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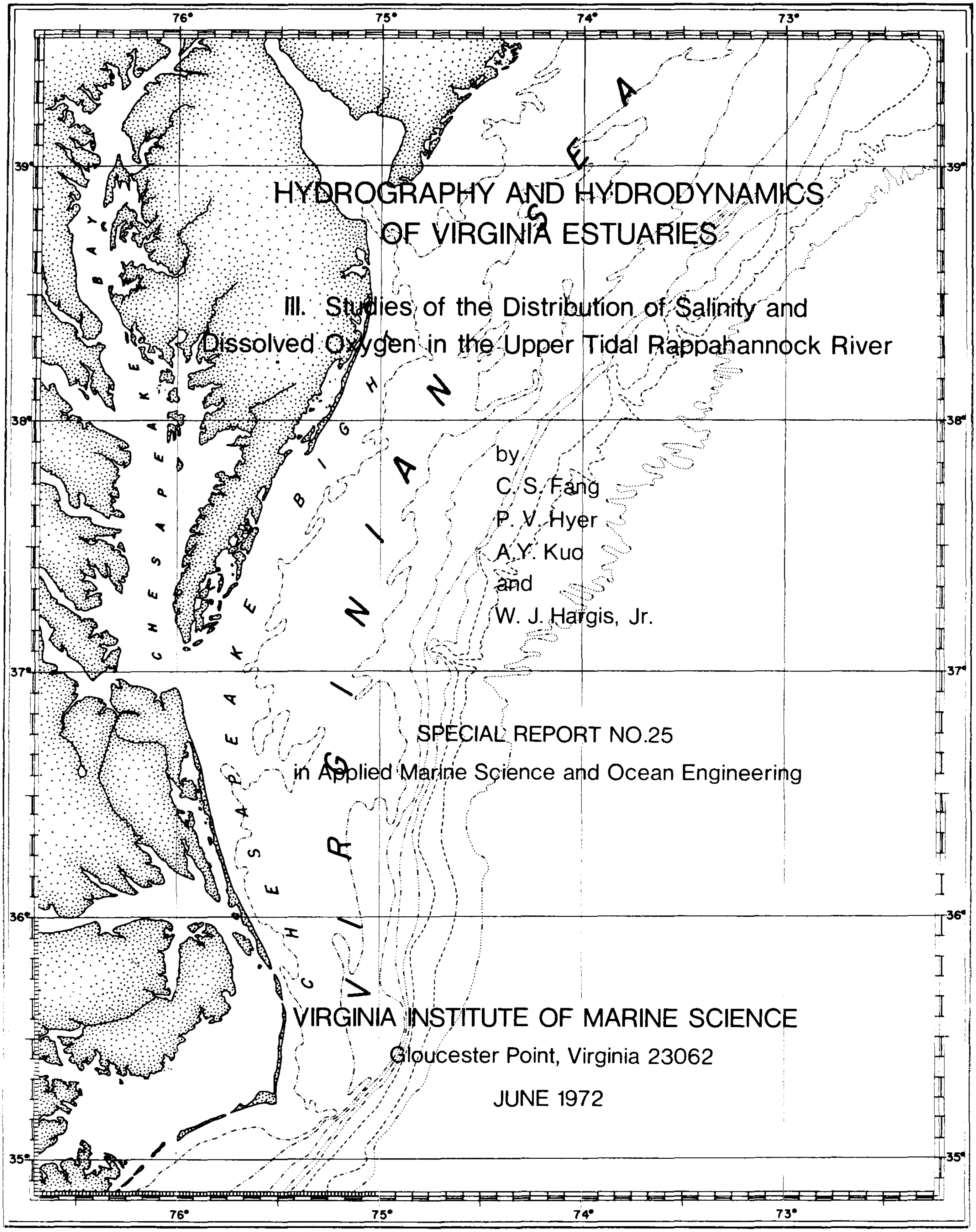

HYDROGRAPHY AND HYDRODYNAMICS OF VIRGINIA ESTUARIES

III. Studies of the Distribution of Salinity and Dissolved Oxygen in the Upper Tidal Rappahannock River

by
C. S. Fang
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SPECIAL REPORT NO.25
in Applied Marine Science and Ocean Engineering

VIRGINIA INSTITUTE OF MARINE SCIENCE
Gloucester Point, Virginia 23062
JUNE 1972

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Dr. William J. Hargis, Jr.
Director

June, 1972

TABLE OF CONTENTS

Table of Contents (cont'd)

LIST OF TABLES

LIST OF FIGURES

List of Figures (cont'd)

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ABSTRACT

An intensive hydrographic survey was conducted along the Rappahannock Estuary, Virginia in the summer of 1970. Hourly measurements of salinity, DO, temperature and current were taken continuously for 52 hours at various points in each of the 25 transects chosen. Monthly slack water runs have been conducted continuously since August, 1970. Four mathematical models were set up. One is based on the mass balance equations for salt, BOD and DO, with the convective velocity including both fresh water discharge and tidal current. Taylor's formulation of dispersion coefficient was extended to include the effect of density inhomogeneity in the saline water. The differential equations were solved numerically by an implicit finite difference scheme with Gaussian elimination method. In the second model, the convective velocity included the non-tidal component only. This model is suitable for investigating long term variation of salinity intrusion. The tidal current was treated as a kind of pseudo-turbulence and was incorporated into the dispersion term, with a dispersion coefficient much larger than that of the first model.

The third and forth models are solved by the same mass balance equations as the first two, but employ a segmented network of the water body under consideration, with interface sources and sinks within each segment as in

Thomann's time-dependent model (1967).

In these two models all equations are integrated by a forth-order Runge-Kutta procedure whereby the truncate error is kept within a limit value by changing the time step size. In the salinity model, tidal mixing is simulated by the dispersion term, while the dissolved oxygen model explicitly considers tidal behavior in the advective term. Within each finite volume the concentration is assumed to be completely mixed.

INTRODUCTION

Water and oxygen are the most essential two requirements for the sustainment of life. The most important problems confronting water resource engineers and scientists today concern the prediction and evaluation of future water consumption and water quality control, with respect to different treatment methods and waste effluent discharge into river or estuarine waters.

Each of these receiving water bodies has the capacity to assimilate a certain quantity of introduced waste materials as a direct result of naturally occurring physical, chemical, and biological interactions and conversion processes. Evaluation of the assimilation capacity for a particular river or estuary is a complex and difficult task.

Typical methods used to determine dissolved oxygen levels and other water quality parameters, within the framework of the natural assimilation capacity, include field measurements and testing in the receiving water body, experimentation in verified hydraulic models, and formulation of a rational mathematical model.

Four water quality mathematical models were formulated for the upstream portion of the Rappahannock tidal river system in Southeastern Virginia. Two models, concerned with dissolved oxygen, are, in turn, the explicit model (Thomann's 1967) and the implicit model, both of which solve the unsteady state diffusion equation in finite difference form. The other two models consider estuarine salinity fluctuations and is also based on the same mass balance equation, which again is solved by explicit and implicit schemes respectively. The models are intended to serve as tools to aide in managing and planning the water resources of the Commonwealth, with an overall goal of obtaining maximum use of available resources to support projected urban and industrial growth, while maintaining or improving the present life supporting quality of the fresh and salt water environment of the region. In Virginia, the water quality control problems are the major concern of the State Water Control Board, and the water development aspects are handled by the Division of Water Resources.

The research described in this report was conducted as the second year study in developing a computer-oriented model for use in the planning and management of Virginia tidewater river systems.

DESCRIPTION OF THE STUDY AREA

The Rappahannock River lies wholly in the State of Virginia. It rises in the Blue Ridge Mountains and flows in a general southeasterly direction first, 78 miles across the Piedmont Plateau to the"fall line"at Fredericksburg, head of the river tidewater, then 107 miles across the coastal plain to enter Chesapeake Bay.

For the first 70 miles above the mouth, the stream assumes the characteristics of a tidal estuary; above this it is distinctly fluvial.

The total watershed of the Rappahannock includes 2700 sq. miles, 1590 of which are tributary to the nontidal section of the river. Fredericksburg, with a population of 15,000 is the largest town in the basin. Farming and dairying are the principal industries . Fishing and lumbering industries are also important to the area. An FMC plant near Fredericksburg, is the largest and may be the only existing chemical industry in this basin.

The average annual precipitation in the basin is about 41 inches and the run-off amounts to approximately 35 percent of the total precipitation. At Fredericksburg, where the main stream has a drainage area of 1590 sq. mi., the flow has been known to vary from 10 to 66,000 cubic feet per second, the average flow being about 1700 cubic feet per second.

The mean rise of tide is 1.2 feet at the mouth, increasing to 1.6 feet at Tappahannock (43 miles upstream) and 2.8 feet at Fredericksburg. Occasional variations from these heights occur, due to the direction and force of the wind, with recorded rises of 5 and 6 feet, respectively, at Tappahannock and Fredericksburg. During the periods of low fluvial flow, reversals of the current occur throughout the entire length of tidewater. Salt water extends to about 70 miles above the mouth, the limit of brackish water being reached a few miles above Port Royal.

Climate is such that during the winter months there is little accumulation of precipitation through freezing rain and snow. Low evaporation losses and no transpiration contribute to a relatively large run-off. During summer, high temperatures with consequent high evaporation and transpiration, produce a relatively low percentage of run-off. Near Fredericksburg, the maximum runoff is 66,000 cfs and the minimum runoff is 10 cfs. The mean flow is 1712 cfs.

In the "Rappahannock River Basin," published by Division of Water Resources, Volume I through Volume III have a detailed description of the economics, natural resources, a hydrologic analysis and other information about the basin. Figure 1 is a map of the Rappahannock River tidal portion basin.

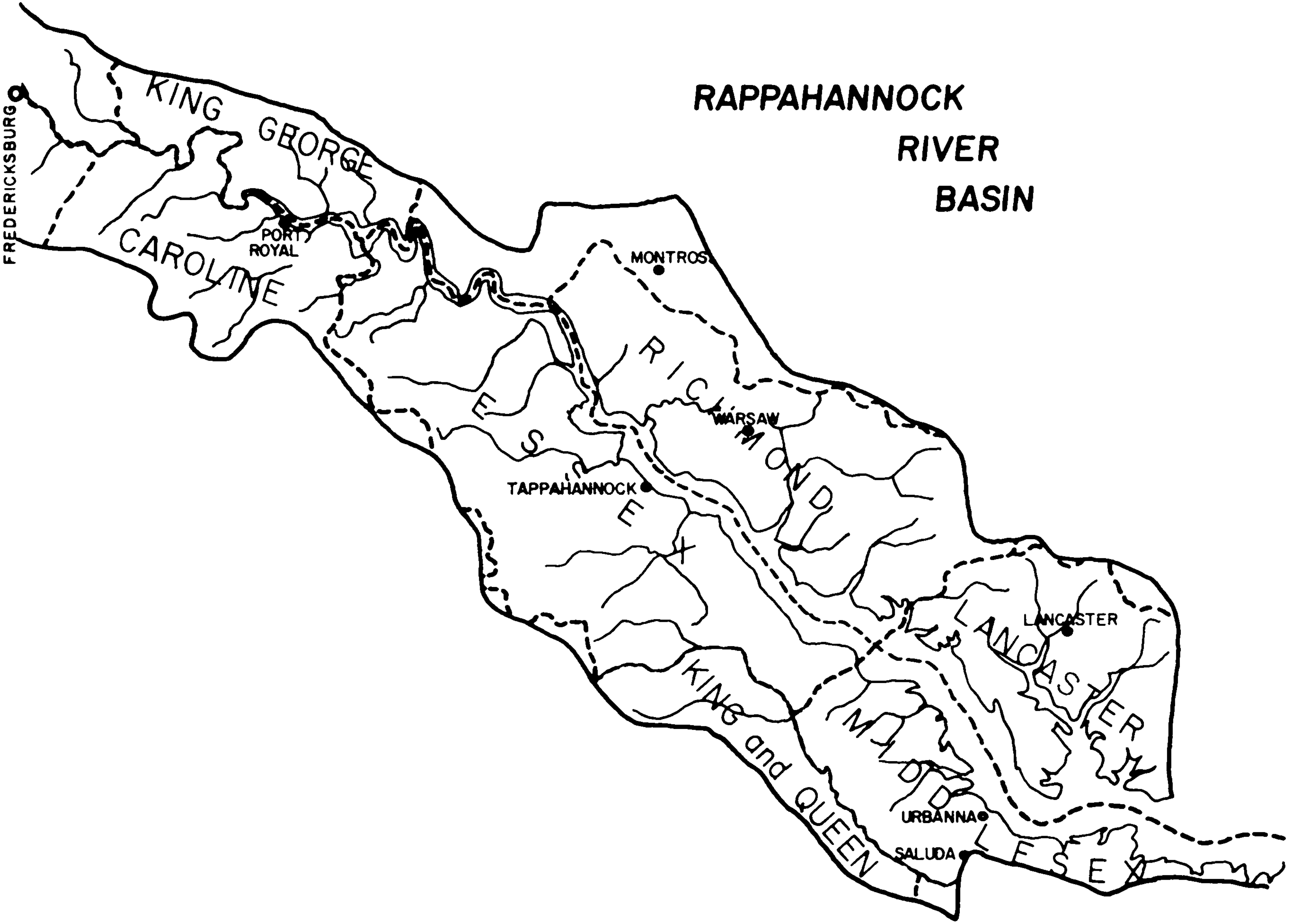

Figure 1. The Rappahannock River Estuary of Virginia. (From Planning Bulletin 219, Volume I. Division of Water Resources)

HYDROGRAPHIC SURVEY

The two most important phenomena to consider in the modeling of an estuary are transport processes and reaction processes. Transport processes are basically hydrodynamic and include advection, turbulent diffusion and, when spatial averaging is involved, dispersion. The reaction processes are chemical and biological including reaeration, deoxygenation, photosynthesis, respiration and other interactions. Both transport processes and reaction processes vary from estuary to estuary. A good estuarine model depends upon the parameter modeled as well as the required spatial and temporal refinement.

In order to construct correct mathematical models for predicting changes in the spatial and temporal distribution of salinity and dissolved oxygen in the Rappahannock River, field data were needed to provide values for the various coefficients and parameters used in modeling as well as for verification purposes. Required information consisted of the following: basin geometry, fresh water discharge, mean cross sectional velocities within successive reaches, mean discharge through cross sections for at least one complete tidal cycle, tidally induced fluctuations in mean salinity and dissolved oyxgen at each cross section, water level fluctuations, spatial distributions of salinity and dissolved oxygen for various flow conditions, and longitudinal changes in biochemical oxygen demand for various flow conditions.

To satisfy these requirements, two types of field survey were planned and executed. The first survey consisted of measurements of temperature, salinity, dissolved oxygen, currents and water levels in the tidal portions of the Rappahannock river. Figure 2 shows the stations occupied during this field operation, while Figure 3 shows the stations schematically, together with landmarks. Measurements were made as close to simultaneously as practicable. A total of 25 transects were occupied during the survey, each having three stations. Distances between transects average two miles.

Salinity samples and temperature-velocity measurements were obtained at hourly intervals for approximately fifty-two consecutive hours at each station. Salinity sampling depths were at six foot increments from surface to bottom (inclusive). Water samples for dissolved oxygen analysis and temperature were taken at hourly intervals, at surface, mid-depth and bottom level for all stations on each transect.

Water samples for salinity and dissolved oxygen analysis were obtained with Frautschy bottles, placed in 4 oz. sample bottles and subjected to laboratory analysis. Dissolved oxygen samples were analyzed using the Azide modification of the Winkler method while salinities were determined with a laboratory model inductance salinometer (Beckman Model RS7-A). Velocities were measured with savonious rotor type current meters. Temperatures were sensed with ARA thermistors attached to the current meter housings. Values for current

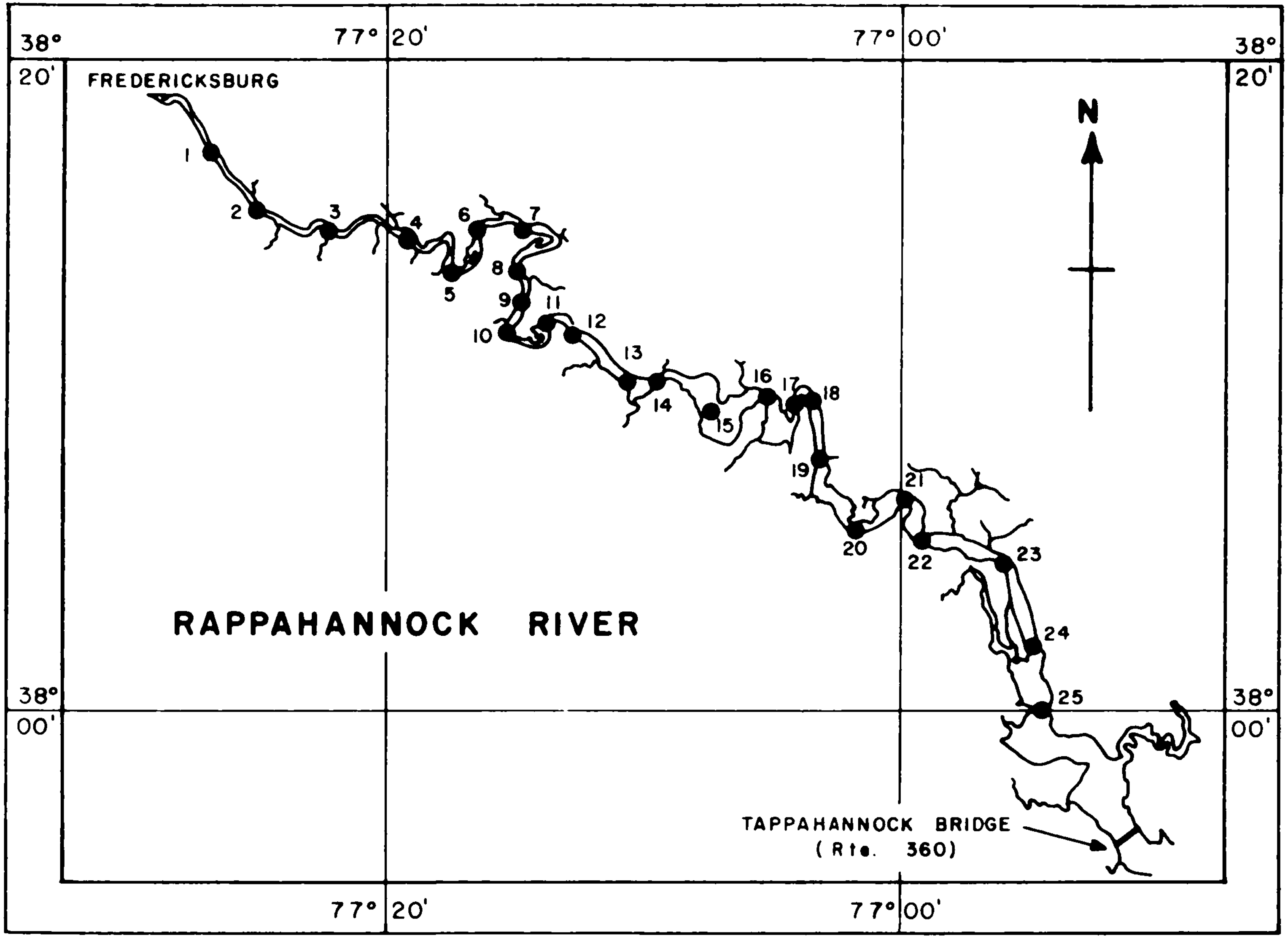

Figure 2. Map of sampling stations occupied in Operation Rappahannock River.

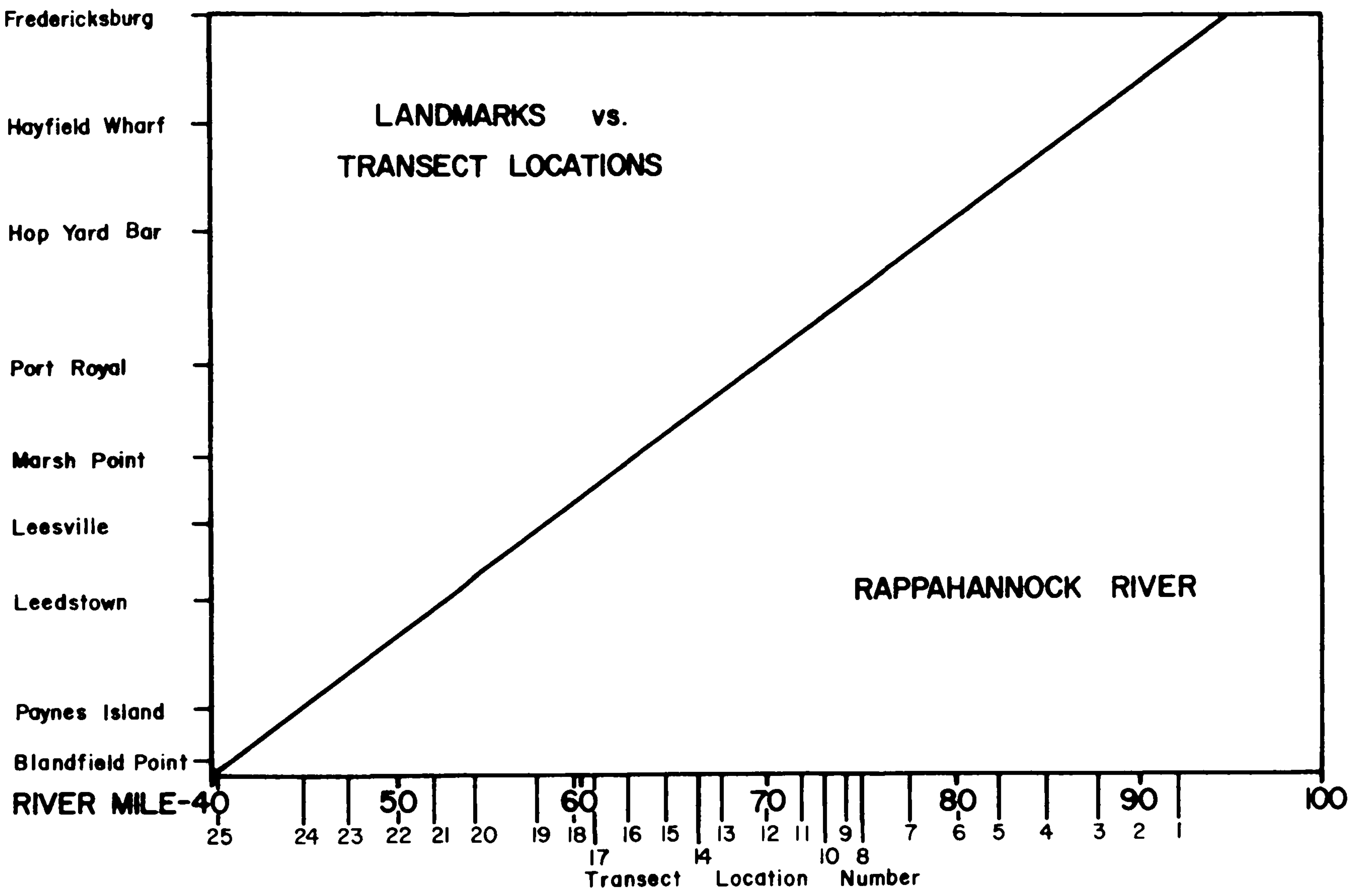

Figure 3. Schematic diagram of stations occupied in Operation Rappahannock River.

speed and direction as well as water temperature were read from deck readout meters. The current meter-thermistor combination was lowered by a hand cranked winch. All sampling was accomplished by two-man crews in small (17 to 22 foot) outboard boats; one boat and crew sampling all stations on a given transect once each hour. The entire survey was completed during a 30 day period in July & August 1970.

Water level fluctuations (tides) were measured at seven locations, all gauges periodically being surveyed for vertical control.

Bathymetry of each transect was obtained from Corps of Engineers, Norfolk District.

A slack water run survey was begun in August 1970 and is continuing. On a monthly basis, temperature is measured; and salinity, dossolved oxygen and BOD samples are taken at local slack water before flood tide (low slack) or slack water before ebb tide (high slack) at a series of stations up the Rappahannock River. If weather permits, both slack waters are sampled. Stations generally coincide with those of the hydrographical survey with sampling starting at Tappahannock and proceeding up the river to follow the progressive wave nature of the tides. One station on each transect is sampled with measurements made six feet below the surface and six feet above the bottom.

A dye study was conducted simultaneously with the hydrographical survey. The results will be in a separate report titled "A Long-Term Dispersion Model of Conservative Substance in the Estuarine Rivers" in December, 1972.

Analysis of Experimental Data

a.) Data Processing - Data collected in the field and the results of laboratory analyses have been permanently recorded on a magnetic disk.

b.) Data Reduction - From the data stored on the disk, various calculations were made. Section averages of the salinity, dissolved oxygen, and temperature were calculated to provide input values for the models. Vertical integrals of the longitudinal component of velocity were calculated. These were used to compute tidal exchange fluxes.

Channel widths were determined from U. S. Geological Survey 7.5 minute quadrangles. Cross-sectional areas were determined by planimetry of the bottom profile data in conjunction with the special survey data supplied by the U.S. Army Corps of Engineers, Norfolk District. Section lengths were determined from C&GS navigation charts. The volume of a section was taken to be the mean of the end cross-sectional areas times the section length.

Tidal exchange fluxes were calculated from the vertical integrals of the longitudinal components of velocity. These were averaged over a cross-section and multiplied by the mean areas, as determined from the bottom profile measurements. This approach is a simplification of Harlacher's method (Troskolanski, 1967).

Tide gauge records were corrected for the elevation of the staff with respect to sea level (1929 datum), for variations in the paper feed rate, and then replotted.

Results

Figure 4 shows the mean depth at transect locations for the Rappahannock River.

Table 1 summarizes the geometric data for the system, showing the cross-sectional areas, widths and hydraulic depths at mean tidal height (U.S.C. & G.S. 1971).

Table 2 shows the local inflow drainage area in the Rappahannock, from Fredericksburg downstream to Tappahannock. Figure 5 is a schematic of the information given in Table 2.

Table 3 is the discharge record of the U. S. Gauging Station near Fredericksburg, Va. during the months of June, July and August of 1970.

Table 4 lists tidal wetland acreage in different counties in estuaries of the Rappahannock River.

Table 5 consists of those calculated minimum average seven and fourteen consecutive day low flow values near the U.S.G.S. Fredericksburg gauging station, with respect to probability of occurrence.

Appendix A shows the slack water runs results.

Appendix B includes the profiles of the cross sections, with local mean low water as the datum (U.S.C. & G.S. 1971).

The results of the tidal observations are shown by the figures in Appendix C. The heights shown are referred to mean sea level (1929 datum plain).

Appendix D is the graphical summary of data collected during Operation Rappahannock, July and August 1970.

Appendix E shows the computed tidal flow for stations 1 through 25. Flood tides are positive, ebb tides negative.

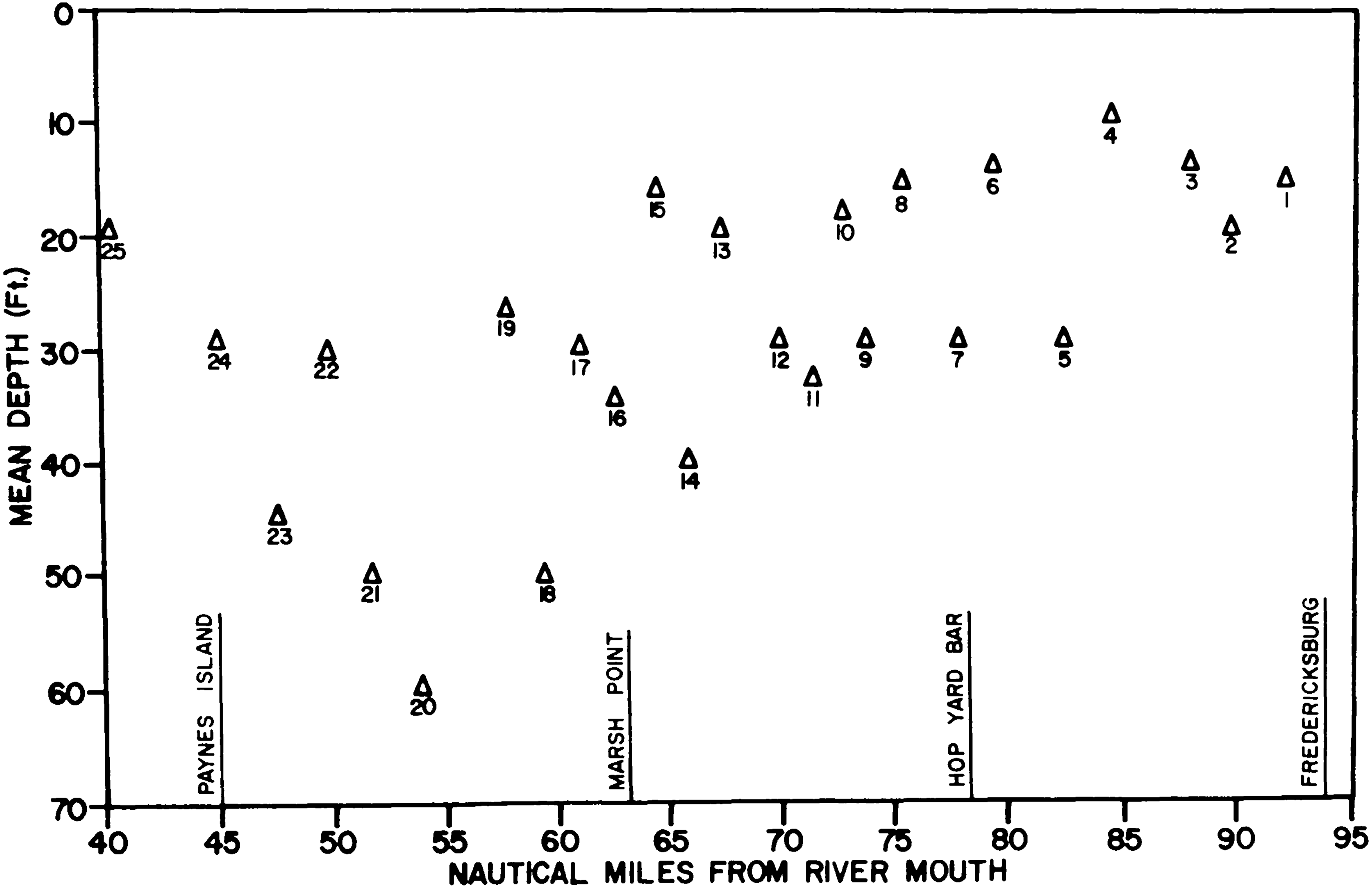

Figure 4. Mean depth at transect locations for the Rappahannock River.

Table 1. Geometrical Data for the Station Locations

Transect	Area (ft^2)	Width (ft.)	Hydraulic Depth (ft. at mean tidal ht.)
1	3967	410	9.7
2	5100	430	11.9
3	5312	430	12.3
4	5558	600	9.3
5	6325	590	10.7
6	6713	920	7.3
7	6875	795	8.6
8	8835	700	12.6
9	9007	575	15.7
10	9750	360	27
11	10220	475	21.5
12	10222	585	17.5
13	16130	2350	6.4
14	11316	475	23.8
15	20600	3650	5.9
16	16816	650	25.9
17	23795	2600	9.1
18	18700	625	29.9
19	23300	1900	12.3
20	24550	1075	22.8
21	28123	1225	22.9
22	36800	3150	11.7
23	29013	1275	22.7
24	36350	2525	14.4
25	43500	3350	13

Table 2. Local Inflow Drainage Area - Rappahannock River

Transect Designation	Distance From Mouth(ft.)	Distance (nautical miles)	Drainage Area Between Transects (sq. miles)	Cumulative Drainage (sq.miles)
1	559000	92.0		1635
			20	
2	546800	90.0		1655
			25	
3	533500	87.8		1680
			40	
4	516500	85.0		1720
			20	
5	501300	82.5		1740
			20	
6	486100	80.0		1760
			3	
7	472700	77.8		1763
			2	
8	455700	75.0		1765
			5	
9	450800	74.2		1770
			5	
10	443600	73.0		1775
			5	
11	436300	71.8		1780
			10	
12	425300	70.0		1790
			30	
13	410700	67.6		1820
			20	
14	402800	66.3		1840
			10	
15	392500	64.6		1850
			20	
16	380400	62.6		1870
			10	
17	369400	60.8		1880
			15	
18	364000	59.9		1895
			15	
19	351200	57.8		1910
			30	
20	328700	54.1		1940
			2	

Table 2 (cont'd)

Transect Designation	Distance From Mouth (ft.)	Distance (nautical miles)	Drainage Area Between Transects (sq. miles)	Cumulative Drainage (sq.miles)
21	316000	52.0		1942
			8	
22	303800	50.0		1950
			20	
23	287400	47.3		1970
			25	
24	273400	45.0		1995
			55	
25	245500	40.4		2050

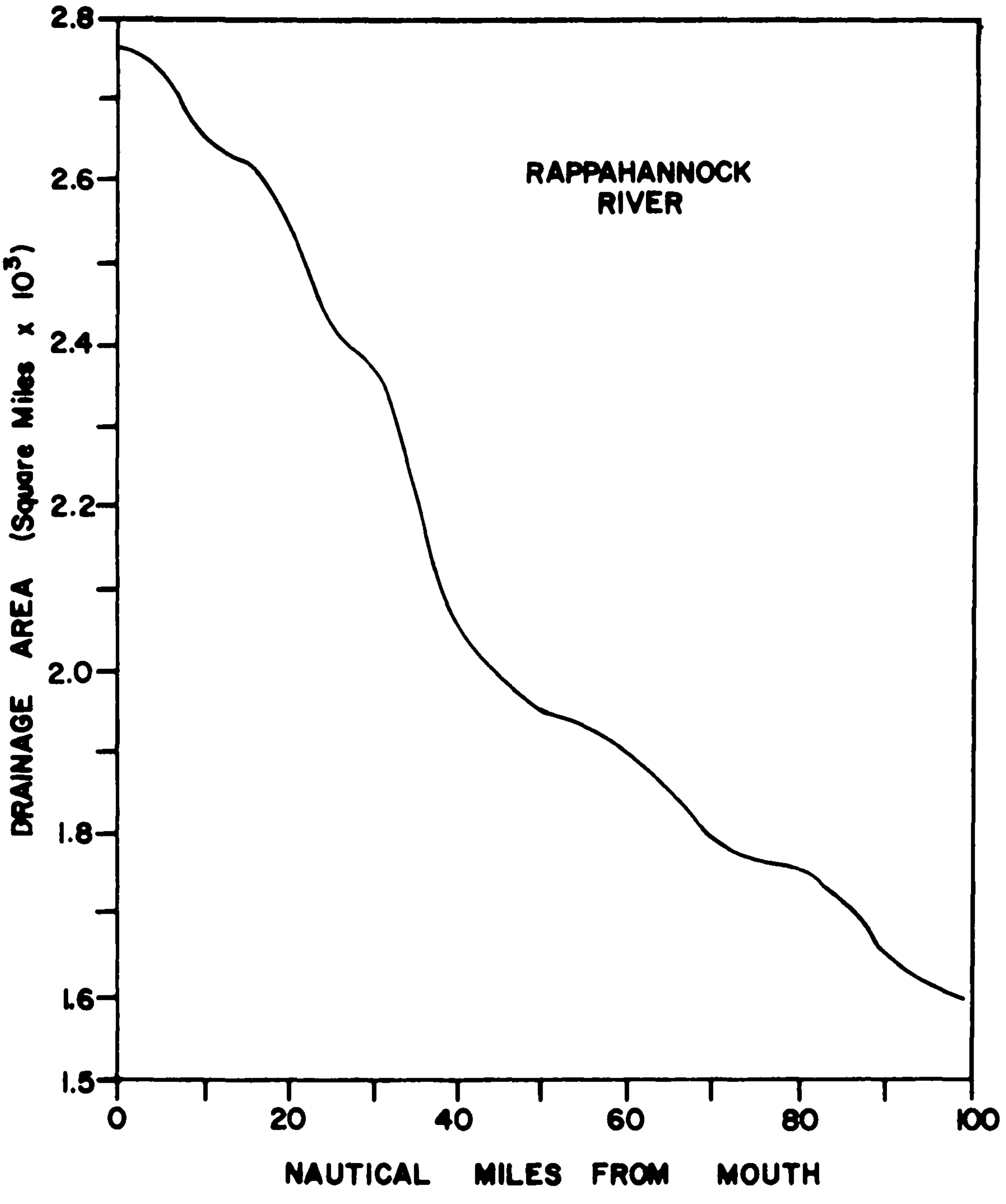

Figure 5. Schematic diagram of local inflow drainage area.

Table 3. Discharge Record at Fredericksburg

Date 1970	Discharge (cfs)	Date 1970	Discharge (cfs)	Date 1970	Discharge (cfs)
June 1	628	July 1	262	Aug. 1	915
2	594	2	250	2	610
3	562	3	272	3	487
4	542	4	252	4	977
5	866	5	340	5	353
6	710	6	390	6	319
7	841	7	309	7	266
8	878	8	242	8	249
9	618	9	214	9	235
10	513	10	3690	10	1110
11	467	11	2480	11	401
12	482	12	1510	12	348
13	511	13	691	13	301
14	475	14	443	14	248
15	445	15	353	15	243
16	409	16	350	16	200
17	513	17	363	17	494
18	600	18	294	18	252
19	509	19	237	19	280
20	430	20	204	20	333
21	382	21	205	21	686
22	350	22	534	22	493
23	366	23	554	23	414
24	362	24	2080	24	353
25	302	25	2290	25	360
26	274	26	956	26	328
27	264	27	627	27	252
28	453	28	467	28	215
29	408	29	403	29	193
30	308	30	497	30	175
-	-	31	1460	31	160

Sum = 15062
Avg = 502.1
Max = 878
Min = 264

Sum = 23491
Avg = 757.8
Max = 3690
Min = 204

Sum = 12250
Avg - 395.2
Max = 1110
Min = 160

TABLE 4. Wetland Acreage

	Wooded Marsh	Marsh	Open Creeks	Woodland	Tidal Flats	Sand	Ponds	Temporary Lakes	Dredged	Total
<u>Rappahannock River</u>										
Stafford County	495	15	0	0	0	0	0	0	0	510
Lancaster County	0	1,636	3,141	0	99	74	175	0	0	5,125
Spotsylvania County	0	0	0	0	0	0	59	0	0	59
Northumberland County	0	165	338	0	0	0	0	0	0	503
Middlesex County	314	1,887	3,379	37	616	22	162	0	11	6,428
Gloucester County	502	440	187	7	0	0	7	0	0	1,143
Matthews County	7	22	224	0	228	0	11	0	0	492
Caroline County	596	510	96	0	0	0	62	0	0	1,264
King George County	292	432	119	0	0	0	0	0	0	843
Essex County	1,849	4,896	1,067	4	0	0	256	0	0	8,072
Richmond County	878	4,628	2,114	22	0	0	185	0	0	7,827
Westmoreland County	48	980	114	0	0	0	33	0	0	1,175
<u>Totals</u>	4,981	15,611	10,779	70	943	96	950	0	11	33,441

Table 5. Minimum Average 7 and 14-Consecutive Day Drought Flows at Fredericksburg Gauging Station (USGS, Richmond, Va.)

Probability of Occurrence of Lower Flow	14 Days cfs	7 Days cfs
0.01	9.85	7.383
0.05	30.79	24.297
0.1	51.986	41.963
0.20	90.94	75.137
0.50	213.592	182.342
0.80	388.204	337.781
0.90	485.455	424.745
0.96	581.846	510.772
0.98	636.448	559.292
0.99	679.117	597.021
0.995	712.443	626.330

BASIC ANALYSIS

Dissolved oxygen concentration is used as a principal index of organic waste pollution in a waterway. As the level of DO concentration is decreased, the capacity of a waterway to assimilate waste discharges is reduced. This is an indicator of required upgrading of treatment facilities for the waste flows. The most important source of replenishment of DO is atmospheric oxygen transfer to the waterway in proportion to the currents and other estuarine parameters. This is called reaeration, and varies as a function of water depth and current velocity in various sections of the estuary.

The production of DO in a volume segment is the external input of oxygen, reaeration, from the atmosphere through the water surface, and the addition of oxygen by photosynthesis. The losses of DO in a volume segment would include the removal of oxygen from the water by diffusion into the benthal layer to satisfy the oxygen demand in the aerobic zone, by the purging action of gases rising from the benthal deposits, and by the respiration of plankton, diatoms and other life.

The biochemical oxygen demand, BOD, is a measure of the oxygen required to reduce waste products by biochemical oxidation. The rate of BOD decay is equal to the product of the first order decay constant, the BOD, and the volume within which the reactions are occurring. Transport of any substance in an estuary is governed by the Law of Conservation of Mass. Waste particles discharged to an estuary are transported from the discharged point by convection and by dispersion. The rate of convective mass transport across any river section is equal to the product of fresh-water runoff, and the contaminant concentration.

Mixing, or dispersion, is a complex function of reversing tidal currents, salinity-induced circulation patterns, fresh-water inflow, and the physical boundaries of the estuary.

Dispersive transport occurs only in the presence of a concentration gradient of the material being transported. The rate of dispersive transport is equal to the product of a dispersion coefficient, E, and the negative of the longitudinal concentration gradient, dL/dx. The dispersion coefficient E is a measure of the estuary's ability to transport material in the direction of a concentration gradient, regardless of the direction of net water movement.

The detail mathematical analysis and the evaluation of all the parameters can be found in VIMS Report 13 (Hyer et.al. 1971).

EXPLICIT SCHEME WATER QUALITY MODELS

Finite-difference equations

The fundamental mass-balance equation must be placed in a finite-difference form in order to be solved using a computer. The equations given below are those used in the computer programs. The reader is referred to the OYR report (Hyer, et.al., 1971) for the derivation. For the oxygen-balance model, equations are needed for dissolved oxygen and BOD:

$$\frac{\partial C_i}{\partial t} - k_{2i}\,(C_{si} - C_i) + k_{1i}L_i - S_iV_i^{-1}$$

$$= \frac{2A_iE_i(C_{i+1} - C_i)\;V_i^{-1}}{D_i + D_{i-1}} + \frac{Q_i}{V_i}\,(C_{i-1} - C_i)\;(1 - \phi_i)$$

$$+ \frac{2A_{i+1}E_{i+1}\;(C_{i+1} - C_i)\;V_i^{-1}}{D_{i+1} + D_i} + \frac{Q_{i+1}}{V_i}\,(C_i - C_{i+1})\phi_{i+1}, \text{ and}$$

$$\frac{\partial L_i}{\partial t} + k_{1i}L_i - \frac{J_i}{V_i}$$

$$= \frac{2A_iE_i(L_i - L_{i-1})V_i^{-1}}{D_i + D_{i-1}} + \frac{Q_i}{V_i}\,(L_{i-1} - L_i)\;(1 - \phi_i)$$

$$+ \frac{2A_{i+1}E_{i+1}(L_{i+1} - L_i)V_i^{-1}}{D_i + D_{i+1}} + \frac{Q_{i+1}}{V_i}\,(L_i - L_{i+1})\phi_{i+1} \qquad (1)$$

Where:

C = dissolved oxygen;

L = biochemical oxygen demand;

i = index of a particular reach;

C_s = saturation concentration of dissolved oxygen;

k_1 = biochemical decay rate;

k_2 = atmospheric reaeration rate;

S = source or sink of dissolved oxygen;

J = source of BOD;

E = dispersion coefficient;

A = cross-sectional area;

V = reach volume;

D = reach length;

Q = volume rate of flow;

ϕ = interpolation factor.

The quantities E, A and Q pertain to the boundary between two reaches. The subscript i refers to the interface upstream of reach i and the subscript i+1 to the downstream interface. It is found necessary in practice to use a formula for ϕ, making it slightly less than 0.5 on the ebb and slightly greater than 0.5 on the flood. In terms of the quantities given above, the formula for ϕ is:

$$\phi_i = 0.5 \ (1 - Q_i \ (\ |Q_i| + \frac{2E_i A_i}{D_{i-1} + D_i} \ )^{-1}). \qquad (2)$$

For the salinity model a single equation is required:

$$\frac{\partial S_i}{\partial t} - \frac{J_i}{V_i}$$

$$= -\frac{2A_iE_i(S_i - S_{i-1})\ V_i^{-1}}{D_i + D_{i-1}} + \frac{Q_i}{V_i}(S_{i-1}\ (1 - \phi_i) + S_i\phi_i)$$

$$+ \frac{2A_{i+1}E_{i+1}(S_{i+1} - S_i)V_i^{-1}}{D_{i+1} + D_i} + \frac{Q_{i+1}}{V_i}(S\ (1 - \phi_{i+1}) + S_{i+1}\phi_{i+1}) \qquad (3)$$

In this equation S represents salinity and J represents the saline loading, if any. The interpolation factor ϕ is calculated so as to prevent numerical instability (Pence, Jeglic and Thomann, 1968).

Evaluation of Parameters

A computer is merely a very fast calculator; the quality of a prediction depends heavily on the reliability of the data used as inputs to the program. All of the quantities used in the equation must be determined from field data or experiment.

Cross-sectional averages of temperature, dissolved oxygen, salinity and longitudinal current were calculated from the summer, 1970 field data. The dissolved oxygen and salinity averages provided initial conditions for the models. The longitudinal current averages were used to calculate tidal current amplitudes for use in the dissolved oxygen model. Temperature was used in the calculation of several other parameters, such as oxygen saturation concentration, decay rate and reaeration rate. The OYR report (Hyer, et.al., 1971) describes the field and laboratory analysis procedures used in determining these variables.

Stream flow for the period of study was deduced from the record of the flow gauge near Fredericksburg (USGS, 1971). Lateral inflow downstream of the gauging station was calculated from the flow gauge record and the drainage area (Seitz, 1971) assuming constant runoff per unit drainage area. This computation is done within the computer program.

Biochemical oxygen demand was determined from samples incubated for five days according to standard procedures. The ultimate BOD was calculated from the five-day BOD disregarding the nitrogenous contribution. The field samples used in the BOD determination were collected during the slack water run of June, 1971.

Organic matter (BOD) is consumed through a decay process whose rate depends on the nature of the organic material and the temperature of the water. The rate of disappearance of BOD is directly proportional to the total amount present, so a simple mathematical expression suffices:

$$\frac{dL}{dt} = - k_1 L \qquad (4)$$

The quantity k_1 is called the decay coefficient and is generally determined empirically. In the program the following form was found satisfactory:

$$k_1 = 0.2\ (1.035)^{T-20} \qquad (5)$$

where k_1 is expressed in day^{-1} and the temperature T is expressed in degrees centigrade (Camp, 1963, p. 247).

Reaeration from the atmosphere replenishes the oxygen consumed by the decaying organic matter. The rate depends on the degree to which the oxygen level falls below the saturation limit. It also depends on the extent of turbulent overturning of the water column. The law expressing the reaeration rate is

$\frac{dC}{dt} = k_2\ (C_s - C)$ where k_2 is the reaeration (6) coefficient, expressed in day^{-1}, C_s is the saturation concentration of dissolved oxygen and C is the dissolved oxygen concentration. The O'Connor-Dobbins formula (Camp, 1963, p. 305) is used for expressing k_2:

$$k_2 = 24\ (DcU\ H^{-3})^{\frac{1}{2}}\theta^{T-20} \qquad (7)$$

Dc = molecular diffusivity of oxygen in water (0.00008/ft^2/hr @ 20C)

H = hydraulic depth (feet)

U = mean tidal velocity (feet per hour)

θ = a constant = 1.010

T = temperature, in degrees centigrade

Examination of the field data revealed a daily cycle to the dissolved oxygen concentration in most of the transects. This was incorporated in the models by including a source term varying sinusoidally with time and having a period of one day. The photosynthesis amplitude was deduced from field data.

The saturation concentration of dissolved oxygen was estimated from laboratory experiment. From tables of saturation concentration (Carritt and Green, 1967) a polynomial equation was determined by a least-squares method:

$$\begin{aligned} C_{SAT} &= 14.6244 - 0.367134\ T \\ &+ 0.0044972\ T^2 - 0.0966\ S \\ &+ 0.00205\ ST + 0.0002739\ S^2 \end{aligned} \tag{8}$$

where T = temp. in C

S = salinity in (parts per thousand)

C_{SAT} = saturation concentration of DO in mg/liter.

The dispersion coefficient E has been calculated from the field data. For the saline portion of the stream the dispersion coefficient is calculated assuming a near-equilibrium at high water slack between advection and dispersion, i.e. assume that the salinity pattern is arrested to a first approximation:

$$E = \frac{Qs}{A\frac{\partial s}{\partial x}} \tag{9}$$

where E = dispersion coefficient

Q = fresh water discharge

S = salinity

A = cross-sectional area.

This formula does not hold for fresh water, where the mixing mechanism is different. Instead, the Modified Taylor's Equation (Harleman, Lee and Hall, 1967) is used to determine the dispersion coefficient:

$$E = 77\ (n)\ V_t\ (R)^{5/6} \qquad (10)$$

where n = Manning's roughness coefficient, V_t = average tidal velocity, and R = the average hydraulic radius in the reach. Table 6 shows calculated dispersion coefficients in the explicit model, with respect to individual transects.

For the short-term prediction of dissolved oxygen and BOD, it is inappropriate to use the dispersion coefficients calculated for use in the long-term salinity prediction model. The reason for this conclusion is that tidal flushing and shear flow turbulence cause the longitudinal dispersion observed over a long period, while for time scales smaller than a tidal period, tidal velocity is included in the advection term and shear flow turbulence alone is acting as a dispersion mechanism. It has been found in operating the dissolved oxygen model that reducing the dispersion coefficients to about five percent of the values used in the salinity model gives adequate representation of the dissolved oxygen sag regions.

Cross-sectional areas were determined by the U. S. Army Corps of Engineers. Reach lengths were measured from USC&GS navigation charts. Hydraulic depths (used in calculating the reaeration coefficient) were determined from

Table 6

Calculated Dispersion Coefficients Rappahannock River

Transect	Distance From River Mouth, Statute Miles	Dispersion Coefficient ft^2/sec	Dispersion Coefficient mi^2/day
1	105.9	20	0.06
2	103.3	20	0.06
3	100.9	30	0.09
4	97.7	40	0.12
5	94.8	50	0.15
6	92.0	30	0.09
7	89.4	30	0.09
8	86.2	50	0.15
9	85.3	60	0.2
10	83.9	160	0.5
11	82.5	120	0.4
12	80.5	90	0.3
13	77.8	40	0.12
14	76.2	160	0.5
15	74.3	50	0.15
16	72.0	140	0.4
17	69.9	80	0.2
18	68.8	190	0.6
19	66.4	90	0.3
20	62.2	130	0.4
21	59.8	150	0.5
22	57.5	80	0.2
23	54.4	170	0.5
24	51.7	100	0.3
25	49.3	290	0.9
26	46.4	620	1.9
27	41.1	1210	3.7
28	36.9	1500	4.6

stream width and cross-sectional area data supplied by the Corps of Engineers.

Program Inputs

VIMS Scientific Report #13 (Hyer, et.al., 1971) will serve as a guide for most of the input variables. Others are described in the DECS-III report (Jeglic, 1967). Below summarizes the variables peculiar to the Rappahannock models, and their significance.

a. Namelist CONTRL. Separate decks are used for the two models; there is no dual-purpose program (single variable or two variables, depending on input conditions) as was developed for OYR. Hence the input SINGL is no longer needed. The variable LNAME has been eliminated from the oxygen-balance model. The input array PFREQ has been eliminated from both models.

b. Namelist MODEL. New entries to both models include AGAGE, AHEAD and DRAER. The entries AGAGE and AHEAD represent the drainage areas upstream of the gauging station and between the gauging station and the first reach, respectively. The array DRAER is the drainage area of each individual reach. These entries are used to calculate the lateral inflow automatically, given the gauge flow. The oxygen balance model also contains the array PHAMP, which is the observed photosynthesis amplitudes. If omitted, PHAMP is simply replaced by an array of zeros.

In namelist INITL, both programs have the entries QGAGE and QPASS. The first of these is used, together with

AGAGE, AHEAD, and DRAER to compute the lateral inflows. The entry QPASS represents the flow that actually passes the flow gauge and enters the first reach. The entries QGAGE and QPASS will differ from one another if and only if there is water impoundment between the gauge and the first reach. Many of the entries used in the oxygen balance model are absent from the single-variable program. These include U, P, C, TEMP, CUPP and CLOW.

The namelist TIMDEP has most of the same variables as INITL for the respective program. It lacks the initial distributions C and L. It contains in addition to logical variables, RECYCL and PRINT. The first of these is used to signal the end of a run, so that the computer can reinitialize to start another run. The other, PRINT, is an array specifying the printing of certain outputs; it replaces the variable PFREQ. The appropriate instructions are as follows:

PRINT (1) = T specifies the printing out of hydraulic, load, and geometrical conditions;

PRINT (3) = T causes the printing of the integration history;

In the salinity-prediction model, PRINT(4) = T causes the printing of the eddy diffusivity and river discharge obtaining at the beginning of the integration interval just completed. In the oxygen-balance model PRINT(4) = T causes the printing of the reaeration and decay coefficients. These variables are all preset to F (no print) before each time step.

Salinity Model Verification

The slack water run program was used to provide verification data for the salinity prediction model. Salinity distributions collected at high water slack on August 18, October 8 and December 10, 1970 and February 19, 1971 were verified using the model. Initial conditions were taken from the results of the intensive field survey of July and August, 1970. Boundary conditions were taken from the results of the slack water runs themselves. Median gauge flow for the thirty days preceding the beginning of a particular time step was used to compute the fresh water discharge existing at that time. Figures 6 through 9 show the field data and model predictions.

Oxygen-Balance Model Verification

The time-dependent model of dissolved oxygen is intended for short-range prediction up to a week on an hourly basis, including the daily temperature cycle, the tidal exchange distribution and fresh water discharge and the daily photosynthesis cycle.

The data collected during the summer 1970 field study were used to verify the oxygen-balance model. While the various transects were sampled over a period of more than a month, it was necessary to treat the sampling periods as though they had all occurred at the same time in order to compare the results with the model prediction. Since the diurnal photosynthesis cycle appeared to be the dominant short-term fluctuation, the records were compared with model results according to hour of day; i.e. samples taken at 1200 were compared with model results at 1200, etc. The initial dissolved oxygen distribution was that for 2200 hrs. Temperature and salinity distributions are kept constant throughout the model run. The rate of input loading was determined from two sources: (1) the reported discharges for Fredericksburg, Tappahannock and the American Viscose plant near Fredericksburg, according to the Water Control Board; and (2) estimates of the naturally occurring sources of organic matter needed to maintain quasi-steady values of BOD, i.e. values steady except for tidal fluctuation. This last procedure was also used to estimate primary or benthal oxygen demand (the variable P in the model).

Upstream and downstream boundary conditions for dissolved oxygen and BOD were determined empirically from field data. Those for DO are expressed as a function of temperature only:

Upstream: $C = 9.7 - 0.244T + 0.0030T^2$

Downstream: $C = 8.5 - 0.213T + 0.0026T^2$

where C is the dissolved oxygen concentration in parts per million and T is the temperature in degrees centigrade.

The model was run with the above initial conditions and varying parameters for a period of six days. Verification consisted of comparing observed DO maxima and minima over the daily range with model predictions. The results are shown in figures 15 and 16. The agreement is generally better than 0.5 parts per million. The observed results for transect 14 have been omitted as being questionable, since many of them show dissolved oxygen concentrations far in excess of saturation.

Generally the observed dissolved oxygen concentration for a given transect followed a diurnal cycle. Figures 10 and 11 show model results for such situations, reaches 11 and 18. In each of those figures the two transects shown are the two transects bordering the model reach shown in the figure. In other cases, the dissolved oxygen fluctuation was a mixture of diurnal and tidal oscillations. In such cases the model predicted the extreme maximum and minimum dissolved oxygen concentration occurring in the transects bordering the model reach. Figures 12 to 14 shows such cases for reaches 1, 4 and 7.

Comments on the Salinity Model

The salinity model developed for the Rappahannock River can be used to predict the high water slack salinity distribution as a function of time and river location, given river flow and a downstream boundary condition.

There are some limitations to the usefulness of the model. It can predict the salinity at high water slack only. Furthermore, the model predicts only seasonally prevalent values of salinity but does not take into account the tidal current cycle or wind condition occurring on a given day. The model is severely limited by the location

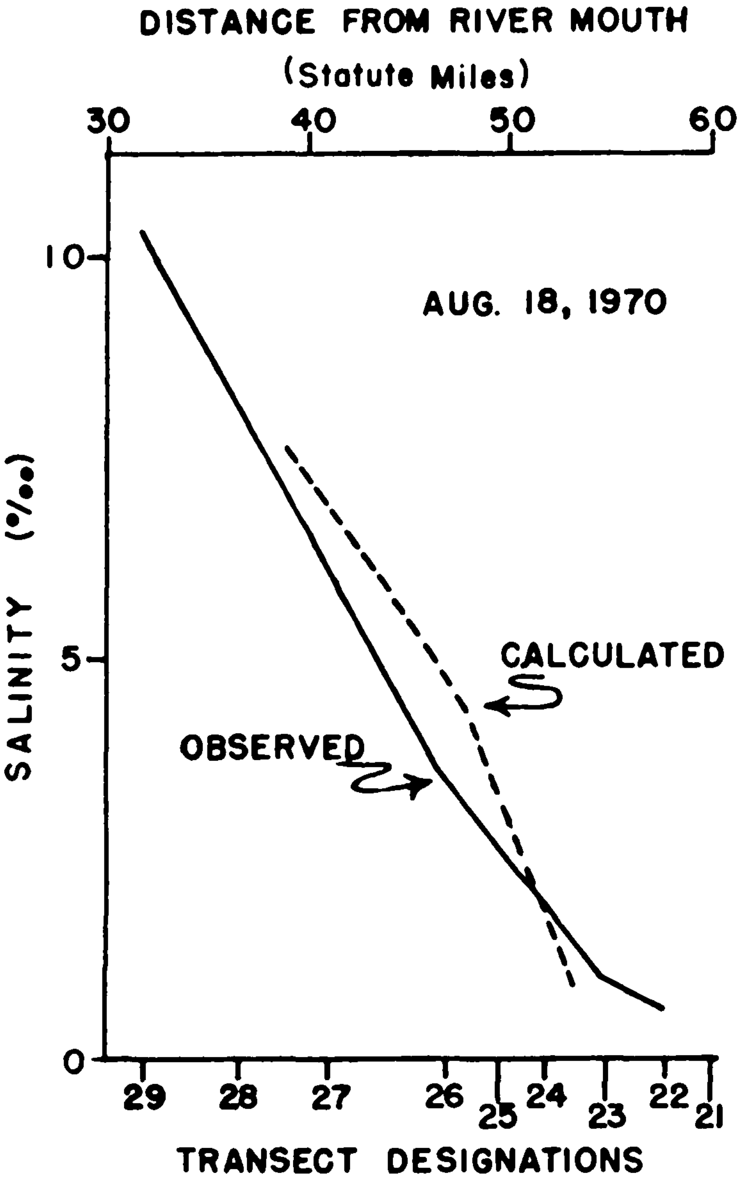

Figure 6. Salinity verification calculated and observed Rappahannock distributions for August 18, 1970.

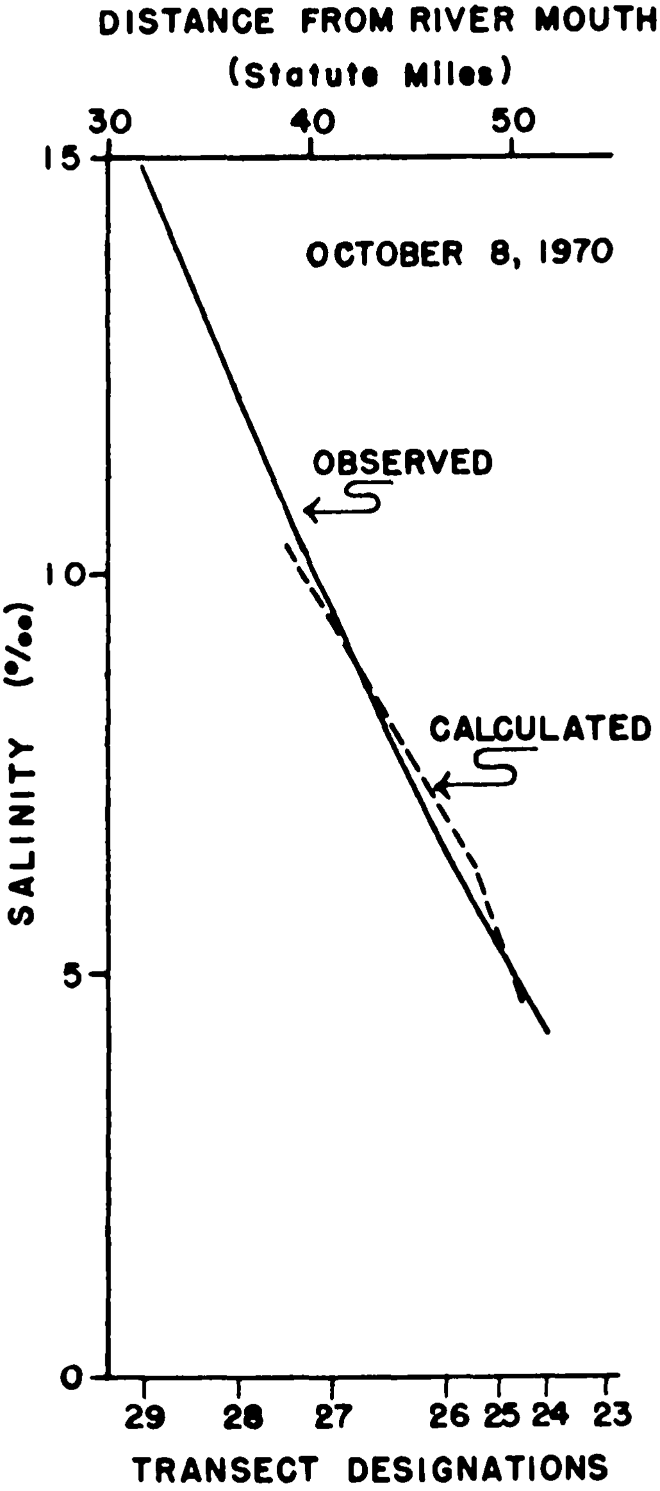

Figure 7. Salinity verification calculated and observed Rappahannock distributions for October 8, 1970.

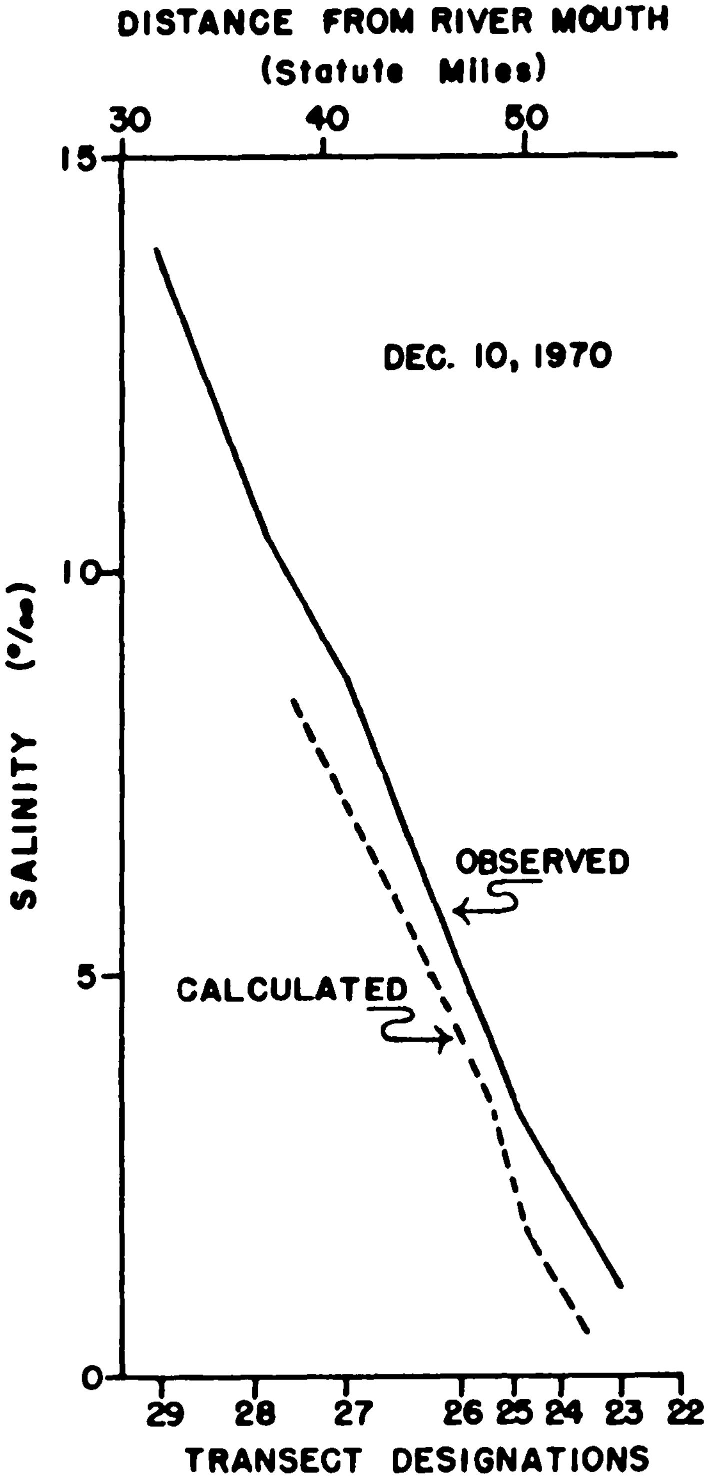

Figure 8. Salinity verification-calculated and observed Rappahannock distributions for December 10, 1970.

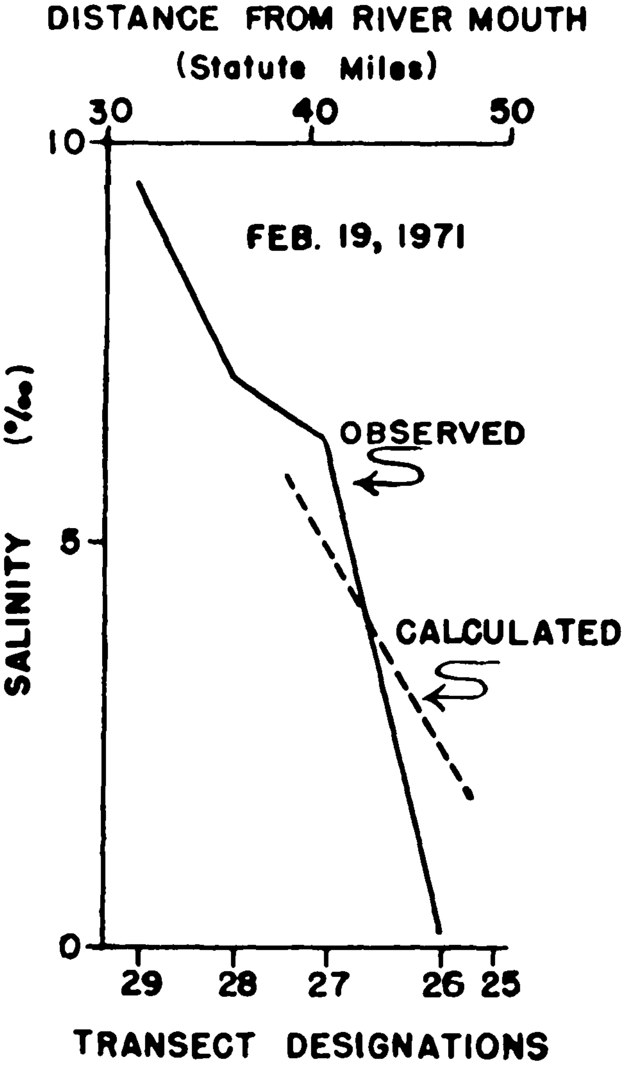

Figure 9. Salinity verification-calculated and observed Rappahannock distributions for February 19, 1971.

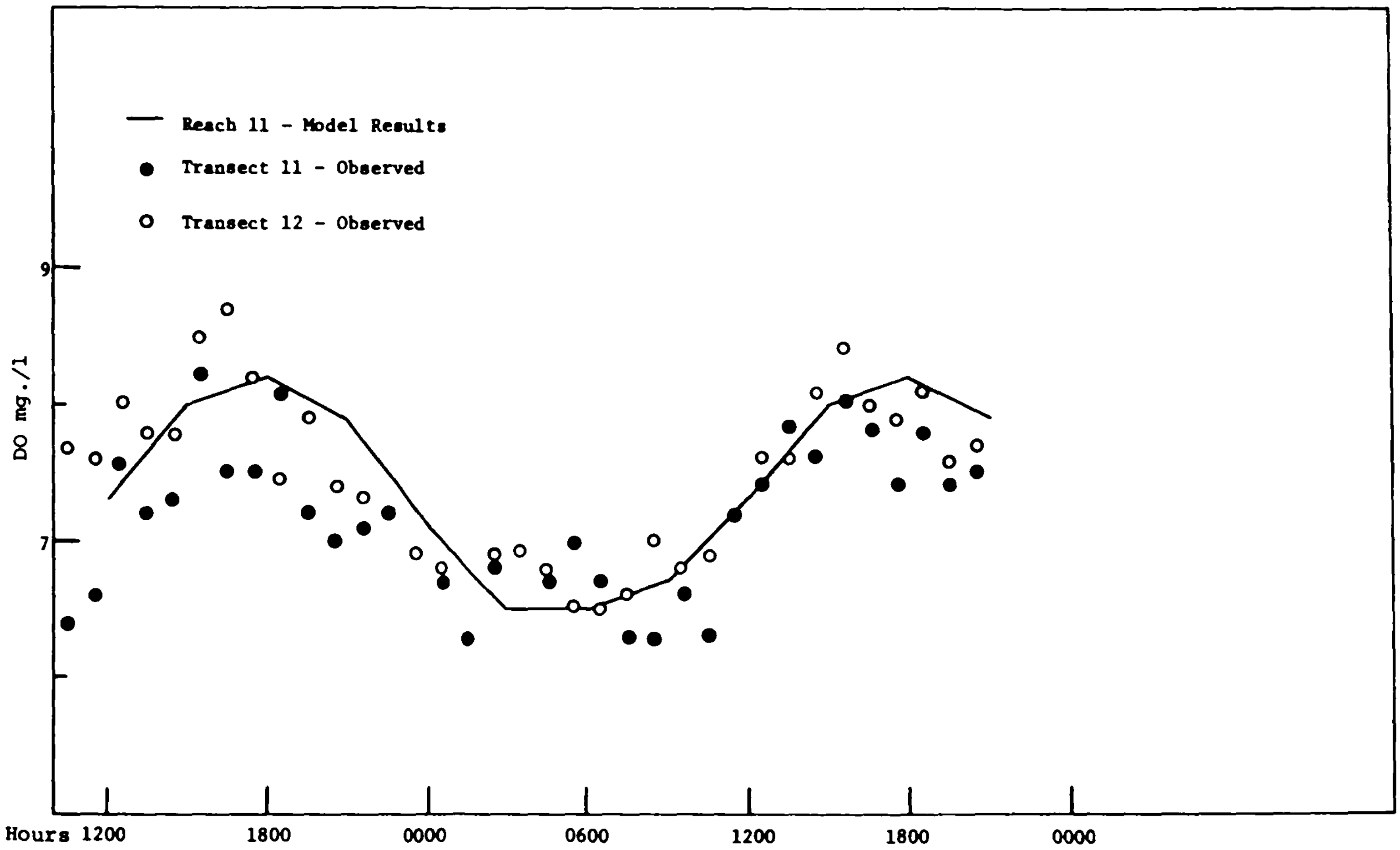

Figure 10. DO verification - Reach 11 model results compared with observed values at adjacent transects starting July 30, 1970.

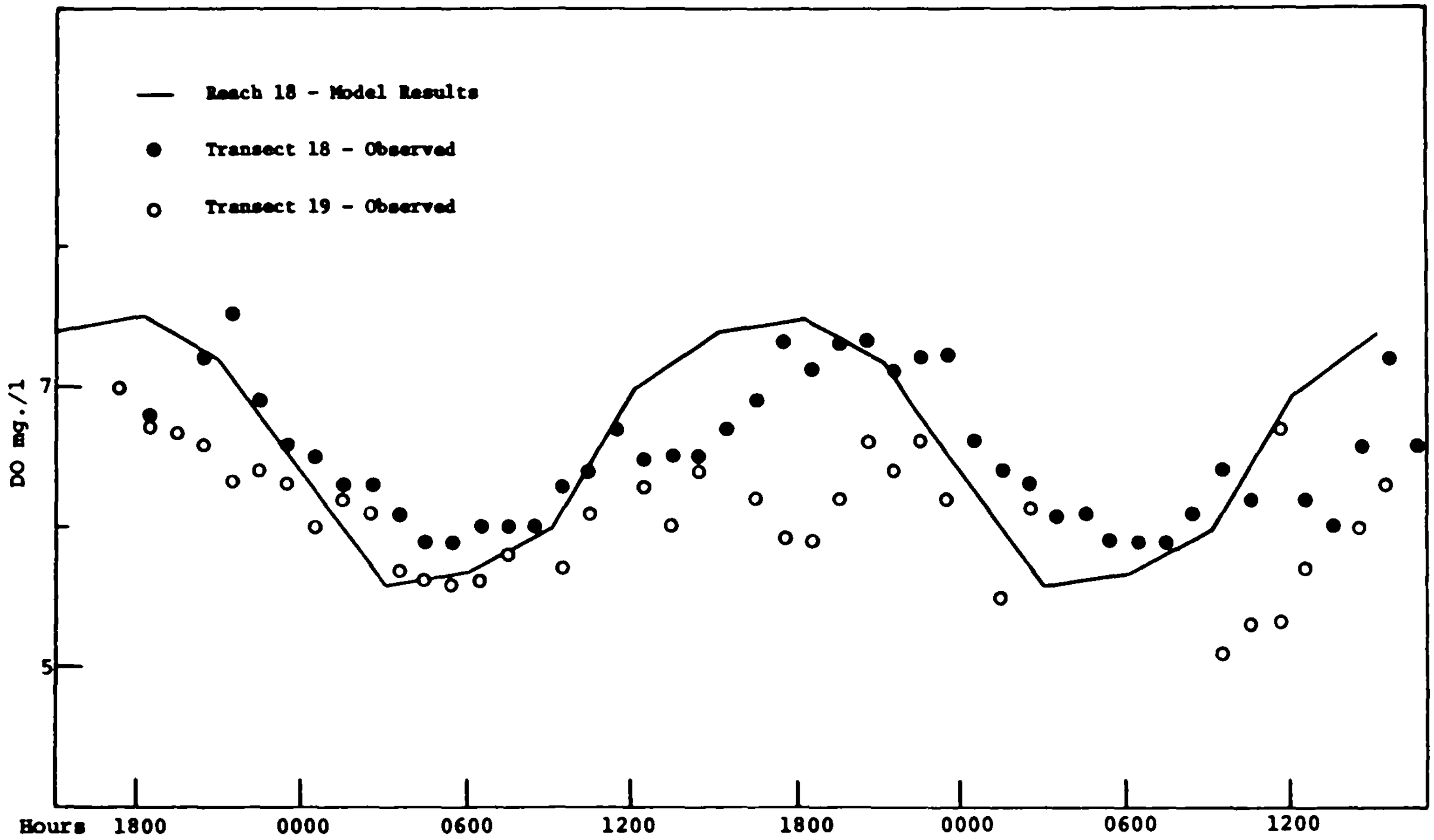

Figure 11. DO verification - Reach 18 model results compared with observed values at adjacent transects starting July 15, 1970.

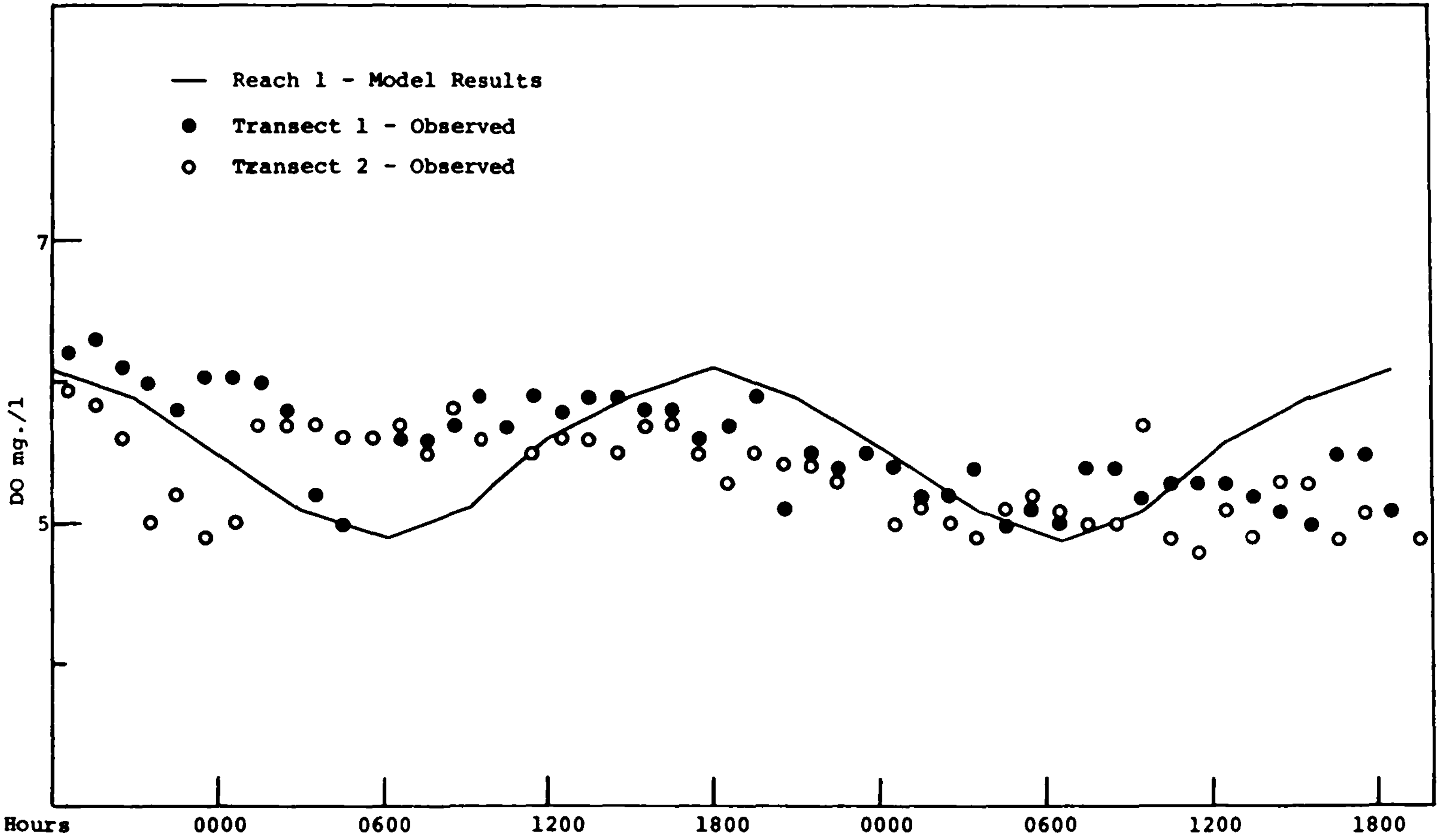

Figure 12. DO verification - Reach 1 model results compared with observed values at adjacent transects starting July 26, 1970.

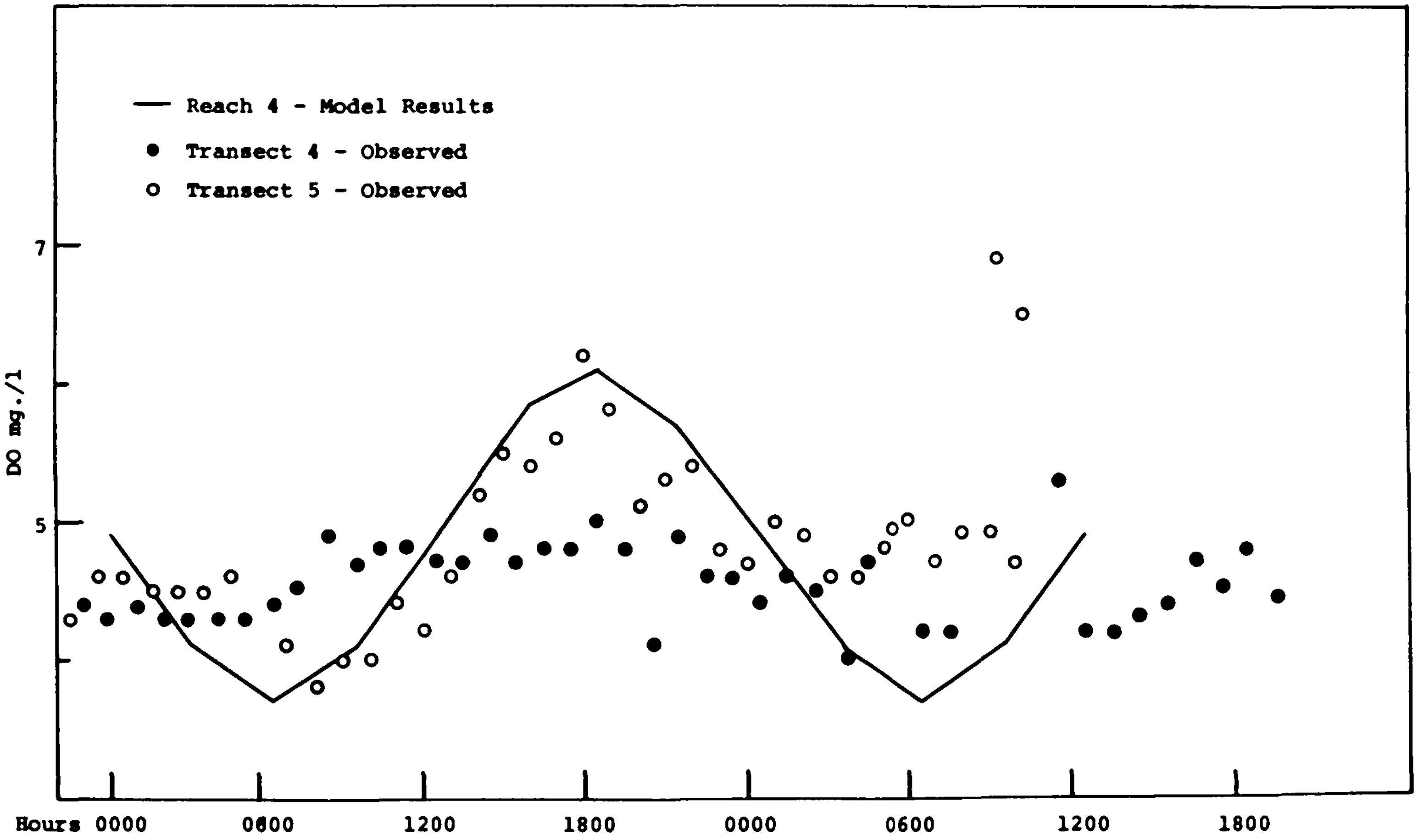

Figure 13. DO verification - Reach 4 model results compared with observed values at adjacent transects starting July 26, 1970 (4) and July 28, 1970 (5).

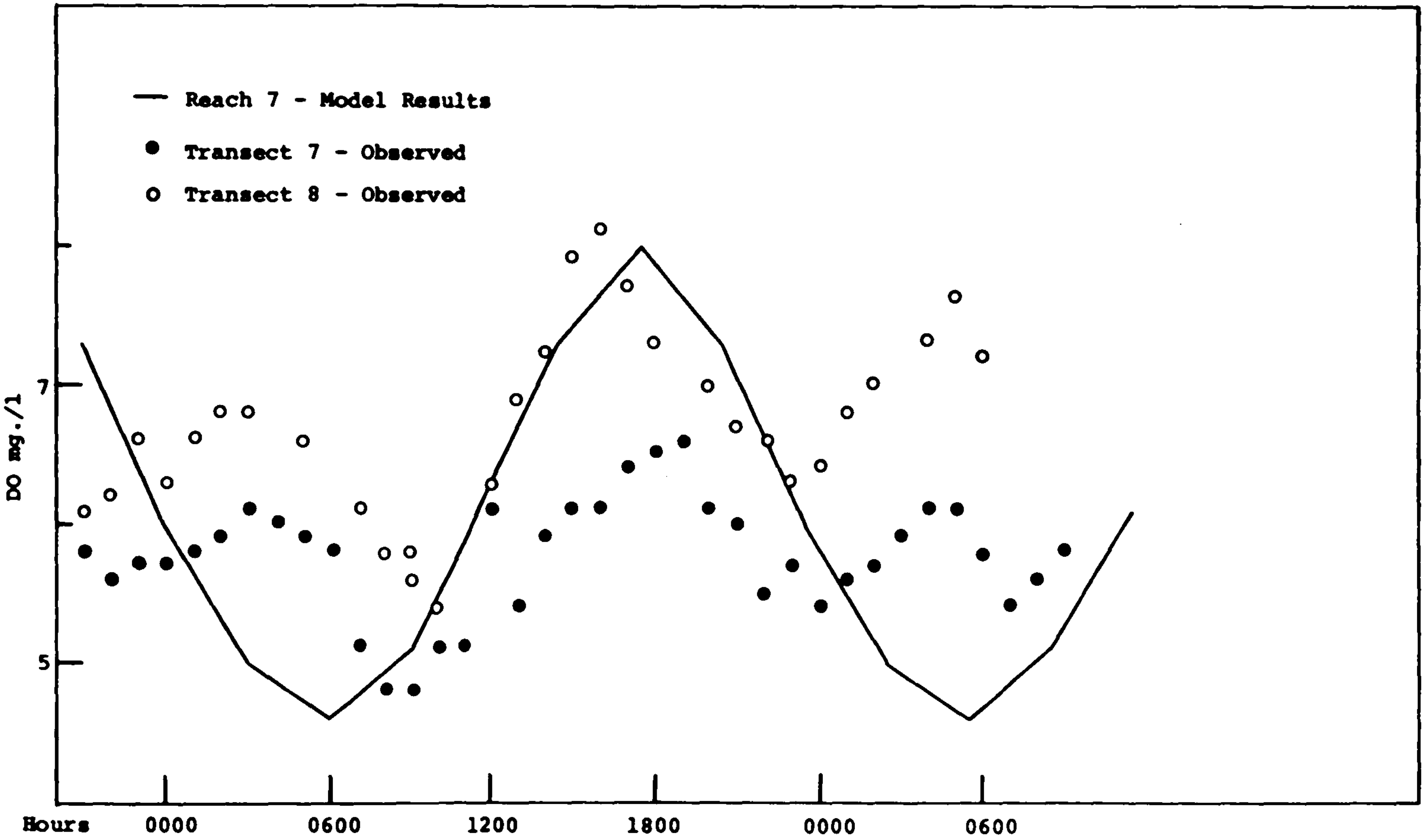

Figure 14. DO verification - Reach 7 model results compared with observed values at adjacent transects starting July 28, 1970.

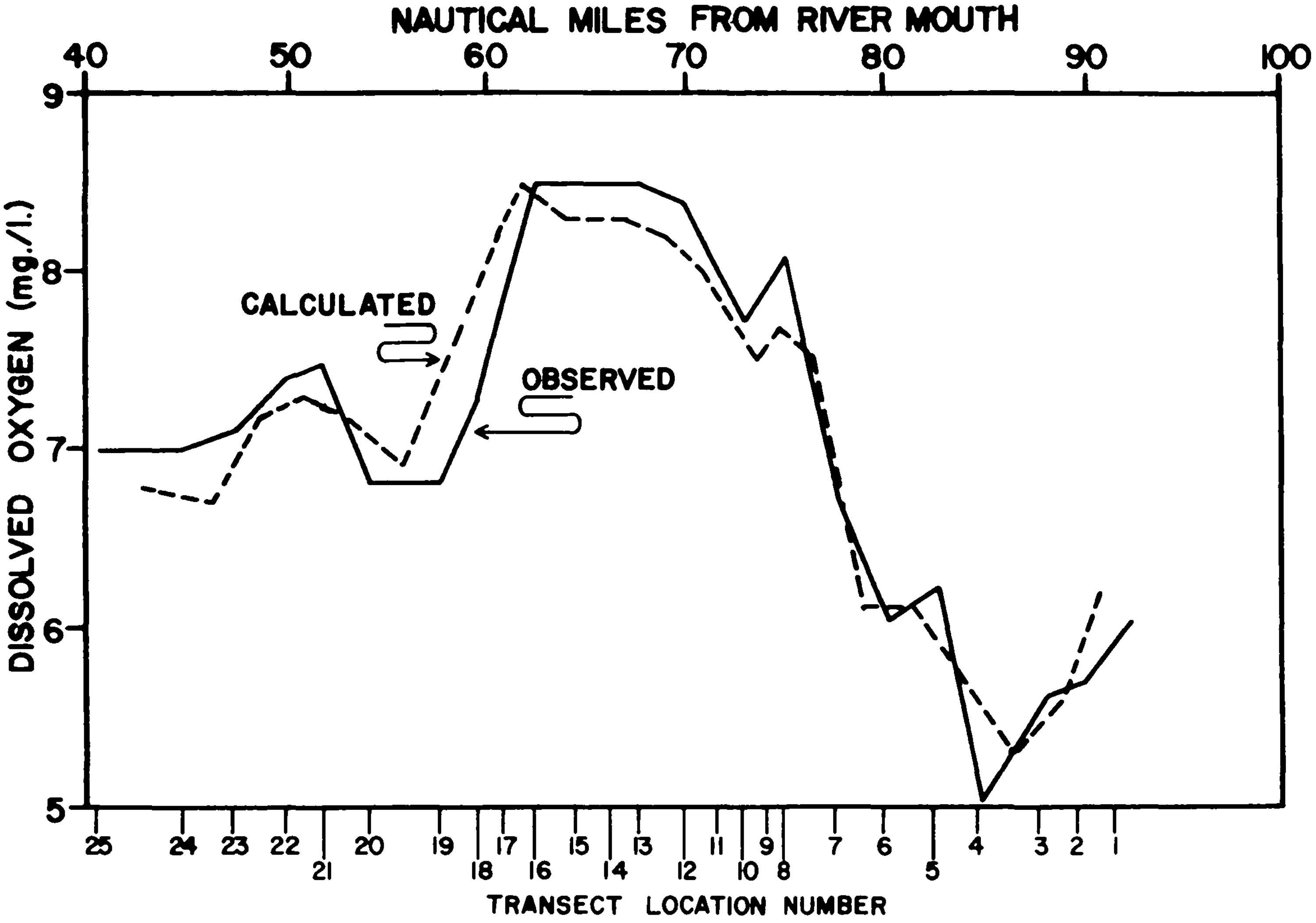

Figure 15. DO verification, calculated and observed maximum daily Rappahannock distributions.

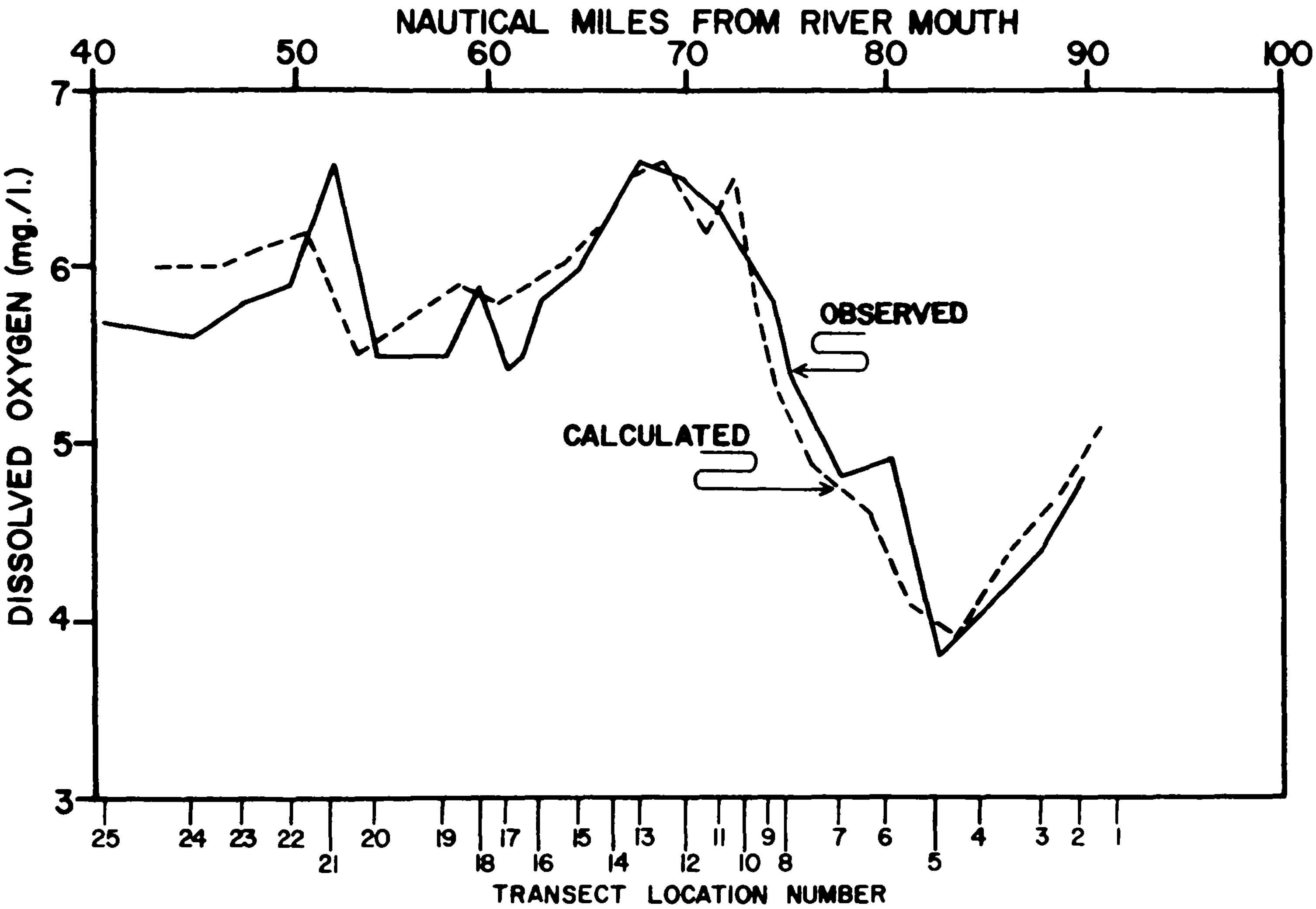

Figure 16. DO verification, calculated and observed minimum daily Rappahannock distributions.

of the downstream boundary. The boundary occurs at a point having highly variable salinity, so that the results obtained are sensitive to the boundary values chosen. There is uncertainty in assigning appropriate boundary conditions for flows lower than those actually observed. It was found that river discharge needed to be weighted in order to predict the salinity distribution occurring during periods of high flow; the unweighted discharge tended to exaggerate greatly the flushing rate occurring during high flows.

Comments on the Oxygen Balance Model

The dissolved oxygen model developed for the Rappahannock River is designed to predict the dissolved oxygen and biochemical oxygen demand on an hourly basis under known conditions of river flow and temperature over a period of several days. Tidal motion and photosynthesis are included in the model. Primary oxygen or biochemical loading may be imposed on any reach.

The model has been verified for the conditions existing during the intensive survey of the summer of 1970. While the temperature ranged from twenty-five to thirty degrees centigrade and the river flow was in the neighborhood of four hundred cubic feet per second, these are not the extreme conditions which might be encountered. Presumably an extreme-condition prediction will have greater uncertainty than that of the verification run. The initial BOD concentration used in the model is an observed distribution from a slack water run of June, 1971. However, in verifying the model, it was found necessary to reduce the BOD concentration in certain reaches because the dissolved oxygen concentration used for initial conditions was so close to saturation. There is a drawback in that the primary oxygen demand and biochemical loading are estimated values (known numicipal and industrial loads are too small to explain the observed oxygen deficits) chosen to maintain roughly level concentrations of DO and BOD, over and above the diurnal and tidal cycles. Loss of BOD through settling has not been included in this model, since it is an unknown quantity.

ONE-DIMENSIONAL IMPLICIT SCHEME

Water Quality Model

This model is to predict the long-term variation of dissolved oxygen, biochemical oxygen demand and salinity intrusion in the upper Rappahannock estuary, with initial and boundary conditions given. 'Long term' means that the model was designed for period of computation more than one month and time step greater than one tidal cycle.

The basic framework for a mathematical model of water quality is the mass balance equation, which simulates the transport of dissolved substances in a water body. For a roughly sectionally homogeneous estuarine river, it is often more practical to use the one-dimensional form,

$$\frac{\partial C}{\partial t} + U\frac{\partial C}{\partial x} = \frac{1}{A}\frac{\partial}{\partial x}\left(AE\frac{\partial C}{\partial x}\right) + R \qquad (11)$$

where

t, time;

x, distance along the estuarine river;

U, cross-sectional mean velocity

A, cross-sectional area;

E, dispersion coefficient;

R, sources and sinks;

C, cross-sectional mean concentration.

The one-dimensional equation is obtained by integrating the three-dimensional equation over a cross-section.

The dependent variables such as velocity, concentration, dispersion coefficient, sources and sinks, are then functions of x and t only. The lateral variation of axial velocity and the transport due to lateral convection and diffusion are not explicitly represented in the equation, but are lumped into a single dispersion term. The concept of dispersion[2] was first illustrated by Taylor (1953, 1954) both theoretically and experimentally. Aris (1956) gave a rigorous mathematical proof of this dispersion representation of the interaction between lateral diffusion and the 'shear effect', i.e. the lateral variation of axial velocity. Subsequent extensions of this dispersion concept have been made by Elder (1959), Okubo (1964), Bowden (1965), Fischer (1967), and Holley et. al. (1970).

Finite Difference Approximation

The one-dimensional mass balance equation was applied to a seventy-mile reach of the Rappahannock River of Virginia from a transect seven miles downstream of Tappahannock to a transect near Fredericksburg, upstream of the tidal limit. The differential equation was approximated by finite difference forms. The finite difference equations were integrated

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[2] In this paper, the term 'dispersion' has the definition suggested by Holley (1968), which is widely accepted by engineers. Scientists often treat 'dispersion' and 'diffusion' as synonymous.

numerically for the concentrations of biochemical oxygen demand (BOD), dissolved oxygen (DO) and salt. A number of transects along the reach of the estuary was chosen and the dependent variables were evaluated at each transect.

The equations for BOD and DO are coupled:

$$\frac{\partial B}{\partial t} + U\frac{\partial B}{\partial x} = \frac{1}{A}\frac{\partial}{\partial x}\left(AE\frac{\partial B}{\partial x}\right) - k_1 B + R_b \text{ , and} \tag{12}$$

$$\frac{\partial C}{\partial t} + U\frac{\partial C}{\partial x} = \frac{1}{A}\frac{\partial}{\partial x}\left(AE\frac{\partial C}{\partial x}\right) - k_1 B + k_2\,(C_s - C) + p \tag{13}$$

where

B, BOD in ppm;

C, DO in ppm;

D_s, saturated oxygen concentration in ppm;

k_1, deoxygenation coefficient in $(\text{day})^{-1}$;

k_2, reaeration coefficient in $(\text{day})^{-1}$;

R_b, BOD sources and sinks;

p, photosynthesis and respiration.

Since there may be some oxygen sags or high BOD concentrations along an estuarine river, the backward difference approximation is used for the first order spatial derivative in the convective term. Hence, only the carbonaceous BOD's are considered because there is no major livestock industry along the Rappahannock River. The finite difference forms of equations 12 and 13 are the following:

$$\frac{B_i' - B_i}{\Delta t} + \frac{1}{2}\ (U_i'\ \frac{B_{m+1}' - B_m'}{\Delta x_m} + U_i\ \frac{B_{n+1} - B_n}{\Delta x_n}\ )$$

$$= \frac{1}{A_i}\ (\frac{1}{\Delta x_{i-1} + \Delta x_i})\ \{(\frac{A_iE_i + A_{i+1}E_{i+1}}{2})\ (\frac{B_{i+1} - B_i}{\Delta x_i})$$

$$-(\frac{A_{i-1}E_{i-1} + A_iE_i}{2})\ (\frac{B_i - B_{i-1}}{\Delta x_{i-1}}) + (\frac{A_iE_i' + A_{i+1}E_{i+1}'}{2})\ (\frac{B_{i+1}' - B_i'}{\Delta x_i})$$

$$-(\frac{A_{i-1}E_{i-1}' + A_iE_i'}{2})\ (\frac{B_i' - B_{i-1}'}{x_{i-1}})\} - \frac{1}{2}\ (k_{1i}'B_i' + k_{1i}B_i) + R_{bi} \qquad (14)$$

$$\frac{C_i' - C_i}{\Delta t} + \frac{1}{2}\ (U_i'\ \frac{C_{m+1}' - C_m'}{\Delta x_m} + U_i\ \frac{C_{n+1} - C_n}{\Delta x_n}$$

$$= \frac{1}{A_i}\ (\frac{1}{\Delta x_{i-1} + \Delta x_i})\ \{(\frac{A_iE_i + A_{i+1}E_{i+1}}{2})\ (\frac{C_{i+1} - C_i}{\Delta x_i})$$

$$-(\frac{A_{i-1}E_{i-1} + A_iE_i}{2})\ (\frac{C_i - C_{i-1}}{\Delta x_{i-1}}) + (\frac{A_iE_i' + A_{i+1}E_{i+1}'}{2})\ (\frac{C_{i+1}' - C_i'}{\Delta x_i})$$

$$-(\frac{A_{i-1}E_{i-1}' + A_iE_i'}{2})\ (\frac{C_i' - C_{i-1}'}{\Delta x_{i-1}})\} - \frac{1}{2}\ (k_{1i}'B_i' + k_{1i}B_i)$$

$$+ \frac{1}{2}\ \{k_{2i}'\ (C_s' - C_i') + k_{2i}(C_s - C_i)\} + p_i \qquad (15)$$

where

$m = i$ if $U_i' \leq 0$;

$m = i-1$ if $U_i' > 0$;

$n = i$ if $U_i \leq 0$;

$n = i-1$ if $U_i > 0$;

i is the number of the transect counting from the upstream boundary; Δt is the time increment; Δx_i is the distance between ith and (i+1)th transects; the primes designate the quantities at the end of the time increment and the unprimed quantities are those at the beginning of the time increment.

Salt is a conservative substance and its mass balance equation may be written as

$$\frac{\partial S}{\partial t} + U\frac{\partial S}{\partial x} = \frac{1}{A}\frac{\partial}{\partial x}\left(AE\frac{\partial S}{\partial x}\right) - \frac{q}{A}S \qquad (16)$$

where S is the salinity and q us the lateral fresh water inflow. The central difference approximation is used for the first order spatial derivative in the convection term. The finite difference form is

$$\begin{aligned}
&\frac{S_i' - S_i}{\Delta t} + \frac{1}{2}\left(U_i'\frac{S_{i+1}' - S_{i-1}'}{\Delta x_{i-1} + \Delta x_i} + U_i\frac{S_{i+1} - S_{i-1}}{\Delta x_{i-1} + \Delta x_i}\right) \\
&= \frac{1}{A_i}\left(\frac{1}{\Delta x_{i-1} + \Delta x_i}\right)\left\{\left(\frac{A_iE_i + A_{i+1}E_{i+1}}{2}\right)\left(\frac{S_{i+1} - S_i}{\Delta x_i}\right)\right. \\
&- \left(\frac{A_{i-1}E_{i-1} + A_iE_i}{2}\right)\left(\frac{S_i - S_{i-1}}{\Delta x_{i-1}}\right) + \left(\frac{A_iE_i' + A_{i+1}E_{i+1}}{2}\right)\left(\frac{S_{i+1}' - S_i'}{\Delta x_i}\right) \\
&\left.- \left(\frac{A_{i-1}E_{i-1}' + A_iE_i'}{2}\right)\left(\frac{S_i' - S_{i-1}'}{\Delta x_{i-1}}\right)\right\} - \frac{q_i}{A_i}S_i \qquad (17)
\end{aligned}$$

If we can measure or estimate U_i, A_i, E_i, k_{1i}, k_{2i}, R_{bi}, C_s and p_i for all selected transects of the estuarine river, and with appropriate initial and boundary conditions, we may integrate equations 14, 15 and 17 to obtain the variations of BOD, DO and salinity along the estuary as time proceeds.

Boundary Conditions

Because of convective and dispersive transport, the concentration at one transect will depend on the concentrations at the two adjacent transects. If N is the number of transects chosen in the reach of the estuary, then there will be N unknowns (B_i', C_i' or S_i') for each system of equations (14, 15, or 17), while there are only (N-2) equations for each system. Two boundary conditions have to be established before the system of (N-2) simultaneous equations become determinant.

Upstream Boundary: The transect farthest upstream is located beyond the tidal limit, upstream of Fredericksburg. There is no concentrated BOD source upstream of it, and its concentration is not affected by the BOD source five miles downstream at Fredericksburg. Therefore, both the BOD and DO concentration are assumed to be constants with values obtained from field measurement. The salinity is kept 0.1, the value assumed for fresh water.

Downstream Boundary: The most downstream transect is also located far away from concentrated BOD sources. A constant value, obtained from field data, is assumed for the BOD concentration. The DO concentrations at the two most downstream transects are assumed to be equal, since the field data indicate the DO level is fairly uniform along this part of the river.

A technique combining linear extrapolation and a semi-explicit scheme is used to estimate the salinity boundary conditions. The salinity at the downstream boundary at the beginning of the time step is used as a boundary condition to estimate the salinity of the other transects at the end of the time step. The boundary condition is then refined by linear extrapolation from the estimated salinities at the two transects immediately upstream.

Time Scales of the Models

In solving the mass balance equation with a digital computer, the equation is integrated numerically over successive time intervals. During the process of each integration step, the parameters such as velocity, dispersion coefficient, etc. assume representative values for that time interval, i.e., some kind of average over the time interval. In an estuarine river, the convective velocity oscillates with a period of about 12.5 hours. It is apparent that a numerical model with a time increment greater than a tidal cycle will not be able to describe the time variation of convective velocity induced by tidal fluctuation. Only a model with a time increment much smaller than a tidal cycle can fully describe the time variation of tidal velocity. The selection of the time increment will depend on the response time of the system and the purpose of the model.

Since BOD has a deoxygenation coefficient, k_1, of order of 10^{-1} per day, i.e., it has a characteristic life time on the order of ten days. BOD concentration will reach a new state of equilibrium in the order of ten days after the change of input parameters in the system. The reaeration coefficient for the DO concentration is also on the order of 10^{-1} per day. Therefore, even if the model is for long term variations of the BOD and DO concentrations (for example, seasonal), it needs to be run for a simulated time on the order of ten days for each set of input parameters corresponding to each seasonal condition, to arrive at the equilibrium concentration fields for that season. It is not necessary to run the model continuously from season to season throughout the year. Thus, one can afford to have the time increment of the numerical computation be much smaller than a tidal cycle, and the time variation of the tidal velocity may be included in the model.

The salinity variation in an estuarine river is mainly governed by the fresh water discharge, which varies with a time scale on the order of several months. The response time of the salinity distribution in the Rappahannock River is on the order of months too. Therefore, the salinity distribution in the river never stays at an equilibrium state for a prolonged period. Accordingly, it is necessary to run the mathematical model with simulated time continuously from season to season in order to predict the long term variation of the salinity intrusion. Hence, a time increment of numerical computation shorter than a tidal cycle is not economical. A model with "slack tide approximation" is more suitable for the long term variation of salinity intrusion. In this model, the time increment is an integral multiple of a tidal cycle and the salinity assumes the value at high water slack. The convective velocity is the velocity averaged over a tidal cycle, i.e. the velocity due to fresh water flow only. The transport of salt by the oscillating tidal currents is incorporated into the dispersion term, resulting in a dispersion coefficient an order of magnitude larger than that used in the "real time"[3] model, the model with the convective velocity including the tidal component.

Evaluation of Parameters

Velocity U: In an estuarine river, the current velocity may be decomposed into two parts,

$$U\ (x,t) = U_f\ (x,t) + U_t\ (x,t) \tag{18}$$

where U_f is the non-tidal component due to fresh water inflow and U_t is the oscillating tidal component. In the "real time" model, the tidal current is approximated by a sinusoidal function of time with period T, and phase

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[3] The distinction between these two types of models has been discussed by Harleman (1971)

difference f(x),

$$U_t\ (x,t) = U_T\ (x)\ \mathrm{Sin}\left\{\frac{2\pi}{T}\ t + f\ (x)\right\} \qquad (19)$$

where U_T (x) is the amplitude. $U_T(x)$ and f(x) are obtained from field measurements. The non-tidal component U_f is calculated by the equation,

$$U_f\ (x,t) = \frac{Q(x,t)}{G(x,t)} \qquad (20)$$

Q (x,t) is the fresh water discharge from the drainage area upstream of the transect located at distance x; this is estimated from the stream gauge record at upstream end, assuming the fresh water discharge to be proportional to drainage area. G (x,t) is the cross-sectional area of the transect; it is estimated by

$$G\ (x,t) = A\ (x)\quad 1 + \left\{\frac{Q(x,t)}{Q_T(x)}\right\}^{\mu} \qquad (21)$$

where A (x) is the cross-sectional area below mean sea level, Q_T (x) is the average tidal discharge from field data and μ is a constant less than unity.

In the model of "slack tide approximation", the convective velocity includes only the non-tidal component. Some time delay is allowed for the recorded stream flow at the upstream boundary to reach the transect concerned.

Dispersion Coefficient E: In a "real time" model, the dominant mechanism of longitudinal dispersion is the interaction of lateral turbulent diffusion and velocity shear. Taylor's formulation has been successfully modified and extended to tidal rivers (Holley, et.al., 1970, Harleman, 1971), with the dispersion coefficient for a tidal river with a large width to depth ratio expressed as

$$E = \alpha n|U|h^{5/6} \tag{22}$$

where n is Manning's friction coefficient; $|U|$ is the absolute value of the velocity; h is the hydraulic radius; and α is a constant of order 10^2. Equation (22) was tested in the "real time" model of the Rappahannock River; the results showed a salinity distribution lower than that of field data. It is known that the presence of density stratification due to salinity intrusion enhances the vertical shear and increases the dispersion coefficient. Therefore equation (22) was modified to

$$E = \alpha n|U|h^{5/6}(1 + \beta S) \tag{23}$$

where β is a constant and S is the salinity.

The convective velocity in the model with "slack tide approximation" includes only the non-tidal component. The transport of salt by the oscillating tidal current is incorporated into the dispersion term. In addition to the contribution from the vertical "shear effect", the dispersion coefficient should include a term, E_t, corresponding to the convection by the tidal component. No theory on this dispersion has yet been developed; researchers have generally resorted to the salinity field data to estimate the dispersion coefficient empirically.

In this Rappahannock River model, a simple phenomenological theory was formulated for the dispersion due to tidal current. By dimensional argument, the dispersion coefficient may be written as

$$E_t = \lambda u \ell$$

where λ is a constant of order of unity; u and ℓ are velocity and length scales of the mechanism involved. The apparent choice of the velocity scale is the amplitude of the tidal current. There are several possible choices of length scale. The tidal excursion distance seems to be the obvious one. In most estuarine rivers of the Chesapeake Bay, including the Rappahannock,

$$u \approx 1 \text{ ft/sec, tidal excursion} \approx 1.4 \times 10^4 \text{ ft.}$$

$$\text{and } u\ell \approx 40 \text{ mile}^2\text{/day}$$

which is an order of magnitude larger than empirical values. Furthermore, if the tidal current is uniform throughout each cross-section of the river, E_t will be zero regardless of the tidal excursion distance. It is the non-uniformity of the tidal current within a cross-section which induces longitudinal dispersion. For a wide and straight estuarine river, Holley, et.al. (1970) showed that the time scale of transverse mixing was much larger than a tidal cycle while that of vertical mixing was much smaller. Therefore, the depth will be the choice for the length scale, giving

$$u\ell \approx 0.1 \text{ mile}^2/\text{day},$$

which is an order of magnitude smaller than empirical data. In reality, most estuarine rivers have large curvatures and secondary flows always exist. Hence the time scale of transverse mixing may have the same order of magnitude as that of the vertical one, even though the width of the estuary is much larger than the depth. In this case, the choice of length scale would be the characteristic length of the cross section, i.e. the square root of the cross-sectional area. In the model for the Rappahannock River, the following was used:

$$E_t = \lambda\sqrt{A}\ U_T$$

Results and Discussion

Two mathematical models were set up for a 70-mile reach of the Rappahannock River estuary. One is a "real time" model and the other is a "slack tide approximation".

The "real time" model was used for the coupled system of BOD and DO equations; it was also used to describe the fluctuation of salinity distribution within a tidal cycle. The constants in equation (23) were adjusted and verified with field data until the model outputs of salinity distribution agreed with field data. Figure 17 shows the comparison between the salinity distributions of the model output and the field data. Figures 18 through 22 show the variation of DO concentration as a function of time at various transects. As shown in the figures, the model outputs of DO concentration at most transects show a semi-diurnal fluctuation because of the tidal current. This semi-diurnal fluctuation is associated with gradient of DO concentration along the estuary and it diminishes at transects far away from concentrated BOD sources, (e.g. transect #24), where the model output becomes almost constant with respect to time. At about half of the 28 transects, the DO field data showed a somewhat diurnal fluctuation as typified by the data at transect #24. This fluctuation is attributed to photosynthesis and respiration. It was attempted to model the diurnal fluctuation with a single source and sink term representing photosynthesis and respiration; this failed to give results which agreed with field data, because the field data at the different transects had dissimilar functional characteristics. The results shown in figures 18 through 22 are from the model leaving out photosynthesis and respiration. Figure 23 shows the DO distribution, averaged over a 24-hour period, along the estuary. The minimum DO concentration occurs about 7 miles downstream of the primary BOD sources, domestic and industrial, near Fredericksburg. In order to predict the possible nuisance conditions of low DO concentration at low fresh water inflow, the model was run with a 100 cfs fresh water discharge, the fourteen-consecutive-day low flow with an occurrence rate of once in ten years. The resulting DO distribution is also shown in figure 23.

The model with "slack tide approximation" was used to simulate the long term variation of salinity intrusion. Figure 24 shows the salinity distribution from the model output and the field data from slack water runs at high water slack. The slack water run data of August 18, 1970 was used as the initial conditions of the model. The salt intruded upstream in the dry season as shown by the model output and slack water run data of October 8. The salt was washed downstream in the wet months as shown by the salinity distribution of December 10. Figure 25 shows a sample of the salinity intrusion predicted by the mathematical model, assuming that 50% of the fresh water runoff was diverted out of the estuarine river. Contrary to the natural case when the salinity decreased from October to December, the salinity kept increasing, except at the upstream end.

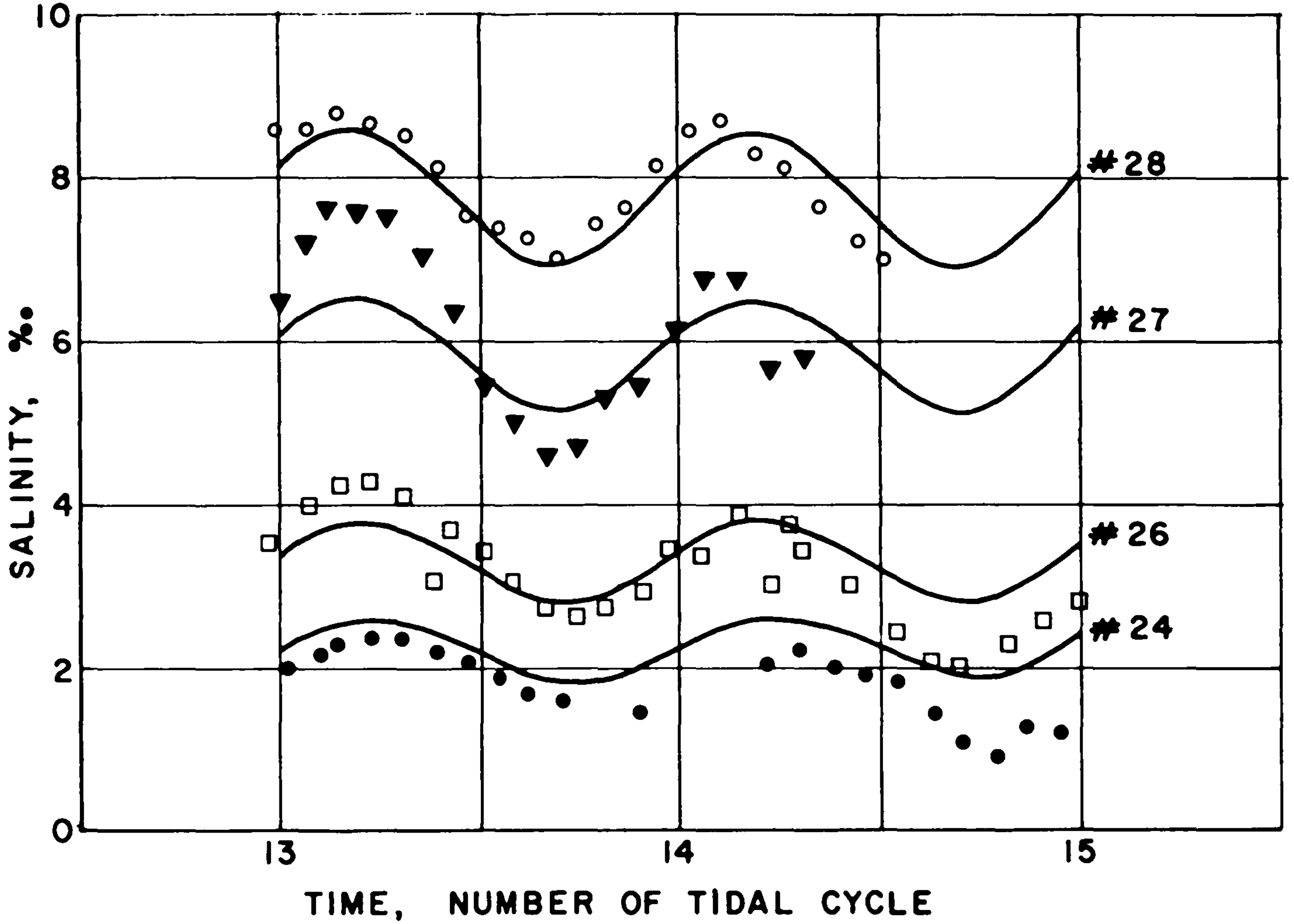

Figure 17. Variation of salinity with time.
(The abscissa is the number of tidal cycles after computation begins. The data points are field data at transects no. 28 (open circles), no. 27 (triangles), no. 26 (squares) and no. 24 (solid circles). The solid curves are model outputs at the corresponding transects).

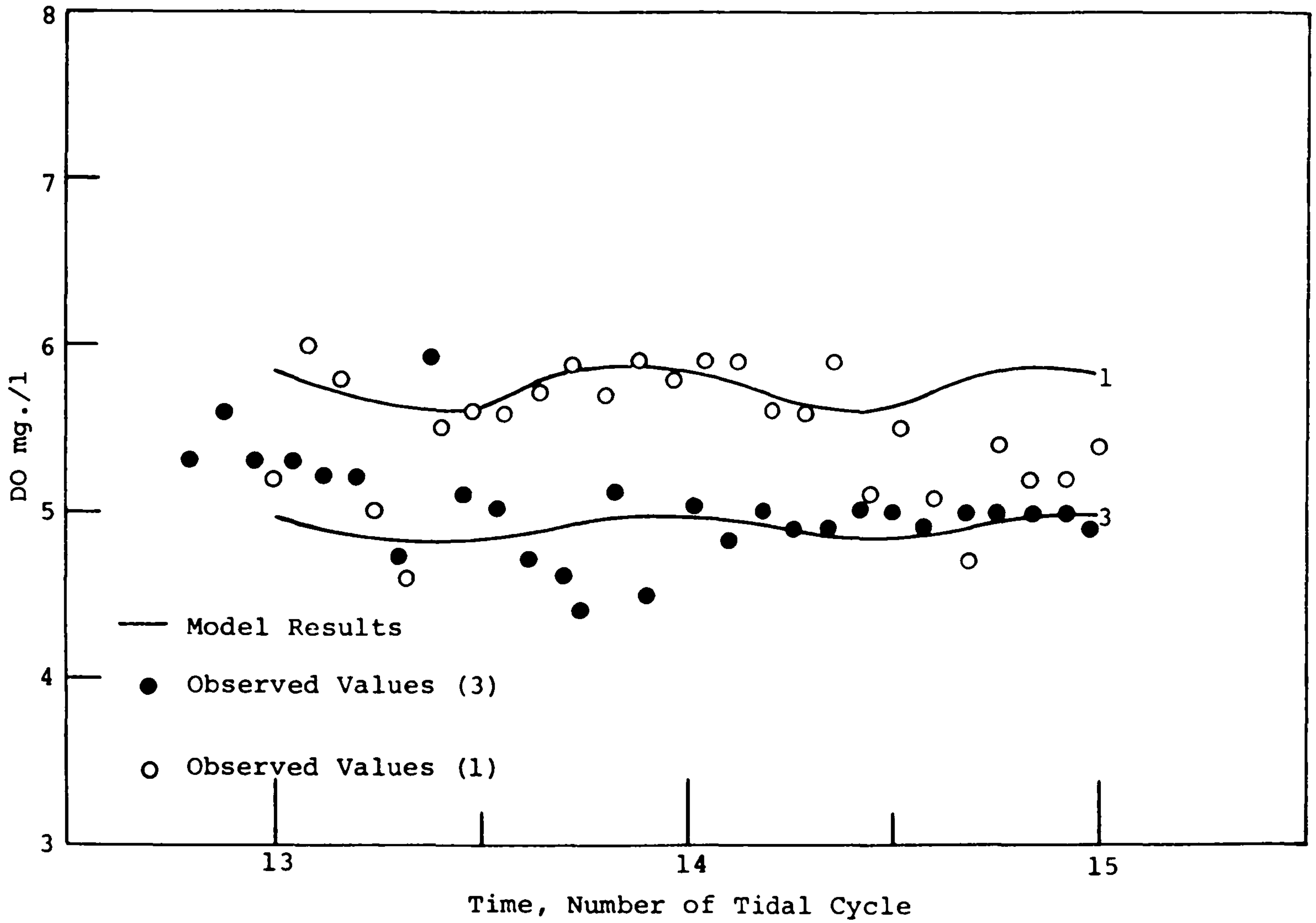

Figure 18. Variation of DO with time, model results and observed values at transects 1 and 3.

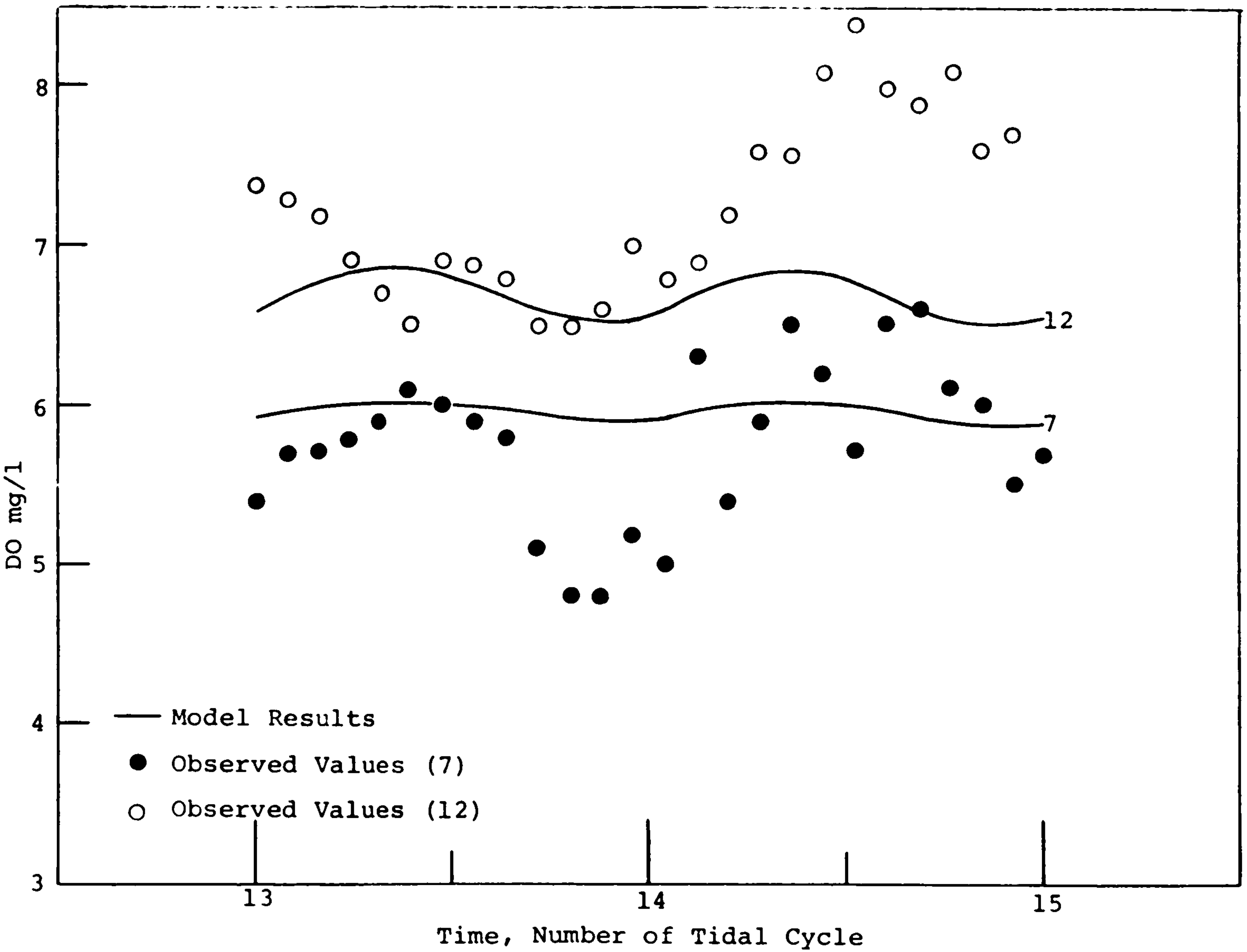

Figure 19. Variation of DO with time, model results and observed values at transects 12 and 7.

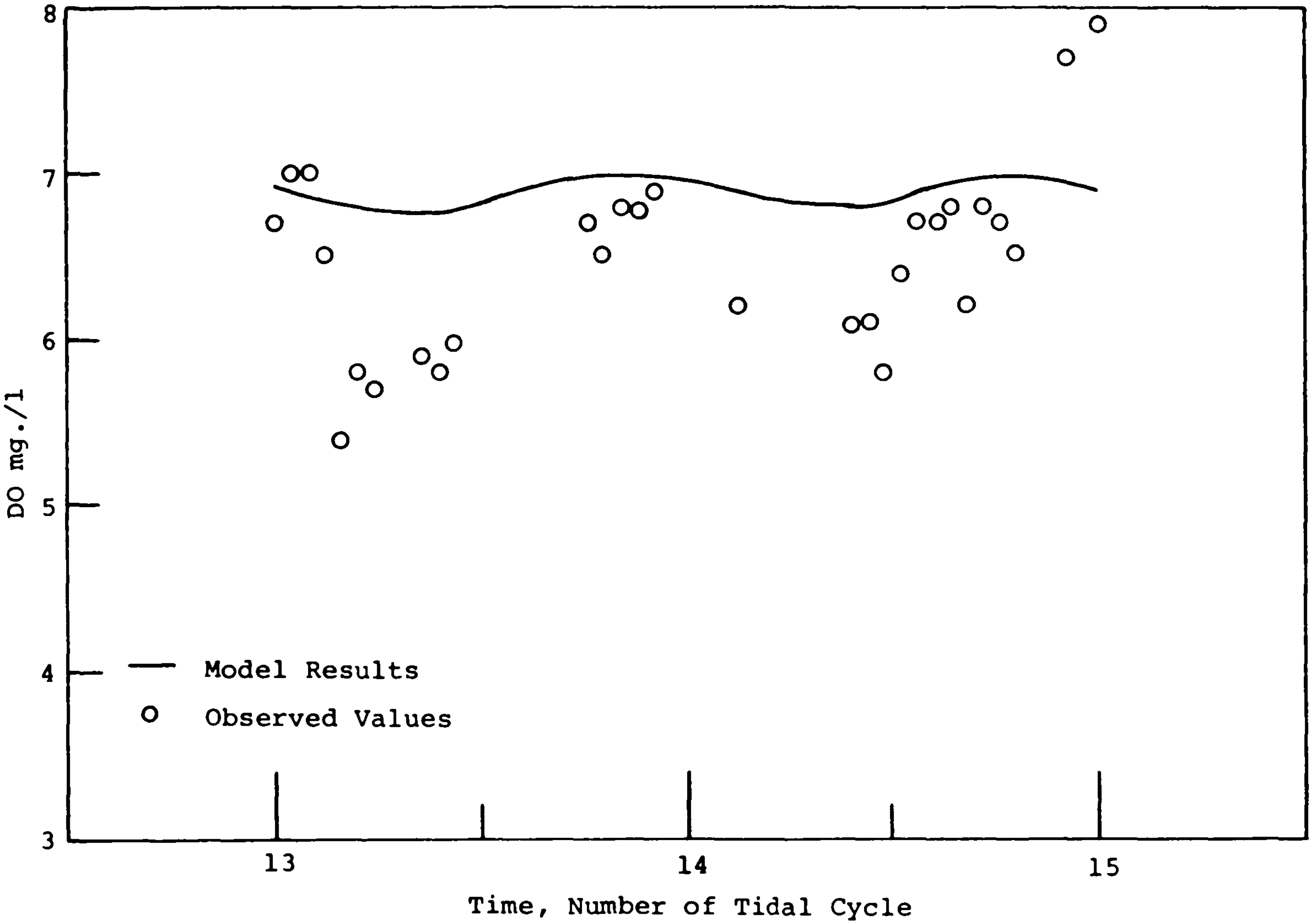

Figure 20. Variation of DO with time, model results and observed values at transect 17.

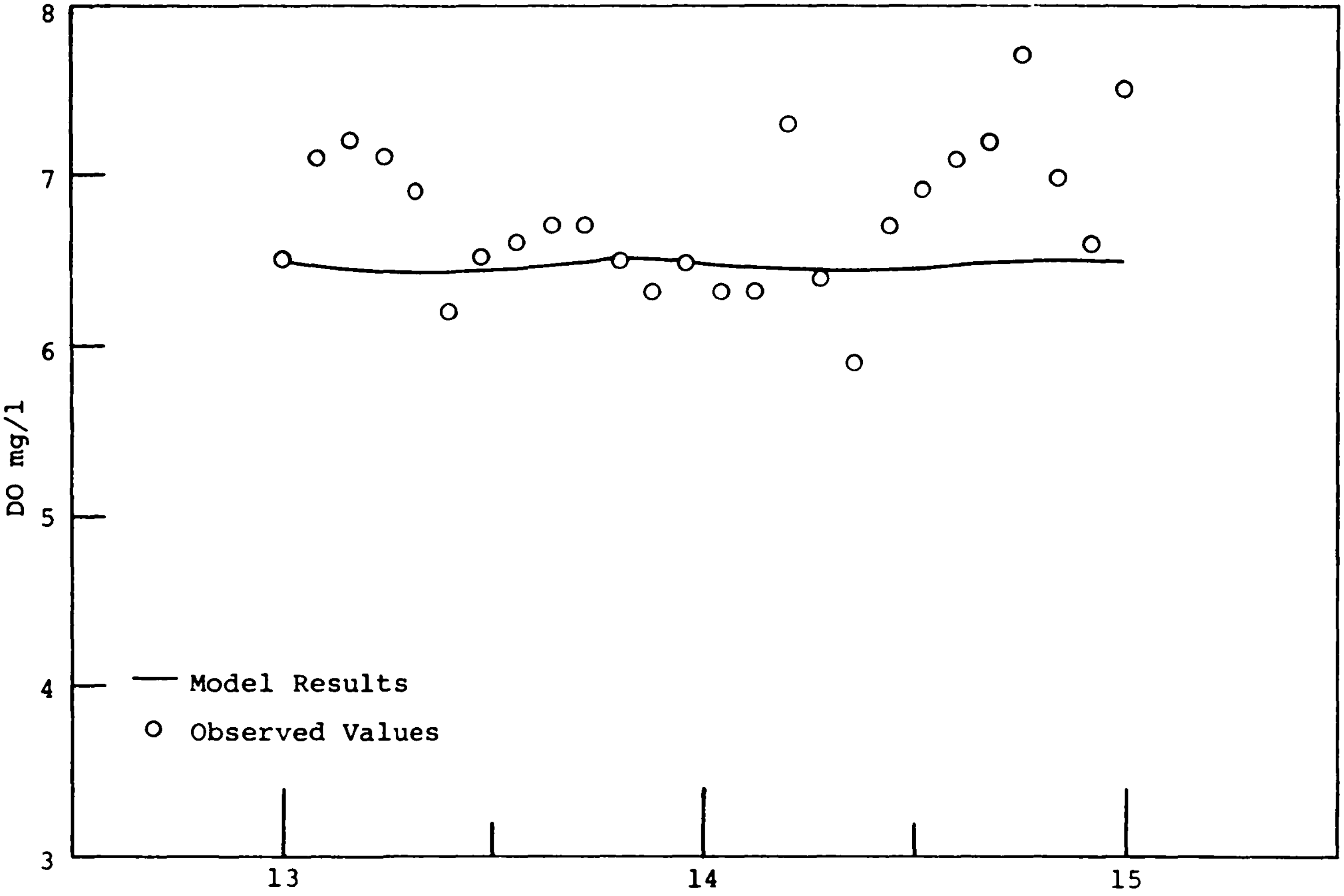

Figure 21. Variation of DO with time, model results and observed values at transect 21.

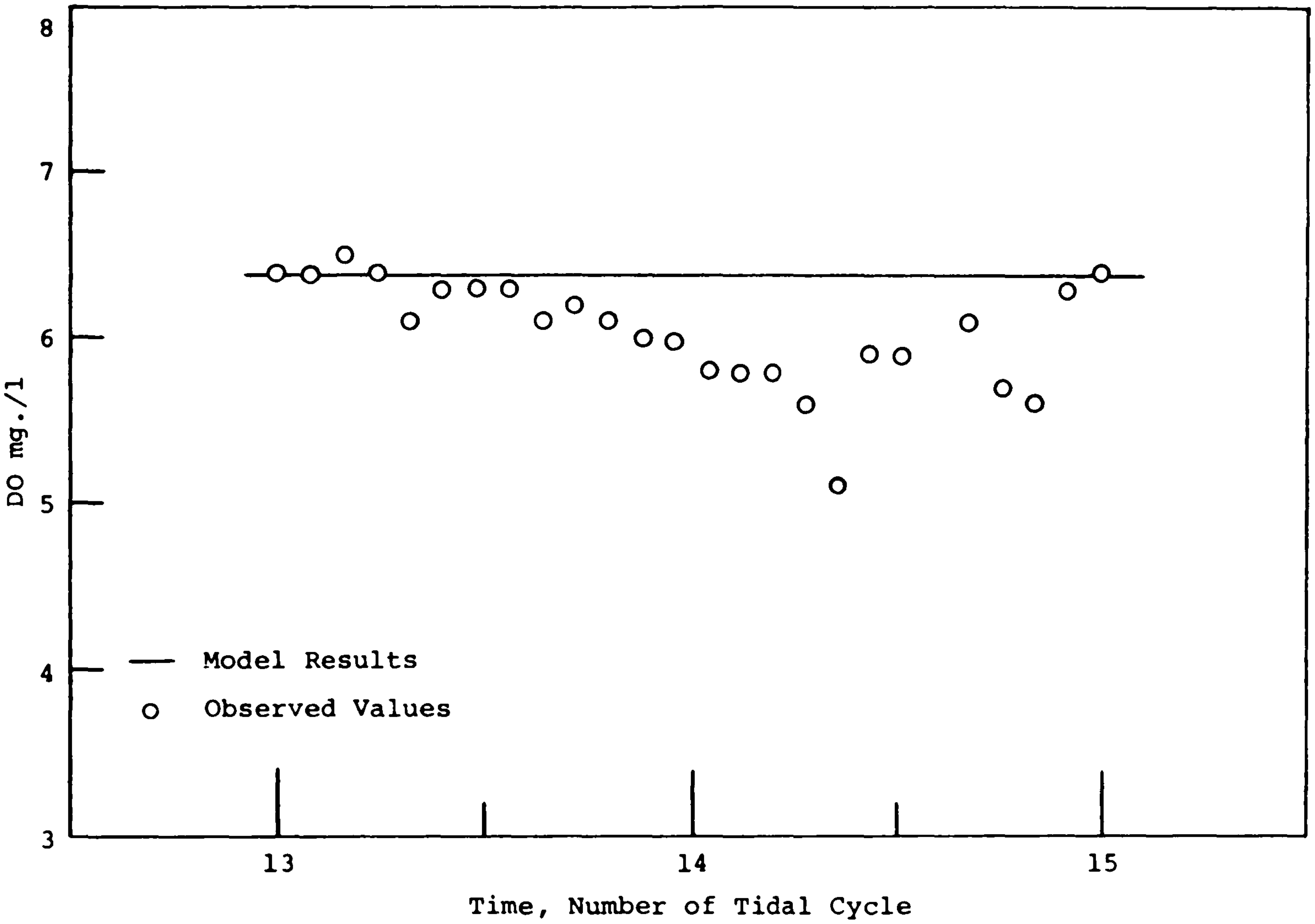

Figure 22. Variation of DO with time, model results and observed values at transect 24.

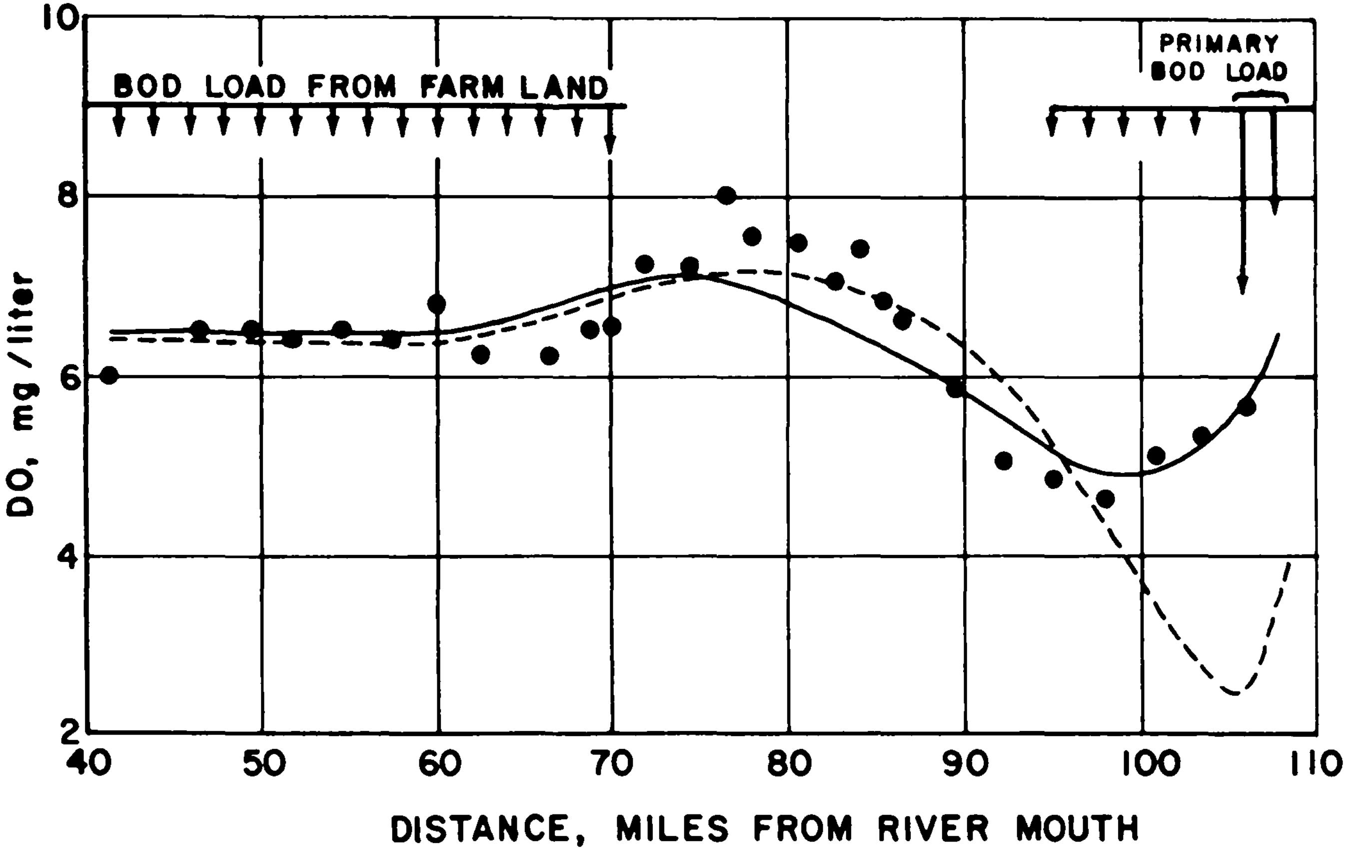

Figure 23. The distribution of DO concentration (averaged over 24 hour period) along the estuarine river.
(The data points are field data and the solid curve is the model output with fresh water discharge at 748 cfs, the value at the time of field operations. The dashed curve is the predicted DO distribution with a fresh water discharge of 100 cfs).

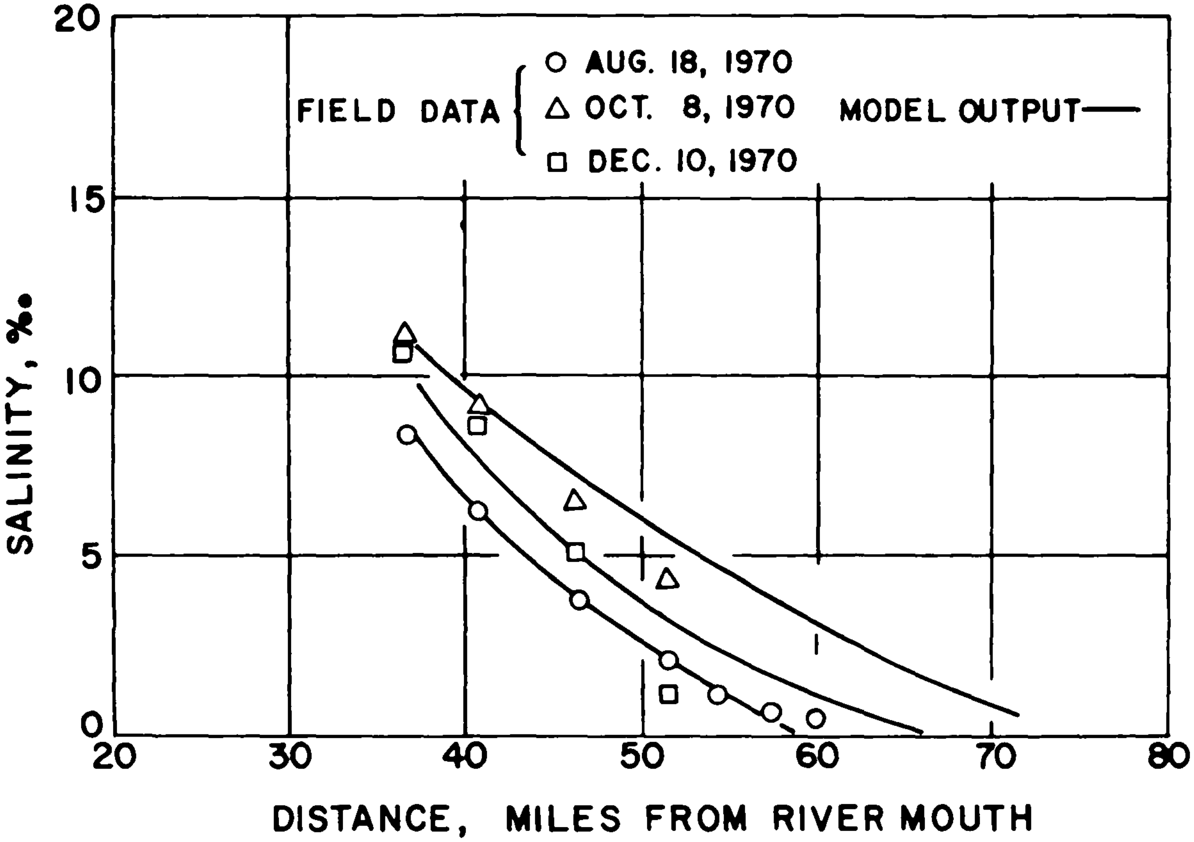

Figure 24. Salinity distribution along the estuarine river.

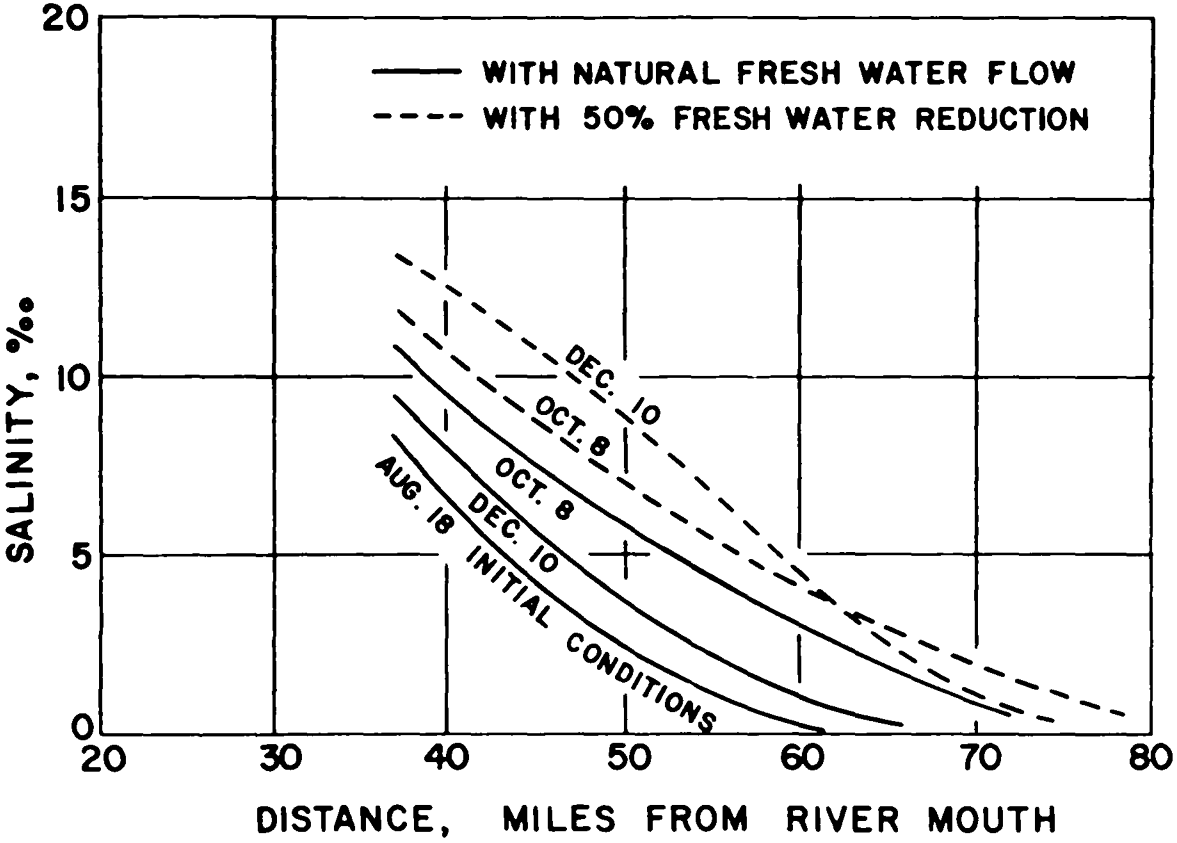

Figure 25. Comparison of salinity distributions for natural fresh water discharge of 1970 and for reduced fresh water discharge.

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APPENDICES

APPENDIX A

RESULTS OF SLACK WATER RUNS

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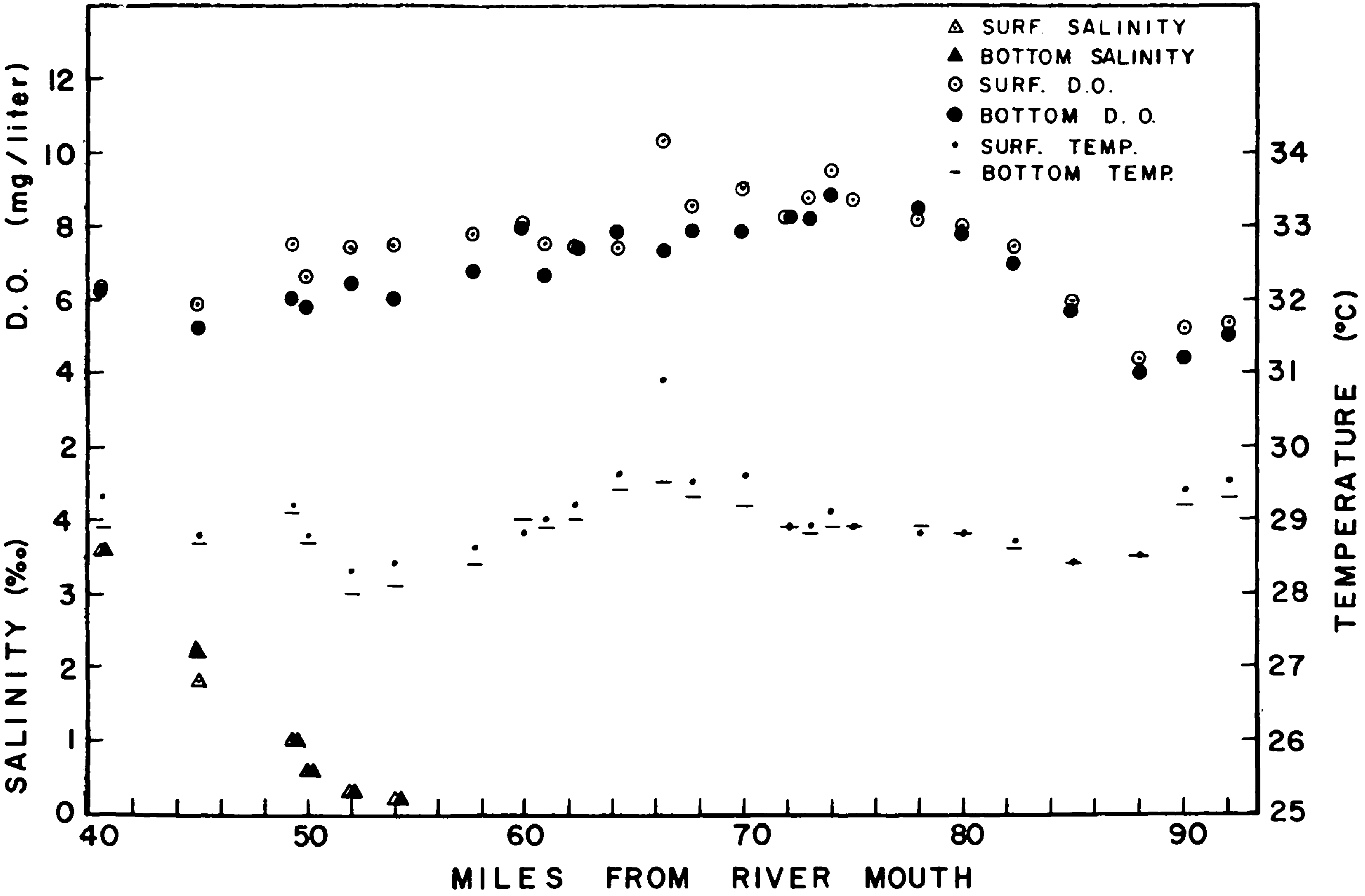

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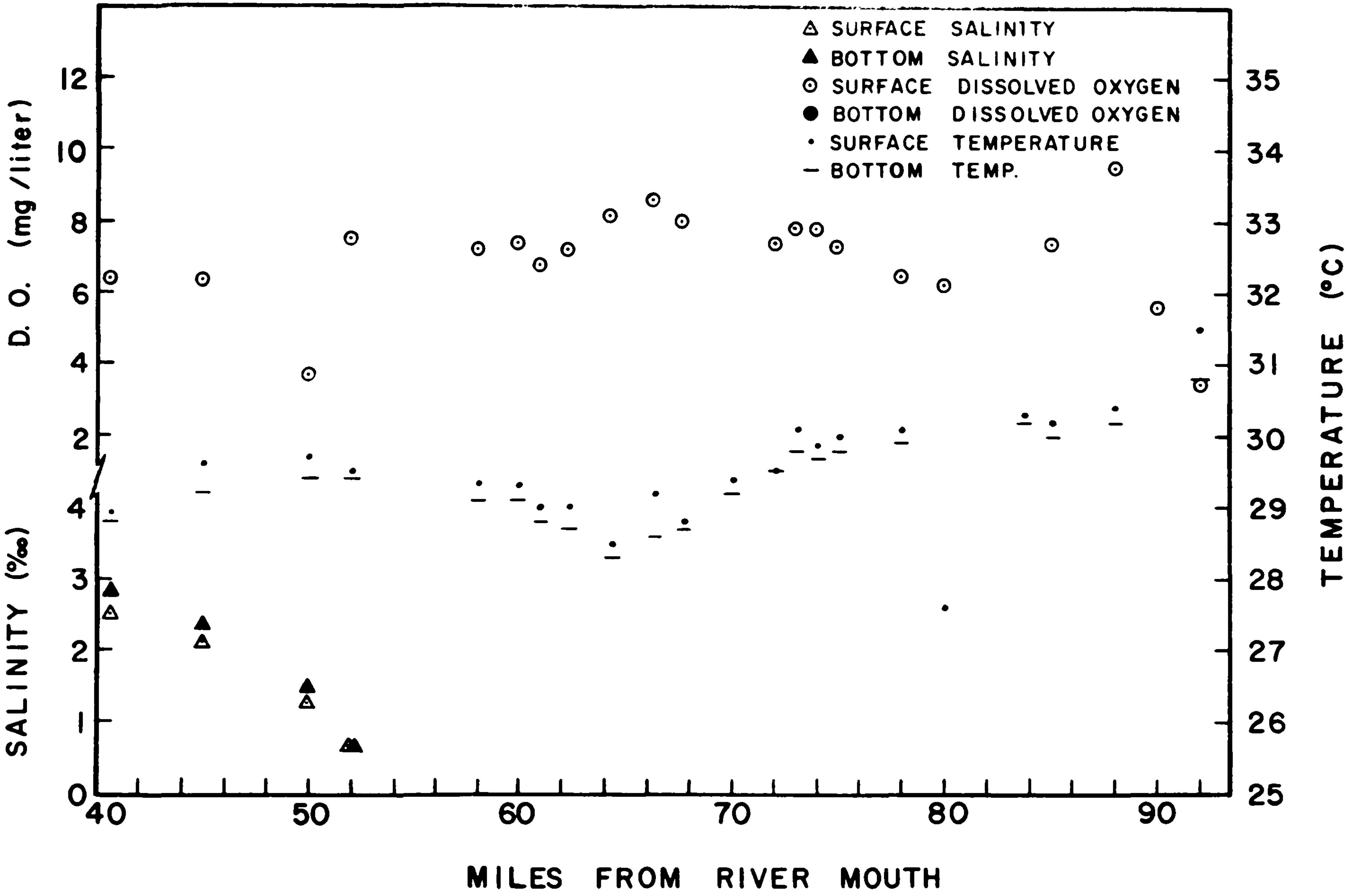
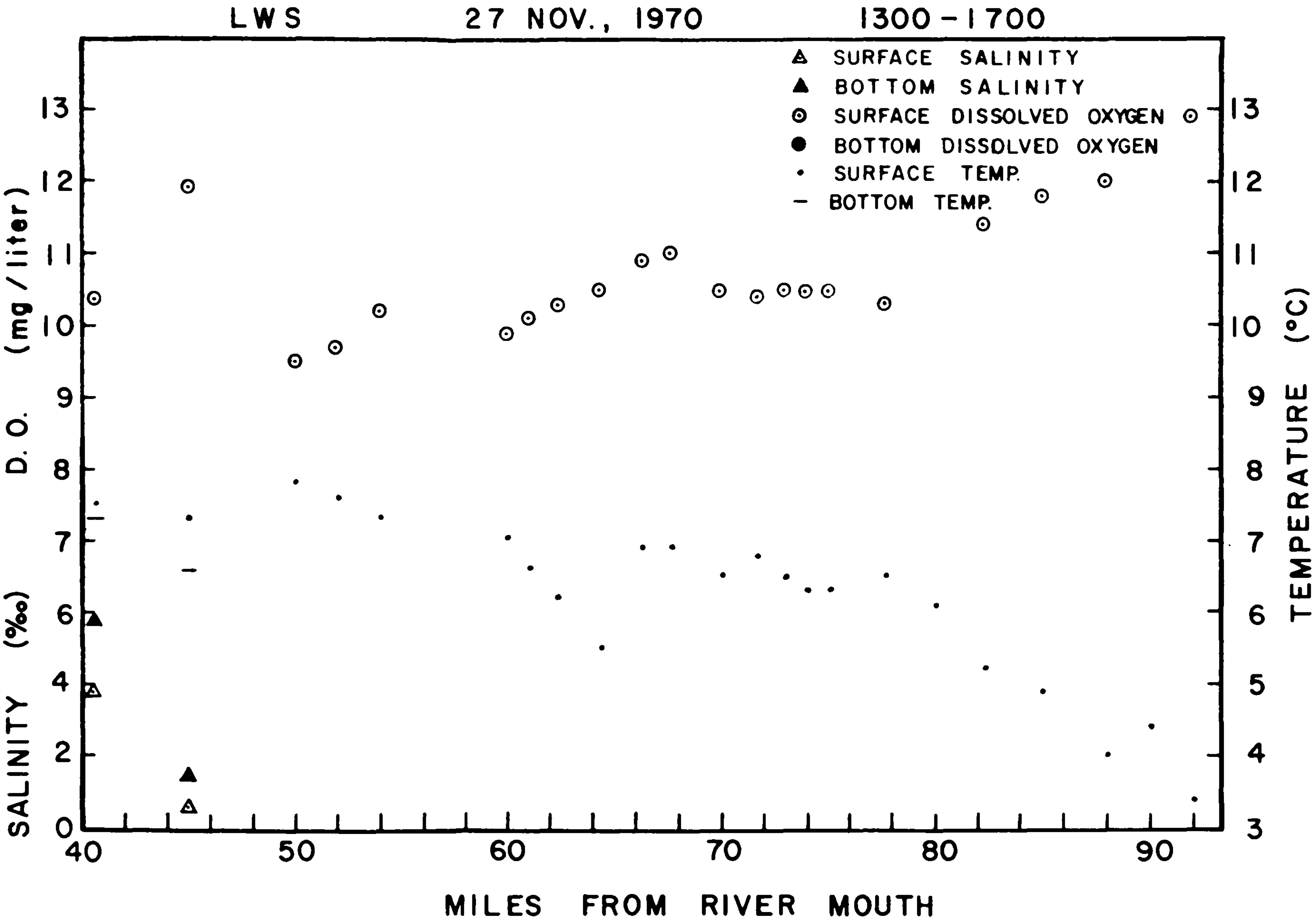
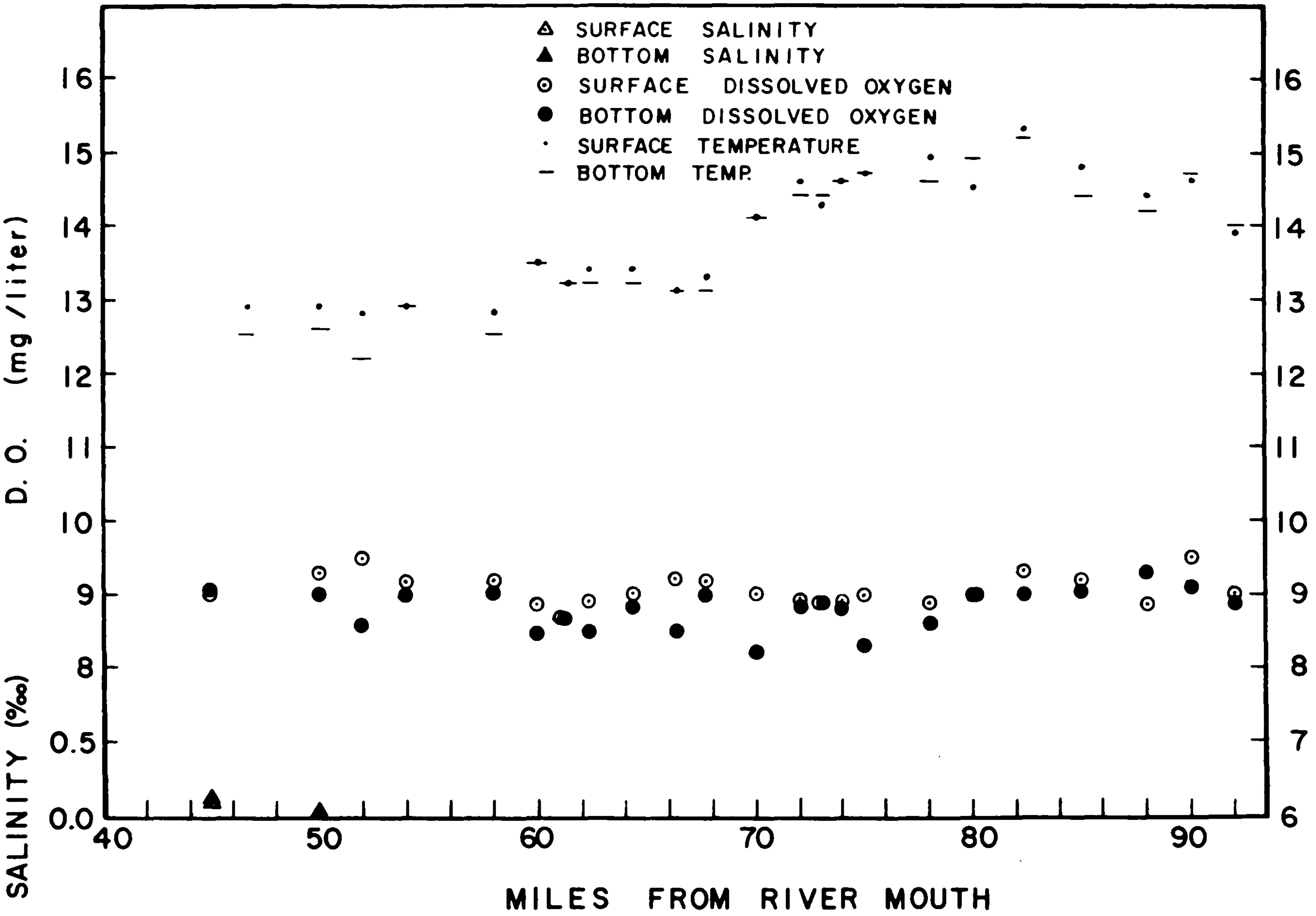
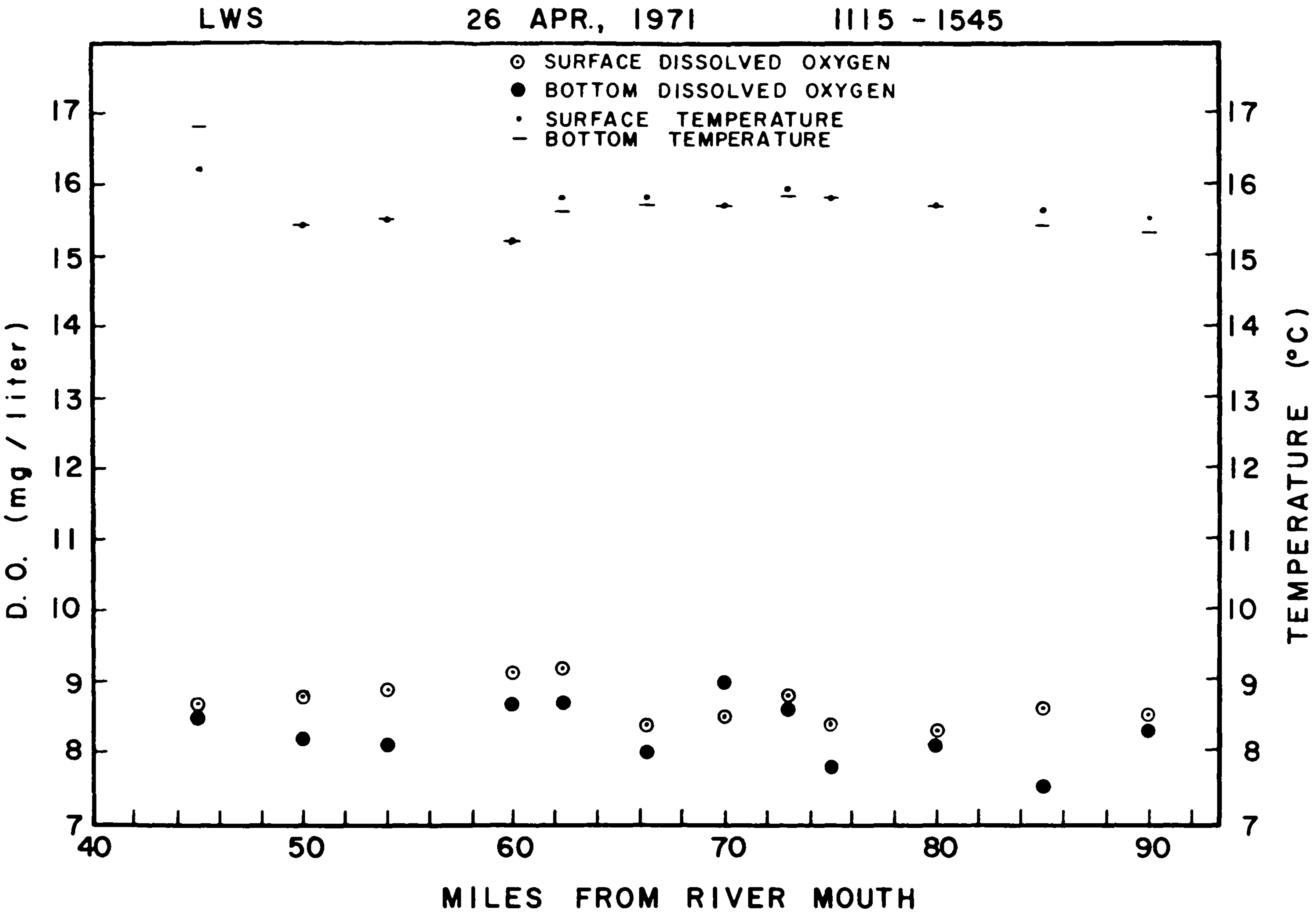


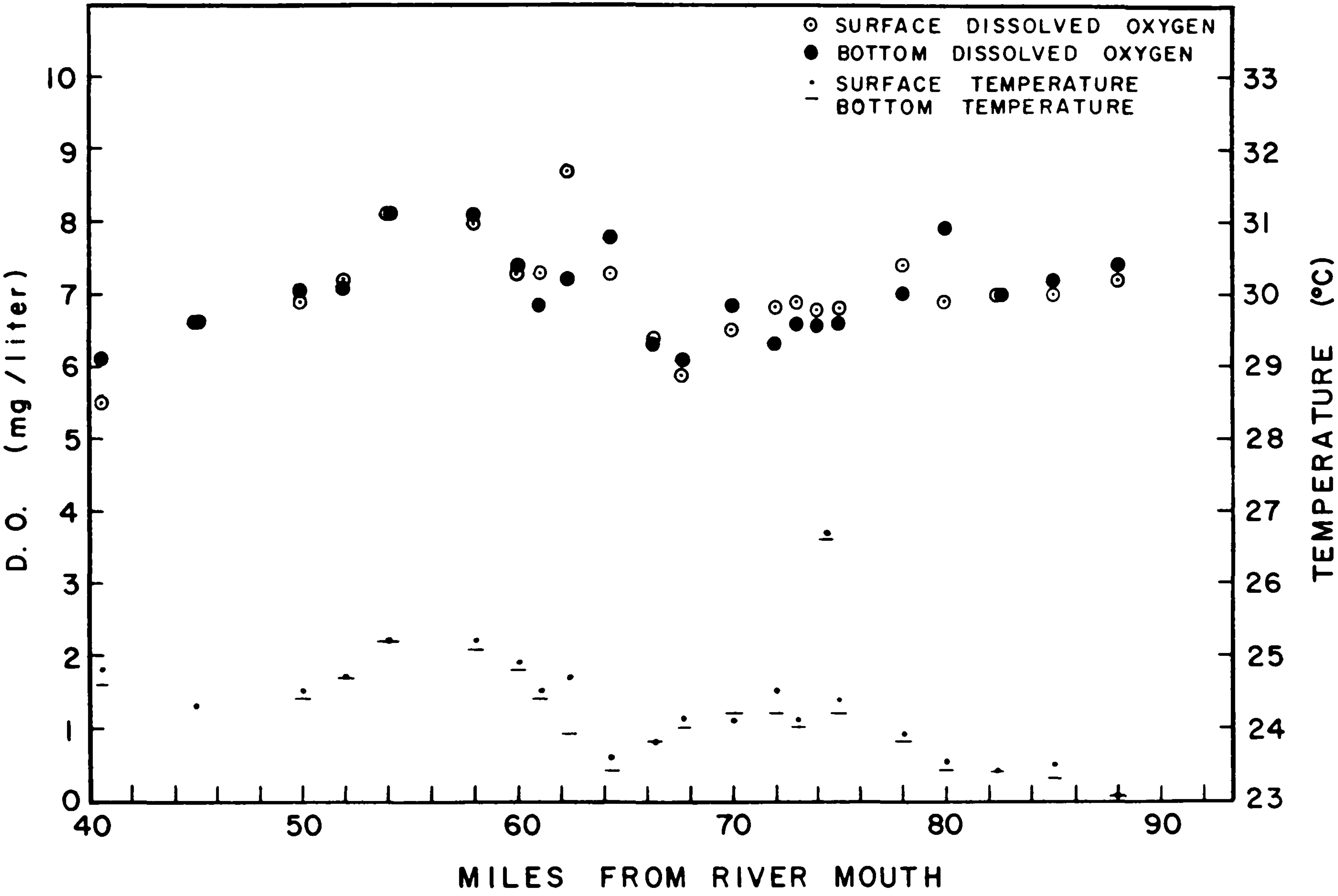

LWS
27 NOV., 1970
1300-1700
SURFACE SALINITY
BOTTOM SALINITY
SURFACE DISSOLVED OXYGEN
BOTTOM DISSOLVED OXYGEN
SURFACE TEMP.
BOTTOM TEMP.
D. O. (mg / liter)
SALINITY (‰)
TEMPERATURE (°C)
0
2
4
6
7
8
9
10
11
12
13
3
4
5
6
7
8
9
10
11
12
13
40
50
60
70
80
90
MILES FROM RIVER MOUTH

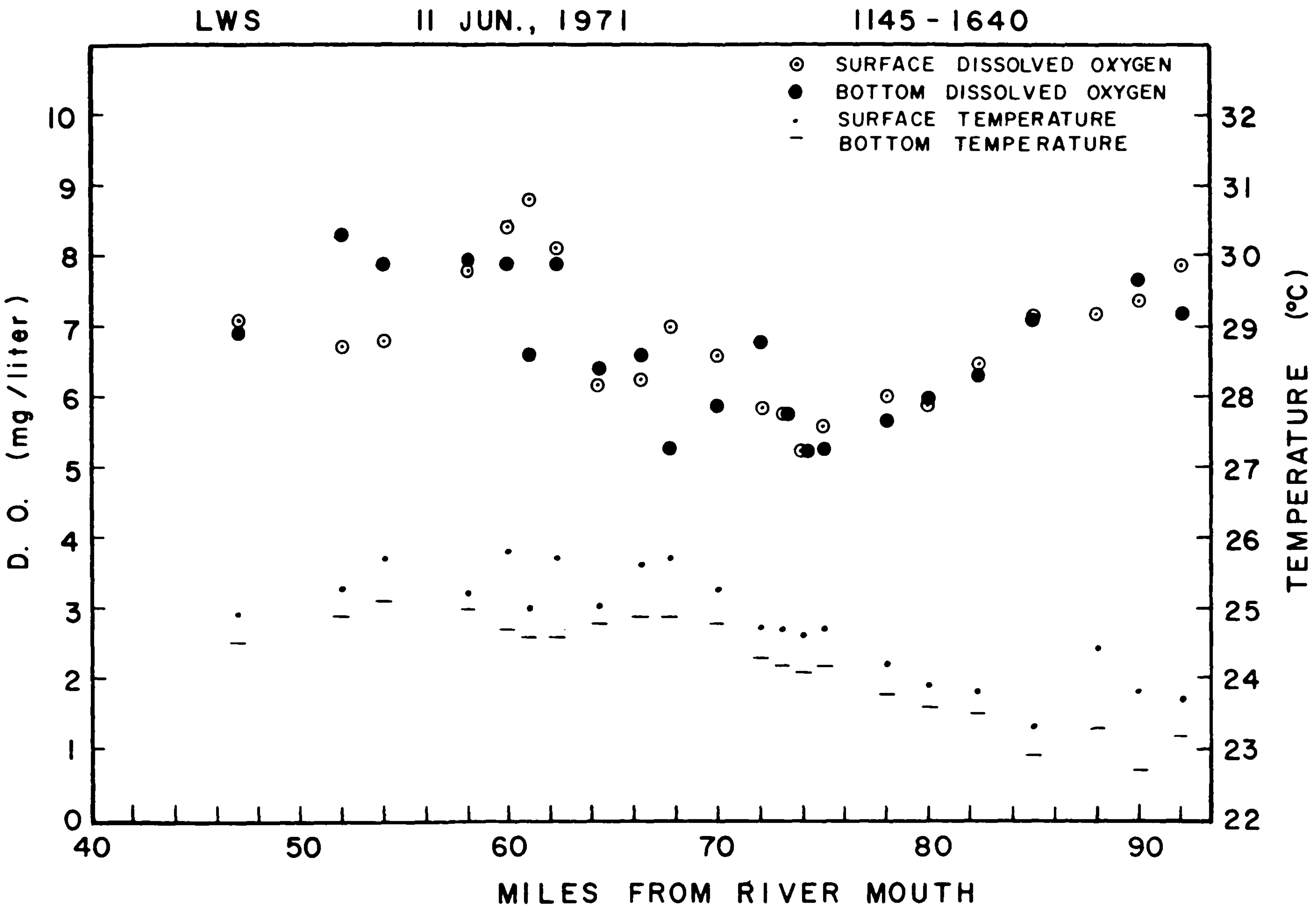
HWS 16 APR., 1971 0710 – 1204

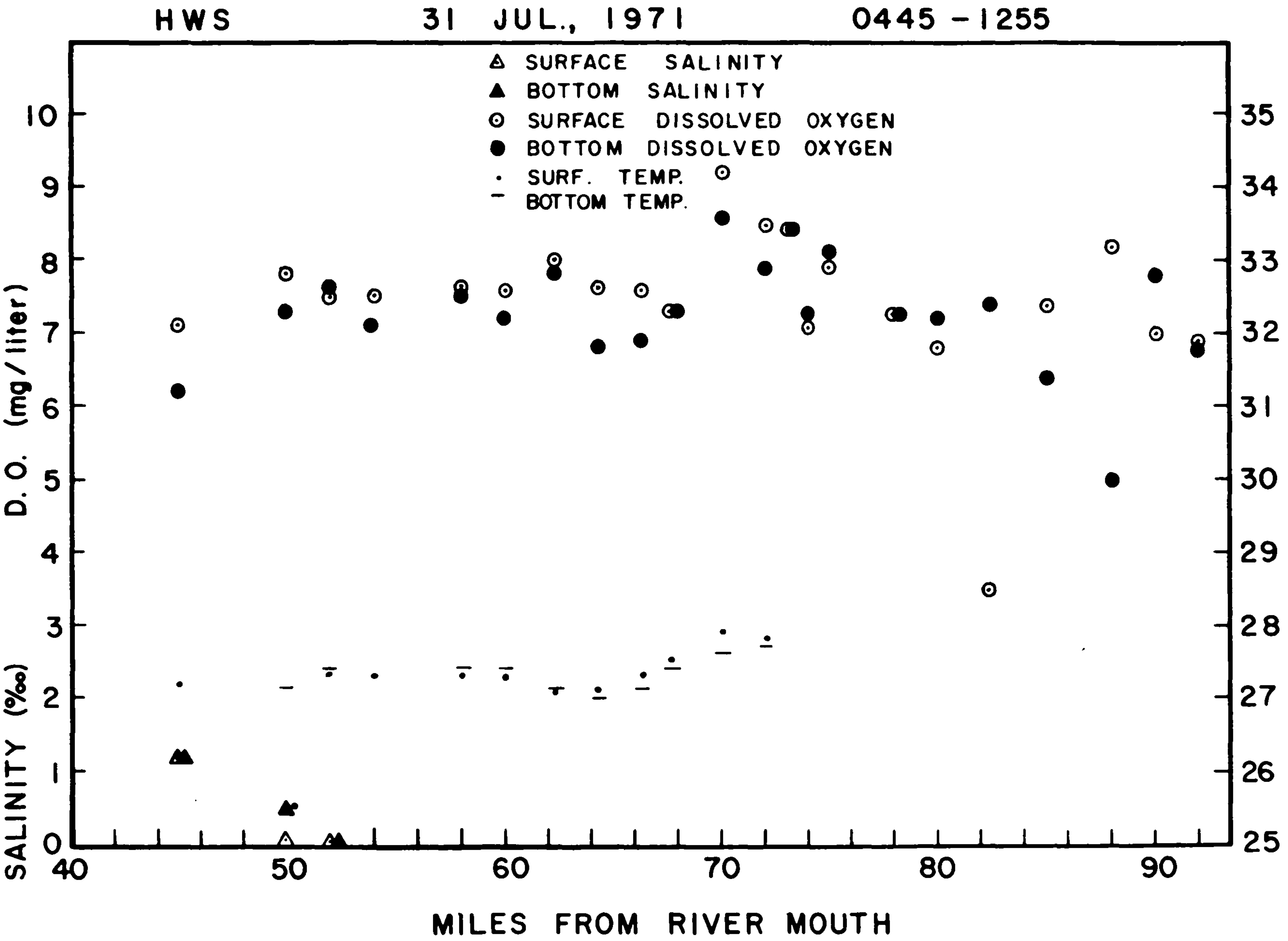



LWS
26 APR., 1971
1115 - 1545
⊙ SURFACE DISSOLVED OXYGEN
● BOTTOM DISSOLVED OXYGEN
• SURFACE TEMPERATURE
— BOTTOM TEMPERATURE
D. O. (mg / liter)
TEMPERATURE (°C)
7
8
9
10
11
12
13
14
15
16
17
40
50
60
70
80
90
MILES FROM RIVER MOUTH

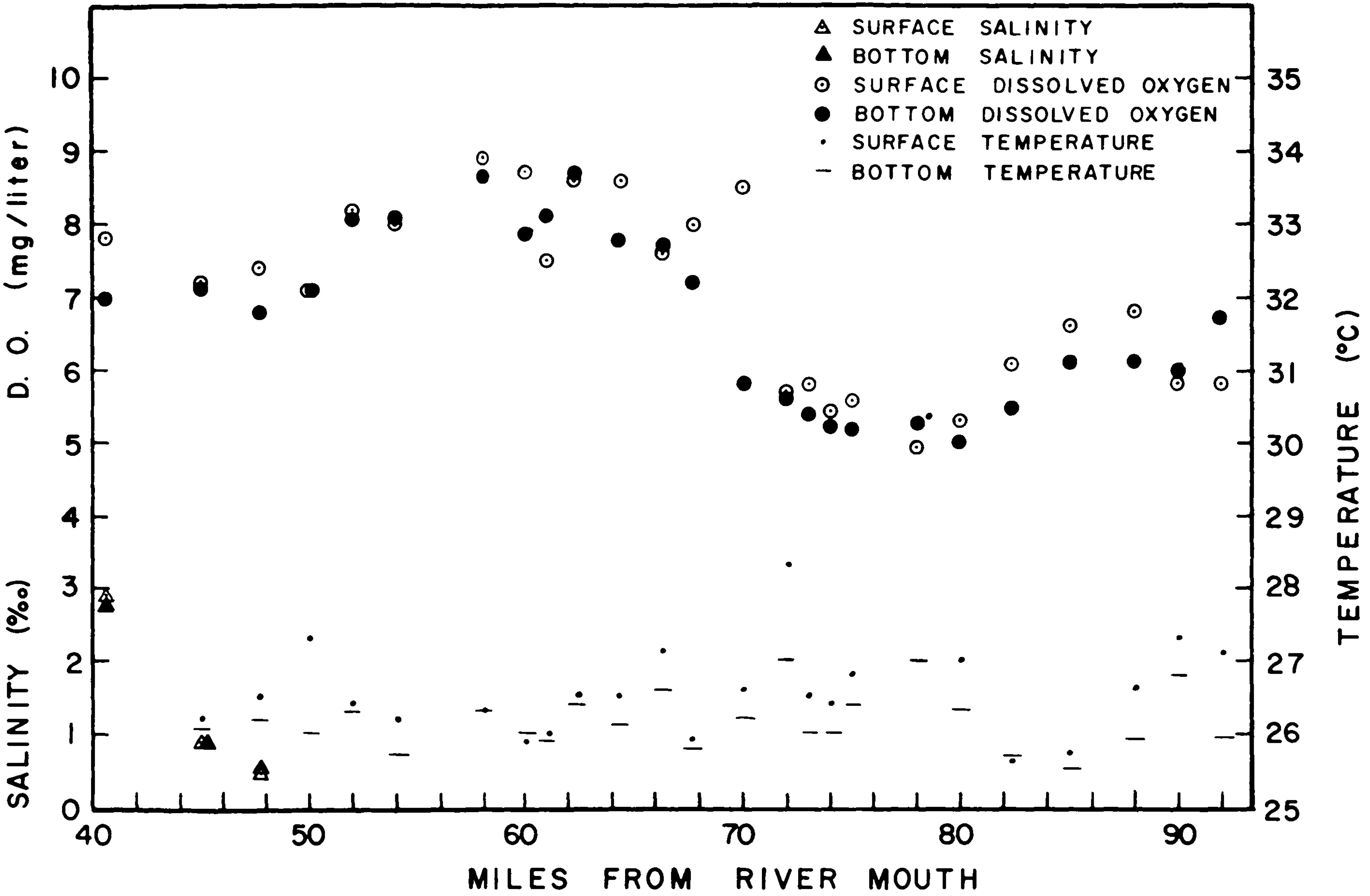
LWS 9 JUN., 1971 1105 - 1545

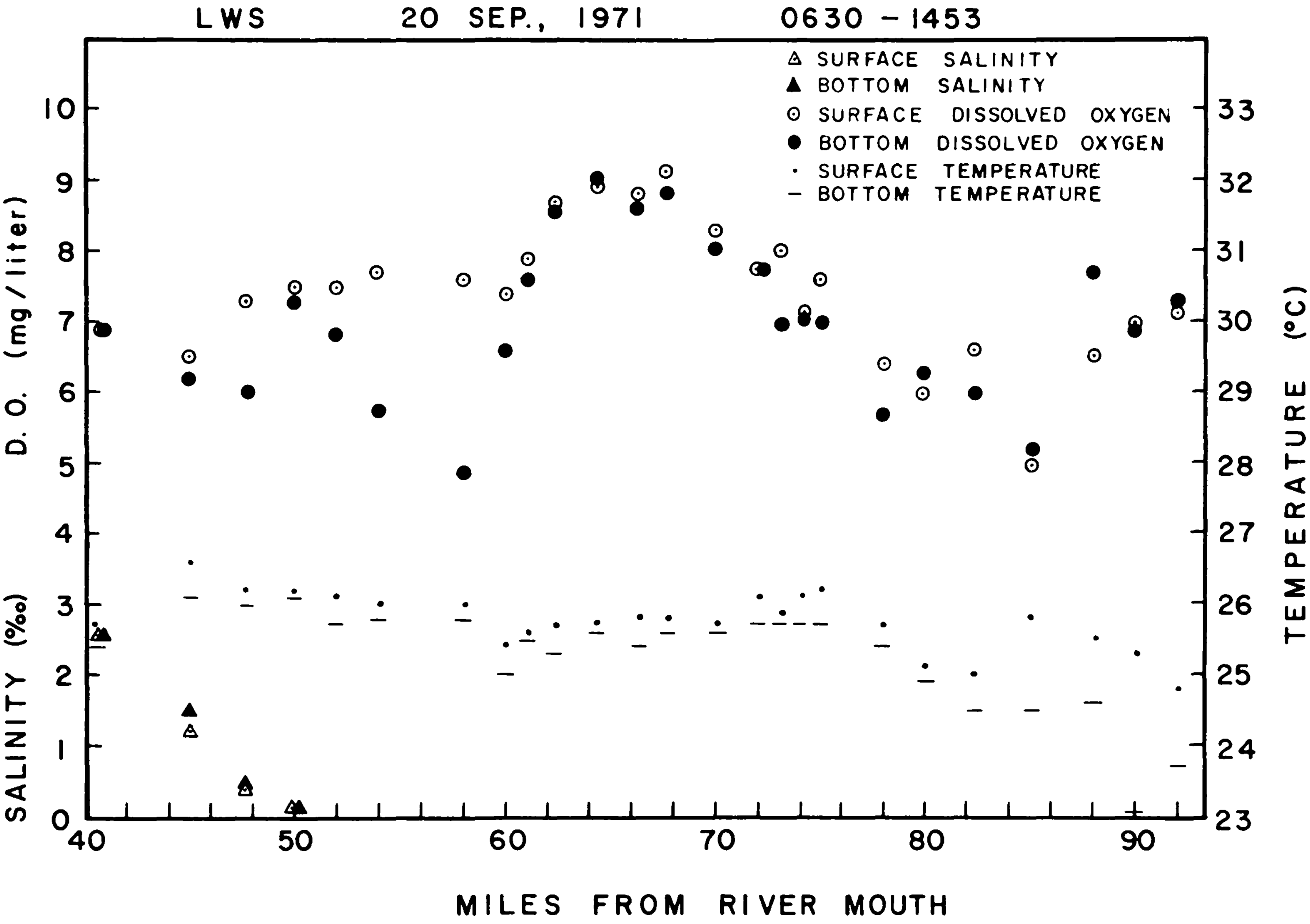


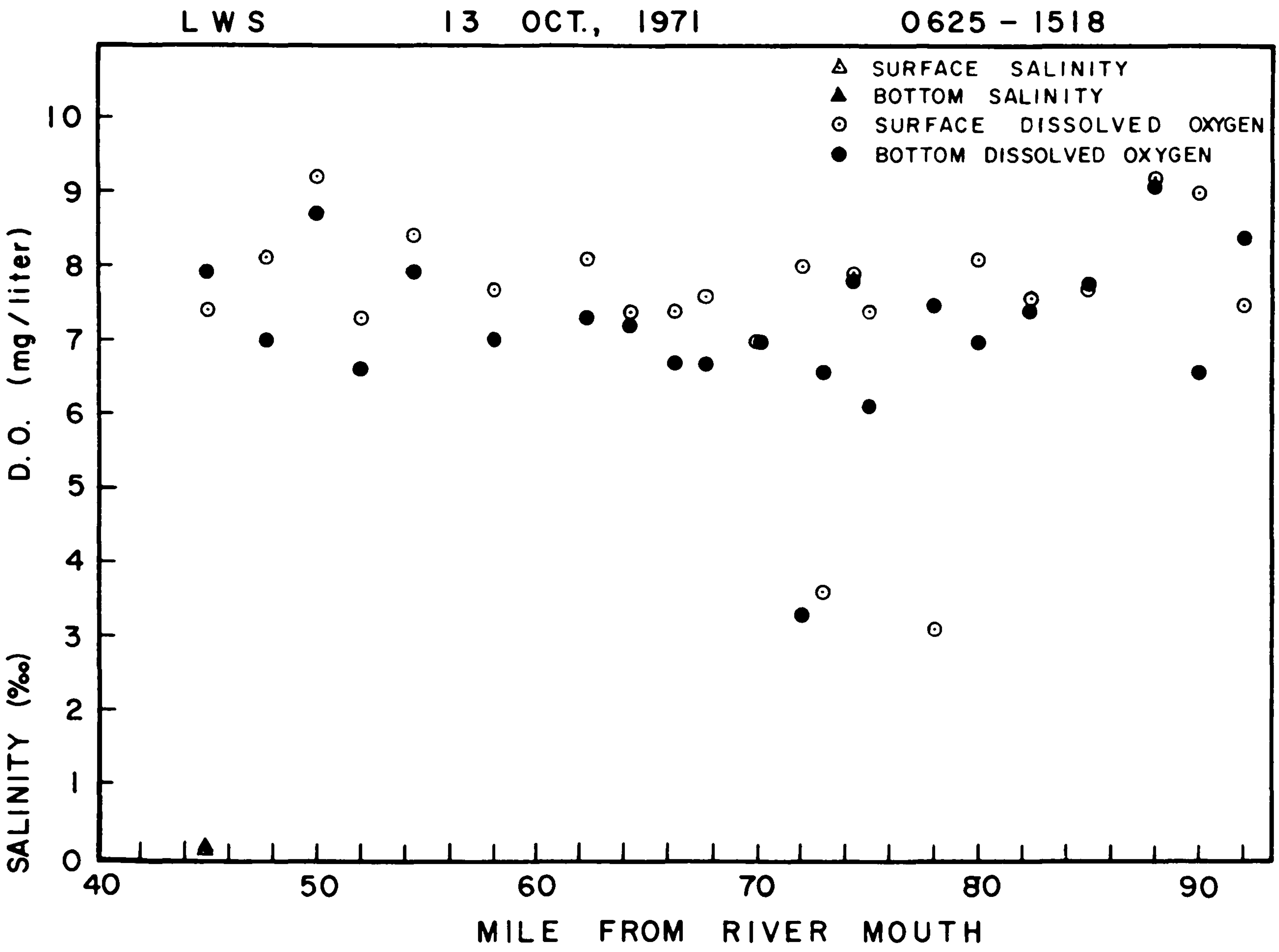

LWS
11 JUN., 1971
1145 - 1640
SURFACE DISSOLVED OXYGEN
BOTTOM DISSOLVED OXYGEN
SURFACE TEMPERATURE
BOTTOM TEMPERATURE
D. O. (mg / liter)
0
1
2
3
4
5
6
7
8
9
10
TEMPERATURE (°C)
22
23
24
25
26
27
28
29
30
31
32
40
50
60
70
80
90
MILES FROM RIVER MOUTH


HWS
31 JUL., 1971
0445 - 1255
SURFACE SALINITY
BOTTOM SALINITY
SURFACE DISSOLVED OXYGEN
BOTTOM DISSOLVED OXYGEN
SURF. TEMP.
BOTTOM TEMP.
D. O. (mg/liter)
SALINITY (‰)
TEMPERATURE (°C)
MILES FROM RIVER MOUTH
10
9
8
7
6
5
4
3
2
1
0
35
34
33
32
31
30
29
28
27
26
25
40
50
60
70
80
90

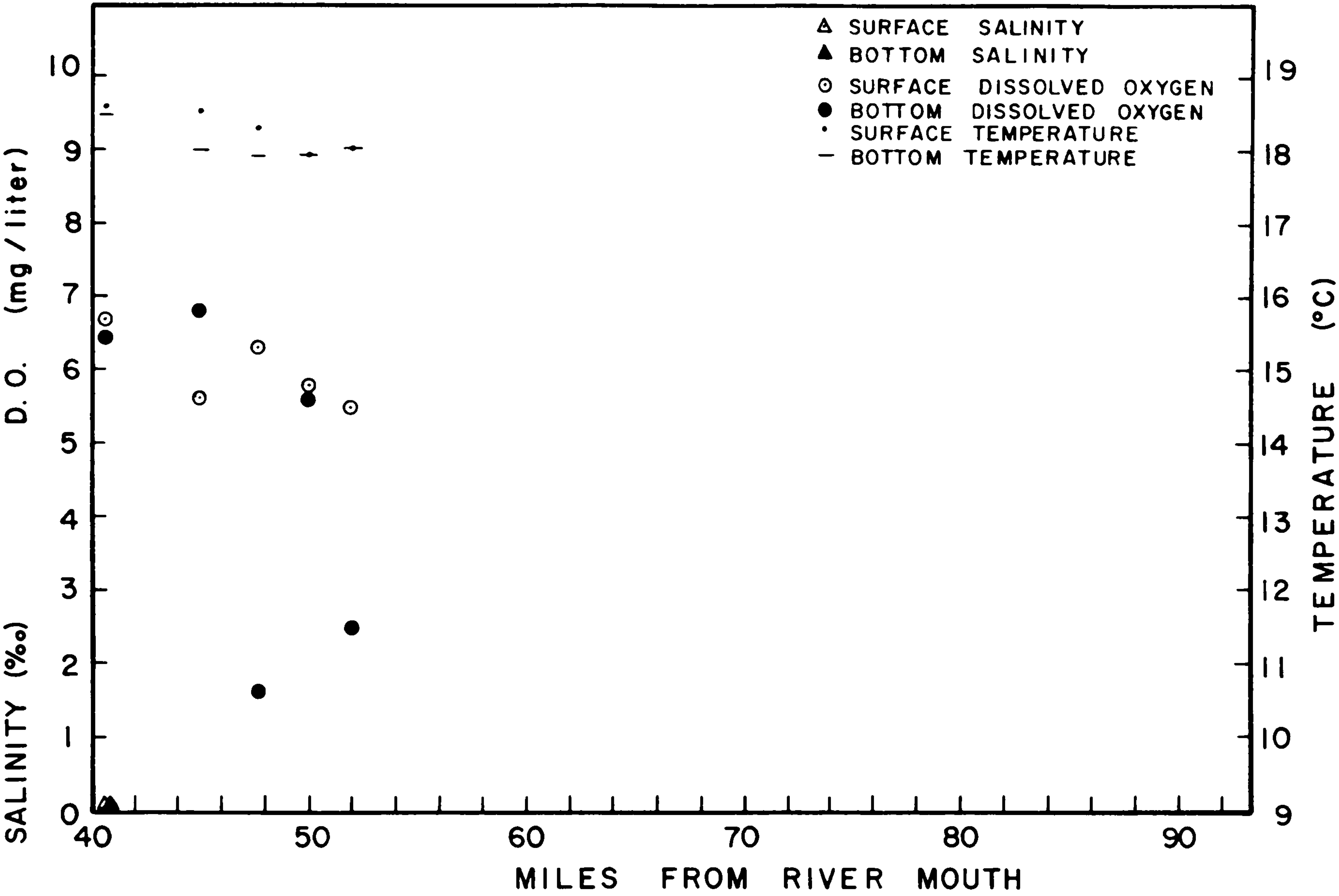
HWS 31 AUG., 1971 0620 - 1428



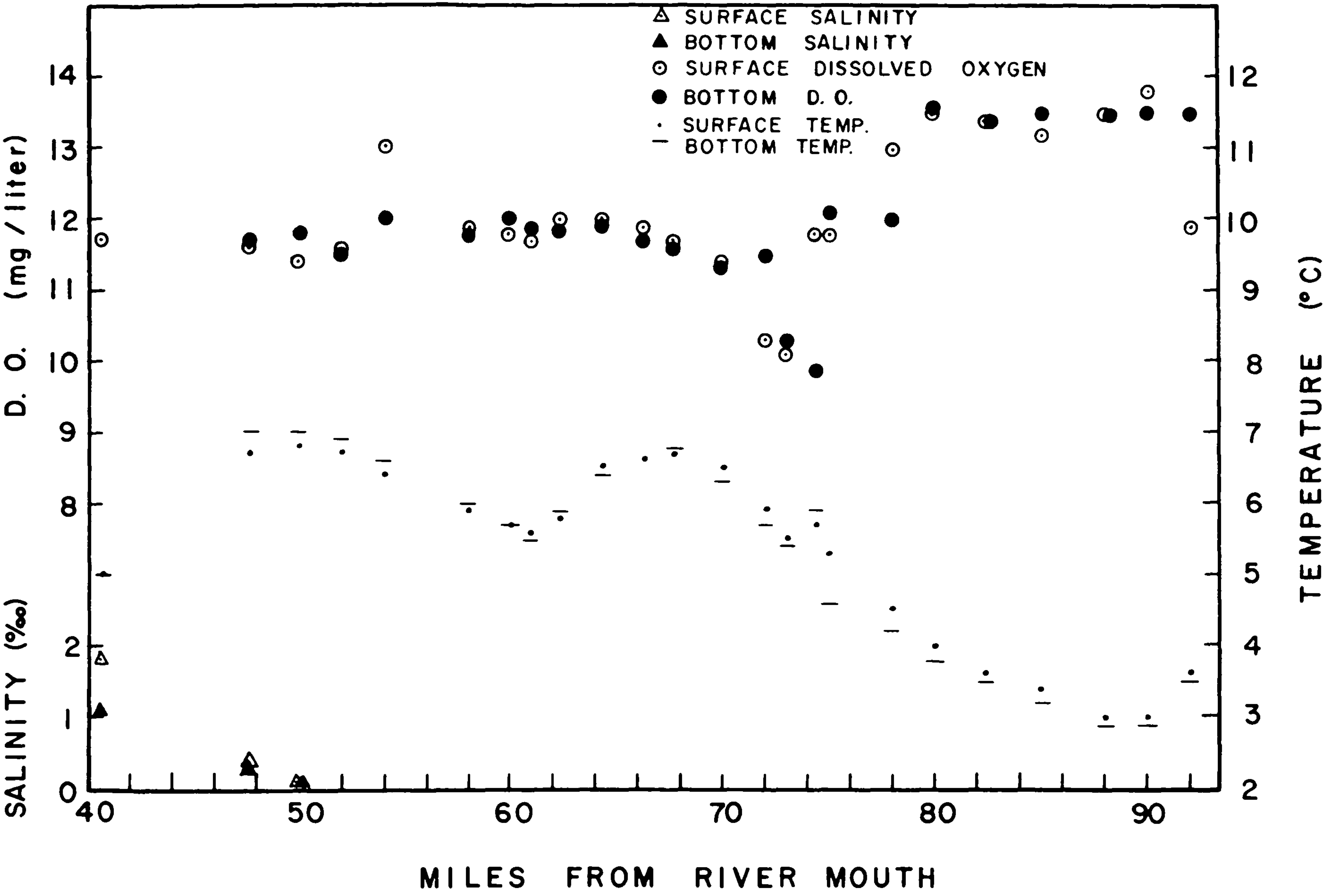

LWS 20 SEP., 1971 0630 - 1453
△ SURFACE SALINITY
▲ BOTTOM SALINITY
⊙ SURFACE DISSOLVED OXYGEN
● BOTTOM DISSOLVED OXYGEN
· SURFACE TEMPERATURE
— BOTTOM TEMPERATURE
D. O. (mg/liter)
SALINITY (‰)
TEMPERATURE (°C)
MILES FROM RIVER MOUTH
0
1
2
3
4
5
6
7
8
9
10
23
24
25
26
27
28
29
30
31
32
33
40
50
60
70
80
90


LWS
13 OCT., 1971
0625 - 1518
△ SURFACE SALINITY
▲ BOTTOM SALINITY
⊙ SURFACE DISSOLVED OXYGEN
● BOTTOM DISSOLVED OXYGEN
D.O. (mg/liter)
SALINITY (‰)
0
1
2
3
4
5
6
7
8
9
10
40
50
60
70
80
90
MILE FROM RIVER MOUTH

LWS 27 OCT., 1971 1200 - 1600

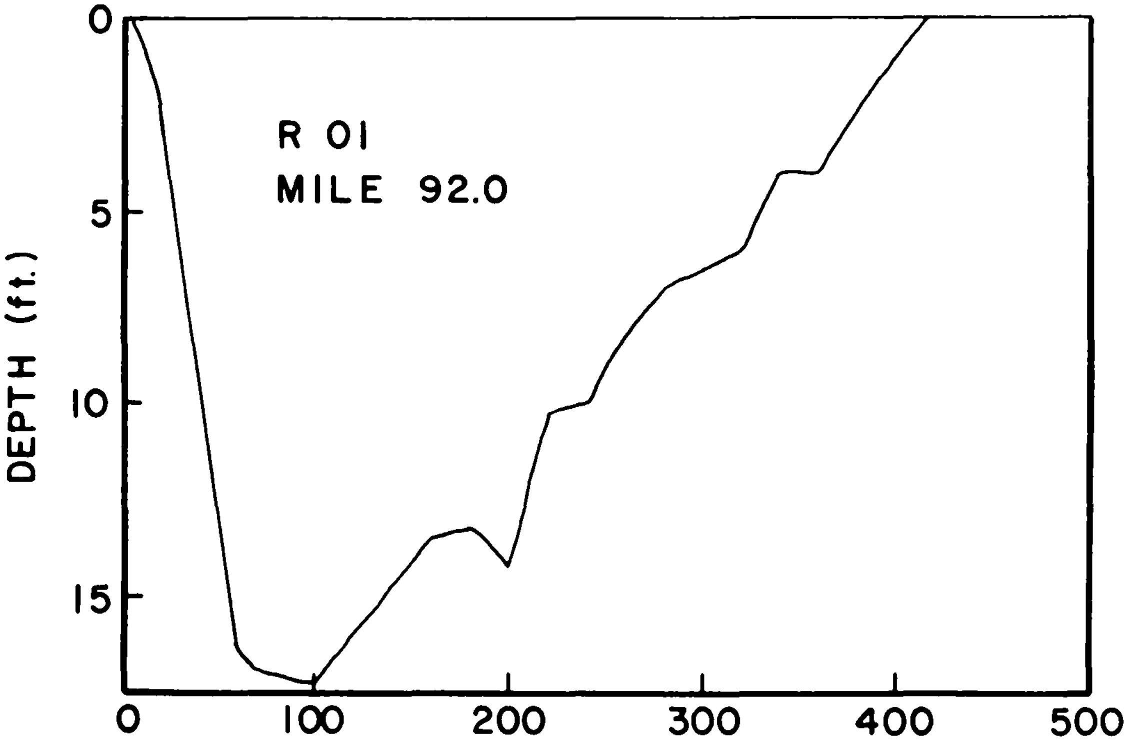


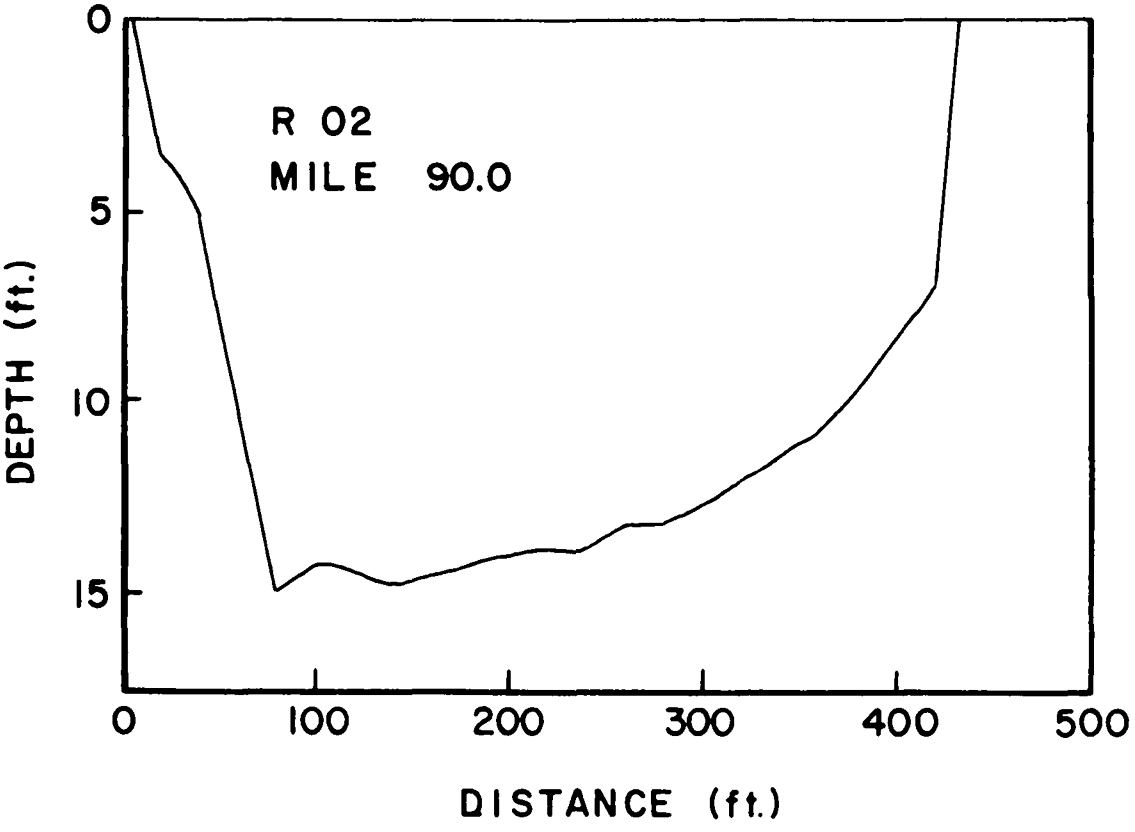
HWS 24 NOV., 1971 0824 - 1339

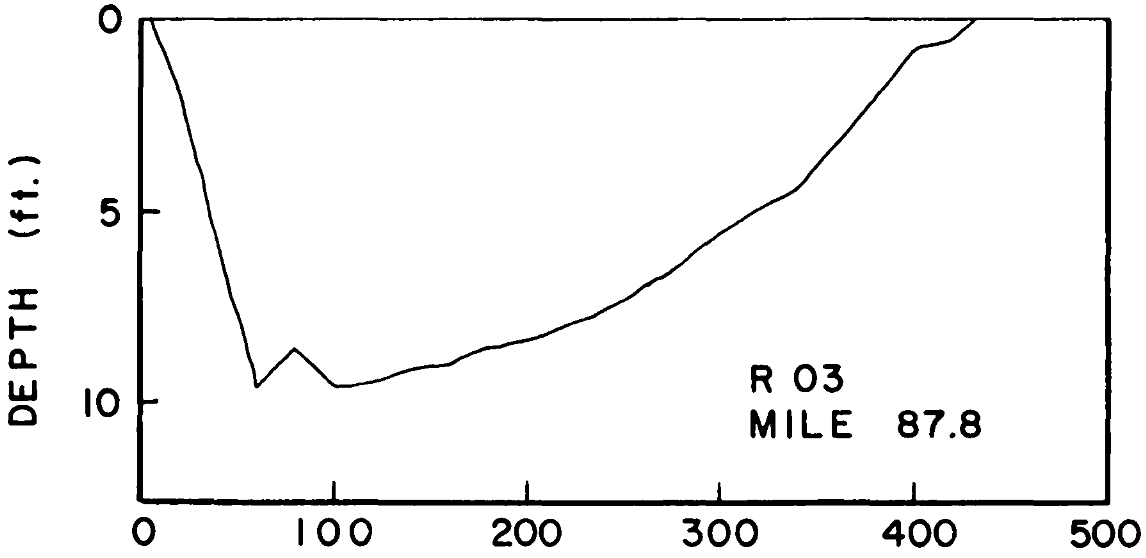


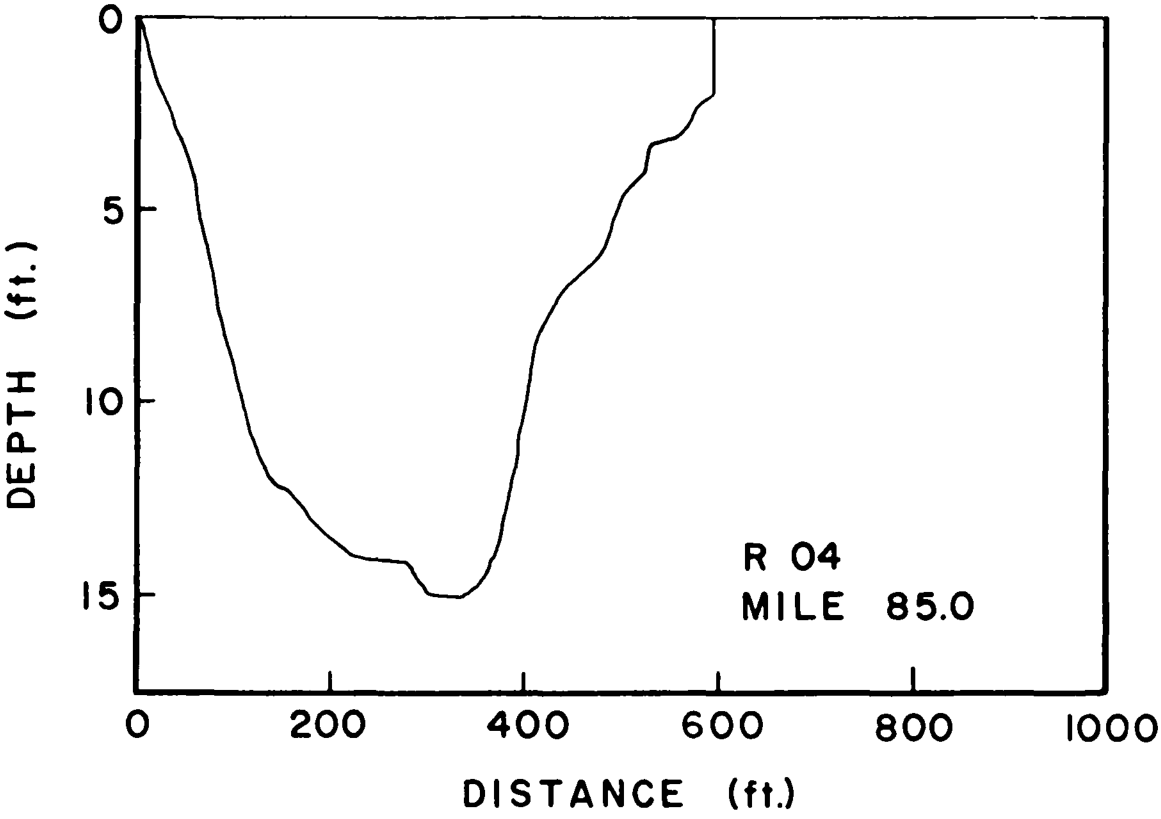
APPENDIX B

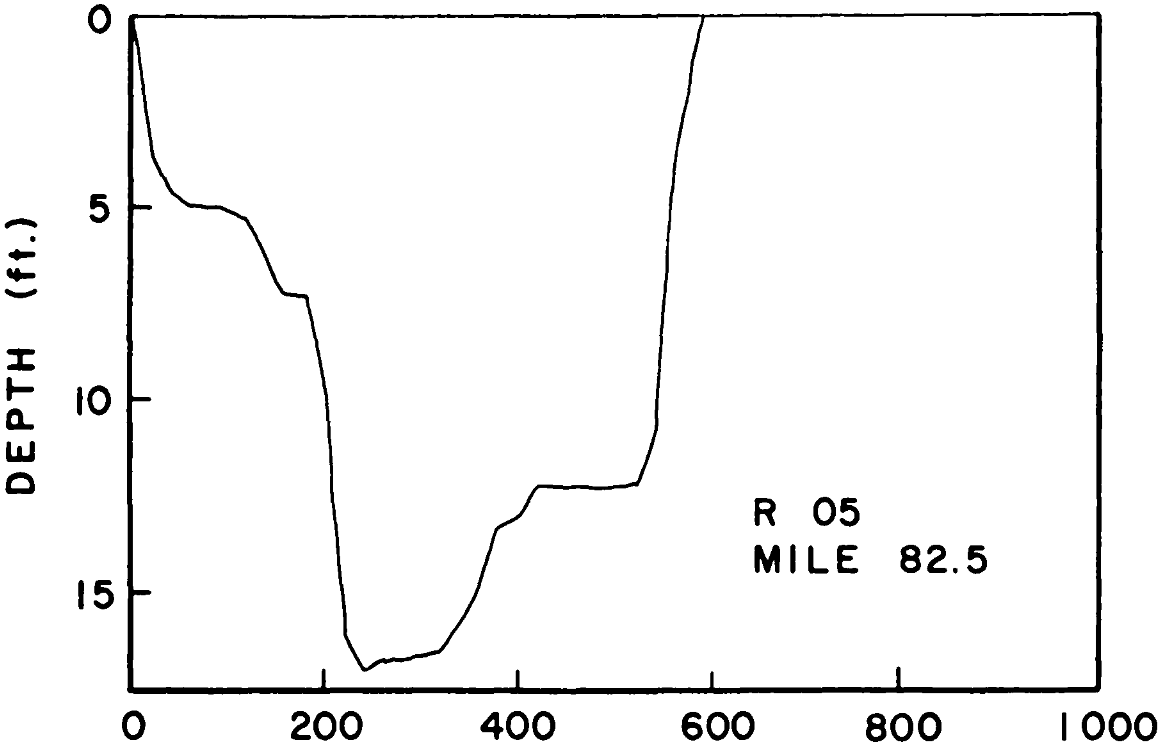
CROSS-SECTIONAL PROFILES

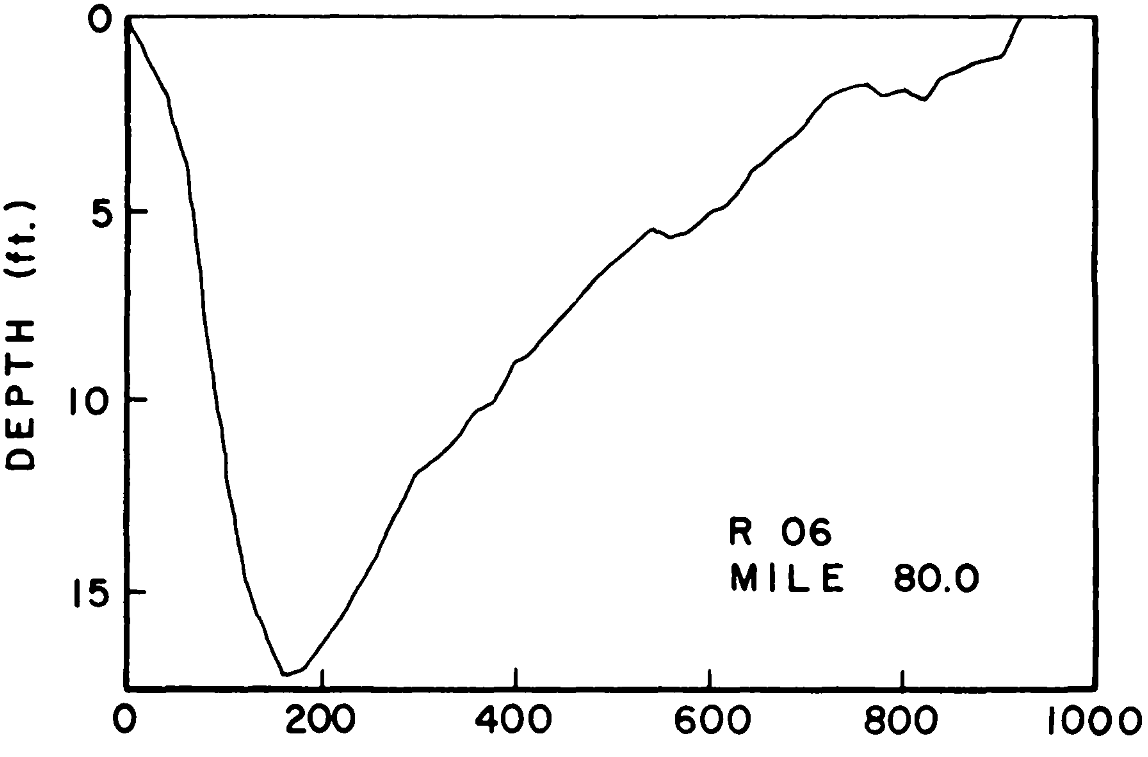

R 01
MILE 92.0
DEPTH (ft.)
0
5
10
15
0
100
200
300
400
500

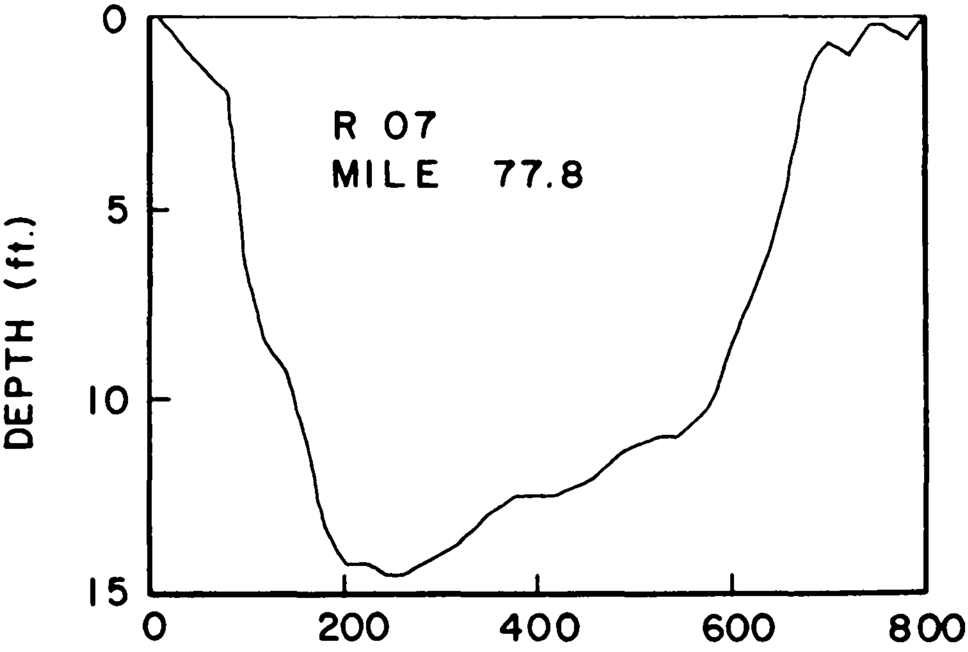

R 02
MILE 90.0
DEPTH (ft.)
0
5
10
15
0
100
200
300
400
500
DISTANCE (ft.)

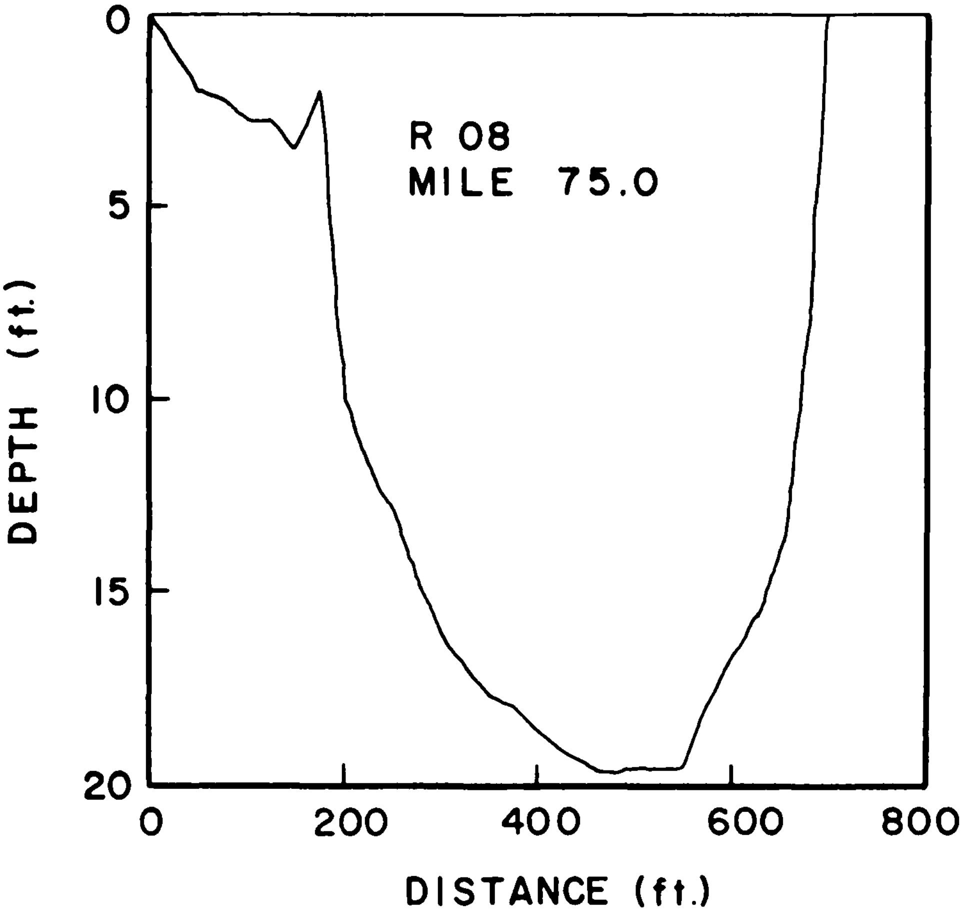

DEPTH (ft.)
0
5
10
0
100
200
300
400
500
R 03
MILE 87.8

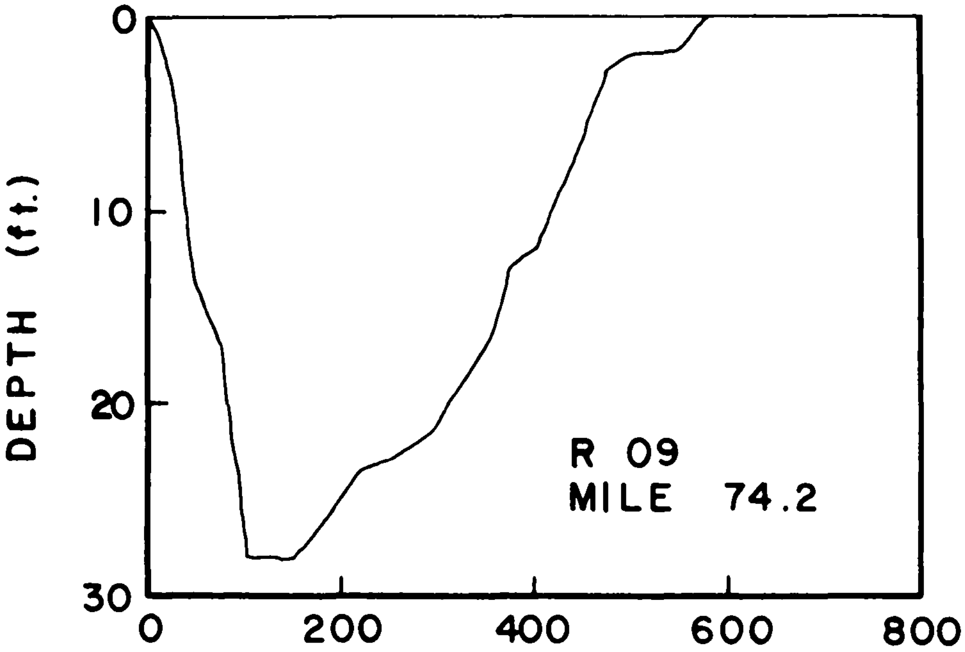

DEPTH (ft.)
0
5
10
15
0
200
400
600
800
1000
DISTANCE (ft.)
R 04
MILE 85.0

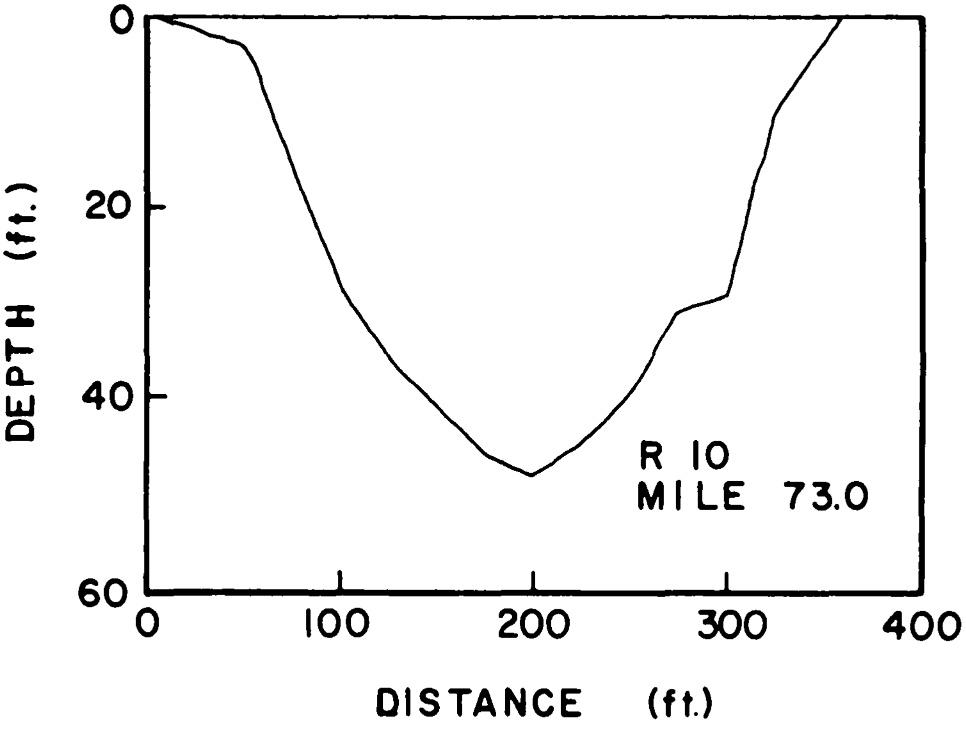

R 05
MILE 82.5
DEPTH (ft.)
0
5
10
15
0
200
400
600
800
1000

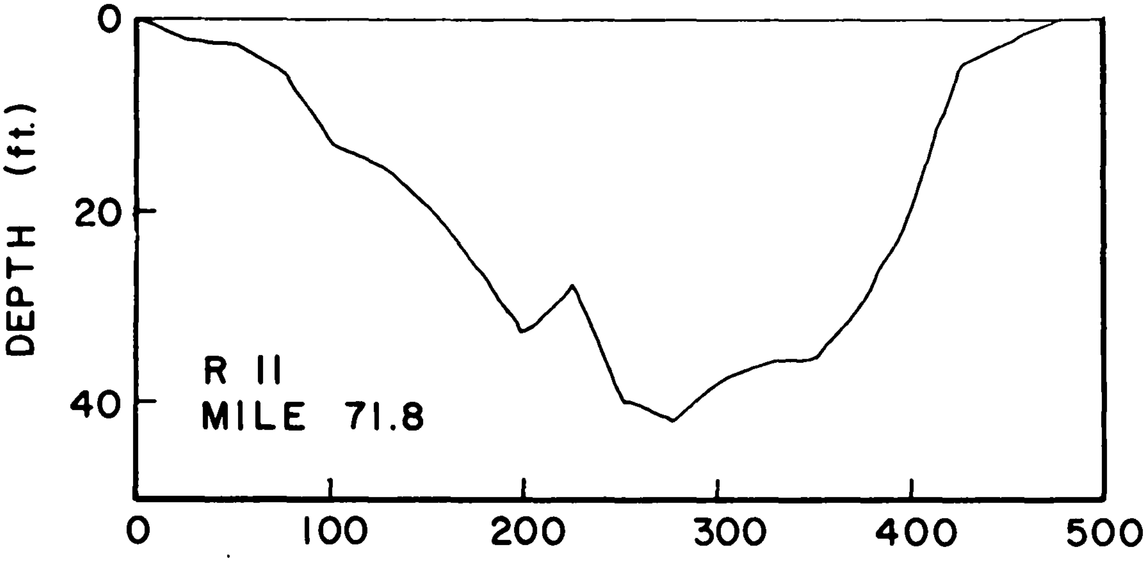

R 06
MILE 80.0
DEPTH (ft.)
0
5
10
15
0
200
400
600
800
1000
DISTANCE (ft.)

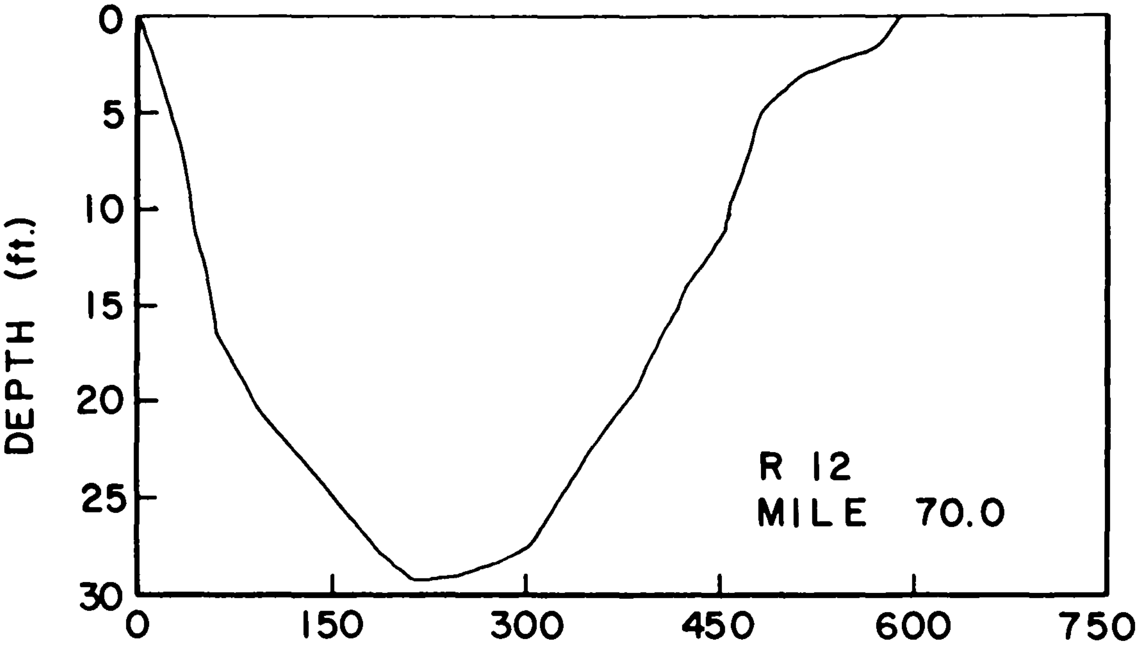

R 07
MILE 77.8
DEPTH (ft.)
0
5
10
15
0
200
400
600
800

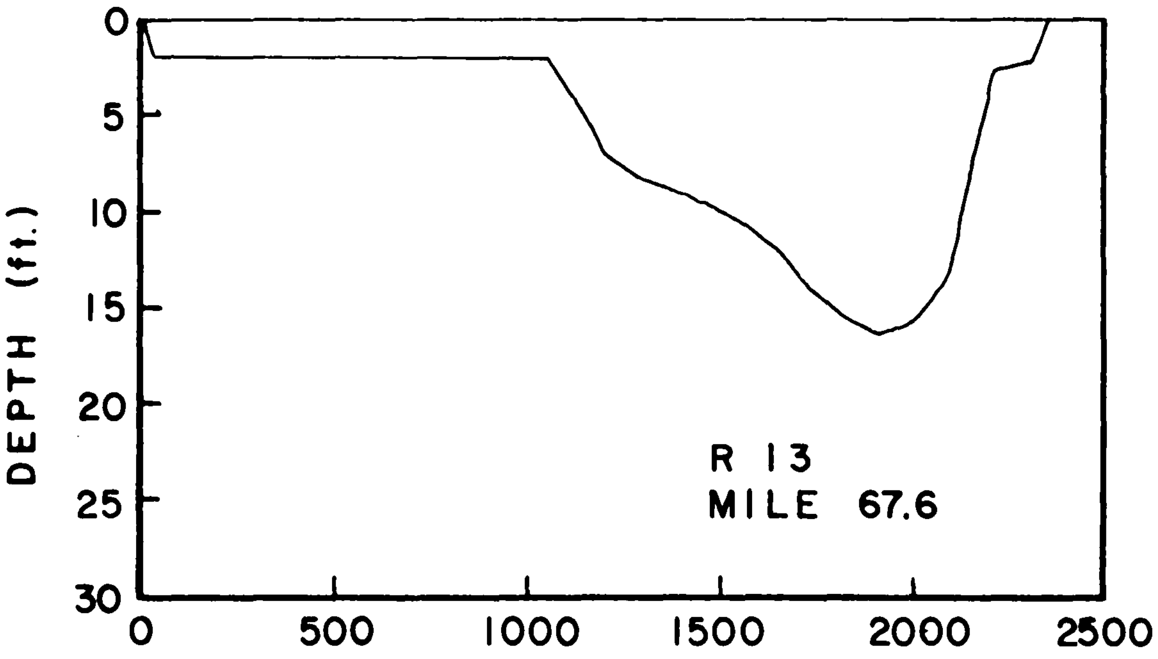

R 08
MILE 75.0
DEPTH (ft.)
0
5
10
15
20
0
200
400
600
800
DISTANCE (ft.)

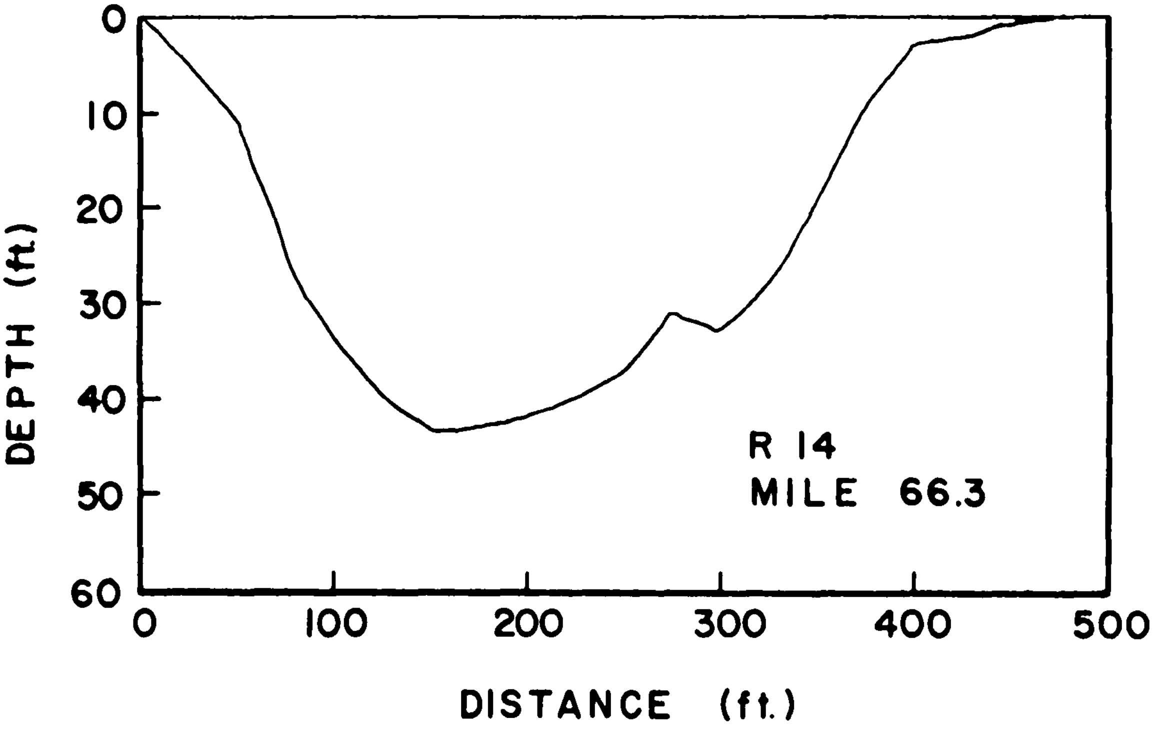

0
10
20
30
DEPTH (ft.)
0
200
400
600
800
R 09
MILE 74.2

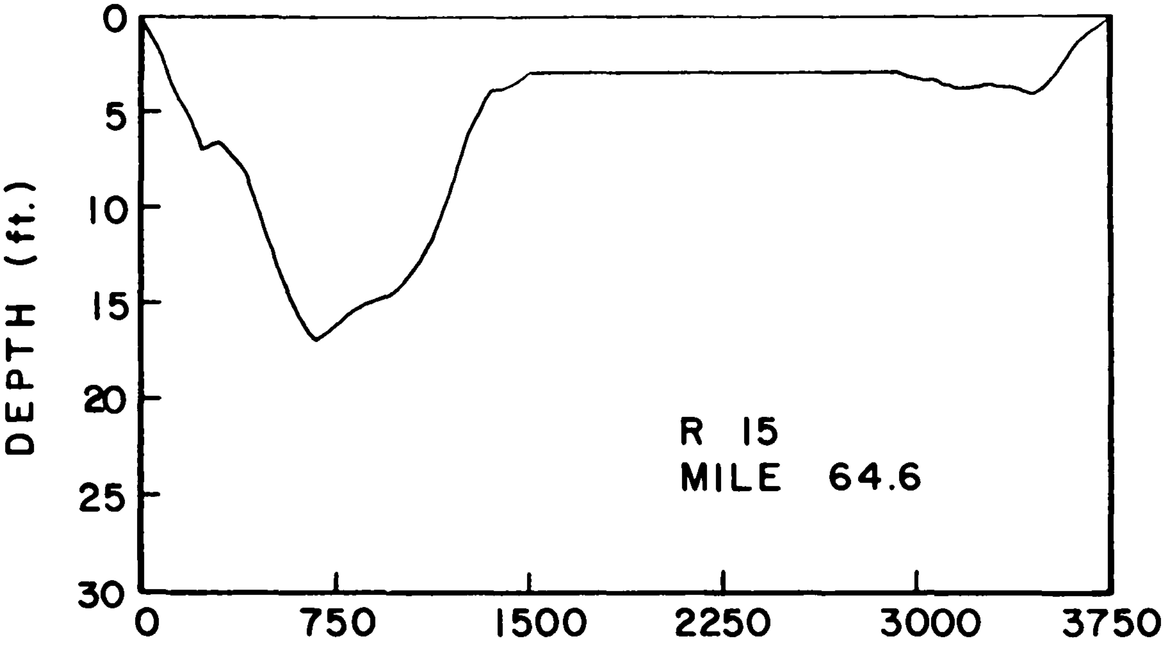

0
20
40
60
DEPTH (ft.)
0
100
200
300
400
DISTANCE (ft.)
R 10
MILE 73.0

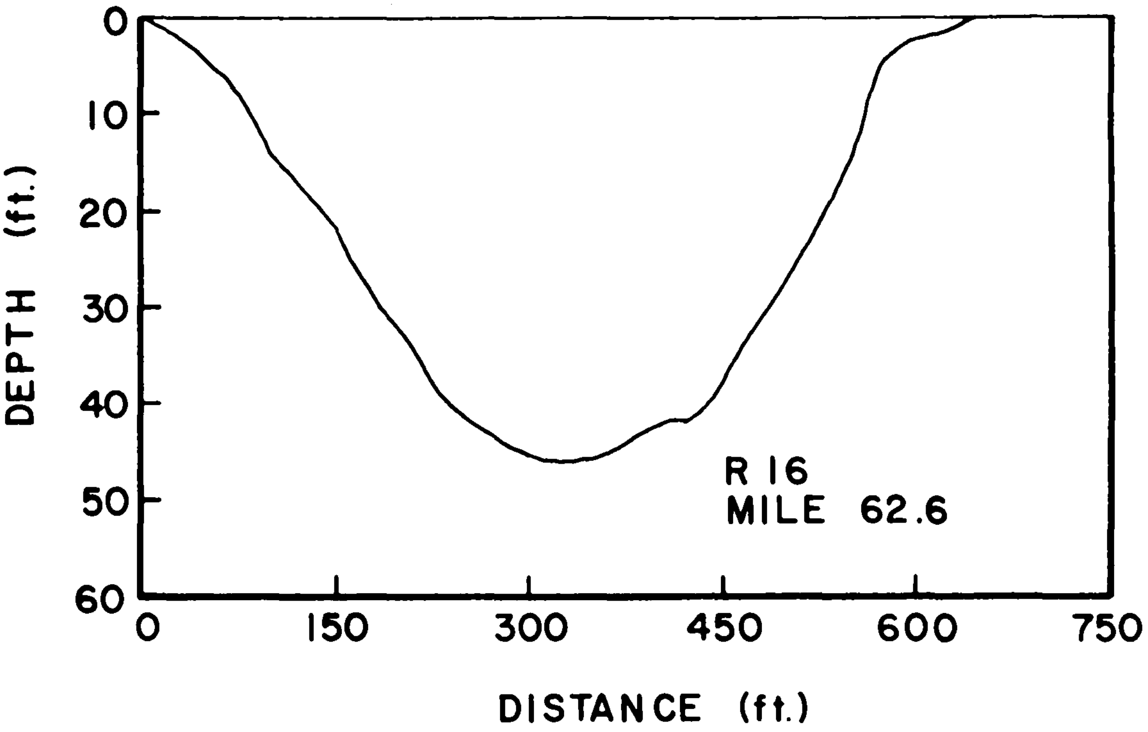

0
20
40
DEPTH (ft.)
R 11
MILE 71.8
0
100
200
300
400
500

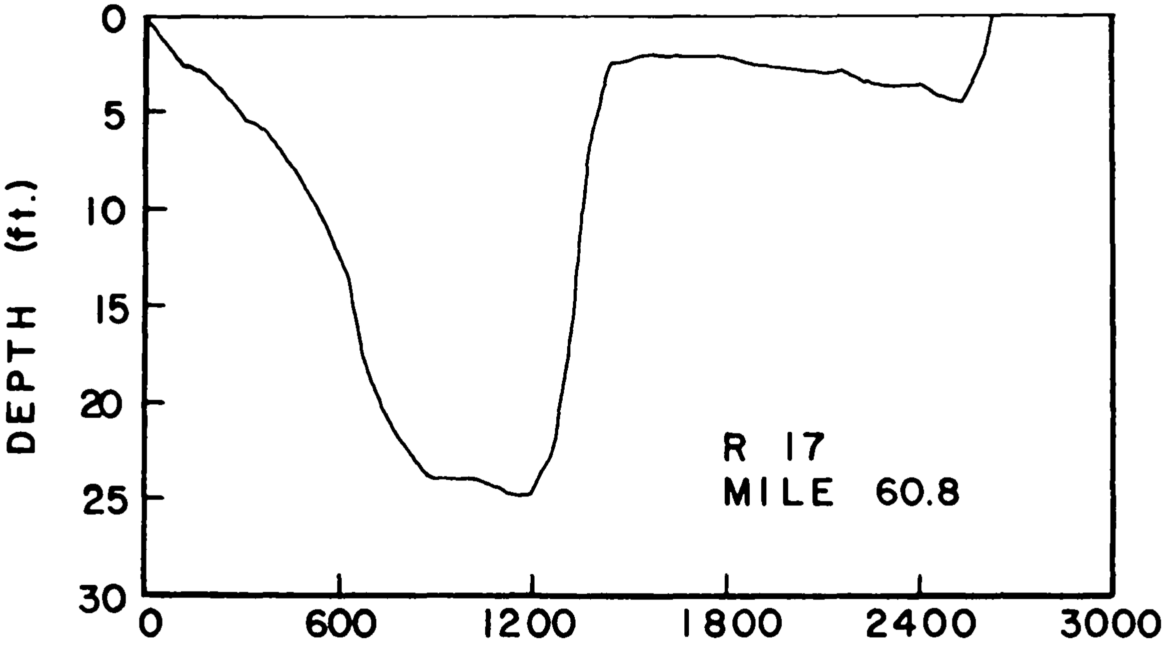

0
5
10
15
20
25
30
DEPTH (ft.)
R 12
MILE 70.0
0
150
300
450
600
750

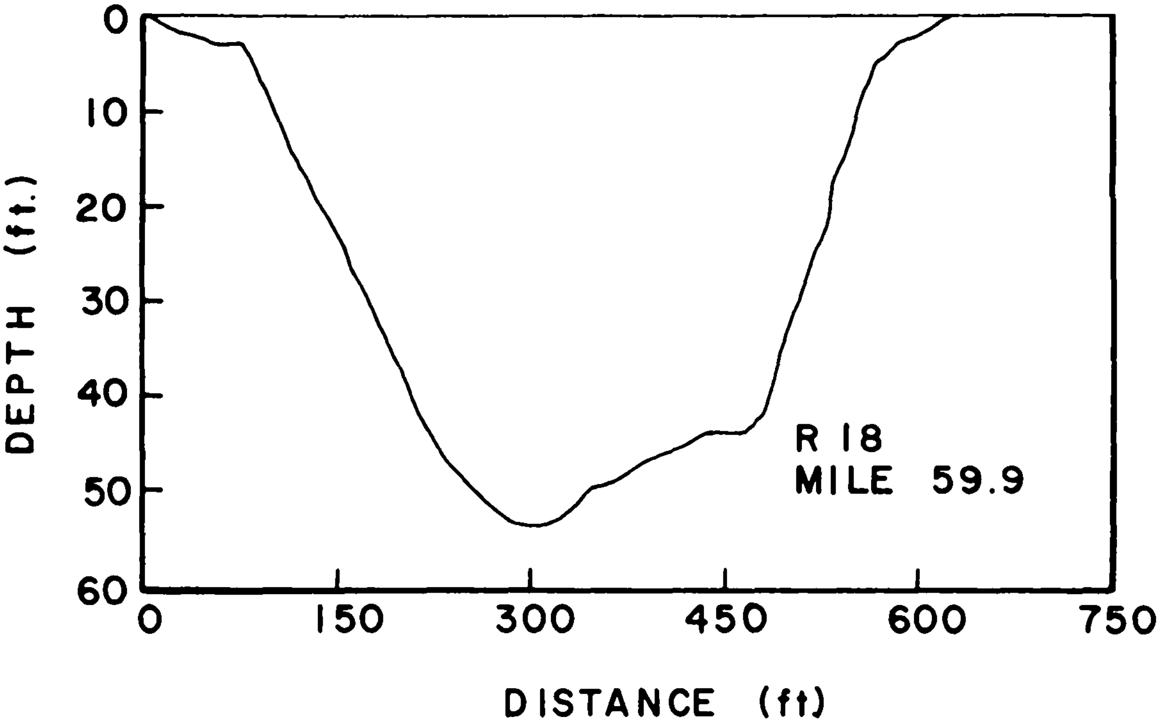

DEPTH (ft.)
0
5
10
15
20
25
30
0
500
1000
1500
2000
2500
R 13
MILE 67.6

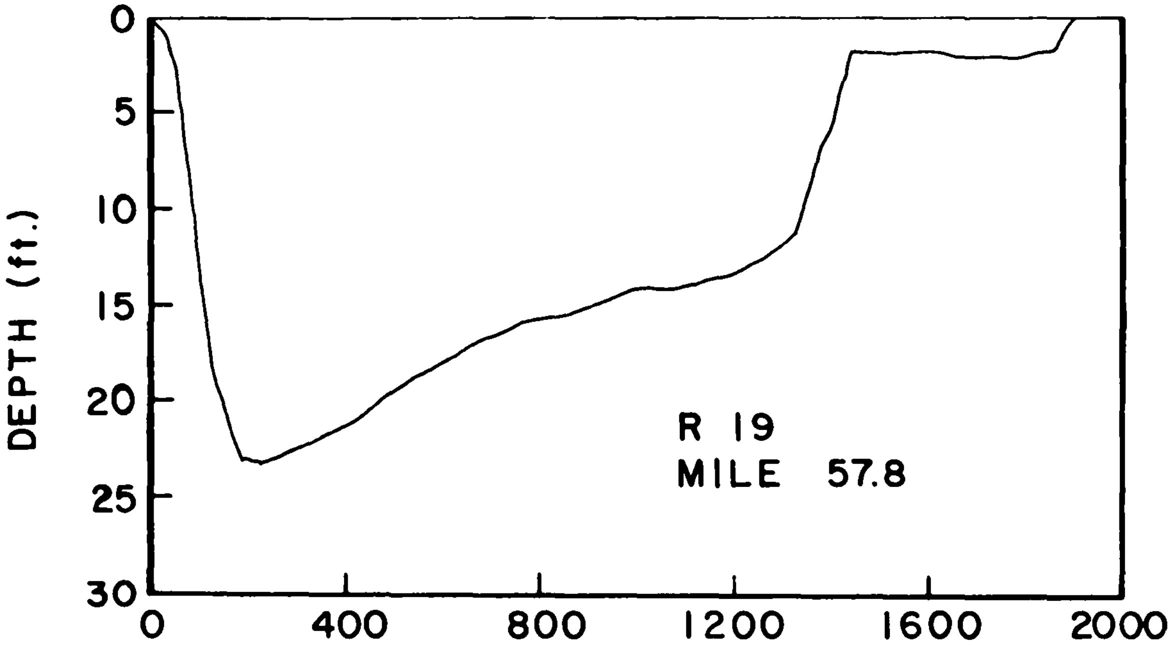

DEPTH (ft.)
0
10
20
30
40
50
60
0
100
200
300
400
500
R 14
MILE 66.3
DISTANCE (ft.)

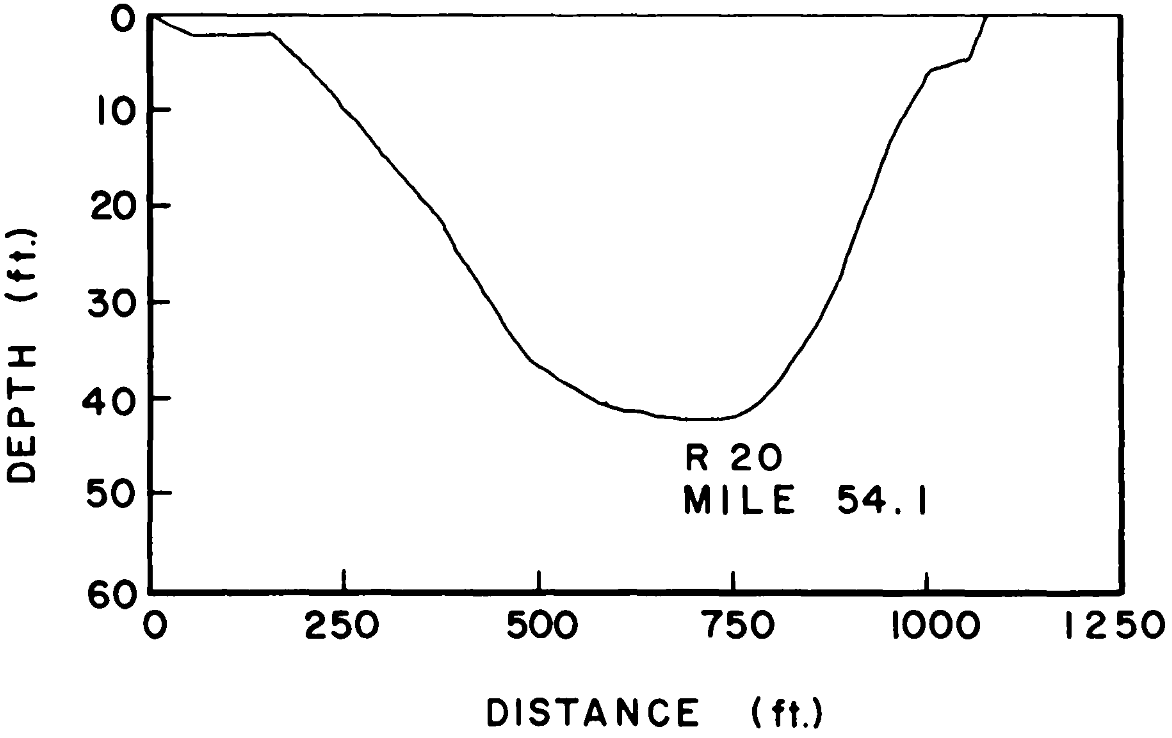

DEPTH (ft.)
0
5
10
15
20
25
30
0
750
1500
2250
3000
3750
R 15
MILE 64.6

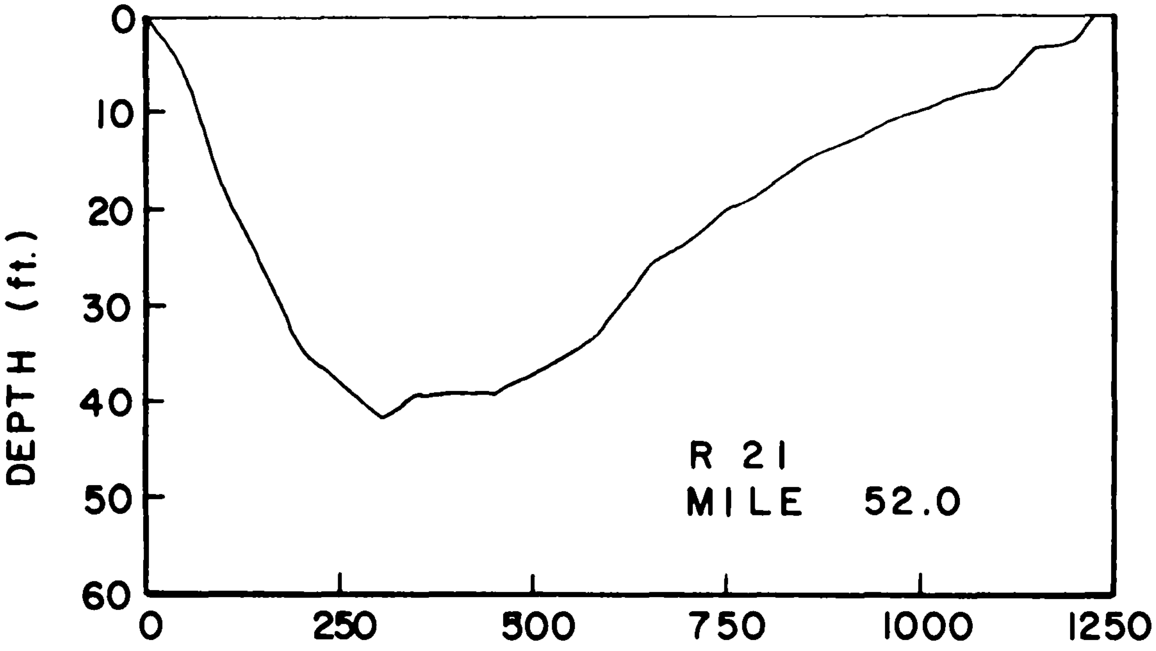

DEPTH (ft.)
0
10
20
30
40
50
60
0
150
300
450
600
750
R 16
MILE 62.6
DISTANCE (ft.)

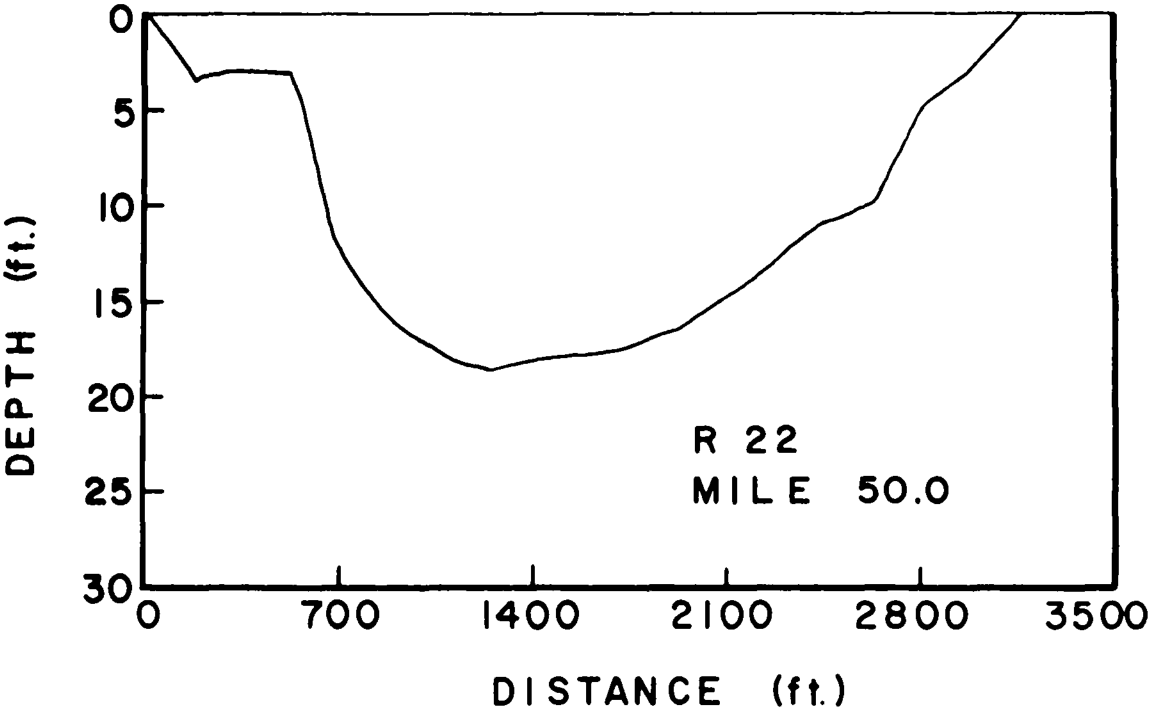

DEPTH (ft.)
0
5
10
15
20
25
30
0
600
1200
1800
2400
3000
R 17
MILE 60.8

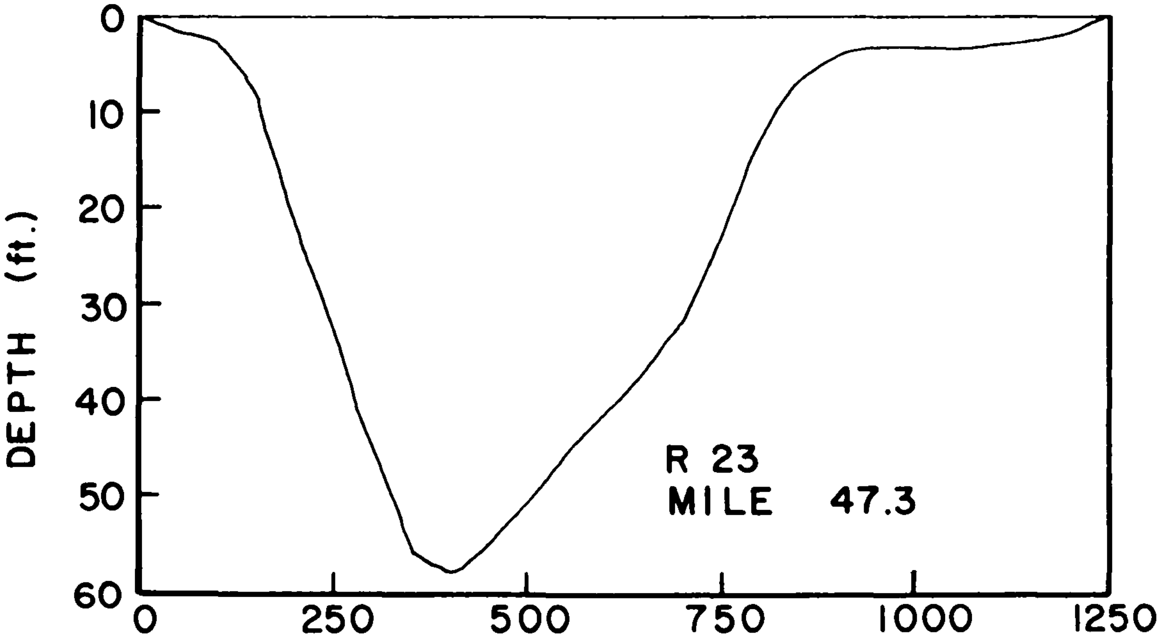

DEPTH (ft.)
0
10
20
30
40
50
60
0
150
300
450
600
750
R 18
MILE 59.9
DISTANCE (ft)

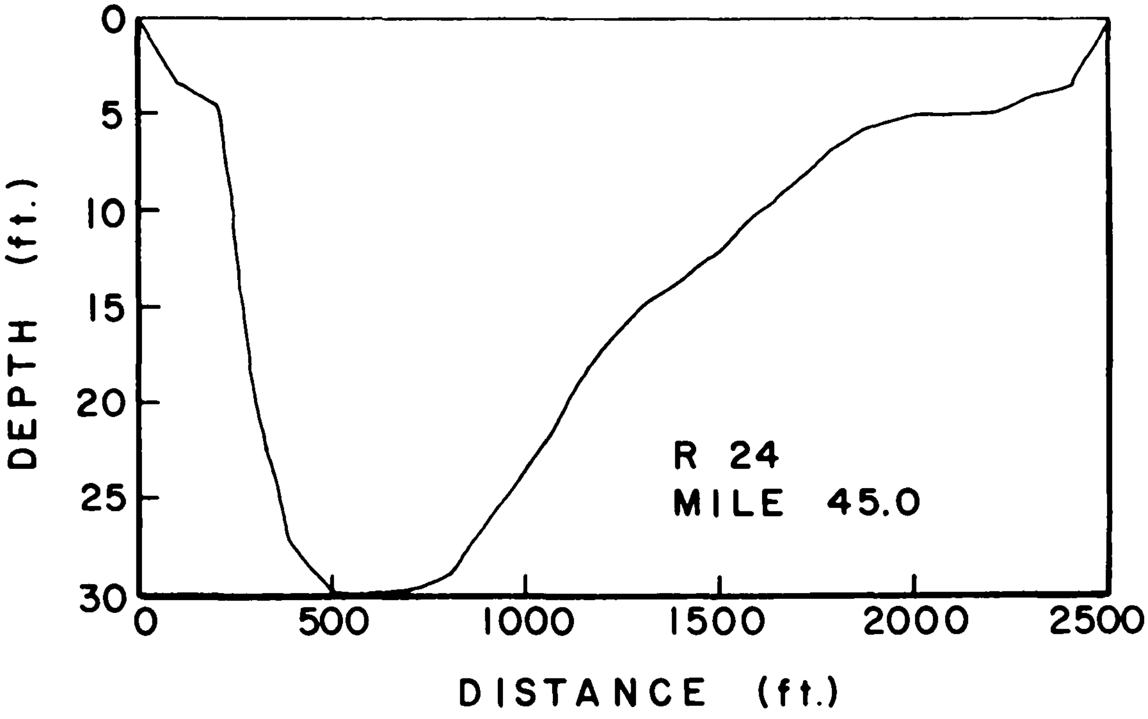

DEPTH (ft.)
0
5
10
15
20
25
30
0
400
800
1200
1600
2000
R 19
MILE 57.8

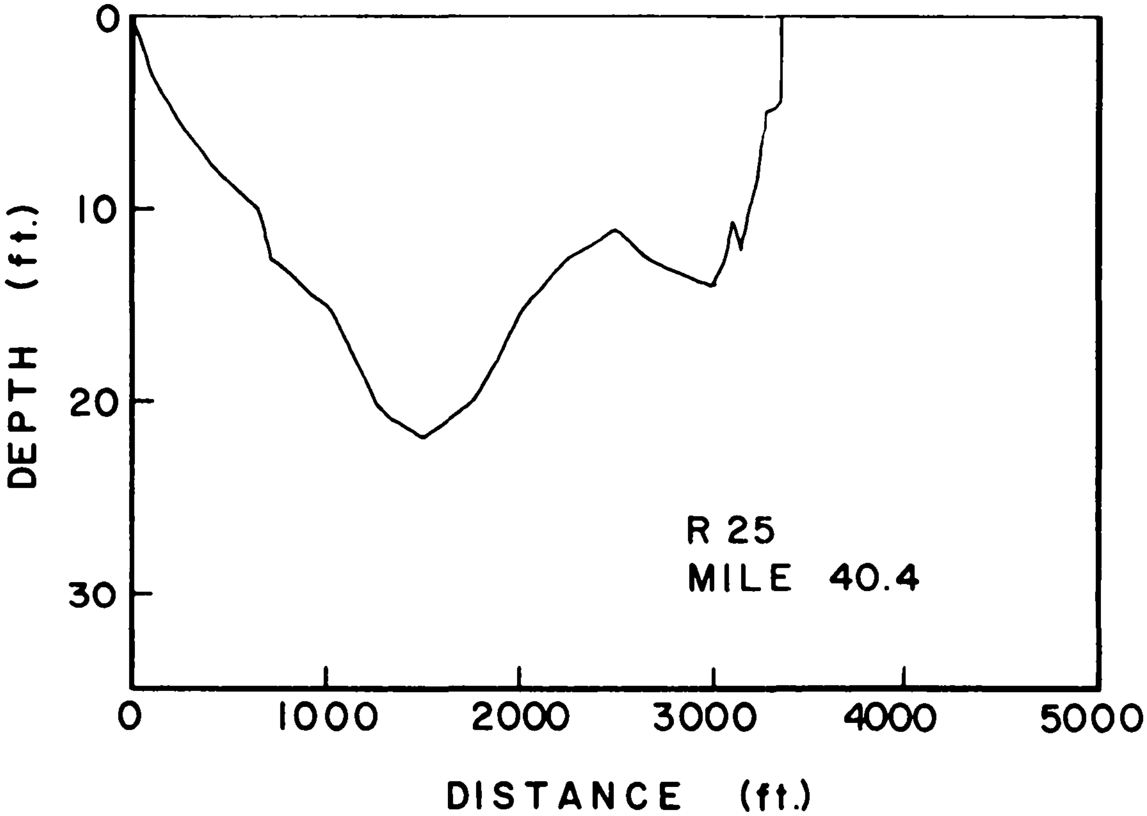

DEPTH (ft.)
0
10
20
30
40
50
60
0
250
500
750
1000
1250
R 20
MILE 54.1
DISTANCE (ft.)


DEPTH (ft.)
0
10
20
30
40
50
60
0
250
500
750
1000
1250
R 21
MILE 52.0


DEPTH (ft.)
0
5
10
15
20
25
30
0
700
1400
2100
2800
3500
R 22
MILE 50.0
DISTANCE (ft.)

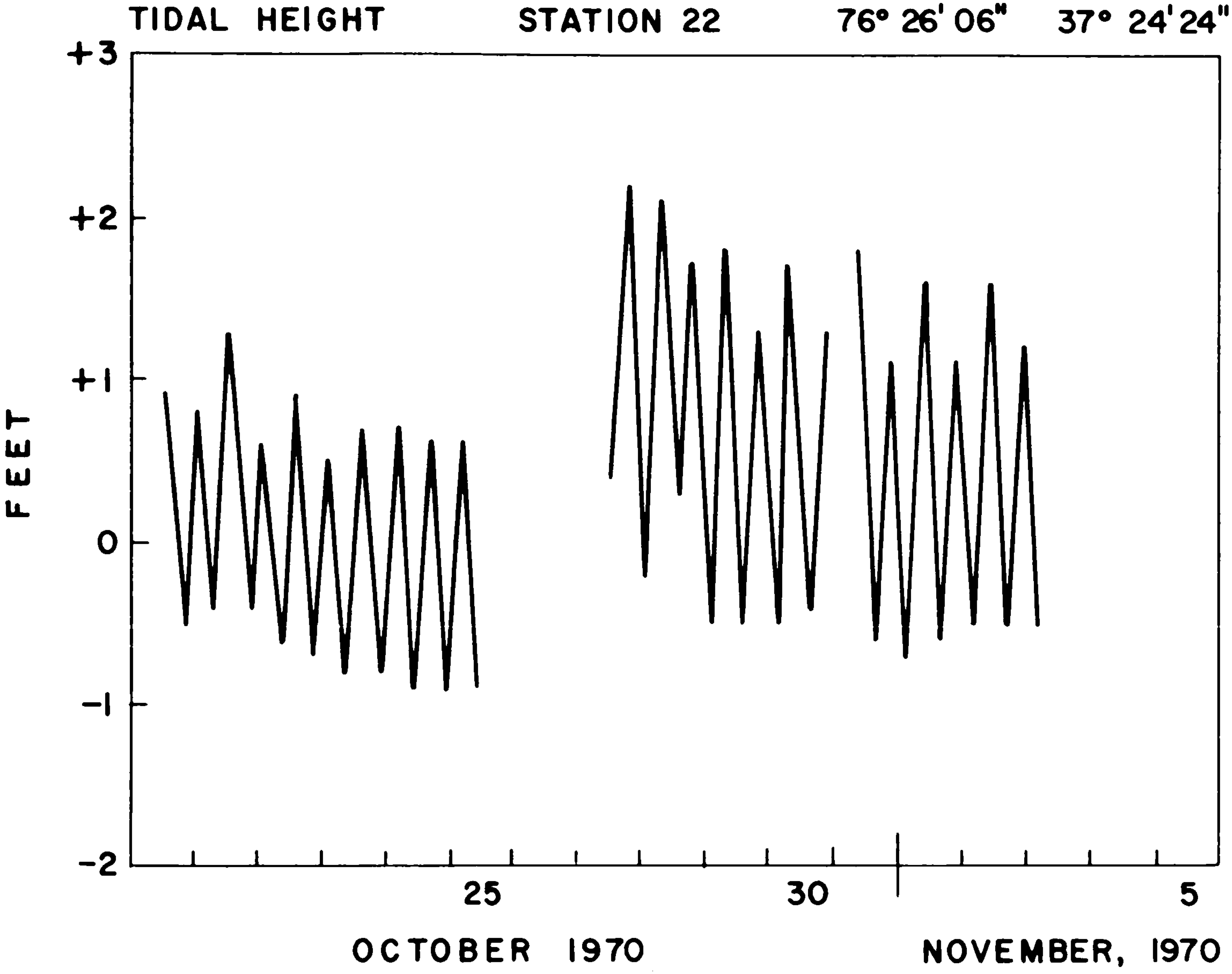

DEPTH (ft.)
0
10
20
30
40
50
60
0
250
500
750
1000
1250
R 23
MILE 47.3

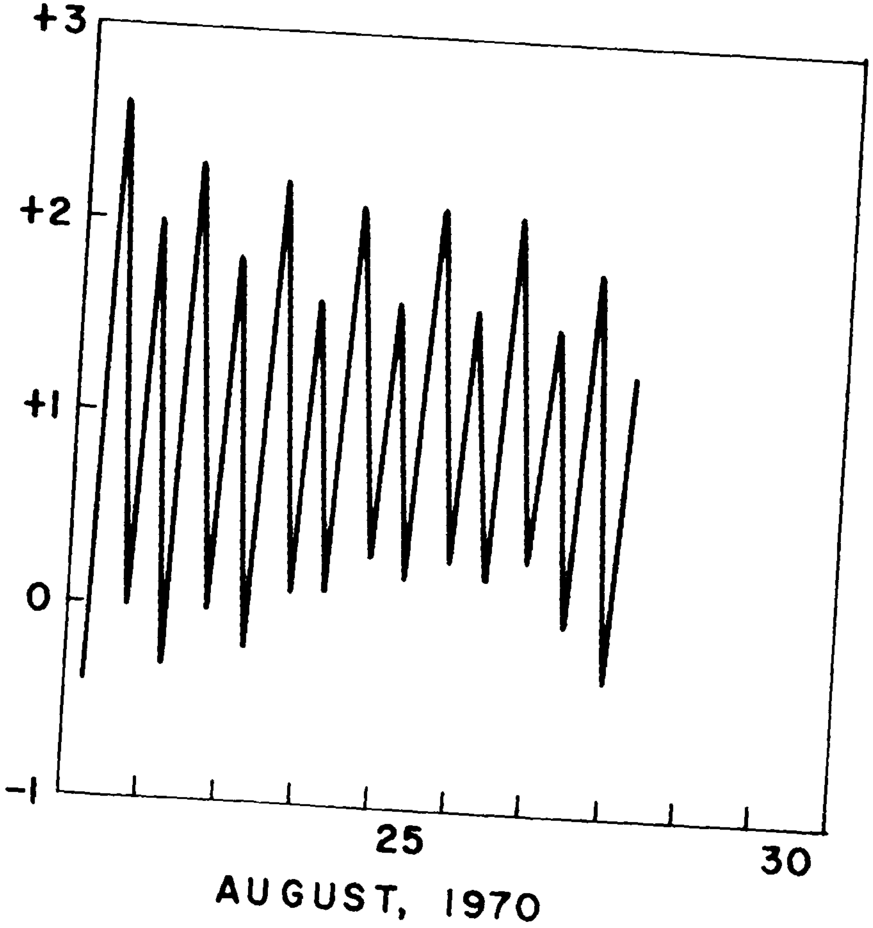

DEPTH (ft.)
0
5
10
15
20
25
30
0
500
1000
1500
2000
2500
R 24
MILE 45.0
DISTANCE (ft.)

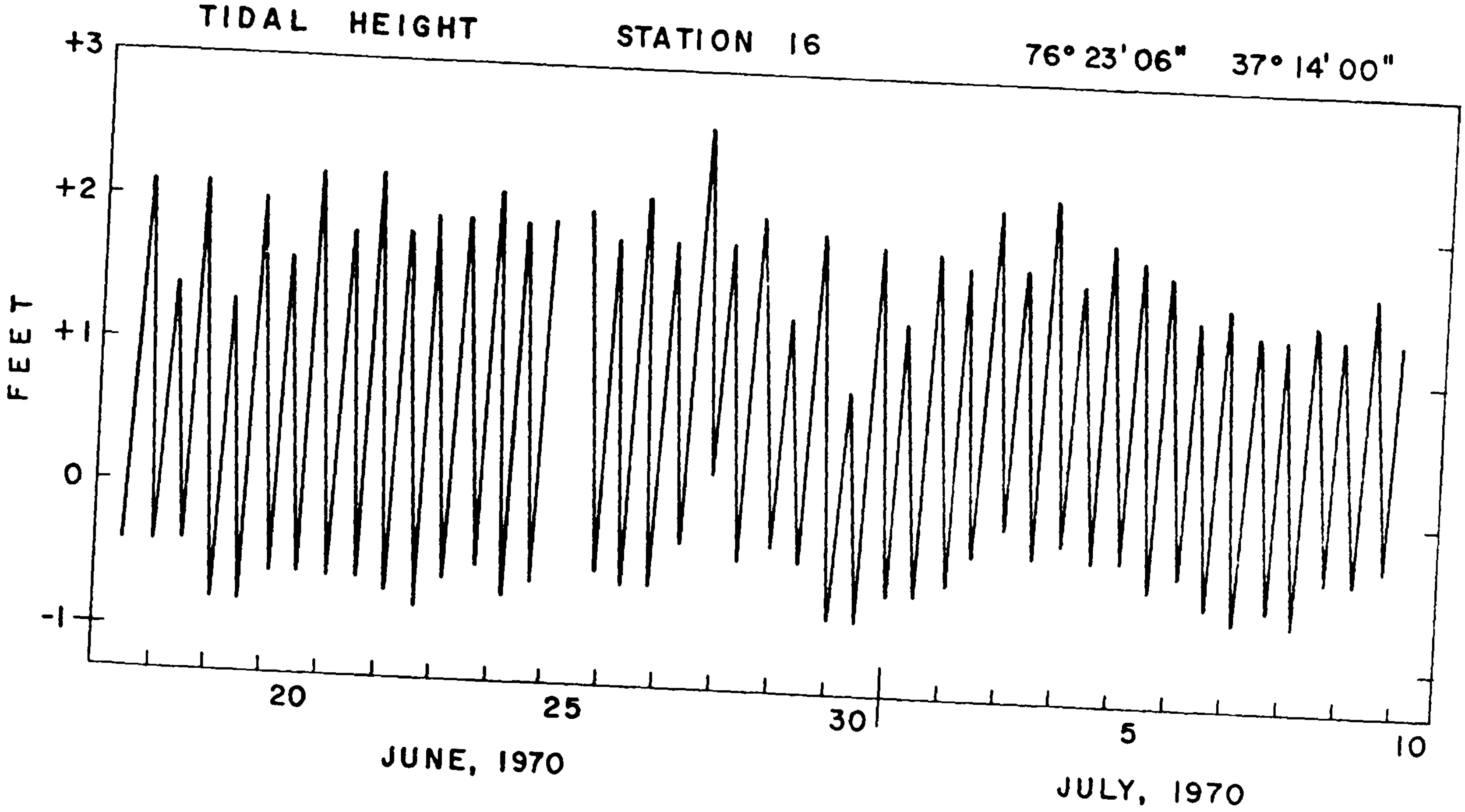

0
10
20
30
DEPTH (ft.)
0
1000
2000
3000
4000
5000
DISTANCE (ft.)
R 25
MILE 40.4

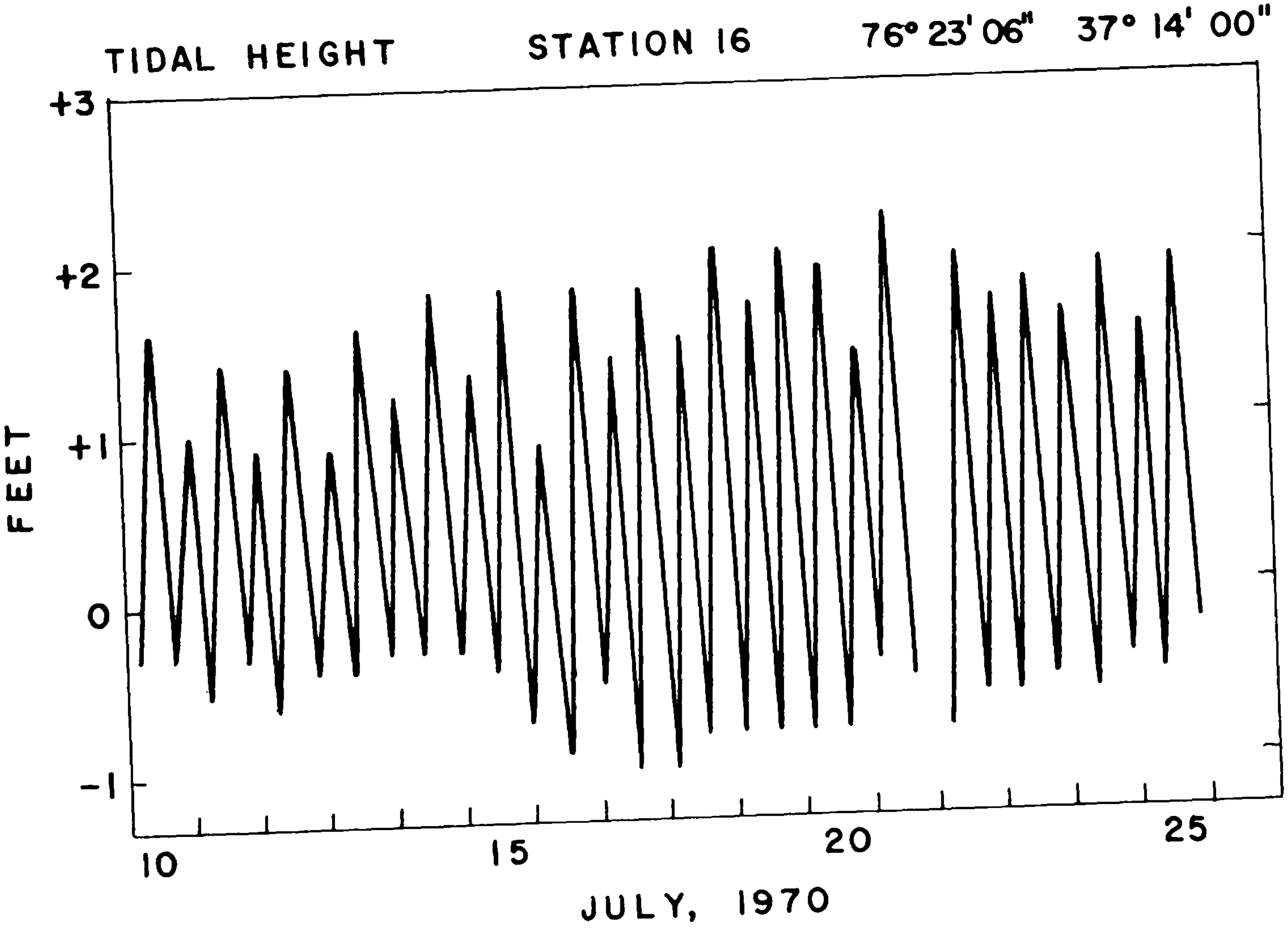
APPENDIX C

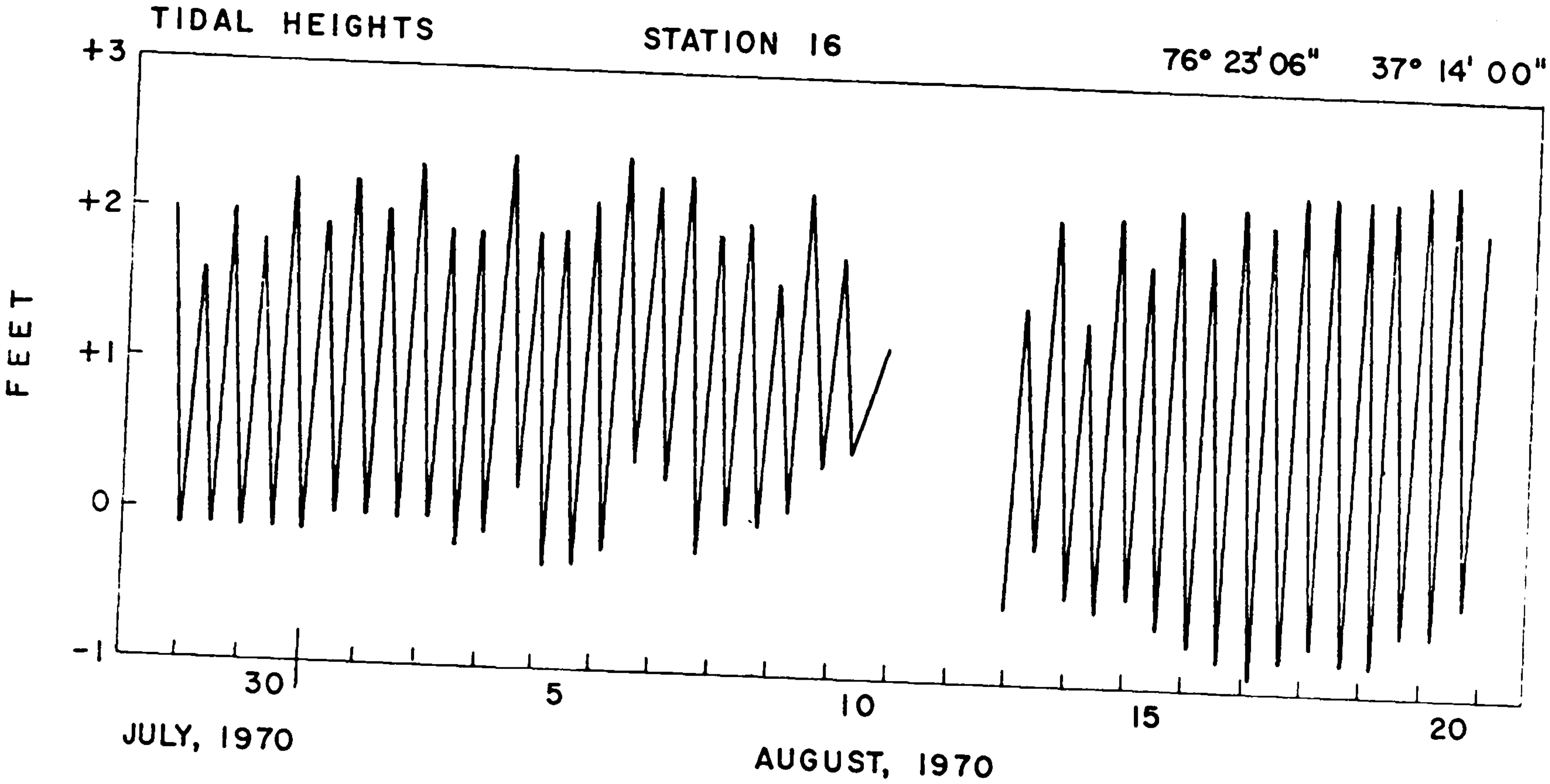
TIDAL OBSERVATIONS

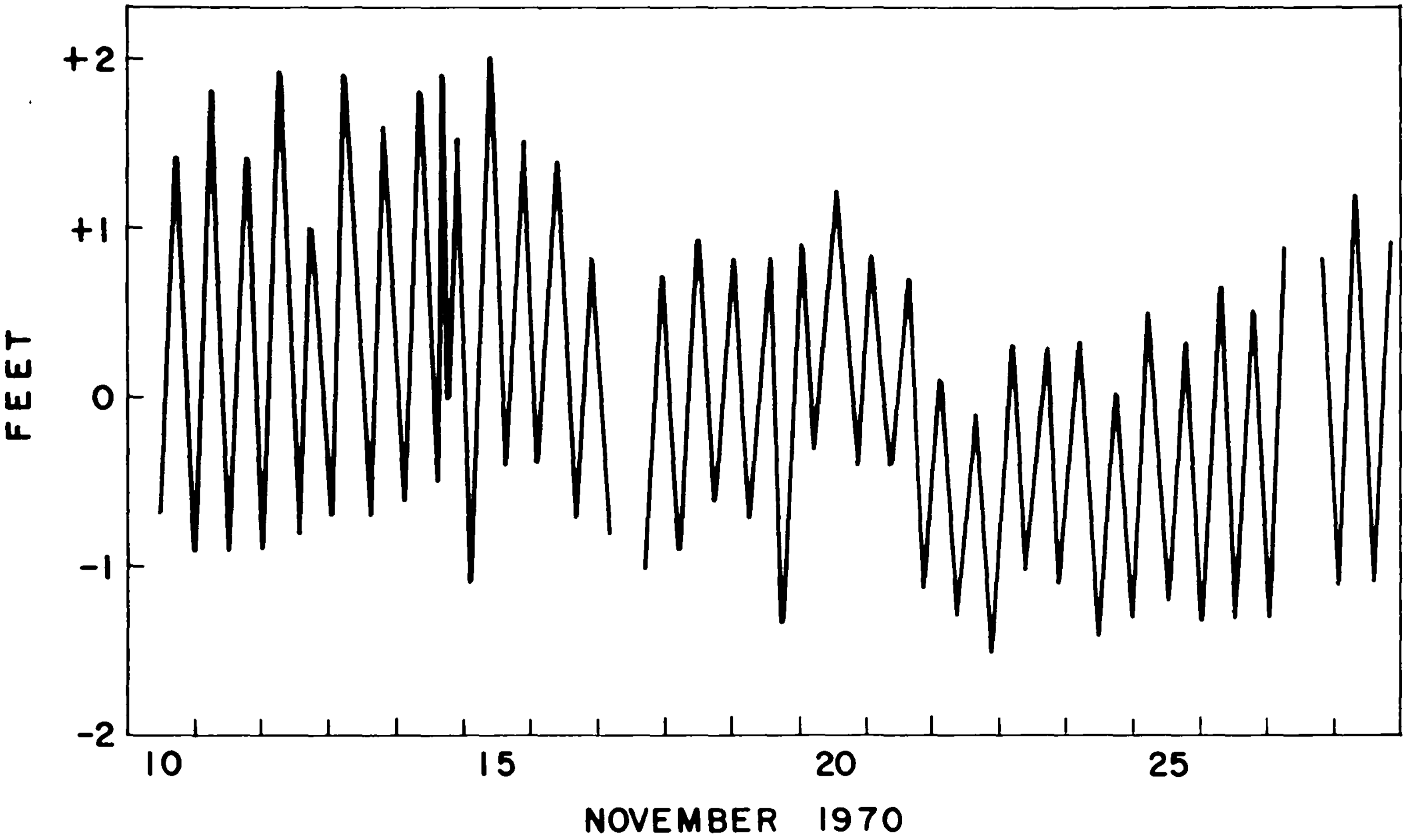

TIDAL HEIGHT
STATION 22
76° 26' 06"
37° 24' 24"
+3
+2
+1
0
-1
-2
FEET
25
30
5
OCTOBER 1970
NOVEMBER, 1970

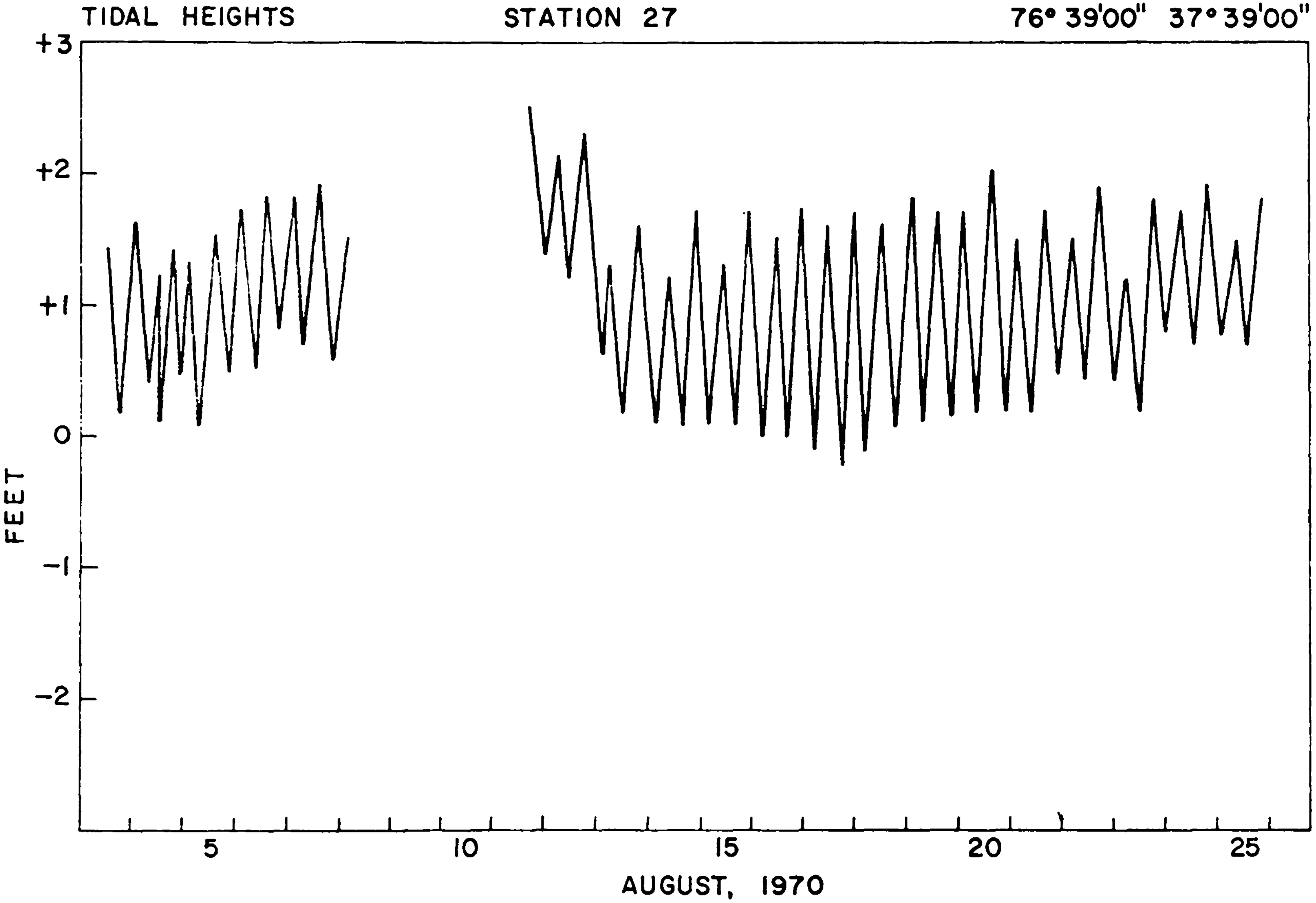

+3
+2
+1
0
-1
25
30
AUGUST, 1970


TIDAL HEIGHT
STATION 16
76° 23' 06"
37° 14' 00"
FEET
+3
+2
+1
0
-1
20
25
30
5
10
JUNE, 1970
JULY, 1970

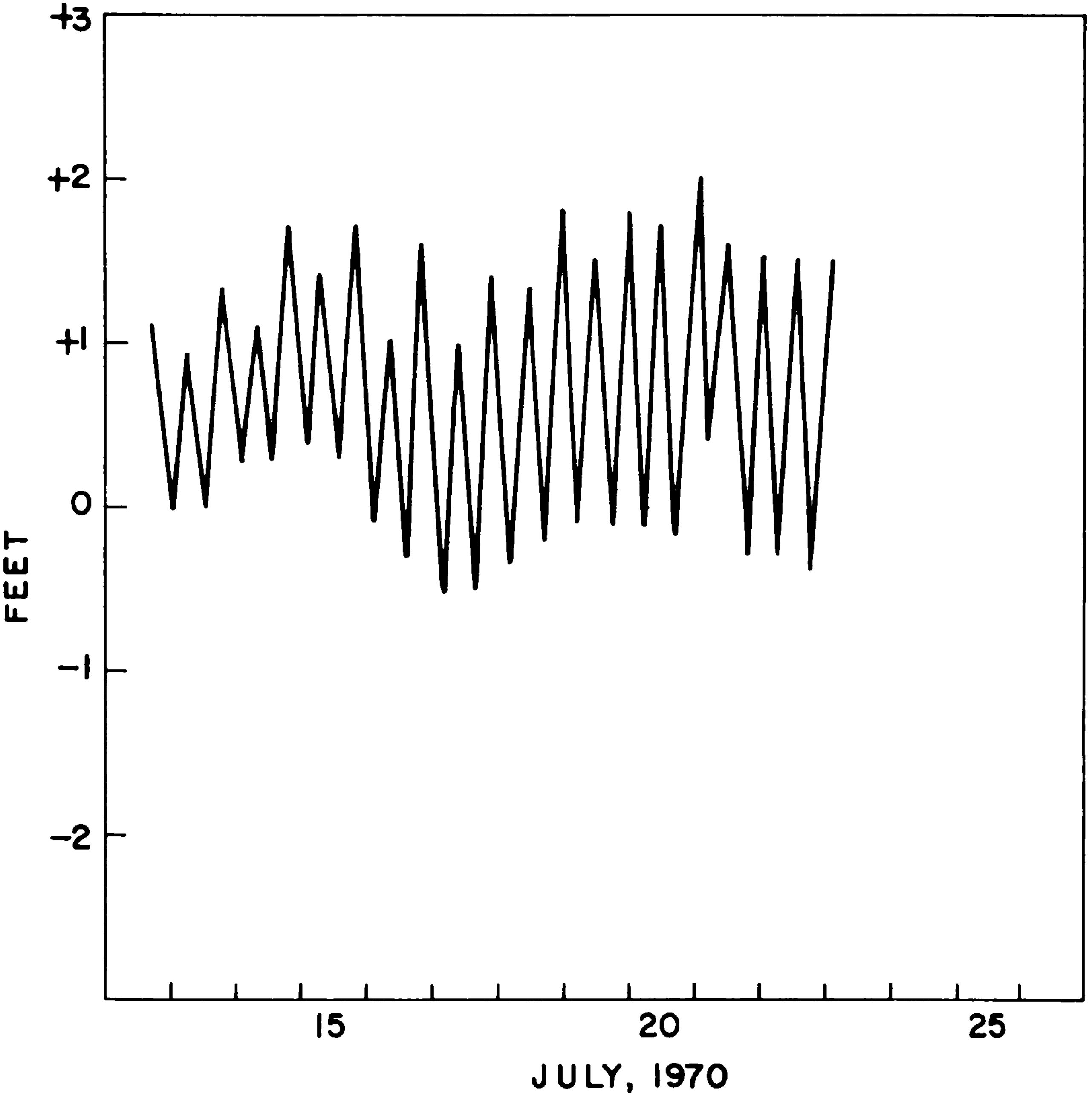

TIDAL HEIGHT STATION 16 76° 23' 06" 37° 14' 00"


TIDAL HEIGHTS
STATION 16
76° 23' 06"
37° 14' 00"
FEET
+3
+2
+1
0
-1
30
5
10
15
20
JULY, 1970
AUGUST, 1970

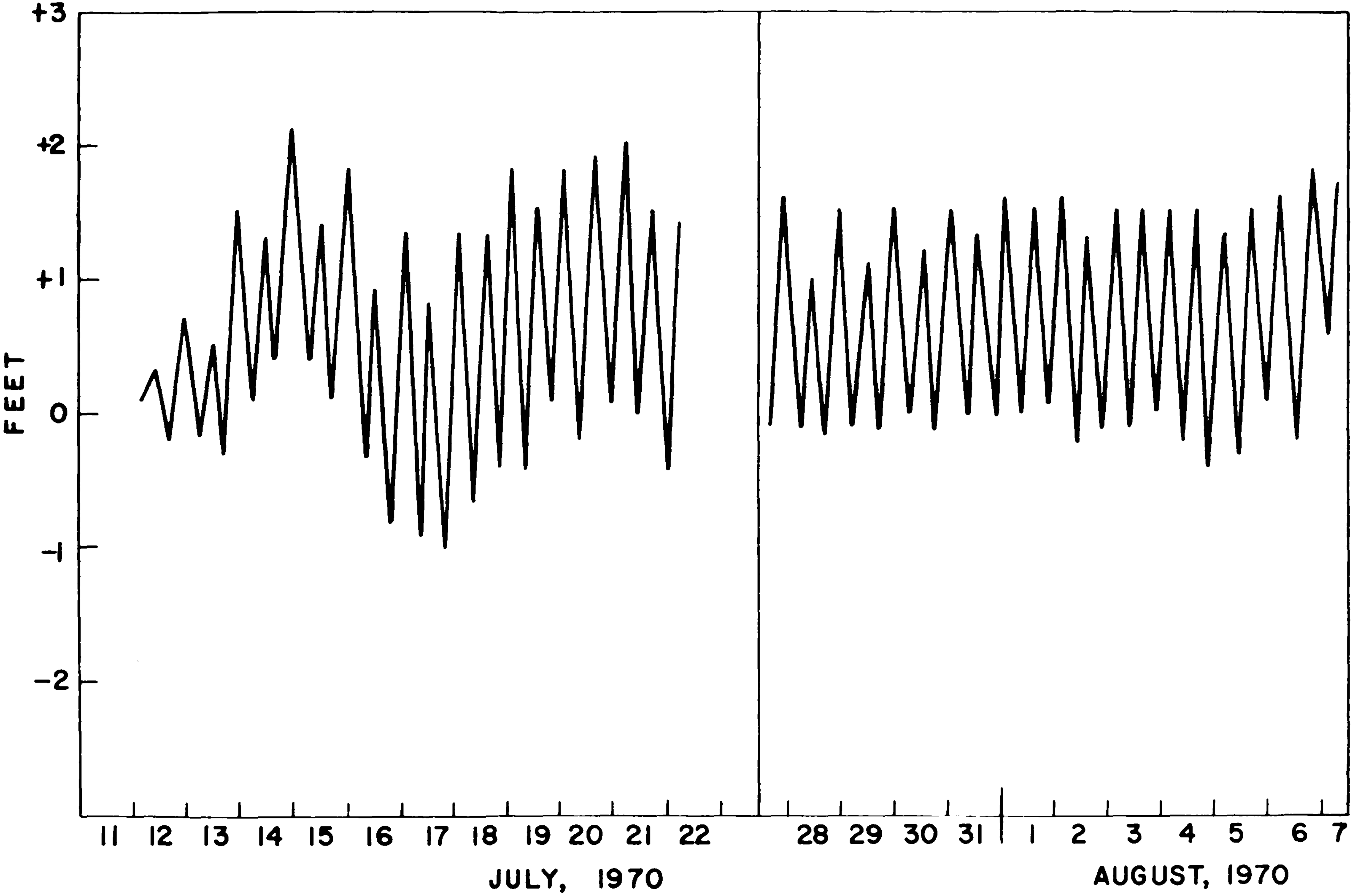

TIDAL HEIGHTS STATION 22 76° 26' 06" 37° 24' 24"


TIDAL HEIGHTS
STATION 27
76° 39'00" 37° 39'00"
+3
+2
+1
0
-1
-2
FEET
5
10
15
20
25
AUGUST, 1970

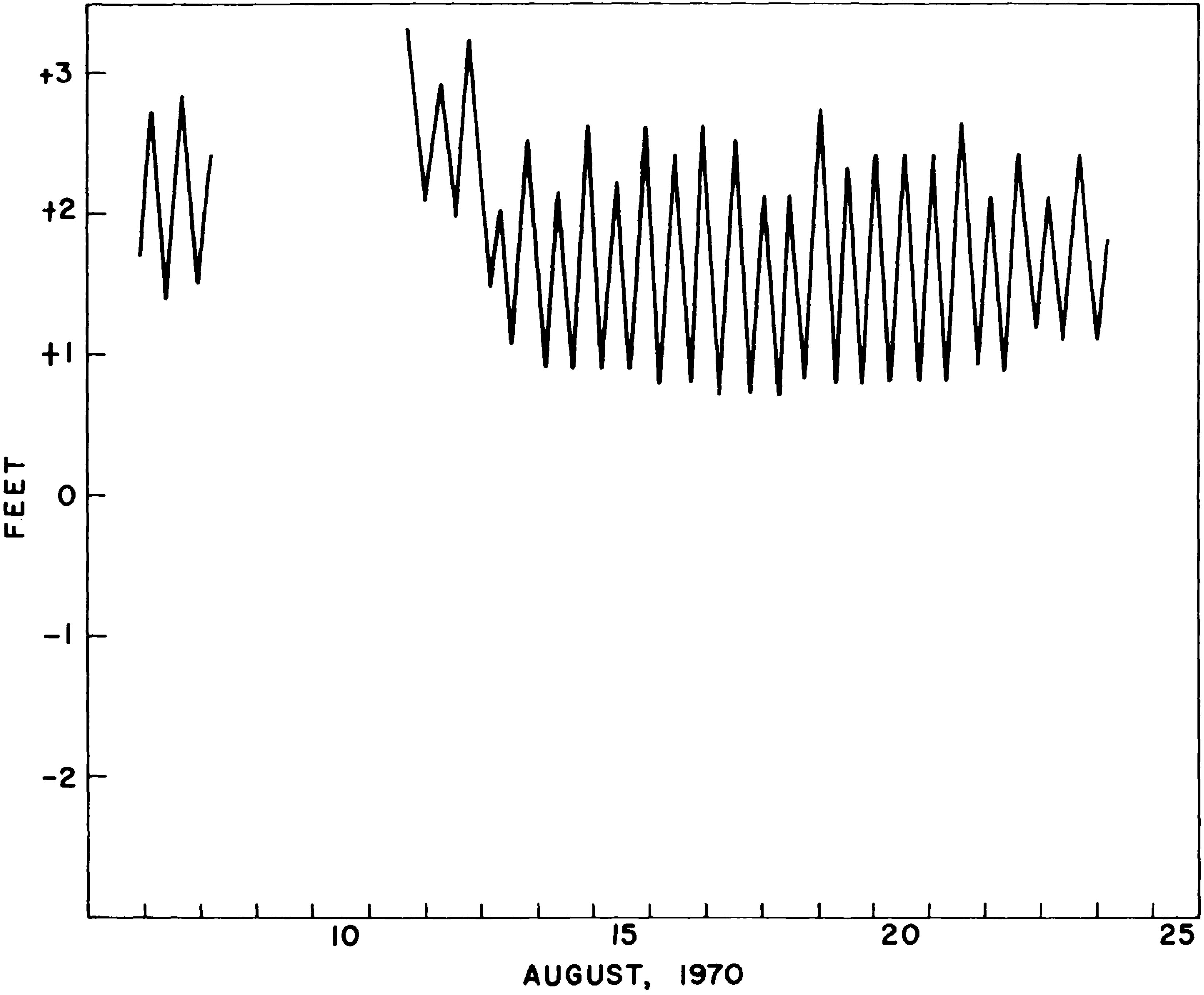
TIDAL HEIGHTS STATION 27 36° 39'00" 37° 39'00"

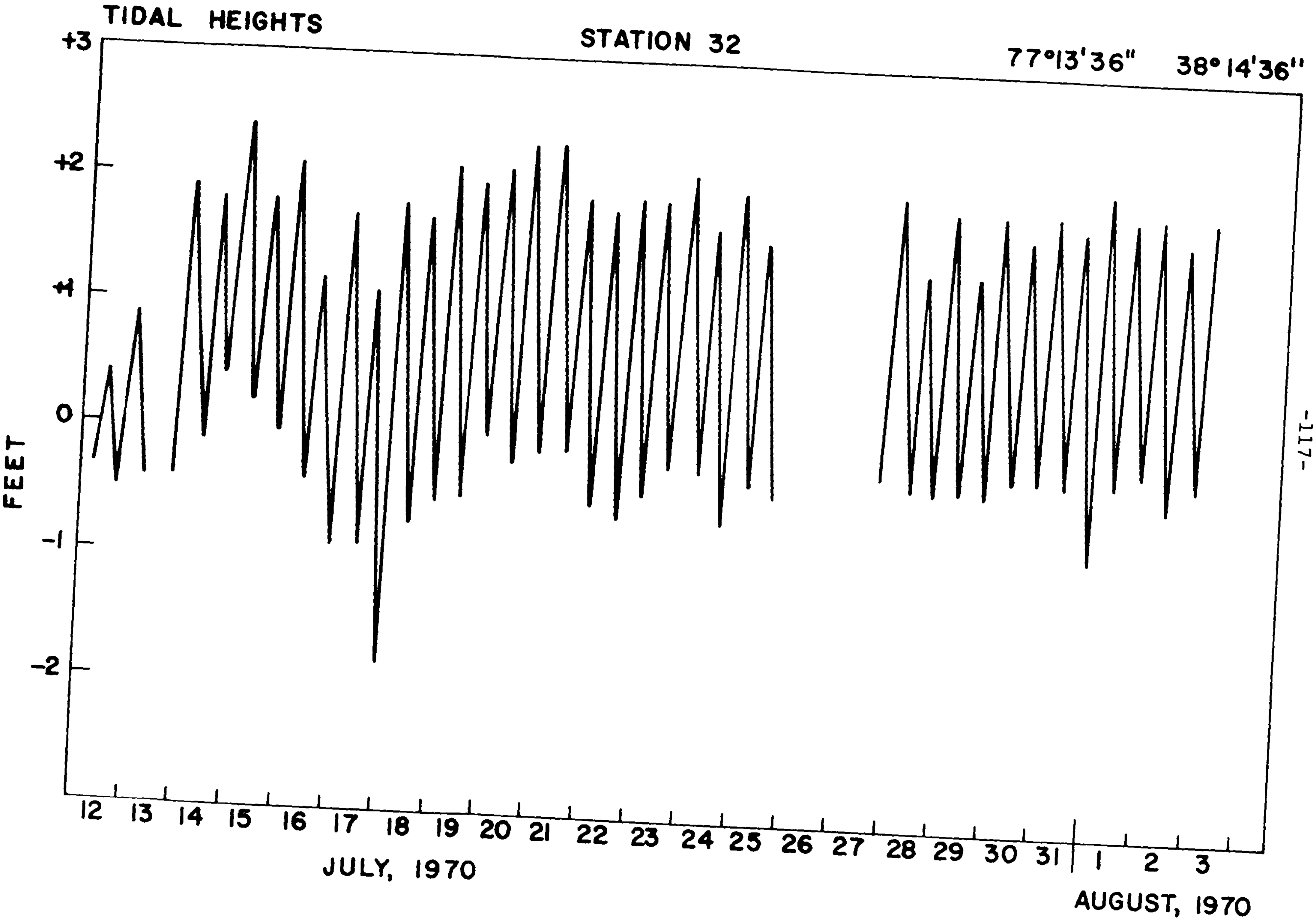


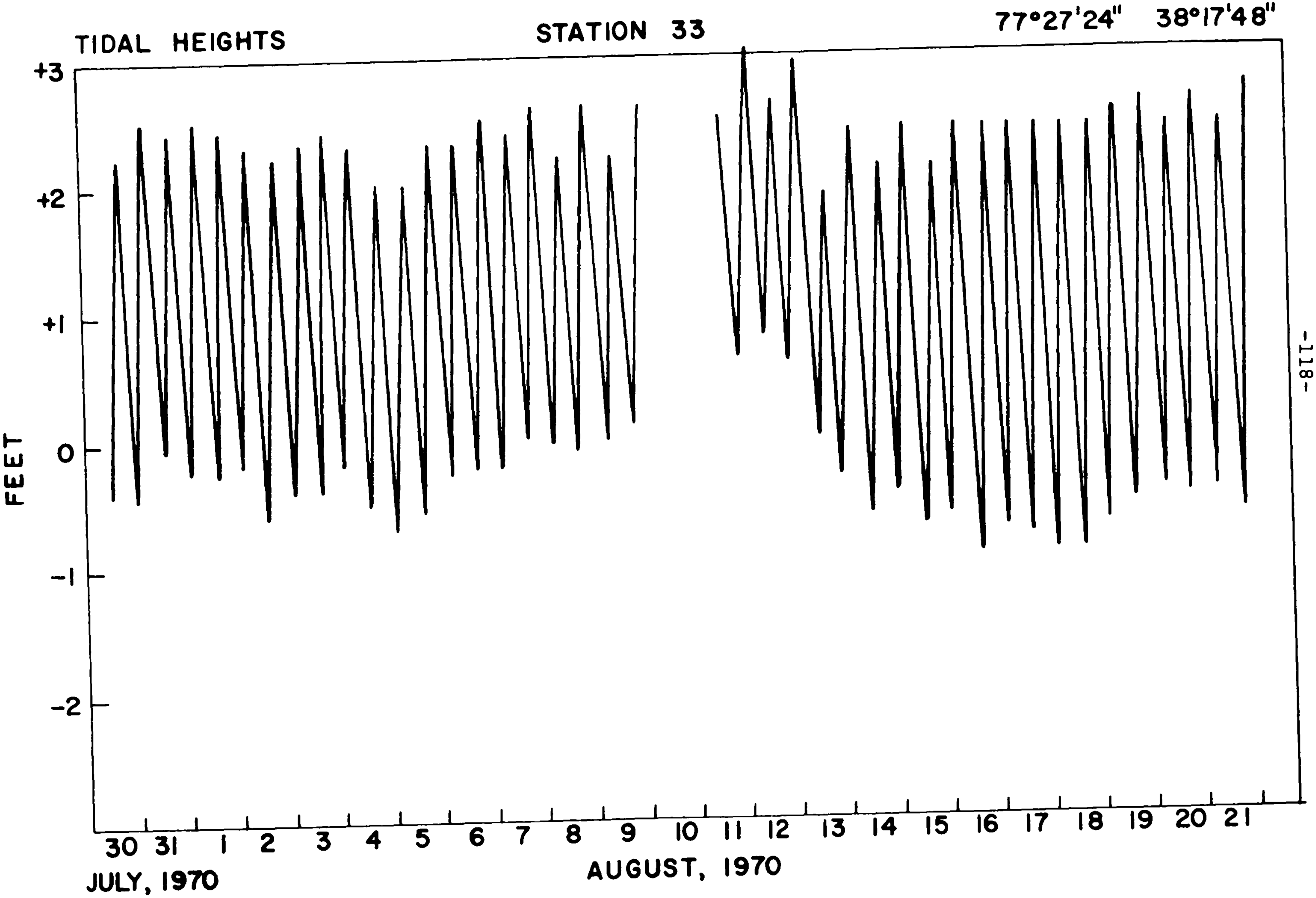
TIDAL HEIGHTS STATION 31 77°02'18" 38°05'24"



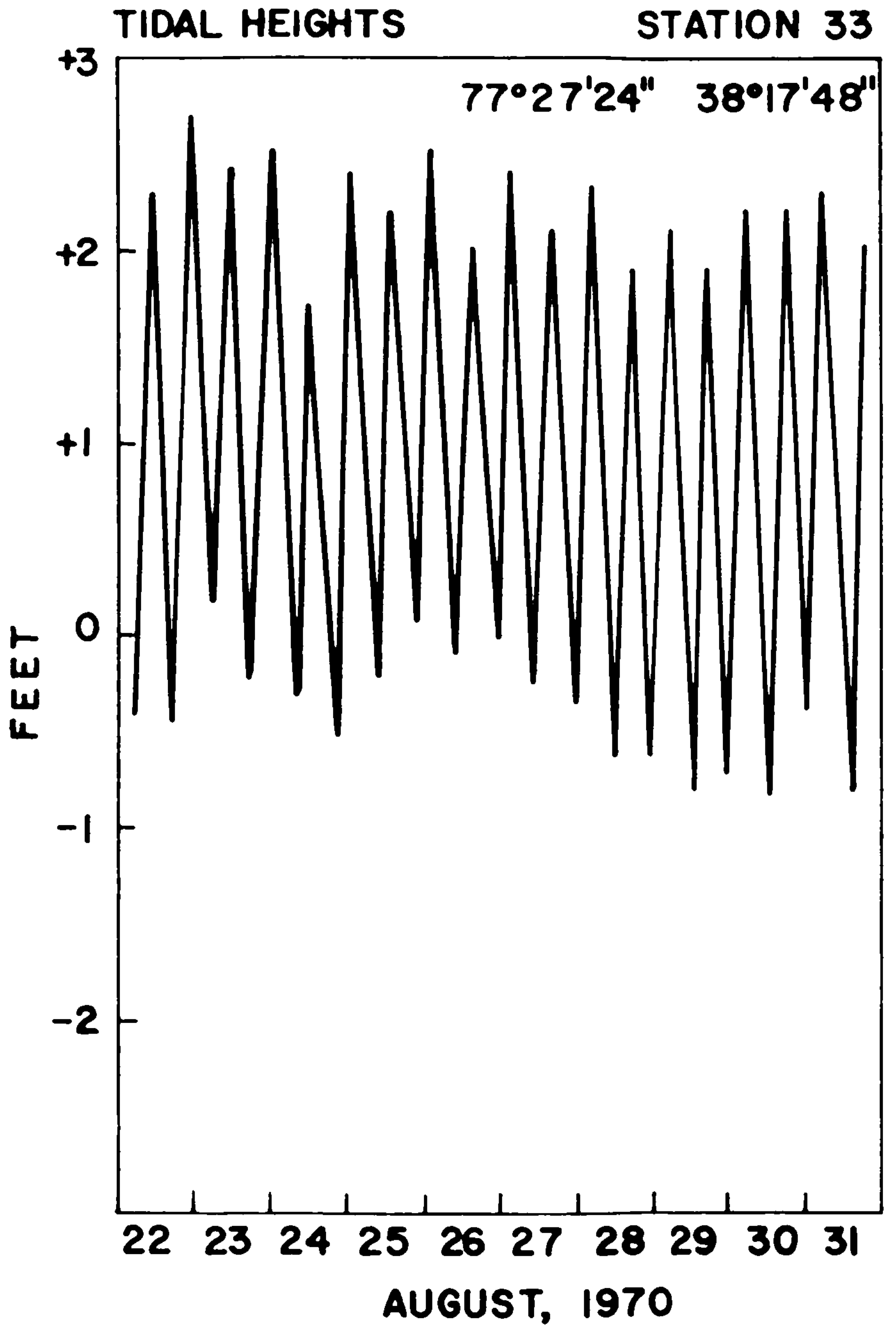
TIDAL HEIGHTS STATION 28 76°40'18" 37°45'18"



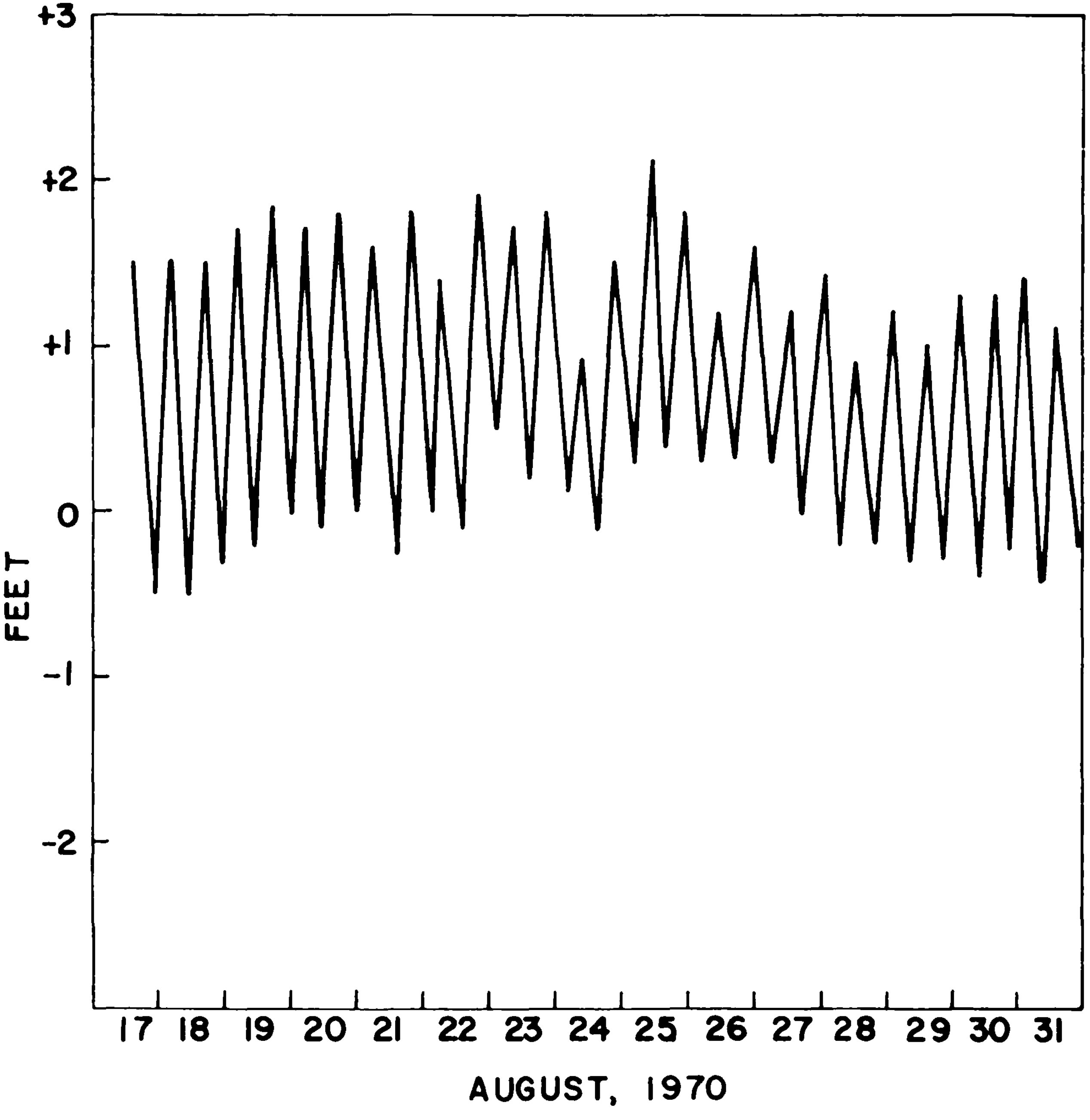

TIDAL HEIGHTS
STATION 32
77°13'36"
38°14'36"
FEET
+3
+2
+1
0
-1
-2
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
JULY, 1970
1
2
3
AUGUST, 1970

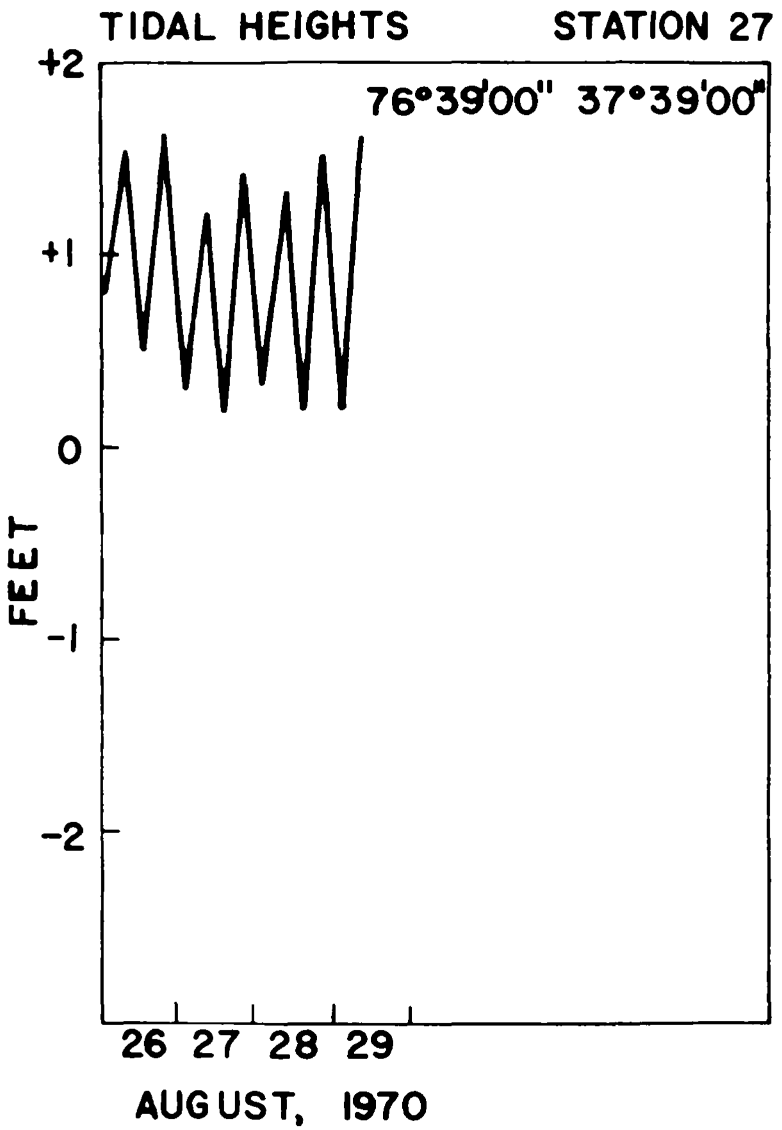


TIDAL HEIGHTS STATION 33 77°27'24" 38°17'48"

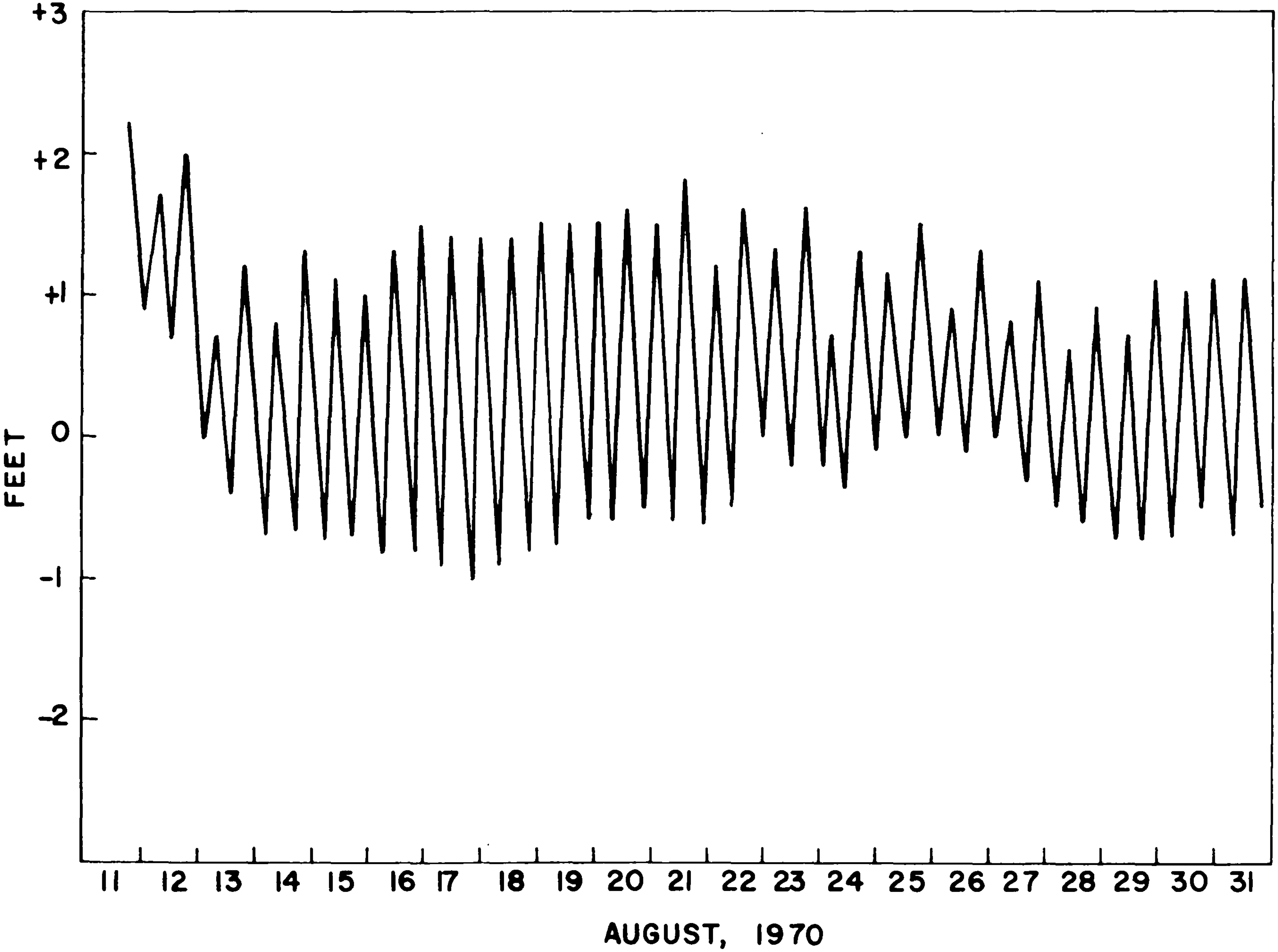

TIDAL HEIGHTS
STATION 33
77°27'24"
38°17'48"
+3
+2
+1
0
-1
-2
FEET
22
23
24
25
26
27
28
29
30
31
AUGUST, 1970

TIDAL HEIGHTS STATION 31 77°02'18" 38°05'24"

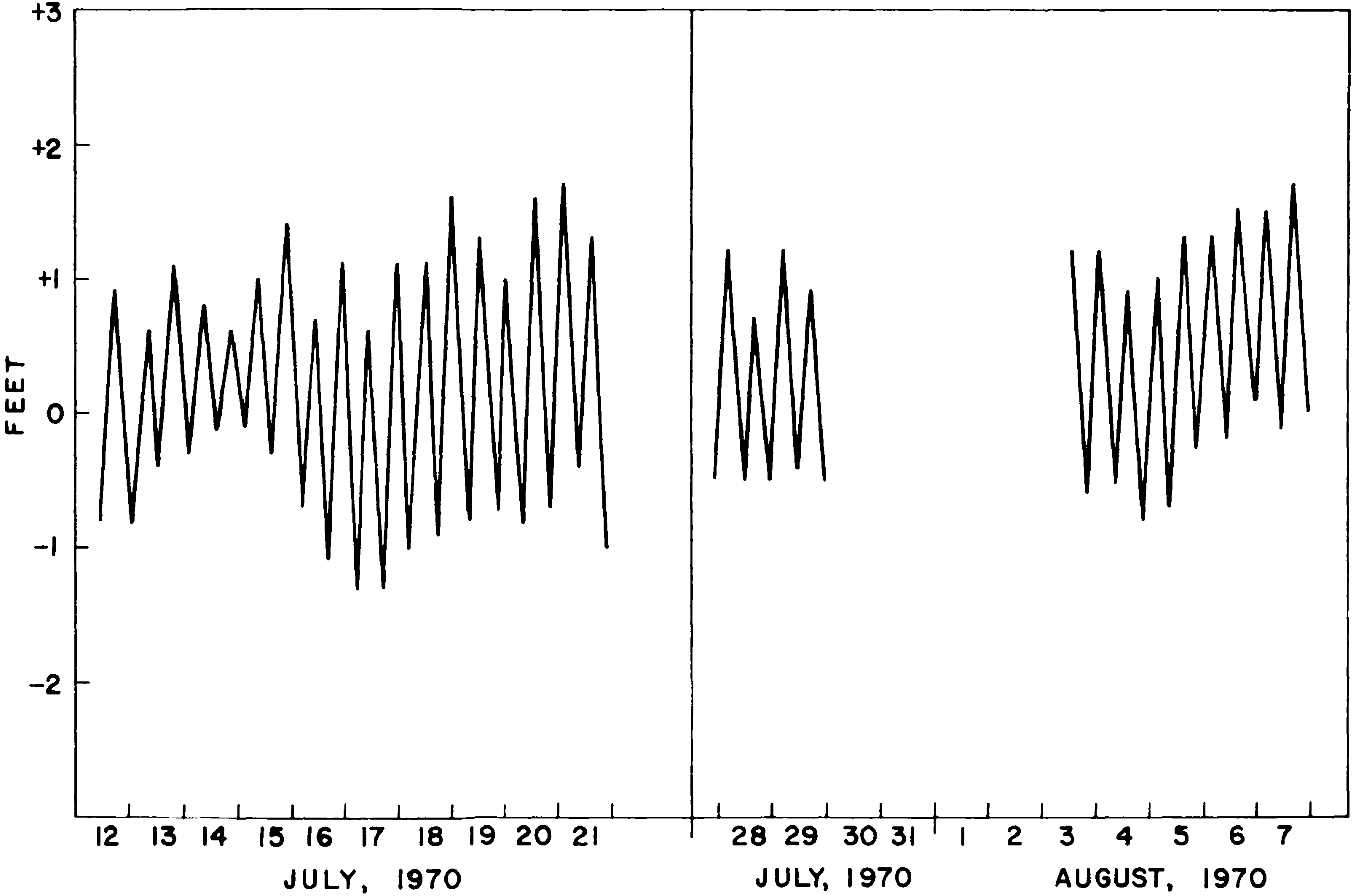



TIDAL HEIGHTS
STATION 27
76°39'00" 37°39'00"
+2
+1
0
-1
-2
FEET
26
27
28
29
AUGUST, 1970

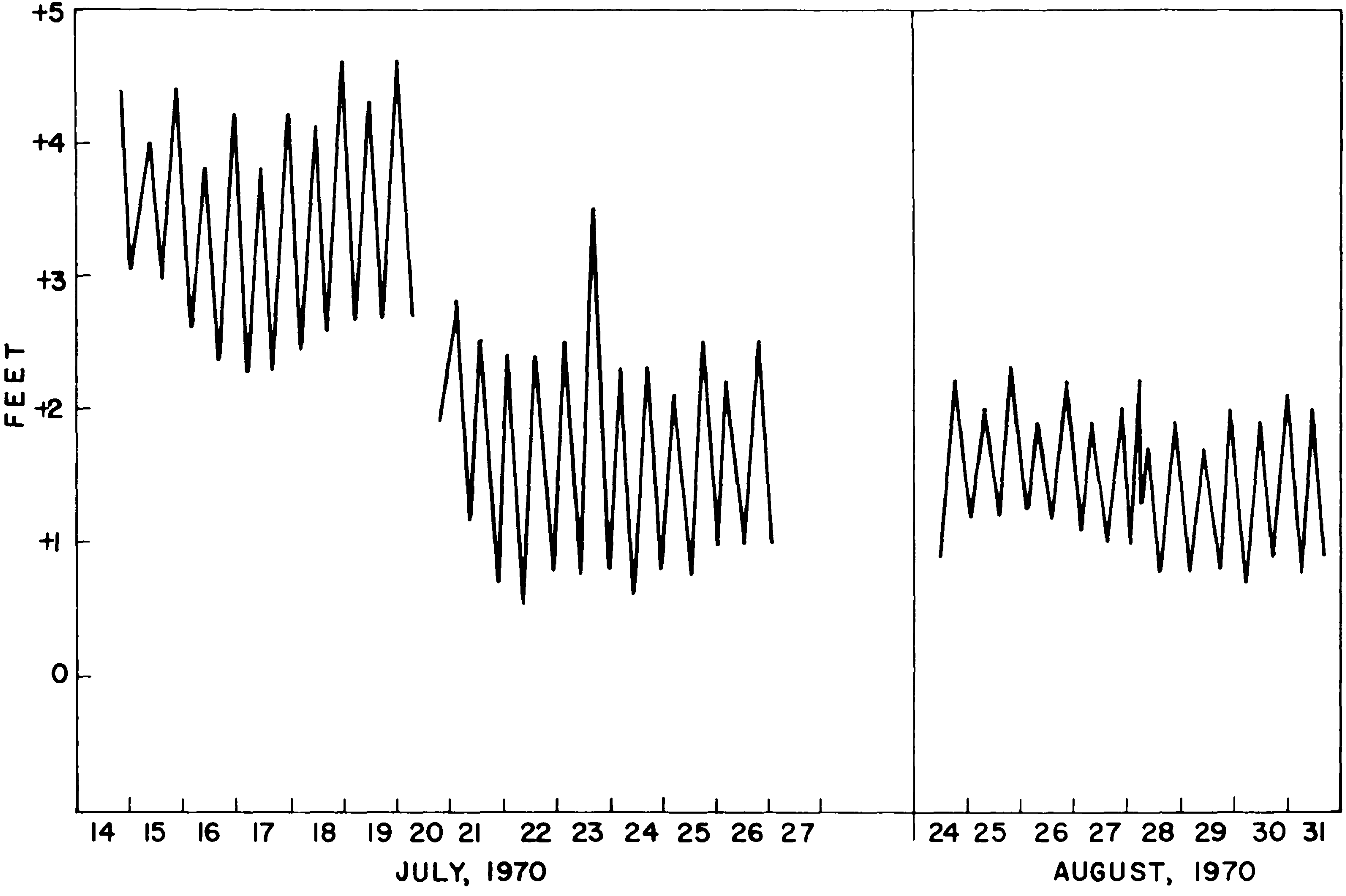
TIDAL HEIGHTS STATION 29 76°47'00" 37°52'24"

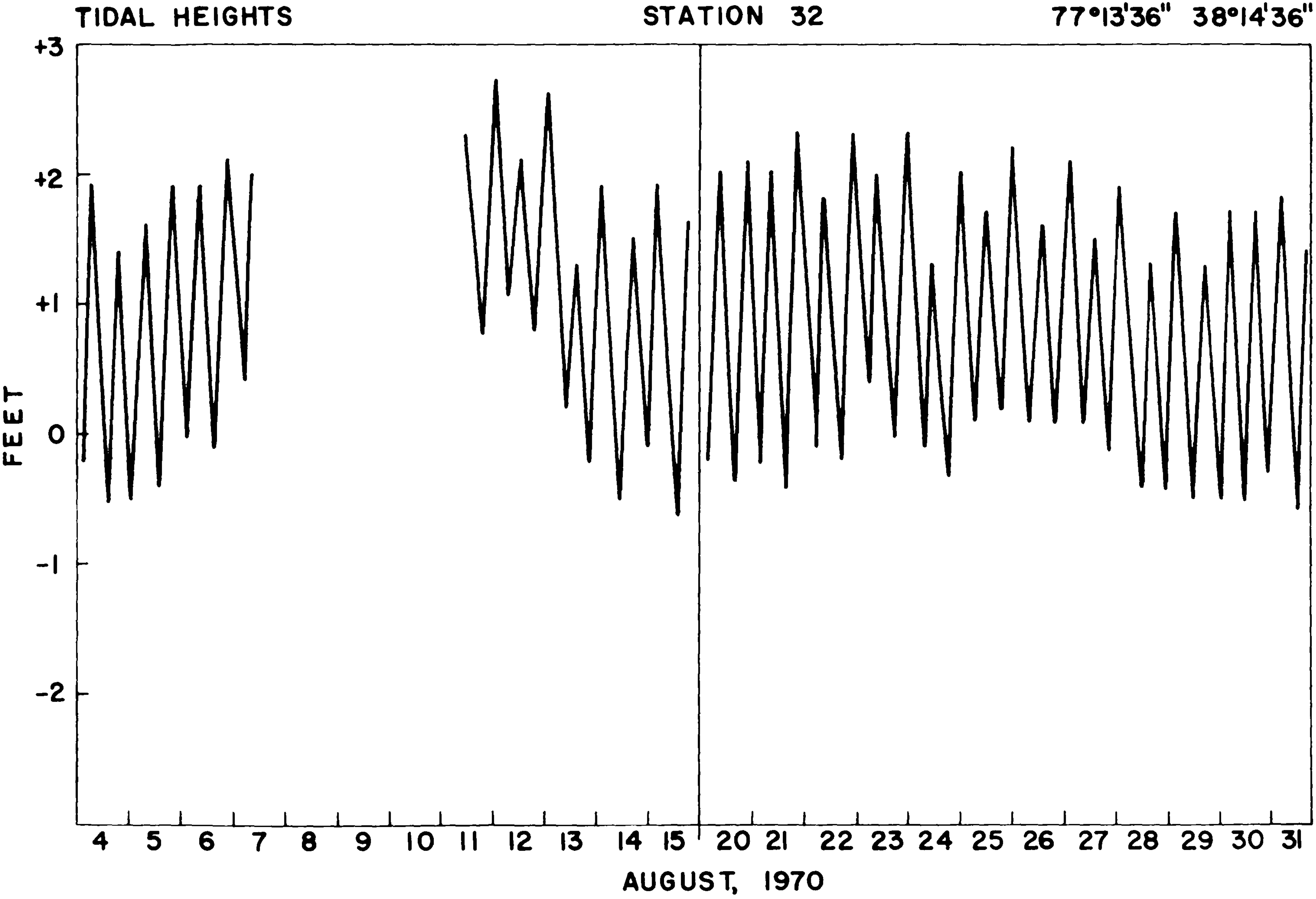


TIDAL HEIGHTS **STATION 29** **76°47'00" 37°52'24"**



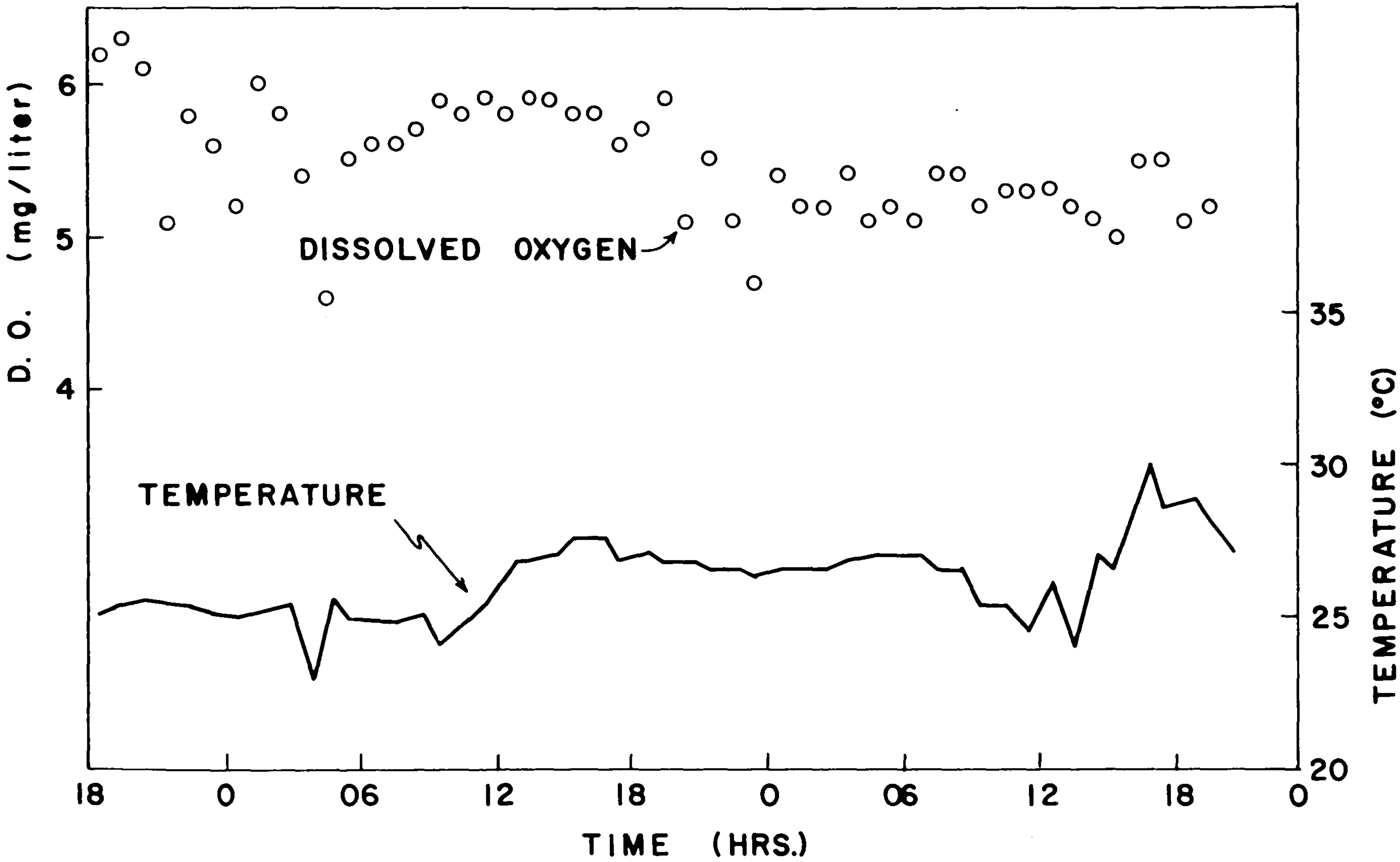
TIDAL HEIGHTS STATION 28 76°40'18" 37°45'18"

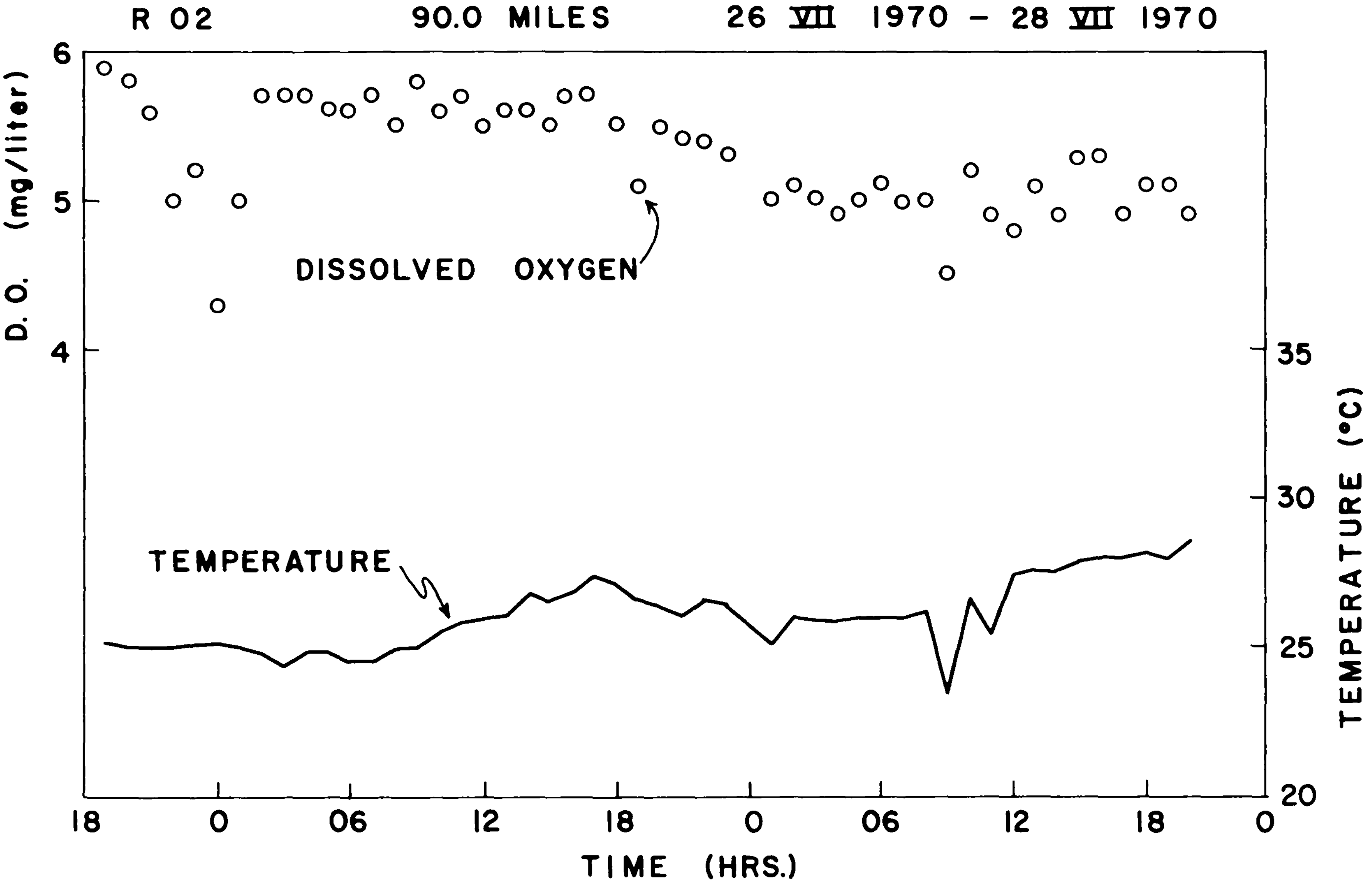


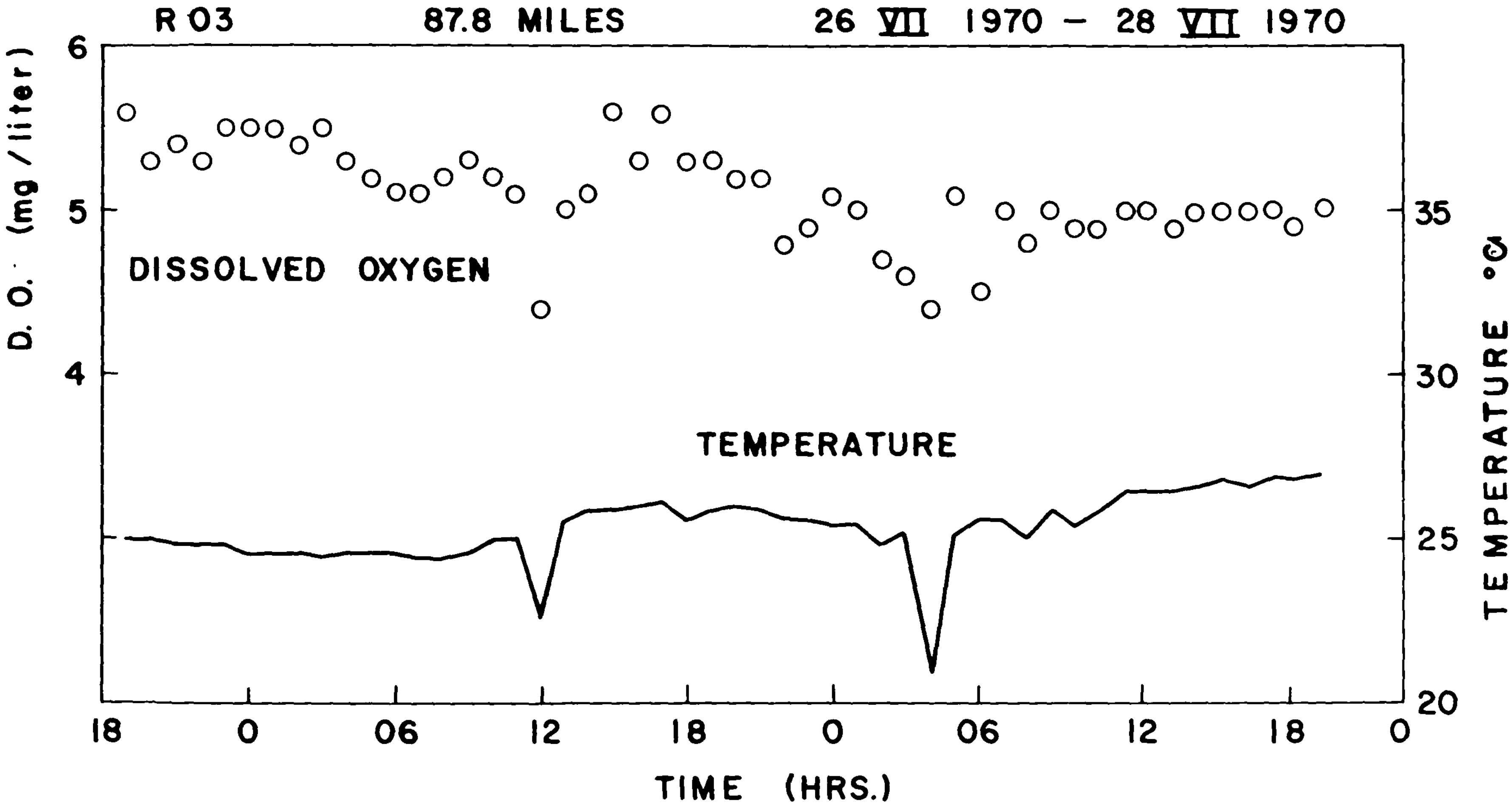

TIDAL HEIGHTS
STATION 32
77°13'36" 38°14'36"
FEET
+3
+2
+1
0
-1
-2
4
5
6
7
8
9
10
11
12
13
14
15
20
21
22
23
24
25
26
27
28
29
30
31
AUGUST, 1970

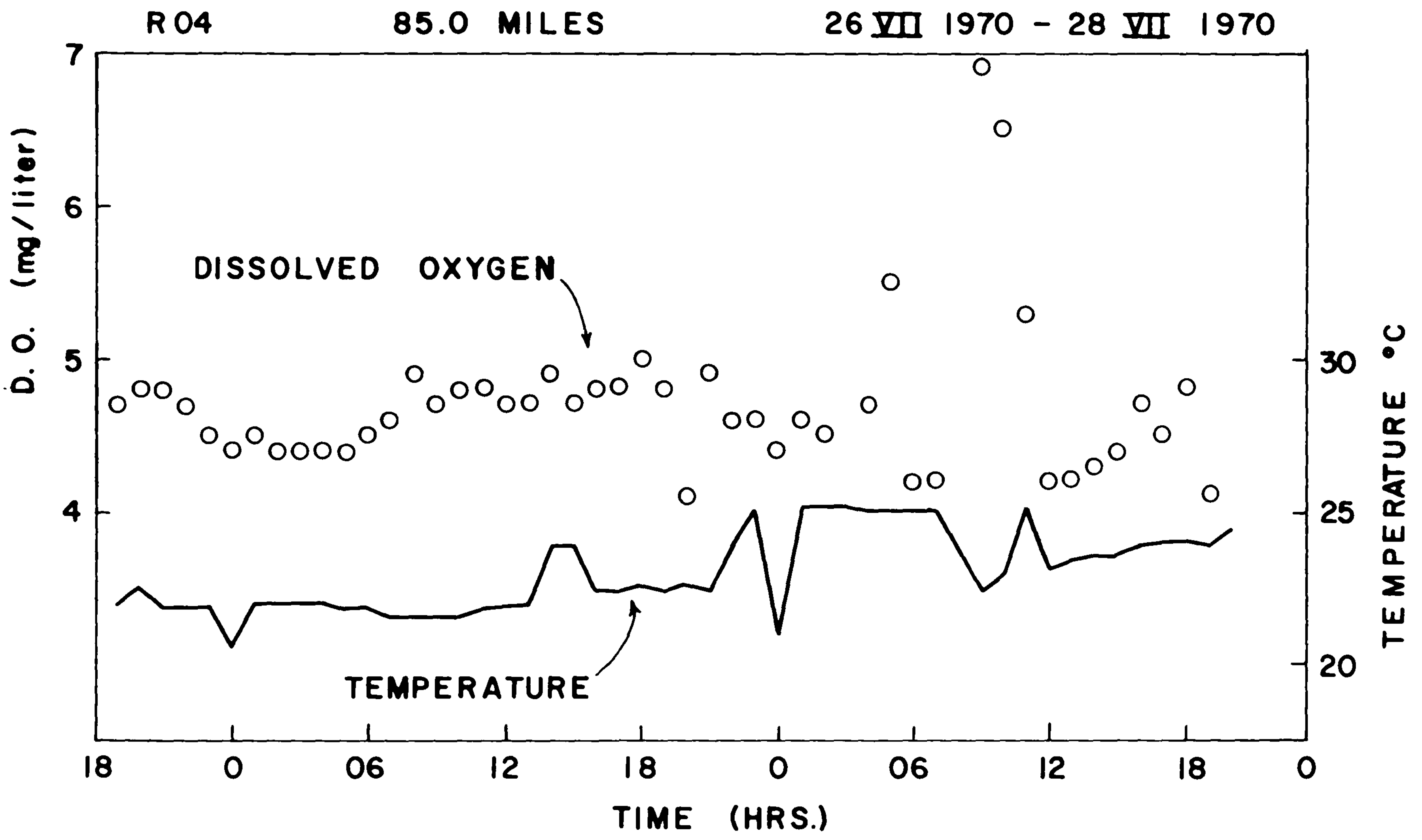
APPENDIX D

SUMMARY OF RAPPAHANNOCK FIELD DATA

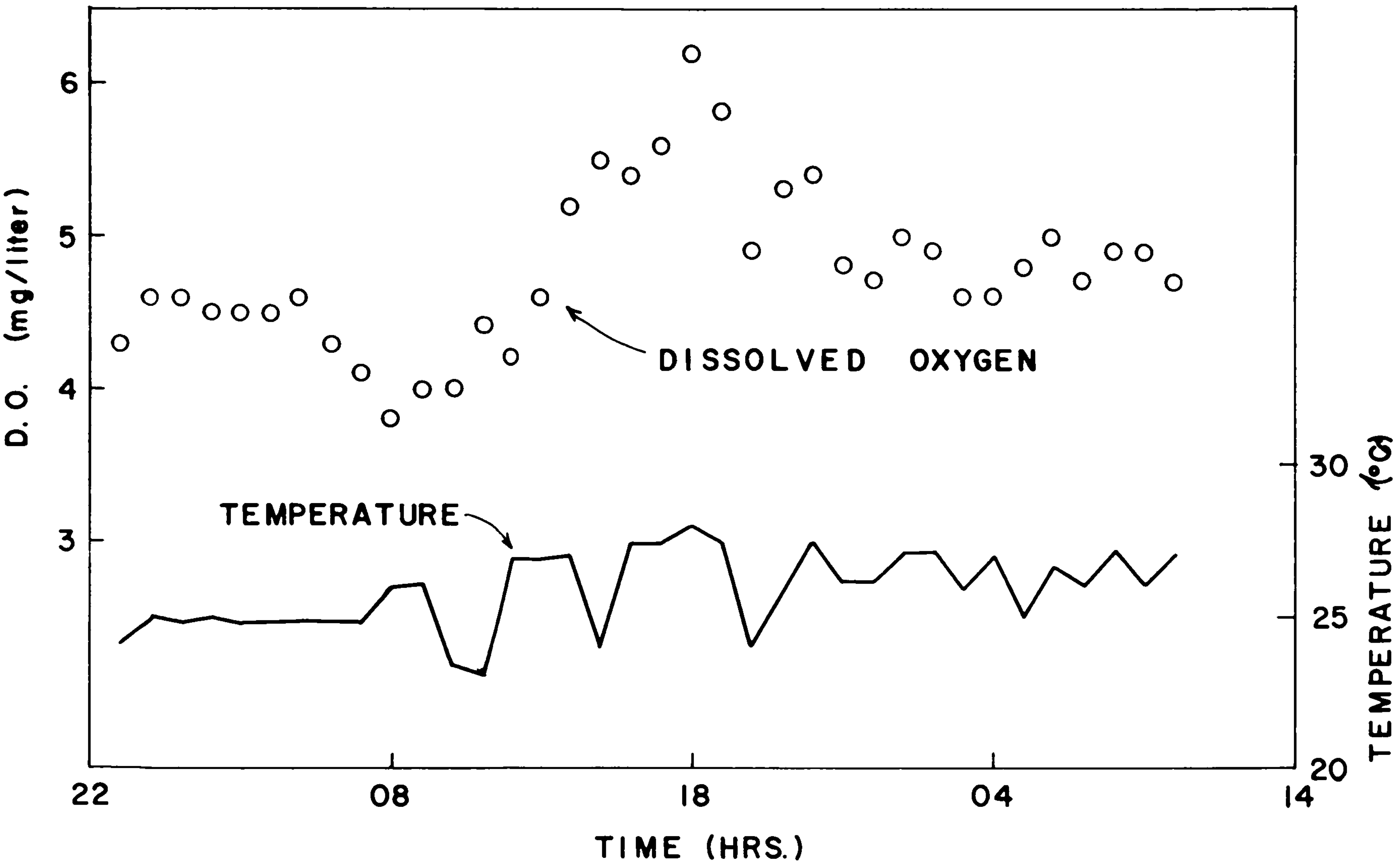

R 01 92.0 MILES 26 VII 1970 – 28 VII 1970


R 02 90.0 MILES 26 VII 1970 – 28 VII 1970

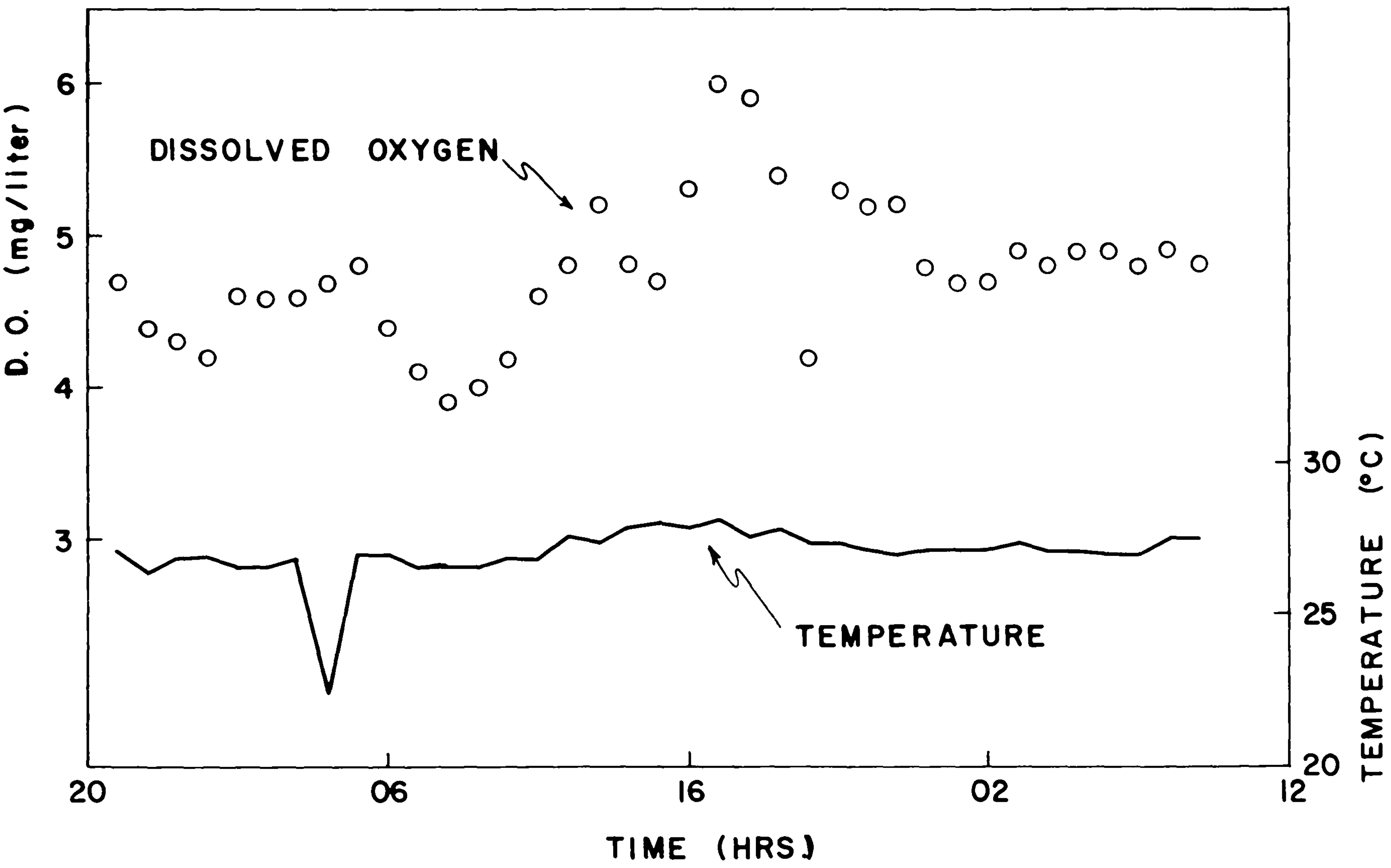

R 03
87.8 MILES
26 VII 1970 – 28 VII 1970
D. O. (mg / liter)
6
5
4
DISSOLVED OXYGEN
TEMPERATURE
TEMPERATURE °C
35
30
25
20
18
0
06
12
18
0
06
12
18
0
TIME (HRS.)

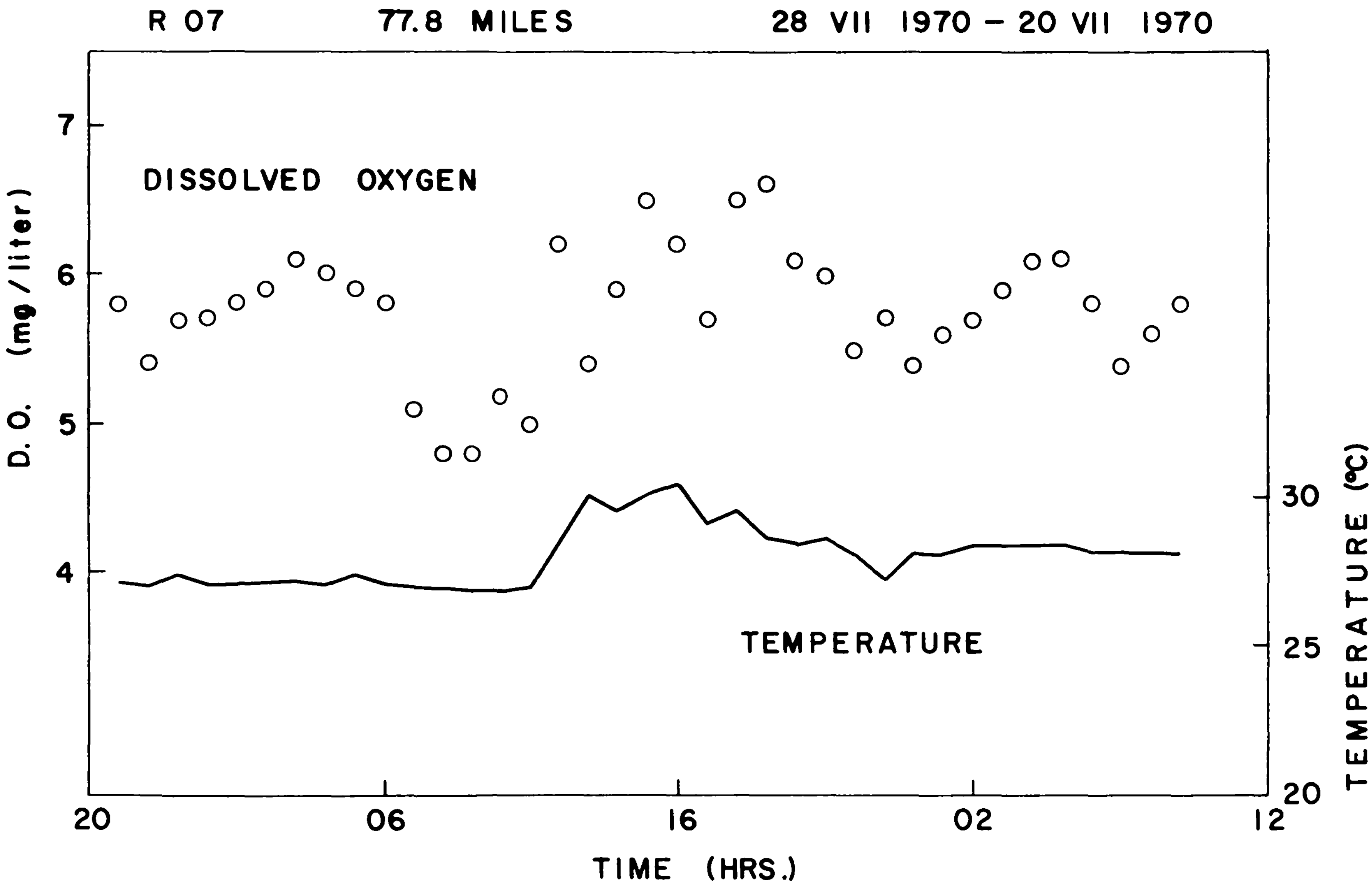

R04
85.0 MILES
26 VII 1970 - 28 VII 1970
D. O. (mg/liter)
7
6
5
4
DISSOLVED OXYGEN
TEMPERATURE
TEMPERATURE °C
30
25
20
18
0
06
12
18
0
06
12
18
0
TIME (HRS.)

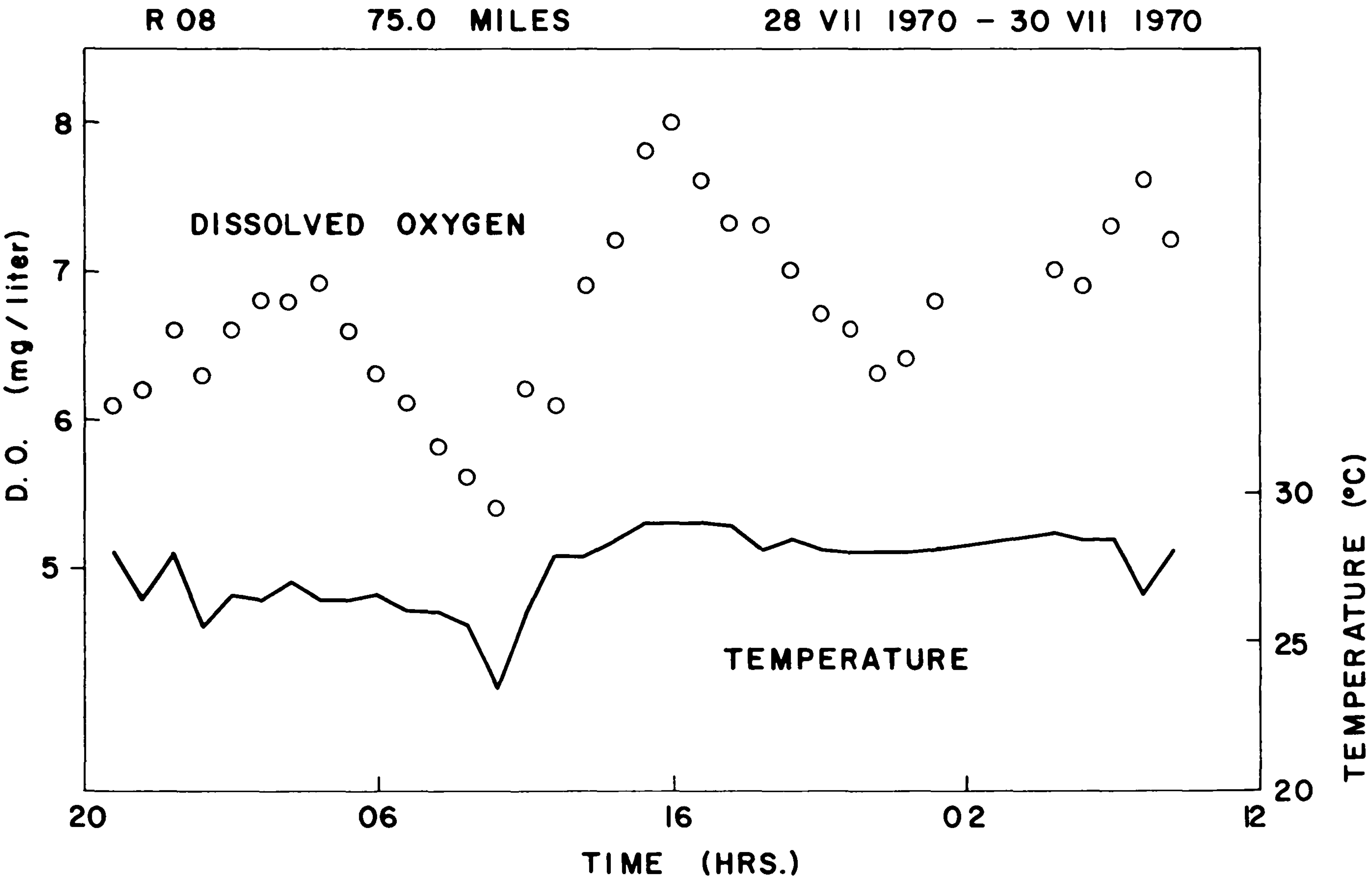
R 05 82.5 MILES 28 VII 1970 – 30 VII 1970



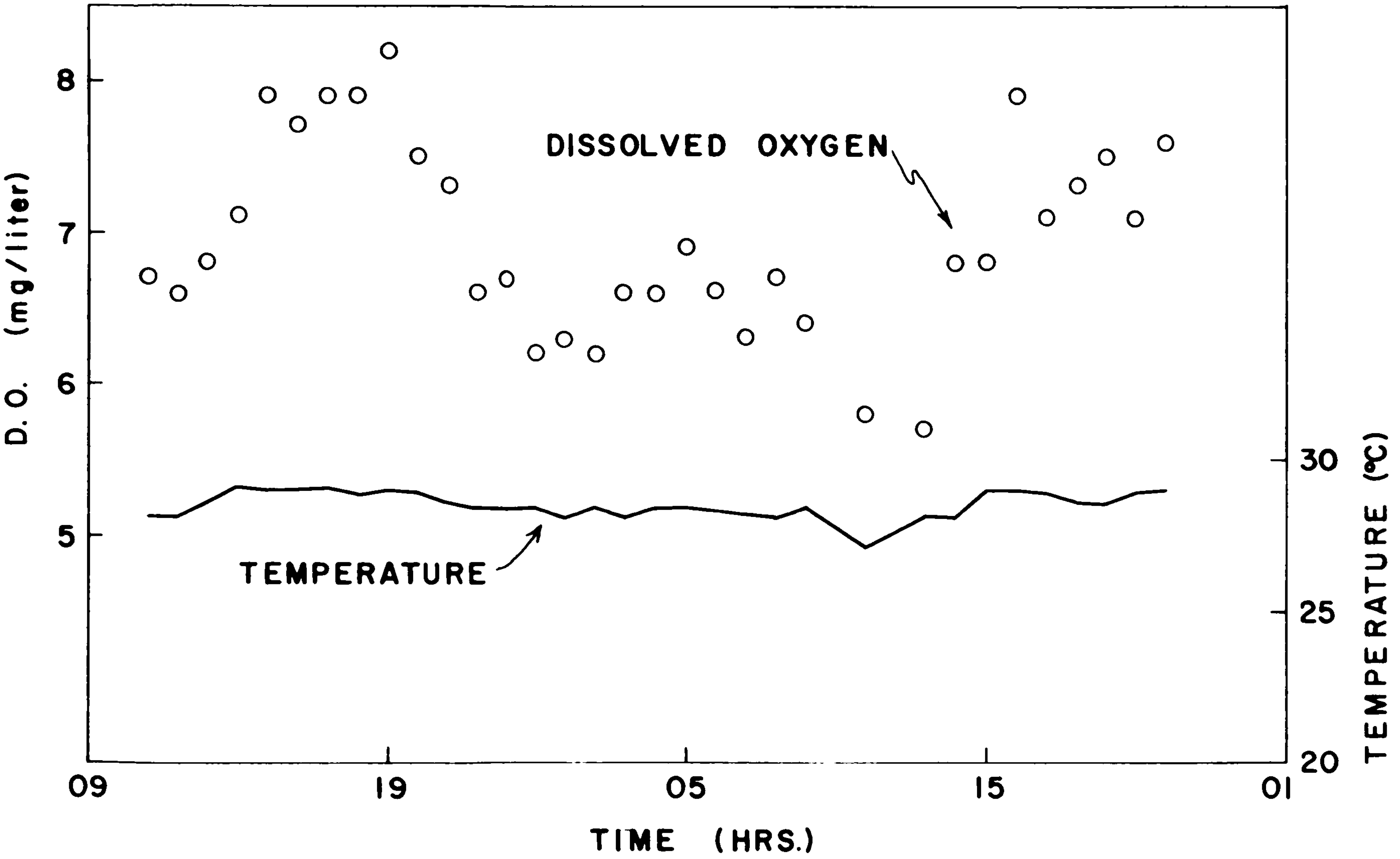
R 06 80.0 MILES 28 VII 1970 — 30 VII 1970

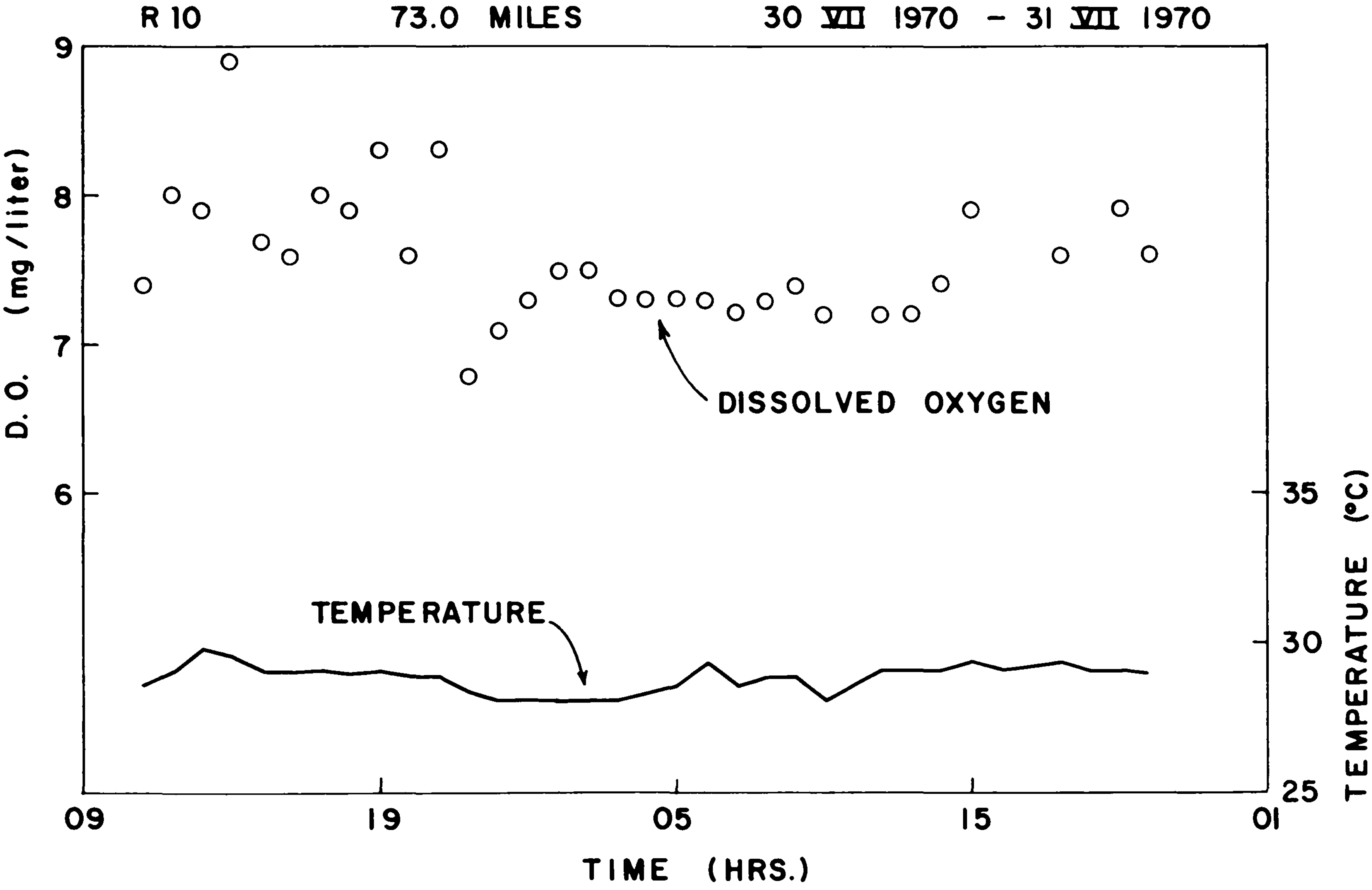


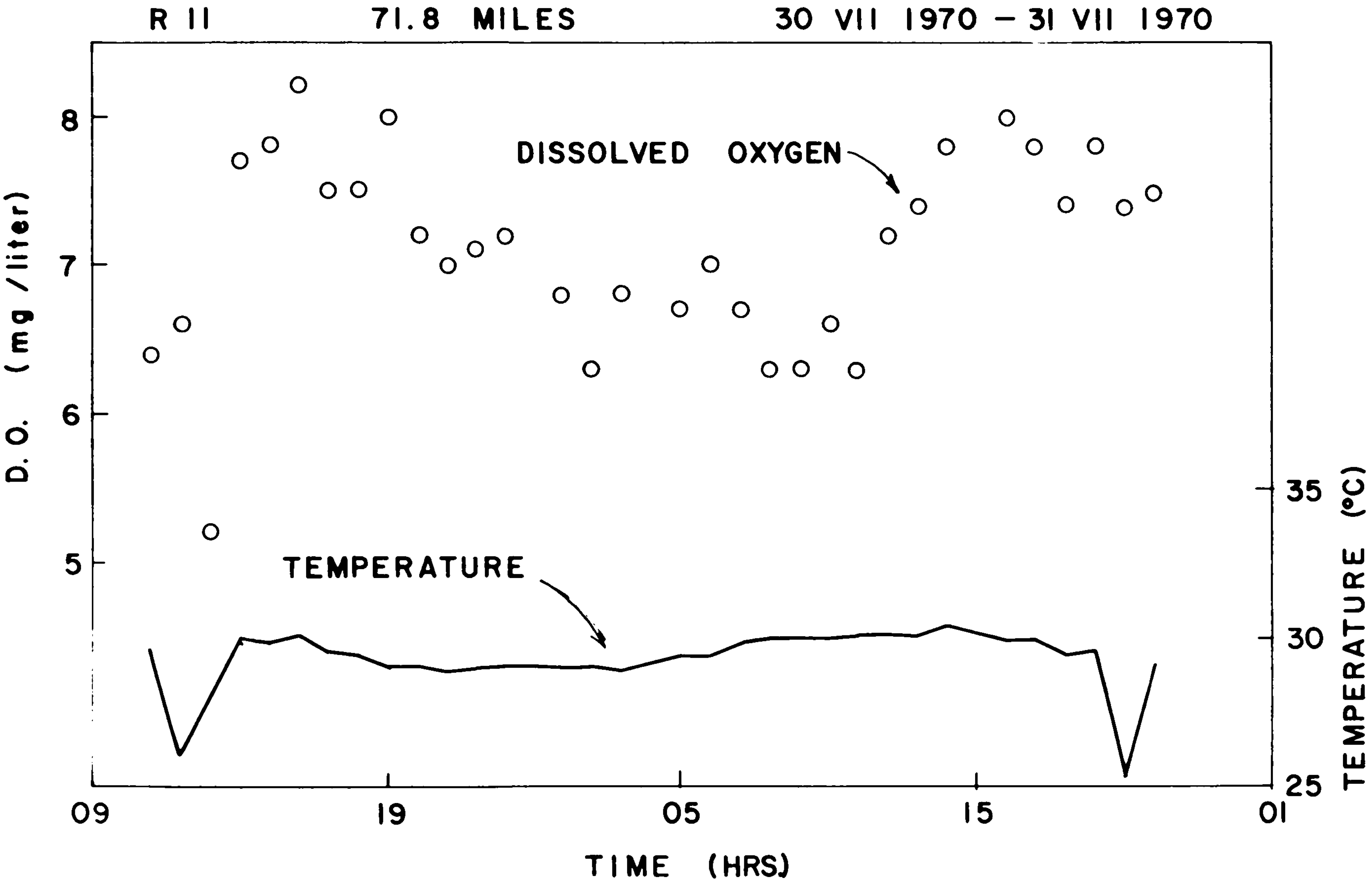

R 07
77.8 MILES
28 VII 1970 – 20 VII 1970
DISSOLVED OXYGEN
TEMPERATURE
D. O. (mg / liter)
7
6
5
4
TEMPERATURE (°C)
30
25
20
20
06
16
02
12
TIME (HRS.)


R 08
75.0 MILES
28 VII 1970 – 30 VII 1970
DISSOLVED OXYGEN
TEMPERATURE
D.O. (mg / liter)
8
7
6
5
TEMPERATURE (°C)
30
25
20
TIME (HRS.)
20
06
16
02
12

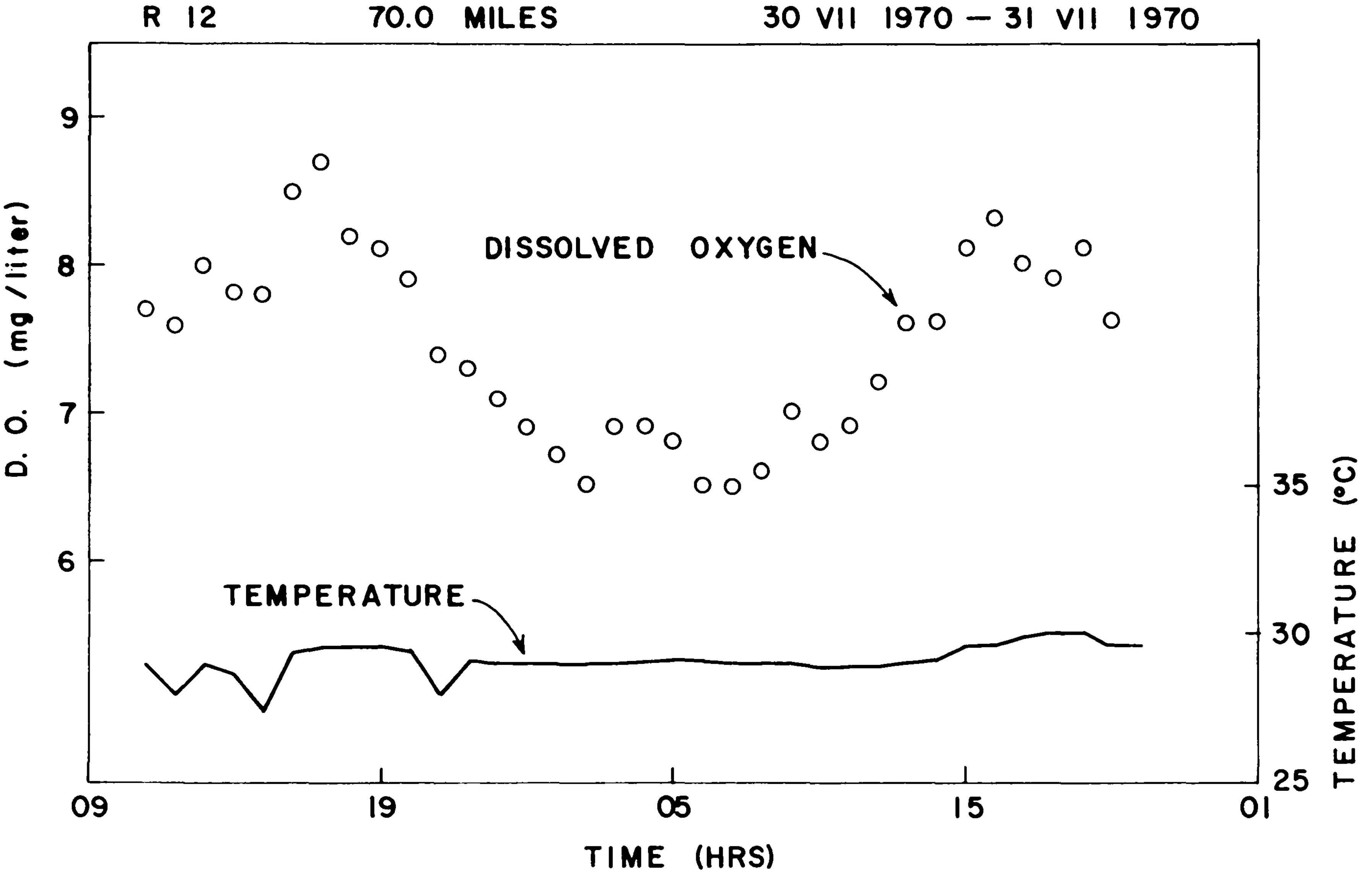
R 09 74.2 MILES 30 VII 1970 – 31 VII 1970

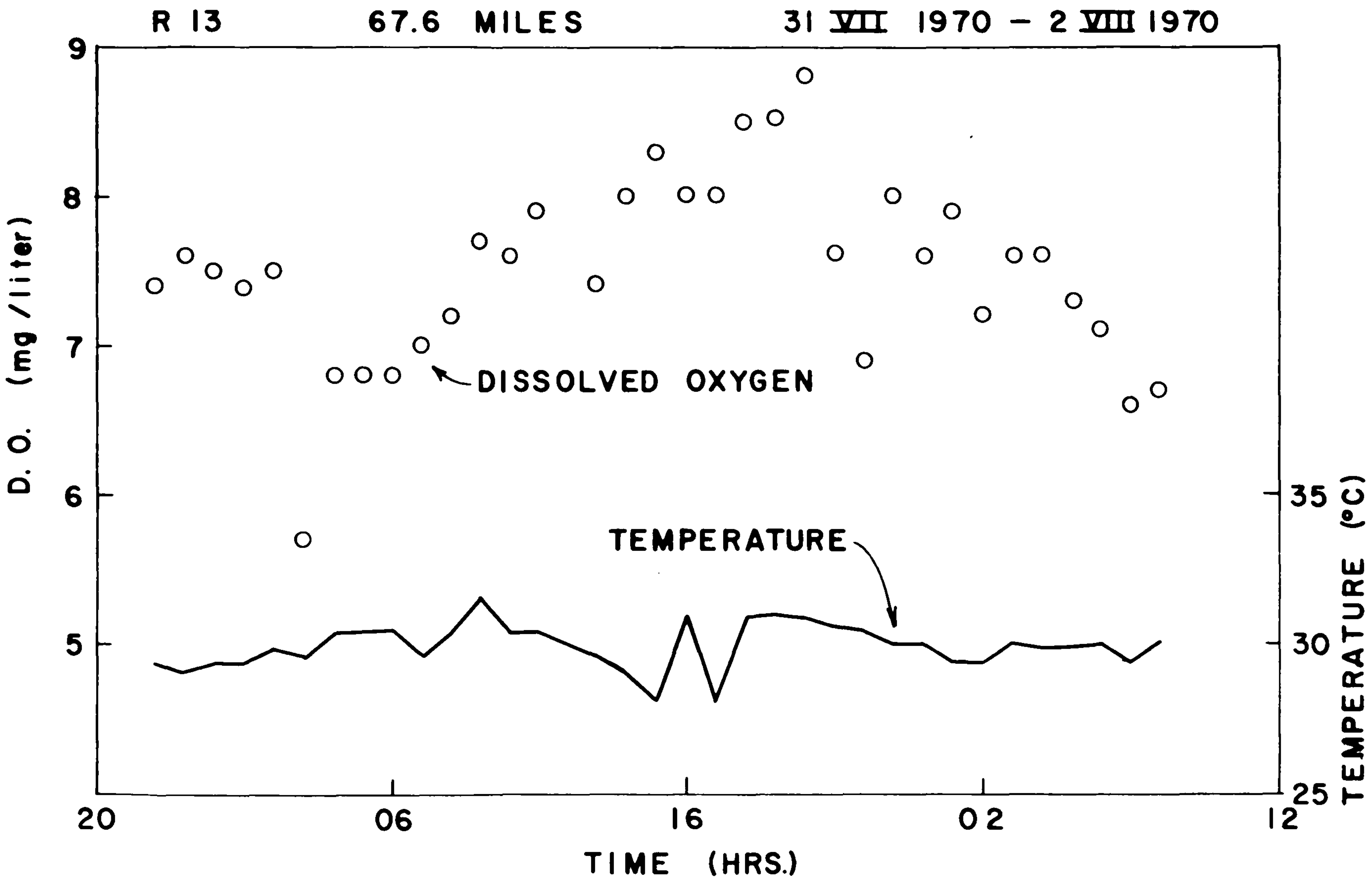


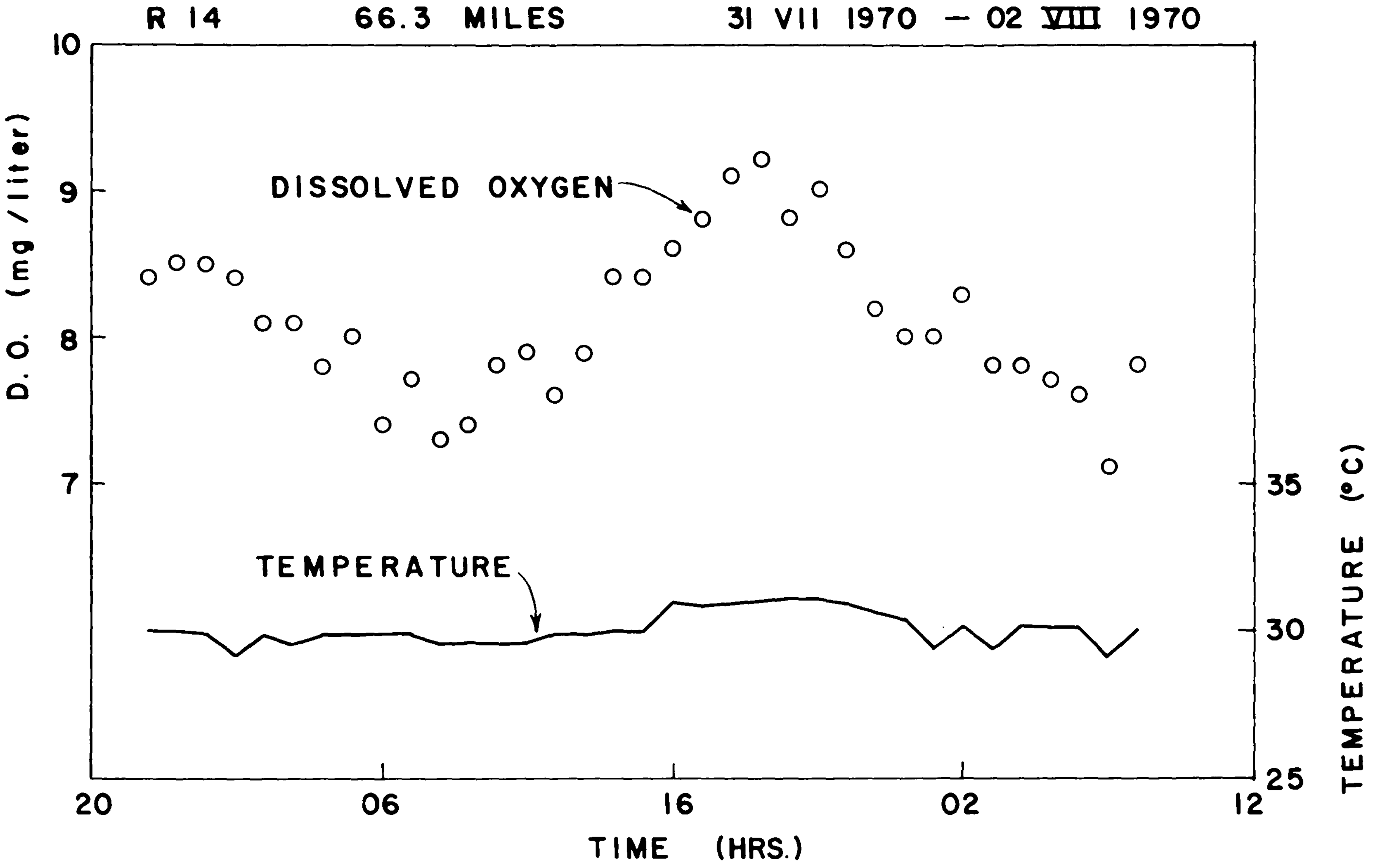

R 10
73.0 MILES
30 VII 1970 – 31 VII 1970
D. O. (mg/liter)
9
8
7
6
DISSOLVED OXYGEN
TEMPERATURE
35
30
25
TEMPERATURE (°C)
09
19
05
15
01
TIME (HRS.)

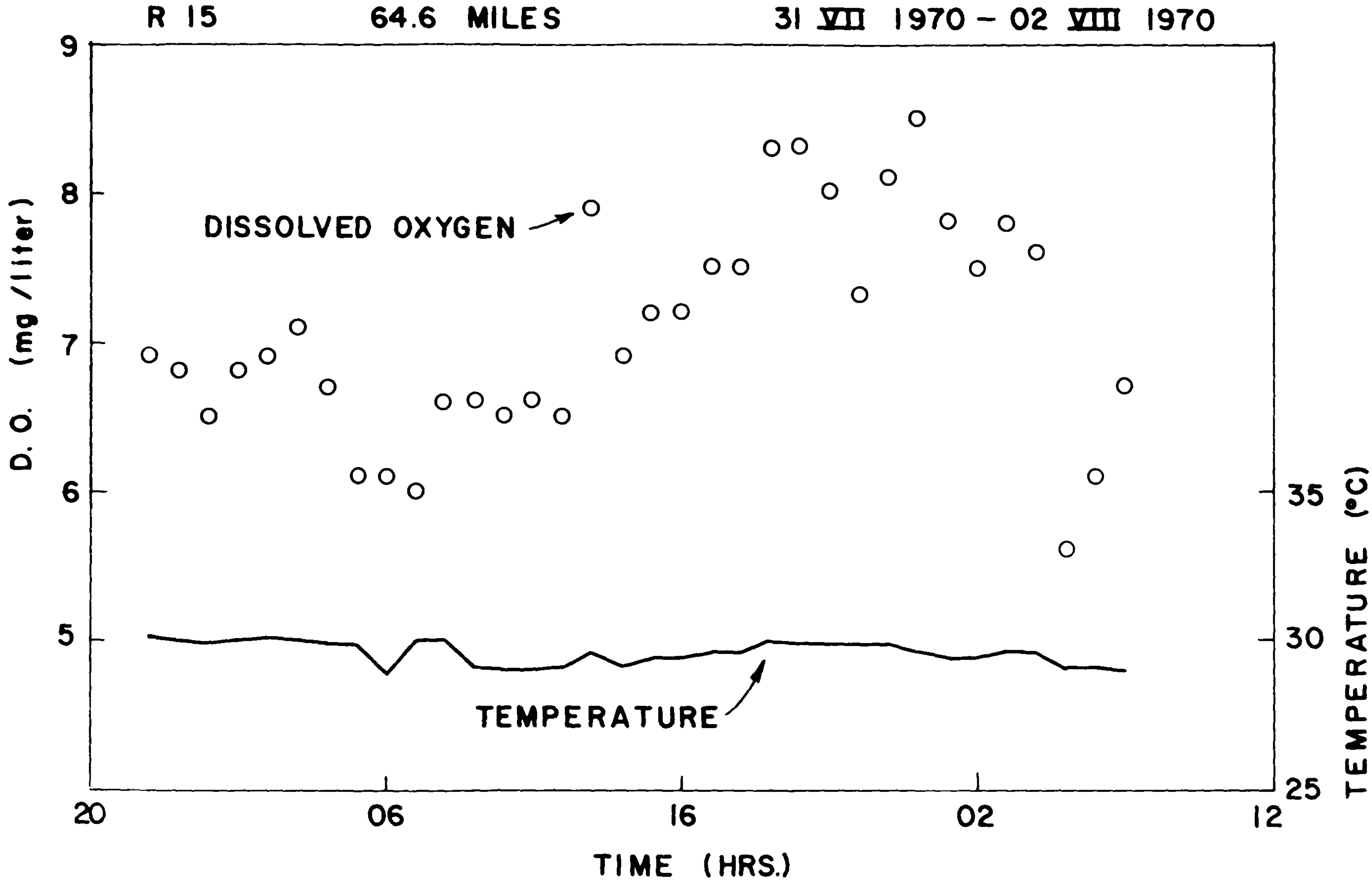


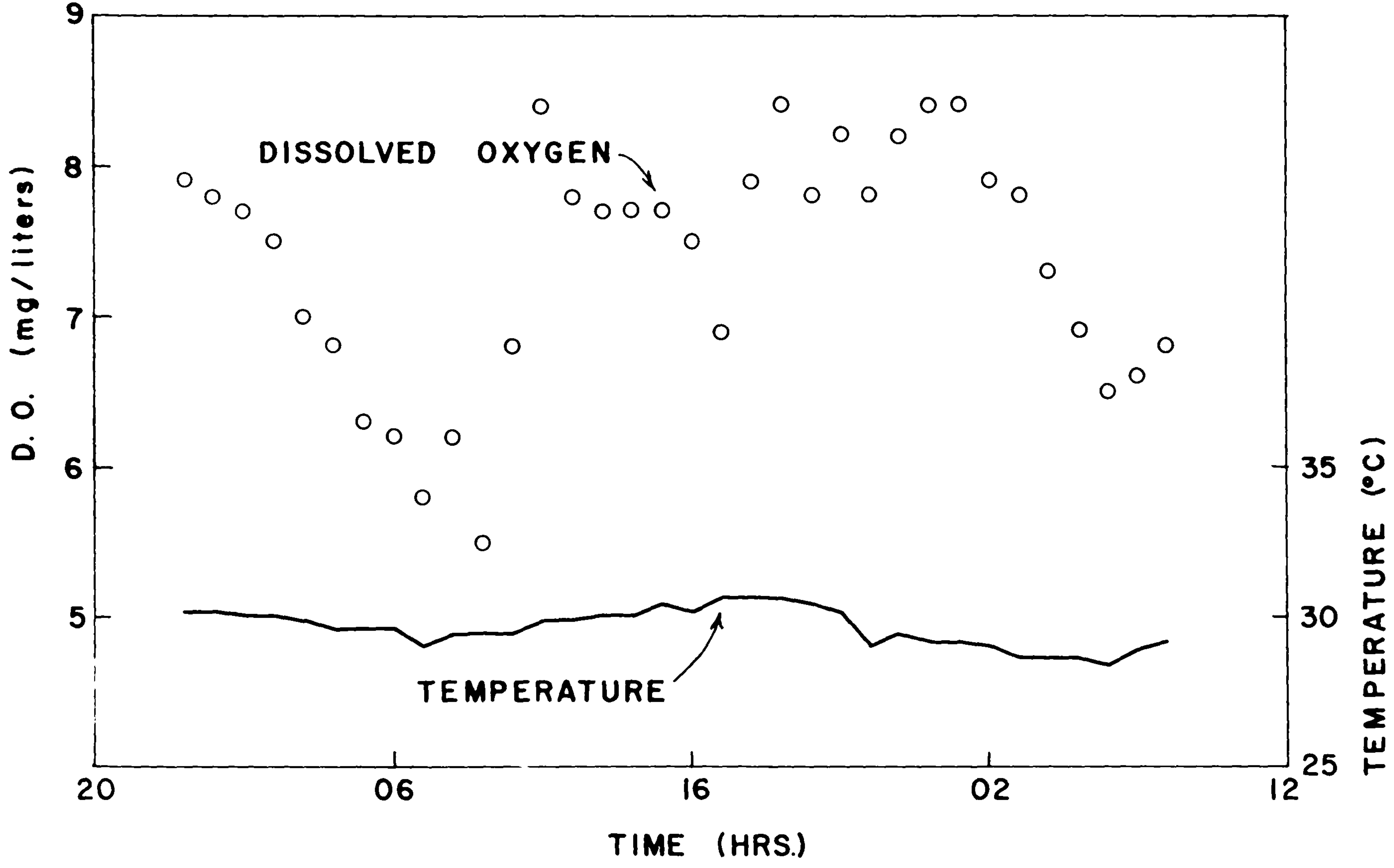
R 11
71.8 MILES
30 VII 1970 – 31 VII 1970
D.O. (mg / liter)
8
7
6
5
DISSOLVED OXYGEN
TEMPERATURE
35
30
25
TEMPERATURE (°C)
09
19
05
15
01
TIME (HRS)


R 12
70.0 MILES
30 VII 1970 — 31 VII 1970
D. O. (mg / liter)
9
8
7
6
DISSOLVED OXYGEN
TEMPERATURE
35
30
25
TEMPERATURE (°C)
09
19
05
15
01
TIME (HRS)

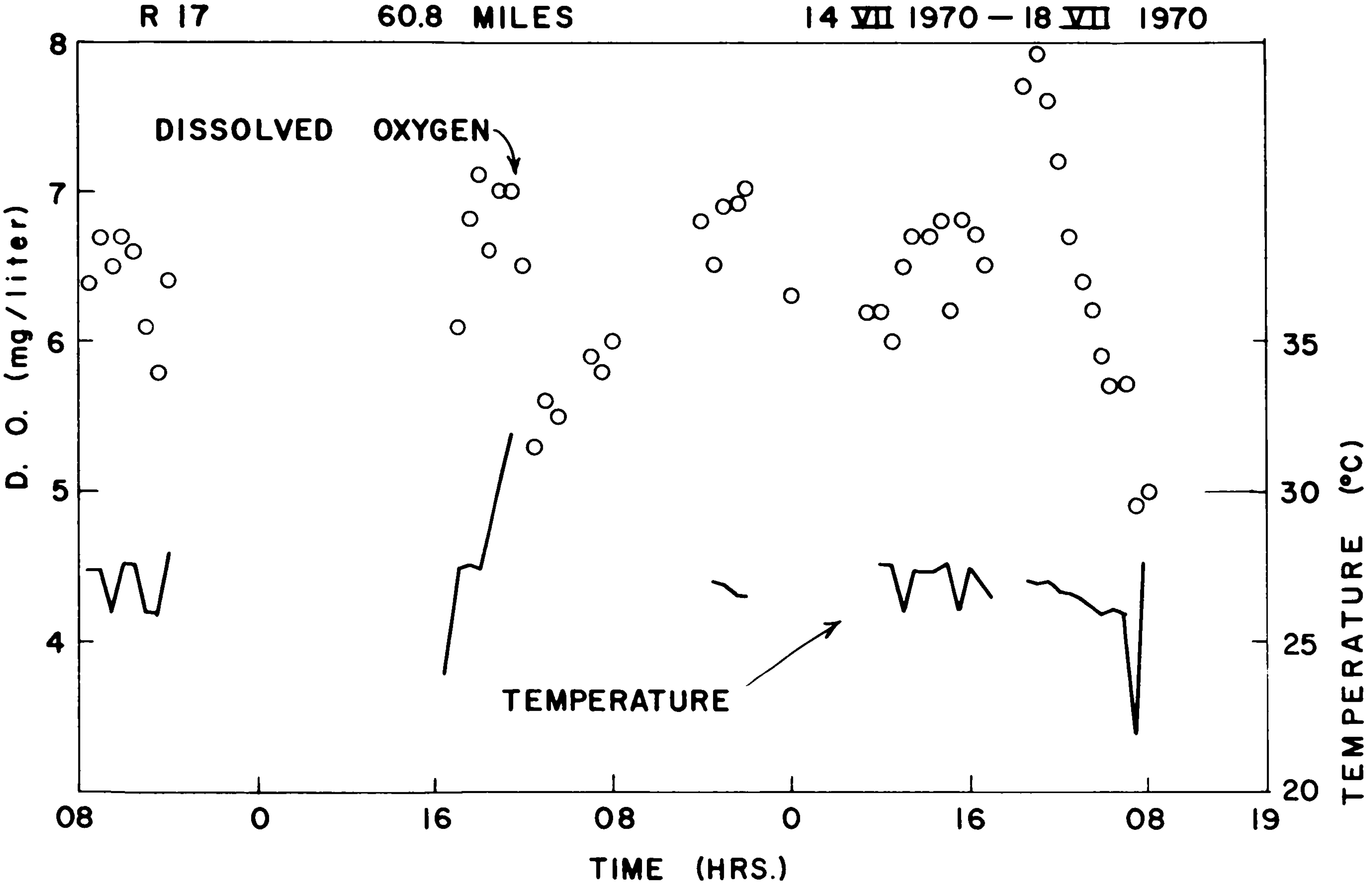

R 13
67.6 MILES
31 VII 1970 – 2 VIII 1970
D. O. (mg/liter)
9
8
7
6
5
DISSOLVED OXYGEN
TEMPERATURE
TEMPERATURE (°C)
35
30
25
20
06
16
02
12
TIME (HRS.)

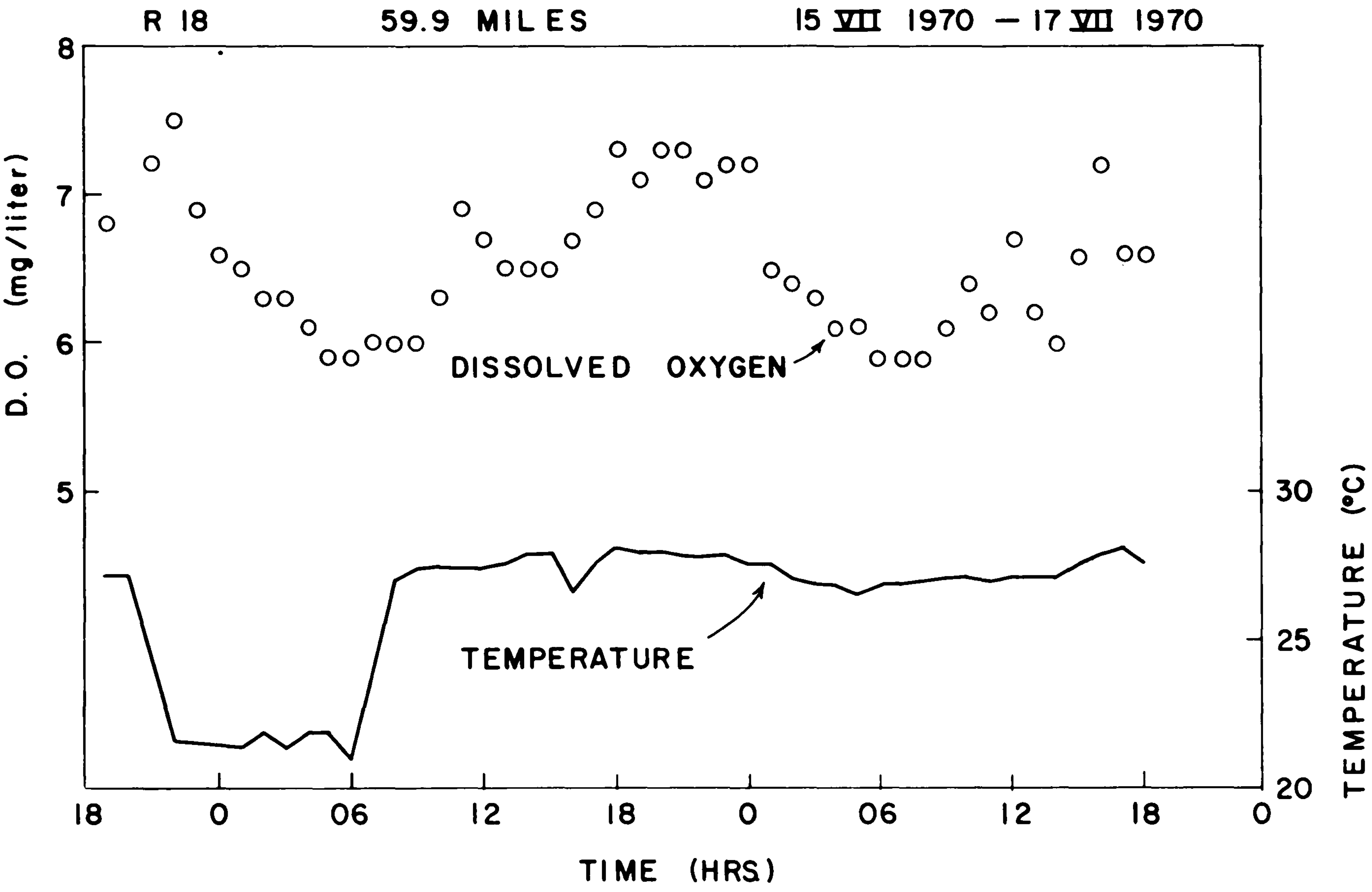

R 14
66.3 MILES
31 VII 1970 — 02 VIII 1970
D.O. (mg/liter)
10
9
8
7
DISSOLVED OXYGEN
TEMPERATURE
35
30
25
TEMPERATURE (°C)
20
06
16
02
12
TIME (HRS.)

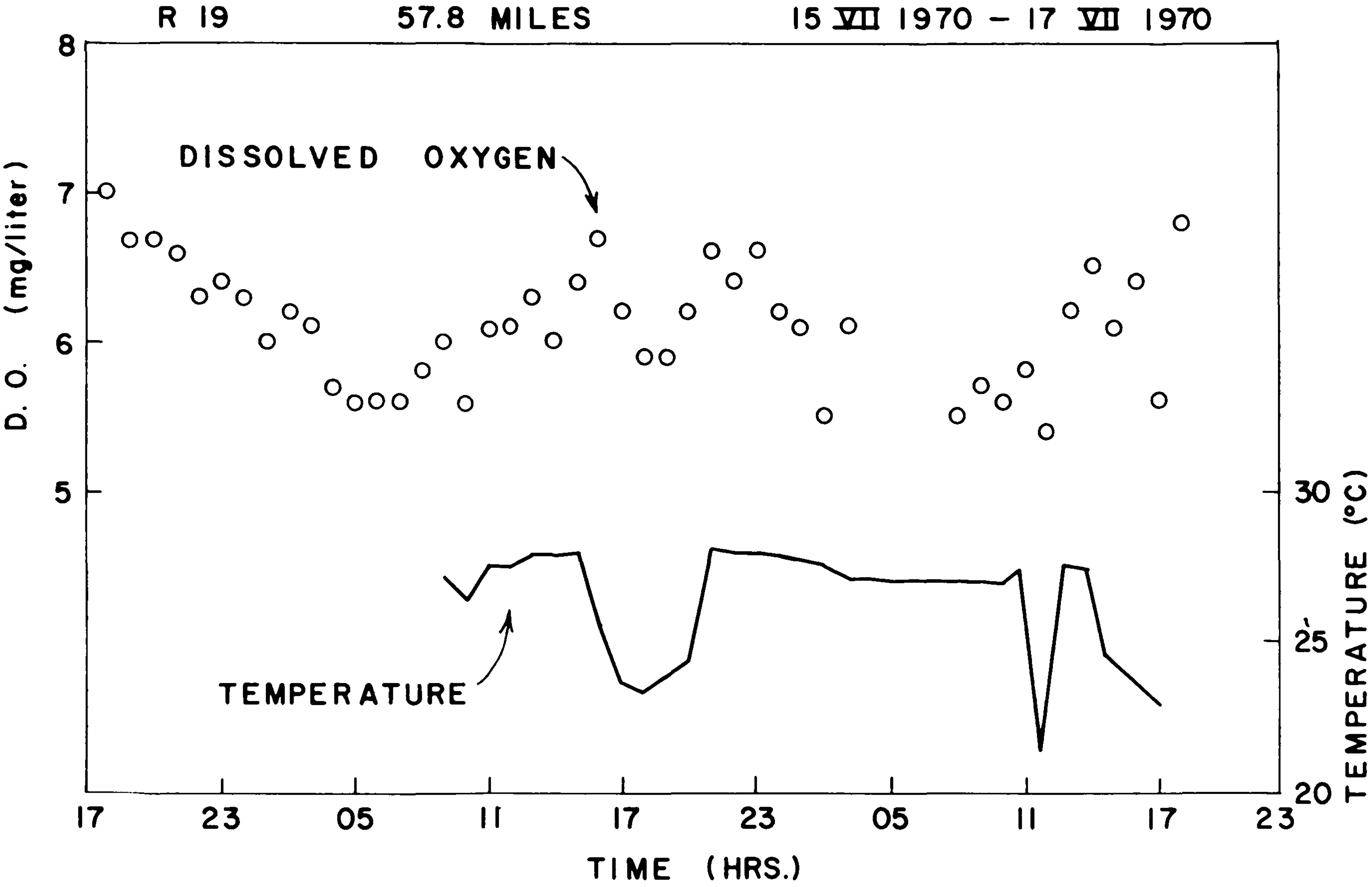

R 15
64.6 MILES
31 VII 1970 – 02 VIII 1970
D. O. (mg / liter)
9
8
7
6
5
DISSOLVED OXYGEN
TEMPERATURE
35
30
25
TEMPERATURE (°C)
20
06
16
02
12
TIME (HRS.)

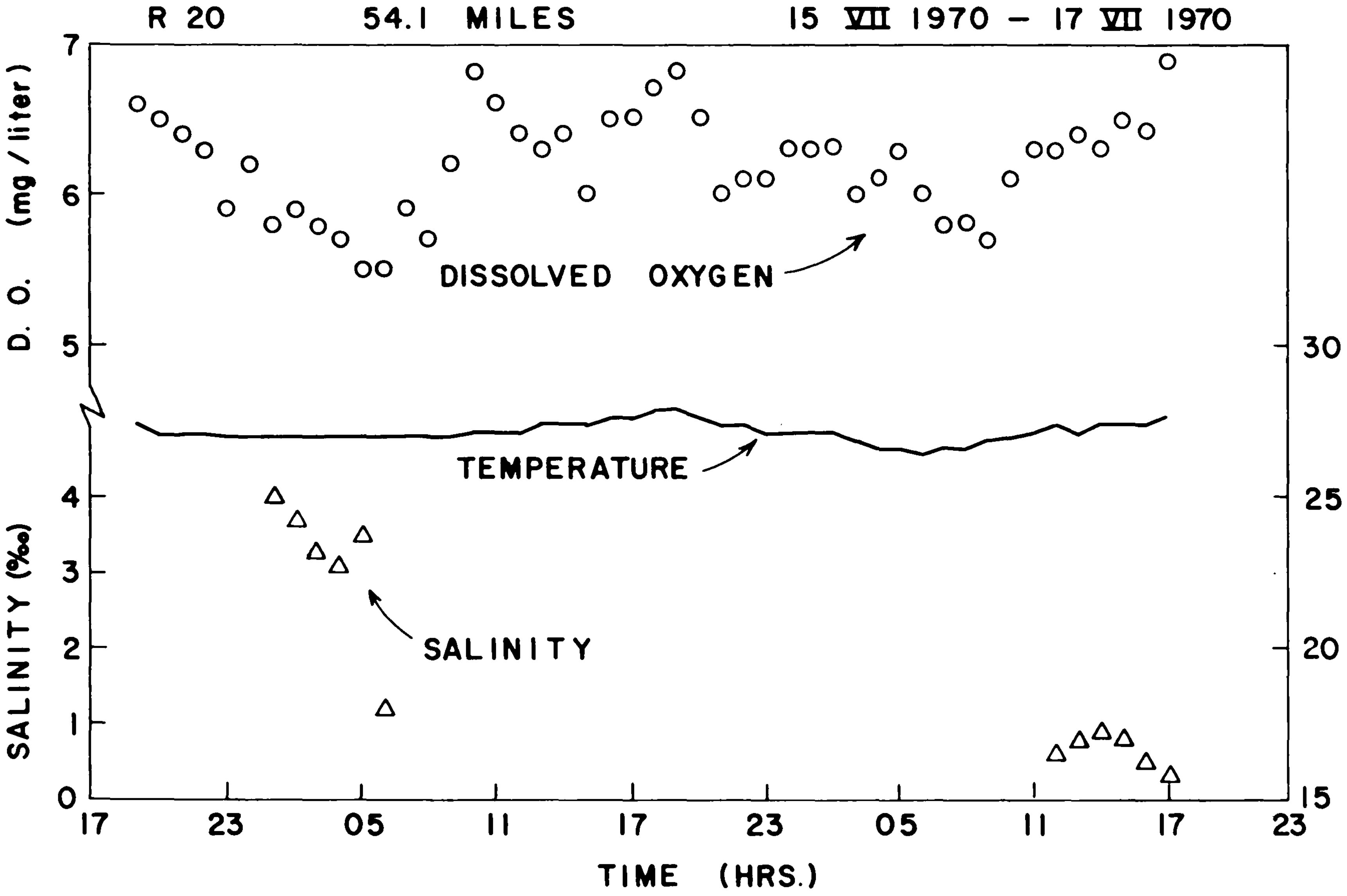


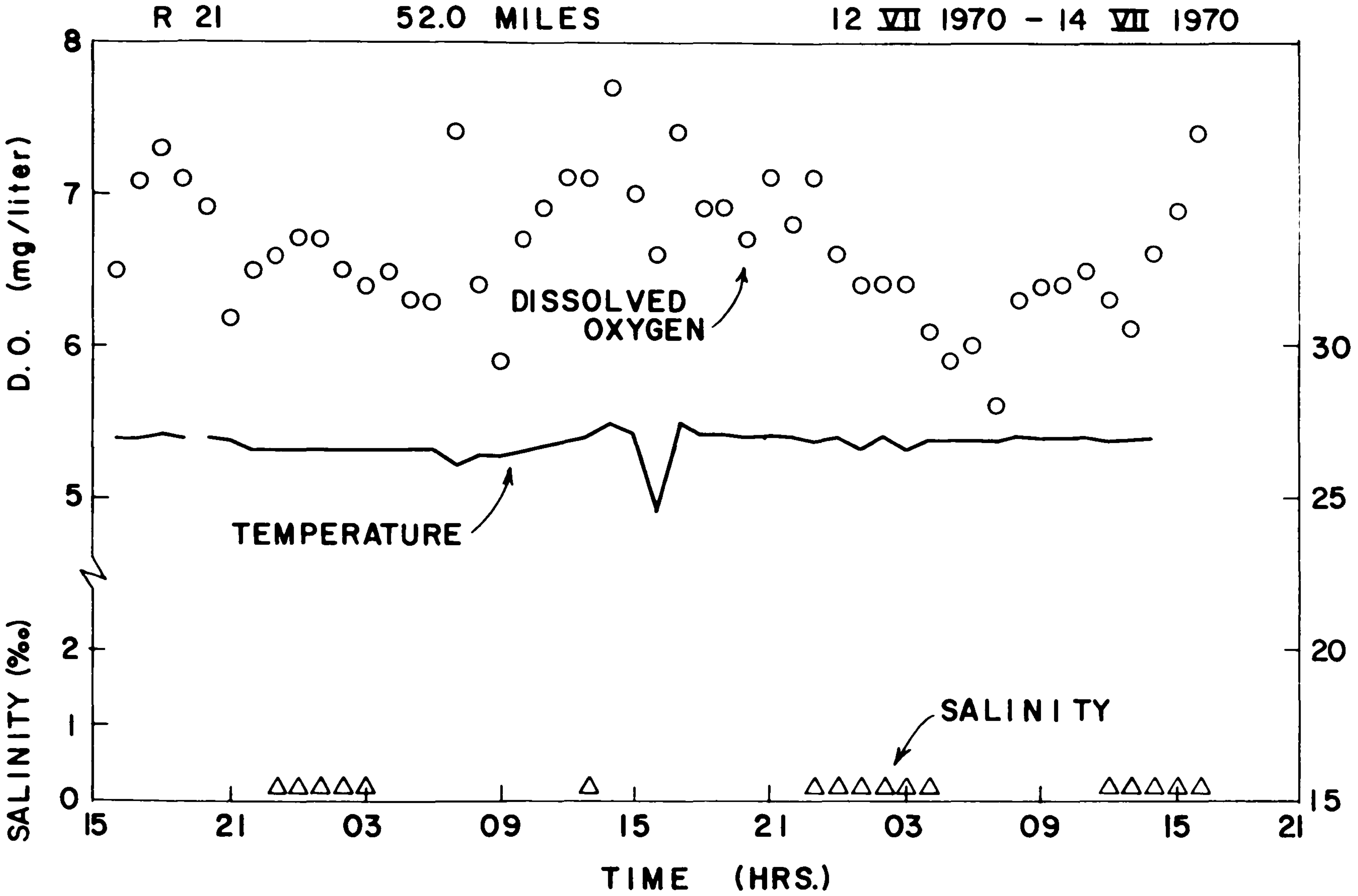
R 16 62.6 MILES 31 VII 1970 – 02 VIII 1970

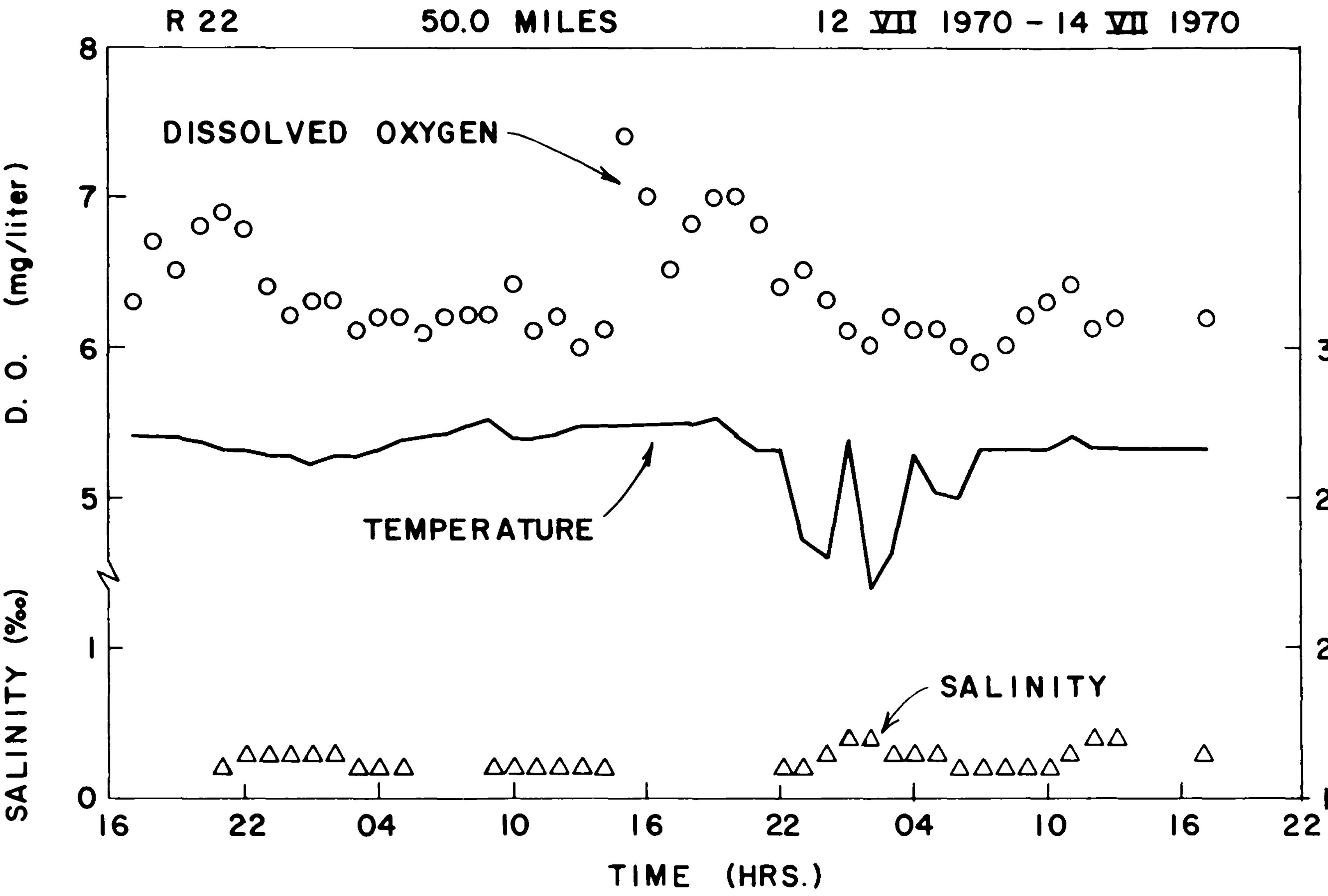

R 17
60.8 MILES
14 VII 1970 — 18 VII 1970
DISSOLVED OXYGEN
TEMPERATURE
D. O. (mg/liter)
8
7
6
5
4
TEMPERATURE (°C)
35
30
25
20
08
0
16
08
0
16
08
19
TIME (HRS.)

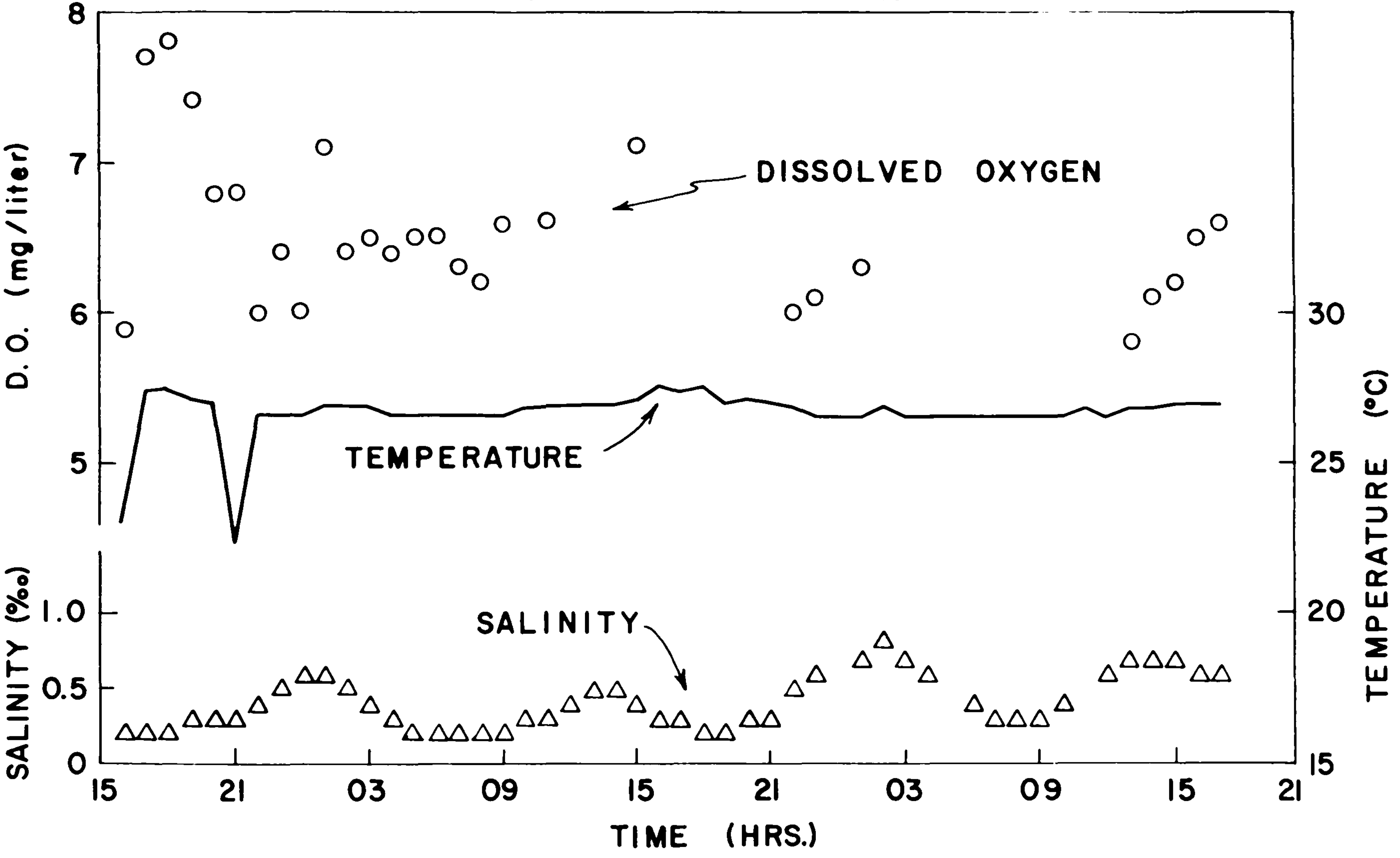

R 18
59.9 MILES
15 VII 1970 — 17 VII 1970
D. O. (mg/liter)
8
7
6
5
TEMPERATURE (°C)
30
25
20
DISSOLVED OXYGEN
TEMPERATURE
18
0
06
12
18
0
06
12
18
0
TIME (HRS)


R 19
57.8 MILES
15 VII 1970 – 17 VII 1970
DISSOLVED OXYGEN
TEMPERATURE
D. O. (mg/liter)
8
7
6
5
TEMPERATURE (°C)
30
25
20
17
23
05
11
17
23
05
11
17
23
TIME (HRS.)

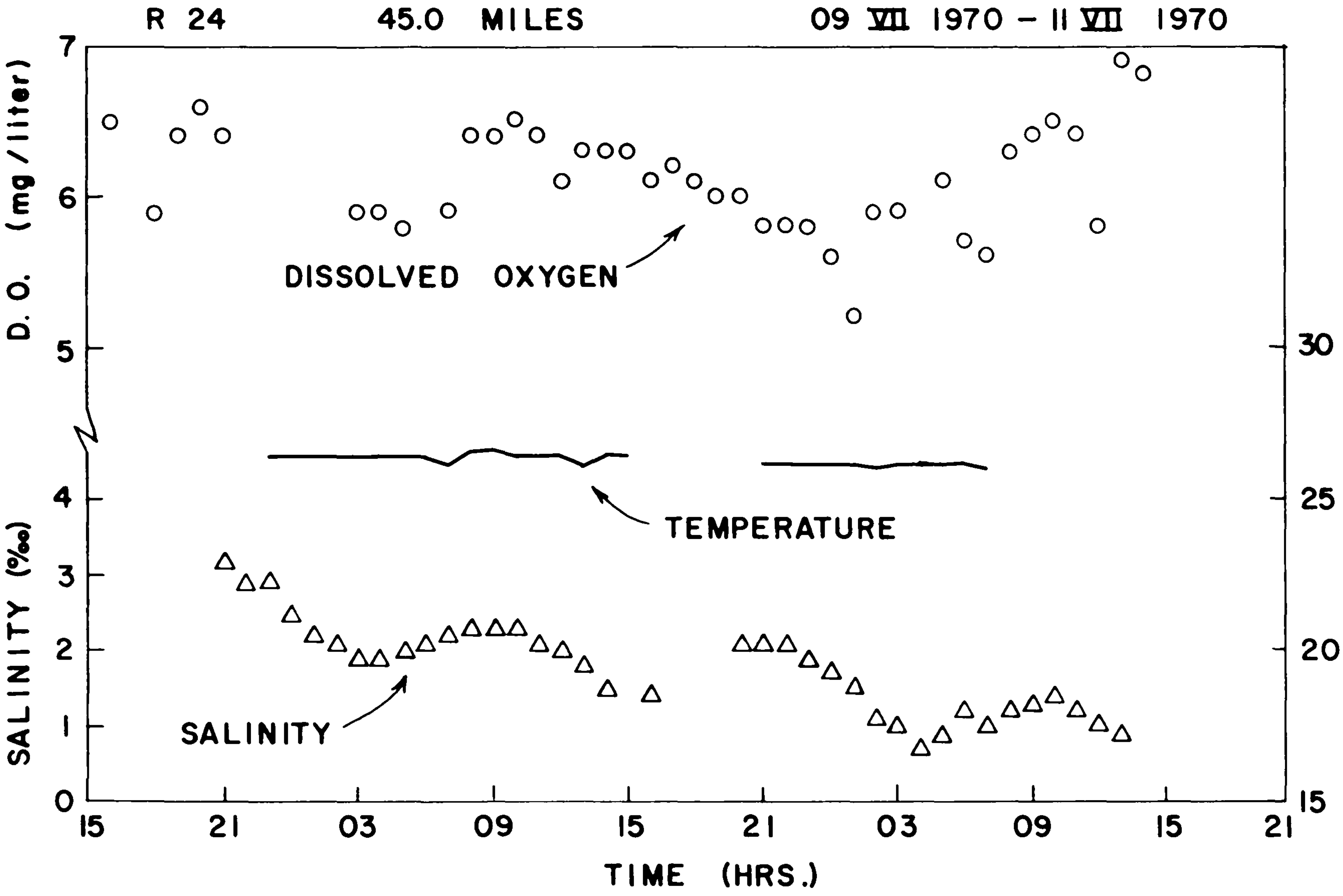

R 20
54.1 MILES
15 VII 1970 – 17 VII 1970
D. O. (mg / liter)
7
6
5
DISSOLVED OXYGEN
TEMPERATURE
SALINITY
SALINITY (‰)
4
3
2
1
0
30
25
20
15
TEMPERATURE (°C)
17
23
05
11
17
23
05
11
17
23
TIME (HRS.)

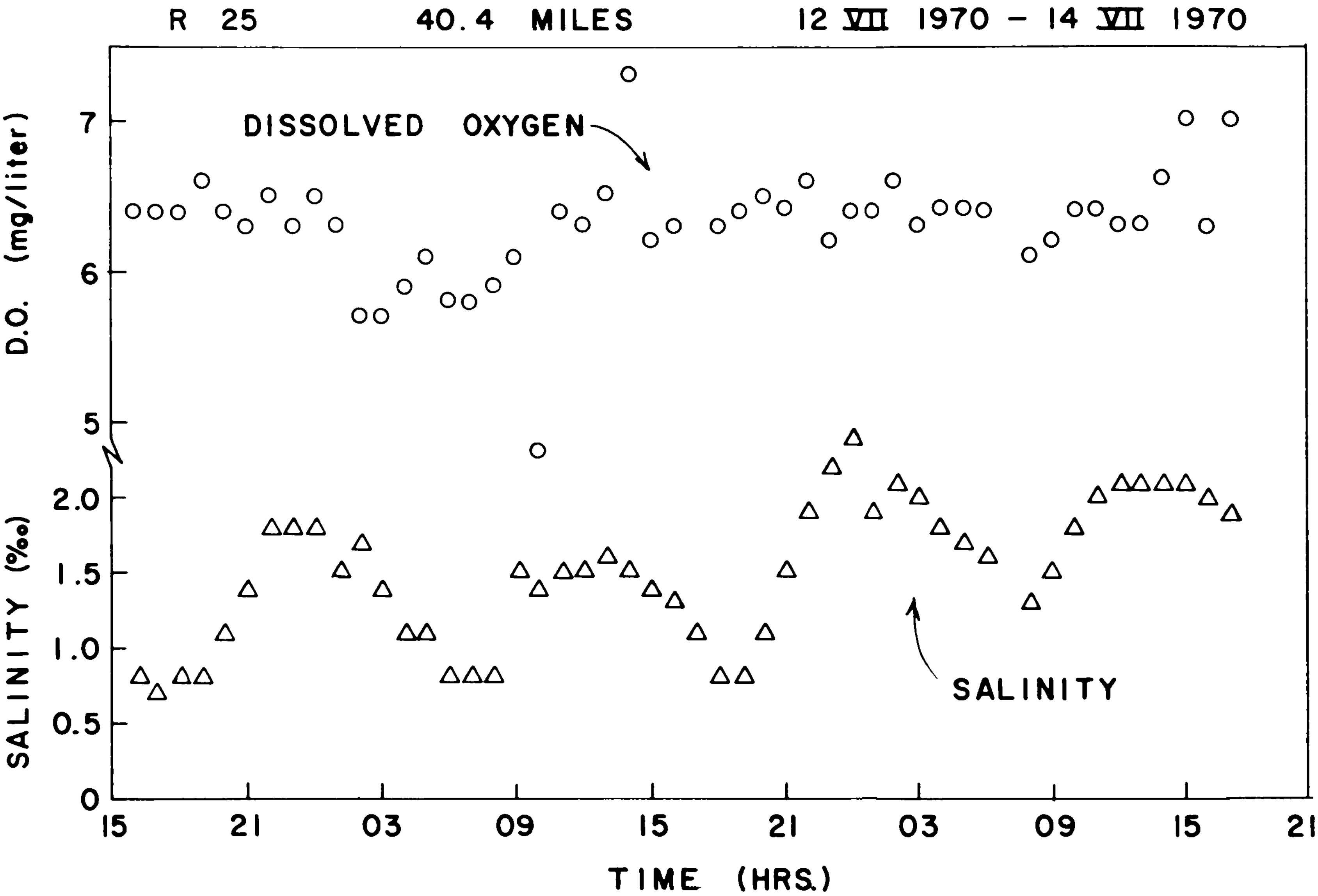

R 21
52.0 MILES
12 VII 1970 - 14 VII 1970
D.O. (mg/liter)
8
7
6
5
SALINITY (‰)
2
1
0
TEMPERATURE (°C)
30
25
20
15
DISSOLVED OXYGEN
TEMPERATURE
SALINITY
15
21
03
09
15
21
03
09
15
21
TIME (HRS.)


R 22
50.0 MILES
12 VII 1970 - 14 VII 1970
DISSOLVED OXYGEN
TEMPERATURE
SALINITY
D. O. (mg/liter)
SALINITY (‰)
TEMPERATURE (°C)
TIME (HRS.)
8
7
6
5
1
0
30
25
20
15
16
22
04
10
16
22
04
10
16
22



R 23 47.3 MILES 12 VII 1970 - 14 VII 1970


R 24
45.0 MILES
09 VII 1970 – 11 VII 1970
D. O. (mg / liter)
7
6
5
DISSOLVED OXYGEN
TEMPERATURE
SALINITY (‰)
4
3
2
1
0
SALINITY
TEMPERATURE (°C)
30
25
20
15
15
21
03
09
15
21
03
09
15
21
TIME (HRS.)


R 25
40.4 MILES
12 VII 1970 – 14 VII 1970
DISSOLVED OXYGEN
SALINITY
D.O. (mg/liter)
SALINITY (‰)
7
6
5
2.0
1.5
1.0
0.5
0
15
21
03
09
15
21
03
09
15
21
TIME (HRS.)

APPENDIX E

COMPUTED TIDAL FLOWS

In The Following Table, A Positive Value Indicates Up Stream Flow and a Negative Value indicates Down Stream Flow V (velocity) is given in feet per second, and Q (volume-transport) is given in thousands of cubic feet per second.

		1-A		1-B		1-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 26	1800	-0.52	-1.87	-0.39	-1.40	-0.33	-1.19	
26	1830							-1.40
26	1900	-0.46	-1.66	-0.39	-1.40	-0.20	-0.72	
26	1930							-1.40
26	2000			-0.39	-1.40			
26	2030	-0.33	-1.19					-0.94
26	2100	-0.39	-1.40	-0.26	-0.94	-0.26	-0.94	
26	2130							0.00
26	2200	0.00	0.00			0.13	0.47	
26	2230							0.25
26	2300	0.07	0.25	0.13	0.47	0.07	0.25	
26	2330							0.25
July 27	0000	0.07	0.25			0.07	0.25	
27	0030							0.00
27	0100	-0.13	-0.47	-0.07	-0.25	-0.07	-0.25	
27	0130							-0.25
27	0200	-0.13	-0.47			-0.07	-0.25	
27	0230							-0.25
27	0300	-0.20	-0.72	-0.13	-0.47	-0.20	-0.72	
27	0330							-0.47
27	0400			-0.20	-0.72	-0.13	-0.47	
27	0430							-0.72
27	0500	-0.20	-0.72	-0.26	-0.94	-0.33	-1.19	
27	0530							-0.94
27	0600	-0.26	-0.94	-0.46	-1.66	-0.39	-1.40	
27	0630							-1.40
27	0700	-0.33	-1.19	-0.33	-1.19	-0.39	-1.40	
27	0730							-1.19
27	0800	-0.33	-1.19	-0.26	-0.94	-0.13	-0.47	
27	0830					-0.33	-1.19	-0.94
27	0900	-0.46	-1.66	-0.33	-1.19			
27	0930							-1.19
27	1000	-0.39	-1.40	-0.26	-0.94	-0.20	-0.72	
27	1030							-0.72
27	1100	-0.13	-0.47	-0.13	-0.47	-0.13	-0.47	
27	1130							-0.25
27	1200	0.26	0.94	0.26	0.94	0.07	0.25	
27	1230							0.47
27	1300	0.07	0.25	0.13	0.47	0.07	0.25	
27	1330							0.25
27	1400	0.07	0.25	0.07	0.25	0.20	0.72	
27	1430							0.25
27	1500	-0.07	-0.25	-0.07	-0.25	-0.13	-0.47	
27	1530							-0.47
27	1600	-0.20	-0.72	-0.20	-0.72	-0.39	-1.40	
27	1630							-1.19
27	1700	-0.39	-1.40	-0.52	-1.87	-0.07	-0.25	
27	1730							-1.19

Date 1970	Hour	1-A V ft/sec	1-A Q cu.ft/sec	1-B V	1-B Q	1-C V	1-C Q	Avg. Q
July 27	1800	-0.39	-1.40	-0.33	-1.19	-0.07	-0.25	
27	1830							-0.94
27	1900	-0.39	-1.40	-0.26	-0.94	-0.26	-0.94	
27	1930							-0.94
27	2000	-0.33	-1.19	-0.26	-0.94	-0.26	-0.94	
27	2030							-0.72
27	2100	-0.13	-0.47	-0.26	-0.94	-0.20	-0.72	
27	2130							-0.72
27	2200	-0.07	-0.25	-0.07	-0.25	0.00	0.00	
27	2230							0.00
27	2300	0.00	0.00	0.13	0.47	-0.26	-0.94	
27	2330							-0.25
July 28	0000	0.20	0.72	0.20	0.72			
28	0030							0.47
28	0100			0.00	0.00	-0.20	-0.72	
28	0130							0.00
28	0200	0.13	0.47			-0.13	-0.47	
28	0230							-0.47
28	0300	-0.13	-0.47	-0.13	-0.47	-0.13	-0.47	
28	0330							-0.25
28	0400	0.13	0.47	-0.26	-0.94	-0.20	-0.72	
28	0430							-0.94
28	0500	-0.39	-1.40	-0.33	-1.19	-0.13	-0.47	
28	0530							-0.72
28	0600	-0.13	-0.47	-0.26	-0.94	-0.20	-0.72	
28	0630							-0.94
28	0700	-0.33	-1.19	-0.39	-1.40	-0.26	-0.94	
28	0730							-0.25
28	0800	0.33	1.19	0.33	1.19	0.26	0.94	
28	0830							1.19
28	0900	0.33	1.19	0.33	1.19	0.20	0.72	
28	0930							0.94
28	1000	0.33	1.19	0.26	0.94	0.07	0.25	
28	1030							0.72
28	1100	0.20	0.72	0.20	0.72	0.26	0.94	
28	1130							0.25
28	1200			-0.07	-0.25	-0.20	-0.72	
28	1230							-0.25
28	1300	-0.07	-0.25	0.00	0.00	0.00	0.00	
28	1330							0.00
28	1400	-0.07	-0.25	0.00	0.00	0.07	0.25	
28	1430							0.00
28	1500	0.00	0.00	0.00	0.00	0.00	0.00	
28	1530							0.00
28	1600	0.00	0.00	-0.07	-0.25	0.00	0.00	
28	1630							0.25
28	1700			0.20	0.72	0.20	0.72	
28	1730							0.94

		1-A		1-B		1-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 28	1800	0.39	1.40	0.39	1.40	0.13	0.47	
28	1830							0.94
28	1900					0.07	0.25	
28	1930	0.13	0.47	0.07	0.25			0.47
28	2000					0.13	0.47	
28	2030							0.47

		2-A		2-B		2-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 26	1800	-0.20	-0.88	-0.52	-2.29			
26	1830					-0.33	-1.45	-1.45
26	1900	-0.20	-0.88	-0.46	-2.02			
26	1930					-0.46	-2.02	-1.72
26	2000	-0.13	-0.57	-0.33	-1.45			
26	2030					-0.13	-0.57	-0.57
26	2100	0.00	0.00	-0.20	-0.88			
26	2130					-0.26	-1.14	-0.31
26	2200	0.39	1.72	0.46	2.02			
26	2230					0.59	2.60	0.88
26	2300	-0.46	-2.02	0.33	1.45			
26	2330					0.33	1.45	1.14
July 27	0000	0.07	0.31	0.26	1.14			
27	0030					0.20	0.88	0.57
27	0100	-0.07	-0.31	0.07	0.31			
27	0130					0.07	0.31	0.00
27	0200	-0.13	-0.57	-0.07	-0.31			
27	0230					-0.07	-0.31	-0.31
27	0300	-0.07	-0.31	-0.20	-0.88			
27	0330					-0.26	-1.14	-0.88
27	0400	-0.13	-0.57	-0.46	-2.02			
27	0430					-0.33	-1.45	-1.72
27	0500	-0.33	-1.45	-0.66	-2.90			
27	0530					-0.39	-1.72	-2.02
27	0600	-0.33	-1.45	-0.59	-2.60			
27	0630					-0.33	-1.45	-1.72
27	0700	-0.33	-1.45	-0.46	-2.02			
27	0730					-0.39	-1.72	-1.72
27	0800	-0.39	-1.72	-0.46	-2.02			
27	0830					-0.33	-1.45	-1.45
27	0900	-0.20	-0.88	-0.39	-1.72			
27	0930					-0.13	-0.57	-0.57
27	1000	0.13	0.57	-0.26	-1.14			
27	1030					-0.20	-0.88	-0.57
27	1100	0.00	0.00	0.00	0.00			
27	1130					0.13	0.57	0.88
27	1200	0.46	2.02	0.72	3.17			
27	1230					0.59	2.60	2.29
27	1300	0.13	0.57	0.33	1.45			
27	1330					0.33	1.45	0.88
27	1400	-0.07	-0.31	0.00	0.88			
27	1430					-0.20	-0.88	0.00
27	1500	0.00	0.00	0.00	0.00			
27	1530					-0.13	-0.57	0.00
27	1600	0.07	0.31	-0.20	-0.88			
27	1630					-0.26	-1.14	-0.57
27	1700	-0.07	-0.31	-0.07	-0.31			
27	1730					-0.07	-0.31	-0.88

		2-A		2-B		2-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 27	1800	-0.33	-1.45	-0.66	-2.90			
27	1830					-0.59	-2.60	-1.72
27	1900	-0.07	-0.31	-0.39	-1.72			
27	1930					-0.52	-2.29	-1.72
27	2000	-0.26	-1.14	-0.39	-1.72			
27	2030					-0.39	-1.72	-1.45
27	2100	-0.20	-0.88	0.13	0.57			
27	2130					-0.33	-1.45	-0.31
27	2200	0.00	0.00	-0.20	-0.88			
27	2230					0.26	1.14	0.88
27	2300	0.46	2.02					
27	2330							0.00
July 28	0000							0.00
28	0030							0.88
28	0100	0.20	0.88	0.20	0.88			
28	0130					-0.07	-0.31	0.31
28	0200	0.07	0.31	0.13	0.57			
28	0230					0.00	0.00	0.00
28	0300	-0.07	-0.31	-0.20	-0.88			
28	0330					-0.20	-0.88	-0.88
28	0400	-0.13	-0.57	-0.07	-0.31			
28	0430					-0.20	-0.88	-0.88
28	0500	-0.39	-1.72	-0.33	-1.45			
28	0530					-0.33	-1.45	-1.14
28	0600	-0.07	-0.31	-0.39	-1.72			
28	0630					-0.26	-1.14	-1.45
28	0700	-0.20	-0.88	-0.46	-2.02			
28	0730					-0.39	-1.72	-0.88
28	0800	0.33	1.45	0.46	2.02			
28	0830					0.26	1.14	1.14
28	0900	0.20	0.88	0.26	1.14			
28	0930					0.26	1.14	0.88
28	1000	0.07	0.31	0.26	1.14			
28	1030					0.33	1.45	0.88
28	1100	0.00	0.00	0.07	0.31			
28	1130					0.33	1.45	0.31
28	1200	-0.26	-1.14	-0.26	-1.14			
28	1230					-0.46	-2.02	-1.72
28	1300	-0.39	-1.72	-0.59	-2.60			
28	1330					-0.59	-2.60	-2.60
28	1400	-0.13	-0.57	-0.13	-0.57			
28	1430					-0.33	-1.45	-0.57
28	1500	-0.07	-0.31	-0.13	-0.57			
28	1530					-0.13	-0.57	-0.31
28	1600	0.13	0.57	0.13	0.57			
28	1630					0.07	0.31	0.57
28	1700	0.13	0.57	0.39	1.72			
28	1730					0.33	1.45	1.45
28	1800	0.33	1.45	0.52	2.29			
28	1830					0.59	2.60	1.72
28	1900	0.00	0.00	0.52	2.29			
28	1930					0.59	2.60	2.60

		3-A		3-B		3-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 26	1700	0.52	2.55	-0.52	-2.55	-0.59	-2.89	
26	1730							-0.98
26	1800	0.46	2.25	-0.52	-2.55	-0.59	-2.89	
26	1830							-0.98
26	1900	0.46	2.25	-0.52	-2.55	-0.39	-1.91	
26	1930							-0.98
26	2000	0.33	1.62	-0.39	-1.91	-0.39	-1.91	
26	2030							-1.91
26	2100	0.07	0.34	-0.13	-0.64	-0.07	-0.34	
26	2130							-0.64
26	2200	-0.39	-1.91	0.59	2.89	0.66	3.23	
26	2230							0.64
26	2300	-0.72	-3.53	0.85	4.16	0.52	2.55	
26	2330							2.25
July 27	0000	-0.13	-0.64	0.39	1.91	0.20	0.98	
27	0030							0.64
27	0100	-0.26	-1.27	0.13	0.64	0.00	0.00	
27	0130							0.00
27	0200	0.00	0.00	0.07	0.34	-0.07	-0.34	
27	0230							-0.98
27	0300	-0.26	-1.27	-0.26	-1.27	-0.20	-0.98	
27	0330							-1.27
27	0400	-0.33	-1.62	-0.39	-1.91	-0.33	-1.62	
27	0430							-1.91
27	0500	-0.46	-2.25	-0.46	-2.25	-0.52	-2.55	
27	0530							-2.55
27	0600	-0.46	-2.25	-0.52	-2.55	-0.39	-1.91	
27	0630							-2.25
27	0700	-0.39	-1.91	-0.46	-2.25	-0.46	-2.25	
27	0730							-1.91
27	0800	-0.39	-1.91			-0.39	-1.91	
27	0830							-1.91
27	0900	-0.33	-1.62	-0.46	-2.25	-0.33	-1.62	
27	0930							-1.62
27	1000	-0.26	-1.27	-0.33	-1.62	-0.33	-1.62	
27	1030							-0.98
27	1100	0.00	0.00	0.20	0.98	0.07	0.34	
27	1130							2.25
27	1200	0.79	3.87	0.79	3.87	0.46	2.25	
27	1230							1.91
27	1300	0.26	1.27	0.39	1.91	0.07	0.34	
27	1330							0.98
27	1400	0.07	0.34	0.20	0.98	0.07	0.34	
27	1430							0.34
27	1500	0.00	0.00	-0.07	-0.34	-0.13	-0.64	
27	1530							-0.98
27	1600	-0.26	-1.27	-0.33	-1.62	-0.62	-1.27	
27	1630							-1.91
27	1700	-0.52	-2.55	-0.59	-2.89	-0.39	-1.91	
27	1730							-2.55
27	1800	-0.59	-2.89	-0.59	-2.89	-0.52	-2.55	
27	1830							-2.25

		3-A		3-B		3-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 27	1900	-0.39	-1.91	-0.33	-1.62	-0.46	-2.25	
27	1930							-1.91
27	2000	-0.33	-1.62	-0.52	-2.55	-0.39	-1.91	
27	2030							-1.62
27	2100	-0.26	-1.27	-0.33	-1.62	-0.33	-1.62	
27	2130							1.91
27	2200	0.20	0.98	0.46	2.25	0.52	2.55	
27	2230							3.23
27	2300	0.79	3.87	0.79	3.87	0.46	2.25	
27	2330							2.25
July 28	0000	0.59	2.89	0.59	2.89			
28	0030							0.98
28	0100	0.33	1.62	0.20	0.98	0.13	0.64	
28	0130							0.64
28	0200	0.13	0.64	0.07	0.34	0.07	0.34	
28	0230							0.00
28	0300	-0.07	-0.34	0.00	0.00	-0.07	-0.34	
28	0330							0.00
28	0400	0.26	1.27	-0.26	-1.27	-0.20	-0.98	
28	0430							-1.62
28	0500	-0.33	-1.62	-0.46	-2.25	-0.39	-1.91	
28	0530							-1.91
28	0600	-0.33	-1.62	-0.52	-2.55	-0.59	-2.89	
28	0630							-1.91
28	0700	-0.39	-1.91	-0.46	-2.25	-0.20	-0.98	
28	0730							1.62
28	0800	0.33	1.62	0.39	1.91	0.33	1.62	
28	0830							1.62
28	0900	0.26	1.27	0.33	1.62	0.07	0.34	
28	0930							0.98
28	1000	0.26	1.27	0.33	1.62	0.33	1.62	
28	1030							1.27
28	1100	0.20	0.98	0.20	0.98	0.13	0.64	
28	1130							0.00
28	1200	-0.20	-0.98	-0.39	-1.91	-0.52	-2.55	
28	1230							-2.55
28	1300	-0.72	-3.53	-0.72	-3.53	-0.59	-2.89	
28	1330							-2.55
28	1400	-0.33	-1.62	-0.46	-2.25	-0.13	-0.64	
28	1430							-1.27
28	1500	-0.13	-0.64	-0.13	-0.64	-0.13	-0.64	
28	1530							-0.34
28	1600	0.07	0.34	-0.13	-0.64	0.13	0.64	
28	1630							0.34
28	1700	0.20	0.98	0.26	1.27	0.26	1.27	
28	1730							1.62
28	1800	0.52	2.55	0.52	2.55	0.39	1.91	
28	1830							2.55
28	1900	0.52	2.55	0.52	2.55	0.33	1.62	
28	1930							2.25

		4-A		4-B		4-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 26	1800	-0.66	-3.23					-3.23
26	1830			-0.85	-4.16	-0.85	-4.16	-3.87
26	1900	-0.66	-3.23			-0.79	-3.87	
26	1930			-0.85	-4.16			-3.23
26	2000	-0.52	-2.55	-0.72	-3.53	-0.52	-2.55	
26	2030							1.27
26	2100	0.00	0.00	0.39	1.91	0.33	1.62	
26	2130							4.51
26	2200	0.59	2.89	1.05	4.14	1.05	5.14	
26	2230							5.44
26	2300	0.85	4.16	1.31	6.42	1.11	5.44	
26	2330							2.89
July 27	0000	0.46	2.25	0.66	3.23	0.59	2.89	
27	0030							1.62
27	0100	0.20	0.98	0.39	1.91	0.33	1.62	
27	0130							0.00
27	0200	0.13	0.64	-0.13	-0.64	-0.07	-0.34	
27	0230							-1.27
27	0300	-0.33	-1.62	-0.33	-1.62	-0.62	-1.27	
27	0330							-3.23
27	0400	-0.66	-3.23	-0.66	-3.23	-0.72	-3.53	
27	0430							-4.16
27	0500	-0.92	-4.51	-0.92	-4.51	-0.79	-3.87	
27	0530							-3.87
27	0600	-0.79	-3.87	-0.92	-4.51	-0.66	-3.23	
27	0630							-3.53
27	0700	-0.79	-3.87	-0.85	-4.16	-0.66	-3.23	
27	0730							-3.23
27	0800	-0.59	-2.89	-0.72	-3.53			
27	0830					-0.52	-2.55	-3.23
27	0900	-0.79	-3.87	-0.66	-3.23			
27	0930					-0.39	-1.91	-2.25
27	1000	-0.39	-1.91	-0.46	-2.25	-0.26	-1.27	
27	1030							-3.87
27	1100	0.66	3.23	0.92	4.51			
27	1130					0.92	4.51	5.44
27	1200	0.92	4.51	1.25	6.12	1.31	6.42	
27	1230							3.53
27	1300	0.52	2.55	0.92	4.51	0.79	3.87	
27	1330							1.91
27	1400	0.46	2.25	0.39	1.91	0.26	1.27	
27	1430							1.27
27	1500	0.26	1.27	-0.26	-1.27			
27	1530					-0.33	-1.62	-2.55
27	1600	-0.66	-3.23	-0.79	-3.87			
27	1630					-0.79	-3.87	-4.80
27	1700	-0.98	-4.80	-1.18	-5.78	-1.05	-5.14	
27	1730							-4.51
27	1800	-0.79	-3.87	-0.98	-4.80			
27	1830					-0.98	-4.80	-4.16

Date	Hour	4-A		4-B		4-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 27	1900	-0.66	-3.23	-0.92	-4.51	-0.79	-3.87	
27	1930							-2.25
27	2000	-0.46	-2.25	-0.59	-2.89			
27	2030					-0.66	-3.23	-2.55
27	2100			-0.39	-1.91			
27	2130					-0.39	-1.91	0.98
27	2200			0.39	1.91			
27	2230					0.52	2.55	3.23
27	2300							0.00
27	2330							2.89
July 28	0000			0.72	3.53			
28	0030							3.53
28	0100			0.66	3.23			
28	0130							0.98
28	0200			0.20	0.98			
28	0230							-0.64
28	0300			-0.13	-0.64			
28	0330							-1.62
28	0400			-0.33	-1.62			
28	0430							-2.89
28	0500			-0.59	-2.89			
28	0530							-3.87
28	0600			-0.79	-3.87			
28	0630							-3.87
28	0700			-0.79	-3.87			
28	0730							0.00
28	0800			-0.66	-3.23			
28	0830					-0.46	-2.25	-2.89
28	0900			-0.59	-2.89			
28	0930					-0.46	-2.25	-2.25
28	1000			-0.52	-2.55			
28	1030					-0.39	-1.91	-1.91
28	1100			-0.39	-1.91			
28	1130					-0.20	-0.98	1.62
28	1200					0.79	3.87	
28	1230							4.80
28	1300			1.18	5.78	1.05	5.14	
28	1330							3.23
28	1400			0.79	3.87	0.66	3.23	
28	1430							1.62
28	1500			0.33	1.62	0.33	1.62	
28	1530							-1.62
28	1600			-0.39	-1.91	-0.33	-1.62	
28	1630							-3.23
28	1700			-0.59	-2.89	-0.79	-3.87	
28	1730							-4.16
28	1800			-0.92	-4.51	-0.92	-4.51	
28	1830							-3.87
28	1900			-0.92	-4.51	-0.79	-3.87	

		5-A		5-B		5-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 28	2200	-0.20	-1.16	-0.33	-1.91	-0.07	-0.41	
28	2230							0.41
28	2300	0.20	1.16	0.52	3.02	-0.59	-3.42	
28	2330							1.91
July 29	0000	1.11	6.44	1.51	8.76	0.72	4.18	
29	0030							6.44
29	0100	1.18	6.84	1.25	7.25	0.79	4.58	
29	0130							4.93
29	0200	0.59	3.42	0.39	2.26	0.33	1.91	
29	0230							2.26
29	0300	0.39	2.26	0.20	1.16	0.07	0.41	
29	0330							0.75
29	0400	0.07	0.41	-0.13	-0.75	-0.13	-0.75	
29	0430							-0.75
29	0500	-0.13	-0.75	-0.26	-1.51	-0.39	-2.26	
29	0530							-3.02
29	0600	-0.79	-4.58	-0.79	-4.58	-0.59	-3.42	
29	0630							-4.18
29	1330							7.25
29	1400	1.25	7.25					
29	2030							-4.58
29	2100	-0.79	-4.58	-0.72	-4.18	-0.52	-3.02	
29	2130							-3.42
29	2200	-0.46	-2.67	-0.20	-1.16	-0.39	-2.26	
29	2230							-2.26
29	2300	-0.52	-3.02	-0.26	-1.51	-0.07	-0.41	
29	2330							0.41
July 30	0000	0.46	2.67	0.79	4.58			
30	0030							6.44
30	0100	1.38	8.00	1.11	6.44	0.98	5.68	
30	0130							6.44
30	0200	1.11	6.44	1.05	6.09	0.85	4.93	
30	0230							5.34
30	0300	0.79	4.58	0.46	2.67	0.39	2.26	
30	0330							2.67
30	0400	0.39	2.26	0.33	1.91	0.20	1.16	
30	0430							1.51
30	0530							-2.26
30	0600	-0.39	-2.26	-0.46	-2.67	-0.46	-2.67	
30	0630							-3.02
30	0700	-0.66	-3.83	-0.79	-4.58	-0.66	-3.83	
30	0730							-4.58
30	0800	-0.85	-4.93	-1.05	-6.09	-0.66	-3.83	
30	0830							-4.93
30	0900	-0.85	-4.93	-0.85	-4.93	-0.52	-3.02	
30	0930							-4.18

Date 1970	Hour	6-A		6-B		6-C		Avg.
		V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 28	2030	-0.13	-0.78	-0.66	-3.96	-0.46	-2.76	
28	2100	-0.13	-0.78	-0.66	-3.96	-0.46	-2.76	-2.34
28	2130							0.00
28	2200	-0.20	-1.20	-0.26	-1.56	-0.13	-0.78	-1.20
28	2230							0.00
28	2300	-0.13	-0.78	0.52	3.12	-0.13	-0.78	0.42
28	2330							0.00
July 29	0000	0.72	4.32	0.66	3.96			4.32
29	0030					0.79	4.74	
29	0100	0.85	5.10	1.25	7.50			6.30
29	0130					0.98	5.88	
29	0200	0.46	2.76	0.52	3.12			3.96
29	0230					0.98	5.88	
29	0300	-0.13	-0.78	-0.20	-1.20			-1.20
29	0330					-0.26	-1.56	
29	0400	-0.39	-2.34	-0.52	-3.12			-2.76
29	0430					-0.46	-2.76	
29	0500	-0.59	-3.54	-0.72	-4.32			3.54
29	0530					-0.52	-3.12	
29	0600	-0.79	-4.74	-0.92	-5.52			-4.74
29	0630					-0.66	-3.96	
29	0700	-0.85	-5.10	-1.05	-6.30	-0.85	-5.10	-5.52
29	0730							0.00
29	0800	-0.59	-3.54	-0.72	-4.32	-0.33	-1.98	-3.12
29	0830							0.00
29	0900	-0.39	-2.34	-0.66	-3.96	-0.39	-2.34	-2.76
29	0930							0.00
29	1000	-0.39	-2.34	-0.46	-2.76			-2.76
29	1030							0.00
29	1100			-0.33	-1.98			-1.98
29	1130							0.00
29	1200	0.46	2.76	0.13	0.78	0.33	1.98	1.98
29	1230							0.00
29	1300	0.72	4.32	0.66	3.96	0.72	4.32	4.32
29	1330							0.00
29	1400	-0.98	-5.88	0.92	5.52	0.66	3.96	1.20
29	1430							0.00
29	1500	0.46	2.76	0.72	4.32	0.33	1.98	3.12
29	1530							0.00
29	1600			0.26	1.56			1.56
29	1630							0.00
29	1700			0.07	0.42			0.42
29	1730							0.00
29	1800			-0.85	-5.10			-5.10
29	1830							0.00
29	1900			-1.11	-6.66			-6.66
29	1930							0.00
29	2000	-0.98	-5.88	-0.98	-5.88			-4.32
29	2030					-0.26	-1.56	

Date 1970		Hour	6-A V ft/sec	6-A Q cu.ft/sec	6-B V	6-B Q	6-C V	6-C Q	Avg. Q
July	29	2100	-0.72	-4.32	-0.79	-4.74			-4.74
	29	2130							0.00
	29	2200	-0.59	-3.54	-0.66	-3.96			-2.76
	29	2230					-0.07	-0.42	
	29	2300	-0.20	-1.20	0.07	0.42			-0.42
	29	2330							0.00
July	30	0000	0.72	4.32	0.72	4.32	0.72	4.32	4.32
	30	0030							0.00
	30	0100	0.98	5.88	1.05	6.30			5.52
	30	0130					0.79	4.74	
	30	0200	0.79	4.74	0.92	5.52			5.52
	30	0230							0.00
	30	0300	-0.66	-3.96	0.72	4.32	0.98	5.88	1.20
	30	0330					0.66	3.96	
	30	0400	0.26	1.56	0.33	1.98	0.33	1.98	1.98
	30	0430							0.00
	30	0500	0.07	0.42	0.07	0.42			0.42
	30	0530					0.00	0.00	
	30	0600	-0.46	-2.76	-0.52	-3.12			-2.76
	30	0630					-0.46	-2.76	
	30	0700	-0.92	-5.52	-0.92	-5.52			-4.74
	30	0730					-0.52	-3.12	
	30	0800	-0.92	-5.52	-0.98	-5.88			-5.10
	30	0830					-0.66	-3.96	
	30	0900	-0.59	-3.54	-0.79	-4.74	-0.66	-3.96	-4.32

		7-A		7-B		7-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 28	2000	0.59	3.83					
28	2030			0.59	3.83	0.33	2.14	
28	2100	0.52	3.38					2.99
28	2130			0.46	2.99	0.33	2.14	
28	2200	0.13	0.84					0.84
28	2230			0.13	0.84	0.00	0.00	
28	2300	-0.46	-2.99			-0.52	-3.38	-3.38
28	2330			-0.59	-3.83			
July 29	0000	-0.85	-5.52	-1.11	-7.21	-1.05	-6.82	-6.37
29	0030							0.00
29	0100	-0.79	-5.13			-0.79	-5.13	-5.52
29	0130			-0.98	-6.37			
29	0200	-0.52	-3.38					-3.38
29	0230			-0.59	-3.83	-0.52	-3.38	
29	0300	-0.20	-1.30					-2.53
29	0330			-0.33	-2.14	-0.13	-0.84	
29	0400	0.00	0.00					-0.45
29	0430			0.07	0.45	0.00	0.00	
29	0500	0.39	2.53			0.46	2.99	2.14
29	0530			0.46	2.99			
29	0600							5.98
29	0630	0.92	5.98	0.92	5.98	0.72	4.68	
29	0700	0.98	6.37			0.66	4.29	5.13
29	0730			0.85	5.52			
29	0800	0.92	5.98	0.85	5.52	0.72	4.68	5.52
29	0830							0.00
29	0900	0.72	4.68	0.66	4.29			4.68
29	0930					0.52	3.38	
29	1000	0.59	3.83	0.59	3.83	0.39	2.53	3.38
29	1030							0.00
29	1100	-0.20	-1.30	-0.26	-1.69	-0.13	-0.84	-1.30
29	1130							0.00
29	1200			0.85	5.52	0.98	6.37	5.98
29	1230							0.00
29	1300	0.92	5.98	1.11	7.21	1.05	6.82	6.37
29	1330							0.00
29	1400	0.85	5.52	0.92	5.98	0.72	4.68	5.52
29	1430							0.00
29	1500	0.26	1.69			0.20	1.30	2.14
29	1530			0.39	2.53			
29	1600	-0.13	-0.84	-0.07	-0.45	0.07	0.45	-0.45
29	1630							0.00
29	1700	-0.52	-3.38					-2.99
29	1730			-0.39	-2.53	-0.39	-2.53	
29	1800	-0.79	-5.13					-4.68
29	1830			-0.92	-5.98	-0.85	-5.52	
29	1900	-0.48	-5.98					-5.98
29	1930			-0.98	-6.37	-0.92	-5.98	

		7-A		7-B		7-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 29	2000	-0.85	-5.52					-5.52
29	2030			-0.85	-5.52	-0.72	-4.68	
29	2100	-0.72	-4.68					-4.68
29	2130			-0.26	-4.68	-0.66	-4.29	
29	2200	-0.33	-2.14					-2.99
29	2230			-0.26	-1.69	-0.20	-1.30	
29	2300	-0.07	-0.45					-0.84
29	2330			0.00	0.00	0.00	0.00	
July 30	0000	0.72	4.68					2.53
30	0030			0.72	4.68	0.92	5.98	
30	0100	0.79	5.13					5.98
30	0130			1.11	7.21	0.98	6.37	
30	0200	0.72	4.68					5.98
30	0230			0.98	6.37	0.79	5.13	
30	0300	0.66	4.29					4.68
30	0330			0.72	4.68	0.66	4.29	
30	0400	0.33	2.14					2.99
30	0430			0.33	2.14	0.33	2.14	
30	0500	0.00	0.00					0.84
30	0530			0.00	0.00	0.00	0.00	
30	0600	-0.52	-3.38					-2.14
30	0630			-0.52	-3.38	-0.52	-3.38	
30	0700	-0.85	-5.52					-4.68
30	0730			-0.85	-5.52	-0.72	-4.68	
30	0800	-0.98	-5.98					-5.13
30	0830			-0.92	-5.98	-0.72	-4.68	
30	0900	-0.79	-5.13	-0.72	-4.68			-4.68
30	0930					-0.66	-4.29	

		8-A		8-B		8-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 28	2000							0.00
28	2030	-0.39	-3.08	-0.85	-6.71	-0.46	-3.63	
28	2100	-0.26	-2.05	-0.46	-3.63	-0.20	-1.58	-3.63
28	2130							0.00
28	2200	0.13	1.03	0.72	5.69	0.92	7.27	7.27
28	2230							0.00
28	2300	0.79	6.24	1.25	9.87			7.74
28	2330					1.11	8.77	
July 29	0000	0.92	7.27	1.11	8.77	1.11	8.77	8.29
29	0030							0.00
29	0100	0.79	6.24	1.25	9.87	1.11	8.77	8.29
29	0130							0.00
29	0200	0.59	4.66	0.85	6.71	0.72	5.69	5.69
29	0230							0.00
29	0300	0.20	1.58	0.26	2.05	0.20	1.58	1.58
29	0330							0.00
29	0400	-0.26	-2.05	-0.39	-3.08			-3.08
29	0430					-0.46	-3.63	
29	0500	-0.26	-2.05	-0.72	-5.69	-0.85	-6.71	-4.66
29	0530							0.00
29	0600	-0.52	-4.11	-1.11	-8.77	-0.85	-6.71	-6.71
29	0630							0.00
29	0700	-0.98	-7.74	-1.05	-8.29	-0.85	-6.71	-7.27
29	0730							0.00
29	0800	-0.79	-6.24	-1.05	-8.29	-0.66	-5.21	-6.71
29	0830							0.00
29	0900	-0.66	-5.21	-0.92	-7.27	-0.59	-4.66	-5.69
29	0930							0.00
29	1000	-0.46	-3.63	-0.72	-5.69	-0.46	-3.63	-4.66
29	1030							0.00
29	1100	0.26	2.05	-0.39	-3.08	0.39	3.08	0.55
29	1130							0.00
29	1200	0.52	4.11	1.11	8.77	1.11	8.77	7.27
29	1230							0.00
29	1300	0.59	4.66	1.38	10.90	1.38	10.90	8.77
29	1330							0.00
29	1400	0.46	3.63	0.98	7.74			5.69
29	1430							0.00
29	1500	-0.26	-2.05					-2.05
29	1530							0.00
29	1600			-0.20	-1.58			-1.58
29	1630							0.00
29	0800	-0.26	-2.05	-0.98	-7.74	-0.59	-4.66	-4.66
29	0830							0.00
29	0900			-0.92	-7.27	-0.66	-5.21	-6.24
29	0930	-0.66	-5.21					

		9-A		9-B		9-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 30	1000	0.79	6.48	0.92	7.54	0.52	4.26	
30	1030							4.26
30	1100	0.52	4.26	0.66	5.41	0.26	2.13	
30	1130							2.71
30	1200	0.13	1.07	0.13	1.07	-0.13	-1.07	
30	1230							-2.13
30	1300	-0.59	-4.84	-0.52	-4.26	-0.66	-5.41	
30	1330							-6.97
30	1400	-1.05	-8.61	-1.31	-10.74	-0.72	-5.90	
30	1430							-8.61
30	1500	-1.05	-8.61	-1.38	-11.32	-0.66	-5.41	
30	1530							-7.54
30	1600	-0.79	-6.48	-1.18	-9.68	-0.39	-3.20	
30	1630							-5.90
30	1700	-0.46	-3.77	-0.59	-4.84	-0.26	-2.13	
30	1730							-1.07
30	1800	0.13	1.07	0.07	0.57	0.13	1.07	
30	1830							0.57
30	1900	0.98	8.04	1.25	10.25	0.52	4.26	
30	1930							6.97
30	2000	0.72	5.90	1.44	11.81	0.52	4.26	
30	2030							7.54
30	2100	0.85	6.97	1.38	11.32			
30	2130							8.04
30	2200	0.66	5.41	1.11	9.10	0.52	4.26	
30	2230							6.84
30	2300	0.66	5.41	0.85	6.97	0.26	2.13	
30	2330							4.26
July 31	0000	0.20	1.64	0.20	1.64	-0.46	-3.77	
31	0030							-1.64
31	0100	-0.72	-5.90	-0.79	-6.48	-0.92	-7.54	
31	0130							-7.54
31	0200	-1.18	-9.68	-1.51	-12.38	-1.18	-9.68	
31	0230							-10.74
31	0300	-1.25	-10.25	-1.44	-11.81	-1.18	-9.68	
31	0330							-9.68
31	0400	-0.98	-8.04	-1.25	-10.25	-1.25	-10.25	
31	0430							-8.61
31	0500	-0.59	-4.84	-0.66	-5.41	-0.46	-3.77	
31	0530							-2.71
31	0600	0.13	1.07	0.13	1.07	0.00	0.00	
31	0630							2.71
31	0700	0.85	6.97	1.11	9.10	0.52	4.26	
31	0730							2.13
31	0800	1.05	8.61			0.20	1.64	
31	0830			1.18	9.68			6.48
31	0900	0.98	8.04	1.18	9.68	0.46	3.77	
31	0930							0.00

		9-A		9-B		9-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 31	1000	0.79	6.48	1.05	8.61	0.20	1.64	
31	1030							5.41
31	1100	0.79	6.48	0.98	8.04	0.20	1.64	
31	1130							0.00
31	1200	0.52	4.26	0.85	6.97	0.00	0.00	
31	1230							3.20
31	1300	0.20	1.64	0.20	1.64			
31	1330							-4.26
31	1400	0.52	-4.26					
31	1430							-8.61
31	1500	-1.25	-10.25	-1.51	-12.38	-0.52	-4.26	
31	1530							-4.84
31	1600	-1.11	-9.10	-1.51	-12.38	-0.07	-0.57	
31	1630							-5.90
31	1700	-0.46	-3.77	-0.66	-5.41	-0.26	-2.13	
31	1730							0.57
31	1800	0.07	0.57	-0.07	-0.57	0.20	1.64	
31	1830							0.57
31	1900	0.59	4.84	0.92	7.54	0.39	3.20	
31	1930							6.48
31	2000	1.11	9.10	0.98	8.04	0.79	6.48	
31	2030							7.54

			10-A		10-B		10-C		Avg.
Date		Hour	V	Q	V	Q	V	Q	Q
1970			ft/sec	cu.ft/sec					
July	30	1000	0.66	6.01	0.98	8.92			
	30	1030							4.19
	30	1100			0.66	6.01			
	30	1130							-0.64
	30	1200			-0.07	-0.64			
	30	1230							-5.37
	30	1300			-0.59	-5.37			
	30	1330							-13.10
	30	1400			-1.44	-13.10			
	30	1430							-7.73
	30	1500	-0.85	-7.73	-1.38	-12.56	-1.18	-10.74	
	30	1530							-9.55
	30	1600	-0.59	-5.37	-0.92	-8.37	-0.39	-3.55	
	30	1630							-4.73
	30	1700	-0.26	-2.37	-0.33	-3.00	-0.20	-1.82	
	30	1730							-1.18
	30	1800	0.13	1.18	0.39	3.55	0.39	3.55	
	30	1830							5.37
	30	1900	0.98	8.92	1.11	10.10	0.92	8.37	
	30	1930							10.10
	30	2000	1.25	11.37	1.18	10.74	1.05	9.55	
	30	2030							10.10
	30	2100	1.18	10.74	1.18	10.74	1.05	9.55	
	30	2130							8.92
	30	2200	0.12	6.55	0.79	7.19	0.59	5.37	
	30	2230							4.73
	30	2300	0.33	3.00	0.52	4.73	0.39	3.55	
	30	2330							3.00
July	31	0000	0.07	0.64	-0.13	-1.18	-0.33	-3.00	
	31	0030							-3.55
	31	0100	-0.66	-6.01	-0.85	-7.73	-0.92	-8.37	
	31	0130							-8.73
	31	0200	-0.92	-8.37	-0.98	-8.92	-1.18	-10.74	
	31	0230							-10.74
	31	0300	-1.38	-12.56					
	31	0330							0.00
	31	0400							0.00
	31	0430			-0.92	-8.37			-8.37
	31	0500			-0.85	-7.73			
	31	0530							3.00
	31	0600			0.33	3.00			
	31	0630							11.37
	31	0700			1.25	11.37			
	31	0730							11.92
	31	0800			1.31	11.92			
	31	0830							9.55
	31	0900			1.05	9.55			
	31	0930							9.55

Date 1970	Hour	10-A V ft/sec	 Q cu.ft/sec	10-B V	 Q	10-C V	 Q	Avg. Q
July 31	1000			1.05	9.55			
31	1030							0.00
31	1100			0.98	8.92			
31	1130							8.92
31	1200			0.72	6.55			
31	1230							3.55
31	1300			0.07	0.64			
31	1330							7.73
31	1400			0.85	7.73			
31	1430							-13.74
31	1500			-1.51	-13.74			
31	1530							-11.37
31	1600			-1.18	-10.74			
31	1630							0.00
31	1700			-0.46	-4.19			
31	1730							-2.37
31	1800			-0.07	-0.64			
31	1830							6.01
31	1900			0.66	6.01			
31	1930							11.37
31	2000	1.25	11.37	1.38	12.56	1.31	11.92	
31	2030							11.92

		11-A		11-B		11-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 30	1000	0.39	3.74	0.66	6.34			
30	1030					0.59	5.66	4.42
30	1100	0.07	0.67	0.52	4.99			
30	1130					0.20	1.92	3.17
30	1200			-0.13	-1.25			
30	1230					-0.20	-1.92	-2.50
30	1300	-0.46	-4.42	-0.72	-6.91			
30	1330					-0.66	-6.34	-7.58
30	1400	-0.92	-8.83	-1.11	-10.66			
30	1430					-0.72	-6.91	-10.80
30	1500	-1.38	-13.25	-1.25	-12.00			
30	1530					-0.72	-6.91	-9.41
30	1600	-0.98	-9.41	-0.85	-8.16			
30	1630					-0.46	-4.42	-5.66
30	1700	-0.52	-4.99	-0.33	-3.17			
30	1730					-0.07	-0.67	-0.67
30	1800	0.20	1.92	0.20	1.92			
30	1830					0.13	1.25	3.17
30	1900	0.59	5.66	1.11	10.66			
30	1930					1.11	10.66	9.41
30	2000	0.72	6.91	1.31	12.58			
30	2030					1.11	10.66	9.41
30	2100	0.52	4.99	1.38	13.25			
30	2130					1.05	10.08	8.83
30	2200	0.33	3.17	0.26	2.50			
30	2230					-0.33	-3.17	0.00
30	2300			-0.72	-6.91			
30	2330					-0.13	-1.25	-2.50
July 31	0000	0.13	1.25	-0.07	-0.67			
31	0030					0.46	4.42	-1.25
31	0100	-0.79	-7.58	-1.18	-11.33			
31	0130					-1.11	-10.66	-10.66
31	0200	-1.18	-11.33	-1.44	-13.82			
31	0230					-1.11	-10.66	-12.00
31	0300							0.00
31	0330							0.00
31	0400							0.00
31	0430							-3.17
31	0500	-0.33	-3.17	-0.26	-2.50			
31	0530					-0.20	-1.92	-0.67
31	0600	0.33	3.17	0.52	4.99			
31	0630					0.79	7.58	6.34
31	0700	0.72	6.91	1.18	11.33			
31	0730					1.05	10.80	9.41
31	0800	0.79	7.58	1.51	14.50			
31	0830					1.31	12.58	11.33
31	0900	0.59	5.66	1.31	12.58			
31	0930					1.11	10.66	9.41

		11-A		11-B		11-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 31	1000	0.52	4.99	1.25	12.00			
31	1030					0.98	9.41	8.16
31	1100	0.33	3.17	0.98	9.41			
31	1130					0.85	8.16	6.91
31	1200	0.39	3.74	0.72	6.91			
31	1230					0.52	4.99	3.74
31	1300	0.07	0.67	-0.13	-1.25			
31	1330					-0.13	-1.25	-3.17
31	1400	-0.79	-7.58	-0.92	-8.83			
31	1430					-0.85	-8.16	-8.83
31	1500	-0.98	-9.41	-1.44	-13.82			
31	1530					-0.98	-9.41	-11.33
31	1600	-1.11	-10.66	-1.18	-11.33			
31	1630					-0.72	-6.91	-7.58
31	1700	-0.46	-4.42	-0.66	-6.34			
31	1730					-0.26	-2.50	-2.50
31	1800	0.13	1.25	0.13	1.25			
31	1830					0.20	1.92	2.50
31	1900	0.46	4.42	0.98	9.41			
31	1930					0.92	8.83	8.16
31	2000	0.72	6.91	1.44	13.82			
31	2030					1.31	12.58	13.25

			12-A		12-B		12-C		Avg.
Date		Hour	V	Q	V	Q	V	Q	Q
1970			ft/sec	cu.ft/sec					
July	30	1000	0.59	5.78	0.92	9.02			
	30	1030					0.52	5.10	7.06
	30	1100	-0.20	-1.96	0.39	3.82			
	30	1130					0.07	0.69	0.69
	30	1200	-0.07	-0.69	-0.20	-1.96			
	30	1230					-0.26	-2.55	-3.82
	30	1300	-0.85	-8.33	-0.85	-8.33			
	30	1330					-0.85	-8.33	-10.29
	30	1400	-1.31	-12.84	-1.31	-12.84			
	30	1430					-0.92	-9.02	-11.56
	30	1500	-1.38	-13.52	-1.31	-12.84			
	30	1530					-0.85	-8.33	-10.88
	30	1600	-1.18	-11.56	-1.11	-10.88			
	30	1630					-0.46	-4.51	-6.47
	30	1700	-0.46	-4.51	-0.26	-2.55			
	30	1730					0.00	0.00	-0.69
	30	1800	0.13	1.27	0.26	2.55			
	30	1830					0.13	1.27	1.96
	30	1900	1.11	10.88	1.31	12.84			
	30	1930					0.92	9.02	10.29
	30	2000	0.92	9.02	1.18	11.56			
	30	2030					0.98	9.60	9.02
	30	2100	0.66	6.47	1.44	14.11			
	30	2130					0.98	9.60	10.88
	30	2200	0.92	9.02	1.25	12.25			
	30	2230					0.59	5.78	4.51
	30	2300	-0.39	-3.82	0.98	9.60			
	30	2330					0.59	5.78	4.51
July	31	0000	-0.13	-1.27	0.07	0.69			
	31	0030					-0.39	-3.82	-5.78
	31	0100	-1.31	-12.84	-1.38	-13.52			
	31	0130					-1.05	-10.29	-4.51
	31	0200	0.98	9.60	-1.71	-16.76			
	31	0230					-1.25	-12.25	-12.84
	31	0300			-0.92	-9.02			
	31	0330	-1.18	-11.56			-0.92	-9.02	-9.60
	31	0400			-0.79	-7.74			
	31	0430	-0.46	-4.51			-0.72	-7.06	-5.78
	31	0500	-0.52	-5.10	-0.46	-4.51			
	31	0530					-0.33	-3.23	-1.96
	31	0600	0.33	3.23	0.39	3.82			
	31	0630					0.66	6.47	5.78
	31	0700	0.72	7.06	1.44	14.11			
	31	0730					1.11	10.88	11.56
	31	0800	0.92	9.02	1.71	16.76			
	31	0830					0.79	7.74	11.56
	31	0900	1.05	10.29					
	31	0930							0.00

Date 1970		Hour	12-A V ft/sec	 Q cu.ft/sec	12-B V	 Q	12-C V	 Q	Avg. Q
July	31	1000			-1.11	-10.88			
	31	1030					-0.59	-5.78	-8.33
	31	1100							0.00
	31	1130							0.00
	31	1200							0.00
	31	1230							0.69
	31	1300	0.07	0.69					
	31	1330					0.13	1.27	6.47
	31	1400	1.18	11.56	1.11	10.88			
	31	1430					0.98	9.60	8.33
	31	1500	0.52	5.10	1.05	10.29			
	31	1530					0.72	7.06	10.29
	31	1600	1.38	13.52	1.18	11.56			
	31	1630					0.98	9.60	9.02
	31	1700	0.72	7.06	0.66	6.47			
	31	1730					0.07	0.69	2.55
	31	1800	0.00	0.00	0.13	1.27			
	31	1830					-0.13	-1.27	-1.27
	31	1900							0.00
	31	1930							0.00
	31	2000			0.07	0.69			
	31	2030					-0.13	-1.27	-1.96

		13-A		13-B		13-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 31	2100	0.00	0.00	1.18	18.17			
31	2130					1.25	19.25	17.09
31	2200			1.05	16.17	0.98	15.09	
31	2230	0.52	8.01					11.09
31	2300	0.59	9.09	0.98	15.09	0.66	10.16	
31	2330							9.09
Aug. 1	0000	0.20	3.08	0.46	7.08	-0.07	-1.08	
1	0030							1.08
1	0100	-0.52	-8.01	-0.59	-9.09	-0.46	-7.08	
1	0130							-9.09
1	0200					-0.59	-9.09	
1	0230							-18.17
1	0300					-1.18	-18.17	
1	0330							-17.09
1	0400					-1.11	-17.09	
1	0430							-10.16
1	0500					-0.66	-10.16	
1	0530							-2.00
1	0600					-0.13	-2.00	
1	0630							5.08
1	0700					0.33	5.08	
1	0730							14.17
1	0800			0.92	14.17			
1	0830							9.09
1	0900	0.59	9.09	1.18	18.17			
1	0930					1.38	21.25	19.25
1	1000	1.11	17.09					
1	1030			1.11	17.09			18.17
1	1100			1.18	18.17			
1	1130							0.00
1	1200			0.66	10.16			
1	1230							4.00
1	1300	-0.07	-1.08	-0.20	-3.08			
1	1330					-0.20	-3.08	-3.08
1	1400	-0.33	-5.08	-0.98	-15.09			
1	1430					-0.79	-12.17	-15.09
1	1500	-1.25	-19.25	-1.31	-20.17			
1	1530							-20.17
1	1600			-1.11	-17.09			
1	1630					-0.92	-14.17	-14.17
1	1700			-0.92	-14.17	-0.72	-11.09	
1	1730	-1.25	-19.25					-15.09
1	1800	-0.79	-12.17	-0.72	-11.09			
1	1830					-0.39	-6.01	-5.08
1	1900			-0.13	-2.00	0.07	1.08	
1	1930	0.07	1.08					1.08
1	2000							0.00
1	2030	0.66	10.16	0.92	14.17			12.17

		13-A		13-B		13-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
Aug. 1	2100					0.79	12.17	
1	2130	1.05	16.17	1.31	20.17			18.17
1	2200					1.25	19.25	
1	2230							11.09
1	2300	0.72	11.09	1.11	17.09			
1	2330					1.11	17.09	17.09
Aug. 2	0000							0.00
2	0030							2.00
2	0100	0.13	2.00	0.20	3.08			
2	0130					0.07	1.08	2.00
2	0200	-0.72	-11.09					
2	0230							-11.09
2	0300	-1.38	-21.25	-1.11	-17.09			
2	0330					-0.98	-15.09	-18.17
2	0400	-1.18	-18.17	-1.11	-17.09			
2	0430					-0.98	-15.09	-16.17
2	0500	-1.05	-16.17	-0.98	-15.09			
2	0530					-0.72	-11.09	-13.09
2	0600	-0.46	-7.08	-0.52	-8.01			
2	0630					-0.33	-5.08	-6.01
2	0700	-0.13	-2.00	-0.07	-1.08			
2	0730					0.00	0.00	-1.08

		14-A		14-B		14-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 31	2100	1.25	14.00					
31	2130			1.57	17.58	1.25	14.00	14.67
31	2200	1.05	11.76					
31	2230			1.57	17.58	0.92	10.30	12.43
31	2300	0.92	10.30					
31	2330			1.57	17.58	0.79	8.85	9.52
Aug. 1	0000	0.13	1.46					
1	0030			-0.07	-0.78	-0.26	-2.91	-5.15
1	0100	-1.11	-12.43					
1	0130			-0.92	-10.30	-0.92	-10.30	-12.43
1	0200	-1.57	-17.58					
1	0230			-1.77	-19.82	-1.38	-15.46	-16.91
1	0300	-1.44	-16.13					
1	0330			-1.77	-19.82	-1.57	-17.58	-17.58
1	0400	-1.38	-15.46					
1	0430			-1.31	-14.67	-1.31	-14.67	-13.22
1	0500	-0.98	-10.98					
1	0530			-0.92	-10.30	-0.46	-5.15	-6.61
1	0600	-0.33	-3.70					
1	0630			-0.33	-3.70	0.00	0.00	1.46
1	0700	0.72	8.06					
1	0730			0.85	9.52	0.66	7.39	9.52
1	0800	1.11	12.43					
1	0830			1.77	19.82	1.77	19.82	17.58
1	0900	1.25	14.00					
1	0930			1.84	20.61	1.51	16.91	17.58
1	1000	1.31	14.67					
1	1030			1.90	21.28	1.38	15.46	16.13
1	1100	1.11	12.43					
1	1130			1.57	17.58	0.85	9.52	13.22
1	1200	1.18	13.22					
1	1230			1.11	12.43	0.98	10.98	7.39
1	1300	-0.26	-2.91					
1	1330			-0.13	-1.46	-0.13	-1.46	-0.78
1	1400	0.07	0.78					
1	1430			-1.05	-11.76	-1.11	-12.43	-8.06
1	1500	0.00	0.00					
1	1530			-1.77	-19.82	-1.11	-12.43	-15.46
1	1600	-1.25	-14.00					
1	1630			-1.38	-15.46	-0.92	-10.30	-12.43
1	1700	-1.11	-12.43					
1	1730			-1.31	-14.67	-0.85	-9.52	-10.30
1	1800	-0.59	-6.61					
1	1830			-0.72	-8.06	-0.20	-2.24	-2.24
1	1900	0.26	2.91					
1	1930			0.33	3.70	0.13	1.46	5.15
1	2000	0.85	9.52					
1	2030			1.25	14.00	0.98	10.98	10.30

		14-A		14-B		14-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
Aug. 1	2100	0.52	5.82					
1	2130			1.90	21.28	1.44	16.13	17.58
1	2200	1.44	16.13					
1	2230			1.57	17.58	1.64	18.37	18.37
1	2300	1.11	12.43					
1	2330			1.51	16.91	1.51	16.91	14.00
Aug. 2	0000	0.85	9.52					
2	0030			1.38	15.46	1.25	14.00	14.67
2	0100							0.00
2	0130			0.07	0.78	0.07	0.78	0.78
2	0200	-1.25	-14.00					
2	0230			-1.18	-13.22	-1.25	-14.00	-15.46
2	0300	-1.84	-20.61					
2	0330			-1.31	-14.67	-1.77	-19.82	-16.91
2	0400	-1.38	-15.46					
2	0430			-1.51	-16.91	-1.31	-14.67	-16.13
2	0500							0.00
2	0530			-1.05	-11.76	-0.85	-9.52	-9.52
2	0600	-0.66	-7.39					
2	0630			-0.66	-7.39			-3.70
2	0700	-0.07	-0.78					
2	0730			0.00	0.00	0.07	0.78	0.00

		15-A		15-B		15-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 31	2130	1.11	22.64	1.77	36.11			
31	2200	1.05	21.42	1.57	32.03	1.05	21.42	25.50
31	2230					0.85	17.34	
31	2300	0.79	16.12	1.18	24.07			17.34
31	2330					0.66	13.46	
Aug. 1	0000	0.20	4.08	0.39	7.96			0.00
1	0030					-0.59	-12.04	
1	0100	-0.66	-13.46	-1.31	-26.72			-18.77
1	0130					-0.85	-17.34	
1	0200	-1.25	-25.50	-1.25	-25.50			-21.42
1	0230					-0.72	-14.69	
1	0300	-1.11	-22.64	-1.11	-22.64			-19.99
1	0330					-0.66	-13.46	
1	0400	-0.79	-16.12	-0.85	-17.34			-14.69
1	0430					-0.39	-7.96	
1	0500	-0.46	-9.38	-0.46	-9.38			-6.73
1	0530					-0.07	-1.43	
1	0600	-0.20	-4.08	0.00	0.00			0.00
1	0630					0.20	4.08	
1	0700	0.39	7.96	0.72	14.69			13.46
1	0730					0.85	17.34	
1	0800	1.05	21.42	0.98	19.99			19.99
1	0830					0.92	18.77	
1	0900	1.18	24.07	1.31	26.72			24.07
1	0930					1.11	22.64	
1	1000	1.05	21.42	2.36	48.14			34.88
1	1030					1.64	33.46	
1	1100	1.57	32.03	2.36	48.14			37.54
1	1130					1.64	33.46	
1	1200	0.66	13.46	1.11	22.64			16.12
1	1230					0.46	9.38	
1	1300	-0.33	-6.73	-0.52	-10.61			-9.38
1	1330					-0.66	-13.46	
1	1400	-0.85	-17.34	-1.05	-21.42			-17.34
1	1430					-0.59	-12.04	
1	1500	-1.18	-24.07	-1.11	-22.64			-18.77
1	1530					-0.59	-12.04	
1	1600	-0.85	-17.34	-0.98	-19.99			-16.12
1	1630					-0.59	-12.04	
1	1700	-0.72	-14.69	-0.59	-12.04			-10.61
1	1730					-0.26	-5.30	
1	1800	-0.26	-5.30	-0.26	-5.30			-4.08
1	1830					-0.13	-2.65	
1	1900	0.33	6.73	0.07	1.43			-5.30
1	1930					0.33	6.73	
1	2000	0.59	12.04	0.92	18.77			17.34
1	2030					0.98	19.99	

		15-A		15-B		15-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
Aug. 1	2100	1.05	21.42	1.44	29.38			24.07
1	2130					1.18	24.07	
1	2200	1.11	22.64	1.77	36.11			26.72
1	2230					1.05	21.42	
1	2300	0.79	16.12	1.64	33.46			22.64
1	2330					0.98	19.99	
Aug. 2	0000	0.85	17.34	1.18	24.07			17.34
2	0030					0.46	9.38	
2	0100	0.07	1.43	-0.07	-1.43			-5.30
2	0130					-0.79	-16.12	
2	0200	-0.79	-16.12	-1.25	-25.50			-18.77
2	0230					-0.66	-13.46	
2	0300	-1.05	-21.42	-1.25	-25.50			-10.99
2	0330					-0.66	-13.46	
2	0400	-0.92	-18.77	-1.05	-21.42			-16.12
2	0430					-0.39	-7.96	
2	0500	-0.66	-13.46	-0.72	-14.69			-12.04
2	0530					-0.33	-6.73	
2	0600	-0.33	-6.73	-0.33	-6.73			-5.30
2	0630					-0.07	-1.43	
2	0700	-0.07	-1.43	0.07	1.43			2.65
2	0730					0.33	6.73	

		16-A		16-B		16-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 31	2200	-0.59	-9.68					
31	2230			0.59	9.68	-0.39	-6.40	-1.15
31	2300	-0.26	-4.26					
31	2330			0.39	6.40	-0.13	-2.13	6.40
Aug. 1	0000	0.85	13.94					
1	0030			0.98	16.07	0.85	13.94	17.22
1	0100	1.25	20.50					
1	0130			1.17	29.03	1.71	28.04	25.75
1	0200	1.18	19.35					
1	0230			1.90	31.16	1.64	26.90	25.75
1	0300	1.18	19.35					
1	0330			1.77	29.03	1.38	22.63	20.50
1	0400	0.66	10.82					
1	0430			1.44	23.62	0.98	16.07	19.35
1	0500							0.00
1	0530							0.00
1	0600							0.00
1	0630							0.00
1	0700							0.00
1	0730							0.00
1	0800							0.00
1	0830							11.81
1	0900	0.72	11.81					
1	0930			1.44	23.62	1.18	19.35	20.50
1	1000	1.05	17.22					
1	1030			1.38	22.63	0.59	9.68	15.90
1	1100	0.79	12.96					
1	1130			1.05	17.22	0.46	7.54	5.41
1	1200	-0.46	-7.54					
1	1230			0.52	8.53	-0.13	-2.13	-1.15
1	1300	-0.59	-9.68					
1	1330			-1.05	-17.22	-0.72	-11.81	-7.54
1	1400	0.52	8.53					
1	1430			0.52	8.53	0.00	0.00	5.41
1	1500	0.52	8.53					
1	1530			0.52	8.53	-1.25	-20.50	-6.40
1	1600	-0.46	-7.54					
1	1630			-0.52	-8.53	0.00	0.00	-3.28
1	1700	-0.13	-2.13					
1	1730			-0.46	-7.54	-0.07	-1.15	-2.13
1	1800	0.00	0.00					
1	1830			0.00	0.00	0.00	0.00	6.40
1	1900	1.38	22.63			0.13	2.13	
1	1930			0.20	3.28			8.53
1	2000	-1.05	-17.22			0.26	4.26	
1	2030			1.11	18.20			8.53
1	2100	0.20	3.28					
1	2130			0.39	6.40			6.40

		16-A		16-B		16-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
Aug. 1	2200					0.13	2.13	
1	2230							2.13
1	2300					0.20	3.28	
1	2330			0.26	4.26			3.28
Aug. 2	0000	0.13	2.13			0.07	1.15	
2	0030			0.13	2.13			1.15
2	0100	-0.07	-1.15			-0.07	-1.15	
2	0130			0.07	1.15			0.00
2	0200							0.00
2	0230							0.00
2	0300					0.00	0.00	
2	0330							0.00
2	0400							0.00
2	0430			0.07	1.15			0.00
2	0500	0.00	0.00					
2	0530			0.07	1.15			1.15
2	0600							0.00
2	0630			0.00	0.00			0.00
2	0700					0.20	3.28	
2	0730			0.13	2.13			2.13

		17-A		17-B		17-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 16	1530							8.58
16	1600	0.39	8.58					
16	1630			0.59	12.98	0.72	15.84	15.84
16	1700	0.85	18.70	1.25	27.50			
16	1730					0.92	20.24	23.10
16	1800	1.05	23.10	1.64	36.08			
16	1830					1.11	24.42	28.82
16	1900	1.11	24.42	1.64	36.08			
16	1930					1.11	24.42	31.68
16	2000	1.57	34.54					
16	2030							0.00
16	2100							0.00
16	2130							0.00
16	2200							0.00
16	2230							0.00
16	2300							0.00
16	2330							0.00
July 17	0000							0.00
17	0030							0.00
17	0100							0.00
17	0130							0.00
17	0200							0.00
17	0230							0.00
17	0300							0.00
17	0330							0.00
17	0400							0.00
17	0430							0.00
17	0500							0.00
17	0530							0.00
17	0600							0.00
17	0630							0.00
17	0700			-1.84	-40.48			
17	0730							-40.48
17	0800	-1.77	-38.94	-1.77	-38.94			
17	0830					-1.31	-28.82	-36.08
17	0900	-1.84	-40.48	-1.97	-43.34			
17	0930					-1.25	-27.50	-33.22
17	1000	-1.31	-28.82	-1.90	-41.80			
17	1030					-1.11	-24.42	-30.36
17	1100	-1.18	-25.96	-1.18	-25.96			
17	1130					0.00	0.00	-10.12
17	1200	-0.26	-5.72	0.52	11.44			
17	1230					1.05	23.10	24.42
17	1300	1.77	38.94	2.10	46.20			
17	1330					1.90	41.80	43.34
17	1400	1.84	40.48	1.97	43.34			
17	1430					1.57	34.54	34.54
17	1500	1.25	27.50	1.57	34.54			
17	1530					1.18	25.96	30.36

		17-A		17-B		17-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 17	1600							0.00
17	1630							-5.72
17	1700	-0.26	-5.72	-0.26	-5.72			
17	1730					-0.46	-10.12	-8.58
17	1800							0.00
17	1830							0.00
17	1900							0.00
17	1930							0.00
17	2000							0.00
17	2030							0.00
17	2100							0.00
17	2130							0.00
17	2200							0.00
17	2230							0.00
17	2300							0.00
17	2330							0.00
July 18	0000	1.97	43.34	2.30	50.60			43.34
18	0030					1.90	41.80	44.66
18	0100	1.90	41.80	2.30	50.60			
18	0130					2.03	44.66	41.80
18	0200	1.38	30.36	2.16	47.52			
18	0230					1.71	37.62	41.80
18	0300							0.00
18	0330							8.58
18	0400	0.39	8.58	0.39	8.58			
18	0430					0.20	4.40	2.86
18	0500	-0.13	-2.86	-0.26	-5.72			
18	0530					-0.46	-10.12	-5.72
18	0600	-1.05	-23.10	-1.51	-33.22			
18	0630					-0.79	-17.38	-28.82
18	0700	-1.57	-34.54					
18	0730					-0.98	-21.56	-21.56
18	0800							0.00

Date	Hour	18-A		18-B		18-C		Avg.
		V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 15	1730							0.00
15	1800							0.00
15	1830							-14.22
15	1900			-0.79	-14.22			
15	1930					-0.66	-11.88	-11.88
15	2000							0.00
15	2030							-3.60
15	2100			-0.20	-3.60			
15	2130					0.72	12.96	18.90
15	2200			1.38	24.84			
15	2230					1.05	18.90	19.98
15	2300			1.18	21.24			
15	2330					1.18	21.24	25.92
July 16	0000			1.71	30.78			
16	0030					1.84	33.12	31.86
16	0100	1.71	30.78	1.71	30.78			
16	0130					1.77	31.86	28.26
16	0200	1.18	21.24	1.11	19.98			
16	0230					1.05	18.90	16.56
16	0300	0.52	9.36	0.39	7.02			
16	0330					0.13	2.34	0.00
16	0400	-0.66	-11.88	-0.59	-10.62			
16	0430					-0.66	-11.88	-12.96
16	0500	-0.85	-15.30	-0.85	-15.30			
16	0530					-0.66	-11.88	-14.22
16	0600	-0.92	-16.56	-0.98	-17.64			
16	0630					-1.38	-24.84	-15.30
16	0700	-0.13	-2.34	-0.20	-3.60			
16	0730					-1.11	-19.98	-11.88
16	0800							0.00
16	0830	-1.18	-21.24					-21.24
16	0900			-1.18	-21.24			
16	0930	-0.98	-17.64			-1.25	-22.50	-17.64
16	1000	-0.66	-11.88			-1.05	-18.90	
16	1030							0.00
16	1100							0.00
16	1130							22.50
16	1200	1.25	22.50	0.98	17.64			
16	1230					0.92	16.56	21.24
16	1300	1.57	28.26	1.44	25.92			
16	1330					1.57	28.26	25.92
16	1400	1.18	21.24	1.64	29.52			
16	1430					1.18	21.24	21.24
16	1500	0.66	11.88	0.85	15.30			
16	1530					0.46	8.28	4.68
16	1600	-0.59	-10.62					
16	1630			-1.31	-23.58	-0.79	-14.22	-18.90
16	1700	-0.92	-16.56	-1.11	-19.98			
16	1730					-0.92	-16.56	-19.98

		18-A		18-B		18-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 16	1800	-1.25	-22.50	-1.25	-22.50			
16	1830					-1.25	-22.50	-22.50
16	1900	-1.18	-21.24					
16	1930			-1.71	-30.78	-1.25	-22.50	-22.50
16	2000	-0.85	-15.30					
16	2030			-1.18	-21.24	-1.38	-24.84	-21.24
16	2100			-0.98	-17.64	-0.92	-16.56	
16	2130					-0.66	-11.88	-10.62
16	2200	-0.13	-2.34	-0.26	-4.68			
16	2230					-0.13	-2.34	4.68
16	2300	1.11	19.98	1.11	19.98			
16	2330							28.26
July 17	0000	2.03	36.54	2.23	40.14			
17	0030							38.88
17	0100	2.16	38.88	2.23	40.14			
17	0130							34.20
17	0200	1.64	29.52	2.16	38.88			
17	0230							30.78
17	0300	1.31	23.58	1.57	28.26			
17	0330							19.98
17	0400	0.66	11.88	0.66	11.88			
17	0430							1.26
17	0500	-0.59	-10.62	-0.52	-9.36			
17	0530							-16.56
17	0600	-1.25	-22.50	-1.31	-23.58			
17	0630							-23.58
17	0700	-1.38	-24.84					
17	0730			-1.25	-22.50	-1.51	-27.18	-23.58
17	0800	-1.18	-21.24	-1.31	-23.58			
17	0830					-1.57	-28.26	-24.84
17	0900	-1.25	-22.50	-1.25	-22.50			
17	0930			-0.98	-17.64	-1.31	-23.58	-21.24
17	1000	-1.18	-21.24	-1.31	23.58			
17	1030					-1.31	-23.58	-19.98
17	1100	-0.79	-14.22	-0.85	-15.30			
17	1130					-0.79	-14.22	-7.02
17	1200	0.46	8.28	0.07	1.26			
17	1230					0.72	12.96	15.30
17	1300	1.71	30.78	2.23	40.14			
17	1330							35.46
17	1400	1.71	30.78	2.23	40.14			
17	1430					1.11	19.98	30.78
17	1500	1.77	31.86	1.77	31.86			
17	1530							31.86
17	1600							0.00
17	1630							-12.96
17	1700	-0.72	-12.96	-0.46	-8.28			
17	1730					-0.46	-8.28	-8.28

		19-A		19-B		19-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 15	1700	-0.97	-23.92	-1.44	-37.44			
15	1730					-1.25	-32.50	-34.06
15	1800	-1.31	-34.06	-1.71	-44.46			
15	1830					-1.71	-44.46	-37.44
15	1900	-0.98	-25.48	-1.51	-39.26			
15	1930					-0.92	-23.92	-30.68
15	2000	-1.11	-28.86	-1.11	-28.86			
15	2030					-0.59	-15.34	-22.10
15	2100	-0.07	-1.82	-0.33	-8.58			
15	2130					0.46	11.96	1.82
15	2200	0.20	5.20	1.18	30.68			
15	2230					1.25	32.50	35.88
15	2300	1.71	44.46	1.64	42.64			
15	2330					1.31	34.06	37.44
July 16	0000	1.38	35.88	1.57	40.82			
16	0030					1.25	32.50	35.88
16	0100	1.31	34.06	1.44	37.44			
16	0130					0.79	20.54	28.86
16	0200	1.05	27.30	1.18	30.68			
16	0230					0.52	13.52	18.72
16	0300	0.33	8.58	0.52	13.52			
16	0330					-0.26	-6.76	0.00
16	0400	-0.39	-10.14	-0.39	-10.14			
16	0430					-0.66	-17.16	-20.54
16	0500	-1.25	-32.50	-1.25	-32.50			
16	0530					-1.25	-32.50	-32.50
16	0600	-1.18	-30.68	-1.71	-44.46			
16	0630					-1.31	-34.06	-37.44
16	0700	-1.31	-34.06	-1.44	-37.44			
16	0730					-1.11	-28.86	-34.06
16	0800	-1.38	-35.88	-1.71	-44.46			
16	0830							-34.06
16	0900	-1.18	-30.68	-1.11	-28.86	-1.11	28.86	
16	0930					-0.92	-23.92	-25.48
16	1000	-0.92	-23.92	-1.05	-27.30			
16	1030					-0.39	-10.14	-11.96
16	1100	0.07	1.82	-0.13	-3.38			
16	1130					0.52	13.52	6.76
16	1200	0.33	8.58	1.44	37.44			
16	1230					1.25	32.50	39.26
16	1300	1.77	46.02	1.71	44.46			
16	1330					1.25	32.50	25.48
16	1400	0.07	1.82	1.75	32.50			
16	1430					0.46	11.96	20.54
16	1500	0.72	18.72	0.66	17.16			
16	1530					-0.07	-1.82	1.82
16	1600	-0.33	-8.58	-0.59	-15.34			
16	1630					-0.85	-22.10	-20.54
16	1700	-1.05	-27.30	-1.11	-28.86			
16	1730					-1.31	-34.06	-28.86

Date	Hour	19-A		19-B		19-C		
		V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 16	1800	-0.98	-25.48	-1.14	-37.44			
16	1830					-1.38	-35.88	-35.88
16	1900	-1.25	-32.50	-1.51	-39.26			
16	1930					-1.51	-39.26	-37.44
16	2000	-1.44	-37.44	-1.51	-39.26			
16	2030					-0.92	-23.92	-30.68
16	2100	-1.05	-27.30	-1.05	27.30			
16	2130					-0.39	-10.14	-18.72
16	2200	-0.39	-10.14	-0.46	-11.96			
16	2230					-0.20	-5.20	3.38
16	2300	0.52	13.52	0.66	17.16			
16	2330					0.72	18.72	28.86
July 17	0000	1.51	39.26	1.11	28.86			
17	0030					1.71	44.46	35.88
17	0100							0.00
17	0130							23.92
17	0200	0.92	23.92	1.38	35.88			
17	0230					1.18	35.88	28.86
17	0300	0.66	17.16	1.11	28.86			
17	0330					0.72	18.72	17.16
17	0400	0.20	5.20	0.52	13.52			
17	0430					0.20	5.20	1.82
17	0500	-0.52	-13.52	-0.20	-5.20			
17	0530					-0.46	-11.96	-17.16
17	0600	-1.25	-32.50	-1.11	-28.86			
17	0630					-1.05	-27.30	-27.30
17	0700	-0.92	-23.92	-1.38	-35.88			
17	0730					-1.18	-30.68	-32.50
17	0800	-1.11	-28.86	-1.64	-42.64			
17	0830					-1.05	-27.30	-35.88
17	0900	-1.38	-35.88	-1.84	-47.84			
17	0930					-1.18	-30.68	-37.44
17	1000	-1.38	-35.88	-1.31	-34.06			
17	1030					-1.11	-28.86	-28.86
17	1100	-0.92	-23.92	-1.05	-27.30			
17	1130					-0.52	-13.52	-10.14
17	1200	0.66	17.16	0.33	8.58			
17	1230							27.30
17	1300	1.71	44.46	1.90	49.40			
17	1330					2.03	52.78	35.88
17	1400	0.26	6.76	0.26	6.76			
17	1430					1.71	44.46	28.86
17	1500	1.31	34.06	1.38	35.88			
17	1530					0.79	20.54	28.86
17	1600							0.00
17	1630							-15.34
17	1700	-0.59	-15.34	-0.26	-6.76			
17	1730					-0.79	-20.54	-13.52

		20-A		20-B		20-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 15	1830			-1.38	-34.22			
15	1900			-1.18	-29.26			-27.53
15	1930					-1.05	-26.04	
15	2000	-0.39	-9.67	-0.85	-21.08			-14.63
15	2030					-0.59	-14.63	
15	2100	-0.07	-1.74	0.20	4.96			4.96
15	2130					0.46	11.41	
15	2200	0.59	14.63	1.11	27.53			27.53
15	2230					1.64	40.67	
15	2300	-0.72	-17.86					-17.86
15	2330							0.00
July 16	0000	-0.92	22.82	2.10	52.08			26.04
16	0030					2.03	50.34	
16	0100	-0.32	-1.05	1.64	40.67			19.59
16	0130					1.71	42.41	
16	0200	-0.22	-0.72	1.18	29.26			11.41
16	0230					1.05	26.04	
16	0300	-0.16	-0.52	0.39	9.67			1.74
16	0330					0.26	6.45	
16	0400	-0.18	-0.59	-0.59	-14.63			-16.37
16	0430					-0.85	-21.08	
16	0500	-0.28	-0.92					-31.00
16	0530			-1.44	-35.71	-1.31	-32.49	
16	0600	-0.34	-1.11	-1.64	-40.67			-35.71
16	0630					-1.64	-40.67	
16	0700	-0.30	-0.98					-24.30
16	0730							0.00
16	0800	-0.26	-0.85					-21.08
16	0830							0.00
16	0900	-0.26	-0.85	-1.31	-32.49			-24.30
16	0930					-0.72	-17.86	
16	1000	0.16	-0.52					-11.41
16	1030			-0.46	-11.41			
16	1100	-0.08	-0.26			-0.13	-3.22	8.18
16	1130			0.79	19.59			
16	1200	-0.06	-0.20	1.44	35.71	0.66	16.37	21.08
16	1230					1.57	38.94	
16	1300	-0.20	0.66	1.90	47.12			24.30
16	1330					1.84	45.63	
16	1400	-0.20	0.66	1.11	27.53			12.90
16	1430					1.05	26.04	
16	1500	-0.20	0.66	0.46	11.41			3.22
16	1530					0.46	11.41	
16	1600	-0.20	0.66	-0.46	-11.41			-12.90
16	1630					-0.52	-12.90	
16	1700					-0.98	-24.30	-24.30
16	1730							0.00
16	1800			-1.18	-29.26	-0.98	-24.30	-21.08
16	1830	-0.39	-9.67					

		20-A		20-B		20-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 16	1900			-0.33	-8.18	-1.31	-32.49	-21.08
16	1930	-0.85	-21.08					
16	2000	-0.79	-19.59	-1.38	-34.22	-1.31	-32.49	-27.53
16	2030							0.00
16	2100					-1.18	-29.26	-29.26
16	2130							0.00
16	2200	0.00	0.00					4.96
16	2230			0.26	6.45	0.39	9.67	
16	2300	0.56	14.63	1.18	29.26			26.04
16	2330					1.44	35.71	
July 17	0000	-0.26	-6.45	1.71	42.41			31.00
17	0030					2.30	57.04	
17	0100	-0.92	-22.82	2.30	57.04			29.26
17	0130					2.23	55.30	
17	0200	-0.85	-21.08	2.23	55.30			26.04
17	0230					1.90	47.12	
17	0300	-0.79	-19.59	1.38	34.22			12.90
17	0330					0.98	24.30	
17	0400	-0.66	-16.37	0.20	4.46			-3.22
17	0430					0.07	1.74	
17	0500	-0.07	-1.74	-0.07	-1.74			-1.74
17	0530					-0.13	-3.22	
17	0600	-1.25	-31.00	-1.77	-43.90			-40.67
17	0630					-1.90	-47.12	
17	0700	-1.25	-31.00	-1.71	-42.41			-38.94
17	0730					-1.77	-43.90	
17	0800	-1.44	-35.71	-1.44	-35.71			-37.45
17	0830					-1.64	-40.67	
17	0900	-1.31	32.49	-1.71	-42.41			-38.94
17	0930					-1.64	-40.67	
17	1000	-1.05	26.04	-1.44	-35.71			-31.00
17	1030					-1.18	-29.26	
17	1100	-0.46	-11.41	-0.52	-12.90			-9.67
17	1130					-0.20	-4.96	
17	1200	0.59	14.63	0.72	17.86			1.74
17	1230					0.92	22.82	
17	1300	-0.66	-16.37	2.10	52.08			31.00
17	1330					2.30	57.04	
17	1400	-0.85	-21.08	2.82	69.44			34.22
17	1430					2.23	55.30	
17	1500	-0.92	-22.82	1.38	34.22			
17	1530					1.44	35.71	
17	1600	-0.72	-17.86	0.59	14.63			1.74
17	1630					0.33	8.18	
17	1700	-0.79	-19.59	-0.79	-19.59	-0.26	-6.45	-14.63

Station 21B

Date 1970	Time	V ft/sec	Q cu.ft/sec
July 12	1600	-0.89	-26.01
	1700	-0.65	-18.83
	1800	-0.22	- 6.41
	1900	0.56	16.22
	2000	1.13	32.94
	2100	1.37	40.10
	2200	1.30	38.04
	2300	1.04	30.43
July 13	0000	0.55	16.15
	0100	-0.19	- 5.55
	0200	-0.78	-22.70
	0300	-1.05	-30.58
	0400	-1.36	-33.14
	0500	-1.03	-30.03
	0600	-0.80	-23.45
	0700	-0.29	- 8.42
	0800	0.41	11.87
	0900	0.45	13.11
	1000	1.04	30.22
	1100	1.10	32.11
	1200	0.78	22.73
	1300	0.37	10.89
	1400	-0.18	- 5.26
	1500	-0.73	-21.27
	1600	-1.01	-29.36
	1700	-1.17	-33.99
	1800	-0.81	-23.57
	1900	-0.22	- 6.32
	2000	0.76	22.30
	2100	1.29	37.51
	2200	1.52	44.21
	2300	1.30	38.04
July 14	0000	1.12	32.80
	0100	0.60	17.35
	0200	-0.05	- 1.56
	0300	-0.63	-18.37
	0400	-1.03	-29.98
	0500	-1.22	-35.55
	0600	-1.17	-33.99
	0700	-0.86	-25.17
	0800	-0.39	-11.34
	0900	1.21	35.31
	1000	0.99	28.99
	1100	1.07	31.10
	1200	0.96	27.90
	1300	0.70	20.29
	1400	0.34	9.95
	1500	-0.14	- 4.14
	1600	-0.74	-21.29
	1700	-1.00	-29.16
	1800	-1.09	-31.82

		22-A		22-B		22-C		Avg.
Date 1970	Hour	V ft/sec	Q cu.ft/sec	V	Q	V	Q	Q
July 12	2100	1.11	43.51	1.57	61.54			
12	2130					1.44	56.45	54.10
12	2200	1.11	43.51	1.31	51.35			
12	2230					1.05	41.16	41.16
12	2300	0.85	33.32	1.11	43.51			
12	2330					0.52	20.38	20.38
July 13	0000	0.00	0.00	0.26	10.19			
13	0030					-0.13	-5.10	-2.74
13	0100	-0.33	-12.94	-0.46	-18.00			
13	0130					-0.72	-28.22	28.22
13	0200	-0.92	-36.06	-1.05	-41.16			
13	0230					-0.85	-33.32	-43.51
13	0300	-1.51	-59.19	1.38	-54.10			
13	0330					-1.31	-51.35	-54.10
13	0400	-1.38	-54.10	-1.51	-59.19			
13	0430					-1.18	-46.26	-51.35
13	0500	-1.18	-46.26	-1.11	-43.51			
13	0530					-0.85	-33.32	-36.06
13	0600	-0.72	-28.22	-0.66	-25.87			
13	0630					-0.39	-15.29	15.29
13	0700	-0.20	-7.84	-0.13	-5.10			
13	0730					0.33	12.94	7.84
13	0800	0.46	18.03	0.52	20.38			
13	0830					0.79	30.97	25.87
13	0900	0.72	28.22	0.92	36.06			
13	0930					0.98	38.42	38.42
13	1000	1.11	43.51	1.38	54.10			
13	1030					1.05	41.16	43.51
13	1100	0.98	38.42	1.11	43.51			
13	1130					0.85	33.32	33.32
13	1200	0.52	20.38	0.66	25.87			
13	1230					0.33	12.94	18.03
13	1300	0.33	12.94	0.13	5.10			
13	1330					-0.26	-10.19	-2.74
13	2130					1.38	54.10	54.10
13	2200	1.38	54.10	1.17	67.03			
13	2230					1.64	64.29	56.45
13	2300	1.11	43.51	1.51	59.19			
13	2330					1.05	41.16	41.16
July 14	0000	0.66	25.87	0.59	23.13			
14	0030					0.20	7.84	15.29
14	0100	0.26	10.19	0.20	7.84			
14	0130					-0.18	-5.10	-2.74
14	0200	-0.26	-10.19	-0.46	-18.03			
14	0230					-0.52	-20.38	-23.13

Date 1970	Hour	22-A V ft/sec	22-A Q cu.ft/sec	22-B V	22-B Q	22-C V	22-C Q	Avg. Q
July 14	0300	-0.72	-28.22	-0.85	-33.32			
14	0330					-0.72	-28.22	-30.97
14	0400			-1.18	-46.26			
14	0430	-1.11	-43.51			-1.05	-41.16	-46.26
14	0500	-1.25	-49.00	-1.25	-49.00			
14	0530					-0.98	-38.42	-43.51
14	0600	-1.18	-46.26	-1.11	-43.54			
14	0630					-0.66	-25.87	-33.32
14	0700	-0.72	-28.22	-0.52	-20.38			
14	0730					-0.20	-7.84	-10.19
14	0800	-0.13	-5.10	0.13	5.10			
14	0830					0.46	18.03	12.94
14	0900	0.39	15.29	0.52	20.38			
14	0930							20.38

Date 1970		Hour	25-A V ft/sec	 Q cu.ft/sec	25-B V	 Q	25-C V	 Q	Avg. Q
July	12	1500	-0.72	-33.84	-0.85	-39.95			
	12	1530					-0.92	-43.24	-39.95
	12	1600	-0.85	-39.95	-0.66	-31.02			
	12	1630					-0.46	-21.62	-12.22
	12	1700	0.20	9.40	0.26	12.22			
	12	1730					0.13	6.11	15.51
	12	1800	0.59	27.73	0.85	39.95			
	12	1830					0.52	24.44	39.95
	12	1900	1.18	55.46					
	12	1930							61.57
	12	2000							0.00
	12	2030							52.17
	12	2100	1.11	52.17					
	12	2130			1.18	55.46	0.85	39.95	43.24
	12	2200			0.98	46.06	0.72	33.84	
	12	2230	0.59	27.73	0.33	15.51			31.02
	12	2300	0.39	18.33					
	12	2330							15.51
July	13	0000							0.00
	13	0030							-37.13
	13	0100	-0.79	-37.13	-0.66	-31.02			
	13	0130					-0.66	-31.02	-33.84
	13	0200			-1.38	-64.86	-0.92	-43.24	
	13	0230	-1.05	-49.35					-58.75
	13	0300							0.00
	13	0330							-58.75
	13	0400	-1.25	-58.75	-1.31	-61.57			
	13	0430					-0.85	-39.95	-43.24
	13	0500			-0.79	-37.13	-0.59	-27.73	
	13	0530	-0.46	-21.62					-21.62
	13	0600	-0.13	-6.11	-0.20	-9.40			
	13	0630					0.07	3.29	3.29
	13	0700			-0.26	12.22	0.26	12.22	
	13	0730	0.46	21.62					18.33
	13	0800	0.46	21.62	0.92	43.24			
	13	0830					0.66	31.02	37.13
	13	0900	0.72	33.84	0.98	46.06			
	13	0930					0.72	33.84	27.73
	13	1000	0.07	3.29	0.92	43.24			
	13	1030					0.79	37.13	33.86
	13	1100	0.39	18.33	0.79	37.13			
	13	1130					0.46	21.62	31.02
	13	1200			0.39	18.33	0.70	9.40	
	13	1230							0.00
	13	1300	-0.26	-12.22	-0.13	-6.11	-0.26	-12.22	
	13	1330							-18.33
	13	1400	-0.72	-33.84	-0.79	-37.13			
	13	1430					-0.72	-33.84	-24.44
	13	1500	-0.07	-3.29	-1.18	-55.46			
	13	1530					-1.31	-61.57	-58.75

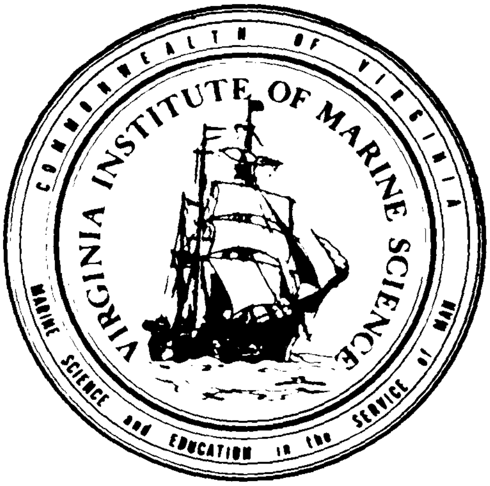
Station 23B

Date 1970	Time	V ft/sec	Q cu.ft/sec
July 12	1500	-1.30	-39.45
	1600	-0.96	-28.85
	1700	-0.55	-16.66
	1800	0.33	9.93
	1900	1.16	35.20
	2000	1.28	38.83
	2100	1.91	57.67
	2200	1.71	51.74
	2300	0.96	29.07
July 13	0000	0.16	4.72
	0100	-0.59	-17.77
	0200	-1.32	-40.07
	0300	-1.41	-42.67
	0400	-1.41	-42.57
	0500	-1.13	-34.18
	0600	-0.62	-18.64
	0700	0.18	5.56
	0800	0.81	24.55
	0900	1.29	39.17
	1000	1.66	50.30
	1100	1.03	31.03
	1200	0.57	17.10
	1300	-0.56	-16.83
	1400	-0.85	-25.84
	1500	-1.26	-38.08
	1600	-1.49	-45.13
	1700	-1.22	-37.01
	1800	-0.48	-14.60
	1900	0.56	16.96
	2000	1.40	42.45
	2100	1.93	58.54
	2200	1.74	52.70
	2300	1.77	53.42
July 14	0000	0.88	26.71
	0100	0.08	2.53
	0200	-0.62	-18.72
	0300	-1.12	-33.89
	0400	-1.47	-44.56
	0500	-1.47	-44.44
	0600	-1.01	-30.53
	0700	-0.41	-12.49
	0800	0.29	6.61
	0900	0.96	29.07
	1000	1.37	41.38
	1100	1.32	40.09
	1200	1.03	31.03
	1300	0.44	13.36
	1400	-0.02	- .45
	1500	-0.72	-21.82
	1600	-1.01	-30.44
	1700	-1.23	-37.26

Station 24B

Date 1970	Time	V ft/sec	Q cu.ft/sec
July 9	1500	-0.85	-33.54
	1600	0.74	29.24
	1700	1.34	52.54
	1800	1.52	59.89
	1900	1.46	57.41
	2000	1.18	46.26
	2100	0.60	23.65
	2200	-0.51	-20.03
	2300	-0.99	-38.74
July 10	0000	-1.36	-53.48
	0100	-1.51	-59.42
	0200	-1.29	-50.57
	0300	-0.88	-34.70
	0400	-0.71	-27.81
	0500	0.01	.55
	0600	0.82	32.25
	0700	0.81	31.68
	0800	0.79	31.09
	0900	0.69	27.09
	1000	-0.17	- 6.62
	1100	-0.63	-24.94
	1200	-0.97	-37.96
	1300	-1.25	-49.32
	1400	-1.22	-48.07
	1500	-0.90	-35.48
	1600	-0.42	-16.33
	1700	0.21	8.29
	1800	0.75	29.45
	1900	1.14	44.76
	2000	1.08	42.26
	2100	0.60	23.48
	2200	-0.19	- 7.26
	2300	-0.63	-24.94
July 11	0000	-1.15	-45.23
	0100	-1.41	-55.38
	0200	-1.64	-64.67
	0300	-1.49	-58.70
	0400	-1.14	-44.89
	0500	-0.23	- 9.07
	0600	0.47	18.52
	0700	0.95	37.28
	0800	1.20	47.21
	0900	0.93	36.46
	1000	0.18	7.04
	1100	-0.48	-18.87
	1200	-1.00	-39.38
	1300	-1.25	-49.28
	1400	-1.35	-53.02

		25-A		25-B		25-C		Avg.
Date	Hour	V	Q	V	Q	V	Q	Q
1970		ft/sec	cu.ft/sec					
July 13	1600	-0.70	-9.40	-0.20	-9.40			
13	1630					-1.05	-49.35	-27.73
13	1700	-0.98	-46.06	-0.92	-43.24			
13	1730					-0.79	-37.13	-27.73
13	1800	-0.07	-3.29					
13	1830			0.07	3.29			21.62
13	1900	0.85	39.95	0.85	39.95			
13	1930					0.98	46.06	46.06
13	2000	1.18	55.46	1.57	73.79			
13	2030					1.38	64.86	70.97
13	2100	1.57	73.79	0.33	15.51			
13	2130					-0.79	-37.13	12.22
13	2200	1.05	49.35	1.31	61.57			
13	2230							39.95
13	2300	0.72	33.84	0.72	33.84			
13	2330					0.20	9.40	21.62
July 14	0000	0.20	9.40	0.33	15.51	0.39	18.33	
14	0030							9.40
14	0100	0.00	0.00	0.07	3.29			
14	0130					-0.07	-3.29	-6.11
14	0200			-0.66	-31.02	-0.33	-15.51	
14	0230	-0.66	-31.02					-37.13
14	0300	-1.05	-49.35	-1.18	-55.46			
14	0330					-1.18	-55.46	-49.35
14	0400					-0.85	-39.95	
14	0430							-37.13
14	0500					-0.79	-37.13	
14	0530							-43.24
14	0600					-0.92	-43.24	
14	0630							0.00
14	0700							0.00
14	0730							9.40
14	0800					0.20	9.40	
14	0830							37.13
14	0900					0.79	37.13	
14	0930							52.17
14	1000					1.11	52.17	
14	1030							33.84
14	1100					0.72	33.84	
14	1130							37.13
14	1200	0.79	37.13	0.85	39.95			
14	1230					0.39	18.33	24.44
14	1300	0.13	6.11					
14	1330					-0.07	-3.29	-6.11
14	1400	-0.33	-15.51	-0.39	-18.33	-0.46	-21.62	
14	1430							-24.44
14	1500	-0.66	-31.02	-0.66	-31.02	-0.72	-33.84	
14	1530							-31.02
14	1600	-0.66	-31.02	-0.92	-43.24	-0.98	-46.06	
14	1630							-46.06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