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James River slack water data report : temperature, salinity, dissolved oxygen, 1971 - 1980

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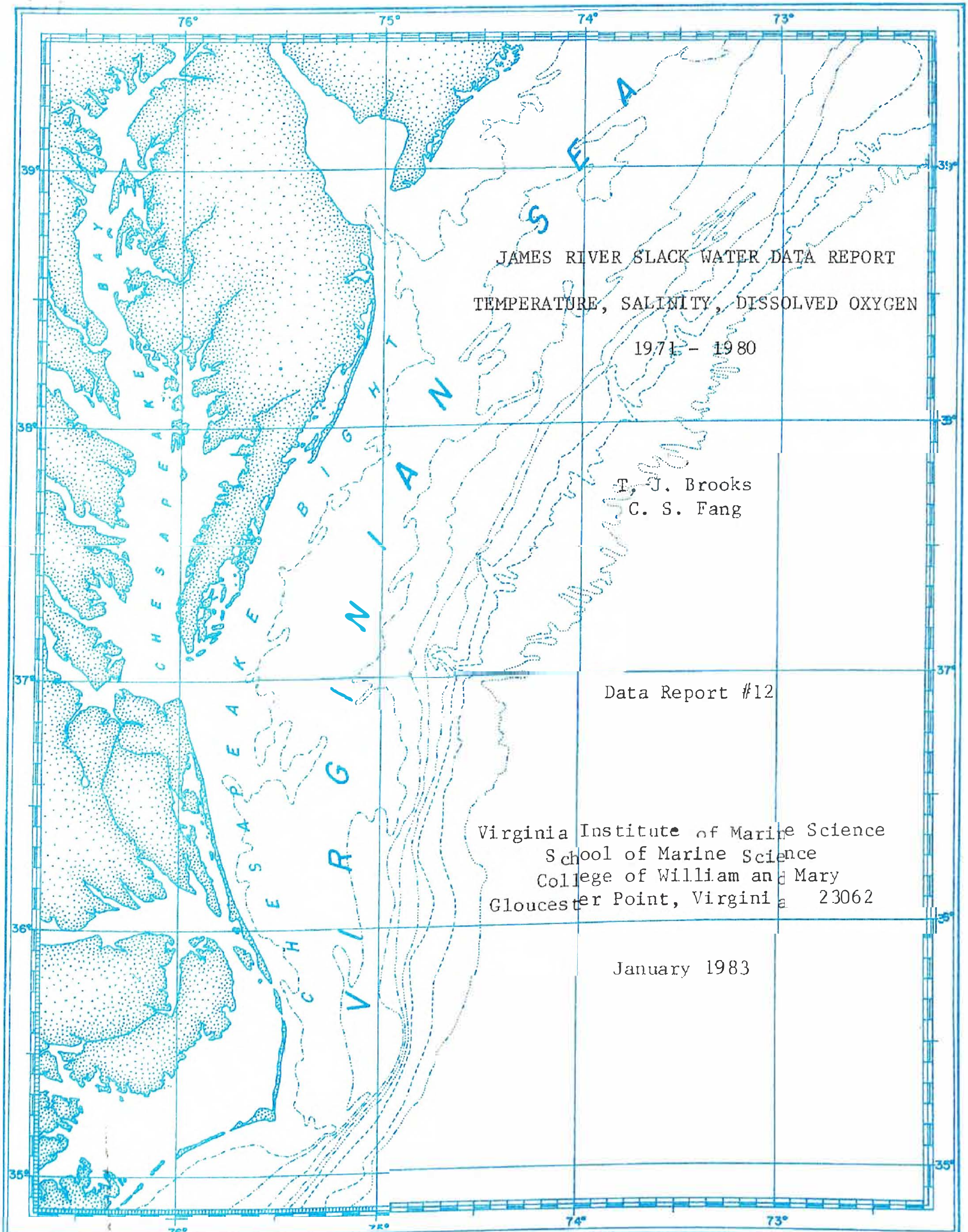

JAMES RIVER SLACK WATER DATA REPORT

TEMPERATURE, SALINITY, DISSOLVED OXYGEN

1971 - 1980

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Data Report #12

Virginia Institute of Marine Science
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ACKNOWLEDGEMENTS

We express our appreciation to the following VIMS scientific personnel for their suggestions and contributions to the development of this monitoring program: Dr. John M. Zeigler, Associate Dean, for his encouragement and leadership; Dr. Bruce Neilson and Dr. A. Y. Kuo for their periodic reviews of the program and design of the field work and the lab analysis; Drs. Evon Ruzecki, Paul Hyer, Christopher Welch, and Carl Cerco for their suggestions for improving the monitoring program.

Over the past ten years, many students and technicians in the Department of Physical Oceanography and Hydraulics have shared in the hard work and the frustrations that accompany bad weather conditions and the problems of boats and instruments. They also have suggested many improvements based on their accumulated field experience. We particularly thank the following persons for their long time contribution to the program by conducting the field work: Messrs. W. Matthews, S. Snyder, K. Worrell, J. Cumbee and S. Fenstermacher. We also thank Ms. Nancy Courtney for the data reduction and Mr. Hugh Brooks for the development of the interfacing program and the selection of the Surface II options.

The funding of this project is jointly supported by the Virginia State Water Control Board and the Virginia Institute of Marine Science through the Cooperative State Agencies program.

INTRODUCTION

The slack water survey program, which has been supported by the State Water Control Board and the Virginia Institute of Marine Science under the Cooperative State Agencies program, provides an extended series of temperature, salinity, dissolved oxygen and nutrient measurements along the James River. These have been used to:

1) establish, verify, and update mathematical and physical hydraulic models;

2) provide a baseline against which effects of unusual events have been measured;

and could be used to:

3) establish annual and longer period "climatological" trends in response to changing natural phenomena and man-made modifications to the estuary;

4) provide a basis against which fluctuations in biota could be compared.

This report contains station locations, survey schedules, field procedures, sample handling procedures, and data reduction and storage procedures. In addition, 10 years of contoured temperature, salinity, and dissolved oxygen data is presented.

The primary purpose of this report is to provide the data in a format which we believe will be useful to others. Analysis and interpretation of the data is underway and this will be the subject of a later report.

I. SLACK WATER SURVEY PROGRAM

A. Description of the Study Area

The James River is the southernmost major tributary of the Chesapeake Bay and the largest tributary estuary in Virginia as can be seen in Figure 1. The tidal portion of the James River extends 169 kilometers from the river mouth in a generally north-west direction to Richmond (Division of Water Resources, 1969). This portion of the river drains an area of 8,801 square kilometers. The 370 kilometers of river above Richmond drain an additional 17,501 square kilometers (Seitz, 1971). The average discharge near Richmond is 215.4 cubic meters per second based on 46 years of record. The discharge, including the canal flow, has ranged from 10.5 to 8,860 cubic meters per second (USGS, Water Resources Data for Virginia, 1981).

The water surface area of the tidal James River is 658 square kilometers at mean low water. The mean low water volume is 2.398×10^9 cubic meters. Figure 2 is a plot of the mean tidal range which is 0.75 meters at the mouth and 1.05 meters near Richmond. Figure 3 shows the time difference for high and low water relative to Hampton Roads. The duration of tidal rise and the duration of tidal fall is presented in Figure 4 (Cronin, 1971).

The climate in the study area is classified as humid subtropical. The average annual air temperature in the James River basin is 14.8° C. Average monthly air temperatures range from 3.9°C in January to 25.6° C in July. The average annual precipitation in the basin is 110.8 centimeters (NOAA, Climatological Data, 1980).

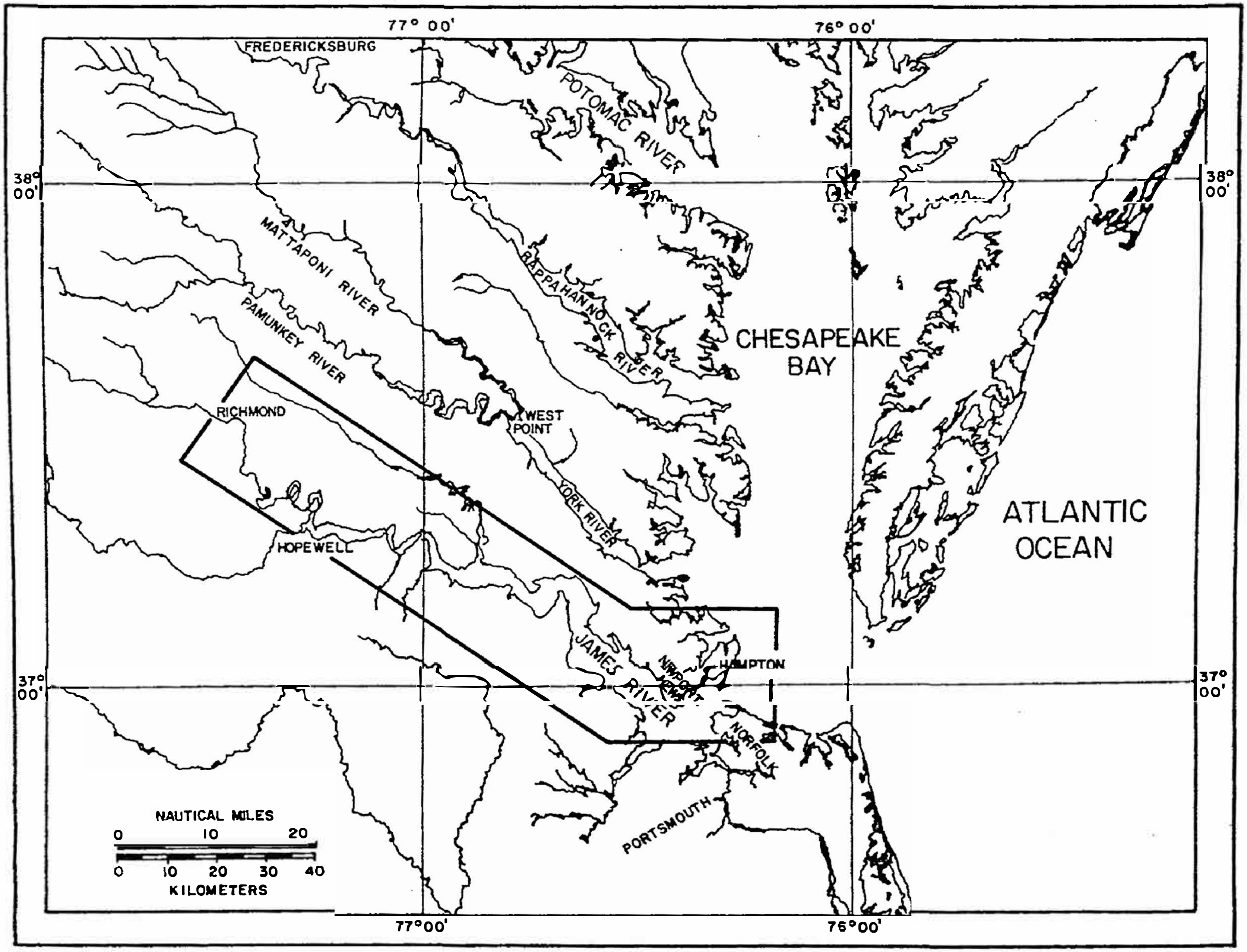


Figure 1. Map Locating the James River Within Virginia

FIGURE 2. MEAN TIDAL RANGE

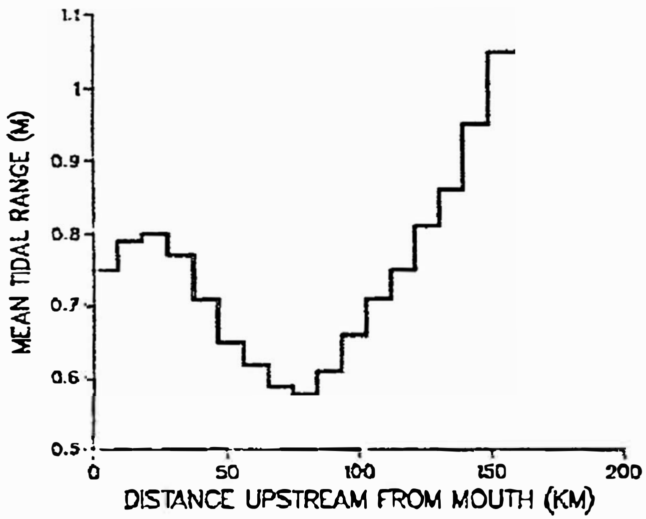


FIGURE 3. TIME DIFFERENCE FOR HIGH AND LOW WATER RELATIVE TO HAMPTON ROADS

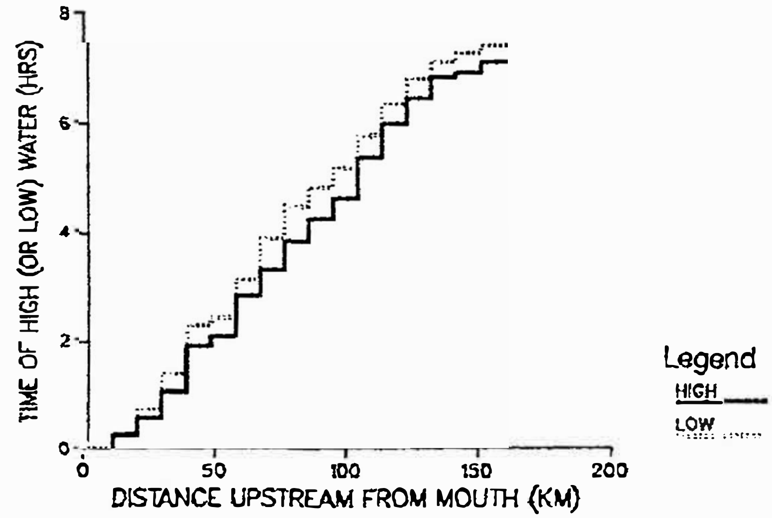
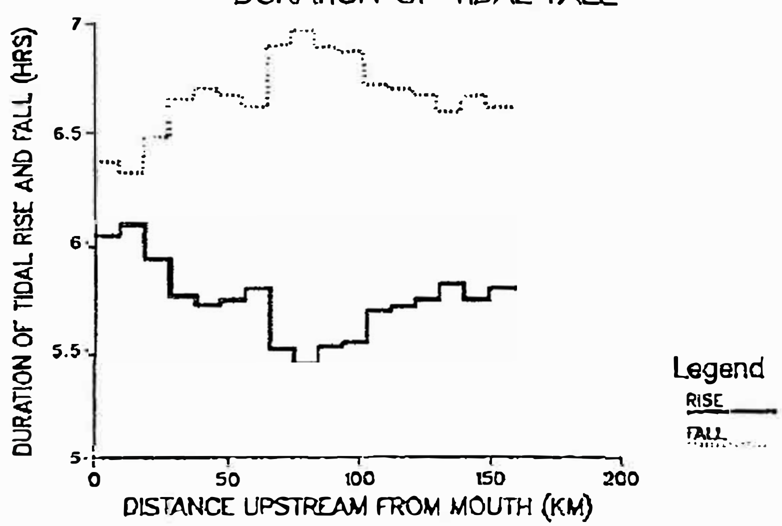


FIGURE 4. DURATION OF TIDAL RISE AND DURATION OF TIDAL FALL



(Cronin, 1971)

B. Slack Water Survey Criteria

A slack water survey is made by taking water samples at designated locations while following either the high or low water slack wave (slack water before ebb tide or slack water before flood tide respectively) as it progresses upstream from the estuary mouth. Most stations are located near the middle of the navigation channel. Water samples from at least two points in the water column, one near the surface and one near the bottom, are taken at each station. At stations of sufficient depth additional points in the water column may be sampled. (See section C, "Field Procedures", for more detailed information.) The locations of the most frequently sampled stations are shown in Figure 5, where the station designation refers to the distance from the river mouth in kilometers. Table 1 lists each station by its kilometer designation, latitude and longitude, and water depth.

A reasonable time table for collecting the samples is 15-20 minutes at the first station. This estimate includes the time spent getting the equipment organized and situated in the boat. Stations up river average 5 to 10 minutes each.

Every effort is made to complete a slack water survey once it has started. The decision to abort a survey may be made when weather conditions, and more importantly wave conditions, have reached such a point that the slack water time table can not be met. In some cases a few of the stations near the river mouth can be skipped and the survey continued upstream. If half of the river is skipped in order to find more tranquil water conditions the lower portion is rescheduled for no

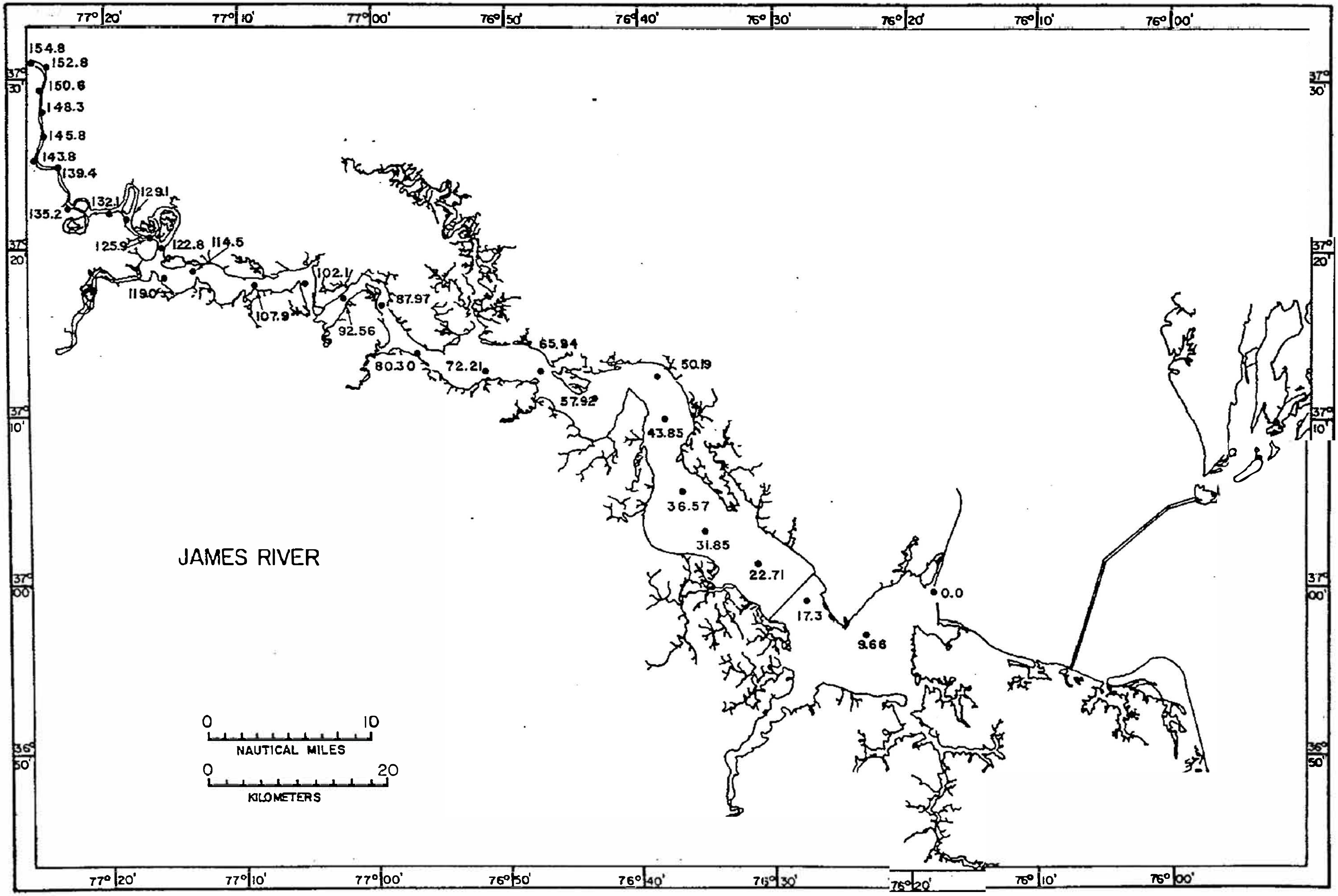


Figure 5. Map of the James River Showing the Station Locations

Table 1. James River Slack Water Survey Stations

Distance (km)	Latitude (north)	Longitude (west)	Depth (m)
00.00	36-59.8'	76-18.2'	25.5
09.66	36-57.3'	76-23.5'	13.5
17.30	36-59.4'	76-27.6'	10.8
22.71	37-01.6'	76-31.3'	12.0
31.85	37-03.4'	76-35.6'	07.2
36.57	37-05.7'	76-37.2'	07.2
43.85	37-09.3'	76-38.5'	15.9
50.19	37-12.4'	76-39.1'	07.5
57.92	37-11.4'	76-43.7'	07.2
65.94	37-12.9'	76-47.6'	14.4
72.21	37-13.0'	76-51.8'	07.2
80.30	37-14.2'	76-56.9'	10.2
87.97	37-17.1'	76-59.4'	14.4
92.56	37-17.3'	77-02.5'	07.8
102.1	37-18.3'	77-04.9'	07.5
107.9	37-18.1'	77-08.8'	08.1
114.5	37-19.0'	77-13.2'	07.5
119.0	37-18.4'	77-15.6'	06.2
122.8	37-20.2'	77-16.3'	07.2
125.9	37-21.2'	77-17.3'	07.2
129.1	37-22.2'	77-18.6'	07.2
132.1	37-22.8'	77-20.4'	07.2
135.2	37-22.9'	77-22.4'	07.2
139.4	37-24.6'	77-23.7'	07.2
143.8	37-25.7'	77-25.6'	07.2
145.8	37-26.7'	77-25.2'	07.2
148.3	37-28.1'	77-25.3'	05.1
150.6	37-29.3'	77-25.3'	05.1
152.8	37-30.4'	77-25.1'	05.1
154.8	37-31.4'	77-25.2'	05.1

later than the next day. When this is not possible the entire slack water survey is rescheduled.

Surveys usually are conducted monthly, except in the winter, by two-person crews in small outboard boats which are able to keep pace with the slack wave. Winter sampling is generally suspended due to the over-saturation of dissolved oxygen and the low temperatures. The months during which slack water surveys have been conducted are presented in Table 2.

The slack water surveys are scheduled so that the field crews spend the least possible amount of time working during darkness. Usually, the surveys start no earlier than one hour before daylight and are run no later than one hour after sunset. This policy is mainly a safety consideration in an effort to avoid running the boats at top speeds in a limited visibility situation. Since they are the longest, the James and Rappahannock rivers are given first priority as to scheduling dates.

Prior to 1978 when daily precipitation was greater than 0.3 of an inch the survey was postponed for a period of usually three days. This sometimes caused problems as far as scheduling the surveys, especially when the month was drawing to a close. Since 1978 the policy has been changed and the surveys are no longer postponed due to rain.

Figures 6a-j show daily fresh water discharge and the date of each slack water survey. The fresh water discharge is measured near Cartersville (USGS, Water Resources Data for Virginia, Water Years 1971 - 1981) and represents approximately 66.5% of the drainage area of

Table 2. Months of Slack Water Surveys (High and Low) for 1971-1980

James River

	1971		1972		1973		1974		1975		1976		1977		1978		1979		1980	
	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L
January				(X)	X													Δ		
February					X		X													
March			(X)	(X)	X													Δ		
April			(X)	X			(X)			Δ		(X)		Δ	X	X		Δ		
May			X	X	(X)			(X)	Δ		(X)	(X)			X	X		Δ		
June		X			(X)		(X)					(X)		Δ		Δ		Δ	X	
July							(X)	(X)				Δ	Δ	Δ		Δ	Δ	Δ	Δ	
August		X						(X)	X	Δ	Δ	Δ	Δ		Δ	Δ		Δ	X	Δ
September	X	X	X	(X)				(X)		Δ			Δ	Δ	Δ		Δ	Δ	Δ	
October	(X)		(X)	(X)	(X)	(X)		Δ		Δ		Δ	Δ		Δ			Δ		Δ
November				(X)				(X)	X		Δ	Δ				Δ		Δ		
December	(X)		X				(X)									Δ				

X: Temperature, Salinity, D.O.
(X): T, S, D.O., B.O.D.
Δ: T, S, D.O., B.O.D., Chlorophyll and/or Nutrients

H: High water slack; slack before ebb
L: Low water slack; slack before flood

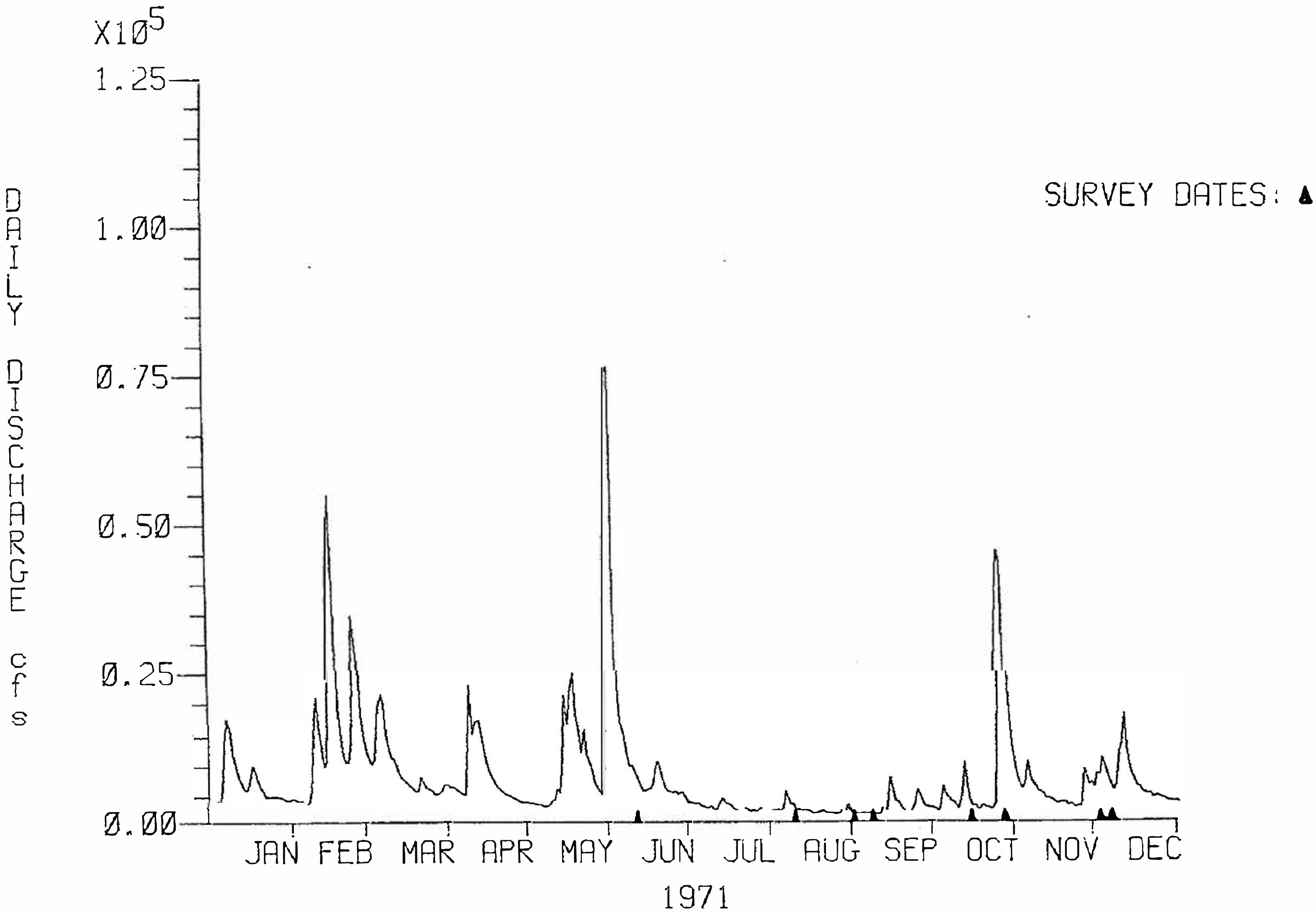


Figure 6a. Fresh Water Discharge and Slack Water Survey Dates, 1971

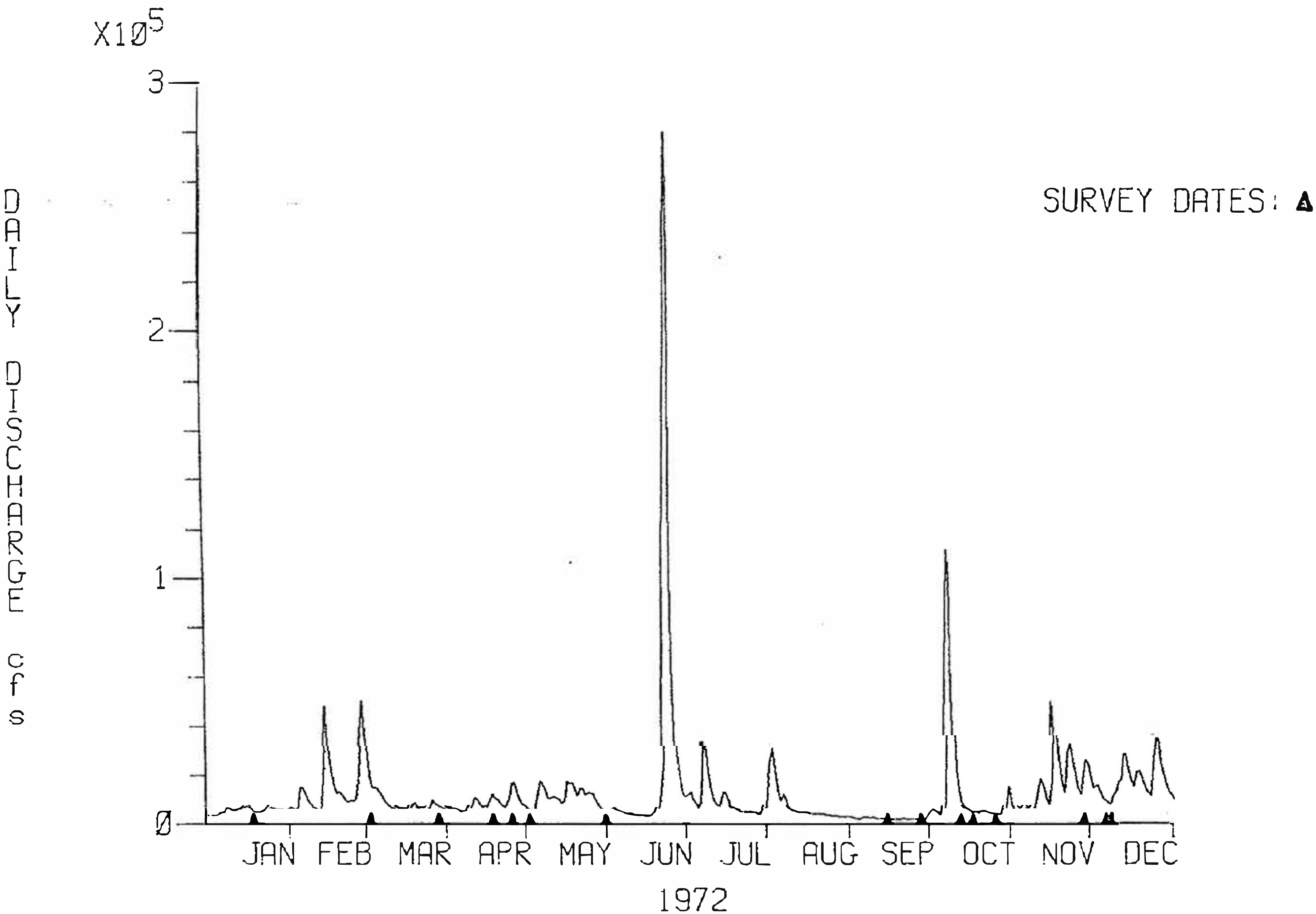


Figure 6b. Fresh Water Discharge and Slack Water Survey Dates, 1972

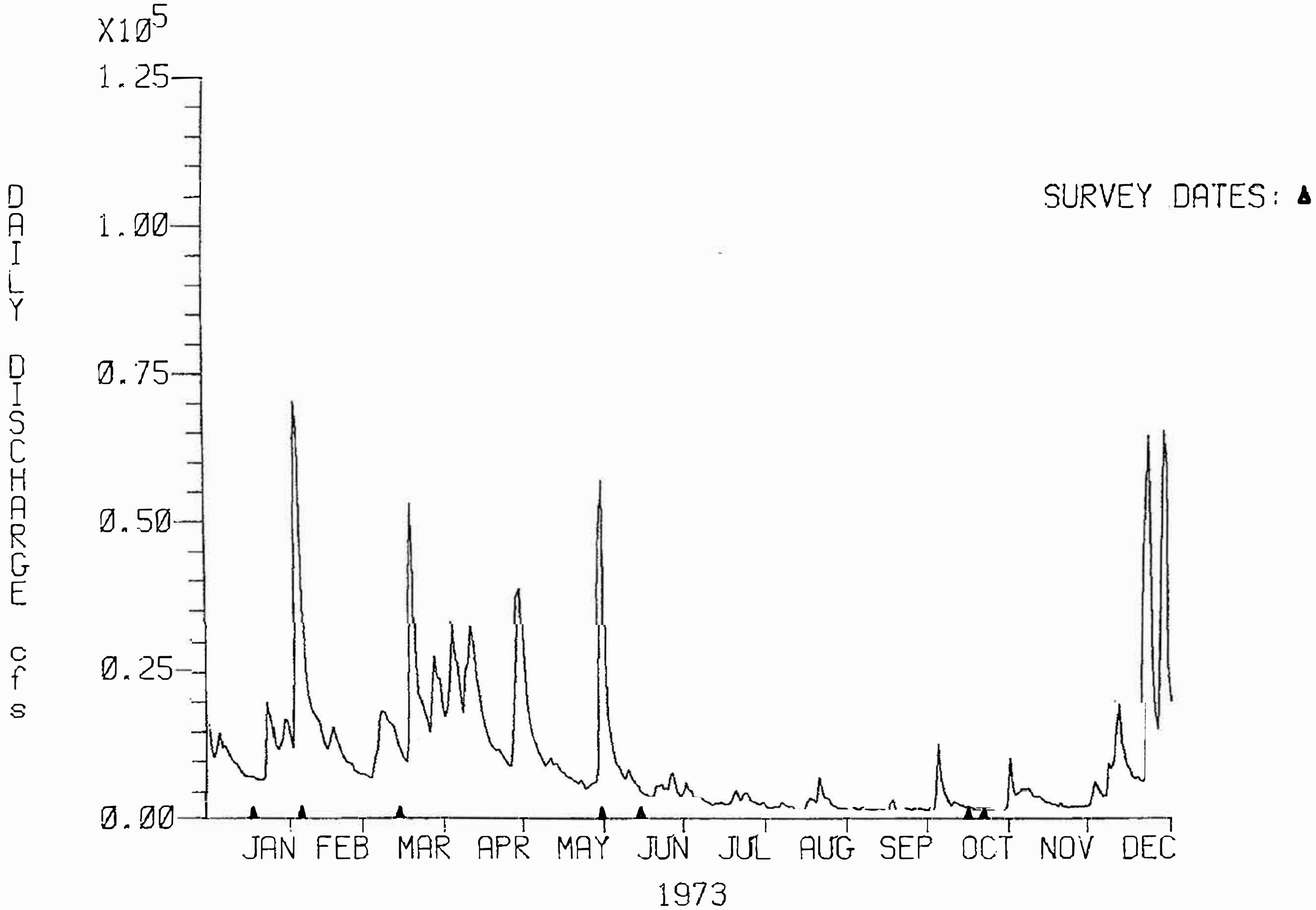


Figure 6c. Fresh Water Discharge and Slack Water Survey Dates, 1973

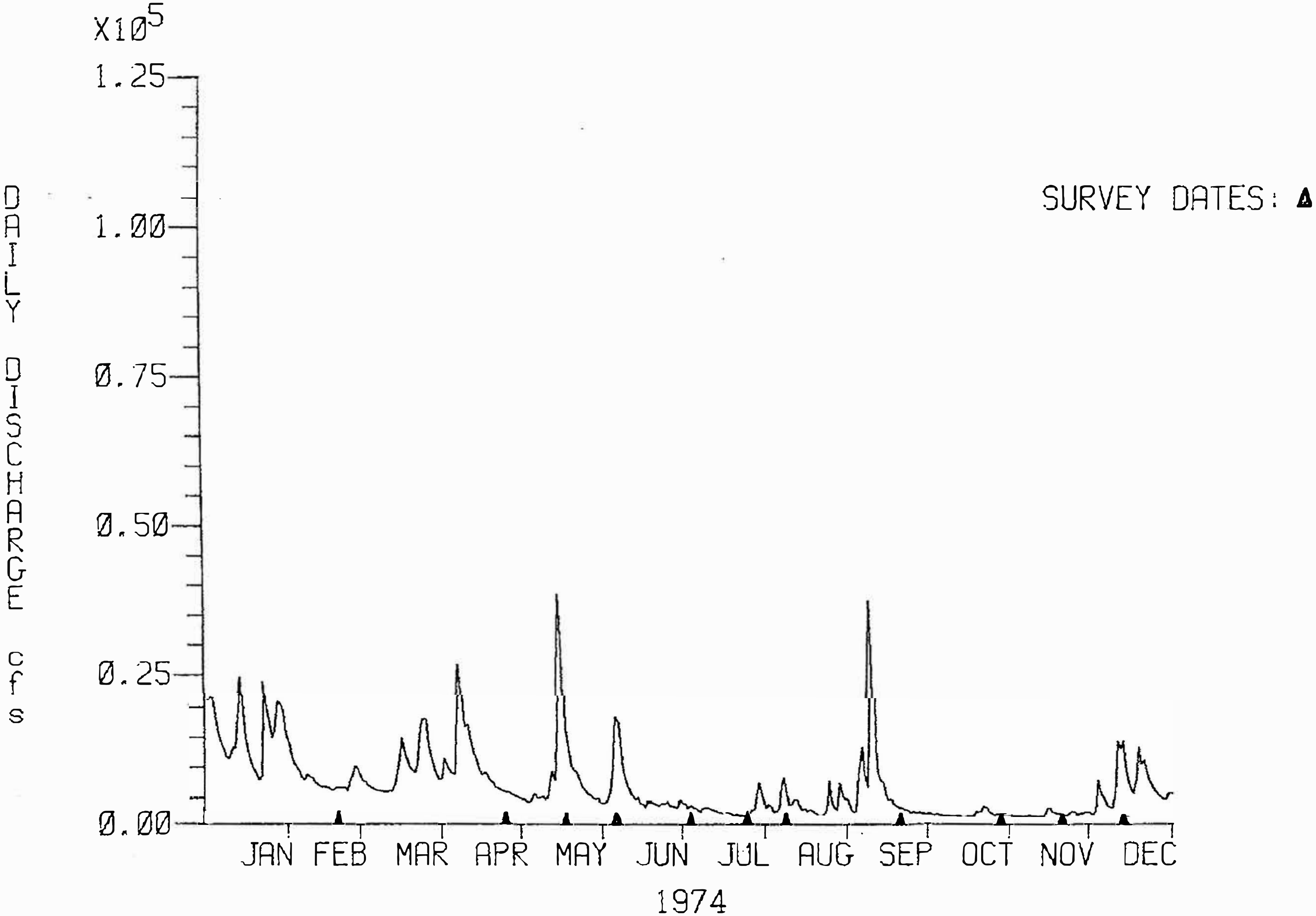


Figure 6d. Fresh Water Discharge and Slack Water Survey Dates, 1974

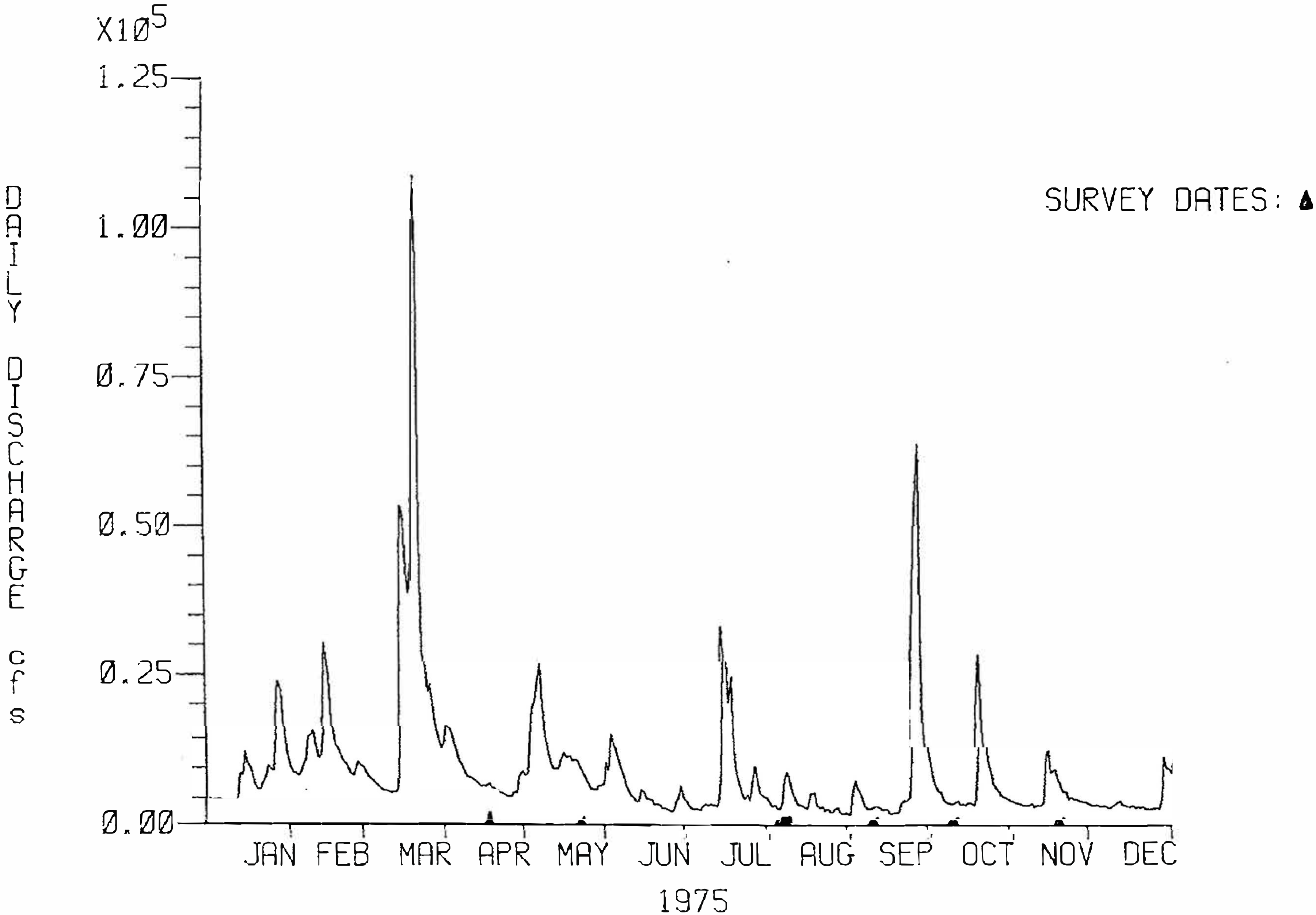


Figure 6e. Fresh Water Discharge and Slack Water Survey Dates, 1975

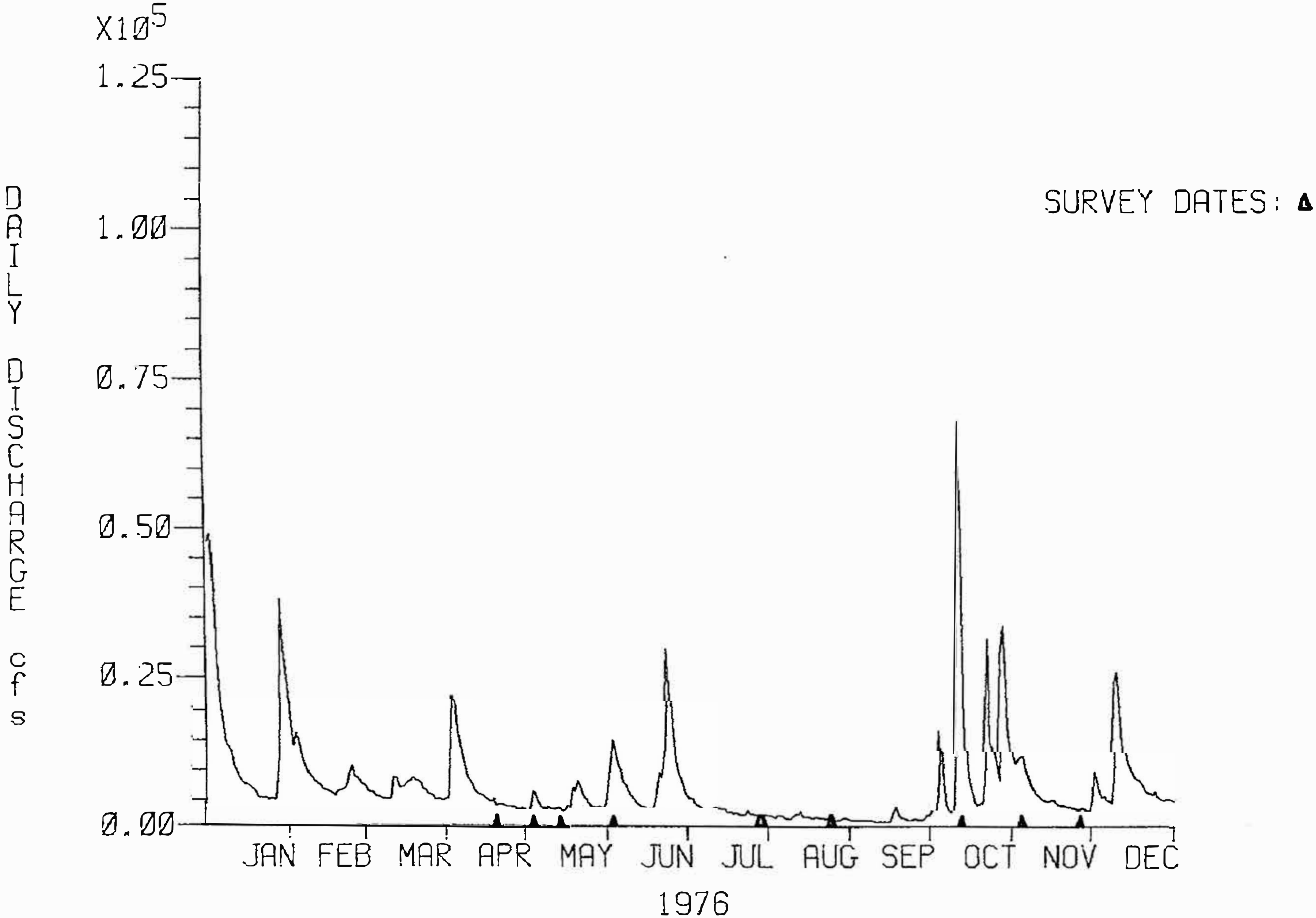


Figure 6f. Fresh Water Discharge and Slack Water Survey Dates, 1976

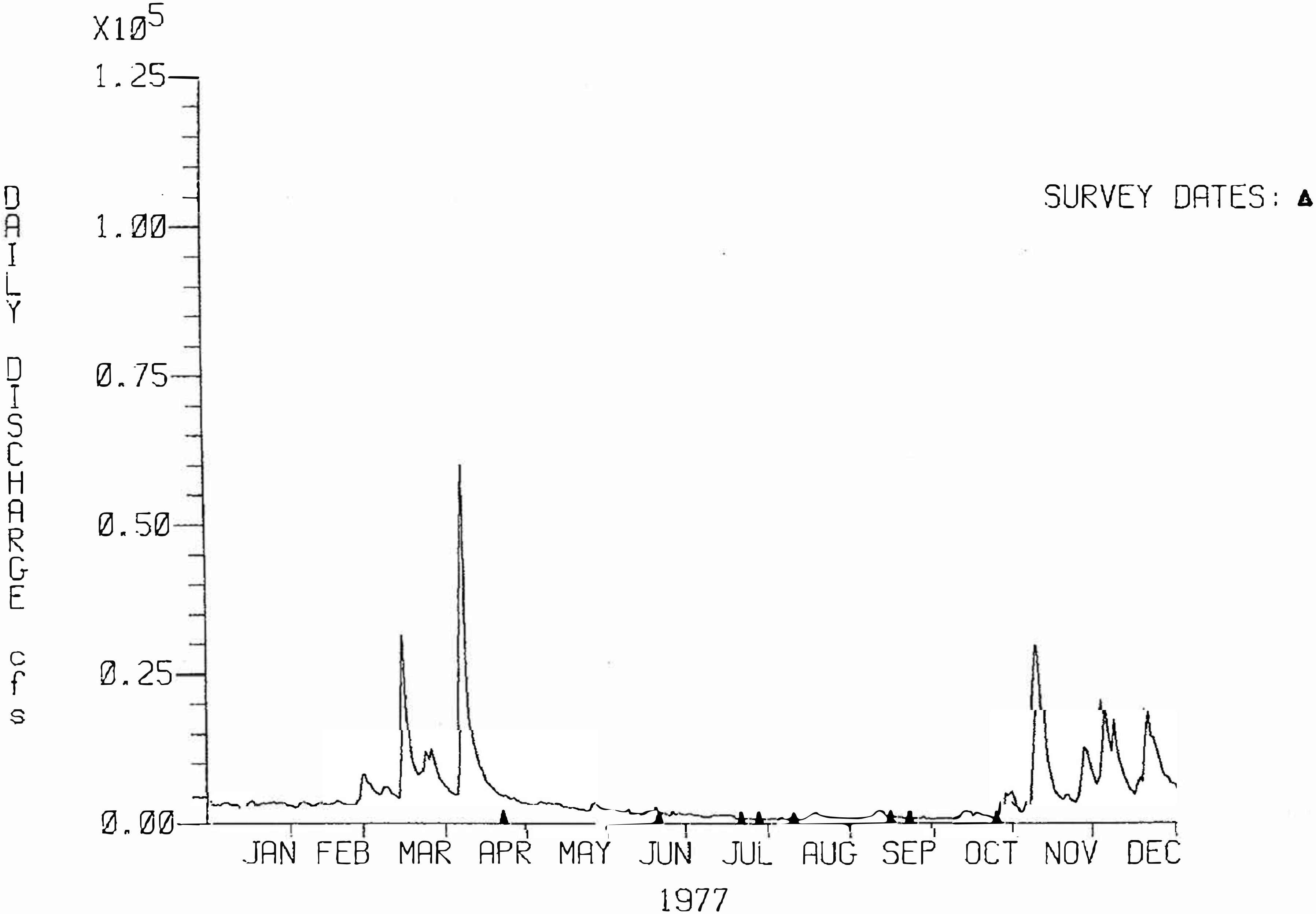


Figure 6g. Fresh Water Discharge and Slack Water Survey Dates, 1977

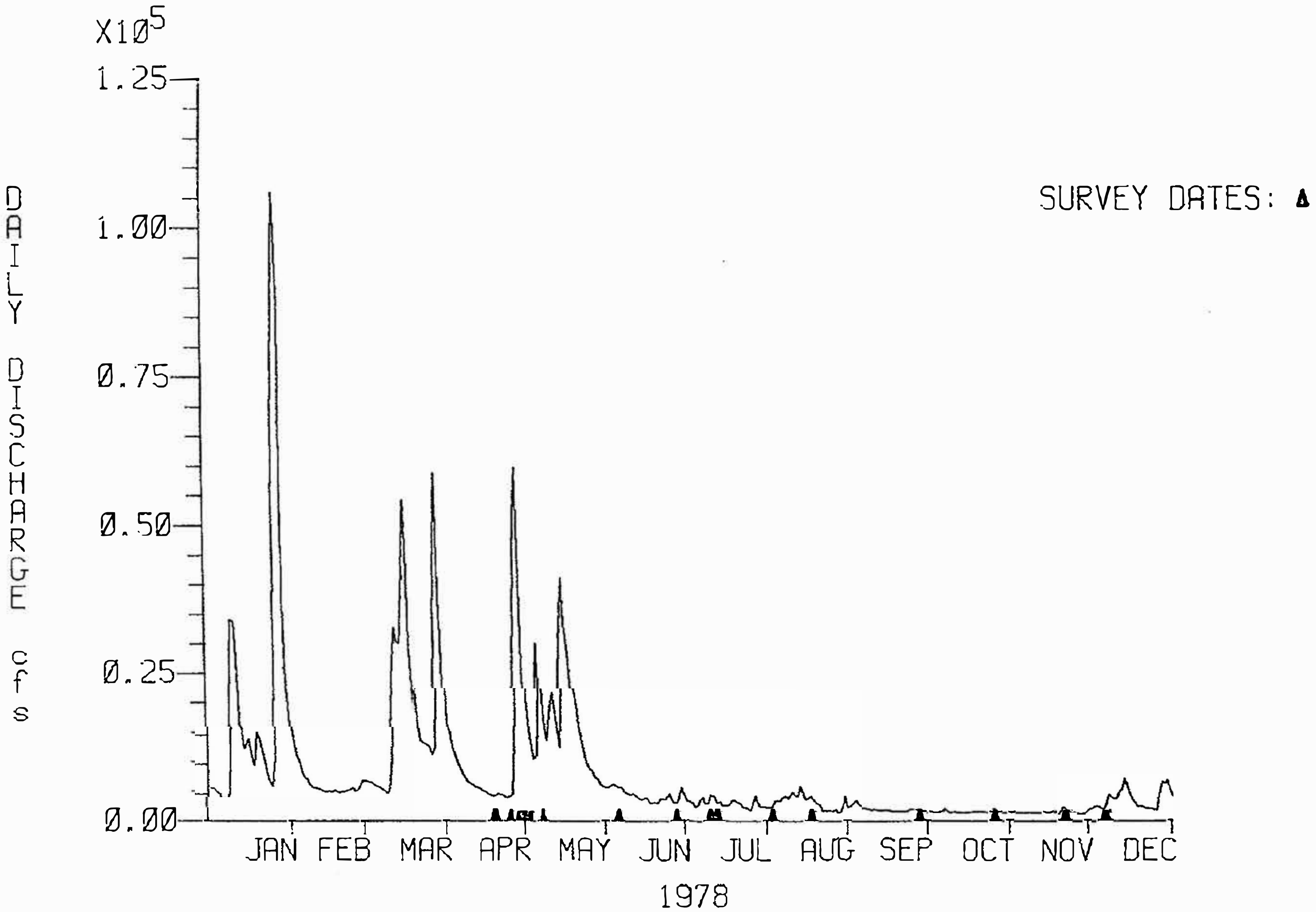


Figure 6h. Fresh Water Discharge and Slack Water Survey Dates, 1978

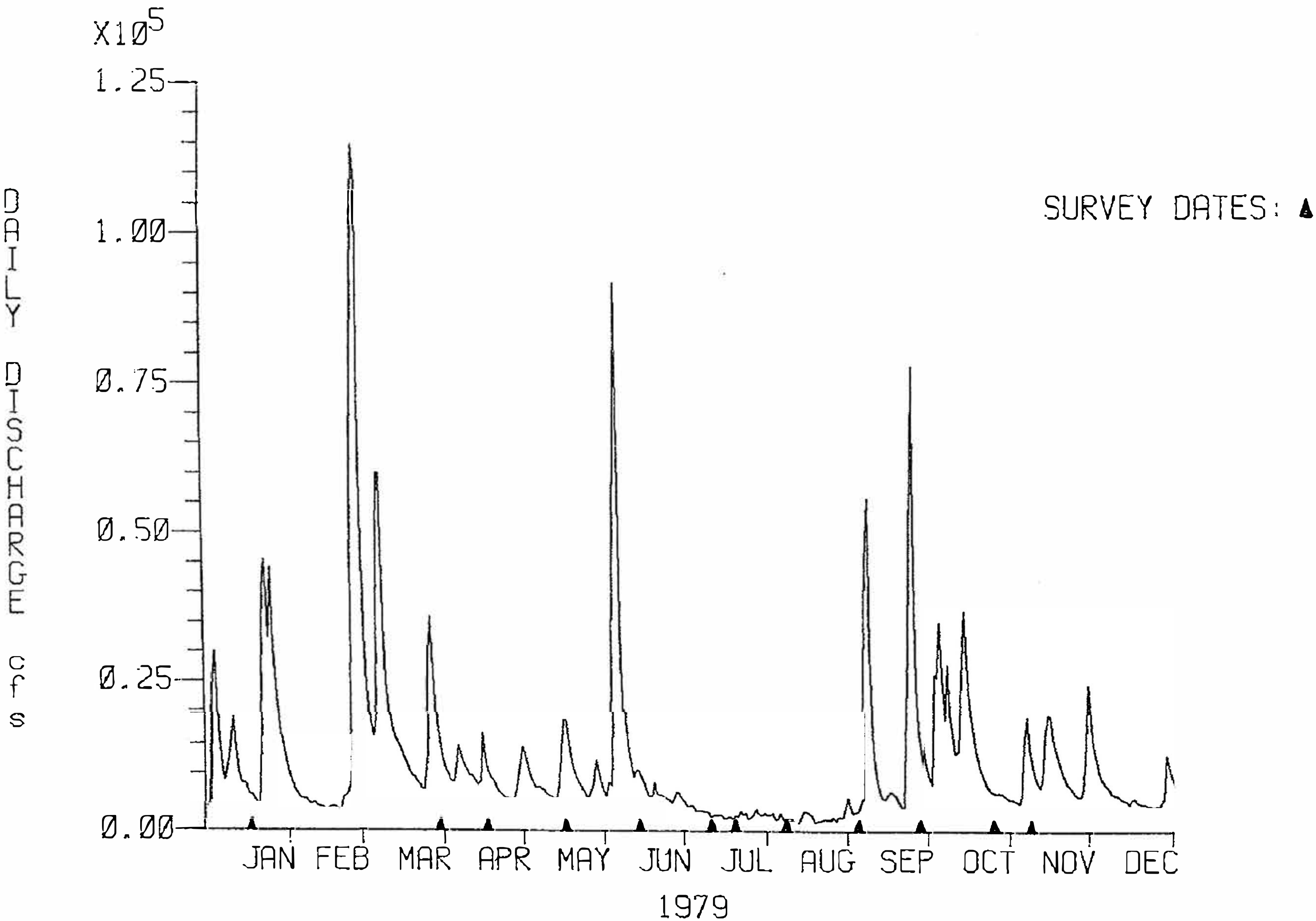


Figure 6i. Fresh Water Discharge and Slack Water Survey Dates, 1979

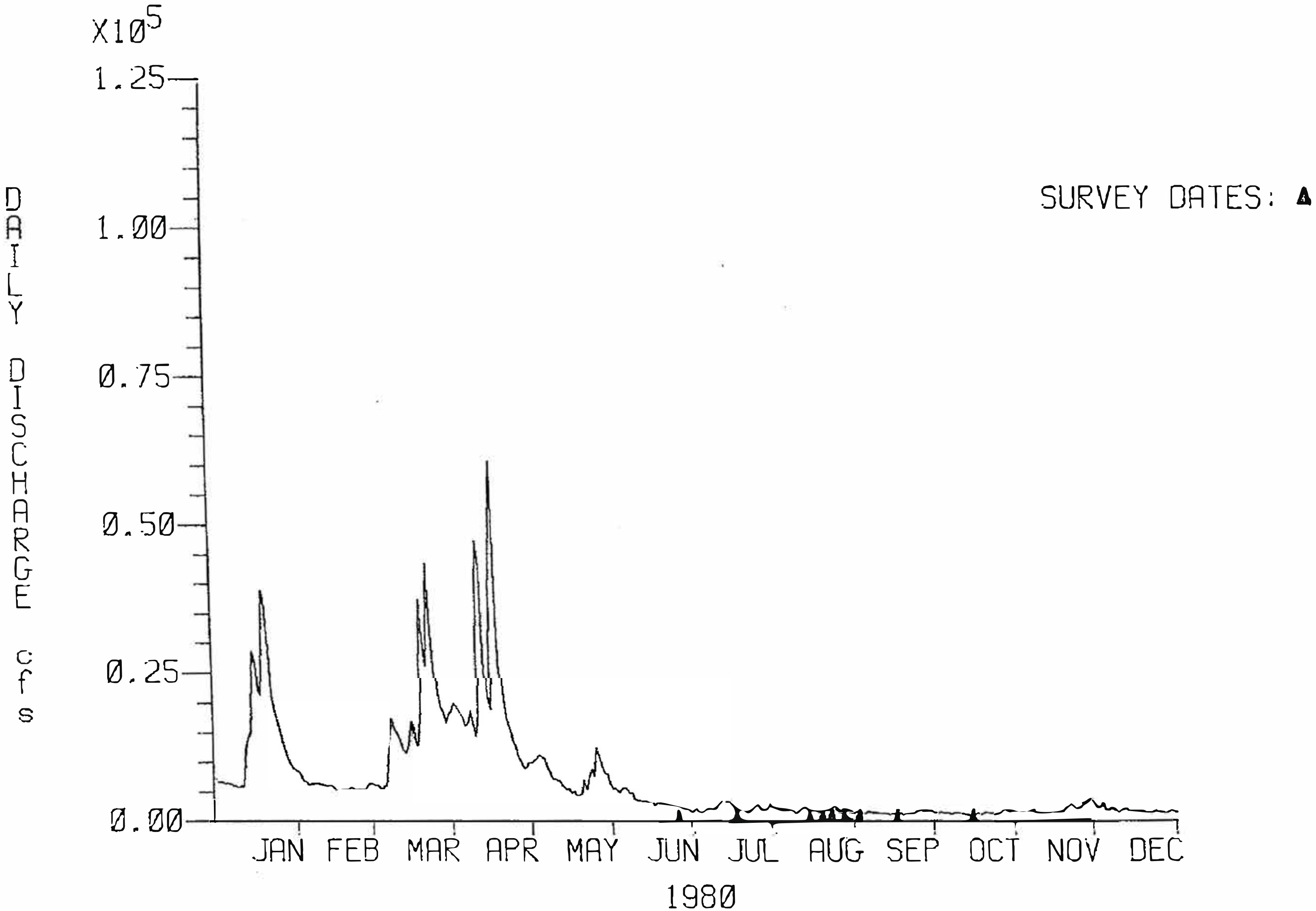


Figure 6j. Fresh Water Discharge and Slack Water Survey Dates, 1980

the James River basin (Seitz, 1971). Figures 7a-j show average predicted tide heights and the date of each slack water survey. The tidal data is from Sewells Point and is presented as the average of the high tide heights for each day and the average of the low tide heights for each day (NOAA, Tide Tables, 1970-1979).

C. Field Procedures

Several types of samples are collected during each survey. Temperature readings, salinity, and dissolved oxygen samples are taken during each slack water survey. Conductivity readings and biochemical oxygen demand samples are often taken. Since 1974, nutrient concentrations and chlorophyll 'a' have been measured at least a few times each year, as indicated in Table 2.

Sampling depths vary with the parameter being considered. Temperature, conductivity, and salinity are sampled every two meters between the surface and the bottom. Dissolved oxygen samples are collected at the surface, mid-depth, and bottom. Biochemical oxygen demand, nutrients, and chlorophyll 'a' samples are collected at the surface and bottom.

Temperature measurements are made with either an Interocean Model 513 CTD instrument or a Hydrolab Model ARA ET-100 thermistor. Conductivity measurements are made with a modified Interocean Model 513 CTD instrument. Water samples for the other analyses are collected by pumping water with a modified bilge pump from the desired sampling depth or with a weighted 5-liter PVC Frautschy bottle attached to a

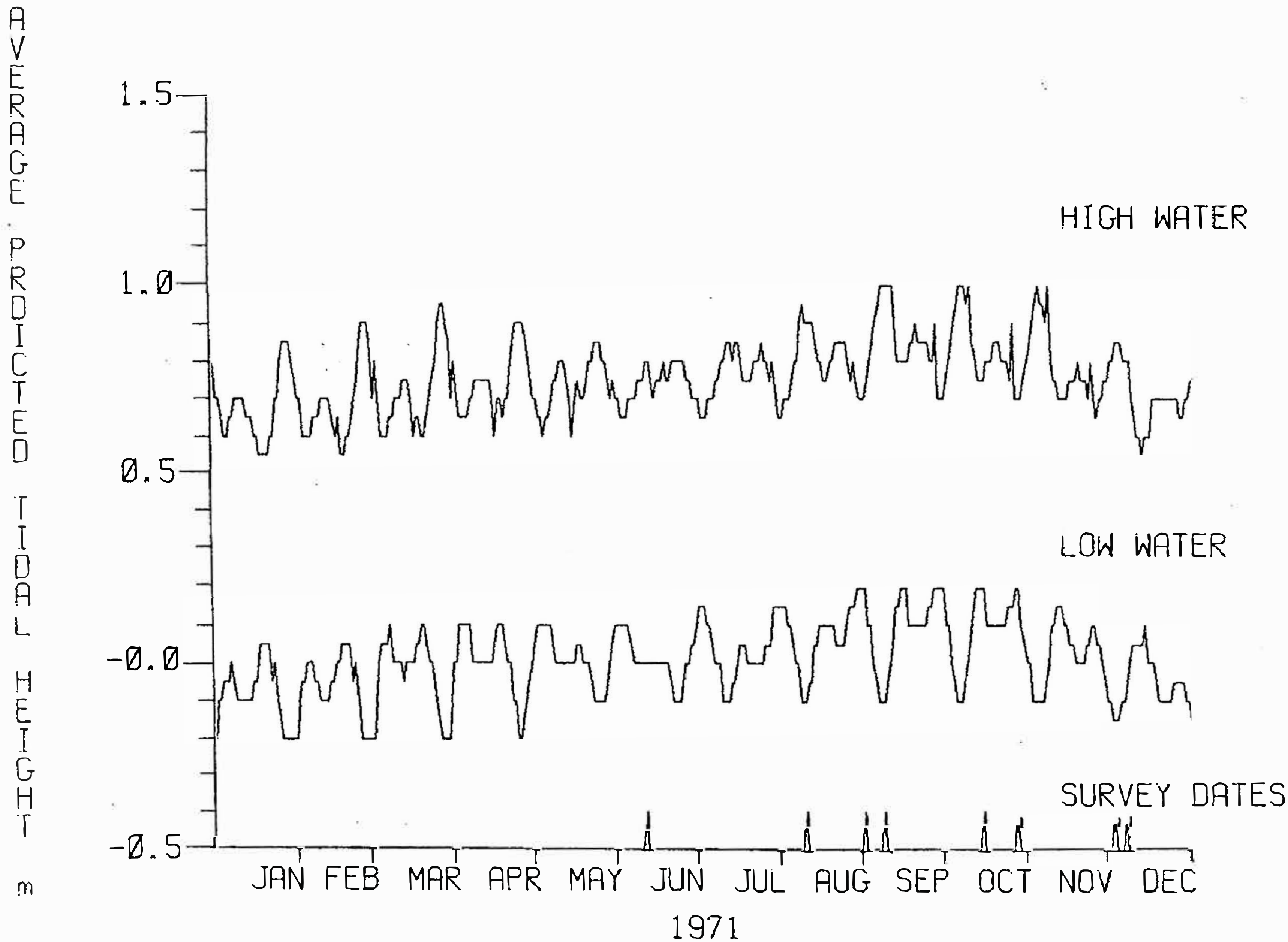


Figure 7a. Average Predicted Tide and Slack Water Survey Dates, 1971

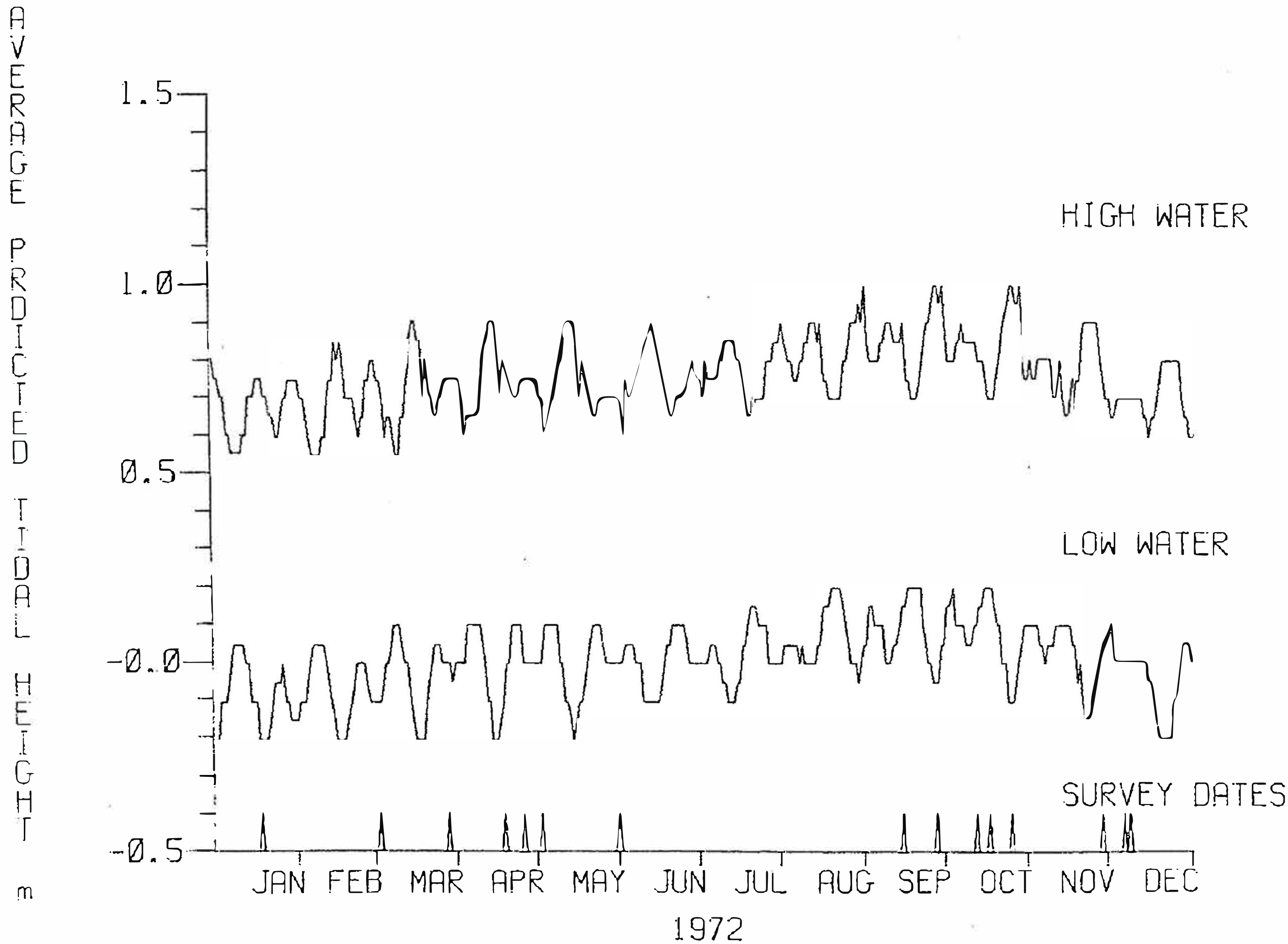


Figure 7b. Average Predicted Tide and Slack Water Survey Dates, 1972

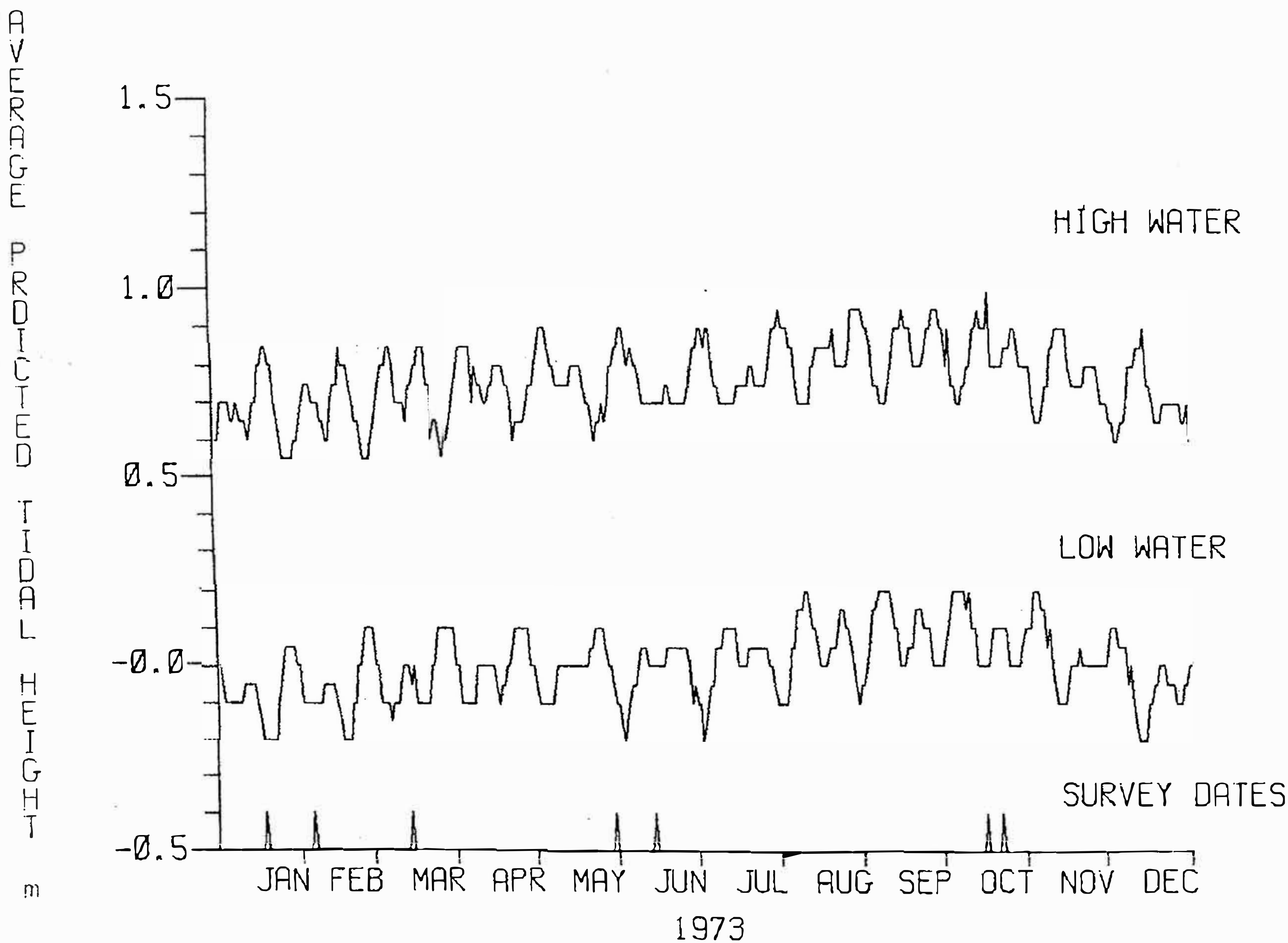


Figure 7c. Average Predicted Tide and Slack Water Survey Dates, 1973

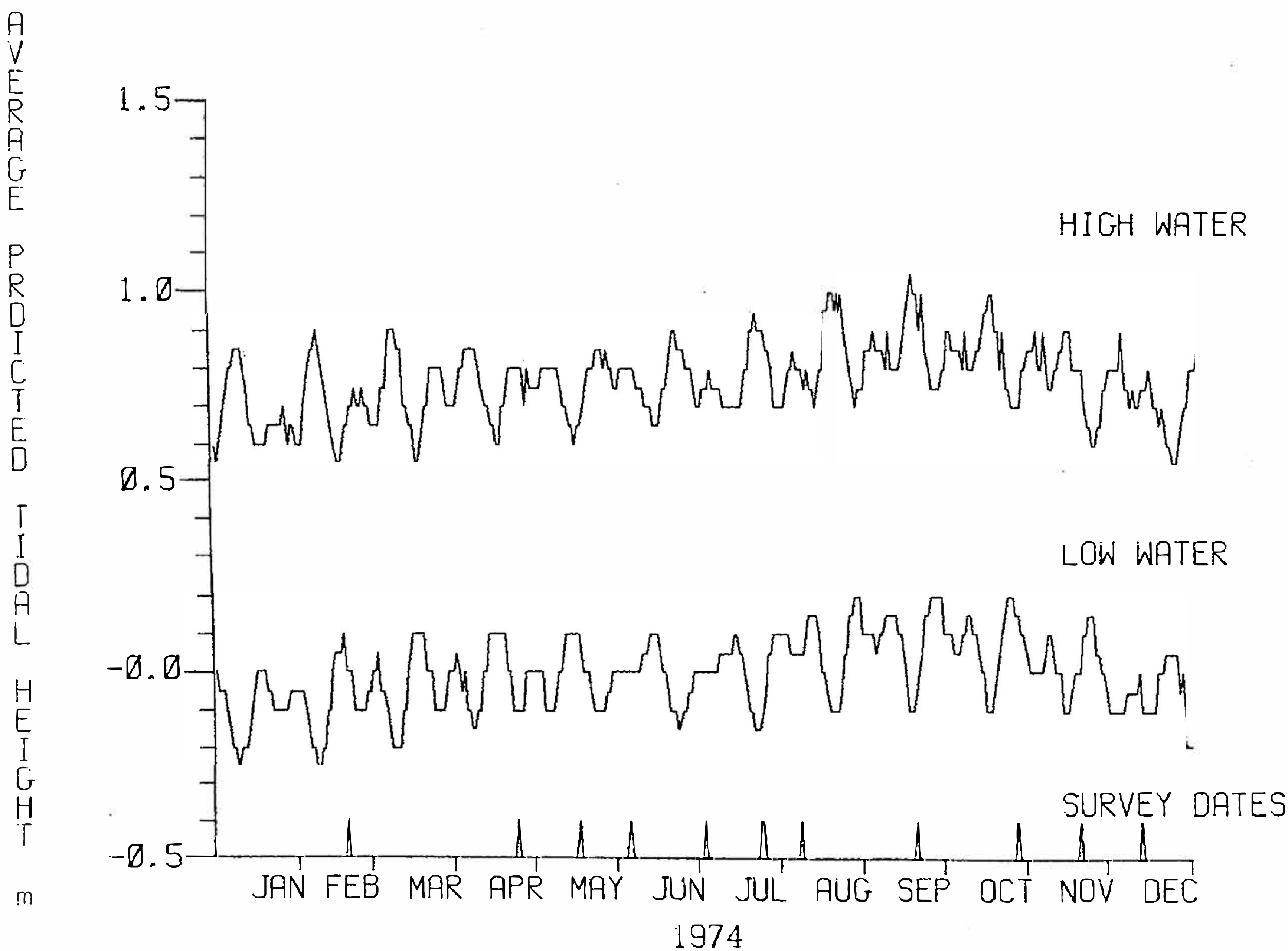


Figure 7d. Average Predicted Tide and Slack Water Survey Dates, 1974

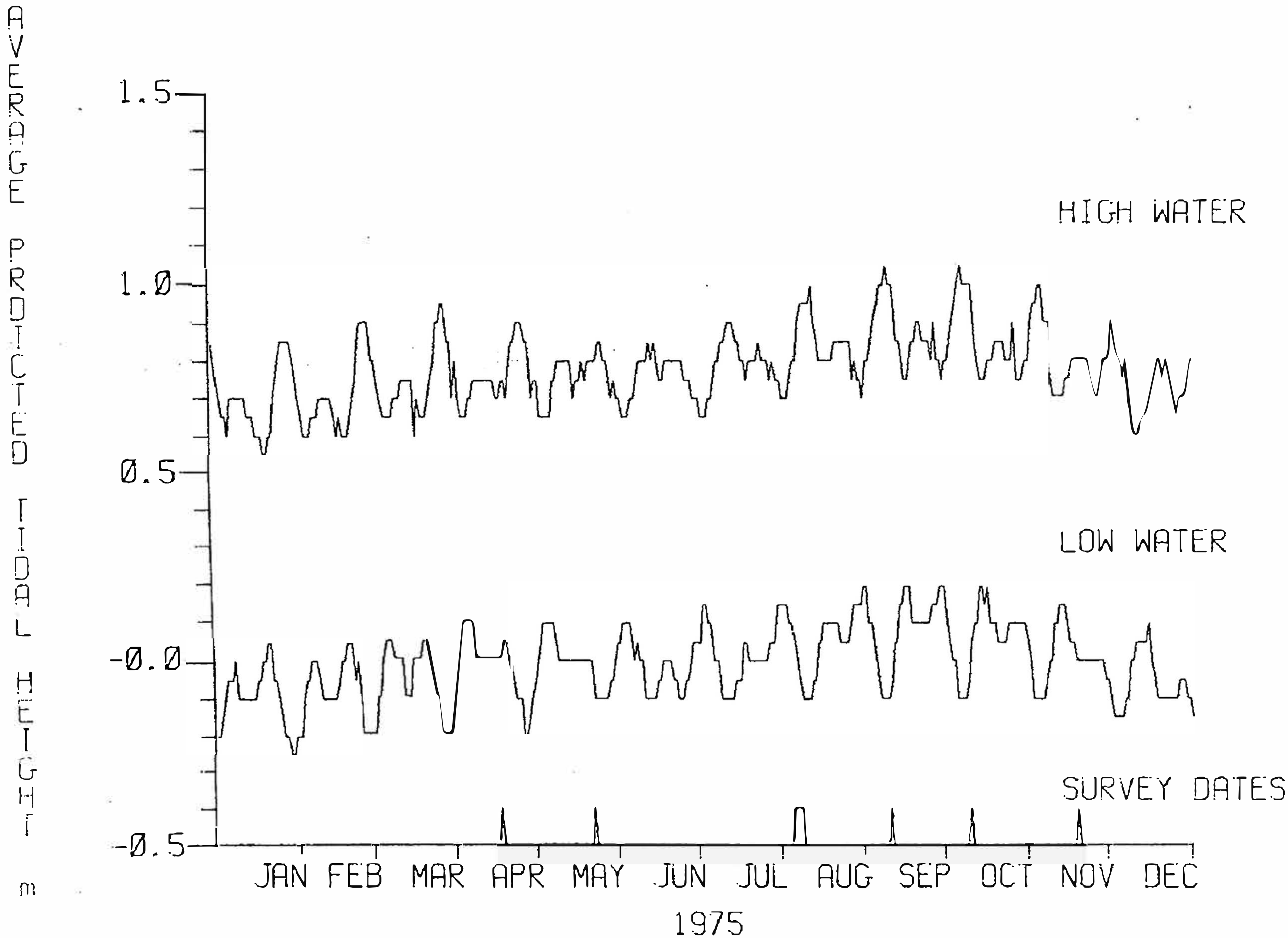


Figure 7e. Average Predicted Tide and Slack Water Survey Dates, 1975

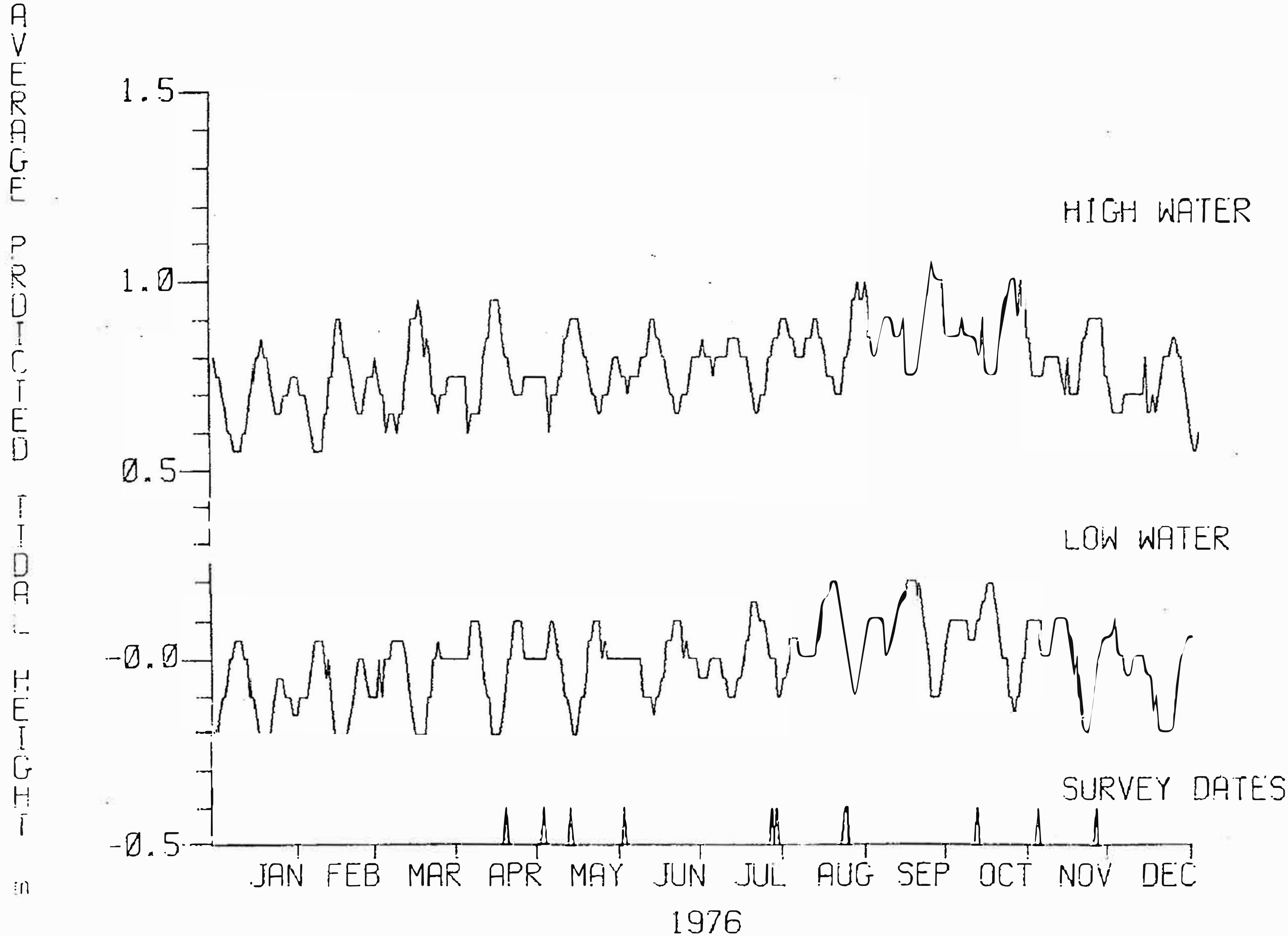


Figure 7f. Average Predicted Tide and Slack Water Survey Dates, 1976

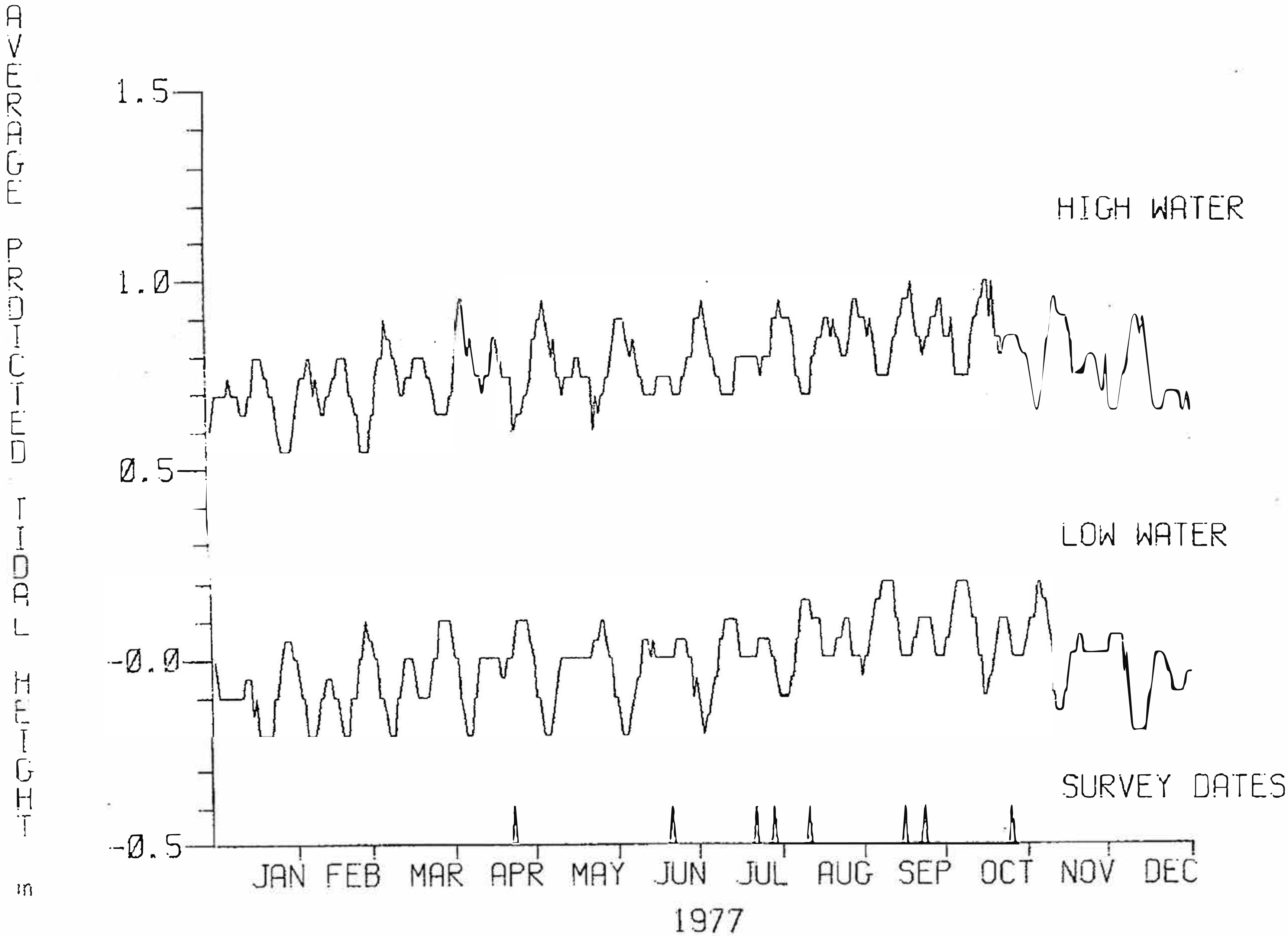


Figure 7g. Average Predicted Tide and Slack Water Survey Dates, 1977

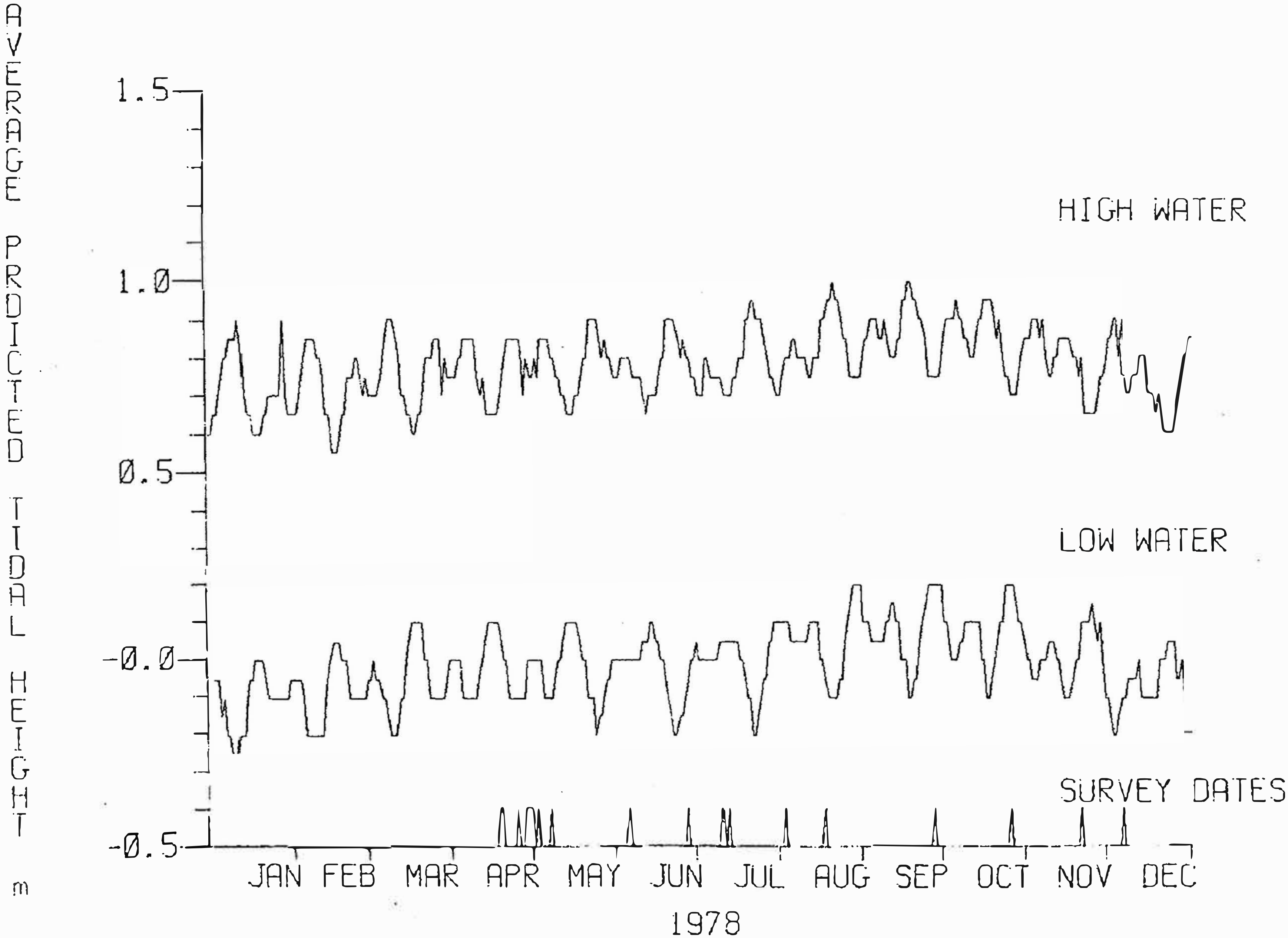


Figure 7h. Average Predicted Tide and Slack Water Survey Dates, 1978

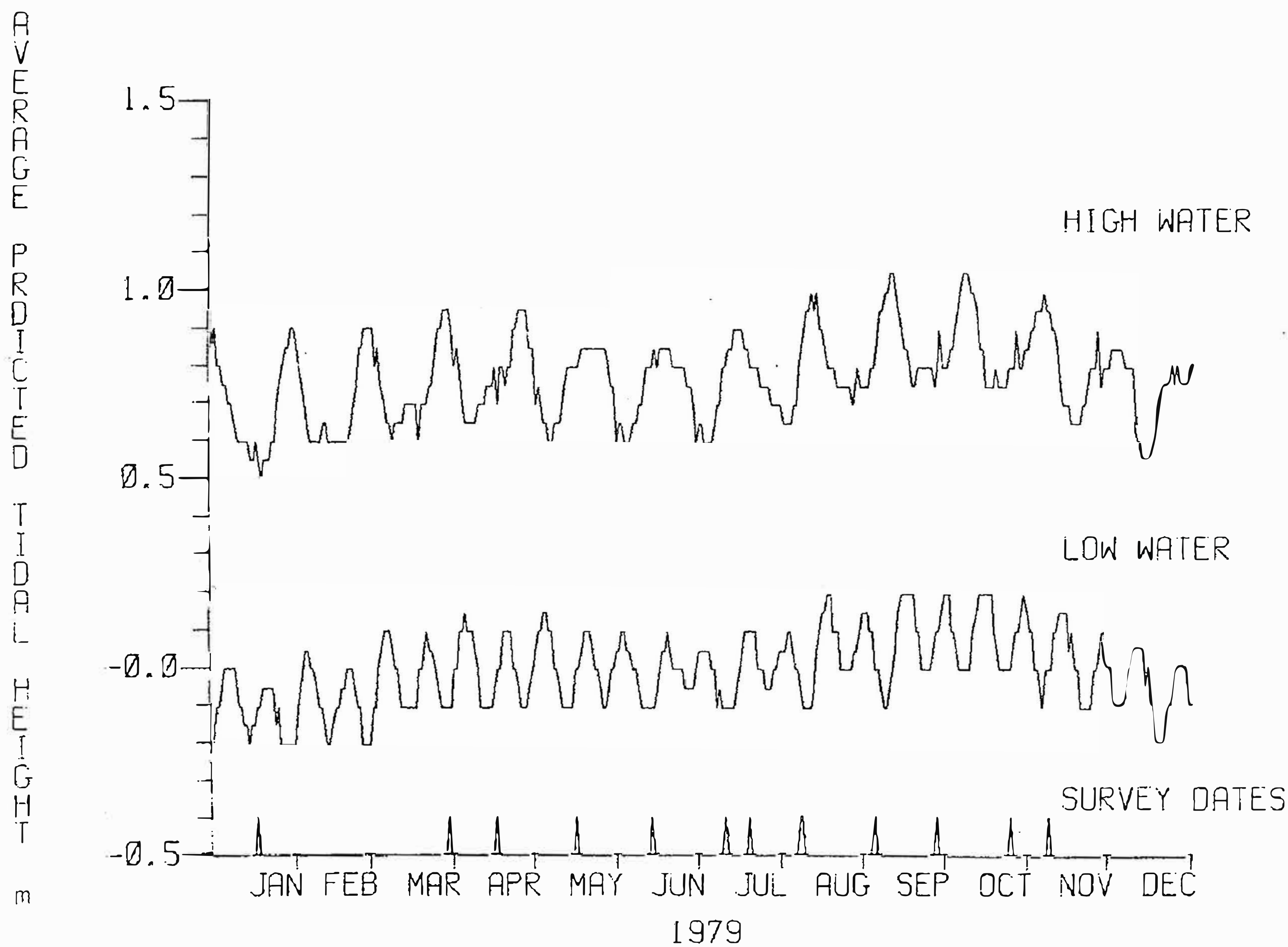


Figure 7i. Average Predicted Tide and Slack Water Survey Dates, 1979

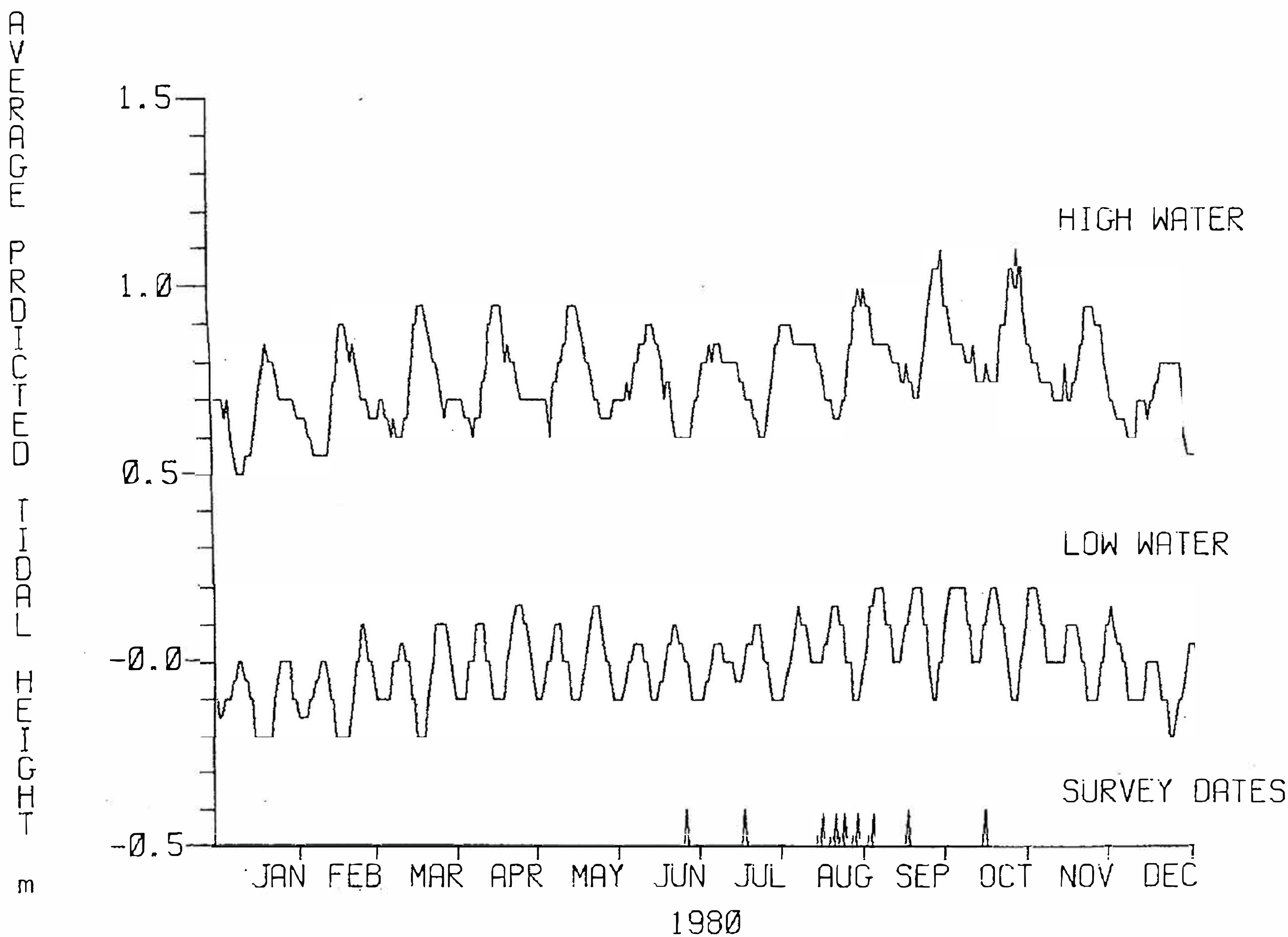


Figure 7j. Average Predicted Tide and Slack Water Survey Dates, 1980

metered line. The bottle is lowered by the hand line to the desired sampling depth, then closed by a messenger and pulled to the surface. At the surface, the water is placed in appropriate containers for various laboratory analyses. While in the field, the instrument readings and sample bottle numbers are recorded on an Oceanography Form 1 as illustrated in Figure 8.

D. Sample Handling Procedures

Samples for salinity are placed in 125-ml sample-rinsed glass bottles. When brought back to the laboratory the samples are run on an Industrial Instrument Laboratory Salinometer Model RS7A. Salinity is sometimes calculated from temperature and conductivity readings taken from the Interocean Model 513 CTD instrument.

Samples for dissolved oxygen analysis are placed in 125-ml sample-rinsed glass bottles. Reagents are added immediately in preparation for the azide modification of the Winkler procedure to be conducted later in the laboratory.

Biochemical oxygen demand (BOD) samples are collected in standard 300 ml glass stoppered BOD bottles. Nutrient samples are collected in 1 liter plastic "cubitainers". Chlorophyll samples are collected in opaque plastic containers. All three types of samples are placed on ice immediately after collection and until they can be processed in the laboratory. Nutrient and chlorophyll samples are filtered within 24 hours of collection. The details of the laboratory procedures and analytical methods can be found in other VIMS reports such as "Water

OCEANOGRAPHY FORM 1 (REVISED 1977)

CRUISE	JAMES	STATION	72.21
OBSERVERS	WORRELL SCOTT	TIME	1030

DATE						STATION TIME E.S.T.			LAT. N.					LONG. W.					CRUISE DESIGNATION					CARD CODE						
DAY		MO.		YR.					DEG.		MIN.		1/10	DEG.		MIN.		1/10												
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	4	0	8	8	0	0	9	5	3	7	1	3	1	7	6	5	5	0	0	S	J	0	3	0	0	5	3	7	0	4

RIVER CODE		STATION LOCATION					VESS. CODE		DEPTH TO BOTTOM				TIDE	DISK VIS.		WIND DIR.		WIND SPD.		AIR TEMP in DEGREES				FREE FORM FIELD
32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56–80
J	A	7	2	.	2	1	T	H	0	0	0	8	L	0	3									

DEPTH	SAMPLE TIME	CODE	FINAL	CODE	FINAL	CODE	FINAL	CODE	FINAL	CODE	FINAL	CODE	FINAL	CODE	FINAL
1.0		GB	28.75	8B	4.26			6B	6.0						
3.0		GB	28.75	8B	4.26			6B	5.9						
5.0		GB	28.85	8B	4.46			6B	6.0						
7.0		GB	28.75	8B	5.11			6B	6.0						

Corrected Temperatures — Corrected Conductivity — Dissolved Oxygen

DEPTH	TEMP.	CONDUCTIVITY	SALINITY	D.O.	B.O.D.	NUTRIENTS	CHLOROPHYLL	COLIFORM	-------	INST. CODE
1	28.7	4.0		6.0						CSTD
3	28.7	4.0		5.9						
5	28.8	4.2		6.0						ARA
7	28.7	4.9		6.0						
8 btm										---
										PG__ OF__

Field Data

Figure 8. Sample Oceanography Form 1

Quality in the York River" (Sturm and Neilson,1977).

E. Data Reduction and Storage

Central to the reduction of data collected by the Department of Physical Oceanography and Hydraulics is the Oceanography Form 1. The Form 1 serves the dual purpose of providing a sheet for field and laboratory use as well as a form from which oceanographic data may be entered to the computer-based storage system via either punched cards or magnetic tape.

The data are available on request. Printouts of work done by the Department of Physical Oceanography and Environmental Engineering are kept in the department library and in the VIMS library.

II. DISCUSSION

A. General Information

In an effort to describe the James River more uniformly, the sampling program in 1979 included two important features. First, sampling was scheduled throughout the year. This sampling plan provided winter data that had been rare in the past. Second, at least one survey per month was conducted at slack before flood providing standardization of the data collected.

Several sampling stations were added to each slack water survey in 1980. The six additional stations were located between 9 and 73 kilometers upstream from the river mouth in an effort to better describe conditions in that region.

B. River Discharge

James River discharge, measured at Cartersville, during the 1971-1980 study period covered a wide range of values. The maximum daily average discharge was 2.8×10^5 cfs. This occurred on 22 June 1972 due to the heavy rains of Tropical Storm Agnes. Minimum daily average discharge was 555 cfs and occurred on 10 August 1977. Mean daily freshwater flow at Cartersville, during the study period, averaged 8704 cfs. The greatest total discharge for a given year during the 10 year study was 4.76×10^6 cubic feet in 1972. The year with the least total discharge was 1977 with 1.75×10^6 cubic feet.

C. Temperature

Water temperatures in the James River showed a seasonal pattern following the air temperature pattern through the year. Minimum temperatures around 4° C were observed in January. The water temperatures increased through the spring reaching maximum temperatures around 30° C in July. Water temperatures declined in August and continued to decrease through the fall.

D. Salinity

Salinity in the James River decreased from the mouth to the head of the estuary. The salt content of the water tended to increase with depth.

Salt regularly intruded from the Cheseapeake Bay to the region around kilometer 66. The 1971-1980 slack water data set showed a maximum intrusion of the 1 ppt isohaline as far upstream as kilometer 100. The minimum intrusion of the 1 ppt isohaline was to kilometer 29. This report does not include data from the study of Tropical Storm Agnes. That study reported a minimum intrusion distance of 20 kilometers (Andersen, Davis, Lynch, Schubel (ed.), 1973).

In addition to longitudinal movements of the salinity intrusion, salinity has also been observed to undergo variable degrees of vertical stratification. This variation is demonstrated in the sequence of salinity profiles from 14 August through 2 September 1980 where the estuarine stratification appears to be cyclical and this cycle appears to be related to the spring neap tidal cycle (Cerco, 1982).

E. Dissolved Oxygen

The dissolved oxygen concentration in an estuary is dependent on several physical and biological factors. The solubility of oxygen is influenced by temperature and salinity. Turbulence affects atmospheric reaeration rates. Metabolism and the decomposition of organic material exert demands on the available oxygen.

The dissolved oxygen values in the James River showed a seasonal pattern. The highest values, around 12 mg/l, were reported in the winter during the time of low temperatures and reduced oxygen demand. The level of dissolved oxygen decreased through the spring reaching minimum values around 6 mg/l in the summer during the season of low fresh water discharge and increased temperatures and salinities.

The State Water Control Board has set the water quality standards for acceptable levels of dissolved oxygen (State Water Control Board, 1980). The minimum allowable oxygen concentration for estuarine waters is 4.0 mg/l. The daily average concentrations should exceed 5.0 mg/l. Although the dissolved oxygen values in the James River were generally above these levels, values less than 4.0 mg/l have occcurred between May and October. The minimum value recorded was 0.7 mg/l which occurred at kilometer 66 on 27 September 1979.

During the study period, minimum dissolved oxygen values during May through October were often found to be lower than 4.0 mg/l between kilometer 50 and kilometer 150. In May a dissolved oxygen sag developed around kilometer 100 which maintained itself through September. Downstream of the zone influenced by Richmond and Hopewell municipal and industrial waste waters, the mean dissolved oxygen values were found to be in excess of 5.0 mg/l.

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APPENDICES

A. Longitudinal Contours

B. Temperature (^{o}C)

C. Salinity (ppt)

D. Dissolved Oxygen (mg/ℓ)

A. LONGITUDINAL CONTOURS

Longitudinal contours of temperature, salinity and dissolved oxygen have been generated for each of the slack water surveys. A listing of these surveys is contained in Table 3. The bottom profile is based on the water depth at mean low water as taken from National Ocean Survey charts at the most frequently sampled slack water stations.

Temperature, salinity, and dissolved oxygen values are recorded at each depth sampled. When the sampling is taken at an angle to the vertical because of bottom currents or sampling is slightly off-station, the sampled bottom depth can be deeper than the bottom profile. In this case, the sampling depths for the entire cast at that station are scaled so the bottom depths correspond to each other. When the bottom depth sampled is shallower than the bottom of the profile, the sample depths are used as recorded.

SURFACE II is a computer software system developed by the Kansas Geological Survey for computer contouring and graphics display. The user is able to specify plotting options by selecting appropriate operation commands. The isotherms, isohalines, and lines of constant dissolved oxygen in this report have been drawn using a SURFACE II plotting package and Tectronix plotter. When a parameter has been measured by more than one method the most complete data set is used.

TABLE 3. DATES OF SLACK WATER SURVEYS AND CONTOURS GENERATED
JAMES RIVER

DATE D/M/Y	CRUISE	SLACK	TEMPERATURE	SALINITY	DISSOLVED OXYGEN
110671	OSJ01	L	T	S	D
100871	OSJ02	L	N	N	D
010971	OSJ03	H	T	S	D
080971	OSJ04	L	T	S	D
151071	OSJ05	H	T	S	D
281071	OSJ06	H	T	S	D
031271	OSJ07	H	T	S	D
071271	OSJ08	H	T	N	D
180172	OSJ01	L	T	S	D
020372	OSJ02	L	T	S	D
280372	OSJ03	H	T	N	D
180472	OSJ04	L	T	S	D
250472	OSJ05	H	T	N	D
020572	OSJ06	L	T	S	N
310572	OSJ07	H	T	N	D
140972	OSJ08	L	T	S	D
270972	OSJ09	H	T	S	D
121072	OSJ10	L	T	S	D
171072	OSJ11	L	T	N	D
251072	OSJ12	H	T	N	D
281172	OSJ15	L	T	S	D
061272	OSJ13	H	N	N	N
081272	OSJ14	H	T	S	N
180173	OSJ01	H	T	S	N
050273	OSJ02	H	T	S	N
140373	OSJ03	H	T	S	N
300573	OSJ04	H	T	S	D
140673	OSJ05	H	T	S	D
161073	OSJ06	L	T	S	D
221073	OSJ07	H	T	S	D

H: HIGH WATER SLACK, SLACK BEFORE EBB
T: TEMPERATURE GENERATED
S: SALINITY GENERATED

L: LOW WATER SLACK, SLACK BEFORE FLOOD
D: DISSOLVED OXYGEN GENERATED
N: NO CONTOUR GENERATED (NO DATA AVAILABLE OR NOT ENOUGH TO CONTOUR)

TABLE 3. (Cont'd)

DATE D/M/Y	CRUISE	SLACK	TEMPERATURE	SALINITY	DISSOLVED OXYGEN
190274	OSJ01	H	T	S	D
240474	OSJ02	H	T	S	D
170574	OSJ03	L	T	S	D
050674	OSJ04	H	T	S	D
030774	OSJ05	H	T	S	D
240774	OSJ06	L	T	S	D
250774	OSJ07	L	T	S	D
080874	OSJ08	L	T	S	D
200974	OSJ09	L	T	S	D
281074	OSJ10	L	T	S	D
201174	OSJ11	L	T	S	D
131274	OSJ12	H	T	S	D
170475	OSJ01	L	T	S	D
220575	OSJ02	H	T	S	D
050875	OSJ03	H	N	N	N
060875	OSJ04	L	N	N	N
070875	OSJ05	H	N	N	N
080875	OSJ06	L	N	N	N
100975	OSJ07	L	T	S	D
101075	OSJ08	L	T	S	D
191175	OSJ09	H	T	S	N
190476	OSJ01	L	T	S	D
030576	OSJ02	L	T	S	D
130576	OSJ03	H	T	S	D
020676	OSJ04	L	T	S	D
270776	OSJ05	L	T	N	N
290776	OSJ06	L	T	S	D
230876	OSJ07	L	N	N	N
240876	OSJ08	H	N	N	N
121076	OSJ09	L	T	S	D
041176	OSJ10	H	T	S	D
261176	OSJ11	L	T	S	D

H: HIGH WATER SLACK, SLACK BEFORE EBB

L: LOW WATER SLACK, SLACK BEFORE FLOOD

T: TEMPERATURE GENERATED

D: DISSOLVED OXYGEN GENERATED

S: SALINITY GENERATED

N: NO CONTOUR GENERATED (NO DATA AVAILABLE OR NOT ENOUGH TO CONTOUR)

TABLE 3. (Cont'd)

DATE D/M/Y	CRUISE	SLACK	TEMPERATURE	SALINITY	DISSOLVED OXYGEN
220477	OSJ01	L	T	S	D
200677	OSJ02	L	T	S	D
210777	OSJ03	L	T	S	D
280777	OSJ04	H	T	S	D
100877	OSJ05	H	T	S	D
150977	OSJ06	L	T	S	D
220977	OSJ07	H	T	S	D
251077	OSJ08	H	T	S	D
180478	OSJ01	H	N	N	N
190478	OSJ02	H	N	N	N
250478	OSJ03	L	T	N	N
280478	OSJ04	L	N	N	N
290478	OSJ05	L	N	N	N
300478	OSJ06	L	N	N	N
020578	OSJ07	H	N	N	N
070578	OSJ08	L	T	N	N
050678	OSJ09	L	T	S	D
270678	OSJ10	L	T	S	D
100778	OSJ11	L	T	N	D
120778	OSJ12	L	T	S	D
020878	OSJ13	H	T	S	D
170878	OSJ14	L	T	S	D
170878	OSJ17	H	T	N	D
270978	OSJ18	H	T	S	D
261078	OSJ19	H	T	S	D
211178	OSJ20	L	T	S	D
061278	OSJ21	L	T	S	D

H: HIGH WATER SLACK, SLACK BEFORE EBB

T: TEMPERATURE GENERATED

S: SALINITY GENERATED

L: LOW WATER SLACK, SLACK BEFORE FLOOD

D: DISSOLVED OXYGEN GENERATED

N: NO CONTOUR GENERATED (NO DATA AVAILABLE OR NOT ENOUGH TO CONTOUR)

TABLE 3. (Cont'd)

DATE D/M/Y	CRUISE	SLACK	TEMPERATURE	SALINITY	DISSOLVED OXYGEN
170179	OSJ01	L	T	S	D
290379	OSJ02	L	T	N	D
160479	OSJ03	L	T	S	D
160579	OSJ04	L	T	S	D
130679	OSJ05	L	T	S	D
100779	OSJ06	L	T	S	D
190779	OSJ07	H	T	S	D
070879	OSJ08	L	T	N	D
080879	OSJ09	L	T	S	D
040979	OSJ10	H	T	S	D
270979	OSJ11	L	T	S	D
251079	OSJ12	L	T	S	D
081179	OSJ13	L	T	S	D
250680	OSJ01	H	T	S	D
170780	OSJ02	H	T	S	D
140880	OSJ03	L	T	S	D
190880	OSJ04	L	T	S	D
220880	OSJ05	H	T	S	D
220880	OSJ06	L	T	S	D
270880	OSJ07	H	T	S	D
270880	OSJ08	L	T	S	D
020980	OSJ09	H	T	S	D
160980	OSJ10	H	T	S	D
151080	OSJ11	L	T	S	D

H: HIGH WATER SLACK, SLACK BEFORE EBB

T: TEMPERATURE GENERATED

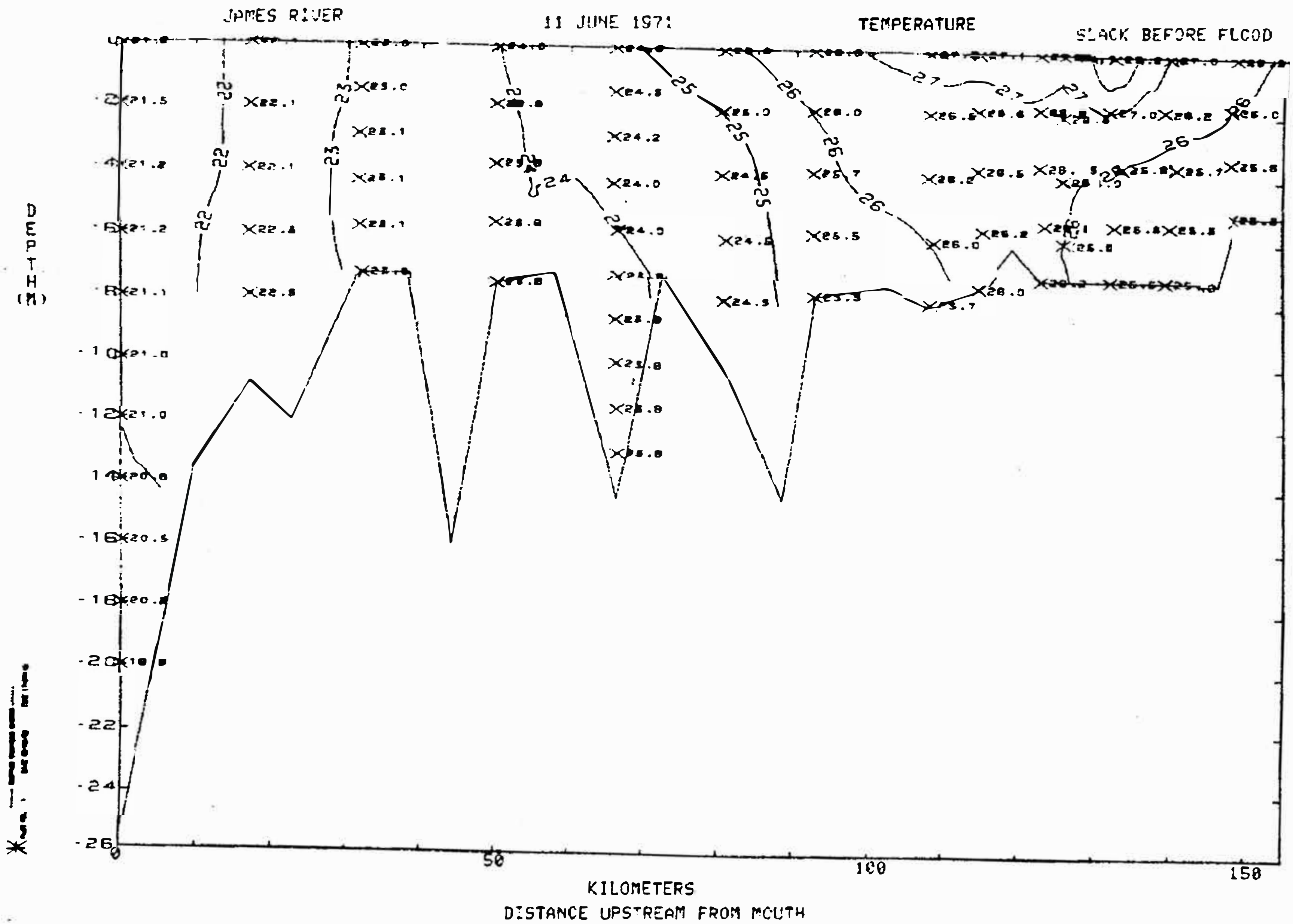
S: SALINITY GENERATED

L: LOW WATER SLACK, SLACK BEFORE FLOOD

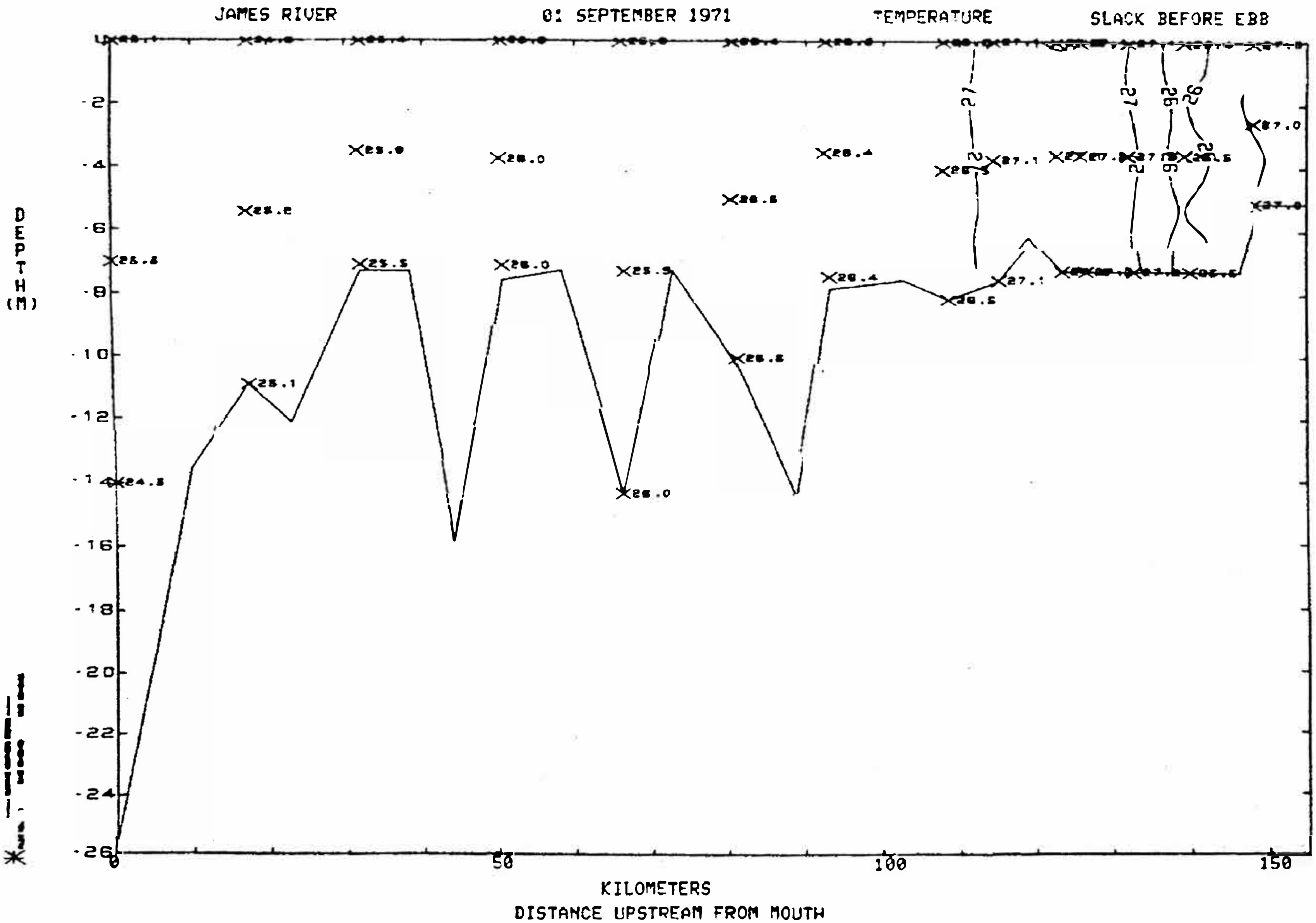
D: DISSOLVED OXYGEN GENERATED

N: NO CONTOUR GENERATED (NO DATA AVAILABLE OR NOT ENOUGH TO CONTOUR)

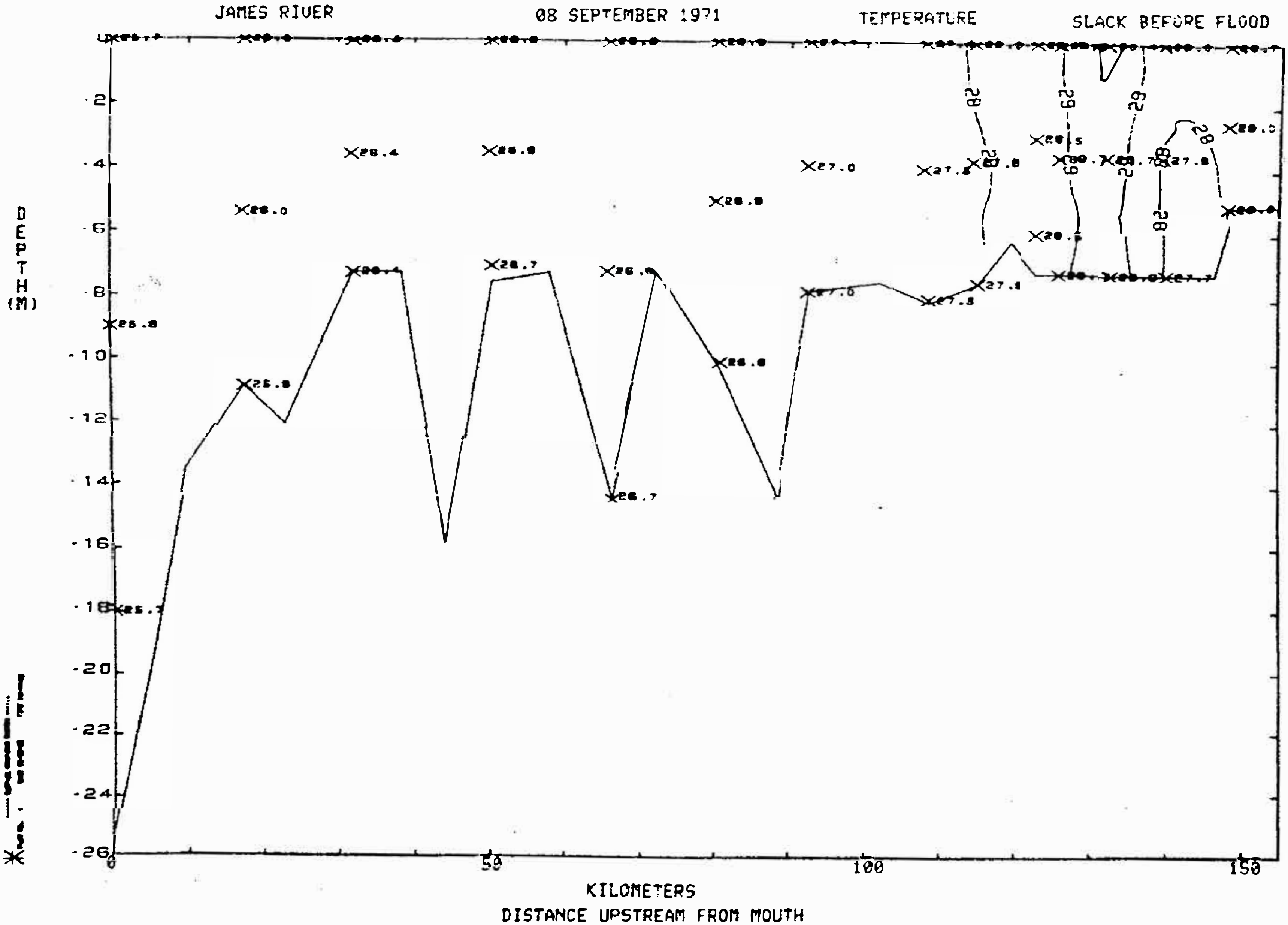
B. Temperature (^{o}C)

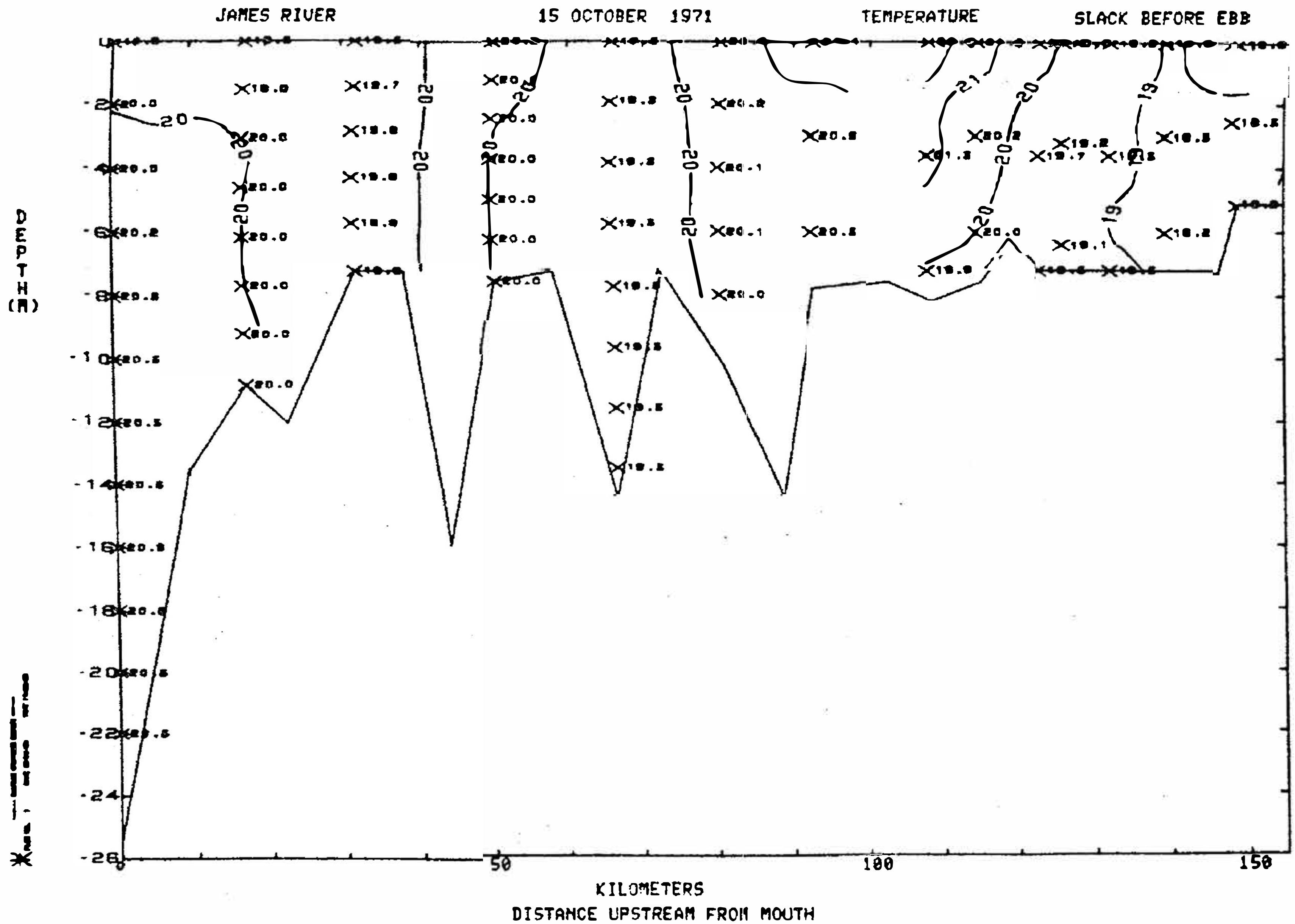


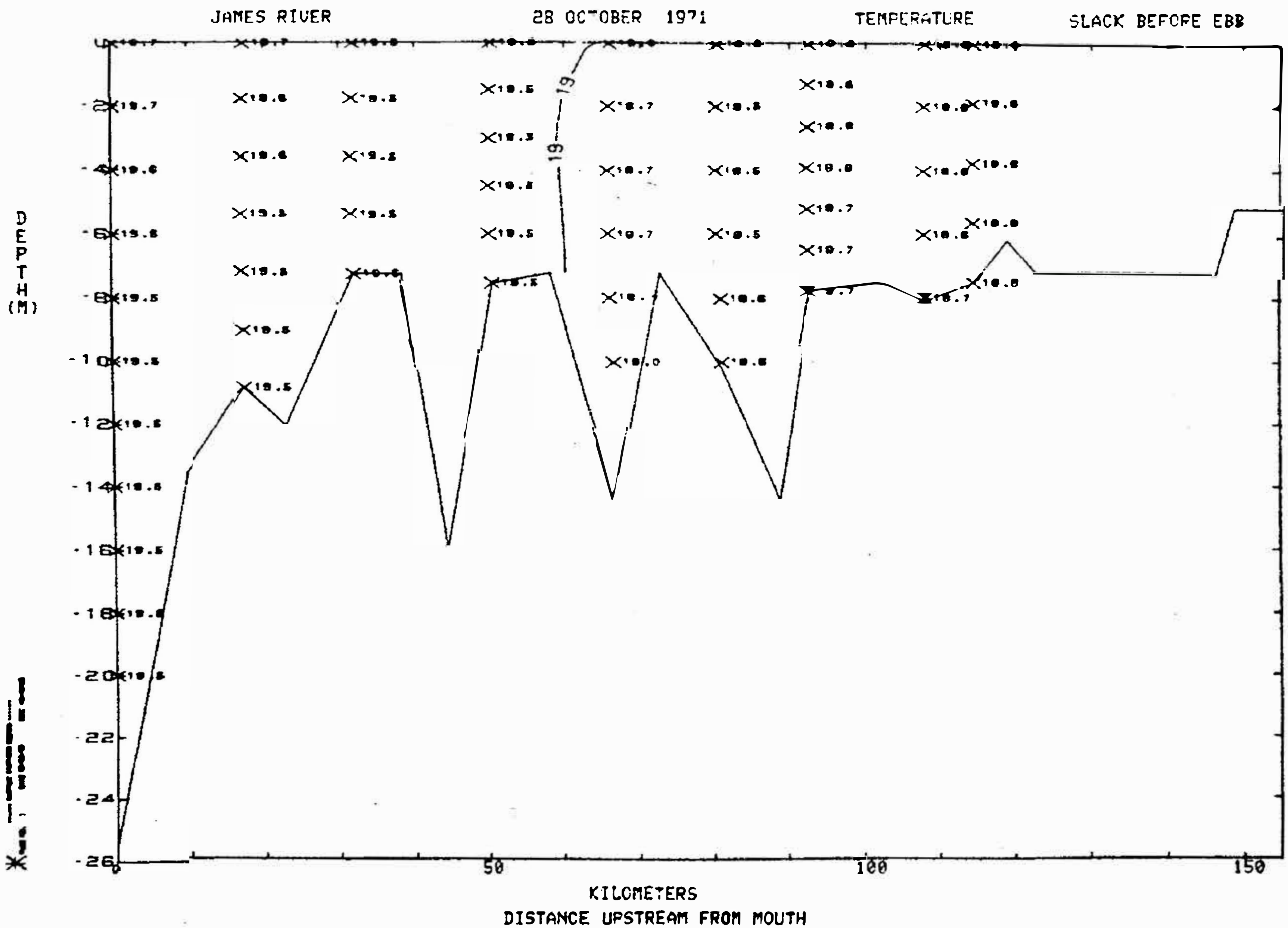
JAMES RIVER
11 JUNE 1971
TEMPERATURE
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
22
23
24
25
26
27

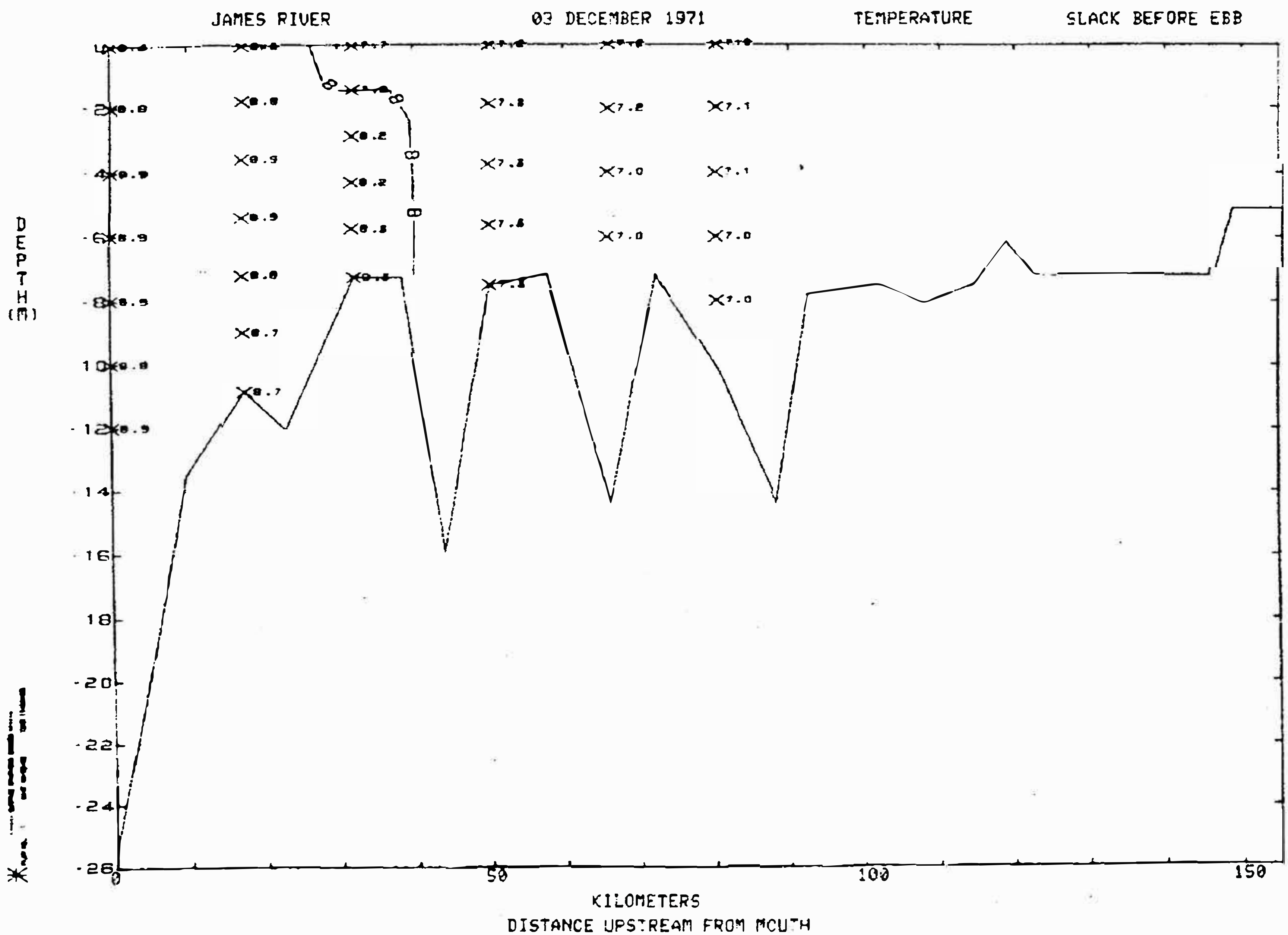


JAMES RIVER
01 SEPTEMBER 1971
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

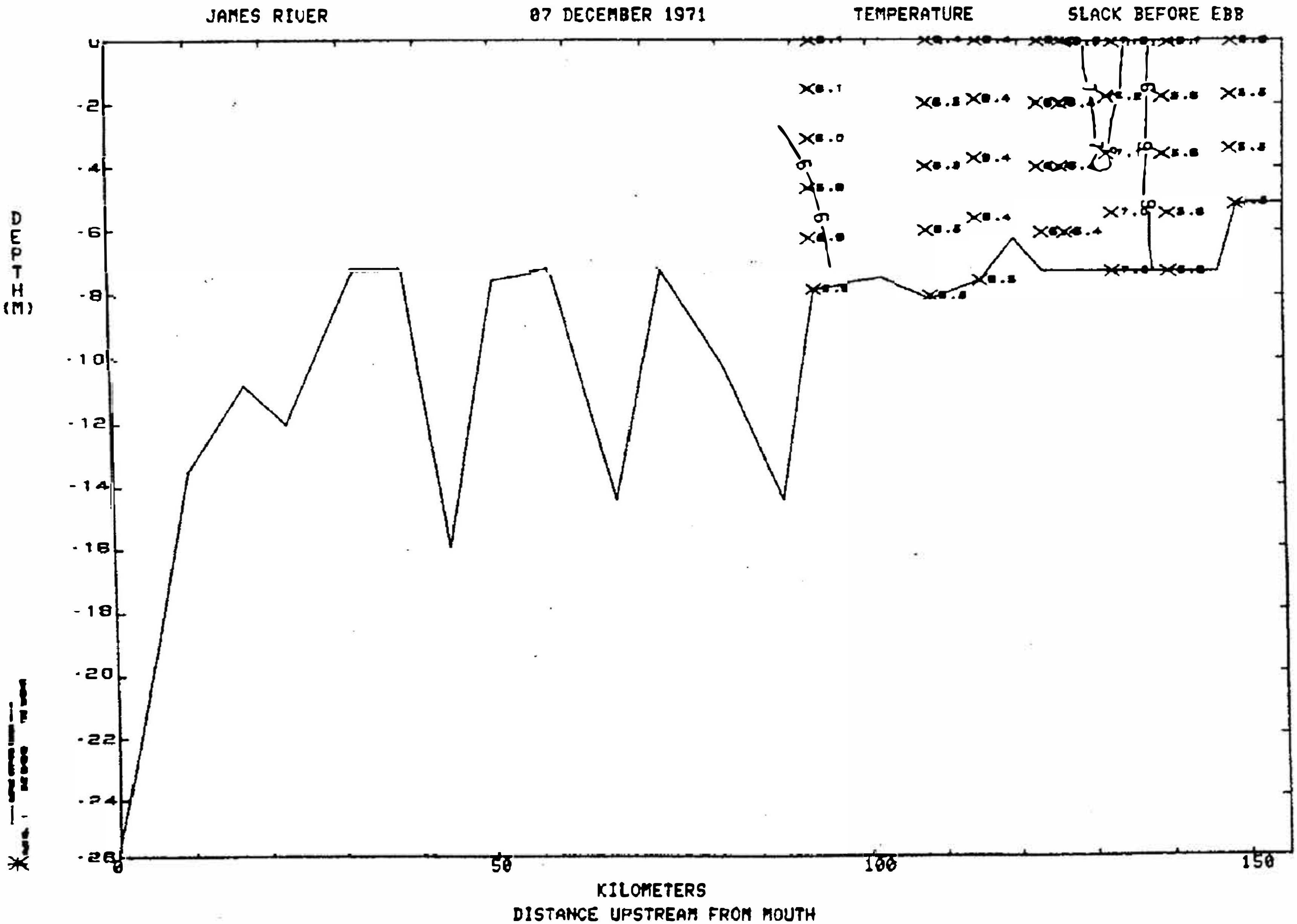

JAMES RIVER
08 SEPTEMBER 1971
TEMPERATURE
SLACK BEFORE FLOOD
DEPTH (M)
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
15 OCTOBER 1971
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
28 OCTOBER 1971
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
19
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

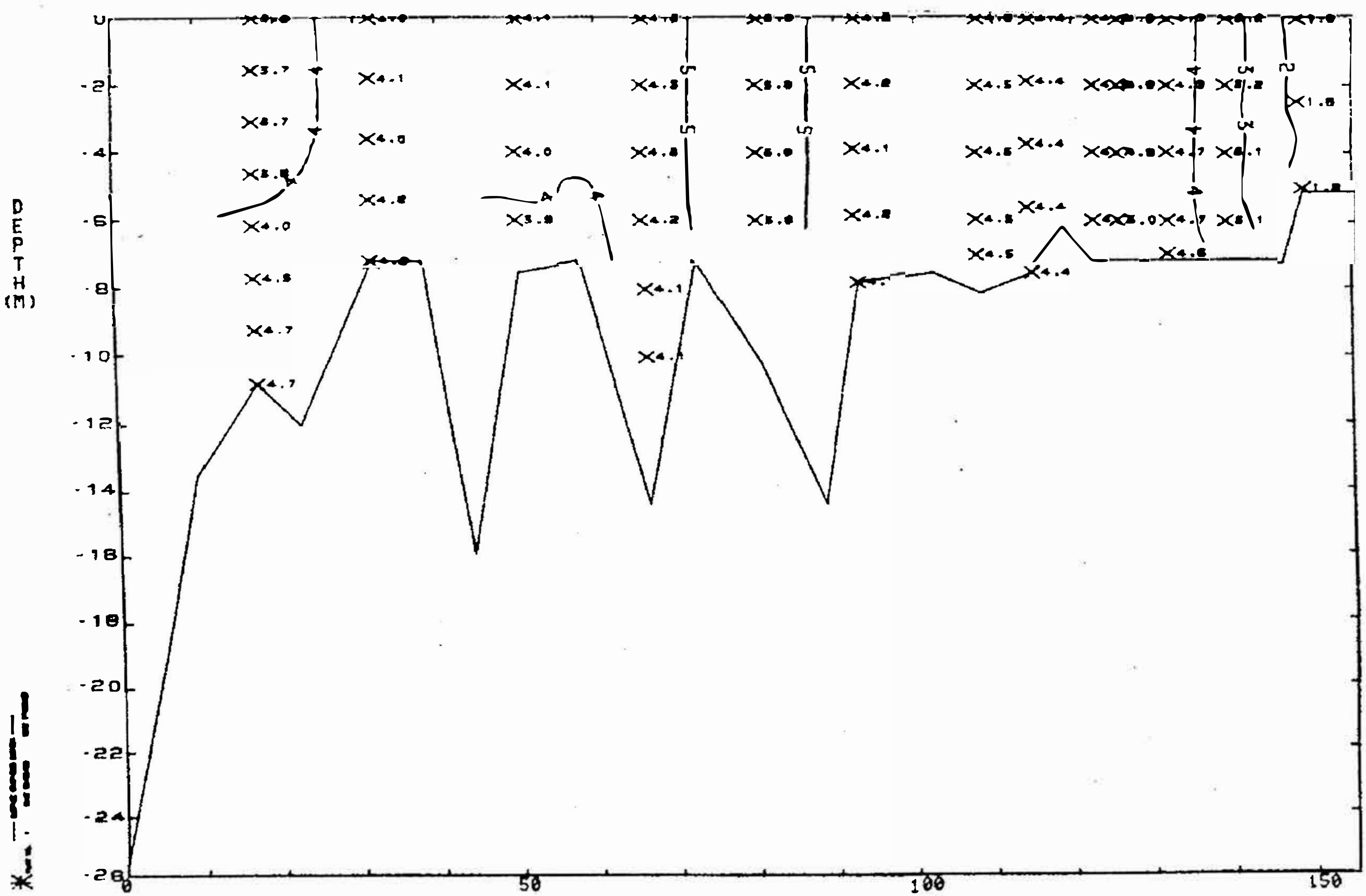


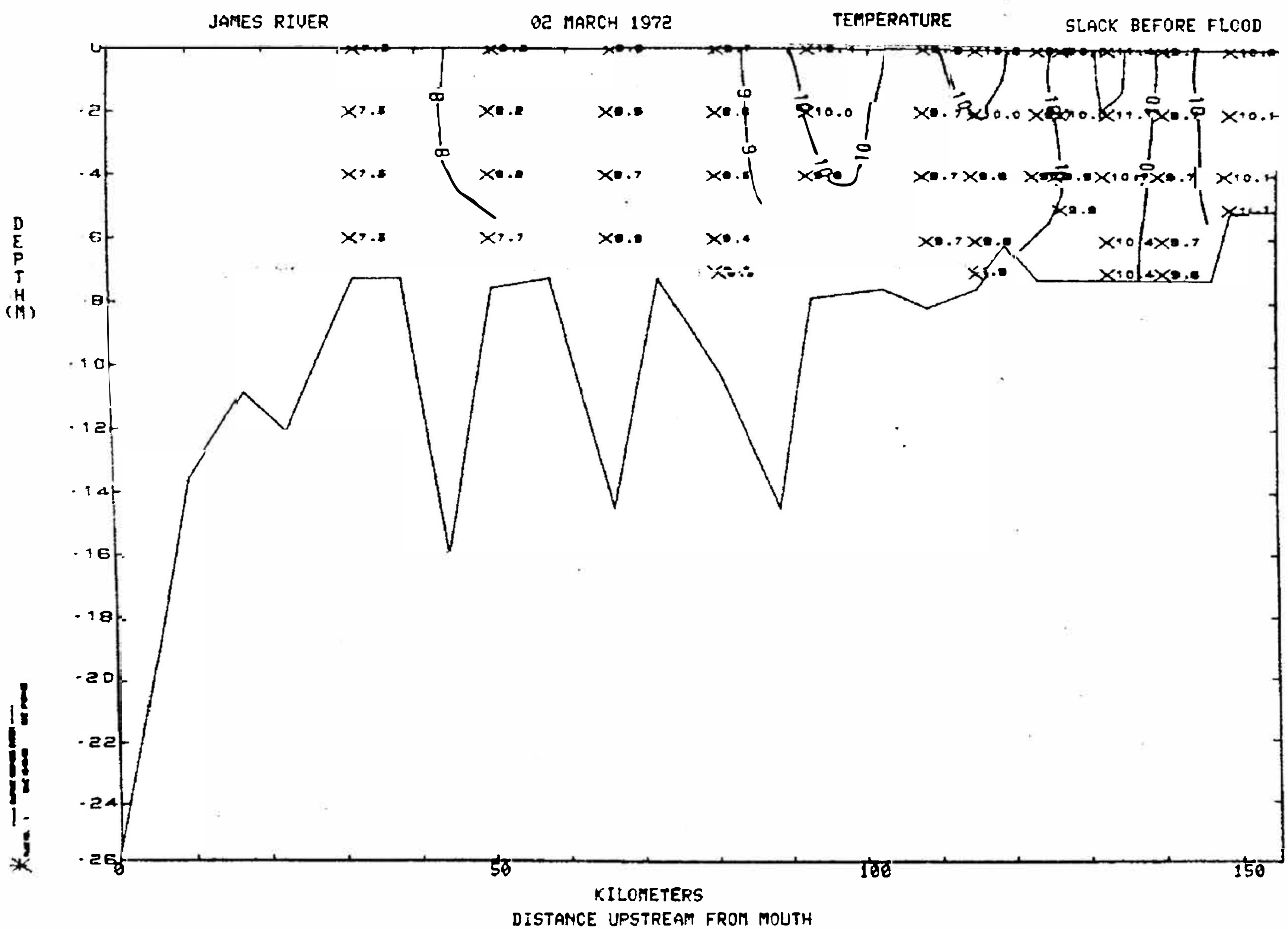
JAMES RIVER
03 DECEMBER 1971
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

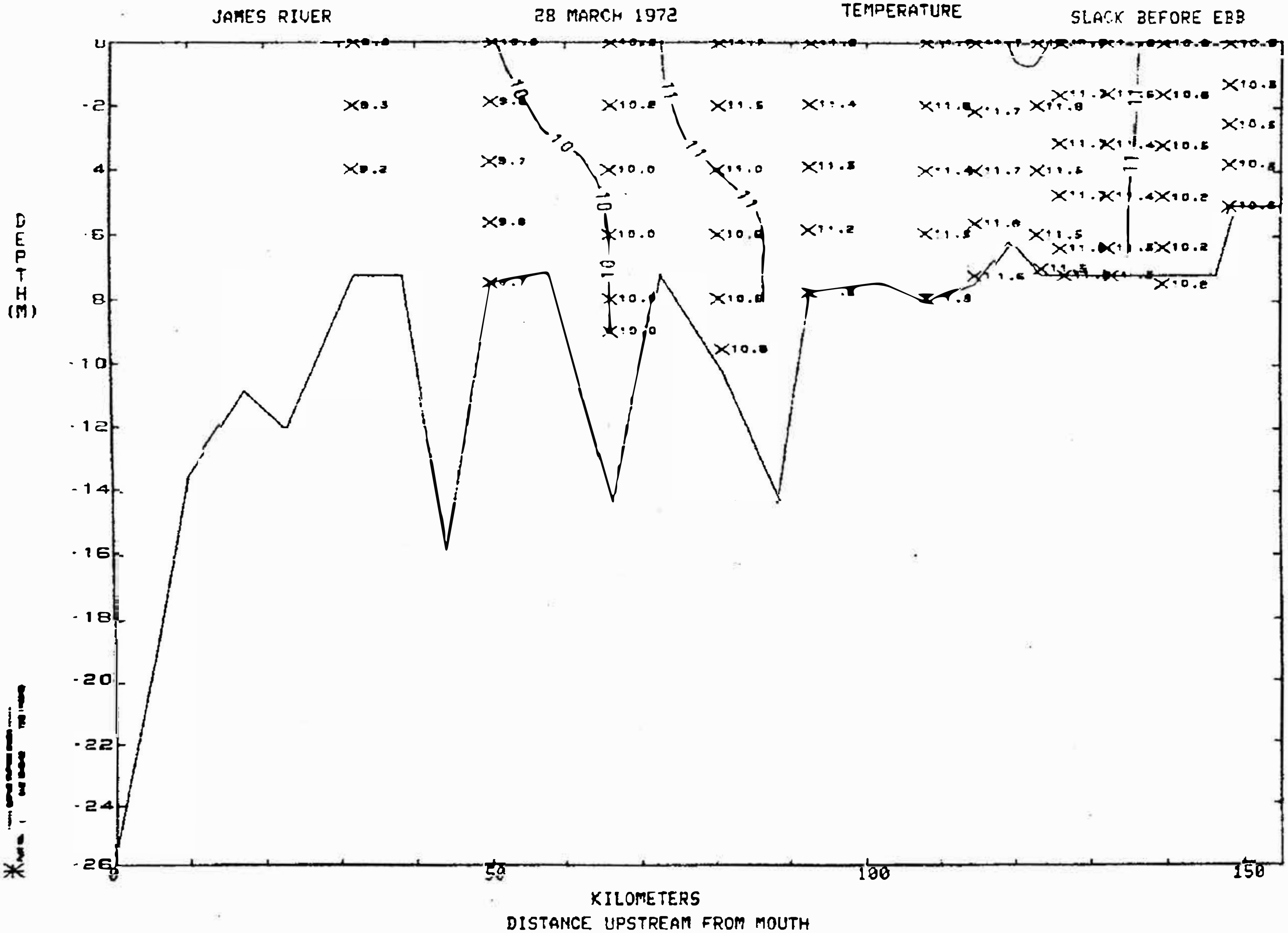


JAMES RIVER
07 DECEMBER 1971
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

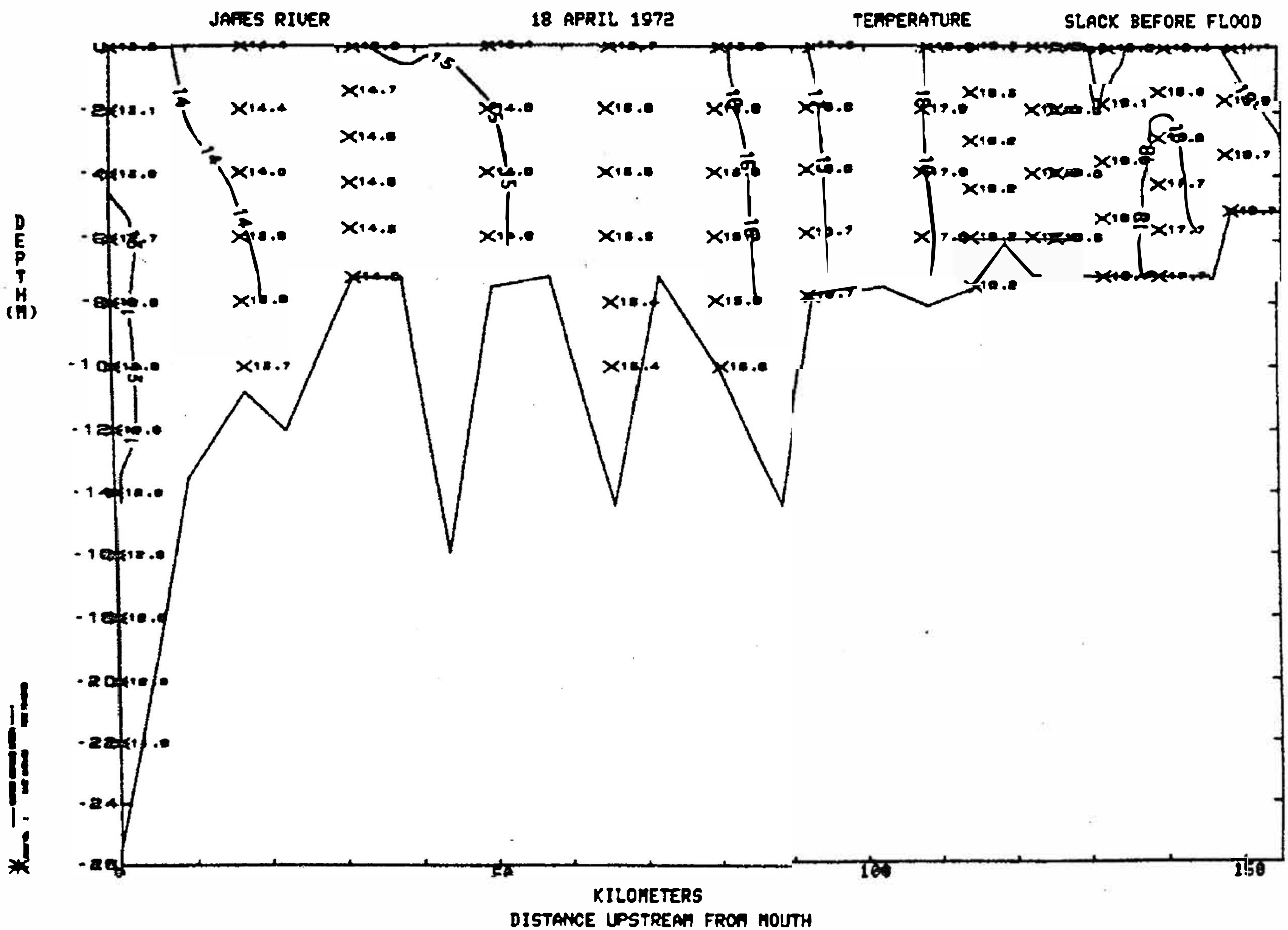
JAMES RIVER 18 JANUARY 1972 TEMPERATURE SLACK BEFORE FLOOD



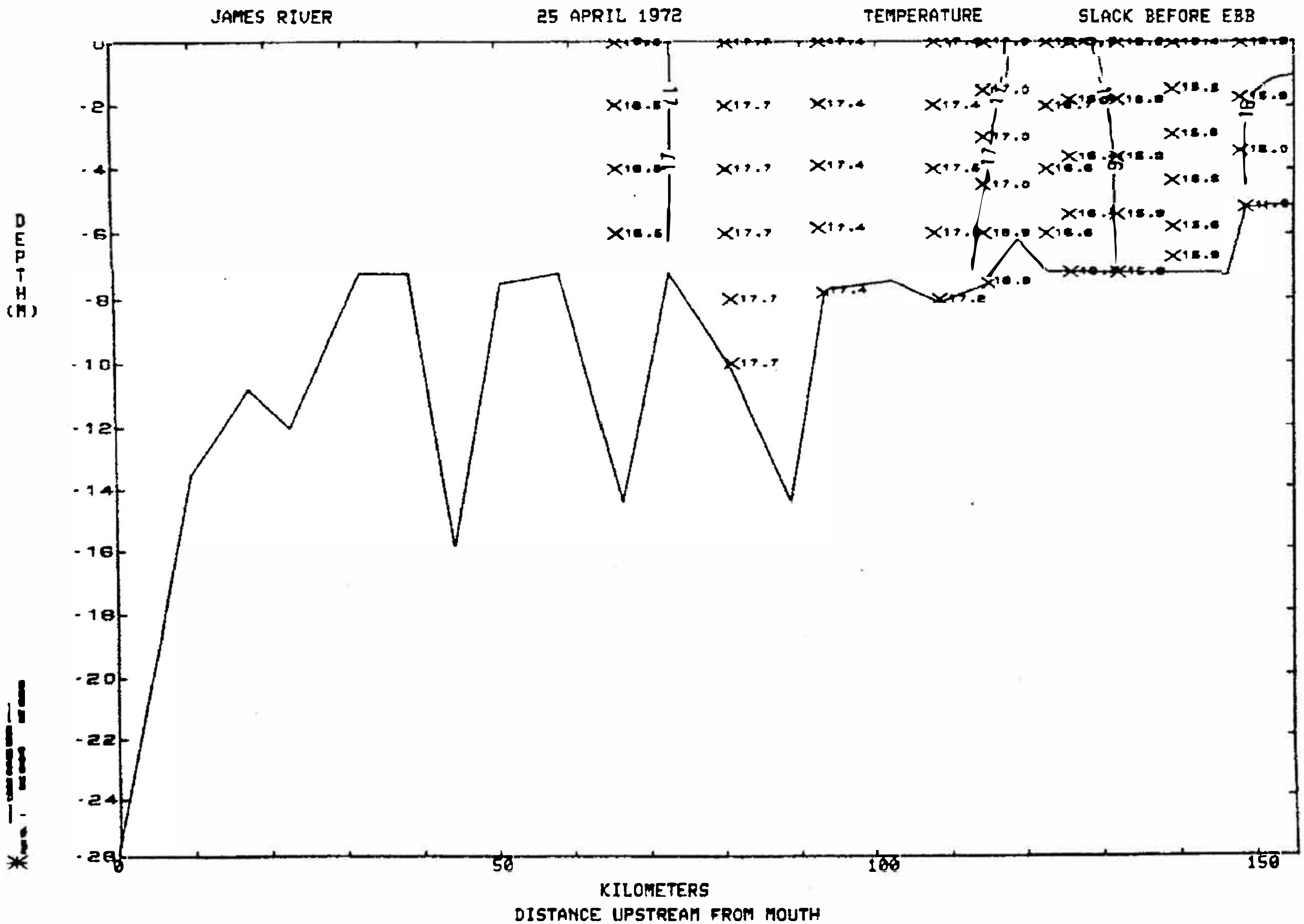

JAMES RIVER
02 MARCH 1972
TEMPERATURE
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



JAMES RIVER
28 MARCH 1972
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



JAMES RIVER
18 APRIL 1972
TEMPERATURE
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
25 APRIL 1972
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150
-2
-4
-6
-8
-10
-12
-14
-16
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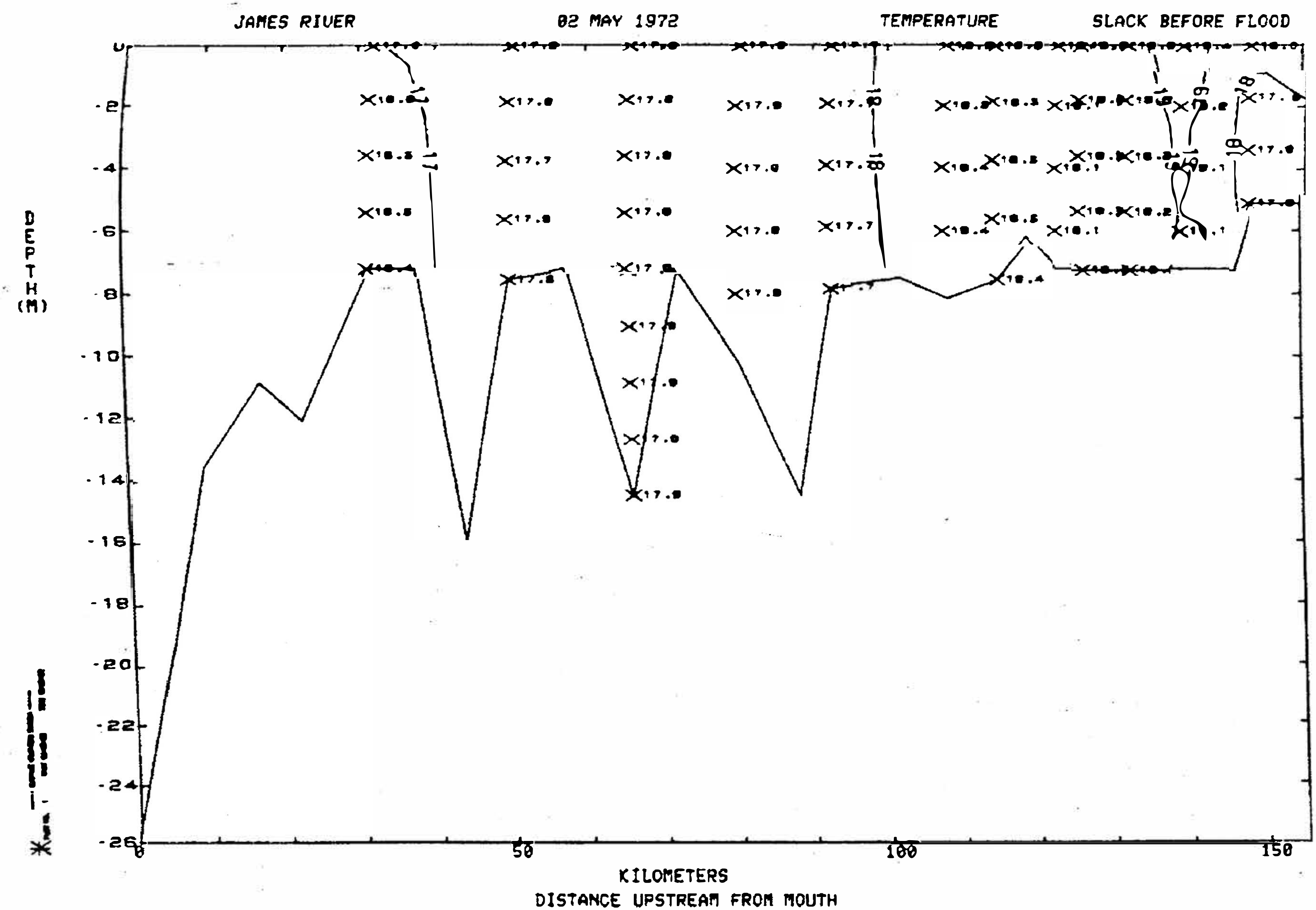
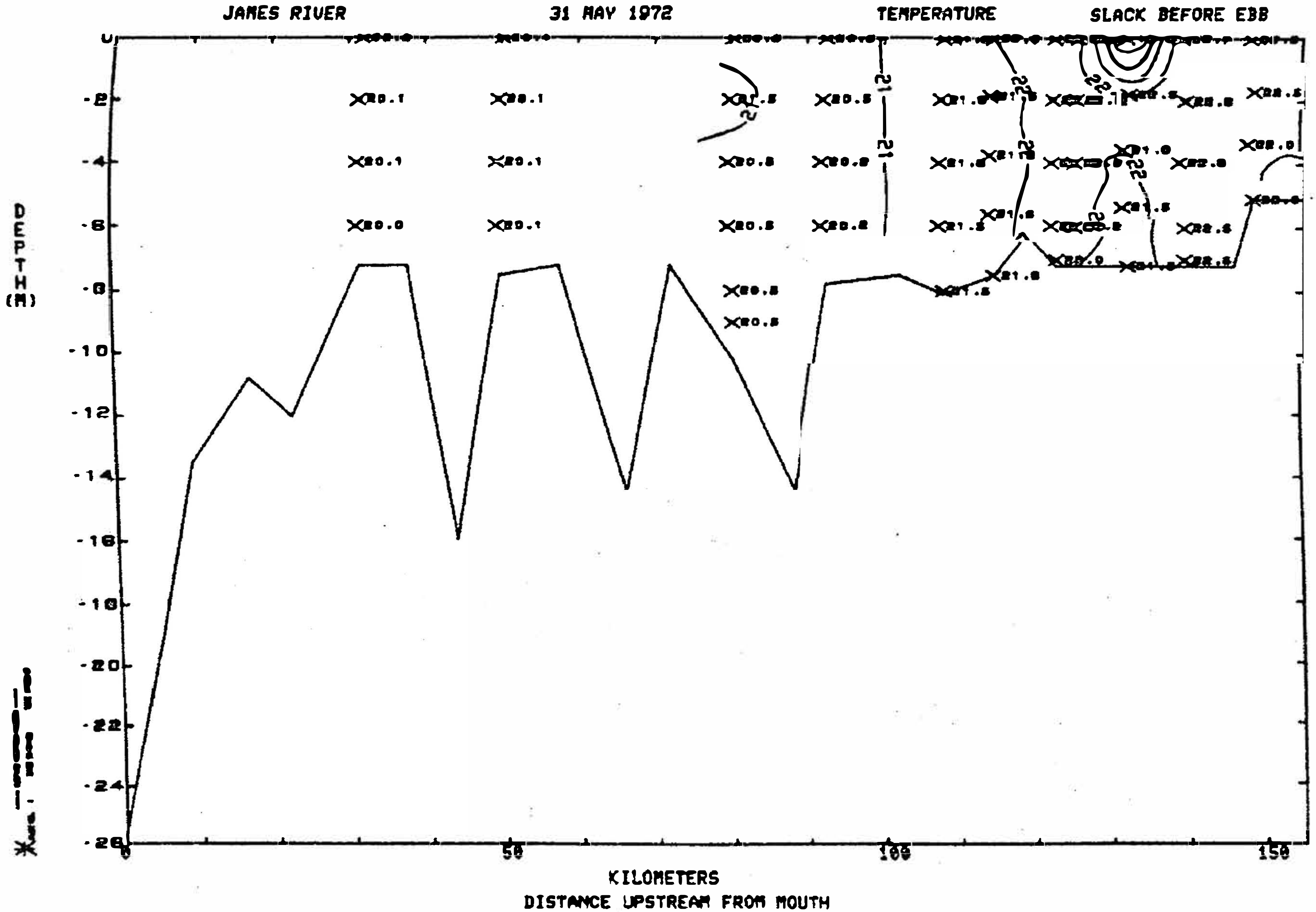
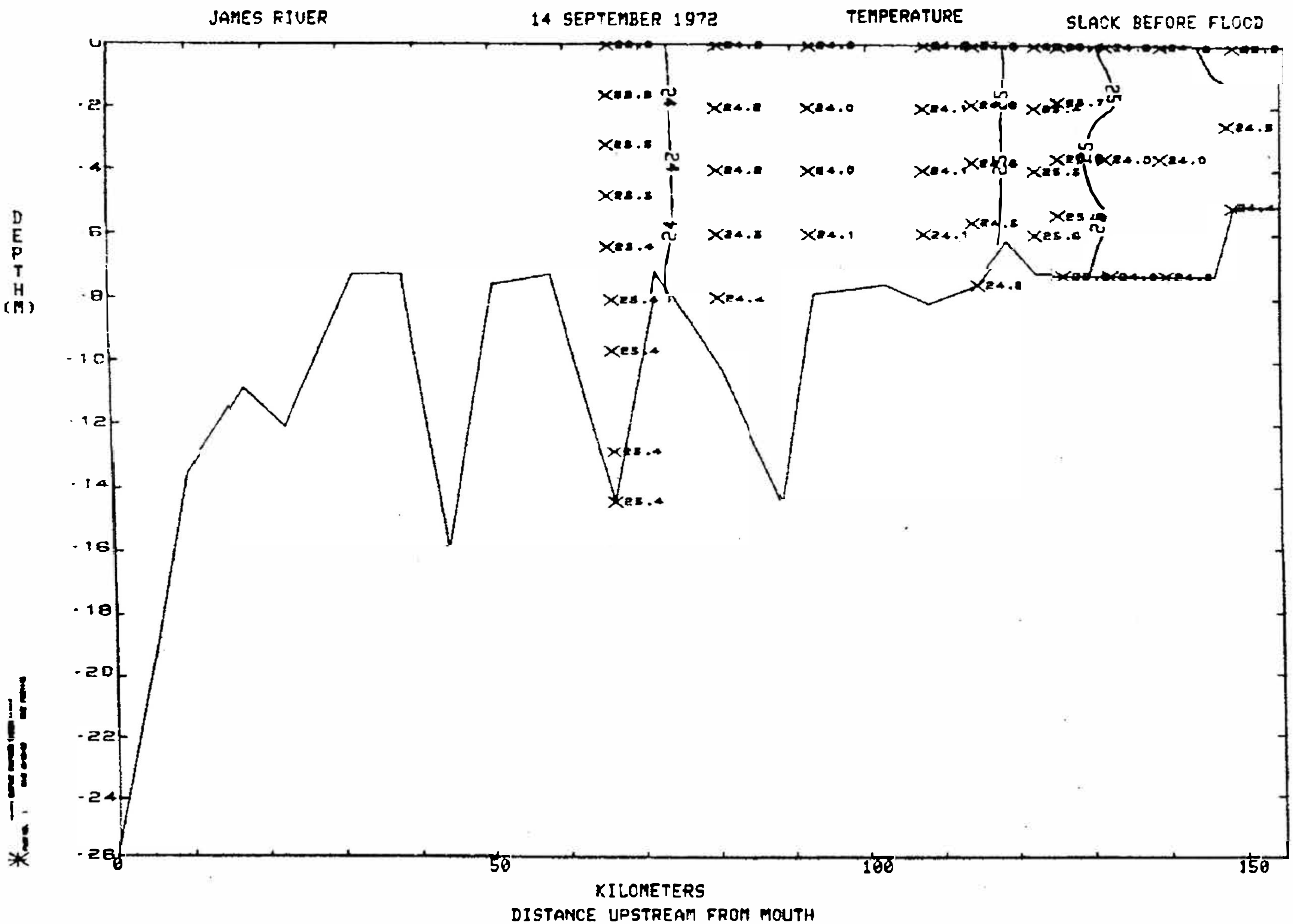
-20
-22
-24
-26



JAMES RIVER
02 MAY 1972
TEMPERATURE
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
31 MAY 1972
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



JAMES RIVER
14 SEPTEMBER 1972
TEMPERATURE
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150
-2
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-8
-10
-12
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-16
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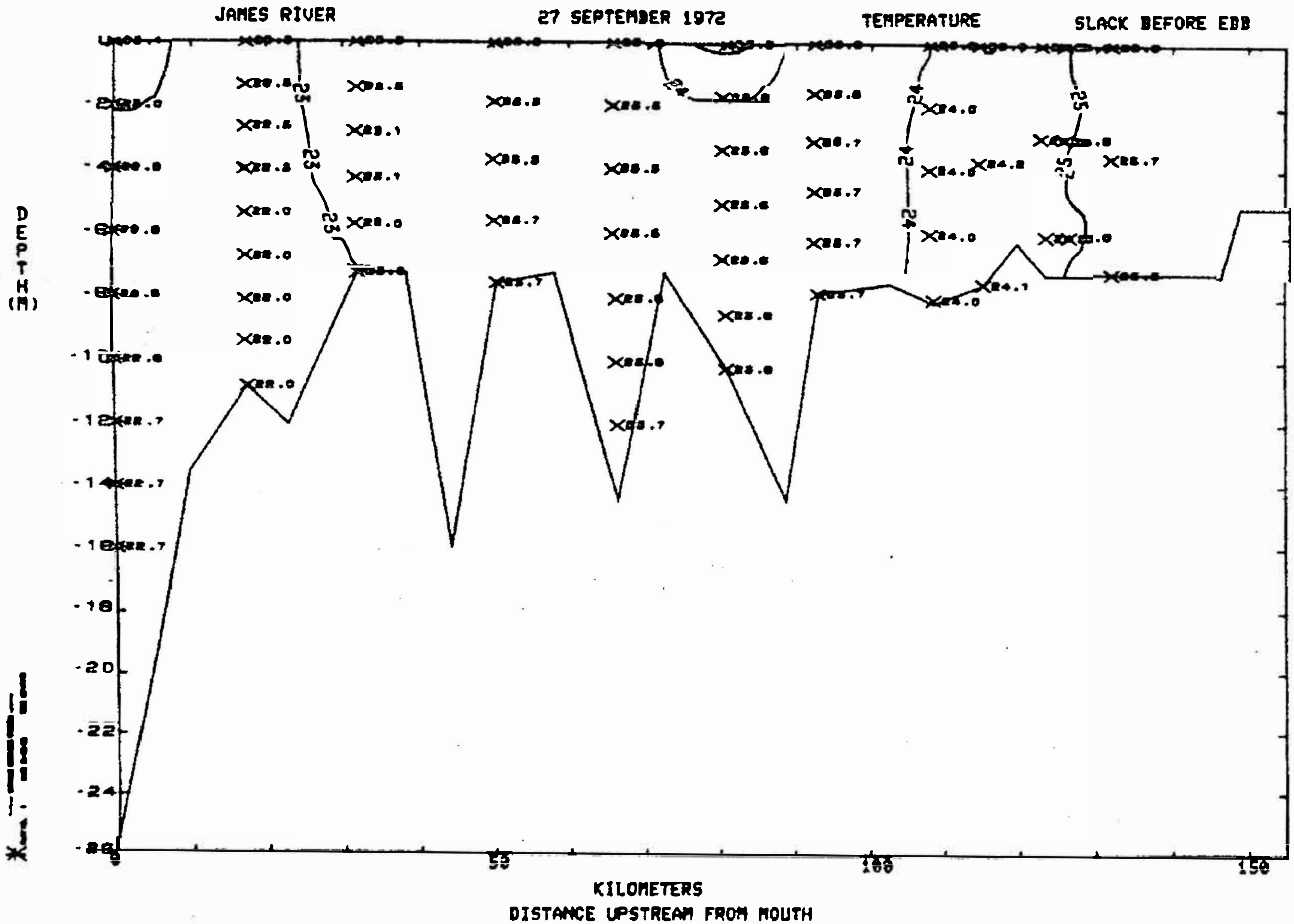
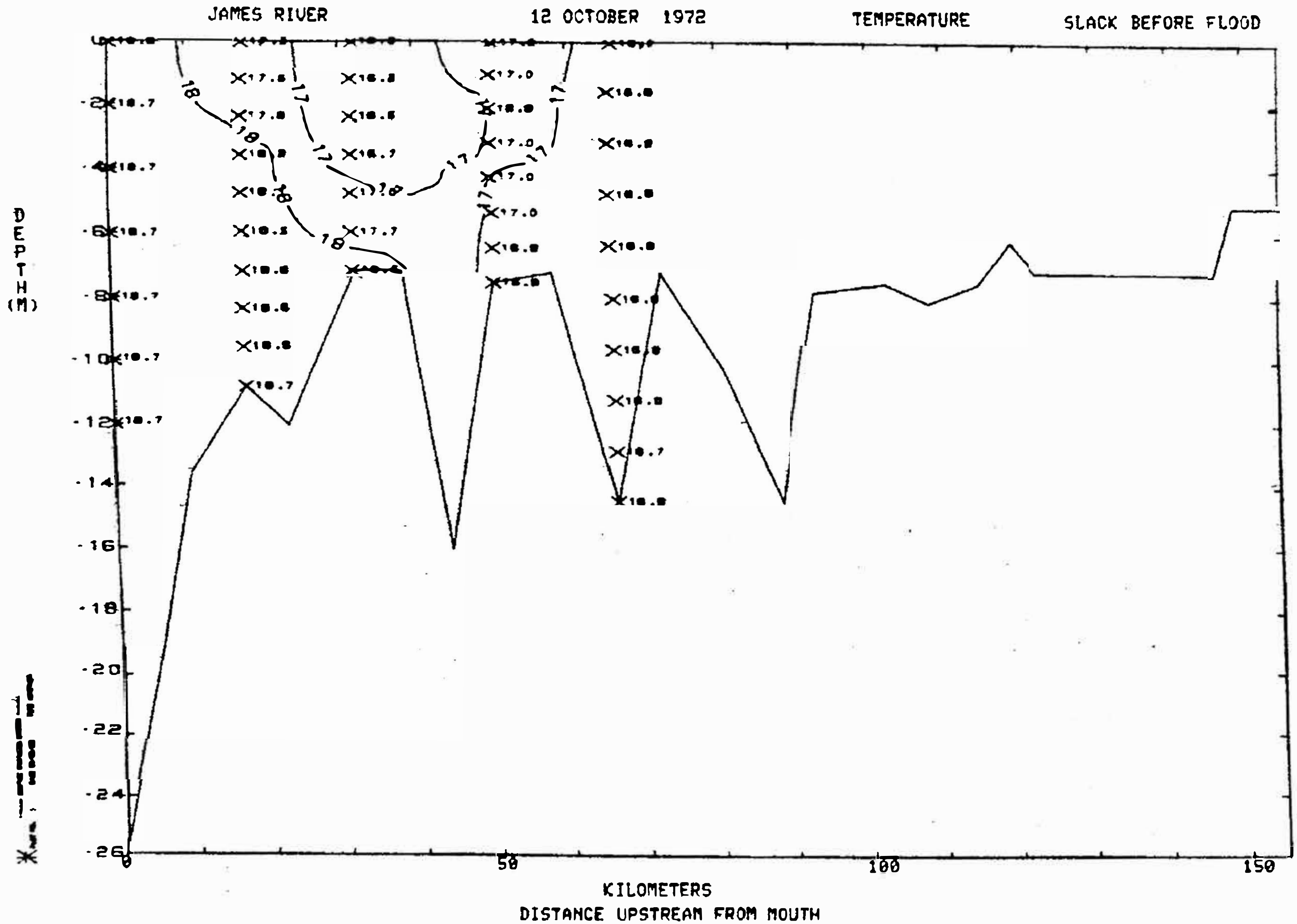
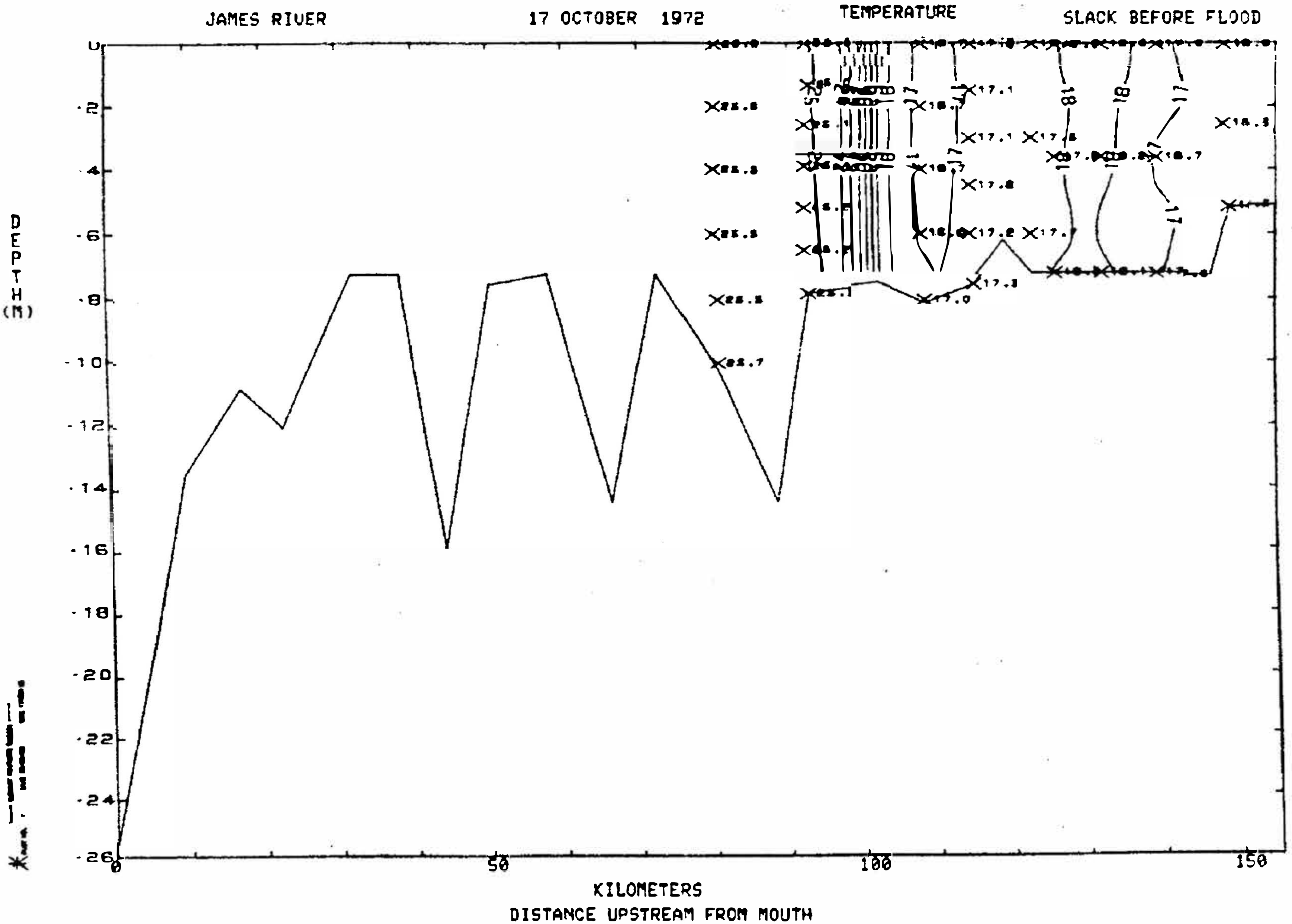
-24
-26
24
25

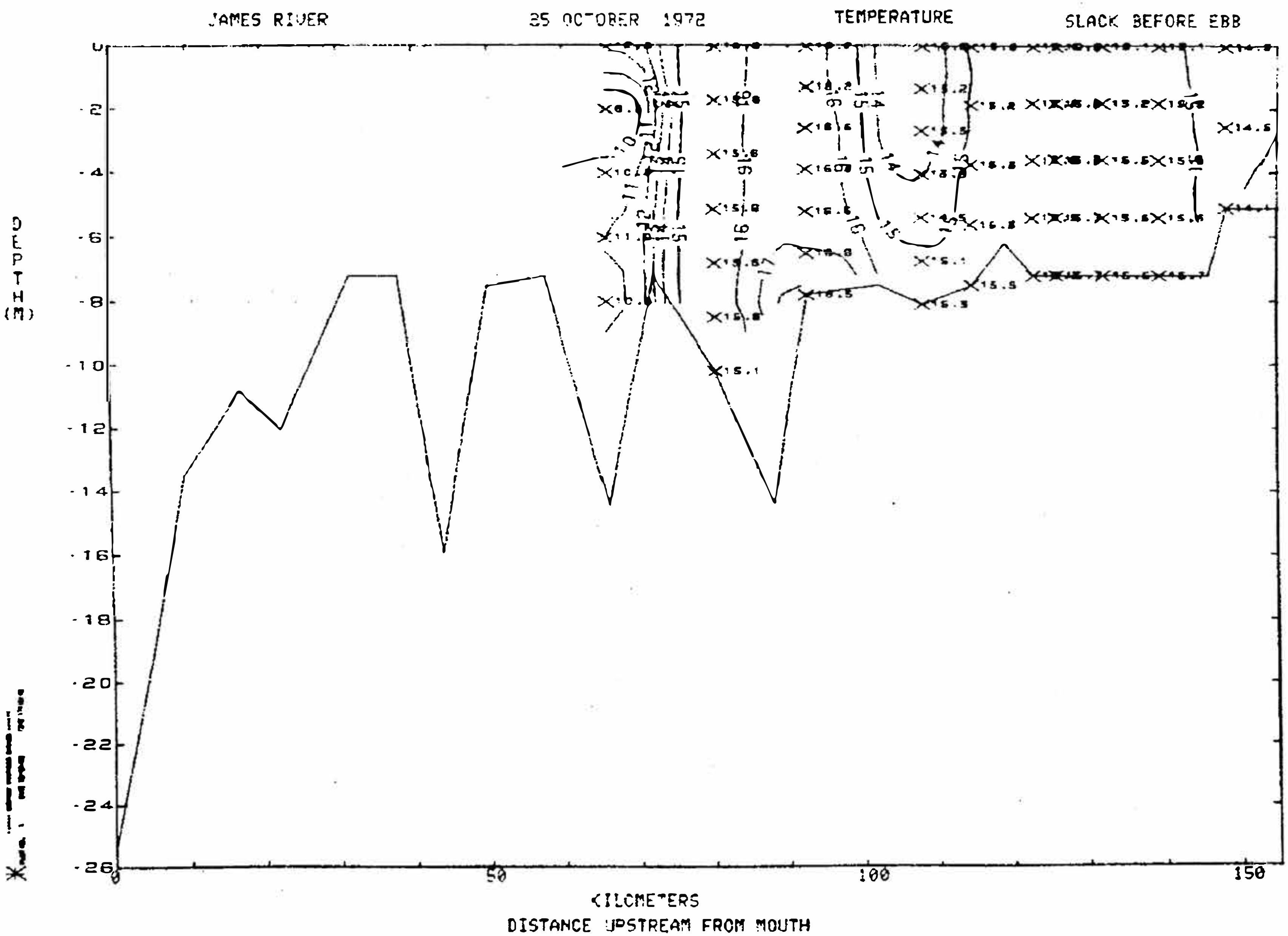

JAMES RIVER
27 SEPTEMBER 1972
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
-18
-20
-22
-24
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



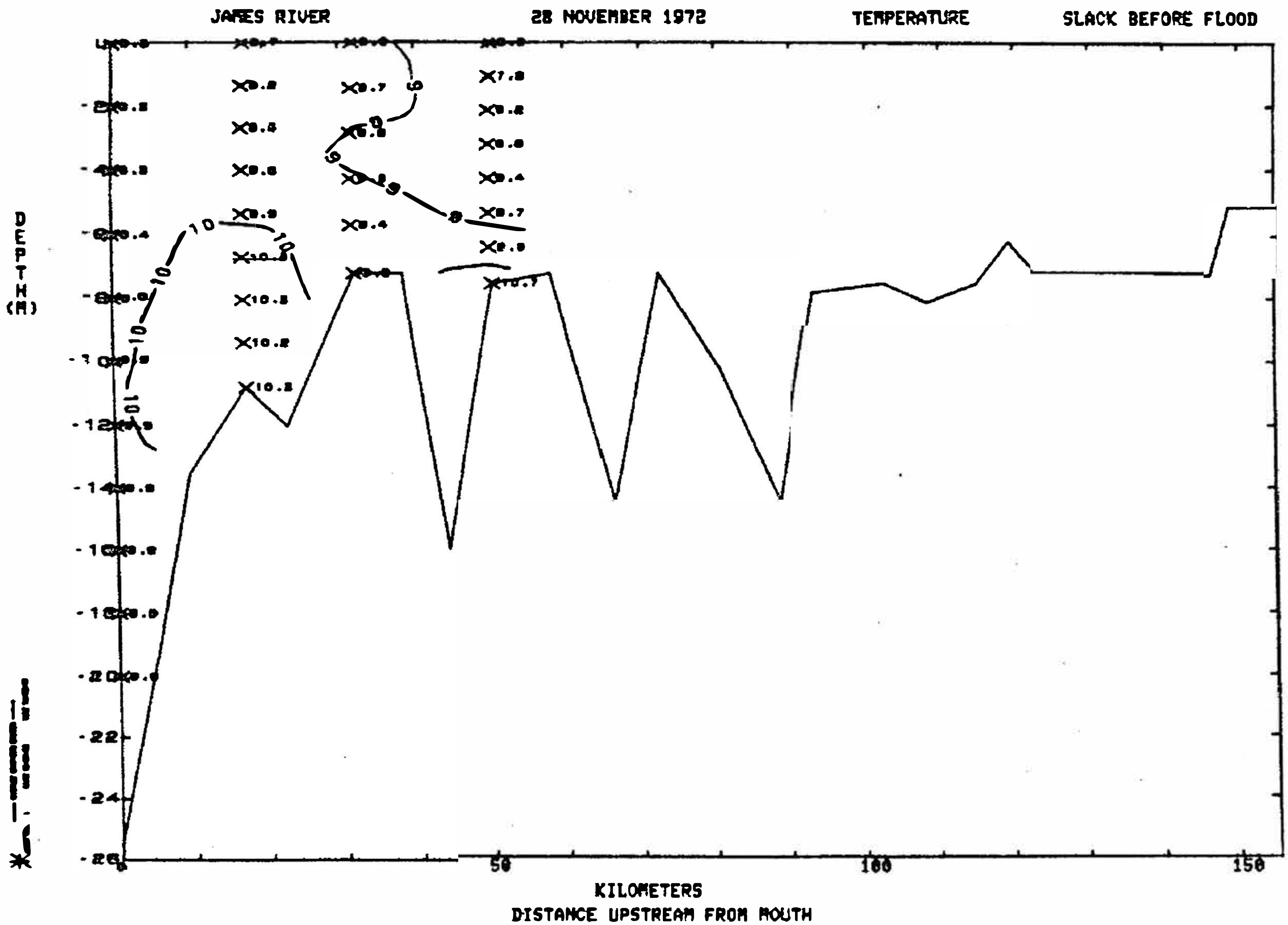
JAMES RIVER
12 OCTOBER 1972
TEMPERATURE
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



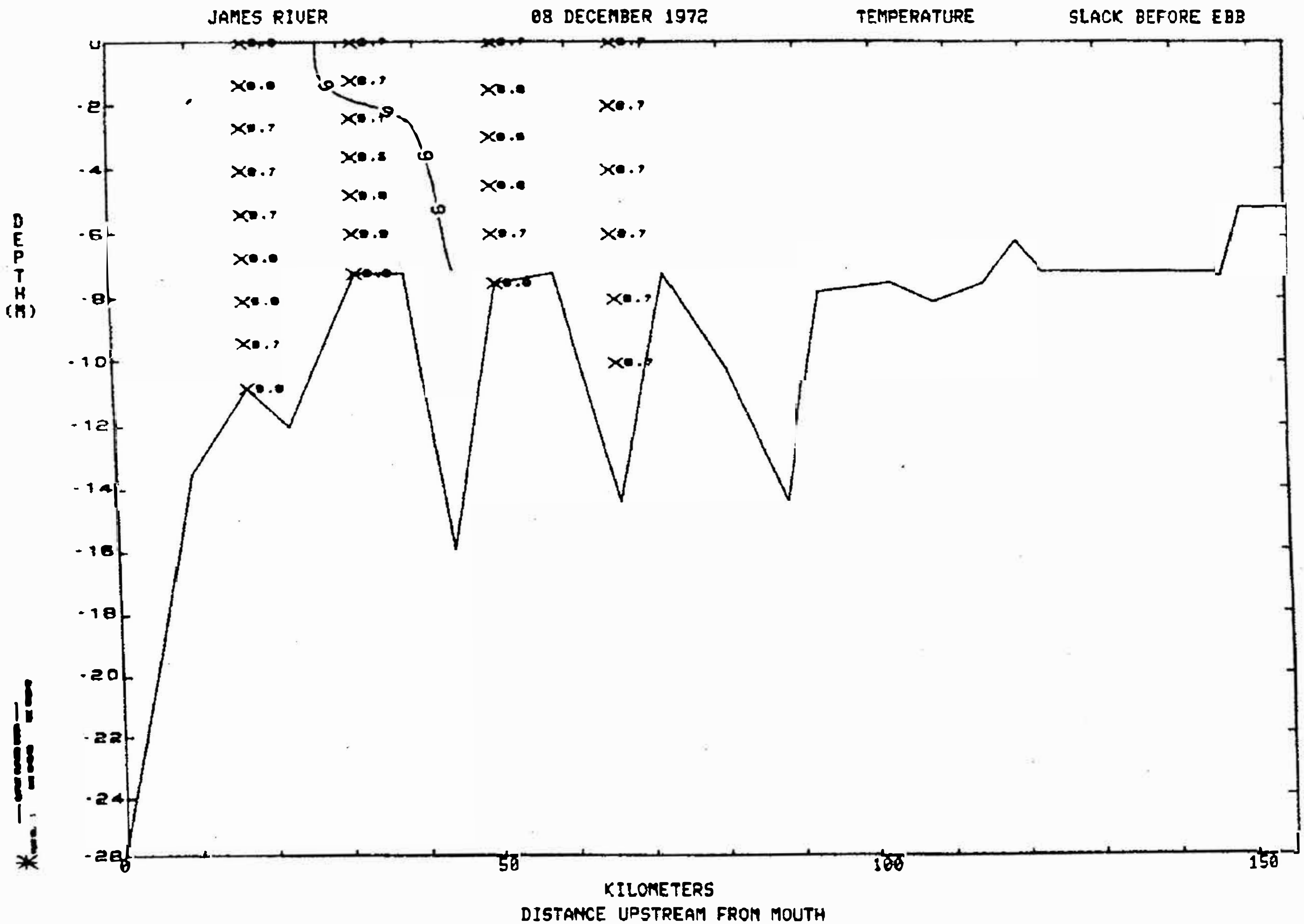
JAMES RIVER
17 OCTOBER 1972
TEMPERATURE
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

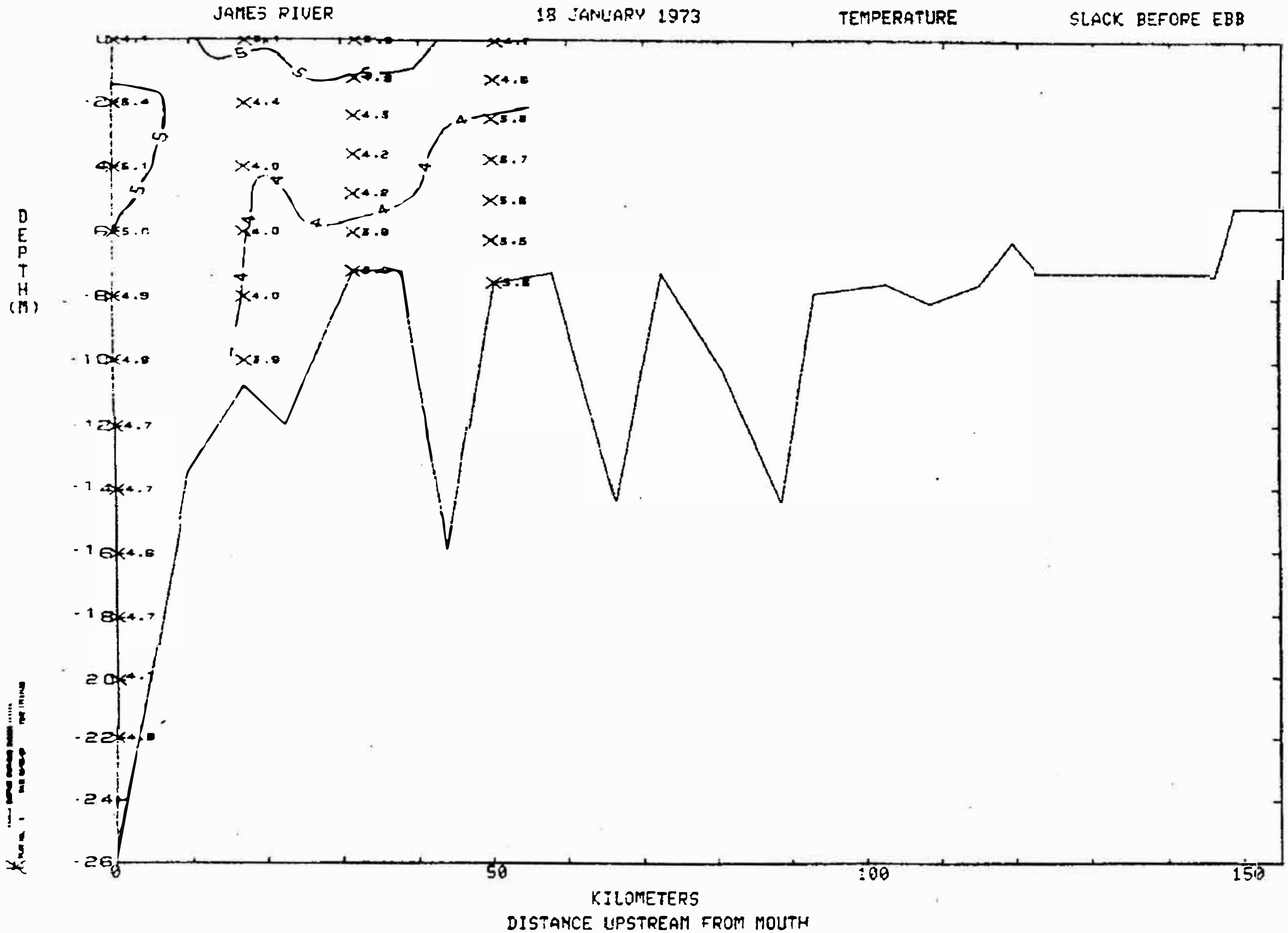


JAMES RIVER
25 OCTOBER 1972
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



JAMES RIVER
28 NOVEMBER 1972
TEMPERATURE
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
50
100
150
-22
-24


JAMES RIVER
08 DECEMBER 1972
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



JAMES RIVER
18 JANUARY 1973
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150
-2
-4
-6
-8
-10
-12
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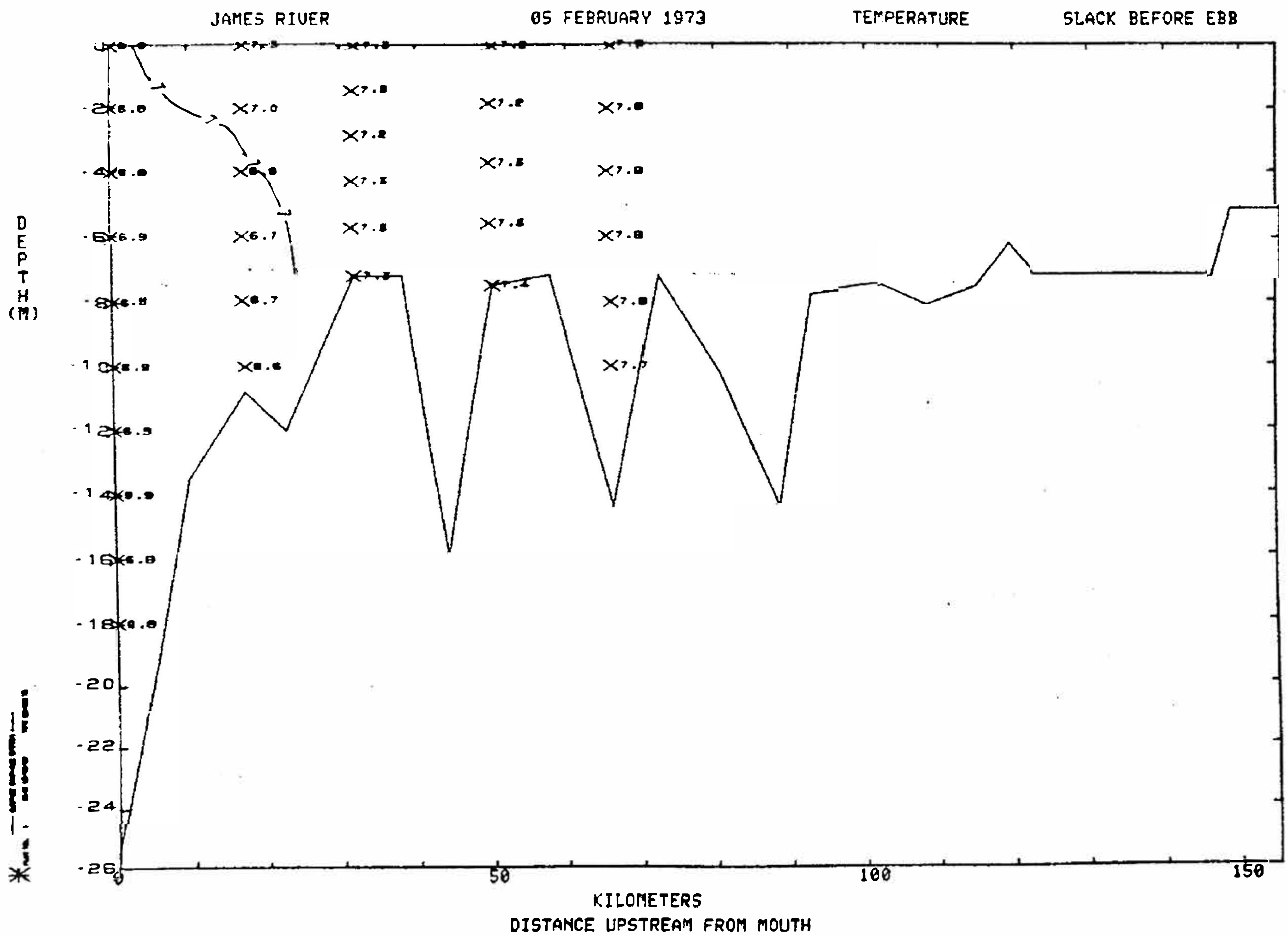
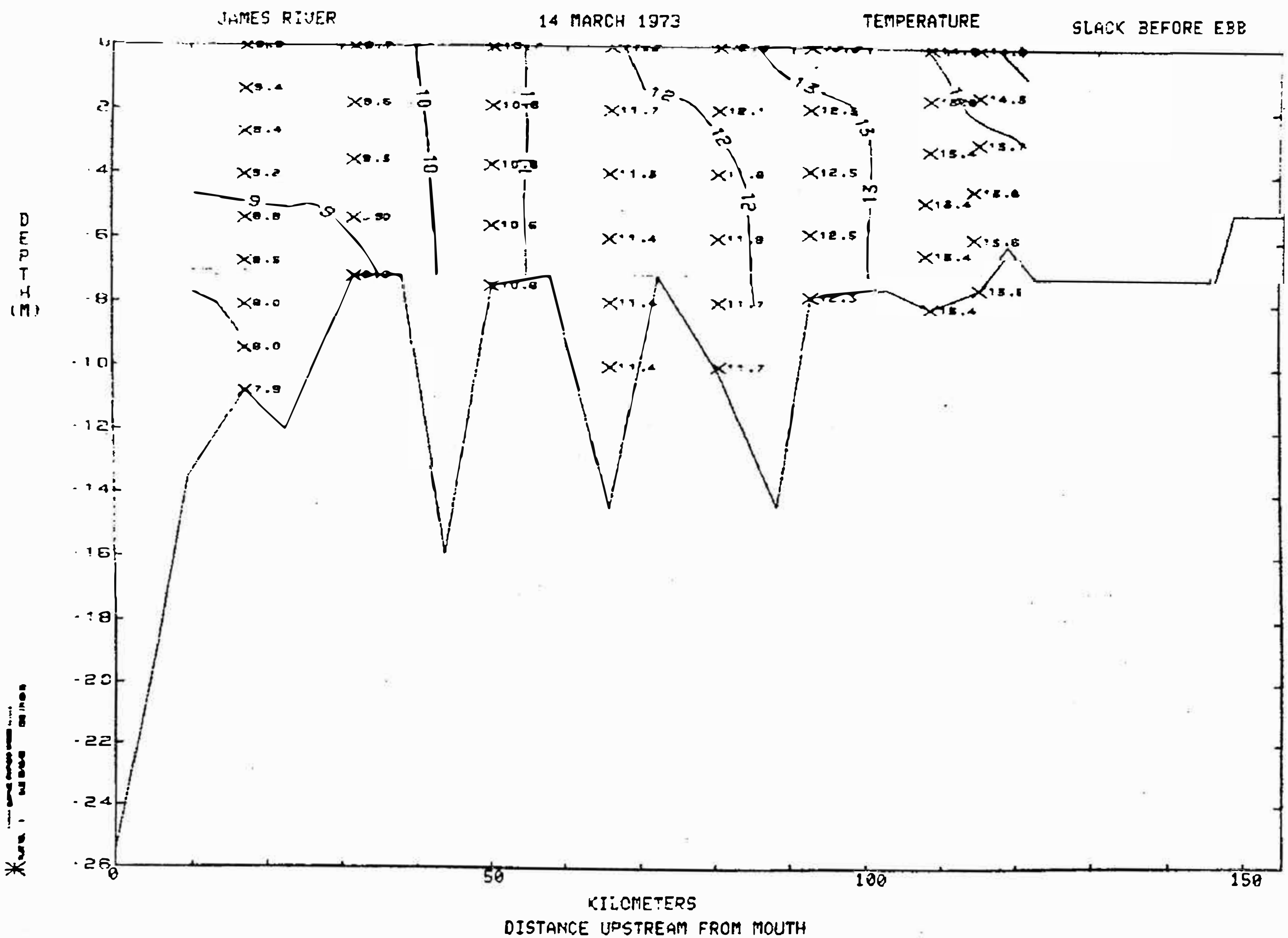
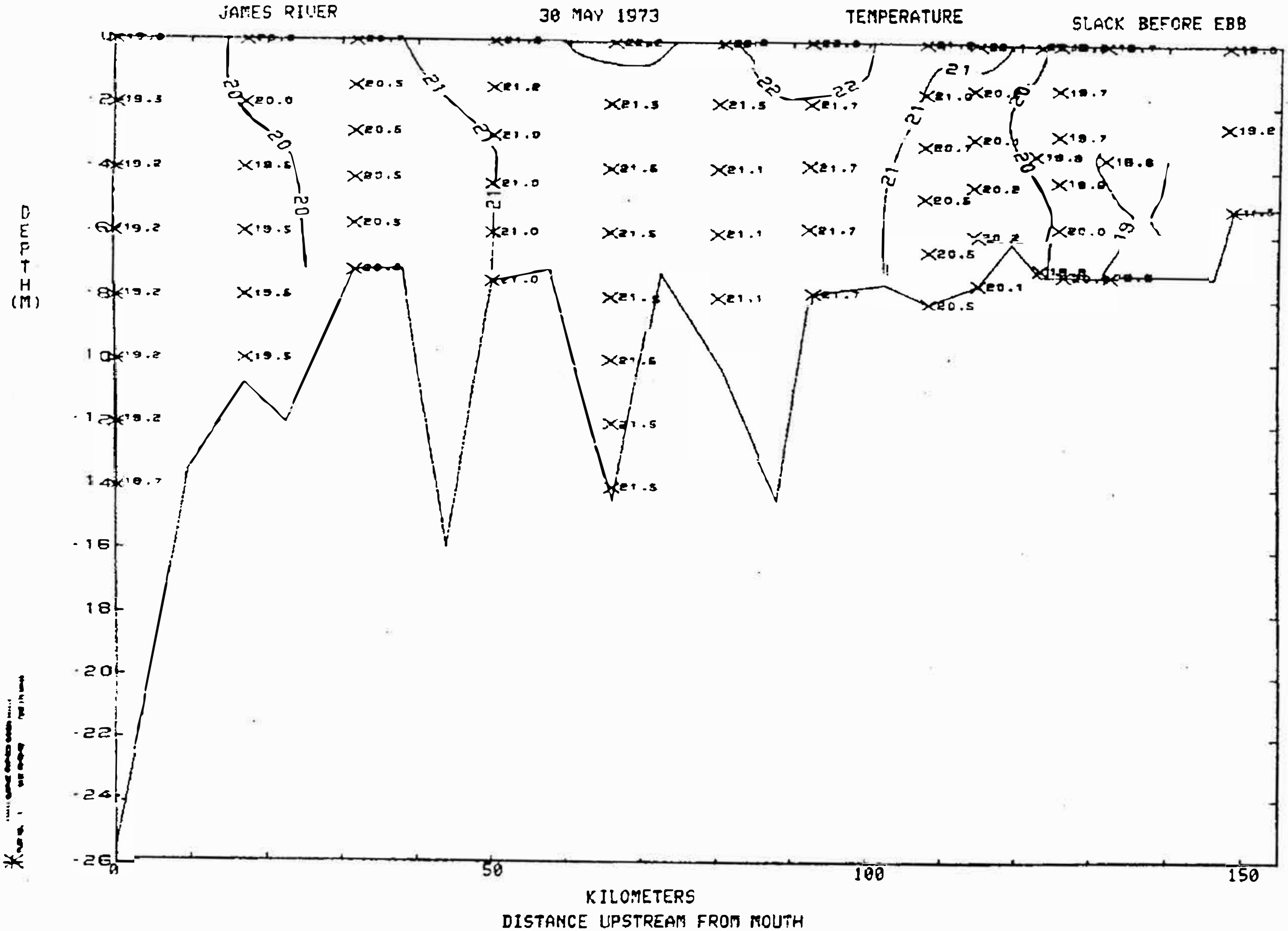
-20
-22
-24
-26

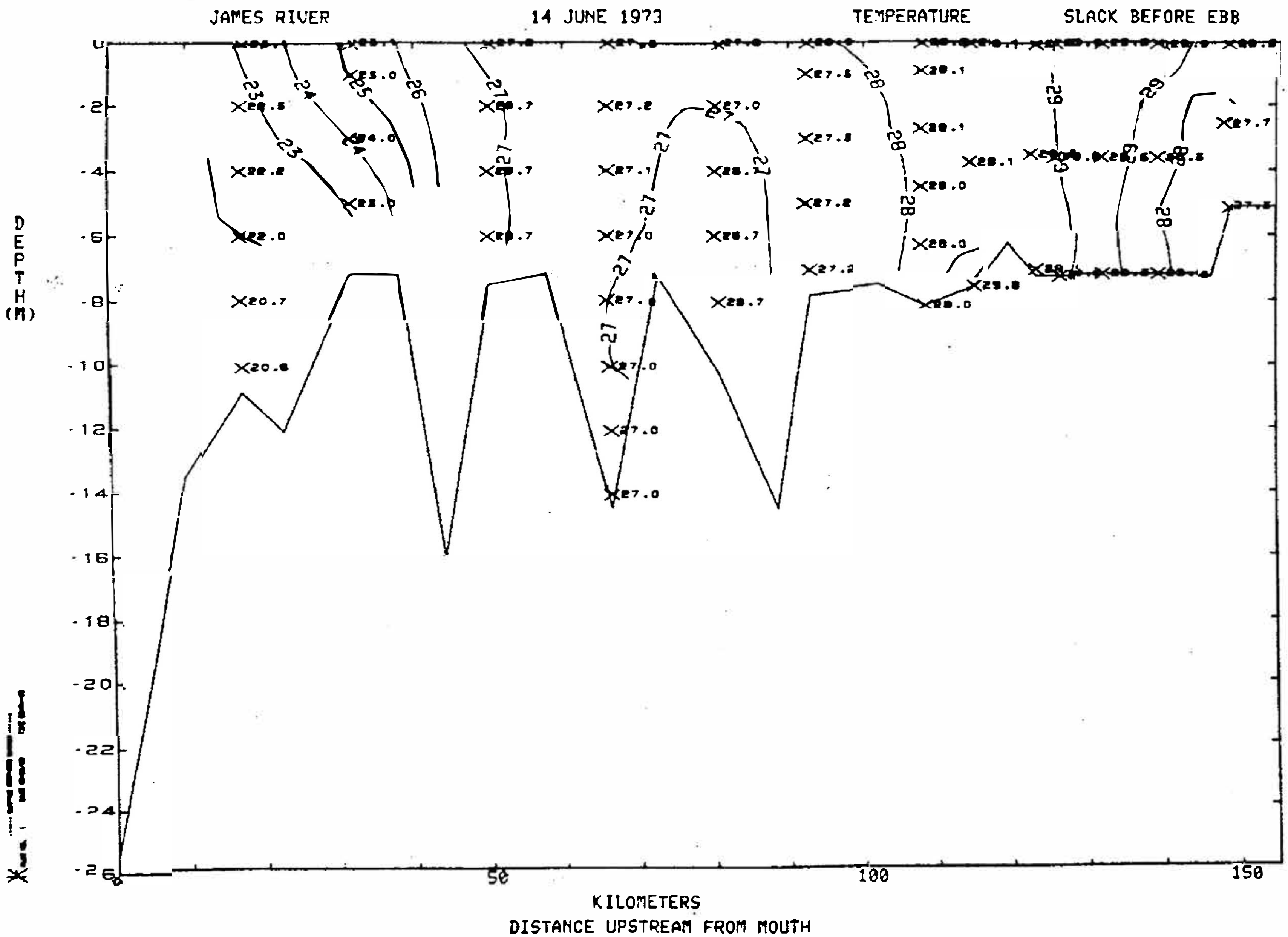


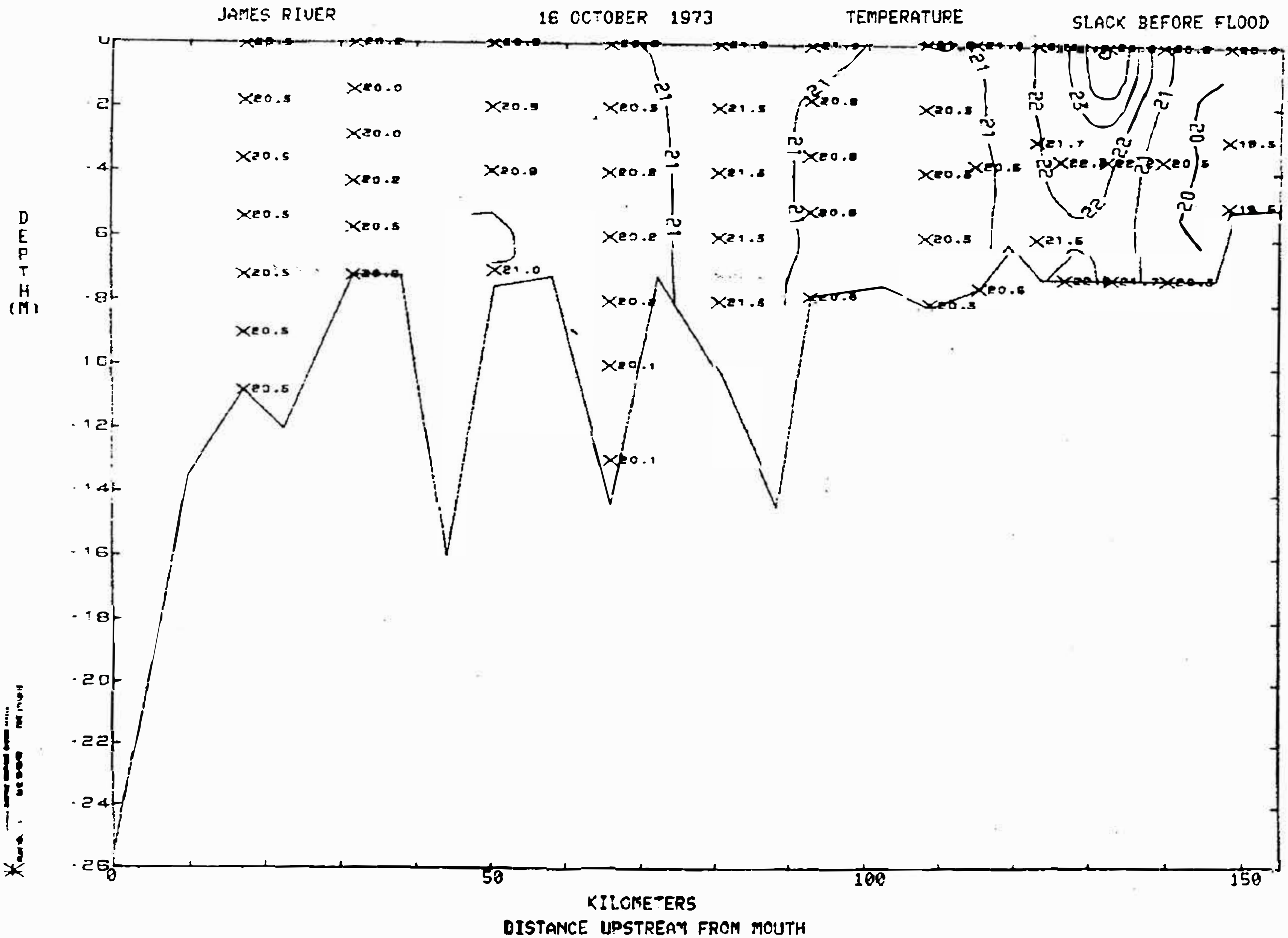
JAMES RIVER
05 FEBRUARY 1973
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
14 MARCH 1973
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
2
4
6
8
10
12
14
16
18
20
22
24
26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
9
10
11
12
13

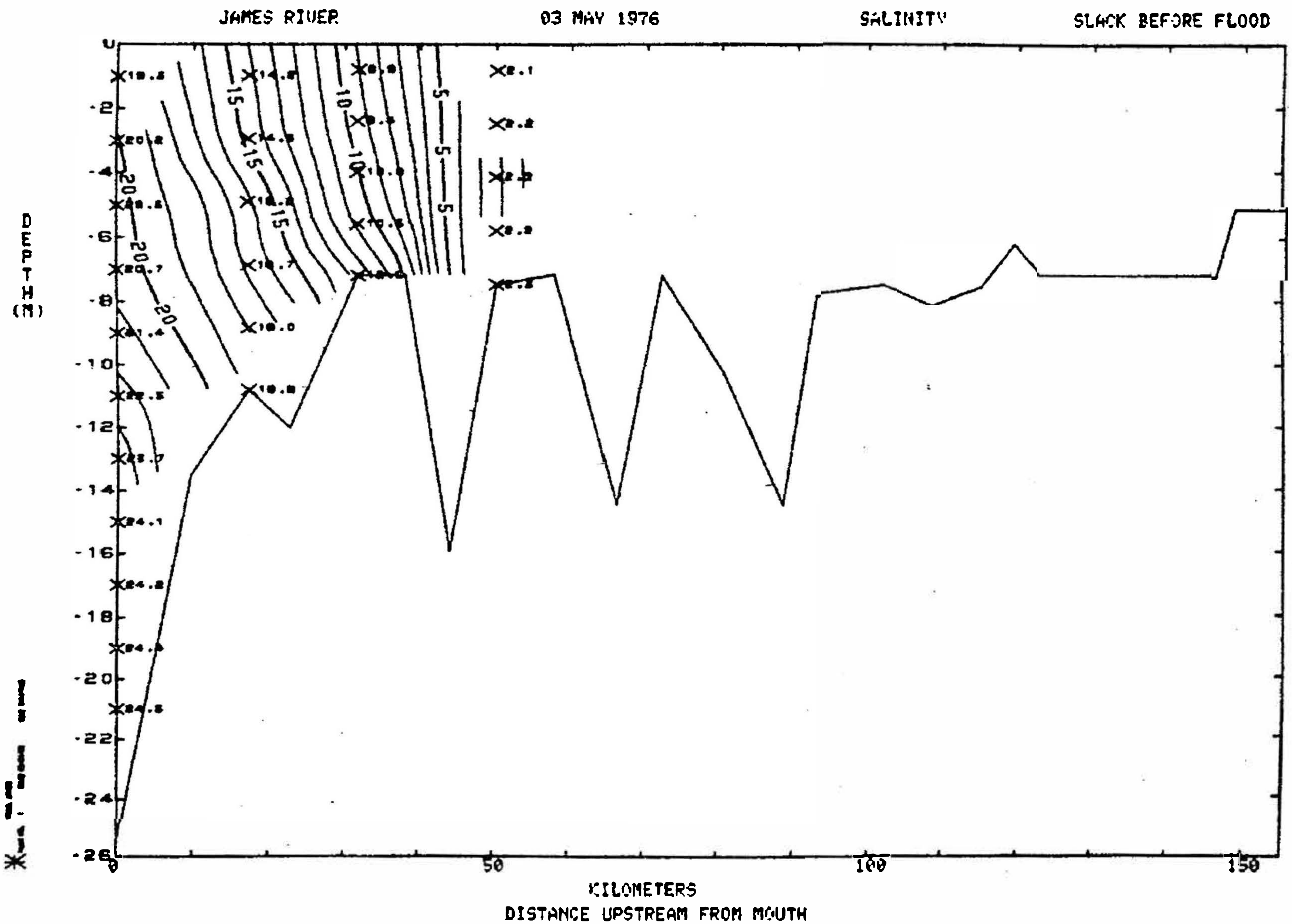


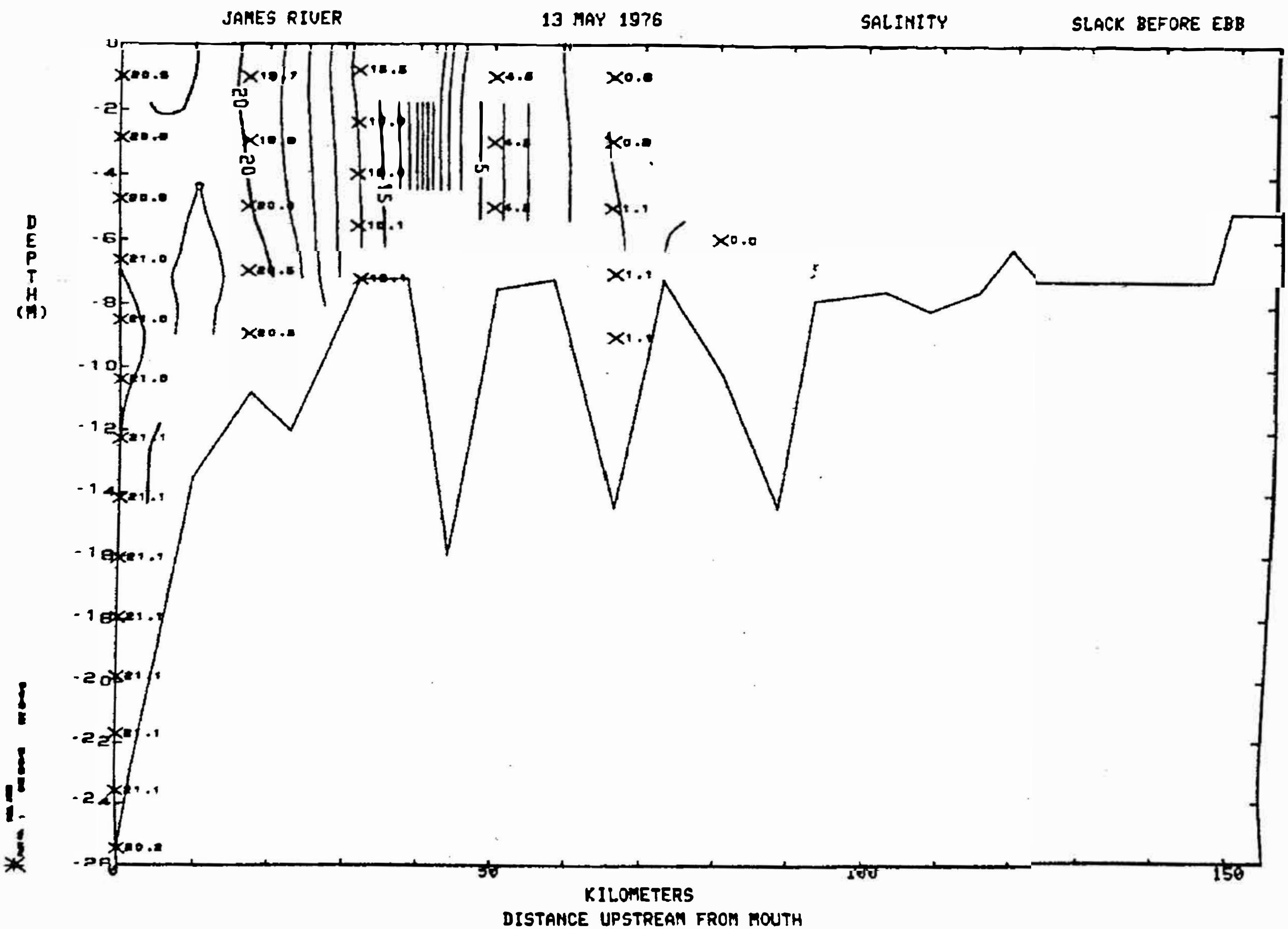
JAMES RIVER
30 MAY 1973
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

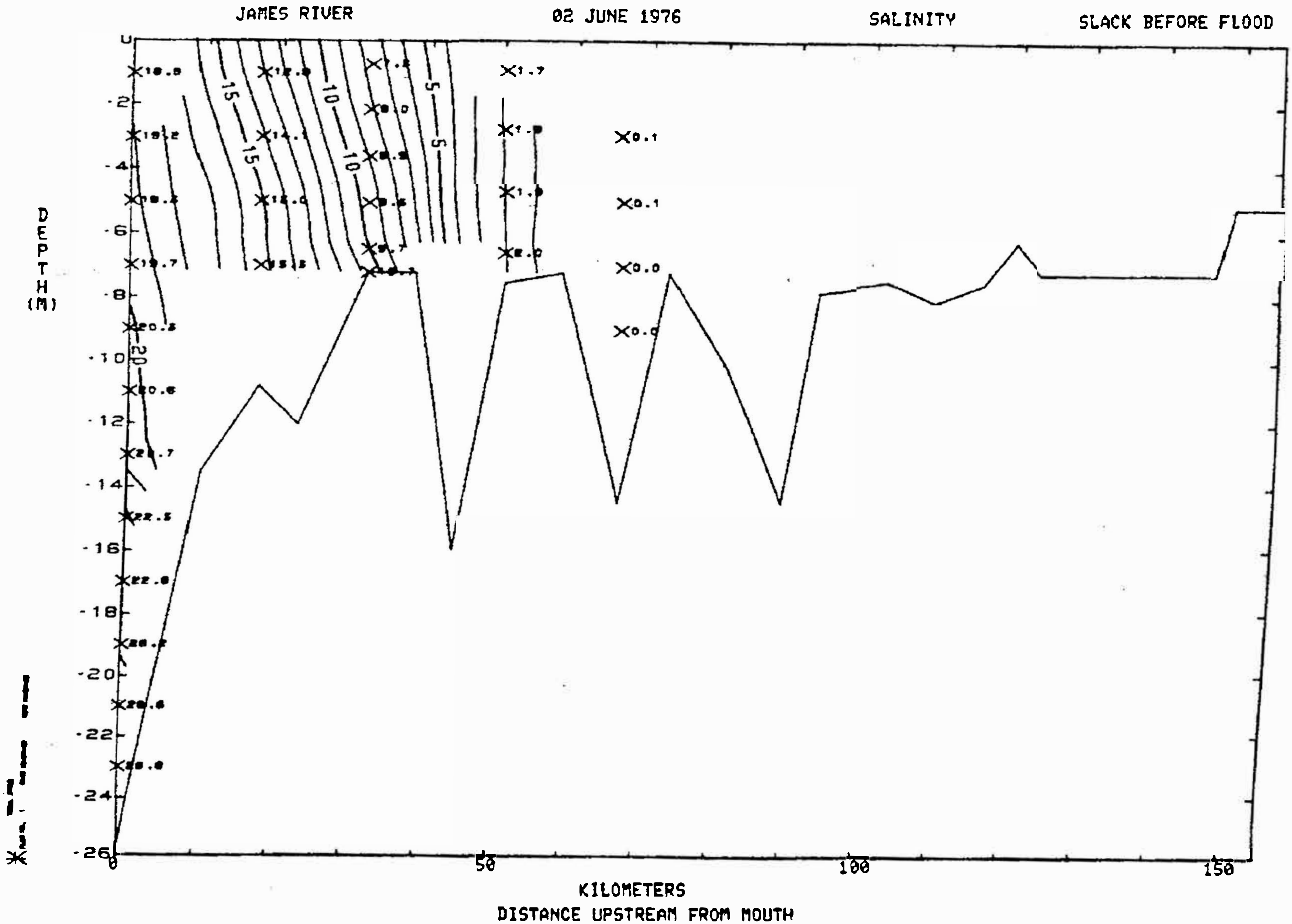

JAMES RIVER
14 JUNE 1973
TEMPERATURE
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

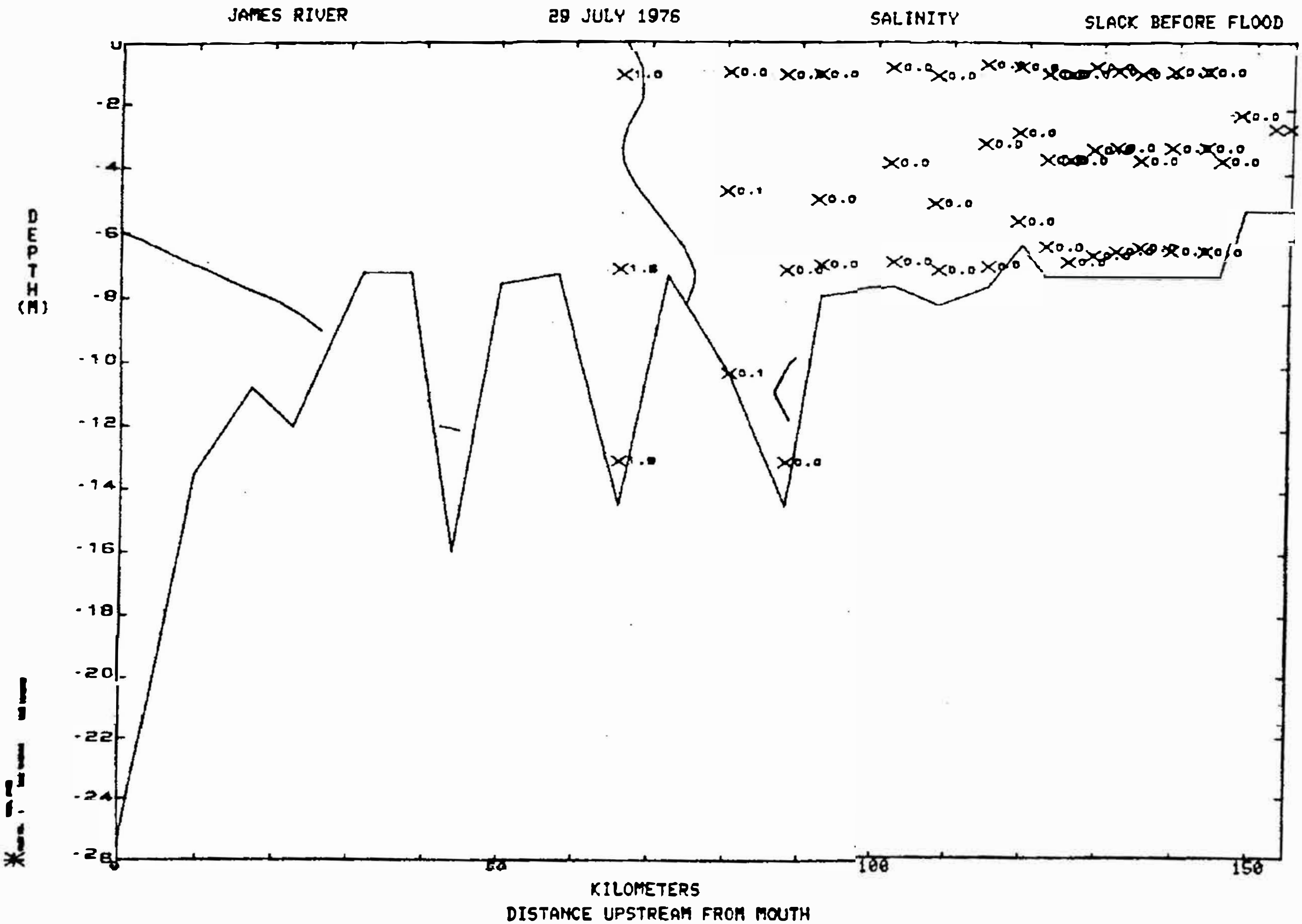


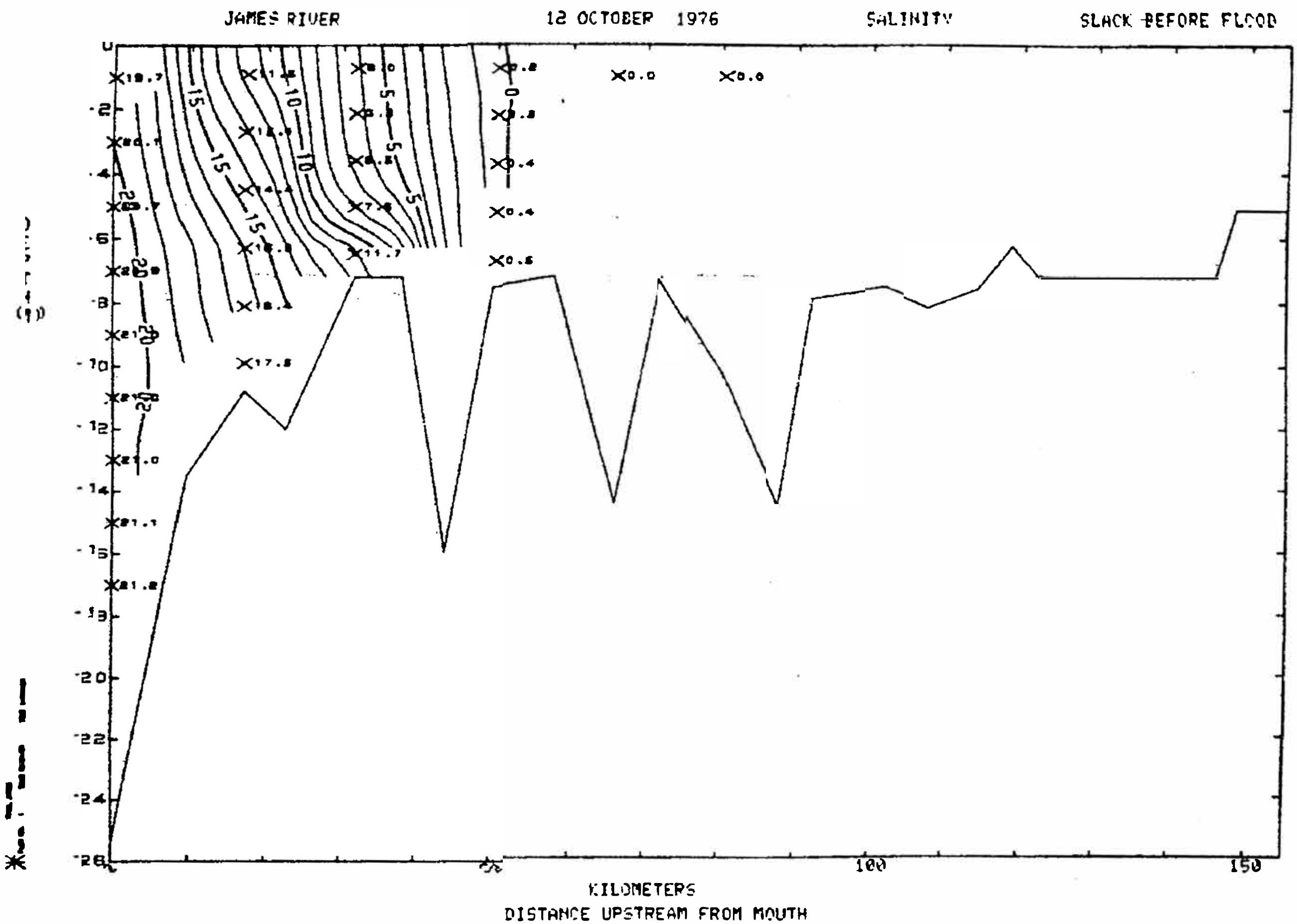
JAMES RIVER
16 OCTOBER 1973
TEMPERATURE
SLACK BEFORE FLOOD
DEPTH (M)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
20.5
20.0
20.2
20.9
21.0
21.5
20.1
20.8
21.7
22.3
21
22
23
20

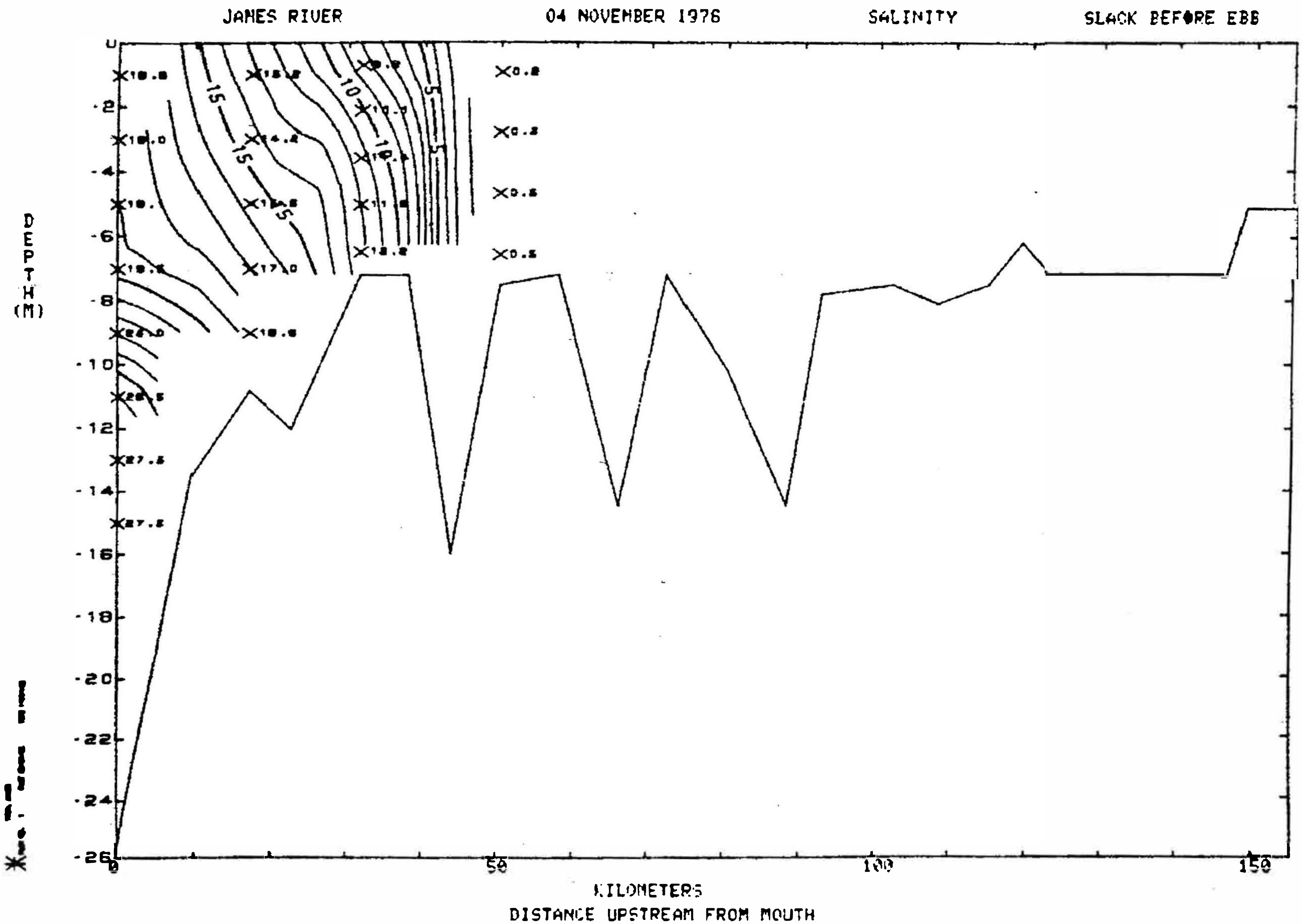

JAMES RIVER
03 MAY 1976
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

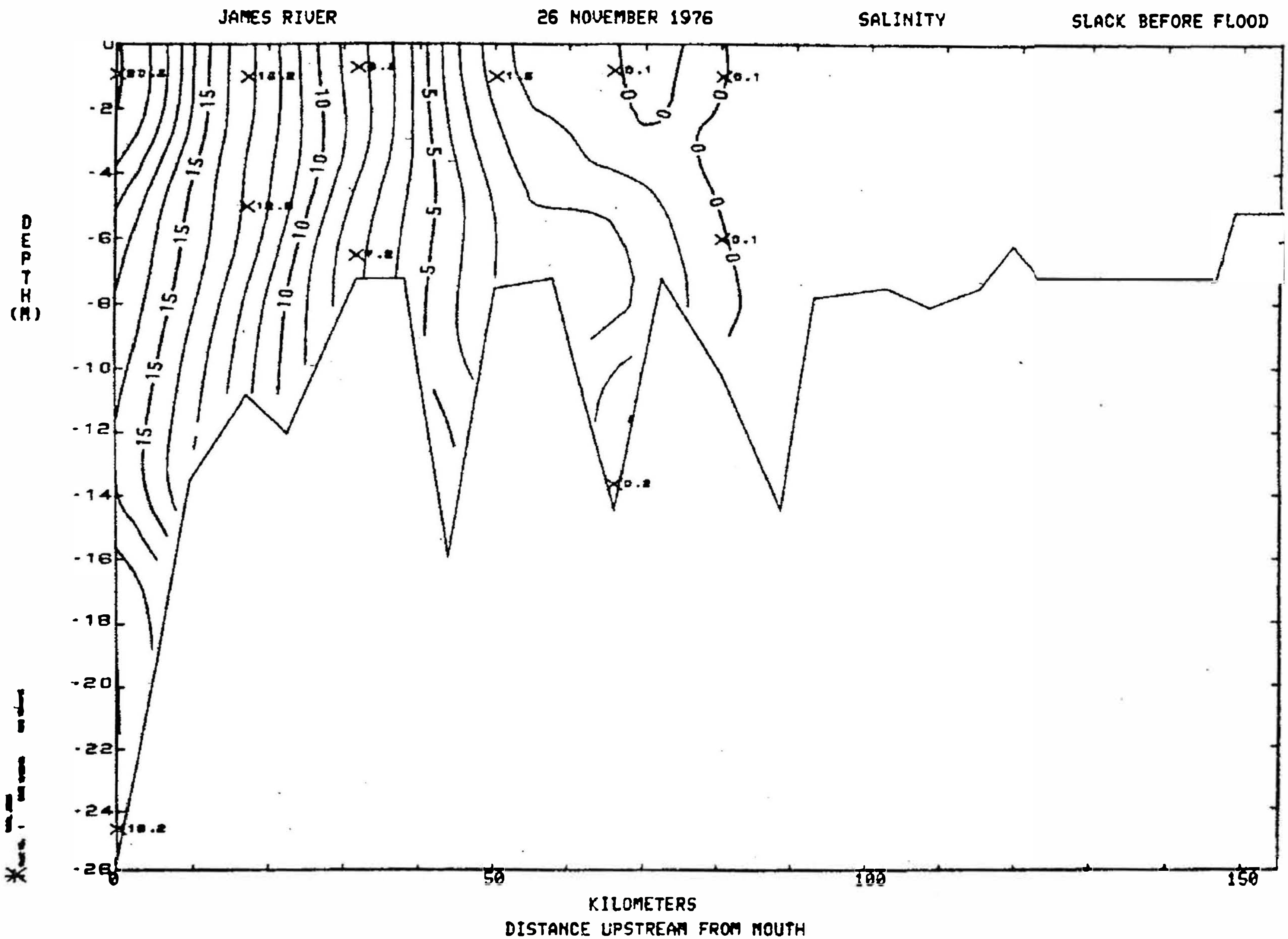

JAMES RIVER
13 MAY 1976
SALINITY
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
02 JUNE 1976
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

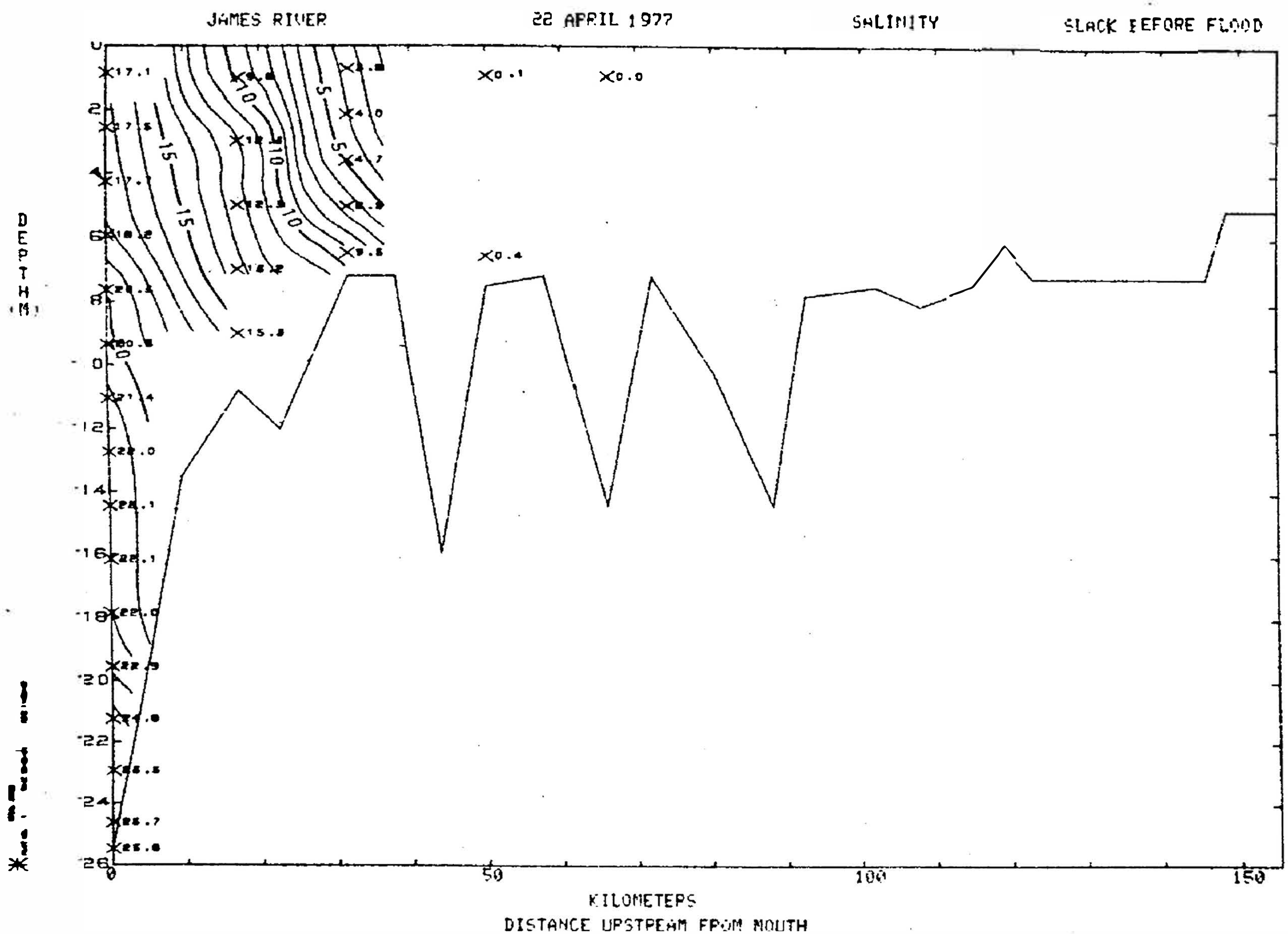

JAMES RIVER
29 JULY 1976
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
12 OCTOBER 1976
SALINITY
SLACK BEFORE FLOOD
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
100
150

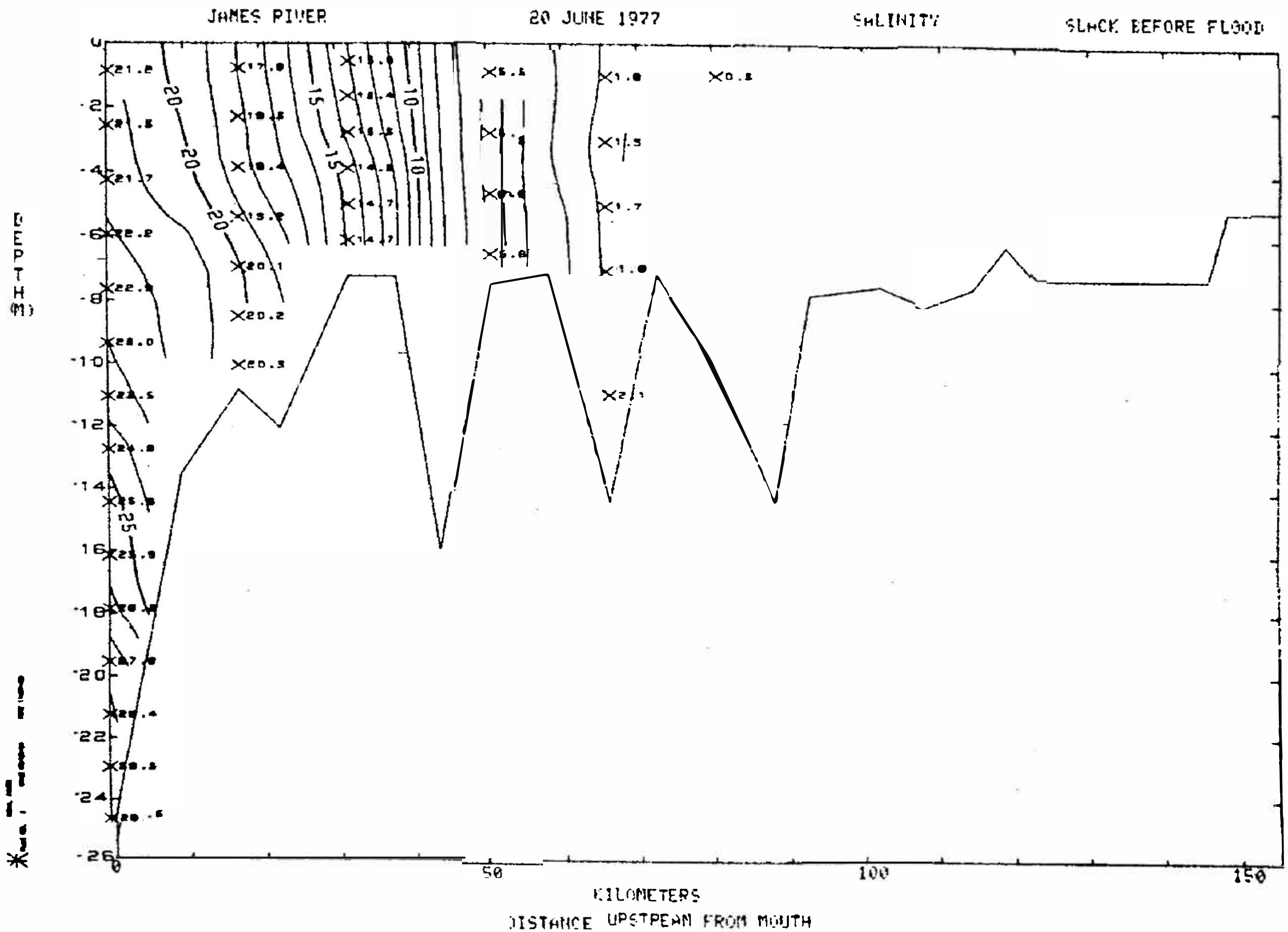

JAMES RIVER
04 NOVEMBER 1976
SALINITY
SLACK BEFORE EBB
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
15
10
5
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

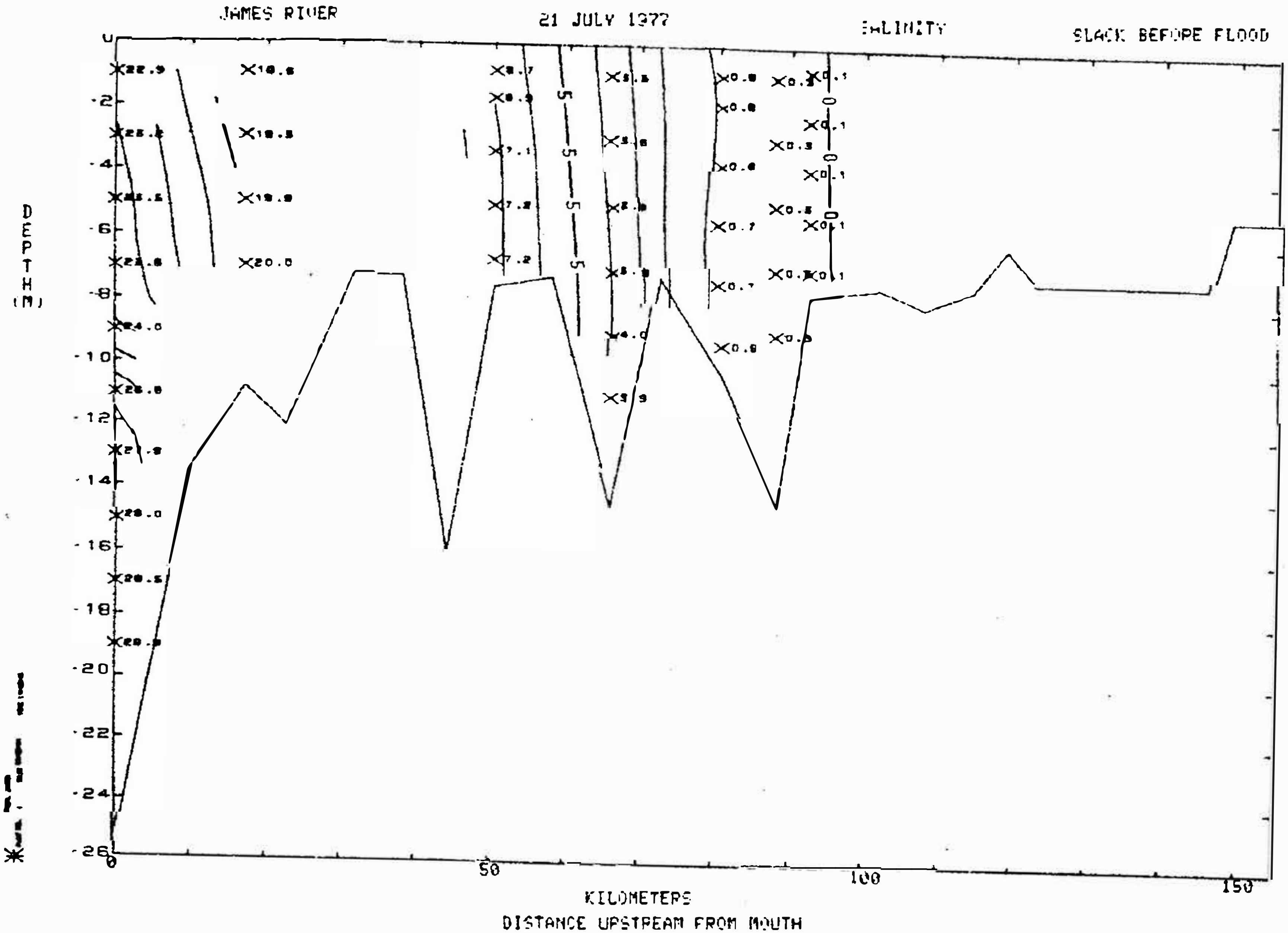


JAMES RIVER
26 NOVEMBER 1976
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
15
10
5
0
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

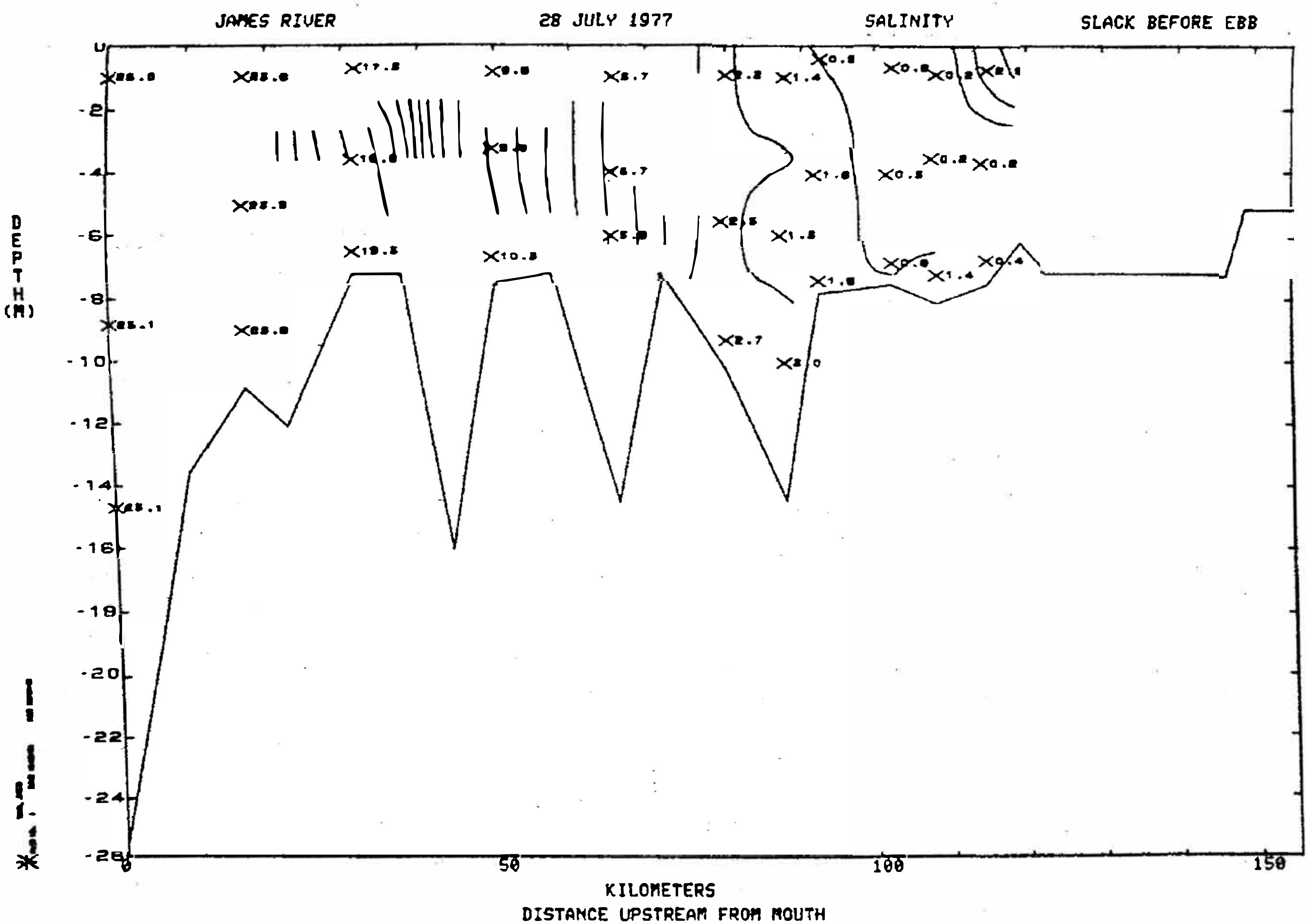


JAMES RIVER
22 APRIL 1977
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
20 JUNE 1977
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



JAMES RIVER
21 JULY 1977
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
28 JULY 1977
SALINITY
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
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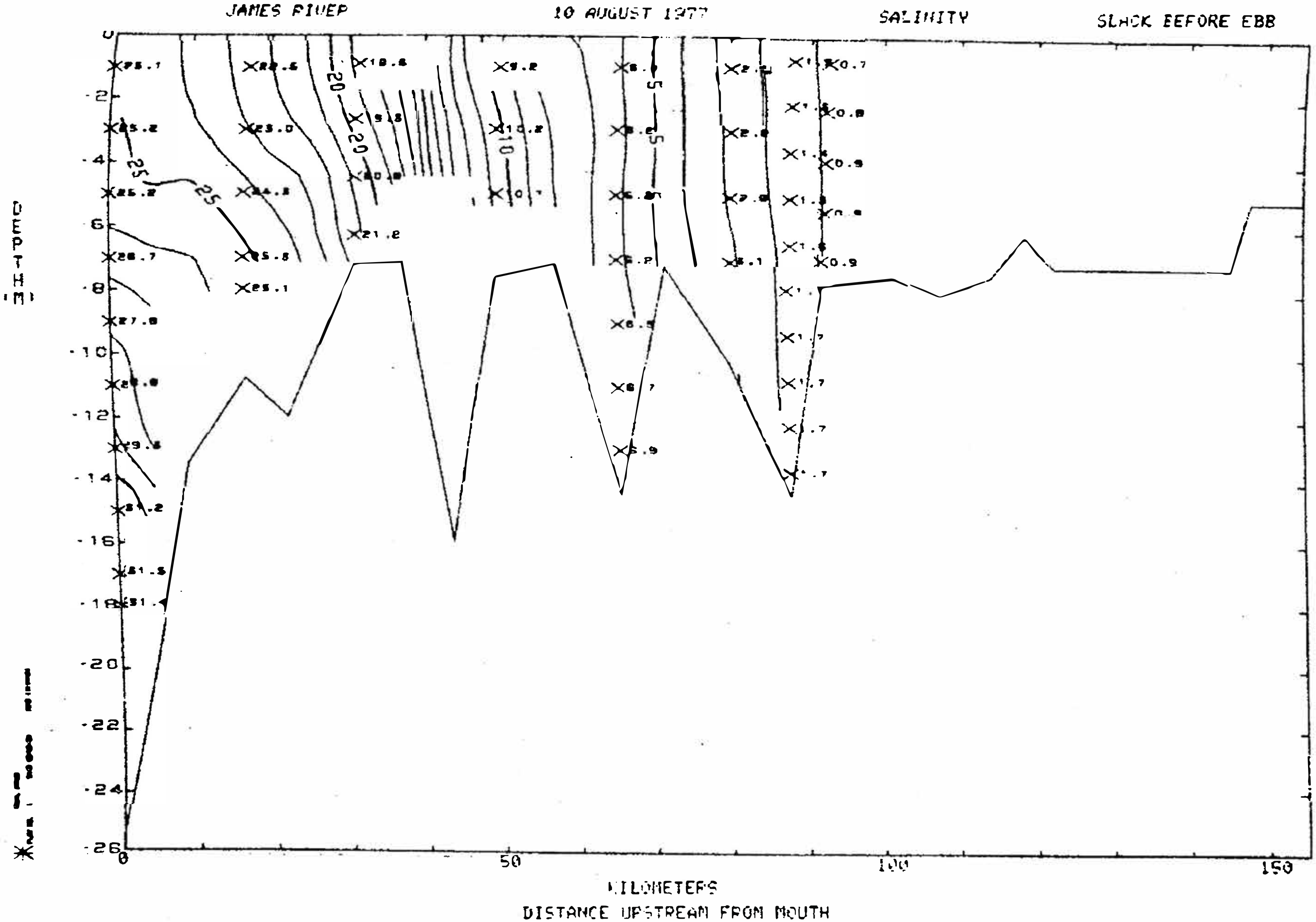
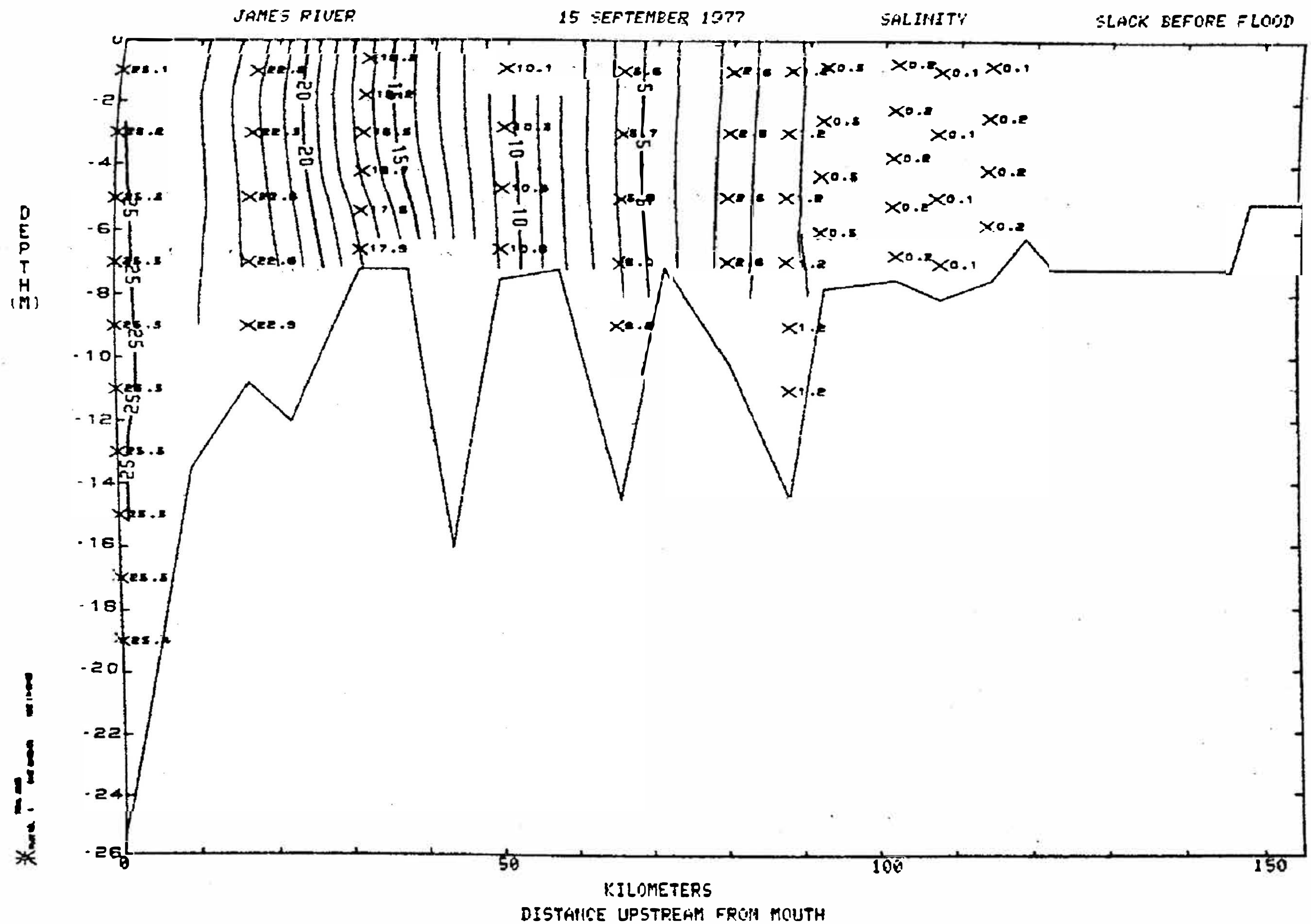
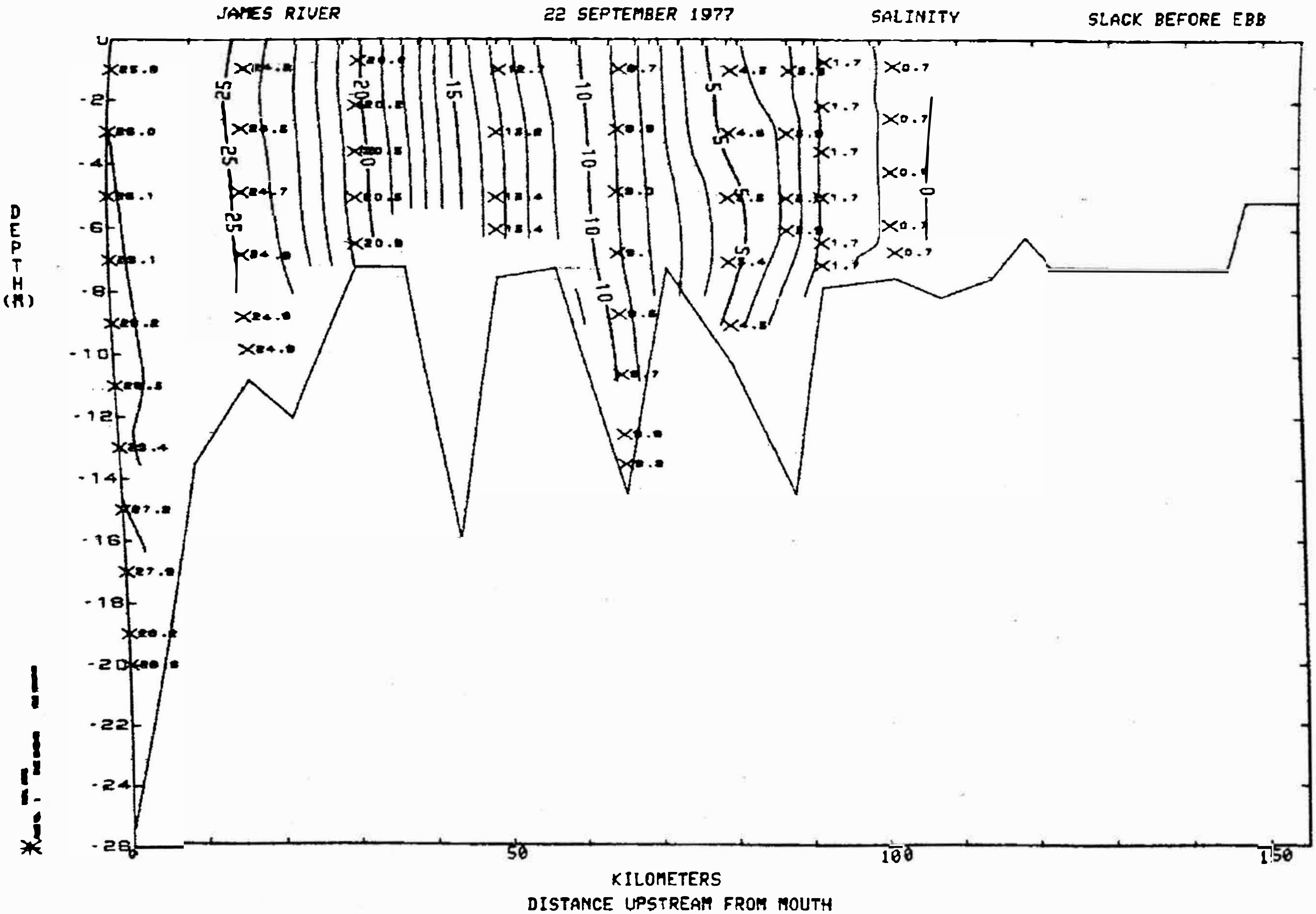
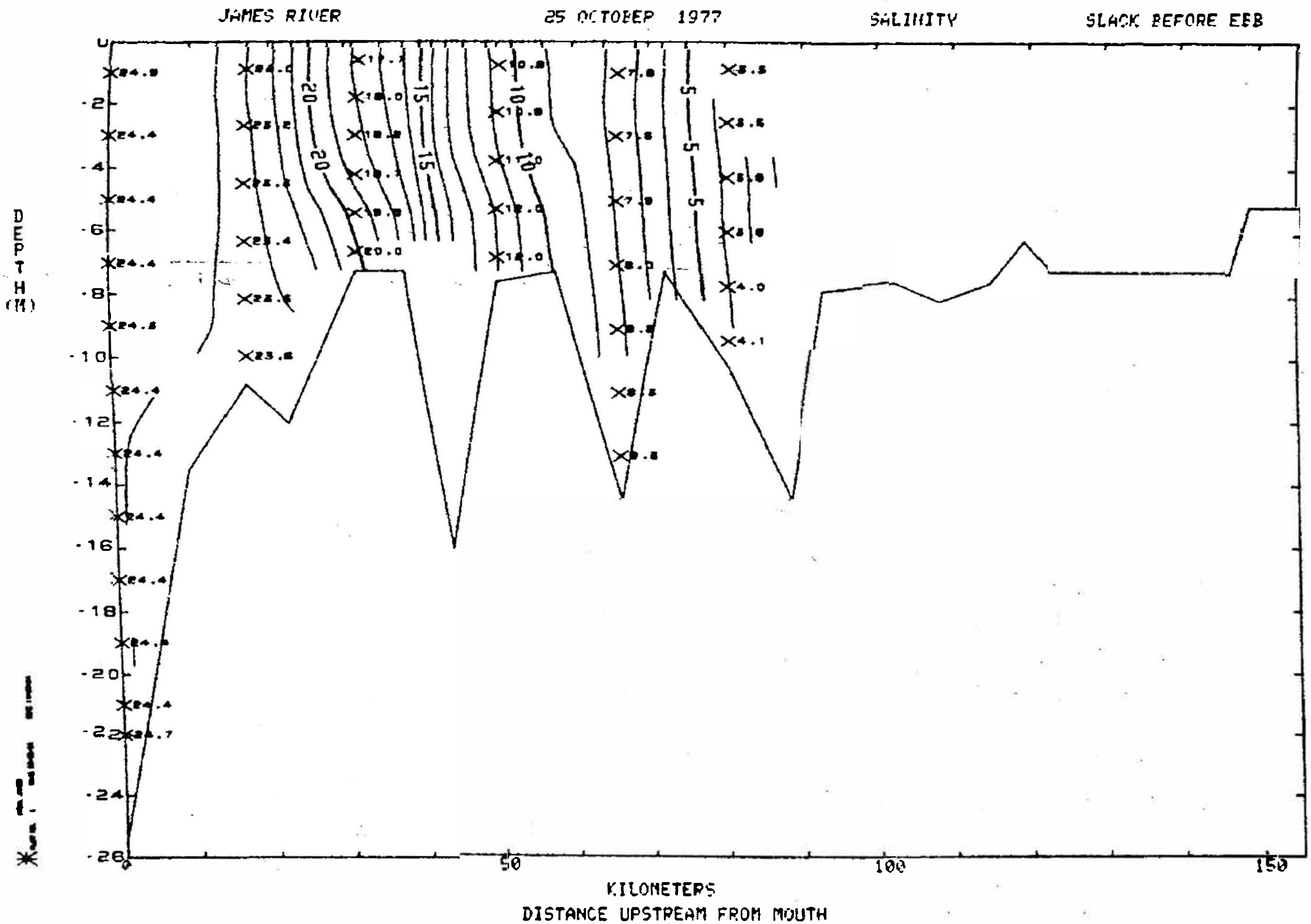
-20
-22
-24
-26


JAMES RIVER
10 AUGUST 1977
SALINITY
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

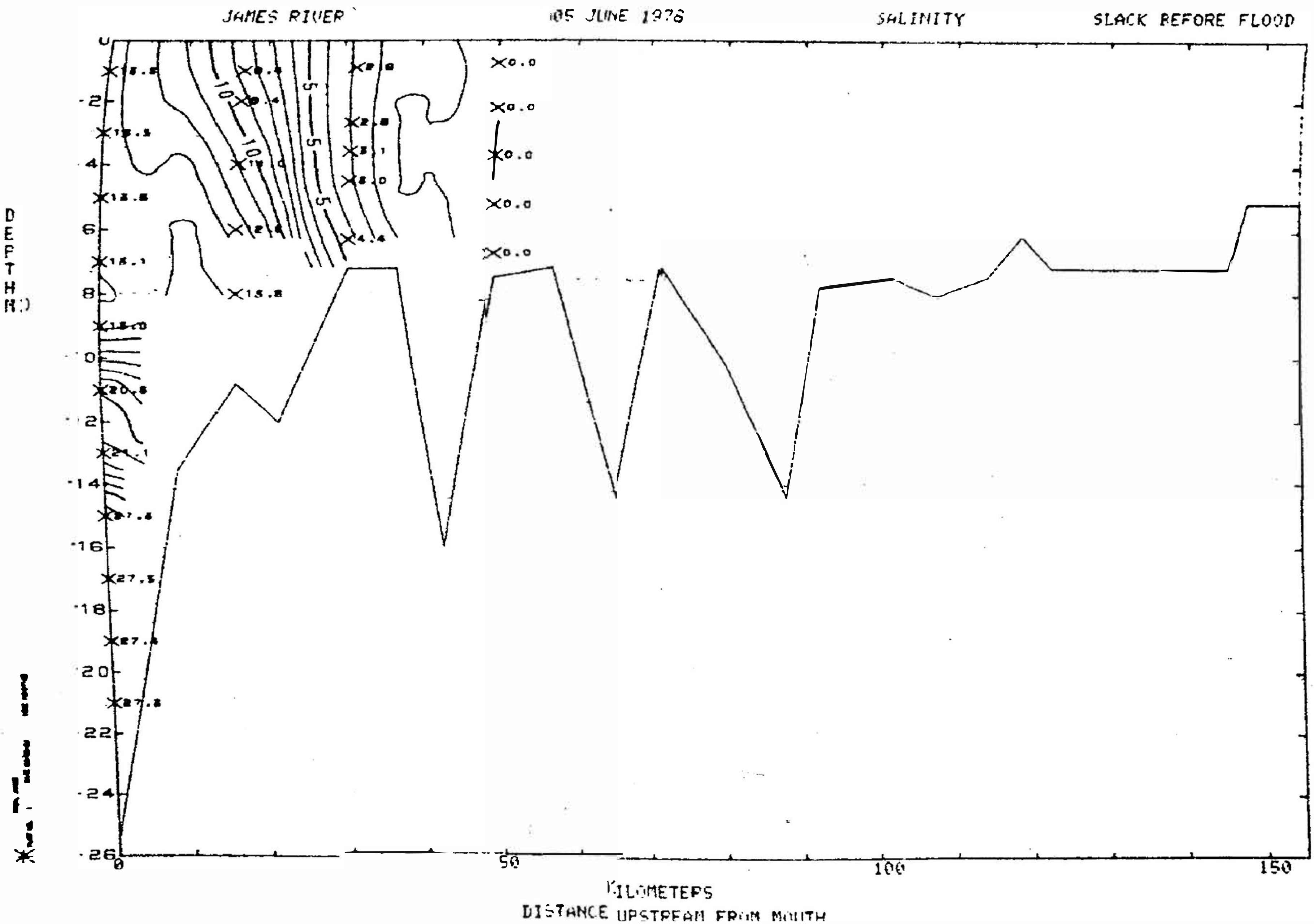


JAMES RIVER
15 SEPTEMBER 1977
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

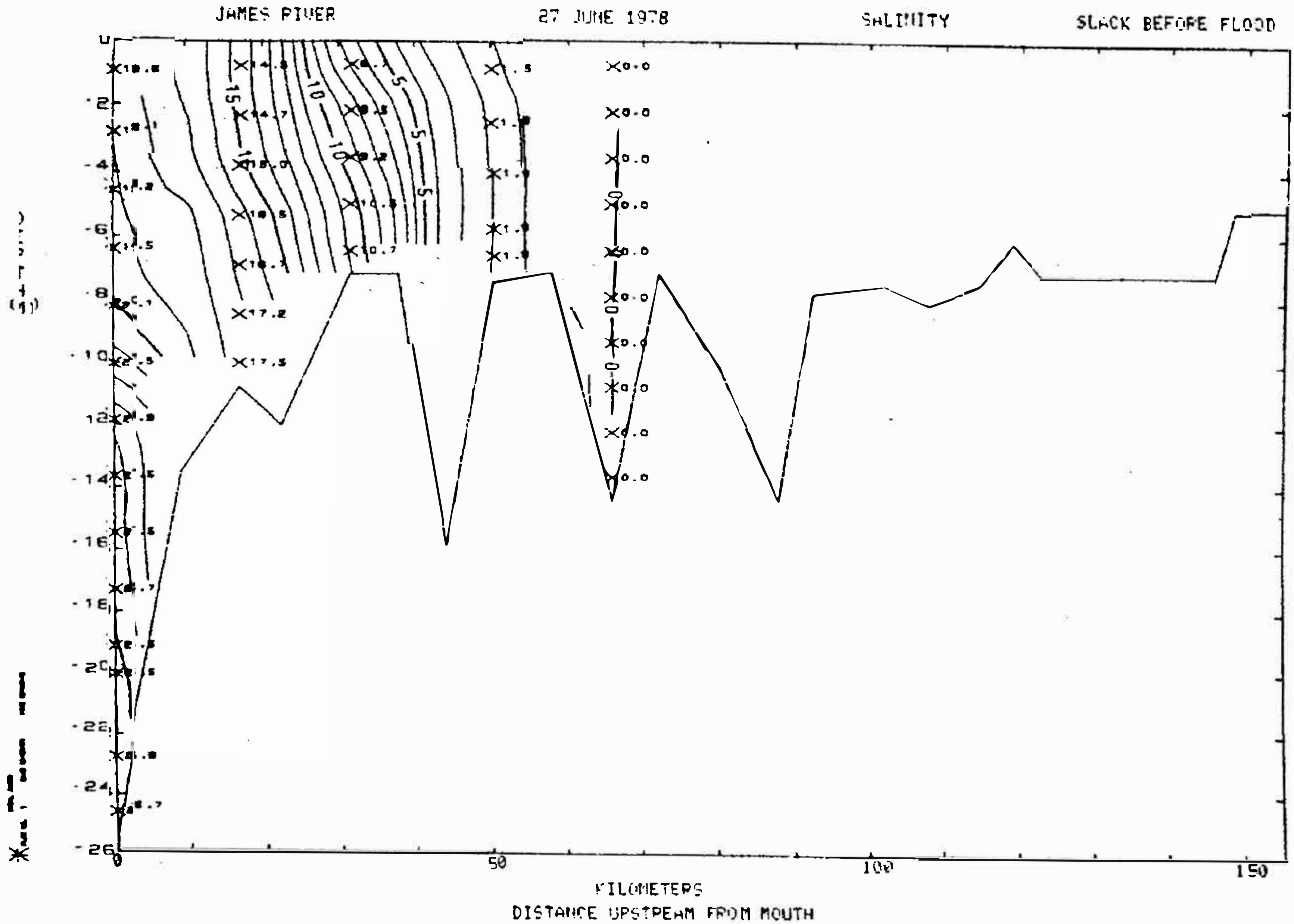

JAMES RIVER
22 SEPTEMBER 1977
SALINITY
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
25
20
15
10
5
0
50
100
150



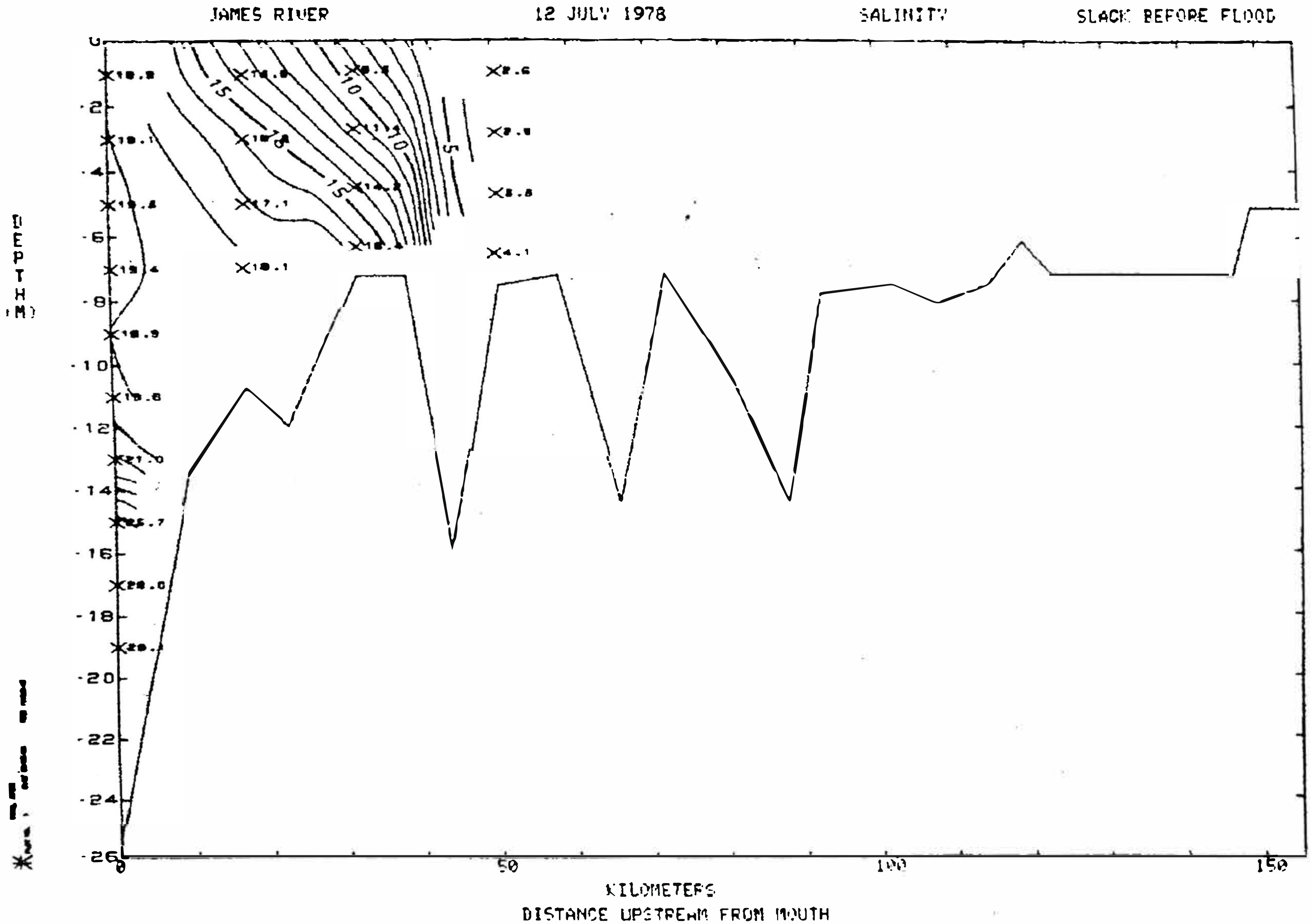
JAMES RIVER
25 OCTOBER 1977
SALINITY
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



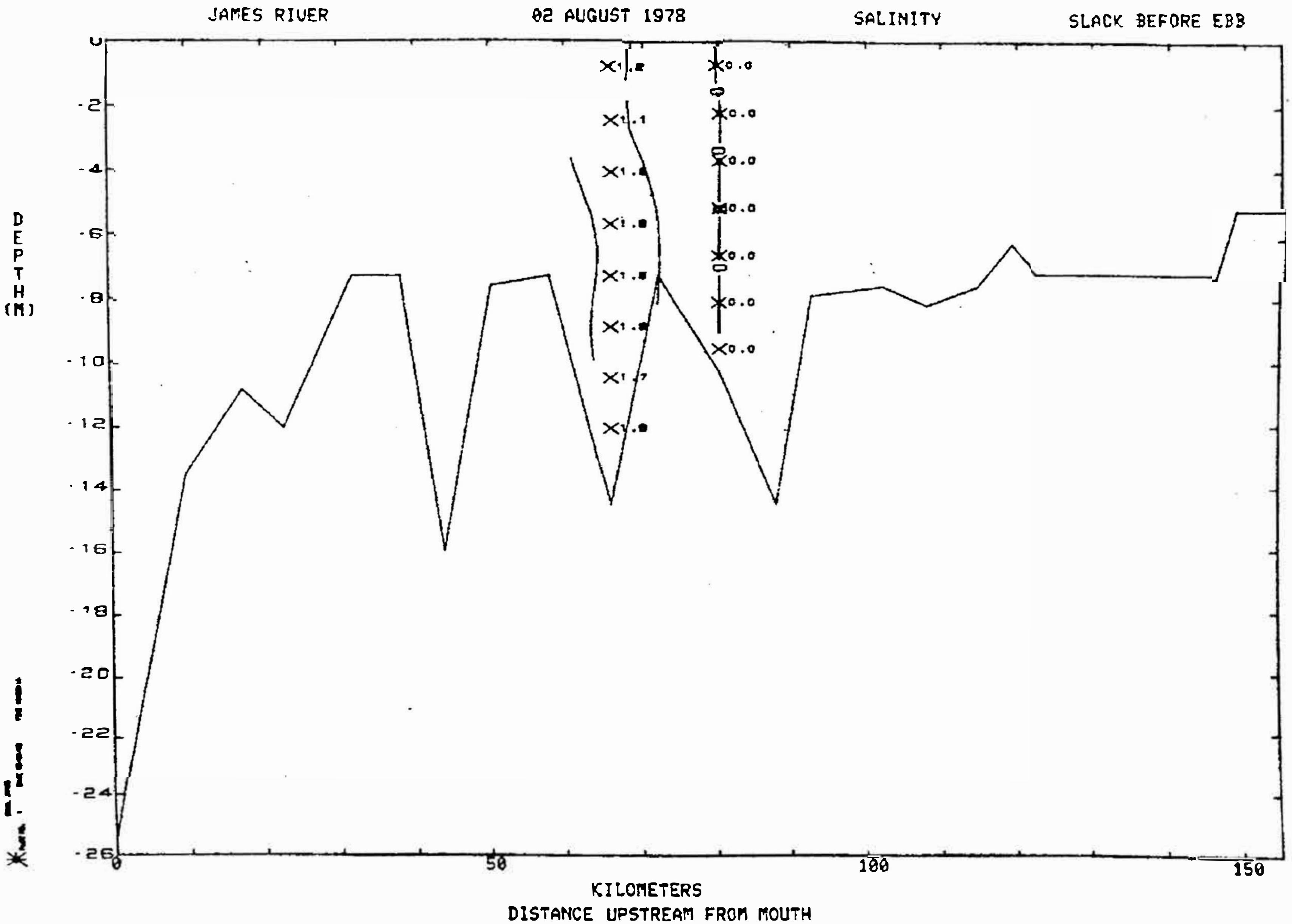
JAMES RIVER
05 JUNE 1976
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

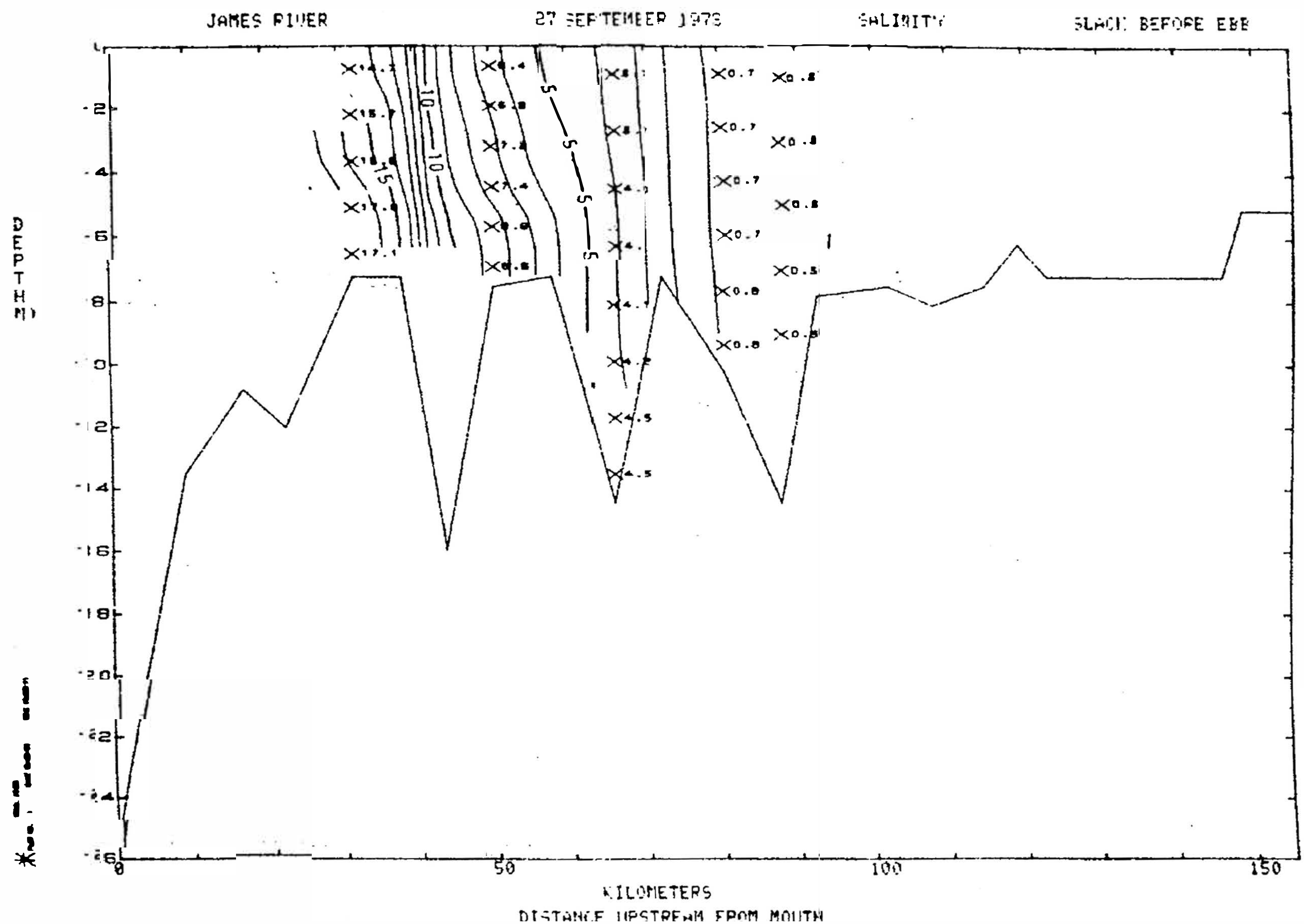


JAMES RIVER
27 JUNE 1978
SALINITY
SLACK BEFORE FLOOD
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



JAMES RIVER
12 JULY 1978
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
02 AUGUST 1978
SALINITY
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0.0


JAMES RIVER
27 SEPTEMBER 1979
SALINITY
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
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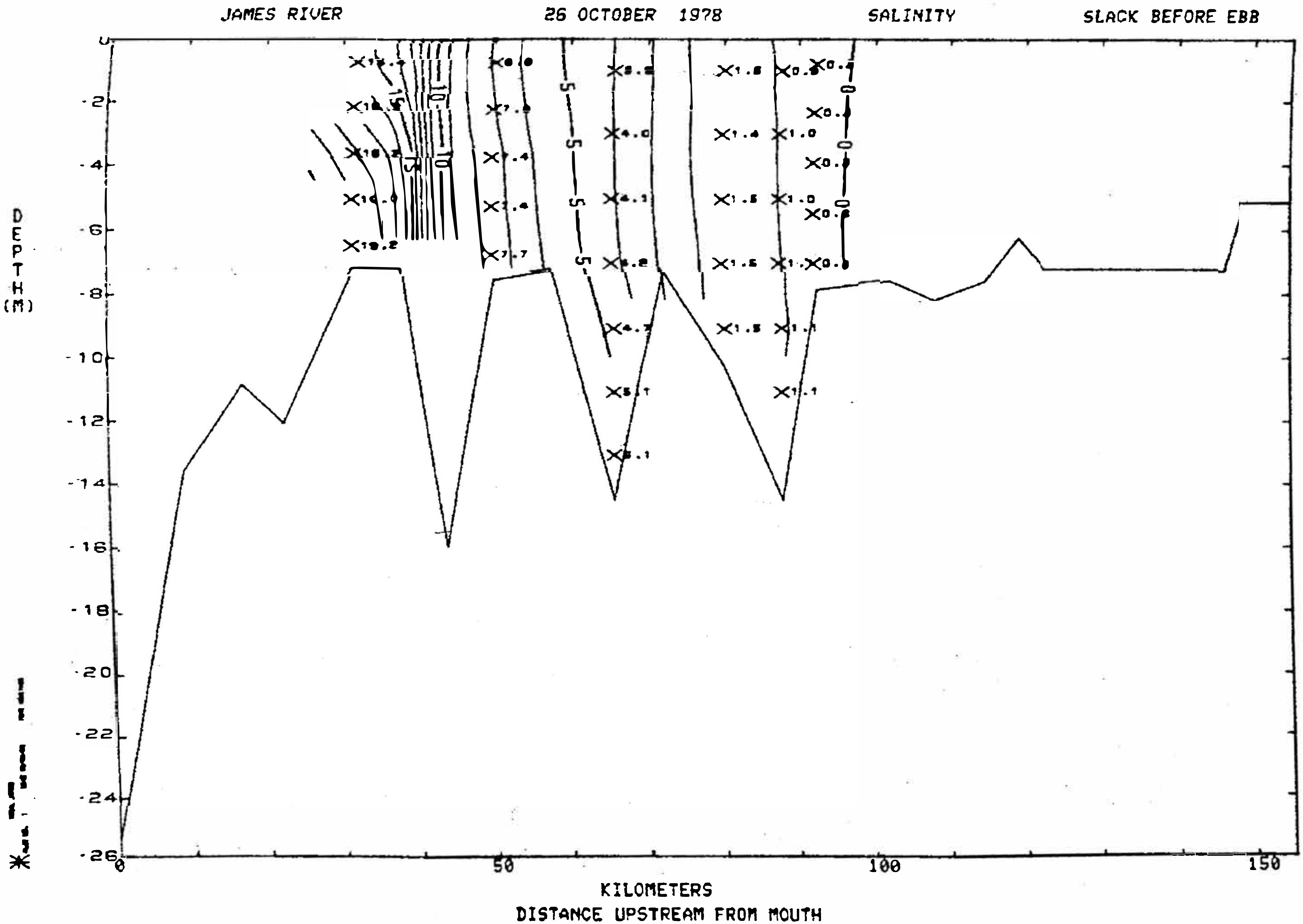
-24
-26
15
10
5


JAMES RIVER
26 OCTOBER 1978
SALINITY
SLACK BEFORE EBB
DEPTH (M)
0
-2
-4
-6
-8
-10
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-14
-16
-18
-20
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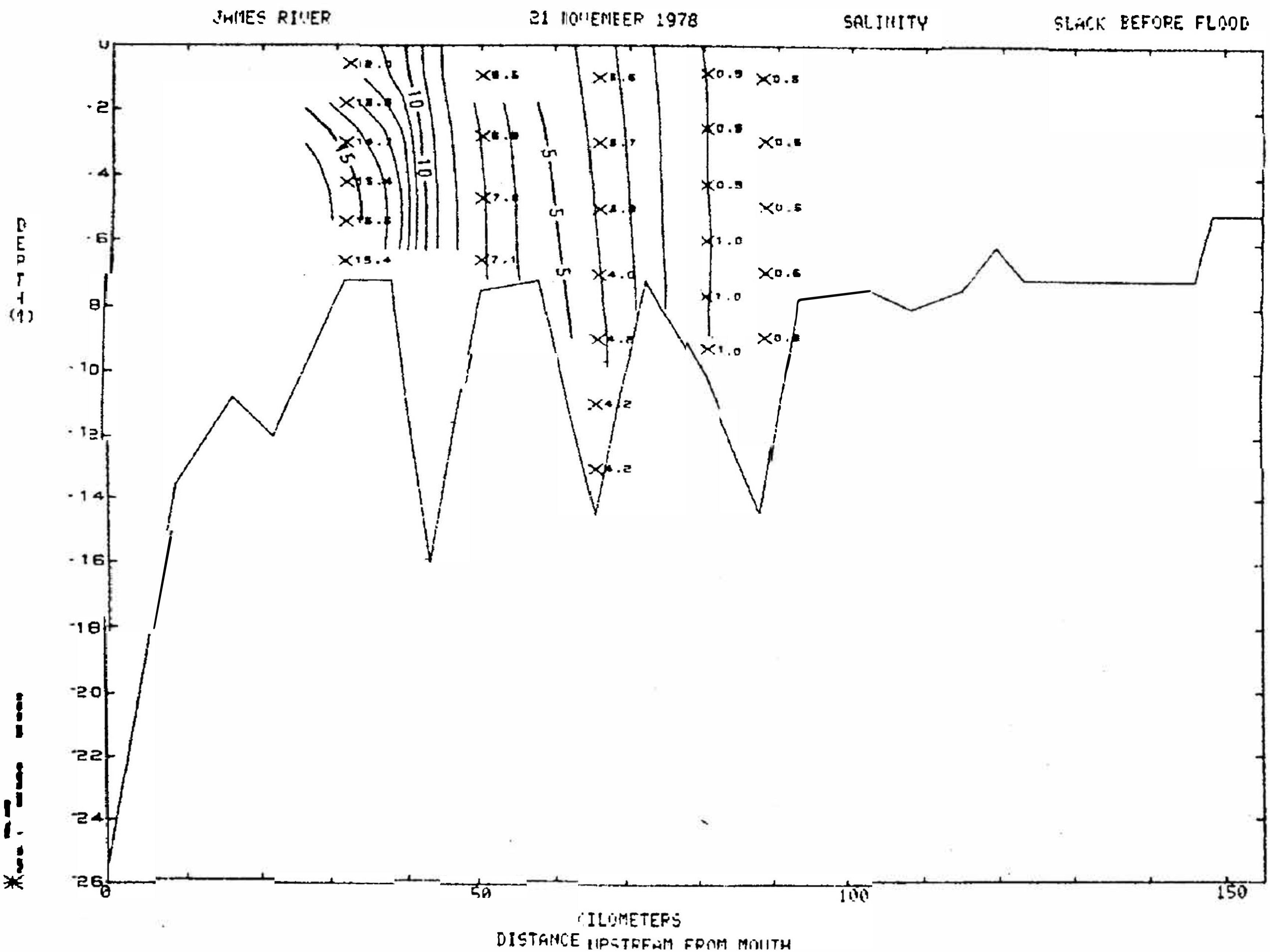
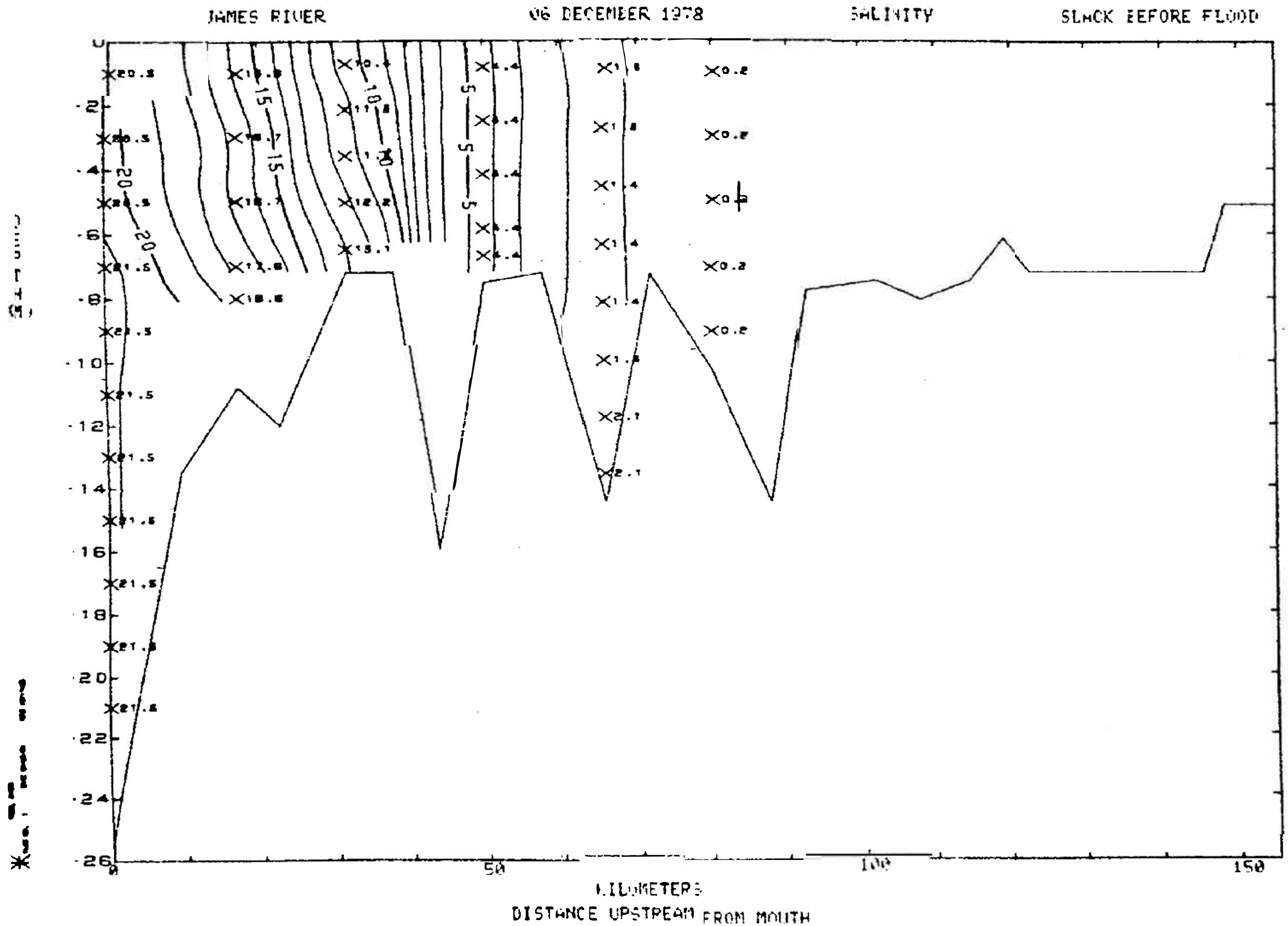
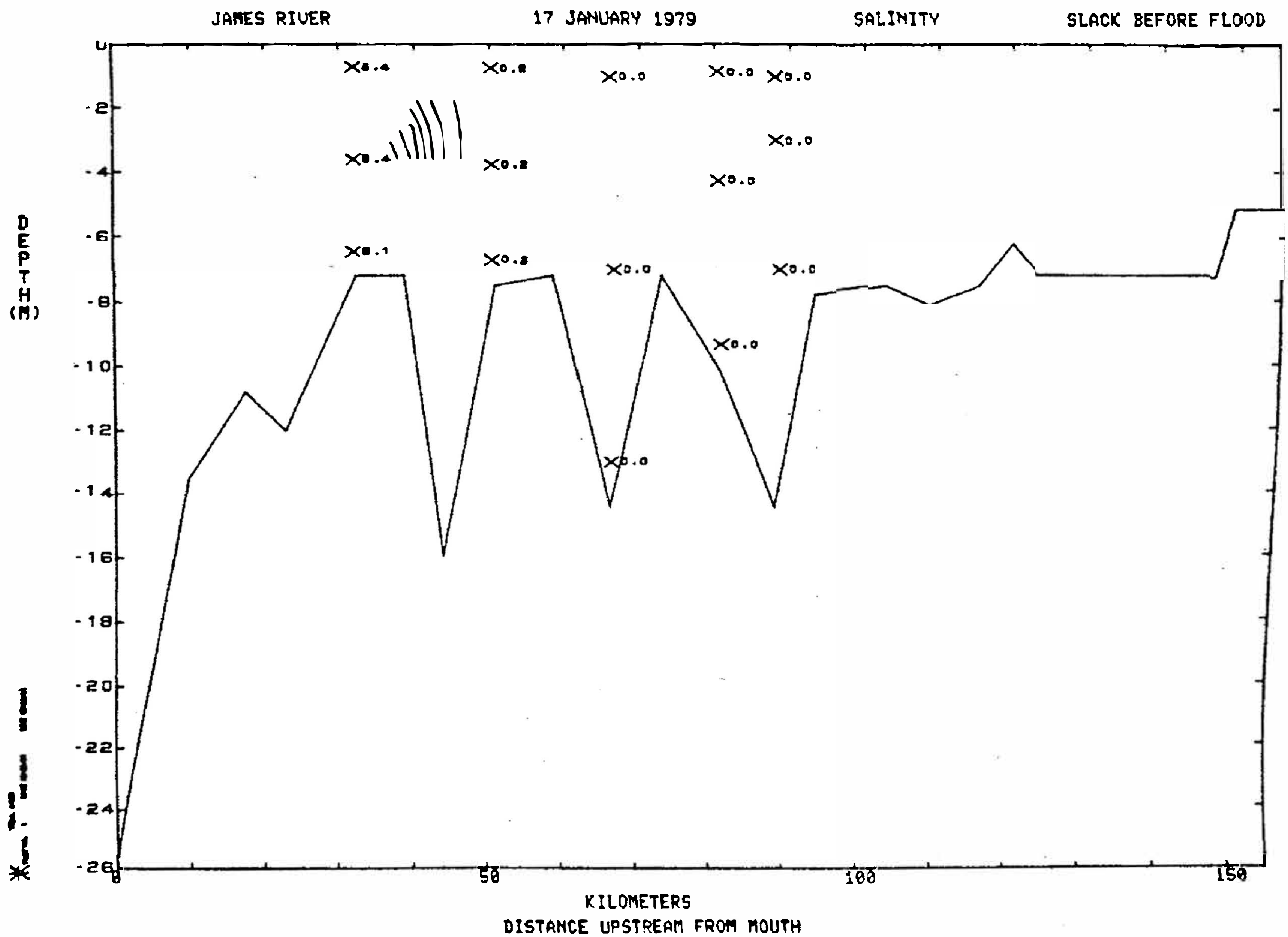
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



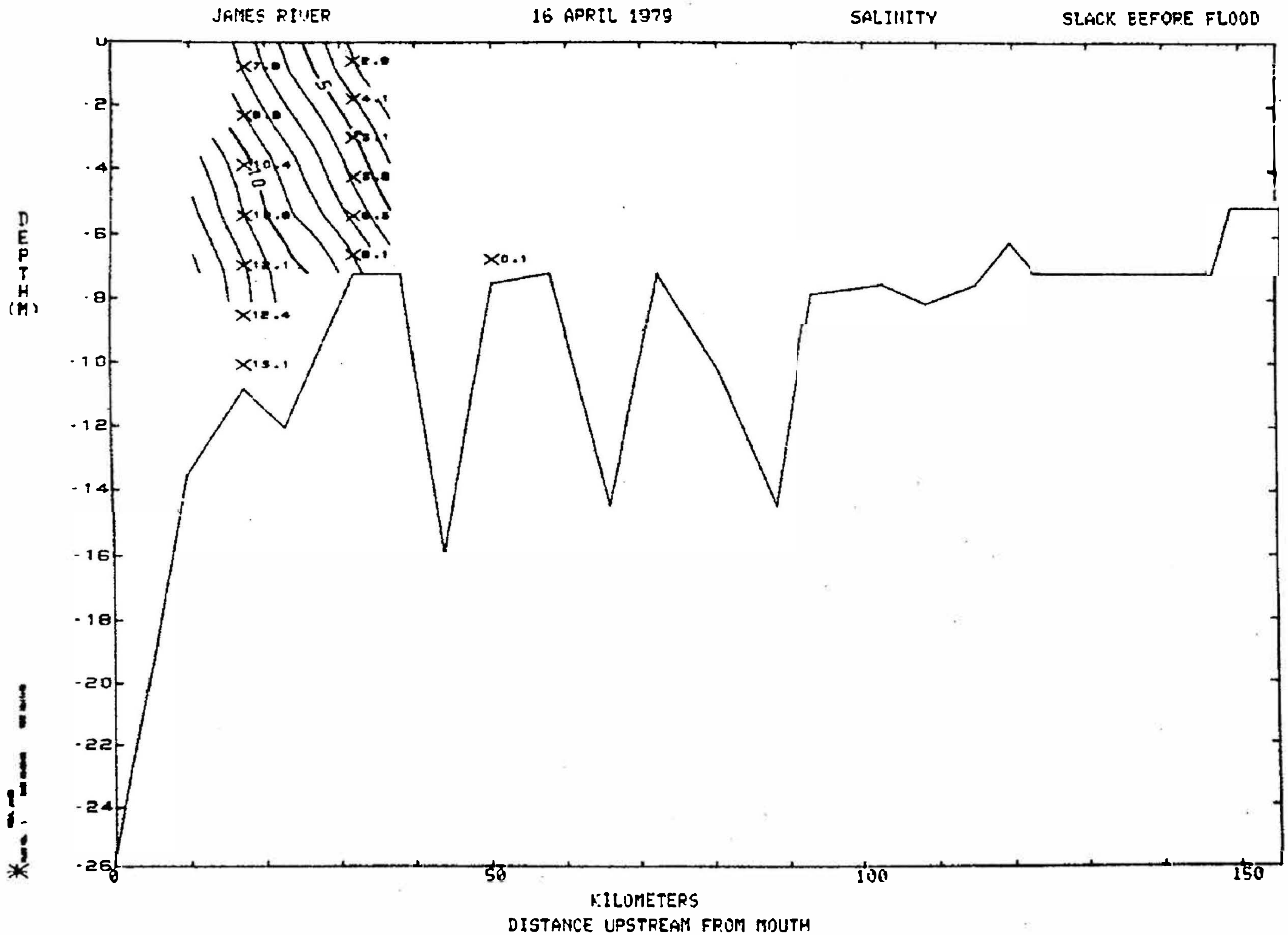
JAMES RIVER
21 NOVEMBER 1978
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



JAMES RIVER
06 DECEMBER 1978
SALINITY
SLACK BEFORE FLOOD
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



JAMES RIVER
17 JANUARY 1979
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
16 APRIL 1979
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
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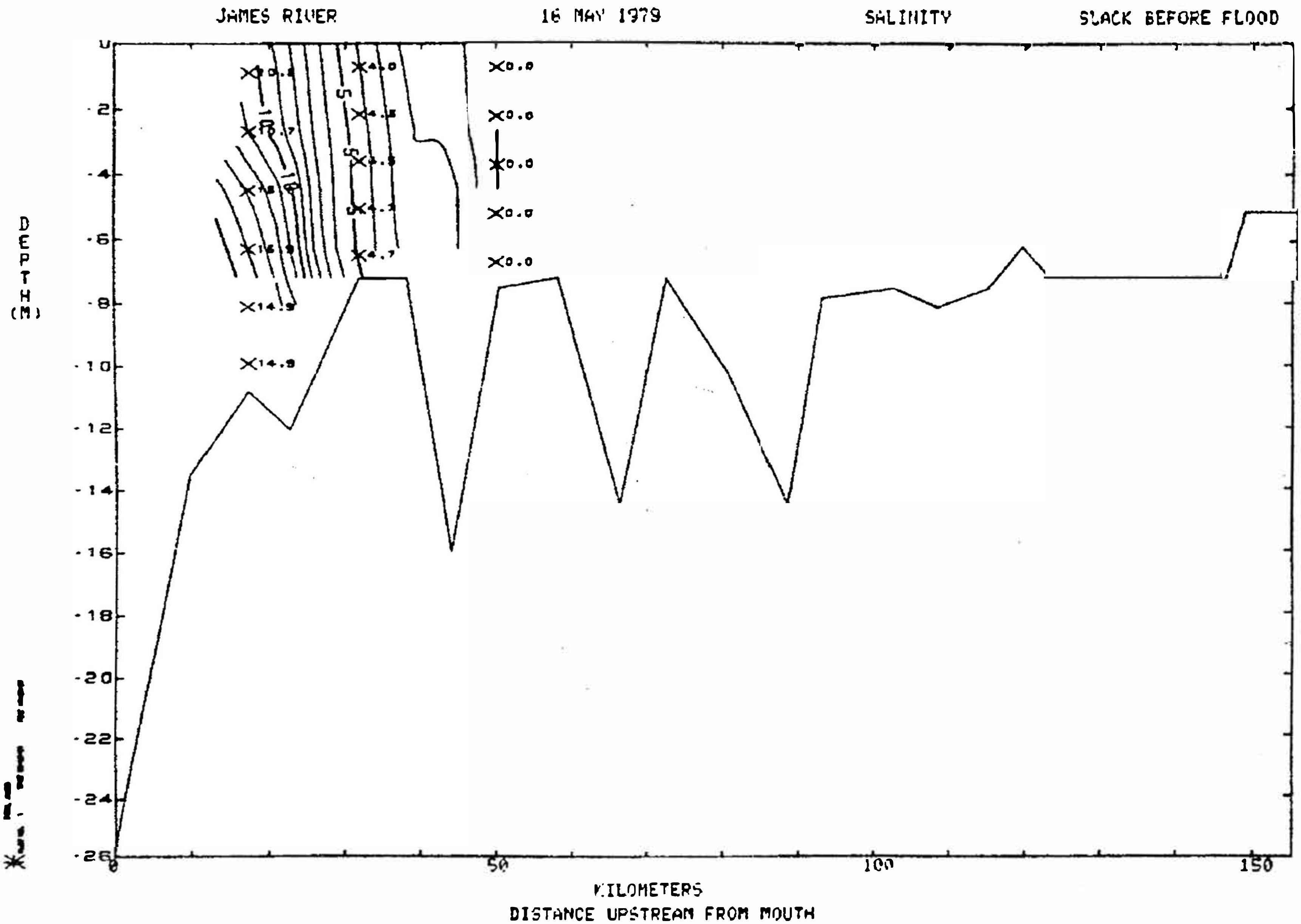
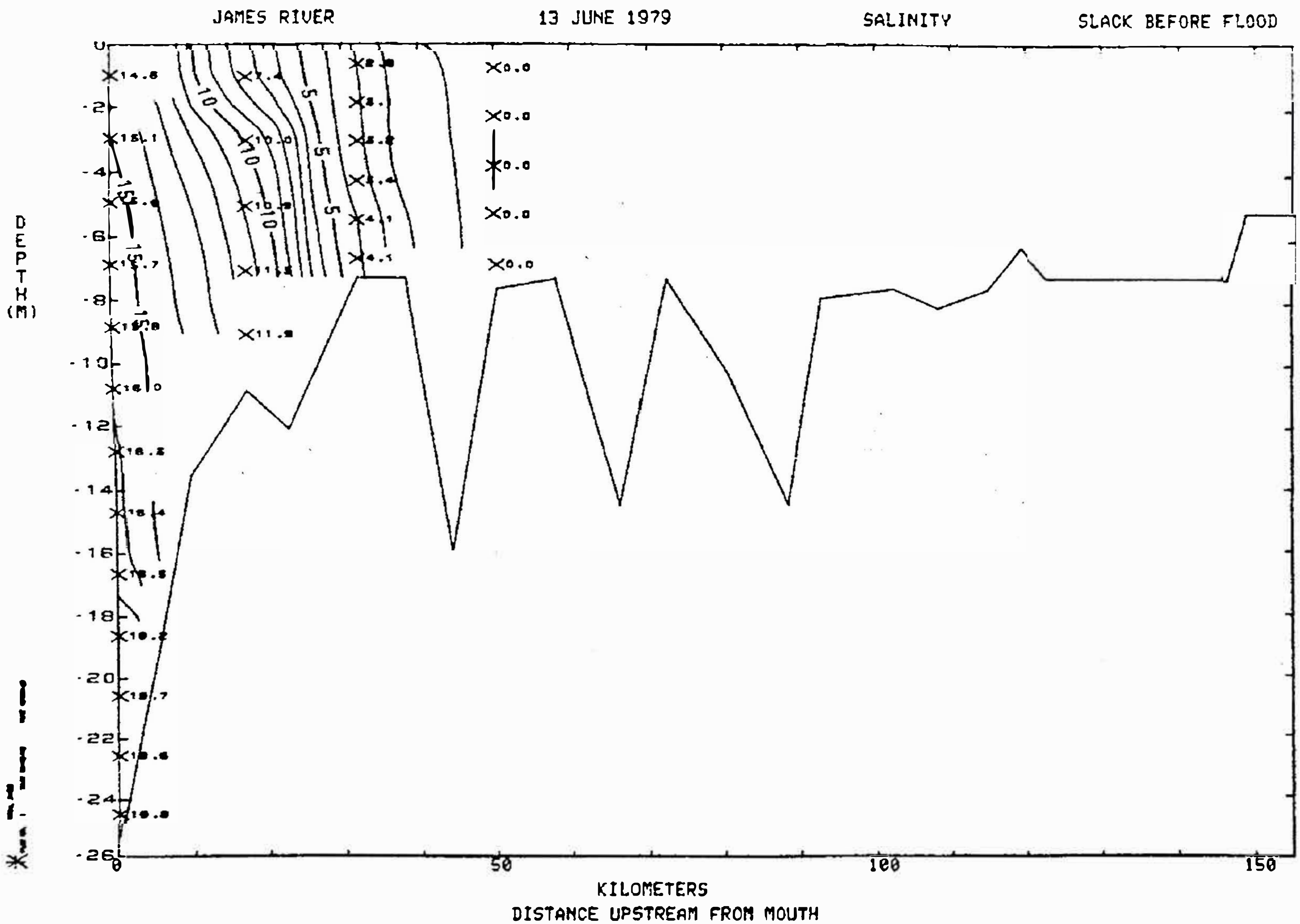
10.4
12.1
12.4
13.1
2.9
4.1
0.1



JAMES RIVER
16 MAY 1979
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



JAMES RIVER
13 JUNE 1979
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150
0
-2
-4
-6
-8
-10
-12
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-16
-18
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-22
-24
-26
10
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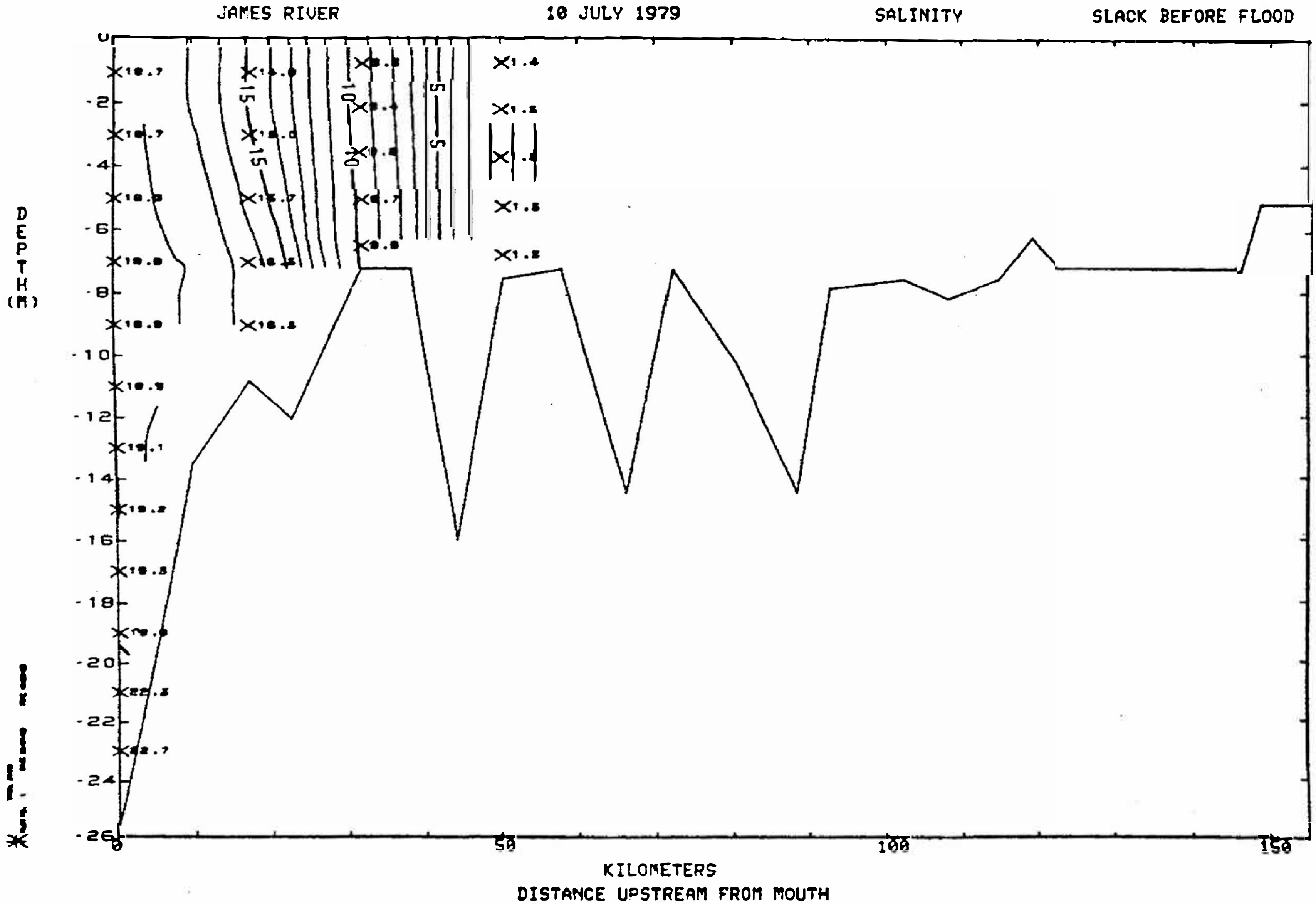
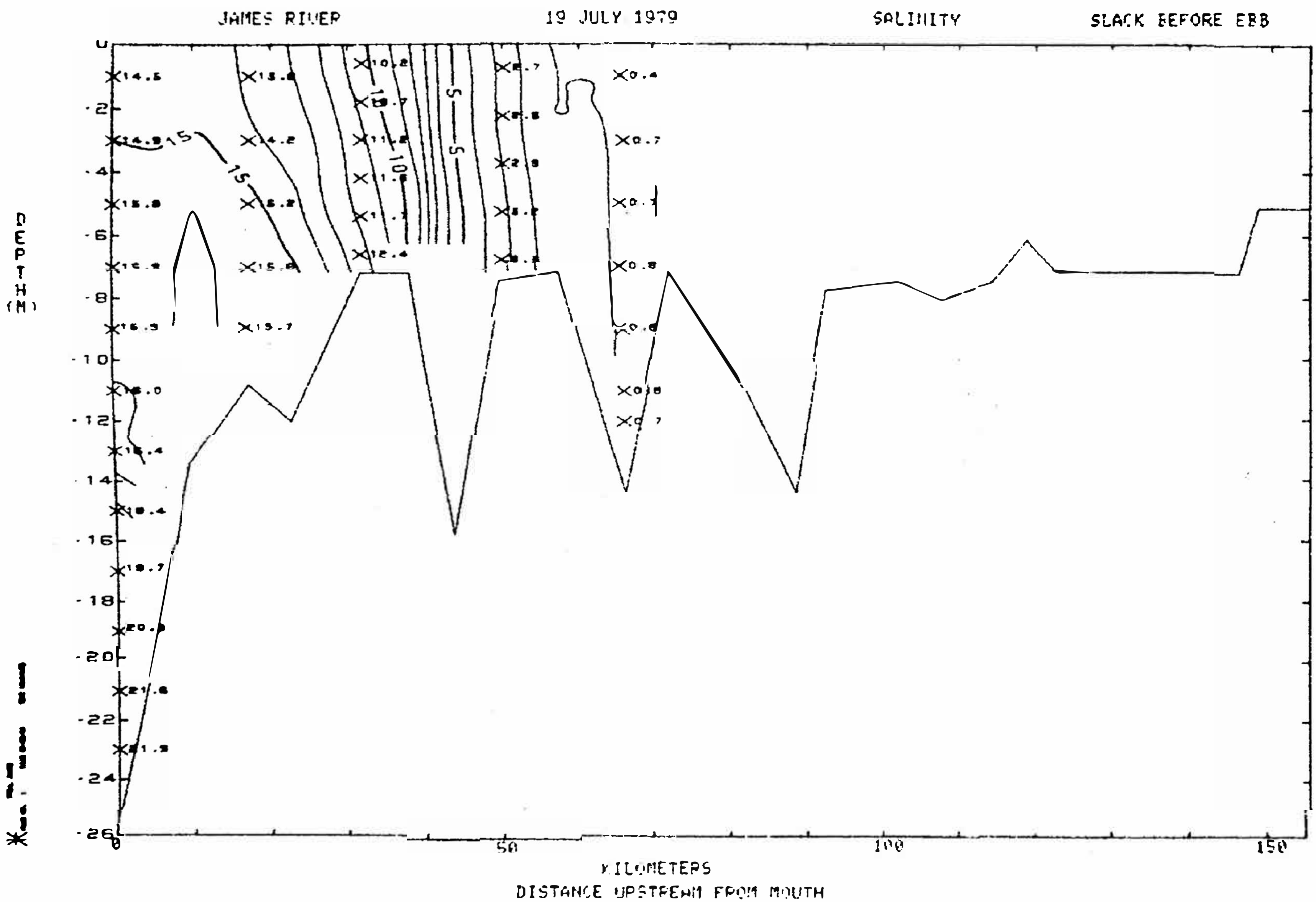
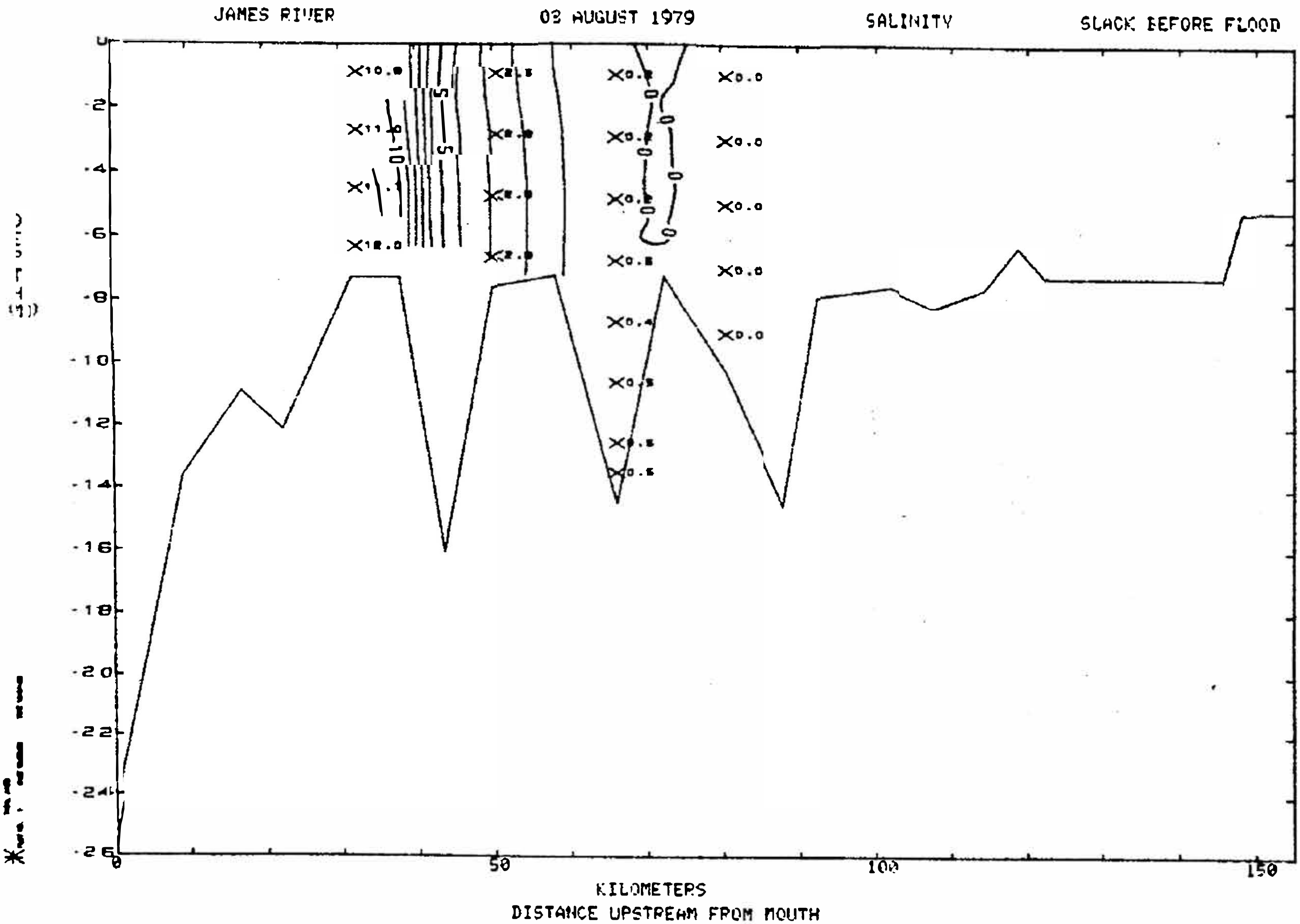
15
14.6
11.9
0.0



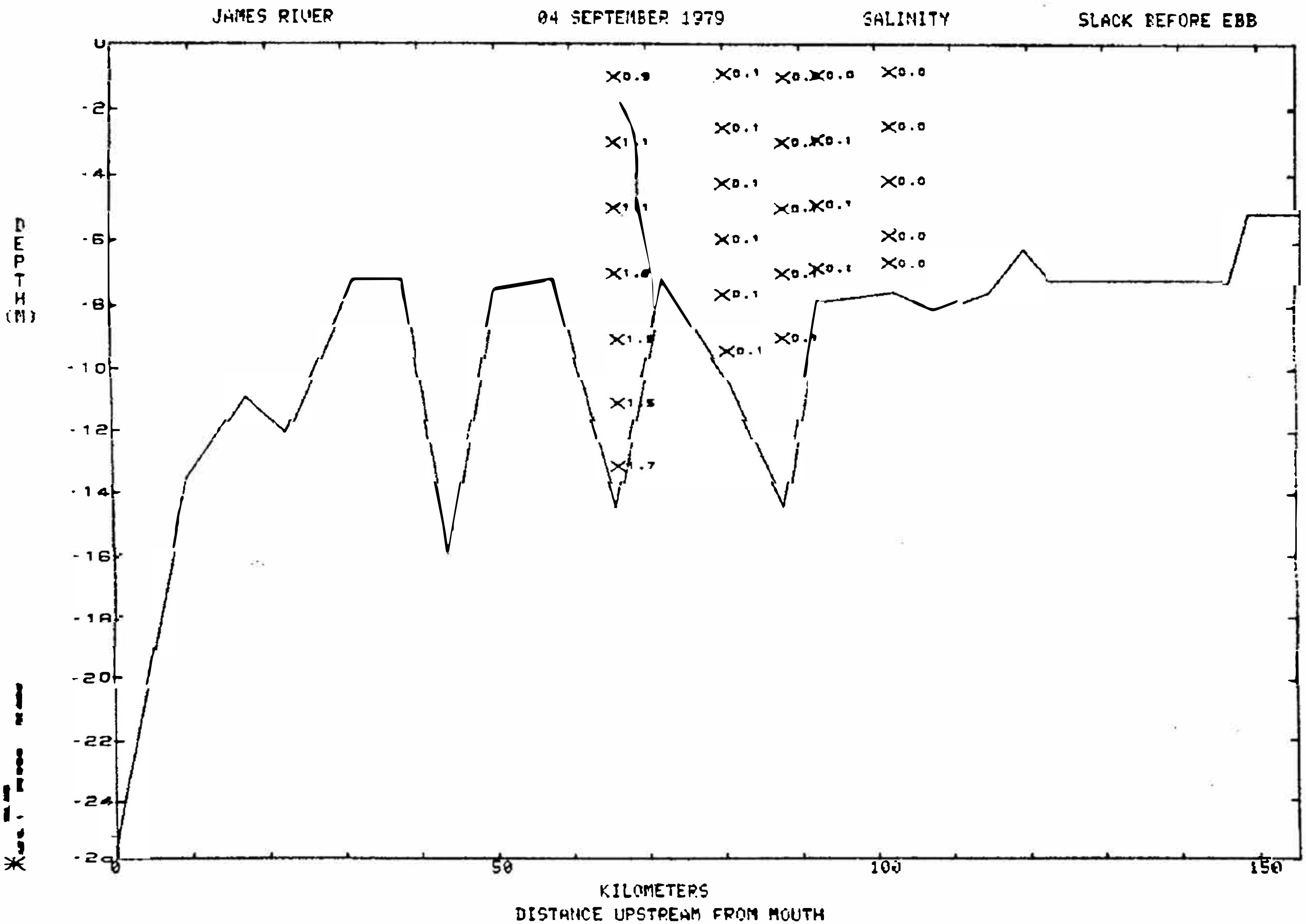
JAMES RIVER
10 JULY 1979
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



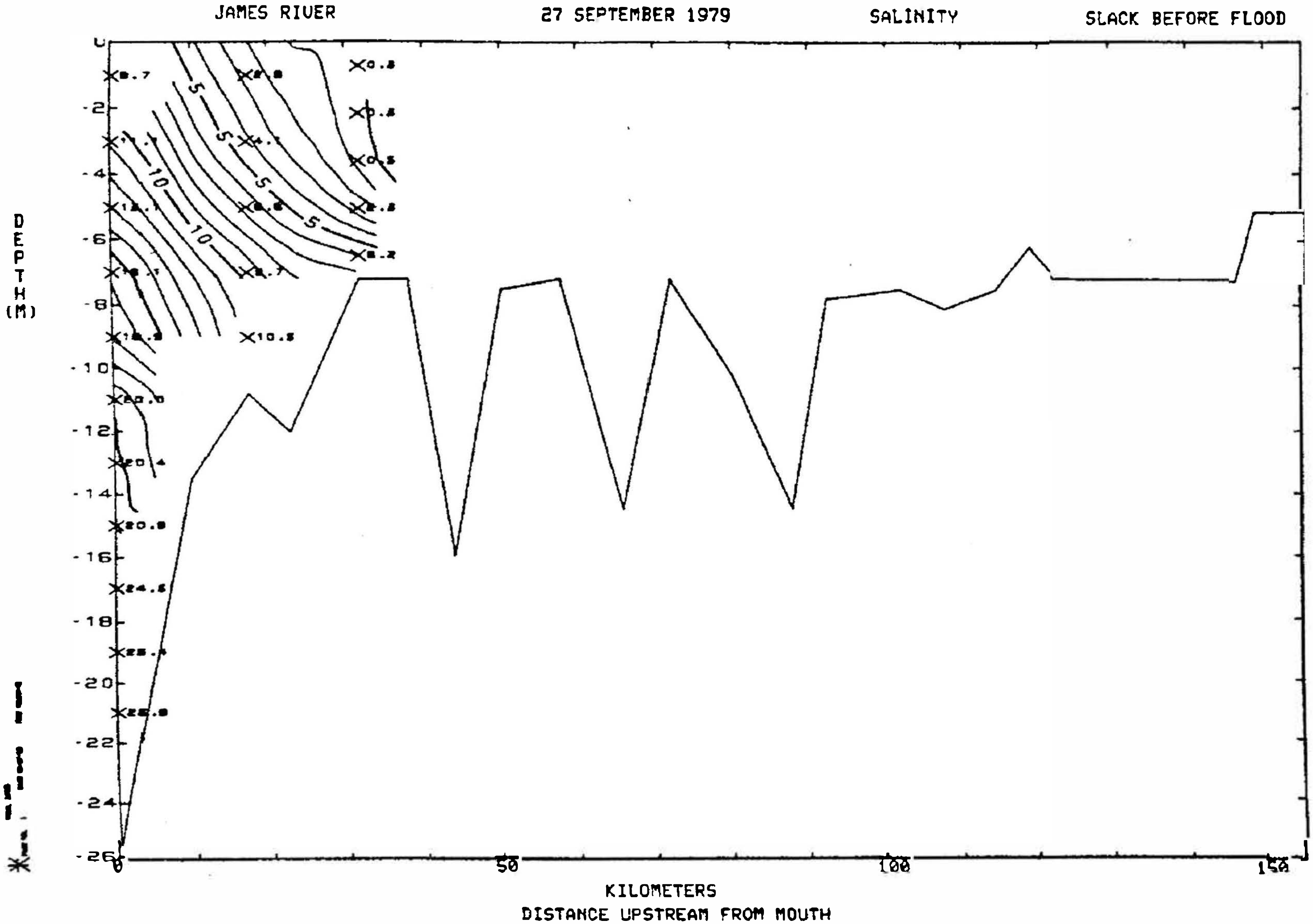
JAMES RIVER
19 JULY 1979
SALINITY
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

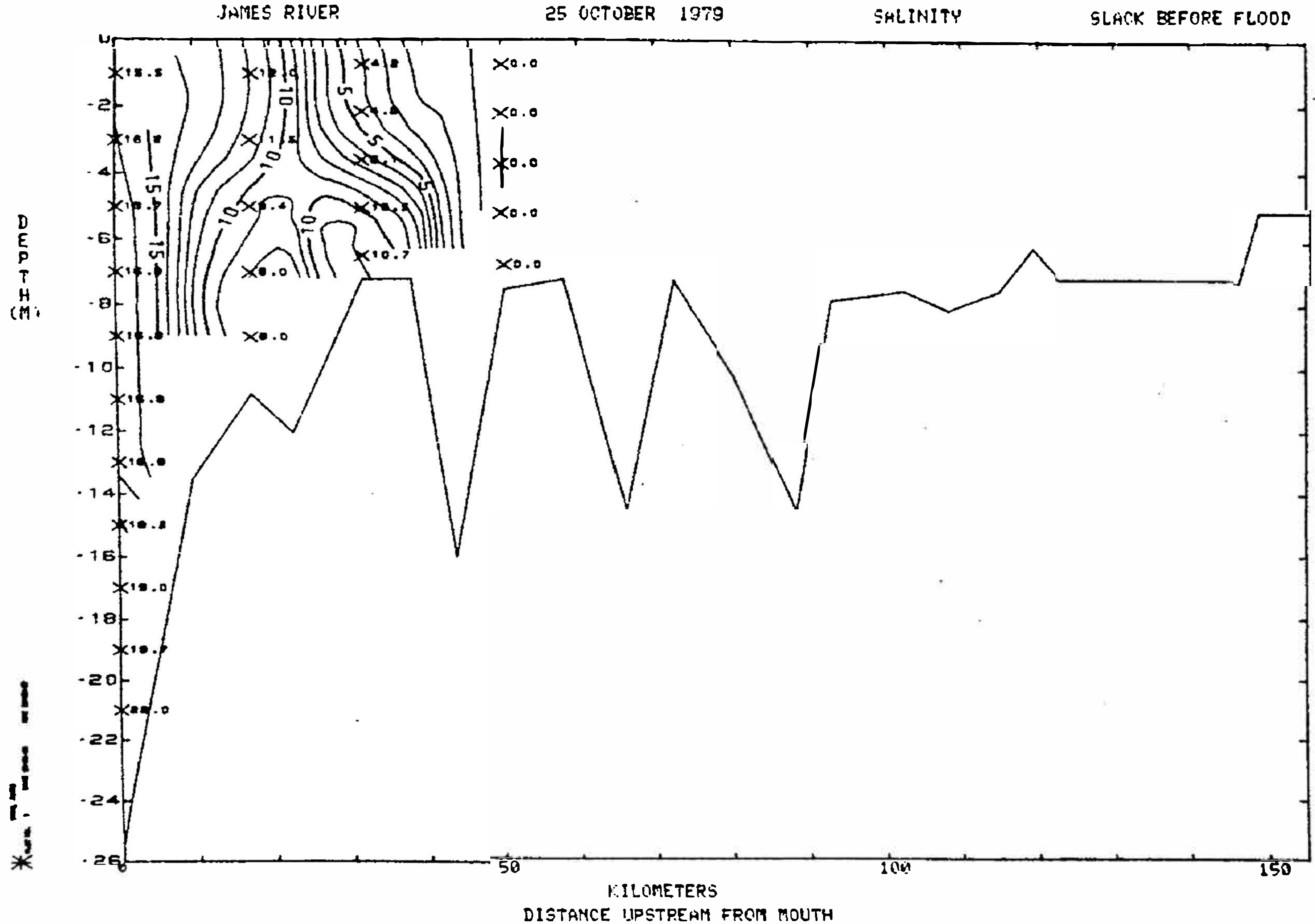


JAMES RIVER
03 AUGUST 1979
SALINITY
SLACK BEFORE FLOOD
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

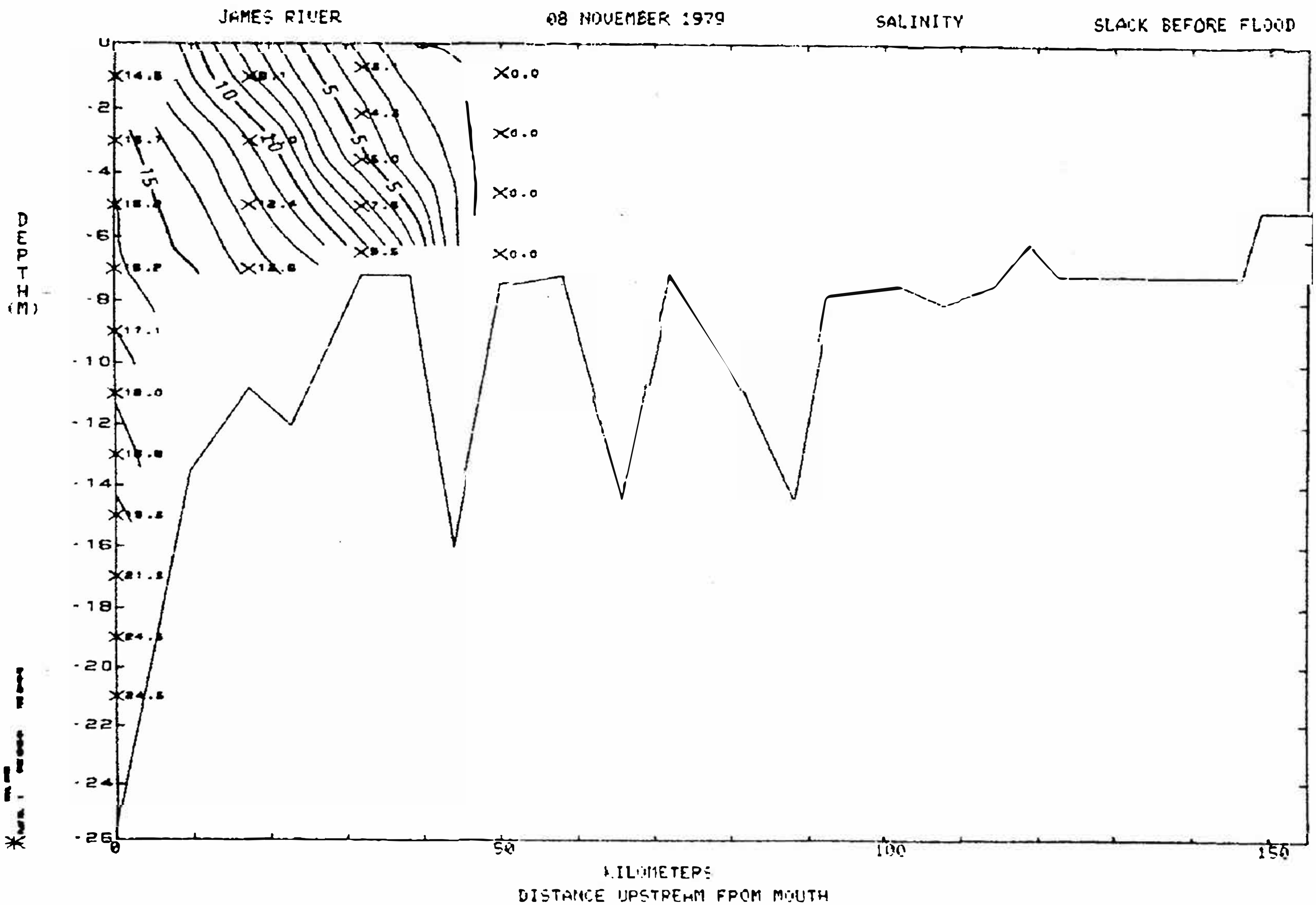


JAMES RIVER
04 SEPTEMBER 1979
SALINITY
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150

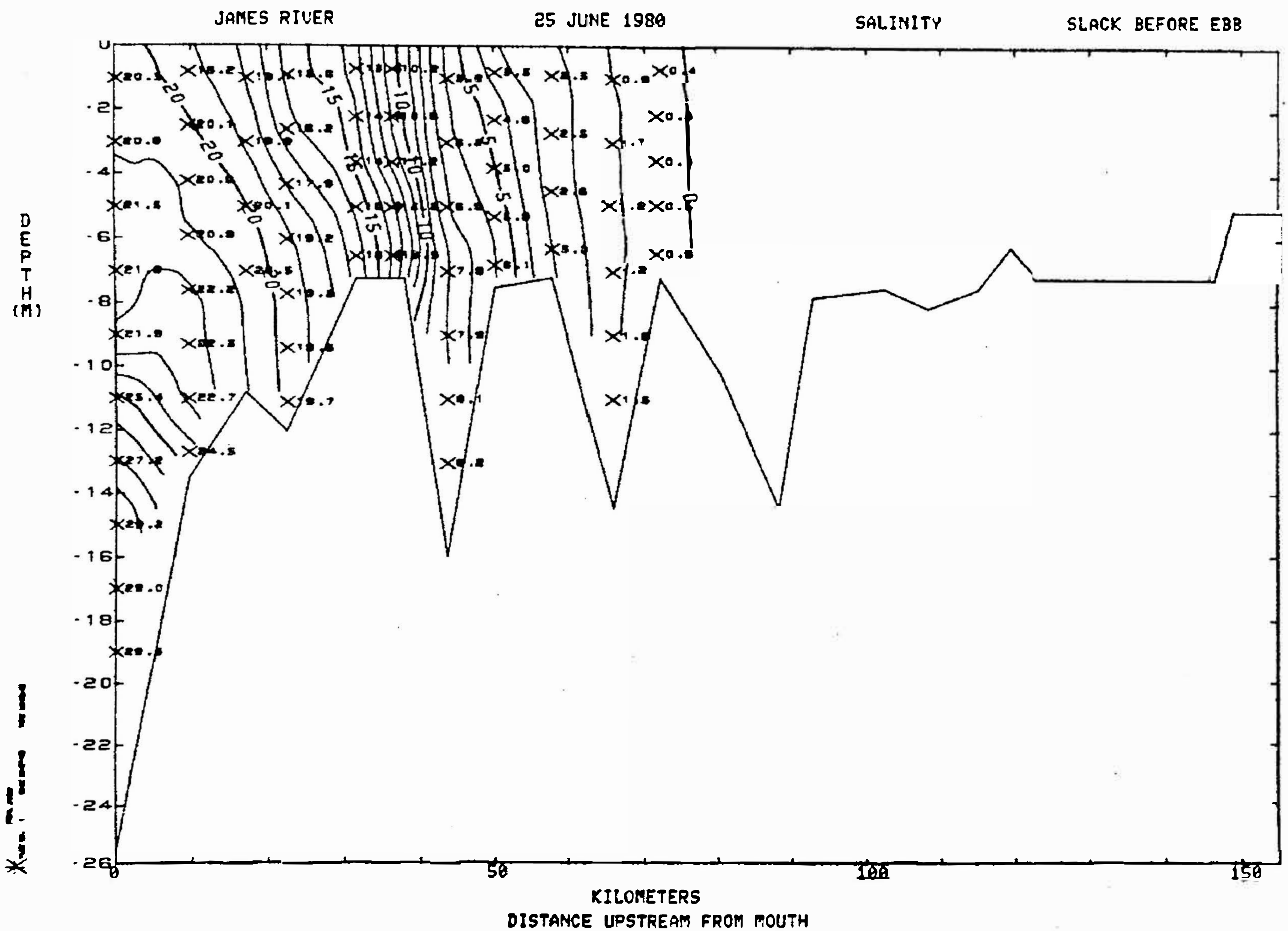

JAMES RIVER
27 SEPTEMBER 1979
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

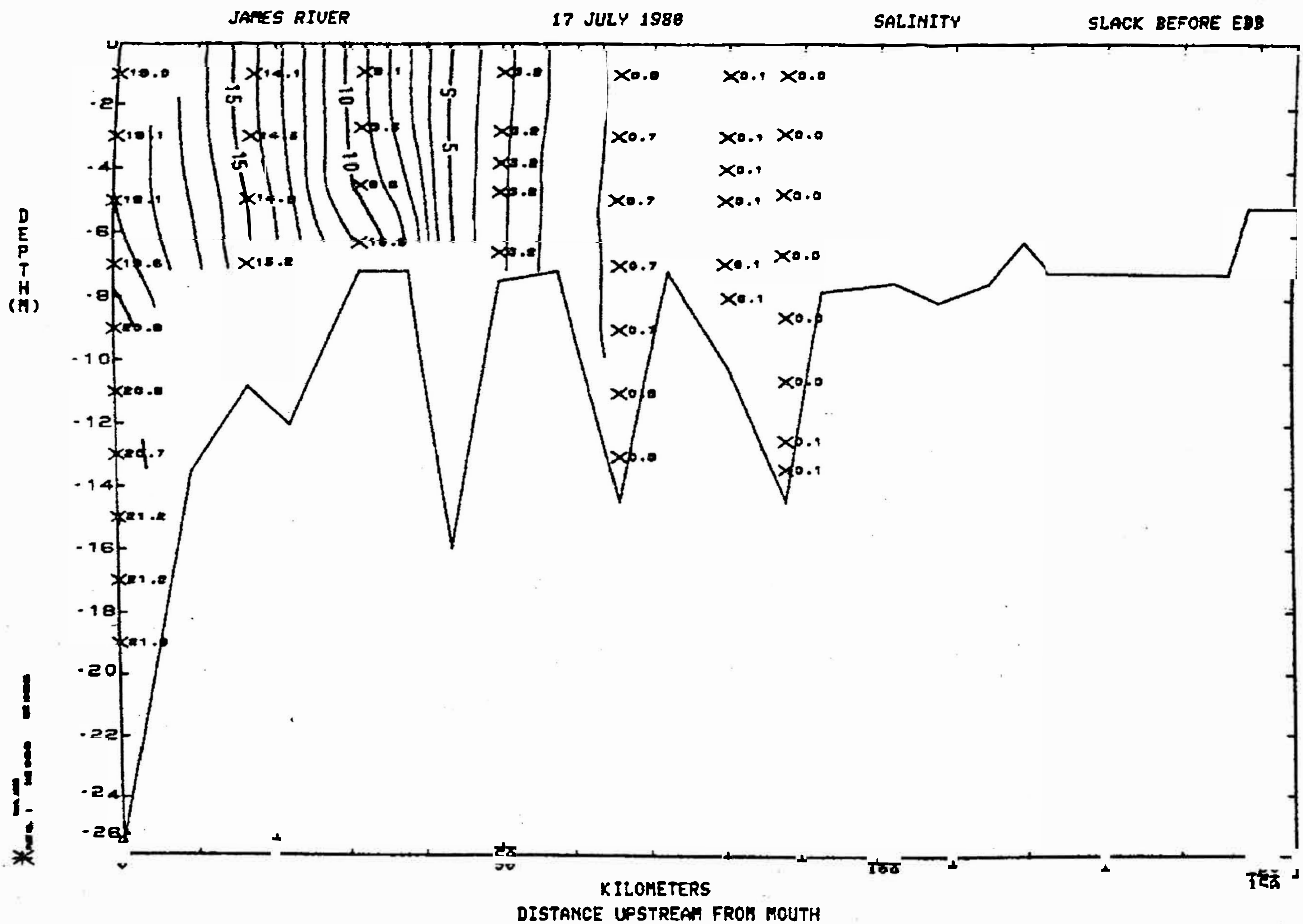


JAMES RIVER
25 OCTOBER 1979
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
50
100
150
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
15
10
5

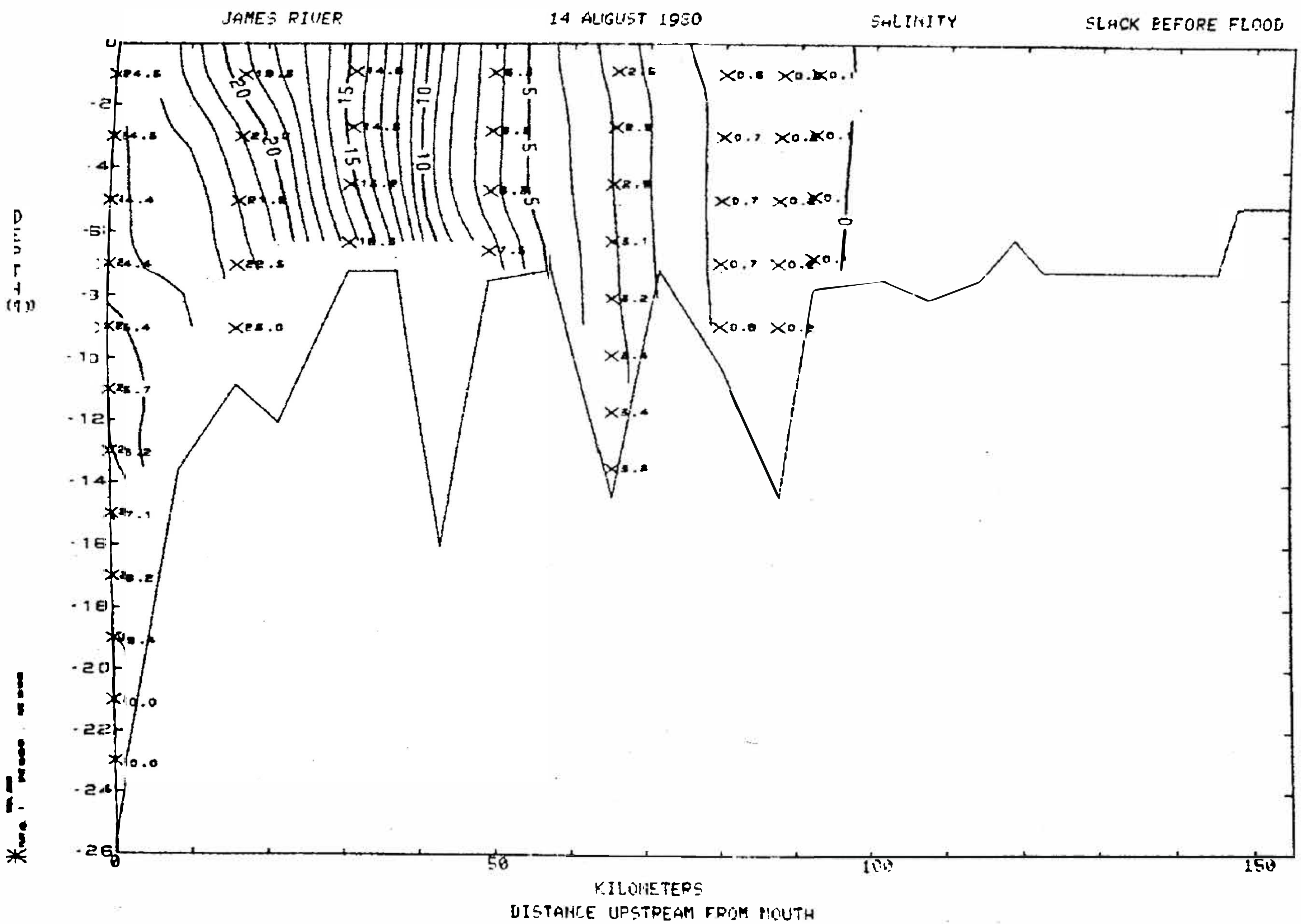


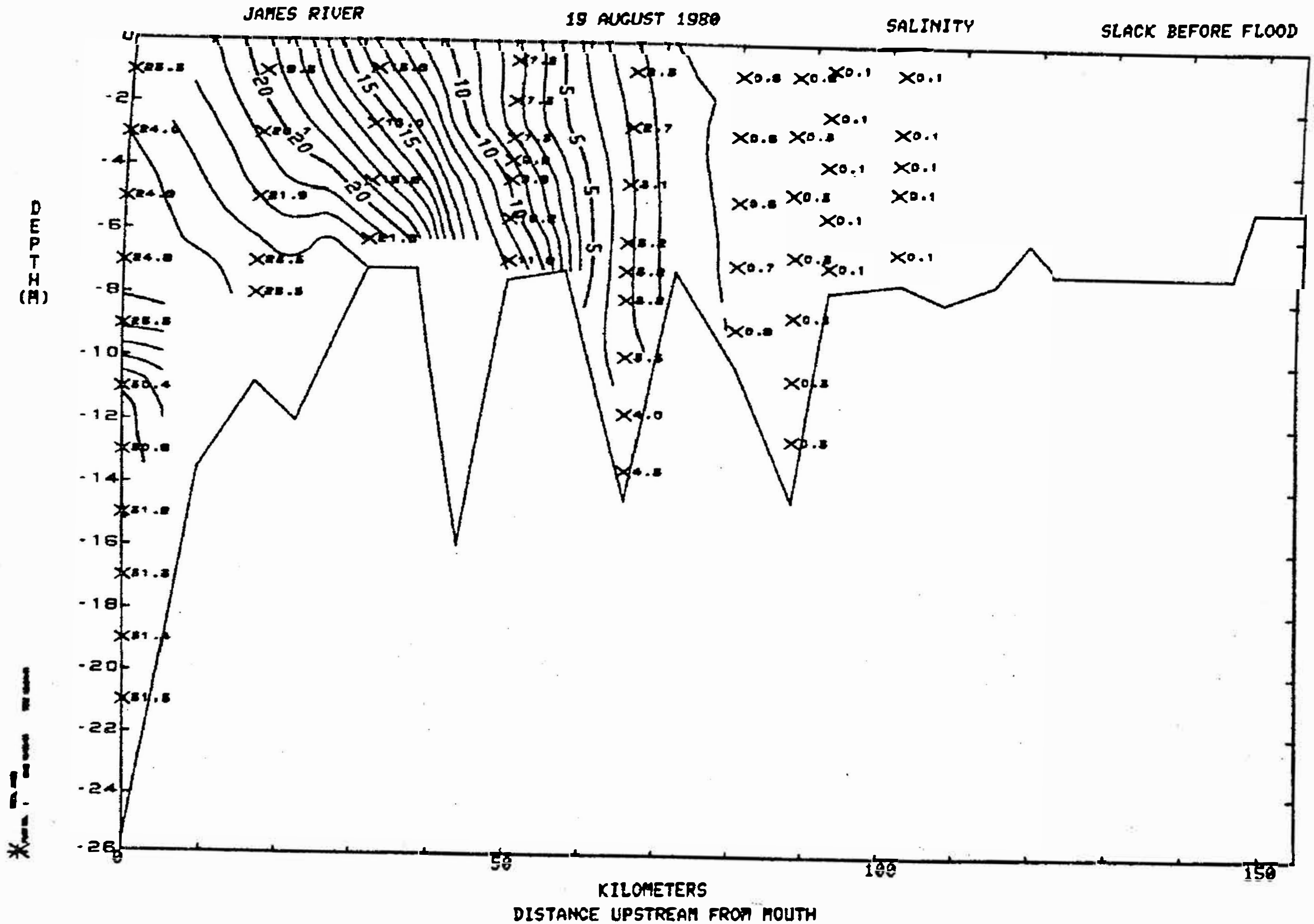
JAMES RIVER
08 NOVEMBER 1979
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

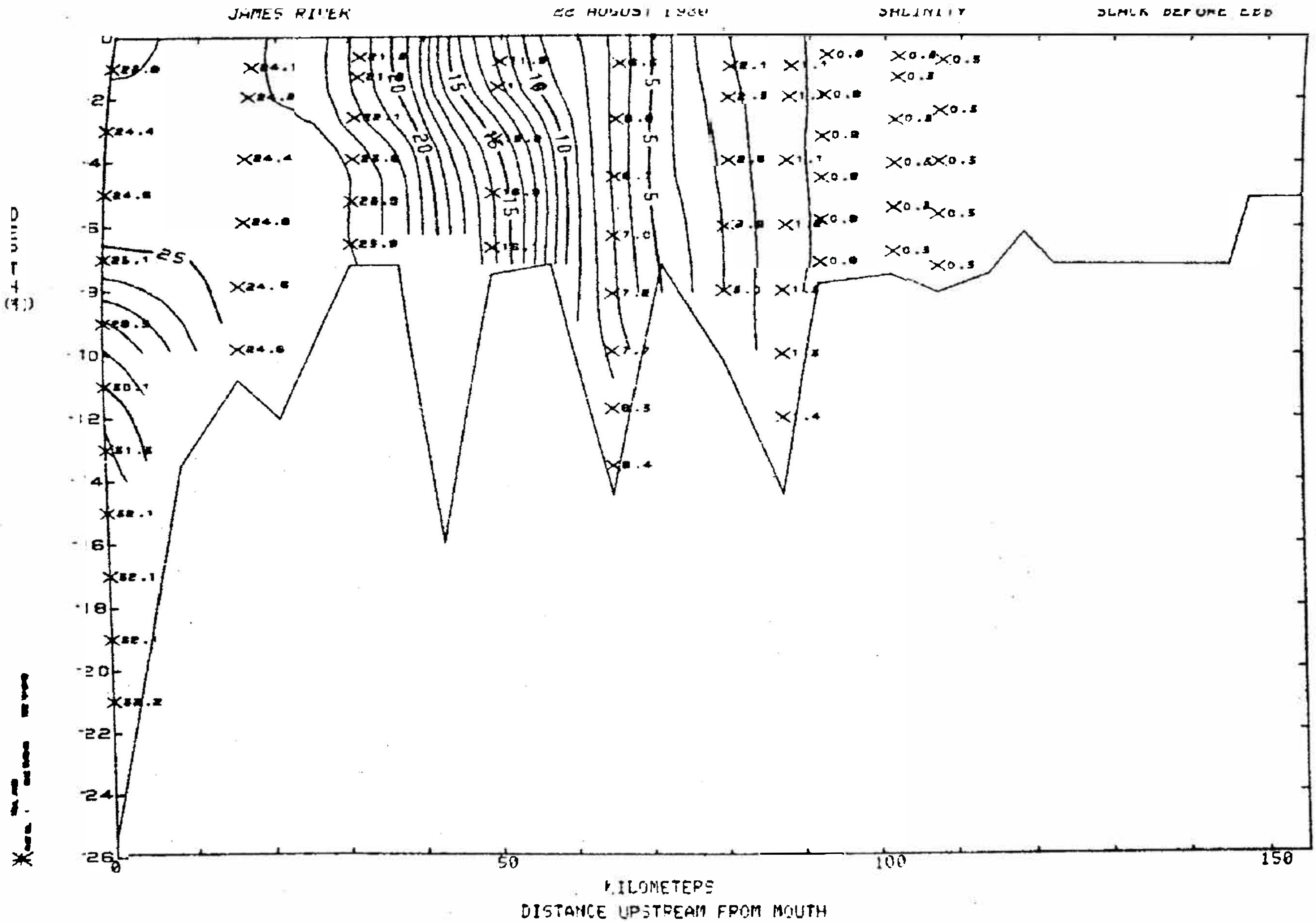

JAMES RIVER
25 JUNE 1980
SALINITY
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

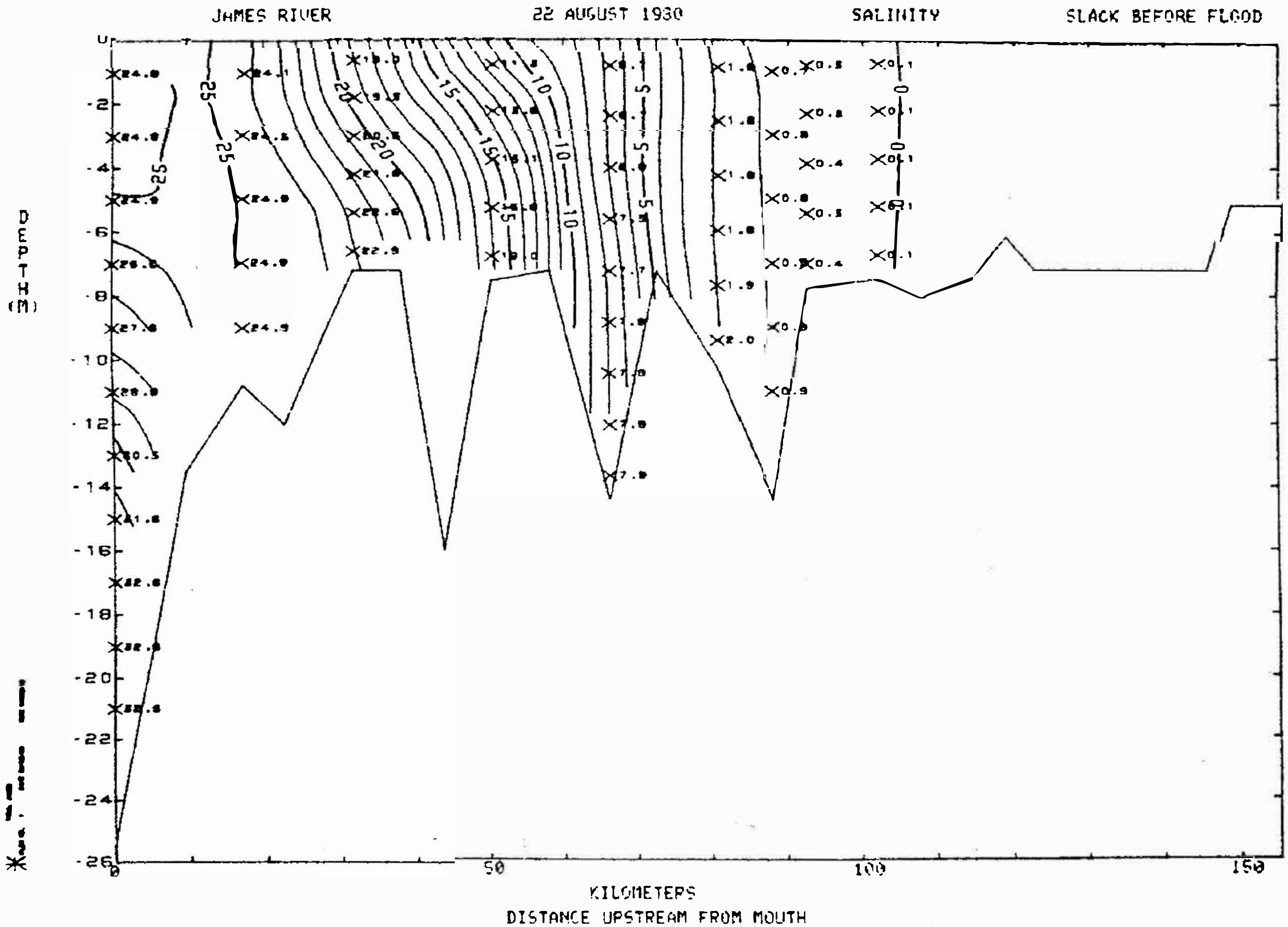


JAMES RIVER
17 JULY 1988
SALINITY
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
14 AUGUST 1980
SALINITY
SLACK BEFORE FLOOD
20
15
10
5
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
19 AUGUST 1980
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
22 AUGUST 1980
SALINITY
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



JAMES RIVER
22 AUGUST 1930
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
25
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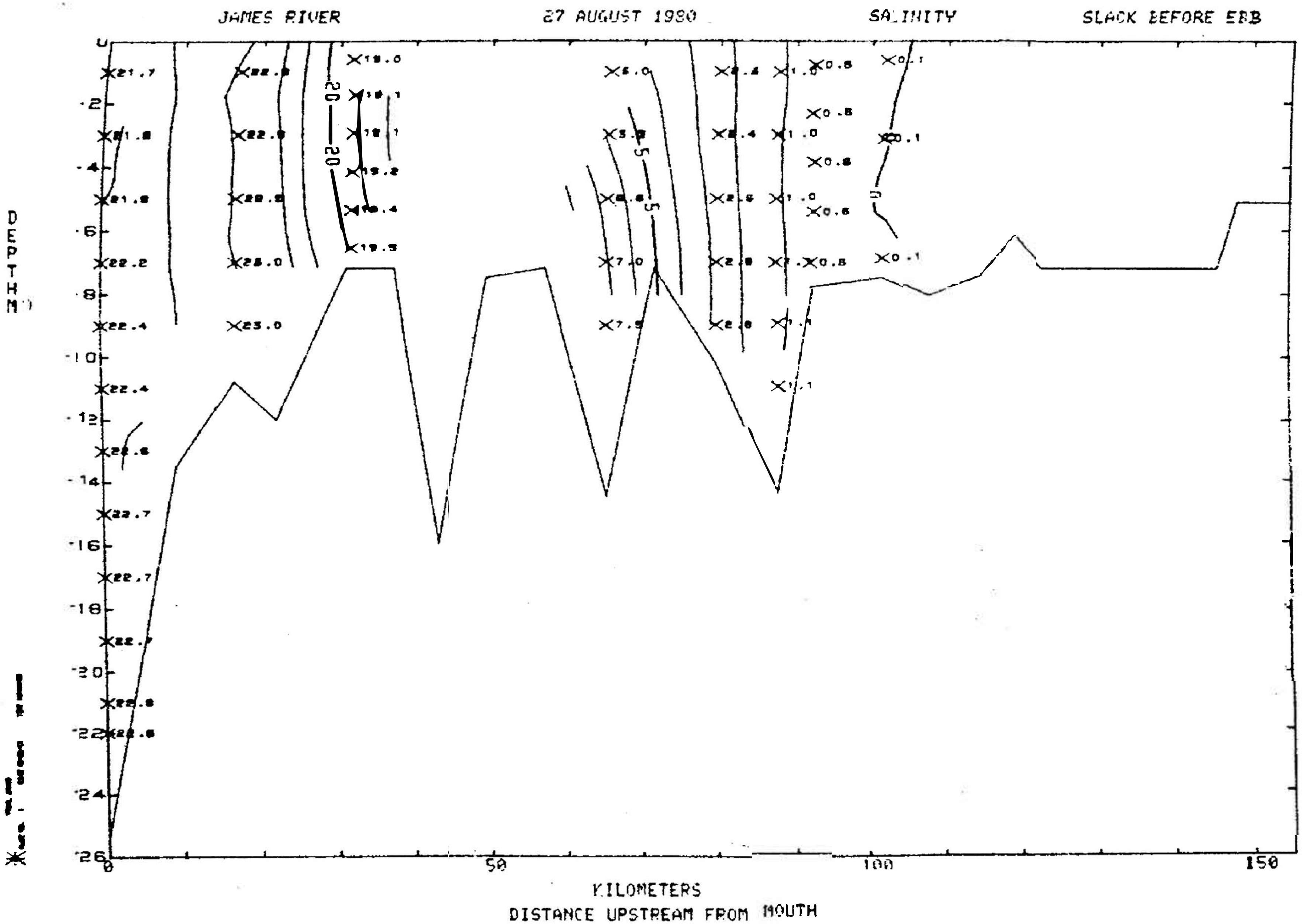
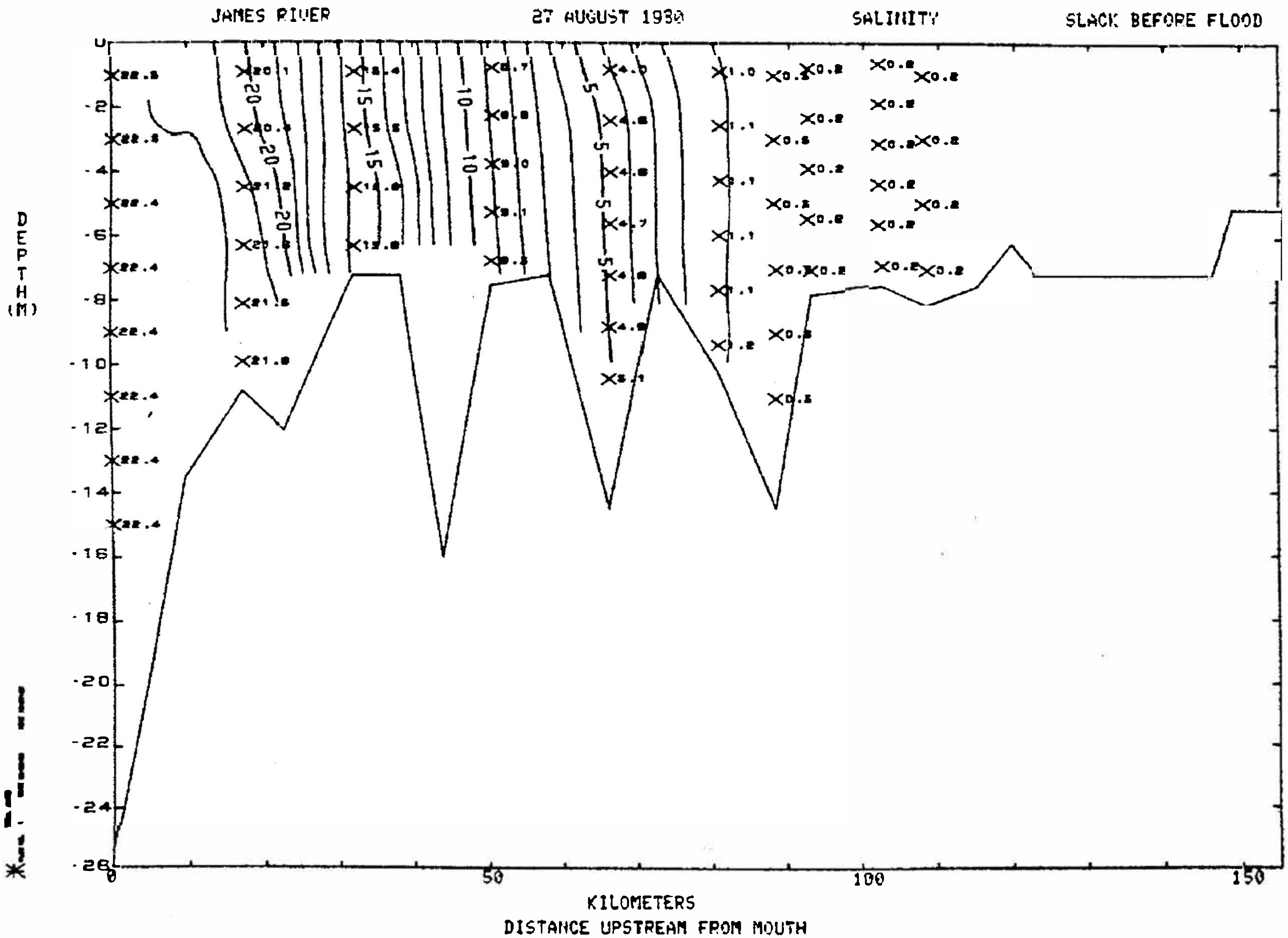
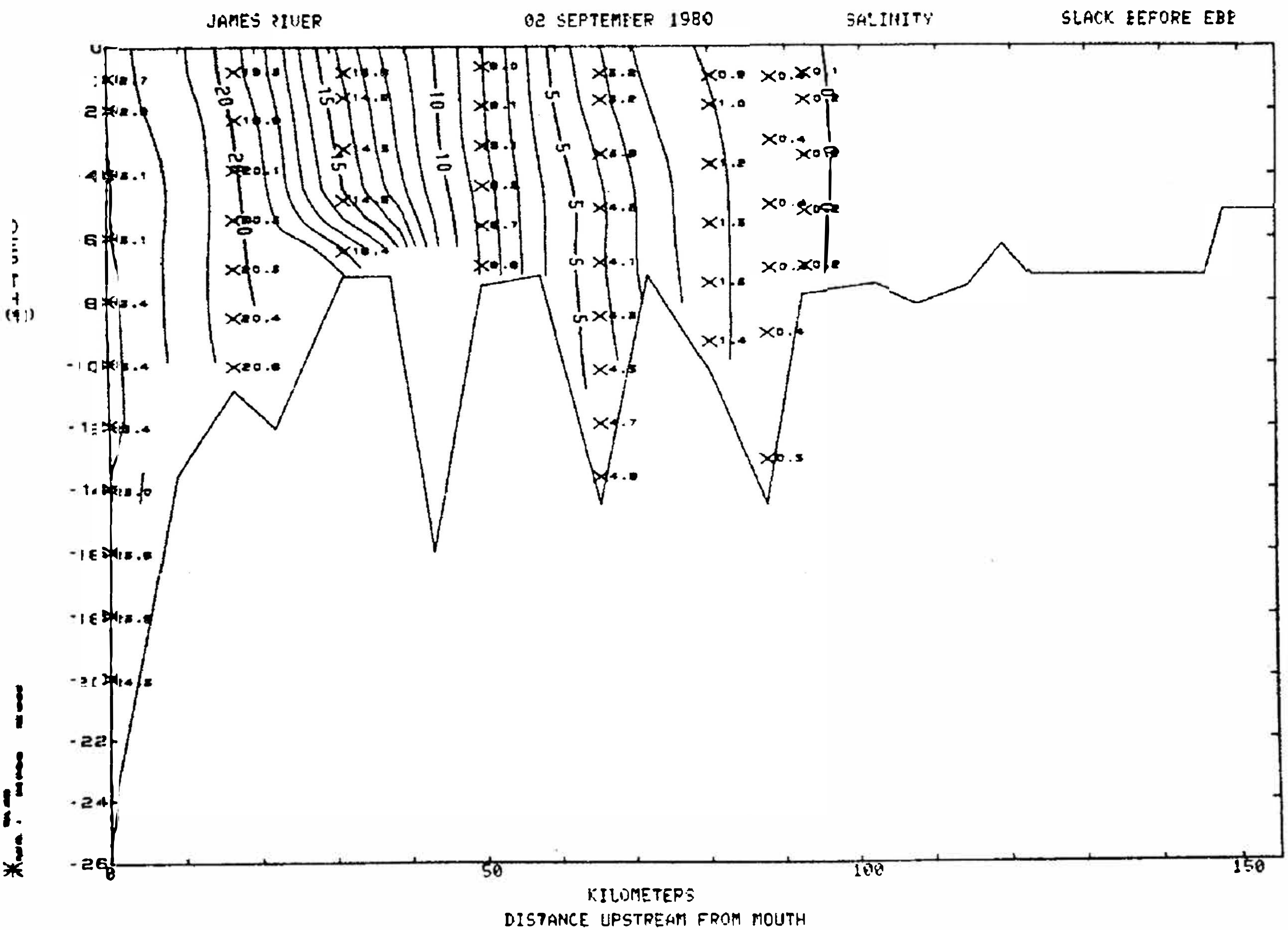
15
10
5
0

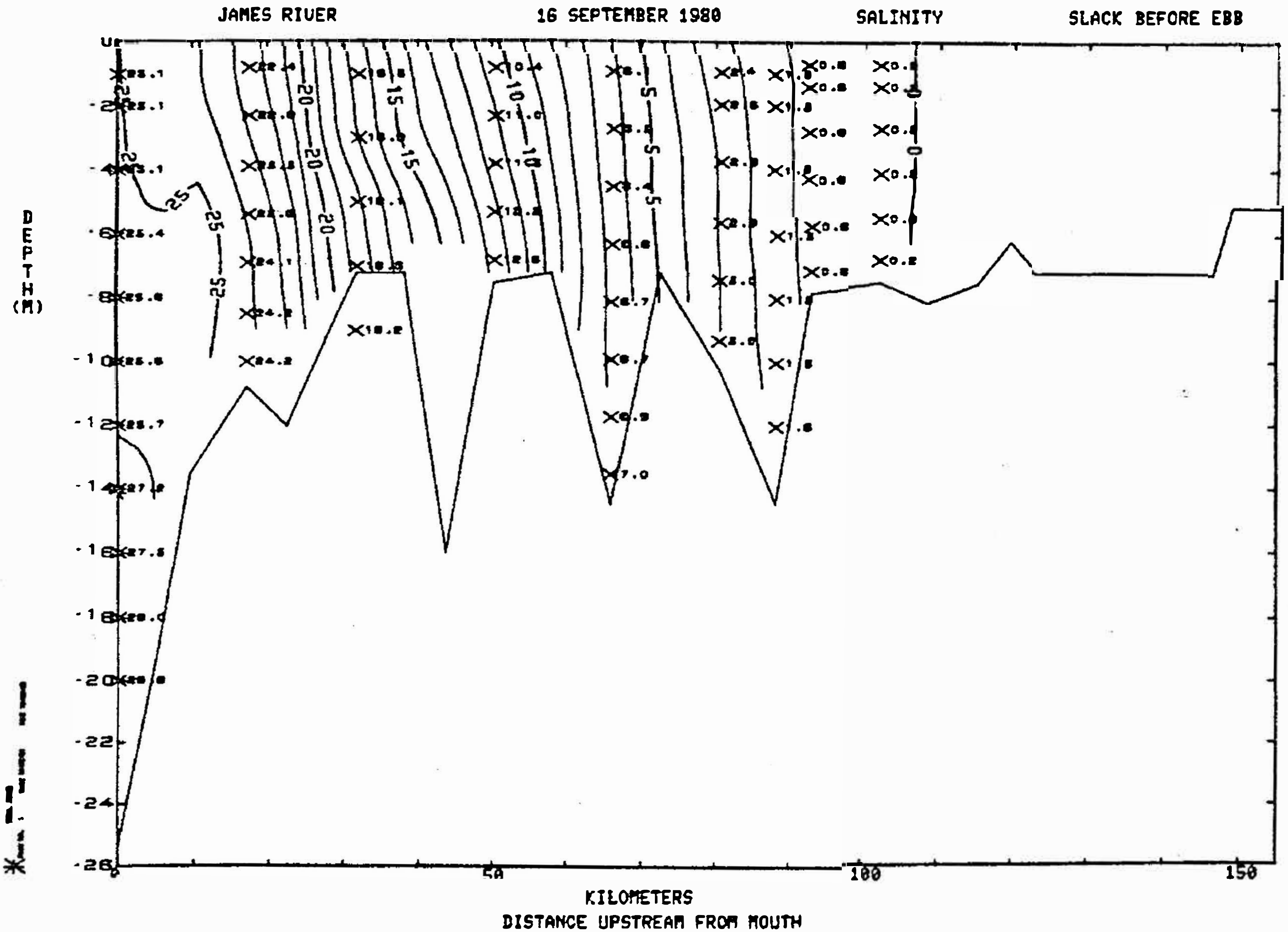


JAMES RIVER
27 AUGUST 1980
SALINITY
SLACK BEFORE EBB
DEPTH M
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150

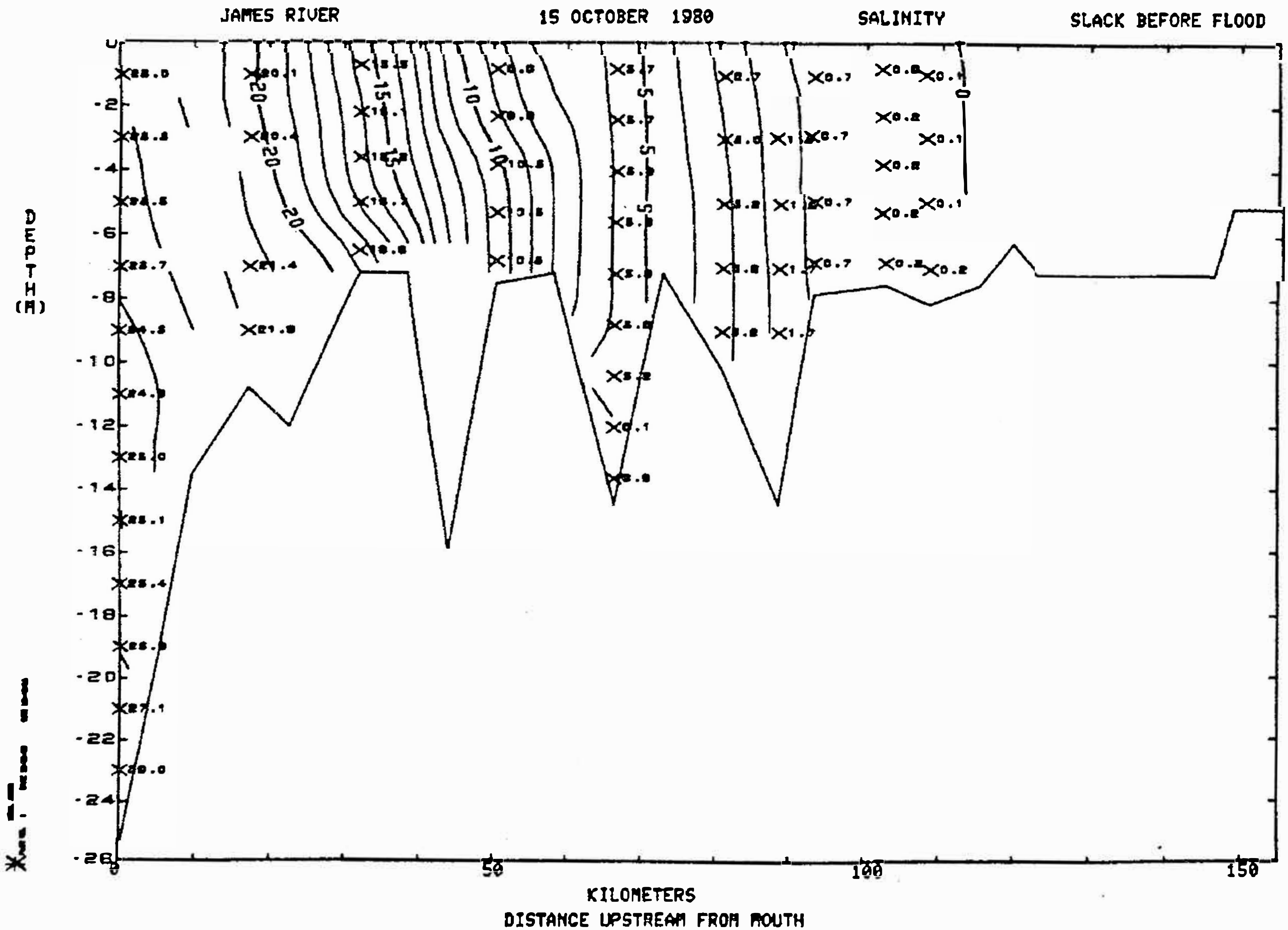

JAMES RIVER
27 AUGUST 1980
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



JAMES RIVER
02 SEPTEMBER 1980
SALINITY
SLACK BEFORE EBB
20
15
10
5
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

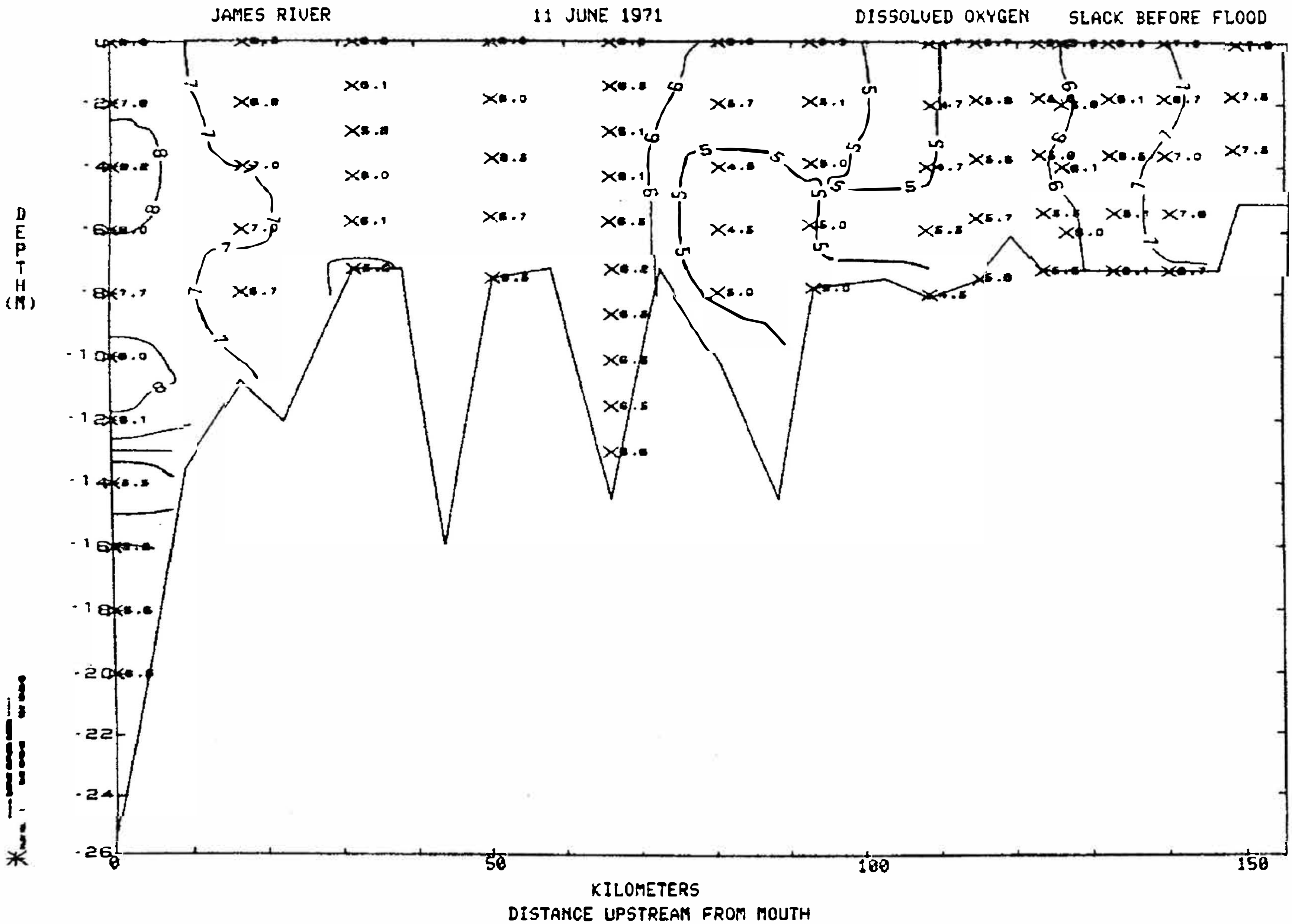


JAMES RIVER
16 SEPTEMBER 1980
SALINITY
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

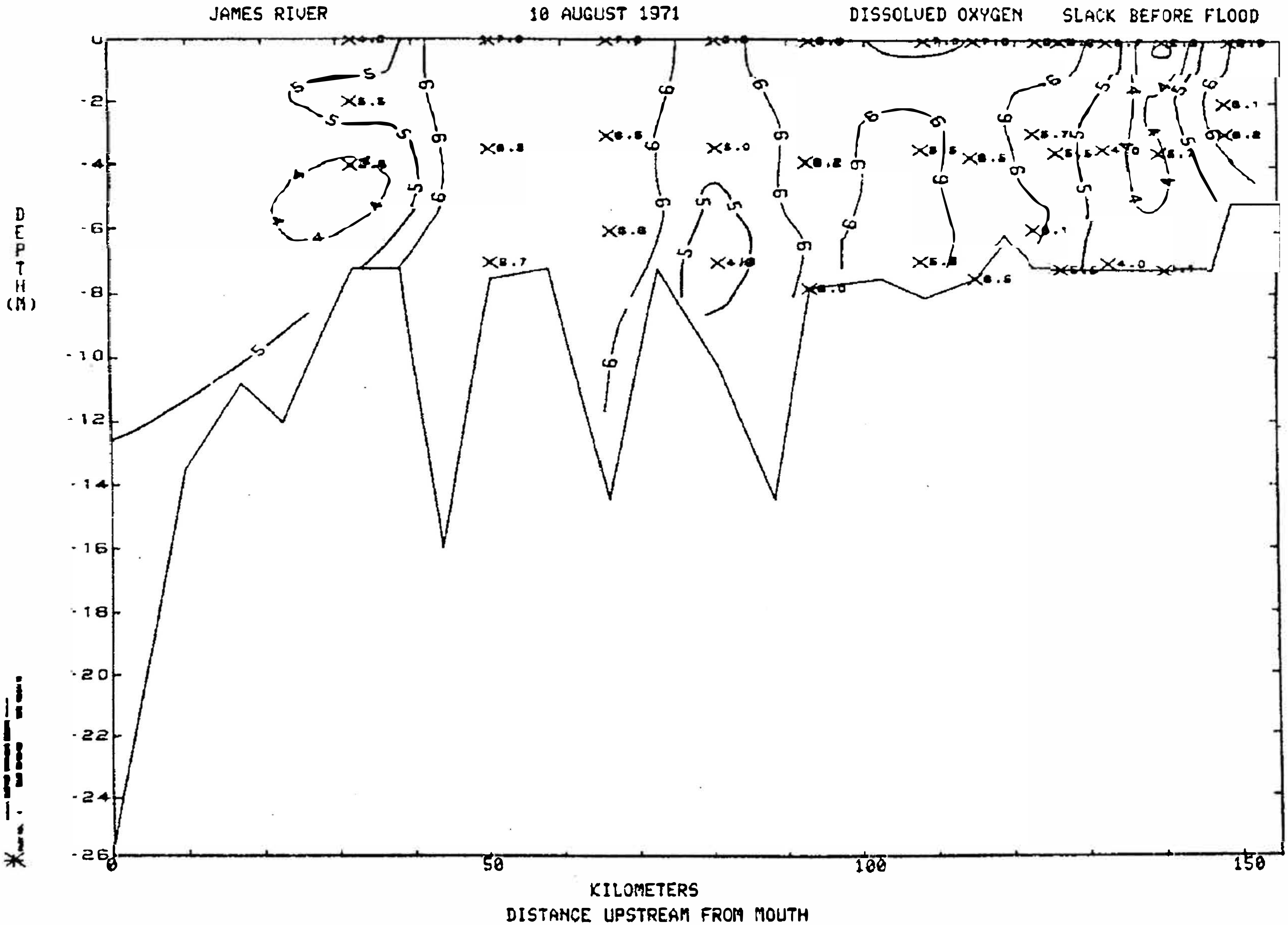


JAMES RIVER
15 OCTOBER 1980
SALINITY
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

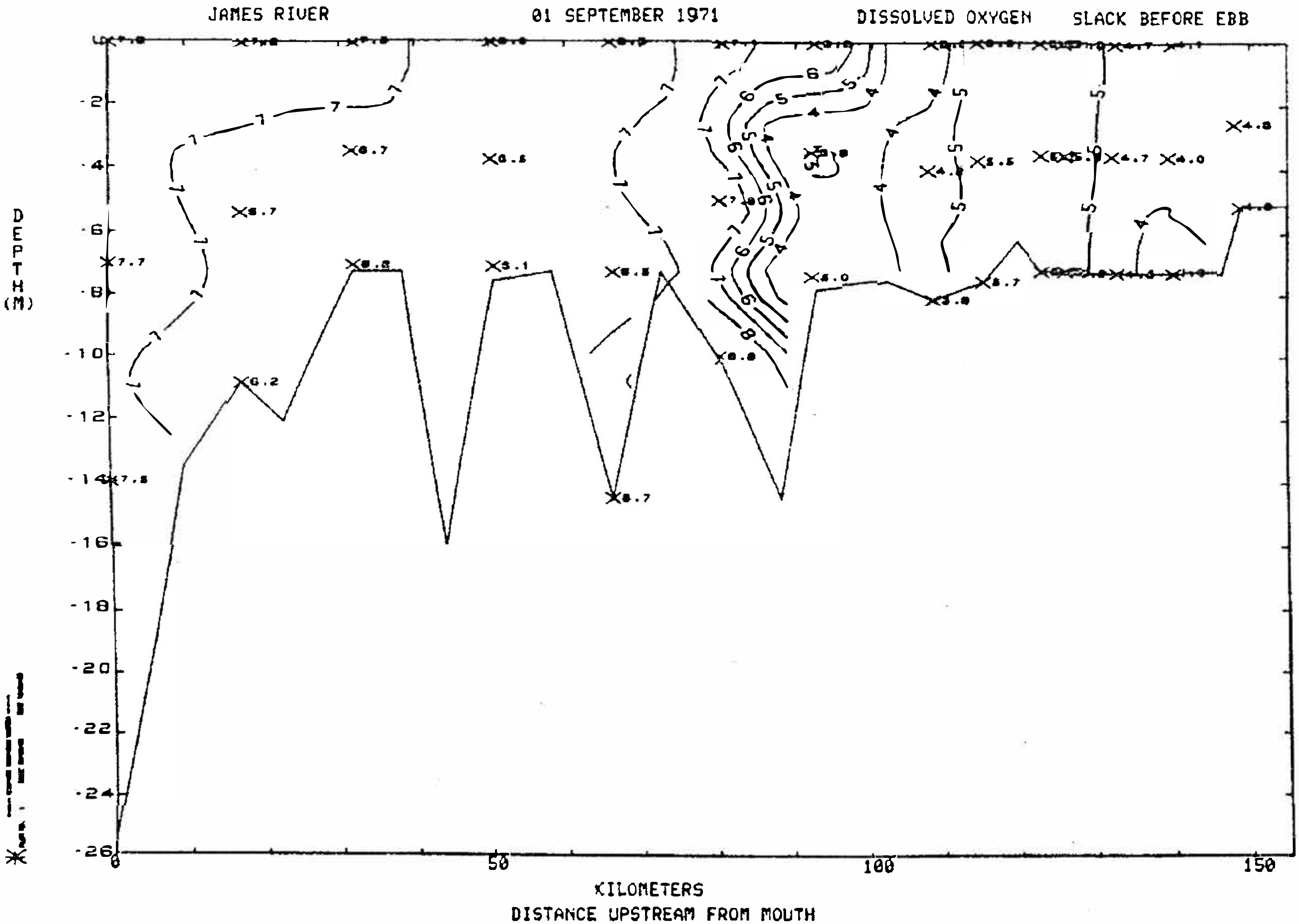
D. Dissolved Oxygen (mg/ℓ)



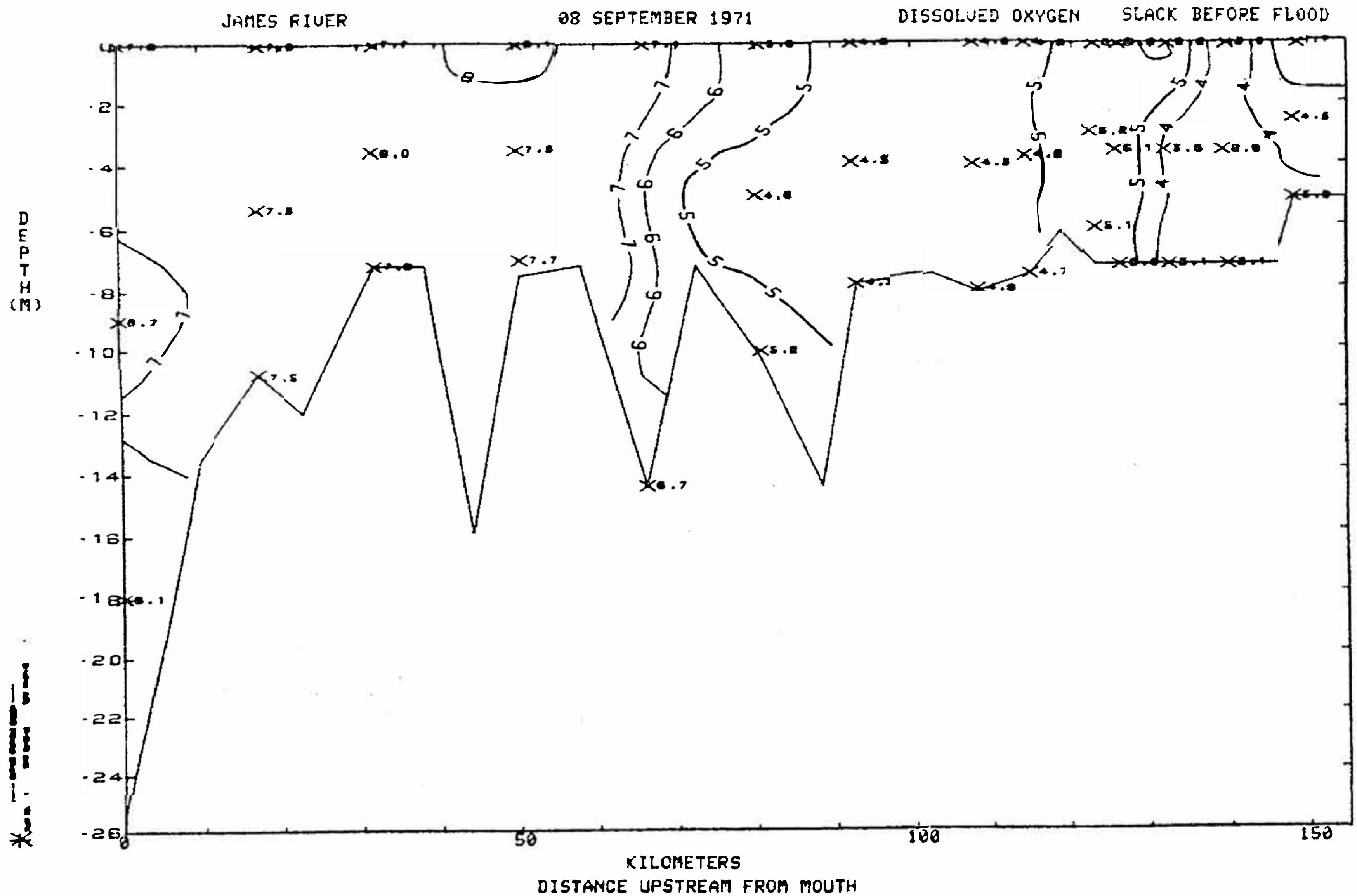
JAMES RIVER
11 JUNE 1971
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

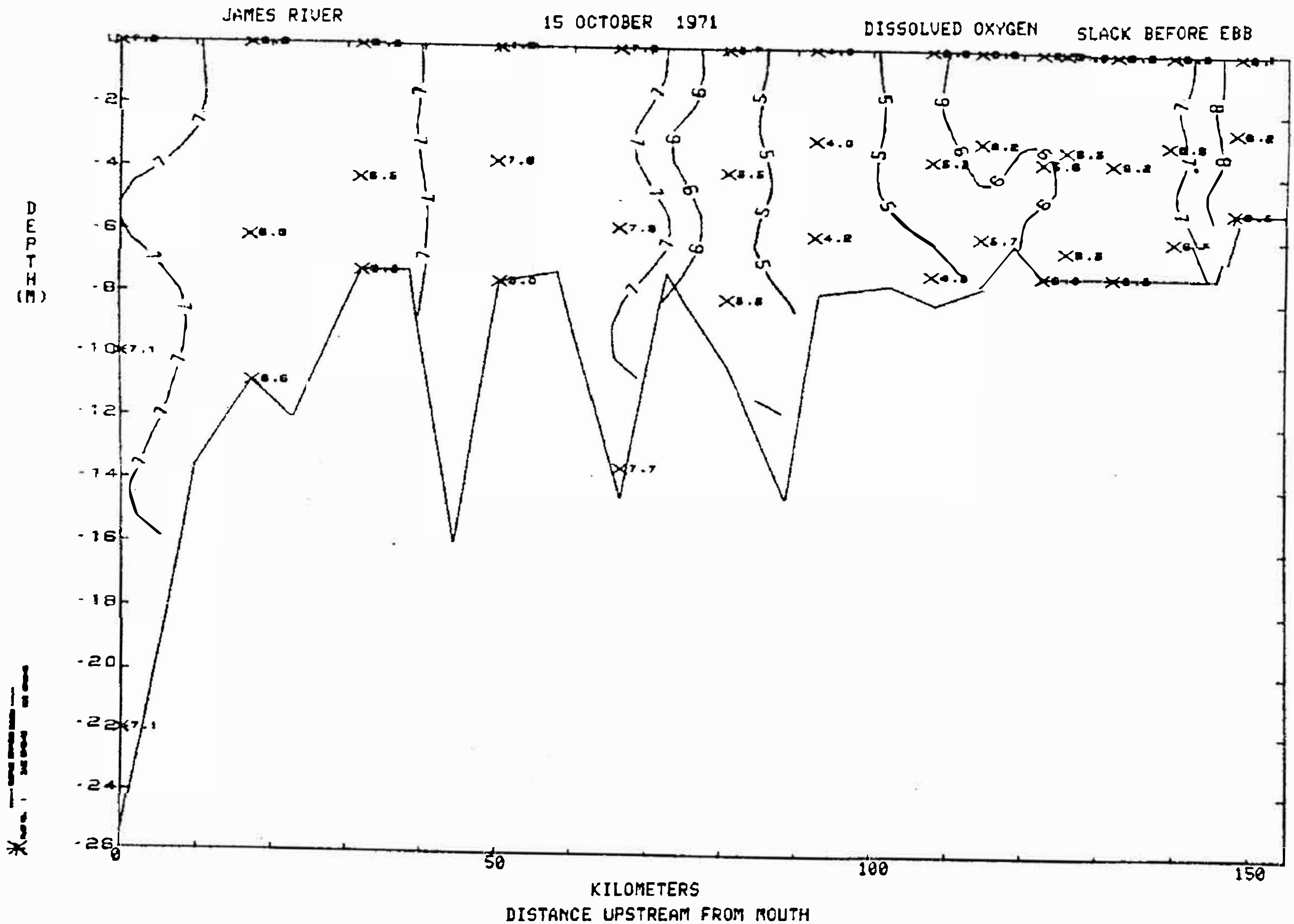


JAMES RIVER
10 AUGUST 1971
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26

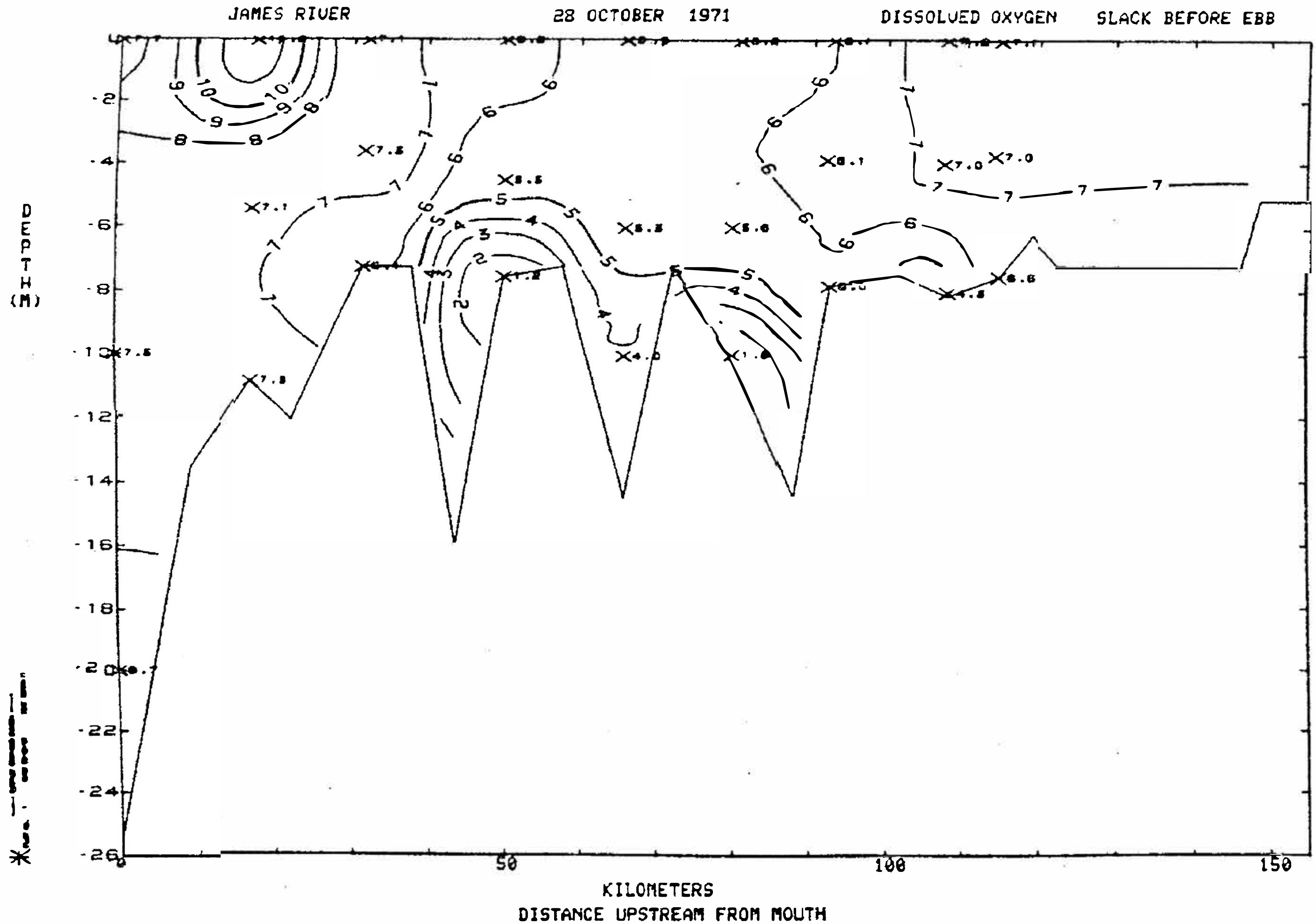


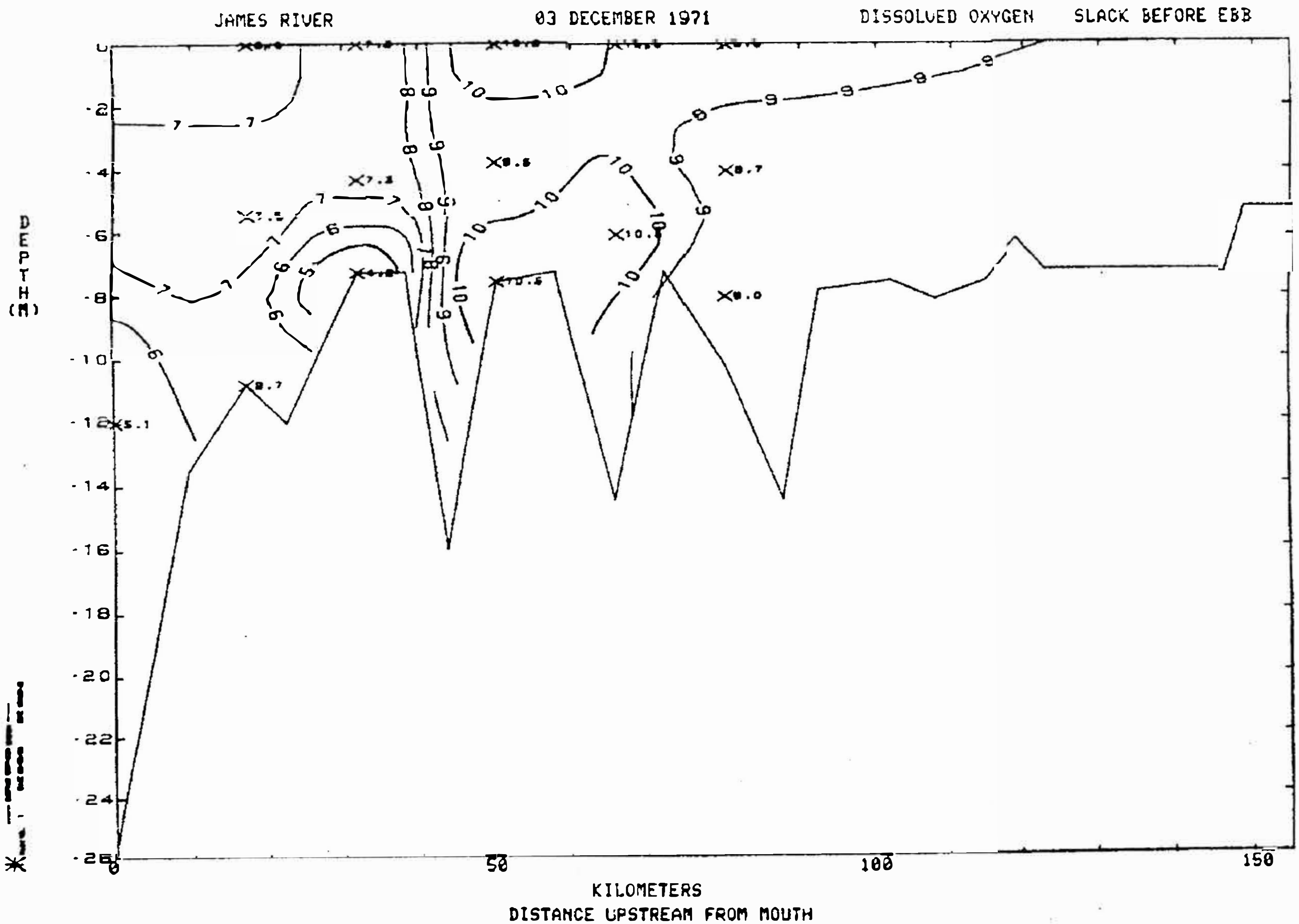
JAMES RIVER
01 SEPTEMBER 1971
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
08 SEPTEMBER 1971
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

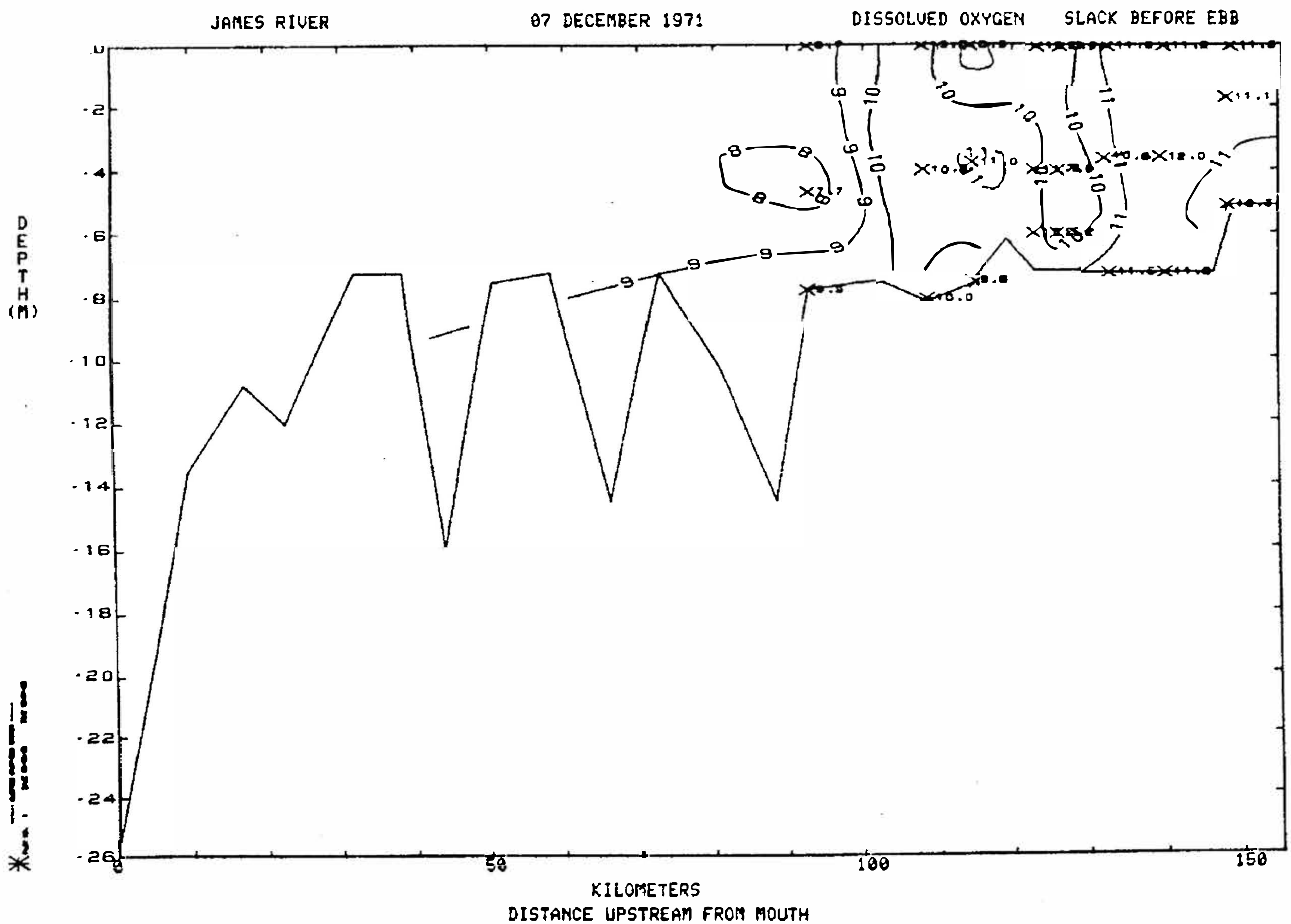


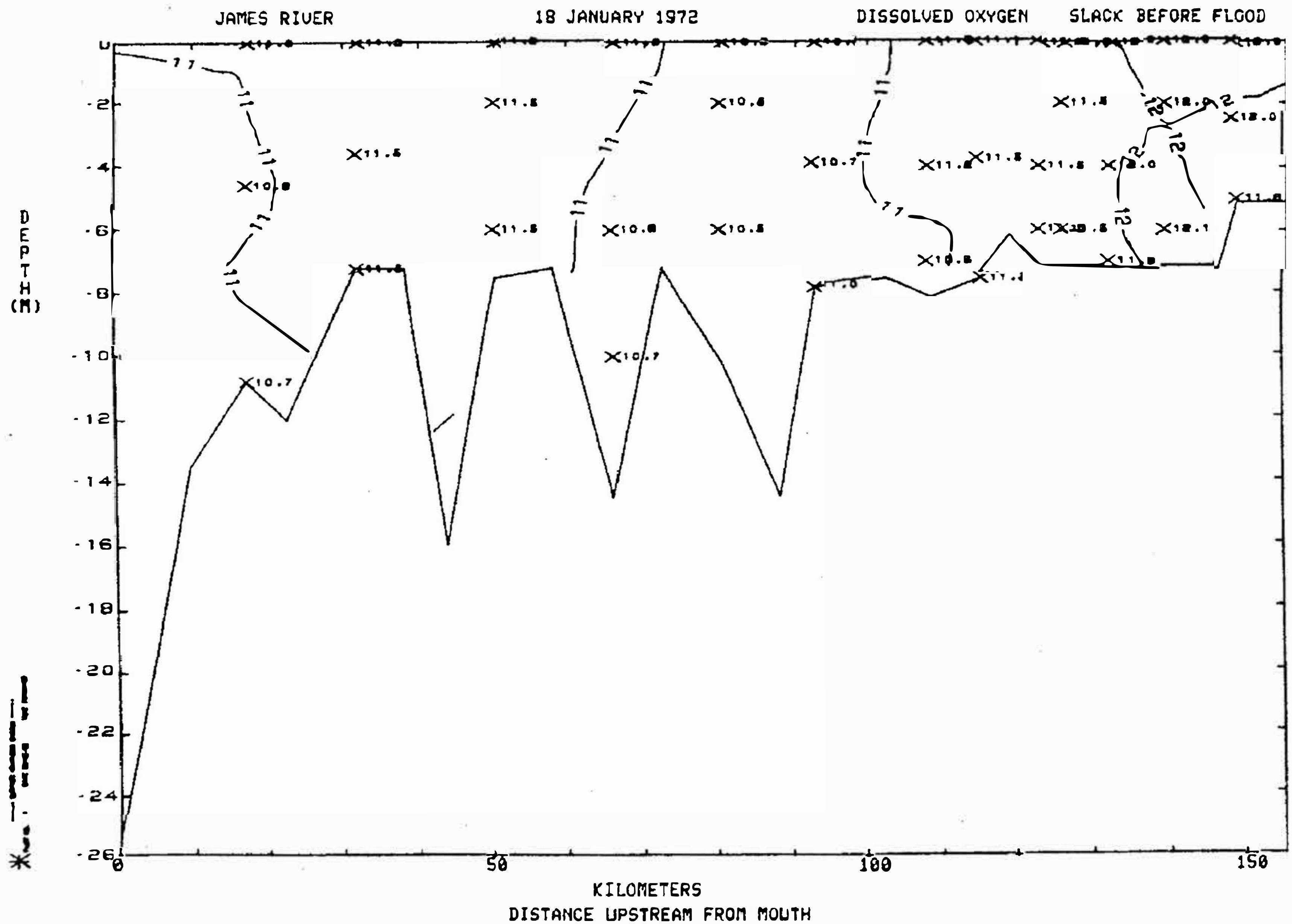
JAMES RIVER
15 OCTOBER 1971
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
28 OCTOBER 1971
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

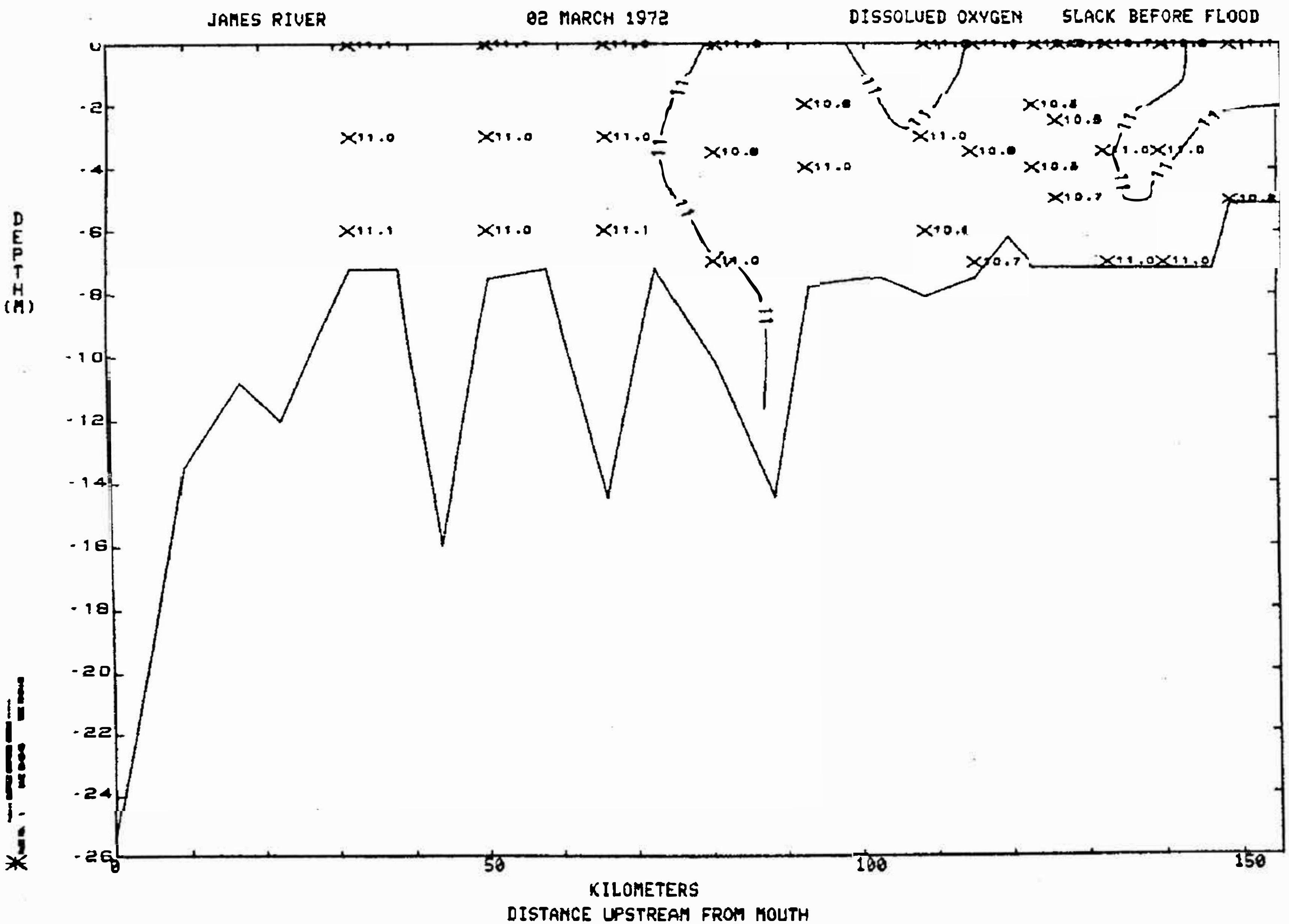


JAMES RIVER
03 DECEMBER 1971
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

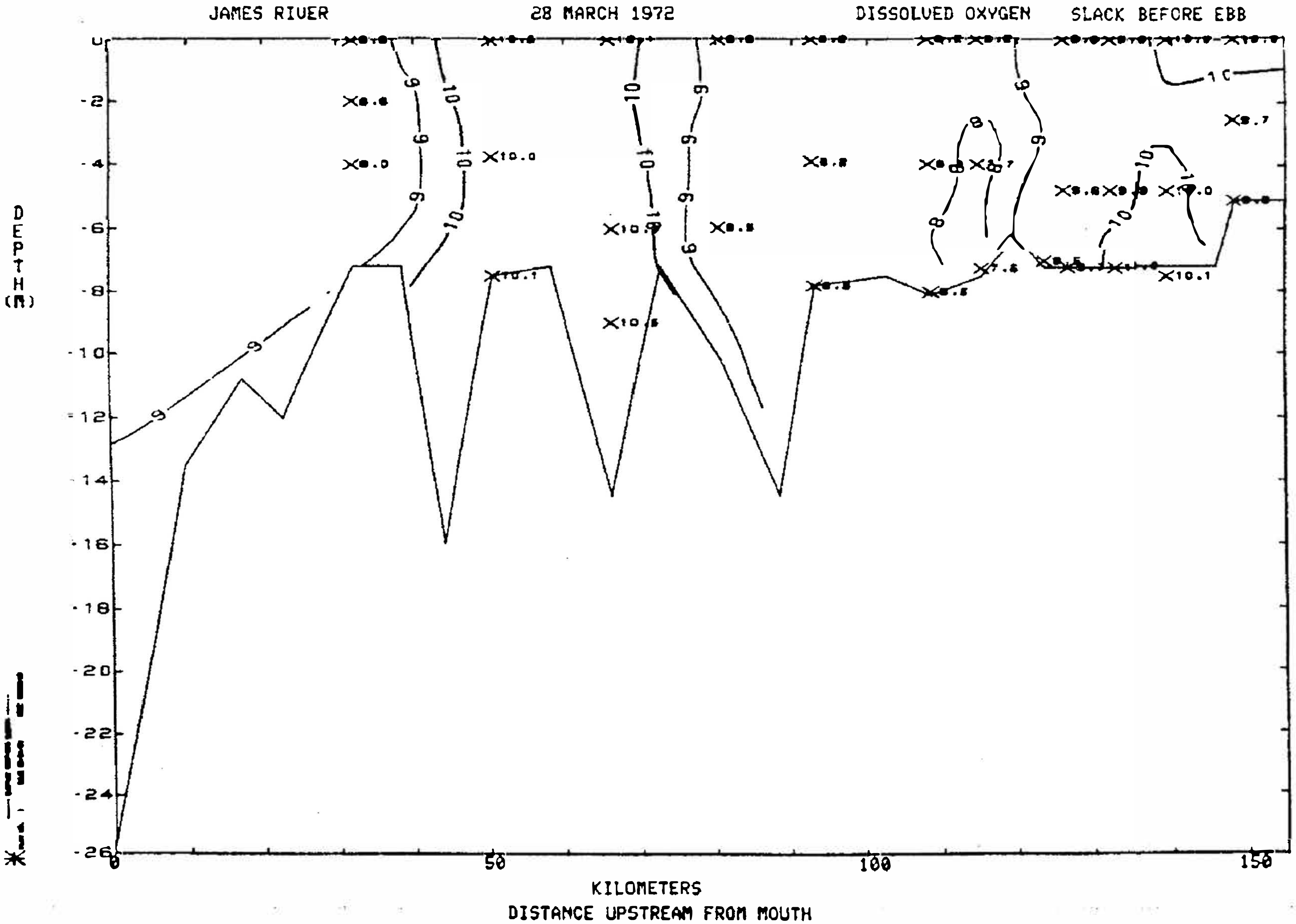

JAMES RIVER
07 DECEMBER 1971
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



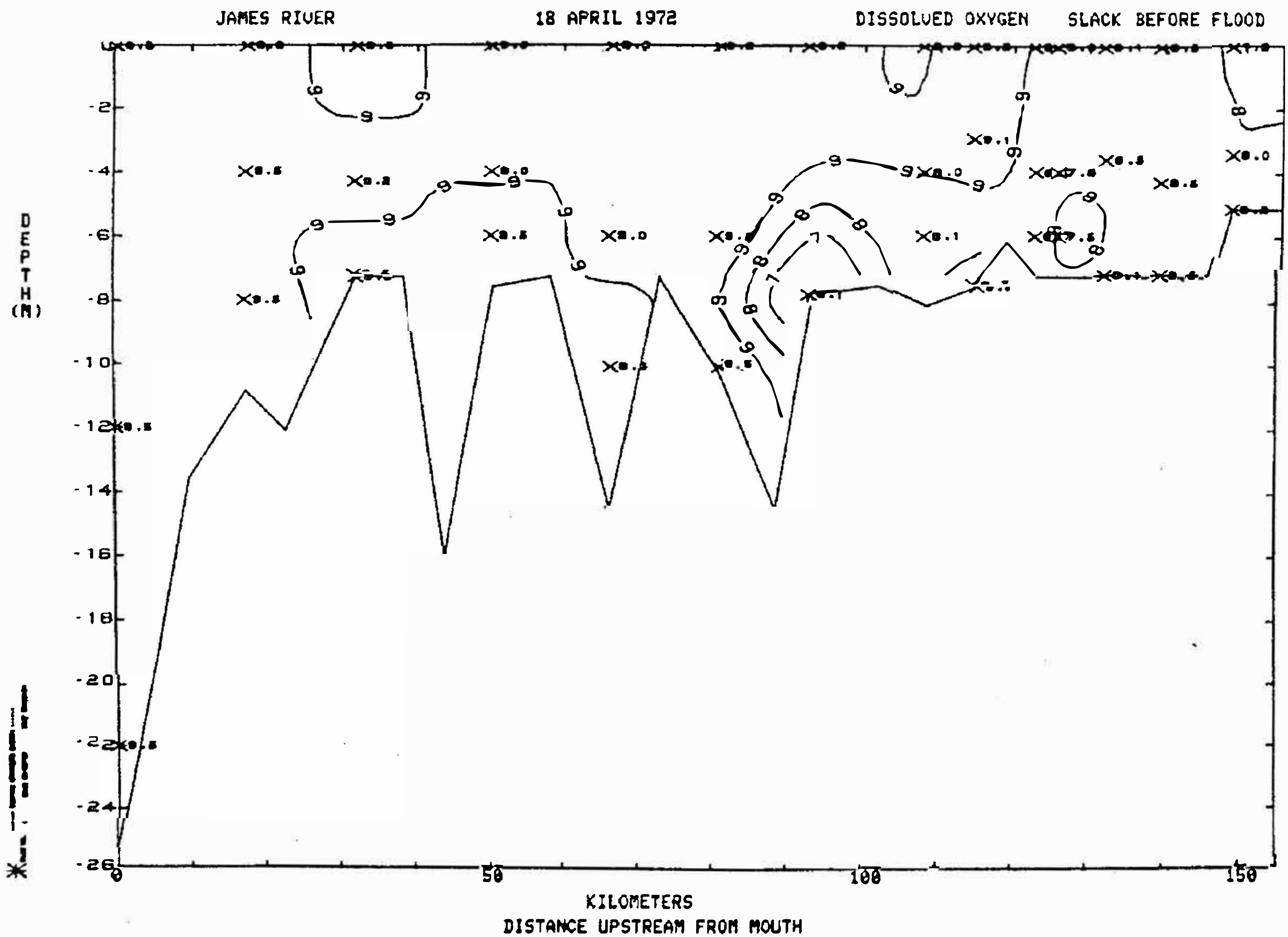
JAMES RIVER
18 JANUARY 1972
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26

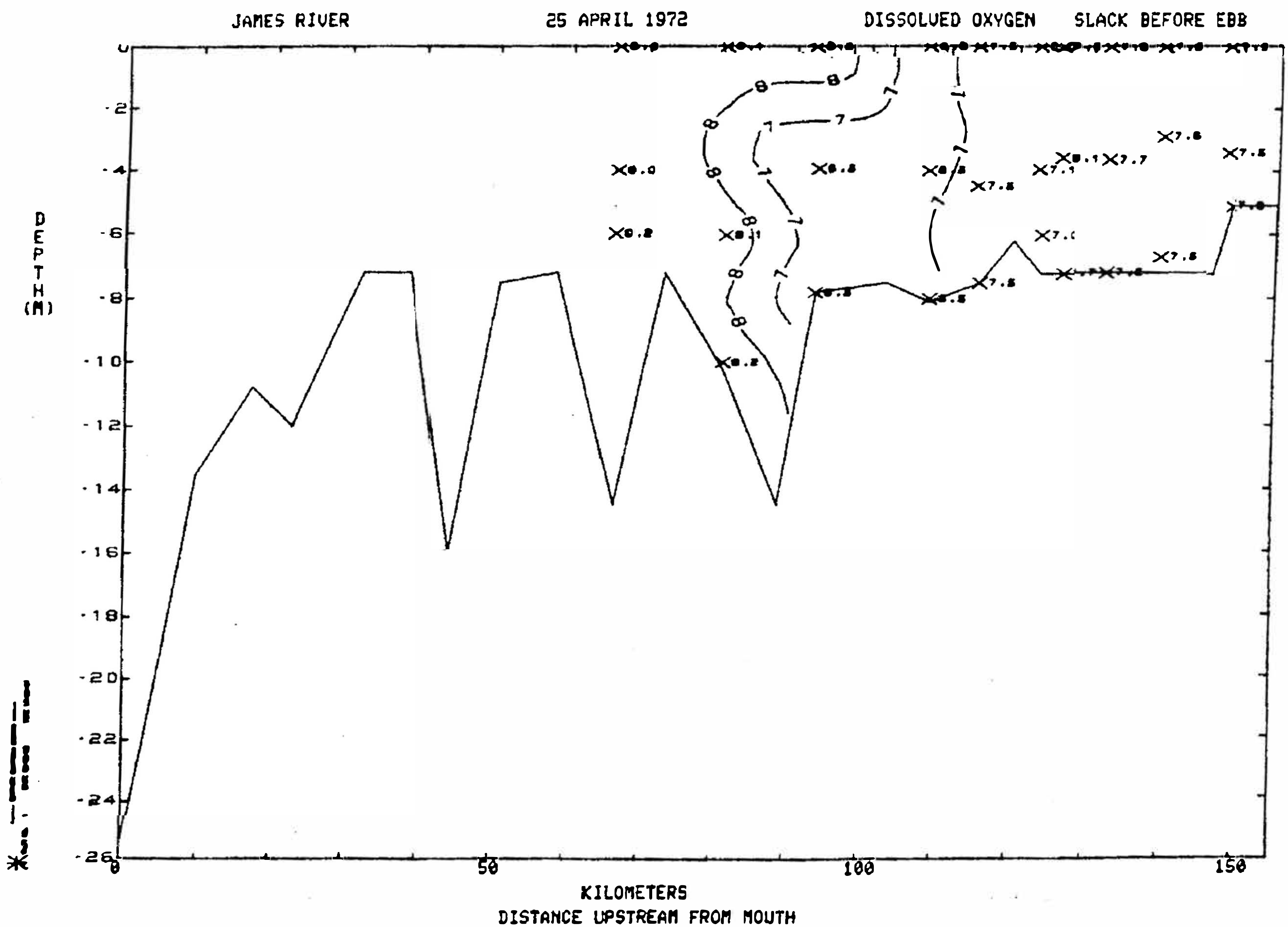


JAMES RIVER
02 MARCH 1972
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

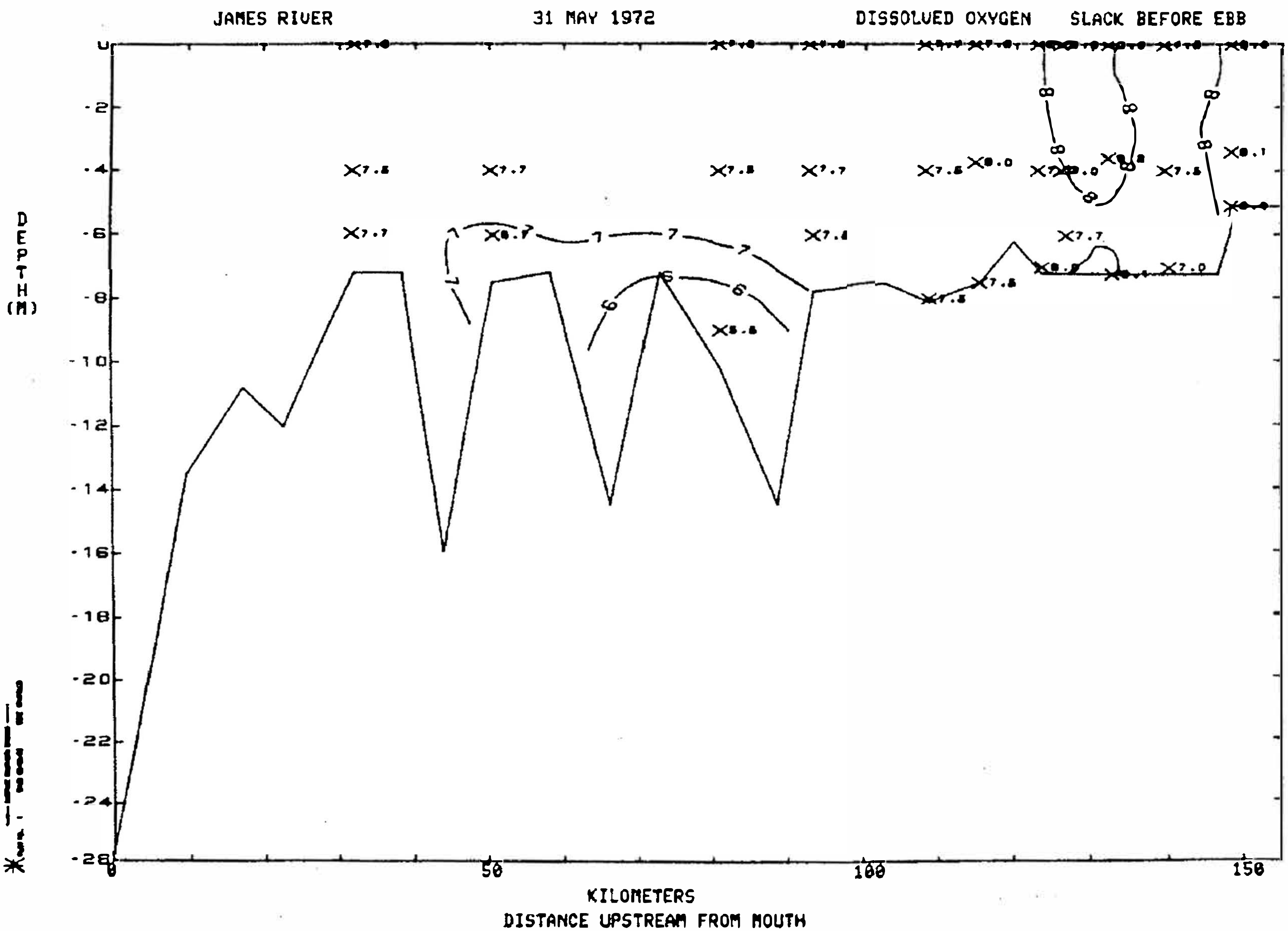


JAMES RIVER
28 MARCH 1972
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
18 APRIL 1972
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26

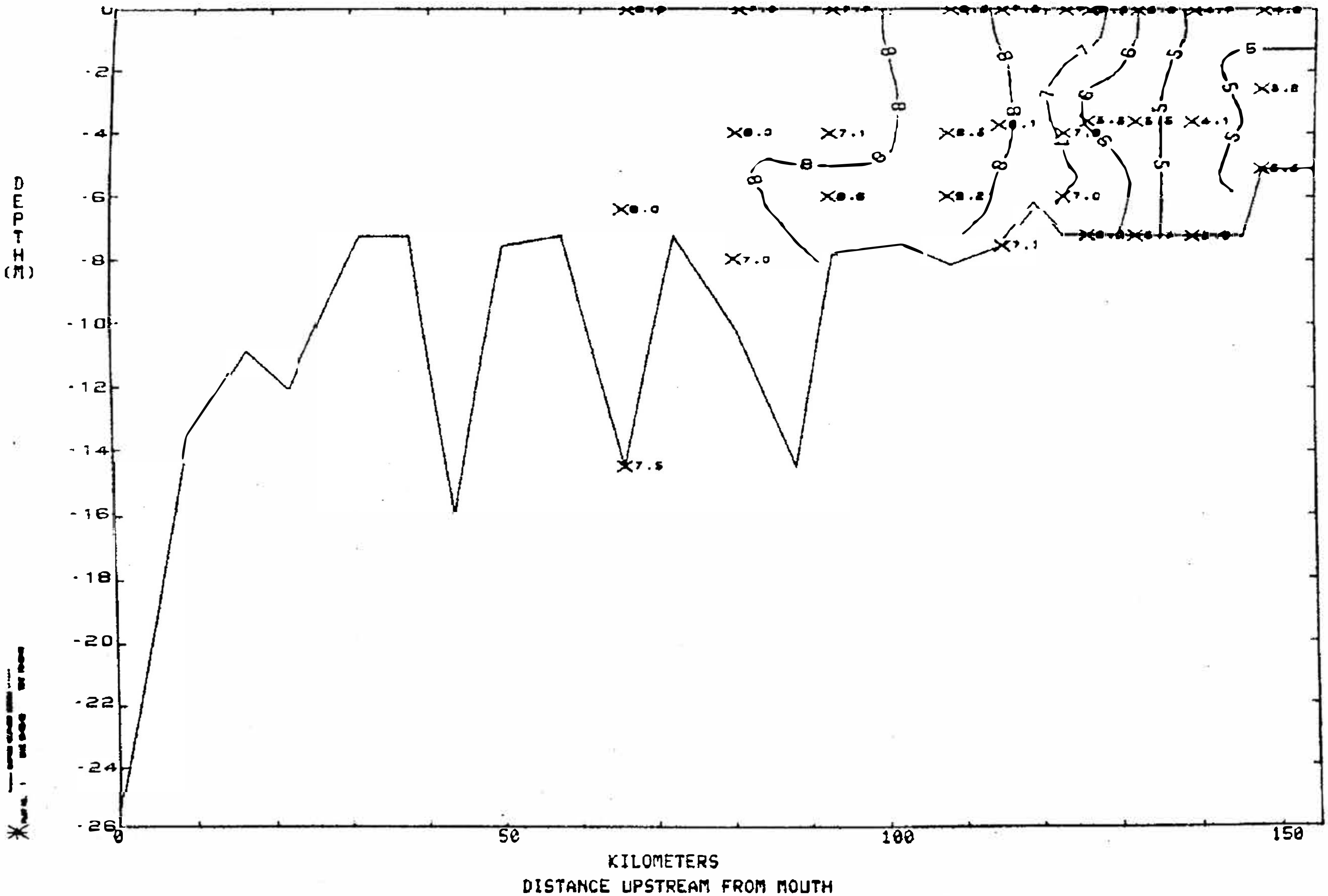


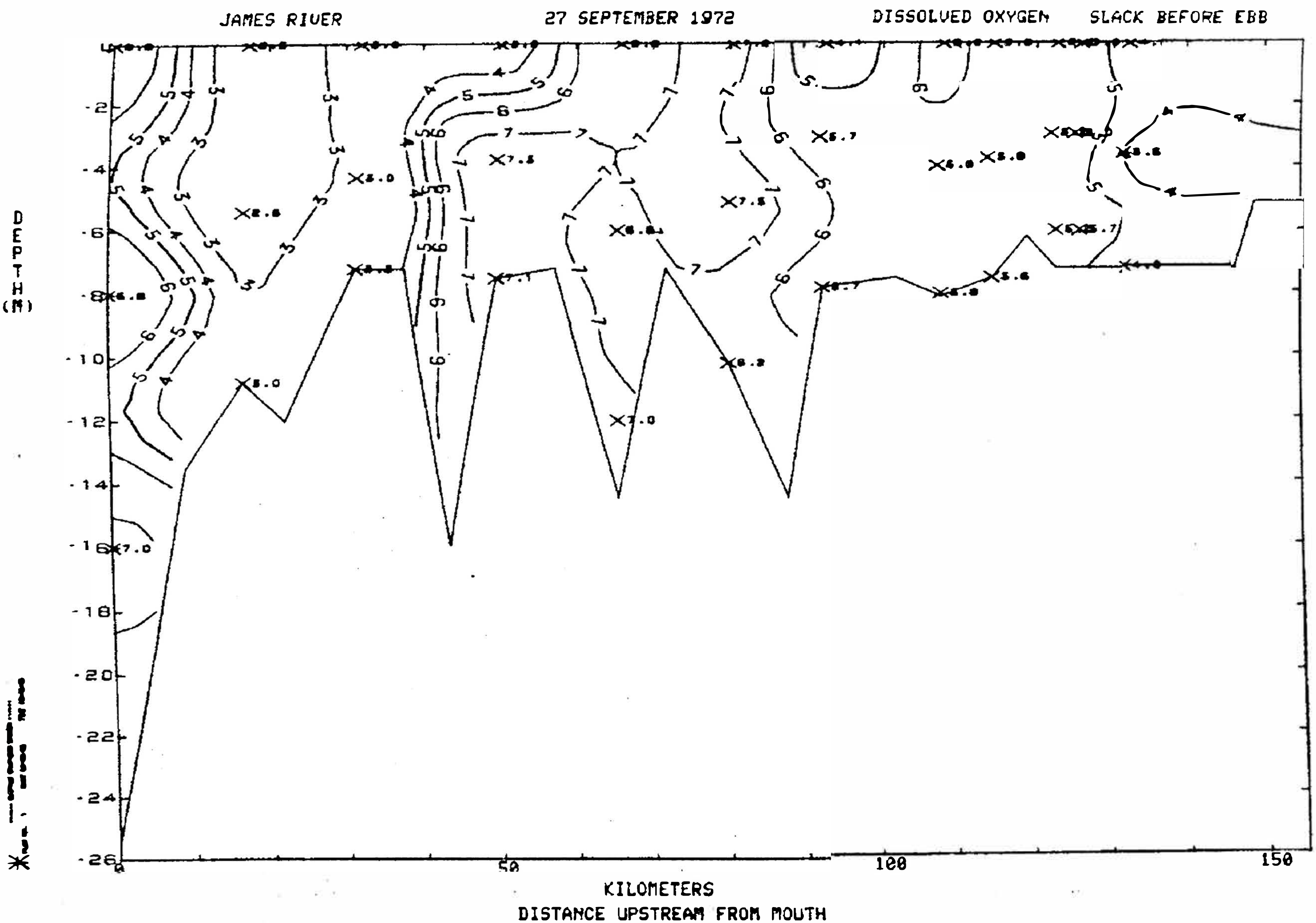
JAMES RIVER
25 APRIL 1972
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

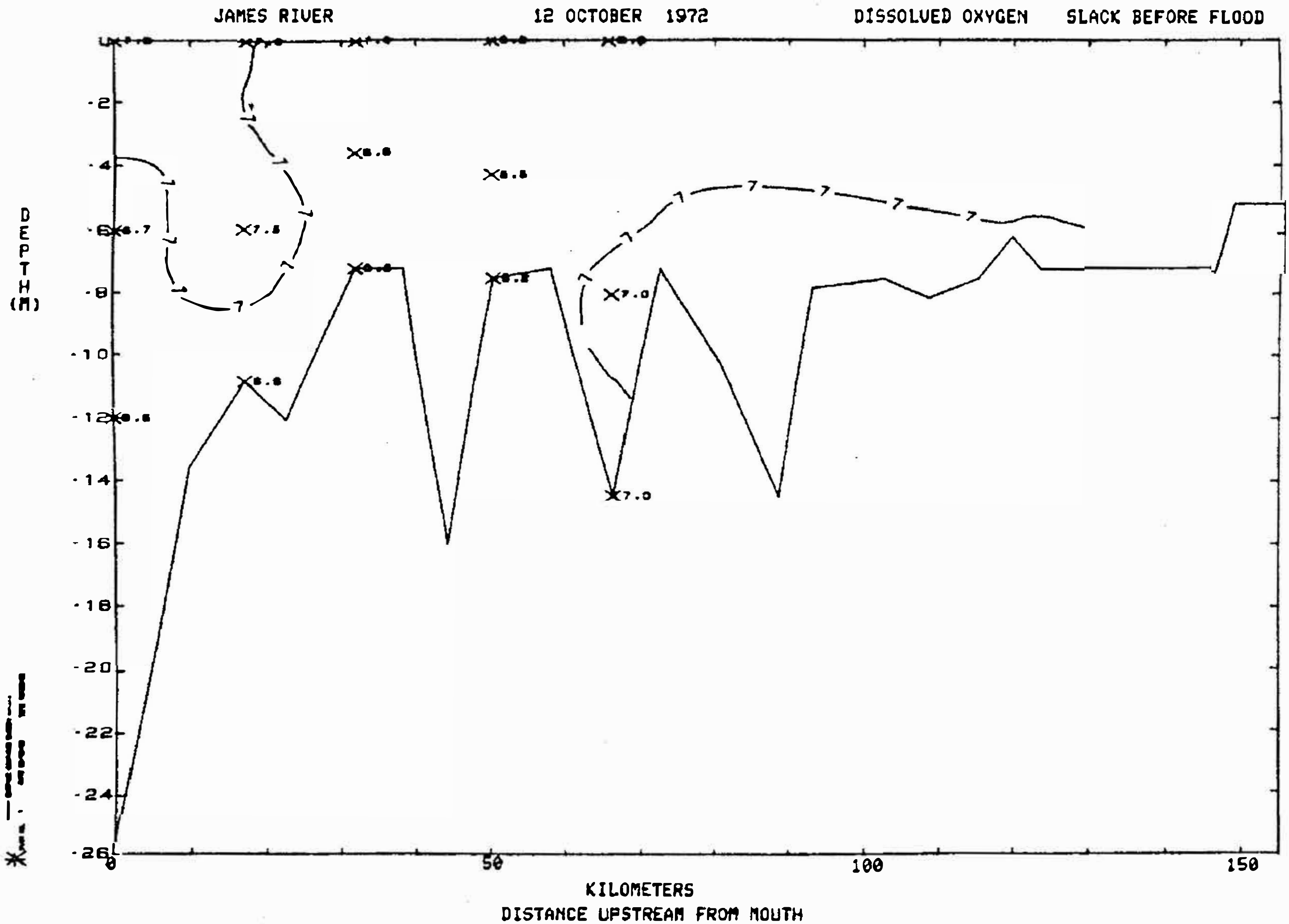


JAMES RIVER
31 MAY 1972
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

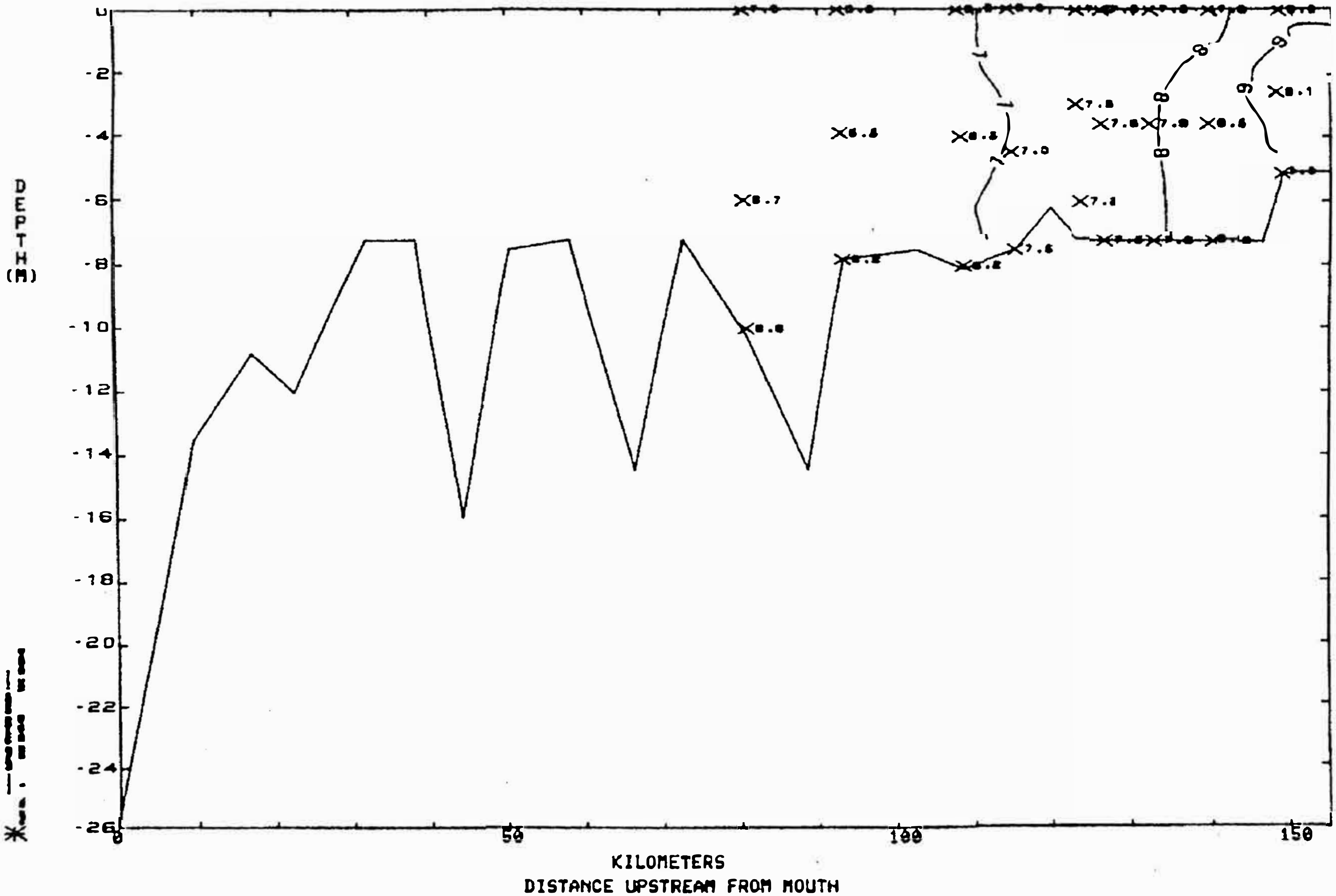
JAMES RIVER 14 SEPTEMBER 1972 DISSOLVED OXYGEN SLACK BEFORE FLOOD

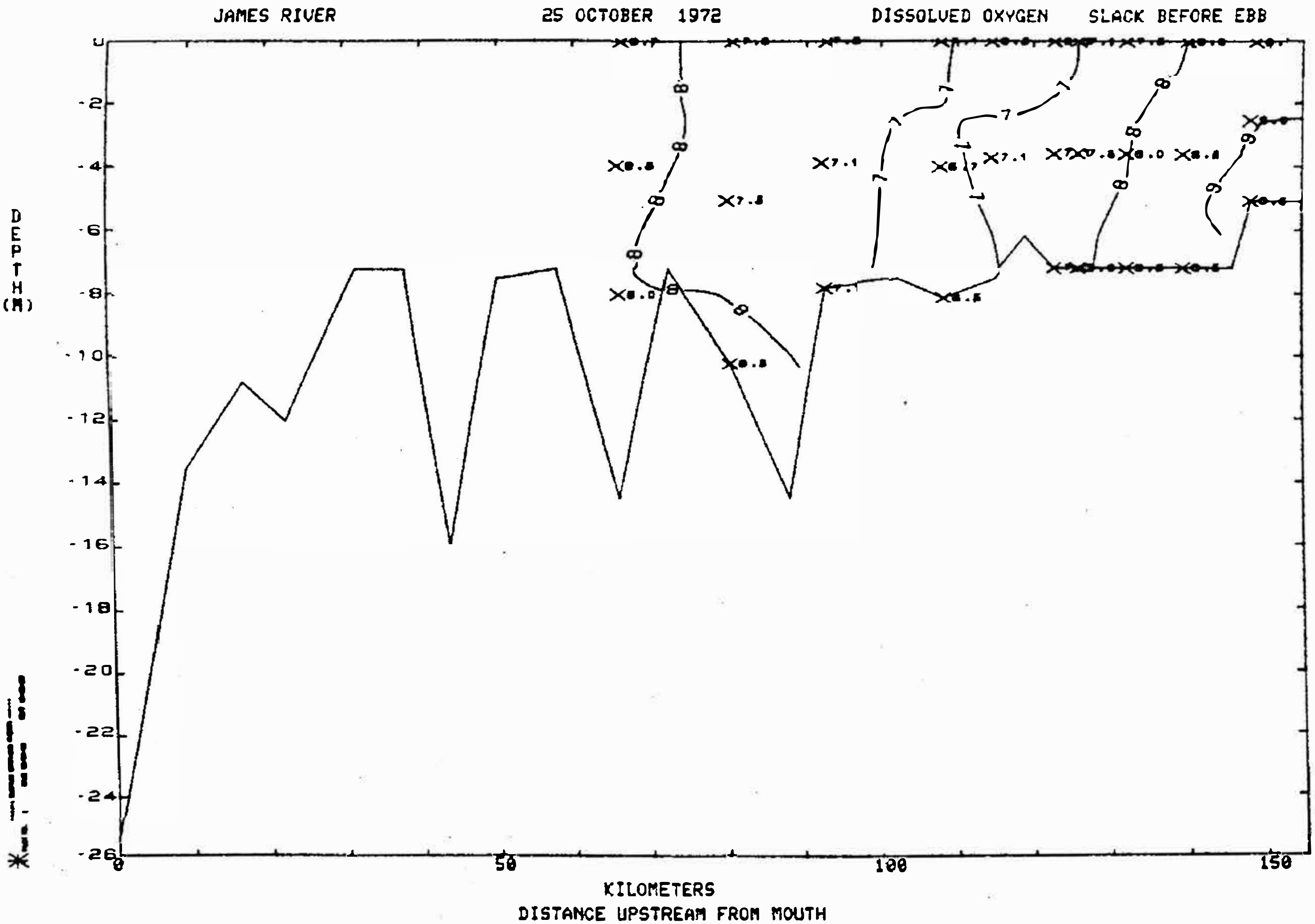



JAMES RIVER
27 SEPTEMBER 1972
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

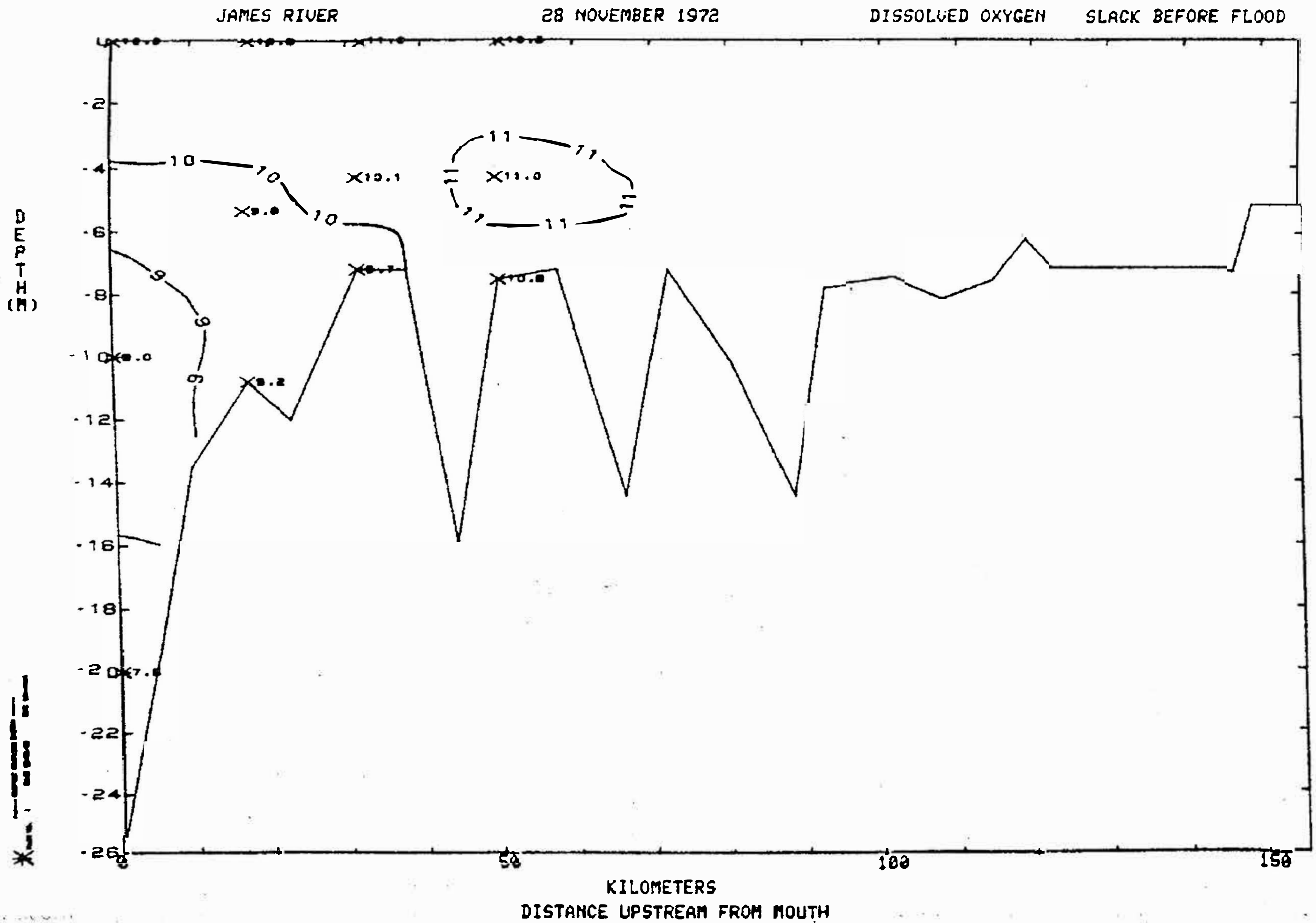

JAMES RIVER
12 OCTOBER 1972
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

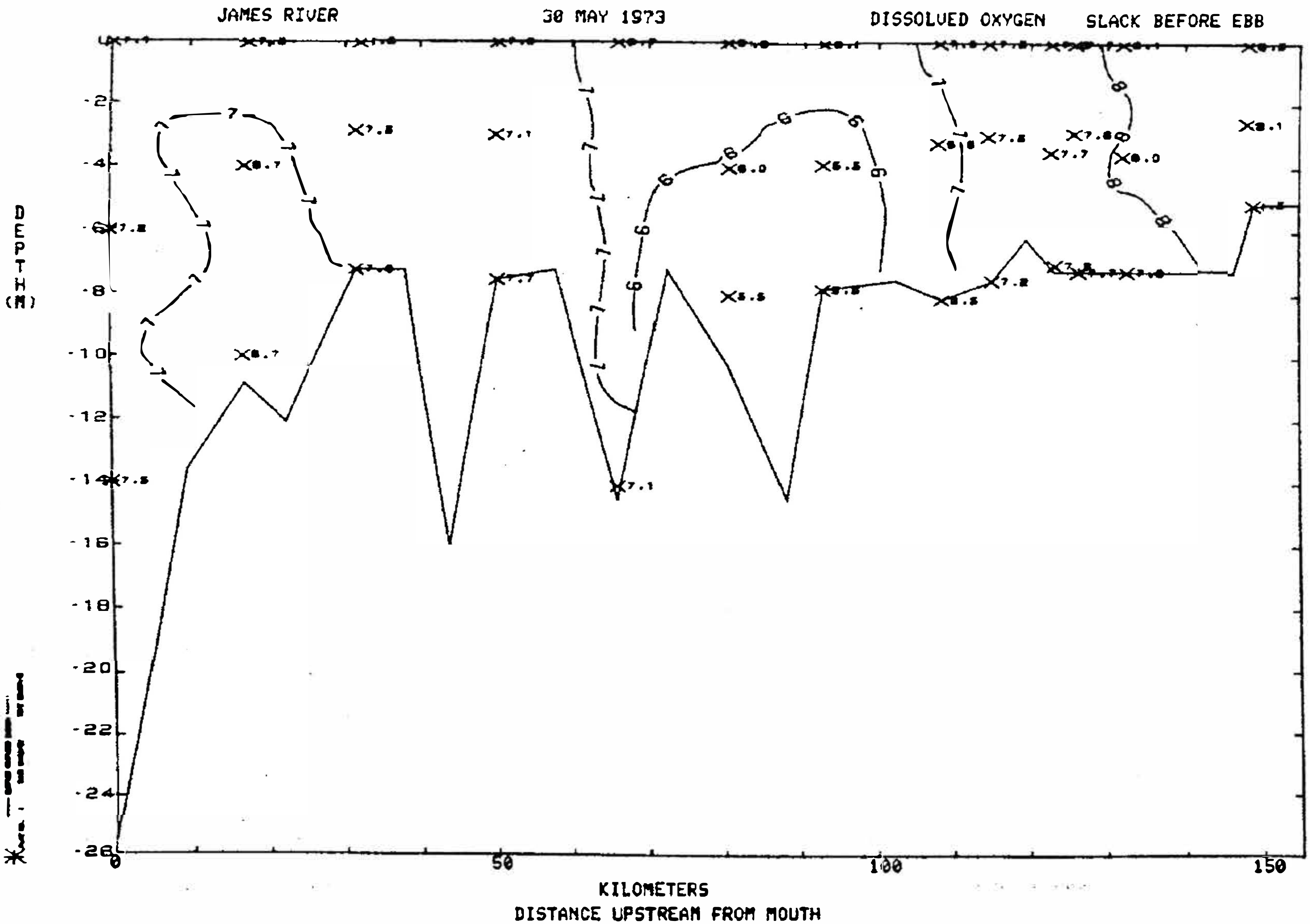
JAMES RIVER 17 OCTOBER 1972 DISSOLVED OXYGEN SLACK BEFORE FLOOD



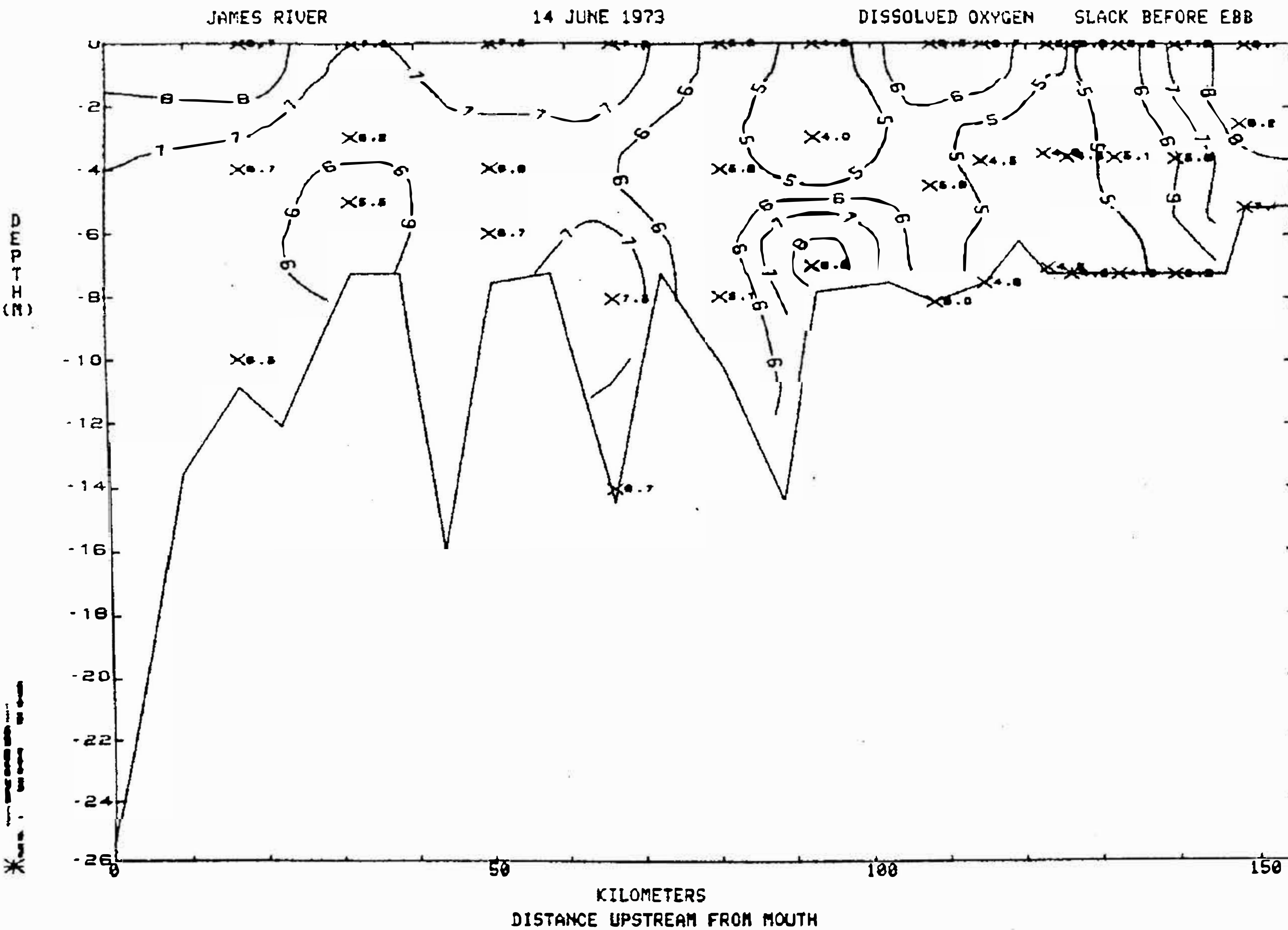


JAMES RIVER
25 OCTOBER 1972
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

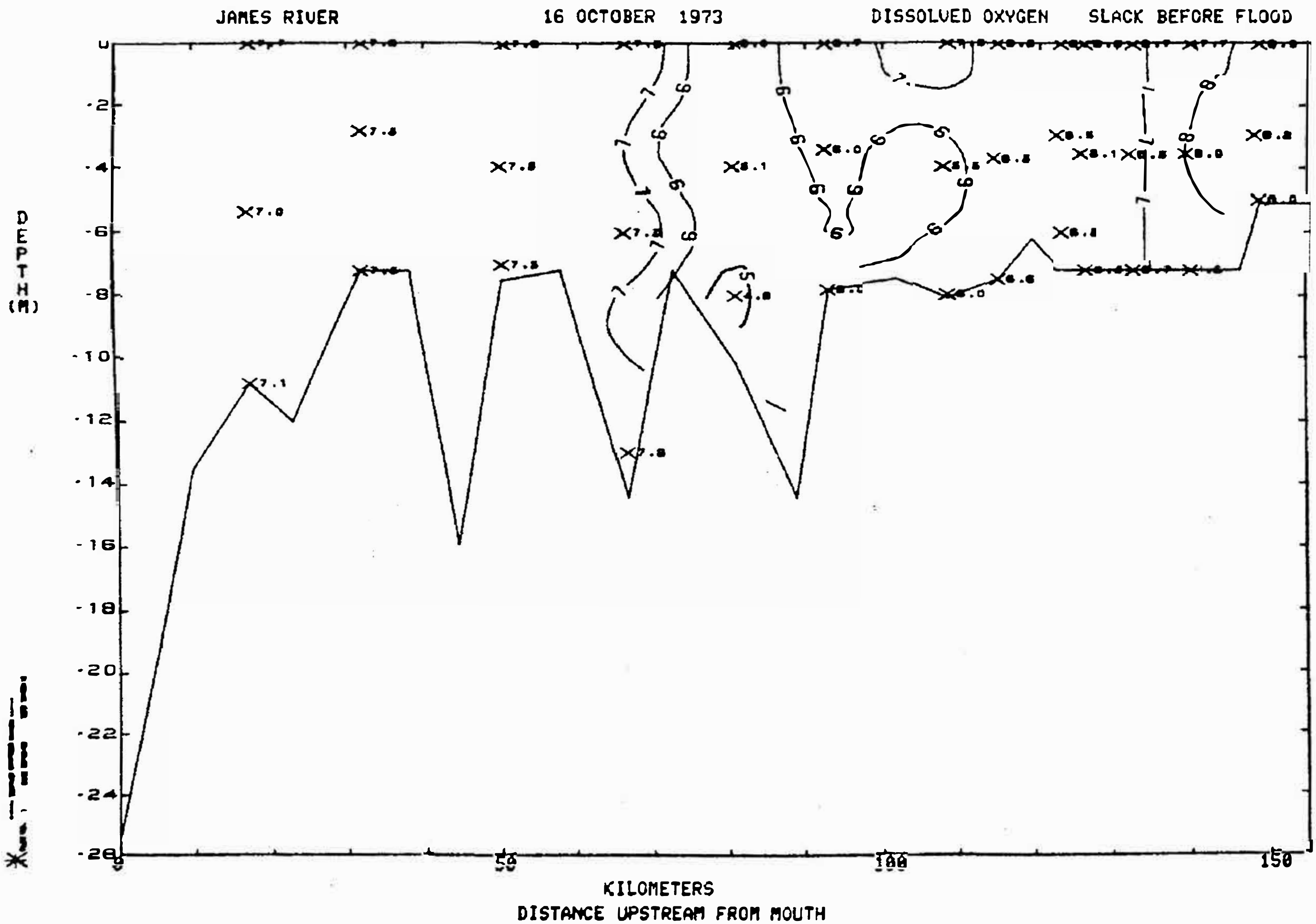

JAMES RIVER
28 NOVEMBER 1972
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

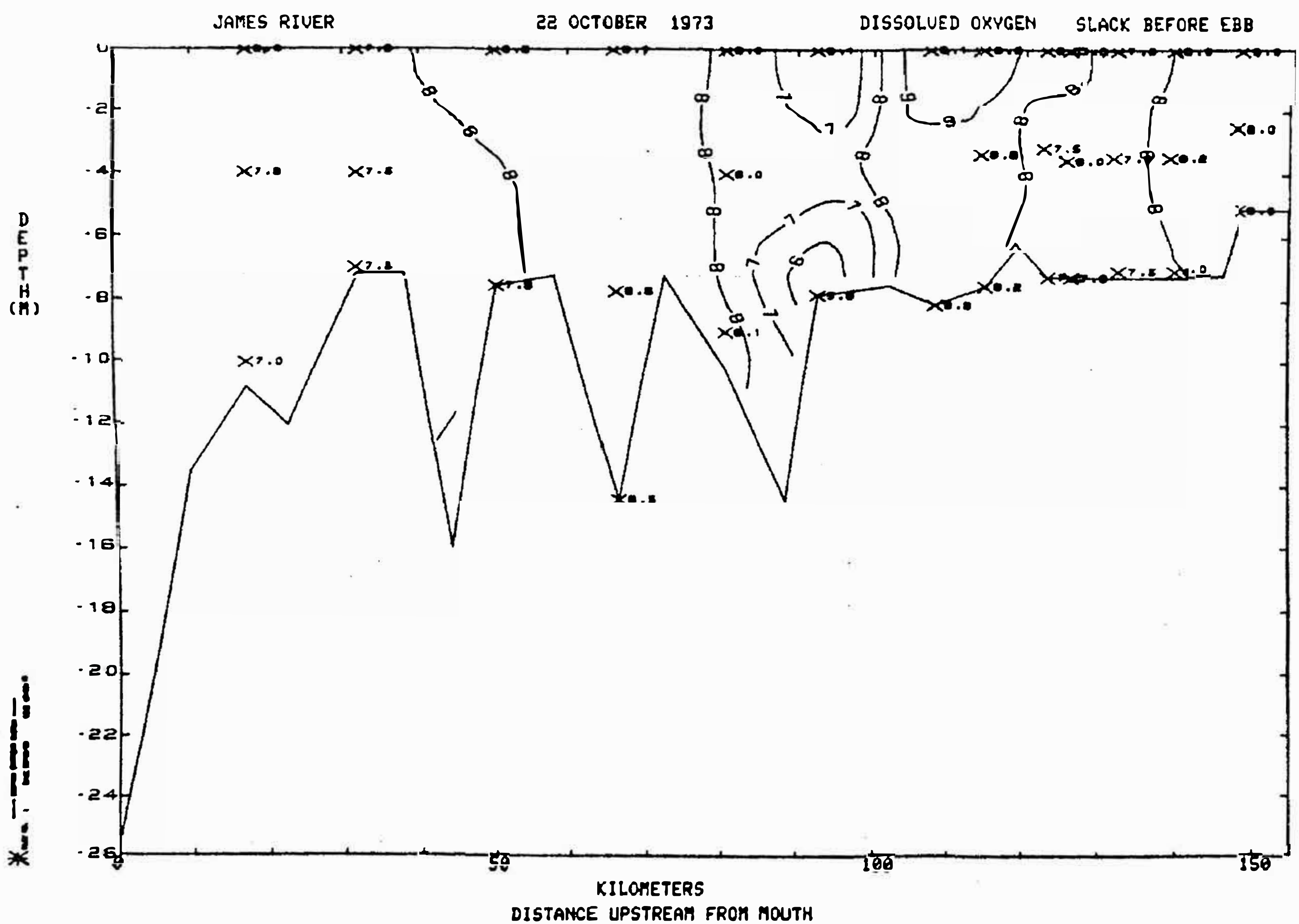


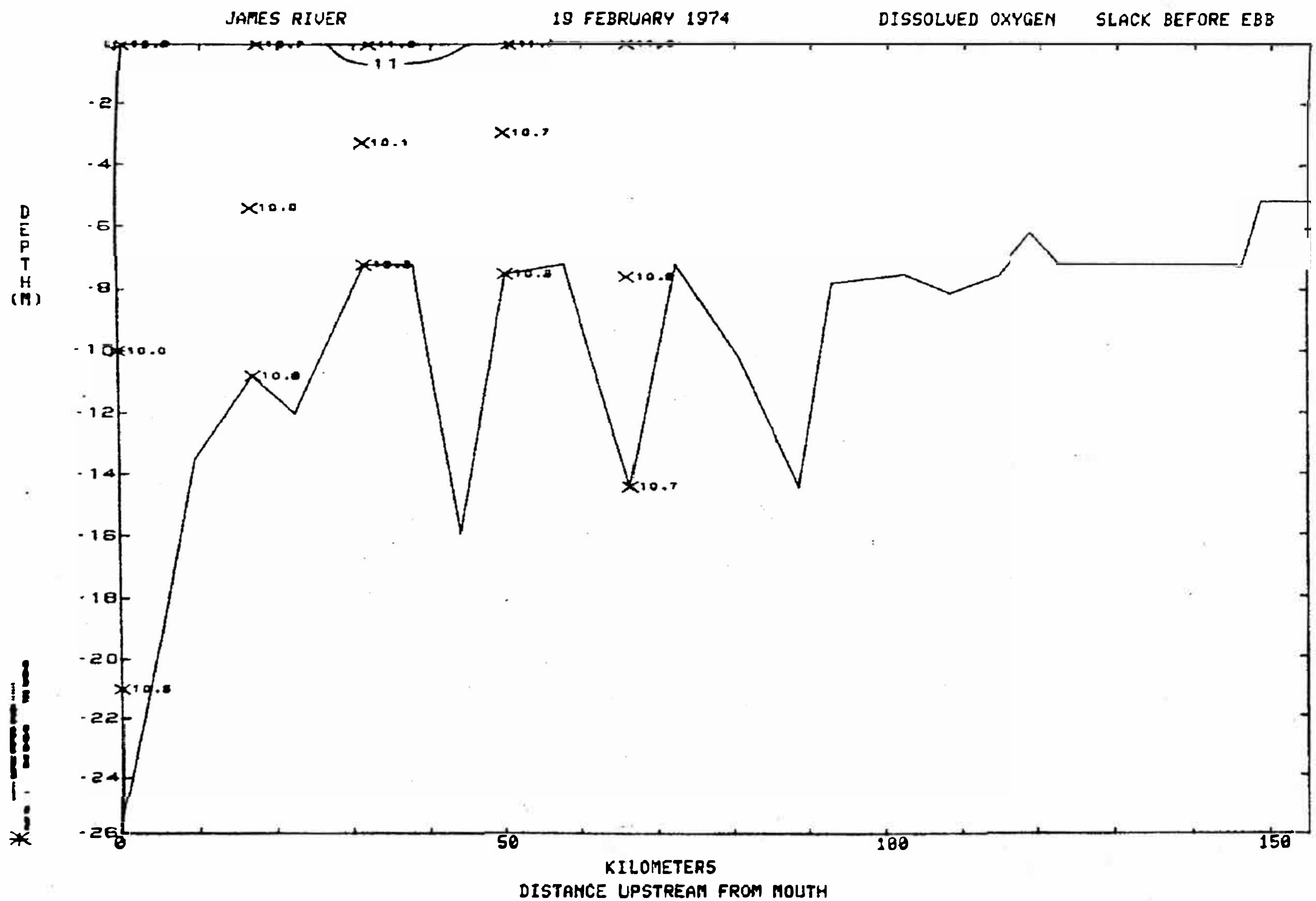
JAMES RIVER
30 MAY 1973
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

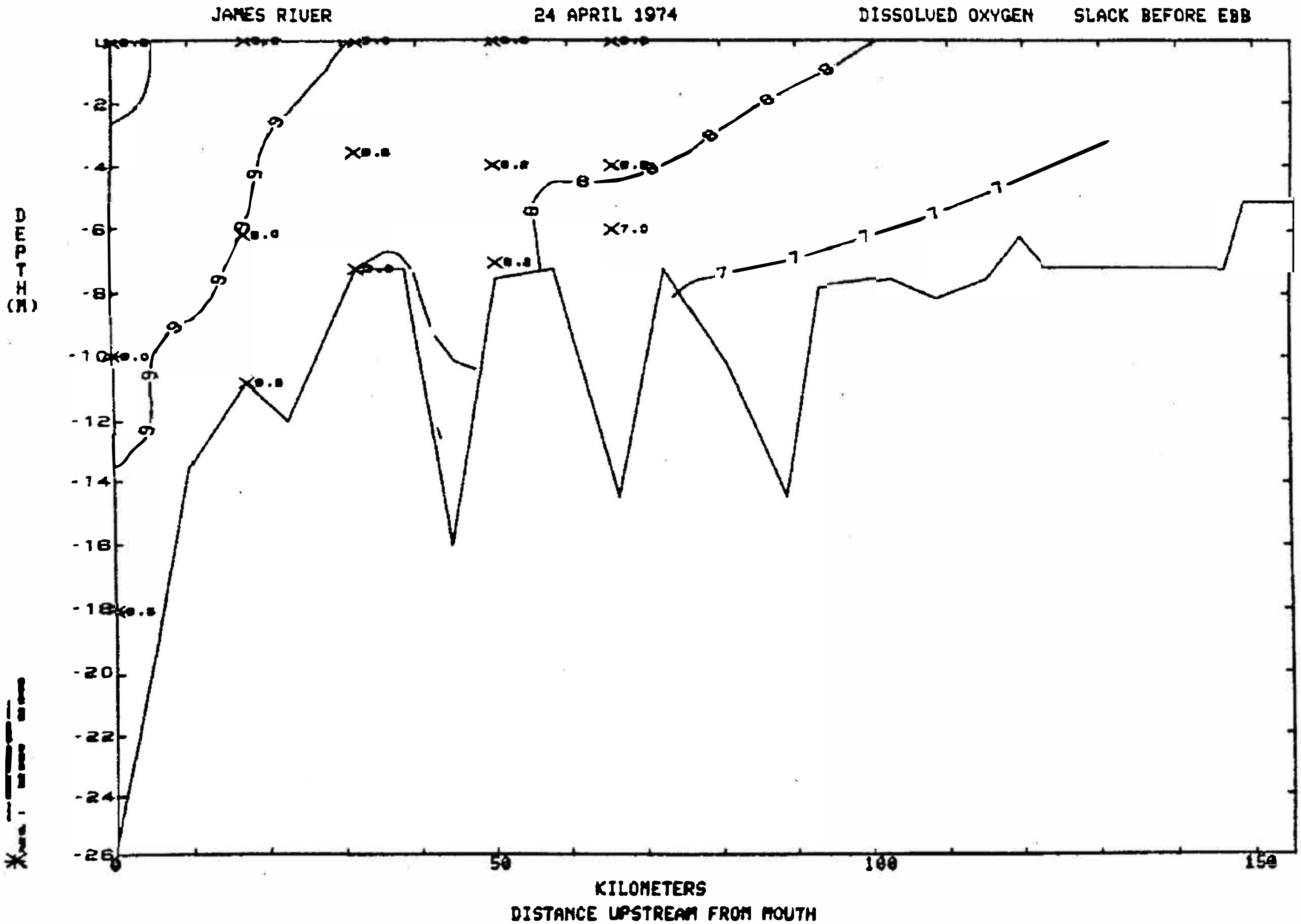


JAMES RIVER
14 JUNE 1973
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26

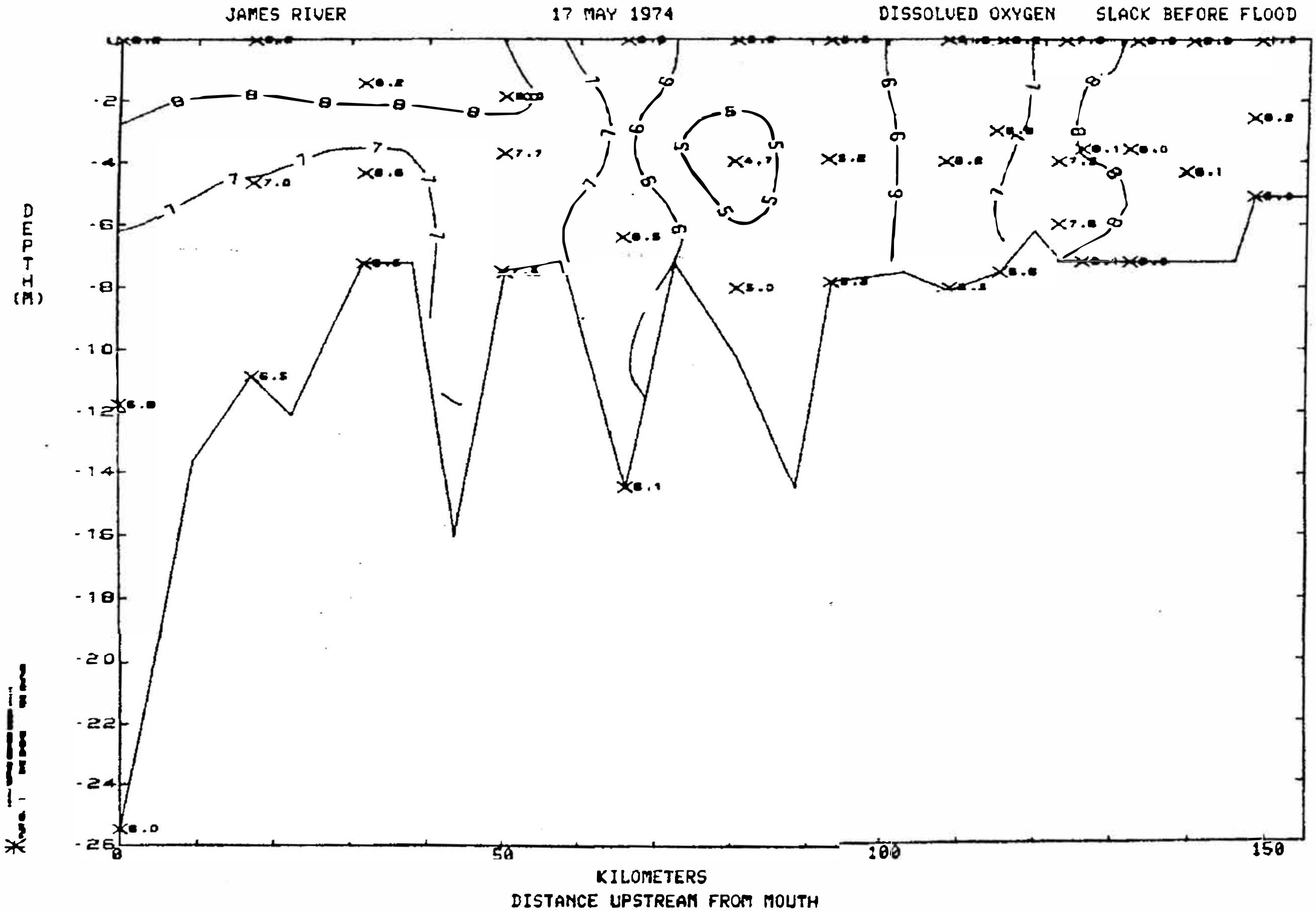

JAMES RIVER
16 OCTOBER 1973
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

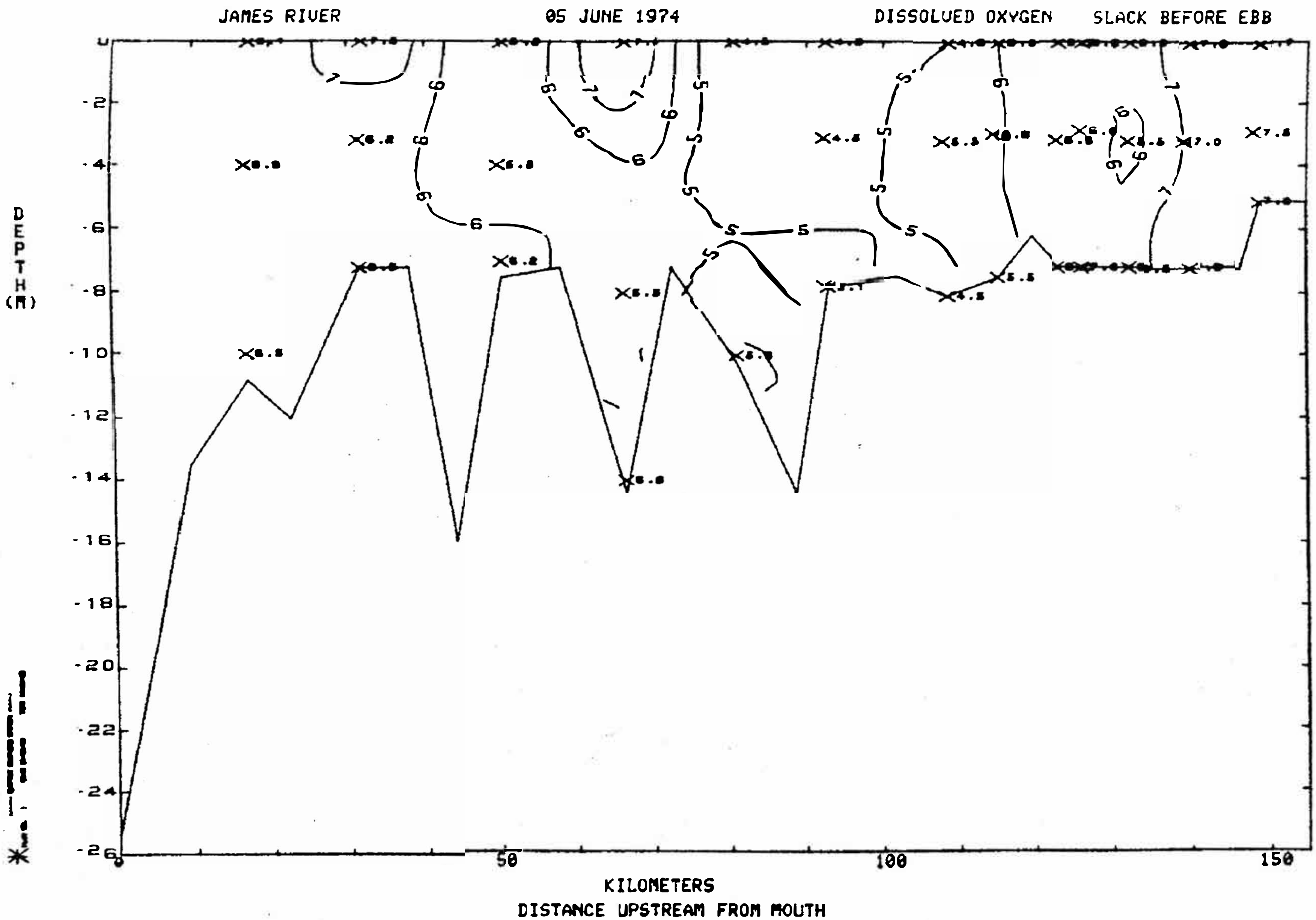

JAMES RIVER
22 OCTOBER 1973
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
19 FEBRUARY 1974
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
11
10.1
10.7
10.0
10.0
10.8
10.7
10.5
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

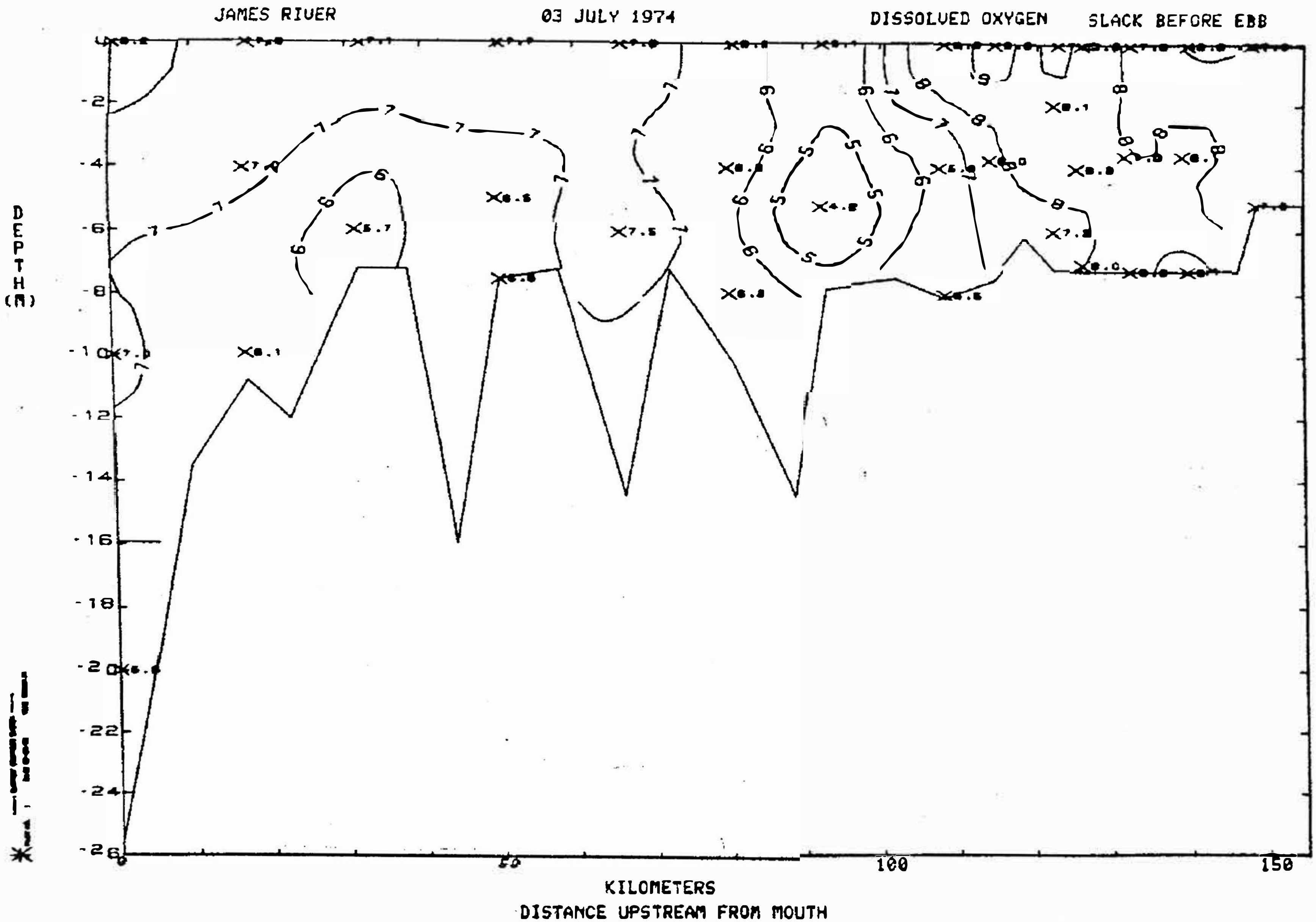


JAMES RIVER
24 APRIL 1974
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

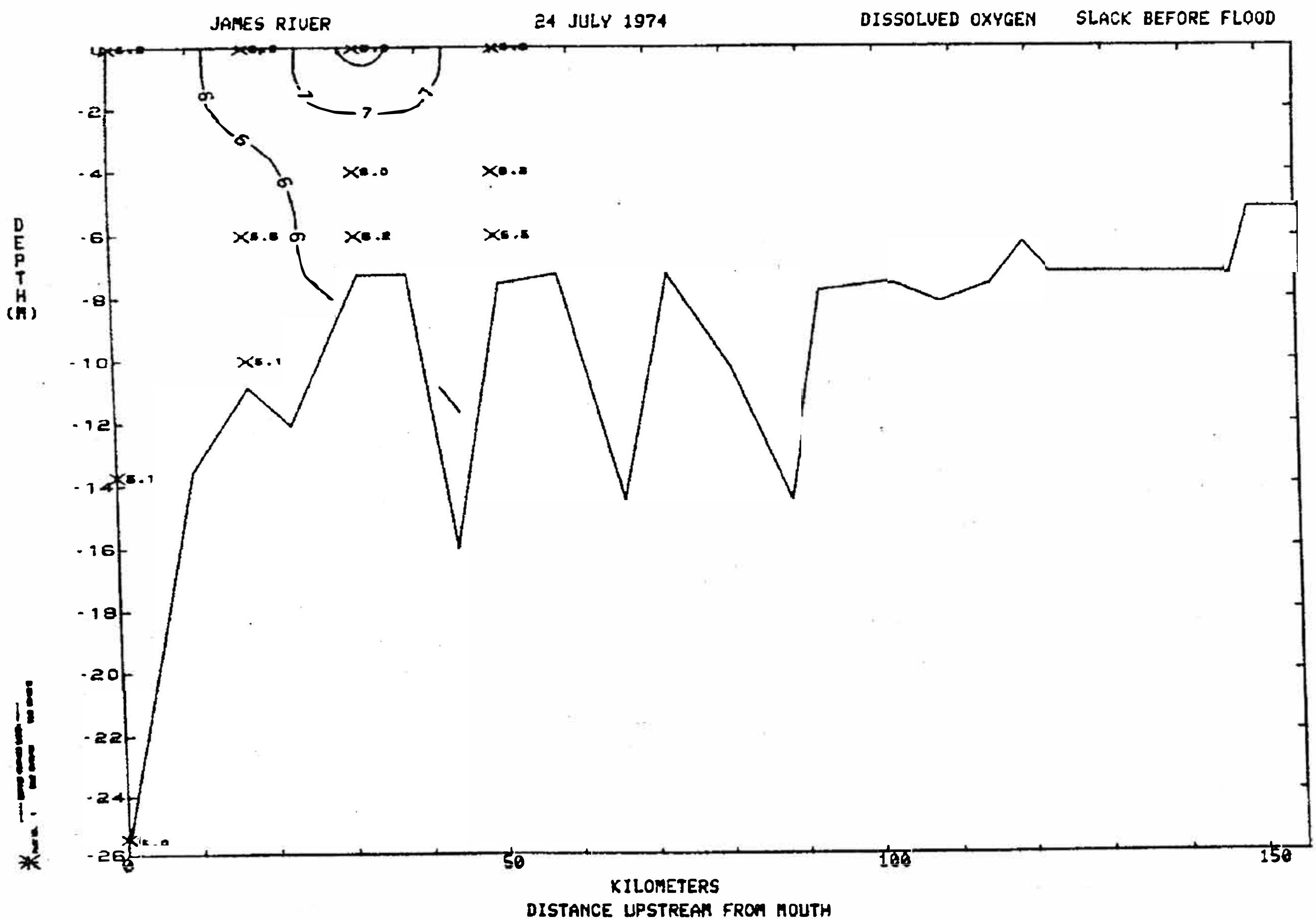

JAMES RIVER
17 MAY 1974
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



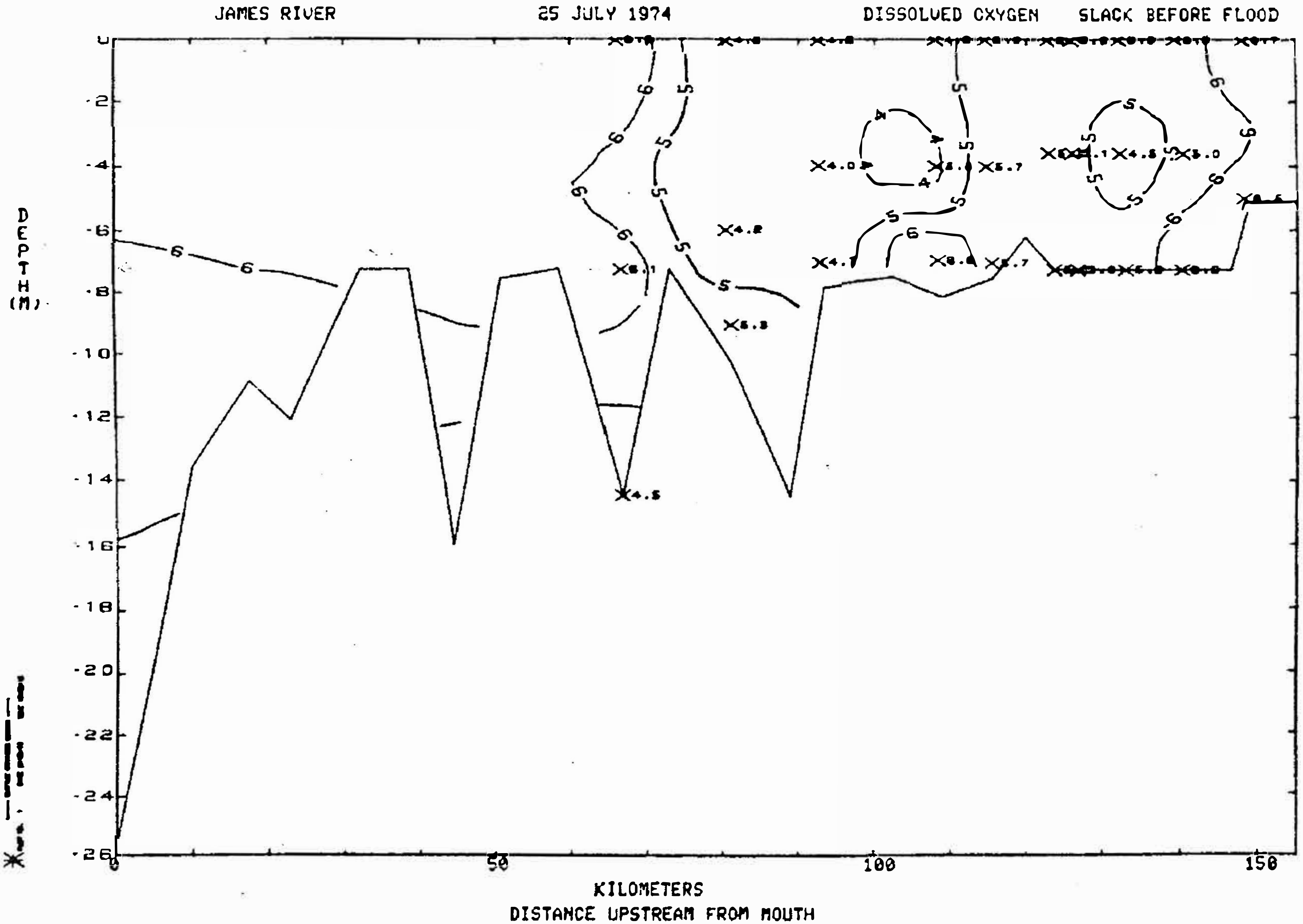
JAMES RIVER
05 JUNE 1974
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



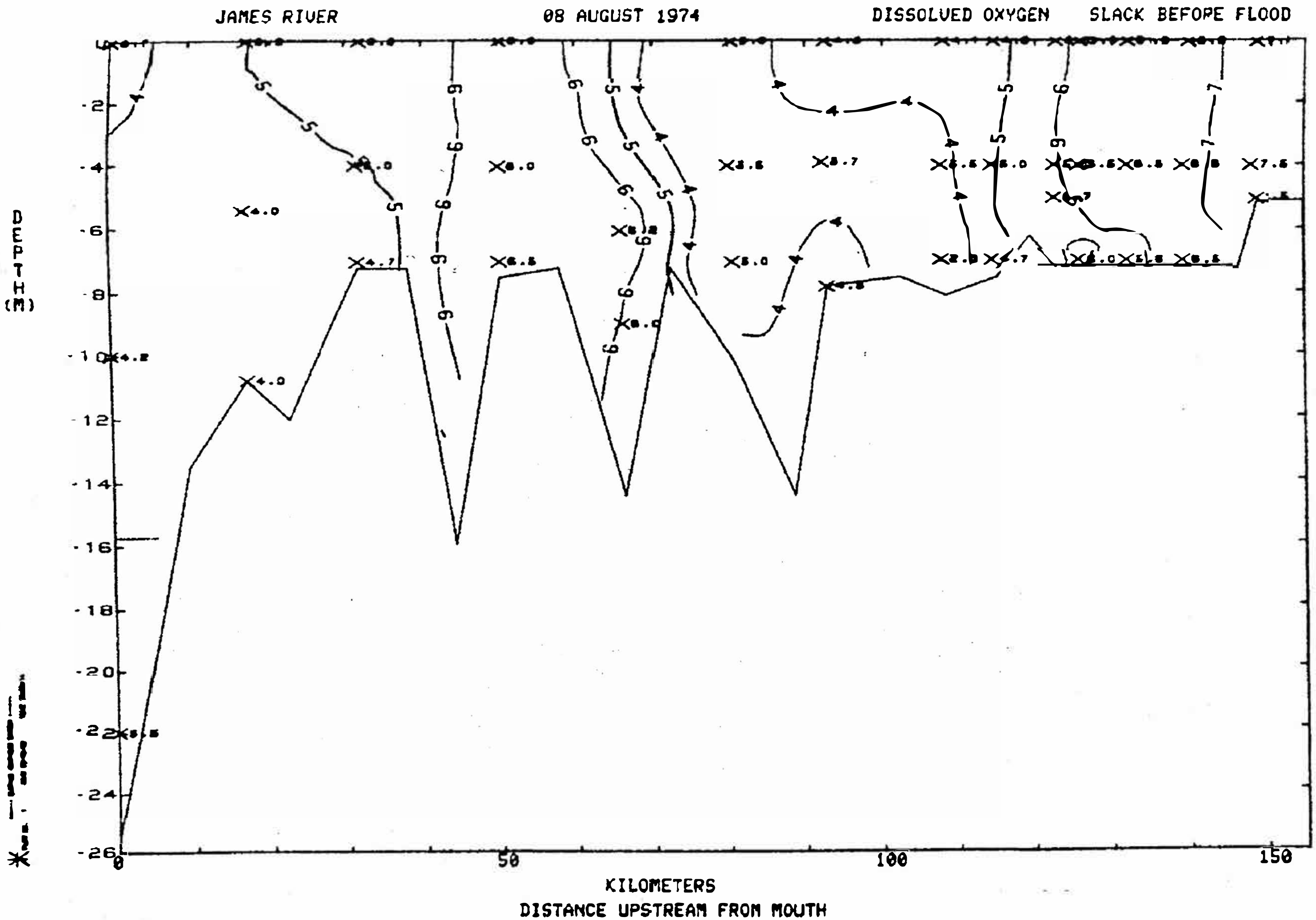
JAMES RIVER
03 JULY 1974
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

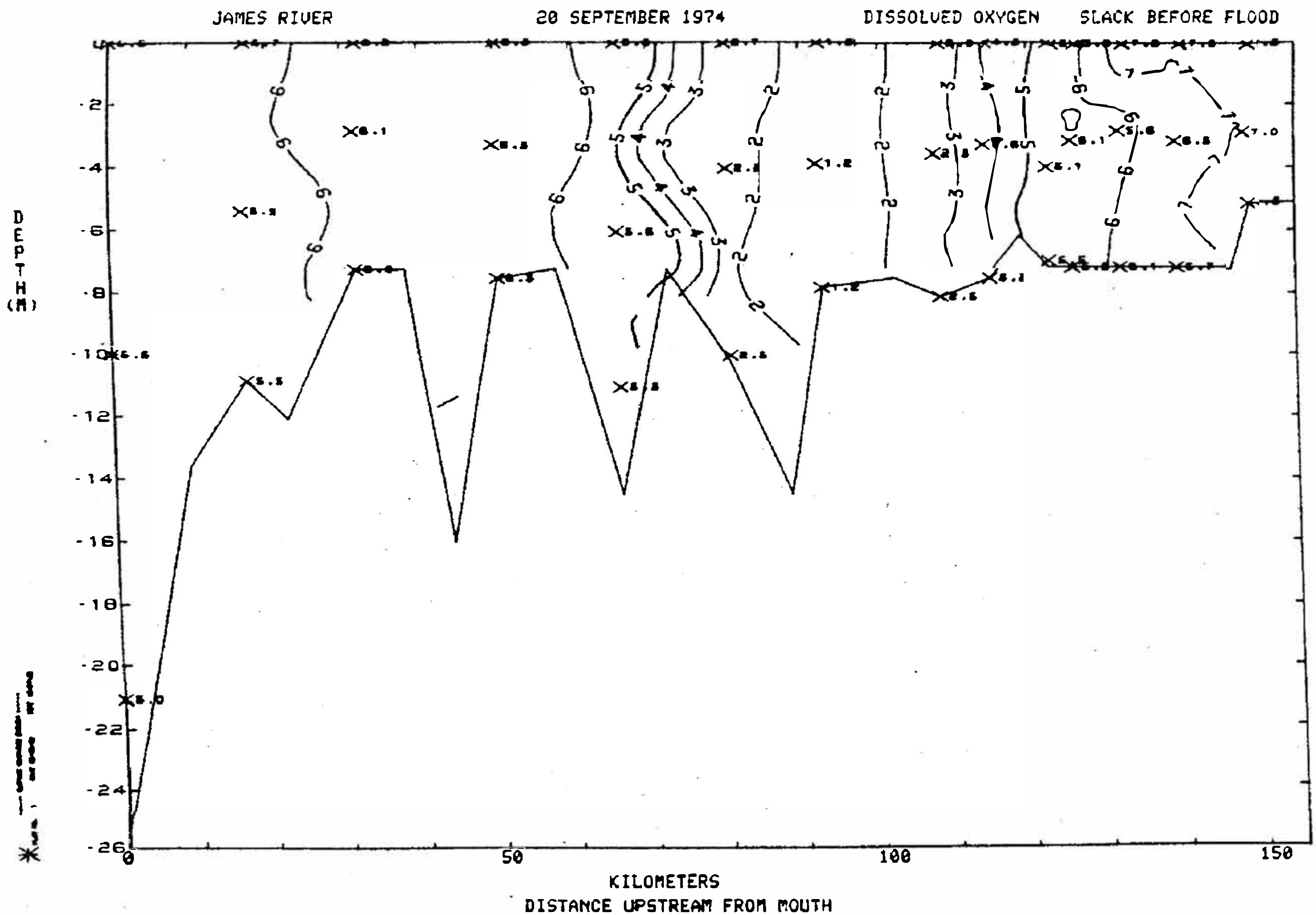


JAMES RIVER
24 JULY 1974
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

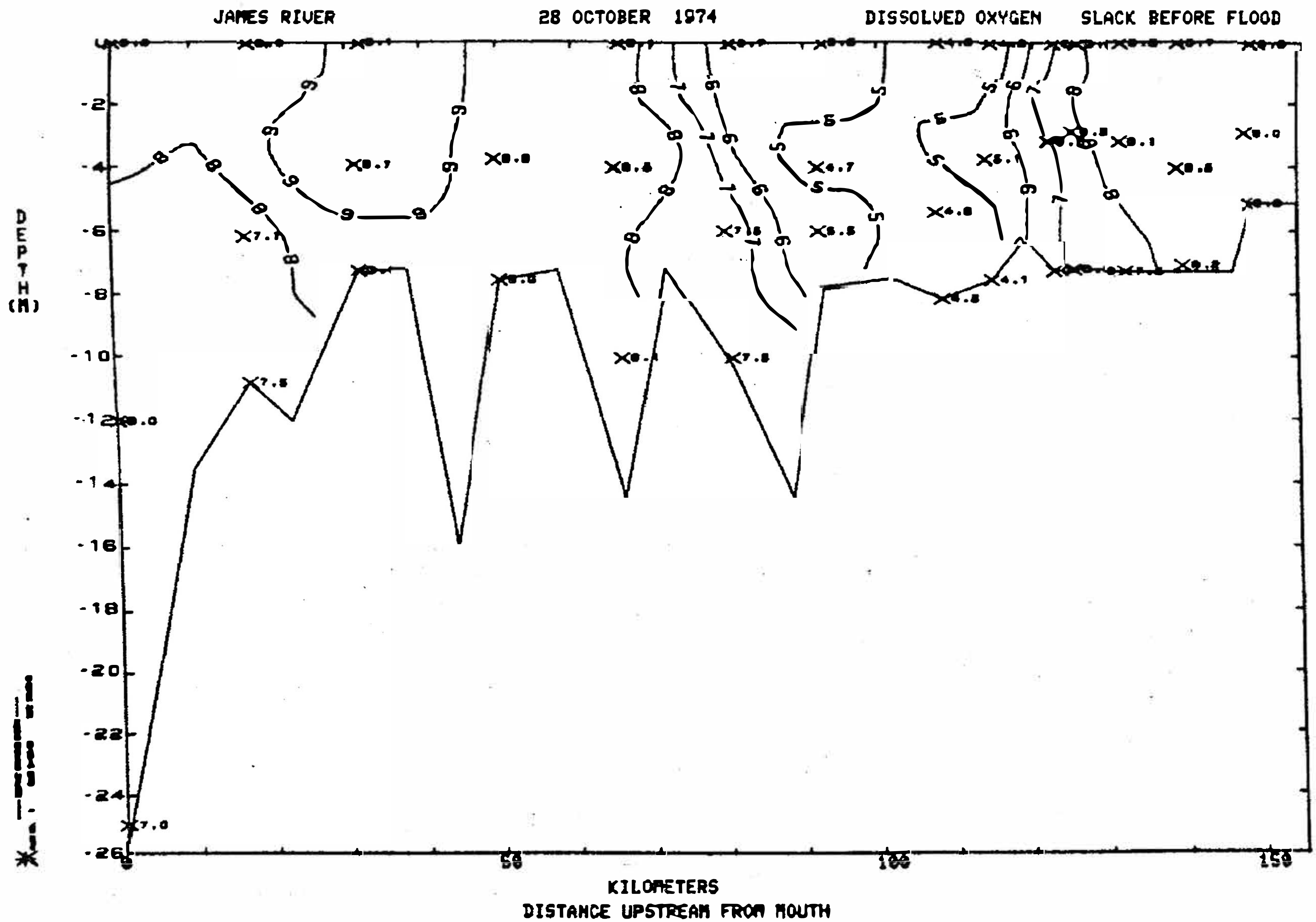


JAMES RIVER
25 JULY 1974
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
0
50
100
150
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26

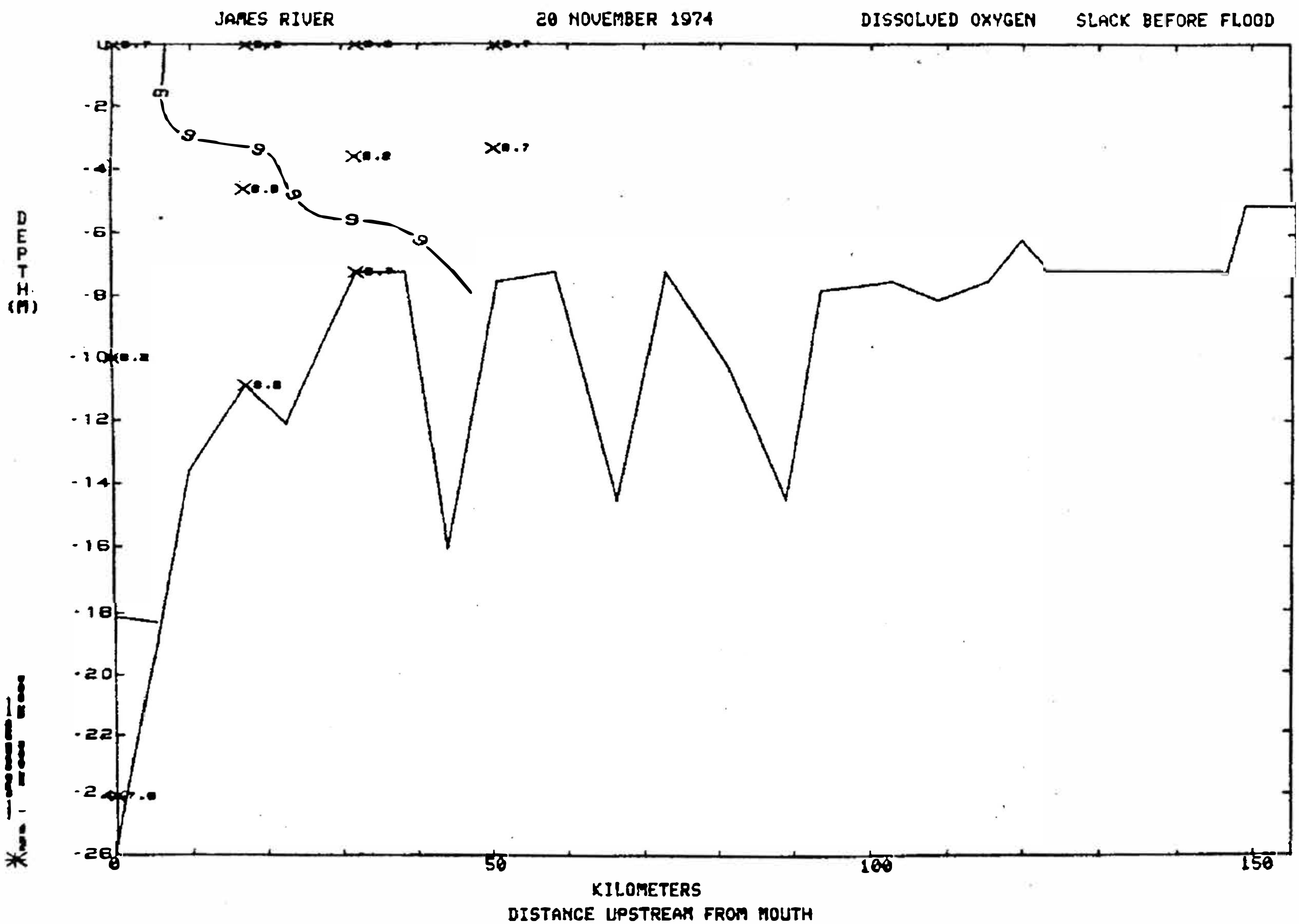

JAMES RIVER
08 AUGUST 1974
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



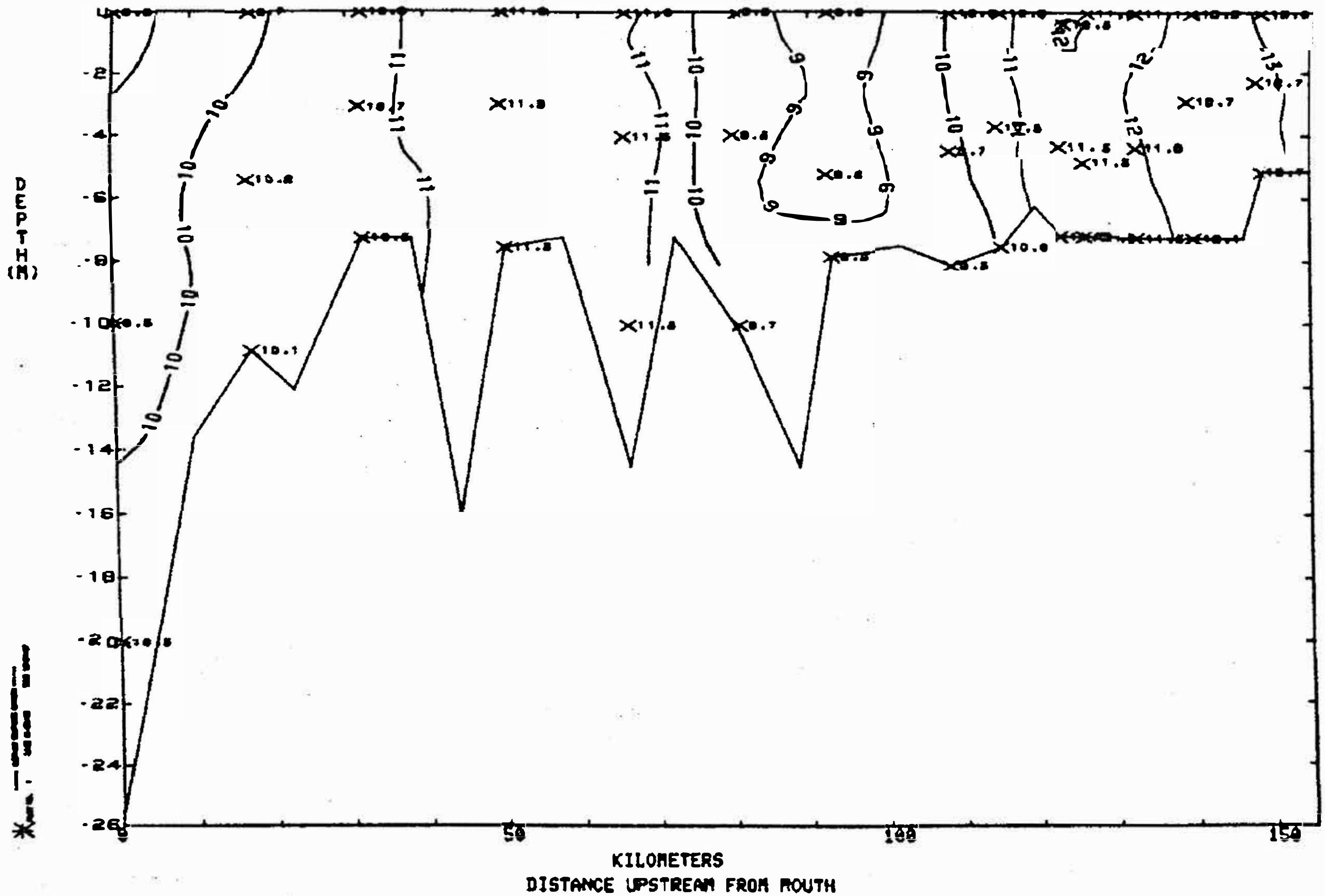
JAMES RIVER
20 SEPTEMBER 1974
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

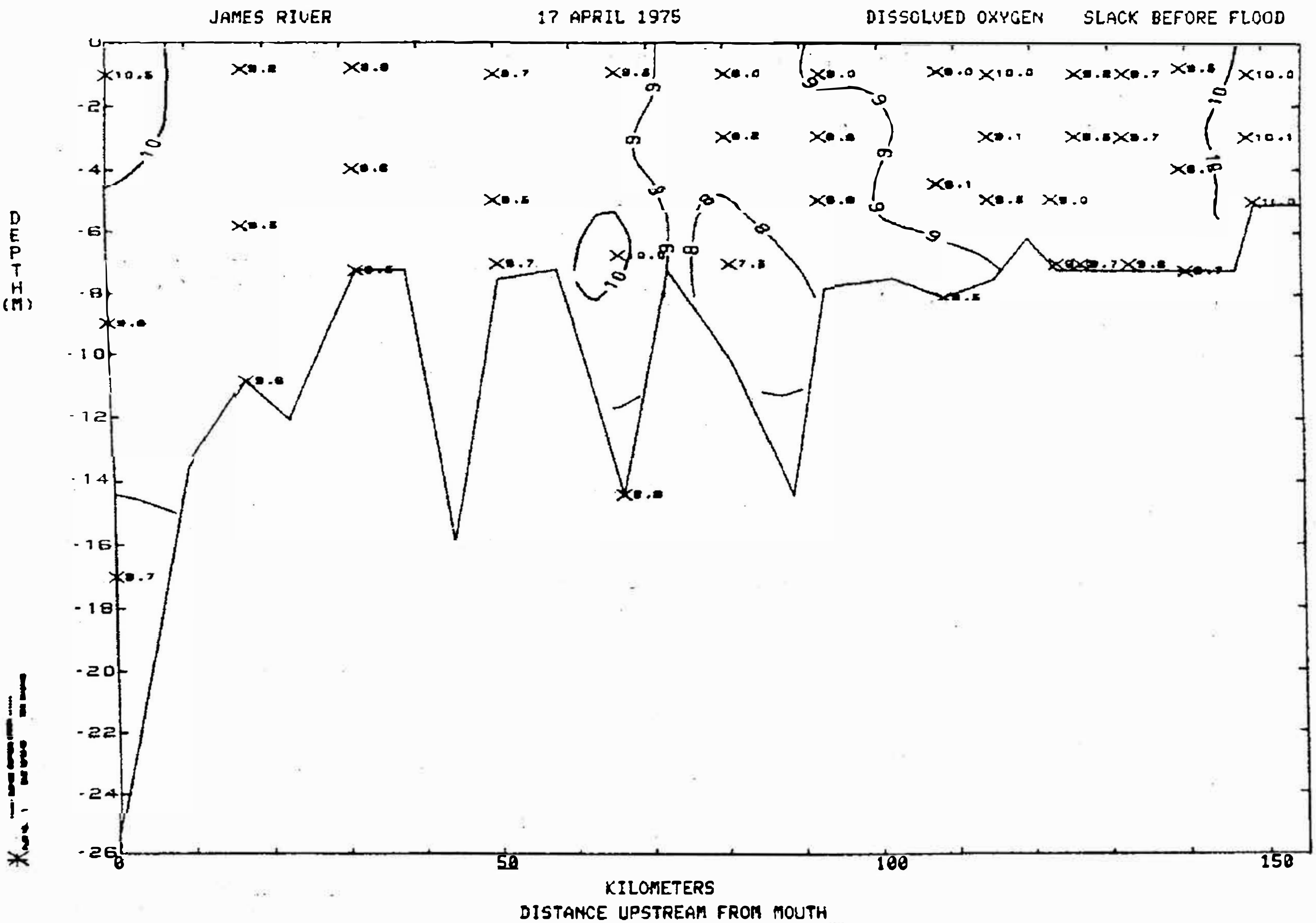


JAMES RIVER
28 OCTOBER 1974
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

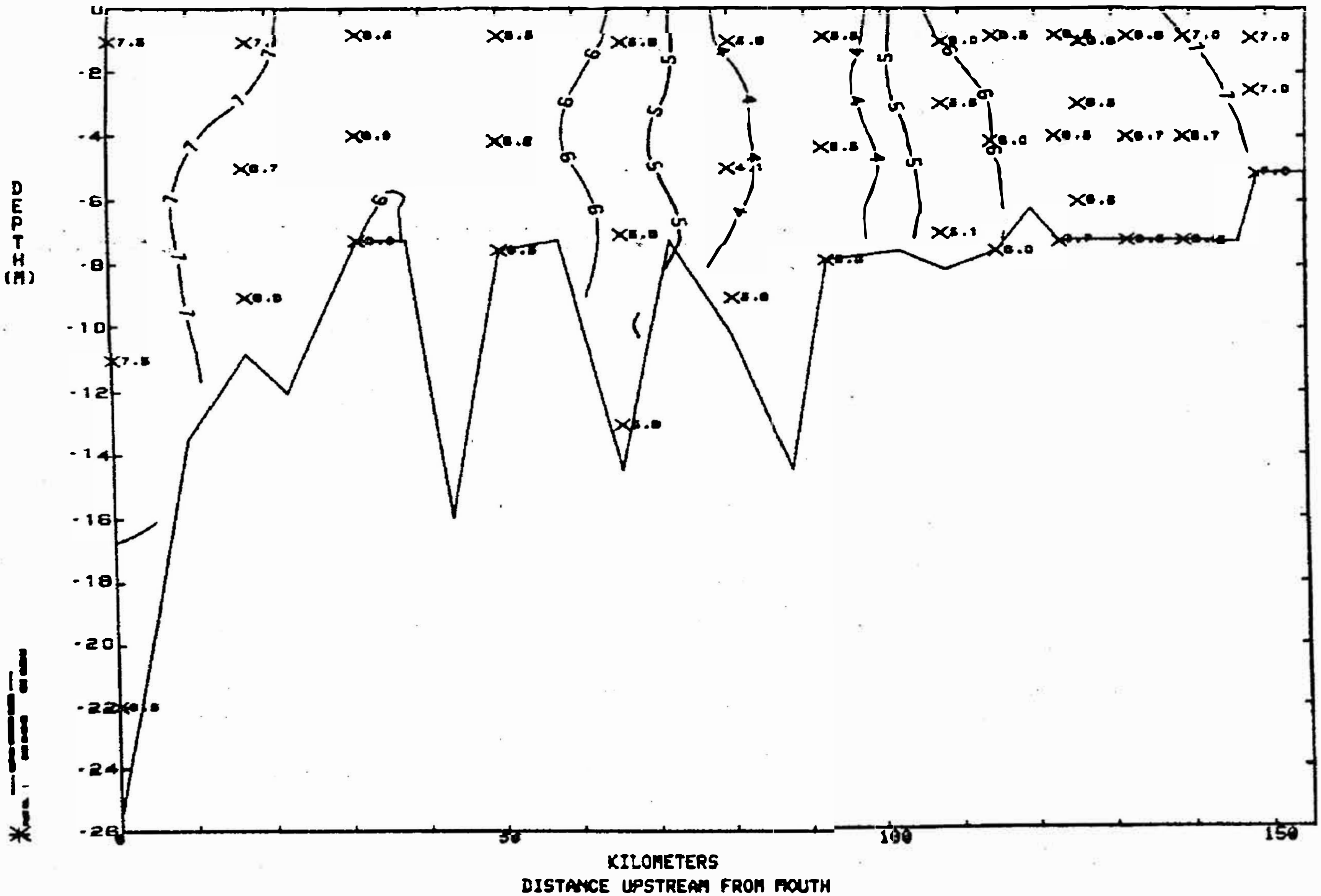

JAMES RIVER
20 NOVEMBER 1974
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

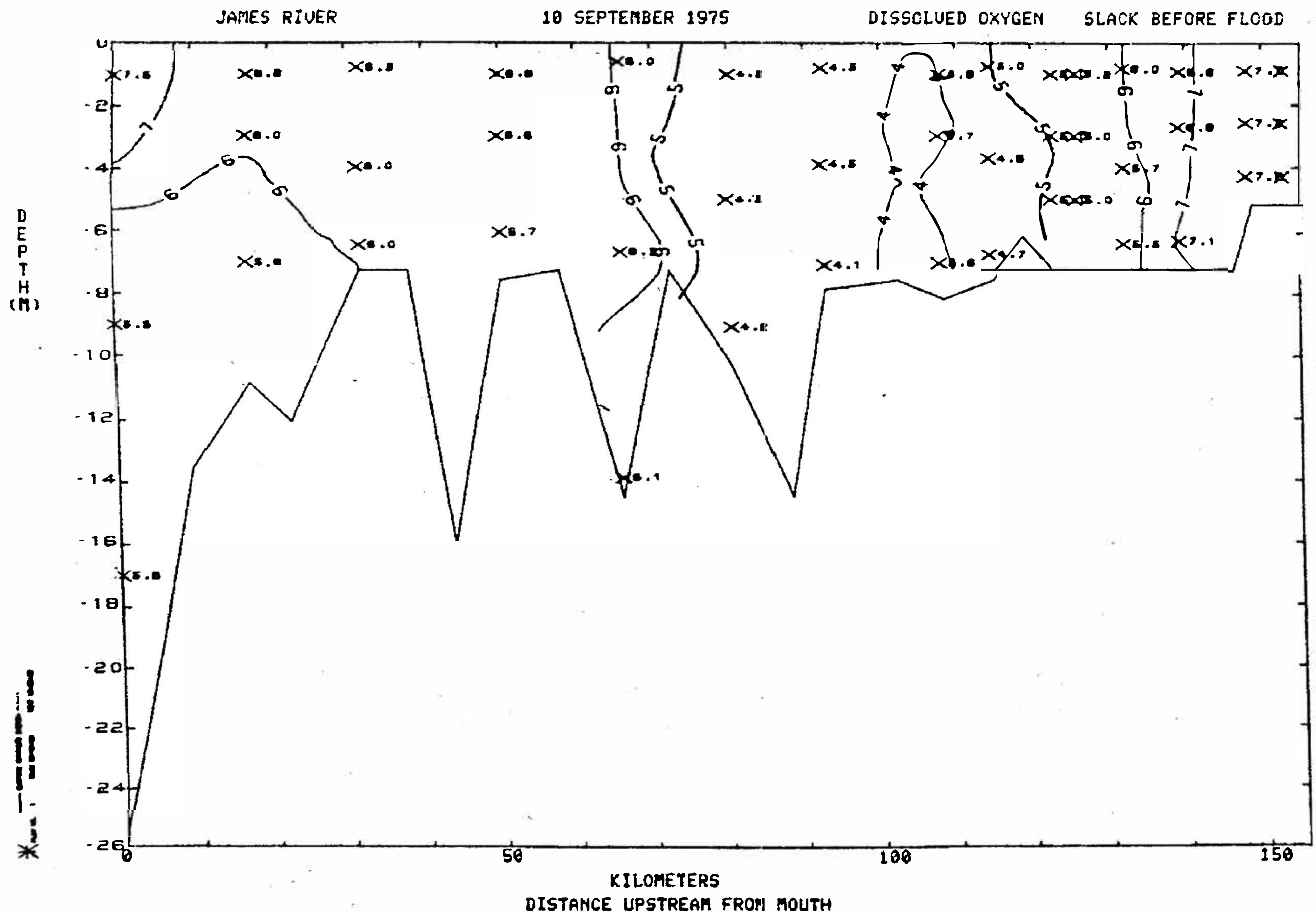
JAMES RIVER 13 DECEMBER 1974 DISSOLVED OXYGEN SLACK BEFORE EBB

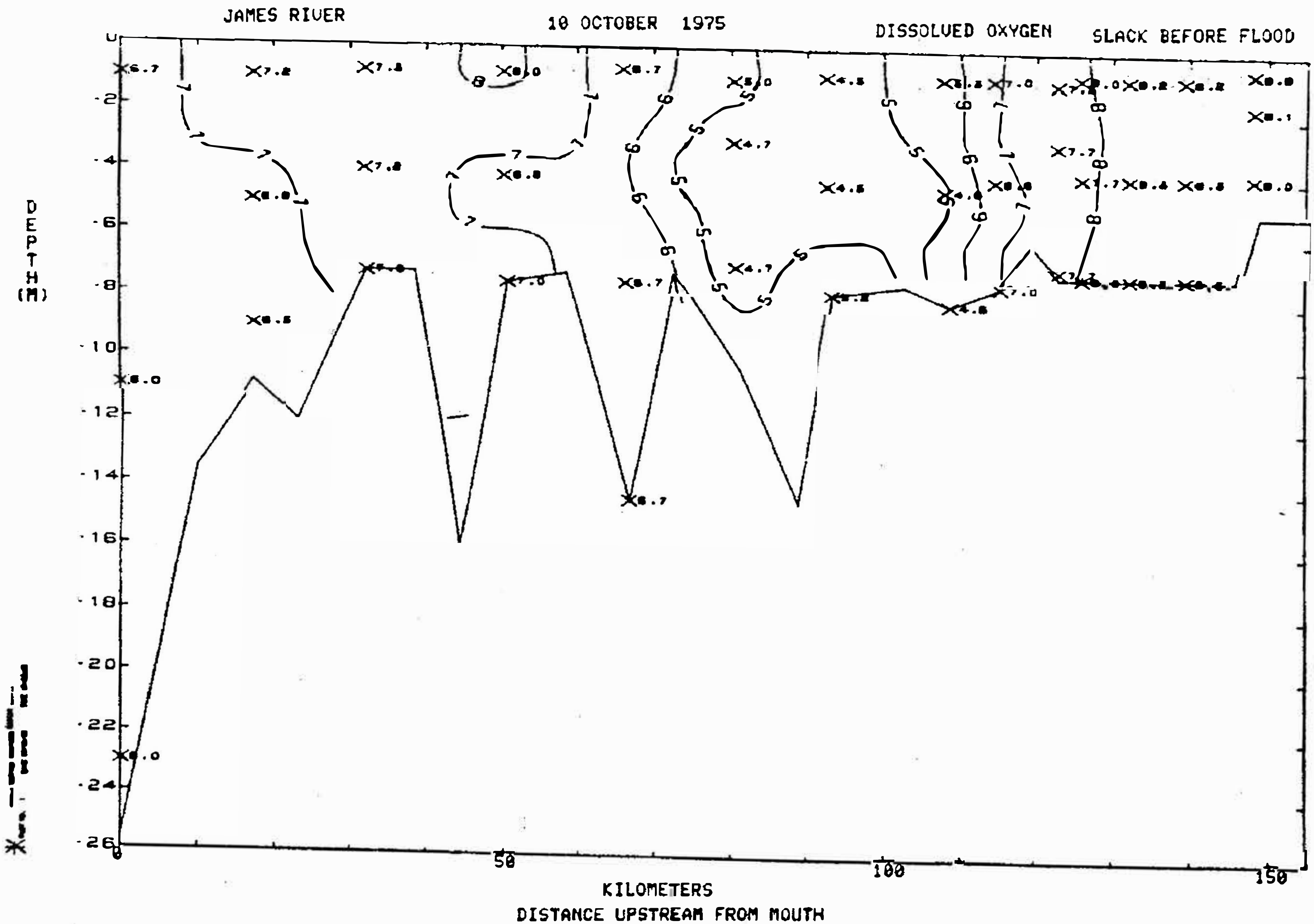



JAMES RIVER
17 APRIL 1975
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

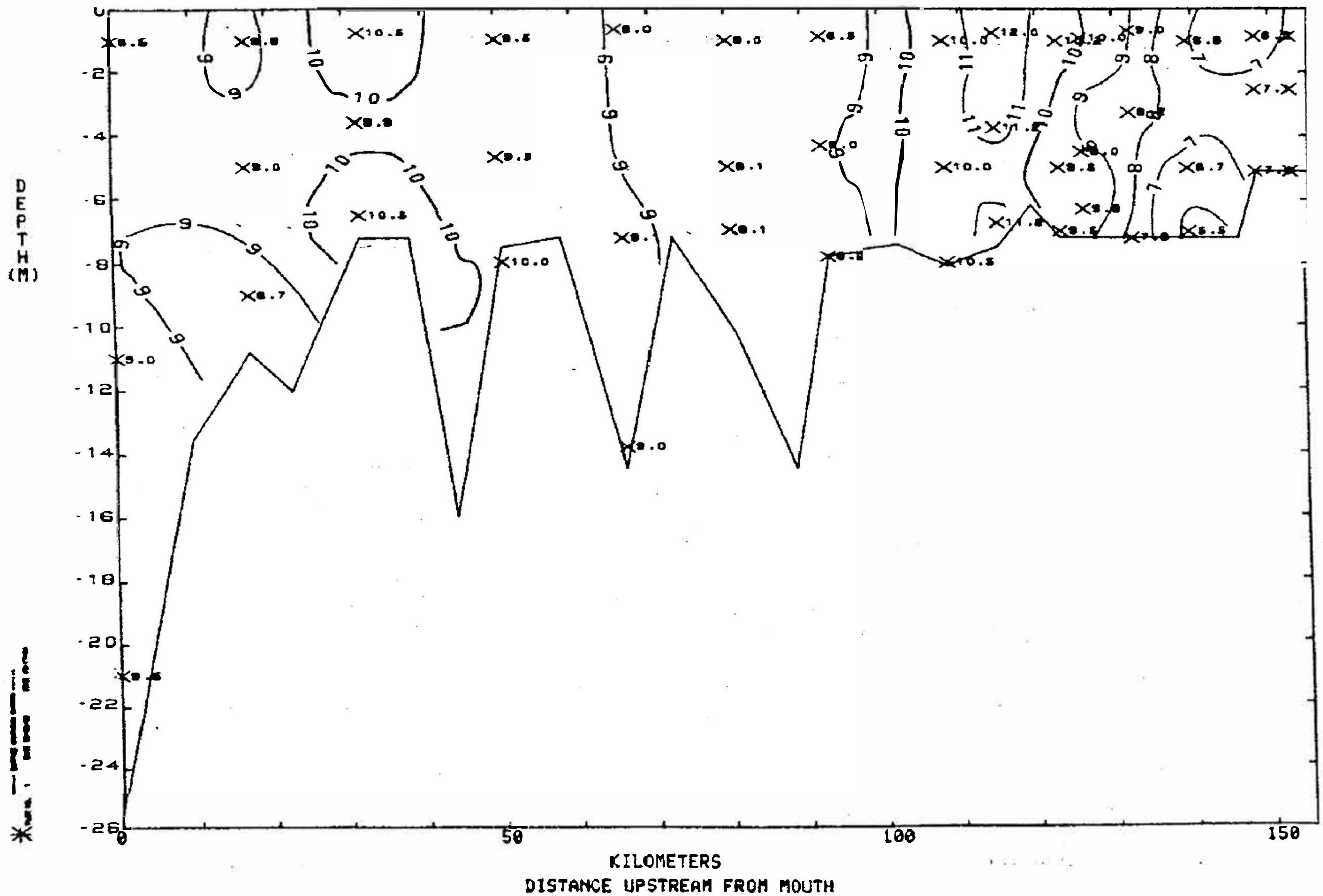
JAMES RIVER 22 MAY 1975 DISSOLVED OXYGEN SLACK BEFORE EBB

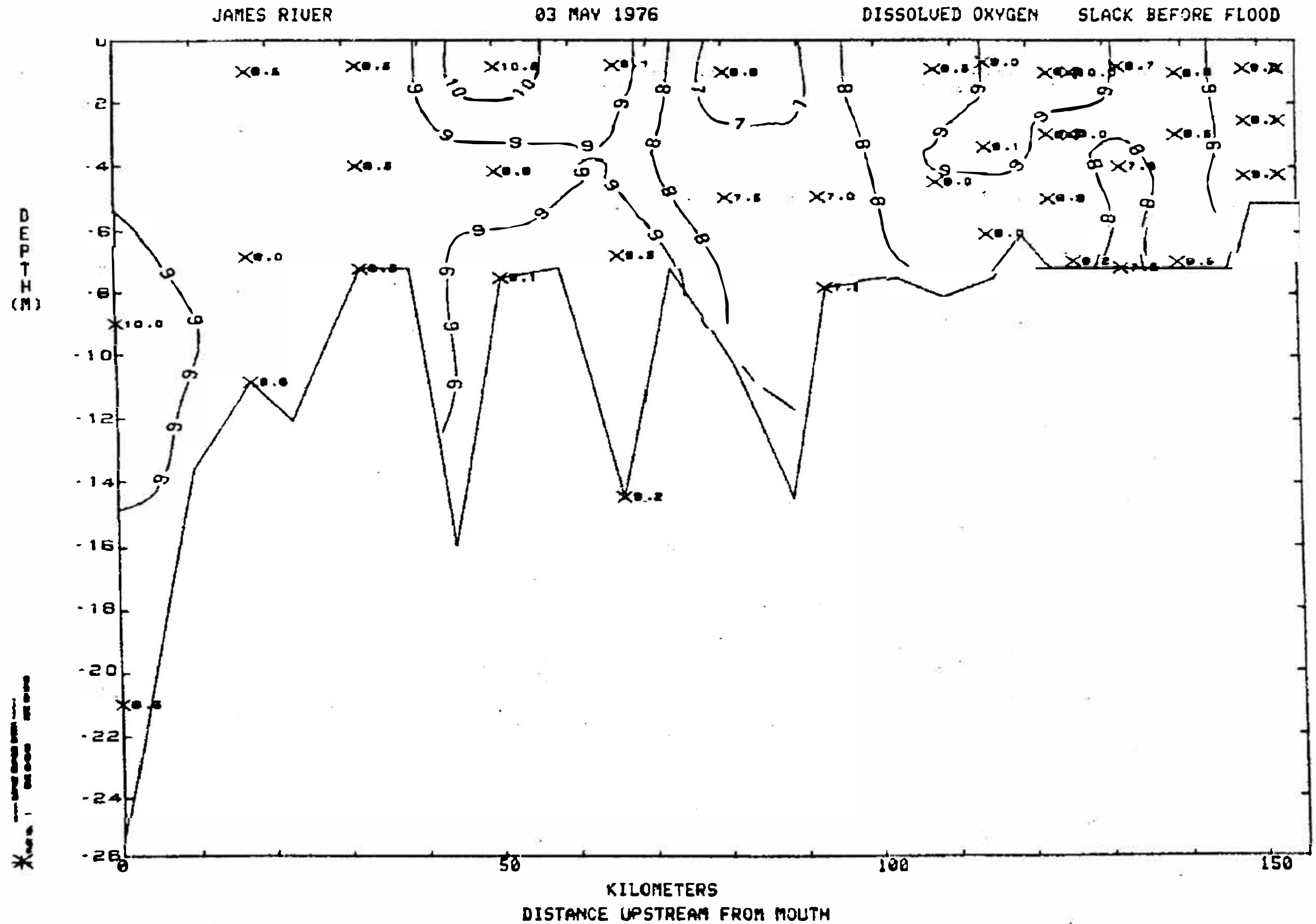



JAMES RIVER
10 SEPTEMBER 1975
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
10 OCTOBER 1975
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

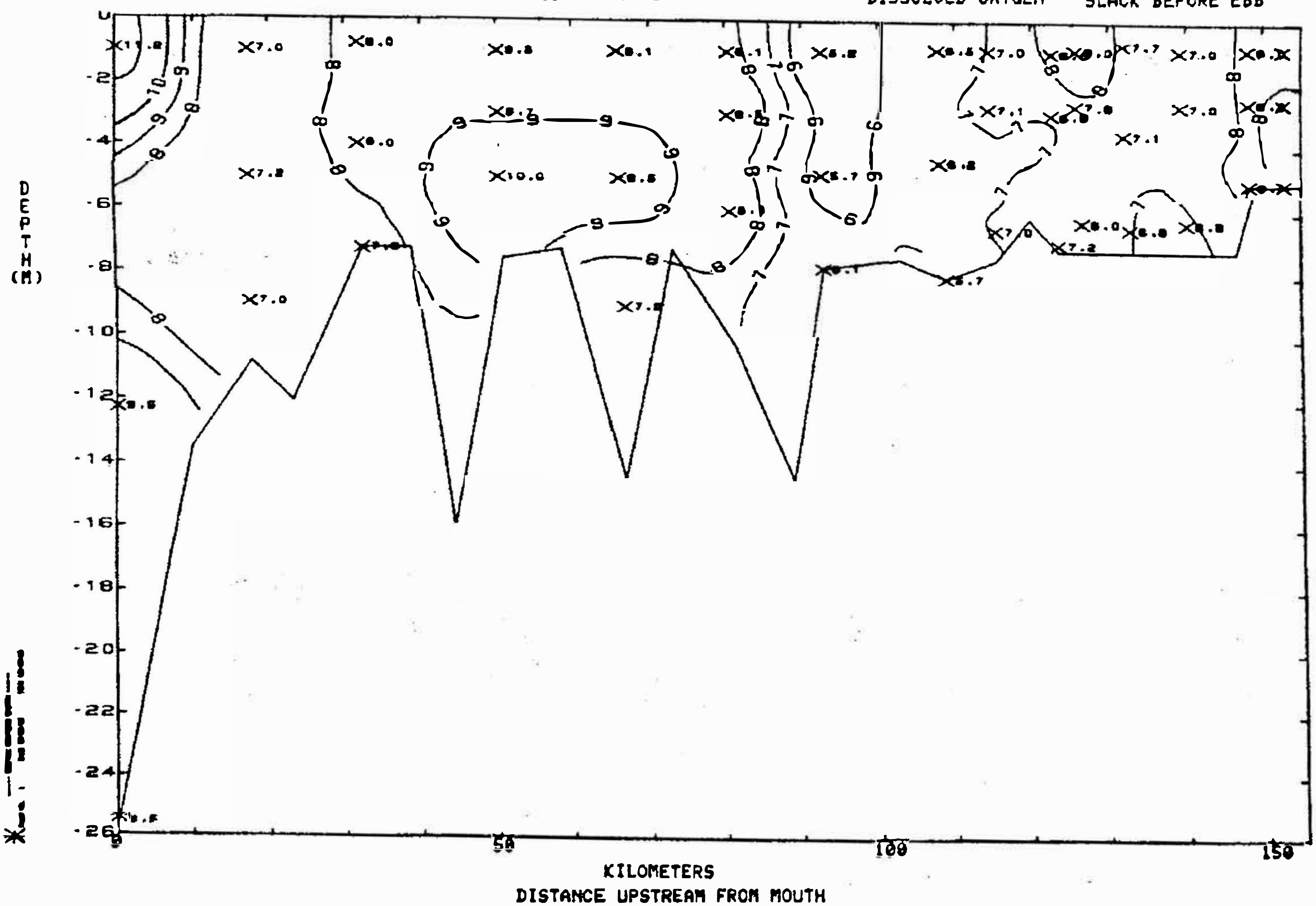
JAMES RIVER 19 APRIL 1976 DISSOLVED OXYGEN SLACK BEFORE FLOOD

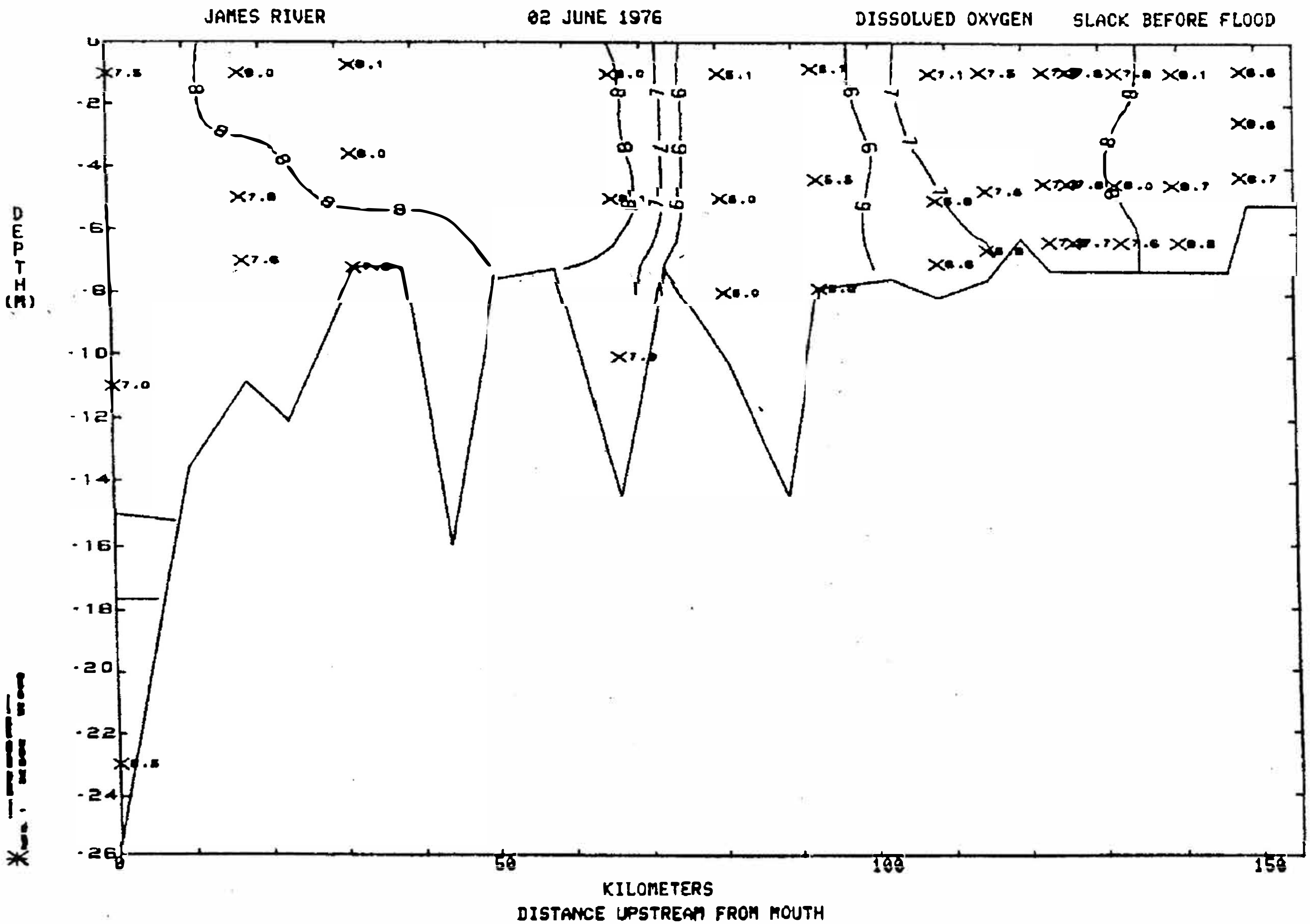




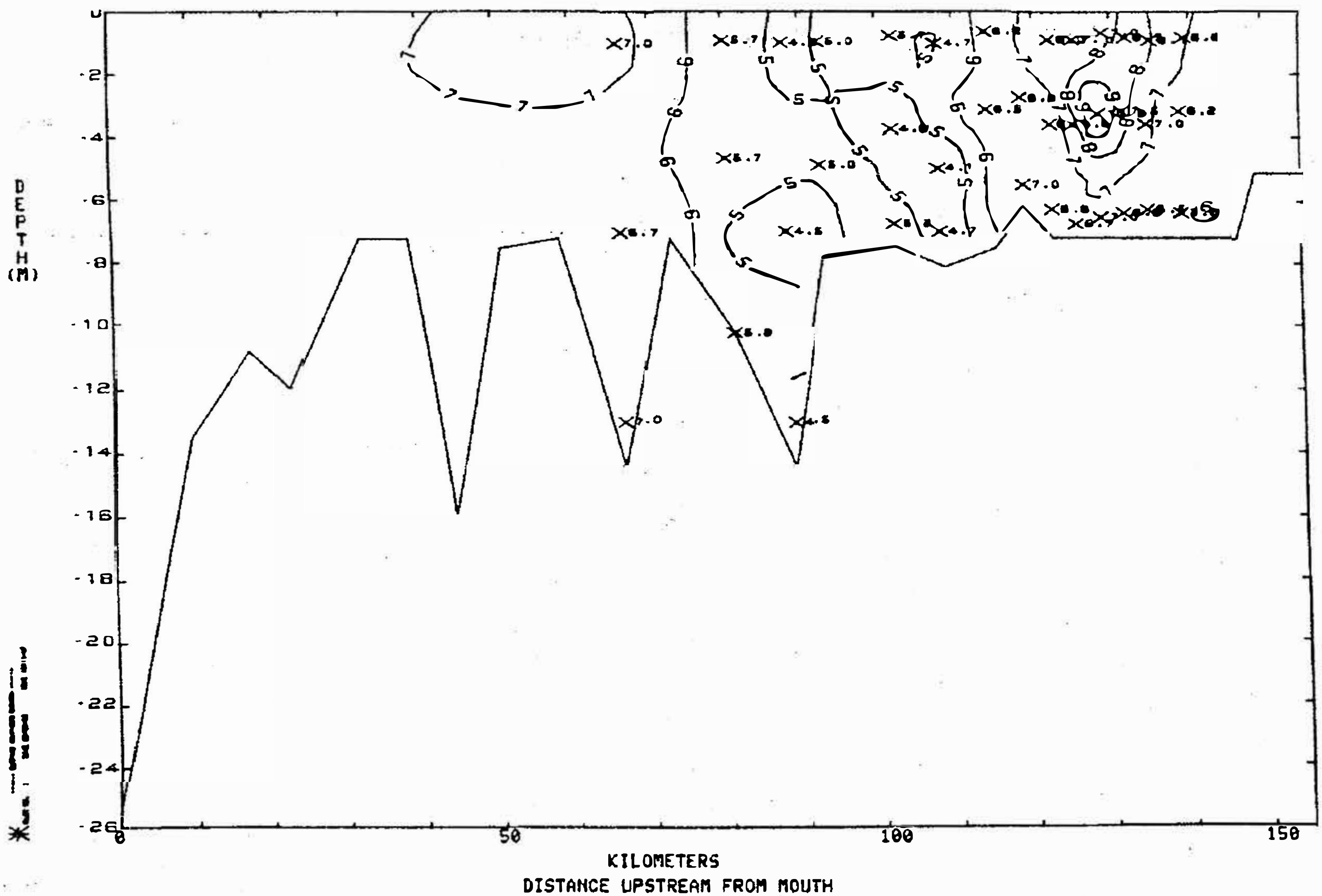
JAMES RIVER
03 MAY 1976
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

JAMES RIVER 13 MAY 1976 DISSOLVED OXYGEN SLACK BEFORE EBB

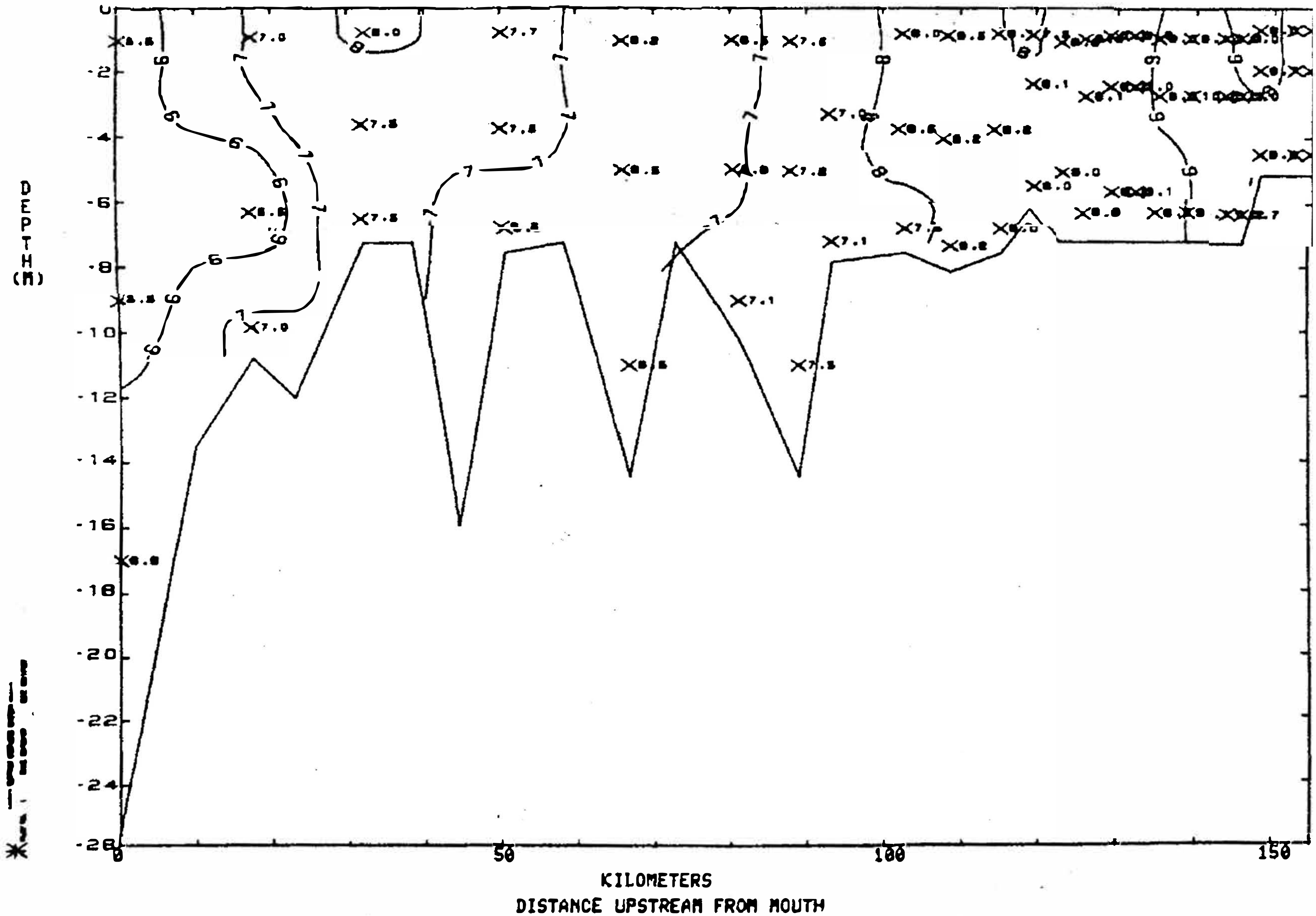



JAMES RIVER
02 JUNE 1976
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

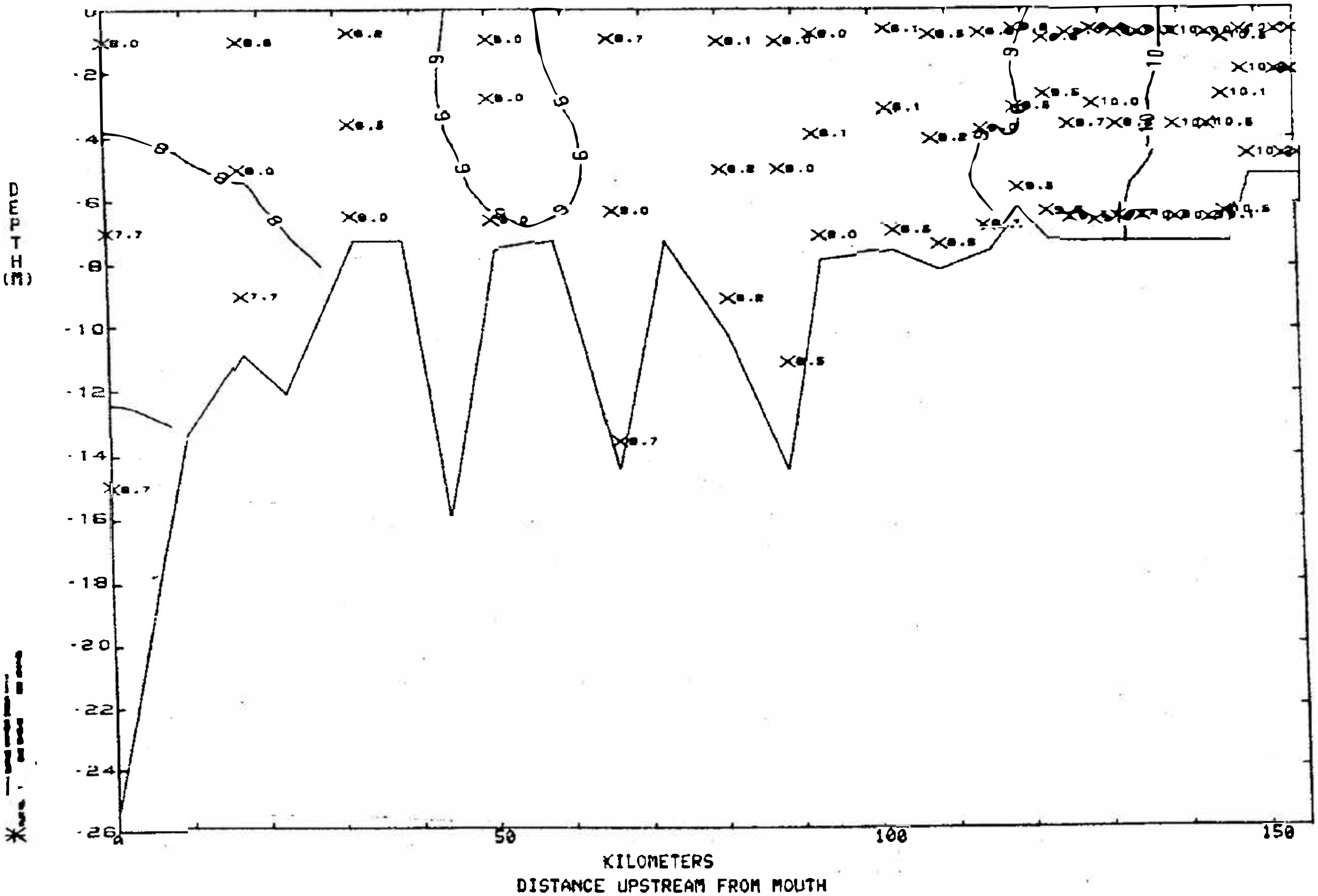
JAMES RIVER 29 JULY 1976 DISSOLVED OXYGEN SLACK BEFORE FLOOD

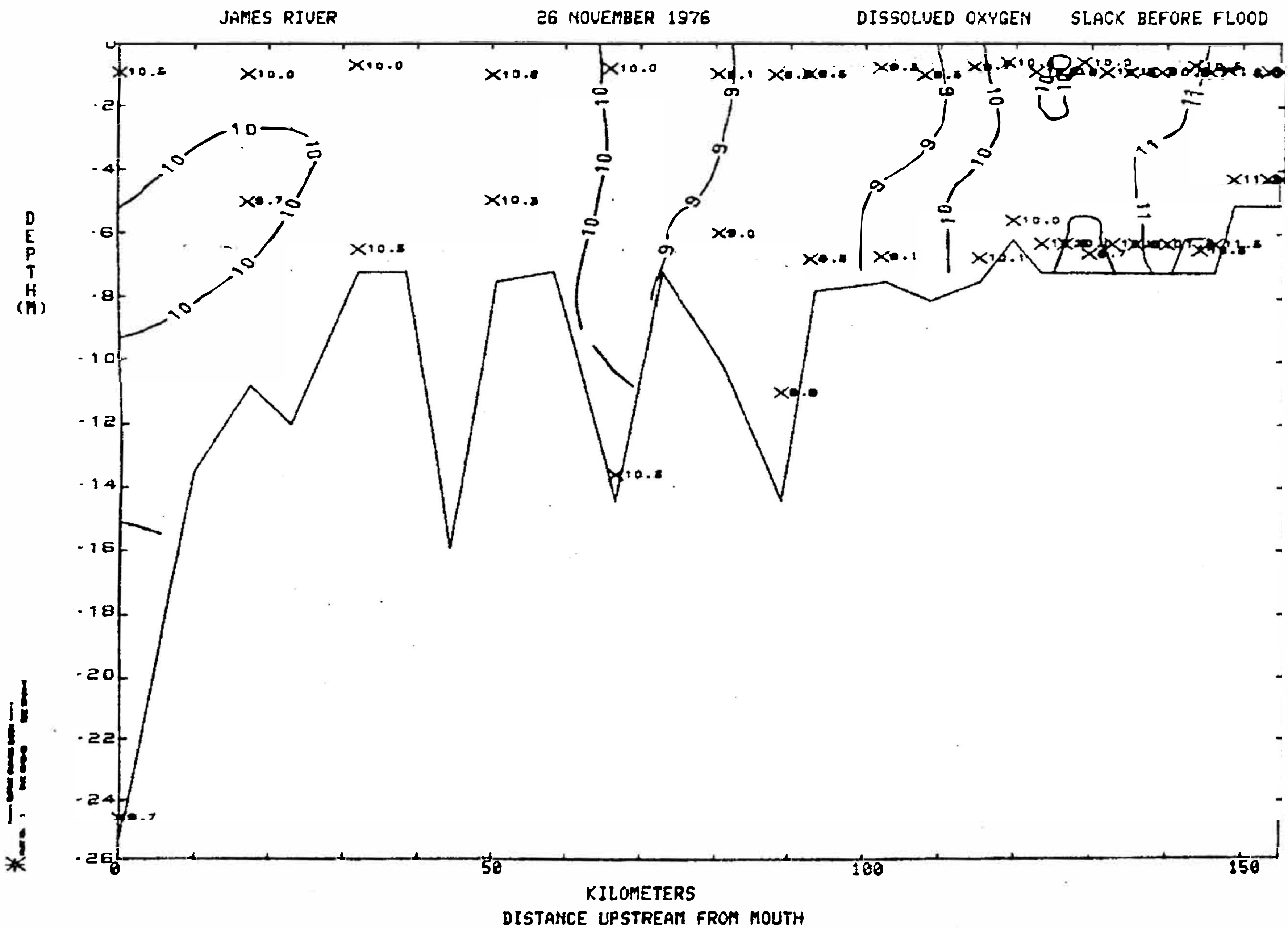


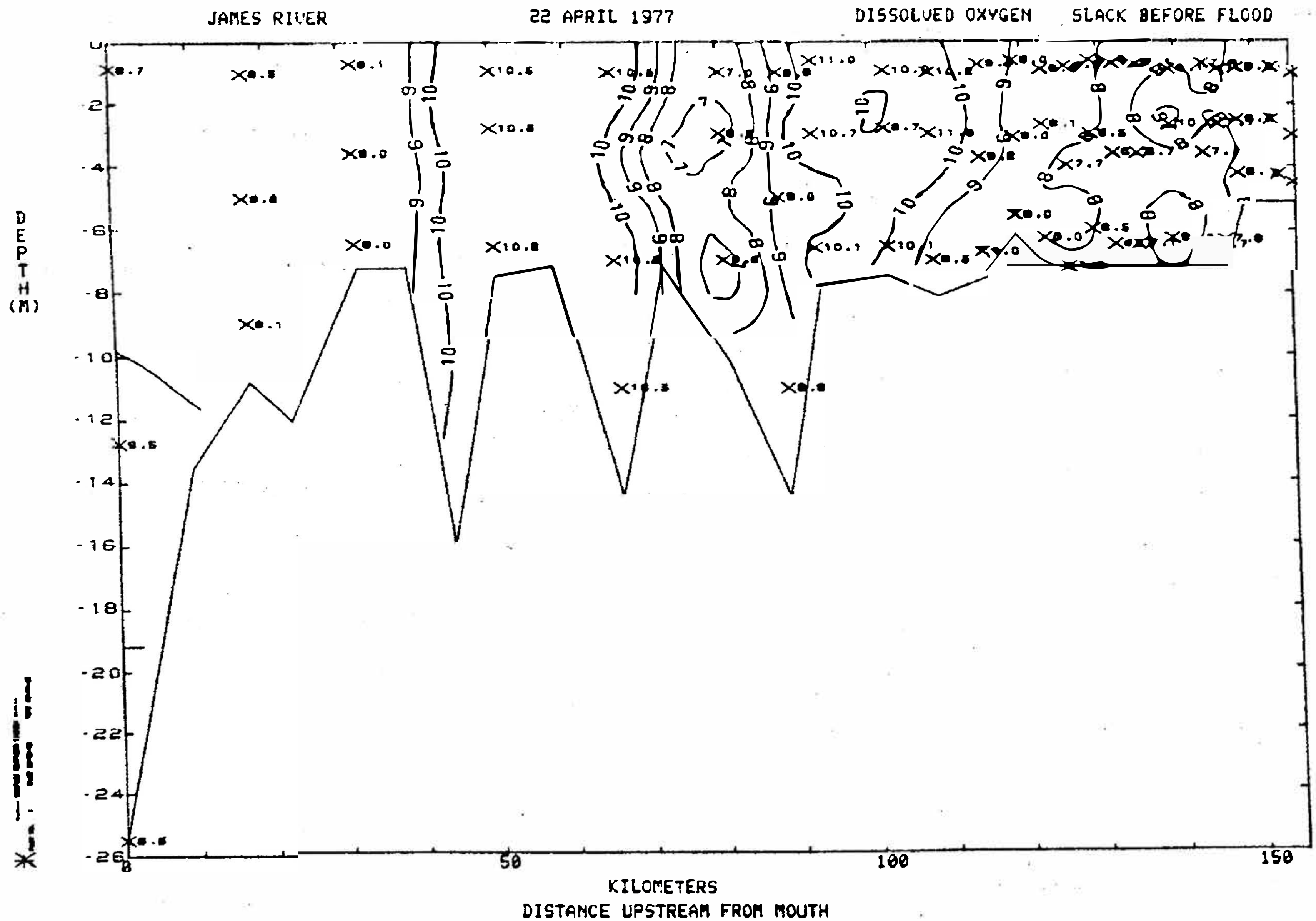
JAMES RIVER 12 OCTOBER 1976 DISSOLVED OXYGEN SLACK BEFORE FLOOD

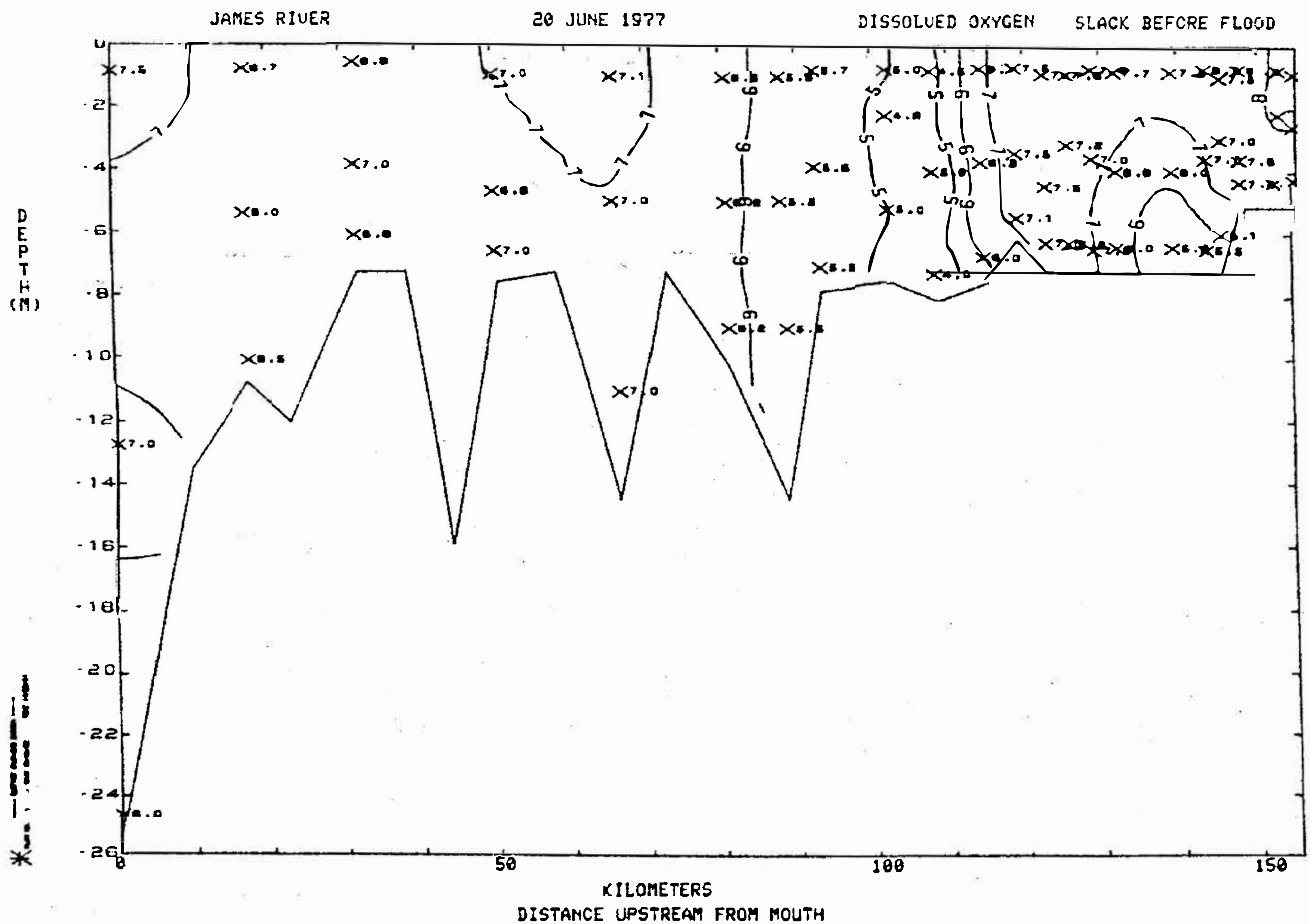


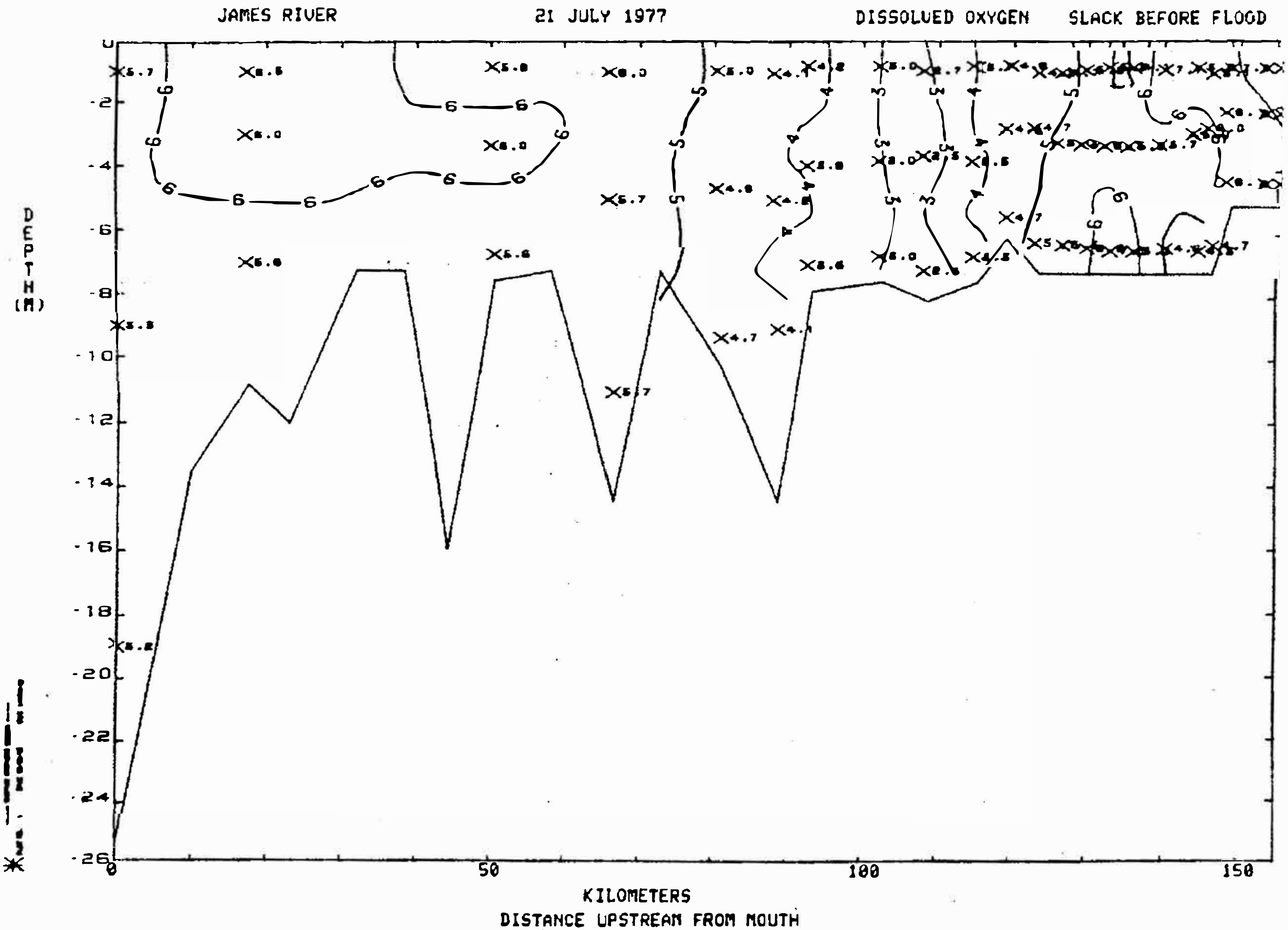
JAMES RIVER 04 NOVEMBER 1976 DISSOLVED OXYGEN SLACK BEFORE EBB

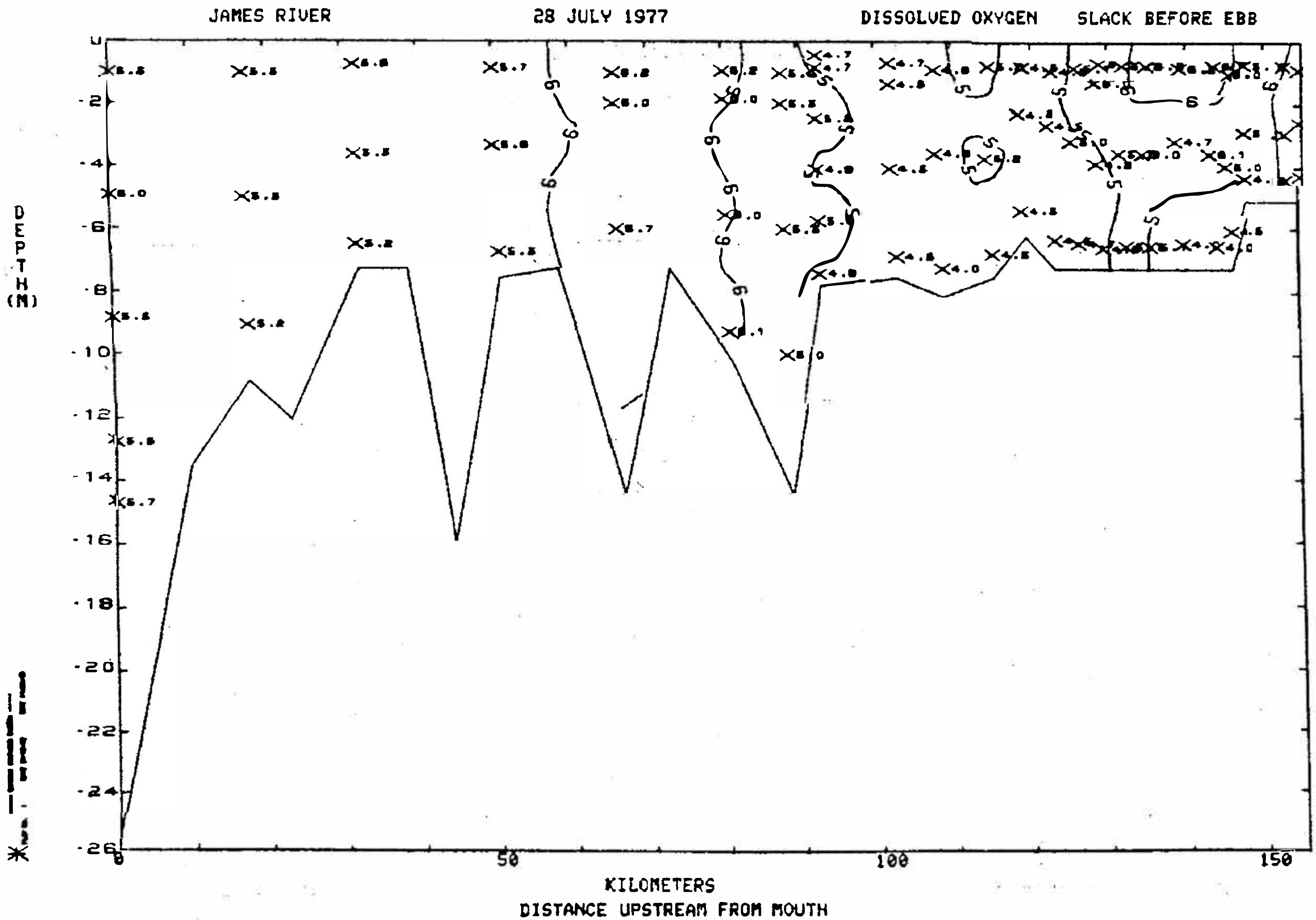


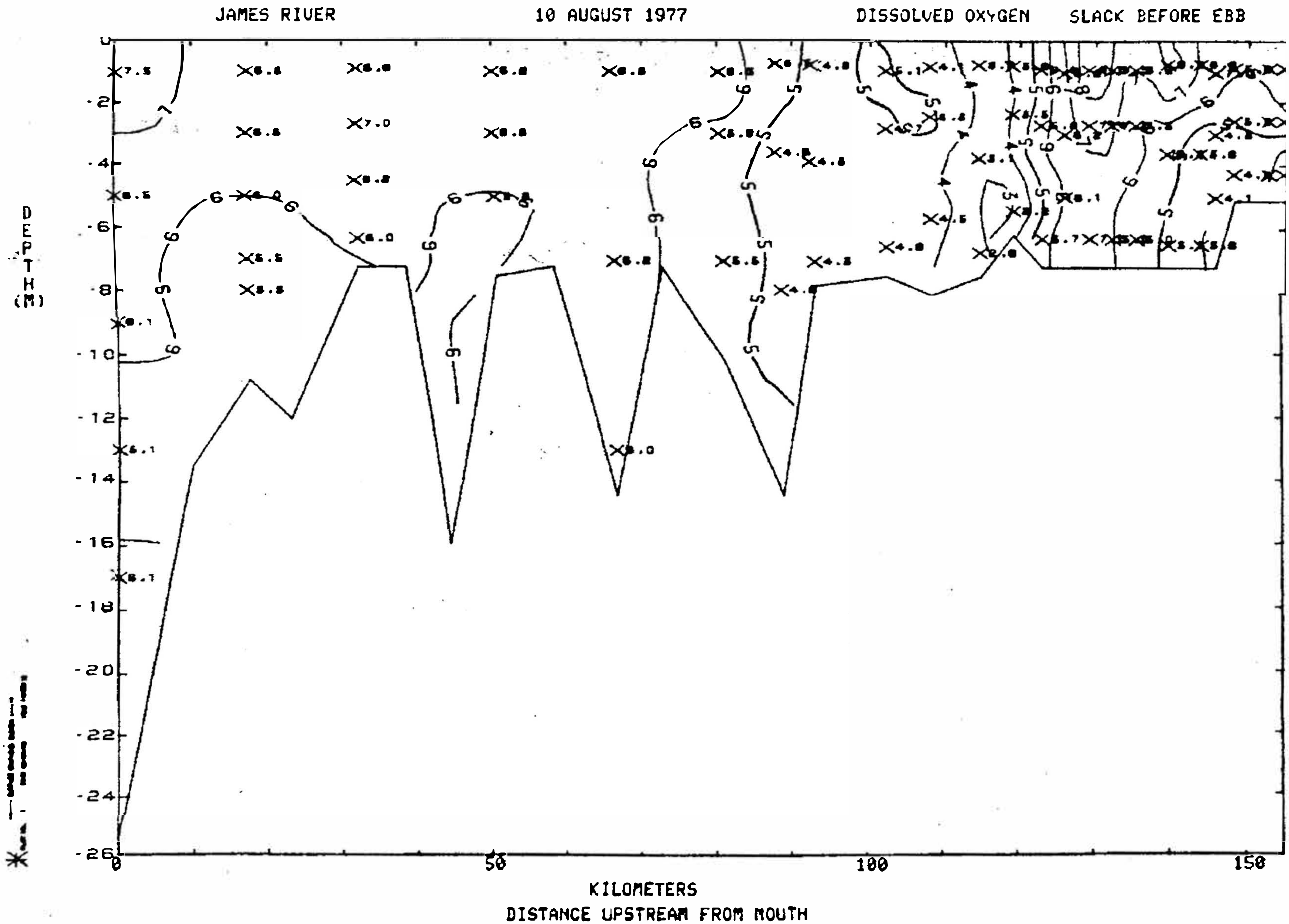

JAMES RIVER
26 NOVEMBER 1976
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

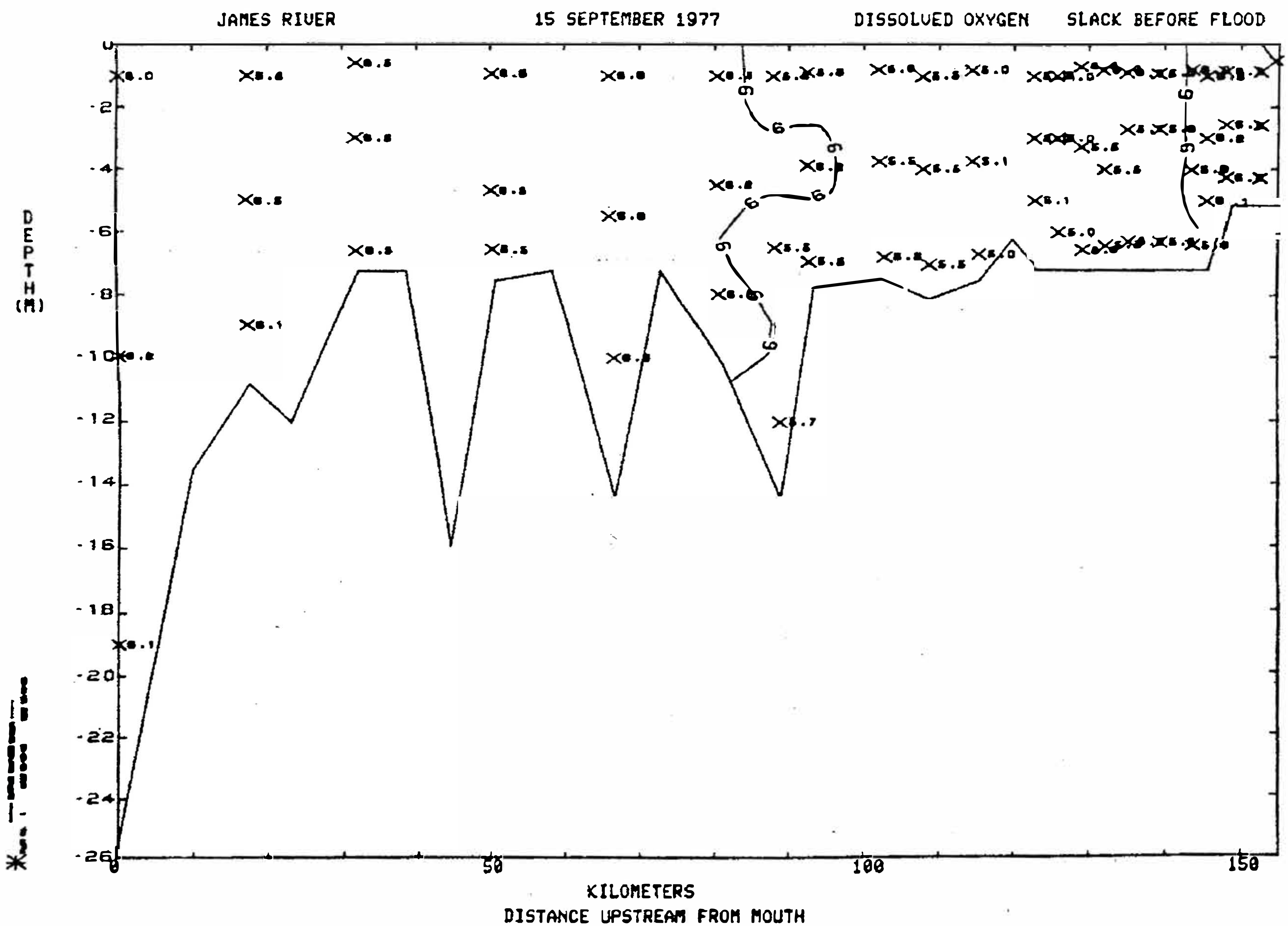

JAMES RIVER
22 APRIL 1977
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
20 JUNE 1977
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

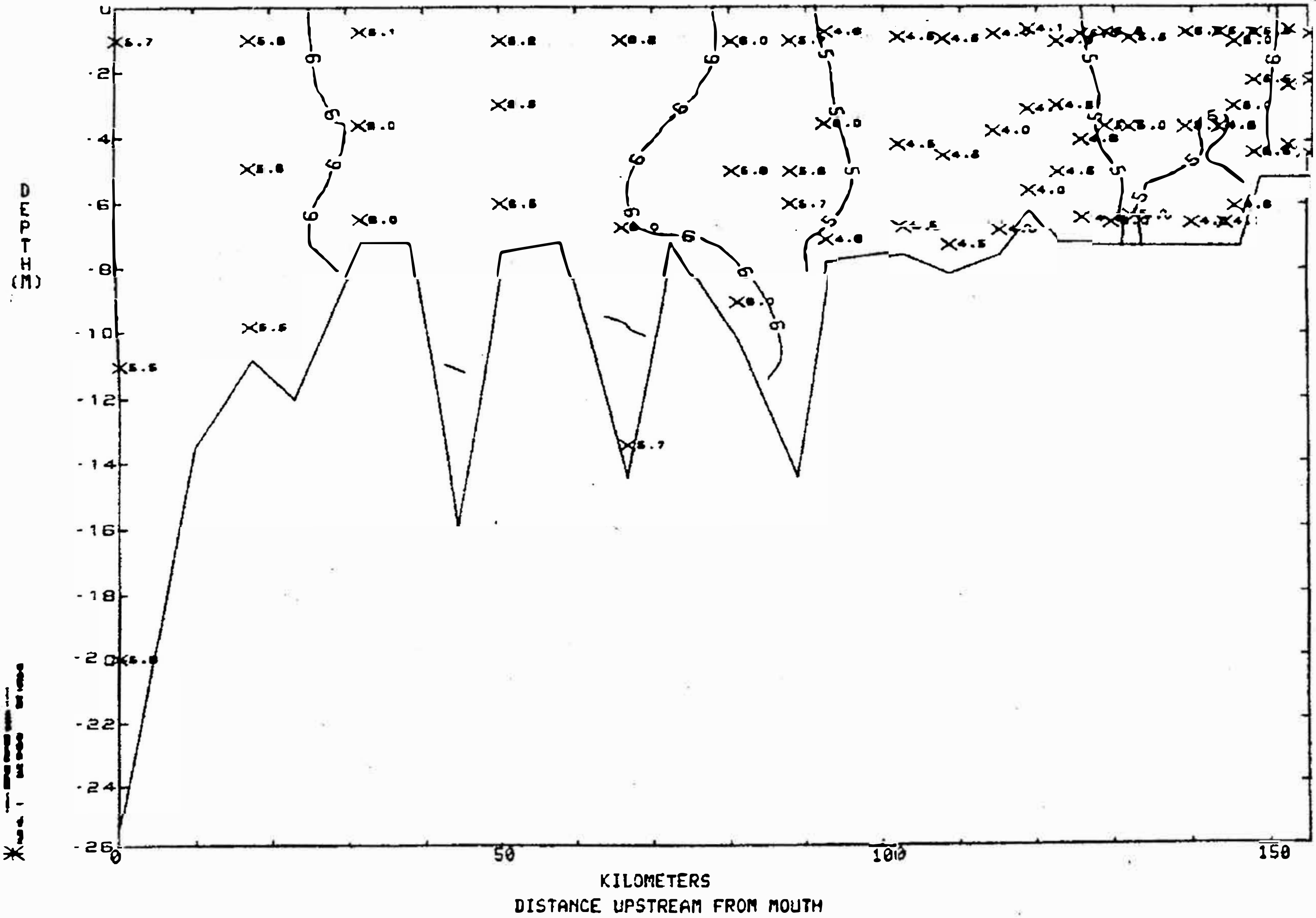

JAMES RIVER
21 JULY 1977
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

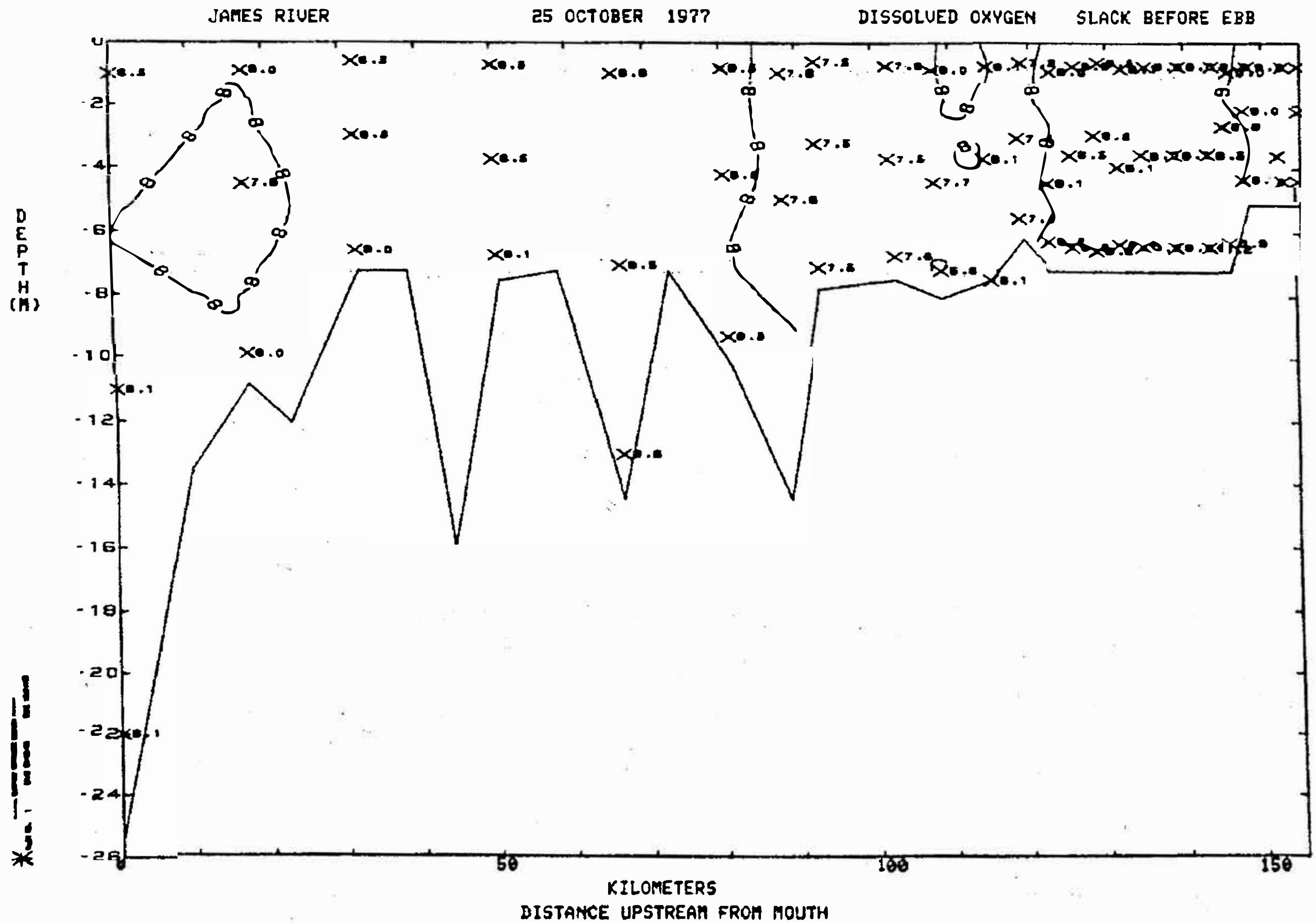

JAMES RIVER
28 JULY 1977
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
10 AUGUST 1977
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

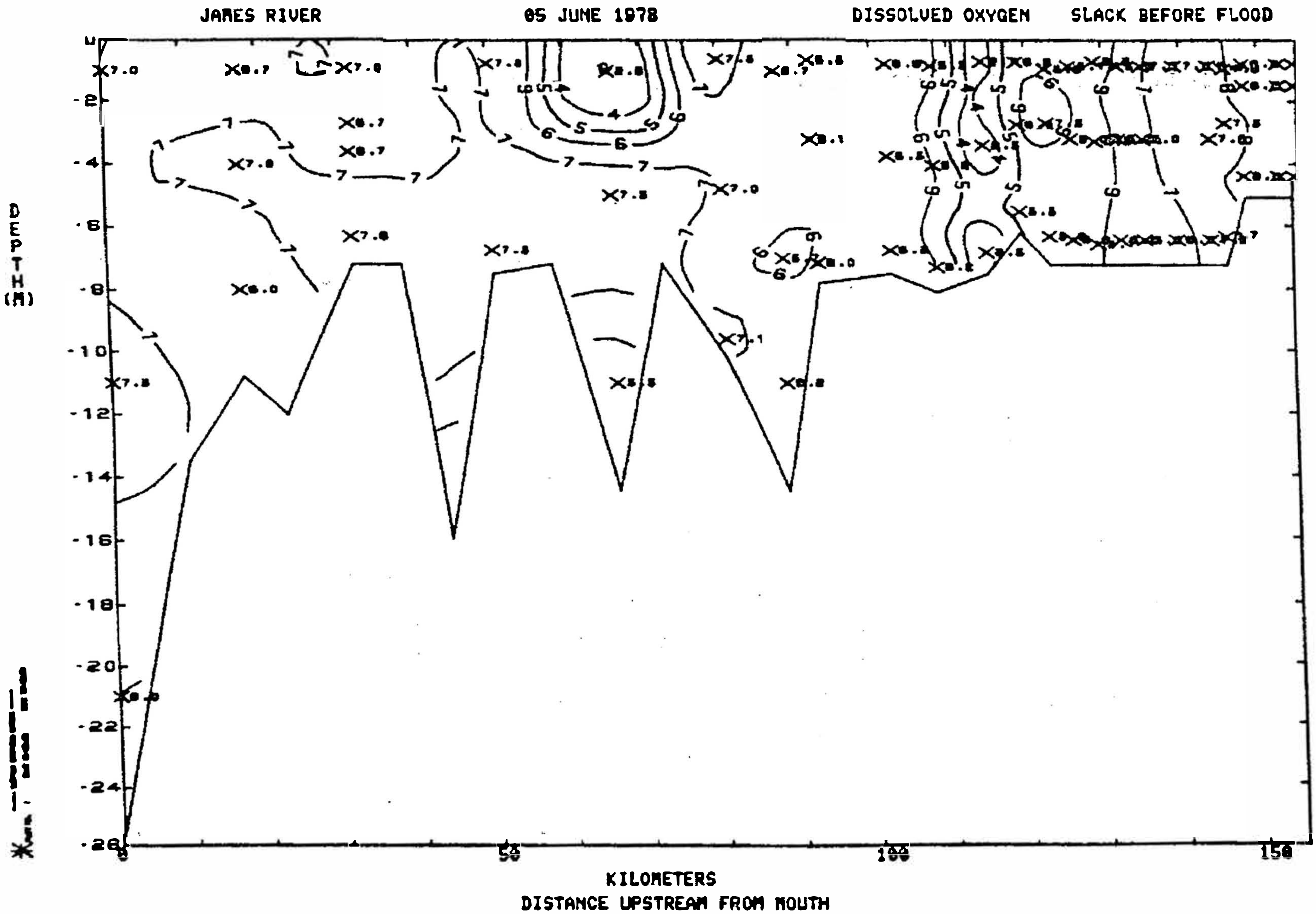

JAMES RIVER
15 SEPTEMBER 1977
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

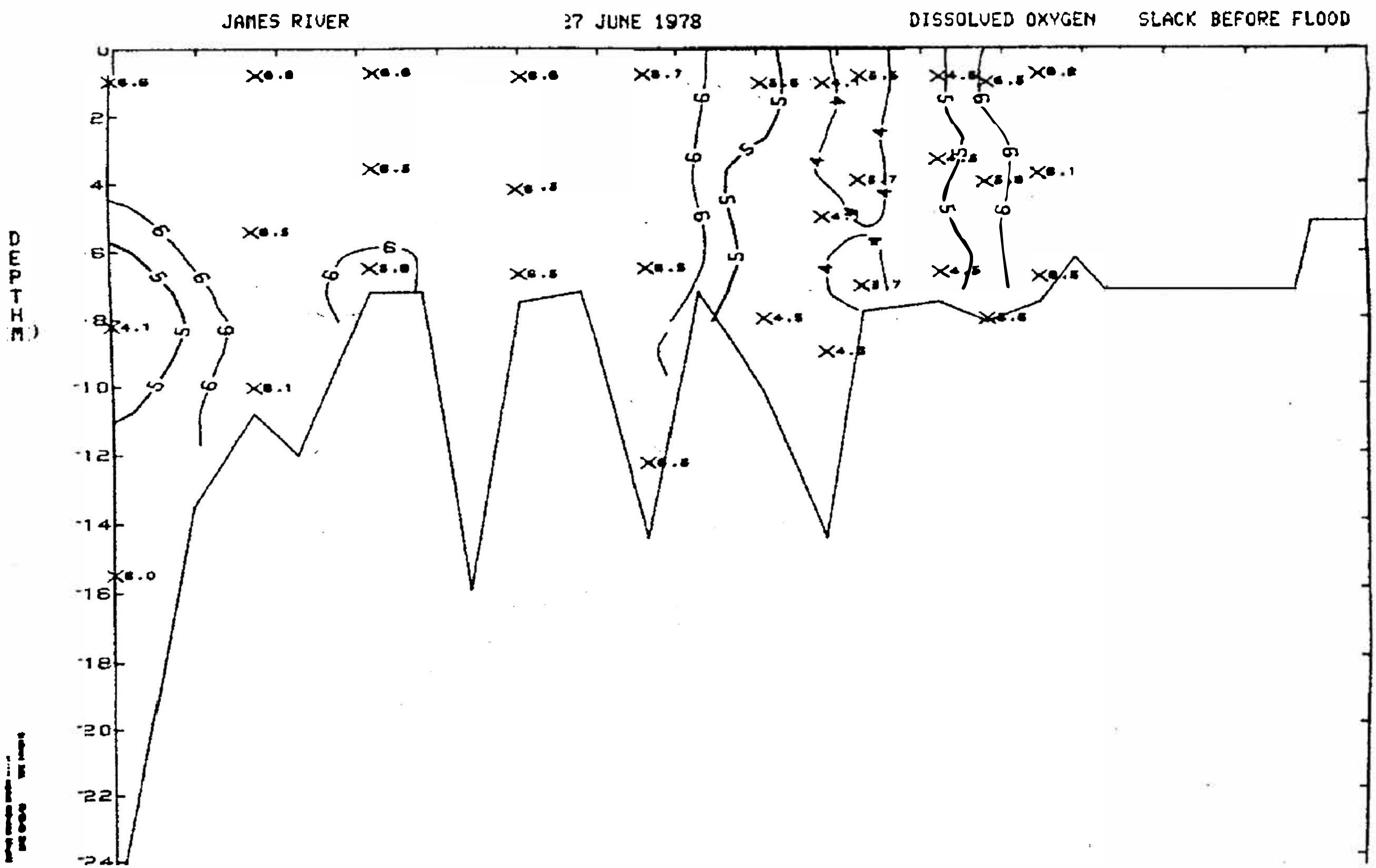
JAMES RIVER 22 SEPTEMBER 1977 DISSOLVED OXYGEN SLACK BEFORE EBB

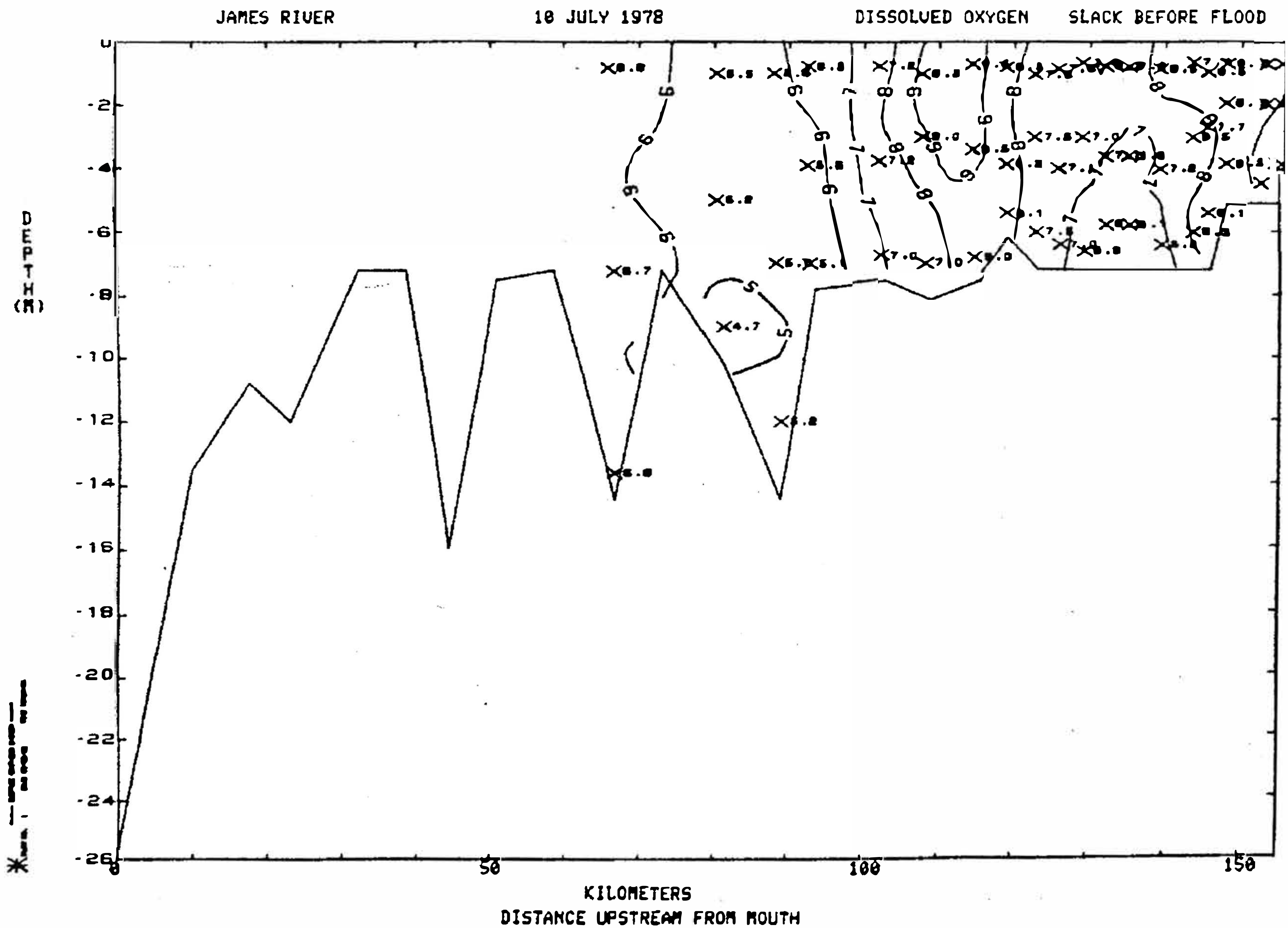




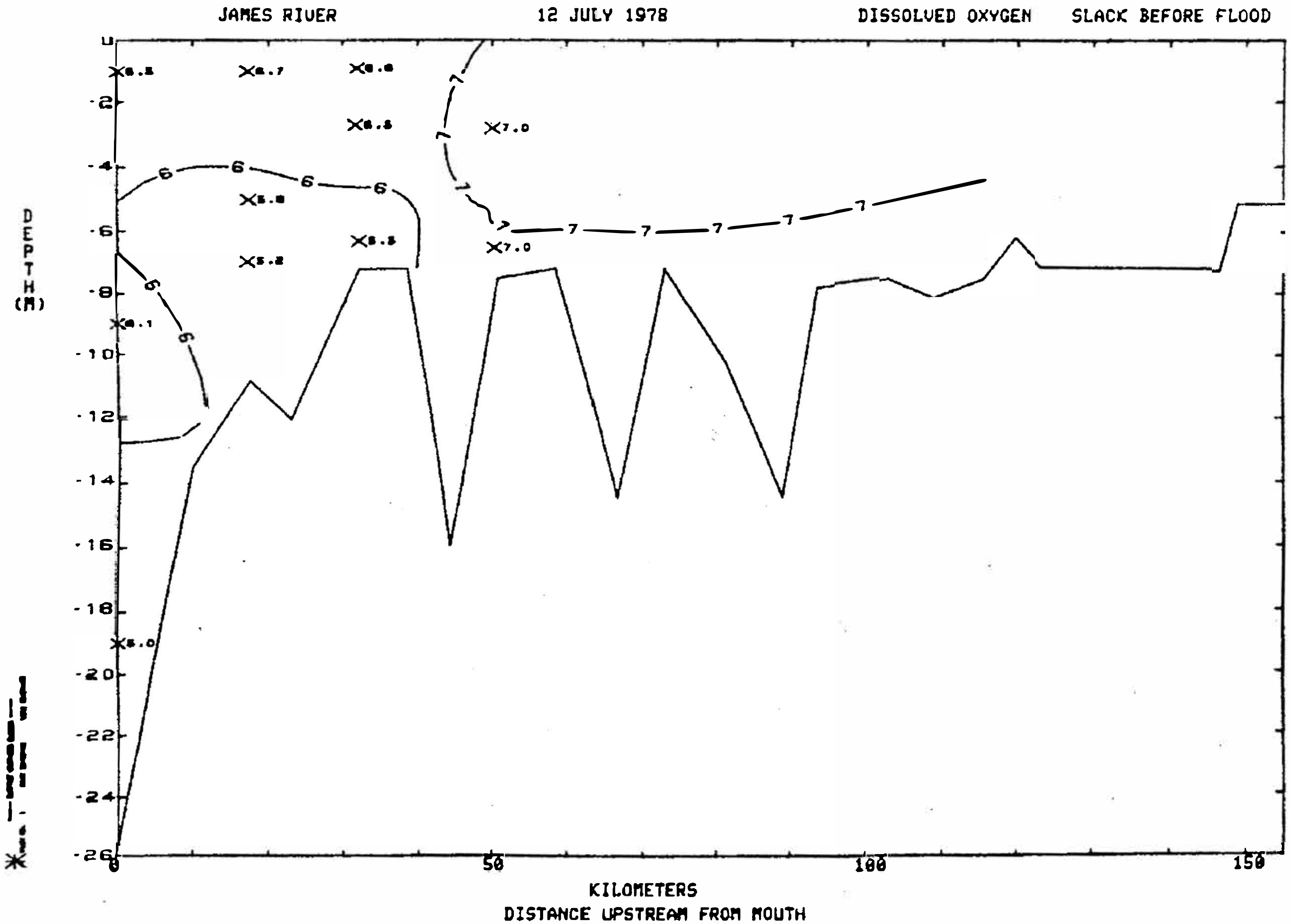
JAMES RIVER
25 OCTOBER 1977
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
05 JUNE 1978
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

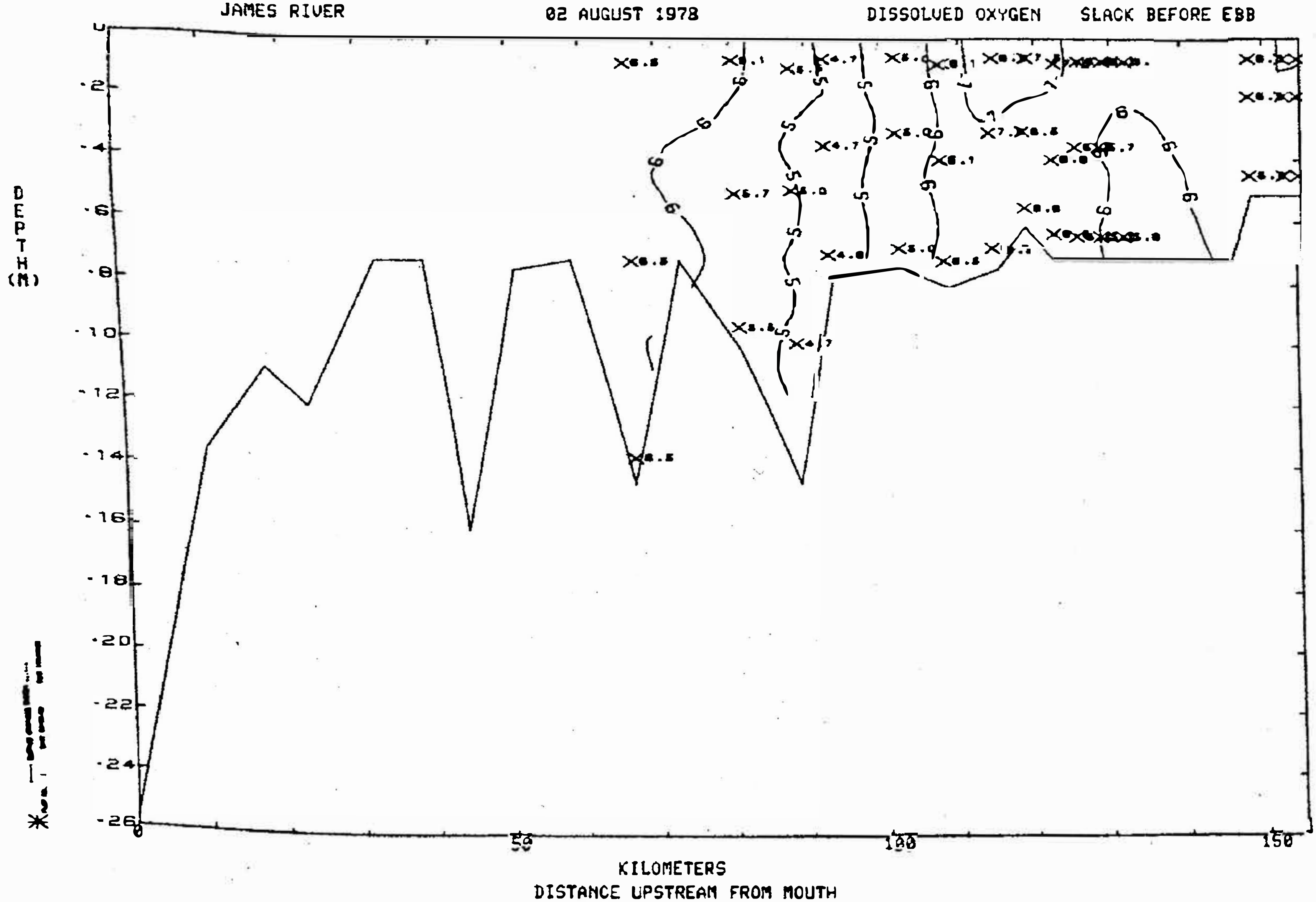

JAMES RIVER
27 JUNE 1978
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
0
2
4
6
8
10
12
14
16
18
20
22
24



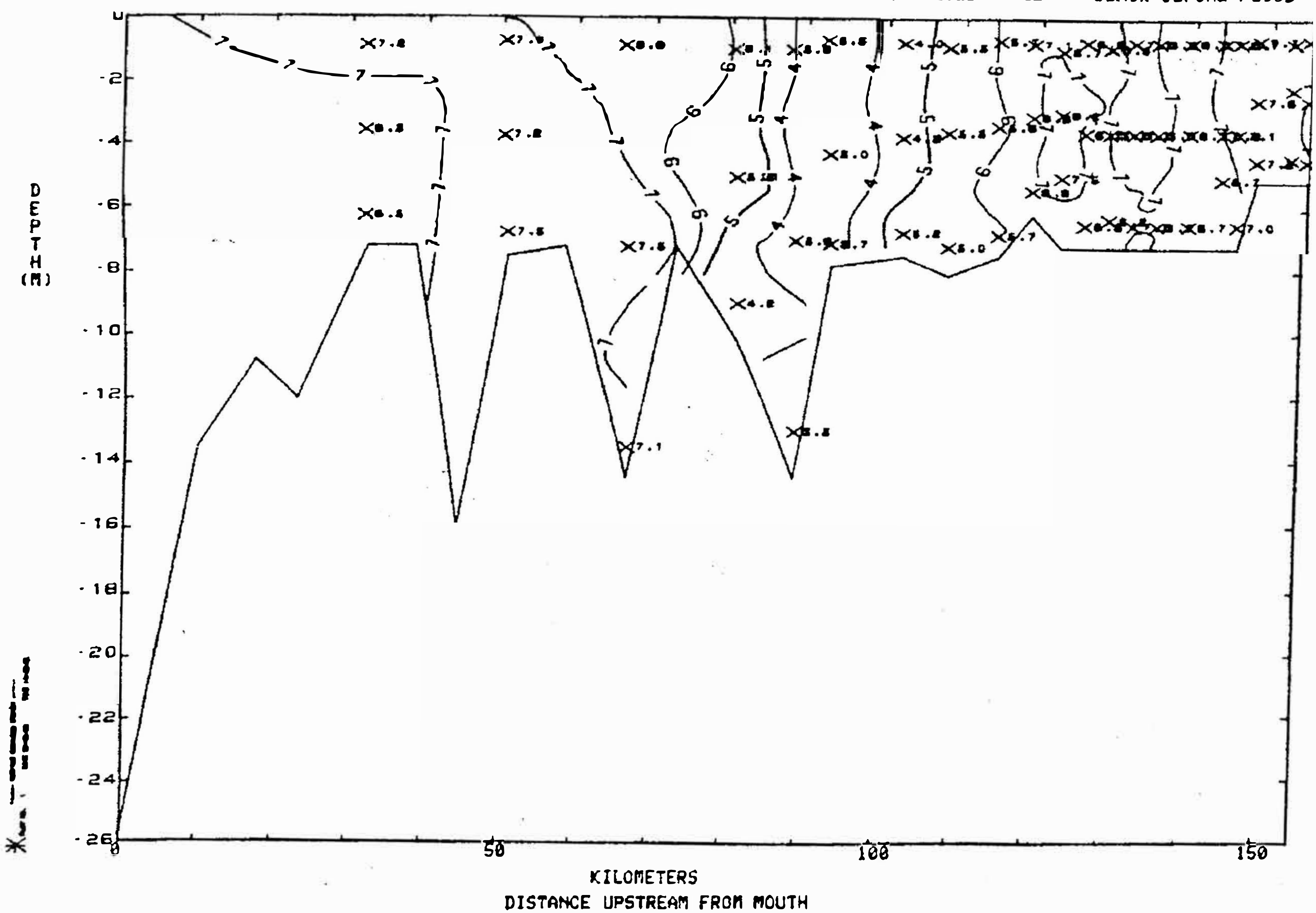
JAMES RIVER
10 JULY 1978
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
12 JULY 1978
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
6
7
7.0
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

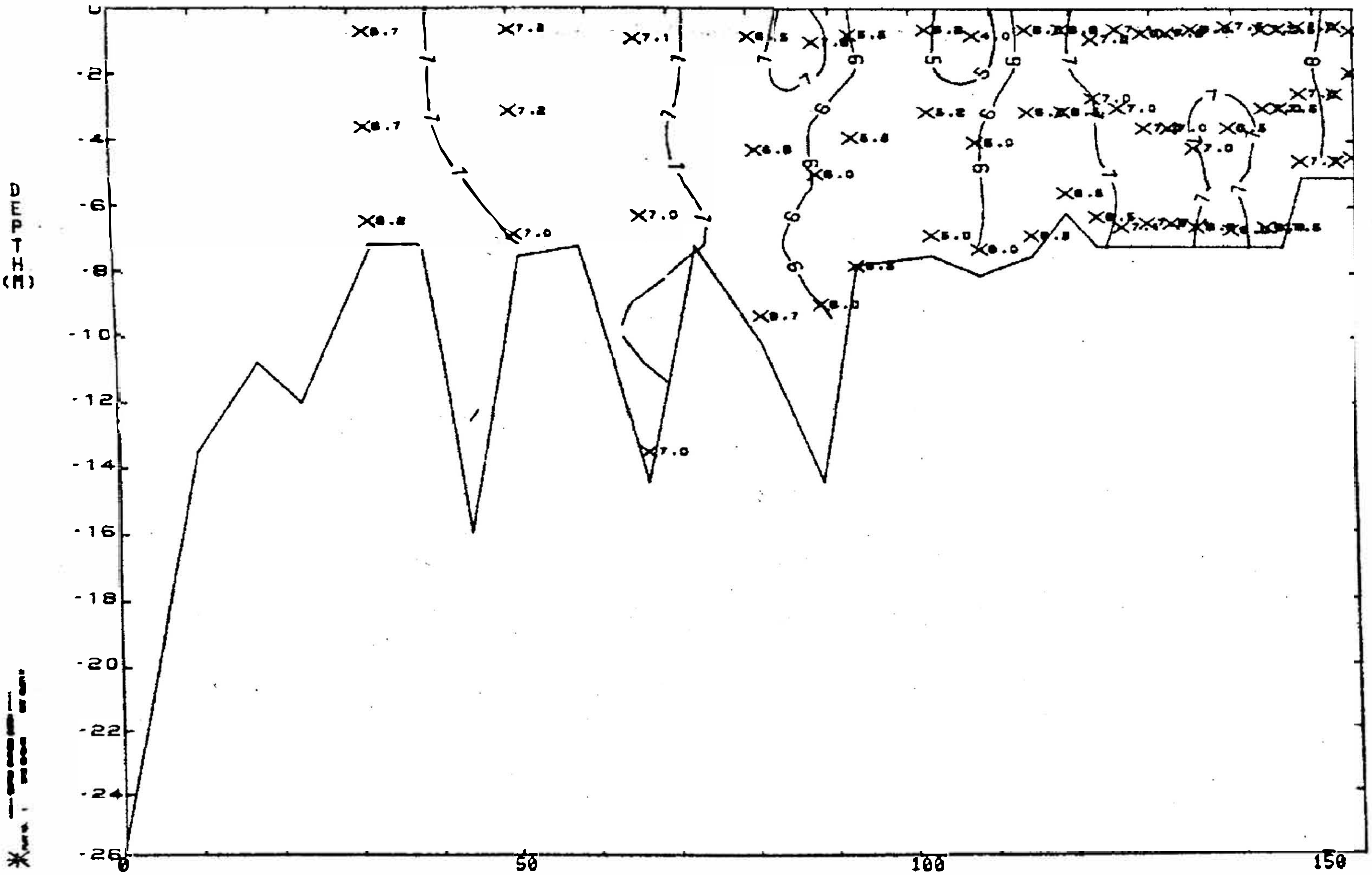
JAMES RIVER 02 AUGUST 1978 DISSOLVED OXYGEN SLACK BEFORE EBB

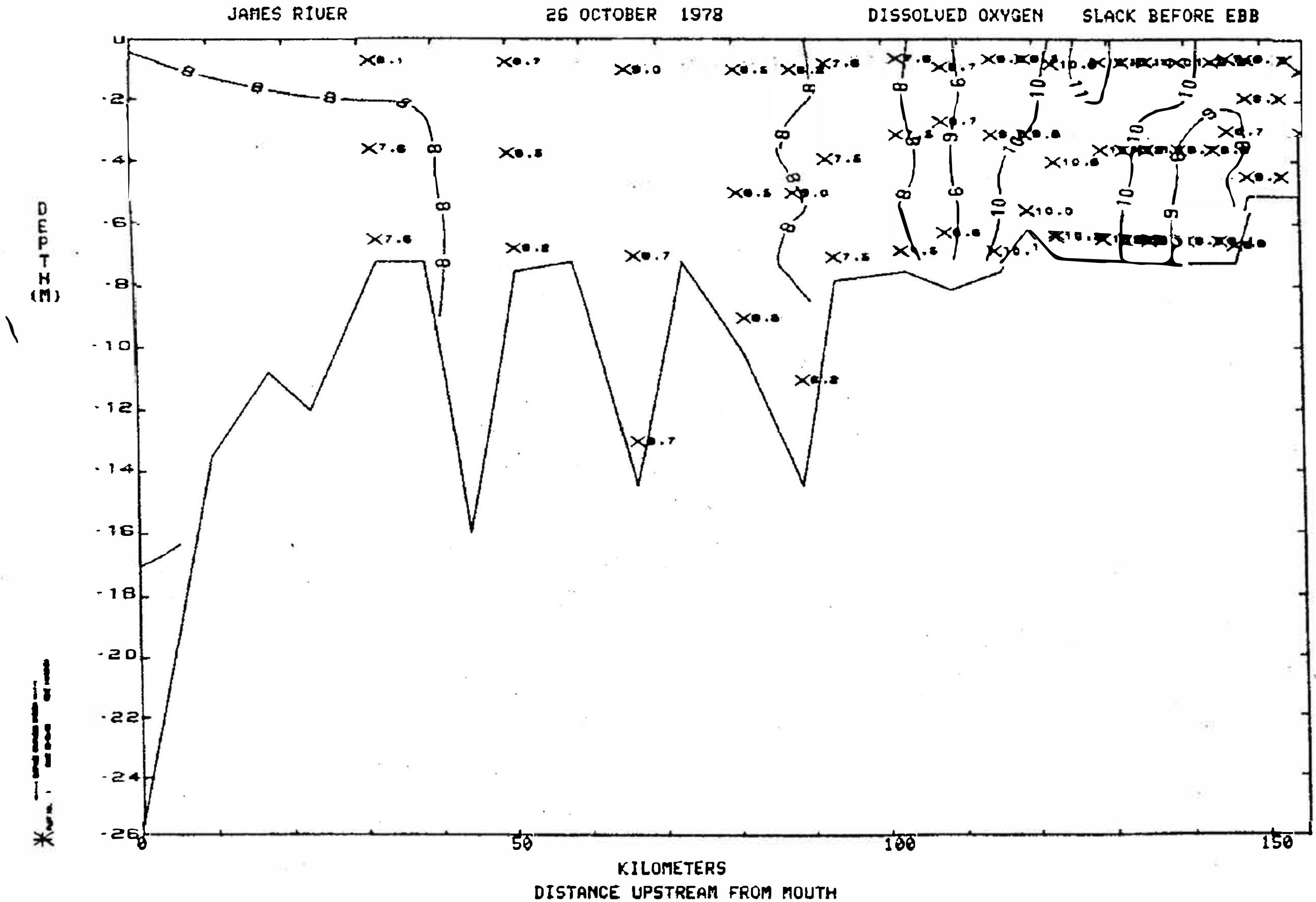


JAMES RIVER 17 AUGUST 1978 DISSOLVED OXYGEN SLACK BEFORE FLOOD

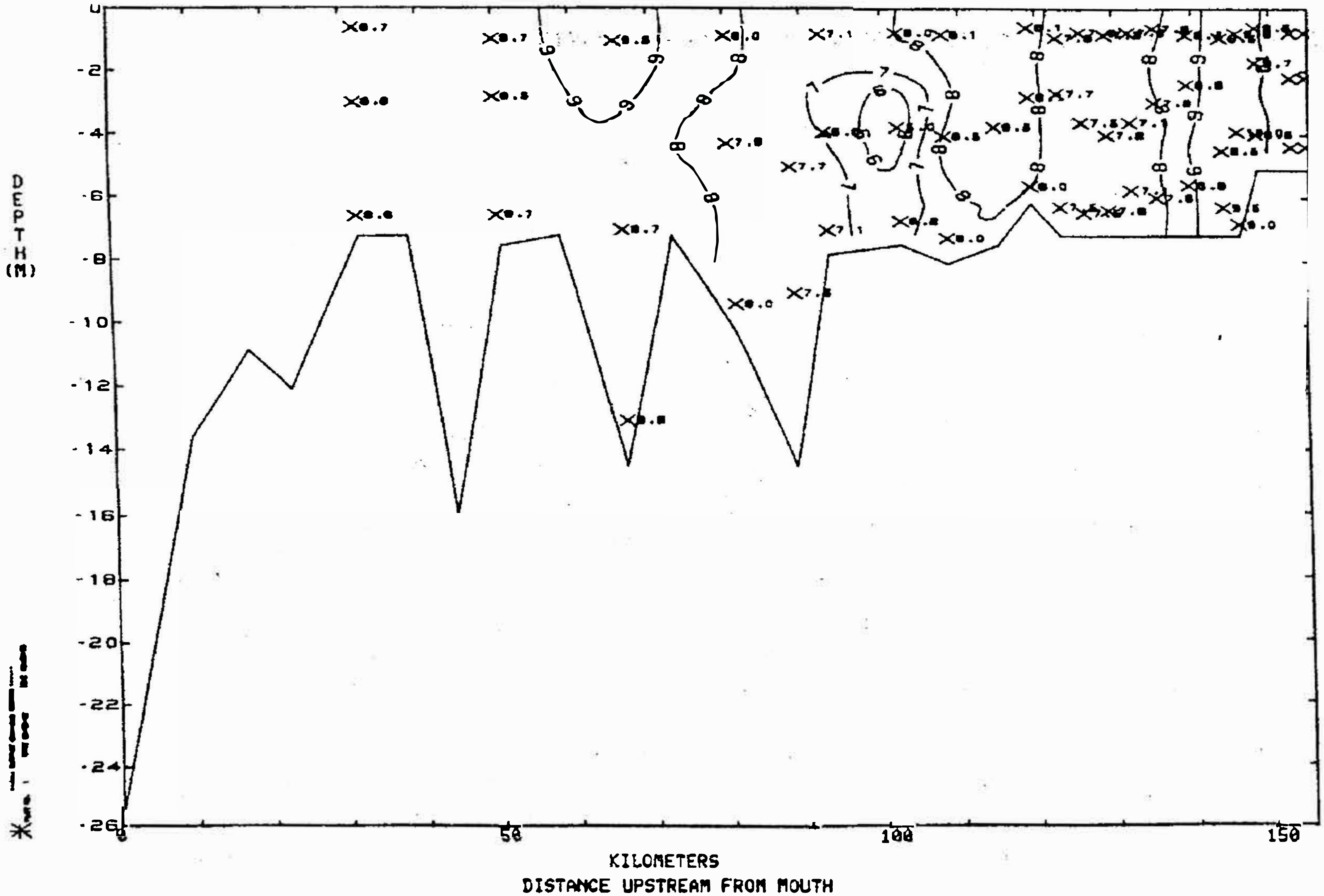


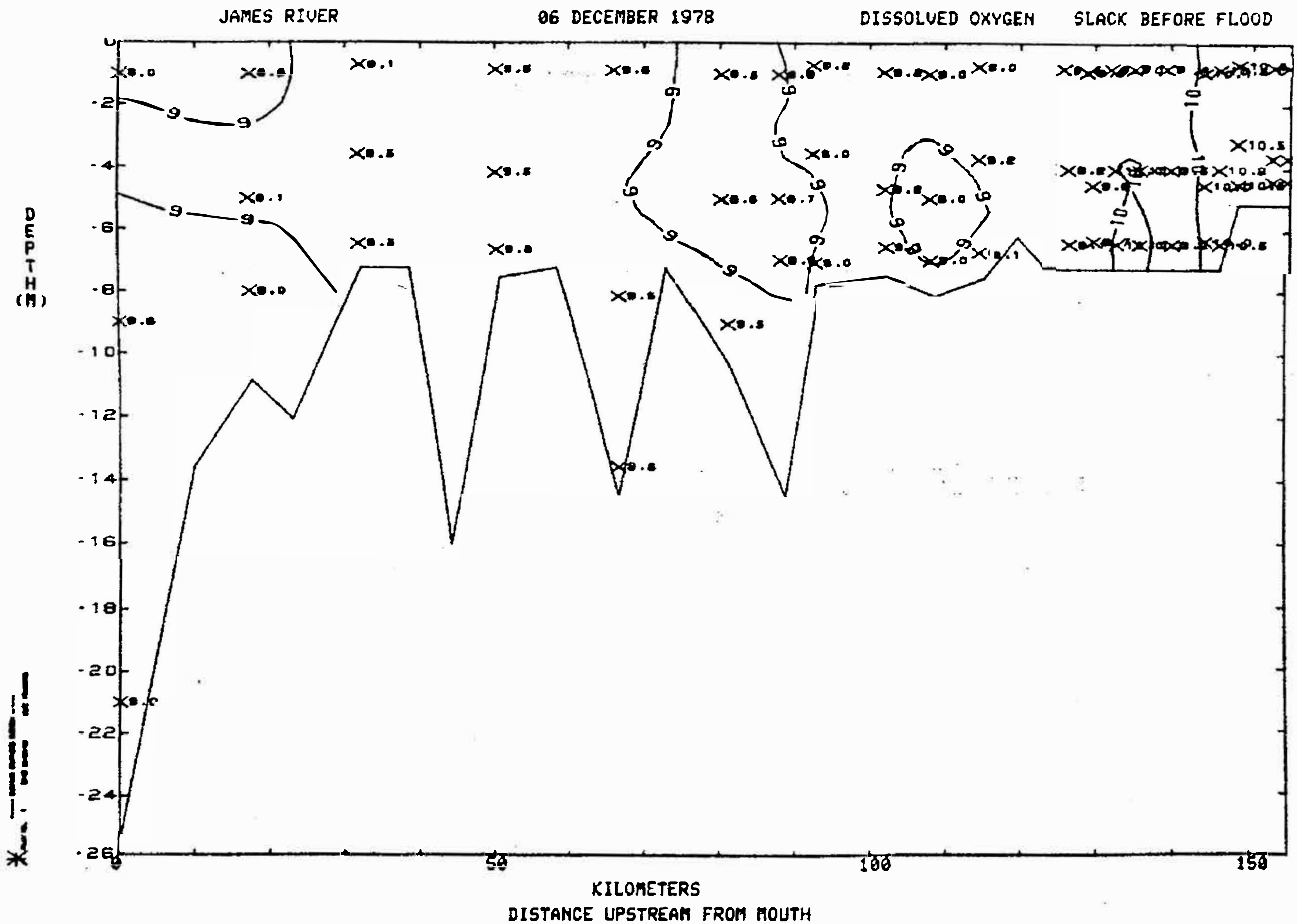
JAMES RIVER 27 SEPTEMBER 1978 DISSOLVED OXYGEN SLACK BEFORE EBB



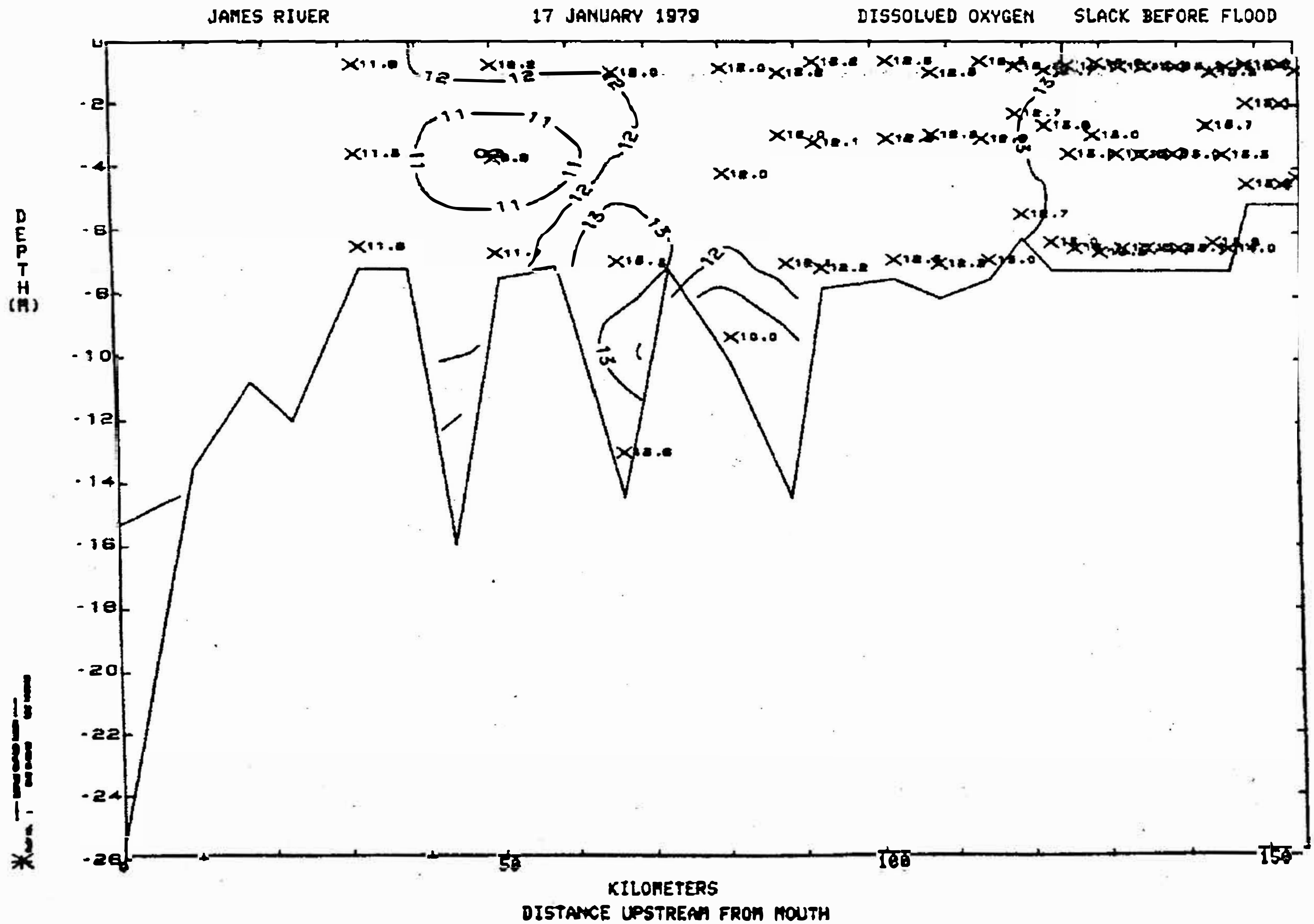

JAMES RIVER
26 OCTOBER 1978
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

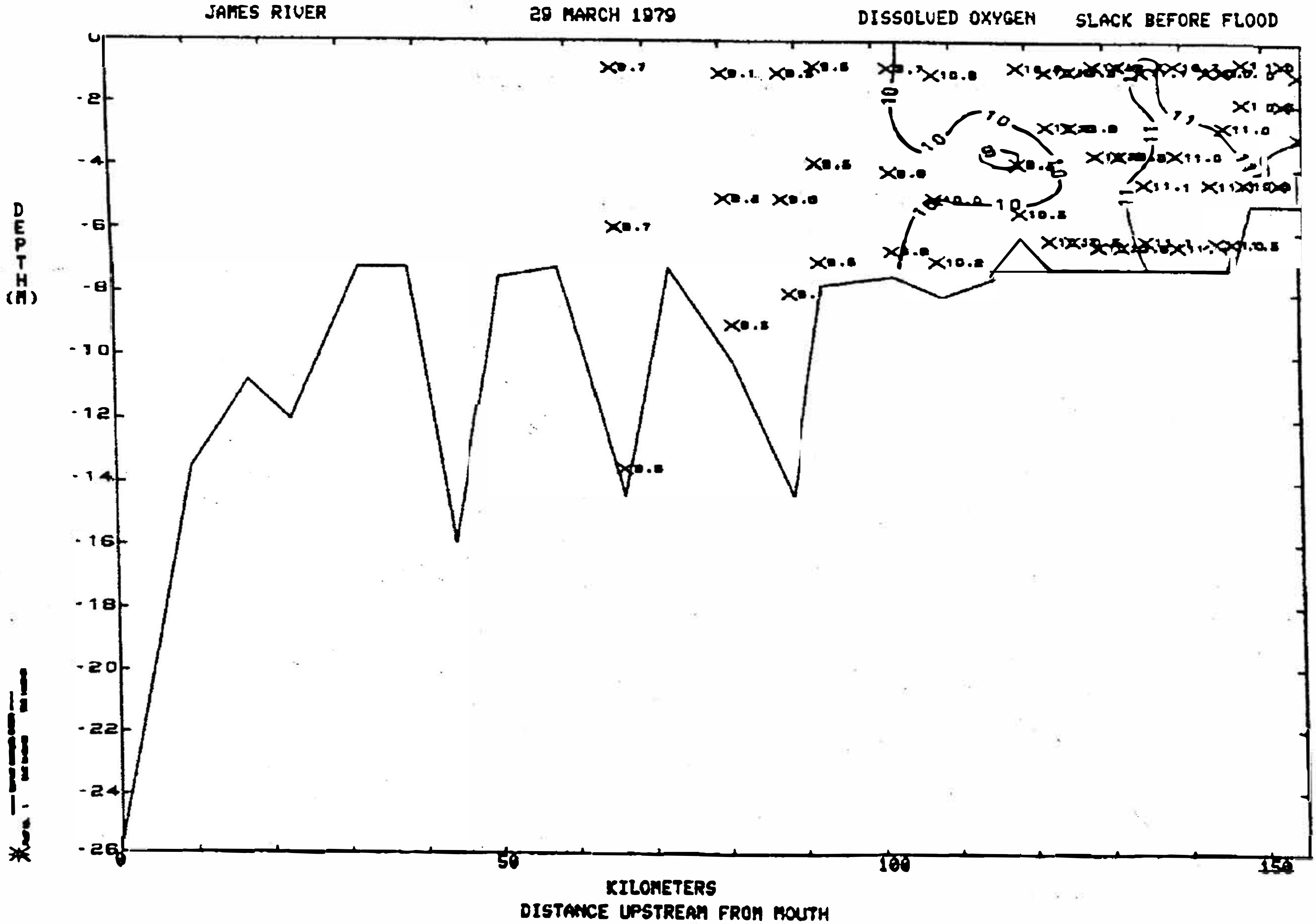
JAMES RIVER 21 NOVEMBER 1978 DISSOLVED OXYGEN SLACK BEFORE FLOOD



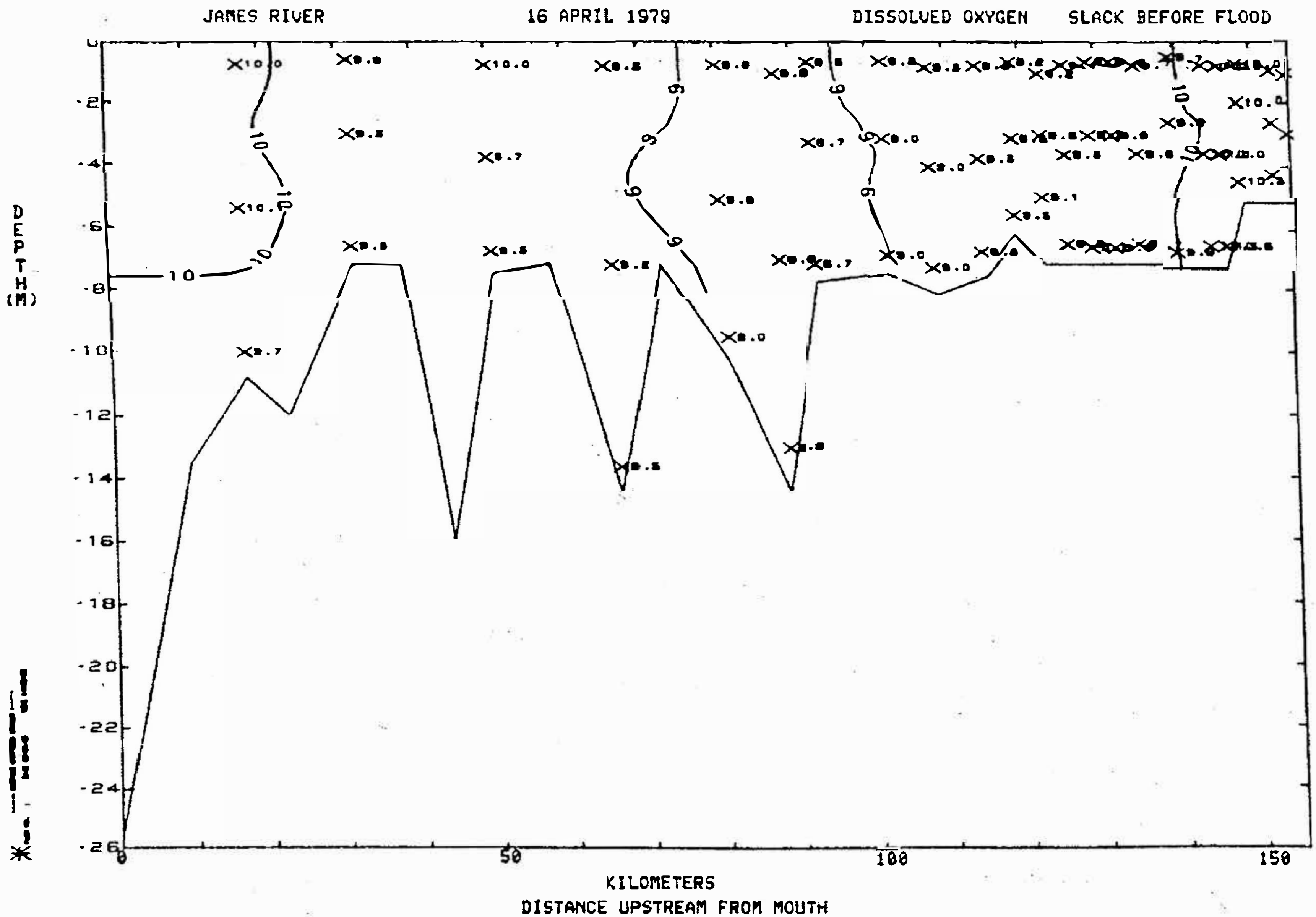


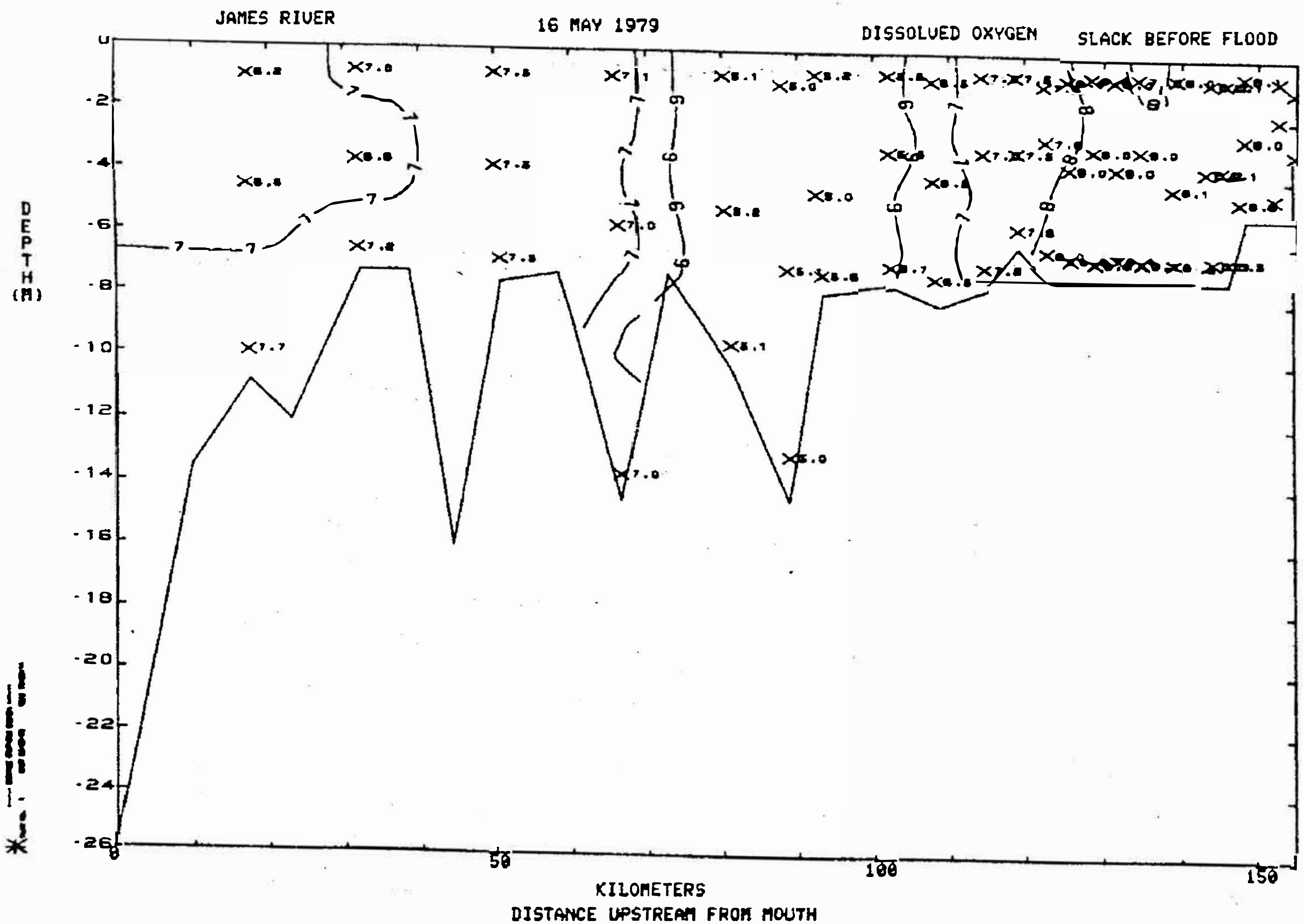
JAMES RIVER
06 DECEMBER 1978
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
17 JANUARY 1979
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

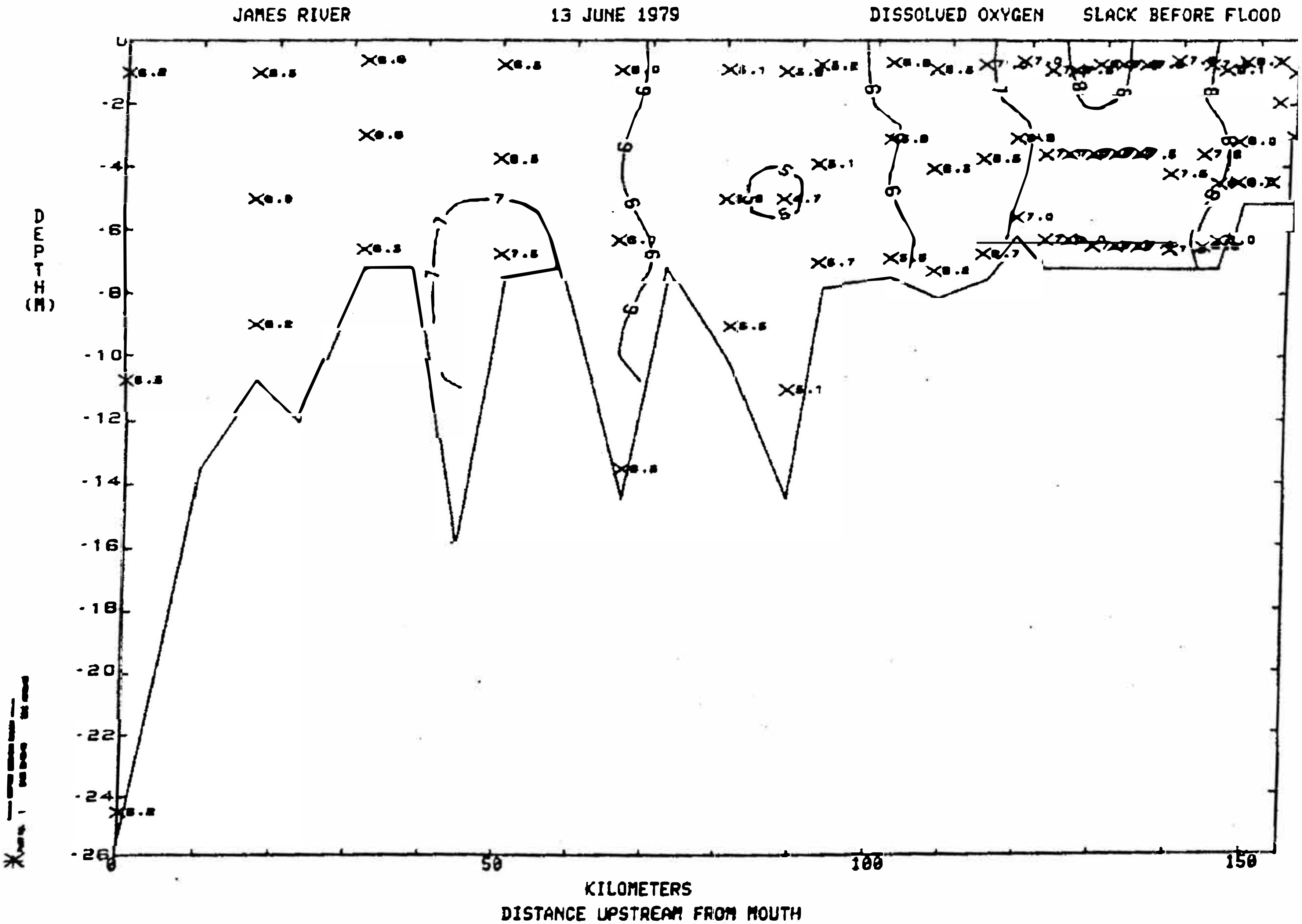


JAMES RIVER
29 MARCH 1979
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

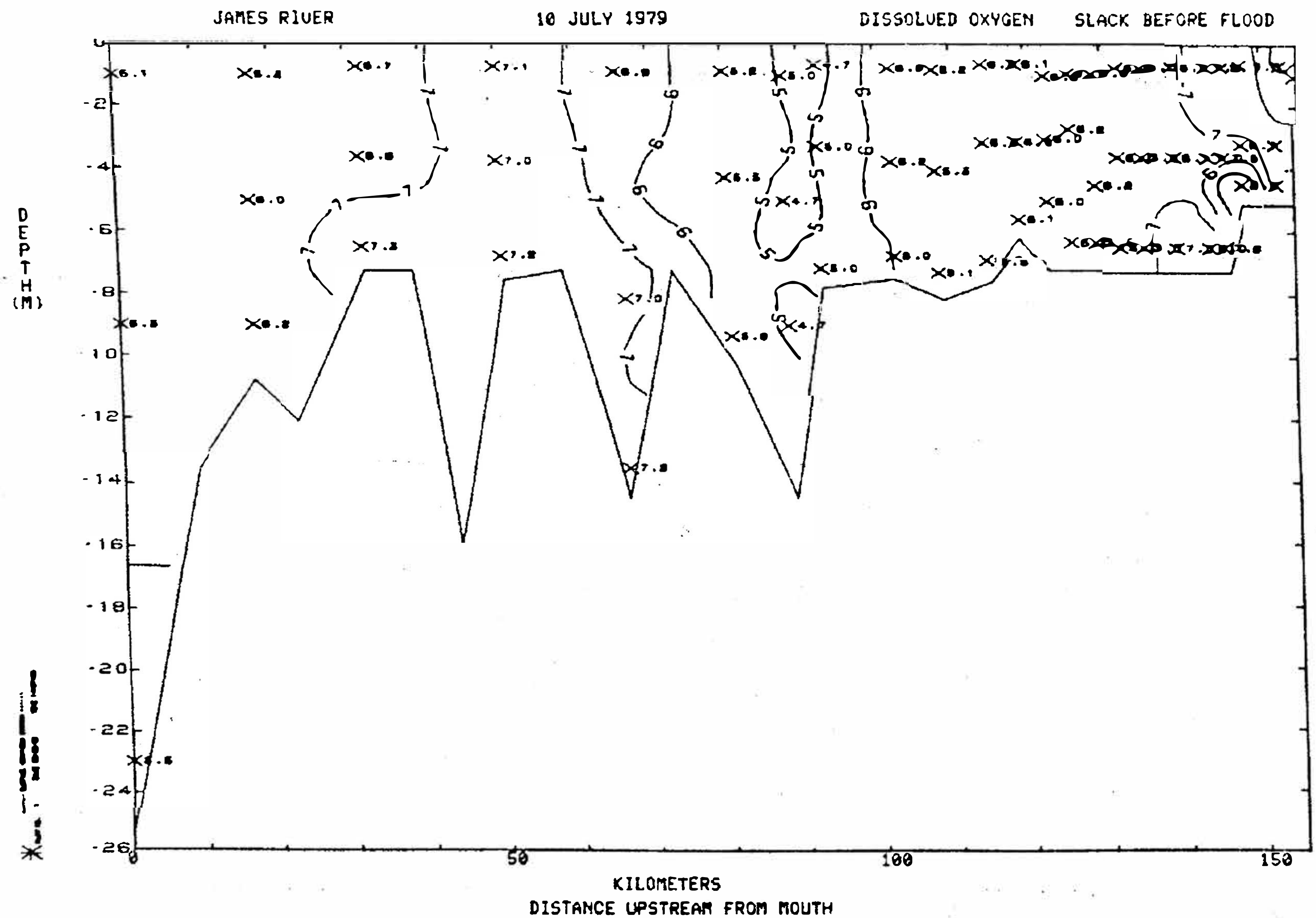

JAMES RIVER
16 APRIL 1979
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

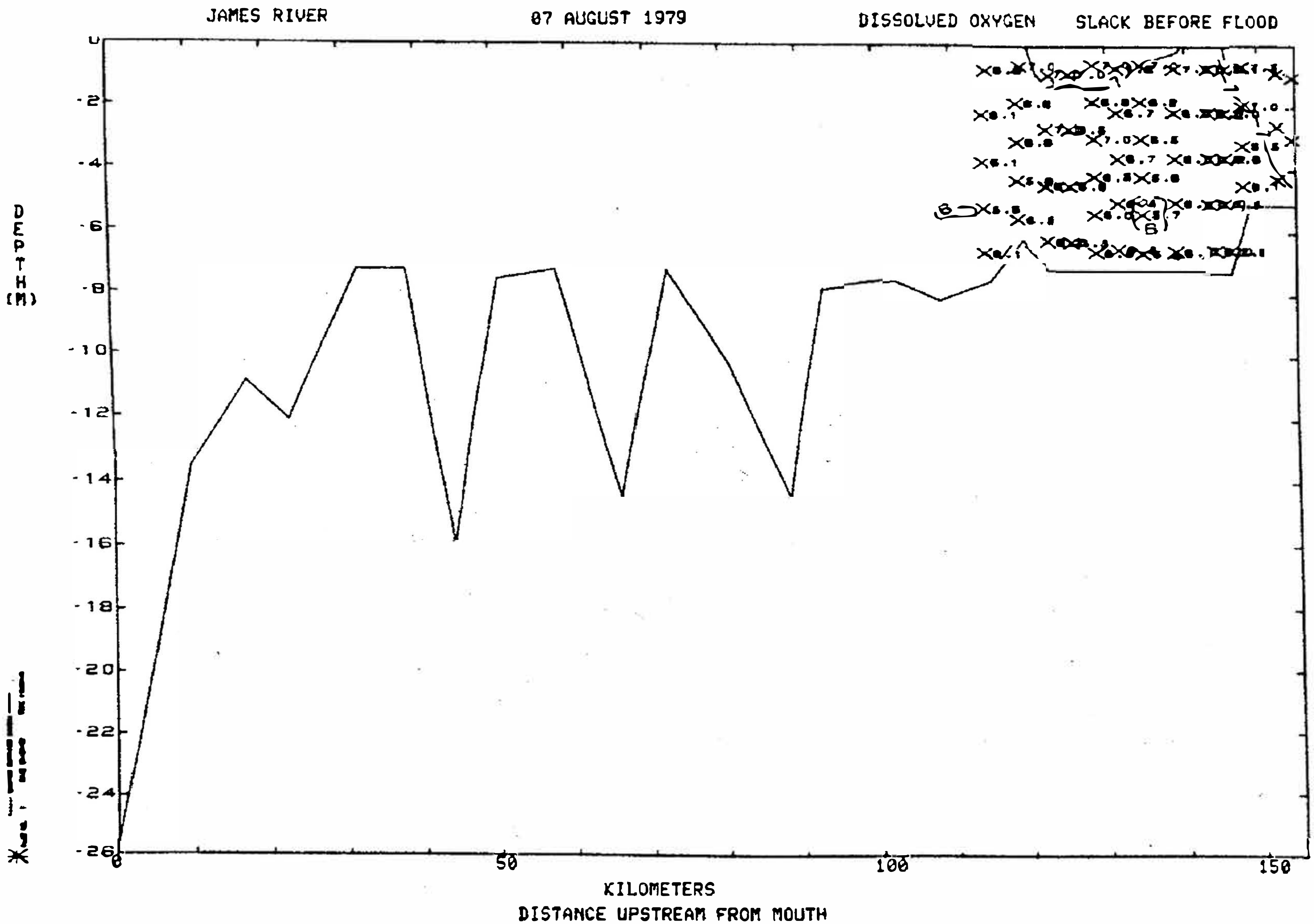


JAMES RIVER
16 MAY 1979
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

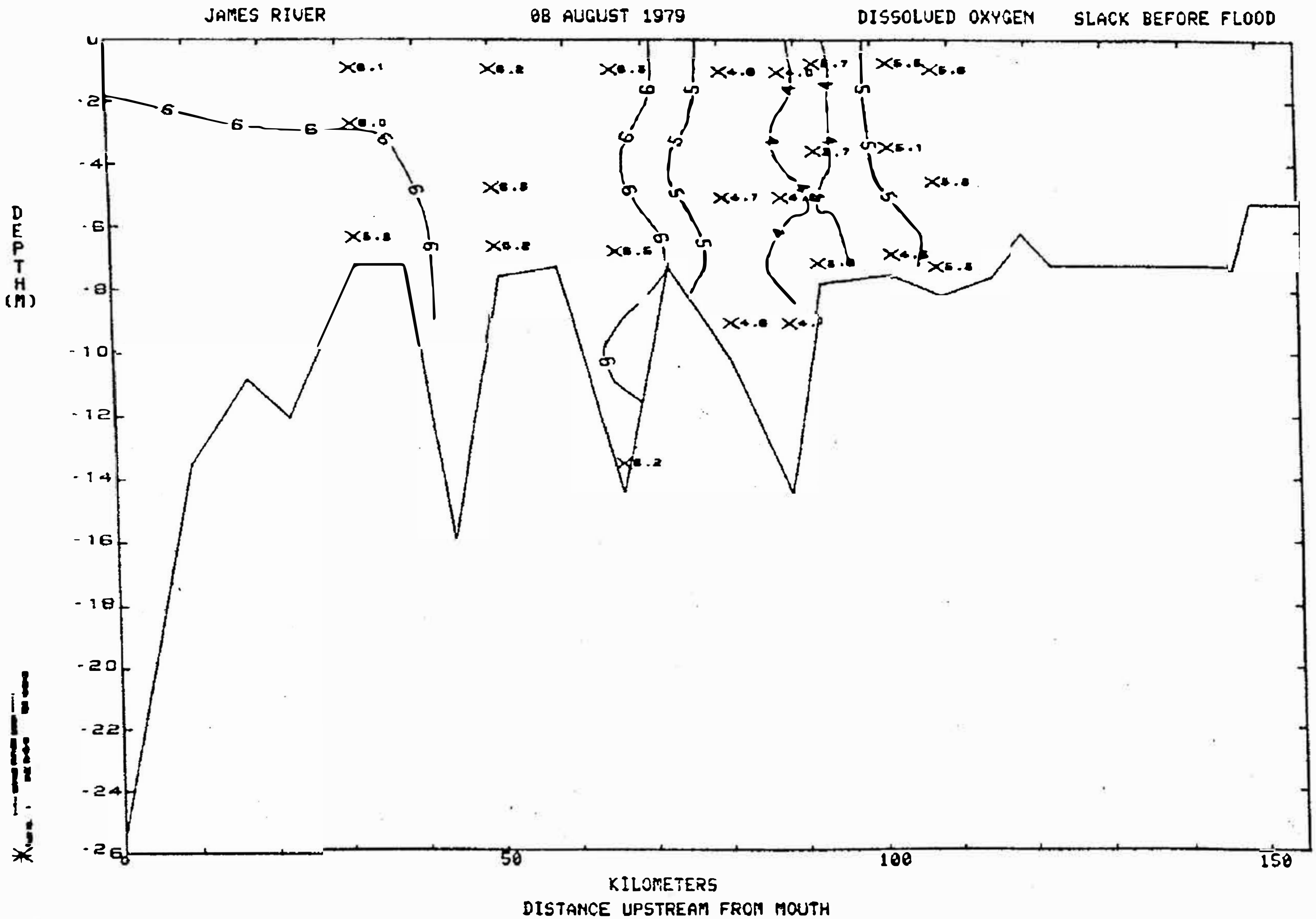


JAMES RIVER
13 JUNE 1979
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
10 JULY 1979
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

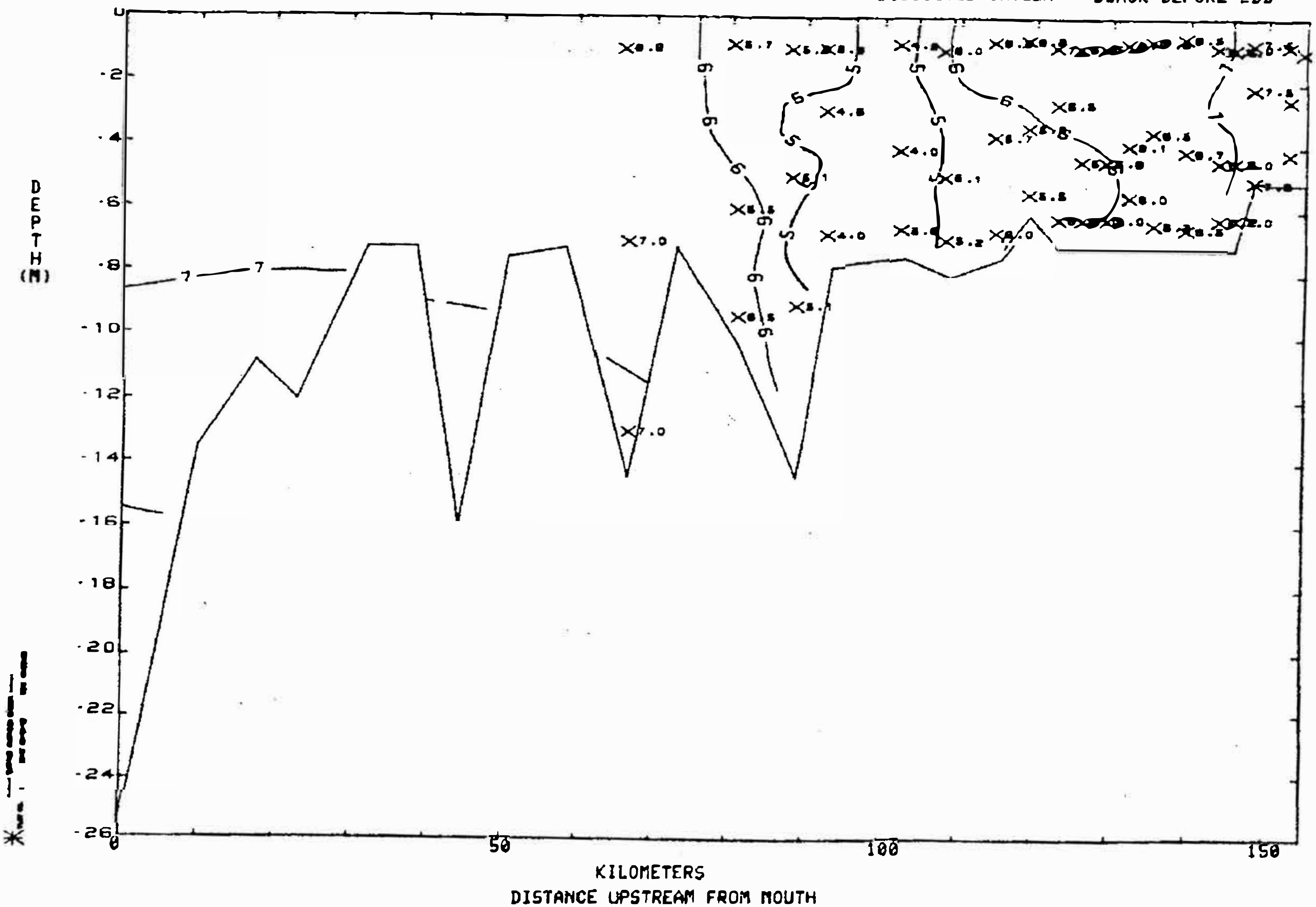


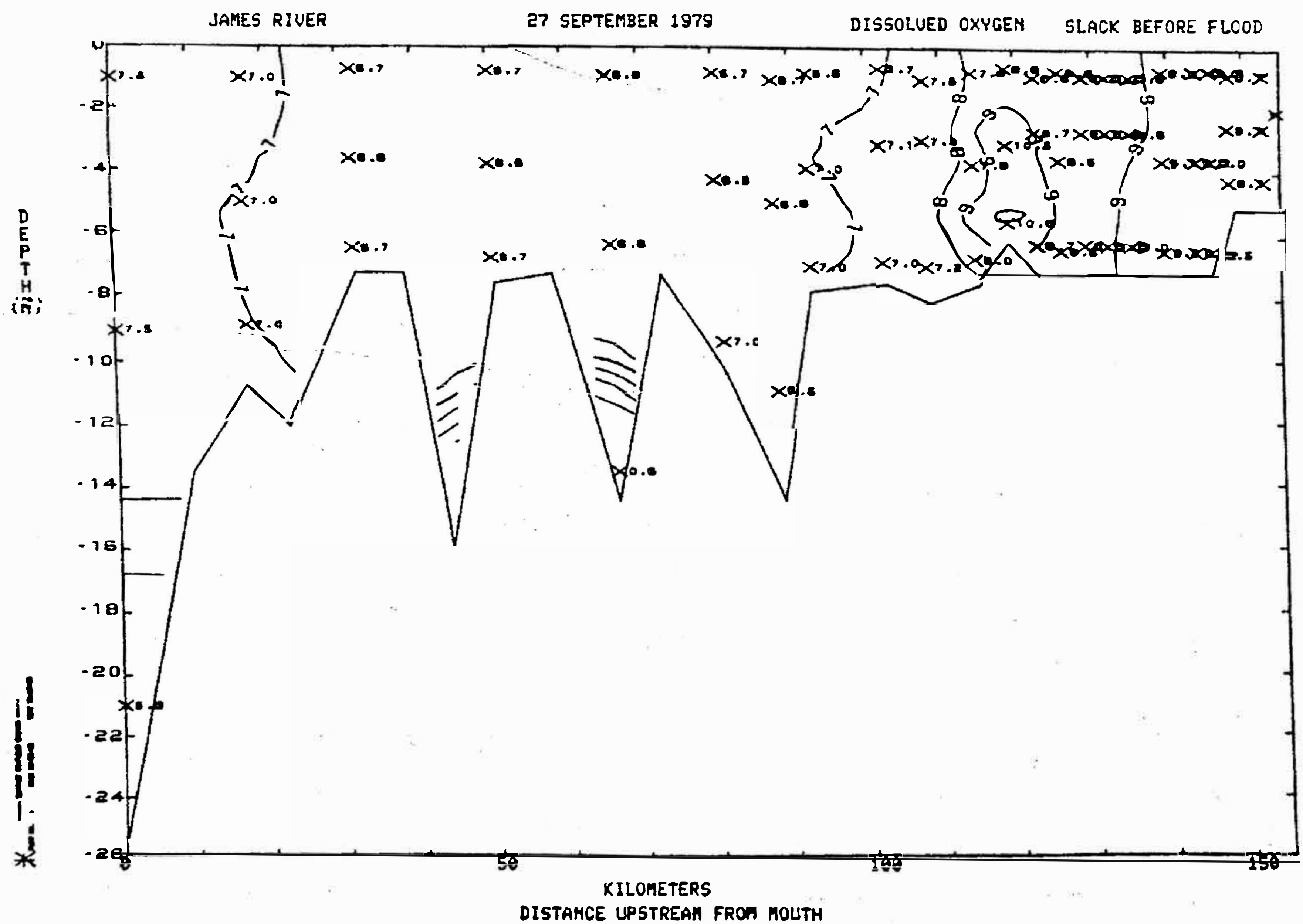
JAMES RIVER
07 AUGUST 1979
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



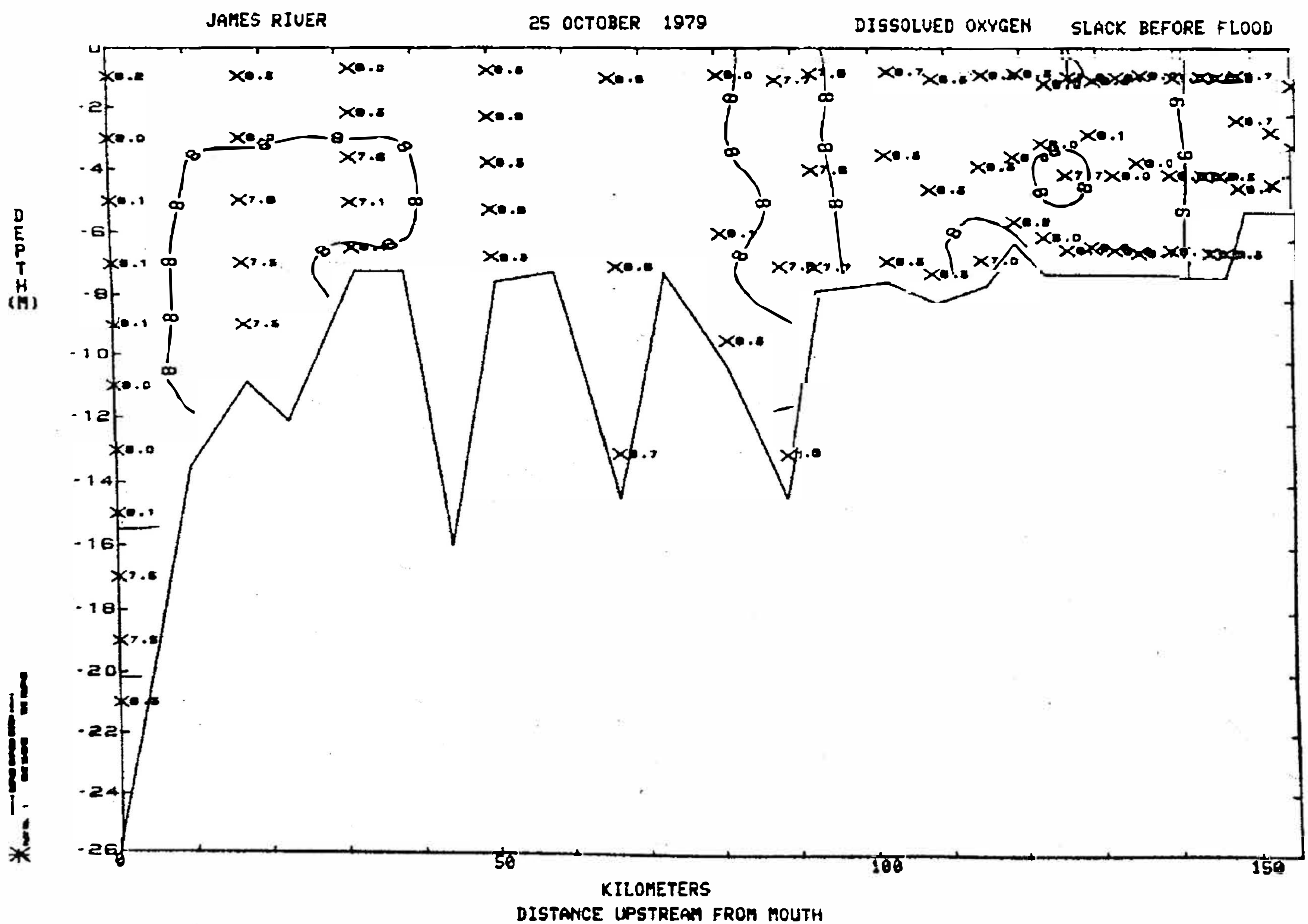
JAMES RIVER
08 AUGUST 1979
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

JAMES RIVER 04 SEPTEMBER 1979 DISSOLVED OXYGEN SLACK BEFORE EBB



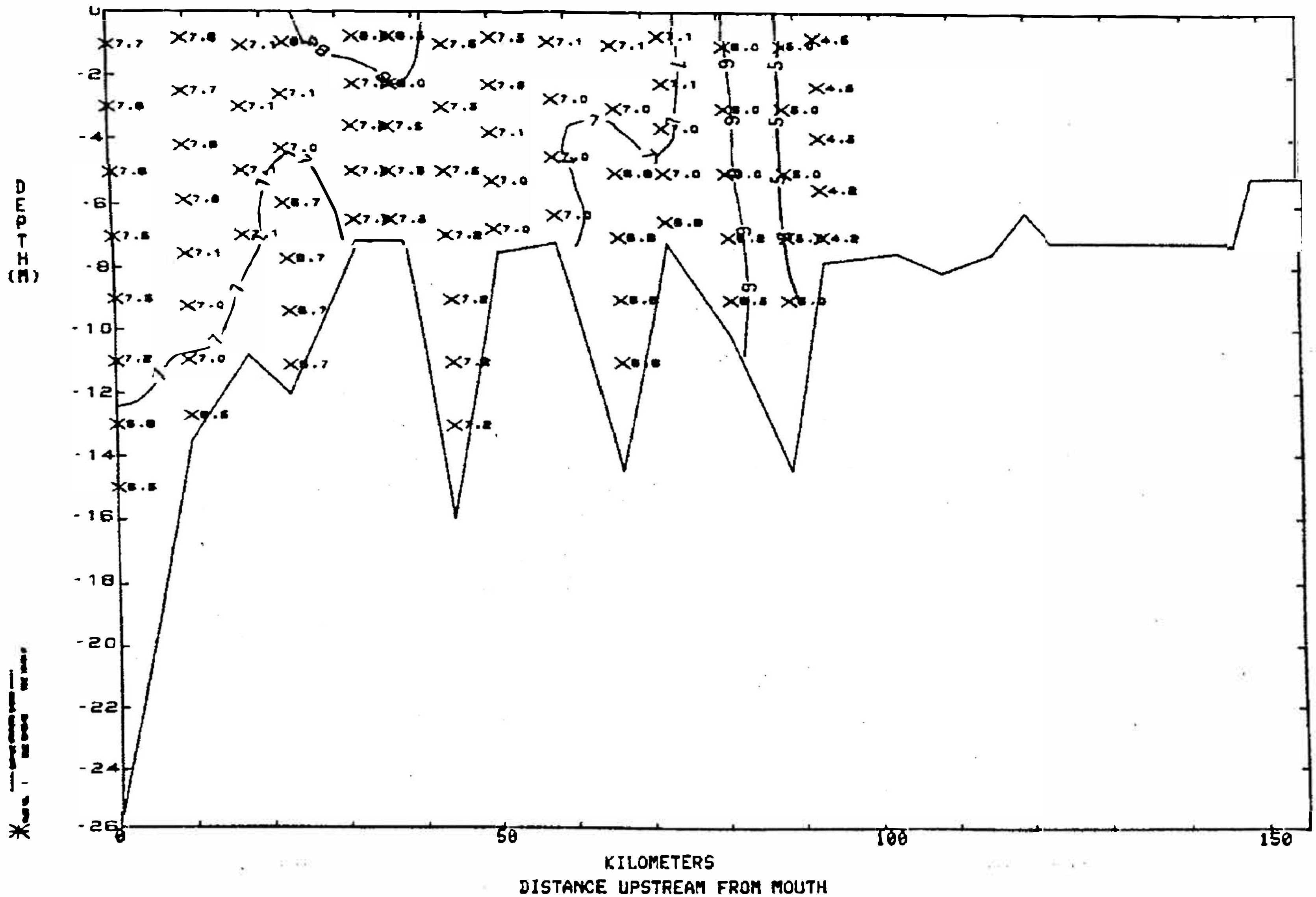


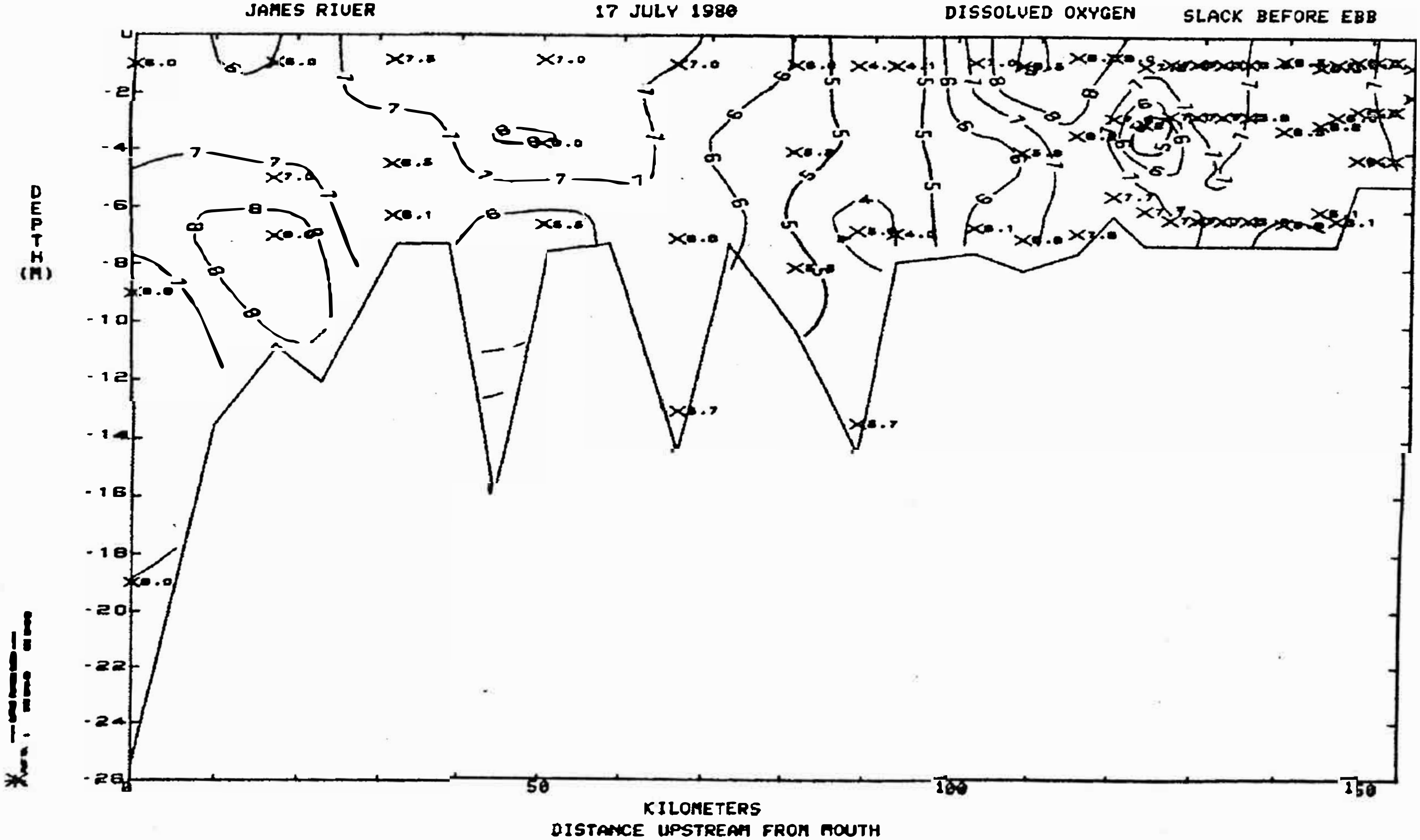
JAMES RIVER
27 SEPTEMBER 1979
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



JAMES RIVER
25 OCTOBER 1979
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

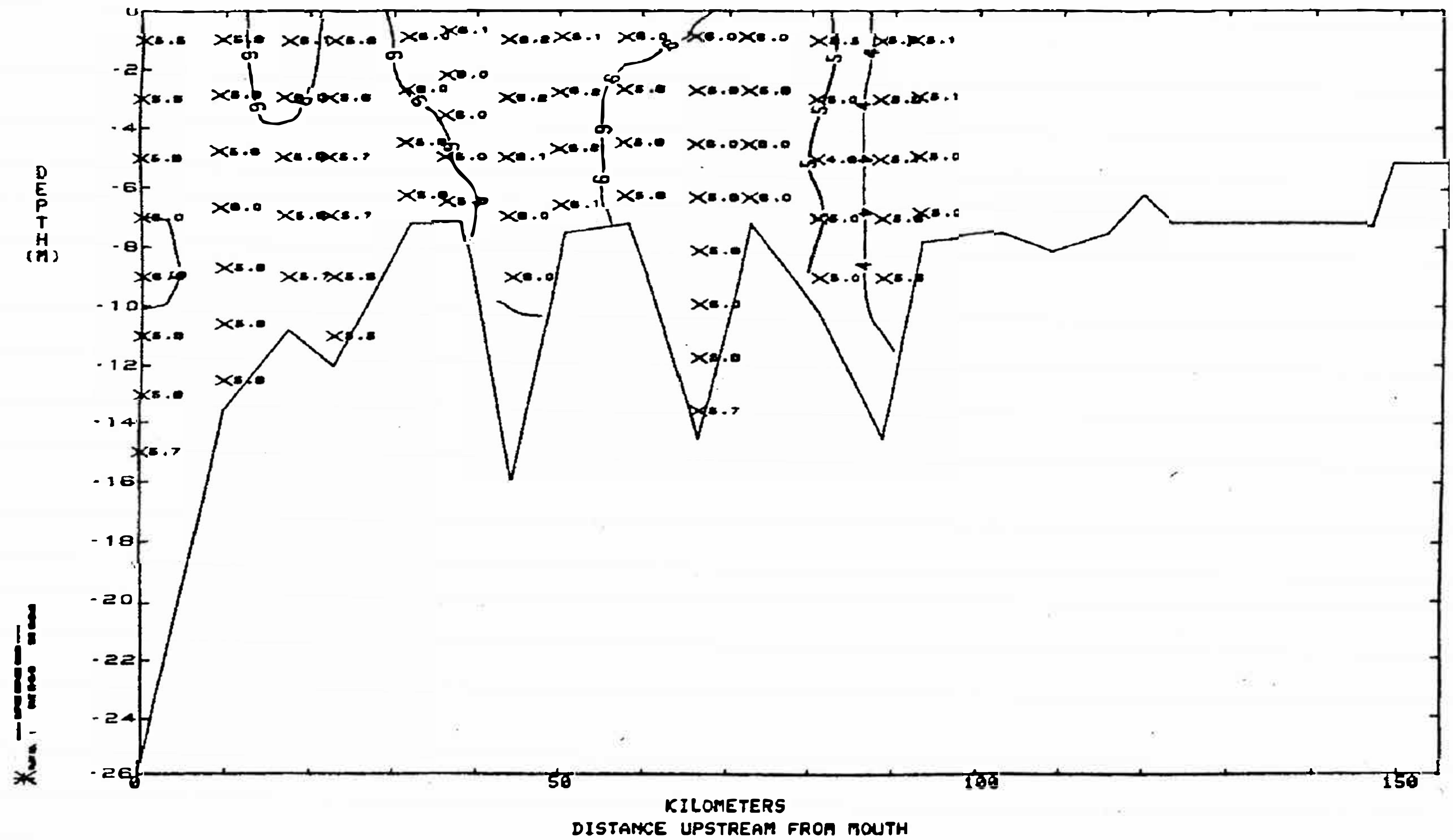
JAMES RIVER 25 JUNE 1980 DISSOLVED OXYGEN SLACK BEFORE EBB

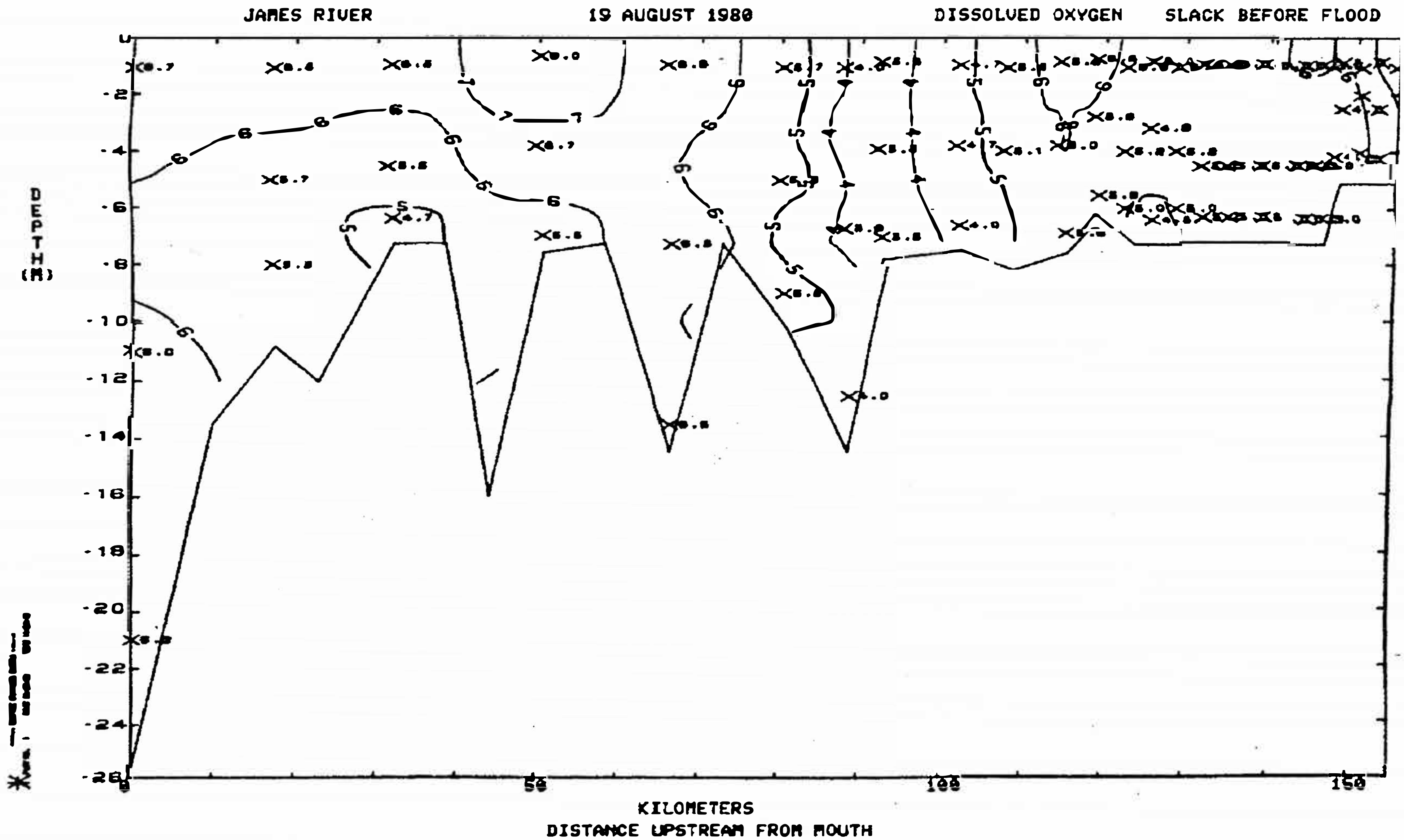


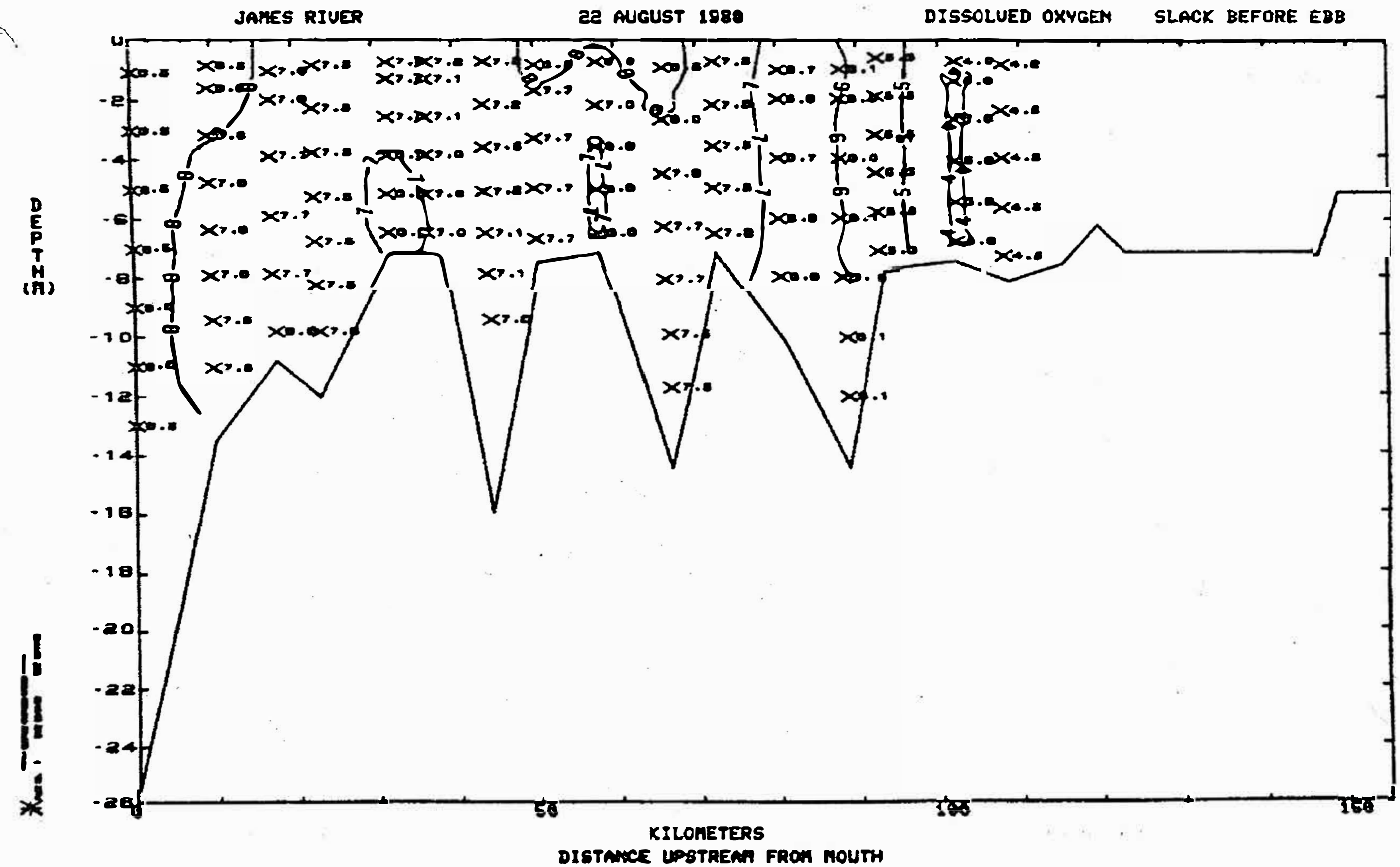


JAMES RIVER
17 JULY 1980
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

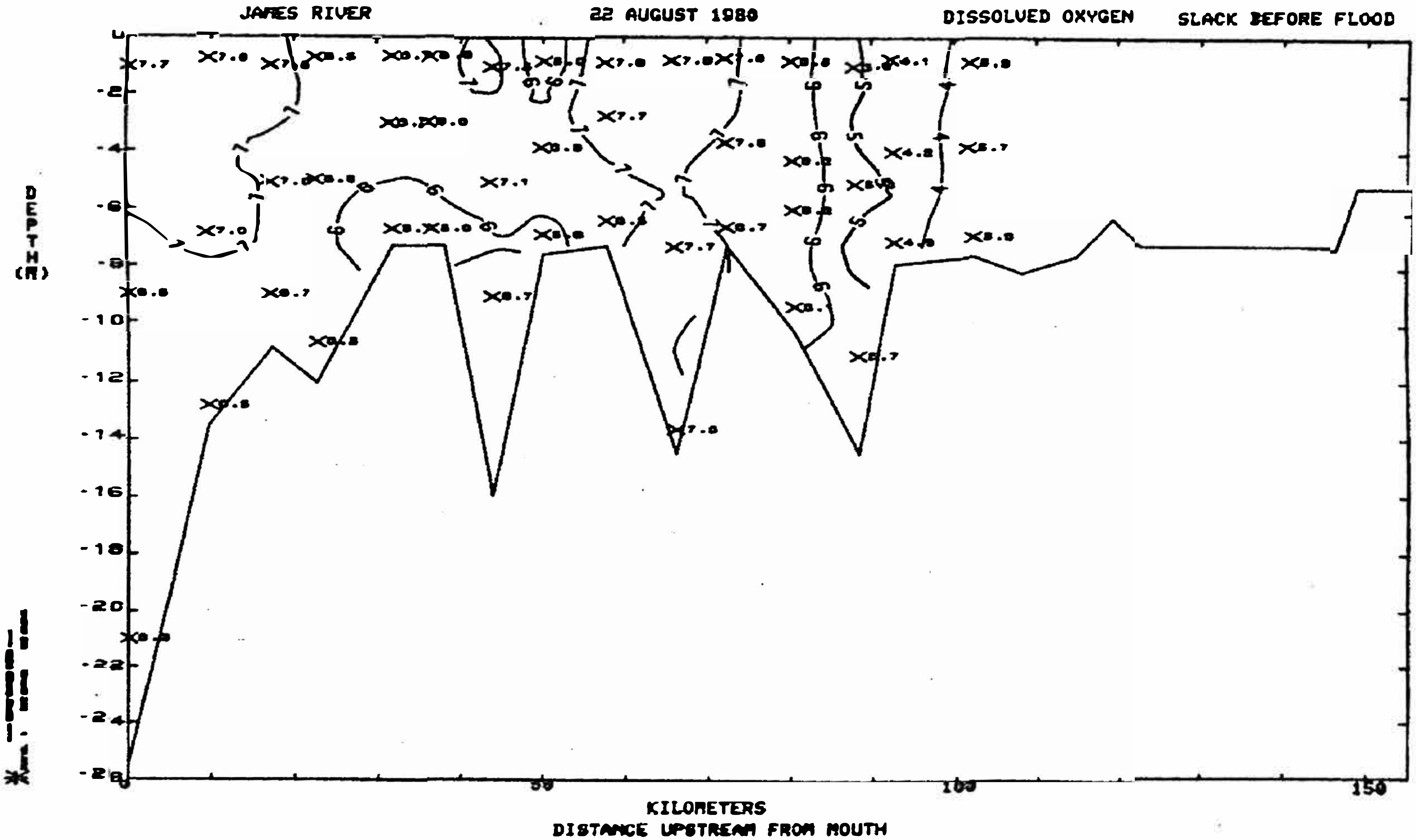
JAMES RIVER 14 AUGUST 1980 DISSOLVED OXYGEN SLACK BEFORE FLOOD



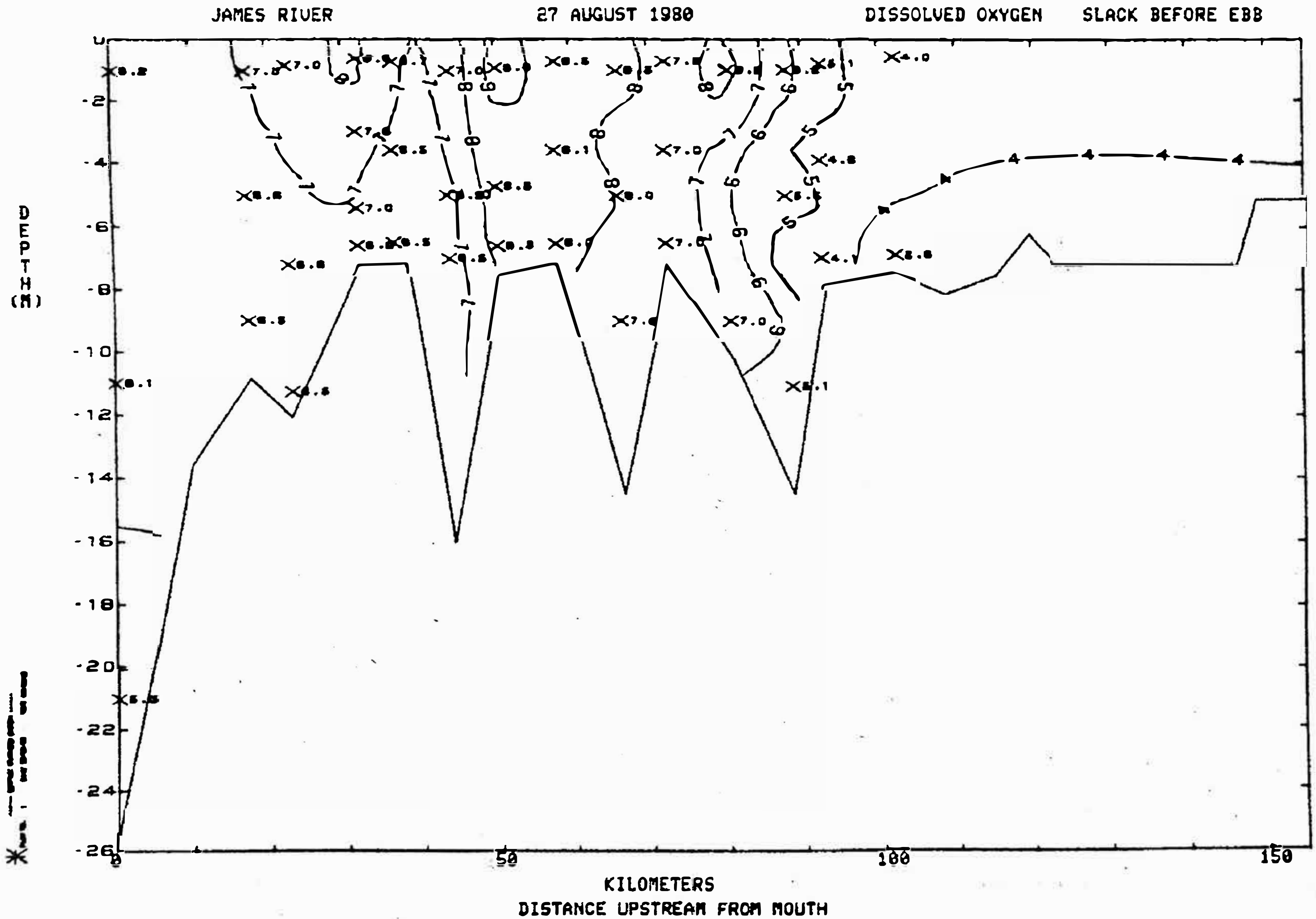

JAMES RIVER
19 AUGUST 1980
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

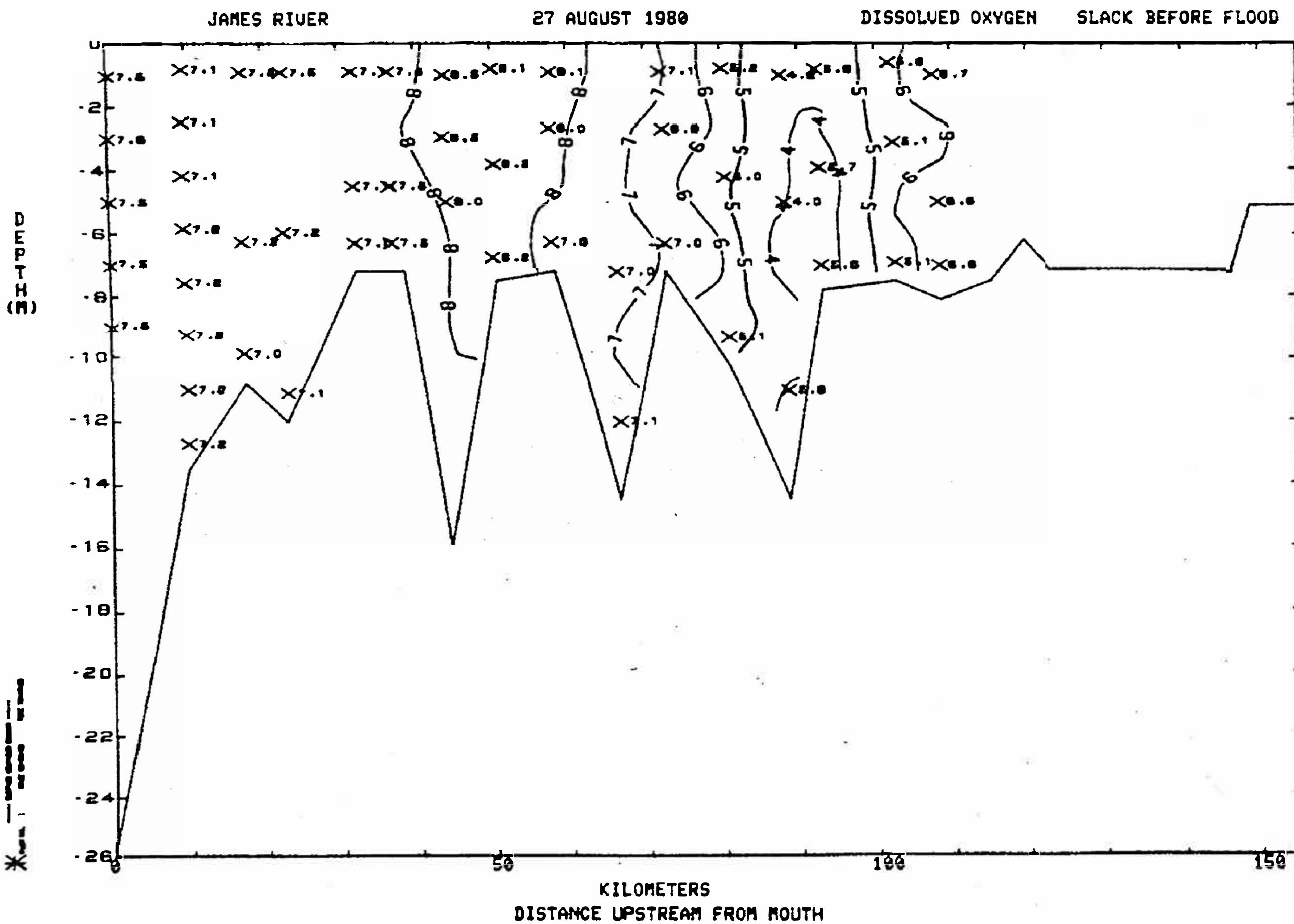


JAMES RIVER
22 AUGUST 1980
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

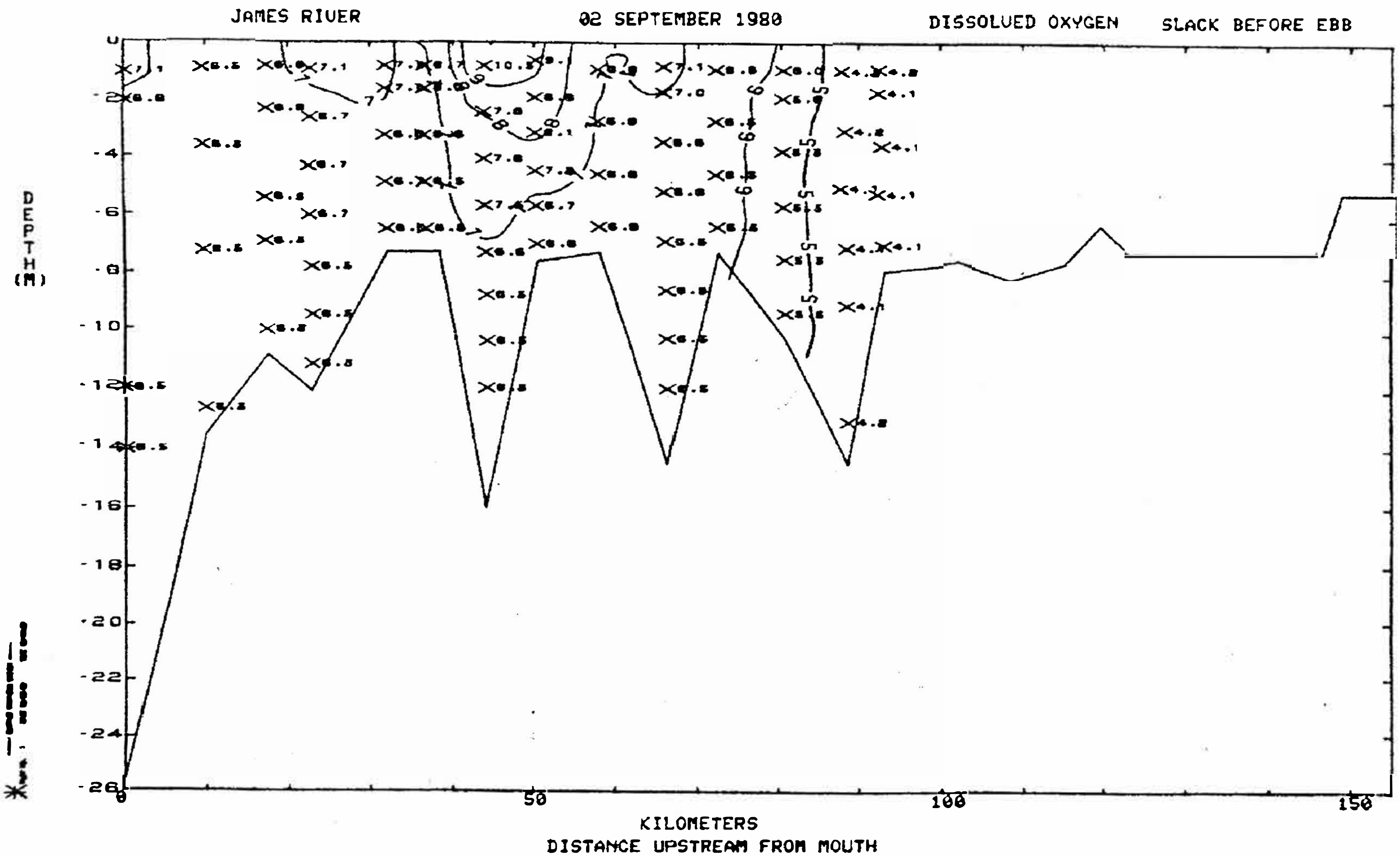


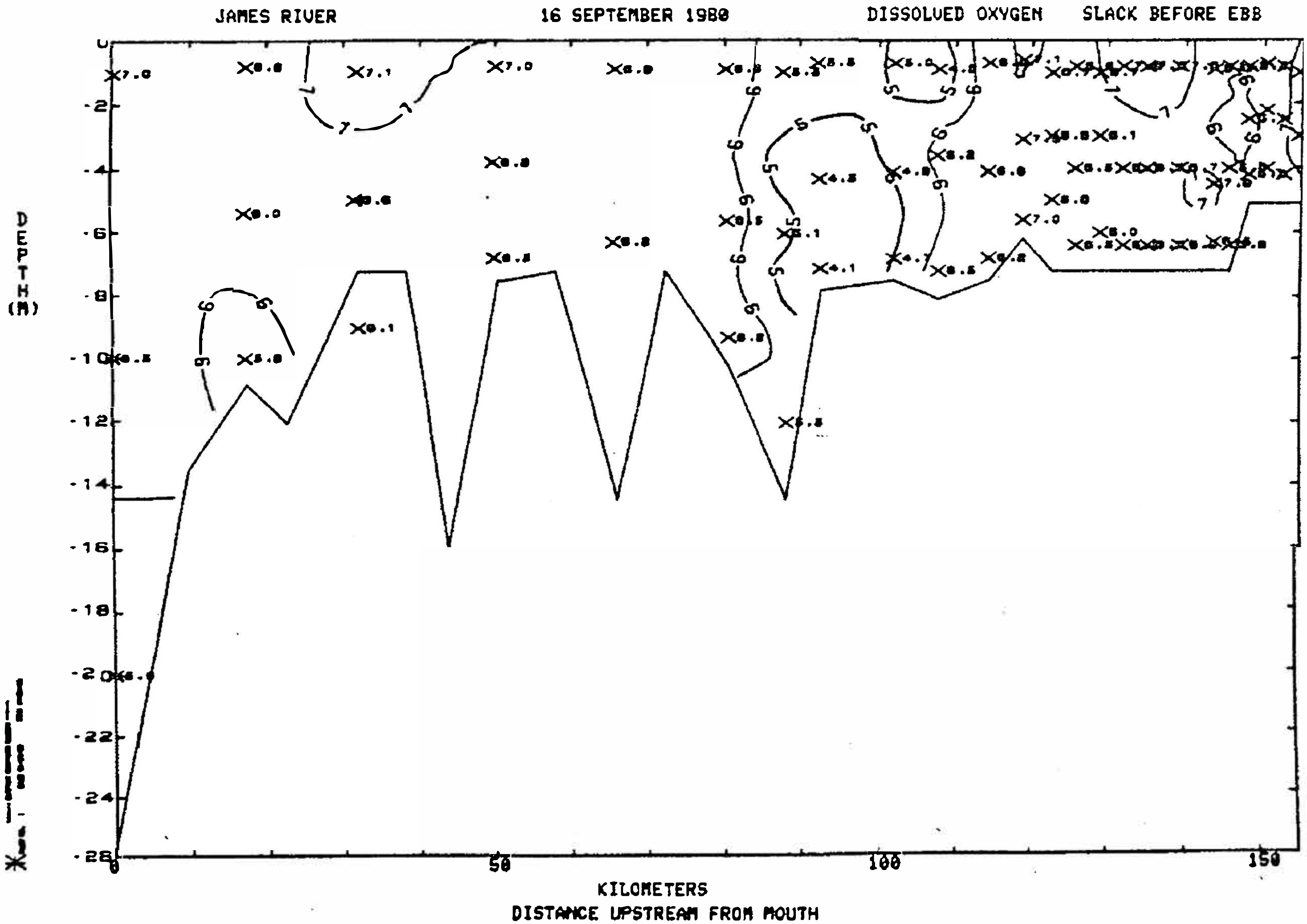
JAMES RIVER
22 AUGUST 1980
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
27 AUGUST 1980
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH



JAMES RIVER
27 AUGUST 1980
DISSOLVED OXYGEN
SLACK BEFORE FLOOD
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
02 SEPTEMBER 1980
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
0
50
100
150
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH


JAMES RIVER
16 SEPTEMBER 1980
DISSOLVED OXYGEN
SLACK BEFORE EBB
DEPTH (M)
KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

VIRGINIA INSTITUTE OF MARINE SCIENCE