WATER-QUALITY ASSESSMENT OF THE ILLINOIS RIVER BASIN, ARKANSAS

By J. E. Terry, E. E. Morris, J. C. Petersen, and M. E. Darling

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CONVERSION FACTORS

Selected conversion factors for terms in this report are listed below:

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.6463	million gallons per day (Mgal/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot per second (ft/s)	0.6818	mile per hour (mi/h)
foot (ft)	0.3048	meter (m)
gallon (gal)	3.785	liter (L)
inch (in)	2.54	centimeter (cm)
inch (in)	25.4	millimeter (mm)
mile (mi)	1.609	kilometer (km)
milligram per liter (mg/L)	62.44×10^{-6}	pound per cubic foot (lb/ft^3)
microgram per liter ($\mu g/L$)	62.44×10^{-9}	pound per cubic foot (lb/ft^3)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
pound (lb)	0.454	kilogram (kg)
square foot (ft^2)	0.0929	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)

Discharge (ft^3/s) $\times$ concentration (mg/L) $\times$ 5.3896 = total load of constituent (lb/d)

$°Fahrenheit = 9/5(°C) + 32$

$°Celsius = 5/9(°F - 32)$

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ABSTRACT

A water-quality assessment was made of the Illinois River, Muddy Fork, Spring Creek, and Osage Creek in northwest Arkansas. The assessment involved collecting data to define present conditions and to calibrate and verify a steady-state digital, stream, water-quality model. The model was then used to simulate changes in instream water quality resulting from changes in nutrient loading. The primary index to stream water quality used was the diel-minimum dissolved-oxygen concentration.

The city of Fayetteville has proposed to divert a part (9.2 cubic feet per second) of its projected wastewater-treatment plant discharge to the Illinois River. Muddy Fork, Spring Creek, and Osage Creek currently receive waste effluent from the cities of Prairie Grove, Springdale, and Rogers, respectively. The diel-minimum dissolved-oxygen standard for each of these streams is 4.0 mg/L (milligrams per liter) under projected loading conditions.

Data collected during synoptic surveys indicate that none of the four streams meet Arkansas state standards for diel-minimum dissolved oxygen, total phosphorus, and fecal coliform bacteria. In addition, the increase in water temperature in Spring Creek and Osage Creek downstream from the Springdale and Rogers wastewater-treatment plant, respectively, exceeds Arkansas standards.

Computed dissolved-oxygen deficits indicate that benthal demand is the most significant dissolved-oxygen sink in each of the four streams. Steady-state model simulations and analyses of stormwater runoff samples indicate that dissolved-oxygen deficits due to benthal demands are the result of both point and non-point sources. Ultimate carbonaceous biochemical oxygen demand and nitrification also create significant dissolved-oxygen deficits, especially in Spring Creek.

Model simulations indicate that Muddy Fork and Illinois River will not meet the Arkansas state standard of 4.0 mg/L diel-minimum dissolved oxygen for any projected effluent limits used for the Prairie Grove and Fayetteville wastewater-treatment plants, respectively. Spring Creek can meet the 4.0 mg/L standard if the Springdale wastewater-treatment plant effluent concentrations of ultimate carbonaceous biochemical oxygen demand and ammonia as nitrogen are less than or equal 7.5 and 2.0 mg/L, respectively, and the effluent is saturated with dissolved oxygen. Osage Creek will meet dissolved-oxygen standards if the effluent concentrations of ultimate carbonaceous biochemical oxygen demand and ammonia as nitrogen from the Rogers wastewater-treatment plant are less than or equal to 15.0 and 5.0 mg/L, respectively, and if the effluent is saturated with dissolved oxygen. If the Rogers effluent contains only 5.0 mg/L of dissolved oxygen, ultimate carbonaceous biochemical oxygen demand and ammonia as nitrogen concentrations in the effluent must be less than or equal to 7.5 and 2.0 mg/L, respectively, or Osage Creek dissolved-oxygen concentrations will not meet standards.

INTRODUCTION

Purpose and Scope

The Illinois River basin in northwest Arkansas was identified by the Arkansas Department of Pollution Control and Ecology as an area of intensive study under Section 208 of Public Law 92-500 (amended). This basin was identified because of the influence on water quality of municipal wastes discharged to streams in the study area. The U.S. Geological Survey in cooperation with the Arkansas Department of Pollution Control and Ecology assessed the quality of water in the Illinois River and its tributaries that receive municipal wastes in order to simulate the effects of projected changes in waste loading. This report gives the results of modeling the Illinois River, Muddy Fork, Spring Creek, and Osage Creek. Results include model projections of stream DO (see inside front cover for list of all abbreviations found in this report) under varying treatment levels of municipal-waste discharges.

Report Format

The first seven sections in this report present general information, types of data collected, and tools used in the water-quality assessment of Muddy Fork, Spring Creek, Osage Creek, and Illinois River. The study area is described, and data interpretation criteria and techniques are defined.

The next four sections specifically address the water-quality assessments of Muddy Fork, Spring Creek, Osage Creek, and Illinois River, respectively. Stream hydrology is described in each of these sections; data collected on each stream is discussed with respect to established criteria; and, the results of model calibration, verification, projections, and sensitivity analyses are presented. Each of these four sections conclude with a water-quality assessment of the subject stream for observed conditions and for projected changes in point-source waste-loading under $Q_{7/10}$ conditions.

The last two sections in the report are a general summary and selected reference list, respectively. The five attachments are included to document modeling techniques not discussed in previous reports and to substantiate calibration and verification of the four stream models.

Study Area Description

The Illinois River basin is in the Ozark Plateaus province in northwest Arkansas and northeast Oklahoma. The study area comprises 635 mi^2, 575 mi^2 of which are in Arkansas (fig. 1). Principal tributaries to the Illinois River in Arkansas include Muddy Fork, Clear Creek, and Osage Creek. Osage Creek has two large tributaries that have perennial flow--Little Osage Creek and Spring Creek--and several small perennial tributaries. Lake Frances, a reservoir formed by a dam on the Illinois River, is used as a water supply for Siloam Springs.

The basin can be divided into two somewhat different geologic and topographic areas by a line extending from about the northwest corner of Washington County bordering Oklahoma to a midpoint between Fayetteville and Springdale. North of this line, the basin is underlain mostly by limestone; south of this line, the basin is underlain by alternating beds of limestone, shale, and sandstone. The area north of the line has greater topographic relief; the streams have steep gradients (as much as 50 ft/mi for the upper Osage Creek and for Spring Creek) and are more deeply incised in the bedrock. In contrast, topographic relief in the area south of the line is less, and maximum stream gradients are much less steep (about 4.1 ft/mi for Muddy Fork, 7.0 ft/mi for Illinois River and 7.7 ft/mi for lower Osage Creek).

The contribution of the ground-water discharge to the streamflow in the basin is directly related to the permeability of the geologic units along the reaches of the streams. Geologic units throughout the Illinois River basin generally have low primary permeability. However, higher secondary permea-

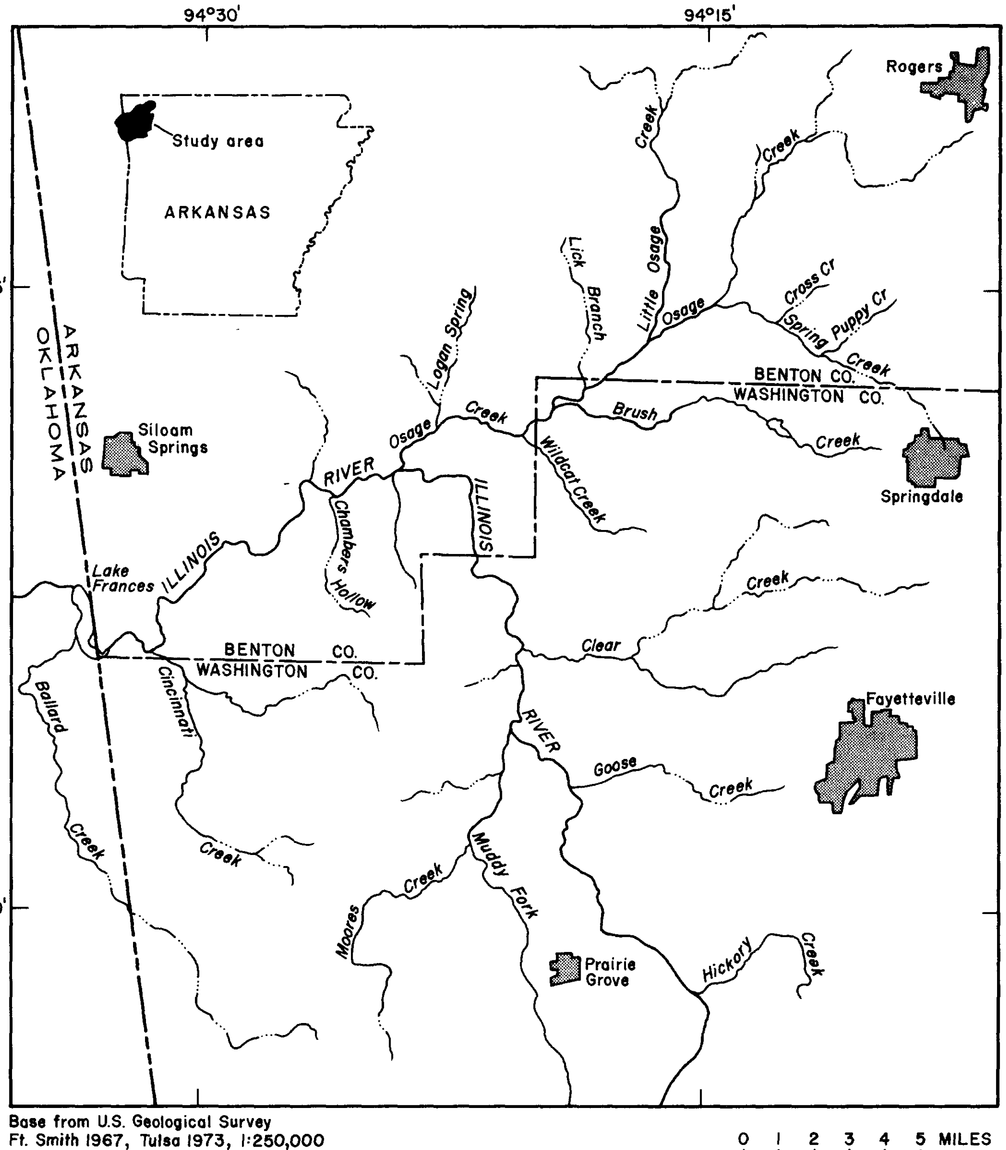

Figure 1.--Illinois River basin.

bility is afforded by joints and fractures in weathered zones of the rocks. In the northern part of the basin, the secondary permeability is further enhanced by the dissolution of the limestone.

Sediments, varying in size from clays to large boulders, are present in the streams. Exposed bedrock and the larger sediments provide excellent habitat for attached algae which are quite prevalent in the streams. Fine sediments and organic matter are present in pools and in Lake Frances.

Previous Investigations

A report by Heiple and Jeffus (1970) includes data showing a significant increase in orthophosphate and nitrate and a reduction in DO to less than 6.0 mg/L in the Illinois River, Osage Creek, and Spring Creek during the summertime low-flow period. Lamonds (1972) showed the similarity of surface-water quality and ground-water quality at low flow with reference to dissolved solids and hardness. Reed (1973), showed that BOD concentrations from municipal WWTP's in the Illinois River basin exceeded the low-flow assimilative capacity of receiving streams. Mitchell (1974) recommended that all municipal wastes in the Illinois River basin be discharged to the Illinois River via two regional WWTP's, one in the eastern part of the basin and the other in the western part. A study by Kittle, Short, and Rice (1974) concluded that regional WWTP's on the Illinois River would be detrimental to water quality and might greatly exceed the waste-assimilative capacity of the river. Noland (1976) found that fecal coliform bacteria concentrations sometimes exceeded State water-quality standards. Environmental Engineers, Inc. (1976) determined that Spring Creek could probably assimilate a 5-day BOD of 15 mg/L from the Springdale WWTP under $Q_{7/10}$ low-flow conditions. Bowen (1978) found that nonpoint sources contribute significant nutrient concentrations to streams in the Illinois River basin.

POLLUTION SOURCES

Nonpoint Sources

Washoff from streets of several population centers in the study area carries pollutants to streams. The largest population centers, based on the 1976 census (Bureau of Census, 1979), are: Fayetteville (population 33,946), Springdale (population 20,647), Rogers (population 14,982), and Bentonville (population 6,779). Because these cities are located on the perimeter of the basin some of the washoff from these population centers flows into other drainage basins.

Other towns in the basin have populations smaller than 2,000. These include: Prairie Grove, Lincoln, Farmington, Lowell, Elm Springs, Cave Springs, Tontitown, and Bethel Heights. The combined population of these towns is 7,400.

Most of the land in the basin is used for cattle farming. In many places cattle have access to the streams for drinking. Consequently, wastes containing organic carbon, nitrogen and phosphorus from cattle-farming operations enter the streams with ease.

Extensive poultry farming contributes some wastes to the streams. It is common practice to use the waste litter from poultry houses to fertilize pastureland in the basin. This litter is a source of high concentrations of nitrogen and phosphorus.

The Ozark National Forest covers a large part of the west-central part of the basin. Some organic detritus is contributed to streams from these wooded areas.

Point Sources

Three municipal waste-treatment plants discharge to streams in the Illinois River basin. These are Prairie Grove, discharging to Muddy Fork, Springdale, discharging to Spring Creek, and Rogers, discharging to Osage Creek. Wastes from these treatment plants are discharged near the headwaters of the streams, where natural flows generally are very low during the summer and fall.

WATER QUALITY DATA-COLLECTION AND INTERPRETATION CRITERIA

During the periods September 5-9, November 27-30, 1978, July 23-27, 1979, and August 24 - September 5, 1981, when flows were relatively steady, synoptic water sampling for physical, chemical, and biological parameters was conducted on streams throughout the Illinois River basin. Additional stormwater runoff samples were collected during April, May and August of 1981.

Water samples were collected and analyzed according to methods described by Guy and Norman (1970), Greeson and others (1977), Fishman and Brown (1976), Goerlitz and Brown (1972), Stevens and others (1975), Guy (1969), American Public Health Association and others (1975), the U.S. Geological Survey National Handbook (1977), and Skougstad and others (1979).

Representative bed-material samples were collected by shovel, refrigerated, and analyzed for streambed oxygen demand by a procedure modified from Nolan and Johnson (1979).

Physical Characteristics

Physical water-quality characteristics measured during the study were suspended solids, water temperature, and total dissolved solids.

Suspended Solids

Suspended solids generally can be related to stream turbidity. There are several sources of suspended solids in streams: 1) Sediment washed off the watershed, 2) sediments scoured from the streambed, 3) particulate matter discharged by a WWTP, 4) and algal growth derived from dissolved nutrients in the water. Concentrations of suspended solids in a stream vary as new sources are added, as particles are deposited or resuspended and as organic matter is produced and consumed. Turbidity, and consequently light penetration, depends upon these concentrations and the type of suspended material. The state of Arkansas uses suspended solids as one criterion for "permitting" point-source discharges.

Water Temperature

Typically, surface-water temperature varies continually in response to changes in solar radiation and changing seasons. Temperature is highest in the late afternoon and lowest in the early morning. Seasonal temperature is highest in July, August, and September and lowest in December and January.

High water temperatures lower the solubility of oxygen and increase the rates of oxygen-consuming reactions, reaeration rates, and photosynthetic-oxygen production. In the Arkansas water-quality standards (Arkansas Department of Pollution Control and Ecology, 1981) it is stated that "during any month of the year, heat shall not be added to any stream in excess of the amount that will elevate the temperature of the water more than 5°F [2.8°C]".

Dissolved Solids

Dissolved-solids values represent the total concentration of dissolved material in water. Dissolved-solids values are widely used in evaluating water quality and are a convenient means of comparing waters with one another. When dissolved solids are not measured directly an estimated value may be obtained from specific conductance measurements by use of an appropriate multiplication factor. Hem (1970, p. 99) defines the dissolved-solids to specific-conductance ratio expected in natural waters to range from 0.54 to 0.96. Using the lower value of 0.54 as a multiplication factor one can estimate minimal dissolved-solids concentrations from measured specific conductance values. Dissolved solids can be treated as a conservative constituent. The Arkansas standard (Arkansas Department of Pollution Control and Ecology, 1981), for total dissolved solids is 300 mg/L in the Illinois River Basin.

Chemical and Biochemical Characteristics

Selected chemical and biochemical water-quality characteristics measured during the study were chloride, sulfate, pH, DO, CBODU, streambed oxygen demand, net photosynthetic DO production, and nutrients.

Chloride and Sulfate

The Arkansas standard (Arkansas Department of Pollution Control and Ecology, 1981) for both chloride and sulfate is 20 mg/L in the Illinois River Basin. These standards apply to the mainstem of the Illinois and all tributaries considered in this study. Both point and nonpoint waste sources are possible contributors of these constituents to a stream.

pH

The pH of a solution refers to its hydrogen-ion activity and can range from 0 to 14. Water with pH values less than 7 is acidic; water with pH values more than 7 is alkaline. The pH of most natural water ranges from 6 to 8.5 (Hem, 1970, p. 93). Where aquatic photosynthesis takes up and releases dissolved carbon dioxide, pH may fluctuate dielly and the maximum pH value may sometimes reach as high as 9.0 (Hem, 1970, p. 93). Arkansas standards (Arkansas Department of Pollution Control and Ecology, 1981) state, "The pH of water in the stream or lake must not fluctuate in excess of 1.0 pH unit, within the range of 6.0 to 9.0, over a period of 24 hours. The pH shall not be below 6.0 or above 9.0 due to wastes discharged to the receiving waters."

Dissolved Oxygen

Dissolved oxygen is a very important parameter in natural waters; it is essential to all biota which respire aerobically. Fish and other desirable clean-water organisms require sufficient DO concentrations to survive and propagate. Arkansas water-quality standards (Arkansas Department of Pollution Control and Ecology, 1981) define streams in the Illinois River basin as smallmouth bass fisheries. These same standards require that 24-hour (diel) minimum instantaneous DO concentrations be greater than or equal to 6.0 mg/L. The only exception to this standard can be those streams whose flow at $Q_{7/10}$ is at least 50 percent treated effluent immediately downstream from the effluent outfall. Under these exceptional conditions the diel minimum DO concentration must be greater than or equal to 4.0 mg/L.

The DO concentration of flowing water can be effected by several processes and is therefore highly variable. Oxygen in rivers is consumed by bacterial decomposition of suspended, dissolved, and deposited organic matter, oxidation of ammonia and nitrite by nitrifying bacteria (nitrification), and the respiration of aquatic organisms. Oxygen is replenished in natural water primarily by the diffusion of oxygen into the water from the atmosphere (reaeration) and by photosynthesis.

Reaeration will not result in DO concentrations greater than saturation (the concentration of oxygen in the water that is in equilibrium with the oxygen concentration in the atmosphere). At a barometric pressure of 760 mm mercury (sea level) and a temperature of 10°C, water is saturated with oxygen when it contains about 11.3 mg/L. At 29°C, water is saturated with oxygen when it contains about 7.7 mg/L.

During daylight hours, algae are both producers and consumers of oxygen. In some favorable river environments algal photosynthesis can raise DO concentrations much higher than saturation. Suitable environments include slow-moving rivers that have large pools where phytoplankton can fluorish and shallow streams that have a stable substrate for periphyton. Under such conditions, if light penetration and nutrient supplies are sufficient, algae can become a larger contributor of oxygen to the river than reaeration. At night, in the absence of sunlight, algae are oxygen consumers. Where algal photosynthesis has resulted in supersaturated-oxygen concentrations, oxygen diffuses from the water, tending toward equilbrium. Because of the net oxygen production during the day and losses to respiration and diffusion at night, the diel pattern is higher DO concentration during the day and lower concentrations during the night. This diel pattern is characteristic of water with significant algal communities.

During summer months, when streamflow is low and water temperature is high, the DO concentration of a stream can be depleted by high organic loading. Such loading is common downstream from a WWTP with secondary or less treatment.

Dissolved-oxygen concentration was measured approximately three times during each 24-hour-sampling period; once during collection of water-quality samples, once after darkness, and once near sunrise. In addition, a continuous temperature and DO concentration monitor was used at selected sampling sites and numerous additional temperature and DO measurements were being made at other sites.

The DO concentration generally was lowest in the early morning hours at all of the Illinois River basin sampling sites. This condition is due to cumulative nighttime respiration and the absence of DO production. Differences between nighttime and midday DO concentrations at several sites indicate that photosynthetic activity was significant during the study.

Carbonaceous Biochemical Oxygen Demand

Carbonaceous biochemical oxygen demand (CBOD) is a single stage reaction defining the quantity of oxygen used by organisms in the water column as they consume organic material. Demands can be defined for any period of time, but are typically defined for periods of 5 days or until complete assimilation of CBOD occurs. The maximum quantity of DO required for the complete assimilation of carbonaceous material in a given parcel of water is defined as the "ultimate CBOD" (CBODU).

Water collected during each sampling period was analyzed for CBOD according to methods described by Pickering (written commun., 1980). To inhibit nitrification, 2-chloro-6 (trichloromethyl) pyridine was introduced into each sample. The observed decline in DO concentration in each sample was then assumed to be only due to the respiration of those organisms that consume carbonaceous material. DO concentrations in each sample were recorded initially and on day 1 of the test; thereafter, concentrations were recorded every other day for a period of 20 days.

The single-stage decay of carbonaceous material can be defined by the first order kinetics model expressed in the following equation:

$$L_t = L_o e^{-kt} \qquad (1)$$

where

t = time (in days),

e = base of natural logarithms,

L_t = concentration of CBOD remaining after t days, (milligrams per liter),

L_o = initial concentration of CBOD at time zero, CBODU, (milligrams per liter), and

k = first-order CBOD decay rate, base e, (per day)

L_o and k are determined by defining a best-fit curve for the time-series DO data recorded during the laboratory CBODU tests. This fitting is accomplished using a computer program described by Jennings and Bauer (1976).

The fitting methods available in the program are:

1) the Thomas method (Thomas, 1950),

2) the least-squares method (Reed and Theriault, 1931), and

3) the nonlinear least-squares method (Barnwell, 1980).

Estimates of L_o and k produced by the fitting procedure with the smallest computed root mean-square error are considered most accurate. The reaction coefficients, k, determined in this manner represent deoxygenation rates, because deposition is not accounted for in the "bottle-time" tests.

The Arkansas Department of Pollution Control and Ecology sets WWTP effluent limits based on a 5-day BOD. To obtain a 5-day BOD from an ultimate demand, a conversion factor of 0.67 is used (Velz, 1970, p. 145).

Streambed Oxygen Demand

The streambed oxygen demand is a measure of the quantity of oxygen removed from overlying waters by processes occurring through a unit area of streambed in unit time. The demand from the streambed for oxygen is primarily due to the decay of natural organic detritus such as leaves and to the decay of settleable organics contributed by man from both point and nonpoint sources.

"Streambed oxygen demand," as used in this report, does not include the respiration of periphyton nor does it include the respiration of benthic invertebrates and bacteria attached to noncollectable substrates. These noncollectable substrates include submerged trees, aquatic macrophytes, bedrock outcrops, large gravel, and boulders. The term "benthic oxygen demand" (benthal demand) as used in this report, has a broader meaning than streambed oxygen demand and includes the bacterial and invertebrate oxygen demands from non-collectable substrates.

Representative bed-material samples are collected by use of grab samplers or a shovel. Approximately 20 pounds of the top 2 to 3 inches (50 to 80 millimeters) of bed material are collected in a large pan. The surface of the material is covered with plastic wrap. The sample is then chilled and transported to the laboratory for analysis. Analysis is begun within 24 hours of collection.

A respirometer, adapted from Nolan and Johnson (1979), is used in the determination of streambed oxygen demand in the laboratory test. The respirometer (fig. 2) consists of a cylinder 1 foot in diameter (.305 meters) constructed from clear acrylic pipe with acrylic end plates, a DO probe and container, a continuous recorder, a peristaltic pump, and polyethylene tubing.

The bed-material sample is placed on the bottom of the respirometer to a depth of 1 inch (25 millimeters). The surface area of the sample is 0.743 square foot (0.069 square meter). The inlet

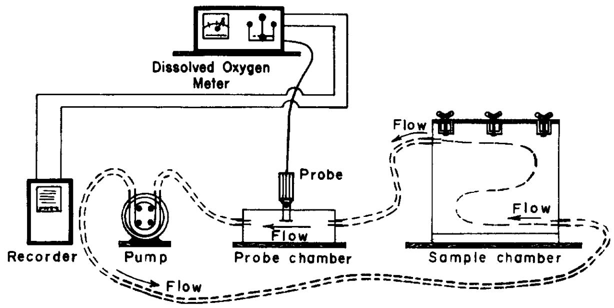

Figure 2.--Respirometer used for measuring streambed oxygen demand.

port is 1.18 inches (30 millimeters) above the sample surface, and the exit port is 3.54 inches (90 millimeters) below the lid of the respirometer. After a sample has been placed in the respirometer and the DO probe has been calibrated, the respirometer is filled with 2.25 gallons (8.53 liters) of aerated, demineralized water, the peristaltic pump is started, and the lid is placed on the respirometer forming an airtight container. The system is operated at room temperature (21°C ± 1°C) for 4 to 8 hours.

The first step in calculating the oxygen demand of the sample is to examine the DO versus time plot obtained from the continuous recorder. Initial DO (O_i) and final DO (O_f) are determined from that portion of the plot where oxygen consumption versus time is constant (fig. 3). DO concentrations less than 2 mg/L are not used in rate determinations because of changing rates of oxygen demand by aquatic organisms during low DO periods. As a control, the analysis is also done without streambed material using demineralized water, and the appropriate blank correction is made in the final calculation as follows:

$$SOD = [[(O_i - O_f) - (B_i - B_f)]V/SA] \div \Delta t \qquad (2)$$

where

SOD = Streambed oxygen demand, (grams per square meter per day),

O_i = DO initial, (milligrams per liter),

O_f = DO final, (milligrams per liter),

B_i = blank DO initial, (milligrams per liter),

B_f = blank DO final, (milligrams per liter),

V = volume confined water, (cubic meters),

SA = sample surface area, (square meters), and

$\Delta t = t_i - t_f$, change in time, (days).

Streambed oxygen demand values differ considerably between streams. Butts and Evans (1978) found that for several streams in the state of Illinois, values ranged from 0.27 (g/m^2)/d for a clean stream to 9.3 (g/m^2)/d for a very polluted stream.

Net Photosynthetic Dissolved-Oxygen Production

Net photosynthetic DO production, defined as the difference between gross photosynthesis and algal respiration, is an integral component in the community metabolism of most streams. Hereafter in this report net photosynthetic DO production will be referred to as "net DO production". In this study net DO production was determined from an analysis of a diel series of DO and temperature measurements and chlorophyll *a* measurements made at selected sampling sites. A typical set of curves for such diel data is shown in figure 4. An approach developed by Odum (1956) was used to solve the oxygen-balance equation for each set of diel data collected. This analysis yields net daytime productivity, total nighttime respiration, and total 24-hour community metabolism.

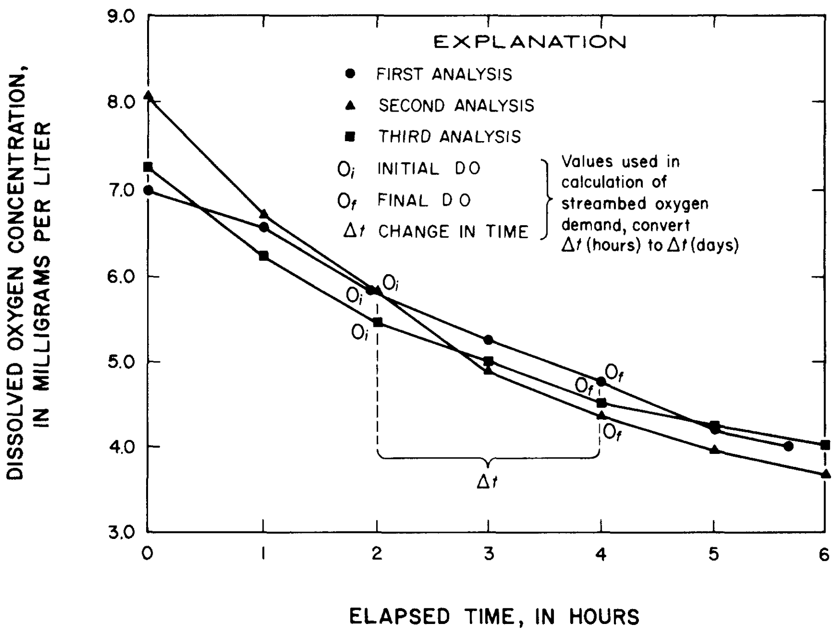

Figure 3.--Dissolved oxygen curves resulting from three respirometer analyses of a Muddy Fork bed-material sample collected on September 4, 1981.

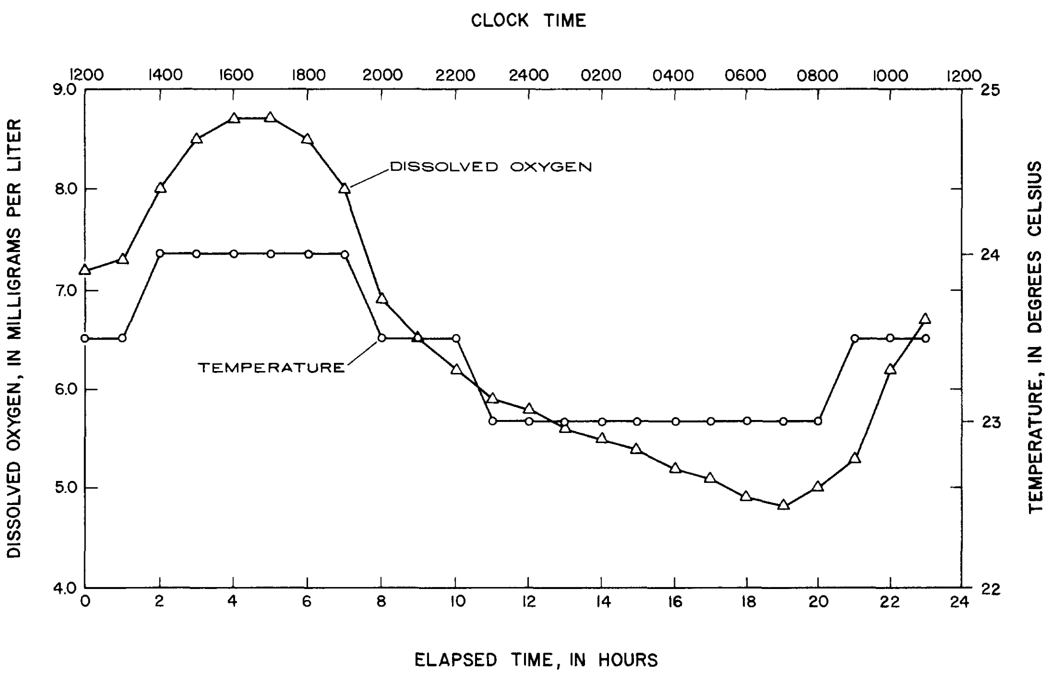

Figure 4.--Diel dissolved oxygen and temperature curves for Illinois River at Savoy, site no. 19, station no. 07194800, September 5-6 1979.

The Odum methodology has been coded into a digital program and documented by Stephens and Jennings (1976). The program solves the oxygen-balance equation at a single station or as the difference between upstream and downstream stations. In this study, the single-station analysis was used. Problem solution is for the following oxygen balance equation:

$$X = P - R \pm D + \Phi \qquad (3)$$

where

X = rate of change of dissolved oxygen per unit area,

P = rate of photosynthetic production per unit area,

R = rate of community respiration per unit area,

D = rate of gain or loss of oxygen through diffusion (reaeration), and

Φ = rate of accrual of oxygenated water.

In addition to the diel DO and temperature data, values for some additional parameters must be supplied to the program to solve the preceding equation. For these analyses, the additional parameters necessary are as follows:

1. oxygen diffusion coefficient,

$$DIFC = k_2 \times 9.07/(BP/29.92)$$

where

DIFC = diffusion coefficient, (grams per cubic meters per hour

k_2 = reaeration coefficient, (per hour),

9.07 = DO saturation, (milligrams per liter at 20°C), and

BP = barometric pressure, (inches of mercury),

2. barometric pressure, (inches of mercury),

3. stream depth, (meters), and

4. time of sunrise and sunset.

An example of printed results from the program is shown in figure 5.

Using, as an example, the results of the Odum analysis (fig. 5) and observed chlorophyll *a* concentrations of 1.04 μg/L for phytoplankton and 8.31 μg/L for periphyton, the following procedure was used to derive values for net photosynthetic DO production at each station.

Equalities:

1) Net daytime oxygen production = gross photosynthesis + [daytime benthal demand + daytime BOD + daytime respiration of periphyton + daytime respiration phytoplankton].

2) Nighttime respiration = nighttime benthal demand + nighttime BOD + respiration of periphyton + nightrespiration of phytoplankton.

3) 24-hour community metabolism = net daytime oxygen production + respiration.

4) Algal respiration = -0.025 (chlorophyll a concentration), Shindala, 1972).

Assumptions:

1. Daytime benthal demand and BOD = nighttime benthal demand and BOD.

2. Daytime algal respiration = nighttime algal respiration.

3. Periphyton respiration = phytoplankton respiration; in the absence good periphyton data.

Computations:

Phytoplankton chlorophyll a = 1.04 μg/L, therefore, by equality 4 *phytoplankton respiration = -0.025 (1.04 μg/L) = -0.026* $(g/m^3)/d$ *of oxygen.*

Periphyton chlorophyll a = 8.31 μg/L, therefore, by equality 4 *periphyton respiration = -0.025 (8.315 μg/L) = 0.208* $(g/m^3)/d$ *of oxygen.*

By equality 2, *nighttime benthal demand + nighttime BOD = nighttime respiration - nighttime respiration of periphyton - nighttime respiration of phytoplankton*

$= -4.931 - (-0.026/2) - (-0.208/2)$

$= -4.814\ (g/m^3)/d.$

```
                                   OXYGEN METABOLISM

STATION NUMBER 01:   SR2I:ST05:08/25-08/26:PC-CLR

NET DAYTIME PROD.     1.939 GM 02/M3/DAY    0.605 GM C /M3/DAY    1.299 GM 02/M2/DAY     0.405 GM C /M2/DAY
NIGHT RESPIRATION    -4.931 GM 02/M3/DAY   -1.538 GM C /M3/DAY   -3.304 GM 02/M2/DAY    -1.031 GM C /M2/DAY
*PRODUCTION DURING TIME PERIOD 0630 TO 1945 HRS
                                       P/R RATIO      0.3931

24 HOUR COMMUNITY METABOLISM=     -2.005 GM 02/M2/DAY
(DIFFERENCE BETWEEN NET DAILY PRODUCTION AND NIGHT RESPIRATION)
```

Figure 5.--Example printout of results of Odum single station method for determining community metabolism at site 5, Illinois River.

Define:

Net DO production = gross photosynthesis + daytime respiration of periphyton + daytime respiration of phytoplankton + nighttime respiration of periphyton + nighttime respiration of phytoplankton.

By equality 1, *net DO production = net daytime production - [daytime benthal demand + daytime BOD] + nighttime respiration of periphyton + nighttime respiration of phytoplankton.*

Therefore, using assumptions 1 and 2,

$$\text{net DO production} = 1.939 - (-4.814) + (-.208/2) + (-.026/2)$$
$$= 6.64\ (g/m^3)/d, \text{ and}$$
$$= 6.64\ (mg/L)/d.$$

Nutrients

Plants, including algae, require carbon, nitrogen, phosphorus, and potassium, as well as trace amounts of other elements to grow (Hynes, 1970). Potassium, a common constituent in river water, seldom limits plant growth. Forms of nitrogen dissolved in water include organic, ionized ammonia (NH_4^+), un-ionized ammonia (NH_3), nitrite, and nitrate. Of these forms, nitrate is the most readily available for plant growth and is the predominant form present in streams, except, when there is a man-made source of ammonia present or under reducing conditions when denitrification occurs. Forms of phosphorus in water include orthophosphate and the bound phosphate in soluble or particulate form. Dissolved forms of nitrate and phosphate are rapidly taken up by plants. Consequently, their concentrations in natural water are usually low.

Nutrient enrichment may encourage blooms of nuisance algae. Such blooms are common in lakes (Wetzel, 1975, p. 659) but are seldom seen in rivers. A principal reason for the absence of blooms in rivers is an unfavorable environment for planktonic algae because of river currents. Many algae present in rivers are not truly planktonic but are members of the periphyton (attached) community that have become dislodged because of river currents or overgrowth.

The concentration of all nutrients showed a decline downstream in the Illinois River basin. This trend is caused by several factors working simultaneously in the stream. Organic-N is decomposed by bacterial action and hydrolysis to form ammonia-N. Ammonia-N is oxidized to NO_2-N mainly through the action of bacteria belonging to the genus *Nitrosomonas*. The resulting NO_2-N is quickly oxidized to NO_3-N by bacteria of the genus *Nitrobacter*. The resulting NO_3-N is assimilated by algae and higher plants. Lesser reactions in the nitrogen cycle of a river include microbial fixation of molecular nitrogen in water and bottom sediments and microbial reduction of NO_3-N and NO_2-N to ammonia-N, and to the gaseous products nitrous oxide and molecular nitrogen.

PO_4-P concentrations typically show a decline downstream. Several factors affect instream concentrations of PO_4-P. Algae and, to a lesser extent, bacteria (Hynes, 1970, p. 46) and aquatic macrophytes (Wetzel, 1975, p. 227) remove PO_4-P from solution for growth. Bacterial action on organically-bound phosphorus releases PO_4-P to the stream. Phosphorus is continually removed from and added to the streambed by a series of complex processes, generally with a net loss to the streambed. During a storm, however, fast river velocities may scour the riverbed and resuspend a large amount of phosphorus and carry it downstream.

Arkansas standards (Arkansas Department of Pollution Control and Ecology, 1981) state that "Materials stimulating algal growth shall not be present in concentrations sufficient to cause objectionable algal densities or other nuisance aquatic vegetation. As a guideline, total phosphorus shall not exceed 100 μg/L in streams or 50 μg/L in lakes and reservoirs except in waters highly laden with natural silts or color which reduce the penetration of sunlight needed for plant photosynthesis, or in other waters where it can be demonstrated that algal production will not interfere with or adversely affect beneficial uses and/or fish and wildlife propagation. The Commission may establish alternative nutrient limitations for lakes, reservoirs and streams, and shall incorporate such limitations into appropriate water quality management plans."

Biological Characteristics

The stream biological community was selectively sampled for phytoplankton, periphyton, and coliform bacteria. These organisms can be useful indicators of overall river water quality.

Phytoplankton

Phytoplankton are an assemblage of microscopic plants that drift passively with the currents of rivers and lakes. In its broadest sense, the term phytoplankton includes algae, fungi, and bacteria. However, only the algae were considered in this study. Although large phytoplankton communities generally are found in lakes, some slow moving streams may contain significant populations, particularly in sidearms or among rooted aquatic plants (Greeson, 1982).

Phytoplankton populations can directly affect the pH, DO concentration, concentrations of certain inorganic constituents (particularly nutrients), turbidity, and color of surface water. Phytoplankton cause problems in domestic water supplies when their concentrations reach "nuisance" levels. Some of the problems caused by "nuisance" organisms are blooms, taste, odor, clogging of sand filters, and toxicity (Palmer, 1959).

During biomass production by the process of photosynthesis, phytoplankton can be an important source of DO during daylight hours. However, plants also respire, a process which requires oxygen. Given the right conditions--warm water (high rate of respiration) low light levels, and little or no wind (low rate of oxygen transfer from atmosphere to water)--phytoplankton may cause oxygen depletions in a body of water, resulting in fishkills or in severe mortality of certain insects (Greeson, 1982). Cellular chlorophyll *a* content was used in this report to estimate biomass production and respiration on a proportional basis.

There are no applicable water-quality standards for phytoplankton in water used for recreation. However, esthetic considerations by users may limit recreational use when algal blooms are present. In addition to imparting turbidity and color, algal blooms have been known to impart grassy, moldy, or fishy odors to water and produce substances toxic to livestock and man (Palmer, 1959).

Periphyton

Periphyton are the assemblage of algae, fungi, and bacteria which are attached to or live on submerged objects in streams and lakes. In the stream environment they are the most important biomass producers.

Factors that influence periphyton growth include current velocity, stream temperature, light intensity, and stream depth. Another factor, and probably the most important, is the nature of the substrate, its texture, stability, and porosity affects the composition of the periphyton community.

Water quality has an important influence on the periphyton community; conversely, the periphyton is an important influence on water quality. Below many sewage outfalls nitrogen and phosphorus concentrations decrease downstream partly as a result of periphyton uptake.

Periphyton communities were measured in this study by means of artificial substrates. These substrates consisted of plastic strips which were placed in a stream according to mean stream depth and amount of shading found at the sampling point. After appropriate exposure time (15 to 30 days) analyses of these substrate samples were used to compare community structure. They also were used to measure rate of colonization, or the amount of biomass accumulated in a given unit of time in a given area; this information yields a relative measure of the productivity of a stream.

Another useful measurement on periphyton samples is the autotrophic index. Autotrophic refers to organisms in which organic matter is synthesized from inorganic substances (photosynthesis) as compared to heterotrophic organisms, which require organic material as a source of nutrition.

The autotrophic index is the ratio of biomass to chlorophyll *a*. A high value for this index indicates a community with a large number of heterotrophic organisms (bacteria and fungi). A low value indicates a community with predominately autotrophic organisms (Greeson, 1979). Ratios of 50 to 100 have been found in organically unpolluted waters (Weber, 1973). Ratios greater than 100 may indicate organic pollution (Weber and McFarland, 1969 in Greeson, 1979; Weber, 1973). The chlorophyll *a* content may also be used to estimate periphyton production and respiration.

Total Coliform Bacteria

The coliform group, by definition, is the aerobic and facultative anaerobic, gram-negative, non-spore forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C. For the method used in this report, the coliform group is defined as all the organisms which produce colonies with a golden-green metallic sheen within 24 hours when incubated at 35°C on M-Endo medium. The test does not differentiate between coliforms of fecal and non-fecal origin; therefore soil bacteria normally account for a large percentage of organisms identified (Greeson, 1981).

The Arkansas State Board of Health has the responsibility of approving or disapproving surface waters for swimming and for drinking water supply, and it has issued rules and regulations pertaining to such uses. It is stated in these regulations that the coliform group shall not exceed 1,000 colonies per 100 milliliters as a monthly average value (either most probable number or membrane filter count) for waters substantially used for body contact aquatic sports; nor exceed this number in more than twenty percent of the samples examined during any one month; nor exceed 2,400 colonies per 100 milliliters on any day except during periods of stormwater runoff; provided, however, that no fecal contamination is known to be present. In other waters, the coliform bacteria group shall not exceed 5,000 colonies per 100 milliliters as a monthly average value (either most probable number or membrane filter count); nor exceed this number in more than twenty percent of the samples examined during any month; nor exceed 20,000 colonies per 100 milliliters in more than 5 percent of such samples. Arithmetic averages will be used. The Arkansas Department of Pollution Control and Ecology has no criterion for total coliforms.

Fecal Coliform Bacteria

Fecal coliform are that part of the coliform group that are present in the intestines and feces of warmblooded animals. They are capable of producing gas from lactose in a suitable culture medium at 44.5°C. For purposes of this study, the fecal coliform group is defined as all organisms which produce blue colonies within 24 hours when incubated at 44.5°C ± 0.2°C on m-FC medium.

The Arkansas Department of Pollution Control and Ecology has established fecal coliform criteria for all surface waters except those used for public water supply or as a specifically delineated outdoor bathing place (Arkansas Department of Pollution Control and Ecology, 1981). For a class A water, such as the Illinois River and its tributaries, between April 1 and Septebmer 30, the fecal coliform content shall not exceed a geometric mean of 200 colonies per 100 mL nor shall more than 10 percent of the total samples during any 30-day period exceed 400 colonies per 100 mL. The remainder of the calendar year, class A waters shall have the same protection as class B waters. For class B waters the fecal coliform content shall not exceed 2000 colonies per 100 mL in more than 10 percent of the samples taken in any 30-day period.

INSTREAM REAERATION COEFFICIENT

Reaeration is the single most important source of dependable oxygenation in a stream. This process goes on at a rate that is proportional to the existing DO deficit. The deficit is defined as the difference between the existing DO concentration in a stream and the possible saturation concentration at the existing water temperature.

The following equation is often used to express the rate of absorption of oxygen per unit time (rate of reaeration);

$$dc/dt = k_2(C_s - C) \quad (4)$$

where,

dc/dt = reaeration rate, (milligrams per liter per day),

k_2 = reaeration coefficient, (per day),

C_s = DO saturation concentration at a given temperature, (milligrams per liter), and

C = existing DO concentration, (milligrams per liter).

The above units are used for convenience in this study; other consistent units may be used. The most difficult variable to define in this equation is k_2. However, in order to adequately simulate DO dynamics in a stream it is essential.

The reaeration coefficient expresses the effect of stream hydraulic properties upon the rate of reaeration. Available data indicate that there is a functional relationship between k_2 and mean velocity, mean depth, and/or channel slope. This relationship has been defined differently by various investigators and a number of predictive equations are available.

An oxygen balance is often attained in stream water-quality simulations by using one of the available predictive equations to estimate k_2. Some simulations are also attempted in which the reaeration coefficient is treated as the only unknown in the oxygen balance equation and values of k_2 are adjusted until computed DO concentrations match those that have been observed reasonably well. There are significant problems associated with each of these techniques for defining k_2, especially the latter. A more viable method for defining k_2 is a field measurement of the coefficient for the particular stream and flow conditions being studied.

Measurement Technique

Reaeration coefficients were measured for selected reaches of Spring Creek, Osage Creek, and Illinois River. The measurement technique involves the use of low molecular-weight hydrocarbon gas and rhodamine WT dye as "tracers". This particular technique was first described by Rathbun and others (1975).

The hydrocarbon gas tracer technique is based on the observation that the rate coefficient for the tracer gas desorbing from water and the rate coefficient for oxygen being absorbed by the same water are related by a proportionality constant such that,

$$k_2 = k_T\Theta \quad (5)$$

where,

k_2 = reaeration coefficient, (per day),

k_T = desorption coefficient for the hydrocarbon gas, (per day), and

Θ = experimentally determined proportionality constant.

Values of Θ for ethylene and propane were determined from a series of mixing-tank experiments in which k_2 and k_T were measured simultaneously (Rathbun and others, 1978). These values are 1.15 and 1.39 for ethylene and propane, respectively.

The rhodamine WT dye is used as a dispersion-dilution tracer. However, it is recognized that the dye is not completely conservative and provisions are built into the computation procedure to correct for dye losses.

The low molecular-weight hydrocarbon gas and rhodamine WT dye solution are injected into the stream as a short continuous injection. A continuous injection is necessary because the solubilities of ethylene and propane are so small that an instantaneous point-source injection would require a quantity of tracer solution too large to handle easily for most streams. The injection is continued only long enough to get sufficient tracer gas into the stream to obtain measurable concentrations downstream. Although plateau concentrations may be obtained at the first sampling site, only peak concentrations are usually obtained at sites farther downstream. Complete dye concentration-versus-time curves should be obtained and discharge measurements made in case dye loss corrections are necessary.

The gas and dye concentration-versus-time curves obtained at the beginning and end of a stream reach are used to define the gas desorption rate coefficient for that reach. Examples of the curves that can be obtained are shown in figures 6 and 7.

Details of the field procedures for measuring reaeration coefficient have been described by Rathbun and others (1975), Shultz and others (1976), Rathbun (1977), and Rathbun and others (1978). These publications are recommended to the interested reader.

Data Interpretation

There are two computational procedures for determining a gas desorption coefficient from gas and dye data collected at two or more sampling sites within a stream reach of interest. One is based on the peak gas concentration observed at each site and the other is based on the areas under the gas concentration-versus-time curves at each site.

The basic equation for determining the gas desorption coefficient using the peak method is:

$$k_T = [1/(t_d - t_u)] \ln [(C_T/C_D)_u/(C_T/C_D)_d] \qquad (6)$$

where,

k_T = desorption coefficient for the hydrocarbon gas, (per day),

t = time of arrival of peak gas concentration,

C_T = peak concentration of gas, (micrograms per liter), and

C_D = peak concentration of dispersion-dilution tracer, (micrograms per liter).

Subscripts d and u indicate downstream and upstream, respectively.

An assumption is made in equation 6 that the dispersion-dilution tracer is conservative. Under many stream conditions, rhodamine WT dye is not completely conservative. In such cases the following procedure can be used to account for possible dye losses:

$$Q_2A_2 = Q_3A_3J_3 = Q_4A_4J_4 \qquad (7)$$

where,

Q = discharge, (cubic feet per second),

A = area under the dye concentration-versus-time curve, and

J = correction factor used to maintain equality.

The subscripts 2, 3, and 4 indicate sampling sites in a downstream direction. Complete mixing is required for this correction to be valid. Equation 6 then takes the following form between hypothetical sampling sites 3 and 4:

$$k_T = [1/(t_4 - t_3)] \ln [(C_{T_3}/C_{D_3}J_3)/(C_{T_4}/C_{D_4}J_4)] \qquad (8)$$

where all variables are as previously defined.

The area method can be used if mixing is complete at each sampling site. This computation has the advantage that dye concentrations are not needed. The basic form of the equation is as follows:

$$k_T = [1/(\bar{t}_d - \bar{t}_u)] \ln (A_u/A_d) \qquad (9)$$

where,

A = area under the gas concentration-versus-time curve, and

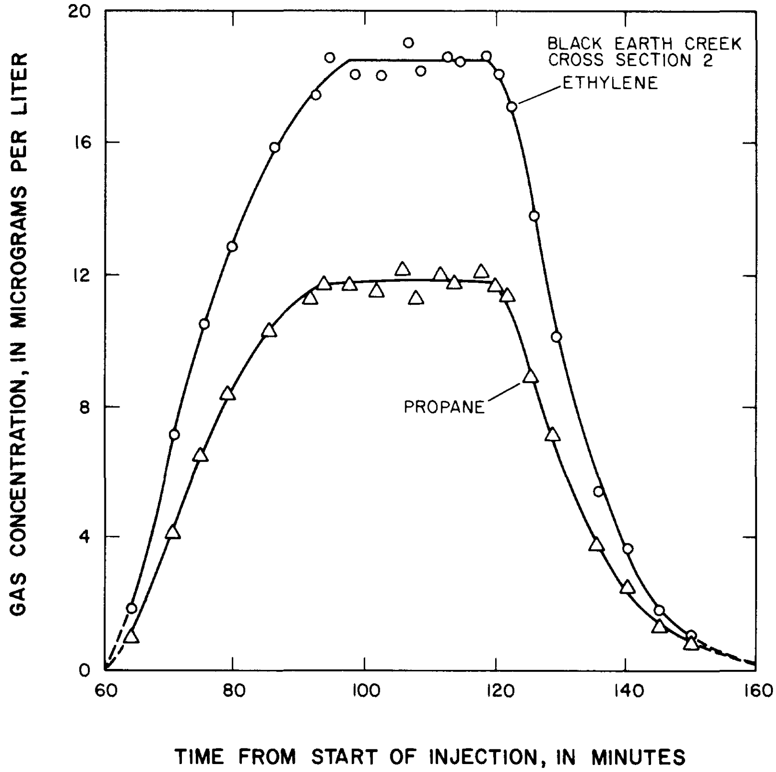

Figure 6.--Example of gas concentration versus time curve (Rathbun and Grant, 1978).

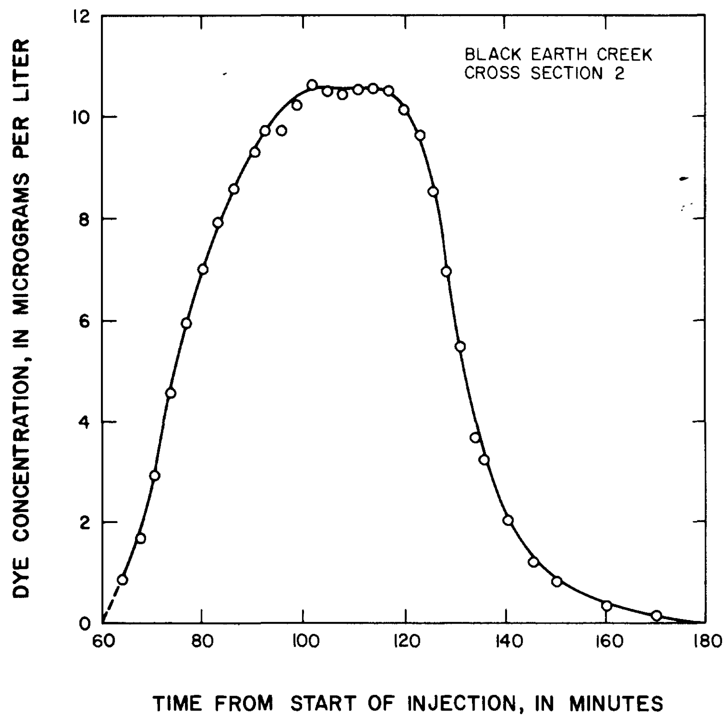

Figure 7.--Example of dye concentration versus time curve (Rathbun and Grant, 1978).

$\bar{t}$ = time of arrival of the centroid of the gas tracer mass.

The subscripts u and d indicate upstream and downstream, respectively.

For best results in defining k_T, the percent difference in peak gas concentrations from the upstream to the downstream sampling sites should be at least 20 percent greater than the percent difference in peak dye concentrations. If the percent difference in peak gas concentrations is significantly less than 20 percent greater than the percent difference in peak dye concentrations, then k_T will be biased by dispersion and may not reflect a true desorption coefficient.

After application of equations 6, 8, and/or 9, k_2 can be determined by substituting the resulting k_T value and the appropriate value of Θ into equation 5. These values of k_2 are representative of the flow conditions and water temperature during the gas and dye injection and sampling period.

Details on the derivation and application of equations 6-9 are given by Rathbun and others (1975) and Rathbun and Grant (1978). The interested reader should refer to these publications for further explanation.

Computations of k_T using equation 6 are the most representative for Spring Creek, Osage Creek, and Illinois River. Possible incomplete mixing and problems in defining complete dye concentration-versus-time curves made dye loss corrections to the peak method and/or area method computations questionable. Only ethylene was used as a gas tracer in these studies. The value of Θ in all of the k_2 computations is therefore 1.15.

TIME OF TRAVEL

Time of travel refers to the movement of water or waterborne materials from point to point in a stream for steady or gradually varied flow conditions (Hubbard and others, 1982). The most accurate method for determining times of travel is by observing the movement of a conservative tracer that behaves in the same manner as the water particles in the stream. Flourescent dyes, although not completely conservative, and established dye tracing techniques are often used. A measure of instream dye movement is therefore a measure of water particle movement and can be translated into mean velocities for steady and gradually varied flows.

Measurement Technique

The appropriate data needed for measuring time of travel can be obtained by "slug injecting" a fluorescent dye into a stream at a given location and tracing (or measuring) the resulting dye cloud at other downstream locations. The degree of fluorescence can be determined by use of a fluorometer. Dye concentration is proportional to fluorescence. The dye cloud passage at each sampling site is defined by a plot of dye concentration versus time (fig. 8). The time required for the movement of the dye cloud between sampling sites is the time of travel. Knowing the time of travel and distance between sampling sites, mean velocities can be computed. Mean velocities are usually best reflected by the traveltime of the peak concentrations in the dye cloud between sampling sites. For the most reliable results the dye should be well mixed at each sampling site.

Velocity Interpretation

Stream velocity, and consequently time of travel, varies with discharge. For purposes of steady-state stream water-quality modeling it is ideal to have mean stream velocities defined by travel times measured for the discharge of interest. However, this may not always be possible. If only one time-of-travel data set can be collected, it should be done at a steady discharge within a range for which channel geometry (mean cross sectional area, mean width, and mean depth) would remain unchanged. Adequate mean channel width can be computed from field measurements made at frequent distance intervals. Mean cross sectional area can then be "fit" on the basis of measured mean velocities and associated discharges. The following relation is used,

$$A = Q_a/V_a \qquad (10)$$

where,

A = mean cross sectional area, (square feet),

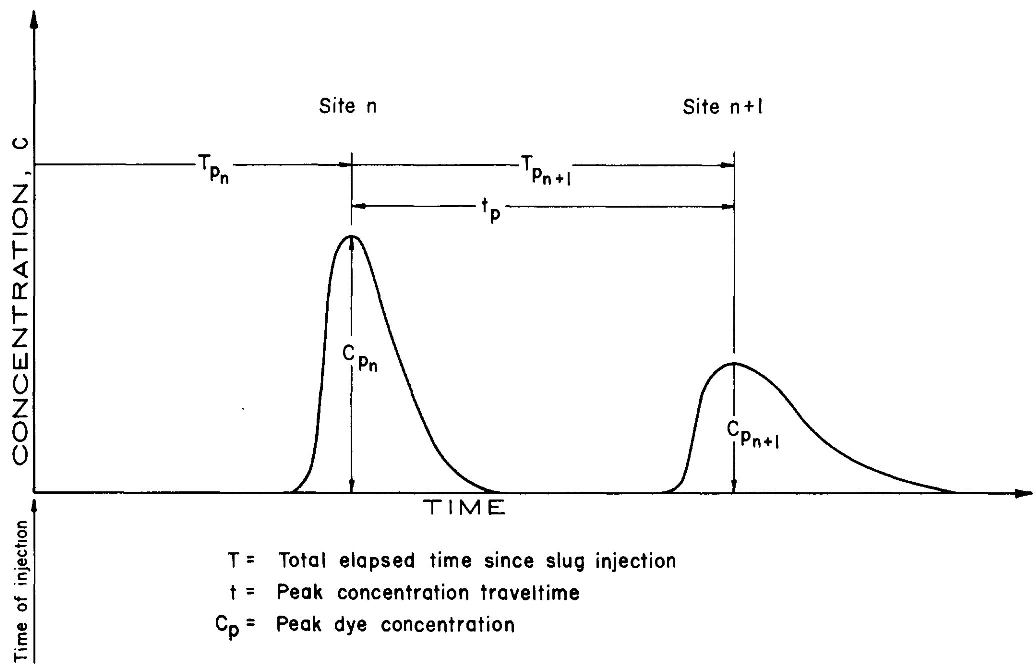

Figure 8.—Definition of the concentration versus time curves resulting from an instantaneous dye injection, (modified from Hubbard and others, 1982).

Q_a = discharge measured during time of travel data collection, (cubic feet per second), and

V_a = mean velocity derived from the time of travel data, (feet per second).

Mean channel depth can then be derived as the ratio of mean cross-sectional area to mean channel width.

Mean velocities for the discharge of interest can then be simulated as follows,

$$V_b = Q_b/A \qquad (11)$$

where,

A = mean cross sectional area, (square feet),

Q_b = the discharge of interest, (cubic feet per second), and

V_b = computed velocity of interest, (feet per second).

This procedure was used to simulate mean velocities and consequently times of travel in the stream models for Muddy Fork, Spring Creek, Osage Creek and Illinois River.

WATER-QUALITY MODEL

According to existing water-quality standards, (Arkansas Department of Pollution Control and Ecology, 1981) a key criterion for determining the "quality" of a stream system is the instream concentration of DO. Various physical and biochemical components simultaneously impact DO in a stream, resulting in both diel and spatial variations in DO concentration. Some of the components help replenish the DO, whereas others consume DO. To determine the assimilative capacity of a stream, existing stream water-quality conditions must first be defined. Projections can then be made to estimate how much additional waste can be discharged to the stream, or how much existing waste discharges must be reduced in order to meet existing water-quality standards.

Digital models are quite commonly used in assessing the capacity of streams to assimilate municipal and/or industrial wasteloads. Guidelines were released in March 1980 by the U.S. Environmental Protection Agency, Region 6, for justifying advanced secondary treatment or advanced waste treatment of municipal sewage (written commun., U.S. Environmental Protection Agency, 1980). These guidelines indicate that any perennial stream into which an effluent greater than 3 ft^3/s is to be discharged must be analyzed for assimilative capacity by using a calibrated and verified, steady-state digital water-quality model based on the Streeter and Phelps (1925) oxygen-sag equation.

Digital Model Description

A modified version of a one-dimensional, steady-state stream water-quality model, described by Bauer and others (1979), was used in this study. The model requires that flow rates and associated inflow constituents from all tributaries and waste discharges be constant. The model is based primarily on the Streeter-Phelps (1925) oxygen-sag equation.

Problem solution is achieved by dividing each reach of a modeled stream system into a number of subreaches. These subreaches generally are defined by the locations of waste and tributary inflow points or significant changes in stream characteristics. In addition to the inflow of waste or tributary sources at the head of each subreach, linear runoff (non-point flow) may be specified along any subreach. All constituents being modeled are assumed to be instantaneously and completely mixed within any stream cross section. The model can be used to simulate and predict concentrations of DO, CBOD, nitrogen forms, total and fecal coliform bacteria, PO_4-P and conservative substances. Output from the model includes tabulations of those concentrations at selected fixed distance intervals and profile plots of concentration versus river mile.

The basic model was modified by the authors of this report to correct some problems in the program and to provide the capability of simulating a more varied set of conditions for any given receiving stream. The primary modifications include the following:

1. The addition of a new subroutine to compute reaeration coefficients for each subreach by any one of eight predictive equations.

2. The addition of a temperature-correction factor for net photosynthetic DO production (algal photosynthesis minus algal respiration), as described by Krenkel and Novotny (1980, p. 397).

3. The imposition of an upper limit of saturation upon projected DO concentrations when projecting the assimilative capacity of a potential receiving stream; the "dependable" DO concentration in the stream should not be greater than saturation. When such conditions occur it is because of the projected effects of net photosynthetic production. Modifications have been made in the model so that, under such circumstances, only that part of photosynthetically produced DO needed to maintain saturation is retained in the water column; the "excess" is assumed lost to the atmosphere. However, if additional or larger demands are placed upon instream DO causing increased deficits, then what had been "excess photosynthesis" is available to maintain saturation until it is depleted.

4. The correction of DO mass-balance computations at point-source inflow locations. Significant errors in DO concentrations at the beginning of a subreach resulted when the point-source discharge was a significant part of the downstream flow and when the temperature of the point-source discharge was significantly different from the water temperature in the subreach.

5. The addition of a technique for simulating the minimum DO profile in a diel cycle. This technique is based on the assumption that the diel fluctuation in DO at any given location along the DO profile is primarily the result of algal DO production and respiration.

To further increase the efficiency and utility of the model, several other minor modifications were made, including some changes in card input and printed output. The modifications described in items 1 through 4 are discussed in detail in an earlier report (Attachment A, in Terry and others, 1982). The simulation technique and associated model modifications mentioned in item 5 above are described in Attachment A of this report.

Calibration and Verification Procedure

The values of some of the components needed to describe the quality of a stream system numerically and the rates at which these components change in the system can be determined directly; the values of others must be determined by trial and error. Model calibration is the process by which these trial-and-error determinations are made. Calibration is considered successful when plausible values have been determined for all components and

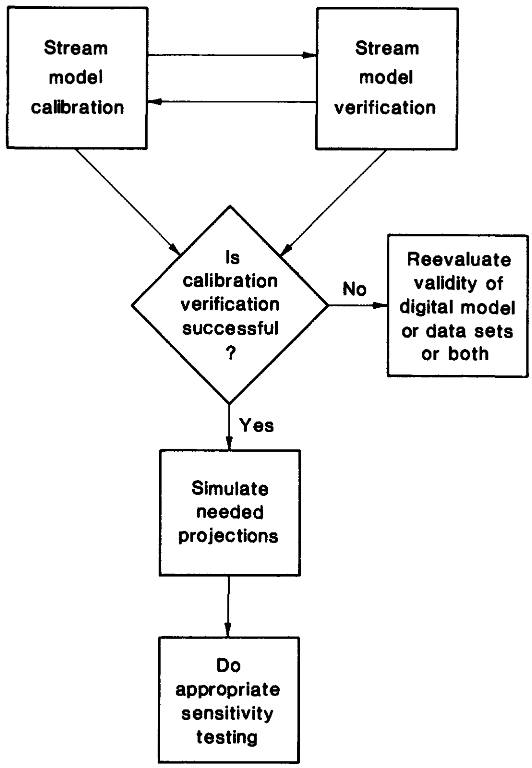

Figure 9.--Procedural flow-chart for modeling applications.

rate coefficients, and a sufficient similarity had been achieved between model results and observed data. If the calibrated model can then be used to adequately forecast data observed in one or more independently collected data sets, then model verification is considered successful. Inherent errors in defining unknown rate coefficients and parameters can be minimized by "fine-tuning" them during the calibration-verification process. Figure 9 illustrates the general modeling procedure which is dependent upon the "fine-tuning" achieved during calibration-verification.

In this study, the variable constituents that are predictable include the following:

1. dissolved oxygen,

2. carbonaceous biochemical oxygen demand,

3. nitrogen forms (organic-N, ammonia-N, NO_2-N, NO_3-N),

4. orthophosphate-P, and

5. fecal and total coliform bacteria.

Those constituents and processes that directly impact the quality of the system, as defined by the instream concentration of DO, are:

1. carbonaceous biochemical oxygen demand,

2. nitrogen transformations,

3. benthic oxygen demand,

4. net DO production, and

5. reaeration.

The values of the "average" benthic oxygen demands and of the following rate coefficients are determined, by subreach, in the calibration and verification process:

KR (k_r) = Average CBOD decay rate coefficient for a subreach, day^{-1} (base *e*).

KD (k_d) = Average CBOD deoxygenation rate coefficient for a subreach, day^{-1}(base *e*).

KORG = Average organic-N forward-reaction coefficient for subreach, day^{-1}(base *e*). Expressed as an average subreach instream rate coefficient.

KNH3 = Average ammonia-N forward-reaction coefficient for a subreach, day^{-1}(base *e*). Expressed as an average subreach instream rate coefficient.

KNO2 = Average NO_2-N forward-reaction coefficient for a subreach, day^{-1}(base *e*). Expressed as an average subreach instream rate coefficient.

KNO3 = Average NO_3-N decay rate for a subreach, day^{-1}(base *e*). Expressed as an average subreach instream rate coefficient.

SKORG = Average organic-N decay rate for a subreach, day^{-1}(base *e*). Expressed as an average subreach instream rate coefficient.

SKNH3 = Average ammonia-N decay rate for a subreach, day^{-1}(base *e*). Expressed as an average subreach instream rate coefficient.

SKNO2 = Average NO_2-N decay rate for a subreach, day^{-1}(base *e*). Expressed as an average subreach instream rate coefficient.

KPO41 = Coefficient for stream bottom-deposit uptake rate in orthophosphate-P equation, day^{-1}(base *e*). Expressed as an average subreach instream rate coefficient.

KCOLF = Average fecal-coliform die-off rate for a subreach, day^{-1} (base *e*). Expressed as an average subreach instream rate coefficient.

KCOLT = Average total-coliform die-off rate for a subreach, day^{-1} (base *e*). Expressed as an average subreach instream rate coefficient.

Some explanation of the dual-decay rates for CBOD, organic-N, ammonia-N, and NO_2-N is necessary. CBOD is removed from the water column at a rate defined by k_r. Part of this removal is due to decay and part may be the result of deposition. Actual decay of the material proceeds at a rate defined by k_d such that $k_d \leq k_r$. If all removal is due to decay, then $k_d = k_r$. The nitrogen-cycle transformation is a biologically-coupled sequentially-mediated reaction involving the decay of organic-N to ammonia-N through NO_2-N to NO_3-N. The forward reaction of each nitrogen form to the next nitrogen form and the associated concentration coupling is determined by the forward-reaction coefficient. These forward reactions--the transformation of one nitrogen form to another--generally are the most significant reactions. However, there are other possible reactions. These include the deposition of organic-N, plant utilization of ammonia-N, reduction of NO_3-N to ammonia-N, and the escape as gas of un-ionized ammonia-N and molecular nitrogen. The rates at which these reactions occur are included in the decay-rate coefficients.

The decay rates describe the total rate of removal of the nitrogen forms from the water; whereas, the forward-reaction coefficients describe the rate at which one form of nitrogen decays sequentially forward to the next form. Therefore, each decay rate should always be greater than, or equal to, its associated forward-reaction coefficient. The rate at which nitrate is utilized is described by the NO_3-N decay rate, which includes reduction of NO_3-N to ammonia-N and, primarily, plant utilization of NO_3-N.

Simulation Techniques

Consistent criteria must be used when:

1. preparing calibration and verification data for input to model,

2. establishing "observed conditions" to which model derived output will be compared,

3. establishing initial values and "adjustment criteria" for model derived rate coefficients and spatially-averaged benthic demands, and

4. preparing data for model simulated projections.

The following discussions are brief summaries of how the preceeding items were addressed in the Muddy Fork, Spring Creek, Osage Creek, and Illinois River models. The methods discussed were used consistently in all four of the stream models.

Calibration-Verification

Following the "fitting" of average subreach channel geometry, as described in the "Time of Travel" section, reaeration coefficients were defined for each subreach to be modeled. For Spring Creek, Osage Creek, and Illinois River, where reaeration coefficients had been measured in selected reaches, each of the eight reaeration coefficient predictive equations available in the digital model were tested to see which one could most accurately predict the measured coefficient, given observed stream geometry and flow conditions. The equation that could successfully reproduce the measured value was then assumed valid for computing reaeration coefficients for the entire length of stream to be modeled and for reasonably similar flow conditions. This assumption could be violated if stream channel characteristics changed significantly or if flow conditions were simulated in which velocities were so slow that a chosen velocity-dependent equation would under predict the reaeration coefficient. When such conditions prevail the Velz (1970) approach, as defined in a predictive equation by Hirsch, R. M., U.S. Geological Survey, written commun. 1980), is used to simulate values for k_2. The Velz-Hirsch equation is not dependent upon velocity and is assumed to define the lower boundary of possible values for reaeration coefficient due to changing flow conditions in a given stream segment.

Net DO production was computed for each site where sufficient data were available. The methodology of these computations is described in the previous section, "Net Photosynthetic Dissolved Oxygen Production." Model structure requires that net DO production be input by subreach. Therefore, values computed at each site on a stream must be distributed and averaged by subreach so that net DO production values are representative for the reaches to which they are applied. Net DO production values are computed for subreach end points by linearly distributing the net DO production values determined at nearby stream sites. The values at subreach end points were then averaged to obtain a subreach-average value for net DO production. The distribution and averaging was done as follows:

$$P_E = [P_A - P_B/D]d_2 + P_B \quad (12)$$

or

$$P_E = P_A - [(P_A - P_B)/D]d_1 \quad (13)$$

where,

P_E = net production at subreach end point *E* downstream from site *A* and upstream from site *B*, (milligrams per liter per day),

P_A, P_B = net DO production computed at sites *A* and *B*, respectively, (milligrams per liter per day),

D = distance from site *A* to site *B*, (miles),

d_1 = distance from site *A* to subreach end point *E*, (miles),

d_2 = distance from subreach end point *E* to site *B*, (miles), and

$$P_a = (P_{E_1} + P_{E_2})/2, \quad (14)$$

P_a = average net DO production for a subreach, (milligrams per liter per day).

Subscripts *1* and *2* designate the two end points of a subreach.

All of the independent calibration (1981 data set) and verification (1979 data set) data input to the models were averaged over a diel period. Model-derived constituent profiles for the previously defined "predictable variables" are therefore diel-average profiles.

Values for k_r were determined by fitting the computed-average CBODU profile, based upon all sources defined, to the observed average profile. Values for the instream deoxygenation coefficient, k_d, were determined from k_1 values and a stream-characteristic correction factor defined by Bosko (1966). Values of k_1 (day^{-1}) are deoxygenation rate coefficients determined from CBODU analyses. They are based on time series data collected during the standard BOD bottle-time test (see page 13). Values of k_1 were then averaged, by subreach, and the following equation applied:

$$k_d = k_1 + n(V/D) \quad (15)$$

where,

k_d = instream deoxygenation rate coefficient, (per day),

k_1 = mean "bottle-time" deoxygenation rate coefficient, (per day),

V = mean stream velocity, (feet per second),

D = mean stream depth, (feet), and

n = coefficient of bed activity.

The dimensionless coefficient n is determined by channel slope in feet per mile. Values of n are obtained as a step function of slope and are given by Tierney and Young (1974) and Zison and others (1978). The second term on the right in equation 15 reflects the importance of organisms in the streambed that utilize CBOD. The k_d values were not adjusted during calibration-verification unless observed data indicated that, in a particular subreach, k_r was less than the computed k_d. In such a case k_d was set equal to the smaller k_r.

The following rationale was established for the definition of all of the nitrogen decay rate and forward reaction rate coefficients. Values for *SKORG* were defined by the observed change in organic-N concentration with distance. Based upon past experience and comparable literature values *KORG* was set equal to 0.05 day^{-1}. The decay rate coefficient and forward reaction rate coefficient were set equal for ammonia-N and also for NO_2-N.

Profiles for nitrogen forms were "fit" sequentially from organic-N through NO_3-N. The values of the reaction coefficient pairs for ammonia-N and NO_2-N and for the NO_3-N decay rate coefficient are functions of the observed loss in that constituent down the river and the source contributions from the preceeding reaction. The equality of the reaction coefficient pairs for ammonia-N and for NO_2-N and the organic-N forward reaction coefficient of 0.05 day^{-1} at 20°C were maintained unless the calibration-verification process dictated that a deviation for a particular subreach was necessary.

Values for *KP041, KCOLF,* and *KCOLT* were determined by the observed change in PO_4-P, fecal coliform, and total coliform concentrations, respectively, with distance. These coefficients have no direct effect upon the model-derived DO profile. They do, however, make it possible to simulate changes in the instream concentrations of PO_4-P, fecal coliforms, and total coliforms resulting from changes in point and nonpoint source loadings.

When the model could adequately simulate observed CBODU and nitrogen form profiles, the only component impacting the DO profile that lacked definition was the spatially-averaged subreach benthic demand. Net algal DO production and reaeration coefficients were defined as independent components. Initial estimates for subreach-average benthic demands, obtained from respirometer analyses of "point" bed material samples, were then adjusted, by subreach, until the computed and observed mean DO profile matched reasonably well. These adjusted values are more representative of spatial subreach averages.

After defining the subreach average benthic demands, the model was calibrated and verified for diel minimum DO profile simulation. Observed mean DO data were removed from the calibration and verification data sets and replaced with diel minimums. The effect of daily net DO production was then adjusted, by subreach, until a match was obtained between model derived and observed minimum DO profiles. This rationale is based upon the fact that, with the exception of minimal impacts due to temperature changes in reaction coefficients, diel fluctuations in the DO profile are primarily the result of algal DO production and respiration.

Projections

After successful calibration and verification, representative input data must be prepared in order to make meaningful simulations for projected changes in constituent loading. Tributary water-quality data used in model calibration and verification should be considered. Flow distributions must also be determined for the stream discharge that is to be simulated.

The discharge simulated for projections on Muddy Fork, Spring Creek, Osage Creek, and Illinois River was the $Q_{7/10}$. Channel geometry was assumed unchanged from calibration and verification conditions. The flow distribution was made for each stream on the basis of known $Q_{7/10}$ values, Hines (1975) and Hunrichs (1983), and linear discharge balance computations.

Constituent loadings for initial upstream flows and point sources were obtained by averaging concentrations observed in the calibration and verification data sets. DO concentrations were not averaged directly; percent saturations were averaged and that average related to saturation at the projected stream temperature.

Reaeration coefficients for the $Q_{7/10}$ projections were computed by the predictive equation chosen for calibration-verification except when velocities were so slow that the Velz equation produced higher values. In such cases the Velz equation was activated in the model to predict k_2 values under $Q_{7/10}$ conditions.

Values of k_d for projections on Muddy Fork, Spring Creek, and Osage Creek were determined by applying the Bosko correction (equation 15), resulting from $Q_{7/10}$ flow velocities, to the subreach average k_1 values determined from the calibration-verification data sets. Because all projections were for secondary treatment or better, projected k_r values were set equal to k_d. This is based upon the assumption that all particulate CBOD would be removed prior to discharge of the effluent.

Under existing conditions, there are no direct point-source waste discharges on the main stem of

Illinois River. Values of k_1 determined from the analyses of samples taken during collection of the calibration and verification data sets were not considered valid to use in computing values of k_d for simulations that included the projected discharge of the Fayetteville WWTP. Values of k_1 determined for nearby Osage Creek under loaded conditions were considered more valid. Consequently, all k_1 values determined for Osage Creek downstream from the Rogers WWTP were averaged. The appropriate Bosko correction (equation 15) reflecting Illinois River $Q_{7/10}$ flow conditions was applied, by subreach, to this average k_1 value. The resulting values of k_d were used for all Illinois River simulations that include the proposed Fayetteville WWTP effluent inflow.

Deposition of particulate matter discharged from a WWTP is assumed to be a significant contributor to the benthic demand. For all of the projected loading scenarios simulated, particulate matter should be removed prior to effluent discharge. The primary constituent present in WWTP effluent that contributes to benthic demands is the carbonaceous material. As discussed earlier, the projected reduction in carbonaceous particulate matter was the basis for reductions in k_r values for Muddy Fork, Spring Creek, and Osage Creek projections. Benthic demands used in Muddy Fork, Spring Creek, and Osage Creek projections were determined as follows:

$$B_{new} = (K_{r_{new}}/K_{r_{exist}})B_{exist} \qquad (16)$$

where,

B = benthic demand (grams per square meter per day),

k_r = CBOD removal rate coefficient, (per day), and

new and *exist* = values used in projections and calibration-verification, respectively.

Because benthic demands defined during calibration-verification on the Illinois River do not reflect contributions of particulate CBOD from an existing WWTP, no changes in benthic demands were deemed necessary in the Illinois River projections. The same values defined during calibration-verification were used in the projections.

Model Sensitivity

The "worst" natural conditions simulated in this study are $Q_{7/10}$ low flows at representative summertime high water-temperatures of 29°C. Each stream model was tested for sensitivity under these conditions. One simulation, with projected WWTP effluent limits imposed, was used for the sensitivity testing for each stream model. The criteria used in choosing the appropriate simulation were that:

1. the instream minimum DO concentrations resulting from the WWTP inflow either meets, or comes closest to meeting the Arkansas standard, (Arkansas Department of Pollution Control and Ecology, 1981)

2. if minimum DO concentrations resulting from WWTP inflow meet standards in more than one simulation, use the simulation in which the projected WWTP effluent limits require the least amount of waste treatment, and

3. if in the simulation chosen, minimum DO concentrations meet standards with DO concentrations in the WWTP effluent set at both 5.0 mg/L and saturation, use the one with 5.0 mg/L DO concentration in the WWTP effluent.

Sensitivity testing was done to evaluate the effects upon the DO concentration profile of controlled changes in various impacting components and rate coefficients in all subreaches. The types of changes imposed include a plus or minus 20-percent change in the following:

1. mean river depths,

2. mean river velocities,

3. reaeration rate coefficients,

4. benthic demands,

5. net photosynthetic production,

6. instream CBOD deoxygenation rate and removal rate coefficients,

7. ORG-N forward-reaction rate and decay rate coefficients,

8. NH3-N forward-reaction rate and decay rate coefficients,

9. NO2-N forward-reaction rate and decay rate coefficients,

10. WWTP dissolved-oxygen concentration,

11. WWTP CBOD concentration,

12. WWTP NH3-N concentration, and a plus or minus 2.0°C change in

13. stream-water temperature.

The effect of each of these changes was determined independently with a separate model run, making a total of 26 sensitivity runs for each of the four stream models. The resulting DO profile for each plus and minus change was plotted and define a dissolved-oxygen sensitivity band for each of the thirteen components and rate coefficients.

According to 1980 U.S. Environmental Protection Agency criteria for justifying advanced secondary treatment/advanced waste treatment effluent limits, (U.S. Environmental Protection Agency, written commun., 1980) the value of any component or rate coefficient may need further evaluation if its DO-sensitivity-band width is greater than 1.0 mg/L. However, a sensitivity band width of 1.0 mg/L or greater does not necessarily imply an error in the value definition for the parameter or coefficient analyzed. Because of stream-system dynamics, an instream DO profile may be particularly sensitive to a given parameter. Desensitizing one parameter at the expense of unrealistically reevaluating others may lead to a poorer definition of instream water-quality dynamics.

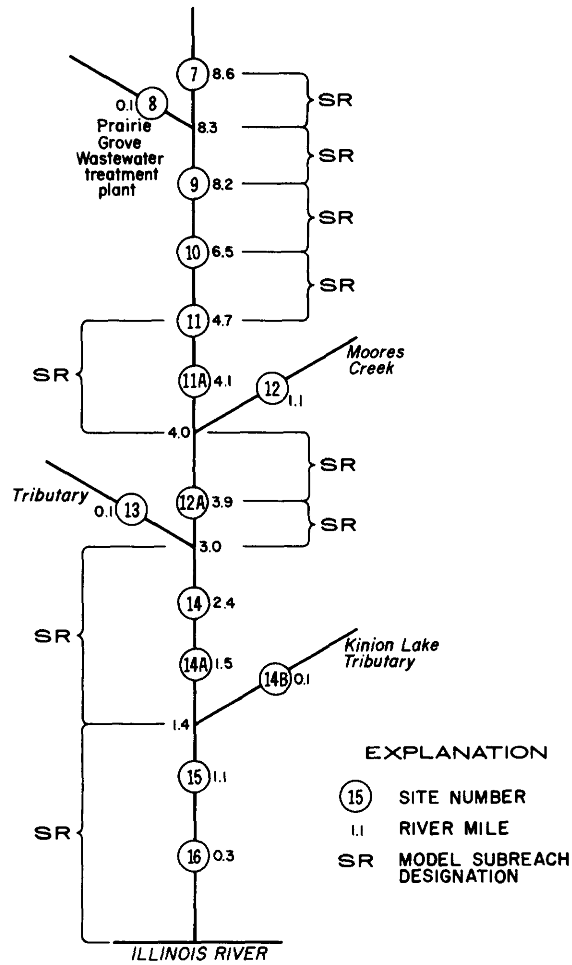

Figure 10.--Schematic of Muddy Fork showing sampling-site and model-subreach locations.

MUDDY FORK ASSESSMENT

Muddy Fork Illinois River (fig. 1) flows generally south to north, through small farms and forest lands, into the main stem of the Illinois River at mile 135.6. It has a total drainage area of 73.6 mi^2 at its mouth (Sullavan and Terry, 1970). The Prairie Grove WWTP is the only point-source waste effluent that discharges into Muddy Fork. The effluent enters the stream at mile 8.3. The reach of Muddy Fork modeled is from mile 8.6 to its mouth (fig. 10). A location index for sites where data were collected for the Muddy Fork assessment is given in table 1.

Surface-Water Hydrology

Muddy Fork is primarily a canopied, pool and riffle type of stream with long pools dominating. Channel slopes range from 4.1 ft/mi to 2.9 ft/mi in a downstream direction.

Cumulative flows in Muddy Fork during collection of the calibration data set (Aug. 24-Sept.5, 1981) ranged from 0.54 ft^3/s at mile 8.6 to 3.5 ft^3/s at the mouth (Attachment B-2, B-3, B-6, and B-21). Cumulative flows during collection of the verification data set (July 23-27, 1979) ranged from 1.0 ft^3/s at mile 8.6 to 4.63 ft^3/s at the mouth (Attachment B-23, B-24, B-27, B-41). In the 1981 data set, 26 percent of the total stream flow immediately downstream from the Prairie Grove WWTP was effluent discharge. In the 1979 data set the effluent discharge amounted to 14 percent of the total streamflow immediately downstream from its point of entry.

An existing $Q_{7/10}$ low flow distribution (fig. 11) was defined on the basis of data presented by Hines, (1975) and Hunrichs (1983). This distribution was established by mass-balancing total discharge at site 16 (table 1). The difference between the sum of initial and point-source $Q_{7/10}$ discharges and the established $Q_{7/10}$ discharge at site 16 was distributed linearly as flow loss between stream mile 8.3 and the mouth, on the basis of percent of total point-source flow contributed (fig. 11).

Water Quality

Physical Characteristics

Suspended solids.-- During the collection of "steady-state" data in 1978, 1979, and 1981 suspended-solids concentrations in Muddy Fork ranged from 4 to 10 mg/L at site 7 upstream from the Prairie Grove WWTP and from 5 to 13 mg/L at sites downstream of the WWTP (table 2). Concentrations in the Prairie Grove WWTP effluent ranged from 25 to 35 mg/L. Tributary inflow concentrations in other tributaries ranged from 6 to 43 mg/L. Concentrations of suspended-solids during stormwater runoff periods were generally at least three times greater than during periods of low

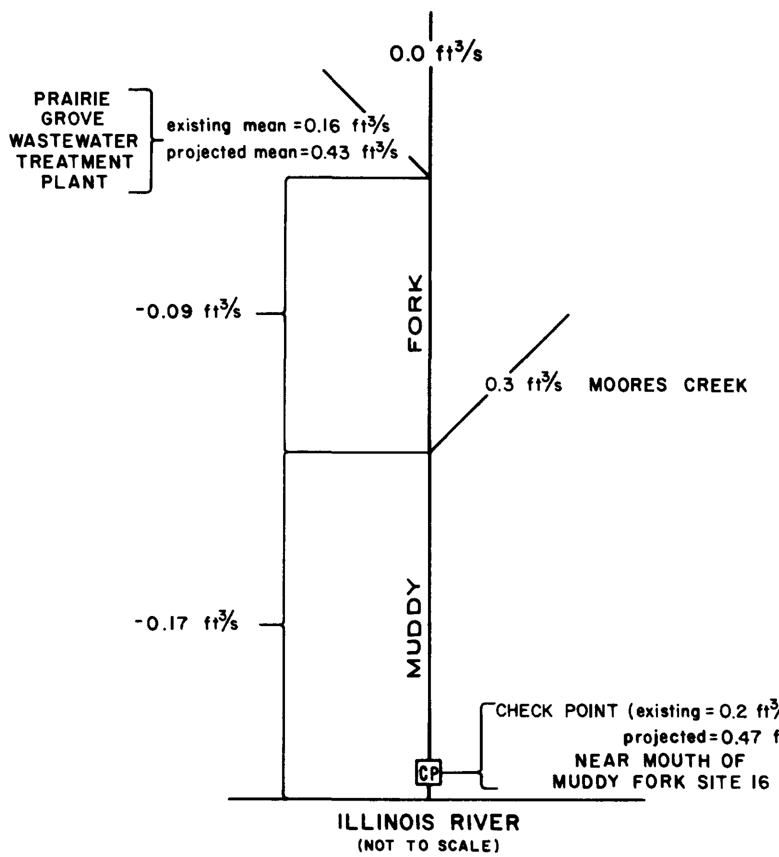

Figure 11.--7-day, 10-year low flow distribution for Muddy Fork.

flow; Mainstem and tributary concentrations ranged from 20 to 81 mg/L (table 3). Sources of suspended solids during higher-flow periods are from resuspension of deposited material and from overland flow of stormwater runoff. Because suspended solids transport attached nutrients and bacteria, nutrients and bacteria may be added to streams by runoff.

Water temperature.-- Although water temperatures of the Prairie Grove WWTP effluent were generally warmer than temperatures upstream from the WWTP effluent (table 4), it appears that the effluent complies with the Arkansas water-quality standard (Arkansas Department of Pollution Control and Ecology, 1981).

Dissolved Solids.-- Dissolved-solids concentrations for the 1978 "steady-state" sampling periods ranged from 169 to 279 mg/L in Muddy Fork, from 386 to 561 mg/L in the Prairie Grove WWTP effluent, and from 128 to 252 mg/L in the tributaries sampled (table 2). These data indicate that Arkansas stream water quality standards (Arkansas Department of Pollution Control and Ecology, 1981) for total dissolved solids were not being violated. Using a dissolved solids to specific conductance ratio of 0.54 (see page 5), minimal dissolved-solids estimates for 1979 and 1981 "steady-state" conditions ranged from 168 to 247 mg/L in the main stem of Muddy Fork.

Minimal dissolved-solids concentrations in stormwater-runoff samples estimated from measured specific conductance values (table 3). Mainstem and tributary concentrations ranged from 76 to 103 mg/L.

Chemical and Biochemical Characteristics

Chloride.-- Chloride concentrations for the 1978 "steady-state" sampling periods ranged from 10 to 17 mg/L in Muddy Fork, from 36 to 44 mg/L in the Prairie Grove WWTP effluent and from 7.5 to 10 mg/L in sampled tributaries (table 2). These data indicate that Arkansas stream water quality standards (Arkansas Department of Pollution Control and Ecology, 1981) for Muddy Fork were not violated.

Sulfate.-- Sulfate concentrations for the 1978 "steady-state" sampling periods ranged from 2.0 to 49 mg/L in Muddy Fork, from 79 to 80 mg/L in the Prairie Grove WWTP effluent and from 1.0 to 22 mg/L in sampled tributaries (table 2). The data indicate that Arkansas water quality standards (Arkansas Department of Pollution Control and Ecology, 1981) were violated at five sites.

pH.-- Values of pH in the Muddy Fork ranged from 7.4 to 8.2, from 7.1 to 7.3 in the WWTP effluent, and from 7.2 to 7.9 in tributary inflows (table 2).

Dissolved oxygen.-- The DO concentration ranged from 2.6 to 17.0 mg/L, in Muddy Fork, and from 0.5 to 6.9 mg/L in the Prairie Grove WWTP effluent. Tributary inflow concentrations ranged from 2.6 to 9.3 mg/L (table 4). According to Arkansas water-quality standards an instantaneous minimum DO concentration in Muddy Fork shall be greater than or equal to 4.0 mg/L. DO concentrations of less than 4.0 mg/L were observed downstream from the WWTP.

Ultimate carbonaceous biochemical oxygen demand.-- During "steady-state" conditions CBODU ranged from 2.0 to 5.7 mg/L at site 7 upstream from the Prairie Grove WWTP outfall and from 2.2 to 34 mg/L downstream from the outfall (table 2). CBODU concentrations of the effluent ranged from 36 to 92 mg/L. CBODU concentrations in tributaries ranged from 2.6 to 13 mg/L. CBODU concentrations of storm water-runoff samples (mainstem and tributary) ranged from 6.1 to greater than 26 mg/L (table 3).

Streambed oxygen demand.-- A "streambed oxygen demand" of 3.20 $(g/m^2)/d$ was measured for a sample collected at site 7 upstream from the WWTP. "Streambed oxygen demands" downstream from the WWTP were lower and ranged from 0.70 to 1.85 $(g/m^2)/d$ (table 5).

Net photosynthetic dissolved-oxygen production. --"Net DO production" was calculated as discussed previously in the general "Net Photosynthetic Dissolved-Oxygen Production" section, and ranged from 0.2 to 1.9 (mg/L)/d (table 6). Chlorophyll *a* concentrations used in calculations were distance-weighted estimates based on actual chlorophyll *a* concentrations at sites 7, 9, and 15. For modeling purposes net DO production was calculated for each subreach (see "Simulation Techniques" section and Attachments B-6 and B-27).

Table 1.--Muddy Fork index for site name and identification number, U.S. Geological Survey station number, and location

Site Name	Site Identification Number	USGS Station Number	Location	
			Latitude	Longitude
Muddy Fork at county road bridge near Prairie Grove	7	355920094200200	355920	0942002
Prairie Grove WWTP	8	355953094195700	355953	0941957
Muddy Fork 500 feet from Prairie Grove WWTP	9	355936094200200	355936	0942002
Muddy Fork at bridge near Viney Grove	10	360029094205500	360029	0942055
Muddy Fork at bridge upstream from Moores Creek	11	360120094214400	360120	0942144
Muddy Fork at mouth of Moores Creek	11A	360142094215700	360142	0942157
Moores Creek at bridge upstream from Muddy Fork	12	360110094222500	360110	0942225
Muddy Fork downstream from Moores Creek	12A	360147094220300	360147	0942203
Muddy Fork tributary near Rose Cemetery	13	360209094212300	360209	0942123
Muddy Fork at bridge southwest of Weaver Hill	14	360239094210800	360239	0942108
Muddy Fork west of Weaver Hill	14A	360317094210100	360317	0942101
Unnamed tributary at Weaver Hill	14B	360320094210400	360320	0942104
Muddy Fork at Weaver Hill	15	360330094210100	360330	0942101
Muddy Fork 1/4 mile upstream from mouth	16	07194790	360410	0942054

Table 2.--Chemical, physical, and bacteriological data, Muddy Fork, tributary streams, and Prairie Grove wastewater-treatment plant effluent

[Five-digit numbers in parentheses are STORET parameter codes used for computer storage of data]

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (μmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
7	8.6	9-05-78	1345	0.80	351	7.5	3.1	0.20	230	1,000
		11-27-78	1410	4.3	---	---	5.7	.10	K1,300	2,700
		7-23-79	1420	1.0	367	7.5	3.0	.13	840	1,300
		8-24-81	1700	.59	410	7.6	2.0	.18	1,100	---
8[W]	8.3	9-05-78	Composite	.19	920	7.1	---	---	K2,600,000	---
		11-27-78	---do---	.15	571	7.3	---	---	110	950
		7-24-79	---do---	.13	691	7.3	92	.13	K8,800	K16,000
		8-25-81	---do---	.19	480	7.2	36	.09	<50	<100
9	8.2	9-05-78	1201	---	---	---	---	---	---	---
		7-23-79	1315	---	458	7.6	34	---	K20,000	K37,000
		8-12-81	1347	---	---	---	---	---	---	---
		8-24-81	1800	.99	430	7.5	6.3	.34	K200	K6,000

See footnotes at end of table

Table 2.--Chemical, physical, and bacteriological data, Muddy Fork, tributary streams, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (mg/L) (70300)	Suspended solids (residue at 105°C) (mg/L) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
7	9-05-78	1345	226	--	10	2.0
	11-27-78	1410	248	--	10	49
	7-23-79	1420	---	10	--	----
	8-24-81	1700	---	4	--	----
8[W]	9-05-78	Composite	561	--	44	79
	11-27-78	---do---	386	--	36	80
	7-24-79	---do---	---	35	--	----
	8-25-79	---do---	---	25	--	----
9	9-05-78	1201	---	--	17	----
	7-23-79	1315	---	12	--	----
	8-12-81	1347	---	--	--	----
	8-24-81	1800	---	12	--	----

See footnotes at end of table

Table 2.--Chemical, physical, and bacteriological data, Muddy Fork, tributary streams, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L) as P) (00665)
7	9-05-78	1345	0.31	0.05	0.01	1.9	0.02	0.04
	11-27-78	1410	.61	.08	.03	1.4	.18	.20
	7-23-79	1420	.18	.06	.02	2.1	.01	.01
	8-24-81	1700	.73	.11	.02	2.3	.05	.19
8[W]	9-05-78	Composite	5.8	9.2	.61	6.3	.84	-----
	11-27-78	---do---	3.0	6.8	.22	14	11	12
	7-24-79	---do---	---	6.8	.82	14	13	18
	8-25-81	---do---	3.8	.54	.24	11	11	21
9	9-05-78	1201	.81	.07	.03	1.9	1.1	-----
	7-23-79	1315	1.2	3.3	.31	4.3	4.0	5.1
	8-12-81	1347	----	----	---	---	---	-----
	8-24-81	1800	1.9	.25	.07	2.9	1.9	2.8

See footnotes at end of table

Table 2.--Chemical, physical, and bacteriological data, Muddy Fork, tributary streams, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (μmho/cm at 25°C) (00095)	pH (units (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
10	6.5	9-05-78	1600	0.76	468	7.4	---	---	2 200	8,000
		11-27-78	1430	5.5	---	---	6.3	.13	K2,800	4,000
		7-23-79	1450	.93	393	7.8	5.0	.13	-----	----
		8-24-81	1845	.75	430	7.6	3.5	.23	K8,000	----
11	4.7	9-05-78	1630	.63	417	8.2	---	---	83	200
		11-29-78	0917	4.1	429	7.6	---	---	400	K1,200
		7-23-79	1645	.87	391	7.9	2.6	.26	K170	180
		8-12-81	1313	----	---	---	---	---	-----	-----
		8-25-81	1640	.87	430	7.8	2.8	.23	K780	K900
11a	4.1	7-24-79	1450	1.0	415	7.5	6.2	.17	700	1,100
		8-25-81	1840	.75	430	7.7	3.6	.22	780	2,200
12T	4.0	9-05-78	1715	.48	265	7.7	---	---	2,800	8,000
		11-29-78	1039	2.5	260	7.7	---	---	500	4,600
		7-23-79	1715	.54	279	7.8	13	.07	K1,300	520
		8-25-81	1715	.92	300	7.4	5.5	.14	2,900	K17,000

See footnotes at end of table

Table 2.--Chemical, physical, and bacteriological data, Muddy Fork, tributary streams, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (70300)	Suspended solids (residue at 105°C) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
10	9-05-78	1600	279	--	17	21
	11-27-78	1430	232	--	10	29
	7-23-79	1450	---	10	--	--
	8-24-81	1845	---	12	--	--
11	9-05-78	1630	254	--	15	15
	11-29-78	0917	201	--	10	31
	7-23-79	1645	---	8	--	--
	8-12-81	1313	---	--	--	--
	8-25-81	1640	---	7	--	--
11a	7-24-79	1450	---	8	--	--
	8-25-81	1840	---	13	--	--
12[T]	9-05-78	1715	154	--	7.5	3.0
	11-29-78	1039	128	--	7.5	12
	7-23-79	1715	---	11	----	----
	8-25-81	1715	---	42	----	----

See footnotes at end of table

Table 2.--Chemical, physical, and bacteriological data, Muddy Fork, tributary streams, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
10	9-05-78	1600	0.81	0.07	0.03	1.9	1.1	---
	11-27-78	1430	.57	.21	.06	1.7	.77	.84
	7-23-79	1450	.53	.12	.07	2.5	.50	1.5
	8-24-81	1845	1.4	.19	.05	2.2	.80	.95
11	9-05-78	1630	.03	.03	.01	.17	.50	----
	11-29-78	0917	----	.11	.03	2.0	.55	.60
	7-23-79	1645	.50	.06	.03	1.8	.30	.39
	8-12-81	1313	----	----	----	----	----	----
	8-25-81	1640	1.0	.18	.08	1.5	.33	.34
11a	7-24-79	1450	.47	.20	.14	1.6	.23	.26
	8-25-81	1840	1.5	.22	.06	1.6	.22	.25
12[T]	9-05-78	1715	.11	.56	.11	.68	.08	.16
	11-29-78	1039	----	.08	.02	1.5	.07	.09
	7-23-79	1715	.92	.36	.29	.64	.07	.26
	8-25-81	1715	2.7	1.2	.21	1.1	.14	.23

See footnotes at end of table

Table 2.--Chemical, physical, and bacteriological data, Muddy Fork, tributary streams, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	River mile	Date of collection	Time of collection (hour)	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemicl oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
12a	3.9	7-24-79	1420	1.8	363	7.6	8.3	.04	370	K1,000
		8-25-81	1900	1.8	380	7.6	3.3	.18	K190	K250
13[T]	3.0	9-06-78	1345	.24	370	7.2	---	---	290	3,400
		11-29-78	1805	.37	246	7.7	4.5	.10	K1,100	2,200
		7-24-79	1550	.21	406	7.2	8.3	.10	1,000	-----
		8-25-81	1605	.11	440	7.2	2.6	.27	K60	2,400
14	2.4	9-06-78	1415	2.1	328	7.8	---	---	670	2,100
		11-29-78	1053	7.1	337	7.7	---	---	400	2,100
		7-24-79	1635	2.0	358	7.7	5.3	.06	K200	K220
		8-25-81	1545	1.9	380	7.7	2.5	.14	K64	K250
14a	1.5	7-25-79	1150	2.2	354	7.8	3.7	---	K270	K350
14b[T]	1.4	7-25-79	1215	1.4	279	7.9	---	---	K100	K400

See footnotes at end of table

Table 2.--Chemical, physical, and bacteriological data, Muddy Fork, tributary streams, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (70300)	Suspended solids (residue at 105°C) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
12a	7-24-79	1420	---	--	---	----
	8-25-81	1900	---	11	---	----
13[T]	9-06-78	1345	252	--	9.0	1.0
	11-29-78	1805	160	--	10	22
	7-24-79	1550	---	6	---	----
	8-25-81	1605	---	43	---	----
14	9-06-78	1415	204	--	12	6.0
	11-29-78	1053	180	--	10	21
	7-24-79	1635	---	5	---	----
	8-25-81	1545	---	8	---	----
14a	7-25-79	1150	---	5	---	----
14b[T]	7-25-79	1215	---	--	---	----

See footnotes at end of table

Table 2.--Chemical, physical, and bacteriological data, Muddy Fork, tributary streams, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
12a	7-24-79	1420	0.57	0.21	0.16	1.4	0.16	0.18
	8-25-81	1900	.97	.43	.10	1.6	.15	.21
13[T]	9-06-78	1345	---	.01	.01	4.7	.02	.03
	11-29-78	1805	---	.08	.01	.99	.12	.16
	7-24-79	1550	.51	.13	.08	3.6	.04	.06
	8-25-81	1605	.84	.15	<.02	4.3	.05	.08
14	9-06-78	1415	---	.04	.02	.29	.08	.28
	11-29-78	1053	---	.13	.04	2.0	.48	.50
	7-24-79	1635	.38	.08	.05	1.6	.09	.10
	8-25-81	1545	.68	.14	<.02	1.6	.13	.16
14a	7-25-79	1150	.48	.10	.06	1.4	.05	.13
14b[T]	7-25-79	1215	.17	---	---	---	---	---

See footnotes at end of table

Table 2.--Chemical, physical, and bacteriological data, Muddy Fork, tributary streams, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	River mile	Date of collection	Time of collection (hour)	Discharge (ft^3/s)	Specific conductance (μmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform total (colonies per 100 mL) (31501)
15	1.1	9-06-78	1201	3.3	---	---	---	---	---	----
		7-25-79	1310	4.8	---	---	---	---	---	----
		8-25-81	1510	3.6	360	7.8	2.2	.19	360	1,700
16	0.3	9-06-78	1515	3.3	288	7.8	6.5	.11	1,400	8,000
		11-29-78	1500	13	---	---	4.5	.08	K1,300	3,300
		7-25-79	1430	4.0	311	7.9	2.7	---	610	K1,700
		8-12-81	1232	----	---	---	---	---	---	----

See footnotes at end of table

Table 2.--Chemical, physical, and bacteriological data, Muddy Fork, tributary streams, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (70300)	Suspended solids (residue at 105°C) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
15	9-06-78	1201	---	---	---	---
	7-25-79	1310	---	---	---	---
	8-25-81	1510	---	7	---	---
16	9-06-78	1515	169	---	12	3.0
	11-29-78	1500	202	---	10	19
	7-25-79	1430	---	5	---	---
	8-12-81	1232	---	---	---	---

Table 2.--Chemical, physical, and bacteriological data, Muddy Fork, tributary streams, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
15	9-06-78	1201	---	---	---	----	---	---
	7-25-79	1310	---	---	---	----	---	---
	8-25-79	1510	0.52	0.13	<.02	1.1	0.09	0.11
16	9-06-78	1515	.60	.05	.01	.63	.07	.15
	11-29-78	1500	.63	.10	.02	1.8	.36	.43
	7-25-79	1430	.31	.09	.06	1.2	.04	.12
	8-12-81	1232	---	---	---	----	---	---

K Plate count was outside ideal range.
T Tributary.
W Wastewater-treatment plant effluent.

Table 3.--Comparison of analyses of Muddy Fork stormwater-runoff samples to means calculated from steady-state flow analyses in table 2

[Five digit numbers are STORET parameter codes used for computer storage of data]

Site number	River mile	"Steady-state" mean (S) or "Runoff" (R) sample	Date of collection	Time of collection	Discharge (ft^3/s) (00061)	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00310)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)
		R	4-23-81	0140	37	16.5	7.1	72	190	7.6
12[T]	4.0	R	5-14-81	0211	18	16.0	7.7	78	140	7.5
		S	-------	----	1.1	----	---	--	276	---
		R	4-22-81	2320	69	16.0	7.4	75	180	7.8
16	0.3	R	5-13-81	1130	77	16.5	7.8	80	180	7.7
		S	-------	----	7	----	---	--	300	---

See footnote at end of table

Table 3.--Comparison of analyses of Muddy Fork stormwater-runoff samples to means calculated from steady-state flow analyses in table 2--Continued

Site number	"Steady-state" mean (S) or "Runoff" (R) sample	Date of collection	Time of collection (hour)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Streptococci, fecal (colonies per 100 mL) (31673)	Suspended solids (residue at 105°C) (mg/L) (00530)
	R	4-23-81	0140	>26	----	>3,000	3,300	81
12[T]	R	5-14-81	0211	6.6	0.16	3,000	9,000	20
	S	-------	----	9.2	----	1,900	----	26
	R	4-22-81	2320	>16	----	>1,000	>3,300	56
16	R	5-13-81	1130	6.1	.16	2,400	3,200	34
	S	-------	----	4.6	----	1,100	----	5

See footnote at end of table

Table 3.--Comparison of analyses of Muddy Fork stormwater-runoff samples to means calculated from steady-state flow analyses in table 2--Continued

Site number	"Steady-state" mean (S) or "Runoff" (R) sample	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P (00665)
	R	4-23-81	0140	2.1	0.25	0.07	1.2	0.25	0.41
12[T]	R	5-14-81	0211	1.6	.07	.02	0.98	.07	.23
	S	-------	----	1.2	.5	.16	1.0	.09	.18
	R	4-22-81	2320	.80	.30	.06	1.2	.44	.50
16	R	5-13-81	1130	1.6	.12	.04	1.7	.12	.29
	S	-------	----	.51	.08	.03	1.2	.16	.23

[T] Tributary.

Table 4.--Dissolved-oxygen and temperature data for Muddy Fork, tributaries, and Prairie Grove wastewater-treatment plant effluent

[Five-digit numbers in parentheses are STORET parameter codes used for computer storage of data]

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
7	9-05-78	1345	24.5	7.1	86
	7-23-79	1420	22.5	9.5	110
		2230	20.0	6.8	75
	7-24-79	0655	19.0	7.4	80
	8-24-81	1700	24.0	8.0	94
		2315	24.5	5.0	60
	8-25-81	0445	20.0	5.4	59
	9-03-81	1730	22.0	6.1	69
		1830	22.0	5.8	66
		1930	21.5	5.5	62
		2030	21.5	5.3	60
		2130	21.0	5.2	58
		2230	21.0	5.1	57
		2330	20.5	5.0	55
	9-04-81	0030	20.5	4.9	54
		0130	20.0	4.9	53
		0230	20.0	4.8	52
		0330	19.5	4.7	51
		0430	19.5	4.7	51
		0530	19.0	4.7	51
		0630	19.0	4.6	50
7	9-04-81	0730	19.0	4.7	51
		0830	19.0	4.7	51
		0930	19.0	4.9	53
		1030	19.5	4.9	53
		1130	20.0	5.1	55
		1230	20.5	5.4	59
		1330	21.0	5.5	61
		1430	21.5	5.9	66
		1530	22.0	6.0	68
8[W]	9-05-78	1340	27.5	3.3	42
		2225	26.5	0.5	6
	9-06-78	0645	24.5	0.5	6
	7-23-79	1400	25.0	6.9	84
		2220	25.0	6.9	84
	7-24-79	0610	24.0	6.6	78
	8-24-81	2335	24.5	4.3	51
	8-25-81	0435	23.0	2.9	34
9	9-05-78	1330	26.0	5.2	64
	7-23-79	1315	22.0	7.8	90

See footnotes at end of table

Table 4.--Dissolved-oxygen and temperature data for Muddy Fork, tributaries, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
9	7-24-79	0630	21.0	5.8	65
	8-24-81	1800	24.0	5.3	62
		2330	22.5	4.6	53
	8-25-81	0425	22.5	4.1	47
	9-03-81	1615	22.5	5.6	64
		1715	22.5	5.7	66
		1815	23.0	5.7	66
		1915	23.0	5.6	65
		2015	23.0	5.3	62
		2115	22.5	5.3	61
		2215	22.5	5.1	59
		2315	22.0	4.8	55
	9-04-81	0015	22.0	4.6	52
		0115	22.0	4.6	52
		0215	22.0	4.5	51
		0315	21.0	4.5	50
		0415	21.0	4.3	48
		0515	20.5	4.3	47
		0615	20.5	4.6	51
		0715	20.0	4.6	50
		0815	20.0	4.6	50
		0915	20.0	4.7	51
		1015	20.0	4.8	52
9	9-04-81	1115	20.0	5.1	55
		1215	20.0	5.2	57
		1315	20.5	5.3	58
		1415	21.5	5.4	61
		1515	21.5	5.4	61
10	9-05-78	1600	27.0	8.5	108
		2300	25.5	5.1	62
	9-06-78	0720	24.0	4.1	49
	7-23-79	1450	24.0	6.6	78
		2250	24.0	4.1	49
	7-24-79	0715	23.0	4.2	49
	8-24-81	1845	24.5	4.2	50
		2300	23.0	3.5	41
	8-25-81	0500	22.0	3.6	41
	9-03-81	1550	24.5	4.5	54
	9-04-81	0020	23.0	4.8	56
		0520	21.5	4.9	56
		1245	23.5	5.3	62
11	9-05-78	1630	28.0	17.0	218

Table 4.--Dissolved-oxygen and temperature data for Muddy Fork, tributaries, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
11	9-08-78	1445	25.0	8.3	101
	9-09-78	0800	23.5	4.5	53
	7-23-79	1645	24.0	8.6	102
	7-25-79	2145	25.0	5.4	66
	8-04-79	0643	22.0	4.9	56
	8-25-81	0030	23.5	4.1	47
		0520	22.0	3.6	40
		1640	24.0	5.5	65
11a	7-24-79	1450	24.0	3.1	37
	8-25-81	1840	25.5	4.7	57
		2325	24.5	3.7	44
	8-26-81	0520	23.5	3.7	43
12[T]	9-05-78	1715	26.0	2.6	32
	7-23-79	1715	24.0	5.1	61
	7-25-79	2150	26.0	3.1	38
	8-04-79	0645	21.0	3.6	40
12[T]	8-25-81	0025	23.0	3.2	37
		0510	22.0	3.0	34
		1715	24.5	3.3	39
12a	7-24-79	1420	25.0	4.8	58
	8-25-81	1900	24.5	4.4	52
		2315	23.5	3.2	37
	8-26-81	0510	22.5	2.6	30
13[T]	9-06-78	1345	17.5	7.7	81
	7-24-79	1550	16.0	6.2	63
	7-25-79	2225	16.0	7.7	78
	8-04-79	0653	14.0	7.6	74
	8-25-81	0040	17.0	7.4	76
		0525	17.0	7.4	76
		1605	17.5	7.2	75
14	9-06-78	1415	25.0	10.4	127
	7-24-79	1635	24.0	5.8	69

See footnotes at end of table

Table 4.--Dissolved-oxygen and temperature data for Muddy Fork, tributaries, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
14	7-25-79	2215	25.0	6.0	73
	8-04-79	0658	20.0	5.0	55
	8-25-81	0050	23.0	5.5	64
		0530	22.0	5.0	57
		1545	24.5	5.8	69
	9-03-81	1540	24.5	5.2	63
	9-04-81	0005	23.5	5.2	61
		0600	22.5	4.8	56
		1235	22.0	5.0	57
14a	7-25-79	1150	24.5	7.5	90
14b[T]	7-25-79	1215	22.0	9.3	107
15	9-06-78	1400	25.0	7.8	95
	11-28-78	1520	7.5	10.0	83
	7-25-79	1315	24.0	7.0	83
	8-04-79	0708	18.5	5.2	56

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
15	8-25-81	0105	23.5	5.5	65
		0545	23.0	5.5	64
		1510	24.0	6.8	68
	9-04-81	1645	23.5	6.1	71
		1745	23.5	5.8	68
		1845	23.5	5.7	67
		1945	23.0	5.5	64
		2045	23.0	5.3	62
		2145	23.0	5.2	68
		2245	23.0	5.2	68
		2345	23.0	5.1	59
	9-05-81	0045	22.5	5.1	59
		0145	22.5	5.1	59
		0245	22.5	5.1	59
		0345	22.0	5.2	59
		0445	22.0	5.2	59
		0545	21.5	5.2	58
		0645	21.5	5.2	58
		0745	21.5	5.2	58
		0845	21.5	5.3	60
		0945	21.5	5.4	61
		1045	22.0	5.6	64
		1145	22.0	5.7	65
		1245	22.5	5.9	67
		1345	23.0	6.0	70
		1445	23.0	6.1	71

See footnotes at end of table

Table 4.--Dissolved-oxygen and temperature data for Muddy Fork, tributaries, and Prairie Grove wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
16	9-06-78	1515	27.0	9.2	116
	9-09-78	0750	23.5	5.1	60
	7-25-79	1430	25.0	7.8	95
		2225	25.0	8.0	98
	9-03-81	1530	26.0	7.1	88
		2345	23.5	5.9	69
16	9-04-81	0550	22.5	5.5	64
		1230	23.0	6.5	76
	9-05-81	0900	21.5	5.6	64
		1125	23.0	5.2	60
		1330	24.0	6.7	80
		1532	24.5	7.2	87
		1715	24.5	7.4	89
	9-06-81	0035	24.0	5.9	70
		0520	21.0	4.7	53

T Tributary.
W Wastewater-treatment plant effluent.

Table 5.--Bottom-material analyses for Muddy Fork

[Five-digit numbers in parentheses are STORET parameter codes used for computer storage of data]

Site number and (river mile)	Date of collection	Streambed oxygen demand [(g/m^2)/d at 20°C]	Total inorganic carbon in bottom material (g/kg as C) (00686)	Total organic carbon in bottom material (g/kg as C)	Total organic plus ammonia nitrogen in bottom material (mg/kg as N) (00626)	Total phosphorus in bottom material (mg/kg as P) (00668)
7 (8.6)	9-04-81	3.20	---	---	---	---
9 (8.2)	8-04-79	0.70	0.1	7.8	546	830
	9-04-81	1.85	---	---	---	---
15 (1.1)	9-03-81	1.35	---	---	---	---

Table 6.--Net photosynthetic dissolved-oxygen production at selected sites on Muddy Fork

Site Number	River Mile	Date (1981)	Net photosynthetic dissolved oxygen production [(mg/L)/d at 20°C]
7	8.6	September 3-4	1.9
9	8.2	September 3-4	1.1
15	1.1	September 4-5	0.2

Nutrients.-- Analyses indicate nutrient enrichment of Muddy Fork (and its tributaries). Analyses of stormwater-runoff samples (table 3) indicate that the Prairie Grove WWTP is not necessarily the sole cause of the nutrient enrichment. Nutrient concentrations, particularly organic nitrogen and total phosphorus, generally were greater during runoff conditions than during "steady-state" conditions. This suggests that nutrients deposited on the streambed were resuspended as velocities increased and/or that overland runoff of stormwater transported nutrients into the streams.

During "steady-state" conditions organic-N concentrations (table 2) ranged from 0.18 to 0.73 mg/L at site 7 upstream from the Prairie Grove WWTP effluent and from 0.03 to 1.9 mg/L downstream from the WWTP effluent. Concentrations in the effluent ranged from 3.0 to 5.8 mg/L. Tributary inflow concentrations ranged from 0.11 to 2.7 mg/L. Concentrations of organic-N in stormwater-runoff samples (mainstem and tributary) ranged from 0.80 to 2.1 mg/L and were generally one-and-a-half to two times greater than mean "steady-state" concentrations (table 3).

During "steady-state" conditions, ammonia-N concentrations (table 2) ranged from 0.05 to 0.11 mg/L at site 7 and from 0.03 to 3.3 mg/L at sites downstream of the WWTP effluent. Concentrations in the WWTP effluent ranged from 0.54 to 9.2 mg/L. Tributary inflow concentrations ranged from 0.01 to 1.2 mg/L. Ammonia-N concentrations in stormwater-runoff samples (mainstem and tributary) ranged from 0.07 to 0.30 mg/L (table 3).

Concentrations of NO_2-N (table 2) in "steady-state" condition samples ranged from 0.01 to 0.31 mg/L at site 7 and from 0.01 to 0.31 mg/L at sites downstream of the WWTP effluent. Concentrations of NO_2-N in the effluent ranged from 0.22 to 0.61 mg/L and in tributary inflows ranged from 0.01 to 0.29 mg/L. Concentrations in runoff samples (mainstem and tributary) ranged from 0.02 to 0.07 mg/L (table 3).

During "steady-state" conditions, NO_3-N concentrations (table 2) ranged from 1.4 to 2.3 mg/L at site 7 and from 0.17 to 4.3 mg/L at sites downstream from the WWTP effluent. NO_3-N concentrations in the WWTP effluent ranged from 6.3 to 14 mg/L and ranged from 0.64 to 4.7 mg/L in tributary inflows. Concentrations in runoff samples (mainstem and tributary) ranged from 0.98 to 1.7 mg/L (table 3).

During the "steady-state" conditions, PO_4-P and phosphorus-P concentrations generally decreased downstream from the WWTP effluent (table 2 and Attachment B-12 and B-33). PO_4-P concentrations ranged from 0.01 to 0.18 mg/L at site 7 and from 0.04 to 4.0 mg/L downstream from the WWTP effluent. PO_4-P concentrations ranged from 0.84 to 13 mg/L in the WWTP effluent.

Inflow concentrations ranged from 0.07 to 0.16 mg/L in other tributaries. PO_4-P concentrations in runoff samples (mainstem and tributary) ranged from 0.07 to 0.44 mg/L (table 3).

Phosphorus-P concentrations (table 2) during "steady-state" conditions ranged from 0.01 to 0.20 mg/L at site 7 and from 0.10 to 5.1 mg/L downstream from the Prairie Grove WWTP effluent. Phosphorus-P concentrations in the WWTP effluent ranged from 12 to 21 mg/L and ranged from 0.03 to 0.26 mg/L in tributary inflows. Arkansas water-quality standards (Arkansas Department of Pollution Control and Ecology, 1981) suggest as a "guideline" that phosphorus-P concentrations not exceed 0.100 mg/L in streams. This guideline concentration was exceeded in 79 percent of the "steady-state" samples collected in the Muddy Fork basin during this study. Phosphorus-P concentrations in runoff samples ranged from 0.23 to 0.50 mg/L (table 3).

Biological Characteristics

Phytoplankton.-- Phytoplankton densities were 3100 cells/mL at site 9 and 720 cells/mL at site 11 (table 7). Neither density indicates an algal bloom. The most dominant genera of phytoplankton were *Nitzschia, Navicula,* and *Cryptomonas* (table 7). *Nitzschia* and *Navicula* are among the most commonly occurring and most dominant genera of phytoplankton of the United States (Greeson, 1982). Phytoplankton chlorophyll *a* concentrations (table 8) were also higher at site 9 (11.5 μg/L) than at site 11 (8.52 μg/L).

Periphyton.-- Periphyton organic weights ranged from 3.6 to 7.2 g/m^2 (table 8). The dominant genera were *Coleochaete* and *Cocconeis* (table 9). Chlorophyll *a* concentrations ranged from 41.0 to 72.5 mg/m^2 (table 8).

Total and fecal coliform bacteria.-- Total coliform bacteria ranged from 180 to 37,000 colonies per 100 mL in the Muddy Fork and its tributaries (table 2). Fecal coliform bacteria (table 2) ranged from 230 to 1300 colonies per 100 mL at site 7 and from 64 to 20,000 colonies per 100 mL downstream from the Prairie Grove WWTP effluent. Fecal coliform bacteria ranged from less than 50 to 2,600,000 colonies per 100 mL in the WWTP effluent. In tributaries, concentrations near the mouth ranged from 60 to 2900 colonies per 100 mL. Most observed fecal coliform bacteria concentrations in Muddy Fork, and several in Muddy Fork tributaries, were greater than the Arkansas water-quality standard for April 1 to September 30 (Arkansas Department of Pollution Control and Ecology, 1981) of 200 colonies per 100 mL (geometric mean). Fecal coliform bacteria concentrations in runoff samples exceeded 1000 colonies per 100 mL (table 3).

Reaeration Coefficient

Measurement of reaeration coefficients by the gas injection method should be done at or near the flow of interest, especially if the coefficients can be measured for only one flow condition. However, for medium or low-flow conditions in Muddy Fork, mean velocities are very slow and prohibit the use of the gas injection measurement procedure. During collection of the 1981 data set mean velocities ranged form 0.01 ft/s to a maximum of 0.05 ft/s.

When very slow velocities prevail, most predictive equations that are velocity dependent underpredict the reaeration coefficient. Under such conditions the Velz (1970) approach, as defined in a predictive equation by Hirsch (Hirsch, R. M., U.S. Geological Survey, written commun., 1980) is well suited. The equation, which is not velocity dependent, takes the following form;

$$k_2 = [-ln[1-2((m \times 1.42 \times 1.1^{T-20}/60)/\pi(30.48 \times h)^2)^{.5}] \times 1440] \div m \quad (17)$$

$$m = 2.279 + 0.721 \times h, \text{ if } h < 2.26$$
$$= 13.94 \times ln(h) - 7.45, \text{ if } h \geq 2.26$$

where,

m = mixing interval,

h = mean stream depth, and

T = stream temperature.

This equation is available in the digital model (Attachment A, Terry and others, 1982) and was used to compute k_2 in the Muddy Fork calibration, verification, and projections. Values of k_2, by subreach, computed during calibration and verification are shown on Attachment B-7 and B-28 under the column heading KA. Values of k_2, by subreach, computed for $Q_{7/10}$ low-flow projections are given in table 10.

Table 7.--Phytoplankton taxonomy and densities, for Muddy Fork

Scientific name	Common name	cells/milliliter Site 9	cells/milliliter Site 11
Chlorophyta	Green algae		
.Chlorophyceae			
..Chlorococcales			
...Micractiniaceae			
....*Micractinium*		120	---
...Oocystaceae			
....*Ankistrodesmus*		---	14
...Scenedesmaceae			
....*Scenedesmus*		120	86
..Volvocales			
...Chlamydomonadaceae			
....*Chlamydomonas*		58	100
Chrysophpyta	Yellow-green algae		
.Bacillariophyceae	Diatoms		
..Centrales	Centric diatoms		
...Coscinodiscaceae			
....*Cyclotella*		200	14
..Pennales	Pennate diatoms		
...Fragilariaceae			
....*Fragilaria*		29	---
....*Synedra*		120	---
...Gomphonemataceae			
....*Gomphonema*		58	14
...Naviculaceae	Naviculoids		
....*Navicula* [1]		1,200	14
...Nitzschiaceae			
....*Nitzschia* [1]		1,100	---
Cryptophyta			
.Cryptophyceae			
..Cryptomonadales			
...Cryptomonadaceae			
....*Chroomonas* [1]		---	360
Euglenophyta	Euglenoids		
.Euglenophyceae			
..Euglenales			
...Euglenaceae			
....*Euglena*		---	43
....*Trachelomonas*		120	72

[1]Dominant organism, cell counts greater than or equal to 15 percent of total count for the station.

Table 8.--Phytoplankton and periphyton analyses for Muddy Fork

[Five digit numbers in parentheses are STORET parameter codes used for computer storage of data]

Site number	River mile	Date of collection	Chlorophyll *a*, phytoplankton, chroma-Fl (µg/L) (70953)	Chlorophyll *b*, phytoplankton chroma-Fl (µg/L) (70954)	Phytoplankton (cells per mL) (60050)	Chlorophyll *a*, periphyton, chroma-Fl (mg/m^2) (70957)	Chlorophyll *b*, periphyton chroma-Fl (mg/m^2) (70958)	Periphyton; organic weight (g/m^2)	Biomass chlorophyll ratio periphyton (units) (70950)
9	8.2	8-12-81	----	----	----	72.5	21.4	7.2	99.3
		8-24-81	11.5	2.32	3,100	----	----	---	----
11	4.7	8-12-81	----	----	----	62.7	15.4	3.6	56.8
		8-25-81	8.52	<.01	720	----	----	---	----
16	0.3	8-12-81	----	----	----	41.0	7.63	4.8	117

Table 9.--Periphyton taxa at Site 16, Muddy Fork

[Periphyton strips placed in creek on 7-15-81, removed 8-12-81]

Scientific name	Common name
Chlorophyta	Green algae
.Chlorophyceae	
..Oedogoniales	
...Oedogoniaceae	
....*Oedogonium*	
..Ulotrichales	
...Coleochaetaceae	
....*Coleochaete* [1]	
..Zygnematales	
...Desmidiaceae	Placoderm desmids
....*Closterium*	
Chrysophyta	Yellow-green algae
.Bacillariophyceae	Diatoms
..Centrales	Centric diatoms
...Coscinodiscaceae	
....*Melosira*	
..Pennales	Pennate diatoms
...Achnanthaceae	
....*Achnanthes*	
....*Cocconeis* [1]	
...Cymbellaceae	
....*Amphora*	
...Gomphonemataceae	
....*Gomphonema*	
...Naviculaceae	Naviculoids
....*Frustulia*	
....*Gyrosigma*	
....*Navicula*	
....*Pinnularia*	
...Nitzschiaceae	
....*Nitzschia*	
...Surirellaceae	
....*Surirella*	
Cyanophyta	Blue-green algae
.Cyanophyceae	
..Hormogonales	Filamentous blue-greens
...Oscillatoriaceae	
....*Lyngbya*	
....*Oscillatoria*	

[1]Dominant organism, estimated to be greater than 15 percent of total algal cells on sampling strip.

Table 10.--Model-derived velocities and reaeration coefficients for Muddy Fork low-flow projections

[Stream temperature = 29°C; discharge from Prairie Grove wastewater-treatment plant = 0.43 ft^3/s]

Subreach		Mean	Mean	
Begin Mile	End Mile	Discharge (ft^3/s)	Velocity (ft/s)	k_2 (day^{-1})
8.3	8.2	0.430	0.006	2.63
8.2	6.5	.410	.006	2.63
6.5	4.7	.370	.005	2.63
4.7	4.0	.345	.005	2.63
4.0	3.9	.640	.011	3.09
3.9	3.0	.620	.010	3.09
3.0	1.4	.565	.008	3.28
1.4	0.0	.500	.007	1.20

Mean Velocity Interpretation

Time-of-travel data were collected on Muddy Fork for discharges ranging from 2.0 to 5.5 ft^3/s (fig. 12). The discharges observed during the collection of the calibration and verification data sets ranged from 0.54 ft^3/s at mile 8.6 to 3.50 ft^3/s at the mouth and from 1.0 ft^3/s at mile 8.6 to 4.63 ft^3/s at the mouth, respectively.

Mean cross-sectional areas were computed for Muddy Fork, by subreach, using techniques described in the earlier "Time of Travel" section. Many channel-width measurements and observations were made during the collection of the 1979 and 1981 data sets. The ratio of the "subreach average" cross-sectional areas to "subreach average" channel widths were used to define "subreach average" depths. This data is shown in Attachment B-6 and B-25 for the calibration and verification data sets, respectively.

The mean velocities for the calibration and verification data sets are shown in table 11. These velocities are the result of the "fitted" channel geometry, based upon the measured times of travel (fig. 12) and the flow distributions for each data set. The velocities computed for the $Q_{7/10}$ low-flow projections with the projected Prairie Grove WWTP flow imposed are shown in table 10.

Stream Model

Calibration and Verification

Attachment B contains the results of model calibration and verification. Model calibration output is on Attachments B-2 through B-22; verification output is on Attachments B-23 through B-42. The Muddy Fork model was calibrated and verified using data collected in 1981 and 1979, respectively.

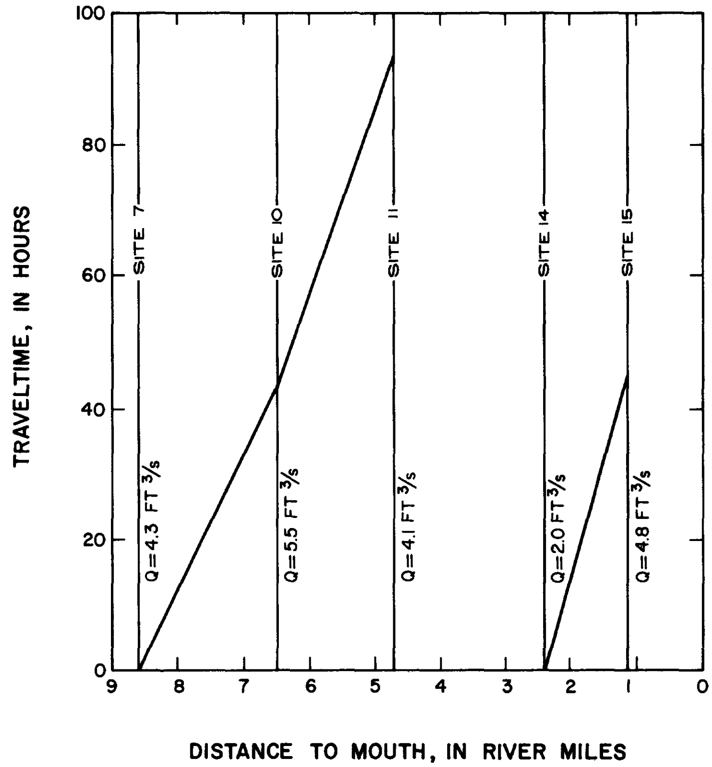

Figure 12.--Traveltime of peak dye concentration in Muddy Fork, for discharges noted at each site (modified from Lamb, 1983).

The success of the model calibration-verification procedure is illustrated by the "goodness-of-fit" between the model-derived and observed concentration profiles for the predictable variables. These profiles are shown on Attachments B-11 through B-20 and B-32 through B-40. The values of those coefficients and parameters defined during the calibration-verification process (as discussed in the "Calibration and Verification Procedure" section) are included on Attachment B-6 and B-7 and again on Attachment B-27 and B-28.

Values of k_d obtained by application of the Bosko equation (equation 15) to subreach average k_l values are shown on Attachments B-7 and B-28. Velocities were so slow in Muddy Fork (table 11) that the Bosko correction (equation 15) is ineffective. Values of k_d are equal to the subreach average k_l values.

Two DO profiles were "fitted" for the calibration data set, the diel mean profile and the diel-minimum profile (Attachment B-19 and B-20). Subreach average benthic demands, directly resulting from the "fitting" of the mean DO profile, are shown on Attachment B-6 and B-27. The adjustment factors used in fitting the model-derived, diel-minimum DO profile to the observed minimum profile (as discussed in the "Simulation Techniques" section) are shown on Attachment B-6 and B-27. Verification of the "fitting" of the diel-minimum DO profile is shown on Attachment B-40.

Projections

Muddy Fork simulations were made for projected Prairie Grove WWTP effluent limits. The limits for CBODU, TSS, ammonia-N, and PO_4-P respectively, in mg/L, are:

1) 45, 30, 15, 10

Table 11.--Mean velocities, by subreach, for the 1979 and 1981 data sets collected on Muddy Fork

Subreach		Velocities	
Begin Mile	End Mile	1979	1981
8.6	8.3	0.016	0.009
8.3	8.2	.013	.011
8.2	6.5	.014	.011
6.5	4.7	.014	.011
4.7	4.0	.014	.011
4.0	3.9	.028	.028
3.9	3.0	.030	.028
3.0	1.4	.029	.025
1.4	0.0	.057	.049

2) 30, 20, 10, 10

3) 15, 15, 10, 10

4) 15, 15, 5, 5

5) 7.5, 5, 2, 1

Each of these projections was simulated twice; once using an effluent DO concentration at saturation and once using a DO concentration of 5.0 mg/L. All projections were made using a Prairie Grove WWTP discharge of 0.43 ft^3/s, $Q_{7/10}$ stream conditions, and water temperatures reflecting summertime highs (29°C).

In addition, for comparative purposes, a simulation was made at $Q_{7/10}$, low-flow conditions and water temperatures of 29°C using "as surveyed" effluent concentrations and discharge. This simulation reflects water quality conditions at $Q_{7/10}$ flows in Muddy Fork with existing waste loading.

Because of the very slow velocities that are characteristic in Muddy Fork under $Q_{7/10}$ conditions, the ineffectiveness of the Bosko correction (equation 15) is even more pronounced. Therefore k_d values remained unchanged from calibration-verification to projections. For the preceding reasons and the availability of natural carbonaceous material in particulate form, no change was made in k_r values determined during calibration-verification. Consequently, no adjustments were made in subreach average benthic demands defined during the calibration process.

The results of the Muddy Fork projection simulations are shown in table 12. Average DO deficits are shown in table 13. When the net photosynthetic DO deficit is negative, net photosynthetic DO production is an oxygen source. Deficits resulting from the benthic demands are the most significant. Muddy Fork will not meet the Arkansas diel-minimum DO standard (Arkansas Department of Pollution Control and Ecology, 1981) of 4.0 mg/L with any of the projected Prairie Grove WWTP effluent limits imposed. Simulations for projected effluent limit number 5 indicate instream minimum DO concentrations only slightly higher than the "as surveyed" simulation (table 12).

Table 12.—Muddy Fork model-simulation summary at 7-day, 10-year low flow using existing and projected loadings from the Prairie Grove wastewater-treatment plant

Initial River Conditions		Prairie Grove WWTP									Instream Total Suspended Solids[1]			Downstream Dissolved Oxygen Profile Sag				Projected concentrations and loadings at the mouth of Muddy Fork													
Discharge (ft^3/s)	Dissolved oxygen (mg/L)	Discharge (ft^3/s)	Dissolved oxygen (mg/L)	CBODU (mg/L)	Total organic-N (mg/L)	Total ammonia-N (mg/L)	Total NO2-N (mg/L)	Total NO3-N (mg/L)	Total PO4-P (mg/L)	Total suspended solids (mg/L)	Concentration (mg/L)	Location (mile)	Water Temperature (°C)	Minimum resulting from Prairie Grove effluent (mg/L)	Location (mile)	Absolute minimum (mg/L)	Location (mile)	Discharge (ft^3/s)	Dissolved oxygen (mg/L)	CBODU (mg/L)	CBODU (lb/d)	Total organic-N (mg/L)	Total organic-N (lb/d)	Total Ammonia-N (mg/L)	Total Ammonia-N (lb/d)	Total NO2-N (mg/L)	Total NO2-N (lb/d)	Total NO3-N (mg/L)	Total NO3-N (lb/d)	Total PO4-P (mg/L)	Total PO4-P (lb/d)
0.0	0.0	[2]0.16	[2]4.3	[2]64	[2]3.40	[2]3.67	[2]0.53	[2]12.50	[2]12	[2]30	30	8.3	29	1.65	8.10	1.28	3.90	0.20	4.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.22	0.000	0.000
.0	.0	.43	7.7	45	.00	15	.00	.00	10	30	30	8.3	29	0.00	8.20	0.00	8.20	.47	4.07	.00	.00	.00	.00	.00	.00	.00	.00	.37	.937	.003	.008
.0	.0	.43	7.7	30	.00	10	.00	.00	10	20	20	8.3	29	.00	8.20	.00	8.20	.47	4.07	.00	.00	.00	.00	.00	.00	.00	.00	.32	.811	.003	.008
.0	.0	.43	7.7	15	.00	10	.00	.00	10	15	15	8.3	29	.00	8.20	.00	8.20	.47	4.07	.00	.00	.00	.00	.00	.00	.00	.00	.32	.811	.003	.008
.0	.0	.43	7.7	15	.00	5.0	.00	.00	5.0	15	15	8.3	29	.45	8.10	.45	8.10	.47	4.07	.00	.00	.00	.00	.00	.00	.00	.00	.28	.709	.003	.008
.0	.0	.43	7.7	7.5	.00	2.0	.00	.00	1.0	5	5	8.3	29	1.69	8.10	1.27	4.50	.47	4.07	.00	.00	.00	.00	.00	.00	.00	.00	.25	.633	.003	.008
.0	.0	.43	5.0	45	.00	15	.00	.00	10	30	30	8.3	29	.00	8.20	.00	8.20	.47	4.07	.00	.00	.00	.00	.00	.00	.00	.00	.37	.937	.003	.008
.0	.0	.43	5.0	30	.00	10	.00	.00	10	20	20	8.3	29	.00	8.20	.00	8.20	.47	4.07	.00	.00	.00	.00	.00	.00	.00	.00	.32	.811	.003	.008
.0	.0	.43	5.0	15	.00	10	.00	.00	10	15	15	8.3	29	.00	8.20	.00	8.20	.47	4.07	.00	.00	.00	.00	.00	.00	.00	.00	.32	.811	.003	.008
.0	.0	.43	5.0	15	.00	5.0	.00	.00	5.0	15	15	8.3	29	.44	8.10	.44	8.10	.47	4.07	.00	.00	.00	.00	.00	.00	.00	.00	.28	.709	.003	.008
.0	.0	.43	5.0	7.5	.00	2.0	.00	.00	1.0	5	5	8.3	29	1.68	8.10	1.27	4.50	.47	4.07	.00	.00	.00	.00	.00	.00	.00	.00	.25	.633	.003	.008

[1]Represents mass balance immediately downstream from Prairie Grove WWTP.
[2]Existing WWTP conditions (mean of 1979 and 1981 data)

Table 13.--Average dissolved oxygen deficits in Muddy Fork, by subreach, for simulations that include projected changes in ultimate carbonaceous biochemical oxygen demand and ammonia-nitrogen concentrations from the Prairie Grove wastewater-treatment plant

[Deficits in milligrams per liter]

Stream discharge = 7-day, 10-year low flow, Temperature = 29°C

Subreach: Beginning mile	Subreach: Ending mile	CBOD deficit	Benthal deficit	Net photosynthetic deficit	Ammonia-N deficit	Nitrite-N deficit
CBODU = 45 mg/L, Ammonia-N = 15 mg/L						
8.3	8.2	2.94	3.508	-0.788	5.433	1.131
8.2	6.5	.28	5.315	- .365	.666	.284
6.5	4.7	.03	4.507	- .573	.001	.000
4.7	4.0	.03	4.780	1.362	.000	.000
4.0	3.9	.12	4.072	1.031	.099	.012
3.9	3.0	.09	3.186	.262	.007	.001
3.0	1.4	.03	3.085	- .202	.001	.000
1.4	0.0	.02	2.578	- .240	.000	.000
CBODU = 30 mg/L, Ammonia-N = 10 mg/L						
8.3	8.2	1.96	3.508	-0.788	3.622	0.754
8.2	6.5	.19	5.315	- .365	.444	.189
6.5	4.7	.02	4.507	- .573	.000	.000
4.7	4.0	.02	4.780	1.362	.000	.000
4.0	3.9	.12	4.072	1.031	.099	.012
3.9	3.0	.09	3.186	.262	.007	.001
3.0	1.4	.03	3.085	- .202	.001	.000
1.4	0.0	.02	2.578	- .240	.000	.000
CBODU = 15 mg/L, Ammonia-N = 10 mg/L						
8.3	8.2	0.98	3.508	-0.788	3.622	0.754
8.2	6.5	.09	5.315	- .365	.444	.189
6.5	4.7	.01	4.507	- .573	.000	.000
4.7	4.0	.01	4.780	1.362	.000	.000
4.0	3.9	.12	4.072	1.031	.099	.012
3.9	3.0	.09	3.186	.262	.007	.001
3.0	1.4	.03	3.085	- .202	.001	.000
1.4	0.0	.02	2.578	- .240	.000	.000

Table 13.--Average dissolved oxygen deficits in Muddy Fork, by subreach, for simulations that include projected changes in ultimate carbonaceous biochemical oxygen demand and ammonia-nitrogen concentrations from the Prairie Grove wastewater-treatment plant--Continued

[Deficits in milligrams per liter]

Stream discharge = 7-day, 10-year low flow, Temperature = 29°C

Subreach						
Beginning mile	Ending mile	CBOD deficit	Benthal deficit	Net photosynthetic deficit	Ammonia-N deficit	Nitrite-N deficit
CBODU = 15 mg/L, Ammonia-N = 5 mg/L						
8.3	8.2	0.98	3.508	-0.788	1.811	0.377
8.2	6.5	.98	5.315	- .365	.222	.095
6.5	4.7	.01	4.507	- .573	.000	.000
4.7	4.0	.01	4.780	1.362	.000	.000
4.0	3.9	.12	4.072	1.031	.099	.012
3.9	3.0	.09	3.186	.262	.007	.001
3.0	1.4	.03	3.085	- .202	.001	.000
1.4	0.0	.02	2.578	- .240	.000	.000
CBODU = 7.5 mg/L, Ammonia-N = 2 mg/L						
8.3	8.2	0.49	3.508	-0.788	0.724	0.151
8.2	6.5	.05	5.315	- .365	.089	.038
6.5	4.7	.00	4.507	- .573	.000	.000
4.7	4.0	.00	4.780	1.362	.000	.000
4.0	3.9	.12	4.072	1.031	.099	.012
3.9	3.0	.09	3.186	.262	.007	.001
3.0	1.4	.03	3.085	- .202	.001	.000
1.4	0.0	.02	2.578	- .240	.000	.000
Existing Conditions (see table 12)						
8.3	8.2	0.98	3.785	-0.851	0.880	0.359
8.2	6.5	.03	5.680	- .390	.066	.026
6.5	4.7	.00	4.735	- .602	.001	.000
4.7	4.0	.00	4.972	1.417	.000	.000
4.0	3.9	.23	4.675	1.184	.066	.009
3.9	3.0	.14	3.644	.299	.001	.000
3.0	1.4	.03	3.327	- .218	.000	.000
1.4	0.0	.00	3.564	- .332	.000	.000

Sensitivity Testing

The highest simulated minimum instream DO concentration resulting from the imposition of a projected effluent limit at Prairie Grove WWTP was 1.69 mg/L (table 12). The effluent limit imposed was number 5 (CBODU = 7.5 mg/L and Ammonia-N = 2.0 mg/L), with the effluent DO concentration set at saturation (7.7 mg/L). Model sensitivity analyses were run using this simulation.

The criteria used, and the components and rate coefficients tested for sensitivity, are listed in the "Model Sensitivity" section. Figures 13 through 25 show the resulting sensitivity bands.

For the flow conditions in the simulation tested, the DO profile is more sensitive to changes in reaeration coefficient, subreach average benthic demands, and mean stream depths than any other parameters tested. The sensitivity bands for these parameters are shown in figures 17, 18, and 23. The sensitivity of the DO profile to these parameters is not surprising considering the extremely slow velocities simulated (table 10).

Muddy Fork Conclusions

Under existing conditions, Muddy Fork does not meet Arkansas standards for the following parameters: diel-minimum DO, phosphorus-P, and fecal coliform bacteria. Stormwater runoff sampling indicates that significant nutrient loads may be contributed to the stream during runoff periods. Nutrient loads contribute to benthic demands at low flow and may be resuspended in the water column when velocities increase, or when the streambed is disturbed for any reason.

Both measured and simulated times of travel on Muddy Fork are very slow for medium (4.8 ft^3/s) to low (0.2 ft^3/s) flows near the mouth. Consequently, mean velocities are very slow and reaction times for all non-conservative, reacting parameters are very long.

Model simulations indicate that benthic demands result in the most significant oxygen deficits and are the main reason that Muddy Fork will not meet DO standards. Nonpoint sources are probably the primary contributors to these projected benthic demands.

Diel-minimum DO concentrations in Muddy Fork resulting in part from the instream waste concentrations discharged by the Prairie Grove WWTP, will not meet the diel-minimum DO concentration standard of 4.0 mg/L (Arkansas Department of Pollution Control and Ecology, 1981) for any of the projected effluent limits simulated. The highest minimum DO concentration simulated (1.69 mg/L) resulted from the imposition of projected effluent limit number 5 (CBODU = 7.5 mg/L and NH_3-N = 2.0 mg/L) with effluent DO concentrations set at saturation (7.7 mg/L). However, this minimum of 1.69 mg/L is only slightly higher than the minimum of 1.65 mg/L created by the "as surveyed" low-flow simulation. The difference of 0.04 mg/L is not significant. Simulations indicate that none of the projected effluent limits for the Prairie Grove WWTP result in an improvement in Muddy Fork DO concentrations.

Sensitivity testing indicates that the DO profile is most sensitive to stream depths, reaeration coefficients, and benthic demands. This is not surprising considering the extremely slow velocities simulated (maximum of 0.011 ft/s, table 10).

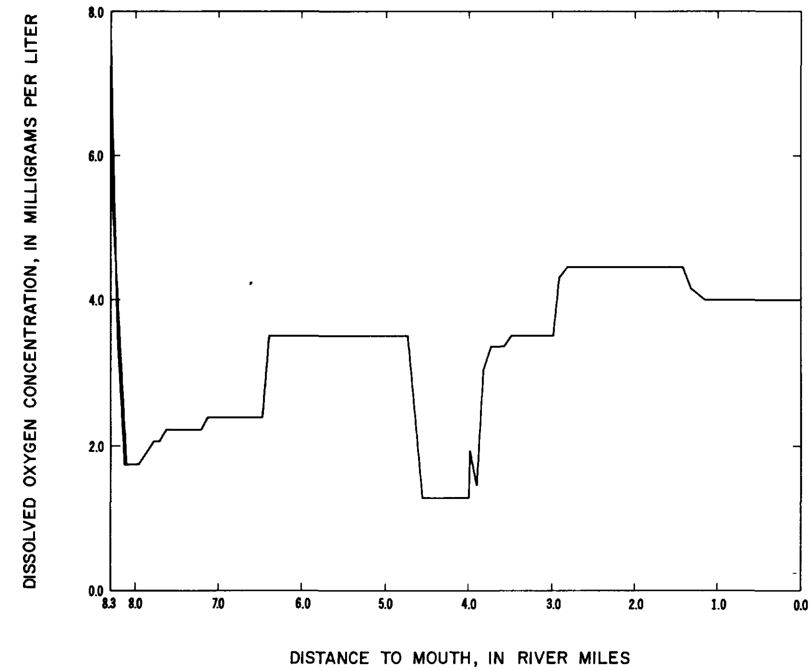

Figure 13.--Band reflecting the sensitivity of Muddy Fork dissolved-oxygen concentrations to a plus or minus 20-percent change in the dissolved-oxygen concentrations of the effluent from the Prairie Grove wastewater-treatment plant; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the wastewater-treatment plant is 7.g mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

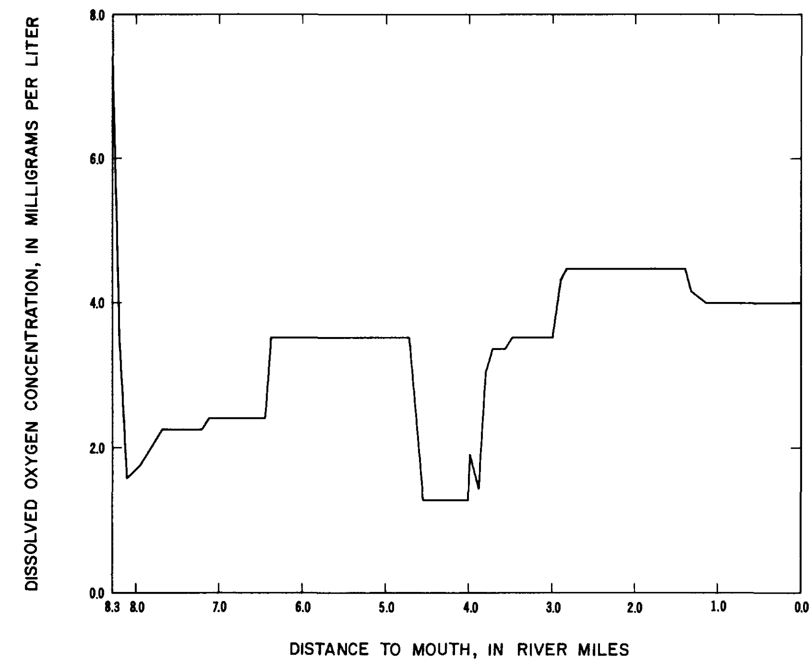

Figure 14.--Band reflecting the sensitivity of Muddy Fork dissolved-oxygen concentrations to a plus or minus 20-percent change in the ammonia forwater reaction and decay rates; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Prairie Grove wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

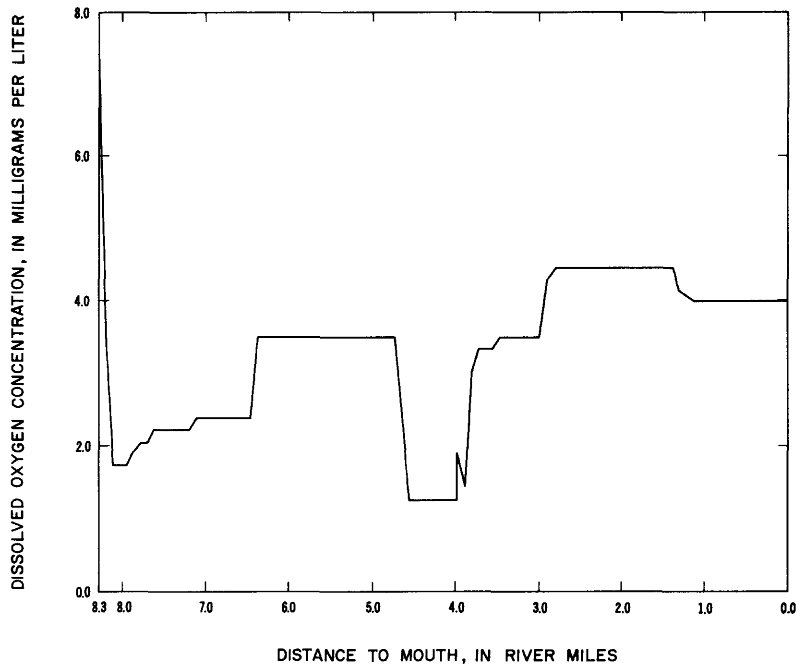

Figure 15.--Band reflecting the sensitivity of Muddy Fork dissolved-oxygen concentrations to a plus or minus 20-percent change in the organic nitrogen forward reaction and decay rates; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Prairie Grove wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

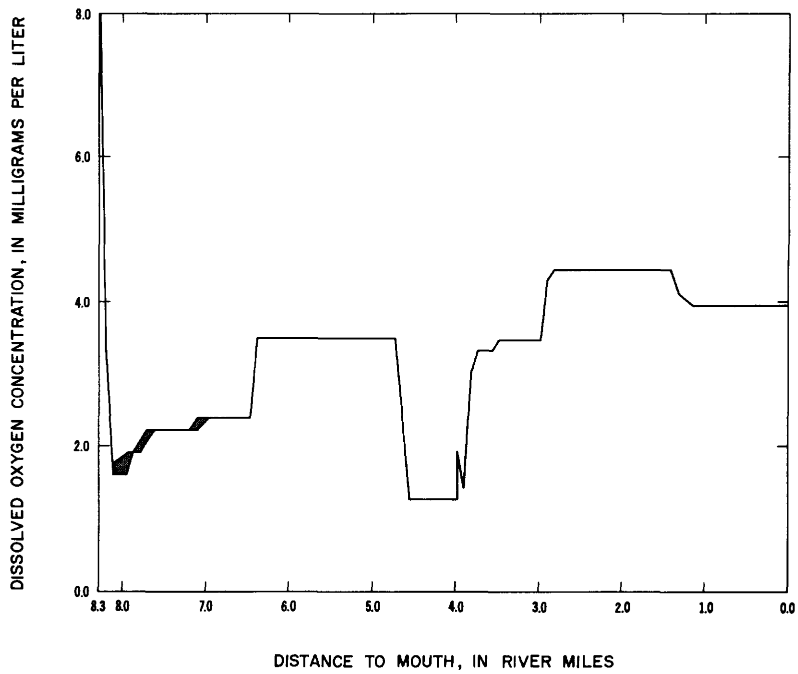

Figure 16.--Band reflecting the sensitivity of Muddy Fork dissolved-oxygen concentrations to a plus or minus 20-percent change in the ammonia concentration of the effluent from the Prairie Grove wastewater-treatment plant; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

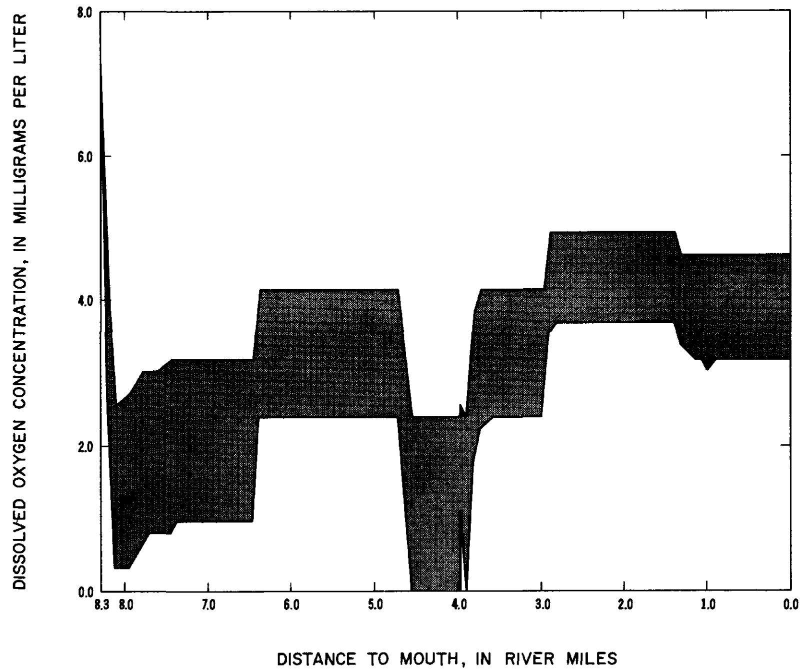

Figure 17.--Band reflecting the sensitivity of Muddy Fork dissolved-oxygen concentrations to a plus or minus 20-percent change in the reaeration coefficients; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Prairie Grove wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

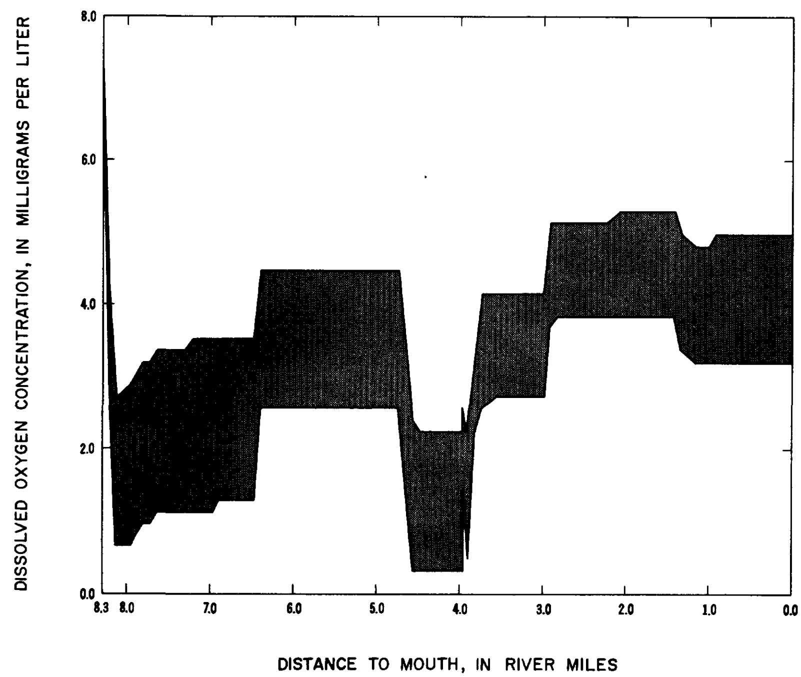

Figure 18.--Band reflecting the sensitivity of Muddy Fork dissolved-oxygen concentrations to a plus or minus 20-percent change in the benthic demands; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for Prairie Grove wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

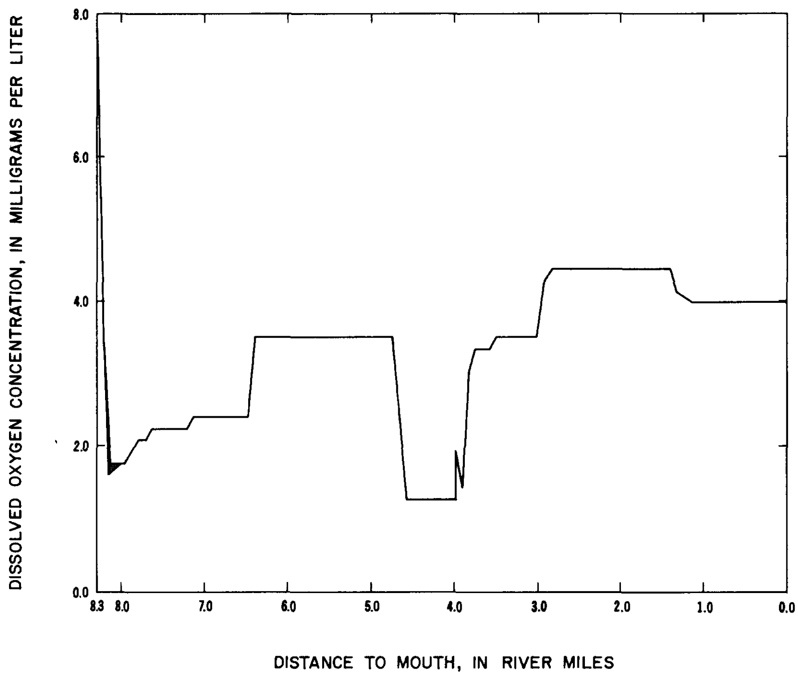

Figure 19.--Band reflecting the sensitivity of Muddy Fork dissolved-oxygen concentrations to a plus or minus 20-percent change in the carbonaceous biochemical oxygen demand of the effluent from the Prairie Grove wastewater-treatment plant; water temperature is 29°C, the wasteload projection for Prairie Grove wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

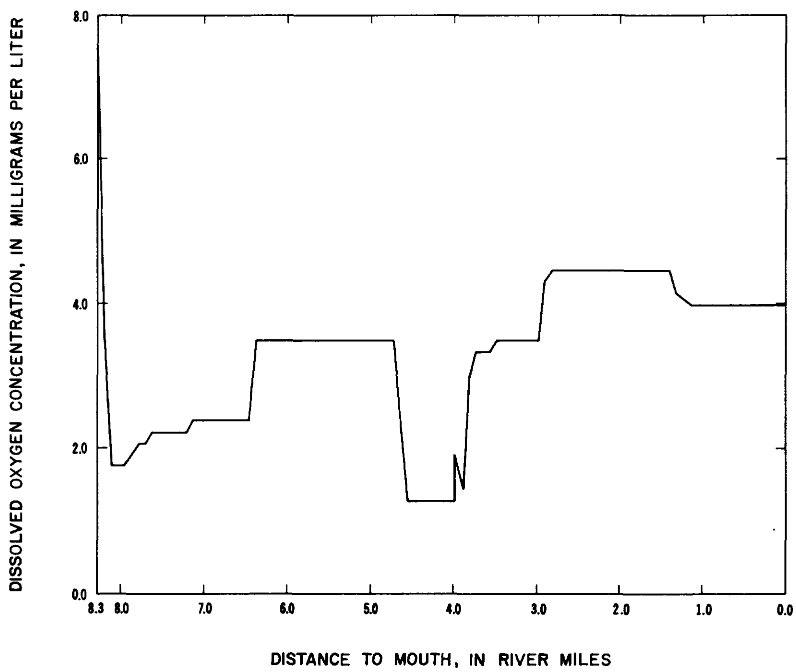

Figure 20.--Band reflecting the sensitivity of Muddy Fork dissolved-oxygen concentrations to a plus or minus 20-percent change in the nitrite forward reaction and decay rates; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for Prairie Grove wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

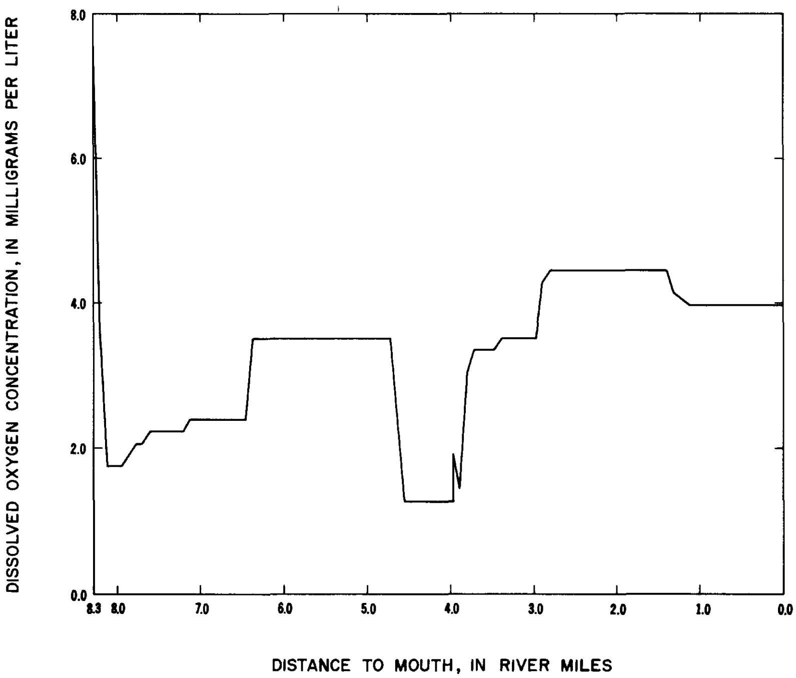

Figure 21.--Band reflecting the sensitivity of Muddy Fork dissolved-oxygen concentrations to a plus or minus 20-percent change in the deoxygenation and removal rates for carbonaceous material; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Prairie Grove wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

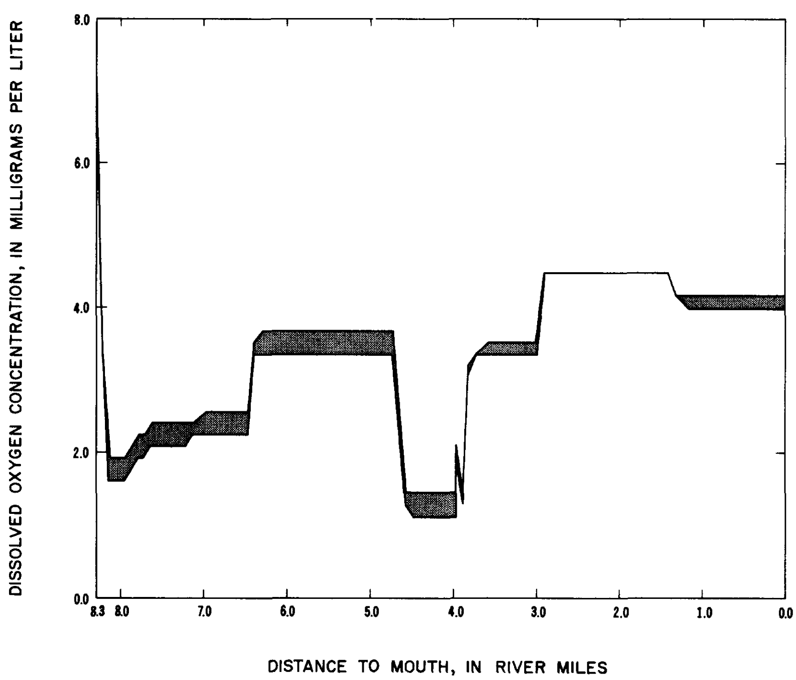

Figure 22.--Band reflecting the sensitivity of Muddy Fork dissolved-oxygen concentrations to a plus or minus 20-percent change in the net photosynthetic production; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Prairie Grove wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

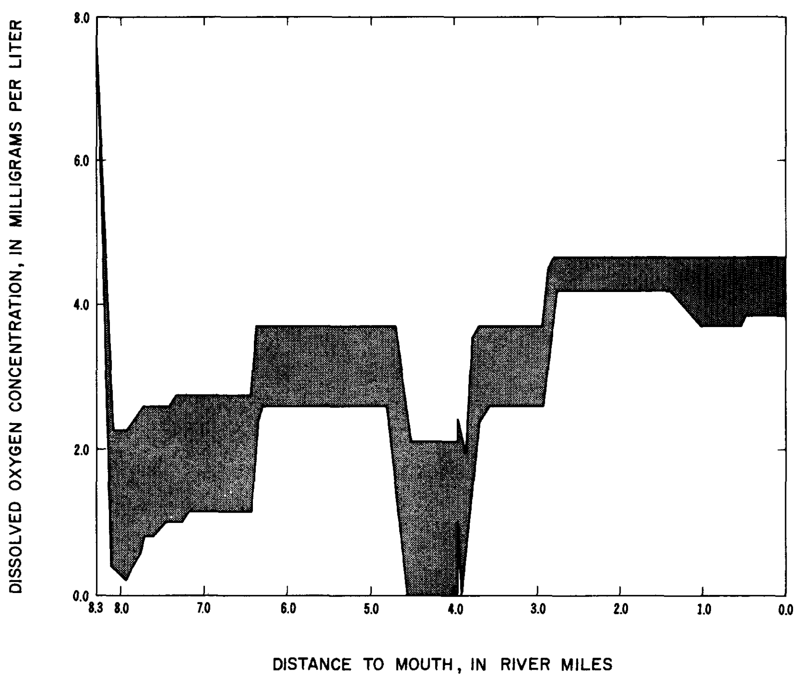

Figure 23.--Band reflecting the sensitivity of Muddy Fork dissolved-oxygen concentrations to a plus or minus 20-percent change in mean river depths; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Prairie Grove wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

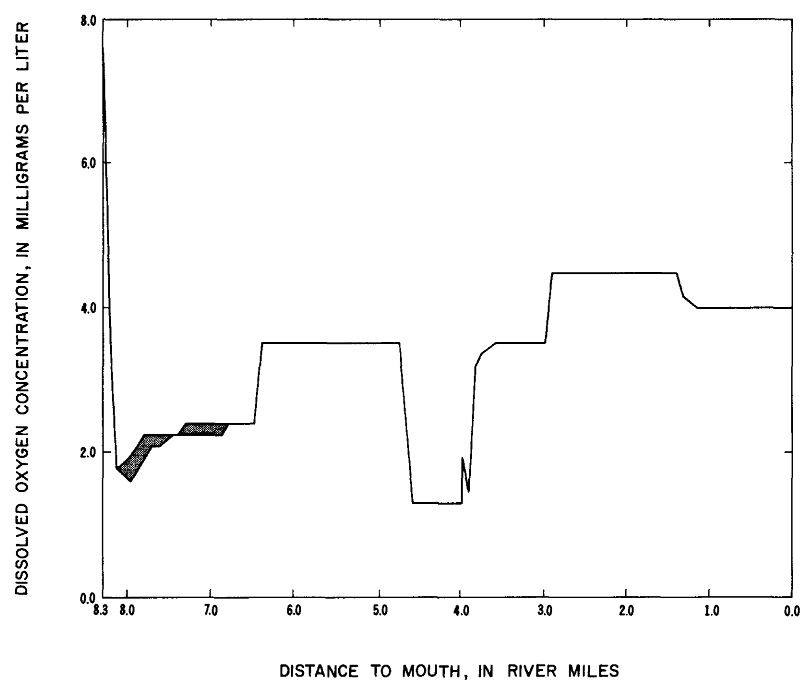

Figure 24.--Band reflecting the sensitivity of Muddy Fork dissolved-oxygen concentrations to a plus or minus 20-percent change in mean river velocities; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Prairie Grove wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

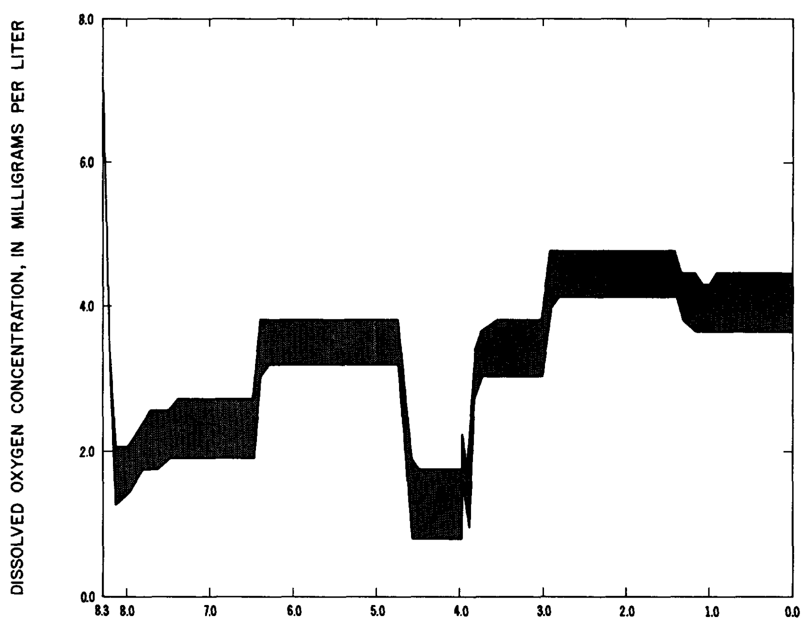

Figure 25.--Band reflecting the sensitivity of Muddy Fork dissolved-oxygen concentrations to a plus or minus 2.0-degree celsius change in water temperature; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Prairie Grove wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

SPRING CREEK ASSESSMENT

Spring Creek (fig. 1) flows generally east to west through primarily pasture lands, into Osage Creek at mile 17.1. It has a total drainage area of 36.8 mi^2 (Sullavan and Terry, 1970). The drainage area of Osage Creek upstream from Spring Creek is 42.5 mi^2 (Sullavan and Terry, 1970). The Springdale WWTP is the only point-source waste effluent that discharges into Spring Creek. The effluent enters the stream at mile 6.1. The reach of Spring Creek modeled is from mile 6.2 to its mouth (fig. 26). A location index for sites where data were collected for the Spring Creek assessment is given in table 14.

Surface Water Hydrology

Spring Creek is primarily a pool and riffle type of stream. Channel slopes range from 50 ft/mi to 13.6 ft/mi in a downstream direction.

Cumulative flows in Spring Creek during collection of the calibration data set (Aug. 24-Sept. 5, 1981) ranged from 8.7 ft^3/s at mile 6.2 to 29.7 ft^3/s at the mouth (Attachment C-2, C-3, C-6, and C-21). Cumulative flows during collection of the verification data set (July 23-27, 1979) ranged from 5.9 ft^3/s at mile 6.2 to 27.1 ft^3/s at the mouth (Attachment C-23, C-24, C-27, C-42). In the 1981 data set, 58 percent of the total streamflow immediately downstream from the Springdale WWTP was effluent discharge. In the 1979 data set the effluent discharge amounted to 72 percent of the total streamflow immediately downstream from its point of entry. These percentages are based on 24-hour average discharges from the Springdale WWTP.

Continuous hourly discharge data obtained from the Springdale WWTP for selected days indicate substantial variation over a 24-hour period (fig. 27.) This variation in WWTP discharge causes an unsteady-flow condition in Spring Creek. Averaging the WWTP discharge over a 24 hour period results in a quasi-steady inflow to Spring Creek and helps stabilize flow balances downstream. However, there are still some inherent problems in defining "good" times of travel and steady constituent transport. Similar problems occur when analyses are required on any stream for a "naturally occurring"

Table 14.--Spring Creek index for site name and identification number, U.S. Geological Survey station number, and location

Site Name	Site Identification Number	USGS Station Number	Location	
			Latitude	Longitude
Spring Creek at county road bridge upstream from Springdale WWTP	40	361249094094200	361249	0940942
Springdale WWTP effluent	41	361246094095200	361246	0940952
Spring Creek downsream from Springdale WWTP	41A	361255094100100	361255	0941001
Spring Creek at county road bridge by sewage disposal	42	361301094102200	361301	0941022
Spring Creek at bridge southwest of Sharp Cemetery	43	361322094112100	361322	0941121
Puppy Creek at county bridge south of church	44	361330094112700	361330	0941127
Spring Creek downstream from Puppy Creek	44A	361327094113900	361327	0941139
Spring Creek 2 miles northeast of Elm Springs	45	361356094121400	361356	0941214
Spring Creek 1/2 mile upstream of Cross Creek	45A	361412094124900	361412	0941249
Cross Creek at bridge on county road	46	361423094124200	361423	0941242
Spring Creek downstream from Cross Creek	46A	361414094125900	361414	0941259
Spring Creek at bridge on county road	47	361425094133200	361425	0941332
Spring Creek at Highway 112 bridge	48	361437094141900	361437	0941419

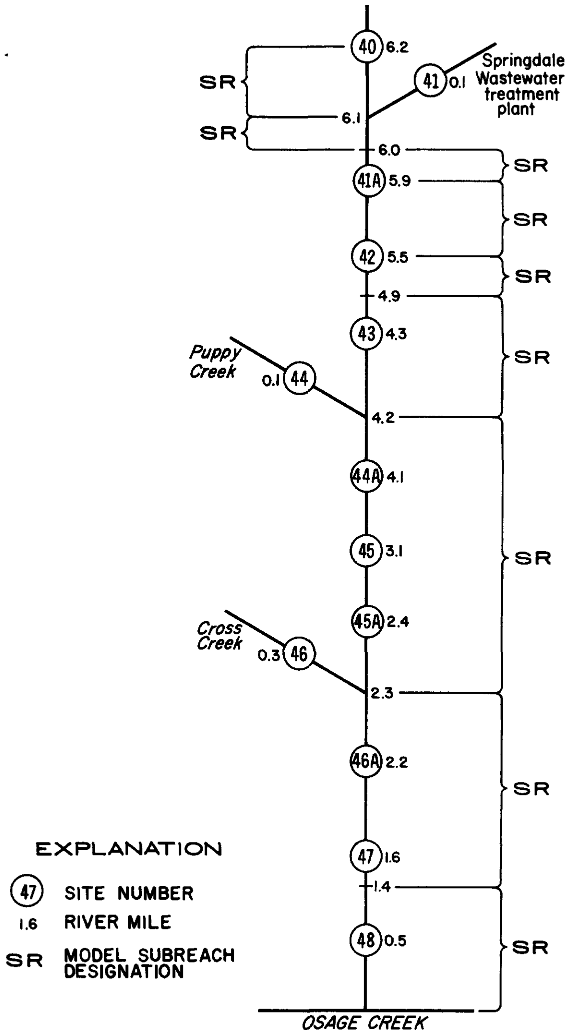

Figure 26.--Schematic of Spring Creek showing sampling-site and model-subreach locations.

steadyflow condition that is masked by a manmade unsteady inflow.

An existing $Q_{7/10}$ low-flow distribution (fig. 28) was defined on the basis of data presented by Hines (1975), and Hunrichs (1983). This distribution was established by mass-balancing total discharge at the mouth of Spring Creek, using Hunrichs' estimate of $Q_{7/10}$. The difference between the sum of initial and point-source $Q_{7/10}$ discharges and the established $Q_{7/10}$ discharge at the mouth was distributed linearly as flow loss between stream mile 6.2 and the mouth (fig. 28).

Water Quality

Physical Characteristics

Suspended solids.-- During the collection of "steady-state" data in 1978, 1979 and 1981, suspended-solids concentrations in Spring Creek were 8 mg/L at site 40 upstream from the Springdale WWTP and ranged from 6 to 17 mg/L downstream of the WWTP (table 15). Concentrations in the Springdale WWTP effluent ranged from 9 to 20 mg/L. Concentrations near the mouth of tributaries ranged from 1 to 7 mg/L. In tributaries, concentrations of suspended-solids during stormwater-runoff periods were 4 to 330 times greater than during periods of lower flow. Concentrations ranged from 28 to 663 mg/L (table 16). Sources of suspended solids during higher-flow periods are resuspension of deposited material and overland flow of stormwater-runoff. Because suspended solids transport attached nutrients and bacteria, nutrients and bacteria may be added to streams by runoff.

Water temperature.-- Water temperatures of the Springdale WWTP effluent were generally 6°C to 9°C warmer than temperatures upstream of the WWTP effluent (table 17). Temperatures at sites 41a, 42 and 43 were generally 4°C to 9°C warmer than at site 40 and indicate that the WWTP may increase water temperature in Spring Creek more than the 2.8°C allowed by the Arkansas water-quality standard (Arkansas Department of Pollution Control and Ecology, 1981).

Dissolved solids.-- Dissolved-solids concentrations for the 1978 "steady-state" sampling periods ranged from 154 to 393 mg/L in Spring Creek, from 298 to 351 mg/L in the Springdale WWTP effluent, and from 203 to 221 mg/L in the only tributary sampled (table 15). These data indicate that Arkansas stream water quality standards (Arkansas Department of Pollution Control and Ecology, 1981) for total dissolved solids were being violated at one site.

Minimal dissolved-solids concentrations in stormwater-runoff samples of tributaries (table 16) estimated from measured specific conductance values ranged from 76 to 246 mg/L.

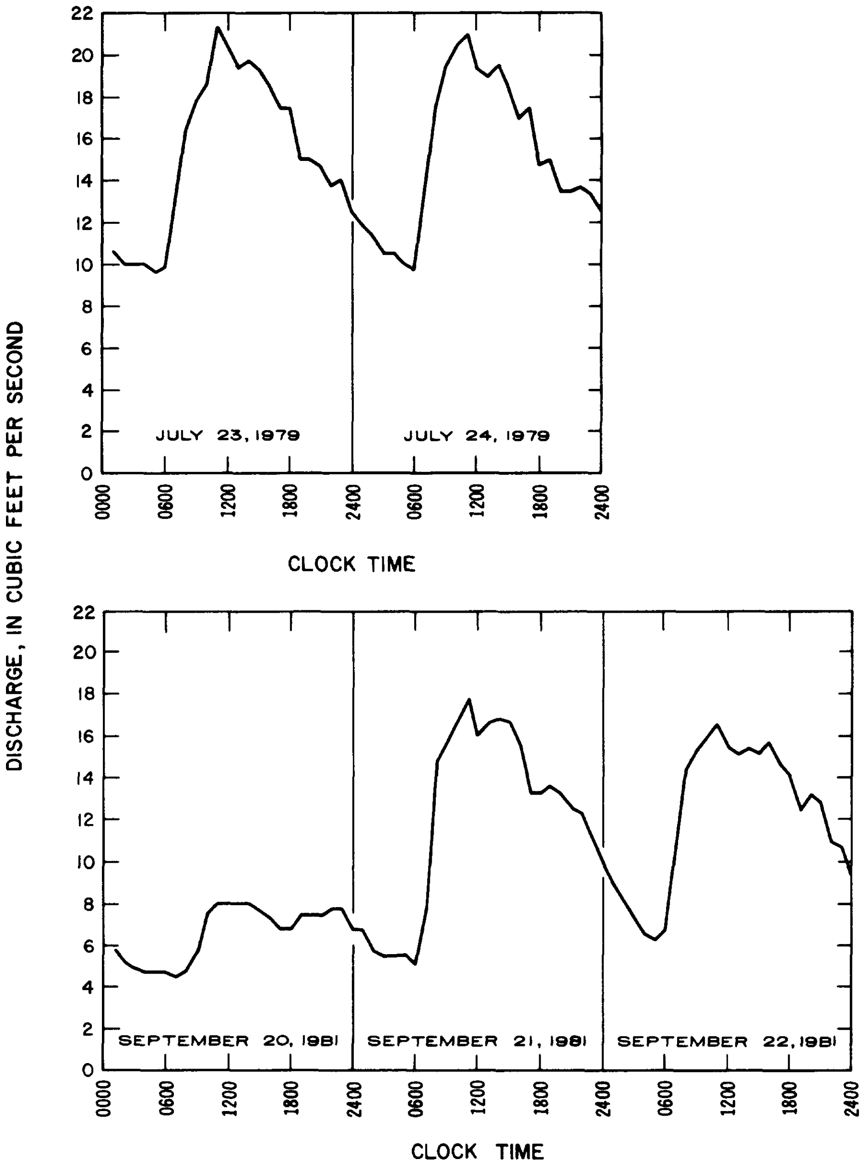

Figure 27.--Springdale wastewater treatment plant discharge for selected days.

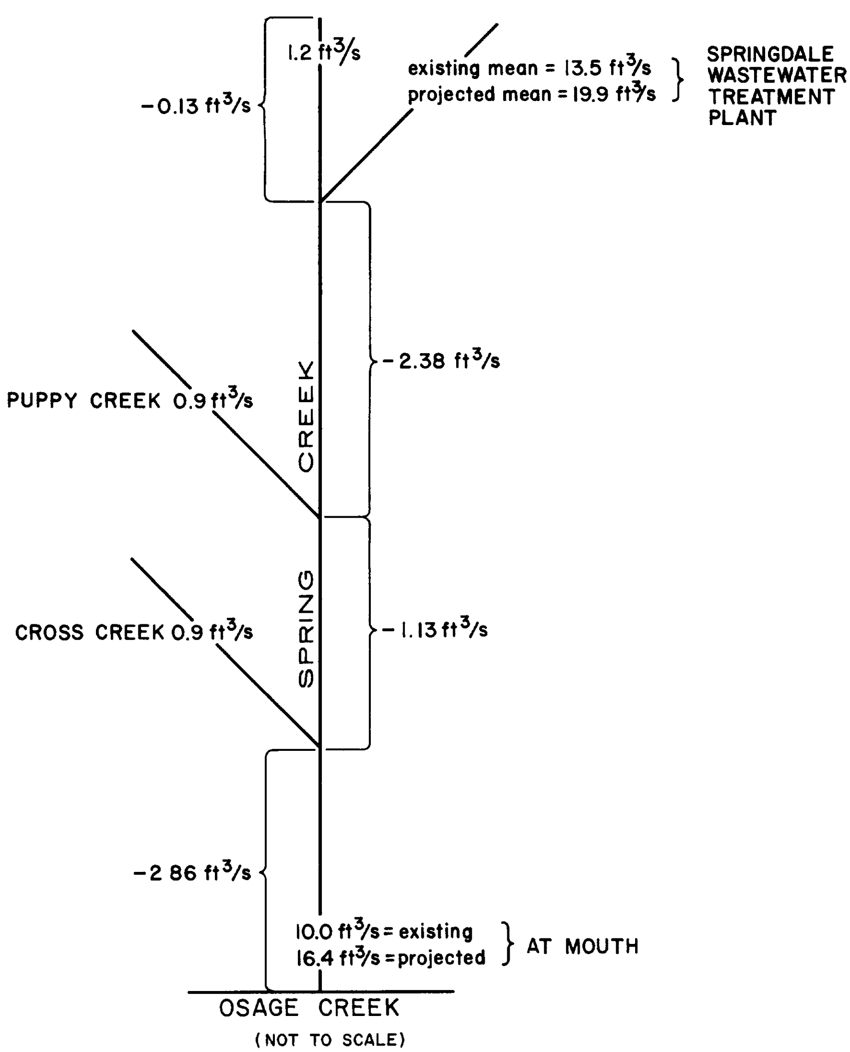

Figure 28.--7-day, 10-year low flow distribution for Spring Creek.

Chemical and Biochemical Characteristics

Chloride.-- Chloride concentrations for the 1978 "steady-state" sampling periods ranged from 8.5 to 51 mg/L in Spring Creek, from 33 to 51 mg/L in the Springdale WWTP and from 8.5 to 10 in the only tributary sampled (table 15). The data indicate that Arkansas water quality standards (Arkansas Department of Pollution Control and Ecology, 1981) for chloride were violated at four sites.

Sulfate.-- Sulfate concentrations for the 1978 "steady-state" sampling periods ranged from 5.0 to 44 mg/L in Spring Creek, from 36 to 44 mg/L in the Springdale WWTP effluent and from 1.0 to 5.0 mg/L in the only tributary sampled (table 15). The data indicate that Arkansas water quality standards (Arkansas Department of Pollution Control and Ecology, 1981) for sulfate were violated at four sites.

pH.-- Values of pH ranged from 7.1 to 7.9 in Spring Creek, from 7.1 to 7.5 in the WWTP effluent, and from 7.4 to 7.8 in tributary inflows (table 15).

Dissolved oxygen.-- The DO concentration in Spring Creek ranged from 7.0 to 10.9 mg/L at site 40 upstream from the Springdale WWTP outfall and from 3.5 to 9.3 mg/L downstream of the

WWTP (table 17). Concentrations in the WWTP effluent ranged from 7.0 to 8.0 mg/L and tributary inflow concentrations ranged from 4.9 to 10.1 mg/L. According to the Arkansas water-quality standards (Arkansas Department of Pollution Control and Ecology, 1981) an instantaneous minimum DO concentration in Spring Creek shall be greater than or equal to 4.0 mg/L.

Ultimate carbonaceous biochemical oxygen demand.-- During "steady-state" conditions CBODU concentrations ranged from 2.0 to 5.4 mg/L at site 40 upstream from the Springdale WWTP outfall and from 4.5 to 49 mg/L downstream from the effluent (table 15). CBODU concentrations of the effluent exceeded 10 mg/L. The CBODU concentrations of tributary inflows ranged from 1.8 to 6.3 mg/L. The CBODU concentrations of stormwater-runoff samples ranged from 14 to 23 mg/L (table 16).

Streambed oxygen demand.-- A "streambed oxygen demand" of 0.66 $(g/m^2)/d$ was measured for a sample collected at site 40 upstream from the WWTP outfall. "Streambed oxygen demands" downstream from the WWTP outfall were slightly higher and ranged from 0.81 to 1.58 $(g/m^2)/d$ (table 18).

Net photosynthetic dissolved-oxygen production. --"Net DO production" was calculated as discussed previously in the general "Net Photosynthetic Dissolved-Oxygen Production" section. It ranged from 2.8 to 17.0 (mg/L)/d (table 19). Chlorophyll *a* concentrations used in calculations were distance weighted estimates based on actual chlorophyll *a* concentrations at sites 42, 45, and 47. For modeling purposes net DO production was calculated for each subreach (see "Simulation Techniques" section and Attachment C-6 and C-27).

Nutrients.-- Analyses indicate nutrient enrichment of Spring Creek and its tributaries. Analyses of stormwater-runoff samples (table 16) indicate that the Springdale WWTP is not the sole cause of the nutrient enrichment. Nutrient concentrations, particularly organic-N and total phosphorus, generally were greater during stormwater-runoff conditions than during "steady-state" conditions (table 15). This suggests that nutrients deposited on the streambed were resuspended as velocities increased and/or that overland runoff of stormwater transported nutrients into the streams.

During "steady-state" conditions organic-N concentrations (table 15) ranged from 0.20 to 0.43 mg/L at site 40 upstream from the Springdale WWTP effluent and from 0.95 to 3.2 mg/L downstream from the WWTP effluent. Concentrations in the effluent ranged from 1.9 to 4.2 mg/L and in tributary inflows ranged from 0.38 to 1.8 mg/L. In tributaries, concentrations of organic-N in stormwater-runoff samples ranged from 1.5 to 2.9 mg/L and were approximately one-and-a-half to five times greater than mean "steady-state" concentrations (table 16).

During "steady-state" conditions, ammonia-N concentrations (table 15) ranged from 0.05 to 0.39 mg/L at site 40 and from 0.06 to 3.5 mg/L at sites downstream from the WWTP effluent. Concentrations in the WWTP effluent ranged from 1.8 to 5.4 mg/L and tributary inflow concentrations ranged from 0.07 to 0.13 mg/L. In tributaries, ammonia-N concentrations in stormwater-runoff ranged from 0.17 to 0.53 mg/L (table 16).

The NO_2-N concentrations (table 15) in "steady-state" condition samples ranged from 0.01 to 0.03 mg/L at site 40 and from 0.03 to 3.6 mg/L at sites downstream from the WWTP effluent. The NO_2-N concentrations in the effluent ranged from 0.33 to 1.1 mg/L and in tributary inflows ranged from 0.00 to 0.09 mg/L. In tributaries, concentrations in runoff samples ranged from 0.05 to 0.09 mg/L (table 16).

During "steady-state" conditions, NO_3-N concentrations (table 15) ranged from 2.8 to 3.5 mg/L at site 40 and from 5.5 to 15 mg/L at sites downstream from the WWTP effluent. The NO_3-N concentrations in the WWTP effluent ranged from 5.5 to 13 mg/L and ranged from 1.4 to 4.2 mg/L in tributary inflows. In tributaries, concentrations in runoff samples ranged from 1.1 to 4.0 mg/L (table 16).

During the "steady-state" conditions, PO_4-P and phosphorus-P concentrations generally decreased downstream from the WWTP effluent (table 15 and Attachment C-12 and C-33). PO_4-P concentrations ranged from 0.03 to 0.20 mg/L at site 40 and from 1.2 to 5.2 mg/L downstream from the WWTP effluent. PO_4-P concentrations ranged from 3.8 to 6.9 mg/L in the WWTP effluent. Other tributary inflow concentrations ranged from 0.03 to 0.29 mg/L. In tributaries, PO_4-P concentrations in runoff samples ranged from 0.31 to 0.91 mg/L (table 16).

Phosphorus-P concentrations (table 15) during "steady-state" conditions ranged from 0.05 to 0.65 mg/L at site 40 and from 1.2 to 7.0 mg/L downstream from the Springdale WWTP effluent. Phosphorus-P concentrations in the WWTP effluent ranged from 4.4 to 9.3 mg/L and ranged from 0.06 to 0.33 mg/L in tributary inflows. Arkansas water-quality standards (Arkansas Department of Pollution Control and Ecology, 1981) suggest as a "guideline" that total phosphorus-P concentrations not exceed 0.100 mg/L in streams. This guideline concentration was exceeded in 86 percent of the "steady-state" samples collected in the Spring Creek basin during this study. Phosphorus-P concentrations in runoff samples ranged from 0.71 to 1.5 mg/L (table 16).

Biological Characteristics

Phytoplankton.-- Observed phytoplankton densities were 4900 cells/mL at site 42 and 920 cells/mL at site 47 (table 20). Neither density indicates an algal bloom. At both sites the most dominant genus of phytoplankton was *Oscillatoria* (table 20). Phytoplankton chlorophyll *a* concentrations (table 21) were also higher at site 42 (7.09 µg/L) than at site 47 (2.35 µg/L).

Periphyton.-- Periphyton organic weights ranged from 1.03 to 1.41 g/m^2 (table 21). The dominant genera were *Navicula* and *Oscillatoria* (table 22). Periphyton chlorophyll *a* concentrations ranged from 7.73 to 18.5 g/m^2 (table 21).

Total and fecal coliform bacteria.-- Total coliform bacteria ranged from <1 to 25,000 colonies per 100 mL in Spring Creek and its tributaries (table 15). Fecal coliform bacteria (table 15) ranged from 420 to 740 colonies per 100 mL at site 40 and from <1 to 2100 colonies per 100 mL downstream from the Springdale WWTP outfall. Fecal coliform bacteria ranged from <3 to 400 colonies per 100 mL in the WWTP effluent. Tributary inflow concentrations ranged from 33 to 15,000 colonies per 100 mL. Most observed fecal coliform bacteria concentrations in Spring Creek, and several in Spring Creek tributaries, were greater than the Arkansas water-quality standard for April 1 to September 30 (Arkansas Department of Pollution Control and Ecology, 1981) of 200 colonies per 100 mL (geometric mean). Fecal coliform bacteria concentrations in runoff samples ranged from 96,000 to 670,000 colonies per 100 mL.

Reaeration Coefficient

Reaeration coefficients were measured in three reaches of Spring Creek using the hydrocarbon gas injection technique described in the "Instream Reaeration Coefficient" section. The stream reaches for which the measurements were made are upstream from Puppy Creek between miles 5.4 and 4.2 (fig. 26).

Ethylene gas and rhodamine WT dye were injected at mile 5.5. Samples were collected at miles 5.4, 4.9, and 4.2. Table 23 contains the resulting calculated values for k_T and k_2. As discussed in the "Instream Reaeration Coefficient" section, equations 6 and 5, were used to define k_T and k_2, respectively.

The Bennett-Rathbun reaeration coefficient predictive equation, which is available in the digital model used, reproduced the measured k_2 values reasonably well. The equation takes the following form,

$$k_2 = 8.76u^{0.607}h^{-1.689}(2.303)(1.0241)^{T-20} \quad (18)$$

where,

k_2 is as previously defined,

u = mean stream velocity, (feet per second),

h = mean stream depth, (feet), and

T = water temperature, °C.

Between stream miles 5.5 and 4.2 a mean cross-sectional area and depth of 24 ft^2 and 1.1 ft, respectively, were determined from observed data. Using the discharge of 22.7 ft^3/s and water temperature of 24.5°C measured during the gas injection experiment, and applying equation 18 yields a k_2 value of 18 day^{-1}. This is approximately 30 percent different than the measured values. Because of possible errors in geometry determination and in measurement of k_2 and discharge, this difference was considered acceptable. Therefore, the Bennett-Rathbun equation was used to simulate k_2 values for Spring Creek. Values of k_2, by subreach, computed during calibration-verification are shown on Attachment C-7 and C-28 under the column heading KA. Values of k_2, by subreach, computed for $Q_{7/10}$ low-flow projections are given in table 24.

Mean Velocity Interpretation

Time-of-travel data were collected on Spring Creek for a discharge of 23.8 ft^3/s at site 48 (figure 29). The discharges observed during the collection of the calibration and verification data sets ranged from 8.7 ft^3/s at mile 6.2 to 29.7 ft^3/s at the mouth and from 5.9 ft^3/s at miles 6.2 to 27.1 ft^3/s at the mouth, respectively.

Mean cross-sectional areas were computed for Spring Creek, by subreach, using techniques described in the earlier "Time of Travel" section. Many channel width measurements and observations were made during the collection of the 1979 and 1981 data sets. The ratio of the "subreach average" cross-sectional areas to "subreach average" channel widths were used to define "subreach average" depths. This data is shown in Attachment C-6 and C-27 for the calibration and verification data sets, respectively.

The mean velocities for the calibration and verification data sets are shown in table 25. These velocities are the result of the "fitted" channel geometry, based upon the measured times of travel (fig. 29) and the flow distributions for each data set. Mean velocities computed for the $Q_{7/10}$ low-flow projections with the projected Springdale WWTP flow imposed are given in table 24.

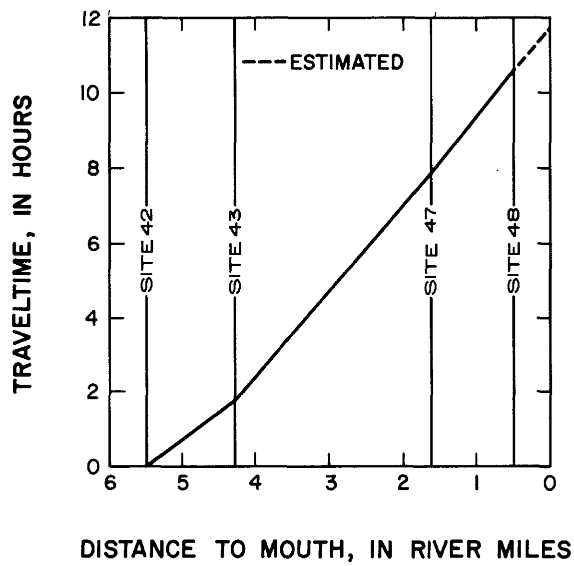

Figure 29.--Traveltime of peak dye concentration in Spring Creek, for a discharge of 23.8 cubic feet per second at site 48 (modified from Lamb, 1983).

Table 15.--Chemical, physical, and bacteriological data, Spring Creek, tributary streams, and Springdale wastewater-treatment plant effluent

[Five-digit numbers in parentheses are STORET parameter codes used for computer storage of data]

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimat carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
40	6.2	9-05-78	1400	4.4	332	7.9	5.4	0.11	420	1,600
		11-27-78	1515	14	276	7.4	2.9	.08	580	1,400
		7-23-79	1400	5.9	331	7.7	3.1	.16	K540	800
		8-24-81	1215	8.7	370	7.4	2.0	.23	740	----
41W	6.1	9-05-78	Composite	12	453	7.1	---	----	<56	<120
		11-27-78	---do---	26	423	7.5	>61	----	110	----
		7-23-79	---do---	15	---	---	>32	----	K400	K400
		8-25-79	---do---	12	510	7.2	>10	----	<3	<5
41a	5.9	7-23-79	1415	--	371	7.6	---	----	17	25
		8-24-79	1315	19	500	7.4	>12	----	0	1
42	5.5	9-05-78	1700	17	420	7.2	---	----	160	1,000
		11-27-78	1530	30	323	7.4	49	.12	3	K12
		7-24-79	1230	18	346	7.1	---	----	11	K25
		8-24-81	1145	22	460	7.3	---	----	<1	<1

See footnotes at end of table

Table 15.--Chemical, physical, and bacteriological data, Spring Creek, tributary streams, and Springdale wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (70300)	Suspended solids (residue at 105°C) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
40	9-05-78	1400	230	---	13	5.0
	11-27-78	1515	154	---	8.5	13
	7-23-79	1400	---	8	----	---
	8-24-81	1215	---	8	----	---
41[W]	9-05-78	Composite	351	---	51	44
	11-27-78	---do---	298	---	33	36
	7-23-79	---do---	---	20	----	---
	8-25-79	---do---	---	9	----	---
41a	7-23-79	1415	---	12	----	---
	8-24-81	1315	---	11	----	---
42	9-05-78	1700	300	---	40	36
	11-27-78	1530	223	---	17	24
	7-24-79	1230	---	10	----	---
	8-24-81	1145	---	6	----	---

See footnotes at end of table

Table 15.--Chemical, physical, and bacteriological data, Spring Creek, tributary streams, and Springdale wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
40	9-05-78	1400	0.20	0.39	0.01	2.9	0.03	0.05
	11-27-78	1515	.39	.05	.01	2.8	.20	.20
	7-23-79	1400	.22	.15	.03	3.2	.06	.65
	8-24-81	1215	.43	.08	.01	3.5	.26	.26
41[W]	9-05-78	Composite	4.0	1.8	.33	12	5.6	----
	11-27-78	---do---	1.9	3.0	.18	9.8	3.8	4.4
	7-23-79	---do---	---	5.4	1.1	15	6.9	8.1
	8-25-81	---do---	4.2	5.1	.43	13	6.7	9.3
41a	7-23-79	1415	1.6	1.8	.32	6.0	1.9	3.8
	8-24-81	1315	3.1	3.2	.27	8.5	3.9	7.0
42	9-05-78	1700	3.0	.50	.50	10	4.4	----
	11-27-78	1530	1.4	.92	.18	6.2	1.6	1.8
	7-24-79	1230	1.9	3.5	3.6	12	5.2	5.7
	8-24-81	1145	3.2	2.9	.99	8.8	4.8	6.3

See footnotes at end of table

Table 15.--Chemical, physical, and bacteriological data, Spring Creek, tributary streams, and Springdale WWTP effluent--Continued

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
43	4.3	9-05-78	1715	20	409	7.3	----	---	560	4,000
		11-27-78	1545	36	316	7.4	22	.06	3	K38
		7-24-79	1300	17	444	7.2	----	---	1,100	2,400
		8-24-81	1500	22	500	7.2	----	---	1,100	3,000
44[T]	4.2	9-05-78	1720	.75	350	7.8	5.8	.09	K5,700	8,000
		11-27-78	1600	7.1	---	---	3.7	.06	K3,400	K4,200
		7-24-79	1300	1.8	346	7.8	2.1	---	1,200	4,100
		8-24-81	1530	1.9	400	7.7	5.4	---	K15,000	K25,000
44a	4.1	7-24-79	1315	-----	445	7.2	----	---	------	------
45	3.1	7-25-79	1255	19	---	---	----	---	------	------
		9-01-81	1300	-----	---	---	----	---	------	------
45a	2.4	7-25-79	1105	-----	406	7.5	----	---	K630	K1,200

See footnotes at end of table

Table 15.--Chemical, physical, and bacteriological data, Spring Creek, tributary streams, and Springdale wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (70300)	Suspended solids (residue at 105°C) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
43	9-05-78	1715	393	--	37	32
	11-27-78	1545	220	--	15	23
	7-24-79	1300	---	13	----	---
	8-24-81	1500	---	6	----	---
44[T]	9-05-78	1720	221	--	10	1.0
	11-27-78	1600	203	--	8.5	8.0
	7-24-79	1300	---	7	----	----
	8-24-81	1530	---	6	----	----
44a	7-24-79	1315	---	14	----	----
45	7-25-79	1255	---	--	----	----
	9-01-81	1300	---	--	----	----
45a	7-25-79	1105	---	16	----	----

See footnotes at end of table

Table 15.--Chemical, physical, and bacteriological data, Spring Creek, tributary streams, and Springdale wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
43	9-05-78	1715	----	0.16	0.22	9.0	3.8	----
	11-27-78	1545	----	.58	.23	6.4	1.6	1.6
	7-24-79	1300	1.8	.85	3.4	12	4.4	4.4
	8-24-81	1500	1.6	.74	1.4	8.6	3.7	5.3
44[T]	9-05-78	1720	.81	.08	.02	2.4	.06	.08
	11-27-78	1600	----	.13	.01	4.2	.21	.24
	7-24-79	1300	.59	.07	.07	3.0	.11	.14
	8-24-81	1530	1.8	.13	.02	3.2	.29	.33
44a	7-24-79	1315	2.8	.85	3.4	13	4.2	4.3
45	7-25-79	1255	----	----	----	----	----	----
	9-01-81	1300	----	----	----	----	----	----
45a	7-25-79	1105	1.2	.76	2.0	6.0	2.7	3.0

See footnotes at end of table

Table 15.--Chemical, physical, and bacteriological data, Spring Creek, tributary streams, and Springdale wastewater-treatment plant effluent--Continued

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (μmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base e deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
46-T	2.3	9-05-78	1735	0.38	302	7.7	5.0	0.31	1,100	2,200
		11-27-78	1615	1.0	290	7.5	2.7	.14	K2,100	2,400
		7-24-79	1345	.50	304	7.5	6.3	.13	830	830
		8-24-81	1700	.13	360	7.4	1.8	----	K33	620
46a	2.2	7-25-79	1100	-----	406	7.4	---	----	K200	1,200
47	1.6	9-05-78	1745	22	413	7.6	---	----	-----	6,000
		11-27-78	1615	49	307	7.6	8.5	.12	K1,100	1,500
		7-24-79	1400	25	392	7.7	14	.09	1,300	----
		8-24-81	1715	26	420	7.7	5.9	.12	550	880
		9-01-81	----	----	---	---	----	----	-----	----
48	0.5	9-05-78	1800	24	398	7.9	----	----	2,100	4,400
		11-27-78	1630	53	302	7.6	7.5	.10	K1,100	1,800
		7-24-79	1430	27	388	7.7	14	.08	K180	690
		8-24-81	1730	30	400	7.8	4.5	.13	410	490

See footnotes at end of table

Table 15.--Chemical, physical, and bacteriological data, Spring Creek, tributary streams, and Springdale wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (70300)	Suspended solids (residue at 105°C) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
46T	9-05-78	1735	188	---	7.5	1.0
	11-27-78	1615	181	---	7.5	5.0
	7-24-79	1345	---	4	----	----
	8-24-81	1700	---	1	----	----
46a	7-25-79	1100	---	17	----	----
47	9-05-78	1745	290	--	35	29
	11-27-78	1615	206	--	12	18
	7-24-79	1400	---	13	----	----
	8-24-81	1715	---	14	----	----
	9-01-81	----	---	--	----	----
48	9-05-78	1800	262	--	28	22
	11-27-78	1630	202	--	12	17
	7-24-79	1430	---	11	----	----
	8-24-81	1730	---	4	----	----

See footnotes at end of table

Table 15.--Chemical, physical, and bacteriological data, Spring Creek, tributary streams, and Springdale wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
46[T]	9-05-78	1735	0.50	0.12	0.03	1.4	0.03	0.06
	11-27-78	1615	----	.07	.01	3.0	.10	.10
	7-24-79	1345	.45	.10	.09	2.2	.06	.11
	8-24-81	1700	.38	.07	.00	1.8	.16	.16
46a	7-25-79	1100	1.5	.14	.16	8.0	2.8	3.1
47	9-05-78	1745	----	.06	.06	9.4	3.0	----
	11-27-78	1615	----	.18	----	5.7	1.2	1.2
	7-24-79	1400	1.5	.12	.53	7.0	2.5	3.4
	8-24-81	1715	1.3	.12	.18	6.8	2.0	3.2
	9-01-81	----	----	----	----	---	----	----
48	9-05-78	1800	1.5	.06	.04	7.6	2.2	----
	11-27-78	1630	.95	.15	.08	5.5	1.2	1.2
	7-24-79	1430	1.2	.10	.23	7.1	2.4	2.8
	8-24-81	1730	1.1	.12	.03	5.6	1.5	2.7

[K] Plate count was outside ideal range.
[T] Tributary.
[W] Wastewater-treatment plant effluent.

Table 16.--Comparison of analyses of Spring Creek stormwater-runoff samples to means calculated from steady-state flow analyses in table 15

[Five digit numbers are STORET parameter codes used for computer storage of data]

Site number	River mile	"Steady-state" mean (S) or "Runoff" (R) sample	Date of collection	Time of collection	Discharge (ft^3/s) (00061)	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00310)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)
		R	5-13-81	1545	9.0	15.0	8.0	78	245	8.0
44[T]	4.2	R	5-31-81	0945	.94	15.0	8.5	83	455	7.0
		S	-------	----	2.9	----	---	--	365	---
46[T]	2.3	R	5-13-81	1920	12	16.5	8.5	87	140	7.6
		S	-------	----	.50	----	---	--	314	---

See footnotes at end of table

Table 16.--Comparison of analyses for Spring Creek stormwater-runoff samples to means calculated from steady-state flow analyses in table 15--Continued

Site number	"Steady-state" mean (S) or "Runoff" (R) sample	Date of collection	Time of collection (hour)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Streptococci, fecal (colonies per 100 mL) (31673)	Suspended solids (residue at 105°C) (mg/L) (00530)
	R	5-13-81	1545	17	0.12	K101,000	K335,000	173
44T	R	5-31-81	0945	14	.05	K670,000	K160,000	28
	S	-------	----	4.2	----	6,320	--------	6
46T	R	5-13-81	1920	23	.14	K96,000	K227,000	663
	S	-------	----	4.0	----	1,000	-------	2

See footnotes at end of table

Table 16.--Comparison of analyses for Spring Creek stormwater-runoff samples to means calculated from steady-state flow analyses in table 15--Continued

Site number	"Steady-state" mean (S) or "Runoff" (R) sample	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P (00665)
	R	5-13-81	1545	2.9	0.19	0.06	4.0	0.31	0.84
44[T]	R	5-13-81	0945	1.5	.17	.09	3.3	.50	.71
	S	-------	----	1.1	.10	.03	3.2	.17	.20
46[T]	R	5-13-81	1920	2.6	.53	.05	1.1	.91	1.5
	S	-------	----	.44	.09	.03	2.1	.09	.10

[K] Plate count was outside ideal range.
[T] Tributary.

Table 17.--Dissolved-oxygen and temperature data for Spring Creek, tributaries, and Springdale wastewater-treatment plant effluent

[Five-digit numbers in parentheses are STORET parameter codes used for computer storage of data]

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
40	9-05-78	1600	24.0	10.1	121
		2230	19.0	7.0	75
	9-06-78	0645	17.0	7.7	80
	11-27-78	1515	12.0	9.5	88
	7-23-79	1400	20.0	10.9	120
		2200	17.5	7.7	81
	7-24-79	0600	16.0	7.8	80
	8-24-81	1215	19.5	8.9	95
		2230	18.0	7.6	80
	8-25-81	0440	17.5	7.4	77
	8-30-81	1500	20.0	9.4	102
		1600	20.0	9.0	98
		1700	20.0	8.7	95
		1800	20.0	8.4	91
		1900	19.0	8.0	86
		2000	19.0	7.6	82
		2100	18.0	7.3	77
		2200	18.0	7.2	76
		2300	18.0	7.2	76
		2400	18.0	7.2	76
40	8-31-81	0100	18.0	7.2	76
		0200	18.0	7.2	76
		0300	18.0	7.2	76
		0400	18.0	7.2	76
		0500	18.0	7.2	76
		0600	18.0	7.2	76
		0700	18.0	7.2	76
		0800	17.5	7.2	75
		0900	18.0	7.5	79
		1000	18.0	7.9	83
		1100	18.5	8.3	88
		1200	19.0	8.6	93
		1300	19.5	8.9	96
		1400	20.0	8.9	97
		1500	20.0	8.9	97
41[W]	9-05-78	1600	28.5	7.8	101
		2230	27.5	7.4	94
	9-06-78	0640	25.5	7.3	89
	7-23-79	1400	26.0	8.0	99
		2215	27.0	7.7	97

See footnotes at end of table

Table 17.--Dissolved-oxygen and temperature data for Spring Creek, tributaries, and Springdale wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
41W	7-24-79	0600	26.0	7.2	89
	8-24-81	1300	26.5	7.3	90
		2235	27.5	7.3	92
	8-25-81	0450	26.5	7.0	90
41a	7-23-79	1415	24.5	8.7	104
		2010	27.0	7.4	93
	7-24-79	0600	25.0	7.4	89
	8-24-81	1315	26.5	7.6	94
		2250	24.5	7.4	88
	8-25-81	0455	18.5	7.1	76
42	9-05-78	1700	28.0	6.4	82
	9-09-78	0645	22.0	4.1	47
	11-27-78	1530	12.0	9.3	86
	7-27-79	0740	22.0	4.0	46
	8-24-81	1145	23.5	6.1	71
		2220	23.0	4.7	55
42	8-25-81	0430	21.0	4.6	51
	8-31-81	1545	26.0	6.7	82
		1645	26.0	6.1	74
		1745	25.0	5.9	71
		1845	25.0	5.5	66
		1945	24.0	5.3	62
		2045	24.0	5.3	62
		2145	23.5	5.2	61
		2245	23.5	5.3	62
		2345	23.0	5.1	59
	9-01-81	0045	23.0	5.0	58
		0145	23.0	4.9	57
		0245	22.5	5.0	58
		0345	22.0	4.8	55
		0445	22.0	4.8	55
		0545	21.5	4.9	55
		0645	21.5	5.0	56
		0745	21.5	5.2	58
		0845	22.0	5.8	66
		0945	23.5	5.7	67
		1045	24.0	6.0	71
		1145	24.0	6.0	71
		1245	24.0	5.8	68
		1345	24.0	5.8	68
		1445	24.0	5.7	67

See footnotes at end of table

Table 17.--Dissolved-oxygen and temperature data for Spring Creek, tributaries, and Springdale wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
42	9-01-81	1545	24.0	5.7	67
		1645	24.0	5.7	67
43	9-05-78	1715	28.0	6.5	83
	9-09-78	0655	21.5	3.5	40
	11-27-78	1545	11.5	8.8	81
	7-25-79	1000	23.0	5.9	69
	7-27-79	0750	21.5	4.7	53
	8-24-81	1500	25.0	6.2	75
		2310	22.5	3.5	40
	8-25-81	0510	22.0	4.1	47
	8-31-81	1530	25.5	6.5	79
		1630	25.5	6.5	79
		1730	25.0	6.1	74
		1830	24.5	5.5	66
		1930	24.0	4.8	57
		2030	23.5	4.6	54
		2130	23.5	4.5	53
		2230	23.0	4.5	52
		2330	23.0	4.5	52
43	9-01-81	0030	22.5	4.5	52
		0130	22.5	4.5	52
		0230	22.5	4.5	52
		0330	22.0	4.6	52
		0430	22.0	4.7	53
		0530	21.5	4.8	54
		0630	21.5	4.9	55
		0730	21.5	5.0	56
		0830	21.0	5.6	62
		0930	21.0	6.3	70
		1030	21.5	7.1	80
		1130	22.0	6.8	77
		1230	22.5	6.2	71
		1330	23.0	6.1	79
		1430	23.0	6.2	72
		1530	23.5	6.2	73
		1630	23.5	6.1	71
44T	9-05-78	1720	27.0	7.6	96
	11-27-78	1600	13.5	10.0	96
	7-25-79	1015	20.0	8.5	93
	8-24-81	1530	22.5	11.8	136
		2320	18.5	6.9	73
	8-25-81	0515	18.5	6.0	64

See footnotes at end of table

Table 17.--Dissolved-oxygen and temperature data for Spring Creek, tributaries, and Springdale wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
44a	7-24-79	1315	25.0	7.1	87
	7-27-79	1010	22.5	6.1	70
45	7-25-79	1100	23.0	4.7	55
	8-24-81	1600	24.0	8.3	98
		2325	22.0	4.8	54
	8-25-81	0535	21.0	5.0	56
45a	7-25-79	1105	23.0	4.6	54
46T	9-05-78	1735	28.5	7.3	95
	11-27-78	1615	11.0	10.1	92
	7-25-79	1110	22.5	9.4	109
	8-24-81	1700	24.0	7.6	89
		2335	21.0	5.6	62
	8-25-81	0550	20.0	4.9	53
46a	7-25-79	1100	23.0	4.7	55
47	9-05-78	1745	27.5	6.9	87
	9-09-78	0700	22.0	4.3	49
	11-27-78	1615	11.0	9.3	84
	7-25-79	1130	23.5	6.1	72
	7-27-79	0800	22.0	4.6	53
	8-24-81	1715	24.0	7.9	93
		2340	23.0	4.8	56
	8-25-81	0555	21.5	4.7	53
	9-01-81	1730	23.0	7.5	87
		1830	23.0	6.8	79
		1930	23.0	6.7	79
		2030	23.0	6.5	76
		2130	22.5	5.2	69
		2230	22.5	5.0	58
		2330	22.5	4.9	57
	9-02-81	0030	22.0	4.8	55
		0130	22.0	4.7	54
		0230	21.5	4.8	54
		0330	21.5	4.8	54
		0430	21.0	4.9	54
		0530	21.0	5.0	56

See footnotes at end of table

Table 17.--Dissolved-oxygen and temperature data for Spring Creek, tributaries, and Springdale wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
47	9-02-81	0630	20.5	5.0	55
		0730	20.5	5.2	57
		0830	20.5	5.8	64
		0930	21.0	6.4	71
		1030	21.0	7.0	78
		1130	21.5	7.4	81
		1230	22.0	7.8	89
		1330	22.5	8.0	92
		1430	22.5	8.0	92
		1515	23.0	8.3	96
48	9-05-78	1800	27.5	6.7	85
	9-09-78	0705	22.0	4.7	54
	11-27-78	1630	11.0	9.6	87
	7-25-79	1220	24.0	6.9	82
	7-27-79	0815	22.5	4.4	51
	8-24-81	1730	24.5	7.6	91
		2345	23.0	4.9	57
48	8-25-81	0600	21.5	4.9	56
	9-01-81	1730	23.5	8.7	102
		1830	23.0	8.0	93
		1930	23.0	7.3	85
		2030	23.0	6.6	77
		2130	22.5	6.0	69
		2230	22.5	5.7	66
		2330	22.0	5.5	63
	9-02-81	0030	22.0	5.4	61
		0130	22.0	5.3	60
		0230	22.0	5.2	59
		0330	21.5	5.2	58
		0430	21.5	5.1	57
		0530	21.0	5.2	58
		0630	21.0	5.2	58
		0730	21.0	5.3	59
		0830	21.0	5.9	66
		0930	21.0	6.4	71
		1030	21.0	7.1	79
		1130	21.5	7.6	85
		1230	22.0	7.9	90
		1330	23.0	8.3	97
		1430	23.5	8.3	97

T Tributary.
W Wastewater-treatment plant effluent.

Table 18.--Bottom-material analyses for Spring Creek

[Five-digit numbers in parentheses are STORET parameter codes used for computer storage of data]

Site number and (river mile)	Date of collection	Streambed oxygen demand ($g \cdot m^{-2} \cdot day^{-1}$ at 20°C)	Total organic plus ammonia nitrogen in bottom material (mg/kg as N) (00626)	Total nitrite plus nitrate nitrogen in bottom material (mg/kg as N) (00633)	Total ammonia nitrogen in bottom material (mg/kg as N) (00611)	Total phosphorus in bottom material (mg/kg as P) (00668)
40 (6.2)	8-30-81	0.66	---	---	---	---
42 (5.5)	8-31-81	0.81	---	---	---	---
43 (4.3)	8-29-81	0.82	---	---	---	---
47 (1.6)	8-29-81	0.83	---	---	---	---
48 (0.5)	11-27-78	----	260	0.0	8.9	490
	8-28-81	1.58	---	---	---	---

Table 19.--Net photosynthetic dissolved-oxygen production at selected sites on Spring Creek

Site number	River mile	Date (1981)	Net photosynthetic dissolved oxygen production [(mg/L)/d at 20°C]
40	6.2	August 30-31	8.4
42	5.5	August 31 - September 1	2.8
43	4.3	August 31 - September 1	8.8
47	1.6	September 1-2	17.0
48	0.5	September 1-2	24.1

Stream Model

Calibration and Verification

Attachment C contains the results of model calibration and verification. Model calibration output is on Attachments C-2 through C-22; verification output is on Attachments C-23 through C-43. The Spring Creek model was calibrated and verified using data collected in 1981 and 1979, respectively.

The success of the model calibration-verification procedure is illustrated by the "goodness-of-fit" between the model-derived and observed concentration profiles for the predictable variables. These profiles are shown on Attachments C-11 through C-20 and C-32 through C-41. The values of these coefficients and parameters defined during the calibration-verification process (as discussed in the "Calibration and Verification Procedure" section) are included on attachments C-6 and C-7 and again on Attachments C-27 and C-28. Values of k_d resulting from application of the Bosko equation (equation 15) to subreach average k_l values are shown in Attachment C-7 and C-28.

Two DO profiles were "fitted" for both the calibration and verification data sets, the diel-mean profile and the diel-minimum profile (Attachments C-19 and C-20 and Attachments C-40 and C-41). Subreach-average benthic demands, directly resulting from the "fitting" of the mean DO profile, are shown on Attachments C-6 and C-27. The adjustment factors used in fitting the model-derived diel-minimum DO profile to the observed minimum profile (as discussed in the "Simulation Techniques" section) are shown on Attachments C-6 and C-27. Verification of the "fitting" of the diel-minimum DO profile is shown on Attachment C-41.

Projections

Spring Creek simulations were made for projected Springdale WWTP effluent limits. The limits for CBODU, TSS, ammonia-N, and PO_4-P, respectively, in mg/L are:

1) 45, 30, 15, 10

2) 30, 20, 10, 10

3) 15, 15, 10, 10

4) 15, 15, 5, 5

5) 15, 10, 3, 5

Table 20.--Phytoplankton taxonomy and densities for Spring Creek

Scientific name	Common name	cells/milliliter Site 45	Site 47
Chlorophyta	Green algae		
.Chlorophyceae			
..Chlorococcales			
...Scenedesmaceae			
....*Scenedesmus*		57	---
Chrysophyta	Yellow-green algae		
.Bacillariophyceae	Diatoms		
..Centrales	Centric diatoms		
...Coscinodiscaceae			
....*Cyclotella*		140	14
..Pennales	Pennate diatoms		
...Achnanthaceae			
....*Cocconeis*		---	29
...Fragilariaceae			
....*Synedra*		29	---
...Gomphonemataceae			
....*Gomphonema*		14	---
...Naviculaceae	Naviculoids		
....*Navicula*		100	43
...Nitzschiaceae			
....*Nitzschia*		57	72
Cyanophyta	Blue-green algae		
..Hormogonales	Filamentous blue-greens		
...Oscillatoriaceae			
....*Oscillatoria* [1]		620	750
Euglenophyta	Euglenoids		
.Euglenophyceae			
..Euglenales			
...Euglenaceae			
....*Trachelomonas*		100	14

[1]Dominant organism, cell counts greater than or equal to 15 percent of total count for the station.

Table 21.--Phytoplankton and periphyton analyses for Spring Creek

[Five digit numbers in parentheses are STORET parameter codes used for computer storage of data]

Site number	River mile	Date of collection	Chlorophyll *a*, phytoplankton, chroma-Fl (µg/L) (70953)	Chlorophyll *b*, phytoplankton chroma-Fl (µg/L) (70954)	Phytoplankton (cells per mL) (60050)	Chlorophyll *a*, periphyton, chroma-Fl (mg/m^2) (70957)	Chlorophyll *b*, periphyton chroma-Fl (mg/m^2) (70958)	Periphyton; organic weight (g/m^2)	Biomass chlorophyll ratio periphyton (units) (70950)
42	5.5	8-24-81	7.09	2.37	4,900	----	----	----	----
45	3.1	9-01-81	2.92	<.01	1,100	18.5	3.96	1.41	76.2
47	1.6	8-24-81	2.35	<.01	920	----	----	----	----
		9-01-81	----	----	----	7.73	4.21	1.03	133

Table 22.--Periphyton taxa at Site 45, Spring Creek

[Periphyton strips placed in creek on 8-12-81, removed 9-01-81]

Scientific name	Common name
Chlorophyta	Green algae
.Chlorophyceae	
..Oedogoniales	
...Oedogoniaceae	
....*Oedogonium*	
Chrysophyta	Yellow-green algae
.Bacillariophyceae	Diatoms
..Centrales	Centric diatoms
...Coscinodiscaceae	
....*Cyclotella*	
..Pennales	Pennate diatoms
...Achnanthaceae	Yellow-green algae
....*Cocconeis*	
...Cymbellaceae	Centric diatoms
....*Cymbella*	
...Gomphonemataceae	
....*Gomphonema*	
...Naviculaceae	Naviculoids
....*Navicula* [1]	
....*Pinnularia*	
...Nitzschiaceae	
....*Nitzschia*	
Cyanophyta	Blue-green algae
.Cyanophyceae	
..Hormogonales	Filamentous blue-greens
...Oscillatoriaceae	
....*Oscillatoria* [1]	
Euglenophyta	Euglenoids
.Euglenophyceae	
..Euglenales	
...Euglenaceae	
....*Euglena*	

[1]Dominant organism, estimated to be greater than 15 percent of total algal cells on sampling strip.

Table 23.--Ethylene desorption rate and reaeration rate coefficients for selected reaches of Spring Creek

[Discharge = 22.7 ft^3/s]

Stream Reach					
Begin mile	End mile	k_T (day^{-1})	k_2 (day^{-1})	[a]Percent difference	Stream temperature (°C)
5.5	4.9	12.6	14.4	27	24.5
4.9	4.2	12.2	14.1	37	24.5
5.5	4.2	12.3	14.2	53	24.5

[a] Difference between percent change in gas concentration and percent change in dye concentration

6) 7.5, 5, 3, 2

7) 7.5, 5, 2, 1

Each of these projections was simulated twice; once using an effluent DO concentration of 5.0 mg/L and once using a DO concentration at saturation. All projections were made using a Springdale WWTP discharge of 19.9 ft^3/s, $Q_{7/10}$ stream conditions, and water temperatures reflecting summertime highs (29°C).

In addition, for comparative purposes, a simulation was made at $Q_{7/10}$, low-flow conditions and water temperatures of 29°C using "as surveyed" effluent concentrations and discharge. This simulation reflects water quality conditions at $Q_{7/10}$ flows in Spring Creek with existing waste loading.

Values of k_d resulting from a Bosko correction (equation 15) of subreach average k_l values for $Q_{7/10}$ low-flow velocities are shown in table 26. For reasons discussed in the "Simulation Techniques" section k_r was set equal to k_d in each subreach and benthic demands were modified, by subreach, using equation 16 (table 26).

The results of the Spring Creek projection simulations are shown in table 27. Average DO deficits are shown in table 28. When the net photosynthetic DO deficit is negative, net photosynthetic DO production is an oxygen source. The ammonia-N deficits tend to be the most significant except between river miles 2.3 and 0.0 where benthal deficits dominate. When projected ammonia-N concentrations in the WWTP effluent are less than 10 mg/L, benthal deficits dominate between miles 4.2 and 0.0. CBOD deficits are more significant than benthal DO deficits between miles 6.2 and 2.3 when the projected CBODU concentration from the WWTP is greater than or equal to 22.5 mg/L. Spring Creek will meet the Arkansas diel-minimum DO standard (Arkansas Department of Pollution Control and Ecology, 1981) of 4.0 mg/L with projected Springdale WWTP effluent limit 7 (CBODU = 7.5 mg/L, ammonia-N = 2.0 mg/L) imposed and effluent DO-concentrations set at saturation (7.7 mg/L). The simulation for "as surveyed" effluent conditions under $Q_{7/10}$ low-flow conditions results in an instream diel-minimum DO concentration of 0.0 mg/L (table 27).

Sensitivity Testing

The Spring Creek simulation with the projected Springdale effluent limit number 7 imposed and effluent DO concentration set to saturation (7.7 mg/L) was used for sensitivity testing. The criteria

Table 24.--Model-derived velocities and reaeration rate coefficients for Spring Creek low-flow projections

[Stream temperature = 29°C; discharge from Springdale wastewater-treatment plant = 19.9 ft^3/s]

Subreach Begin Mile	Subreach End Mile	Mean Discharge (ft^3/s)	Mean Velocity (ft/s)	k_2 (day^{-1})
6.2	6.1	1.14	0.114	10.03
6.1	6.0	20.9	.870	27.46
6.0	5.9	20.8	.866	27.36
5.9	5.5	20.5	.854	30.47
5.5	4.9	19.8	.825	18.96
4.9	4.2	19.0	.792	18.48
4.2	2.3	18.9	.555	12.39
2.3	1.4	18.7	.550	18.05
1.4	0.0	17.3	.468	20.85

used, and the parameters and coefficients tested for sensitivity, are listed in the "Model Sensitivity" section. Figures 30 through 42 show the resulting sensitivity bands.

For the flow conditions in the simulation tested, the DO profile is more sensitive to changes in reaeration coefficients and mean stream depths than any other parameter tested. The DO sensitivity bands for these parameters are shown in figures 34 and 40. The sensitivity of these parameters is not surprising considering the relatively fast velocities simulated (table 24) These two parameters are sensitive to velocity, especially if it is relatively fast, because k_2 is directly proportional to velocity and inversely proportional to depth as defined by Bennett-Rathbun in equation 18.

Spring Creek Conclusions

Under existing conditions, Spring Creek does not meet Arkansas standards (Arkansas Department of Pollution Control and Ecology, 1981) for the following parameters: diel-minimum DO, total phosphorus-P, water temperature, and fecal coliform bacteria. Stormwater-runoff sampling indicates that significant nutrient loads may be contributed to the stream during runoff periods. Nutrient loads contribute to benthic demands at lowflow and may be resuspended in the water column when velocities increase, or when the streambed is disturbed for any reason.

Both measured and simulated times of travel on Spring Creek are relatively fast for medium (29.7 ft^3/s) to low (10 ft^3/s) flows near the mouth.

Table 25.--Mean velocities, by subreach, for the 1979 and 1981 data sets collected on Spring Creek

Subreach		Velocities	
Begin Mile	End Mile	1979	1981
6.2	6.1	0.590	0.870
6.1	6.0	.812	.834
6.0	5.9	.752	.800
5.9	5.5	.754	.854
5.5	4.9	.744	.918
4.9	4.2	.723	.936
4.2	2.3	.559	.735
2.3	1.4	.657	.761
1.4	0.0	.705	.755

Consequently, mean velocities are relatively fast and reaction times for all nonconservative, reacting parameters are short. Simulations indicate that the most significant DO deficits are the ammonia deficit, benthal deficit, and the CBODU deficit. The ammonia-N deficits tend to be the largest except in subreaches 8 and 9 where benthal deficits dominate. When projected ammonia-N concentrations in the WWTP effluent are less than 10 mg/L, benthal deficits also dominate in subreach 7. CBODU deficits are more significant than benthal deficits in subreaches 1 through 7 when the projected CBODU concentration from the WWTP is greater than or equal to 22.5 mg/L.

Diel-minimum DO concentrations in Spring Creek resulting in part from the instream waste concentrations discharged by the Springdale WWTP will meet the diel-minimum DO concentration standard (Arkansas Department of Pollution Control and Ecology, 1981) of 4.0 mg/L with projected effluent limit number 7 (CBODU = 7.5 mg/L and ammonia-N = 2.0 mg/L) imposed and effluent DO concentration set at saturation (7.7 mg/L). The other projected effluent limits tested result in instream diel-minimum DO concentrations less than 4.0 mg/L. The simulated instream diel-minimum DO concentration of 4.26 mg/L (table 27) resulting from projected effluent limit number 7 is significantly higher than the diel minimum of 0.0 mg/L simulated for the "as surveyed" effluent conditions under $Q_{7/10}$ streamflow conditions.

Sensitivity testing indicates that the DO profile is most sensitive to stream depths and reaeration coefficients. This is not surprising considering the relatively fast velocities simulated (maximum of 0.916 ft/s, table 24).

Table 26.--Modified components and rate coefficients for Spring Creek simulations that include projected effluent limits for the Springdale wastewater-treatment plant

Subreach				
Begin mile	End mile	k_d (day^{-1})	k_r (day^{-1})	Benthic oxygen demand [(g/m^2)/d]
6.2	6.1	0.28	0.28	0.33
6.1	6.0	.49	.49	1.19
6.0	5.9	.48	.48	1.06
5.9	5.5	.45	.45	2.00
5.5	4.9	.35	.35	2.14
4.9	4.2	.34	.34	2.27
4.2	2.3	.23	.23	2.05
2.3	1.4	.26	.26	4.05
1.4	0.0	.23	.23	4.61

Table 27.—Spring Creek model-simulation summary at 7-day, 10-year low flow using existing and projected loadings from the Springdale wastewater-treatment plant

Initial River Conditions		Spring Creek WWTP										Instream Total Suspended Solids[1]			Downstream Dissolved Oxygen Profile Sag				Projected concentrations and loadings at the mouth of Spring Creek													
Discharge (ft³/s)	Dissolved oxygen (mg/L)	Discharge (ft³/s)	Dissolved oxygen (mg/L)	CBODU (mg/L)	Total organic-N (mg/L)	Total ammonia-N (mg/L)	Total NO2-N (mg/L)	Total NO3-N (mg/L)	Total PO4-P (mg/L)	Total suspended solids (mg/L)		Concentration (mg/L)	Location (mile)	Water Temperature (°C)	Minimum resulting from Prairie Grove effluent (mg/L)	Location (mile)	Absolute minimum (mg/L)	Location (mile)	Discharge (ft³/s)	Dissolved oxygen (mg/L)	CBODU (mg/L)	CBODU (lb/d)	Total organic-N (mg/L)	Total organic-N (lb/d)	Total Ammonia-N (mg/L)	Total Ammonia-N (lb/d)	Total NO2-N (mg/L)	Total NO2-N (lb/d)	Total NO3-N (mg/L)	Total NO3-N (lb/d)	Total PO4-P (mg/L)	Total PO4-P (lb/d)
1.2	6.1	[2]13.58	[2]7.2	[2]27	[2]4.10	[2]5.25	[2]0.76	[2]14.00	[2]6.8	[2]14.5		14	6.1	29	0.00	5.60	0.00	5.60	10.08	0.43	6.16	334.6	0.80	43.43	0.02	1.77	0.01	0.88	3.40	184.71	1.337	72.64
1.2	6.1	19.9	7.7	7.5	.00	2.0	.00	.00	1.0	5.0		5.2	6.1	29	4.26	5.00	4.26	5.00	16.40	6.53	5.41	478.2	.06	5.30	.01	0.88	.01	.88	0.97	85.74	0.352	31.11
1.2	6.1	19.9	7.7	7.5	.00	3.0	.00	.00	2.0	5.0		5.2	6.1	29	3.25	5.10	3.25	5.10	16.40	6.52	5.41	478.2	.06	5.30	.02	1.77	.01	.88	1.36	120.21	.694	61.34
1.2	6.1	19.9	7.7	15	.00	5.0	.00	.00	5.0	15		14.6	6.1	29	1.03	5.20	1.03	5.20	16.40	6.41	10.42	921.0	.06	5.30	.02	1.77	.02	1.77	2.13	188.27	1.721	152.11
1.2	6.1	19.9	7.7	15	.00	10	.00	.00	10	15		14.6	6.1	29	.00	5.70	.00	5.70	16.40	6.34	10.42	921.0	.06	5.30	.05	4.42	.03	2.65	4.07	359.75	3.433	303.44
1.2	6.1	19.9	7.7	22.5	.00	5.0	.00	.00	10	15		14.6	6.1	29	.88	5.10	.88	5.10	16.40	6.32	15.43	1363.8	.06	5.30	.02	1.77	.02	1.77	2.13	188.27	3.433	303.44
1.2	6.1	19.9	7.7	30	.00	10	.00	.00	10	20		19.4	6.1	29	.00	5.70	.00	5.70	16.40	6.17	20.44	1806.7	.06	5.30	.05	4.42	.03	2.65	4.07	359.75	3.433	303.44
1.2	6.1	19.9	7.7	45	.00	15	.00	.00	10	30		28.8	6.1	29	.00	5.80	.00	5.80	16.40	5.94	30.46	2692.3	.06	5.30	.07	6.19	.04	3.54	6.00	530.34	3.433	303.44
1.2	6.1	19.9	5.0	7.5	.00	2.0	.00	.00	1.0	5.0		5.2	6.1	29	3.85	5.20	3.85	5.20	16.40	6.53	5.41	478.2	.06	5.30	.01	.88	.01	.88	.97	85.74	.352	31.11
1.2	6.1	19.9	5.0	7.5	.00	3.0	.00	.00	2.0	5.0		5.2	6.1	29	2.80	5.30	2.80	5.30	16.40	6.52	5.41	478.2	.06	5.30	.02	1.77	.01	.88	1.36	120.21	.694	61.34
1.2	6.1	19.9	5.0	15	.00	5.0	.00	.00	5.0	15.0		14.6	6.1	29	.54	5.30	.54	5.30	16.40	6.41	10.42	921.0	.06	5.30	.02	1.77	.02	1.77	2.13	188.27	1.721	152.11
1.2	6.1	19.9	5.0	15	.00	10	.00	.00	10	15		14.6	6.1	29	.00	5.80	.00	5.80	16.40	6.34	10.42	921.0	.06	5.30	.02	4.42	.03	2.65	4.07	359.75	3.433	303.44
1.2	6.1	19.9	5.0	22.5	.00	5.0	.00	.00	10	15		14.6	6.1	29	.40	5.30	.40	5.30	16.40	6.32	15.43	1363.8	.06	5.30	.02	1.77	.02	1.77	2.13	188.27	3.433	303.44
1.2	6.1	19.9	5.0	30	.00	10	.00	.00	10	20		19.4	6.1	29	.00	5.80	.00	5.80	16.40	6.17	20.44	1806.7	.06	5.30	.05	4.42	.03	2.65	4.07	359.75	3.433	303.44
1.2	6.1	19.9	5.0	45	.00	15	.00	.00	10	30		28.8	6.1	29	.00	5.90	.00	5.90	16.40	5.94	30.46	2692.3	.06	5.30	.07	6.19	.04	3.54	6.00	530.34	3.433	303.44

[1]Represents mass balance immediately downstream from Springdale WWTP.
[2]Existing treatment-plant conditions (mean of 1979 and 1981 data)

Table 28.--Average dissolved oxygen deficits in Spring Creek, by subreach, for simulations that include projected changes in ultimate carbonaceous biochemical oxygen demand and ammonia-nitrogen concentrations from the Springdale wastewater-treatment plant

Stream discharge = 7-day, 10-year low flow, Temperature = 29°C

Subreach						
Beginning mile	Ending mile	CBOD deficit	Benthal deficit	Net photosynthetic deficit	Ammonia-N deficit	Nitrite-N deficit
CBODU = 45 mg/L, Ammonia-N = 15 mg/L						
6.2	6.1	0.05	0.100	-0.452	0.166	0.002
6.1	6.0	.20	.049	- .046	3.264	.003
6.0	5.9	.20	.044	- .033	3.040	.007
5.9	5.5	.18	.089	.170	4.357	.299
5.5	4.9	.15	.078	.138	1.534	.365
4.9	4.2	.15	.086	.101	.846	.380
4.2	2.3	.13	.099	.000	.217	.388
2.3	1.4	.13	.240	.028	.017	.082
1.4	0.0	.12	.357	- .118	.034	.024
CBODU = 30 mg/L, Ammonia-N = 10 mg/L						
6.2	6.1	0.05	0.100	-0.452	0.166	0.007
6.1	6.0	.14	.049	- .046	2.176	.002
6.0	5.9	.13	.044	- .044	2.027	.005
5.9	5.5	.12	.089	.170	2.905	.199
5.5	4.9	.10	.078	.138	1.022	.243
4.9	4.2	.10	.086	.101	.564	.234
4.2	2.3	.09	.099	.000	.145	.258
2.3	1.4	.09	.240	.028	.048	.054
1.4	0.0	.08	.357	- .118	.022	.016

Table 28.--Average dissolved oxygen deficits in Spring Creek, by subreach, for simulations that include projected changes in ultimate carbonaceous biochemical oxygen demand and ammonia-nitrogen concentrations from the Springdale wastewater-treatment plant--Continued

Stream discharge = 7-day, 10-year low flow, Temperature = 29°C

Subreach: Beginning mile	Subreach: Ending mile	CBOD deficit	Benthal deficit	Net photosynthetic deficit	Ammonia-N deficit	Nitrite-N deficit
CBODU = 22.5 mg/L, Ammonia-N = 5 mg/L						
6.2	6.1	0.05	0.100	-0.452	0.166	0.002
6.1	6.0	.10	.049	- .456	1.089	.001
6.0	5.9	.10	.044	- .033	1.454	.002
5.9	5.5	.09	.089	.170	1.454	.100
5.5	4.9	.08	.078	.138	.511	.122
4.9	4.2	.07	.086	.101	.282	.127
4.2	2.3	.07	.099	.000	.073	.130
2.3	1.4	.07	.240	.028	.024	.028
1.4	0.0	.06	.357	- .118	.012	.008
CBODU = 15 mg/L, Ammonia-N = 10 mg/L						
6.2	6.1	0.05	0.100	-0.452	0.166	0.002
6.1	6.0	.07	.049	- .046	2.176	.002
6.0	5.9	.07	.044	- .033	2.027	.005
5.9	5.5	.06	.089	.170	2.905	.199
5.5	4.9	.05	.078	.138	1.022	.243
4.9	4.2	.05	.086	.101	.564	.254
4.2	2.3	.04	.099	.000	.145	.259
2.3	1.4	.04	.240	.028	.048	.054
1.4	0.0	.04	.357	- .118	.023	.016

Table 28.--Average dissolved oxygen deficits in Spring Creek, by subreach, for simulations that include projected changes in ultimate carbonaceous biochemical oxygen demand and ammonia-nitrogen concentrations from the Springdale wastewater-treatment plant--Continued

Stream discharge = 7-day, 10-year low flow, Temperature = 29°C

Subreach						
Beginning mile	Ending mile	CBOD deficit	Benthal deficit	Net photosynthetic deficit	Ammonia-N deficit	Nitrite-N deficit
CBODU = 15 mg/L, Ammonia-N = 5 mg/L						
6.2	6.1	0.05	0.100	-0.452	0.166	0.002
6.1	6.0	.07	.049	- .046	1.089	.001
6.0	5.9	.07	.044	- .033	1.014	.002
5.9	5.5	.06	.089	.170	1.454	.100
5.5	4.9	.05	.078	.138	.511	.122
4.9	4.2	.05	.086	.101	.282	.127
4.2	2.3	.04	.099	.000	.073	.130
2.3	1.4	.04	.240	.028	.024	.028
1.4	0.0	.04	.357	- .118	.012	.008
CBODU = 7.5 mg/L, Ammonia-N = 3 mg/L						
6.2	6.1	0.05	0.100	-0.452	0.166	0.002
6.1	6.0	.03	.049	- .046	.654	.001
6.0	5.9	.03	.044	- .033	.609	.002
5.9	5.5	.03	.089	.170	.872	.060
5.5	4.9	.03	.078	.138	.307	.073
4.9	4.2	.03	.086	.101	.170	.076
4.2	2.3	.02	.099	.000	.044	.072
2.3	1.4	.02	.240	.028	.015	.017
1.4	0.0	.02	.357	- .118	.007	.005

Table 28.--Average dissolved oxygen deficits in Spring Creek, by subreach, for simulations that include projected changes in ultimate carbonaceous biochemical oxygen demand and ammonia-nitrogen concentrations from the Springdale wastewater-treatment plant--Continued

Stream discharge = 7-day, 10-year low flow, Temperature = 29°C

Subreach: Beginning mile	Subreach: Ending mile	CBOD deficit	Benthal deficit	Net photosynthetic deficit	Ammonia-N deficit	Nitrite-N deficit
CBODU = 7.5 mg/L, Ammonia-N = 2 mg/L						
6.2	6.1	0.05	0.100	-0.452	0.166	0.002
6.1	6.0	.03	.049	- .046	.436	.000
6.0	5.9	.03	.044	- .033	.406	.001
5.9	5.5	.03	.089	.170	.582	.040
5.5	4.9	.03	.078	.138	.205	.049
4.9	4.2	.03	.086	.101	.113	.051
4.2	2.3	.02	.099	.000	.030	.052
2.3	1.4	.02	.240	.028	.010	.011
1.4	0.0	.02	.357	- .118	.005	.003
Existing Conditions (see table 27)						
6.2	6.1	0.04	0.302	-0.452	0.166	0.002
6.1	6.0	.17	.116	- .065	1.554	.007
6.0	5.9	.13	.117	- .047	1.404	.010
5.9	5.5	.11	.253	.243	1.762	.235
5.5	4.9	.09	.291	.201	.484	.220
4.9	4.2	.08	.337	.149	.206	.186
4.2	2.3	.06	.572	.000	.039	.069
2.3	1.4	.05	1.235	.042	.013	.010
1.4	0.0	.04	2.152	- .183	.008	.004

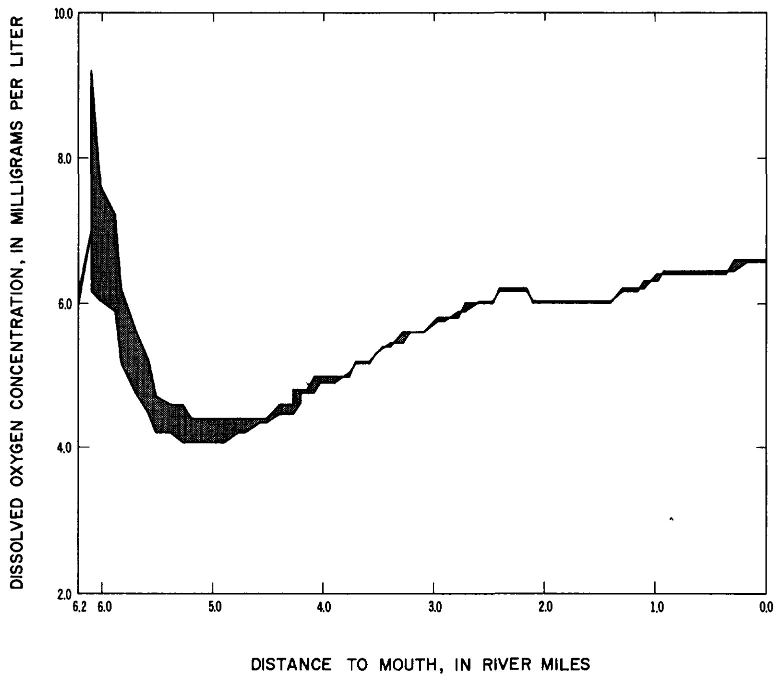

Figure 30.--Band reflecting the sensitivity of Spring Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the dissolved oxygen concentration of the effluent from the Springdale wastewater-treatment plant; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

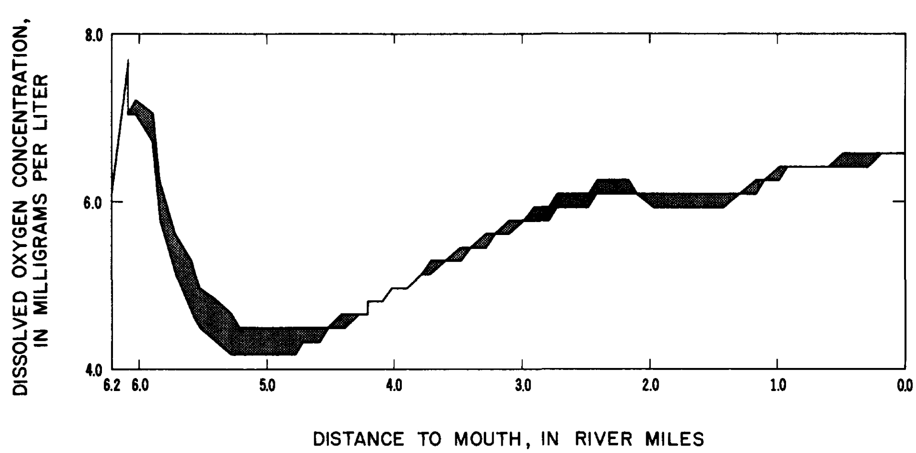

Figure 31.--Band reflecting the sensitivity of Spring Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the ammonia forward reaction and decay rates; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Springdale wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

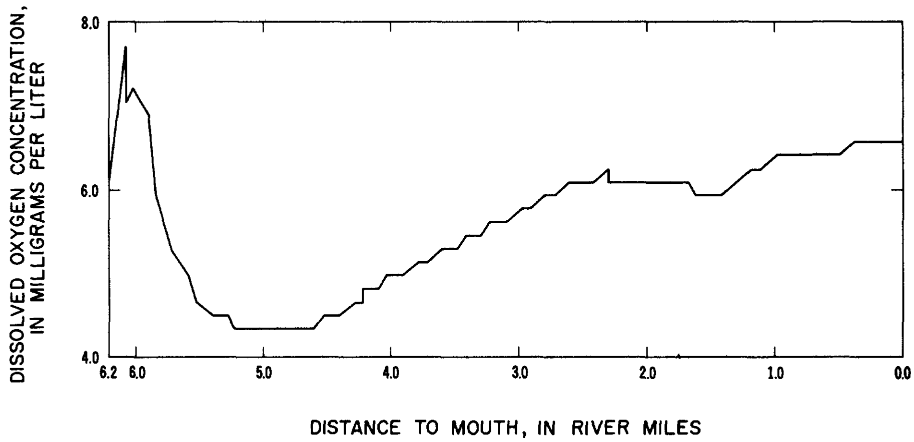

Figure 32.--Band reflecting the sensitivity of Spring Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the organic nitrogen forward reaction and decay rates; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Springdale wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L idssolved oxygen.

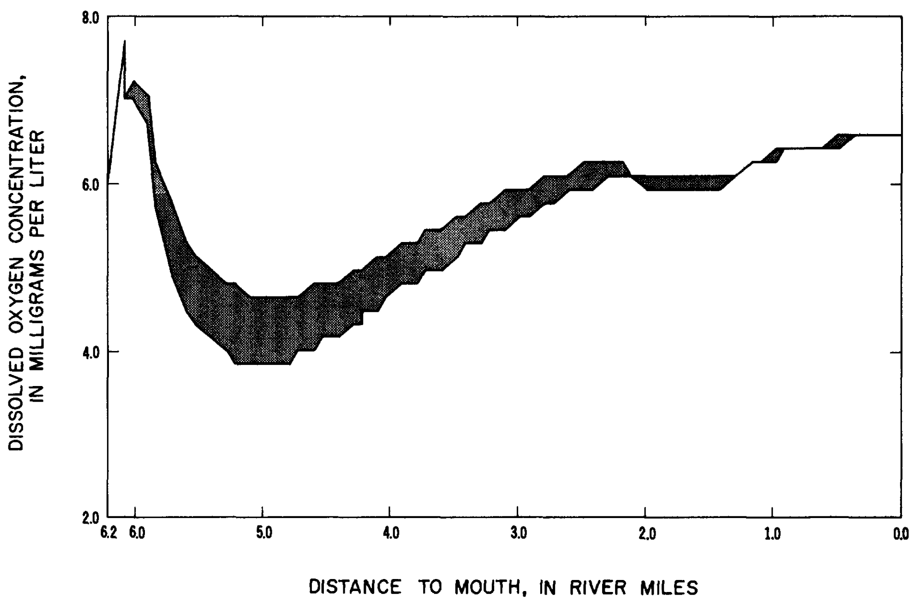

Figure 33.--Band reflecting the sensitivity of Spring Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the ammonia concentration of the effluent from the Springdale wastewater-treatment plant; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

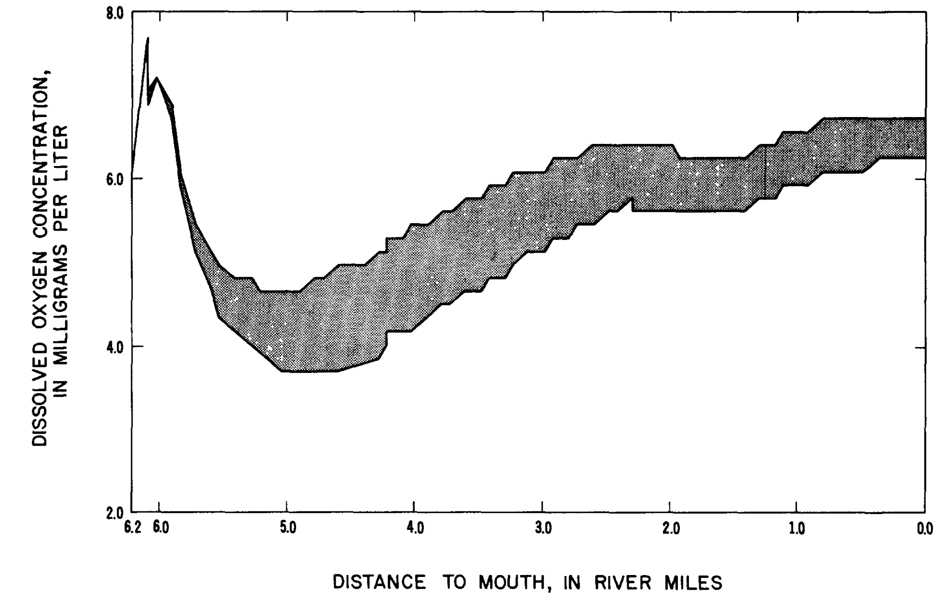

Figure 34.--Band reflecting the sensitivity of Spring Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the reaeration coefficients; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Springdale wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

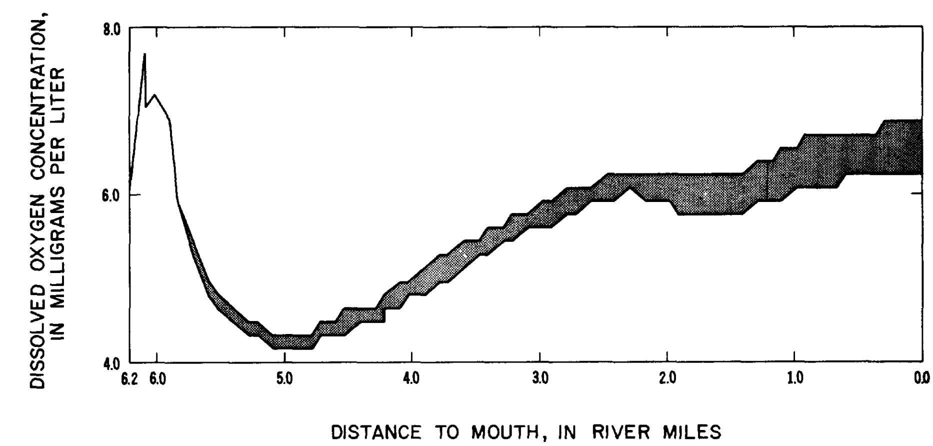

Figure 35.--Band reflecting the sensitivity of Spring Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the benthic demands; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Springdale wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

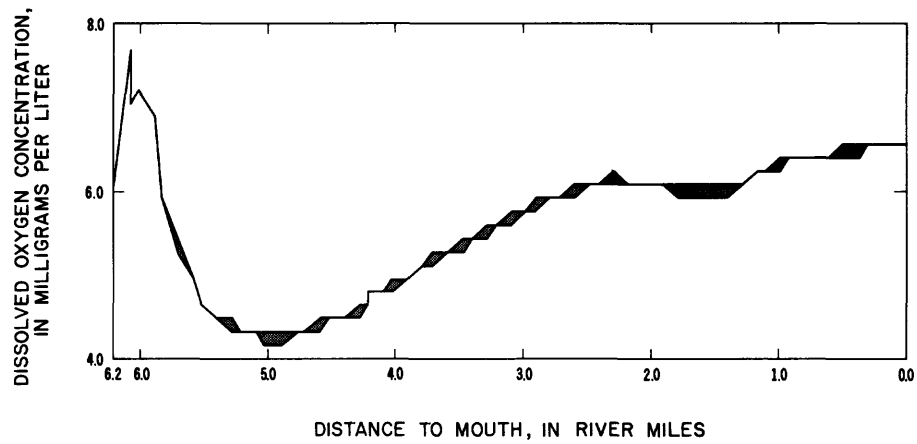

Figure 36.--Band reflecting the sensitivity of Spring Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the ultimate carbonaceous biochemical oxygen demand of the effluent from the Springdale wastewater-treatment plant; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

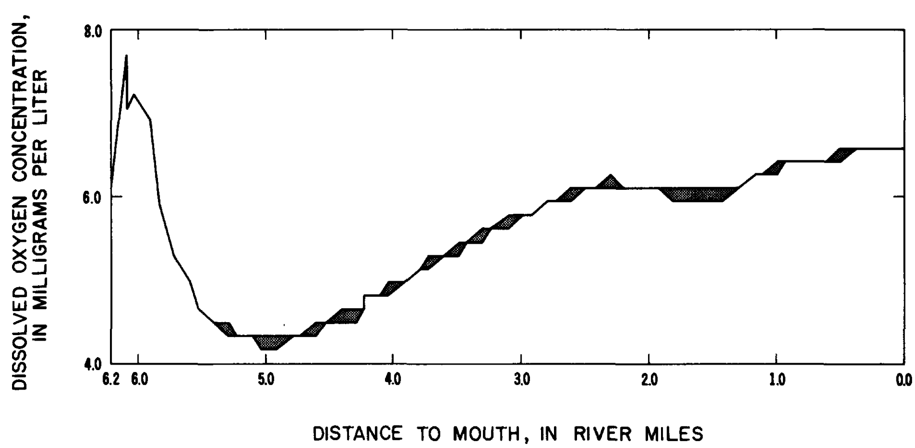

Figure 37.--Band reflecting the sensitivity of Spring Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the nitrite forward reaction and decay rates; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Springdale wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

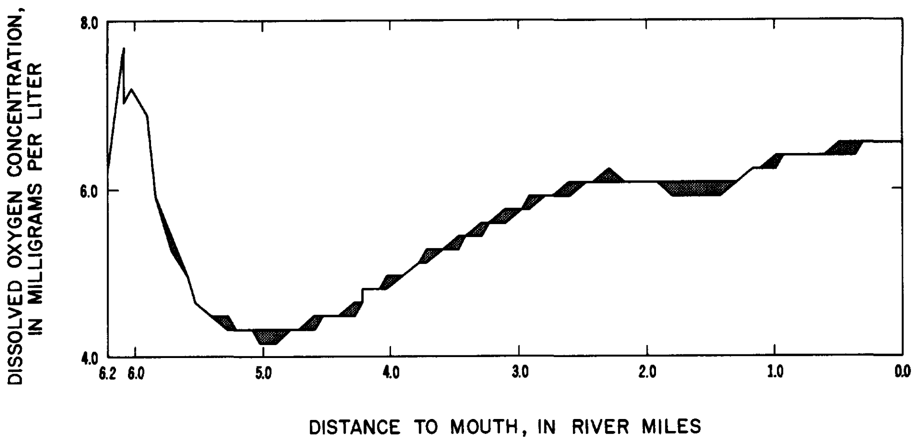

Figure 38.--Band reflecting the sensitivity of Spring Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the deoxygenation and removal rates for carbonaceous material; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Springdale wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

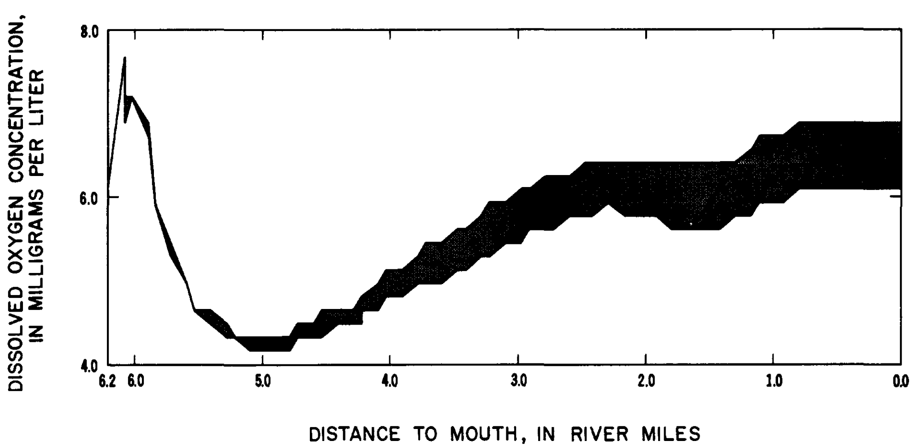

Figure 39.--Band reflecting the sensitivity of Spring Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the net photosynthetic production; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Springdale wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand; 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

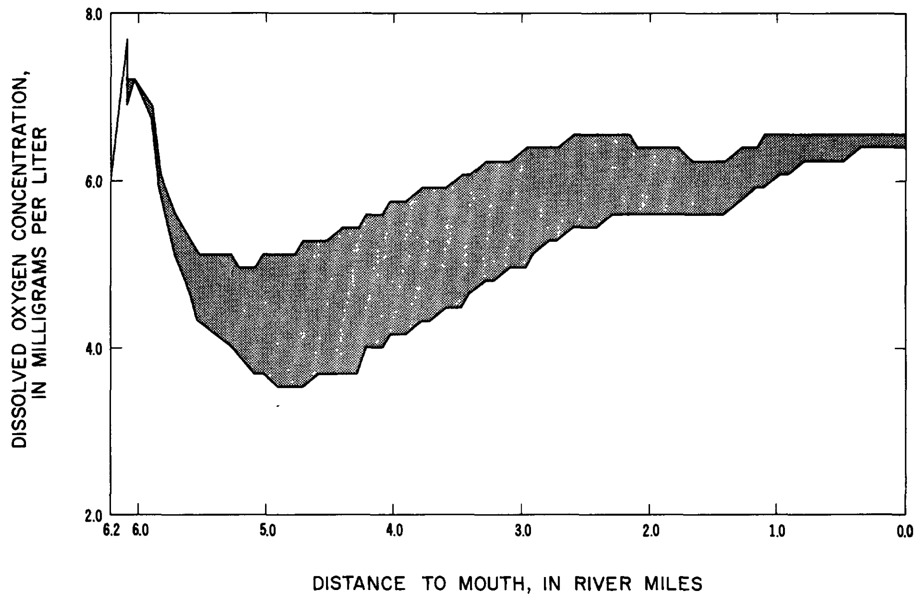

Figure 40.--Band reflecting the sensitivity of Spring Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in mean river depths; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Springdale wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

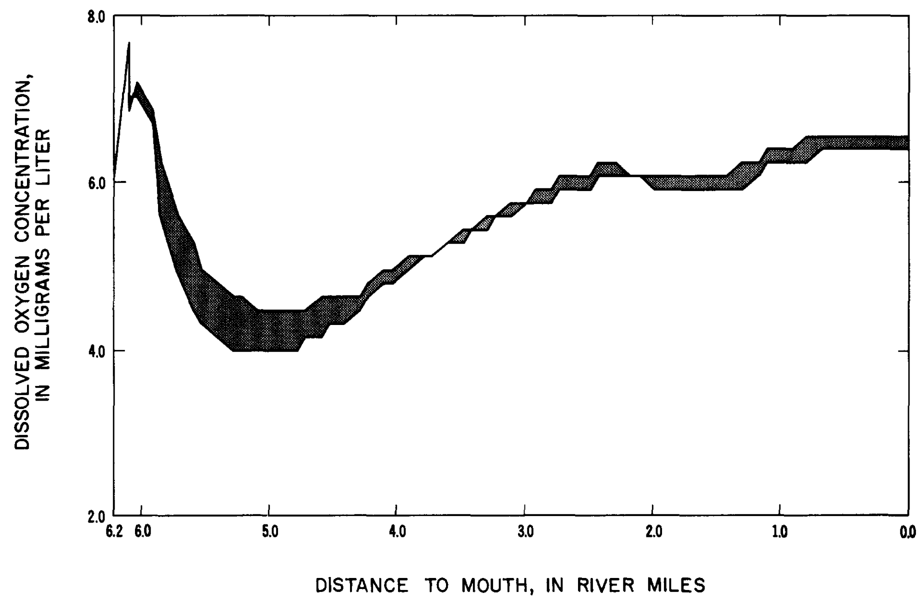

Figure 41.--Band reflecting the sensitivity of Spring Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in mean river velocities; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Springdale wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

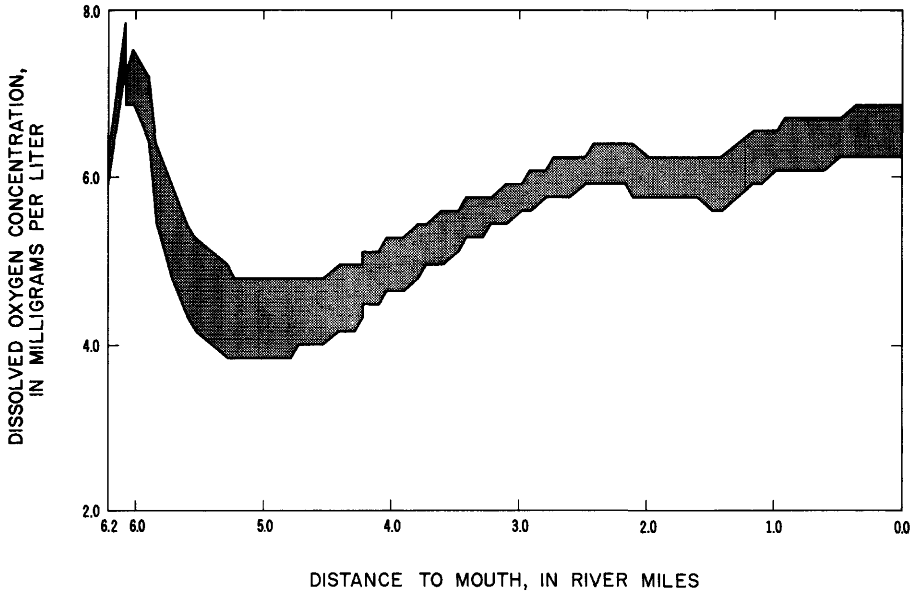

Figure 42.--Band reflecting the sensitivity of Spring Creek dissolved-oxygen concentrations to a plus or minus 2.0-degree celsius change in water temperature; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Springdale wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

OSAGE CREEK ASSESSMENT

Osage Creek (fig. 1) flows generally from northeast to southwest through pasture lands, small farms, and forested land into the Illinois River at mile 123.7. It has a total drainage area of 206 mi^2 at its mouth (Sullavan and Terry, 1970). The Rogers WWTP is the only point-source that discharges waste effluent directly into Osage Creek. The effluent currently enters the stream at mile 21.0. A proposed inflow point for the Rogers WWTP is at mile 20.0. The reach of Osage Creek modeled is from mile 21.1 to its mouth (fig. 43). A location index for sites where data were collected for the Osage Creek assessment is given in table 29.

Surface-Water Hydrology

Osage Creek is a partially canopied pool and riffle stream with some large pools. Channel slopes range from 50 ft/mi to 7.71 ft/mi in a downstream direction.

Cumulative flows in Osage Creek during collection of the calibration data set (Aug. 24-Sept. 5, 1981) ranged from 9.9 ft^3/s at mile 21.1 to 84.2 ft^3/s at the mouth (Attachment D-2, D-3, D-6, and D-21). Cumulative flows during collection of the verification data set (July 23-27, 1979) ranged from 6.5 ft^3/s at mile 21.1 to 90.3 ft^3/s at the mouth (Attachment D-23, D-24, D-27, D-42). In the 1981 data set, 39 percent of the total streamflow immediately downstream from the Rogers WWTP was effluent discharge. In the 1979 data set, the effluent discharge amounted to 40 percent of the total streamflow immediately downstream from its point of entry. These percentages are based on 24-hour average discharges from the Rogers WWTP.

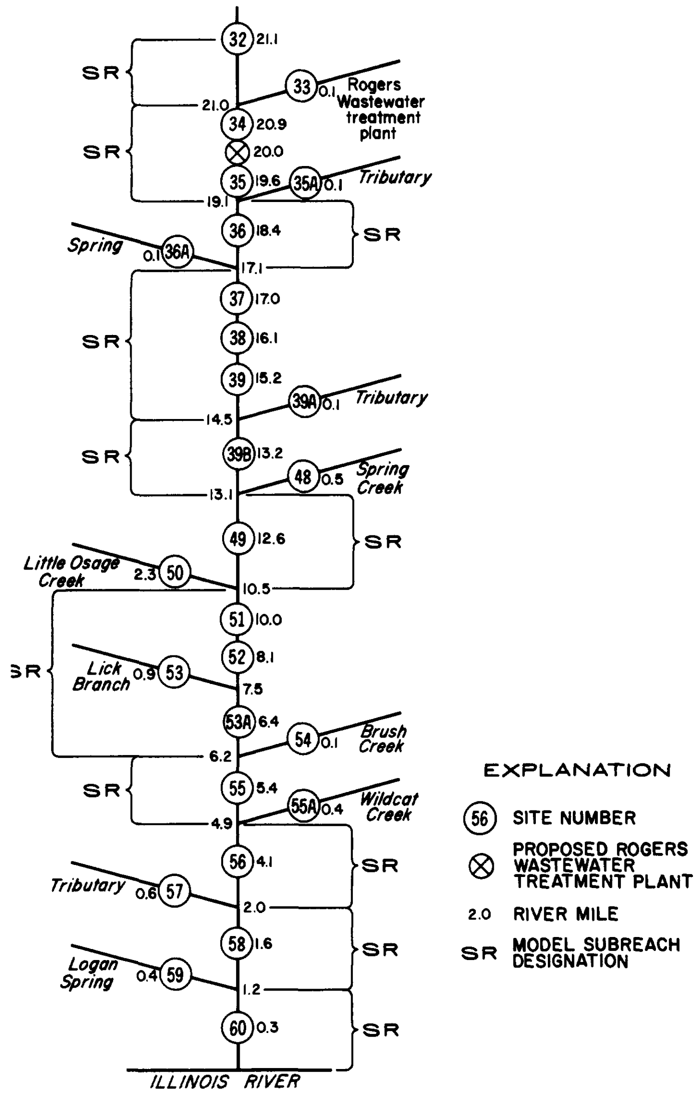

Figure 43.--Schematic of Osage Creek showing sampling-site and model-subreach locations.

Continuous hourly discharge data obtained from the Rogers WWTP for selected days indicate substantial variation over a 24-hour period (fig. 44). This variation in WWTP discharge causes an unsteady-flow condition in Osage Creek. Averaging the WWTP discharge over a 24-hour period simulates a quasi-steady inflow to Osage Creek and helps balance total flow downstream. However, there are still some inherent problems in defining times of travel and steady constituent transport. Similar problems occur when analyses are required on any stream for a "naturally occurring" steady flow condition that is masked by a manmade unsteady inflow. Discharges in Osage Creek are also affected by the Springdale WWTP downstream from the mouth of Spring Creek.

An existing $Q_{7/10}$ low-flow distribution (fig. 45) was defined on the basis of data presented by Hines (1975), and Hunrichs (1983). This distribution was established by mass-balancing total discharge at site 51 (table 29). The difference between the sum of initial and point-source $Q_{7/10}$ discharges and the established $Q_{7/10}$ discharge at site 51 was distributed linearly as flow loss between stream miles 21.1 and 10.0 (site 51) (fig. 45). From mile 10.0 to the mouth, tributary inflow was defined by Hunrichs (1983). No flow loss was assumed downstream from mile 10.0.

Table 29.--Osage Creek index for site name, and identification number, U.S. Geological Survey station number and location

Site Name	Site Identification Number	USGS Station Number	Location	
			Latitude	Longitude
Osage Creek at southeast corner of minnow farm	32	361855094111100	361855	0941111
Rogers WWTP	33	361854094111700	361854	0941117
Osage Creek near minnow farm	34	361853094112300	361853	0941123
Osage Creek one half mile south of Hart Cemetery	35	361822094123500	361822	0941235
Unnamed tributary near Liberty Bell	35A	361756094124300	361756	0941243
Osage Creek at dead end road	36	361756094131000	361756	0941310
Unnamed stream near Highway 112 north of Osage Creek	36A	361703094133500	361703	0941335
Osage Creek at bridge on Highway 112	37	361700094133600	361700	0941336
Osage Creek at bridge one mile north of Cave Springs	38	361634094140100	361634	0941401
Osage Creek on Highway 264 at Cave Springs	39	361556094141400	361556	0941414
Southwest of Cave Springs	39A	07194900	361528	0941402
Osage Creek upstream from Spring Creek	39B	361443094143700	361443	0941437
Spring Creek at Highway 112 bridge	48	361437094141900	361437	0941419
Osage Creek at county road bridge	49	361426094151300	361426	0941513
Little Osage Creek at Healing Springs	50	07194950	361514	0941614
Osage Creek near Elm Springs, Arkansas	51	07195000	361319	0941718
Osage Creek in bend by county road	52	361236094183800	361236	0941838
Lick Branch at county road bridge	53	361257094184500	361257	0941845
Osage Creek at end of county road	53A	361208094193300	361208	0941933
Brush Creek northwest of Thornsberry Church	54	361202094193000	361202	0941930
Osage Creek at county road bridge	55	361148094201600	361148	0942016
Wildcat Branch on Highway 68	55A	361117094201300	361117	0942013
Osage Creek three fourths mile below Wildcat Branch	56	361138094210500	361138	0942105
Galey Hollow at Logan	57	361201094230000	361201	0942300
Osage Creek at Logan	58	361128094231700	361128	0942317
Logan Springs below Fish Hatchery	59	361133094232700	361133	0942327
Osage Creek at Highway 68 bridge	60	361048094240600	361048	0942406

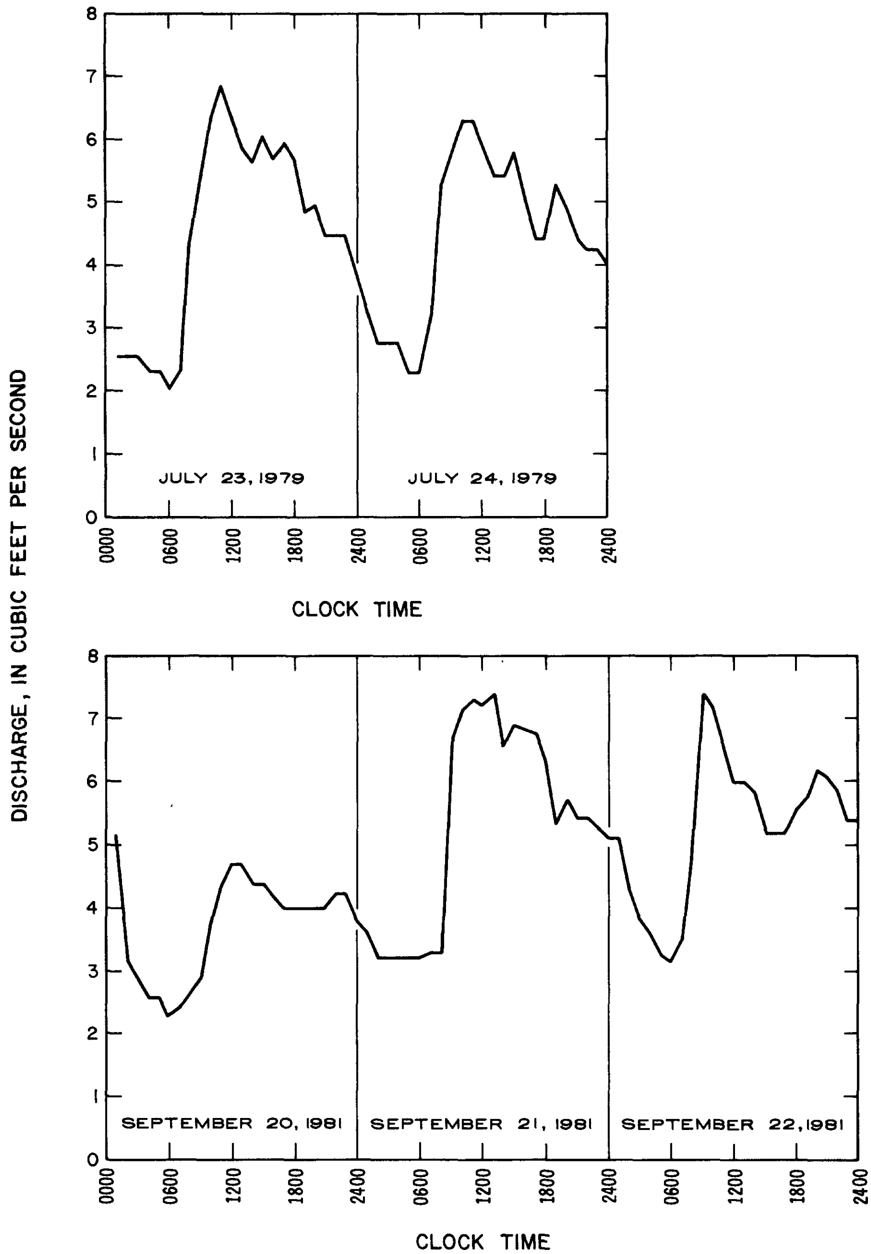

Figure 44.--Rogers wastewater-treatment plant discharge for selected days.

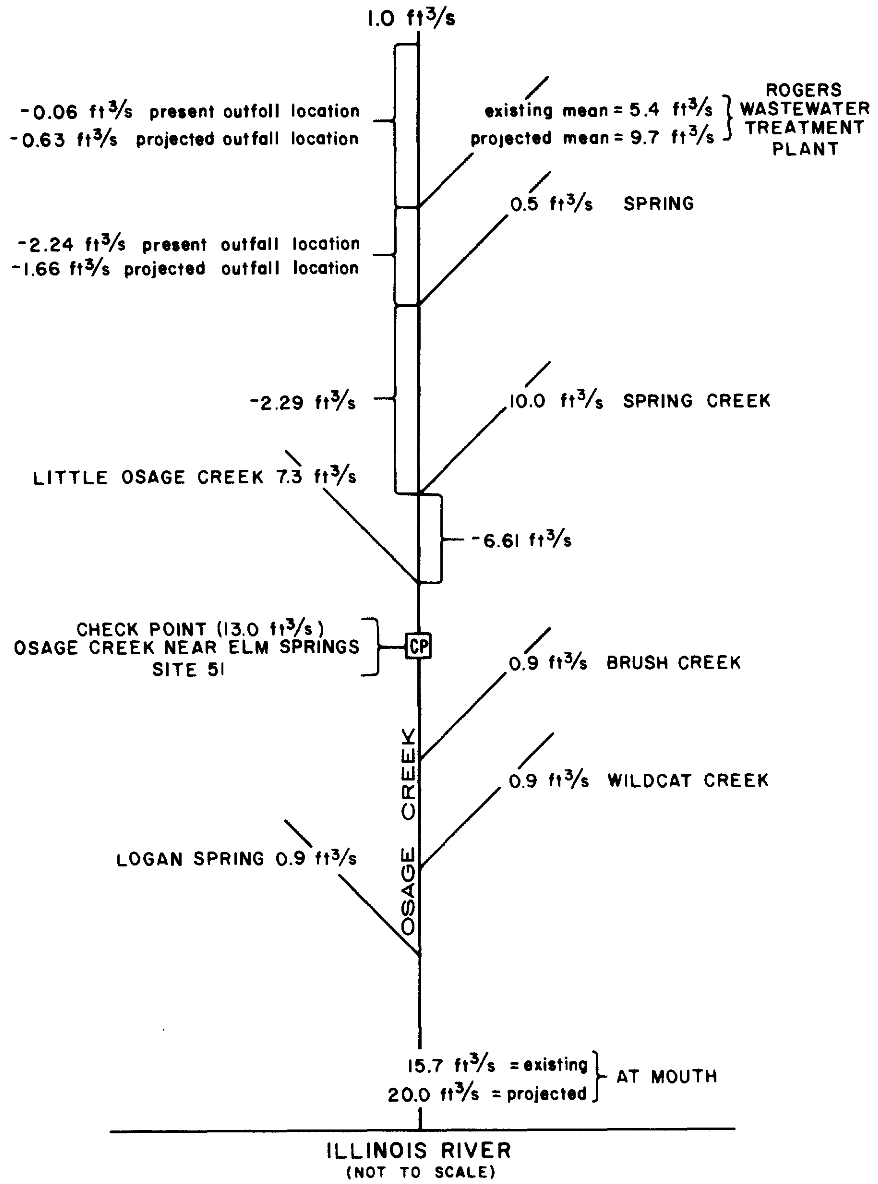

Figure 45.--7-day, 10-year low flow distribution for Osage Creek.

Water Quality

Physical Characteristics

Suspended solids.-- During the collection of "steady-state" data in 1978, 1979, and 1981, suspended-solids concentrations in Osage Creek ranged from 5 to 7 mg/L at site 32 upstream from the Rogers WWTP and from 4 to 19 mg/L downstream (table 30). Concentrations in the Rogers WWTP effluent ranged from 18 to 25 mg/L. Tributary inflow concentrations ranged from 1 to 39 mg/L. The concentration of suspended solids at site 35a during stormwater-runoff was more than 40 times greater than in nearby tributaries during periods of lower flow (table 31). Because site 35a was not sampled during "steady-state" conditions, table 31 compares site 35a with sites on two nearby tributaries. Sources of suspended solids during higher flow periods are resuspension of deposited material and overland flow of stormwater runoff. Nutrients and bacteria attached to suspended solids may be transported into streams by stormwater runoff.

Water temperature.-- Temperatures of the Rogers WWTP effluent were generally 3 to 5°C warmer than temperatures of Osage Creek upstream of the WWTP effluent (table 32). Temperatures at sites 34 and 35 were generally 3 to 4°C warmer than at site 32 and indicate that the WWTP effluent may increase water temperatures in Osage Creek more than the 2.8°C allowed by the Arkansas water-quality standard (Arkansas Department of Pollution Control and Ecology, 1981).

Dissolved solids.-- Dissolved-solids concentrations for the 1978 "steady-state" sampling periods ranged from 157 to 262 mg/L in Osage Creek, from 280 to 320 mg/L in the Rogers WWTP effluent, and from 142 to 262 mg/L in tributaries sampled (table 30). The data indicate that Arkansas stream water quality standards (Arkansas Department of Pollution Control and Ecology, 1981) for total dissolved solids were being violated at one site.

The minimal dissolved-solids concentrations in the stormwater-runoff sample at site 35a (table 31) estimated from the measured specific conductance value was 184 mg/L.

Chemical and Biochemical Characteristics

Chloride.-- Chloride concentrations for the 1978 "steady-state" sampling periods ranged from 6.0 to 24 mg/L in Osage Creek, from 36 to 52 mg/L in the Rogers WWTP effluent and from 7.5 to 28 mg/L in sampled tributaries (table 30). The data indicate that Arkansas stream water quality standards (Arkansas Department of Pollution Control and Ecology, 1981) for chloride were violated at four sites.

Sulfate.-- Sulfate concentrations for the 1978 "steady-state" sampling periods ranged from 6.0 to 17 mg/L in Osage Creek, from 34 to 40 mg/L in the Rogers WWTP effluent and from 2 to 22 mg/L in sampled tributaries (table 30). The data indicate that Arkansas stream water quality standards (Arkansas Department of Pollution Control and Ecology, 1981) for sulfate were violated at one site.

pH.-- Values of pH in Osage Creek, ranged from 7.0 to 8.1, were 7.3 in the WWTP effluent, and ranged from 7.2 to 8.4 in tributary inflows (table 30).

Dissolved oxygen.-- DO concentrations in Osage Creek ranged from 5.9 to greater than 10 mg/L at site 32 upstream from the Rogers WWTP outfall and from 2.2 to 10.5 mg/L downstream from the WWTP outfall (table 32). Concentrations in the WWTP effluent ranged from 4.5 to 6.3 mg/L and tributary inflow concentrations ranged from 4.4 to 15.3 mg/L. Accoring to Arkansas water-quality standards (Arkansas Department of Pollution Control and Ecology, 1981) an instantaneous minimum DO concentration in Osage Creek shall be greater than or equal to 4.0 mg/L.

Ultimate carbonaceous biochemical oxygen demand.-- During "steady-state" conditions CBODU ranged from 2.1 to 3.2 mg/L at site 32 upstream from the Rogers WWTP outfall and from 2.6 to 28 mg/L downstream from the outfall (table 30). CBODU concentrations in the effluent ranged from 25 to 66 mg/L. Tributary inflow concentrations ranged from 1.6 to 7.5 mg/L. The CBODU concentration in the stormwater-runoff sample was greater than 50 mg/L (table 31).

Streambed oxygen demand.-- A "streambed oxygen demand" of 0.65 $(g/m^2)/d$ was measured for a sample collected at site 32 upstream of the Rogers WWTP outfall. "Streambed oxygen demands" downstream from the WWTP ranged from 0.55 to 0.94 $(g/m^2)/d$ (table 33).

Net photosynthetic dissolved-oxygen production. --"Net DO production" was calculated as discussed previously in the general "Net Photosynthetic Dissolved-Oxygen Production" section. It ranged from 1.4 to 8.8 (mg/L)/d (table 34). Chlorophyll *a* concentrations used in calculations were distance-weighted estimates based on actual chlorophyll *a* concentrations at sites 35, 39, 51, and 58. For modeling purposes net DO production was calculated for each subreach (see "Simulation Techniques" section and Attachment D-6 and D-27).

Nutrients.-- Analyses indicate nutrient enrichment of Osage Creek and its tributaries (table 30). Analyses of one stormwater-runoff sample (table 31) at site 35a indicate that the Rogers WWTP is not the sole cause of the nutrient enrichment. Nutrient concentrations were much greater in the single runoff sample than during "steady-state" conditions at the two nearby tributaries. This suggests that nutrients deposited on the streambed were resuspended as velocities increased and/or that overland runoff of stormwater transported nutrients into the stream.

During "steady-state" conditions organic-N concentrations (table 30) ranged from 0.28 to 1.5 mg/L at site 32 upstream from the Rogers WWTP effluent and from 0.22 to 1.8 mg/L downstream from the WWTP effluent. Concentrations in the effluent ranged from 2.2 to 5.2 mg/L and in tributary inflows ranged from 0.20 to 1.5 mg/L. The concentration of organic-N in the stormwater-runoff sample was 8.2 mg/L and was more than eight times greater than mean "steady-state" concentrations for nearby tributaries (table 31).

During "steady-state" conditions, ammonia-N concentrations (table 30) ranged from 0.08 to 0.15 mg/L at site 32 and from 0.01 to 1.9 mg/L at sites downstream from the WWTP effluent. Concentrations in the WWTP effluent ranged from 1.0 to 3.0 mg/L. Tributary inflow concentrations ranged from 0.02 to 0.19 mg/L. Ammonia-N concentration in the stormwater-runoff sample was 3.8 mg/L (table 31).

The NO_2-N concentrations (table 30) in "steady-state" condition samples ranged from 0.01 to 0.04 mg/L at site 32 and from 0.01 to 0.81 mg/L at sites downstream from the WWTP effluent. The NO_2-N concentrations in the effluent ranged from 0.04 to 0.77 mg/L and in tributary inflows ranged from 0.01 to 0.23 mg/L. The concentration in the runoff sample was 0.10 mg/L (table 31).

During "steady-state" conditions, NO_3-N concentrations (table 30) ranged from 2.6 to 4.6 mg/L at site 32 and from 0.52 to 8.3 mg/L at sites downstream from the WWTP effluent. The NO_3-N concentrations in the WWTP effluent ranged from 6.0 to 8.1 mg/L and ranged from 1.1 to 7.6 mg/L in tributary inflows. The concentration in the stormwater-runoff sample was 0.87 mg/L (table 31).

During the "steady-state" conditions, PO_4-P and phosphorus-P concentrations generally decreased downstream from the WWTP effluent (table 30 and Attachment D-12 and D-33). PO_4-P concentrations ranged from 0.03 to 0.09 mg/L at site 32 and from 0.44 to 5.9 mg/L downstream from the WWTP effluent. PO_4-P concentrations ranged from 3.8 to 11 mg/L in the WWTP effluent. Tributary inflow concentrations ranged from 0.01 to 2.4 mg/L. The PO_4-P concentration in the stormwater-runoff sample was 0.93 mg/L (table 31).

Phosphorus-P concentrations (table 30) during "steady-state" conditions ranged from 0.05 to 0.11 mg/L at site 32 and from 0.44 to 7.3 mg/L downstream from the Rogers WWTP effluent. Phosphorus-P concentrations in the WWTP effluent ranged from 4.2 to 14 mg/L and ranged from 0.02 to 2.8 mg/L in tributary inflows. Arkansas water-quality standards (Arkansas Department of Pollution Control and Ecology, 1981) suggest as a "guideline" that total phosphorus-P concentrations not exceed 0.100 mg/L in streams. This guideline was exceeded in 83 percent of the "steady-state" samples collected in the Osage Creek basin (excluding Spring Creek and its tributaries) during this study. The phosphorus-P concentration in the stormwater runoff sample was 3.0 mg/L (table 31).

Biological Characteristics

Phytoplankton.-- Phytoplankton densities ranged from 380 to 1,200 cells/mL (table 35). These densities do not indicate an algal bloom. The most dominant genera of phytoplankton were *Anacystis, Coelastrum* and *Anabaena* (table 35). These genera are typically found in eutrophic waters; *Anacystis* and *Anabaena* are common genera associated with algal blooms (Greeson, 1982). Phytoplankton chlorophyll *a* concentrations ranged from 1.59 to 2.76 μg/L (table 36).

Periphyton.-- Periphyton organic-weights ranged from 1.03 to 4.6 g/m^2 (table 36). The dominant genera were *Coleochaete, Lyngbya* and *Oscillatoria* (table 37). *Lyngbya* is commonly found in eutrophic waters (Greeson, 1982). Periphyton chlorophyll *a* concentrations ranged from 7.73 to 73.5 mg/m^2 (table 36).

Total and fecal coliform bacteria.-- Total coliform bacteria ranged from 12 to 18,000 colonies per 100 mL in Osage Creek and its tributaries (table 30). Fecal coliform bacteria (table 30) ranged from 330 to 2,100 per 100 mL at site 32 and from 3 to 5,400 colonies per 100 mL downstream from the Rogers WWTP outfall. Fecal coliform bacteria ranged from less than 50 to greater than 170 per 100 mL in the WWTP effluent. Tributary inflow concentrations ranged from 70 to 5,400 per 100 mL. Most observed fecal coliform bacteria concentrations in Osage Creek, and several in Osage Creek tributaries, were greater than the Arkansas water-quality standard for April 1 to September 30 (Arkansas Department of Pollution Control and Ecology, 1981) of 200 colonies per 100 mL (geometric mean). The fecal coliform bacteria concentration in the runoff sample was 143,000 colonies per 100 mL.

Reaeration Coefficient

Reaeration coefficients were measured in three reaches of Osage Creek using the hydrocarbon gas injection technique described in the "Instream Reaeration Coefficient" section. The stream reaches for which the measurements were made are downstream from Brush Creek between miles 6.1 and 4.2 (fig. 43).

Ethylene gas and rhodamine WT dye were injected at mile 6.5. Samples were collected at miles 6.1, 5.4, and 4.2. Table 38 contains the resulting calculated values for k_T and k_2. As discussed in the "Instream Reaeration Coefficient" section, equations 6 and 5 were used to define k_T and k_2, respectively.

The Bennett-Rathbun reaeration coefficient predictive equation, which is available in the digital model used, can reproduce the measured k_2 values reasonably well. The expression, which was numbered as equation 18 in an earlier section of this report, takes the following form,

$$k_2 = 8.76u^{0.607}h^{-1.689}(2.303)(1.0241)^{T-20}$$

where,

k_2 is as previously defined,

u = mean stream velocity, (feet per second),

h = mean stream depth, (feet), and

T = water temperature, °C.

Between stream miles 6.1 and 5.4 a mean cross-sectional area and depth of 58 ft^2 and 1.6 ft, respectively, were observed during the gas and dye sampling period. Using the discharge of 51.4 ft^3/s and water temperature of 21°C measured during the gas injection experiment, and applying equation 18 yields a k_2 value of 8.4 day^{-1}. A mean cross-sectional area and depth of 80 ft^2 and 1.2 ft, respectively, were observed between miles 5.4 and 4.2. Inserting these values, along with the discharge and temperature data, into equation 14 yields a k_2 value of 11.3 day^{-1}. These computed values of k_2 compare very well to those measured (table 38). Therefore, the Bennett-Rathbun equation was used to simulate k_2 values for Osage Creek. Values of k_2, by subreach, computed during calibration-verification are shown on Attachment D-7 and D-28 under the column heading "KA". Values of k_2, by subreach, computed for $Q_{7/10}$ low-flow projections are given in table 39.

Mean Velocity Interpretation

Time of travel data were collected on Osage Creek for an average discharge of 56 ft^3/s at site 51. The reaches studied are from mile 21.1 to the mouth (fig 46). The discharges observed during the collection of the calibration and verification data sets ranged from 9.9 ft^3/s at mile 21.1 to 84.2 ft^3/s at the mouth and from 6.5 ft^3/s at mile 21.1 to 90.3 ft^3/s at the mouth, respectively.

Mean cross-sectional areas were computed for Osage Creek, by subreach, using techniques described in the earlier "Time of Travel" section. Many channel-width measurements and observations were made during the collection of the 1979 and 1981 data sets. The ratio of the "subreach-average" cross-sectional areas to "subreach-average" channel-widths were used to define "subreach average" depths. This data is shown in Attachment D-6 and D-27 for the calibration and verification data sets, respectively.

The mean velocities for the calibration and verification data sets are shown in table 40. These velocities are the result of the "fitted" channel geometry, based upon the measured times of travel (fig. 46) and the flow distributions for each data set. Mean velocities computed for the $Q_{7/10}$ low-flow projections with the projected Rogers WWTP flow imposed are given in table 34.

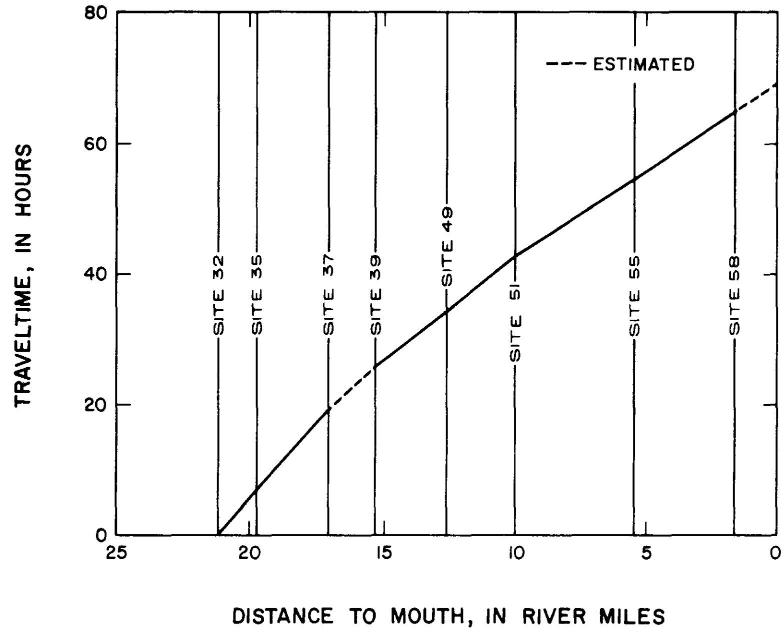

Figure 46.--Traveltimes of peak dye concentrations in Osage Creek for an average discharge of 56 cubic feet per second at site 51.

Stream Model

Calibration and Verification

Attachment D contains the results of model calibration and verification. Model calibration output is on Attachment D-2 through D-22; verification output is on Attachment D-23 through D-43. The Osage Creek model was calibrated and verified using data collected in 1981 and 1979, respectively.

The success of the model calibration-verification procedure is illustrated by the "goodness-of-fit" between the model-derived and observed concentration profiles for the predictable variables. Those profiles are shown on Attachments D-11 through D-20 and D-32 through D-41. The values of these coefficients and parameters defined during the calibration-verification process (as discussed in the "Calibration and Verification Procedure" section) are included on Attachment D-6 and D-7 and again on Attachments D-27 and D-28. Values of k_d resulting from application of the Bosko equation (equation 15) to subreach average k_l values are shown in Attachment D-7 and D-28.

Two DO profiles were "fitted" for both the calibration and verification data sets, the diel-mean profile and the diel-minimum profile (Attachments D-19 and D-20 and Attachment D-40 and D-41). Subreach-average benthic demands, directly resulting from the "fitting" of the mean DO profile, are shown on Attachment D-6 and D-27. The adjustment factors used in fitting the model-derived diel-minimum DO profile to the observed diel-minimum profile (as discussed in the "Simulation Techniques" section) are shown on Attachment D-6 and D-27. Verification of the "fitting" of the diel-minimum DO profile is shown on Attachment C-41.

Projections

Osage Creek simulations were made for projected Rogers WWTP effluent limits. CBODU, TSS, ammonia-N, and PO_4-P, respectively, in mg/L, are:

1. 45, 30, 15, 10

2. 30, 20, 10, 10

3. 15, 15, 10, 10

4. 15, 15, 5, 5

5. 7.5, 5, 3, 2

6. 7.5, 5, 2, 1

Each of these projections was simulated twice; once using an effluent DO concentration of 5.0 mg/L and once using a DO concentration at saturation. All projections were made using a Rogers WWTP discharge of 9.75 ft^3/s, $Q_{7/10}$ stream conditions, and water temperatures reflecting summertime highs (29°C). The WWTP effluent was input at the projected location at mile 20.0, 1 mile downstream from the existing point of entry.

For comparative purposes, two additional simulations were made at $Q_{7/10}$, low-flow conditions and water temperatures of 29°C using "as surveyed" effluent concentrations and discharge; one with the effluent inflow located at the existing entry point, the other with the entry point at the proposed location. The former simulation reflects water quality conditions at $Q_{7/10}$ flows in Osage Creek with existing waste loading as compared to the latter which reflects the effects of "as surveyed" effluent loading at the proposed new location.

Values of k_d resulting from a Bosko correction (equation 15) of subreach-average k_l values for $Q_{7/10}$ low-flow velocities are shown in table 41. For reasons discussed in the "Simulation Techniques" section, k_r was set equal to k_d in each subreach and benthic demands were modified, by subreach, using equation 16 (table 41).

The results of the Osage Creek projection simulations are shown in table 42. Average DO deficits caused by oxygen sinks are shown in table 43. When the net photosynthetic DO deficit is negative, net photosynthetic DO production is an oxygen source. The ammonia deficits are the most significant between river miles 20.0 and 19.6 when projected ammonia concentrations equal or exceed 10 mg/L. When projected CBODU concentrations in the WWTP effluent equal or exceed 30 mg/L, CBOD deficits dominate between river miles 19.6 and 14.5. Except for these two conditions, DO deficits created by benthal demands are the most significant in each subreach for all projections simulated. Osage Creek will meet the Arkansas diel-minimum DO standard of 4.0 mg/L (Arkansas Department of Pollution Control and Ecology, 1981) with projected Rogers WWTP effluent limits 3, 4, 5, or 6 imposed and effluent DO concentrations set at saturation (7.7 mg/L). The standard of 4.0 mg/L can also be met with effluent limit 6 imposed and the effluent DO concentration set at 5.0 mg/L. Both the simulation for "as surveyed" effluent loading at the existing inflow point and the simulation for "as surveyed" effluent loading at the proposed new location result in instream diel-minimum DO concentrations of 0.0 mg/L (table 42).

Table 30--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent

[Five-digit numbers in parentheses are STORET parameter codes used for computer storage of data]

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
32	21.1	9-05-78	1430	4.5	---	---	----	----	490	490
		11-28-78	1100	19	---	---	3.2	0.07	330	2,600
		7-23-79	1500	6.5	255	7.7	2.9	.09	K800	800
		8-25-81	1400	----	280	7.2	2.1	.19	K2,100	K7,900
33[W]	21.0	9-06-78	Composite	7.1	258	7.3	----	----	50	125
		11-28-78	---do---	7.5	406	7.3	----	----	50	50
		7-23-79	---do---	4.4	---	---	66	----	K67	100
		8-25-81	---do---	6.4	430	7.3	25	.13	>170	>800
34	20.9	9-05-78	----	12	---	---	----	----	-----	-----
		7-23-79	1530	11	---	---	>25	----	-----	-----
		8-25-81	1730	12	370	7.1	6.4	.18	280	K590

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (mg/L) (70300)	Suspended solids (residue at 105°C) (mg/L) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
32	9-05-78	1430	157	--	6.5	1.0
	11-28-78	1100	144	--	6.0	6.0
	7-23-79	1500	---	7	----	----
	8-25-81	1400	---	5	----	----
33[W]	9-06-78	Composite	320	--	52	40
	11-28-78	---do---	280	--	36	34
	7-23-79	---do---	---	25	----	----
	8-25-81	---do---	---	18	----	----
34	9-05-78	----	---	--	----	----
	7-23-79	1530	---	18	----	----
	8-25-81	1730	---	8	----	----

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L) as P) (00665)
32	9-05-78	1430	0.35	0.12	0.03	3.8	0.03	0.05
	11-28-78	1100	.28	.09	.01	2.6	.09	.12
	7-23-79	1500	----	.08	.04	3.5	.04	.11
	8-25-81	1400	1.5	.15	.02	4.6	.06	.06
33[W]	9-06-78	Composite	2.7	1.5	.10	8.1	7.9	----
	11-28-78	---do---	2.2	3.0	.04	7.5	3.8	4.2
	7-23-79	---do---	3.6	2.5	.45	6.0	11	14
	8-25-81	---do---	5.2	1.0	.77	7.5	5.1	5.9
34	9-05-78	----	----	---	----	----	----	----
	7-23-79	1530	----	1.9	.16	.52	5.9	7.3
	8-25-81	1730	1.8	.73	.29	5.4	1.5	2.4

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
35	19.6	9-07-78	0745	13	330	7.2	28	0.05	370	1,700
		11-28-78	1130	28	261	7.2	----	----	3	K12
		7-24-79	1130	14	---	---	----	----	-----	----
		7-24-79	1535	-----	344	7.2	18	----	730	8,000
		8-25-81	1230	17	350	7.3	7.1	.11	>750	>2,700
36	18.4	7-23-79	1700	16	314	7.4	14	.17	1,000	800
		8-25-81	1145	20	330	7.4	4.6	.11	K5,400	K14,000
36a[T]	17.1	9-07-78	----	.88	---	---	----	----	-----	------
		11-28-78	----	.62	---	---	----	----	-----	------
		7-25-79	1345	1.1	302	7.8	7.4	.08	260	880
37	17.0	9-07-78	0830	13	330	7.4	----	----	660	720
		11-28-78	1230	29	320	7.6	7.7	.10	270	5,300
		7-24-79	1515	17	328	7.4	12	.14	620	620
		8-25-81	1100	19	350	7.4	4.6	.11	>1,200	>4,000

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (70300)	Suspended solids (residue at 105°C) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
35	9-07-78	0745	212	--	24	14
	11-28-78	1130	178	--	14	13
	7-24-79	1130	---	--	--	--
	7-24-79	1535	---	5	--	--
	8-25-81	1230	---	4	--	--
36	7-23-79	1700	---	18	--	--
	8-25-81	1145	---	6	--	--
36a[T]	9-07-78	----	---	--	--	--
	11-28-78	----	---	--	--	--
	7-25-79	1345	---	1	--	--
37	9-07-78	0830	209	--	22	--
	11-28-78	1230	177	--	14	12
	7-24-79	1515	---	11	--	--
	8-25-81	1100	---	--	--	--

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams and Rogers wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
35	9-07-78	0745	0.90	0.50	0.14	3.7	----	2.4
	11-28-78	1130	.99	.23	.04	3.8	1.2	1.2
	7-24-79	1130	----	----	----	----	----	---
	7-24-79	1535	1.4	.42	.46	3.8	3.3	3.4
	8-25-81	1230	1.7	.23	.13	5.8	1.6	2.9
36	7-23-79	1700	1.3	.15	.16	.52	5.7	6.0
	8-25-81	1145	1.2	.14	.08	4.9	1.0	2.0
36a[T]	9-07-78	----	----	----	----	----	----	----
	11-28-78	----	----	----	----	----	----	----
	7-25-79	1345	.36	.08	.07	3.2	.02	.08
37	9-07-78	0830	----	.22	.03	3.9	----	2.2
	11-28-78	1230	----	.15	.05	3.6	.85	1.0
	7-24-79	1515	.95	.17	.14	3.2	3.0	3.0
	8-25-81	1100	1.3	.13	.06	5.2	1.1	2.2

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	River mile	Date of collection	Time of collection (hour)	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
38	16.1	9-09-78	----	12	---	---	-----	----	-----	------
		11-28-78	----	31	---	---	-----	----	-----	------
		7-25-79	----	18	---	---	-----	----	-----	------
		8-25-81	1030	19	350	7.4	4.3	0.12	K2,300	K18,000
39	15.2	9-07-78	0900	9.2	323	7.4	7.4	.03	550	2,200
		11-28-78	1300	37	282	7.6	7.7	.08	570	3,600
		7-24-79	1500	20	328	7.6	10	----	620	K1,000
		8-25-81	1000	19	350	7.4	3.9	.12	800	K4,200
39a[T]	14.5	8-25-81	0900	3.5	260	7.7	4.5	.20	170	300
39b	13.2	7-25-79	1200	----	314	7.9	-----	----	230	500
		8-25-81	0830	20	330	7.5	4.0	.15	K1,100	1,600

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (70300)	Suspended solids (residue at 105°C) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
38	9-09-78	----	---	--	--	--
	11-28-78	----	---	--	--	--
	7-25-79	----	---	--	--	--
	8-25-81	1030	---	11	--	--
39	9-07-78	0900	203	--	18	10
	11-28-78	1300	192	--	16	17
	7-24-79	1500	---	5	--	--
	8-25-81	1000	---	11	--	--
	9-01-81	----	---	--	--	--
39a[T]	8-25-81	0900	---	5	--	--
39b	7-25-79	1200	---	7	--	--
	8-25-81	0830	---	15	--	--

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total ortho-phosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
38	9-09-78	----	----	----	----	---	----	----
	11-28-78	----	----	----	----	---	----	----
	7-25-79	----	----	----	----	---	----	----
	8-25-81	1030	1.2	0.12	0.02	5.2	0.89	2.2
39	9-07-78	0900	.74	.08	.01	3.4	----	2.1
	11-28-78	1300	.59	.14	.03	3.8	.83	.96
	7-24-79	1500	.72	.07	.05	3.8	2.8	2.8
	8-25-81	1000	1.3	.14	.02	5.3	1.2	2.3
	9-01-81	----	----	----	----	---	----	----
39a[T]	8-25-81	0900	.91	.19	.04	1.5	.02	.06
39b	7-25-79	1200	.38	.08	.06	3.0	1.4	1.4
	8-25-79	0830	.99	.11	<.02	5.2	1.1	2.2

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	River mile	Date of collection	Time of collection (hour)	Discharge (ft^3/s)	Specific conductance (μmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
48T	13.1	9-05-78	1800	24	398	7.9	---	----	2,100	4,400
		11-27-78	1630	53	302	7.6	7.5	0.10	K1,100	1,800
		7-24-79	1430	27	388	7.7	---	----	K180	690
		8-24-81	1730	30	400	7.8	---	----	410	490
49	12.6	9-07-78	0945	38	358	8.0	---	----	1,700	4,900
		11-28-78	1515	101	308	---	---	----	390	2,500
		7-25-79	1430	41	351	7.8	7.8	.08	420	580
		8-24-81	1200	45	360	7.8	3.8	.14	330	530
50	10.5	9-07-78	1000	20	260	7.4	---	----	550	1,300
		11-28-78	1500	22	264	---	---	----	340	----
		7-24-79	----	23	---	---	---	----	-----	----
		8-24-81	1230	14	290	8.0	2.3	.17	K130	K160

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (70300)	Suspended solids (residue at 105°C) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
48T	9-05-78	1800	262	--	28	22
	11-27-78	1630	202	--	12	17
	7-24-79	1430	---	11	----	----
	8-24-81	1730	---	4	----	----
49	9-07-78	0945	239	--	22	14
	11-28-78	1515	192	--	14	13
	7-25-79	1430	---	7	----	----
	8-24-81	1200	---	11	----	----
50	9-07-78	1000	161	--	7.0	1.0
	11-28-78	1500	167	--	7.0	4.0
	7-24-79	----	---	--	----	----
	8-24-81	1230	---	12	----	----

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total ortho-phosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
48[T]	9-05-78	1800	1.5	0.06	0.04	7.6	2.2	----
	11-27-78	1630	.95	.15	.08	5.5	1.2	1.2
	7-24-79	1430	1.2	.10	.23	7.1	2.4	2.8
	8-24-81	1730	1.1	.12	.03	5.6	1.5	2.7
49	9-07-78	0945	1.0	.06	.04	3.7	----	2.4
	11-28-78	1515	.72	.07	.05	5.2	.79	.97
	7-25-79	1430	1.0	.07	.09	5.3	2.0	2.1
	8-24-81	1200	.95	.15	.02	4.4	1.1	2.1
50	9-07-78	1000	.42	.03	.01	2.5	----	.22
	11-28-78	1500	----	.03	.01	3.2	.07	.11
	7-24-79	----	----	----	----	---	----	----
	8-24-81	1230	.57	.12	.01	2.5	.02	.03

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	River mile	Date of collection	Time of collection (hour)	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
51	10.0	9-07-78	1045	50	353	8.0	9.1	0.08	930	1,800
		11-28-78	1530	129	---	---	---	----	400	2,700
		7-25-79	1500	57	325	7.8	2.9	.25	390	K400
		8-25-81	0845	60	370	7.7	3.6	.12	420	6,500
52	8.1	9-07-78	1445	60	340	8.1	---	----	940	1,700
		11-28-78	1600	97	291	7.9	5.2	.10	K310	K1,300
		7-25-79	----	60	---	---	---	----	----	-----
		8-24-81	1420	56	350	7.8	3.3	.16	390	K380
53T	7.5	11-28-78	1615	1.5	234	7.8	5.2	.10	230	530
53a	6.4	8-24-81	1515	61	350	7.6	2.6	.17	260	K550

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (70300)	Suspended solids (residue at 105°C) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
51	9-07-78	1045	231	--	20	11
	11-28-78	1530	186	--	13	11
	7-25-79	1500	---	11	----	----
	8-25-81	0845	---	13	----	----
	9-01-81	1530	---	--	----	----
52	9-07-78	1445	224	--	20	11
	11-28-78	1600	184	--	13	11
	7-25-79	----	---	--	----	----
	8-24-81	1420	---	11	----	----
53[T]	11-28-78	1615	140	--	7.5	4.0
53a	8-24-81	1515	---	13	----	----

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total ortho-phosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
51	9-07-78	1045	0.76	0.03	0.03	3.7	----	1.9
	11-28-78	1530	----	.05	.02	4.0	0.64	.72
	7-25-79	1500	.26	.07	.07	4.3	1.3	1.5
	8-25-81	0845	1.3	.14	<.02	4.9	1.2	1.9
	9-01-81	1530	----	----	----	---	----	----
52	9-07-78	1445	.70	.05	.02	3.9	1.5	1.7
	11-28-78	1600	.66	.04	.01	4.0	.65	.75
	7-25-79	----	----	----	----	---	----	----
	8-24-81	1420	.61	.11	.01	3.6	.98	1.1
53T	11-28-78	1615	----	.02	.01	2.0	.05	.09
53a	8-24-81	1515	.52	.09	.01	3.3	.96	1.1

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	River mile	Date of collection	Time of collection (hour)	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
54[T]	6.2	9-07-78	1415	10	238	7.3	4.0	0.14	70	380
		11-28-78	1645	19	235	8.0	1.7	.10	260	K1100
		7-26-79	----	12	---	---	---	----	-----	-----
		8-24-81	1725	8.3	280	7.8	3.1	.16	1700	-----
55	5.4	9-07-78	1345	56	298	7.9	7.3	.03	600	1400
		11-28-78	1720	121	275	7.9	---	----	K360	2400
		7-25-79	2100	69	---	---	>6.0	----	K200	700
		8-24-81	1630	70	340	7.7	3.0	.21	K190	310
55a[T]	4.9	9-07-78	1315	3.0	248	8.4	5.0	.12	5400	8000
		11-28-78	1730	25	271	8.0	1.6	.09	K1200	1400
		7-26-79	----	3.3	---	---	---	----	-----	-----
		8-24-81	1800	2.4	300	8.1	3.3	.18	1800	K1800

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (70300)	Suspended solids (residue at 105°C) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
54[T]	9-07-78	1415	149	--	9.0	3.0
	11-28-78	1645	142	--	8.5	5.0
	7-26-79	----	---	--	---	---
	8-24-81	1725	---	15	---	---
55	9-07-78	1345	190	--	16	8.0
	11-28-78	1720	169	--	11	9.0
	7-25-79	2100	---	16	--	---
	8-24-81	1630	---	19	--	---
55a[T]	9-07-78	1315	159	--	18	3.0
	11-28-78	1730	173	--	18	5.0
	7-26-79	----	---	--	--	---
	8-24-81	1800	---	9	--	---

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total ortho-phosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
54[T]	9-07-78	1415	----	0.04	0.01	1.5	0.14	0.21
	11-28-78	1645	----	.03	.01	3.6	.06	.09
	7-26-79	----	----	----	----	----	----	----
	8-24-81	1725	0.74	.11	.01	2.6	.05	.07
55	9-07-78	1345	.93	.04	.01	3.0	1.2	1.6
	11-28-78	1720	----	.03	.01	3.6	.53	.60
	7-25-79	2100	.22	.07	.07	4.0	1.0	1.2
	8-24-81	1630	.55	.10	.01	3.2	.84	.96
55a[T]	9-07-78	1315	.24	.05	.01	1.6	.07	.14
	11-28-78	1730	----	.02	.01	3.4	.06	.10
	7-26-79	----	----	----	----	----	----	----
	8-24-81	1800	.61	.06	.01	1.9	.11	.11

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	River mile	Date of collection	Time of collection (hour)	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
56	4.1	9-08-78	0745	70	308	7.6	6.0	0.03	290	1,400
		11-28-78	1710	153	274	7.8	3.8	.10	K1,800	K2,400
		7-26-79	----	84	---	---	----	----	-----	-----
		8-24-81	1600	81	340	7.7	4.5	.22	200	K280
57-T	2.0	8-25-81	1600	.20	250	8.4	3.0	.21	1,000	5,400
58	1.6	9-07-78	1810	83	300	7.4	10	.02	240	1,000
		11-29-78	0945	168	274	7.7	----	----	200	750
		7-25-79	2115	87	302	7.8	5.6	.07	K210	500
		8-25-81	1530	82	330	7.9	2.7	.17	180	200
59-T	1.2	9-07-78	1845	3.2	213	8.0	3.1	.15	200	700
		11-29-78	1000	7.0	---	---	---	----	K47	800
		7-26-79	1700	3.7	238	7.7	5.3	.13	K110	K450
		8-26-81	1200	2.8	235	7.2	3.2	.23	K5,000	>800

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number[a]	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (70300)	Suspended solids (residue at 105°C) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
56	9-08-78	0745	185	--	16	7.0
	11-28-78	1710	177	--	12	9.0
	7-26-79	----	---	--	----	---
	8-24-81	1600	---	11	----	---
57[T]	8-25-81	1600	---	5	----	---
58	9-07-78	1810	181	--	15	7.0
	11-29-78	0945	140	--	12	9.0
	7-25-79	2115	---	13	----	---
	8-25-81	1530	---	9	----	---
	9-01-81	1605	---	--	----	---
59[T]	9-07-78	1845	182	--	7.5	2.0
	11-29-78	1000	123	--	7.0	3.0
	7-26-79	1700	---	--	----	---
	8-26-81	1200	---	39	----	---

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and and Rogers wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
56	9-08-78	0745	----	0.08	0.01	2.4	0.70	0.87
	11-28-78	1710	----	.03	.01	3.6	.49	.55
	7-26-79	----	----	----	----	---	----	----
	8-24-81	1600	1.5	.34	.81	8.3	3.1	4.6
57[T]	8-25-81	1600	1.2	.17	<.02	1.9	.03	.03
58	9-07-78	1810	----	.04	.01	2.7	.60	.77
	11-29-78	0945	.43	.06	.01	3.5	.44	.44
	7-25-79	2115	.38	.08	.06	3.6	.75	.83
	8-25-81	1530	1.0	.10	<.02	3.3	.79	.79
	9-01-81	1605	----	----	----	---	----	----
59[T]	9-07-78	1845	.86	.05	.01	2.6	.01	.14
	11-29-78	1000	.41	.09	.02	1.4	.03	.05
	7-26-79	1700	.20	.09	----	---	----	----
	8-26-81	1200	.68	.14	<.02	1.1	.05	.08

See footnotes at end of table

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and and Rogers wastewater-treatment plant effluent--Continued

Site number	River mile	Date of collection	Time of collection (hour)	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
60	0.3	9-07-78	1545	85	293	7.9	3.5	0.05	250	780
		7-26-79	1630	--	302	7.8	2.6	.18	K130	580
		8-26-81	1100	--	300	7.0	2.9	.19	>600	>1,600

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (70300)	Suspended solids (residue at 105°C) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
60	9-07-78	1545	176	--	14	6.0
	7-26-79	1630	---	--	--	---
	8-26-81	1100	---	18	--	---

Table 30.--Chemical, physical, and bacteriological data, Osage Creek, tributary streams, and and Rogers wastewater-treatment plant effluent--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
60	9-07-78	1545	0.51	0.05	0.01	0.95	0.76	0.79
	7-26-79	1630	.70	.01	----	----	----	----
	8-26-81	1100	.79	.09	<.02	3.3	.80	.80

K Plate count was outside ideal range.
T Tributary.
W Wastewater-treatment plant effluent.

Table 31.--Comparison of analyses of Osage Creek stormwater-runoff samples to means calculated from steady-state flow analyses in table 30

[Five digit numbers are STORET parameter codes used for computer storage of data]

Site number	River mile	"Steady-state" mean (S) or "Runoff" (R) sample	Date of collection	Time of collection	Discharge (ft^3/s) (00061)	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00310)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)
35a^T	19.1	R	5-13-81	1400	13	16.5	6.4	65	340	6
36a^T	17.1	S	-------	----	2.6	----	---	--	302	7
39a^T	14.5	S	8-25-81	0900	3.5	----	---	--	260	7

See footnote at end of table

Table 31.--Comparison of analyses for Osage Creek stormwater-runoff samples to means calculated from steady-state flow analyses in table 30--Continued

Site number	"Steady-state" mean (S) or "Runoff" (R) sample	Date of collection	Time of collection (hour)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Streptococci, fecal (colonies per 100 mL) (31673)	Suspended solids (residue at 105°C) (mg/L) (00530)
35a[T]	R	5-13-81	1400	>50	----	K143,000	K148,000	222
36a[T]	S	-------	----	7.4	0.08	260	--------	1
39a[T]	S	8-25-81	0900	4.5	.20	170	--------	5

See footnotes at end of table

Table 31.--Comparison of analyses for Osage Creek stormwater-runoff samples to means of steady-state flow analyses in table 30--Continued

Site number	"Steady-state" mean (S) or "Runoff" (R) sample	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P (00665)
35a[T]	R	5-13-81	1400	8.2	3.8	0.10	0.87	0.93	3.0
36a[T]	S	-------	----	.36	.08	.07	3.2	.02	.08
39a[T]	S	8-25-81	0900	.91	.19	.04	1.5	.02	.18

[K] Plate count was outside ideal range.
[T] Tributary.

Table 32.--Dissolved-oxygen and temperature data for Osage Creek, tributaries, and Rogers wastewater-treatment plant effluent

[Five-digit numbers in parentheses are STORET parameter codes used for computer storage of data]

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
32	9-05-78	1430	21.0	7.8	88
		2140	21.0	7.0	79
	9-06-78	0610	17.5	6.3	66
	11-28-78	1100	12.0	9.9	92
	7-23-79	1500	20.0	10.1	111
		2245	18.0	7.5	89
	7-24-79	0635	16.5	7.2	74
	8-25-81	0605	17.5	6.6	69
		1400	20.0	8.9	98
		2305	18.5	6.7	70
	8-27-81	0815	17.0	8.0	83
		0915	17.0	8.6	89
		1015	17.0	9.6	99
		1115	18.0	>10	--
		1215	18.5	>10	--
		1315	19.5	>10	--
		1415	19.5	9.7	105
		1515	20.0	9.8	108
		1615	20.0	10.0	110
		1715	20.0	9.8	107
		1815	20.0	9.5	103
32	8-27-81	1915	19.0	8.3	89
		2015	18.5	6.8	73
		2115	17.5	5.9	61
		2215	17.0	6.0	62
		2315	17.0	6.3	65
	8-28-81	0015	16.5	6.8	69
		0115	16.0	6.4	65
		0215	16.0	6.5	66
		0315	16.0	6.5	66
		0415	16.0	6.6	67
		0515	16.0	6.6	67
		0615	16.0	6.6	67
		0715	16.0	6.7	68
		0815	16.0	7.4	75
		0915	16.0	8.4	85
		1015	17.0	9.3	96
33[W]	9-05-78	1430	26.0	5.8	72
	9-06-78	0610	24.5	5.8	70
	7-23-79	1530	26.0	6.2	76
		2245	26.5	5.4	68
	7-24-79	0635	25.5	6.3	77

See footnotes at end of table

Table 32.--Dissolved-oxygen and temperature data for Osage Creek, tributaries, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
33[W]	8-25-81	0610	25.5	4.8	58
		1530	28.0	4.5	57
		2310	21.0	5.3	59
34	9-05-78	1430	25.0	6.3	77
		2145	23.0	6.0	70
	9-06-78	0610	20.0	6.3	69
	11-28-78	1115	12.5	9.7	92
	7-23-79	1530	23.0	8.3	96
		2250	22.0	6.3	72
	7-24-79	0640	19.5	6.8	74
	8-25-81	0615	19.5	5.5	60
		1730	23.5	6.0	70
		2315	23.0	4.1	48
	8-29-81	1330	24.0	8.4	99
		1430	24.0	8.1	95
		1530	23.5	7.9	92
		1630	24.0	7.7	91
		1730	23.5	7.3	85
		1830	23.0	6.8	79
		1930	23.0	6.4	74
		2030	22.5	6.0	69
34	8-29-81	2130	22.0	5.8	66
		2230	22.0	5.6	64
		2330	22.0	5.6	64
	8-30-81	0030	21.5	5.6	63
		0130	21.0	5.7	63
		0230	21.0	5.8	64
		0330	20.0	5.9	64
		0430	20.0	5.8	63
		0530	20.0	5.9	64
		0630	20.0	6.0	65
		0730	19.5	6.1	66
		0830	20.0	6.6	72
		0930	20.5	7.0	77
		1030	22.0	7.2	82
		1130	22.5	7.4	85
		1230	23.0	7.5	87
35	9-07-78	0745	20.5	2.8	31
	11-28-78	1130	11.0	8.9	81
	7-25-79	1400	22.0	6.0	69
		2305	22.5	2.4	28
	7-27-79	0850	20.0	3.8	42
	8-25-81	1230	21.5	7.9	88

See footnotes at end of table

Table 32.--Dissolved-oxygen and temperature data for Osage Creek, tributaries, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
35	8-25-81	2255	22.5	2.7	31
	8-26-81	0555	20.0	2.7	29
	8-28-81	1330	22.0	8.0	91
		1430	23.0	8.1	94
		1530	23.0	7.6	88
		1630	23.0	7.0	81
		1730	23.0	5.8	68
		1830	23.0	5.6	65
		1930	23.0	4.3	50
		2030	22.5	2.6	30
		2130	22.0	2.3	26
		2230	22.0	2.2	26
		2330	21.5	2.2	25
	8-29-81	0030	21.0	2.2	25
		0130	21.0	2.3	26
		0230	20.5	2.3	25
		0330	20.0	2.4	26
		0430	20.0	2.4	26
		0530	20.0	2.5	27
		0630	19.5	2.7	29
		0730	19.0	2.8	30
		0830	19.0	3.3	36
		0930	19.0	4.1	44
		1030	19.5	5.7	62
		1130	20.0	7.1	77
		1230	20.5	7.8	86

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
36	7-23-79	1700	21.0	6.4	72
	8-25-81	1145	20.5	6.8	74
36a[T]	9-07-78	0830	17.0	7.4	77
	11-28-78	1230	7.5	10.0	83
	7-25-79	1345	20.0	8.3	91
37	9-07-78	0830	20.5	4.8	53
	9-08-78	1750	24.0	7.6	90
	9-09-78	0715	20.5	4.6	51
	11-28-78	1230	9.0	9.4	82
	7-25-79	1350	22.0	6.3	72
		2255	23.0	4.5	52
	7-27-79	0840	21.0	4.0	45
	8-25-81	1100	20.5	6.6	72
		2240	22.0	6.1	69
	8-26-81	0540	20.5	5.4	59

See footnotes at end of table

Table 32.--Dissolved-oxygen and temperature data for Osage Creek, tributaries, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)	Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
38	9-07-78	0845	21.0	5.5	62	38	8-31-81	0100	22.5	6.4	74
								0200	22.5	6.3	72
	9-09-78	0720	20.5	5.5	61			0300	22.0	6.2	71
								0400	22.0	6.1	69
38	11-28-78	1215	8.5	8.3	71			0500	22.0	6.1	69
								0600	21.5	6.1	69
	7-25-79	1325	22.0	5.7	66			0700	21.5	6.0	67
		2245	23.0	4.7	55			0800	21.5	6.1	69
								0900	21.0	6.1	68
	7-27-79	0830	21.0	4.8	54			1000	21.0	6.2	69
								1100	21.5	6.3	71
	8-25-81	1030	20.5	6.4	72			1200	21.5	6.5	73
		2230	22.0	6.7	76			1300	22.0	6.8	77
	8-26-81	0530	20.5	5.7	63			1400	22.5	6.9	79
	8-30-81	1400	22.0	8.2	93						
		1500	22.0	7.9	90	39	9-07-78	0900	22.0	6.3	72
		1600	22.5	8.0	92						
		1700	23.0	8.0	93		9-09-78	0725	20.5	5.7	63
		1800	23.0	7.9	92						
		1900	23.5	7.7	90		11-28-78	1300	9.0	9.4	82
		2000	23.5	7.5	88						
		2100	23.5	7.3	85		7-25-79	1310	23.0	7.4	86
		2200	23.5	6.9	81			2240	23.0	4.3	50
		2300	23.0	6.7	78						
		2400	23.0	6.5	76		7-27-79	0825	21.0	5.3	60

Table 32.--Dissolved-oxygen and temperature data for Osage Creek, tributaries, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
39	8-25-81	1000	21.0	6.4	72
		2225	22.0	6.1	69
	8-26-81	0525	21.0	5.4	60
	8-29-81	1415	23.0	8.3	97
		1515	23.0	8.4	98
		1615	23.0	8.4	98
		1715	22.5	7.7	89
		1815	22.0	7.5	86
		1915	22.0	7.2	83
		2015	22.0	6.7	77
		2115	22.0	6.4	74
		2215	21.5	6.1	69
		2315	21.5	6.0	67
	8-30-81	0015	21.5	5.9	66
		0115	21.0	5.9	66
		0215	21.0	5.9	66
		0315	21.0	5.9	66
		0415	21.0	5.9	66
		0515	20.5	5.9	65
		0615	20.5	5.9	65
		0715	20.0	5.9	64
		0815	20.0	6.2	67
		0915	20.5	6.4	70
		1015	21.5	6.9	78
		1115	22.0	7.4	84
		1215	22.0	7.5	85
		1315	23.0	7.9	92

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
39a[T]	8-25-81	0900	24.5	9.1	108
		2215	26.5	9.6	119
	8-26-81	0520	25.0	8.3	100
39b	7-25-79	1200	23.5	9.1	107
	8-25-81	0830	21.0	6.2	55
48[T]	9-05-78	1800	27.5	6.7	85
	9-09-78	0705	22.0	4.7	54
	11-27-78	1630	11.0	9.6	87
	7-25-79	1220	24.0	6.9	82
	7-27-79	0815	22.5	4.4	51
	8-24-81	1730	24.5	7.6	91
		2345	23.0	4.9	57
	8-25-81	0600	21.5	4.9	56
	9-01-81	1730	23.5	8.7	102
		1830	23.0	8.0	93
		1930	23.0	7.3	85

See footnotes at end of table

Table 32.--Dissolved-oxygen and temperature data for Osage Creek, tributaries, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
48[T]	9-01-78	2030	23.0	6.6	77
		2130	22.5	6.0	69
		2230	22.5	5.7	66
		2330	22.0	5.5	63
	9-02-81	0030	22.0	5.4	61
		0130	22.0	5.3	60
		0230	22.0	5.2	59
		0330	21.5	5.2	58
		0430	21.5	5.1	57
		0530	21.0	5.2	58
		0630	21.0	5.2	58
		0730	21.0	5.3	59
		0830	21.0	5.9	66
		0930	21.0	6.4	71
		1030	21.0	7.1	79
		1130	21.5	7.6	85
		1230	22.0	7.9	90
		1330	23.0	8.3	97
		1430	23.5	8.3	97
49	9-07-78	0945	22.0	6.6	76
	9-09-78	0725	21.0	5.7	64
	11-28-78	1515	11.0	10.2	93
49	7-25-79	1430	25.0	9.3	113
	7-27-79	0810	22.0	5.5	63
	8-24-81	1200	23.0	9.3	108
		2230	23.5	6.5	76
	8-25-81	0530	22.0	5.5	63
	9-02-81	1530	24.5	9.8	118
		2240	23.5	6.0	71
	9-03-81	0500	21.5	5.7	65
	9-05-81	0930	21.0	6.7	75
		1210	23.0	8.3	96
		1440	25.0	9.5	116
		1650	26.5	9.3	116
		2300	25.0	5.4	66
	9-06-81	0634	21.5	5.5	62
50[T]	9-07-78	1000	20.0	10.0	110
	9-09-78	0745	21.0	6.5	73
	11-28-78	1500	9.5	12.2	107

See footnotes at end of table

Table 32.--Dissolved-oxygen and temperature data for Osage Creek, tributaries, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
50[T]	8-24-81	1230	21.0	9.4	104
		2300	18.0	5.4	57
	8-25-81	0545	18.0	6.3	66
51	9-05-78	1345	27.0	9.9	122
	9-07-78	1045	22.5	7.2	84
	11-28-78	1530	9.5	10.4	91
	7-25-79	1500	20.5	8.6	96
	8-24-81	2245	24.5	6.4	76
	8-25-81	0530	22.0	5.9	67
		0845	22.5	6.4	74
	9-02-81	1545	23.5	8.8	103
		1645	23.5	8.5	99
		1745	23.5	8.1	95
		1845	23.5	7.8	91
		1945	23.5	7.4	87
		2045	23.5	7.0	82
		2145	23.0	6.7	78
		2245	23.0	6.5	76
		2345	23.0	6.5	76
	9-03-82	0045	23.0	6.3	73
51	9-03-81	0145	22.5	6.2	71
		0245	22.5	6.2	71
		0345	22.0	6.2	71
		0445	22.0	6.1	69
		0545	22.0	6.1	69
		0645	21.5	6.2	70
		0745	21.5	6.3	71
		0845	21.5	6.5	73
		0945	21.5	7.0	79
		1045	21.5	7.2	81
		1145	22.0	7.6	86
		1245	22.5	8.0	92
		1345	23.0	8.3	97
52	9-07-78	1445	24.5	7.9	95
	11-28-78	1600	9.0	10.4	90
	8-24-81	1420	23.5	7.5	89
	9-02-81	1600	23.0	8.4	98
		2320	23.5	6.3	74
	9-03-81	0525	22.5	6.2	72
53[T]	11-28-78	1615	14.5	9.7	95

See footnotes at end of table

Table 32.--Dissolved-oxygen and temperature data for Osage Creek, tributaries, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
53a	9-07-78	1415	24.5	6.8	82
	11-28-78	1650	8.5	10.2	87
	8-24-81	1515	23.0	7.1	87
54[T]	9-07-78	1415	27.5	6.2	78
	11-28-78	1645	10.0	11.0	97
	8-24-81	1725	25.0	7.7	93
55	9-07-78	1345	24.5	7.5	90
	9-09-78	0805	21.5	6.8	77
	11-28-78	1720	8.5	10.4	89
	7-25-79	2100	24.5	7.1	86
	8-24-81	1630	24.0	7.5	88
		2335	24.0	6.4	75
55	9-02-81	1630	23.0	8.0	93
		2355	23.0	6.6	77
	9-03-81	0615	22.0	6.4	74
	9-04-81	1155	22.5	7.0	81
	9-05-81	0835	21.5	6.9	78
		1045	22.0	7.2	83
		1300	23.0	7.9	92
		1540	24.0	7.9	94
		1730	24.0	7.7	92
		2335	23.5	6.3	74
	9-06-81	0608	22.0	6.3	72
55a[T]	9-07-78	1315	26.5	15.3	191
	11-28-78	1730	9.0	10.8	94
	8-24-81	1800	27.5	10.0	126
		2330	23.0	4.9	57
	8-25-81	0645	21.0	5.4	60
56	9-08-78	0745	21.5	6.6	75
	11-28-78	1710	8.5	10.1	86

See footnotes at end of table

Table 32.--Dissolved-oxygen and temperature data for Osage Creek, tributaries, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
56	8-24-81	1600	24.5	7.9	94
	8-25-81	0645	22.0	6.1	69
57[T]	8-25-81	1600	27.0	10.1	126
		2200	19.0	6.4	69
	8-26-81	0525	17.0	7.1	73
58	9-07-78	1810	25.0	7.5	91
	11-29-78	0945	6.5	10.5	85
	7-26-79	1640	24.0	8.2	98
	8-25-81	1530	25.0	8.3	100
		2200	24.0	6.8	80
	8-26-81	0520	22.0	6.0	68
	9-02-81	1640	23.5	8.3	98
	9-03-81	0025	23.0	6.6	77
		0630	22.0	6.7	77
	9-05-81	0855	21.5	6.9	78
		1135	22.5	7.6	88
		1355	23.5	7.8	92
		1600	24.0	8.1	96
58	9-05-81	1755	24.0	7.9	94
		2400	23.5	6.7	79
	9-06-81	0552	22.0	6.6	76
59[T]	9-07-78	1845	20.0	8.9	98
	11-29-78	1000	9.0	10.8	94
	7-26-79	1700	22.0	8.0	92
	8-26-81	1200	19.5	7.1	77
60	9-07-78	1545	25.0	7.9	96
	9-09-78	0815	22.0	7.0	80
	7-26-79	1630	24.0	7.9	94
	8-26-81	1100	21.5	6.6	74
		2230	22.5	6.8	78
	8-27-81	0615	21.5	6.6	74
	9-02-81	1700	23.5	8.3	97
		1800	23.5	8.2	96
		1900	23.5	8.0	93

See footnotes at end of table

Table 32.--Dissolved-oxygen and temperature data for Osage Creek, tributaries, and Rogers wastewater-treatment plant effluent--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)	Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
60	9-02-81	2000	23.5	7.7	90	60	9-03-81	0600	22.0	6.9	78
		2100	23.5	7.6	89			0700	22.0	6.8	77
		2200	23.5	7.4	87			0800	22.0	6.8	77
		2300	23.0	7.3	85			0900	22.0	6.9	78
		2400	23.0	7.2	84			1000	22.0	7.2	82
	9-03-81	0100	23.0	7.1	83			1100	22.5	7.3	84
		0200	23.0	6.9	80			1200	23.0	7.5	87
		0300	23.0	6.9	80			1300	23.0	7.6	88
		0400	22.5	6.9	79			1400	23.5	7.8	91
		0500	22.5	6.9	79						

[T] Tributary.
[W] Wastewater-treatment plant effluent.

Table 33.--Bottom-material analyses for Osage Creek

[Five-digit numbers in parentheses are STORET parameter codes used for computer storage of data]

Site number and (river mile)	Date of collection	Streambed oxygen demand [$(g/m^2)/d$ at 20°C]	Total inorganic carbon in bottom material (g/kg as C) (00686)	Total organic carbon in bottom material (g/kg as C)	Total organic plus ammonia nitrogen in bottom material (mg/kg as N) (00626)	Total nitrite plus nitrate nitrogen in bottom material (mg/kg as N) (00633)	Total ammonia nitrogen in bottom material (mg/kg as N) (00611)	Total phosphorus in bottom material (mg/kg as P) (00668)
32 (21.1)	8-27-81	0.65	---	---	----	---	--	---
35 (19.6)	11-28-78	.55	---	---	1600	0.0	47	750
	8-03-79	----	0.1	3.8	516	---	--	830
	8-27-81	.94	---	---	----	---	--	---
39 (15.2)	8-29-81	.72	---	---	----	---	--	---
58 (1.6)	9-02-81	.74	---	---	----	---	--	---

Table 34.--Net photosynthetic dissolved-oxygen production at selected sites on Osage Creek

Site number	River mile	Date (1981)	Net photosynthetic dissolved oxygen production [(mg/L)/d at 20°C]
32	21.1	August 27-28	6.6
34	20.9	August 29-30	1.4
35	19.6	August 28-29	5.2
38	16.1	August 30-31	1.8
39	15.2	August 29-30	4.1
49	12.6	September 5-6	8.8
51	10.0	September 2-3	4.6
55	5.4	September 5-6	2.7
58	1.6	September 5-6	3.0
60	0.3	September 2-3	2.6

Table 35.--Phytoplankton taxonomy and densities for Osage Creek

Scientific name	Common name	cells/milliliter Site 35	Site 39	Site 51	Site 58
Chlorophyta	Green algae				
.Chlorophyceae					
..Chlorococcales					
...Chlorococcaceae					
....*Planktosphaeria*		---	---	---	110
...Coelastraceae					
....*Coelastrum* [1]		---	---	170	390
...Oocystaceae					
....*Ankistrodesmus*		14	28	---	14
....*Oocystis* [1]		---	83	---	14
...Scenedesmaceae					
....*Scenedesmus* [1]		---	110	28	110
..Volvocales					
...Chlamydomonadaceae					
....*Carteri*		---	---	---	28
....*Chlamydomonas*		14	---	14	---
Chrysophyta	Yellow-green algae				
.Bacillariophyceae	Diatoms				
..Centrales	Centric diatoms				
...Coscinodiscaceae					
....*Cyclotella*		---	---	56	---
..Pennales	Pennate diatoms				
...Achnanthaceae					
....*Achnanthes*		29	---	---	---
....*Cocconeis*		---	28	---	---
...Cymbellaceae					
....*Cymbella*		---	---	14	14
...Fragilariaceae					
....*Fragilaria*		---	---	---	28
....*Synedra*		---	---	---	14
...Gomphonemataceae					
....*Gomphonema* [1]		72	14	---	28
...Naviculaceae	Naviculoids				
....*Navicula*		---	56	14	---
...Nitzschiaceae					
....*Nitzschia* [1]		100	28	170	14

[1]Dominant organism, cell counts greater than or equal to 15 percent of total count for the station.

Table 35.--Phytoplankton taxonomy and densities for Osage Creek--Continued

		cells/milliliter			
Scientific name	Common name	Site 35	Site 39	Site 51	Site 58
Cyanophyta	Blue-green algae				
.Cyanophyceae					
..Chroococcales					
...Chroococcaceae	Coccoid blue-greens				
....*Anacystis* [1]		---	---	750	28
..Hormogonales	Filamentous blue-greens				
...Nostocaceae					
....*Anabaena* [1]		220	---	---	---
...Oscillatoriaceae					
....*Lyngbya*		---	28	---	---
Euglenophyta	Euglenoids				
.Euglenophyceae					
..Euglenales					
...Euglenaceae					
....*Euglena*		---	---	---	14

[1]Dominant organism, cell counts greater than or equal to 15 percent of total count for the station.

Table 36.--Phytoplankton and periphyton analyses for Osage Creek and downstream site on Spring Creek

Site number	River mile	Date of collection	Chlorophyll *a*, phytoplankton, chroma-Fl (μg/L) (70953)	Chlorophyll *b*, phytoplankton, chroma-Fl (μg/L) (70954)	Phytoplankton (cells per mL) (60050)	Chlorophyll *a*, periphyton, chroma-Fl (mg/m^2) (70957)	Chlorophyll *b*, periphyton chroma-Fl (mg/m^2) (70958)	Periphyton; organic weight (g/m^2)	Biomass/chlorophyll ratio, periphyton (units (70950)
35	19.6	8-25-81	2.55	<0.01	450	-----	----	---	-----
39	15.2	8-25-81	1.59	<.01	380	-----	----	---	-----
		9-01-81	----	----	---	56.5	4.6	4.6	81.4
47	13.1	8-24-81	2.35	<.01	920	-----	----	---	-----
		9-01-81	----	----	---	7.73	4.21	1.0	133
51	10.0	8-25-81	2.76	<.01	1200	-----	----	---	-----
		9-01-81	----	----	----	73.5	5.37	3.8	51.7
58	1.6	8-25-81	1.93	<.01	810	-----	----	---	-----
		9-01-81	----	----	----	37.6	7.77	2.0	53.2

Table 37.--Periphyton taxa present in samples from Osage Creek

[Periphyton strips placed in creek on 8-12-81, removed 9-01-81]

Scientific name	Common name	Station 39	Station 51
Chlorophyta	Green algae		
.Chlorophyceae			
..Chlorococcales			
...Scenedesmaceae			
....*Scenedesmus*		X	---
..Ulotrichales			
...Coleochaetaceae			
....*Coleochaete*		X	*
Chrysophyta	Yellow-green algae		
.Bacillariophyceae	Diatoms		
..Pennales	Pennate diatoms		
...Achnanthaceae			
....*Achnanthes*		---	X
....*Cocconeis*		X	X
....*Rhoicosphenia*		---	X
...Cymbellaceae			X
....*Cymbella*		X	X
...Eunotraceae			
....*Eunotia*		---	X
...Fragilariaceae			
....*Fragilaria*		X	X
...Gamphonemataceae			
....*Gomphonema*		X	X
...Naviculaceae	Naviculoids		
....*Navicula*		X	X
...Nitzschiaceae			
....*Nitzschia*		X	X
...Surirellaceae			
....*Surirella*		X	---
Cyanophyta	Blue-green algae		
.Cyanophyceae			
..Chroococcales	Coccoid blue-greens		
...Chroococccaceae			
....*Anacystis*		X	---
..Hormogonales	Filamentous blue-greens		
...Oscillatoriaceae			
....*Lyngbya*		*	X
....*Oscillatoria*		X	*

X Indicates organism present
* Indicates a dominant organism, estimated to be greater than 15 percent of total algal cells on sampling strip

Table 38.--Ethylene desorption rate and reaeration rate coefficients for selected reaches of Osage Creek

[Discharge = 51.4 ft^3/s]

Stream Reach Begin mile	Stream Reach End mile	k_T (day^{-1})	k_2 (day^{-1})	Percent difference[a]	Stream temperature (°C)
6.1	5.4	7.26	8.35	18	21.0
5.4	4.2	9.85	11.33	35	21.0
6.1	4.2	9.16	10.53	30	21.0

[a] Difference between percent change in gas concentration and percent change in dye concentration

Table 39.--Model-derived velocities and reaeration rate coefficients for Osage Creek low-flow projections

[Stream temperature = 29°C; Discharge from Rogers wastewater-treatment plant = 9.75 ft^3/s]

Subreach Begin mile	Subreach End mile	Mean discharge (ft^3/s)	Mean velocity (ft/s)	k_2 (day^{-1})
20.0	19.6	10.0	0.173	1.33
19.6	17.1	9.18	.158	1.33
17.1	14.5	8.22	.175	3.48
14.5	13.1	7.08	.151	3.48
13.1	10.5	13.4	.145	3.28
10.5	6.2	17.4	.164	3.28
6.2	4.9	18.3	.155	2.19
4.9	2.0	19.2	.142	2.19
2.0	1.2	19.2	.141	3.71
1.2	0.0	20.1	.143	3.48

Table 40.--Mean velocities, by subreach, for the 1979 and 1981 data sets collected on Osage Creek

Subreach		Velocities	
Begin mile	End mile	1979	1981
21.1	21.0	0.224	0.341
21.0	19.6	.232	.313
19.6	17.1	.276	.313
17.1	14.5	.389	.386
14.5	13.1	.388	.467
13.1	10.5	.421	.537
10.5	6.2	.559	.580
6.2	4.9	.593	.590
4.9	2.0	.580	.570
2.0	1.2	.628	.567
1.2	0.0	.645	.571

Table 41.--Modified components and rate coefficients for Osage Creek simulations that include projected effluent limits for the Rogers wastewater-treatment plant

Subreach				Benthic oxygen
Begin mile	End mile	k_d (day^{-1})	k_r (day^{-1})	demand [(g/m^2)/d]
20.0	19.6	0.17	0.17	3.11
19.6	17.1	.15	.15	1.55
17.1	14.5	.18	.18	1.40
14.5	13.1	.15	.15	1.35
13.1	10.5	.14	.14	4.36
10.5	6.2	.16	.16	5.11
6.2	4.9	.15	.15	1.55
4.9	2.0	.14	.14	1.77
2.0	1.2	.14	.14	2.35
1.2	0.0	.15	.15	2.44

Table 42.—Osage Creek model-simulation summary at 7-day, 10-year low flow using existing and projected loadings from the Rogers wastewater-treatment plant

Initial River Conditions		Rogers WWTP										Instream Total Suspended Solids[1]			Downstream Dissolved Oxygen Profile Sag				Projected concentrations and loadings at the mouth of Osage Creek													
Discharge (ft³/s)	Dissolved oxygen (mg/L)	Discharge (ft³/s)	Dissolved oxygen (mg/L)	CBODU (mg/L)	Total organic-N (mg/L)	Total ammonia-N (mg/L)	Total NO2-N (mg/L)	Total NO3-N (mg/L)	Total PO4-P (mg/L)	Total suspended solids (mg/L)	Concentration (mg/L)	Location (mile)	Water Temperature (°C)	Minimum resulting from Prairie Grove effluent (mg/L)	Location (mile)	Absolute minimum (mg/L)	Location (mile)	Discharge (ft³/s)	Dissolved oxygen (mg/L)	CBODU (mg/L)	CBODU (lb/d)	Total organic-N (mg/L)	Total organic-N (lb/d)	Total Ammonia-N (mg/L)	Total Ammonia-N (lb/d)	Total NO2-N (mg/L)	Total NO2-N (lb/d)	Total NO3-N (mg/L)	Total NO3-N (lb/d)	Total PO4-P (mg/L)	Total PO4-P (lb/d)
0.94	6.45	[2]5.40	[2]5.2	[2]45.5	[2]4.4	[2]1.75	[2]0.61	[2]6.75	[2]8.1	[2]21.5	19.2	21.0	29	0.00	20.7	0.00	20.7	15.70	4.61	0.42	35.54	0.04	3.38	0.00	0.00	0.00	0.00	0.63	53.31	0.139	11.76
.37	6.45	[3]5.40	[3]5.2	[3]45.5	[3]4.4	[3]1.75	[3].61	[3]6.75	[3]8.1	[3]21.5	20.5	20.0	29	.00	19.7	.00	19.7	15.71	4.61	.42	35.56	.04	3.39	.00	.00	.00	.00	.63	53.34	.154	13.04
.37	6.45	9.75	7.7	7.5	.0	2.0	.00	.00	1.0	5.0	5.0	20.0	29	6.22	19.6	4.28	7.3	20.06	6.74	1.41	152.44	.03	3.24	.00	.00	.00	.00	.66	71.36	.167	18.06
.37	6.45	9.75	7.7	7.5	.0	3.0	.00	.00	2.0	5.0	5.0	20.0	29	6.06	19.5	4.28	7.3	20.06	6.74	1.41	152.44	.03	3.24	.00	.00	.00	.00	.66	71.36	.220	23.78
.37	6.45	9.75	7.7	15	.0	5.0	.00	.00	5.0	15	14.7	20.0	29	5.21	19.0	4.24	7.2	20.06	6.73	1.63	176.23	.03	3.24	.00	.00	.00	.00	.66	71.36	.381	41.19
.37	6.45	9.75	7.7	15	.0	10	.00	.00	10	15	14.7	20.0	29	4.03	18.9	4.03	18.9	20.06	6.73	1.63	176.23	.03	3.24	.00	.00	.00	.00	.67	72.44	.647	69.95
.37	6.45	9.75	7.7	30	.0	10	.00	.00	10	20	19.5	20.0	29	2.86	18.5	2.86	18.5	20.06	6.70	2.06	222.72	.03	3.24	.00	.00	.00	.00	.67	72.44	.647	69.95
.37	6.45	9.75	7.7	45	.0	15	.00	.00	10	30	29.1	20.0	29	.40	18.3	.40	18.3	20.06	6.67	2.50	270.29	.03	3.24	.00	.00	.00	.00	.68	73.52	.647	69.95
.37	6.45	9.75	5.0	7.5	.0	2.0	.00	.00	1.0	5.0	5.0	20.0	29	4.06	19.6	4.06	19.6	20.06	6.74	1.41	152.44	.03	3.24	.00	.00	.00	.00	.66	71.36	.167	18.06
.37	6.45	9.75	5.0	7.5	.0	3.0	.00	.00	2.0	5.0	5.0	20.0	29	3.92	19.6	3.92	19.6	20.06	6.73	1.41	152.44	.03	3.24	.00	.00	.00	.00	.66	71.36	.220	23.78
.37	6.45	9.75	5.0	15	.0	5.0	.00	.00	5.0	5.0	14.7	20.0	29	3.39	19.6	3.39	19.6	20.06	6.73	1.63	176.23	.03	3.24	.00	.00	.00	.00	.66	71.36	.381	41.19
.37	6.45	9.75	5.0	15	.0	10	.00	.00	10	15	14.7	20.0	29	2.40	19.2	2.40	19.2	20.06	6.73	1.63	176.23	.03	3.24	.00	.00	.00	.00	.67	72.44	.647	69.95
.37	6.45	9.75	5.0	30	.0	10	.00	.00	10	20	19.5	20.0	29	1.49	18.9	1.49	18.9	20.06	6.70	2.06	222.72	.03	3.24	.00	.00	.00	.00	.67	72.44	.647	69.95
.37	6.45	9.75	5.0	45	.0	15	.00	.00	10	30	29.1	20.0	29	.00	19.3	.00	19.3	20.06	6.67	2.50	270.29	.03	3.24	.00	.00	.00	.00	.68	73.52	.647	69.95

[1] Represents mass balance immediately downstream from Rogers WWTP.
[2] Existing treatment plant conditions (mean of 1979 and 1981 data) at existing outfall.
[3] Existing treatment plant conditions (mean of 1979 and 1981 data) at proposed outfall.

Table 43.--Average dissolved oxygen deficits in Osage Creek, by subreach, for simulations that include projected changes in ultimate carbonaceous biochemical oxygen demand and ammonia-nitrogen concentrations from the Rogers wastewater-treatment plant

[Deficits in milligrams per liter]

Stream discharge = 7-day, 10-year low flow, Temperature = 29°C

Subreach: Beginning mile	Subreach: Ending mile	CBOD deficit	Benthal deficit	Net photosynthetic deficit	Ammonia-N deficit	Nitrite-N deficit
			CBODU = 45 mg/L, Ammonia-N = 15 mg/L			
20.0	19.6	0.37	0.195	0.048	0.556	0.042
19.6	17.1	.33	.106	- .174	.102	.052
17.1	14.5	.25	.141	.026	.005	.005
14.5	13.1	.20	.156	.100	.004	.002
13.1	10.5	.10	.509	- .311	.002	.001
10.5	6.2	.04	.519	- .152	.004	.001
6.2	4.9	.04	.136	- .201	.002	.001
4.9	2.0	.03	.168	- .029	.001	.001
2.0	1.2	.02	.302	- .043	.001	.000
1.2	0.0	.02	.294	- .205	.002	.001
			CBODU = 30 mg/L, Ammonia-N = 10 mg/L			
20.0	19.6	0.25	0.195	0.048	0.371	0.025
19.6	17.1	.22	.106	- .174	.068	.035
17.1	14.5	.17	.141	.026	.003	.003
14.5	13.1	.14	.156	.100	.003	.001
13.1	10.5	.07	.509	- .311	.001	.001
10.5	6.2	.03	.519	- .152	.004	.001
6.2	4.9	.03	.136	- .201	.002	.001
4.9	2.0	.02	.168	- .029	.001	.001
2.0	1.2	.02	.302	- .043	.001	.000
1.2	0.0	.02	.294	- .205	.002	.001

Table 43.--Average dissolved oxygen deficits in Osage Creek, by subreach, for simulations that include projected changes in ultimate carbonaceous biochemical oxygen demand and ammonia-nitrogen concentrations from the Rogers wastewater-treatment plant--Continued

Stream discharge = 7-day, 10-year low flow, Temperature = 29°C

Subreach						
Beginning mile	Ending mile	CBOD deficit	Benthal deficit	Net photosynthetic deficit	Ammonia-N deficit	Nitrite-N deficit
CBODU = 15 mg/L, Ammonia-N = 10 mg/L						
20.0	19.6	0.12	0.195	0.046	0.371	0.028
19.6	17.1	.11	.106	- .174	.068	.035
17.1	14.5	.09	.141	.026	.003	.003
14.5	13.1	.07	.156	.100	.003	.001
13.1	10.5	.05	.509	- .311	.001	.001
10.5	6.2	.03	.519	- .152	.004	.001
6.2	4.9	.02	.136	- .201	.002	.001
4.9	2.0	.02	.168	- .029	.001	.001
2.0	1.2	.02	.302	- .043	.001	.000
1.2	0.0	.02	.294	- .205	.002	.001
CBODU = 15 mg/L, Ammonia-N = 5 mg/L						
20.0	19.6	0.12	0.195	0.048	0.186	0.014
19.6	17.1	.11	.106	- .174	.034	.018
17.1	14.5	.09	.141	.026	.002	.002
14.5	13.1	.07	.156	.100	.001	.001
13.1	10.5	.05	.509	- .311	.001	.000
10.5	6.2	.03	.519	- .152	.004	.001
6.2	4.9	.02	.136	- .201	.002	.001
4.9	2.0	.02	.168	- .029	.001	.001
2.0	1.2	.02	.302	- .043	.001	.000
1.2	0.0	.02	.294	- .205	.002	.001

Table 43.--Average dissolved oxygen deficits in Osage Creek, by subreach, for simulations that include projected changes in ultimate carbonaceous biochemical oxygen demand and ammonia-nitrogen concentrations from the Rogers wastewater-treatment plant--Continued

Stream discharge = 7-day, 10-year low flow, Temperature = 29°C

Subreach						
Beginning mile	Ending mile	CBOD deficit	Benthal deficit	Net photosynthetic deficit	Ammonia-N deficit	Nitrite-N deficit
CBODU = 7.5 mg/L, Ammonia-N = 3 mg/L						
20.0	19.6	0.06	0.195	0.048	0.111	0.008
19.6	17.1	.06	.106	- .174	.021	.010
17.1	14.5	.04	.141	.026	.001	.001
14.5	13.1	.04	.156	.100	.001	.000
13.1	10.5	.04	.509	- .311	.001	.000
10.5	6.2	.02	.519	- .152	.004	.001
6.2	4.9	.02	.136	- .201	.002	.001
4.9	2.0	.02	.168	- .029	.001	.001
2.0	1.2	.01	.302	- .043	.001	.000
1.2	0.0	.01	.294	- .205	.002	.001
CBODU = 7.5 mg/L, Ammonia-N = 2 mg/L						
20.0	19.6	0.06	0.195	0.048	0.074	0.006
19.6	17.1	.06	.106	- .174	.014	.007
17.1	14.5	.04	.141	.026	.001	.001
14.5	13.1	.04	.156	.100	.001	.000
13.1	10.5	.04	.509	- .311	.001	.000
10.5	6.2	.02	.519	- .152	.004	.001
6.2	4.9	.02	.136	- .201	.002	.001
4.9	2.0	.02	.168	- .029	.001	.001
2.0	1.2	.01	.302	- .043	.001	.000
1.2	0.0	.01	.294	- .205	.002	.001

Table 43.--Average dissolved oxygen deficits in Osage Creek, by subreach, for simulations that include projected changes in ultimate carbonaceous biochemical oxygen demand and ammonia-nitrogen concentrations from the Rogers wastewater-treatment plant--Continued

Stream discharge = 7-day, 10-year low flow, Temperature = 29°C

Subreach: Beginning mile	Subreach: Ending mile	CBOD deficit	Benthal deficit	Net photosynthetic deficit	Ammonia-N deficit	Nitrite-N deficit
Observed Loading at New Discharge Point (see table 37)						
20.0	19.6	0.57	1.529	0.084	0.093	0.101
19.6	17.1	.24	.960	-.326	.010	.017
17.1	14.5	.03	.810	.052	.002	.001
14.5	13.1	.01	1.227	.236	.001	.001
13.1	10.5	.04	1.030	-.458	.001	.000
10.5	6.5	.03	.863	-.098	.005	.002
6.2	4.9	.01	.453	-.261	.002	.001
4.9	2.0	.01	.606	-.037	.002	.001
2.0	1.2	.00	.814	-.055	.001	.000
1.2	0.0	.01	.755	-.755	-.257	.001
Existing Conditions (see table 42)						
20.0	19.6	0.37	1.504	0.082	0.038	0.044
19.6	17.1	.11	.989	.335	.002	.003
17.1	14.5	.02	.812	.050	.001	.000
14.5	13.1	.00	1.230	.237	.001	.000
13.1	10.5	.04	1.031	-.458	.001	.000
10.5	6.5	.02	.864	-.198	.005	.002
6.2	4.9	.01	.454	-.261	.002	.001
4.9	2.0	.01	.607	-.037	.002	.001
2.0	1.2	.00	.814	-.055	.001	.000
1.2	0.0	.01	.755	-.257	.003	.001

Sensitivity Testing

The Osage Creek simulation with the projected Rogers effluent limit number 3 imposed and effluent DO concentration set to saturation (7.7 mg/L) was used for sensitivity testing. The criteria used, and the parameters and coefficients tested for sensitivity, are listed in the "Model Sensitivity" section. Figures 47 through 59 show the resulting sensitivity bands.

For the flow conditions in the simulation tested, the DO profile is more sensitive to changes in reaeration coefficients, net subreach average benthic demands, and DO production than any other parameter tested. The DO sensitivity bands for these parameters are shown in figures 51, 52, and 56. Each of the processes defined by these parameters seem to have equal impact upon the Osage Creek DO profile. Like changes in either, therefore, precipitate similar changes in the resulting DO profile.

Osage Creek Conclusions

Under existing conditions, Osage Creek does not meet standards (Arkansas Department of Pollution Control and Ecology, 1981) for the following parameters: diel-minimum DO, total phosphorus, water temperature, and fecal coliform bacteria. Stormwater-runoff sampling indicates that significant nutrient loads may be contributed to the stream during runoff periods. The nutrients contribute to benthic demands at low flow and may be resuspended in the water column when velocities increase, or when the streambed is disturbed for any reason.

Simulations indicate that generally, the largest DO deficits result from benthic demands (table 43). Exceptions to this are in subreach 1, when effluent ammonia-N concentrations equal or exceed 10 mg/L and, in subreaches 2 through 4 when effluent CBODU concentrations equal or exceed 30 mg/L. For these exceptions, DO deficits resulting from nitrification (ammonia-N to NO_2-N) and CBODU, respectively, are the largest.

Diel-minimum DO concentrations in Osage Creek resulting in part from the instream waste concentrations discharged by the Rogers WWTP will meet the diel-minimum DO concentration standard (Arkansas Department of Pollution Control and Ecology, 1981) of 4.0 mg/L with projected effluent limits number 3, 4, 5, or 6 imposed and effluent DO concentrations set at saturation (7.7 mg/L). The standard of 4.0 mg/L can also be met with effluent limit 6 imposed and the effluent DO concentration set at 5.0 mg/L (table 42). Both of the $Q_{7/10}$ simulations for "as surveyed" effluent loadings--one at the existing inflow location and one at the proposed new inflow location--result in instream diel-minimum DO concentration of 0.0 mg/L (table 42).

Sensitivity testing indicates that the DO profile is most sensitive to net DO production, benthic demands, and reaeration coefficients.

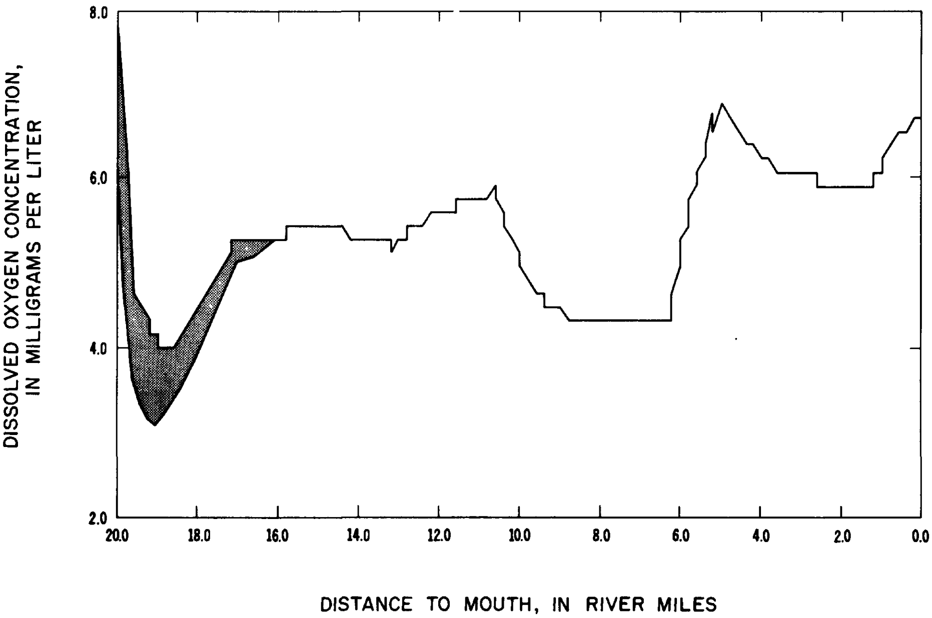

Figure 47.--Band reflecting the sensitivity of Osage Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the dissolved oxygen concentration of the effluent from the Rogers wastewater-treatment plant; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the wastewater-treatment plant is 15 mg/L ultimate biochemical oxygen demand, 10.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

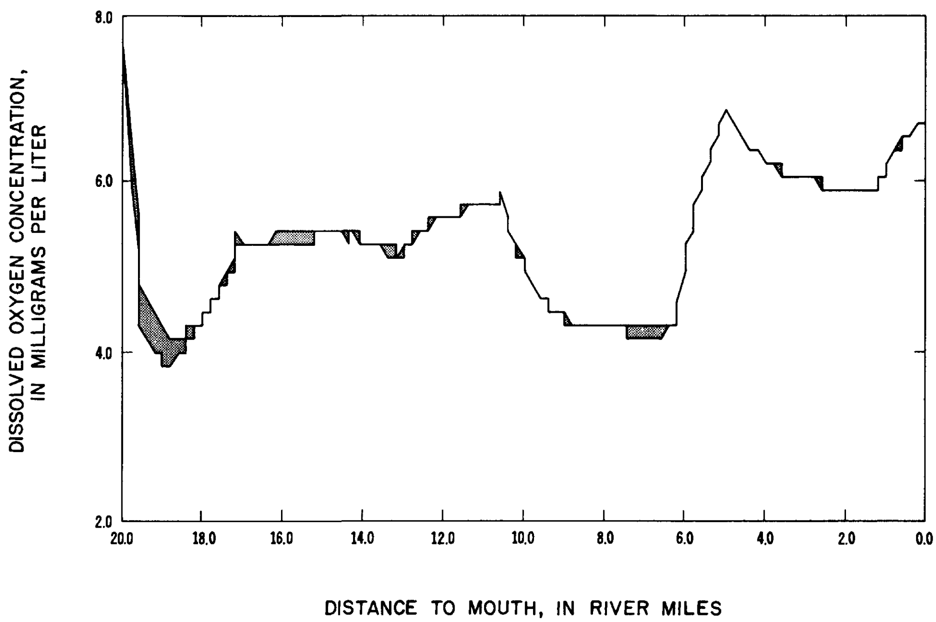

Figure 48.--Band reflecting the sensitivity of Osage Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the ammonia forward reaction and decay rates; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Rogers wastewater-treatment plant is 15.0 mg/L ultimate biochemical oxygen demand, 10.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

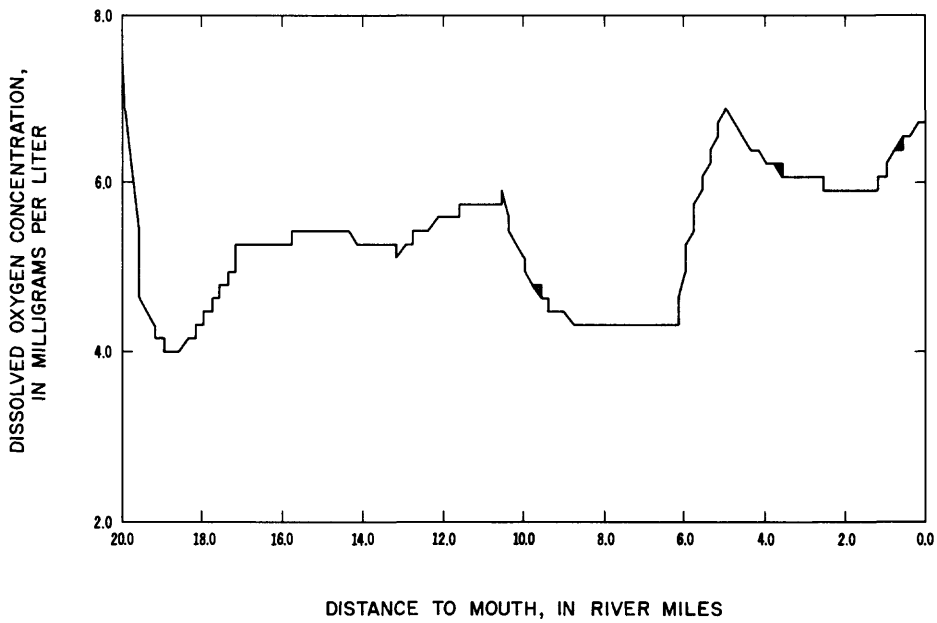

Figure 49.--Band reflecting the sensitivity of Osage Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the organic nitrogen forward reaction and decay rates; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Rogers wastewater-treatment plant is 15.0 mg/L ultimate biochemical oxygen demand, 10.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

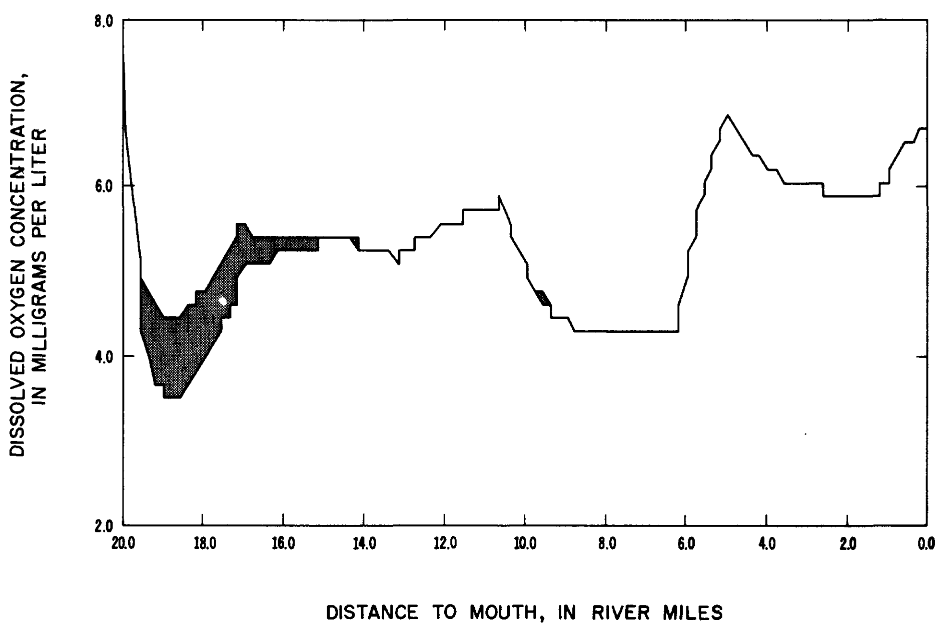

Figure 50.--Band reflecting the sensitivity of Osage Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the ammonia concentration of the effluent from the Rogers wastewater-treatment plant; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the wastewater-treatment plant is 15.0 mg/L ultimate biochemical oxygen demand, 10.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

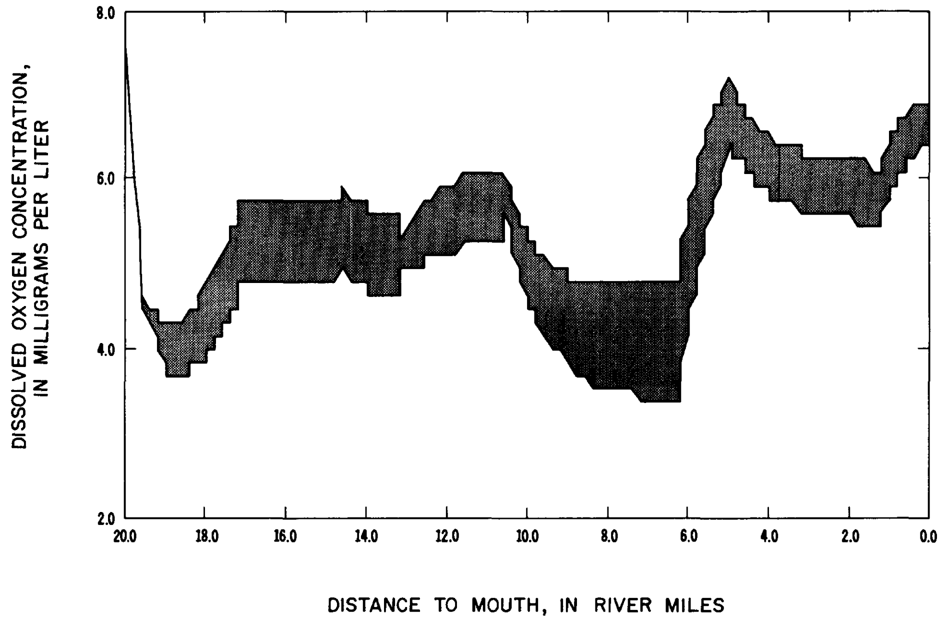

Figure 51.--Band reflecting the sensitivity of Osage Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the reaeration coefficients; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Rogers wastewater-treatment plant is 15.0 mg/L ultimate biochemical oxygen demand, 10.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

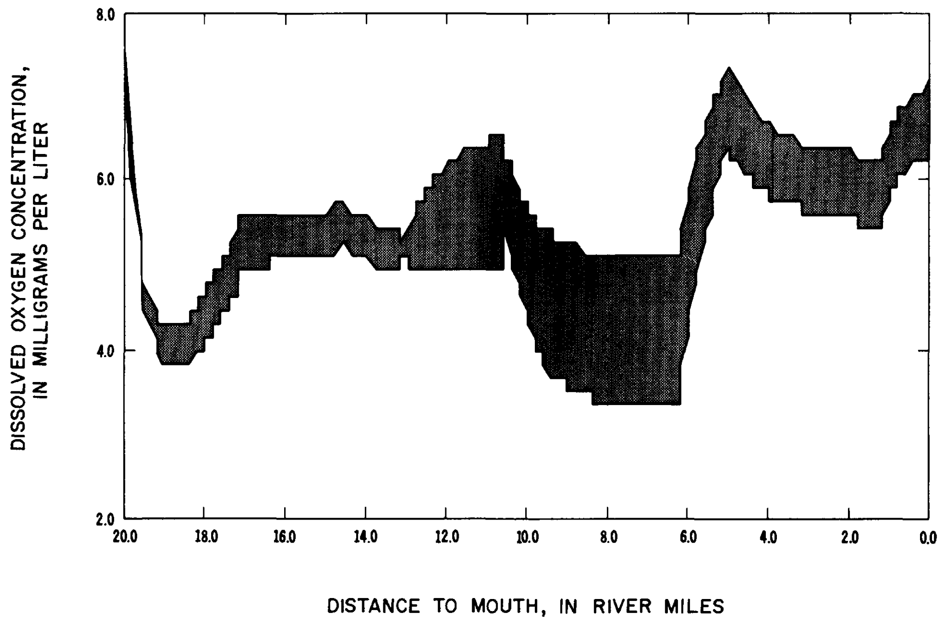

Figure 52.--Band reflecting the sensitivity of Osage Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the benthic demands; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Rogers wastewater-treatment plant is 15.0 mg/L ultimate biochemical oxygen demand, 10.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

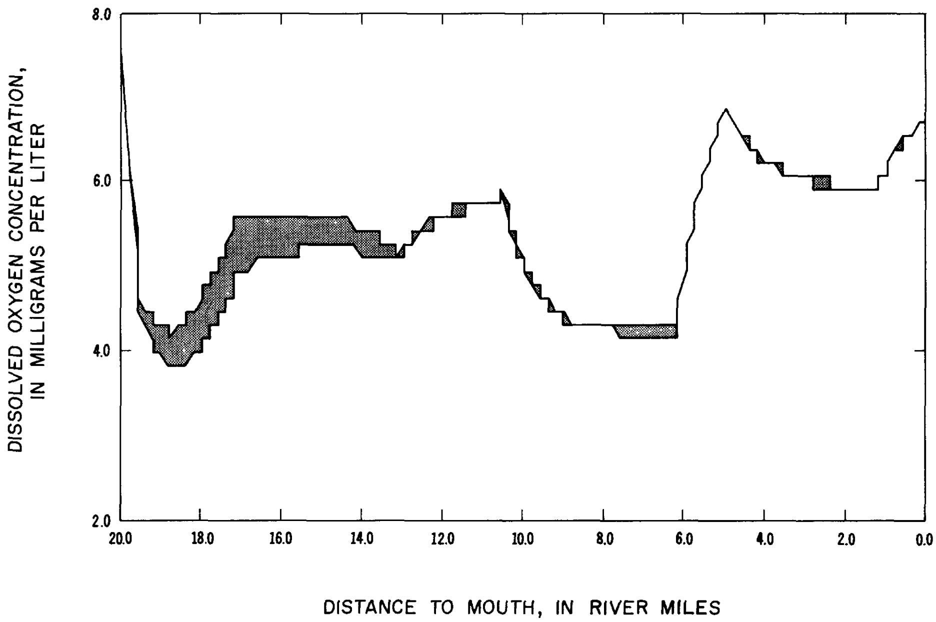

Figure 53.--Band reflecting the sensitivity of Osage Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the ultimate carbonaceous biochemical oxygen demand of the effluent from the Rogers wastewater-treatment plant; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Rogers wastewater-treatment plant is 15.0 mg/L ultimate biochemical oxygen demand, 10.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

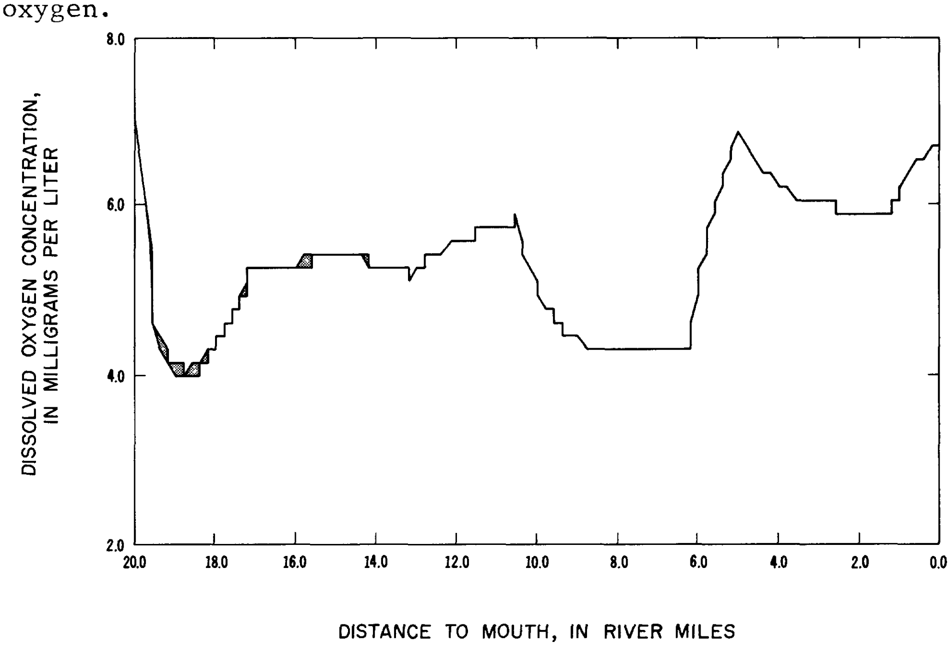

Figure 54.--Band reflecting the sensitivity of Osage Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the nitrite forward reaction and decay rates; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Rogers wastewater-treatment palnt is 15.0 mg/L ultimate biochemical oxygen demand, 10.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

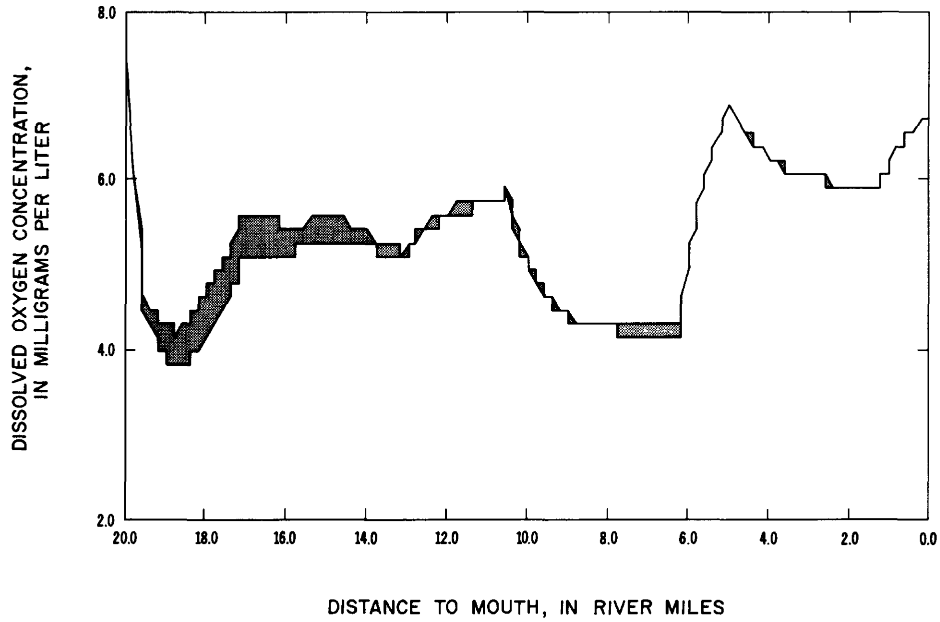

Figure 55.--Band reflecting the sensitivity of Osage Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the deoxygenation and removal rates for carbonaceous material; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Rogers wastewater-treatment plant is 15.0 mg/L ultimate biochemical oxygen demand, 10.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

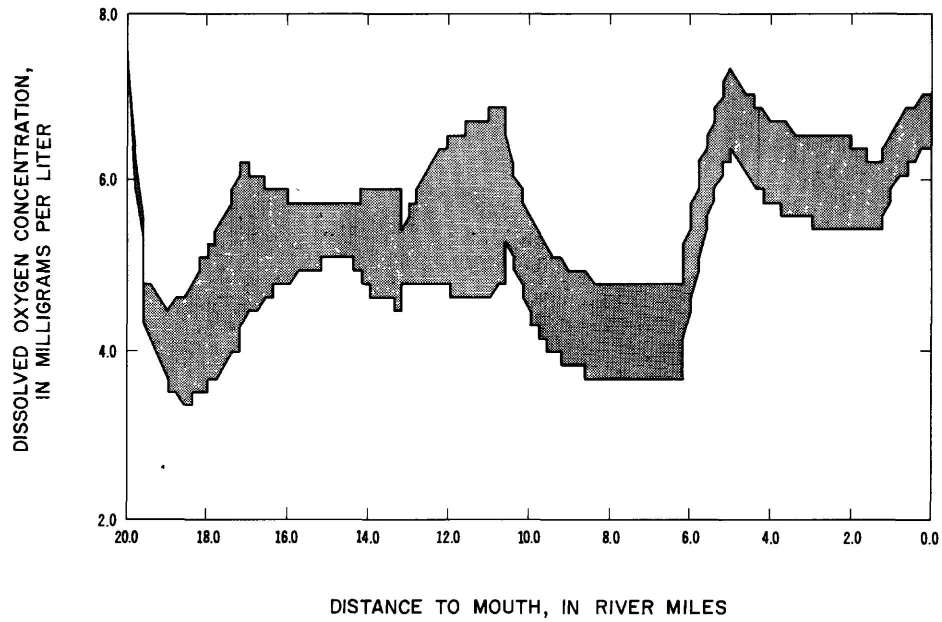

Figure 56.--Band reflecting the sensitivity of Osage Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in the net photosynthetic production; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Rogers wastewater-treatment plant is 15.0 mg/L ultimate biochemical oxygen demand, 10.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

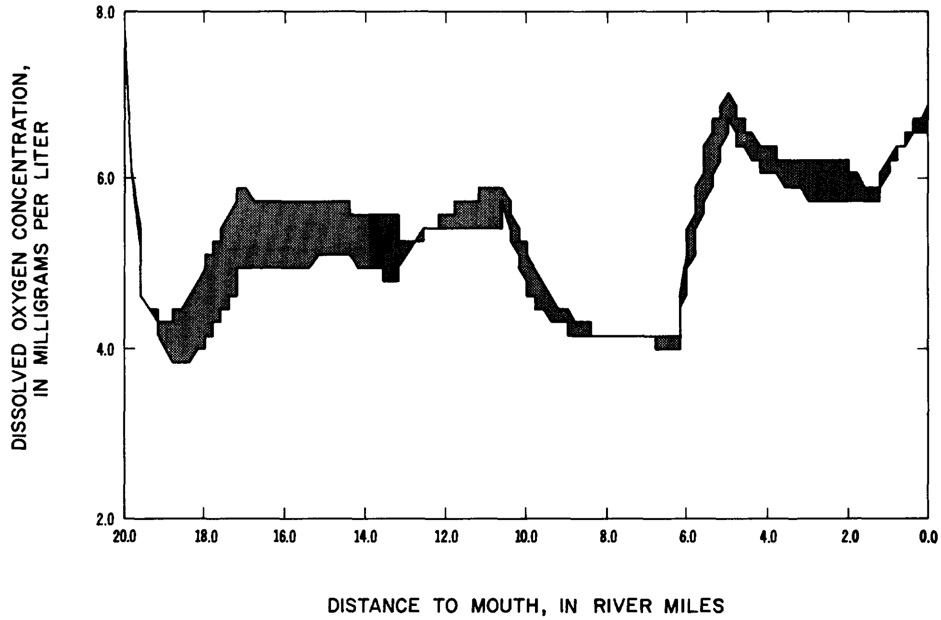

Figure 57.--Band reflecting the sensitivity of Osage Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in mean river depths; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Rogers wastewater-treatment plant is 15.0 mg/L ultimate biochemical oxygen demand, 10.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

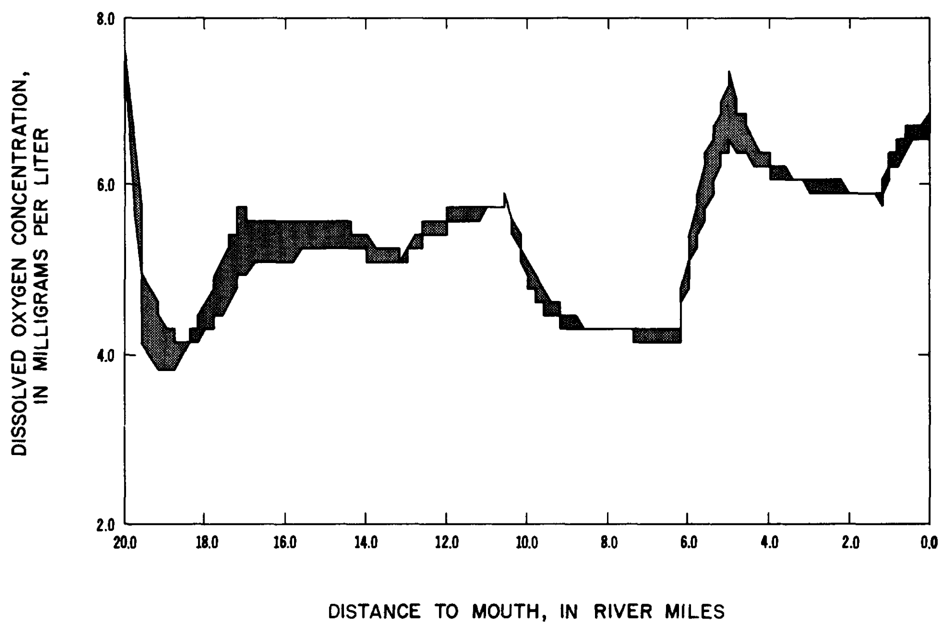

Figure 58.--Band reflecting the sensitivity of Osage Creek dissolved-oxygen concentrations to a plus or minus 20-percent change in mean river velocities; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Rogers wastewater-treatment plant is 15.0 mg/L ultimate biochemical oxygen demand, 10.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

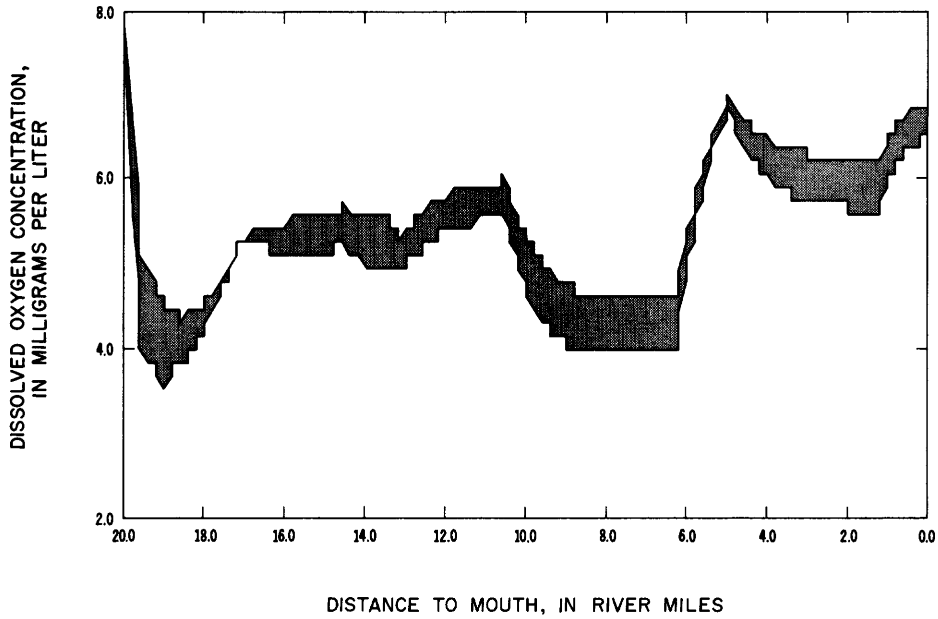

Figure 59.--Band reflecting the sensitivity of Osage Creek dissolved-oxygen concentrations to a plus or minus 2.0-degree celsius change in water temperature; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Rogers wastewater-treatment plant is 15.0 mg/L ultimate biochemical oxygen demand, 10.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

ILLINOIS RIVER ASSESSMENT

Illinois River (fig. 1) flows generally south to north to a point upstream from Osage Creek and then from east to west, through Lake Frances into Oklahoma. It has a drainage area of approximately 567 mi^2 (Sullavan and Terry, 1970) at site 79 and 635 mi^2 (USGS, 1978) at site 83 (fig. 60). There are no municipal WWTP's currently discharging directly into Illinois River. A proposed location for the Fayetteville WWTP inflow is at mile 138.7 (fig. 60), 0.3 mile upstream from Goose Creek. The reach of Illinois River modeled is from mile 144.5 to mile 109.0 (fig. 60). A location index for sites where data were collected for the Illinois River assessment is given in table 44.

Surface-Water Hydrology

Illinois River is primarily a pool and riffle stream with long, deep pools dominating near Lake Frances. Channel slopes range from 7.0 ft/mi to 1.8 ft/mi in a downstream direction.

Cumulative flows in Illinois River during collection of the calibration data set (Aug. 24-Sept. 5, 1981) ranged from 1.4 ft^3/s at mile 144.5 to 128.1 ft^3/s at mile 109.0 (Attachment E-2, E-3, E-6, and E-21). Cumulative flows during collection of the verification data set (July 23-27, 1979) ranged from 0.52 ft^3/s at mile 144.5 to 125.7 ft^3/s at mile 109.0 (Attachment E-23, E-24, E-27, and E-41). The most significant tributaries are Clear Creek and Osage Creek.

An existing $Q_{7/10}$ low-flow distribution (fig. 61) was defined on the basis of data presented by Hines (1975), and Hunrichs (1983). This distribution was established by mass-balancing total discharge at sites 19, 72, and 83 (table 44). The difference between the sum of initial and point-source $Q_{7/10}$ discharges and the established $Q_{7/10}$ discharge at site 19 was distributed linearly as flow gain between stream mile 138.7 and mile 133.1 (fig. 61). This distribution resulted in a flow increase between miles 138.7 and 133.1 of 0.09 ft^3/s per mile. The difference between the $Q_{7/10}$ discharge at site 19, plus intervening tributary $Q_{7/10}$ discharges, and the established $Q_{7/10}$ discharge of site 72 was distributed in a similar manner to mile 115.5. This resulted in a flow increase of 1.55 ft^3/s per mile. This positive flow incrementation was assumed valid to mile 109.0. The resulting $Q_{7/10}$ discharge is 56 ft^3/s (fig. 61). In addition, an estimate of flow loss through Lake Frances was computed on the basis of potential evaporation (Kohler and others, 1959), lake area, and estimated travel time. The resulting value of 20 ft^3/s checks well against the flow loss of 21.61 ft^3/s (fig. 61) needed to match the established $Q_{7/10}$ discharge at mile 106.2 (site 83).

Water Quality

Physical Characteristics

Suspended solids.-- During the collection of "steady-state" data in 1978, 1979, and 1981, suspended-solids concentrations in Illinois River ranged from 3 to 41 mg/L (table 45). Tributary inflow concentrations ranged from 1 to 18 mg/L. Concentrations of suspended-solids during stormwater-runoff periods were 2 to 10 times greater than during periods of lower flow (table 46). Concentrations ranged from 30 to 98 mg/L. Sites H3 and H4 were not sampled during "steady-state" conditions and are compared in table 46 and in the following discussion with site 1. Data for site 5a may be compared directly. Sources of suspended solids during higher flow periods are resuspension of deposited material and overland flow of stormwater runoff. Nutrients and bacteria attached to suspended solids may be transported into streams by stormwater runoff.

Water temperature.-- Water temperatures ranged from 6.0 to 29.5°C in Illinois River. Tributary inflow temperatures ranged from 6.0 to 28.0°C (table 47).

Dissolved solids.-- Dissolved-solids concentrations for the 1978 "steady-state" sampling periods ranged from 116 to 197 mg/L in Illinois River and from 101 to 225 mg/L in tributaries sampled (table 45). The data indicate that Arkansas stream water quality standards (Arkansas Department of Pollution Control and Ecology, 1981) for dissolved solids were not being violated.

Minimal dissolved-solids concentrations in stormwater-runoff samples (table 46) estimated from measured specific conductance values ranged from 108 to 162 mg/L.

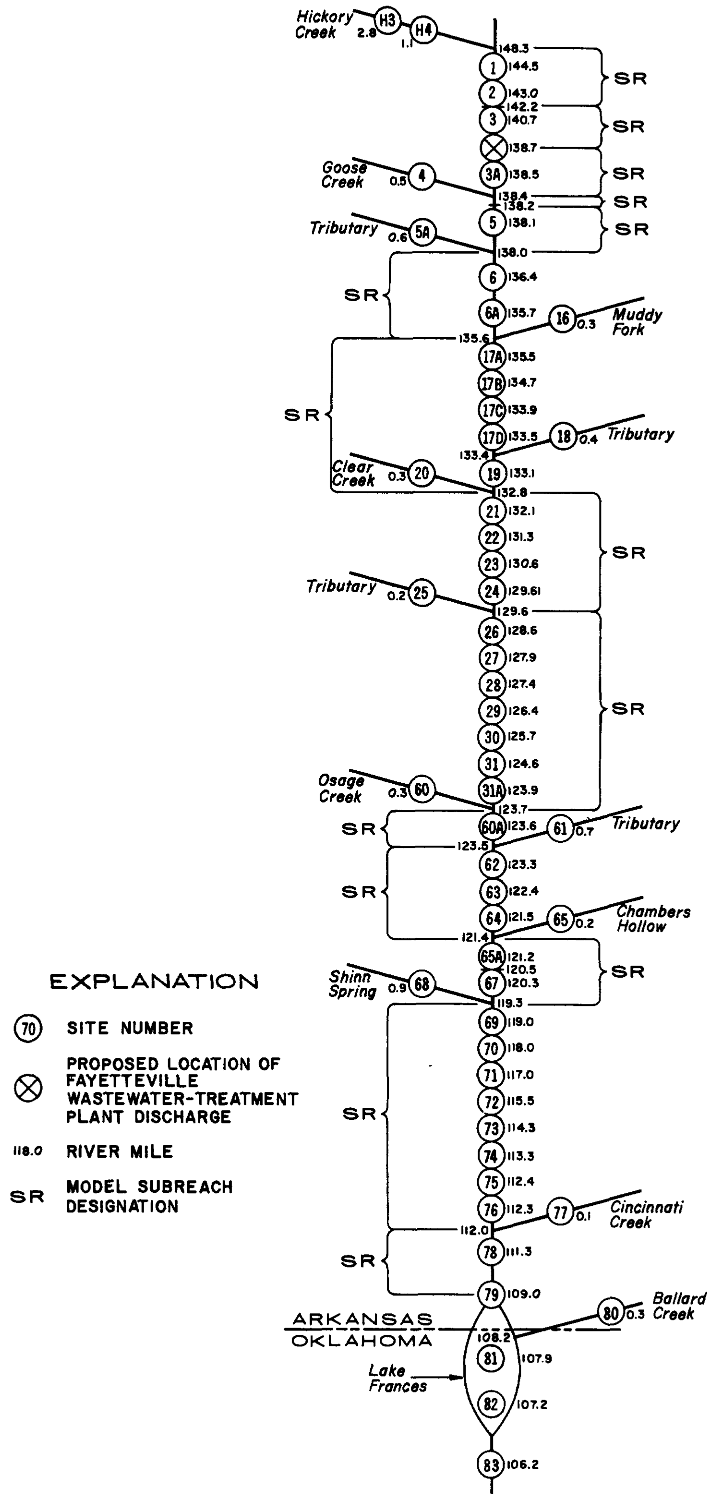

Figure 60.--Schematic of the Illinois River showing sampling-site and model-subreach locations.

Table 44.--Illinois River index for site name and identification number, U.S. Geological Survey station number, and location

Site Name	Site Identification Number	USGS Station Number	Location Latitude	Location Longitude
Hickory Creek near Greenland	H3	355916094125800	355916	0941258
Hickory Creek near Mountain Gap church	H4	355819094140700	355819	0941407
Illinois River at Highway 62 near Prairie Grove	1	355930094173600	355930	0941736
Illinois River at bridge west of Walnut Grove	2	360018094181000	360018	0941810
Illinois River at bridge north of Viney Grove	3	360131094191500	360131	0941915
Illinois River at mouth of Goose Creek	3A	360258094185900	360258	0941859
Goose Creek half mile from Illinois River	4	360304094183400	360304	0941834
Illinois River at bridge downstream from Goose Creek	5	360316094190600	360316	0941906
Tributary near Elkhorn Springs	5A	360334094184100	360335	0941841
Illinois River 1 mile from Muddy Fork	6	360401094201700	360401	0942017
Illinois River at mouth of Muddy Fork	6A	360423094204600	360423	0942046
Muddy Fork one fourth mile upstream from mouth	16	360410094205400	360410	0942054
Illinois River one eighth mile downstream from Muddy Fork	17A	360431094204600	360431	0942046
Illinois River 1 mile downstream from Muddy Fork	17B	360456094203200	360456	0942032
Illinois River east of Lake Weddington	17C	360533094202300	360533	0942023
Illinois River upstream from tributary near Savoy	17D	360554094203100	360554	0942031
Illinois River tributary near Savoy at county road bridge	18	360550094205100	360550	0942051
Illinois River at Savoy, Arkansas	19	07194800	360611	0942039
Clear Creek at brige near Savoy	20	360612094201000	360612	0942010
Illinois River west of Savoy	21	360638094204800	360638	0942048
Illinois River northwest of Savoy	22	360711094204900	360711	0942049
Illinois River southwest of Whiteoak Church	23	360746094204000	360746	0942040
Illinois River at county road bridge	24	360805094212900	360805	0942129
Unnamed stream at county road bridge	25	360813094212800	360813	0942128
Illinois River at Washington and Benton county line	26	360832094214400	360832	0942144
Illinois River mile and half south of Robinson	27	360901094215700	360901	0942157
Illinois River southwest of Robinson	28	360930094220200	360930	0942202

Table 44.--Illinois River index for site name, and identification number, U.S. Geological Survey station number and location--Continued

Site Name	Site Identification Number	USGS Station Number	Location	
			Latitude	Longitude
Illinois River at Robinson	29	361016094215300	361016	0942153
Illinois River west of Robinson	30	361031094223300	361031	0942233
Illinois River northeast of Pedro	31	361032094233200	361032	0942332
Illinois River upstream from Osage Creek	31A	361036094240600	361036	0942406
Osage Creek at Highway 68 bridge	60	361048094240600	361048	0942406
Illinois River downstream from Osage Creek	60A	361035094241900	361035	0942419
Illinois River tributary at Pedro	61	361008094241400	361008	0942414
Illinois River half mile downstream from Osage Creek	62	361027094243400	361027	0942434
Illinois River 2 miles south of Gallatin	63	361028094252700	361028	0942527
Illinois River upstream of Chambers Hollow	64	360959094260300	360959	0942603
Chambers Hollow at mouth at road cross	65	360953094261200	360953	0942612
Illinois River downstream from Chambers Hollow	65A	361007094260800	361007	0942608
Illinois River at roadside park	67	361024094270100	361024	0942701
Shinn Spring at Highway 68 bridge	68	361021094273300	361021	0942733
Illinois River near Gum Springs	69	360929094271200	360929	0942712
Illinois River southeast of Gum Springs	70	360855094274900	360855	0942749
Illinois River south of Gum Springs	71	360835094282900	360835	0942829
Illinois River near Siloam Springs, Arkansas	72	07195400	360841	0942941
Illinois River 3 miles southeast of Siloam Springs	73	360759094301100	360759	0943011
2 miles east of Lake Frances	74	360721094305800	360721	0943058
Illinois River northwest of Nicodemus Church	75	360703094312500	360703	0943125
Illinois River southwest of Nicodemus Church	76	360621094312000	360621	0943120
Cincinnati Creek at mouth	77	360613094314300	360613	0943143
Illinois River south of Siloam Springs, Arkansas	78	07195430	360631	0943200
Illinois River at Benton and Adair County line	79	360606094330500	360606	0943305
Ballard Creek at Watts, Oklahoma	80	360622094335400	360622	0943354
Lake Frances near south end	81	360649094333000	360649	0943330
Lake Frances near north end	82	360727094333800	360727	0943338
Illinois River near Watts, Oklahoma	83	07195500	360748	0943412

Chloride.-- Chloride concentrations for the 1978 "steady state" sampling periods ranged from 9.0 to 14 mg/L in Illinois River and from 7.5 to 14 mg/L in tributaries sampled (table 45). The data indicate that Arkansas water quality standards (Arkansas Department of Pollution Control and Ecology, 1981) for chloride were not violated.

Sulfate.-- Sulfate concentrations for the 1978 "steady state" sampling periods ranged from 1.0 to 24 mg/L in Illinois River and from 1.0 to 25 mg/L in tributaries sampled (table 45). The data indicate that Arkansas water quality standards (Arkansas Department of Pollution Control and Ecology, 1981) for sulfate were violated at five sites.

pH.-- Values of pH ranged from 6.8 to 8.8 in Illinois River and from 6.8 to 8.2 in its tributary inflows (table 45).

Dissolved oxygen.-- Dissolved-oxygen concentration ranged from 3.8 to 16.2 mg/L, in Illinois River and tributary inflow concentrations ranged from 4.5 to 12.4 mg/L (table 47). According to Arkansas water-quality standards (Arkansas Department of Pollution Control and Ecology, 1981), an instantaneous minimum DO concentration in Illinois River shall be greater than or equal to 6.0 mg/L.

Ultimate carbonaceous biochemical oxygen demand.-- During "steady-state" conditions CBODU ranged from 1.5 to 10 mg/L (table 45). Tributary inflow concentrations ranged from 1.2 to 6.5 mg/L. Concentrations of CBODU in stormwater-runoff samples ranged from 5.1 to 10 mg/L (table 46).

Streambed oxygen demand.-- Measured streambed oxygen demands showed significant variation between sampling sites. Values ranged from 0.08 to 1.82 $(g/m^2)/d$ (table 48).

Net photosynthetic dissolved-oxygen production. --"Net DO production" was calculated as discussed previously in the general "Net Photosynthetic Dissolved-Oxygen Production" section. It ranged from 0.23 to 3.2 (mg/L)/d (table 49). Chlorophyll *a* concentrations used in calculations were distance-weighted estimates based on actual chlorophyll *a* concentrations at sites 5, 19, 31, and

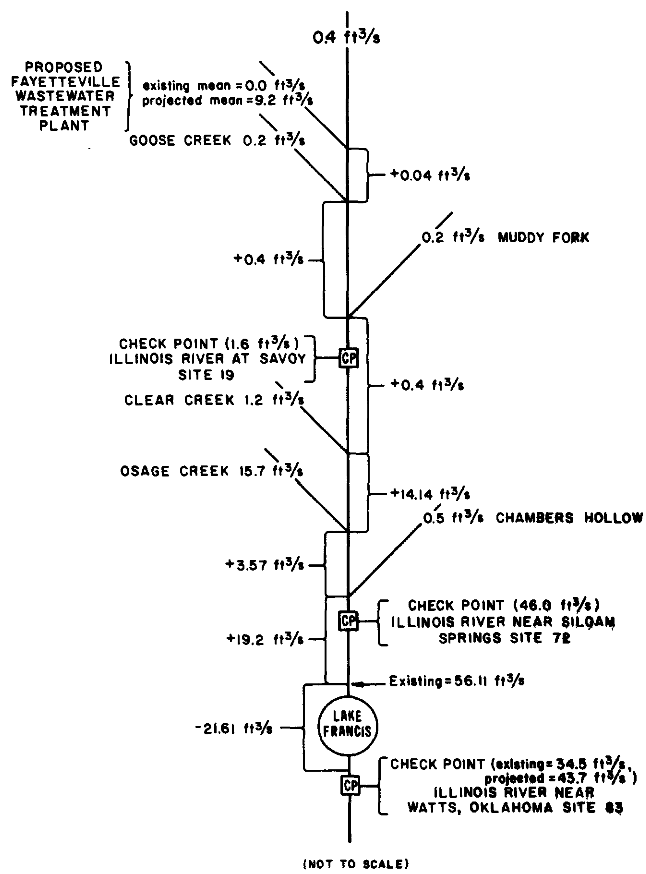

Figure 61.--7-day, 10-year low flow distribution for Illinois River.

72. For modeling purposes net DO production was calculated for each subreach (see "Simulation Techniques" section and Attachments E-6 and E-27).

Nutrients.-- Analyses indicate nutrient enrichment of Illinois River and its tributaries (table 45). Nutrients were not diluted during the stormwater-runoff events sampled (table 46). This suggests that nutrients deposited on the streambed were resuspended as velocities increased and/or that overland stormwater-runoff transported nutrients into the streams.

During "steady-state" conditions organic-N concentrations (table 45) ranged from 0.0 to 1.1 mg/L in Illinois River and from 0.0 to 1.0 mg/L in its tributary inflows. Concentrations of organic-N in stormwater-runoff samples ranged from 0.71 to 1.5 mg/L (table 46).

During "steady-state" conditions, ammonia-N concentrations (table 45) ranged from 0.01 to 0.91 mg/L in Illinois River and from 0.1 to 0.25 mg/L in tributary inflows. Ammonia-N concentrations in stormwater runoff ranged from 0.04 to 0.28 mg/L (table 46).

NO_2-N concentrations (table 45) in "steady-state" condition samples ranged from 0.01 to 0.06 mg/L in Illinois River and ranged from 0.01 to 0.07 mg/L in tributary inflows. Concentrations in stormwater-runoff samples ranged from 0.00 to 0.05 mg/L (table 46).

During "steady-state" conditions, NO_3-N concentrations (table 45) ranged from 0.06 to 2.6 mg/L in Illinois River and from 0.05 to 3.3 mg/L in tributary inflows. Concentrations in stormwater-runoff samples ranged from 0.39 to 0.85 mg/L (table 46).

During the "steady-state" conditions, PO_4-P and phosphorus-P concentrations generally decreased downstream (table 45 and Attachment E-12 and E-33). Concentrations are higher downstream from Muddy Fork and downstream from Osage Creek. PO_4-P concentrations ranged from 0.01 to 0.61 mg/L in Illinois River and from 0.01 to 0.80 mg/L in tributary inflows. PO_4-P concentrations in runoff samples ranged from 0.00 to 0.16 mg/L (table 46).

Phosphorus-P concentrations (table 45) during "steady-state" conditions ranged from 0.03 to 0.61 mg/L in Illinois River and from 0.03 to 0.80 mg/L in tributary inflows. Arkansas water-quality standards (Arkansas Department of Pollution Control and Ecology, 1981) suggest as a "guideline" that phosphorus-P concentrations not exceed 0.100 mg/L in streams. This guideline concentration was exceeded in 45 percent of the "steady-state" samples collected in the Illinois River basin (excluding Muddy Fork and Osage Creek basins). Phosphorus-P concentrations in stormwater runoff samples ranged from 0.09 to 0.18 mg/L (table 46).

Biological Characteristics

Phytoplankton.-- Phytoplankton densities ranged from 260 to 470 cells/mL (table 50). The most dominant genera of phytoplankton were *Nitzschia, Oscillatoria, Melosira* and *Navicula* (table 50). These genera are among the most commonly occurring and most dominant genera of phytoplankton of the United States (Greeson, 1982). Phytoplankton-chlorophyll *a* concentrations (table 51) ranged from 1.04 to 4.0 μg/L.

Periphyton.-- Periphyton organic weights ranged from 0.71 to 4.8 g/m^2 (table 51). The dominant genera were *Coleochaete, Lyngbya* and *Oscillatoria* (table 52). Periphyton chlorophyll *a* concentrations ranged from 4.61 to 50.9 mg/m^2 (table 46).

Total and fecal coliform bacteria.-- Total-coliform bacteria ranged from 50 to 4800 colonies per 100 mL in Illinois River and its tributary inflows (table 45). Fecal coliform bacteria (table 45) ranged from 33 to 3700 colonies per 100 mL in Illinois River and from 7 to 6500 colonies per 100 mL in tributary inflows. Several observed fecal coliform bacteria concentrations in Illinois River and its tributary inflows were greater than the Arkansas water-quality standard for April 1 to September 30 (Arkansas Department of Pollution Control and Ecology, 1981) of 200 colonies per 100 mL (geometric mean). Fecal coliform bacteria concentrations in stormwater-runoff samples were 6 to 60 times higher than concentrations in comparable "steady-state" samples and ranged from 610 to 53,000 colonies per 100 mL (table 46).

Reaeration Coefficient

Reaeration coefficients were measured in six reaches of Illinois River using the hydrocarbon gas injection technique described in the "Instream Reaeration Coefficient" section. The stream reaches for which the measurements were made are between miles 133.6 and 132.9 and miles 122.4 and 120.3 (fig. 60).

Ethylene gas and rhodamine WT dye were first injected at mile 134.1. Samples were collected at miles 133.6, 133.1, and 132.9. The second injection was at mile 123.0 and samples were collected at miles 122.4, 121.5, and 120.3. Table 53 contains the resulting calculated values for k_T and k_2. As discussed in the "Instream Reaeration Coefficient" section, equation 6 and 5 were used to define k_T and k_2, respectively.

The Bennett-Rathbun reaeration coefficient predictive equation, which is available in the digital model used, can reproduce the measured k_2 values reasonably well. The expression, which was numbered as equation 18 in an earlier section of this report, is

$$k_2 = 8.76u^{0.607}h^{-1.689}(2.303)(1.0241)^{T-20}$$

where,

k_2 is as previously defined,

u = mean stream velocity, (feet per second),

h = mean stream depth,(feet), and

T = water temperature, °C.

Between stream miles 135.6 and 132.8 a mean cross-sectional area and depth of 78 ft^2 and 1.13 ft, respectively, was observed (Attachment E-6). Using the discharge of 10.6 ft^3/s and water temperature of 19°C measured during the gas injection study, and applying equation 18 yields a k_2 value of 4.7 day^{-1}. This value is approximately 40 percent different than the measured value of 3.42 day^{-1} (table 53). This difference was considered acceptable because the measured value of 3.42 day^{-1} is representative of a 0.65 mile reach and, the mean geometry used in the Bennett-Rathbun calculation is representative of a 2.8 mile reach. Between miles 123.5 and 121.4 the mean cross-sectional area and mean depth was 272 ft^2 and 2.72 ft, respectively, (Attachment E-6). Using the discharge of 84.8 ft^3/s and water temperature of 26.0°C observed during the gas-injection study and applying equation 14 yields a k_2 value of 2.12 day^{-1}. The measured value between miles 122.4 and 121.5 is 2.78 day^{-1} (table 53). Based upon these and other similar calculations the Bennett-Rathbun equation was considered an acceptable tool for simulating k_2 values for Illinois River downstream from mile 138.0.

Upstream from mile 138.0 mean velocities are very slow for discharges observed during collection of the calibration and verification data sets (table 54). For reasons discussed in the earlier "Simulation Techniques" section the Velz predictive equation (equation 17) was used to simulate k_2 values between miles 144.5 and 138.0. Velocities simulated for the $Q_{7/10}$ low flow projections were very slow for the entire reach of Illinois River modeled. Equation 17 was used to compute all k_2 values in Illinois River low-flow simulations. Values of k_2, by subreach, computed during calibration-verification are shown on Attachment E-7 and E-28 under the column heading KA. Values of k_2, by subreach, computed for $Q_{7/10}$ low-flow projections are given in table 55.

Mean Velocity Interpretation

Time-of-travel data were collected on Illinois River upstream from Osage Creek for a discharge of 10.5 ft^3/s at site 19 (mile 133.1). The reaches studied are shown in figure 62. Downstream from Osage Creek time-of-travel data have been collected at three discharges ranging from 80 ft^3/s to 240 ft^3/s at site 72 (mile 115.5) (figure 63). The discharges observed during the collection of the calibration and verification data sets ranged from 1.4 ft^3/s at mile 144.5 to 128.1 ft^3/s at mile 109.0 and from 0.52 ft^3/s at mile 144.5 to 125.7 ft^3/s at mile 109.0, respectively.

Mean cross-sectional areas were computed for Illinois River, by subreach, using techniques described in the earlier "Time of Travel" section. Many channel-width measurements and observations were made during the collection of the 1979 and 1981 data sets. The ratio of the "subreach-average" cross sectional areas to "subreach-average" channel widths were used to define "subreach average" depths. This data is shown in Attachment E-6 and E-27 for the calibration and verification data sets, respectively.

The mean velocities for the calibration and verification data sets are shown in table 54. These velocities are the result of the "fitted" channel geometry, based upon the measured times of travel (fig. 62 and 63) and the flow distributions for each data set as discussed in the "Simulation Techniques" section. Mean velocities computed for the $Q_{7/10}$ low-flow projections with the projected Fayetteville WWTP flow imposed are given in table 55. The Arkansas Department of Pollution Control and Ecology conducted a time-of-travel study, using rhodamine WT dye under low-flow conditions between river miles 138.4 and 136.5 (Niall O'Shaughnessy, Arkansas Department of Pollution Control and Ecology, written commun., Sept., 1982). The resulting velocities and associated discharges are given in table 56. These compare well to the simulated low-flow velocities at comparable discharges.

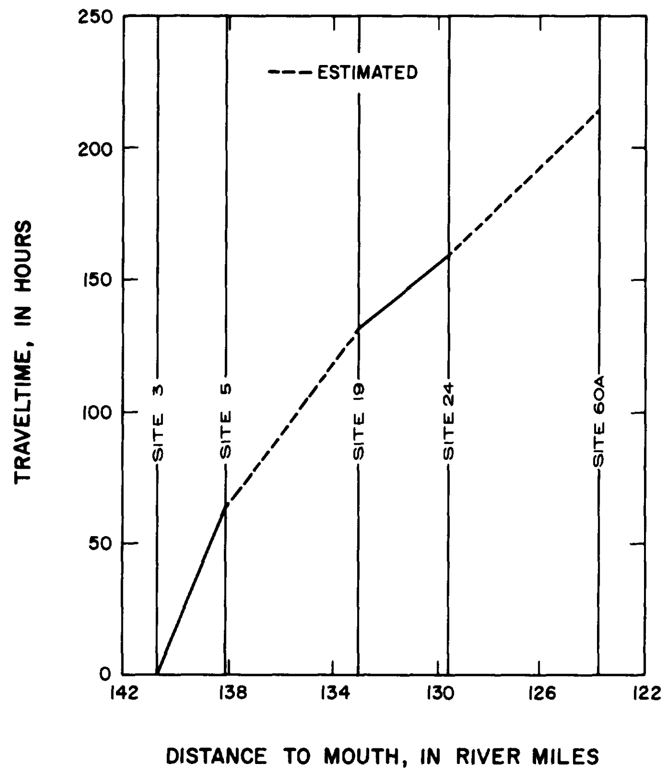

Figure 62.--Traveltime of peak dye concentrations in upper Illinois River for a discharge of 10.5 cubic feet per second at site 19 (modified from Lamb, 1983).

Stream Model

Calibration and Verification

Attachment E contains the results of model calibration and verification. Model calibration output is on Attachment E-2 through E-22; verification output is on Attachment E-23 through C-42. The Illinois River model was calibrated and verified using data collected in 1981 and 1979, respectively.

The success of the model calibration-verification procedure is illustrated by the "goodness of fit" between the model derived and observed concentration profiles for the predictable variables. These profiles are shown on Attachments E-11 through E-20 and E-32 through E-40. The values of these coefficients and parameters defined during the calibration-verification process (as discussed in the "Calibration and Verification Procedure" section) are included on Attachment E-6 and E-7 and again on Attachments E-27 and E-28. Values of k_d resulting from application of the Bosko equation (equation 15) to subreach average k_1 values are shown in Attachments E-7 and E-28.

Two DO profiles were "fitted" for the calibration data set, the diel-mean profile and the diel-minimum profile (Attachment E-19 and E-20). Subreach-average benthic demands, directly resulting from the "fitting" of the mean DO profile, are shown on Attachment E-6 and E-27. The adjustment factors used in fitting the model-derived, diel-minimum DO profile to the observed-minimum profile (as discussed in the "Simulation Techniques" section) are shown on Attachments E-6 and E-27. Verification of the "fitting" of the diel-minimum DO profile is shown on Attachment E-40.

Projections

Illinois River simulations were made for projected Fayetteville WWTP effluent limits. The limits for BODU, TSS, ammonia-N, and PO_4 respectively, in mg/L, are;

1. 45, 30, 15, 10

2. 30, 20, 10, 10

3. 15, 15, 10, 10

4. 15, 15, 5, 5

5. 15, 10, 3, 5

6. 7.5, 5, 3, 2

7. 7.5, 5, 2, 1

Each of these projections was simulated twice; once using an effluent DO concentration of 5.0 mg/L and once using a DO concentration at saturation. All projections were made assuming that the Fayetteville WWTP effluent would enter Illinois River at mile 138.7 with a discharge of 9.2 ft^3/s, that $Q_{7/10}$ stream conditions prevail, and that water temperatures reflect summertime highs (29°C).

In addition, for comparative purposes, a simulation was made at $Q_{7/10}$, low-flow conditions and water temperatures of 29°C without the Fayetteville WWTP inflow. This simulation reflects water quality conditions at $Q_{7/10}$ flows in Illinois River with existing waste loading.

Values of k_d used in the Illinois River simulations that include the Fayetteville WWTP inflow are shown in table 57. These values were determined by applying the Bosko correction (equation 15) to an average k_l value for Osage Creek. The rationale for this is discussed in the "Simulation Techniques" section. Values of k_r were set equal to the resulting k_d values in each subreach. Benthic demands determined during calibration - verification were not modified for projection simulations (see "Simulation Techniques" section).

The results of the Illinois River projection simulations are shown in table 58. The DO standard for Illinois River will change from 6.0 to 4.0 mg/L because the river flow immediately downstream from the effluent outfall will be at least 50 percent treated effluent under $Q_{7/10}$ low-flow conditions. Average DO deficits caused by oxygen sinks are shown in table 59. The benthal deficits tend to be the most significant. Ammonia deficits are higher between river miles 138.4 and 138.0 when the Fayetteville WWTP effluent ammonia concentration equals or exceeds 15 mg/L. The simulation for $Q_{7/10}$ low-flow conditions with no WWTP in place results in an instream diel-minimum DO concentration of 0.13 mg/L (table 58). Illinois River will not meet the Arkansas diel-minimum DO standard (Arkansas Department of Pollution Control and Ecology, 1981) of 4.0 mg/L with any of the projected effluent limits imposed at the proposed Fayetteville WWTP. However, because of the effect of reduced travel times due to the proposed Fayetteville WWTP inflow, absolute DO minimums downstream from the proposed inflow point are higher than 0.3 mg/L for simulations including projected effluent limits 3, 4, 5, 6, and 7 (effluent DO = 7.7 mg/L) and 4, 5, 6, and 7 (effluent DO = 5.0 mg/L).

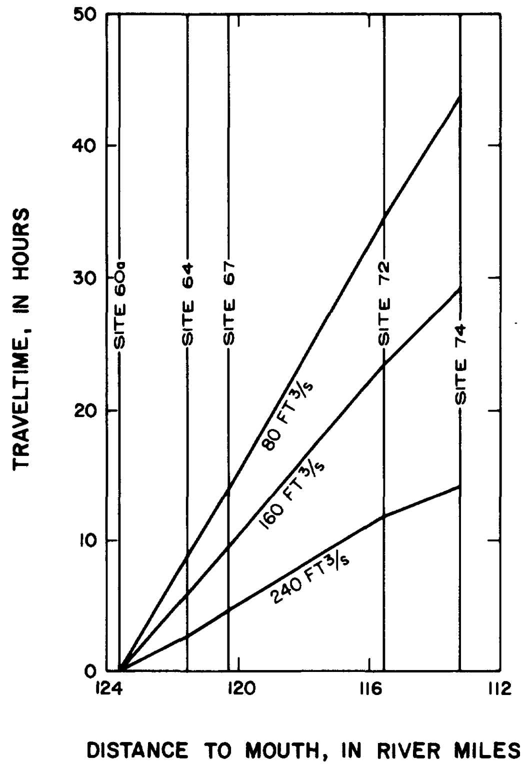

Figure 63.--Traveltime of peak dye concentrations, lower Illinois River, for selected discharge at site 72 (modified from Lamb, 1983).

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams

[Five-digit numbers in parentheses are STORET parameter codes used for computer storage of data]

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
1	144.5	9-05-78	1430	0.07	306	6.8	-----	----	K53	180
		1-27-78	1520	16	217	7.5	4.8	0.09	K2,900	K4,800
		7-23-79	1530	.52	237	7.2	10	.09	130	130
		7-24-81	1300	1.5	100	7.5	8.6	.17	240	K180
2	143.0	9-05-78	1520	.74	---	---	-----	----	-----	-----
		1-27-78	1600	19	228	7.5	4.9	.10	200	4,000
		7-24-79	1015	1.9	---	---	-----	----	-----	-----
		8-24-81	1415	1.8	100	7.5	2.8	.19	140	240
3	140.7	9-06-78	0830	.48	323	7.7	3.0	.08	400	1,600
		11-29-78	1020	11	250	7.6	-----	----	900	K1,200
		7-23-79	1620	2.0	316	7.5	3.2	.17	170	300
		8-24-81	1500	2.0	260	7.6	2.6	.20	150	K110
3a	138.5	7-25-79	1015	2.9	315	7.6	2.1	.29	730	830
		8-25-81	1345	2.3	300	8.0	3.3	.17	580	K850

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River, and tributary streams--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (mg/L) (70300)	Suspended solids (residue at 105°C) (mg/L) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
1	9-05-78	1430	185	--	14	4.0
	11-27-78	1520	154	--	9.0	24
	7-23-79	1530	---	22	----	----
	8-24-81	1300	---	41	----	----
2	9-05-78	1520	---	--	----	----
	11-27-78	1600	168	--	9.0	22
	7-24-79	1015	---	--	----	----
	8-24-81	1415	---	6	----	----
3	9-06-78	0830	197	--	11	1.0
	11-29-78	1020	155	--	9.5	22
	7-23-79	1620	---	8	----	----
	8-24-81	1500	---	4	----	----
3a	7-25-79	1015	---	4	----	----
	8-25-81	1345	---	8	----	----

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
1	9-05-78	1430	0.47	0.01	0.01	0.06	0.01	0.08
	11-27-78	1520	.36	.09	.02	.57	.06	.13
	7-23-79	1530	.61	.10	.05	.15	.01	.10
	8-24-81	1300	1.1	.14	.01	.15	.07	.18
2	9-05-78	1520	----	----	----	----	----	----
	11-27-78	1600	----	.10	.02	.88	.07	.14
	7-24-79	1015	----	----	----	----	----	----
	8-24-81	1415	.47	.13	.01	1.3	.05	.10
3	9-06-78	0830	----	.06	.01	1.9	.01	.03
	11-29-78	1020	----	.09	.02	.91	.06	.08
	7-23-79	1620	----	.04	.02	2.1	.01	.08
	8-24-81	1500	.50	.15	.02	.89	.05	.10
3a	7-25-79	1015	.13	.08	.04	2.3	.04	.08
	8-25-81	1345	.85	.10	<.02	1.2	.05	.06

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
4T	138.4	9-06-78	0915	0.57	316	7.9	---	----	710	1,900
		11-27-78	1715	3.7	---	---	---	----	410	790
		7-25-79	0830	.94	328	7.6	3.0	0.20	1,600	-----
		8-25-81	1235	1.2	380	7.9	3.0	.15	K6,500	K9,400
5	138.1	9-06-78	0850	4.0	298	7.8	---	----	220	1,200
		11-28-78	1650	18	281	7.9	3.1	.14	540	800
		7-25-79	0910	6.0	314	7.6	2.4	----	1,300	-----
		8-25-81	1440	3.9	330	7.9	1.7	.20	900	K1,000
5aT	138.0	8-25-81	1200	.28	320	7.7	1.9	.21	K10	K240
6	136.4	9-06-78	1430	5.7	281	7.9	1.9	.25	120	225
		11-28-78	1610	24	278	7.8	2.7	.11	430	K450
		7-25-79	1050	7.2	296	7.8	2.7	.16	89	330
		8-26-81	1445	13	290	7.7	2.7	.20	400	>4,000

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (mg/L) (70300)	Suspended solids (residue at 105°C) (mg/L) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
4[T]	9-06-78	0915	186	--	10	1.0
	11-27-78	1715	225	--	12	25
	7-25-79	0830	---	17	--	----
	8-25-81	1235	---	7	--	----
5	9-06-78	0850	185	--	12	1.0
	11-28-78	1650	192	--	12	23
	7-25-79	0910	---	3	--	----
	8-25-81	1440	---	5	--	----
5a[T]	8-25-81	1200	---	3	--	----
6	9-06-78	1430	172	--	12	2.0
	11-28-78	1610	184	--	10	18
	7-25-79	1050	---	6	--	----
	8-26-81	1445	---	11	--	----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
4[T]	9-06-78	0915	1.0	0.04	0.01	1.6	0.02	0.03
	11-27-78	1715	----	.04	.01	2.2	.19	.19
	7-25-79	0830	.36	.12	.07	1.7	.02	.08
	8-25-81	1235	1.1	.13	<.02	2.0	.08	.11
5	9-06-78	0850	----	.03	.01	2.2	.02	.03
	11-28-78	1650	----	.04	.01	1.8	.16	.16
	7-25-79	0910	.41	.09	.06	2.3	.01	.07
	8-25-81	1440	.93	.17	<.02	1.6	.04	.07
5a[T]	8-25-81	1200	.37	.14	<.02	.5	.04	.04
6	9-06-78	1430	.78	.17	.01	1.5	.01	.03
	11-28-78	1610	.33	.04	.01	1.4	.14	.14
	7-25-79	1050	.17	.08	.05	1.8	.01	.06
	8-26-81	1445	.74	.14	<.02	1.2	.03	.05

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River, and tributary streams--Continued

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
6a	135.7	7-25-79	1410	7.2	284	7.9	4.2	----	44	280
15	135.6	8-25-81	1510	3.6	360	7.8	2.2	1.9	360	1,700
16[T]	135.6	9-06-78	1515	3.3	288	7.8	6.5	.11	1,400	8,000
		11-29-78	1500	13	---	---	4.5	.08	K1,300	3,300
		7-25-79	1430	4.0	311	7.9	2.7	----	610	K1,700
		8-12-81	----	----	---	---	---	----	-----	-----
17a	135.5	9-06-78	1015	11	283	8.0	---	----	120	K280
		11-28-78	1155	41	---	---	3.8	.11	K2,200	3,800
		7-25-79	1500	11	291	8.0	3.8	.11	K190	K200
17b	134.7	7-26-79	1010	11	---	---	---	----	-----	-----
17c	133.9	9-06-78	1110	9.0	---	---	---	----	-----	-----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (mg/L) (70300)	Suspended solids (residue at 105°C) (mg/L) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
6a	7-25-79	1410	---	2	--	----
15	8-25-81	1510	---	7	--	----
16T	9-06-78	1515	169	-	12	3.0
	11-29-78	1500	202	-	10	19
	7-25-79	1430	---	5	--	----
	8-12-81	----	---	-	--	----
17a	9-06-78	1015	172	-	11	20
	11-28-78	1155	197	-	12	18
	7-25-79	1500	---	3	--	----
17b	7-26-79	1010	---	-	--	----
17c	9-06-78	1110	---	-	--	----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
6a	7-25-79	1410	0.17	0.07	0.05	1.6	0.01	0.05
15	8-25-81	510	.52	.13	<.02	1.1	.09	.11
16[T]	9-06-78	1515	.60	.05	.01	.63	.07	.15
	11-29-78	1500	.63	.10	.02	1.8	.36	.43
	7-25-79	1430	.31	.09	.06	1.2	.04	.12
	8-12-81	----	----	----	----	---	----	----
17a	9-06-78	1015	.98	.01	.01	1.0	.02	.06
	11-28-78	1155	.62	.30	.02	1.6	.34	.43
	7-25-79	1500	.37	.07	.06	1.4	.01	.08
17b	7-26-79	1010	----	----	----	---	----	----
17c	9-06-78	1110	----	----	----	---	----	----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River, and tributary streams--Continued

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (μmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
19	133.1	9-06-78	1545	--	---	---	2.6	0.08	100	K200
		11-28-78	0945	58	---	---	4.3	.08	K1200	1400
		7-26-79	0940	11	288	7.7	4.1	.14	K140	K600
		8-11-81	----	--	---	---	---	----	-----	----
		8-26-81	1130	14	290	7.7	3.0	.21	K3700	----
20[T]	132.8	9-06-78	1600	13	253	8.1	1.4	.04	110	250
		11-28-78	1425	44	---	---	---	----	K450	1900
		7-26-79	0930	--	268	7.9	2.9	.13	240	K600
		8-26-81	1200	20	280	7.9	1.9	.21	500	K900
21	132.1	9-06-78	1300	23	---	---	---	----	-----	----
		7-25-79	1540	34	265	7.9	2.9	.11	K33	K280
22	131.3	9-09-78	----	23	---	---	---	----	-----	----
		7-26-79	1345	29	---	---	---	----	-----	----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (mg/L) (70300)	Suspended solids (residue at 105°C) (mg/L) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
19	9-06-78	1545	161	--	12	2.0
	11-28-78	0945	183	--	10	17
	7-26-79	0940	---	--	----	----
	8-11-81	----	---	--	----	----
	8-26-81	1130	---	8	----	----
20T	9-06-78	1600	150	--	12	3.0
	11-28-78	1425	174	--	9.5	13
	7-26-79	0930	---	--	----	----
	8-26-81	1200	---	13	----	----
21	9-06-78	1300	---	--	----	----
	7-25-79	1540	---	11	----	----
22	9-09-78	----	---	--	----	----
	7-26-79	1345	---	--	----	----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
19	9-06-78	1545	0.65	0.01	0.01	0.76	0.01	0.06
	11-28-78	0945	----	.10	.01	1.4	.15	.20
	7-26-79	0940	.31	.03	----	----	----	----
	8-11-81	----	----	----	----	----	----	----
	8-26-81	1130	.67	.11	<.02	.8	.03	.06
20[T]	9-06-78	1600	.10	.18	.01	.91	.01	.03
	11-28-78	1425	----	.05	.01	1.4	.07	.09
	7-26-79	0930	.29	.01	----	----	----	----
	8-26-81	1200	.46	.08	<.02	1.0	.02	.05
21	9-06-78	1300	----	----	----	----	----	----
	7-25-79	1540	.17	.07	.06	1.4	.01	.07
22	9-09-78	----	----	----	----	----	----	----
	7-26-79	1345	----	----	----	----	----	----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
23	130.6	9-09-78	----	24	---	---	---	----	-----	------
		7-26-79	----	30	---	---	---	----	-----	------
24	129.6	9-06-78	1645	23	260	8.2	1.5	0.13	80	K300
		11-29-78	1130	-----	287	---	---	----	320	1,000
		7-26-79	1130	32	---	---	---	----	-----	------
		8-26-81	1235	38	270	7.6	2.4	.21	K1,200	1,100
25[T]	129.6	8-26-81	1310	.12	280	6.8	3.8	.26	>600	>2,000
26	128.6	11-29-78	1030	78	---	---	---	----	-----	------
28	127.4	9-07-78	1040	25	---	---	---	----	-----	------
29	126.4	11-29-78	1215	85	---	---	---	----	-----	------
30	125.7	11-29-78	1305	80	---	---	---	----	-----	------

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (mg/L) (70300)	Suspended solids (residue at 105°C) (mg/L) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
23	9-09-78	----	---	--	--	----
	7-26-79	----	---	--	--	----
24	9-06-78	1645	156	--	11	3.0
	11-29-78	1130	121	--	10	14
	7-26-79	1130	---	--	--	----
	8-26-81	1235	---	12	--	----
25[T]	8-26-81	1310	---	8	--	----
26	11-29-78	1030	---	--	--	----
28	9-07-78	1040	---	--	--	----
29	11-29-78	1215	---	--	--	----
30	11-29-78	1305	---	--	--	----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
23	9-09-78	----	----	----	----	----	----	----
	7-26-79	----	----	----	----	----	----	----
24	9-06-78	1645	0.98	0.02	0.01	0.72	0.01	0.03
	11-29-78	1130	.43	.16	.01	1.6	.08	.09
	7-26-79	1130	----	----	----	----	----	----
	8-26-81	1235	.49	.13	.02	.87	.04	.06
25[T]	8-26-81	1310	.85	.15	<.02	.2	.06	.12
26	11-29-78	1030	----	----	----	----	----	----
28	9-07-78	1040	----	----	----	----	----	----
29	11-29-78	1215	----	----	----	----	----	----
30	11-29-78	1305	----	----	----	----	----	----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
31	124.6	9-08-78	0815	23	263	7.4	1.5	0.08	K210	500
		11-29-78	0930	125	272	7.7	2.1	.16	500	980
		7-26-79	1530	37	266	7.7	3.1	.11	K130	K220
		8-26-81	1030	39	260	7.2	2.5	----	>600	>2,700
31a	123.9	7-27-79	1005	39	263	7.6	2.4	.15	870	3,500
60[T]	123.7	9-07-78	1545	85	293	7.9	3.5	.05	250	780
		7-26-79	1630	------	302	7.8	2.6	.18	K130	580
		8-26-81	1100	------	300	7.0	2.9	.19	>600	>1,600
60a	123.6	7-27-79	1020	147	290	7.7	3.8	.08	1,200	1,200
61[T]	123.5	9-06-78	----	.52	---	---	---	----	----	-----
		11-29-78	1200	1.3	235	7.8	2.0	.14	K90	580
		7-26-79	1515	.30	247	7.5	4.0	.08	K500	2,000
		8-25-81	0940	1.0	270	7.6	2.6	.10	370	1,200

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (mg/L) (70300)	Suspended solids (residue at 105°C) (mg/L) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
31	9-08-78	0815	150	--	11	3.0
	11-29-78	0930	143	--	9.5	14
	7-26-79	1530	---	--	----	----
	8-26-81	1030	---	24	----	----
31a	7-27-79	1005	---	--	----	----
60T	9-07-78	1545	176	--	14	6.0
	7-26-79	1630	---	--	----	----
	8-26-81	1100	---	18	----	----
60a	7-27-79	1020	---	--	----	----
61T	9-06-78	----	---	--	----	----
	11-29-78	1200	128	--	7.5	5.0
	7-26-79	1515	---	--	----	----
	8-25-81	0940	---	1	----	----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
31	9-08-78	0815	0.00	0.91	0.01	0.59	0.01	0.08
	11-29-78	0930	.40	.06	.01	1.4	.07	.08
	7-26-79	1530	.38	.01	----	----	----	----
	8-26-81	1030	.76	.12	<.02	.9	.10	.14
31a	7-27-79	1005	.18	.01	----	----	----	----
60[T]	9-07-78	1545	.51	.05	.01	.95	.76	.79
	7-26-79	1630	.70	.01	----	----	----	----
	8-26-81	1100	.79	.09	<.02	3.3	.80	.80
60a	7-27-79	1020	.35	.01	----	----	----	----
61[T]	9-06-78	----	----	----	----	----	----	----
	11-29-78	1200	----	.06	.01	.94	.03	.05
	7-26-79	1515	.60	.02	----	---	----	----
	8-25-81	0940	.23	.14	<.02	.3	.04	.03

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
62	123.3	9-07-78	1412	97	---	---	---	----	----	----
		11-29-78	1405	218	---	---	---	----	----	----
64	121.5	9-07-78	1510	102	---	---	---	----	----	----
		9-08-78	0900	------	282	7.8	3.8	0.04	120	620
		11-29-78	1405	299	275	8.0	---	----	200	1,300
		7-26-79	1440	------	292	7.9	3.9	.09	K370	K600
		8-25-81	1030	125	320	7.8	2.1	.14	90	120
65T	121.4	9-07-78	----	.61	---	---	---	----	----	----
		11-29-78	1130	2.6	245	7.9	---	----	7	450
		7-26-79	1500	.70	232	7.8	3.5	.14	K89	K300
		8-25-81	1100	1.0	370	7.7	1.3	.12	33	K40
65a	121.2	7-26-79	1455	------	291	7.8	2.4	.14	K180	K300
		8-25-81	1130	126	320	7.7	1.6	.20	93	K220

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (mg/L) (70300)	Suspended solids (residue at 105°C) (mg/L) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
62	9-07-78	1412	---	--	--	----
	11-29-78	1405	---	--	--	----
64	9-07-78	1510	---	--	--	----
	9-08-78	0900	169	--	14	5.0
	11-29-78	1405	120	--	11	11
	7-26-79	1440	---	--	--	----
	8-25-81	1030	---	14	--	----
65T	9-07-78	----	---	--	--	----
	11-29-78	1130	101	--	10	7.0
	7-26-79	1500	---	--	--	----
	8-25-81	1100	---	2	--	----
65a	7-26-79	1455	---	--	--	----
	8-25-81	1130	---	10	--	----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
62	9-07-78	1412	----	----	----	----	----	----
	11-29-78	1405	----	----	----	----	----	----
64	9-07-78	1510	----	----	----	----	----	----
	9-08-78	0900	0.14	0.03	0.01	1.9	.61	.61
	11-29-78	1405	----	.09	.01	2.5	.28	.29
	7-26-79	1440	.41	.01	----	----	----	----
	8-25-81	1030	.88	.12	<.02	2.1	.54	.54
65[T]	9-07-78	----	----	----	----	----	----	----
	11-29-78	1130	----	.07	.01	.86	.03	.04
	7-26-79	1500	.09	.01	----	----	----	----
	8-25-81	1100	.56	.11	<.02	.7	.04	.04
65a	7-26-81	1455	.21	.06	----	----	----	----
	8-25-81	1130	.95	.15	<.02	2.2	.52	.53

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (μmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
67	120.3	9-07-78	1630	104	288	7.8	3.8	0.14	150	K450
		11-29-78	1100	240	285	7.7	---	----	310	850
		7-26-79	1400	153	294	7.8	2.6	.12	K140	K250
		8-25-81	1430	128	330	7.5	2.0	.16	73	K180
68T	119.3	8-25-81	1500	1.0	260	7.7	1.4	.14	58	230
70	118.0	9-08-78	1115	107	---	---	---	----	----	----
		11-30-78	1020	223	---	---	---	----	----	----
72	115.5	9-08-78	1030	99	275	8.1	---	----	K53	K120
		11-29-78	1545	340	274	7.9	---	----	270	880
		7-26-79	1015	---	292	7.8	4.0	.14	K33	K200
		8-26-81	0815	128	290	7.1	2.0	.26	150	>1,600

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (mg/L) (70300)	Suspended solids (residue at 105°C) (mg/L) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
67	9-07-78	1630	166	--	14	5.0
	11-29-78	1100	140	--	12	10
	7-26-79	1400	---	--	--	----
	8-25-81	1430	---	8	--	----
68T	8-25-81	1500	---	2	--	----
70	9-08-78	1115	---	--	--	----
	11-30-78	1020	---	--	--	----
72	9-08-78	1030	166	--	13	4.0
	11-29-78	1545	140	--	11	10
	7-26-79	1015	---	--	--	----
	8-26-81	0815	---	16	--	----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River, tributary streams, and and tributary streams--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
67	9-07-78	1630	0.80	0.04	0.01	1.4	0.49	0.49
	11-29-78	1100	.23	.06	.01	2.6	.26	.28
	7-26-79	1400	.20	----	----	----	----	----
	8-25-81	1430	.66	.10	<.02	2.2	.48	.50
68[T]	8-25-81	1500	.47	.14	<.02	.4	.03	.03
70	9-08-78	1115	----	----	----	----	----	----
	11-30-78	1020	----	----	----	----	----	----
72	9-08-78	1030	.39	.02	.01	1.7	.41	.41
	11-29-78	1545	.65	.07	.01	2.5	.27	.30
	7-26-79	1015	.44	.03	----	----	----	----
	8-26-81	0815	.67	.07	<.02	1.9	.44	.44

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River and tributary streams--Continued

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
74	113.3	9-08-78	1600	97	270	7.6	7.0	0.13	K70	K200
		11-29-78	1245	-----	272	8.0	---	----	220	830
		7-26-79	1300	-----	289	7.9	4.4	.06	K67	K150
		8-26-81	0900	168	282	7.6	2.4	----	>600	>1,600
76	112.3	9-08-78	1549	108	---	---	---	----	----	-----
		11-30-78	1340	243	---	---	---	----	----	-----
77T	112.0	9-08-78	1030	3.5	255	7.7	1.2	.04	410	410
		11-29-78	----	12	283	8.2	---	----	K60	K180
78	111.3	9-07-78	1815	106	267	7.7	3.7	.06	K93	K150
		11-29-78	1330	247	271	7.9	---	----	200	680
		7-26-79	1100	-----	289	7.8	3.3	.13	K56	K100
		8-26-81	1000	-----	290	7.3	2.1	----	>300	>1,600

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River, tributary streams, and and tributary streams--Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (mg/L) (70300)	Suspended solids (residue at 105°C) (mg/L) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
74	9-08-78	1600	116	--	12	4.0
	11-29-78	1245	149	--	12	10
	7-26-79	1300	---	--	----	----
	8-26-81	0900	---	14	----	----
76	9-08-78	1549	---	--	----	----
	11-30-78	1340	---	--	----	----
77T	9-08-78	1030	151	--	7.5	2.0
	11-29-78	----	131	--	1.9	9.0
78	9-07-78	1815	162	--	13	3.0
	11-29-78	1330	128	--	10	10
	7-26-79	1100	---	--	----	----
	8-26-81	1000	---	14	----	----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River, tributary streams, and and tributary streams--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
74	9-08-78	1600	----	0.04	0.01	1.0	0.34	0.34
	11-29-78	1245	----	.06	.01	2.5	.28	.31
	7-26-79	1300	0.52	.01	----	----	----	----
	8-26-81	0900	.83	.12	<.02	1.9	.42	.42
76	9-08-78	1549	----	----	----	----	----	----
	11-30-78	1340	----	----	----	----	----	----
77[T]	9-08-78	1030	.40	.01	.01	.76	.01	.07
	11-29-78	----	----	.06	.01	1.8	.04	.05
78	9-07-78	1815	.52	.01	.01	1.3	.32	.32
	11-29-78	1330	.42	.08	.01	2.3	.26	.26
	7-26-79	1100	.32	.01	----	----	----	----
	8-26-81	1000	.82	.14	<.02	1.7	.34	.36

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River, tributary streams, and and tributary streams--Continued

Site number	River mile	Date of collection	Time of collection	Discharge (ft^3/s)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Coliform, total (colonies per 100 mL) (31501)
79	109.0	9-07-78	1715	----	270	8.8	5.7	0.05	10	50
		11-30-78	1100	----	272	7.8	4.2	.03	K40	100
80[T]	108.2	9-08-78	1000	5.1	210	7.8	---	----	K170	K600
		11-29-78	1400	9.0	235	7.7	---	----	K7	----
		7-26-79	1115	12	229	7.5	1.5	.15	K56	K280
81	107.9	11-30-78	1030	----	266	7.8	2.8	.15	170	----
82	107.2	11-30-78	1000	----	266	---	3.1	.12	290	----
83	106.2	8-26-81	1200	196	250	7.5	4.6	.29	K890	----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River, tributary streams, and and tributary streams-Continued

Site number	Date of collection	Time of collection	Dissolved solids (residue at 180°C) (mg/L) (70300)	Suspended solids (residue at 105°C) (mg/L) (00530)	Dissolved chloride (mg/L) (00940)	Dissolved sulfate (mg/L) (00945)
79	9-07-78	1715	160	--	12	4.0
	11-30-78	1100	---	--	10	11
80[T]	9-08-78	1000	122	--	7.5	3.0
	11-29-78	1400	111	--	7.5	7.0
	7-26-79	1115	---	--	----	----
81	11-30-78	1030	---	--	11	10
82	11-30-78	1000	--	--	11	10
83	8-26-81	1200	---	13	----	----

See footnotes at end of table

Table 45.--Chemical, physical, and bacteriological data, Illinois River, tributary streams, and and tributary streams--Continued

Site number	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total orthophosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P) (00665)
79	9-07-78	1715	0.40	0.01	0.01	1.2	0.27	0.32
	11-30-78	1100	----	----	.01	2.3	.22	.28
80[T]	9-08-78	1000	.00	.25	.01	.36	.01	.08
	11-29-78	1400	----	.06	.01	.55	.04	.05
	7-26-79	1115	.13	.01	----	----	----	----
81	11-30-78	1030	.51	.09	.01	2.1	.21	.27
82	11-30-78	1000	.48	.15	.01	1.8	.24	.33
83	8-26-81	1200	1.1	.30	.04	.44	.12	.19

[K] Plate count was outside ideal range.
[T] Tributary.
[W] WWTP effluent.

Table 46.--Comparison of analyses of Illinois River stormwater-runoff samples to means calculated from steady-state flow analyses in table 45

[Five digit numbers are STORET parameter codes used for computer storage of data]

Site number	River mile	"Steady-state" mean (S) or "Runoff" (R) sample	Date of collection	Time of collection	Discharge (ft^3/s) (00061)	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00310)	Specific conductance (µmho/cm at 25°C) (00095)	pH (units) (00400)
H3	148.3	R	7-28-81	1050	----	----	----	----	----	---
H4	148.3	R	7-28-81	1200	----	----	----	----	----	---
1	144.5	S	-------	----	4.5	----	----	----	215	---
		R	4-22-81	0040	2.4	15.5	7.4	74	256	7.8
5a	138.0	R	5-14-81	0100	2.0	15.0	7.1	70	300	7.6
		S	8-25-81	1200	.28	----	----	----	320	7.7
		R	4-22-81	2155	128	17.0	8.6	90	----	---
		R	4-23-81	0300	290	16.5	8.4	87	----	---
20	132.8	[A]R	Composite	----	----	----	----	----	235	7.8
		R	5-13-81	2140	21	16.0	9.7	98	200	7.5
		S	-------	----	26	----	----	----	267	---

See footnotes at end of table

Table 46.--Comparison of analyses of Illinois River stormwater-runoff samples to means calculated from steady-state flow analyses in table 45--Continued

Site number	"Steady-state" mean (S) or "Runoff" (R) sample	Date of collection	Time of collection (hour)	Ultimate carbonaceous biochemical oxygen demand (mg/L) (00320)	Base *e* deoxygenation rate coefficient for carbonaceous biochemical oxygen demand (day^{-1} at 20°C) (82133)	Coliform, fecal (colonies per 100 mL) (31625)	Streptococci, fecal (colonies per 100 mL) (31673)	Suspended solids (residue at 105°C) (mg/L) (00530)
H3	R	7-28-81	1050	5.1	0.12	K53,000	K41,000	98
H4	R	7-28-81	1200	10	.09	K 5,500	K22,000	78
1	S	-------	----	7.8	----	830	-------	32
	R	4-22-81	0040	>7.7	----	2,800	K2,400	30
5a	R	5-14-81	0100	3.8	.12	K610	K1,100	35
	S	8-25-81	1200	1.9	.21	K10	-------	3
	R	4-22-81	2155	------	----	-------	-------	---
	R	4-23-81	0300	------	----	-------	-------	---
20	AR	Composite	----	>21	----	>3,000	>3,300	221
	R	5-13-81	2140	11	.14	27,000	84,000	186
	S	-------	----	2.1	----	320	-------	13

See footnotes at end of table

Table 46.--Comparison of analyses of Illinois River stormwater-runoff samples to means calculated from steady-state flow analyses in table 45--Continued

Site number	"Steady-state" mean (S) or "Runoff" (R) sample	Date of collection	Time of collection	Total organic nitrogen (mg/L as N) (00605)	Total ammonia (mg/L as N) (00610)	Total nitrite (mg/L as N) (00615)	Total nitrate (mg/L as N) (00620)	Total ortho-phosphate (mg/L as P) (70507)	Total phosphorus (mg/L as P (00665)
H3	R	7-28-81	1050	0.72	0.28	0.05	0.39	0.16	0.18
H4	R	7-28-81	1200	.71	.08	.03	.39	.00	.09
1	S	-------	----	.64	.08	.02	.23	.04	.12
	R	4-22-81	0040	.85	.08	.01	.80	.04	.05
5a	R	5-14-81	0100	1.5	.04	.00	.85	.06	.17
	S	8-25-81	1200	.37	.14	<.02	.5	.04	.04
	R	4-22-81	2155	----	----	----	----	----	----
	R	4-23-81	0300	----	----	----	----	----	----
20	[A]R	Composite	----	.80	.15	.03	.85	.15	.24
	R	5-13-81	2140	1.5	.13	.05	.82	.13	.35
	S	-------	----	.28	.08	.01	1.1	.03	.06

[A] Data applies to composite of samples collected on 4-22-81 at 2155 and 4-23-81 at 0300.
[K] Plate count was outside ideal range.

Table 47.--Dissolved-oxygen and temperature data for Illinois River and tributaries

[Five-digit numbers in parentheses are STORET parameter codes used for computer storage of data]

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
1	9-05-78	1430	29.5	5.2	68
	11-27-78	1520	8.5	9.6	82
	7-23-79	1530	29.0	9.8	127
	7-25-79	1720	28.5	9.0	117
	8-04-79	0615	22.0	6.1	70
	8-24-81	1300	26.0	9.1	111
		1500	28.0	9.3	118
		1600	28.5	9.6	123
		1700	29.0	9.5	123
		1800	29.5	9.8	128
		1900	29.0	9.8	127
		2000	28.5	9.7	124
		2100	28.0	9.4	119
		2200	27.5	9.1	115
		2300	27.0	9.0	113
		2400	27.0	8.8	110
	8-25-81	0100	26.5	8.6	106
		0200	26.0	8.4	102
		0300	26.0	8.0	98
		0400	26.0	7.7	94
1	8-25-81	0500	26.0	7.5	92
		0600	25.5	7.3	89
		0700	25.5	6.9	84
		0800	25.0	6.8	82
		0900	25.5	7.1	86
		1000	26.0	7.5	92
		1100	26.5	7.8	96
		1200	27.5	8.1	102
		1300	28.0	8.6	108
		1400	28.5	9.0	115
2	9-05-78	1520	23.0	8.4	98
	11-27-78	1600	8.5	9.7	83
	8-24-81	1415	24.0	7.8	92
		1500	25.0	7.8	94
		1600	25.0	8.2	99
		1700	25.0	8.3	100
		1800	25.5	8.4	101
		1900	25.5	8.3	100
		2000	25.0	8.0	96
		2100	25.0	7.8	94

Table 47.--Dissolved-oxygen and temperature data for Illinois River and tributaries--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
2	8-24-81	2200	25.0	7.5	90
		2300	24.5	7.3	87
		2400	24.5	7.0	83
	8-25-81	0100	24.0	6.8	80
		0200	24.0	6.5	77
		0300	23.5	6.2	73
		0400	23.0	6.0	70
		0500	23.0	5.7	66
		0600	23.0	5.6	65
		0700	22.5	5.4	62
		0800	22.5	5.3	61
		0900	22.5	5.3	61
		1000	22.5	5.4	62
		1100	23.0	5.4	63
		1200	23.0	5.6	65
		1300	23.5	6.1	71
		1400	24.5	6.6	79
3	9-06-78	0830	23.5	4.7	55
	11-29-78	1020	7.0	9.1	75
	7-23-79	1620	24.0	9.0	107
		2200	25.5	7.3	89
	8-04-79	0728	23.5	5.5	65
	8-24-81	1500	24.5	8.0	95
3	8-24-81	2245	23.5	6.2	73
	8-25-81	0350	23.0	5.7	66
3a	7-25-79	1015	22.5	5.6	65
	8-25-81	1345	25.0	8.5	102
	8-26-81	0025	23.0	6.2	72
4[T]	9-06-78	0915	20.0	6.8	75
	7-25-79	0830	22.0	8.0	92
	8-25-81	1235	26.0	9.9	122
	8-26-81	0040	22.5	5.5	53
5	9-06-78	0850	22.0	5.5	63
	9-09-78	0815	23.0	3.8	44
	7-25-79	0910	22.5	6.3	73
		2240	24.0	8.2	98
	8-04-79	0719	21.5	5.5	62
	8-25-81	0120	23.5	5.2	61

See footnotes at end of table

Table 47.--Dissolved-oxygen and temperature data for Illinois River and tributaries--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
5	8-25-81	0555	22.5	4.6	54
		1440	23.5	9.2	108
		1545	23.5	8.8	97
		1645	23.5	8.8	97
		1745	23.5	8.7	101
		1845	23.5	8.6	101
		1945	23.5	8.5	99
		2045	23.5	7.9	92
		2145	23.5	7.8	91
		2245	23.5	7.4	87
		2345	23.5	7.8	91
	8-26-81	0045	23.5	5.9	69
		0145	23.5	5.5	64
		0245	23.0	4.9	57
		0345	23.0	4.5	52
		0445	23.0	4.3	50
		0545	23.0	4.8	56
		0645	23.0	5.1	59
		0745	22.5	5.9	68
		0845	22.0	6.3	72
		0945	21.0	6.3	70
		1045	21.0	5.8	64
		1145	21.0	5.6	62
		1245	21.0	5.7	63
		1345	21.0	5.7	63
5a[T]	8-25-81	0130	21.5	4.8	55

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
5a[T]	8-25-81	0600	21.0	5.1	57
		1200	23.0	8.4	98
6	9-06-78	1430	25.5	8.0	98
	7-25-79	1050	22.5	7.2	84
	8-26-81	1445	23.0	5.9	69
6a	7-25-79	1410	27.0	10.2	129
16[T]	9-06-78	1515	27.0	9.2	116
	9-09-78	0750	23.5	5.1	60
	7-25-79	1430	25.0	7.8	95
		2255	25.0	8.0	98
	9-03-81	1530	26.0	7.1	88
		2345	23.5	5.9	69
	9-04-81	0550	22.5	5.5	64
		1230	23.0	6.5	76
	9-05-81	0900	21.5	5.6	64
		1125	23.0	5.2	60
		1330	24.0	6.7	80

See footnotes at end of table

Table 47.--Dissolved-oxygen and temperature data for Illinois River and tributaries--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
16[T]	9-05-81	1532	24.5	7.2	87
		1715	24.5	7.4	89
	9-06-81	0035	24.0	5.9	70
		0520	21.0	4.7	53
17a	9-06-78	1015	25.0	6.9	84
	7-25-79	1500	27.0	9.8	124
17b	9-06-78	1050	25.5	6.8	83
	11-28-78	1055	6.5	11.0	89
	7-26-79	1010	25.5	6.2	76
	8-24-81	1515	24.5	8.0	95
17c	9-06-78	1110	26.0	6.8	84
	11-28-78	1020	6.5	10.4	85
	7-26-79	1045	26.0	7.3	90
	8-24-81	1350	25.0	10.0	121

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
18[T]	11-29-78	1110	10.0	8.5	75
19	9-06-78	1545	27.5	8.9	113
	9-09-78	0735	24.5	5.2	63
	7-25-79	2300	26.5	8.0	100
	7-26-79	0940	24.5	6.4	77
		1130	25.0	8.6	105
	9-05-79	1200	23.5	7.2	85
		1300	23.5	7.3	86
		1400	24.0	8.0	95
		1500	24.0	8.5	101
		1600	24.0	8.7	104
		1700	24.0	8.7	104
		1800	24.0	8.5	101
		1900	24.0	8.0	95
		2000	23.5	6.9	81
		2100	23.5	6.5	76
		2200	23.5	6.2	73
		2300	23.0	5.9	69
		2400	23.0	5.8	67
	9-06-79	0100	23.0	5.6	65
		0200	23.0	5.5	64
		0300	23.0	5.4	63
		0400	23.0	5.2	60

See footnotes at end of table

Table 47.--Dissolved-oxygen and temperature data for Illinois River and tributaries--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)	Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
19	9-06-79	0500	23.0	5.1	59	21	9-06-78	1300	28.0	9.0	115
		0600	23.0	4.9	57						
		0700	23.0	4.8	56		7-25-79	1540	27.5	9.7	123
		0800	23.0	5.0	58						
		0900	23.5	5.3	62		8-24-81	1625	25.0	9.7	117
		1000	23.5	6.2	73						
		1100	23.5	6.7	79						
						22	9-06-78	1400	27.5	8.0	101
	8-26-81	1130	22.5	6.2	71						
							11-28-78	1330	8.0	11.6	98
	9-03-81	1520	26.0	7.6	94						
		2325	24.5	6.3	76		7-25-79	1335	26.0	8.2	101
		0535	22.5	5.5	64						
		1220	24.5	7.0	84						
						23	9-06-78	1415	28.0	8.2	105
20	9-06-78	1300	28.0	9.0	115		11-29-78	0930	6.0	11.4	92
		1600	27.0	9.0	114						
							7-25-79	1425	23.5	9.9	116
	9-09-78	0740	24.0	6.3	75						
	11-28-78	1240	8.0	11.4	97	24	9-06-78	1645	27.0	7.9	100
	7-25-79	2310	25.5	8.4	102		9-09-78	0720	25.5	5.8	71
	7-26-79	0930	24.5	7.7	93						
							11-29-78	1130	8.5	9.9	85
	8-26-81	1200	23.0	7.3	85						
		2300	22.5	6.9	79		7-25-79	1535	26.0	9.2	114
	8-27-81	0635	22.5	7.2	83						

Table 47.--Dissolved-oxygen and temperature data for Illinois River and tributaries--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
24	8-26-81	1235	22.5	6.6	76
	9-03-81	1510	25.5	8.0	98
		2305	25.5	6.9	84
	9-04-81	0515	23.5	6.5	76
		1205	23.5	7.1	84
25	7-25-79	1610	25.5	5.8	71
	8-26-81	1310	25.0	6.2	75
26	9-07-78	0950	26.0	6.7	83
	11-29-78	1030	6.0	10.0	81
	8-25-81	0900	24.0	7.0	82
27	9-07-78	1025	26.0	6.7	83
	11-29-78	1125	7.0	9.8	81
	8-25-81	0930	24.0	7.1	84
28	9-07-78	1040	26.5	6.3	79
	8-25-81	1025	23.0	7.8	91
29	9-07-78	1135	26.5	7.2	90
	11-29-78	1215	7.0	10.4	86
	8-25-81	1040	23.0	7.0	81
30	9-07-78	1150	27.0	8.4	106
	11-29-78	1305	7.0	10.4	86
	8-25-81	1120	24.0	8.4	99
31	9-08-78	0815	22.5	6.3	73
	9-09-78	0825	23.0	6.5	76
	11-29-78	0930	5.5	11.8	94
	7-25-79	2200	26.5	6.8	85
	7-26-79	1530	25.5	7.8	95

Table 47.--Dissolved-oxygen and temperature data for Illinois River and tributaries--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)	Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
31	8-26-81	1030	22.5	5.9	68	60[T]	9-07-78	1545	25.0	7.9	96
	9-04-81	1715	25.0	8.2	99		9-09-78	0815	22.0	7.0	80
		1815	25.0	8.2	99						
		1915	25.0	8.1	98		7-26-79	1630	24.0	7.9	94
		2015	25.0	7.7	93						
		2115	24.5	7.5	89		8-26-81	1100	21.5	6.6	74
		2215	24.0	7.3	86			2230	22.5	6.8	78
		2315	24.0	7.1	83		8-27-81	0615	21.5	6.6	74
	9-05-81	0015	24.0	6.8	80						
		0115	23.5	6.7	78		9-02-81	1700	23.5	8.3	97
		0215	23.5	6.6	77			1800	23.5	8.2	96
		0315	23.5	6.6	77			1900	23.5	8.0	93
		0415	23.0	6.5	76			2000	23.5	7.7	90
		0515	23.0	6.4	74			2100	23.5	7.6	89
		0615	23.0	6.4	74			2200	23.5	7.4	87
		0715	22.5	6.4	74			2300	23.0	7.3	85
		0815	22.5	6.4	74			2400	23.0	7.2	84
		0915	22.5	6.6	76		9-03-81	0100	23.0	7.1	83
		1015	23.0	6.8	79			0200	23.0	6.9	80
		1115	23.0	7.2	84			0300	23.0	6.9	80
		1215	23.5	7.4	87			0400	22.5	6.9	79
		1315	24.0	7.6	89			0500	22.5	6.9	79
		1415	24.0	7.7	92			0600	22.0	6.9	78
								0700	22.0	6.8	77
								0800	22.0	6.8	77
31a	8-25-81	1310	24.0	8.0	94			0900	22.0	6.9	78

See footnotes at end of table

Table 47.--Dissolved-oxygen and temperature data for Illinois River and tributaries--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dis-solved oxygen (mg/L) (00300)	Dis-solved oxygen (percent saturation) (00301)
60	9-03-81	1000	22.0	7.2	82
		1100	22.5	7.3	84
		1200	23.0	7.5	87
		1300	23.0	7.6	88
		1400	23.5	7.8	91
60a	7-27-79	1020	23.0	7.3	85
	8-25-81	1310	25.0	8.0	96
61[T]	11-29-78	1200	8.0	10.6	90
	7-26-79	1515	23.5	5.3	62
	8-25-81	0940	20.0	6.6	72
		2230	21.0	5.0	56
	8-26-81	0550	19.5	6.2	66
62	9-07-78	1350	26.5	7.8	98
	11-29-78	1405	7.5	9.8	82
	8-25-81	1330	25.0	7.9	95
63	11-29-78	1440	8.0	9.8	83
	8-25-81	1400	25.0	8.0	96
	9-05-81	1430	21.0	8.1	90
		1530	21.0	8.0	89
		1630	21.0	7.7	86
		1730	21.0	7.4	82
		1830	20.5	7.0	77
		1930	20.5	6.5	71
		2030	20.0	6.2	67
		2130	20.0	6.1	66
		2230	20.0	6.1	66
		2330	20.0	6.1	66
	9-06-81	0030	19.5	6.1	66
		0130	19.5	6.1	66
		0230	19.5	6.0	65
		0330	19.5	6.1	66
		0430	19.5	6.1	66
		0530	19.5	6.1	66
		0630	19.5	6.1	66
		0730	19.5	6.2	67
		0830	19.5	6.5	70
		0930	19.5	6.8	74
		1030	19.5	7.0	76
		1130	20.0	7.2	78
		1230	20.0	7.3	79

See footnotes at end of table

Table 47.--Dissolved-oxygen and temperature data for Illinois River and tributaries--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
64	9-07-78	1510	27.0	8.1	103
	9-08-78	0900	22.5	6.6	77
	11-29-78	1115	5.5	10.3	82
	7-26-79	1440	24.5	8.0	96
	8-25-81	1030	24.0	7.0	82
		2245	19.5	8.8	95
	8-26-81	0600	23.0	8.8	102
	9-04-81	2315	24.0	7.2	86
	9-05-81	0625	22.0	5.5	63
		0950	22.0	6.6	76
		1214	23.0	7.1	83
		1405	23.5	6.7	79
		1640	24.0	8.2	98
65	11-29-78	1130	6.0	11.2	90
	7-26-79	1500	22.0	8.0	92
	8-25-81	1100	21.0	6.9	77
65a	7-26-79	1455	24.5	7.8	94
	8-25-81	1130	24.0	7.0	82
		2250	24.0	6.8	80
67	9-07-78	1630	25.5	7.7	94
	9-08-78	0830	22.5	6.2	72
	9-09-78	0830	22.5	6.6	77
	11-29-78	1100	6.0	9.9	80
		1625	9.0	9.2	80
	7-26-79	1400	24.5	7.8	94
	8-25-81	1430	24.0	7.9	93
		2215	23.0	5.3	62
	8-26-81	0540	19.0	4.2	45
	9-04-81	2345	23.5	6.8	80
	9-05-81	0615	22.0	5.4	62
		0935	22.0	6.7	77
		1200	23.5	6.5	76
		1400	24.0	6.7	80
		1635	24.0	8.2	98

Table 47.--Dissolved-oxygen and temperature data for Illinois River and tributaries--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
68[T]	8-25-81	1500	26.0	8.2	100
		2210	24.0	5.6	66
	8-26-81	0535	22.0	4.5	51
69	9-08-78	1035	24.5	6.3	76
	1-30-78	0945	7.0	10.2	84
70	9-08-78	1100	25.0	6.3	77
	1-30-78	1020	8.0	9.6	81
71	9-08-78	1205	26.0	7.2	89
	11-30-78	1050	7.0	9.8	81
72	9-08-78	1030	24.5	8.6	104
	11-29-78	1545	5.5	11.6	92
	7-26-79	1015	24.0	6.9	82
	8-26-81	0815	23.0	6.7	78
72	9-04-81	1315	23.5	8.5	100
		1520	25.5	9.5	116
		1730	26.0	9.0	111
	9-05-81	0015	23.5	6.7	79
		0510	22.5	6.6	77
73	11-30-78	1205	8.0	9.4	80
74	9-07-78	1800	26.5	10.1	126
	9-08-78	1600	27.5	8.8	111
	11-29-78	1245	7.5	10.9	91
	7-26-79	1300	25.0	9.0	110
	9-04-81	1345	24.5	9.3	112
		1540	26.0	10.3	127
		1710	26.5	9.7	121
	9-05-81	0030	24.0	6.8	81
		0545	22.0	6.5	75
75	9-08-78	1509	27.5	9.1	115
	11-30-78	1300	8.0	9.9	84

See footnotes at end of table

Table 47.--Dissolved-oxygen and temperature data for Illinois River and tributaries--Continued

Site number	Date	Time	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
76	9-08-78	1535	27.0	8.3	105
	11-30-78	1340	9.0	9.6	83
77[T]	9-08-78	1030	24.5	6.0	72
	11-29-78	1315	8.5	12.4	106
	8-26-81	1115	22.0	6.1	69
78	9-07-78	1815	28.0	9.7	124
	11-29-78	1330	7.0	10.8	89
	7-26-79	1100	24.5	6.7	81
	8-26-81	1000	24.0	5.1	60
	9-05-81	1615	25.0	7.8	94
		1715	25.0	8.0	96
		1815	25.0	8.0	96
		1915	25.0	8.5	102
		2015	25.0	8.6	104
		2115	25.0	8.6	104
		2215	25.0	8.4	101

Site number	Date	Time[A]	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
78	9-05-81	2315	25.0	8.2	99
	9-06-81	0015	25.0	8.0	96
		0115	25.0	7.7	93
		0215	25.0	7.5	98
		0315	25.0	7.2	87
		0415	24.5	7.0	83
		0515	24.5	6.7	80
		0615	24.5	6.5	77
		0715	24.0	6.4	75
		0815	24.0	6.3	74
		0915	24.0	6.3	74
		1015	24.0	6.2	73
		1115	24.0	6.3	74
		1215	24.0	6.5	77
		1315	24.5	6.6	79
79[L]	9-07-78	1715,.5	31.0	10.4	140
		1715,2	31.0	10.4	140
		1715,3	29.0	10.2	132
		1715,4	28.0	10.0	128
		1715,5	27.5	9.4	119
		1715,6	27.5	8.0	101
		1715,7	27.0	7.1	90
		1715,8	27.0	6.7	85

See footnotes at end of table

Table 47.--Dissolved-oxygen and temperature data for Illinois River and tributaries--Continued

Site number	Date	Time[a]	Water temperature (°C) (00010)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)
79[L]	9-07-78	1715,9	27.0	6.0	76
		1715,10	26.0	3.6	44
	11-30-78	1100,.5	7.0	10.4	86
80[T]	9-08-78	1000	22.0	5.8	67
	11-29-78	1400	7.0	11.2	93
	7-26-79	1115	22.5	5.8	67
81[L]	9-08-78	1700,.5	33.5	16.2	228
		1700,1	33.5	15.9	224
		1700,2	32.5	15.0	208
		1700,3	30.0	5.3	71
		1700,4	29.5	5.0	66
		1700,5	29.5	4.2	55
82[L]	11-30-78	1000,.5	6.0	10.4	84
	7-26-79	1200,.5	28.0	7.4	95
83	9-08-78	0945	26.5	5.0	62
		1615	28.5	7.2	94
	11-29-78	1445	7.0	11.4	94
	8-26-81	1200	25.0	6.1	74

[A] If a number immediately follows time, it indicates measurement depth, if not, measurements were made at mid-depth.
[L] Lake.
[T] Tributary.

Table 48.--Bottom-material analyses for Illinois River

[Five-digit numbers in parentheses are STORET parameter codes used for computer storage of data]

Site number and (river mile)	Date of collection	Streambed oxygen demand [$(g/m^2)/d$ at 20°C]	Total inorganic carbon in bottom material (g/kg as C) (00686)	Total organic carbon in bottom material (g/kg as C)	Total organic plus ammonia nitrogen in bottom material (mg/kg as N) (00626)	Total nitrite plus nitrate nitrogen in bottom material (mg/kg as N) (00633)	Total ammonia nitrogen in bottom material (mg/kg as N) (00611)	Total phosphorus in bottom material (mg/kg as P) (00668)
2 (143.0)	8-31-81	1.82	---	--	---	---	---	---
5 (138.1)	8-03-79	0.30	0.6	10	576	---	---	370
6 (136.4)	8-31-81	1.70	---	--	---	---	---	---
31 (124.6)	9-02-81	0.74	---	--	---	---	---	---

Table 48.--Bottom-material analyses for Illinois River--Continued

Site number and (river mile)	Date of collection	Streambed oxygen demand [$(g/m^2)/d$ at 20°C]	Total inorganic carbon in bottom material (g/kg as C) (00686)	Total organic carbon in bottom material (g/kg as C)	Total organic plus ammonia nitrogen in bottom material (mg/kg as N) (00626)	Total nitrite plus nitrate nitrogen in bottom material (mg/kg as N) (00633)	Total ammonia nitrogen in bottom material (mg/kg as N) (00611)	Total phosphorus in bottom material (mg/kg as P) (00668)
64 (121.5)	9-02-81	0.42	---	---	----	---	--	---
78 (111.3)	8-28-81	0.08	---	---	----	---	--	---
81 (107.9)	11-30-78	.94	---	---	1700	0.0	64	320
82 (107.2)	11-30-78	----	---	---	560	0.0	11	420

Table 49.--Net photosynthetic dissolved-oxygen production at selected sites on the Illinois River

Site number	River mile	Date (1981)	Net photosynthetic dissolved oxygen production [(mg/L)/d at 20°C]
1	144.5	August 24-25	2.9
2	143.0	August 24-25	3.6
5	138.1	August 25-26	5.5
19	133.1	September 4-5	.23
24	129.6	September 3-4	.14
31	124.6	September 4-5	1.9
63	122.4	September 5-6	.70
64	121.5	September 4-5	2.6
67	120.3	September 4-5	2.7
72	115.5	September 4-5	2.2
74	113.3	September 4-5	3.2
78	111.3	September 5-6	2.0

Table 50.--Phytoplankton taxonomy and densities for Illinois River

Scientific name	Common name	cells/milliliter Site 5	Site 31
Chlorophyta	Green algae		
.Chlorophyceae			
..Chlorococcales			
...Oocystaceae			
....*Ankistrodesmus*		--	14
....*Chodatella*		--	14
....*Dictyosphaerium*		--	56
....*Oocystis*		--	56
Chrysophyta	Yellow-green algae		
.Bacillariophyceae	Diatoms		
..Centrales	Centric diatoms		
...Coscinodiscaceae			
....*Melosira* [1]		100	--
..Pennales			
...Achnanthaceae			
....*Cocconeis*		--	14
...Gomphonemataceae			
....*Gomphonema*		--	56
...Naviculaceae	Naviculoids		
....*Navicula* [1]		29	70
...Nitzschiaceae			
....*Nitzschia* [1]		--	170
Cryptophyta			
.Cryptophyceae			
..Cryptomonadales			
...Cryptomonadaceae			
....*Cryptomonas*		--	14
Cyanophyta	Blue-green algae		
.Cyanophyceae			
..Hormogonales	Filamentous blue-greens		
...Oscillatoriaceae			
....*Oscillatoria* [1]		130	--

[1]Dominant organism, cell counts greater than or equal to 15 percent of total count for the station.

Table 51--Phytoplankton and periphyton analyses for Illinois River and downstream sites on Muddy Fork and Osage Creek

[Five-digit numbers in parenthesis are STORET parameter codes used for computer storage of data]

Site number	River mile	Date of collection	Chlorophyll *a*, phytoplankton, chroma-Fl (µg/L) (70953)	Chlorophyll *b*, phytoplankton, chroma-Fl (µg/L) (70954)	Phytoplankton (cells per mL) (60050)	Chlorophyll *a*, periphyton, chroma-Fl (mg/m^2) (70957)	Chlorophyll *b*, periphyton, chroma-Fl (mg/m^2) (70958)	Periphyton; organic weight (g/m^2)	Biomass/chlorophyll ratio, periphyton (units) (70950)
5	138.1	8-25-81	1.04	<0.01	260	-----	----	----	-----
		9-01-81	----	----	---	4.61	1.85	0.71	155
16	135.6	8-12-81	----	----	---	41.0	7.63	4.8	117
19	133.1	8-11-81	----	----	---	50.9	9.53	4.6	90.4
31	124.6	8-12-81	----	----	---	24.9	3.91	2.5	99.2
		8-26-81	4.68	<.01	470	-----	----	----	-----
58	123.7	8-25-81	1.93	<.01	810	-----	----	----	-----
		9-01-81	----	----	---	37.6	7.77	2.0	53.2
72	115.5	8-11-81	----	----	---	35.0	5.72	2.7	77.1
		8-26-81	4.0	<.01	470	-----	----	----	-----

Table 52.--Periphyton taxa for Illinois River

[Periphyton strips placed at Site 5 on 8-12-81, removed 9-01-81; placed at Site 19 on 7-16-81, removed 8-11-81; placed at Site 31 on 7-15-81; and removed 8-12-81.]

Scientific name	Common name	Station 5	Station 19	Station 31
Chlorophyta	Green algae			
.Chlorophyceae				
..Chlorococcales				
...Coelastraceae				
....*Coelastrum*		X	---	---
...Oocystaceae				
....*Ankistrodesmus*		X	X	---
...Scenedesmaceae				
....*Scenedesmus*		X	X	---
..Oedogoniales				
...Oedogoniaceae				
....*Oedogonium*		---	---	X
..Ulotrichales				
...Chaetophoraceae				
....*Pseudoulvella*		---	---	X
...Coleochaetaceae				
....*Coleochaete*		*	*	*
...Ulotrichaceae				
....*Ulothrix*		X	---	---
..Volvocales				
...Chlamydomonadaceae				
....*Chlamydomonas*		---	---	X
Chrysophyta	Yellow-green algae			
.Bacillariophyceae	Diatoms			
..Centrales	Centric diatoms			
...Coscinodiscaceae				
....*Cyclotella*		---	---	X
..Pennales	Pennate diatoms			
...Achnanthaceae				
....*Achnanthes*		X	---	X
....*Cocconeis*		X	X	X
....*Rhoicosphenia*		---	---	X
...Cymbellaceae				
....*Cymbella*		X	X	X
...Fragilariaceae				
....*Fragilaria*		---	X	X
...Gomphonemataceae				
....*Gomphonema*		X	X	X
...Naviculaceae	Naviculoids			
....*Gyrosigma*		---	---	X
....*Navicula*		X	X	X

X Indicates organism present
* Indicates a dominant organism, estimated to be greater than 15 percent of total algal cells on sampling strip

Table 52.--Periphyton taxa for Illinois River--Continued

Scientific name	Common name	Station 5	Station 19	Station 31
...Nitzschiaceae				
....*Nitzschia*		X	X	X
...Surirellaceae				
....*Surirella*		---	---	X
Cyanophyta	Blue-green algae			
.Cyanophyceae				
..Chroococcales	Coccoid blue-greens			
...Chroococccaceae				
....*Anacystis*		---	---	X
..Hormogonales	Filamentous blue-greens			
...Oscillatoriaceae				
....*Lyngbya*		*	*	X
....*Oscillatoria*		*	*	X

X Indicates organism present
* Indicates a dominant organism, estimated to be greater than 15 percent of total algal cells on sampling strip

Table 53.--Ethylene desorption rate and reaeration rate coefficients for selected reaches of Illinois River

[Discharge = 10.6 ft^3/s between miles 133.6 and 133.0 and 84.8 ft^3/s between miles 122.4 and 120.3]

Stream Reach					Stream
Begin mile	End mile	k_T (day^{-1})	k_2 (day^{-1})	Percent difference[a]	temperature (°C)
133.6	133.1	3.04	3.50	11	19.0
133.1	133.0	2.72	3.13	9	19.0
133.6	133.0	2.97	3.42	9	19.0
122.4	121.5	2.42	2.78	9	26.0
121.5	120.3	5.31	6.11	32	26.0
122.4	120.3	3.96	4.56	12	26.0

[a] Difference between percent change in gas concentration and percent change in dye concentration

Table 54.--Mean velocities, by subreach, for the 1979 and 1981 data sets collected on Illinois River

Subreach		Velocities	
Begin mile	End mile	1979	1981
144.5	142.2	0.017	0.022
142.2	138.7	.030	.028
138.7	138.4	.037	.031
138.4	138.2	.054	.052
138.2	138.0	.069	.052
138.0	135.6	.086	.112
135.6	132.8	.142	.200
132.8	129.6	.290	.318
129.6	123.7	.263	.143
123.7	123.5	.474	.456
123.5	121.4	.472	.460
121.4	119.3	.520	.514
119.3	112.0	.467	.471
112.0	109.0	.140	.143

Table 55.--Model-derived velocities and reaeration rate coefficients for Illinois River low-flow projections

[Stream temperature = 29°C; discharge from proposed Fayetteville wastewater-treatment plant = 92. ft^3/s]

Subreach		Mean	Mean	
Begin mile	End mile	discharge (ft^3/s)	velocity (ft/s)	k_2 (day^{-1})
138.7	138.4	9.62	0.136	3.67
138.4	138.2	9.86	.139	3.67
138.2	138.0	9.88	.139	3.67
138.0	135.6	10.1	.129	4.60
135.6	132.8	10.6	.136	6.38
132.8	129.6	14.5	.127	3.57
129.6	123.7	21.6	.144	3.32
123.7	123.5	42.0	.156	1.85
123.5	121.4	43.8	.161	1.82
121.4	119.3	47.7	.192	2.23
119.3	112.0	55.0	.201	1.26
112.0	109.0	63.0	.070	.50

Table 56.--Mean velocities for the upper Illinois River downstream from the proposed inflow site of the Fayetteville wastewater-treatment plant

[Data provided by the Arkansas Department of Pollution Control and Ecology]

Begin mile	End mile	Discharge	Mean velocity (ft/s)
138.4	138.2	7.1	0.147
138.2	138.0	8.3	.141
138.0	137.6	---	.21
137.6	137.2	---	.12
137.2	136.9	---	.15
136.5	-----	9.2	-----

Table 57.--Modified rate coefficients for Illinois River simulations that include projected effluent limits for the proposed Fayetteville wastewater-treatment plant

Subreach			
Begin mile	End mile	k_d (day^{-1})	k_r (day^{-1})
138.7	138.4	0.15	0.15
138.4	138.2	.15	.15
138.2	138.0	.15	.15
138.0	135.6	.15	.15
135.6	132.8	.16	.16
132.8	129.6	.15	.15
129.6	123.7	.15	.15
123.7	123.5	.15	.15
123.5	121.4	.15	.15
121.4	119.3	.15	.15
119.3	112.0	.15	.15
112.0	109.0	.14	.14

Table 58.—Illinois River model-simulation summary at 7-day, 10-year low flow using existing and projected loadings from the proposed Fayetteville wastewater-treatment plant

Initial River Conditions: Dis-charge (ft³/s)	Initial River Conditions: Dis-solved oxygen (mg/L)	Proposed Fayetteville WWTP: Dis-charge (ft³/s)	Proposed Fayetteville WWTP: Dis-solved oxygen (mg/L)	Proposed Fayetteville WWTP: CBODU (mg/L)	Proposed Fayetteville WWTP: Total organic-N (mg/L)	Proposed Fayetteville WWTP: Total ammonia-N (mg/L)	Proposed Fayetteville WWTP: Total NO2-N (mg/L)	Proposed Fayetteville WWTP: Total NO3-N (mg/L)	Proposed Fayetteville WWTP: Total PO4-P (mg/L)	Proposed Fayetteville WWTP: Total suspended solids (mg/L)	Instream Total Suspended Solids[1]: Concen-tration (mg/L)	Instream Total Suspended Solids[1]: Loca-tion (mile)	Water Tem-pera-ture (°C)	Downstream Dissolved Oxygen Profile Sag: Minimum resulting from Prairie Grove effluent (mg/L)	Downstream Dissolved Oxygen Profile Sag: Loca-tion (mile)	Downstream Dissolved Oxygen Profile Sag: Abso-lute minimum (mg/L)	Downstream Dissolved Oxygen Profile Sag: Loca-tion (mile)	Projected at inflow to Lake Frances: Dis-charge (ft³/s)	Projected: Dis-solved oxygen (mg/L)	Projected: CBODU (mg/L)	Projected: CBODU (lb/d)	Projected: Total organic-N (mg/L)	Projected: Total organic-N (lb/d)	Projected: Total Ammonia-N (mg/L)	Projected: Total Ammonia-N (lb/d)	Projected: Total NO2-N (mg/L)	Projected: Total NO2-N (lb/d)	Projected: Total NO3-N (mg/L)	Projected: Total NO3-N (lb/d)	Projected: Total PO4-P (mg/L)	Projected: Total PO4-P (lb/d)
0.40	6.2	[2]0.00	[2]0.0	[2]0.0	[2]0.00	[2]0.00	[2]0.00	[2]0.00	[2]0.00	[2]0.00	32.0	138.7	29	—	—	0.13	138.2	56.11	6.04	1.13	341.72	0.14	42.34	0.03	9.07	0.01	3.02	0.26	78.63	0.035	10.58
.40	6.2	9.20	7.7	45	.00	15	.00	.00	10	30	30.1	138.7	29	0.00	138.0	.00	138.0	65.31	5.65	1.17	411.83	.15	52.80	.04	14.08	.01	3.52	.47	165.44	.152	53.50
.40	6.2	9.20	7.7	30	.00	10	.00	.00	10	20	20.5	138.7	29	.00	138.0	.00	138.0	65.31	5.74	1.06	373.11	.15	52.80	.04	14.08	.01	3.52	.41	144.32	.152	53.50
.40	6.2	9.20	7.7	15	.00	10	.00	.00	10	15	15.7	138.7	29	.42	138.0	.42	138.0	65.31	5.79	0.95	334.40	.15	52.80	.04	14.08	.01	3.52	.41	144.32	.152	53.50
.40	6.2	9.20	7.7	15	.00	5.0	.00	.00	5.0	15	15.7	138.7	29	1.90	138.0	1.90	138.0	65.31	5.82	.95	334.40	.15	52.80	.03	10.56	.01	3.52	.35	123.20	.097	34.14
.40	6.2	9.20	7.7	15	.00	3.0	.00	.00	5.0	10	10.9	138.7	29	2.49	138.0	2.49	138.0	65.31	5.83	.95	334.40	.15	52.80	.03	10.56	.01	3.52	.33	116.16	.097	34.14
.40	6.2	9.20	7.7	7.5	.00	3.0	.00	.00	2.0	5.0	6.1	138.7	29	2.77	138.0	2.77	138.0	65.31	5.86	.90	316.80	.15	52.80	.03	10.56	.01	3.52	.33	116.16	.064	22.53
.40	6.2	9.20	7.7	7.5	.00	2.0	.00	.00	1.0	5.0	6.1	138.7	29	3.07	138.0	3.07	138.0	65.31	5.86	.90	316.80	.15	52.80	.03	10.56	.01	3.52	.32	112.64	.053	18.66
.40	6.2	9.20	5.0	45	.00	15	.00	.00	10	30	30.1	138.7	29	.00	138.2	.00	138.2	65.31	5.65	1.17	411.83	.15	52.80	.04	14.08	.01	3.52	.47	165.44	.152	53.50
.40	6.2	9.20	5.0	30	.00	10	.00	.00	10	20	20.5	138.7	29	.00	138.0	.00	138.0	65.31	5.74	1.06	373.11	.15	52.80	.04	14.08	.01	3.52	.41	144.32	.152	53.50
.40	6.2	9.20	5.0	5	.00	10	.00	.00	10	15	15.7	138.7	29	.00	138.0	.00	138.0	65.31	5.79	.95	334.40	.15	52.80	.04	14.08	.01	3.52	.41	144.32	.152	53.50
.40	6.2	9.20	5.0	15	.00	5.0	.00	.00	5.0	15	15.7	138.7	29	1.09	138.0	1.09	138.0	65.31	5.82	.95	334.40	.15	52.80	.03	10.56	.01	3.52	.35	123.20	.097	34.14
.40	6.2	9.20	5.0	15	.00	3.0	.00	.00	5.0	10	10.9	138.7	29	1.68	138.0	1.68	138.0	65.31	5.83	.95	334.40	.15	52.80	.03	10.56	.01	3.52	.33	116.16	.097	34.14
.40	6.2	9.20	5.0	7.5	.00	3.0	.00	.00	2.0	5.0	6.1	138.7	29	1.97	138.0	1.97	138.0	65.31	5.86	.90	316.80	.15	52.80	.03	10.56	.01	3.52	.33	116.16	.064	22.53
.40	6.2	9.20	5.0	7.5	.00	2.0	.00	.00	1.0	5.0	6.1	138.7	29	2.27	138.0	2.27	138.0	65.31	5.86	.90	316.80	.15	52.80	.03	10.56	.01	3.52	.32	112.64	.053	18.66

[1]Represents mass balance immediately downstream from Fayetteville WWTP.
[2]Existing river conditions (no WWTP effluent)

Table 59.--Average dissolved oxygen deficits in Illinois River, by subreach for simulations that include projected changes in ultimate carbonaceous biochemical oxygen demand and ammonia-nitrogen concentrations from the proposed Fayetteville wastewater-treatment plant

[Deficits in milligrams per liter]

Stream discharge = 7-day, 10-year low flow, Temperature = 29°C

Subreach						
Beginning mile	Ending mile	CBOD deficit	Benthal deficit	Net photosynthetic deficit	Ammonia-N deficit	Nitrite-N deficit
CBODU = 45 mg/L, Ammonia-N = 15 mg/L						
138.7	138.4	0.59	0.601	-0.012	0.314	0.008
138.4	138.2	.71	1.719	.270	2.247	.150
138.2	138.0	.69	1.429	.240	2.111	.291
138.0	135.6	.61	1.330	- .215	.610	.250
135.6	132.8	.41	.837	.935	.699	.219
132.8	129.6	.25	.504	.214	.108	.066
129.6	123.7	.12	.534	.073	.098	.030
123.7	123.5	.07	.624	.118	.038	.015
123.5	121.4	.06	.575	- .088	.032	.012
121.4	119.3	.04	.527	- .068	.059	.014
119.3	112.0	.03	.203	.000	.033	.014
112.0	109.0	.05	.643	- .591	.017	.006
CBODU = 30 mg/L, Ammonia-N = 10 mg/L						
138.7	138.4	0.39	0.601	-0.012	0.209	0.006
138.4	138.2	.47	1.719	.270	1.499	.100
138.2	138.0	.46	1.429	.240	1.407	.194
138.0	135.6	.41	1.330	- .215	.407	.167
135.6	132.8	.28	.837	.935	.467	.146
132.8	129.6	.17	.504	.214	.072	.044
129.6	123.7	.09	.534	.073	.067	.020
123.7	123.5	.06	.624	.118	.027	.011
123.5	121.4	.05	.575	- .088	.023	.009
121.4	119.3	.04	.527	- .068	.043	.010
119.3	112.0	.03	.203	.000	.026	.010
112.0	109.0	.05	.643	- .591	.016	.006

Table 59.--Average dissolved oxygen deficits in Illinois River, by subreach for simulations that include projected changes in ultimate carbonaceous biochemical oxygen demand and ammonia-nitrogen concentrations from the proposed Fayetteville wastewater-treatment plant--Continued

[Deficits in milligrams per liter]

Stream discharge = 7-day, 10-year low flow, Temperature = 29°C

Subreach						
Beginning mile	Ending mile	CBOD deficit	Benthal deficit	Net photosynthetic deficit	Ammonia-N deficit	Nitrite-N deficit
CBODU = 15 mg/L, Ammonia-N = 10 mg/L						
138.7	138.4	0.20	0.601	-0.012	0.209	0.006
138.4	138.2	.24	1.719	.270	1.499	.100
138.2	138.0	.23	1.429	.240	1.407	.194
138.0	135.6	.21	1.330	- .215	.407	.167
135.6	132.8	.14	.837	.935	.467	.146
132.8	129.6	.09	.504	.214	.072	.044
129.6	123.7	.06	.534	.073	.067	.020
123.7	123.5	.05	.624	.118	.027	.011
123.5	121.4	.04	.575	- .088	.023	.009
121.4	119.3	.03	.527	- .068	.043	.010
119.3	112.0	.02	.203	.000	.026	.010
112.0	109.0	.04	.643	- .591	.016	.006
CBODU = 15 mg/L, Ammonia-N = 5 mg/L						
138.7	138.4	0.20	0.601	-0.012	0.105	0.002
138.4	138.2	.24	1.719	.270	.750	.050
138.2	138.0	.23	1.429	.240	.704	.097
138.0	135.6	.21	1.330	- .215	.204	.084
135.6	132.8	.14	.837	.935	.234	.073
132.8	129.6	.09	.504	.214	.037	.022
129.6	123.7	.06	.534	.073	.035	.011
123.7	123.5	.05	.624	.118	.016	.007
123.5	121.4	.04	.575	- .088	.014	.005
121.4	119.3	.03	.527	- .068	.027	.007
119.3	112.0	.02	.203	.000	.018	.007
112.0	109.0	.04	.643	- .591	.015	.005

Table 59.--Average dissolved oxygen deficits in Illinois River, by subreach for simulations that include projected changes in ultimate carbonaceous biochemical oxygen demand and ammonia-nitrogen concentrations from the proposed Fayetteville wastewater-treatment plant--Continued

[Deficits in milligrams per liter]

Stream discharge = 7-day, 10-year low flow, Temperature = 29°C

Subreach Beginning mile	Subreach Ending mile	CBOD deficit	Benthal deficit	Net photosynthetic deficit	Ammonia-N deficit	Nitrite-N deficit
		CBODU = 15 mg/L, Ammonia-N = 3 mg/L				
138.7	138.4	0.20	0.601	-0.012	0.063	0.002
138.4	138.2	.24	1.719	.270	.451	.030
138.2	138.0	.23	1.429	.240	.423	.059
138.0	135.6	.21	1.330	- .215	.122	.050
135.6	132.8	.14	.837	.935	.141	.044
132.8	129.6	.09	.504	.214	.022	.014
129.6	123.7	.06	.534	.073	.023	.007
123.7	123.5	.05	.624	.118	.011	.005
123.5	121.4	.04	.575	- .088	.010	.004
121.4	119.3	.03	.527	- .068	.021	.005
119.3	112.0	.02	.203	.000	.015	.006
112.0	109.0	.04	.643	- .591	.014	.005
		CBODU = 7.5 mg/L, Ammonia-N = 3 mg/L				
138.7	138.4	0.10	0.61	-0.012	0.063	0.002
138.4	138.2	.12	1.719	.270	.451	.030
138.2	138.0	.12	1.429	.240	.423	.059
138.0	135.6	.11	1.330	- .215	.122	.050
135.6	132.8	.07	.837	.935	.141	.044
132.8	129.6	.05	.504	.214	.022	.014
129.6	123.7	.04	.534	.073	.023	.007
123.7	123.5	.05	.624	.118	.011	.005
123.5	121.4	.04	.575	- .088	.010	.004
121.4	119.3	.03	.527	- .068	.021	.005
119.3	112.0	.02	.203	.000	.015	.006
112.0	109.0	.04	.643	- .591	.014	.005

Table 59.--Average dissolved oxygen deficits in Illinois River, by subreach for simulations that include projected changes in ultimate carbonaceous biochemical oxygen demand and ammonia-nitrogen concentrations from the proposed Fayetteville wastewater-treatment plant--Continued

[Deficits in milligrams per liter]

Stream discharge = 7-day, 10-year low flow, Temperature = 29°C

Subreach: Beginning mile	Subreach: Ending mile	CBOD deficit	Benthal deficit	Net photosynthetic deficit	Ammonia-N deficit	Nitrite-N deficit
CBODU = 7.5 mg/L, Ammonia-N = 2 mg/L						
138.7	138.4	0.20	0.601	-0.012	0.042	0.001
138.4	138.2	.12	1.719	.270	.301	.020
138.2	138.0	.12	1.429	.240	.283	.039
138.0	135.6	.11	1.330	- .215	.082	.034
135.6	132.8	.07	.837	.935	.095	.030
132.8	129.6	.05	.504	.214	.015	.010
129.6	123.7	.04	.534	.073	.017	.005
123.7	123.5	.05	.624	.118	.009	.004
123.5	121.4	.04	.575	- .088	.008	.003
121.4	119.3	.03	.527	- .068	.018	.004
119.3	112.0	.02	.203	.000	.014	.005
112.0	109.0	.04	.643	- .591	.014	.005
Existing Conditions (see table 58)						
138.7	138.4	0.06	2.736	-0.054	0.024	0.008
138.4	138.2	.22	6.187	.973	.101	.035
138.2	138.0	.18	5.146	.863	.078	.027
138.0	135.6	.04	3.742	- .604	.015	.005
135.6	132.8	.00	1.896	2.117	.009	.003
132.8	129.6	.02	1.062	.451	.006	.003
129.6	123.7	.02	.855	.117	.011	.004
123.7	123.5	.06	.782	.148	.006	.004
123.5	121.4	.05	.714	- .109	.007	.003
121.4	119.3	.03	.642	- .082	.016	.004
119.3	112.0	.02	.242	.000	.014	.005
112.0	109.0	.04	.748	- .686	.015	.005

Sensitivity Testing

The Illinois River simulation with the projected Fayetteville effluent limit number 7 imposed and effluent DO concentration set to saturation (7.7 mg/L) was used for sensitivity testing. The criteria used, and the parameters and coefficients tested for sensitivity, are listed in the "Model Sensitivity" section. Figures 64 through 76 show the resulting sensitivity bands.

For the flow conditions in the simulation tested, the DO profile is more sensitive to changes in reaeration coefficients, benthic demands, net algal DO production, and mean stream depth than any other parameters tested. The DO sensitivity bands for these parameters are shown in figures 68, 69, 73, and 74. The processes defined by the first three of these four parameters seem to have equal impact upon the Illinois River DO profile. Like changes in either precipitate similar changes in the resulting DO profile. Changes in mean stream depth significantly impacts the resulting DO profile because the reaeration coefficient, as defined by the Velz equation (equation 17), is very depth dependent.

Illinois River Conclusions

Under existing conditions, Illinois River does not meet standards (Arkansas Department of Pollution Control and Ecology, 1981) for the following parameters: diel-minimum DO, total phosphorus, and fecal coliform bacteria. Stormwater runoff sampling indicates that significant nutrient loads may be contributed to the stream during runoff periods. These contribute to benthic demands at low flow and may be resuspended in the water column when velocities increase, or when the streambed is disturbed for any reason.

Diel-minimum DO concentrations in Illinois River resulting in part from the instream waste discharged by the proposed Fayetteville WWTP will not meet the diel-minimum DO concentration standard of 4.0 mg/L with any of the projected effluent limits imposed. Simulations including either projected effluent limit number 3, 4, 5, 6 or 7, with effluent DO concentrations set to 7.7 mg/L or, effluent limits 4, 5, 6, or 7 with effluent DO concentrations set to 5.0 mg/L, result in higher instream minimum DO concentrations than the 0.13 mg/L minimum simulated for $Q_{7/10}$, "as surveyed conditions" (table 58). This is due to the reduced time of travel resulting from the addition of the WWTP discharge.

Simulations indicate that DO deficits resulting from benthic demands are generally the most significant and are the main reason that Illinois River will not meet DO standards. Nonpoint sources are probably the primary contributors to these projected benthic demands. The ammonia deficits are the largest between river miles 138.4 and 138.0 when ammonia-N concentrations equal or exceed 15 mg/L.

Sensitivity testing indicates that the DO profile is most sensitive to stream depths, reaeration rate coefficients, benthic demands, and net algal DO production.

ILLINOIS RIVER BASIN SUMMARY

Synoptic water quality data were collected on Illinois River, Muddy Fork, Spring Creek, and Osage Creek during the periods September 5-9, November 27-30, 1978, July 23-27, 1979, and August 24 - September 5, 1981, when flows were relatively steady. These data indicate that Arkansas stream standards (Arkansas Department of Pollution Control and Ecology, 1981) Arkansas stream standards for DO, water temperature, total phosphorus-P, and fecal coliform bacteria are frequently violated in streams in the Illinois River basin.

Computed DO deficits indicate that benthic demands significantly impact the DO regime in Illinois River, Muddy Fork, Spring Creek, and Osage Creek. Deficits created by CBODU and nitrogen can also be significant if instream concentrations of these constituents are high.

Neither Illinois River nor Muddy Fork will meet Arkansas DO standards (Arkansas Department of Pollution Control and Ecology, 1981) with any of the projected effluents imposed on the proposed Fayetteville and existing Prairie Grove WWTP, respectively. Spring Creek can meet DO standards if the Springdale effluent concentrations of CBODU and ammonia-N are less than or equal to

7.5 and 2.0 mg/L, respectively, and the effluent is saturated with DO. Osage Creek can meet Arkansas standards for DO if the Rogers WWTP effluent contains concentrations of CBODU and ammonia-N less than or equal to 15.0 and 5.0 mg/L, respectively, and if the effluent is saturated with DO. If the Rogers WWTP effluent contains only 5.0 mg/L DO, then CBODU and ammonia-N concentrations must be less than or equal to 7.5 and 2.0 mg/L, respectively, in order for Osage Creek to meet Arkansas DO standards. Each individual stream assessment section should be referenced for detailed analyses and modeling results.

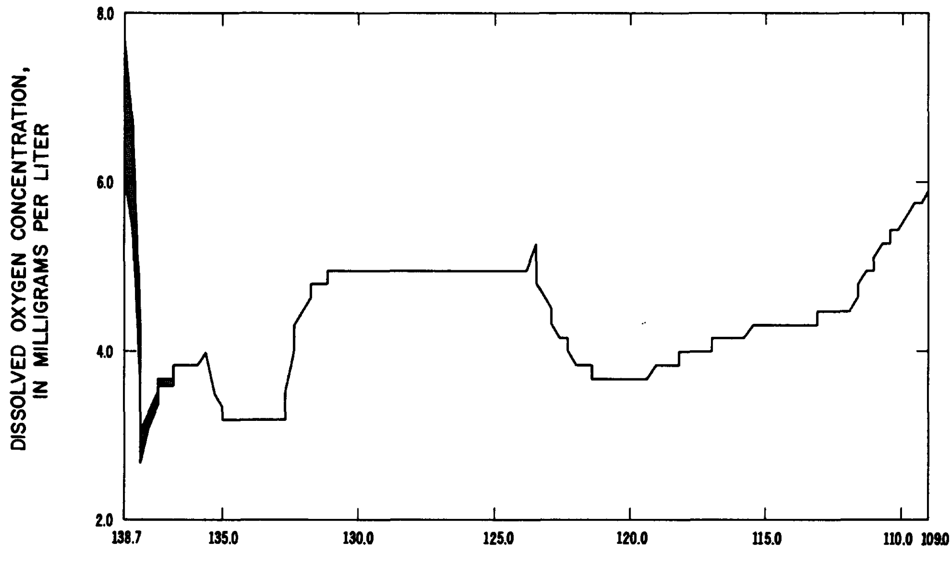

Figure 64.--Band reflecting the sensitivity of Illinois River dissolved-oxygen concentrations to a plus or minus 20-percent change in the dissolved oxygen concentrations of the effluent from the Fayetteville wastewater-treatment plant; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

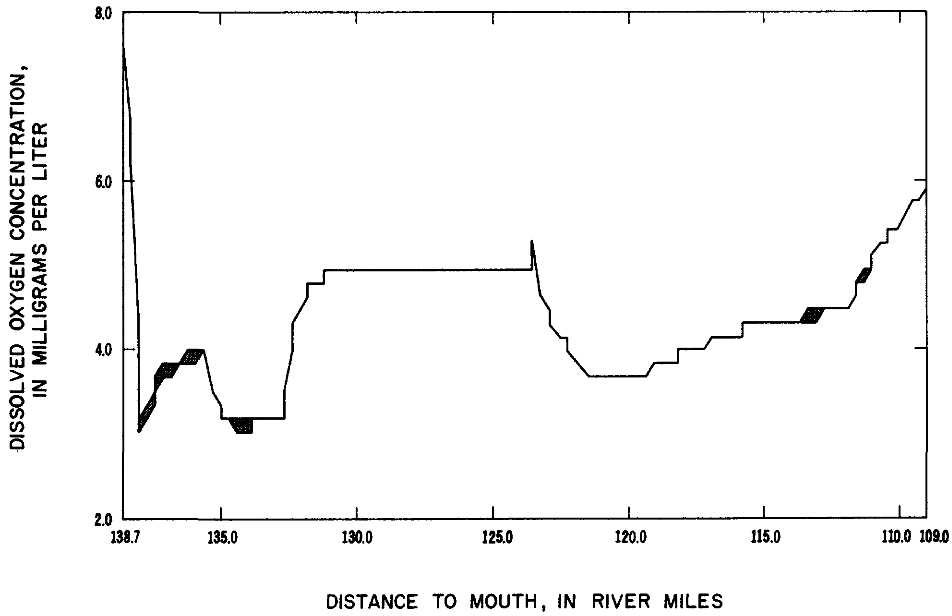

Figure 65.--Band reflecting the sensitivity of Illinois River dissolved-oxygen concentrations to a plus or minus 20-percent change in the ammonia forward reaction and decay rates; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Fayetteville wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

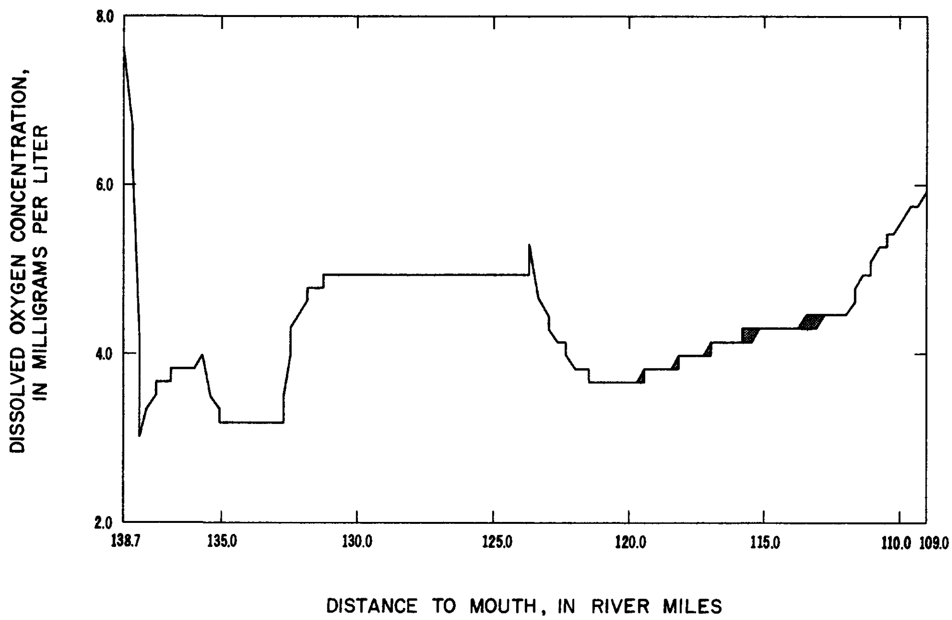

Figure 66.--Band reflecting the sensitivity of Illinois River dissolved-oxygen concentrations to a plus or minus 20-percent change in the organic nitrogen forward reaction and decay rates; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Fayetteville wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

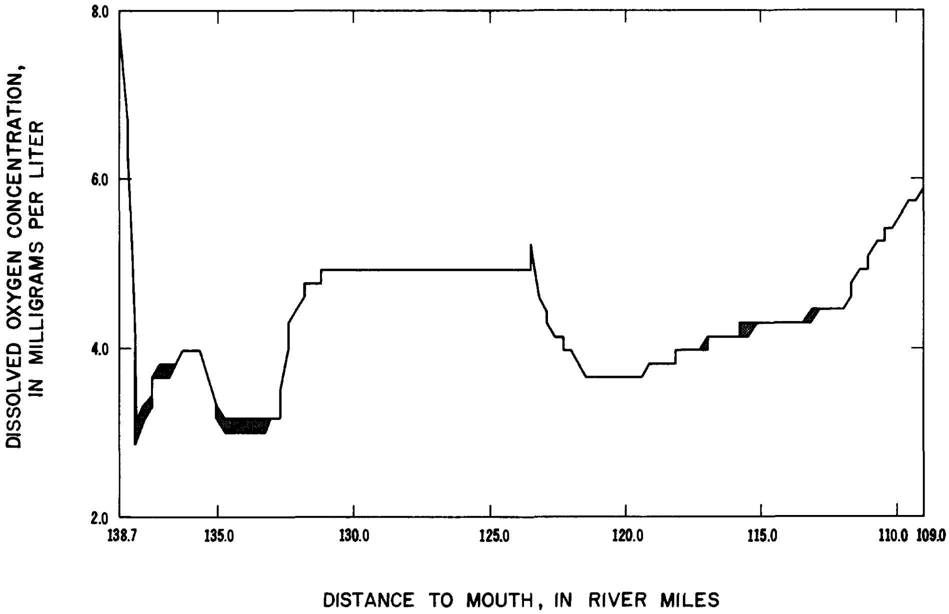

Figure 67.--Band reflecting the sensitivity of Illinois River dissolved-oxygen concentrations to a plus or minus 20-percent change in the ammonia concentration of the effluent from the Fayetteville wastewater-treatment plant; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Fayetteville wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

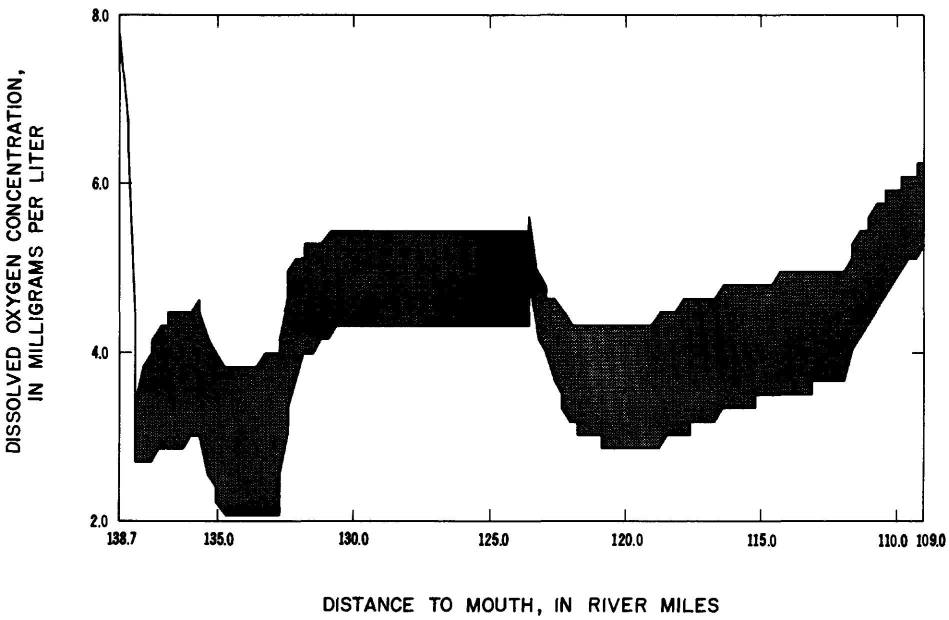

Figure 68.--Band reflecting the sensitivity of Illinois River dissolved-oxygen concentrations to a plus or minus 20-percent change in the reaeration coefficients; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Fayetteville wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

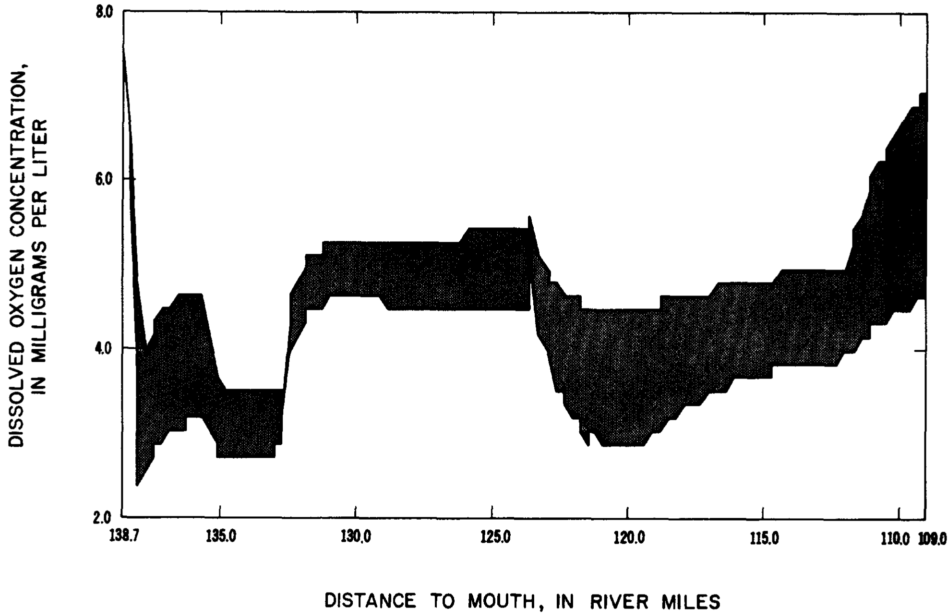

Figure 69.--Band reflecting the sensitivity of Illinois River dissolved-oxygen concentrations to a plus or minus 20-percent change in the benthic demands; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Fayetteville wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

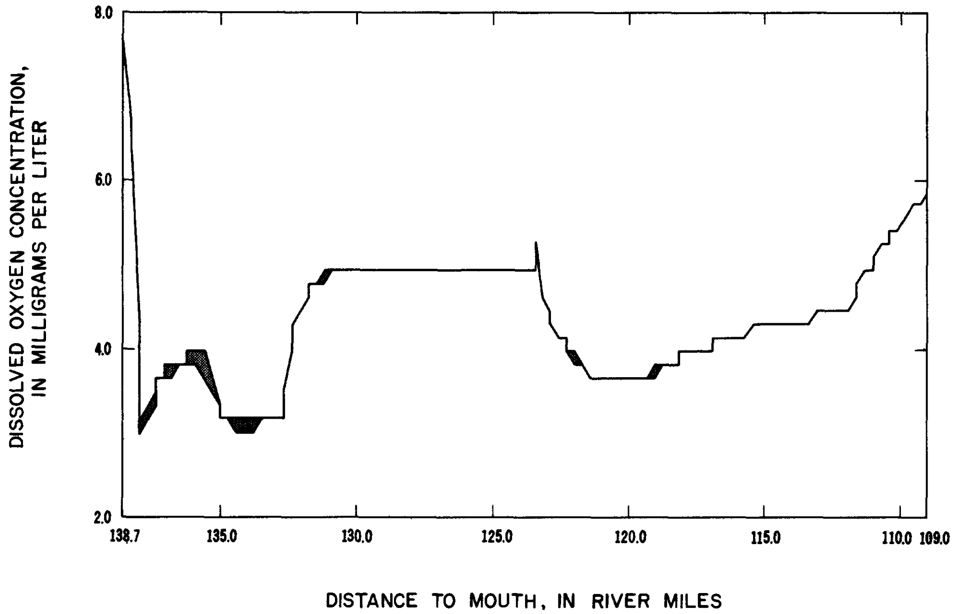

Figure 70.--Band reflecting the sensitivity of Illinois River dissolved-oxygen concentrations to a plus or minus 20-percent change in the ultimate carbonaceous biochemical oxygen demand of the effluent from the Fayetteville wastewater-treatment plant; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Fayetteville wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

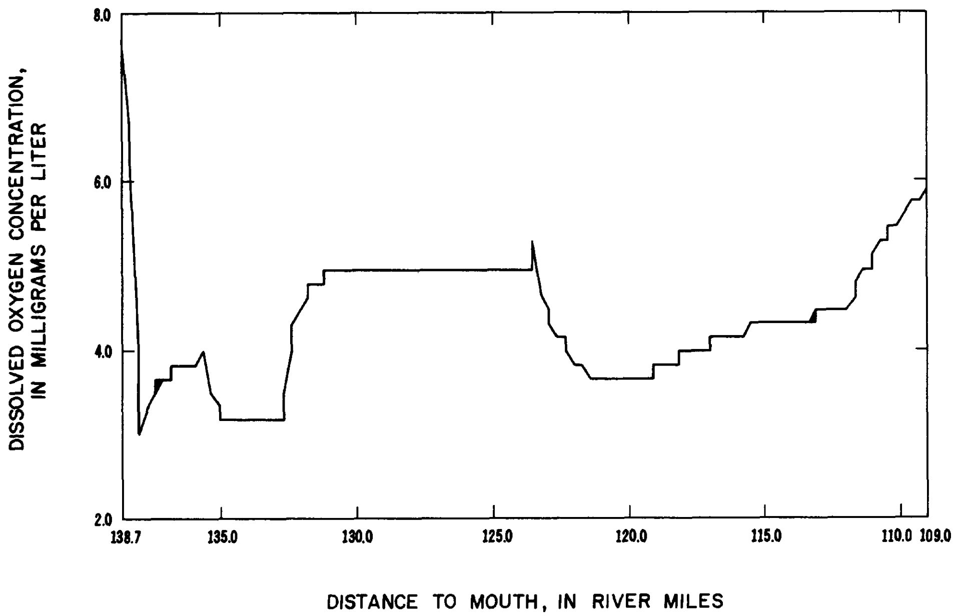

Figure 71.--Band reflecting the sensitivity of Illinois River dissolved-oxygen concentrations to a plus or minus 20-percent change in the nitrite forward reaction and decay rates; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Fayetteville wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

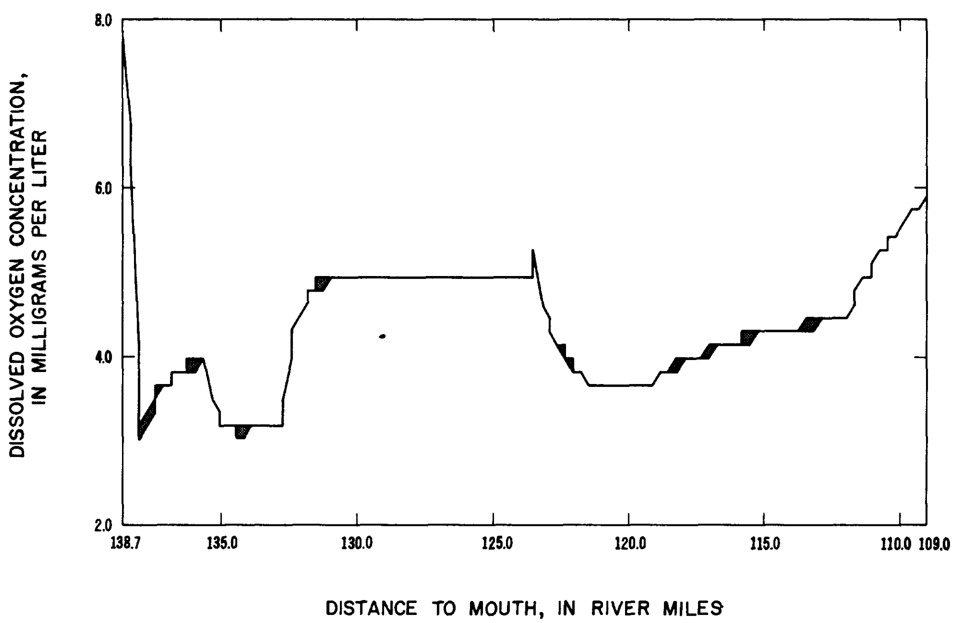

Figure 72.--Band reflecting the sensitivity of Illinois River dissolved-oxygen concentrations to a plus or minus 20-percent change in the deoxygenation and removal rates for carbonaceous material; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Fayetteville wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

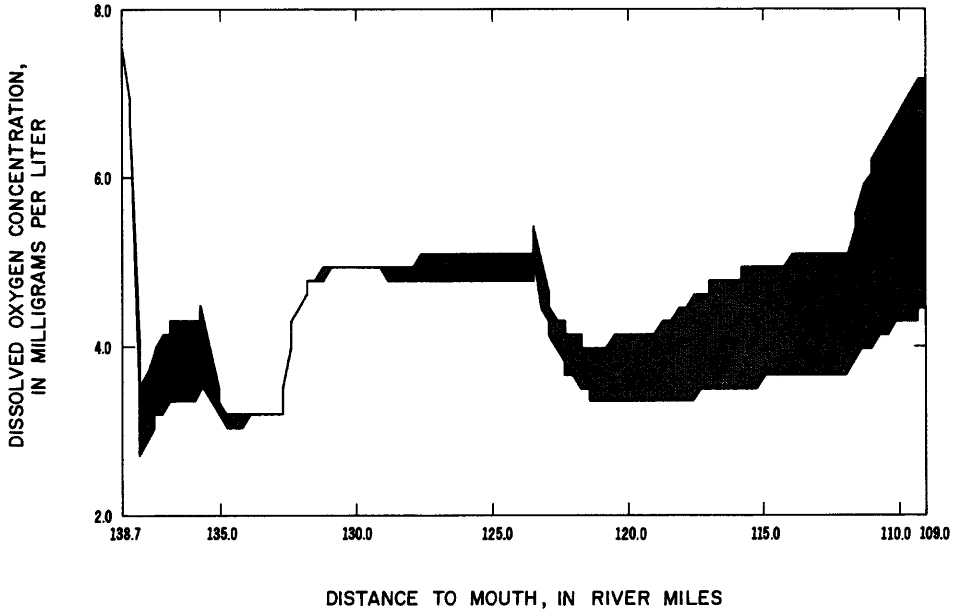

Figure 73.--Band reflecting the sensitivity of Illinois River dissolved-oxygen concentrations to a plus or minus 20-percent change in net photosynthetic production; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Fayetteville wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

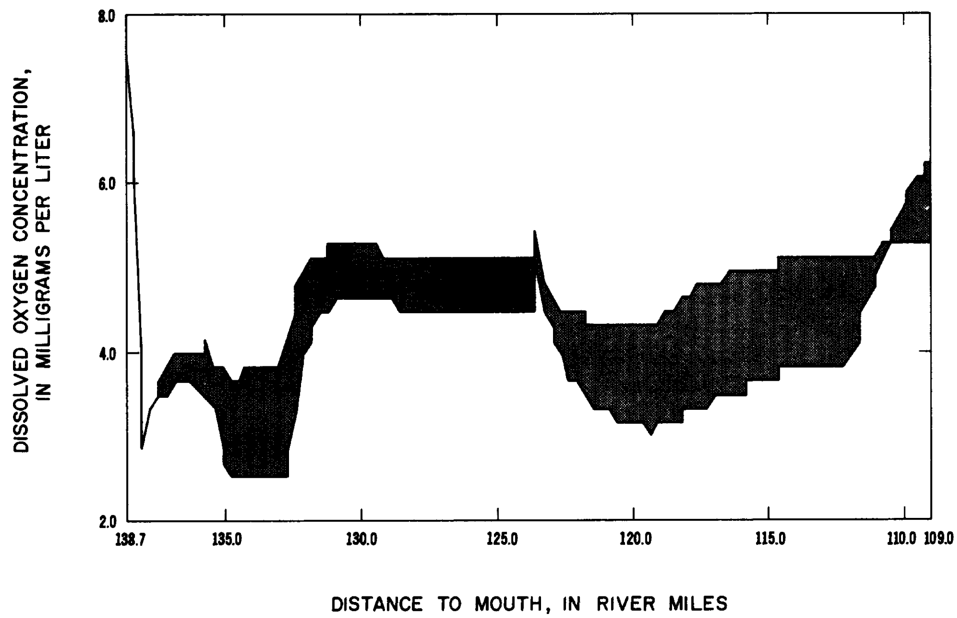

Figure 74.--Band reflecting the sensitivity of Illinois River dissolved-oxygen concentrations to a plus or minus 20-percent change in mean river depths; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Fayetteville wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

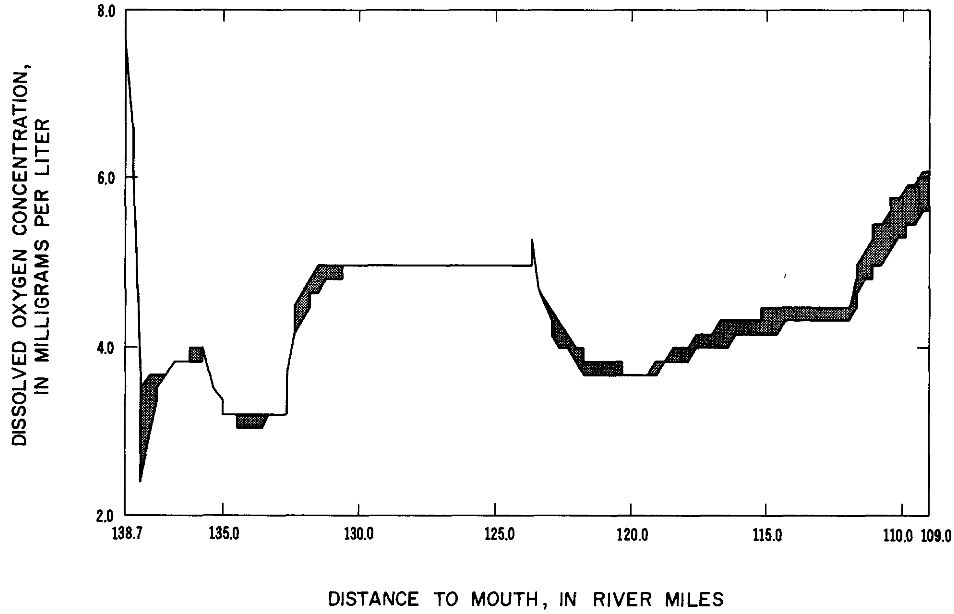

Figure 75.--Band reflecting the sensitivity of Illinois River dissolved-oxygen concentrations to a plus or minus 20-percent change in mean river velocities; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Fayetteville wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

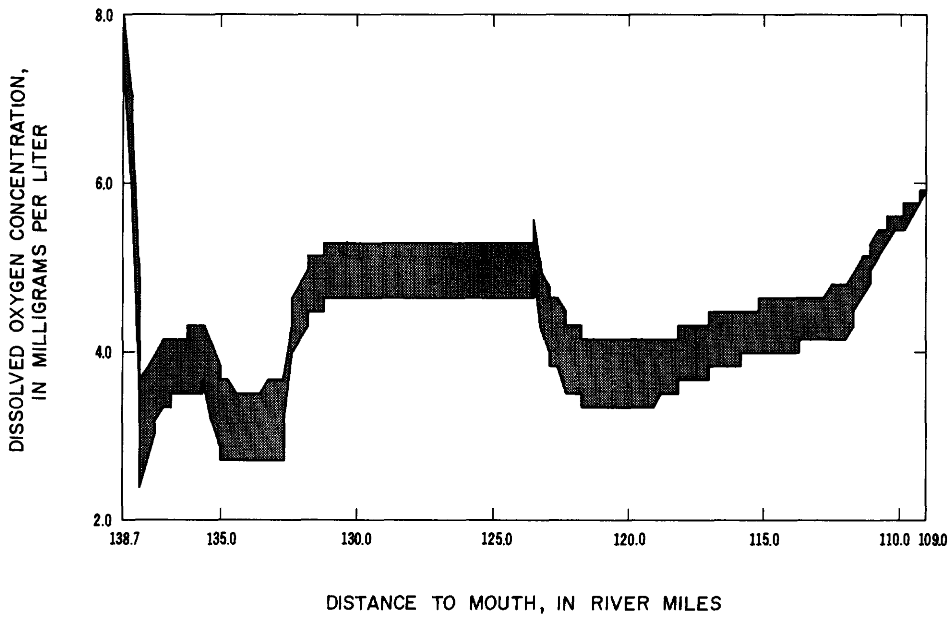

Figure 76.--Band reflecting the sensitivity of Illinois River dissolved-oxygen concentrations to a plus or minus 2.0-degree celsius change in water temperature; water temperature is 29°C, river discharge is equal to the 7-day, 10-year low flow, and the wasteload projection for the Fayetteville wastewater-treatment plant is 7.5 mg/L ultimate biochemical oxygen demand, 2.0 mg/L ammonia, and 7.7 mg/L dissolved oxygen.

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ATTACHMENT A

MODEL MODIFICATIONS

ATTACHMENT A
MODEL MODIFICATIONS

The State of Arkansas and the U.S. Environmental Projection Agency requires that each instream DO standard be evaluated with respect to diel-minimum DO concentrations. They also require that the determination of assimilative capacity of a perennial stream into which an effluent greater than 3 ft^3/s is discharged be made with a steady-state digital water-quality model.

The diel minimum is but one point on each diel-DO curve that occurs at an infinite number of locations along the stream. The longitudinal line connecting this locus of points is the diel-minimum profile. Each point along this profile is the net result of what has occurred to alter the concentration of DO in that parcel of water during some preceding time period. It is very difficult, if not impossible, to simulate this profile with a steady state model unless a basic assumption is made with respect to the causes of a diel-DO cycle.

The strategy employed in this study for both the interpretation and simulation of the diel-minimum DO profile is that, under relatively steady flow conditions, the diel-DO cycle at a given location, is primarily due to algal DO production and respiration. Because the diel minimum is, by definition, the low point in that diel cycle, it is the net result of DO dynamics during the preceding 24-hour period, as reflected by the diel-mean DO profile, and maximum nighttime algal respiration.

A modification was made to the existing model so that the minimum-DO profile can be simulated by "adjusting" the 24-hour net algal DO production values, by subreach, to account for maximum nighttime algal respiration. The following relationship is used:

$$R_m = P_n + A_d \qquad \text{(Ai)}$$

where,

R_m = maximum nighttime respiration that precipitates diel-minimum DO concentrations,

P_n = net diel algal DO production (gross photosynthesis - respiration)

A_d = adjustment factor used to modify the effect of P_n in order to simulate minimum DO concentration.

This adjustment is made, by subreach, after the effects of all other DO sources and sinks have been defined in terms of the diel-mean DO profile, R_m and P_n are at 20°C. Following the application of equation (Ai), R_m is corrected for instream temperature as defined by Terry and others, (1982).

When the model can adequately simulate observed diel-minimum concentrations, R_m values have been defined properly. Projected changes in the diel-minimum DO profile can then be simulated by holding P_n and A_d constant and imposing various changes in point source waste loading, etc. If conditions are such that one cannot assume that P_n will remain relatively unchanged, then this approach might not be applicable.

Minimum DO profiles simulated using this procedure were compared to those simulated using an unsteady model (Jobson, 1980). The resulting minimum profiles matched very well. Further discussion of this comparison is planned for publication at a later date.

ATTACHMENT B

MUDDY FORK CALIBRATION AND VERIFICATION

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                STEADY STATE WATER QUALITY MODEL
                GULF COAST HYDROSCIENCE CENTER
                   U. S. GEOLOGICAL SURVEY
                      (ARKANSAS VERSION)
              DATE OF LAST REVISION, DECEMBER  1980

MUDDY FORK CALIBRATION  (1981  DATA)--MINIMUM DISSOLVED OXYGEN

          DISSOLVED OXYGEN PROFILE REPRESENTS
     ***  DIEL MINIMUMS; NET PHOTOSYNTHETIC DO  ***
          PRODUCTION ADJUSTED ACCORDINGLY.

        NITRIFICATION CYCLE INCLUDED IN MODEL

        NUMBER OF SURRFACHES FOR THIS PROBLEM =    9

            PRINTING INTERVAL (MILES) =   0.100
           STARTING DISTANCE (MILES) =    8.600
  INITIAL CBOD CONC (MG/L) AT STARTING DISTANCE =    2.00
  INITIAL ORGANIC NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.730
  INITIAL AMMONIUM NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.110
  INITIAL NITRITE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.020
  INITIAL NITRATE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   2.300
  INITIAL DO CONC (MG/L) AT STARTING DISTANCE =   5.000
  INITIAL PHOSPHATE CONC (MG/L) AT STARTING DISTANCE =   0.050
  INITIAL TOT. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =    1100.
  INITIAL FEC. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =    1100.
      STREAMFLOW (CFS) AT STARTING DISTANCE =     0.540

      TOTAL SUSPENDED SOLIDS                    =   4.00
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MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN

S U R R E A C H   L I N E A R   R U N O F F   D A T A

SURREACH	Q (CFS)	CROD (MG/L)	ORGANIC (MG/L)	AMMONIA (MG/L)	NITRITE (MG/L)	NITRATE (MG/L)	DO (MG/L)	TSS (MG/L)	SP COND (MG/L)	(MG/L)	PO4 (MG/L)
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.02	0.0	14.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.02	0.0	22.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	14.00	0.92	0.36	0.29	0.64	3.10	11.00	279.00	0.0	0.07
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	1.10	0.17	0.02	0.02	0.25	5.00	1.10	279.00	0.0	0.04

R E A C H D E S C R I P T I O N D A T A (MAJOR TRIBUTARIES AND MAIN STEM)

SUBREACH	CODE	NAME	BEGIN (MILE)	END (MILE)
1	A	UPSTREAM SUBREACH	8.60	8.30
2	A	AT PR. GROVE STP T	8.30	8.20
3	A	AT STA 9	8.20	6.50
4	A	AT STA 10	6.50	4.70
5	A	AT STA 11	4.70	4.00
6	A	ATMOORES CREEK	4.00	3.90
7	A	BL. MOORES CREEK	3.90	3.00
8	A	UNNAMED TRIB	3.00	1.40
9	A	TRIB BL KINION LK	1.40	0.0

KEY: CODE

A ROCKY BOTTOM-POOL RIFFLE-LIGHT VEGETATION
B ROCKY BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
C ROCKY BOTTOM-POOL RIFFLE-HEAVY VEGETATION
D ROCKY BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
E ROCKY BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
F ROCKY BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION
G MUD BOTTOM-POOL RIFFLE-LIGHT VEGETATION
H MUD BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
I MUD BOTTOM-POOL RIFFLE-HEAVY VEGETATION
J MUD BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
K MUD BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
L MUD BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN

INPUT PARAMETERS

CONCENTRATIONS(MG/L) OF --

SUBREACH	CARB BOD	ORG-N	NH3-N	NO2-N	NO3-N	DISSOLVED OXYGEN	PO4	TOT.COLIF.	FEC.COLIF.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	35.00	3.80	0.54	0.24	11.00	2.90	11.00	100.00	50.00
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	5.50	2.70	1.20	0.21	1.10	3.00	0.14	17000.00	2900.00
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	2.60	0.84	0.15	0.01	4.30	7.30	0.05	2400.00	60.00
9	1.10	0.17	0.02	0.02	0.25	5.00	0.04	6800.00	1400.00

DIRECT DISCHARGES(LB/DAY) OF --

SUBREACH	CARBONACEOUS ULT. BOD	ORGANIC NITROGEN	AMMONIA NITROGEN	NITRITE NITROGEN	NITRATE NITROGEN	PHOSPHATE
1	0.0	0.0	0.0	0.0	0.0	0.
2	0.0	0.0	0.0	0.0	0.0	0.
3	0.0	0.0	0.0	0.0	0.0	0.
4	0.0	0.0	0.0	0.0	0.0	0.
5	0.0	0.0	0.0	0.0	0.0	0.
6	0.0	0.0	0.0	0.0	0.0	0.
7	0.0	0.0	0.0	0.0	0.0	0.
8	0.0	0.0	0.0	0.0	0.0	0.
9	0.0	0.0	0.0	0.0	0.0	0.

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN

SUBREACH	NET PHOTOSYNTHETIC DO PRODUCTION (MG/L/DAY @ 20 DEG C)	(FITTING FACTOR FOR MINIMUM DO PROFILE)	BENTHIC DO DEMAND (G/SQM/DAY @ 20 DEG C)
1	1.087	0.0	3.00
2	1.121	0.0	4.00
3	1.014	-0.500	6.00
4	0.793	0.0	5.00
5	0.634	-2.500	5.25
6	0.582	-2.500	5.50
7	0.519	-1.000	4.25
8	0.359	0.0	3.80
9	0.223	0.0	2.80

G E O M E T R Y

SUBREACH	FLOW CHANGE (CFS)	AREA (SQFT)	DEPTH (FT)	SLOPE	TEMP (DEG.CENT)	END MI (MI)
1	0.0	57.	1.76	0.0007800	23.00	8.3
2	0.19	70.	2.32	0.0007800	23.00	8.2
3	0.0	70.	2.32	0.0007800	23.00	6.5
4	0.0	70.	2.32	0.0007800	23.00	4.7
5	0.0	70.	2.32	0.0007800	23.00	4.0
6	0.92	60.	2.10	0.0005500	23.00	3.9
7	0.0	60.	2.10	0.0005500	23.00	3.0
8	0.11	71.	2.00	0.0005500	23.00	1.4
9	1.70	71.	3.39	0.0005500	23.00	0.0

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN

REACTION COEFFICIENTS (/DAY @ 20 DEG C)

SUBREACH	KR	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KCOLF	KCOLT	KPO41	KPO42
1	0.39	0.16	0.02	0.02	0.18	0.18	0.60	0.60	1.10	4.00	1.00	0.01	0.0
2	0.66	0.24	0.02	0.02	0.18	0.18	0.60	0.60	0.04	1.00	1.10	0.11	0.0
3	0.07	0.07	0.02	0.04	0.18	0.18	0.60	0.60	0.04	1.00	1.10	0.11	0.0
4	0.03	0.03	0.03	0.03	0.18	0.18	0.60	0.60	0.05	1.00	1.10	0.08	0.0
5	0.31	0.22	0.03	0.05	0.18	0.18	0.60	0.60	0.01	1.00	1.10	0.08	0.0
6	0.07	0.07	0.05	2.90	0.50	2.00	0.50	3.00	0.01	1.00	1.00	0.59	0.0
7	0.07	0.07	0.05	0.05	0.50	0.50	0.50	2.00	0.01	1.00	1.00	0.01	0.0
8	0.05	0.05	0.05	0.05	0.50	0.50	0.50	2.00	0.01	1.00	1.00	0.06	0.0
9	0.35	0.14	0.05	0.05	0.50	1.60	0.50	0.50	0.01	1.00	1.00	0.01	0.0

TEMPERATURE CORRECTED REACTION COEFFICIENTS (/DAY)

SUBREACH	KR	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KA	KPO41	KPO42
1	0.44	0.18	0.03	0.03	0.23	0.23	0.78	0.78	1.42	2.86	0.01	0.0
2	0.75	0.27	0.03	0.03	0.23	0.23	0.78	0.78	0.05	1.98	0.14	0.0
3	0.08	0.08	0.03	0.05	0.23	0.23	0.78	0.78	0.05	1.98	0.14	0.0
4	0.03	0.03	0.04	0.04	0.23	0.23	0.78	0.78	0.06	1.98	0.10	0.0
5	0.35	0.25	0.04	0.06	0.23	0.23	0.78	0.78	0.01	1.98	0.10	0.0
6	0.08	0.08	0.06	3.76	0.65	2.59	0.65	3.89	0.01	2.32	0.76	0.0
7	0.08	0.08	0.06	0.06	0.65	0.65	0.65	2.59	0.01	2.32	0.01	0.0
8	0.06	0.06	0.06	0.06	0.65	0.65	0.65	2.59	0.01	2.46	0.08	0.0
9	0.40	0.16	0.06	0.06	0.65	2.07	0.65	0.65	0.01	0.90	0.01	0.0

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN

SUBREACH	REAERATION COEFFICIENT DERIVATION
1	KA COMPUTED BY VELZ EQUATION
2	KA COMPUTED BY VELZ EQUATION
3	KA COMPUTED BY VELZ EQUATION
4	KA COMPUTED BY VELZ EQUATION
5	KA COMPUTED BY VELZ EQUATION
6	KA COMPUTED BY VELZ EQUATION
7	KA COMPUTED BY VELZ EQUATION
8	KA COMPUTED BY VELZ EQUATION
9	KA COMPUTED BY VELZ EQUATION

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN

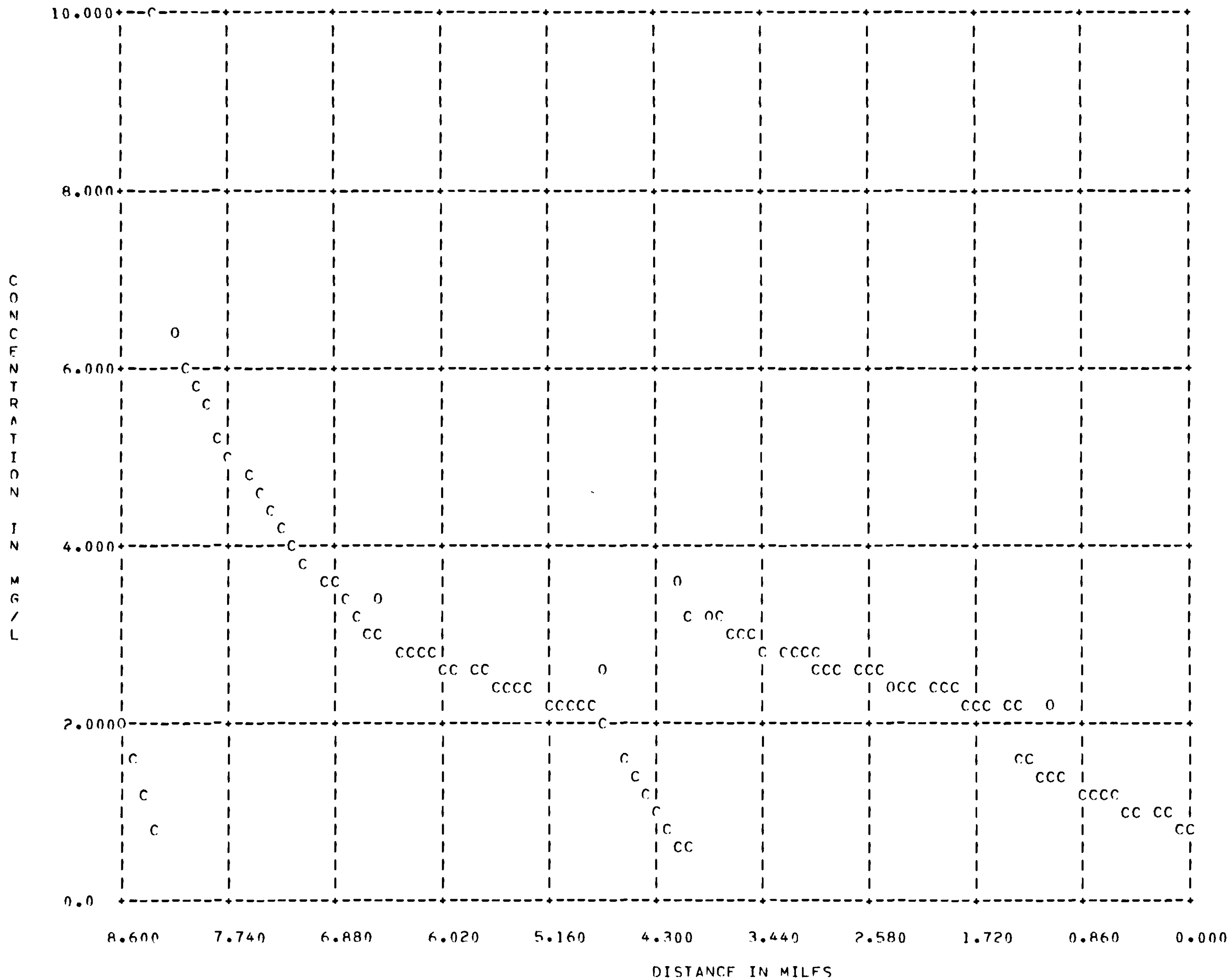
SUBREACH	DO SATURATION (MG/L)
1	8.551
2	8.551
3	8.551
4	8.551
5	8.551
6	8.551
7	8.551
8	8.551
9	8.551

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN

OBSERVED MEASUREMENTS

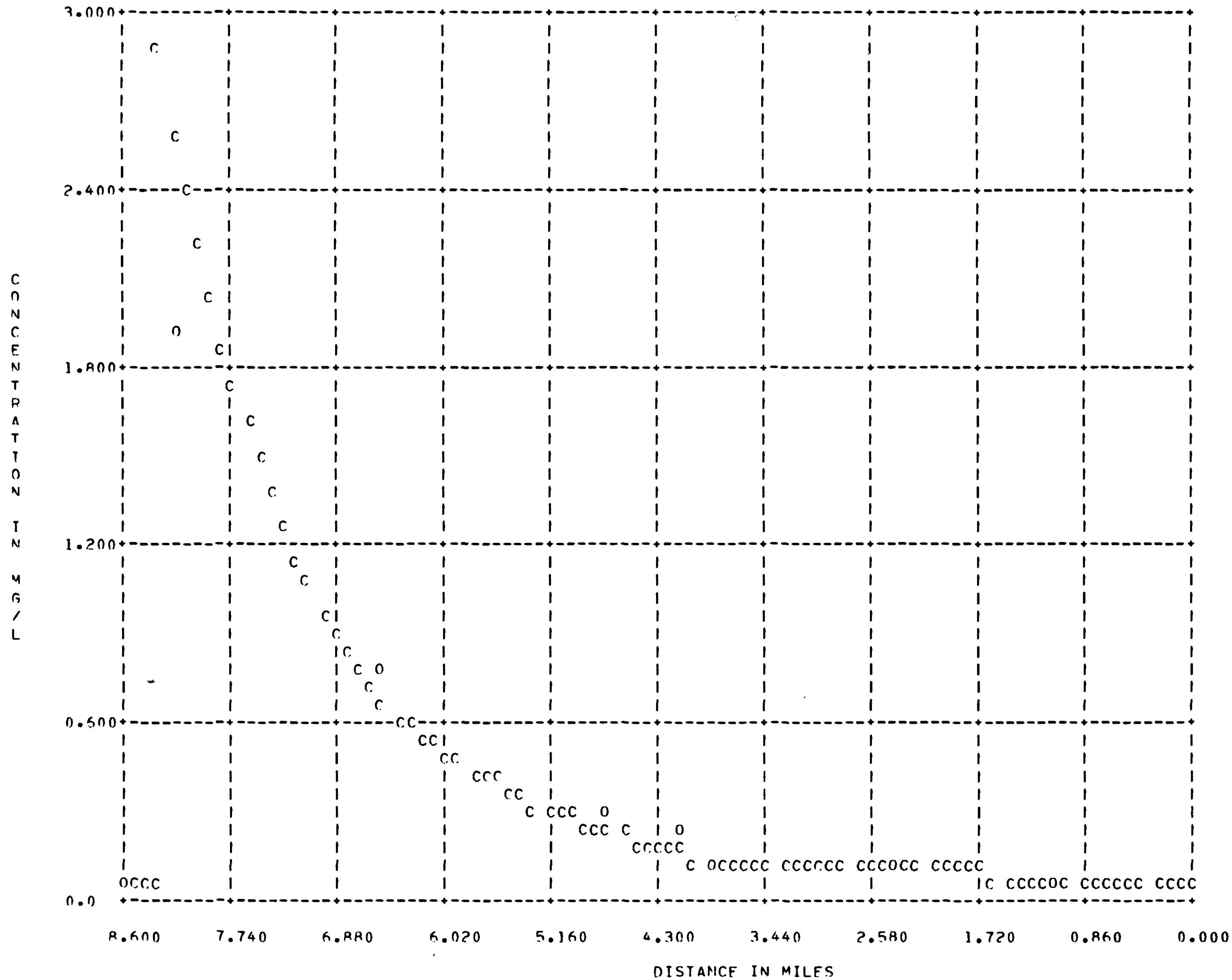
DISTANCE (MI)	DO CONC (MG/L)	TSS (MG/L)	SP COND (MG/L)	(MG/L)	CBODU (MG/L)	NBODU (MG/L)	ORG-N (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)	TOTAL COLIFORM	FECAL COLIFORM	PO4 (MG/L)
8.60	5.00	4.00	410.00	0.0	2.00	0.0	0.73	0.11	0.02	2.30	1100.	1100.	0.05
8.20	4.10	12.00	430.00	0.0	6.30	0.0	1.90	0.25	0.07	2.90	6000.	200.	1.90
6.50	3.50	12.00	430.00	0.0	3.50	0.0	1.40	0.19	0.05	2.20	8000.	8000.	0.80
4.70	3.60	7.00	430.00	0.0	2.70	0.0	1.00	0.18	0.08	1.50	900.	780.	0.33
4.10	3.70	13.00	430.00	0.0	3.60	0.0	1.50	0.22	0.06	1.60	2200.	780.	0.22
3.90	2.60	11.00	380.00	0.0	3.20	0.0	0.97	0.43	0.10	1.60	250.	190.	0.15
2.40	5.00	8.00	380.00	0.0	2.50	0.0	0.68	0.14	0.01	1.60	250.	64.	0.13
1.10	5.50	7.00	360.00	0.0	2.20	0.0	0.52	0.13	0.01	1.10	1700.	360.	0.09

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED CBOD CONCENTRATIONS VERSUS DISTANCE

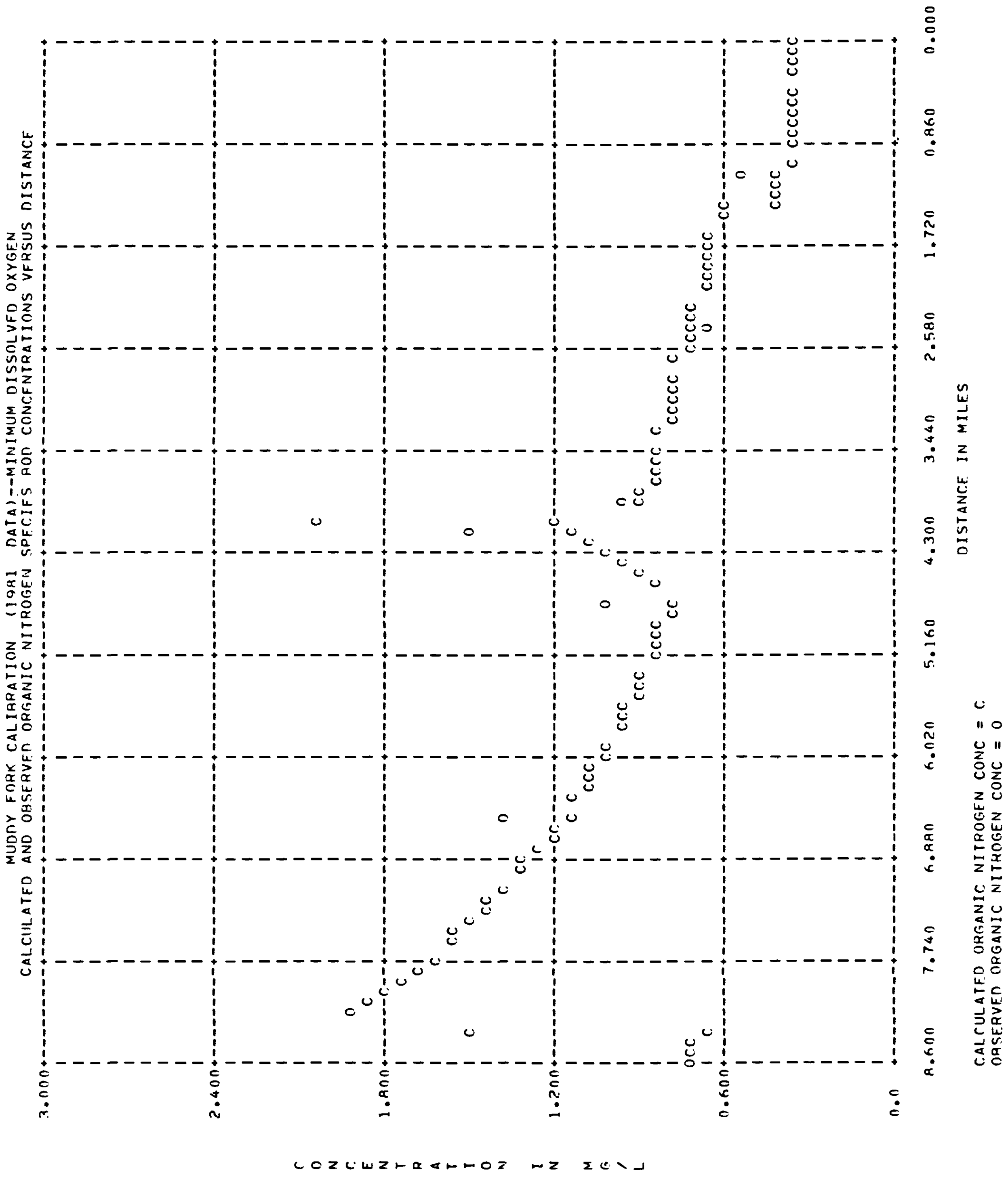


CALCULATED CBODU CONC = C
OBSERVED CBODU CONC = O

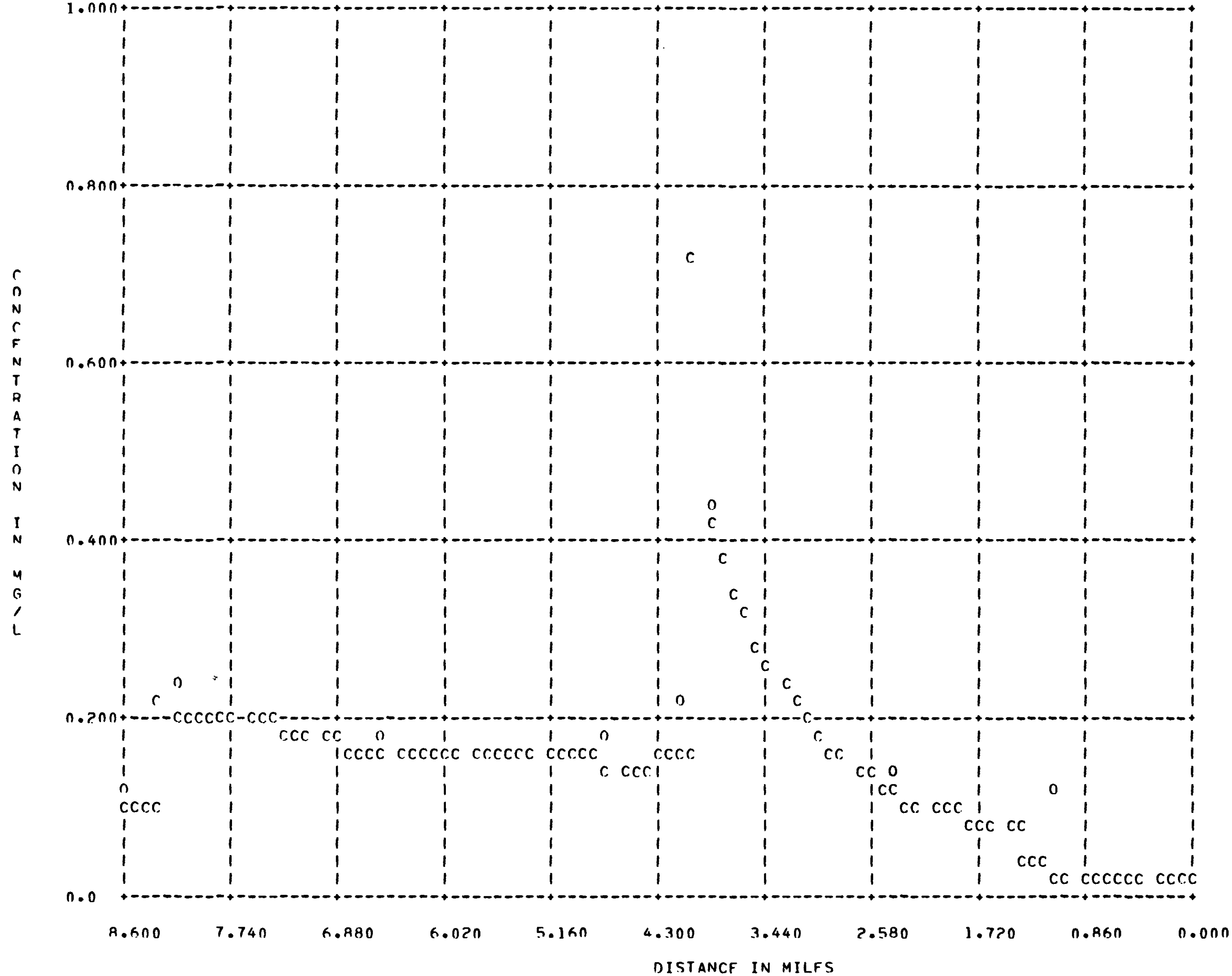
MUDDY FORK CALIBRATION (1991 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED PO4 CONCENTRATIONS VERSUS DISTANCE



CALCULATED PO4 CONC = C
OBSERVED PO4 CONC = O

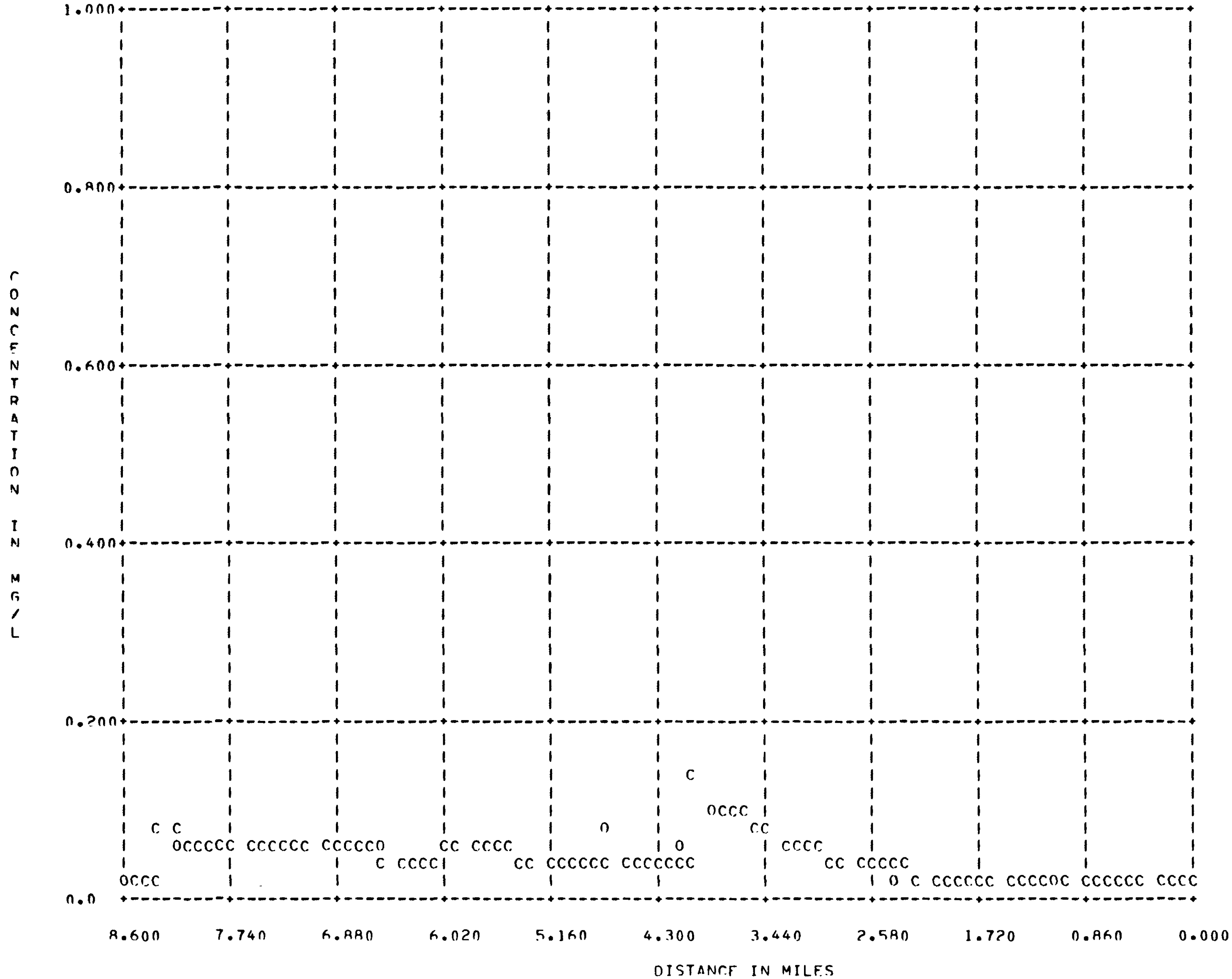

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED ORGANIC NITROGEN SPECIES ROD CONCENTRATIONS VERSUS DISTANCE
3.000
2.400
1.800
1.200
0.600
0.0
CONCENTRATION IN MG/L
8.600
7.740
6.880
6.020
5.160
4.300
3.440
2.580
1.720
0.860
0.000
DISTANCE IN MILES
CALCULATED ORGANIC NITROGEN CONC = C
OBSERVED ORGANIC NITROGEN CONC = O

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED AMMONIA NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



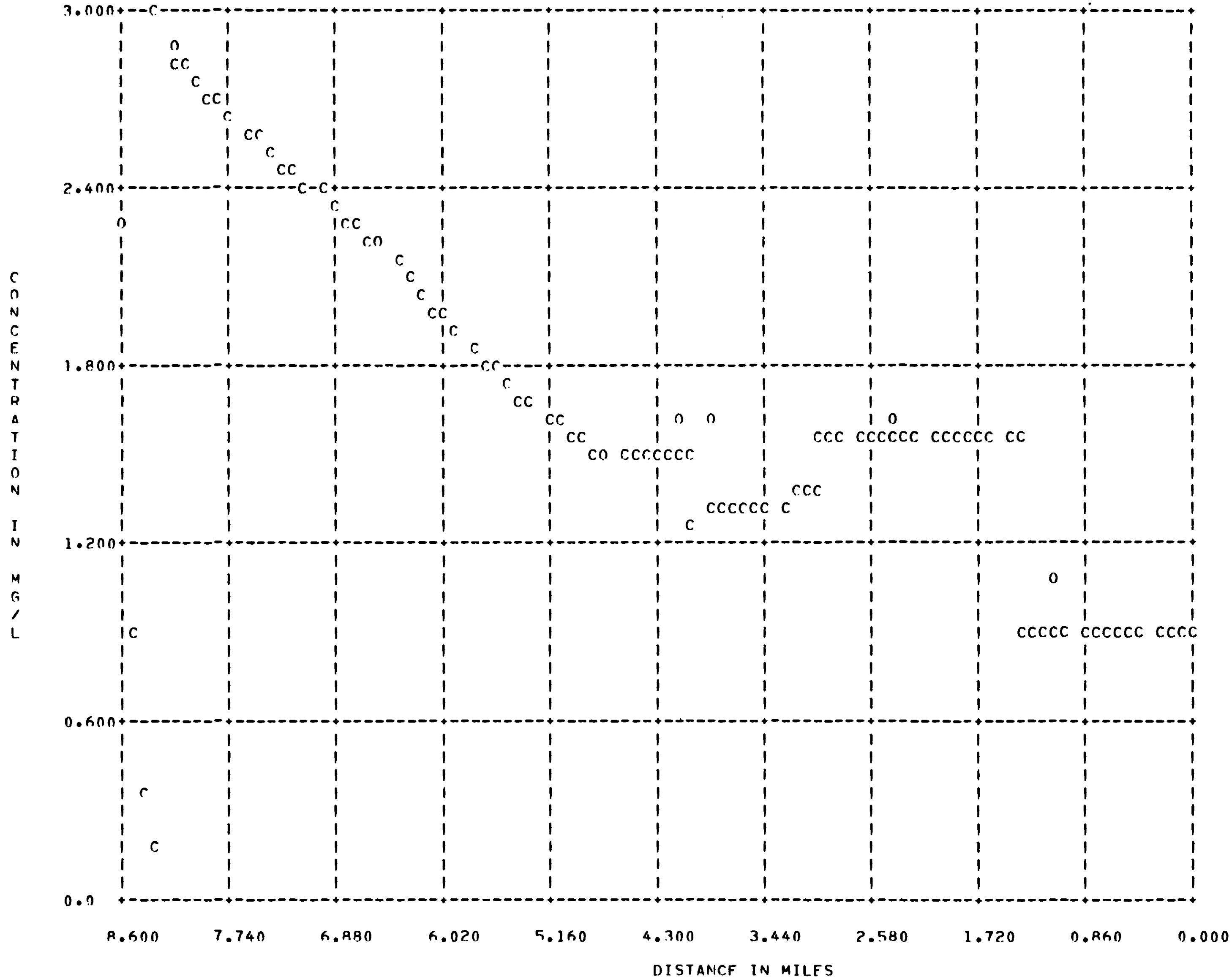
CALCULATED AMMONIA NITROGEN CONC = C
OBSERVED AMMONIA NITROGEN CONC = O

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED NITRITE NITROGEN SPECIES ROD CONCENTRATIONS VERSUS DISTANCE



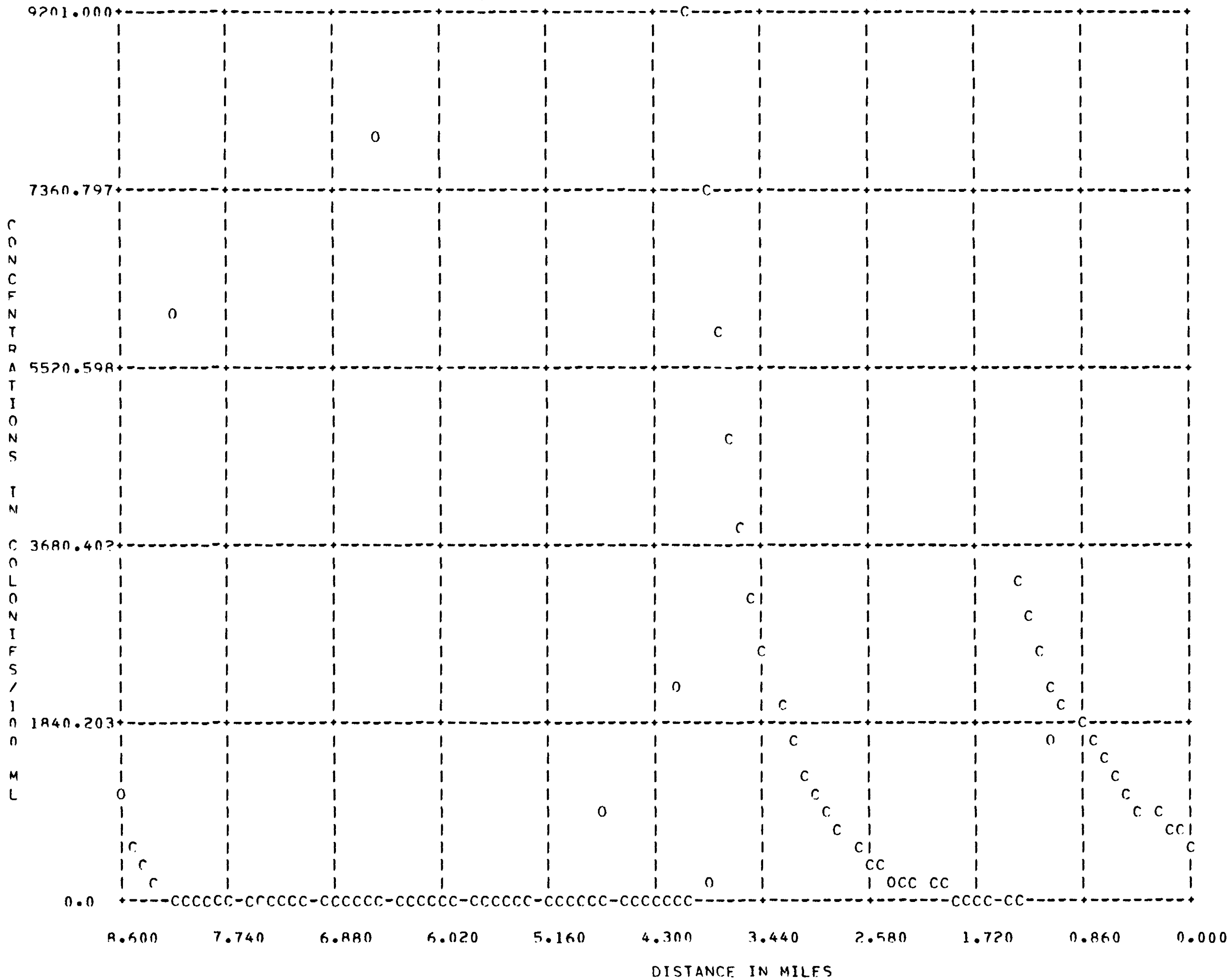
CALCULATED NITRITE NITROGEN CONC = C
OBSERVED NITRITE NITROGEN CONC = O

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED NITRATE NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



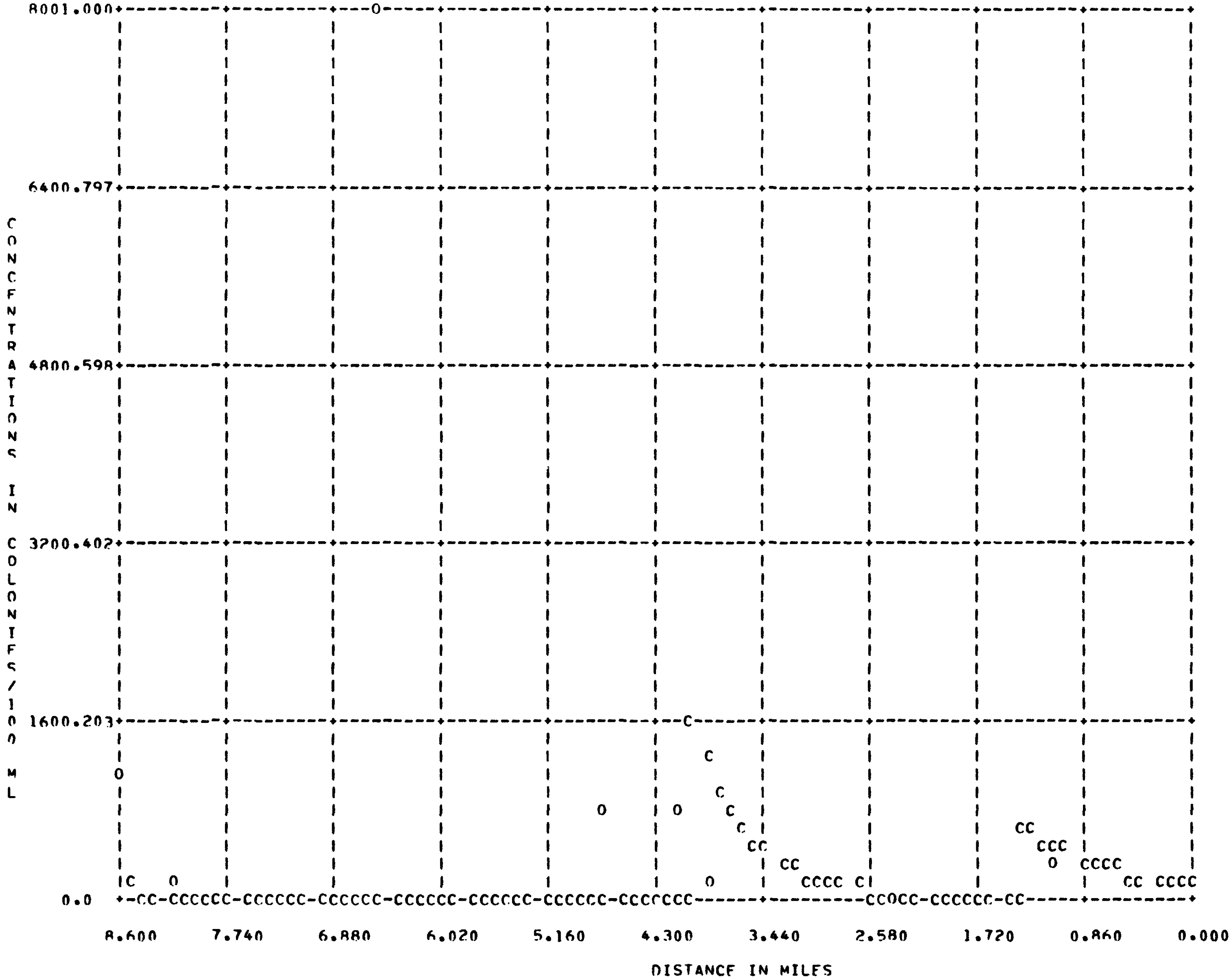
CALCULATED NITRATE NITROGEN CONC = C
OBSERVED NITRATE NITROGEN CONC = O

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED TOTAL COLIFORM CONCENTRATIONS VERSUS DISTANCE



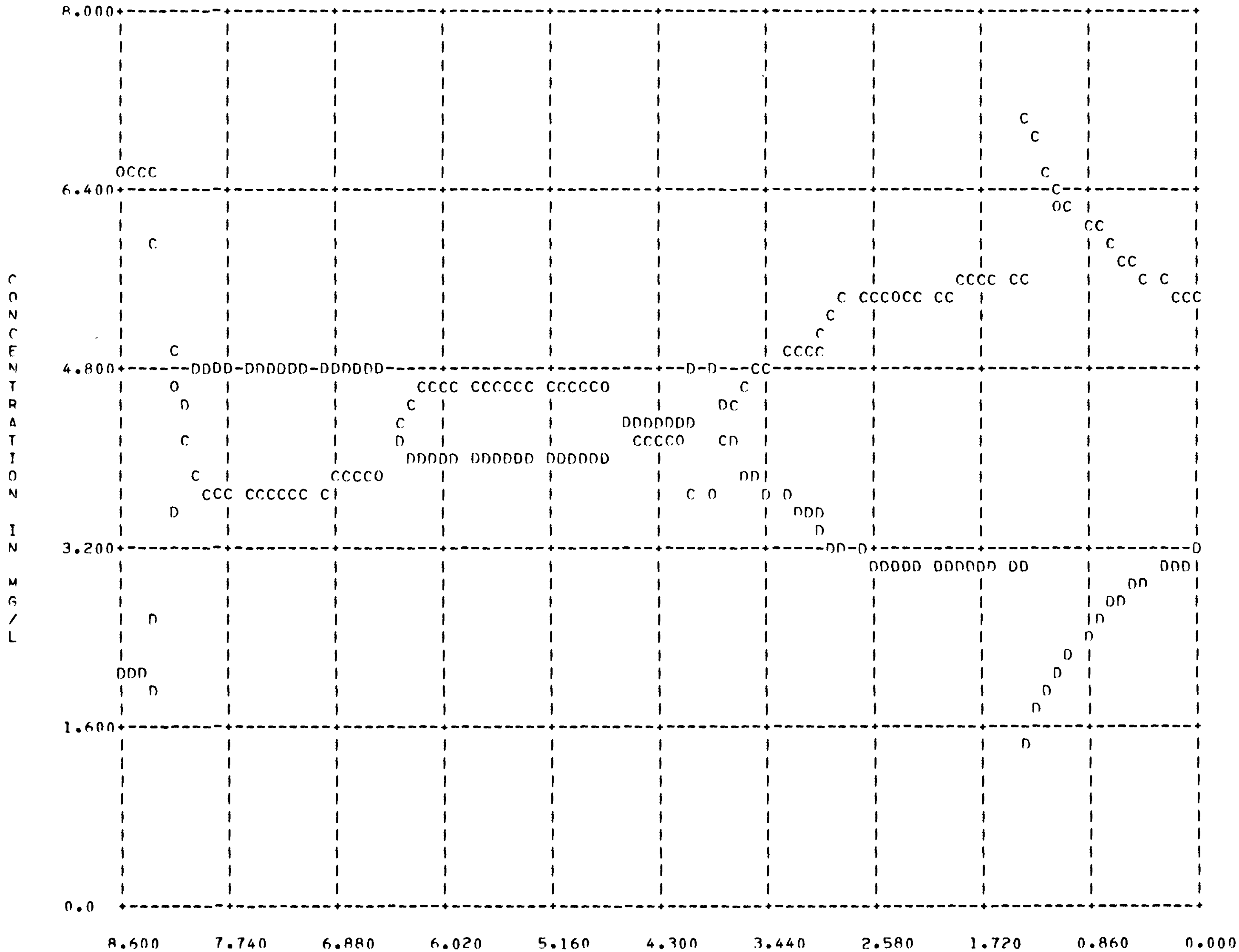
CALCULATED TOTAL COLIFORM CONC = C
OBSERVED TOTAL COLIFORM CONC = O

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED FECAL COLIFORM CONCENTRATIONS VERSUS DISTANCE



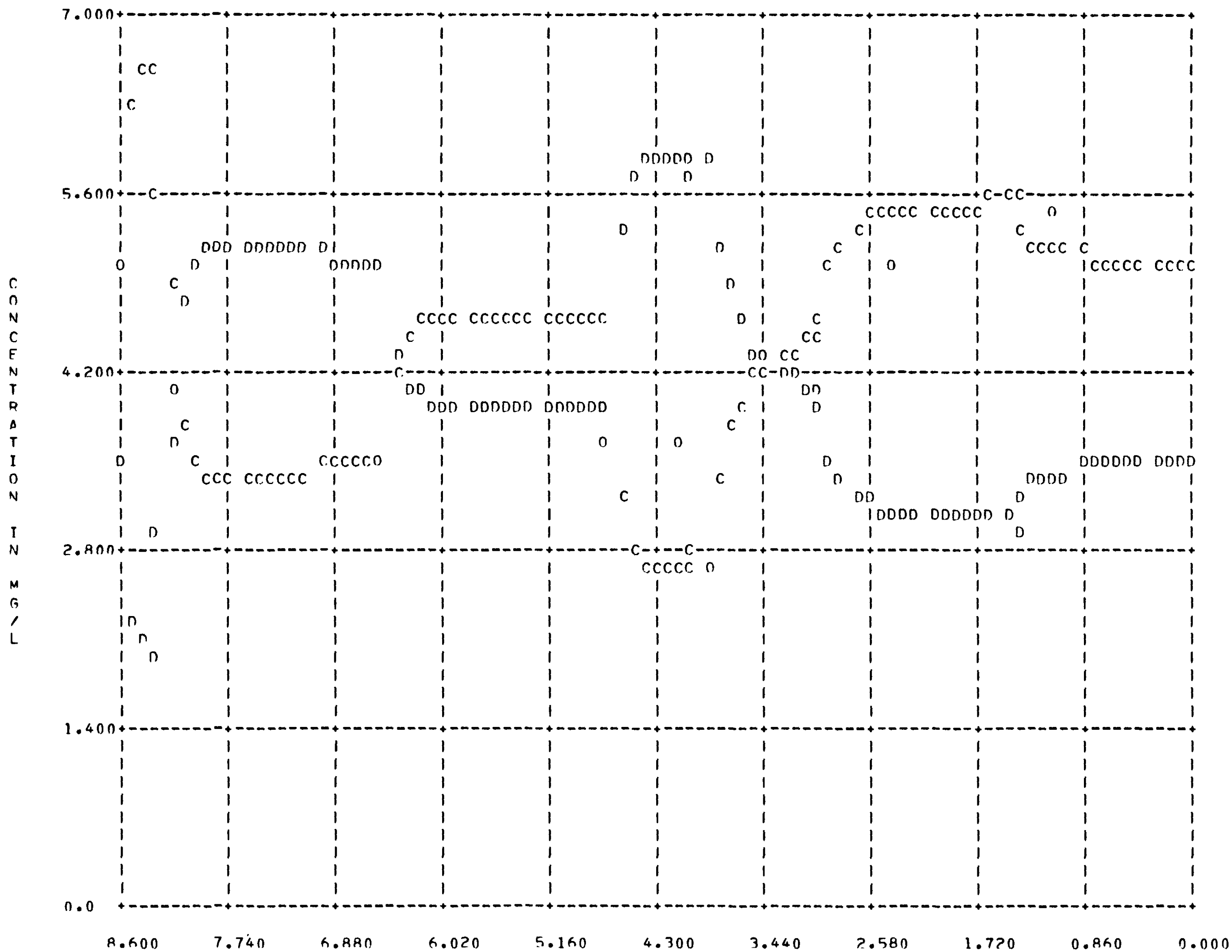
CALCULATED FECAL COLIFORM CONC = C
OBSERVED FECAL COLIFORM CONC = O

MUDDY FORK CALIBRATION (1981 DATA)--MEAN DISSOLVED OXYGEN
CALCULATED AND OBSERVED DO CONCENTRATIONS AND DO DEFICIT VERSUS DISTANCE



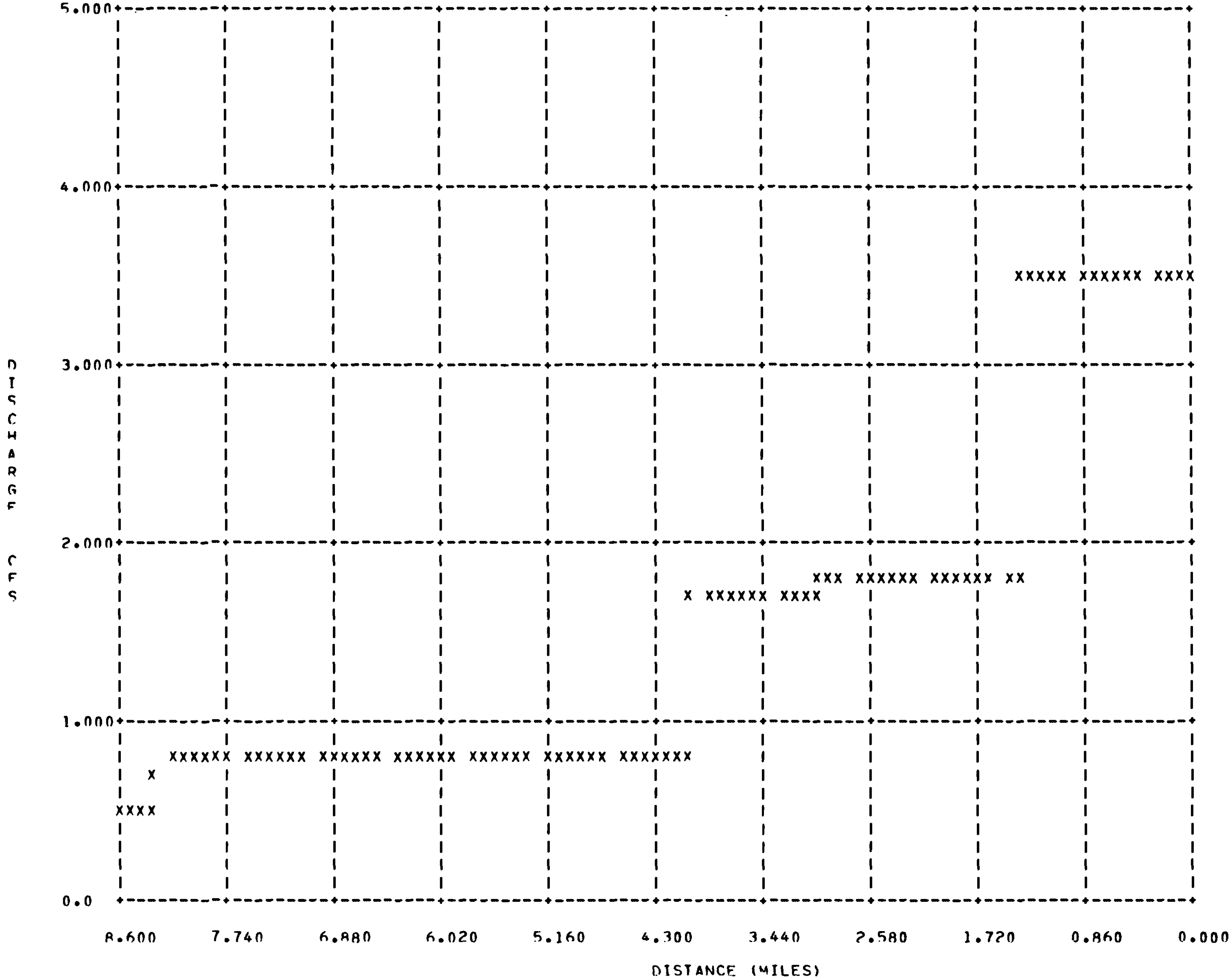
CALCULATED DO CONC = C
OBSERVED DO CONC = O
DO DEFICIT = D

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED DO CONCENTRATIONS AND DO DEFICIT VERSUS DISTANCE

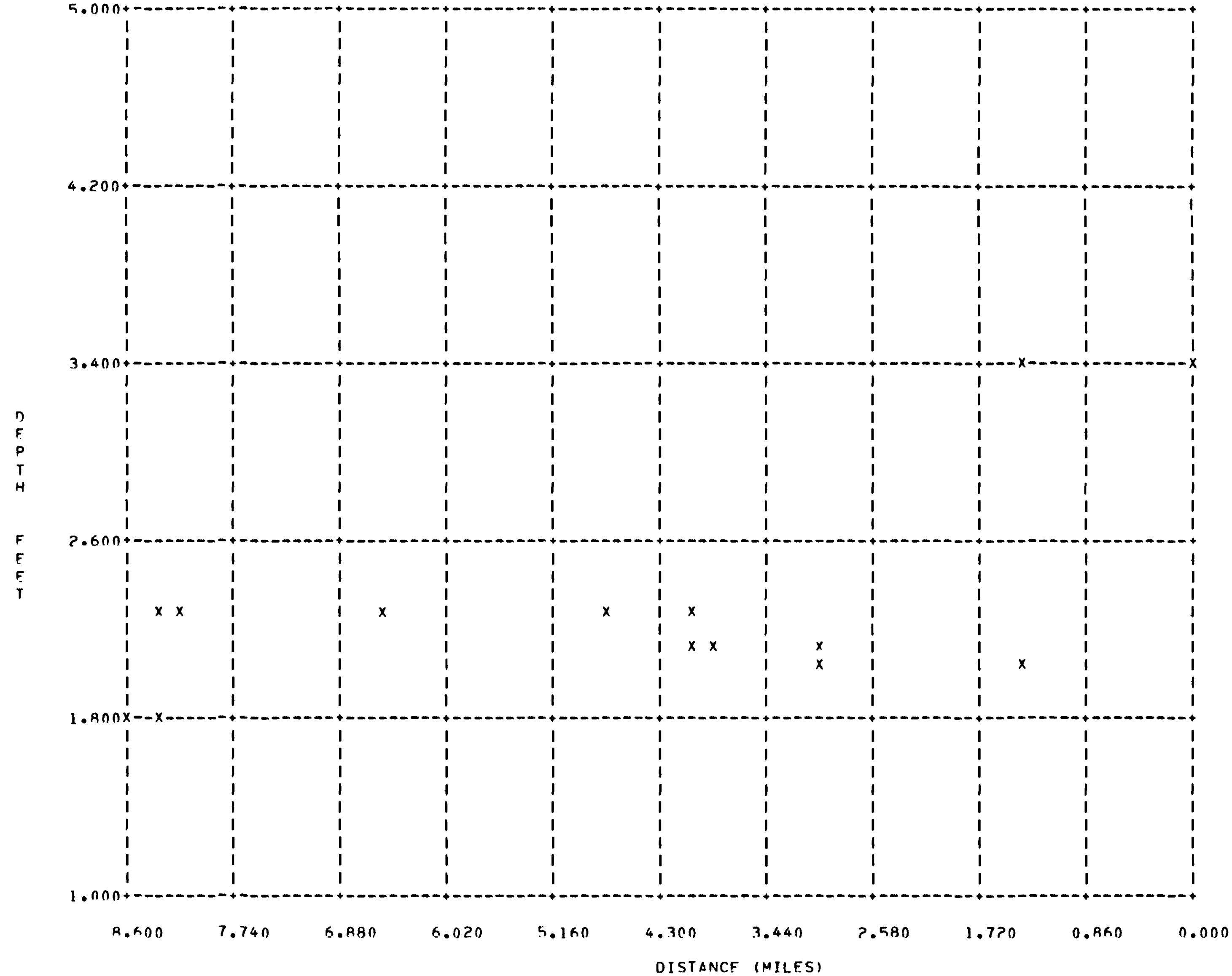


CALCULATED DO CONC = C
OBSERVED DO CONC = O
DO DEFICIT = D

MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN
DISCHARGE (CFS) VERSUS DISTANCE (MILES)



MUDDY FORK CALIBRATION (1981 DATA)--MINIMUM DISSOLVED OXYGEN
DEPTH (FEET) VERSUS DISTANCE (MILES)



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                STEADY STATE WATER QUALITY MODEL
                 GULF COAST HYDROSCIENCE CENTER
                    U. S. GEOLOGICAL SURVEY
                      (ARKANSAS VERSION)
             DATE OF LAST REVISION, DECEMBER  1980


MUDDY FORK VERIFICATION  (1979  DATA)--MINIMUM DISSOLVED OXYGEN

          DISSOLVED OXYGEN PROFILE REPRESENTS
     ***  DIEL MINIMUMS; NET PHOTOSYNTHETIC DO   ***
          PRODUCTION ADJUSTED ACCORDINGLY.

        NITRIFICATION CYCLE INCLUDED IN MODEL


        NUMBER OF SUBREACHES FOR THIS PROBLEM =     9


            PRINTING INTERVAL (MILES) =   0.100

           STARTING DISTANCE (MILES) =    8.600

  INITIAL CBOD CONC (MG/L) AT STARTING DISTANCE =    3.00

  INITIAL ORGANIC NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.180

  INITIAL AMMONIUM NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.060

  INITIAL NITRITE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.020

  INITIAL NITRATE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   2.100

  INITIAL DO CONC (MG/L) AT STARTING DISTANCE =   6.800

  INITIAL PHOSPHATE CONC (MG/L) AT STARTING DISTANCE =   1.000

  INITIAL TOT. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =    1300.

  INITIAL FEC. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =     840.

      STREAMFLOW (CFS) AT STARTING DISTANCE =     1.000

      TOTAL SUSPENDED SOLIDS                  =  10.00
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MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN

S U B R E A C H L I N E A R R U N O F F D A T A

SUBREACH	Q (CFS)	CBOD (MG/L)	ORGANIC (MG/L)	AMMONIA (MG/L)	NITRITE (MG/L)	NITRATE (MG/L)	DO (MG/L)	TSS (MG/L)	SP COND (MG/L)	(MG/L)	PO4 (MG/L)
1	-0.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.02	0.0	14.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	22.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.33	14.00	0.92	0.36	0.29	0.64	3.10	11.00	279.00	0.0	0.07
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	1.20	1.10	0.17	0.02	0.02	0.25	5.00	1.10	279.00	0.0	0.04

R E A C H D E S C R I P T I O N D A T A (MAJOR TRIBUTARIES AND MAIN STEM)

SUBREACH	CODE	NAME	BEGIN (MILE)	END (MILE)
1	A	UPSTREAM SUBREACH	8.60	8.30
2	A	AT PP. GROVE STP T	8.30	8.20
3	A	AT STA 9	8.20	6.50
4	A	AT STA 10	6.50	4.70
5	A	AT STA 11	4.70	4.00
6	A	ATMOORES CREEK	4.00	3.90
7	A	BL. MOORES CREEK	3.90	3.00
8	A	UNNAMED TRIB	3.00	1.40
9	A	TRIB BL KINION LK	1.40	0.0

KEY: CODE

- A ROCKY BOTTOM-POOL RIFFLE-LIGHT VEGETATION
- B ROCKY BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
- C ROCKY BOTTOM-POOL RIFFLE-HEAVY VEGETATION
- D ROCKY BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
- E ROCKY BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
- F ROCKY BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION
- G MUD BOTTOM-POOL RIFFLE-LIGHT VEGETATION
- H MUD BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
- I MUD BOTTOM-POOL RIFFLE-HEAVY VEGETATION
- J MUD BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
- K MUD BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
- L MUD BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION

MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN

I N P U T   P A R A M E T E R S

CONCENTRATIONS(MG/L) OF --

SUBREACH	CARB BOD	ORG-N	NH3-N	NO2-N	NO3-N	DISSOLVED OXYGEN	PO4	TOT.COLIF.	FEC.COLIF.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	92.10	3.00	6.80	0.82	14.00	6.60	13.00	16000.00	8800.00
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	12.80	0.92	0.36	0.29	0.64	3.10	0.07	4600.00	500.00
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	8.30	0.51	0.13	0.08	3.60	6.20	0.04	1000.00	1000.00
9	1.10	0.17	0.02	0.02	0.25	5.00	0.04	400.00	100.00

DIRECT DISCHARGES(LB/DAY) OF --

SUBREACH	CARBONACEOUS ULT. BOD	ORGANIC NITROGEN	AMMONIA NITROGEN	NITRITE NITROGEN	NITRATE NITROGEN	PHOSPHATE
1	0.0	0.0	0.0	0.0	0.0	0.
2	0.0	0.0	0.0	0.0	0.0	0.
3	0.0	0.0	0.0	0.0	0.0	0.
4	0.0	0.0	0.0	0.0	0.0	0.
5	0.0	0.0	0.0	0.0	0.0	0.
6	0.0	0.0	0.0	0.0	0.0	0.
7	0.0	0.0	0.0	0.0	0.0	0.
8	0.0	0.0	0.0	0.0	0.0	0.
9	0.0	0.0	0.0	0.0	0.0	0.

MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN

SUBREACH	NET PHOTOSYNTHETIC DO PRODUCTION (MG/L/DAY @ 20 DEG C)	(FITTING FACTOR FOR MINIMUM DO PROFILE)	BENTHIC DO DEMAND (G/SQM/DAY @ 20 DEG C)
1	1.087	0.0	3.00
2	1.121	0.0	4.00
3	1.014	-0.500	6.00
4	0.793	0.0	5.00
5	0.634	-2.500	5.25
6	0.582	-2.500	5.50
7	0.519	-1.000	4.25
8	0.359	0.0	3.80
9	0.223	0.0	2.80

G E O M E T R Y

SUBREACH	FLOW CHANGE (CFS)	AREA (SQFT)	DEPTH (FT)	SLOPE	TEMP (DEG.CENT)	END MI (MI)
1	0.0	57.	1.76	0.0007800	21.00	8.3
2	0.13	70.	2.32	0.0007800	22.00	8.2
3	0.0	70.	2.32	0.0007800	23.00	6.5
4	0.0	70.	2.32	0.0007800	24.00	4.7
5	0.0	70.	2.32	0.0007800	24.00	4.0
6	0.54	60.	2.10	0.0005500	25.00	3.9
7	0.0	60.	2.10	0.0005500	25.00	3.0
8	0.21	71.	2.00	0.0005500	25.00	1.4
9	1.40	71.	3.39	0.0005500	25.00	0.0

MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN

REACTION COEFFICIENTS (/DAY @ 20 DEG C)

SUBREACH	KR	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KCOLF	KCOLT	KPO41	KPO42
1	0.39	0.16	0.02	0.02	0.18	0.18	0.60	0.60	1.10	4.00	1.00	0.01	0.0
2	0.66	0.24	0.02	0.02	0.18	0.18	0.60	0.60	0.04	1.00	1.10	0.11	0.0
3	0.07	0.07	0.02	0.04	0.18	0.18	0.60	0.60	0.04	1.00	1.10	0.11	0.0
4	0.03	0.03	0.03	0.03	0.18	0.18	0.60	0.60	0.05	1.00	1.10	0.08	0.0
5	0.31	0.22	0.03	0.05	0.18	0.18	0.60	0.60	0.01	1.00	1.10	0.08	0.0
6	0.07	0.07	0.05	2.90	0.50	2.00	0.50	3.00	0.01	1.00	1.00	0.59	0.0
7	0.07	0.07	0.05	0.05	0.50	0.50	0.50	2.00	0.01	1.00	1.00	0.01	0.0
8	0.05	0.05	0.05	0.05	0.50	0.50	0.50	2.00	0.01	1.00	1.00	0.06	0.0
9	0.35	0.14	0.05	0.05	0.50	1.60	0.50	0.50	0.01	1.00	1.00	0.01	0.0

TEMPERATURE CORRECTED REACTION COEFFICIENTS (/DAY)

SUBREACH	KR	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KA	KPO41	KPO42
1	0.41	0.16	0.02	0.03	0.20	0.20	0.65	0.65	1.20	2.60	0.01	0.0
2	0.72	0.26	0.02	0.03	0.21	0.21	0.71	0.71	0.05	1.88	0.13	0.0
3	0.08	0.08	0.03	0.05	0.23	0.23	0.78	0.78	0.05	1.98	0.14	0.0
4	0.04	0.04	0.04	0.04	0.25	0.25	0.85	0.85	0.07	2.07	0.11	0.0
5	0.37	0.26	0.04	0.07	0.25	0.25	0.85	0.85	0.01	2.07	0.11	0.0
6	0.09	0.09	0.08	4.46	0.77	3.08	0.77	4.62	0.02	2.55	0.91	0.0
7	0.09	0.09	0.08	0.08	0.77	0.77	0.77	3.08	0.02	2.55	0.02	0.0
8	0.06	0.06	0.08	0.08	0.77	0.77	0.77	3.08	0.02	2.71	0.09	0.0
9	0.44	0.18	0.08	0.08	0.77	2.46	0.77	0.77	0.02	1.00	0.02	0.0

MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN

SUBREACH	REAERATION COEFFICIENT DERIVATION
1	KA COMPUTED BY VELZ EQUATION
2	KA COMPUTED BY VELZ EQUATION
3	KA COMPUTED BY VELZ EQUATION
4	KA COMPUTED BY VELZ EQUATION
5	KA COMPUTED BY VELZ EQUATION
6	KA COMPUTED BY VELZ EQUATION
7	KA COMPUTED BY VELZ EQUATION
8	KA COMPUTED BY VELZ EQUATION
9	KA COMPUTED BY VELZ EQUATION

MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN

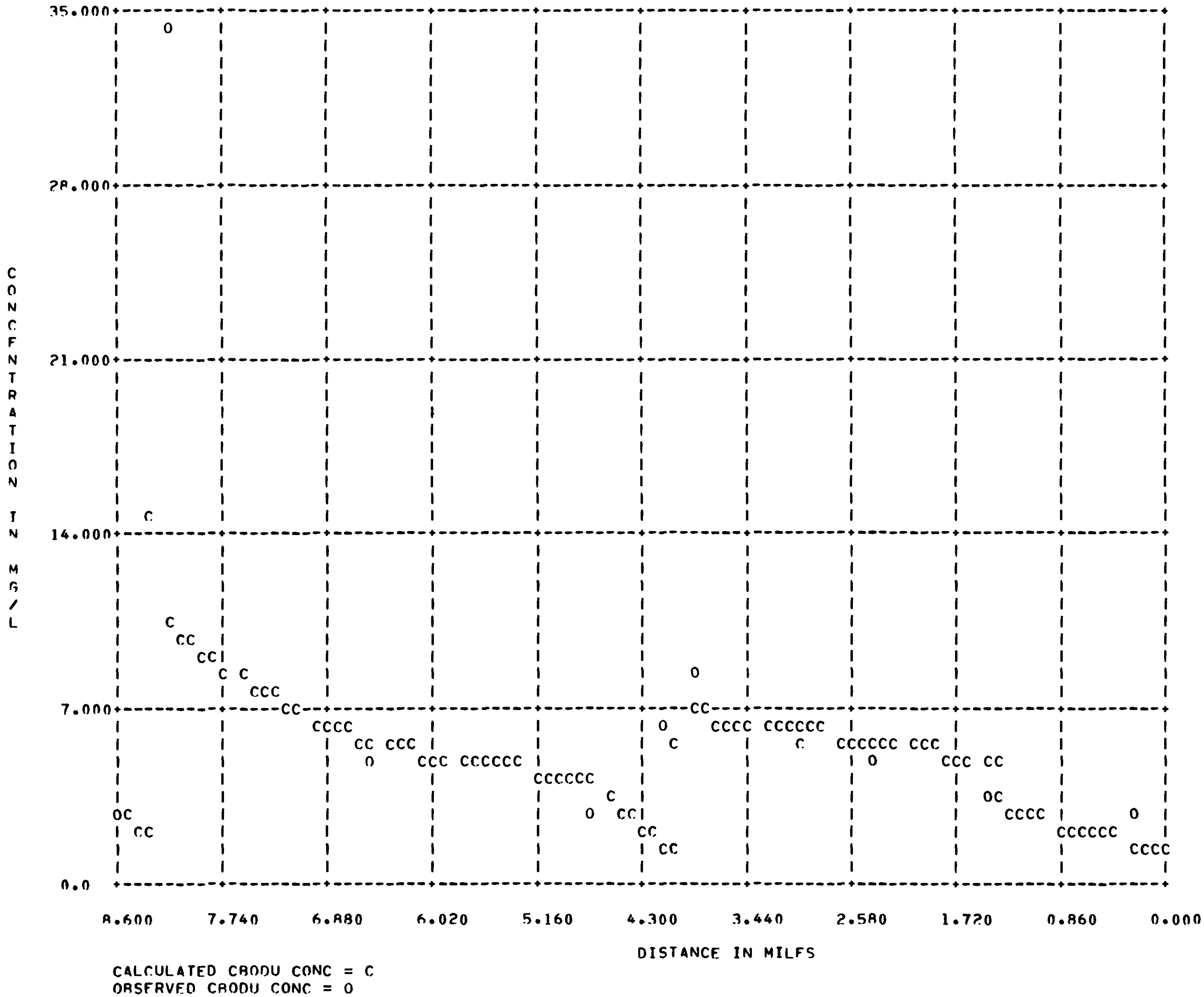
SUBREACH	DO SATURATION (MG/L)
1	8.888
2	8.717
3	8.551
4	8.390
5	8.390
6	8.235
7	8.235
8	8.235
9	8.235

MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN

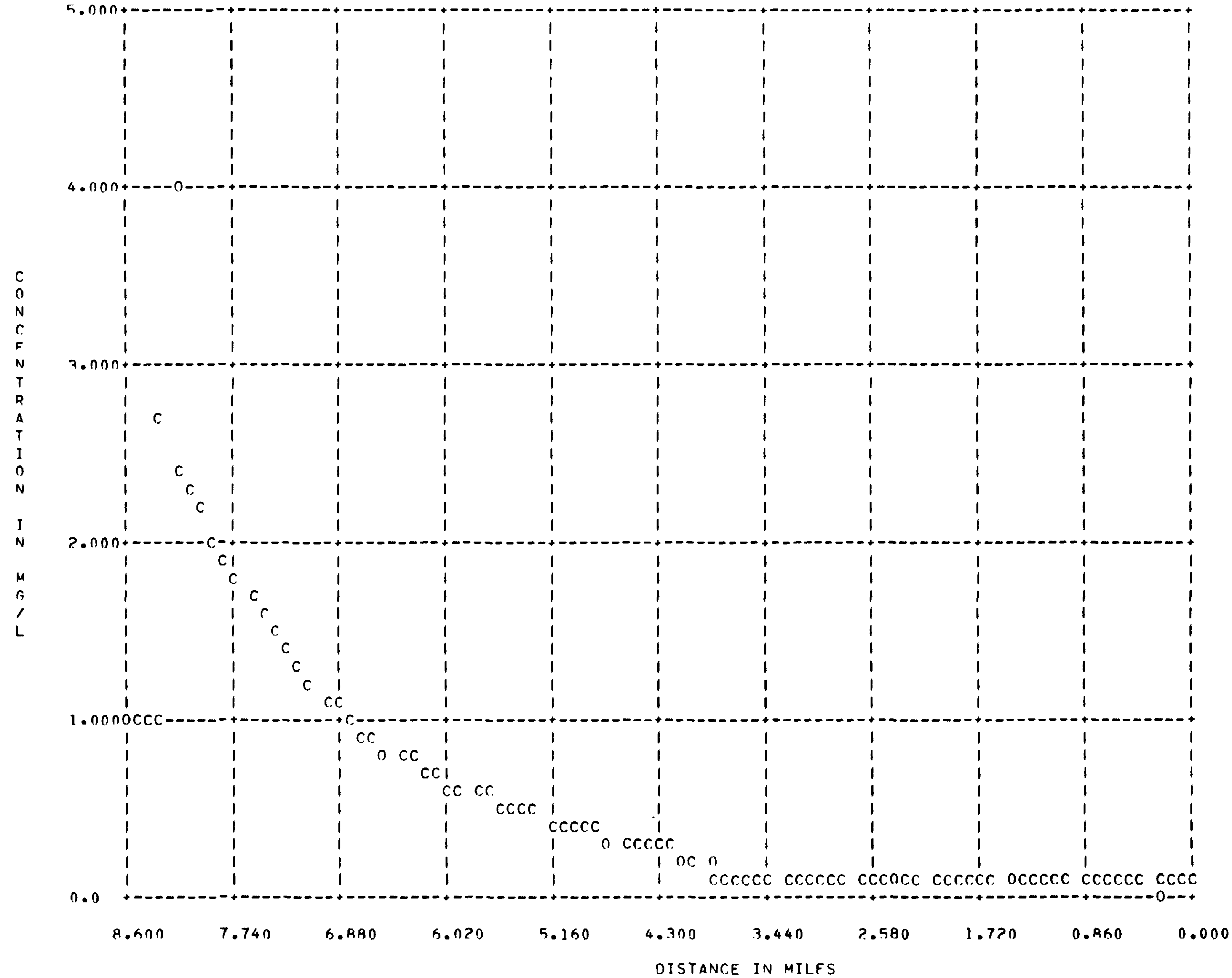
O B S E R V E D   M E A S U R E M E N T S

DISTANCE (MI)	DO CONC (MG/L)	TSS (MG/L)	SP COND (MG/L)	(MG/L)	CBODU (MG/L)	NBODU (MG/L)	ORG-N (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)	TOTAL COLIFORM	FECAL COLIFORM	PO4 (MG/L)
8.60	6.80	10.00	367.00	0.0	3.00	0.0	0.18	0.06	0.02	2.10	13.	8.	1.00
8.20	5.80	12.00	458.00	0.0	34.00	0.0	1.20	3.30	0.31	4.30	370.	200.	4.00
6.50	4.10	10.00	393.00	0.0	5.00	0.0	0.53	0.12	0.07	2.50	40.	3.	0.77
4.70	4.90	8.00	391.00	0.0	2.60	0.0	0.50	0.06	0.03	1.80	2.	2.	0.30
4.10	2.50	8.00	415.00	0.0	6.10	0.0	0.47	0.20	0.14	1.60	11.	7.	0.23
3.90	2.80	0.0	363.00	0.0	8.30	0.0	0.57	0.21	0.16	1.40	10.	4.	0.16
2.40	5.00	5.00	358.00	0.0	5.20	0.0	0.38	0.08	0.05	1.60	2.	2.	0.09
1.50	5.20	5.00	354.00	0.0	3.70	0.0	0.48	0.10	0.06	1.40	4.	3.	0.05
0.30	5.30	5.00	311.00	0.0	2.70	0.0	0.31	0.09	0.06	1.20	17.	6.	0.04

MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED CBOD CONCENTRATIONS VERSUS DISTANCE

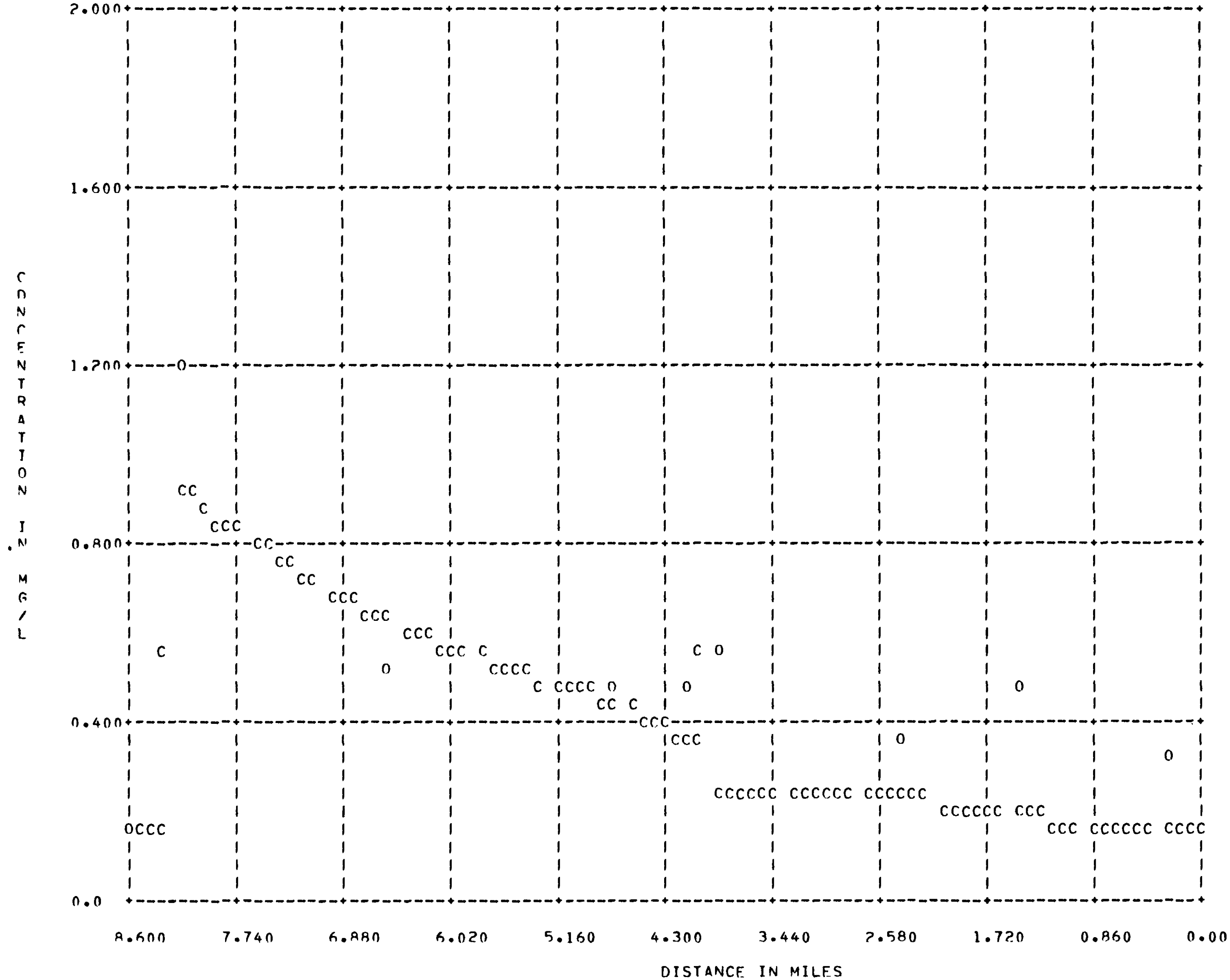


MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED PO4 CONCENTRATIONS VERSUS DISTANCE

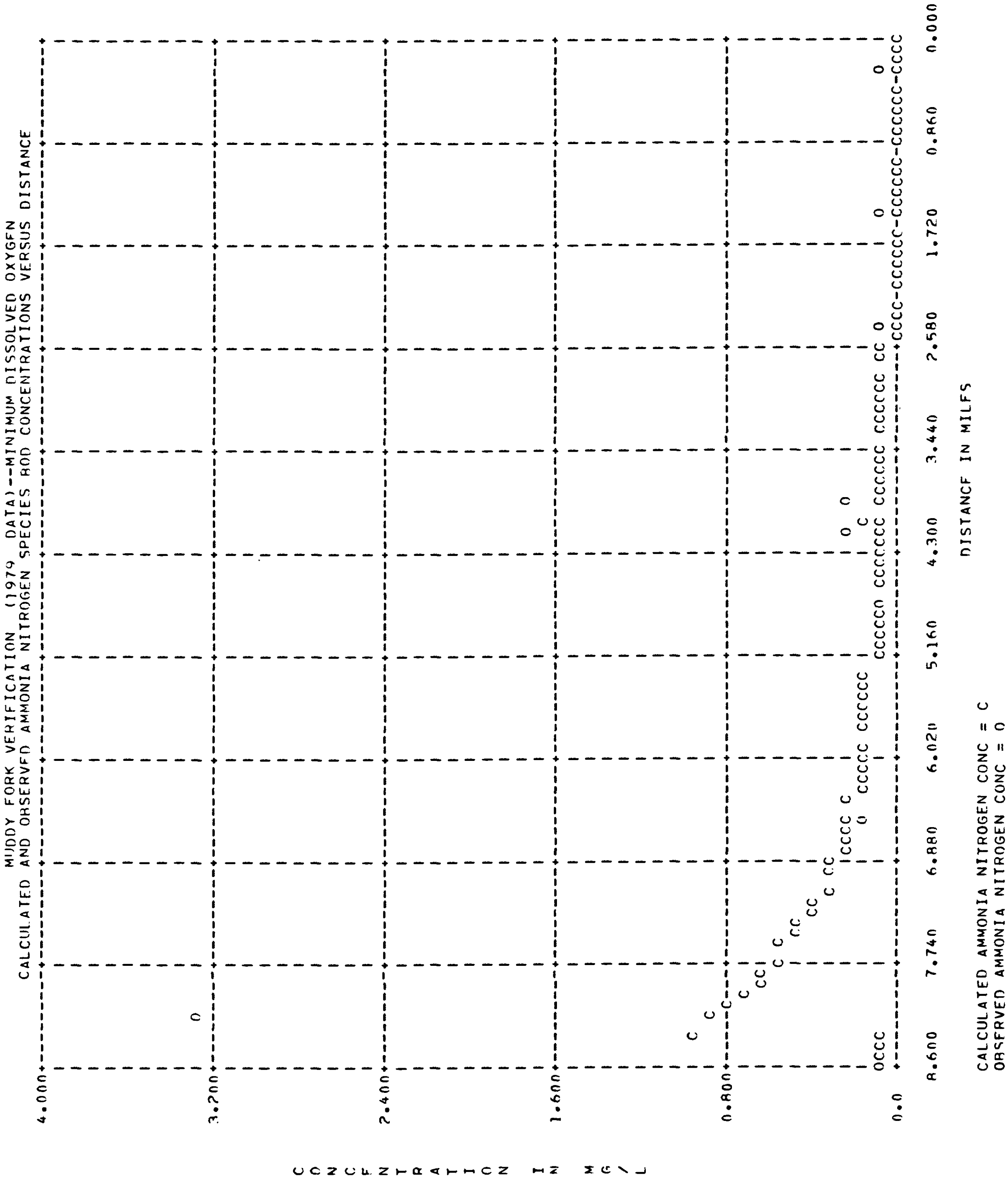


CALCULATED PO4 CONC = C
OBSERVED PO4 CONC = O

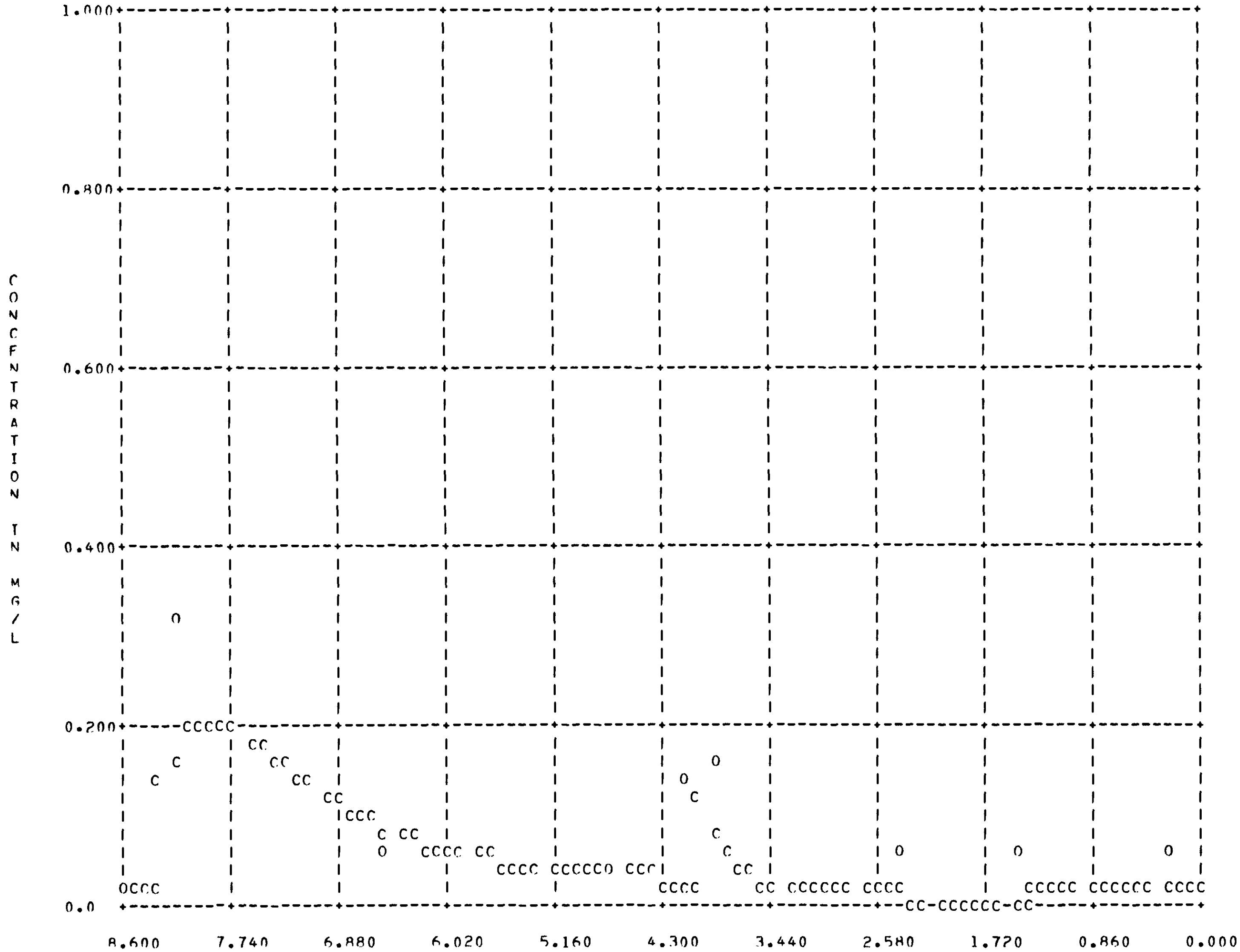
MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED ORGANIC NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



CALCULATED ORGANIC NITROGEN CONC = C
OBSERVED ORGANIC NITROGEN CONC = O

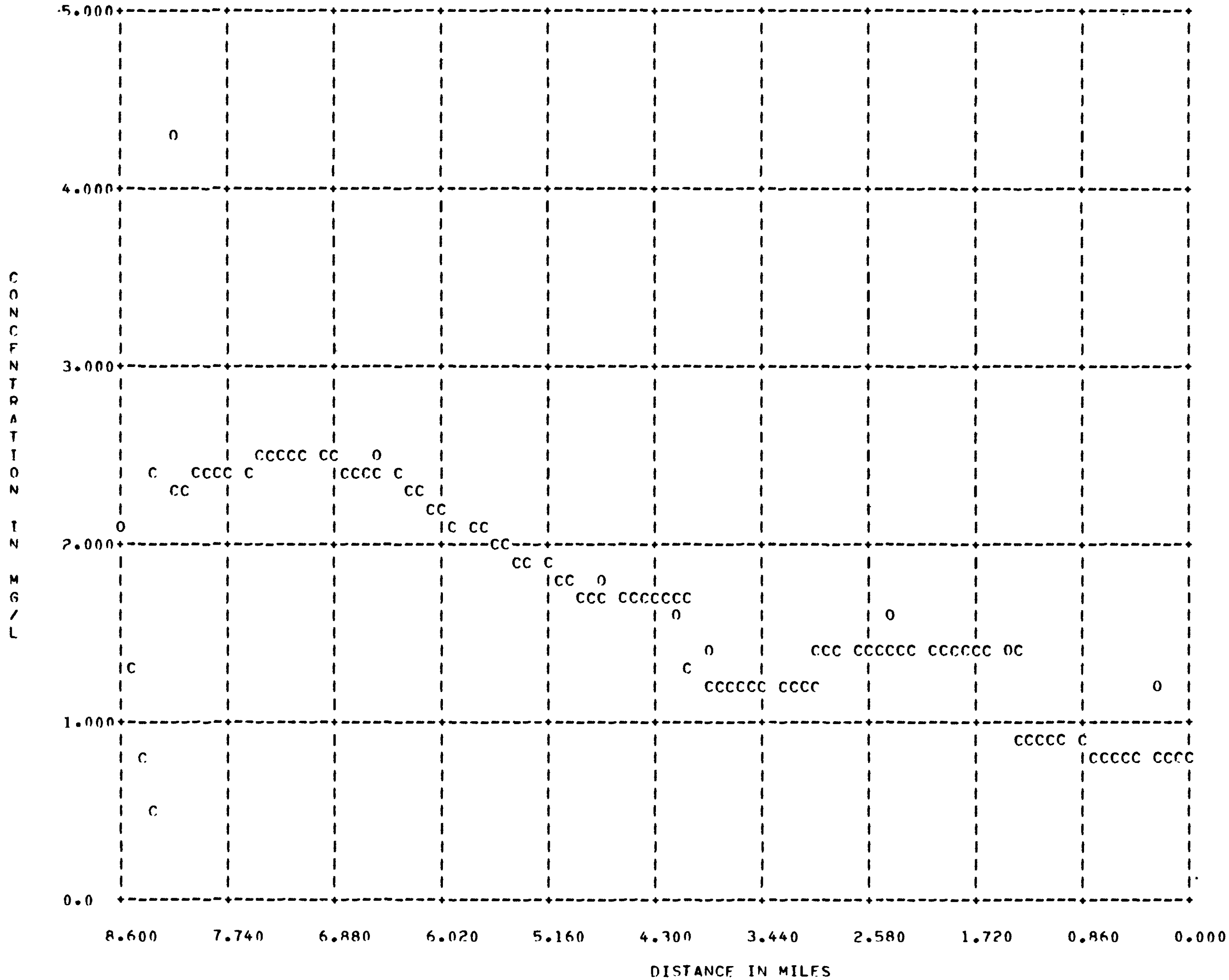

MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED AMMONIA NITROGEN SPECIES ROD CONCENTRATIONS VERSUS DISTANCE
4.000
3.200
2.400
1.600
0.800
0.0
CONCENTRATION IN MG/L
8.600
7.740
6.880
6.020
5.160
4.300
3.440
2.580
1.720
0.860
0.000
DISTANCE IN MILES
CALCULATED AMMONIA NITROGEN CONC = C
OBSERVED AMMONIA NITROGEN CONC = O

MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED NITRITE NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



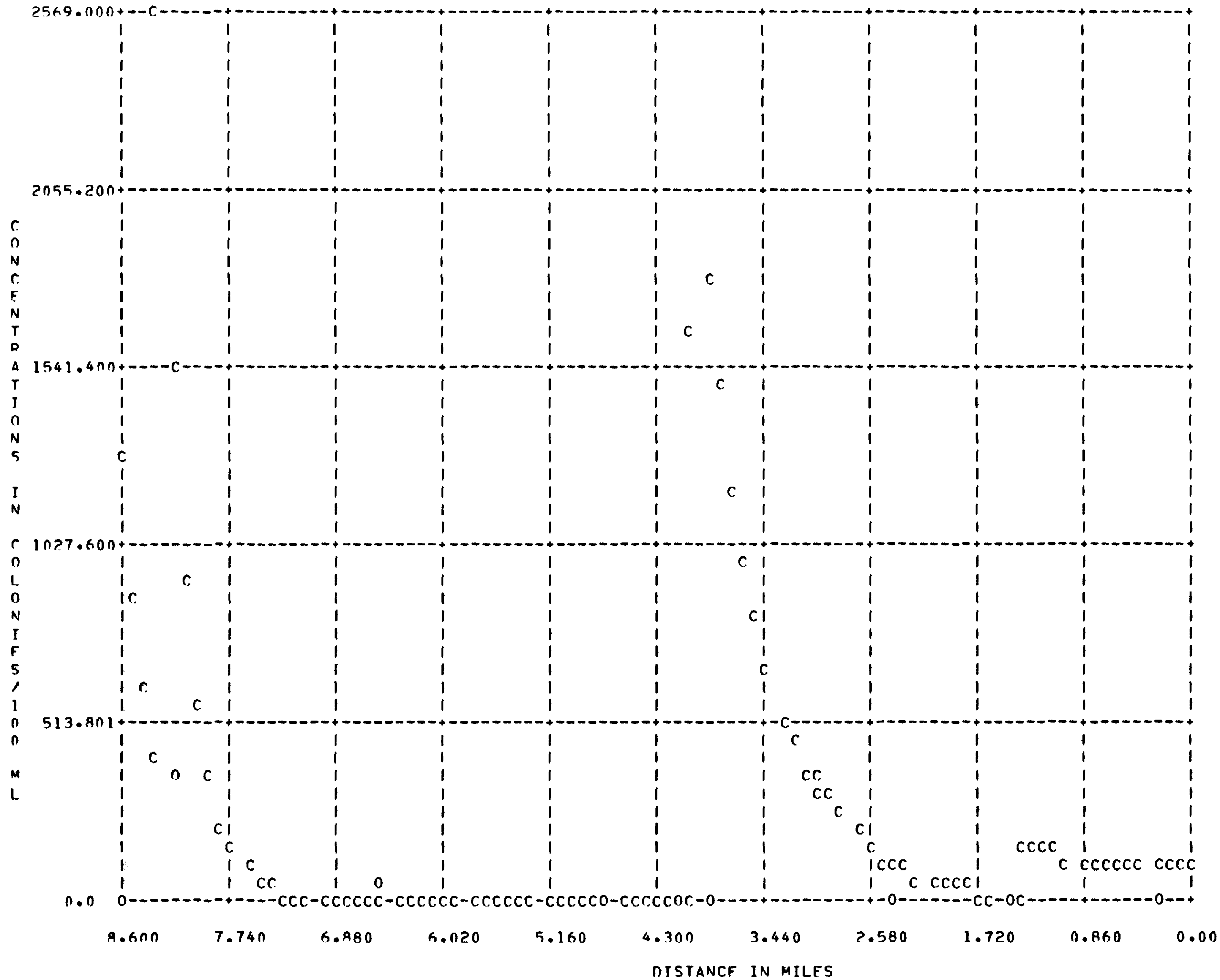
CALCULATED NITRITE NITROGEN CONC = C
OBSERVED NITRITE NITROGEN CONC = O

MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED NITRATE NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



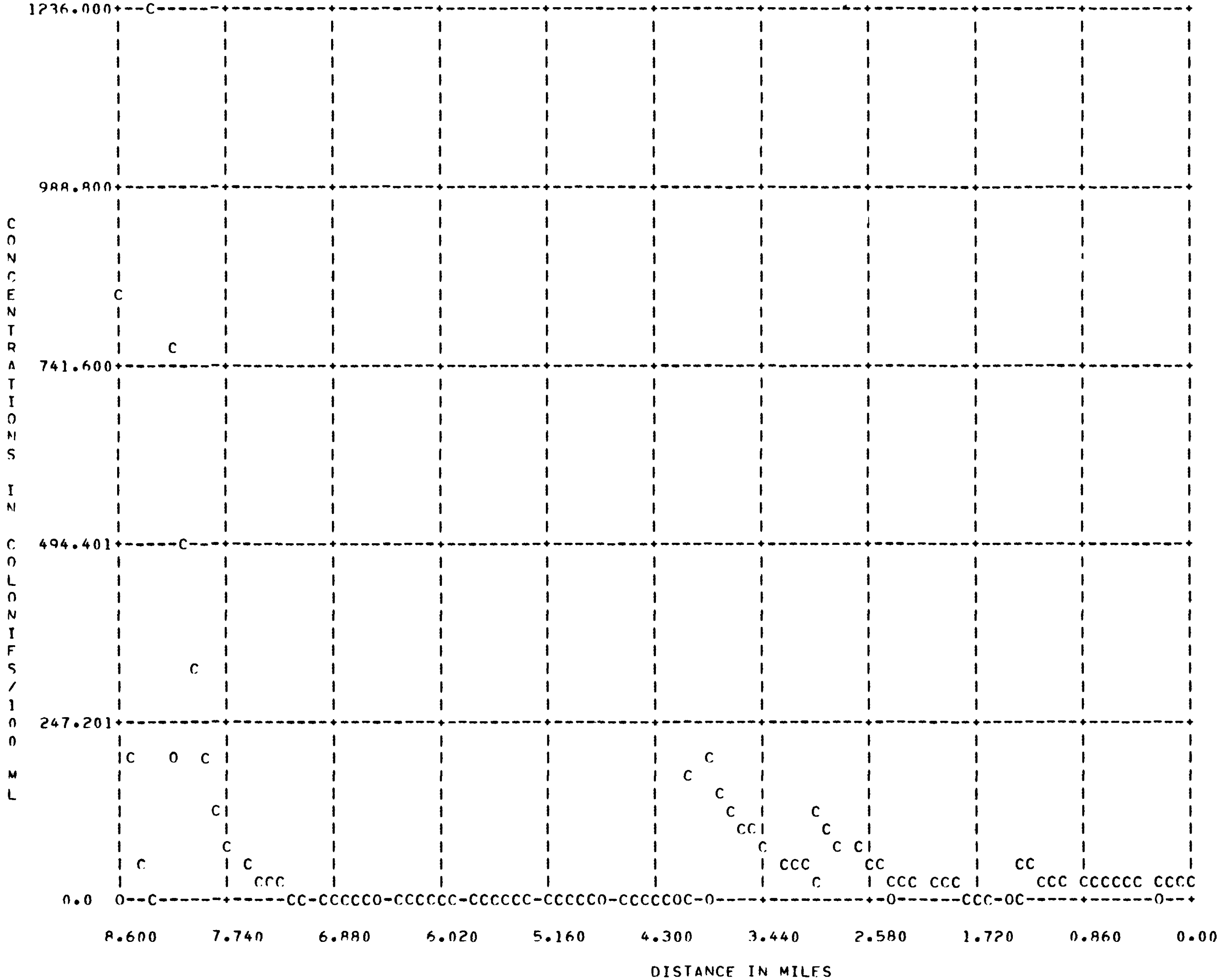
CALCULATED NITRATE NITROGEN CONC = C
OBSERVED NITRATE NITROGEN CONC = O

MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED TOTAL COLIFORM CONCENTRATIONS VERSUS DISTANCE



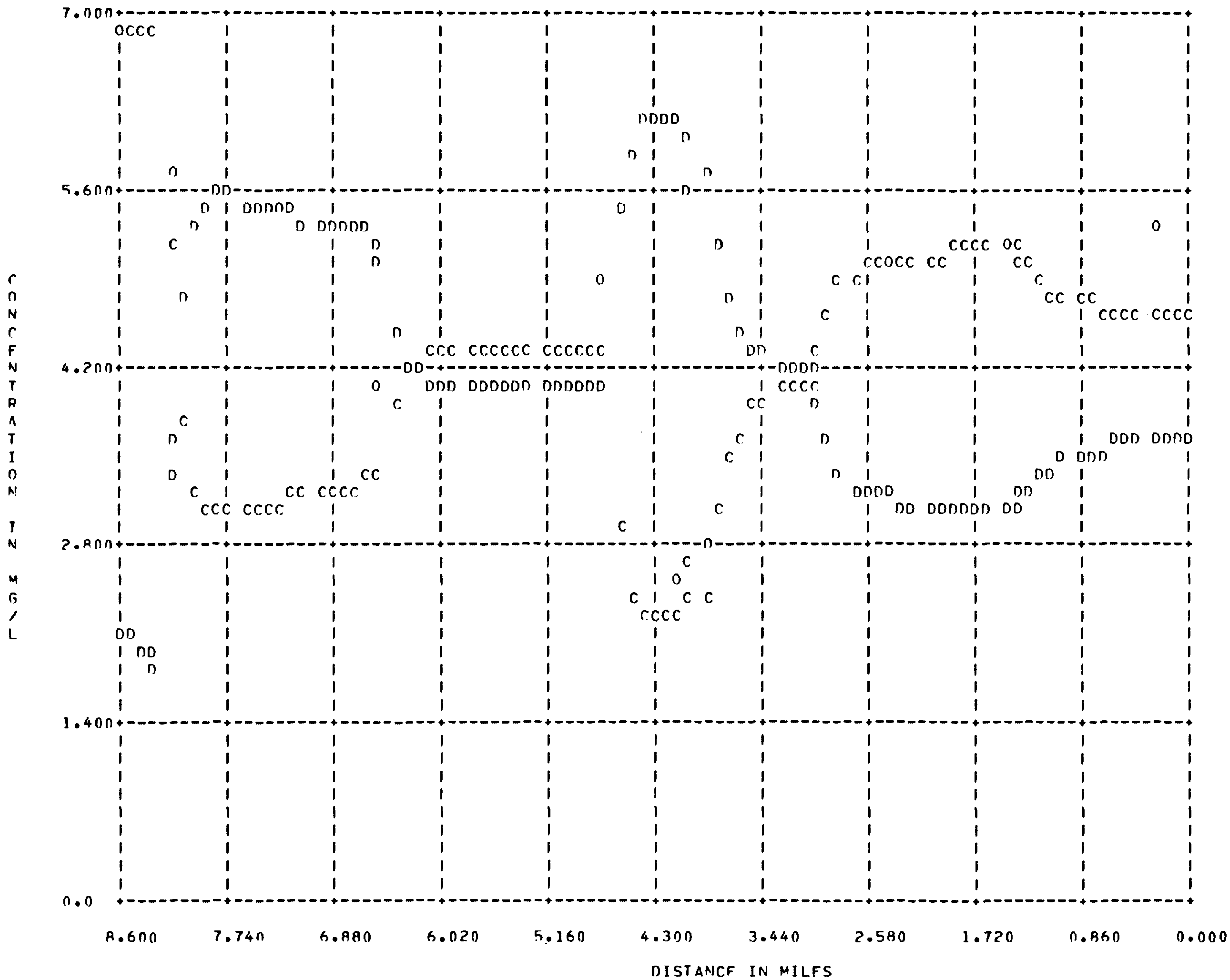
CALCULATED TOTAL COLIFORM CONC = C
OBSERVED TOTAL COLIFORM CONC = O

MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED FECAL COLIFORM CONCENTRATIONS VERSUS DISTANCE



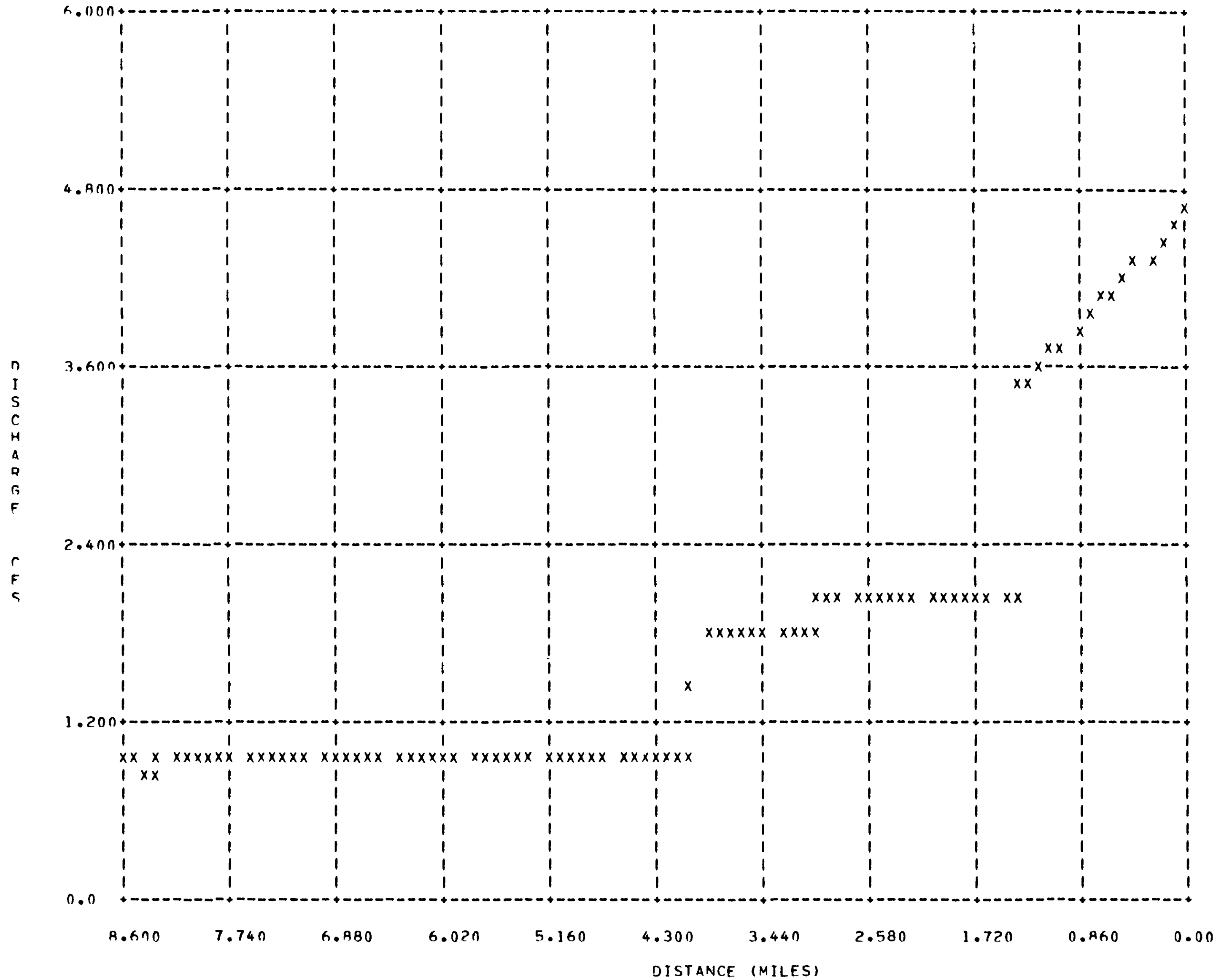
CALCULATED FECAL COLIFORM CONC = C
OBSERVED FECAL COLIFORM CONC = O

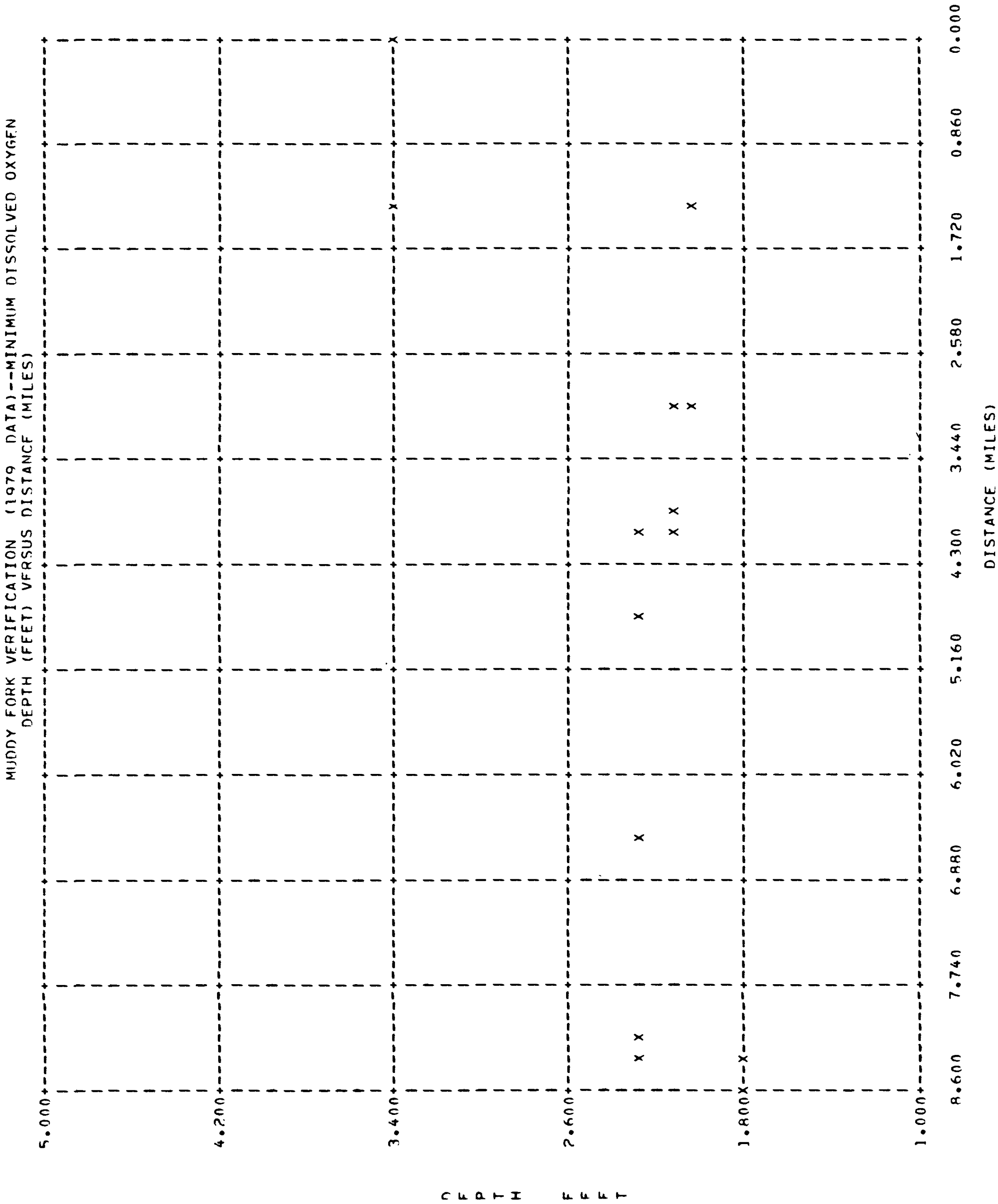
MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED DO CONCENTRATIONS AND DO DEFICIT VERSUS DISTANCE



CALCULATED DO CONC = C
OBSERVED DO CONC = O
DO DEFICIT = D

MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN
DISCHARGE (CFS) VERSUS DISTANCE (MILES)




MUDDY FORK VERIFICATION (1979 DATA)--MINIMUM DISSOLVED OXYGEN
DEPTH (FEET) VERSUS DISTANCE (MILES)
DISTANCE (MILES)
DEPTH FEET
5.000
4.200
3.400
2.600
1.800
1.000
8.600
7.740
6.880
6.020
5.160
4.300
3.440
2.580
1.720
0.860
0.000

ATTACHMENT C

SPRING CREEK CALIBRATION AND VERIFICATION

```
                    STEADY STATE WATER QUALITY MODEL

                    GULF COAST HYDROSCIENCE CENTER

                       U. S. GEOLOGICAL SURVEY

                          (ARKANSAS VERSION)

                 DATE OF LAST REVISION, DECEMBER  1980


SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN

         DISSOLVED OXYGEN PROFILE REPRESENTS
    ***  DIEL MINIMUMS: NET PHOTOSYNTHETIC DO   ***
         PRODUCTION ADJUSTED ACCORDINGLY.

        NITRIFICATION CYCLE INCLUDED IN MODEL


        NUMBER OF SUBREACHES FOR THIS PROBLEM =     9


            PRINTING INTERVAL (MILES) =   0.100

           STARTING DISTANCE (MILES) =    6.200

  INITIAL CBOD CONC (MG/L) AT STARTING DISTANCE =    2.00

  INITIAL ORGANIC NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.430

  INITIAL AMMONIUM NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.080

  INITIAL NITRITE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.010

  INITIAL NITRATE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   3.500

  INITIAL DO CONC (MG/L) AT STARTING DISTANCE =   7.200

  INITIAL PHOSPHATE CONC (MG/L) AT STARTING DISTANCE =   0.260

  INITIAL TOT. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =     740.

  INITIAL FEC. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =     740.

      STREAMFLOW (CFS) AT STARTING DISTANCE =     8.700

      TOTAL SUSPENDED SOLIDS                    =   8.00
```

SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN

SUBREACH LINEAR RUNOFF DATA

SUBREACH	Q (CFS)	CBOD (MG/L)	ORGANIC (MG/L)	AMMONIA (MG/L)	NITRITE (MG/L)	NITRATE (MG/L)	DO (MG/L)	TSS (MG/L)	SP COND (MG/L)	(MG/L)	PO4 (MG/L)
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	-1.65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	2.60	4.00	0.50	0.10	0.10	2.50	6.00	6.00	370.00	0.0	0.25
5	0.45	4.00	0.50	0.10	0.10	2.50	6.00	6.00	370.00	0.0	0.25
6	0.45	4.00	0.50	0.10	0.10	2.50	6.00	6.00	370.00	0.0	0.25
7	1.00	4.00	0.50	0.10	0.10	2.50	6.00	6.00	370.00	0.0	0.25
8	0.50	4.00	0.50	0.10	0.10	2.50	6.00	6.00	370.00	0.0	0.25
9	3.60	4.00	0.50	0.10	0.10	2.50	6.00	6.00	370.00	0.0	0.25

R E A C H   D E S C R I P T I O N   D A T A   (MAJOR TRIBUTARIES AND MAIN STEM)

SUBREACH	CODE	NAME	BEGIN (MILE)	END (MILE)
1	A	UPSTREAM SUBREACH	6.20	6.10
2	A	SPRINGDALE STP EFF	6.10	6.00
3	A		6.00	5.90
4	A		5.90	5.50
5	A		5.50	4.90
6	A		4.90	4.20
7	A	PUPPY CREEK	4.20	2.30
8	A	CROSS CREEK	2.30	1.40
9	A	NEAR MOUTH	1.40	0.0

KEY: CODE

A	ROCKY BOTTOM-POOL RIFFLE-LIGHT VEGETATION
B	ROCKY BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
C	ROCKY BOTTOM-POOL RIFFLE-HEAVY VEGETATION
D	ROCKY BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
E	ROCKY BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
F	ROCKY BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION
G	MUD BOTTOM-POOL RIFFLE-LIGHT VEGETATION
H	MUD BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
I	MUD BOTTOM-POOL RIFFLE-HEAVY VEGETATION
J	MUD BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
K	MUD BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
L	MUD BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION

SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN

I N P U T   P A R A M E T E R S

CONCENTRATIONS(MG/L) OF --

SUBREACH	CARB BOD	ORG-N	NH3-N	NO2-N	NO3-N	DISSOLVED OXYGEN	PO4	TOT.COLIF.	FEC.COLIF.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	22.00	4.20	5.10	0.43	13.00	7.20	6.70	5.00	3.00
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.00	3.00
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	5.40	1.80	0.13	0.02	3.20	8.20	0.29	25000.00	15000.00
8	1.80	0.38	0.07	0.0	1.80	6.00	0.16	620.00	33.00
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIRECT DISCHARGES(LB/DAY) OF --

SUBREACH	CARBONACEOUS ULT. BOD	ORGANIC NITROGEN	AMMONIA NITROGEN	NITRITE NITROGEN	NITRATE NITROGEN	PHOSPHATE
1	0.0	0.0	0.0	0.0	0.0	0.
2	0.0	0.0	0.0	0.0	0.0	0.
3	0.0	0.0	0.0	0.0	0.0	0.
4	0.0	0.0	0.0	0.0	0.0	0.
5	0.0	0.0	0.0	0.0	0.0	0.
6	0.0	0.0	0.0	0.0	0.0	0.
7	0.0	0.0	0.0	0.0	0.0	0.
8	0.0	0.0	0.0	0.0	0.0	0.
9	0.0	0.0	0.0	0.0	0.0	0.

SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN

SUBREACH	NET PHOTOSYNTHETIC DO PRODUCTION (MG/L/DAY @ 20 DEG C)	(FITTING FACTOR FOR MINIMUM DO PROFILE)	BENTHIC DO DEMAND (G/SQM/DAY @ 20 DEG C)
1	8.400	-3.000	1.00
2	5.600	-2.000	2.00
3	5.600	-3.000	2.00
4	2.800	-16.000	4.00
5	6.000	-16.000	5.50
6	6.000	-13.000	6.00
7	10.000	-10.000	8.00
8	16.600	-18.000	14.00
9	21.200	-16.000	18.00

G E O M E T R Y

SUBREACH	FLOW CHANGE (CFS)	AREA (SQFT)	DEPTH (FT)	SLOPE	TEMP (DEG.CENT)	END MI (MI)
1	0.0	10.	0.80	0.0094700	18.00	6.10
2	12.15	24.	0.90	0.0047300	23.00	6.00
3	0.0	24.	0.90	0.0047300	23.00	5.90
4	0.0	24.	0.84	0.0037900	23.00	5.50
5	0.0	24.	1.10	0.0035000	23.00	4.90
6	0.0	24.	1.10	0.0035000	23.00	4.20
7	1.80	34.	1.23	0.0031900	23.00	2.30
8	0.13	34.	0.98	0.0031600	23.00	1.40
9	0.0	37.	0.85	0.0025700	23.00	0.0

SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN

R E A C T I O N   C O E F F I C I E N T S (/DAY @ 20 DEG C)

SUBREACH	KR	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KCOLF	KCOLT	KPO41	KPO42
1	0.85	0.85	0.05	2.00	2.00	2.00	0.30	0.30	0.10	1.00	1.00	0.10	0.0
2	0.90	0.47	0.05	3.00	5.00	5.00	0.30	0.30	0.10	1.00	1.00	0.10	0.0
3	0.90	0.47	0.05	3.00	5.00	5.00	0.30	0.30	0.10	1.00	1.00	0.10	0.0
4	0.90	0.47	0.05	3.00	10.00	10.00	4.00	4.00	0.10	1.00	1.00	0.10	0.0
5	0.90	0.38	0.05	1.50	6.00	6.00	3.00	3.00	0.10	1.00	1.00	0.30	0.0
6	0.90	0.38	0.05	1.50	6.00	6.00	3.00	3.00	0.10	1.00	1.00	0.30	0.0
7	0.90	0.28	0.05	0.50	3.00	3.00	6.00	6.00	2.30	1.00	1.00	0.80	0.0
8	0.90	0.34	0.05	0.30	3.00	3.00	8.00	8.00	0.20	1.00	1.00	0.80	0.0
9	0.90	0.34	0.05	0.30	3.00	3.00	8.00	8.00	0.10	1.00	1.00	0.80	0.0

TEMPERATURE CORRECTED REACTION COEFFICIENTS (/DAY)

SUBREACH	KR	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KA	KPO41	KPO42
1	0.78	0.78	0.04	1.68	1.68	1.68	0.25	0.25	0.08	26.58	0.08	0.0
2	1.03	0.54	0.06	3.89	6.48	6.48	0.39	0.39	0.13	23.19	0.13	0.0
3	1.03	0.54	0.06	3.89	6.48	6.48	0.39	0.39	0.13	22.61	0.13	0.0
4	1.03	0.54	0.06	3.89	12.95	12.95	5.18	5.18	0.13	26.43	0.13	0.0
5	1.03	0.44	0.06	1.94	7.77	7.77	3.89	3.89	0.13	17.51	0.39	0.0
6	1.03	0.44	0.06	1.94	7.77	7.77	3.89	3.89	0.13	17.73	0.39	0.0
7	1.03	0.32	0.06	0.65	3.89	3.89	7.77	7.77	2.98	12.72	1.04	0.0
8	1.03	0.39	0.06	0.39	3.89	3.89	10.36	10.36	0.26	19.07	1.04	0.0
9	1.03	0.39	0.06	0.39	3.89	3.89	10.36	10.36	0.13	24.20	1.04	0.0

SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN

SUBREACH	REAERATION COEFFICIENT DERIVATION
1	KA COMPUTED BY BENNETT - RATHBUN EQUATION
2	KA COMPUTED BY BENNETT - RATHBUN EQUATION
3	KA COMPUTED BY BENNETT - RATHBUN EQUATION
4	KA COMPUTED BY BENNETT - RATHBUN EQUATION
5	KA COMPUTED BY BENNETT - RATHBUN EQUATION
6	KA COMPUTED BY BENNETT - RATHBUN EQUATION
7	KA COMPUTED BY BENNETT - RATHBUN EQUATION
8	KA COMPUTED BY BENNETT - RATHBUN EQUATION
9	KA COMPUTED BY BENNETT - RATHBUN EQUATION

SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN

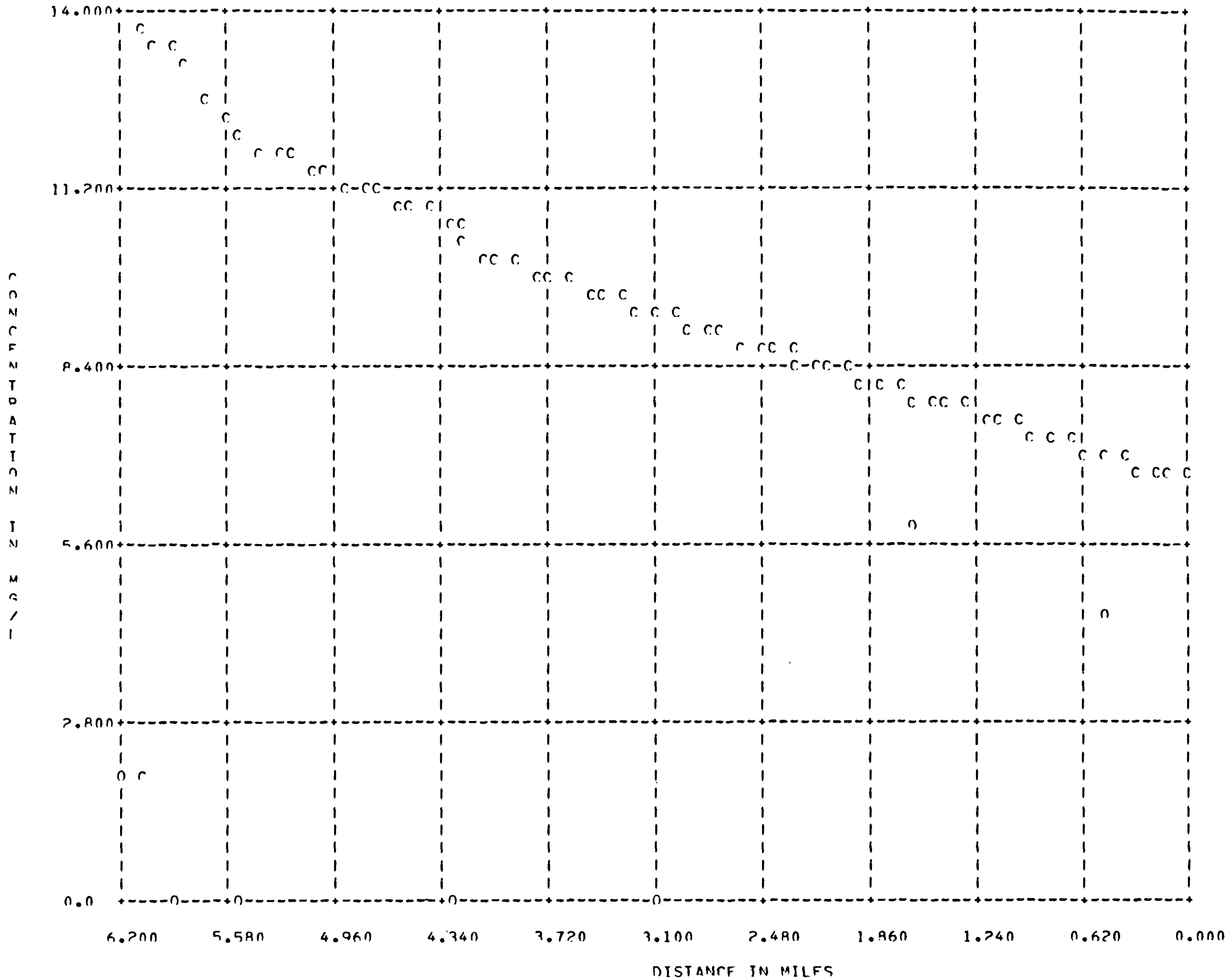
SUBREACH	DO SATURATION (MG/L)
1	9.442
2	8.551
3	8.551
4	8.551
5	8.551
6	8.551
7	8.551
8	8.551
9	8.551

SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN

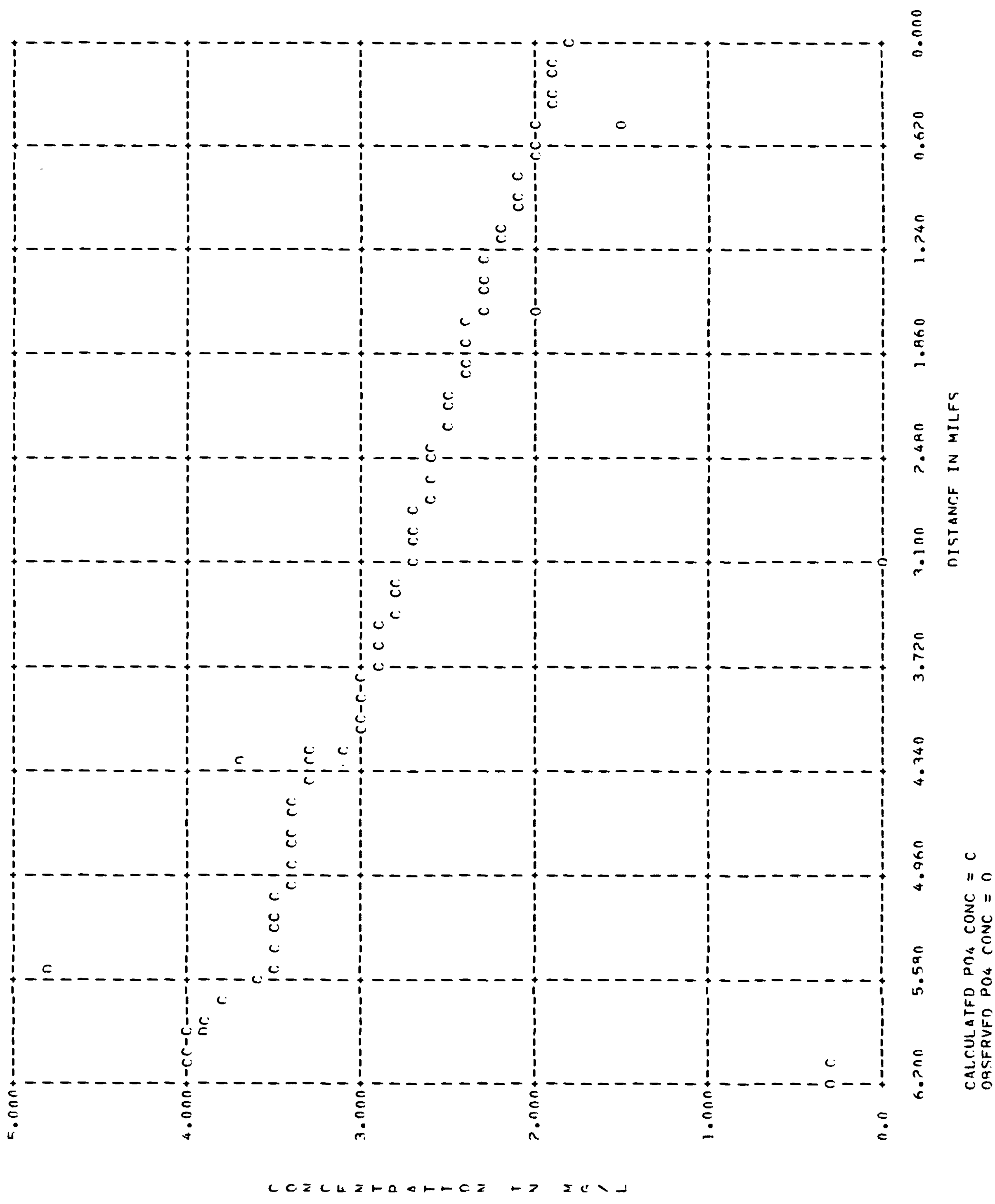
O B S E R V E D   M E A S U R E M E N T S

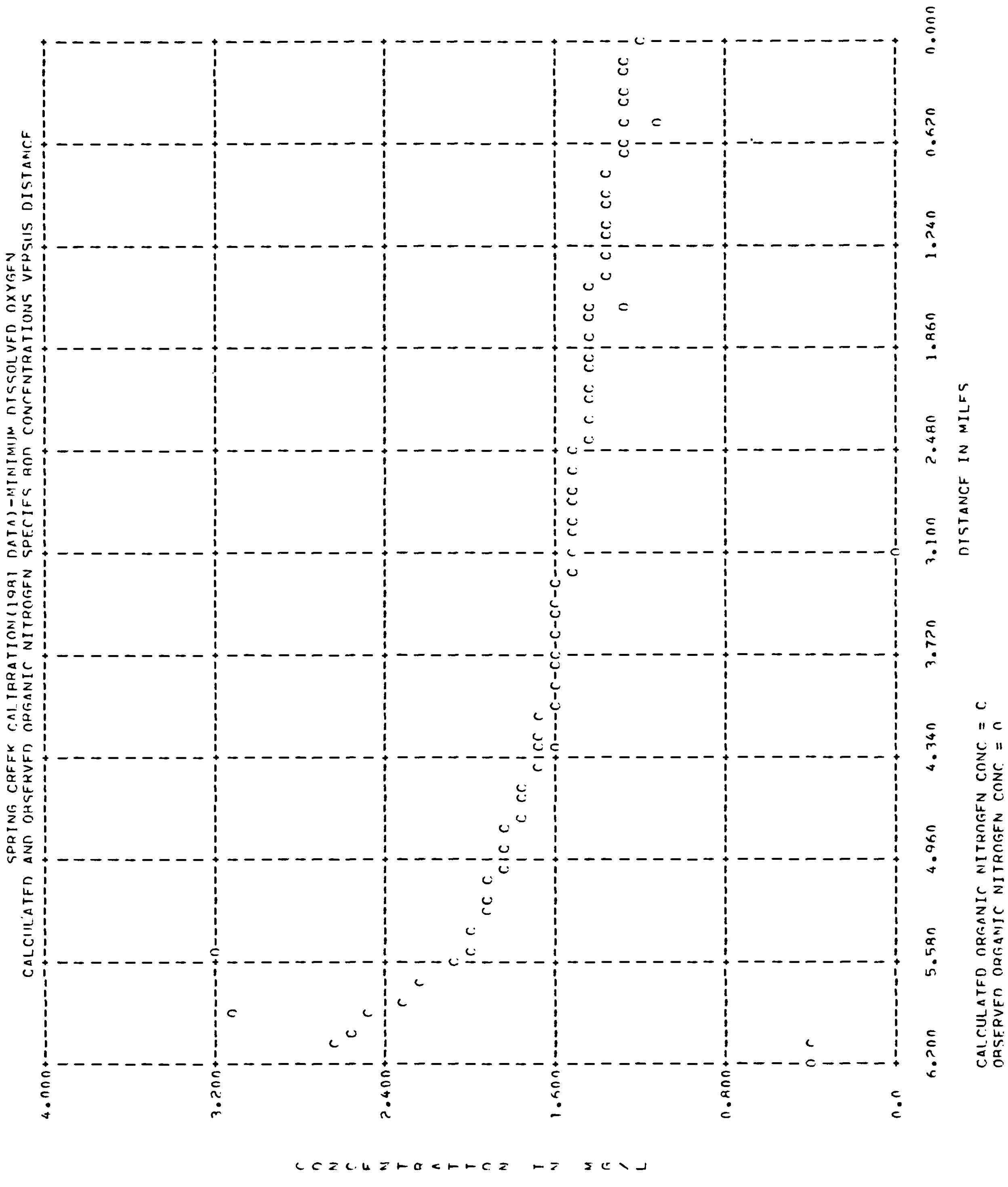
DISTANCE (MI)	DO CONC (MG/L)	TSS (MG/L)	SP COND (MG/L)	(MG/L)	CBODU (MG/L)	NBODU (MG/L)	ORG-N (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)	TOTAL COLIFORM	FECAL COLIFORM	PO4 (MG/L)
6.20	7.20	8.00	370.00	0.0	2.00	0.0	0.43	0.08	0.01	3.50	740.	740.	0.26
5.90	7.10	11.00	500.00	0.0	0.0	0.0	3.10	3.20	0.27	8.50	1.	0.	3.90
5.50	4.80	6.00	460.00	0.0	0.0	0.0	3.20	2.90	0.99	8.80	0.	0.	4.80
4.30	4.50	6.00	500.00	0.0	0.0	0.0	1.60	0.74	1.40	8.60	3000.	1100.	3.70
3.10	5.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	0.0
1.60	4.80	4.00	420.00	0.0	5.90	0.0	1.30	0.12	0.18	6.80	880.	550.	2.00
0.50	4.90	4.00	400.00	0.0	4.50	0.0	1.10	0.12	0.03	5.60	490.	410.	1.50

SPRING CREEK CALIBRATION(198) DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED CBOD CONCENTRATIONS VERSUS DISTANCE

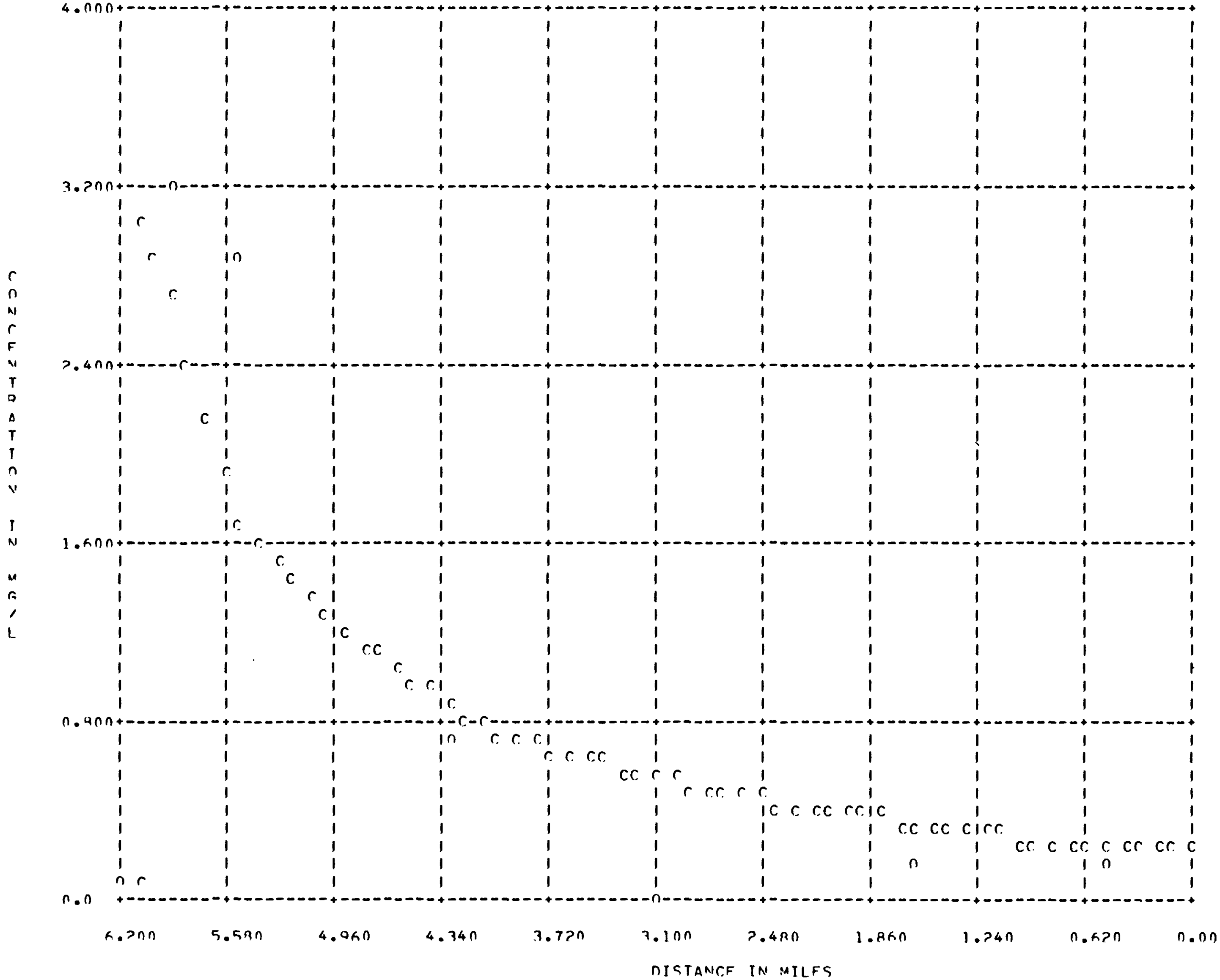


CALCULATED CBODU CONC = C
OBSERVED CBODU CONC = O


SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED PO4 CONCENTRATIONS VERSUS DISTANCE
CONCENTRATION IN MG/L
5.000
4.000
3.000
2.000
1.000
0.0
DISTANCE IN MILES
6.200
5.580
4.960
4.340
3.720
3.100
2.480
1.860
1.240
0.620
0.000
CALCULATED PO4 CONC = C
OBSERVED PO4 CONC = O

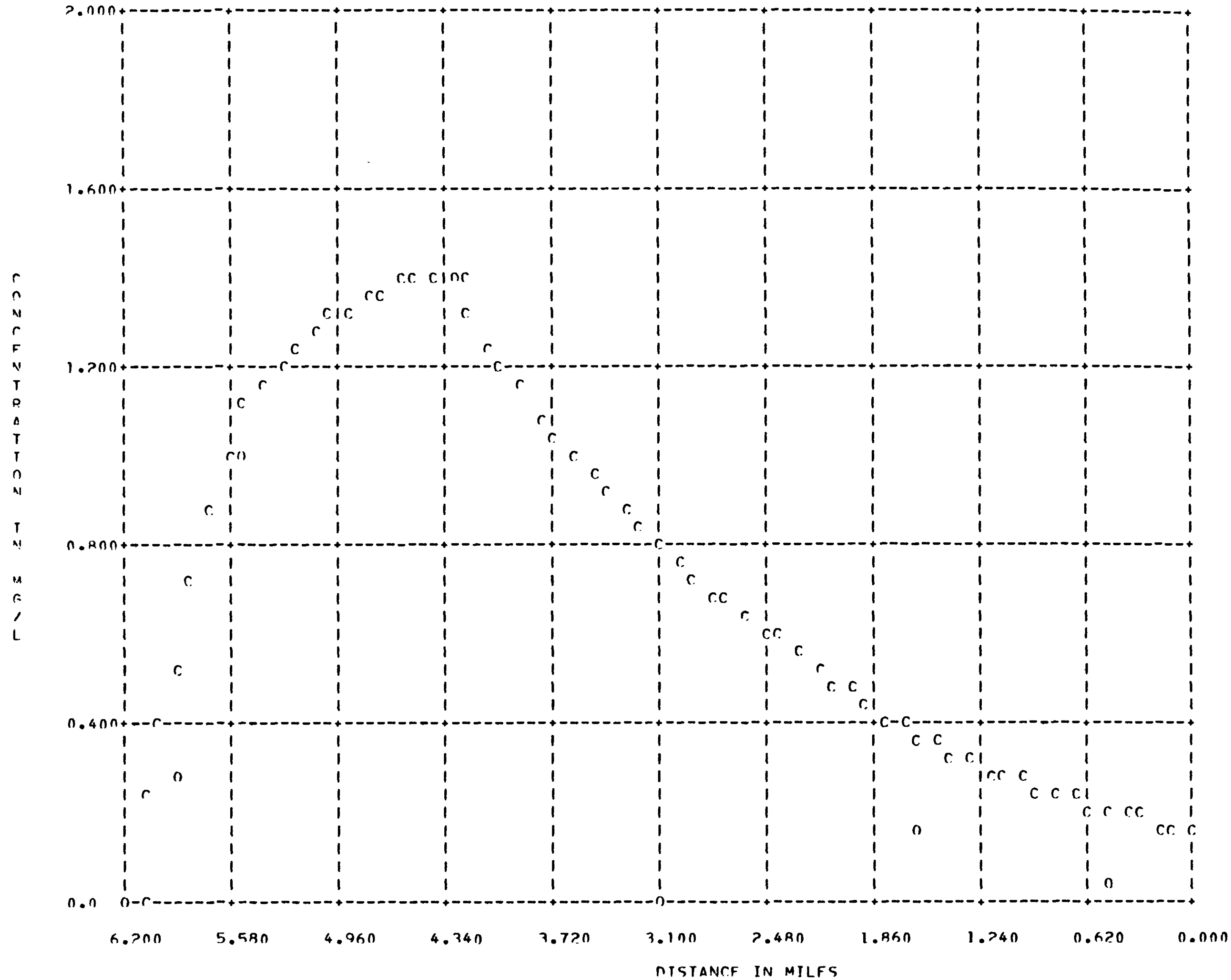

SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED ORGANIC NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE
4.000
3.200
2.400
1.600
0.800
0.0
CONCENTRATION IN MG/L
6.200
5.580
4.960
4.340
3.720
3.100
2.480
1.860
1.240
0.620
0.000
DISTANCE IN MILES
CALCULATED ORGANIC NITROGEN CONC = C
OBSERVED ORGANIC NITROGEN CONC = O

SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED AMMONIA NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



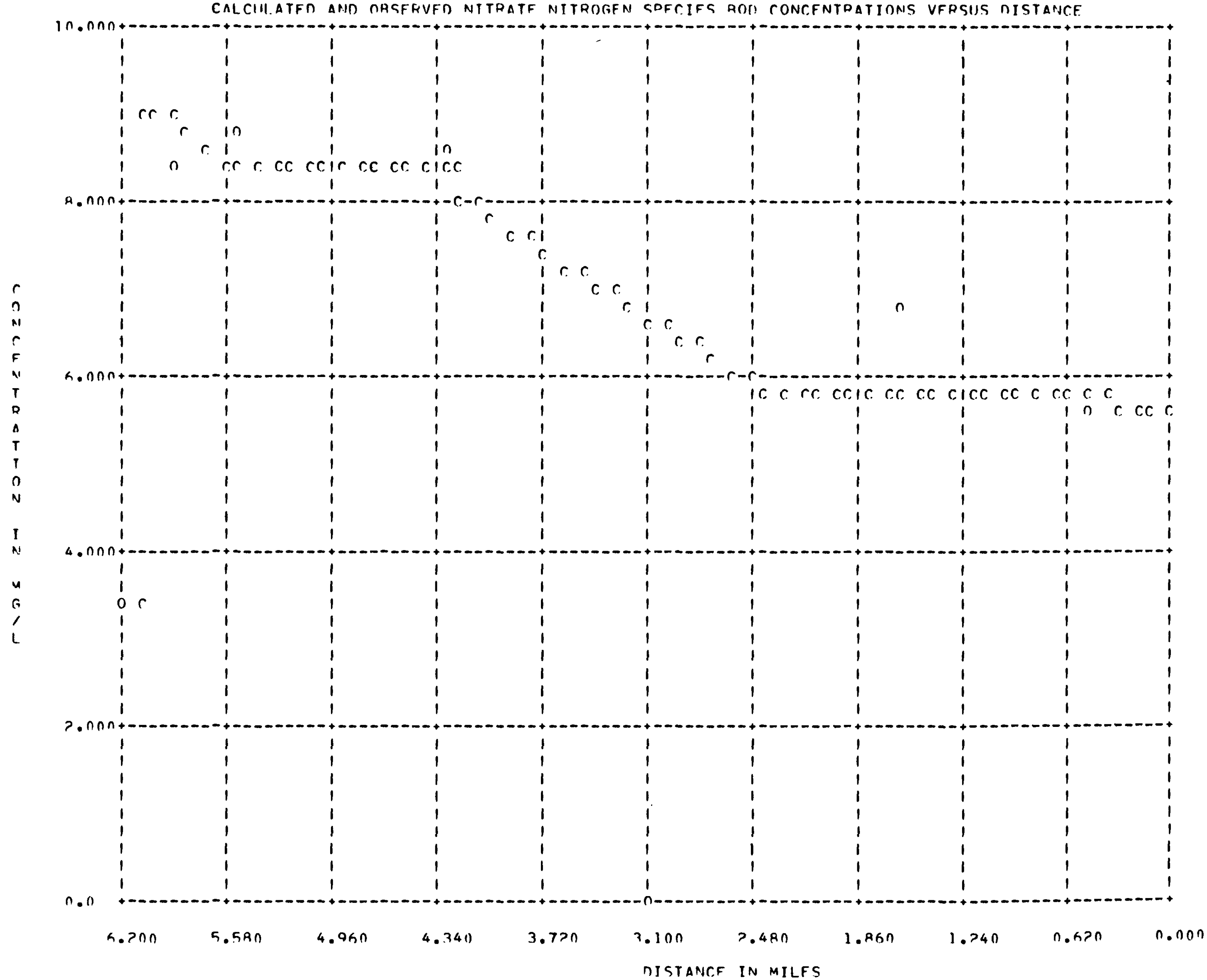
CALCULATED AMMONIA NITROGEN CONC = C
OBSERVED AMMONIA NITROGEN CONC = O

SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED NITRITE NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



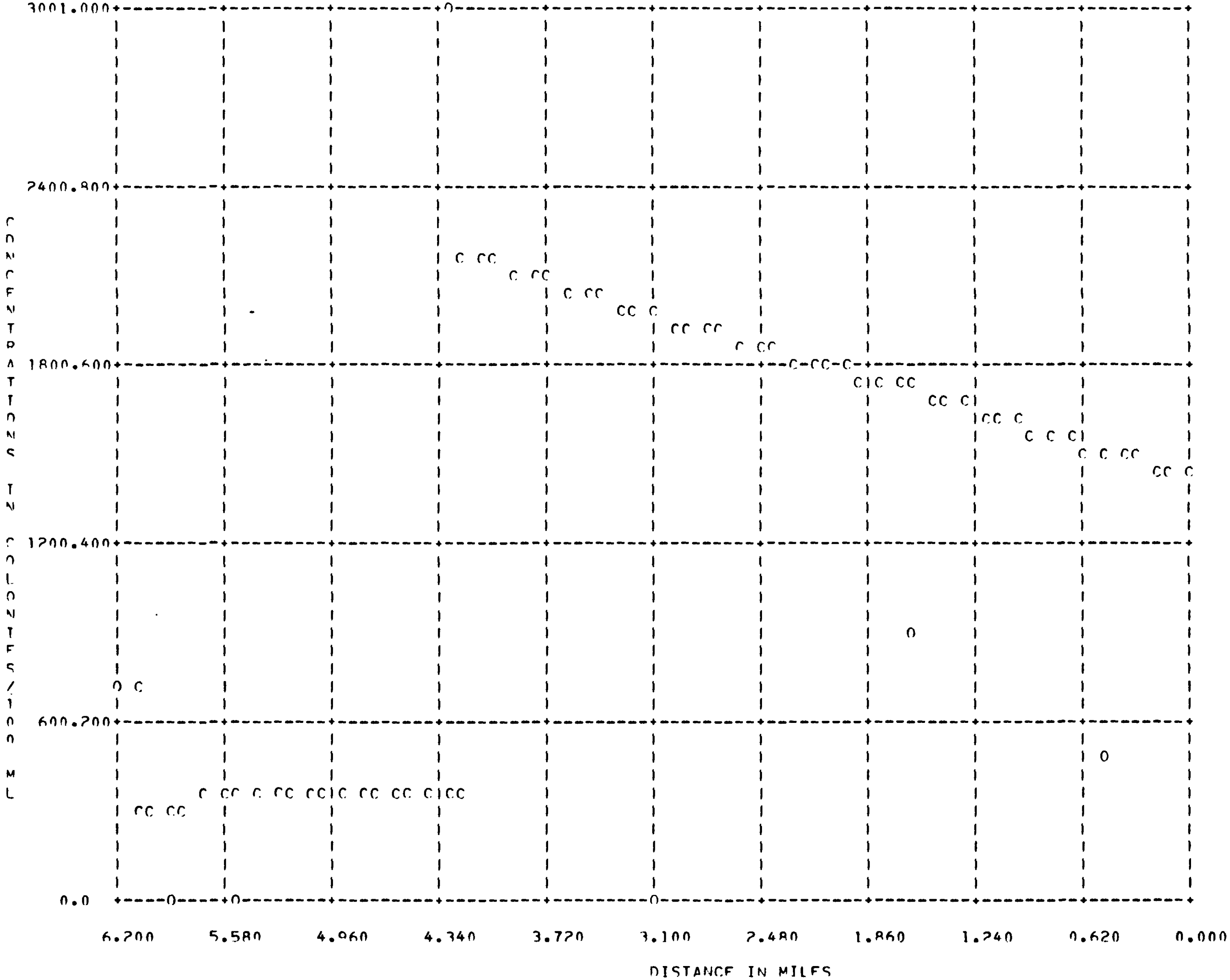
CALCULATED NITRITE NITROGEN CONC = C
OBSERVED NITRITE NITROGEN CONC = O

SPRING CREEK CALIBRATION(1991 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED NITRATE NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



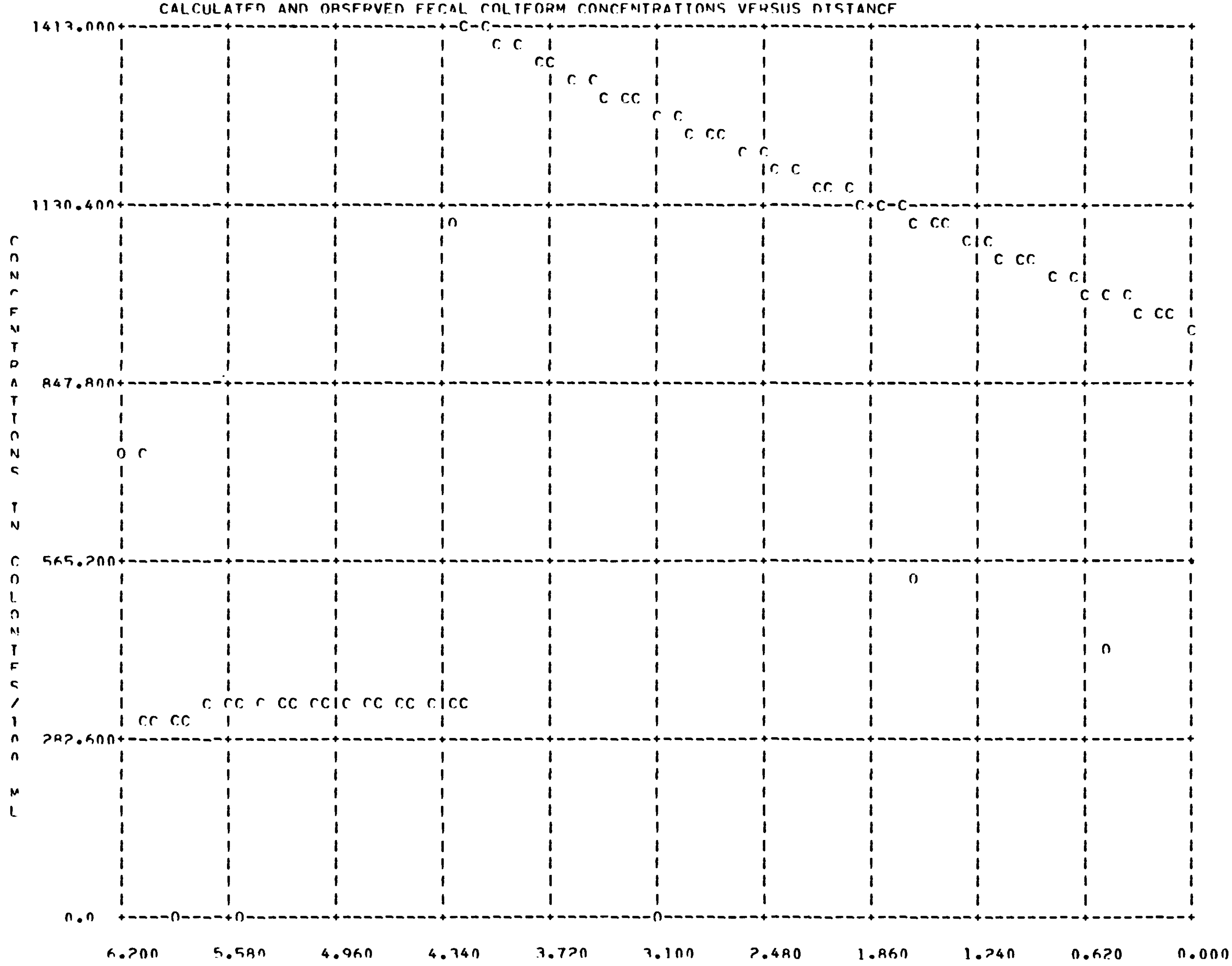
CALCULATED NITRATE NITROGEN CONC = C
OBSERVED NITRATE NITROGEN CONC = O

SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED TOTAL COLIFORM CONCENTRATIONS VERSUS DISTANCE



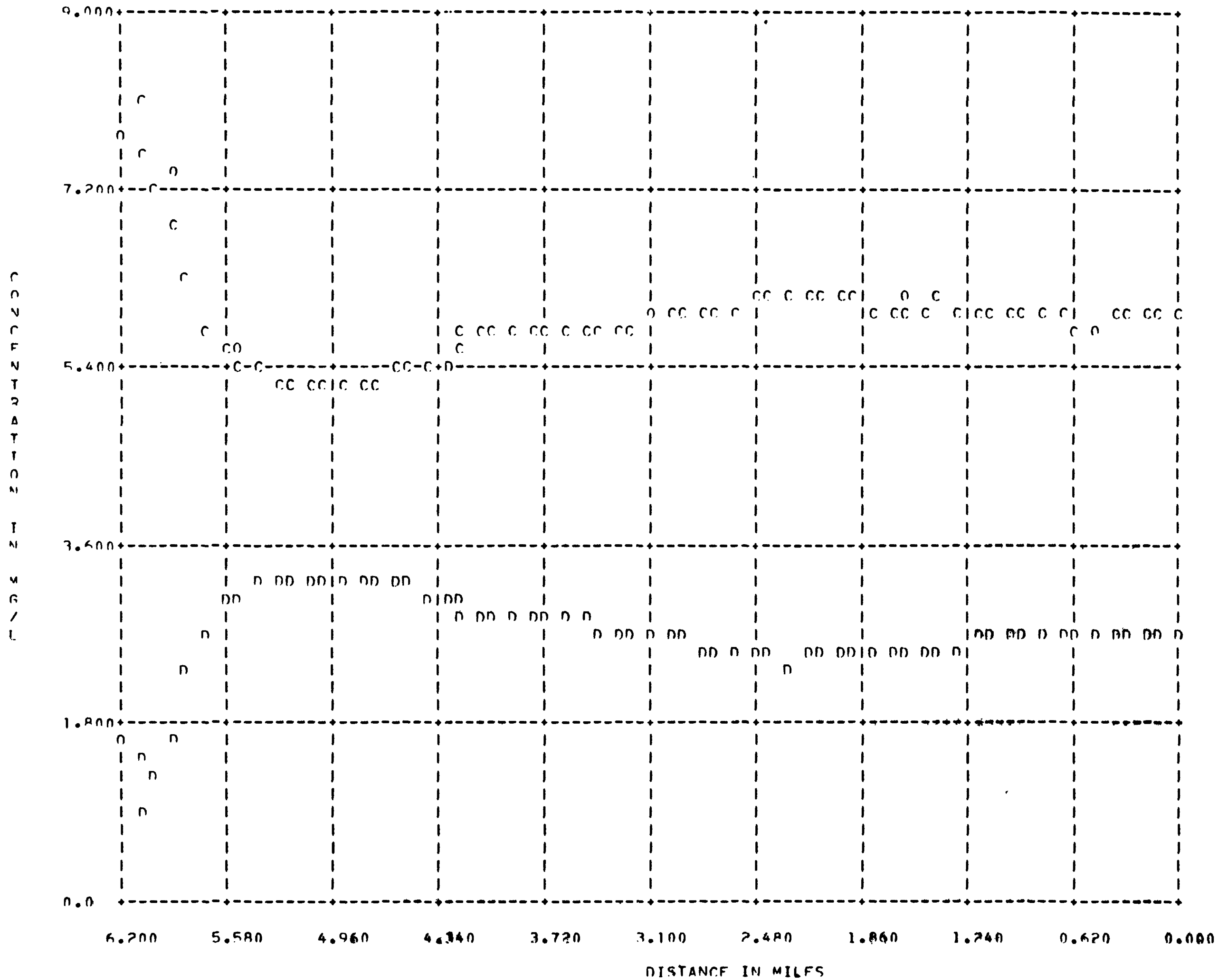
CALCULATED TOTAL COLIFORM CONC = C
OBSERVED TOTAL COLIFORM CONC = O

SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED FECAL COLIFORM CONCENTRATIONS VERSUS DISTANCE



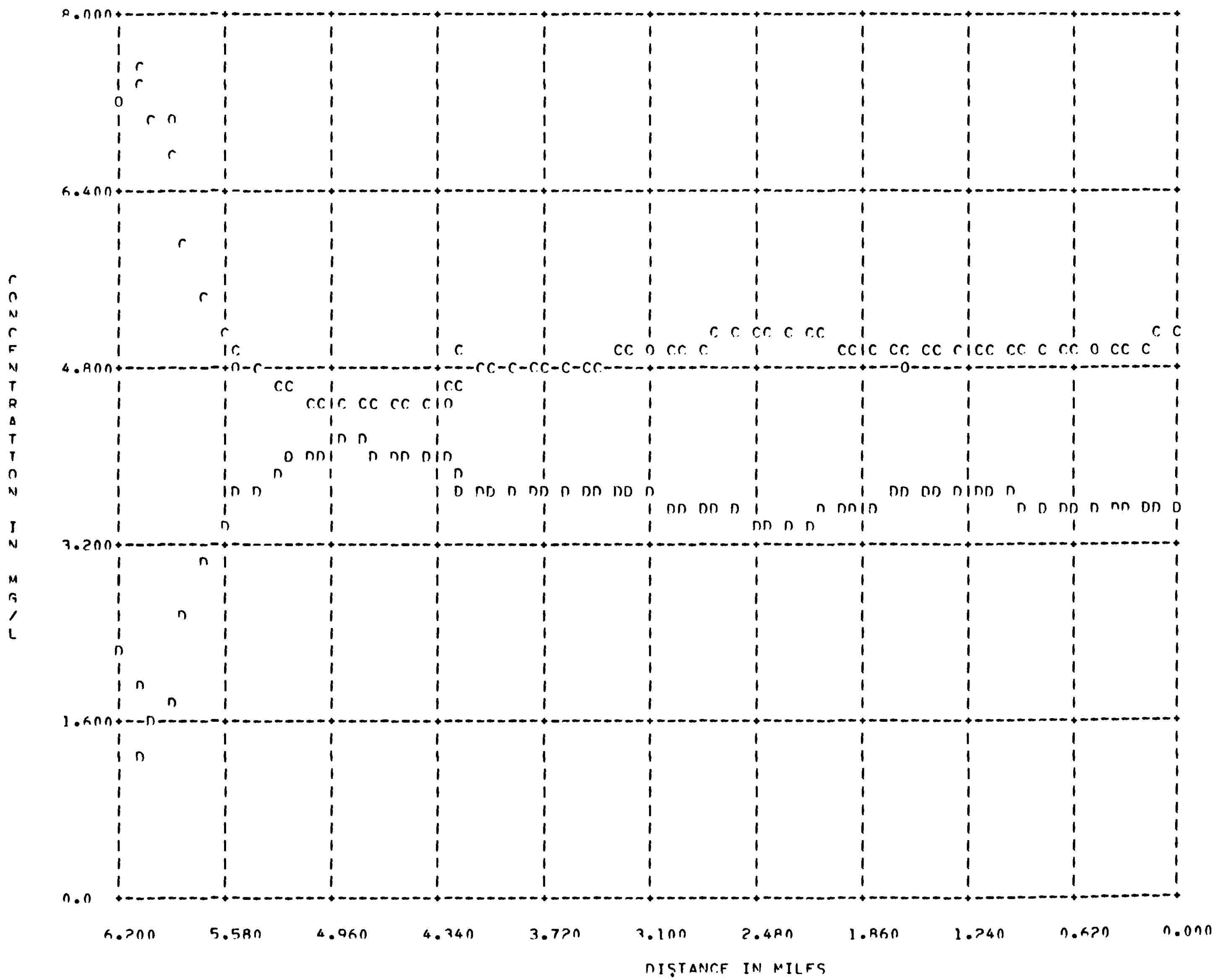
CALCULATED FECAL COLIFORM CONC = C
OBSERVED FECAL COLIFORM CONC = O

SPRING CREEK CALIBRATION(1981 DATA)-MEAN DISSOLVED OXYGEN
CALCULATED AND OBSERVED DO CONCENTRATIONS AND DO DEFICIT VERSUS DISTANCE



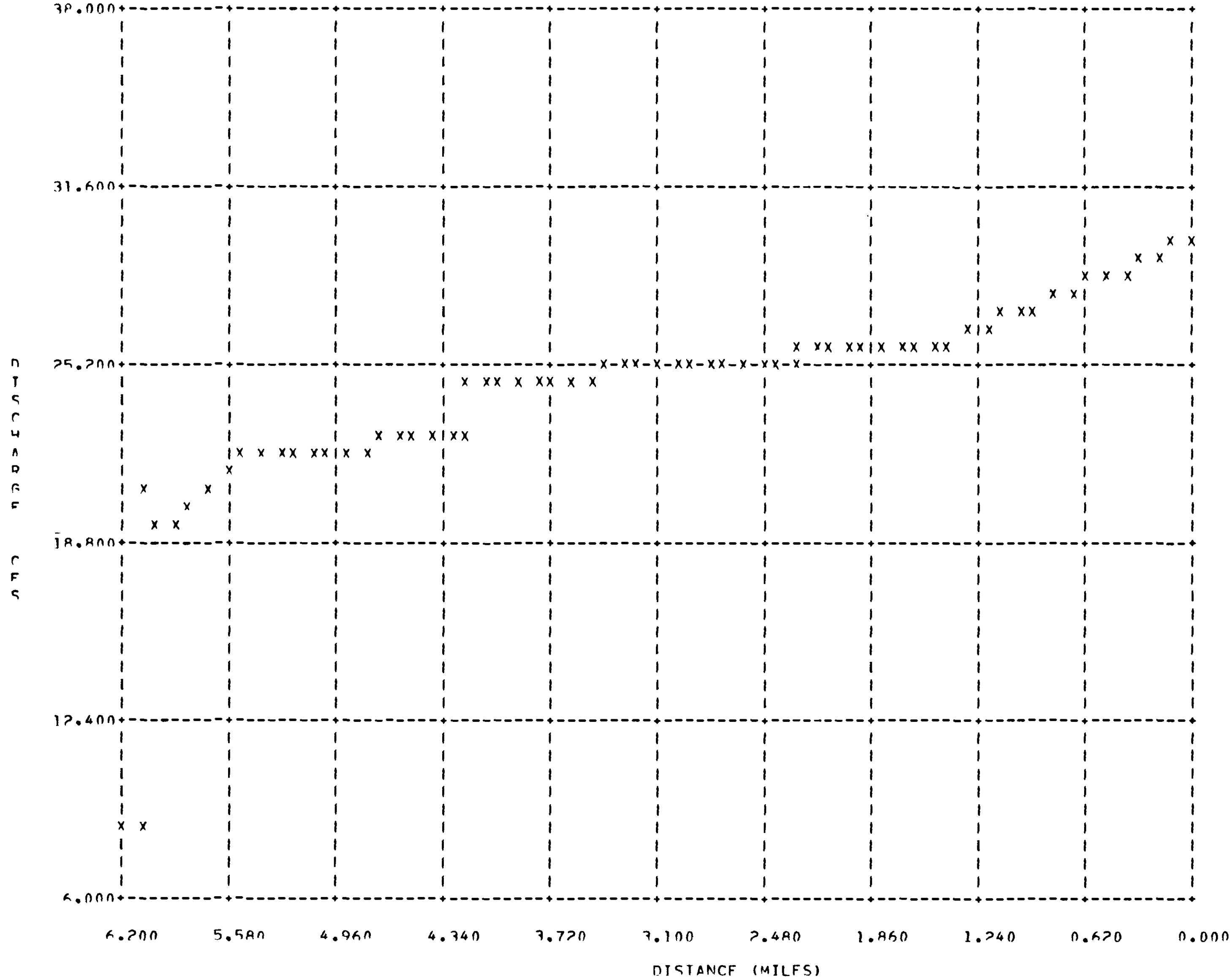
CALCULATED DO CONC = C
OBSERVED DO CONC = O
DO DEFICIT = D

SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED DO CONCENTRATIONS AND DO DEFICIT VERSUS DISTANCE

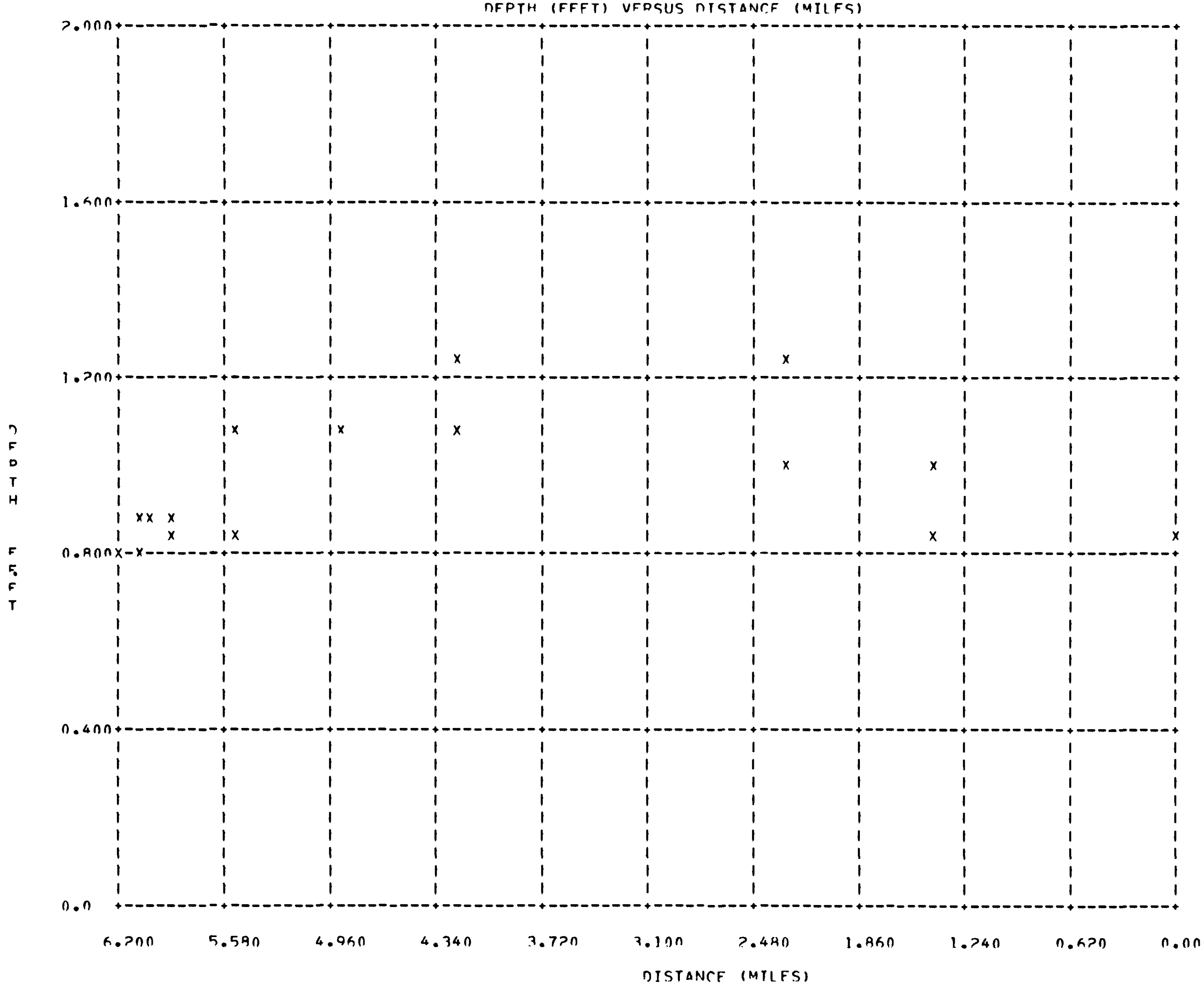


CALCULATED DO CONC = C
OBSERVED DO CONC = O
DO DEFICIT = D

SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN
DISCHARGE (CFS) VERSUS DISTANCE (MILES)



SPRING CREEK CALIBRATION(1981 DATA)-MINIMUM DISSOLVED OXYGEN
DEPTH (FEET) VERSUS DISTANCE (MILES)



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                STEADY STATE WATER QUALITY MODEL

                GULF COAST HYDROSCIENCE CENTER

                   U. S. GEOLOGICAL SURVEY

                      (ARKANSAS VERSION)

             DATE OF LAST REVISION, DECEMBER  1980


SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN

          DISSOLVED OXYGEN PROFILE REPRESENTS
     ***  DIEL MINIMUMS; NET PHOTOSYNTHETIC DO  ***
          PRODUCTION ADJUSTED ACCORDINGLY.

         NITRIFICATION CYCLE INCLUDED IN MODEL


         NUMBER OF SUBREACHES FOR THIS PROBLEM =    9


              PRINTING INTERVAL (MILES) =   0.100

             STARTING DISTANCE (MILES) =    6.200

  INITIAL CBOD CONC (MG/L) AT STARTING DISTANCE =    3.10

  INITIAL ORGANIC NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.220

  INITIAL AMMONIUM NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.150

  INITIAL NITRITE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.030

  INITIAL NITRATE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   3.200

  INITIAL DO CONC (MG/L) AT STARTING DISTANCE =   7.800

  INITIAL PHOSPHATE CONC (MG/L) AT STARTING DISTANCE =   0.060

  INITIAL TOT. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =     800.

  INITIAL FEC. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =     540.

      STREAMFLOW (CFS) AT STARTING DISTANCE =     5.900

      TOTAL SUSPENDED SOLIDS                    =    8.00
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SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN

S U B R E A C H   L I N E A R   R U N O F F   D A T A

SUBREACH	Q (CFS)	CBOD (MG/L)	ORGANIC (MG/L)	AMMONIA (MG/L)	NITRITE (MG/L)	NITRATE (MG/L)	DO (MG/L)	TSS (MG/L)	SP COND (MG/L)	(MG/L)	PO4 (MG/L
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	-3.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.10	0.0	0.0	0.0	300.00	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	-0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	-0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.20	4.00	0.50	0.10	0.10	2.50	6.00	6.00	370.00	0.0	0.25
8	5.50	4.00	0.50	0.10	0.10	2.50	6.00	6.00	370.00	0.0	0.25
9	2.00	4.00	0.50	0.10	0.10	2.50	6.00	6.00	370.00	0.0	0.25

REACH DESCRIPTION DATA (MAJOR TRIBUTARIES AND MAIN STEM)

SUBREACH	CODE	NAME	BEGIN (MILE)	END (MILE)
1	A	UPSTREAM SUBREACH	6.20	6.10
2	A	SPRINGDALE STP EFF	6.10	6.00
3	A		6.00	5.90
4	A		5.90	5.50
5	A		5.50	4.90
6	A		4.90	4.20
7	A	PUPPY CREEK	4.20	2.30
8	A	CROSS CREEK	2.30	1.40
9	A	NEAR MOUTH	1.40	0.0

KEY: CODE

- A ROCKY BOTTOM-POOL RIFFLE-LIGHT VEGETATION
- B ROCKY BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
- C ROCKY BOTTOM-POOL RIFFLE-HEAVY VEGETATION
- D ROCKY BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
- E ROCKY BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
- F ROCKY BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION
- G MUD BOTTOM-POOL RIFFLE-LIGHT VEGETATION
- H MUD BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
- I MUD BOTTOM-POOL RIFFLE-HEAVY VEGETATION
- J MUD BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
- K MUD BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
- L MUD BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION

SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN

I N P U T   P A R A M E T E R S

CONCENTRATIONS(MG/L) OF --

SUBREACH	CARB BOD	ORG-N	NH3-N	NO2-N	NO3-N	DISSOLVED OXYGEN	PO4	TOT.COLIF.	FEC.COLIF.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	32.00	4.00	5.40	1.10	15.00	7.60	6.90	400.00	400.00
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.00	3.00
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	2.10	0.59	0.07	0.07	3.00	7.80	0.11	4100.00	1200.00
8	6.30	0.45	0.10	0.09	2.20	9.20	0.06	830.00	830.00
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DIRECT DISCHARGES(LB/DAY) OF --

SUBREACH	CARBONACEOUS ULT. BOD	ORGANIC NITROGEN	AMMONIA NITROGEN	NITRITE NITROGEN	NITRATE NITROGEN	PHOSPHATE
1	0.0	0.0	0.0	0.0	0.0	0.
2	0.0	0.0	0.0	0.0	0.0	0.
3	0.0	0.0	0.0	0.0	0.0	0.
4	0.0	0.0	0.0	0.0	0.0	0.
5	0.0	0.0	0.0	0.0	0.0	0.
6	0.0	0.0	0.0	0.0	0.0	0.
7	0.0	0.0	0.0	0.0	0.0	0.
8	0.0	0.0	0.0	0.0	0.0	0.
9	0.0	0.0	0.0	0.0	0.0	0.

SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN

SUBREACH	NET PHOTOSYNTHETIC DO PRODUCTION (MG/L/DAY @ 20 DEG C)	(FITTING FACTOR FOR MINIMUM DO PROFILE)	BENTHIC DO DEMAND (G/SQM/DAY @ 20 DEG C)
1	8.400	-3.000	1.00
2	5.600	-2.000	2.00
3	5.600	-3.000	2.00
4	2.800	-16.000	4.00
5	6.000	-16.000	5.50
6	6.000	-13.000	6.00
7	12.000	-10.000	8.00
8	16.600	-18.000	14.00
9	21.200	-16.000	18.00

G E O M E T R Y

SUBREACH	FLOW CHANGE (CFS)	AREA (SQFT)	DEPTH (FT)	SLOPE	TEMP (DEG.CENT)	END MI (MI)
1	0.0	10.	0.80	0.0094700	18.00	6.10
2	15.10	24.	0.90	0.0047300	26.00	6.00
3	0.0	24.	0.90	0.0047300	26.00	5.90
4	0.0	24.	0.84	0.0037900	25.00	5.50
5	0.0	24.	1.10	0.0035000	25.00	4.90
6	0.0	24.	1.10	0.0035000	25.00	4.20
7	1.80	34.	1.23	0.0031900	25.00	2.30
8	0.50	34.	0.98	0.0031600	25.00	1.40
9	0.0	37.	0.85	0.0025700	25.00	0.0

SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN

R E A C T I O N   C O E F F I C I E N T S (/DAY @ 20 DEG C)

SUBREACH	KR	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KCOLF	KCOLT	KPO41	KPO42
1	0.85	0.64	0.05	2.00	2.00	2.00	0.30	0.30	0.10	1.00	1.00	0.10	0.0
2	0.90	0.47	0.05	3.00	5.00	5.00	0.30	0.30	0.10	1.00	1.00	0.10	0.0
3	0.90	0.47	0.05	3.00	5.00	5.00	0.30	0.30	0.10	1.00	1.00	0.10	0.0
4	0.90	0.44	0.05	3.00	10.00	10.00	4.00	4.00	0.10	1.00	1.00	0.10	0.0
5	0.90	0.34	0.05	1.50	6.00	6.00	3.00	3.00	0.10	1.00	1.00	0.30	0.0
6	0.90	0.34	0.05	1.50	6.00	6.00	3.00	3.00	0.10	1.00	1.00	0.30	0.0
7	0.90	0.26	0.05	0.50	3.00	3.00	6.00	6.00	2.30	1.00	1.00	0.80	0.0
8	0.90	0.33	0.05	0.30	3.00	3.00	8.00	8.00	0.20	1.00	1.00	0.80	0.0
9	0.90	0.33	0.05	0.30	3.00	3.00	8.00	8.00	0.10	1.00	1.00	0.80	0.0

TEMPERATURE CORRECTED REACTION COEFFICIENTS (/DAY)

SUBREACH	KR	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KA	KPO41	KPO42
1	0.78	0.58	0.04	1.68	1.68	1.68	0.25	0.25	0.08	20.36	0.08	0.0
2	1.19	0.62	0.08	5.03	8.39	8.39	0.50	0.50	0.17	24.51	0.17	0.0
3	1.19	0.62	0.08	5.03	8.39	8.39	0.50	0.50	0.17	23.39	0.17	0.0
4	1.13	0.55	0.08	4.62	15.39	15.39	6.15	6.15	0.15	25.71	0.15	0.0
5	1.13	0.43	0.08	2.31	9.23	9.23	4.62	4.62	0.15	16.16	0.46	0.0
6	1.13	0.43	0.08	2.31	9.23	9.23	4.62	4.62	0.15	15.89	0.46	0.0
7	1.13	0.33	0.08	0.77	4.62	4.62	9.23	9.23	3.54	11.25	1.23	0.0
8	1.13	0.42	0.08	0.46	4.62	4.62	12.31	12.31	0.31	18.29	1.23	0.0
9	1.13	0.42	0.08	0.46	4.62	4.62	12.31	12.31	0.15	24.19	1.23	0.0

SUBREACH	REAERATION COEFFICIENT DERIVATION
1	KA COMPUTED BY BENNETT - RATHBUN EQUATION
2	KA COMPUTED BY BENNETT - RATHBUN EQUATION
3	KA COMPUTED BY BENNETT - RATHBUN EQUATION
4	KA COMPUTED BY BENNETT - RATHBUN EQUATION
5	KA COMPUTED BY BENNETT - RATHBUN EQUATION
6	KA COMPUTED BY BENNETT - RATHBUN EQUATION
7	KA COMPUTED BY BENNETT - RATHBUN EQUATION
8	KA COMPUTED BY BENNETT - RATHBUN EQUATION
9	KA COMPUTED BY BENNETT - RATHBUN EQUATION

SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN

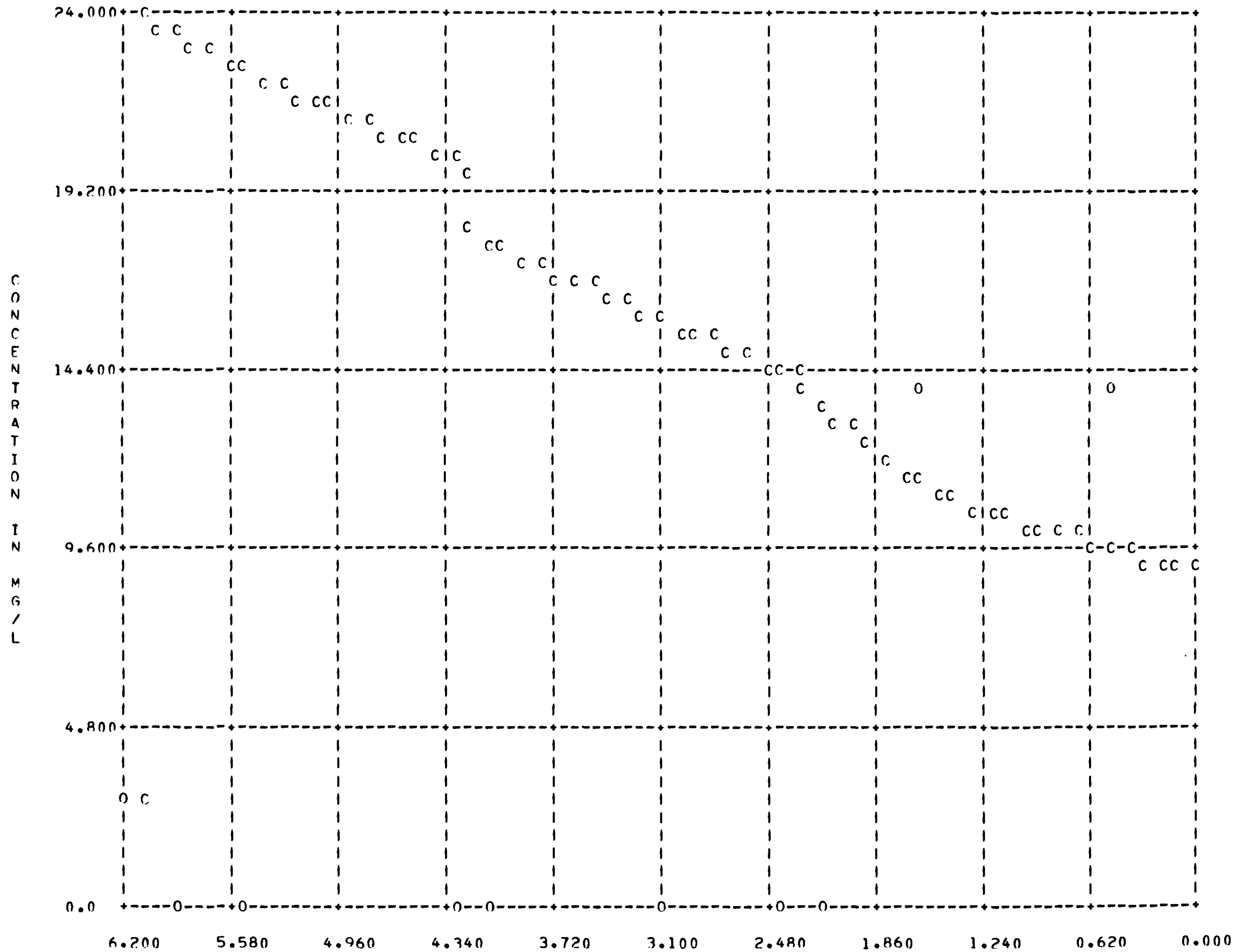
SUBREACH	DO SATURATION (MG/L)
1	9.442
2	8.085
3	8.085
4	8.235
5	8.235
6	8.235
7	8.235
8	8.235
9	8.235

SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN

O B S E R V E D   M E A S U R E M E N T S

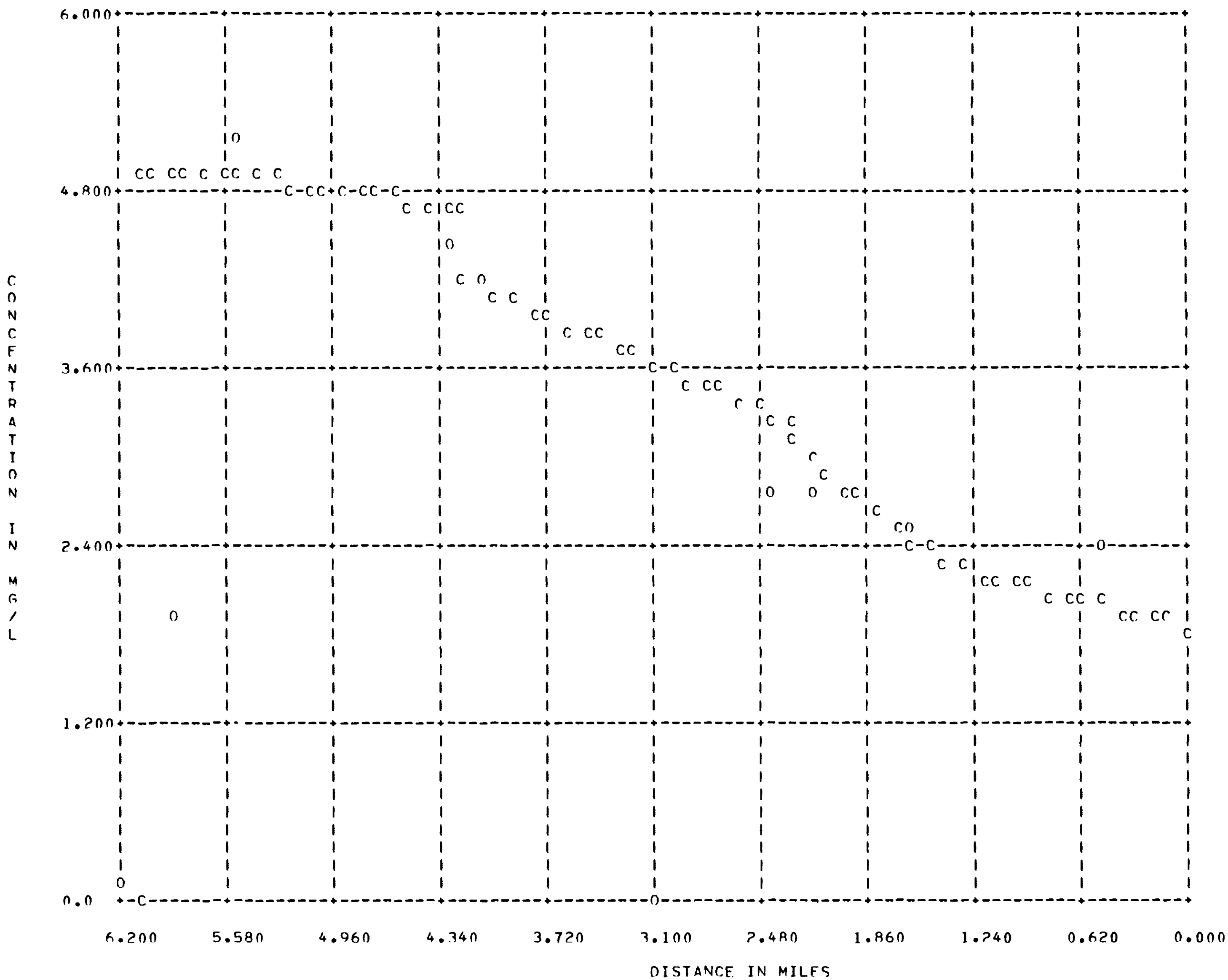
DISTANCE (MI)	DO CONC (MG/L)	TSS (MG/L)	SP COND (MG/L)	(MG/L)	CBODU (MG/L)	NBODU (MG/L)	ORG-N (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)	TOTAL COLIFORM	FECAL COLIFORM	PO4 (MG/L)
6.20	7.80	8.00	331.00	0.0	3.10	0.0	0.22	0.15	0.03	3.20	800.	540.	0.06
5.90	7.40	12.00	371.00	0.0	0.0	0.0	1.60	1.80	0.32	6.00	25.	17.	1.90
5.50	3.70	10.00	346.00	0.0	0.0	0.0	1.90	3.50	3.60	12.00	25.	11.	5.20
4.30	4.10	13.00	444.00	0.0	0.0	0.0	1.80	0.85	3.40	12.00	2400.	1100.	4.40
4.10	0.0	14.00	445.00	0.0	0.0	0.0	2.80	0.85	3.40	13.00	0.	0.	4.20
3.10	3.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	0.0
2.40	0.0	16.00	406.00	0.0	0.0	0.0	1.20	0.76	2.00	6.00	1200.	630.	2.70
2.20	0.0	17.00	406.00	0.0	0.0	0.0	1.50	0.14	0.16	8.00	1200.	200.	2.80
1.60	4.00	13.00	392.00	0.0	14.00	0.0	1.50	0.12	0.53	7.00	1300.	1300.	2.50
0.50	0.0	11.00	388.00	0.0	14.00	0.0	1.20	0.10	0.23	7.10	690.	180.	2.40

SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED CBOD CONCENTRATIONS VERSUS DISTANCE

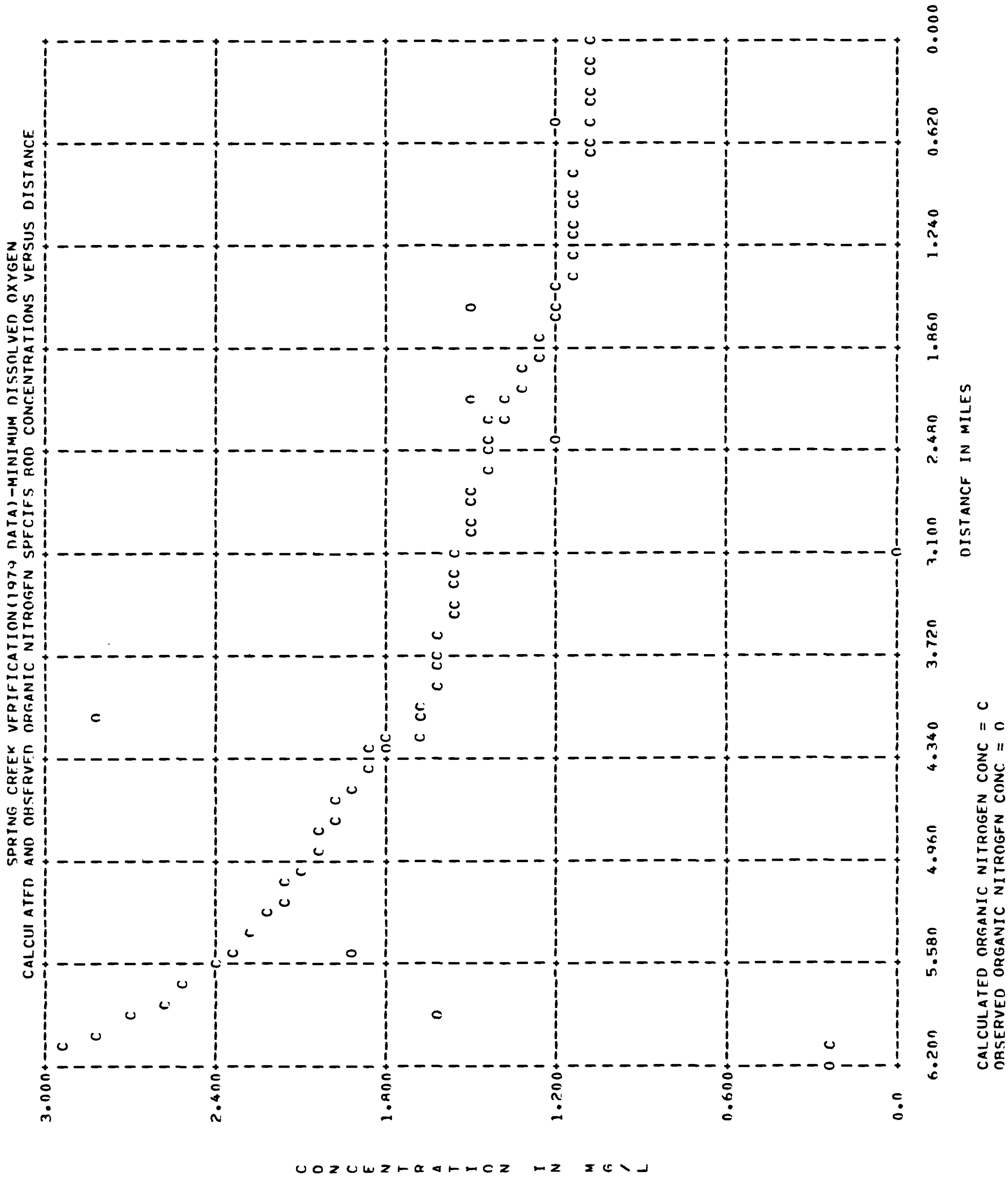


CALCULATED CBODU CONC = C
OBSERVED CBODU CONC = O

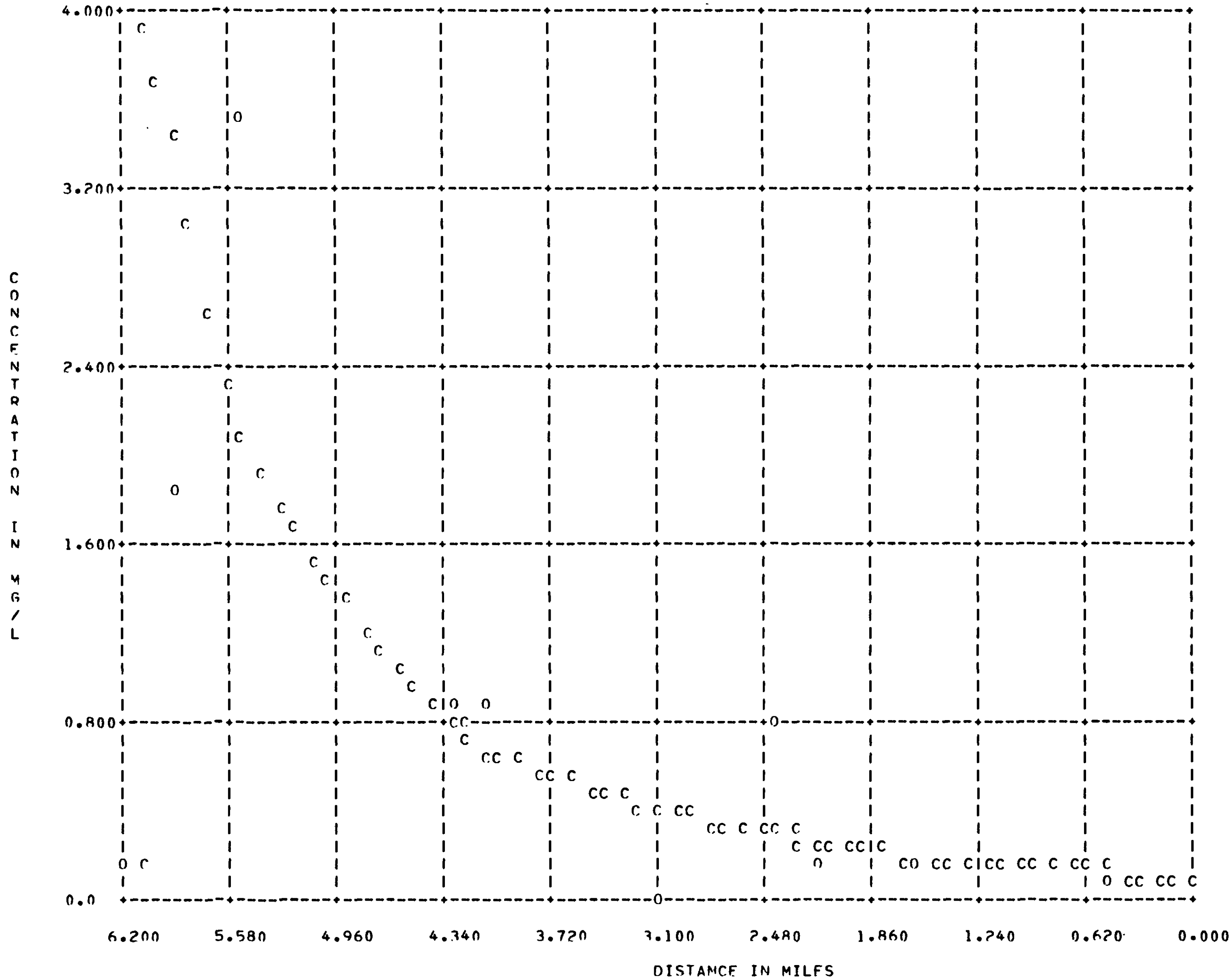
SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED PO4 CONCENTRATIONS VERSUS DISTANCE



CALCULATED PO4 CONC = C
OBSERVED PO4 CONC = O

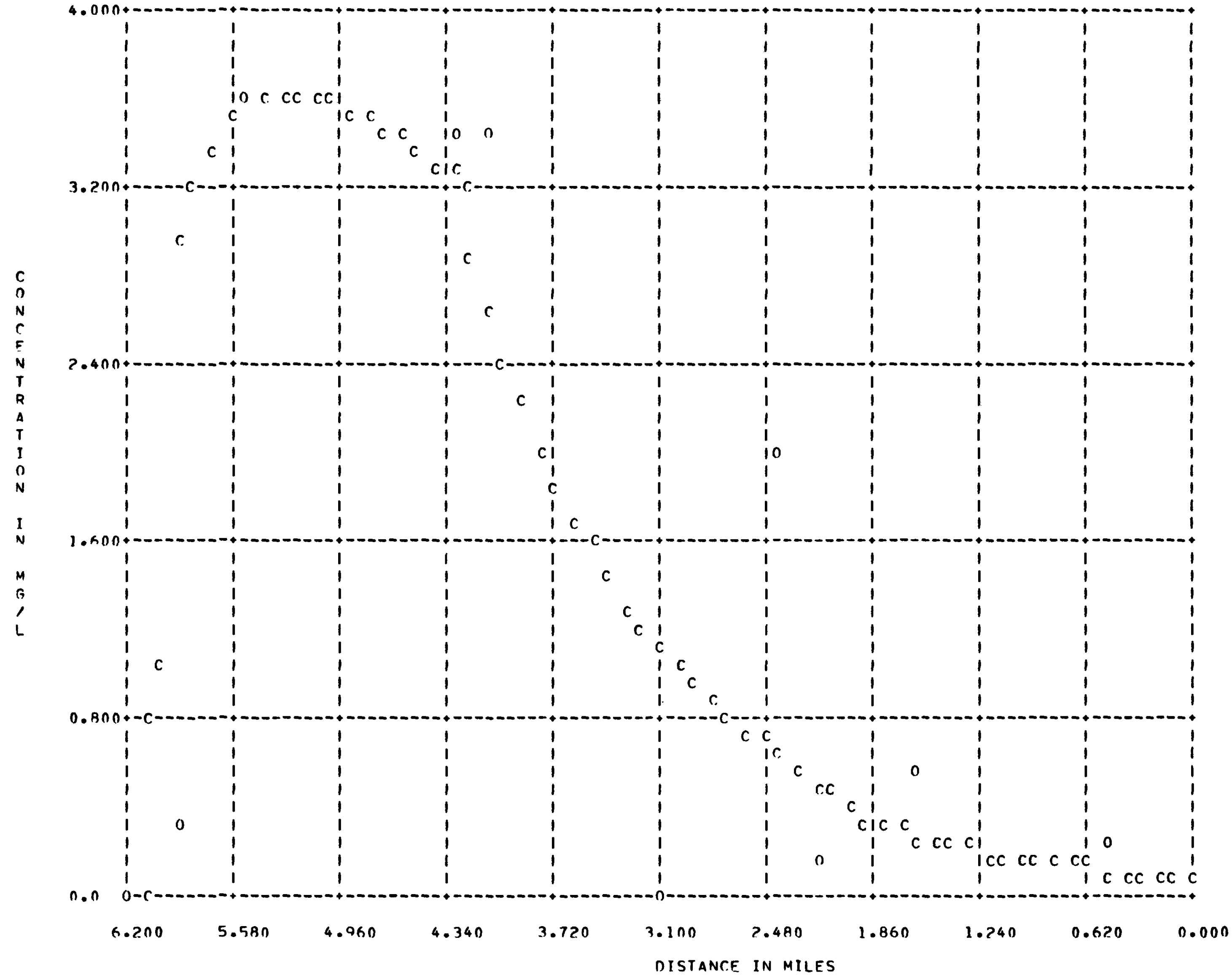

SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED ORGANIC NITROGEN SPECIES ROD CONCENTRATIONS VERSUS DISTANCE
3.000
2.400
1.800
1.200
0.600
0.0
CONCENTRATION IN MG/L
6.200
5.580
4.960
4.340
3.720
3.100
2.480
1.860
1.240
0.620
0.000
DISTANCE IN MILES
CALCULATED ORGANIC NITROGEN CONC = C
OBSERVED ORGANIC NITROGEN CONC = O

SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED AMMONIA NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



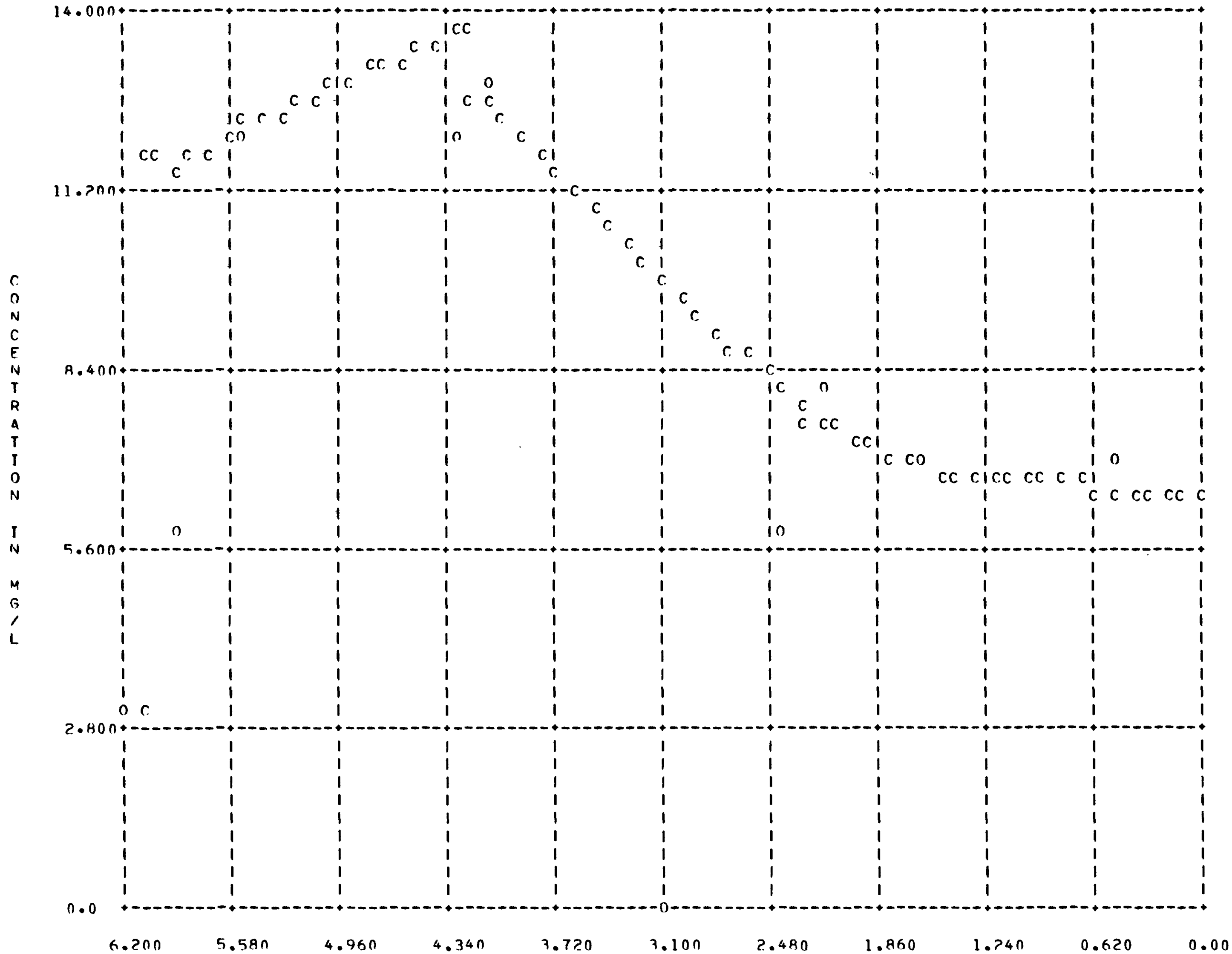
CALCULATED AMMONIA NITROGEN CONC = C
OBSERVED AMMONIA NITROGEN CONC = O

SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED NITRITE NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



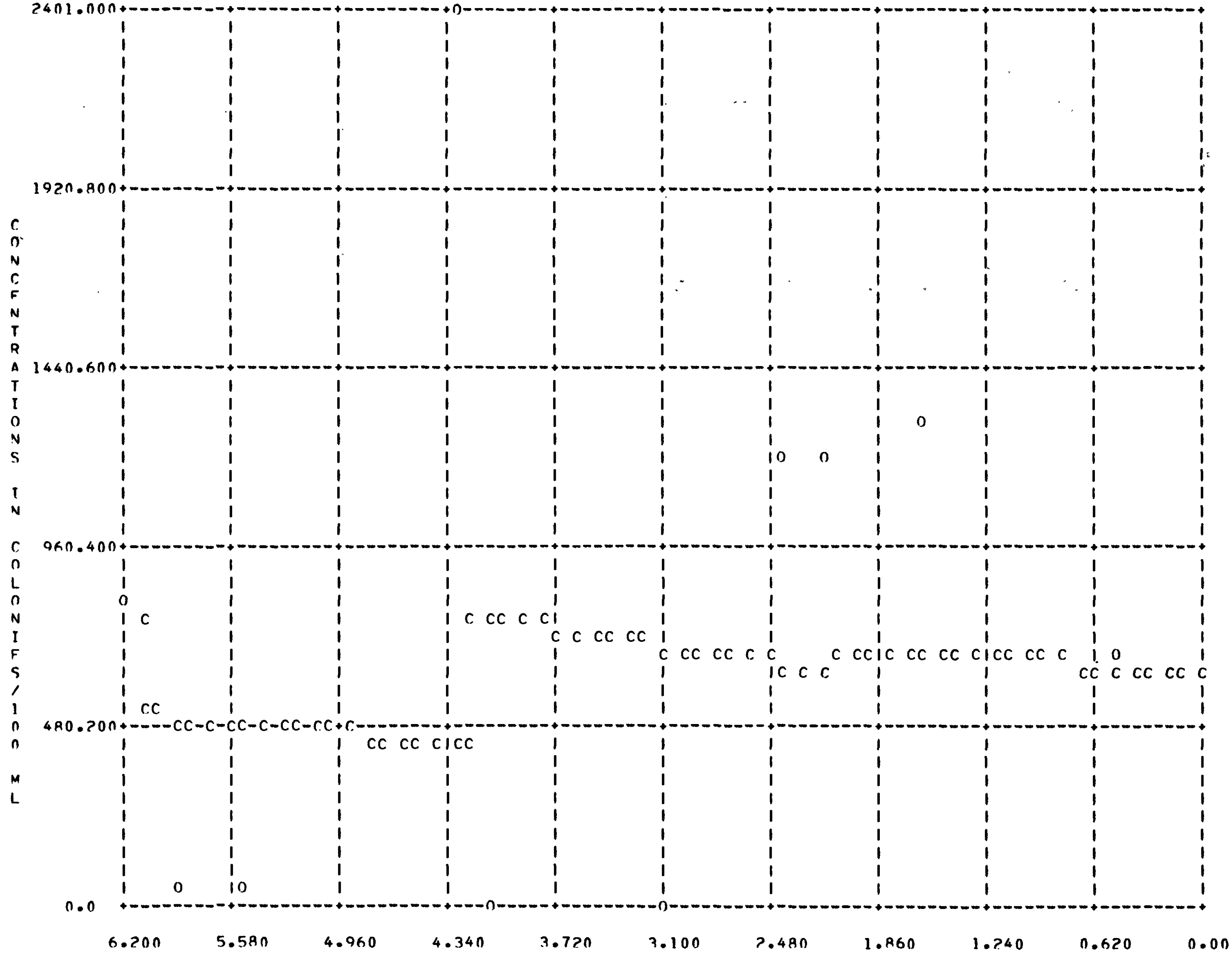
CALCULATED NITRITE NITROGEN CONC = C
OBSERVED NITRITE NITROGEN CONC = O

SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED NITRATE NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



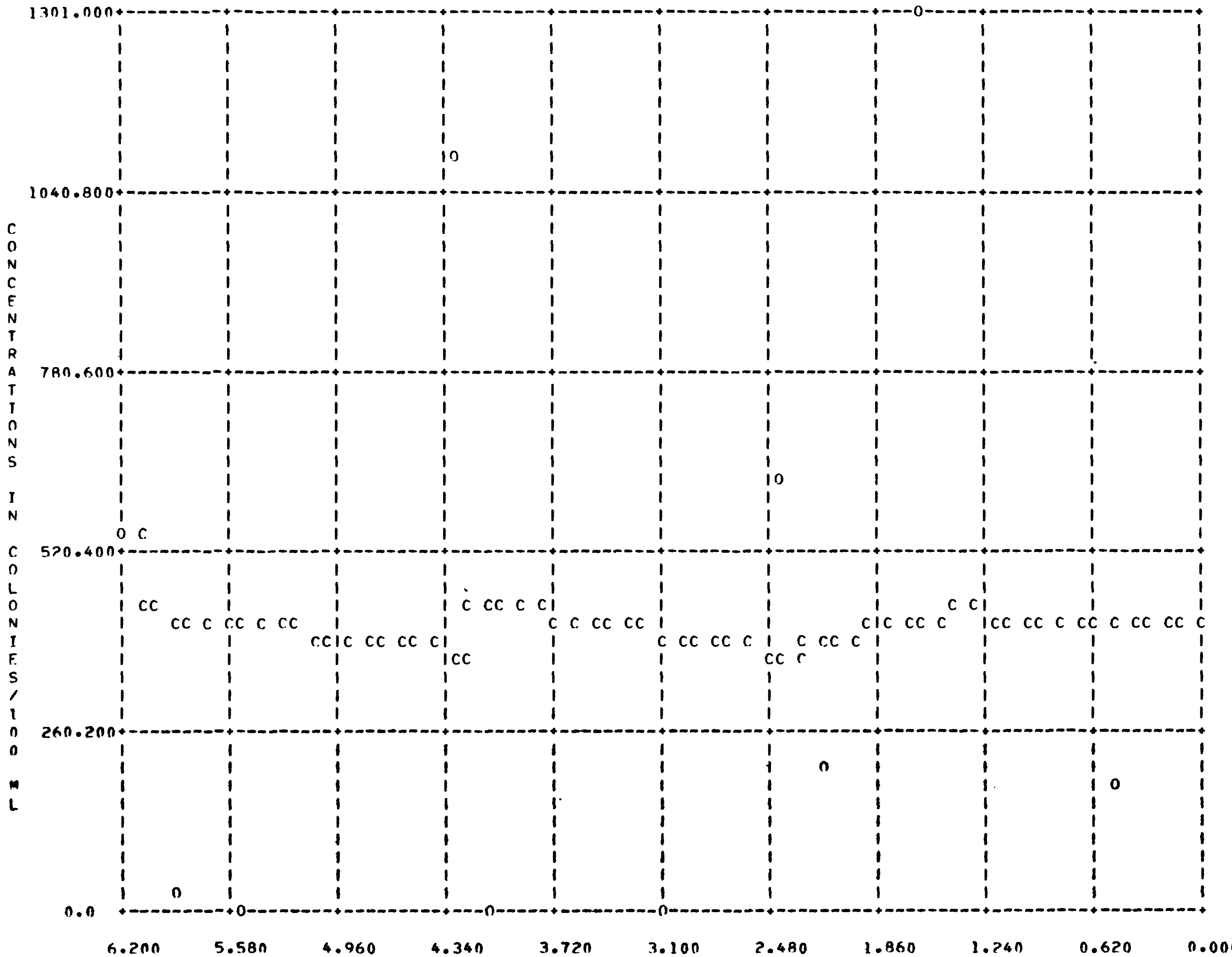
CALCULATED NITRATE NITROGEN CONC = C
OBSERVED NITRATE NITROGEN CONC = O

SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED TOTAL COLIFORM CONCENTRATIONS VERSUS DISTANCE



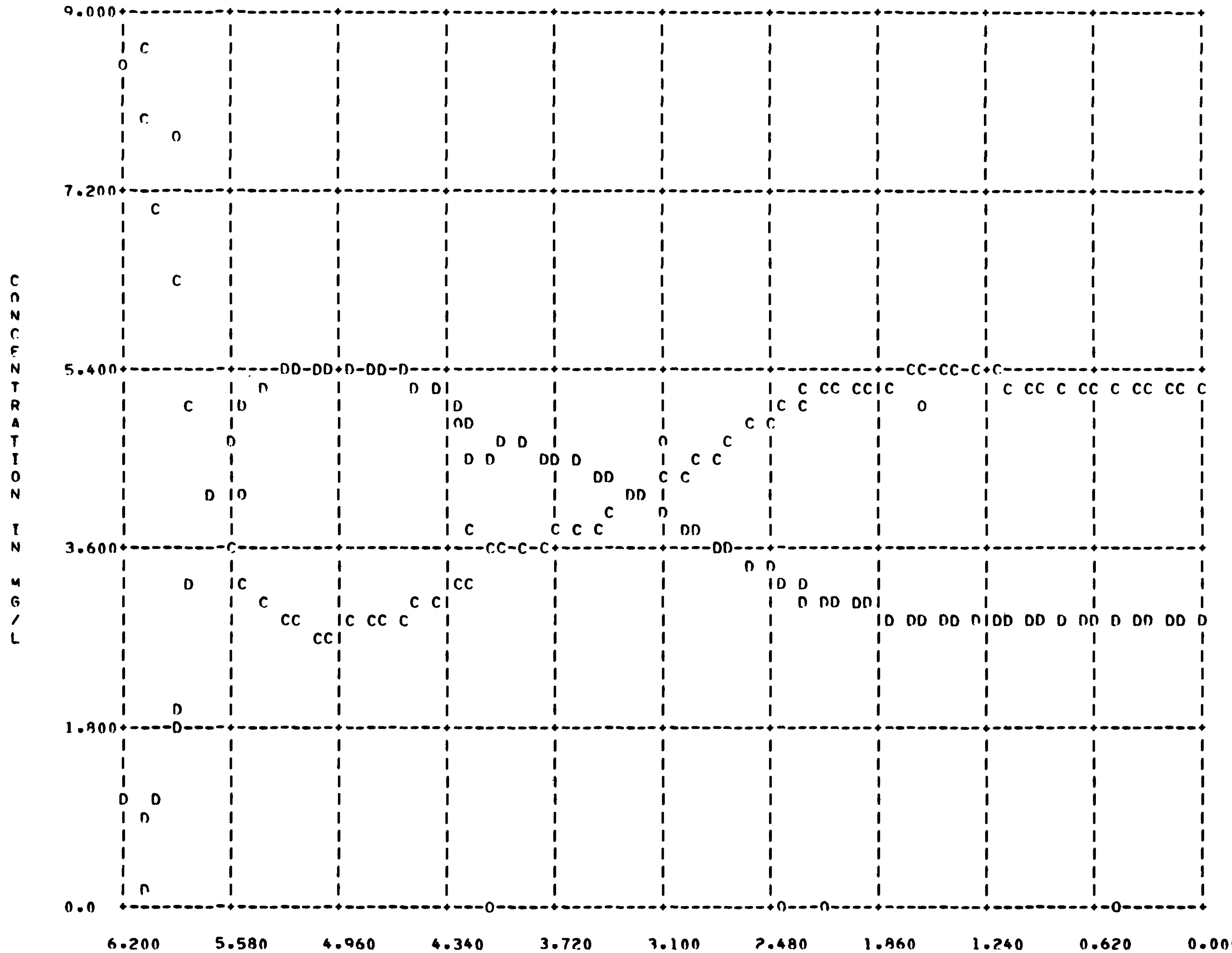
CALCULATED TOTAL COLIFORM CONC = C
OBSERVED TOTAL COLIFORM CONC = O

SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED FECAL COLIFORM CONCENTRATIONS VERSUS DISTANCE



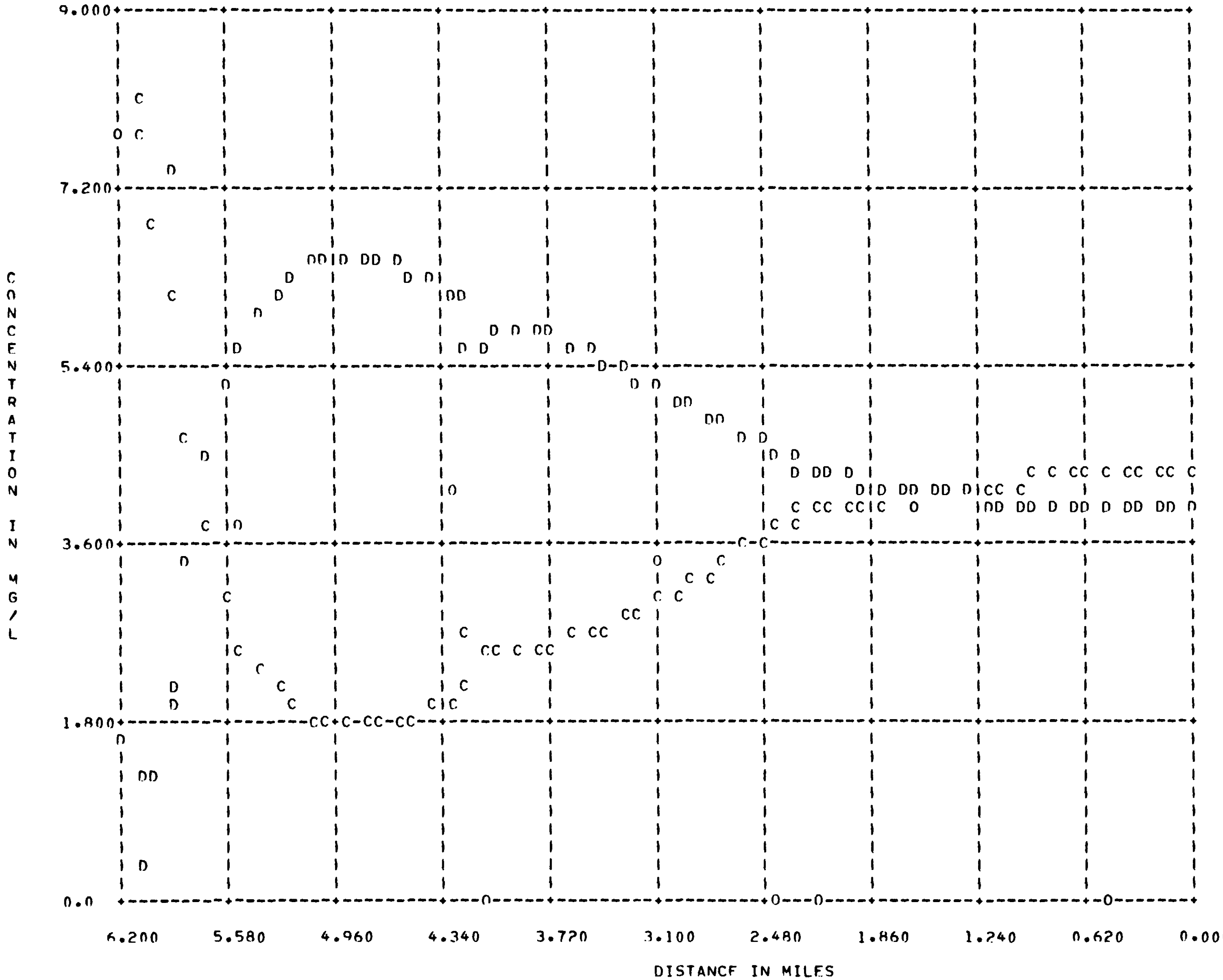
CALCULATED FECAL COLIFORM CONC = C
OBSERVED FECAL COLIFORM CONC = O

SPRING CREEK VERIFICATION(1979 DATA)-MEAN DISSOLVED OXYGEN
CALCULATED AND OBSERVED DO CONCENTRATIONS AND DO DEFICIT VERSUS DISTANCE

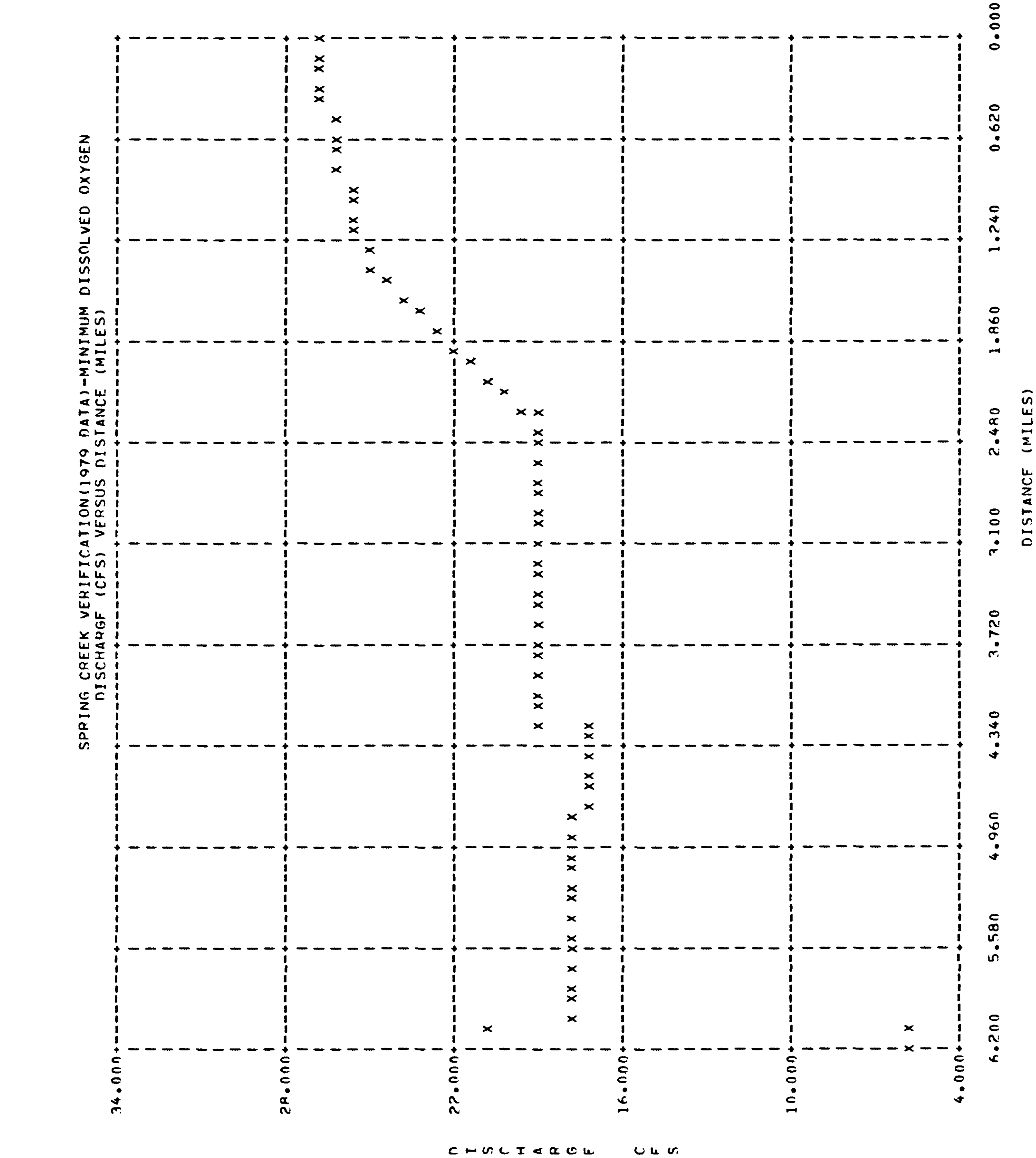


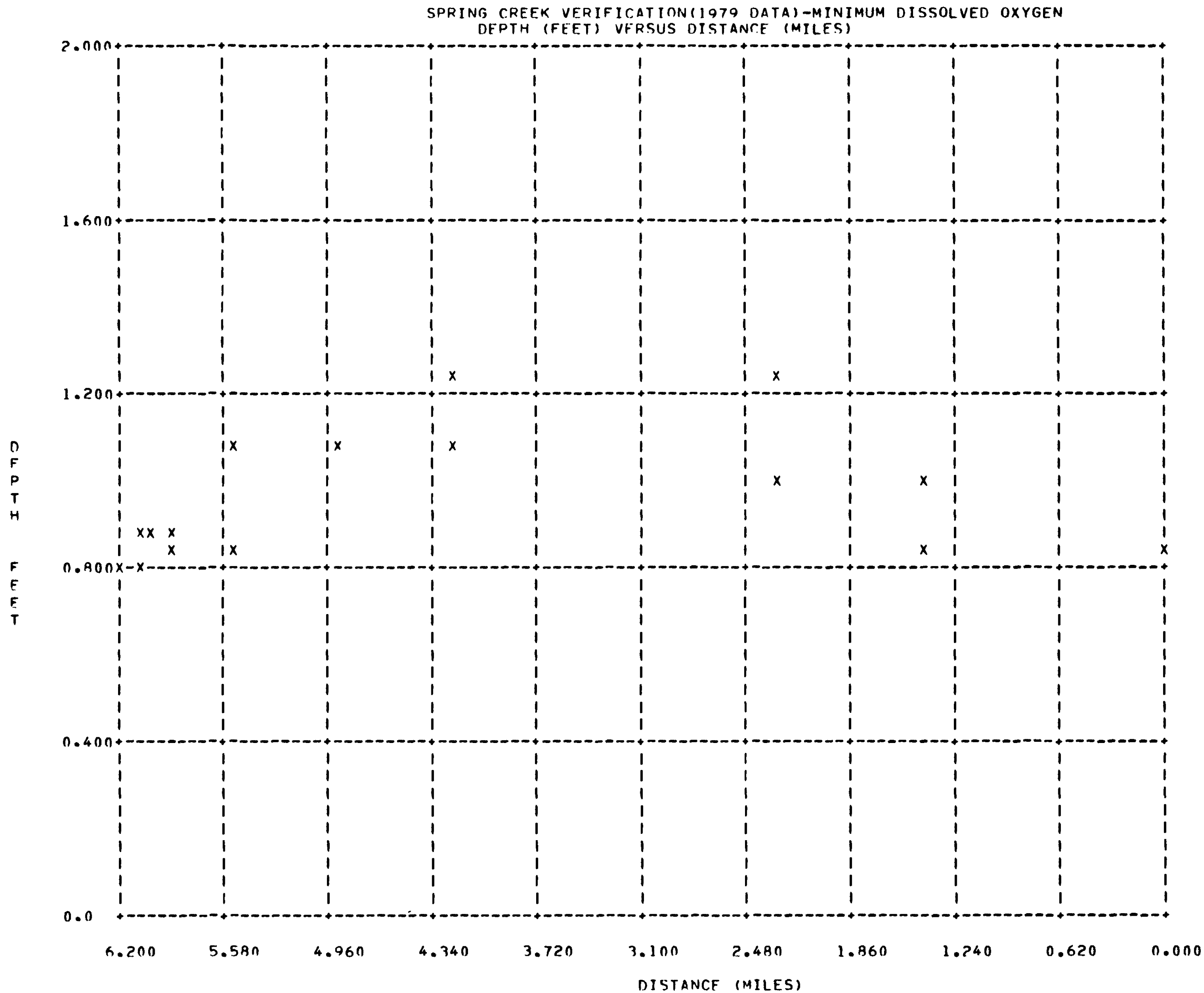
CALCULATED DO CONC = C
OBSERVED DO CONC = O
DO DEFICIT = D

SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED DO CONCENTRATIONS AND DO DEFICIT VERSUS DISTANCE



CALCULATED DO CONC = C
OBSERVED DO CONC = O
DO DEFICIT = D


SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN
DISCHARGE (CFS) VERSUS DISTANCE (MILES)
DISCHARGE CFS
34.000
28.000
22.000
16.000
10.000
4.000
0.000
0.620
1.240
1.860
2.480
3.100
3.720
4.340
4.960
5.580
6.200
DISTANCE (MILES)



SPRING CREEK VERIFICATION(1979 DATA)-MINIMUM DISSOLVED OXYGEN
DEPTH (FEET) VERSUS DISTANCE (MILES)
DEPTH FEET
2.000
1.600
1.200
0.800
0.400
0.0
6.200
5.580
4.960
4.340
3.720
3.100
2.480
1.860
1.240
0.620
0.000
DISTANCE (MILES)

ATTACHMENT D

OSAGE CREEK CALIBRATION AND VERIFICATION

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                    STEADY STATE WATER QUALITY MODEL
                    GULF COAST HYDROSCIENCE CENTER
                       U. S. GEOLOGICAL SURVEY
                          (ARKANSAS VERSION)
                 DATE OF LAST REVISION. DECEMBER  1980

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN

         DISSOLVED OXYGEN PROFILE REPRESENTS
    ***  DIEL MINIMUMS; NET PHOTOSYNTHETIC DO  ***
         PRODUCTION ADJUSTED ACCORDINGLY.

        NITRIFICATION CYCLE INCLUDED IN MODEL

        NUMBER OF SUBREACHES FOR THIS PROBLEM =   11

            PRINTING INTERVAL (MILES) =   0.100
           STARTING DISTANCE (MILES) =   21.100
  INITIAL CBOD CONC (MG/L) AT STARTING DISTANCE =    2.08
  INITIAL ORGANIC NITROGEN CONC (MG/L) AT STARTING DISTANCE =   1.500
  INITIAL AMMONIUM NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.150
  INITIAL NITRITE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.020
  INITIAL NITRATE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   4.600
  INITIAL DO CONC (MG/L) AT STARTING DISTANCE =   5.900
  INITIAL PHOSPHATE CONC (MG/L) AT STARTING DISTANCE =   0.060
  INITIAL TOT. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =    7900.
  INITIAL FEC. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =    2100.
      STREAMFLOW (CFS) AT STARTING DISTANCE =    9.900

      TOTAL SUSPENDED SOLIDS                    =   5.00
```

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN

SUBREACH LINEAR RUNOFF DATA

SUBREACH	Q (CFS)	CBOD (MG/L)	ORGANIC (MG/L)	AMMONIA (MG/L)	NITRITE (MG/L)	NITRATE (MG/L)	DO (MG/L)	TSS (MG/L)	SP COND (MG/L)	(MG/L)	PO4 (MG/L)
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	3.70	3.00	1.00	0.10	0.01	3.50	6.70	8.00	300.00	0.0	0.20
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	-3.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	-1.40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	-1.70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	1.40	3.00	1.00	0.10	0.01	3.50	6.70	8.00	300.00	0.0	0.20
9	8.50	3.00	2.00	0.10	0.01	3.50	6.70	8.00	300.00	0.0	0.20
10	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0

R E A C H D E S C R I P T I O N D A T A (MAJOR TRIBUTARIES AND MAIN STEM)

SUBREACH	CODE	NAME	BEGIN (MILE)	END (MILE)
1		ABOVE RODGERS STP	21.10	21.00
2		AT RODGERS STP	21.00	19.60
3		BL. STA. 35	19.60	17.10
4		A SPRING 36A	17.10	14.50
5		TRIB. 39A	14.50	13.10
6		SPRING CREEK	13.10	10.50
7		LITTLE OSAGE CREEK	10.50	6.20
8		BRUSHY CREEK	6.20	4.90
9		WILDCAT CREEK	4.90	2.00
10		TRIB. 57	2.00	1.20
11		LOGAN	1.20	0.0

KEY: CODE

A ROCKY BOTTOM-POOL RIFFLE-LIGHT VEGETATION
B ROCKY BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
C ROCKY BOTTOM-POOL RIFFLE-HEAVY VEGETATION
D ROCKY BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
E ROCKY BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
F ROCKY BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION
G MUD BOTTOM-POOL RIFFLE-LIGHT VEGETATION
H MUD BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
I MUD BOTTOM-POOL RIFFLE-HEAVY VEGETATION
J MUD BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
K MUD BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
L MUD BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN

I N P U T   P A R A M E T E R S

CONCENTRATIONS(MG/L) OF --

SUBREACH	CARB BOD	ORG-N	NH3-N	NO2-N	NO3-N	DISSOLVED OXYGEN	PO4	TOT.COLIF.	FEC.COLIF.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	25.04	5.20	1.00	0.77	7.50	4.50	5.10	800.00	170.00
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	4.49	0.99	0.11	0.01	5.20	8.30	0.02	300.00	170.00
6	4.53	1.10	0.12	0.03	5.60	4.90	1.50	490.00	410.00
7	2.28	0.57	0.12	0.01	2.50	5.40	0.02	160.00	130.00
8	3.15	0.74	0.11	0.01	2.60	4.90	0.05	1700.00	1700.00
9	3.25	0.61	0.06	0.01	1.90	4.90	0.11	1800.00	1800.00
10	3.05	1.00	0.10	0.01	3.30	6.40	0.03	5400.00	1000.00
11	3.23	0.68	0.14	0.01	1.10	6.00	0.05	5000.00	5000.00

DIRECT DISCHARGES(LB/DAY) OF --

SUBREACH	CARBONACEOUS ULT. BOD	ORGANIC NITROGEN	AMMONIA NITROGEN	NITRITE NITROGEN	NITRATE NITROGEN	PHOSPHATE
1	0.0	0.0	0.0	0.0	0.0	0.
2	0.0	0.0	0.0	0.0	0.0	0.
3	0.0	0.0	0.0	0.0	0.0	0.
4	0.0	0.0	0.0	0.0	0.0	0.
5	0.0	0.0	0.0	0.0	0.0	0.
6	0.0	0.0	0.0	0.0	0.0	0.
7	0.0	0.0	0.0	0.0	0.0	0.
8	0.0	0.0	0.0	0.0	0.0	0.
9	0.0	0.0	0.0	0.0	0.0	0.
10	0.0	0.0	0.0	0.0	0.0	0.
11	0.0	0.0	0.0	0.0	0.0	0.

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN

SUBREACH	NET PHOTOSYNTHETIC DO PRODUCTION (MG/L/DAY @ 20 DEG C)	(FITTING FACTOR FOR MINIMUM DO PROFILE)	BENTHIC DO DEMAND (G/SQM/DAY @ 20 DEG C)
1	6.605	0.0	0.50
2	4.303	-5.000	14.00
3	4.303	-2.000	7.50
4	2.610	-3.000	4.00
5	6.682	-8.000	4.50
6	8.855	-5.000	6.00
7	4.659	-2.500	6.50
8	2.662	0.0	4.00
9	2.857	-2.500	5.00
10	3.040	-2.500	5.00
11	2.589	0.0	5.00

G E O M E T R Y

SUBREACH	FLOW CHANGE (CFS)	AREA (SQFT)	DEPTH (FT)	SLOPE	TEMP (DEG.CENT)	END MI (MI)
1	0.0	29.	1.90	0.0094700	19.00	21.0
2	6.40	58.	3.20	0.0027000	21.00	19.6
3	0.0	58.	3.20	0.0027000	21.00	17.1
4	0.0	47.	1.90	0.0021000	21.00	14.5
5	3.50	47.	1.90	0.0020400	22.00	13.1
6	29.70	92.	2.00	0.0017100	23.00	10.5
7	13.60	106.	2.00	0.0015000	23.00	6.2
8	8.30	118.	2.50	0.0015000	23.00	4.9
9	2.40	135.	2.50	0.0015800	24.00	2.0
10	0.20	136.	1.80	0.0027000	24.00	1.2
11	2.80	140.	1.90	0.0014600	22.00	0.0

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN

REACTION COEFFICIENTS (/DAY @ 20 DEG C)

SUBREACH	KR	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KCOLF	KCOLT	KPO41	KPO4
1	0.55	0.25	0.05	0.40	0.20	0.20	1.55	1.55	0.10	0.01	0.25	0.10	0.0
2	0.75	0.19	0.05	0.75	0.20	2.00	1.55	1.55	0.20	0.01	0.75	0.25	0.0
3	0.75	0.19	0.05	0.75	0.20	2.00	1.55	1.55	0.20	0.01	0.75	0.25	0.0
4	0.50	0.19	0.05	0.50	0.20	0.20	1.55	1.55	0.20	0.01	0.50	0.25	0.0
5	0.50	0.16	0.05	0.40	0.20	0.20	1.55	1.55	0.90	0.01	0.50	0.01	0.0
6	0.20	0.17	0.05	0.40	0.20	0.20	1.55	1.55	0.10	0.01	0.50	0.01	0.0
7	0.20	0.26	0.05	2.00	0.50	0.50	1.55	1.55	0.10	0.50	0.50	0.01	0.0
8	0.40	0.18	0.05	0.20	0.50	0.50	1.55	1.55	0.10	0.50	0.50	0.01	0.0
9	0.40	0.19	0.05	0.20	0.50	0.50	1.55	1.55	0.10	5.00	0.50	0.01	0.0
10	0.30	0.22	0.05	0.20	0.50	0.50	1.55	1.55	0.10	0.50	0.50	0.01	0.0
11	0.30	0.25	0.05	0.20	1.00	1.00	1.55	1.55	0.10	2.00	0.50	0.01	0.0

TEMPERATURE CORRECTED REACTION COEFFICIENTS (/DAY)

SUBREACH	KR	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KA	KPO41	KPO42
1	0.53	0.24	0.05	0.37	0.18	0.18	1.42	1.42	0.09	3.47	0.09	0.0
2	0.79	0.19	0.05	0.82	0.22	2.18	1.69	1.69	0.22	1.43	0.27	0.0
3	0.79	0.19	0.05	0.82	0.22	2.18	1.69	1.69	0.22	1.52	0.27	0.0
4	0.52	0.20	0.05	0.55	0.22	0.22	1.69	1.69	0.22	4.16	0.27	0.0
5	0.55	0.17	0.06	0.48	0.24	0.24	1.84	1.84	1.07	4.51	0.01	0.0
6	0.23	0.20	0.06	0.52	0.26	0.26	2.01	2.01	0.13	4.61	0.01	0.0
7	0.23	0.29	0.06	2.59	0.65	0.65	2.01	2.01	0.13	4.83	0.01	0.0
8	0.46	0.20	0.06	0.26	0.65	0.65	2.01	2.01	0.13	3.35	0.01	0.0
9	0.48	0.22	0.07	0.28	0.71	0.71	2.19	2.19	0.14	3.36	0.01	0.0
10	0.36	0.26	0.07	0.28	0.71	0.71	2.19	2.19	0.14	6.02	0.01	0.0
11	0.33	0.28	0.06	0.24	1.19	1.19	1.84	1.84	0.12	5.26	0.01	0.0

SUBREACH	REAERATION COEFFICIENT DERIVATION
1	KA COMPUTED BY BENNETT - RATHBUN EQUATION
2	KA COMPUTED BY BENNETT - RATHBUN EQUATION
3	KA COMPUTED BY BENNETT - RATHBUN EQUATION
4	KA COMPUTED BY BENNETT - RATHBUN EQUATION
5	KA COMPUTED BY BENNETT - RATHBUN EQUATION
6	KA COMPUTED BY BENNETT - RATHBUN EQUATION
7	KA COMPUTED BY BENNETT - RATHBUN EQUATION
8	KA COMPUTED BY BENNETT - RATHBUN EQUATION
9	KA COMPUTED BY BENNETT - RATHBUN EQUATION
10	KA COMPUTED BY BENNETT - RATHBUN EQUATION
11	KA COMPUTED BY BENNETT - RATHBUN EQUATION

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN

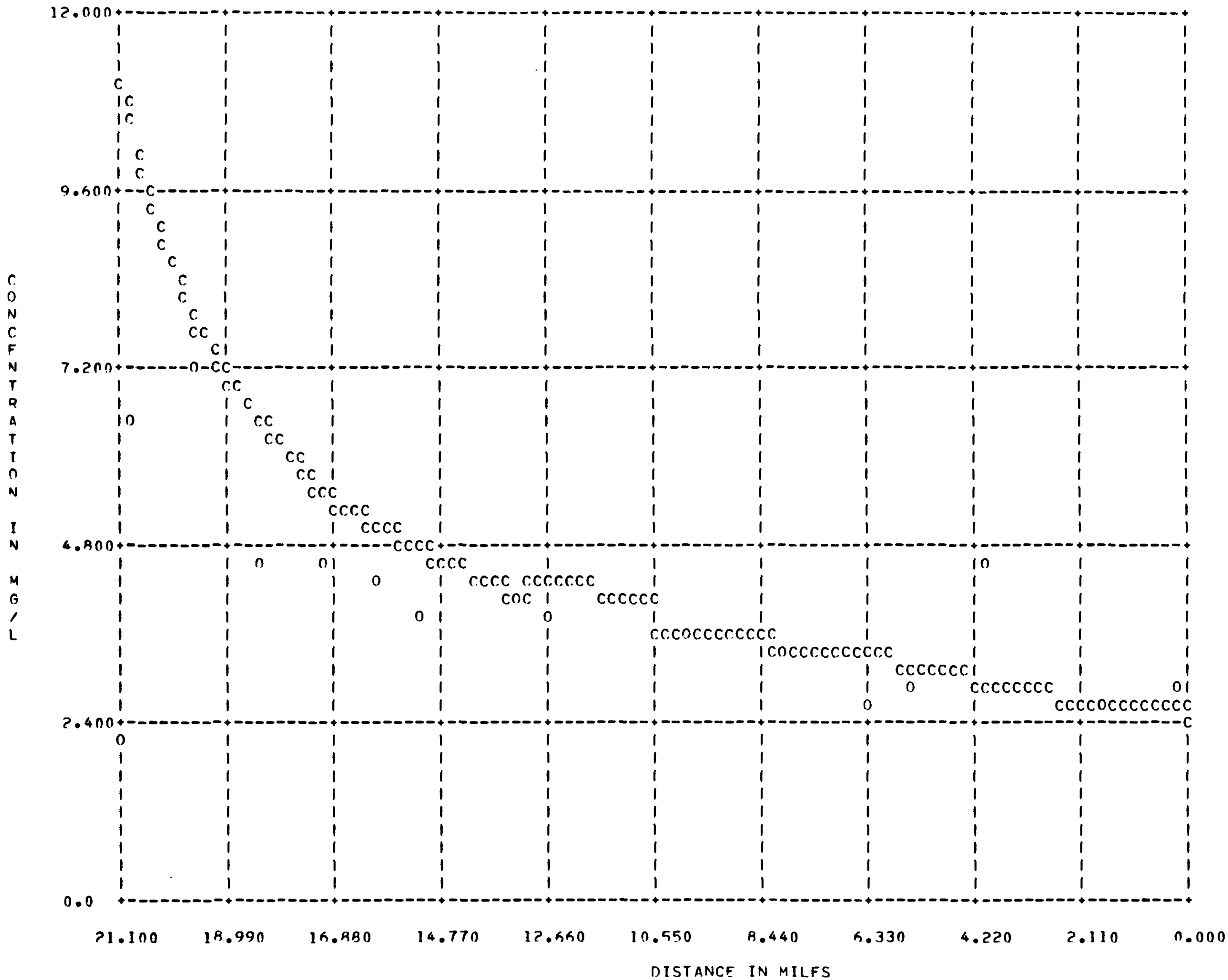
SUBREACH	DO SATURATION (MG/L)
1	9.251
2	8.888
3	8.888
4	8.888
5	8.717
6	8.551
7	8.551
8	8.551
9	8.390
10	8.390
11	8.717

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN

O B S E R V E D   M E A S U R E M E N T S

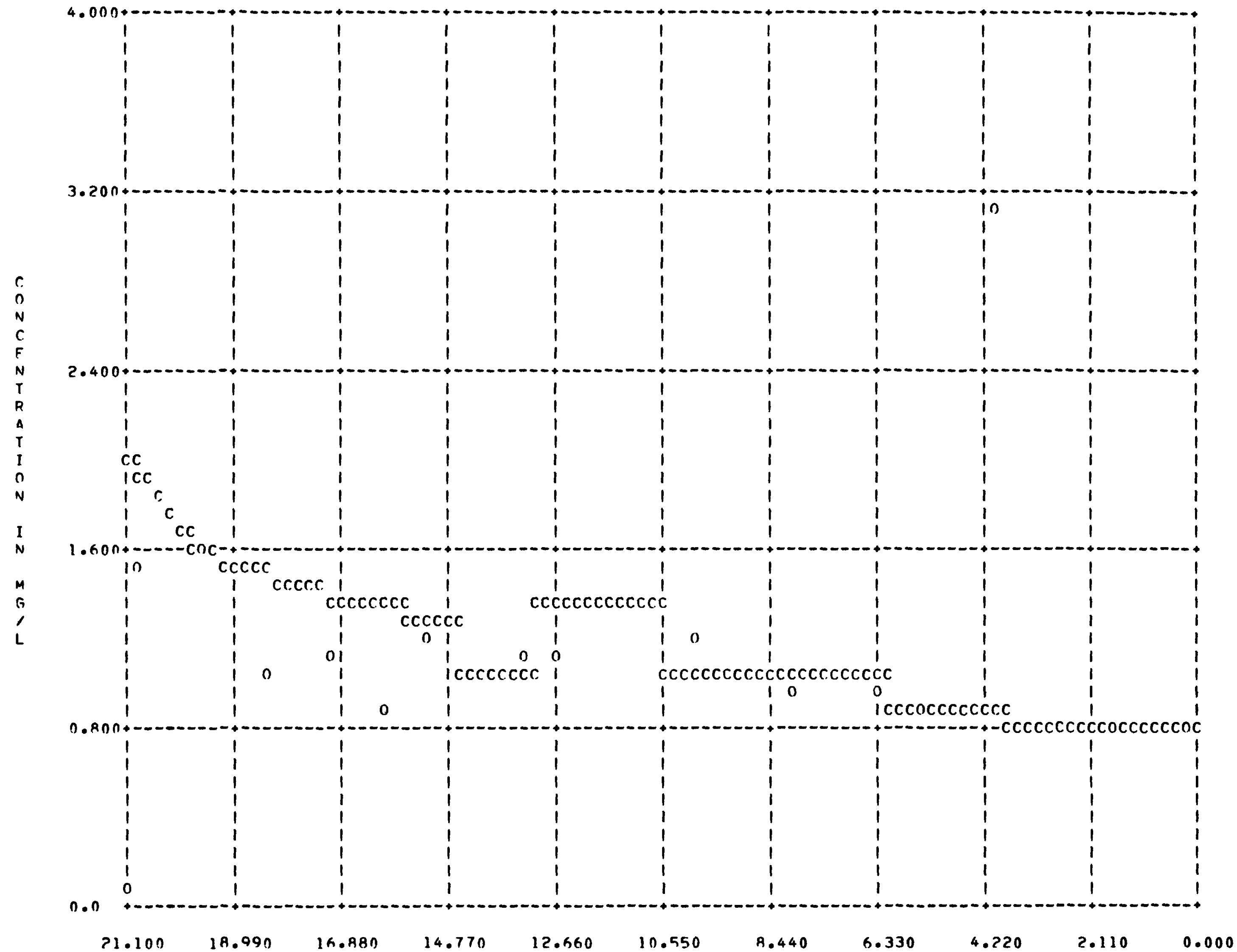
DISTANCE (MI)	DO CONC (MG/L)	TSS (MG/L)	SP COND (MG/L)	(MG/L)	CBODU (MG/L)	NBODU (MG/L)	ORG-N (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)	TOTAL COLIFORM	FECAL COLIFORM	PO4 (MG/L)
21.10	5.90	5.00	280.00	0.0	2.08	0.0	1.50	0.15	0.02	4.60	7900.	2100.	0.06
20.90	5.60	8.00	370.00	0.0	6.36	0.0	1.80	0.73	0.29	5.40	590.	280.	1.50
19.60	2.20	4.00	350.00	0.0	7.08	0.0	1.70	0.23	0.13	5.80	2700.	750.	1.60
18.40	0.0	6.00	330.00	0.0	4.56	0.0	1.20	0.14	0.08	4.90	14000.	5400.	1.00
17.00	5.40	76.00	350.00	0.0	4.57	0.0	1.30	0.13	0.06	5.20	0.	0.	1.10
16.10	6.00	11.00	350.00	0.0	4.26	0.0	1.20	0.12	0.02	5.20	18000.	2300.	0.89
15.20	5.90	11.00	350.00	0.0	3.90	0.0	1.30	0.14	0.02	5.30	4200.	800.	1.20
13.20	0.0	15.00	390.00	0.0	3.97	0.0	0.99	0.11	0.01	5.20	1600.	1100.	1.10
12.60	5.40	11.00	360.00	0.0	3.75	0.0	0.95	0.15	0.02	4.40	530.	330.	1.10
10.00	6.10	13.00	370.00	0.0	3.64	0.0	1.30	0.14	0.01	4.90	6500.	420.	1.20
8.10	6.20	11.00	0.0	0.0	3.26	0.0	0.61	0.11	0.01	3.60	390.	390.	0.98
6.40	0.0	13.00	350.00	0.0	2.61	0.0	0.52	0.09	0.01	3.30	550.	260.	0.96
5.40	6.30	19.00	340.00	0.0	2.95	0.0	0.55	0.10	0.01	3.20	310.	190.	0.84
4.10	6.10	11.00	340.00	0.0	4.49	0.0	1.50	0.34	0.81	8.30	280.	200.	3.10
1.60	6.00	9.00	330.00	0.0	2.68	0.0	1.00	0.10	0.01	3.30	200.	180.	0.79
0.30	6.80	18.00	300.00	0.0	2.89	0.0	0.79	0.09	0.01	3.30	1600.	600.	0.80

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED CBOD CONCENTRATIONS VERSUS DISTANCE



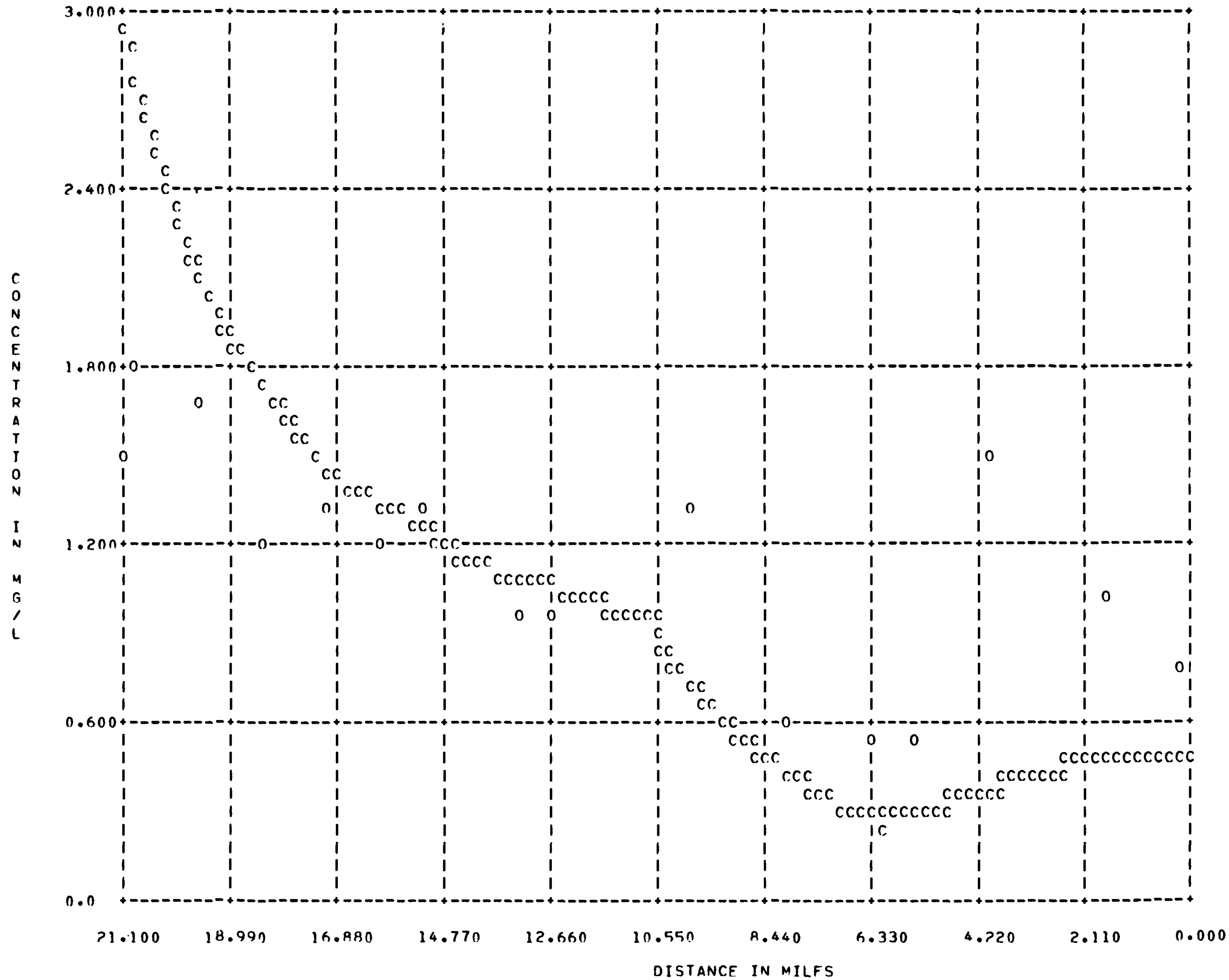
CALCULATED CBODU CONC = C
OBSERVED CBODU CONC = 0

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED PO4 CONCENTRATIONS VERSUS DISTANCE



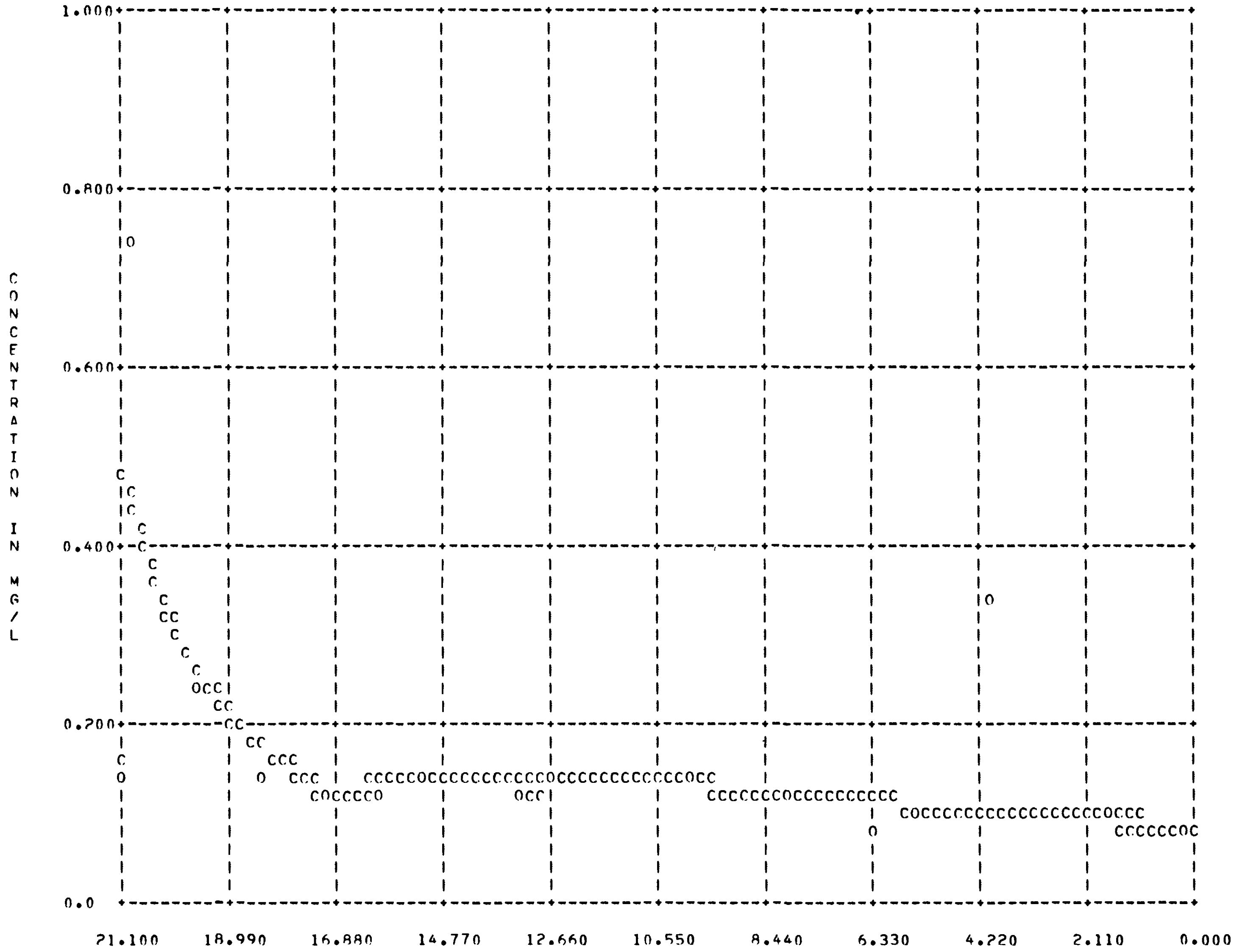
CALCULATED PO4 CONC = C
OBSERVED PO4 CONC = 0

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED ORGANIC NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE

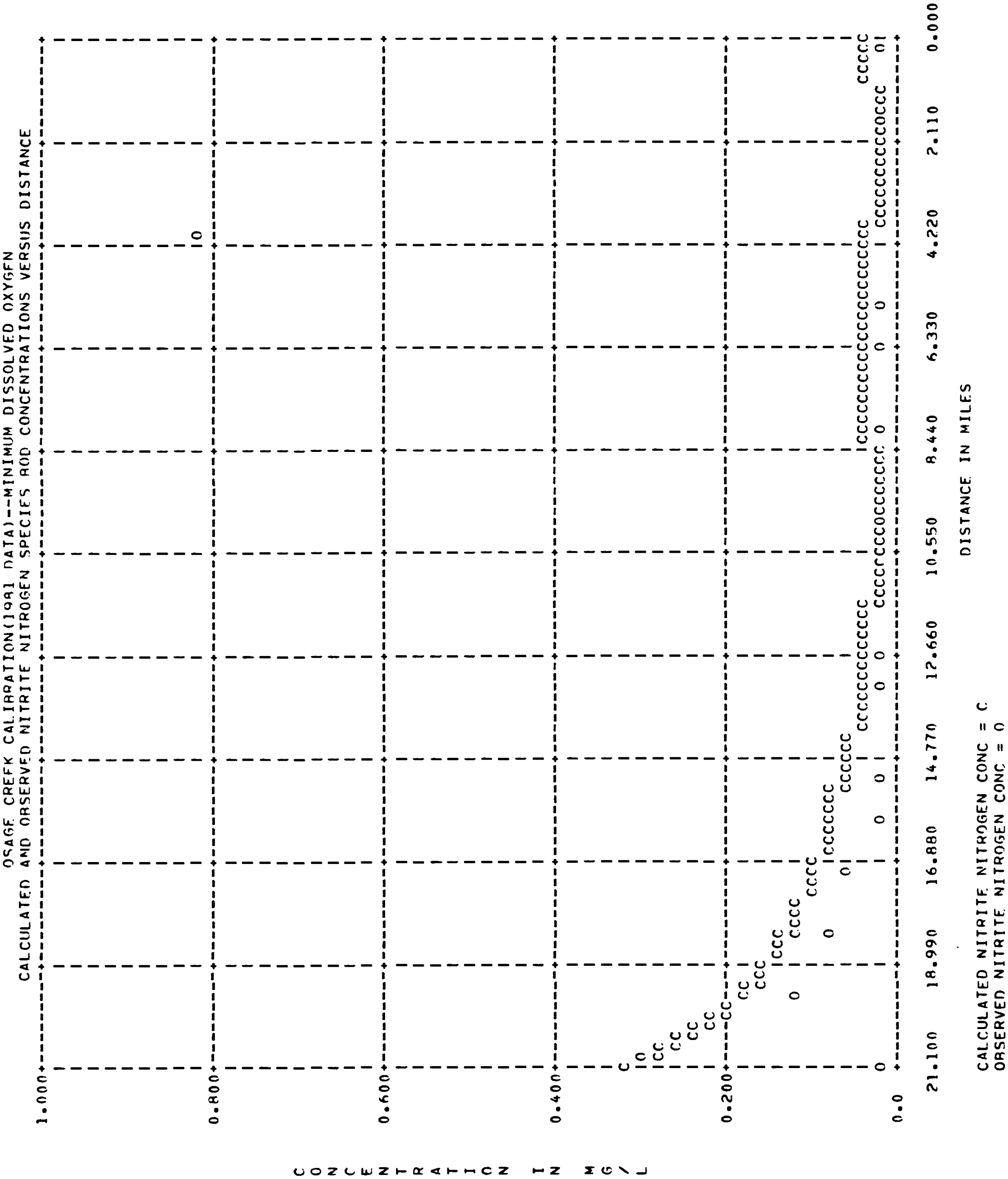


CALCULATED ORGANIC NITROGEN CONC = C
OBSERVED ORGANIC NITROGEN CONC = O

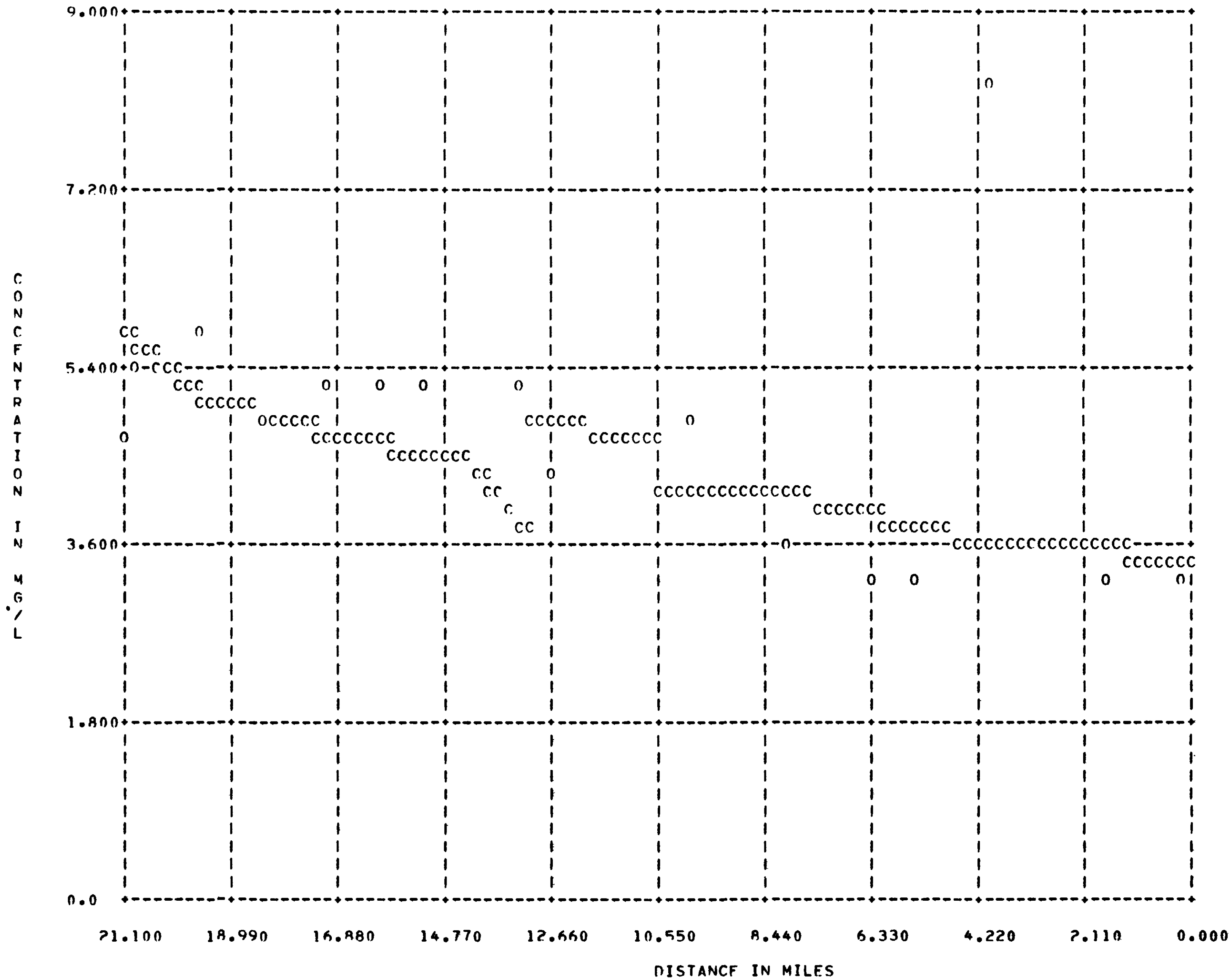
OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED AMMONIA NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



CALCULATED AMMONIA NITROGEN CONC = C
OBSERVED AMMONIA NITROGEN CONC = O

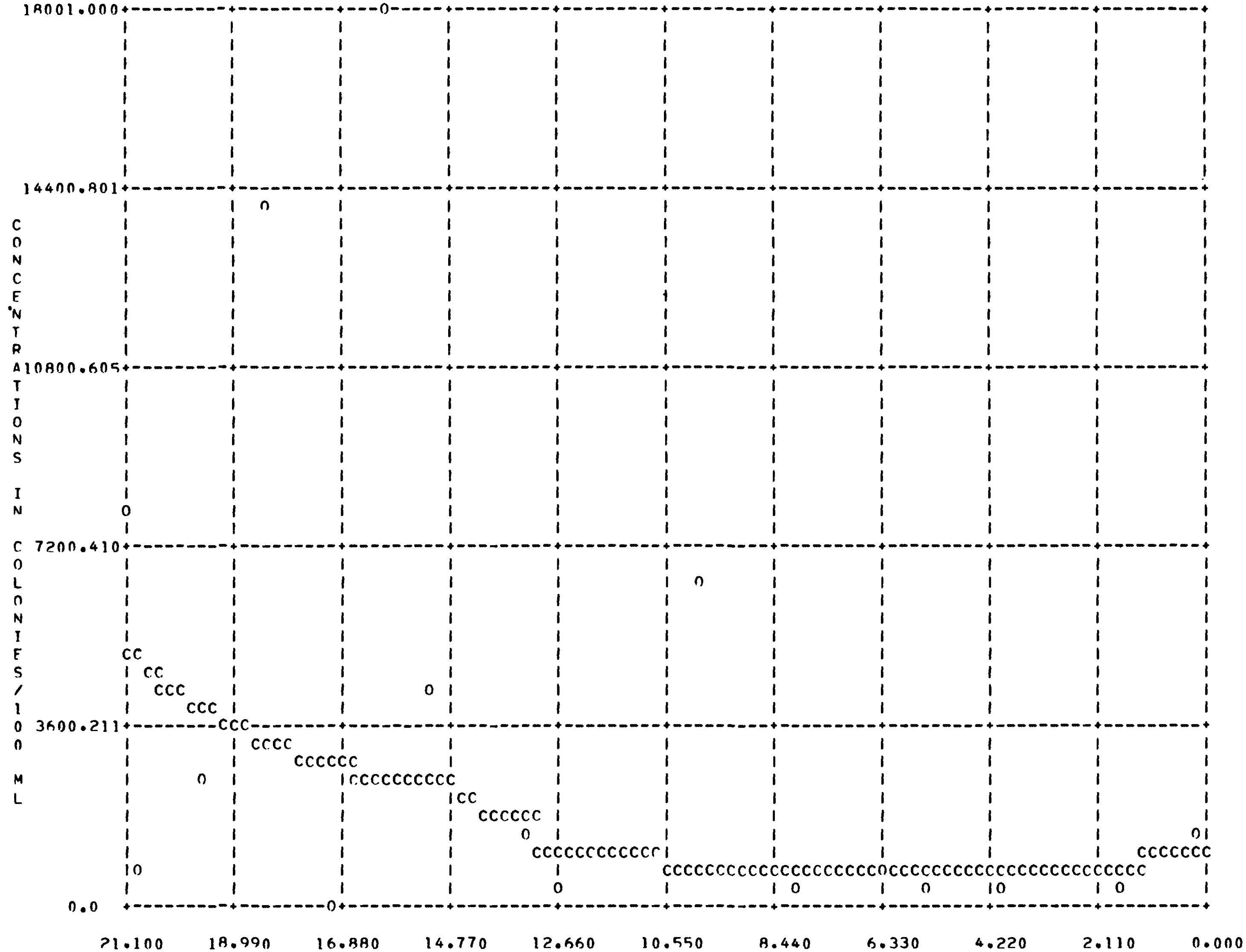

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED NITRITE NITROGEN SPECIES AND CONCENTRATIONS VERSUS DISTANCE
CONCENTRATION IN MG/L
1.000
0.800
0.600
0.400
0.200
0.0
21.100
18.990
16.880
14.770
12.660
10.550
8.440
6.330
4.220
2.110
0.000
DISTANCE IN MILES
CALCULATED NITRITE NITROGEN CONC = C
OBSERVED NITRITE NITROGEN CONC = O

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED NITRATE NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



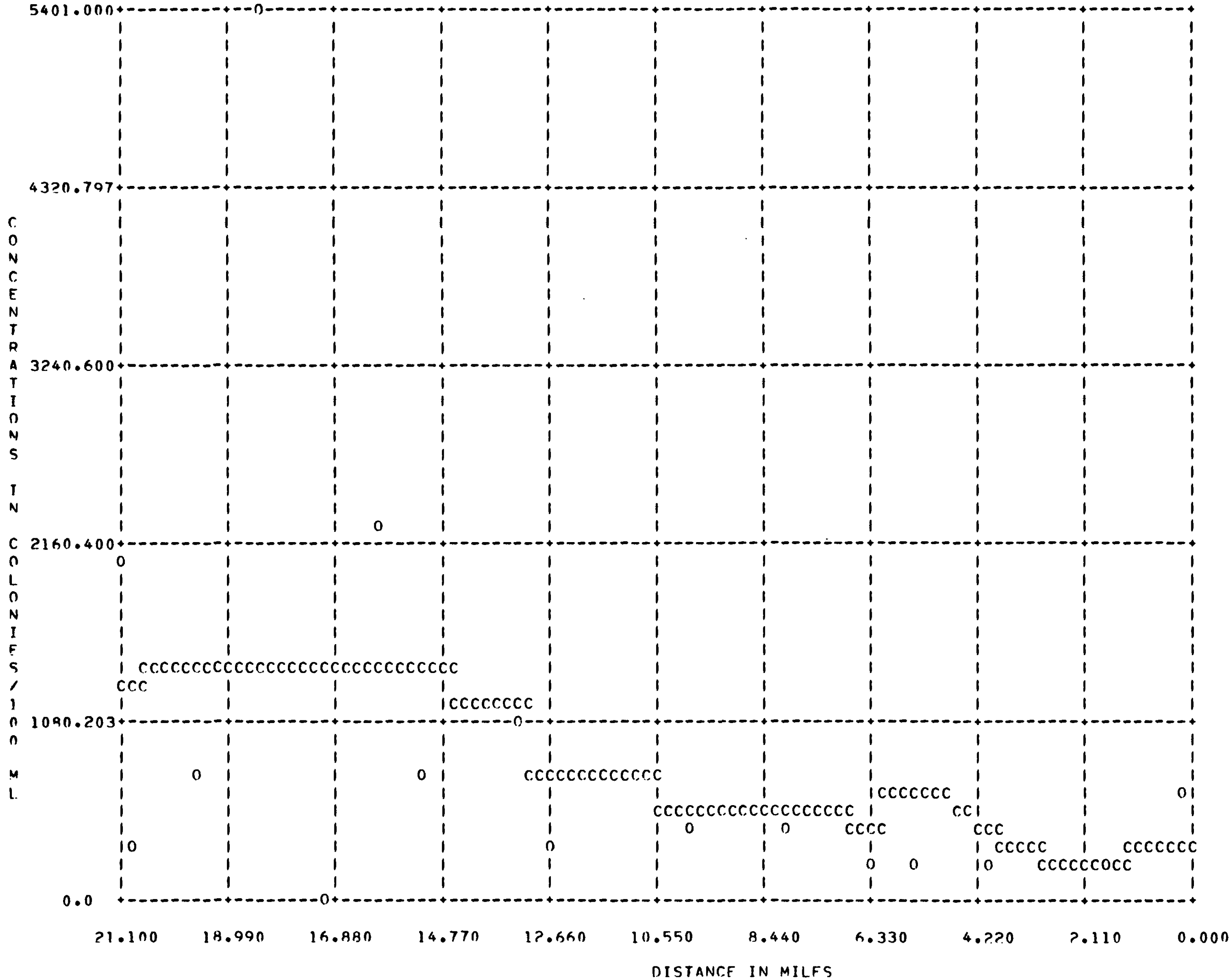
CALCULATED NITRATE NITROGEN CONC = C
OBSERVED NITRATE NITROGEN CONC = 0

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED TOTAL COLIFORM CONCENTRATIONS VERSUS DISTANCE



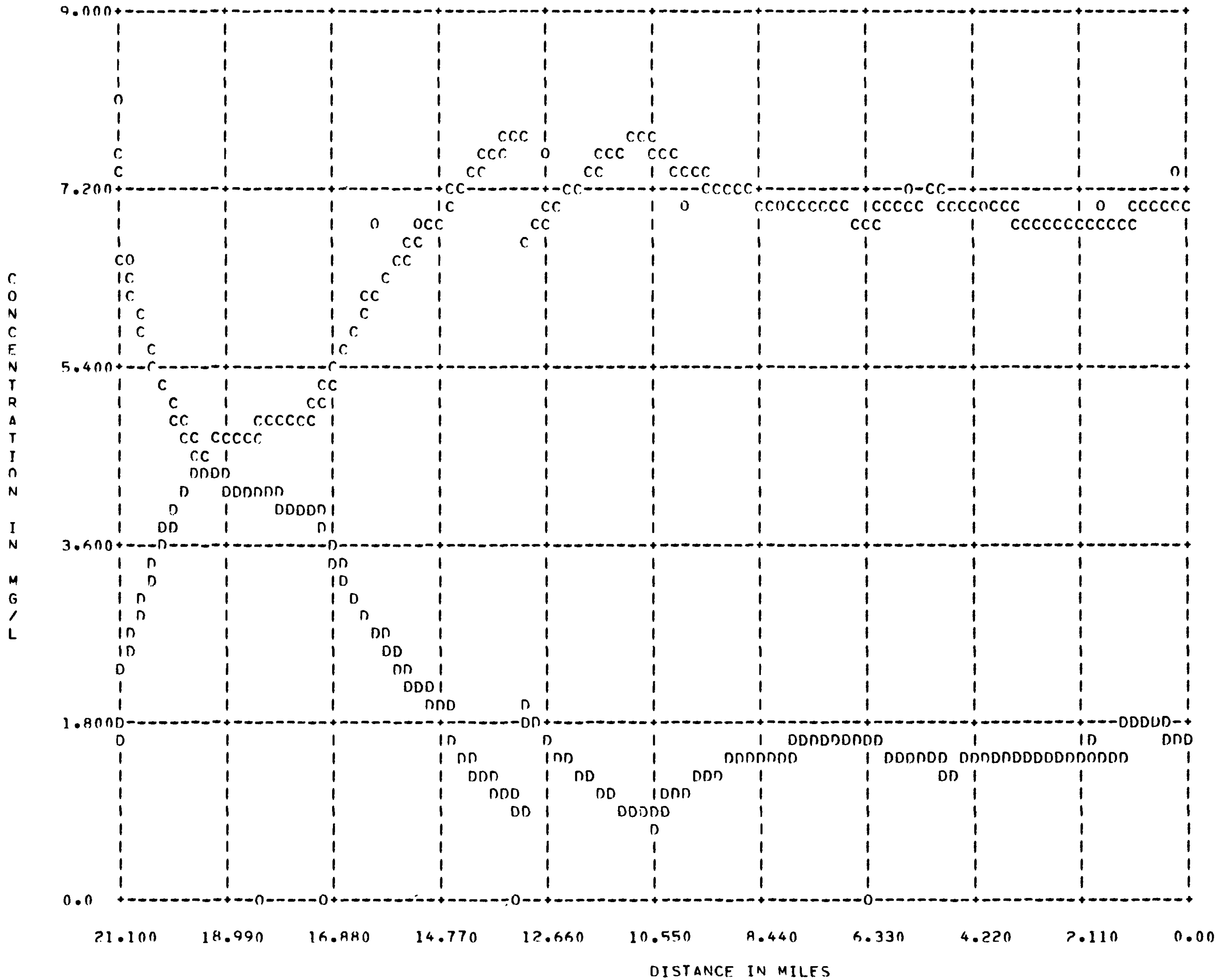
CALCULATED TOTAL COLIFORM CONC = C
OBSERVED TOTAL COLIFORM CONC = O

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED FECAL COLIFORM CONCENTRATIONS VERSUS DISTANCE



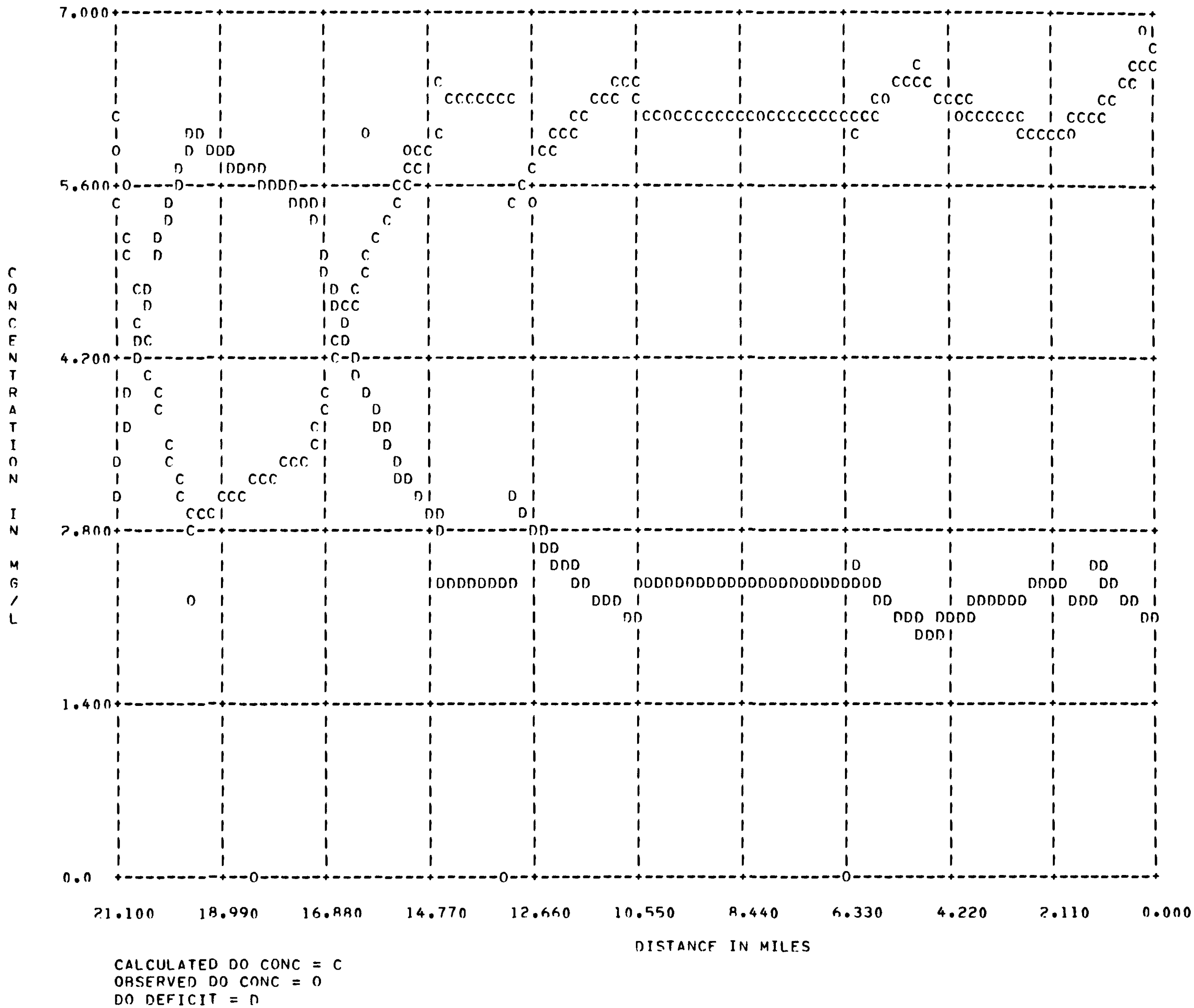
CALCULATED FECAL COLIFORM CONC = C
OBSERVED FECAL COLIFORM CONC = 0

OSAGE CREEK CALIBRATION(1991 DATA)--MEAN DISSOLVED OXYGEN
CALCULATED AND OBSERVED DO CONCENTRATIONS AND DO DEFICIT VERSUS DISTANCE

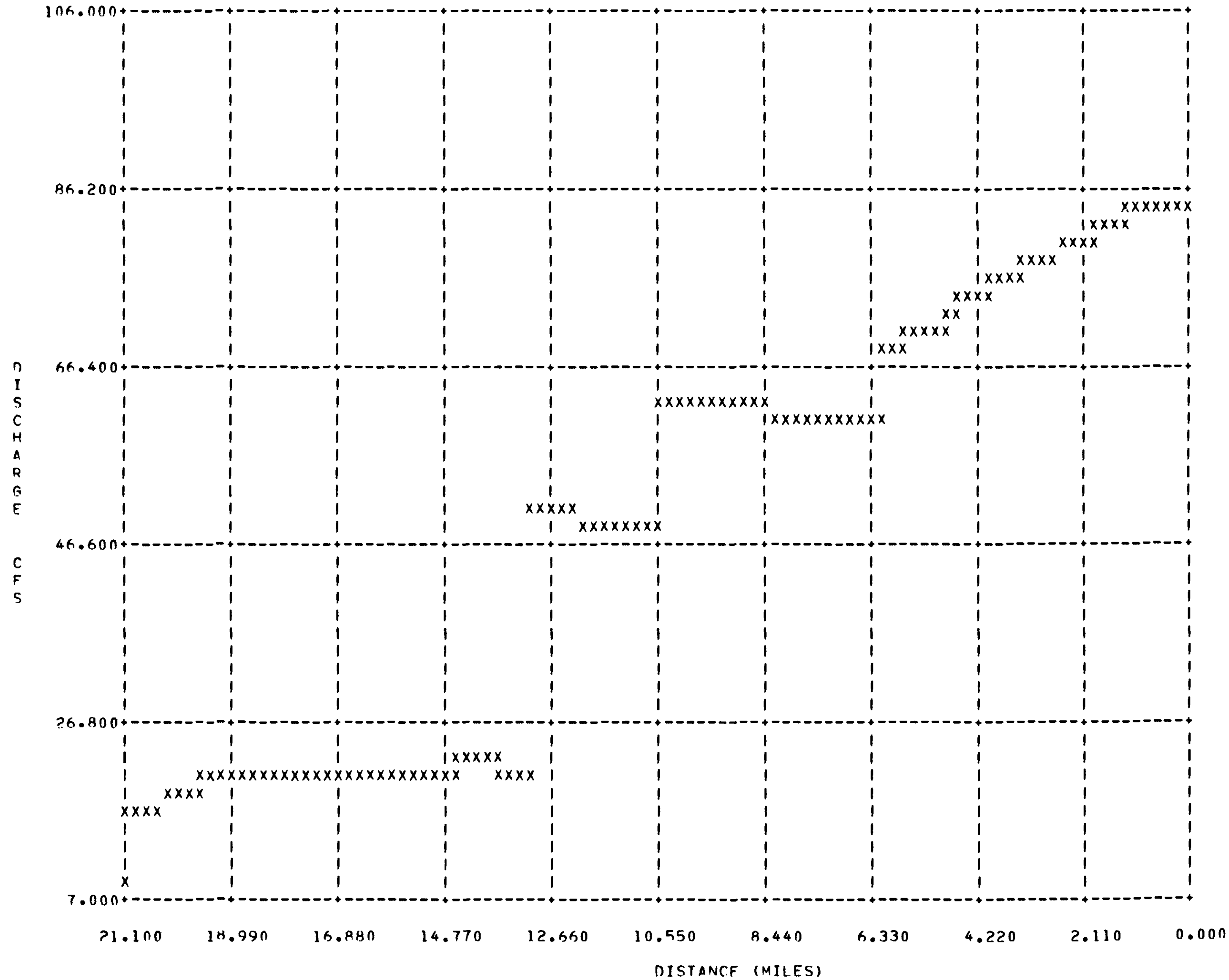


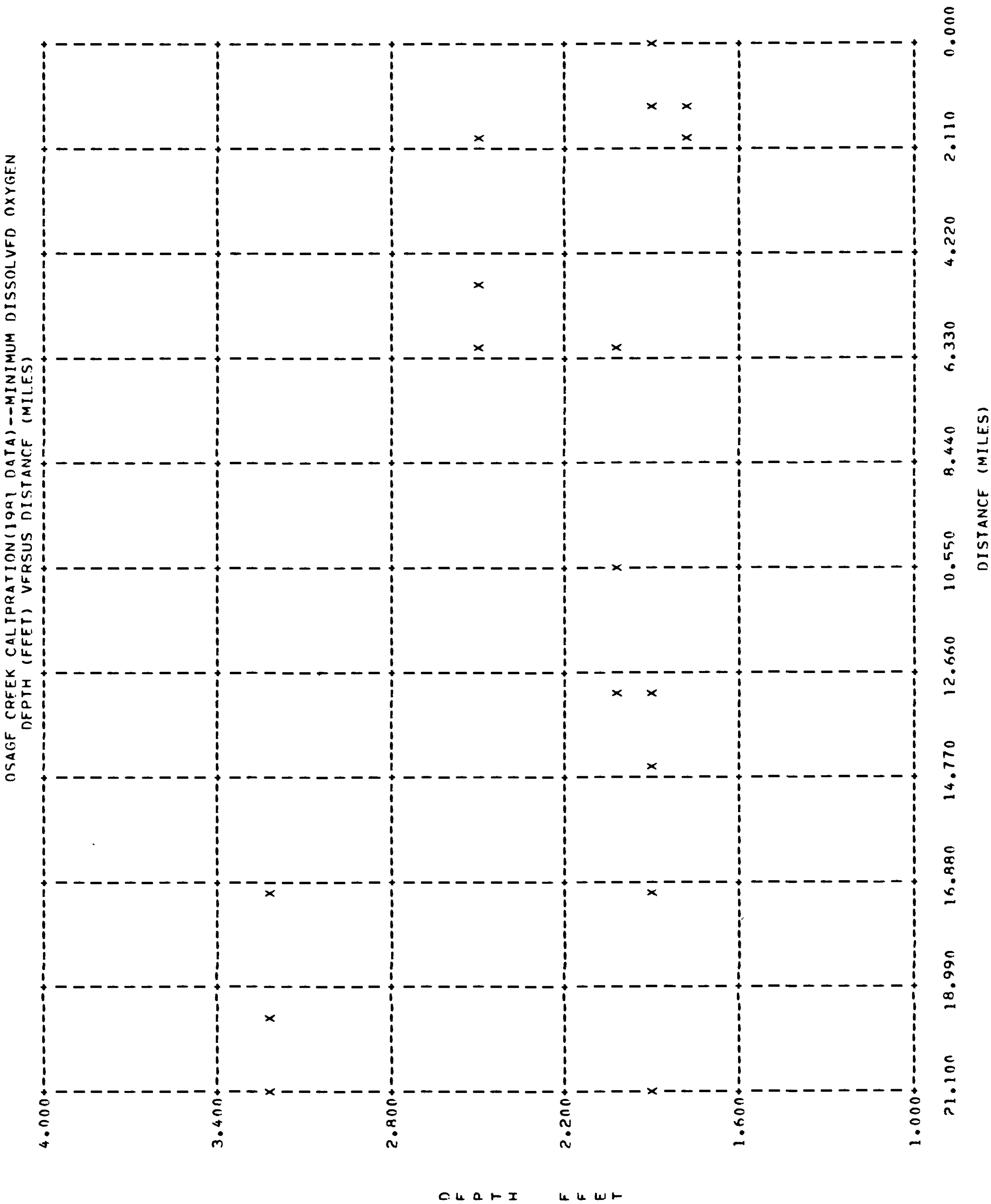
CALCULATED DO CONC = C
OBSERVED DO CONC = O
DO DEFICIT = D

OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED DO CONCENTRATIONS AND DO DEFICIT VERSUS DISTANCE



OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN
DISCHARGE (CFS) VERSUS DISTANCE (MILES)





OSAGE CREEK CALIBRATION(1981 DATA)--MINIMUM DISSOLVED OXYGEN
DEPTH (FEET) VERSUS DISTANCE (MILES)
4.000
3.400
2.800
2.200
1.600
1.000
DEPTH FEET
0.000
2.110
4.220
6.330
8.440
10.550
12.660
14.770
16.880
18.990
21.100
DISTANCE (MILES)

```
                    STEADY STATE WATER QUALITY MODEL

                    GULF COAST HYDROSCIENCE CENTER

                       U. S. GEOLOGICAL SURVEY

                          (ARKANSAS VERSION)

                 DATE OF LAST REVISION, DECEMBER  1980


OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN


           DISSOLVED OXYGEN PROFILE REPRESENTS
      ***  DIEL MINIMUMS: NET PHOTOSYNTHETIC DO   ***
           PRODUCTION ADJUSTED ACCORDINGLY.

          NITRIFICATION CYCLE INCLUDED IN MODEL


          NUMBER OF SUBREACHES FOR THIS PROBLEM =   11


              PRINTING INTERVAL (MILES) =   0.100

             STARTING DISTANCE (MILES) =   21.100

   INITIAL CBOD CONC (MG/L) AT STARTING DISTANCE =    2.90

   INITIAL ORGANIC NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.320

   INITIAL AMMONIUM NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.080

   INITIAL NITRITE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.040

   INITIAL NITRATE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   3.500

   INITIAL DO CONC (MG/L) AT STARTING DISTANCE =   7.200

   INITIAL PHOSPHATE CONC (MG/L) AT STARTING DISTANCE =   0.090

   INITIAL TOT. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =    2600.

   INITIAL FEC. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =     330.

       STREAMFLOW (CFS) AT STARTING DISTANCE =     6.500

       TOTAL SUSPENDED SOLIDS                  =    7.00
```

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN

S U B R E A C H   L I N E A R   R U N O F F   D A T A

SUBREACH	Q (CFS)	CBOD (MG/L)	ORGANIC (MG/L)	AMMONIA (MG/L)	NITRITE (MG/L)	NITRATE (MG/L)	DO (MG/L)	TSS (MG/L)	SP COND (MG/L)	(MG/L)	PO4 (MG/L)
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	5.10	3.00	1.00	0.10	0.01	3.50	6.70	8.00	300.00	0.0	0.20
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	2.40	3.00	1.00	0.10	0.01	3.50	6.70	8.00	300.00	0.0	0.20
5	-9.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	-4.30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	-1.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	11.60	3.00	2.00	0.10	0.01	3.50	6.70	8.00	300.00	0.0	0.20
10	2.50	3.00	2.00	0.10	0.01	3.50	6.70	8.00	300.00	0.0	0.20
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

R E A C H   D E S C R I P T I O N   D A T A   (MAJOR TRIBUTARIES AND MAIN STEM)

SUBREACH	CODE	NAME	BEGIN (MILE)	END (MILE)
1		ABOVE RODGERS STP	21.10	21.00
2		RODGERS STP	21.00	19.60
3		B. STA.35	19.60	17.10
4		A SPRING 36A	17.10	14.50
5		TRIB. 39A	14.50	13.10
6		SPRING CREEK	13.10	10.50
7		LITTLE OSAGE CREEK	10.50	6.20
8		BRUSHY CREEK	6.20	4.90
9		WILDCAT CREEK	4.90	2.00
10		TRIB. 57	2.00	1.20
11		LOGAN	1.20	0.0

KEY: CODE

A ROCKY BOTTOM-POOL RIFFLE-LIGHT VEGETATION
B ROCKY BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
C ROCKY BOTTOM-POOL RIFFLE-HEAVY VEGETATION
D ROCKY BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
E ROCKY BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
F ROCKY BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION
G MUD BOTTOM-POOL RIFFLE-LIGHT VEGETATION
H MUD BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
I MUD BOTTOM-POOL RIFFLE-HEAVY VEGETATION
J MUD BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
K MUD BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
L MUD BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN

I N P U T   P A R A M E T E R S

CONCENTRATIONS(MG/L) OF --

SUBREACH	CARB BOD	ORG-N	NH3-N	NO2-N	NO3-N	DISSOLVED OXYGEN	PO4	TOT.COLIF.	FEC.COLIF.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	66.00	3.60	2.50	0.45	6.00	5.40	11.00	100.00	67.00
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	7.40	0.36	0.08	0.07	3.20	7.40	0.02	880.00	260.00
5	7.80	0.99	0.11	0.01	5.20	8.80	0.02	300.00	170.00
6	14.00	1.20	0.10	0.23	7.10	4.40	2.40	690.00	180.00
7	2.30	0.50	0.10	0.01	2.50	6.50	0.02	130.00	145.00
8	3.60	0.74	0.10	0.01	0.80	4.90	0.15	1040.00	885.00
9	4.10	0.24	0.05	0.01	1.60	4.90	0.18	4900.00	3600.00
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	5.30	0.20	0.09	0.01	1.90	6.00	0.03	690.00	180.00

DIRECT DISCHARGES(LB/DAY) OF --

SUBREACH	CARBONACEOUS ULT. BOD	ORGANIC NITROGEN	AMMONIA NITROGEN	NITRITE NITROGEN	NITRATE NITROGEN	PHOSPHATE
1	0.0	0.0	0.0	0.0	0.0	0.
2	0.0	0.0	0.0	0.0	0.0	0.
3	0.0	0.0	0.0	0.0	0.0	0.
4	0.0	0.0	0.0	0.0	0.0	0.
5	0.0	0.0	0.0	0.0	0.0	0.
6	0.0	0.0	0.0	0.0	0.0	0.
7	0.0	0.0	0.0	0.0	0.0	0.
8	0.0	0.0	0.0	0.0	0.0	0.
9	0.0	0.0	0.0	0.0	0.0	0.
10	0.0	0.0	0.0	0.0	0.0	0.
11	0.0	0.0	0.0	0.0	0.0	0.

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN

SUBREACH	NET PHOTOSYNTHETIC DO PRODUCTION (MG/L/DAY @ 20 DEG C)	(FITTING FACTOR FOR MINIMUM DO PROFILE)	BENTHIC DO DEMAND (G/SQM/DAY @ 20 DEG C)
1	6.605	0.0	0.50
2	4.303	-5.000	14.00
3	4.303	-2.000	7.50
4	2.610	-3.000	4.00
5	6.682	-8.000	4.50
6	8.855	-5.000	6.00
7	4.659	-2.500	6.50
8	2.662	0.0	4.00
9	2.857	-2.500	5.00
10	3.040	-2.500	5.00
11	2.589	0.0	5.00

G E O M E T R Y

SUBREACH	FLOW CHANGE (CFS)	AREA (SQFT)	DEPTH (FT)	SLOPE	TEMP (DEG.CENT)	END MI (MI)
1	0.0	29.	1.90	0.0094700	18.00	21.0
2	4.40	58.	3.20	0.0027000	21.00	19.6
3	0.0	58.	3.20	0.0027000	21.00	17.1
4	1.10	47.	1.90	0.0021000	22.00	14.5
5	3.50	47.	1.90	0.0020400	24.00	13.1
6	27.40	92.	2.00	0.0017100	24.00	10.5
7	22.60	106.	2.00	0.0015000	21.00	6.[illegible]
8	11.50	118.	2.50	0.0015000	25.00	4.9
9	3.30	135.	2.50	0.0015800	24.00	2.0
10	0.0	136.	1.80	0.0027000	24.00	1.2
11	3.70	140.	1.90	0.0014600	24.00	0.0

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN

R E A C T I O N   C O E F F I C I E N T S (/DAY @ 20 DEG C)

SUBREACH	KR	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KCOLF	KCOLT	KPO41	KPO42
1	0.55	0.21	0.05	0.40	0.20	0.20	1.55	1.55	0.10	0.01	0.25	0.10	0.0
2	0.75	0.18	0.05	0.75	0.20	2.00	1.55	1.55	0.20	0.01	0.75	0.25	0.0
3	0.75	0.18	0.05	0.75	0.20	2.00	1.55	1.55	0.20	0.01	0.75	0.25	0.0
4	0.50	0.18	0.05	0.50	0.20	0.20	1.55	1.55	0.20	0.01	0.50	0.25	0.0
5	0.50	0.15	0.05	0.40	0.20	0.20	1.55	1.55	0.90	0.01	0.50	0.01	0.0
6	0.20	0.16	0.05	0.40	0.20	0.20	1.55	1.55	0.10	0.01	0.50	0.01	0.0
7	0.20	0.25	0.05	2.00	0.50	0.50	1.55	1.55	0.10	0.50	0.50	0.01	0.0
8	0.40	0.18	0.05	0.20	0.50	0.50	1.55	1.55	0.10	0.50	0.50	0.01	0.0
9	0.40	0.19	0.05	0.20	0.50	0.50	1.55	1.55	0.10	5.00	0.50	0.01	0.0
10	0.30	0.22	0.05	0.20	0.50	0.50	1.55	1.55	0.10	0.50	0.50	0.01	0.0
11	0.30	0.26	0.05	0.20	1.00	1.00	1.55	1.55	0.10	2.00	0.50	0.01	0.0

TEMPERATURE CORRECTED REACTION COEFFICIENTS (/DAY)

SUBREACH	KR	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KA	KPO41	KPO42
1	0.50	0.19	0.04	0.34	0.17	0.17	1.30	1.30	0.08	2.62	0.08	0.0
2	0.79	0.19	0.05	0.82	0.22	2.18	1.69	1.69	0.22	1.19	0.27	0.0
3	0.79	0.19	0.05	0.82	0.22	2.18	1.69	1.69	0.22	1.33	0.27	0.0
4	0.55	0.20	0.06	0.59	0.24	0.24	1.84	1.84	0.24	4.04	0.30	0.0
5	0.60	0.18	0.07	0.56	0.28	0.28	2.19	2.19	1.27	4.23	0.01	0.0
6	0.24	0.19	0.07	0.56	0.28	0.28	2.19	2.19	0.14	4.07	0.01	0.0
7	0.21	0.27	0.05	2.18	0.55	0.55	1.69	1.69	0.11	4.50	0.01	0.0
8	0.50	0.22	0.08	0.31	0.77	0.77	2.38	2.38	0.15	3.52	0.02	0.0
9	0.48	0.22	0.07	0.28	0.71	0.71	2.19	2.19	0.14	3.39	0.01	0.0
10	0.36	0.27	0.07	0.28	0.71	0.71	2.19	2.19	0.14	6.20	0.01	0.0
11	0.36	0.31	0.07	0.28	1.41	1.41	2.19	2.19	0.14	5.75	0.01	0.0

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN

SUBREACH	REAERATION COEFFICIENT DERIVATION
1	KA COMPUTED BY BENNETT - RATHBUN EQUATION
2	KA COMPUTED BY BENNETT - RATHBUN EQUATION
3	KA COMPUTED BY BENNETT - RATHBUN EQUATION
4	KA COMPUTED BY BENNETT - RATHBUN EQUATION
5	KA COMPUTED BY BENNETT - RATHBUN EQUATION
6	KA COMPUTED BY BENNETT - RATHBUN EQUATION
7	KA COMPUTED BY BENNETT - RATHBUN EQUATION
8	KA COMPUTED BY BENNETT - RATHBUN EQUATION
9	KA COMPUTED BY BENNETT - RATHBUN EQUATION
10	KA COMPUTED BY BENNETT - RATHBUN EQUATION
11	KA COMPUTED BY BENNETT - RATHBUN EQUATION

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN

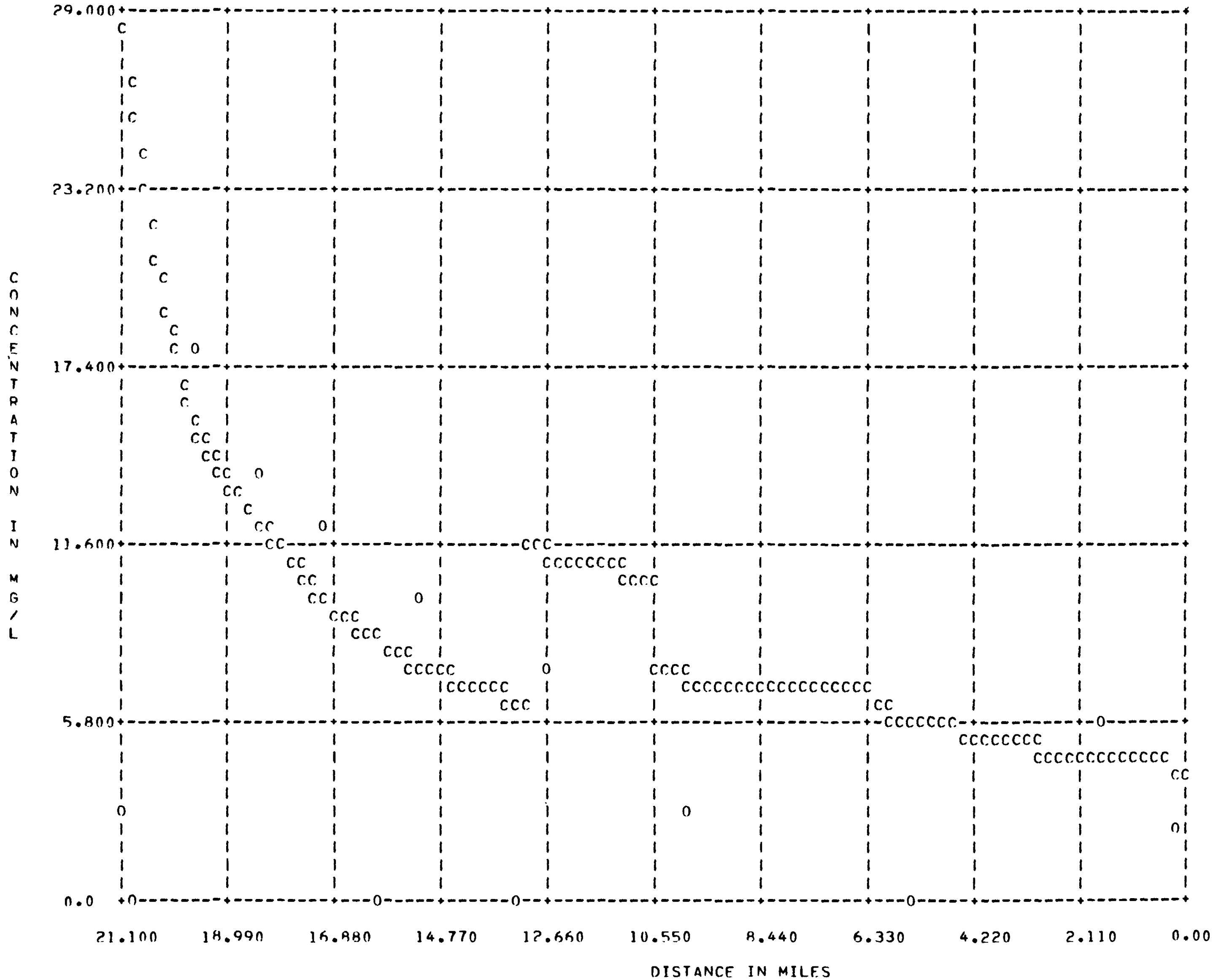
SUBREACH	DO SATURATION (MG/L)
1	9.442
2	8.888
3	8.888
4	8.717
5	8.390
6	8.390
7	8.888
8	8.235
9	8.390
10	8.390
11	8.390

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN

O B S E R V E D   M E A S U R E M E N T S

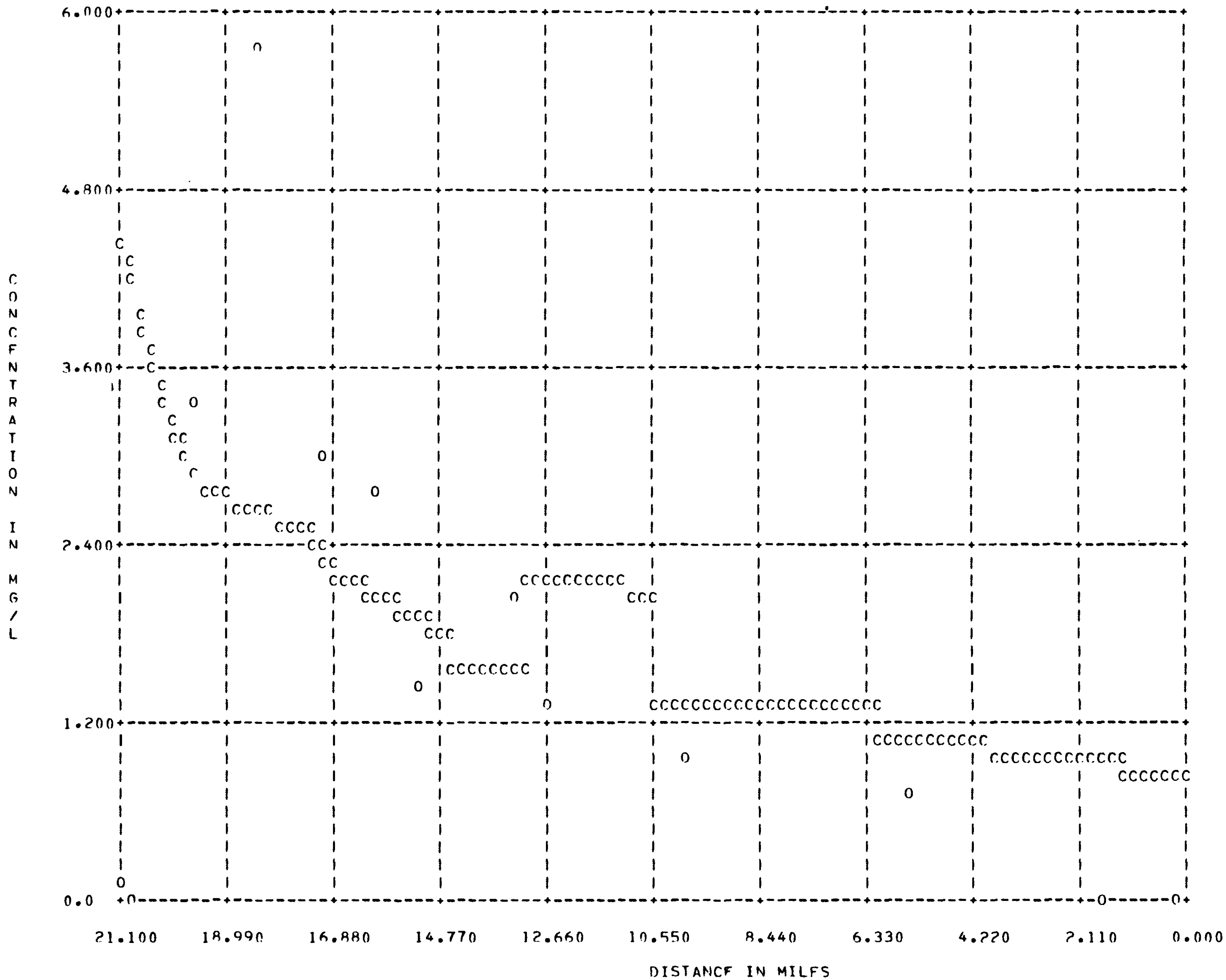
DISTANCE (MI)	DO CONC (MG/L)	TSS (MG/L)	SP COND (MG/L)	(MG/L)	CBODU (MG/L)	NBODU (MG/L)	ORG-N (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)	TOTAL COLIFORM	FECAL COLIFORM	PO4 (MG/L)
21.10	7.20	7.00	255.00	0.0	2.90	0.0	0.32	0.08	0.04	3.50	2600.	330.	0.09
20.90	6.30	18.00	0.0	0.0	0.0	0.0	0.0	1.90	0.16	0.52	0.	0.	0.0
19.60	2.40	5.00	344.00	0.0	18.00	0.0	1.40	0.42	0.46	3.80	8000.	730.	3.30
18.40	0.0	18.00	314.00	0.0	14.00	0.0	1.30	0.15	0.16	0.52	800.	1000.	5.70
17.00	4.00	11.00	328.00	0.0	12.00	0.0	0.95	0.17	0.14	3.20	620.	620.	3.00
16.10	4.70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	2.80
15.20	4.30	5.00	328.00	0.0	10.00	0.0	0.72	0.07	0.05	3.80	1000.	620.	1.40
13.20	0.0	7.00	314.00	0.0	0.0	0.0	0.38	0.08	0.06	3.00	500.	230.	2.00
12.60	5.50	7.00	351.00	0.0	7.80	0.0	1.00	0.07	0.09	5.30	580.	420.	1.30
10.00	5.70	11.00	325.00	0.0	2.90	0.0	0.26	0.07	0.07	4.30	400.	390.	1.00
5.40	6.50	16.00	0.0	0.0	0.0	0.0	0.22	0.07	0.07	4.00	700.	200.	0.75
1.60	6.00	13.00	302.00	0.0	5.60	0.0	0.38	0.08	0.06	3.60	500.	210.	0.0
0.30	6.50	0.0	0.0	0.0	2.60	0.0	0.70	0.01	0.0	0.0	580.	130.	0.0

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED CBOD CONCENTRATIONS VERSUS DISTANCE



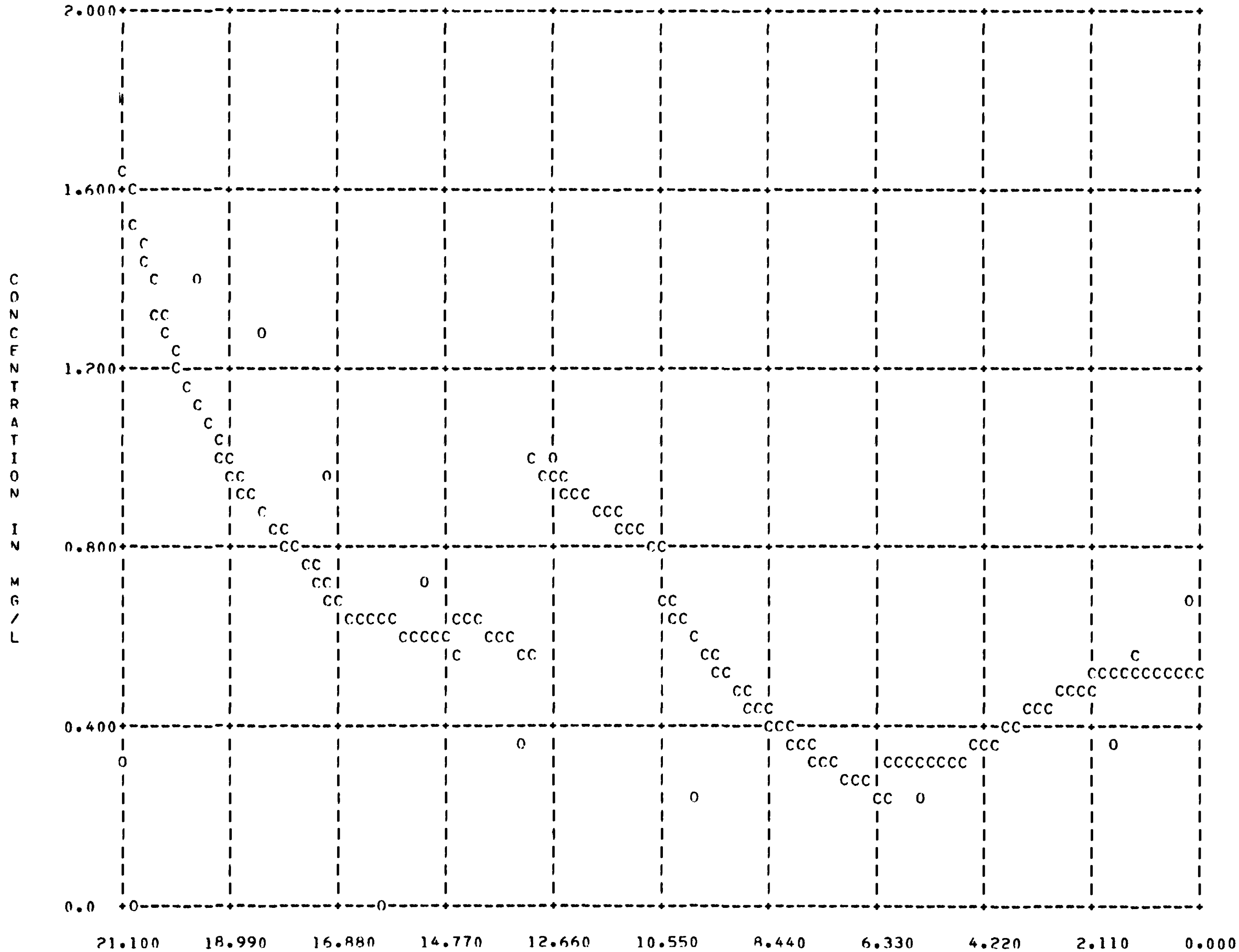
CALCULATED CBODU CONC = C
OBSERVED CBODU CONC = 0

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED PO4 CONCENTRATIONS VERSUS DISTANCE



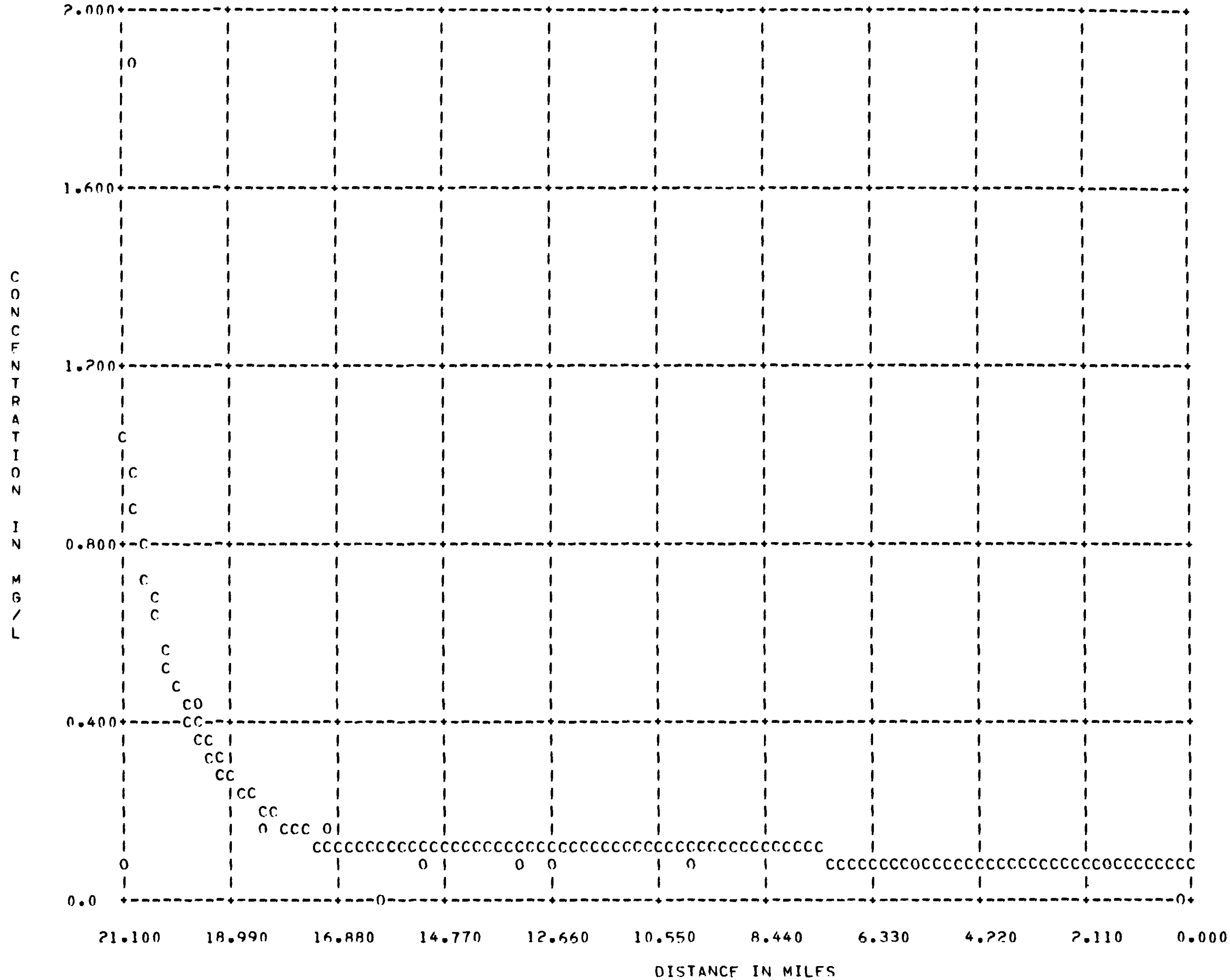
CALCULATED PO4 CONC = C
OBSERVED PO4 CONC = O

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED ORGANIC NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



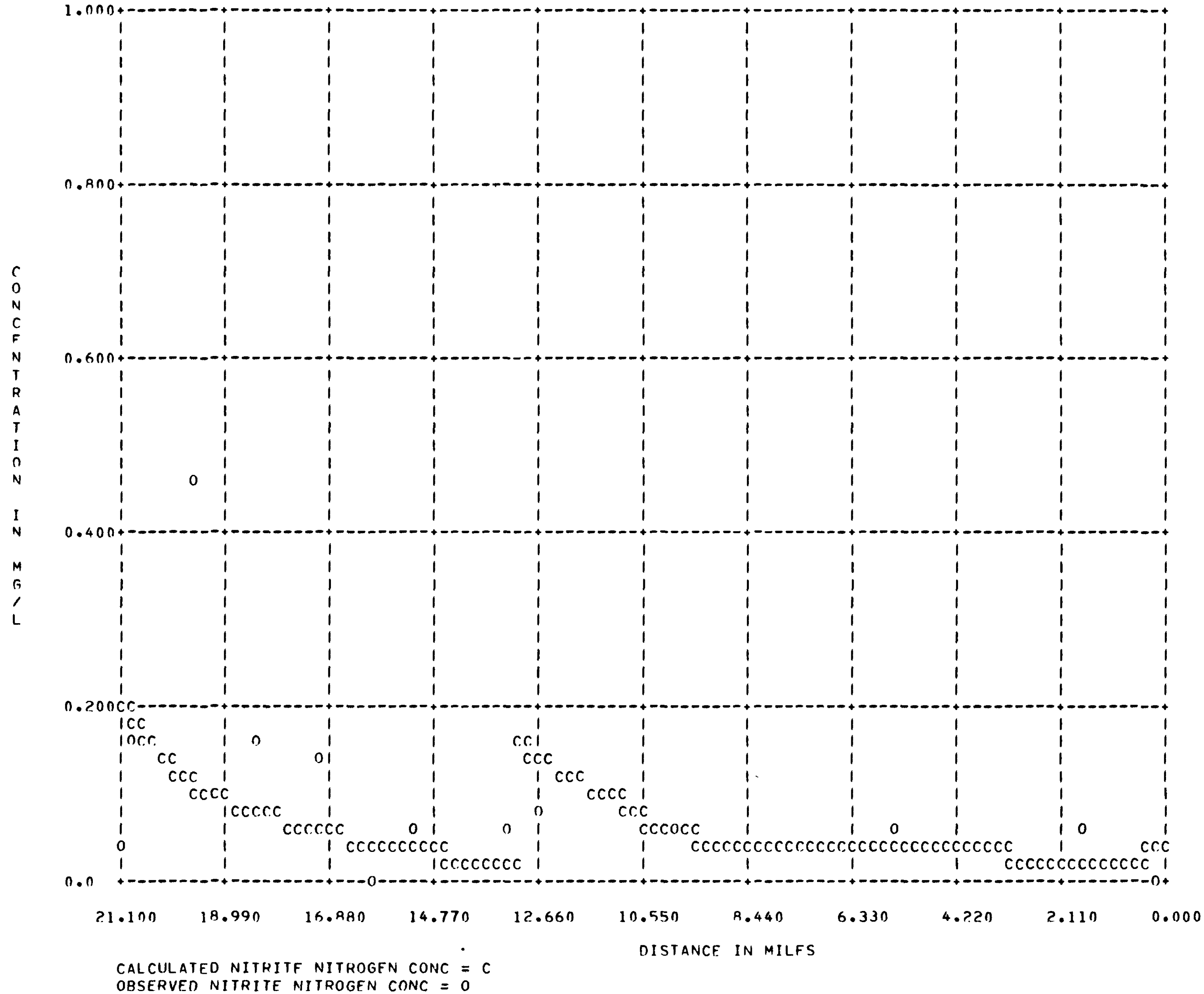
CALCULATED ORGANIC NITROGEN CONC = C
OBSERVED ORGANIC NITROGEN CONC = O

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED AMMONIA NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE

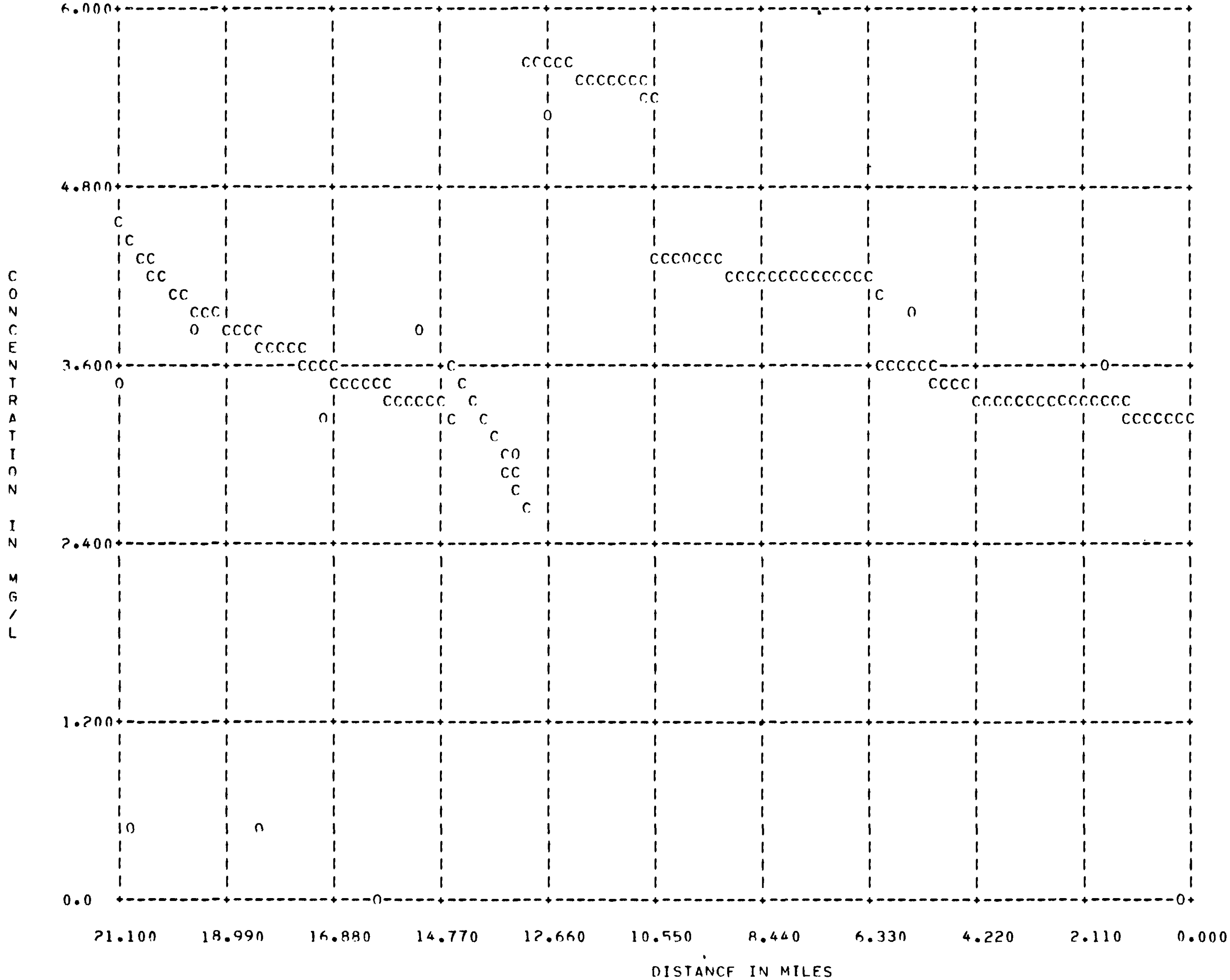


CALCULATED AMMONIA NITROGEN CONC = C
OBSERVED AMMONIA NITROGEN CONC = O

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED NITRITE NITROGEN SPECIES ROD CONCENTRATIONS VERSUS DISTANCE

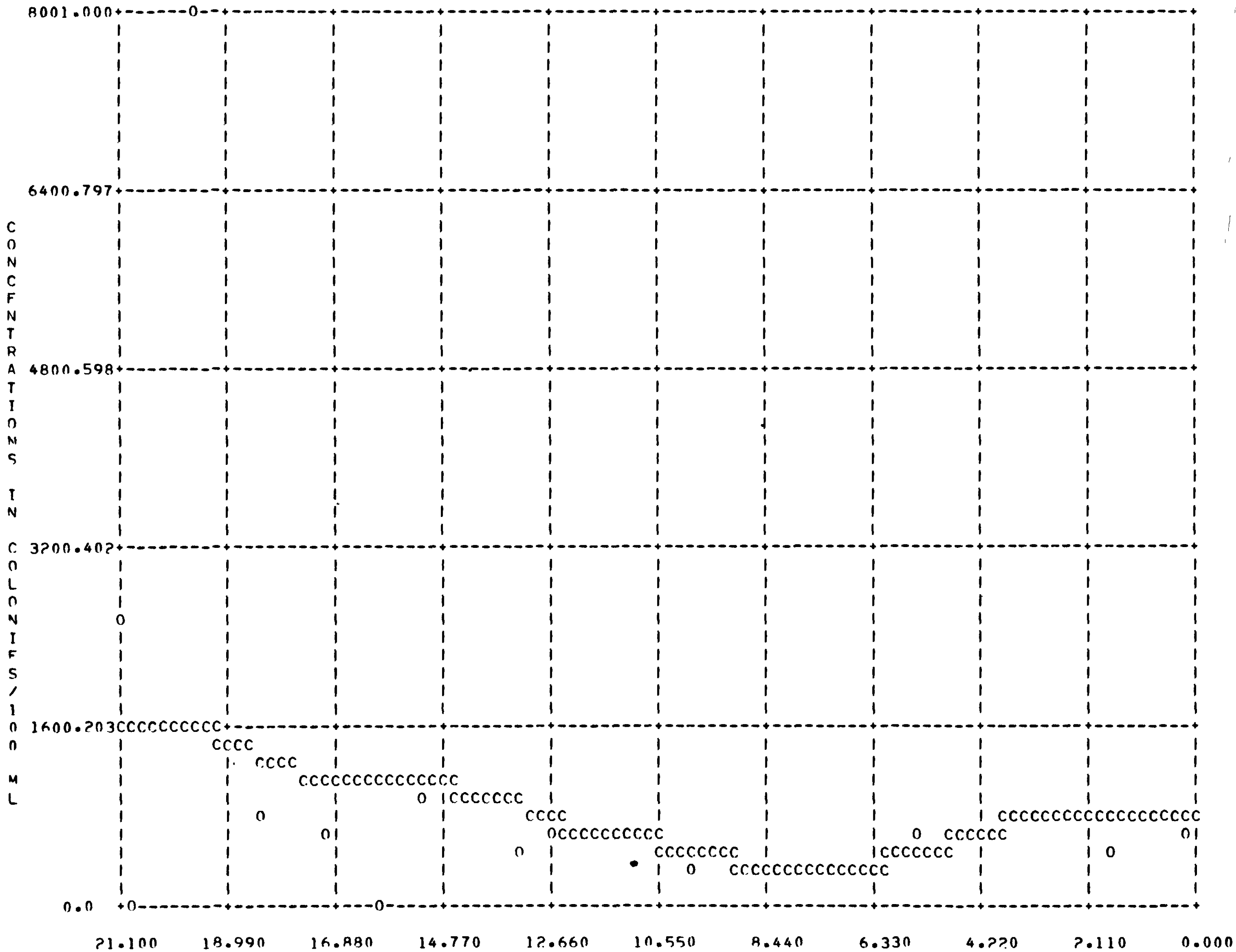


OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED NITRATE NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



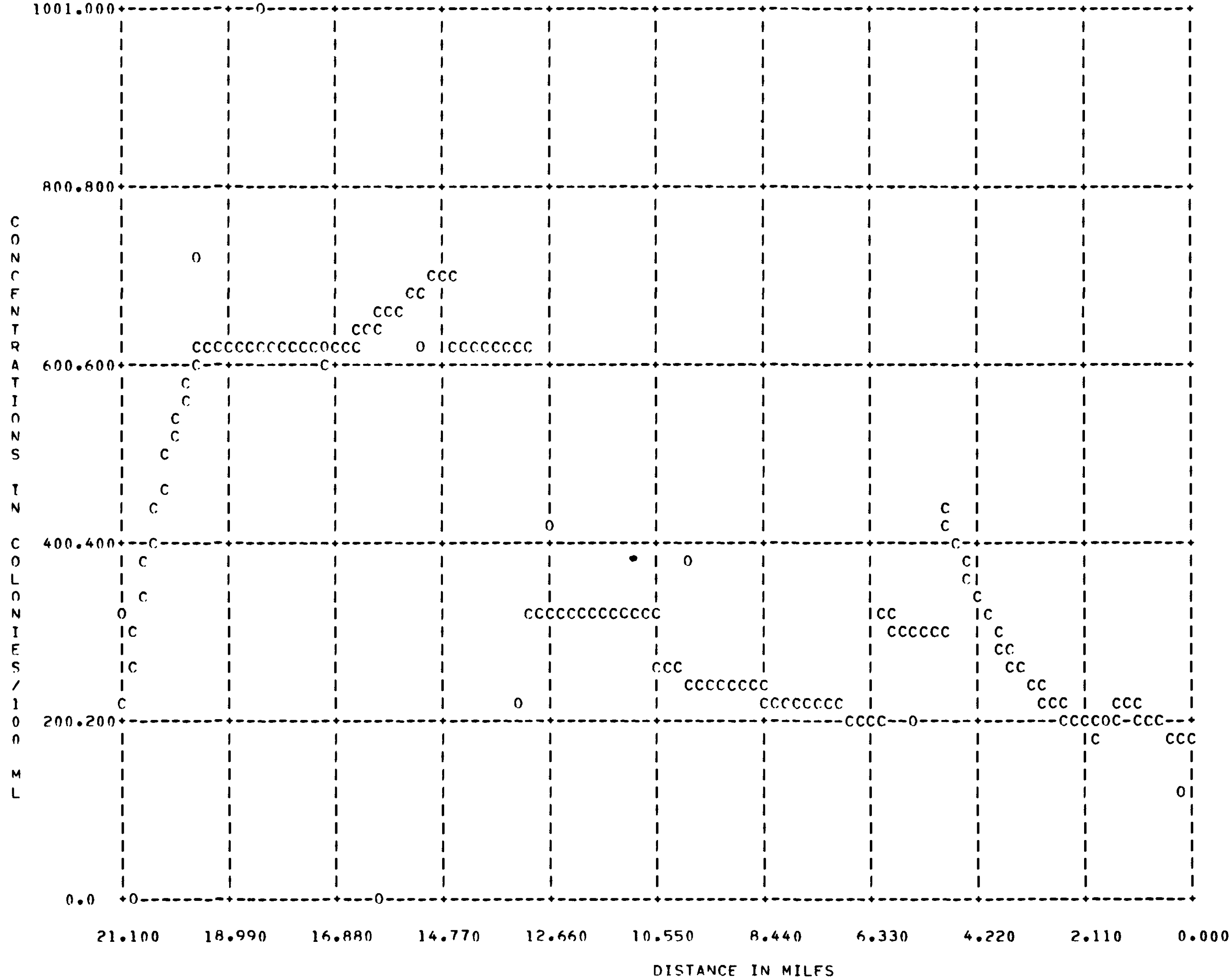
CALCULATED NITRATE NITROGEN CONC = C
OBSERVED NITRATE NITROGEN CONC = O

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED TOTAL COLIFORM CONCENTRATIONS VERSUS DISTANCE

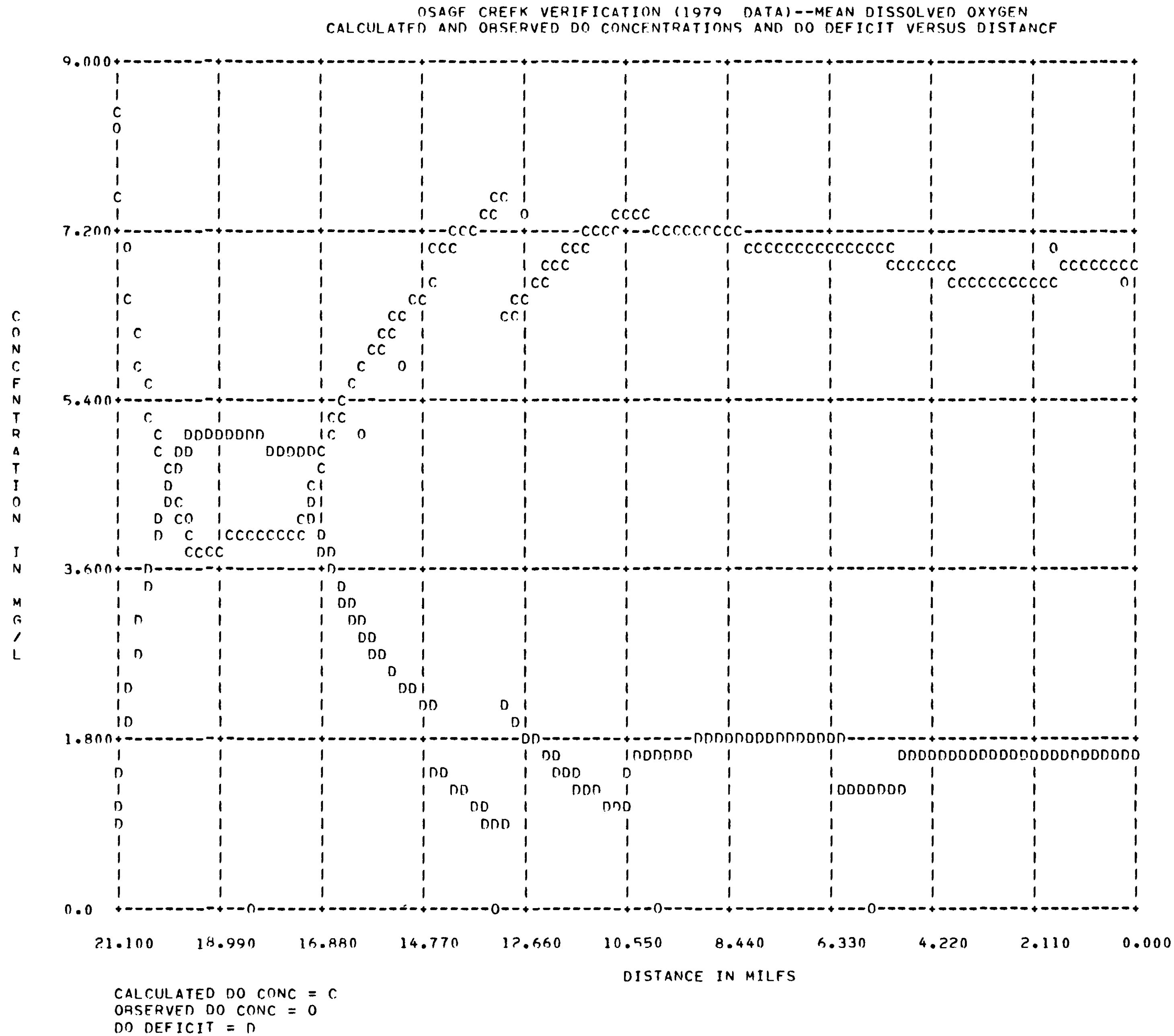


CALCULATED TOTAL COLIFORM CONC = C
OBSERVED TOTAL COLIFORM CONC = 0

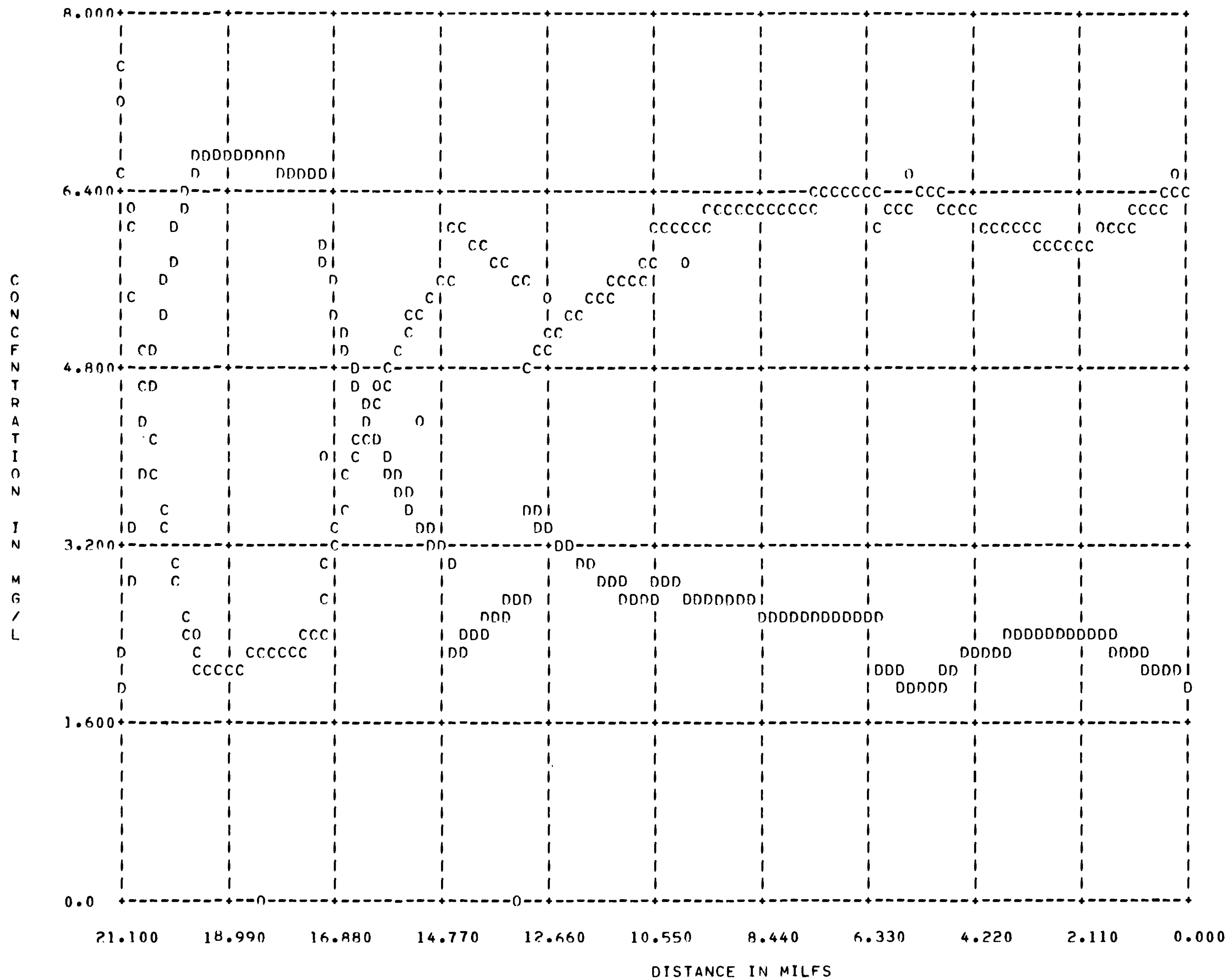
OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED FECAL COLIFORM CONCENTRATIONS VERSUS DISTANCE



CALCULATED FECAL COLIFORM CONC = C
OBSERVED FECAL COLIFORM CONC = O

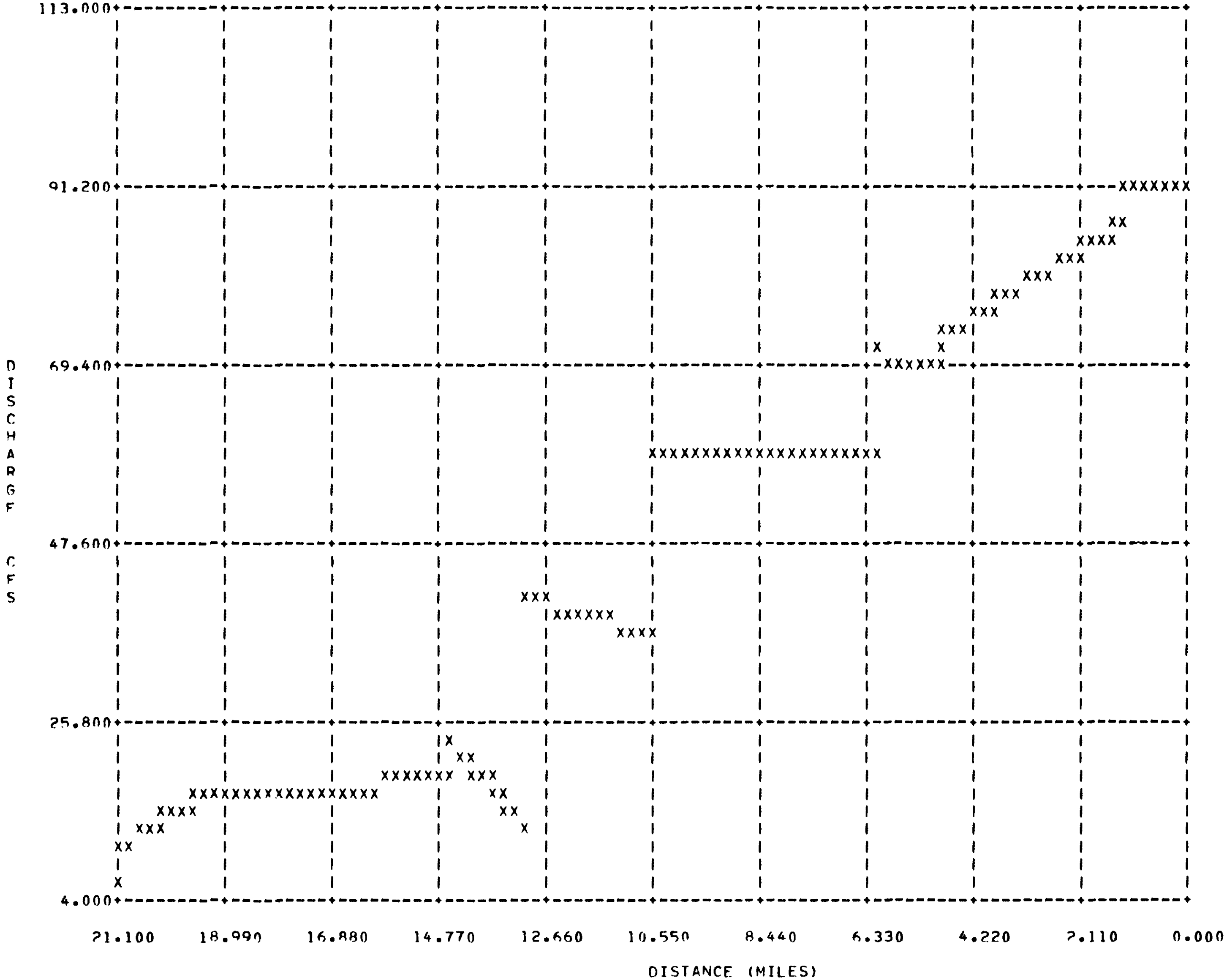

OSAGE CREEK VERIFICATION (1979 DATA)--MEAN DISSOLVED OXYGEN
CALCULATED AND OBSERVED DO CONCENTRATIONS AND DO DEFICIT VERSUS DISTANCE
CONCENTRATION IN MG/L
9.000
7.200
5.400
3.600
1.800
0.0
21.100
18.990
16.880
14.770
12.660
10.550
8.440
6.330
4.220
2.110
0.000
DISTANCE IN MILES
CALCULATED DO CONC = C
OBSERVED DO CONC = O
DO DEFICIT = D

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN
CALCULATED AND OBSERVED DO CONCENTRATIONS AND DO DEFICIT VERSUS DISTANCE

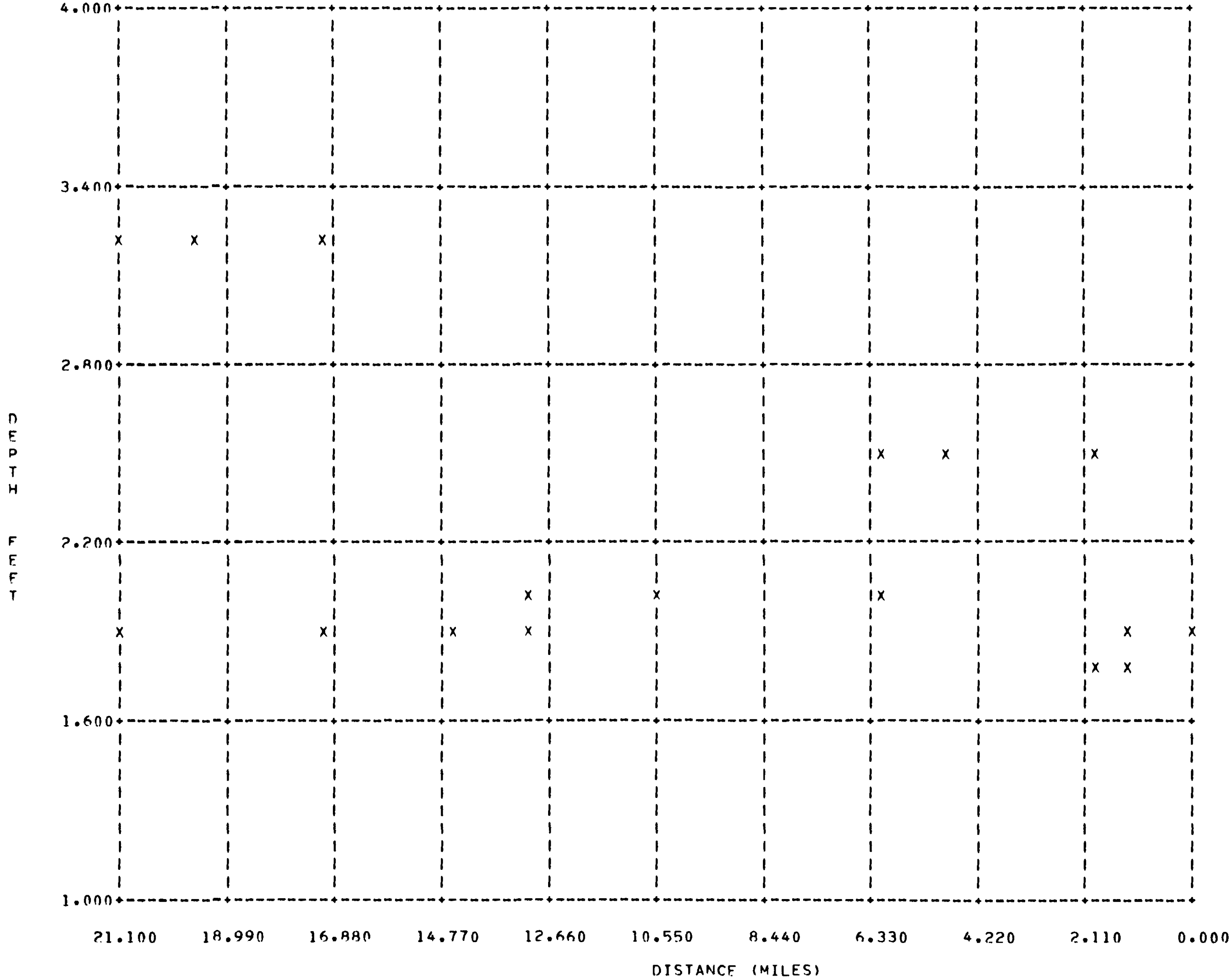


CALCULATED DO CONC = C
OBSERVED DO CONC = O
DO DEFICIT = D

OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN
DISCHARGE (CFS) VERSUS DISTANCE (MILES)



OSAGE CREEK VERIFICATION(1979 DATA)--MINIMUM DISSOLVED OXYGEN
DEPTH (FEET) VERSUS DISTANCE (MILES)



ATTACHMENT E

ILLINOIS RIVER CALIBRATION AND VERIFICATION

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                STEADY STATE WATER QUALITY MODEL
                GULF COAST HYDROSCIENCE CENTER
                   U. S. GEOLOGICAL SURVEY
                      (ARKANSAS VERSION)
              DATE OF LAST REVISION, DECEMBER  1980


ILLINOIS RIVER CALIBRATION,1981 DATA,MIN  DO SET

        DISSOLVED OXYGEN PROFILE REPRESENTS
   ***  DIEL MINIMUMS: NET PHOTOSYNTHETIC DO  ***
        PRODUCTION ADJUSTED ACCORDINGLY.

        NITRIFICATION CYCLE INCLUDED IN MODEL


        NUMBER OF SUBREACHES FOR THIS PROBLEM =   14


             PRINTING INTERVAL (MILES) =   0.200
            STARTING DISTANCE (MILES) =  144.500
  INITIAL CBOD CONC (MG/L) AT STARTING DISTANCE =    8.60
  INITIAL ORGANIC NITROGEN CONC (MG/L) AT STARTING DISTANCE =   1.100
  INITIAL AMMONIUM NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.140
  INITIAL NITRITE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.010
  INITIAL NITRATE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.150
  INITIAL DO CONC (MG/L) AT STARTING DISTANCE =   6.800
  INITIAL PHOSPHATE CONC (MG/L) AT STARTING DISTANCE =   0.070
  INITIAL TOT. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =     240.
  INITIAL FEC. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =     240.
      STREAMFLOW (CFS) AT STARTING DISTANCE =     1.400
```

SUBREACH LINEAR RUNOFF DATA

SUBREACH	Q	CBOD	ORGANIC	AMMONIA	NITRITE	NITRATE	DO	PO4
	(CFS)	(MG/L)	(MG/L)	(MG/L)	(MG/L)	(MG/L)	(MG/L)	(MG/L)
1	0.40	2.6	0.5	0.1	0.0	1.1	5.8	0.1
2	0.30	2.6	0.5	0.1	0.0	1.1	5.8	0.1
3	0.20	2.6	0.1	0.1	0.0	1.1	5.8	0.1
4	0.40	2.6	3.0	0.1	0.0	1.1	5.8	0.1
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
6	9.10	2.6	1.0	0.1	0.0	1.1	5.8	0.1
7	-2.60	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	3.80	2.6	0.5	0.1	0.0	1.1	5.8	0.1
9	0.50	6.0	0.5	0.1	0.0	1.1	5.8	0.1
10	0.10	2.6	1.0	0.1	0.0	1.1	5.8	0.0
11	0.90	2.6	0.5	0.1	0.0	1.1	5.8	0.1
12	2.00	2.6	0.5	0.1	0.0	1.1	5.8	0.1
13	-1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

R E A C H   D E S C R I P T I O N   D A T A   (MAJOR TRIBUTARIES AND MAIN STEM)

SUBREACH	CODE	NAME	BEGIN (MILE)	END (MILE)
1	A	UPSTREAM	144.50	142.20
2	A		142.20	138.70
3	A	PROPOSED F'VILLE STP	138.70	138.40
4	A	GOOSE CREEK	138.40	138.20
5	A	BL .2 MI GOOSE CREEK	138.20	138.00
6	A	UNNAMED TRIB.	138.00	135.60
7	A	MUDDY FORK	135.60	132.80
8	A	CLEAR CREEK	132.80	129.60
9	A	UNNAMED TRIB.	129.60	123.70
10	A	OSAGE CREEK	123.70	123.50
11	A	UN-NAMED TRIBUTARY	123.50	121.40
12	A	CHAMBERS HOLLOW	121.40	119.30
13	A	SHINN SPRING	119.30	112.00
14	A	CINCINNATI CREEK	112.00	109.00

KEY: CODE

- A ROCKY BOTTOM-POOL RIFFLE-LIGHT VEGETATION
- B ROCKY BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
- C ROCKY BOTTOM-POOL RIFFLE-HEAVY VEGETATION
- D ROCKY BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
- E ROCKY BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
- F ROCKY BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION
- G MUD BOTTOM-POOL RIFFLE-LIGHT VEGETATION
- H MUD BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
- I MUD BOTTOM-POOL RIFFLE-HEAVY VEGETATION
- J MUD BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
- K MUD BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
- L MUD BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION

INPUT PARAMETERS

CONCENTRATIONS(MG/L) OF --

SUBREACH	CARB BOD	ORG-N	NH3-N	NO2-N	NO3-N	DISSOLVED OXYGEN	PO4	TOT.COLIF.	FEC.COLIF.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	3.00	1.10	0.13	0.01	2.00	5.20	0.08	9400.00	6500.00
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.90	0.37	0.14	0.01	0.50	4.80	0.04	240.00	10.00
7	2.20	0.52	0.13	0.01	1.10	5.50	0.09	1700.00	360.00
8	1.90	0.46	0.08	0.01	1.00	6.90	0.02	900.00	500.00
9	3.80	0.85	0.15	0.01	0.19	5.50	0.06	2000.00	600.00
10	2.89	0.79	0.09	0.01	3.30	6.80	0.80	1600.00	600.00
11	2.60	0.23	0.14	0.01	0.26	5.00	0.04	1200.00	370.00
12	1.30	0.56	0.11	0.01	0.70	5.80	0.04	40.00	33.00
13	1.40	0.47	0.14	0.01	0.41	4.50	0.03	230.00	58.00
14	1.20	0.40	0.01	0.01	0.76	5.80	0.01	410.00	410.00

DIRECT DISCHARGES(LB/DAY) OF --

SUBREACH	CARBONACEOUS ULT. BOD	ORGANIC NITROGEN	AMMONIA NITROGEN	NITRITE NITROGEN	NITRATE NITROGEN	PHOSPHATE
1	0.0	0.0	0.0	0.0	0.0	0.
2	0.0	0.0	0.0	0.0	0.0	0.
3	0.0	0.0	0.0	0.0	0.0	0.
4	0.0	0.0	0.0	0.0	0.0	0.
5	0.0	0.0	0.0	0.0	0.0	0.
6	0.0	0.0	0.0	0.0	0.0	0.
7	0.0	0.0	0.0	0.0	0.0	0.
8	0.0	0.0	0.0	0.0	0.0	0.
9	0.0	0.0	0.0	0.0	0.0	0.
10	0.0	0.0	0.0	0.0	0.0	0.
11	0.0	0.0	0.0	0.0	0.0	0.
12	0.0	0.0	0.0	0.0	0.0	0.
13	0.0	0.0	0.0	0.0	0.0	0.
14	0.0	0.0	0.0	0.0	0.0	0.

ILLINOIS RIVER CALIBRATION,1981 DATA,MIN DO SET

SUBREACH	NET PHOTOSYNTHETIC DO PRODUCTION (MG/L/DAY @ 20 DEG C)	(FITTING FACTOR FOR MINIMUM DO PROFILE)	BENTHIC DO DEMAND (G/SQM/DAY @ 20 DEG C)
1	3.400	-1.900	4.00
2	4.600	-1.000	4.70
3	5.100	-5.000	3.20
4	5.200	-7.000	7.20
5	5.400	-7.000	6.00
6	5.400	-4.000	4.50
7	0.140	-7.000	2.40
8	0.180	-1.500	2.00
9	1.000	-1.500	2.50
10	0.690	-1.500	4.00
11	1.650	-1.000	4.00
12	2.600	-2.000	4.00
13	2.500	-2.500	2.00
14	2.170	-0.400	4.00

G E O M E T R Y

SUBREACH	FLOW CHANGE (CFS)	AREA (SQFT)	DEPTH (FT)	SLOPE	TEMP (DEG.CENT)	END MI (MI)
1	0.0	71.	2.38	0.0013300	25.00	142.20
2	0.0	71.	1.82	0.0013300	24.00	138.70
3	0.0	71.	1.82	0.0013300	24.00	138.40
4	1.20	71.	1.82	0.0012400	23.00	138.20
5	0.0	71.	1.82	0.0012400	23.00	138.00
6	0.28	78.	1.50	0.0012400	23.00	135.60
7	3.60	78.	1.13	0.0013600	24.00	132.80
8	20.10	114.	1.86	0.0010800	25.00	129.60
9	0.12	150.	1.98	0.0008000	24.00	123.70
10	84.30	270.	2.70	0.0008200	25.00	123.50
11	1.00	272.	2.72	0.0008200	24.00	121.40
12	1.00	248.	2.48	0.0008500	24.00	119.30
13	1.00	274.	3.30	0.0008500	24.00	112.00
14	0.01	900.	6.00	0.0003400	25.00	109.00

ILLINOIS RIVER CALIBRATION.1981 DATA.MIN DO SET

REACTION COEFFICIENTS (/DAY @ 20 DEG C)

SUBREACH	KP	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KCOLF	KCOLT	KPO41	KPO42
1	0.06	0.06	0.05	0.07	0.60	0.60	3.00	3.00	0.01	0.50	0.50	0.01	0.0
2	0.02	0.02	0.05	0.05	0.05	0.05	0.50	0.50	0.01	0.50	0.50	0.01	0.0
3	0.02	0.02	0.05	0.05	0.05	0.05	0.50	0.50	0.01	0.50	0.50	0.01	0.0
4	0.10	0.10	0.05	0.05	0.30	0.30	1.50	1.50	0.01	0.50	0.50	0.07	0.0
5	0.10	0.10	0.05	0.05	0.30	0.30	1.50	1.50	0.01	0.50	0.50	0.07	0.0
6	0.05	0.05	0.05	0.20	0.10	0.10	1.70	1.70	0.01	0.50	0.50	0.02	0.0
7	0.01	0.01	0.05	0.05	0.20	0.20	1.50	1.50	0.50	0.50	0.50	0.07	0.0
8	0.03	0.03	0.05	0.05	0.05	0.05	1.50	1.50	0.10	0.50	0.50	0.02	0.0
9	0.03	0.03	0.05	0.05	0.10	0.10	1.00	1.00	0.01	0.50	0.50	0.02	0.0
10	0.19	0.13	0.05	0.10	0.10	0.10	1.00	1.00	0.25	1.00	1.00	0.03	0.0
11	0.20	0.13	0.05	0.10	0.10	0.10	1.00	1.00	0.25	1.00	1.00	0.03	0.0
12	0.10	0.10	0.05	0.10	0.30	0.30	1.00	1.00	0.10	1.00	1.00	0.30	0.0
13	0.10	0.10	0.05	0.10	0.50	0.50	2.00	2.00	0.15	1.00	1.00	0.10	0.0
14	0.10	0.10	0.05	0.10	0.30	0.30	1.50	1.50	0.17	1.00	1.00	0.20	0.0

TEMPERATURE CORRECTED REACTION COEFFICIENTS (/DAY)

SUBREACH	KP	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KA	KPO41	KPO42
1	0.08	0.08	0.08	0.11	0.92	0.92	4.62	4.62	0.02	2.04	0.02	0.0
2	0.02	0.02	0.07	0.07	0.07	0.07	0.71	0.71	0.01	2.89	0.01	0.0
3	0.02	0.02	0.07	0.07	0.07	0.07	0.71	0.71	0.01	2.89	0.01	0.0
4	0.11	0.11	0.06	0.06	0.39	0.39	1.94	1.94	0.01	2.75	0.09	0.0
5	0.11	0.11	0.06	0.06	0.39	0.39	1.94	1.94	0.01	2.75	0.09	0.0
6	0.06	0.06	0.06	0.26	0.13	0.13	2.20	2.20	0.01	2.89	0.03	0.0
7	0.01	0.01	0.07	0.07	0.28	0.28	2.12	2.12	0.71	6.79	0.10	0.0
8	0.04	0.04	0.08	0.08	0.08	0.08	2.31	2.31	0.15	3.98	0.03	0.0
9	0.04	0.04	0.07	0.07	0.14	0.14	1.41	1.41	0.01	3.07	0.03	0.0
10	0.24	0.16	0.08	0.15	0.15	0.15	1.54	1.54	0.38	2.64	0.05	0.0
11	0.24	0.16	0.07	0.14	0.14	0.14	1.41	1.41	0.35	2.55	0.04	0.0
12	0.12	0.12	0.07	0.14	0.42	0.42	1.41	1.41	0.14	3.19	0.42	0.0
13	0.12	0.12	0.07	0.14	0.71	0.71	2.82	2.82	0.21	1.87	0.14	0.0
14	0.13	0.13	0.08	0.15	0.46	0.46	2.31	2.31	0.26	0.34	0.31	0.0

ILLINOIS RIVER CALIBRATION,1981 DATA,MIN DO SET

SUBREACH	REAERATION COEFFICIENT DERIVATION
1	KA COMPUTED BY VELZ EQUATION
2	KA COMPUTED BY VELZ EQUATION
3	KA COMPUTED BY VELZ EQUATION
4	KA COMPUTED BY VELZ EQUATION
5	KA COMPUTED BY VELZ EQUATION
6	KA COMPUTED BY BENNETT - RATHBUN EQUATION
7	KA COMPUTED BY BENNETT - RATHBUN EQUATION
8	KA COMPUTED BY BENNETT - RATHBUN EQUATION
9	KA COMPUTED BY BENNETT - RATHBUN EQUATION
10	KA COMPUTED BY BENNETT - RATHBUN EQUATION
11	KA COMPUTED BY BENNETT - RATHBUN EQUATION
12	KA COMPUTED BY BENNETT - RATHBUN EQUATION
13	KA COMPUTED BY BENNETT - RATHBUN EQUATION
14	KA COMPUTED BY BENNETT - RATHBUN EQUATION

ILLINOIS RIVER CALIBRATION,1981 DATA.MIN DO SET

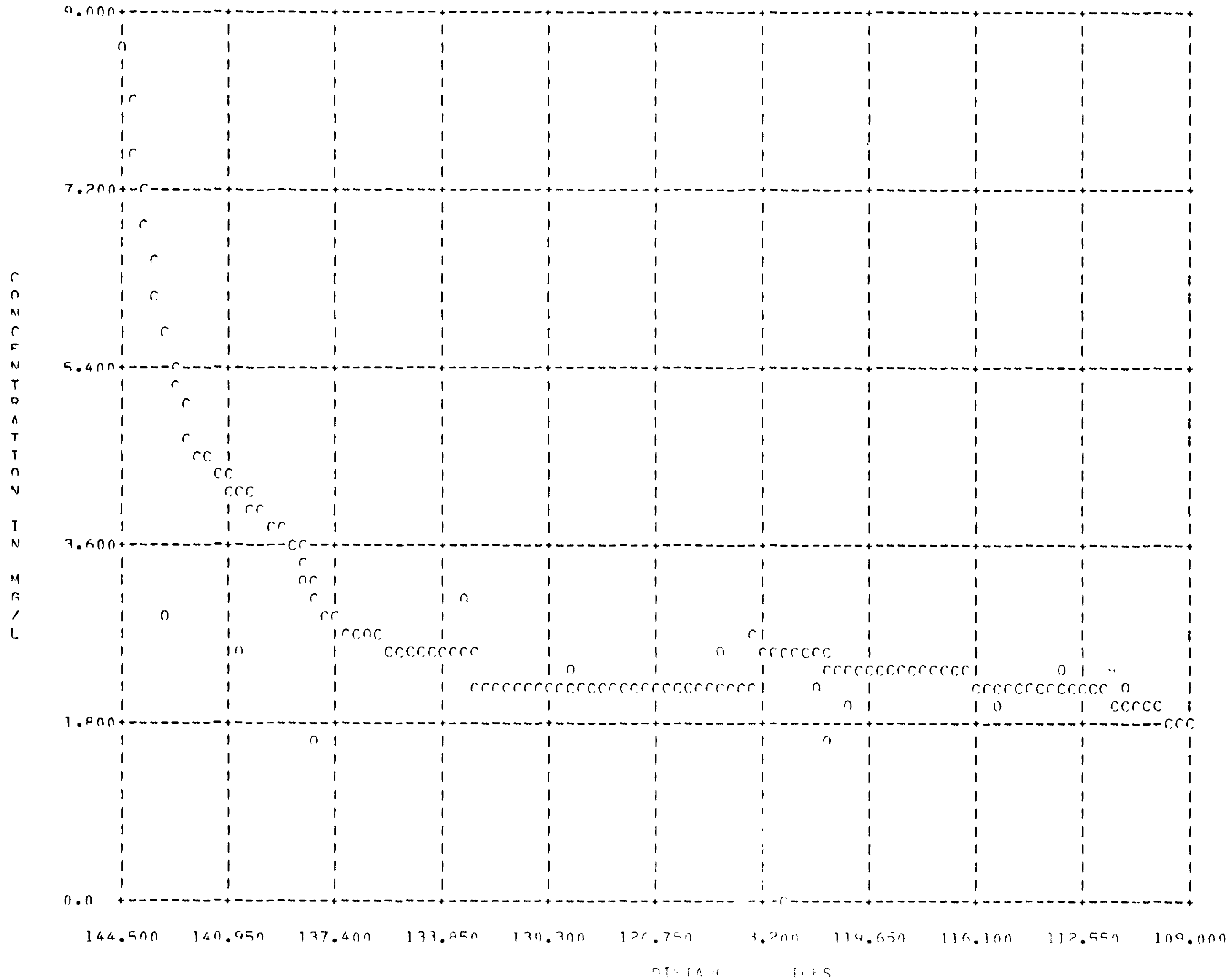
SUBREACH	DO SATURATION (MG/L)
1	8.235
2	8.390
3	8.390
4	8.551
5	8.551
6	8.551
7	8.390
8	8.235
9	8.390
10	8.235
11	8.390
12	8.390
13	8.390
14	8.235

ILLINOIS RIVER CALIBRATION,1991 DATA.MIN DO SET

O B S E R V E D   M E A S U R E M E N T S

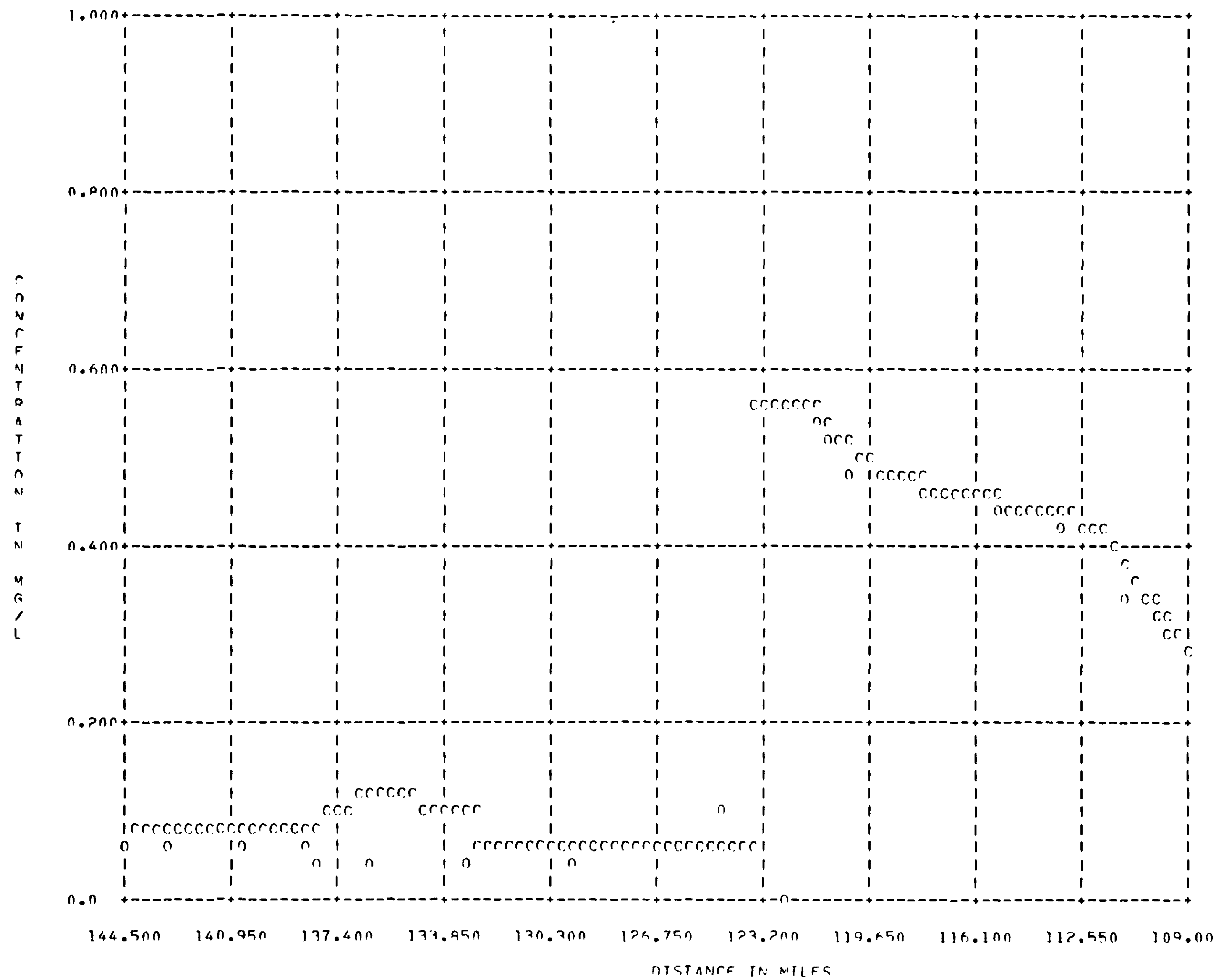
DISTANCE (MI)	DO CONC (MG/L)	CBODU (MG/L)	NBODU (MG/L)	ORG-N (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)	TOTAL COLIFORM	FECAL COLIFORM	PO4 (MG/L)
144.50	6.80	8.60	0.0	1.10	0.14	0.01	0.15	240.	240.	0.07
143.00	5.30	2.80	0.0	0.47	0.13	0.01	1.30	240.	140.	0.05
140.70	5.70	2.60	0.0	0.50	0.15	0.02	0.89	150.	150.	0.05
138.50	5.70	3.30	0.0	0.85	0.10	0.01	1.20	850.	580.	0.05
138.10	4.60	1.70	0.0	0.93	0.17	0.01	1.60	1000.	900.	0.04
136.40	5.10	2.70	0.0	0.74	0.14	0.01	1.20	4000.	400.	0.03
133.10	5.50	3.00	0.0	0.67	0.11	0.01	0.81	3700.	3700.	0.03
129.60	6.50	2.40	0.0	0.49	0.13	0.02	0.87	1200.	1200.	0.04
124.60	6.40	2.50	0.0	0.76	0.12	0.01	0.86	2700.	600.	0.10
122.40	6.00	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	0.0
121.50	5.50	2.10	0.0	0.88	0.12	0.01	2.20	120.	90.	0.54
121.20	6.80	1.60	0.0	0.95	0.15	0.01	2.20	220.	93.	0.52
120.30	5.40	2.00	0.0	0.66	0.10	0.01	2.20	180.	73.	0.48
115.50	6.60	2.00	0.0	0.67	0.07	0.01	1.90	0.	150.	0.44
113.30	6.50	2.40	0.0	0.83	0.12	0.01	1.90	0.	0.	0.42
111.30	6.20	2.10	0.0	0.82	0.14	0.01	1.70	0.	0.	0.34

ILLINOIS RIVER CALIBRATION,1981 DATA,MIN. DO SET
CALCULATED AND OBSERVED CBOD CONCENTRATIONS VERSUS DISTANCE

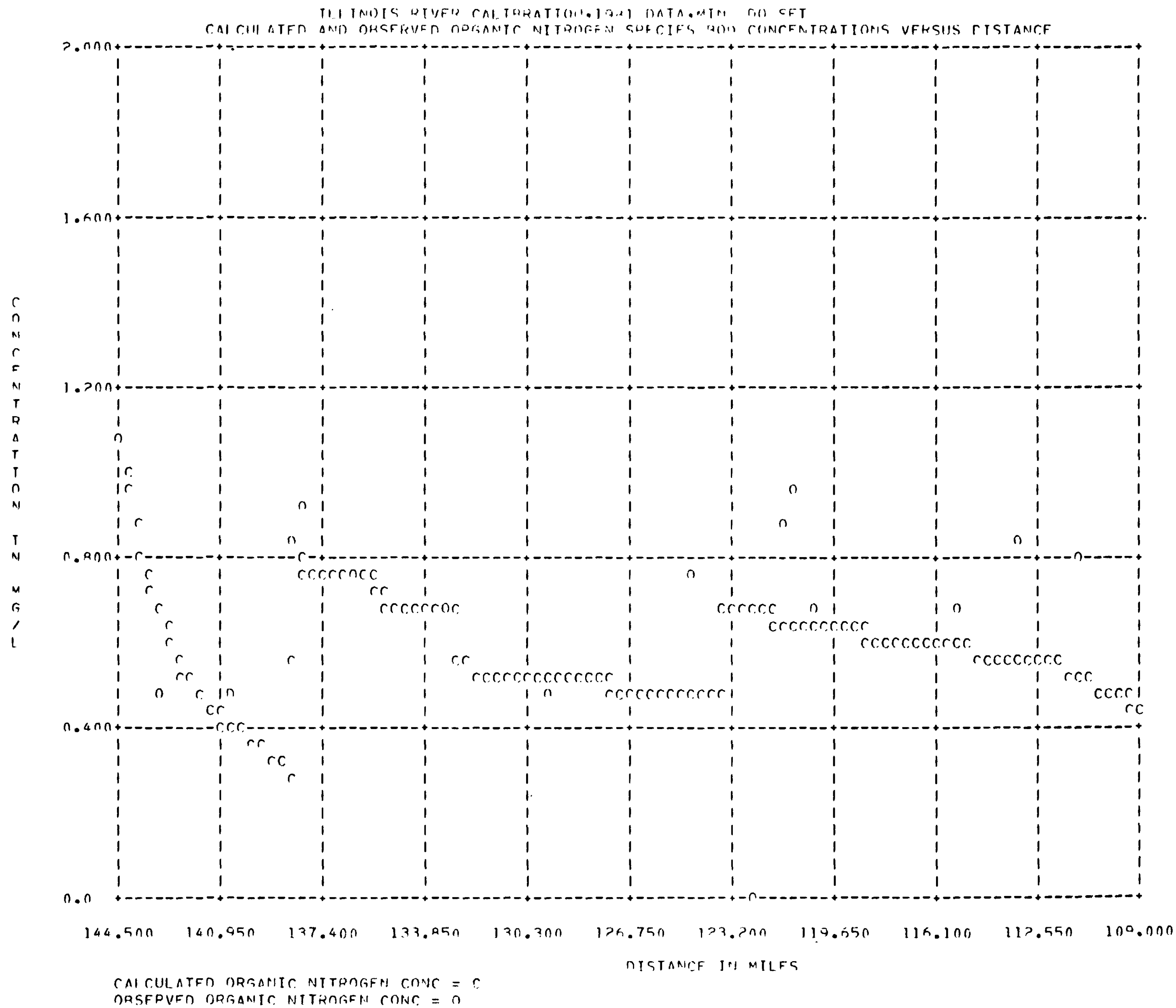


CALCULATED CBODU CONC = C
OBSERVED CBODU CONC = O

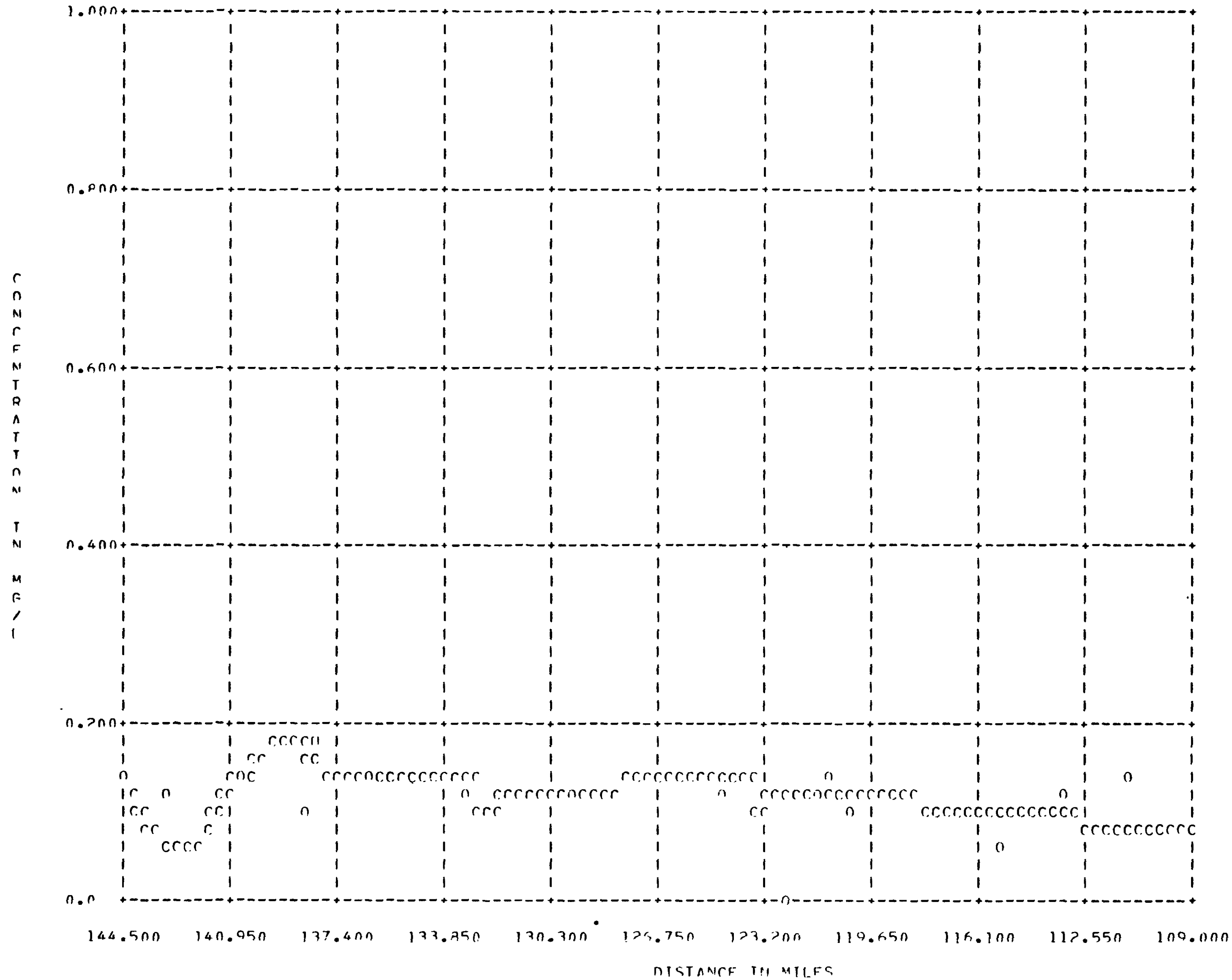
ILLINOIS RIVER CALIBRATION,1981 DATA,MIN. DO SET
CALCULATED AND OBSERVED PO4 CONCENTRATIONS VERSUS DISTANCE



CALCULATED PO4 CONC = C
OBSERVED PO4 CONC = O

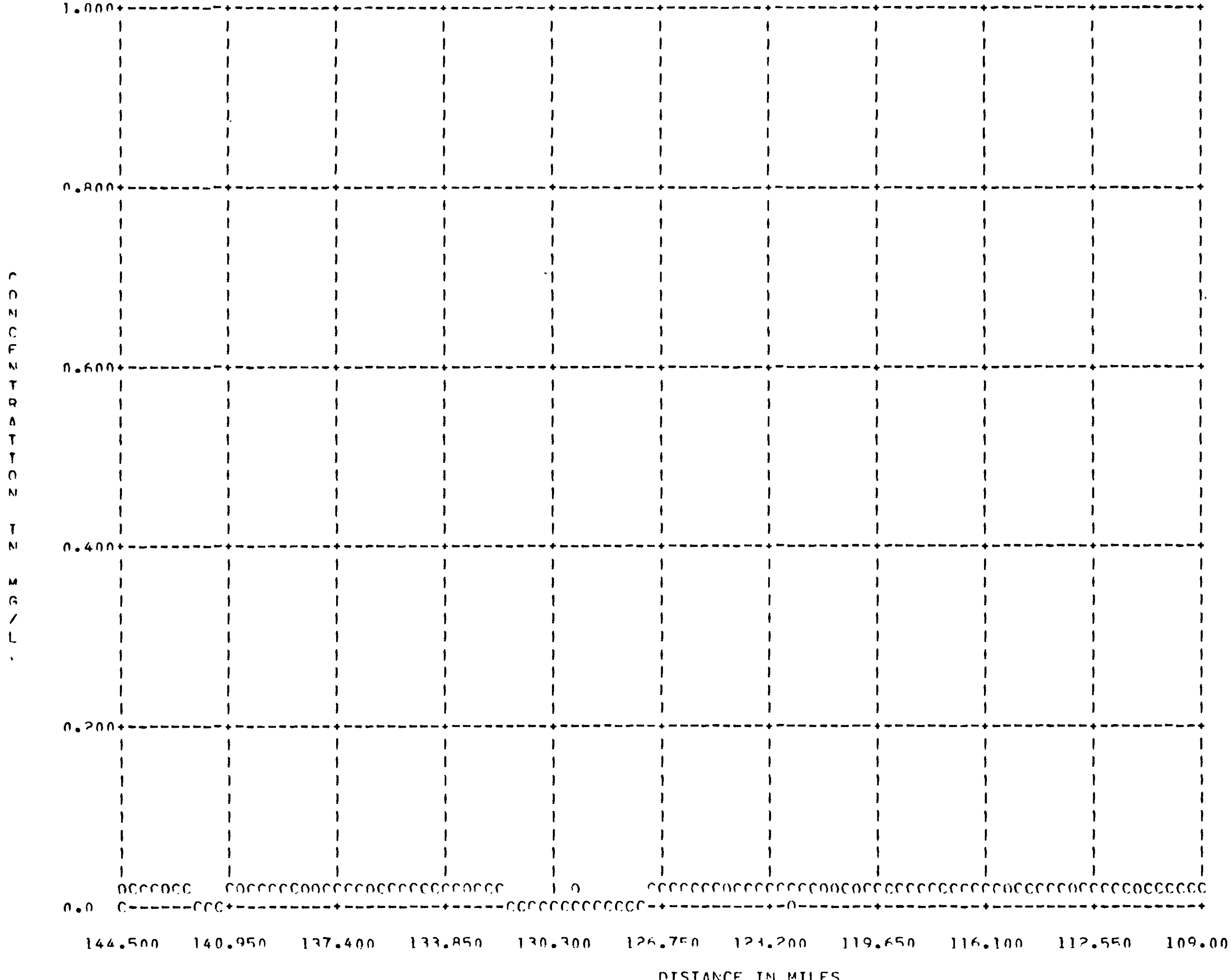

ILLINOIS RIVER CALIBRATION,1981 DATA,MIN. DO SET
CALCULATED AND OBSERVED ORGANIC NITROGEN SPECIES 900 CONCENTRATIONS VERSUS DISTANCE
2.000
1.600
1.200
0.800
0.400
0.0
CONCENTRATION IN MG/L
144.500
140.950
137.400
133.850
130.300
126.750
123.200
119.650
116.100
112.550
109.000
DISTANCE IN MILES
CALCULATED ORGANIC NITROGEN CONC = C
OBSERVED ORGANIC NITROGEN CONC = O

ILLINOIS RIVER CALIBRATION,19[illegible]1 DATA,MIN. DO SET
CALCULATED AND OBSERVED AMMONIA NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



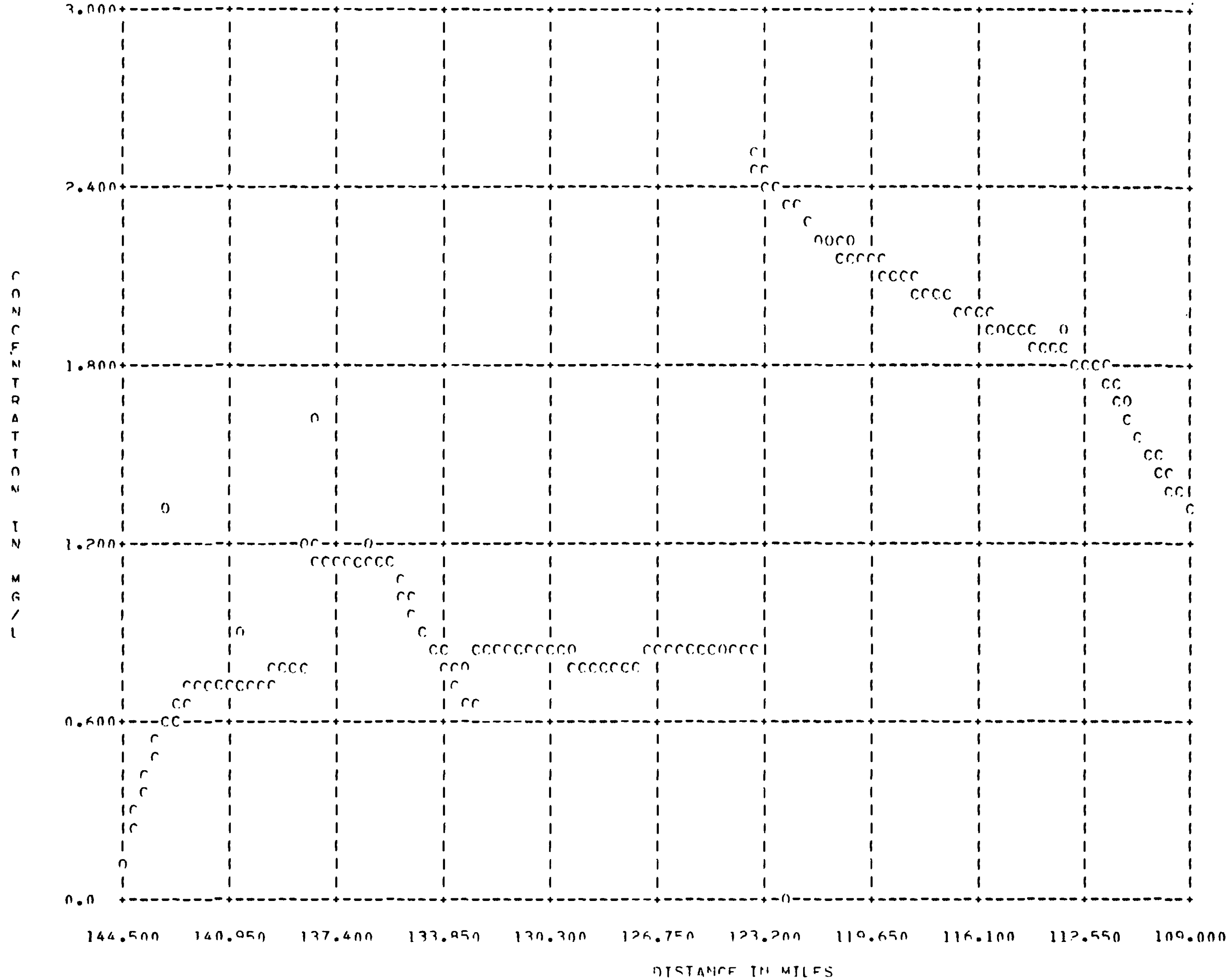
CALCULATED AMMONIA NITROGEN CONC = C
OBSERVED AMMONIA NITROGEN CONC = O

ILLINOIS RIVER CALIBRATION,1931 DATA,MIN. DO SET
CALCULATED AND OBSERVED NITRITE NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE



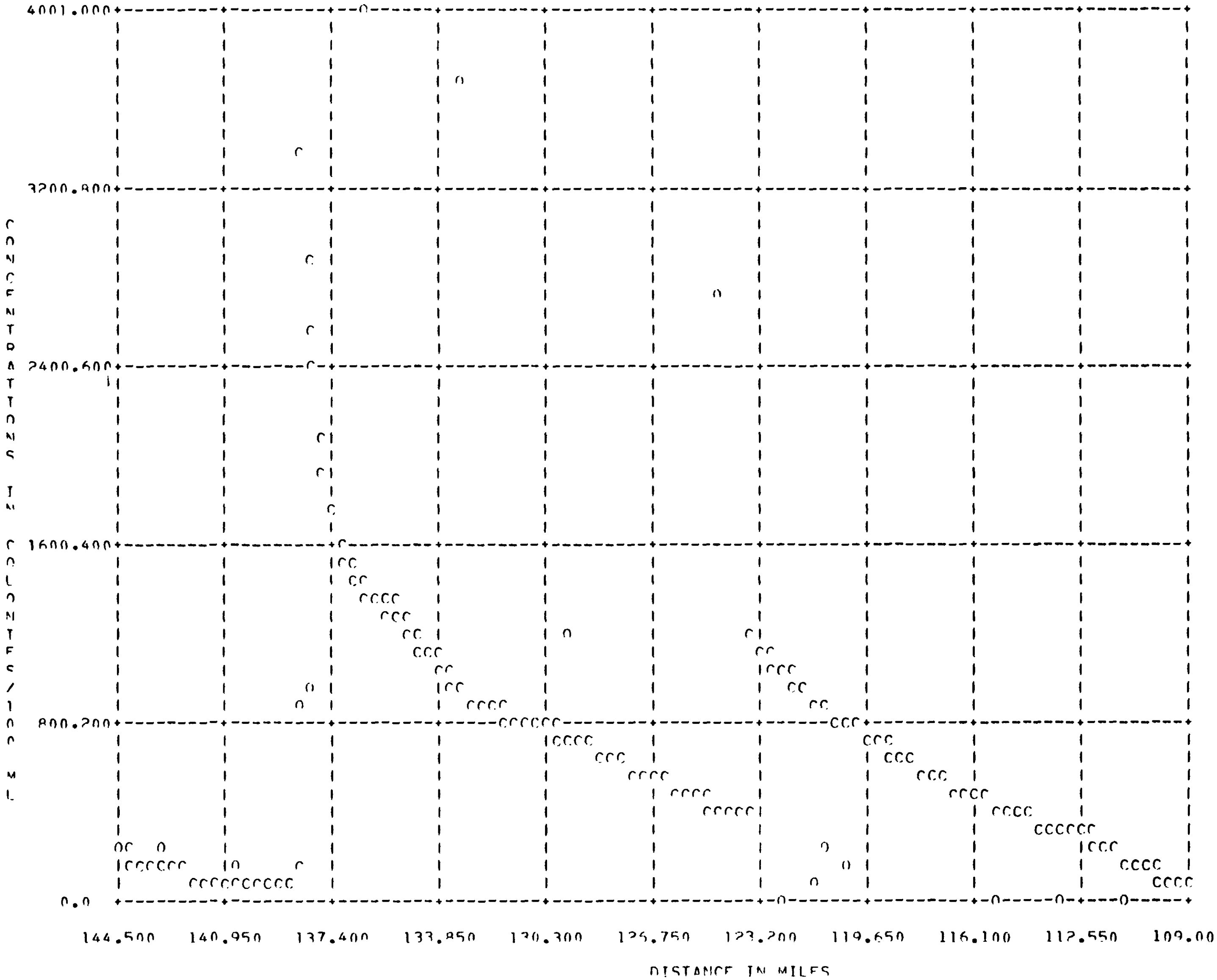
CALCULATED NITRITE NITROGEN CONC = C
OBSERVED NITRITE NITROGEN CONC = O

ILLINOIS RIVER CALIBRATION.1971 DATA.MIN. DO SET
CALCULATED AND OBSERVED NITRATE NITROGEN SPECIES AND CONCENTRATIONS VERSUS DISTANCE



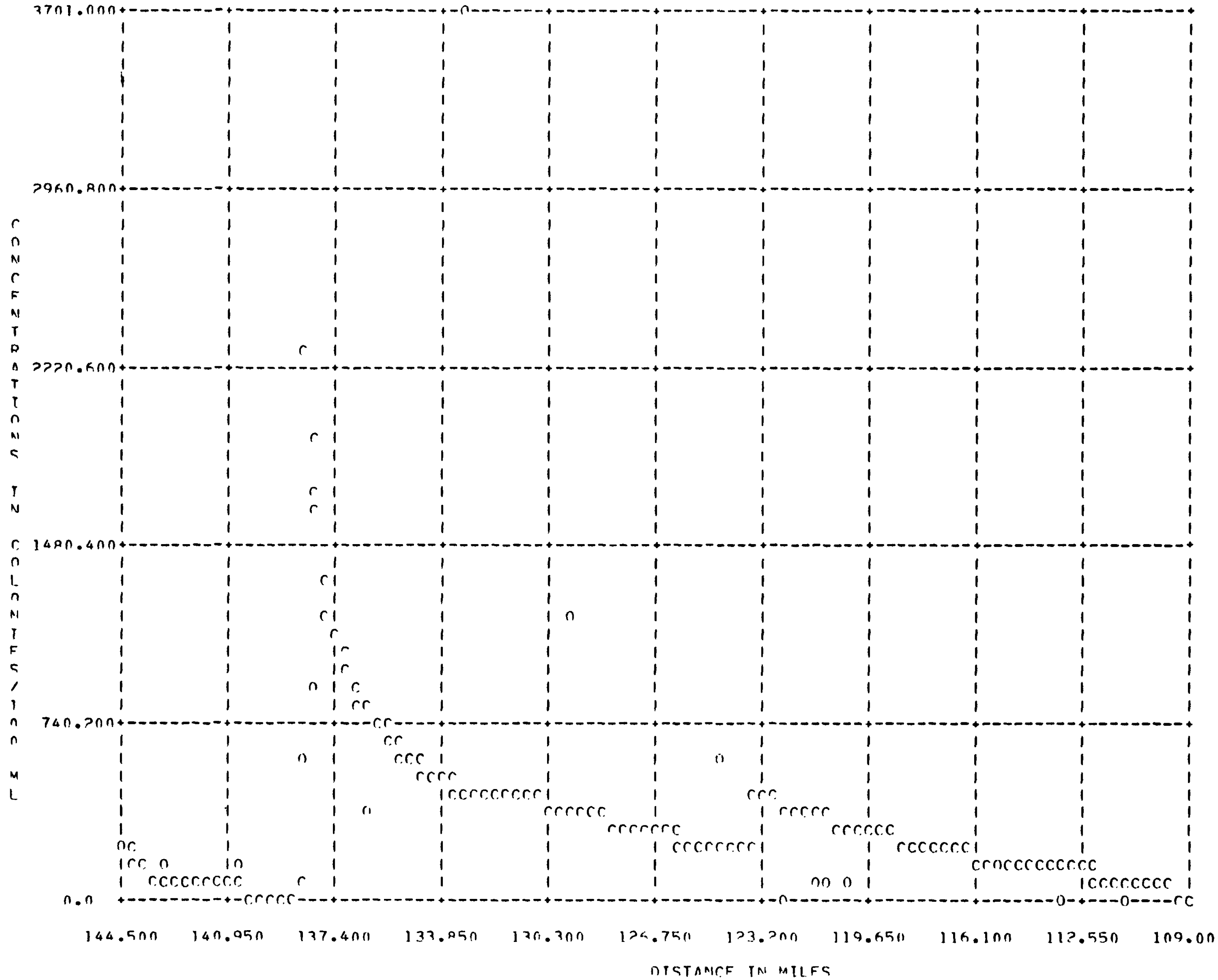
CALCULATED NITRATE NITROGEN CONC = C
OBSERVED NITRATE NITROGEN CONC = O

ILLINOIS RIVER CALIBRATION,1981 DATA,MIN. DO SET
CALCULATED AND OBSERVED TOTAL COLIFORM CONCENTRATIONS VERSUS DISTANCE



CALCULATED TOTAL COLIFORM CONC = C
OBSERVED TOTAL COLIFORM CONC = O

ILLINOIS RIVER CALIBRATION,1981 DATA,MIN. DO SET
CALCULATED AND OBSERVED FECAL COLIFORM CONCENTRATIONS VERSUS DISTANCE



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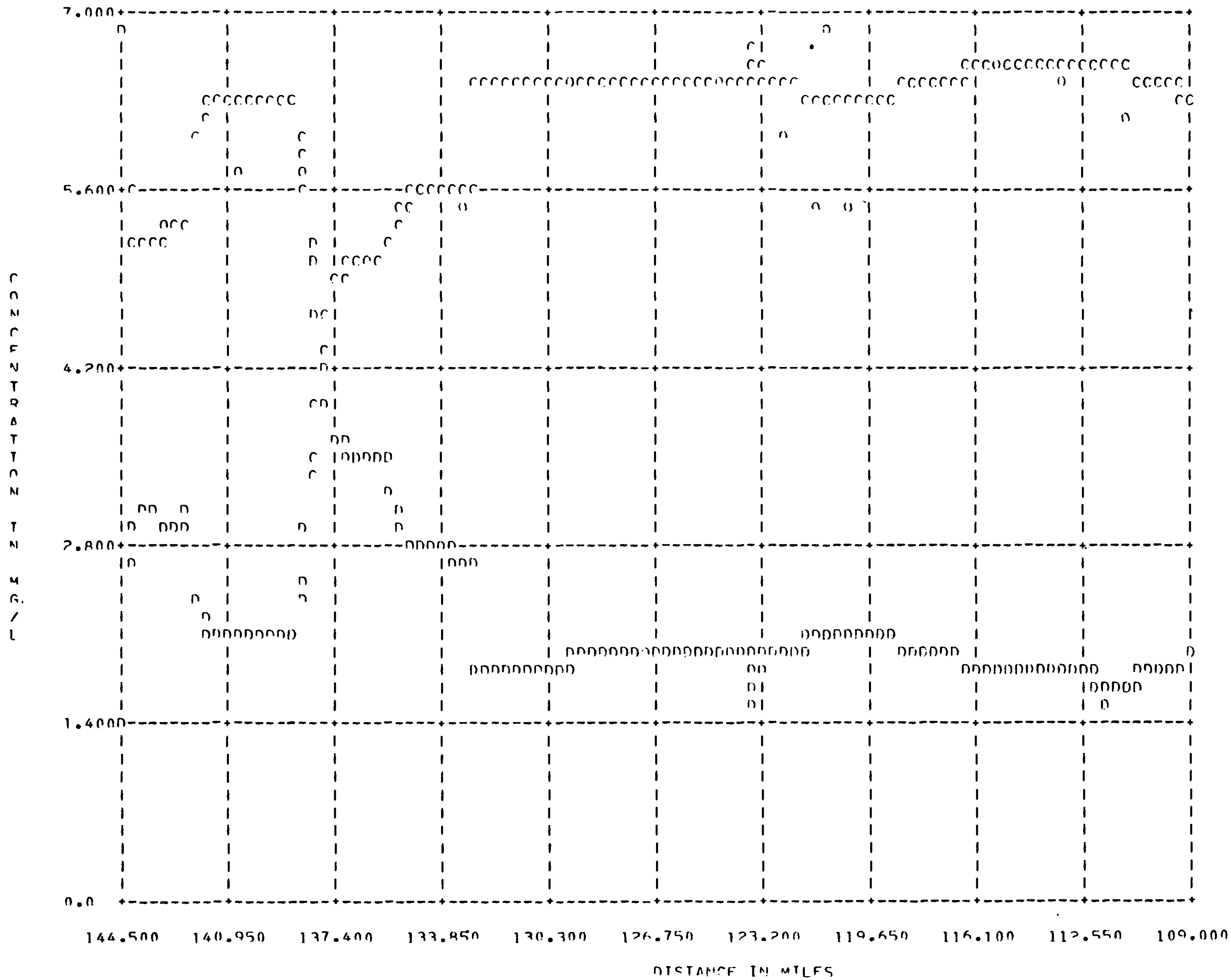
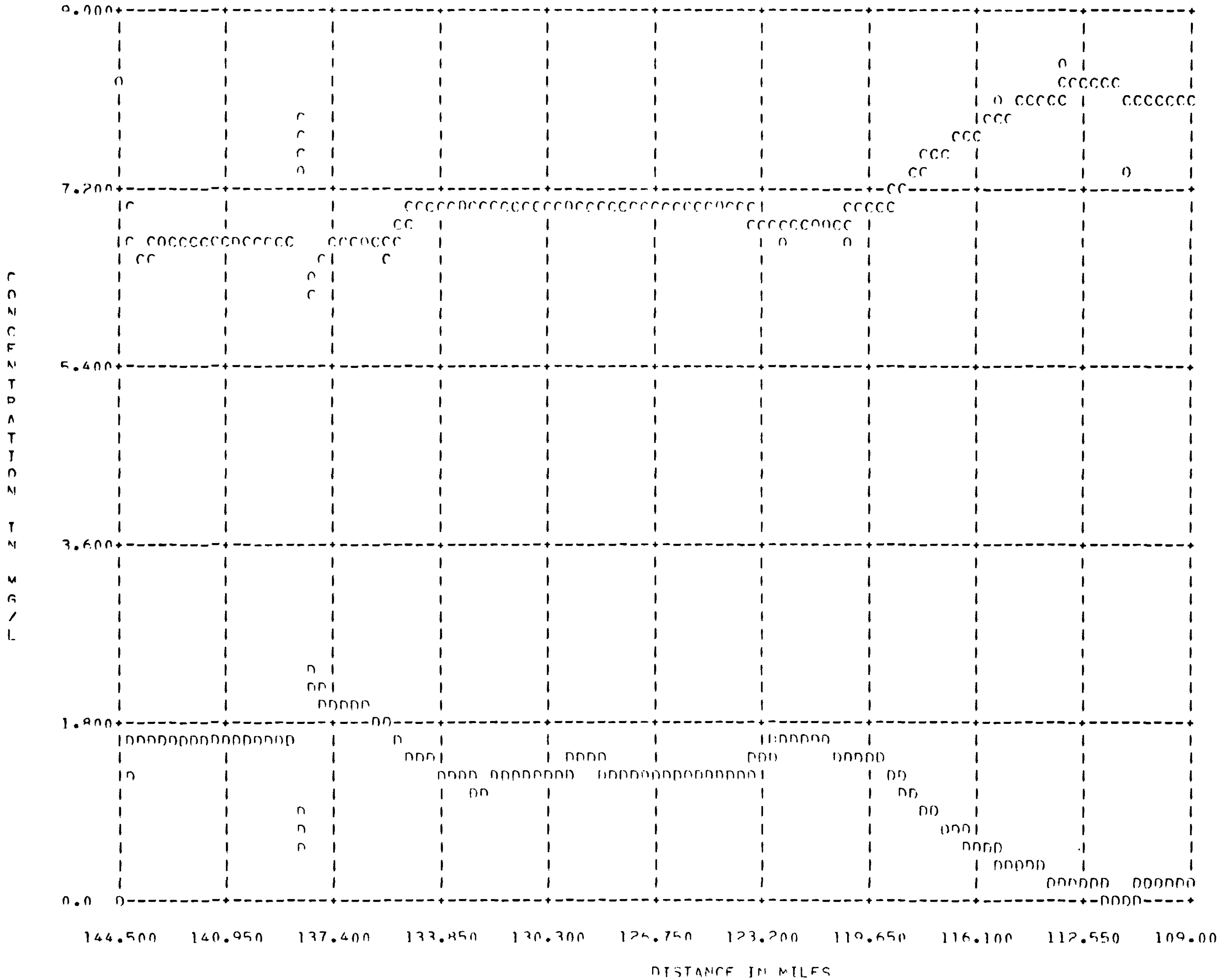
OBSERVED FECAL COLIFORM CONC = O

ILLINOIS RIVER CALIBRATION,1981 DATA,4IN DO SET
CALCULATED AND OBSERVED DO CONCENTRATIONS AND DO DEFICIT VERSUS DISTANCE

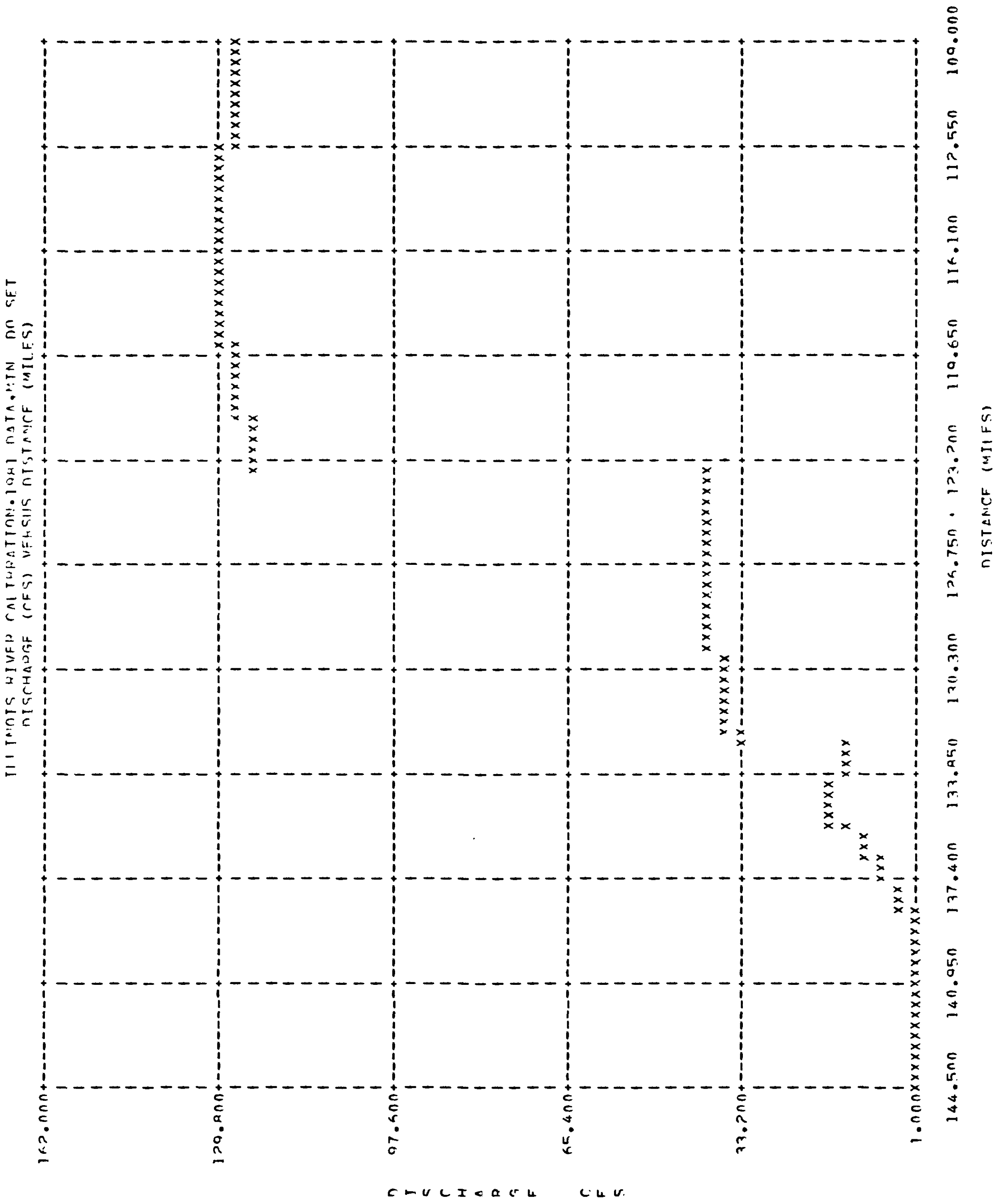


CALCULATED DO CONC = C
OBSERVED DO CONC = O
DO DEFICIT = D

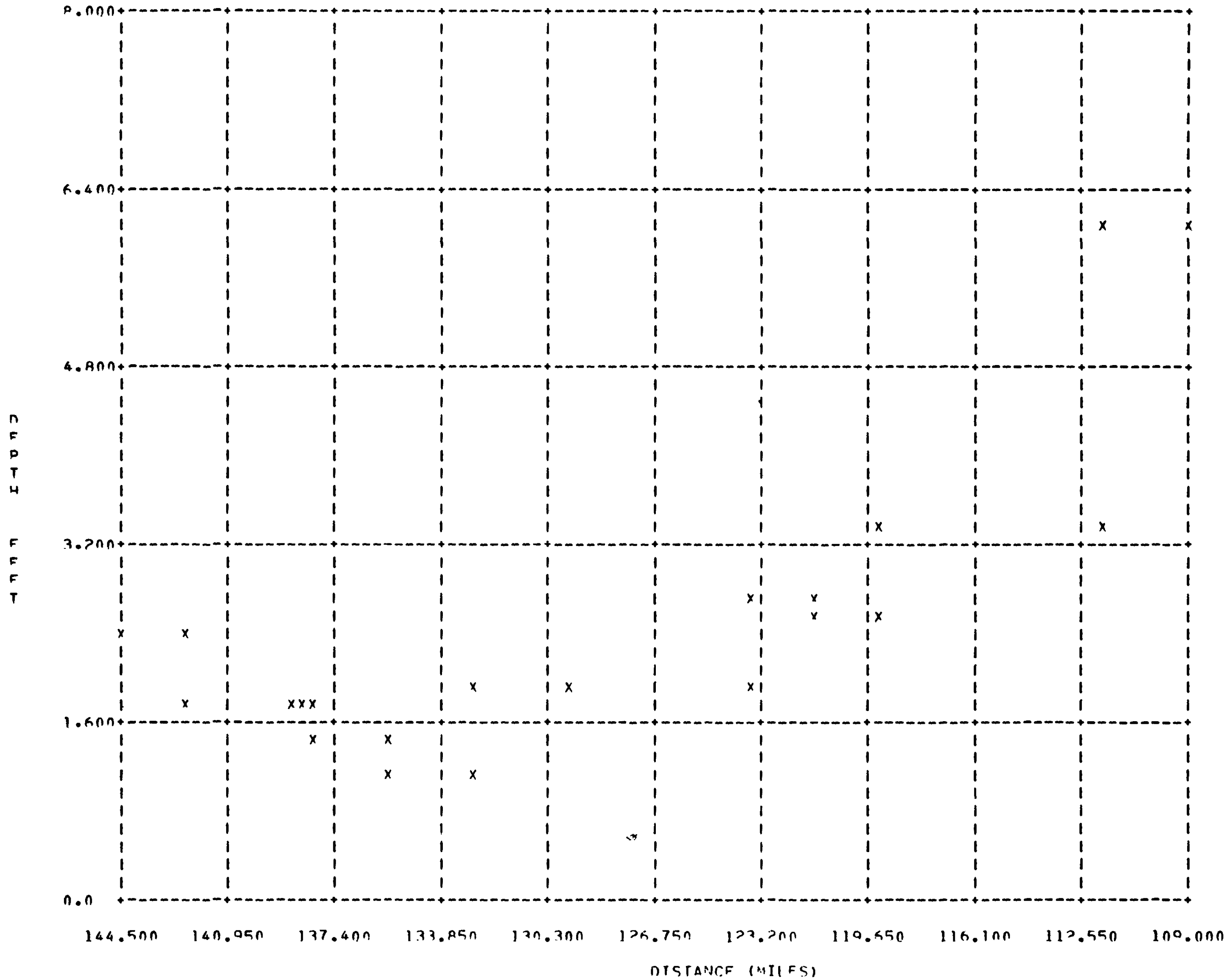
ILLINOIS RIVER CALIBRATION,1981 DATA,MEAN DO SET
CALCULATED AND OBSERVED DO CONCENTRATIONS AND DO DEFICIT VERSUS DISTANCE



CALCULATED DO CONC = C
OBSERVED DO CONC = O
DO DEFICIT = D


ILLINOIS RIVER CALIBRATION.1981 DATA.MIN. DO SET
DISCHARGE (CFS) VERSUS DISTANCE (MILES)
162.000
129.800
97.600
65.400
33.200
1.000
144.500
140.950
137.400
133.850
130.300
126.750
123.200
119.650
116.100
112.550
109.000
DISTANCE (MILES)
DISCHARGE CFS

ILLINOIS RIVER CALIBRATION,1981 DATA,MIN DO SET
DEPTH (FEET) VERSUS DISTANCE (MILES)



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STEADY STATE WATER QUALITY MODEL

GULF COAST HYDROSCIENCE CENTER

U. S. GEOLOGICAL SURVEY

(ARKANSAS VERSION)

DATE OF LAST REVISION, DECEMBER  1980


ILLINOIS RIVER VERIFICATION '79 DATA, MININUM DO SET

       DISSOLVED OXYGEN PROFILE REPRESENTS
   ***  DIEL MINIMUMS: NET PHOTOSYNTHETIC DO   ***
       PRODUCTION ADJUSTED ACCORDINGLY.

      NITRIFICATION CYCLE INCLUDED IN MODEL


      NUMBER OF SUBREACHES FOR THIS PROBLEM =    14



          PRINTING INTERVAL (MILES) =    0.200

         STARTING DISTANCE (MILES) =  144.500

 INITIAL CBOD CONC (MG/L) AT STARTING DISTANCE =   10.00

 INITIAL ORGANIC NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.610

 INITIAL AMMONIUM NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.100

 INITIAL NITRITE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.050

 INITIAL NITRATE NITROGEN CONC (MG/L) AT STARTING DISTANCE =   0.150

 INITIAL DO CONC (MG/L) AT STARTING DISTANCE =   6.400

 INITIAL PHOSPHATE CONC (MG/L) AT STARTING DISTANCE =   0.010

 INITIAL TOT. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =     130.

 INITIAL FEC. COLIF. CONC (COL/100ML) AT STARTING DISTANCE =     130.

     STREAMFLOW (CFS) AT STARTING DISTANCE =     0.520
```

ILLINOIS RIVER VERIFICATION '79 DATA, MINIMUM DO SET

S U B R E A C H   L I N E A R   R U N O F F   D A T A

SUBREACH	Q	CBOD	ORGANIC	AMMONIA	NITRITE	NITRATE	DO	PO4
	(CFS)	(MG/L)	(MG/L)	(MG/L)	(MG/L)	(MG/L)	(MG/L)	(MG/L)
1	1.38	2.6	0.5	0.1	0.0	1.1	5.8	0.1
2	0.50	2.6	0.5	0.1	0.0	1.1	5.8	0.1
3	0.50	2.6	0.1	0.1	0.0	1.1	5.8	0.1
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
5	2.16	2.6	1.0	0.1	0.0	1.1	5.8	0.1
6	0.92	2.6	1.0	0.1	0.0	1.1	5.8	0.1
7	-0.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	-2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	4.88	6.0	0.5	0.1	0.0	1.1	5.8	0.1
10	0.0	0.0	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	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	-4.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

R E A C H   D E S C R I P T I O N   D A T A   (MAJOR TRIBUTARIES AND MAIN STEM)

SUBREACH	CODE	NAME	BEGIN (MILE)	END (MILE)
1	A	UPSTREAM	144.50	142.20
2	A		142.20	138.70
3	A	PROPOSED F'VILLE STP	138.70	138.40
4	A	GOOSE CREEK	138.40	138.20
5	A	BL .2 MI GOOSE CREEK	138.20	138.00
6	A	UNNAMED TRIB.	138.00	135.60
7	A	MUDDY FORK	135.60	132.80
8	A	CLEAR CREEK	132.80	129.60
9	A	UNNAMED TRIB.	129.60	123.70
10	A	OSAGE CREEK	123.70	123.50
11	A	UN-NAMED TRIBUTARY	123.50	121.40
12	A	CHAMBERS HOLLOW	121.40	119.30
13	A	SHINN SPRING	119.30	112.00
14	A	CINCINNATI CREEK	112.00	109.00

KEY: CODE

A ROCKY BOTTOM-POOL RIFFLE-LIGHT VEGETATION
B ROCKY BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
C ROCKY BOTTOM-POOL RIFFLE-HEAVY VEGETATION
D ROCKY BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
E ROCKY BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
F ROCKY BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION
G MUD BOTTOM-POOL RIFFLE-LIGHT VEGETATION
H MUD BOTTOM-POOL RIFFLE-MEDIUM VEGETATION
I MUD BOTTOM-POOL RIFFLE-HEAVY VEGETATION
J MUD BOTTOM-CHANNEL CONTROL-LIGHT VEGETATION
K MUD BOTTOM-CHANNEL CONTROL-MEDIUM VEGETATION
L MUD BOTTOM-CHANNEL CONTROL-HEAVY VEGETATION

ILLINOIS RIVER VERIFICATION '79 DATA, MININUM DO SET

I N P U T   P A R A M E T E R S

CONCENTRATIONS(MG/L) OF --

SUBREACH	CARB BOD	ORG-N	NH3-N	NO2-N	NO3-N	DISSOLVED OXYGEN	PO4	TOT.COLIF.	FEC.COLIF.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	3.00	0.36	0.12	0.07	1.70	6.50	0.02	1600.00	1300.00
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.90	0.37	0.14	0.01	0.50	4.80	0.04	240.00	10.00
7	2.70	0.31	0.09	0.06	1.20	6.40	0.09	1700.00	610.00
8	2.90	0.29	0.01	0.0	0.62	7.50	0.02	600.00	240.00
9	3.80	0.85	0.15	0.01	0.19	5.50	0.06	2000.00	600.00
10	4.30	0.70	0.01	0.03	3.20	6.50	0.88	580.00	130.00
11	4.00	0.60	0.02	0.02	1.10	4.60	0.14	2000.00	500.00
12	3.50	0.09	0.01	0.02	1.10	5.80	0.14	300.00	890.00
13	1.20	0.40	0.01	0.01	0.76	5.80	0.14	1700.00	940.00
14	0.0	0.0	0.0	0.0	0.0	5.80	0.01	1700.00	940.00

DIRECT DISCHARGES(LB/DAY) OF --

SUBREACH	CARBONACEOUS ULT. BOD	ORGANIC NITROGEN	AMMONIA NITROGEN	NITRITE NITROGEN	NITRATE NITROGEN	PHOSPHATE
1	0.0	0.0	0.0	0.0	0.0	0.
2	0.0	0.0	0.0	0.0	0.0	0.
3	0.0	0.0	0.0	0.0	0.0	0.
4	0.0	0.0	0.0	0.0	0.0	0.
5	0.0	0.0	0.0	0.0	0.0	0.
6	0.0	0.0	0.0	0.0	0.0	0.
7	0.0	0.0	0.0	0.0	0.0	0.
8	0.0	0.0	0.0	0.0	0.0	0.
9	0.0	0.0	0.0	0.0	0.0	0.
10	0.0	0.0	0.0	0.0	0.0	0.
11	0.0	0.0	0.0	0.0	0.0	0.
12	0.0	0.0	0.0	0.0	0.0	0.
13	0.0	0.0	0.0	0.0	0.0	0.
14	0.0	0.0	0.0	0.0	0.0	0.

ILLINOIS RIVER VERIFICATION '79 DATA. MINIMUM DO SET

SUBREACH	NET PHOTOSYNTHETIC DO PRODUCTION (MG/L/DAY @ 20 DEG C)	(FITTING FACTOR FOR MINIMUM DO PROFILE)	BENTHIC DO DEMAND (G/SQM/DAY @ 20 DEG C)
1	3.400	-1.000	4.00
2	4.600	-1.000	4.70
3	5.100	-5.000	3.20
4	5.200	-7.000	7.20
5	5.400	-7.000	6.00
6	5.400	-4.000	4.50
7	0.140	-7.000	2.40
8	0.180	-1.500	2.00
9	1.000	-1.500	2.50
10	0.590	-1.500	4.00
11	1.650	-1.000	4.00
12	2.600	-2.000	4.00
13	2.500	-2.500	2.00
14	2.170	-0.400	4.00

G E O M E T R Y

SUBREACH	FLOW CHANGE (CFS)	AREA (SQFT)	DEPTH (FT)	SLOPE	TEMP (DEG.CENT)	END MI (MI)
1	0.0	71.	2.38	0.0013300	26.00	142.20
2	0.0	71.	1.82	0.0013300	24.00	138.70
3	0.0	71.	1.82	0.0013300	22.00	138.40
4	0.94	71.	1.82	0.0012400	23.00	138.20
5	0.0	71.	1.82	0.0012400	23.00	138.00
6	0.28	78.	1.50	0.0012400	24.00	135.60
7	4.00	78.	1.13	0.0013600	25.00	132.80
8	23.00	114.	1.86	0.0010800	25.00	129.60
9	0.12	150.	1.98	0.0008000	25.00	123.70
10	91.00	270.	2.70	0.0008200	23.00	123.50
11	0.30	272.	2.72	0.0008200	24.00	121.40
12	0.70	248.	2.49	0.0008500	24.00	119.30
13	1.20	274.	3.30	0.0008500	25.00	112.00
14	0.01	900.	6.00	0.0003400	25.00	109.00

ILLINOIS RIVER VERIFICATION '79 DATA. MINIMUM DO SET

R E A C T I O N   C O E F F I C I E N T S (/DAY @ 20 DEG C)

SUBREACH	KR	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KCOLF	KCOLT	KPO41	KPO42
1	0.06	0.06	0.05	0.07	0.60	0.60	3.00	3.00	0.01	0.50	0.50	0.01	0.0
2	0.02	0.02	0.05	0.05	0.05	0.05	0.50	0.50	0.01	0.50	0.50	0.01	0.0
3	0.02	0.02	0.05	0.05	0.05	0.05	0.50	0.50	0.01	0.50	0.50	0.01	0.0
4	0.10	0.10	0.05	0.05	0.30	0.30	1.50	1.50	0.01	0.50	0.50	0.07	0.0
5	0.10	0.10	0.05	0.05	0.30	0.30	1.50	1.50	0.01	0.50	0.50	0.07	0.0
6	0.05	0.05	0.05	0.20	0.10	0.10	1.70	1.70	0.01	0.50	0.50	0.02	0.0
7	0.01	0.01	0.05	0.05	0.20	0.20	1.50	1.50	0.50	0.50	0.50	0.07	0.0
8	0.03	0.03	0.05	0.05	0.05	0.05	1.50	1.50	0.10	0.50	0.50	0.02	0.0
9	0.03	0.03	0.05	0.05	0.10	0.10	1.00	1.00	0.01	0.50	0.50	0.02	0.0
10	0.19	0.13	0.05	0.10	0.10	0.10	1.00	1.00	0.25	1.00	1.00	0.03	0.0
11	0.20	0.13	0.05	0.10	0.10	0.10	1.00	1.00	0.25	1.00	1.00	0.03	0.0
12	0.10	0.10	0.05	0.10	0.30	0.30	1.00	1.00	0.10	1.00	1.00	0.30	0.0
13	0.10	0.10	0.05	0.10	0.50	0.50	2.00	2.00	0.15	1.00	1.00	0.10	0.0
14	0.10	0.10	0.05	0.10	0.30	0.30	1.50	1.50	0.17	1.00	1.00	0.20	0.0

TEMPERATURE CORRECTED REACTION COEFFICIENTS (/DAY)

SUBREACH	KR	KD	KORG	SKORG	KNH3	SKNH3	KNO2	SKNO2	KNO3	KA	KPO41	KPO42
1	0.08	0.08	0.08	0.12	1.01	1.01	5.03	5.03	0.02	2.14	0.02	0.0
2	0.02	0.02	0.07	0.07	0.07	0.07	0.71	0.71	0.01	2.89	0.01	0.0
3	0.02	0.02	0.06	0.06	0.06	0.06	0.59	0.59	0.01	2.62	0.01	0.0
4	0.11	0.11	0.06	0.06	0.39	0.39	1.94	1.94	0.01	2.75	0.09	0.0
5	0.11	0.11	0.06	0.06	0.39	0.39	1.94	1.94	0.01	2.75	0.09	0.0
6	0.06	0.06	0.07	0.28	0.14	0.14	2.40	2.40	0.01	2.53	0.03	0.0
7	0.01	0.01	0.08	0.08	0.31	0.31	2.31	2.31	0.77	5.66	0.11	0.0
8	0.04	0.04	0.08	0.08	0.08	0.09	2.31	2.31	0.15	3.75	0.03	0.0
9	0.04	0.04	0.08	0.08	0.15	0.15	1.54	1.54	0.02	2.94	0.03	0.0
10	0.22	0.15	0.06	0.13	0.13	0.13	1.30	1.30	0.32	2.57	0.04	0.0
11	0.24	0.16	0.07	0.14	0.14	0.14	1.41	1.41	0.35	2.59	0.04	0.0
12	0.12	0.12	0.07	0.14	0.42	0.42	1.41	1.41	0.14	3.22	0.42	0.0
13	0.13	0.13	0.08	0.15	0.77	0.77	3.08	3.09	0.23	1.91	0.15	0.0
14	0.13	0.13	0.08	0.15	0.46	0.46	2.31	2.31	0.26	0.33	0.31	0.0

ILLINOIS RIVER VERIFICATION '79 DATA, MININUM DO SET

SUBREACH	REAERATION COEFFICIENT DERIVATION
1	KA COMPUTED BY VELZ EQUATION
2	KA COMPUTED BY VELZ EQUATION
3	KA COMPUTED BY VELZ EQUATION
4	KA COMPUTED BY VELZ EQUATION
5	KA COMPUTED BY VELZ EQUATION
6	KA COMPUTED BY BENNETT - RATHBUN EQUATION
7	KA COMPUTED BY BENNETT - RATHBUN EQUATION
8	KA COMPUTED BY BENNETT - RATHBUN EQUATION
9	KA COMPUTED BY BENNETT - RATHBUN EQUATION
10	KA COMPUTED BY BENNETT - RATHBUN EQUATION
11	KA COMPUTED BY BENNETT - RATHBUN EQUATION
12	KA COMPUTED BY BENNETT - RATHBUN EQUATION
13	KA COMPUTED BY BENNETT - RATHBUN EQUATION
14	KA COMPUTED BY BENNETT - RATHBUN EQUATION

ILLINOIS RIVER VERIFICATION '79 DATA, MININUM DO SET

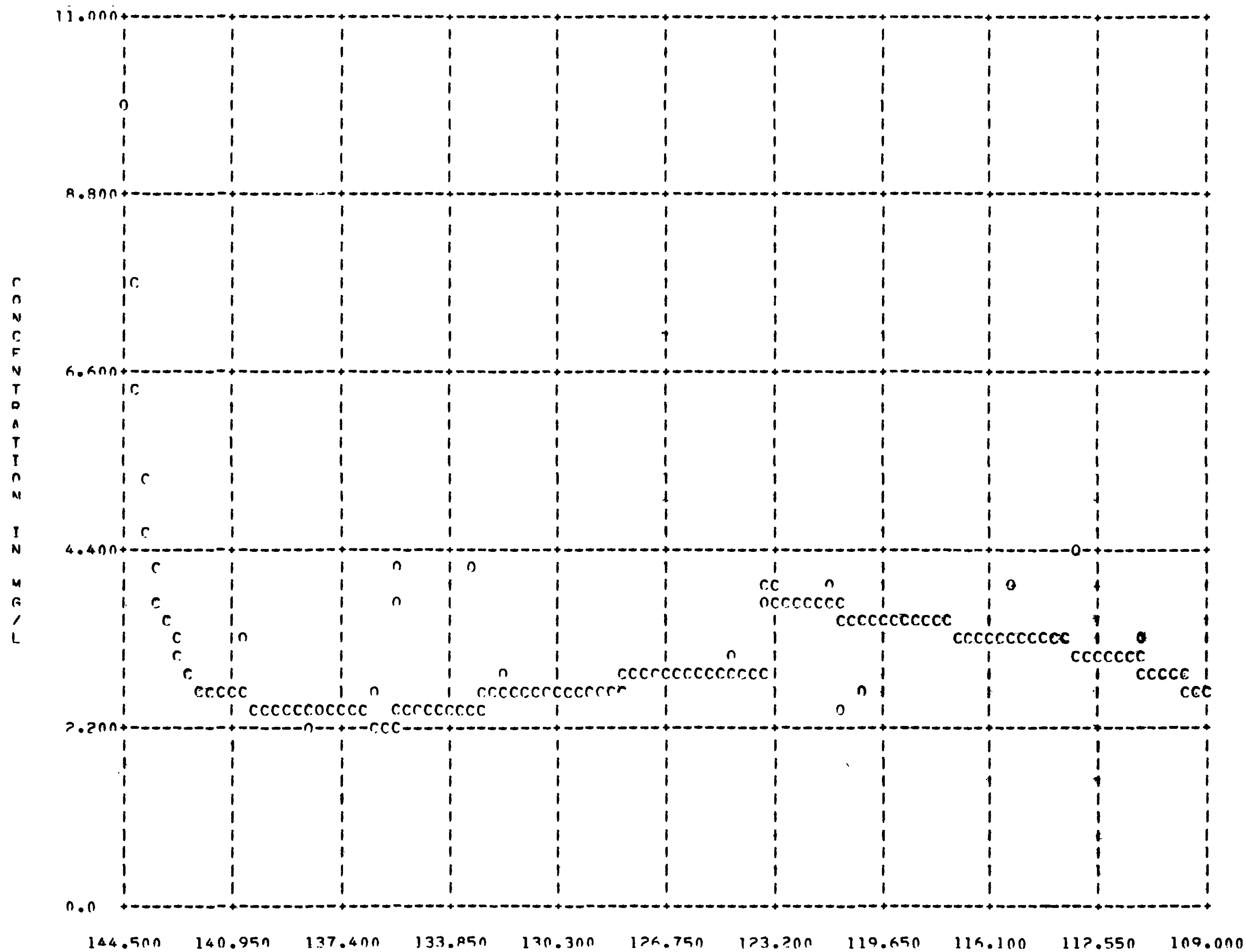
SUBREACH	DO SATURATION (MG/L)
1	8.085
2	8.390
3	8.717
4	8.551
5	8.551
6	8.390
7	8.235
8	8.235
9	8.235
10	8.551
11	8.390
12	8.390
13	8.235
14	8.235

ILLINOIS RIVER VERIFICATION '79 DATA, MININUM DO SET

O B S E R V E D   M E A S U R E M E N T S

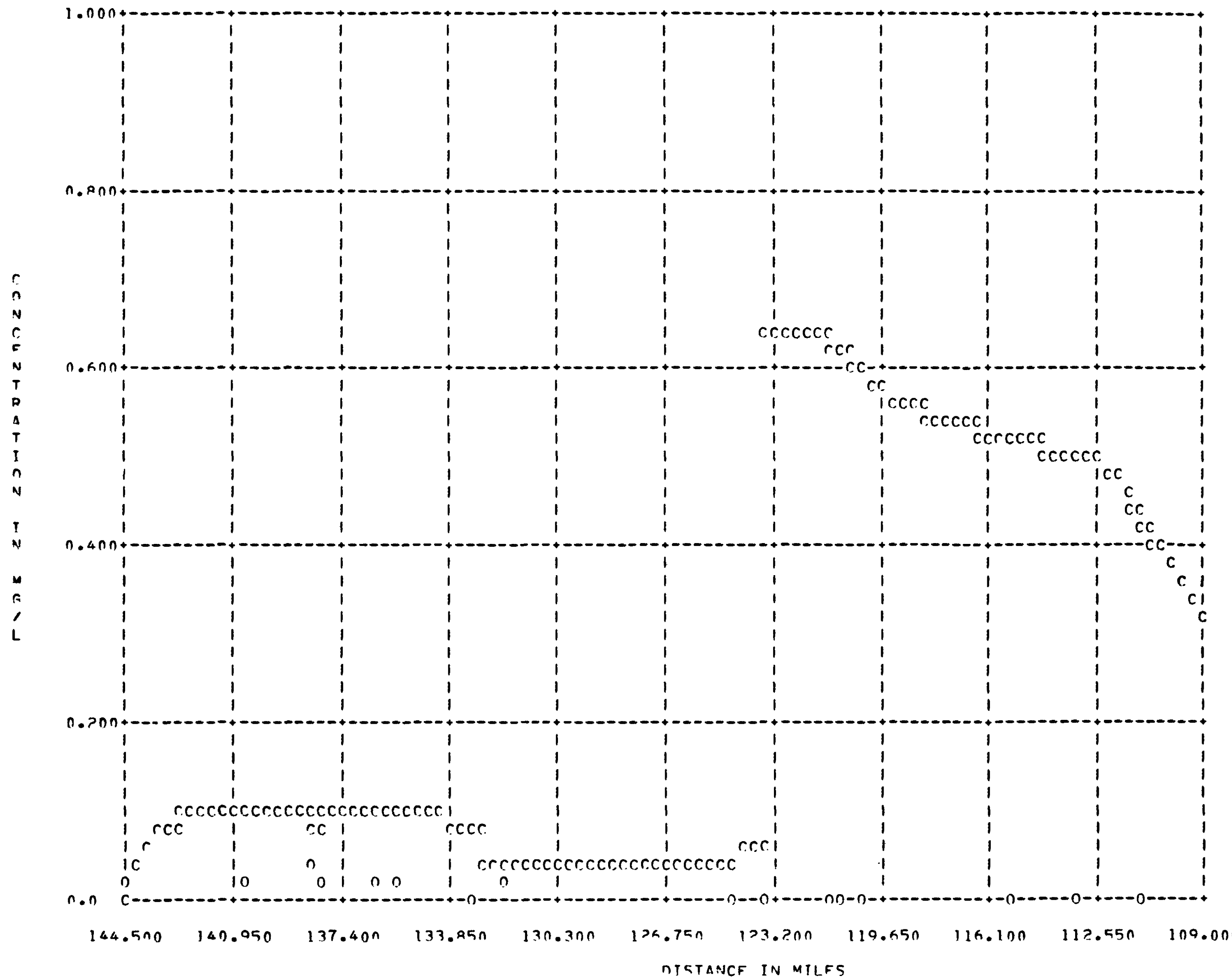
DISTANCE (MI)	DO CONC (MG/L)	CBODU (MG/L)	NBODU (MG/L)	ORG-N (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)	TOTAL COLIFORM	FECAL COLIFORM	PO4 (MG/L)
144.50	6.40	10.00	0.0	0.61	0.10	0.05	0.15	130.	130.	0.01
140.70	6.70	3.20	0.0	0.29	0.04	0.02	2.10	300.	170.	0.01
138.50	4.50	2.10	0.0	0.13	0.10	0.04	2.30	830.	730.	0.04
138.40	4.30	2.40	0.0	0.41	0.09	0.06	2.30	1300.	1300.	0.01
136.40	0.0	2.70	0.0	0.17	0.08	0.05	1.80	330.	489.	0.01
135.70	0.0	4.20	0.0	0.17	0.07	0.05	1.60	280.	44.	0.01
135.50	0.0	3.80	0.0	0.37	0.07	0.06	1.40	200.	190.	0.01
133.10	4.80	4.10	0.0	0.31	0.03	0.0	0.0	600.	140.	0.0
132.10	6.70	2.90	0.0	0.17	0.07	0.06	1.40	280.	33.	0.01
124.60	6.00	3.10	0.0	0.38	0.01	0.0	0.0	220.	130.	0.0
123.60	0.0	3.70	0.0	0.35	0.01	0.0	0.0	1200.	1200.	0.0
121.50	6.60	3.90	0.0	0.41	0.01	0.0	0.0	120.	90.	0.0
121.20	7.70	2.40	0.0	0.21	0.06	0.0	0.0	300.	180.	0.0
120.30	6.30	2.60	0.0	0.20	0.0	0.0	0.0	250.	140.	0.0
115.50	5.80	4.00	0.0	0.44	0.03	0.0	0.0	200.	33.	0.0
113.30	6.30	4.40	0.0	0.52	0.01	0.0	0.0	150.	67.	0.0
111.30	6.60	3.30	0.0	0.32	0.01	0.0	0.0	100.	56.	0.0

ILLINOIS RIVER VERIFICATION '79 DATA, MINIMUM DO SET
CALCULATED AND OBSERVED CBOD CONCENTRATIONS VERSUS DISTANCE



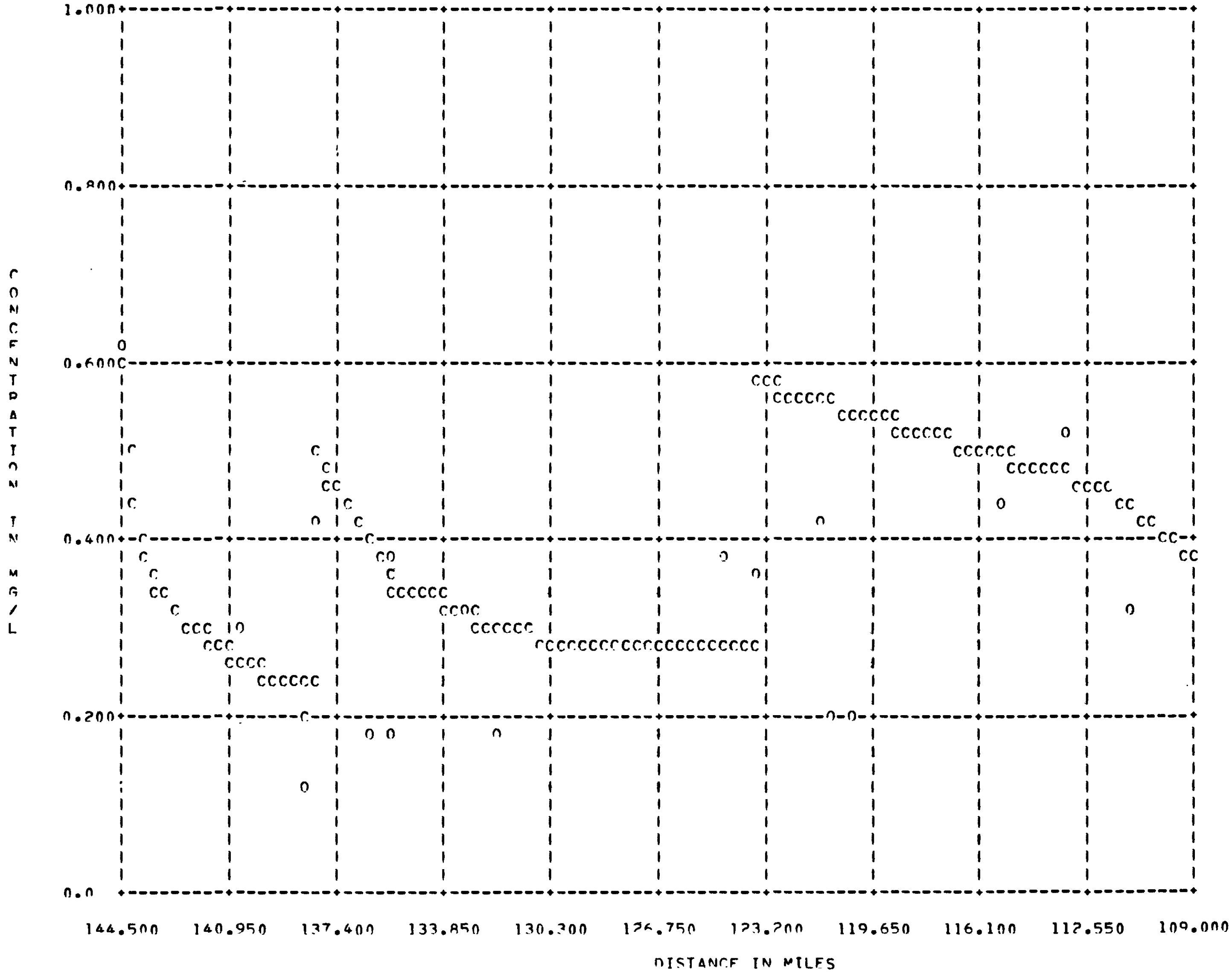
CALCULATED CBODU CONC = C
OBSERVED CBODU CONC = O

ILLINOIS RIVER VERIFICATION '79 DATA, MINIMUM DO SET
CALCULATED AND OBSERVED PO4 CONCENTRATIONS VERSUS DISTANCE



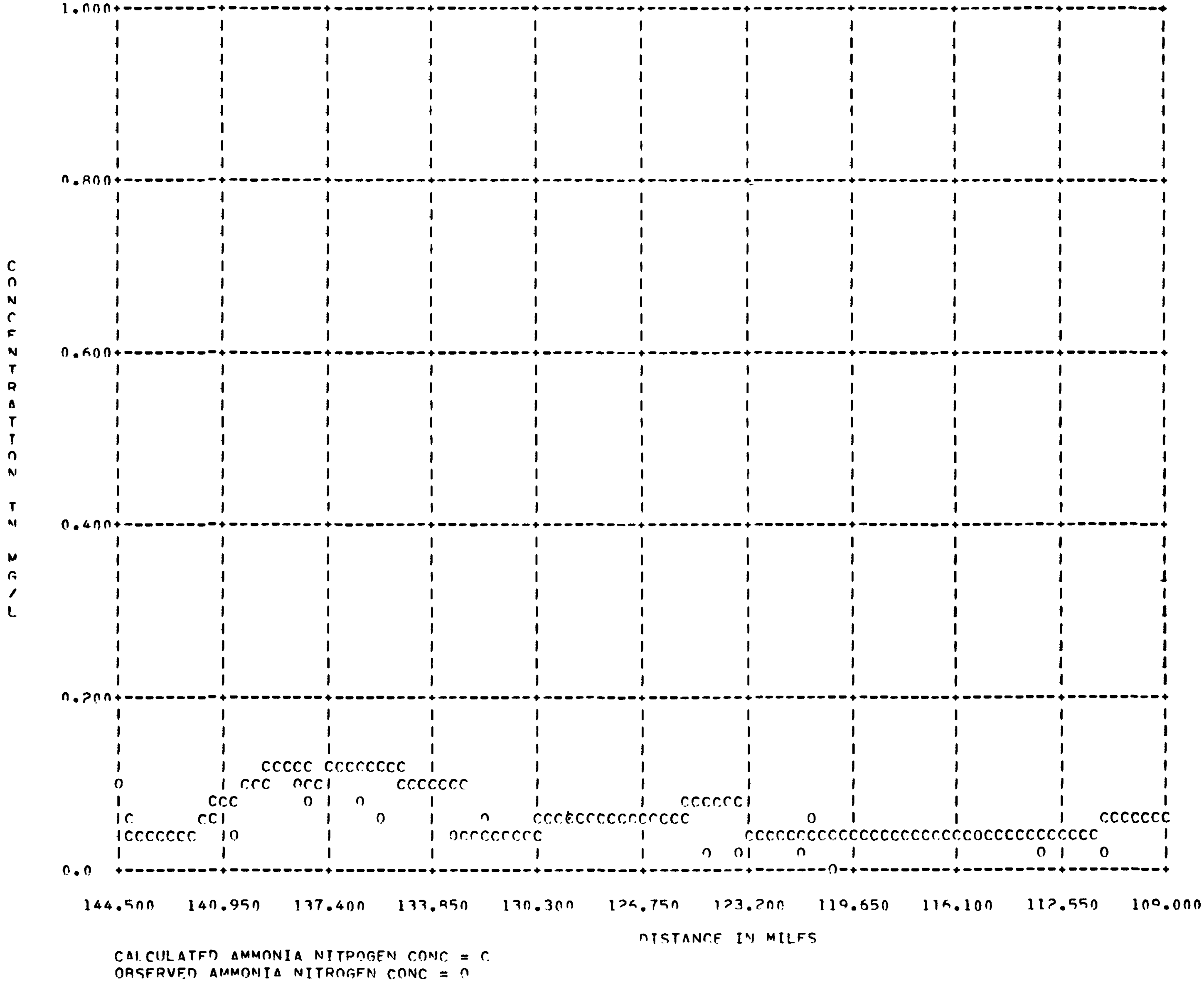
CALCULATED PO4 CONC = C
OBSERVED PO4 CONC = 0

ILLINOIS RIVER VERIFICATION '79 DATA, MINIMUM DO SET
CALCULATED AND OBSERVED ORGANIC NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE

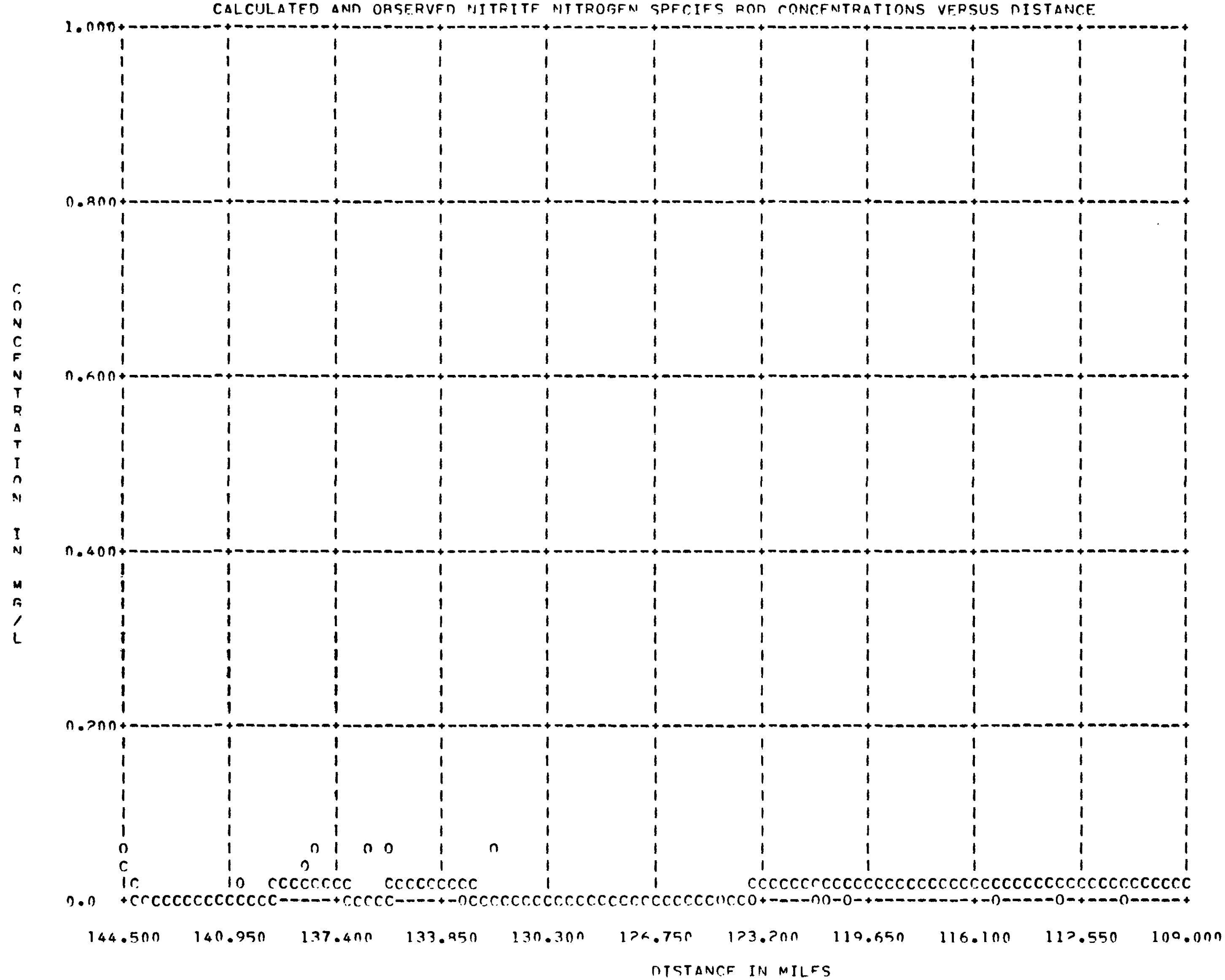


CALCULATED ORGANIC NITROGEN CONC = C
OBSERVED ORGANIC NITROGEN CONC = O

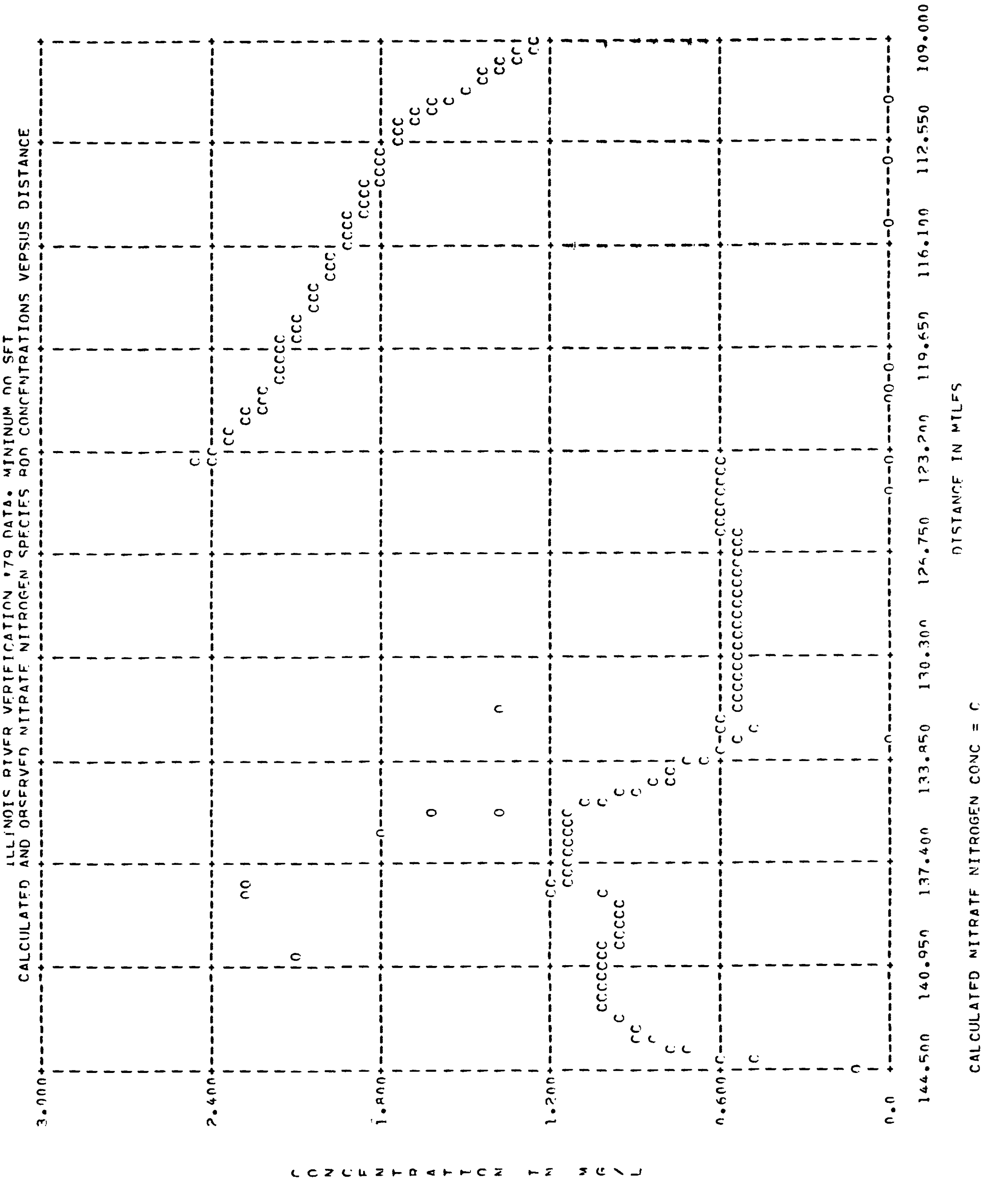
ILLINOIS RIVER VERIFICATION '79 DATA, MINIMUM DO SET
CALCULATED AND OBSERVED AMMONIA NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE

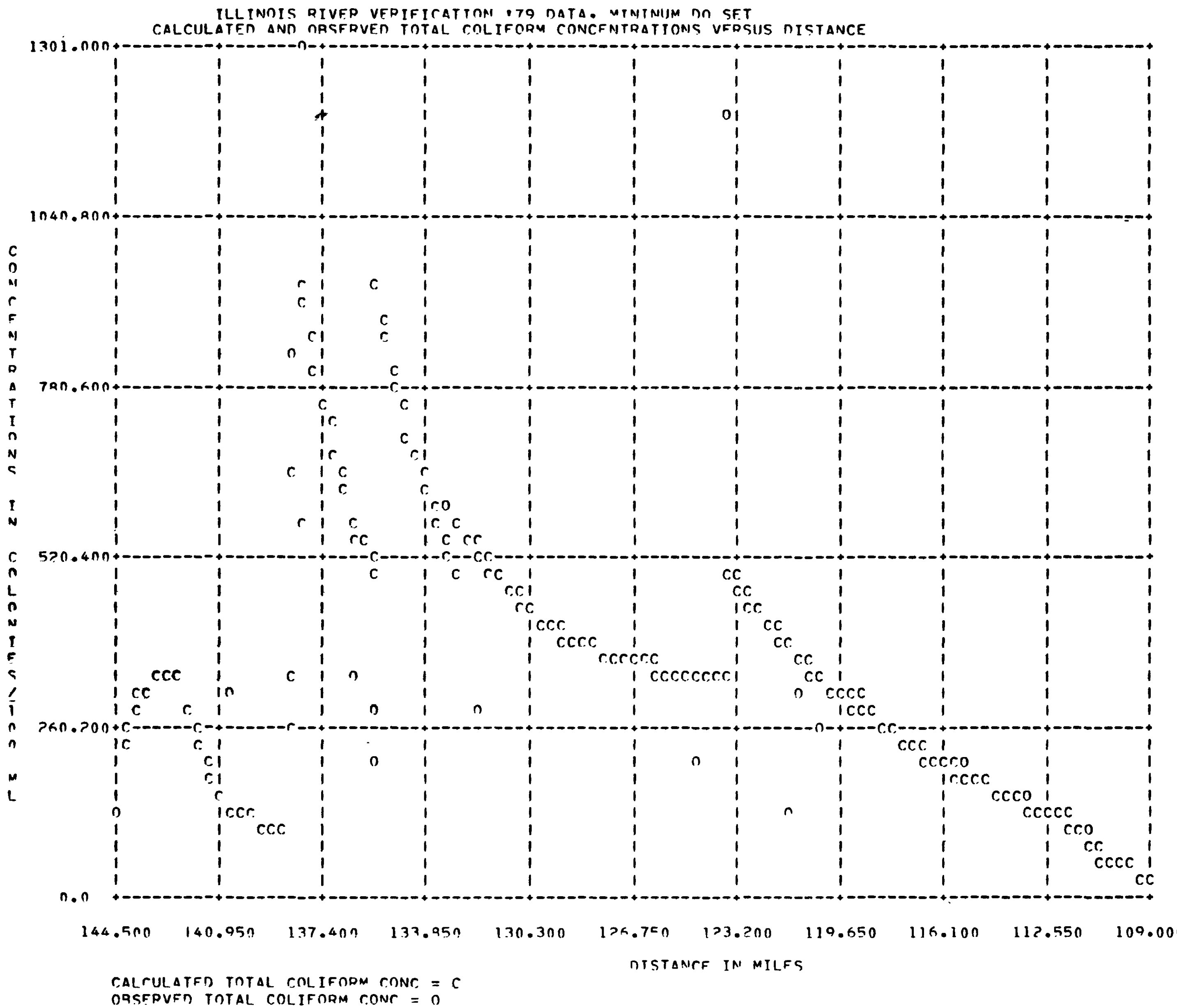


ILLINOIS RIVER VERIFICATION '79 DATA. MINIMUM DO SET
CALCULATED AND OBSERVED NITRITE NITROGEN SPECIES BOD CONCENTRATIONS VERSUS DISTANCE

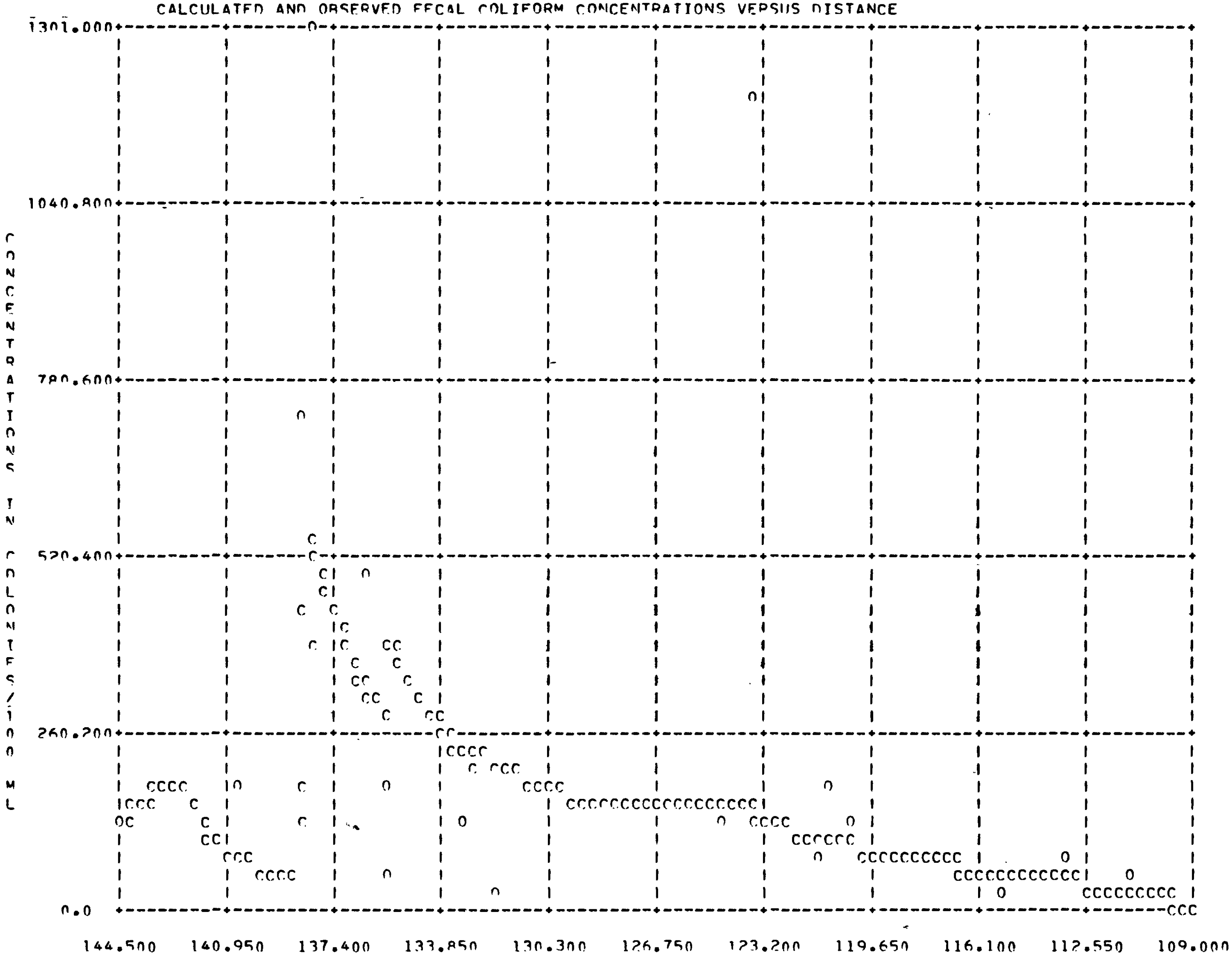


CALCULATED NITRITE NITROGEN CONC = C
OBSERVED NITRITE NITROGEN CONC = O


ILLINOIS RIVER VERIFICATION '79 DATA. MINIMUM DO SET
CALCULATED AND OBSERVED NITRATE NITROGEN SPECIES FOR CONCENTRATIONS VERSUS DISTANCE
3.000
2.400
1.800
1.200
0.600
0.0
CONCENTRATION IN MG/L
144.500
140.950
137.400
133.850
130.300
126.750
123.200
119.650
116.100
112.550
109.000
DISTANCE IN MILES
CALCULATED NITRATE NITROGEN CONC = C
OBSERVED NITRATE NITROGEN CONC = O

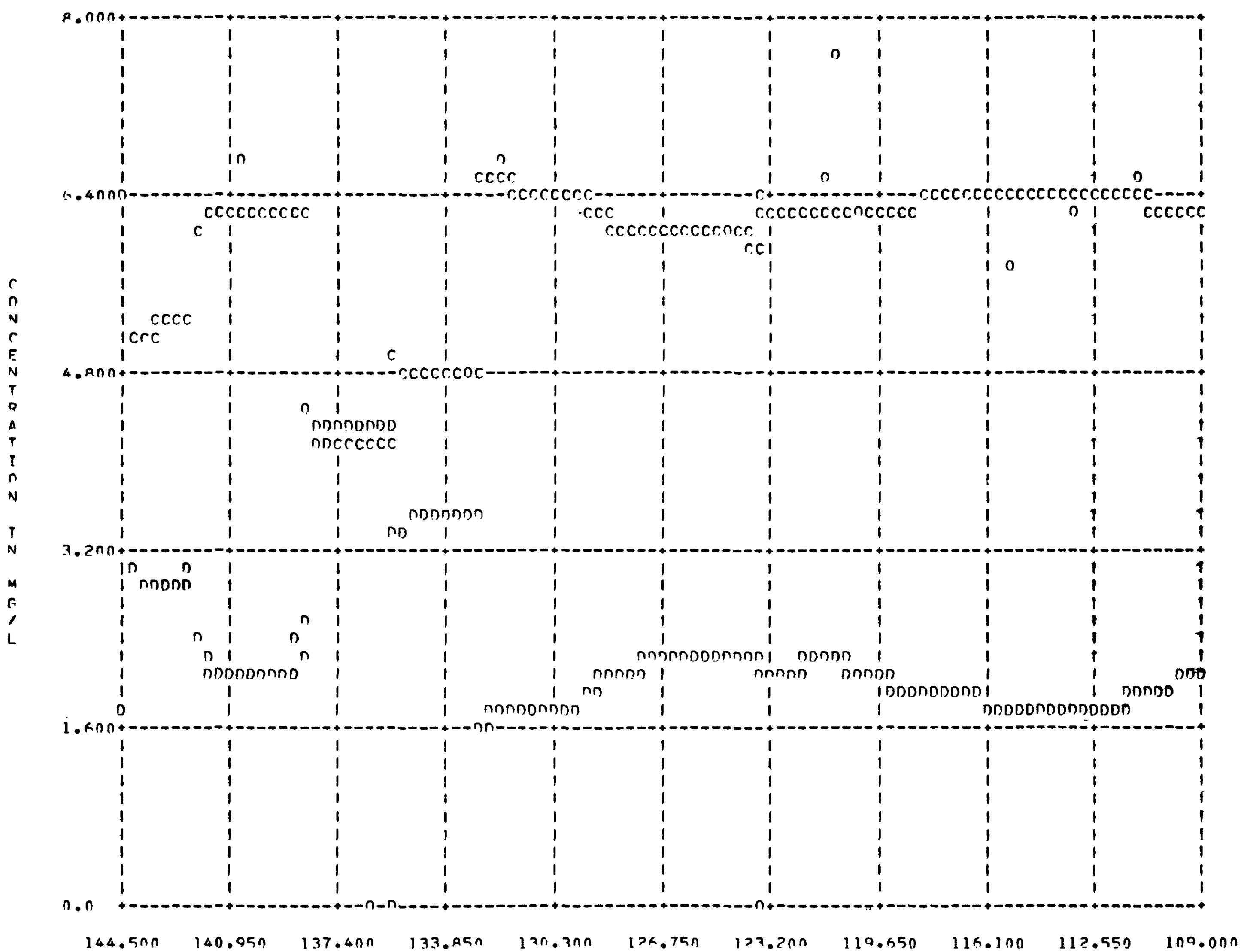

ILLINOIS RIVER VERIFICATION '79 DATA. MINIMUM DO SET
CALCULATED AND OBSERVED TOTAL COLIFORM CONCENTRATIONS VERSUS DISTANCE
1301.000
1040.800
780.600
520.400
260.200
0.0
CONCENTRATIONS IN COLONIES/100 ML
144.500
140.950
137.400
133.950
130.300
126.750
123.200
119.650
116.100
112.550
109.000
DISTANCE IN MILES
CALCULATED TOTAL COLIFORM CONC = C
OBSERVED TOTAL COLIFORM CONC = O

ILLINOIS RIVER VERIFICATION '79 DATA, MINIMUM DO SET
CALCULATED AND OBSERVED FECAL COLIFORM CONCENTRATIONS VERSUS DISTANCE



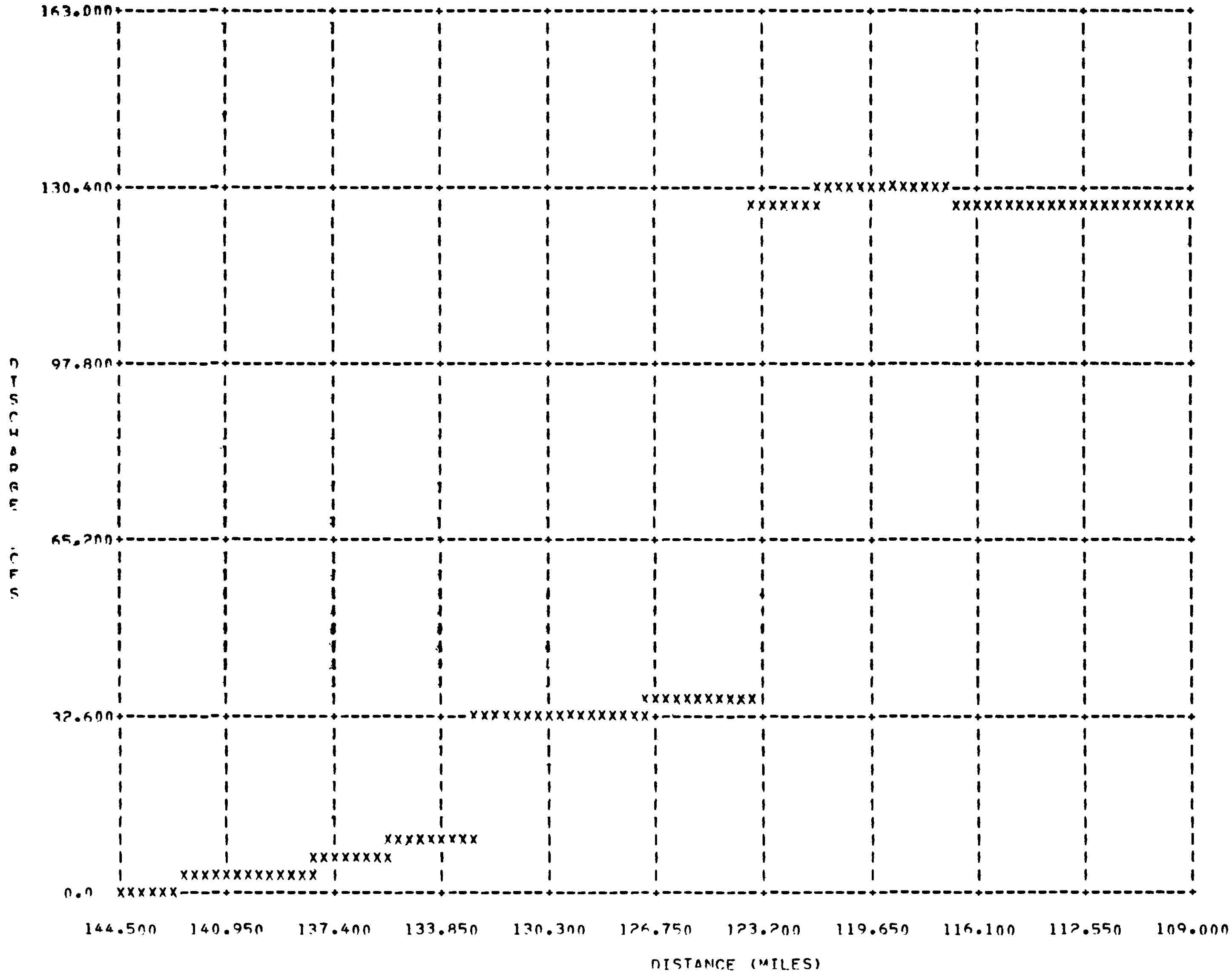
CALCULATED FECAL COLIFORM CONC = C
OBSERVED FECAL COLIFORM CONC = O

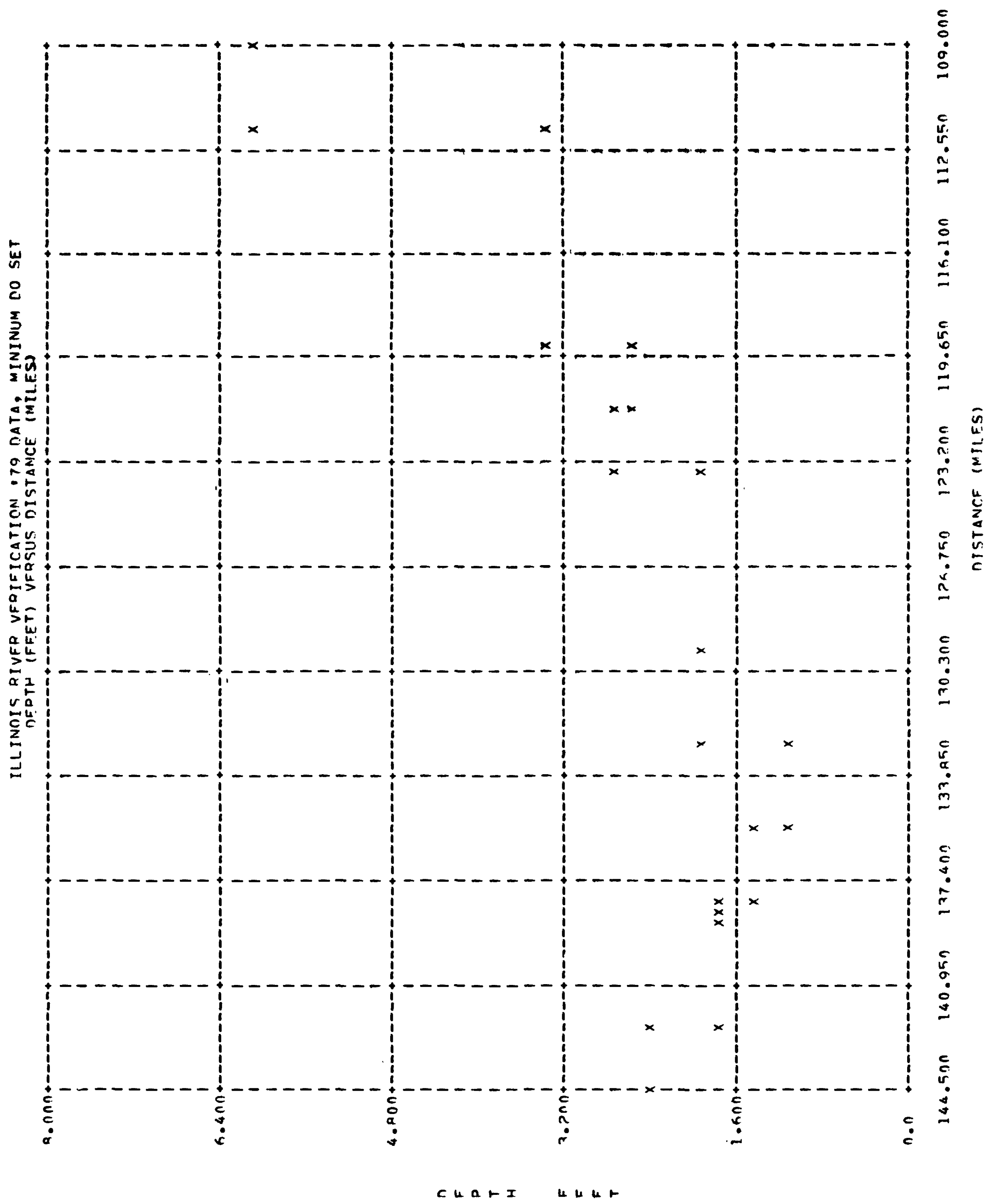
ILLINOIS RIVER VERIFICATION '79 DATA. MINIMUM DO SET
CALCULATED AND OBSERVED DO CONCENTRATIONS AND DO DEFICIT VERSUS DISTANCE



CALCULATED DO CONC = C
OBSERVED DO CONC = O
DO DEFICIT = D

ILLINOIS RIVER VERIFICATION '79 DATA, MININUM DO SET
DISCHARGE (CFS) VERSUS DISTANCE (MILES)




ILLINOIS RIVER VERIFICATION '79 DATA, MINIMUM DO SET
DEPTH (FEET) VERSUS DISTANCE (MILES)
DEPTH FEET
8.000
6.400
4.800
3.200
1.600
0.0
144.500
140.950
137.400
133.850
130.300
126.750
123.200
119.650
116.100
112.550
109.000
DISTANCE (MILES)