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Investigation of oyster larvae and spat and certain important environmental factors in an horizontally stratified estuary : final report on project 3-7-R

William J. Hargis Jr.
Virginia Institute of Marine Science

INVESTIGATION OF OYSTER LARVAE AND SPAT AND CERTAIN IMPORTANT ENVIRONMENTAL FACTORS IN AN HORIZONTALLY STRATIFIED ESTUARY

Final Report on Project 3-7-R

by

William J. Hargis, Jr., Principal Investigator

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Gloucester Point, Virginia

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Reasonable progress has been made toward attaining the objectives of this project (No. 3-7-R). Considerable additional and new knowledge of the physical structure and dynamics of a theoretically horizontally-stratified estuary and the movement of the larvae and setting (spatfall) of juvenile Crassostrea virginica has been developed. Sedimentary processes, flushing times and the spatial and temporal distribution of the biological entities have also been investigated. Of especial interest have been the design, construction and verification of an hydraulic model of the system and the use of this scientific device to simulate movement of larvae by dye and to make "time of passage studies", as described below. Later utilization will involve similar studies.

Other interesting studies involved the comparison of structure and dynamics of the estuary as indicated by model studies with those suggested by the Ketchum-type mathematical model.

Details will be presented below under appropriate phase headings.

PERSONNEL

The grant-supported personnel during the year (1 July 1965-30 June 1966) have been:

Position Title	Number
Marine Scientist C	1
Marine Scientist B	1
Marine Scientist A	2
Clerk Typist B	1
Graduate Assistants	7
Laboratory Technician A	2
Summer Aides	6

Additional Institute personnel not charged to the contract have been engaged in several of the oceanographic and geological phases and in related biological research. Activities of all have combined to make the study more productive.

PHASE I

Laboratory Physical and Biological Simulation Studies

(The Model Work)

Following completion of the construction and verification stages on the James River hydraulic model during the early quarters of this project, the research or study phase was undertaken. Model investigations followed protocols established over the last two years by consultation between VIMS' biologists and oceanographers, Waterways Experiment Station (U.S. Army Corps of Engineers) personnel and Dr. D. W. Pritchard and updated by information available from recent prototype and biological studies.

These tests, specifically designed to answer questions concerning the changes in physical parameters, i.e., salinity, currents and level of no-net motion considered biologically significant, expected to result from channel deepening, were laid out in the following order:

1) Model studies without and with the channel configuration changes, simulating a prototype biological year (February to November) featuring an experimental hydrograph of low average flows (low freshwater input).

2) Model studies without and with the channel, simulating a prototype biological year (February to November) featuring an experimental hydrograph with high average flows (high freshwater input).

(The purpose of these tests was,and is, to permit bracketing the changes in salinity and other physical parameters resulting from the bottom geometry changes to be brought about by channel deepening. This will help establish upper and lower limits, high and low-flow years of changes.)

3) Model studies without channel configuration changes utilizing steady-state hydrographs (single flows) chosen to represent specific biologically important times of the year. These are (a) an high-flow period, 11,000 cfs, to represent late winter-early spring freshet times, thought important to drills and oysters; (b) a medium flow period, 3, 200 cfs, to represent late spring-early summer, important to breeding of predatory snails; and (c) a low-flow period,

1,000 cfs, representing the late summer period, known to be important to oyster larvae.

/These tests are to permit accurate spatial determination (areal changes) of the effects of the channel deepening on the presumed biologically important parameters of salinity, currents and level of no-net motion at specific fixed flows. Steady flows (versus the more normal transient flows as described immediately above) permit running the model to a "steady-state" condition and hence more methodical and accurate work. They also permit certain dye studies./

In addition to the above physical studies, two series of dye experiments were developed and undertaken by VIMS' personnel operating on site at Vicksburg. One involved dye releases upstream to determine "time of passage" of fresh water, i.e., how long it takes a dye-tagged water mass to move from the fall line into estuarine zone and thence to the sea. These experiments indicate flushing rates, important to pollution studies, and time required for freshets to affect the lower estuary, important to oyster production. The second series involved simulating oyster larval swarms from point sources in the lower estuary, whence larvae are believed by some to originate. (As shown immediately below, results of these dye studies have provided some fascinating insights into the workings of a tidal tributary not suspected.)

Resultant quantitative and qualitative data from the model studies have been acquired for future analysis. Large numbers of observations have been made.

It is believed that this is one of the first large-scale estuarine studies in which effort has been made to utilize correlated

modeling techniques and biological studies.

A direct result thus far has been increasing familiarity of VIMS' personnel with the James River model and actual potentials and problems associated with its use. We are one of the few institutions with such a facility and developing capability in its use.

RESULTS OF DYE STUDIES

The hydraulic tests conducted on the James River model have provided an opportunity for some dye tests to be run concurrently with the major test program. VIMS supplied the personnel for dye test design, sampling, and analysis. The tests were intended to elucidate circulation features of particular interest to biologists and physical oceanographers at VIMS. The major aims were:

1) To obtain flushing times for the estuary that would be useful in checking physical calculations relating to a Ketchum-type model of the James River.
2) To simulate spawn of oyster larvae by dye releases and to determine the locations in the James that larvae from given release points could reach before death.

The following dye tests were conducted:

a) Release of pontacyl pink dye at Richmond with 11,500 cfs steady flow, undeepened channel, deepened Hampton Roads channel and turning basins, for flushing study.
b) Release of pontacyl pink dye at Richmond with 3,200 cfs steady flow, undeepened channel, deepened Hampton Roads channel and turning basins, for flushing study.

c) Concurrent release of Uranine dye on Hampton Bar and Nansemond Ridge for oyster larvae transport study.

d) Release of pontacyl pink dye at Richmond and of Uranine at mouth of Chickahominy with 1,000 cfs steady flow, undeepened channel, deepened Hampton Roads turning basin, for flushing study.

e) Concurrent release of pontacyl pink dye at locations near those in test (c) for oyster larvae.

f) Consecutive releases of pontacyl, Uranine and pontacyl dyes at Richmond during flow peaks of transient flow year 1949 test with undeepened channel, deepened Hampton Roads turning basin for flushing studies.

Exact locations of oyster dye releases are given on accompanying chart, Fig. 1.

FLUSHING STUDIES

Flushing studies serve two main purposes. Under steady state (constant river flow) conditions they permit checks on the Ketchum model as adapted by VIMS' oceanographers, Ruzecki and MacIntyre. The Ketchum model calculations have been completed but doubts as to their theoretical validity exist. Ketchum treated the case of an estuary with a uniform standing wave tide. The James has a non-uniform progressive wave tide that is not compatable with the mathematical justifications of the Ketchum model given by Arons and Stommel. It is hoped that flushing times from the Vicksburg model and some discussion with Ketchum and Stommel will resolve this problem. Even with these uncertain bases, the Ketchum model

gives flushing times that are believed to be approximately correct, a point which can be checked with the James model flushing studies.

Side purposes of flushing studies are 1) to determine the length of time and given pollutant would remain in a given region of the James River, and 2) the length of time required for a pulse of fresh water to affect the salinity at various points in the estuarine reaches of the tidal river. The transient test (f) was ideal for the pulse studies. In all tests concentrations of residual dye (as pollutant or freshwater accumulations) were observed and recorded.

Dye releases were made in slugs because it was desired to identify dye with a time of release, and the technique was simpler in the available time. Special information such as entrapment of dye (water masses and pollutants) in river bends and side channels could not have been obtained otherwise.

OYSTER LARVAE DYE STUDIES

In the oyster larvae dye studies, only slug releases were possible because we wished to use the dye to simulate the planktonic stages of a single brood of oysters, i.e. about two weeks. A continuous dye release would not have allowed this. The oyster life span in the model is given by the time scaling factor of the model. Under the generally accepted (by VIMS) premise that oyster larvae are planktonic for about 15 days and then must set or die, it was calculated that the 15-day life span of the prototype larvae equaled 216 minute life span in the model. All dye tests to study oyster larvae were therefore terminated 250 minutes after dye release on spawning grounds.

Concentrations and volumes of dye released in slugs for the test series:

(a) 2 liters pontacyl pink, concentration 1,250 ppm. (Released at Richmond).

(b) 2 liters pontacyl pink, concentration 1,250 ppm. (Released at Richmond).

(b)[1] 1 liter Uranine, concentration 1,000 ppm. (Releases at point indicated in red on chart on slack before flood).

(c) 2 liters pontacyl pink, concentration 2,500 ppm. (Released at mile No. 45).

(c)[1] 1 liter pontacyl pink, concentration 1,000 ppm. Diluted with salt water from model, locations of release indicated in yellow on map. Releases on slack before flood.

(d) 1 liter pontacyl pink, concentration 5,000 ppm.

1 liter Uranine, concentration 5,000 ppm.

1 liter pontacyl pink, concentration 5,000 ppm.

Successive release at Richmond during annual hydrograph run.

Elapsed Time Scales

All elapsed times measured in minutes from:

a) Richmond release.

b) Richmond release.

c) Richmond release - oyster dye added 182 min. later

d) Oyster dye release - 21 min. before dye release at Richmond and 133 min. before dye release at mile No. 45.

e) Oyster dye release at positions given in map.

f) 1st pontacyl pink dye release - after 591 min.

Sample of Uranine added - after about 1650 min. sample of pontacyl pink added.

General Information

Dye concentrations were determined in the conventional manner with a fluorometer. The slight interference of pontacyl pink in Uranine analysis was corrected by a simple assumption. The Uranine result was reduced by 0.05 x conc. pontacyl pink present. Converse correction was not necessary.

Photographic records of dye movements were made on polaroid color film. Some Kodachrome II slides were also made. These photos are not sufficiently good to be included in the report. All dye photography was carried out by VIMS' personnel. Time elapse photography would be very useful but was not possible during early studies.

In tests (c) and (e), oyster larvae managed the voyage from release (spawning) point in Hampton Roads to end (setting area) points on the seed beds in times well within their model life span times. Thus, the areas of dye release may be considered as oyster larvae source areas and Pritchard's suggested scheme of upstream transport of oyster larvae is accorded some experimental support.

Preliminary Analysis

Time of Passage Experiment

In the time of passage tests (a) (b) and (d), the reduction in river flow from one test to the next produces a corresponding slow down in passage of the center of the dye slug downstream.

Figures 2, 3 and 9 show time of passage at 11,500, 3,200 and 1,000 cfs river flows respectively. Elapsed time and distance are used to record the position of the head and tail of the dye mass after given times.

The distance (miles) between head and tail is obviously a measure of the amount the dye has diffused, while the slope of the lines indicates the speed with which the dye mass moves downstream (the greater the slope, the lower the speed).

The general result that with reduction of river flow by a factor of 10, horizontal diffusion more than doubles and the center of dye moves toward the mouth at least three times more slowly is apparent from these graphs. For detailed analysis, mathematical procedures must be applied to the data. This task has not yet been undertaken.

Oyster Larvae Experiment

The results of the oyster larvae may be seen by study of Figures 4, 5, 6, 7 and 8 and 10, 11, 12, 13 and 14 which present graphs of dye concentrations at fixed positions (stations) as a function of time after oyster dye release.

For example, Figure 10 shows a high concentration at the James River Bridge soon after oyster dye release with a gradual decrease with time. The graphs in Figures 11, 12 and 14 show the same phenomena at upriver stations. The graph on Page 24 (Fig. 13) shows that dye concentration at station 59 continues to tail off after experiment is ended by oyster larvae death. That is, no outside dye interferes. Figure 14 shows that larvae concentration is still increasing at Burwells Bay area, while in downstream areas, it has begun to decrease at the end of the experiment. (Data used in preparing the graphs are in the files of the Department of Physical and Geological Oceanography and will serve as a basis for more detailed investigation at a later time.)

Much better data could be gleaned from model test runs designed solely for dye studies. The present work was carried out under quite

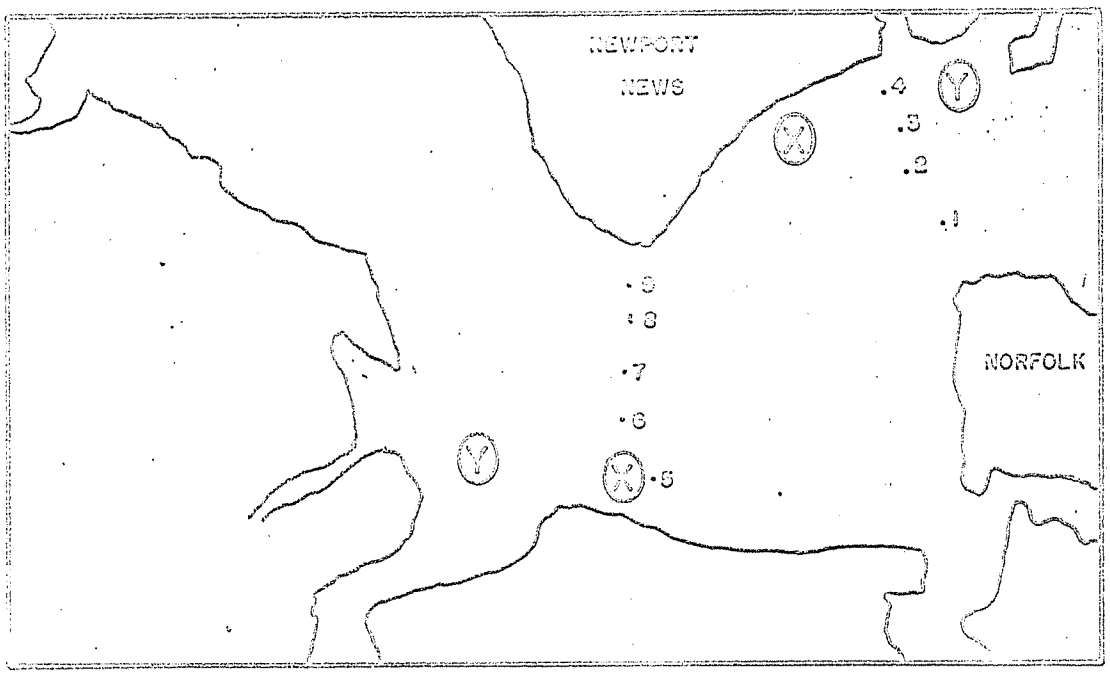
unfavorable conditions: personnel sufficient for complete sampling could not be provided, simultaneous hydraulic testing cluttered the model with sampling devices and people, time was not available for running slugs of dye from Richmond to Newport News, because model had to be stopped and made ready for new hydraulic tests.

Fig. 1 OYSTER LARVAL STUDIES

LOCATIONS OF DYE RELEASES

TEST (c)' – (X)

TEST (c)' – (Y)



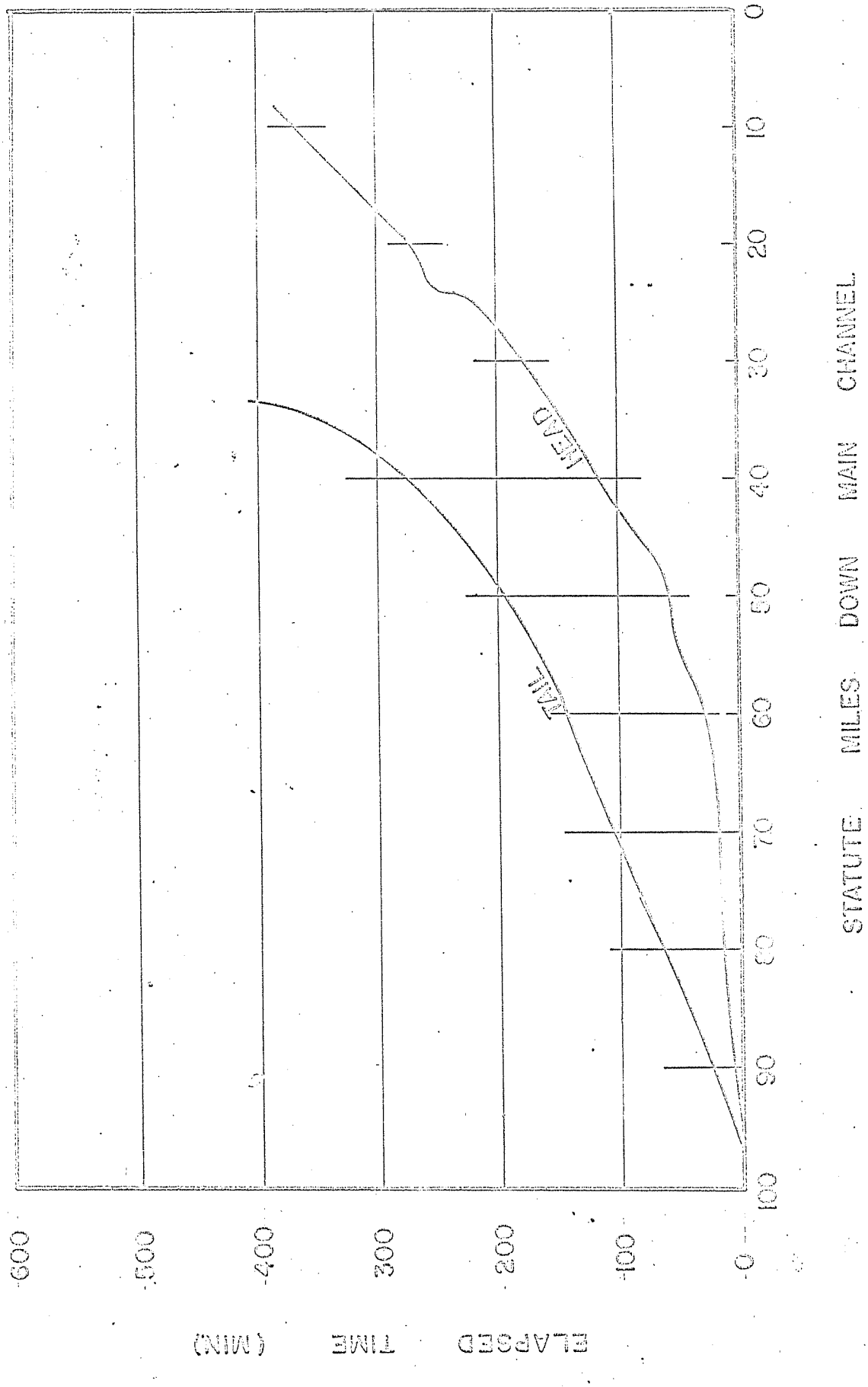
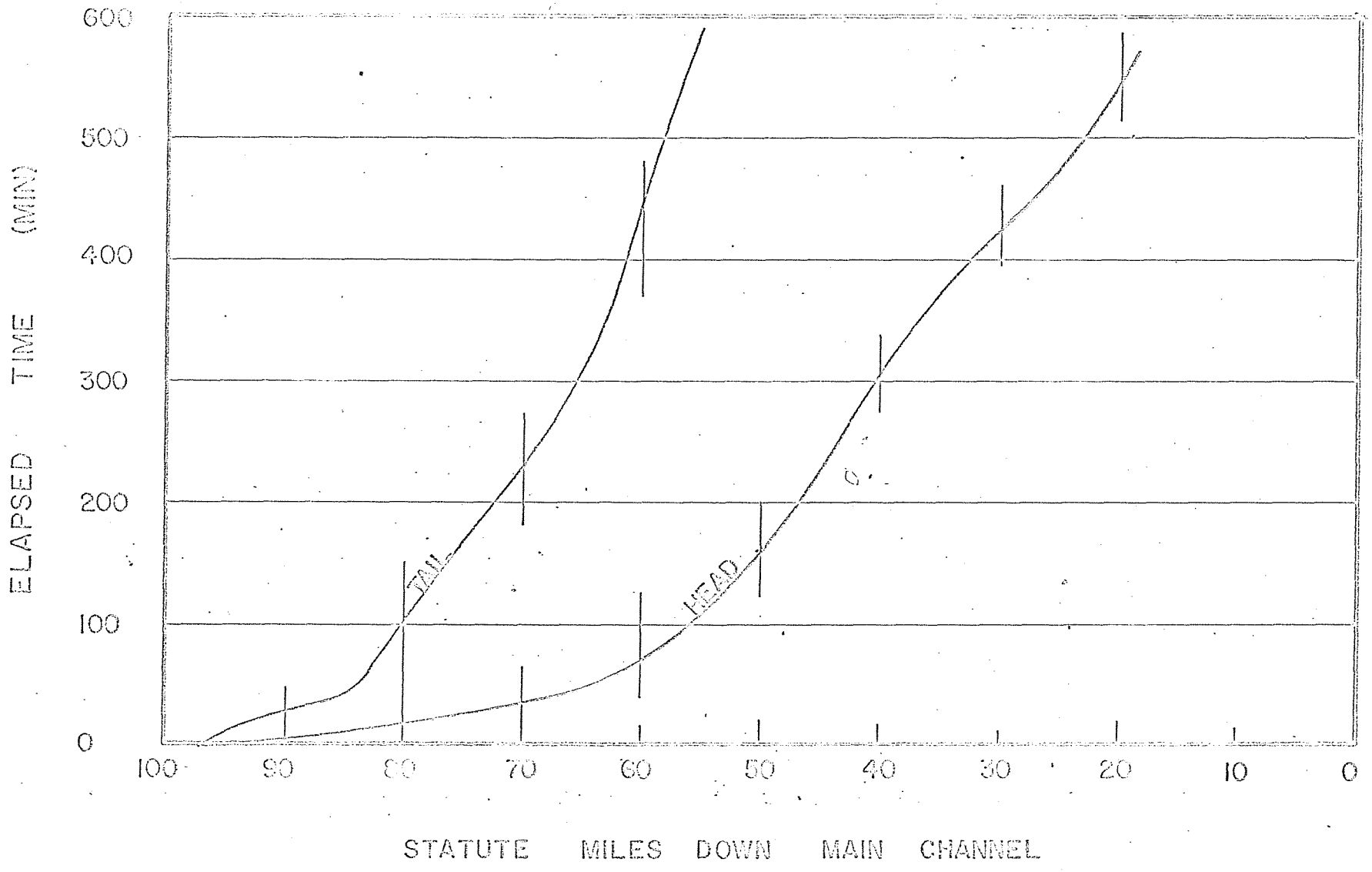
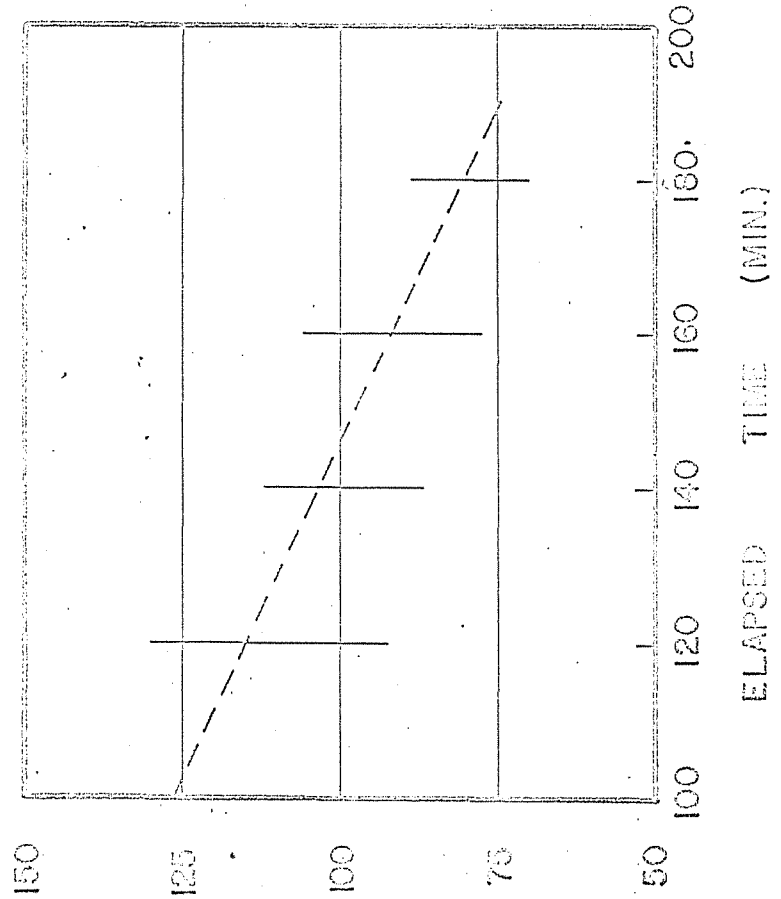


Fig. 2 [illegible] (a) — 11,500 CFS SDF DATA

Fig. 3 TEST (b) — 3,200 CFS SBF DATA




SBE CALC.
STATION 9
TEST (b')
Fig. 4
150
125
100
75
50
CONC. PPB
100
120
140
160
180
200
ELAPSED TIME (MIN.)

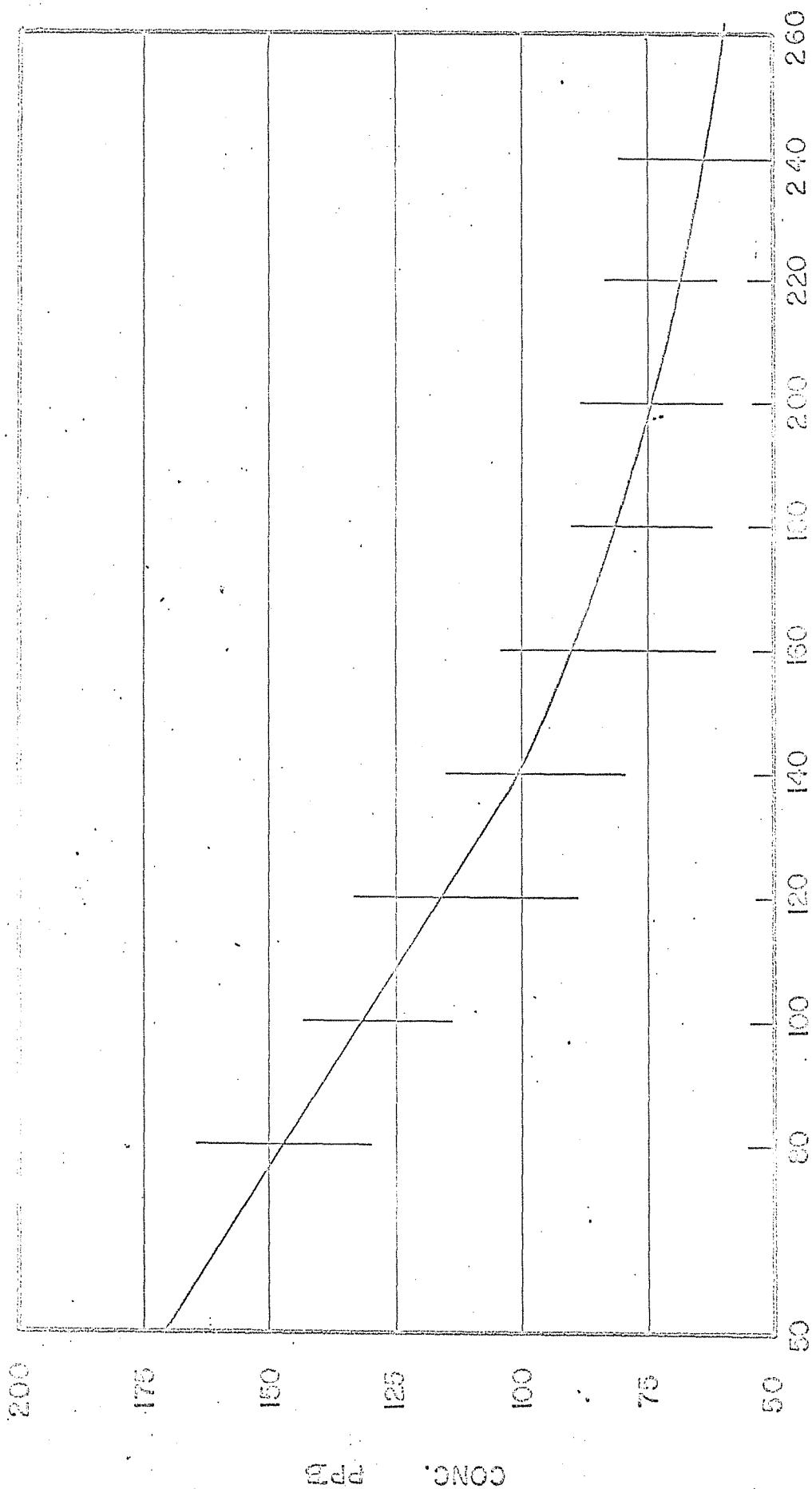


Fig. 5 (1st) (1) STATION 6S

Fig. 6 TEST (b') STATIONS 13 (---) SBE DATA

12 (——)

10 (– – –)

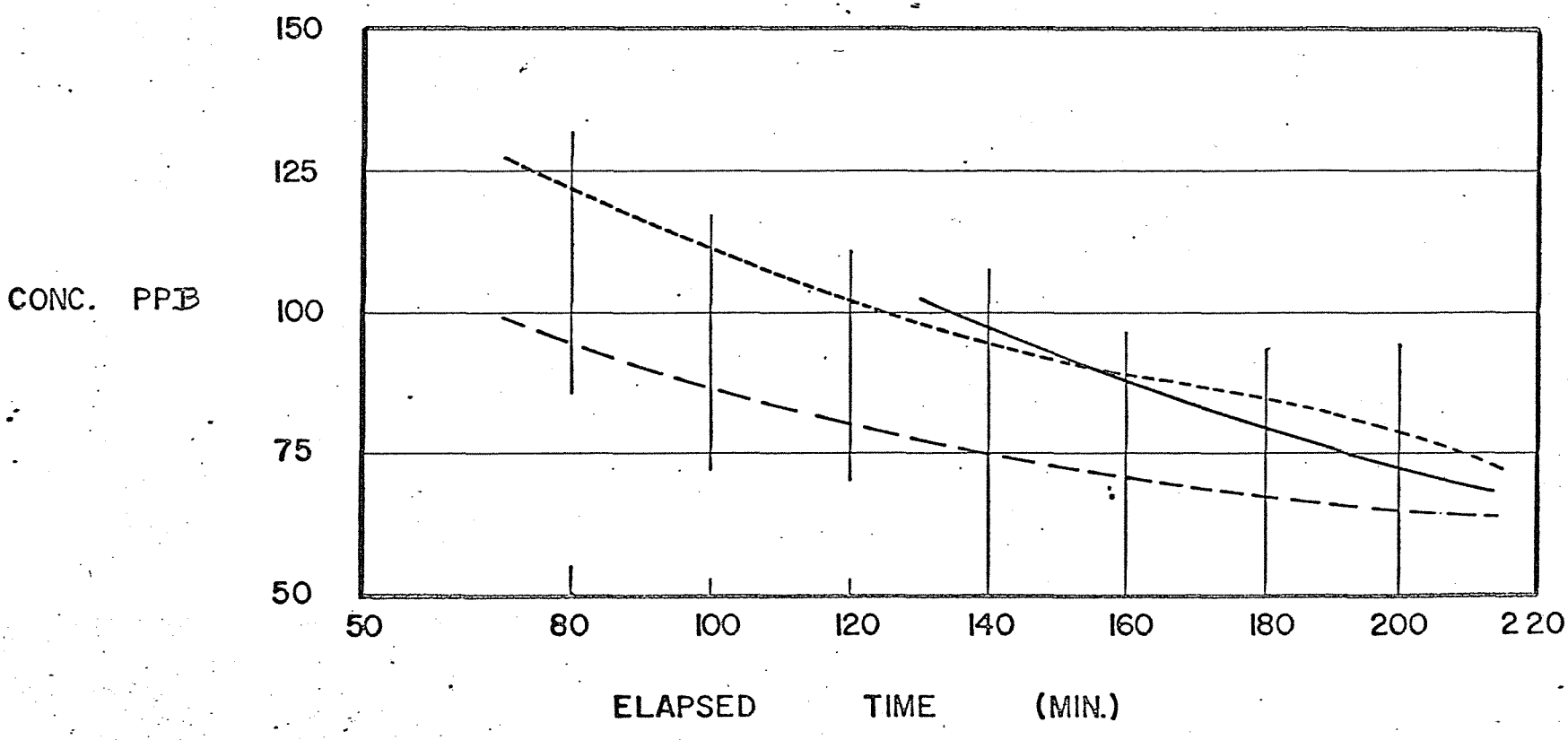


Fig. 7 TEST (b') STATIONS 57B (---)
54 (— —)
69 (——) SBE DATA

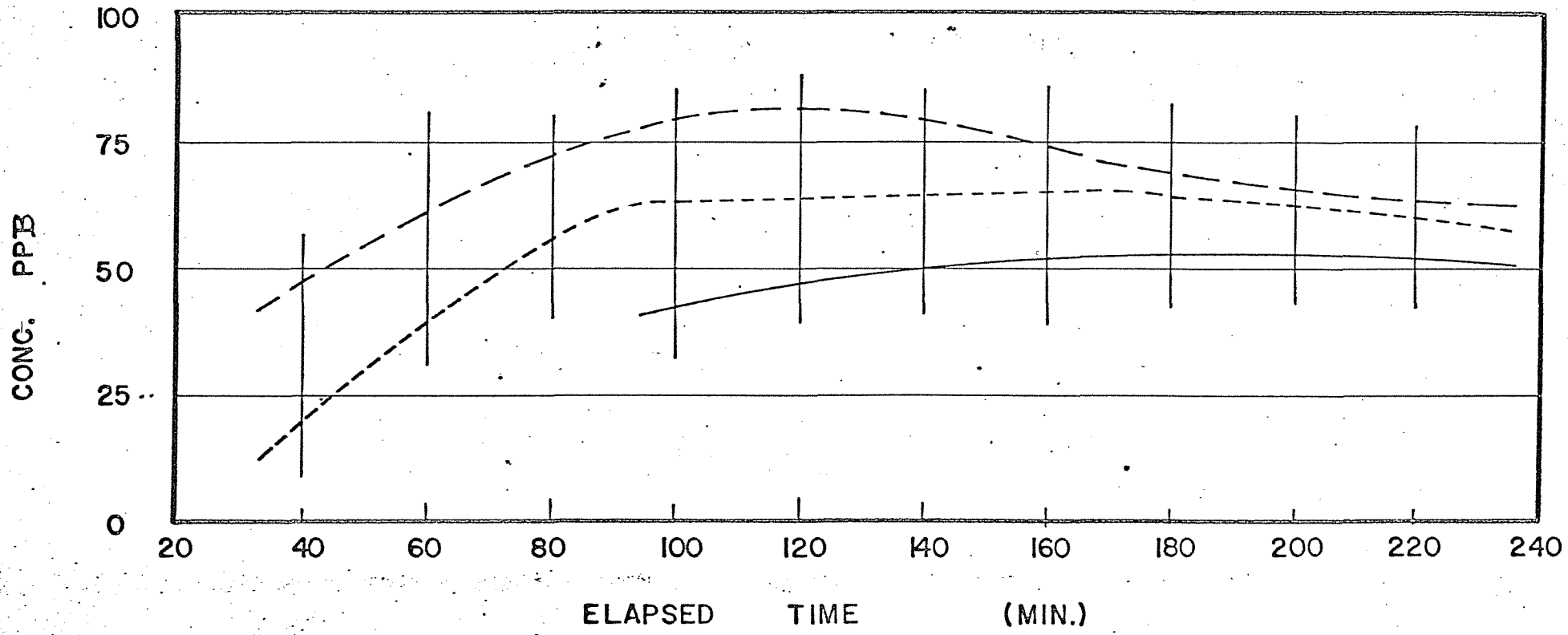


Fig. 8 TEST (b') STATIONS (AS GIVEN) SBE DATA

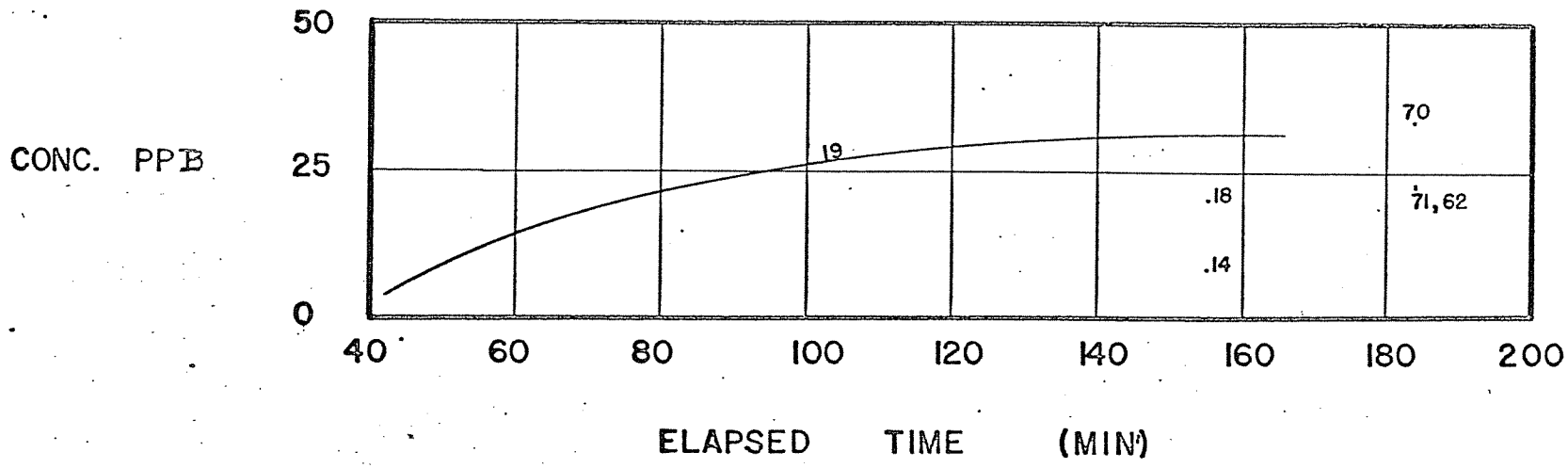
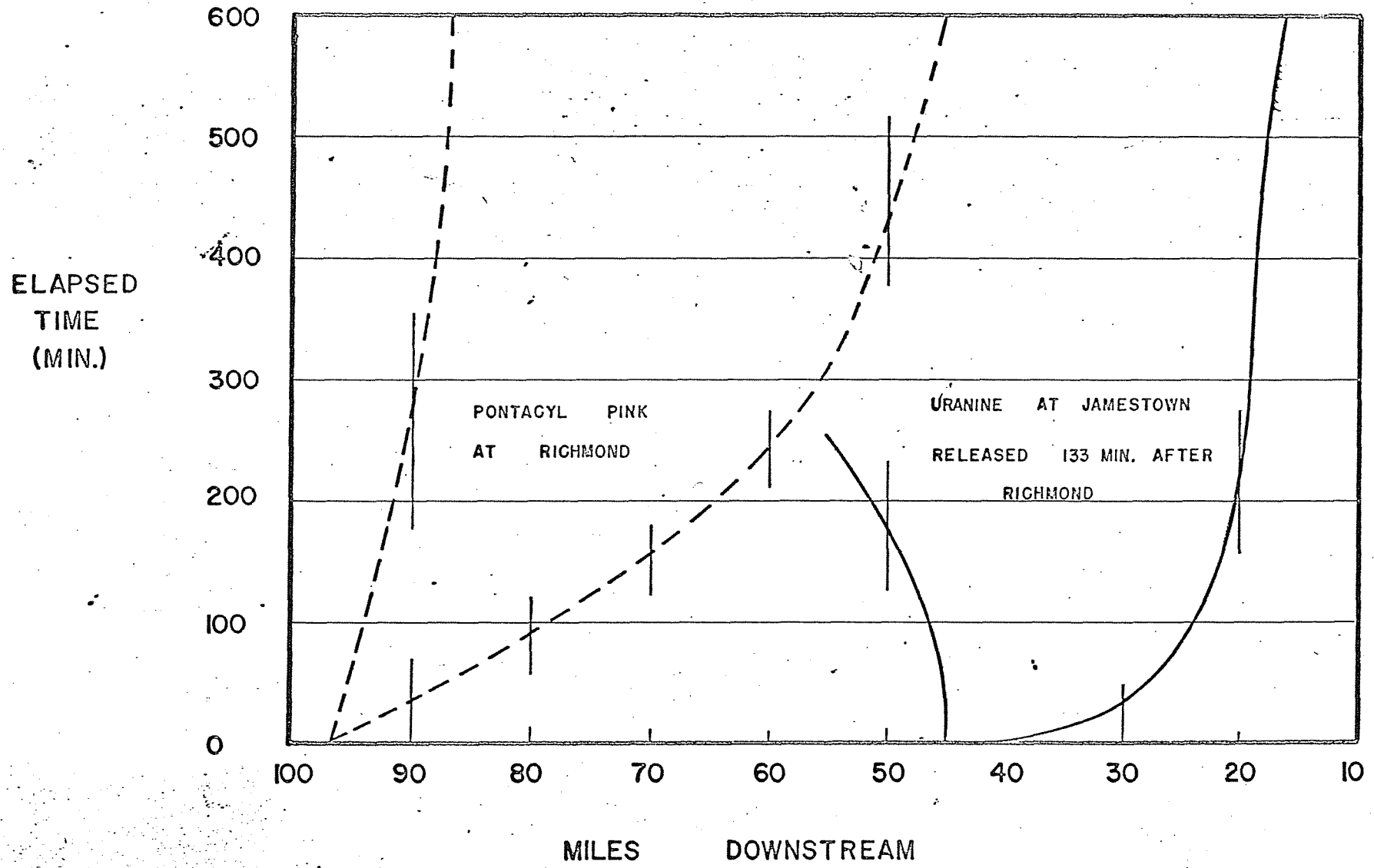


Fig. 9 TEST (c)— 1,000 CTS. SBF DATA



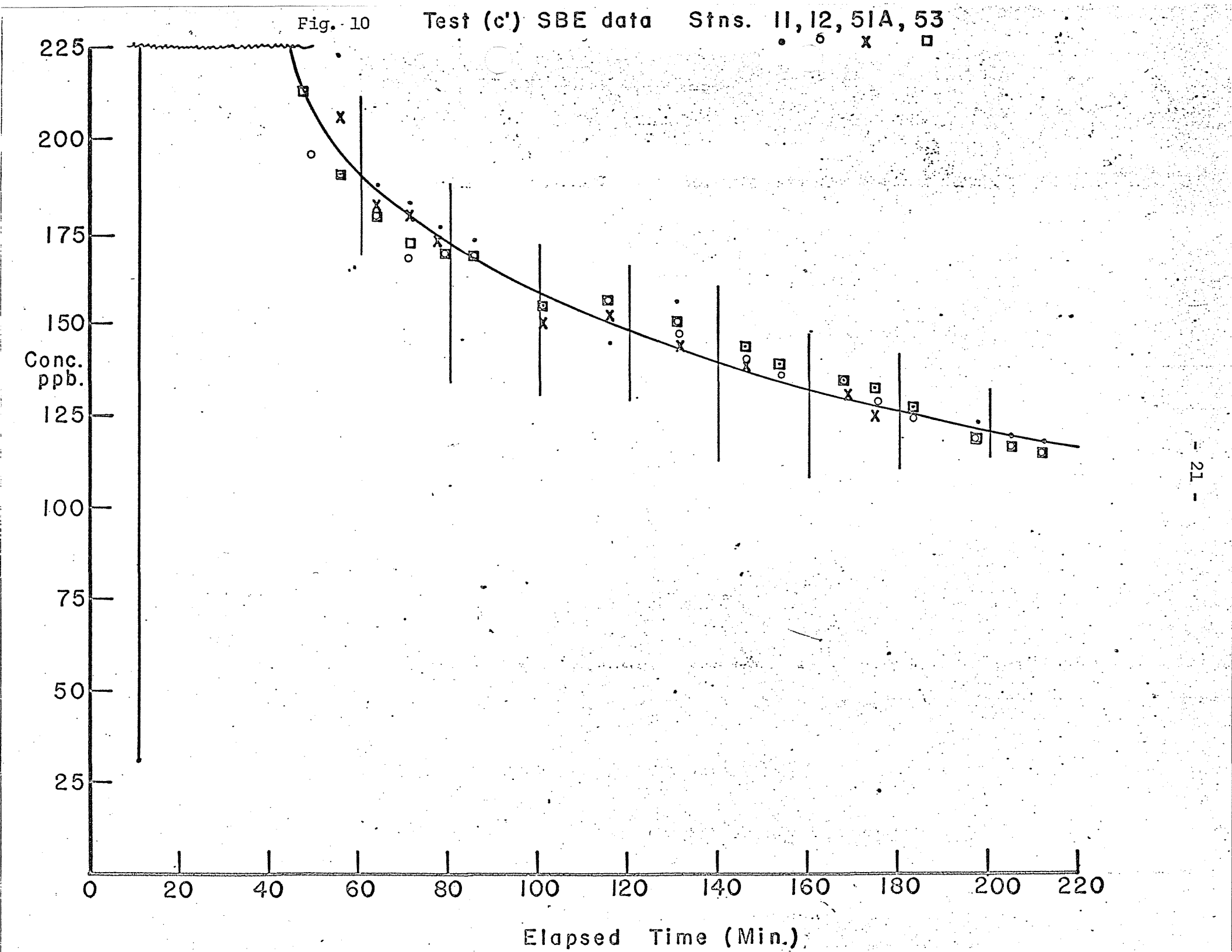


Fig. 10
Test (c') SBE data Stns. 11, 12, 51A, 53
225
200
175
150
Conc. ppb.
125
100
75
50
25
0
20
40
60
80
100
120
140
160
180
200
220
Elapsed Time (Min.)

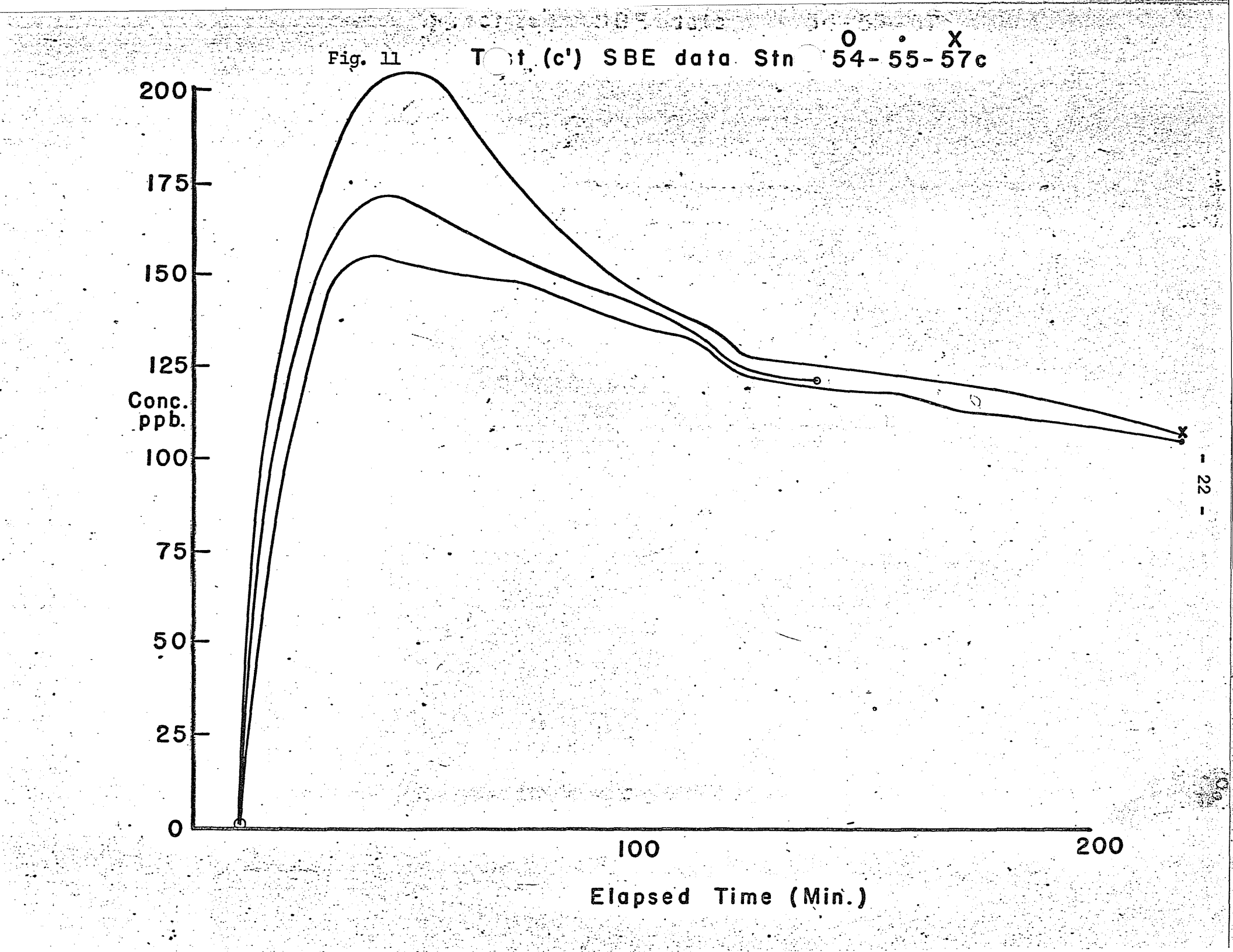


Fig. 11 Test (c') SBE data Stn 54-55-57c
O • X
200
175
150
125
Conc. ppb.
100
75
50
25
0
100
200
Elapsed Time (Min.)

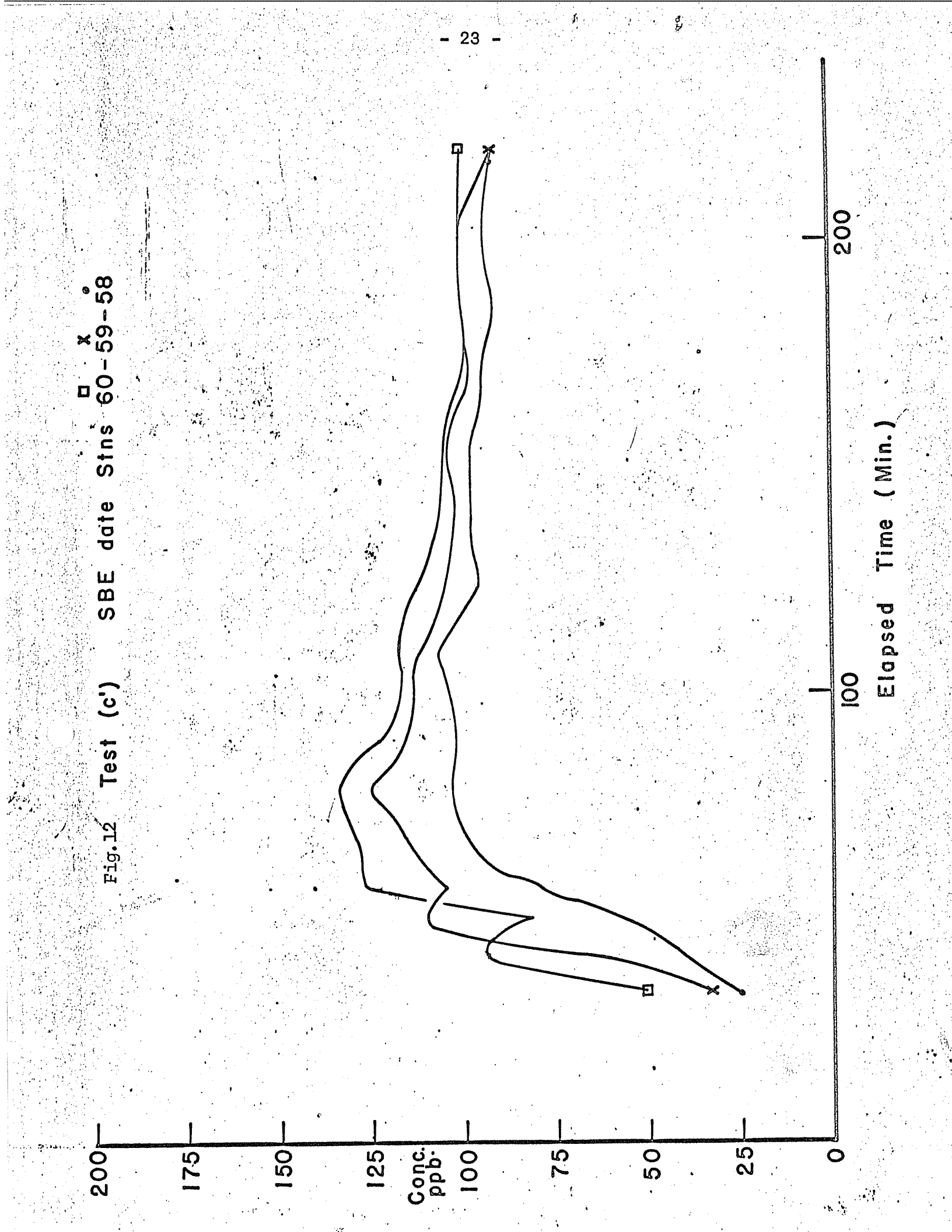
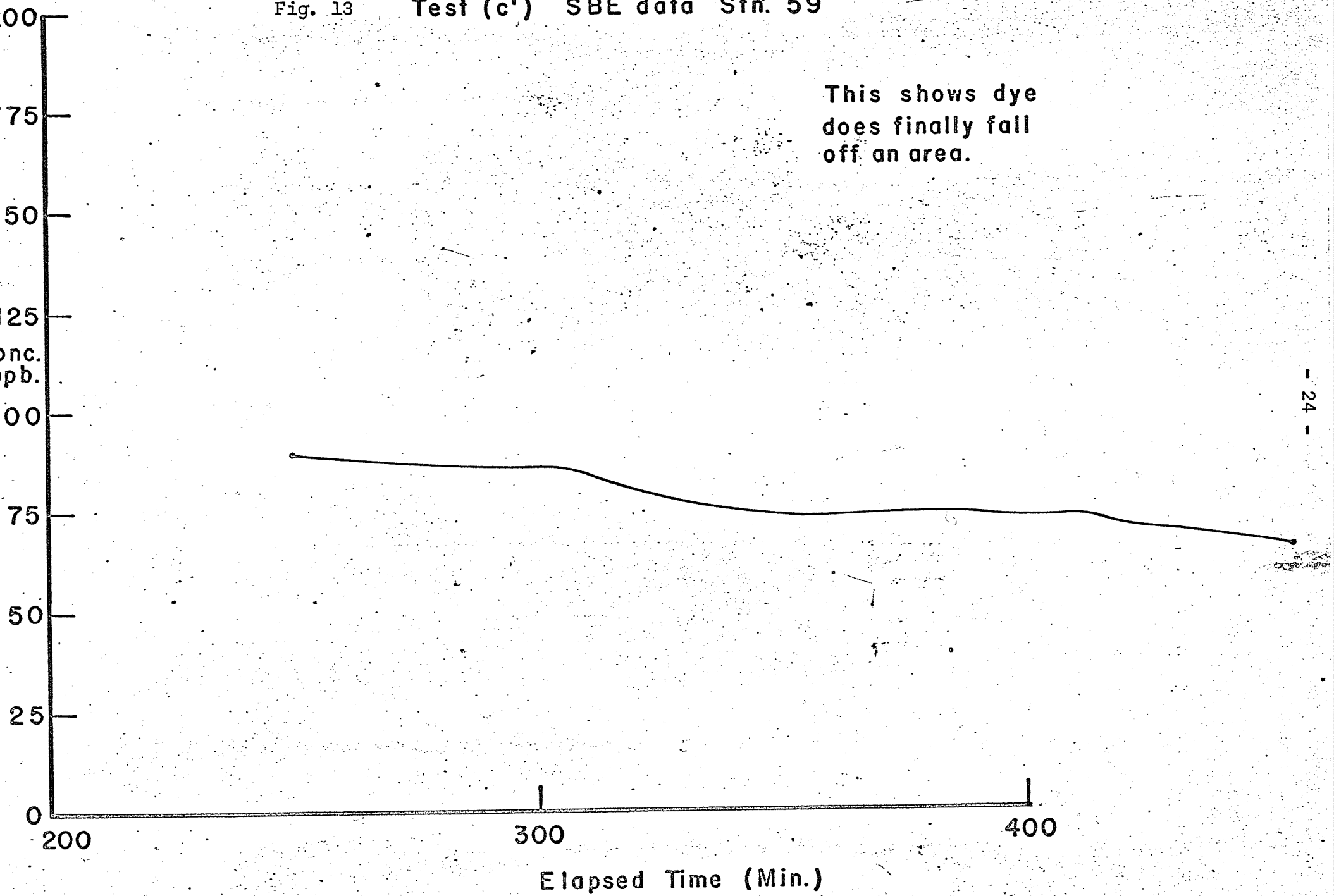

Test (c')
SBE date Stns 60-59-58
Conc. ppb.
200
175
150
125
100
75
50
25
0
100
200
Elapsed Time (Min.)

Fig.12

Fig. 13 Test (c') SBE data Stn. 59



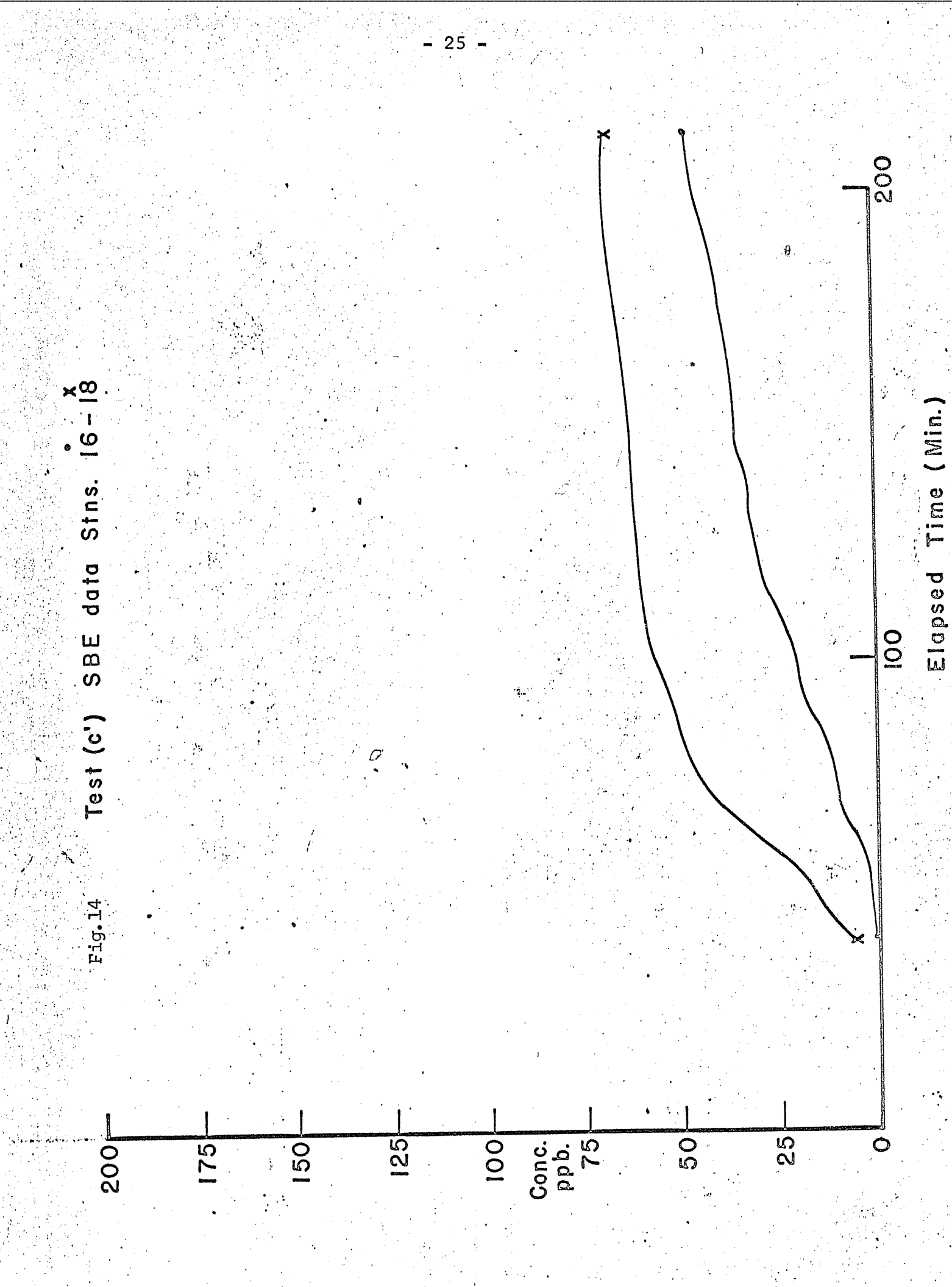

Test (c') SBE data Stns. 16-18
Conc. ppb.
200
175
150
125
100
75
50
25
0
100
200
Elapsed Time (Min.)

Fig.14

PHASE II

Continual Observations of the Ecologically Important Physical and Chemical Features in the Estuary

A. Same-Slack Cruises

Personnel of the Department of Physical and Geological Oceanography continue to make monthly sections of the James estuary. These studies, designed to provide biologists with pertinent physical data, also served to monitor salinity intrusion and recovery during this period when rainfall levels appear to be returning to normal from previous extreme lows.

DETAILED REPORTING OF MONTHLY CRUISES

"SLACK RUNS"

Activities:

Monthly slack water runs were made from Thimble Shoal Light to the head of salt water intrusion up the James River. Salinity samples at 3 meter depths, dissolved oxygen samples at surface and bottom, temperatures at the surface and Secchi disk (turbidity) readings were taken monthly at regular stations. Samples were taken at three stations across the river at the James River Bridge and at Wreck Shoal and one station at Hampton Flats. Station locations are shown in the chart presented in Fig. 15. Water samples were taken with a Kemmerer bottle. Oxygen samples were fixed immediately and both they and salinity samples were taken to the Institute chemistry laboratories where salinities were titrated on an Industrial Instruments RS-7a salinometer (to an accuracy of 0.03 ppt.) and oxygens were titrated chemically to an accuracy of 0.02 mg/l.

JAMES ESTUARY

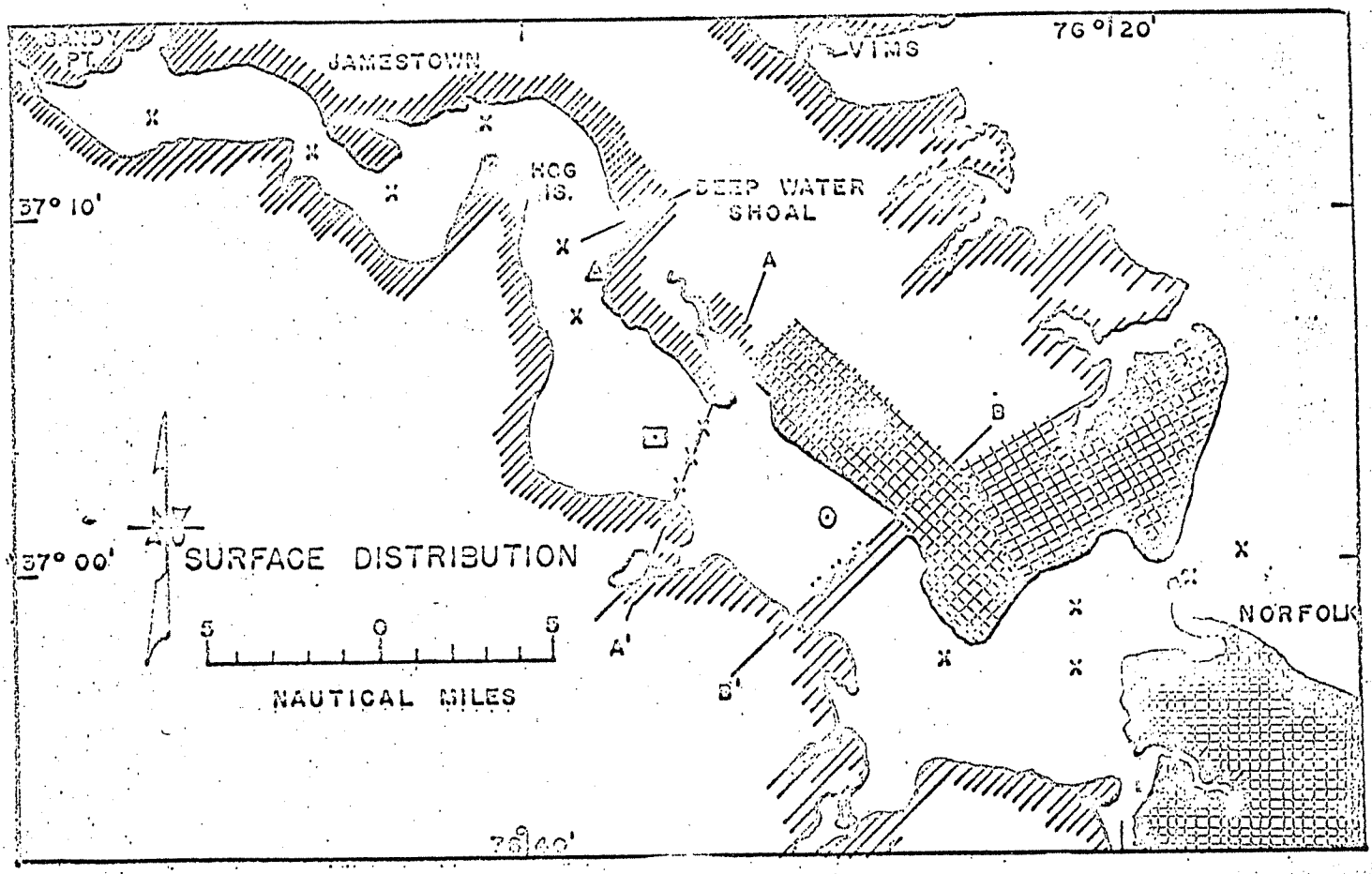


Fig. 15 Locations of slack run stations and monitoring stations.

⁘— Slack Water Stations

⊙— Miles Watch House

⊡— Wreck Shoal Platform

△— Commerce Pier

Slack water cruises were made near the middle of each month on slack before ebb and on slack before flood tides. One boat was used in the Hampton Roads area to follow slack water from Thimble Shoal to Pier 9 above Newport News Point. At times the water was too rough to include the Thimble Shoal station in the sampling. A second boat started sampling at the James River Bridge and followed the slack to the head of the salt intrusion. The salt intrusion (1ppt.) varied from near Deep Water Shoals during wet periods to above Brandon Point during very low river inflow periods.

Because of the relatively slow speed of the boats used and the time interval of 6 hours between high and low slack water, several days were needed to complete sampling. When high winds made sampling unfeasible, 5 or 6 days might elapse before both slack runs could be completed, and during this time salinity conditions sometimes changed. Only during the longer daylight hours of summer and on the shorter Hampton Roads run could both high and low slacks be completed on the same day.

The slack run data and analyses of the laboratory were checked for accuracy, put on IBM cards and then typed on "print-out" sheets and used for plotting and drafting distributions on longitudinal and transverse section of the river. Data for July 1965 through June 1966 are included in the addendum of this report.

Results

Seasonal resumé of hydrographic climate based on slack water runs, July 1965 - July 1966.

Changes in salinity values and the extent of salt water intrusion up the James River reflect the amount of rainfall and melting snow over

the entire river basin which correlate very closely with the amount of fresh water entering the river at Richmond. In general, salinities are lowest during the late winter and in the spring and highest during late summer and early fall.

1965 was a dry year which had been preceded by two dry years. As a result, 1965's salinities were abnormally high as sea salts intruded even further upstream. These conditions caused industrial and civil authorities at Hopewell concern that salt water from the river might corrode and foul plant equipment and affect drinking water. In addition, there is good evidence that low freshwater flows at Richmond caused sewage treatment products to accumulate more heavily than usual below Richmond. These products used up oxygen in the river during decomposition when the water warmed in the spring, producing fish kills in the area.

In a tidal estuary such as the James, fresh water travels downstream in the upper layer of water during ebb and the heavier saltier water wedges its way upriver underneath on the flood. During the periods of low rainfall and low river inflow, the waters become more vertically mixed and salinity differences between surface and bottom are less. This vertical stratification is greater at slack before flood than at high slack since ebbing favors the flow of fresh water downstream in the surface layer. Salinity differences between high slack and low slack at a given station also will be less during dry periods since less fresh water is moving downstream.

Salinity is especially important in the oyster seed-bed area of the James because oyster drills and diseases move up the river as the salinity increases in the proper time sequence. Oysters can tolerate lower

salinities than their pests so that the best seed producing areas are in waters lower than certain salinity limits for predators.

During July and August of 1965, salinities gradually increased throughout the estuary. Surface values at Thimble Shoal Light (TSL) increased from 21.94 to 24.62 ppt. Surface salinities at Wreck Shoal (Nun 12) went from 10.52 to 14.08 ppt. and surface-to-bottom (d 39 feet) differences varied from 4.39 to 6.35 ppt. The salt water front (selected at 1 ppt. surface) gradually moved up the river, reaching Sandy Point above the Chickahominy on the high slack in the middle of August.

During September, October and November, salinities continued to increase and the salt front moved up the river. Surface salinities at TSL increased from 24.51 to 26.02 ppt. At Wreck Shoal values were 16.06 to 20.36 at the surface. Vertical stratification at Wreck Shoal (surface to bottom) was small (0.48 to 2.87 ppt.) indicating a low flow of fresh water. Salt water continued to be pushed up the river, reaching a surface level of 1.54 ppt. on low slack at Brandon Point in November. High slack sampling would have shown even higher salinity values.

The river was saltiest in December, reaching a salinity of 2.49 ppt. at Brandon Point on low slack. Wreck Shoal surface salinity was 20.58 on high slack. During January and February salinities declined. Brandon Point, which had dropped to 1.35 ppt. salt on low slack in January, was down to 0.44 ppt. on the low slack sampling in February. Wreck Shoal surface salinity had decreased to 13.17 and 16.44 ppt. on the two slack tides sampled in February.

In March, April, and May 1966, slack water runs showed that salinities in the river were near normal for this season. Surface salinities at TSL ranged from 18.84 to 20.88 ppt. At Wreck Shoal they decreased from

13.20 to 3.59 ppt. Unusually high stratification was found at Wreck Shoal on low slack in May. The differences between surface and bottom was 9.14 ppt. (top 3.59, bottom 13.73). This difference could have been due to excess stratification with warmed-up fresh water on top of a colder heavier bottom layer which retarded mixing. A salt water intrusion of 0.44 ppt. which had been recorded at Brandon Point on low slack in February had receded to Deep Water Shoal (0.45 ppt.) on the same tide in May--a distance of 22 miles in 3 months. It is evident that increasing river inflow can cause the salt water intrusion to recede down the river much faster than the more nearly steady-state conditions in Chesapeake Bay and the ocean (salt sump) can cause it to advance up the river during time of low inflow.

The slack water sampling across the river at the James River Bridge and at Wreck Shoal further indicated that salinities are generally higher on the north side of the river as shown earlier by CBI scientists.

B. Special Oceanographic Studies

1. Evaluation of the Ketchum mathematical modeling technique against prototype and hydraulic model by physical oceanographers continues. Elements of this work were discussed above in the model dye study portion of the report.

2. Continuous Monitoring of Water Parameters

Activities:

The Department of Oceanography has maintained instruments at Miles Watch House just above the James River Bridge to give a continuous record of salinity and temperature during the period 1 July 1965-1 July 1966. Also, a recording tide gauge has been installed there to trace

tidal height variations on the river. These instruments are visited by boat each week and serviced, cleaned and repaired. An Industrial Instruments temperature compensated salinometer RQ-1 with sensor at a depth of 2 meters continuously records electrical conductivity of the water, which can be converted to salinity by reading off a chart. Water samples taken for salinity checks in the laboratory each time the instrument is serviced show the instrument to be accurate to better than 1 ppt. A Bristol Company thermograph directly records the water temperature at the same depth. It is checked with a stem thermometer each week and is accurate to $\pm 0.5°F$.

In February of 1965 two salinometers and two thermographs were installed at a newly built VIMS platform at Point of Shoal near Wreck Shoal in the important seed-oyster producing area of the river. These instruments monitored salinity and temperature at depths of 2 meters and 6 meters until they disappeared when the platform was carried away by unusually heavy ice in late January 1966. A table of average bi-monthly salinities from the Wreck Shoal Platform for 1965 is included as Table I.

When the slack water runs in December of 1965 showed that salinity intrusion was much farther up the river than usual and threatening Hopewell, a salinometer was installed at Buckland Wharf on the north side of the river about 9 miles below City Point. This instrument recorded maximum salinity values 0.4 to 1.4 ppt. from January 3 to February 4, 1966, when it was removed to prevent ice damage.

Since March 2, 1966, a salinometer has been maintained at the Commerce Pier of the Reserve Fleet just above Mulberry Point.

TABLE I

1965 Average Bi-Monthly Salinities at Miles Watch House (6 Feet)

Date	Max.	Min.	Mean
Jan. 1-12	18.1	14.6	16.4
Jan. 21-31	15.6	11.4	13.5
Feb. 1-15	14.5	9.2	11.8
Feb. 16-28	11.6	6.5	9.1
Mar. 1-15	13.5	8.4	11.0
Mar. 16-31	12.7	7.6	10.2
Apr. 1-15	12.7	8.2	10.4
Apr. 23-30	13.5	9.6	11.6
May 1-15	12.7	9.0	10.8
May 16-31	15.0	10.4	12.7
June 1-15	17.9	13.3	15.6
June 16-30	18.0	14.9	16.5
July 1-15		Data Missing	
July 16-31	18.7	15.9	17.3
Aug. 1-15	20.3	18.0	19.2
Aug. 16-31	21.8	19.8	20.8
Sept. 1-15	21.8	20.2	21.0
Sept. 16-30	21.7	19.8	20.8
Oct. 1-15	21.3	20.3	20.8
Oct. 16-31	22.1	20.3	21.2
Nov. 1-15	22.4	20.7	21.6
Nov. 16-30	22.1	20.1	21.1
Dec. 1-15	21.8	20.5	21.1
Dec. 16-31	22.0	20.4	21.2

Results

Daily maximum and minimum salinities at Miles Watch House have been plotted for the period July 1965 to July 1966 and are included in this report (Fig. 16). Gaps in the graph are due to such things as malfunction of the salinometer or bad weather making servicing impossible. These continuous observations make it possible to correlate salinity changes with fresh water inflow, weather and wind conditions and unusually high or low tides. A table showing average bi-monthly salinities at Miles Watch House for 1965 is also included in the report (Table II). The Buckland Wharf salinity record revealed remarkable short-term fluctuations, with rapid increases up to 1.5 ppt. accompanying northeast storms prior to passage of weather "fronts."

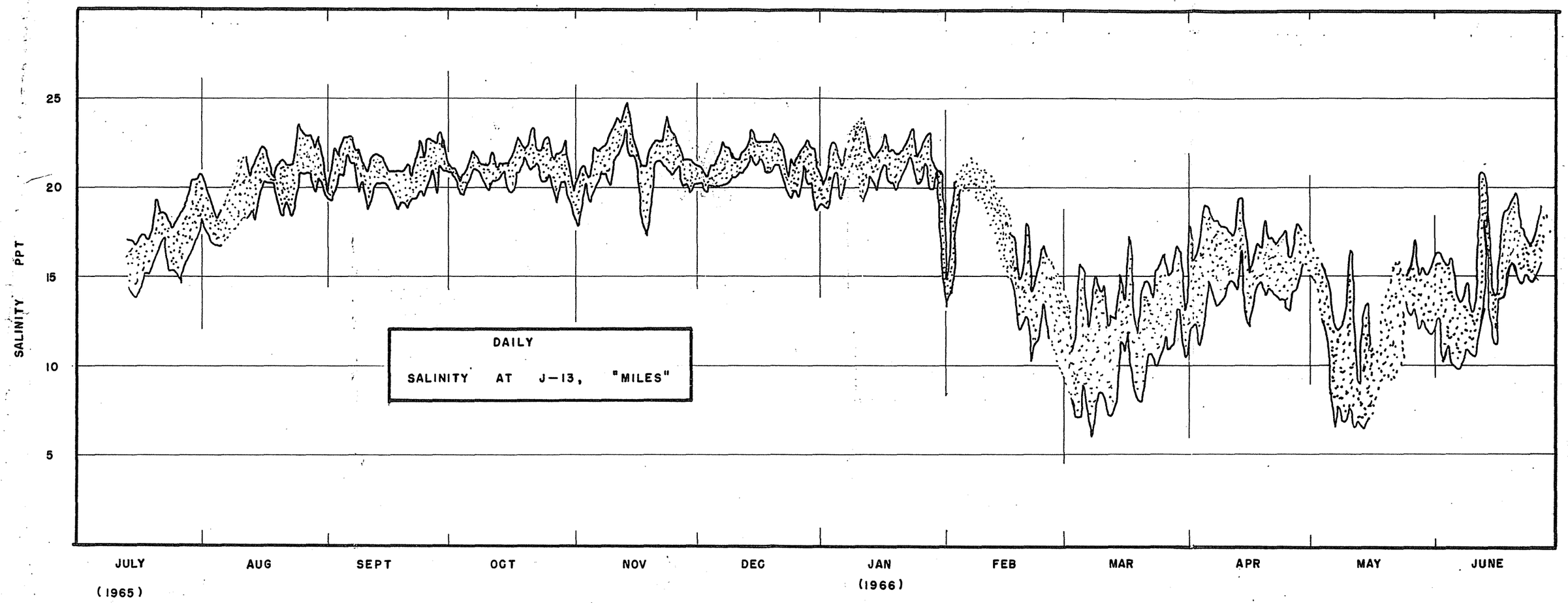


Fig. 16 Annual hydrography of salinity, $^{o}/_{oo}$ at "Miles".

TABLE II

1965 Average Salinities (°/oo) at Wreck Shoal Platform (6 feet)

Date	Max.	Min.	Mean
Jan. 21	(11.9)		
Feb. 11-16	10.6	2.4	6.5
Mar. 2-6	12.0	5.3	8.6
Mar. 7-24	12.3*	4.9*	8.6*
April 1-14	7.5*	3.9*	5.7*
April 15-27	6.1	1.7	3.9
May 1-15	7.1*	4.4*	5.8*
May 16-31	10.3*	6.4*	8.4*
June 1-15	11.9*	7.8*	9.8*
June 16-29	13.2*	10.1*	11.6*
July 14-26	13.2	10.9	12.0
Aug. 19-31	18.3	15.8	17.0
Sept. 9-22	19.0	15.8	17.4
Oct. 1-15	20.5	15.9	18.2
Oct. 16-31	20.9	16.2	18.6
Nov. 1-15	20.9	17.6	19.2
Nov. 16-30	20.2	18.1	19.2
Dec. 1-15	20.0	17.9	19.0
Dec. 16-31	19.6	18.2	18.9

* 19 1/2 feet depth

( ) From Slack Water Run.

C. Processing and Analysis of Existing Hydrographic Data

Status of hydrographic data processing in various categories is listed. In addition to routine processing, a computer program has been developed to rapidly scan and identify irregular data and make computations of mean salinity and predominate flows.

Status of Hydrographic Data Punchcard Processing

Designation		Completion
A---	Applied Science - 1964	100%
	Applied Science - 1965	80%
	Applied Science - 1966 Of data received, completion is about:	50%
ICBR CCUR	Crustaceology - pre-1964 These data are being entered on Forms 1 by the Crustaceology Department. Of those received, completion is about:	50%
ICBR	Crustaceology - Ichthyology Trawl Surveys - 1964	100%
	Crustaceology - Ichthyology Trawl Surveys - 1965	100%
	Crustaceology - Ichthyology Trawl Surveys - 1966 Of data received, completion is about:	40%
E---	Ecology-Pollution James River Cruises - 1965	100%
	Ecology-Pollution James River Cruises - 1966	100%
IATL	Ichthyology - Continental Shelf Cruises	100%
ICNP	Ichthyology - Crustaceology Nursery Project - 1965	80%
	Ichthyology - Crustaceology Nursery Project - 1966 Of data received, completion is about:	30%
MA--	Macons Cruises - 1963-64	100%
M---	Malacology - pre-1964	95%
	Malacology - 1964	100%

MO--	Malacology - 1965	100%
	Malacology - 1966 Of data received, completion is about:	50%
0---	Oceanography - pre-1964 All data which have thus far been designated for punchcard processing are in process or completed	95%
00--	James River Model Cruises (1964)	100%
05--	James River Slack Water Runs - 1964	100%
	James River Slack Water Runs - 1965	100%
	James River Slack Water Runs - 1966 One cruise in process	85%
06--	James River Sediment Study (1965) Processed to completion with sediment quantity entered instead of "pH"	100%
	Rappahannock River Sediment Study (1965) Processed to completion with sediment quantity entered instead of "pH"	100%
	Rappahannock River Sediment Study (1966) No data yet received	0%
07--	Rappahannock River Slack Water Runs (1965)	100%
S---	Student Training Cruises - pre-1965	100%
	Student Training Cruises - 1965	100%
SHS-	Ichthyology-Oceanography-Continental Shelf Cruises-1966 Of data received, completion is about:	30%
KITE	Operation KITE - 1965	100%
TAIL	Operation TAIL - 1965	100%
WACH	Wachapreague Laboratory Daily Observations	20%

In addition to the editing program, other computer programs under construction include:

1. Dynamic heights from oceanic station data
2. WES (Waterways Experiment Station) Net Currents - For model data
3. WES Average Salinities - For model data

The following programs have been completed. All are in IBM 1620 Fortran II, unless otherwise specified.

1. H-Field Duplicate (a machine language duplicating program is also used).
2. Organize and Rearrange, to standardize format in old hydro data.

   (Rearrange is also available in SPS.)
3. Put in 8--Used to replace tidal current code "0" with "8" (We also have a machine language program which can be used to a limited extent to distinguish zeros from blanks.)
4. Isolate Bottom Salinities (2 versions), a data retrieval program.
5. New Sigma-t--uses oceanic station data.
6. Average Salinities. Written at the Waterways Experiment Station for their GE 225 computer.

During the past few months, all the punchcard hydrographic data have been duplicated and the duplicate copies are being filed in a geographical system, which should greatly facilitate retrieval for future studies.

D. Hydrographic Data From Operations KITE and TAIL Activities:

Salinity and current velocities were plotted with time for each depth interval and at each of the 5 stations occupied. Current data were

further analyzed by planimetry of areas under the time-velocity curves and the net non-tidal or predominate flows were calculated.

Results

Figures 17 and 18 show the distribution of net and predominate flows and the trend of the level of no-net-motion observed during Operations KITE and TAIL. The James River Bridge section shows a typical "two-way" system with upstream flow on the right side of the channel and over Brown Shoals, whereas downstream flow persists on the left. At upstream and downstream stations, a distance from James River Bridge, the data show a "two layered" system in the channel with upstream flowing water near the bottom and downstream flowing water near the surface. Integration of these trends with the cross-sectional patterns at James River Bridge suggests that the level of no-net-motion at the upstream and downstream stations was inclined at a high angle.

When these results are compared with similar data of Operation Oyster Spat in 1950 and net flows taken in Rocklanding Shoal Channel in 1964, Figure 19, it is evident that the flows in 1965 were weaker than in 1950 and the level of no-net-motion was "lower"--probably more inclined--a condition which is in keeping with the abnormally low river inflow and good mixing of the estuary at this season.

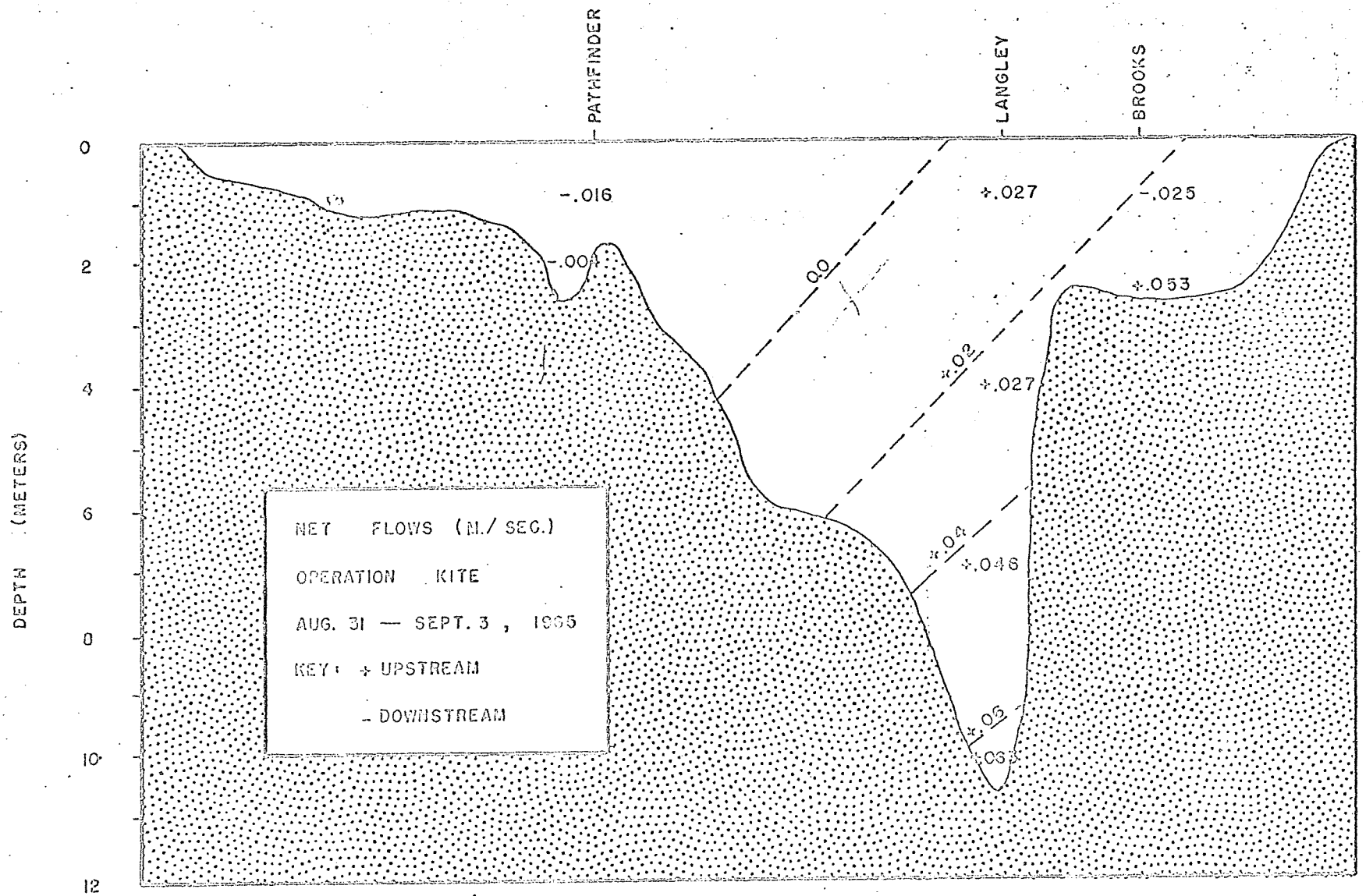


Fig.17 Cross section of James Estuary near James River Bridge showing trends and levels of net velocity obtained in Operation KITE.

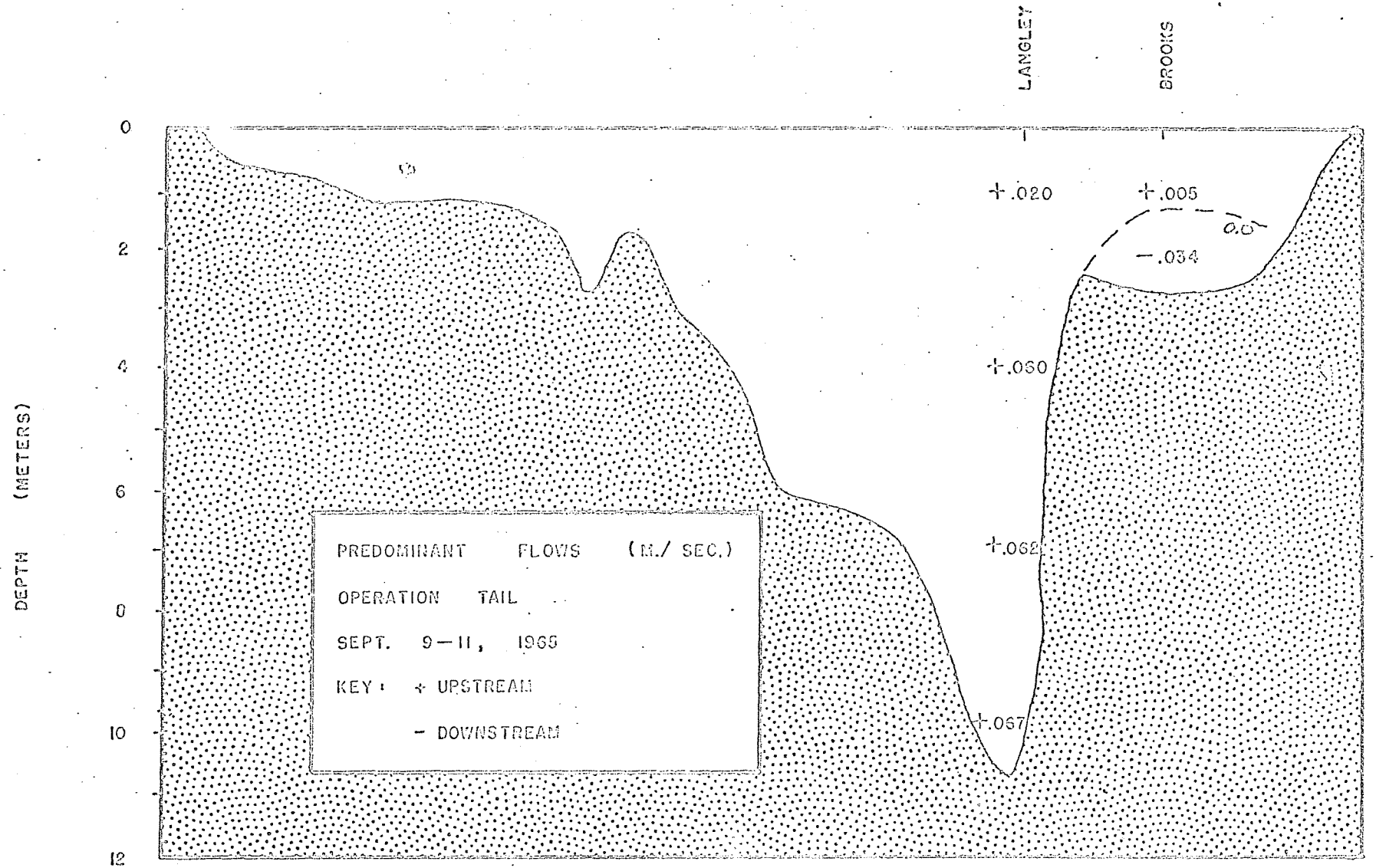


Fig. 18 Cross section of James Estuary near James River Bridge showing trends and levels of net velocity obtained in Operation TAIL.

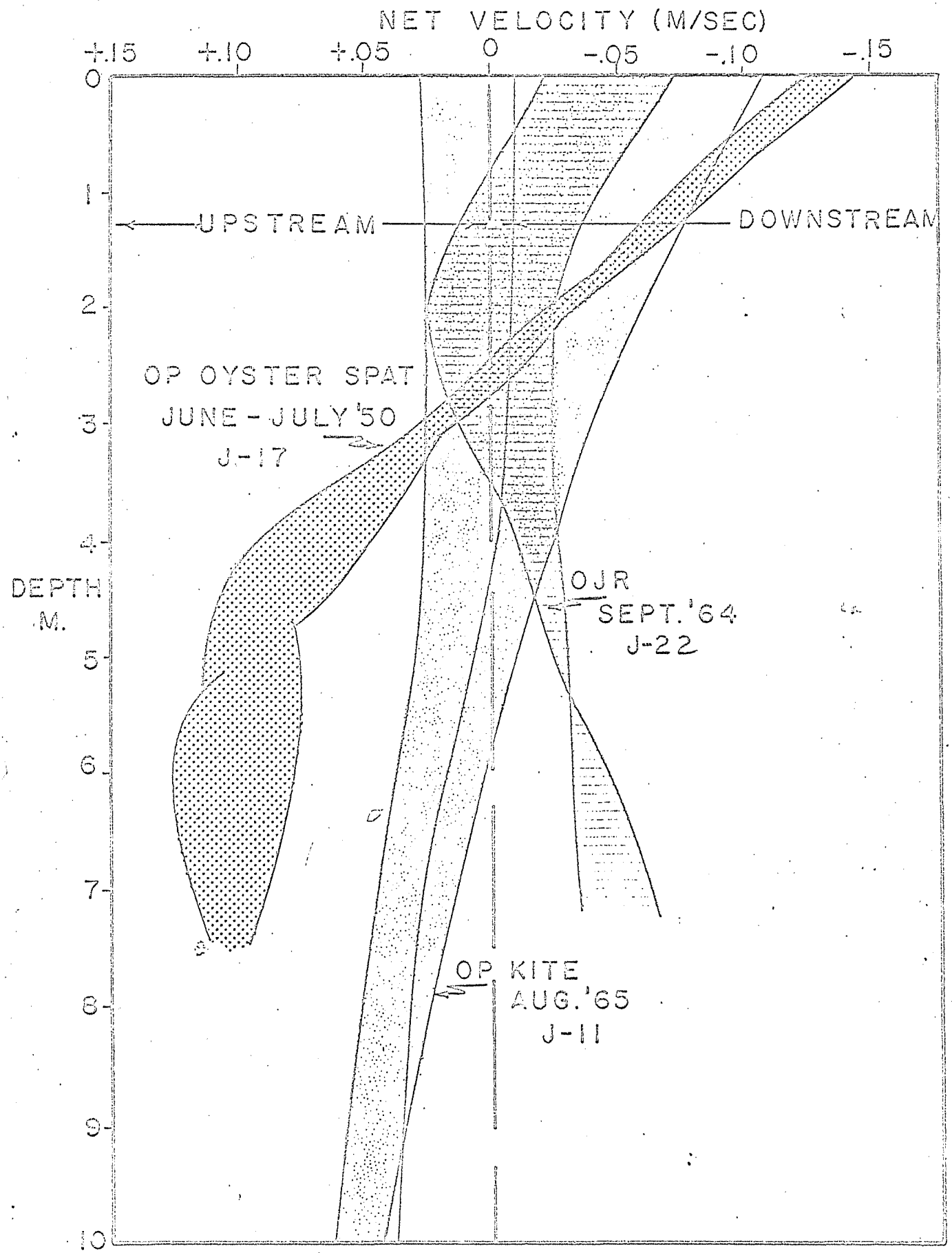


Fig. 19 Vertical distribution of net flows for various surveys.

PHASE III

Spatial and Temporal Distribution of Oyster Larvae in an Horizontally Stratified Estuary

Biological data from the multistation studies (Operations KITE, last week in August, and TAIL, first week in September) of spatial and temporal distribution of oyster larvae in the lower James in 1965, continue under analysis. Considerable effort has been given over to evaluating reliability of previous counts.

Results seem to indicate that larvae are distributed unevenly in the area of the James sampled, with greater quantities available in the water downstream than upstream, channelward than shoalward, and at high slack water than at other stages of the tide. It appears difficult to detect differences in vertical distribution and to distinguish quantitatively between species in the samples.

Results

Figure 20 depicts the distribution of the vessels and sampling stations for Operation KITE (Stations A, B, C, D and E) and TAIL (Stations A, B, D and F). Total counts of larvae were lower in KITE than they were in TAIL. Fewer larvae were probably available during the earlier sampling period. Maximum counts seldom exceeded 400 or 500 larvae and the majority of samples fall in a 100-200 range or less. Distribution vertically appears to be rather uniform, particularly when bottom samples are not filled with suspended material. In general, samples at 1 meter seem to have about as many larvae as samples at other depths.

By counting total bivalve larvae, which we were forced to do by the relative scarcity of oyster larvae, we have learned certain details of how

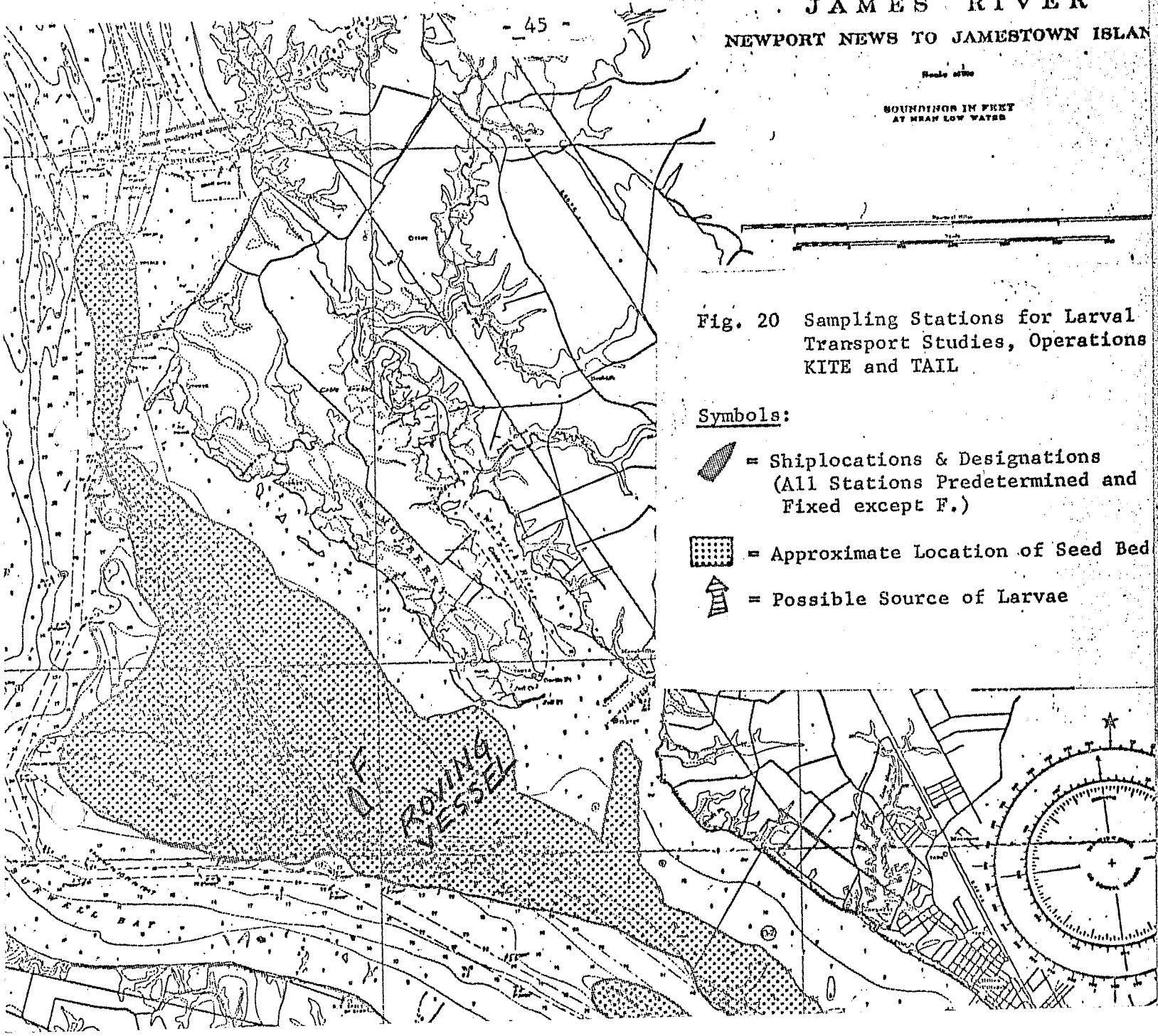


Fig. 20 Sampling Stations for Larval Transport Studies, Operations KITE and TAIL

Symbols:

= Shiplocations & Designations (All Stations Predetermined and Fixed except F.)

= Approximate Location of Seed Bed

= Possible Source of Larvae

larval transport is accomplished. At present it appears that all or most species are subject to the same transport system. Hence it may not be necessary to work with oyster larvae alone in this or future studies.

In Operation KITE we found more larvae in the down river station than at LANGLEY (A) and much fewer at the PATHFINDER (E) station on the western shore in shoal waters. Data from both KITE and TAIL indicate that more larvae are taken at downriver stations than those farther up.

Fluctuations in abundance with stage of tidal cycle appear to be several times the magnitude of counting errors. The same pattern of higher counts from maximum flood to maximum ebb with most around high slack water persists. Counting error has been observed to range as much as 2 to 1 but the fluctuations with the tidal cycle often go as much as 5 to 1. The distinct patterns of greater abundance around high slack water could only be observed if these observations were true. Nevertheless, the fluctuations with tidal cycle may be artifacts resulting from our choice of stations.

According to the samples counted, vertical distribution of larvae tends to be rather uniform. This does not mean that larvae are randomized in the water, for this probably seldom occurs in nature, but any clump distribution that exists was minimized by the length of sampling and the trends which result from many samples. Apparently fewer larvae are found in samples which have large quantities of suspended materials. Seemingly there is no basis for assuming that vertical migrations occur. Our samples indicate similar timing of fluctuations regardless of night or day conditions. Since we find fewer larvae in detritus-filled samples, there seems no reason at this time to believe that larvae come from the

bottom or the sides of the river. A tentative explanation of the fluctuations observed is that we are simply observing the movement of larvae from Hampton Roads into the seed area during late flood and the reversal of this during early ebb. In short, it appears that there is a rather steep gradient in the abundance of larvae from Hampton Roads as one goes up the James River and our stations were located in such a position as to observe a shift of this gradient upriver at times near high slack water.

PHASE IV

Controlled Studies of Responses of Oyster Larvae to Environmental Characteristics

Consultation with Dr. Haskin of Rutgers, who has reported larval studies in the literature, reveals that he, and likely many other workers, have utilized "wild or natural" larvae in their experiments while ours have been laboratory-reared. This line is being followed to determine the possible effects of conditioning on results of laboratory experimentation with oyster larvae.

I. Light Determinations in the James Estuary

Studies of larval behavior under experimental conditions were carried out in order to discover possible mechanisms for distributions revealed by field studies. Most of the experiments involved the interaction of light with other environmental and endogenous factors. Hence, one of the first steps was to determine actual conditions of illumination in the James estuary. To this end, observations of light were made during every hour in the daylight hours of five days in late August and early September 1965. Five monochromatic Corning glass filters were employed on

a Yentsch submarine photometer (with no filter) for readings at meter intervals, starting at 1 meter and extending down to the bottom (about 10.5 m). Typical results for one such hourly observation are given for 1200, 2 September 1965, as the percentage composition by peak wavelength at four selected depths. It should be noted that though the monochromatic filters were not calibrated with a radiometer, they were judged about equal, except that the blue filter was somewhat more dense.

COLOR OF FILTER	PERCENT COMPOSITION AT DEPTH (m)			
	1	4	7	10
BLUE	8	2	<1	<1
GREEN	13	21	14	<1
GREEN-YELLOW	39	70	76	99
RED	39	7	9	<1

Results of these field determinations were used as a guide in designing laboratory experiments.

II. Brief Statement of Methods and Materials for Larval Experiments

Experimental designs included consideration of intensity and wavelength of light, age and size of larvae, types of motile behavior, distribution of larvae in vertical and horizontal planes, temperature and salinity of medium, photic history of larvae, hydrostatic pressure, axis of orientation of both transmitted and reflected light, and endogenous periodicities of behavior.

A. Light treatment. High intensity light with an original spectrum similar to that of sunlight was produced by a 900-w xenon arc lamp. Several successive methods were employed for cooling the light

beam, after which it was conducted by a system of tubes, lenses, and mirrors to the experimental site inside a small dark room, where incident light was kept to a minimum.

B. Salinity. This parameter was controlled by mixing primary solutions to obtain desired salinities which were then automatically read and recorded by a conduction salinometer. Salinity of the medium was either constant or automatically varied as a sinusoidal function, to mimic tidal salinity changes.

C. Temperature. While in no case was temperature closely controlled, it was always within a few degrees C of larval culture temperature. Temperatures of various points in the experimental set-up could be monitored at any time by means of thermisters which were led into a 10-channel indicator.

D. Pressure was measured manometrically at the experimental site.

E. Larvae of known history were obtained from the VIMS' Larval Culture Laboratory which is operated by the Malacology Department.

III. Results and Discussion

A. Types of Motile Behavior

1. Net movements in the horizontal axis are accomplished by several types of motion behavior: Rectilinear swimming over a direct course, of as much as 50 cm; brief spurts of swimming upward and to the side, in a sustained vertical zig-zag; and lateral circus movements in one direction.

2. Net movements in the vertical axis are accomplished by various types of behavior: Rectilinear upward swimming or downward falling (with

valves closed) until a physical barrier is reached, such as the bottom or air-water surface; and upward or downward helical spirals.

B. Responses to Light in the Horizontal Axis

1. It was found that aggregates of larvae moved back and forth along the length of a horizontal tube (Fig. 21) in positive or negative response to a light beam originating at one end. Regardless of wavelength light of high intensity seemed to repell the aggregates, while light of low intensity attracted them. Blue-violet light nearly always inhibited swimming so that the aggregate dropped to the bottom of the tube and remained. Red light repelled mature ("eye-spot") larvae but attracted straight hinge stages. Light in the yellow-green area attracted late umbo stages at lower intensities and repelled them at higher intensities, but a shift in spectral peaks from 538 to 554 mμ neutralized this ambivalent reaction.

2. In a circular Petri dish, (Fig. 22) larvae aggregated in areas of low intensity illumination by means of negative klinokinesis: e.g., in high-intensity areas angular velocity of swimming turns was low. This had the effect of increasing the radius of turning and hence decreasing the rate of turning so as to bring larvae out of areas of high intensity and into the dimly lighted portion of the chamber. Here, angular velocity increased sharply with the effect of retaining larvae in the low-intensity area. While this was the general pattern of response, it was interesting to note that on occasion changes in intensity of basic illumination of the chamber caused a transient increase in number of larvae swimming in the lighted portion.

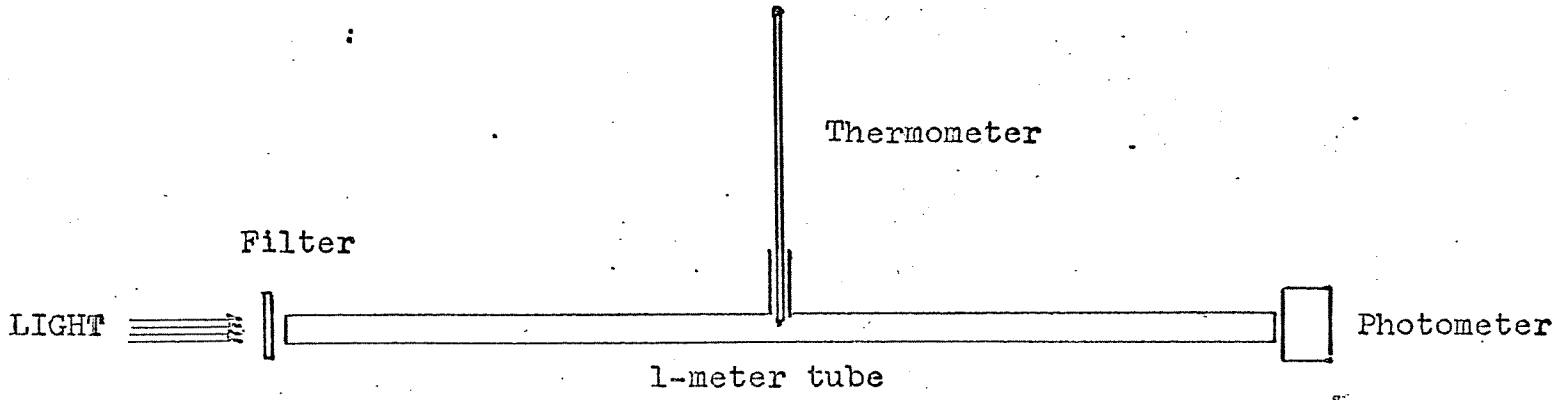


Fig.21. Horizontal glass tube apparatus

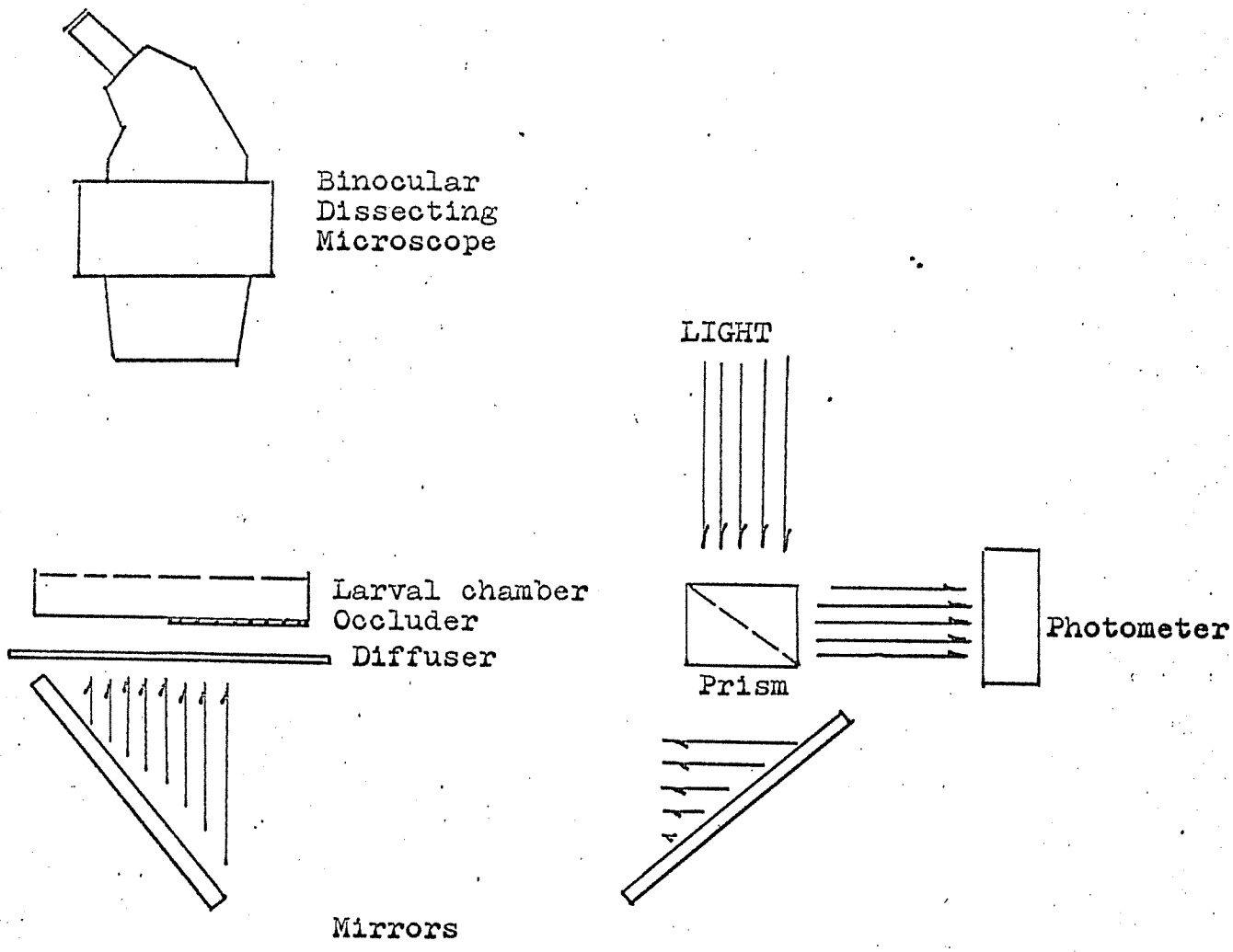


Fig.22. Circular chamber for studying kinesis

3. A similar dish-like chamber was made with wedge-shaped patterns of translucent color material (Fig. 22) from beneath which light was directed upward. The purpose of this preliminary experiment was to exploit the klino-kinetic effect so as to study "color preferences". The materials used were not corrected for neutral density, hence interpretation of results is restricted to the statement that there appeared to be significant aggregations in the green-yellow portions of the chamber.

C. Responses to Light in the Vertical Axis.

In this series of experiments, larvae were placed in a 1-m high tubular column (Fig. 23) containing about 2 liters of filtered seawater. Light was introduced from the top and could be varied as to both intensity and wavelength. Larval movements were observed visually and their distribution was determined by direct sampling at five points spaced at 25-cm intervals on the column.

1. Distribution of larvae under condtions of darkness was somewhat variable, but was usually strongly bimodal, with one major fraction at the top of the column and the other swimming at the bottom. It should be pointed out that at no time did the total of five combined samples from any point in the column greatly exceed 10% of the introduced population, and it was usually no more than 1%. Hence, it must be inferred that most of the population did not swim under the conditions in the column.

2. The bimodal distribution of larvae mentioned above was affected either not at all or in a variable manner by the introduction of low- and moderate-intensity unfiltered (except for infra-red) light.

3. There was no significant relationship between the vertical distribution and mean length of larvae in the column.

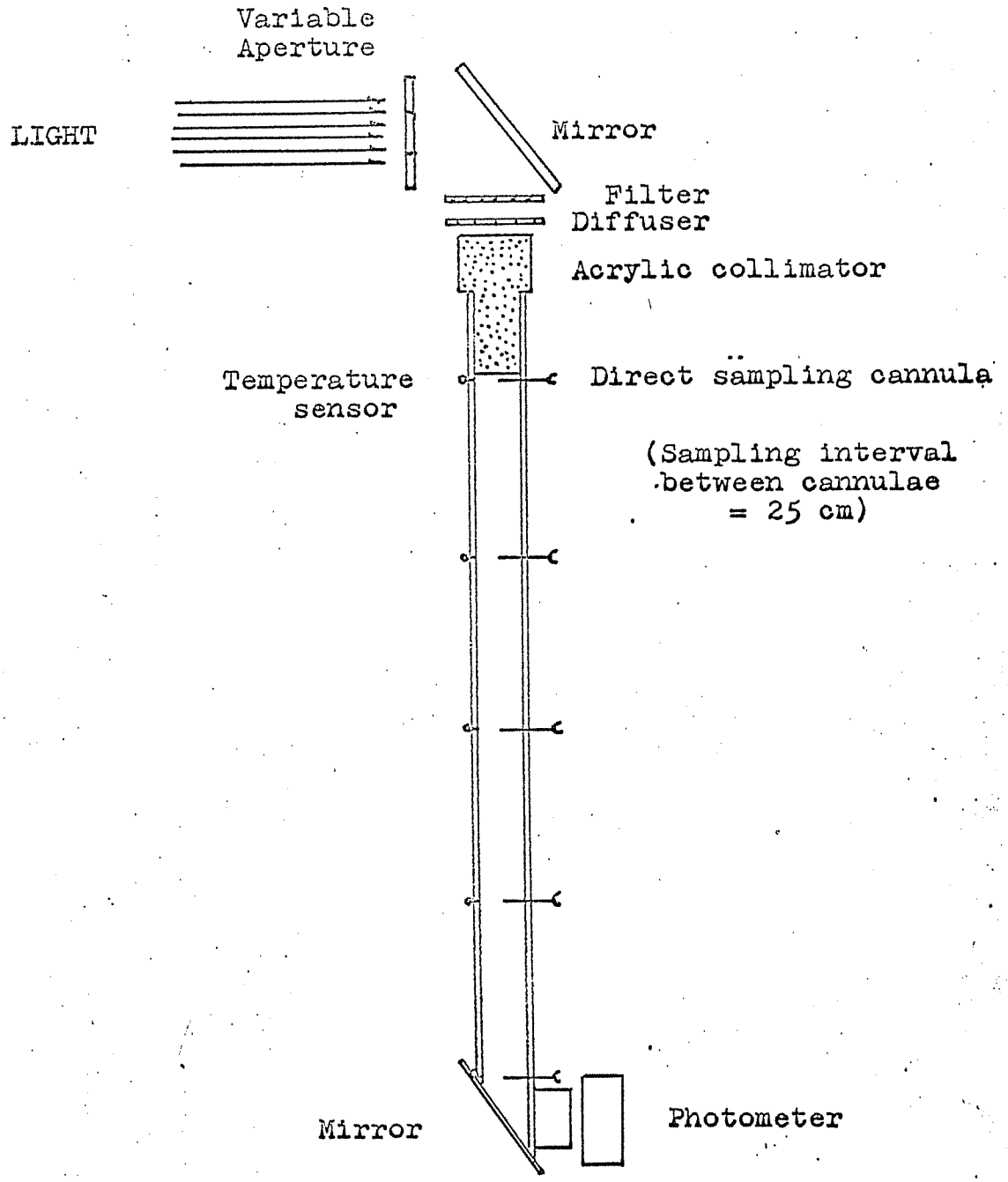


Fig. 23. Vertical column apparatus

D. Responses to Light in a Modified Haskin Cell.

In these experiments, larvae, usually no more than 300 at a time, were placed in a small acrylic and teflon cell (Fig. 24) through which filtered seawater was pumped at rates of no more than 0.5 ml/min. Light was brought into the cell from above, at a normal angle to the axis of photographic or visual observation. Photographs were made either to corroborate visual observations on a demand schedule with a 35-mm SLR camera, or to supplant visual observations with a 16-mm reflex motion picture camera rigged for time-lapse operation. In the latter case, 7-second time exposures were taken every 15 minutes throughout a 24-hour period. Photographs in darkness were made with infrared transmitted light.

1. Under constant conditions of salinity, temperature, and yellow-green light, there was no tendency toward recurring patterns of activity; rather, there was usually a steady decrease of swimming after about 3 hours. Microscopic examination of larvae subsequent to the experiment disclosed that most of them were still alive, and furthermore recommenced swimming after having been removed from the Haskin cell. These observations militate against the existence of tide-related cycles of swimming activity.

2. Under constant conditions of temperature and yellow-green light but continuously varying, "tidal" changes of salinity, there was a similar decrease of swimming activity which was not related to the experimental variable.

3. Under constant conditions of salinity and temperature, but with stepwise changes in white light intensity, there was a slight but not consistent variation in swimming activity.

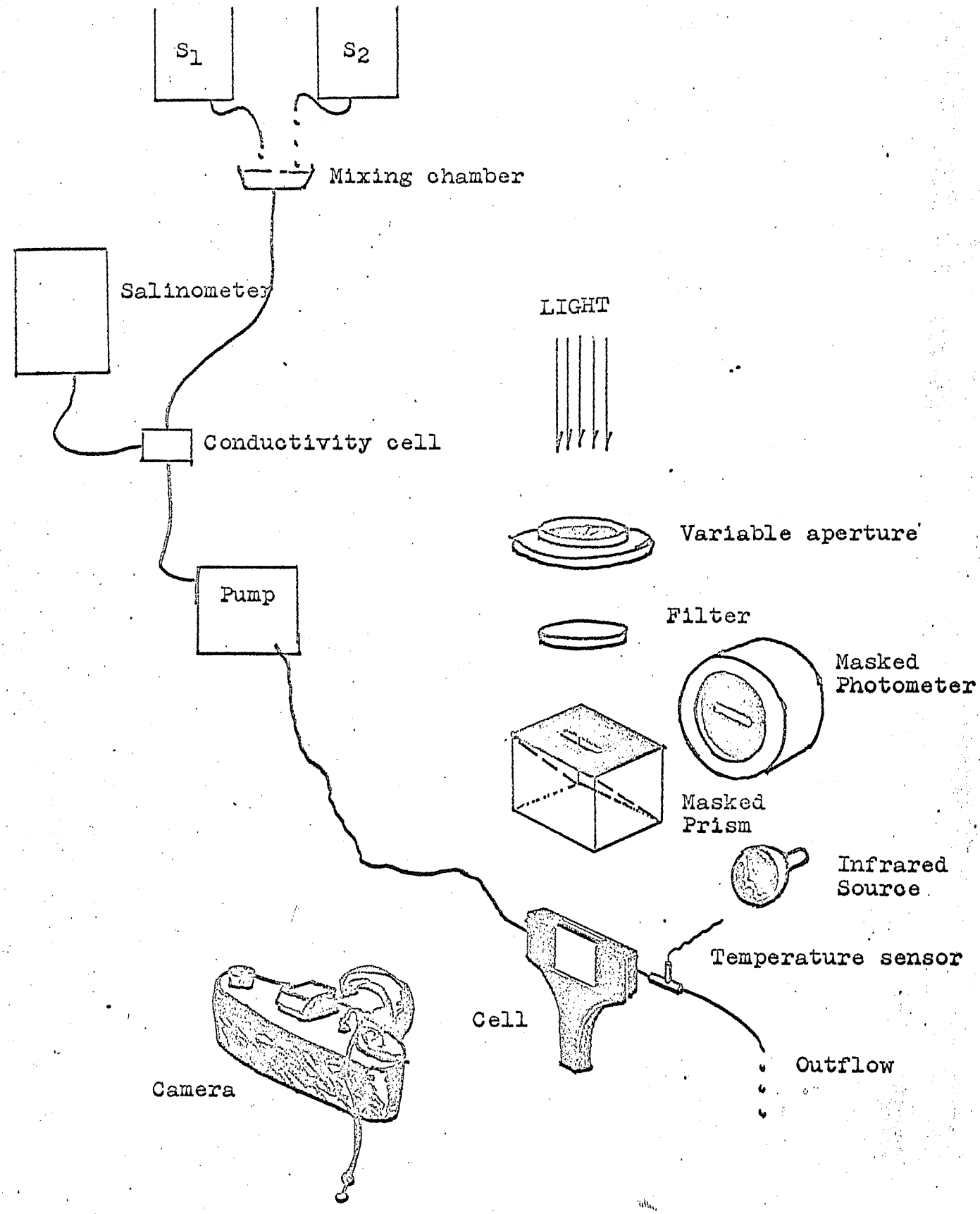


Fig.24.Modified Haskin cell and associated apparatus

4. Under constant conditions of salinity and temperature, but with changes in wavelength of illumination, results were difficult to interpret. With 8-day larvae, red light elicited strong swimming activity and white light (of higher intensity) inhibited it. Yellow-green light at first slightly increased but later inhibited swimming. Blue light strongly inhibited activity.

5. Steadily increasing hydrostatic pressure to a maximum equivalent to that beneath a 3-m seawater column was accompanied by a correlated decrease in swimming activity under constant conditions of temperature, salinity and light. This factor may have been responsible for the steady decreases in activity described above, because after modifying the cell design to eliminate pressure increases, larvae continued to swim actively as long as five hours after the beginning of the experiment.

IV. Summary

Only very limited evidence has been obtained from the foregoing experiments which would support the notion that light is a primary factor in vertical distribution of oyster larvae. However, some indications have emerged from this study.

First, there is no question that larval activity is inhibited by the presence of light in the blue part of the visible spectrum. Because blue light is so rapidly scattered in turbid estuarine waters (it is probable that the greater part of the energy in this end of the spectrum is prevented from penetrating below 1 m), it is conceivable that it could act as an inhibitory stimulus in nature and thus force larval populations out of the surface layer.

Second, our observations of klinokinesis suggest a promising avenue of further investigation, particularly with respect to the relationship between activity rates and optimal intensities of both monochromatic and white light. This concept has not been adequately explored previously, and could easily serve as the focal point of the next series of experiments.

PHASE V

Study of Transport of Suspended Particles in the James Estuary

SEDIMENT STUDIES

Activities:

1. Transport of Suspended Particles:

Laboratory analyses of suspended materials collected concurrently with measurements of salinity and velocity consist of:

A. Total concentrations of 650 water samples determined by filtering known volumes through millipore filters (0.8μ size) and weighing both the filter and the filter with the sediment.

B. Particle concentrations 62μ of samples that were pre-seived thru a 62μ screen, were further filtered and weight differences determined as for the total concentrations. While gravimeteric determinations are very time-consuming, this is the best method available at present to attain relatively high accuracy. Concentration values of both total and coarse fractions were compiled into time-depth graphs for each station.

C. Coarse particle residues were further analyzed by examining the filters under the microscope and making a frequency count of the different constituents present. These data were compiled into time-percentage frequency graphs and compared with variations of tidal flow.

D. To determine values of sediment transport, total concentrations were multiplied with velocities obtained concurrently every 30 minutes and the product was integrated with the cross sectional area of the channel for each station.

Results

1. Transport of Suspended Particles:

The suspended particles greater than 62 microns make up less than 3% of the total particle concentration. Most of the suspended detritus is finer than 62 microns. The coarse particles consist of an admixture of organic detritus, diatoms, "light" minerals chiefly quartz, mica and fecal pellets; floccules and silty aggregates are scarce.

The quantity and composition of suspended sediment fluctuates with current velocity producing marked variation with time and with depth over a tidal cycle. Figure 25 shows these variations for a representative station in the Rocklanding Shoal Channel. High proportions of relatively light materials, as organic detritus and plankton are present in the near surface water, particularly near slack water, whereas relatively heavy materials are proportionately higher near the bottom, especially at maximum current. Of note are the relatively

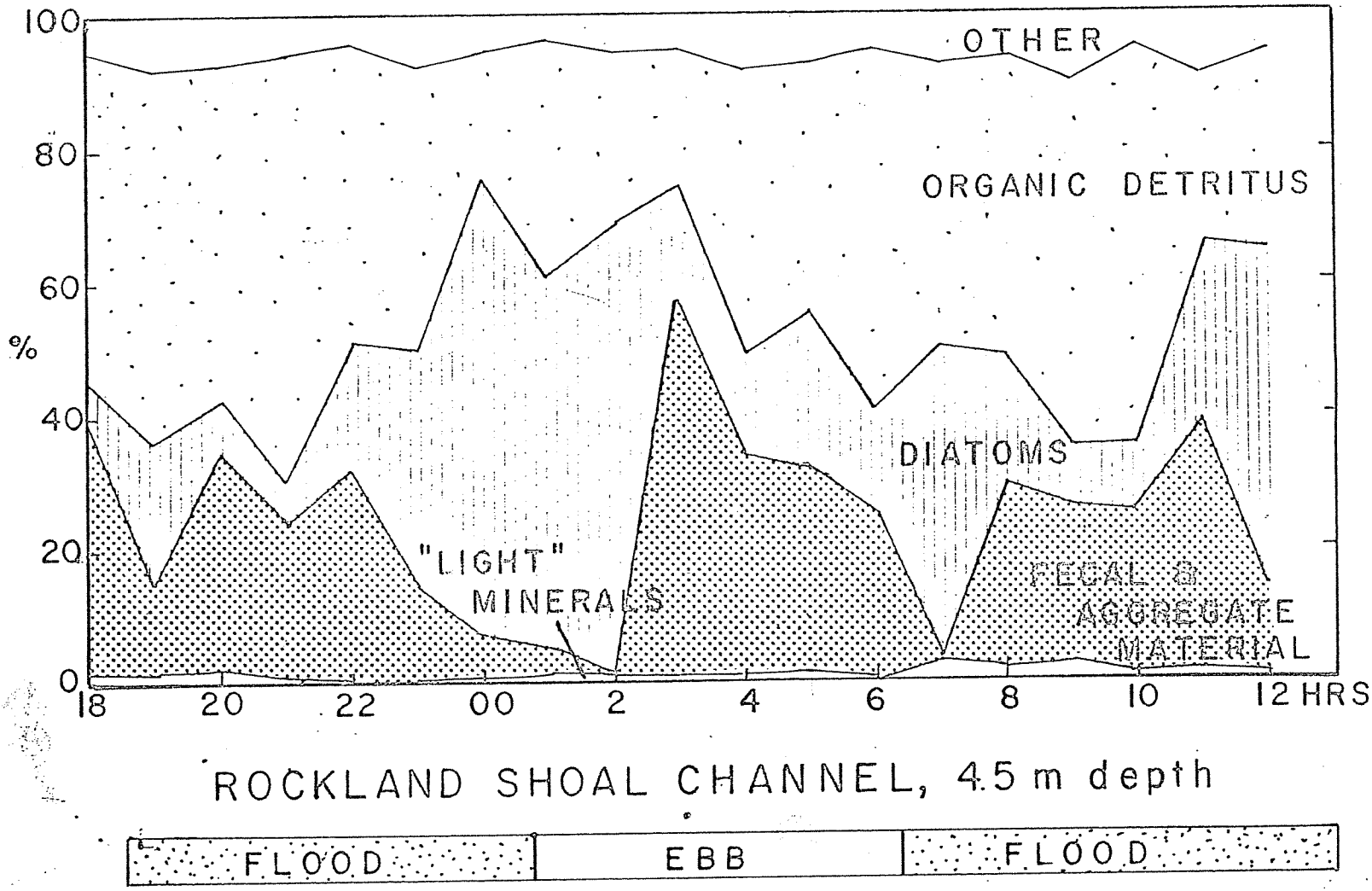


Fig. 25 . Variation in sediment particle composition in relation to flow.

higher proportions in the combined group, coal-cinder-fly ash, which make up 4% of the coarse particles at the Rocklanding Shoal Channel station. Relatively heavy coal particles are most abundant near the bottom, whereas relatively light fly ash particles are most common near the surface.

The distributions and tidal variations of coarse particles lead to a selective transport of different constituents according to their hydrodynamic characteristics. It may be expected that oyster larvae in different stages of development would behave similarly, depending on their relative weight and settling rates in the water. Relatively light particles, as organic detritus, fly ash, and plankton, present in near surface waters, particularly over the shoals, will be transported seaward in the downstream flow of near-surface waters. Occasional wave agitation acting with tidal turbulence over the shoals deters settling and assists downstream transport. Relatively heavy particles, as quartz, coal, and fecal pellets, that settle rapidly and spend the greater part of their "suspended history" near the bottom, are transported headward by the net upstream flow and by differential settling that favors net headward movement.

2. Foraminiferal studies at head of James during the salt intrusion:

Monthly samples taken at eight stations in the James Estuary, from June to December 1965, indicate that Foraminifera migrate upstream during periods of salt wedge intrusion (Fig. 26). Figure 27 shows the variations of living numbers at station J28 near Jamestown. Temperature, as well as salinity, is shown to be important in influencing abundance of Foraminifera because temperature, below a

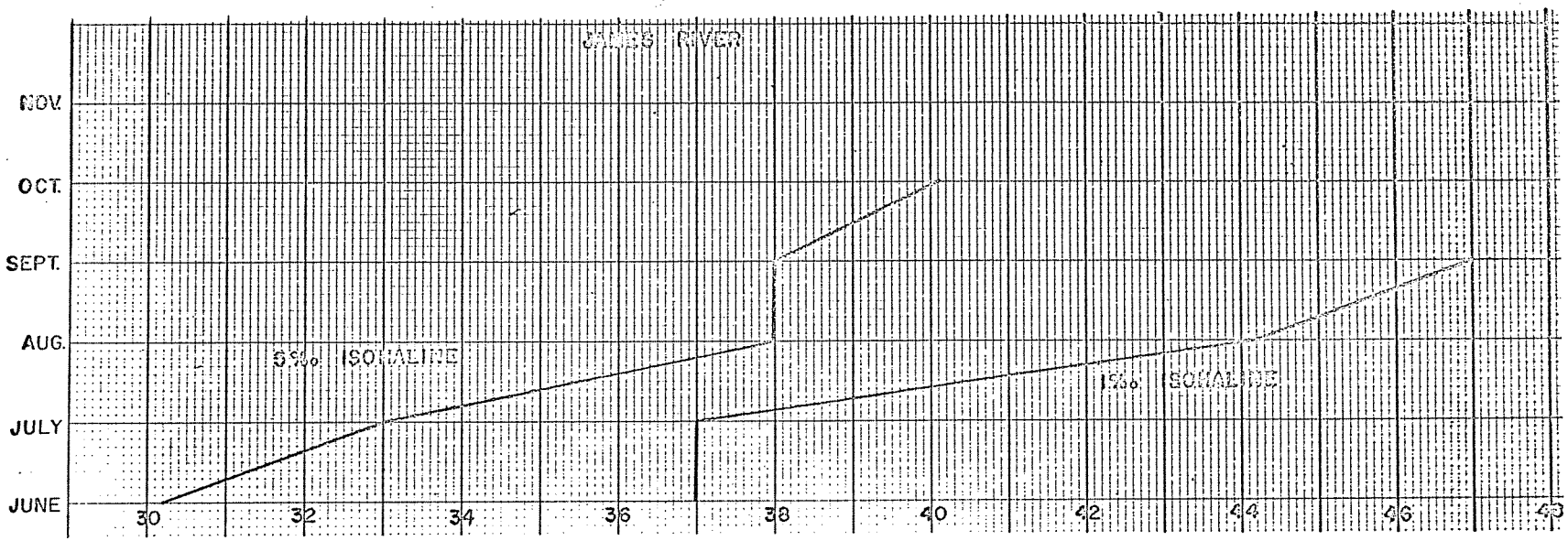


Fig. 26 Monthly trends of $5^{o}/oo$ and $1^{o}/oo$ isohaline with distance upstream near head of James Estuary.

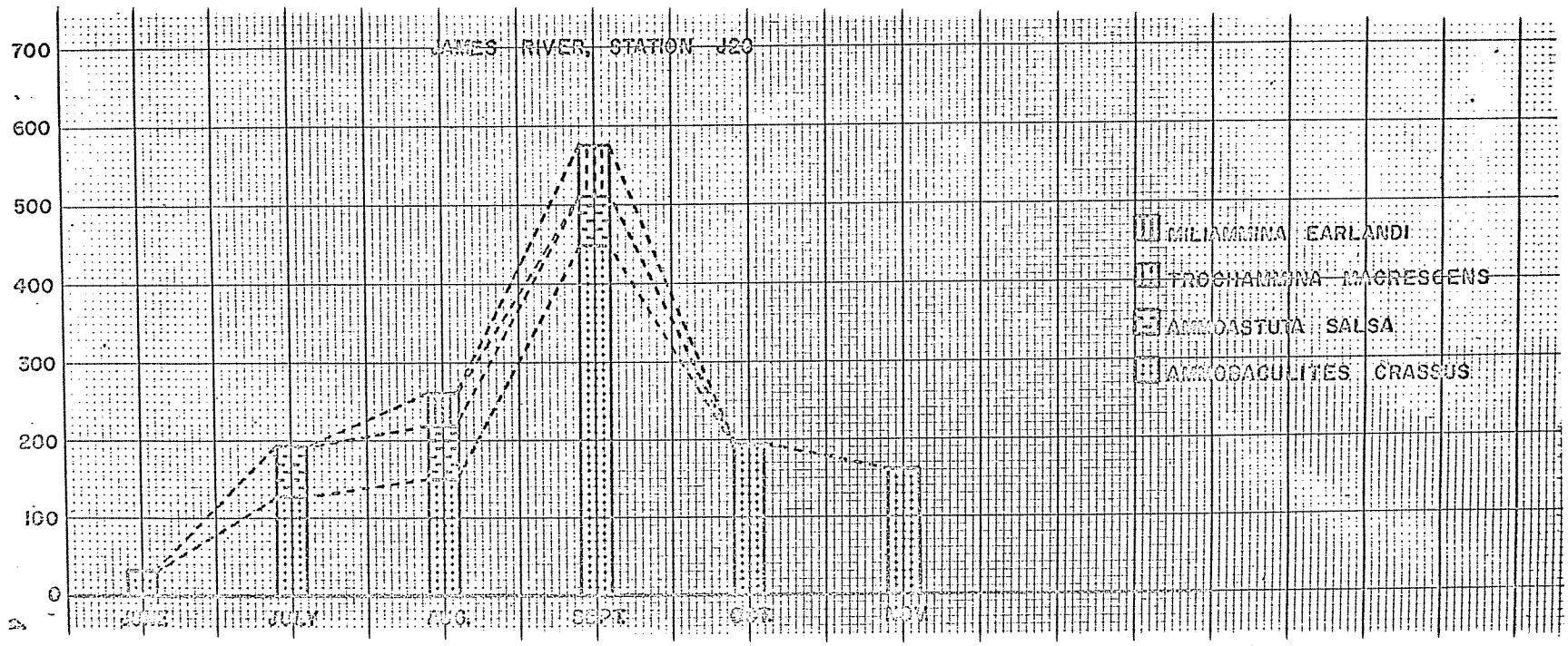


Fig. 27 Variations in Foraminifera composition during the salinity intrusion, J-28 near Jamestown.

certain point, affects abundance of the organisms, whereas salinity acts as a limit to their distribution. Living specimens were recognized easily by staining in a saturated solution of Rose Bengal and counting wet. Size distributions indicate wide variations, both from month to month and from station to station at the same time; these may reflect changes in reproduction, but more probably are natural variations in the populations. Fluctuations in living/total ratios are correlated with unstable ecological conditions and duration of foraminiferal habitation at one place rather than being indicators of relative sedimentation rates.

These trends indicate the relatively rapid response by micro-organisms to physico-chemical changes in the estuary. They suggest that large concentrations of oyster larvae may be transported upstream, by high saline flow during times of intrusion beyond the range of the setting grounds. In this way larvae may be "lost," and concentrations "diluted" in the main estuary itself.

Activities:

Bottom Geometry and Rate of Sedimentation Studies:

The character of the estuary floor was delineated by more than 14 detailed transverse profiles compiled from Coast Survey boat sheet soundings. In addition, 18 new profiles were obtained by Edo fathograms to update areas where coverage was not available.

To define the distribution of bottom changes, rate of sedimentation and scour, transverse profiles were constructed from successive surveys: 1873, 1910-17, 1945-50. In addition, individual depths were compared for the same surveys and the distribution of bottom changes

compiled into a smooth chart (Fig. 28). The chart is the chief product of this study; profiles will be drafted in final form at a later date.

Results

The profiles and sedimentation chart shows that there are large areas of substantial change in the estuary floor during the past 30 years. The floor is quite dynamic, ever-changing in form in response to changes in tidal flow and works of man. The results are highlighted by the following information:

A. Most areas of oyster bars show an increased depth, or decreased height, of 2-4 feet in the recent 30-year period. This deepening is believed to be due to removal of shell by tonging over the years. The depletion amounts to about 43,560,000 cubic yards--8 times greater than the amount of material to be removed by the proposed 35-foot channel deepening cutting through the oyster grounds. Of course, this type of deepening generally occurs in depths of from 10-25 feet rather than in deeper channel sections. However, there is no doubt that significant change in the bottom geometry results.

B. The chief estuarine-wide sites of high sedimentation are: (a) off the mouth of the Chickahominy River, (b) Tribell Shoal (just east of Jamestown) channel, (c) Burwells Bay channel and adjacent shoals.

C. The Burwells Bay channel has rapidly silted up within the last thirty years. This may be related to deepening of the Rocklanding Shoal channel--a channel which is free of siltation and carries most of the upstream flow. Although siltation has slowed down in the Burwells Bay area, adjacent oyster grounds can be expected to be continually covered.

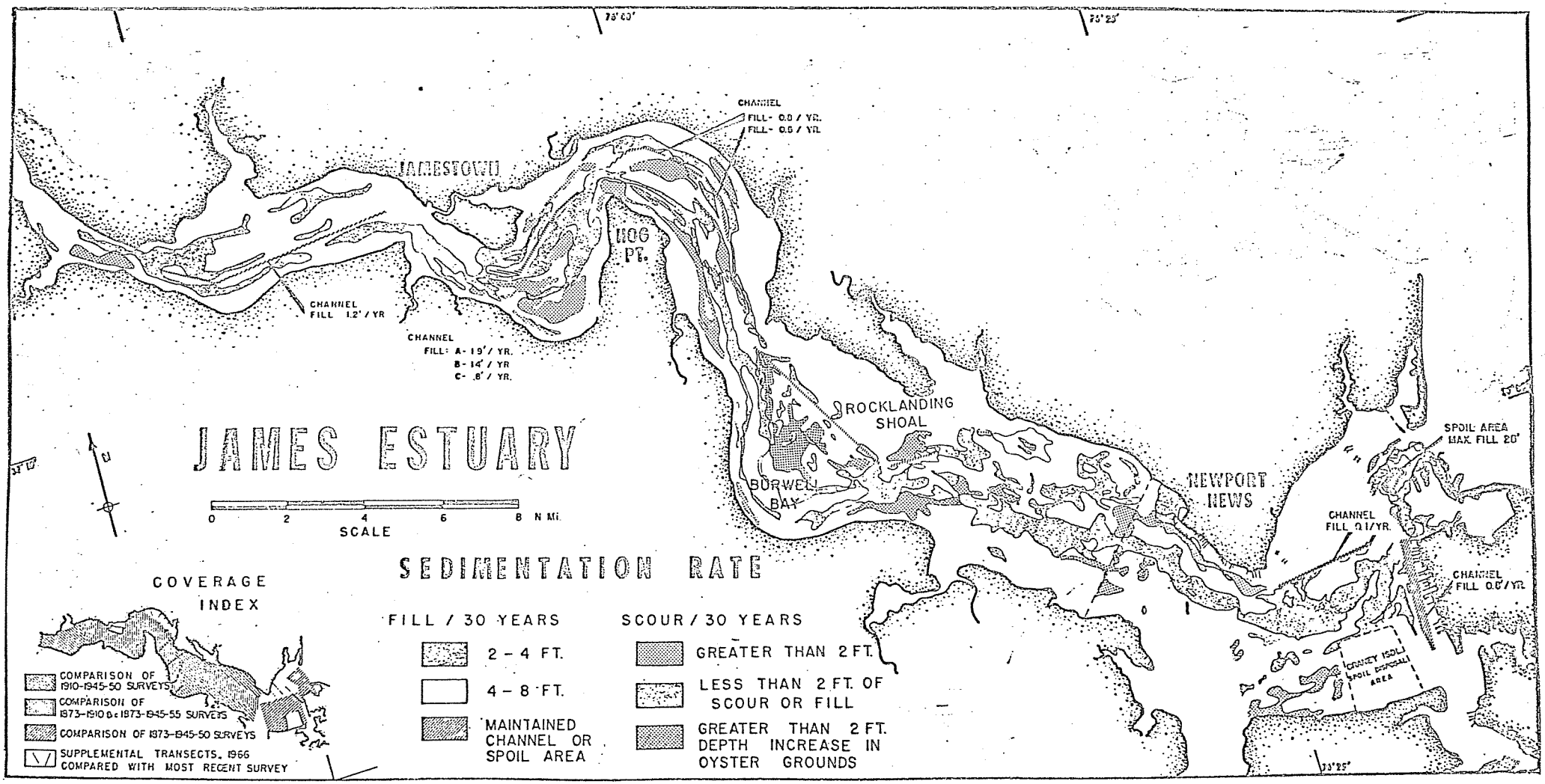

JAMES ESTUARY
JAMESTOWN
HOG PT.
ROCKLANDING SHOAL
BURWELL BAY
NEWPORT NEWS
CHANNEL FILL 0.0 / YR.
CHANNEL FILL 1.2' / YR
CHANNEL FILL: A- 19' / YR. B- 14' / YR C- .8' / YR.
SPOIL AREA MAX. FILL 20'
CHANNEL FILL 0.1/YR.
CHANNEL FILL 0.0'/YR.
CRANEY ISDLI SPOIL DISPOSAL AREA
0 2 4 6 8 N Mi.
SCALE
SEDIMENTATION RATE
FILL / 30 YEARS
2 - 4 FT.
4 - 8 FT.
MAINTAINED CHANNEL OR SPOIL AREA
SCOUR / 30 YEARS
GREATER THAN 2 FT.
LESS THAN 2 FT. OF SCOUR OR FILL
GREATER THAN 2 FT. DEPTH INCREASE IN OYSTER GROUNDS
COVERAGE INDEX
COMPARISON OF 1910-1945-50 SURVEYS
COMPARISON OF 1873-1910 & 1873-1945-55 SURVEYS
COMPARISON OF 1873-1945-50 SURVEYS
SUPPLEMENTAL TRANSECTS, 1966 COMPARED WITH MOST RECENT SURVEY

Fig. 28

D. In the cross section between Newport News point and Craney Island disposal area, moderate rates of fill, in the 30-year period prior to reclamation of the disposal area in 1954-57, were reversed to high rates of scour. Sediment is deposited elsewhere, downstream in pier basins or upstream on the oyster grounds, producing hard "pavement" of shell and gravel on the estuary floor off Newport News.

E. Entrance reaches south of Old Point Comfort were shoaled from about 95 feet to 67 feet by uncontrolled disposal of spoil during, and shortly after, World War II. This material is gradually being scoured and redistributed upstream into pier basins and deeper parts of the oyster grounds.

F. Changes in depth in the vicinity of the reserve fleet are very small despite the substantial reduction in the cross sectional area of flow produced by the reserve vessels.

3. Bottom Characteristics:

Activities:

Cores and bottom samples are presently being collected regularly and processed in the sedimentation laboratory for analyses of grain size, pH, Eh, color, minor structures, bottom penetration, water content, carbonate percentage, and organic carbon content.

Results

This phase of the study has not yet been terminated but additional results will be reported elsewhere. It is anticipated that the information will delineate substrate conditions suitable for oyster setting

and growth. Special attention is being given to potential "new" oyster grounds in upstream areas.

Respectfully submitted,

William J. Hargis, Jr.

William J. Hargis, Jr.
Principal Investigator

8/2/66