WATER QUALITY CONDITIONS IN THE TIDAL RAPPAHANNOCK RIVER : LONGITUDINAL AND DOME SURVEYS IN 1993

by

Kyeong Park and Albert Y. Kuo

Data Report No. 54

School of Marine Science/Virginia Institute of Marine Science
The College of William and Mary in Virginia
Gloucester Point, VA 23062

August 1994

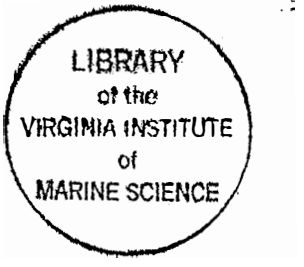
WATER QUALITY CONDITIONS

IN THE TIDAL RAPPAHANNOCK RIVER

: LONGITUDINAL AND DOME SURVEYS IN 1993

by

Kyeong Park and Albert Y. Kuo



Data Report No. 54

School of Marine Science/Virginia Institute of Marine Science
The College of William and Mary in Virginia
Gloucester Point, VA 23062

August 1994

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

This study was conducted as a part of the Hypoxia Project funded by the Virginia Chesapeake Bay Initiative Programs.

The field surveys described in this report would not have been possible without the contributions of many individuals. The dedication of Laboratory Specialist Samuel Wilson to all aspects of the surveys is gratefully acknowledged. We wish to thank William Shannon, Steven Snyder, William Stockhausen, Kevin Curling and Jian Shen for their enthusiastic participation in field surveys. We also wish to thank Captain Charles Machen and Mate Lewie Lawrence of R/V Langley for their excellent support in dome surveys. Many Thanks to Betty Salley, Grace Battisto and other individuals at the Nutrient Analysis Laboratory for sample analysis.

INTRODUCTION

Previous field surveys and modeling studies (Kuo et al. 1991; Park et al. 1993) indicated the presence of three different water quality regimes in the tidal Rappahannock River (Fig. 1), a western shore tributary of Chesapeake Bay:

: Region I - hypoxic conditions during summer in the bottom water between km 0-55

: Region II - high chlorophyll concentration between km 80-147

: Region III - waste water discharges from sewage treatment plants

To study the differences among these 3 reaches of the river, two types of field surveys were conducted during the summer of 1993: 1) longitudinal surveys in Region III and 2) benthic flux surveys using domes in Region I and II. This data report describes these field surveys and presents the data collected from them, consisting of two parts: Part I for longitudinal surveys and Part II for dome surveys. The analysis of the data will be presented in another special report.

PART I. LONGITUDINAL SURVEY

I-1. Introduction

Field surveys during the summer of 1990 and modeling studies using these field data (Kuo et al. 1991; Park et al. 1993) indicated that the water quality conditions in the upper 30 km reach from the fall line at Fredericksburg (176.5 km from the river mouth) are directly influenced by the waste water discharges from sewage treatment plants. These discharges introduce significant amounts of phosphorus into the water column and raise ambient concentrations of dissolved phosphate, PO4d, by a factor of three (Fig. I-1). With elevated PO4d concentrations in the water column, PO4d tends to sorb to the sediments, both suspended and bottom (Froelich 1988).

The flux of a particulate material to the bottom is quantified by:

$$F_C = C \cdot W \tag{1}$$

where F_C = downward flux (g m^{-2} day^{-1}); C = particulate concentration (g m^{-3}); W = settling velocity (m day^{-1}). If the concentration of particulate phosphorus increases, the flux of phosphorus to the bottom increases, even if the settling velocity remains constant.. A priori there is no particular evidence that the settling velocity would be significantly different between the upper 30 km reach and its downriver portion of the Rappahannock River. Then, there should be a longitudinal gradient with respect to the phosphorus enrichment in sediments, both suspended and bottom.

The above reasoning motivated a field program, which will be referred to as the longitudinal survey, over the upper 60 km reach of the tidal Rappahannock River during the summer of 1993. The data from these longitudinal surveys are presented in Part I of this data report. Chapter I-2 describes the sampling stations and Chapter I-3 describes the methodology, data acquisition and lab analysis. The entire data set is presented in tabular

format in Chapter I-4.

I-2. Sampling Stations

Seven sampling stations were selected from the upper 60 km reach of the tidal Rappahannock River (Table I-1 and Fig. I-2). The most upriver station, L6, is upriver of the fall line so that it represents the conditions in the fall line freshwater discharges. Station L0 is inside the shallow embayment, Portobago Bay (Fig. I-2), so that it represents the conditions in shallow water. The other five stations, L1 to L5, are in the main channel.

I-3. Methodology

I-3-1. Data Acquisition

Four surveys were conducted approximately once a month during the summer of 1993: May 6, June 8, July 6 and August 3. For all four surveys, water samples were taken from a 23-ft open boat using a Frautchii bottle. Water samples were taken from two depths at Stations L1 to L5 (Table I-1): surface (1 m below surface) and bottom (1 m above bottom). At Station L6, a Frautchii bottle was lowered from the bridge on US 1 to collect water samples. At the two surveys on June 8 and July 6, water samples were taken using a Frautchii bottle from mid-depth at Station L0. Suspended sediment concentration tends to be low during slack tide. Since the water samples were analyzed for suspended sediment concentrations, samples were taken near maximum ebb at each station proceeding from the most downriver station to upriver direction. The water samples were filtered within two hours of collection through a 47 mm Whatman GF/F glass fiber filter to separate the dissolved and particulate fractions: 13 mm Whatman GF/F glass fiber filters were used for total particulate carbon/nitrogen. The filters and filtrates were prepared for the parameters listed in Table I-2, stored in ice, brought back to, and analyzed at the Nutrient Analysis Laboratory (NAL), Virginia Institute of Marine Science.

For all four surveys, bottom sediment cores were taken using a Phleger gravity corer at Stations L1, L3 and L5. The oxic top portion of the sediment cores was removed and placed into a plastic test tube. The test tubes were stored in ice, brought back to the NAL, and analyzed for parameters listed in Table I-2.

In addition to the water and bottom sediment sampling, the longitudinal surveys also included the followings. At Stations L0 to L5, vertical profiles of water temperature and dissolved oxygen (DO) were obtained using a Applied MicroSystem CTD (Conductivity-Temperature-Depth) and a YSI (Yellow Strings Instrument) DO meter, respectively: all seven stations are upriver of saline estuarine portion of the river and thus salinity is zero. At two depths, surface and bottom, winkler bottle samples were taken using a Frautchii bottle and pH was measured using a pH meter (Beckman and Orion). The winkler bottle samples were analyzed for DO at the NAL to check the performance of the YSI DO meter and probe. Secchi disk depths were also recorded. At Station L6, which was accessed from the bridge on US 1, water temperature and pH were measured using a pH meter, and winkler bottle samples were taken for DO measurement. All parameters measured, either *in situ* or at the laboratory, are listed in Table I-2.

I-3-2. Laboratory Analysis

The water and bottom sediment samples were analyzed for the water quality parameters listed in Table I-2 at the NAL. The analytical methods, which are briefly described in this section, generally follow the methods in EPA (1979), NAL Procedures Manual (1994) and Standard Methods (1992).

A. Dissolved oxygen: Dissolved oxygen was measured using the Winkler titration method, and is reported in mass per unit volume of water (g m^{-3}).

B. Filter: The residue retained on the pre-weighted and pre-muffled filter was dried to a constant weight at 103 to 105°C to measure total suspended solid. Then, the filter was

further muffled to a constant weight at 500±50°C to measure total fixed solid. The weight lost on ignition is the total volatile solid. Total particulate carbon and total particulate nitrogen were measured using a Carlo Erba NA1500 C/N analyzer following the procedure in NAL Procedures Manual (1994), which is an adaptation of the method in Menzel & Vaccaro (1964). Total particulate phosphorus was measured using the method in Aspila et al. (1976), which muffles the filter followed by the extraction with hydrochloric acid. Particulate (sorbed) inorganic phosphorus was measured using the same method as total particulate phosphorus except that the filter was not muffled before extraction with acid. The extracts, after dilution, were analyzed for dissolved phosphate using a continuous flow analyzer. The filters for chlorophyll 'a' and phaeophytin were treated with $MgCO_3$ upon filtering, and then ground, extracted with 90% acetone and measured using a scanning spectrophotometer. All particulate parameters are reported in mass per unit volume of water ($g\ m^{-3}$) except chlorophyll 'a' and phaeophytin ($mg\ m^{-3}$).

C. Filtrate: Total dissolved nitrogen and total dissolved phosphorus were measured using alkaline persulfate digestion method, which is an adaptation of the method in D'Elia et al. (1977). Dissolved phosphate was measured using a colorimetric method. Ammonium was measured using a phenalytic method, and nitrite+nitrate was measured using a cadmium reduction method. All dissolved parameters, which were measured using continuous flow analyzers, are reported in mass per unit volume of water ($g\ m^{-3}$).

D. Bottom sediment: The sediment samples were dried to a constant weight at 103 to 105° C. Total solid was measured in percentage from the weight difference before and after drying at 103 to 105°C. Total fixed solid was measured in percentage from the weight difference before and after igniting to a constant weight at 500±50°C. Total solid and total fixed solid are reported in mass per mass of sediment (0.01 g g-1). All other parameters for sediment samples were measured using a known mass of dried sediment samples. The mass of total carbon and total nitrogen was measured by employing the same method used for total

particulate carbon/nitrogen for water column filters. The total inorganic phosphorus samples were directly extracted with hydrochloric acid. The total phosphorus samples were muffled in a furnace for approximately 2 hours at 550°C, and then the phosphorus was extracted with hydrochloric acid. The extracts, after dilution, were analyzed for dissolved phosphate using a continuous flow analyzer. Total carbon, total nitrogen, total phosphorus and total inorganic phosphorus are reported in mass per mass of total solid (mg g^{-1}).

I-4. Results

Table I-3 lists the concentrations of all parameters measured from the water and bottom sediment samples taken on May 6, 1993. Table I-4 lists the vertical profiles of temperature, DO and pH, and secchi disk depth for the survey on May 6, 1993. Tables I-5 and I-6 list the corresponding results for the longitudinal survey on June 8, 1993. Tables I-7 and I-8 list the corresponding results for the longitudinal survey on July 6, 1993. Tables I-9 and I-10 list the corresponding results for the longitudinal survey on August 4, 1993.

PART II. DOME SURVEY

II-1. Introduction

Previous modeling studies (Kuo et al. 1991; Park et al. 1993) indicated that relatively low benthic release of nutrients, NH4 and PO4d, is required for model calibration in the lower estuarine portion (Region I in Fig. 1), compared to the lower tidal freshwater portion (Region II), of the tidal Rappahannock River. This was surprising considering the hypoxic conditions during the summer in Region I. Low oxygen concentration in the overlying water has been known to enhance the benthic release of nutrients (Cerco 1989), although some observations suggested that the ammonium benthic release rate is probably controlled by some factor other than the overlying oxygen concentration (Fillos & Swanson 1975). Surveys measuring benthic fluxes of nutrients using domes, which will be referred to as the dome survey, were conducted in Regions I and II during the summer of 1993. The data from these dome surveys are presented in Part II of this data report. Chapter II-2 describes the sampling stations and Chapter II-3 describes the methodology. The entire data set is presented in tabular and graphic formats in Chapter II-4.

II-2. Sampling Stations

Three sampling stations were selected from the tidal Rappahannock River (Table II-1 and Fig. 1). At Station WV, the bottom water becomes hypoxic during summer when the water temperature increases. Station OH was chosen to represent Region II, which is characterized by high chlorophyll concentration. Station TA is between Regions I and II. Stations TA and OH were the deepest point at each cross-section, while Station WV was at the fringe of the main channel.

II-3. Methodology

Benthic fluxes were measured by deploying a dome to the water-sediment interface thereby entrapping a fixed volume of water in contact with a fixed sediment area. Flux of a substance into, or out of, the sediment was evaluated by measuring the change in substance concentration with respect to time. Domes used in the field surveys are described below, followed by the detailed procedure of dome deployment and subsequent sample withdrawal, the overall description of the field surveys, and lab analysis.

II-3-1. Dome Description

Hemispherical domes were used to measure benthic fluxes. The domes are about 0.46 m in diameter, and enclose 25.5 L of water and 1662 cm^2 of sediment area, thus giving the volume to bottom area ratio of 0.153 m. The domes are weighted to partially penetrate the sediment surface aided by a vertical metal flange around the bottom circumference and to isolate the interior from the surroundings (Fig. II-1). A lip around the bottom circumference of the domes prevents them from penetrating too deep into the sediment.

The dome, attached with two lines of rubber hose (length of 22 m and radius of 0.79 cm), forms a closed loop at the manifold (Fig. II-1). A pump (360 gallons per hour) attached inside the dome circulates water continuously within the system (dome and hose) at a rate of 8 L min^{-1}, which is equivalent to 0.68 m sec^{-1} in-hose velocity. Two more lines are attached to the dome: a rope to lower and lift the dome, and an electric wire to provide DC power to the pump. The manifold (Fig. II-1) has a YSI DO probe, a valve for sample withdrawal, and see-through hoses to examine the flow within the system (Fig. II-1). Through a duckbill valve at the top of the dome, ambient water equivalent to the sample volume withdrawn was allowed to enter the dome (Fig. II-1).

The dome with an open bottom so that the dome water is in contact with the sediment is referred to as a flux dome. Both the sediment-water exchange processes and the processes

occurring in the dome water contribute to the changes in substance concentrations in the flux dome. The dome with a sealed bottom so that the dome water is not in contact with the sediment, which is referred to as a control dome, was used to isolate and compensate for the processes occurring solely in the water column. The control domes were identical to the flux domes except the sealed bottom.

II-3-2. Dome Deployment and Sample Withdrawal

One of the more important results of the dome survey is that a protocol was established for dome deployment and sample withdrawal through trial and error. The procedure for deployment of three domes (two flux and one control domes) is described in detail below.

* go to a station on R/V Langley
* deploy a S4 current meter approximately 200 m away from the boat
* anchor the boat
  : when the current is about 1 m sec^{-1}, the seal of the domes on the sediment bottom tends to be broken if the boat drifts more than 4 to 5 meters
  : stable anchoring of the boat is critical for the success of the dome survey
  : we found that four-point mooring is minimal to ensure stable anchoring of R/V Langley
  : when anchoring the boat, to align the boat along the direction of main current helps to reduce the drift of the boat
* while anchoring the boat
  : calibrate the DO meter, pH meter and fluorometer
  : prepare CTD, with DO probe attached
* deploy a lead weight (about 300 lb) from the stern side of the boat, and maintain a vertical winch line from the boat to the weight
  : try to have the weight directly below the boat so that you can maintain the rubber

hose as vertical as possible

* make an open-loop for each of three domes
* lower each of three domes while divers guide it
  : in the order of flux dome, control dome and flux dome
  : for the control dome
    - fill it with surface water
    - at the bottom, divers shake it to get rid of air bubbles and then plug it
  : make sure not to apply force on either rubber hose or electric line but on the rope
* attach DO probes and seal the area around the probe with duct tape
* divers set the dome on the bottom
  : try to sit it horizontally
  : cover the domes with bottom sediment as much as possible (we found this very helpful to ensure the seal)
* as divers come up, they shackle the rope to the winch line at the bottom and the surface (Fig. II-1)
  : make sure to allow some slack on the hose between the dome and the bottom shackle
  : do not shackle the hose or electric line to the winch line
* after deploying all three domes, divers come out of the water
* lower the rubber hose into the water until the manifold is at the water surface
  : make sure the manifold is at the highest point of the system to force the air out
  : shaking the manifold while holding it in the water helps remove air bubbles
* while holding the manifold under water, attach and start a pump at one end of manifold, and then start the bottom pump, that is attached to the dome
* while holding the manifold under water, make a loose loop of extra hose and secure it
* flush the system with surface water for about 30 minutes
* while holding the manifold under water, close the system, then bring the manifold on

the deck and put in a water filled bucket

* closing the manifold is the starting point of the sampling, i.e., time zero sampling for each dome
  : inject 34 mL of dye (20,000 ppb) - since the total water volume within the system is about 34 L (25 L in the dome and 9 L in the hose), the dye concentration after complete mixing should be around 20 ppb.
  : collect DO winkler bottle samples (about 140 mL)
  : measure pH (about 10 mL)
  : withdraw 200 mL of dome water and filter it for total suspended solid and chlorophyll 'a', and nutrients
* For 6 hours or until DO in dome water becomes less than 1.5 g m^{-3}, whichever comes first, do the followings for each dome at hour 0.5, 1 and then every one hour (if substance concentration within the system changes rapidly, take samples more frequently and terminate the experiment earlier)
  : read DO meter at 15 min interval
  : withdraw winkler water sample for DO (about 140 mL)
  : measure pH and dye concentration (about 20 mL)
  : withdraw 150 mL of dome water for chlorophyll 'a', and nutrients
    - at the last sampling, take DO winkler samples first and then make duplicates for all parameters including total suspended solid
* the total volume of water withdrawn from the system is about 2.2 L for 6 hour sampling (excluding the last sampling), which is about 6% of total water volume within the system (34 L)
* post-calibrate all meters
* divers detach the domes from the winch line
* retrieve all gear including S4 current meter

II-3-3. Field Surveys

Three surveys per station were conducted during the summer of 1993 (Table II-2) using R/V Langley. The survey on May 17 at Station TA, which was conducted using two 18-ft open boats, lasted for three hours only. Not all surveys were successful as indicated in Table II-2. At each station, three domes (two flux domes and a control dome) were deployed following the procedure described in Section II-3-2. As shown in Table II-2, not all dome deployments were successful.

As soon as closing the system, the sampling at time zero was conducted. The subsequent sampling was conducted at hour 0.5, 1 and then every hour for 6 hours or until DO in dome water becomes less than 1.5 g m^{-3}, whichever comes first. When substance concentration within the system changes rapidly, samples were taken more frequently and the experiment lasted less than 6 hours. The sampling procedure from the domes is described in Section II-3-2. All parameters measured for the dome water are listed in Table II-3.

In addition to the dome sampling, the dome surveys also included the monitoring of the ambient water column conditions. At the beginning, mid-time and at the end of dome sampling, the followings were conducted for the ambient water column: for the surveys lasted shorter than 4 hours, water column sampling was conducted twice at the beginning and end of sampling. Vertical profiles of water temperature and salinity were obtained using a CTD. For the surface and bottom waters, pH was measured and winkler bottle samples were taken. For hypoxic/anoxic water column, vertical profiles were obtained using a YSI DO meter (e.g., July 21 survey at Station WV). Water samples were taken using a Frautchii bottle and filtered to separate the dissolved and particulate fractions. All filters and filtrates were frozen, brought back to the NAL and analyzed for the parameters listed in Table II-3.

A S4 current meter was deployed at a depth of 1 m above bottom near the dome site for the entire sampling period to obtain the current velocity of the ambient bottom water.

II-3-4. Laboratory Analysis

The dome and ambient water samples were analyzed for the water quality parameters listed in Table II-3 at the NAL using the same analytical methods described in Section I-3-2.

II-4. Results

Figures II-2 to II-4 and Table II-3 show the results for the dome survey at Water View on June 7, 1993. Figure II-2 shows the changes in dome water DO concentrations measured using YSI meters and their linear regression lines. Regression statistics, slope, y-intercept and coefficient of determination, are also listed in Fig. II-2. Some of initial and erroneous values were not included in regression analysis, and the regression lines are drawn through only those values included in regression analysis in Fig. II-2. Figures II-3 and II-4 show the vertical profiles of water column salinity and temperature, respectively. Table II-4 lists the concentrations of all parameters measured from the dome and ambient waters.

Figures II-5 to II-7 and Table II-5 show the results for the dome survey at Owl Hollow on July 19, 1993. Figure II-5 shows the changes in dome water DO concentrations measured using YSI meters and their linear regression lines. Figure II-6 shows the vertical profile of water column temperature: no salinity data from this freshwater station. Figure II-7 shows the bottom current speed. Table II-5 lists the concentrations of all parameters measured from the dome and ambient waters.

Figures II-8 to II-11 and Table II-6 show the results for the dome survey at Tappahannock on July 20, 1993. Figure II-8 shows the changes in dome water DO concentrations measured using YSI meters and their linear regression lines. Figures II-9 and II-10 show the vertical profiles of water column salinity and temperature, respectively. Figure II-11 shows the bottom current speed. Table II-6 lists the concentrations of all parameters measured from the dome and ambient waters.

Figures II-12 to II-16 and Table II-7 show the results for the dome survey at Water

View on July 21, 1993. Figure II-12 shows the changes in dome water DO concentrations measured using YSI meters and their linear regression lines. Figures II-13 and II-14 show the vertical profiles of water column salinity and temperature, respectively. Figure II-15 shows the bottom current speed. Figure II-16 shows the vertical profile of water column DO at this hypoxic station. Table II-7 lists the concentrations of all parameters measured from the dome and ambient waters.

Figures II-17 to II-19 and Table II-8 show the results for the dome survey at Owl Hollow on September 20, 1993. Figure II-17 shows the changes in dome water DO concentrations measured using YSI meters and their linear regression lines. Figure II-18 shows the vertical profile of water column temperature. Figure II-19 shows the bottom current speed. Table II-8 lists the concentrations of all parameters measured from the dome and ambient waters.

Figures II-20 to II-23 and Table II-9 show the results for the dome survey at Tappahannock on September 23, 1993. Figure II-20 shows the changes in dome water DO concentrations measured using YSI meters and their linear regression lines. Figures II-21 and II-22 show the vertical profiles of water column salinity and temperature, respectively. Figure II-23 shows the bottom current speed. Table II-9 lists the concentrations of all parameters measured from the dome and ambient waters.

Figures II-24 to II-28 and Table II-10 show the results for the dome survey at Water View on September 22, 1993. Figure II-24 shows the changes in dome water DO concentrations measured using YSI meters and their linear regression lines. Figures II-25 and II-26 show the vertical profiles of water column salinity and temperature, respectively. Figure II-27 shows the bottom current speed. Figure II-28 shows the vertical profile of water column DO. Table II-10 lists the concentrations of all parameters measured from the dome and ambient waters.

REFERENCES

Aspila, K.I., Agemian, H. and Chau, A.S.Y. 1976. A semi-automated method for the determination of inorganic, organic and total phosphate in sediments. Analyst, 101: 187-197.

Cerco, C.F. 1989. Measured and modelled effects of temperature, dissolved oxygen and nutrient concentration on sediment-water nutrient exchange. Hydrobiologia, 174: 185-194.

D'Elia, C.F., Steudler, P.A. and Corwin, N. 1977. Determination of total nitrogen in aqueous samples using persulfate digestion. Limnology and Oceanography, 22(1): 760-764.

EPA Methods for Chemical Analysis of Water and Wastes. 1979. EPA-600/4-79-020, Environmental Monitoring and Support Laboratory, US EPA.

Fillos, J. and Swanson, W.R. 1975. The release rate of nutrients from river and lake sediments. Water Pollution Control Federation, J., 47(5): 1032-1042.

Froelich, P.N. 1988. Kinetic control of dissolved phosphate in natural rivers and estuaries: a primer on the phosphate buffer mechanism. Limnology and Oceanography, 33(4, part 2): 649-668.

Kuo, A.Y., Neilson, B.J. and Park, K. 1991. A modeling study of the water quality of the upper tidal Rappahannock River. Special Report in Applied Marine Science and Ocean Engineering (SRAMSOE) #314, School of Marine Science/Virginia Institute of Marine Science (SMS/VIMS), The College of William & Mary, VA, 164 pp.

Menzel, D.W. and Vaccaro, R.F. 1964. The measurement of dissolved organic and particulate carbon in seawater. Limnology and Oceanography, 9(1): 138-142.

NAL Standard Operating Procedures Manual. 1994. Nutrient Analysis Laboratory, Department of Physical Sciences, SMS/VIMS, The College of William & Mary, VA.

Park, K., Kuo, A.Y. and Neilson, B.J. 1993. A modeling study of hypoxia and eutrophication in the tidal Rappahannock River. SRAMSOE #322, SMS/VIMS, The College of William and Mary, VA, 158 pp.

Standard Methods. 1992. Standard methods for the examination of water and wastewater (18th edition). American Public Health Association.

Table I-1. Field stations[a] for longitudinal surveys.

Station ID	km from river mouth	Depth[b] (m)	Remarks	Sampling Depth
L0	km 117.0	1.5 m	Portobago Bay	*[d]
L1[c]	km 117.7	4.6 m	Buoy 64	T and B[e]
L2	km 128.8	4.9 m	Buoy 79	T and B[e]
L3[c]	km 138.8	4.9 m	Buoy 88	T and B[e]
L4	km 157.0	5.0 m	Buoy 110	T and B[e]
L5[c]	km 167.5	5.2 m	Buoy 128	T and B[e]
L6	km 176.7		US 1 Bridge	*[f]

[a] Water samples were taken from seven stations L0 to L6.
[b] Water depth at low water.
[c] Bottom sediment core samples were taken from Stations L1, L3 and L5.
[d] Sampling at mid-depth at Station L0.
[e] T = 1 m below surface and B = 1 m above bottom.
[f] At Station L6, samples were collected by lowering a Frautchii bottle from the bridge on US 1.

Table I-2. Water quality parameters measured for water and bottom sediment samples collected by longitudinal surveys.

A. ***IN SITU*:**	
	dissolved oxygen (DO): YSI meter
	Temperature
	pH
	secchi disk depth
B. LABORATORY:	
1. Winkler Bottle:	dissolved oxygen (DO)
2. Filter:	total suspended solid (TSS)
	total fixed solid (TFS)
	total particulate carbon (TPC)
	total particulate nitrogen (TPN)
	total particulate phosphorus (TPP)
	particulate (sorbed) inorganic phosphorus (PO4p)
	chlorophyll 'a' (Chl)
	phaeophytin (Phaeop)
3. Filtrate:	total dissolved nitrogen (TDN)
	total dissolved phosphorus (TDP)
	dissolved phosphate (PO4d)
	ammonium (NH4)[a]
	nitrite+nitrate (NO23)[a]
4. Bottom Sediment:	total solid (STS)[b]
	total fixed solid (STFS)
	total carbon (STC)
	total nitrogen (STN)
	total phosphorus (STP)
	total inorganic phosphorus (SPO4p)

[a] These parameters were measured for samples from Station L0 only.
[b] The first character "S" indicates the parameters measured for the sediment cores.

Table I-3. Water quality parameters[a] measured for water and bottom sediment samples from the longitudinal survey on May 6, 1993.

A. Water Column[b]

ID	TPC	TPN	TDN	TPP	TDP	PO4p	PO4d	Chl	Phaeop	TSS	TFS
RMS Error (±)			0.0000	0.0041	0.0004	0.0041	0.0004		0.0000		0.0
DTL	0.097	0.0190	0.0260	0.0012	0.0020	0.0012	0.0006	1.9500	0.0000	1.4	0.0
L1 Top	1.813	0.2300	0.5648	0.0482	0.0147	0.0169	0.0057	17.6327	8.0025	38.0	23.2
L1 Bot	7.520	0.7520	0.5295	0.2322	0.0159	0.0976	0.0065	30.9720	9.6788	213.0	165.0
L2 Top	1.229	0.1400	0.7850	0.0450	0.0194	0.0137	0.0094	8.7790	3.5116	25.8	14.0
L2 Bot	4.808	0.4815	0.7003	0.1636	0.0247	0.0679	0.0129	9.4919	4.4536	129.3	91.5
L3 Top	1.092	0.1150	0.7011	0.0495	0.0241	0.0259	0.0112	3.7380	18.5031	26.0	11.0
L3 Bot	4.005	0.3750	0.7652	0.1555	0.0342	0.0464	0.0135	7.7430	0.3872	126.5	87.0
L4 Top	1.612	0.1720	0.6454	0.0488	0.0271	0.0178	0.0190	3.8448	0.1922	42.8	26.0
L4 Bot	3.428	0.3100	0.6716	0.1285	0.0312	0.0491	0.0204	3.4176	3.7594	89.5	55.0
L5 Top	1.544	0.1640	0.6179	0.0509	0.0171	0.0250	0.0080	7.2624	0.8715	35.0	20.8
L5 Bot	1.107	0.1450	0.5966	0.0504	0.0212	0.0168	0.0123	7.3692	0.3685	49.5	16.0
L6	5.435	0.5750	0.7809	0.1851	0.0300	0.0491	0.0129	11.2140	9.7188	150.0	109.0
blank	0.184	(0.0100)[d]	(0.0210)	0.0024	0.0035	0.0019	(0.0000)	(0.0000)	1.0317	(-1.2)	(-11.2)

B. Sediment[c]

ID	STC	STN	STP	SPO4p	STS	STFS
RMS Error (±)			0.0038	0.0038		
DTL	0.00	0.000	0.0000	0.0000	0.0000	0.0000
L1	10.81	0.880	0.4207	0.3282	46.2688	10.5687
L3	17.22	1.230	0.5346	0.3390	45.4598	13.5108
			0.5171			
replicate	21.98	1.755	0.6087	0.3465	41.0626	12.3381
L5	30.26	2.390	0.8114	0.4832	27.7725	23.3804
replicate	26.25	2.050	0.6750	0.4130	33.6359	10.8774

[a] The symbols for the parameters are explained in Table I-2.
[b] Water column parameters are in g m^{-3} except Chl and Phaeop in mg m^{-3}.
[c] Sediment parameters are in mg g^{-1} for STC, STN, STP and SPO4p and in % (0.01 g g^{-1}) for STS and STFS.
[d] The values in parenthesis are lower than DTL (detection limit).

Table I-4. Total water depth and secchi disk depth, and vertical profiles of temperature, DO and pH from the longitudinal survey on May 6, 1993.

Station ID (time)[a]	Total Depth (m)	Secchi Depth (m)	Sampling Depth (m)	Temperature (°C)	DO ($g\ m^{-3}$) YSI	DO ($g\ m^{-3}$) Winkler	pH
L1	5.2	0.55	1.0	20.028	8.70	8.47	7.79
(09:32)			2.0	19.984	8.50		
			3.0	19.981	8.55		
			4.0	19.980	8.55		
			4.5	19.981	8.50	8.35	7.39
L2	5.2	0.80	1.0	19.826	7.70	7.51	7.40
(10:30)			2.0	19.780	7.65		
			3.0	19.771	7.60		
			4.0	19.774	7.50		
			4.5	19.771	7.60	7.35	7.48
L3	4.9	0.80	1.0	20.383	7.60	7.49	7.39
(11:02)			2.0	20.353	7.55		
			3.0	20.303	7.50		
			4.0	20.295	7.50		
			4.5	20.293	7.50	7.31	7.51
L4	6.1	0.50	1.0	20.788	7.65	7.47	7.63
(11:56)			2.0	20.784	7.70		
			3.0	20.774	7.60		
			4.0	20.774	7.70		
			5.0	20.773	7.65		
			5.4	20.774	7.65	7.49	7.65
L5	6.1	0.40	1.0	19.708	8.70	8.53	7.61
(12:35)			2.0	19.712	8.65		
			3.0	19.705	8.60		
			4.0	19.724	8.60		
			5.0	19.719	8.60		
			6.0	19.721	8.55	8.53	7.65
L6				21.900		8.69	7.58
(12:30)							

[a] in daylight savings time.

Table I-5. Water quality parameters[a] measured for water and bottom sediment samples from the longitudinal survey on June 8, 1993.

A. Water Column[b]

ID	TPC	TPN	TDN	TPP	TDP	PO4p	PO4d	Chl	Phaeop	TSS	TFS
RMS Error (±)					0.0008		0.0022		0.0000		0.0
DTL	0.0970	0.0190	0.0260	0.0012	0.0020	0.0012	0.0006	0.9500	0.0000	2.0	0.0
L0	1.5560	0.2172	0.6086	0.0668	0.0223	0.0287	0.0101	28.5957	6.9901	51.0	40.0
L1 Top	1.3872	0.2212	0.5970	0.0460	0.0181	0.0246	0.0141	13.4568	11.6626	32.4	25.2
L1 Bot	2.0736	0.2976	0.6709	0.0587	0.0189	0.0265	0.0141	23.3358	13.6330	40.6	32.4
L2 Top	1.3367	0.2104	0.6879	0.0343	0.0170	0.0106	0.0114	13.7452	3.7487	23.0	17.2
L2 Bot	1.7863	0.2412	0.6509	0.0621	0.0134	0.0263	0.0111	15.6248	7.2442	47.4	9.6
L3 Top	1.3691	0.1876	0.6802	0.0342	0.0177	0.0150	0.0121	13.8413	3.3834	21.6	16.0
L3 Bot	1.4790	0.1915	0.6684	0.0800	0.0143	0.0322	0.0097	13.0723	9.2959	68.4	57.6
L4 Top	0.9387	0.1210	0.8406	0.0296	0.0185	0.0079	0.0090	6.2371	1.4034	14.0	12.4
L4 Bot	1.2375	0.1558	0.7802	0.0326	0.0168	0.0112	0.0087	13.8413	(-0.9228)[d]	22.0	8.0
L5 Top	0.7367	0.0925	0.7787	0.0116	0.0181	0.0052	0.0163	2.3122	1.2645	6.1	3.6
L5 Bot	0.6831	0.0840	0.8156	0.0227	0.0236	0.0099	0.0168	3.0758	0.1538	12.8	10.0
L6	0.8421	0.0960	0.6922	0.0168	0.0160	0.0073	0.0084	2.8836	5.1905	21.4	16.4

	NH4	NO23
RMS Error (±)	0.0024	0.0014
DTL	0.0015	0.0008
L0	0.0154	0.2710

B. Sediment[c]

ID	STC	STN	STP	SPO4p	STS	STFS
RMS Error (±)			0.0047	0.0047		
DTL	0.00	0.00	0.0000	0.0000	0.0000	0.0000
L1	8.68	0.86	0.4929	0.4610	50.3859	5.7225
			0.3428			
replicate	9.2	0.81	0.4528	0.3587	50.0384	5.0851
			0.3652			
L3	27.37	1.74	0.6412	0.4225	47.6701	8.9433
replicate	22.52	1.78	0.3851	0.4306	55.7894	8.2675
L5	12.18	1.17	0.4625	0.2642	51.1373	4.7631
replicate	7.21	0.70	0.3226	0.1664	67.1606	3.0858
replicate	12.29	1.11	0.6714	0.2311	54.5942	4.4036

[a, b, c & d] see Table I-3.

Table I-6. Total water depth and secchi disk depth, and vertical profiles of temperature, DO and pH from the longitudinal survey on June 8, 1993.

Station ID (time)[a]	Total Depth (m)	Secchi Depth (m)	Sampling Depth (m)	Temperature (°C)	DO (g m^{-3}) YSI	DO (g m^{-3}) Winkler	pH
L0 (09:30)	1.2	0.3	0.6	24.0	7.20	7.12	7.86
L1 (10:12)	5.5	0.4	1.0	23.75	7.80	7.76	7.80
			2.0	23.75	7.25		
			3.0	23.75	7.20		
			4.0	23.75	7.15		
			4.5	24.00	7.10	7.04	7.74
L2 (11:05)	6.5	0.5	1.0	24.00	7.30	7.32	7.64
			2.0	24.00	7.10		
			3.0	24.00	7.00		
			4.0	24.00	7.00		7.49
			5.0	24.00	6.80		
			5.5	24.00	6.80	6.93	7.49
L3 (11:45)	6.0	0.4	1.0	24.00	8.65	8.64	
			2.0	23.50	8.10		
			3.0	23.50	8.00		
			4.0	23.50	8.00		
			5.0	23.50	7.95	7.88	7.49
L4 (12:30)	6.0	0.9	1.0	23.00	8.20	8.54	7.66
			2.0	23.00	8.00		
			3.0	22.75	7.90		
			4.0	22.75	7.85		
			5.0	22.75	7.80	8.00	7.52

[a] in daylight savings time.

Table I-6. (continued.)

Station ID (time)[a]	Total Depth (m)	Secchi Depth (m)	Sampling Depth (m)	Temperature (°C)	DO (g m^{-3}) YSI	DO (g m^{-3}) Winkler	pH
L5 (13:00)	6.5	1.1	1.0	24.50	8.10	8.34	7.70
			2.0	23.50	7.80		
			3.0	23.00	7.70		
			4.0	23.00	7.60		
			5.0	23.00	7.55	8.20	7.55
L6 (12:45)						8.40	7.93

Table I-7. Water quality parameters[a] measured for water and bottom sediment samples from the longitudinal survey on July 6, 1993.

A. Water Column[b]

ID	TPC	TPN	TDN	TPP	TDP	PO4p	PO4d	Chl	Phaeop	TSS	TFS
RMS Error (±)			0.0000	0.0073	0.0000	0.0073	0.0002		0.0000		0.0
DTL	0.0970	0.0190	0.0260	0.0012	0.0020	0.0012	0.0006	0.9500	0.0000	2.0	0.0
L0	4.4890	0.5940	0.4200	0.0526	0.0224	0.0180	0.0068	55.1088	9.9885	37.5	17.5
L1 Top	4.2197	0.5230	0.3810	0.0271	0.0184	0.0239	0.0074	36.0183	30.3312	30.3	16.5
L1 Bot	8.6820	0.6760	0.4730	0.0699	0.0159	0.0447	0.0091	39.5160	29.6370	99.0	89.0
L2 Top	3.2140	0.4530	0.4530	0.1454	0.0134	0.0149	0.0044	49.6353	19.8541	20.0	6.5
L2 Bot	5.7760	0.5970	0.5580	0.1092	0.0209	0.0243	0.0068	41.9991	14.1270	45.5	28.0
L3 Top	2.5530	0.3390	0.8195	0.0384	0.0140	0.0117	0.0051	33.6420	8.2236	27.5	8.0
L3 Bot	3.3500	0.4260	0.7870	0.0636	0.0139	0.0180	0.0058	(-6.6216)	101.6416	45.5	23.5
L4 Top	2.0877	0.2570	0.9310	0.0288	0.0154	0.0068	0.0041	20.9328	8.3731	11.3	5.0
L4 Bot	2.3575	0.2825	0.8850	0.0282	0.0120	0.0125	0.0058	28.5156	5.6070	27.5	14.5
L5 Top	1.7980	0.1120	1.1530	0.0164	0.0298	0.0070	0.0182	3.7647	6.7765	11.0	4.0
L5 Bot	2.1880	0.1920	1.0160	0.0227	0.0238	0.0070	0.0176	3.9249	4.3174	17.5	9.0
L6	0.7170	0.0550	1.0350	0.0047	0.0293	0.0022	0.0162	1.5272	2.7490	3.2	1.8
blank	0.3320	0.0240	(0.0050)[d]	(0.0001)	0.0040	(0.0001)	0.0058	3.8181	4.1999	(0.0)	0.0

	NH4	NO23
RMS Error (±)	0.0008	0.0023
DTL	0.0015	0.0008
L0	0.0063	0.0025

B. Sediment[c]

ID	STC	STN	STP	SPO4p	STS	STFS
RMS Error (±)			0.0039	0.0039		
DTL	0.00	0.00	0.0000	0.0000	0.0000	0.0000
L1	20.165	1.71	0.7412	0.4737	43.6719	7.3658
				0.5178		
replicate	25.74	2.25	0.9239	0.6342	38.6277	9.9048
				0.6189		
L3	12.36	1.13	0.5477	0.3793	49.2849	5.3718
replicate	17.39	1.34	0.5845	0.3976	50.9252	6.3904
L5	1.87	0.21	0.2274	0.1215	76.8790	1.0719

[a, b, c & d] see Table I-3.

Table I-8. Total water depth and secchi disk depth, and vertical profiles of temperature, DO and pH from the longitudinal survey on July 6, 1993.

Station ID (time)[a]	Total Depth (m)	Secchi Depth (m)	Sampling Depth (m)	Temperature (°C)	DO (g m^{-3}) YSI	DO (g m^{-3}) Winkler	pH
L0	1.3	0.4	0.5	30.141	7.00	7.57	7.81
(09:19)			1.2	29.817	5.40		
L1	5.5	0.4	1.0	30.022	7.10	8.13	7.51
(09:56)			2.0	29.834	6.05		
			3.0	29.824	6.00		
			4.0	29.824	6.00		
			5.0	29.824	5.90	6.34	7.35
L2	5.1	0.5	1.0	29.847	7.20	8.40	7.68
(10:35)			2.0	29.804	6.90		
			3.0	29.800	6.85		
			4.0	29.792	6.80		
			4.5	29.787	6.80	7.08	7.30
L3	4.9	0.6	1.0	29.977	7.30	7.61	7.21
(11:19)			2.0	29.723	6.70		
			3.0	29.717	6.50		
			4.0	29.689	6.45	6.53	7.03
L4	4.0	0.7	1.0	29.256	7.35	8.72	7.98
(12:07)			2.0	28.673	6.80		
			3.0	28.643	6.75		
			3.5	28.627	6.75	7.04	7.09
L5	6.3	0.7	1.0	29.412	6.15	6.40	7.04
(12:39)			2.0	28.931	5.70		
			3.0	28.901	5.70		
			4.0	28.834	5.70		
			5.0	28.817	5.75		
			5.5	28.827	6.20	5.79	6.91
L6				32.400		8.14	7.78
(12:30)							

[a] in daylight savings time.

Table I-9. Water quality parameters[a] measured for water and bottom sediment samples from the longitudinal survey on August 4, 1993.

A. Water Column[b]

ID	TPC	TPN	TDN	TPP	TDP	PO4p	PO4d	Chl	Phaeop	TSS	TFS
RMS Error (±)				0.0000		0.0000	0.0002		0.0000		0.0
DTL	0.0970	0.0190	0.0260	0.0012	0.0020	0.0012	0.0006	0.9500	0.0000	2.0	0.0
L1 Top	3.8150	0.5910	0.3574	0.1028	0.0231	0.0549	0.0080	46.4580	7.7430		
L1 Bot	5.1260	0.6940	0.3450	0.1160	0.0227	0.0601	0.0071	36.0450	24.5106	68.0	43.0
L2 Top	3.3380	0.5085	0.2982	0.1200	0.0160	0.0647	0.0064	38.9820	15.5928	77.0	51.0
L2 Bot	3.3280	0.4920	0.4200	0.1072	0.0203	0.0370	0.0067	54.2010	16.2603		
L3 Top	2.4460	0.3120	0.4036	0.0642	0.0115	0.0258	0.0056	15.6996	11.7747	32.0	16.0
L3 Bot	2.0390	0.2940	0.4164	0.0630	0.0153	0.0262	0.0051	28.6224	21.4668	33.0	14.0
L4 Top	2.3880	0.3500	0.5971	0.0596	0.0159	0.0236	0.0031	40.0500	16.0200	25.0	9.0
L4 Bot	2.5400	0.3360	0.5655	0.0589	0.0123	0.0285	0.0034	36.8460	56.0059	90.0	72.0
L5 Top	1.0085	0.1680	0.6985	0.0413	0.0423	0.0178	0.0305	15.1656	3.4123	13.0	3.5
L5 Bot	1.4345	0.2015	0.6496	0.0276	0.0416	0.0187	0.0322	29.9040	(-3.9249)[d]	6.5	3.5
L6	0.2992	0.0330	0.4127	0.0129	0.0179	0.0073	0.0078	1.9758	2.1734		
blank	0.2940	0.0240	0.0878	0.0020	0.0054	0.0016	0.0015	7.4760	2.9904	2.0	1.0

B. Sediment[c]

ID	STC	STN	STP	SPO4p	STS	STFS
RMS Error (±)			0.0072	0.0072		
DTL	0.00	0.00	0.0000	0.0000	0.0000	0.0000
L1	33.54	2.47	0.7191	0.4587	26.0637	9.5880
replicate	15.01	2.28	0.7125	0.4701	25.8574	9.8033
L3	10.21	1.58	0.5788	0.3355	48.1966	8.4261
replicate	27.12	2.01	0.5723	0.3481	51.5190	9.1584
				0.2820		
L5	13.03	0.15	0.2273	0.1356	70.7204	1.3664
				0.1472		

[a, b, c & d] see Table I-3.

Table I-10. Total water depth and secchi disk depth, and vertical profiles of temperature, DO and pH from the longitudinal survey on August 3, 1993.

Station ID (time)[a]	Total Depth (m)	Secchi Depth (m)	Sampling Depth (m)	Temperature (°C)	DO ($g\ m^{-3}$) YSI	DO ($g\ m^{-3}$) Winkler	pH
L1	4.5	0.3	1.0	28.566	5.70	5.90	8.04
(08:40)			2.0	28.516	5.60		
			3.0	28.374	5.60		
			4.0	28.354	5.50	5.61	7.69
L2	4.75	0.3	1.0	28.905	5.45	5.49	7.46
(09:21)			2.0	28.895	5.40		
			3.0	28.894	5.40		
			3.75	28.894	5.70	5.28	7.38
L3	4.0	0.6	1.0	29.276	6.55	6.79	7.47
(10:06)			2.0	29.262	6.50		
			3.0	29.258	6.45	6.79	7.38
L4	6.5	0.6	1.0	28.922	7.40	7.49	7.65
(10:58)			2.0	28.892	7.35		
			3.0	28.863	7.30		
			4.0	28.866	7.20		
			5.0	28.864	7.30	7.47	7.68
L5	5.5	0.8	1.0	28.279	5.85	5.84	7.45
(11:24)			2.0	28.282	5.80		
			3.0	28.279	5.80		
			4.0	28.298	5.90		
			4.5	28.303	5.90	5.86	7.35
L6				27.300		7.19	8.16
(11:30)							

[a] in daylight savings time.

Table II-1. Field stations for dome surveys.

Station ID	km from river mouth	Depth[a] (m)	Remarks
WV	km 35.4	12.0 m	Water View (Region I)
TA	km 65.8	6.0 m	Tappahannock (between Regions I and II)
OH	km 107.6	10.0 m	Owl Hollow (Region II)

[a] Water depth at low water.

Table II-2. Dome survey dates for each station in summer of 1993.

Station ID	Date		
WV	June 7[a,1]	July 21[b,1]	September 22[2]
TA	*[c]	July 20[1]	September 23[2]
OH	*[c]	July 19[2]	September 20[2]

[a] No data from current meter.
[b] Anoxic bottom water.
[c] Unsuccessful survey: no data are available.
[n] n = 1 or 2 indicates the number of flux domes for data collection.

Table II-3. Parameters measured for dome and ambient waters collected by dome surveys.

A. DOME:	
1. *In Situ*	dissolved oxygen (DO): YSI meter
	Temperature
	dye concentration
	pH
2. Winkler Bottle	dissolved oxygen (DO)
3. Filter	total suspended solid (TSS)[a]
	total dissolved nitrogen (TDN)
	total dissolved phosphorus (TDP)
	chlorophyll 'a' (Chl)
	phaeophytin (Phaeop)
4. Filtrate	ammonium (NH4)
	nitrite+nitrate (NO23)
	dissolved phosphate (PO4d)
B. WATER COLUMN[b]	
1. *In Situ*	dissolved oxygen (DO): YSI meter
	Temperature
	pH
2. Winkler Bottle	dissolved oxygen (DO)
3. Filter	total suspended solid (TSS)[c]
	total dissolved nitrogen (TDN)
	total dissolved phosphorus (TDP)
	chlorophyll 'a' (Chl)
	phaeophytin (Phaeop)
4. Filtrate	ammonium (NH4)
	nitrite+nitrate (NO23)
	dissolved phosphate (PO4d)

[a] TSS for the dome water was measured at time 0 and at the last sampling.

[b] The water column was monitored at the beginning, mid-time and at the end of sampling. For the survey lasted shorter than 4 hours, the water column sampling was conducted twice at the beginning and end of sampling.

[c] TSS for the water column was measured only for the bottom water.

Table II-4. Water quality parameters[a,b] measured for dome and ambient waters from the dome survey at Water View on June 7, 1993.

hr	min	Time	DO	TDN	NH4	NO23	TDP	PO4d	Chl	Phaeop	pH	dye	TSS
RMS Error (±)				0.0000	0.0022	0.0014	0.0000	0.0022		0.000			
DTL			0.080	0.0260	0.0015	0.0008	0.0020	0.0006	0.950	0.000			2.0
Blank				0.0616	0.0025	0.0055	(0.0008)	0.0023	7.690	(-2.307)[b]			(1.5)
Control Dome													
15	45	0.0											
15	50	0.083	6.048	0.6556	0.0591	0.0748	0.0092	0.0046	16.154	10.984	8.60	21.0	37.5
16	30	0.75	9.949	0.7388	0.0829	0.0811	0.0074	0.0063	14.845	8.016	8.79	20.0	
17	0	1.25	7.900	0.7867	0.0894	0.0776	0.0052	0.0050	10.974	12.071	8.56	19.0	
18	0	2.25	7.545	0.9613	0.0997	0.0790	0.0096	0.0053	13.457	3.028	8.64	18.0	
19	0	3.25	11.722	1.0928	0.1130	0.0790	0.0105	0.0053	9.932	10.926	8.67	18.0	
20	0	4.25	6.836	1.1081	0.1156	0.0776	0.0123	0.0046	3.791	17.440	8.72	18.0	
21	0	5.25	6.107	1.5350	0.1227	0.0776	0.0140	0.0073	11.374	9.858	8.68	18.0	
22	0	6.25	5.595	1.5905	0.1292	0.0698	0.0103	0.0040	13.884	10.333	8.91	18.0	23.0
Flux Dome A													
15	50	0.083	7.210	0.6681	0.1468	0.0592	0.0162	0.0104	18.824	7.529	8.74	18.0	72.0
16	30	0.75	7.388	0.8527	0.2181	0.0564	0.0193	0.0134	3.845	23.069	9.05	18.5	
17	0	1.25	6.087	0.9877	0.2807	0.0599	0.0184	0.0158	15.059	11.294	9.13	18.0	
18	0	2.25	5.752	1.0107	0.3702	0.0592	0.0185	0.0182	11.134	12.247	9.22	18.0	
19	0	3.25	5.812	1.2269	0.4321	0.0578	0.0263	0.0216	11.454	12.600	9.29	17.5	
20	0	4.25	5.358	1.5024	0.5411	0.0564	0.0294	0.0253	10.253	20.847	9.24	18.0	
21	0	5.25	4.314	1.6790	0.7268	0.0536	0.0329	0.0294	10.333	23.421	9.18	18.0	
22	0	6.25	3.920	1.7452	0.6237	0.0536	0.0353	0.0348	19.091	7.636	9.38	18.0	44.0
Water Column													
14	59	top	8.806	0.4290	0.0231	0.0677	0.0079	0.0063	7.583	8.341	8.12		
		bot	2.482	0.7008	0.3599	0.1341	0.0085	0.0063	9.532	21.606	8.10		103.5
17	2	top	9.259	0.4028	0.0128	0.0620	0.0096	0.0057	10.680	5.767	8.18		
		bot	3.979	0.7612	0.3172	0.1341	0.0109	0.0063	16.073	6.429	8.16		
20	44	top	9.889	0.3397	0.0069	0.0168	0.0136	0.0057	7.583	4.802	8.15		
		bot	4.728	0.5327	0.1748	0.1087	0.0057	0.0050	9.532	12.709	7.64		32.0

[a] The symbols for the parameters are explained in Table II-3.
[b] Values are in g m^{-3} except Chl and Phaeop in mg m^{-3} and dye in ppb (pH is unitless).
[c] The values in parenthesis are lower than DTL (detection limit).

Table II-5. Water quality parameters[a,b] measured for dome and ambient waters from the dome survey at Owl Hollow on July 19, 1993.

hr	min	Time	DO	TDN	NH4	NO23	TDP	PO4d	Chl	Phaeop	pH	dye	TSS
RMS Error (±)				0.0000	0.0007	0.0000	0.0000	0.0011		0.000			
DTL			0.080	0.0260	0.0015	0.0008	0.0020	0.0006	0.950	0.000			2.0
Blank				0.0901	0.0016	(0.0000)[c]	0.0054	(0.0005)	(0.000)	(0.000)			5.0
Control Dome													
16	45	0.0	9.910	0.3528	0.0226	0.0036	0.0209	0.0137	31.168	15.195	8.34	18.0	57.5
17	15	0.5	8.259	0.3194	0.0131	0.0024	0.0189	0.0137	29.477	14.370	8.71	16.0	
17	45	1.0	8.398	0.3762	0.0096	0.0036	0.0209	0.0143	25.605	30.726	8.90	16.0	
18	45	2.0	9.353	0.4288	0.0119	0.0024	0.0234	0.0156	36.125	12.151	8.91	15.0	
19	45	3.0	8.318	0.4624	0.0110	0.0048	0.0238	0.0156	30.758	14.995	9.05	14.5	
20	45	4.0	7.960	0.5070	0.0203	0.0048	0.0229	0.0156	22.909	14.509	9.02	13.0	
21	45	5.0	7.463	0.5465	0.0086	0.0048	0.0283	0.0156	28.836	19.104	9.00	12.0	
22	45	6.0	9.453	0.5962	0.0079	0.0048	0.0266	0.0162	26.486	11.919	9.00	11.5	37.75
Flux Dome A													
16	45	0.0	9.055	0.4986	0.0600	0.0060	0.0341	0.0288	37.380	30.652	7.99	17.5	89.0
17	15	0.5	7.861	0.4927	0.0726	0.0048	0.0344	0.0420	36.045	39.650	8.69	15.5	
17	45	1.0	6.348	0.3932	0.0726	0.0048	0.0377	0.0312	37.113	33.031	9.04	15.0	
18	45	2.0	6.567	0.4271	0.1007	0.0036	0.0372	0.0324	43.254	(-2.884)	9.05	14.5	
19	45	3.0	6.746	0.5017	0.1194	0.0048	0.0412	0.0330	19.758	18.968	9.16	14.5	
20	45	4.0	6.826	0.5981	0.1451	0.0048	0.0451	0.0330	36.312	14.525	8.97	13.0	
21	45	5.0	7.582	0.5734	0.1614	0.0048	0.0466	0.0342	39.650	(-1.802)	8.75	12.0	
22	45	6.0	7.045	0.5829	0.1878	0.0066	0.0414	0.0324	28.703	16.372	9.06	11.5	47.75

[a] The symbols for the parameters are explained in Table II-3.

[b] Values are in g m^{-3} except Chl and Phaeop in mg m^{-3} and dye in ppb (pH is unitless).

[c] The values in parenthesis are lower than DTL (detection limit).

Table II-5. (continued.)

hr	min	Time	DO	TDN	NH4	NO23	TDP	PO4d	Chl	Phaeop	pH	dye	TSS
RMS Error (±)				0.0000	0.0007	0.0000	0.0000	0.0011		0.000			
DTL			0.080	0.0260	0.0015	0.0008	0.0020	0.0006	0.950	0.000			2.0
Flux Dome B													
16	45	0.0	8.617	0.3252	0.0612	0.0048	0.0288	0.0198	29.263	27.069	8.70	17.0	59.5
17	15	0.5	7.104	0.2798	0.0437	0.0048	0.0293	0.0204	36.579	6.950	8.92	15.5	
17	45	1.0	7.821	0.3242	0.0577	0.0048	0.0303	0.0216	35.324	14.130	9.05	15.0	
18	45	2.0	7.283	0.3496	0.0577	0.0048	0.0313	0.0228	32.442	12.976	9.10	14.0	
19	45	3.0	7.065	0.4642	0.0820	0.0084	0.0352	0.0234	22.909	19.854	9.10	13.5	
20	45	4.0	6.945	0.4433	0.1138	0.0084	0.0323	0.0234	36.045	4.325	9.12	12.0	
21	45	5.0	5.851	0.5108	0.1030	0.0084	0.0347	0.0234	27.982	11.193	9.07	10.0	
22	45	6.0	6.507	0.4655	0.1224	0.0072	0.0338	0.0240	20.559	12.600	9.03	9.0	30.0
Water Column													
17	10	top	9.612	0.3923	0.0072	0.0012	0.0178	0.0029	29.263	29.629	8.00		
		bot	9.572	0.2855	0.0049	0.0012	0.0173	0.0029	39.650	20.906	7.83		47.50
19	58	top	8.000	0.4177	0.0063	0.0012	0.0187	0.0035	34.363	24.436	8.43		
		bot	8.736	0.3210	0.0061	(0.0000)	0.0186	0.0029	31.960	7.812	8.07		
22	50	top	7.781	0.2764	0.0086	0.0012	0.0186	0.0029	30.331	17.440	7.85		
		bot	8.338	0.3884	0.0072	0.0036	0.0211	0.0107	15.272	32.836	7.76		54.5

Table II-6. Water quality parameters[a,b] measured for dome and ambient waters from the dome survey at Tappahannock on July 20, 1993.

hr	min	Time	DO	TDN	NH4	NO23	TDP	PO4d	Chl	Phaeop	pH	dye	TSS
RMS Error (±)				0.0000	0.0007	0.0000	0.0000	0.0011		0.000			
DTL			0.080	0.0260	0.0015	0.0008	0.0020	0.0006	0.950	0.000			2.0
Blank				0.0440	0.0072	0.0024	0.0055	0.0023	(0.000)[c]	(0.000)			3.5
Control Dome													
18	30	0.0	7.463	0.3440	(0.0002)	0.0072	0.0209	0.0150	7.529	3.012	8.03	19.0	44.5
19	0	0.5	7.224	0.3440	0.0156	0.0072	0.0209	0.0143	15.166	0.758	8.05	19.0	
19	30	1.0	7.323	0.3680	0.0133	0.0060	0.0173	0.0137	7.529	0.377	8.16	18.0	
20	30	2.0	7.522	0.4040	0.0250	0.0060	0.0278	0.0143	10.493	(-3.148)	8.28	17.0	
21	30	3.0	6.766	0.4220	0.0180	0.0072	0.0243	0.0156	14.845	(-7.052)	8.34	16.0	
22	30	4.0	8.159	0.4900	0.0189	0.0072	0.0392	0.0162	26.540	(-15.924)	8.43	15.0	
23	30	5.0	8.975	0.4880	0.0107	0.0054	0.0243	0.0162	13.070	(-13.745)	8.40	15.0	52.75
Flux Dome A													
18	30	0.0	6.428	0.4166	0.3203	0.0096	0.0263	0.0222	16.666	(-5.000)	8.13	19.5	68.5
19	0	0.5	6.010	0.5051	0.3857	0.0084	0.0293	0.0240	11.054	(-0.737)	8.11	18.0	
19	30	1.0	6.010	0.6210	0.4914	0.0084	0.0387	0.0264	7.156	30.417	8.27	17.5	
20	30	2.0	5.134	1.1005	0.5661	0.0084	0.0347	0.0300	11.534	(-3.460)	8.30	16.0	
21	30	3.0	4.458	0.9007	0.6674	0.0084	0.0338	0.0318	3.845	4.229	8.34	16.0	
22	30	4.0	4.557	1.0156	0.7406	0.0084	0.0397	0.0330	(0.000)	7.233	8.39	15.0	
23	30	5.0	4.279	1.2468	0.7990	0.0084	0.0323	0.0333	9.265	(-2.243)	8.34	15.0	30.0
Water Column													
18	51	top	8.875	0.1673	0.0096	0.0024	0.0224	0.0095	3.925	4.317	7.93		
		bot	6.388	0.1739	0.0329	0.0048	0.0199	0.0125	14.952	(-9.719)	7.66		44.0
23	25	top	9.453	0.1484	0.0133	0.0036	0.0065	0.0059	7.743	(-2.323)	8.19		
		bot	9.293	0.1382	0.0072	0.0024	0.0149	0.0059	10.733	(-8.229)	7.94		24.5

[a] The symbols for the parameters are explained in Table II-3.

[b] Values are in g m^{-3} except Chl and Phaeop in mg m^{-3} and dye in ppb (pH is unitless).

[c] The values in parenthesis are lower than DTL (detection limit).

Table II-7. Water quality parameters[a,b] measured for dome and ambient waters from the dome survey at Water View on July 21, 1993.

hr	min	Time	DO	TDN	NH4	NO23	TDP	PO4d	Chl	Phaeop	pH	dye	TSS
RMS Error (±)				0.0000	0.0007	0.0000	0.0000	0.0011		0.000			
DTL			0.080	0.0260	0.0015	0.0008	0.0020	0.0006	0.950	0.000			2.0
Blank				(0.0080)[c]	0.0016	0.0024	0.0025	0.0017	(0.000)	(0.000)			3.0
Control Dome													
17	0	-0.5	7.700	0.1760	0.0096	0.0024	0.0645	0.0065	9.943	0.994	8.11		
17	30	0.0	6.010	0.1450	0.0792	0.0048	0.0352	0.0168	3.845	4.229	8.07	20.0	31.50
18	0	0.5	5.791	0.2360	0.0797	0.0036	0.0278	0.0180	7.957	(-2.387)	8.11	19.5	
19	0	1.5	5.950	0.2950	0.0820	0.0036	0.0402	0.0174	7.529	(-2.259)	8.16	18.5	
19	30	2.0	6.010	0.3040	0.0820	0.0084	0.0570	0.0228	3.738	6.728	8.10	17.0	
20	0	2.5	5.174	0.3000	0.0740	0.0084	0.0372	0.0162	3.978	7.161	8.16	16.5	
20	30	3.0	5.134								8.18	16.0	
21	0	3.5	5.492	0.3920	0.0680	0.0084	0.0313	0.0168	3.471	8.678	8.21	16.0	
22	0	4.5	5.035	0.2925	0.0558	0.0060	0.0281	0.0168	3.738	2.990	8.23	15.5	16.50
Flux Dome A													
17	0	-0.5	7.700	0.1760	0.0096	0.0024	0.0645	0.0065	9.943	0.994	8.11		
17	30	0.0	2.169	1.4180	0.7872	0.0048	0.0822	0.0914	23.229	3.872	7.62	21.5	247.0
18	0	0.5	1.652	1.5640	0.9367	0.0072	0.1436	0.1226	22.108	3.685	8.02	22.0	
19	0	1.5	1.831	2.1551	1.2638	0.0072	0.1824	0.1648	13.777	5.511	8.17	23.0	
19	30	2.0	1.711	2.2047	1.2404	0.0072	0.2026	0.2004	37.914	(-21.990)	8.12	21.5	
20	0	2.5	1.353	1.6875	1.3105	0.0078	0.2130	0.2004	30.758	(-30.758)	8.21	21.0	
20	30	3.0	2.408								8.19	22.0	
21	0	3.5	1.035	2.1551	1.4881	0.0060	0.2531	0.2519	22.428	3.738	8.20	20.5	
22	0	4.5	1.274	2.2249	1.5745	0.0054	0.2962	0.2699	22.989	(-1.538)	8.24	20.0	84.5
Water Column													
17	34	top	8.438	0.1760	0.0096	0.0024	0.0645	0.0065	9.943	0.994	8.11		
		bot	0.776	0.4093	0.1357	0.0048	0.0343	0.0342	5.853	1.317	7.70		8.6
21	46	top	8.597	0.3184	0.0037	0.0024	0.0136	0.0041	7.529	(-0.151)	8.17		
		bot	7.164	0.5520	0.0446	0.0024	0.0184	0.0125	6.194	0.310	8.09		15.2

[a] The symbols for the parameters are explained in Table II-3.
[b] Values are in g m^{-3} except Chl and Phaeop in mg m^{-3} and dye in ppb (pH is unitless).
[c] The values in parenthesis are lower than DTL (detection limit).

Table II-8. Water quality parameters[a,b] measured for dome and ambient waters from the dome survey at Owl Hollow on September 20, 1993.

hr	min	Time	DO	TDN	NH4	NO23	TDP	PO4d	Chl	Phaeop	pH	dye	TSS
RMS Error (±)				0.0000	0.0000	0.0000	0.0000	0.0000		0.000			
DTL			0.080	0.0260	0.0015	0.0008	0.0020	0.0006	0.950	0.000			2.0
Blank				(0.0034)[c]	0.0033	(0.0005)	0.0058	0.0035	3.097	(-3.097)			3.5
Control Dome													
15	50	0.0	8.232	0.3630	0.0375	0.0223	0.0170	0.0056	34.363	18.119	7.12		37.5
16	20	0.5	8.064	0.3310	0.0281	0.0252	0.0190	0.0094	35.564	18.375	7.62	22.2	
16	50	1.0	7.686	0.4350	0.0200	0.0216	0.0230	0.0108	38.768	6.461	7.89	22.5	
17	50	2.0	8.064	0.4330	0.0190	0.0219	0.0240	0.0119	38.181	13.217	8.11	21.7	
18	50	3.0	7.938	0.3760	0.0157	0.0224	0.0200	0.0130	37.166	6.194	8.12	19.5	
19	50	4.0	8.106	0.4500	0.0264	0.0234	0.0210	0.0097	32.894	21.531	7.54	18.2	
20	50	5.0	6.510	0.4390	0.0290	0.0220	0.0230	0.0115	38.875	7.177	8.67	17.1	
21	50	6.0	6.111	0.4800	0.0240	0.0210	0.0225	0.0109	38.929	2.131	8.33	16.6	46.5
Flux Dome A													
15	50	0.0	8.127	0.3717	0.0693	0.0254	0.0198	0.0108	26.120	10.448	7.10		46.0
16	20	0.5	8.064	0.4181	0.0859	0.0259	0.0282	0.0206	33.482	4.870	7.54	20.9	
16	50	1.0	7.980	0.4555	0.1035	0.0251	0.0316	0.0268	32.894	4.785	7.70	20.8	
17	50	2.0	7.644	0.5630	0.1535	0.0272	0.0376	0.0308	37.834	4.948	8.00	19.9	
18	50	3.0	7.350	0.5310	0.1957	0.0277	0.1180	0.0305	39.569	0.913	8.02	18.5	
19	50	4.0	6.657	0.6880	0.3104	0.0308	0.1330	0.0309	33.375	11.014	7.86	17.3	
20	50	5.0	6.342	1.0755	0.7733	0.0269	0.0960	0.0201	33.001	13.201	8.77	14.0	
21	50	6.0	6.762	1.2700	1.0288	0.0234	0.1035	0.0251	32.080	5.927	8.38	13.0	38.25

[a] The symbols for the parameters are explained in Table II-3.

[b] Values are in g m^{-3} except Chl and Phaeop in mg m^{-3} and dye in ppb (pH is unitless).

[c] The values in parenthesis are lower than DTL (detection limit).

Table II-8. (continued.)

hr	min	Time	DO	TDN	NH4	NO23	TDP	PO4d	Chl	Phaeop	pH	dye	TSS
RMS Error (±)				0.0000	0.0000	0.0000	0.0000	0.0000		0.000			
DTL			0.080	0.0260	0.0015	0.0008	0.0020	0.0006	0.950	0.000			2.0
Flux Dome B													
15	50	0.0	8.022	0.3250	0.0698	0.0232	0.0140	0.0064	35.244	16.154	7.15		38.0
16	20	0.5	7.623	0.3810	0.0832	0.0237	0.0190	0.0105	36.419	9.932	7.55	22.1	
16	50	1.0	7.623	0.4500	0.1135	0.0239	0.0220	0.0131	36.125	16.749	7.93	22.0	
17	50	2.0	7.308	0.4930	0.1501	0.0245	0.0230	0.0152	30.705	7.983	8.14	20.8	
18	50	3.0	6.636	0.5580	0.1859	0.0255	0.0800	0.0164	37.594	(-1.709)	8.13	19.0	
19	50	4.0	7.035	0.5830	0.2218	0.0257	0.0780	0.0164	32.841	8.539	7.54	16.1	
20	50	5.0	8.337	0.6750	0.2461	0.0255	0.1060	0.0179	34.069	13.628	8.72	15.9	
21	50	6.0	7.518	0.6420	0.2618	0.0237	0.0835	0.0177	33.789	12.805	8.39	16.4	37.25
Water Column													
16	0	top	8.379	0.2580	0.0233	0.0197	0.0100	0.0024	38.875	11.364	7.17		
		bot	8.547	0.2630	0.0166	0.0209	0.0120	0.0028	35.831	21.173	7.22		55.0
18	53	top	8.169	0.2640	0.0151	0.0133	0.0110	0.0022	37.006	5.383	7.52		
		bot	7.560	0.3140	0.0311	0.0165	0.0120	0.0035	33.909	13.564	7.85		
21	49	top	8.463	0.2580	0.0192	0.0035	0.0120	0.0031	37.487	4.061	8.05		
		bot	8.106	0.2830	0.0347	0.0017	0.0120	0.0037	39.917	24.564	8.16		136.0

Table II-9. Water quality parameters[a,b] measured for dome and ambient waters from the dome survey at Tappahannock on September 23, 1993.

hr	min	Time	DO	TDN	NH4	NO23	TDP	PO4d	Chl	Phaeop	pH	dye	TSS
RMS Error (±)				0.0000	0.0000	0.0000	0.0000	0.0000		0.000			
DTL			0.080	0.0260	0.0015	0.0008	0.0020	0.0006	0.950	0.000			2.0
Blank				(0.0058)[c]	0.0054	0.0019	(0.0012)	(0.0002)	(0.000)	0.000			(-2.0)
Control Dome													
16	30	0.0	9.429	0.3100	0.0227	0.0042	0.0166	0.0068	20.933	4.187	7.65	24.0	47.0
17	0	0.5	8.673	0.3096	0.0079	0.0034	0.0188	0.0063	22.989	9.196	7.81	23.0	
17	30	1.0	8.400	0.3152	0.0033	0.0028	0.0181	0.0065	20.025	1.001	7.96	22.6	
18	30	2.0	8.526	0.3452	0.0052	0.0036	0.0156	0.0067	11.962	4.785	8.02	22.0	
19	30	3.0	8.211	0.4005	0.0108	0.0032	0.0186	0.0075	11.000	8.250	7.99	21.3	
20	30	4.0	8.316	0.3496	0.0029	0.0035	0.0149	0.0070	9.932	6.291	8.06	21.2	
21	30	5.0	7.917	0.4134	0.0062	0.0037	0.0179	0.0075	21.120	4.224	8.03	20.1	
22	30	6.0	7.770	0.4078	0.0111	0.0019	0.0160	0.0067	11.882	7.983	7.88	19.3	41.0
Flux Dome A													
16	30	0.0	8.484	0.4349	0.1520	0.0042	0.0213	0.0127	22.855	15.142	7.44	23.0	91.5
17	0	0.5	7.791	0.5056	0.2442	0.0016	0.0210	0.0133	24.564	11.975	7.84	24.0	
17	30	1.0	7.119	0.6060	0.3383	0.0012	0.0202	0.0129	11.962	29.904	7.75	23.2	
18	30	2.0	6.552	0.8231	0.5356	0.0027	0.0207	0.0135	11.855	21.339	8.01	22.1	
19	30	3.0	5.859	0.3151	0.7194	0.0048	0.0269	0.0143	18.263	11.566	7.98	21.1	
20	30	4.0	5.796	0.3322	0.8660	0.0047	0.0219	0.0134	6.355	11.438	8.04	20.1	
21	30	5.0	5.250	1.0617	0.9294	0.0049	0.0193	0.0124	16.180	2.697	7.99	19.6	
22	30	6.0	4.452	1.1422	1.0336	0.0053	0.0203	0.0133	11.107	9.516	7.91	20.0	38.75

[a] The symbols for the parameters are explained in Table II-3.
[b] Values are in g m^{-3} except Chl and Phaeop in mg m^{-3} and dye in ppb (pH is unitless).
[c] The values in parenthesis are lower than DTL (detection limit).

Table II-9. (continued.)

hr	min	Time	DO	TDN	NH4	NO23	TDP	PO4d	Chl	Phaeop	pH	dye	TSS
RMS Error (±)				0.0000	0.0000	0.0000	0.0000	0.0000		0.000			
DTL			0.080	0.0260	0.0015	0.0008	0.0020	0.0006	0.950	0.000			2.0
Flux Dome B													
16	30	0.0	7.497	0.4860	0.1726	0.0010	0.0212	0.0108	12.602	9.452	7.65	29.0	186.0
17	0	0.5	7.959	0.6126	0.2897	0.0033	0.0235	0.0104	12.709	7.308	7.80	26.0	
17	30	1.0	6.237	0.6684	0.3607	0.0037	0.0165	0.0082	17.302	(-1.153)	7.76	24.6	
18	30	2.0	5.817	0.8451	0.5548	0.0043	0.0151	0.0067	12.816	(-3.845)	7.73	23.2	
19	30	3.0	4.851	0.9192	0.6941	0.0050	0.0152	0.0057	5.607	6.168	7.83	22.4	
20	30	4.0	3.612	0.9192	0.7836	0.0049	0.0132	0.0049	6.408	2.563	7.85	21.9	
21	30	5.0	2.415	1.0384	0.8953	0.0063	0.0152	0.0054	13.564	(-8.816)	7.86	20.1	
22	30	6.0	2.184	1.0603	0.9223	0.0058	0.0285	0.0046	6.141	0.326	7.82	20.1	25.5
Water Column													
16	15	top	11.004	0.3069	0.0048	0.0021	0.0189	0.0068	27.305	3.571	7.36		
		bot	9.093	0.2832	0.0062	0.0026	0.0160	0.0073	26.914	2.392	7.16		40.0
19	40	top	10.227	0.2601	0.0068	0.0051	0.0183	0.0080	19.705	1.752	7.86		
		bot	7.854	0.3025	0.0250	0.0186	0.0189	0.0117	12.816	5.126	7.75		
22	4	top	8.547	0.2740	0.0177	0.0164	0.0179	0.0098	10.680	11.748	7.89		
		bot	8.967	0.3242	0.0331	0.0330	0.0199	0.0117	16.981	8.774	7.90		68.0

Table II-10. Water quality parameters[a,b] measured for dome and ambient waters from the dome survey at Water View on September 22, 1993.

hr	min	Time	DO	TDN	NH4	NO23	TDP	PO4d	Chl	Phaeop	pH	dye	TSS
RMS Error (±)				0.0000	0.0000	0.0000	0.0000	0.0000		0.000			
DTL			0.080	0.0260	0.0015	0.0008	0.0020	0.0006	0.950	0.000			2.0
Blank				(0.0056)	(0.0000)	0.0012	0.0037	(0.0003)	7.316	(-4.755)			4.5
Control Dome													
15	30	0.0	6.342	0.4009	0.0398	0.1077	0.0167	0.0075	2.830	9.057	7.43	25.0	38.5
16	0	0.5	7.266	0.3856	0.0263	0.1045	0.0130	0.0061	3.311	8.277	8.06	22.0	
16	30	1.0	7.707	0.3808	0.0266	0.1079	0.0124	0.0062	21.146	(-13.745)	8.01	21.1	
18	0	2.5	6.972	0.4148	0.0124	0.1089	0.0125	0.0056	4.005	(-1.202)	7.97	17.0	
19	0	3.5	6.636	0.4517	0.0125	0.1076	0.0134	0.0060	6.675	2.670	8.09	15.1	
20	0	4.5	7.119	0.4063	0.0038	0.1079	0.0111	0.0053	6.622	0.331	8.18	14.3	
21	0	5.5	6.552	0.4310	0.0043	0.1064	0.0122	0.0050	2.990	5.383	8.18	13.9	
22	0	6.5	6.699	0.4842	0.0148	0.1075	0.0161	0.0056	6.355	2.627	8.21	13.9	23.25
Flux Dome A													
15	30	0.0	7.329	0.6538	0.3282	0.1058	0.0754	0.0676	11.125	4.450	7.61	27.0	46.5
16	0	0.5	8.253	0.7200	0.4605	0.1043	0.0923	0.0865	6.088	4.566	8.04	25.0	
16	30	1.0	8.211	0.8244	0.5389	0.0999	0.0983	0.0920	5.874	8.517	7.99	23.0	
18	0	2.5	7.644	0.9789	0.8367	0.0965	0.1040	0.0985	8.891	1.482	8.10	21.0	
19	0	3.5	6.783	1.0346	0.8589	0.0916	0.1036	0.1013	6.675	0.334	8.18	19.0	
20	0	4.5	6.678	1.0812	0.9096	0.0878	0.1033	0.1028	3.204	(-0.961)	8.16	17.7	
21	0	5.5	5.985	1.1194	0.9848	0.0835	0.1031	0.1023	(0.000)	6.616	8.14	17.3	
22	0	6.5	5.397	1.1045	1.0985	0.0814	0.1026	0.1019	6.434	0.310	8.20	18.0	19.75

[a] The symbols for the parameters are explained in Table II-3.

[b] Values are in g m^{-3} except Chl and Phaeop in mg m^{-3} and dye in ppb (pH is unitless).

[c] The values in parenthesis are lower than DTL (detection limit).

Table II-10. (continued.)

hr	min	Time	DO	TDN	NH4	NO23	TDP	PO4d	Chl	Phaeop	pH	dye	TSS
RMS Error (±)				0.0000	0.0000	0.0000	0.0000	0.0000		0.000			
DTL			0.080	0.0260	0.0015	0.0008	0.0020	0.0006	0.950	0.000			2.0
Flux Dome B													
15	30	0.0	6.573	0.5419	0.2543	0.0984	0.0297	0.0262	12.175	30.438	7.26	26.0	160.2
16	0	0.5	6.069	0.6860	0.3428	0.0976	0.0340	0.0289	12.282	9.212	8.04	22.0	
16	30	1.0										19.0	
18	0	2.5	5.691	0.8410	0.6021	0.0869	0.0500	0.0461	6.088	19.480	7.94	17.9	
19	0	3.5	0.357	0.9330	0.6996	0.0855	0.0580	0.0526	25.632	(-16.661)	8.09	15.2	
20	0	4.5	4.389	0.9476	0.7757	0.0852	0.0605	0.0572			8.14	14.9	
21	0	5.5	3.801	0.9741	0.8375	0.0773	0.0600	0.0557	6.835	7.519	8.11	14.4	
22	0	6.5	3.885	1.0374	0.9361	0.0790	0.0690	0.0647	6.328	2.585	8.14	14.8	41.5
Water Column													
16	12	top	7.917	0.3188	0.0021	0.0782	0.0105	0.0029	10.595	1.457	7.96		
		bot	6.363	0.3327	0.0108	0.1138	0.0099	0.0030	6.408	3.685	7.95		17.25
19	6	top	9.030	0.2723	0.0027	0.0533	0.0086	0.0013	12.015	0.134	8.21		
		bot	9.471	0.3490	0.0083	0.0626	0.0122	0.0021	12.149	2.430	8.21		
22	0	top	8.778	0.2716	(0.0015)	0.0650	0.0078	0.0016	9.644	(0.000)	8.10		
		bot	5.607	0.3849	0.0572	0.1111	0.0126	0.0053	3.204	5.767	7.94		23.0

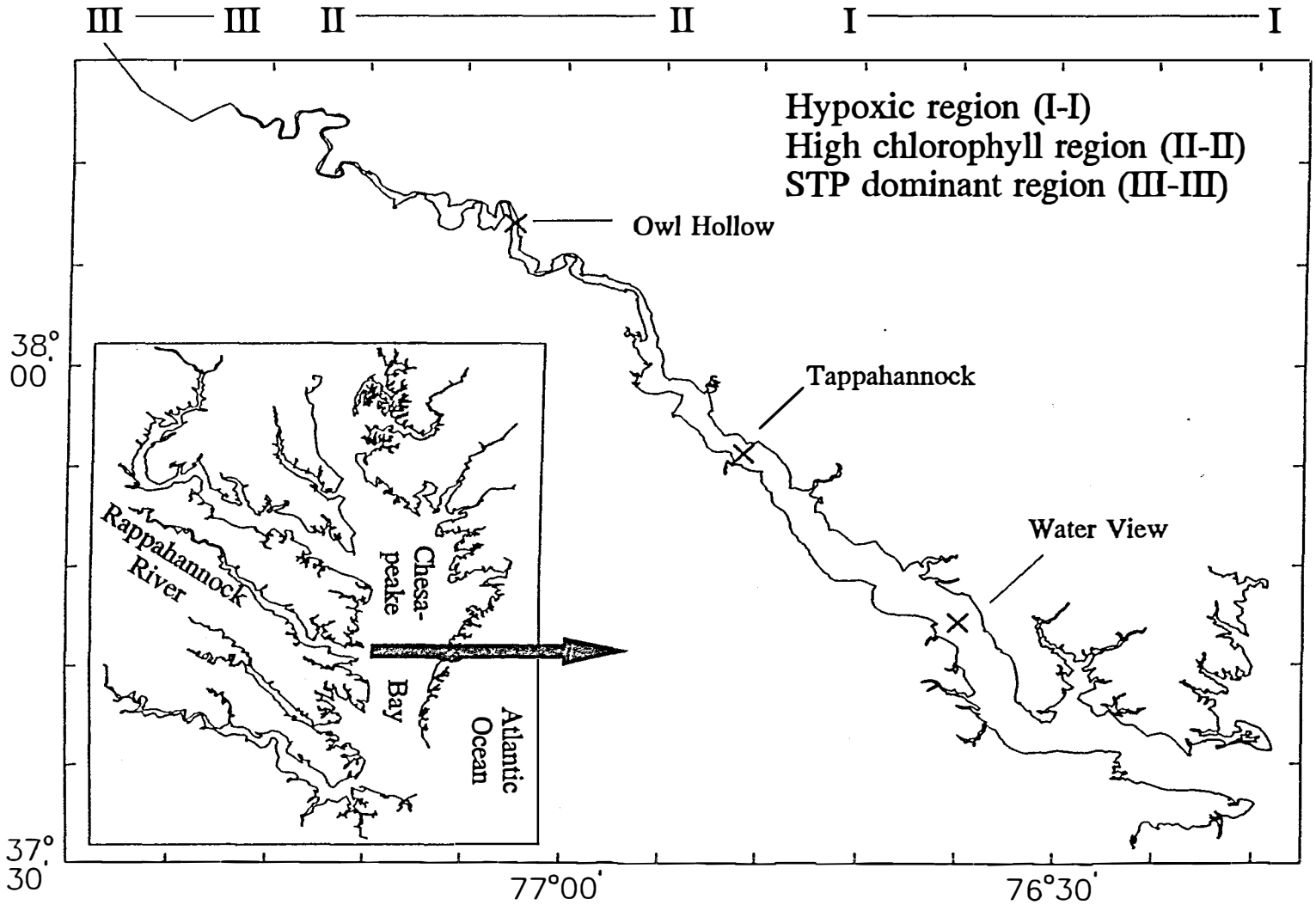


Figure 1. The tidal Rappahannock River from the fall line to the mouth with the lower Chesapeake Bay (insert) and station locations for dome surveys (×).

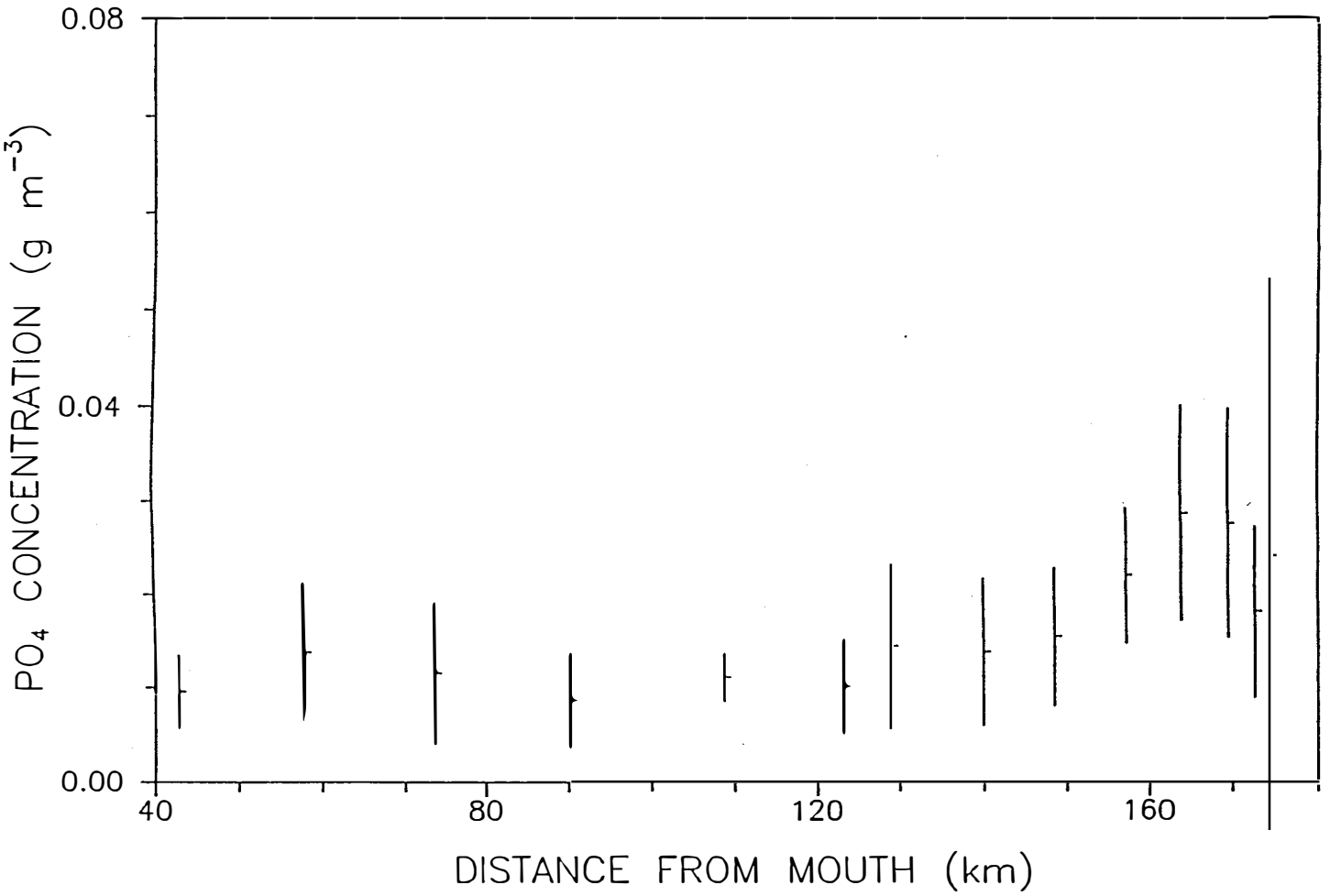


Figure I-1. Overall mean and standard deviation of phosphate concentration from nine slackwater surveys and one intensive survey during the summer of 1990.

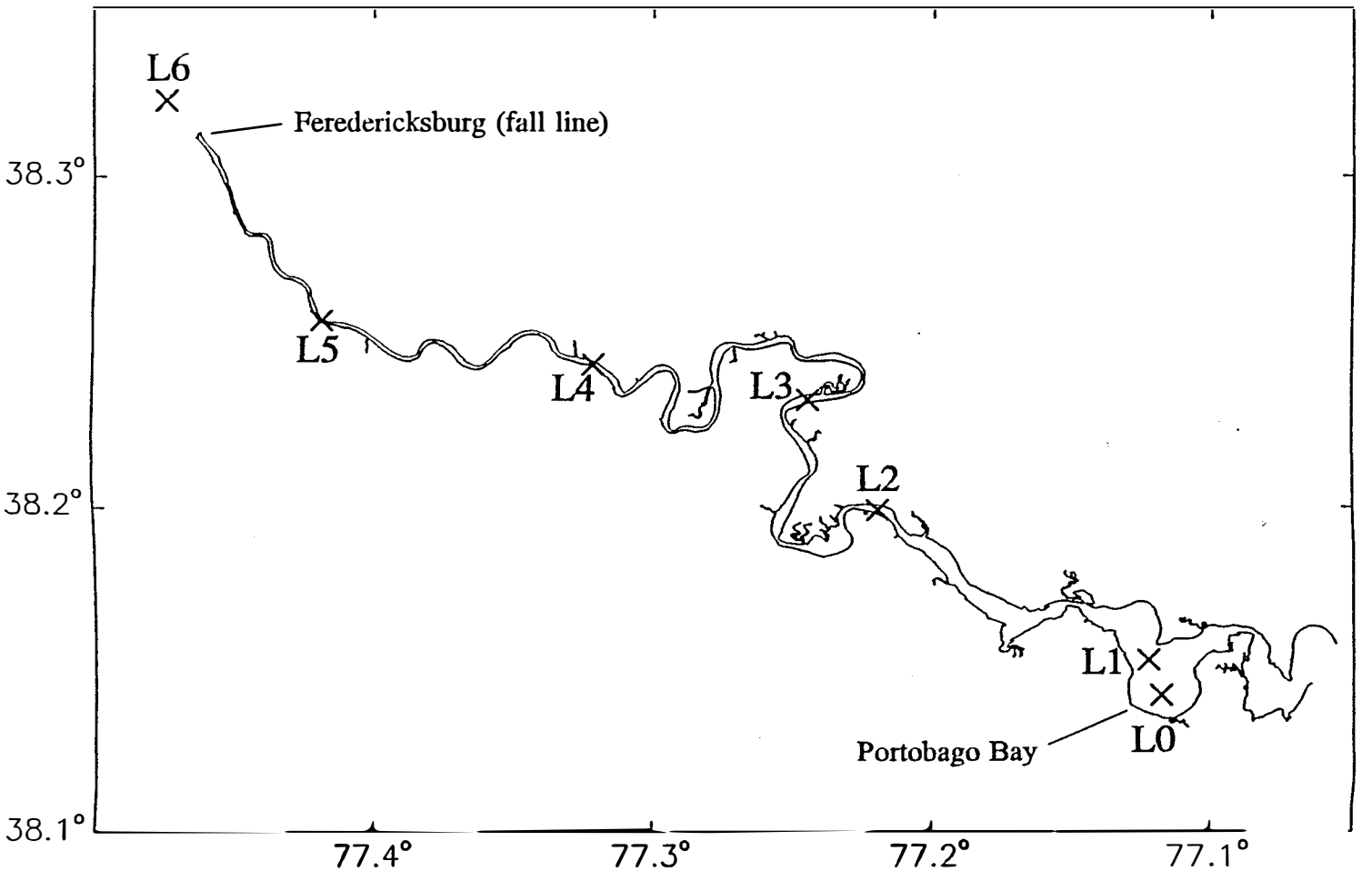


Figure I-2. Upper 60 km reach of the tidal Rappahannock River showing the location of seven stations for longitudinal surveys (×).

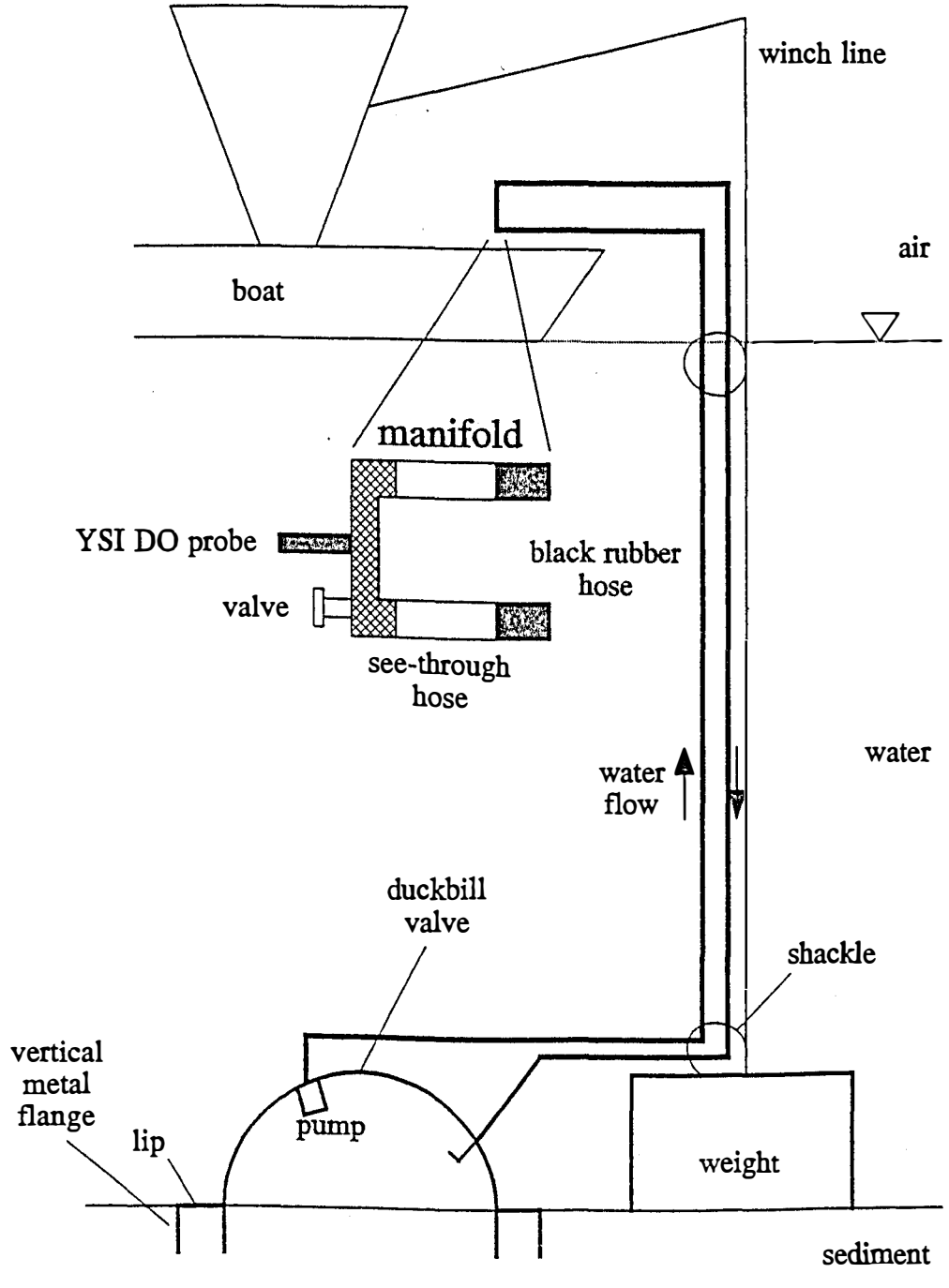


Figure II-1. A diagram showing the dome and its deployment.

Figure II–3. Salinity at Water View on 6/7/93.

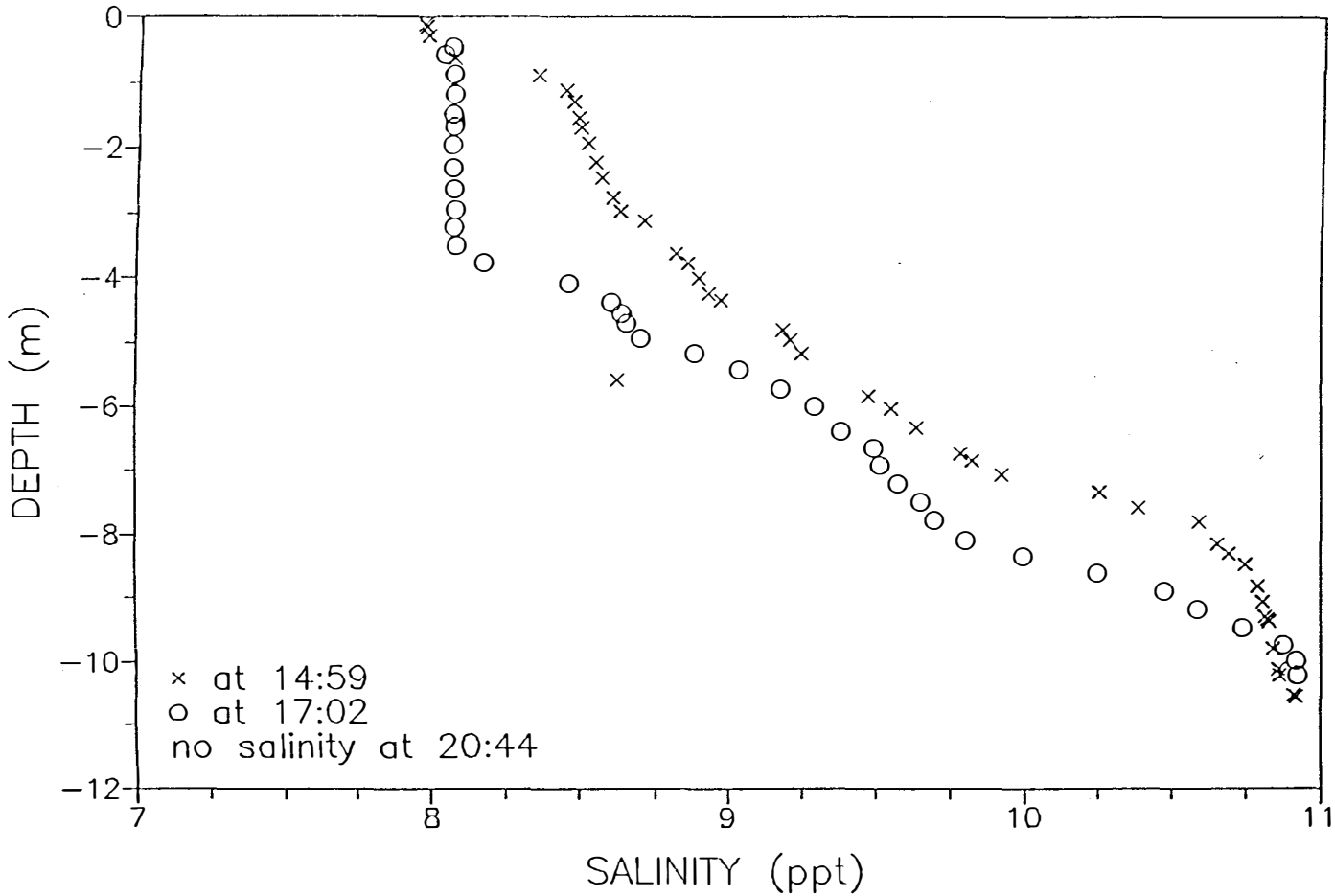


Figure II–4. Temperature at Water View on 6/7/93.

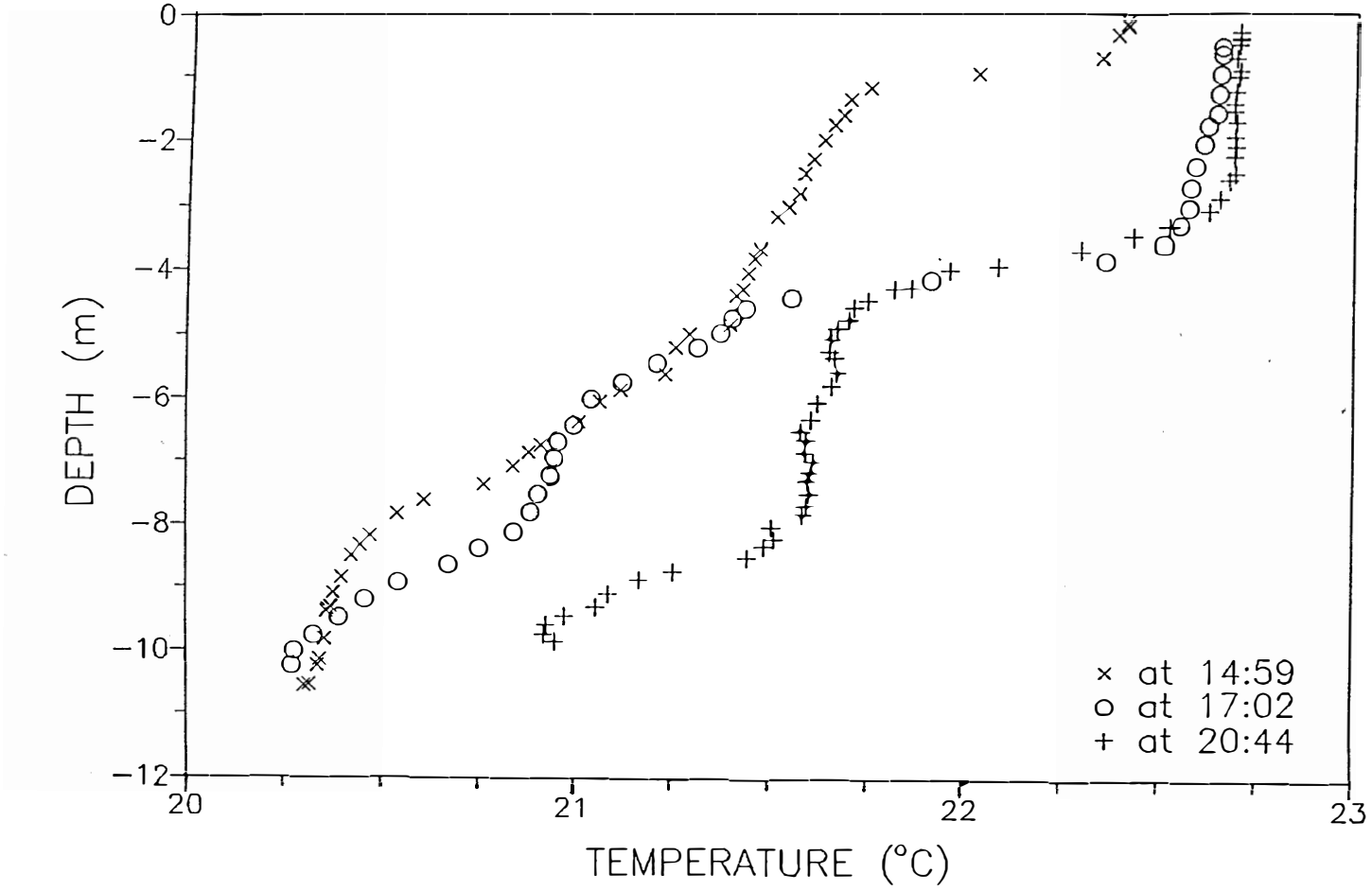


Figure II–5. Dome DO at Owl Hollow on 7/19/93.

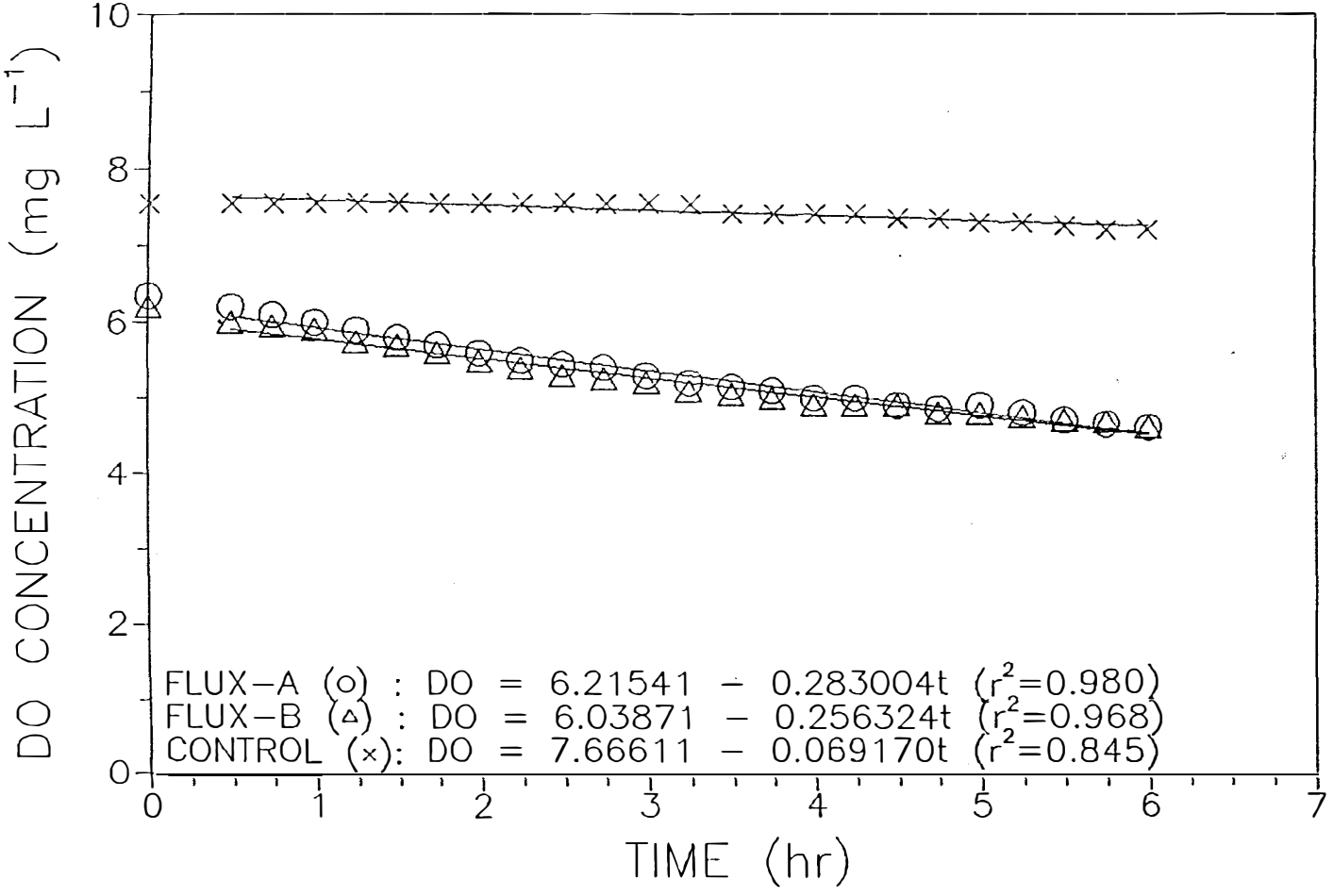


Figure II–6. Temperature at Owl Hollow on 7/19/93.

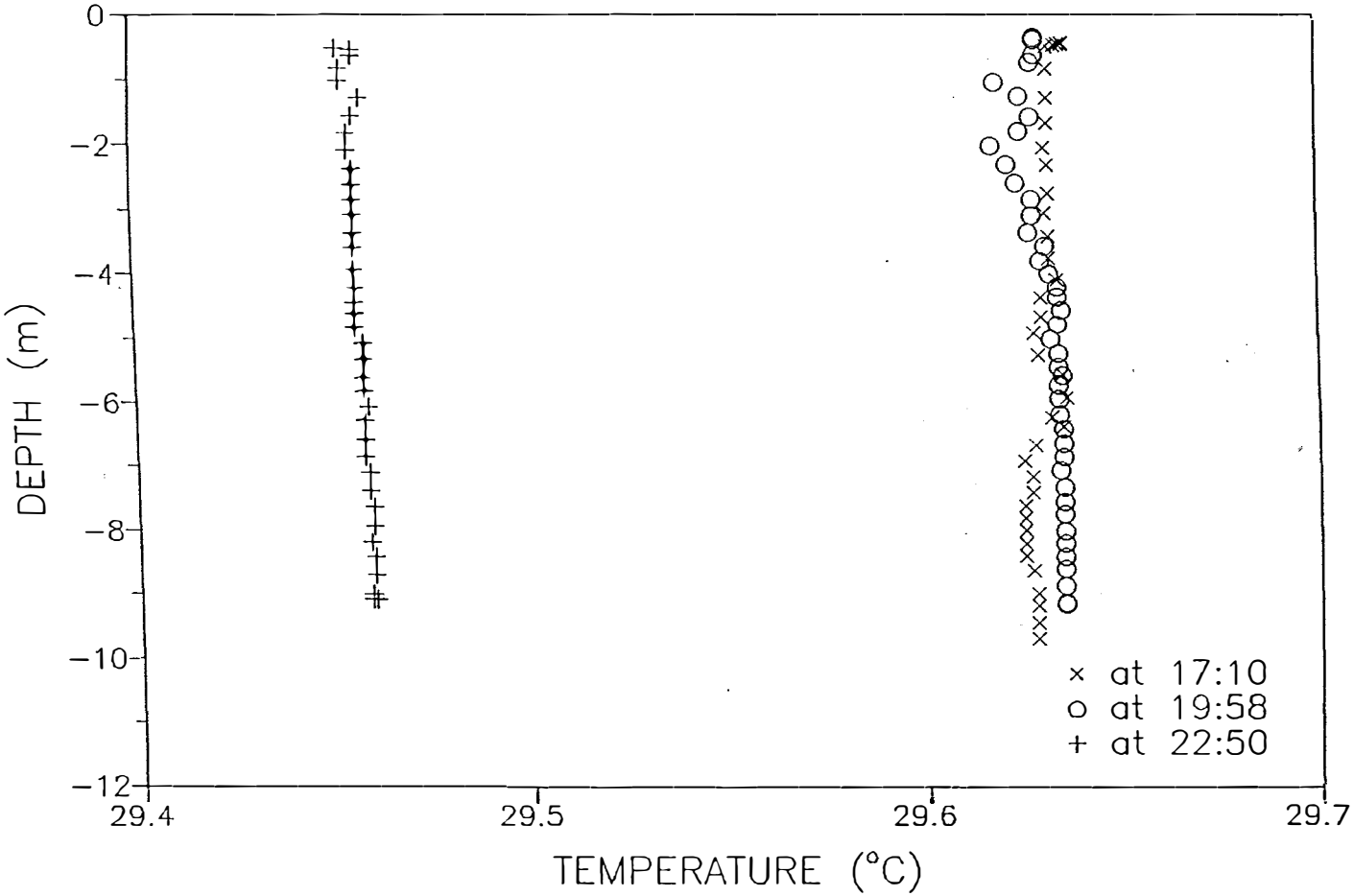


Figure II–7. Bottom current speed at Owl Hollow on 7/19/93.

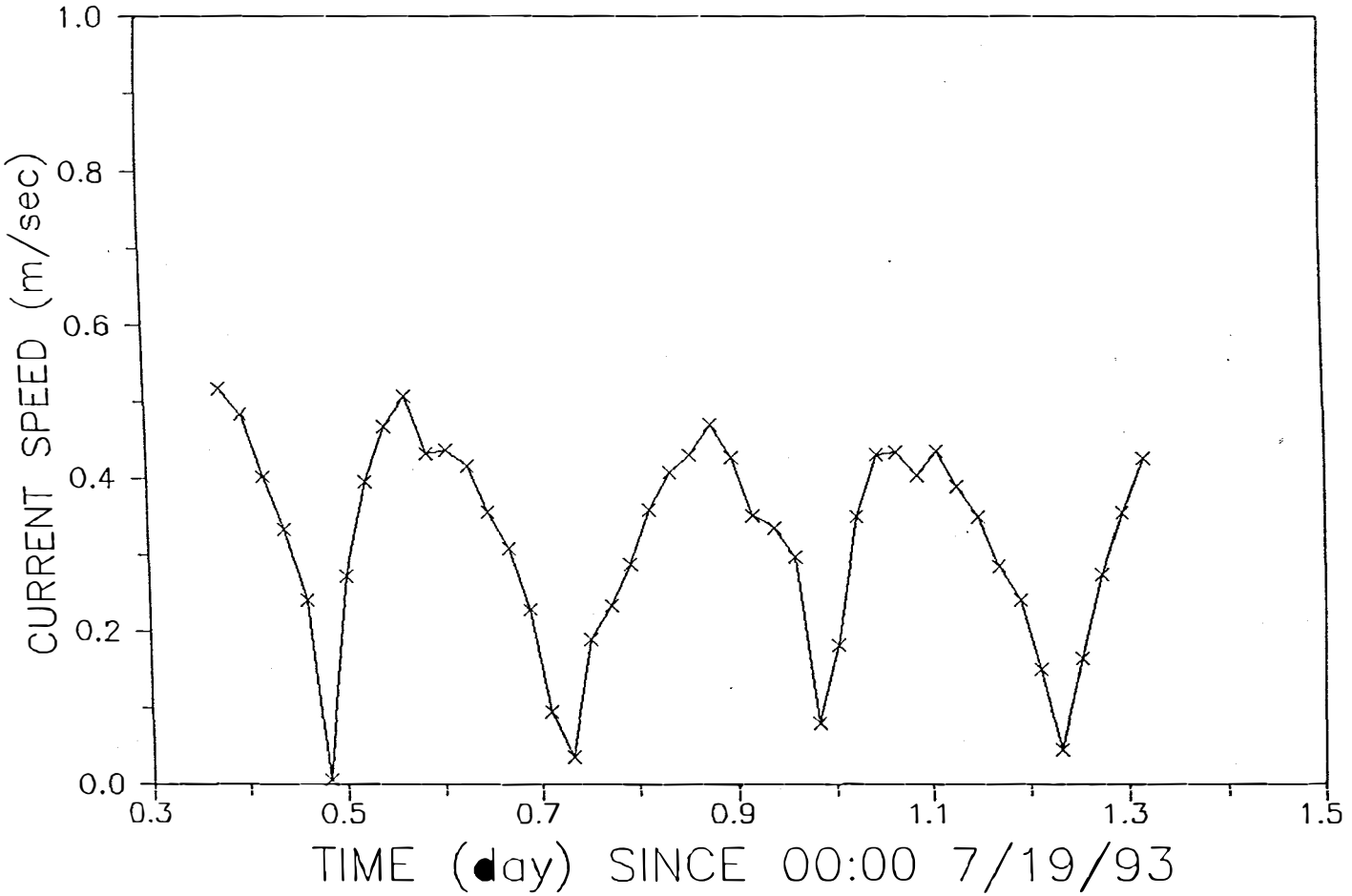


Figure II–8. Dome DO at Tappahannock on 7/20/93.

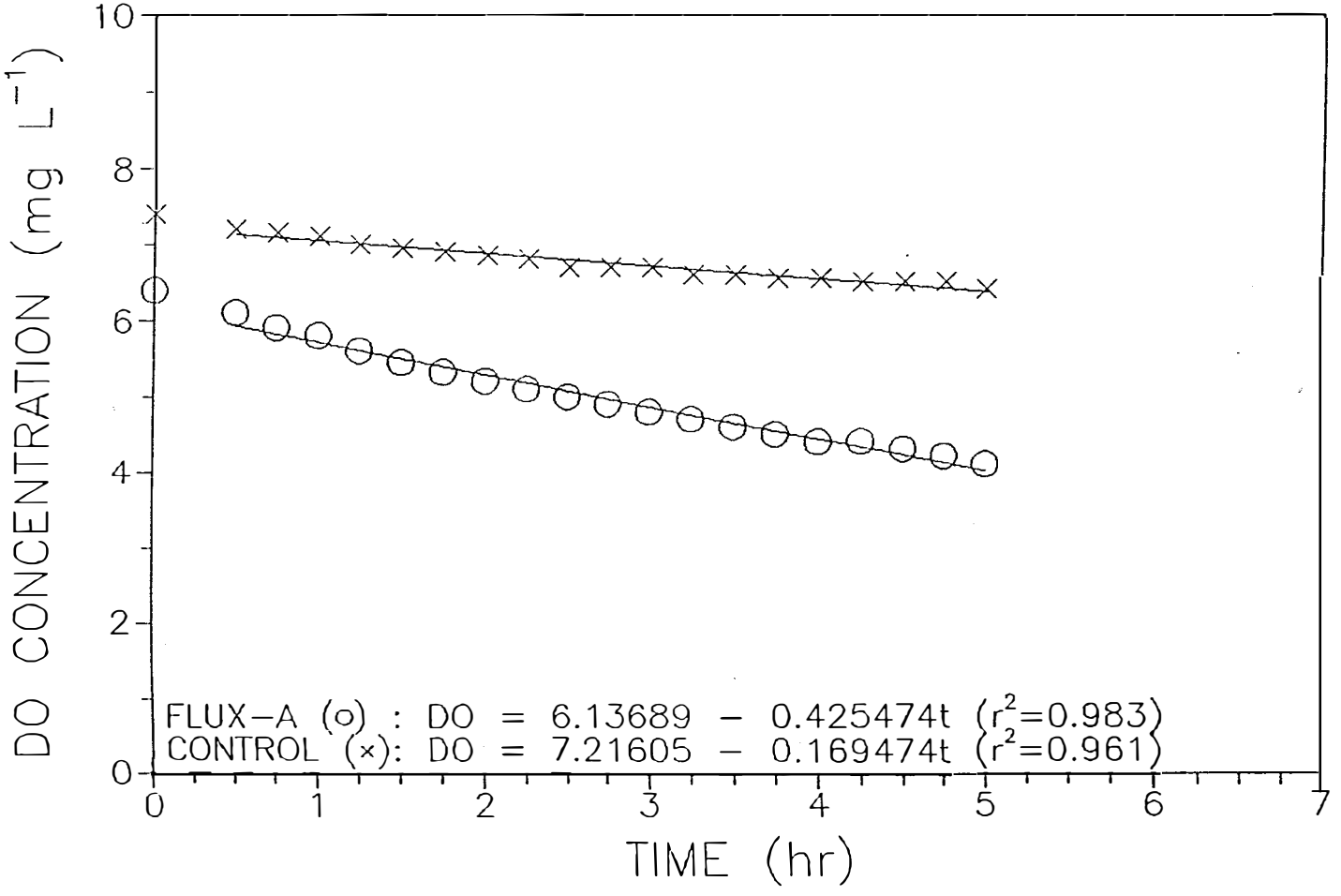


Figure II–9. Salinity at Tappahannock on 7/20/93.

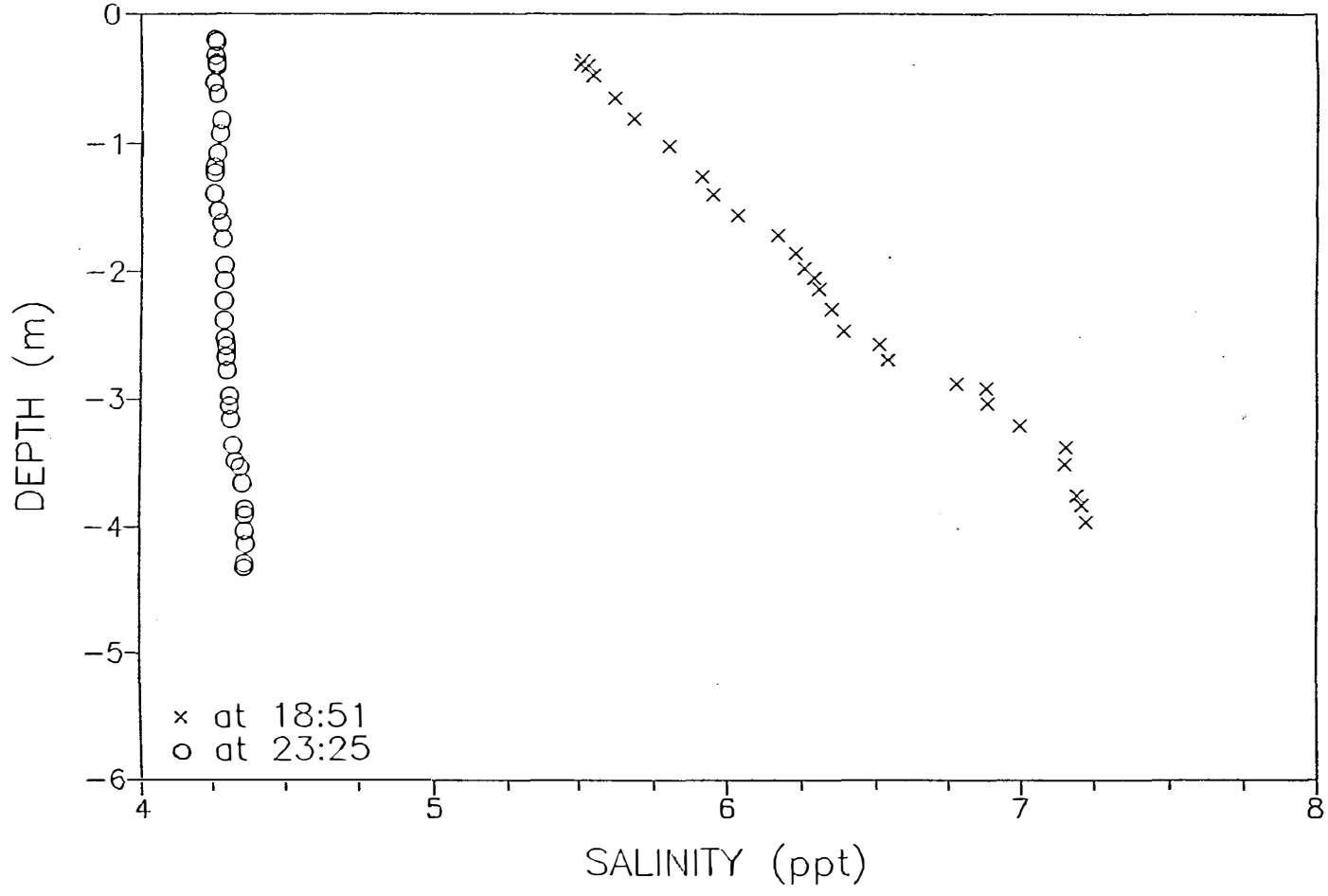


Figure II–10. Temperature at Tappahannock on 7/20/93.

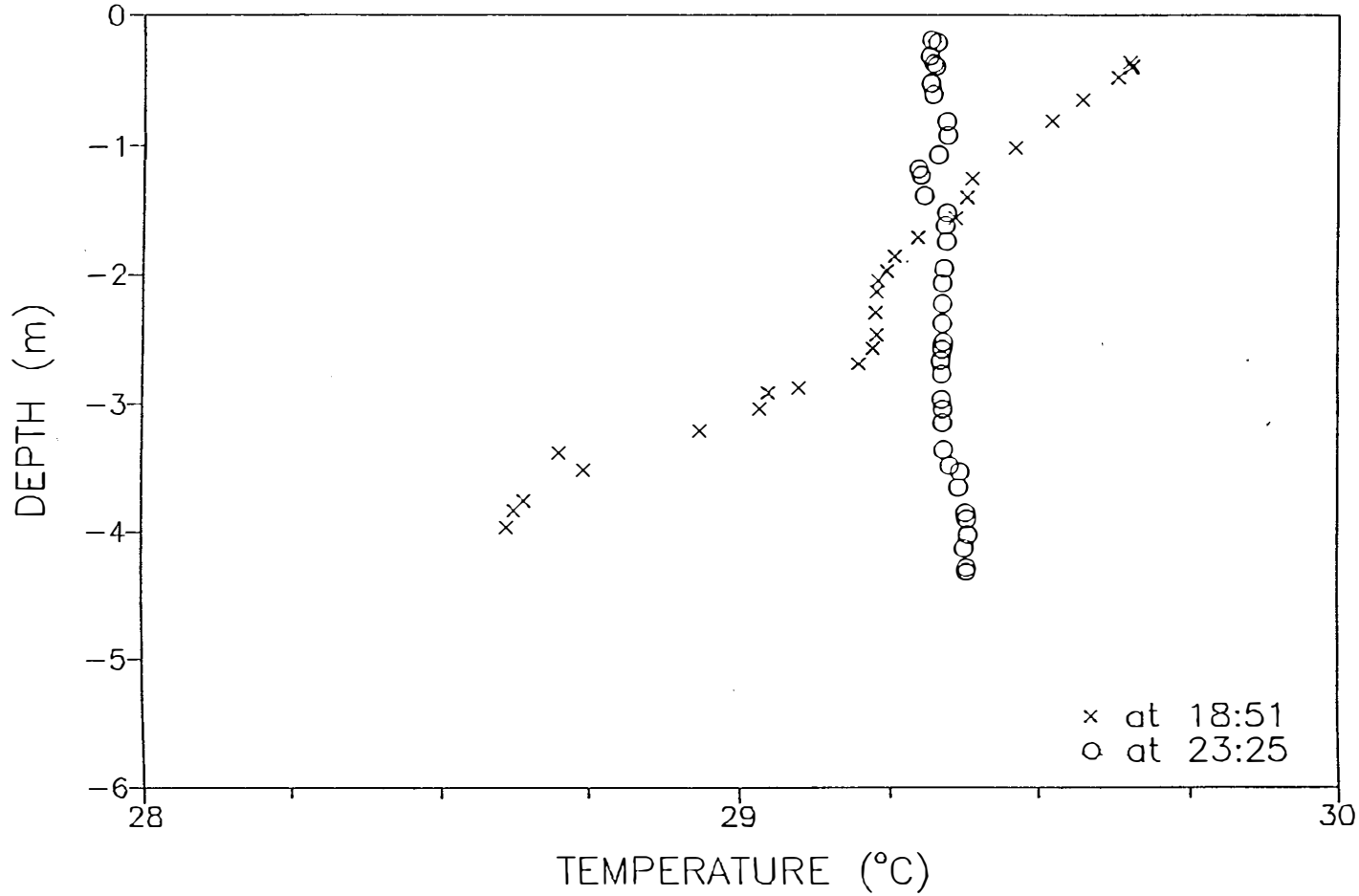


Figure II-11. Bottom current speed at Tappahannock on 7/20/93.

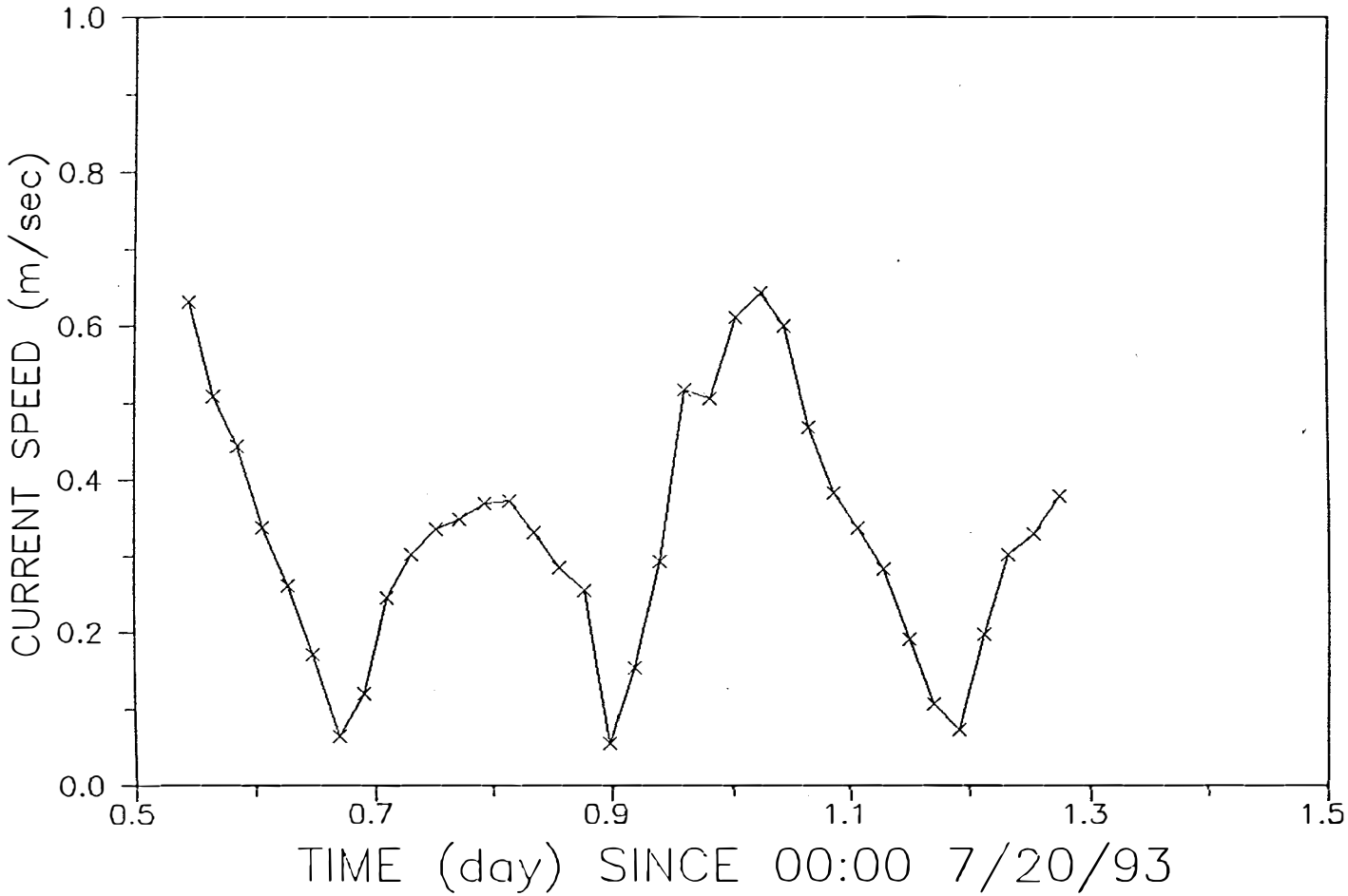


Figure II–12. Dome DO at Water View on 7/21/93.

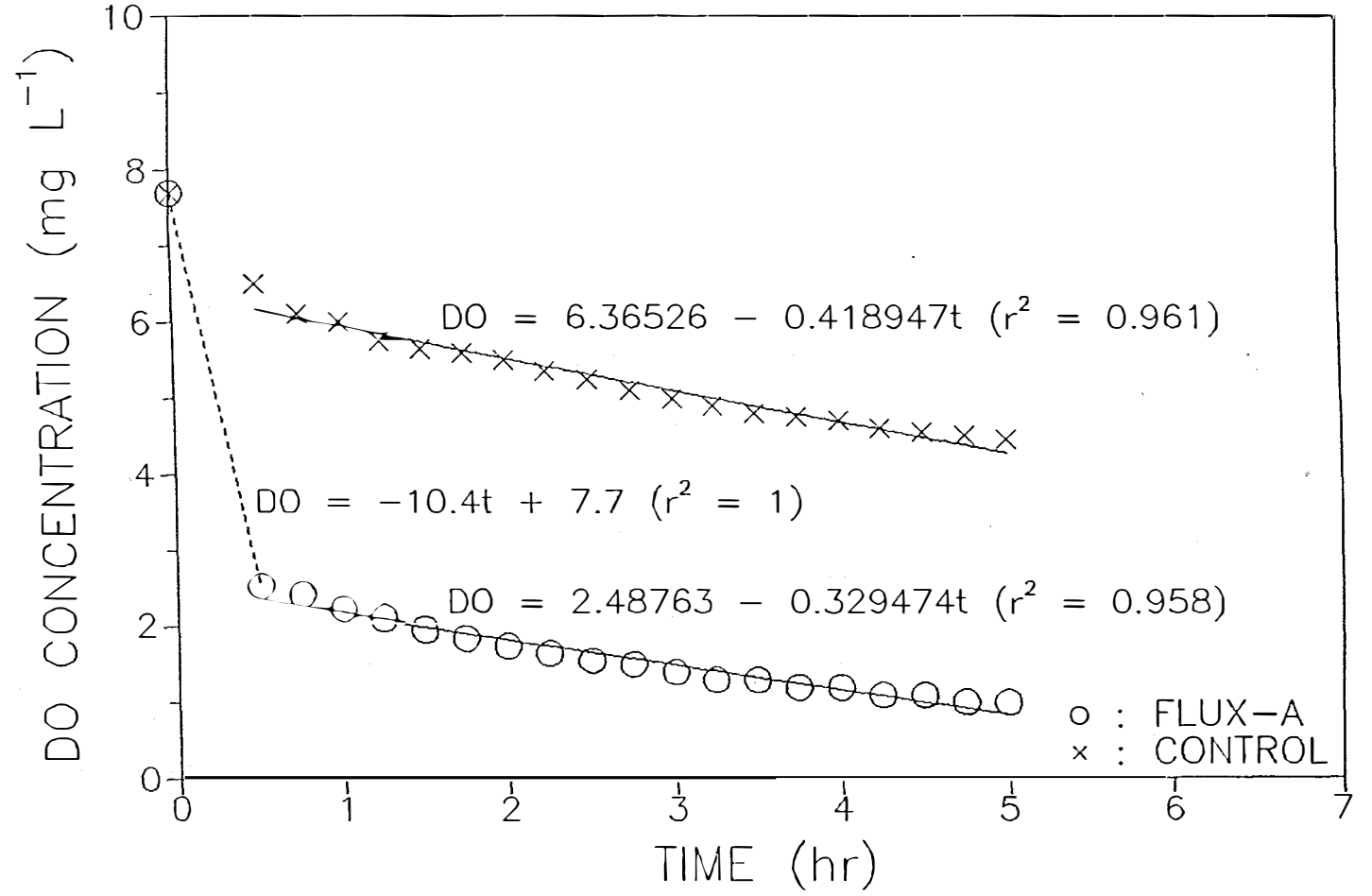


Figure II–13. Salinity at Water View on 7/21/93.

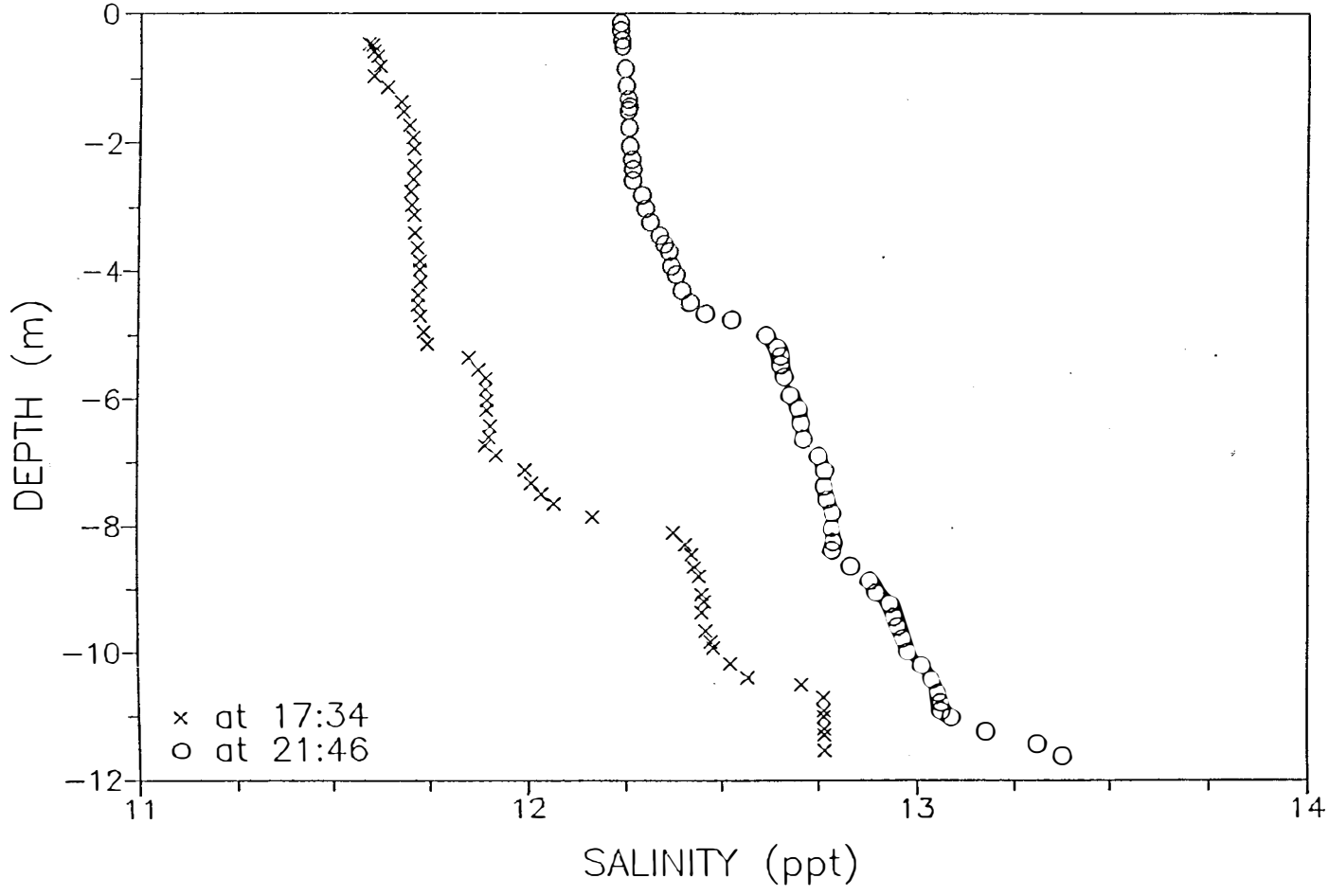


Figure II–14. Temperature at Water View on 7/21/93.

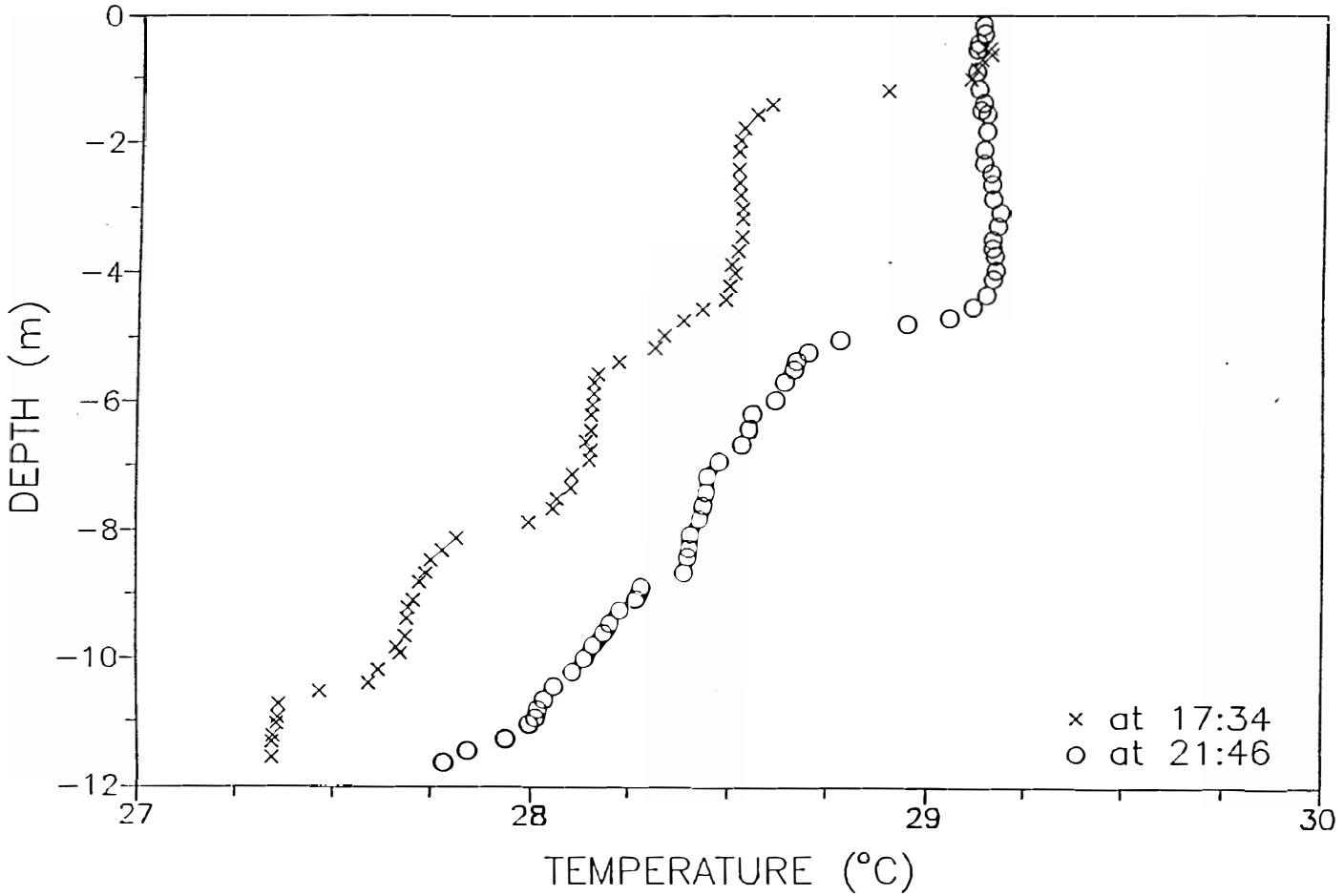


Figure II–15. Bottom Current Speed at Water View on 7/21/93.

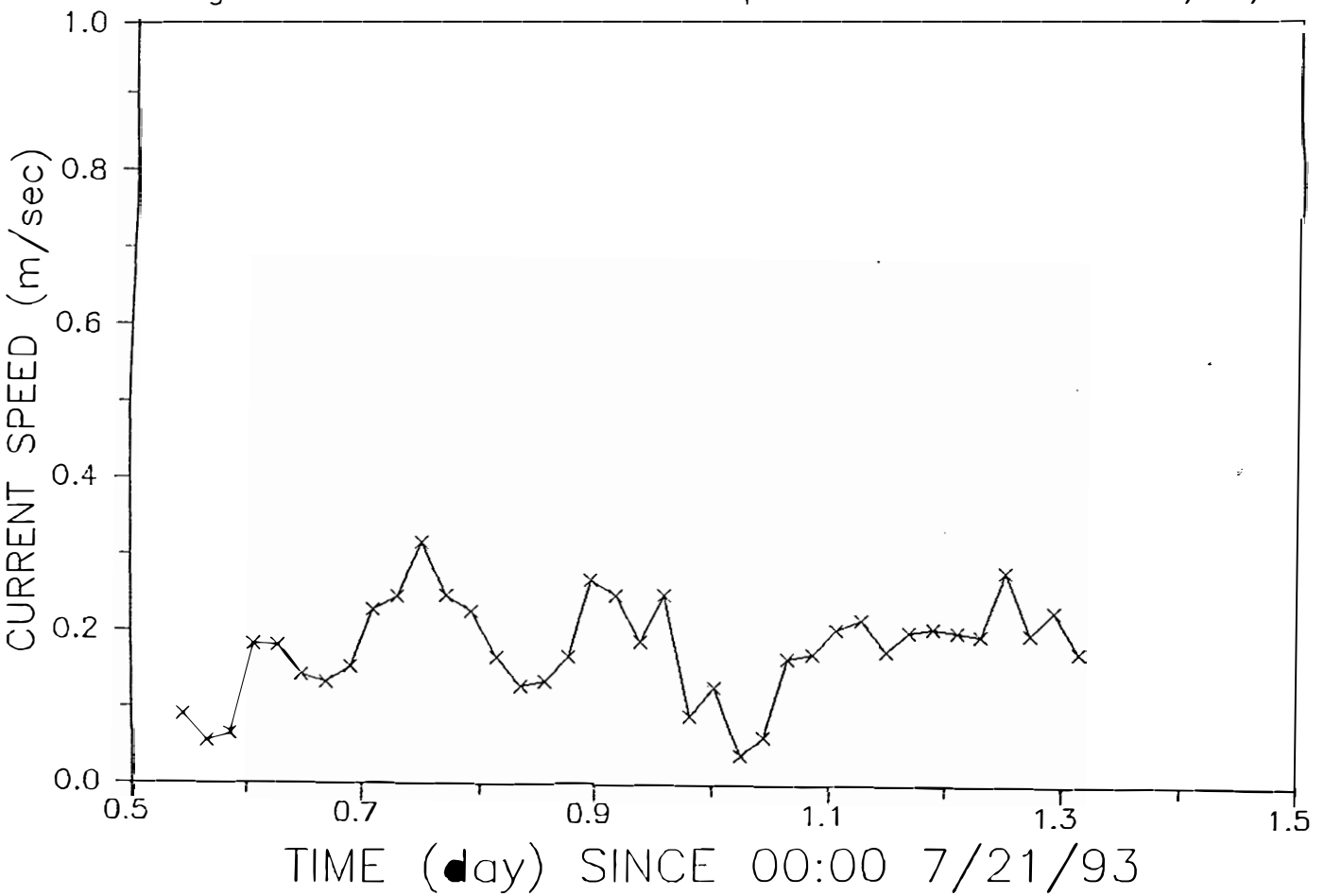


Figure II–16. Water Column DO at Water View on 7/21/93.

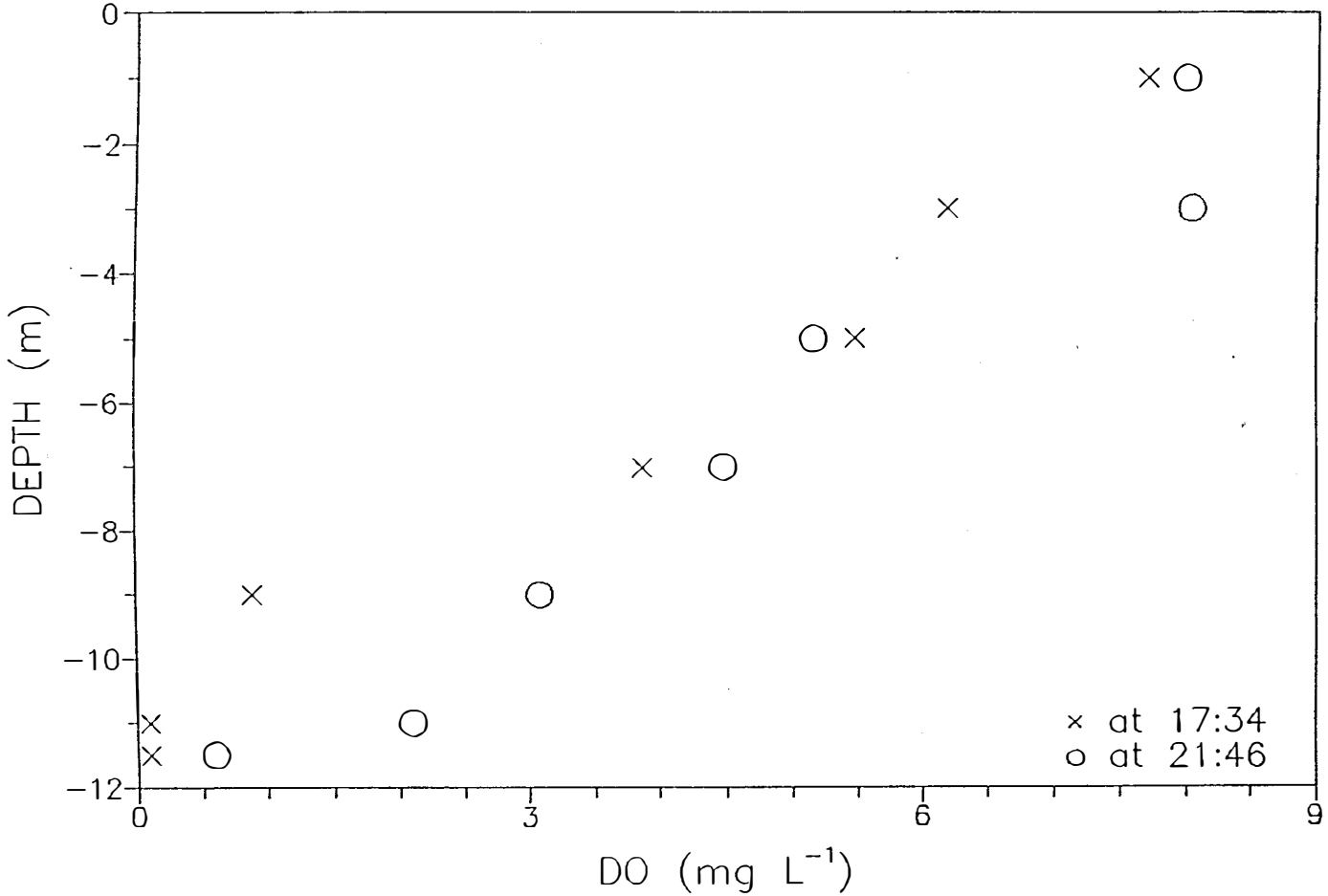


Figure II–17. Dome DO at Owl Hollow on 9/20/93.

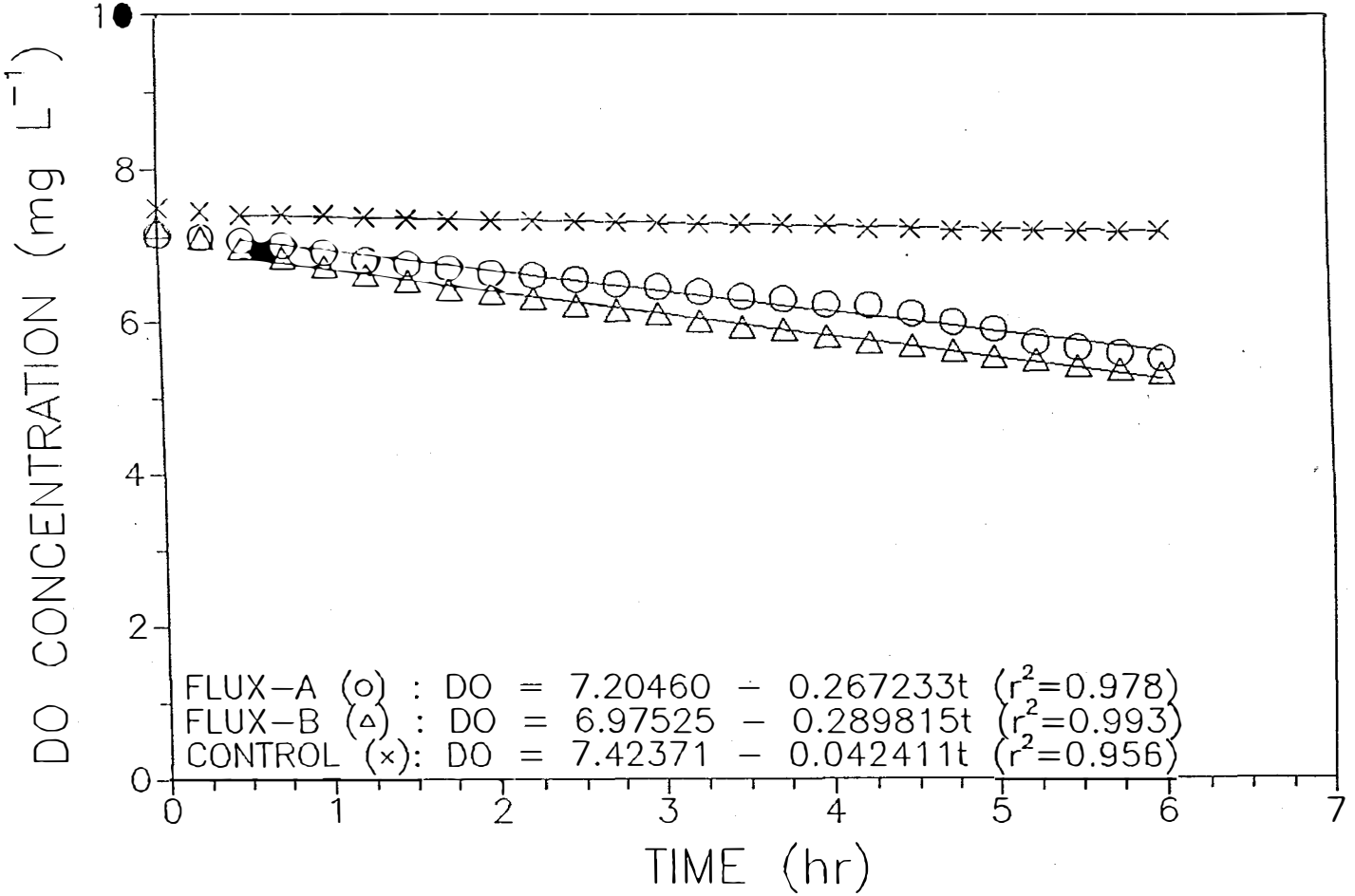


Figure II–18. Temperature at Owl Hollow on 9/20/93.

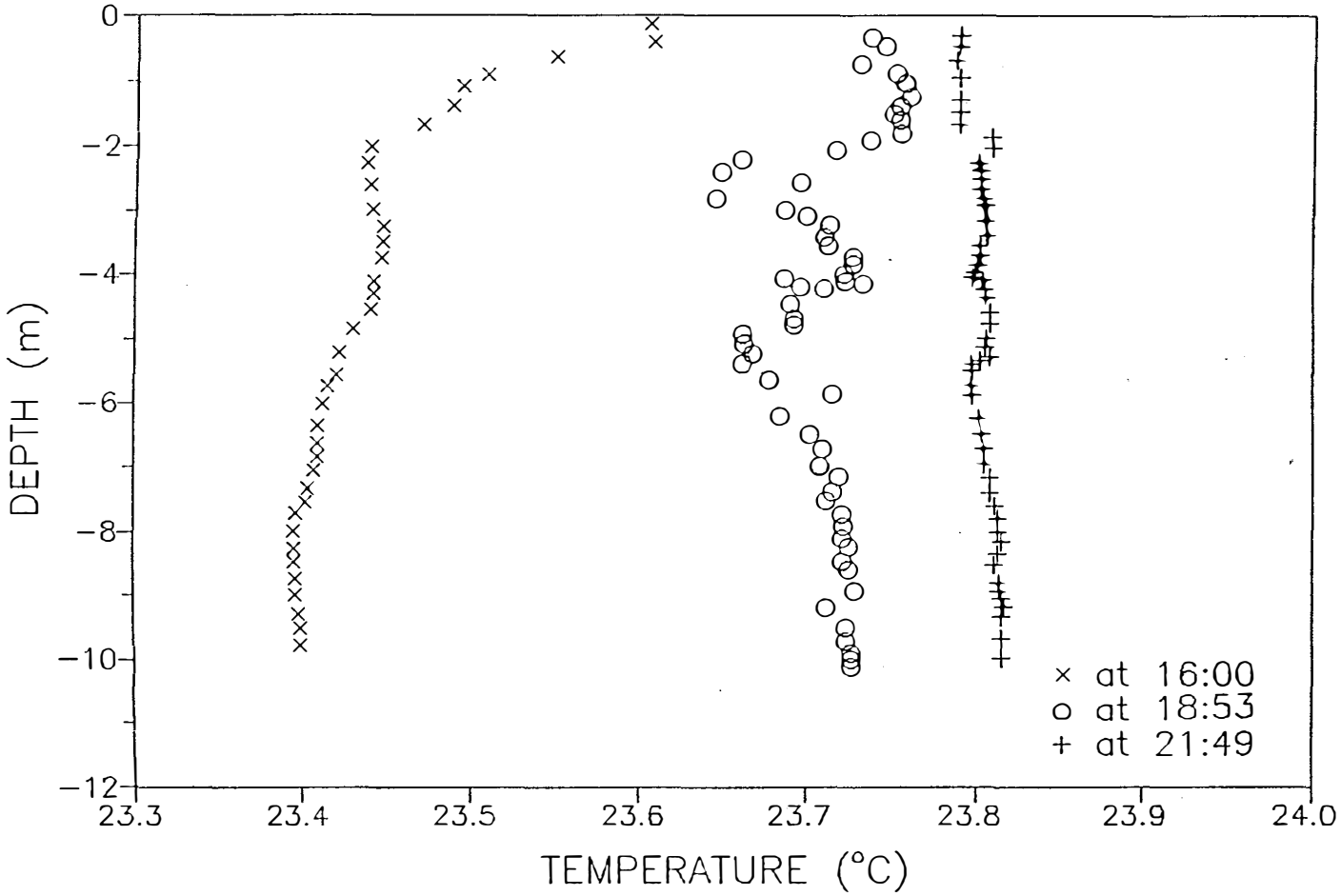


Figure II–19. Bottom current speed at Owl Hollow on 9/20/93.

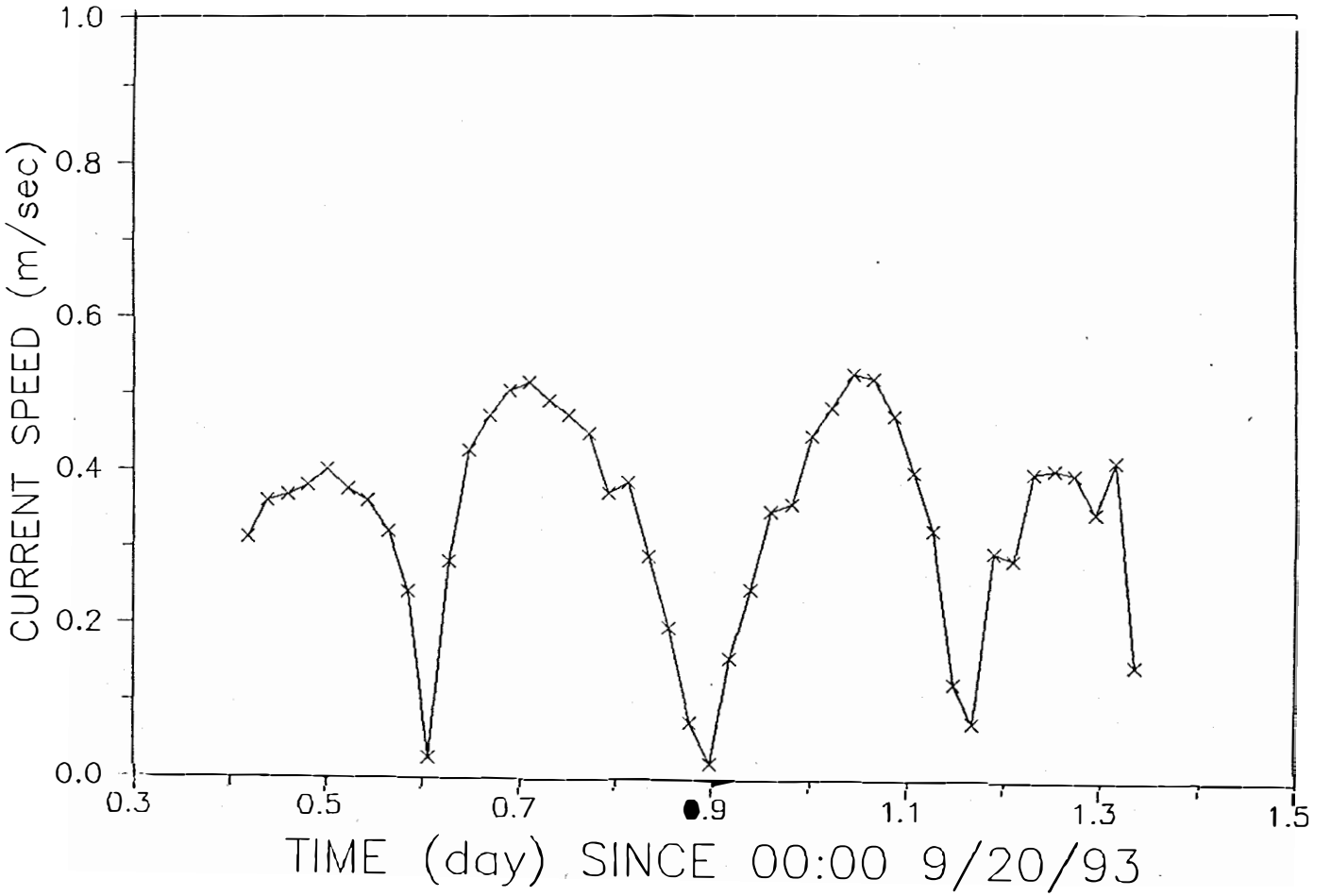


Figure II–20. Dome DO at Tappahannock on 9/23/93.

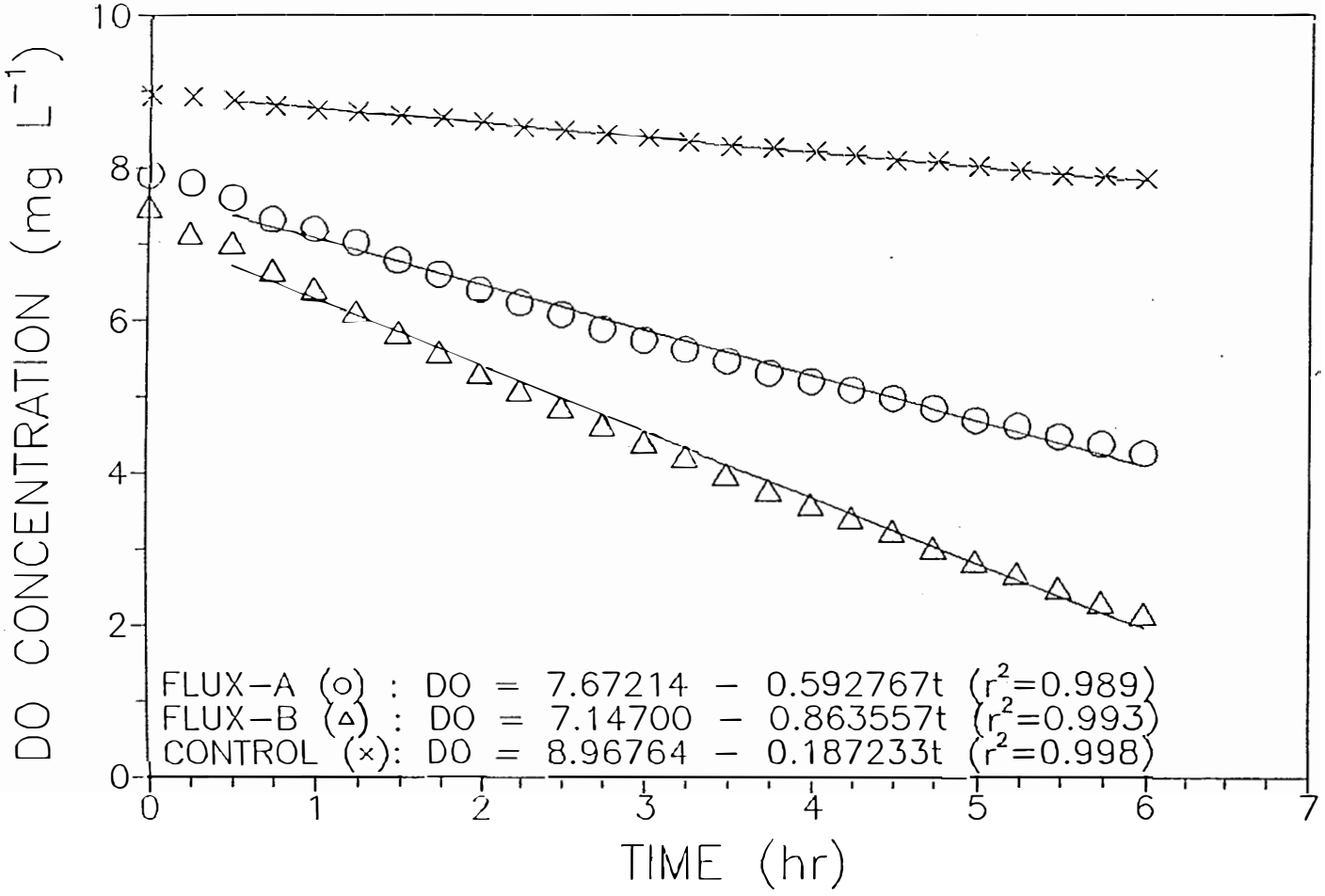


Figure II–21. Salinity at Tappahannock on 9/23/93.

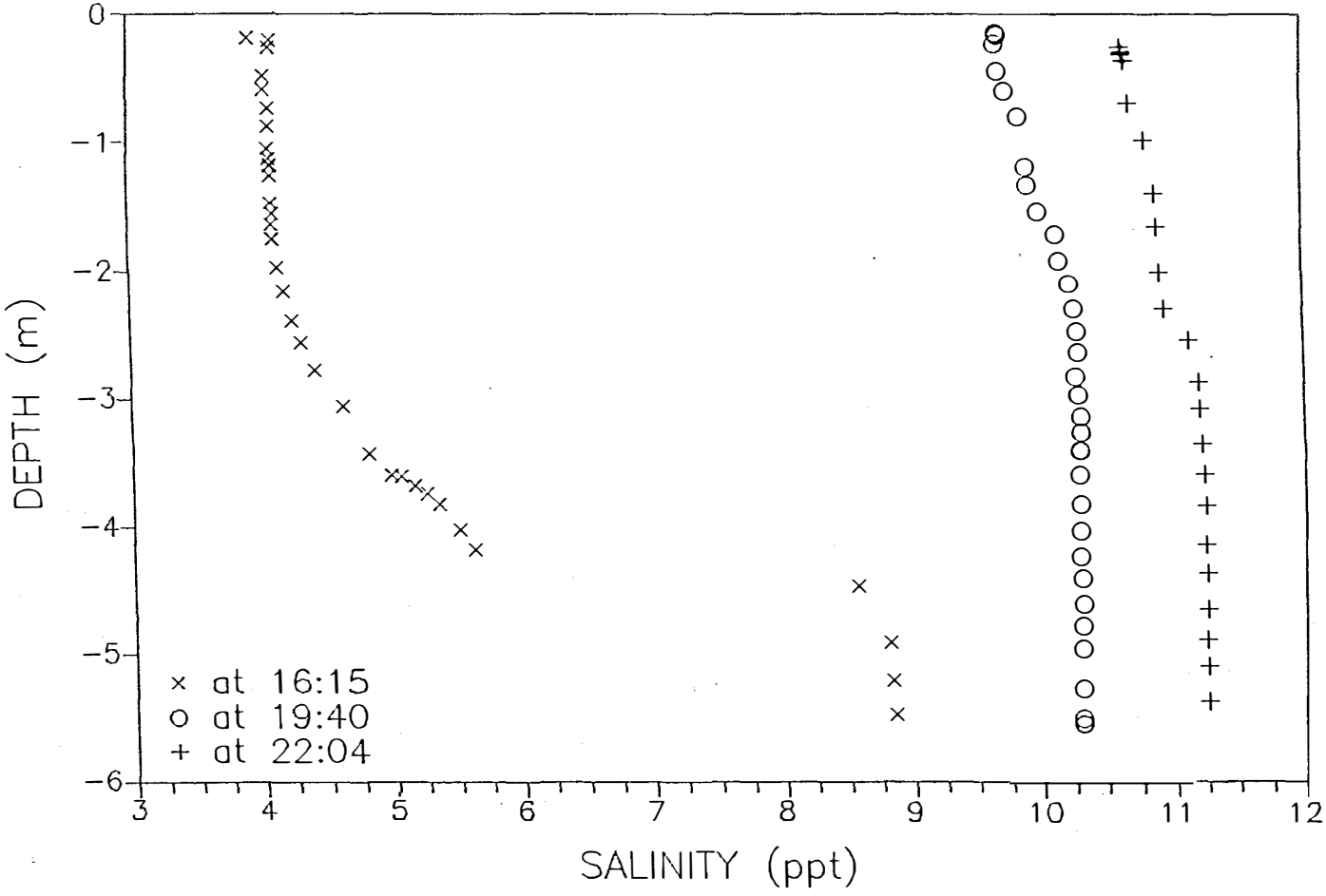


Figure II–22. Temperature at Tappahannock on 9/23/93.

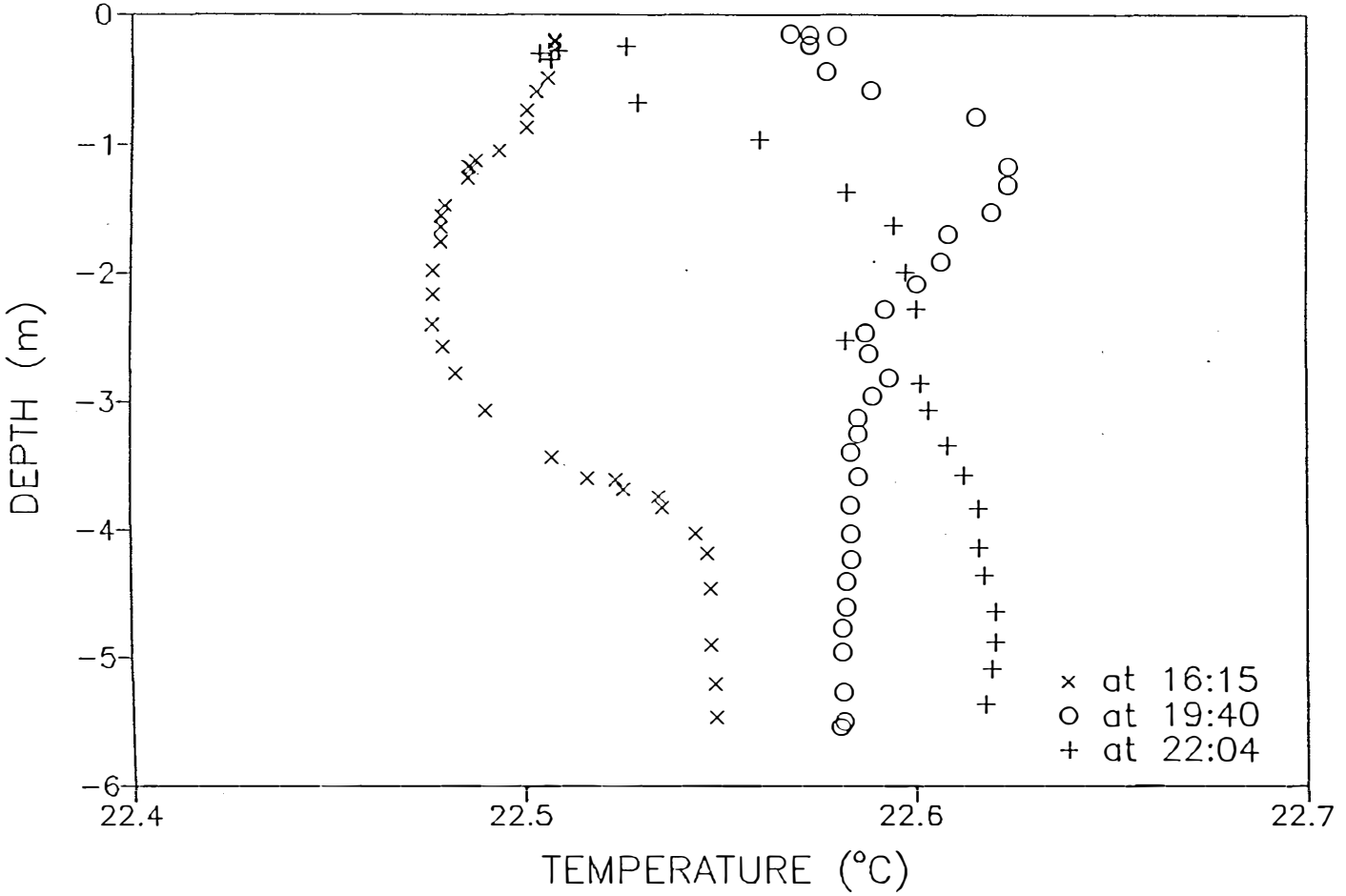


Figure II–23. Bottom current speed at Tappahannock on 9/23/93.

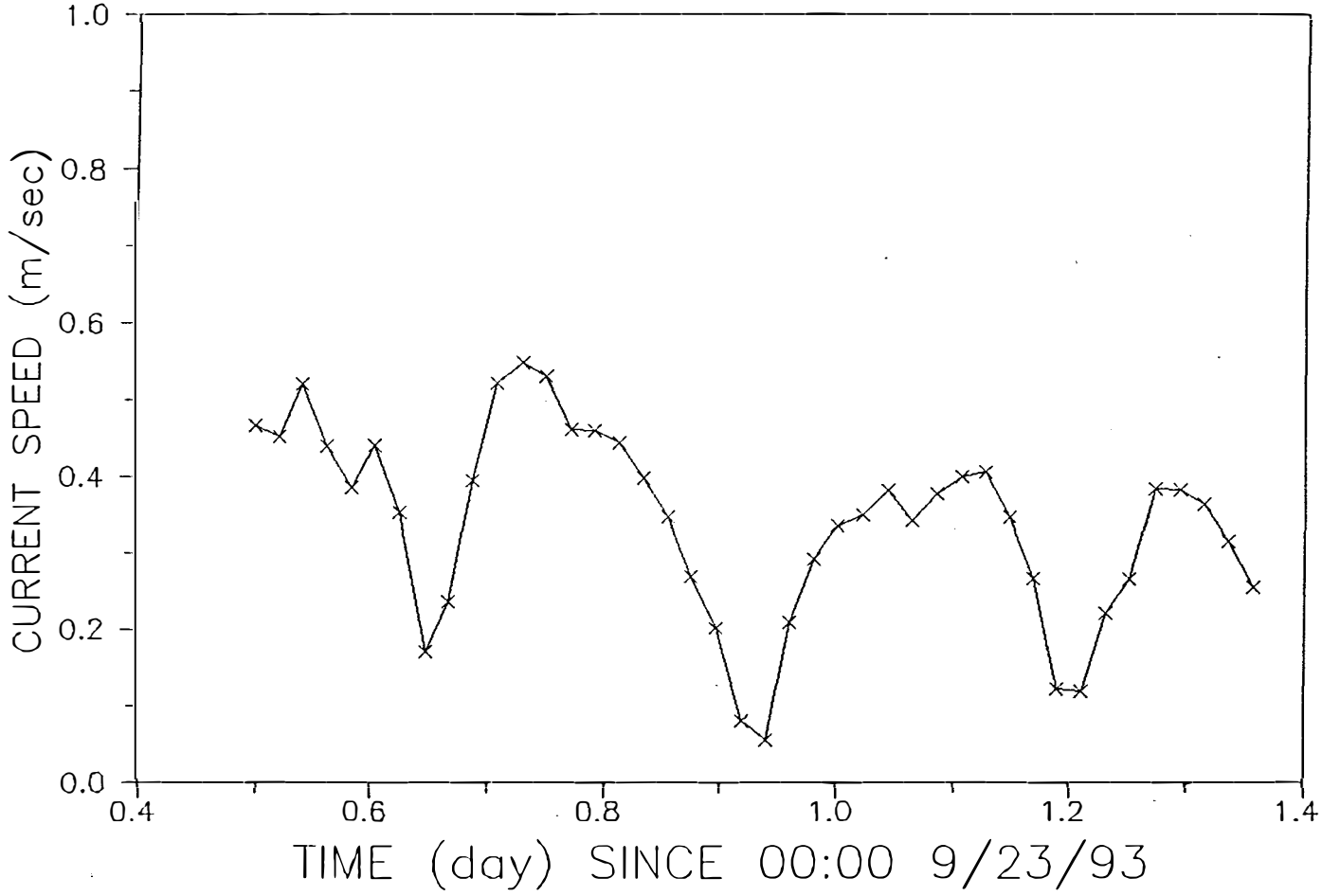


Figure II–24. Dome DO at Water View on 9/22/93.

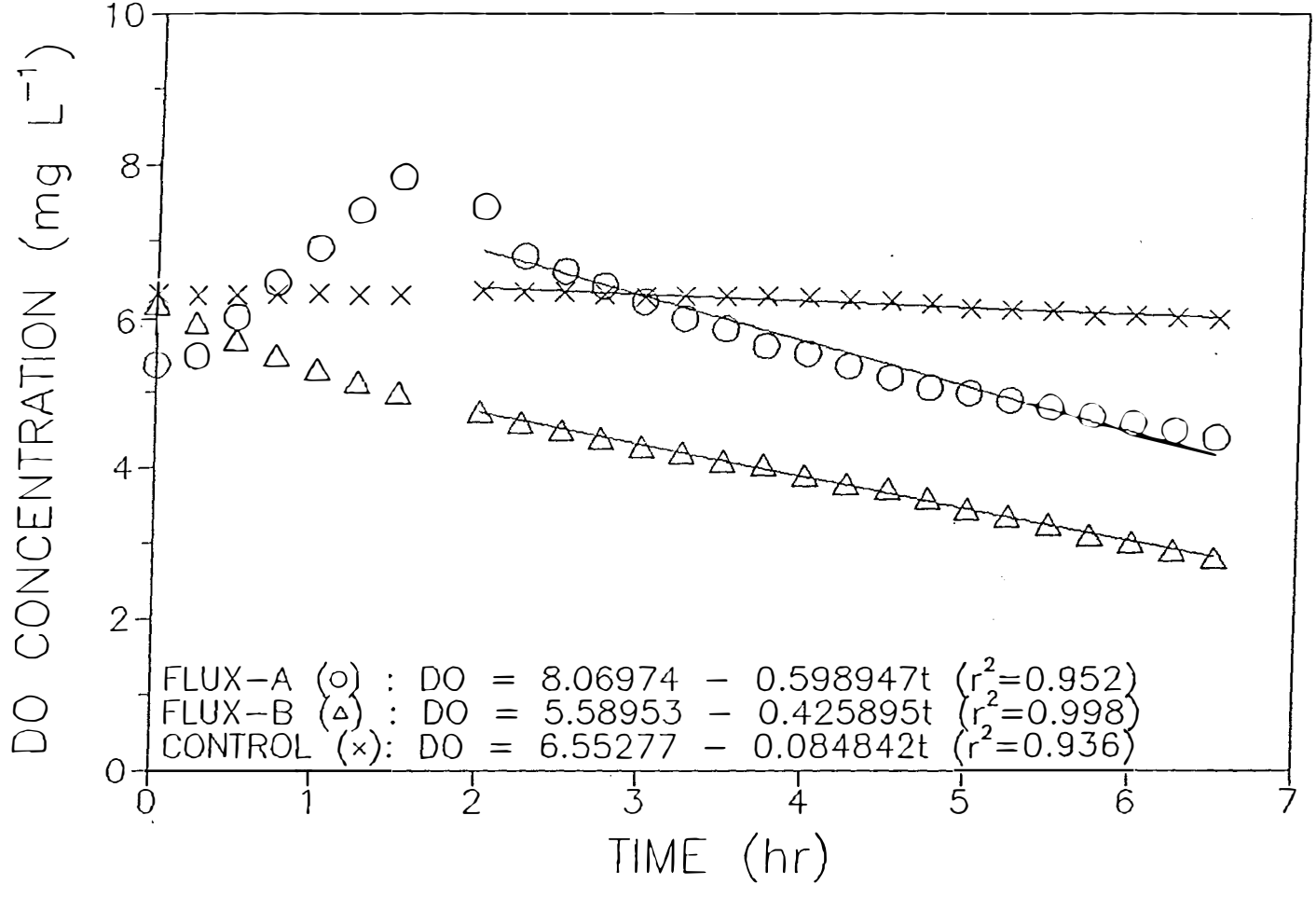


Figure II–25. Salinity at Water View on 9/22/93.

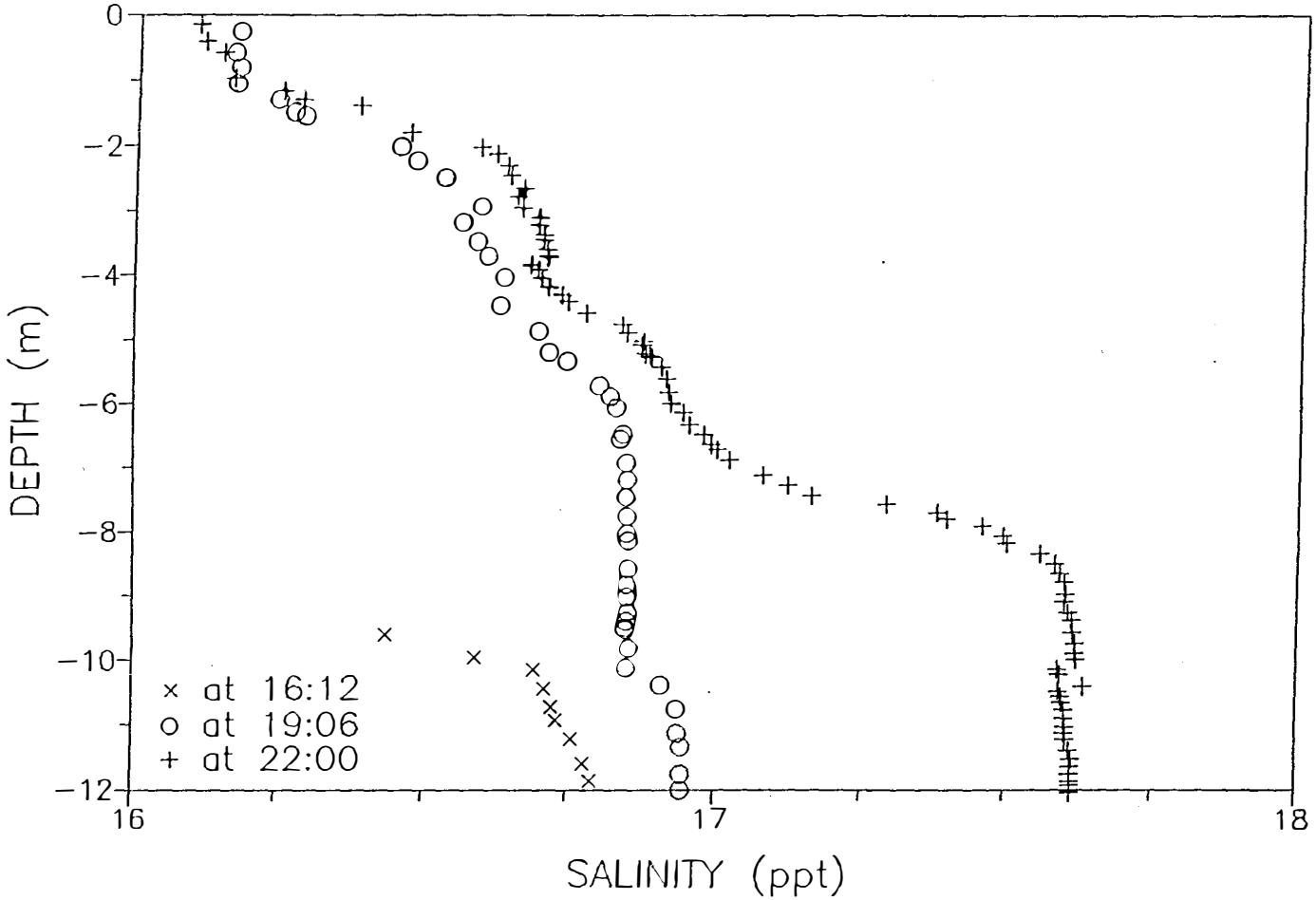


Figure II–26. Temperature at Water View on 9/22/93.

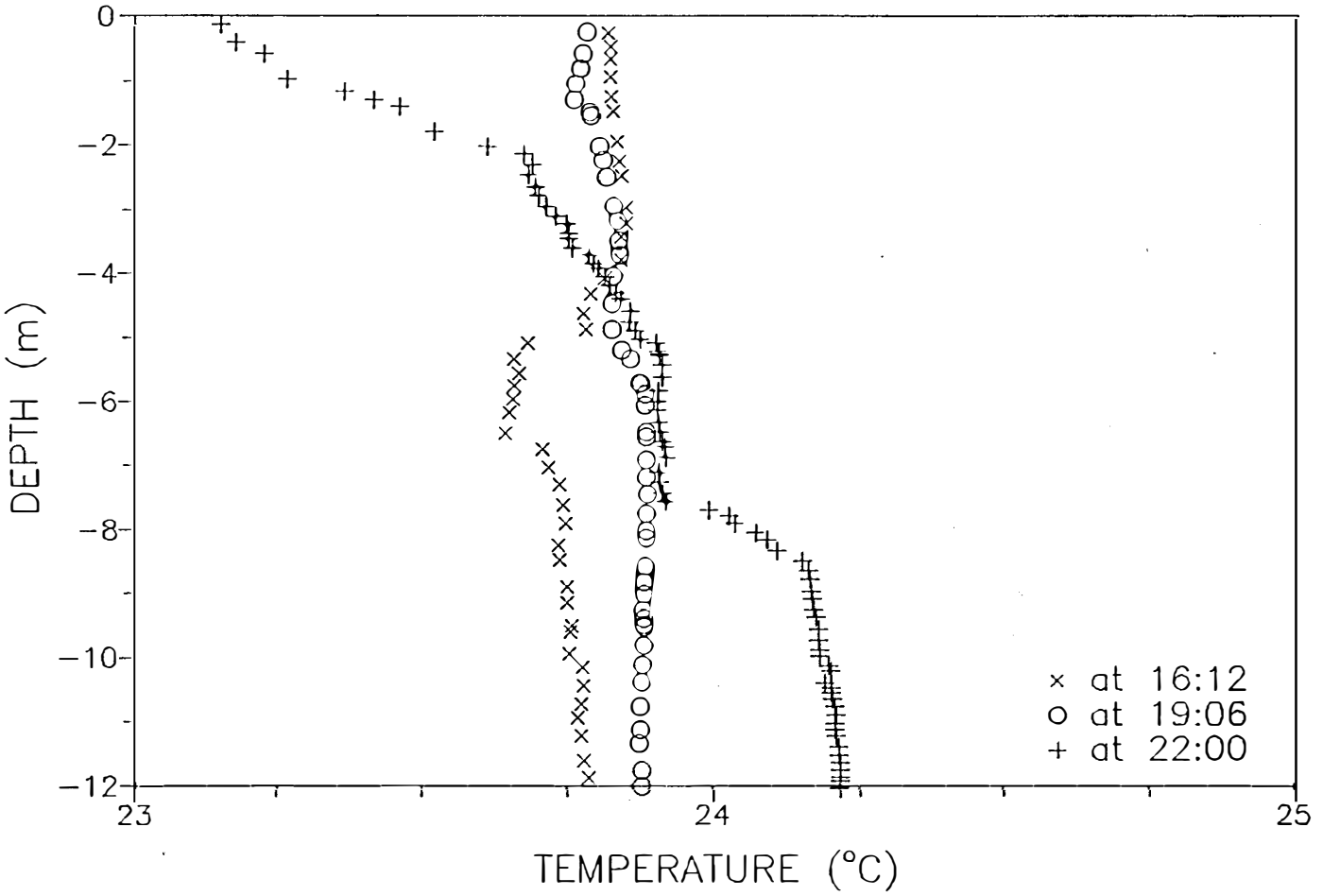


Figure II–27. Bottom current speed at Water View on 9/22/93.

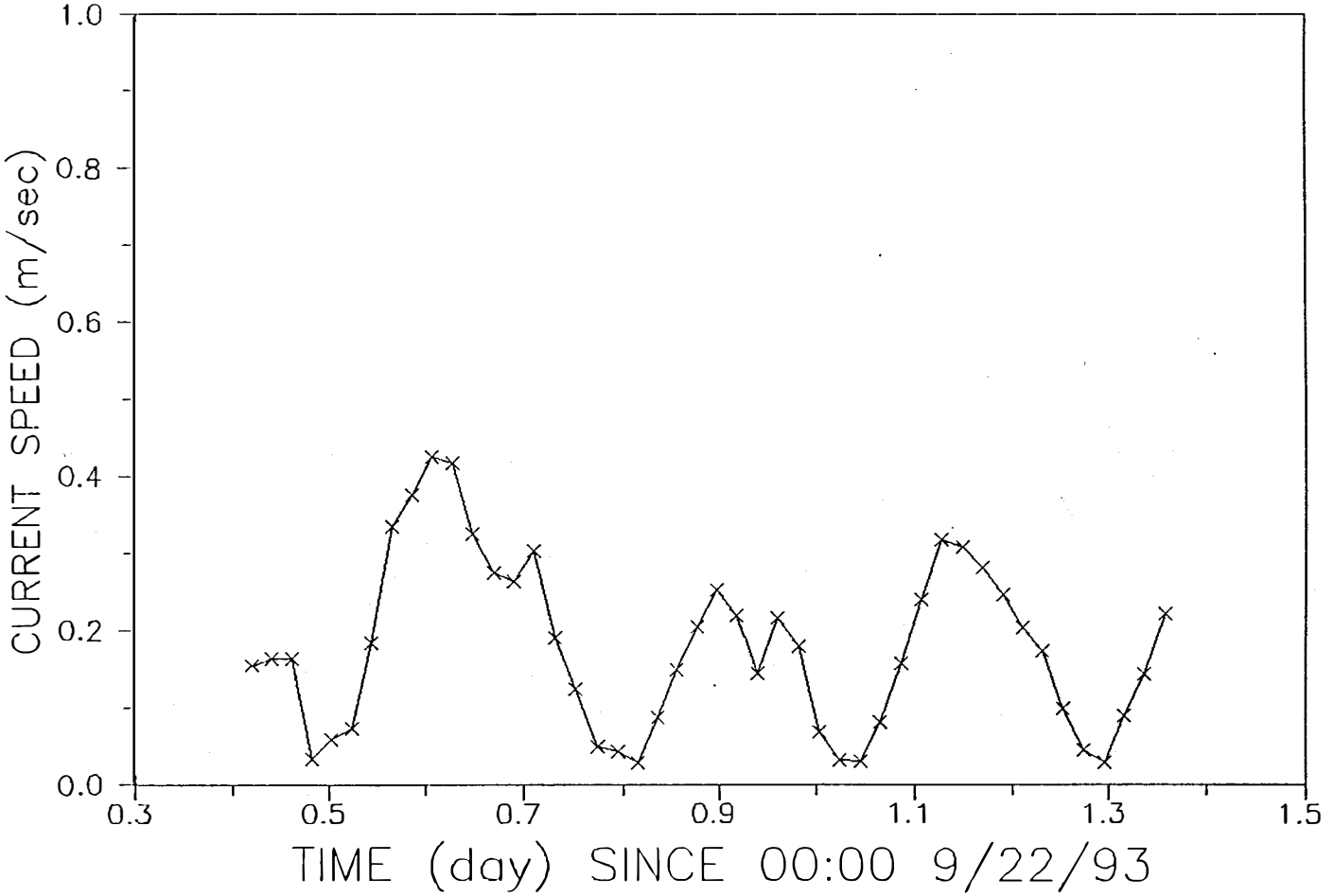


Figure II–28. Water column DO at Water View on 9/22/93.