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SURVEILLANCE AND ANALYSIS

EVALUATION OF LAKE MILNER WATER QUALITY MODEL

ENVIRONMENTAL PROTECTION AGENCY
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EVALUATION OF LAKE MILNER

WATER QUALITY REPORT

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8 JUL

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LAKE MILNER REPORT

I. INTRODUCTION

The Milner reach of the Snake River, between Minidoka Dam and Milner Dam (see Figure 1), is classified as being water quality limited. One of the important limiting water quality parameters is dissolved oxygen, as monitored by the Federal Water Quality Administration (FWQA) and the Environmental Protection Agency (EPA) at Milner Dam, show extended periods of low dissolved oxygen. Conditions have been particularly critical during periods of low flow when the discharges from municipal and industrial waste sources were at their peak. For example, Table 1 gives the frequency with which the minimum daily dissolved oxygen was below 6.0 mg/l* during the 1970 water year. Only those months when the average monthly flows at Minidoka Dam were below 3000 c.f.s. are included in this table. The effects of low dissolved oxygen upon aquatic life have reached serious proportions. Major fish kills occurred in the Milner in 1960, 1961 and 1966 during the food processing season. In addition to the discharge of organic wastes from industrial and municipal sources, the oxygen demand associated with return flow from irrigation wasteways,

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*The State of Idaho (1973) water quality criterion for dissolved oxygen states: "No wastewaters shall be discharged--which--will cause ---the DO concentration to be less than 6 mg/l or 90 per cent of saturation, whichever is greater.

flow from irrigation wasteways, decay of algae in impoundments and bottom sediments all contribute to the observed dissolved oxygen problems.

Reductions in waste discharge since 1971, coupled with above-average flows in the Snake River, have resulted in substantial improvement in the dissolved oxygen of the Milner reach. No dissolved levels below 6.0 mg/l have been observed since 1971. However, dissolved oxygen levels below 90% saturation were measured in October and March of 1973 and January and March of 1974.

Table 1 Frequency with which minimum daily dissolved oxygen was in a given range during water year 1970. Only those months for which the minimum flow at Minidoka Dam was less than 3000 c.f.s. are shown.

Month	Snake River Flow @Minidoka Dam c.f.s.		No. of Days in Month Minimum DO (mg/l) was in Indicated Range			
	Avg.	Min.	0.0-2.0 (mg/l)	2.0-4.0 (mg/l)	4.0-6.0 (mg/l)	6.0 (mg/l)
October	2480	324		1		22
November	1394	296	1	13	10	6
December	1366	1290		2	3	26
January	3118	1420				31
February	2614	1340			1	27
March	1182	135		1	7	22
April	7061	1500			1	29

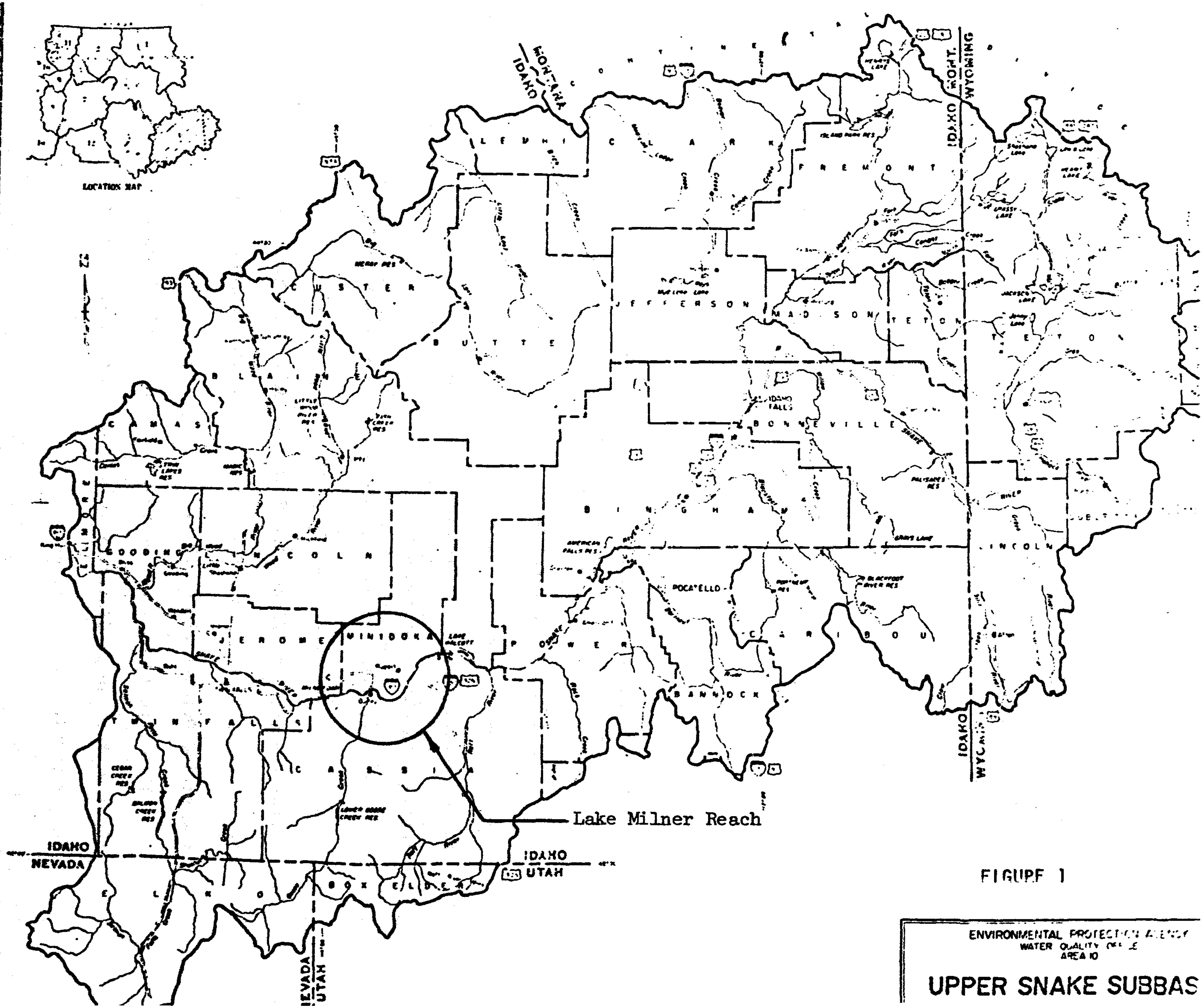
LOCATION MAP
MONTANA
IDAHO
IDAHO
MONT.
WYOMING
LEMHI
CLARK
FREMONT
CUSTER
JEFFERSON
MADISON
TETON
BUTTE
BLAINE
CAMAS
IDAHO FALLS
BONNEVILLE
BINGHAM
AMERICAN FALLS RES
GOODING
LINCOLN
LINCOLN
JEROME
MINIDOKA
POWER
POCATELLO
CARIBOU
BANNOCK
TWIN FALLS
CASSIA
IDAHO
WYOMING
IDAHO
NEVADA
IDAHO
UTAH
ELKO
BOX ELDER
NEVADA
UTAH
Lake Milner Reach
ENVIRONMENTAL PROTECTION AGENCY
WATER QUALITY OFFICE
AREA 10
UPPER SNAKE SUBBAS

FIGURE 1

In the fall of 1974, the Idaho Operations Office of the EPA Region X drafted National Pollutant Discharge Elimination System (NPDES) permits for the industrial waste sources J.R. Simplot and Ore-Ida in the Burley-Heyburn area. Mathematical modelling methods (Yearsley 1974) were used to support the permit writing process. The result of the modelling study showed that the point source discharges would contribute measurably to the violation of dissolved oxygen standards at low river flows, even if the discharge satisfied the appropriate guidelines for best practicable treatment (BPT). The Idaho Operations Office requested a water quality survey in the affected portion of the Snake River. The purpose of the survey was to provide data for validating the mathematical model, as well as to assess ambient water quality during low flow. A compliance monitoring program for industrial and municipal waste sources in the area was designed to be conducted concurrently with the in-stream survey.

The Surveillance and Analysis Division of EPA Region X, in a cooperative program with the National Field Investigation Center (Denver) of EPA and the State of Idaho Department of Health and Welfare, planned and carried out this survey during the period October 21-28, 1974.

This report compares the results from the field observations with those predicted by modelling techniques, as used in the permit writing process.

II. RESULTS OF FIELD STUDIES

The data used to evaluate the mathematical model includes biologic data, geometric data, point and non-point source data, and receiving water quality data. Data collected during other surveys, including those of other agencies, have been used where applicable.

Hydrologic Data

The U.S. Geological Survey records the flow of the Snake River just downstream from the Minidoka Dam. They also monitor the diversion from Lake Milner, as well as the flow just downstream from Milner Dam. During the field study, EPA and State of Idaho personnel gaged the flow in the Snake River at River Mile 652.3 (Highway 27 Bridge). The flow at Minidoka and Milner Dam, according to preliminary estimates by the U.S. Geological Survey, and the results of the measurements made by the survey team, are shown in Table 2. The U.S. Bureau of Reclamation maintained constant flows from Minidoka Dam during the period October 18 - 25, 1974.

Table 2 Observed flow in the Snake River at River Miles 674.7, 652.3 and 640.0.

Observed Stream Flow (c.f.s.)

Date	Minidoka Dam River Mile 674.7	Highway 27 Bridge River Mile 652.3	Milner Dam River Mile 640.0
10/21/74	2730		3168
10/22/74	2680	3221	3102
10/23/74	2700	3127	
10/24/74	2730	3204	

Cross-stream variation of the vertically averaged stream velocity at the Highway 27 Bridge is shown in Figure 2. This data is from the measurement made on October 23, 1974. Average velocities, $\bar{U}$, as estimated from:

$$\bar{u} = \frac{Q}{A} \qquad (1)$$

where,

Q = the river flow, cubic feet/second
A = the cross-sectional area, square feet

are shown in Table 3 for each day that a gaging measurement was made.

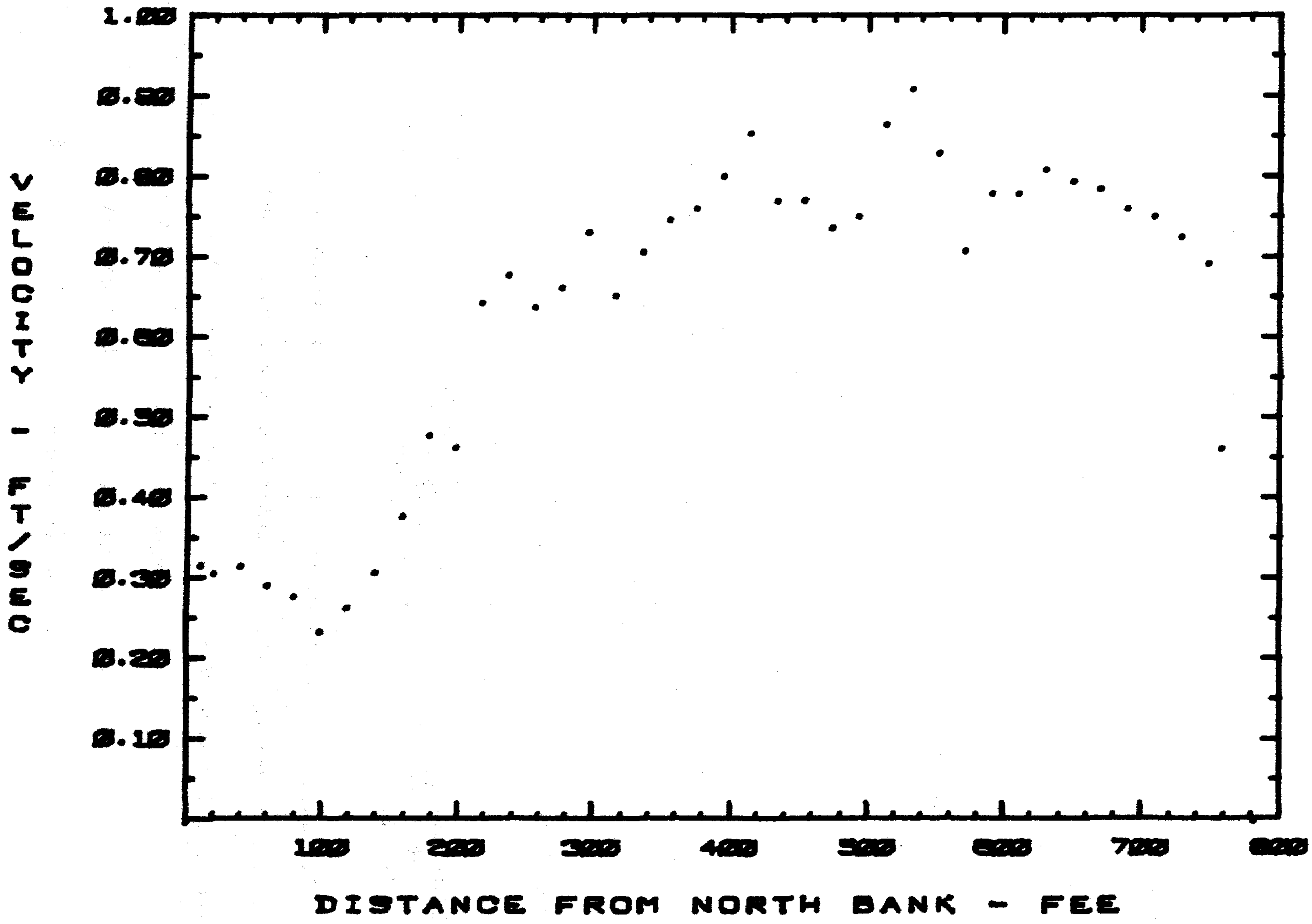

FIGURE 2 PROFILE OF VERTICALLY AVERAGED VELOCITY AT SNAKE RIVER MILE 852.3. 10/23/74

Table 3 Average velocity of the Snake River at Highway 27 Bridge (R.M. 652.3), October 22 - 24, 1974.

Date	Average Velocity (feet/second)
10/22/74	0.52
10/23/74	0.53
10/24/74	0.54

Additional measurements of river velocities were made at other locations in the river. These measurements were made by following a tracer and observing the travel time. The tracers used in this experiment were oranges. Velocity data collected in this manner is shown in Table 4.

Table 4 River velocities in the Milner Reach of the Snake River estimated from the travel time of oranges, October 23, 1974.

River Mile	Date	Velocity (feet/second)
659.6-659.2	10/23/74	0.91
656 -653.8	10/23/74	0.92
642.5-642.3	10/23/74	0.37

Irrigation return flows from ditches and wasteways were also measured during the survey. Standard stream gaging tachniques were used for some of the return flows, while others were simply estimated. The results of these measurements for all the known surface return flows between Minidoka and Milner Dams are shown in Table 5. Locations of the surface drains are given in Figure 3.

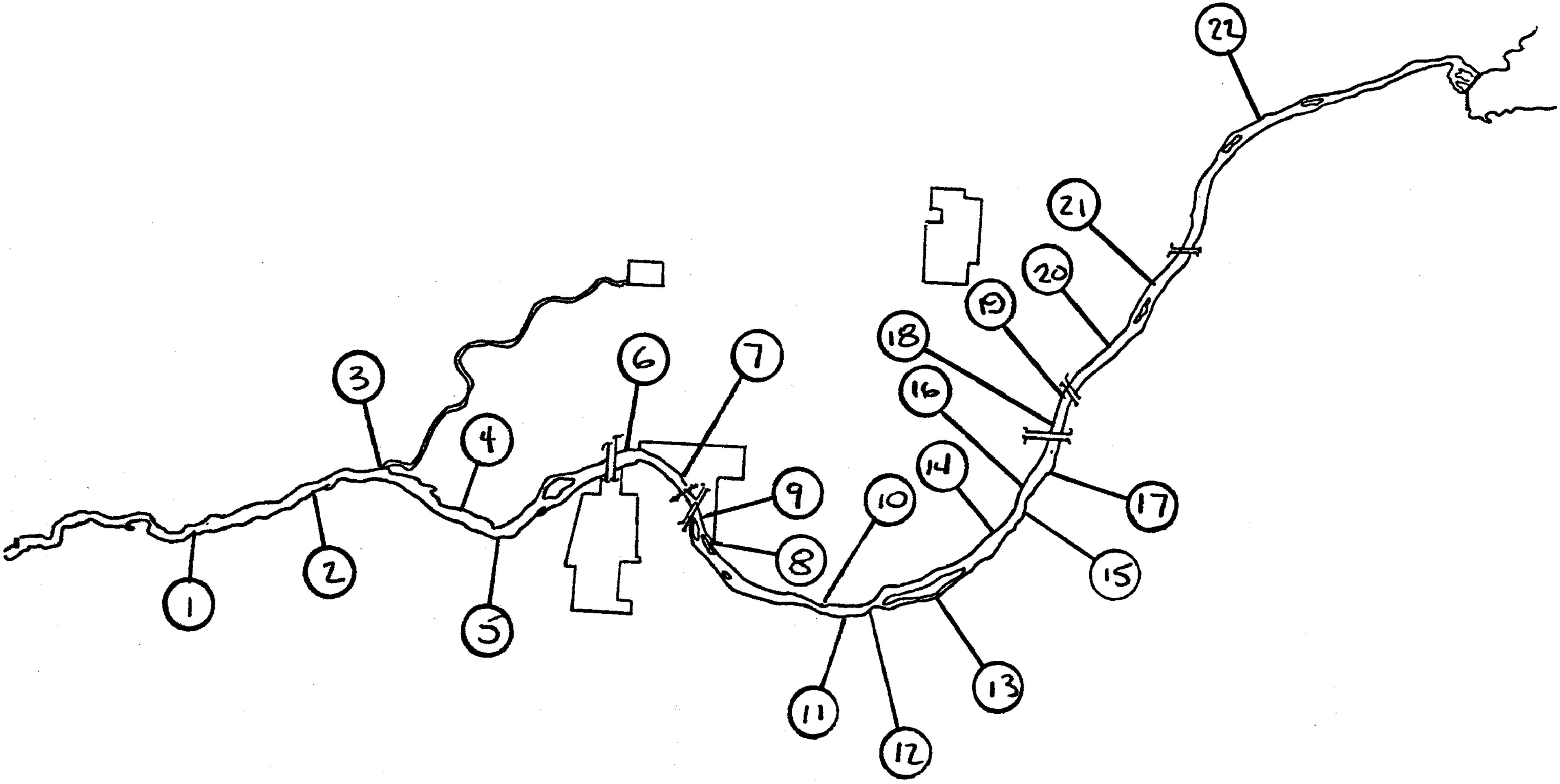

FIGURE 3 MAP SHOWING LOCATIONS OF IRRIGATION RETURN FLOWS IN THE MILNER REACH OF THE SNAKE RIVER.

The average Snake River flow at Milner Dam in Table 2 was 3125 c.f.s. and 3184 c.f.s. at Highway 27 Bridge. Assuming that the hydrologic regimen of the river had reached a steady-state condition, the data implies that the groundwater return to the Snake River is negligible in this segment. The major contribution or return flow, both from surface and groundwater sources, appears to be in the segment between Minidoka Dam (R.M. 675.0) and the Highway 27 Bridge (R.M. 652.3). The average flow at Minidoka Dam, from Table 2 was 434 c.f.s. less than the flow at the Highway 27 Bridge. Measured sources in this segment include the City of Rupert STP and surface returns as given in Table 5. These sources account for 133 c.f.s. Assuming that the ground water return accounts for the deficit, 321 c.f.s. can be ascribed to groundwater return in the segment between Minidoka Dam and the Highway 27 Bridge.

Table 5 Gaged and estimated (est) irrigation return flows between Minidoka and Milner Dams, October, 1974.

Approx. Mile	#	Name	Date		Flow (cfs)
644.9	1	Unknown	10/24	1415	dry
646.7	2	G-20 Lateral	10/24	1405	.5 est
648.0	3	Main Drain	10/22	1415	32.6
			10/24	1200	31.7
649.0	4	D-17 Drain	10/22	1430	1 est
650.3	5	Unknown	10/24	1430	.2 est
653.1	6	Unknown	10/24	1200	5 est
654.2	7	Unknown	10/23	1400	4 est
655.0	9	Goose Creek	10/22	1440	12.3
			10/24	1300	12.3
655.2	8	D-16 Drain	10/22	1630	8.9
657.3	10	Unknown	10/23	1500	.5 est
659.3	11	Duck Creek	10/22	1520	7.1
659.6	12	Spring Creek	10/22	1540	13.5
660.6	13	Marsh Creek	10/22	1600	22.2
			10/24	1340	22.2
662.6	14	Unknown	10/24	1250	1 est
663.1	16	D-5 Drain	10/24	1300	7.2
663.6	15	F Waste Canal	10/24	1330	11.7
663.6	17	Unknown	10/24	1310	.5 est
664.3	18	D-4 Drain	10/23	1520	10 est
664.7	19	Unknown	10/23	1540	dry
666.0	20	Unknown	10/23	1550	.5 est
667.8	21	D-3 Drain	10/23	1620	8.7
671.6	22	Unknown	10/23	1650	.1 est

Geometric Characteristics

Important geometric characteristics of the river, which are needed in the modelling process include the river width, depth and cross-sectional area. Preliminary results of work done by the U.S. Geological Survey, as well as soundings made during the October, 1974 survey were used to estimate these parameters. Table 6 gives the estimates for river width, depth and cross-sectional area for segments within the Milner reach.

Table 6 Geometric characteristics of the Milner reach of the Snake River ([1]Preliminary measurements by the U.S. Geological Survey. [2]Soundings by EPA water quality survey teams).

River Mile	River Width (feet)	Cross-sectional Area (square feet)	Hydraulic Radius (feet)
674.7[1]	460	2,200	4.8
671.2[1]	930	2,200	2.9
668.6[1]	805	3,030	3.8
665.2[1]	820	2,420	3.0
659.8[1]	900	3,460	3.8
654.6[1]	760	4,940	6.5
649.5[1]	790	8,090	10.2
647.3[2]	900	8,010	8.9
645.0[2]	800	8,640	10.8
641.5[2]	1,000	15,000	15.0

Municipal and Industrial Waste Discharge

Discharges of carbonaceous and nitrogenous BOD to Lake Milner from municipal and industrial sources were measured by EPA-NFIC (Denver). These data are summarized in Table 7. These summaries include the average loadings of BOD_5 and NH3 from each of the

Table 7 Average observed flow, temperature, BOD_5, NH_3-N for point source discharges in the Milner reach of the Snake River and tributary streams 10/22/74--10/28/74.

Discharger	Flow (mgd)	Temp. (C)	BOD_5 mg/l	BOD_5 lbs/day	NH_3-N mg/l	NH_3-N lbs/day
1. Amalgamated Sugar Co.	0.86	36.1	4,600	35,000	20.0	140
2. Rupert STP	2.64	20.1	590	11,000	15.7	300
3. J.R. Simplot						
#001	4.67	14.9	100	4,400	6.0	250
#002	0.94	9.1	23	180	0.2	1
4. Heyburn STP	0.20	17.6	230	410	22.3	40
5. Burley STP	1.73	9.8	17	240	7.3	110
6. Bryant's Meats	0.036	14.5	560	200	22.6	6
7. Ore-Ida						
#001	4.42	15.6	38	1,550	3*	100
#002-cooling water only	0.78	18.2	4	30	0.4*	2
#002-cooling water and silt water	1 est	16.6	51	430	3.6	30
#003	0.2*	19.3	5		0.02	21
#004	1.49	13.5	40	510	0.1	1

*Variation betweem samples was more than two orders of magnitude municipal and industrial sources, as measured by EPA-NFIC (Denver). Locations of discharges are shown in Figure 4.

Tributary Waste Loadings

Loadings to Lake Milner from surface and ground water return flow were estimated from the water quality of what were felt to be representative sources. A summary of the carbonaceous BOD (5-day) and ammonia nitrogen for those drain and wells which were sampled is given in Table 8. The Main Drain, which is not a representative surface return is also given in Table 8, since it does have a substantial impact on the Milner reach of the Snake River.

Table 8 Carbonaceous BOD (5-day) and ammonia nitrogen for surface and groundwater return flows to the Lake Milner reach of the Snake River 10/22/74--10/27/74

Surface Returns	Number (see table)	Flow (cfs)	BOD_5 mg/l	NH_3-N mg/l
Goose Creek	9	12	0.6	0.01
Flume @ R.M. 657.3	10	0.5 est	1.4	0.59
Marsh Creek	13	22	0.6	0.02
Drain @ R.M. 663.6	17	0.5 est	1.6	0.10
D-4 Drain	18	10	2.5	0.05
Averages			1.3	0.15
Main Drain	3	32	125	0.7
Groundwater Return				
Spring below Minidoka Dam			0.4	0.01
Shallow well @ Rupert STP			0.6	0.26
Rupert well K & 3rd			0.6	0.23
Averages			0.5	0.17

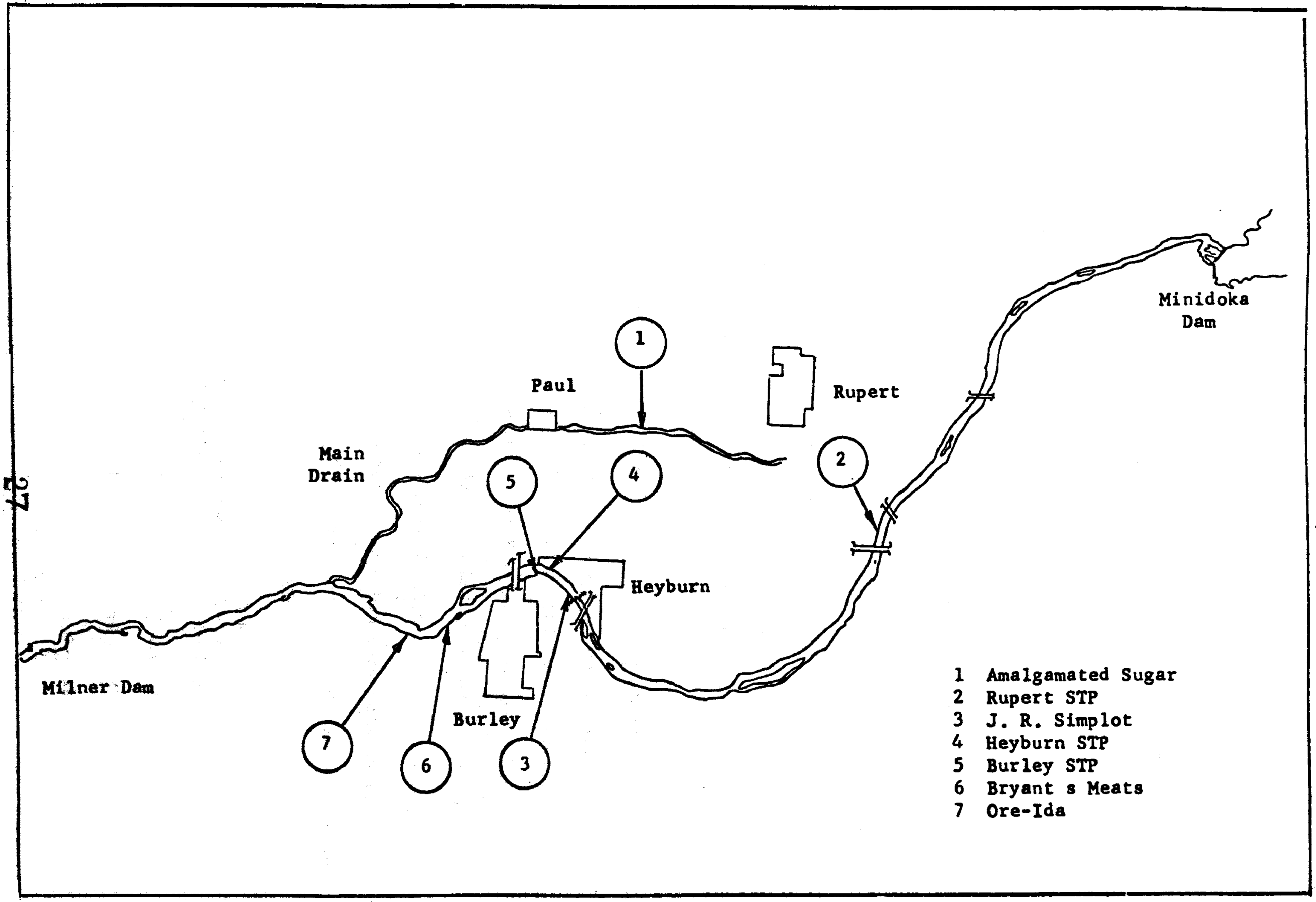

Figure 4 Location of major industrial and municipal discharges in the Lake Milner reach of the Snake River, Idaho (October 1974).

In-stream Water Quality

Water quality parameters measured during the October, 1974 survey include:

1) Temperature
2) Dissolved Oxygen
3) Conductivity
4) pH
5) Biological oxygen demand (2,5,10 and 20-day)
6) Suspended Solids
7) Total Kjeldahl nitrogen
8) Ammonia nitrogen
9) Organic nitrogen
10) Nitrite and Nitrate nitrogen
11) Total phosphorus
12) Chlorophyll a

The first four parameters in the list above were measured in-situ with a Hydrolab Surveyor II. The remaining parameters were measured in the laboratory. The laboratory methods are reported by EPA-NFIC (Denver) (1974).

The location of receiving water quality stations are shown in Figure 5. These stations were chosen to define the water quality at important oundary points. The station at Minidoka Dam (R.M. 675.0) provided a measure of the water quality of Lake Walcott discharge. The station at the U.S. 30 Bridge (R.M. 654.0) provided a reference point for conditions just upstream from those discharges for which NPDES permits were drafted. This station also provided a means for estimating non-point source contributions between Minidoka Dam and the Burley-Heyburn area. The stations at R.M. 652.3 (Highway 27 Bridge) and R.M. 647.2 provided a check for water quality just downstream from major waste discharge sources. The station at Milner Dam (R.M. 640.0) defined the downstream boundary of the reach and was also at the point where we expected the most impact upon water quality waste discharges. The Main Drain constitutes a major waste source, and a station there was necessary to determine the BOD and ammonia loadings.

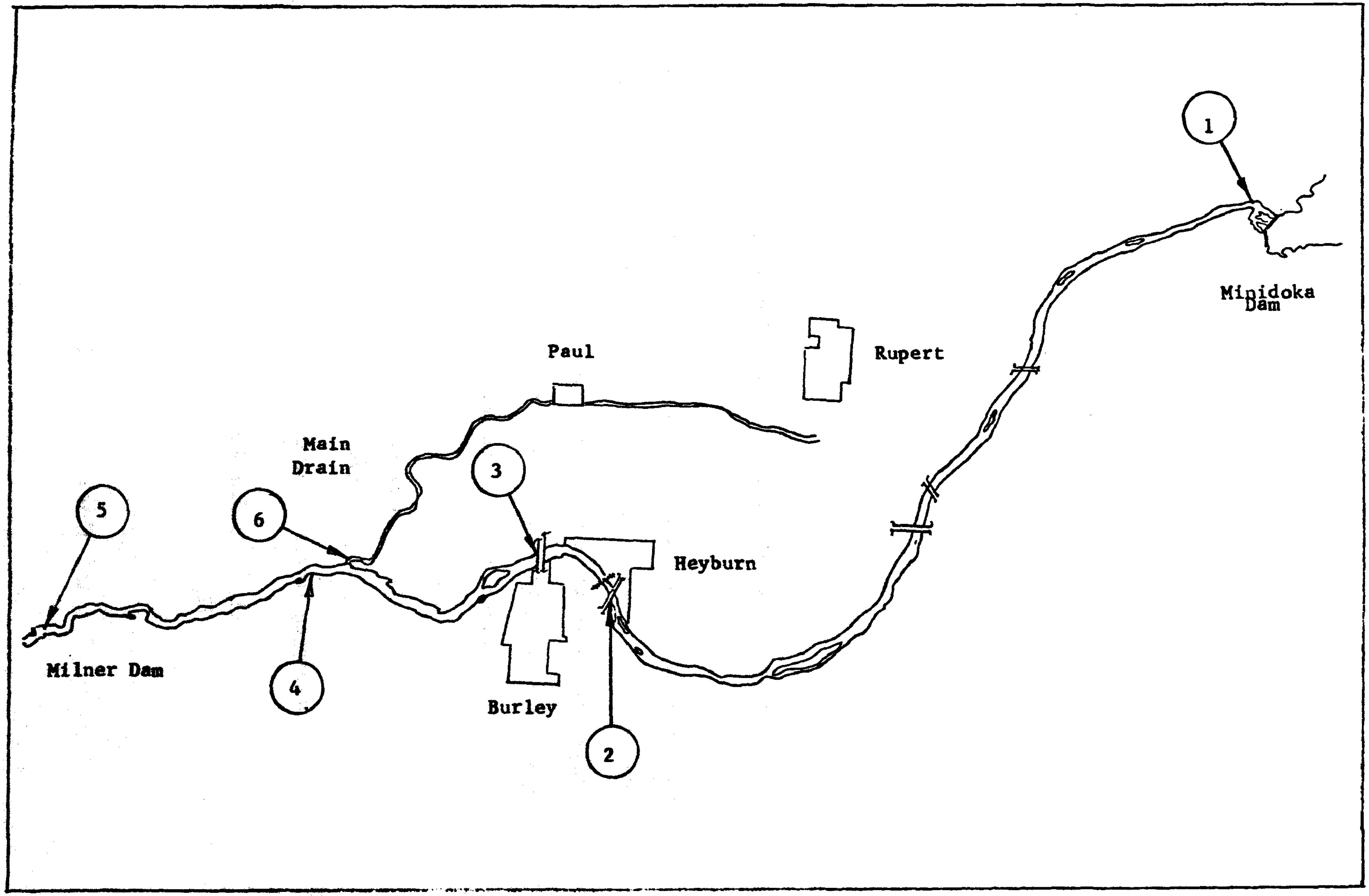

Figure 5 Location of receiving water quality sampling stations in the Lake Milner reach of the Snake River, Idaho. EPA - State of Idaho survey October 1974.

Temperature, dissolved oxygen concentration, pH, conductivity and nutrient levels were measured twice a day at each station. Samples were also taken at 1,2,5 and 10 meters, river depth permitting. Chlorophyll _a_ concentrations were measured at the surface at each of the Snake River stations. Cross-sections were made at each station, except for the Minidoka Dam and Main Drain stations. The purpose of the cross-sections was to determine the extent of lateral variations in water quality. Diurnal measurements of temperature, dissolved oxygen concentration, pH and conductivity were made at two locations. One at Milner Dam from 1810 on 10/22/74 to 910 on 10/23/74, and one at Tom's Marina from 1745 on 10/24/75.

Temperature, dissolved oxygen concentration and dissolved oxygen saturation levels are plotted as a function of river mile in Figures 6, 7 and 8. Minima, means and maxima for temperature, dissolved oxygen concentration, BOD (2, 5, 10 and 20-day), ammonia nitrogen and chlorophyll _a_, as measured during the survey, are given in Table 9.

Contours showing the lateral variations of temperature and dissolved oxygen at those stations where measurements of this type were made are shown in Figures 9 through 20.

In general, the dissolved oxygen levels were at or above the saturation value during the period 10/22/74--10/24/74. Only at Milner Dam were dissolved oxygen levels observed below 100% saturation for this period.

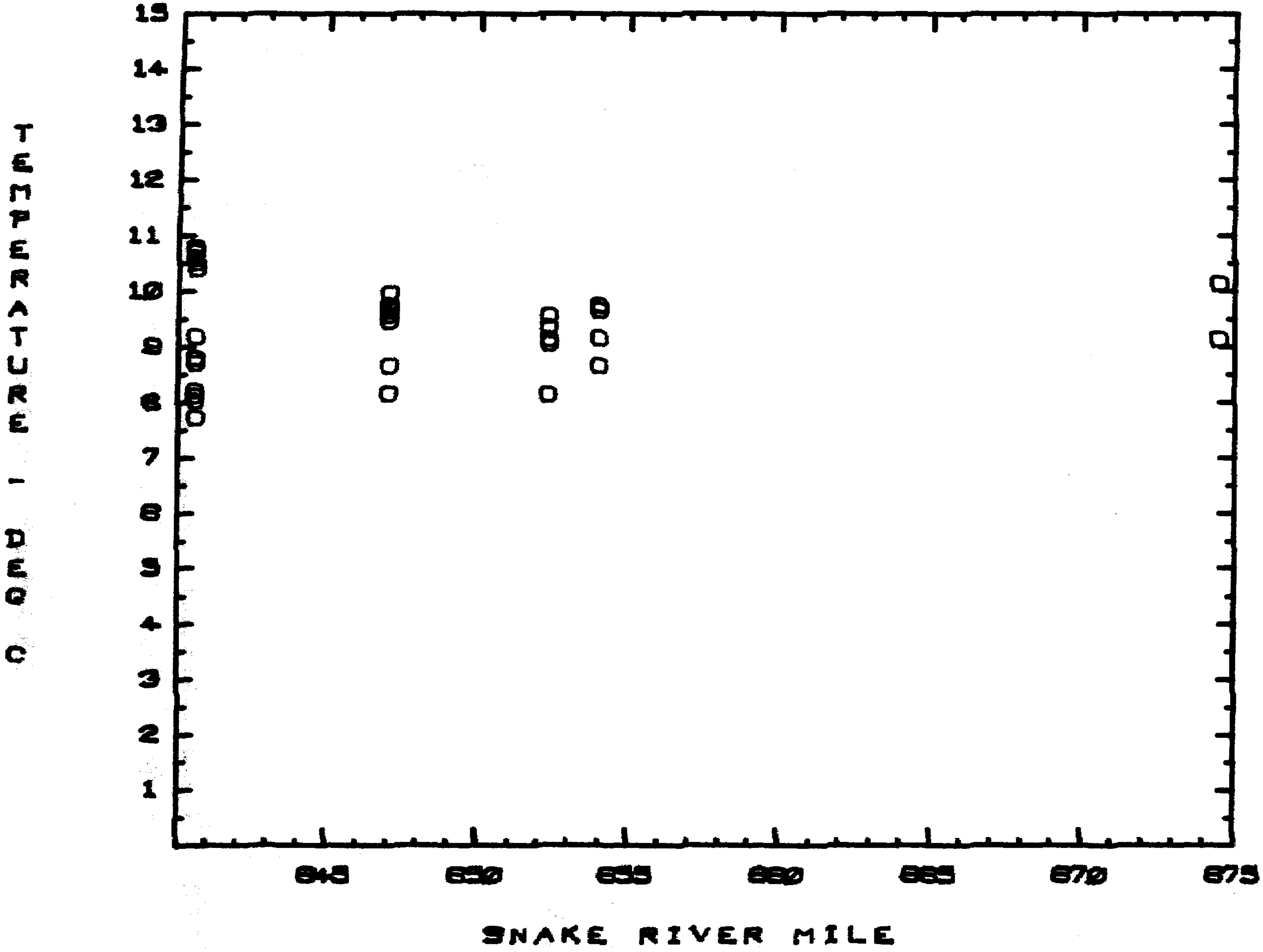

FIGURE 6 OBSERVED TEMPERATURES IN THE MILNER REACH OF THE SNAKE RIVER 10/22/74-10-24/74.

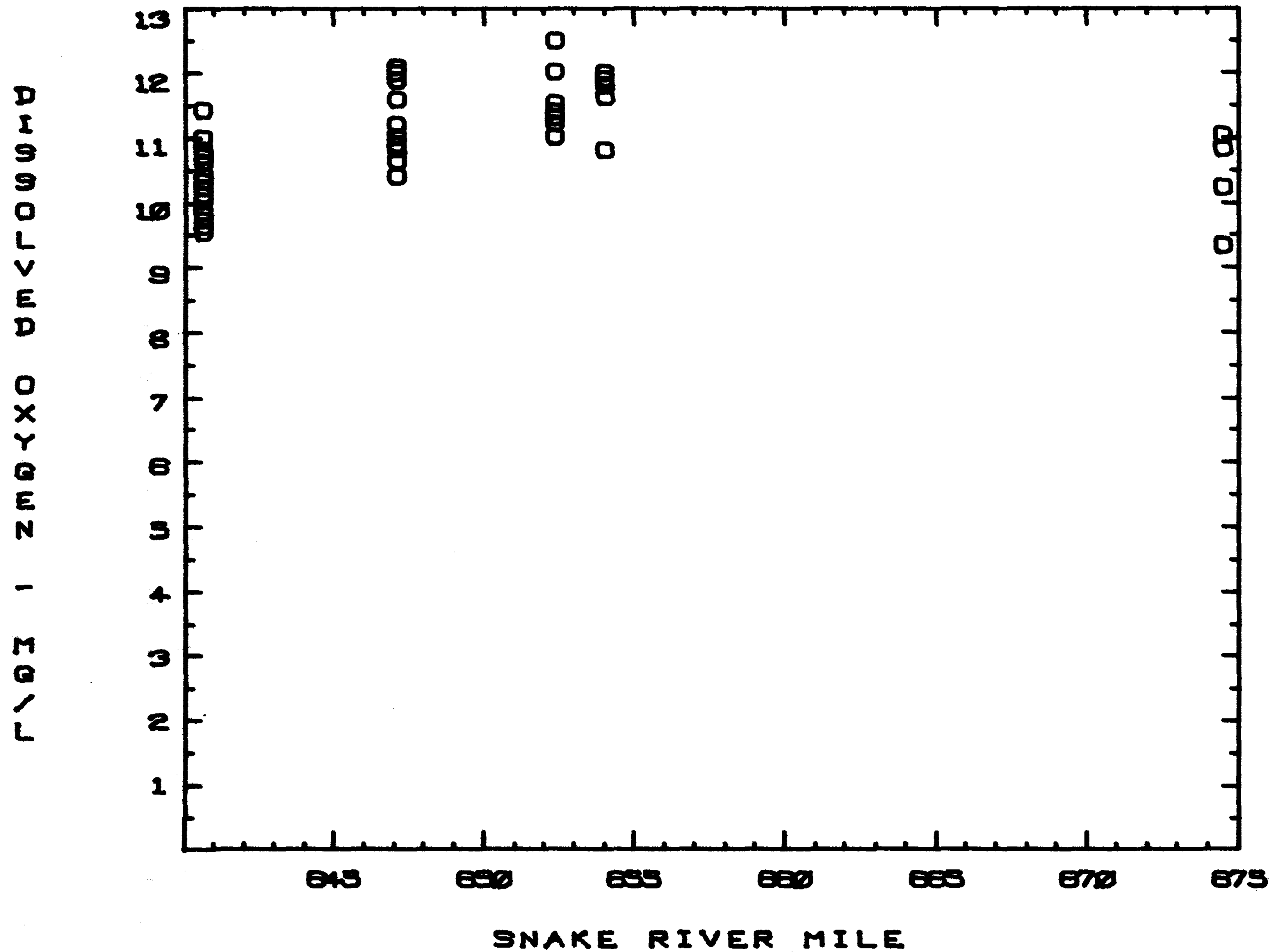

FIGURE 7 OBSERVED DISSOLVED OXYGEN IN THE MILNER REACH OF THE SNAKE RIVER

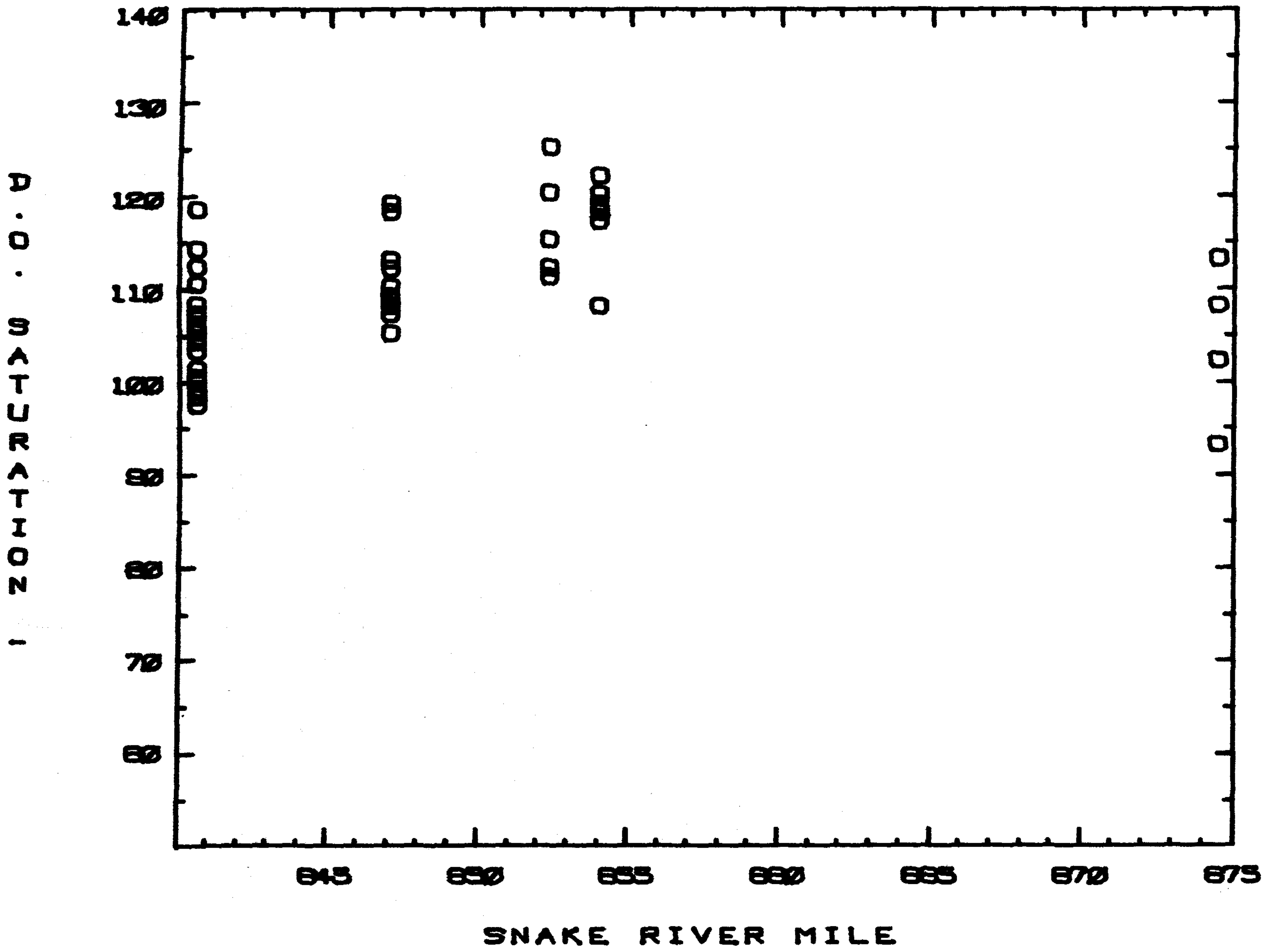

FIGURE 8 OBSERVED D.O. SATURATION IN THE MILNER REACH OF THE SNAKE RIVER 10/22/74-10/24/74.

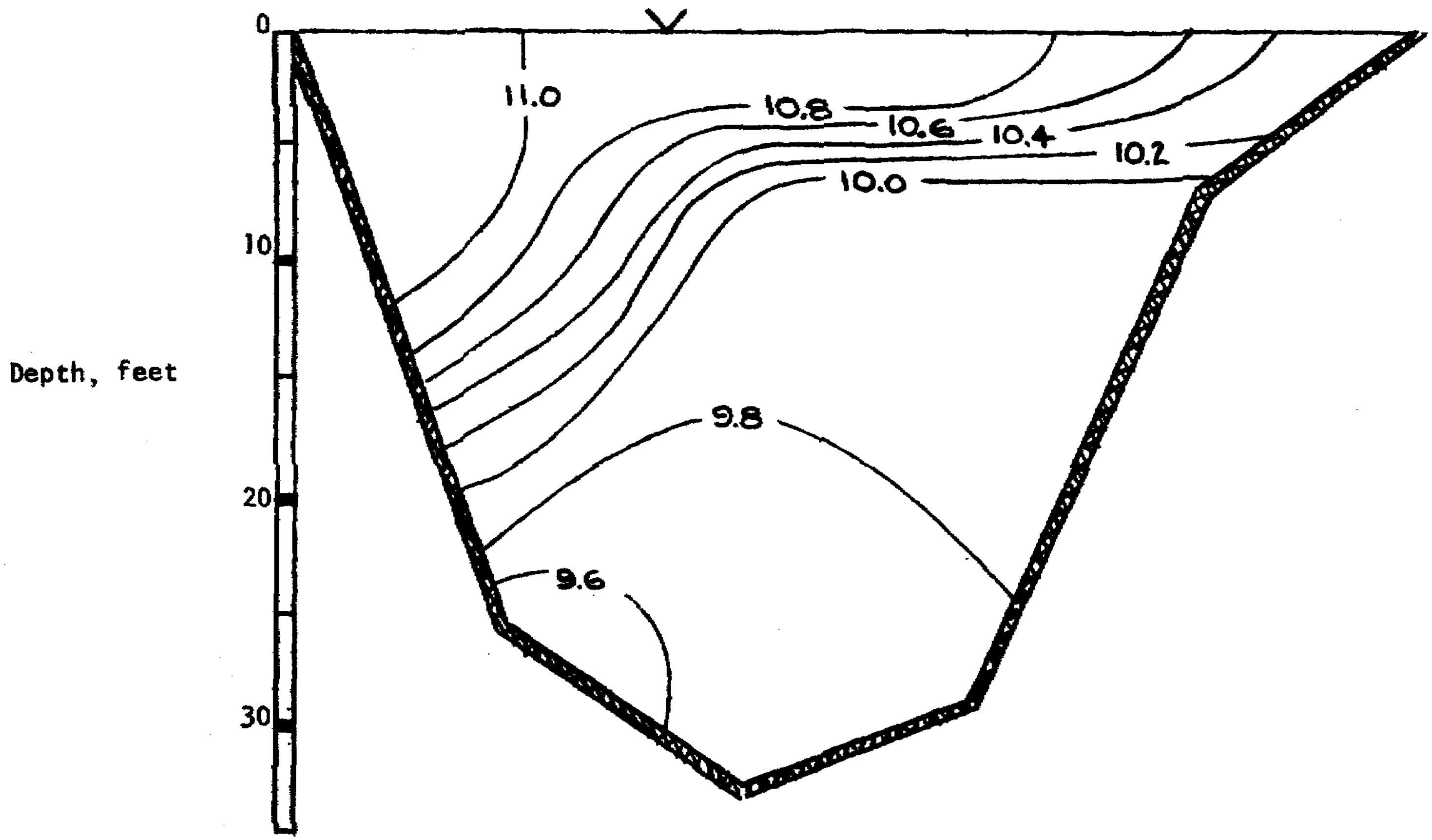

FIGURE 9 Profile of D.O (mg/l) Milner Dam (Snake River Mile 640.0) on 10/22/74

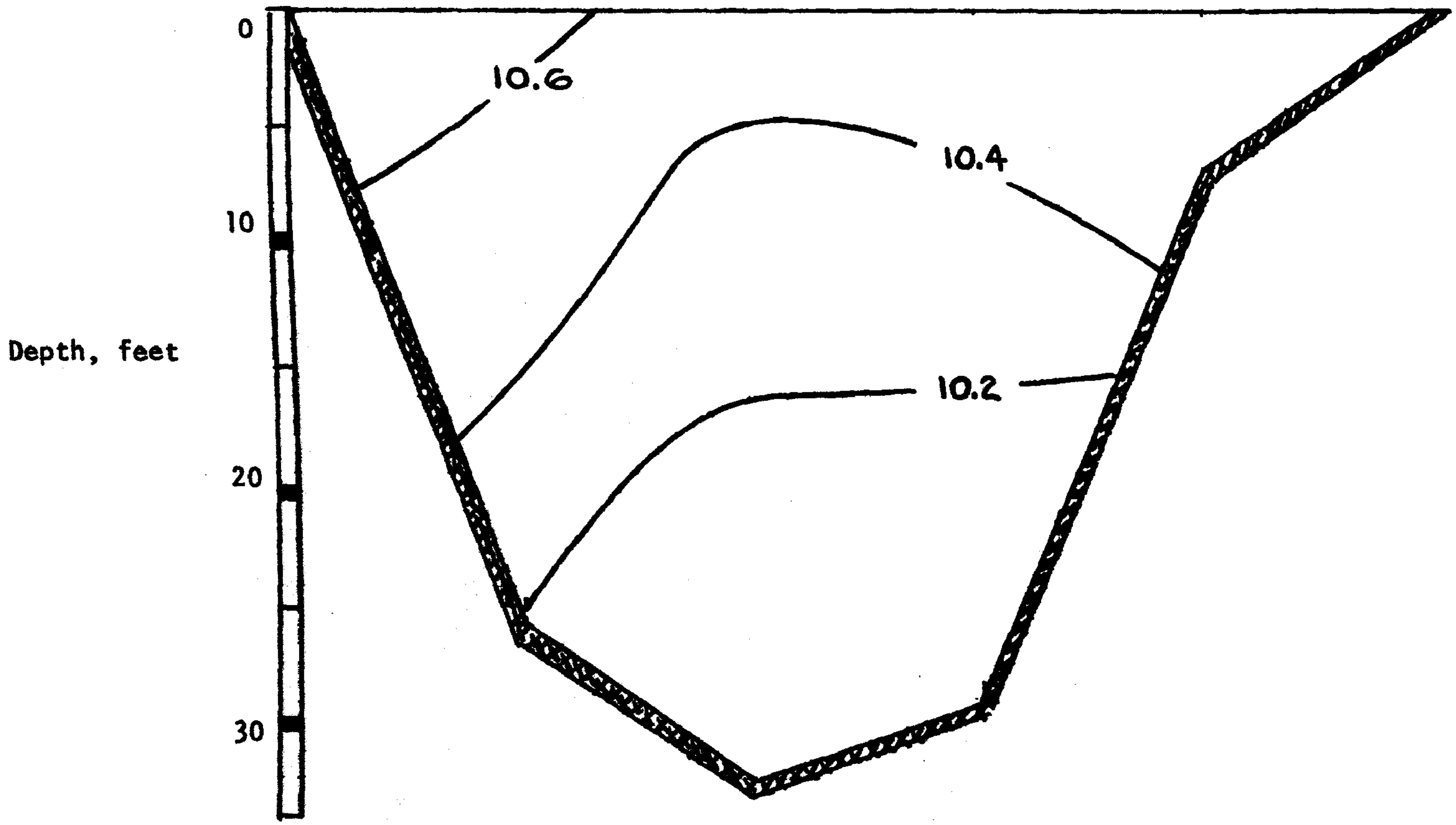

Figure 10 Profile of Temperature (C) at Milner Dam (Snake River Mile 640.0) on 10/22/74

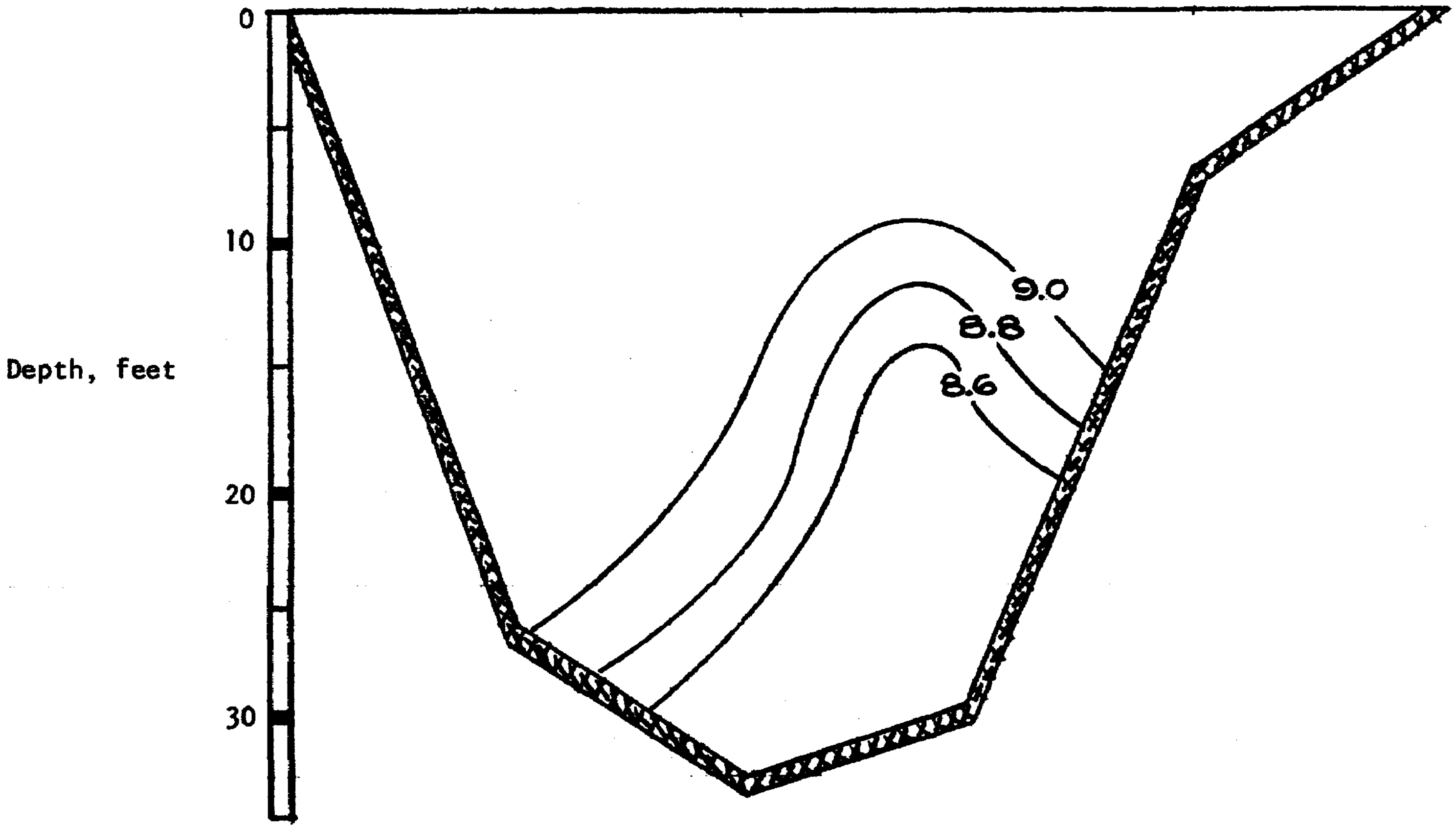

Figure 11 Profile of Temperature (C) at Milner Dam (Snake River Mile 640.0) on 10/23/74

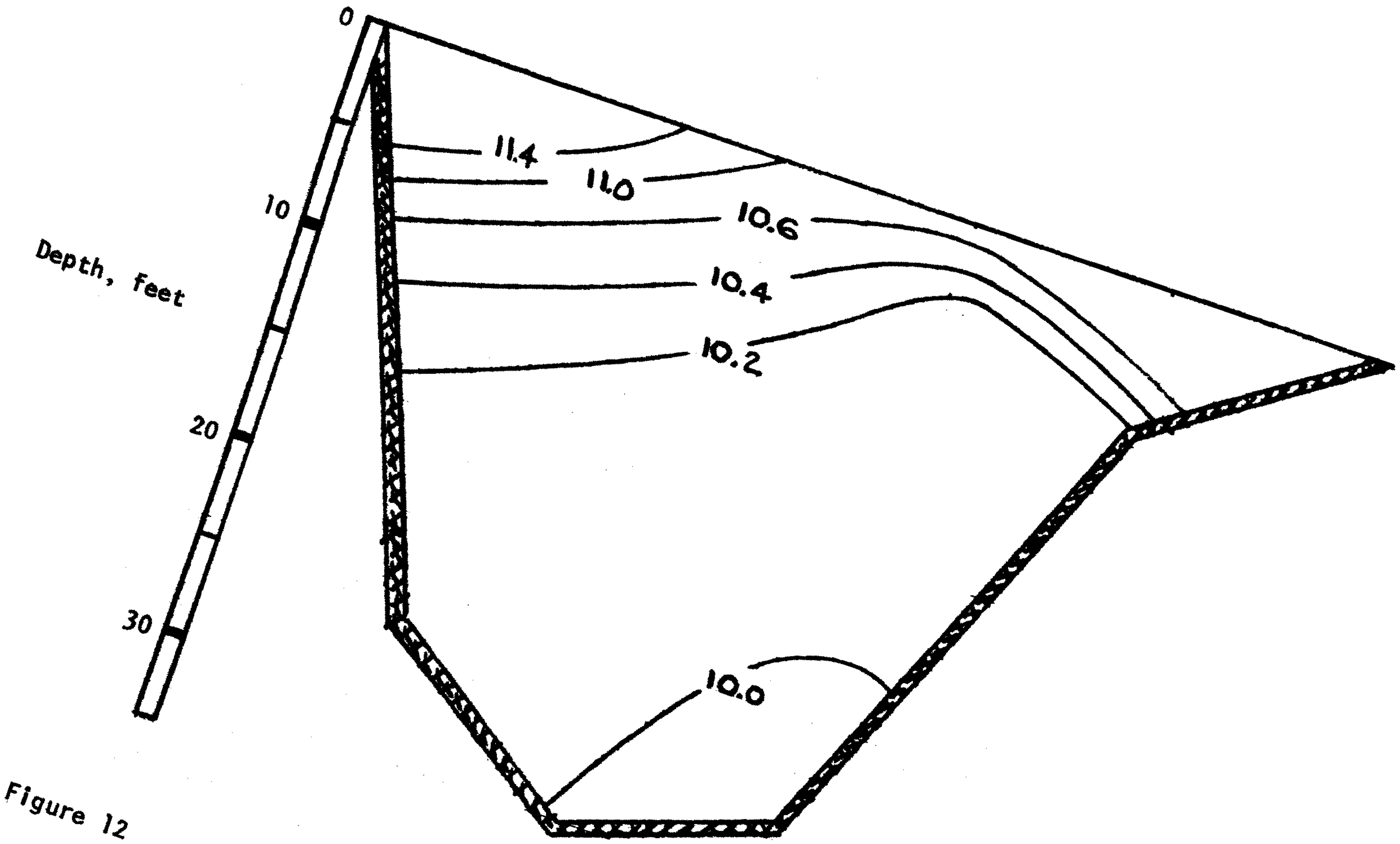

Figure 12 Profile of D.O. (mg/l) at Milner Dam (Snake River Mile 640.0) on 10/23/74

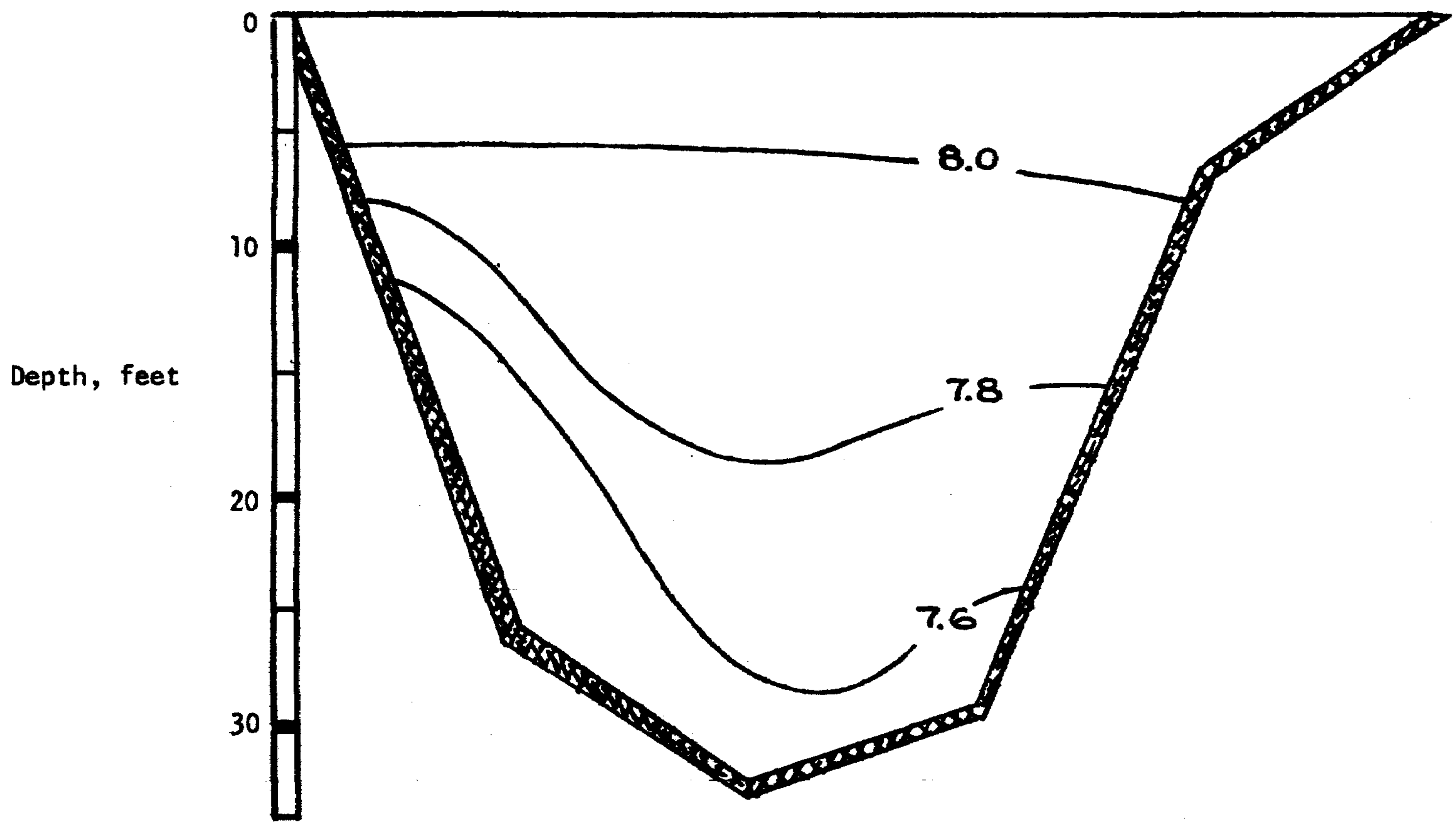

Figure 13   Profile of Temperature (C) at Milner Dam (Snake River Mile 640.0) on 10/24/74

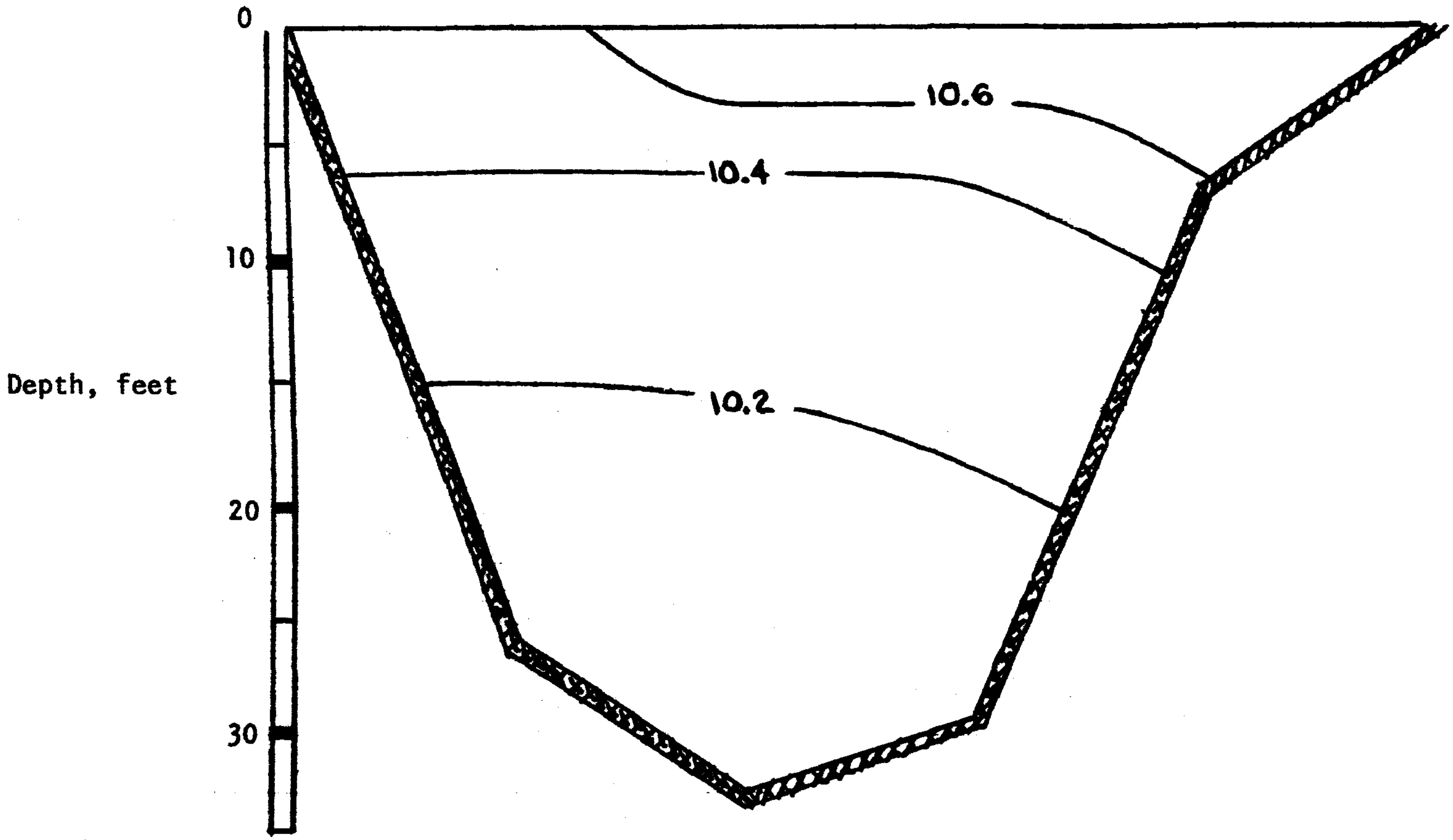

Figure 14 Profile of Temperature (C°) at Milner Dam (Snake River Mile 640.0) on 10/24/74

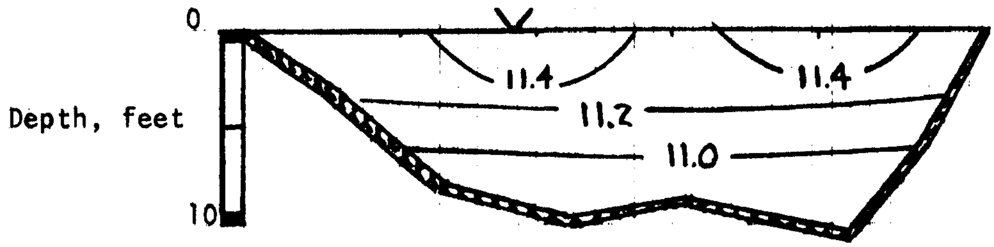

Figure 15 Profile of D.O. (mg/l) at Snake River Mile 652.3 on 10/22/74

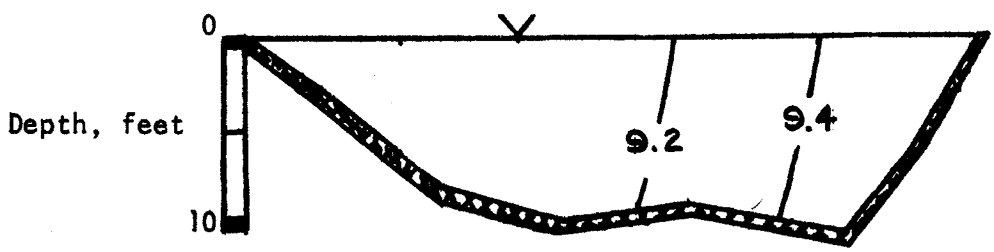

Figure 16 Profile of Temperature (C) at Snake River Mile 652.3 on 10/22/74

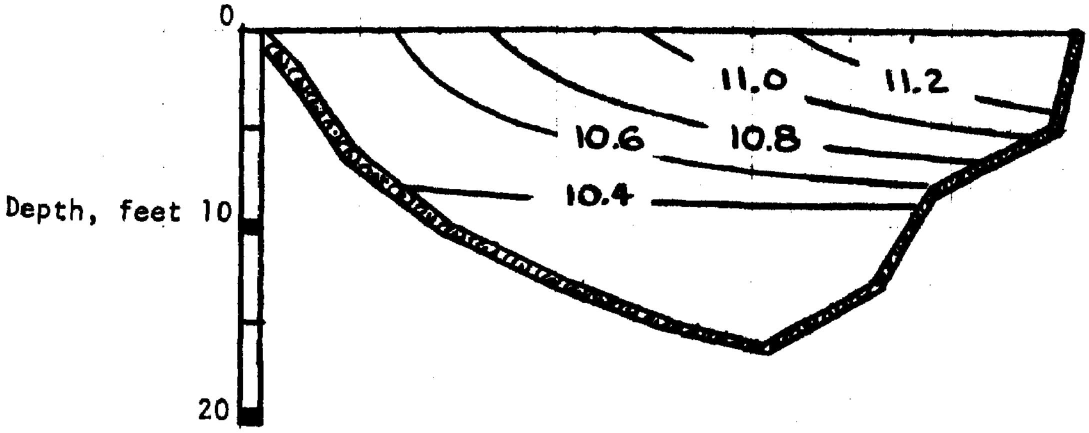

Figure 17 Profile of D.O. (mg/l) at Snake River Mile 649.5 on 10/22/74

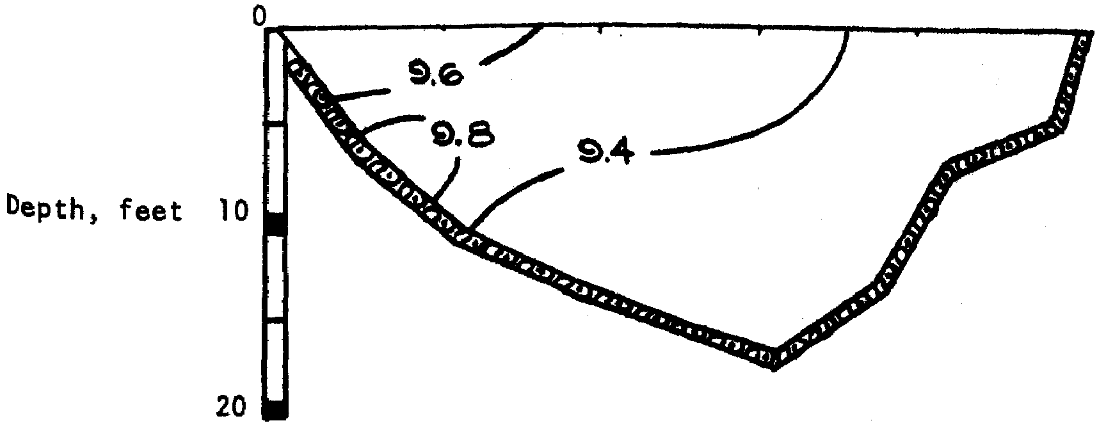

Figure 18 Profile of Temperature (C) at Snake River Mile 649.5 on 10/22/74

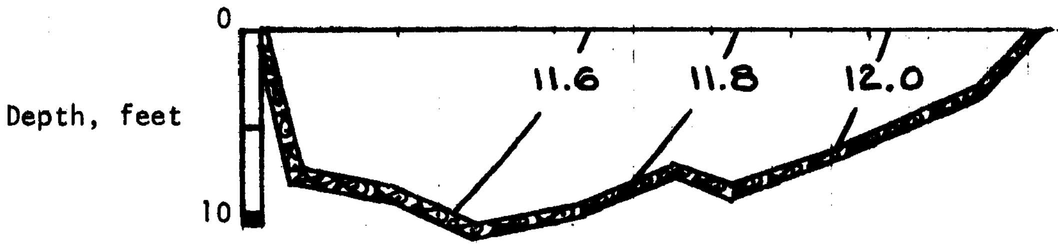

Figure 19 Profile of D.O. (mg/l) at Snake River Mile 654.0 on 10/22/74

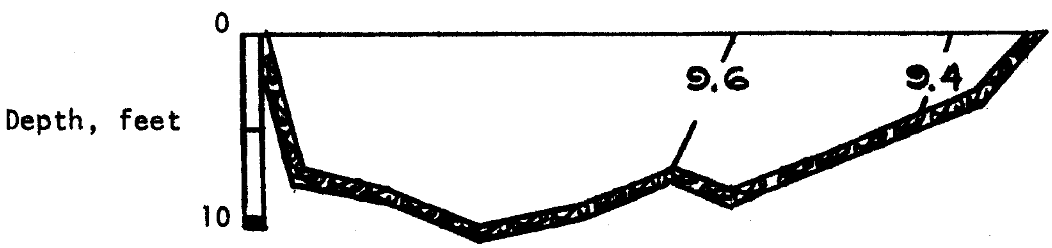

Figure 20 Profile of Temperature (C) at Snake River Mile 654.0 on 10/22/74

In none of the observations, were dissolved oxygen levels below the 90% level. The Snake River in the Milner reach was generally a greenish brown as a result of the algal growth. Secchi disk readings ranged from 2.7 to 3.3 feet.

Cross-sectional and vertical variations of temperature were less than 0.5 C at all stations, including the one at Milner Dam. The dissolved oxygen varied vertically and laterally as much as 0.8 mg/l at the shallower stations, and as much as 1.4 mg/l at Milner Dam.

Solar heating and photosynthetic oxygen production are both surface-related phenomena. For this particular time, however, the data suggests that photosynthesis had a more important role in the dissolved oxygen budget than solar heating had in the heat budget.

Table 9 Observed minima, mean, and maxima for receiving water sampling stations in the Milner reach of the Snake River 10/22/74 -- 10/24/74.

River Mile	674.9			654.0			652.3			647.2			640.0		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Temperature (C)	9.0	9.3	10.0	8.5	9.0	9.6	8.0	8.8	9.4	8.0	8.8	9.8	7.5	9.1	10.6
Dissolved Oxygen (mg/1)	9.3	10.3	11.0	10.8	11.7	12.0	11.0	11.5	12.0	10.4	11.1	12.1	9.5	10.4	11.4
BOD (2-day) (mg/1)	0.5	0.7	0.9	0.7	1.0	1.2	0.7	0.8	1.1	0.8	1.0	1.4	1.0	1.2	1.3
BOD (5-day) (mg/1)	1.3	1.5	1.7	2.5	2.8	3.5	2.4	2.7	3.1	2.4	3.0	3.6	2.7	3.2	3.9
BOD (10-day) (mg/1)				2.5	2.8	3.5				2.6	3.1	3.6	2.7	3.2	3.9
BOD (15-day) (mg/1)				2.7	5.0	6.4				9.8	9.9	10.0	4.4	6.1	7.0
NH_3-N (mg/1)	0.01	0.01	0.03	20.01	20.01	0.02	20.01	0.02	0.04	0.01	0.03	0.06	0.01	0.02	0.08
Chlorophyll a (mg/1)	30.4	32.2	33.5	32.3	34.8	37.1	28.7	32.8	38.0	30.9	35.9	41.4	46.5	55.4	61.4

III. THEORETICAL ANALYSIS

The steady-state dissolved oxygen budget for a vertically and laterally well-mixed stream, in which diffusion and dispersion processes are neglected can be written:

$$u \frac{dC}{dx} = -\frac{K_2 (C - C_{sat})}{86400} - \frac{K_1 L}{86400} + \Phi_c - \Gamma_c \qquad (2)$$

where,

u	=	the stream velocity, feet/second
C	=	the dissolved oxygen concentration mg/l
x	=	the distance along the axis of the stream, positive downstream, feet
K_2	=	the reaeration rate constant, $days^{-1}$
CSat	=	the saturation concentration of dissolved oxygen, mg/l
K	=	the deoxygenation rate, $days^{-1}$
L	=	the carbonaceous biological oxygen demand (BOD), mg/l
Φ_c	=	the dissolved oxygen sources, mg/l/second
Γ_c	=	the dissolved oxygen sinks, mg/l/second

Similarly, the carbonaceous biological oxygen demand (C-BOD), L, is

$$u \frac{dL}{dx} = -\frac{K_1 L}{86400} + \Phi_L - \Gamma_L \qquad (3)$$

where,

Φ_L	=	the BOD sources mg/l/second
Γ_L	=	the BOD sinks, mg/l/second

The nitrogenous biological oxygen demand (N-BOD), N, is

$$u\frac{dN}{dx} = -\frac{K_3 N}{86400} + \Phi_N - \Gamma_N \tag{4}$$

where,

K_3 = the deoxygenation rate for nitrogenous BOD, days^{-1}

Φ_N = the N-BOD sources, mg/l/second

Γ_N = the N-BOD sinks, mg/l/second

The factor, 86400, in equations (2), (3) and (4) is for the purpose of making the dimensions homogeneous. This is a result of expressing the rate constants, K_1 and K_2, in units of days^{-1} and all other parameters in units of seconds.

Sources, Φ_c, for dissolved oxygen included in this model are:

1) Surface and groundwater return flow

2) Photosynthetic, P, oxygen production by algae

Sinks, Γ_c, for dissolved oxygen included in this model are:

1) Oxygen demand, S, associated with bottom sediments

2) Respiration, R, of algae

The sources for BOD are accounted for as boundary conditions, rather than as internal sources. For example, if a BOD source is discharging at the rate, Qw, with a concentration, Lw, into a river with a flow, Qr, and a concentration, Lr, then the effect of the source upon the river, at the point of discharge, is given by computing a new in-stream concentration, Lr, according to:

$$L_r = \frac{Q_w L_w + Q_r L_r}{Q_w + Q_r} \tag{4}$$

Equation (3) implies that the waste mixes instantaneously and uniformly across the river at the time of discharge.

No sinks for BOD are included in the analysis.

The solutions to equations (2), (3) and (4) are, respectively:

$$C = C_{sat} - (C_{sat} - C_o)e^{-\frac{K_2 x}{u}} - \frac{K_1}{K_2 - K_1}\left[e^{-\frac{K_1 x}{u}} - e^{-\frac{K_2 x}{u}}\right] - \frac{K_3}{K_2 K_3}\left[e^{-\frac{K_3 x}{u}} - e^{-\frac{K_2 x}{u}}\right] - \frac{(\Phi_c - \Gamma_c)}{K_2}\left(1 - e^{-\frac{K_2 x}{u}}\right) \tag{5}$$

$$L = L_o e^{-\frac{K_1 x}{u}} + \frac{(\Phi_L - \Gamma_L)}{K_1}\left(1 - e^{-\frac{K_1 x}{u}}\right) \tag{6}$$

and

$$N = N_o e^{-\frac{K_3 x}{u}} + \frac{(\Phi_N - \Gamma_N)}{K_3}\left(1 - e^{-\frac{K_3 x}{u}}\right) \tag{7}$$

The diuranal variations, C_t, dissolved oxygen, as formulated by O'Connor and Di Toro (1970), can be estimated from photosynthesis and respiration of algae:

$$C_t = \sum_{n=1}^{\infty} \frac{\cos(n\pi p) \cdot 4\pi}{p \left\{\left(\frac{\pi}{p}\right)^2 - (2\pi n)^2\right\}} * \cos\left\{2\pi n\left(t - t_o - \frac{p}{2}\right) - \tan^{-1}\left(\frac{2\pi n}{K_2}\right)\right\} \tag{8}$$

where,

Po	=	the maximum rate of dissolved oxygen production by algse, mg/l/day
p	=	the fraction of the day during which photosynthesis occurs
t	=	the fraction of the day elapsed from midnight
t0	=	the time that photosynthesis begins, as a fraction of the day from midnight

IV. COMPARISON OF THEORETICAL ANALYSIS AND FIELD STUDIES

The steady-state and time models described in Chapter III were used to simulate the depth and average dissolved oxygen, C-BOD, and N-BOD in the Lake Milner reach of the Snake River. Mathematically modelling was done only for that portion of the Milner reach between R.M. 654.0 and R.M. 640.0. Waste loadings to this reach of the Snake River were well-defined and the number of receiving water quality stations was adequate. In addition, this reach contained those industrial and municipal discharges examined in the initial study (Yearsley 1974).

In order to estimate concentrations with Equations (5), (6) and (7), the values of certain parameters must be specified, as well as the boundary conditions for river flow and water quality. Those constants required for the steady-state simulation include: the deoxygenation rate, K_1, the reaeration rate, K_2, the nitrification rate, K_3, the oxygen production, $\bar{\Phi}_L$, the oxygen sinks, Γ_L , the river flow, Q, river width, W, and average depth, H.

The deoxygenation rate, K_1, was assumed to be 0.15 $days^{-1}$, base e. This value is the same as that used in permit analysis (Yearsley 1974). Long term measurement of BOD were made at R.M. 654.0, R.M. 647.2 and R.M. 640.0 The theoretical BOD, using a rate constant of 0.15 $days^{-1}$ (base e), is compared to these field observations in Figures 21, 22, and 23.

The reaeration rate, K_2, was computed from the equation by O'Connor and Dobbins (1958):

$$K_2 = \frac{12.9\, u^{1/2}}{H^{3/2}} \tag{9}$$

where,

K_2 = the reaeration rate, $days^{-1}$ (base e)

U = the average stream velocity, feet/second

H = the stream depth, feet

The nitrification rate, K_3, was assumed to be 1.5 $days^{-1}$ (base e).

The deoxygenation rate, K_1, and the intrification rate, K_3, were adjusted for temperature using the following, F_1:

$$F_1 = 1.047^{(T-20)} \tag{10}$$

where,

F_1 = the temperature factor

T = the stream temperature, ^{o}C

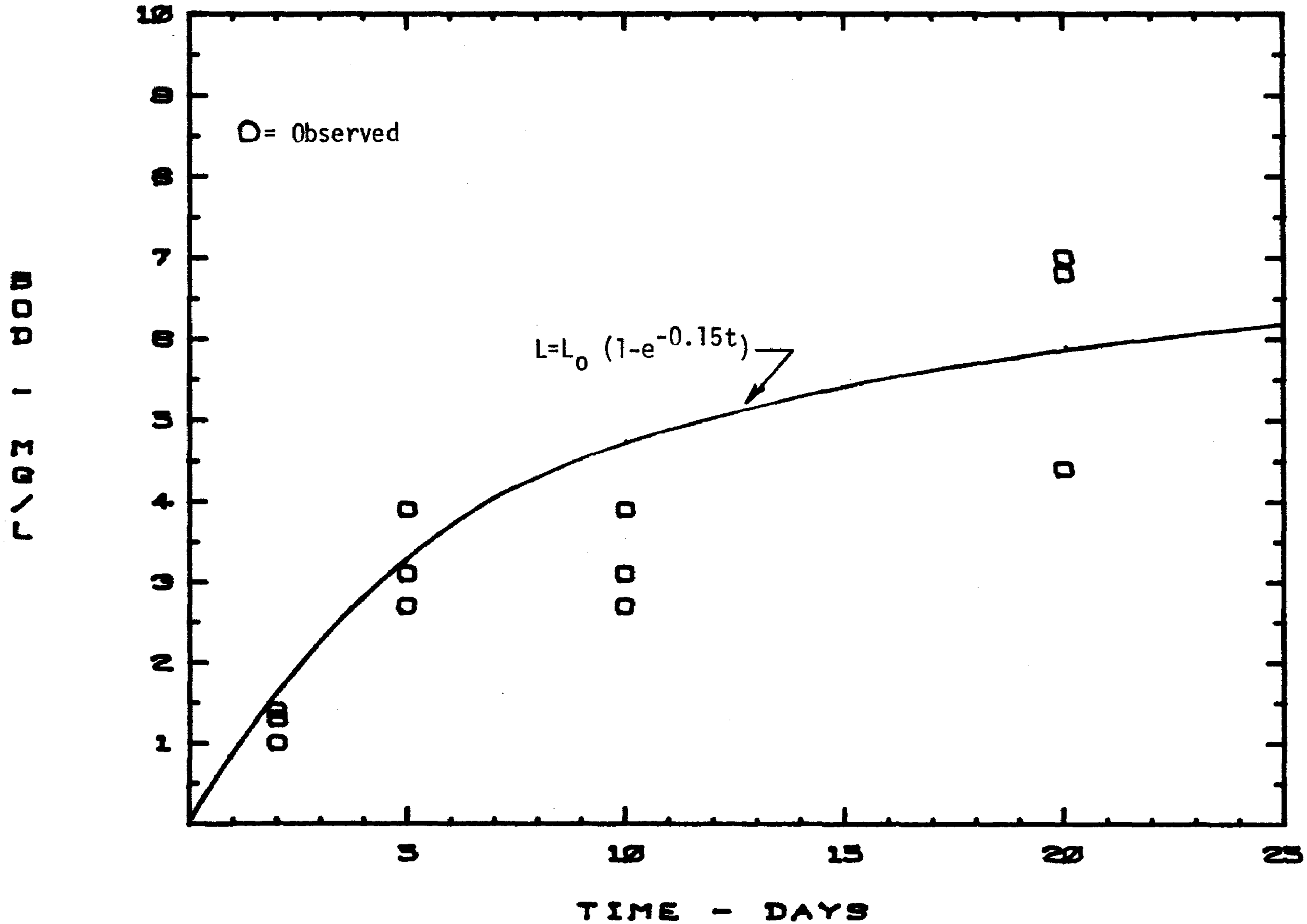

FIGURE 21 OBSERVED BOD AT SNAKE R.M. 640.0.
EPA-NFIC(DENVER)
10/22/74-10/25/7

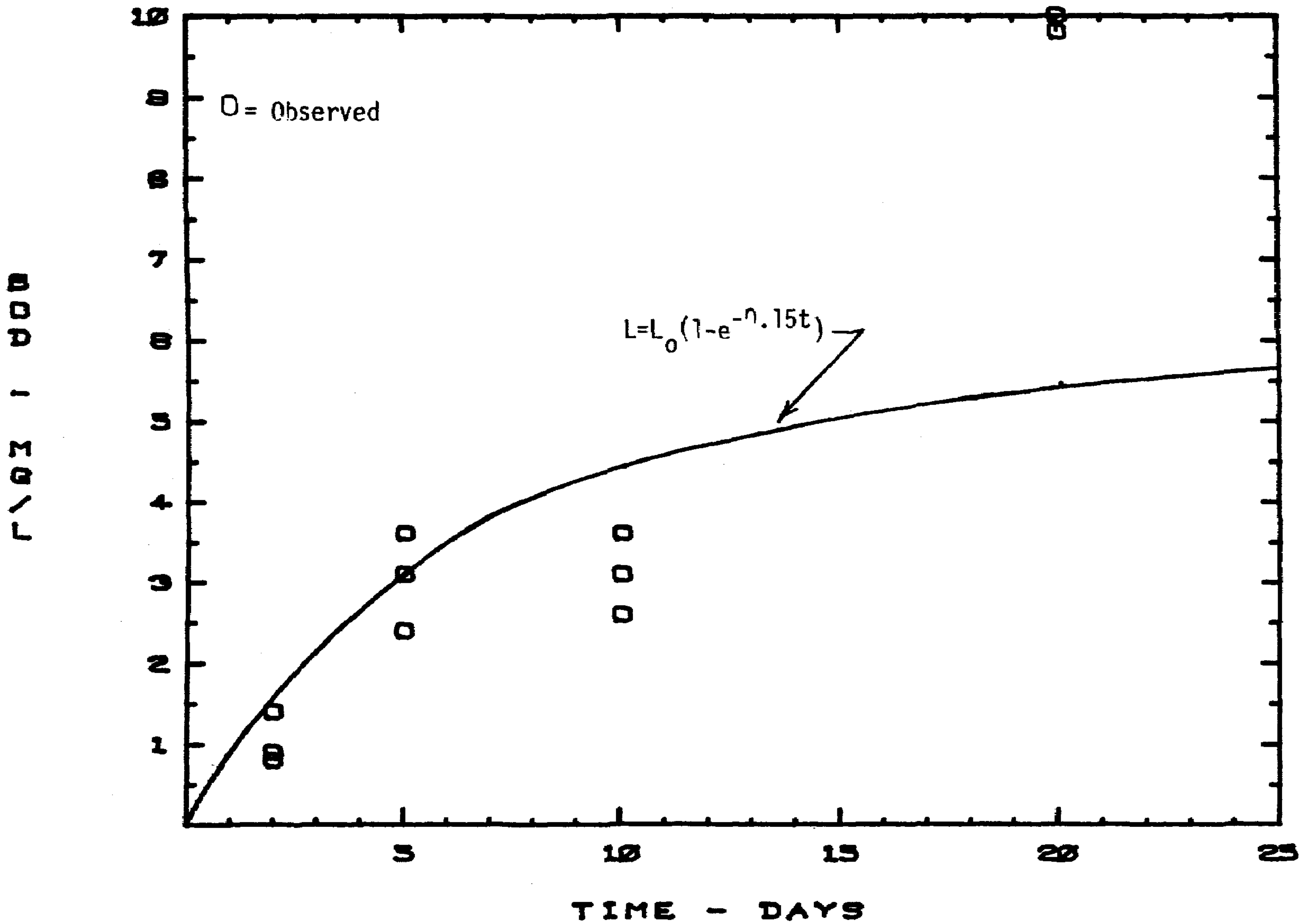

FIGURE 22 OBSERVED BOD AT SNAKE R.M. 847.2.
EPA-NFIC(DENVER) DATA
10/22/74-10/25/74

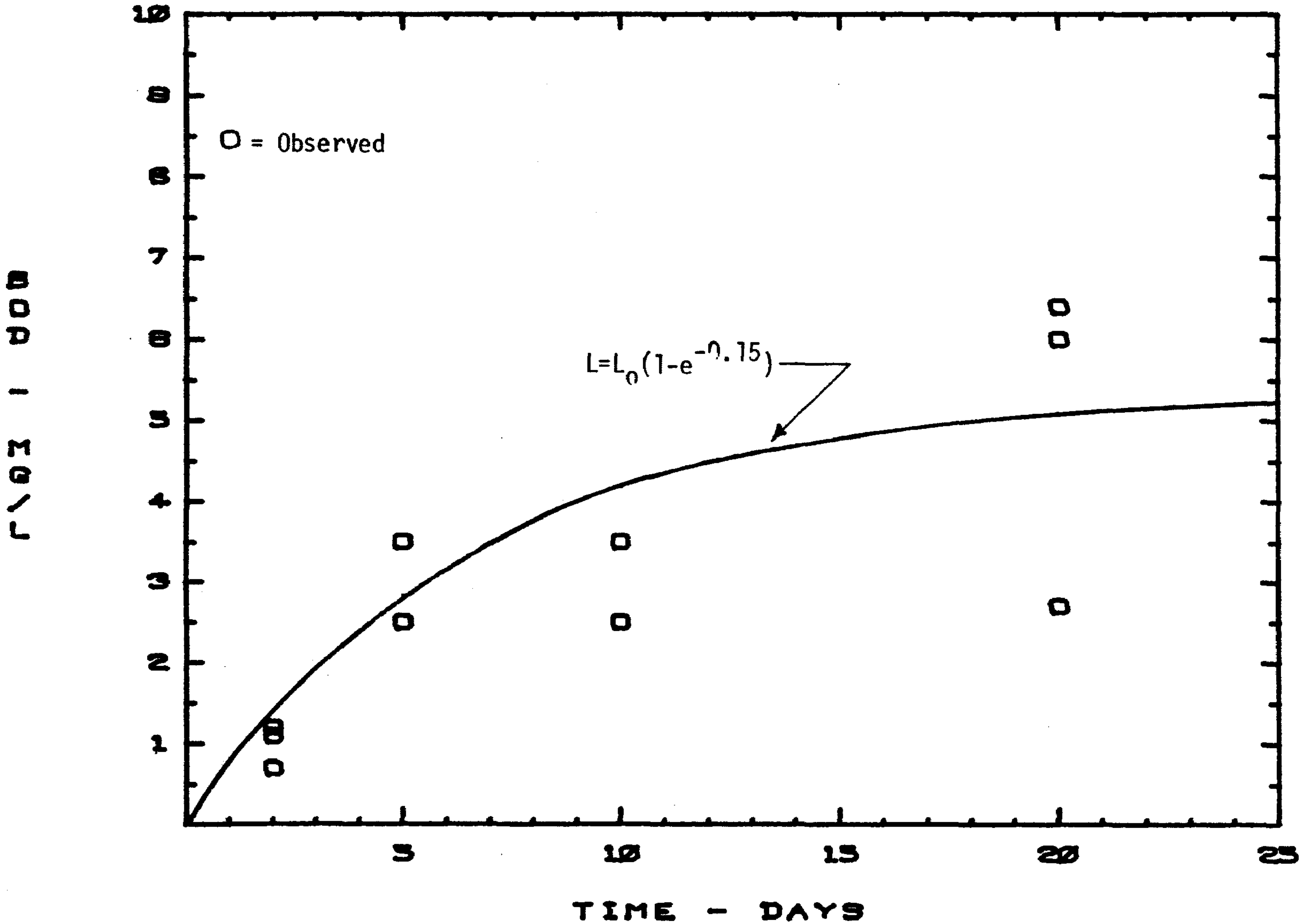

FIGURE 23 OBSERVED BOD AT SNAKE R.M. 854.0.
EPA-NFIC(DENVER) DATA
10/22/74-10/25/74

The reaeration rate, K_2, was adjusted for temperature using the factor, F_2:

$$F_2 = 1.024^{(T-20)} \tag{11}$$

Initial water quality conditions at the upstream boundary of the area modeled (R.M. 654.0) were taken as the average of receiving water quality measurements at the U.S. 30 Bridge. The average carbonaceous BOD loading, W_D, at this location was estimated from:

$$W_D = \frac{5.4 * Q * L_5}{(1 - e^{-5K_1})} \tag{12}$$

where,

Q = the river flow, cubic feet/second

L_5 = the average BOD at R.M. 654.0 (Table 10), mg/l

K_1 = the deoxygenation rate, days^{-1} (base e)

Furthermore, the carbonaceous BOD at this point was assumed to consist of 20,000 lbs/day from the Rupert STP and 72,000 lbs/day from other sources, including discharge from Minidoka Dam and surface and groundwater return flow. The Rupert STP portion of the carbonaceous BOD was treated in the model as a controllable point source, while the remainder was considered to be the background BOD in the river. It is the latter value which is given in Table 11 with the other boundary conditions for flow and water quality.

Table 10 Boundary conditions for the dissolved oxygen model of the Milner reach of the Snake River at R.M. 654.0, October 22 - 24, 1974.

Parameter	Units	Value
Flow	c.f.s.	3.84
Temperature	C	9.0
Dissolved oxygen	mg/l	11.7
Carbonaceous BOD	mg/l	4.2
Nitrogenous BOD	mg/l	0.0

Bulk river velocities, $\bar{u}$, were estimated from Equation (1).

The river flow, Q, in any segment below the Highway 27 Bridge (R.M. 654.0) was assumed to be equal to the average measured river flow at the Highway 27 Bridge (R.M. 652.3) plus the discharge from any surface returns or point sources discharges downstream from R.M. 652.3 (Tables 5 and 7).

The cross-sectional area for each river segment is given in Table 6.

The only dissolved oxygen source identified in the Milner reach of the Snake River was the photosynthesis production of dissolved oxygen by algae. Dissolved oxygen sinks included the respiration of algae and the benthic oxygen demand associated with organic sediments.

The demand associated with bottom sediments was determined from measurements made by Kreizenbeck (1974). The values used for each reach are shown in Table 11. These values are similar to those used in the permit analysis.

A number of different methods were used to estimate the net oxygen produced by algae. First of all, previous research (Bain 1967) has indicated that photosynthesis and respiration by algae can be related directly to cholorphyll a concentrations, ℓ, in the following manner:

$$P_{max} = 0.24 \ \ell \qquad (13)$$

$$R = 0.024 \ \ell \qquad (14)$$

Table 11 Sediment oxygen demand values used in the simulation of dissolved oxygen in the Milner reach of the Snake River. Values are based upon measurements made by Kreizenbeck (1974).

River Mile	Sediment Oxygen Demand (grams/meter^2/day)
654-652	0.89
652-650	1.04
650-648	1.04
648-646	1.85
646-644	1.85
644-641	1.85
641-640	5.32

These rates were considered by the investigator to be applicable when algae are actively growing, and at water temperatures of approximately 20°C. There was no way of assessing the first criterion with available data. The water temperature during the October 1974 survey was generally about 9°C (see Figure 6). Photosynthetic and respiration rates for the October 1974 survey, as computed from Equations (13) and (14) should, therefore, be considered as estimates only.

Time series observations of dissolved oxygen at R.M. 640.0 and R.M. 654.0 were also used to estimate photosynthetic rate. Assuming that the diurnal variation at the uppermost river boundary (Minidoka Dam at R.M. 675.0) is small, and that reaeration rates between Minidoka Dam are high, the diurnal variation in dissolved oxygen is given by Equation 8.

The photoperiod, p, for the Milner reach during October 22-24, 1974 was assumed to be 0.4 (9.6 hours). The time at which photosynthesis began, t, was assumed to be 0.3 (0700) Under these conditions, the values of maximum photosynthesis, Pmax, which appear to best fit the data (Figures 24 and 25) were found to be 15/mg/l/day at Milner Dam (R.M. 640) and 10 mg/l/day at Tom's Marina (R.M. 654).

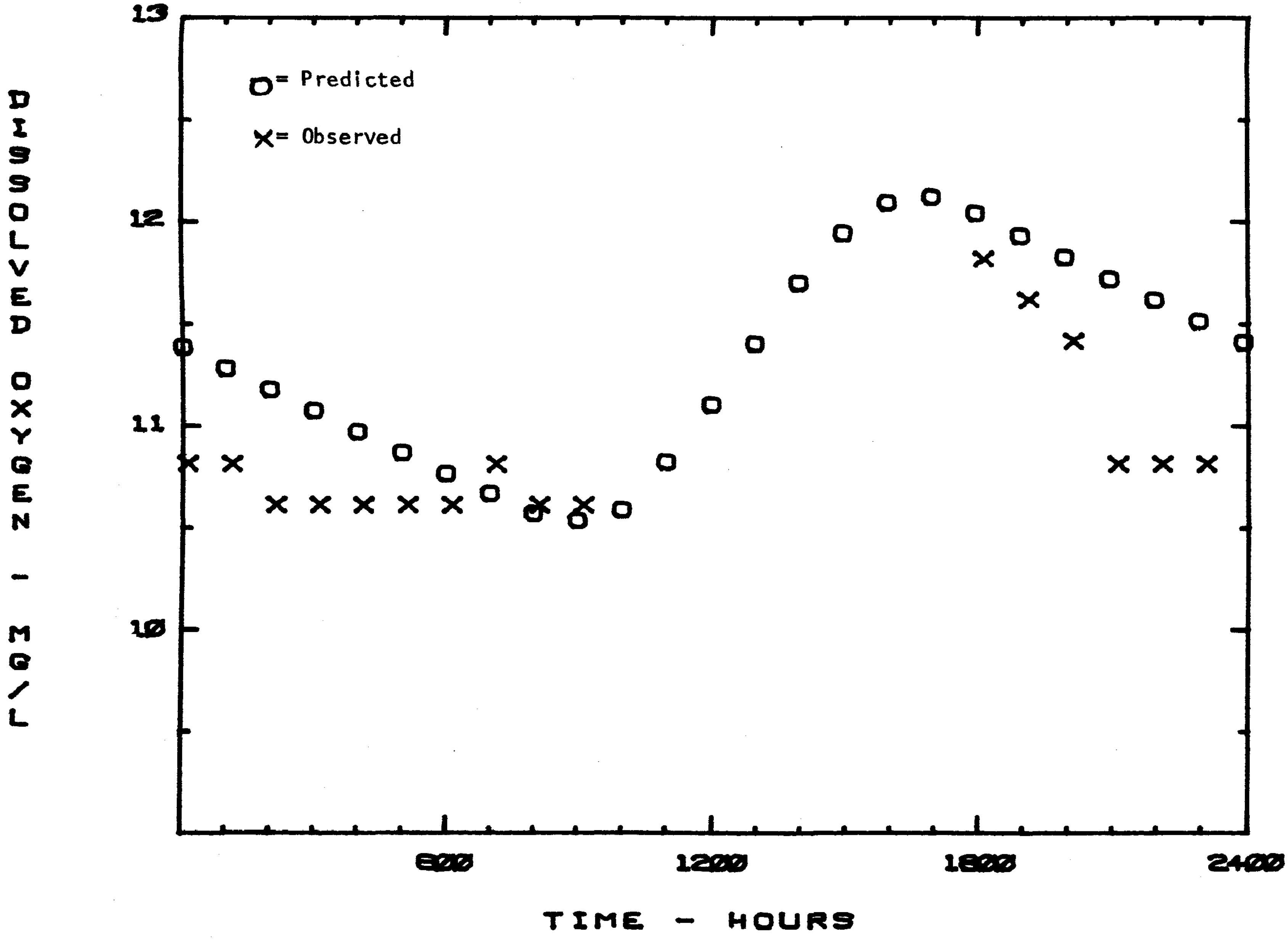

FIGURE 24 PREDICTED AND OBSERVED DIURNAL D.O. VARIATIONS AT R.M. 640. EPA SNAKE RIVER SURVEY 10/23/74.

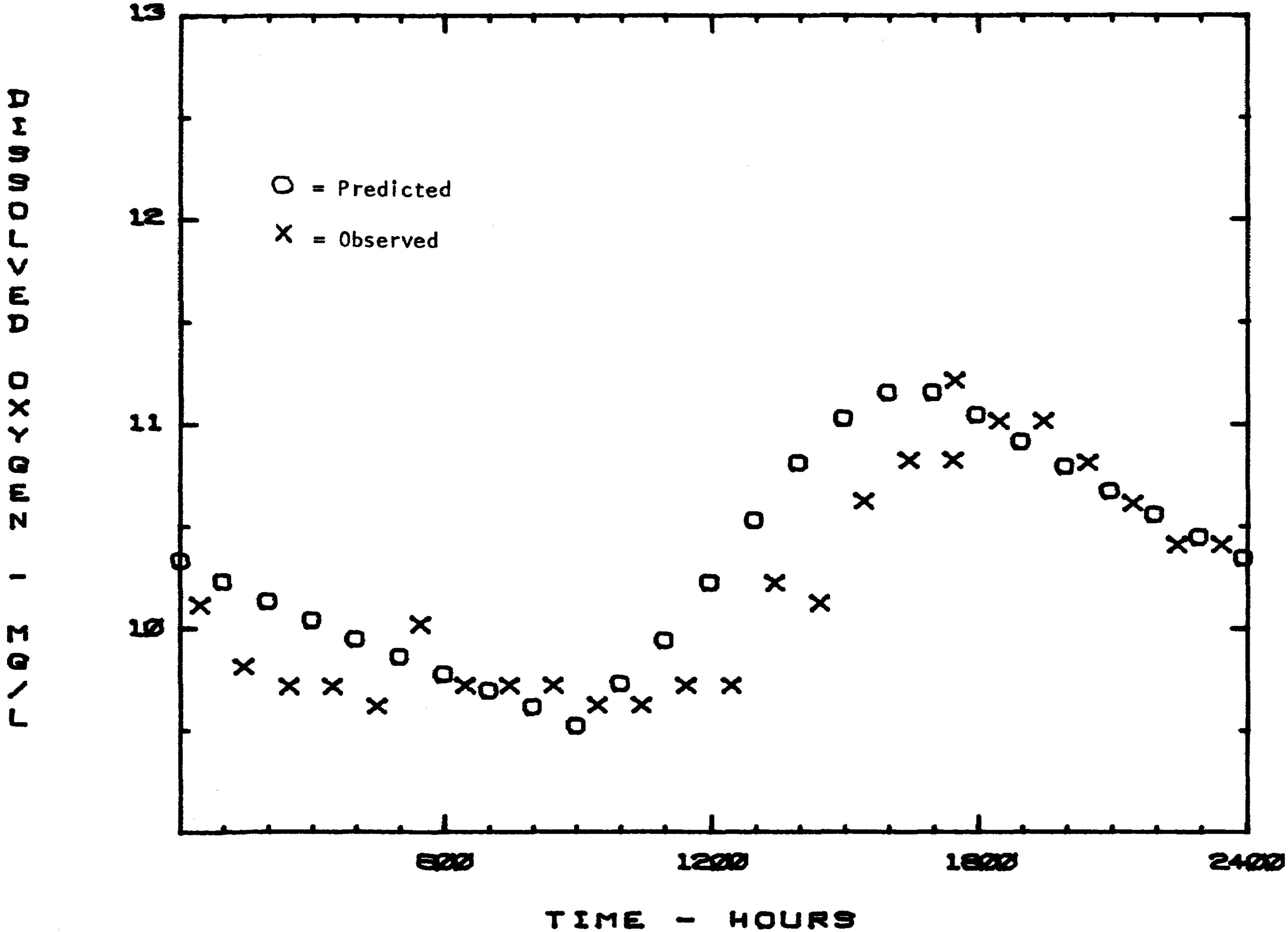

FIGURE 25 PREDICTED AND OBSERVED DIURNAL D.O. VARIATIONS AT R.M. 653. EPA SNAKE RIVER SURVEY 10/24/74.

The average photosynthesis, PAV, can be estimated from:

$$P_{av} = \frac{2 P_{max} * p}{\pi K_2} \tag{15}$$

where,

p = photoperiod, fraction of a day

Pav = the daily average photosynthetic production of oxygen, mg/1/day

Pmax = the maximum photosynthetic production of oxygen, mg/1/day

The permit analysis (Yearsley 1974) was made with the assumption that there was no production or respiration by algae. For the waste loads as given in Table 7, the velocities as estimated by Equations, initial water quality from Table 10 and sediment oxygen demand from Table 11, the simulated dissolved oxygen (Equation 5) without photosynthesis or respiration is given by the dashed line in Figure 26. Proper choice of photosynthesis and respiration rates, keeping all other inputs constant improved the simulation as shown by the solid line in Figure 26.

The rates of photosynthesis and respiration, as predicted by these various methods are shown in Table 12. A great deal of significance should not be given to the fact that the numbers computed in these different ways agree so well. It does indicate, however, that major sources and sinks for dissolved oxygen, as well as the value of important rate constants, have been identified.

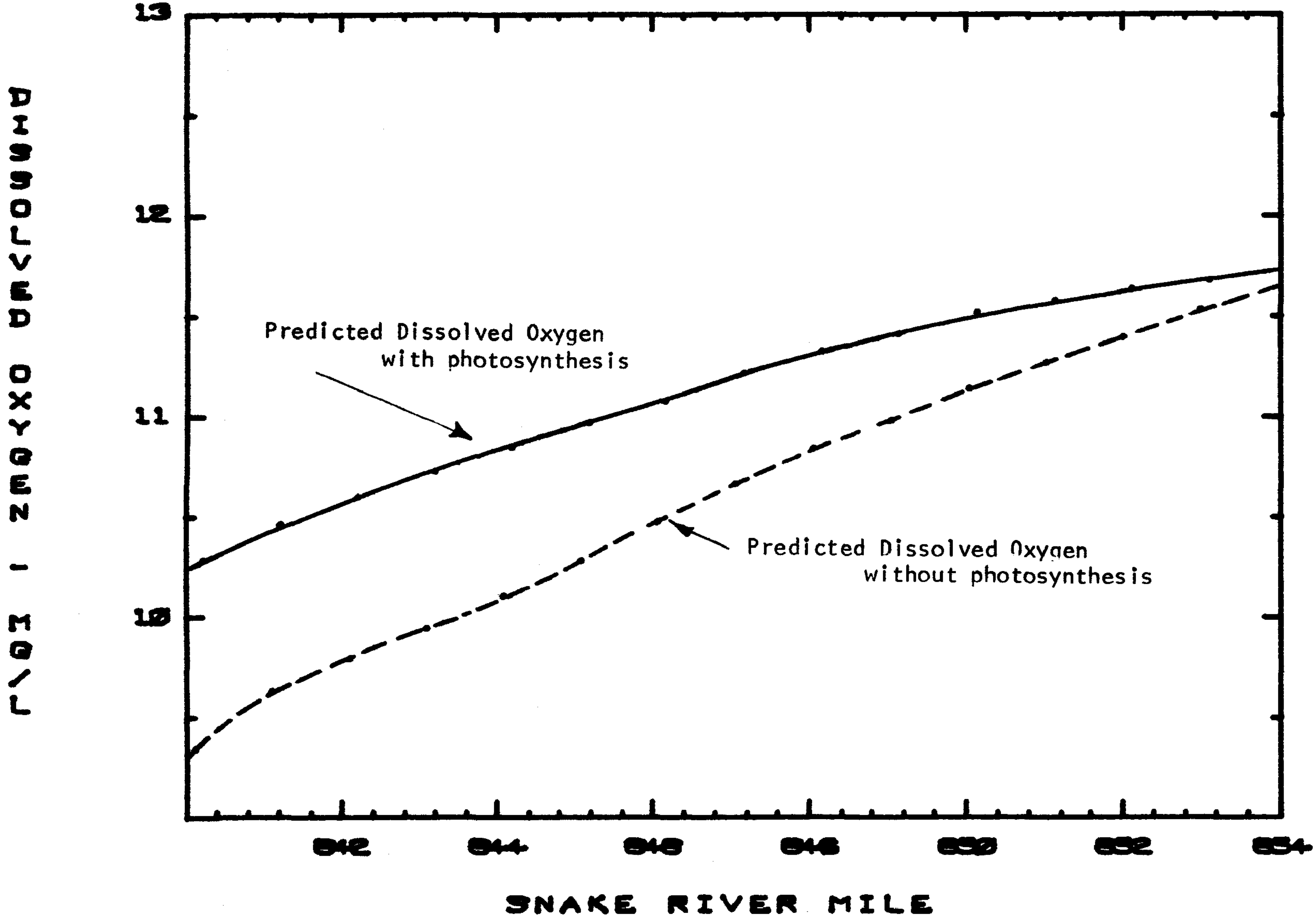

FIGURE 26 PREDICTED D.O. IN THE LAKE MILNER REACH OF THE SNAKE RIVER SHOWING THE EFFECT OF PHOTOSYNTHESIS.

Table 12 Production and respiration rates in the Lake Milner reach of the Snake River from: (1) Comparison of observed and predicted dissolved oxygen in Lake Milner. (2) Chlorophyll a measured by EPA-NFIC (Denver) during the October 1974 survey. (3) Diurnal observations of dissolved oxygen during the October 1974 survey.

Production(P) and Respiration(R) (mg/l/day)

River Mile	(1)		(2)		(3)	
	P	R	P	R	P	R
654-652	2.1	0.84	2.1	0.84	2.0	-
652-650	2.1	0.84	2.0	0.79	-	-
650-648	2.1	0.84	2.2	0.86	-	-
648-646	2.1	0.84	-	-	-	-
646-644	2.1	0.84	-	-	-	-
644-641	2.1	0.84	-	-	-	-
641-640	3.3	0.84	3.4	1.33	2.6	-

Having established that the model included the major contributions to the dissolved oxygen--BOD budget, we then estimated the sensitivity of the model to random error in important parameters. These parameters included the sediment oxygen demand, S; the net oxygen production by algae, P-R; the deoxygenation rate, K_1; the reaeration rate, K_2; and the longitudinal river velocity, $\underline{u}$. It was assumed that each of these parameters consisted of a mean plus a random component. The means were computed as described in Tables 11, 12 and Equations (10), (9) and (1), respectively. The random component was assumed to be normally distributed with a standard deviation proportional to the mean value. The proportionality constants were subjectively chosen. The proportionality constants are shown in Table 13. Twenty-five simulations were performed, with all inputs the same as previously described, except that the random component was added to each of the indicated parameters.

Table 13 Proportionality constants used to estimate standard deviation of important parameters. Standard deviation = x mean value of the parameter.

Parameter	Proportionality constant
Sediment demand, S	0.2
Net algal oxygen production, P-R	0.2
Deoxygenation rate, K_1	0.5
Reaeration rate, K_2	0.5
River velocity, U	0.1

Mean values of the dissolved oxygen, with a band of one standard deviation, as determined from these twenty-five simulations are shown in Figure 27. The minimum, mean and maximum observed dissolved oxygen is also shown.

The random error of these parameters does not explain the variability in the observed data, even though it does estimate the mean of the observed values to within 0.2 mg/l. However, the variability can be accounted for by including the diurnal fluctuations in dissolved oxygen due to photosynthesis. This is shown in Figure 28 where the diurnal variations estimated with Equation 8 have been added to the random variations in the steady-state simulations, as predicted above.

The worst error in predicting the mean of the steady-state dissolved oxygen concentration occurs at the downstream boundary, R.M. 640.0. The difference between the observed mean and one standard deviation below the predicted mean is 0.4 mg/l.

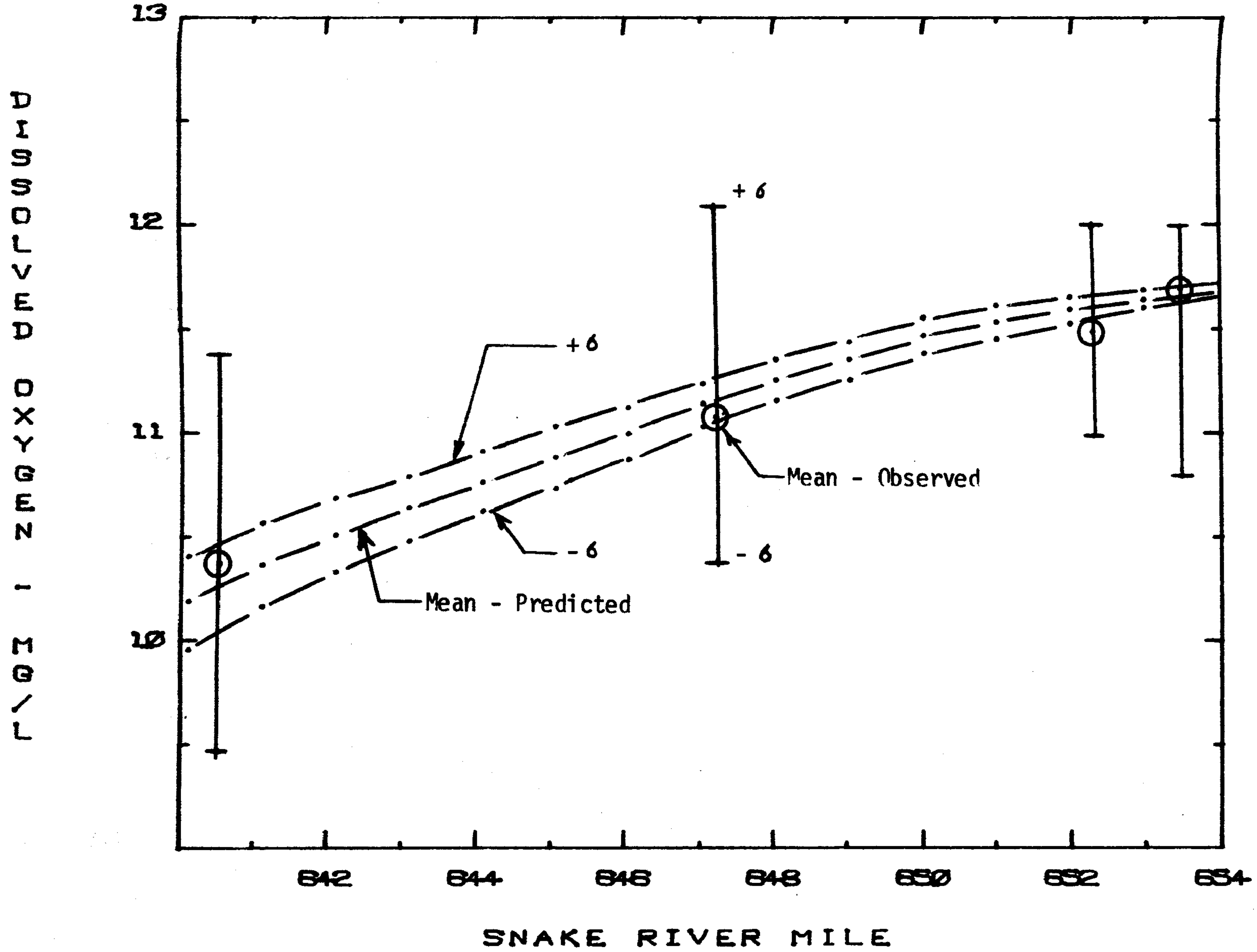

FIGURE 27 PREDICTED AND OBSERVED D.O. IN THE LAKE MILNER REACH OF THE SNAKE RIVER. SURVEY ON 1Ø/22/74-1Ø/24/74.

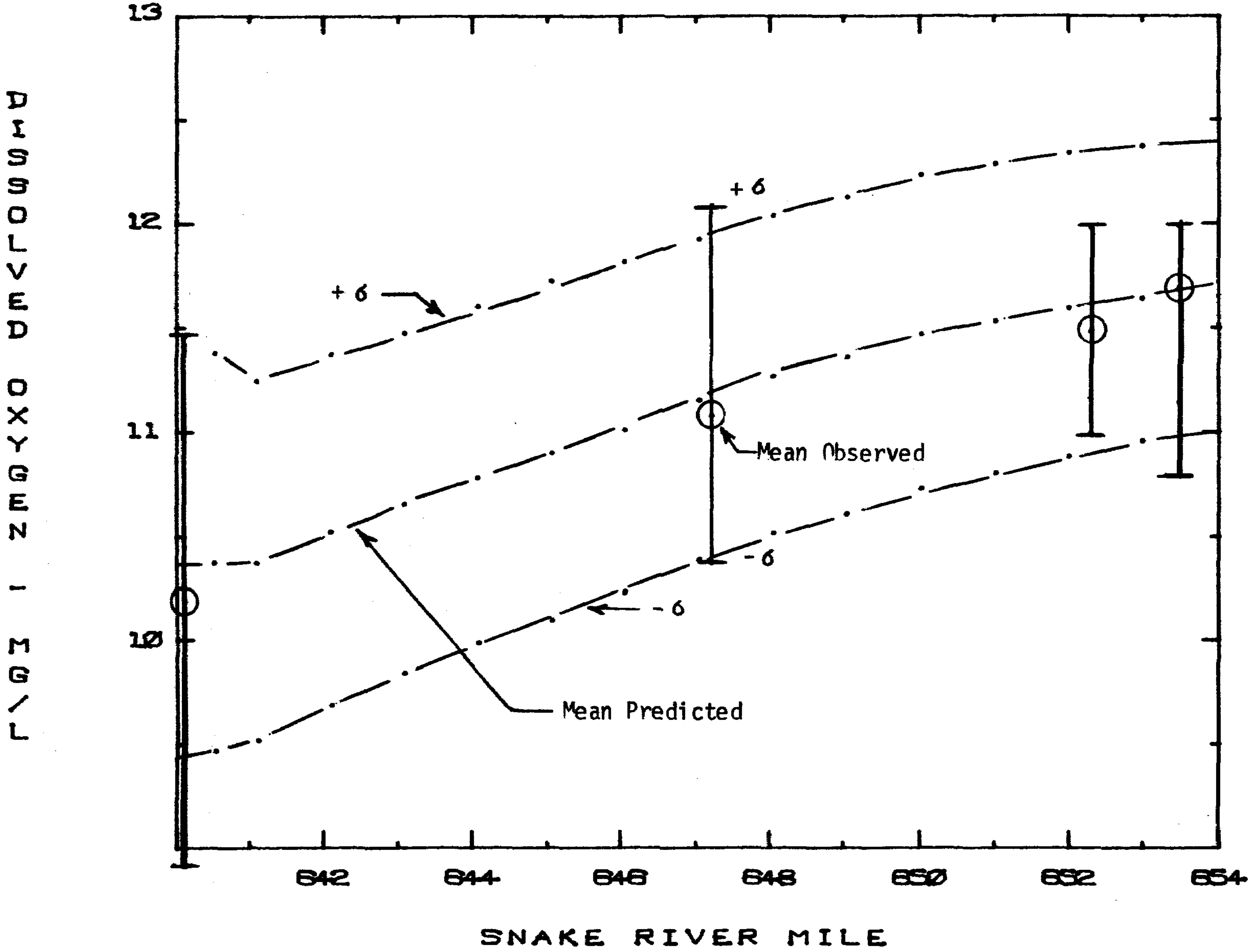

FIGURE 28 PREDICTED AND OBSERVED D.O. IN THE LAKE MILNER REACH OF THE SNAKE RIVER (INCLUDES ESTIMATED PHOTOSYNTHESIS). SURVEY ON 10/22/74-10/24/74.

The mean contribution of each dissolved oxygen sink and percent of total contribution is given in Table 14. Also shown in Table 14 is the net oxygen produced by the difference between photosynthesis and respiration of algae. Discharge from point sources account for 38% of the total demand on the oxygen resource. In-stream or non-point source BOD accounts for 28% of the demand, deaeration 23% and sediment demand 11%. Net oxygen produced by algal activity during this period was 43% of the total oxygen demand. While the contribution by algae at this time appears to be a benefit, the deposition of these same algae may be responsible for the sediment oxygen demand in Lake Milner and downstream reservoirs.

Table 14 Contributions of major dissolved oxygen sources and sinks to the total oxygen budget of the portion of the Milner reach of the Snake River from R.M. 654.0 to R.M. 640. Based upon October, 1974 water quality and hydrologic conditions.

Dissolved oxygen sink	Total oxygen demand (mg/1)	(% of total demand)
Surface transfer	0.59	23
In-stream (background) BOD*	0.72	28
Sediment demand	0.28	11
Point source BOD*	2.57	38

Dissolved oxygen source	Total oxygen demand (mg/1)	(% of total demand)
Net algal oxygen production	1.13	44

V. PREDICTION OF DISSOLVED OXYGEN AT LOW FLOW

The results of comparing the data observed during October 1974 with mean values predicted by the steady-state dissolved oxygen model, indicate that the major oxygen sources and sinks have been identified in the Milner reach of the Snake River. For the river flow waste discharge rates of October 1974, State of Idaho water quality standards for dissolved oxygen were not violated. However, as the river flow decreases, the likelihood of standards violations will increase, as long as the waste discharge rate remains constant. Once the validity of the modelling process has been established, the model should be used to predict water quality which occurs at lower flow regimes.

Initially, the effect of lower flows upon the Snake River was examined for those waste discharges and boundary conditions as observed in October 1974. Random variations, associated with error in the same parameters described previously, were also determined as a function of flow. The mean and standard deviation of the simulated dissolved oxygen are given in Table 15 for various flows between 3184 c.f.s. and 750 c.f.s.

These results indicate that the error associated with the simulation increases as the flow decreases.

Table 15 Variation of mean minimum simulated dissolved oxygen and maximum standard deviation with flow in the Milner reach of the Snake River. Base upon October 1974 water quality conditions.

River Flow (c.f.s.)	Mean Minimum dissolved oxygen (mg/l)	Maximum Standard deviation (mg/l)
3184	10.24	0.23
2000	9.04	0.36
1000	4.55	0.90
750	1.11	1.09

Various waste treatment strategies were also examined. The strategies included:

1) Eliminating the discharge from Simplot and Ore-Ida only

2) Reducing the discharge from all controllable point sources by 50%

3) Eliminating the discharge from all controllable sources

The loading levels from the various dischargers under these conditions are:

Table 16 Organic waste loading levels for point sources in Milner reach of the Snake River, assuming various waste treatment strategies: 1) No discharge from Simplot and Ore-Ida 2) Reduce all point sources by 50% 3) Eliminate all point source discharges

	Level 1 BOD_5 (lbs/day)	Level 2 BOD_5 (lbs/day)	Level 3 BOD_5 (lbs/day)
Rupert STP	11,000	5,500	0
J.R. Simplot	0	2,200	0
Heyburn STP	0	205	0
Burley STP	0	120	0
Bryant's Meats	200	100	0
Ore-Ida	0	1,260	0
Main Drain	41,000	20,500	0

The effect of these strategies upon minimum dissolved oxygen in the Milner reach of the Snake River is shown in Figure 29, as a function of flow. Table 17 gives an estimate of the dissolved oxygen increase, D.O., resulting from each of the strategies. The base waste discharge conditions is taken as October 1974. The dashed line in Figure 29 corresponds to the no discharge condition analyzed in the permit analysis (see Table 6 in Yearsley 1974). Comparison of the no discharge conditions using October 1974 results with that of the permit analysis indicate that water quality is better at higher flows, with the October 1974 results, but poorer at the lower flows. The major differences between the two conditions are associated with in-stream, or background, BOD and the assumptions regarding groundwater return flow. The in-stream ultimate BOD was found to be 4.2 mg/l from the October 1974, but was assumed to be 1.5 mg/l in the permit analysis. The groundwater return flow in the segment of the Snake River from R.M. 654--640 was found to be negligible from the results of the hydrologic studies. The permit analysis assumed that the groundwater return flow was 15 c.f.s. per mile or 210 c.f.s. for the 14 mile segment. The dilution effect of groundwater return flow, in addition to the low background BOD, would bias the permit analysis in favor of higher water quality at the low flows. At the high flows, the results of the October 1974 study would be biased in the same direction due to higher initial dissolved oxygen and net production of oxygen by algae. The latter was not considered in the permit analysis.

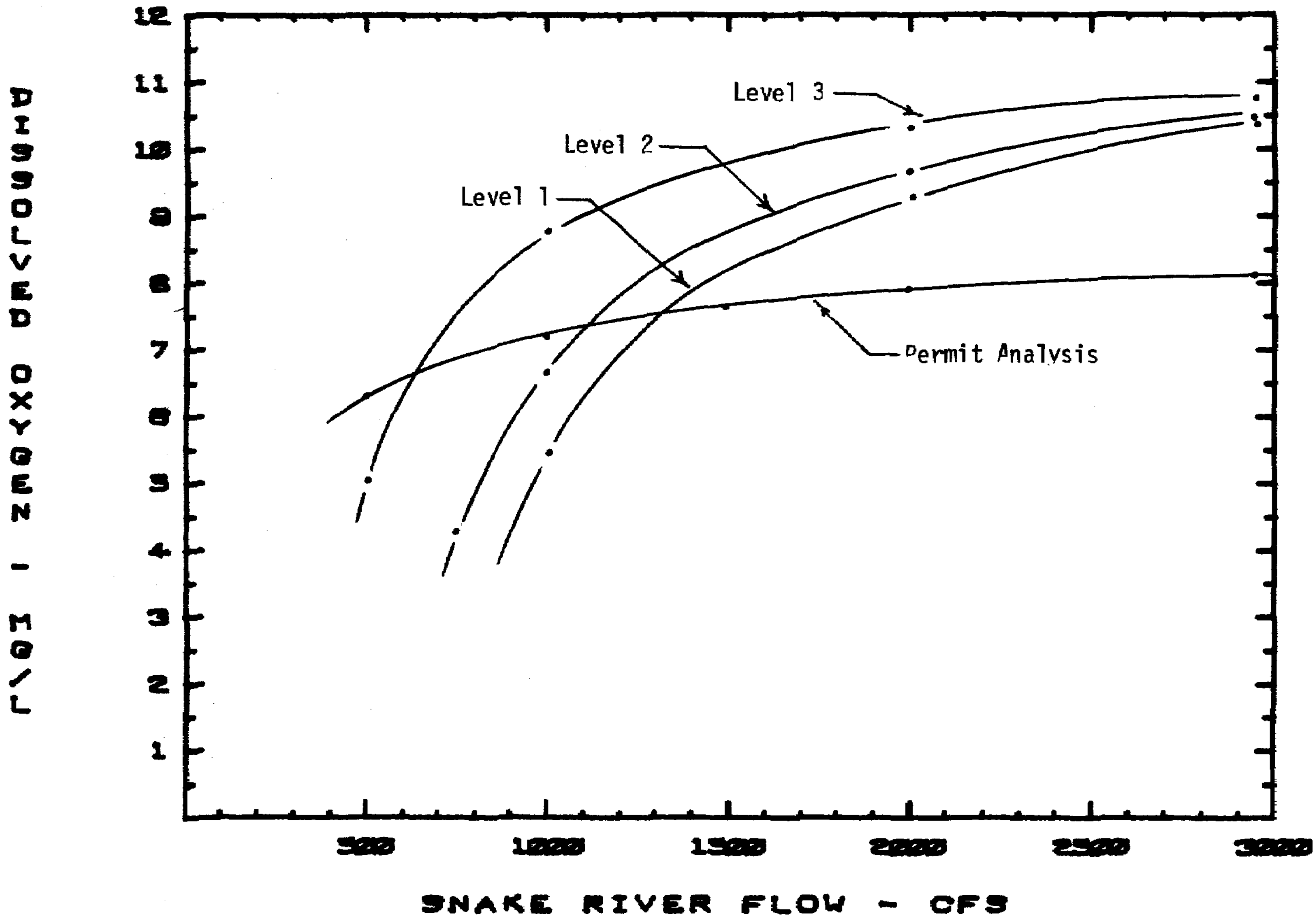

FIGURE 29 DISSOLVED OXYGEN AS A FUNCTION OF FLOW FOR VARIOUS LOADING LEVELS. MILNER REACH OF THE SNAKE RIVER.

Table 17 Improvement in dissolved oxygen, D.O., at various flows, resulting from various treatment strategies.

River Flow (c.f.s.)	Improvement in dissolved oxygen, D.O., (mg/l)		
	Level 1	Level 2	Level 3
3,184	0.15	0.28	0.56
2,000	0.27	0.66	1.30
1,000	0.94	2.16	4.25
750	1.28	3.23	6.35

In order to use the model as a predictive tool, it is necessary to examine the range of validity of the assumptions. The concepts upon which the model described in Chapter IV are based have been verified at low flows in other river systems, e.g., O'Connor and Di Toro (1970). It has not been done in the Milner reach of the Snake River. Important assumptions or principles developed in Chapter IV, which may be affected by reducing the flow include:

1) Reaeration rate, K_2, is a function of river temperature, velocity and depth Equations (9) and (11) only.

2) Deoxygenation rate, K_1, is a function of temperature only.

3) Dispersion effects are negligible.

4) Thermal stratification is unimportant.

5) Sediment demand is a function of temperature only.

The reaeration rate, K_2, is an impoundment river, decreases rapidly as the flow decreases. In the last segment of Lake Milner (R.M. 641.0--640.0), for the October temperature of 9.0°C and for a constant average depth of 15.0 feet, the reaeration rate, K_2, at various river flows, as computed from Equation (9) is given in Table 18.

Table 18 Reaeration rates in Lake Milner (R.M. 641.0--640.0) as a function of river flow. Average depth = 15.0 feet and river temperature 9.0°C.

River Flow (c.f.s.)	Average River Velocity (feet/second)	Reaeration Rate, K_2 ($days^{-1}$)
5,000	0.33	0.10
3,184	0.21	0.08
2,000	0.13	0.06
1,000	0.07	0.04
750	0.03	0.03

According to Bennett and Rathburn (1972), the range of depth for which Equation (9) has been verified varies from 4.0 to 24.2 feet. The range of velocities varies from 0.19 feet/second to 4.20 feet/second. The minimum reaeration rate was 0.32 $days^{-1}$ (base e). Fortescue and Pearson (1967) reported successful use of a similar formulation for predicting reaeration rates as lows as 0.04 $days^{-1}$. Hydroscience (1971) suggests that for water depths greater than approximately 10 feet the reaeration rate is a function of depth, H, only and suggests that the relationship is:

$$K_2 = \frac{2}{H} \tag{16}$$

Busch (1972) suggests that the relationship should be:

$$K_2 = \frac{0.3}{H} \tag{17}$$

The lower value is conservative in favor of improved water quality. Values for reaeration given in Table 17 are within the range of values predicted from Equation (17). A possible source for reaeration in the Milner reach, other than turbulent transfer due to river velocity, is that of wind-mixing. The research available is not conclusive regarding the quantitative nature of this source. Furthermore, while wind speeds observed during the October 1974 survey averaged between 10 and 15 miles per hour for extended periods during the day on Lake Milner, there were equally long periods at night when calm or semi-calm conditions prevailed.

The deoxygenation rate, K_1, is generally assumed to be a function of temperature only. Research indicates, however, that the turbulence associated with high stream velocities may increase deoxygenation rates. Hydroscience (1971) reports experimental results showing that the deoxygenation rate, K_1, varies from 0.1 to -.5 $days^{-1}$ (base e) for rivers with depths of 10 feet or greater. The values obtained from the laboratory should provide a lower bound on the rate since turbulent mixing is at a minimum.

Deposition rates of suspended organic material may increase as the river flow decreases. This results in an apparent increase in the consumption of BOD, but is not reflected in the dissolved oxygen budget as in-stream biological oxygen demand. This increased rate does contribute to the sediment oxygen demand so that while the reaction time may be longer, there will still be the same total oxygen demand.

The effects of longitudinal dispersion were assumed to be negligible in the development of Equations (2), (3) and (4). As shown by Thomann (1973), the maximum dissolved oxygen deficit is similar in dispersive and non-dispersive systems, only when the frequency associated with the discharge is small. That is, when there is no time variation of the discharge rate. The difference between non-dispersive systems increases as the discharge frequency increases. The dispersive nature of the system is measured by a dimensionless number, P:

$$P = \frac{K_1 E}{U^2} \qquad (18)$$

Assuming that the dispersion coefficient E = 300 feet^2/day, U = 0.2 feet/second and K_1 = 0.1 days^{-1} (1.16 x 10^{-5} seconds^{-1}), then P = 0.1. Figure 8 in Thomann (1973) shows that the maximum dissolved oxygen deficit associated with a period of about six (6) days would be attenuated 60% if dispersion were included. The amount of attenuation increases as the flow decreases. There are not adequate time series of all the discharge data during the October, 1974 survey. However, if the mean values for waste discharge, given in Table 7 are accurate, then the simulation associated with those values will be essentially the same whether dispersion is included or not. This is true because there is very little attenuation of the steady-state or long term (i.e., periods greater than approximately 30 days) discharge, when dispersion is included.

Thermal stratification also reduces the vertical mixing and prevents atmospheric oxygen from diffusing to the bottom of the river. In many reservoirs, this results in anoxic conditions in the bottom. WRE (1969) has provided a crude criterion for estimating when a river may be thermally stratified. This criterion is based on a Rayleigh-like number,

$$\overline{\pi} = \frac{LQ}{DV}\sqrt{\frac{\rho_o}{g\beta}} \qquad (19)$$

where,

L	=	reservoir length
D	=	reservoir depth
Q	=	Volume discharge rate
V	=	reservoir volume
ρ_o	=	water density
β	=	Average density gradient
g	=	gravitational constant

For certain simplifying assumptions regarding the density profile, Equation (19) can be reduced to:

$$\overline{F} = 320 \frac{LQ}{DV} \qquad (20)$$

Assuming, L = 73920 feet (14 miles),

D	=	10 feet
V	=	1 x 10 cubic feet (24,000 acre feet), then
$\overline{F}$	=	1.2 at 500 c.f.s. and
$\overline{F}$	=	7.5 at 3184 c.f.s.

As a rule of thumb, WRE (1969) suggests that for values of $\overline{F}$ much less than $1/\pi$ (0.318), the water body will be thermally stratified; for values approximately equal to $1/\pi$, weakly stratified; and for values much greater than $1/\pi$, the water body will be well-mixed. The results for Lake Milner indicate that thermal stratification will not be significant for the flow range 500--3184 c.f.s.

Accumulation of organic sludge on the river bottom increases as the river velocity decreases. Krenkel et al (1969) describe the work of Velz (1958) in which he showed that acute BOD effects from bottom deposits may be expected when the river or reservoir velocity is reduced below 0.6 feet/second. Krenkel at al (1969) also indicate that the oxygen demand associated with these deposits is significantly affected by ion change through the soil, microbiological action and leaching of organic and mineral substances.

In summary, there are certain dangers in extending the mathematical model to lower flow conditions. In the case of deoxygenation rate, K_1, and the reaeration rate, K_2, the justification for doing so is based upon the success of research in other river systems, or maintaining a conservative waste loading. Analysis of important dimensionless parameters indicates that dispersion effects and thermal stratification will not seriously affect the results for flows ranging between 500 and 3184 c.f.s. The percent contribution from sediment demand decreases as the flow decreases, so that the order of the error would be 10% or less, assuming that the sediment demand was in error by 100%.

VI. FINDINGS

The results of the October 1974 field study and mathematical modelling showed:

1. Dissolved oxygen standards were not violated in the Snake River during the period October 22--24, 1974.
2. Groundwater return flow was negligible between R.M. 654.0 and 640.0 of the Snake River during the October, 1974 survey.
3. Oxygen production by algae contributed significantly to the dissolved oxygen budget of Lake Milner. The total contribution amounted to an estimated 1.1 mg/1.
4. Major sources of oxygen demand during the October 22-24, 1974 survey included organic wastes from municipal and industrial wastes sources, surface transfer of oxygen, in-stream (background) biological oxygen demand, sediment oxygen demand and respiration of algae.
5. The steady-state mathematical model for dissolved oxygen simulated the mean observed dissolved oxygen with a maximum difference of 0.2 mg/1. The estimated error associated with

the simulation had a maximum standard deviation of 0.24 mg/l.

6. Discharges from controllable point sources contributed 38% of the total oxygen demand in the Milner reach of the Snake River. Maximum impact occurred in the last six (6) miles (R.M. 646 to 640) of the river.

7. Extrapolation of the mathematical model to low flows indicates that violations of the State of Idaho water quality criterion for dissolved oxygen would occur at river flows of 2,000 c.f.s. at waste loadings equal to those observe during October, 1974.

8. Estimated standard deviation of the simulations increases as the river flow decreases. At 3184 c.f.s. the estimated standard deviation was 0.24 mg/l and 0.90 mg/l at 750 c.f.s. for October, 1974 discharge rates and water quality boundary conditions.

9. The permit analysis (Yearsley 1974) predicted better water quality at low flows than the extrapolation of results from the October, 1974 survey. The discrepancy is due to the lower in-stream BOD and higher groundwater return flow assumed in the permit analysis.

CONCLUSIONS

1. Dissolved oxygen levels in the Milner reach are influenced strongly by river hydrology and point source discharge of organic wastes. Greatest impact from the point source discharges is felt in the last six miles (R.M. 646--640) of the segment. Non-controllable factors, including sediment demand, surface transfer and non-point source BOD, are also important.
2. Steady-state mathematical modelling methods provide reliable means for estimating the impact of waste discharges, sediment oxygen demand, photosynthesis and respiration and surface transfer, when supported by an adequate field study program.
3. The extrapolation of model results to low flow conditions should be done with care. Particularly close attention should be given to the determination of reaeration rates and sedimentation rates at low flows.

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