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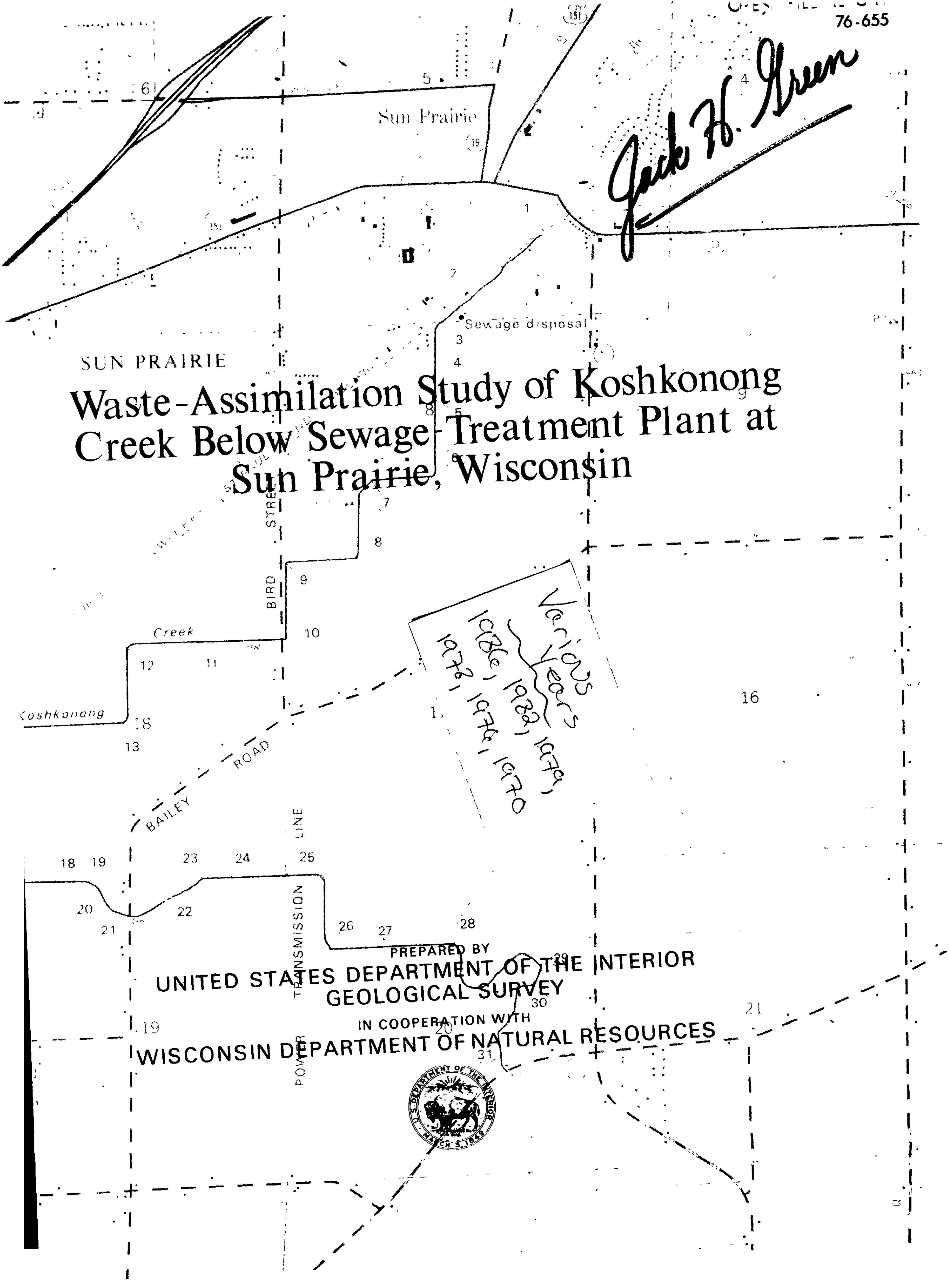


Waste-Assimilation Study of Koshkonong Creek Below Sewage-Treatment Plant at Sun Prairie, Wisconsin

Jack H. Green

Various Years

PREPARED BY

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

IN COOPERATION WITH

WISCONSIN DEPARTMENT OF NATURAL RESOURCES

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WASTE-ASSIMILATION STUDY OF KOSHKONONG CREEK BELOW SEWAGE-TREATMENT PLANT AT SUN PRAIRIE, WISCONSIN

By R. S. Grant

Open-File Report 76-655

Prepared in cooperation with the

Wisconsin Department of Natural Resources

Madison, Wisconsin

November 1976

CONTENTS

ILLUSTRATIONS

TABLES

FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply English units	By	To obtain SI units
miles (mi)	1.609	kilometres (km)
feet (ft)	.3048	metres (m)
square miles (mi^2)	2.59	square kilometres (km^2)
cubic feet per second (ft^3/s)	.028317	cubic metres per second (m^3/s)

WASTE-ASSIMILATION STUDY OF KOSHKONONG CREEK BELOW SEWAGE-TREATMENT PLANT AT SUN PRAIRIE, WISCONSIN

R. S. Grant

ABSTRACT

A waste-load-assimilation study of a reach of Koshkonong Creek below the Sun Prairie, Wisconsin, sewage-treatment-plant (STP) outfall indicated that a high level of treatment would be required to meet Wisconsin water-quality standards. To maintain a minimum dissolved-oxygen concentration of 5 milligrams per litre during the critical summer low-flow period, 5-day carbonaceous biochemical-oxygen demand in waste discharges should not exceed 5 milligrams per litre and ammonium nitrogen should not exceed 1.5 milligrams per litre. Advanced treatment with denitrification is required because stream-reaeration coefficients are not high enough to offset deoxygenation caused by an abundance of attached biological slimes. The slimes apparently consumed dissolved oxygen at a rate of about 110 milligrams per litre per day at the time of the stream survey.

During the critical summer low-flow period, natural stream discharge is very small compared to waste-water discharge, so benefits of dilution are insignificant.

An evaluation of two proposed alternative waste-water discharge sites indicated that the present discharge site is hydraulically superior to these sites.

Stream-reaeration coefficients used in the study were based on measurements using the radioactive-tracer method.

INTRODUCTION

The Federal Water Pollution Control Act of 1965 and the amendments in 1972 require the various States to adopt and meet water-quality standards approved by the Federal Government. The water-quality standards of Wisconsin require, in part, that wastes discharged into a stream do not cause DO (dissolved-oxygen) concentrations to drop below 5.0 mg/l (milligrams per litre) in waters classified for fish, aquatic life, and recreational use. Wastes also are not to cause toxic conditions or excessively high temperatures in the receiving waters.

The purpose of this study was to evaluate the waste-assimilative capacity of a reach of Koshkonong Creek at Sun Prairie, Wis., for determination of waste loading compatible with Wisconsin water-quality standards. The study was done in cooperation with the Wisconsin Department of Natural Resources.

The study area is in northeastern Dane County, Wis., (fig. 1) near Sun Prairie, which has a population of 9,935 (1970 census). Koshkonong Creek heads near Sun Prairie and flows through the south side of the city (fig. 2). The study reach begins in the city and ends at County Trunk Highway T (station 31, fig. 2). The entire reach has been ditched and realined and is bordered by agricultural and undeveloped land downstream from Sun Prairie. During low-flow periods nearly all the discharge of Koshkonong Creek near Sun Prairie is sewage-treatment-plant effluent.

WASTE DISCHARGES

Waste water enters the study reach from the Sun Prairie sewage-treatment plant and from a canning company (Wis. Dept. of Nat. Resources, 1971). The sewage-treatment-plant effluent is discharged just upstream from station 3 (fig. 2). The effluent quantity and quality varies widely. Ground water infiltrates the sewers in the spring when the water table is high and causes much higher discharge and much lower quality effluent to Koshkonong Creek than during other seasons of the year because the plant capacity is not large enough to treat high flows adequately. Waste water from the canning company is discharged periodically into Koshkonong Creek upstream from the municipal sewage-treatment-plant outfall near station 1 (fig. 2) causing DO concentrations less than 5 mg/l upstream from the municipal outfall periodically (fig. 3). However, samples of the cannery effluent were not taken for verification.

During the DO survey May 2, the stream temperature in reach 3-21 ranged from 12.5° to 15.0°C (Celsius), and the stream discharge at station 3 was about 4 ft^3/s (0.1 m^3/s); May 28 the temperature ranged from 12.0° to 15.5°C and the discharge 6 to 10 ft^3/s (0.2 to 0.3 m^3/s); August 23 the temperature ranged from 17.0° to 19.0°C and the discharge 4.5 to 6.5 ft^3/s (0.1 to 0.2 m^3/s); and September 3 the temperature ranged from 16.0° to 19.0°C and the discharge 2.8 to 4.0 ft^3/s (0.08 to 0.11 m^3/s).

Canning-company waste sprayed periodically east of reach 3-6 (fig. 2) may be reaching Koshkonong Creek in high concentrations near station 6 through field-drainage tiles and perhaps surface runoff. This was postulated based on an observed large increase in CBOD (carbonaceous biochemical-oxygen demand) at station 6 (fig. 15) and on field observations that a milky brown substance was discharging into this reach from a field tile during the stream survey. The CBOD concentration of the tile discharge was estimated to be greater than 250 mg/l. There was no apparent increase in NBOD (nitrogeneous biochemical-oxygen demand) at station 6 (fig. 16). The canning company was spraying at the time of the survey.

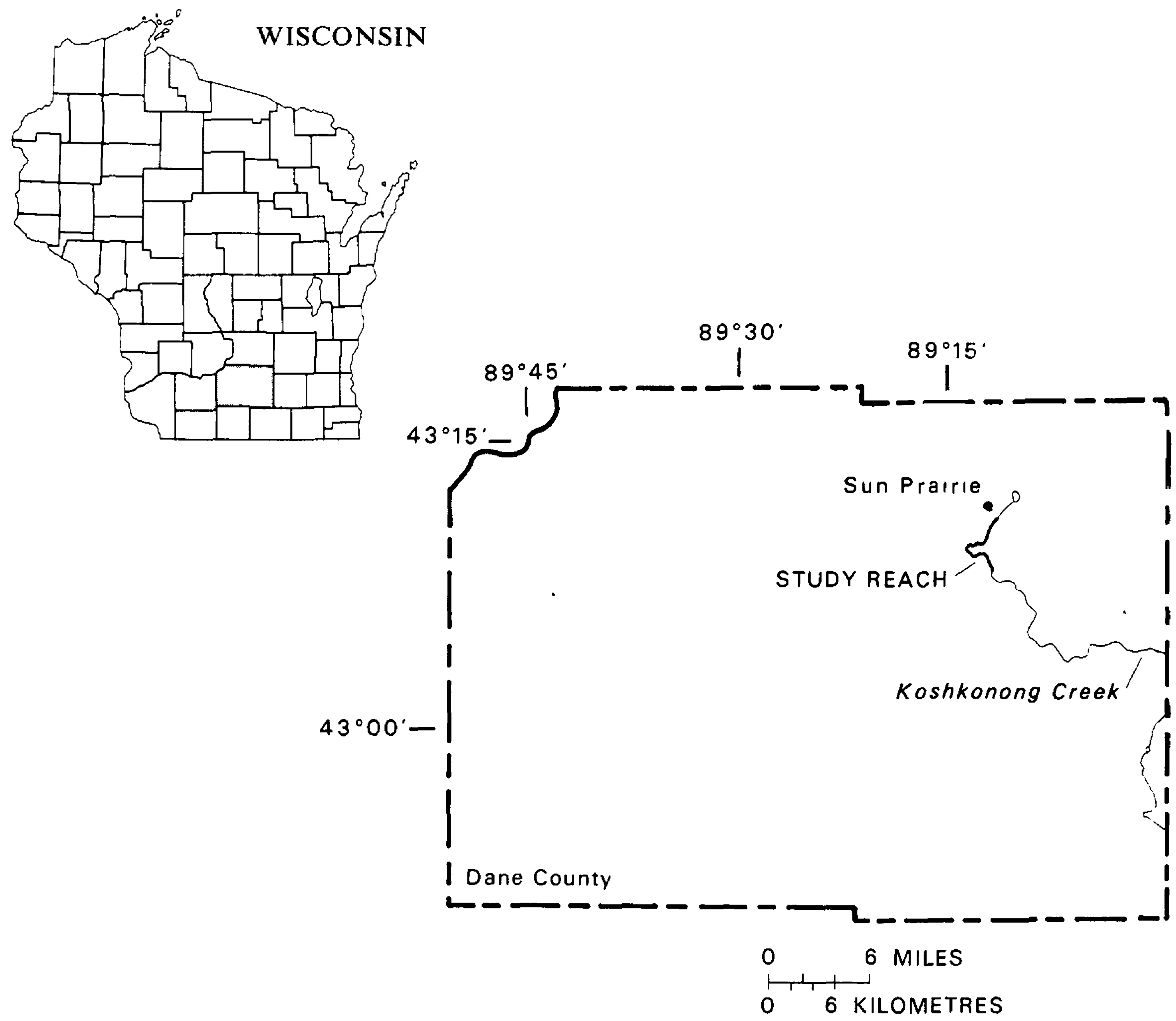


Figure 1. Location of study reach.

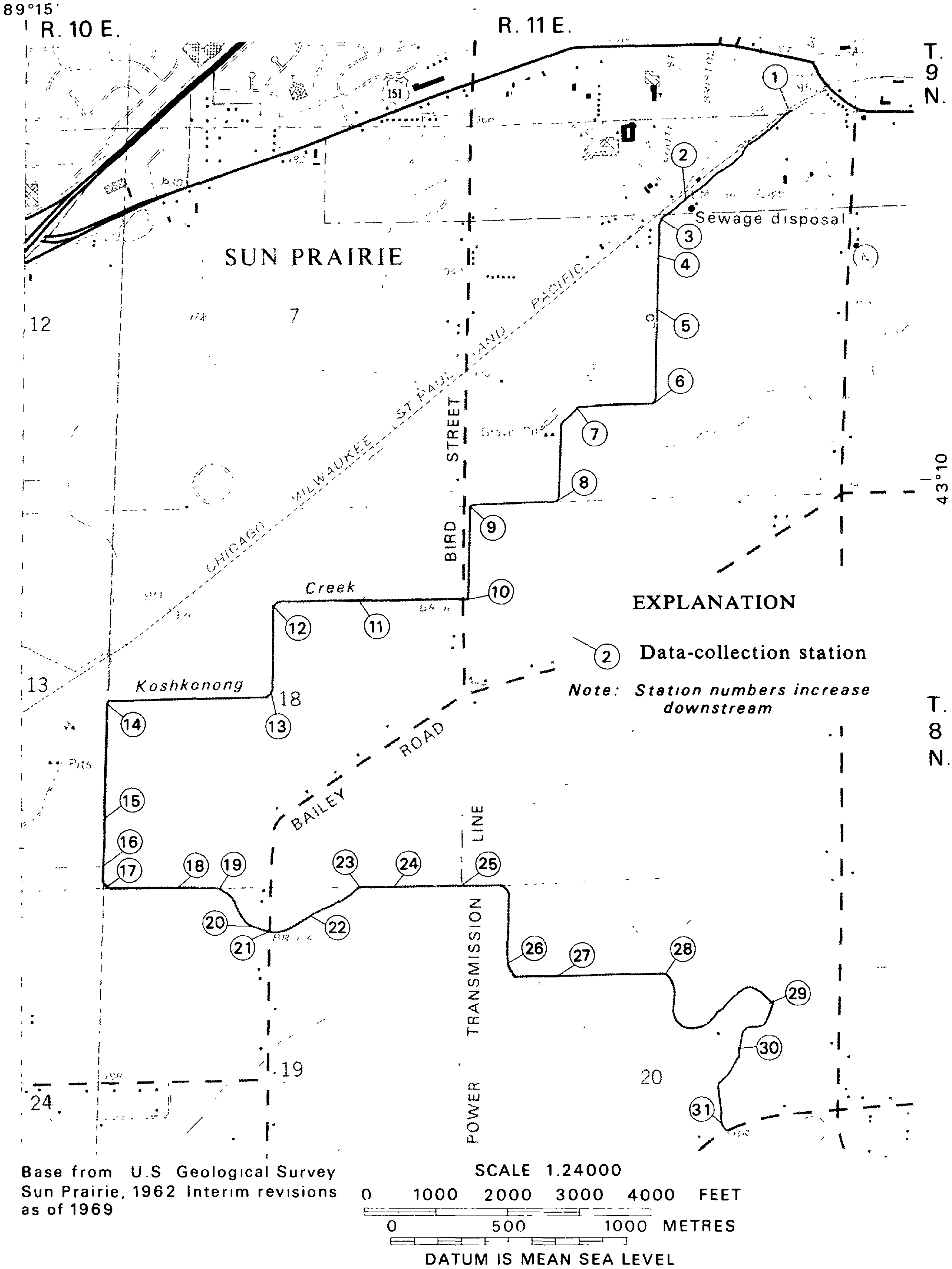


Figure 2. Location of data-collection stations.

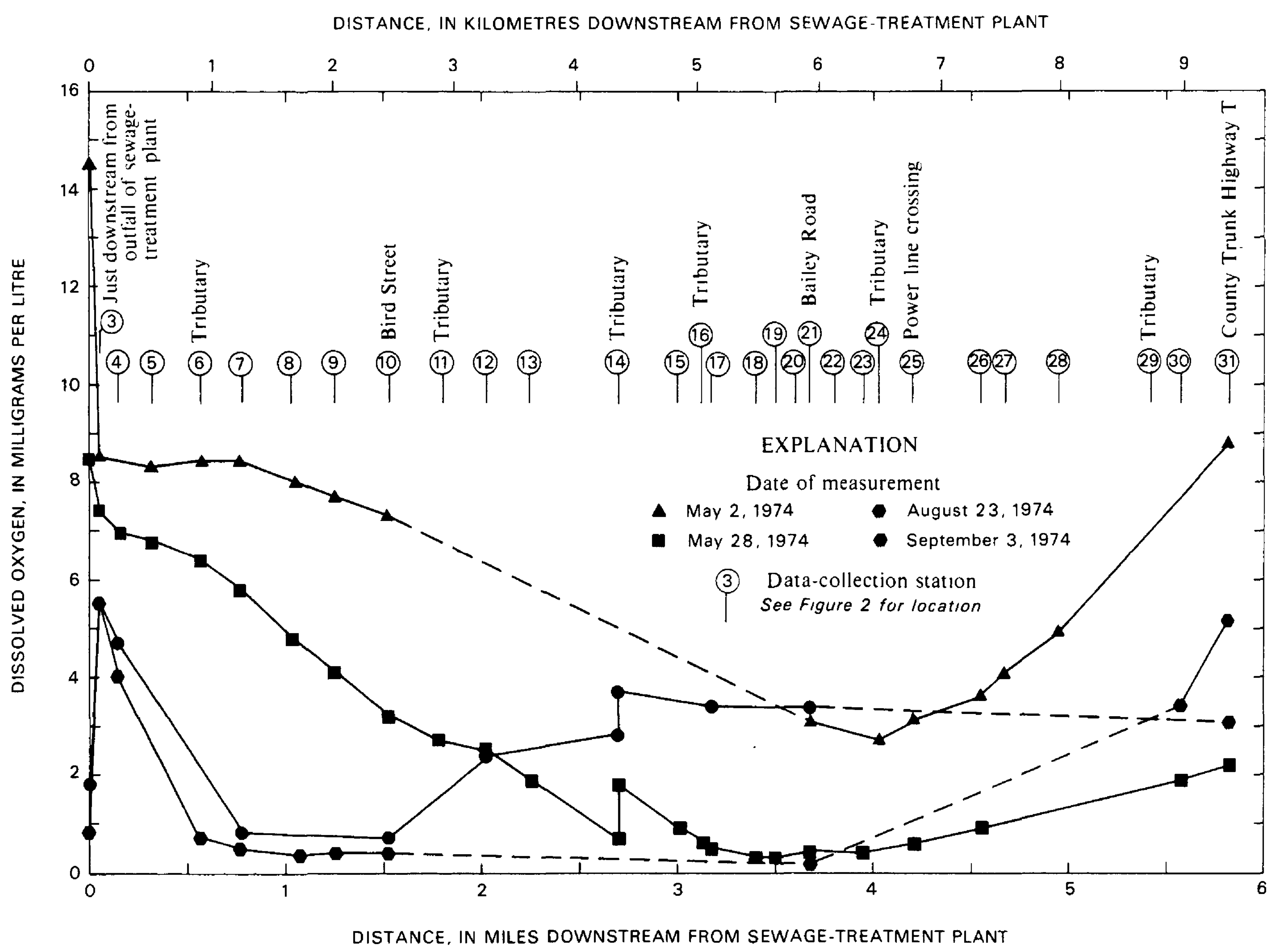


Figure 3. Observed dissolved-oxygen profiles.

CBOD data are presented in figures 4-13. CBOD used in the simulations was that based on using one part sample and five parts dilution water (1:6 dilution).

The curves presented in figure 6 represent CBOD for the same waste-water sample split into three parts. Each part was diluted differently for laboratory analysis. The ultimate CBOD ($CBOD_\mu$) determined from the sample containing 1 part waste water and 19 parts dilution water (1:20 dilution) was 55.0 mg/l. The 1:12 dilution yielded $CBOD_\mu$ = 36.0 mg/l and the 1:6 dilution 26.0 mg/l.

Because of the disparities in $CBOD_\mu$ determined using different dilution ratios, data for 1:6 dilutions only were used in the modeling because these data were available for nearly all the stream CBOD samples taken. The $CBOD_\mu$ for a 1:6 dilution of the sewage-treatment-plant effluent (fig. 5) had to be estimated for this reason, so that all data would be compatible. The estimate agreed very well, however, with a mass-balance computation using 1:6 $CBOD_\mu$ determined upstream and downstream from the municipal outfall.

Based on CBOD data obtained during the stream surveys of September 3 and May 28, 1974, it was found that the $CBOD_\mu$ was about 1.8 times the $CBOD_5$ (5-day CBOD) well downstream from the sewage-treatment plant. Therefore, for the waste-load-allocation analyses $CBOD_5$ was computed using

$$CBOD_5 = \frac{CBOD_\mu}{1.8} .$$

Much of the CBOD is being discharged into Koshkonong Creek as settleable solids (fig. 14). Instream BOD reaction-rate coefficients for the day of the stream survey are presented in figures 15 and 16.

STREAM-MODEL CALIBRATION

A steady-state segmented DO model developed by Bauer and Jennings (1975) was used for this study. The model utilizes a modified Streeter-Phelps equation that incorporates nitrogeneous, benthal, photosynthetic, and respiration effects on the DO balance. The model takes the following form:

$$D_o e^{-K_2 t} = \text{initial DO deficit},$$

$$\frac{K_1 L_u}{K_2 - K_1} \left(e^{-K_1 t} - e^{-K_2 t}\right) = \text{deficit due to CBOD},$$

$$\frac{K_n N}{K_2 - K_n} (e^{-K_n t} - e^{-K_2 t}) = \text{deficit due to NBOD,}$$

$$\frac{R}{K_2} (1 - e^{-K_2 t}) = \text{deficit due to plant respiration,}$$

$$\frac{B}{K_2} (1 - e^{-K_2 t}) = \text{deficit due to bottom deposits, and}$$

$$- \frac{P}{K_2} (1 - e^{-K_2 t}) = \text{mean daily photosynthetic DO production.}$$

Where: K_2 = atmospheric reaeration-rate constant (per day);

K_1 = decay-rate constant for the CBOD (per day);

L_u = ultimate CBOD concentration (milligrams per litre);

K_n = decay-rate constant for the NBOD (per day);

N = NBOD concentration (milligrams per litre);

P = oxygen produced by photosynthesis (milligrams per litre per day);

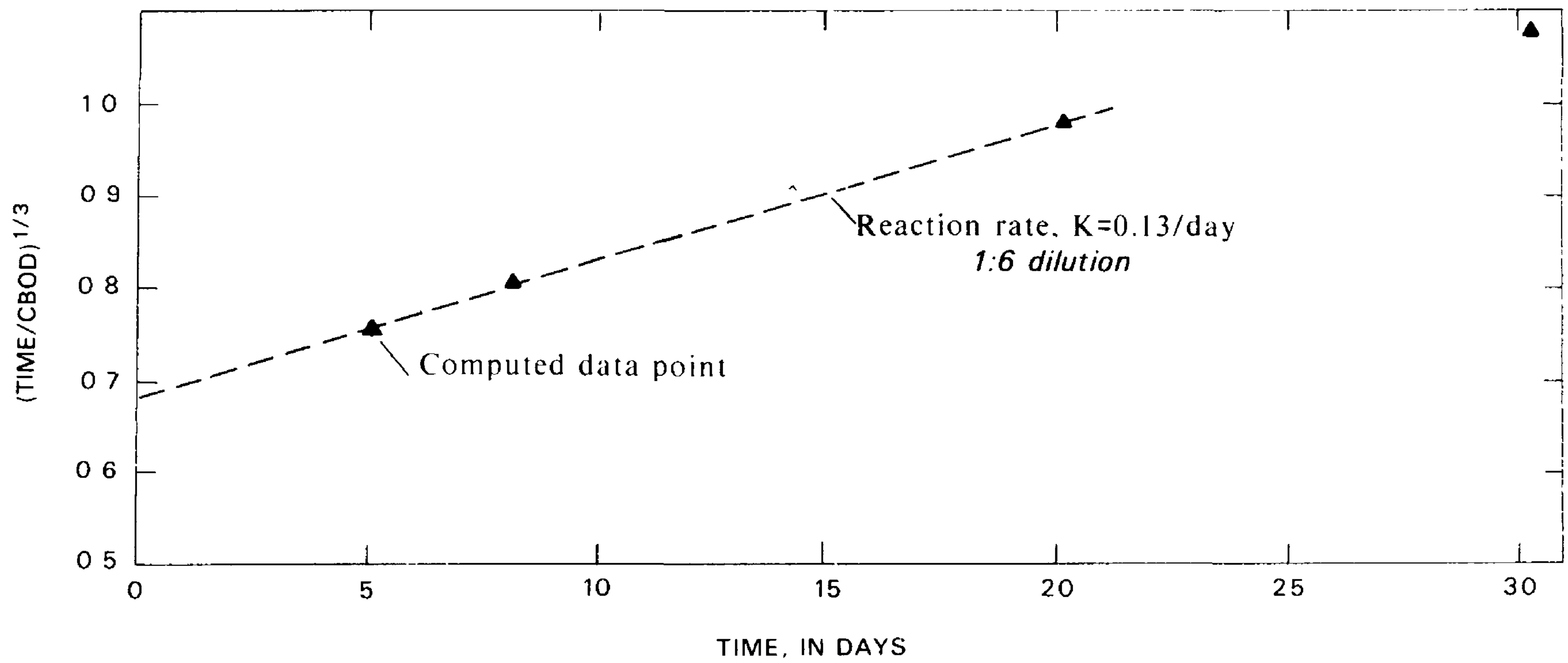
R = oxygen utilized by algal respiration (milligrams per litre per day);

B = oxygen used by the stream-bottom deposits (milligrams per litre per day);

t = elapsed time (days); and

D_o = initial dissolved-oxygen deficit (milligrams per litre).

The model was calibrated by fitting an observed DO profile of Koshkonong Creek for September 3, 1974 (fig. 3), using water-quality data collected that day. Measurements were made of all parameters used in the model except for benthal and algal effects, which were determined using oxygen-balance computations by adjusting the model to fit the observed data through reach 3-21.



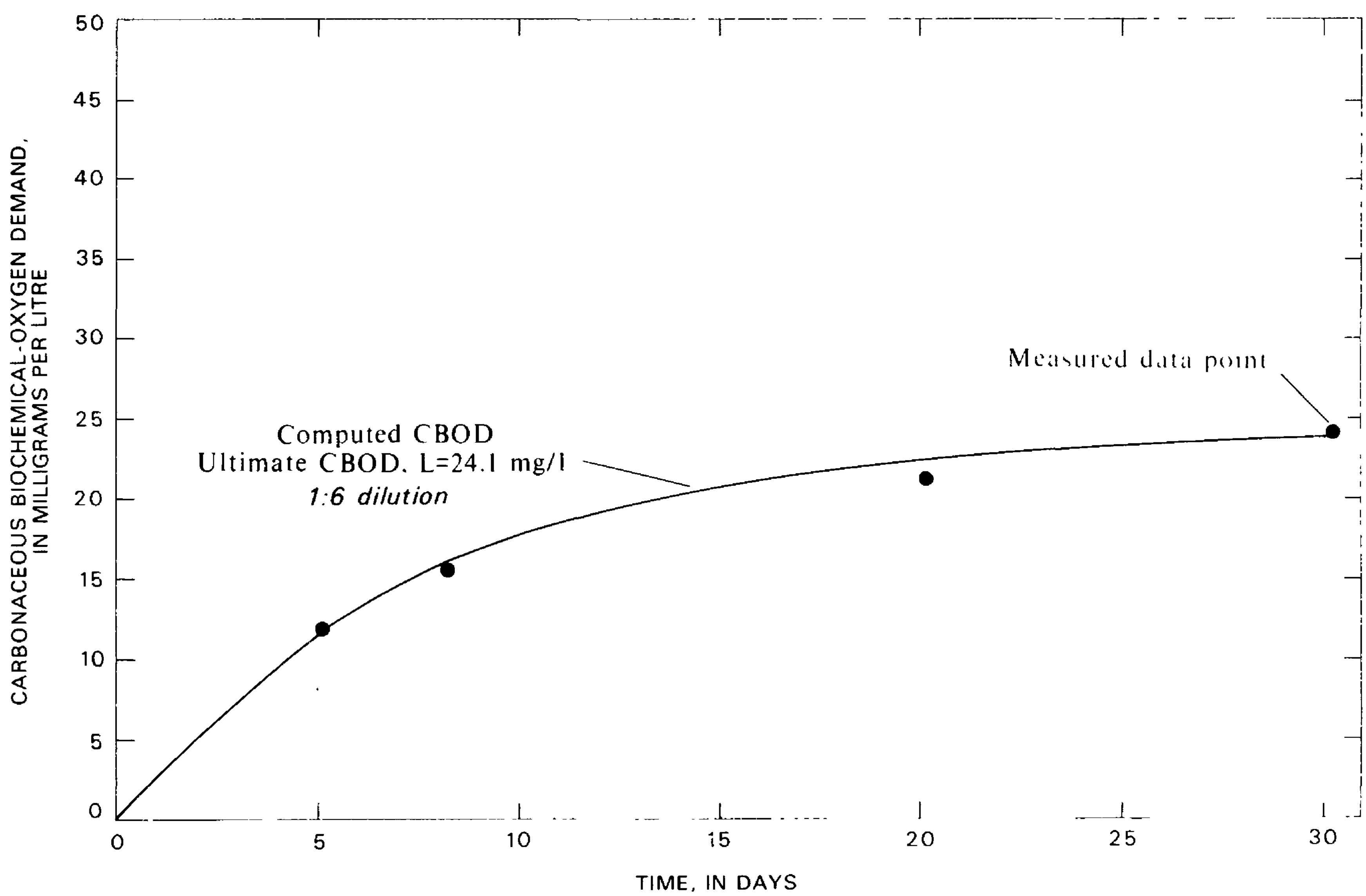


Figure 4. Carbonaceous biochemical-oxygen demand upstream from sewage-treatment plant (station 2), September 3, 1974.

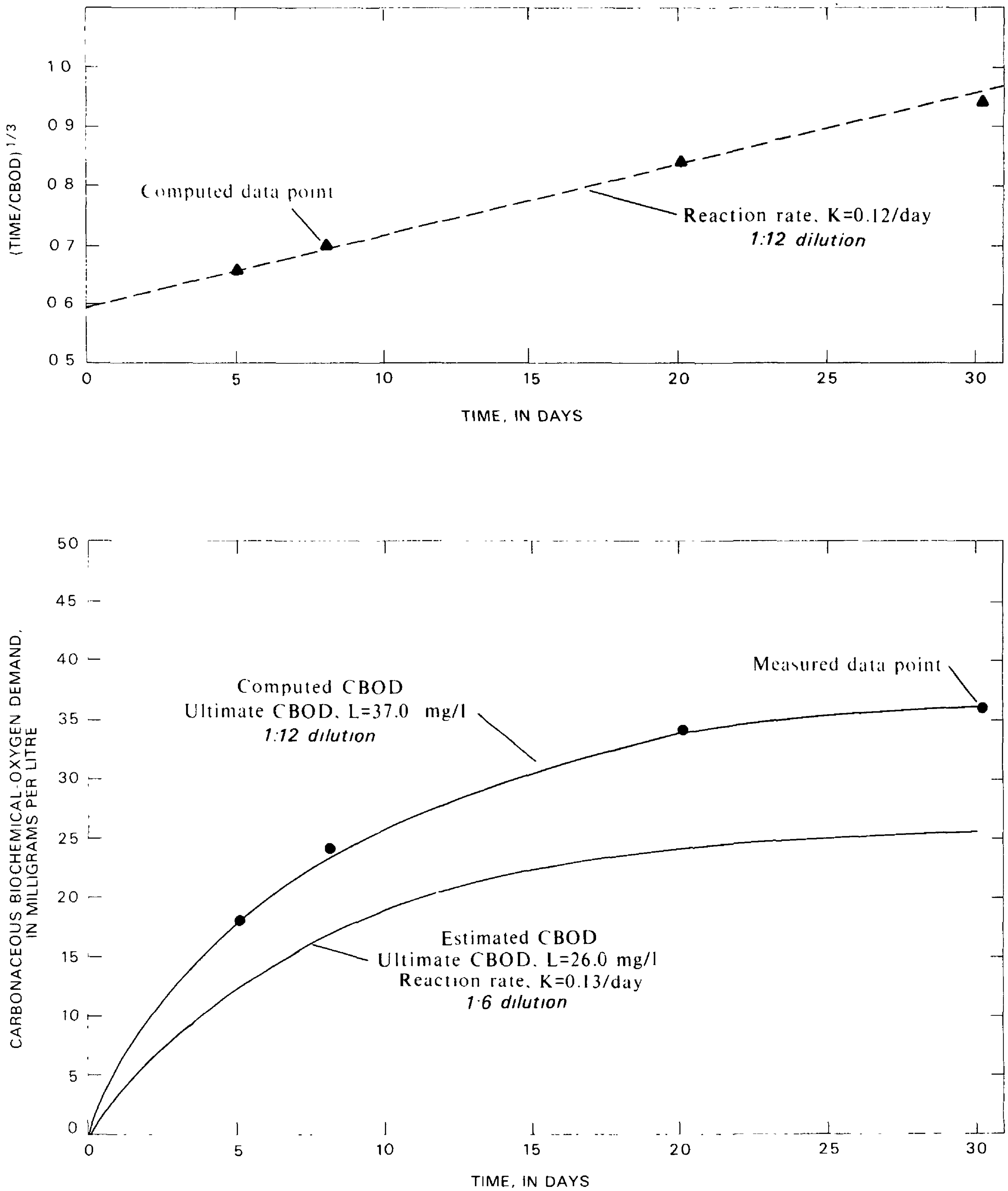


Figure 5. Carbonaceous biochemical-oxygen demand of sewage-treatment plant effluent, September 3, 1974

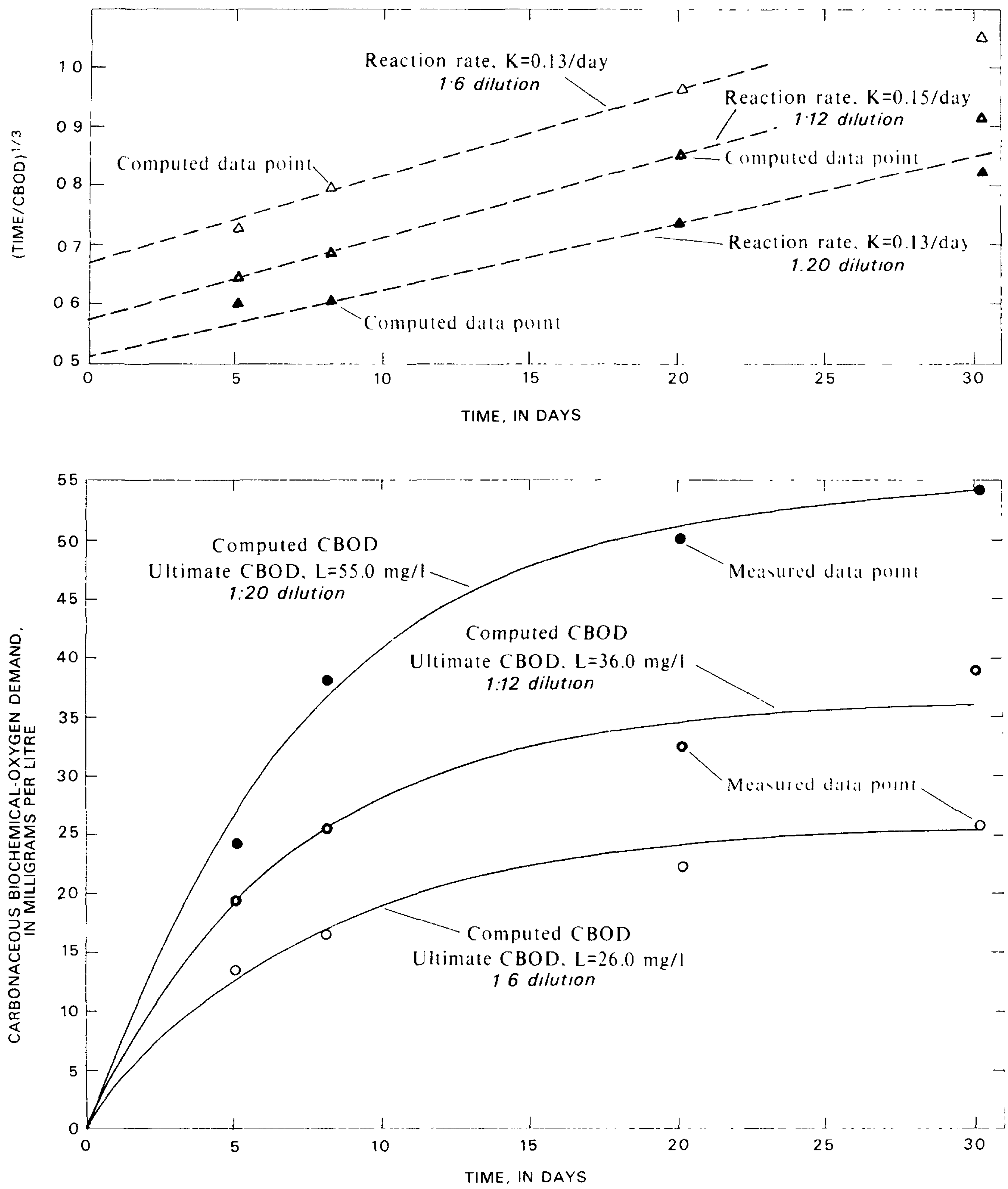


Figure 6. Carbonaceous biochemical-oxygen demand just downstream from outfall of sewage-treatment plant (station 3), September 3, 1974

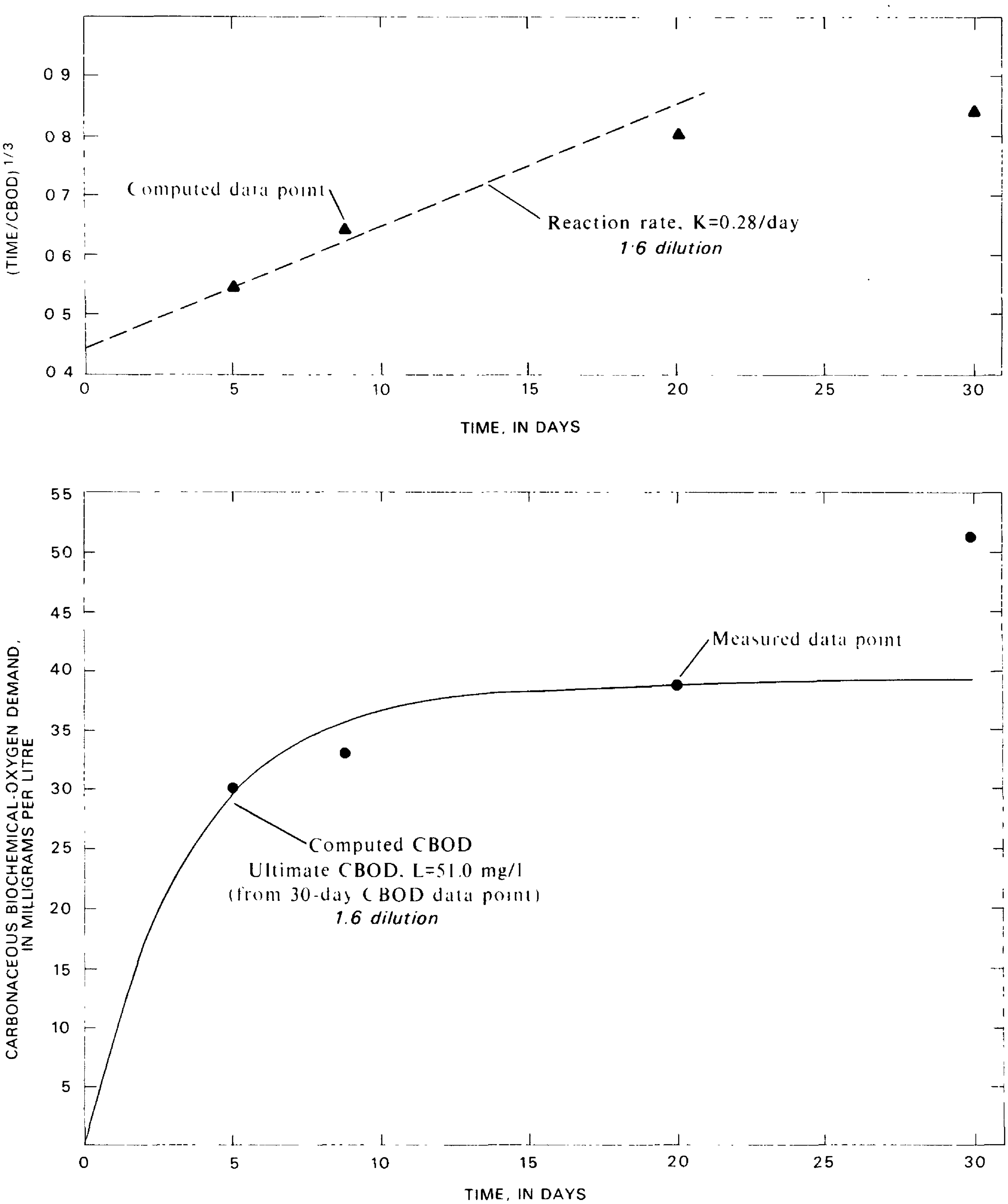
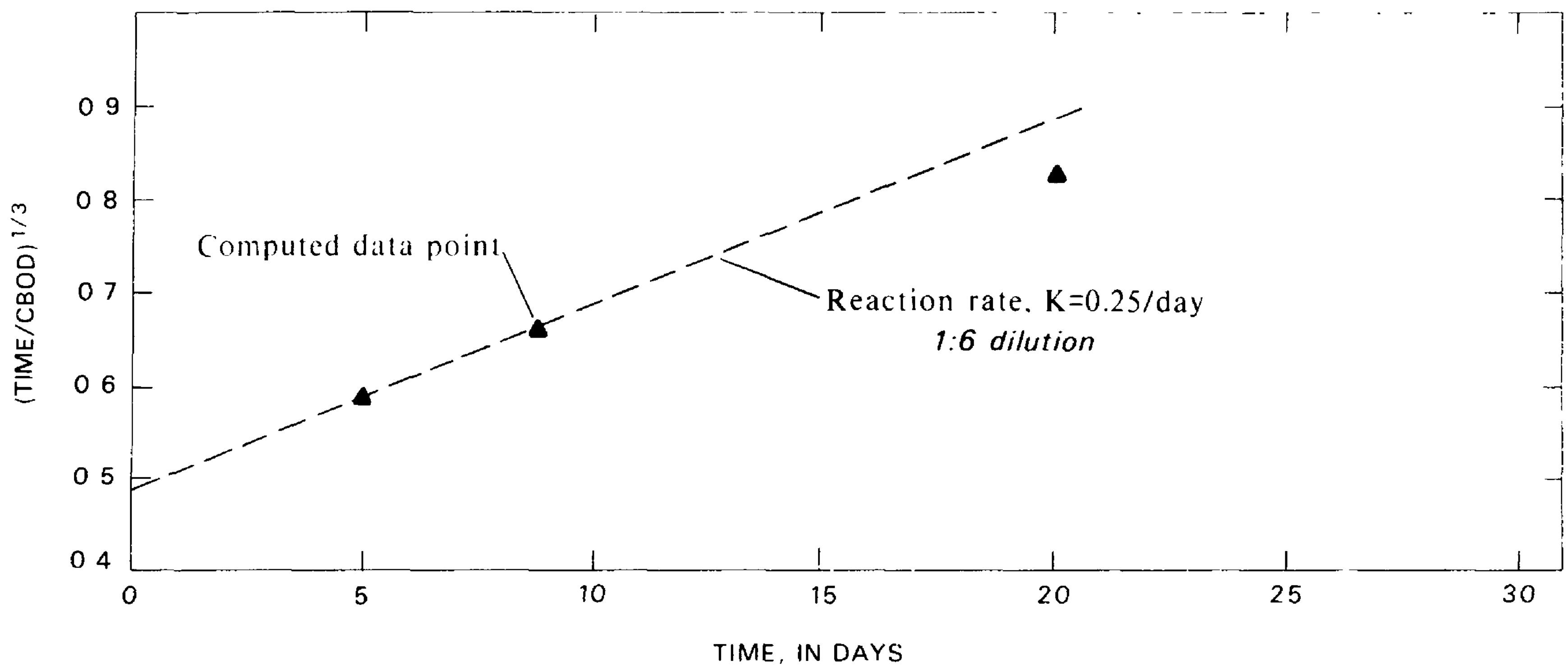


Figure 7. Carbonaceous biochemical-oxygen demand near gravel pit (station 7), September 3, 1974.



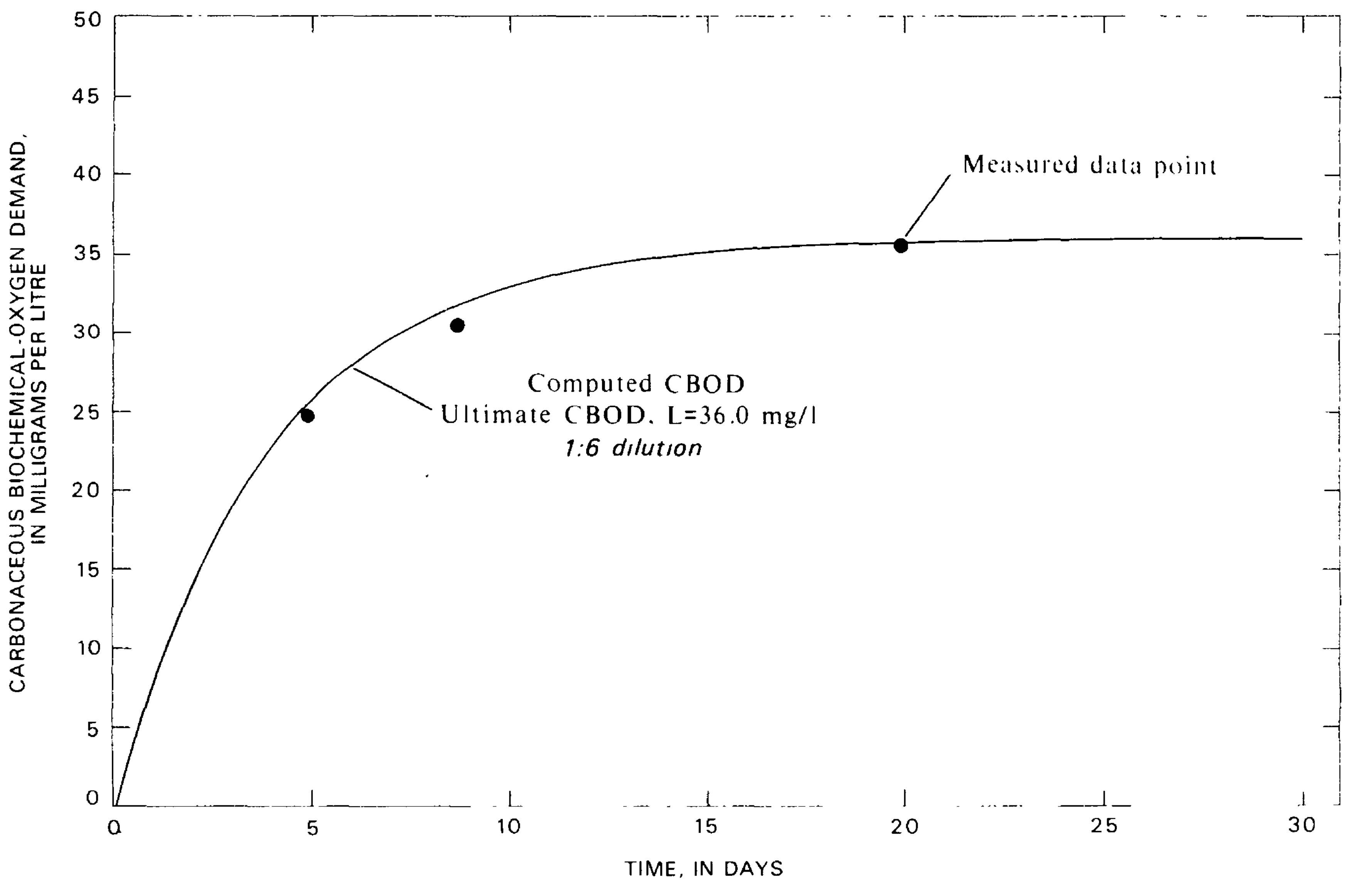


Figure 8. Carbonaceous biochemical-oxygen demand at Bird Street (station 10), September 3, 1974.

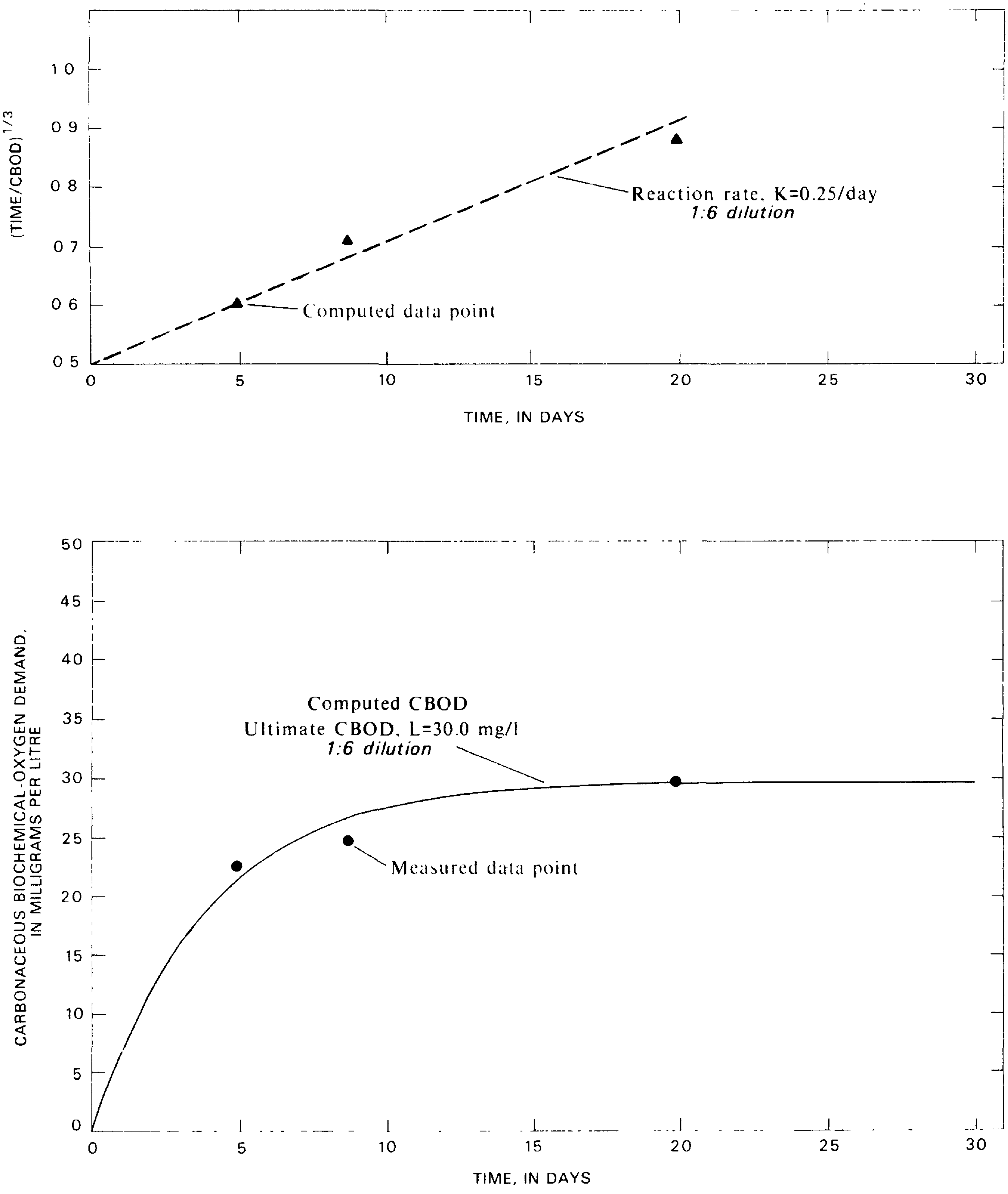
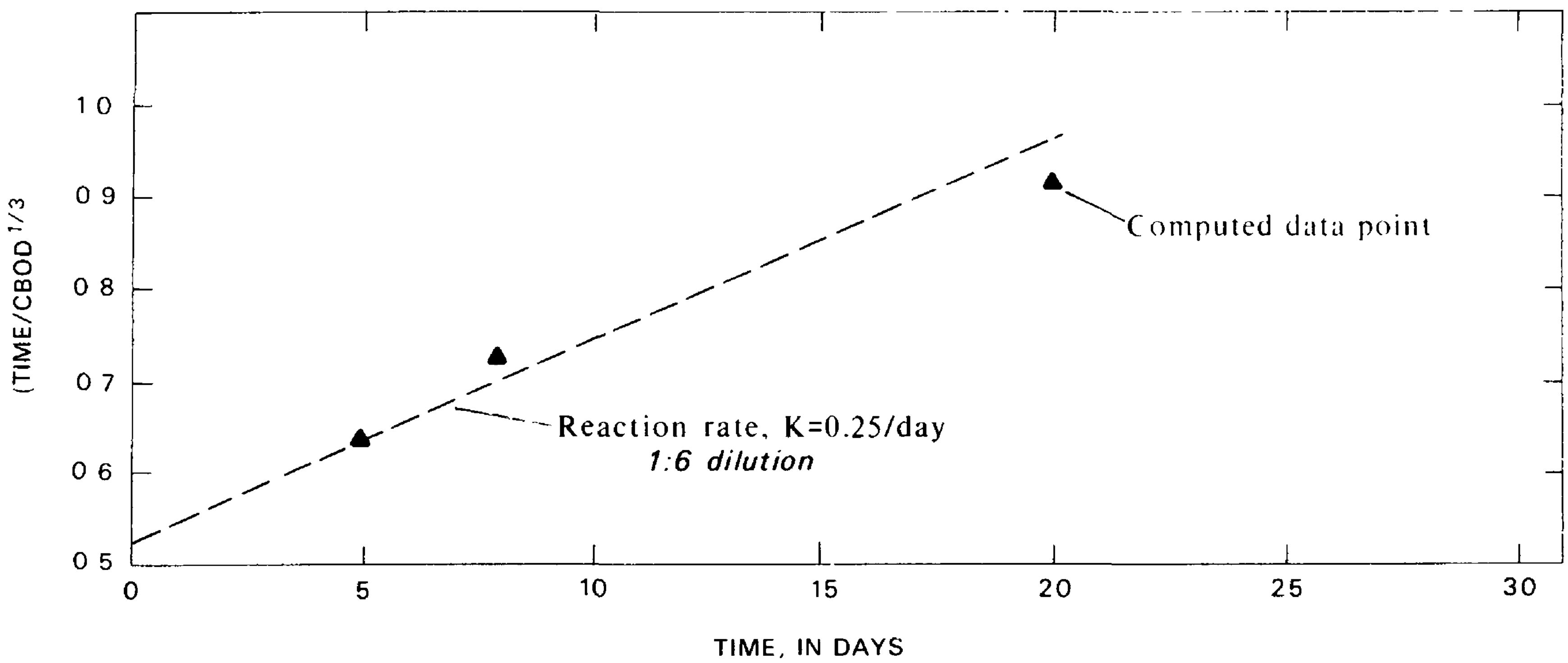


Figure 9. Carbonaceous biochemical-oxygen demand at bend south (station 12). September 3, 1974.



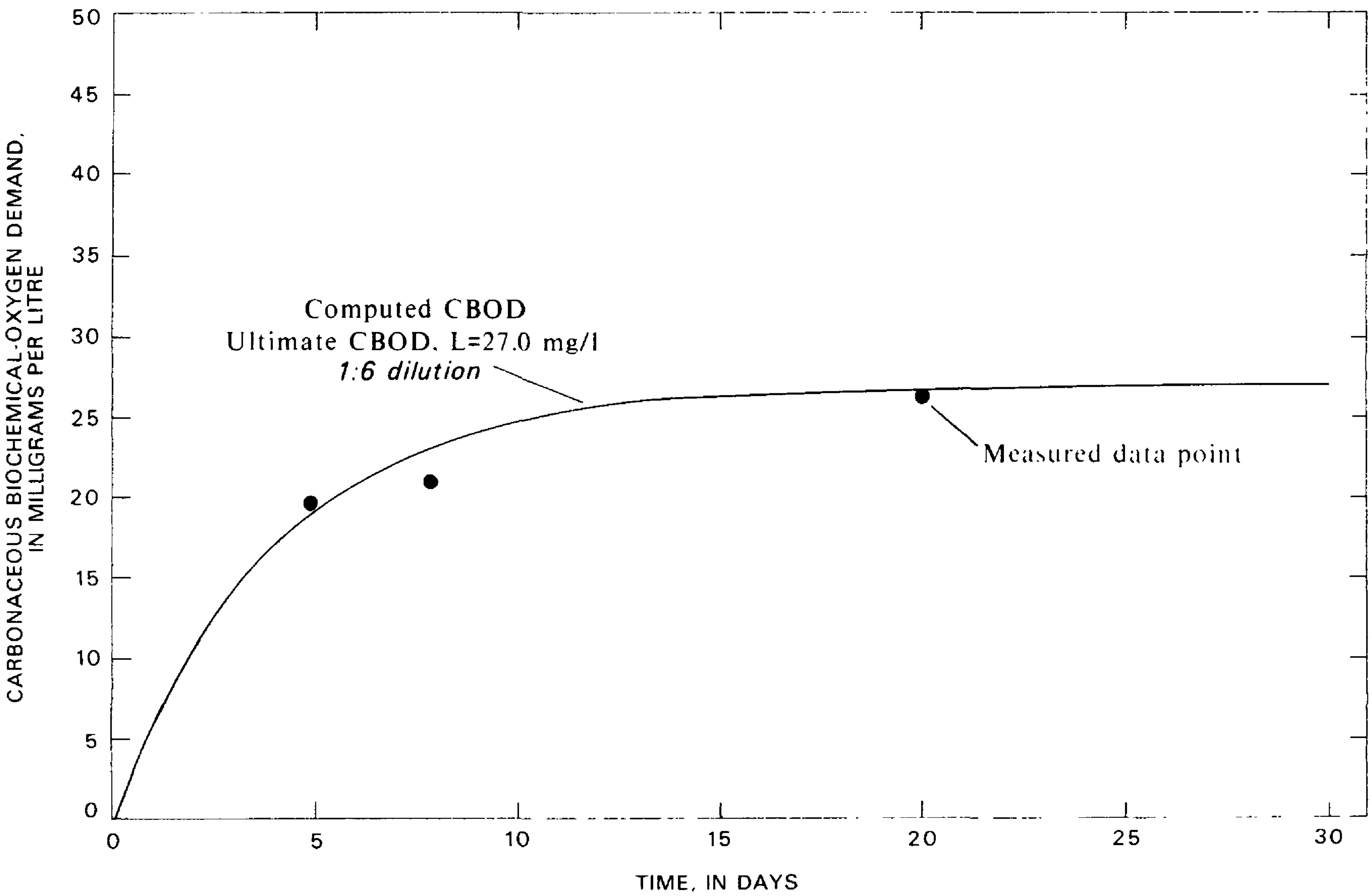


Figure 10. Carbonaceous biochemical-oxygen demand just upstream from tributary (station 14), September 3, 1974.

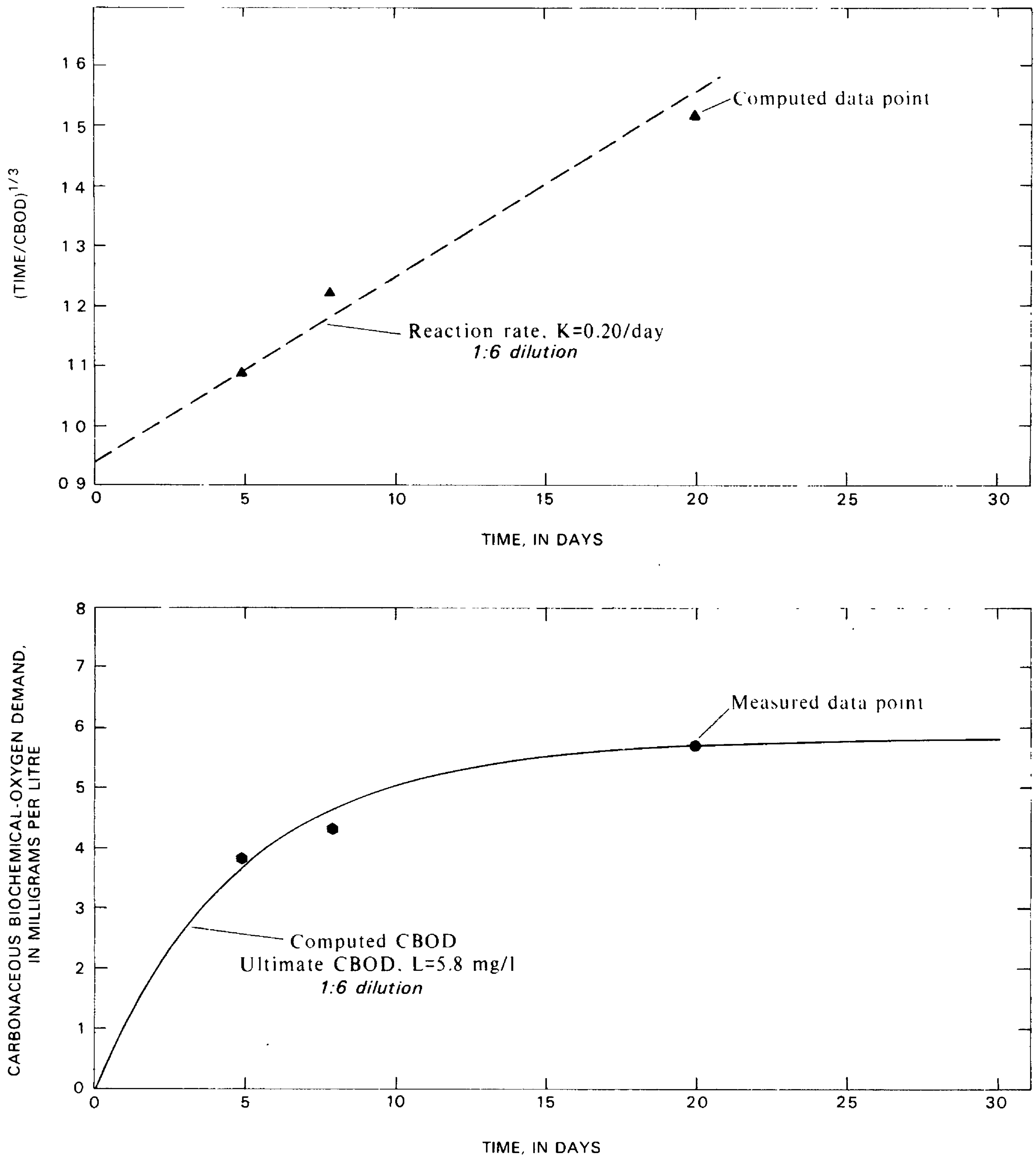
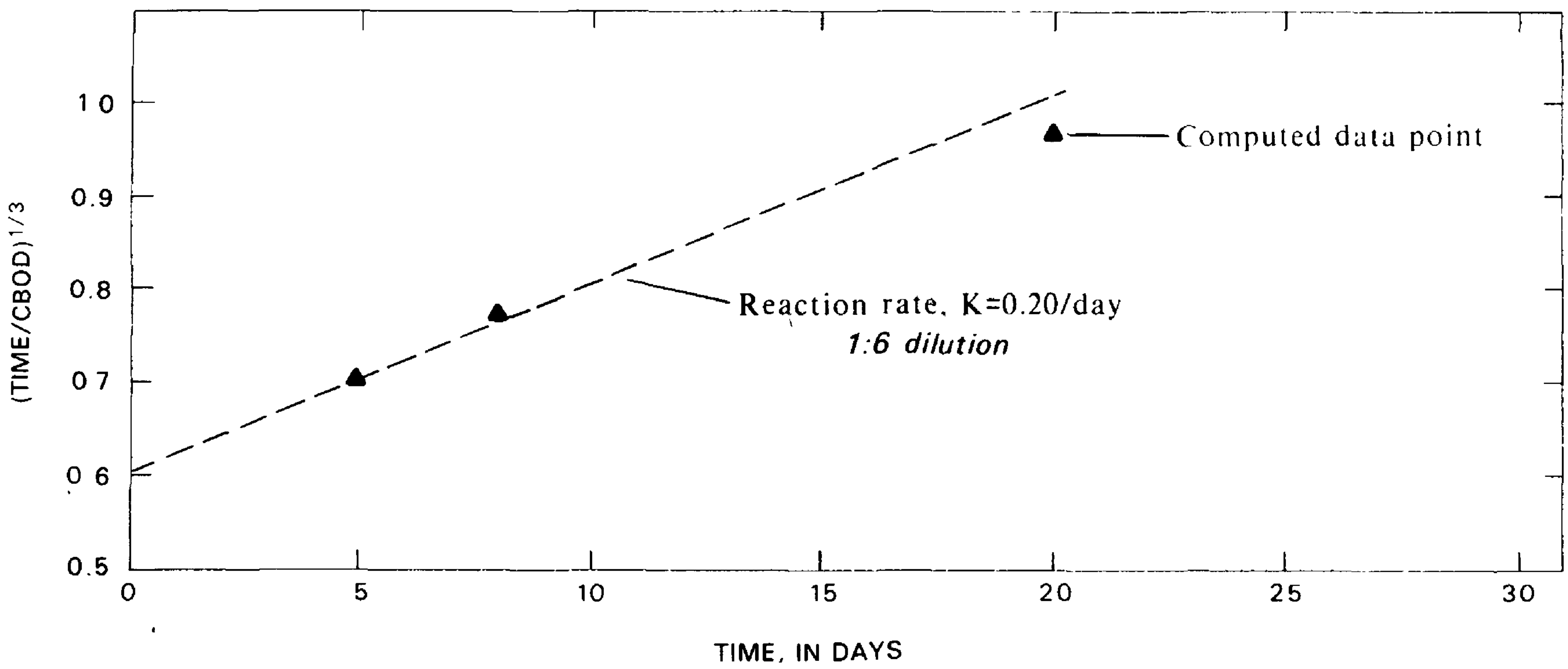


Figure 11 Carbonaceous biochemical-oxygen demand of tributary near station 14, September 3, 1974.



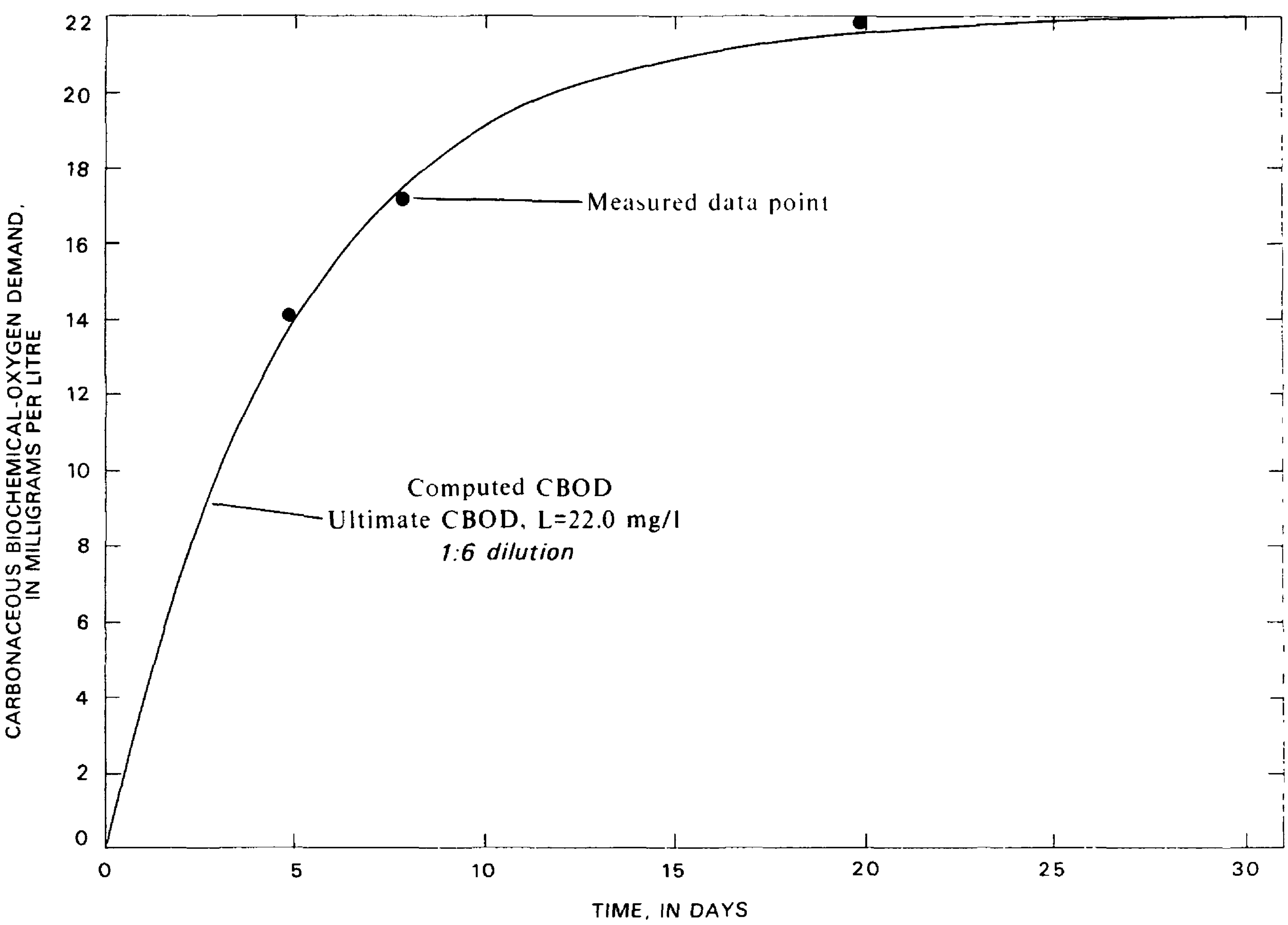
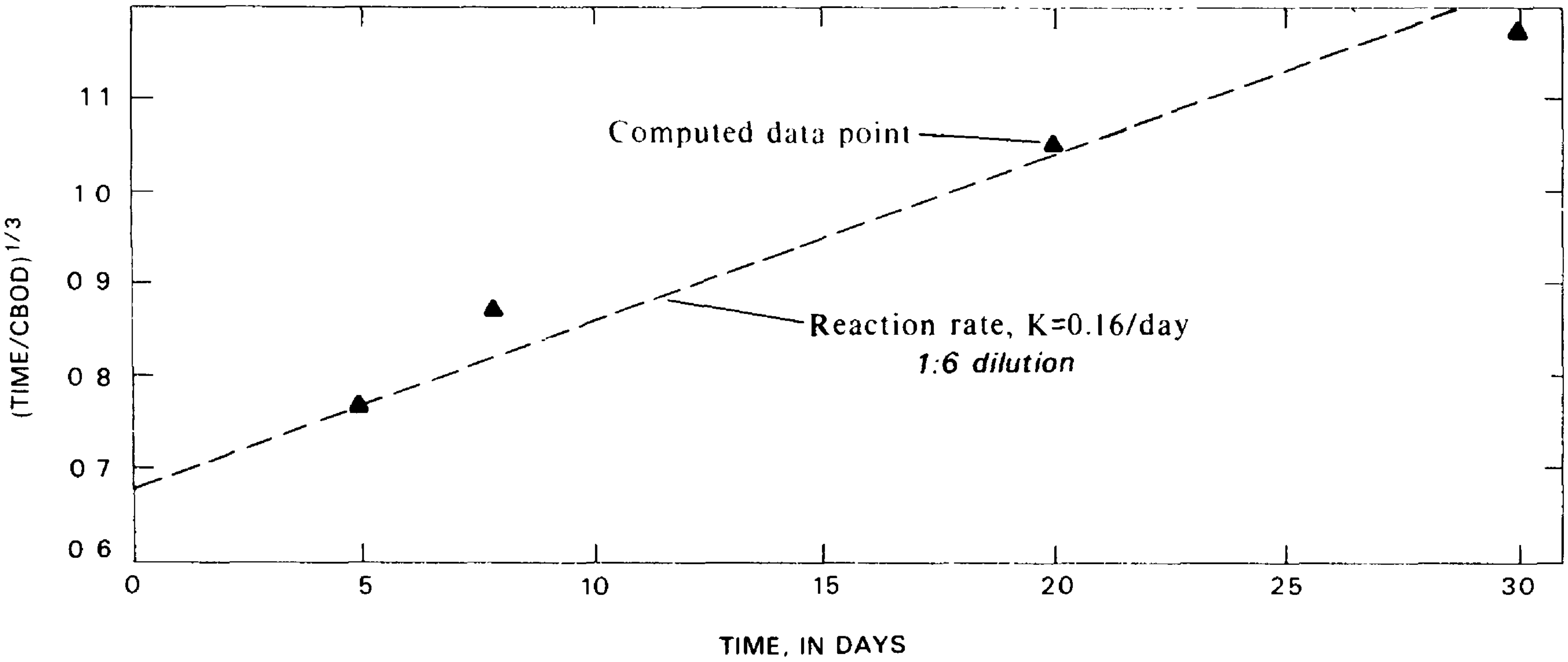


Figure 12. Carbonaceous biochemical-oxygen demand at bend east (station 17), September 3, 1974.



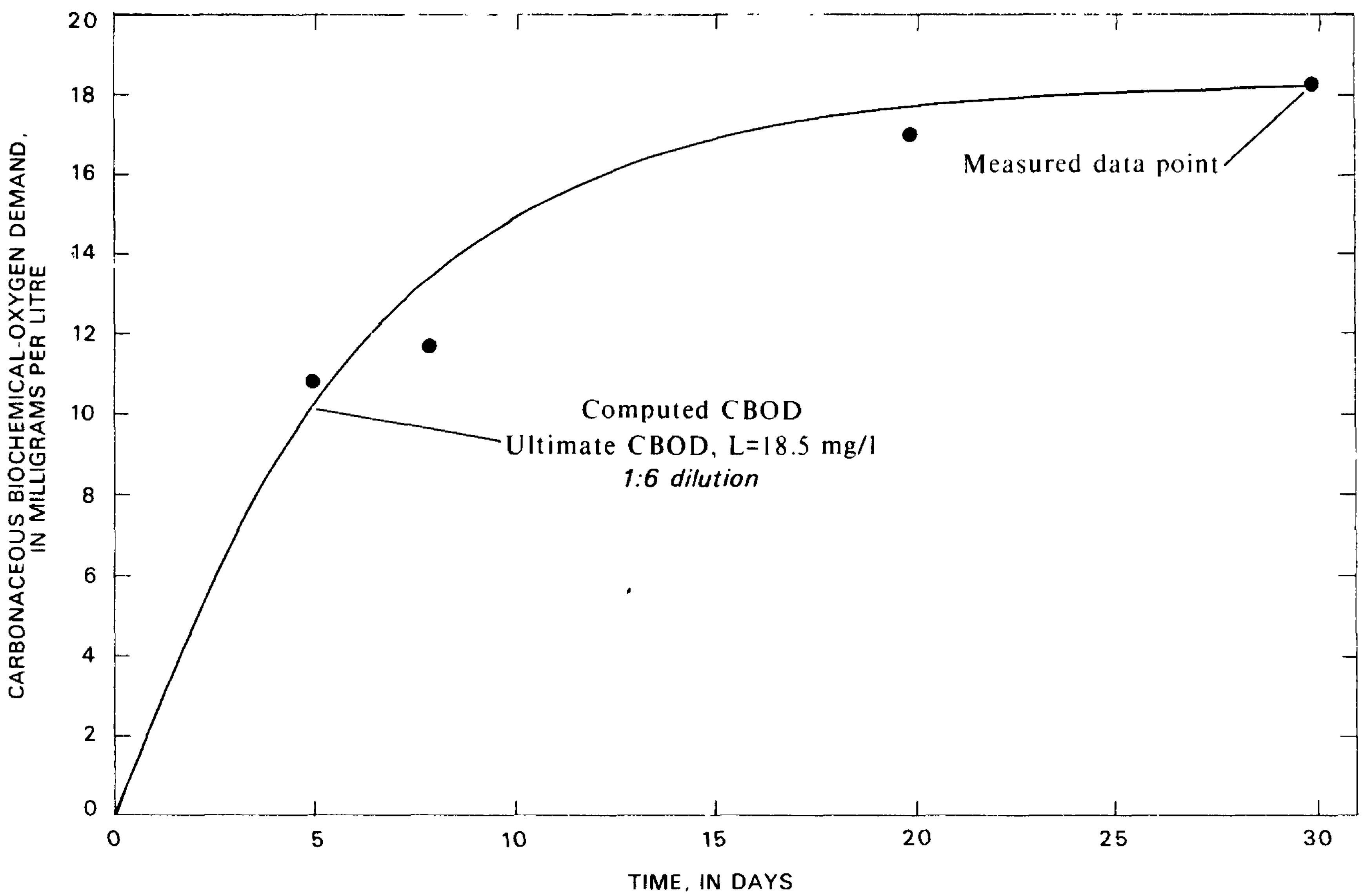


Figure 13. Carbonaceous biochemical-oxygen demand at Bailey Road (station 21), September 3, 1974.

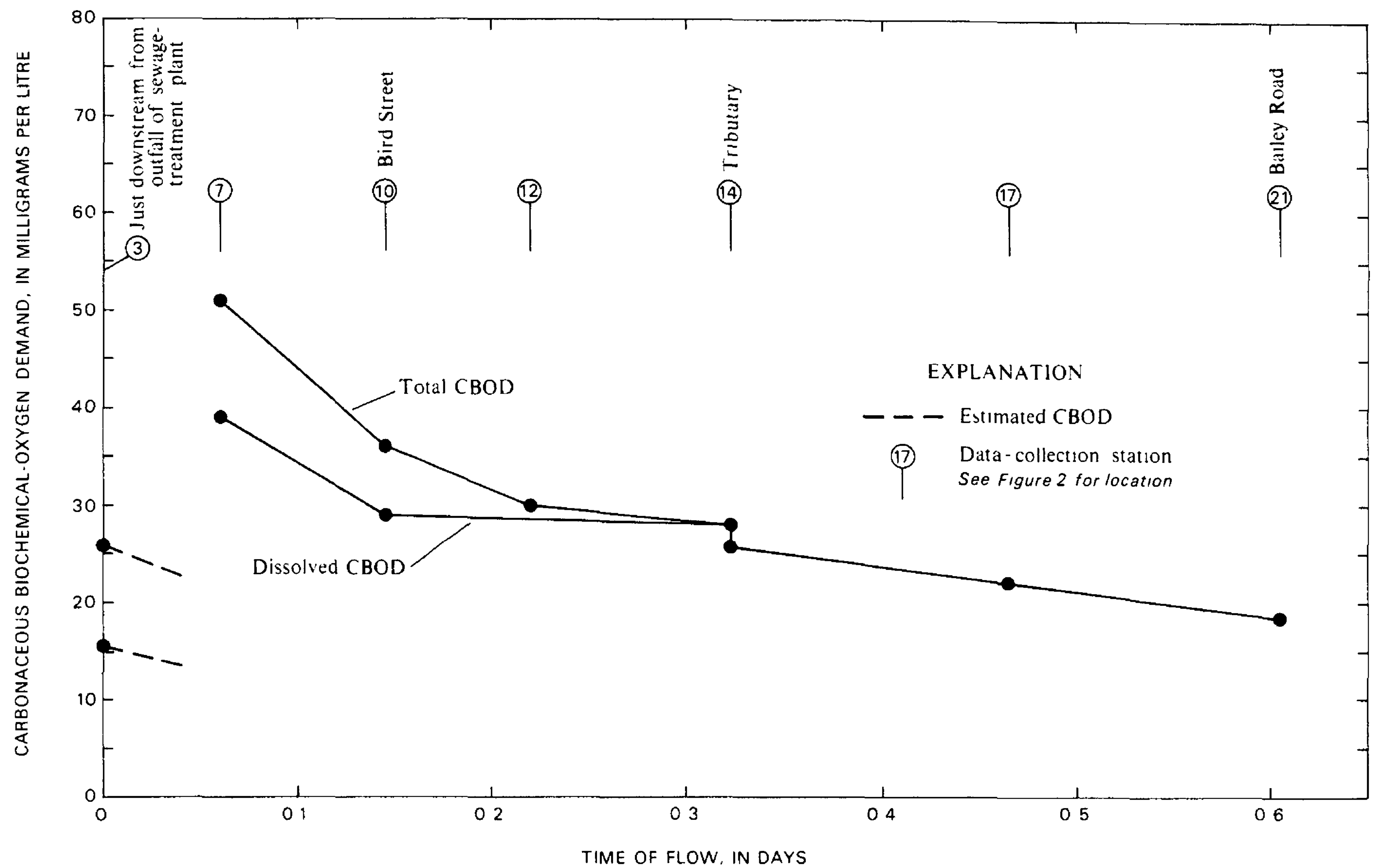


Figure 14. Total and dissolved carbonaceous biochemical-oxygen demand. September 3, 1974.

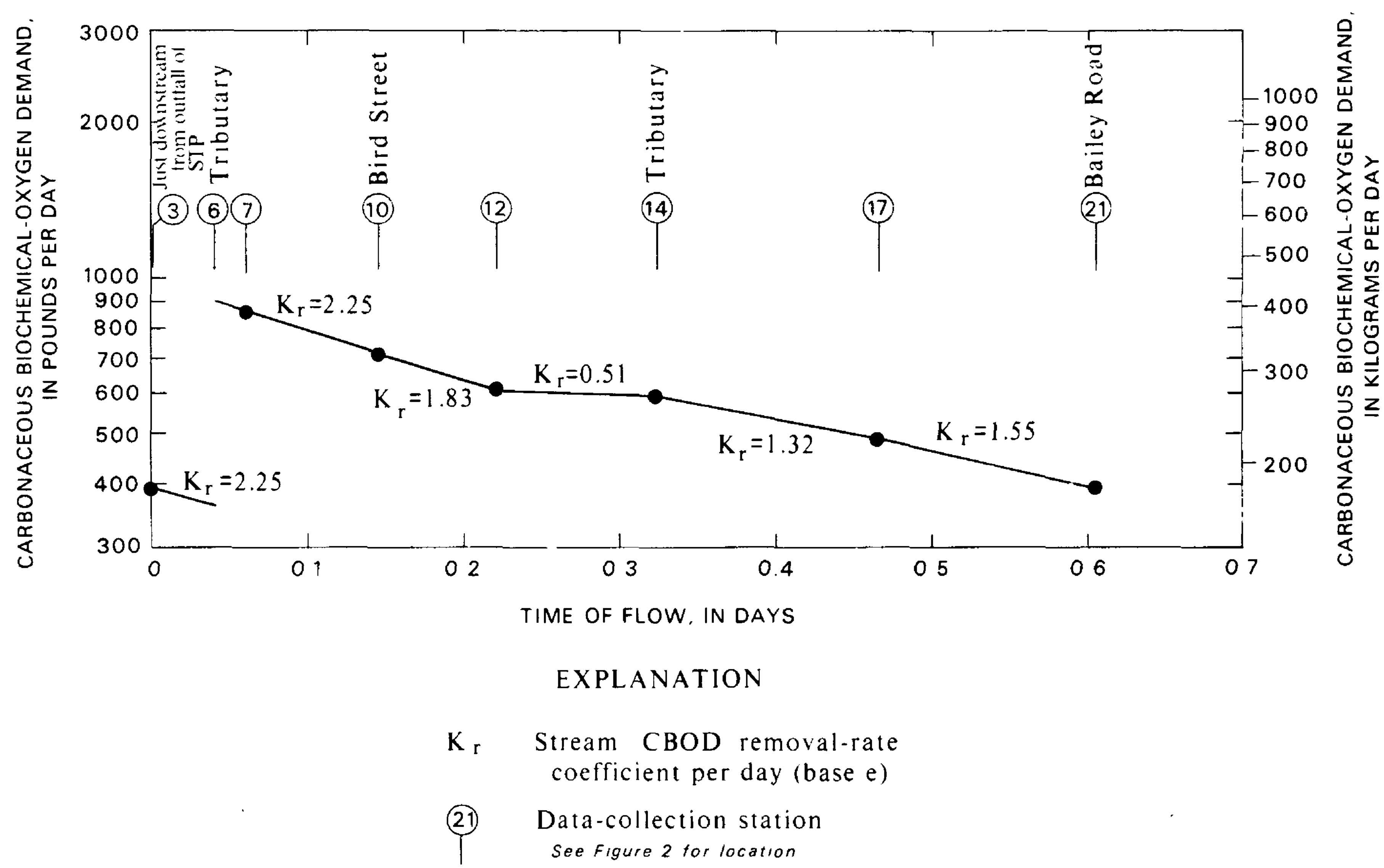
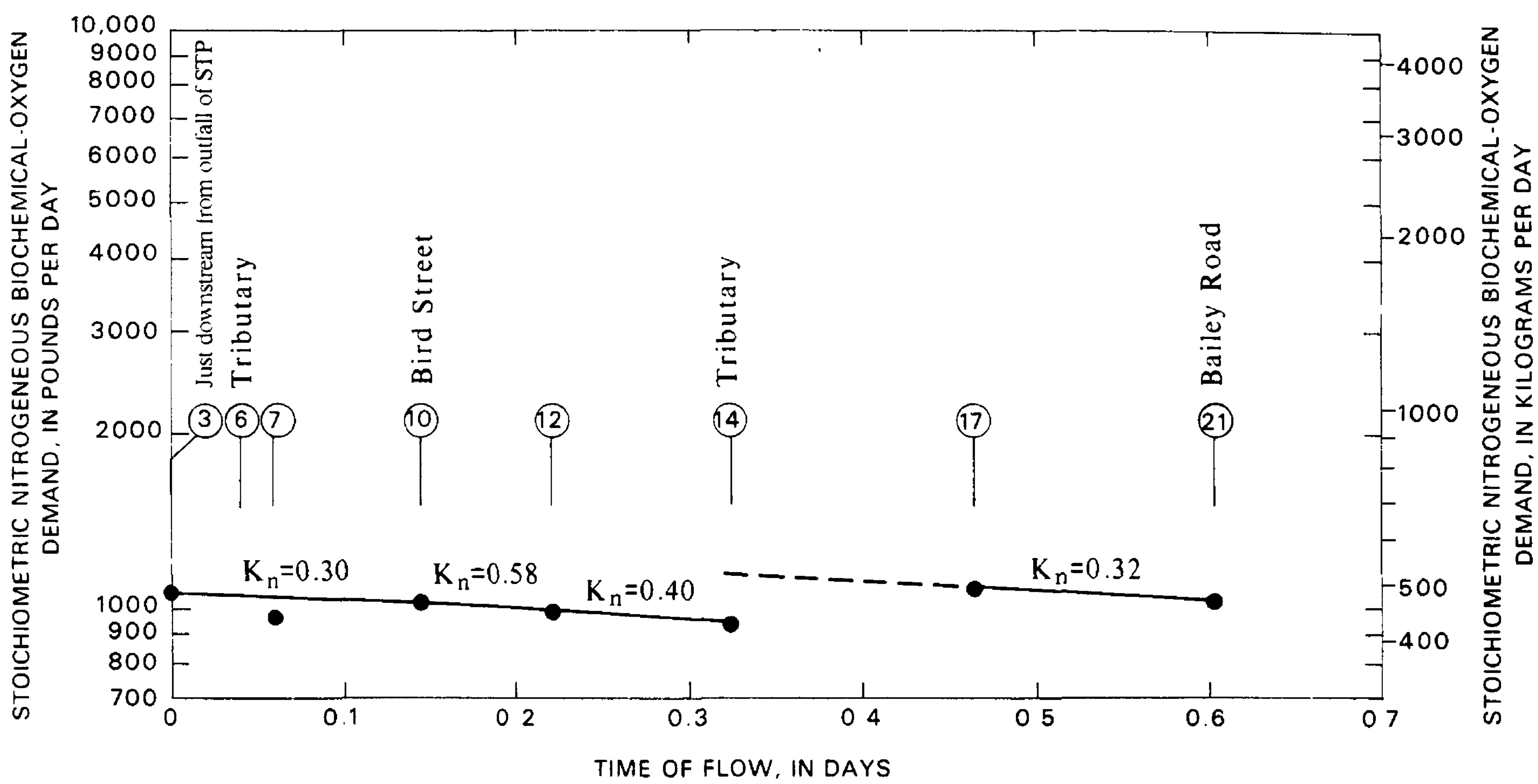


Figure 15. Carbonaceous biochemical-oxygen demand removal-rate coefficients.



EXPLANATION

K_n Stream NBOD removal-rate coefficient per day (base e)

(2) Data-collection station
See Figure 2 for location

Figure 16. Stoichiometric nitrogeneous biochemical-oxygen demand removal-rate coefficients.

Stream-reaeration coefficients were determined using radioactive tracers and the energy-dissipation model. The radiotracer method was used to calibrate the energy-dissipation model:

$$K_2 = C \frac{\Delta h}{t}$$

where: K_2 is the base e reaeration coefficient, per hour;

Δh is the change in water-surface elevation in the stream reach, in feet;

t is the time of flow through the reach, in hours, and

C is the escape coefficient, per foot.

K_2, Δh, and t were measured November 26, 1974, in reach 3-12 (fig. 2) so that C could be computed for each subreach (table 1). C was then corrected to the water temperatures observed during the stream survey of September 3, so that K_2 during the survey could be computed for reach 3-12. For reach 12-21, the C from reach 10-12 was used but corrected to the appropriate water temperatures. For reach 21-31, a C similar to that of reach 3-10 was used because the reaches are somewhat similar.

Total and dissolved carbonaceous and nitrogeneous BOD were determined along with the associated deoxygenation and stream-removal-rate coefficients. Nitrogen compounds at each station were determined for use in computation of stoichiometric NBOD using

$$NBOD = 4.4\ (NH_4\text{-}N + Org\text{-}N) + 1.1\ (NO_2\text{-}N)$$

where: NBOD is nitrogeneous biochemical-oxygen demand, in milligrams per litre;

NH_4-N is ammonium nitrogen concentration, in milligrams per litre;

Org-N is organic nitrogen concentration, in milligrams per litre; and

NO_2-N is nitrite nitrogen concentration, in milligrams per litre.

Organic nitrogen (Org-N) concentration was determined using

$$Org\text{-}N = (KJD\text{-}N) - (NH_3\text{-}N)$$

where: KJD-N is Kjeldahl nitrogen concentration, in milligrams per litre.

Table 1.--Reaeration and hydraulic data, November 26, 1974

Reach	K_2/day		C[1]	Mean water temperature[2]	Δh[3]	t[4]	Slope	Velocity
	Measured	20°C	(20°C)	(°C)	(ft)	(hours)	(ft/mi)	(ft/sec)
3- 7	7.96	9.55	0.076	11.6	7.88	1.50	11.42	0.67
7-10	3.08	3.87	.117	9.5	2.79	2.01	3.72	.54
10-12	2.52	3.28	-----	7.8	.58	1.53	1.16	.48
3-10	5.16	6.36	.087	10.4	10.67	3.52	7.41	.60
7-12	2.84	3.62	.159	8.8	3.37	3.55	2.70	.52
3-12	4.36	5.46	.102	9.6	11.25	5.05	5.80	.56

[1]The escape coefficient (per foot) in the energy-dissipation model $K_2 = C \frac{\Delta h}{t}$. It is computed $C = \frac{K_2/\text{hour}}{(\Delta h/t)}$, where $K_2/\text{hour} = \frac{K_2/\text{day}}{24}$ (@20°C), Δh is in feet, and t is in hours. K_2, Δh, and t were measured.

[2]When K_2 measured.

[3]Change in water-surface elevation in reach.

[4]Time of travel through reach.

Stream discharge was measured using current meters (table 2). Time of travel in the stream was measured using a fluorescent dye tracer.

The values of the various parameters used to calibrate the stream model are included in the "Computer Output" section. All reaction-rate coefficients presented were computed using natural logarithms. Adequate data were not available to verify the calibrated model.

WASTE-LOAD ALLOCATION

Waste-load-allocation studies were made for the current discharge site and two potential discharge sites to see what combinations of waste loading would meet Wisconsin water-quality standards. An instantaneous minimum DO concentration of 5 mg/l was the goal along with nontoxic concentrations of ammonia nitrogen. One allocation run also was made for minimum stream DO of 2 mg/l. Summer and winter allocations were computed using water temperatures of 25° and 5°C, respectively.

Table 2.--Stream discharge during time-of-travel studies and during $Q_{7,10}$ [3]

Date	Station 3[1] (ft^3/s)	Station 10 (ft^3/s)	Station 21 (ft^3/s)
May 8, 1974	5.5	10.4	16.2
May 21, 1974	6.2	[2] 7.5	[2]11.5
August 27, 1974	4.6	4.3	6.6
November 26, 1974	2.6	3.1	----
$Q_{7,10}$	.02	.05	.2

[1]Station 3 is approximately 50 ft downstream from sewage-treatment-plant outfall.

[2]Approximate stream discharge.

[3]Discharges measured during time-of-travel studies include sewage-treatment-plant effluent. The figures for the $Q_{7,10}$ represent natural streamflow only.

Existing Discharge Site

A summary of the results of nine allocation runs for the existing discharge site is presented in table 3. Each run is summarized in one row of the table. A copy of the computations for the second waste-load-allocation analysis is included in the "Computer Output" section.

The reaction-rate coefficients used in the waste-load-allocation runs were the same as in the model-calibration analysis but were corrected to the appropriate temperature. It was assumed that all waste water discharging into Koshkonong Creek would be from the municipal outfall, including waste water from the cannery, and that there would be no runoff from the cannery's waste-water spray irrigation site into Koshkonong Creek.

Benthal oxygen demand by biological slimes in reach 3-10 (fig. 2) was proportioned to the waste loading and was adjusted for temperature also (table 11). Sludge demand was set equal to zero because the high-quality effluent from advanced treatment with denitrification required to meet water-quality standards presumably should eliminate the sludge problem with proper sewage-treatment-plant operation. Effects of the present sludge blank should diminish with time.

Algal effects were not incorporated into the allocation model because photosynthesis cannot be relied upon as a source of dissolved oxygen, especially during warm, cloudy days when deoxygenation rates are high and photosynthetic DO production is low compared with sunny days.

Time of travel used in the allocation studies was the same as that used in the calibration analysis because no stable relationship between time of travel and stream discharge could be developed.

The stream discharge used in the allocation runs was that of the effluent plus the $Q_{7,10}$ (annual minimum 7-day mean discharge that occurs on the average of once in 10 years). The $Q_{7,10}$ is so small that it will have very little beneficial dilution effect on water quality in the study reach (fig. 17).

The resultant loadings shown in table 3 are instantaneous maximum loadings that will produce the corresponding minimum DO concentrations in Koshkonong Creek. Short-term loadings in excess of those shown in table 3 may produce lower DO levels because longitudinal mixing through the DO sag zone may not be great enough for sufficient dampening of effects of short-term excess loads. Therefore, use of daily or long-term waste-load averages as evidence of compliance with water-quality standards may be inapplicable.

Alternative Discharge Sites

A cursory evaluation of alternative discharge sites for Sun Prairie waste water near stations 14 and 21 (fig. 2) was made to see what degree of treatment would be required to meet Wisconsin water-quality standards in

Table 3.--Waste-load-allocation summary

DO effluent[1] (mg/l)	$CBOD_5$[2] (mg/l)	NH_4-N[3] (mg/l)	Minimum DO in stream[4] (mg/l)	Effluent and stream temperature[5] (°C)
6.0	5.0	1.5	4.5	25
7.0	5.0	1.5	5.0	25
8.0	5.0	1.5	5.4	25
8.0	7.0	1.5	4.4	25
8.0	5.0	3.0	5.1	25
8.0	5.0	4.0	4.6	25
6.0	10.0	1.5	[6]2.2	25
8.0	18.3	4.0	5.0	5
6.0	12.8	4.0	5.0	5

[1]Dissolved-oxygen concentration in effluent channel below outfall weir.

[2]5-day carbonaceous BOD of effluent at outfall.

[3]Ammonia nitrogen concentration of effluent at outfall.

[4]Lowest instantaneous dissolved-oxygen concentration computed in the stream for the loading on the same row of the table.

[5]Assumed effluent temperature same as stream temperature during $Q_{7,10}$ low flow.

[6]At station 7 (fig. 2). DO increased to 4.9 mg/l by station 21.

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the reaches of Koshkonong Creek downstream from these locations. Sufficient data were not collected for a thorough evaluation of these sites, but the available data strongly indicate that a higher degree of treatment than that at the present discharge site would probably be necessary to maintain a minimum stream DO of 5 mg/l, primarily because stream-reaeration capacity in the reaches below these proposed sites is much lower than that near the present site.

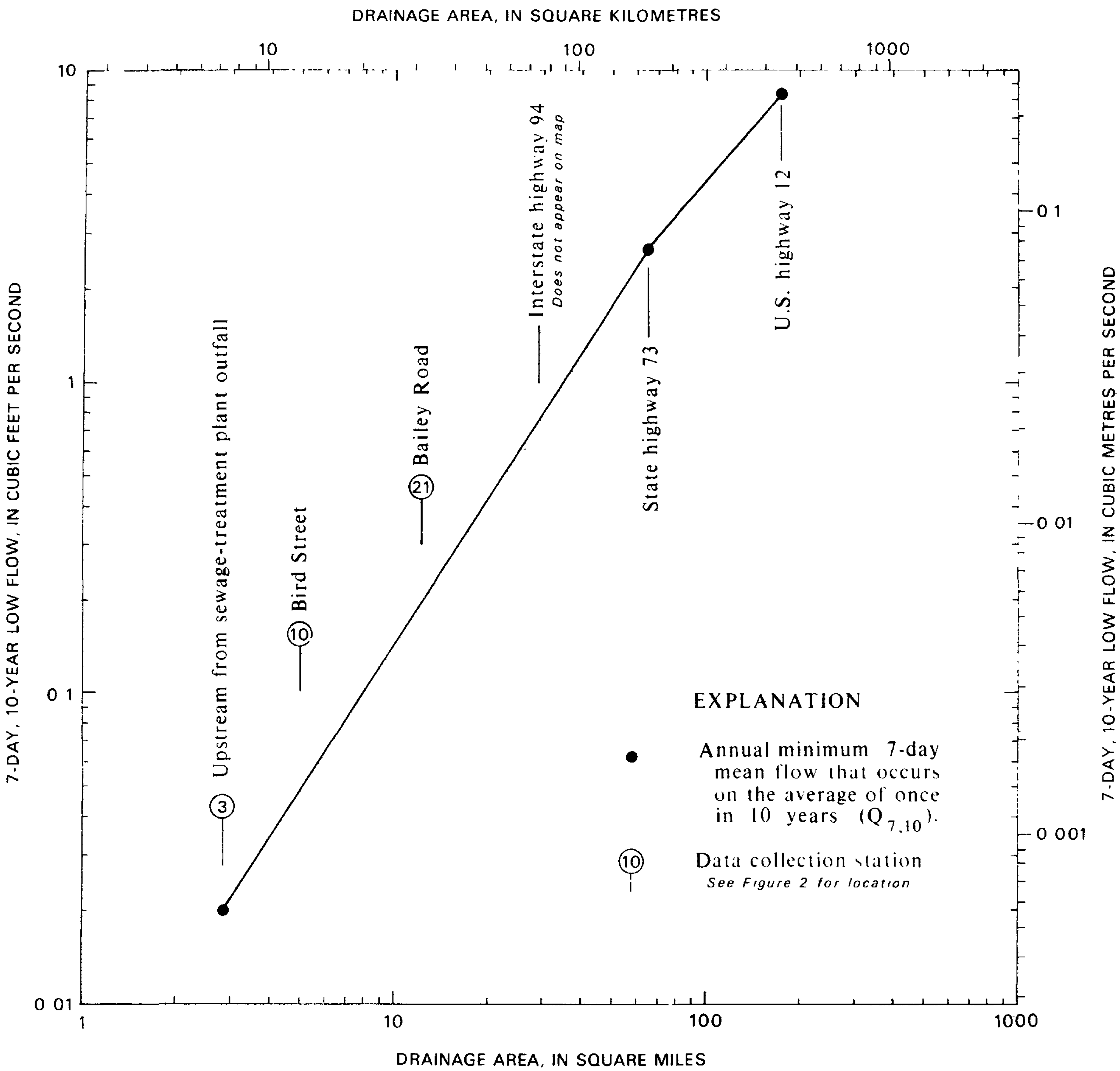

Figure 17. 7-day, 10-year low flow ($Q_{7,10}$)

SUMMARY

Advanced treatment with denitrification of Sun Prairie waste-water discharge to Koshkonong Creek will be necessary to meet Wisconsin water-quality standards, as shown by the waste-load-allocation summary (table 3). Natural stream discharge is very small compared to the waste-water discharge, so benefits of dilution are minimal. The stream-reaeration capacity alone is not high enough to maintain at least 5 mg/l of DO in the stream.

The present discharge site (station 3, fig. 2) will probably require a lower degree of treatment than the alternative sites at stations 14 and 21 for maintaining a minimum DO of 5 mg/l in the study reach.

Ground-water infiltration into the Sun Prairie waste-water-collection system in the spring when the water table is high produces very high discharges into the sewage-treatment plant. Despite the high inflow of ground water to the system the quality of the effluent during these periods is considerably lower than at other times of the year because waste water passes through the treatment plant so fast that it cannot be treated adequately.

High BOD and low dissolved oxygen have been found in Koshkonong Creek upstream from the municipal outfall near the cannery cooling-water outfall. Waste water has been reported to enter the study reach from the cannery (Wis. Dept. Nat. Resources, 1971) and the cause is probably discharge from this source. Samples of the cannery effluent were not taken for verification, however. Also, cannery waste water being sprayed east of reach 3-6 is apparently reaching the stream in strong concentrations through field-drainage tiles and (or) surface runoff.

Removal or enlargement of farm culverts at stations 15 and 20 (fig. 2) along with removal of fallen trees and debris in reach 17-31 would probably alleviate sludge problems and enhance stream-reaeration capacity. Recurring debris accumulations would have to be removed periodically to maintain free-flowing conditions.

The effects of storm sewer discharge on water quality and the computations and evaluation of BOD loading were not investigated.

COMPUTER OUTPUT

The following pages contain computer output for the model-calibration run and the waste-load-allocation run for the critical summer low-flow condition.

STEADY STATE SEGMENTED DISSOLVED OXYGEN MODEL

(Bauer and Jennings, 1975)
U. S. GEOLOGICAL SURVEY

DATE OF LAST REVISION, FEBRUARY 1974

MODEL CALIBRATION RUN FOR 9/3/74-KOSHKONONG CREEK WASTE ASSIMILATION STUDY

NUMBER OF SUBREACHES FOR THIS PROBLEM = 8

INITIAL CBOD CONC (MG/L) AT STARTING DISTANCE = 25.800

INITIAL NBOD CONC (MG/L) AT STARTING DISTANCE = 70.700

INITIAL DO CONC (MG/L) AT STARTING DISTANCE = 5.500

STREAMFLOW (CFS) AT STARTING DISTANCE = 2.840

TABLE 4 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)	NBOD (MG/L)	DO (MG/L)
1	0	0.0	0.0	0.0
2	0	0.0	0.0	0.0
3	0.5	0.0	0.0	8.0
4	0.2	0.0	0.0	8.0
5	0.2	0.0	0.0	8.0
6	0	0.0	0.0	0.0
7	0	0.0	0.0	0.0
8	0	0.0	0.0	0.0

TABLE 5 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
1	A	STATIONS 3-6
2	G	STATIONS 6-7
3	G	STATIONS 7-10
4	J	STATIONS 10-12
5	J	STATIONS 12-14
6	J	STATIONS 14-17
7	J	STATIONS 17-21
8	J	STATIONS 21-31

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

TABLE 6. W A S T E S O U R C E A N D M I N O R T R I B U T A R Y D A T A

SUBREACH	DATE	CODE	NAME	Q (CFS)	CBOD (MG/L)	NBOD (MG/L)	DO (MG/L)	TEMP (DEG. C)
1	9/74	A	SUN PRAIRIE STP	2.6	26.0	75.1	6.3	18.0
	9/74	A	CAN.WASTE NR STA 6	0.3	354.0	0.0	0.0	20.0
6	9/74	A	TRIB NR STATION 14	0.3	5.7	3.0	17.4	19.0

KEY: SOURCE CODE

A U.S.GEOLOGICAL SURVEY-WATER RESOURCES DIVISION-MADISON,WISCONSIN

TABLE 7 INPUT PARAMETERS

CONCENTRATIONS OF --

SUBREACH	CARBONACEOUS ULT. BOD	NITROGENOUS BOD	DO DEFICIT
1	0.0	0.0	0.0
2	354.000	0.0	9.000
3	0.0	0.0	0.0
4	0.0	0.0	0.0
5	0.0	0.0	0.0
6	5.700	3.000	-8.500
7	0.0	0.0	0.0
8	0.0	0.0	0.0

DIRECT DISCHARGES OF --

SUBREACH	CARBONACEOUS ULT. BOD	NITROGENOUS BOD	DO DEFICIT
1	0.0	0.0	0.0
2	0.0	0.0	0.0
3	0.0	0.0	0.0
4	0.0	0.0	0.0
5	0.0	0.0	0.0
6	0.0	0.0	0.0
7	0.0	0.0	0.0
8	0.0	0.0	0.0

SUBREACH	NET PHOTOSYNTHETIC DO PRODUCTION (MG/L/DAY)	BENTHIC DO DEMAND (MG/L/DAY)
1	0 0	110 0
2	0 0	110 0
3	0 0	20 0
4	30.000	0.0
5	15.000	0.0
6	7.000	0.0
7	6.000	0.0
8	0.0	0.0

GEOMETRY

SUBREACH	FLOW CHANGE (CFS)	STATIONS	TRAV.TIME (HRS)	TEMP (DEG.CENT)
1	0.0	3-6	0.97	16.50
2	0.3	6-7	0.45	16.90
3	0.0	7-10	2.08	17.00
4	0.0	10-12	1.80	18.00
5	0.0	12-14	2.45	19.00
6	0.3	14-17	3.38	18.80
7	0.0	17-21	3.37	16.50
8	0.0	21-31	6.92	13.80

TABLE 7. INPUT PARAMETERS- CONTINUED

REACTION COEFFICIENTS (/DAY AT 20 DEG. C)

SUBREACH	KR	K1	KN
1	2.579	0.130	0.343
2	2.539	0.280	0.338
3	2.529	0.280	0.336
4	1.981	0.250	0.632
5	0.527	0.250	0.420
6	1.387	0.250	0.332
7	1.777	0.200	0.364
8	1.975	0.160	0.404

TEMPERATURE CORRECTED REACTION COEFFICIENTS

SUBREACH	KR	K1	KN	K2
1	2.248	0.113	0.299	8.850
2	2.248	0.248	0.299	8.930
3	2.248	0.249	0.299	4.050
4	1.832	0.231	0.584	3.140
5	0.507	0.240	0.404	1.580
6	1.323	0.239	0.317	1.560
7	1.549	0.174	0.317	1.490
8	1.549	0.125	0.317	2.810

SUBREACH	DO SATURATION (MG/L)
1	9.687
2	9.603
3	9.582
4	9.377
5	9.180
6	9.219
7	9.687
8	10.293

TABLE 8 RESULTS OF COMPUTATIONS

					S U B R E A C H		D E F I C I T S					
SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	BENTHAL DEFICIT	PHOTO. DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
1	3	0.0	25.800	70.700	4.187	0.0	0.0	0.0	0.0	0.0	4.187	5.500
1	6	0.040	23.559	69.851	2.928	0.095	0.714	3.738	0.0	0.0	7.474	2.213
SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	BENTHAL DEFICIT	PHOTO. DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
2	6	0.040	53.214	63.582	7.534	0.0	0.0	0.0	0.0	0.0	7.534	2.069
2	7	0.059	51.017	63.226	6.373	0.223	0.328	1.899	0.0	0.0	8.822	0.781
SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	BENTHAL DEFICIT	PHOTO. DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
3	7	0.059	51.017	63.226	8.801	0.0	0.0	0.0	0.0	0.0	8.801	0.781
3	10	0.146	36.186	53.101	5.494	0.723	1.174	1.462	0.0	0.0	8.852	0.730
SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	BENTHAL DEFICIT	PHOTO. DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
4	10	0.146	36.186	53.101	8.647	0.0	0.0	0.0	0.0	0.0	8.647	0.730
4	12	0.221	29.890	48.163	6.532	0.494	1.921	0.0	-2.005	0.0	6.942	2.436
SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	BENTHAL DEFICIT	PHOTO. DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
5	12	0.221	29.890	48.163	6.744	0.0	0.0	0.0	0.0	0.0	6.744	2.436
5	14	0.323	26.971	43.918	5.504	0.627	1.706	0.0	-1.414	0.0	6.423	2.757
SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	BENTHAL DEFICIT	PHOTO. DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
6	14	0.323	25.632	41.343	5.520	0.0	0.0	0.0	0.0	0.0	5.520	3.699
6	17	0.464	21.274	39.539	4.431	0.703	1.618	0.0	-0.885	0.0	5.867	3.352

TABLE 8. RESULTS OF COMPUTATIONS – CONTINUED

SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	SUBREACH DEFICITS: INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	BENTHAL DEFICIT	PHOTO. DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
7	17	0.464	21.274	39.539	6.336	0.0	0.0	0.0	0.0	0.0	6.336	3.352
7	21	0.604	17.115	37.816	5.140	0.421	1.554	0.0	-0.760	0.0	6.354	3.334

SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	SUBREACH DEFICITS: INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	BENTHAL DEFICIT	PHOTO. DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
8	21	0.604	17.115	37.816	6.959	0.0	0.0	0.0	0.0	0.0	6.959	3.334
8	31	0.893	10.951	34.515	3.095	0.332	2.248	0.0	0.0	0.0	5.676	4.617

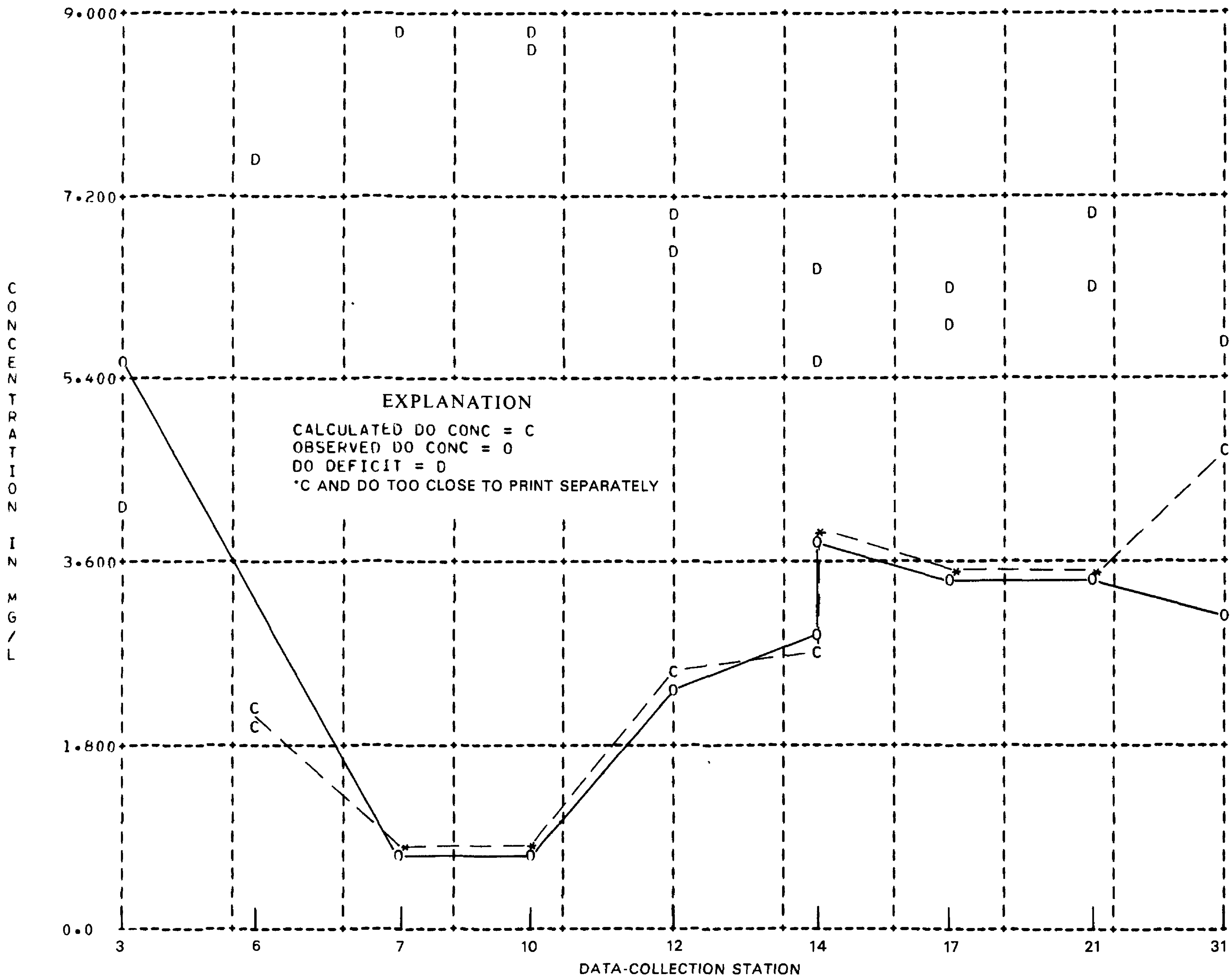

Figure 18. Calculated and observed DO concentrations and DO deficits.

STEADY STATE SEGMENTED DISSOLVED OXYGEN MODEL

(Bauer and Jennings, 1975)

U. S. GEOLOGICAL SURVEY

DATE OF LAST REVISION, FEBRUARY 1974

SUN PRAIRIE WASTE-LOAD ALLOCATION--SUMMER RUN

NUMBER OF SUBREACHES FOR THIS PROBLEM = 8

INITIAL CBOD CONC (MG/L) AT STARTING DISTANCE = 9.000

INITIAL NBOD CONC (MG/L) AT STARTING DISTANCE = 6.600

INITIAL DO CONC (MG/L) AT STARTING DISTANCE = 7.000

STREAMFLOW (CFS) AT STARTING DISTANCE = 2.580

TABLE 9 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)	NBOD (MG/L)	DO (MG/L)
1	0.01	0.0	0.0	8.0
2	0.0	0.0	0.0	8.0
3	0.02	0.0	0.0	8.0
4	0.03	0.0	0.0	8.0
5	0.04	0.0	0.0	8.0
6	0.03	0.0	0.0	8.0
7	0.03	0.0	0.0	8.0
8	0.17	0.0	0.0	8.0

TABLE 10 W A S T E S O U R C E A N D M I N O R T R I B U T A R Y D A T A

SUBREACH	CODE	NAME	Q (CFS)	CBOD-5 (MG/L)	NBOD (MG/L)	DO (MG/L)	TEMP (DEG. C)
1	A	STP EFFLUENT@Q7,10	2.6	5.0	6.6	7.0	25.0

KEY: SOURCE CODE

A U.S.GEOLOGICAL SURVEY-WATER RESOURCES DIVISION-MADISON,WISCONSIN

TA

SUBREACH	CA
1	
2	
3	
4	
5	
6	
7	
8	

TABLE 11 INPUT PARAMETERS-CONTINUED

REACTION COEFFICIENTS (/DAY AT 20 DEG. C)

SUBREACH	KR	K1	KN
1	2.579	0.130	0.343
2	2.539	0.130	0.338
3	2.529	0.130	0.336
4	1.981	0.130	0.632
5	0.527	0.130	0.420
6	1.387	0.130	0.332
7	1.777	0.130	0.364
8	1.975	0.130	0.404

TEMPERATURE CORRECTED REACTION COEFFICIENTS

SUBREACH	KR	K1	KN	K2
1	3.138	0.158	0.417	10.650
2	3.089	0.158	0.411	10.650
3	3.077	0.158	0.409	4.320
4	2.410	0.158	0.769	3.660
5	0.641	0.158	0.511	1.800
6	1.687	0.158	0.404	1.800
7	2.162	0.158	0.443	1.800
8	2.403	0.158	0.492	3.580

SUBREACH	DO SATURATION (MG/L)
1	8.125
2	8.125
3	8.125
4	8.125
5	8.125
6	8.125
7	8.125
8	8.125

TABLE 12 RESULTS OF COMPUTATIONS

					SUBREACH DEFICITS							
SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	PHOTO. DEFICIT	BENTHAL DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
1	3	0.0	9.000	6.600	1.125	0.0	0.0	0.0	0.0	0.0	1.125	7.000
1		0.020	8.431	6.532	0.906	0.025	0.050	0.0	0.975	0.0	1.955	6.170
1	6	0.040	7.897	6.465	1.574	0.023	0.049	0.0	0.975	0.0	2.621	5.504
SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	PHOTO. DEFICIT	BENTHAL DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
2	6	0.040	7.897	6.465	2.621	0.0	0.0	0.0	0.0	0.0	2.621	5.504
2		0.050	7.672	6.440	2.372	0.011	0.024	0.0	0.470	0.0	2.877	5.248
2	7	0.059	7.453	6.415	2.603	0.011	0.024	0.0	0.470	0.0	3.108	5.017
SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	PHOTO. DEFICIT	BENTHAL DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
3	7	0.059	7.453	6.415	3.108	0.0	0.0	0.0	0.0	0.0	3.108	5.017
3		0.103	6.498	6.278	2.568	0.043	0.102	0.0	0.375	0.0	3.089	5.036
3	10	0.146	5.665	6.144	2.552	0.038	0.100	0.0	0.375	0.0	3.065	5.060
SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	PHOTO. DEFICIT	BENTHAL DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
4	10	0.146	5.665	6.144	3.065	0.0	0.0	0.0	0.0	0.0	3.065	5.060
4		0.183	5.146	5.935	2.658	0.030	0.162	0.0	0.0	0.0	2.850	5.275
4	12	0.221	4.674	5.734	2.471	0.027	0.157	0.0	0.0	0.0	2.654	5.471
SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	PHOTO. DEFICIT	BENTHAL DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
5	12	0.221	4.674	5.734	2.654	0.0	0.0	0.0	0.0	0.0	2.654	5.471
5		0.272	4.490	5.544	2.404	0.035	0.140	0.0	0.0	0.0	2.579	5.546
5	14	0.323	4.313	5.361	2.336	0.034	0.135	0.0	0.0	0.0	2.505	5.620
SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	PHOTO. DEFICIT	BENTHAL DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
6	14	0.323	4.313	5.361	2.505	0.0	0.0	0.0	0.0	0.0	2.505	5.620
6		0.393	3.808	5.182	2.195	0.042	0.140	0.0	0.0	0.0	2.378	5.747

TABLE 12 RESULTS OF COMPUTATIONS—CONTINUED

					SUBREACH DEFICITS							
6	17	0.464	3.363	5.009	2.084	0.037	0.136	0.0	0.0	0.0	2.257	5.868

SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	PHOTO. DEFICIT	BENTHAL DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
7	17	0.464	3.363	5.009	2.257	0.0	0.0	0.0	0.0	0.0	2.257	5.868
7		0.534	2.873	4.829	1.979	0.032	0.143	0.0	0.0	0.0	2.154	5.971
7	21	0.604	2.455	4.655	1.889	0.028	0.138	0.0	0.0	0.0	2.054	6.071

SUBREACH	STATION	TRAVEL TIME	CBODU CONC	NBOD CONC	INITIAL DEFICIT	CBOD DEFICIT	NBOD DEFICIT	PHOTO. DEFICIT	BENTHAL DEFICIT	RESPIRE DEFICIT	DO DEFICIT	DO CONC
8	21	0.604	2.455	4.655	2.054	0.0	0.0	0.0	0.0	0.0	2.054	6.071
8		0.748	1.684	4.206	1.191	0.035	0.241	0.0	0.0	0.0	1.467	6.658
8	31	0.893	1.156	3.804	0.852	0.024	0.218	0.0	0.0	0.0	1.094	7.031

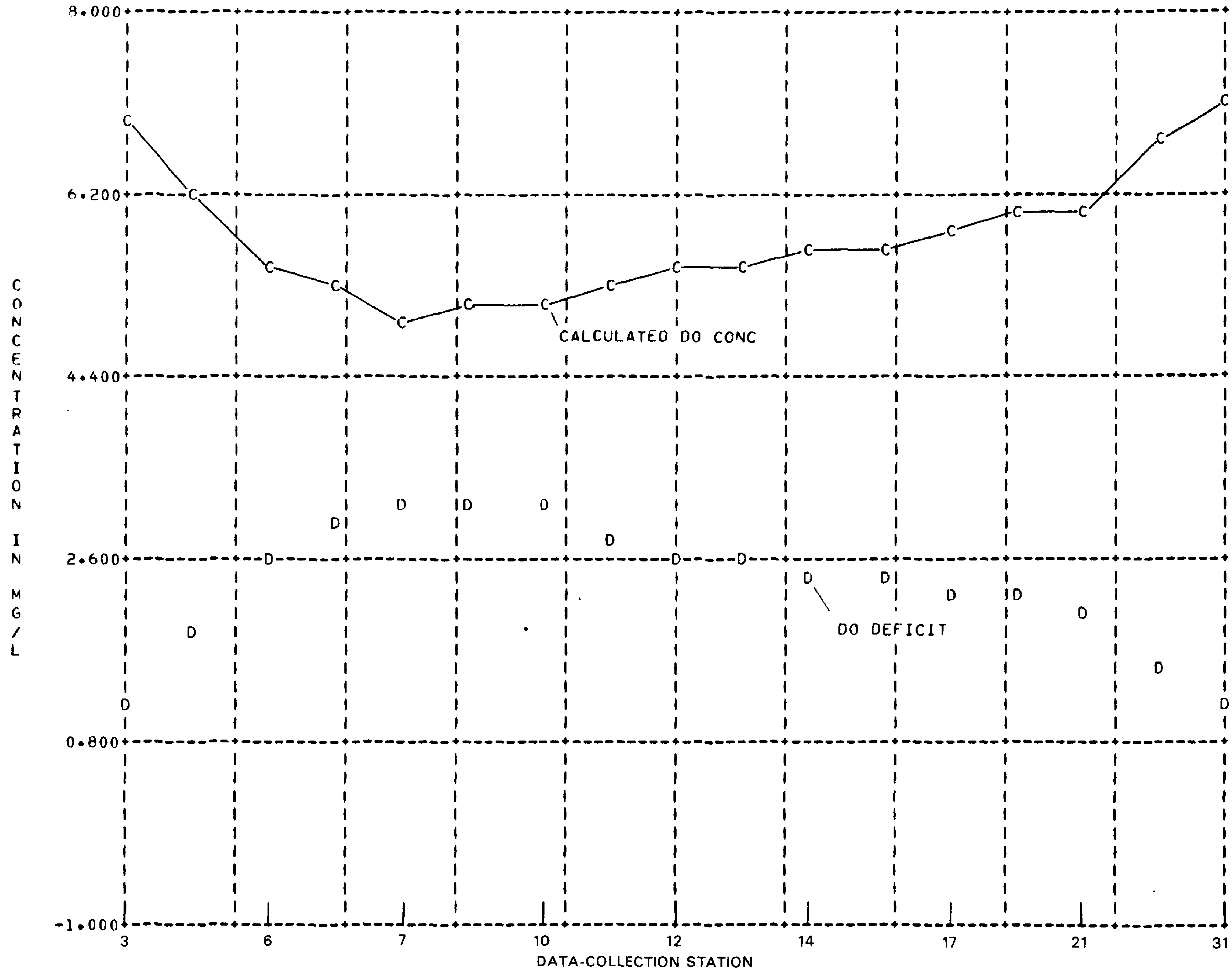

Figure 20. Calculated DO concentrations and DO deficits.

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