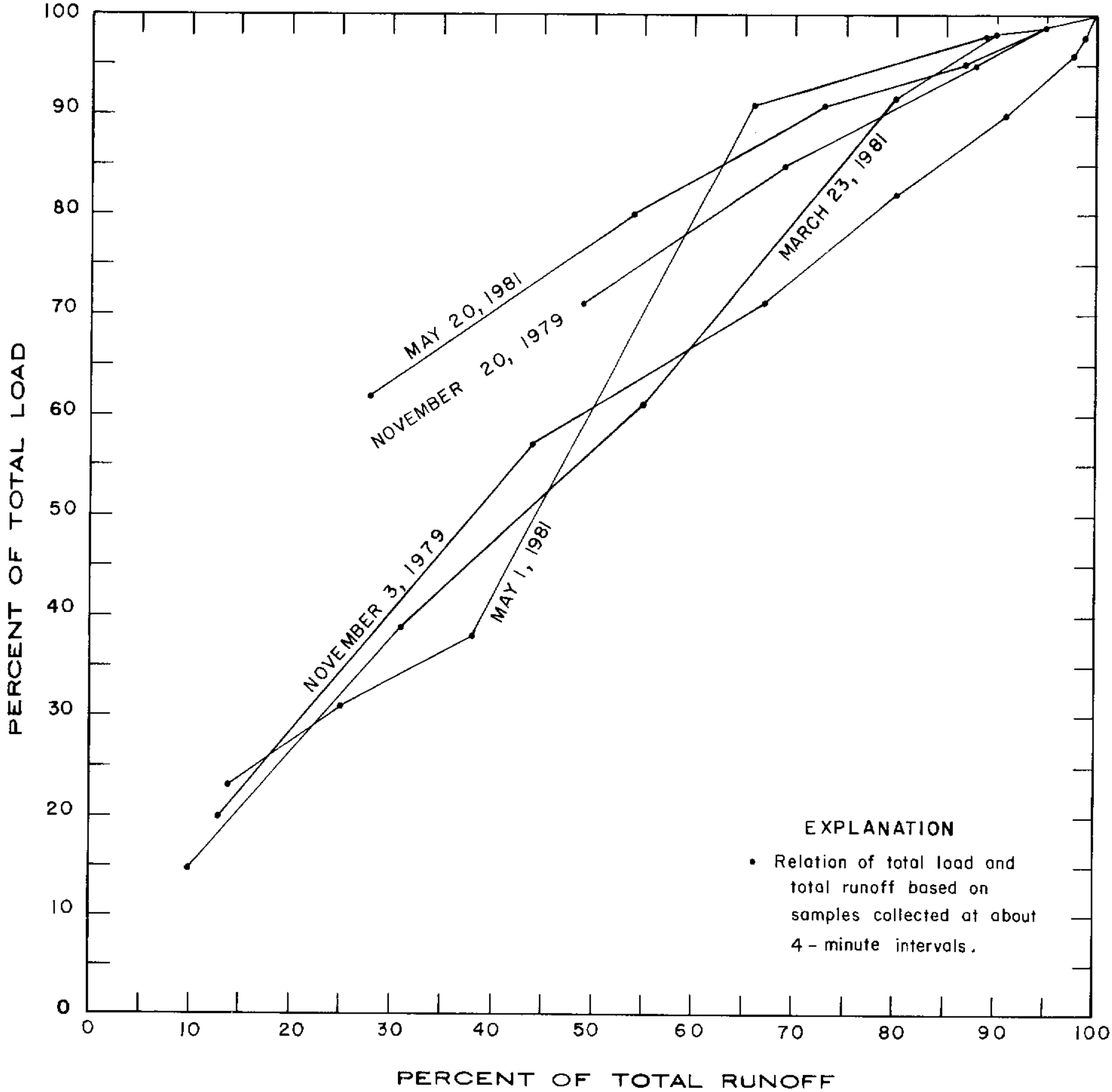


Figure 15.--Percentage of cumulative loads of suspended solids in relation to the percentage of cumulative runoff.

| Storm | Dry days | Traffic volume, in million vehicles | Total runoff, in cubic feet | Average suspended solids, in mg/L | Suspended solids, in pounds | Average dissolved solids, in mg/L | Dissolved solids load, in pounds |
|---|---|---|---|---|---|---|---|
| 11/03/79 | 21 | 1.47 | 1,720 | 32 | 3.7 | 670 | 73.9 |
| 11/20/79 | 17 | 1.10 | 1,120 | 162 | 21.1 | 502 | 46.6 |
| 03/23/81 | 11 | .77 | 45 | 161 | .5 | 360 | .8 |
| 05/01/81 | 35 | 2.29 | 1,700 | 48 | 8.0 | 88 | 9.8 |
| 05/20/81 | 7 | .36 | 2,140 | 14 | 2.7 | 40 | 5.9 |

An examination of the data did not suggest obvious relations between the number of dry days or traffic volume and parameter loads. For example, the events of November 3, 1979, and May 1, 1981, had about the same runoff and peak flow and the highest number of dry days and traffic counts, yet the concentration of dissolved material in the runoff of November 3, 1979, was about seven times greater than that in the runoff of May 1, 1981. Conversely, the May 1, 1981, runoff produced the highest suspended solids load. The absence of obvious relations among antecedent conditions and loading is not uncommon. For instance, in an intensive study of six highway sites, Gupta, Agnew, Gruber, and Kreutzberger (1981, p. 135) found that solids and heavy metals were not highly related to traffic volume, percent imperviousness, or dustfall on a simple correlation basis.

## SUMMARY

Runoff from a heavily-traveled, 1.43-acre bridge section of Interstate 95 in Miami, Fla., was comprehensively monitored for both quality and quantity during five selected storms between November 1979 and May 1981. The primary purpose of the monitoring was to measure the concentrations and loads of selected water-quality parameters that were washed from the bridge surface during stormwater-runoff. Results of this investigation will both supplement the technical data base in the general area of urban hydrology and furnish the Florida Department of Transportation with specific data for its use in assessing the potential for adverse environmental impacts on the State's surface waters caused by roadway runoff.

General study findings:

1. Concentrations of most parameters in the Interstate 95 runoff were quite variable both during individual storm events and among the five storm events; but overall, the ranges in parameter concentration were about the same magnitude reported in the literature for numerous other highway and urban drainages. Specifically for the three-bridge sites studied in cooperation with the Florida Department of Transportation, concentrations of nitrate, phosphorus, lead, and zinc were higher in runoff from the medium-traffic, Interstate 4 site (50,000 ADT) in the Orlando area than at either

the low-traffic, U.S. Highway 27 site (4,000 ADT) near Tallahassee or the Interstate 95 site (70,000 ADT). Levels of cadmium and copper in runoff, however, were about the same at all three sites.

2. For most water-quality parameters, 6 to 11 samples were collected during each of the 5-runoff events at the Interstate 95 study site. Based on these analyses (32 to 44 samples), the average concentrations of selected target parameters were: 437 mg/L (total solids), 81 mg/L (suspended solids), 195 mg/L (total volatile solids), 64 mg/L (suspended volatile solids), 77 mg/L total organic carbon, 223 mg/L (chemical oxygen demand), 4.1 mg/L (total nitrogen), 0.68 mg/L (lead), and 0.37 mg/L (zinc).

3. For general perspective on potential yields from highway drainage, the Interstate 95 data were normalized to estimate the following average, discharge-weighted parameter loads per storm per acre of bridge surface: 28 pounds (total solids), 7.1 pounds (suspended solids), 12.8 pounds (total volatile solids), 4.6 pounds (suspended volatile solids), 4.7 pounds (total organic carbon), 11 pounds (chemical oxygen demand), 0.27 pounds (nitrogen), 0.06 pounds (lead), and 0.03 pounds (zinc). It should be noted, however, that a very large variability existed from storm to storm in the loading of most parameters.

4. Sampling and analyses of rainfall (wetfall) were very limited at Interstate 95, but results did suggest measureable loading to the bridge surface via wetfall. For instance, computations using the available data indicated that 17 percent of the average load of total solids and 13 percent of the average load of suspended solids in the stormwater runoff perhaps originated from material transported directly by wetfall.

5. Among storms of the same relative magnitude of runoff, the most significant factor influencing stormwater loads was parameter concentration. The storms of November 3, 1979, and May 1, 1981, for example, had the same runoff volume; but the Novmeber 3, 1979, event had significantly higher total loads because its runoff contained much higher parameter concentrations.

6. Rainfall intensity and runoff volume (velocity) influenced rates of loading. Using suspended solids, for example, the higher intensity storms transported about 60 percent of their respective loads within the initial 4 minutes (approximately) of runoff, whereas a low-intensity storm transported only about 15 percent of its total load within the first 4 minutes of runoff. Rates of loading for many of the other parameters indicated a similar pattern.

7. A detailed assessment of the relations among antecedent conditions of the roadway and runoff loads was not practicable within the scope of this study; however, a cursory assessment suggested that the total number of antecedent dry days and traffic volume were not conspicuously related to either runoff concentrations or loads.

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SUPPLEMENTARY DATA

STATION NUMBER: 254731080121900

WATER-QUALITY DATA OF STORMWATER RUNOFF AT INTERSTATE 95 MONITOR SITE, MIAMI, FLORIDA

| DATE | TIME | STREAM-FLOW, INSTAN-TANEOUS (CFS) (00061) | TUR-BID-ITY (NTU) (00076) | OXYGEN DEMAND, CHEM-ICAL (HIGH LEVEL) (MG/L) (00340) | SOLIDS, RESIDUE AT 105 DEG. C, TOTAL (MG/L) (00500) | SOLIDS, VOLA-TILE ON IGNI-TION, TOTAL (MG/L) (00505) | SOLIDS, RESIDUE AT 105 DEG. C, DIS-SOLVED (MG/L) (00515) |
|---|---|---|---|---|---|---|---|
| NOV , 1979 | | | | | | | |
| 03... | 1030 | .99 | 22 | 285 | 753 | -- | 700 |
| 03... | 1034 | 2.3 | 14 | 285 | 729 | 31 | 688 |
| 03... | 1038 | 1.8 | 18 | 285 | 718 | 19 | 696 |
| 03... | 1042 | .95 | 18 | 285 | 716 | -- | 686 |
| 03... | 1046 | .84 | 16 | 300 | 717 | -- | 690 |
| 03... | 1050 | .51 | 18 | 305 | 717 | 28 | 686 |
| 03... | 1054 | .18 | 20 | 305 | 681 | -- | 644 |
| 03... | 1058 | .04 | 20 | 315 | 651 | -- | 620 |
| 03... | 1102 | .01 | 20 | 315 | 693 | -- | 663 |
| 03... | 1106 | .01 | 22 | 305 | 692 | -- | 664 |
| 03... | 1110 | .01 | 20 | 315 | 662 | -- | 635 |

| DATE | SOLIDS, VOLA-TILE, DIS-SOLVED (MG/L) (00520) | SOLIDS, SUSP. TOTAL, RESIDUE AT 110 DEG. C (MG/L) (70299) | NITRO-GEN, TOTAL (MG/L AS N) (00600) | NITRO-GEN, ORGANIC TOTAL (MG/L AS N) (00605) | NITRO-GEN, AMMONIA TOTAL (MG/L AS N) (00610) | NITRO-GEN, NITRITE TOTAL (MG/L AS N) (00615) | NITRO-GEN, NITRATE TOTAL (MG/L AS N) (00620) |
|---|---|---|---|---|---|---|---|
| NOV , 1979 | | | | | | | |
| 03... | 222 | 53 | 7.7 | 5.4 | .30 | 1.00 | 1.0 |
| 03... | 242 | 41 | 8.2 | 4.6 | .18 | .79 | 2.6 |
| 03... | 242 | 22 | 8.0 | 4.5 | .12 | .70 | 2.7 |
| 03... | 236 | 30 | 7.6 | 4.0 | .12 | .71 | 2.8 |
| 03... | 227 | 27 | 7.7 | 4.1 | .15 | .71 | 2.7 |
| 03... | 216 | 31 | 7.7 | 4.1 | .13 | .64 | 2.8 |
| 03... | 196 | 37 | 8.1 | 4.5 | .13 | .64 | 2.8 |
| 03... | 200 | 31 | 7.8 | 4.2 | .12 | .64 | 2.8 |
| 03... | 230 | 30 | 7.8 | 4.2 | .12 | .64 | 2.8 |
| 03... | 214 | 28 | 7.9 | 4.2 | .11 | .64 | 2.9 |
| 03... | 230 | 27 | 7.7 | 4.2 | .10 | .56 | 2.8 |

| DATE | PHOS-PHORUS, TOTAL (MG/L AS P) (00665) | CARBON, ORGANIC TOTAL (MG/L AS C) (00680) | CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD) (01027) | CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR) (01034) | COPPER, TOTAL RECOV-ERABLE (UG/L AS CU) (01042) | LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051) | ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN) (01092) |
|---|---|---|---|---|---|---|---|
| NOV , 1979 | | | | | | | |
| 03... | .35 | 92 | -- | -- | 50 | 800 | 280 |
| 03... | .23 | 89 | -- | -- | -- | -- | -- |
| 03... | .23 | 87 | 2 | -- | -- | -- | -- |
| 03... | .23 | 86 | -- | -- | -- | -- | 210 |
| 03... | .23 | 158 | -- | -- | -- | -- | -- |
| 03... | .23 | 114 | 2 | -- | -- | -- | -- |
| 03... | .22 | 95 | -- | -- | 40 | 500 | 250 |
| 03... | .22 | 94 | -- | 15 | -- | -- | -- |
| 03... | .23 | 98 | 1 | -- | -- | -- | -- |
| 03... | .23 | 98 | -- | -- | 40 | 400 | 230 |
| 03... | .23 | 96 | -- | -- | -- | -- | -- |

SUPPLEMENTARY DATA

STATION NUMBER: 254731080121900

WATER-QUALITY DATA OF STORMWATER RUNOFF AT INTERSTATE 95 MONITOR SITE, MIAMI, FLORIDA

| DATE | TIME | STREAM-FLOW, INSTAN-TANEOUS (CFS) (00061) | SPE-CIFIC CON-DUCT-ANCE (UMHOS) (00095) | OXYGEN DEMAND, CHEM-ICAL (HIGH LEVEL) (MG/L) (00340) | SOLIDS, RESIDUE AT 105 DEG. C, TOTAL (MG/L) (00500) | SOLIDS, RESIDUE AT 105 DEG. C, DIS-SOLVED (MG/L) (00515) | SOLIDS, VOLA-TILE, DIS-SOLVED (MG/L) (00520) | SOLIDS, VOLA-TILE, SUS-PENDED (MG/L) (00535) |
|---|---|---|---|---|---|---|---|---|
| NOV , 1979 | | | | | | | | |
| 20... | 0830 | 2.5 | 845 | -- | 1190 | 760 | 240 | 266 |
| 20... | 0834 | .99 | 765 | -- | 868 | 668 | 327 | 150 |
| 20... | 0837 | .95 | 710 | -- | 668 | 516 | 212 | 124 |
| 20... | 0841 | .35 | 640 | 440 | 656 | 500 | 182 | 141 |
| 20... | 0844 | .10 | 710 | 360 | 570 | 437 | 104 | 112 |
| 20... | 0848 | .08 | 660 | 360 | 560 | 460 | 163 | 90 |
| 20... | 0851 | .02 | 660 | 360 | 528 | 416 | 152 | 108 |
| 20... | 0855 | .01 | 670 | 370 | 508 | 420 | 164 | 80 |
| 20... | 0858 | .01 | 662 | 380 | 524 | 388 | 136 | 132 |
| 20... | 0902 | .01 | 690 | 320 | 568 | 456 | 152 | 108 |
| 20... | 0905 | .00 | -- | -- | -- | -- | -- | -- |

| DATE | SOLIDS, SUSP. TOTAL. RESIDUE AT 110 DEG. C (MG/L) (70299) | CARBON, ORGANIC TOTAL (MG/L AS C) (00680) | CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD) (01027) | CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR) (01034) | COPPER, TOTAL RECOV-ERABLE (UG/L AS CU) (01042) | LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051) | ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN) (01092) | PCB, TOTAL (UG/L) (39516) |
|---|---|---|---|---|---|---|---|---|
| NOV , 1979 | | | | | | | | |
| 20... | 433 | 180 | 0 | 30 | 250 | 2400 | 1300 | -- |
| 20... | 200 | 205 | 0 | 20 | 130 | 1400 | 780 | -- |
| 20... | 152 | 150 | 0 | 10 | 100 | 900 | 580 | -- |
| 20... | 156 | 140 | 0 | 0 | 90 | 800 | 540 | -- |
| 20... | 133 | 120 | 0 | 0 | 100 | 900 | 570 | -- |
| 20... | 100 | 120 | 0 | 0 | 90 | 800 | 540 | -- |
| 20... | 112 | 130 | 0 | 0 | 100 | 900 | 550 | -- |
| 20... | 88 | 135 | 0 | 30 | 90 | 800 | 530 | -- |
| 20... | 136 | 135 | 0 | 0 | 90 | 700 | 480 | -- |
| 20... | 112 | 120 | 0 | 0 | 90 | 800 | 520 | -- |
| 20... | -- | -- | -- | -- | 70 | 400 | 430 | .10 |

**SUPPLEMENTARY DATA**

**STATION NUMBER: 254731080121900**

**WATER-QUALITY DATA OF STORMWATER RUNOFF AT INTERSTATE 95 MONITOR SITE, MIAMI, FLORIDA**

| DATE | TIME | STREAM-FLOW, INSTAN-TANEOUS (CFS) (00061) | SPE-CIFIC CON-DUCT-ANCE (UMHOS) (00095) | OXYGEN DEMAND, CHEM-ICAL (HIGH LEVEL) (MG/L) (00340) | SOLIDS, RESIDUE AT 105 DEG. C, TOTAL (MG/L) (00500) | SOLIDS, RESIDUE AT 105 DEG. C, DIS-SOLVED (MG/L) (00515) | SOLIDS, VOLA-TILE, DIS-SOLVED (MG/L) (00520) | SOLIDS, VOLA-TILE, SUS-PENDED (MG/L) (00535) |
|---|---|---|---|---|---|---|---|---|
| MAR , 1981 | | | | | | | | |
| 23... | 0604 | .02 | 840 | 530 | 1030 | 784 | 292 | 90 |
| 23... | 0607 | .04 | 407 | 440 | 585 | 388 | 178 | 103 |
| 23... | 0611 | .05 | 283 | 86 | 390 | 244 | 112 | 72 |
| 23... | 0615 | .05 | 228 | 220 | 390 | 188 | 78 | 94 |
| 23... | 0618 | .02 | 181 | 180 | 243 | 142 | 86 | 47 |
| 23... | 0623 | .01 | 154 | 140 | 179 | 110 | 50 | 35 |
| 23... | 0628 | .01 | -- | -- | -- | -- | -- | -- |
| 23... | 0630 | .00 | -- | -- | -- | -- | -- | -- |
| 23... | 0631 | -- | 24 | 0 | 88 | 68 | -- | -- |

| DATE | SOLIDS, SUSP. TOTAL, RESIDUE AT 110 DEG. C (MG/L) (70299) | NITRO-GEN, TOTAL (MG/L AS N) (00600) | NITRO-GEN, ORGANIC TOTAL (MG/L AS N) (00605) | NITRO-GEN, AMMONIA TOTAL (MG/L AS N) (00610) | NITRO-GEN, NITRITE TOTAL (MG/L AS N) (00615) | NITRO-GEN, NITRATE TOTAL (MG/L AS N) (00620) | NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625) | NITRO-GEN, NO2+NO3 TOTAL (MG/L AS N) (00630) | PHOS-PHORUS, TOTAL (MG/L AS P) (00665) |
|---|---|---|---|---|---|---|---|---|---|
| MAR , 1981 | | | | | | | | | |
| 23... | 250 | 6.2 | 5.8 | .36 | .02 | .06 | 6.16 | .08 | .66 |
| 23... | 197 | 6.9 | 3.5 | .04 | .16 | 3.2 | 3.54 | 3.4 | .02 |
| 23... | 146 | 3.2 | 2.4 | .50 | .01 | .25 | 2.90 | .26 | .15 |
| 23... | 202 | 3.6 | 2.4 | .10 | .08 | 1.0 | 2.50 | 1.1 | .34 |
| 23... | 101 | 2.9 | 1.3 | .08 | .06 | 1.5 | 1.38 | 1.6 | .18 |
| 23... | 69 | 2.1 | 1.1 | .09 | .05 | .85 | 1.19 | .90 | .14 |
| 23... | -- | 1.5 | .66 | .06 | .05 | .75 | .72 | .80 | .08 |
| 23... | -- | -- | -- | - | - | -- | -- | -- | - |
| 23... | 20 | -- | .11 | .16 | .01 | .38 | -- | -- | .00 |

| DATE | CARBON, ORGANIC TOTAL (MG/L AS C) (00680) | CARBON, TOTAL (MG/L AS C) (00690) | CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD) (01027) | CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR) (01034) | COPPER, TOTAL RECOV-ERABLE (UG/L AS CU) (01042) | LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051) | ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN) (01092) | PCB, TOTAL (UG/L) (39516) |
|---|---|---|---|---|---|---|---|---|
| MAR , 1981 | | | | | | | | |
| 23... | 160 | 260 | 8 | 17 | 110 | 2300 | 1000 | -- |
| 23... | 120 | 120 | 3 | 11 | 63 | 1300 | 670 | -- |
| 23... | 75 | 150 | 3 | 12 | 60 | 1300 | 710 | -- |
| 23... | 70 | 110 | 3 | 10 | 63 | 1300 | 730 | -- |
| 23... | 40 | 56 | 2 | 6 | 31 | 650 | 370 | -- |
| 23... | 37 | 39 | 2 | 4 | 27 | 590 | 340 | -- |
| 23... | 51 | 78 | 1 | 2 | 17 | 290 | 200 | -- |
| 23... | -- | -- | -- | -- | -- | -- | -- | <.10 |
| 23... | 4.2 | 6.2 | 1 | 25 | 20 | 0 | 80 | -- |

SUPPLEMENTARY DATA

STATION NUMBER: 254731080121900

WATER-QUALITY DATA OF STORMWATER RUNOFF AT INTERSTATE 95 MONITOR SITE, MIAMI, FLORIDA

| DATE | TIME | STREAM-FLOW, INSTANTANEOUS (CFS) (00061) | SPECIFIC CONDUCTANCE (UMHOS) (00095) | OXYGEN DEMAND, CHEMICAL (HIGH LEVEL) (MG/L) (00340) | SOLIDS, RESIDUE AT 105 DEG. C, TOTAL (MG/L) (00500) | SOLIDS, RESIDUE AT 105 DEG. C, DISSOLVED (MG/L) (00515) | SOLIDS, VOLATILE, DISSOLVED (MG/L) (00520) | SOLIDS, VOLATILE, SUSPENDED (MG/L) (00535) |
|---|---|---|---|---|---|---|---|---|
| MAY , 1981 | | | | | | | | |
| 01... | 1833 | 1.4 | 182 | 154 | 245 | 126 | 54 | 44 |
| 01... | 1837 | .84 | 128 | 140 | 141 | 90 | 52 | 24 |
| 01... | 1841 | .95 | 122 | 110 | 130 | 88 | 50 | 19 |
| 01... | 1844 | 2.1 | 106 | 300 | 192 | 56 | 32 | 53 |
| 01... | 1848 | 1.7 | 202 | 40 | 136 | 112 | 22 | 8 |
| 01... | 1852 | .61 | 64 | 97 | 78 | 60 | 20 | 8 |
| 01... | 1856 | .13 | 75 | 65 | 74 | 66 | 34 | 5 |
| 01... | 1900 | .09 | 90 | 130 | 89 | 68 | 26 | 11 |
| 01... | 1904 | .06 | 129 | 120 | 139 | 124 | 11 | 50 |
| 01... | 1906 | .00 | 18 | 5 | 33 | 28 | -- | -- |

| DATE | SOLIDS, SUSP. TOTAL, RESIDUE AT 110 DEG. C (MG/L) (70299) | OIL AND GREASE, TOTAL RECOV. GRAVIMETRIC (MG/L) (00556) | NITROGEN, TOTAL (MG/L AS N) (00600) | NITROGEN, ORGANIC TOTAL (MG/L AS N) (00605) | NITROGEN, AMMONIA TOTAL (MG/L AS N) (00610) | NITROGEN, NITRITE TOTAL (MG/L AS N) (00615) | NITROGEN, NITRATE TOTAL (MG/L AS N) (00620) | NITROGEN, AMMONIA + ORGANIC TOTAL (MG/L AS N) (00625) | NITROGEN, NO2+NO3 TOTAL (MG/L AS N) (00630) |
|---|---|---|---|---|---|---|---|---|---|
| MAY , 1981 | | | | | | | | | |
| 01... | 119 | -- | 5.8 | 3.7 | .30 | .03 | 1.8 | 4.00 | 1.8 |
| 01... | 51 | -- | 3.7 | 2.1 | .23 | .03 | 1.3 | 2.33 | 1.3 |
| 01... | 42 | -- | 3.3 | 1.8 | .24 | .03 | 1.2 | 2.04 | 1.2 |
| 01... | 136 | -- | .80 | .16 | .18 | .02 | .44 | .34 | .46 |
| 01... | 24 | -- | 1.1 | .78 | .10 | .01 | .24 | .88 | .25 |
| 01... | 18 | -- | 1.3 | .76 | .13 | .02 | .34 | .89 | .36 |
| 01... | 8 | -- | 1.4 | .82 | .13 | .02 | .46 | .95 | .48 |
| 01... | 21 | -- | 1.9 | 1.2 | .13 | .03 | .54 | 1.33 | .57 |
| 01... | 15 | 16 | 2.6 | 1.3 | .18 | .07 | 1.0 | 1.48 | 1.1 |
| 01... | 5 | -- | -- | .22 | .43 | .00 | .42 | -- | -- |

| DATE | PHOSPHORUS, TOTAL (MG/L AS P) (00665) | CARBON, ORGANIC TOTAL (MG/L AS C) (00680) | CARBON, TOTAL (MG/L AS C) (00690) | CADMIUM TOTAL RECOVERABLE (UG/L AS CD) (01027) | CHROMIUM, TOTAL RECOVERABLE (UG/L AS CR) (01034) | COPPER, TOTAL RECOVERABLE (UG/L AS CU) (01042) | LEAD, TOTAL RECOVERABLE (UG/L AS PB) (01051) | ZINC, TOTAL RECOVERABLE (UG/L AS ZN) (01092) |
|---|---|---|---|---|---|---|---|---|
| MAY , 1981 | | | | | | | | |
| 01... | .26 | 37 | 60 | 1 | 16 | 30 | 520 | 230 |
| 01... | .18 | 29 | 40 | 1 | 15 | 15 | 210 | 110 |
| 01... | .15 | 21 | 33 | 1 | 16 | 19 | 280 | 400 |
| 01... | .18 | 25 | 42 | 3 | 26 | 61 | 1300 | 400 |
| 01... | .10 | 14 | 16 | 1 | 11 | 9 | 160 | 50 |
| 01... | .08 | 13 | 18 | 1 | 12 | 10 | 110 | 50 |
| 01... | .09 | 23 | 33 | 1 | 13 | 10 | 90 | 60 |
| 01... | .09 | 34 | 44 | 1 | 11 | 17 | 120 | 70 |
| 01... | .10 | 39 | 48 | -- | -- | -- | -- | -- |
| 01... | .02 | 5.9 | 6.3 | -- | -- | -- | -- | -- |

## SUPPLEMENTARY DATA

STATION NUMBER: 254731080121900

WATER-QUALITY DATA OF STORMWATER RUNOFF AT INTERSTATE 95 MONITOR SITE MIAMI, FLORIDA

| DATE | TIME | STREAM-FLOW, INSTAN-TANEOUS (CFS) (00061) | SPE-CIFIC CON-DUCT-ANCE (UMHOS) (00095) | OXYGEN DEMAND, CHEM-ICAL (HIGH LEVEL) (MG/L) (00340) | SOLIDS, RESIDUE AT 105 DEG. C, TOTAL (MG/L) (00500) | SOLIDS, RESIDUE AT 105 DEG. C, DIS-SOLVED (MG/L) (00515) | SOLIDS, VOLA-TILE, DIS-SOLVED (MG/L) (00520) | SOLIDS, VOLA-TILE, SUS-PENDED (MG/L) (00535) |
|---|---|---|---|---|---|---|---|---|
| MAY , 1981 | | | | | | | | |
| 20... | 1812 | 2.5 | -- | 100 | 143 | 96 | 84 | 26 |
| 20... | 1815 | 2.5 | 43 | 28 | 38 | 24 | 20 | 8 |
| 20... | 1820 | 1.8 | 36 | 26 | 32 | 20 | 20 | 8 |
| 20... | 1825 | 1.4 | 37 | 32 | 35 | 28 | 28 | 6 |
| 20... | 1828 | .80 | 39 | 32 | 39 | 32 | 32 | 7 |
| 20... | 1831 | .35 | 46 | 40 | 31 | 34 | 30 | 7 |
| 20... | 1835 | .10 | 58 | 40 | 51 | 44 | 32 | 7 |

| DATE | SOLIDS, SUSP. TOTAL, RESIDUE AT 110 DEG. C (MG/L) (70299) | OIL AND GREASE, TOTAL RECOV. GRAVI-METRIC (MG/L) (00556) | NITRO-GEN, TOTAL (MG/L AS N) (00600) | NITRO-GEN, ORGANIC TOTAL (MG/L AS N) (00605) | NITRO-GEN, AMMONIA TOTAL (MG/L AS N) (00610) | NITRO-GEN, NITRITE TOTAL (MG/L AS N) (00615) | NITRO-GEN, NITRATE TOTAL (MG/L AS N) (00620) | NITRO-GEN, AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625) |
|---|---|---|---|---|---|---|---|---|
| MAY , 1981 | | | | | | | | |
| 20... | 47 | 16 | 2.0 | .63 | .25 | .04 | 1.1 | .88 |
| 20... | 14 | 4 | .55 | .16 | .15 | .01 | .23 | .31 |
| 20... | 12 | 2 | .59 | .17 | .18 | .01 | .23 | .35 |
| 20... | 7 | 3 | .49 | .06 | .19 | .01 | .23 | .25 |
| 20... | 7 | 3 | .59 | .14 | .19 | .01 | .25 | .33 |
| 20... | 7 | 4 | .69 | .17 | .21 | .02 | .29 | .51 |
| 20... | 7 | 5 | .91 | .29 | .22 | .02 | .38 | .51 |

| DATE | PHOS-PHORUS, TOTAL (MG/L AS P) (00665) | CARBON, ORGANIC TOTAL (MG/L AS C) (00680) | CARBON, TOTAL (MG/L AS C) (00690) | CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD) (01027) | CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR) (01034) | COPPER, TOTAL RECOV-ERABLE (UG/L AS CU) (01042) | LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051) | ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN) (01092) |
|---|---|---|---|---|---|---|---|---|
| MAY , 1981 | | | | | | | | |
| 20... | .14 | 21 | -- | 3 | 8 | 40 | 530 | 320 |
| 20... | .05 | 4.6 | -- | 1 | 14 | 7 | 41 | 50 |
| 20... | .06 | 4.8 | -- | 1 | 12 | 13 | 190 | 90 |
| 20... | .04 | 3.2 | -- | 1 | 12 | 11 | 120 | 70 |
| 20... | .05 | 5.0 | -- | 1 | 10 | 13 | 91 | 60 |
| 20... | .05 | 4.5 | 4.7 | 1 | 14 | 9 | 79 | 50 |
| 20... | .06 | 10 | -- | 1 | 8 | 9 | 92 | 50 |