STATE OF LOUISIANA
DEPARTMENT OF PUBLIC WORKS

Water Resources
TECHNICAL REPORT NO. 7

WATER QUALITY AND WASTE ASSIMILATIVE CAPACITY OF THE PEARL RIVER BELOW BOGALUSA, LOUISIANA

Prepared by

UNITED STATES DEPARTMENT OF THE INTERIOR
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1973

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U.S. Geological Survey

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WATER QUALITY AND WASTE ASSIMILATIVE CAPACITY OF THE PEARL RIVER BELOW BOGALUSA, LOUISIANA

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ABSTRACT

The Pearl River downstream from Bogalusa, La., receives wastes from municipal and industrial sources that are equivalent to approximately 30 tons per day of biochemical oxygen demand. The river has an average discharge of 8,500 cubic feet per second but cannot assimilate the present biodegradable waste load during low-flow conditions. The concentration of dissolved solids is less than 60 milligrams per liter 90 percent of the time, and the occurrence of minor elements is presently not a problem. The pH of the water, which is generally less than 7.0, would be noticeably affected by the discharge of large amounts of acidic or basic wastes, especially during low-flow periods. The disposal of bacteria-laden wastes into the river causes it to be unsafe for primary contact water-recreation uses during low-flow conditions. The effect of biodegradable wastes on the river quality is also emphasized by the drastic changes in the macroinvertebrate communities in the river from above the outfall to Walkiah Bluff. For example, clean-water organisms are present at Bogalusa, absent at Pools Bluff, and present again at Walkiah Bluff. The one-dimensional, mathematical dissolved-oxygen model that relates organic-waste loads to dissolved-oxygen concentration can be used to predict the effect of biodegradable waste on the oxygen concentrations in the river.

INTRODUCTION

Increasing industrialization and population growth in Louisiana have caused problems of waste disposal. The resulting increase in industrial and municipal waste loads is causing various degrees of pollution in Louisiana streams. The Pearl River downstream from Bogalusa, La., is one stream reach in the State that has received large quantities of industrial and municipal wastes for several years. Downstream from the waste outfall near Richardson Landing, the dissolved-oxygen concentration has, at times, been depressed below the level that is necessary for propagation of aquatic life. These effluents have also increased the bacterial population in the stream; and at times, the bacterial concentration has exceeded the maximum recommended limit for primary contact water sports (Federal Water Pollution Control Administration, 1968).

Although the Pearl River has an average daily flow of 8,500 cfs (cubic feet per second), the stream cannot assimilate the present waste load when warm weather and low flows occur simultaneously. It is therefore necessary to devise a waste-management program that will allow use of the stream as a pollution-abatement tool and also protect the environment.

This report describes the quality of water of the Pearl River, the amounts and types of waste discharged into the river, the effects of these wastes on water quality, and the ability and capacity of the river to assimilate these wastes. The study area includes the reach of river from the Louisiana State Highway 10 bridge near Bogalusa to Walkiah Bluff (fig. 1). This report also presents the results of a mathematical model formulated to predict dissolved-oxygen concentrations resulting from waste disposal at various river discharges and waste-disposal rates.

Note.--The U.S. Environmental Protection Agency (written commun., April 1973) has reported that the city of Bogalusa and major industries have installed or are planning to install additional treatment facilities to abate pollution in the Pearl River near Bogalusa. The model presented in this report can be used to assess the impact of the anticipated changes.

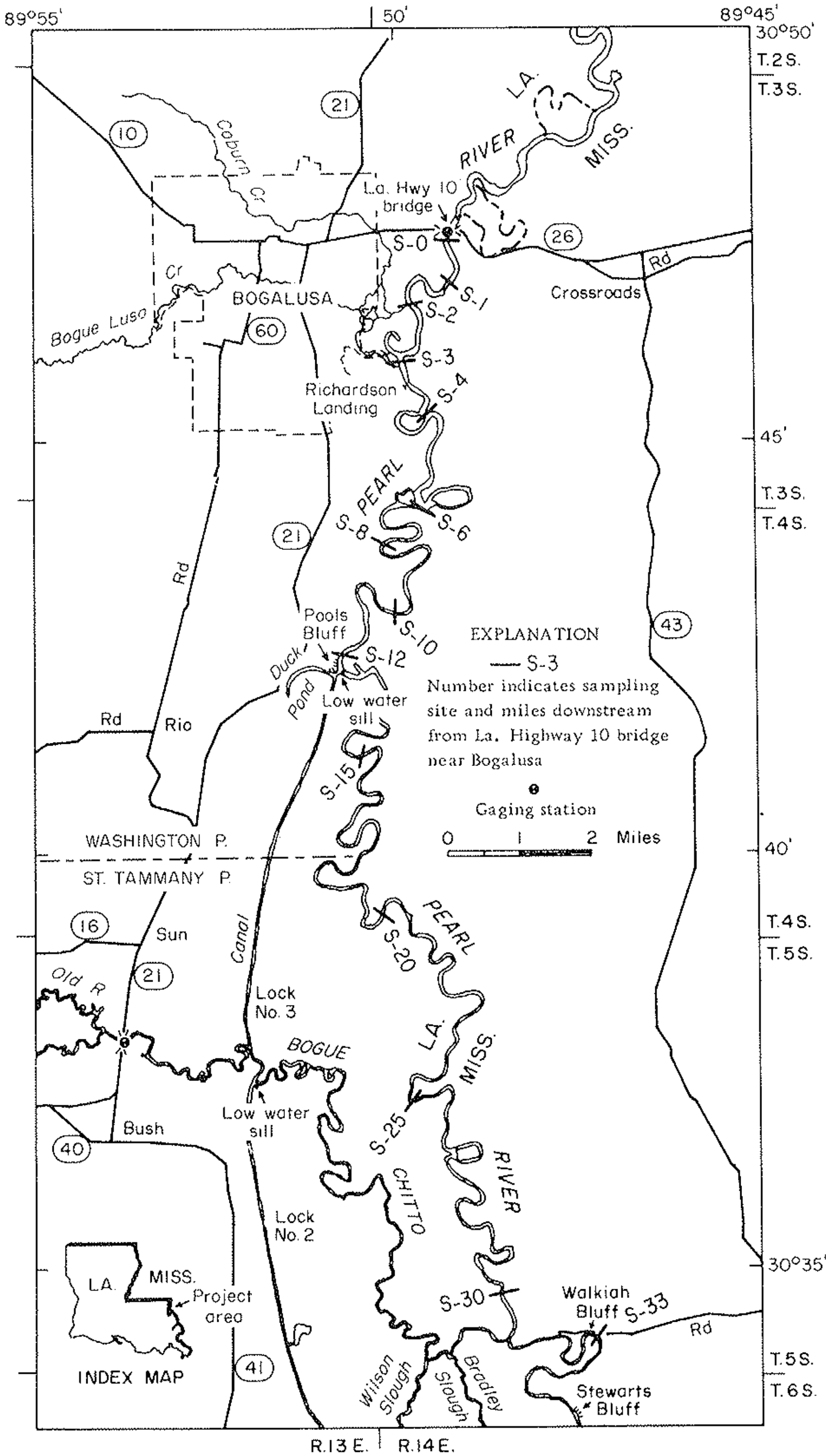

Figure 1. --Study reach of the Pearl River.

CHEMICAL QUALITY

The chemical quality of the Pearl River varies slightly with streamflow. Daily observed variations in specific conductance are usually less than 10 micromhos per centimeter at 25°C.

Data collected near Bogalusa at the Louisiana Highway 10 bridge are used to define the chemical quality of Pearl River water upstream from the pollution outfall near Richardson Landing. Ranges in concentration of the chemical and physical characteristics and their duration of occurrence are shown in table 1.

Table 1.--Variation in chemical and physical characteristics of the Pearl River near Bogalusa, La., with the duration of streamflow, 1963-70

[Chemical constituents, in milligrams per liter]

Characteristics	Observed concentration		Percentage of time values were equal to or less than those shown				
	Minimum	Maximum	90	70	50	30	10
Discharge 1/	------	------	25,000	9,000	4,300	2,500	1,300
Silica	4.2	17	11	10	9	8	6
Iron	.00	.63	--------	-----	-------	-----	-------
Calcium	1.0	26	5	-----	-------	-----	-------
Magnesium	.1	2.8	--------	-----	-------	-----	-------
Sodium	2.3	19	9	-----	7	-----	5
Potassium	.4	3.6	--------	-----	-------	-----	-------
Bicarbonate	2	78	15	12	10	8	6
Sulfate	.0	21	11	8	6	5	3
Chloride	2.8	39	12	10	9	8	6
Fluoride	.0	.5	--------	-----	-------	-----	-------
Nitrate	.0	4.7	--------	-----	-------	-----	-------
Dissolved solids	32	117	60	50	46	43	40
Hardness	5	67	18	15	12	11	9
Specific conductance 2/	31	180	85	73	68	62	53
pH	5.6	7.8	6.6	-----	6.3	-----	6.0
Water temperature 3/	2.0	32.0	29	25	21	15	10
Color 4/	0	100	50	-----	10	-----	5

1/Cubic feet per second.
2/Micromhos per centimeter at 25°C.
3/Degrees Celsius.
4/Units of platinum-cobalt scale.

Pearl River water is a soft, mixed-type water, and concentrations of dissolved solids and most chemical constituents are low; dissolved solids range from 32 to 117 mg/l (milligrams per liter) and 90 percent of the time are equal to or less than 60 mg/l. With an upward adjustment in pH, the water would be suitable for most uses.

The dissolved-solids concentration of the Pearl River increases slightly as a result of discharges from the more mineralized Bogue Lusa and Coburn Creeks. At a discharge of 2,000 cfs, the dissolved-solids concentration increased from 67 mg/l at Bogalusa to 89 mg/l at Pools Bluff. The dissolved-solids concentration of water from Bogue Lusa Creek was 662 mg/l. Sodium, sulfate, and bicarbonate ions account for most of the increase.

Specific conductance, a measure of the ability of water to conduct an electrical current, is related to the number and types of ionized substances in water and can therefore be used to estimate dissolved-solids concentration. For the Pearl River, the dissolved-solids concentration, in milligrams per liter, is about 62 percent of the specific conductance; and unless the natural quality of the water is altered, this relationship should apply in the future.

The concentration of dissolved solids in the Pearl River ranges from 40 to 60 mg/l 80 percent of the time and is highest during periods of low flow. The range is small because ground-water inflow is only slightly more mineralized than overland runoff. Available analyses of shallow ground water in the vicinity of the Pearl River show that dissolved-solids concentrations range from about 20 to 120 mg/l. The mean dissolved solids, however, is probably 50 mg/l or less.

Selected minor element concentrations were determined in samples collected on November 1, 1971, from Bogue Lusa Creek at its mouth an' at two locations on the Pearl River. The results as well as the permissible limits for water used for public supplies are shown in the following table.

Location	Discharge (cfs)	Lead (Pb)	Copper (Cu)	Zinc (Zn)	Mercury (Hg)	Manganese (Mn)
		(Micrograms per liter)				
Pearl River near Bogalusa---	2,050	10	27	18	---	60
Bogue Lusa Creek at mouth--------	50	40	43	58	0.7	170
Pearl River at Pools Bluff--	2,100	15	26	18	<.5	80
Permissible limits----------		50	1,000	5,000	5	150

The concentrations of all minor elements determined are higher in Bogue Lusa Creek than in the Pearl River near Bogalusa. The higher concentrations in Bogue Lusa Creek have little effect on concentrations in the Pearl River at Pools Bluff because of dilution by the much greater flow of the Pearl River.

Concentrations of the determined minor elements, with the exception of manganese, were within the recommended limits suggested by the Federal Water Pollution Control Administration (1968) for water used for public supplies.

Water temperatures of the Pearl River near Bogalusa range from 2.0° to 32.0°C (Celsius). For 1963-71, 90 percent of the time the temperature was equal to or less than 29.0°C, and 50 percent of the time it was equal to or less than 21.0°C (table 1). Average monthly stream temperatures are highest in July and August and lowest in January (fig. 2). Mean monthly temperature durations (fig. 3) show that during July and August, water temperatures are equal to or exceed 26.0°C 90 percent of the time. From April to October, water temperatures are equal to or exceed 21.0°C at least 50 percent of the time.

Heated water discharged into the Pearl River from Bogue Lusa Creek amounts to about 50 cfs and is from 3.0° to 5.0°C warmer than Pearl River water. This warmer water, however, has little or no influence on the temperature of the Pearl River even during low-flow periods because of relative streamflows.

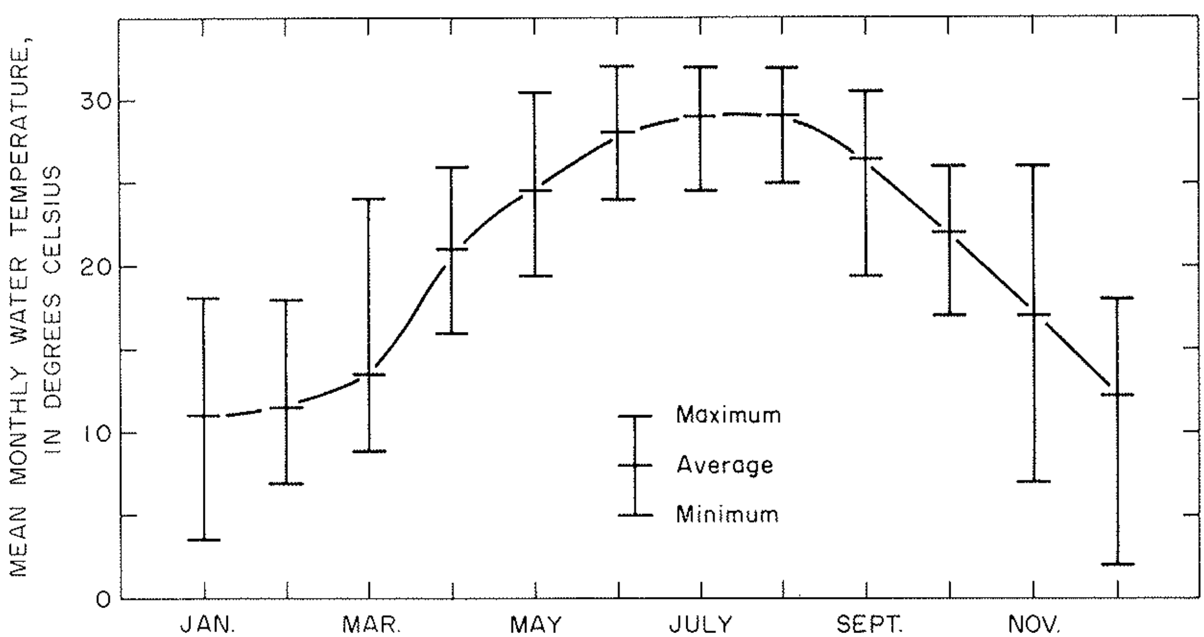

Figure 2. --Variation in mean monthly water temperature in the Pearl River near Bogalusa, La., 1963-71.

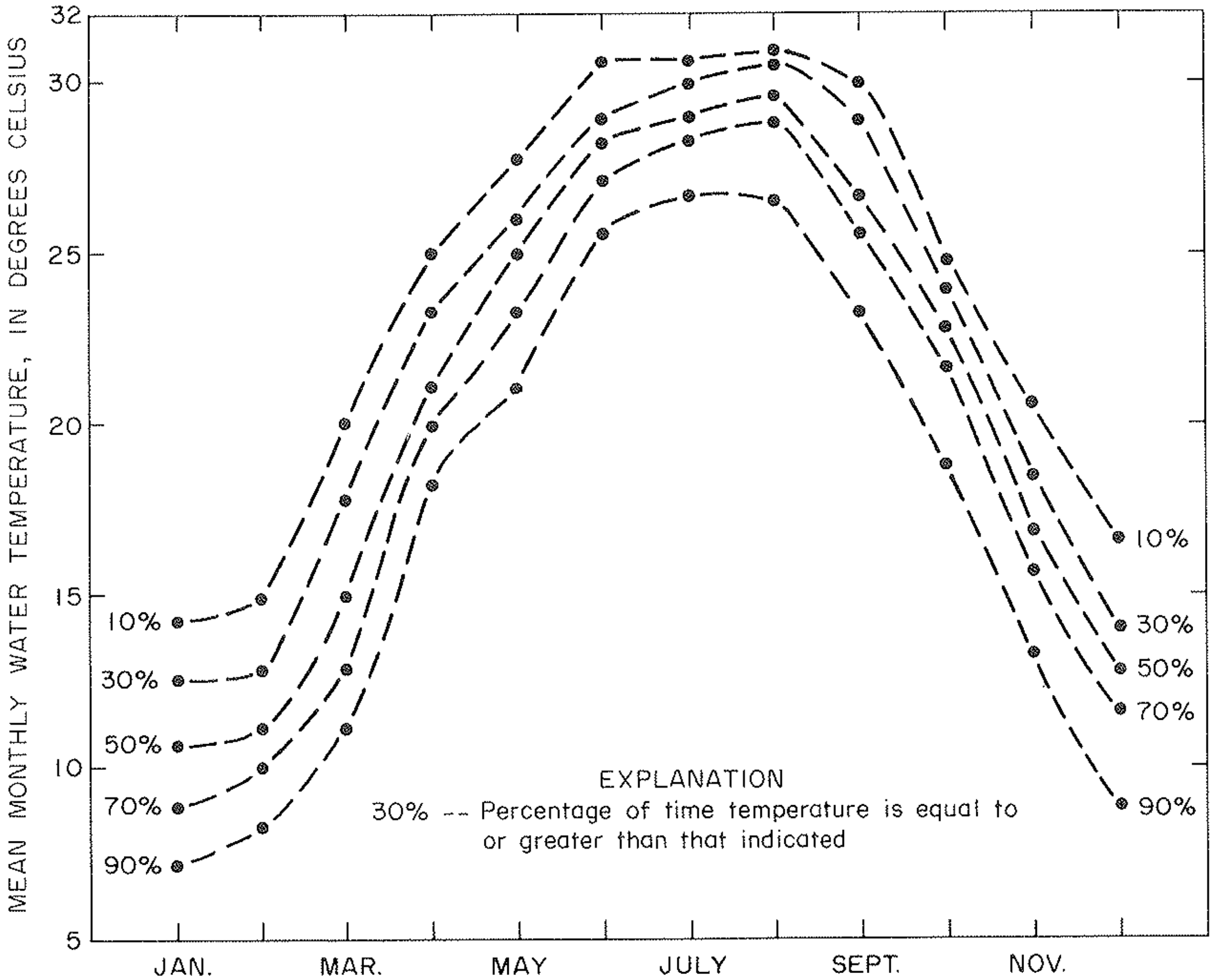

Figure 3. --Mean monthly temperature durations for the Pearl River near Bogalusa, La., 1963-71.

WASTE DISPOSAL AND ASSIMILATION

Municipal waste and papermill waste are the principal sources of pollution in the Pearl River downstream from Bogalusa. These sources discharge three types of waste--chemical (organic and inorganic), bacterial, and thermal--into Bogue Lusa and Coburn Creeks, which in turn carry the wastes into the Pearl River near Richardson Landing. The organic and bacterial wastes significantly affect the quality of the river water.

Inorganic Waste

The load of dissolved solids discharged into the Pearl River by Bogue Lusa and Coburn Creeks is fairly constant and amounts to about 120 tons per day. Chemical constituents that account for most of the dissolved solids are sodium, bicarbonate, and sulfate. The flow added to the Pearl River by Bogue Lusa and Coburn Creeks is insignificant in determining downstream loads and concentrations because they constitute less than 2 percent of the flow of the Pearl River.

Even though the load of dissolved solids added to the river between Bogalusa and Pools Bluff is fairly constant, the percentage of the added load in the river varies inversely with the discharge of the Pearl River. For example, when the discharge is 2,000 cfs, the industrial and municipal wastes added account for about 25 percent of the dissolved-solids load; but when the discharge is 20,000 cfs, they account for about 5 percent of the load.

Inorganic wastes are generally stable and are, therefore, cumulative in amount from source to source. The only significant way to reduce these concentrations is by dilution. At present, inorganic wastes discharged into the Pearl River near Richardson Landing increase the dissolved-solids content of the water by about 20 to 25 mg/l during low-flow periods, but downstream concentrations are generally less than 100 mg/l. If larger amounts of inorganic wastes were discharged into the river, the chemical quality could deteriorate enough to make the water unsuitable for some downstream uses. Figure 4 shows the changes that would occur in the river by adding various inorganic loads at different discharges. The following example illustrates use of figure 4. If the initial concentration of dissolved solids in the river water were 60 mg/l and the discharge were 8,000 cfs, the load would be 1,300 tons per day. If 4,000 tons per day of inorganic waste were added to the river, the total load would be 5,300 tons per day, and the downstream concentration of dissolved solids would be 245 mg/l.

Acidic- and Basic-Waste Assimilation

At present, little or no acidic or basic wastes are discharged into the Pearl River in the vicinity of Bogalusa. In the future, however, any large discharges of wastes of these types could lower or raise the pH to objectionable levels.

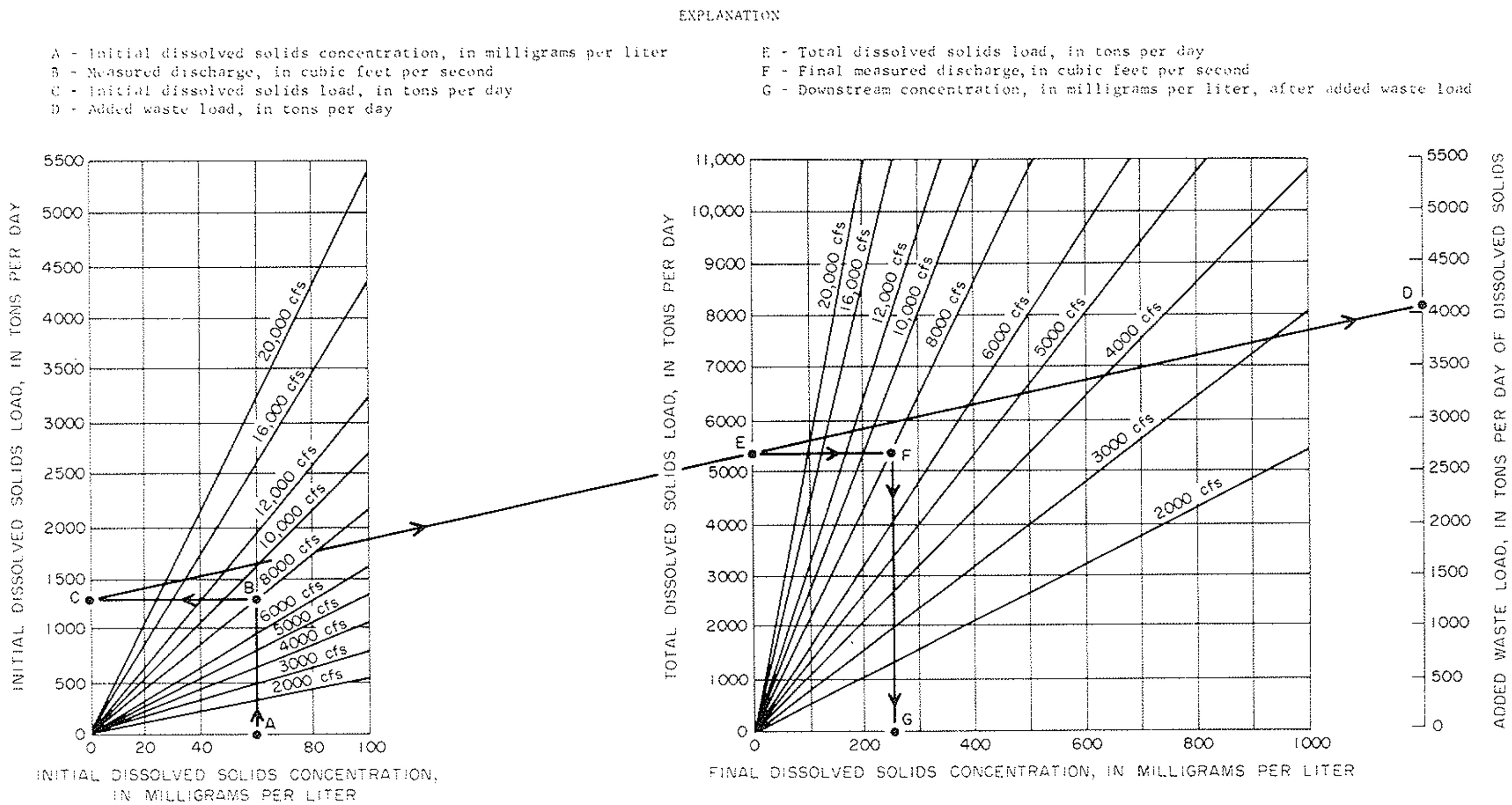

Figure 4. --Nomograph for determining inorganic-waste assimilation.

The buffering capacity of water, the ability of the water to resist a change in pH, is determined by the quantity of acid or base required to change the pH of the water. Acid-buffering curves (fig. 5) and base-buffering curves (fig. 6) show the potential effect of acidic- or basic-waste disposal on the pH of the Pearl River water at varying flow and quality conditions. The buffering capacity per unit volume is related to dissolved solids and alkalinity content and is greatest during low-flow periods when the dissolved-solids concentration and alkalinity are highest. For the purposes of this report the effect of the river bed has not been included. For example, 600 equivalents of acid as hydrogen ion would lower the pH of 1 million gallons of water approximately 0.3 and 0.6 pH units

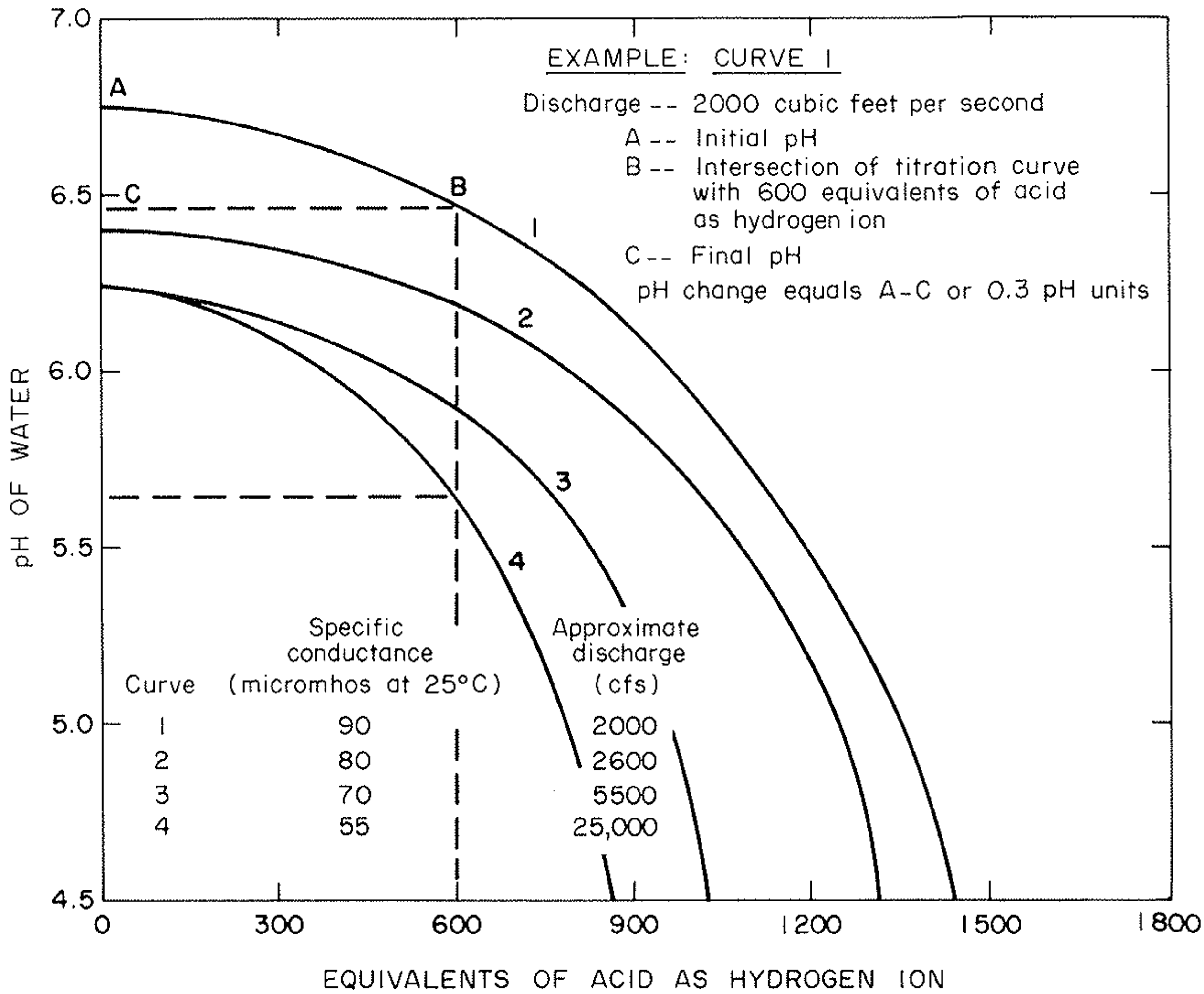

Figure 5. --Buffering-capacity curves for Pearl River water, showing amounts of acid necessary to produce a given pH change in 1 million gallons of water.

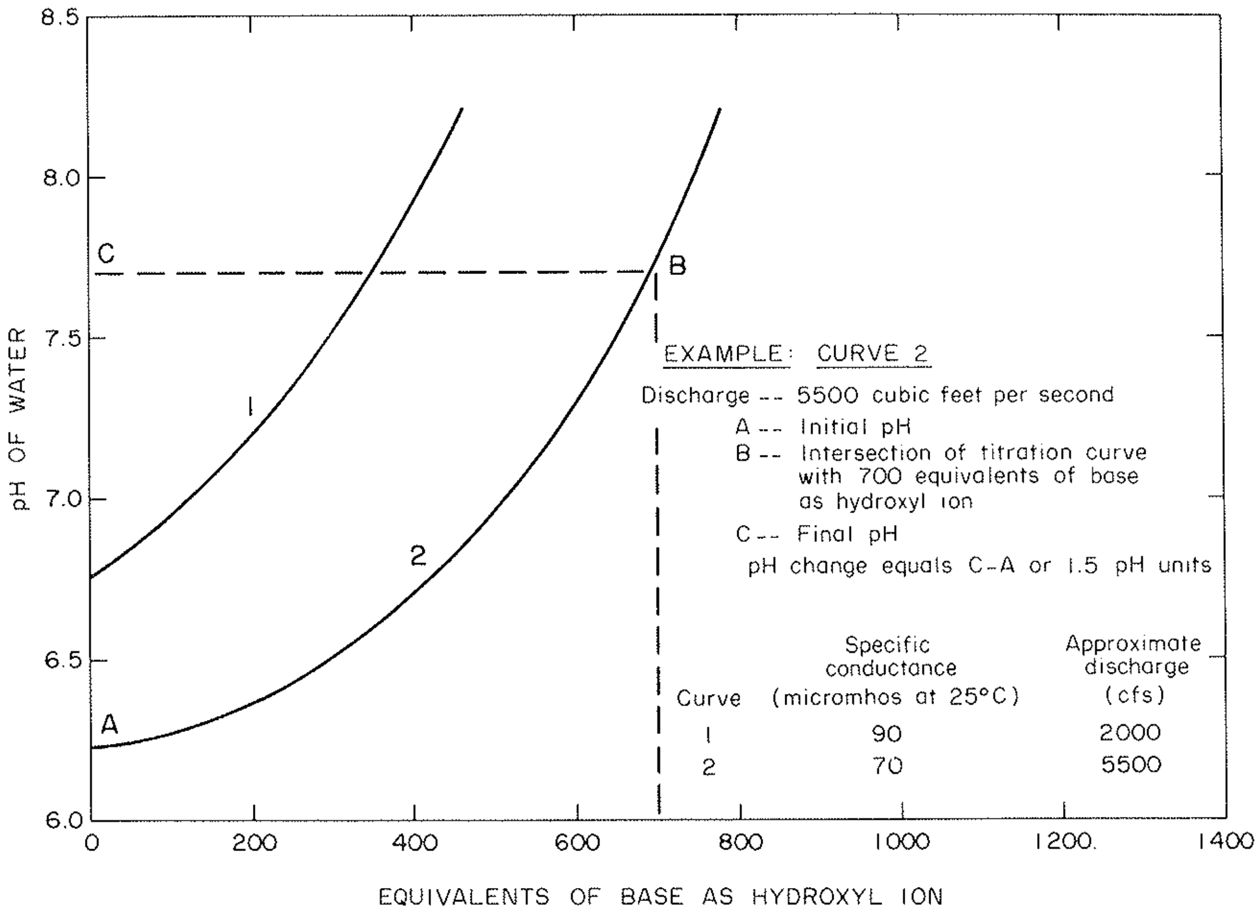

Figure 6.--Buffering-capacity curves for Pearl River water, showing amounts of base necessary to produce a given pH change in 1 million gallons of water.

when the discharge is 2,000 and 25,000 cfs, respectively. Pearl River water tends to be corrosive. This is due mainly to the low pH and the low concentrations of hardness and alkalinity. About 80 percent of the time the pH ranges from 6.0 to 6.6; the hardness ranges from 9 to 18 mg/l; and the alkalinity, as milligrams per liter of calcium carbonate, ranges from 3 to 7. For industrial or municipal purposes, the pH of the water should be adjusted upward to make it less corrosive. The amount of base needed to raise the pH to a desired level can be determined from base-buffering curves (fig. 6). For example, at a discharge of 5,500 cfs, 700 equivalents of base as hydroxyl ion would be required to raise the pH of 1 million gallons of water from 6.2 to 7.7.

The minimum ability of the river to assimilate acidic or basic wastes can also be determined from buffering-capacity curves and river discharge (figs. 7 and 8). For example, a continuous discharge of 300 tons per day of 40 percent hydrochloric acid effluent into the river would lower the pH, downstream after mixing, a maximum of approximately 0.6 and 0.2 pH units when the discharge is 5,500 and 25,000 cfs, respectively. During low-flow periods when the discharge is about 2,000 cfs, 200 tons per day of concentrated hydrochloric acid waste would lower the pH to about 4.5 (fig. 7). This acidic waste would make an already corrosive water highly corrosive.

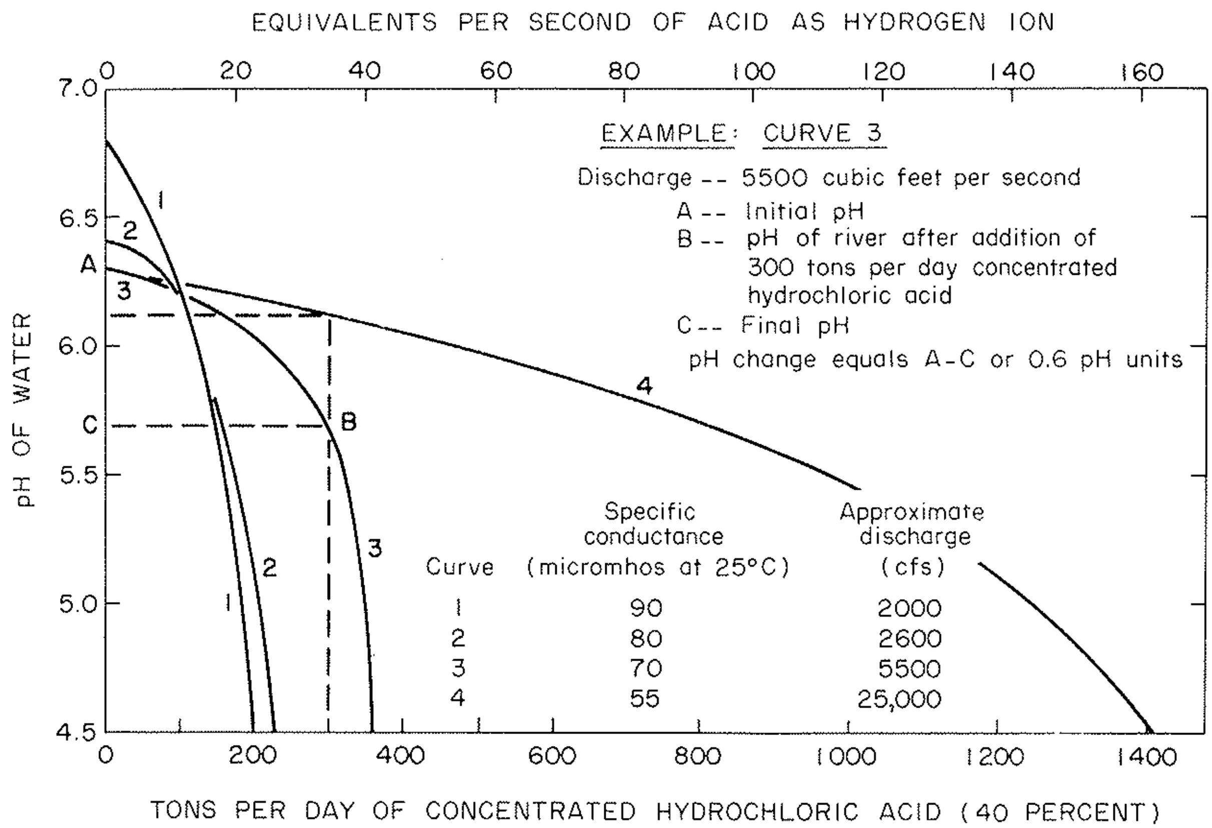

Figure 7.--Acidic-waste assimilation capacity curves.

As previously stated, the buffering capacity of Pearl River water is greatest per unit volume during low flow when the dissolved-solids and alkalinity concentrations are greatest. However, the ability of the river to assimilate acidic or basic wastes is based on the dissolved-solids and alkalinity loads, which are greatest during high-flow periods. For example, at a discharge of 2,000 cfs the dissolved-solids concentration is about 50 mg/l, the alkalinity concentration is about 16 mg/l, and the loads are about 270 and 90 tons per day, respectively. At a discharge of 25,000 cfs the dissolved-solids concentration is about 40 mg/l, the alkalinity concentration is about 14 mg/l, and the loads are about 2,700 and

1,000 tons per day, respectively. Therefore, because the range in dissolved-solids and alkalinity concentrations in Pearl River water is small, the ability of the river to assimilate acidic or basic wastes depends primarily on river discharge and the reaction with bed materials.

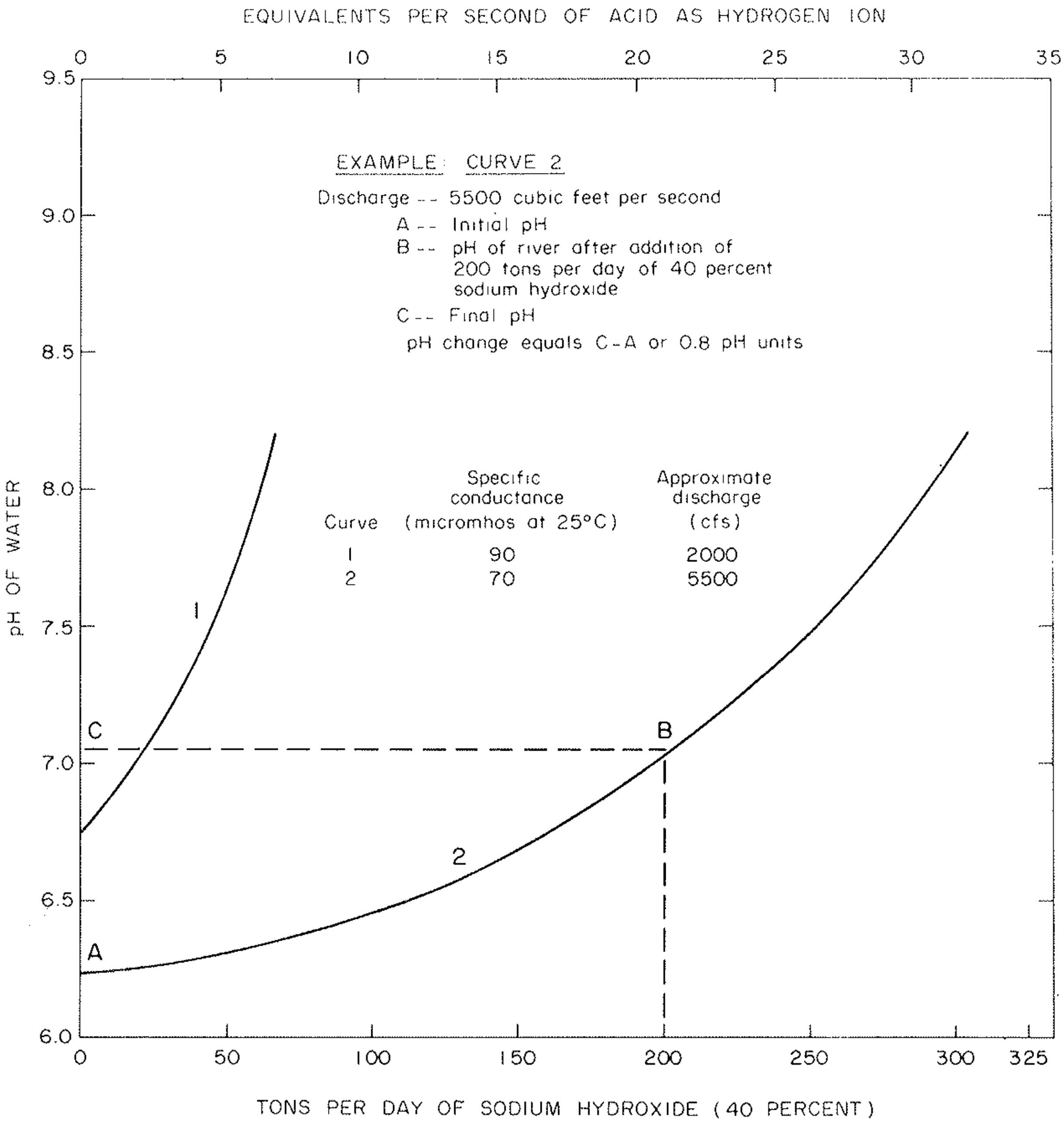

Figure 8. --Basic-waste assimilation capacity curves.

Bacterial Waste

Treated and raw municipal waste is discharged into the Pearl River near Richardson Landing. Approximately 60 percent of this sewage receives primary treatment, and the rest enters the Pearl River as raw sewage.

Three groups of bacteria were studied to indicate the degree of bacterial pollution: total coliform, fecal coliform, and fecal streptococci. The coliform group of bacteria has traditionally been used to measure fecal contamination in streams. However, in testing for total coliform, bacteria of both fecal and nonfecal origins are included in the results. By testing specifically for fecal coliform the concentration of coliform bacteria of fecal origin can be determined.

Fecal coliform concentrations can be used to indicate the absence or presence of pathogenic (disease-causing) organisms. Geldrich (1969) determined a correlation between fecal coliform concentration and the presence of Salmonella (a pathogenic organism) in nonsaline water. The percentage of time that Salmonella are found in different ranges of fecal coliform concentrations is given in the following tabulation:

Range of fecal coliform concentrations (colonies per 100 milliliters)	Percent occurrence of Salmonella
1- 200	28
201-2,000	85
Over 2,000	98

Fecal streptococci are not members of the coliform group of bacteria but are of fecal origin. The source of fecal contamination can be determined by establishing a ratio between fecal coliform and fecal streptococci bacteria. In human fecal material the ratio of fecal coliform concentrations to fecal streptococci concentrations is at least 4 to 1. In the fecal material of other warmblooded animals the fecal coliform to fecal streptococci ratio is significantly less.

Coliform concentrations in the Pearl River above the mouth of Bogue Lusa Creek are relatively low; however, concentrations may increase during periods of overland runoff. Downstream from Richardson Landing, bacterial concentrations increase due to sewage entering the Pearl River from Bogue Lusa Creek (fig. 9). At Pools Bluff, fecal coliform concentrations ranged from 540 to 8,900 colonies per 100 ml (milliliters), and fecal streptococci concentrations ranged from 170 to 800 colonies per 100 ml (table 2).

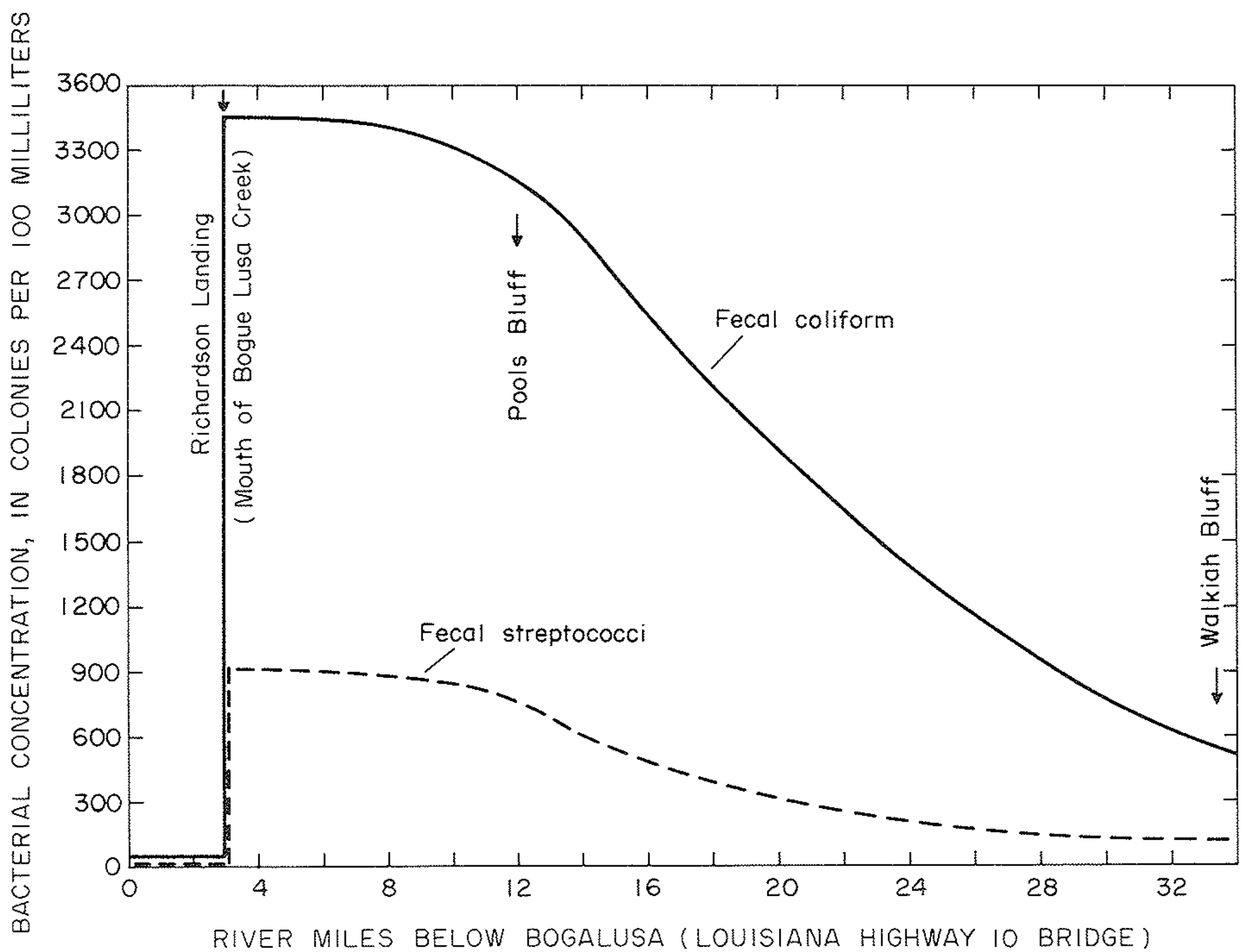

Figure 9. --Fecal coliform and fecal streptococci concentrations downstream from Bogalusa, December 9, 1970.

Table 2.--Bacterial concentrations of the Pearl River at the Louisiana Highway 10 bridge near Bogalusa and at Pools Bluff

[Location: Highway 10 bridge refers to Louisiana Highway 10 bridge]

Date	Location	Colonies per 100 milliliters		
		Total coliform	Fecal coliform	Fecal streptococci
11-17-69	Highway 10 bridge-----------	17	1	1
1-15-70	-----do---------------------	210	-----	200
3-18-70	-----do---------------------	120	26	91
5-27-70	-----do---------------------	36	1	5
9- 2-70	-----do---------------------	400	12	30
9- 2-70	Mile 5----------------------	------	2,200	180
9- 2-70	Pools Bluff-----------------	4,300	1,300	420
9- 2-70	Walkiah Bluff---------------	------	270	64
9-30-70	Highway 10 bridge-----------	410	2	11
12- 9-70	-----do---------------------	50	15	5
12- 9-70	Pools Bluff-----------------	24,000	3,300	800
12- 9-70	Walkiah Bluff---------------	------	880	200
1-20-71	Highway 10 bridge-----------	8,000	1,400	-----
1-20-71	Pools Bluff-----------------	24,000	1,800	-----
1-26-71	-----do---------------------	------	1,200	200
1-27-71	-----do---------------------	------	1,300	230
1-27-71	-----do---------------------	------	1,200	170
3- 3-71	Highway 10 bridge-----------	2,000	550	340
3- 3-71	Pools Bluff-----------------	62,000	-----	200
5-20-71	Highway 10 bridge-----------	1,400	60	46
5-20-71	Pools Bluff-----------------	3,100	540	260
10- 7-71	Highway 10 bridge-----------	------	8	21
10- 7-71	Mile 5----------------------	------	4,700	750
10- 7-71	Pools Bluff-----------------	------	3,000	500
10- 7-71	Walkiah Bluff---------------	------	670	130
11- 9-71	Highway 10 bridge-----------	------	25	11
11- 9-71	Mile 5----------------------	------	1,200	1,700
11- 9-71	Pools Bluff-----------------	------	8,900	1,200
11- 9-71	Walkiah Bluff---------------	------	6,400	490

Bacterial Self-Purification

It is quite difficult for bacteria of fecal origin to survive in a stream because the change in habitat from the intestinal tract of warm-blooded animals to a stream environment is too great. Therefore, bacteria begin to die soon after they enter a stream. The change in temperature and pH, the availability of nutrients, and the competitive life in the stream influence the death rate of the bacteria. The death rate may be determined from Chick's law (Velz, 1970, p. 242), which states that bacteria die at a logarithmic rate; that is, a given percentage of the residual population dies during each successive unit of time. Mathematically, Chick's law may be expressed as

$$\frac{dB}{dt}=KB$$

or integrated to common logs as

$$\log \frac{B}{B_o}=-kt,$$

where B_o is the initial number of bacteria, B is the residual population at time t, and k is the reaction, or death rate.

One deviation in Chick's law is commonly reported. There appears to be an initial lag period preceding the logarithmic death rate. Such an initial lag period was found in the Pearl River between Richardson Landing and Pools Bluff. In this reach of the river there is very little reduction in bacterial concentrations. Downstream from Pools Bluff, the bacteria die off at a logarithmic rate.

In determining death rates of bacteria it is necessary to use an initial concentration that is not in the initial lag phase. For this study the concentration at Pools Bluff was used as the initial concentration. Using an average traveltime of 0.75 day, the death rate (k) between Pools Bluff and Walkiah Bluff was computed to be 0.8 per day. This value agrees closely with other streams of similar size (Velz, 1970, p. 247-248). Graphically, the data show an average residual population of 16 percent after 24 hours (fig. 10). The half-life of the bacteria is about 9 hours, or 0.38 day.

Bacterial populations in the river can be estimated (fig. 10) if the original population and the traveltime are known. For example, with an initial population of 1,000 and a traveltime of 13 hours, the residual population downstream would be 380, or 38 percent of the original population.

Although bacteria die off quite rapidly, the concentrations remaining in the Pearl River below Richardson Landing often exceed the recommended

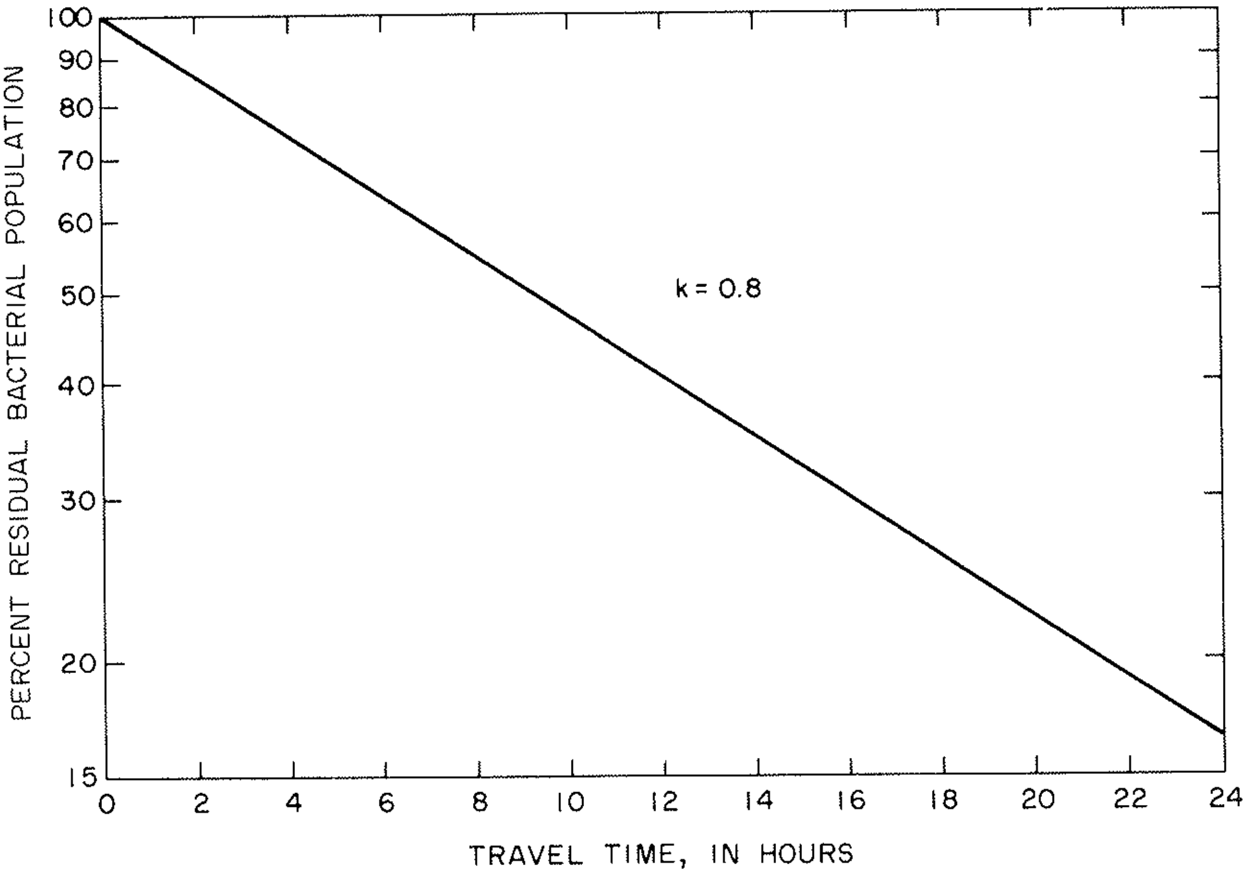

Figure 10.--Death-rate curve of fecal streptococci in the Pearl River between Pools Bluff and Walkiah Bluff.

limit of 200 fecal coliform colonies per 100 ml set forth for primary contact water sports (Federal Water Pollution Control Administration, 1968). Fecal coliform concentrations in the Pearl River at the Louisiana Highway 10 bridge, upstream from the effluent, ranged from 1 to 1,400 colonies per 100 ml and exceeded the recommended limit 20 percent of the time. At Pools Bluff, observed fecal coliform concentrations always exceeded the recommended limits, although during periods of high discharge, bacteria concentrations may fall within the specified limits. At Walkiah Bluff, fecal coliform concentrations ranged from 60 to 820 colonies per 100 ml and exceeded the recommended limits in approximately 60 percent of the samples taken.

ORGANIC-WASTE ASSIMILATION

The ability of a river to assimilate organic waste depends not only on the concentration of the oxygen-demanding waste in the river but on the rate of decomposition of this waste, the dissolved-oxygen concentration in the river water, and the rate of reaeration of the river. The rates are temperature dependent and increase with temperature. The concentration of biodegradable waste is measured as BOD (biochemical oxygen demand), which is a measure of the amount of oxygen used during stabilization of decomposable organic matter by aerobic bacterial action.

As an oxygen-demanding waste moves downstream, it consumes the oxygen in the river water, creating an oxygen deficit, until either the river is devoid of oxygen or the waste is completely decomposed. Oxygen deficit is the difference between the lower oxygen concentration in the river water and the oxygen saturation concentration at the existing water temperature. Simultaneously occurring with this activity is reaeration, the action of the river to replace the used oxygen with oxygen from the atmosphere. The net result of these two activities is known as a dissolved-oxygen sag.

The 10-mile reach of river upstream from the low-water sill at Pools Bluff has a low assimilative capacity for oxygen-demanding waste. This upstream reach generally is deep and has low velocity during base-flow conditions. Consequently, reaeration in this upstream reach of the river is very small. Downstream from the sill, the river stage is not artificially controlled. The average depth is much less than in the upstream reach, and the velocities are somewhat higher; consequently, the reaeration is higher. The controlled reach of the river causes what appears to be a critical oxygen deficit just upstream from the low-water sill. (The critical deficit is the largest oxygen deficit in the dissolved-oxygen sag.) However, the actual critical deficit, as a result of the waste moving downstream, will occur at a distance farther downstream from the sill.

In 1971 and 1972, wastes equivalent to approximately 30 tons per day of BOD were discharged into the Pearl River via Bogue Lusa and Coburn Creeks. The effect of this BOD load on oxygen levels in the river is dependent on many variables, including temperature and discharge (fig. 11). During cool weather, reaction rates decrease, and waste has less effect on the dissolved-oxygen concentrations of the river within the study area (curve B). During warm weather the converse is true, and a more pronounced effect on oxygen concentrations occurs (curves A, C, and F). Data defining curve D were collected during a period when heavy local rainstorms flushed the swamps east of Bogalusa, causing an increased BOD load in the river. Because of this waste increase, the oxygen levels were depressed considerably as far downstream as Pools Bluff. However, at the time of the field observations this waste load had not yet affected the river downstream from the low-water sill. The increased oxygen demand is emphasized by comparing oxygen sag (curve D) with the oxygen sag on the previous day (curve E). Even though the rain caused a decrease in temperature and an increase in flow, the oxygen demand was great enough to depress the oxygen concentation below 2 mg/l.

The oxygen levels in the Pearl River are mainly influenced by biodegradable waste loading and streamflow. For example, when the flow of the Pearl River is 8,000 cfs and the BOD is zero, adding a waste load of 30 tons per day as BOD would result, after mixing, in about 1.5 mg/l of BOD.

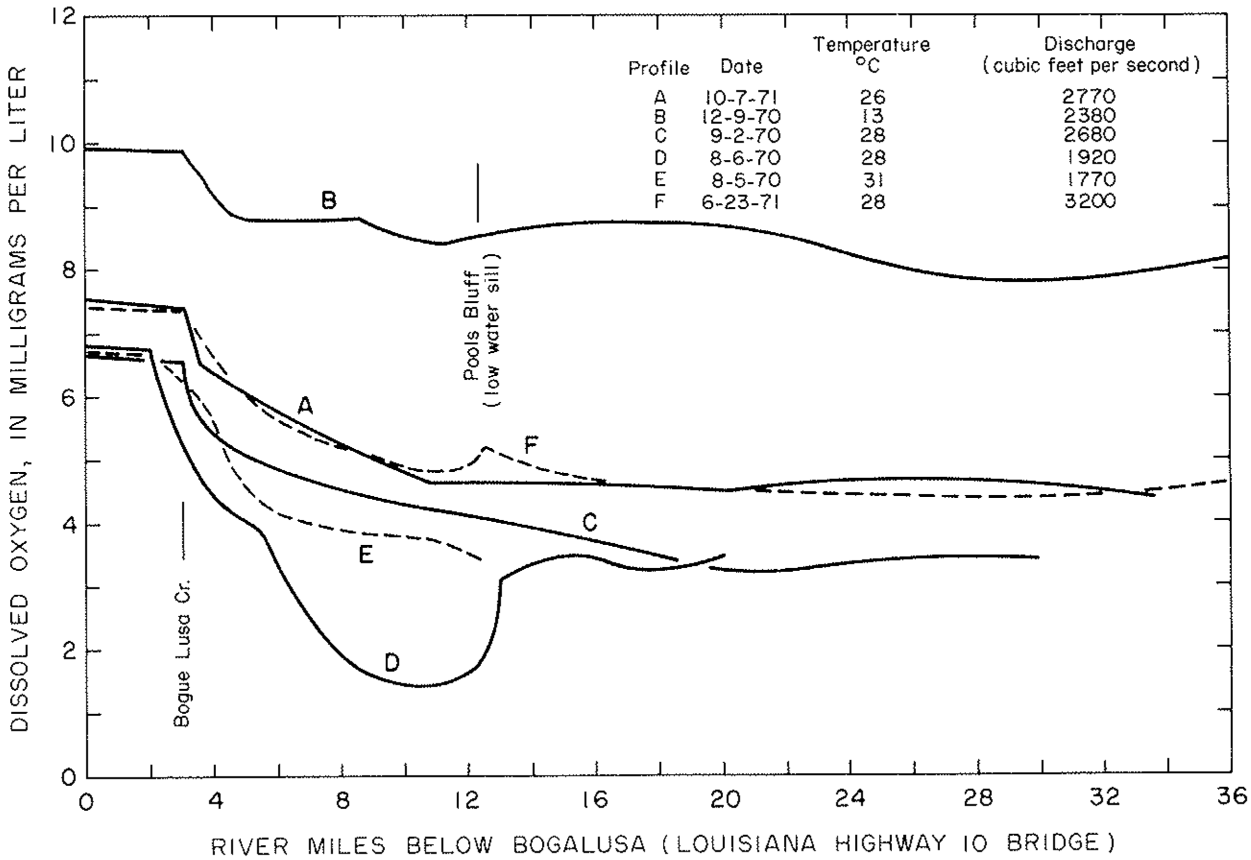

Figure 11.--Selected oxygen profiles in the Pearl River.

This would have a very slight effect on the oxygen levels in the river. However, at a flow of 2,000 cfs the BOD concentration in the river would be about 6.7 mg/l (just below Bogue Lusa Creek) and would depress oxygen levels downstream. Therefore, with a combination of low streamflow, high BOD load, and warm weather, the oxygen in the Pearl River would be rapidly depleted (fig. 11, curve D). It must be understood that these predictions are based on the decomposition rate of papermill and sewage effluents. Consideration must be given to the reaction rate of other organic wastes before they are discharged into the Pearl River.

The most undesirable conditions for waste disposal in the Pearl River occur during low-flow periods in July and August. Generally, low flows occur from June through November, and high temperatures occur from April through October. The probabilities of occurrence of selected streamflows and of selected temperatures during these periods are shown in figures 3 and 12. During these periods the ability of the river to dilute wastes is lessened, the reaction rates are higher, and the ability of the river to assimilate biodegradable wastes is, therefore, very low.

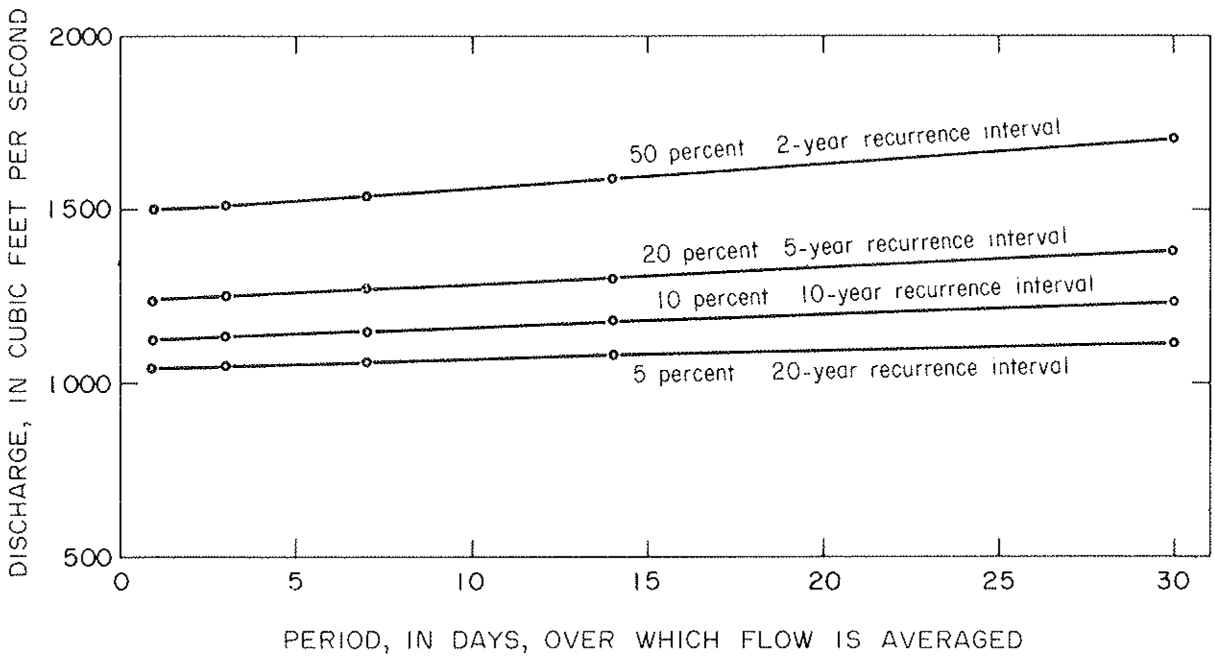

Figure 12. --Probability of low-flow recurrence.

Effects of Organic Waste on Macroinvertebrates

An unpolluted stream environment is capable of supporting many different species of organisms, but because of competition and predation, the number of individuals in each species generally is low. Invertebrate biota commonly found in unpolluted streams include clams and the larvae of the caddisfly, stonefly, and mayfly. In a stream polluted by organic waste the number of different species is reduced because of unfavorable conditions. However, the number of individuals of a specific species that can survive in polluted water increases because of an increased food supply. Organisms commonly found in streams containing organic waste are midge larvae, sludge worms, and snails.

Macroinvertebrate samples from the Pearl River at Pools Bluff and Walkiah Bluff showed the effect of organic pollution. At the Louisiana Highway 10 bridge numerous clams and larvae of mayflies and stoneflies were found, indicating an unpolluted stream. At Pools Bluff very few mayfly and stonefly larvae were found and clams were absent. Midge larvae, snails, and leaches, organisms that survive in polluted waters, were found in large numbers. At Walkiah Bluff, organisms similar to those found at both the Louisiana Highway 10 bridge and Pools Bluff were found. The number of midge larvae found at Walkiah Bluff was less than the number found at Pools Bluff. No snails and leeches were found at Walkiah Bluff. The predominant organisms found at Walkiah Bluff were species of clams, mayfly larvae, and stonefly larvae. The presence of these clean-water organisms indicated that the Pearl River had recovered from the organic pollution.

DISSOLVED-OXYGEN MODEL

A one-dimensional mathematical model was developed to predict the effect of biodegradable waste loads on the oxygen balance in a stream. The calculation model schematic is illustrated in figure 13. The model was formulated to compute dissolved-oxygen concentrations and BOD values at 1-mile intervals downstream from the Louisiana Highway 10 bridge to Walkiah Bluff, but it can be adjusted for intervals of any length and can accommodate waste inflows at any point on the river. If any oxygen level in the computed profile is below specified limits, the model will determine the maximum BOD load allowable that will keep the dissolved-oxygen concentrations within these limits.

To determine the oxygen profile, the equation derived by Streeter and Phelps, as described by Fair and Geyer (1963, p. 842-845), is used and modified accordingly:

$$D_t = \frac{K_1 y}{K_2 - K_1}\left(e^{-K_1 t} - e^{-K_2 t}\right) + D_a e^{-K_2 t},$$

in which D_t (mg/l) is the dissolved-oxygen deficit at time t; K_1 (day-1, base e) is the deoxygenation coefficient; K_2 (day-1, base e) is the reaeration coefficient; y (mg/l) is the BOD at some initial point; and D_a (mg/l) is the oxygen deficit at some starting point. The values for the reaeration coefficient were computed by using the empirical equation developed by Churchill and others (Tennessee Valley Authority, 1962) and converted to a Naperian log base. The values for the deoxygenation coefficient were computed by the "method of moments" from Moore, Thomas, and Snow, as described by Fair and Geyer (1963, p. 521-522). These values for reaeration and deoxygenation were computed at a temperature of 20°C and were adjusted to other temperatures by the following equations (Fair and Geyer, 1963):

$$K_{2_T} = K_{2_{20}} e^{0.018(T-20)}$$

and

$$K_{1_T} = K_{1_{20}} e^{0.046(T-20)},$$

where T is in degrees Celsius. The average velocities were determined by tracer studies at different discharges and are shown in the following table. These velocities are used to compute traveltime between stations.

Average velocity, in miles per hour

Reach	Discharge at Bogalusa, La., gage (cfs)		
	2,000	4,000	6,000
Station 0 to station 12-----------	0.75	1.00	1.25
Station 12 to station 33-----------	1.20	1.25	1.30

To verify the model, a predicted dissolved-oxygen profile was compared to a measured profile (fig. 14). The variation between actual and predicted oxygen values at specific locations on the river is expected because of the inability to obtain precise reaeration determinations. The maximum difference between observed and calculated dissolved-oxygen values was 0.5 mg/l.

The model can be used to predict the effect of biodegradable wastes on the oxygen level of the Pearl River below Bogalusa for different combinations of streamflows, temperatures, and waste loads. For example, at a flow of 2,000 cfs, a temperature of 35°C, and a BOD concentration of 50 mg/l at mile 3, the recommended limit for oxygen will be exceeded at mile 5 (fig. 15). The recommended limit for oxygen is 50 percent of saturation or 4.0 mg/l, whichever is greater (Louisiana Stream Control Commission, oral commun., 1972). Other combinations of BOD, temperature, and streamflow will have pronounced effects on the oxygen levels in the stream (fig. 15). The importance of streamflow and temperature is emphasized by assuming a constant BOD load at mile 3 (fig. 16). At high flow and low temperature, the river can assimilate this waste load within the study reach (curve 1, fig. 16). However, the oxygen levels may still decrease in the undefined reaches downstream from mile 33. As temperature increases and streamflow decreases, the oxygen levels will decrease (curve 4, fig. 16).

This model is applicable only at streamflows of less than 6,000 cfs because reaeration coefficients and velocities were not determined at greater discharges. The previous discussion has been concerned with the oxygen model for a selected reach of the Pearl River. However, the general oxygen model can be readily adapted for any stream that has uncontrolled flow.

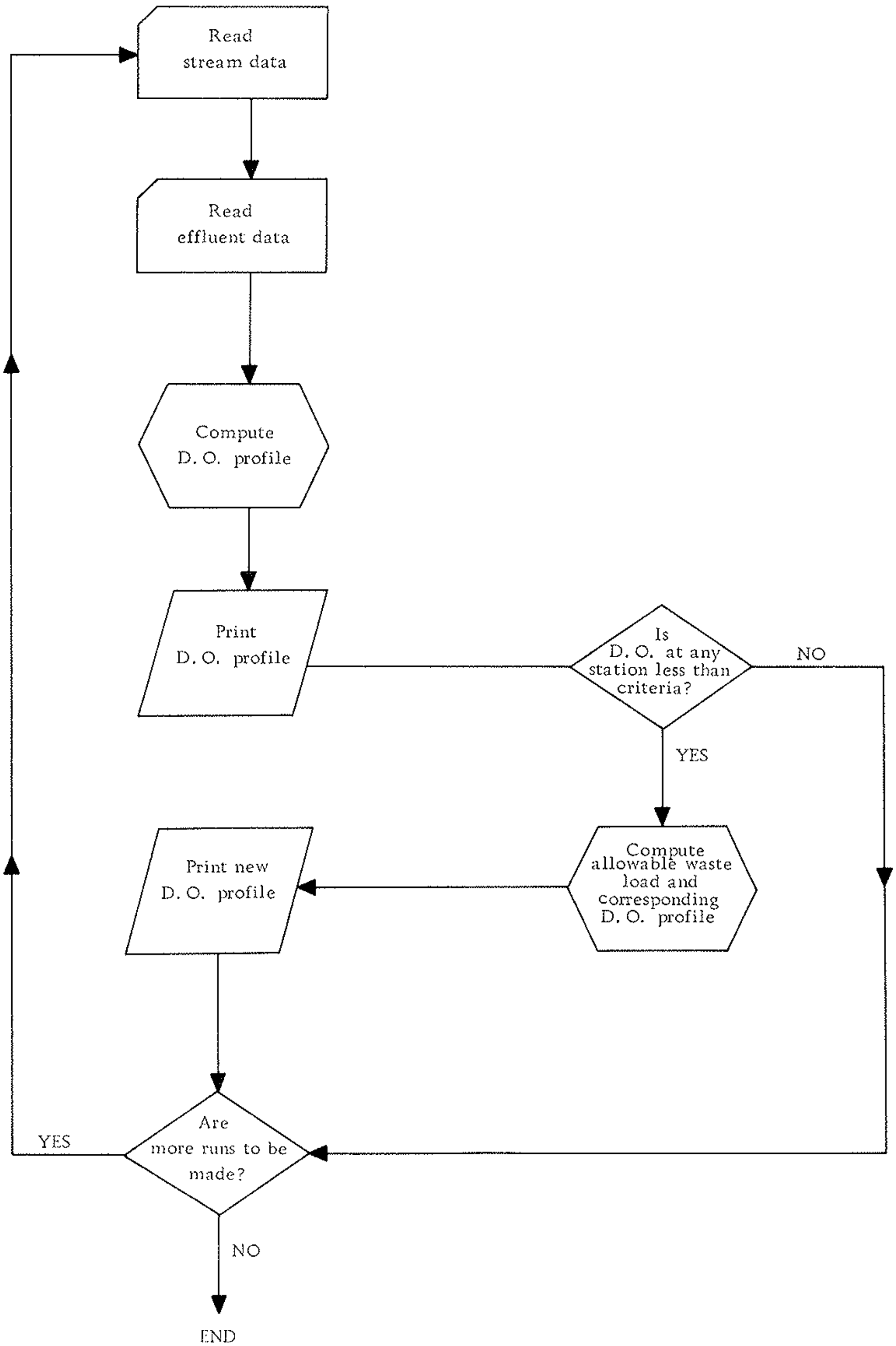

Figure 13. --Calculation flow chart for dissolved-oxygen model.

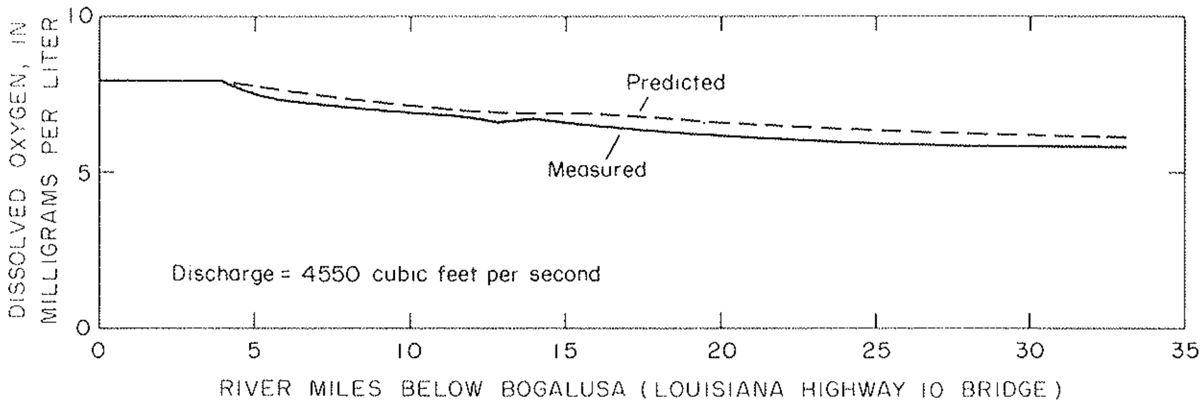

Figure 14. --Comparison of measured and predicted dissolved-oxygen profiles.

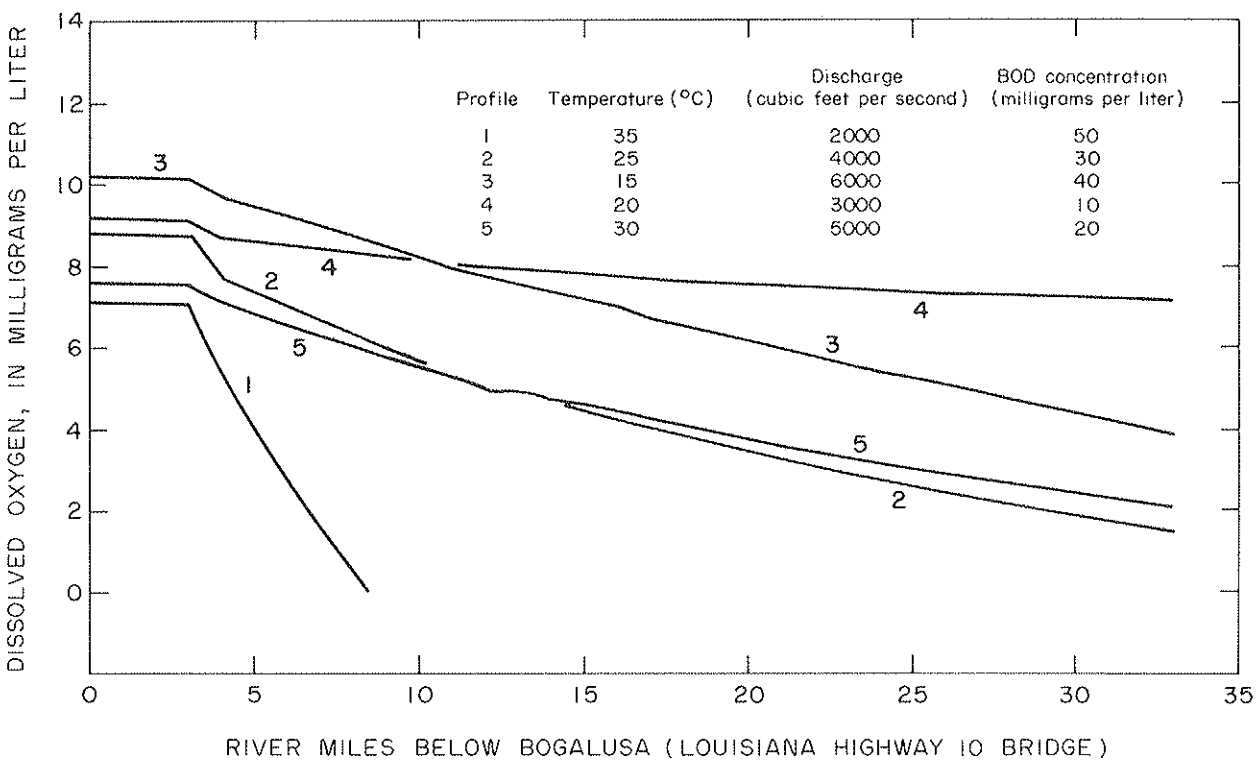

Figure 15. --Predicted dissolved-oxygen profiles.

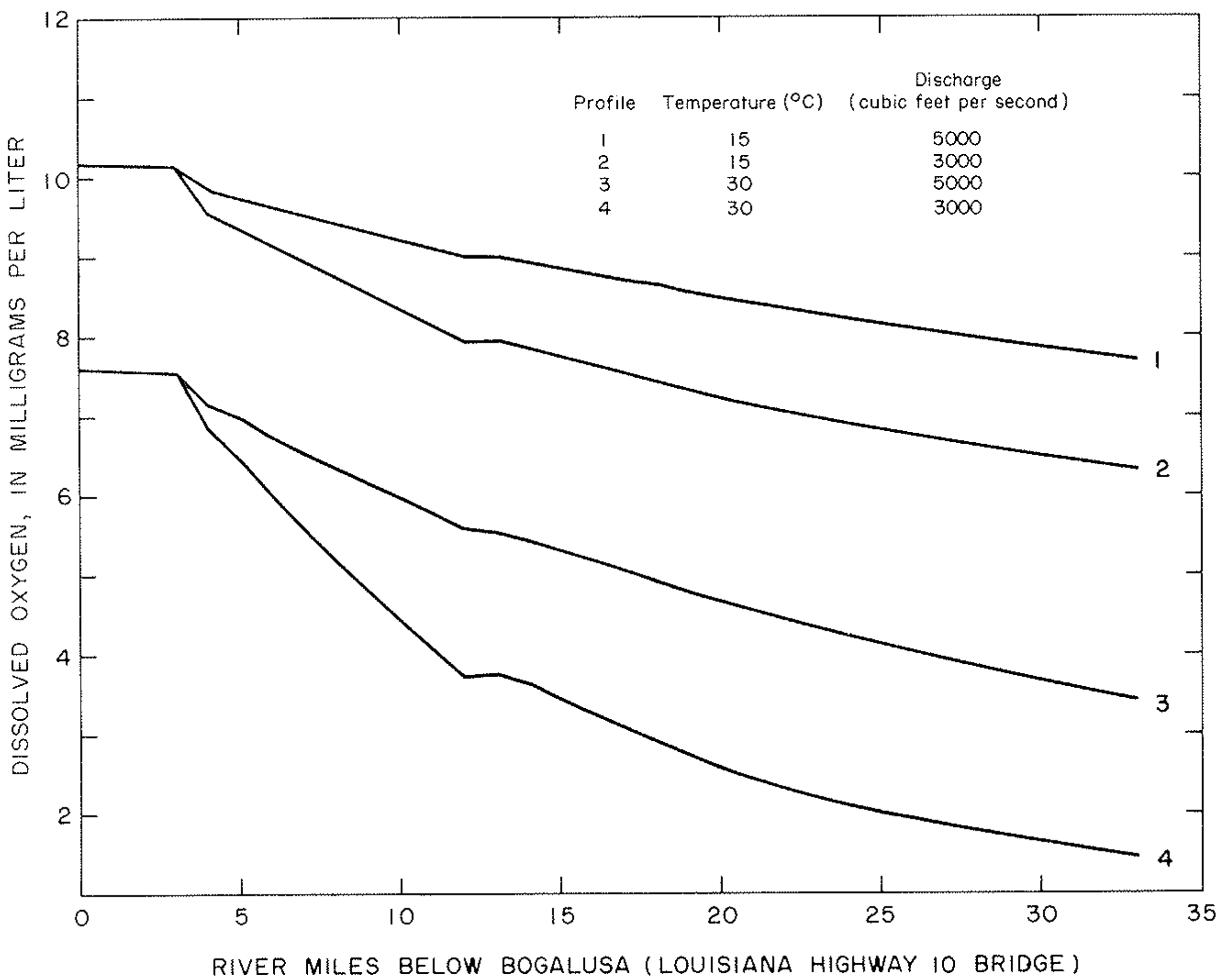

Figure 16.--Predicted dissolved-oxygen profiles as a result of a constant load of biochemical oxygen demand.

FINDINGS AND CONCLUSIONS

Pearl River water is a soft, mixed type, and concentrations of dissolved-solids and most chemical constituents are low: dissolved solids are equal to or less than 60 mg/l 90 percent of the time. Mineralization increases slightly as the water moves downstream from Bogalusa and is due primarily to inflow from Bogue Lusa and Coburn Creeks.

The concentrations of all minor elements determined are higher in Bogue Lusa Creek than in the Pearl River near Bogalusa; however, their effect on concentrations in the Pearl River at Pools Bluff are minimal because of dilution.

The load of dissolved solids discharged into the Pearl River by Bogue Lusa and Coburn Creeks is fairly constant and amounts to about 120 tons per day. When the river discharge is 2,000 cfs, this dissolved-solids load accounts for about 25 percent of the dissolved-solids load of the river.

The ability of the river to assimilate acidic or basic wastes has been determined from buffering-capacity curves and river discharge. During low-flow periods when the discharge is 2,000 cfs or less, about 200 tons per day of concentrated hydroloric acid would lower the pH of the river water to about 4.5. Because of the low dissolved-solids content in Pearl River water, the ability of the river to assimilate acidic or basic wastes depends primarily on river discharge.

Fecal coliform concentrations near Bogalusa ranged from 1 to 1,400 colonies per 100 ml and exceeded the recommended limits of 200 colonies per 100 ml, as set forth for primary contact water sports, 20 percent of the time. At Pools Bluff, fecal coliform concentrations were as high as 3,300 colonies per 100 ml, and all observed values exceeded the recommended limit. Downstream from Pools Bluff, bacteria die off at a constant rate. After 24 hours the residual population is about 16 percent; the half-life of the bacteria is about 9 hours, or 0.38 day.

Macroinvertebrate organisms such as clams and the larvae of the caddisfly, stonefly, and mayfly are commonly found in a clean-water environment and were found at the Louisiana Highway 10 bridge. At Pools Bluff, organisms such as midge larvae, sludge worms, and snails that survive in polluted waters were found in large numbers. At Walkiah Bluff, the presence of numerous clean-water organisms indicated that the river had recovered from organic pollution.

The reach of river downstream from Bogalusa cannot assimilate, during some months, the biodegradable waste that it presently receives. During warm weather and simultaneous low-flow conditions, the oxygen level generally is less than 4.0 mg/l at Pools Bluff and for several miles downstream. A one-dimensional oxygen model was developed for a reach of the Pearl River from the Louisiana Highway 10 bridge to Walkiah Bluff. This model was used to predict the effects of oxygen-demanding waste on the oxygen level in the river at various discharges and water temperatures.

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