APPENDIX A

DETAILED DESCRIPTION OF THE FIELD SURVEY PROCEDURES EMPLOYED FOR THE TEMPERATURE & ECOLOGICAL SURVEYS

FIELD SURVEY PROCEDURES

This chapter summarizes the field survey procedures and techniques employed for the Hudson River thermal and ecological surveys.

A. SURVEY DURATION

A program of temperature surveys was instituted on July 19, 1969 and continued for three months. On August 6, 1969 a program of temperature and ecological surveys was initiated on a regular basis of once a week (Wednesday) for an eleven week period ending October 15, 1969.

B. SURVEY EQUIPMENT

1. Sampling Vehicle

A fairly large boat (16 ft.) equipped with a 65 HP motor was used for the temperature measurements. A considerable space was available for the convenience of a three to four man team and equipment storage.

A smaller boat (12 ft.) equipped with a 6 HP motor was used for the ecological measurements as well as temperature measurements in shallow areas.

2. Temperature Survey Equipment

Six channel and one channel tele-thermometers (Yellow Springs Instrument Co., Inc., Yellow Spring, Ohio) and thermistors with cables with their appropriate probes (up to 30 ft. in length) were used for temperature measurements.

These instruments were regularly checked against two liquid-in-glass precision thermometers certified by the National Bureau of Standards.

The maximum observed correction to standard temperature readings using these thermometers was ±0.02°F. These thermometers were carefully compared with a National Bureau of Standards certified standard in accordance with methods recommended by that institution.

The 30 ft. probe was used to measure temperatures at different depths. A Kemmerer water sampler was used for measurements at depths greater than 30 ft. A weighted cord was used to insure that the temperature measurements were at depths perpendicular to the plane of the water and to avoid stressing the thermistor probe. The probe is loosely affixed to the cord by means of a plastic tape placed at measured intervals corresponding to fixed depth readings.

The location of the boat position in the river was determined by using a sextant and known landmarks. Sextants readings were always accompanied by detailed physical notes relating position to landmarks.

A stop watch with a second hand was used to determine the time of measurements and the fixed time interval between different stations.

Various other equipment such as anchors, ropes, prepared data sheets, tidal current and stage charts, USCGS and USGS maps with the locations of landmarks shown on them, clipboards, etc. A makeshift plywood table that stretches the width of the boat was found to be convenient. It provided a safe stable place for the thermistors and facilitated the actual writing down of the data.

3. Ecological Survey Equipment

These included several fish nets (both seine and fyke), bottom samplers, water samplers, maximum-minimum thermometers, necessary chemicals, glassware and labels. Discussion of this equipment is given in Chapter V.

C. SURVEY PERSONNEL

A three man team is required to perform the field work (both thermal and ecological). In special cases extra men may be needed. The three men must know their respective tasks. In conducting the temperature surveys these tasks are:

1. One man (the operator) steers the boat at a constant velocity (both speed and direction). His task, when the boat stops for a position fix, is to hold the boat as steady as possible using the motor, anchor and/or attached line.

To facilitate moving in a straight line the operator should employ two landmarks, one from which he is proceeding and a forward landmark. Due to tidal currents and wind, one usually cannot determine a straight line by pointing the bow of the boat at a forward landmark. This must be compensated for by crabbing the boat (pointing the bow at a greater angle to the direction of the flow).

2. A second man (the recorder) is responsible for data collection. Once the temperature run has commenced, he takes readings at equal time intervals and records them. Five or ten second time intervals are appropriate.

   Since this man has the most intimate contact with the data, he is responsible for the direction in which the boat is to proceed.

3. A third man (the sextant man) takes the sextant readings and makes sure that the weight and the accompanying temperature probe are properly suspended in the water.

Due to pressure drag the weight will rise in the water depending upon the speed of the boat. To insure that the thermistor is reading the surface water temperature while the boat is in progress, the sextant man must maintain the weight at 6" to 1' below the surface. The proper length of cord to release is easily determined by trial and error. He must also make sure that minor river effects such as waves will not cause the probe to break the surface and read air temperature. Errors of this sort are readily detected by illogical temperature readings.

When the position is known, such as at the discharge, the sextant man by shifting his weight can stabilize the boat's position in this turbulent area. The sextant man is also responsible for recording field notes and meteorological conditions, keeping the probe free of all foreign matter, such as grease from the boat operation, or weeds or algae from the river.

D. TEMPERATURE SURVEY PROCEDURE

The following procedure was followed in almost all of the temperature surveys. Minor modifications, however, were in some cases necessary.

1. Check All Temperature Instruments Against the Precision Thermometers.

If it is determined that recalibration is indicated, follow the procedure outlined in the manufacturer's manual. The temperature instruments should be checked prior to and after each run.

2. Establish the Index Error of the Sextant by Sighting on a Distant Object.

Check this at the end of the survey,also.

3. Establish the River Water Ambient Temperature.

Continuous temperature readings must be taken. Start some distance from the plant, beyond the heated zone determined from previous experience, and move in the opposite direction of the prevailing tidal flow, and towards the opposite shore. Several temperature measurements at different depths must also be taken.

The establishment of the ambient temperature is particularly important and one must be aware of the following:

a) Temperatures in the vicinity of creeks or tributaries, and near facilities which may be discharging heated water or industrial waste, will be higher than normal river ambient.

b) On hot summer days, due to solar effects, the surface temperature will increase during the day and will be higher than the deeper water temperatures.

c) Measurements should not be taken in the wake of a passing boat.

d) Different sections of the river reach under study may have different ambient temperatures due to channel geometry variations and turbulence effects. The ambient temperature, for study purposes, should be selected as close to the plant as possible.

e) Due to wind and solar effects the daily ambient temperature changes during the day. Therefore, establish this value before and after each run.

4. <u>Conduct the Actual Temperature Run.</u>

The procedure varies with the tidal condition, location and orientation of the discharge channel, meteorological conditions, etc. Basically, it consists of running a criss-cross pattern through the effected area. The origin of the criss-cross pattern is normally taken at one end of the temperature spectrum.

The discharge channel is usually used for this purpose.

Start the temperature run by taking temperature measurements at the discharge at several depths. Make continuous surface temperature measurements at equal time intervals (every five seconds) while the boat is moving in the direction of a known landmark at a constant velocity to some fixed station. Determine the location of this station by either taking sextant readings or known float position. Take several temperature measurements at different depths at this station.

Repeat the same procedure while moving to other stations, i.e., take continuous surface readings at equal intervals and depth measurements at these stations. When the recorder indicates that the ambient temperature has been reached, stop this particular leg of the survey. The operator stops and steadies the vehicle, the recorder takes his final reading and the sextant man establishes the boat's position.

Commence the next leg of the criss-cross pattern, in a similar manner, in the direction of the higher temperatures, i.e., moving from the previous ambient location to the shore either upstream or downstream of the discharge channel, depending upon the prevailing tidal condition.

Start another criss-cross leg beginning with the previous shore location and moving towards a new location of the ambient temperature and so on. The run ends when the ambient temperature is reached in the longitudinal, as well as the lateral directions.

The shallowness or steepness of the legs of a particular run is determined by the recorder on the basis of the previous leg readings. If the temperatures are changing rapidly, the recorder will have to take his next series of temperatures very close to the previous leg. If the new leg temperatures are not changing a great deal, a shallow angle will be sufficient. Typical tracks are shown on Figure 2 of the next chapter.

Place more emphasis on depth temperature measurements in the vicinity of the discharge and shallow areas.

5. Obtain Plant Operating Data During the Survey Hours.

To illustrate the criss-cross procedure outlined above, three typical temperature run results corresponding to three different tidal conditions are plotted on Figures 2, 3 and 4 of Chapter II of the report.

E. ECOLOGICAL SURVEY PROCEDURE

Three ecological stations were located in the cove south of the Danskammer discharge. These consisted of three locations 50, 390 and 800 feet south of the discharge, in which decreasing temperatures could be expected as you proceed south of the discharge. These stations were located on the basis of expected temperature rises obtained from the July surveys, which are shown in Appendix B.

The following general procedure was followed in almost all of the ecological runs:

1. Calibrate both temperature instruments. Take continuous surface temperature measurements starting from the heated effluent discharge to south of Station #3. These measurements should reflect temperature distribution outside the cove. Top to bottom temperature measurements should be taken at at least two stations along the way.

2. Anchor the boat several yards north of the station and perform the following:

a) record air temperature, wind speed and other meteorological conditions.

b) take mid-depth (or top and bottom) water samples for salinity and DO determination. Fix the Dissolved Oxygen at the site.

c) take top to bottom temperature measurements (every foot).

d) measure water depth.

e) take bottom sample for bottom organisms count. Prepare label showing date, time, plant, station number and other necessary information. Wash down the sample in the proper jar using river water. Preserve the sample using a mixture of formaldahyde solution and river water. Clean the sampler and jar.

f) set seine net (two persons are needed). One person should go way out with the fish net (a maximum distance of 50') in the vicinity of the station. Always be on the outside of net while pulling the net. The second person should move outside of the net towards the first and takes his place. The first will then move a distance of 50' parallel to the shore. Both men will move towards the shore stretching the net evenly and pulling both the top and bottom together. All hands should meet along the bottom of the fish net.

The third person will prepare a jar of formaldahyde solution, label showing date, time, plant name, net used, station number, and collection number. D-S-S-3-1of 2, 50'X50' on one side and 9/10/69,11:09 on the other, for example, indicates: Danskammer - Station #3 - Collection #1 of 2, 50'X50' procedure, collected on 9/10/69 at 11:09. Preserve fish in the appropriate jars.

g) raise and empty the fyke net and preserve the contents following the procedure outlined in f above. Reset the fyke net at its proper location. The location should be few yards south of the station marker.

3. Move to the next ecological station. Take continuous surface temperature measurements. Repeat step "2" at this station.

4. Repeat step "3" at other ecological stations.

5. End this run by taking continuous surface temperature measurements within and outside the cove. Take top to bottom temperature measurements at several stations.

6. Conduct temperature runs at the selected tidal current conditions. (See the temperature survey procedure outlined in item D).

7. Take DO and salinity samples at the ecological stations at a different tidal condition. A total of 3 samples per station taken 3 to 4 hours apart is satisfactory.

8. Obtain plant operating conditions during the survey hours.

APPENDIX B

EFFECT OF ROSETON COOLING WATER DISCHARGE ON HUDSON RIVER TEMPERATURE DISTRIBUTION AND ECOLOGY

SURVEY DATA, JULY TO OCTOBER, 1969

INTRODUCTION

The following Appendix contains the results of temperature surveys made by Quirk, Lawler & Matusky Engineers during the period of July 18, 1969 to October 15, 1969. The surveys are divided into each day's runs containing the following information:

1. A summary sheet of data extracted from the temperature data collected. On this sheet is found:

    a. Tidal phase of runs made.
    b. The electrical output from Danskammer Plant.
    c. The percent of Hudson River surface width bounded by a temperature rise of 4°F or greater.
    d. The percent of Hudson River cross-sectional area bounded by a temperature rise of 4°F or greater.
    e. The total surface area bounded by a 4°F or greater rise.
    f. The longitudinal extent of the 4°F temperature rise.

2. Several graphs containing plant operating data as measured by plant equipment. These graphs contain:

    a. Tidal current during day of survey.
    b. Electrical output of Danskammer Plant, all units.
    c. Input and output cooling water temperatures over day.
    d. Temperature rise of cooling water through condenser during day.

3. Surface isotherms drawn from data collected during the surveys. These figures contain:

    a. Surface temperature isotherms.
    b. Tidal phase with period of survey marked.
    c. Weather conditions observed during run.
    d. Plant operating data during run.
    e. River ambient temperature during run.

4. Cross-sectional area isotherms showing variations of temperature with width and depth.

The figures are in the order listed above and sectioned by date. An additional section titled "Tidal Average" follows the daily data. This section contains a lateral average of all runs as well as an average of each tidal phase (Maximum Flood, High Water Slack, Maximum Ebb, Low Water Slack). An average cross-sectional graph was constructed from all survey data and included at the end of this section.

TABLE A1

PORTION OF HUDSON RIVER AT DANSKAMMER SUBJECTED TO TEMPERATURE RISE OF 4°F OR GREATER

DATE: July 18, 1969

Total river cross sectional area at critical section - 142,000 ft.^{2}

Total river surface width at critical section* - 3,420 ft.

TIDAL CONDITION	ELECTRICAL OUTPUT (MWE)	% WIDTH	% CROSS-SECTIONAL AREA	SURFACE AREA (ACRES)	LONGITUDINAL EXTENT
Late Ebb	492	19.3	0.73	154.5	3765'
Maximum Flood	494	7.6	1.20	29.7	1300'
Low Water Slack	504	18.7	0.62	51.5	1340'

*Critical section 390 ft. south of discharge.

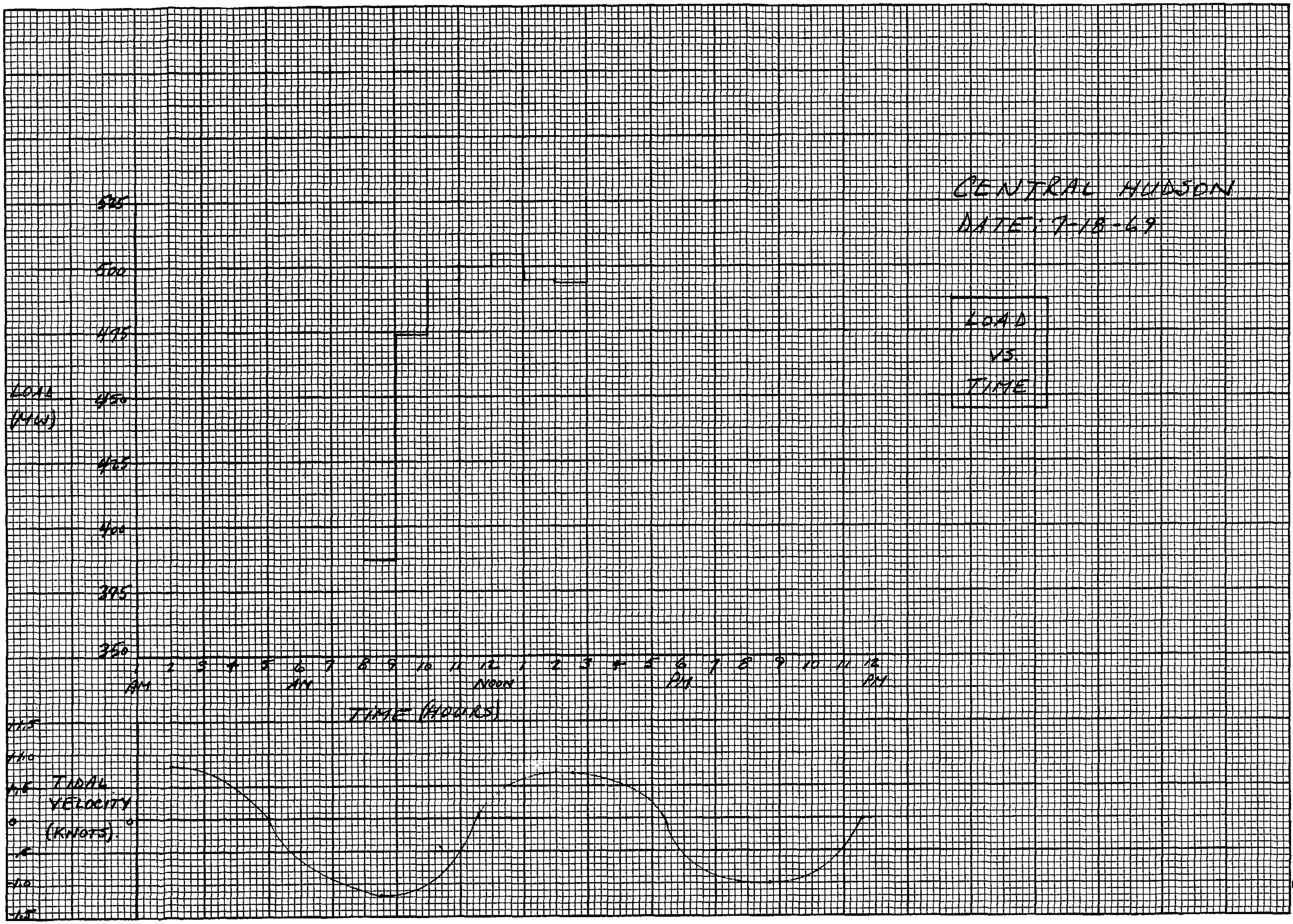
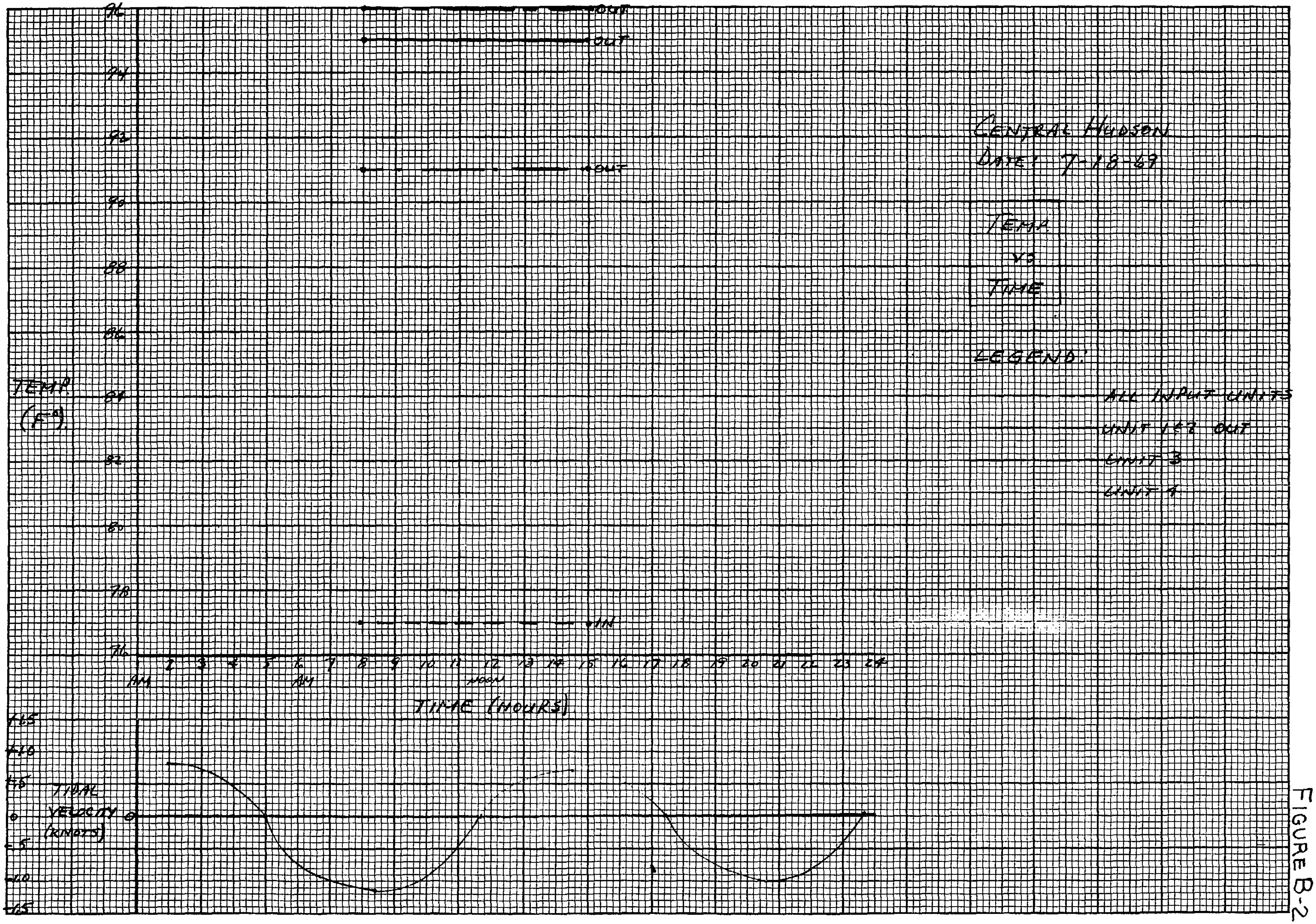

CENTRAL HUDSON
DATE: 7-18-69
LOAD
VS.
TIME
LOAD
(MW)
525
500
475
450
425
400
395
350
1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
9
10
11
12
AM
AM
NOON
PM
PM
TIME (HOURS)
+1.5
+1.0
+.5
0
-.5
-1.0
-1.5
TIDAL
VELOCITY
(KNOTS)
0

FIGURE B-1

FIGURE B-2

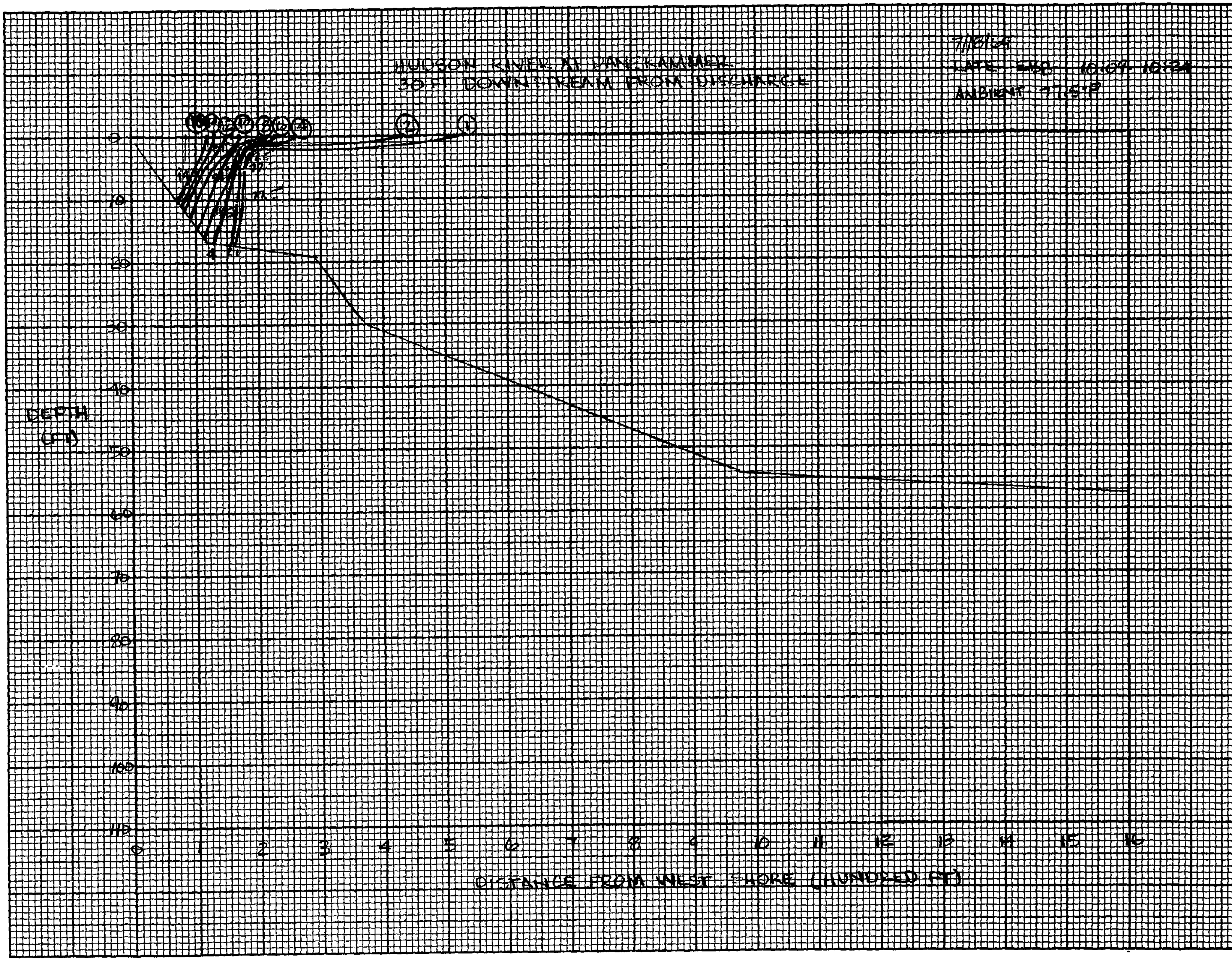

CENTRAL HUDSON
DATE: 7-18-69
TEMP. VS TIME
LEGEND:
ALL INPUT UNITS
UNIT 1 & 2 OUT
UNIT 3
UNIT 4
TEMP. (F°)
96
94
92
90
88
86
84
82
80
78
76
OUT
OUT
OUT
IN
1 AM
2
3
4
5
6 AM
7
8
9
10
11
12 NOON
13
14
15
16
17
18
19
20
21
22
23
24
TIME (HOURS)
TIDAL VELOCITY (KNOTS)
+15
+10
+5
0
-5
-10
-15

LARGE DOCUMENT

LARGE
DOCUMENT

LARGE
DOCUMENT

FIGURE B-6


HUDSON RIVER AT DANSKAMMER
30 FT DOWNSTREAM FROM DISCHARGE
7/18/74
LATE EBB 10:09-10:24
AMBIENT 77.5°F
①
②
④
DEPTH (FT)
0
10
20
30
40
50
60
70
80
90
100
110
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
DISTANCE FROM WEST SHORE (HUNDRED FT)

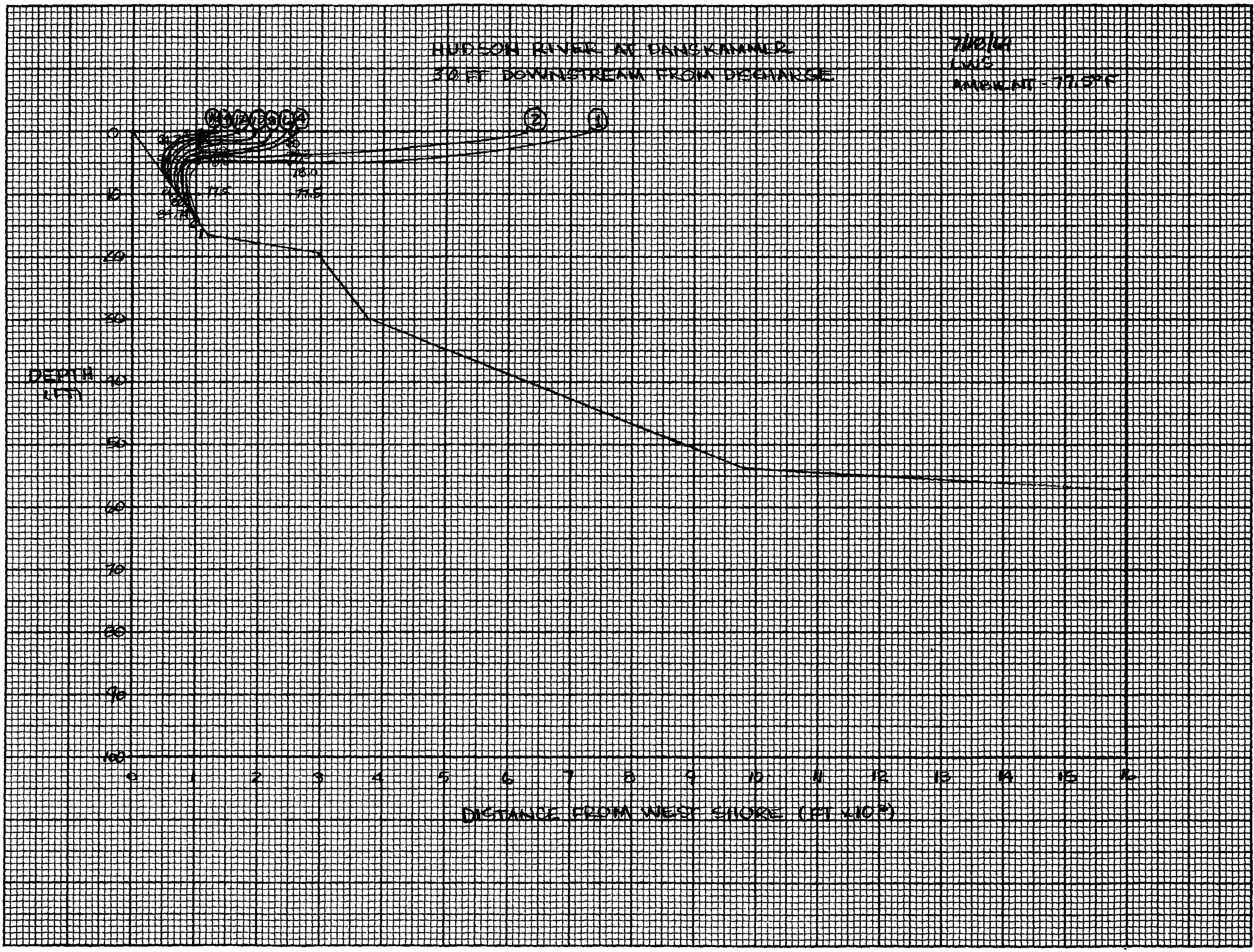
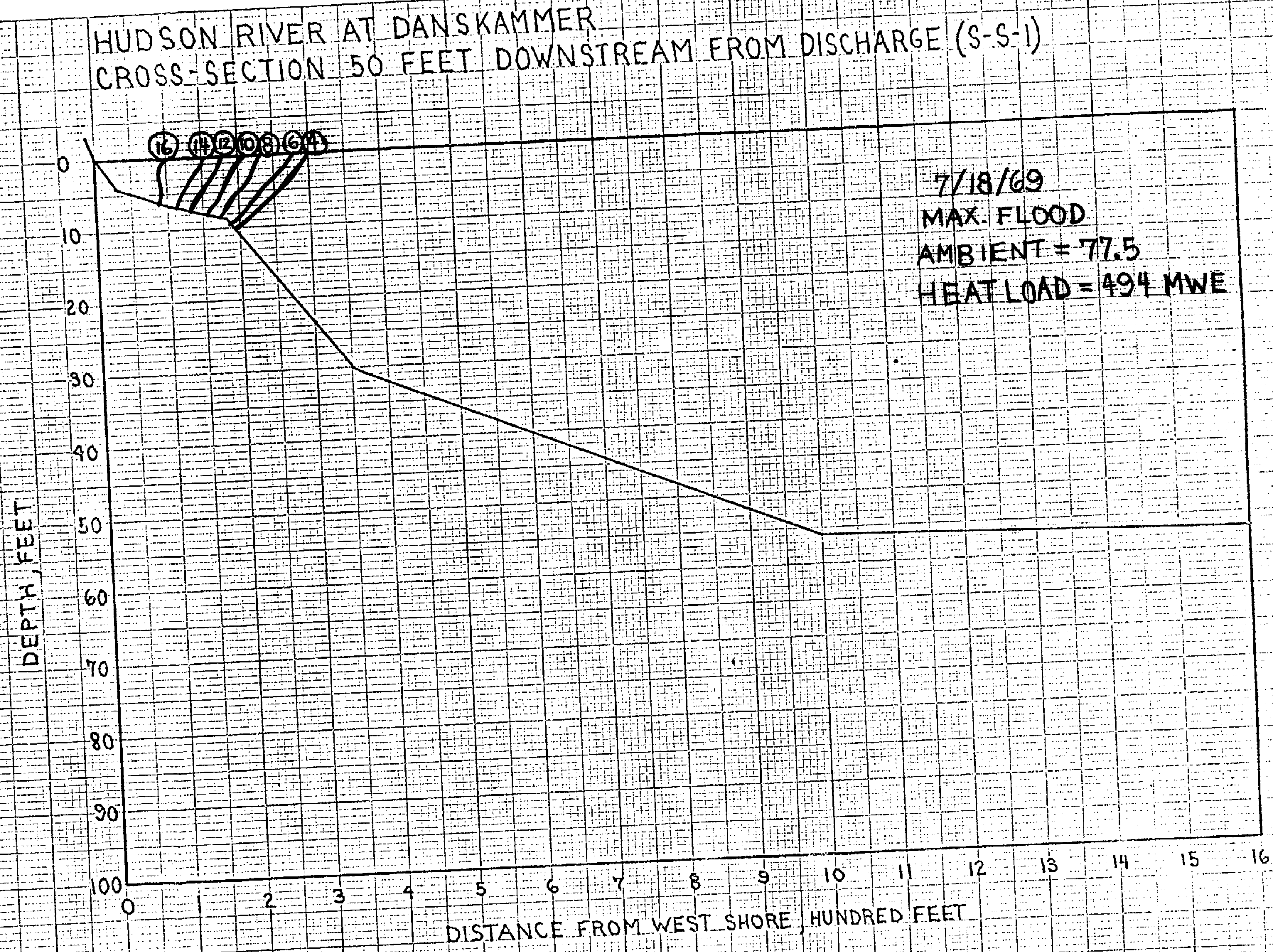

HUDSON RIVER AT DANSKAMMER
30 FT DOWNSTREAM FROM DISCHARGE
7/10/69
LWS
AMBIENT - 77.5°F
①
②
78.0
77.5
77.5
DEPTH (FT)
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
DISTANCE FROM WEST SHORE (FT x10²)

FIGURE B-7



HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)

7/18/69
MAX. FLOOD
AMBIENT = 77.5
HEAT LOAD = 494 MWE

FIGURE B-8

TABLE A2

PORTION OF HUDSON RIVER AT DANSKAMMER SUBJECTED TO TEMPERATURE RISE OF 4°F OR GREATER

DATE: July 30, 1969

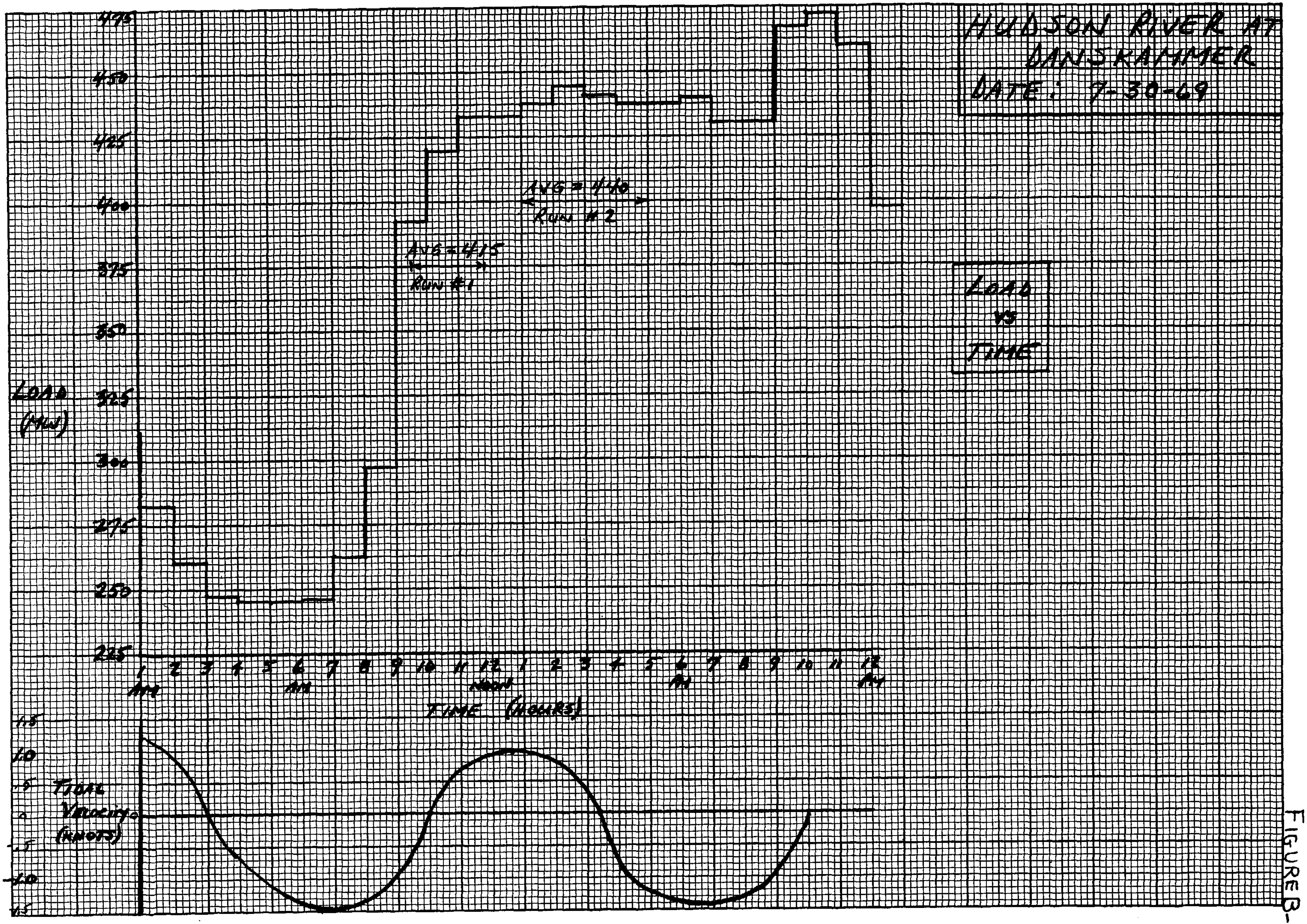
Total river cross sectional area at critical section - 142,000 ft.^{2}

Total river surface width at critical section* - 3,420 ft.

TIDAL CONDITION	ELECTRICAL OUTPUT (MWE)	% WIDTH	% CROSS-SECTIONAL AREA	SURFACE AREA (ACRES)	LONGITUDINAL EXTENT
Late Flood	445	5.5	0.73	11.0	1730
Early Flood	433	20.5	1.43	14.6	1070
High Water Slack to Early Ebb	438	10.0	1.06	78.0	7750

*Critical section 390 ft. south of discharge.

FIGURE B-9

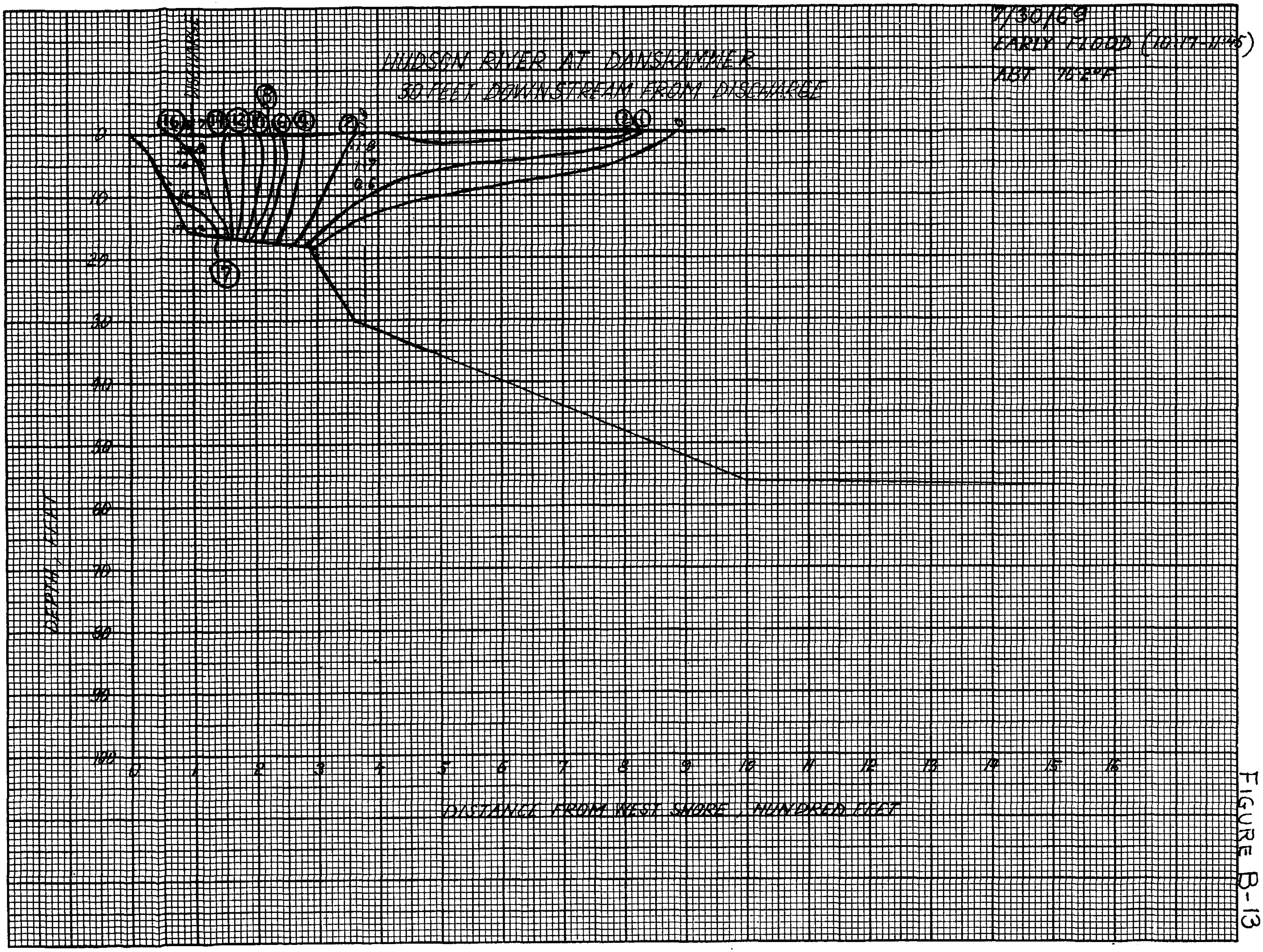

HUDSON RIVER AT
DANSKAMMER
DATE: 7-30-69
LOAD
VS
TIME
LOAD
(MW)
475
450
425
400
375
350
325
300
275
250
225
AVG = 415
RUN #1
AVG = 410
RUN #2
1
AM
2
3
4
5
6
AM
7
8
9
10
11
12
NOON
1
2
3
4
5
6
PM
7
8
9
10
11
12
AM
TIME (HOURS)
TIDAL
VELOCITY
(KNOTS)
1.5
1.0
.5
0
.5
1.0
1.5

LARGE
DOCUMENT

LARGE
DOCUMENT

LARGE
DOCUMENT

KK


HUDSON RIVER AT DANSKAMMER

30 FEET DOWNSTREAM FROM DISCHARGE

7/30/69

EARLY FLOOD (10:17-11:45)

ABT 76.2°F

FIGURE B-13

KK

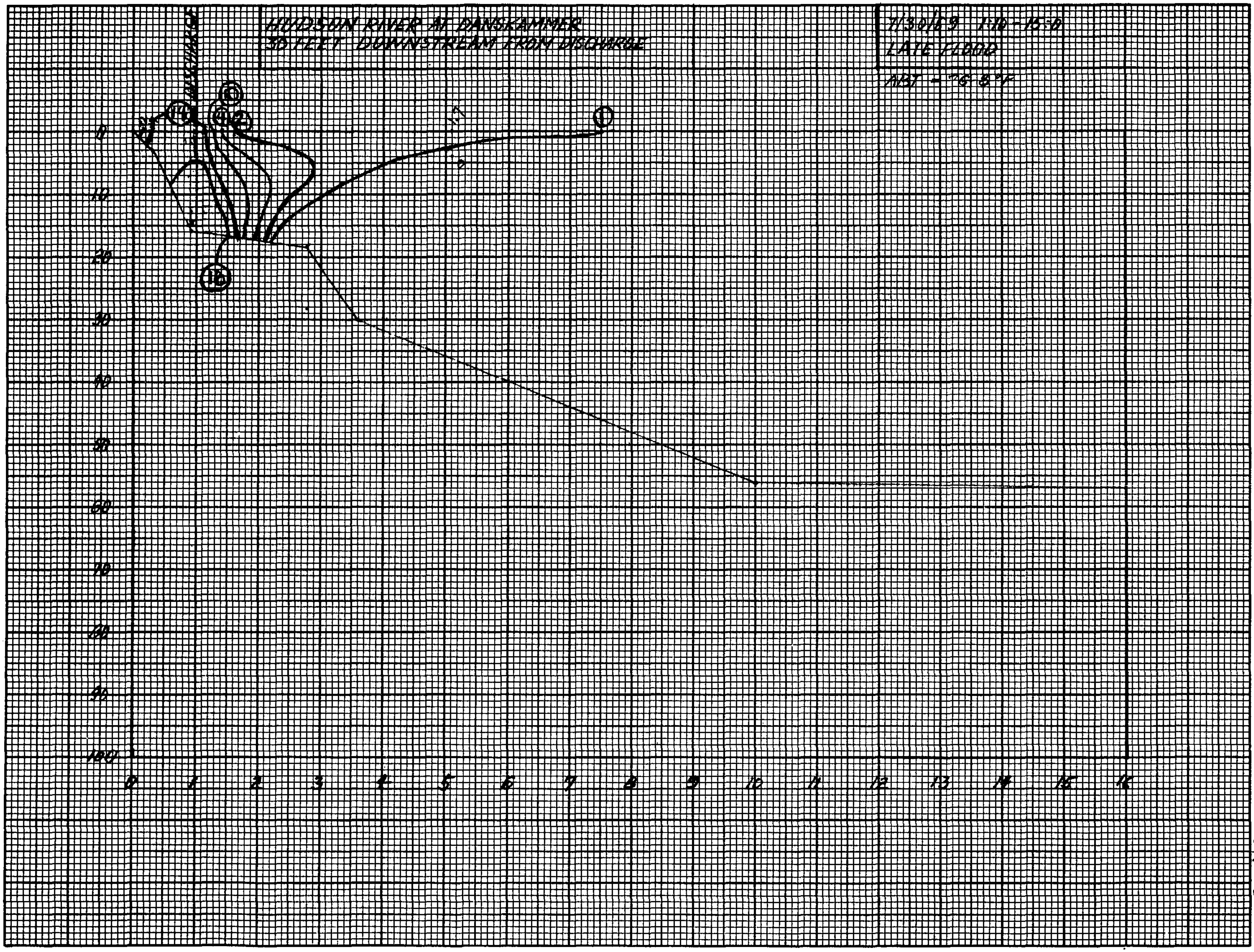
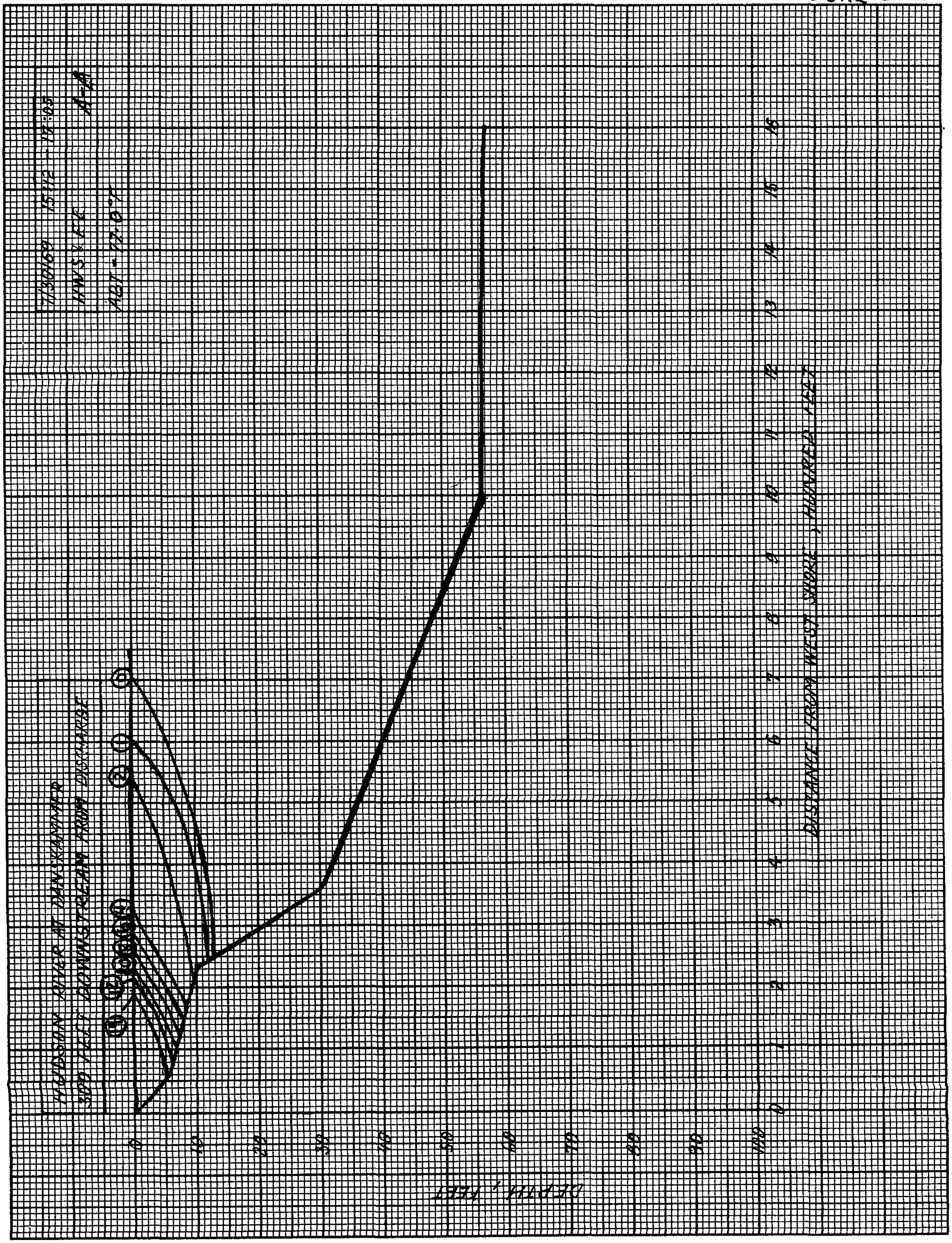


FIGURE B-14

FIGURE B-15


HUDSON RIVER AT DANSKAMMER
300 FEET DOWNSTREAM FROM DISCHARGE
7/30/69 15:12 - 17:05
HWS & FE
A-A
ADT - 12.0°F
0
1
2
13
12
0
10
20
30
40
50
60
70
80
90
100
DEPTH, FEET
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
DISTANCE FROM WEST SHORE, HUNDRED FEET

600 ft

KK

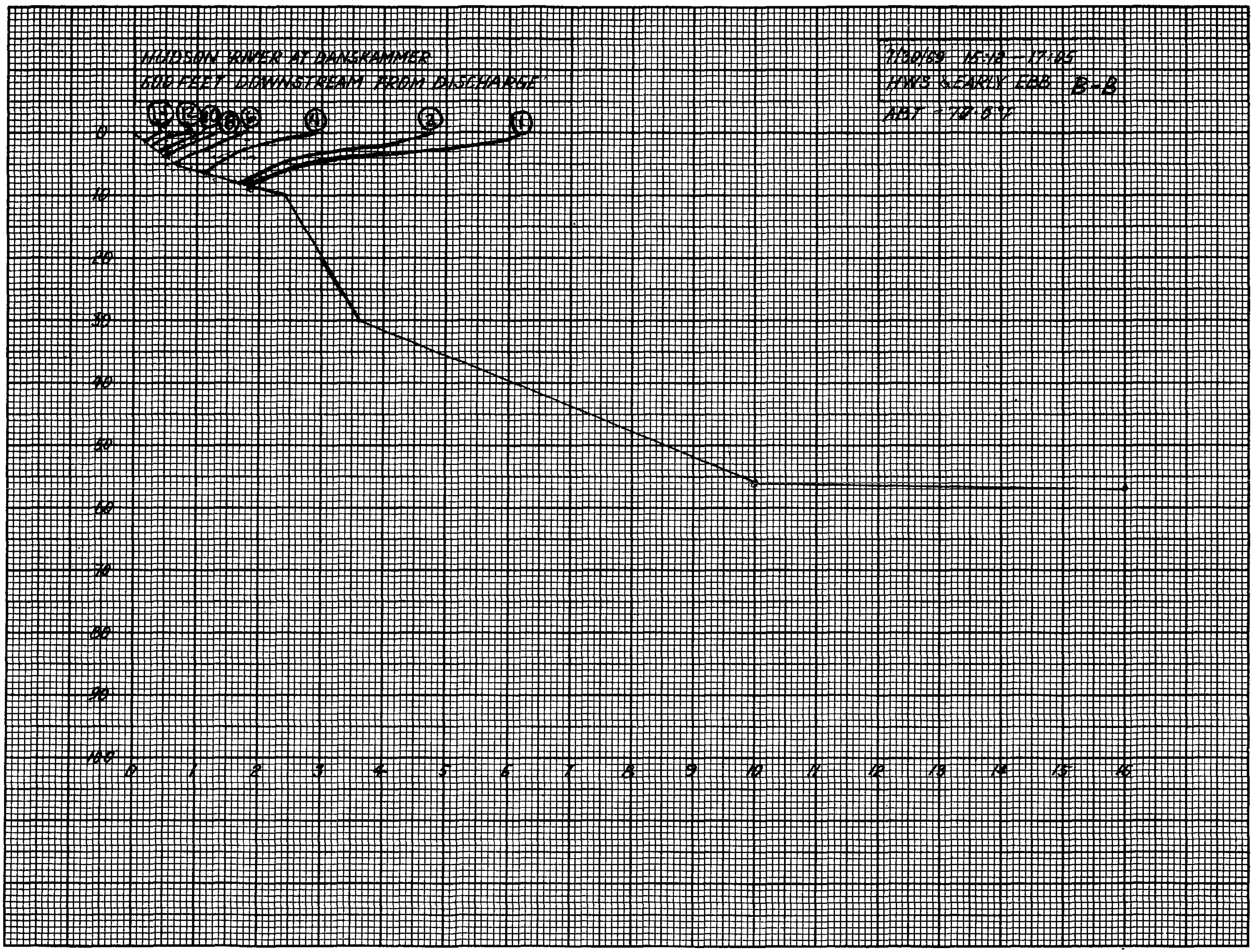


FIGURE B-16

KK

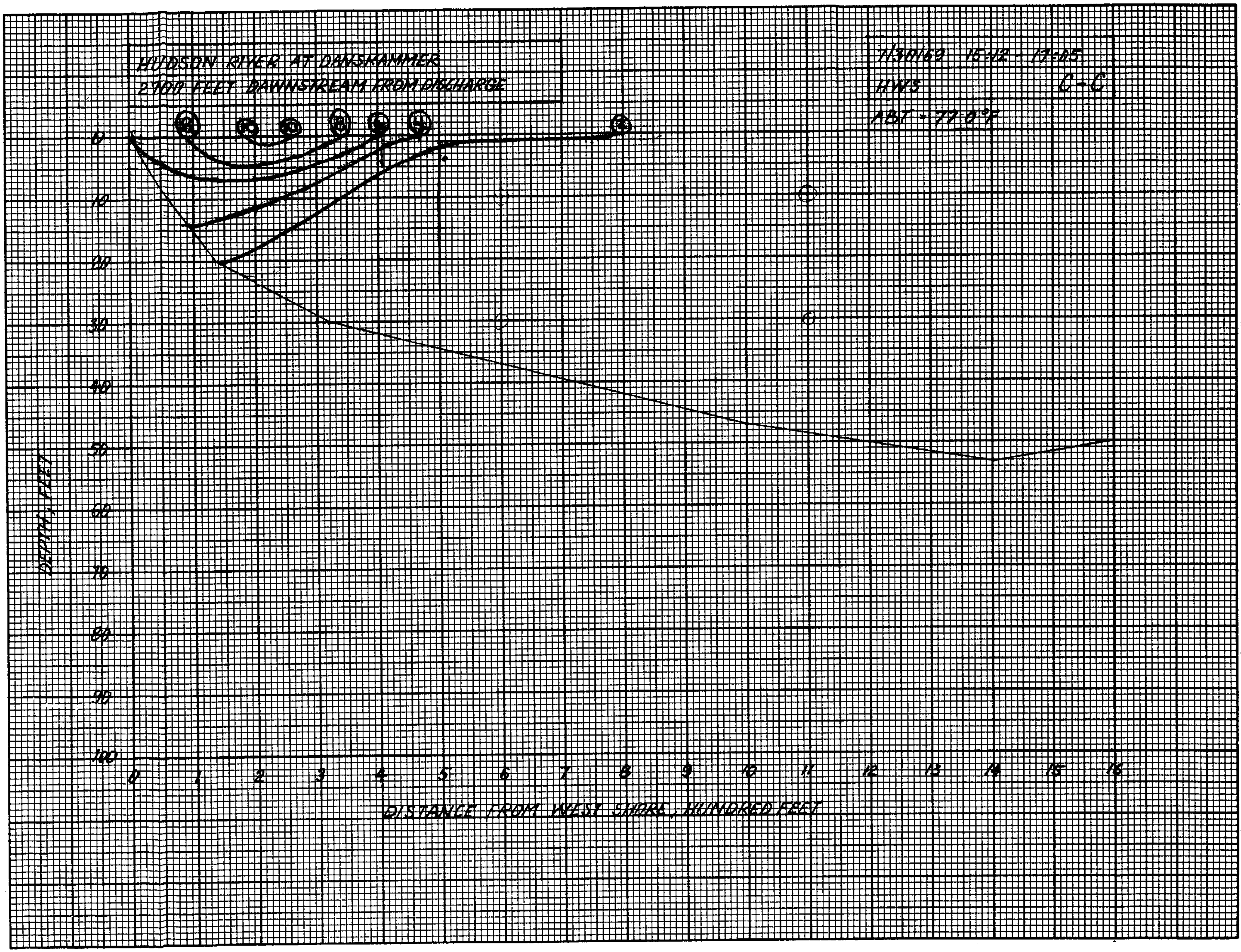


FIGURE B-17

TABLE A3

PORTION OF HUDSON RIVER AT DANSKAMMER SUBJECTED TO TEMPERATURE RISE OF 4°F OR GREATER

DATE: August 6, 1969

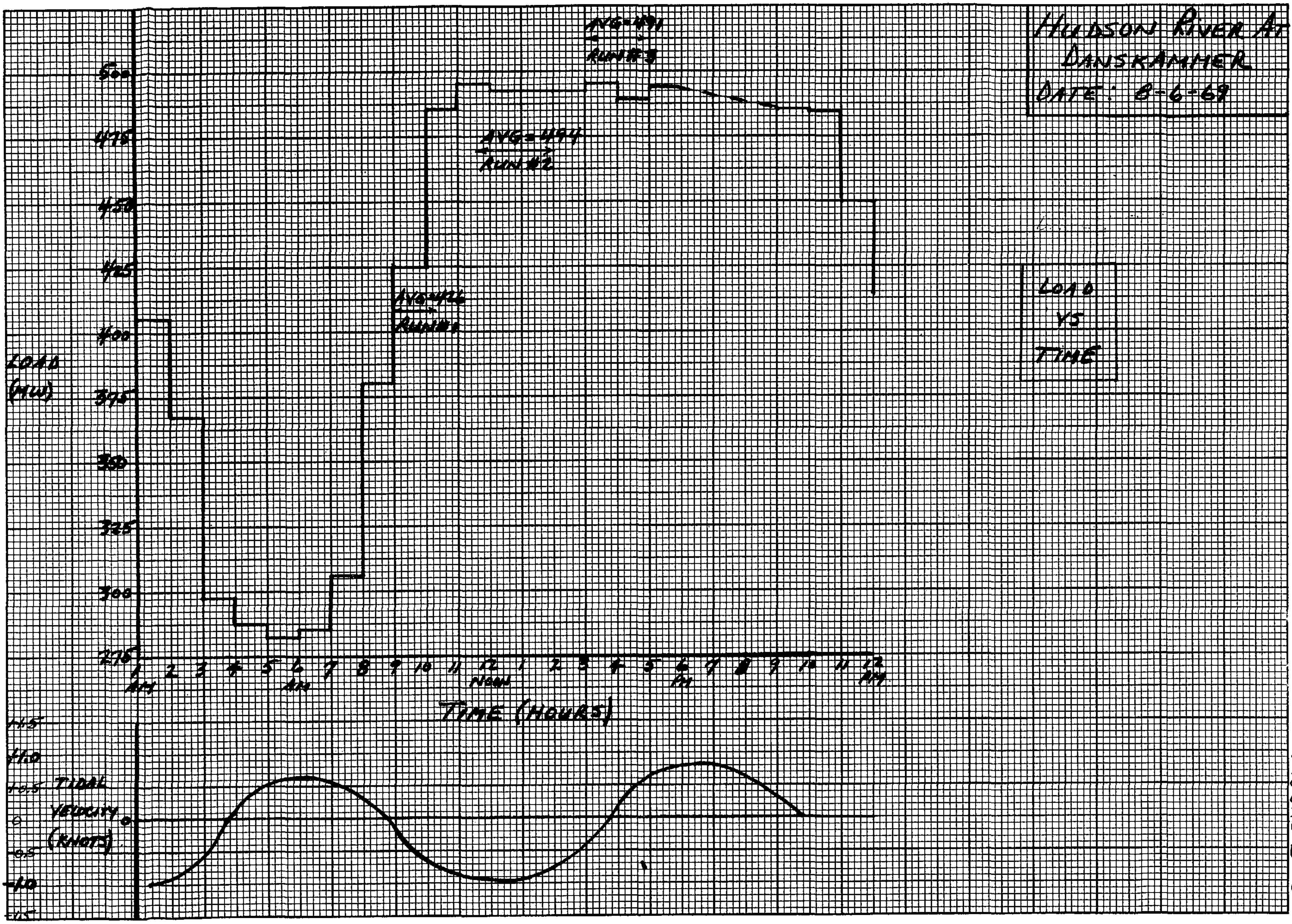
Total river cross sectional area at critical section - 142,000 ft.^{2}

Total river surface width at critical section* - 3,420 ft.

TIDAL CONDITION	ELECTRICAL OUTPUT (MWE)	% WIDTH	% CROSS-SECTIONAL AREA	SURFACE AREA (ACRES)	LONGITUDINAL EXTENT
Early Ebb to High Water Slack	455	11.7	1.19	79.8	5470
Maximum Ebb	493	9.7	-	> 217.5	10,000+
Low Water Slack	494	19.0	2.79	205.5	6000

*Critical section 390 ft. south of discharge.

FIGURE B-18

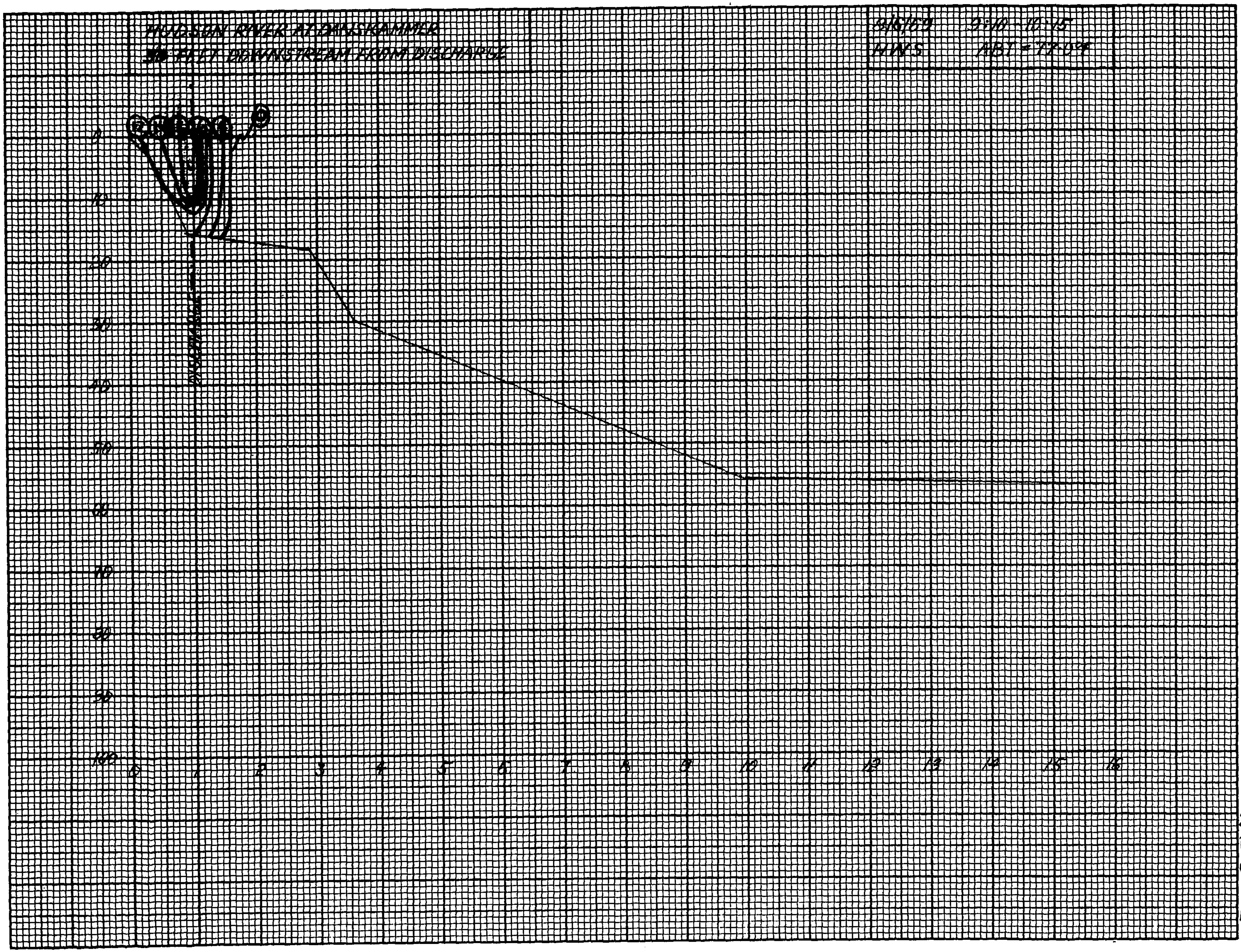

HUDSON RIVER AT
DANSKAMMER
DATE: 8-6-69
LOAD
VS
TIME
LOAD
(MW)
500
475
450
425
400
375
350
325
300
275
AVG=426
RUN#1
AVG=494
RUN#2
AVG=491
RUN#3
1 AM
2
3
4
5
6 AM
7
8
9
10
11
12 NOON
1
2
3
4
5
6 PM
7
8
9
10
11
12 AM
TIME (HOURS)
+1.5
+1.0
+0.5
0
-0.5
-1.0
-1.5
TIDAL
VELOCITY
(KNOTS)
0

LARGE DOCUMENT

LARGE DOCUMENT

LARGE
DOCUMENT

FIGURE B-22



HUDSON RIVER AT DANSKAMMER
FEET DOWNSTREAM FROM DISCHARGE

8/6/69 9:10 - 10:15
HWS ABT = 77.0°F

KK

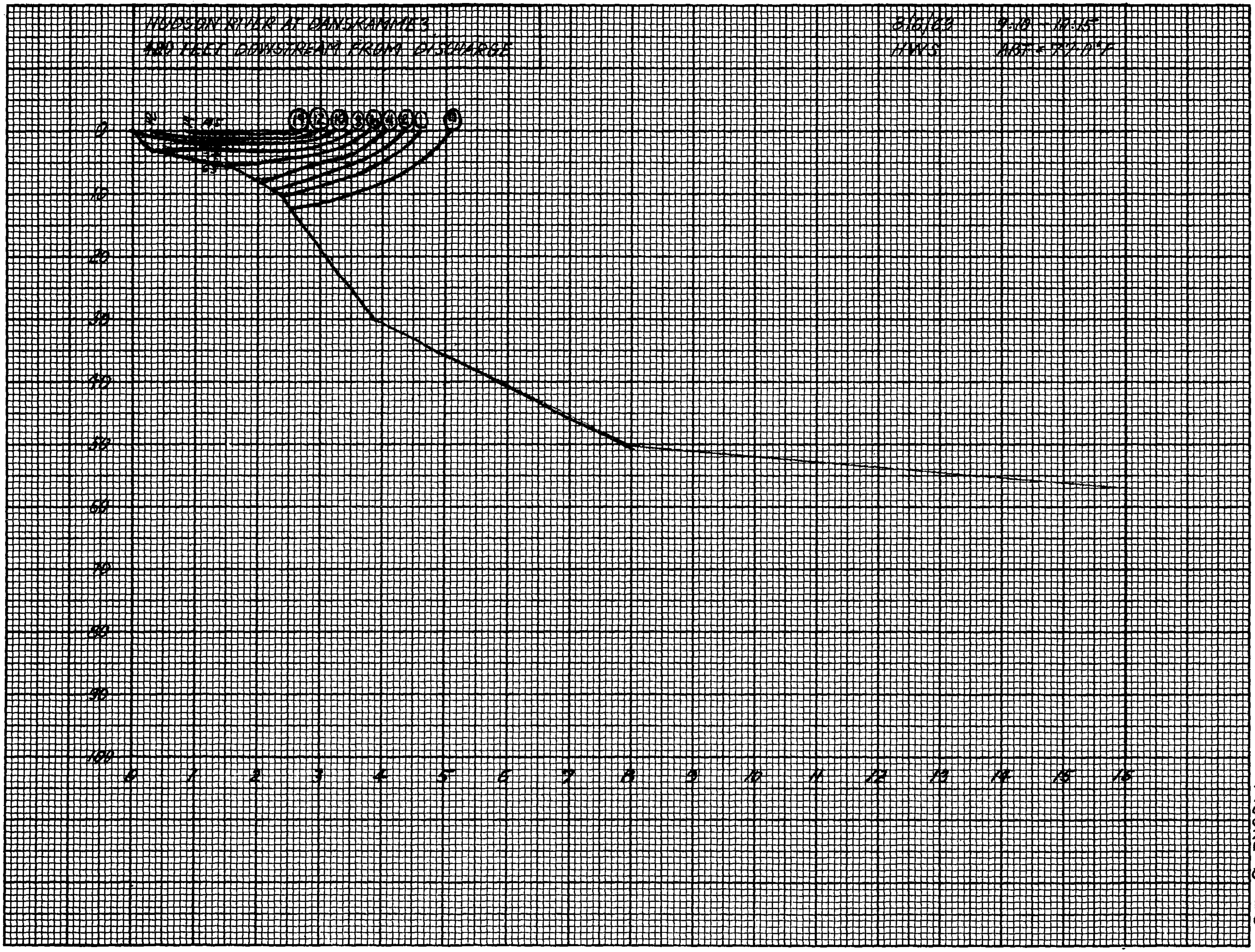
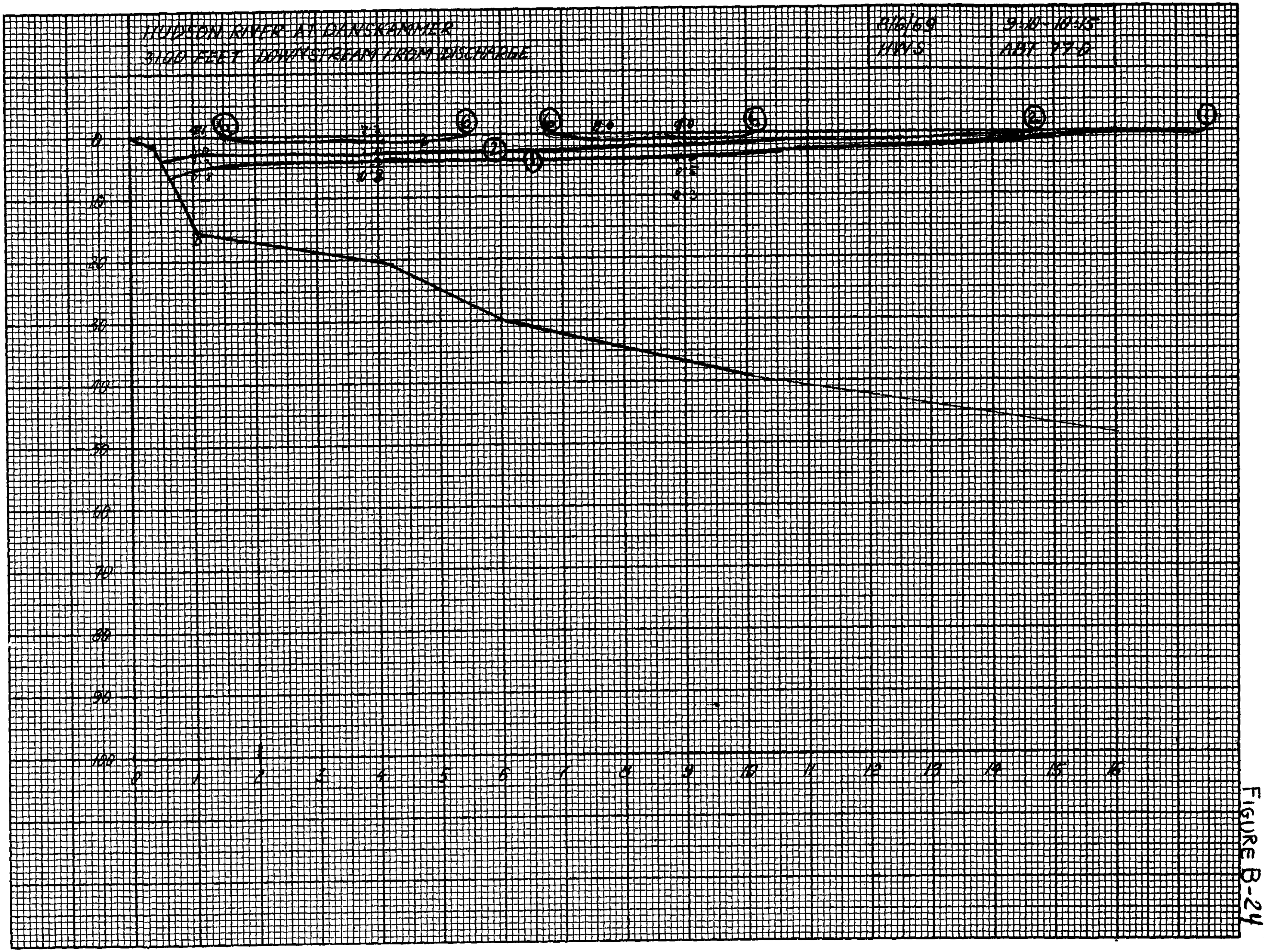


FIGURE B-23



HUDSON RIVER AT DANSKAMMER
3100 FEET DOWNSTREAM FROM DISCHARGE

8/6/69 9:10-10:15
HWS ABT 77.0

FIGURE B-24

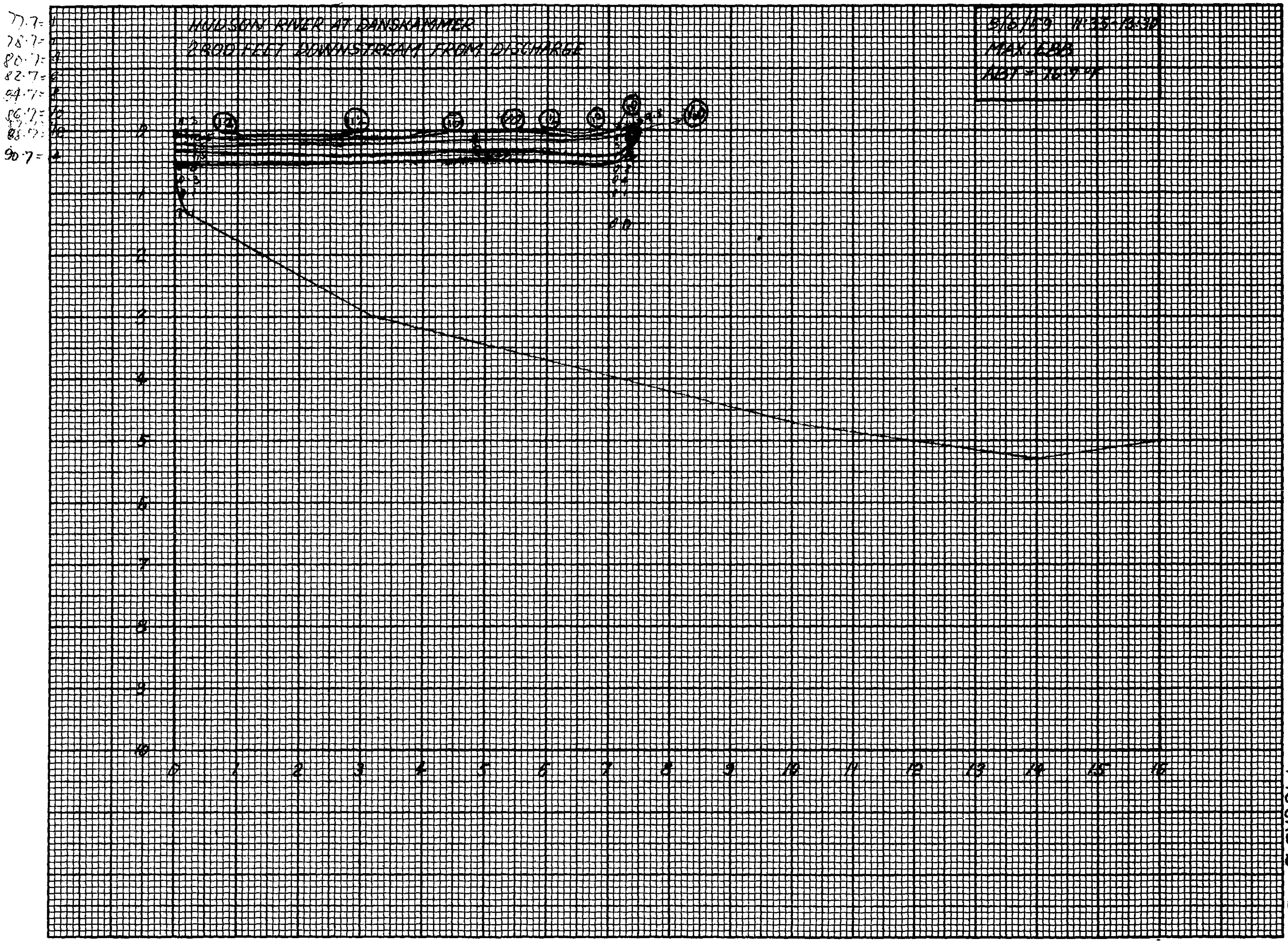

HUDSON RIVER AT DANSKAMMER
2800 FEET DOWNSTREAM FROM DISCHARGE
8/6/69 11:35-12:30
MAX EBB
ABT = 76.7°F
77.7 =
78.7 =
80.7 =
82.7 =
84.7 =
86.7 =
88.7 =
90.7 =
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

FIGURE B-25

KK

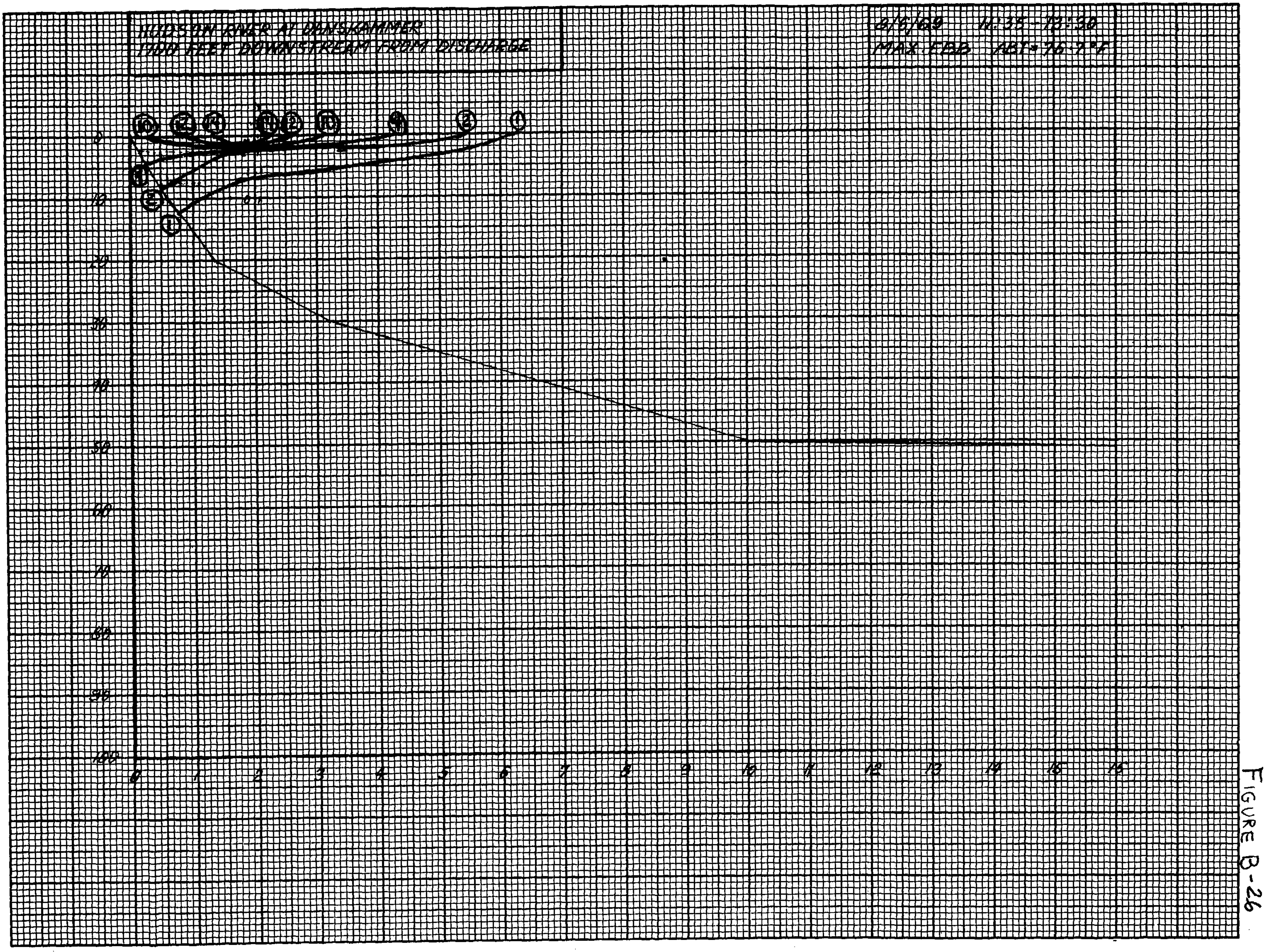
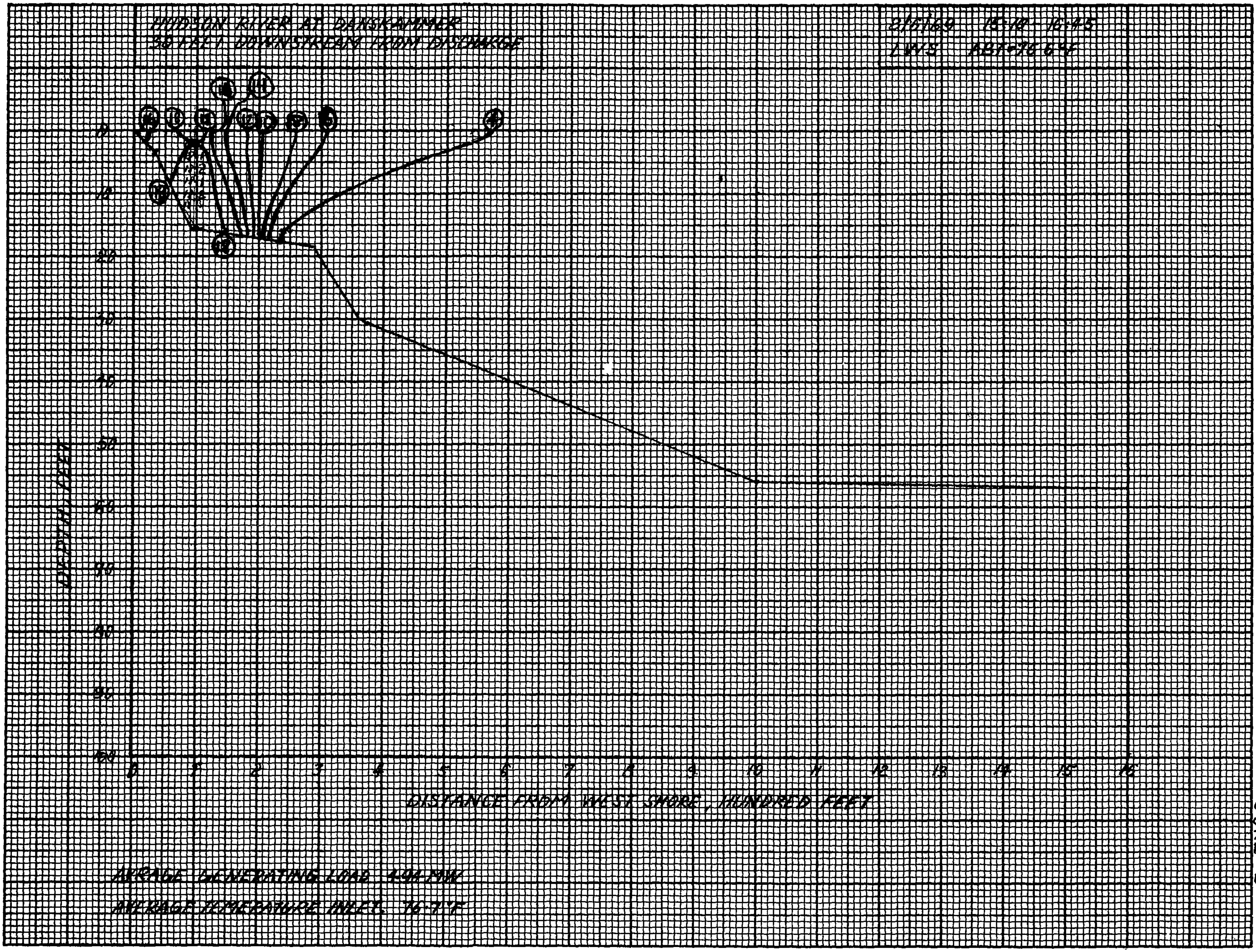


FIGURE B-26

K K

FIGURE B-27



HUDSON RIVER AT DANSKAMMER
50 FEET DOWNSTREAM FROM DISCHARGE

2/5/69 15:10 - 16:45
LWS ABT+76.6°F

AVERAGE GENERATING LOAD 494 MW
AVERAGE TEMPERATURE INLET 76.7°F

TABLE A4

PORTION OF HUDSON RIVER AT DANSKAMMER SUBJECTED TO TEMPERATURE RISE OF 4°F OR GREATER

DATE: August 13, 1969

Total river cross sectional area at critical section - 142,000 ft.^{2}

Total river surface width at critical section* - 3,420 ft.

TIDAL CONDITION	ELECTRICAL OUTPUT (MWE)	% WIDTH	% CROSS-SECTIONAL AREA	SURFACE AREA (ACRES)	LONGITUDINAL EXTENT
Maximum Flood	461	26.3	1.63	25.3	2205
High Water Slack to Early Ebb	470	16.1	0.81	44.0	5080
Maximum Ebb	470	9.1	0.95	176.0	8340

*Critical section 390 ft. south of discharge.

TABLE A5

PORTION OF HUDSON RIVER AT DANSKAMMER SUBJECTED TO TEMPERATURE RISE OF 4°F OR GREATER

DATE: August 20, 1969

Total river cross sectional area at critical section - 142,000 ft.^{2}

Total river surface width at critical section* - 3,420 ft.

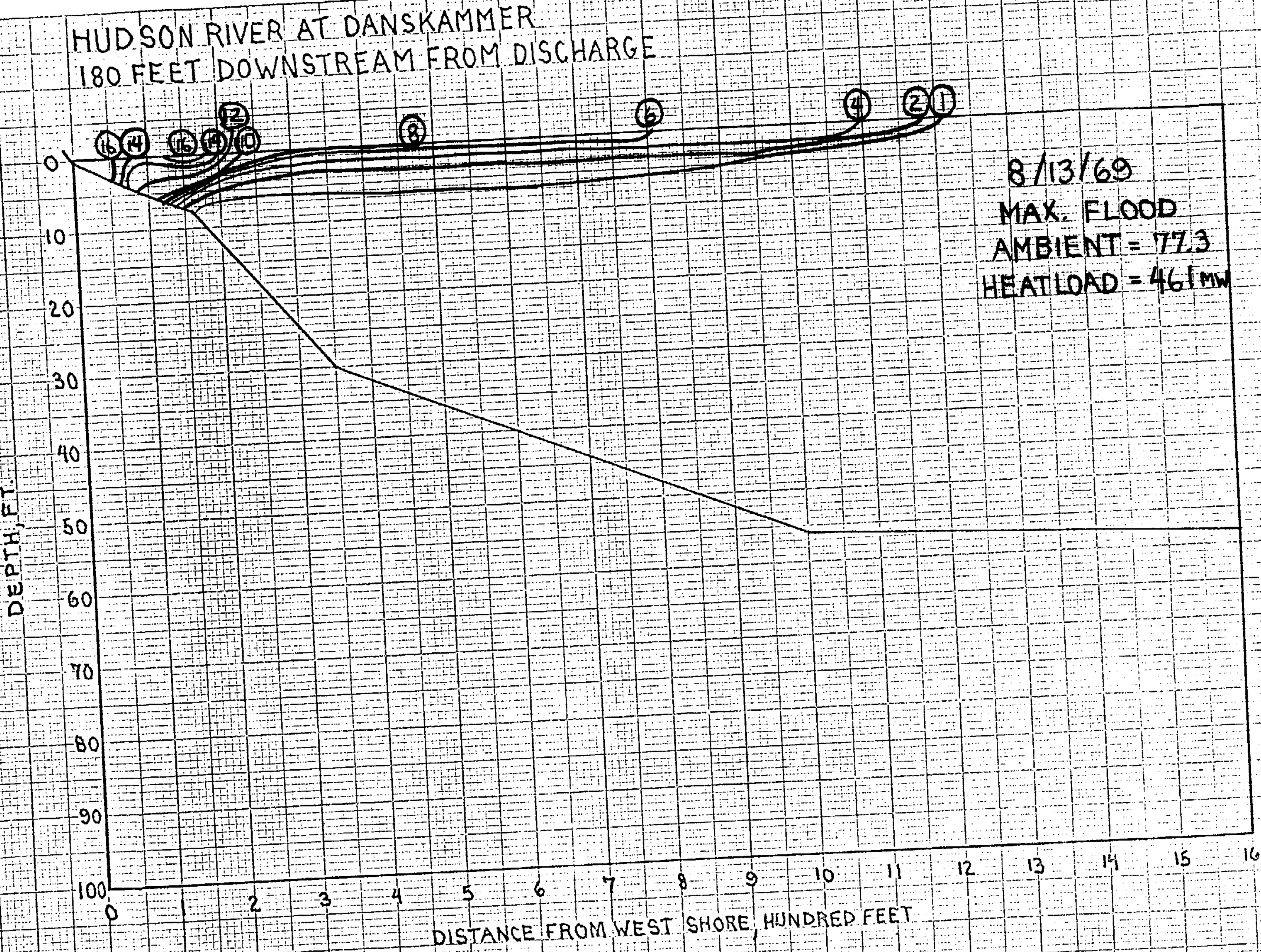
TIDAL CONDITION	ELECTRICAL OUTPUT (MWE)	% WIDTH	% CROSS-SECTIONAL AREA	SURFACE AREA (ACRES)	LONGITUDINAL EXTENT
Maximum Ebb	463	9.7	0.72	33.0	5000
Low Water Slack	458	9.1	0.49	46.5	4330
Maximum Flood	424	4.1	0.52	8.4	5000

*Critical section 390 ft. south of discharge.

LARGE
DOCUMENT

LARGE
DOCUMENT

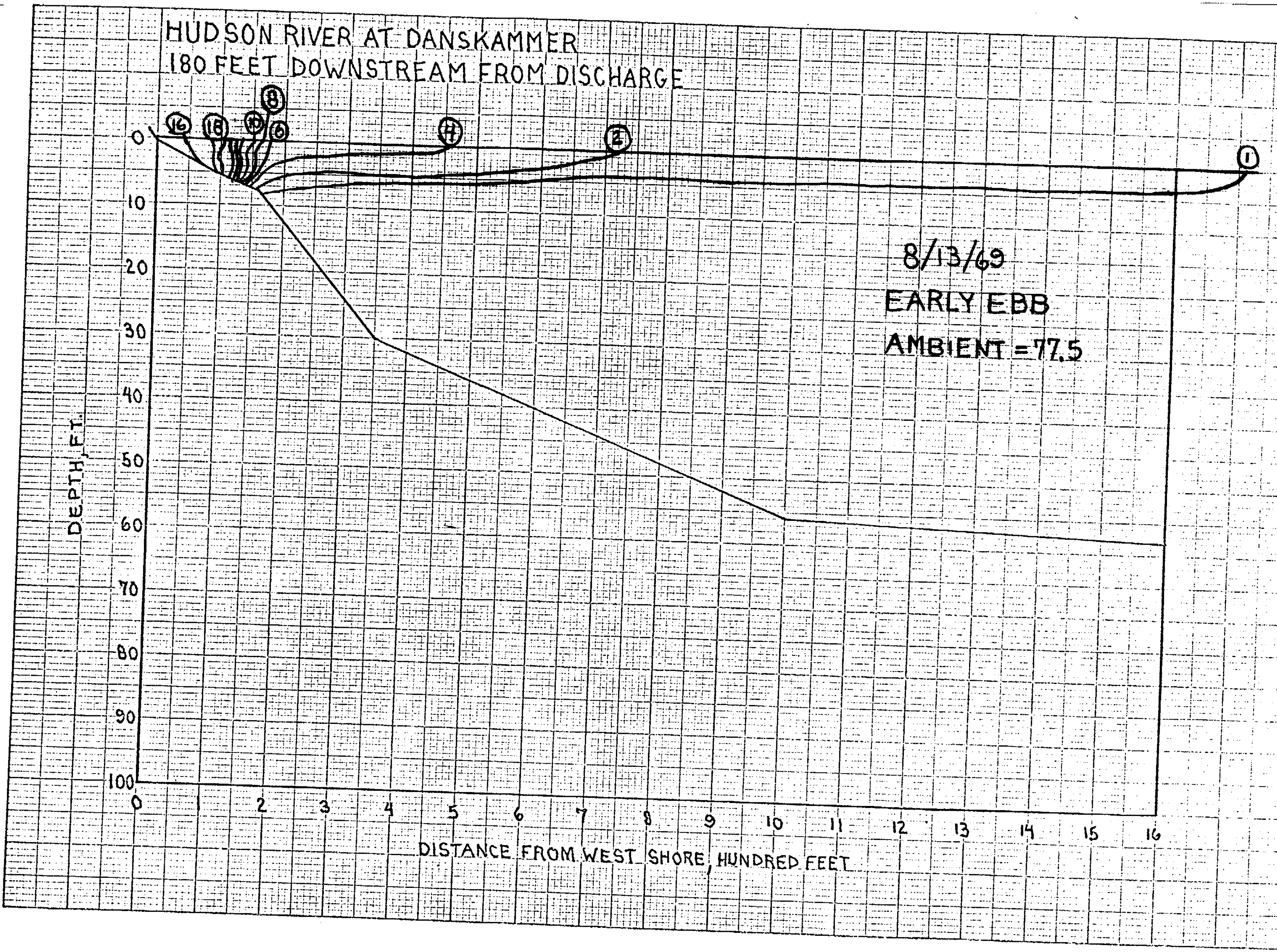
LARGE DOCUMENT



HUDSON RIVER AT DANSKAMMER
180 FEET DOWNSTREAM FROM DISCHARGE

8/13/69
MAX. FLOOD
AMBIENT = 77.3
HEATLOAD = 461 MW

FIGURE B-32


HUDSON RIVER AT DANSKAMMER
180 FEET DOWNSTREAM FROM DISCHARGE

8/13/69

EARLY EBB

AMBIENT = 77.5

FIGURE B-33

HUDSON RIVER AT DANSKAMMER
180 FEET DOWNSTREAM FROM DISCHARGE

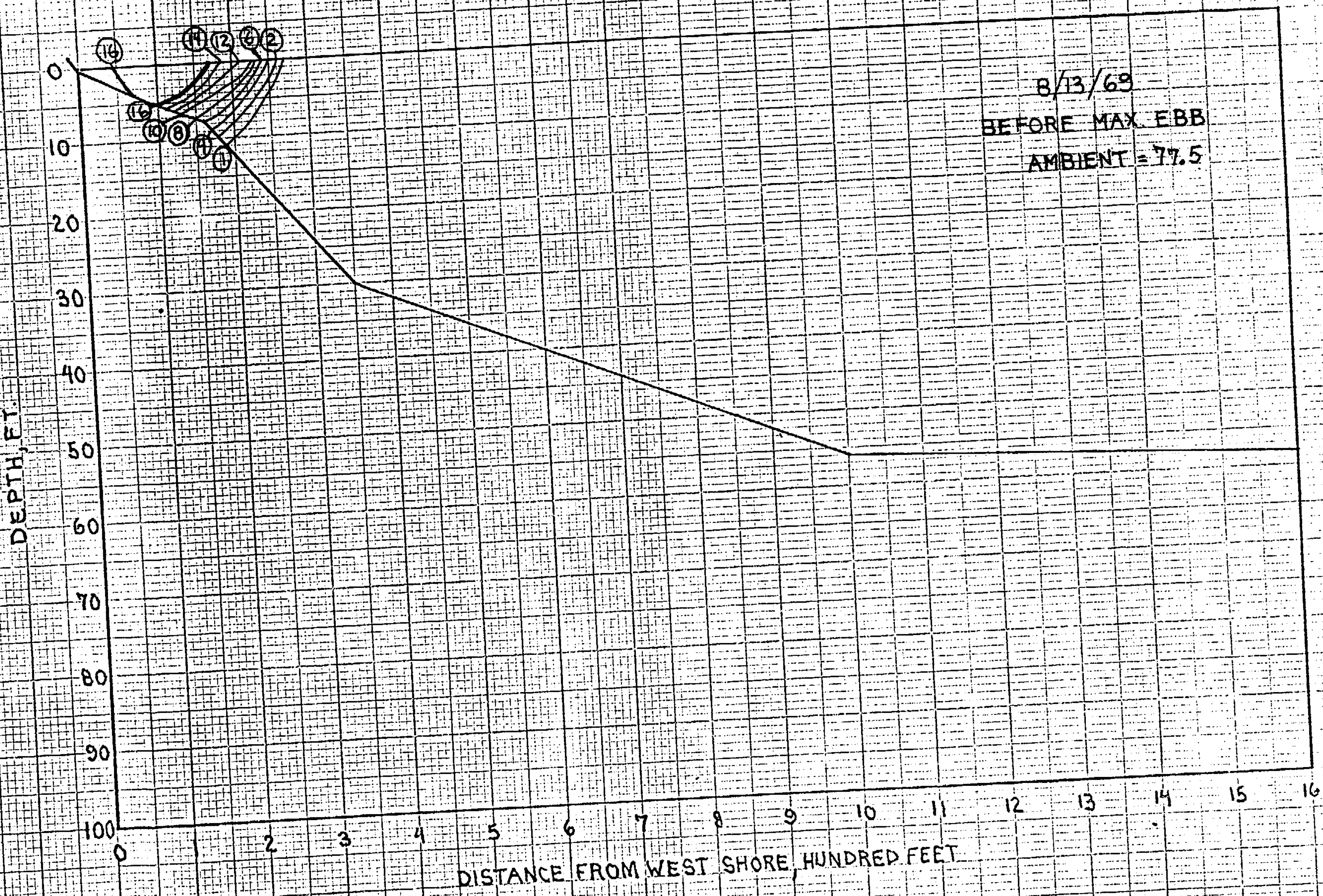


FIGURE B-34

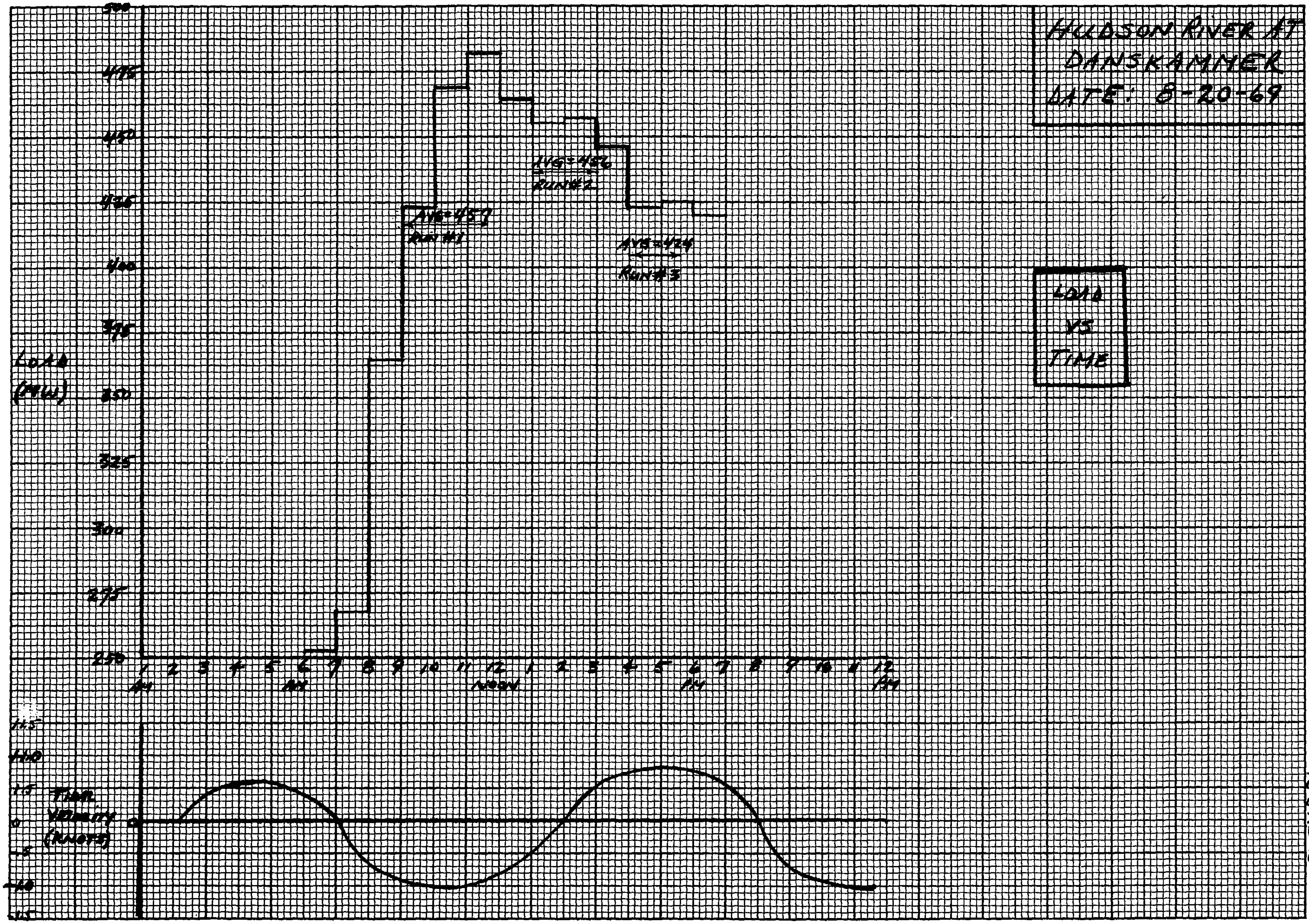

HUDSON RIVER AT
DANSKAMMER
DATE: 8-20-69
LOAD
VS
TIME
LOAD
(MW)
500
475
450
425
400
375
350
325
300
275
250
AVG=457
RUN #1
AVG=456
RUN #2
AVG=424
RUN #3
1 AM
2
3
4
5
6 AM
7
8
9
10
11
12 NOON
1
2
3
4
5
6 PM
7
8
9
10
11
12 PM
TIDAL
VELOCITY
(KNOTS)
+1.5
+1.0
+.5
0
-.5
-1.0
-1.5

FIGURE B-35

LARGE DOCUMENT

LARGE DOCUMENT

LARGE DOCUMENT

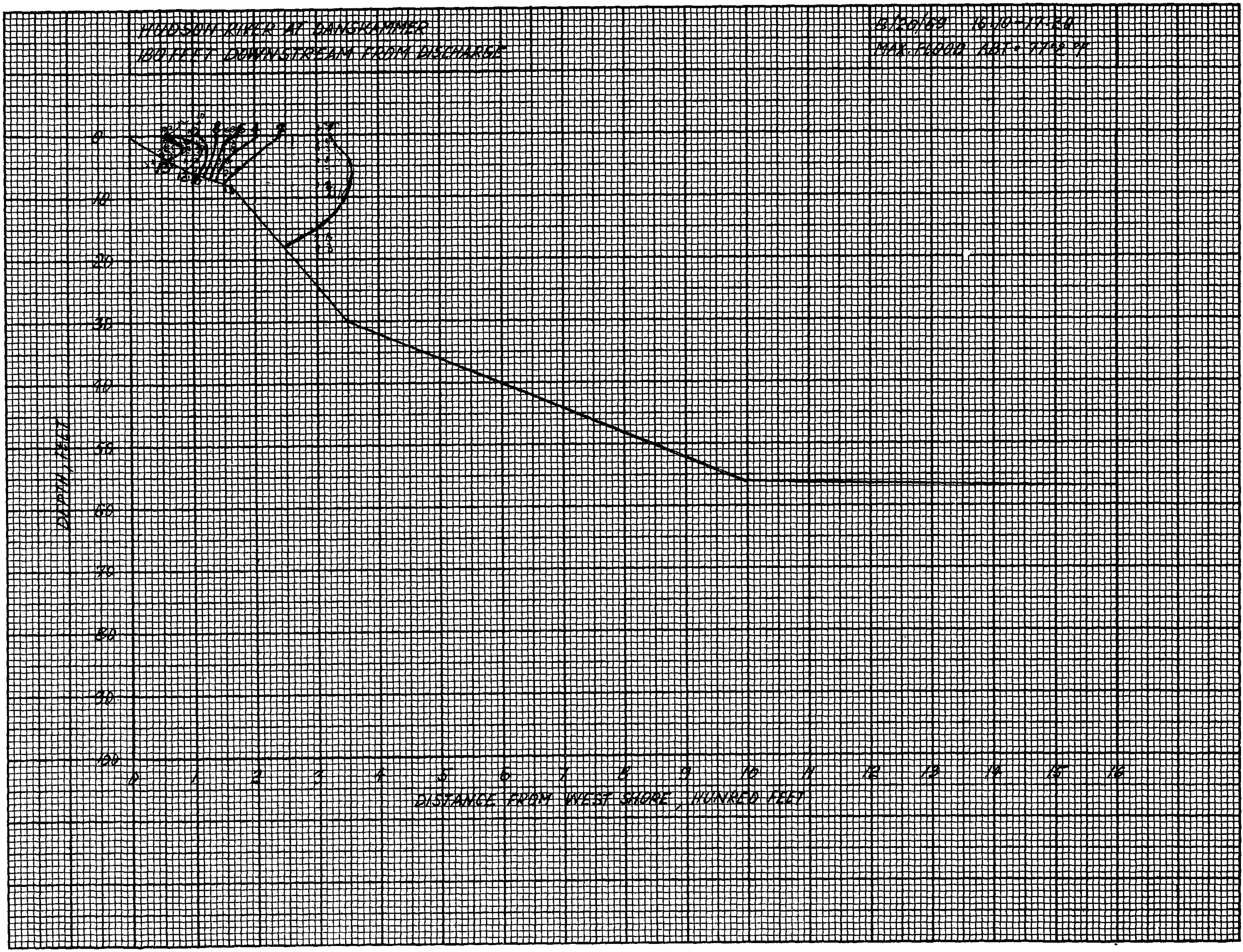
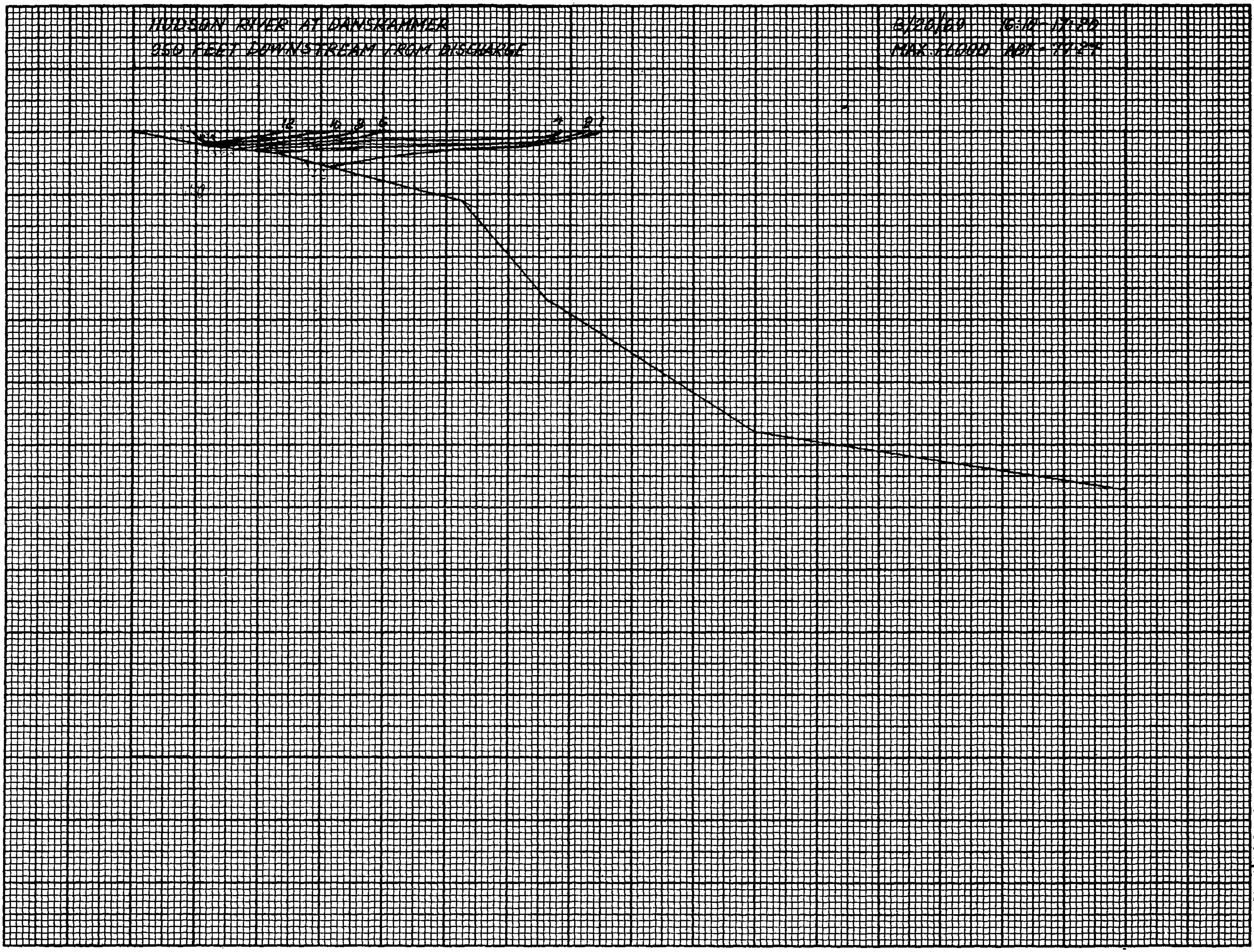

HUDSON RIVER AT DANSKAMMER
180 FEET DOWNSTREAM FROM DISCHARGE
8/20/69 1610-1720
MAX FLOOD ABT • 77.2 °F
DEPTH, FEET
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
DISTANCE FROM WEST SHORE, HUNRED FEET

FIGURE B-39

FIGURE B-40


HUDSON RIVER AT DANSKAMMER
350 FEET DOWNSTREAM FROM DISCHARGE
8/28/69 16:11-17:22
MAX FLOOD ABT - 17:27
12
10
8
6
4
2
1
10

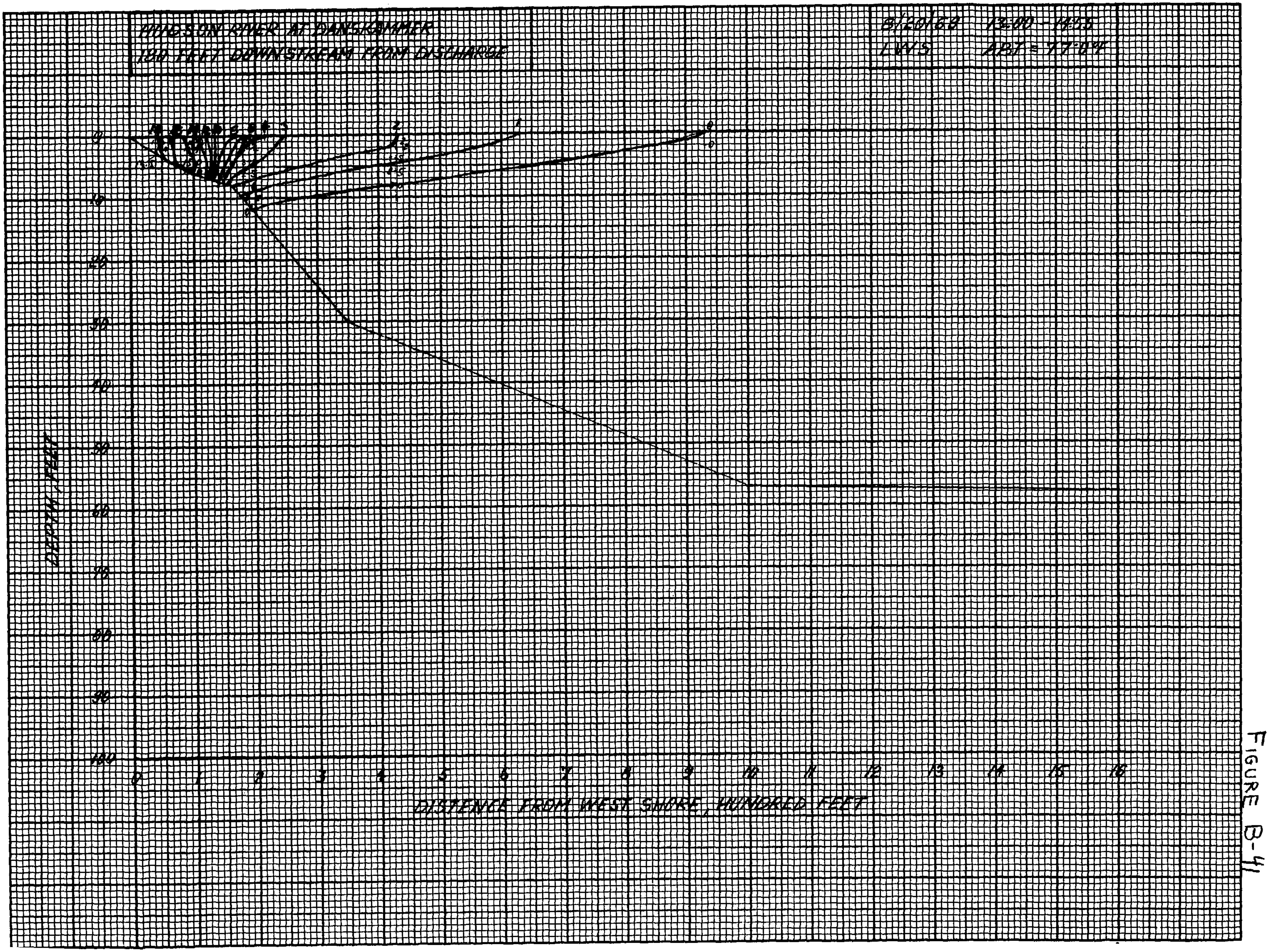
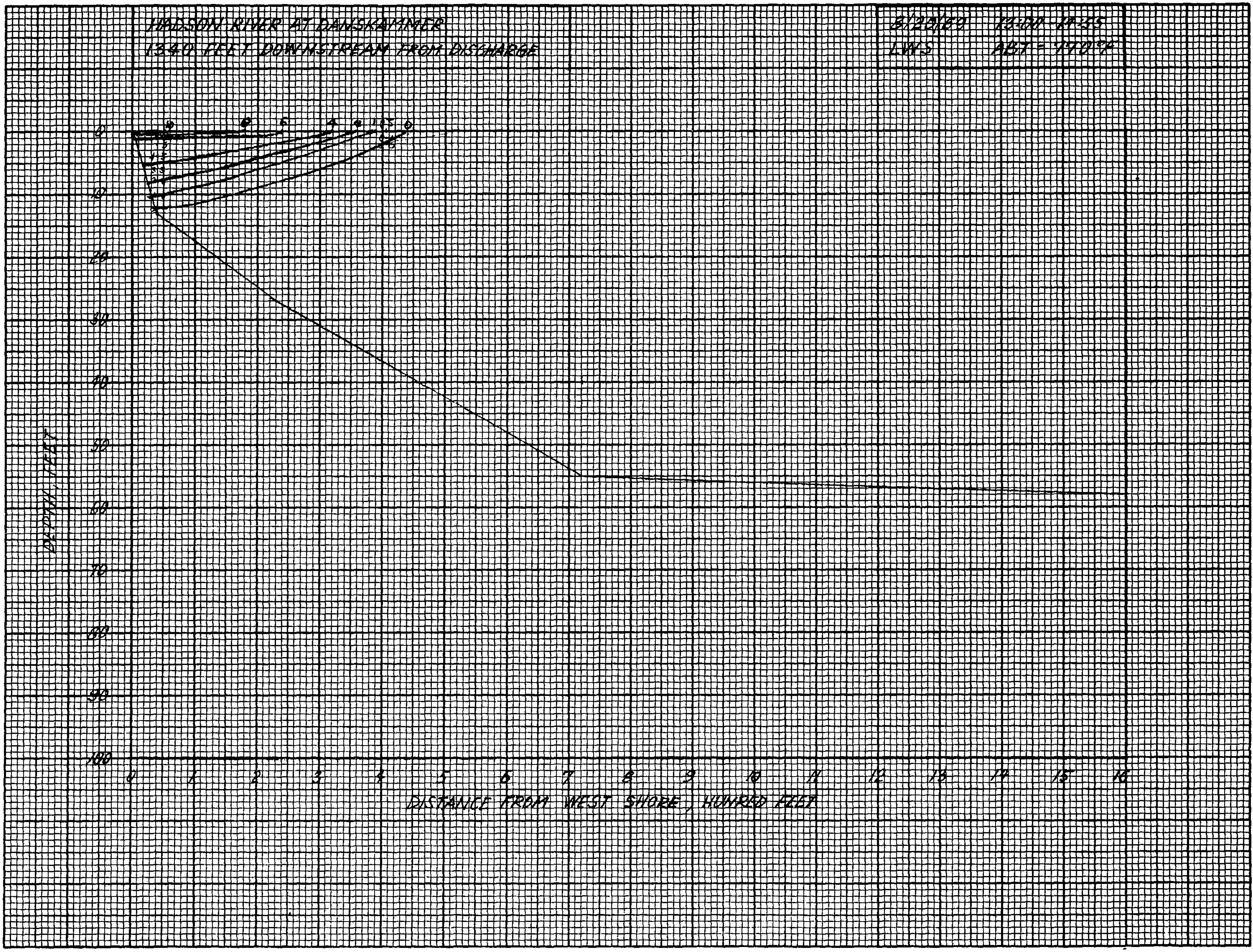

HUDSON RIVER AT DANSKAMMER
180 FEET DOWNSTREAM FROM DISCHARGE
8/20/68 13:00 - 14:55
LWS ABT = 77.0°F
DEPTH, FEET
0
10
20
30
40
50
60
70
80
90
100
DISTENCE FROM WEST SHORE, HUNDRED FEET
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

FIGURE B-41

FIGURE B-42


HUDSON RIVER AT DANSKAMMER
1340 FEET DOWNSTREAM FROM DISCHARGE
8/22/73 13:00-14:35
LWS ABT = 77.0°F
DEPTH, FEET
0
10
20
30
40
50
60
70
80
90
100
DISTANCE FROM WEST SHORE, HUNDRED FEET
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
10
8
6
4
2
1.5
0

HUDSON RIVER AT DANSKAMMER
180 FEET DOWNSTREAM FROM DISCHARGE

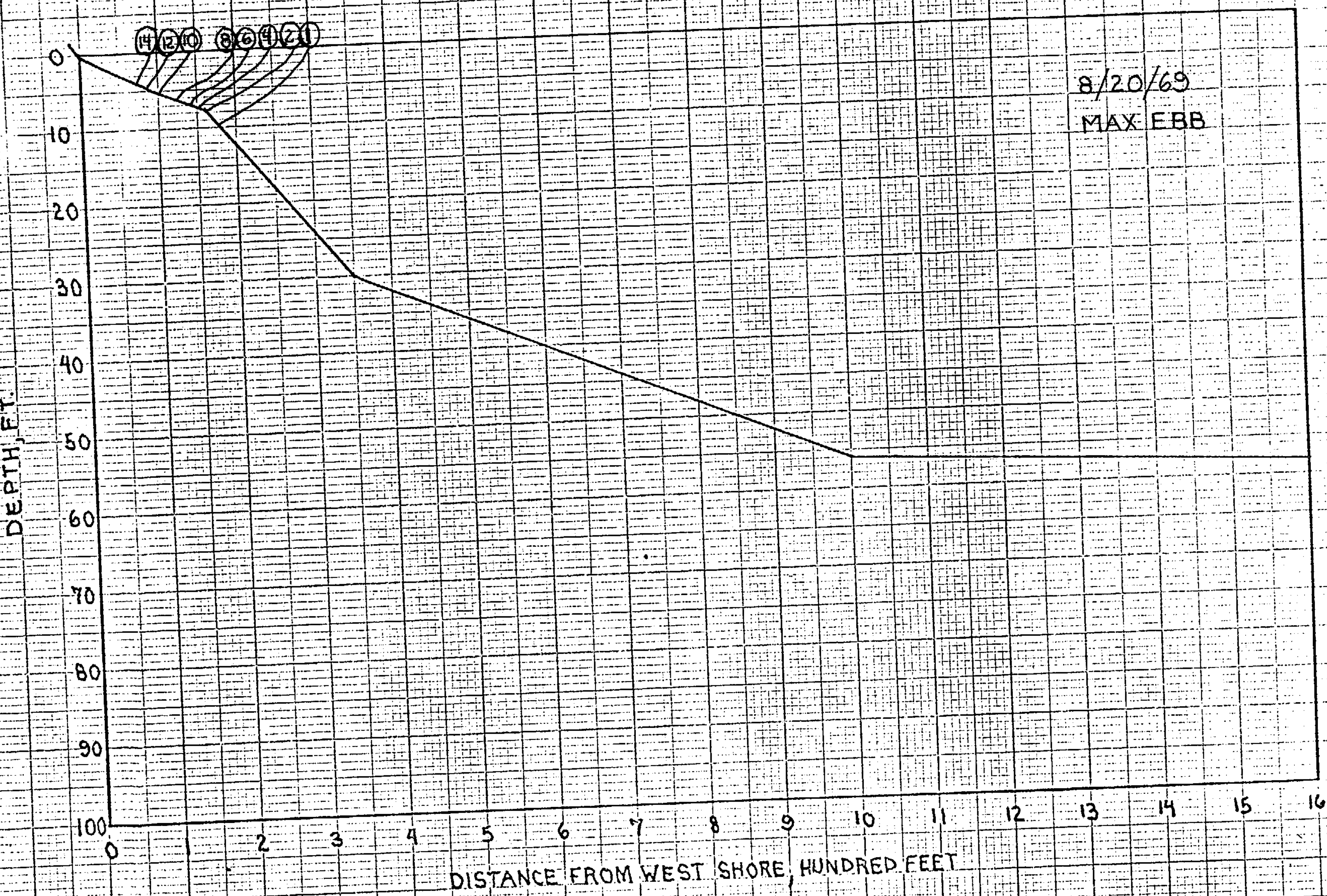


FIGURE B-34

HUDSON RIVER AT DANSKAMMER
2100 FT. DOWNSTREAM FROM DISCHARGE

FIGURE B-44

HUDSON RIVER AT DANSKAMMER
3000 FT DOWNSTREAM FROM DISCHARGE

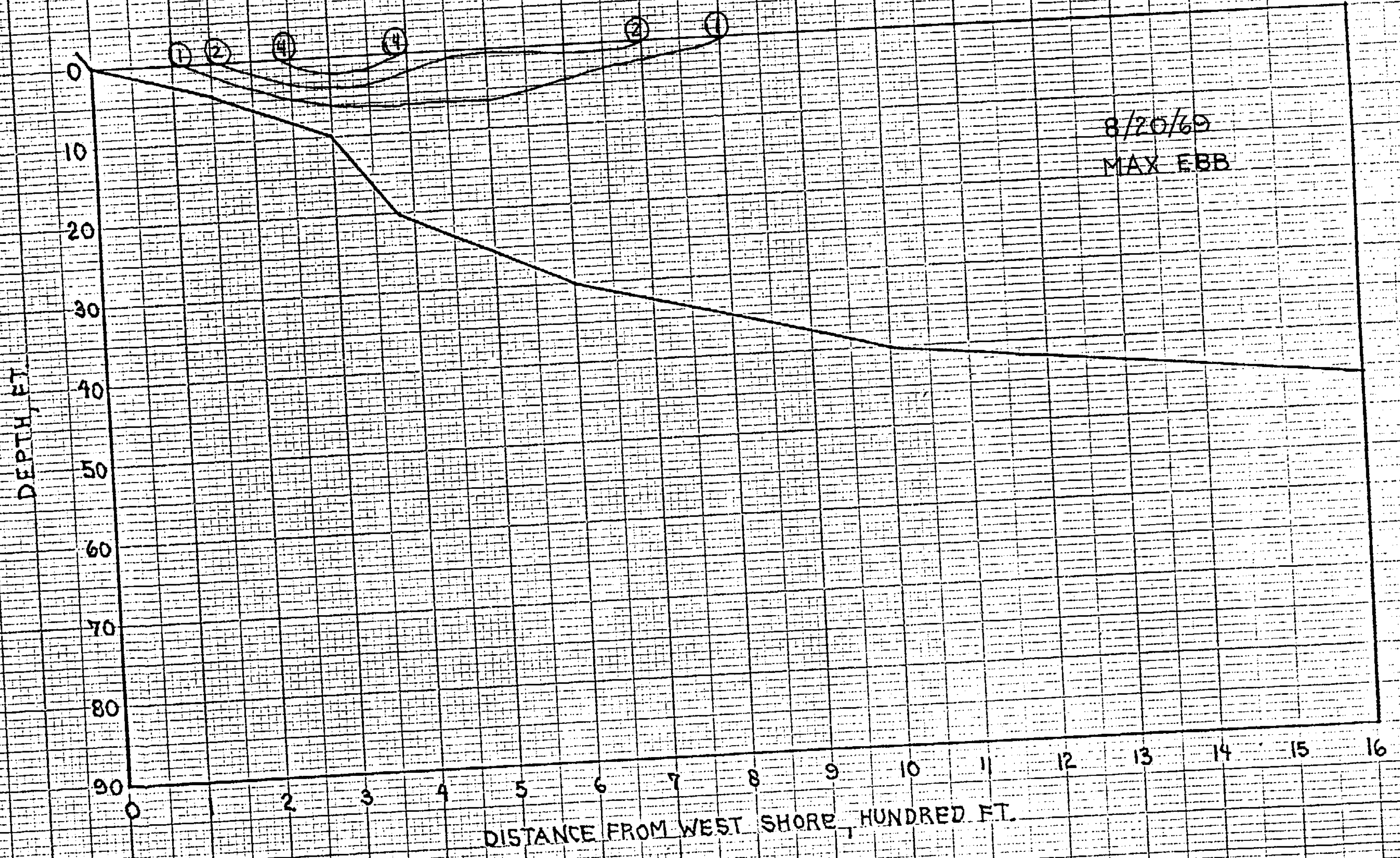


FIGURE B-45

TABLE A6

PORTION OF HUDSON RIVER AT DANSKAMMER SUBJECTED TO TEMPERATURE RISE OF 4°F OR GREATER

DATE: September 10, 1969

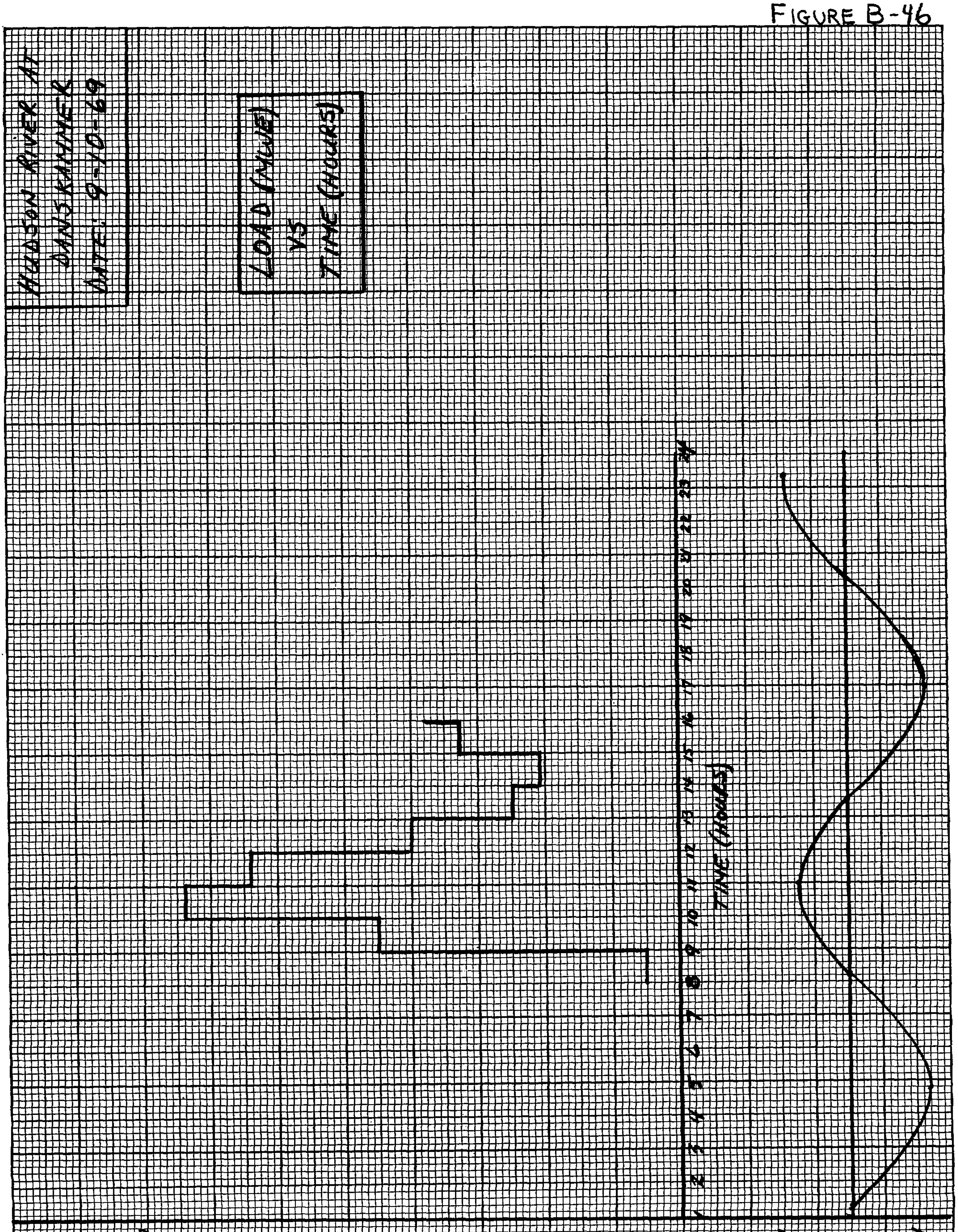
Total river cross sectional area at critical section - 142,000 ft.^{2}

Total river surface width at critical section* - 3,420 ft.

TIDAL CONDITION	ELECTRICAL OUTPUT (MWE)	% WIDTH	% CROSS-SECTIONAL AREA	SURFACE AREA (ACRES)	LONGITUDINAL EXTENT
High Water Slack	393	10.5	1.49	27.8	3280
Maximum Flood	434	11.1	0.97	9.95	1330
Maximum Ebb	408	9.1	0.76	26.1	4080

*Critical section 390 ft. south of discharge.

FIGURE B-46


HUDSON RIVER AT
DANSKAMMER
DATE: 9-10-69
LOAD (MWE)
VS
TIME (HOURS)
LOAD
(MWE)
450
440
430
420
410
400
390
380
370
TIME (HOURS)
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
+1
-1
TIDAL
VELOCITY
(KNOTS)

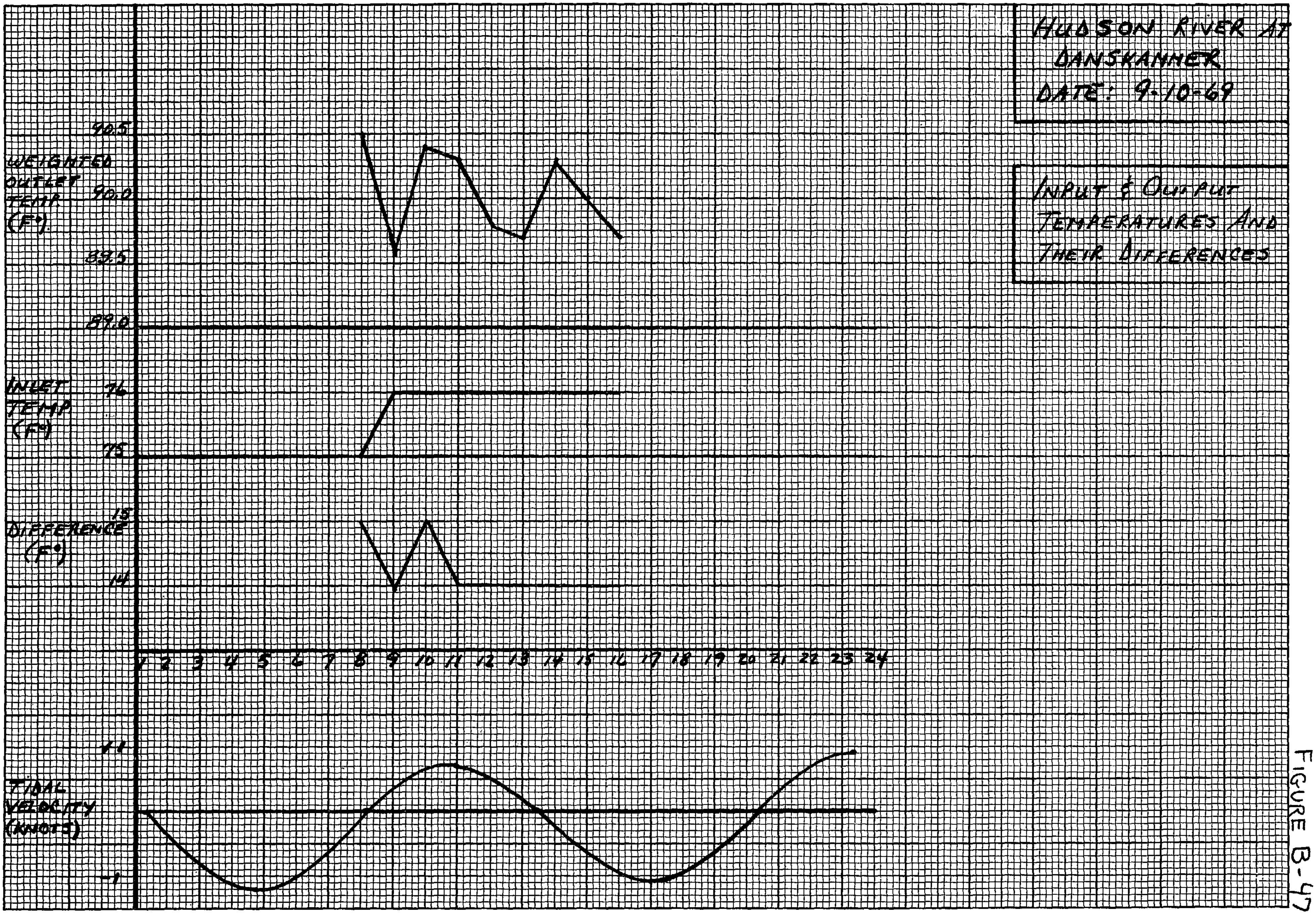

HUDSON RIVER AT
DANSKAMMER
DATE: 9-10-69
INPUT & OUTPUT
TEMPERATURES AND
THEIR DIFFERENCES
WEIGHTED
OUTLET
TEMP
(F°).
90.5
90.0
89.5
89.0
INLET
TEMP
(F°)
76
75
DIFFERENCE
(F°)
15
14
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
TIDAL
VELOCITY
(KNOTS)
+1
-1

FIGURE B-47

LARGE DOCUMENT

LARGE DOCUMENT

LARGE DOCUMENT

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)

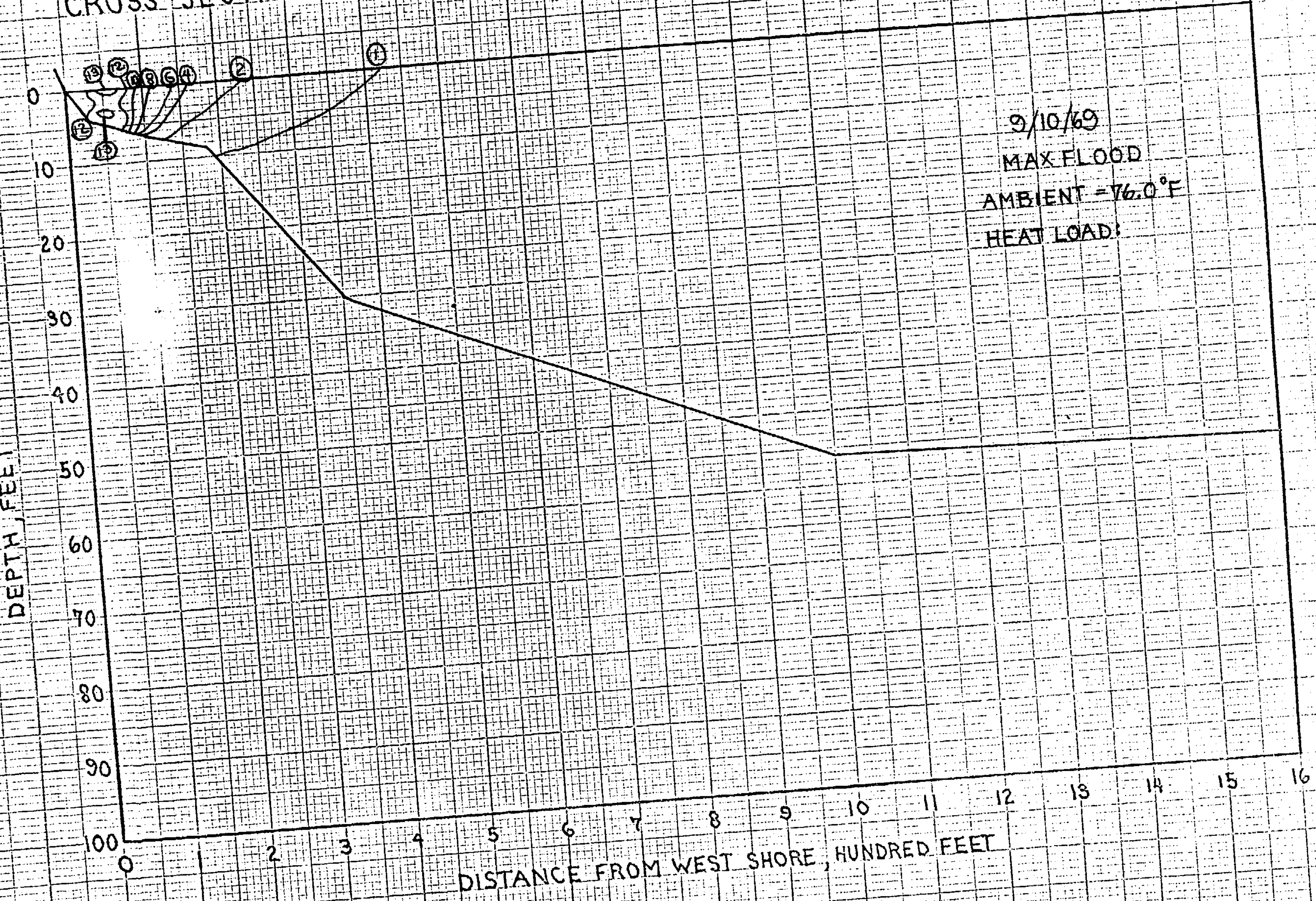
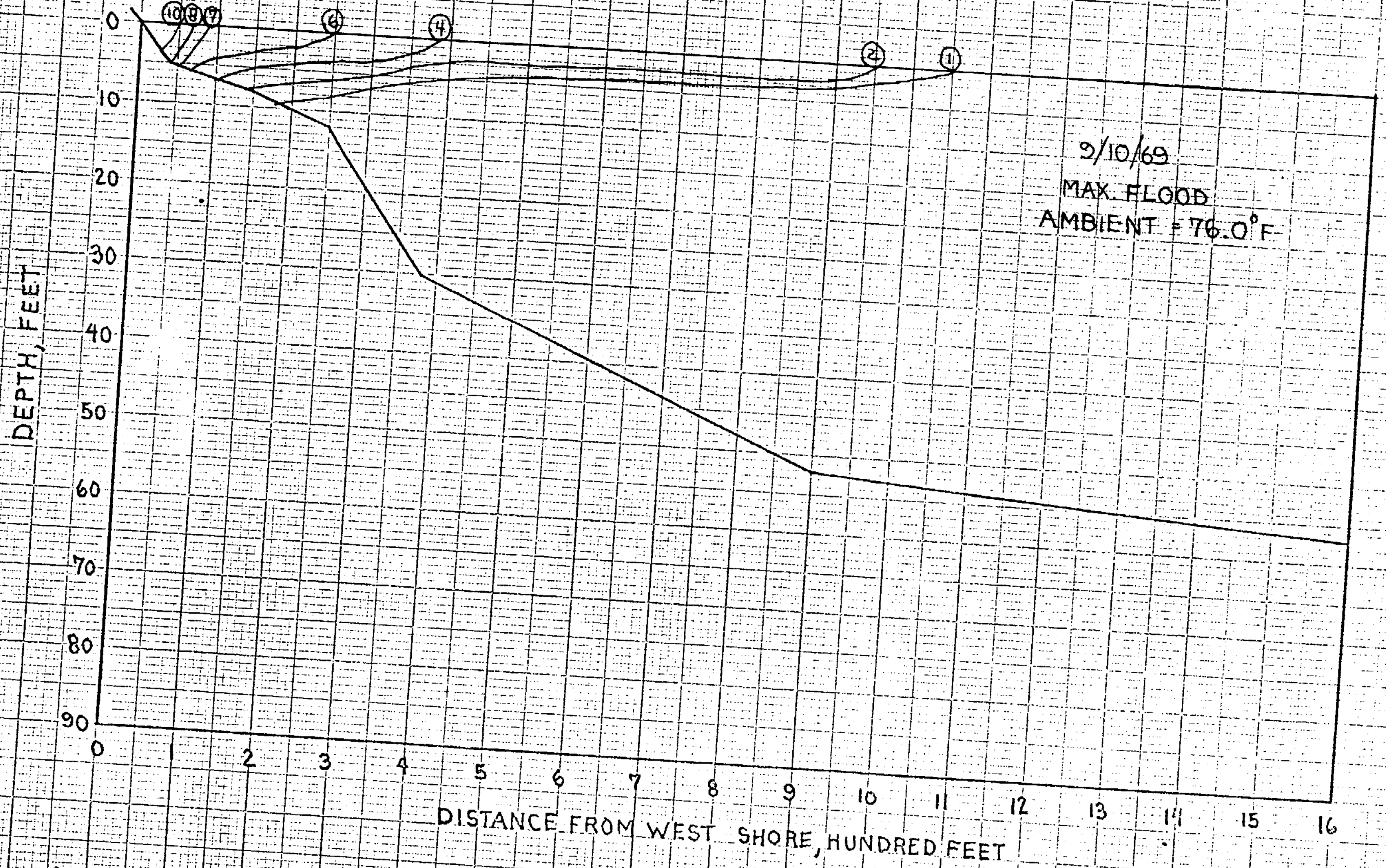


FIGURE B-51

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)



9/10/69
MAX. FLOOD
AMBIENT = 76.0°F

FIGURE B-52

HUDSON RIVER AT DANSKAMMER
800 FT. DOWNSTREAM FROM DISCHARGE (S-S-3)

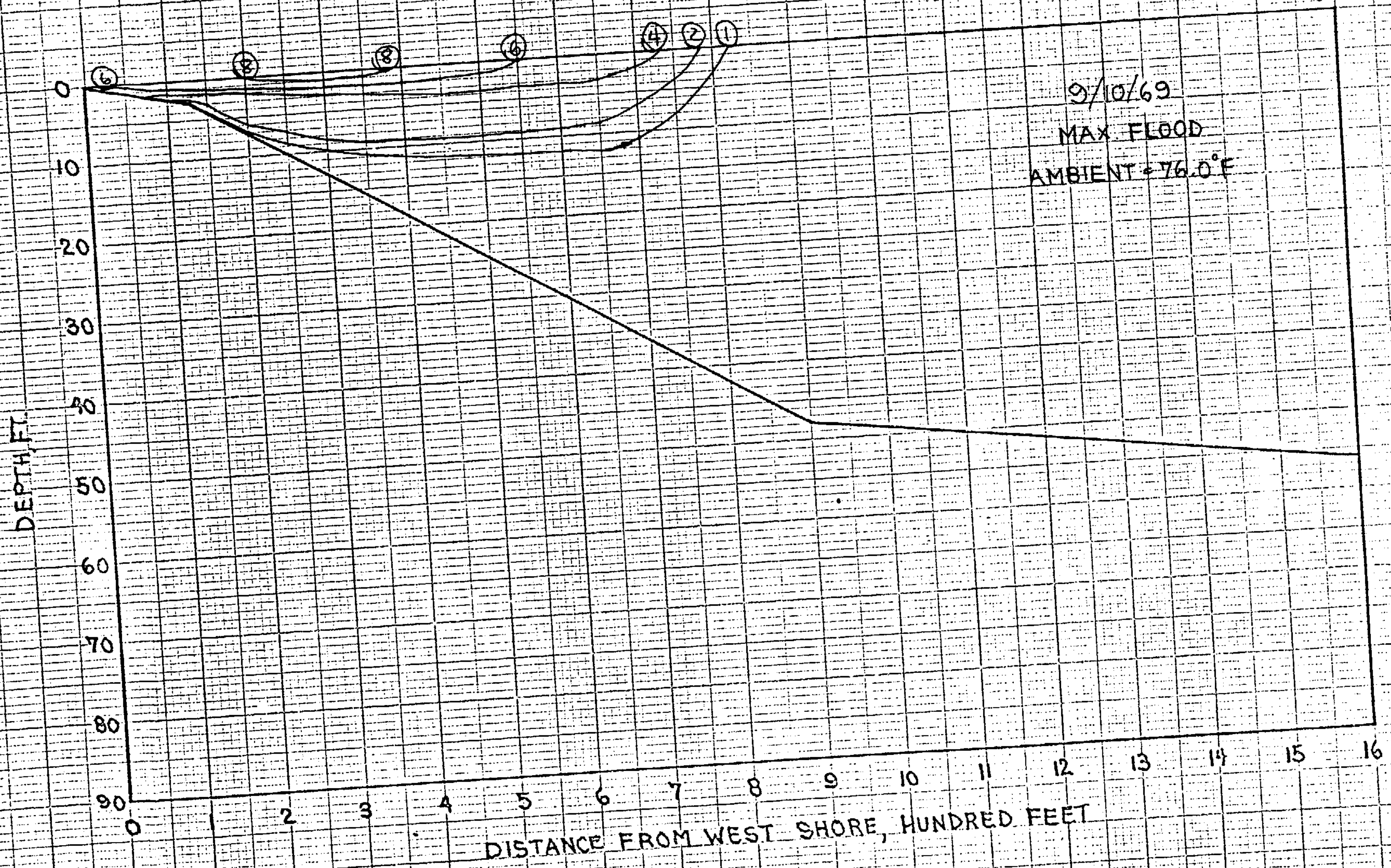


FIGURE B-53

HUDSON RIVER AT DANSKAMMER
1300 FT. DOWNSTREAM FROM DISCHARGE (I-I)

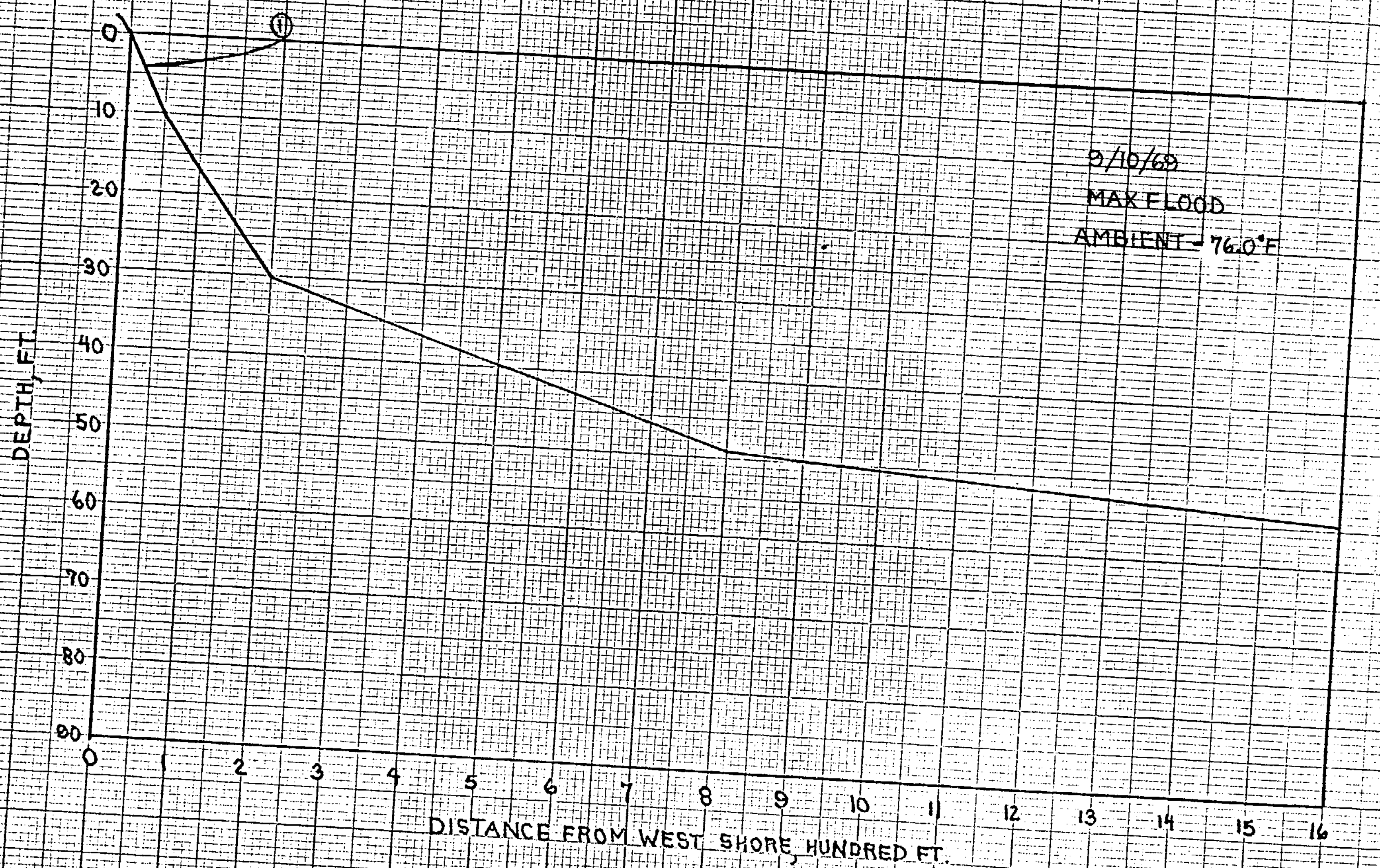
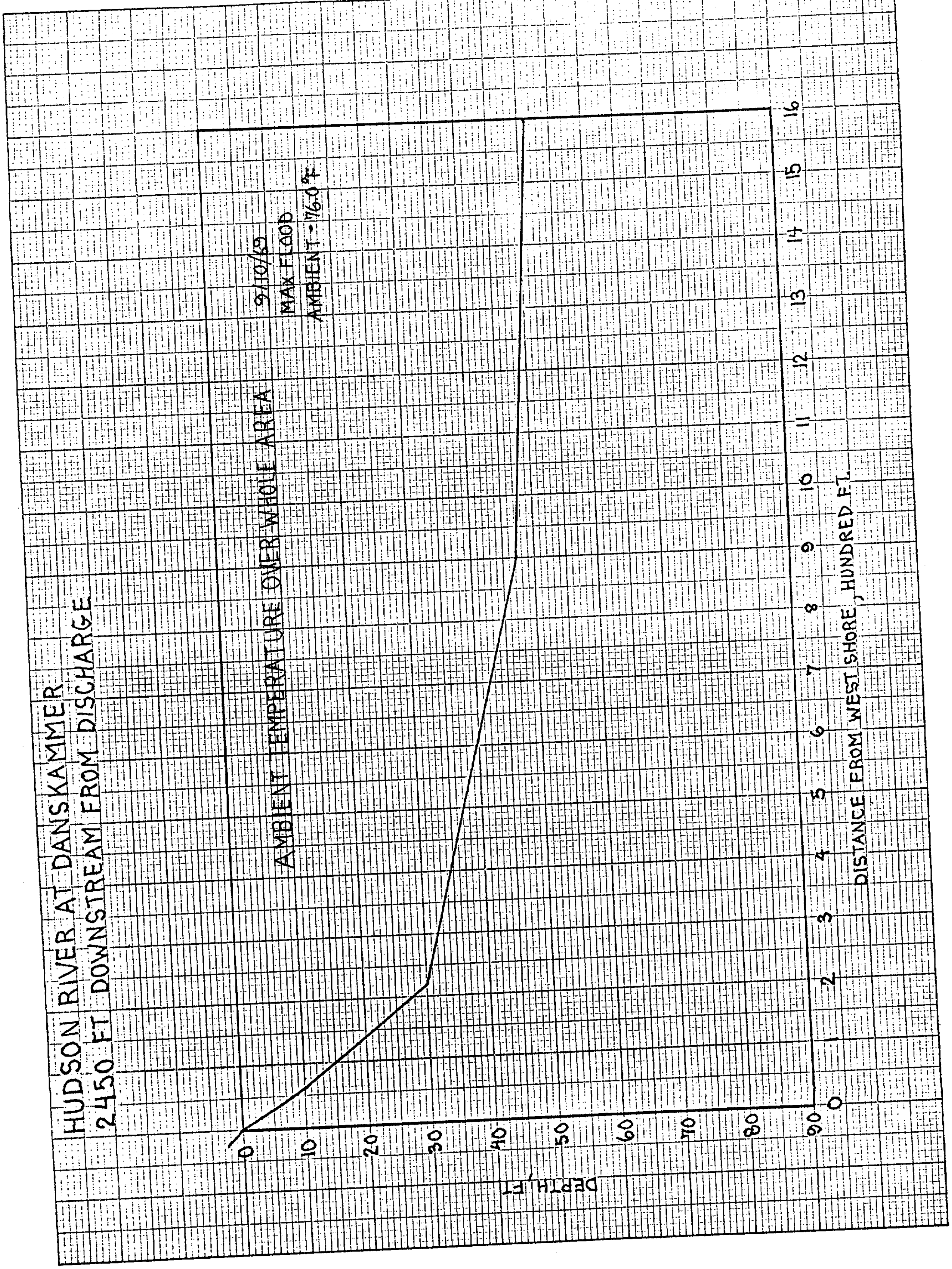


FIGURE B-54

FIGURE B-55



HUDSON RIVER AT DANSKAMMER
2450 FT DOWNSTREAM FROM DISCHARGE

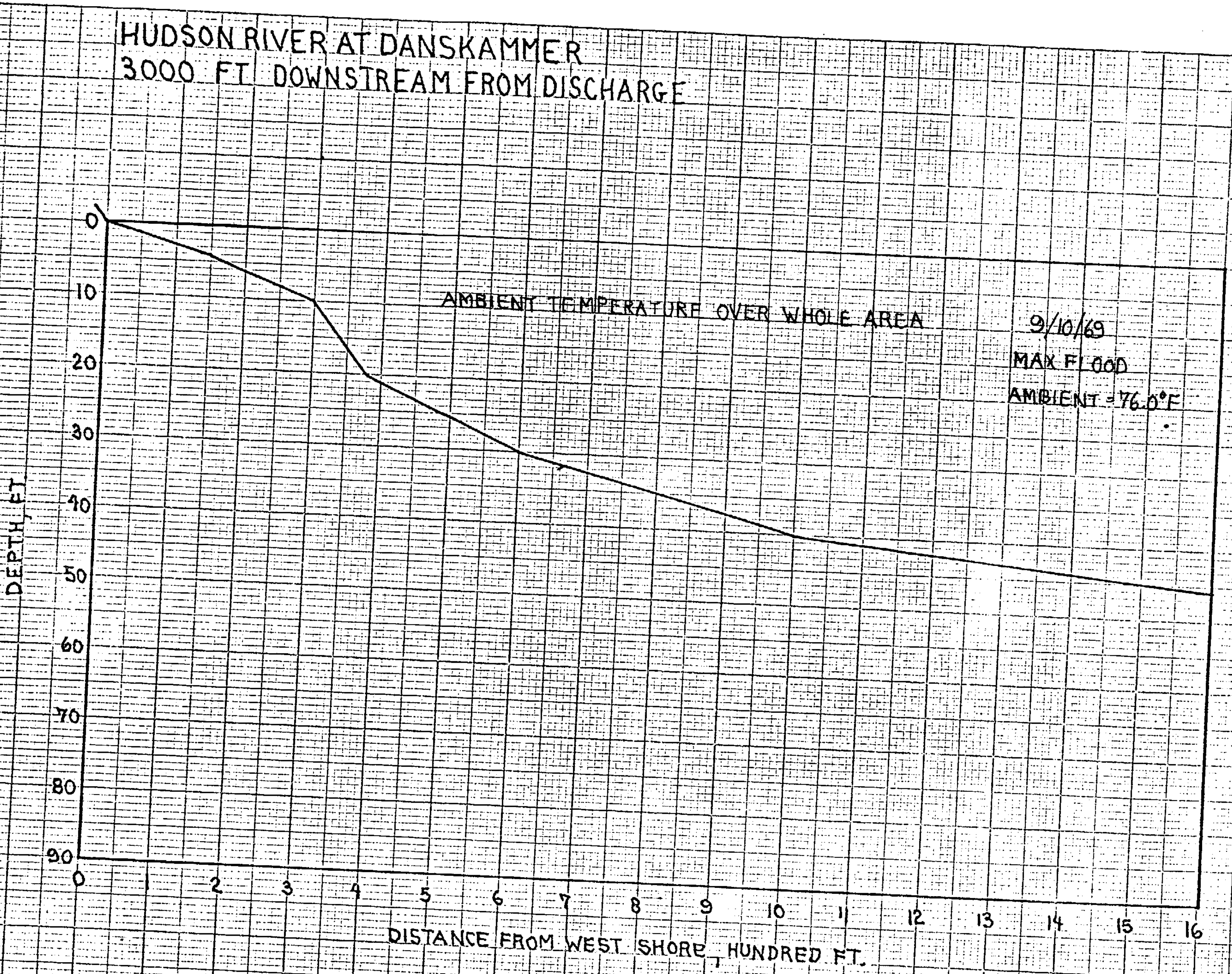

HUDSON RIVER AT DANSKAMMER
3000 FT. DOWNSTREAM FROM DISCHARGE
AMBIENT TEMPERATURE OVER WHOLE AREA
9/10/69
MAX FLOOD
AMBIENT = 76.0°F
DEPTH, FT.
0
10
20
30
40
50
60
70
80
90
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
DISTANCE FROM WEST SHORE, HUNDRED FT.

FIGURE B-56

FIGURE B-57

HUDSON RIVER AT DANSKAMMER
4050 FT DOWNSTREAM FROM DISCHARGE

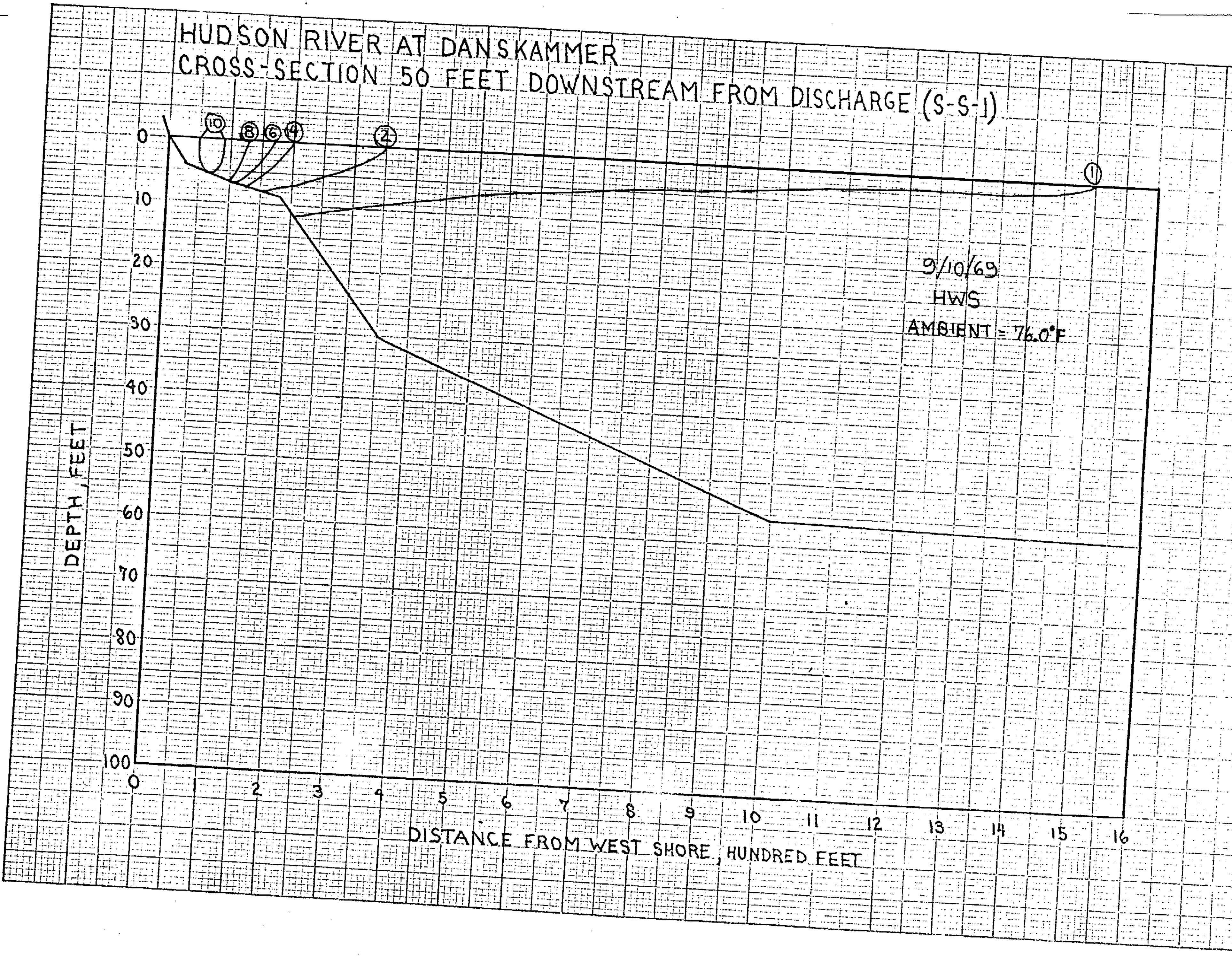
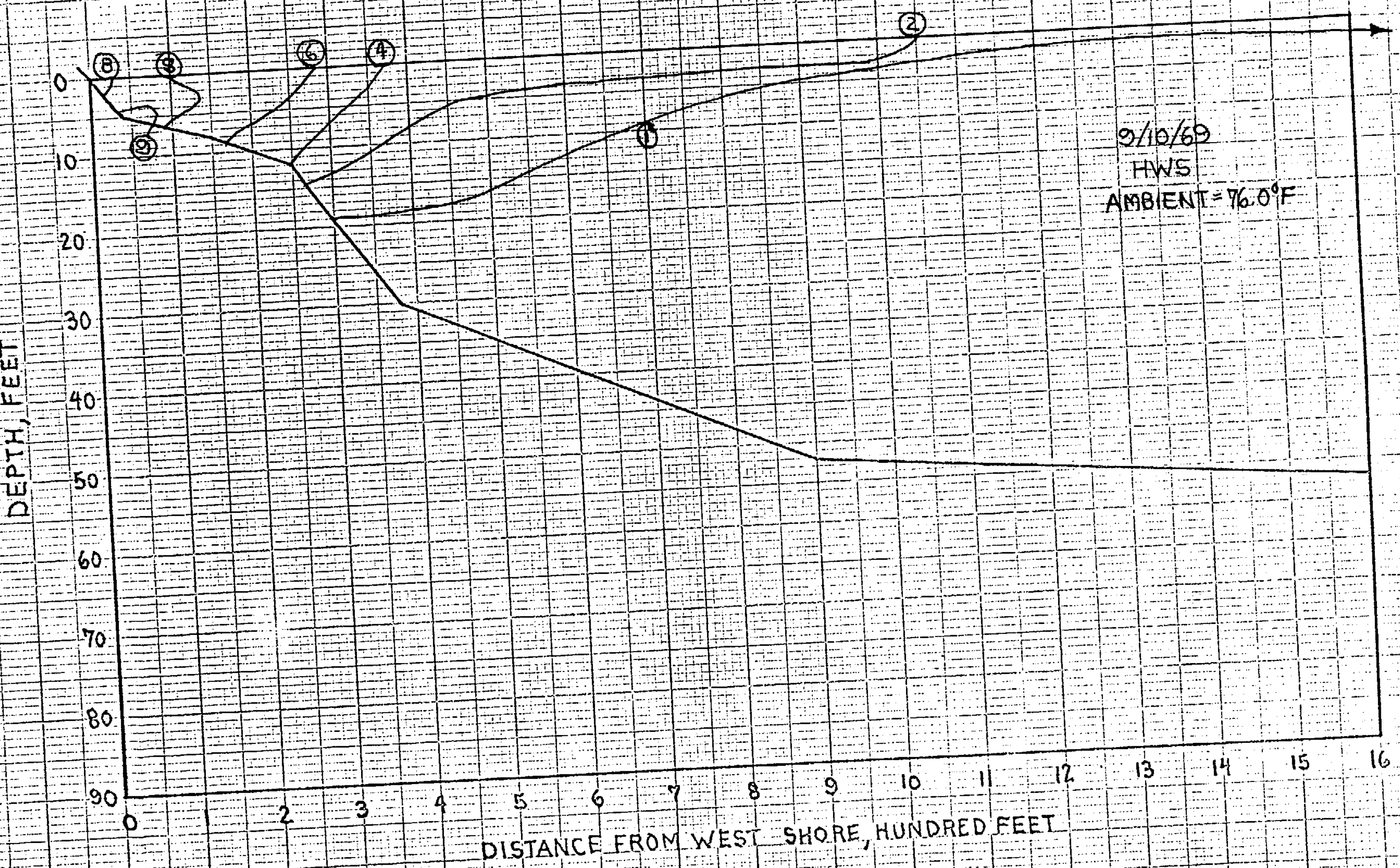

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)
⑩
⑧
⑥
④
②
①
9/10/69
HWS
AMBIENT = 76.0°F
DEPTH, FEET
0
10
20
30
40
50
60
70
80
90
100
0
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
DISTANCE FROM WEST SHORE, HUNDRED FEET

FIGURE B-58

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)



9/10/69
HWS
AMBIENT = 76.0°F

FIGURE B-59.

HUDSON RIVER AT DANSKAMMER
800 FT. DOWNSTREAM FROM DISCHARGE (S-S-3)

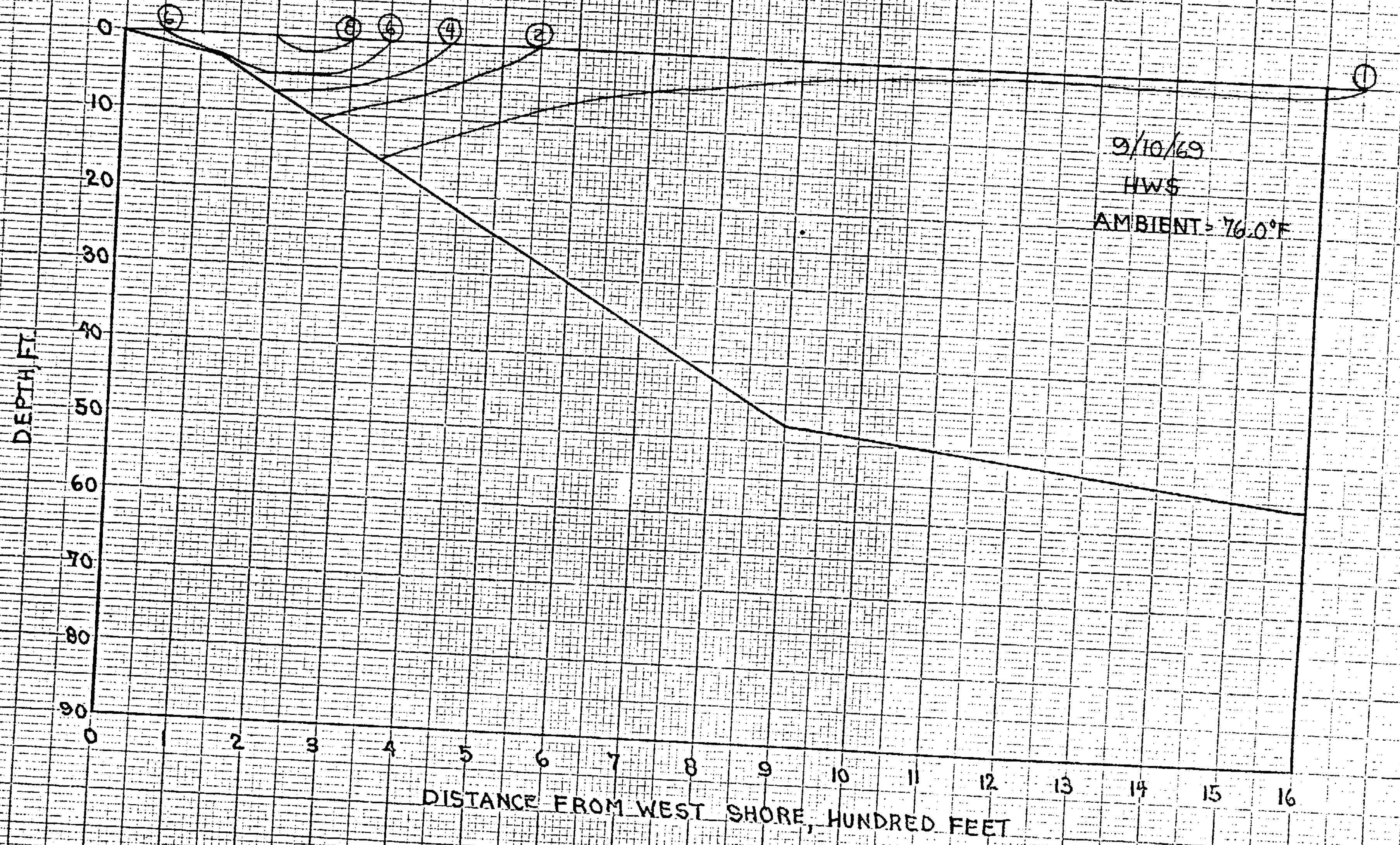
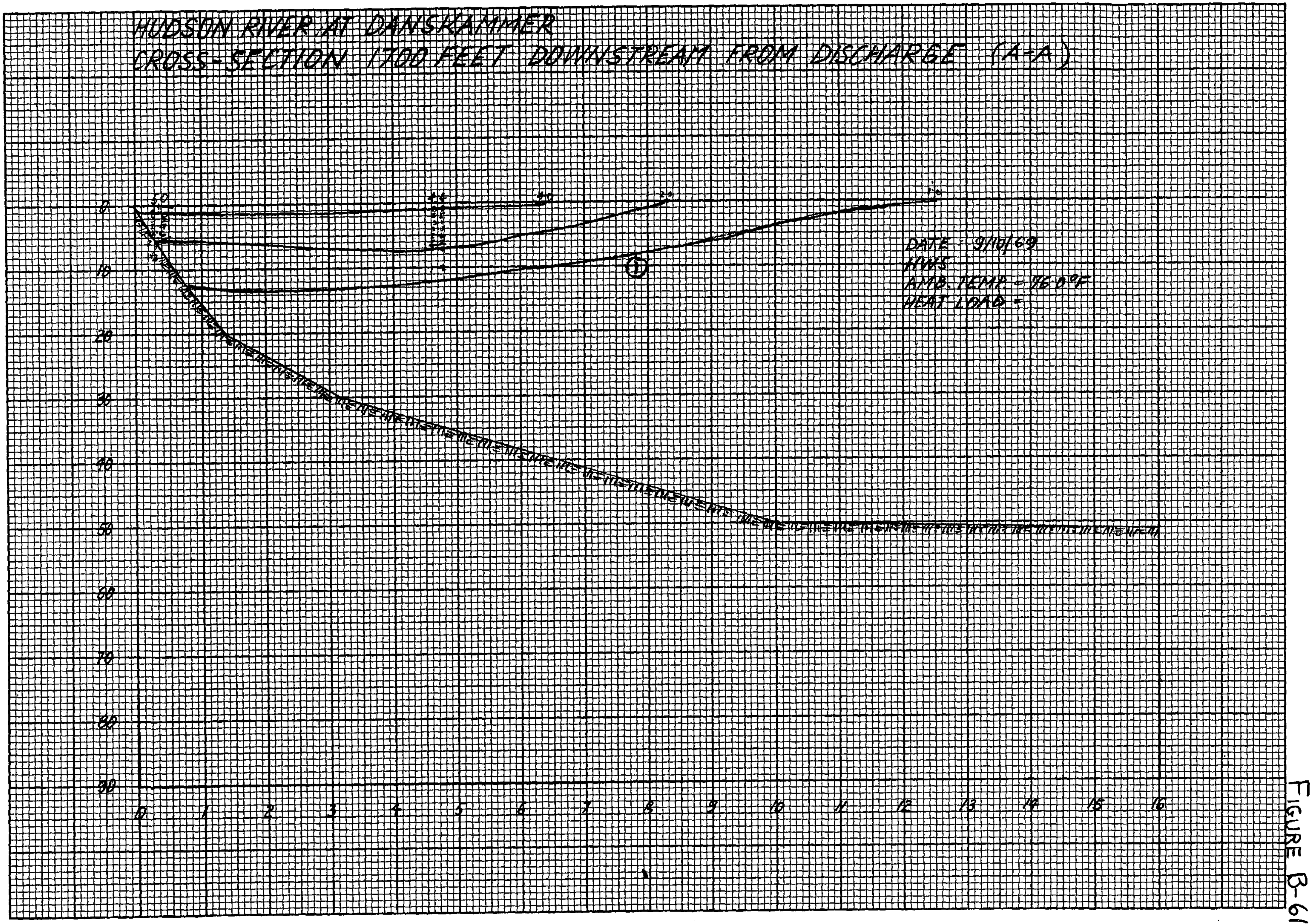


FIGURE B-60

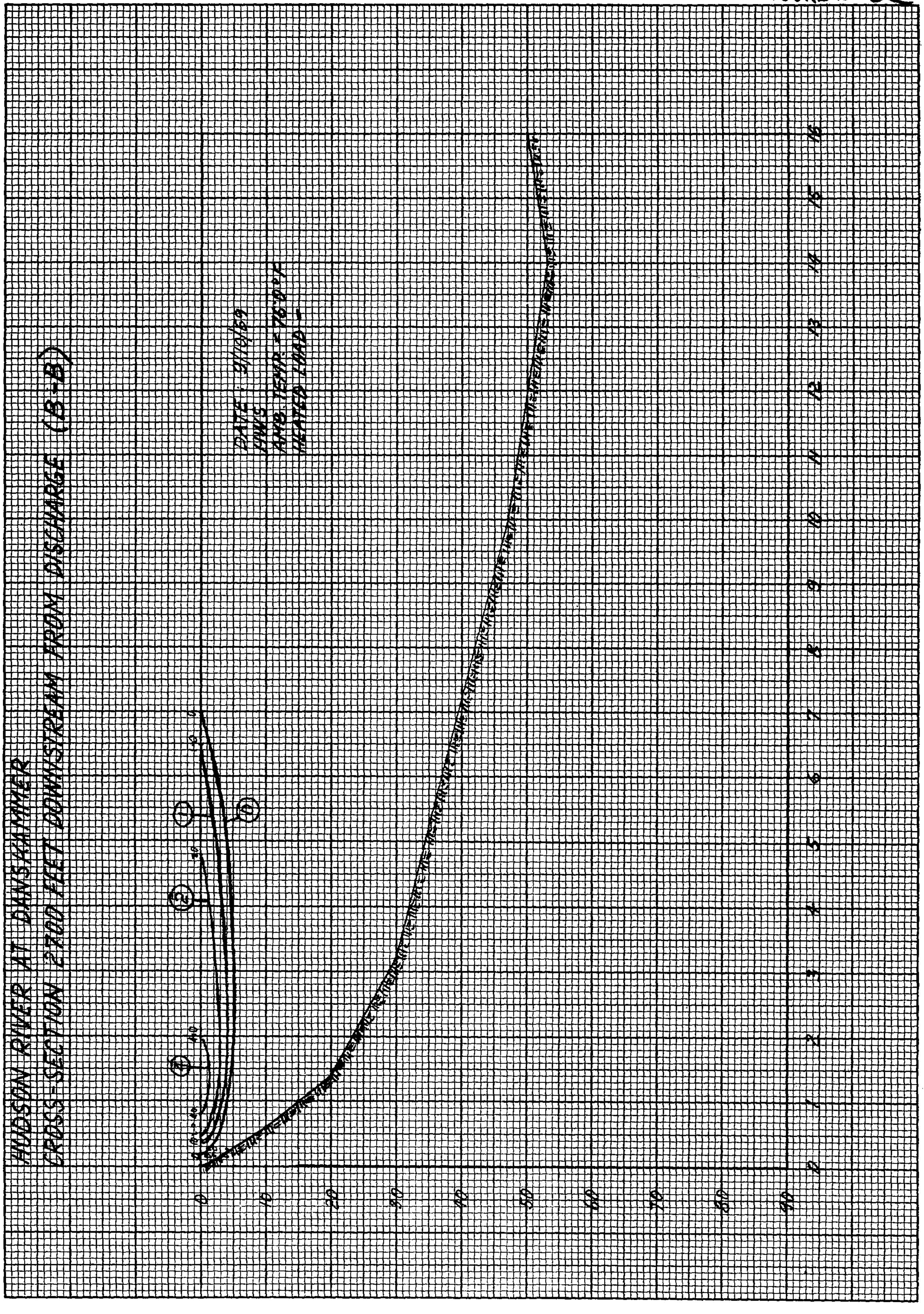
FIGURE B-61

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 1700 FEET DOWNSTREAM FROM DISCHARGE (A-A)



DATE : 9/10/69
HWS
AMB. TEMP. = 76.0°F
HEAT LOAD =

FIGURE B-62

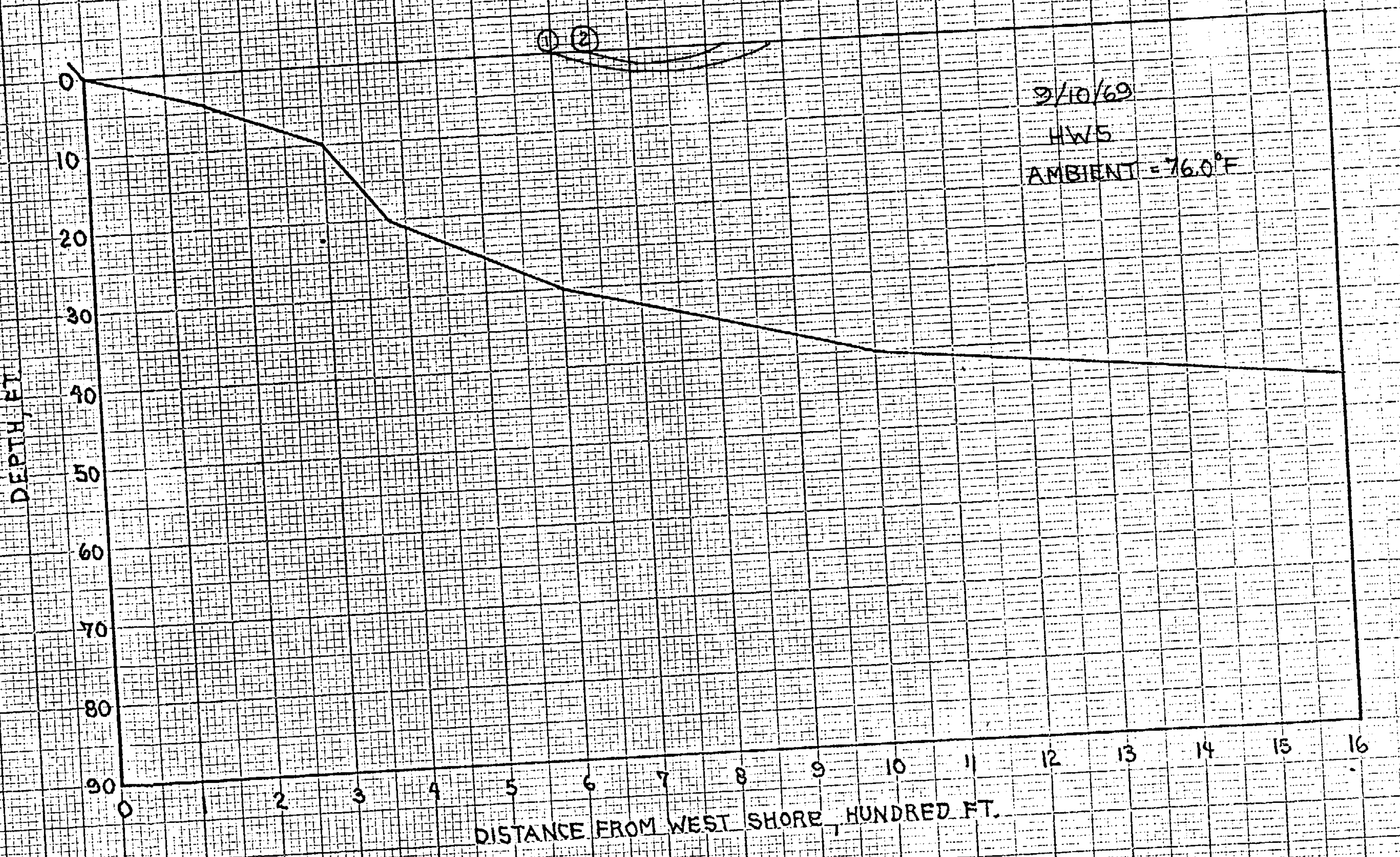


HUDSON RIVER AT DANSKAMMER

CROSS-SECTION 2700 FEET DOWNSTREAM FROM DISCHARGE (B-B)

DATE: 9/10/69
HWS
AMB. TEMP. = 76.0°F
HEATED LOAD –

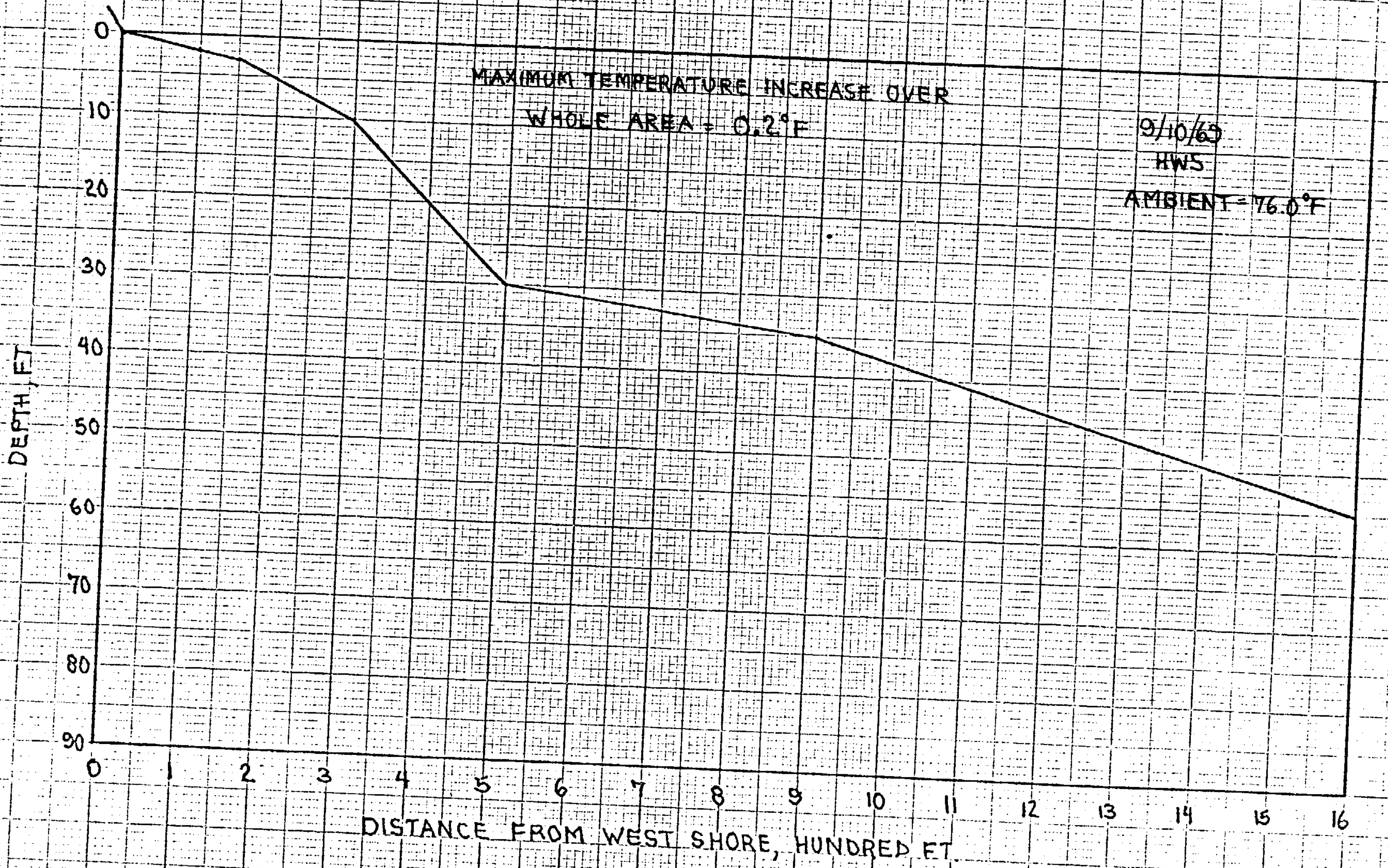
HUDSON RIVER AT DANSKAMMER
3000 FT DOWNSTREAM FROM DISCHARGE



9/10/69
HW5
AMBIENT = 76.0°F

FIGURE B-63

HUDSON RIVER AT DANSKAMMER
4050 FT DOWNSTREAM FROM DISCHARGE



MAXIMUM TEMPERATURE INCREASE OVER
WHOLE AREA = 0.2°F

9/10/69
HWS
AMBIENT = 76.0°F

FIGURE B-64

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)

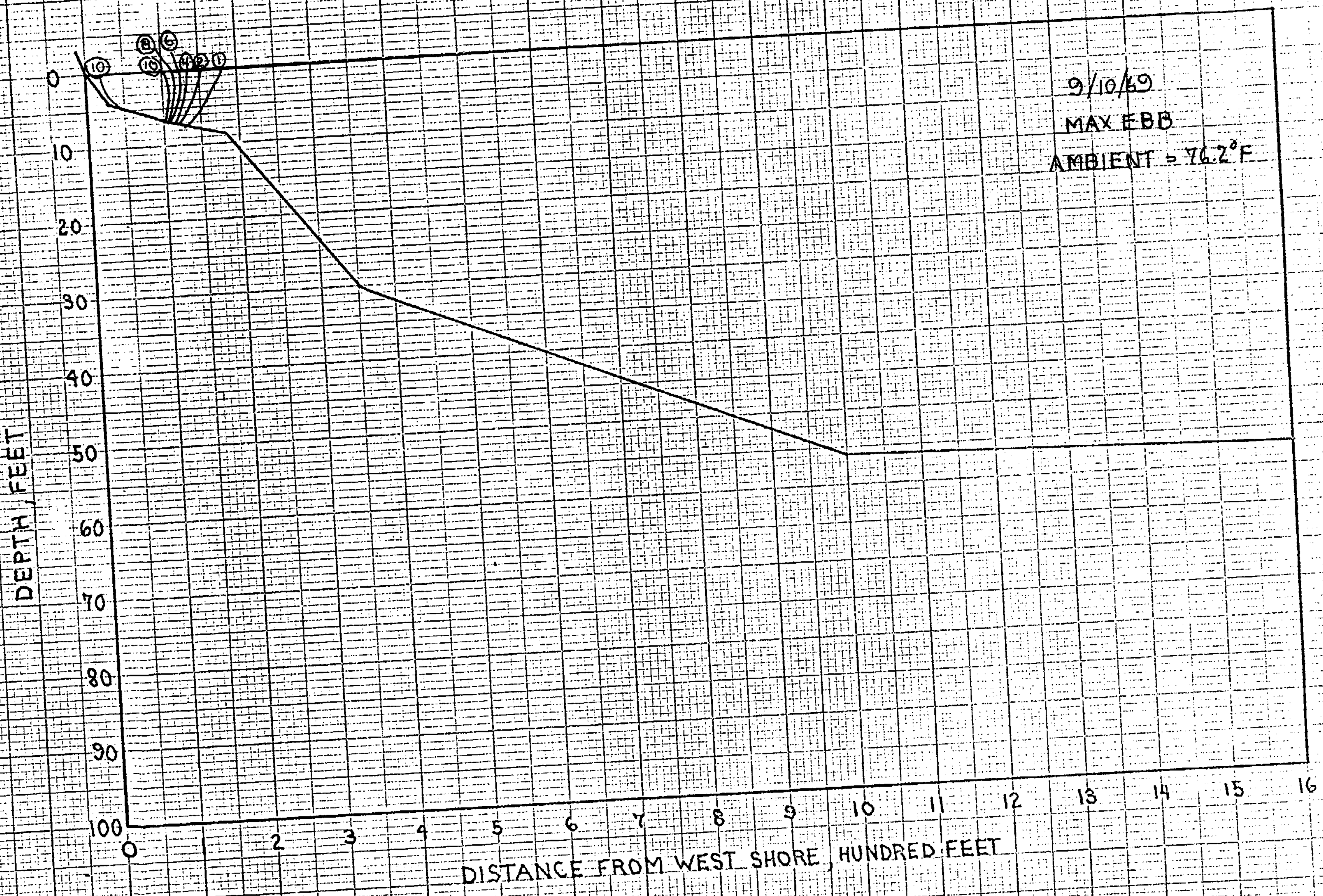


FIGURE B-65

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)

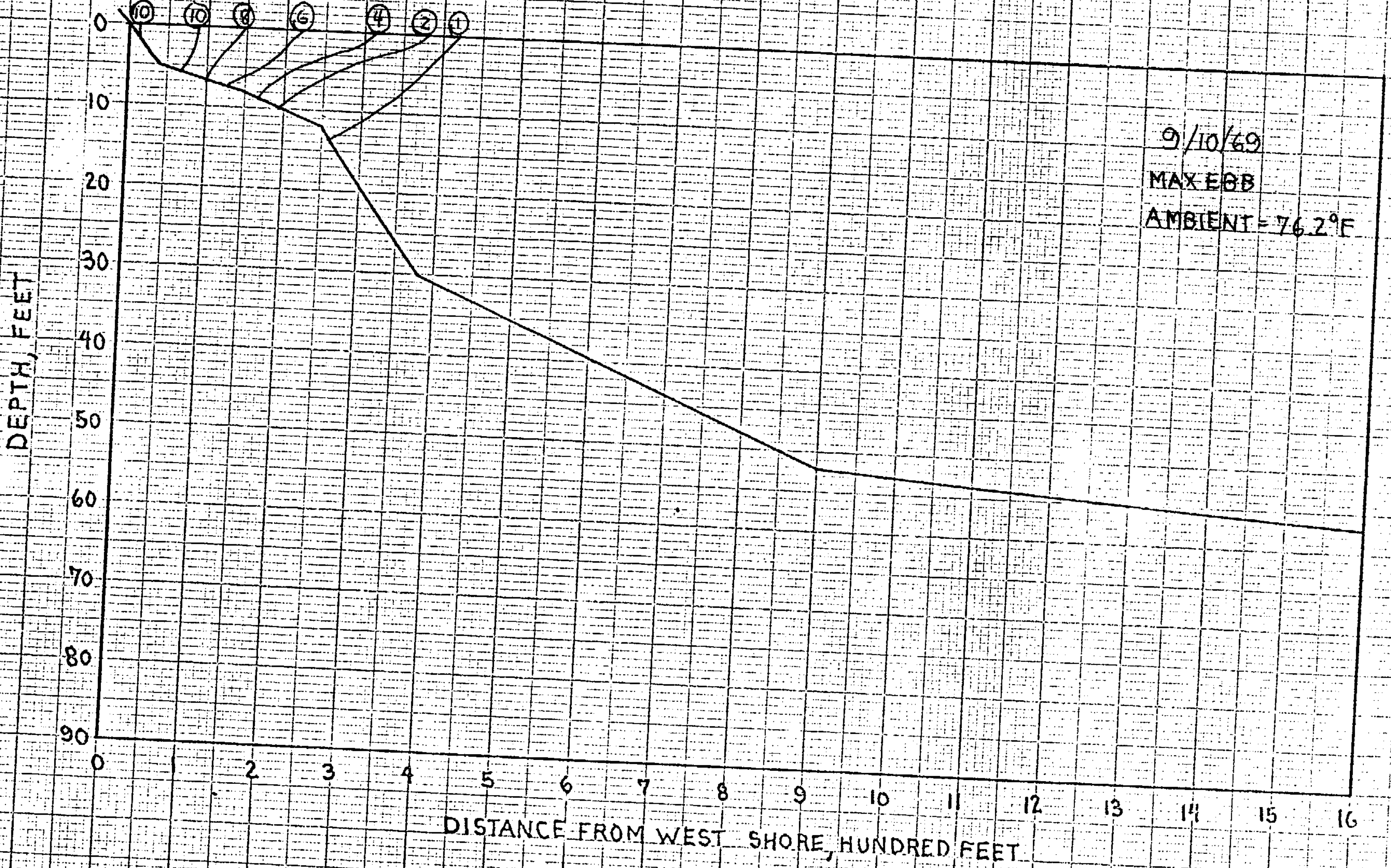


FIGURE B-66

HUDSON RIVER AT DANSKAMMER
800 FT DOWNSTREAM FROM DISCHARGE (S-S-3)

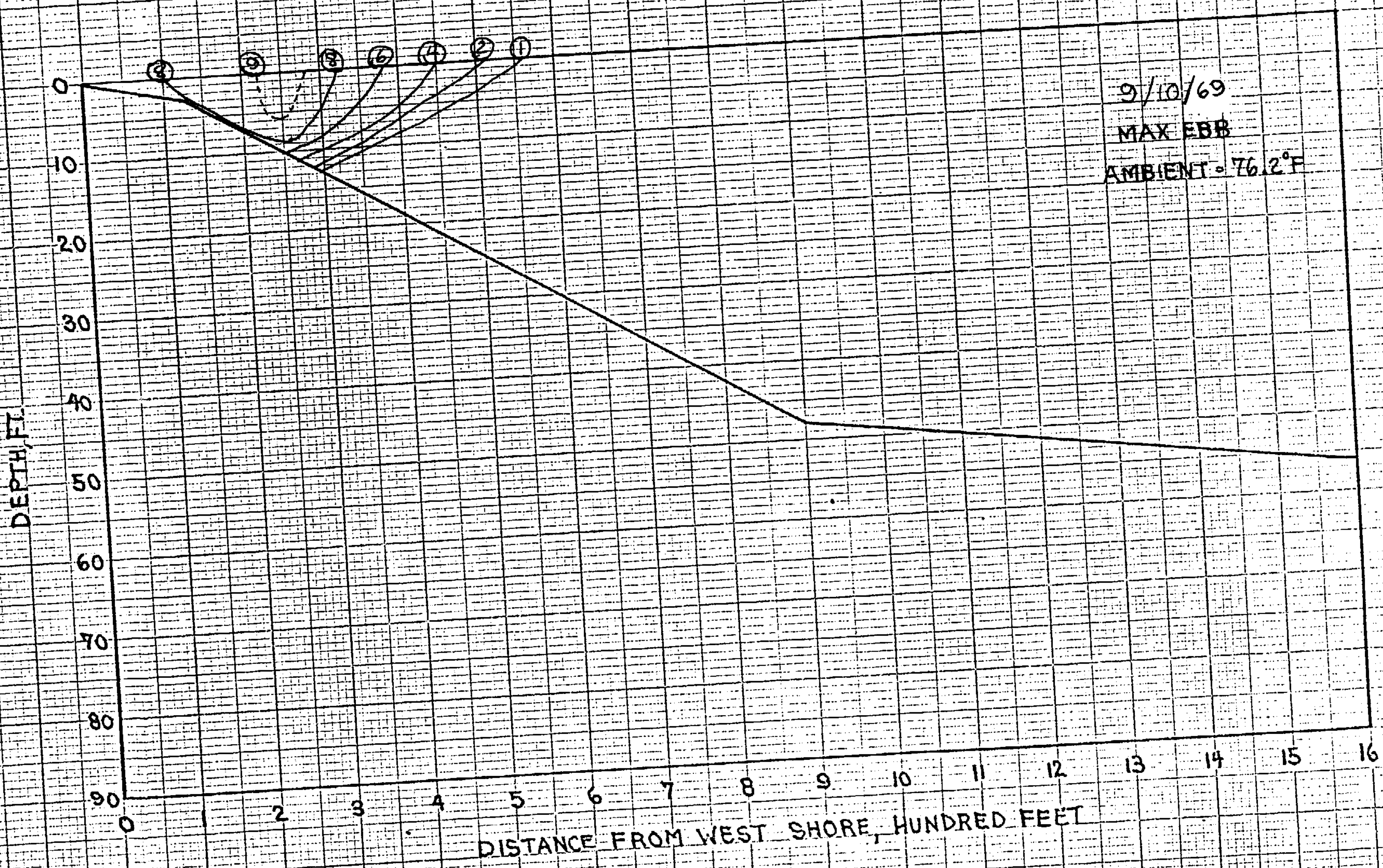
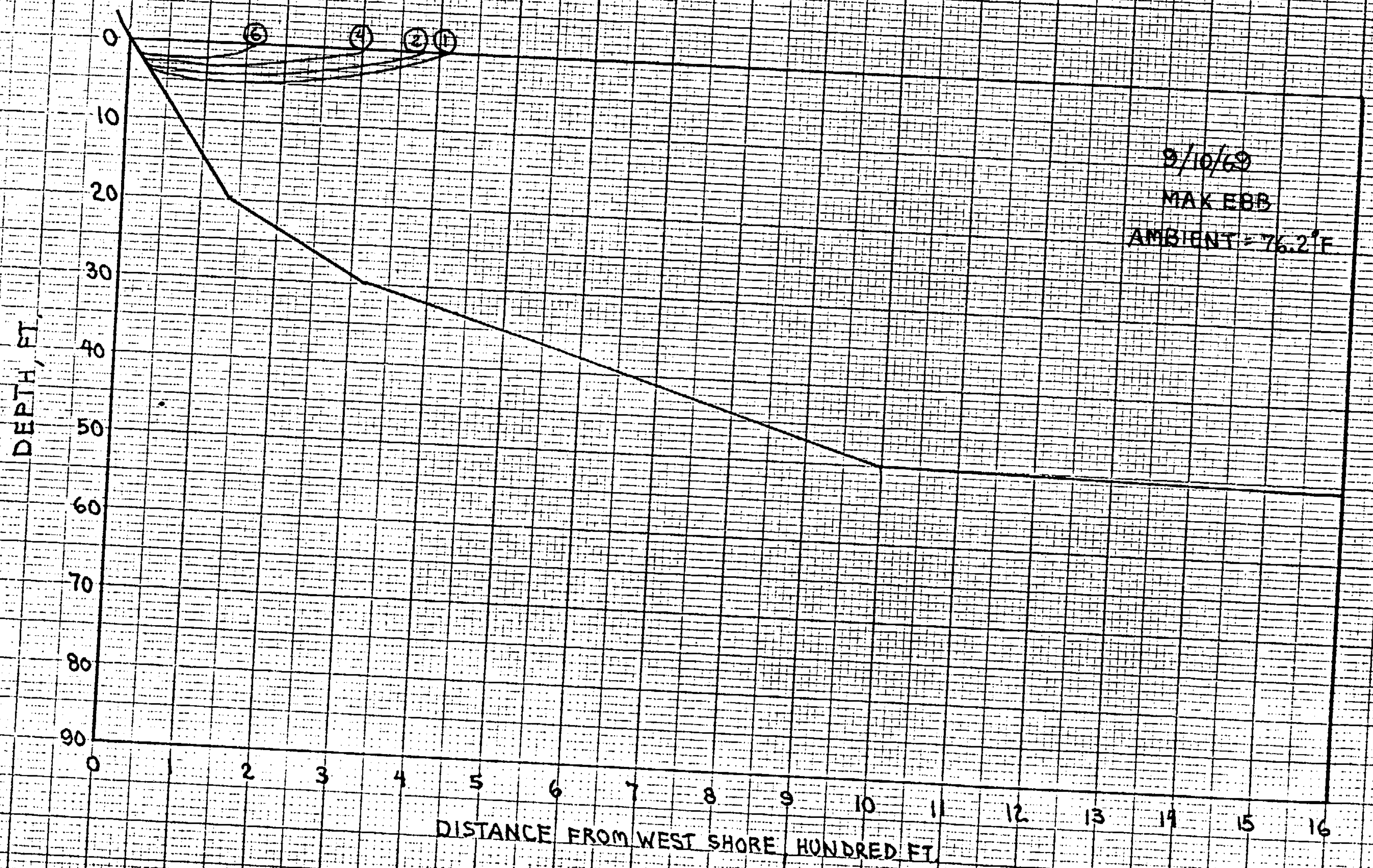


FIGURE B-67

HUDSON RIVER AT DANSKAMMER
1700 FT DOWNSTREAM FROM DISCHARGE



9/10/69
MAX EBB
AMBIENT = 76.2°F.

FIGURE B-68

HUDSON RIVER AT DANSKAMMER
2700 FT. DOWNSTREAM FROM DISCHARGE

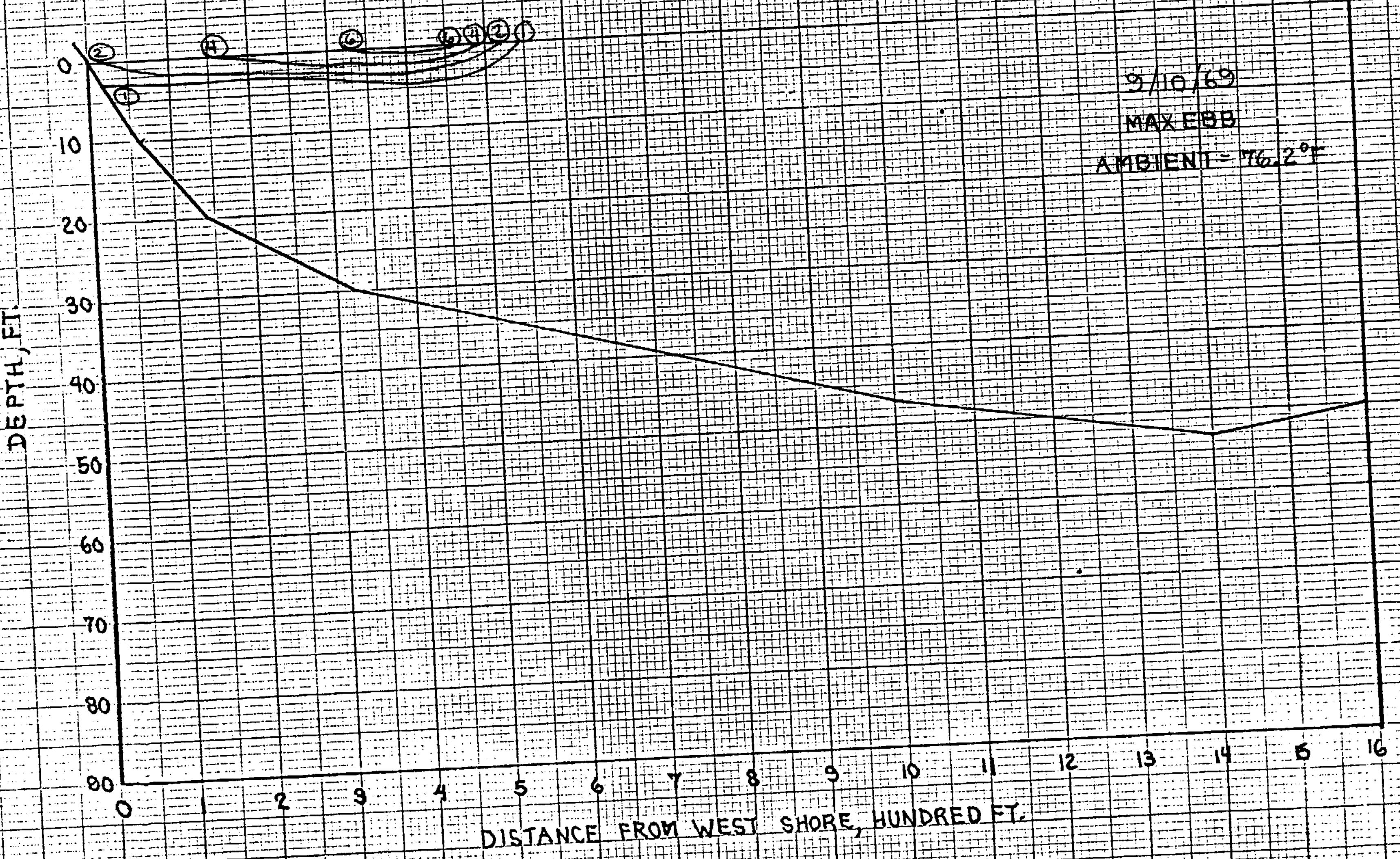


FIGURE B-69

HUDSON RIVER AT DANSKAMMER
3000 FT DOWNSTREAM FROM DISCHARGE

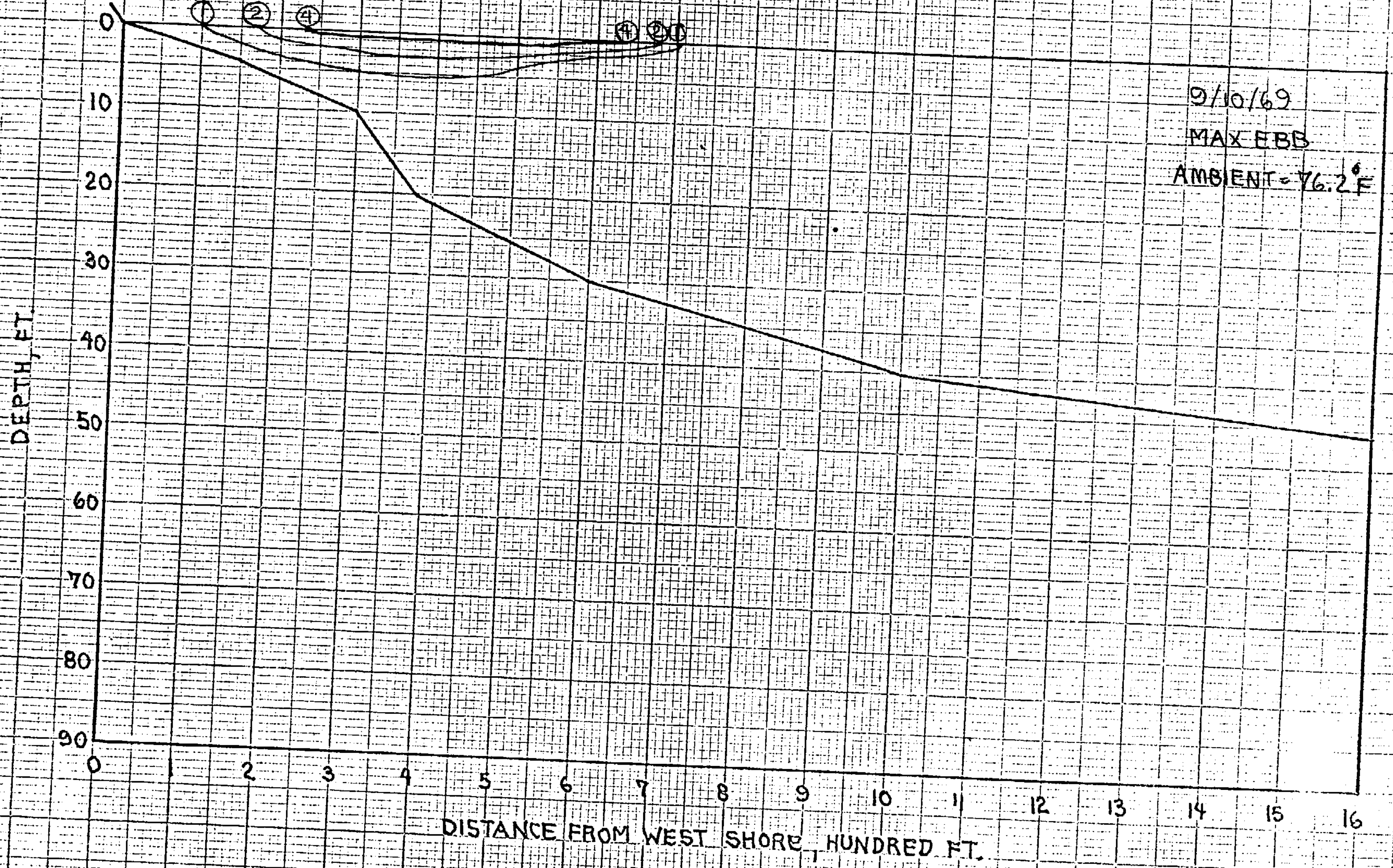


FIGURE B-70

HUDSON RIVER AT DANSKAMMER
4050 FT DOWNSTREAM FROM DISCHARGE

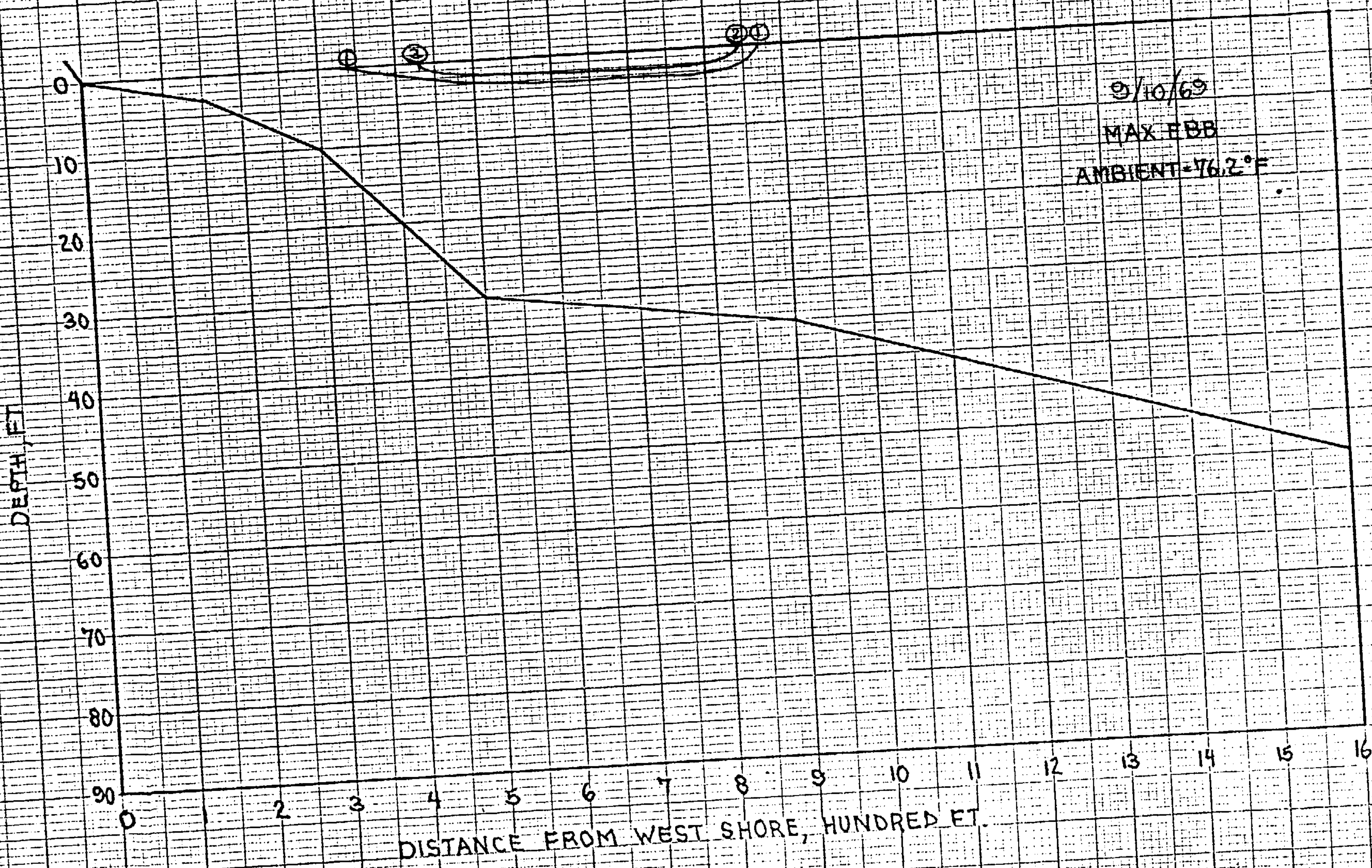


FIGURE B-71

TABLE A7

PORTION OF HUDSON RIVER AT DANSKAMMER SUBJECTED TO TEMPERATURE RISE OF 4°F OR GREATER

DATE: September 17, 1969

Total river cross sectional area at critical section	- 142,000 ft.^{2}
Total river surface width at critical section*	- 3,420 ft.

TIDAL CONDITION	ELECTRICAL OUTPUT (MWE)	% WIDTH	% CROSS-SECTIONAL AREA	SURFACE AREA (ACRES)	LONGITUDINAL EXTENT
Maximum Flood	487	11.1	1.63	13.5	2150
Low Water Slack	499	10.5	1.57	25.1	2400

*Critical section 390 ft. south of discharge.

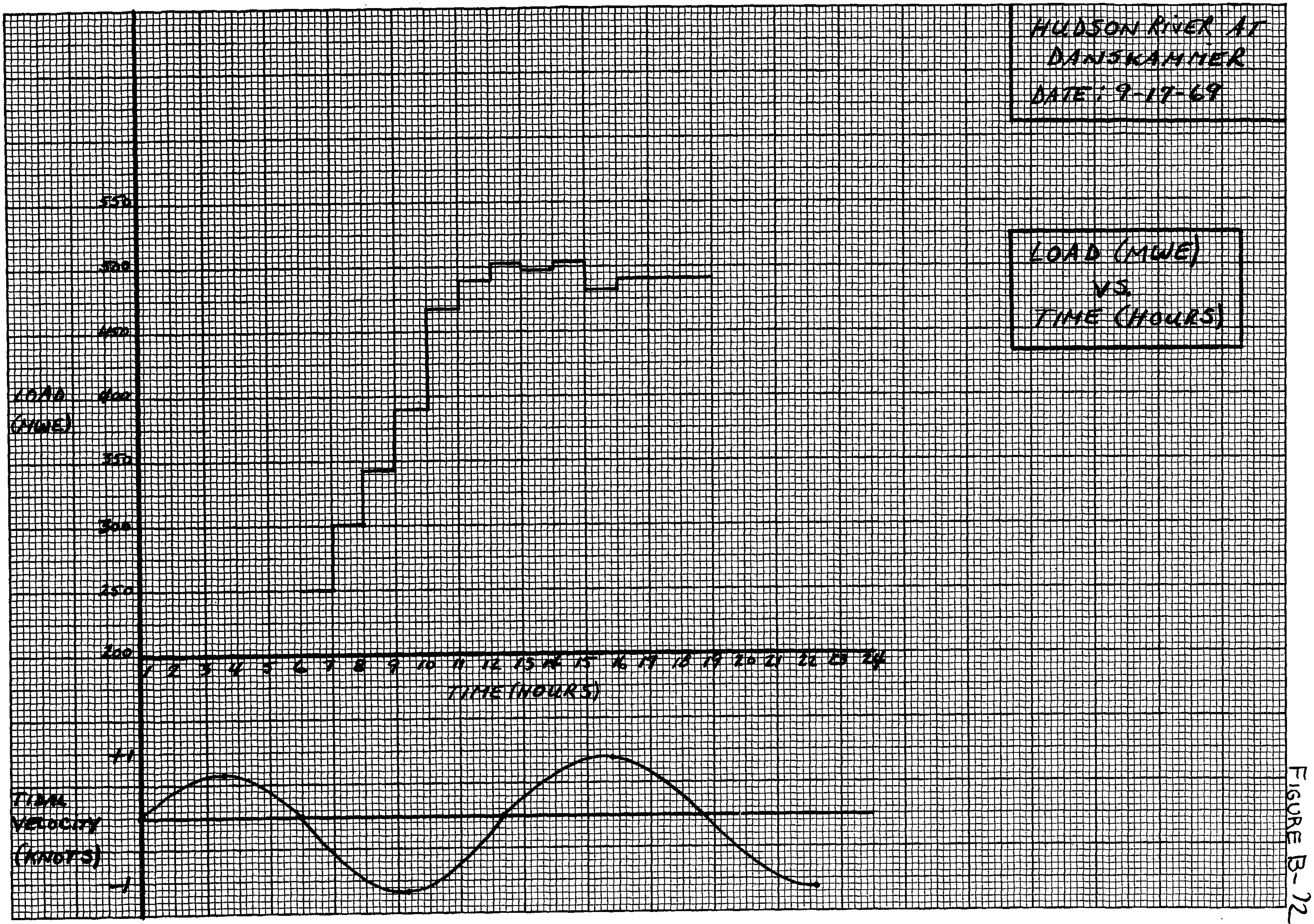

HUDSON RIVER AT
DANSKAMMER
DATE: 9-17-69
LOAD (MWE)
VS.
TIME (HOURS)
LOAD
(MWE)
550
500
450
400
350
300
250
200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
TIME (HOURS)
TIDAL
VELOCITY
(KNOTS)
+1
-1

FIGURE B-72

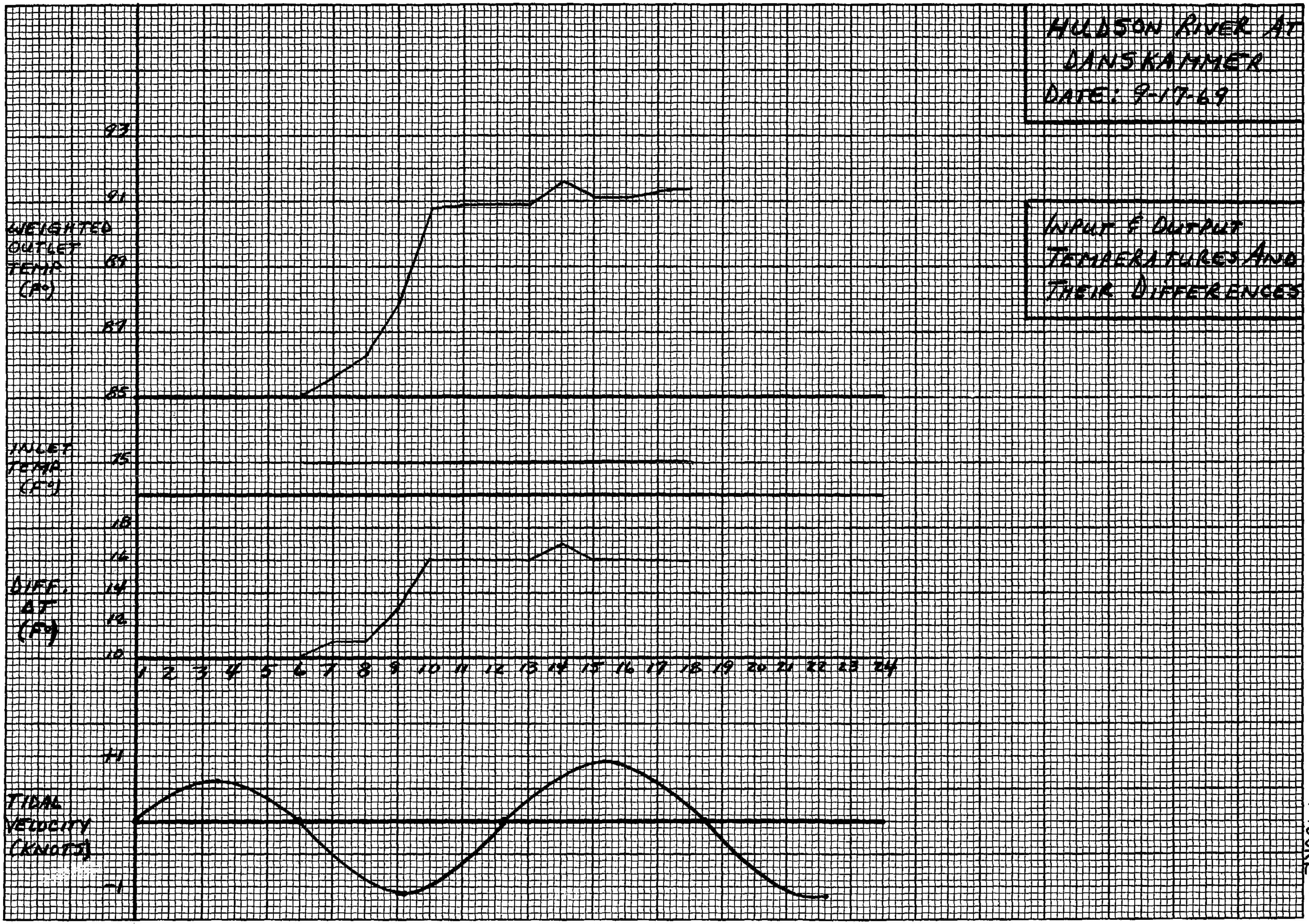
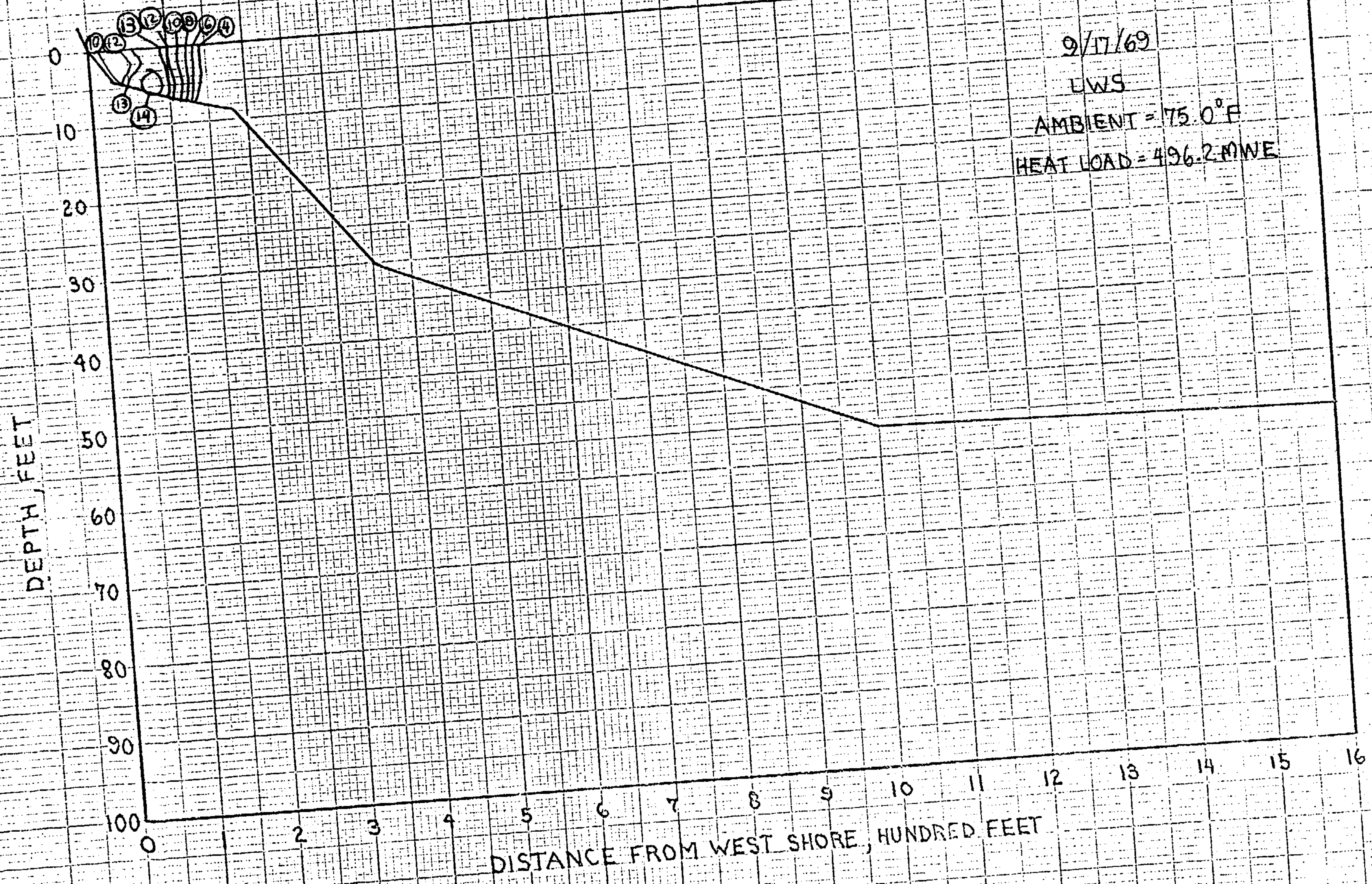

HUDSON RIVER AT
DANSKAMMER
DATE: 9-17-69
INPUT & OUTPUT
TEMPERATURES AND
THEIR DIFFERENCES
WEIGHTED OUTLET TEMP (F°)
93
91
89
87
85
INLET TEMP (F°)
75
DIFF. ΔT (F°)
18
16
14
12
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
TIDAL VELOCITY (KNOTS)
+1
-1

FIGURE B-73

LARGE
DOCUMENT

LARGE
DOCUMENT

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)



9/17/69

LWS

AMBIENT = 75.0°F

HEAT LOAD = 496.2 MWE

FIGURE B-76

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)

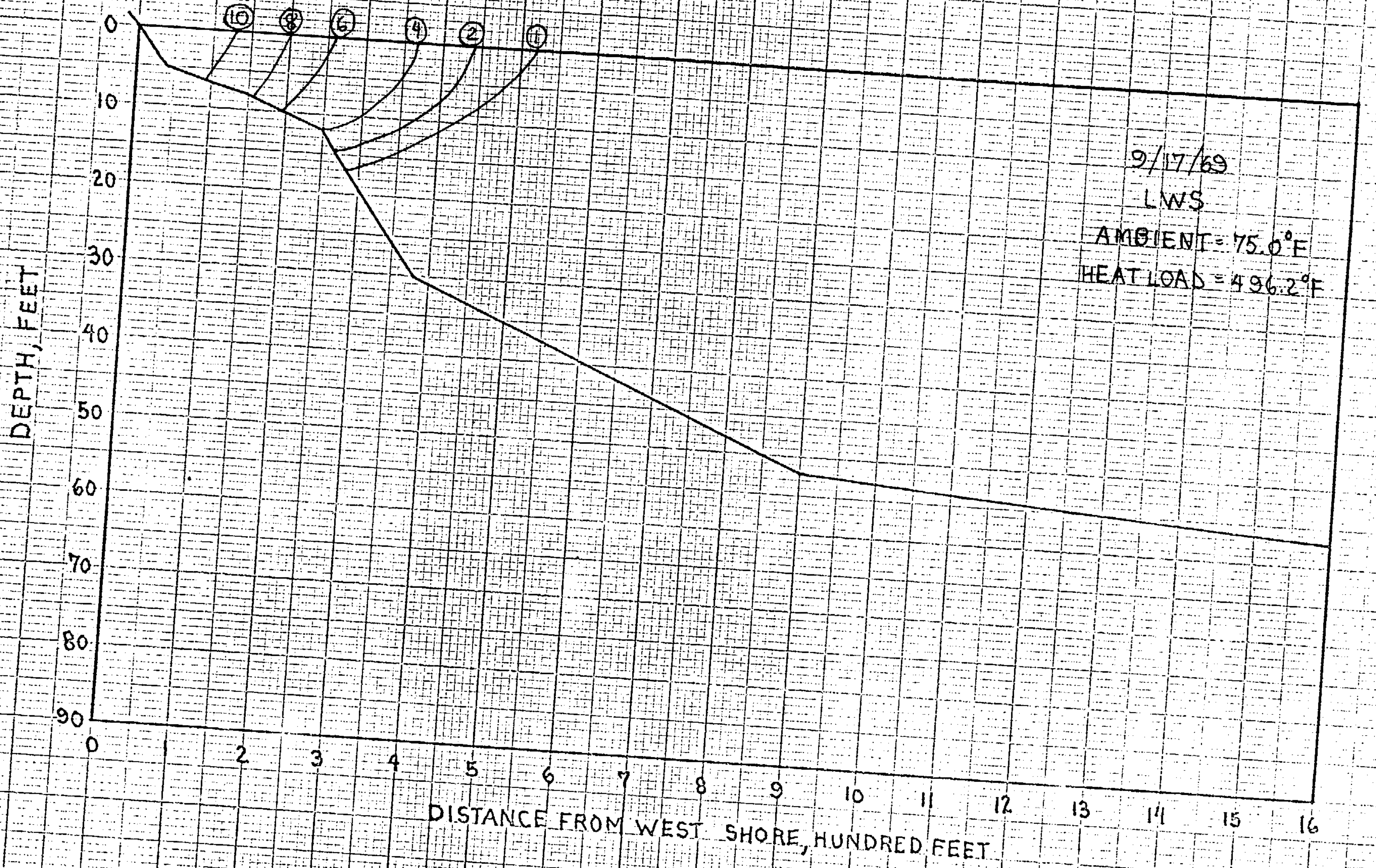
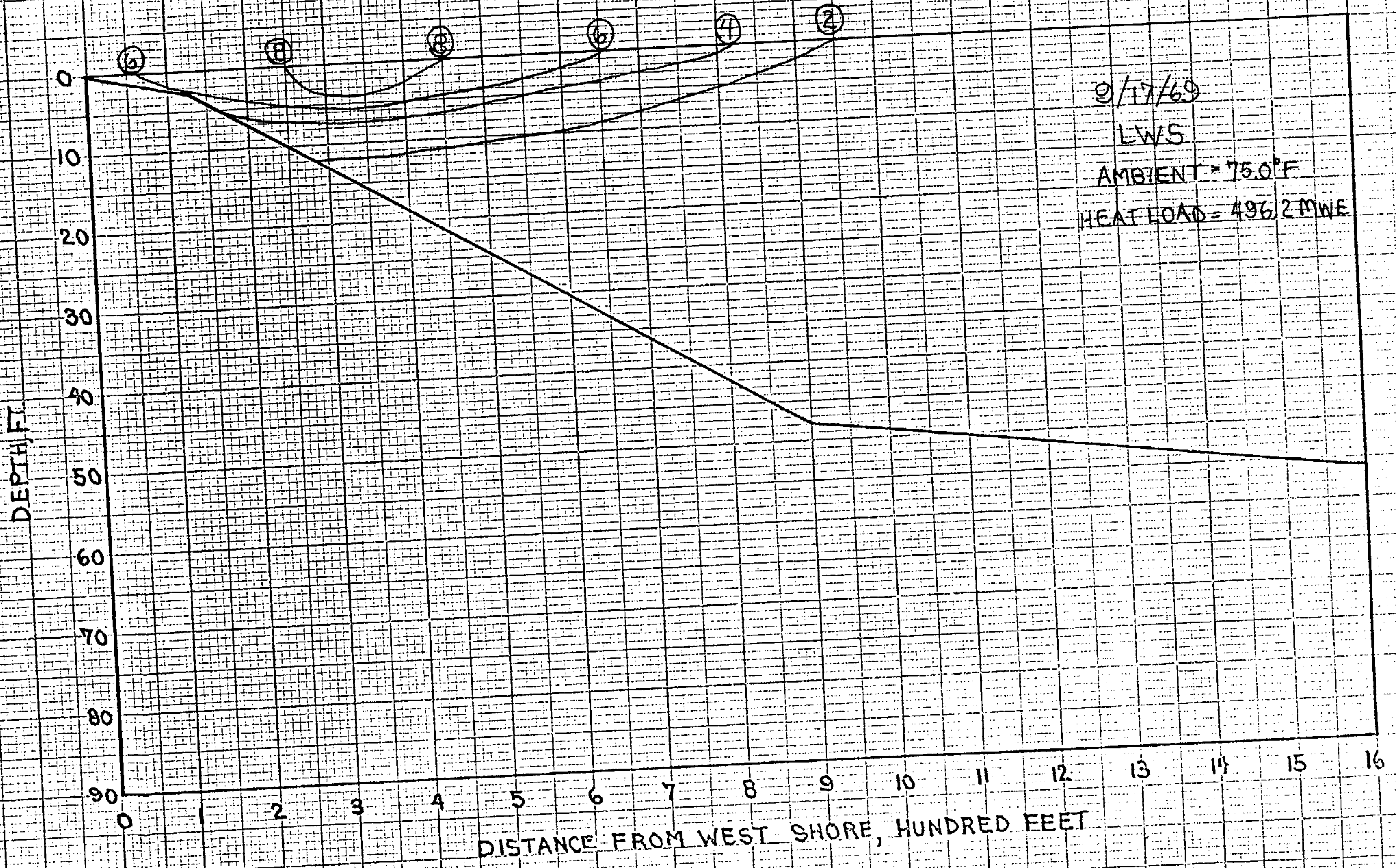


FIGURE B-77

HUDSON RIVER AT DANSKAMMER
800 FT. DOWNSTREAM FROM DISCHARGE (S-S-3)



9/17/69
LWS
AMBIENT = 75.0°F
HEAT LOAD = 496.2 MWE

FIGURE B-78

HUDSON RIVER AT DANSKAMMER
1300 FT. DOWNSTREAM FROM DISCHARGE (I-I)

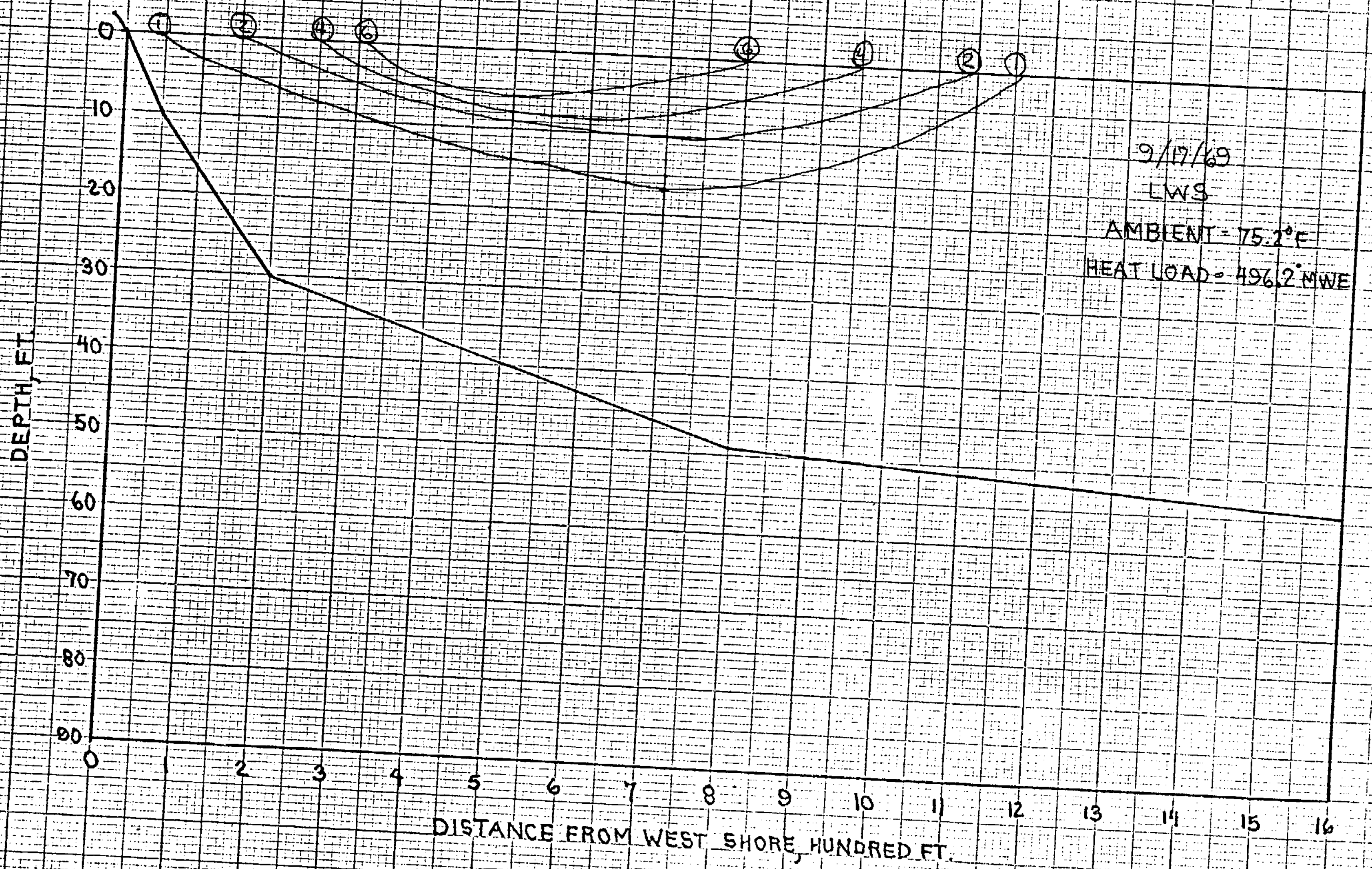
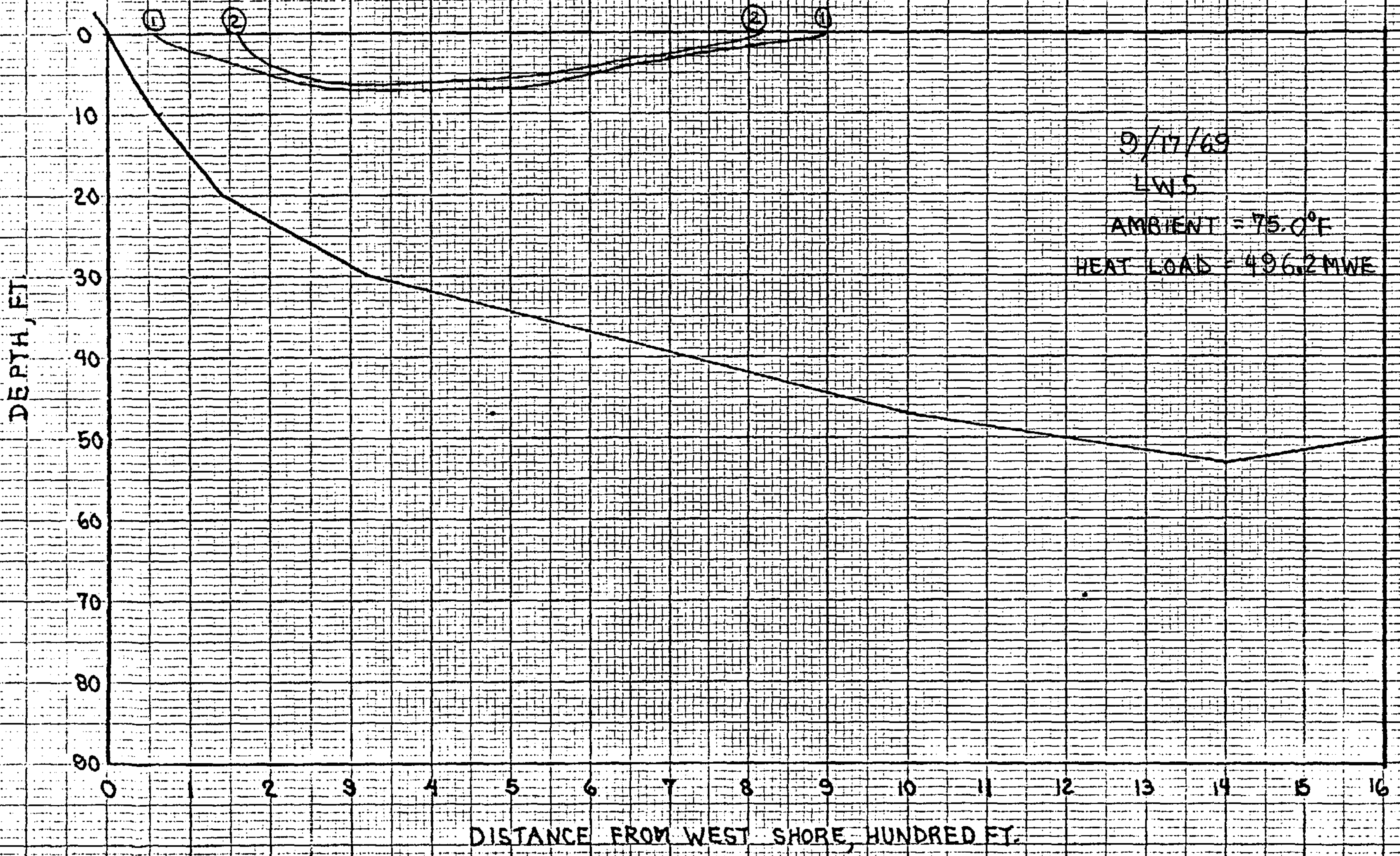


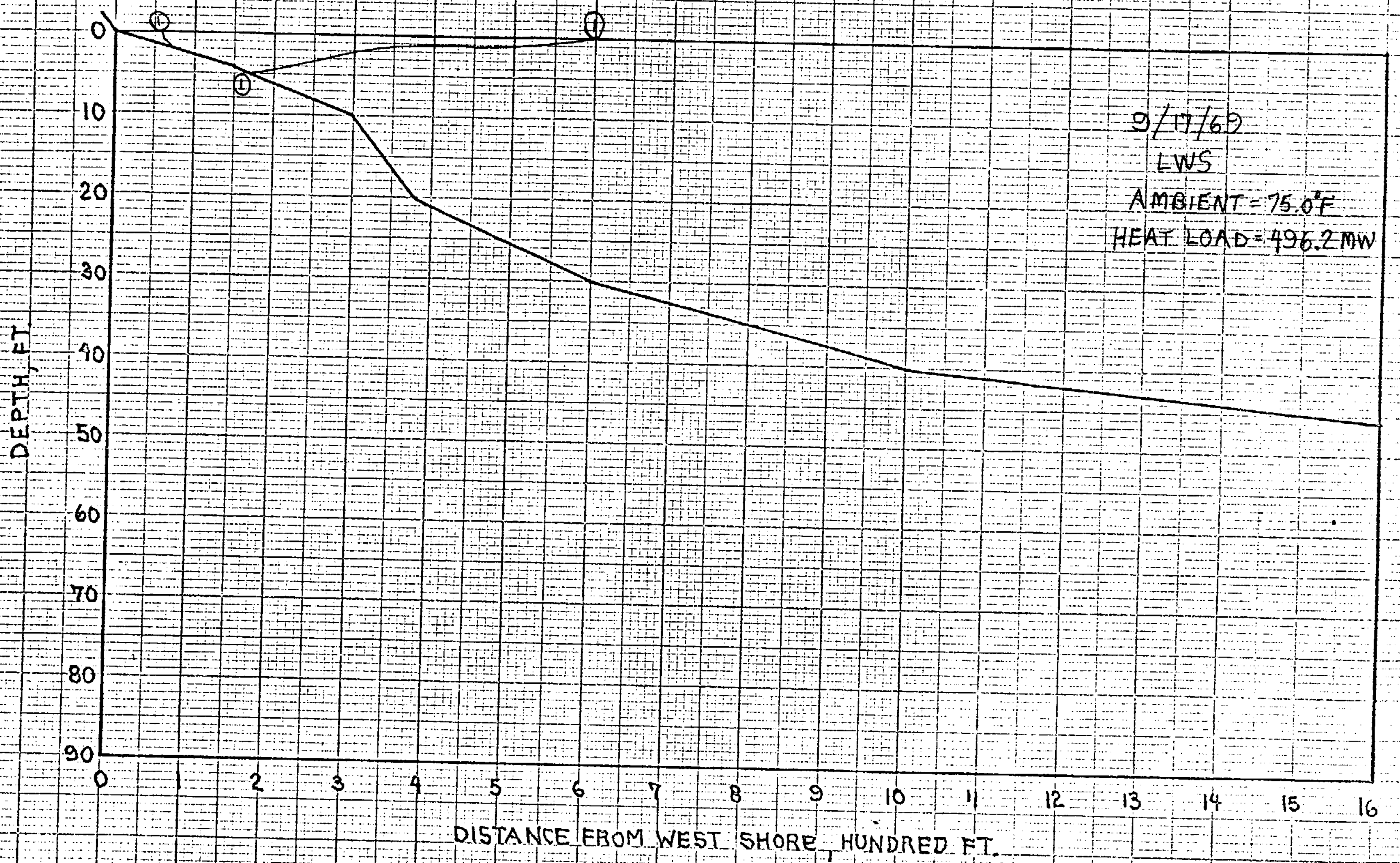
FIGURE B-79

HUDSON RIVER AT DANSKAMMER
2700 FT. DOWNSTREAM FROM DISCHARGE



9/17/69
LWS
AMBIENT = 75.0°F
HEAT LOAD = 496.2 MWE

FIGURE B-80



HUDSON RIVER AT DANSKAMMER
3000 FT DOWNSTREAM FROM DISCHARGE

9/17/69
LWS
AMBIENT = 75.0°F
HEAT LOAD = 496.2 MW

FIGURE B-8

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)

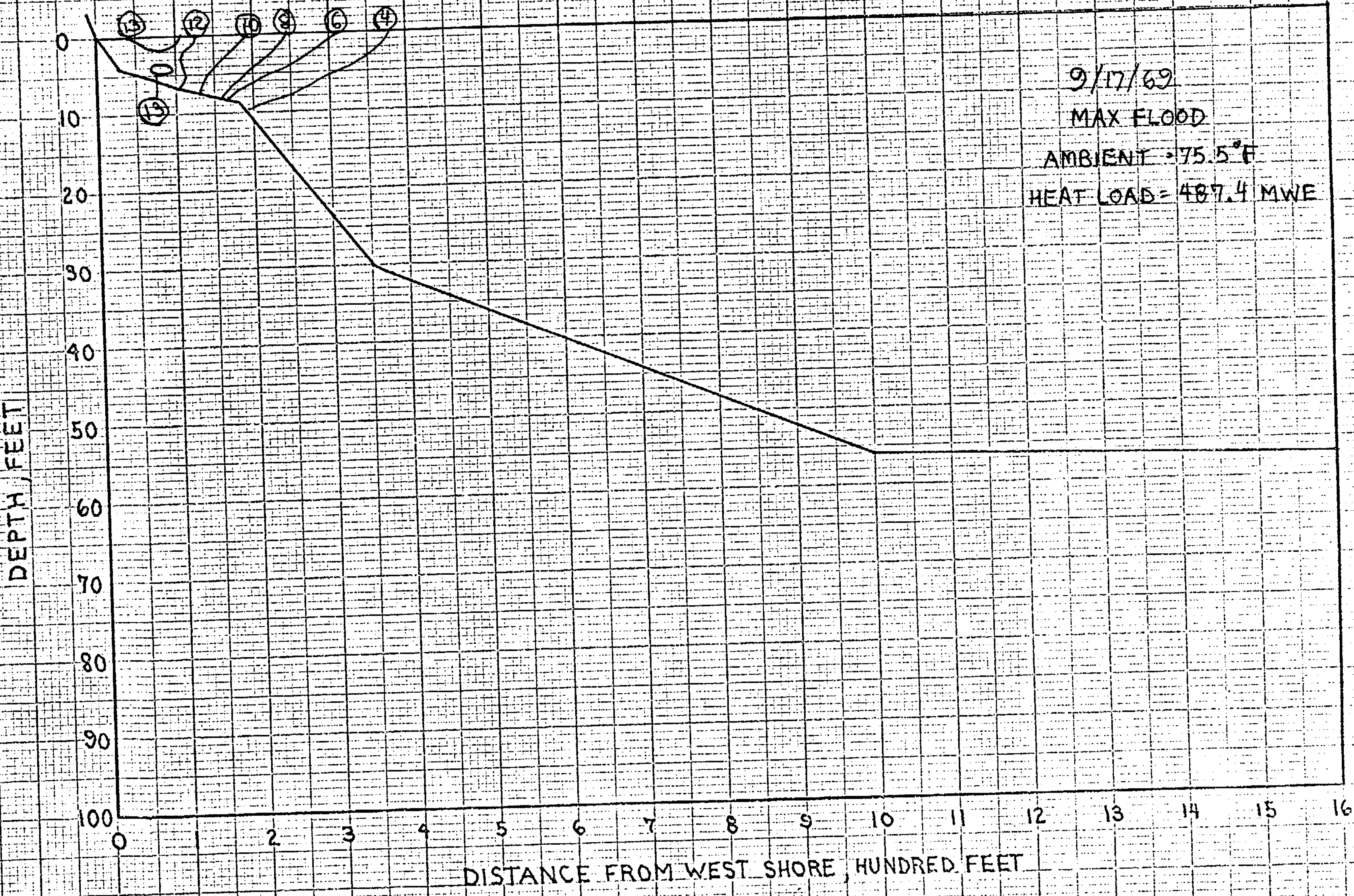
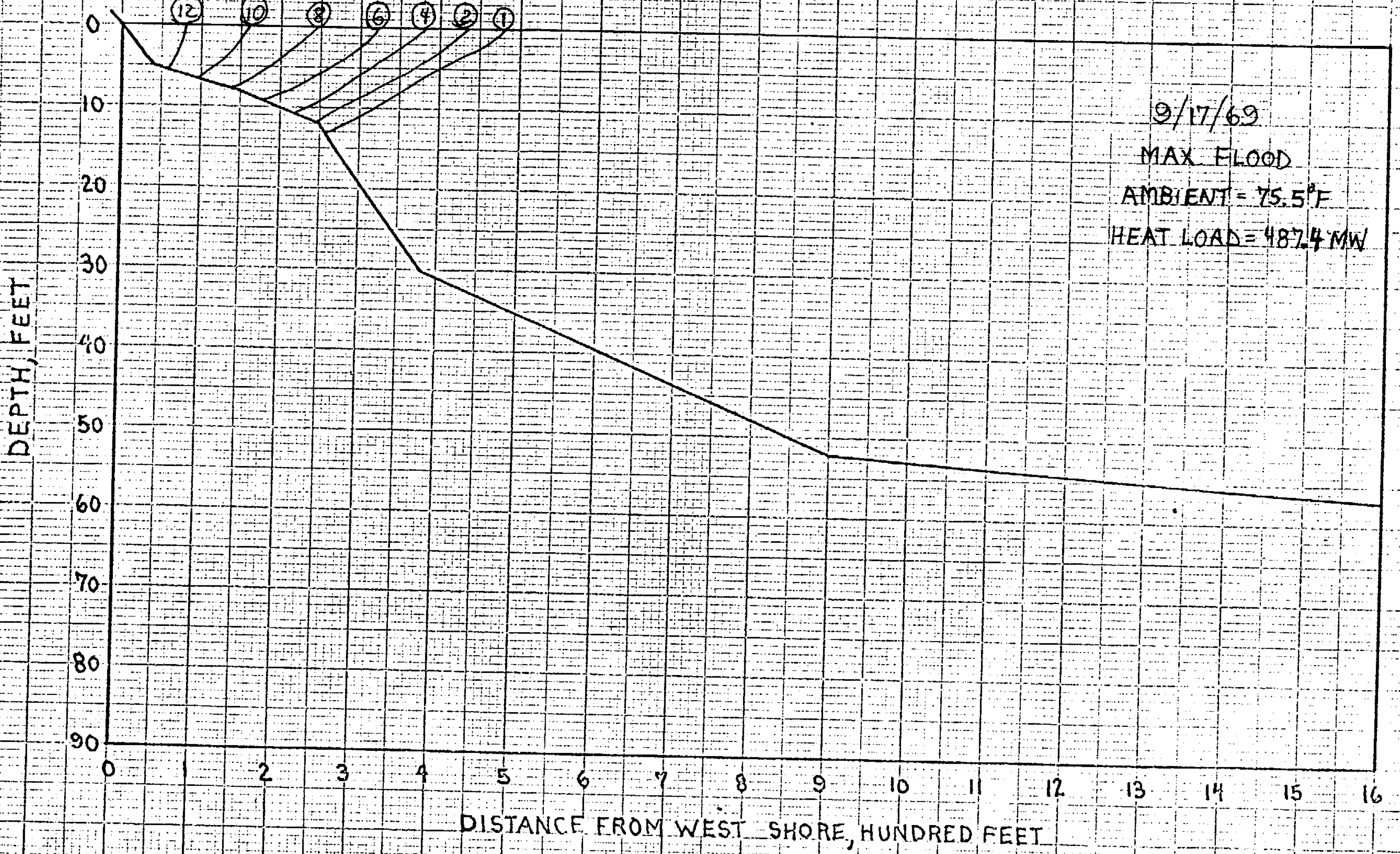


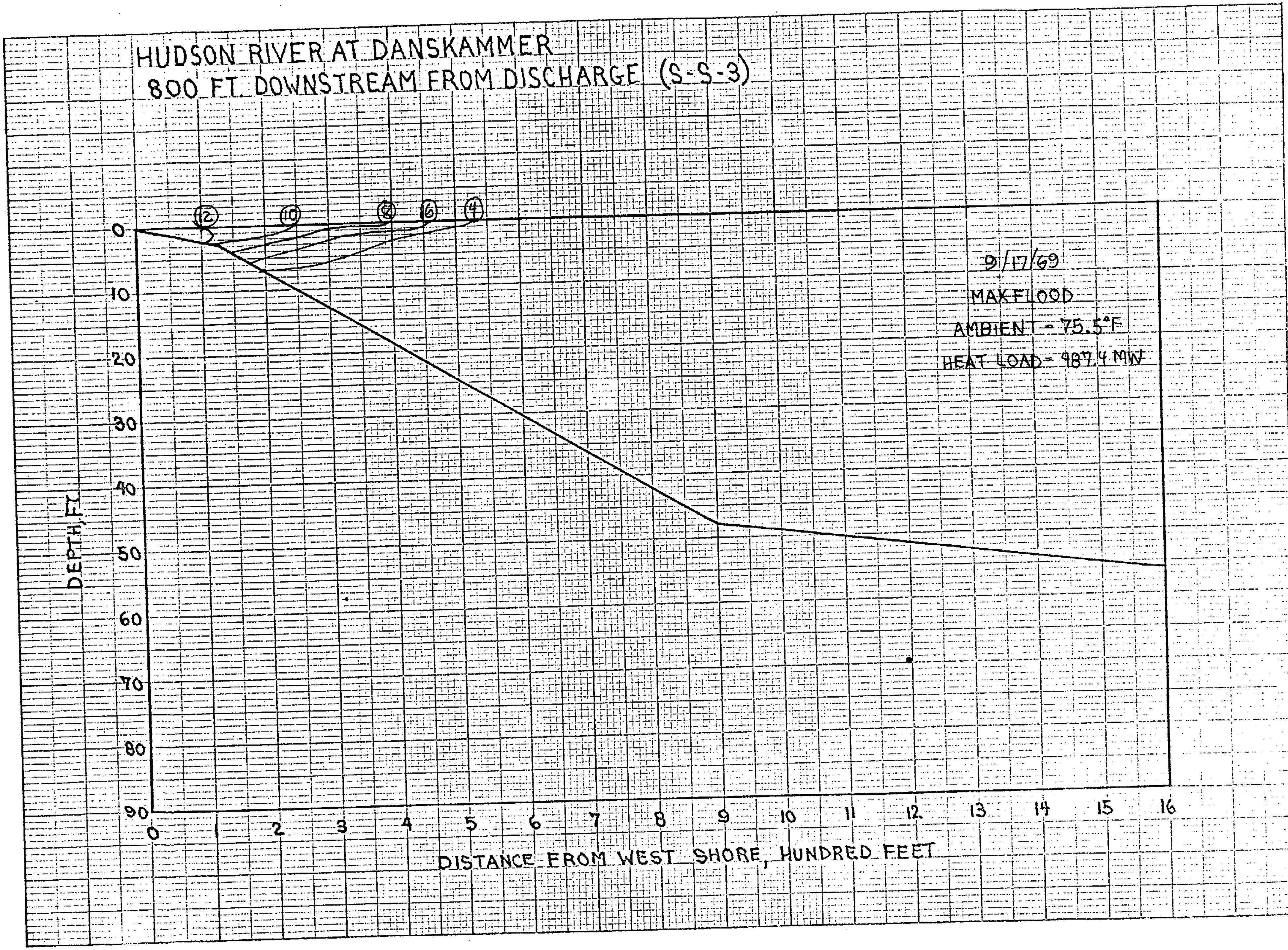
FIGURE B-82

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)



9/17/69
MAX FLOOD
AMBIENT = 75.5°F
HEAT LOAD = 487.4 MW

FIGURE B-83



HUDSON RIVER AT DANSKAMMER
800 FT. DOWNSTREAM FROM DISCHARGE (S-S-3)

9/17/69

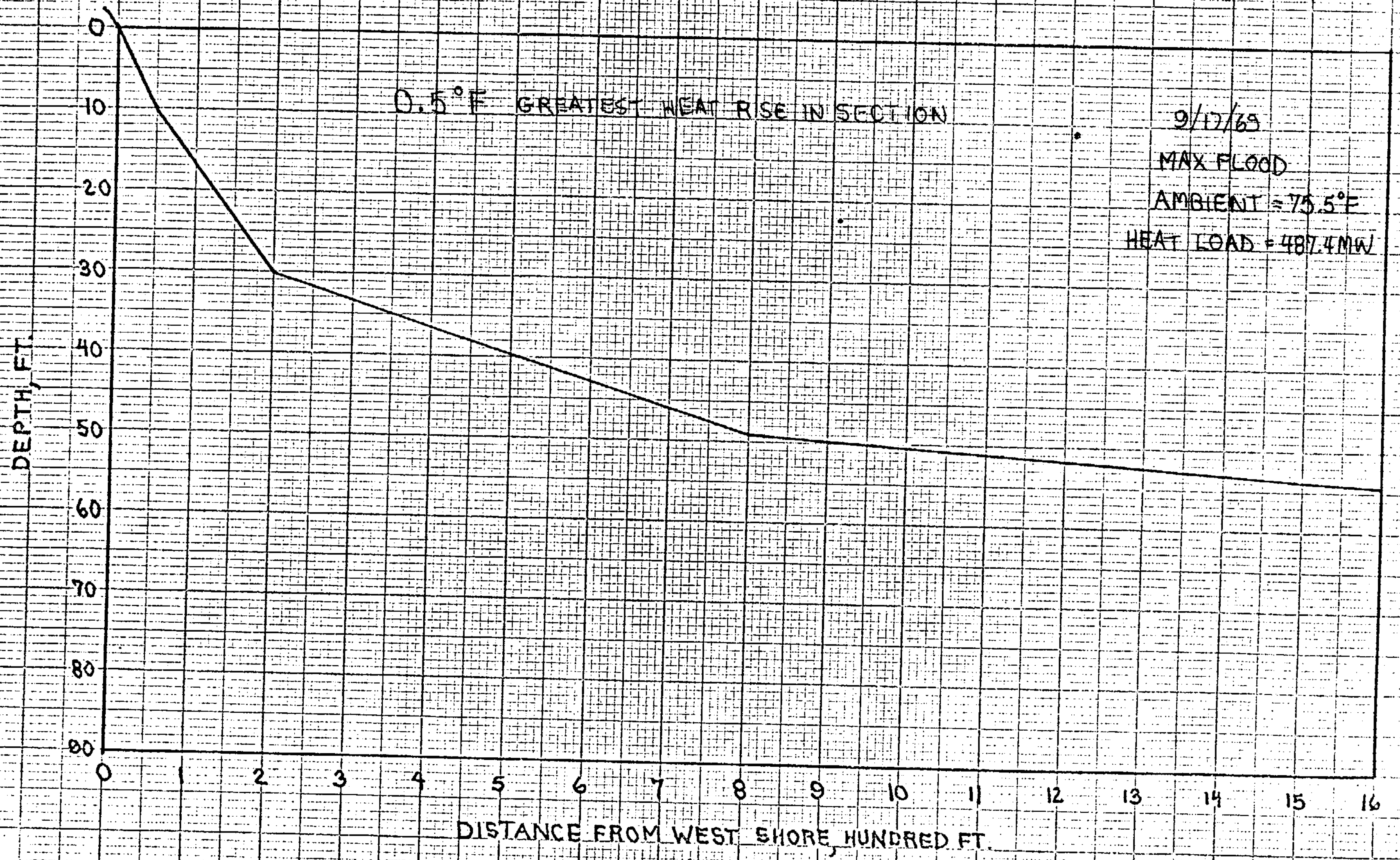
MAX FLOOD

AMBIENT - 75.5°F

HEAT LOAD - 487.4 MW

FIGURE B-84

HUDSON RIVER AT DANSKAMMER
1300 FT. DOWNSTREAM FROM DISCHARGE (I-I)



0.5°F GREATEST HEAT RISE IN SECTION

9/17/69

MAX FLOOD

AMBIENT = 75.5°F

HEAT LOAD = 487.4MW

FIGURE B-85

TABLE A8

PORTION OF HUDSON RIVER AT DANSKAMMER SUBJECTED TO TEMPERATURE RISE OF 4°F OR GREATER

DATE: September 24, 1969

Total river cross sectional area at critical section - 142,000 $ft.^2$

Total river surface width at critical section* - 3,420 ft.

TIDAL CONDITION	ELECTRICAL OUTPUT (MWE)	% WIDTH	% CROSS-SECTIONAL AREA	SURFACE AREA (ACRES)	LONGITUDINAL EXTENT
Maximum Flood	354	0	0	3.33	910
High Water Slack	406	7.6	0.65	13.9	2630

*Critical section 390 ft. south of discharge.

FIGURE B-86

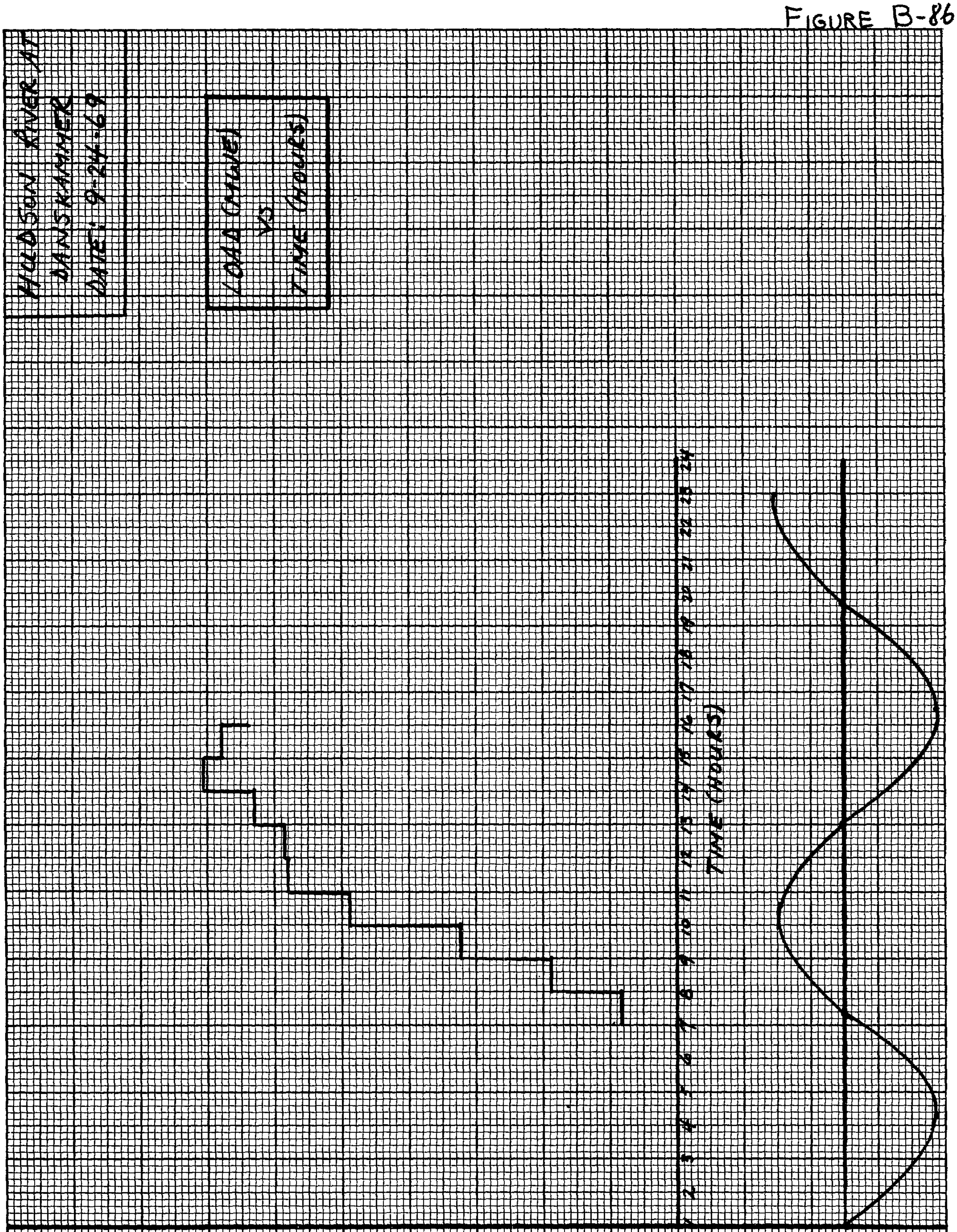
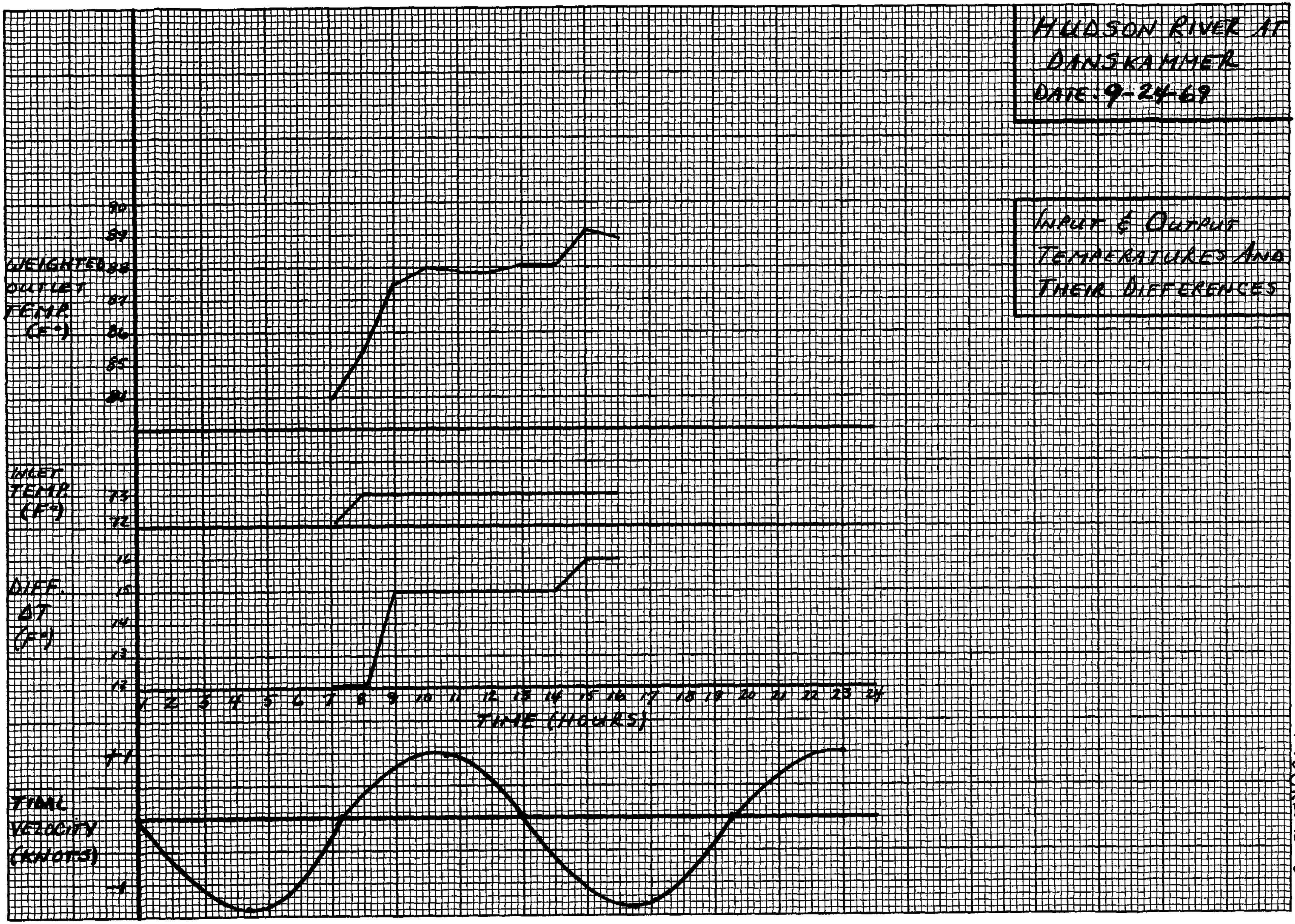

HUDSON RIVER AT
DANSKAMMER
DATE: 9-24-69
LOAD (MWE)
VS
TIME (HOURS)
LOAD
(MWE)
440
420
400
380
360
340
320
300
280
TIME (HOURS)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
TIDAL
VELOCITY
(KNOTS)
+1
-1

FIGURE B-87



HUDSON RIVER AT DANSKAMMER
DATE: 9-24-69

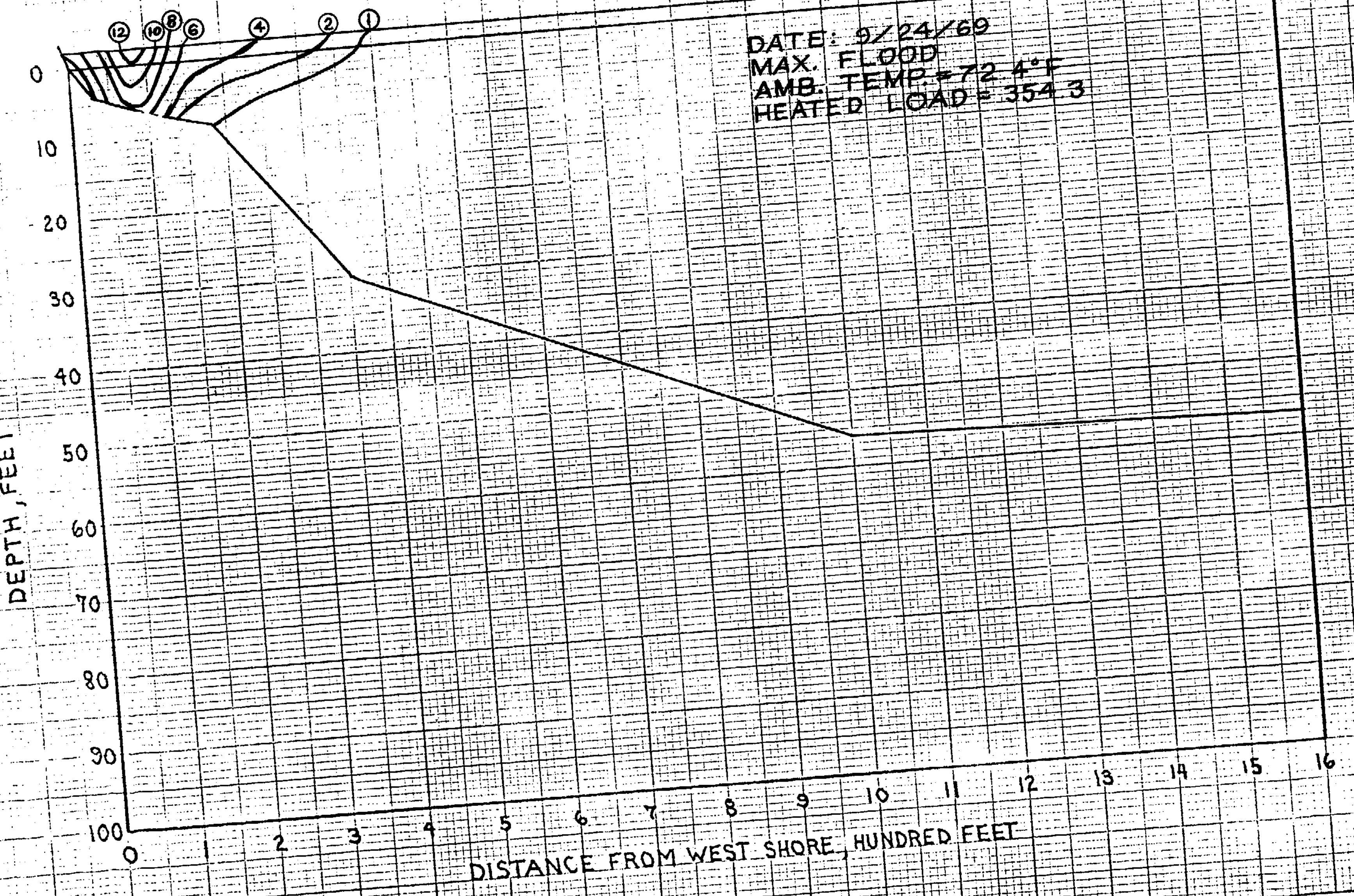
INPUT & OUTPUT TEMPERATURES AND THEIR DIFFERENCES

LARGE DOCUMENT

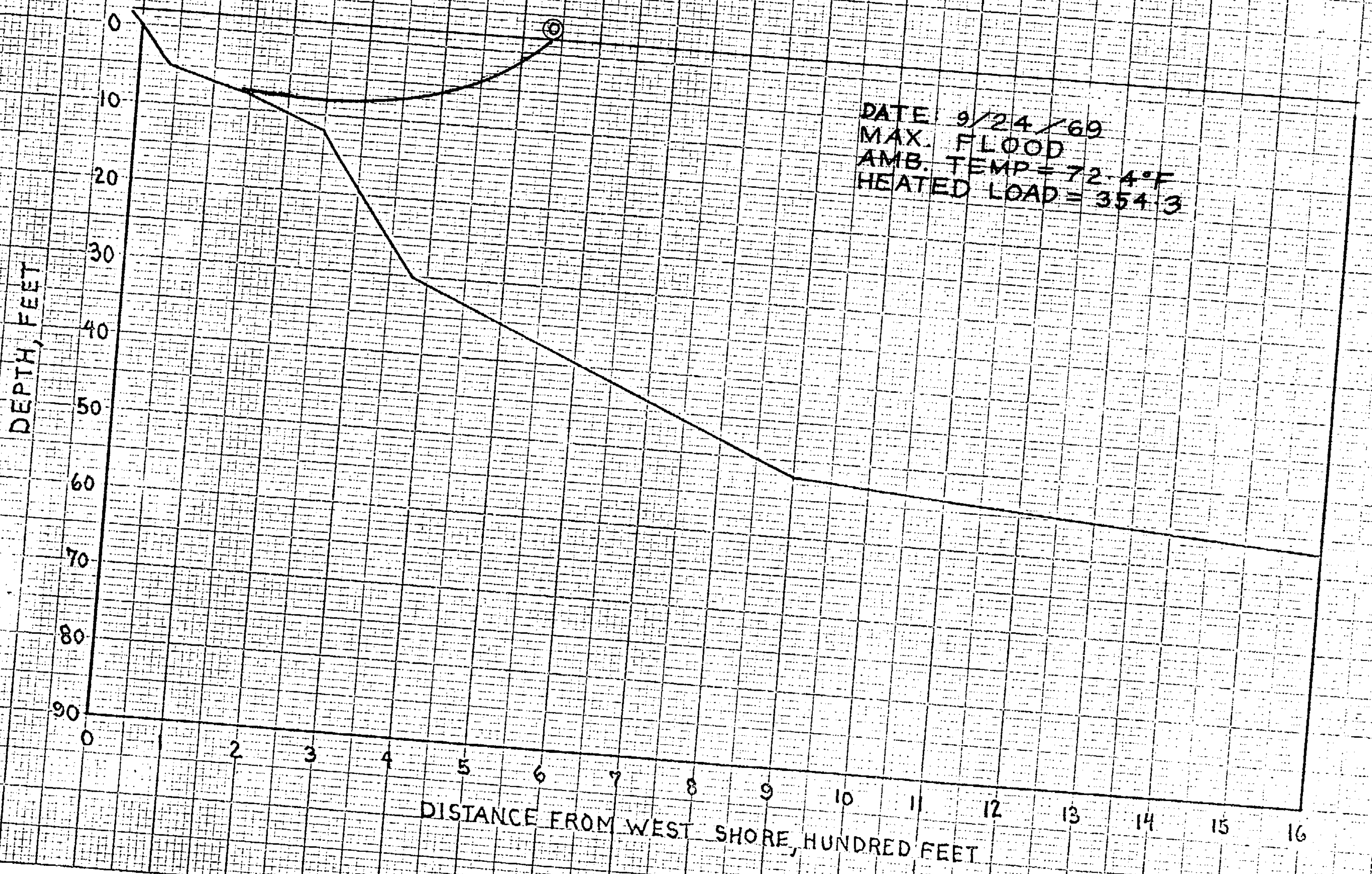
LARGE DOCUMENT

FIGURE B-90

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)



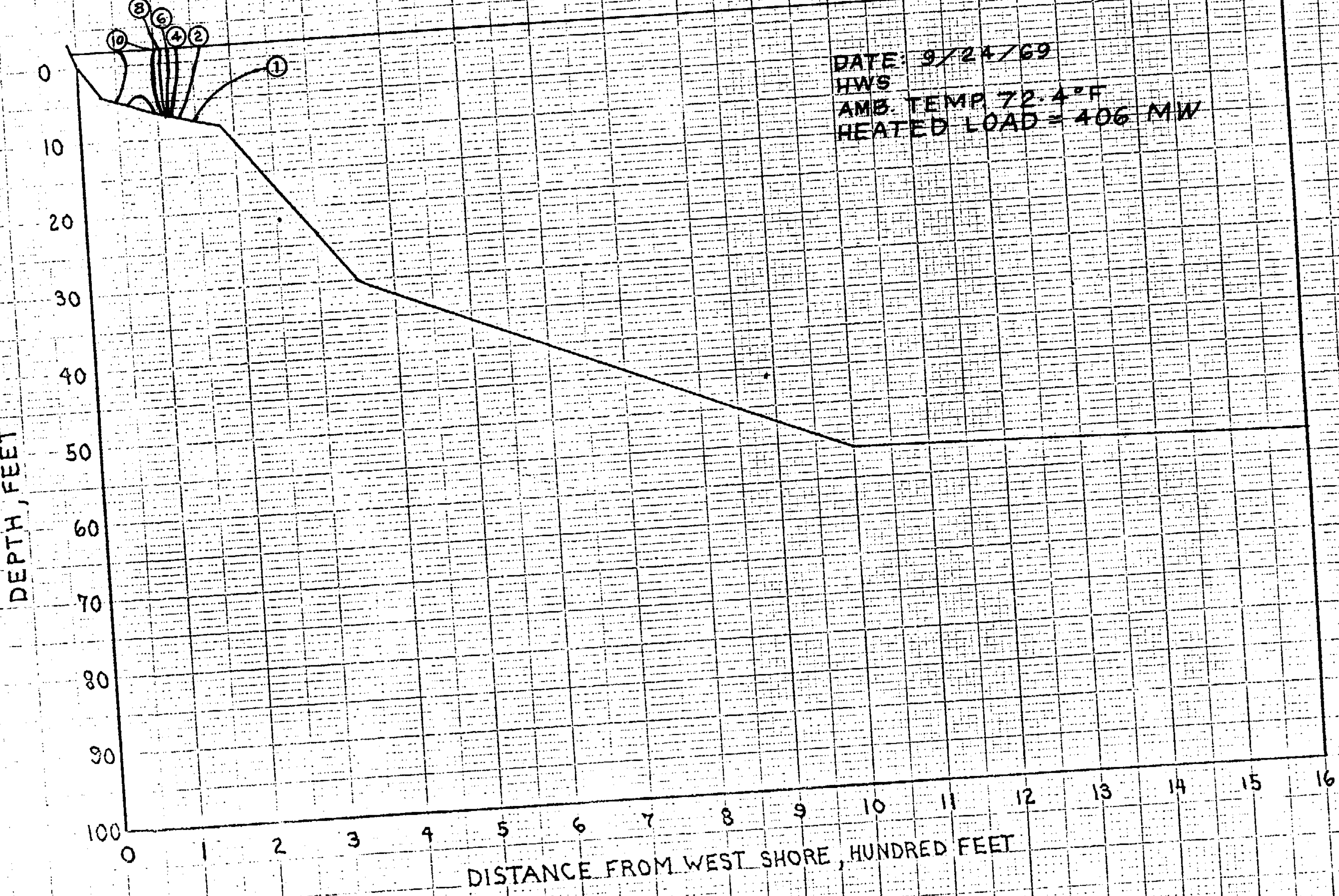
HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)



DATE 9/24/69
MAX. FLOOD
AMB. TEMP = 72.4°F
HEATED LOAD = 354.3

FIGURE B-91

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)



DATE: 9/24/69
HWS
AMB. TEMP 72.4°F
HEATED LOAD = 406 MW

FIGURE B-92

FIGURE B-93

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)

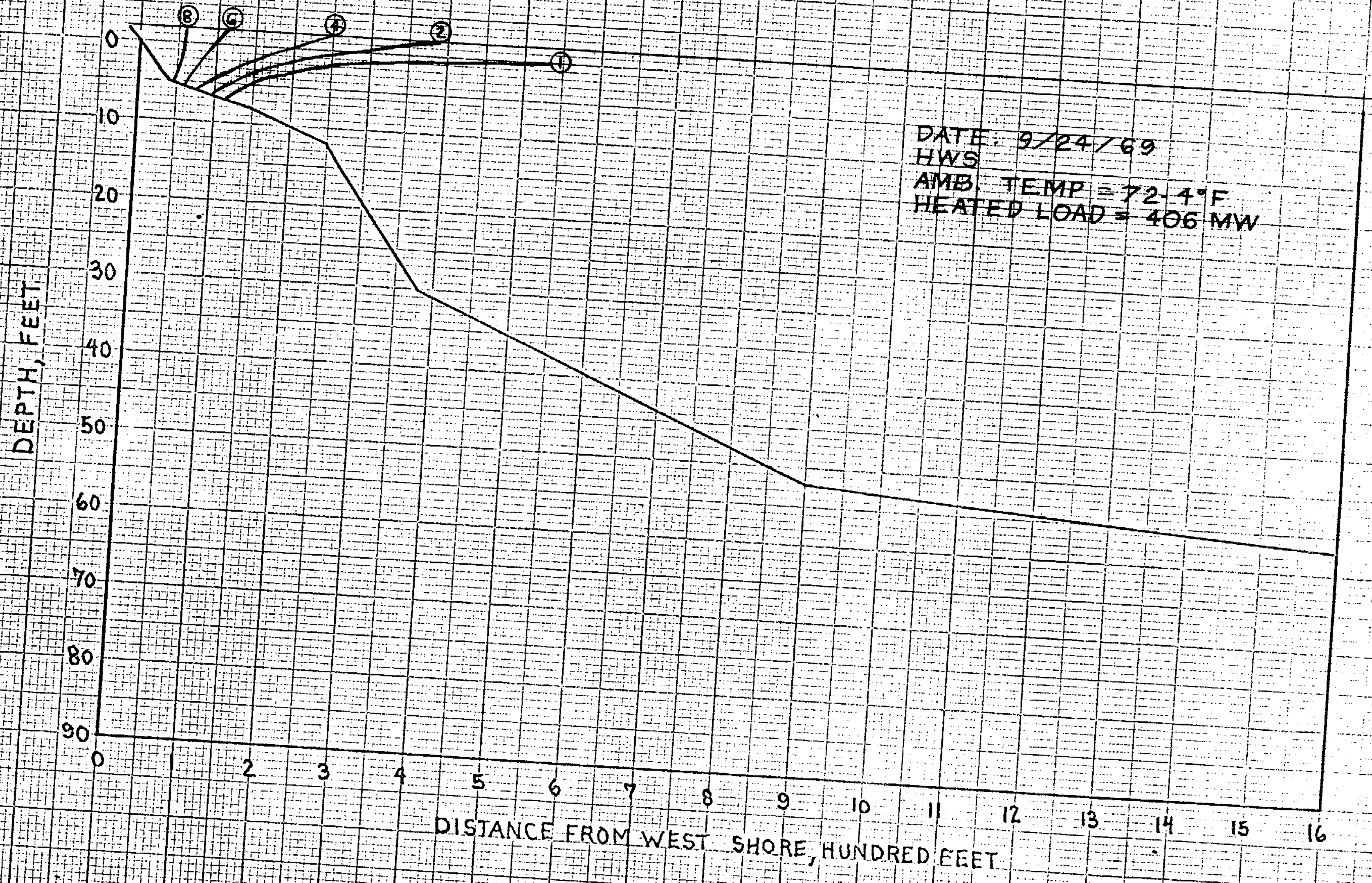


FIGURE B-94

HUDSON RIVER AT DANSKAMMER
800 FT. DOWNSTREAM FROM DISCHARGE (S-S-3)

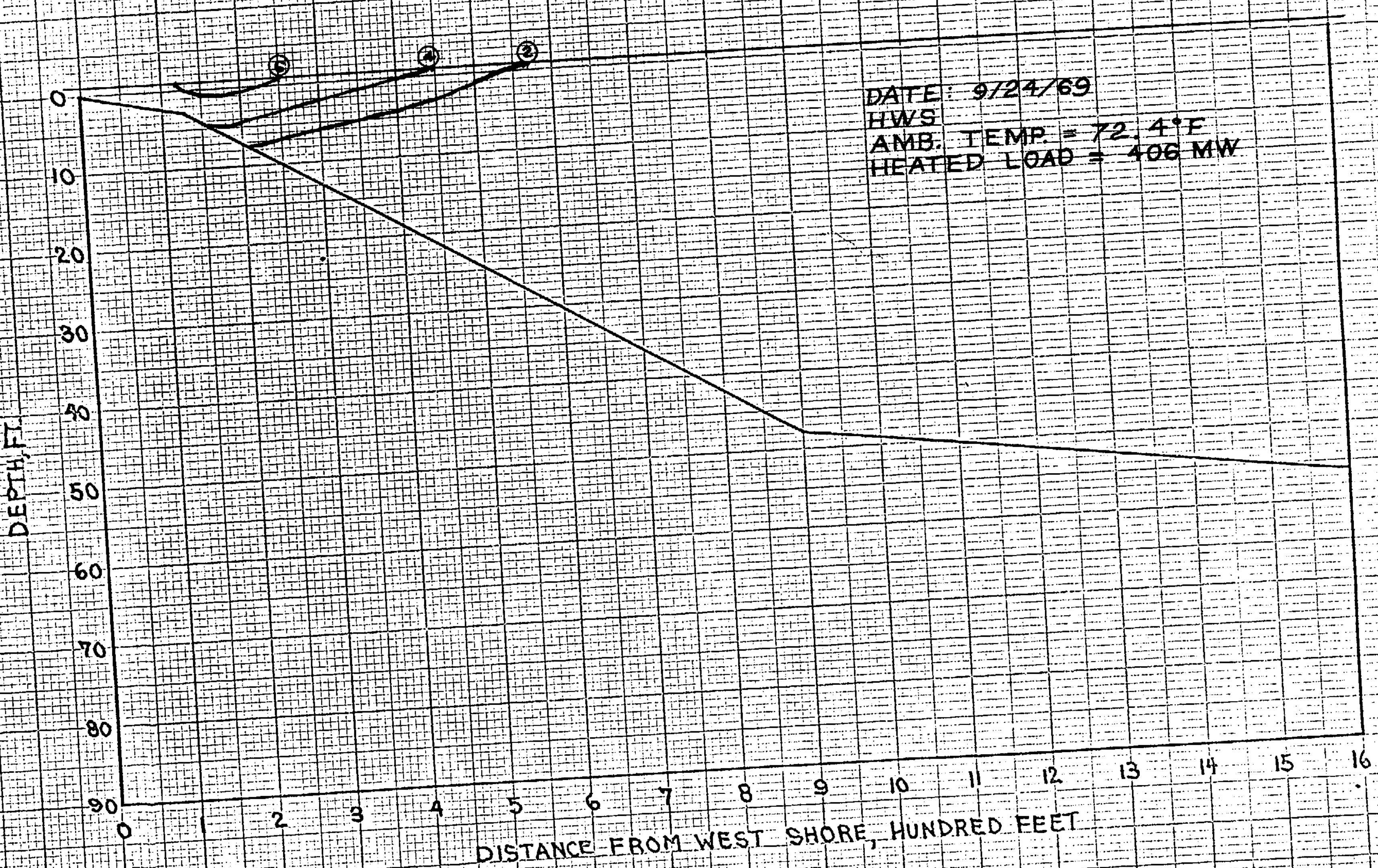
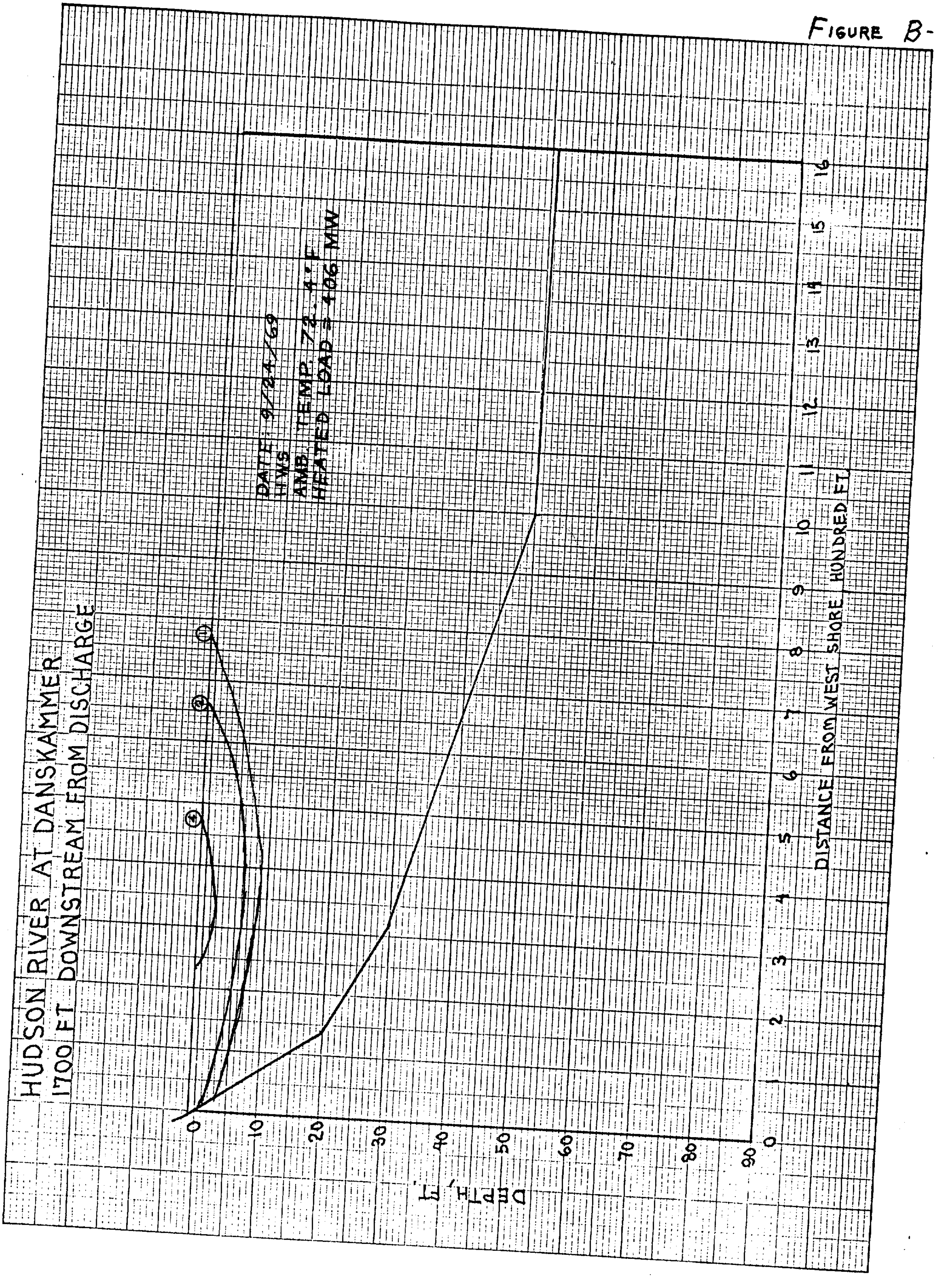
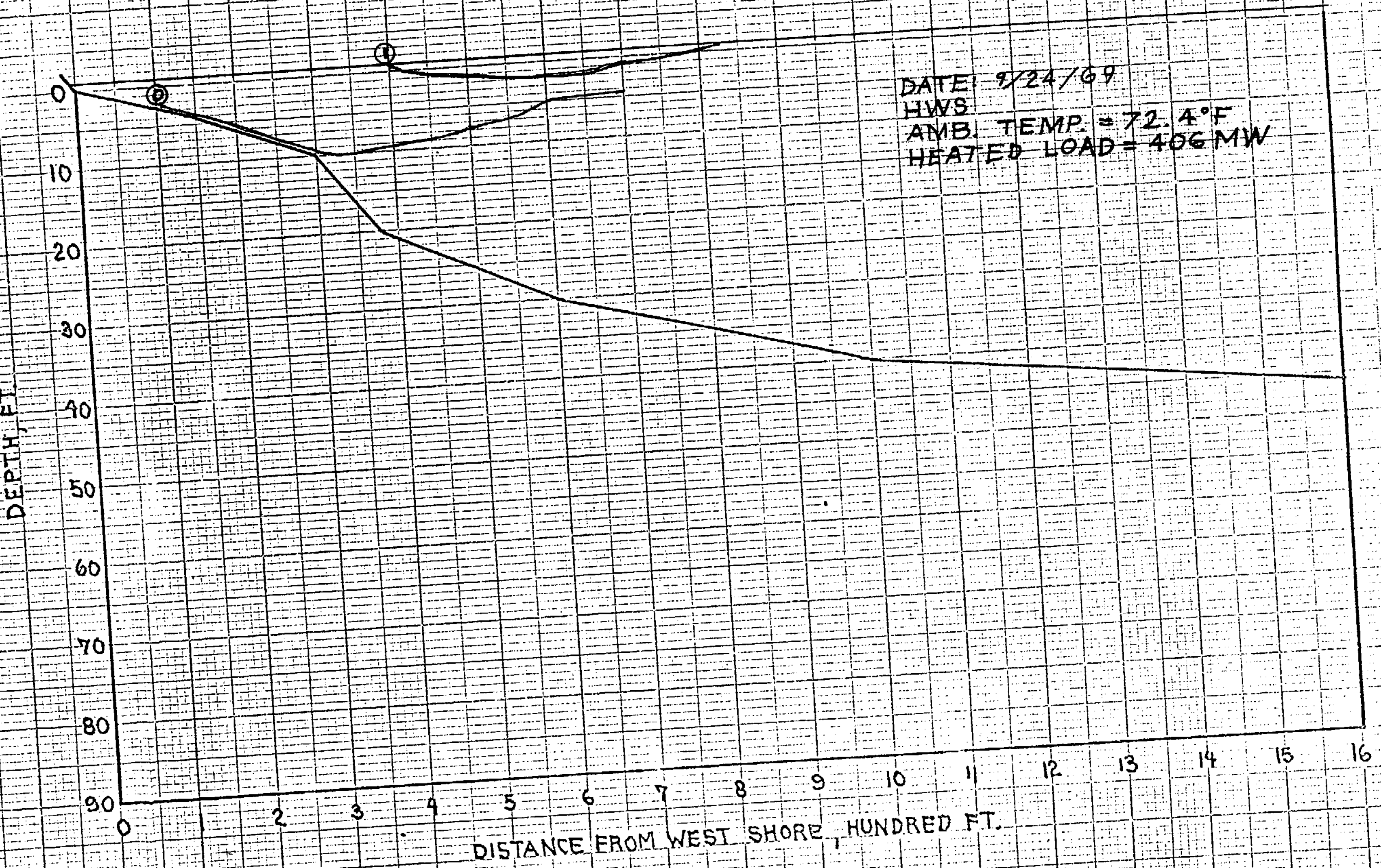


FIGURE B-95



HUDSON RIVER AT DANSKAMMER
1700 FT DOWNSTREAM FROM DISCHARGE

HUDSON RIVER AT DANSKAMMER
3000 FT DOWNSTREAM FROM DISCHARGE



DATE: 9/24/69
HWS
AMB. TEMP. = 72.4°F
HEATED LOAD = 406 MW

FIGURE B-96

TABLE A9

PORTION OF HUDSON RIVER AT DANSKAMMER SUBJECTED TO TEMPERATURE RISE OF 4^{o}F OR GREATER

DATE: October 1, 1969

Total river cross sectional area at critical section - 142,000 ft.^{2}

Total river surface width at critical section* - 3,420 ft.

TIDAL CONDITION	ELECTRICAL OUTPUT (MWE)	% WIDTH	% CROSS-SECTIONAL AREA	SURFACE AREA (ACRES)	LONGITUDINAL EXTENT
Maximum Ebb	435	9.1	0.52	30.6	5070
Low Water Slack	458	15.2	0.65	75.9	6000
Maximum Flood	445	10.5	0.65	8.5	1555

*Critical section 390 ft. south of discharge.

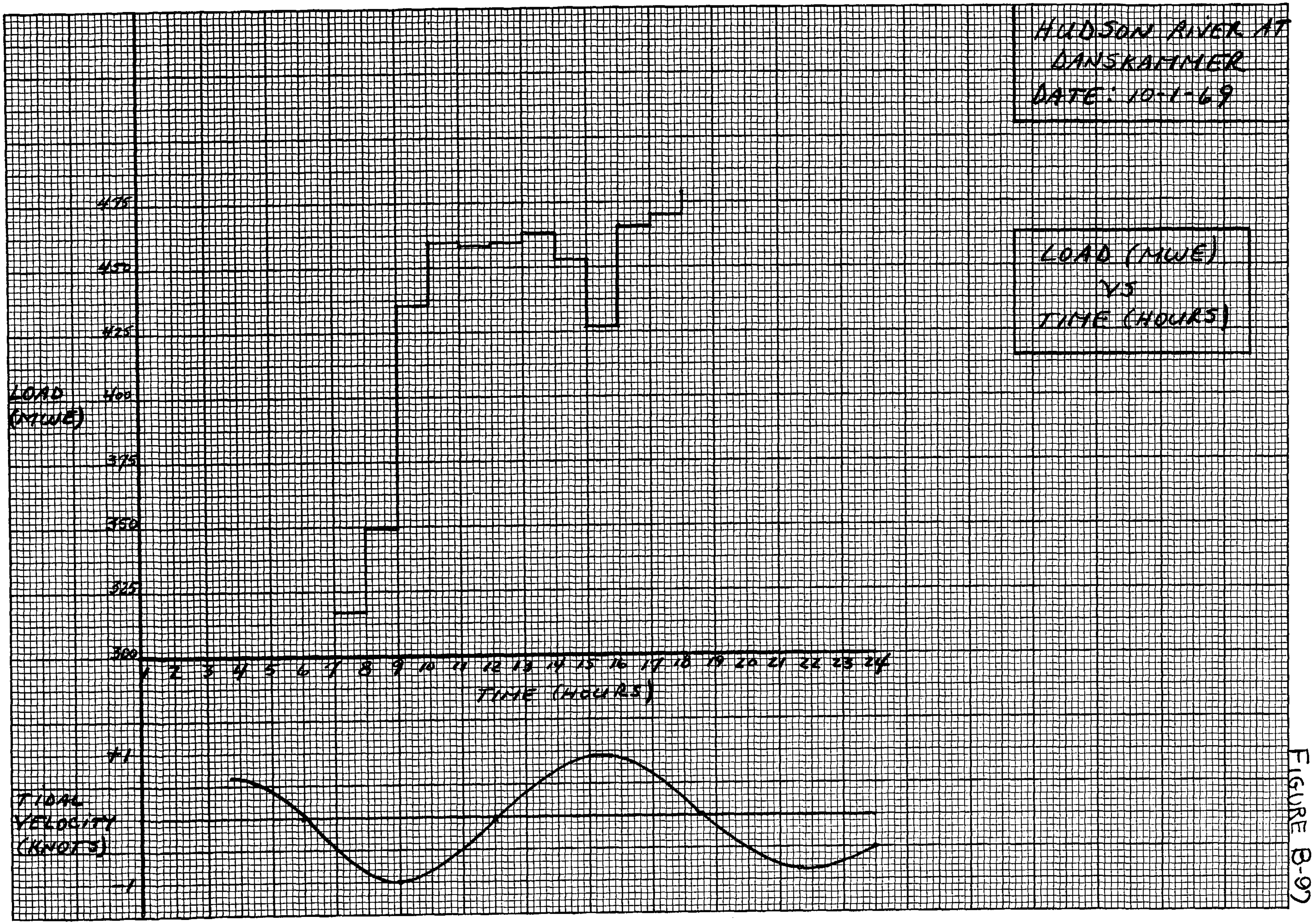

HUDSON RIVER AT
DANSKAMMER
DATE: 10-1-69
LOAD (MWE)
VS
TIME (HOURS)
LOAD (MWE)
475
450
425
400
375
350
325
300
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
TIME (HOURS)
TIDAL VELOCITY (KNOTS)
+1
-1

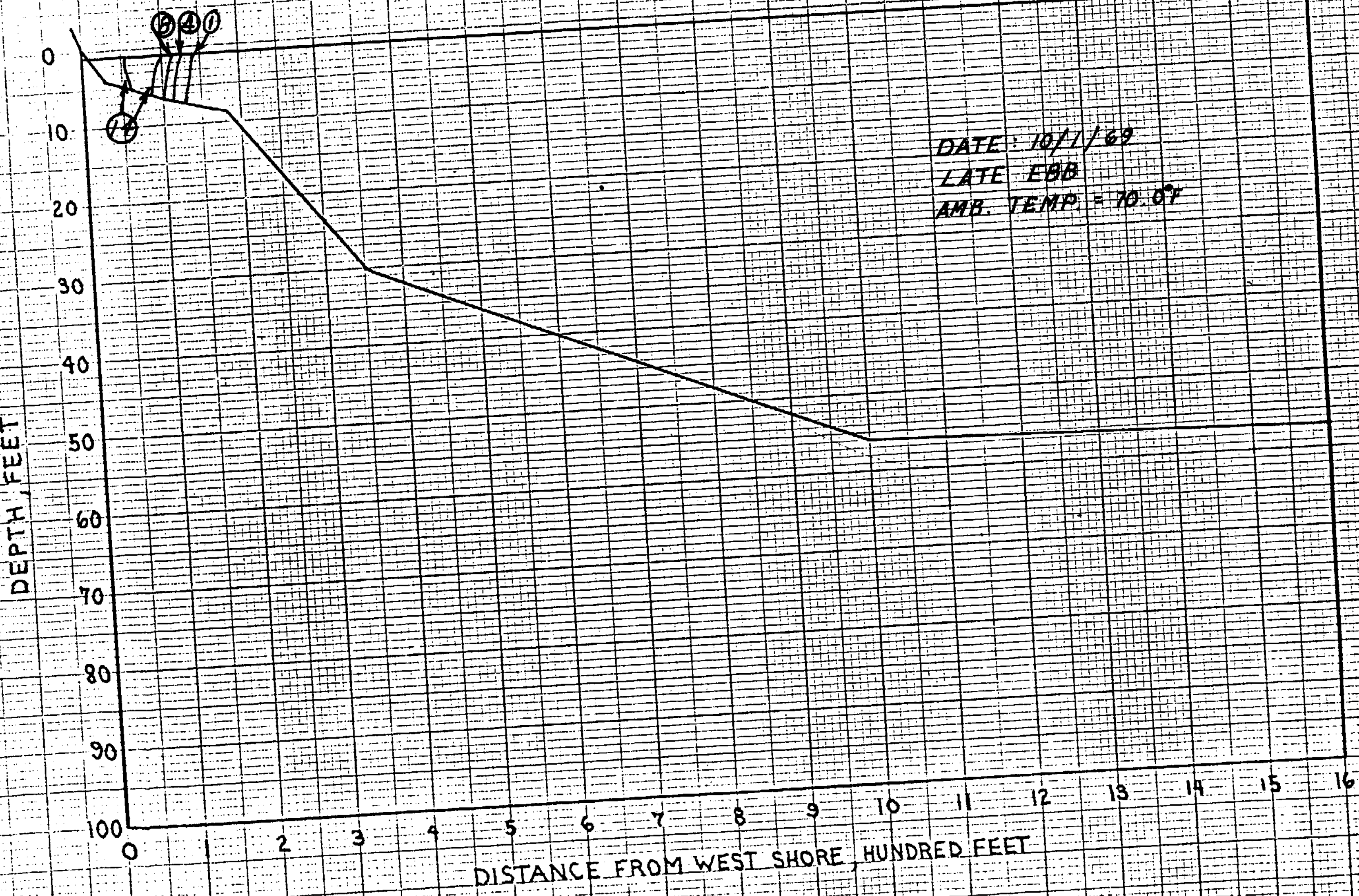
FIGURE B-97

LARGE
DOCUMENT

LARGE DOCUMENT

LARGE DOCUMENT

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)



DATE: 10/1/69
LATE EBB
AMB. TEMP. = 70.0°F

FIGURE B-101

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)

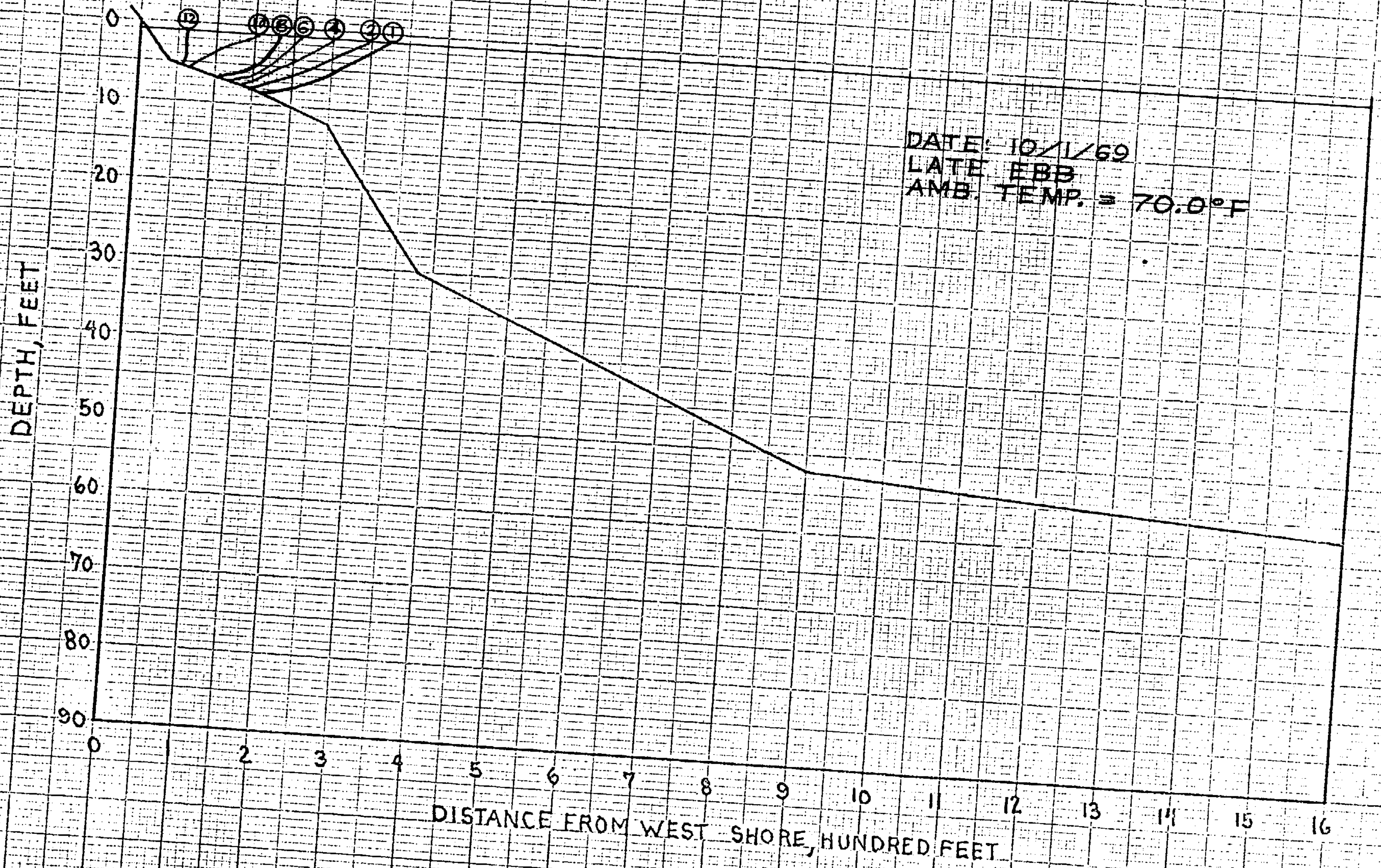
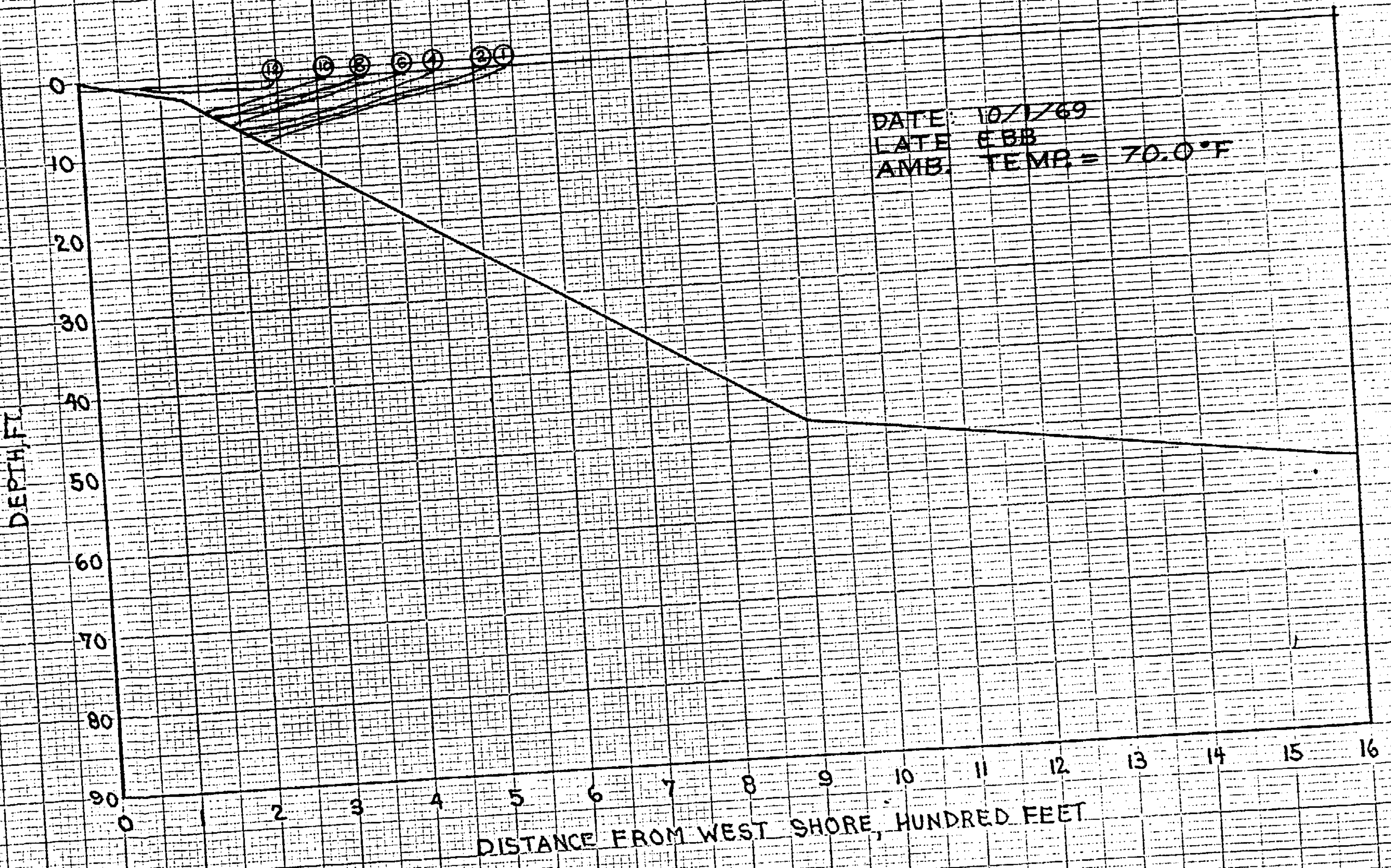


FIGURE B-102

FIGURE B-103

HUDSON RIVER AT DANSKAMMER
800 FT. DOWNSTREAM FROM DISCHARGE (S-S-3)



HUDSON RIVER AT DANSKAMMER
1450 FT. DOWNSTREAM FROM DISCHARGE (I-I)

FIGURE B-104

HUDSON RIVER AT DANSKAMMER
2700 FT. DOWNSTREAM FROM DISCHARGE

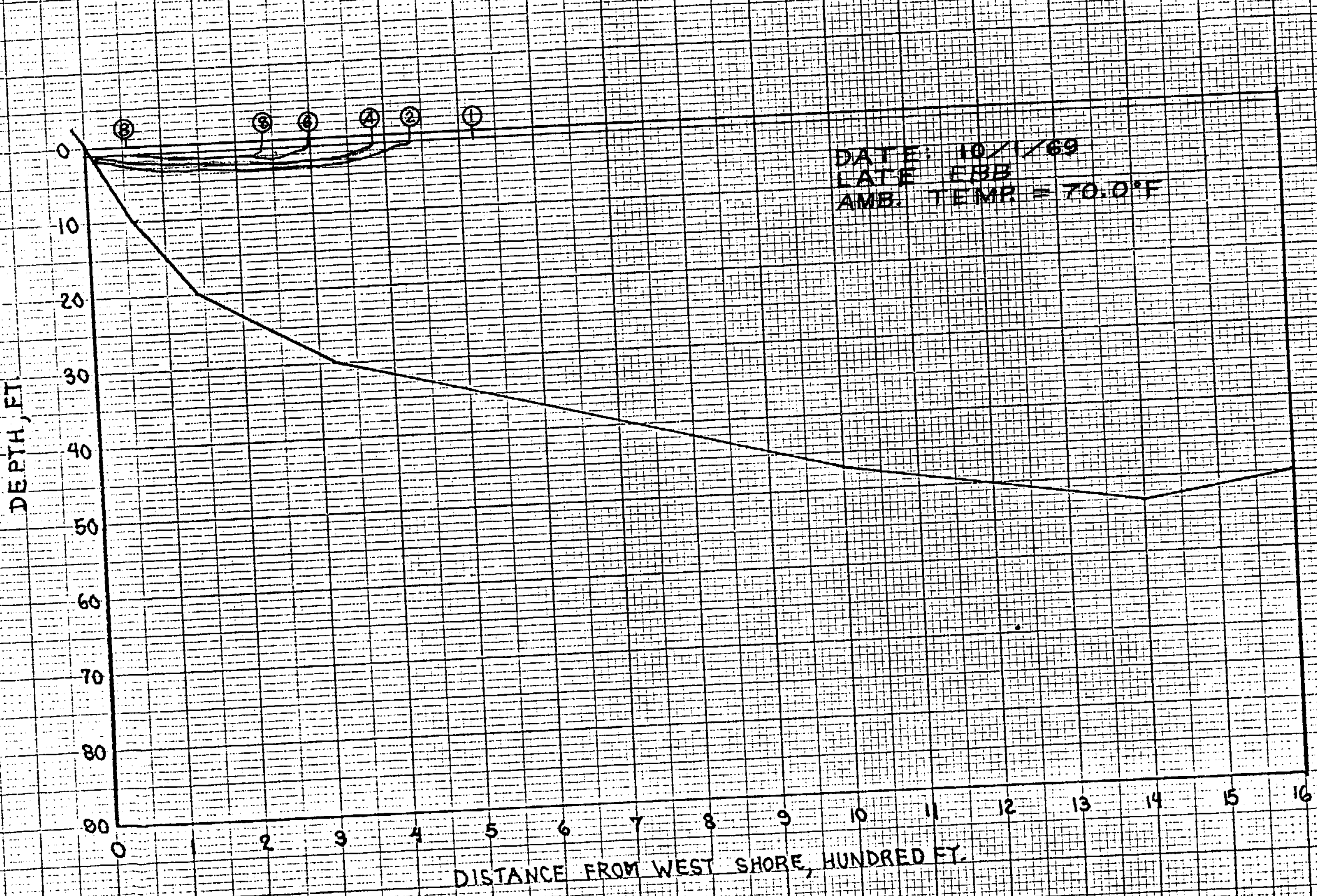


FIGURE B-105

FIGURE B-106

HUDSON RIVER AT DANSKAMMER
3000 FT. DOWNSTREAM FROM DISCHARGE

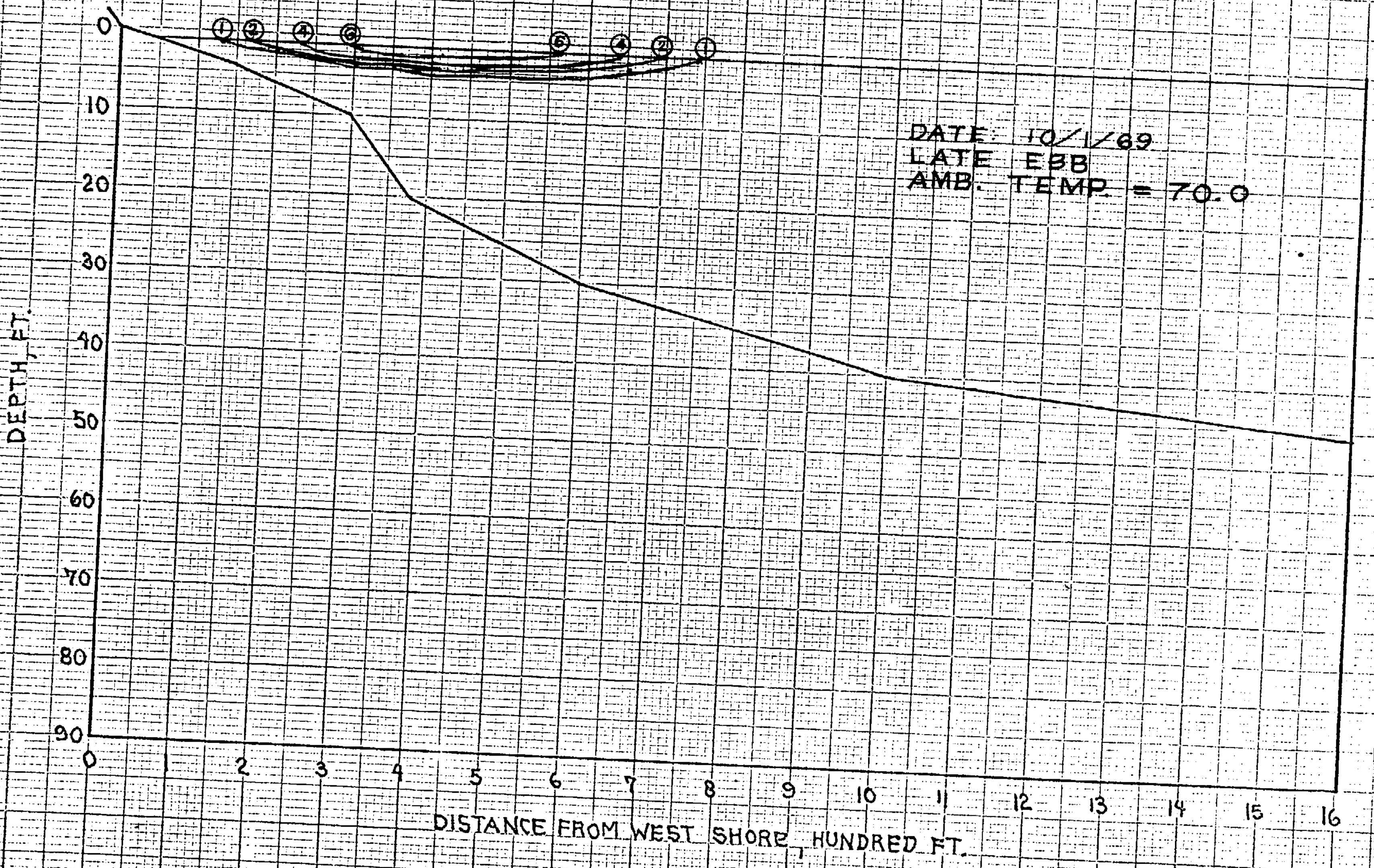
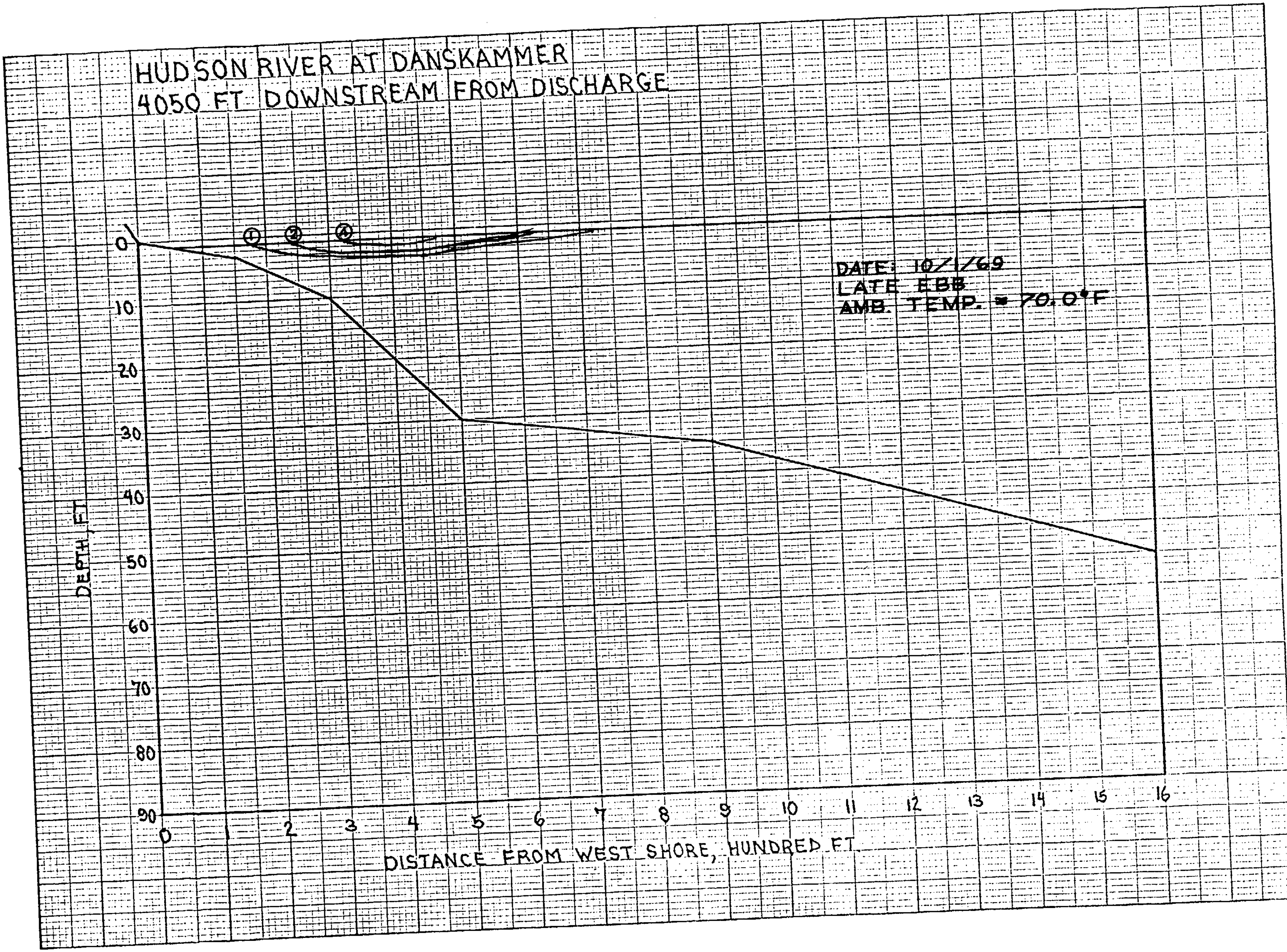
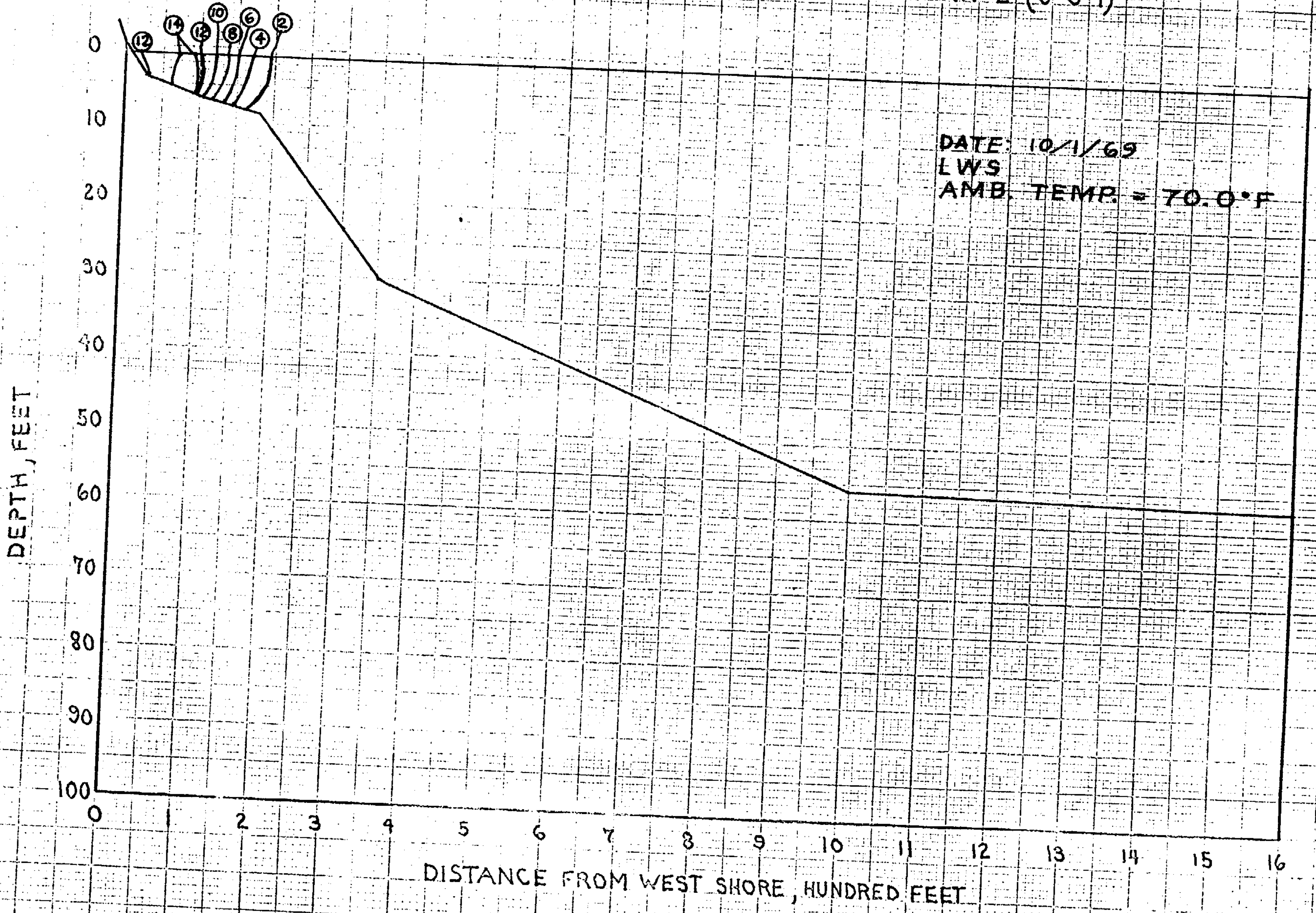


FIGURE B-107

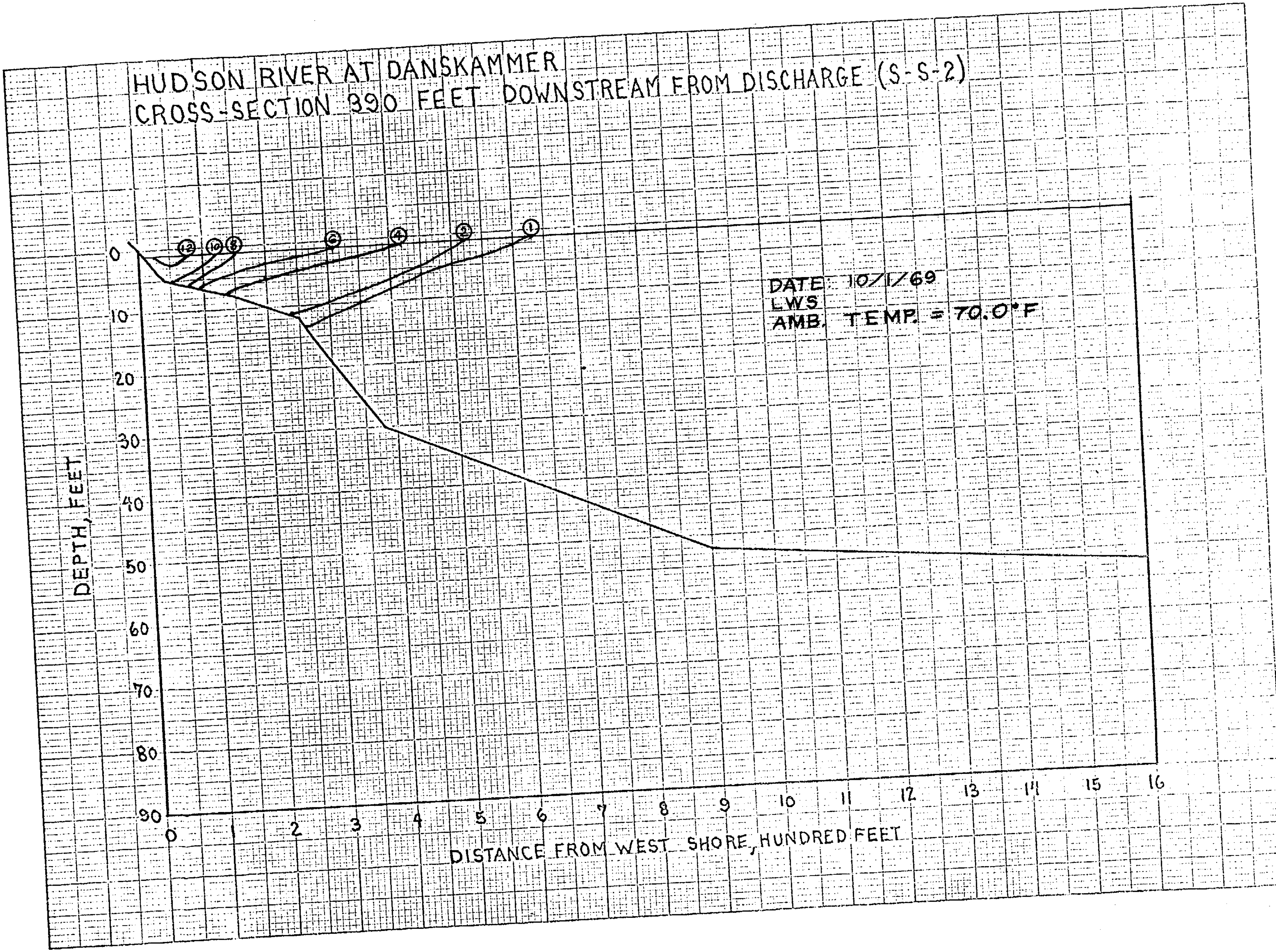

HUDSON RIVER AT DANSKAMMER
4050 FT DOWNSTREAM FROM DISCHARGE
DATE: 10/1/69
LATE EBB
AMB. TEMP. = 70.0°F
①
②
④
DEPTH, FT
0
10
20
30
40
50
60
70
80
90
DISTANCE FROM WEST SHORE, HUNDRED FT
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)



DATE: 10/1/69
LWS
AMB. TEMP. = 70.0°F

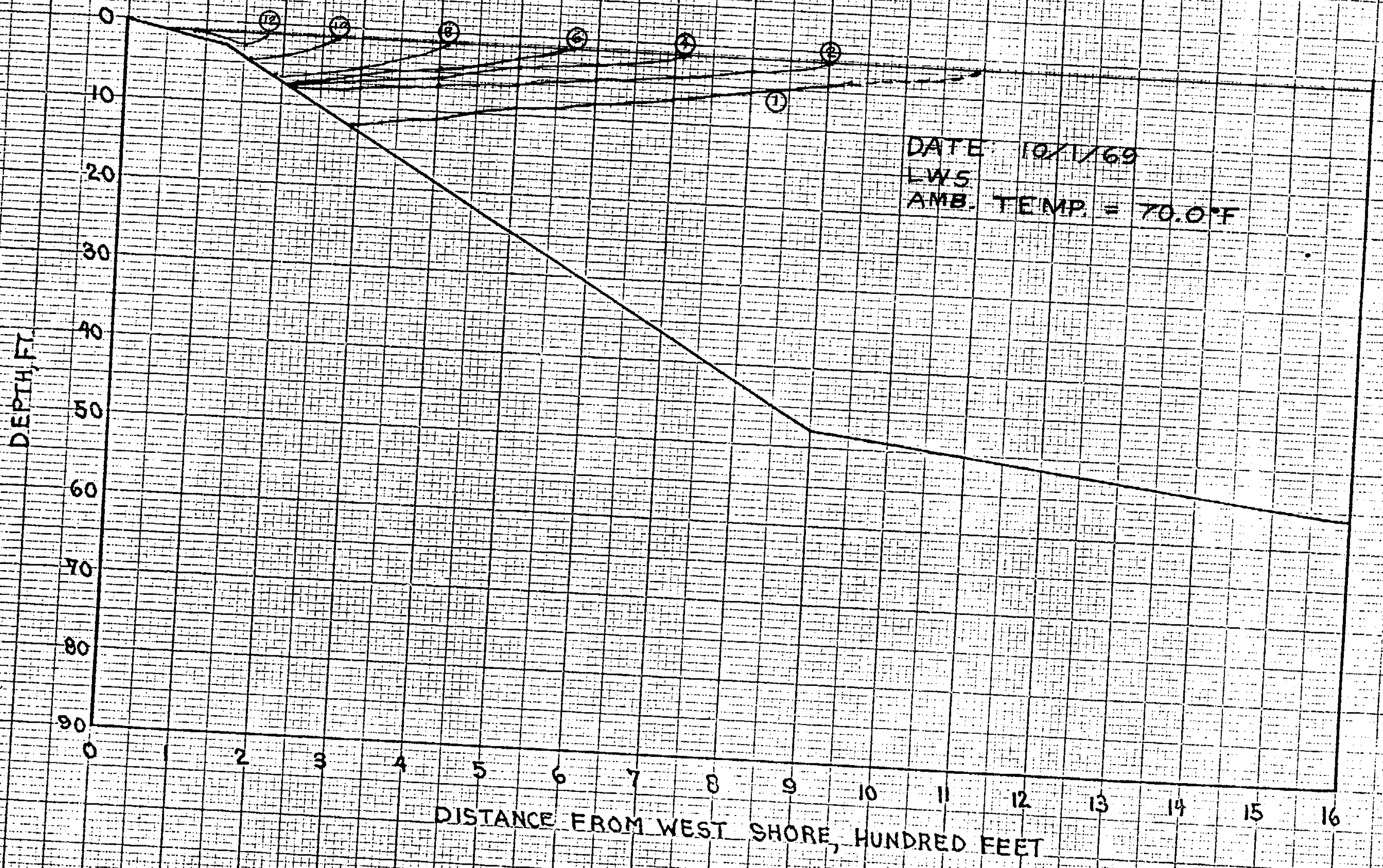
FIGURE B-108


HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)

DATE 10/1/69
LWS
AMB. TEMP. = 70.0°F

FIGURE B-109

HUDSON RIVER AT DANSKAMMER
800 FT. DOWNSTREAM FROM DISCHARGE (S-S-3)



DATE: 10/1/69
LWS
AMB. TEMP. = 70.0°F

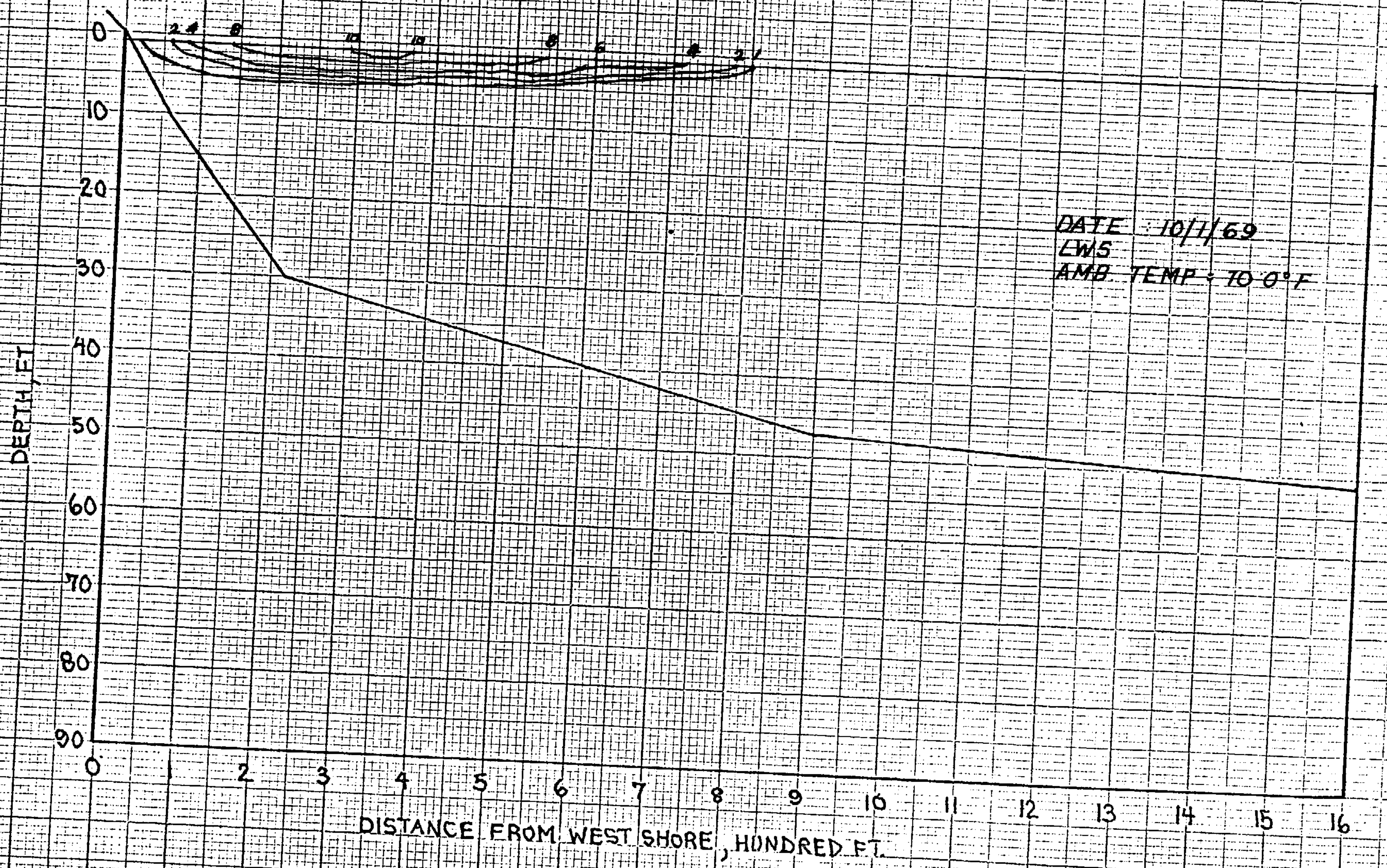
FIGURE B-110

FIGURE B-111

HUDSON RIVER AT DANSKAMMER

CROSS-SECTION 1450 Ft. DOWNSTREAM FROM DISCHARGE (I-I)

HUDSON RIVER AT DANSKAMMER
2450 FT DOWNSTREAM FROM DISCHARGE

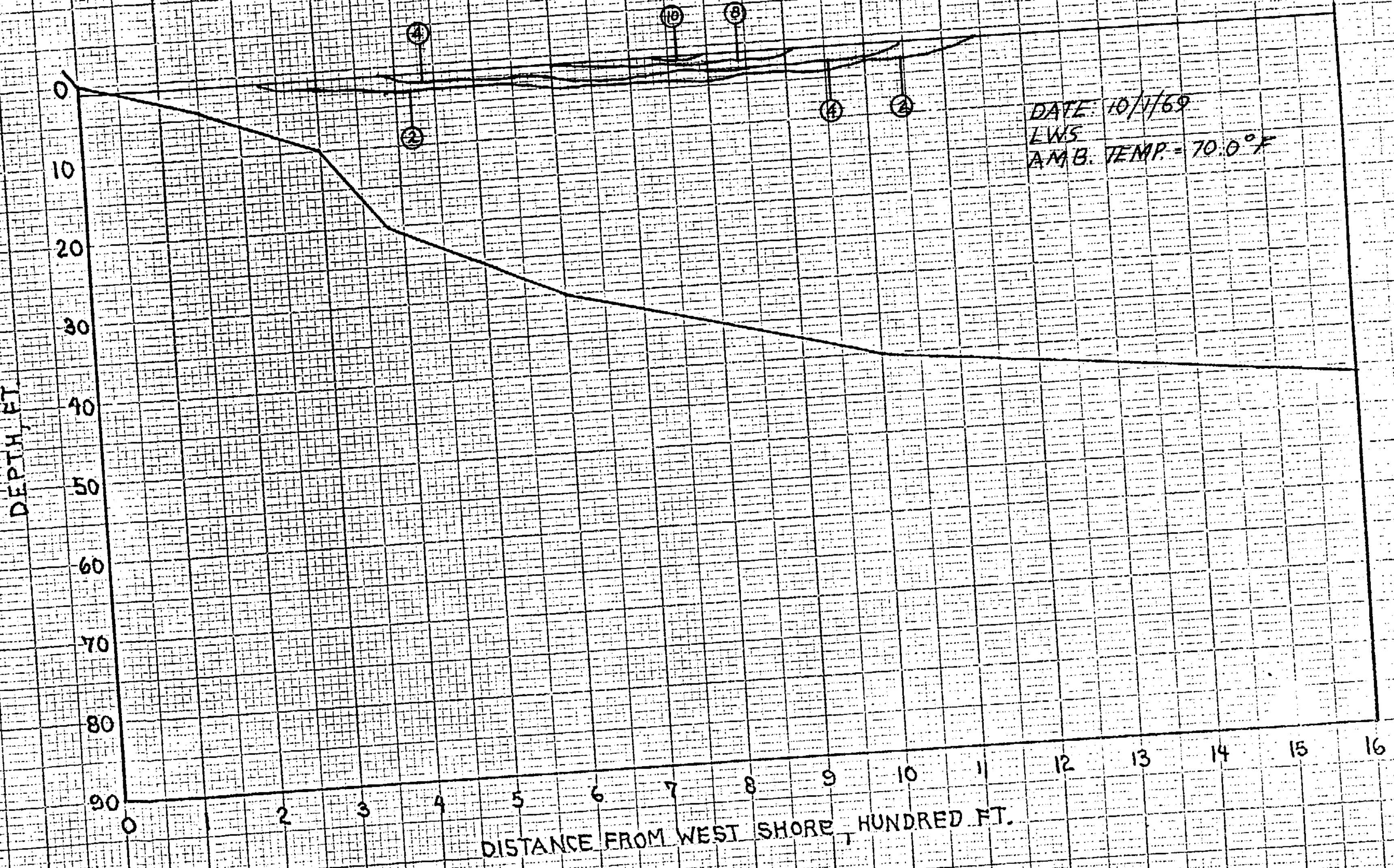


DATE 10/1/69
LWS
AMB. TEMP: 70.0°F

FIGURE B-112

HUDSON RIVER AT DANSKAMMER

CROSS-SECTION 3000 FT. DOWNSTREAM FROM DISCHARGE (5-5-4)



DATE: 10/1/69
LWS
AMB. TEMP. = 70.0°F

FIGURE B-113

HUDSON RIVER AT DANSKAMMER
4050 FT DOWNSTREAM FROM DISCHARGE

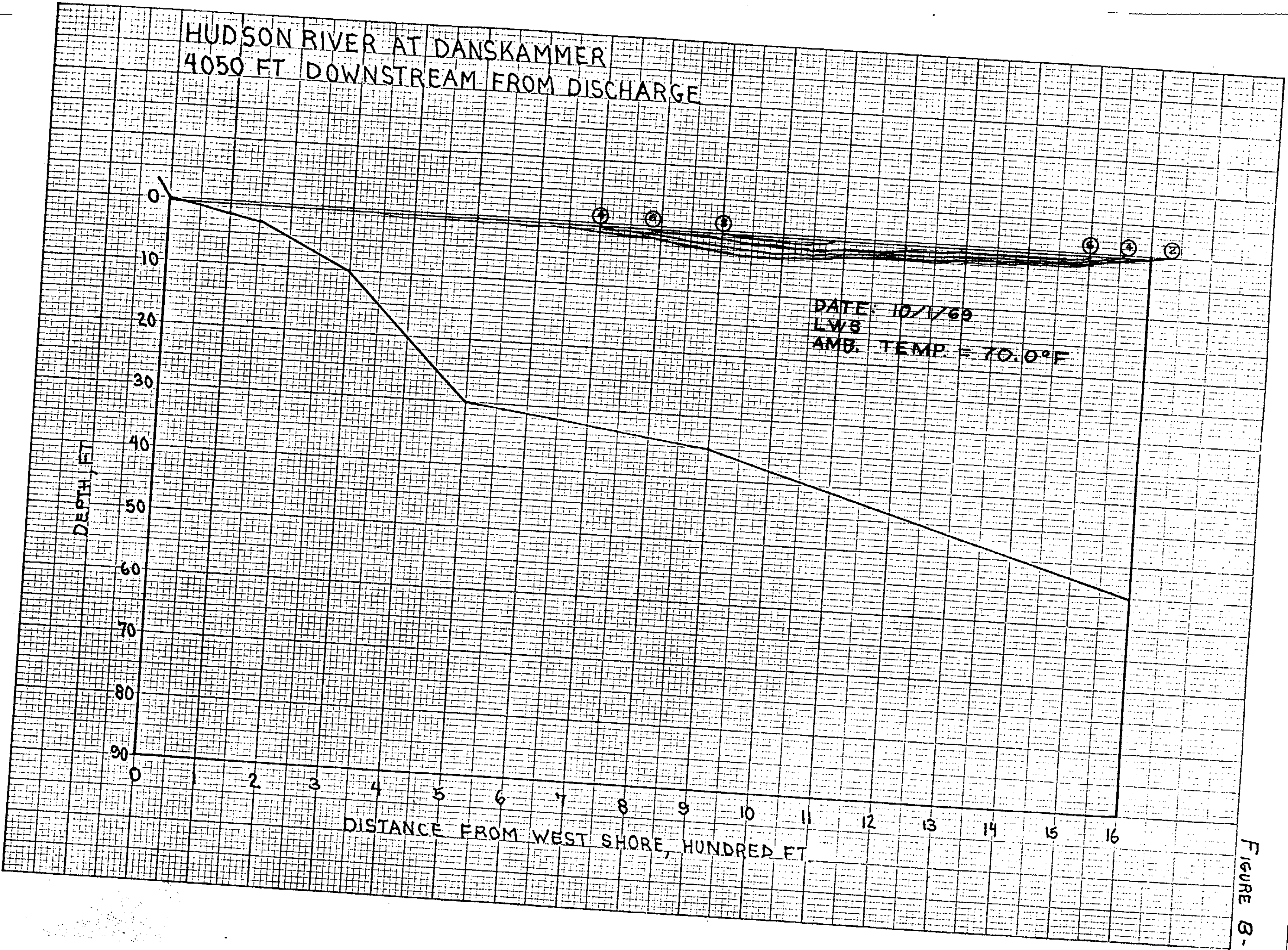
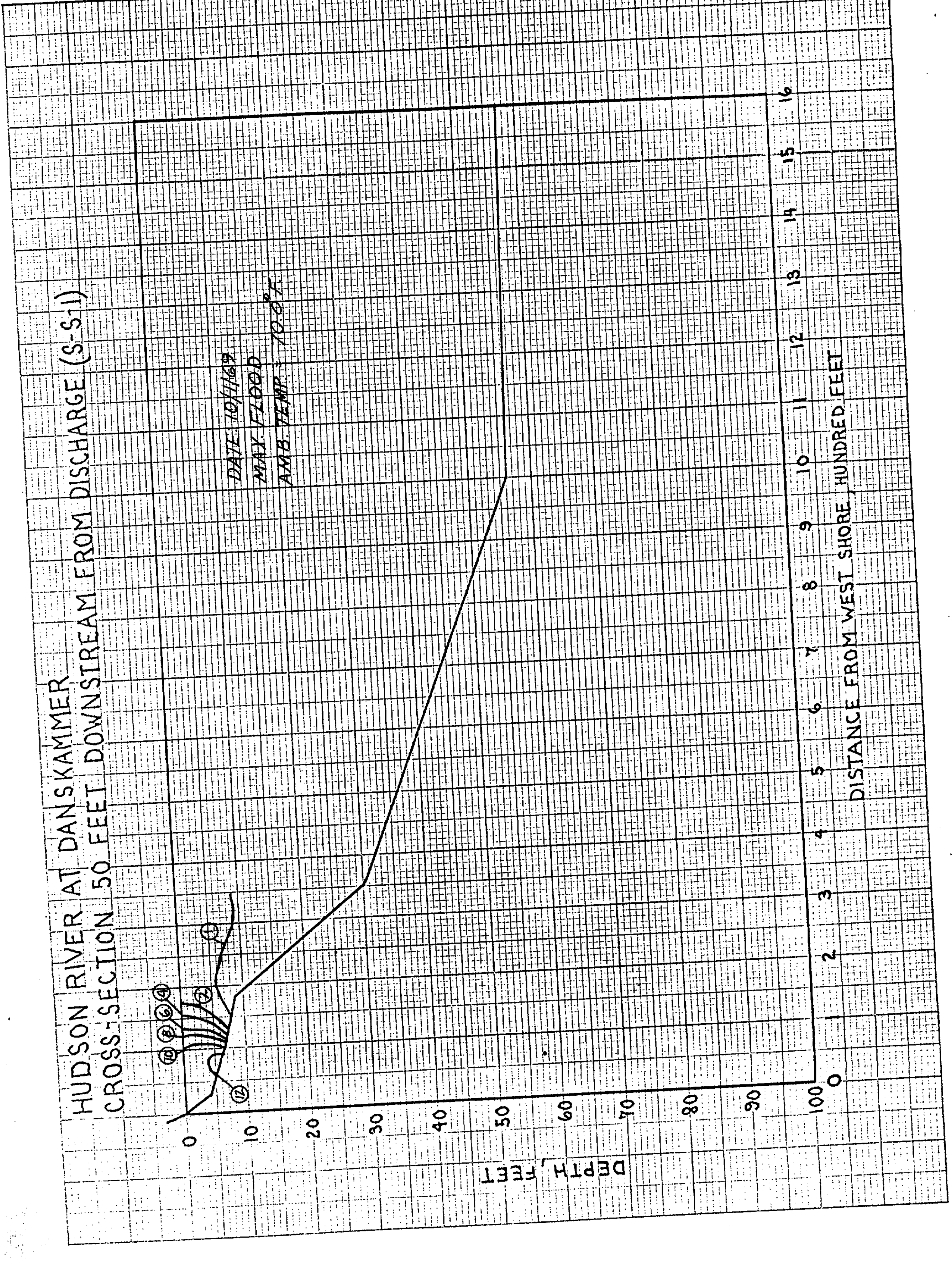


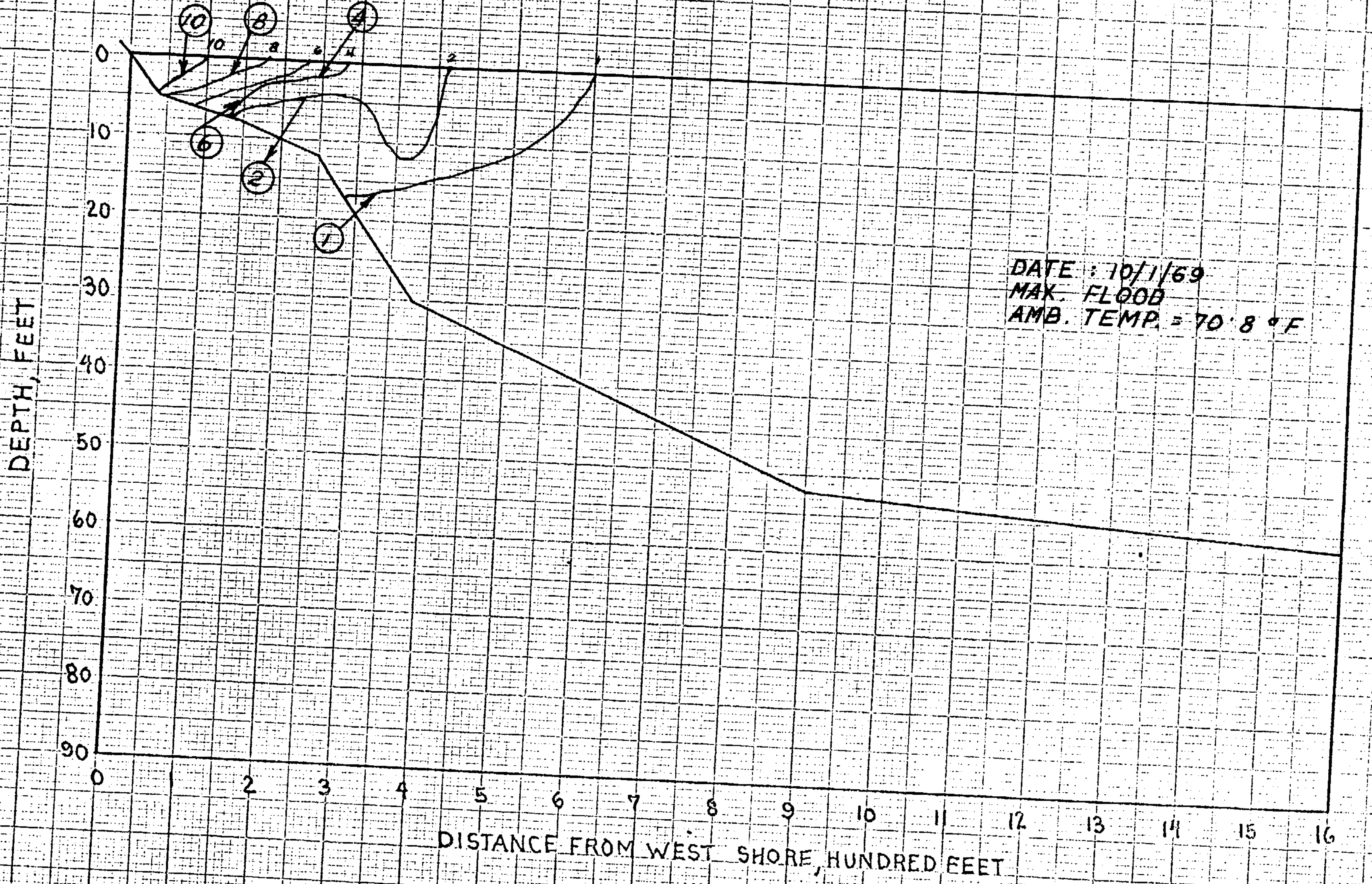
FIGURE B-114



HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)

DATE 10/1/69
MAX FLOOD
AMB TEMP: 70.6°F

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)



DATE : 10/1/69
MAX. FLOOD
AMB. TEMP. = 70.8 °F

FIGURE B-116

HUDSON RIVER AT DANSKAMMER
800 FT. DOWNSTREAM FROM DISCHARGE (S-S-3)

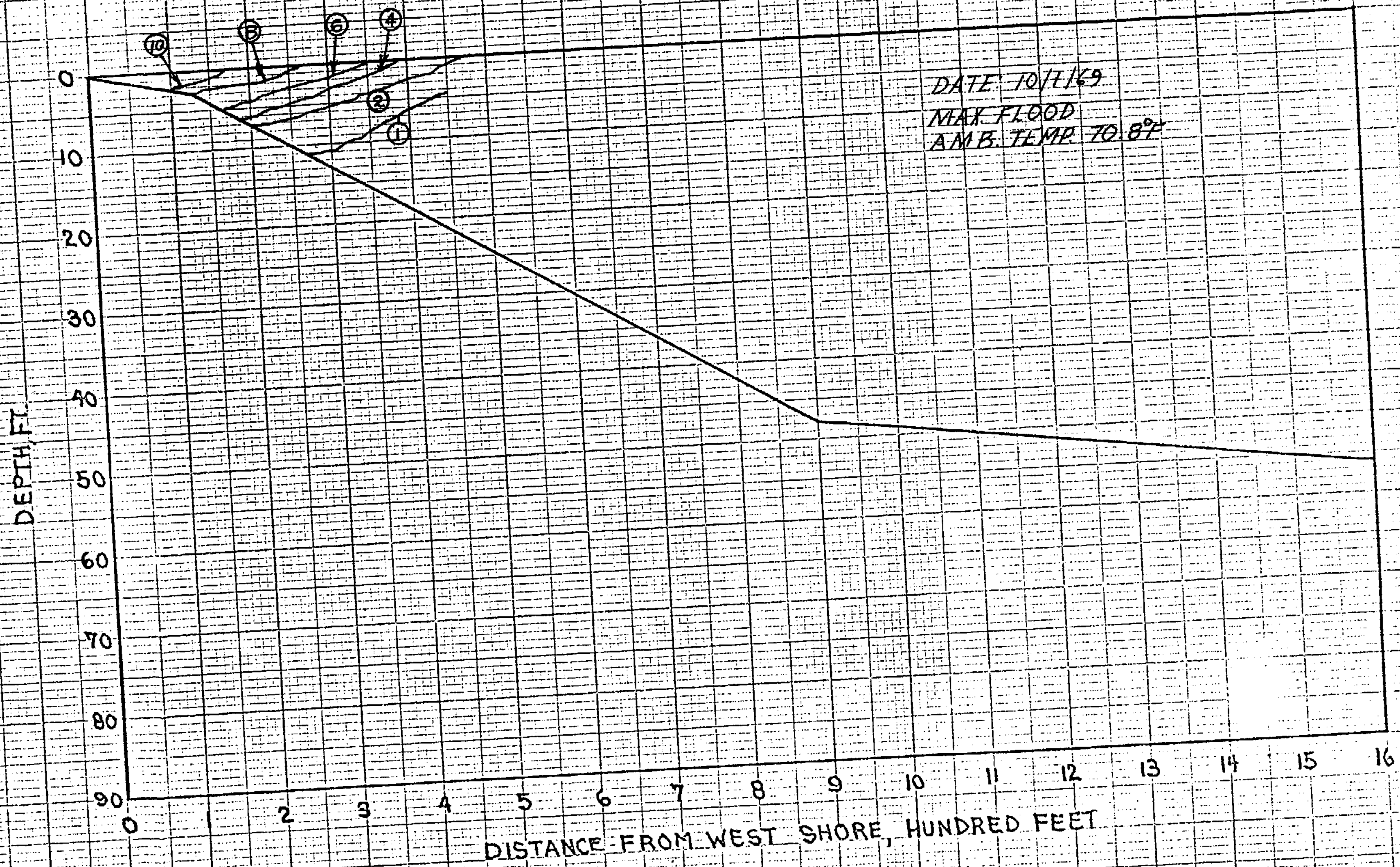


FIGURE B-117

HUDSON RIVER AT DANSKAMMER
1300 FT. DOWNSTREAM FROM DISCHARGE (I-I)

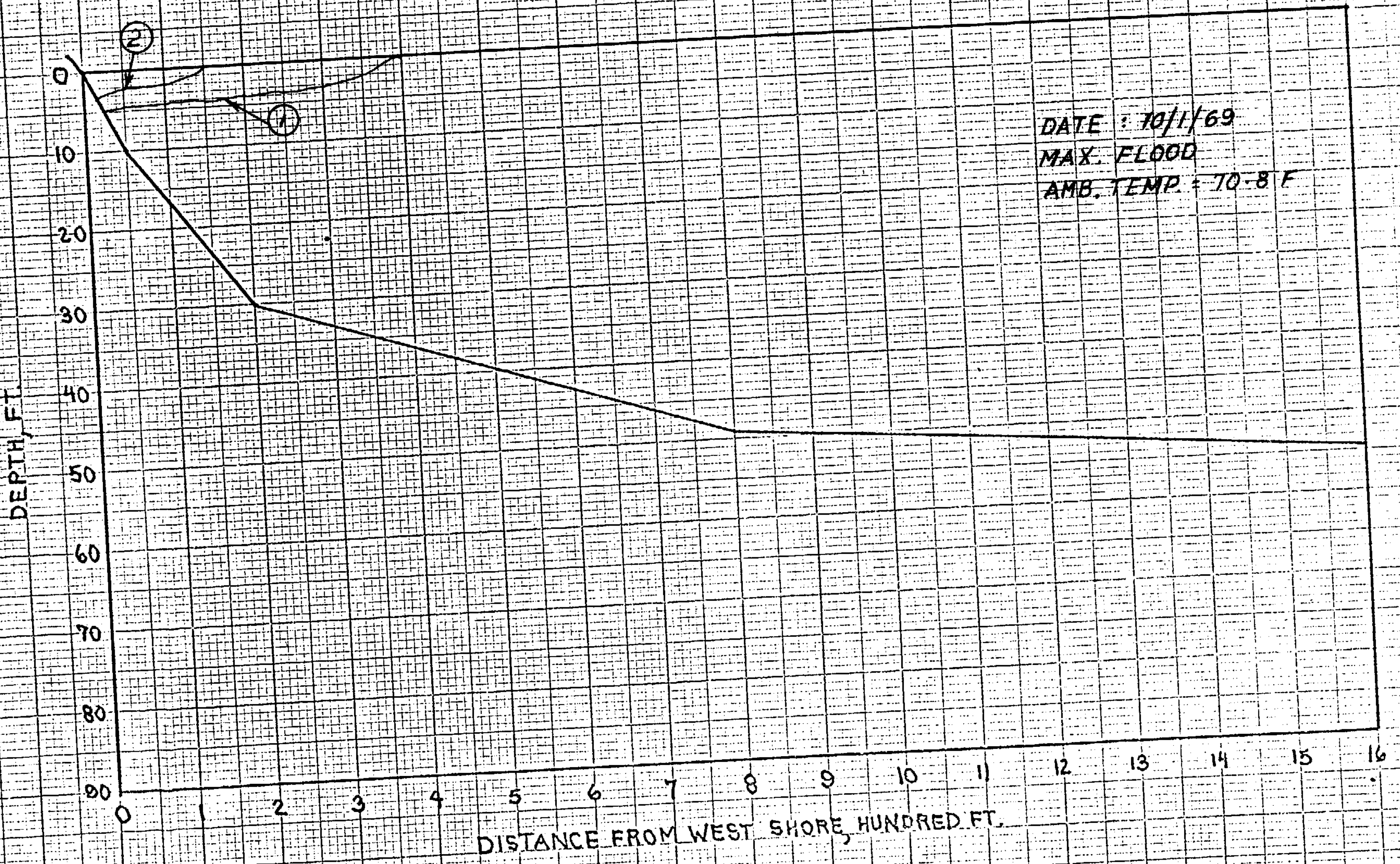


FIGURE B-118

HUDSON RIVER AT DANSKAMMER
1700 FT DOWNSTREAM FROM DISCHARGE

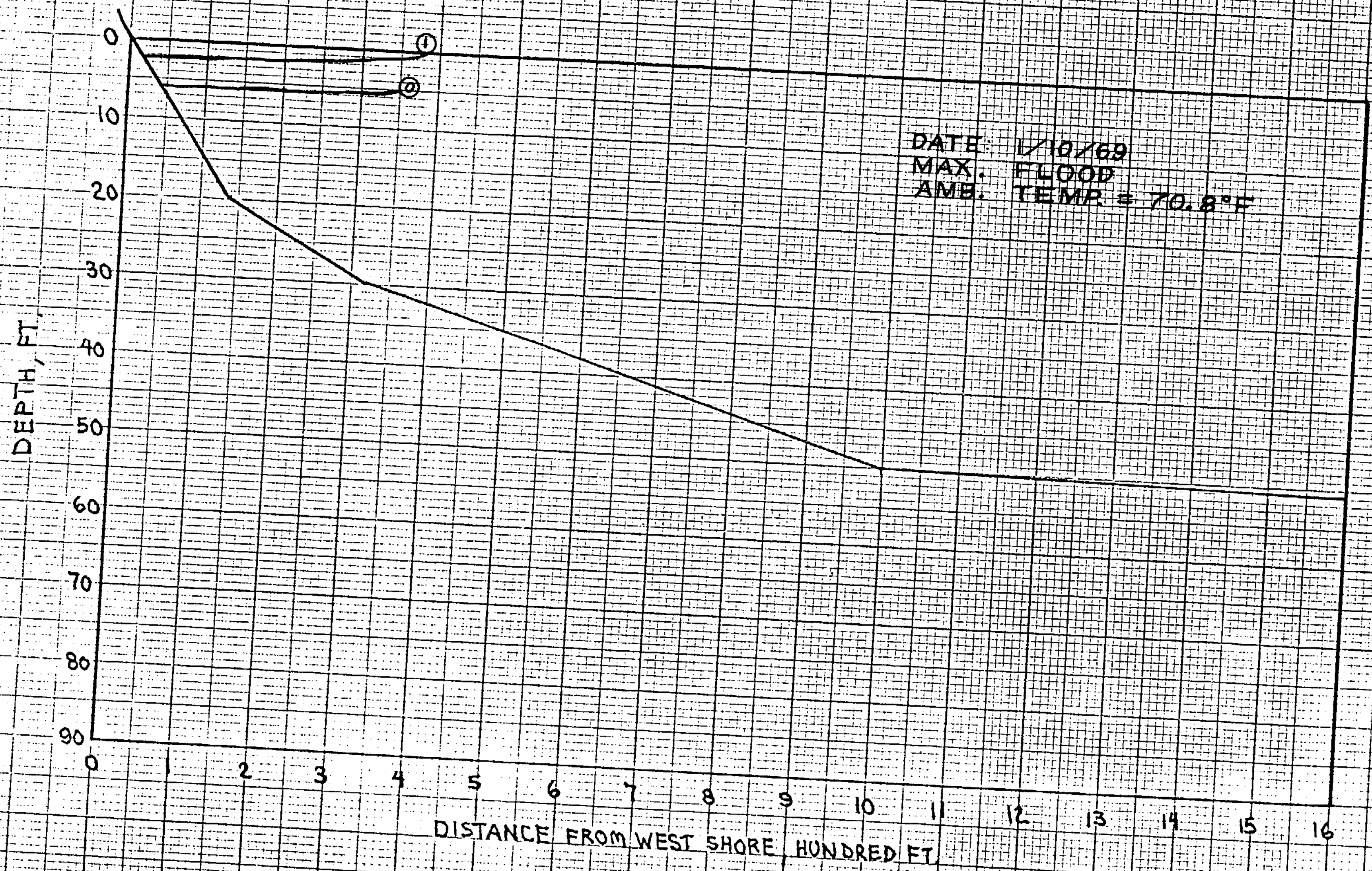
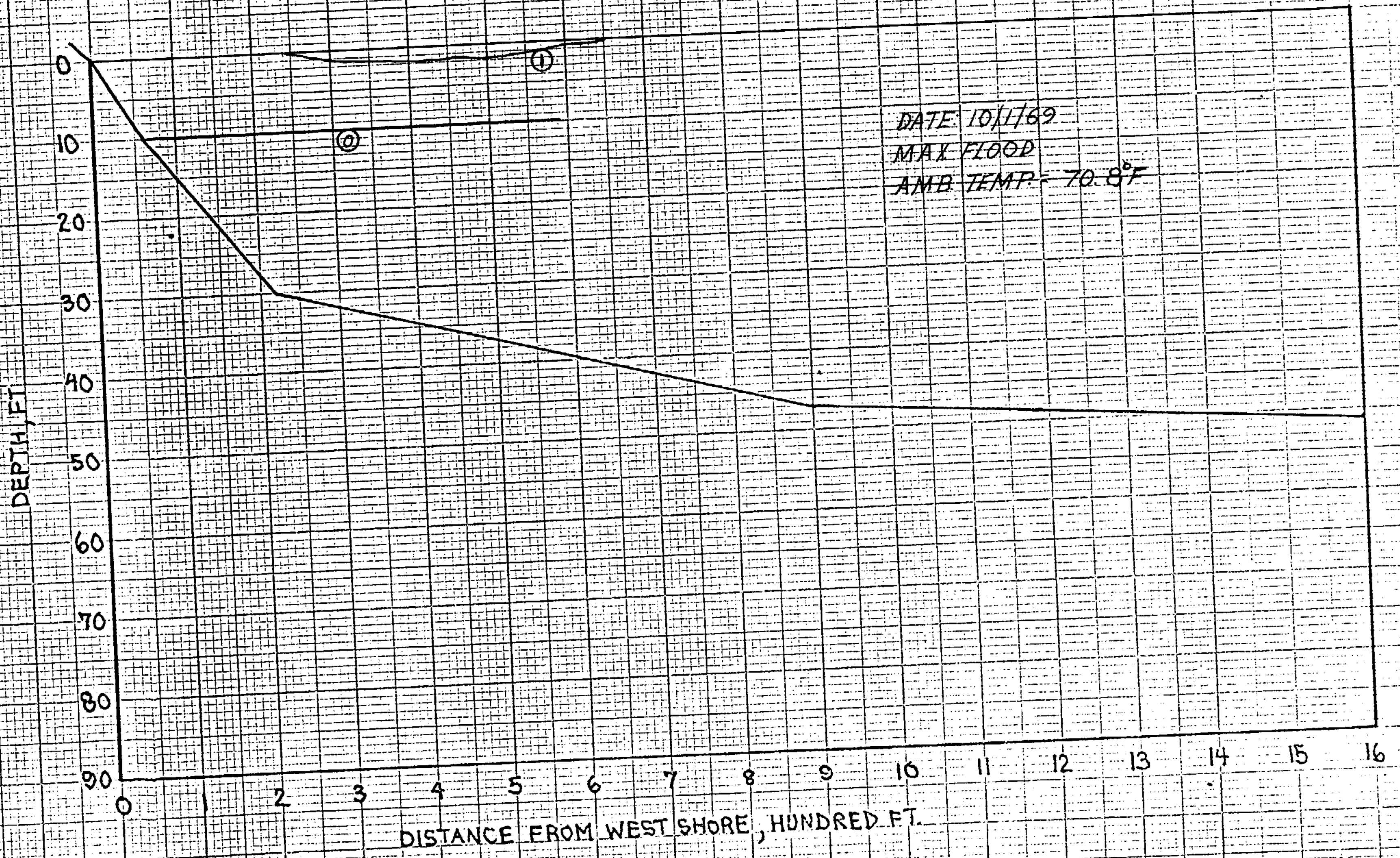


FIGURE B-119

HUDSON RIVER AT DANSKAMMER
2450 FT DOWNSTREAM FROM DISCHARGE



DATE 10/1/69
MAX FLOOD
AMB TEMP = 70.8°F

FIGURE B-120

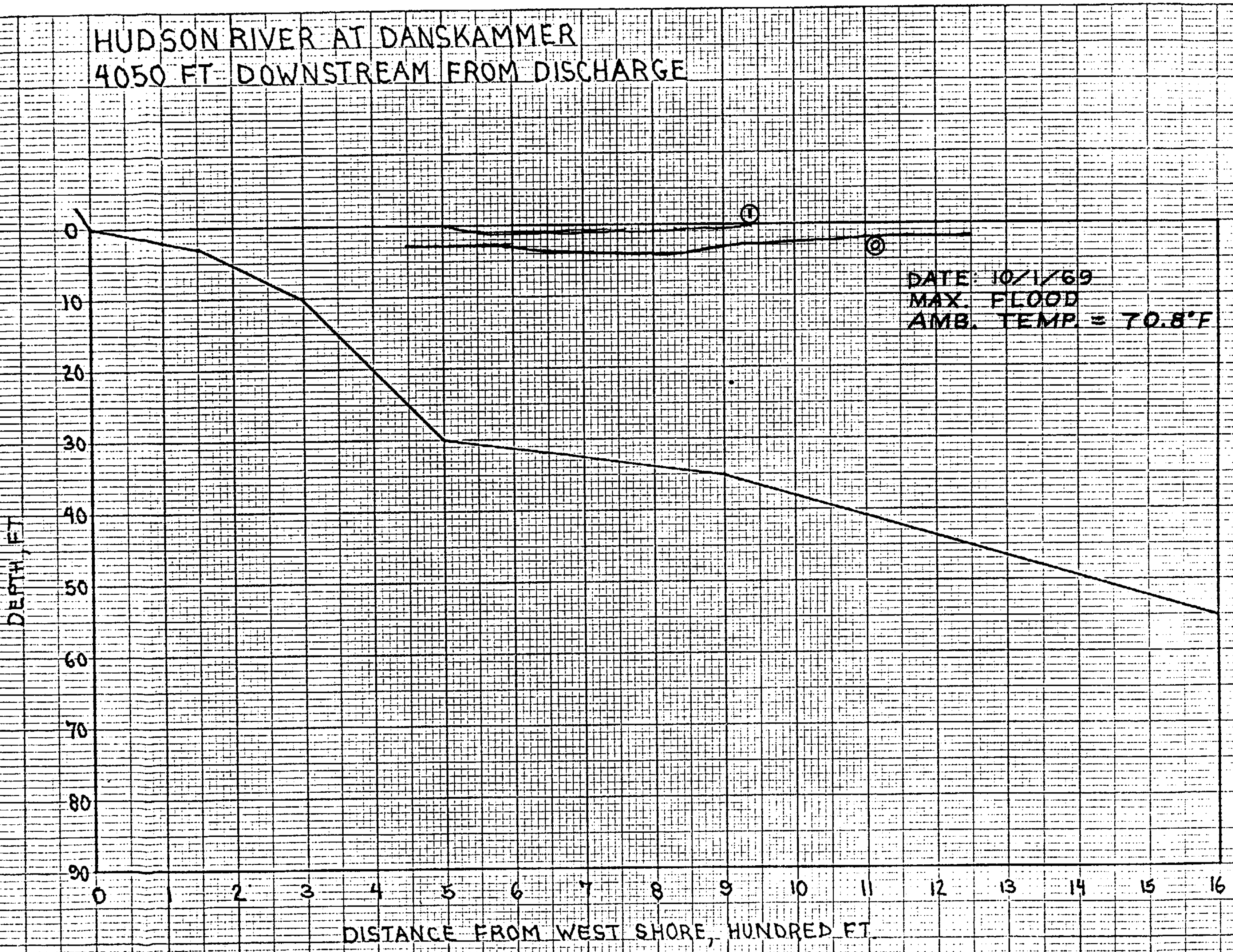

HUDSON RIVER AT DANSKAMMER
4050 FT DOWNSTREAM FROM DISCHARGE
DATE: 10/1/69
MAX. FLOOD
AMB. TEMP. = 70.8°F
①
②
DEPTH, FT
0
10
20
30
40
50
60
70
80
90
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
DISTANCE FROM WEST SHORE, HUNDRED FT

FIGURE B-122

TABLE A10

PORTION OF HUDSON RIVER AT DANSKAMMER SUBJECTED TO TEMPERATURE RISE OF 4°F OR GREATER

DATE: October 8, 1969

Total river cross sectional area at critical section - 142,000 ft.^{2}

Total river surface width at critical section* - 3,420 ft.

TIDAL CONDITION	ELECTRICAL OUTPUT (MWE)	% WIDTH	% CROSS-SECTIONAL AREA	SURFACE AREA (ACRES)	LONGITUDINAL EXTENT
Maximum Flood	271	1.0	0	4.93	1890
High Water Slack	268	13.3	0.87	20.1	2710
Maximum Ebb	258	10.4	0.32	15.9	3520

*Critical section 390 ft. south of discharge.

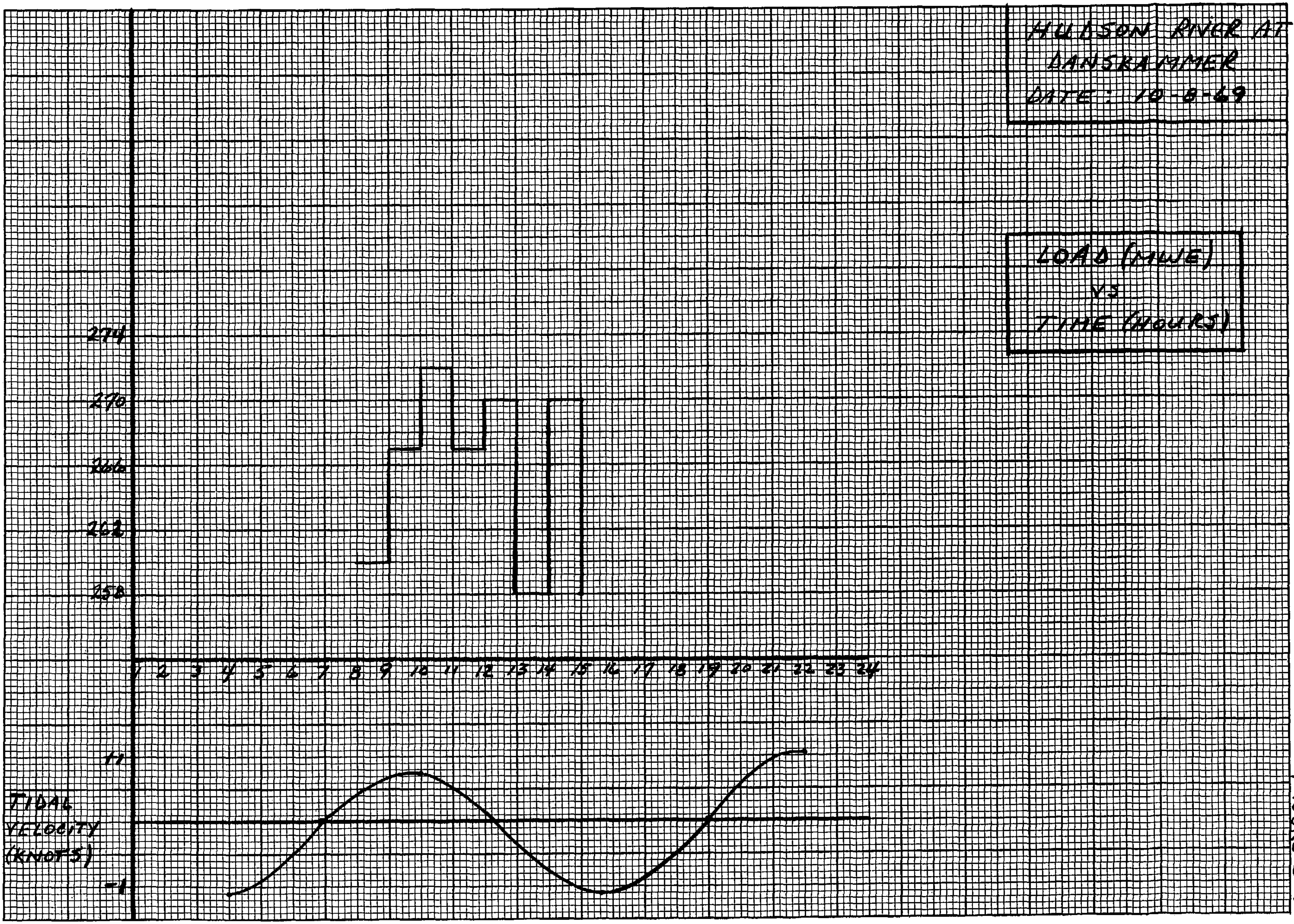

HUDSON RIVER AT
DANSKAMMER
DATE: 10-8-69
LOAD (MWE)
VS
TIME (HOURS)
274
270
266
262
258
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
+1
-1
TIDAL
VELOCITY
(KNOTS)

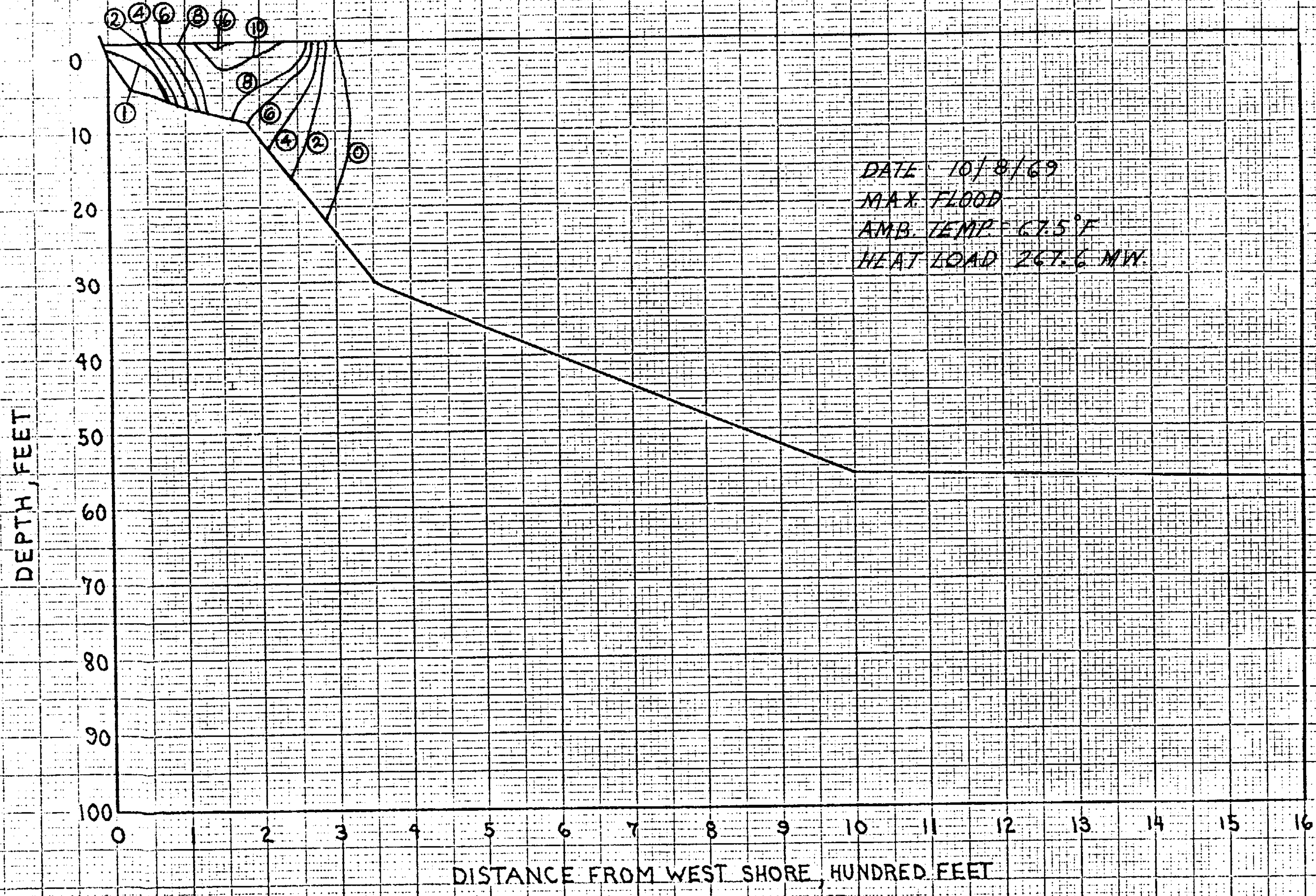
FIGURE B-123

LARGE DOCUMENT

LARGE
DOCUMENT

LARGE
DOCUMENT

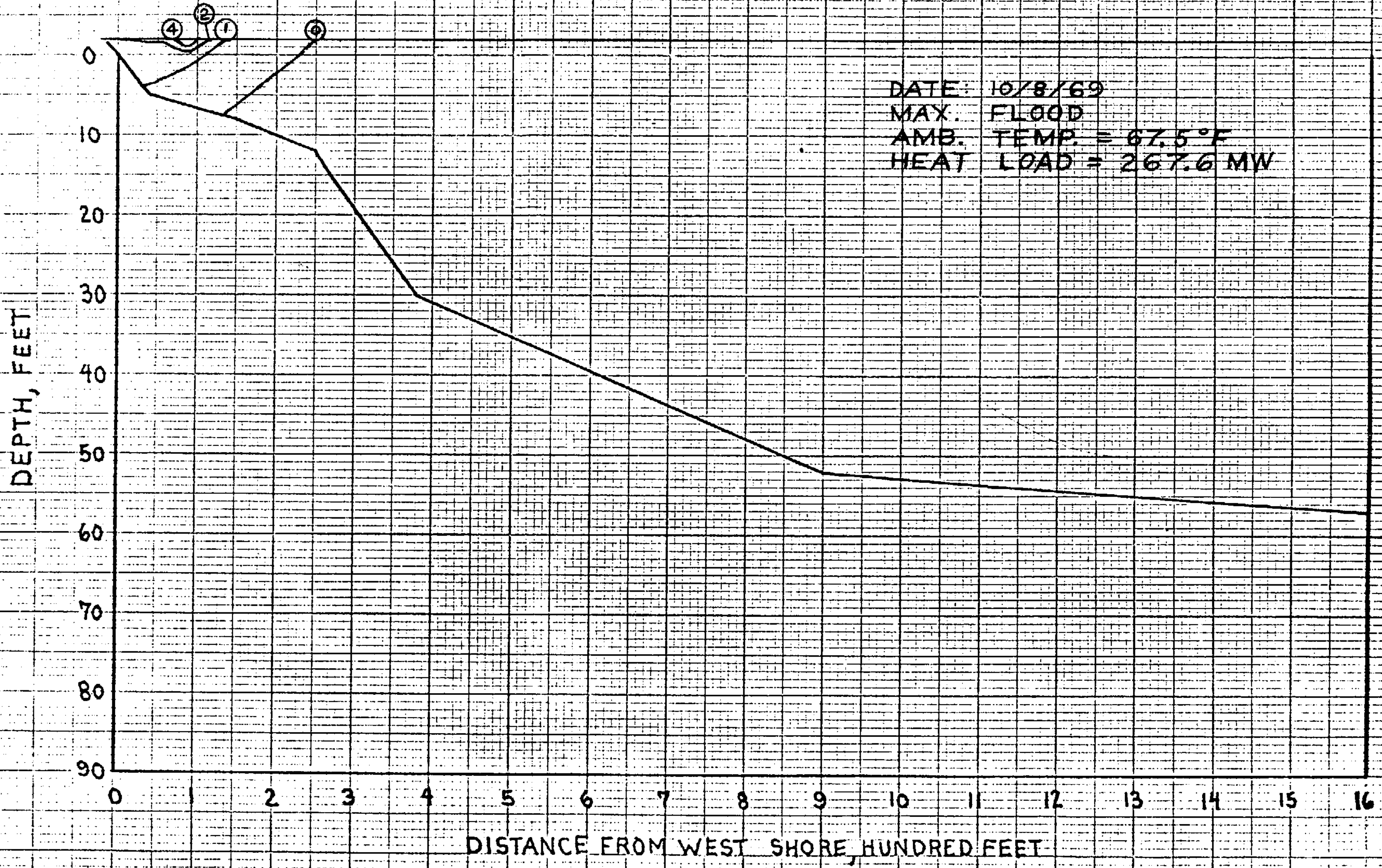
HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)



DATE 10/8/69
MAX. FLOOD
AMB. TEMP. 67.5°F
HEAT LOAD 267.6 MW.

FIGURE B-127

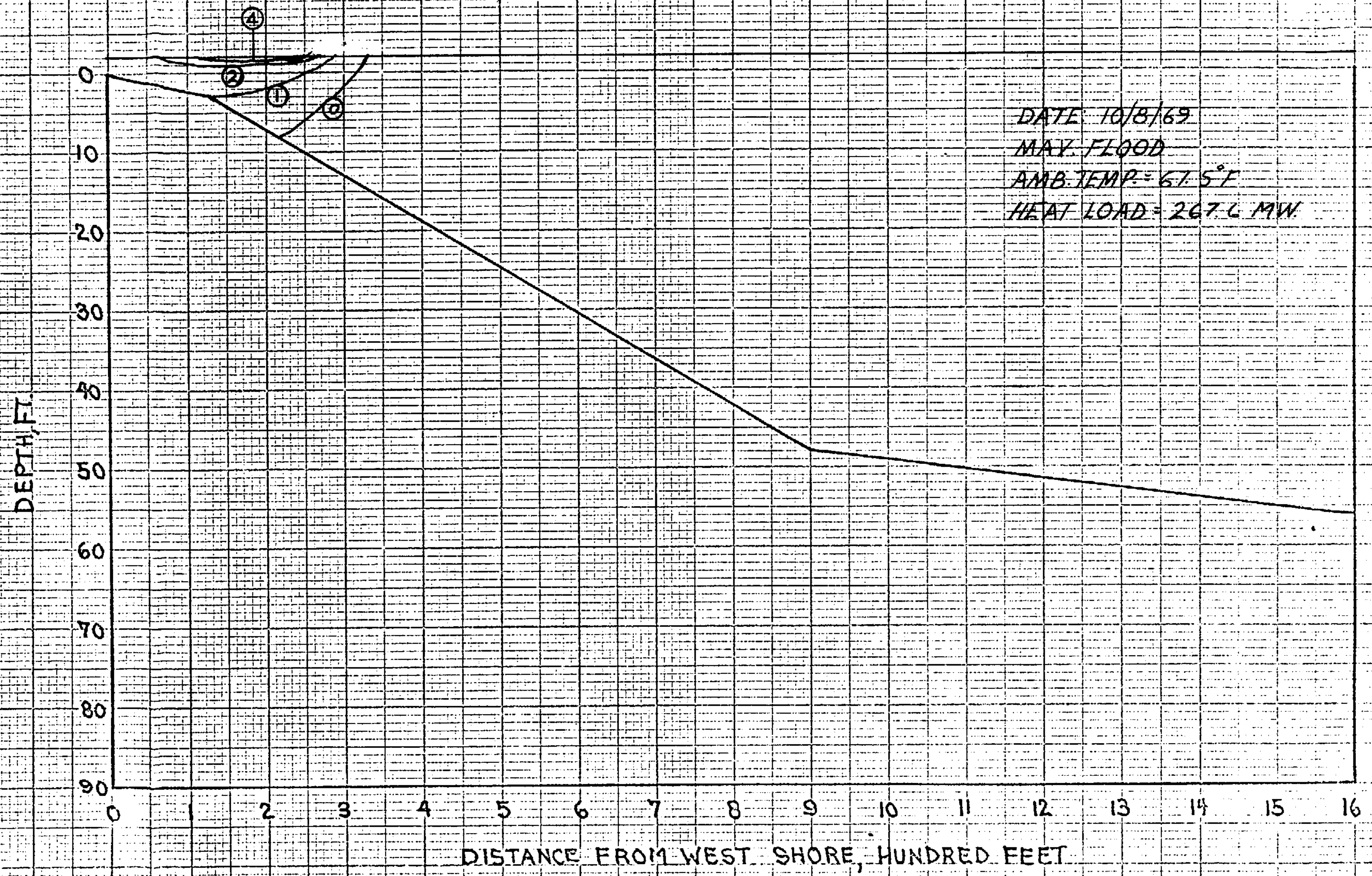
HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)



DATE: 10/8/69
MAX. FLOOD
AMB. TEMP. = 67.5°F
HEAT LOAD = 267.6 MW

FIGURE B-128

HUDSON RIVER AT DANSKAMMER
800 FT. DOWNSTREAM FROM DISCHARGE (S-S-3)

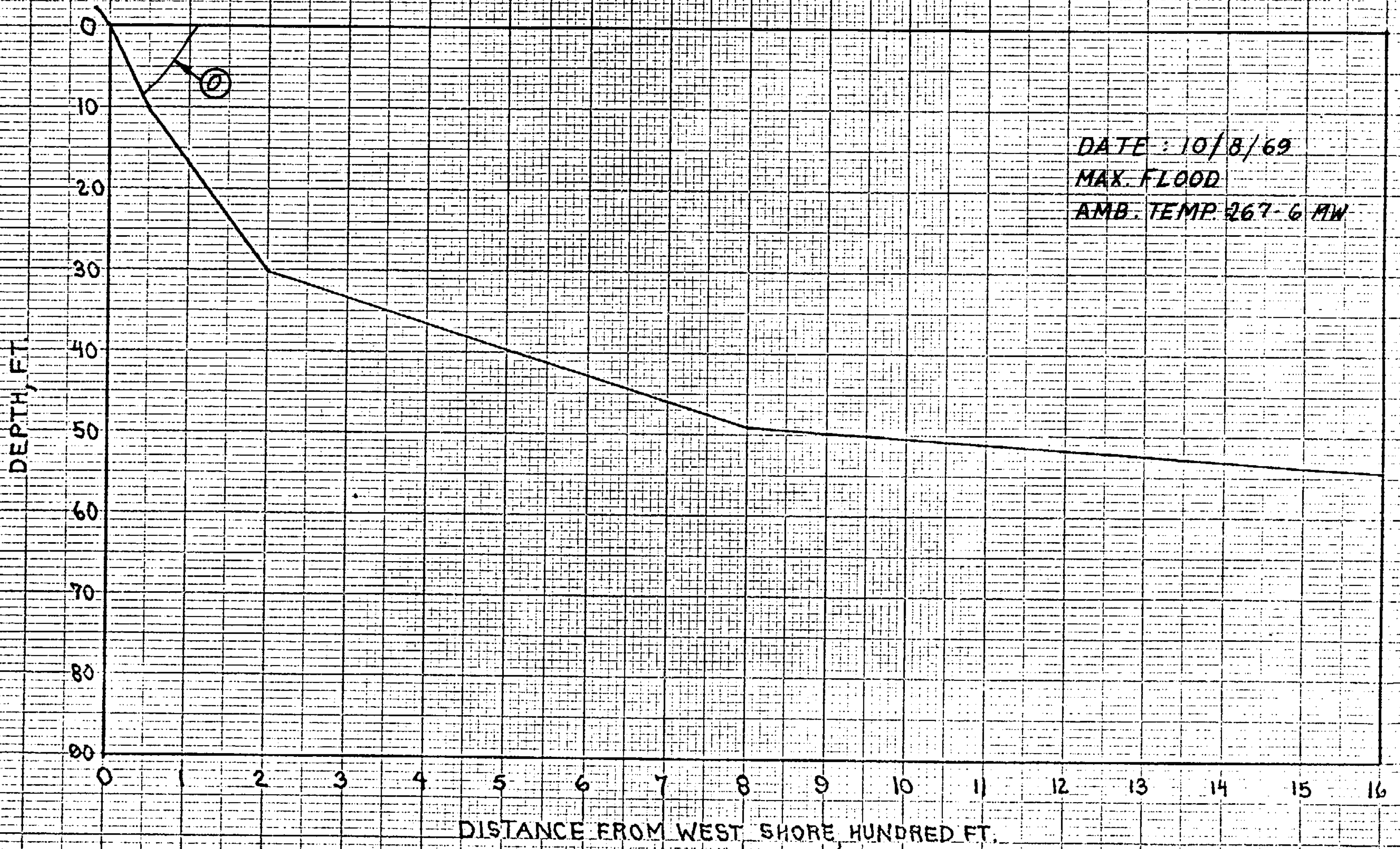


DATE: 10/8/69
MAX. FLOOD
AMB. TEMP. = 67.5°F
HEAT LOAD = 267.6 MW.

FIGURE B-129

FIGURE B-130

HUDSON RIVER AT DANSKAMMER
1300 FT. DOWNSTREAM FROM DISCHARGE (I-I)



DATE: 10/8/69
MAX. FLOOD
AMB. TEMP 267-6 MW

HUDSON RIVER AT DANSKAMMER
1700 FT DOWNSTREAM FROM DISCHARGE

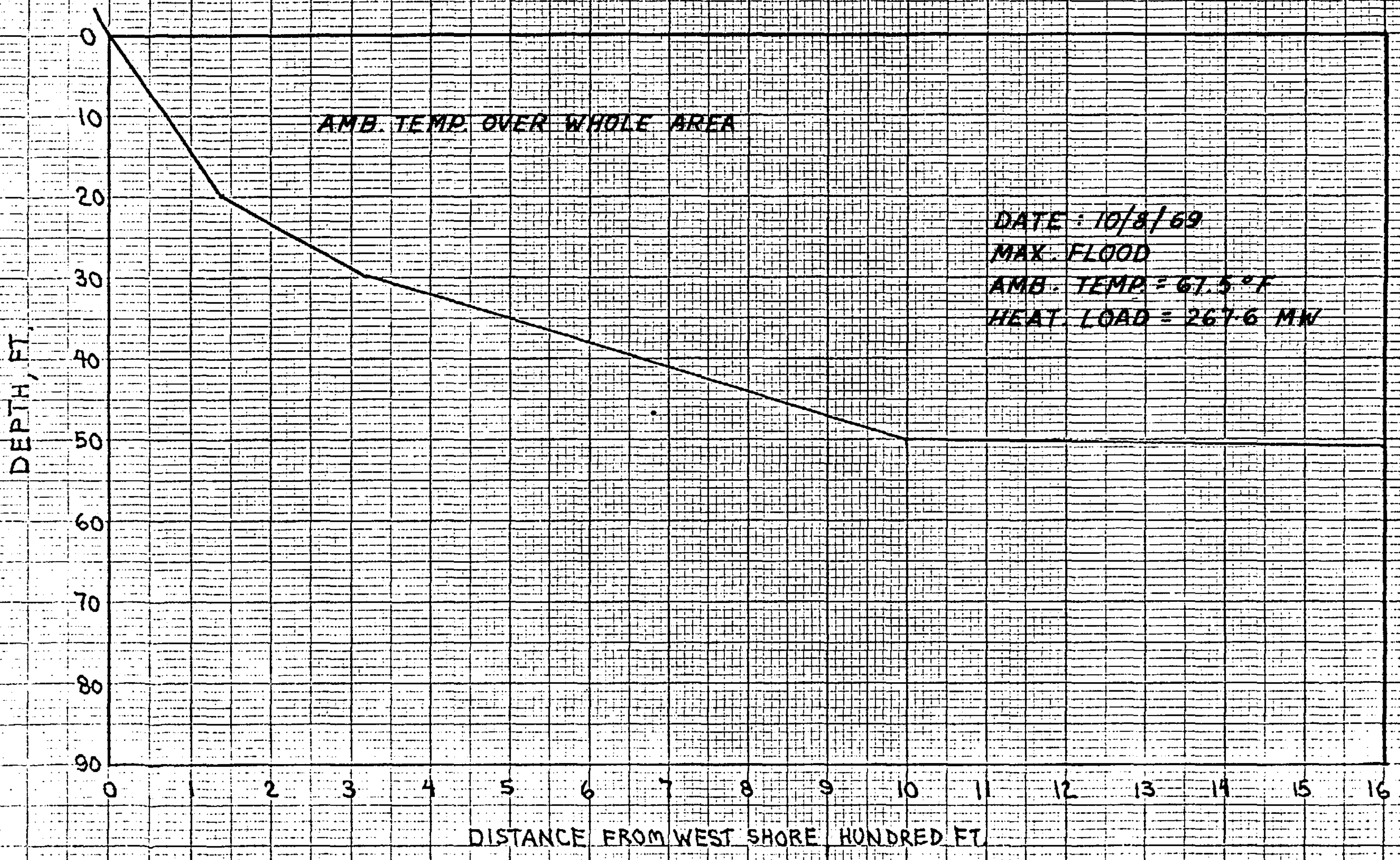
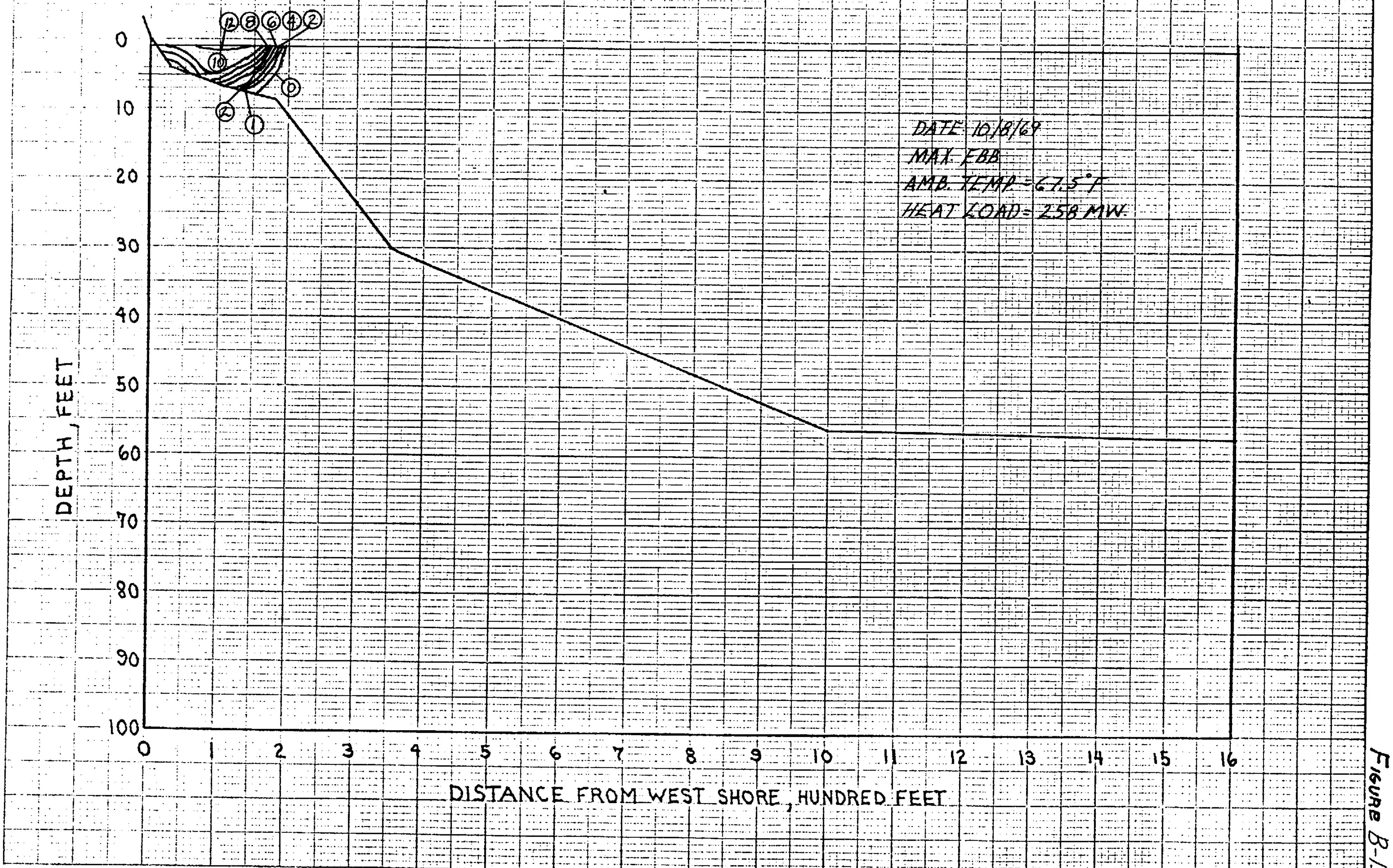


FIGURE B-131

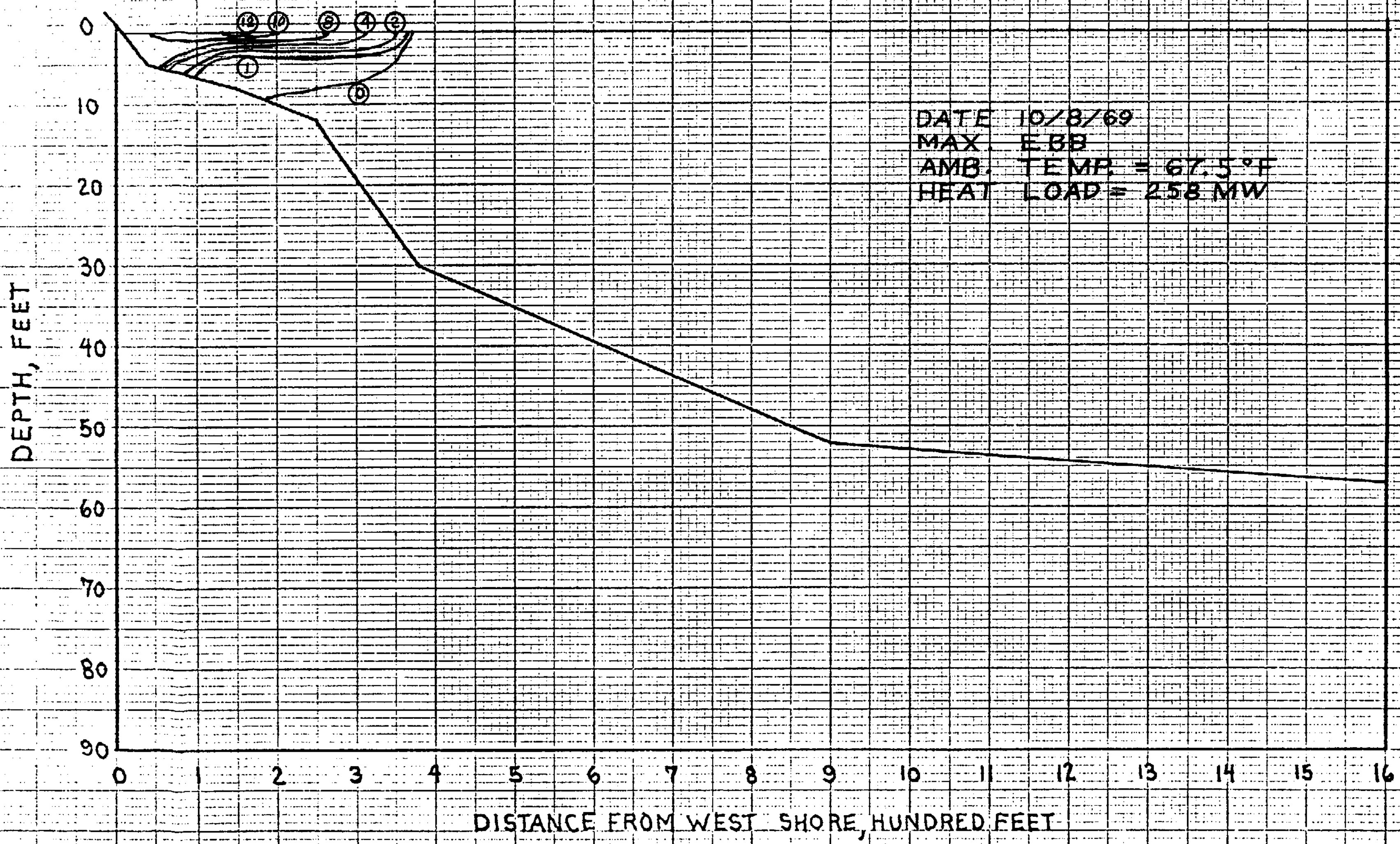
HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)



DATE 10/18/69
MAX. EBB
AMB. TEMP = 67.5°F
HEAT LOAD = 258 MW.

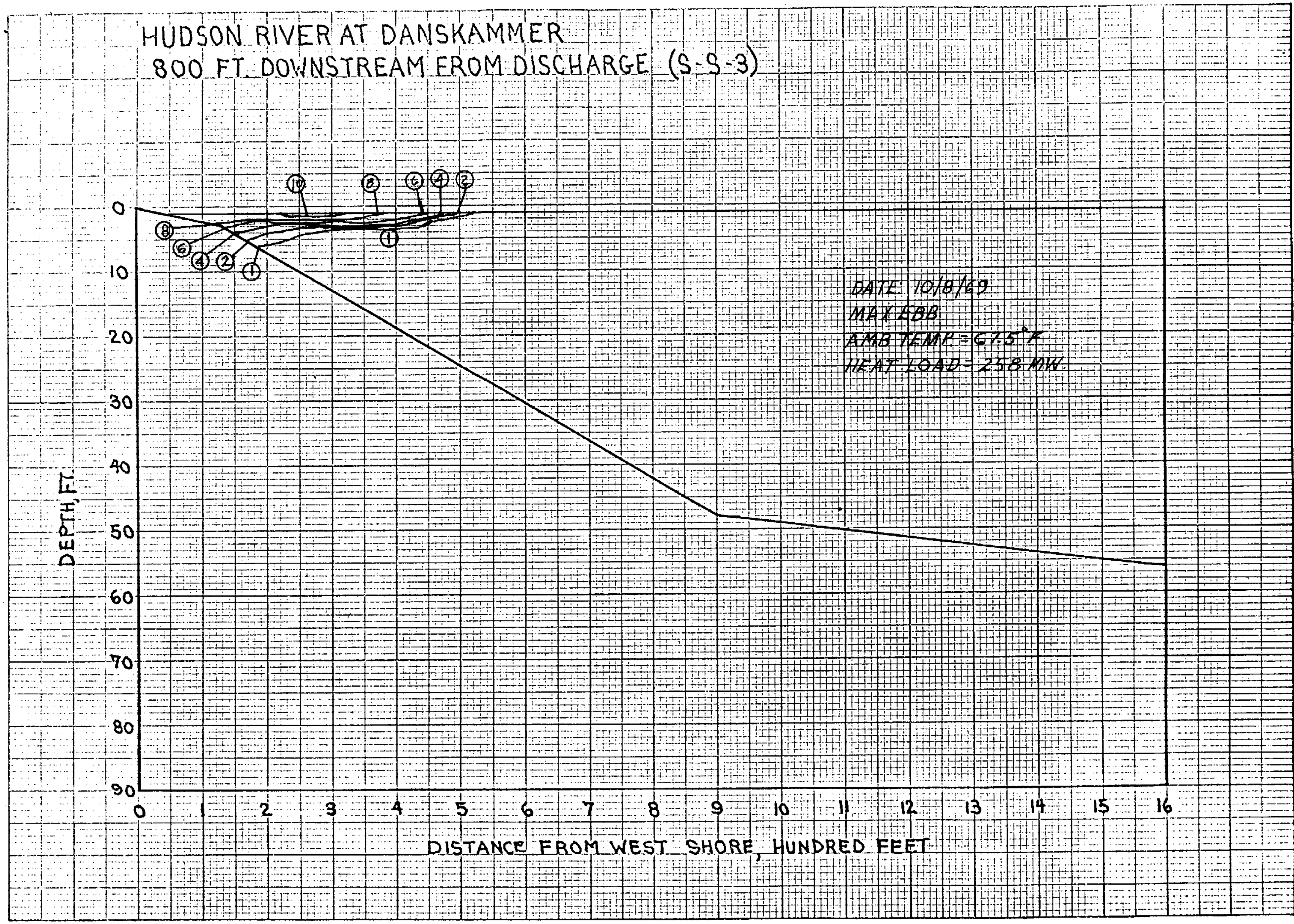
FIGURE B-132

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)



DATE 10/8/69
MAX. EBB
AMB. TEMP. = 67.5°F
HEAT LOAD = 258 MW

FIGURE B-133

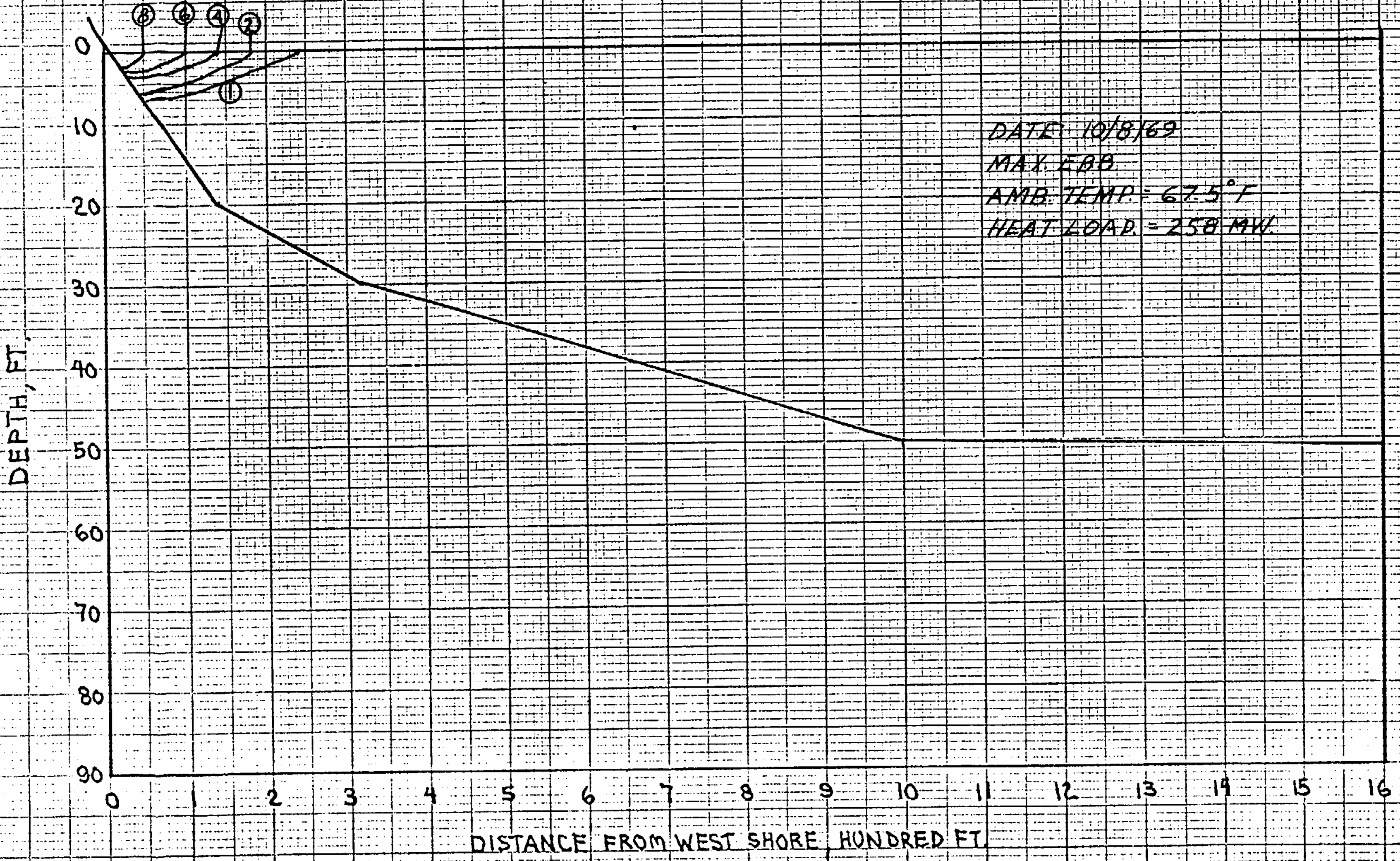


HUDSON RIVER AT DANSKAMMER
800 FT. DOWNSTREAM FROM DISCHARGE (S-S-3)

DATE 10/8/69
MAX EBB
AMB TEMP = 67.5°F
HEAT LOAD = 258 MW

FIGURE B-134

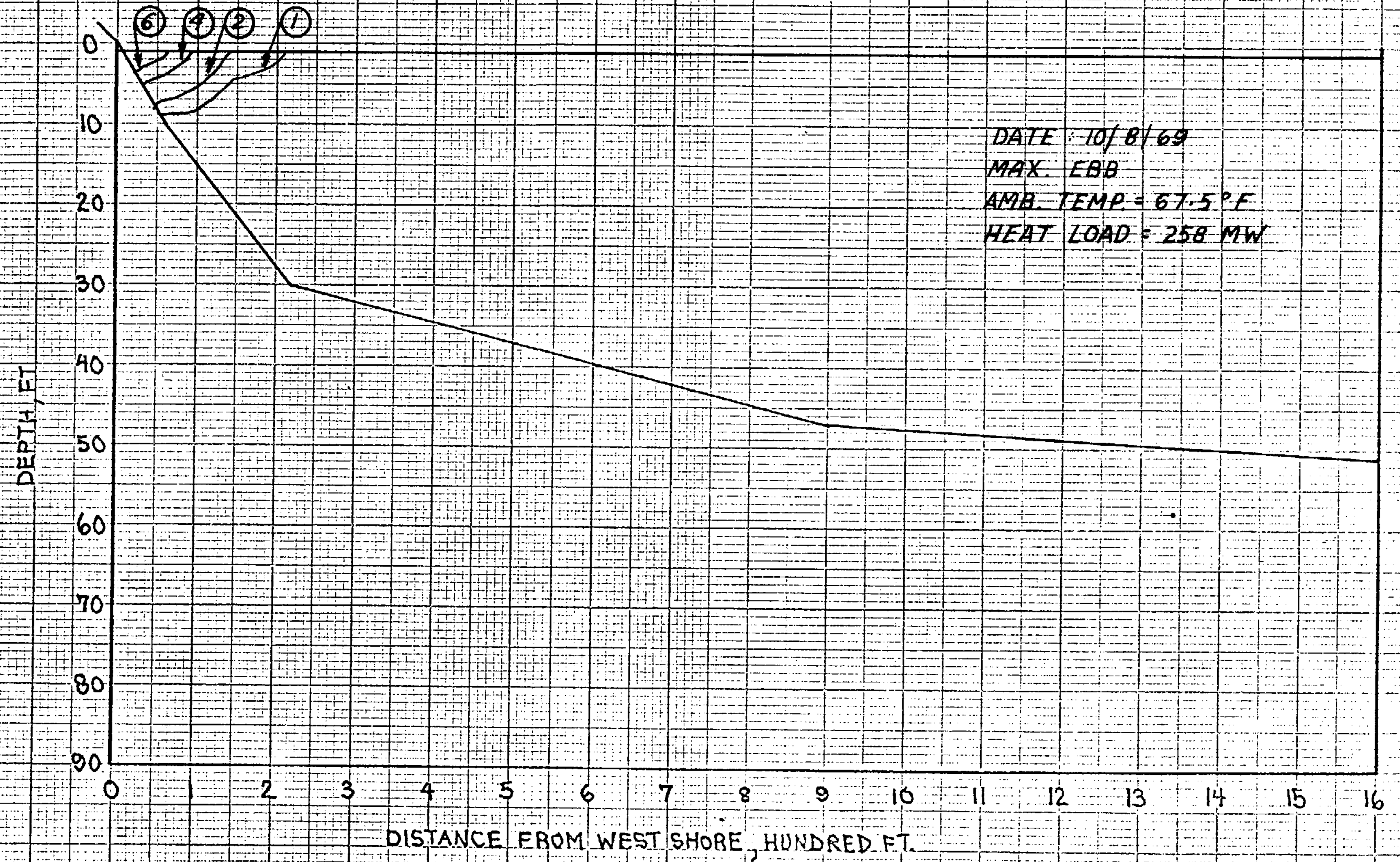
HUDSON RIVER AT DANSKAMMER
1700 FT DOWNSTREAM FROM DISCHARGE



DATE: 10/8/69
MAX EBB
AMB. TEMP. = 67.5°F
HEAT LOAD = 258 MW

FIGURE B-135

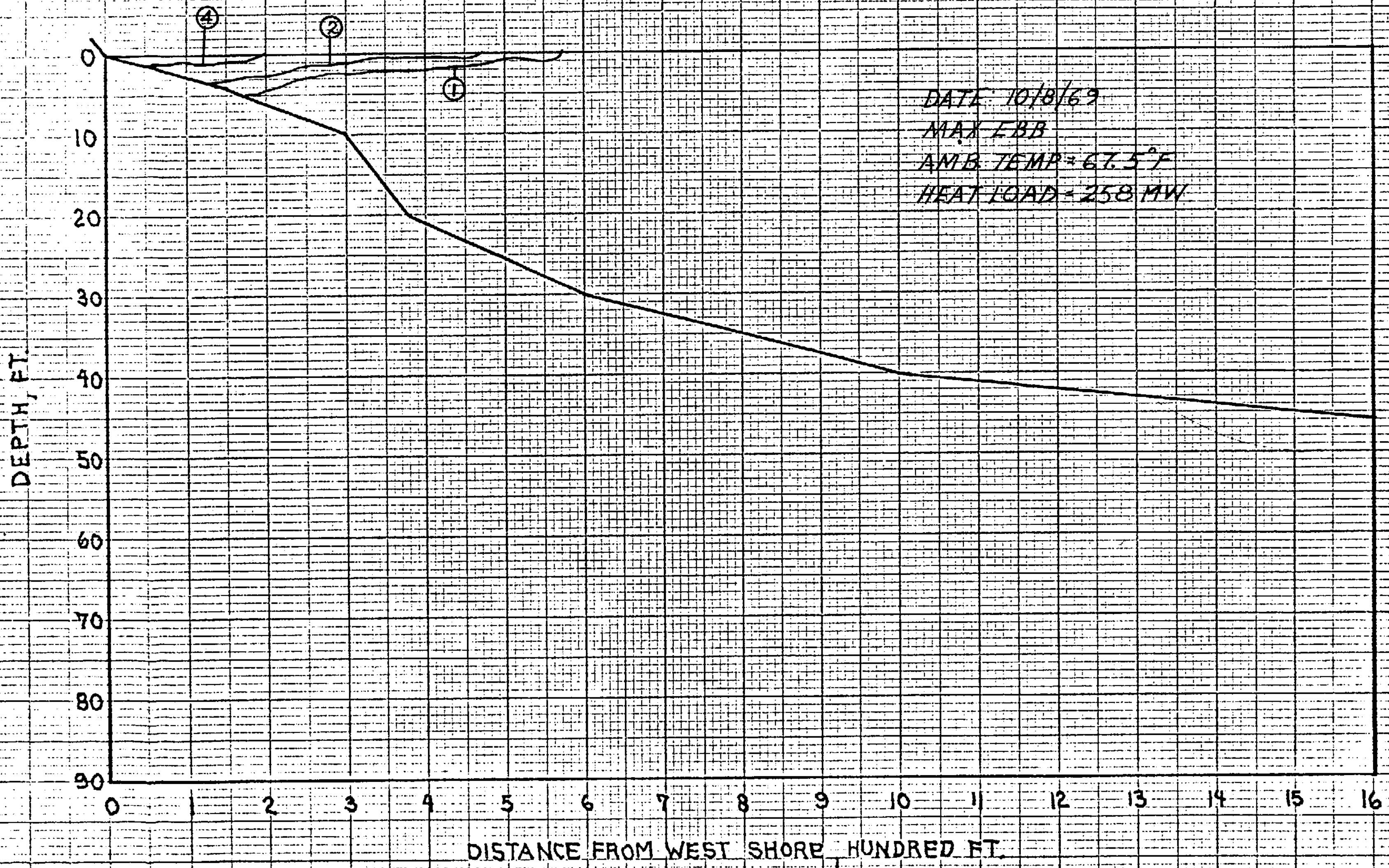
HUDSON RIVER AT DANSKAMMER
2450 FT DOWNSTREAM FROM DISCHARGE



DATE: 10/8/69
MAX. EBB
AMB. TEMP = 67.5°F
HEAT LOAD = 258 MW

FIGURE B-136.

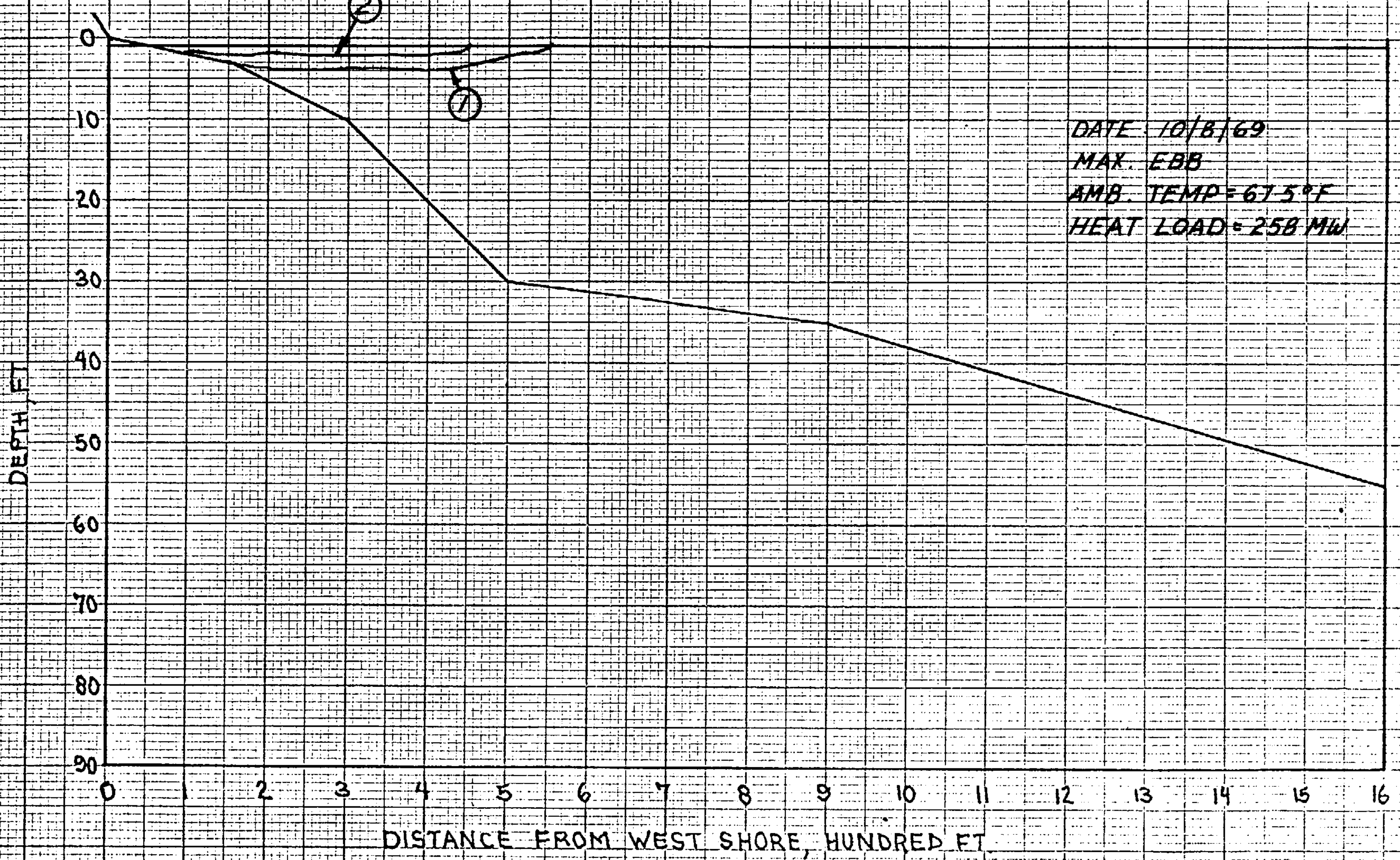
HUDSON RIVER AT DANSKAMMER
3000 FT. DOWNSTREAM FROM DISCHARGE



DATE 10/8/69
MAX EBB
AMB. TEMP = 67.5°F
HEAT LOAD = 258 MW

FIGURE B-137

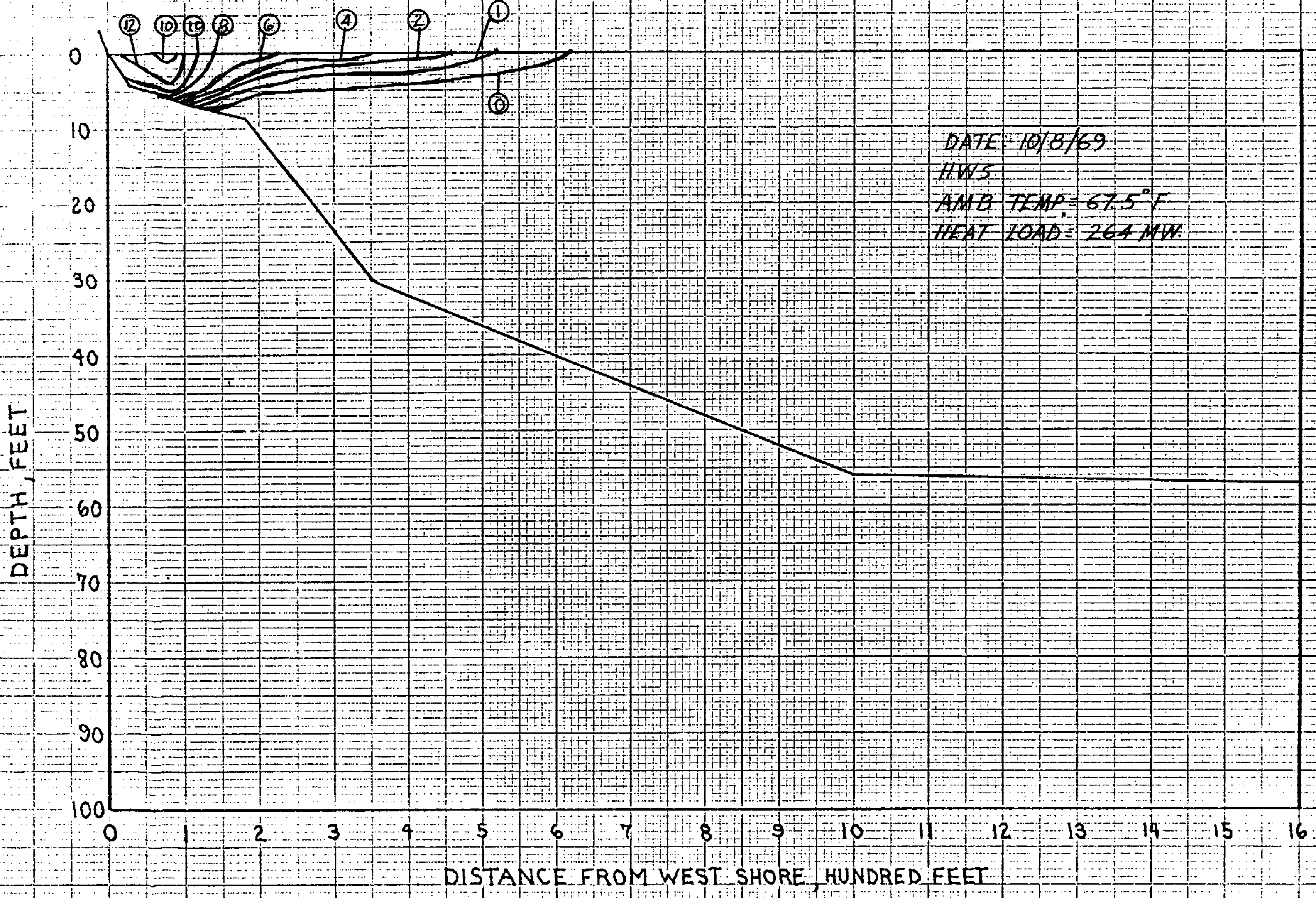
HUDSON RIVER AT DANSKAMMER
4050 FT DOWNSTREAM FROM DISCHARGE (III - III)



DATE 10/8/69
MAX. EBB
AMB. TEMP = 67.5°F
HEAT LOAD = 258 MW

FIGURE B-138

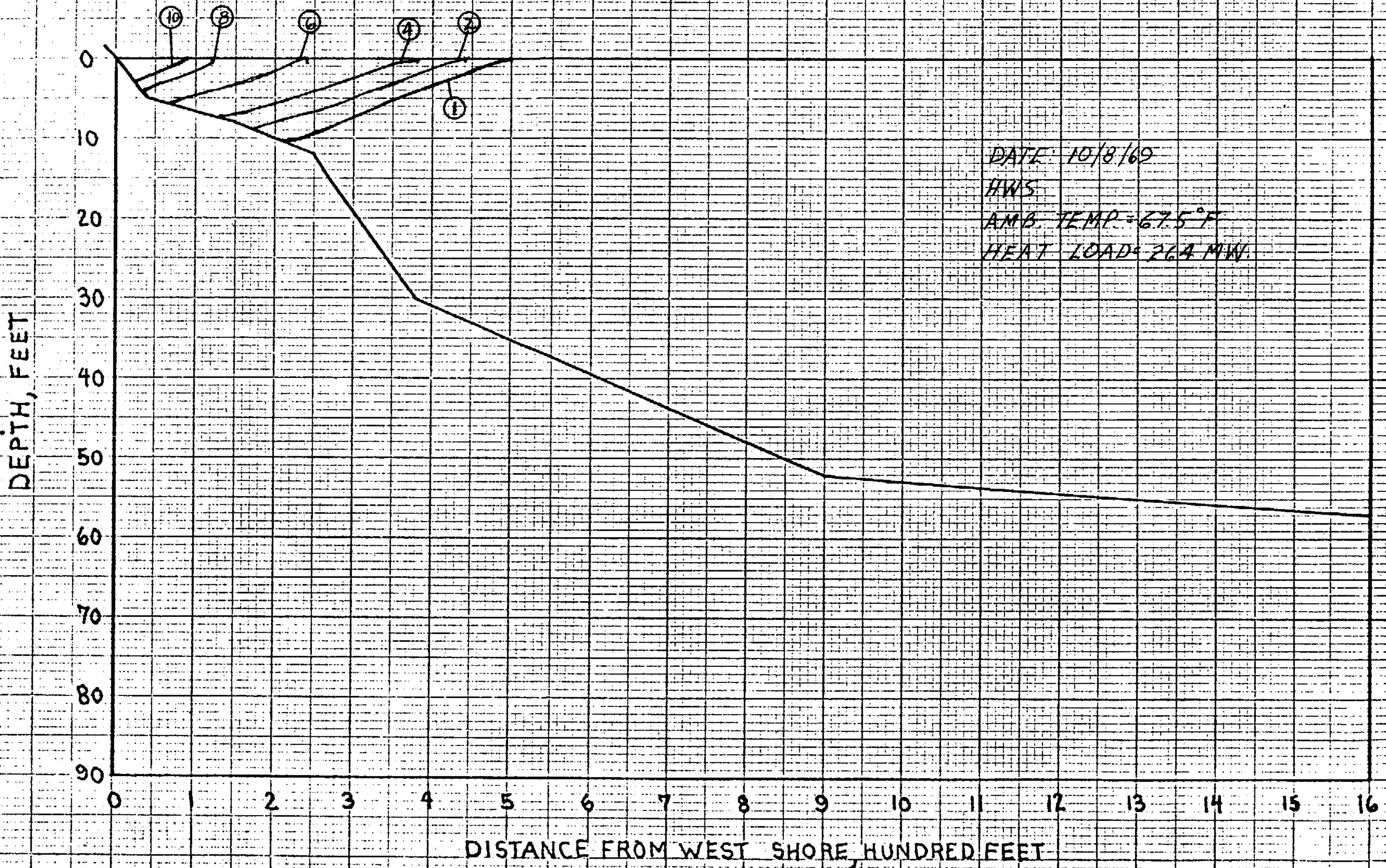
HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)



DATE 10/8/69
HWS
AMB TEMP = 67.5°F
HEAT LOAD = 264 MW

FIGURE B-139

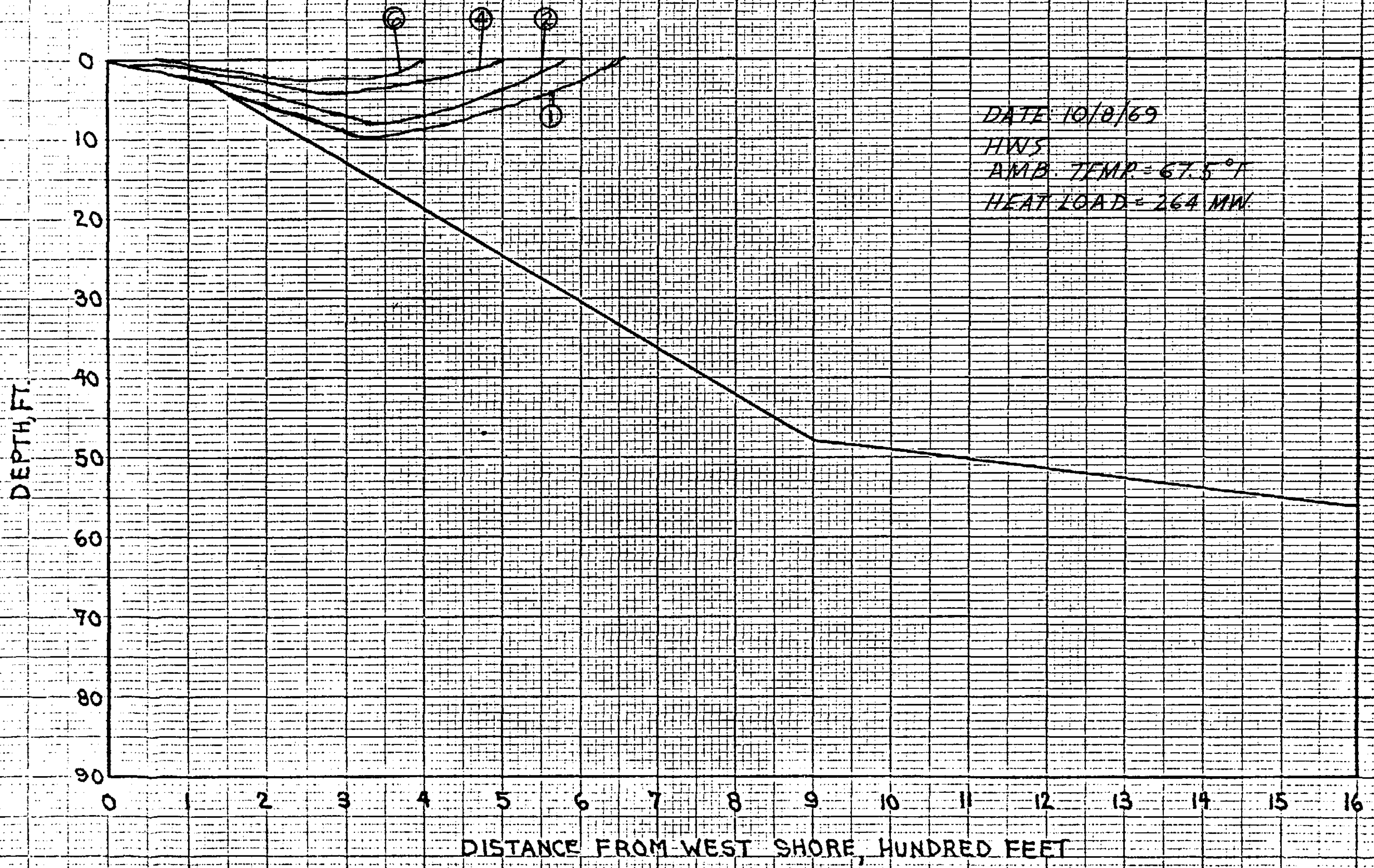
HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)



DATE 10/8/69
HWS
AMB. TEMP.=67.5°F
HEAT LOAD=264 MW.

FIGURE B-140

HUDSON RIVER AT DANSKAMMER
800 FT. DOWNSTREAM FROM DISCHARGE (S-S-3)

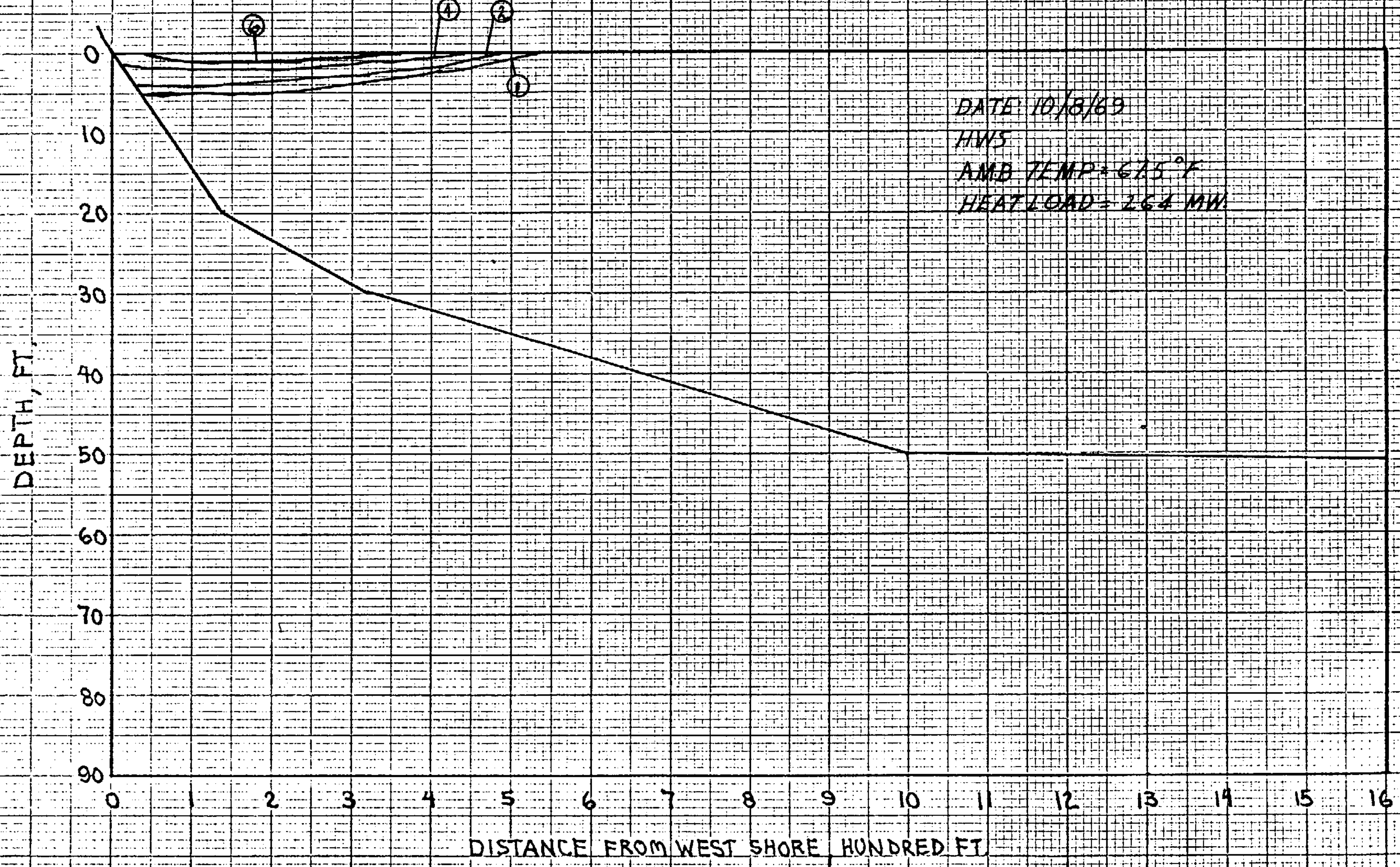


DATE 10/8/69
HWS
AMB. TEMP. = 67.5 °F
HEAT LOAD = 264 MW

FIGURE B-141

FIGURE B-142

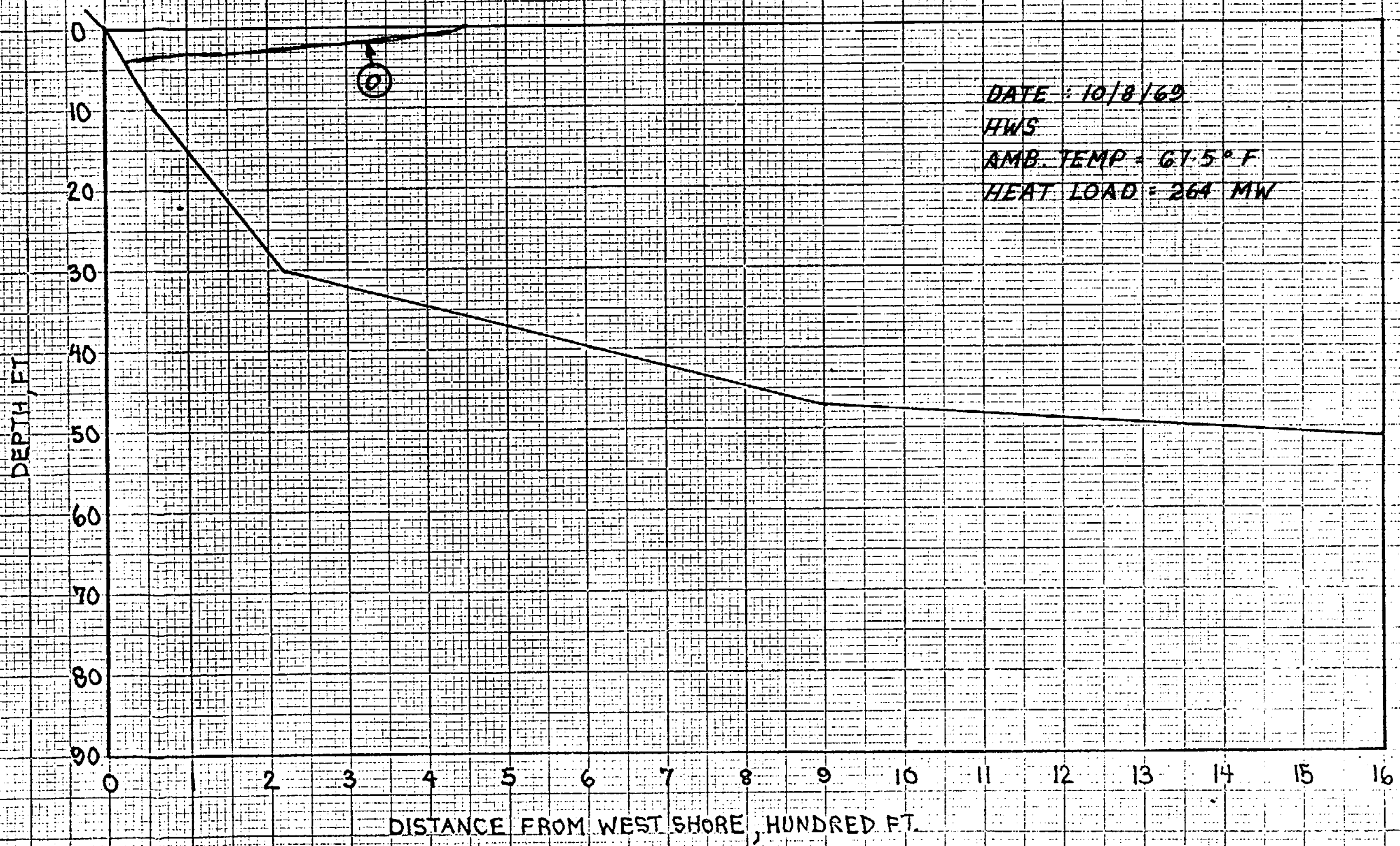
HUDSON RIVER AT DANSKAMMER
1700 FT DOWNSTREAM FROM DISCHARGE



DATE 10/8/69
HWS
AMB TEMP = 67.5 °F
HEAT LOAD = 264 MW

Figure B-143

HUDSON RIVER AT DANSKAMMER
2450 FT DOWNSTREAM FROM DISCHARGE



DATE : 10/8/69
HWS
AMB. TEMP = 67.5° F
HEAT LOAD = 264 MW

HUDSON RIVER AT DANSKAMMER
3000 FT. DOWNSTREAM FROM DISCHARGE

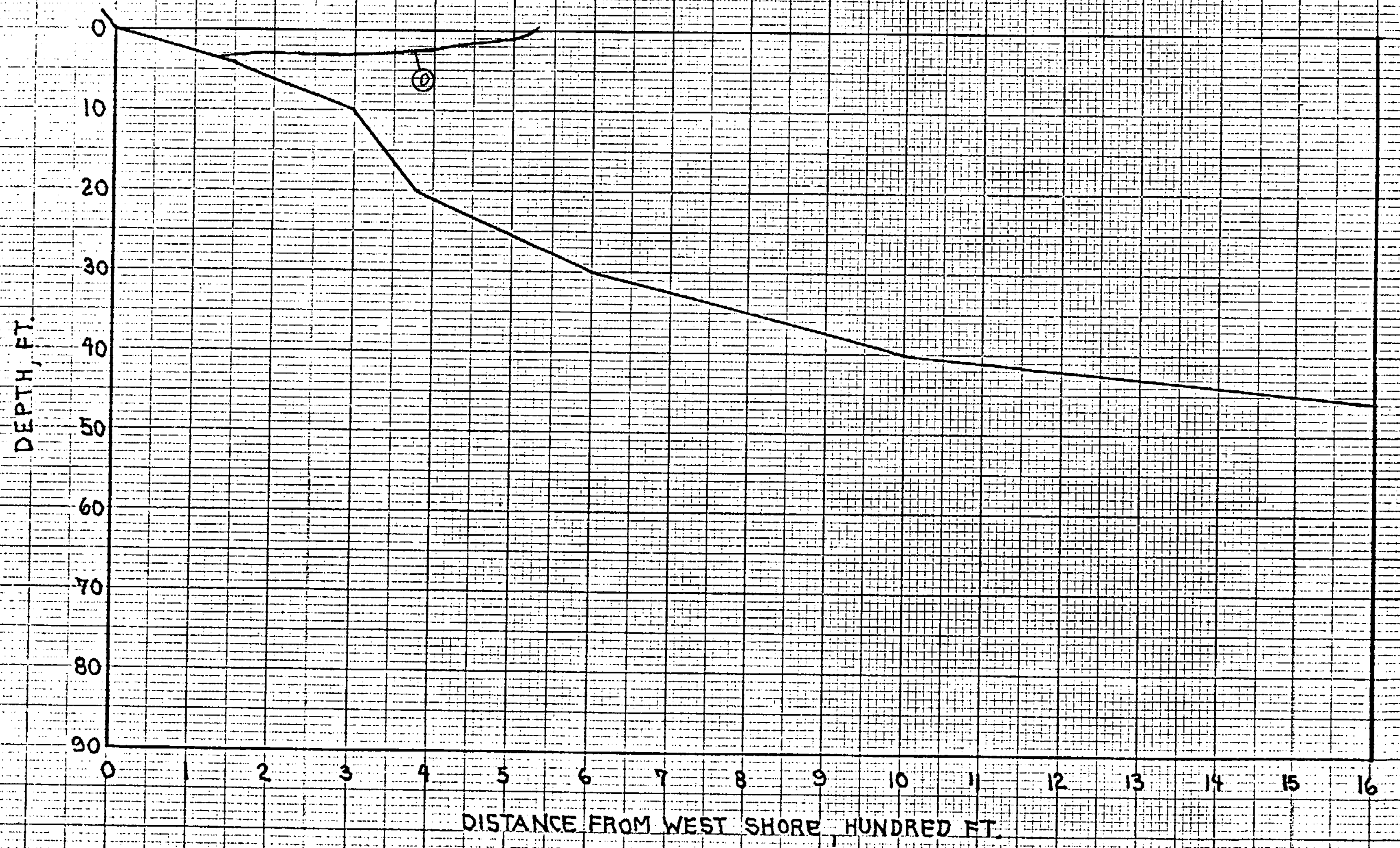


FIGURE B-144

TABLE A11

PORTION OF HUDSON RIVER AT DANSKAMMER SUBJECTED TO TEMPERATURE RISE OF 4°F OR GREATER

DATE: October 15, 1969

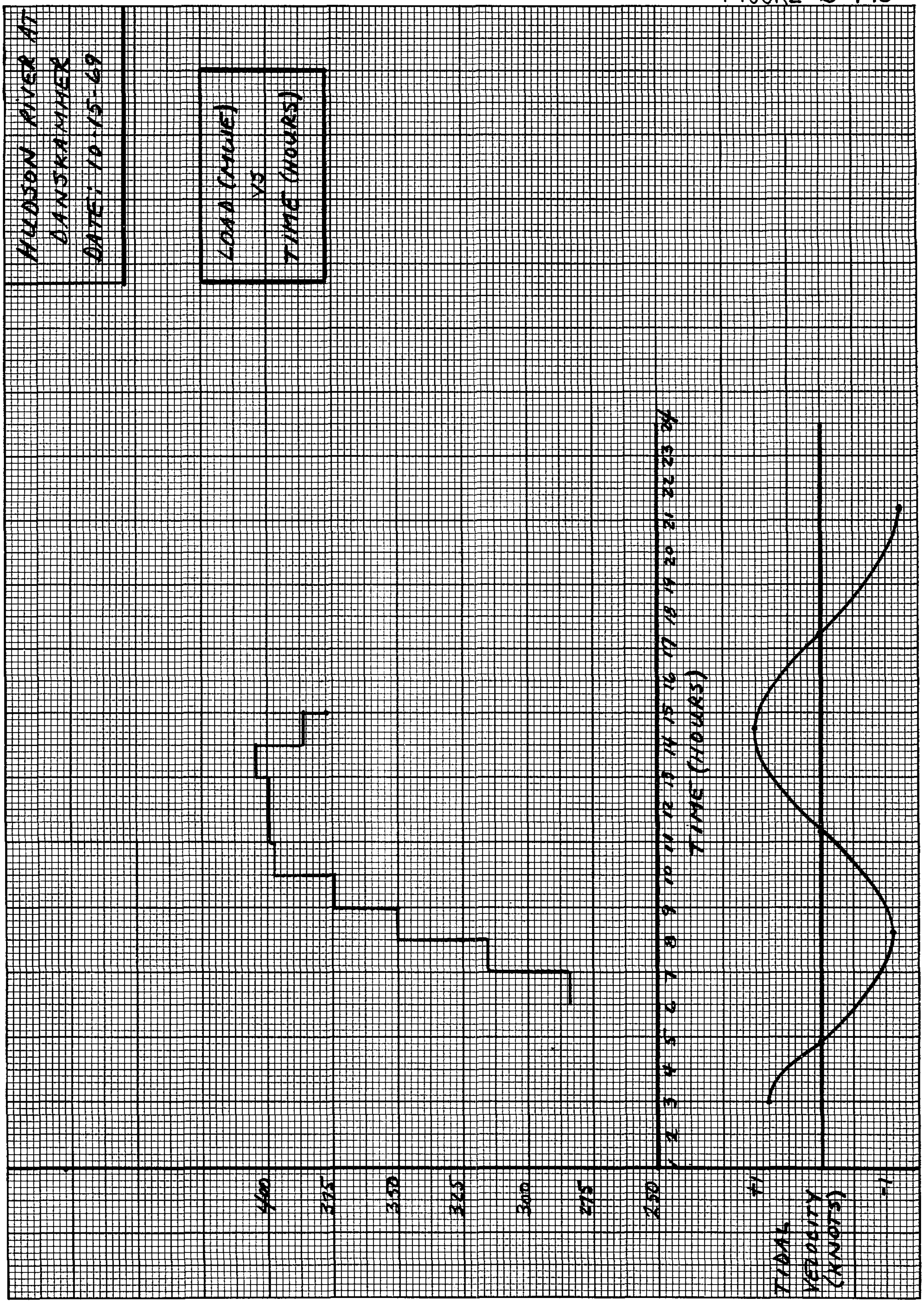
Total river cross sectional area at critical section - 142,000 ft.^{2}

Total river surface width at critical section* - 3,420 ft.

TIDAL CONDITION	ELECTRICAL OUTPUT (MWE)	% WIDTH	% CROSS-SECTIONAL AREA	SURFACE AREA (ACRES)	LONGITUDINAL EXTENT
Late Ebb	409	10.4	0.68	41.2	6870
Low Water Slack	398	14.0	1.22	17.6	2460
Maximum Flood	382	0	0	7.8	1165

*Critical section 390 ft. south of discharge.

FIGURE B-145


HUDSON RIVER AT
DANSKAMMER
DATE: 10-15-69
LOAD (MWE)
VS
TIME (HOURS)
400
375
350
325
300
275
250
+1
-1
TIDAL
VELOCITY
(KNOTS)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
TIME (HOURS)

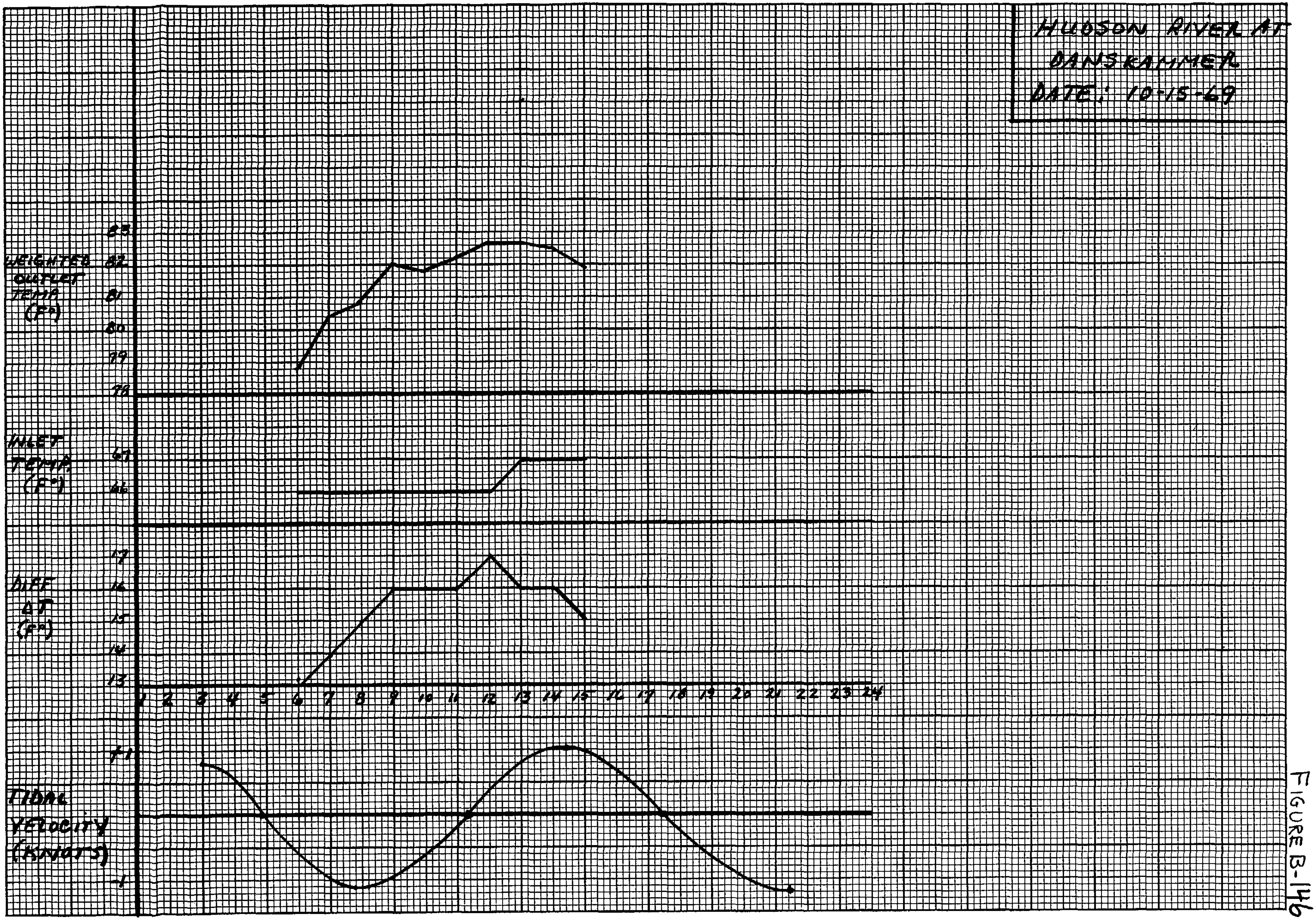

HUDSON RIVER AT
DANSKAMMER
DATE: 10-15-69
WEIGHTED OUTLET TEMP. (F°)
83
82
81
80
79
78
INLET TEMP. (F°)
67
66
DIFF ΔT (F°)
17
16
15
14
13
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
TIDAL VELOCITY (KNOTS)
+1
-1

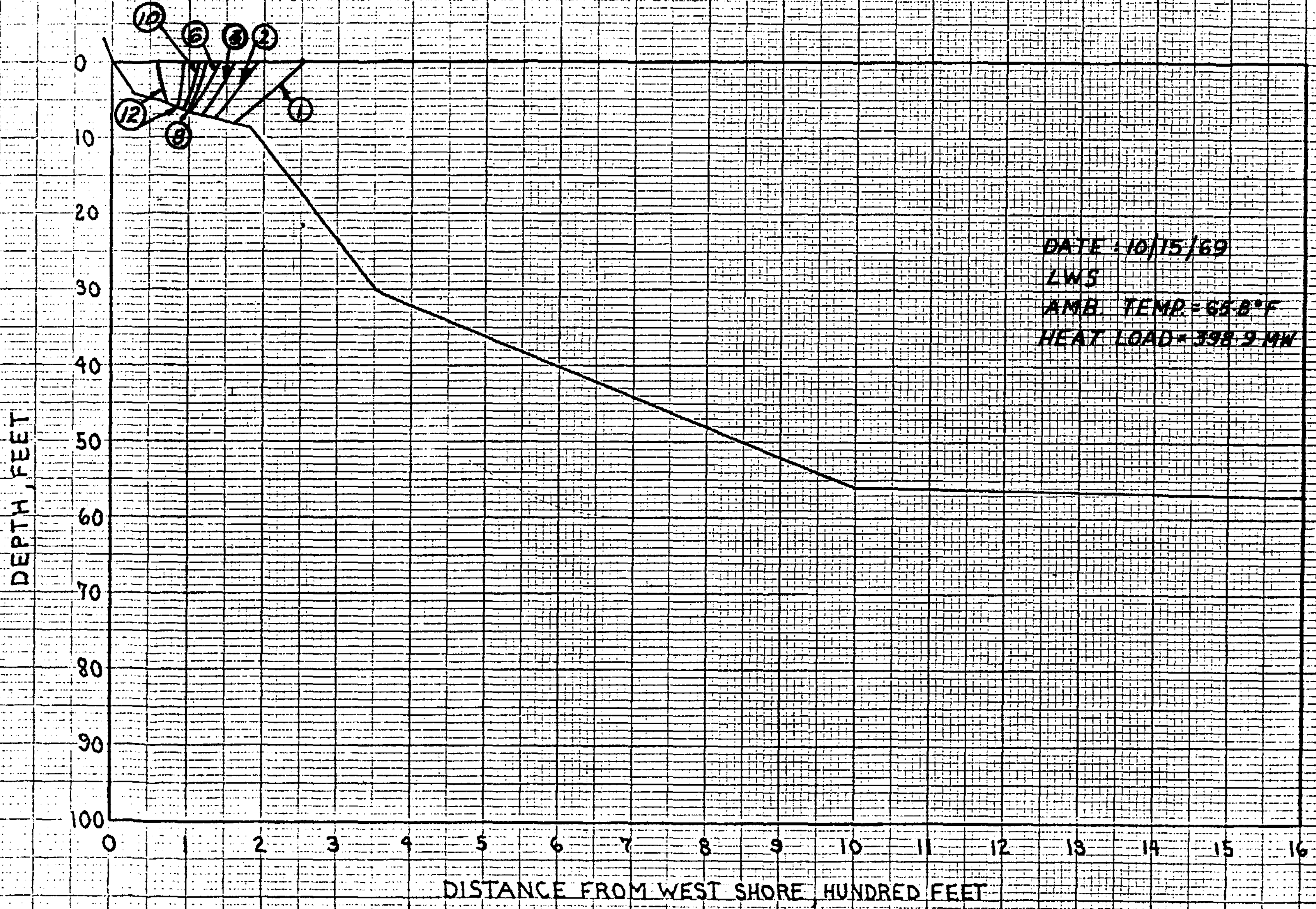
FIGURE B-146

LARGE
DOCUMENT

LARGE DOCUMENT

LARGE DOCUMENT

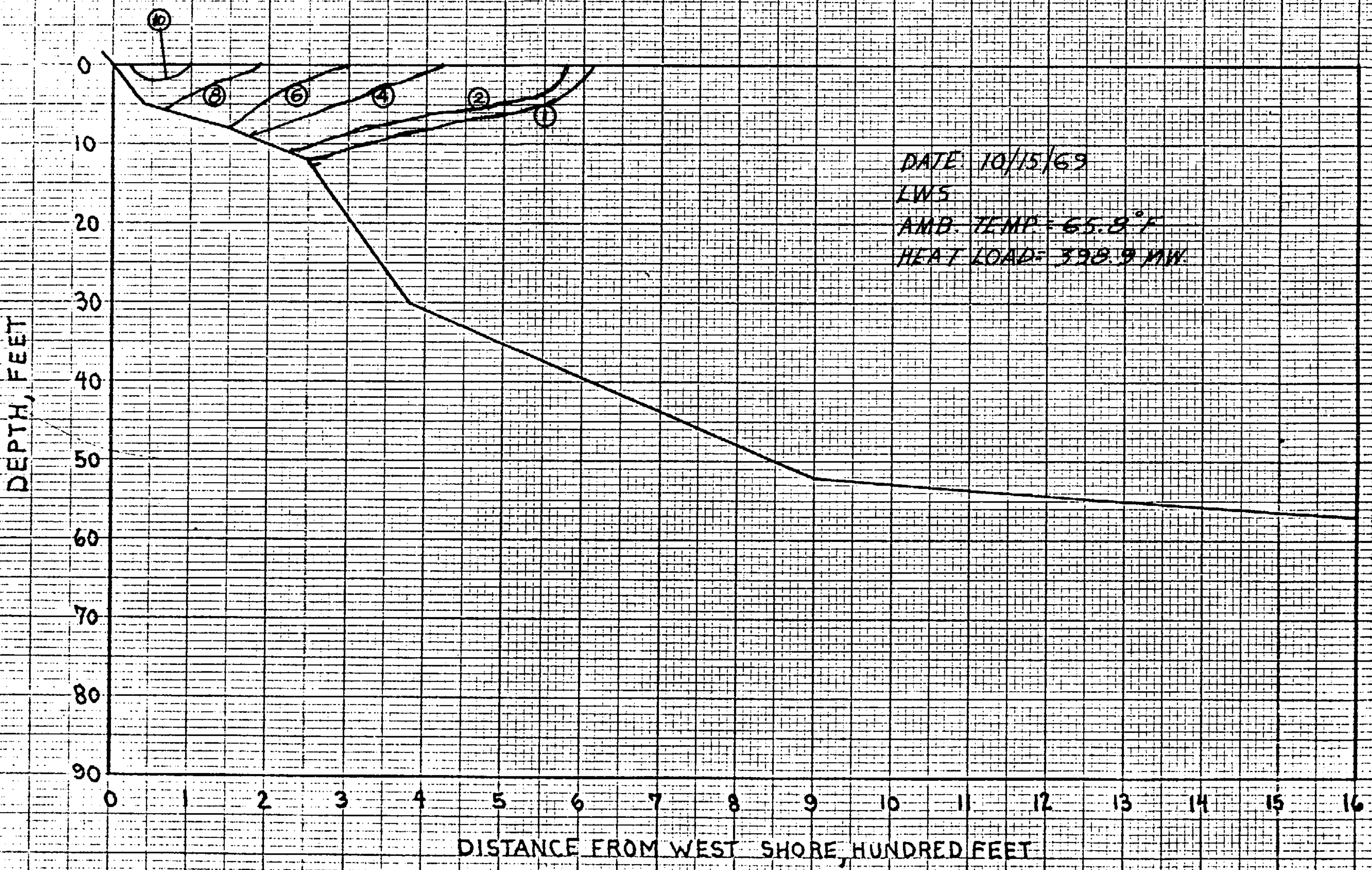
HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)



DATE: 10/15/69
LWS
AMB. TEMP.=65.8°F
HEAT LOAD=398.9 MW

FIGURE B-150

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)



DATE 10/15/69
LWS
AMB. TEMP = 65.8°F
HEAT LOAD = 398.9 MW

FIGURE B-151

HUDSON RIVER AT DANSKAMMER
300 FT. DOWNSTREAM FROM DISCHARGE (S-S-3)

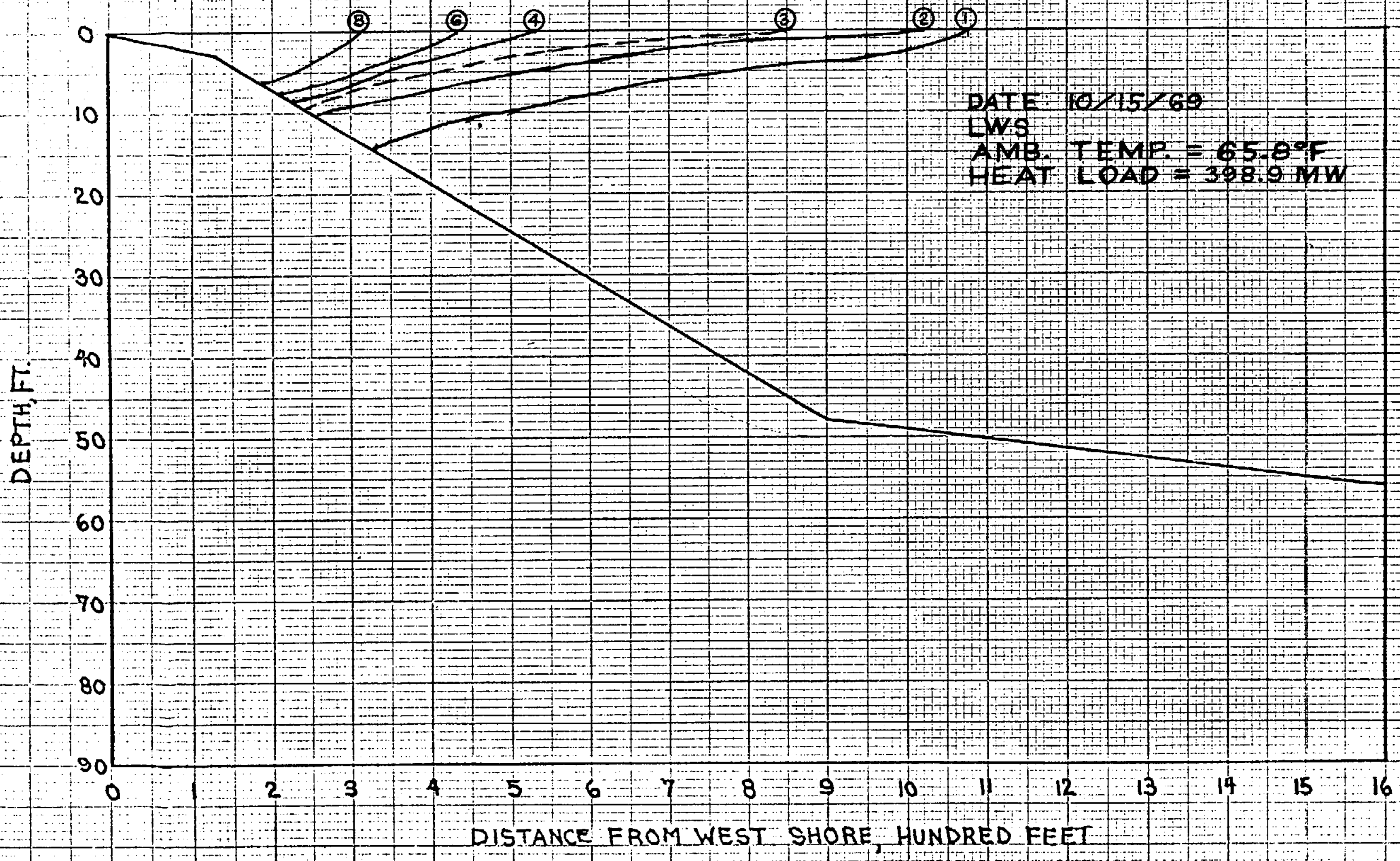
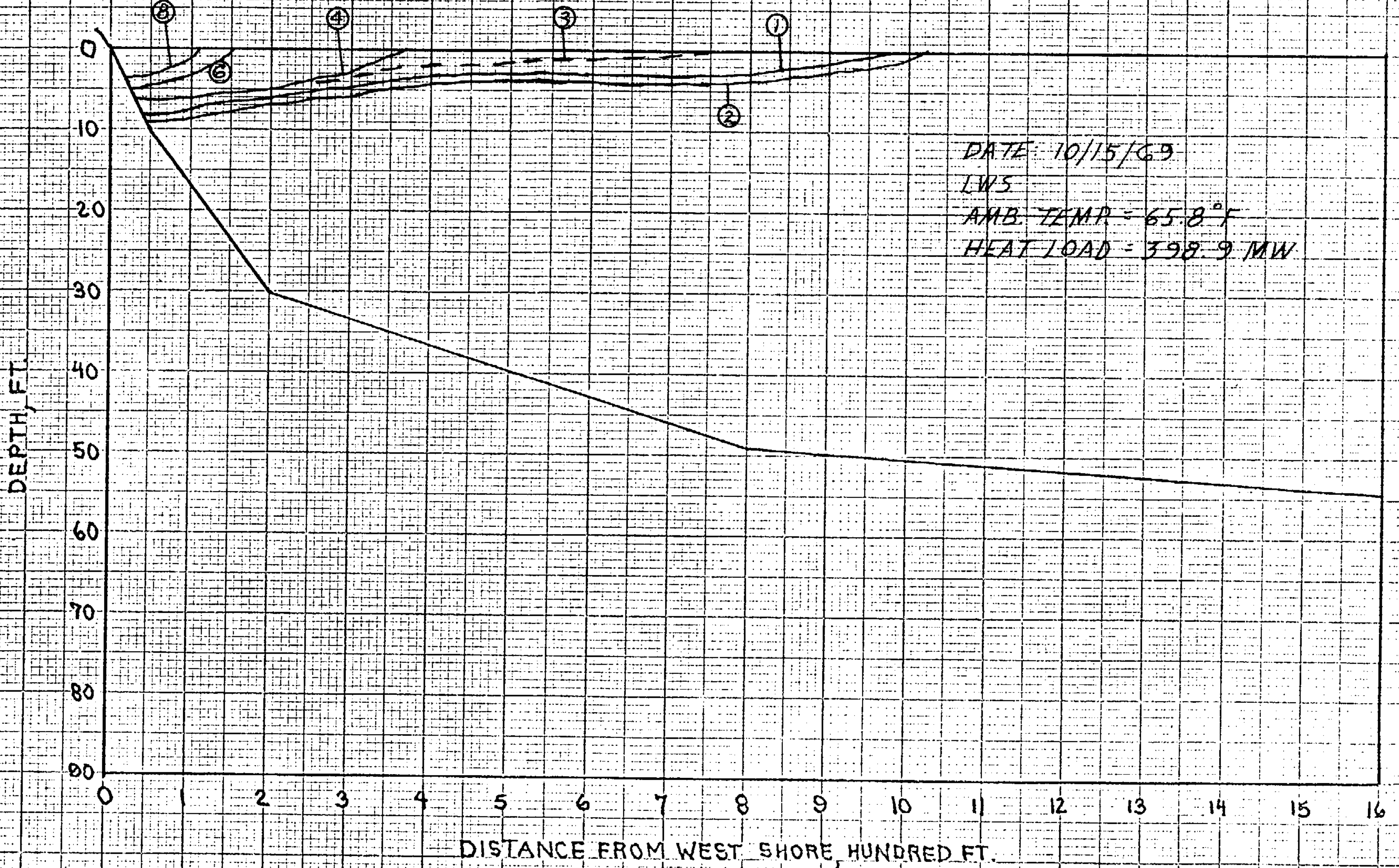


FIGURE B-152

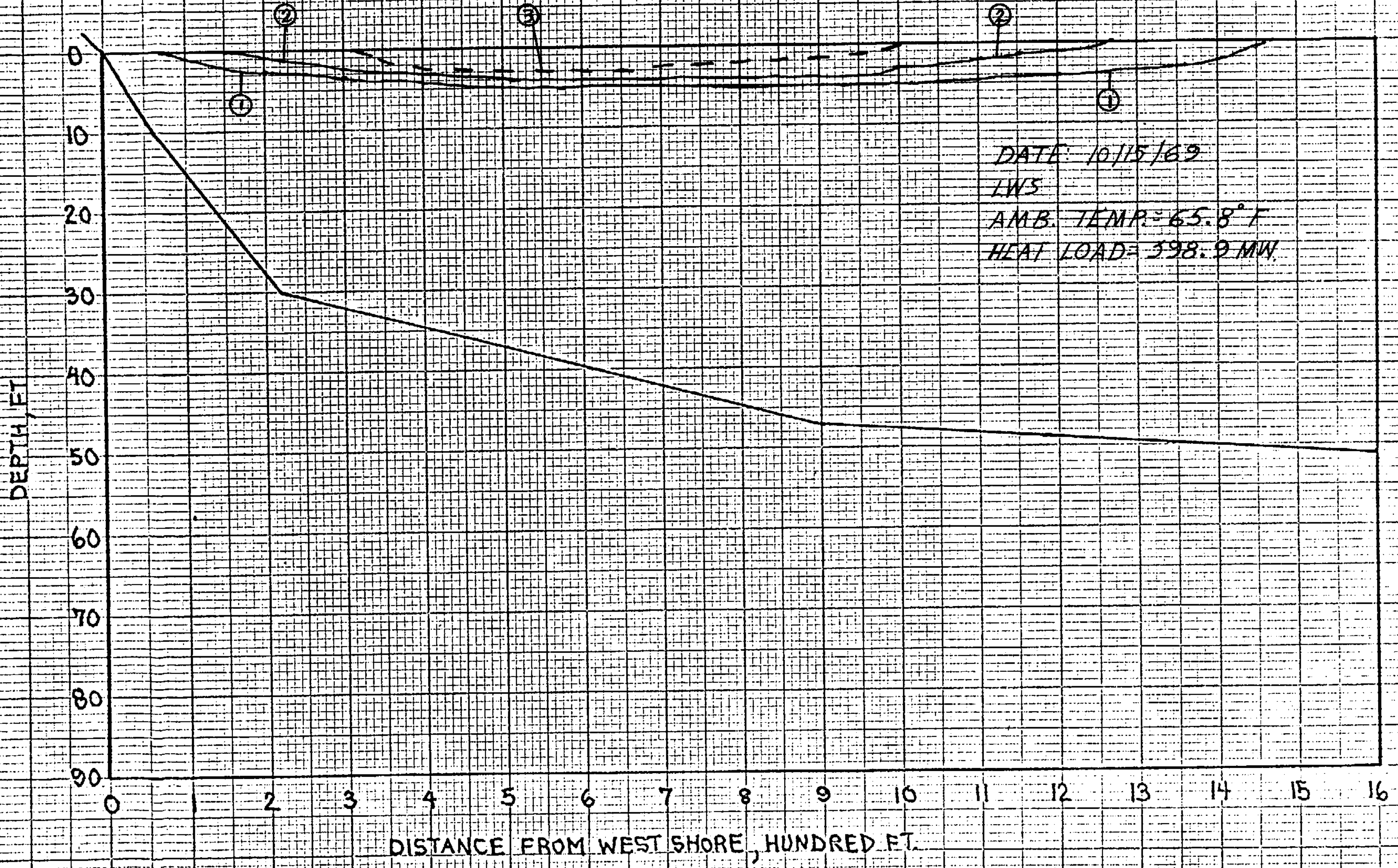
HUDSON RIVER AT DANSKAMMER
1300 FT. DOWNSTREAM FROM DISCHARGE (I-I)



DATE 10/15/69
LWS
AMB. TEMP. = 65.8°F
HEAT LOAD = 398.9 MW

FIGURE B-153

HUDSON RIVER AT DANSKAMMER
2450 FT DOWNSTREAM FROM DISCHARGE



DATE 10/15/69
LWS
AMB. TEMP.=65.8°F
HEAT LOAD=398.9 MW

FIGURE B-154

HUDSON RIVER AT DANSKAMMER
3000 FT. DOWNSTREAM FROM DISCHARGE

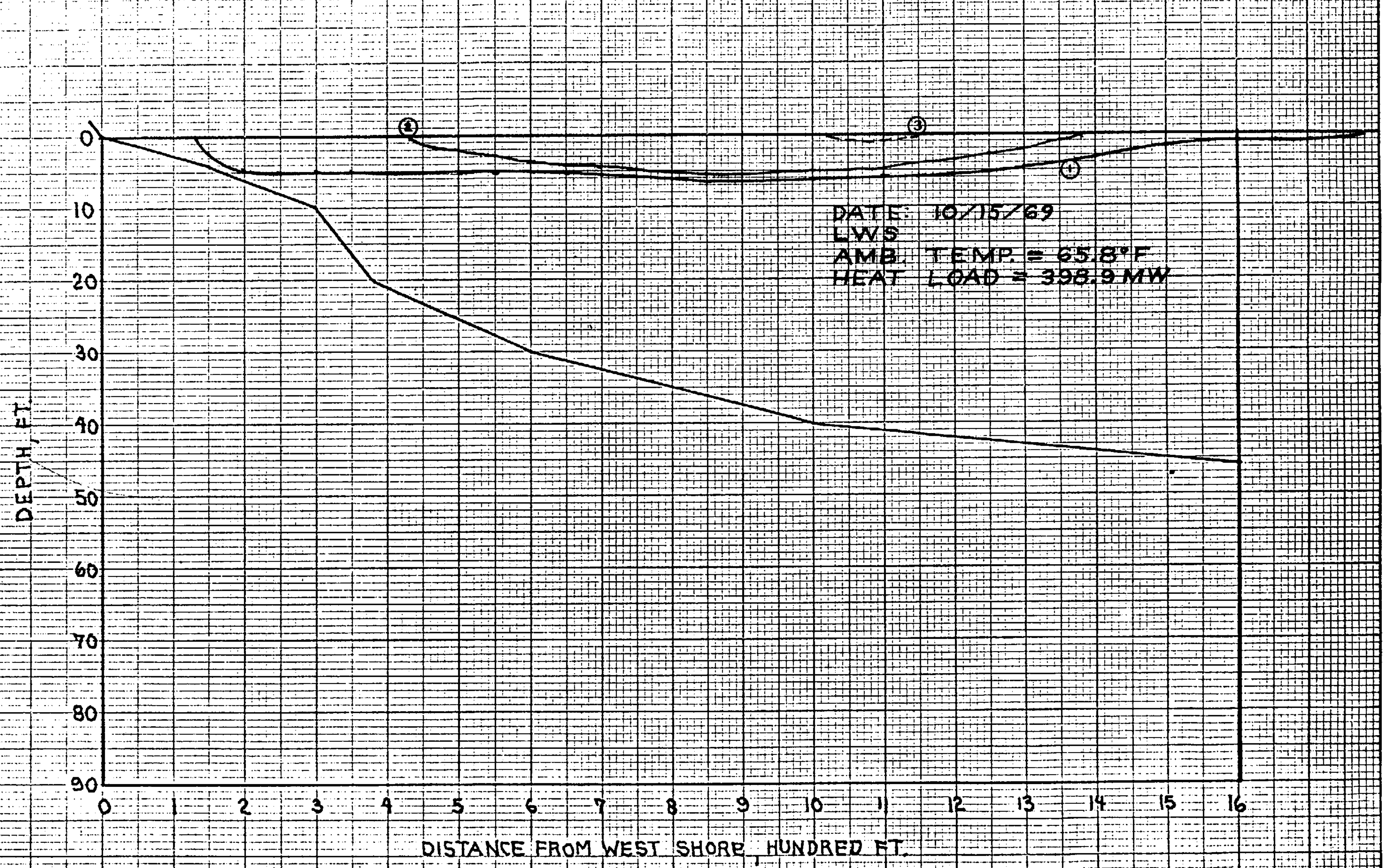


FIGURE B-155

HUDSON RIVER AT DANSKAMMER
4050 FT DOWNSTREAM FROM DISCHARGE

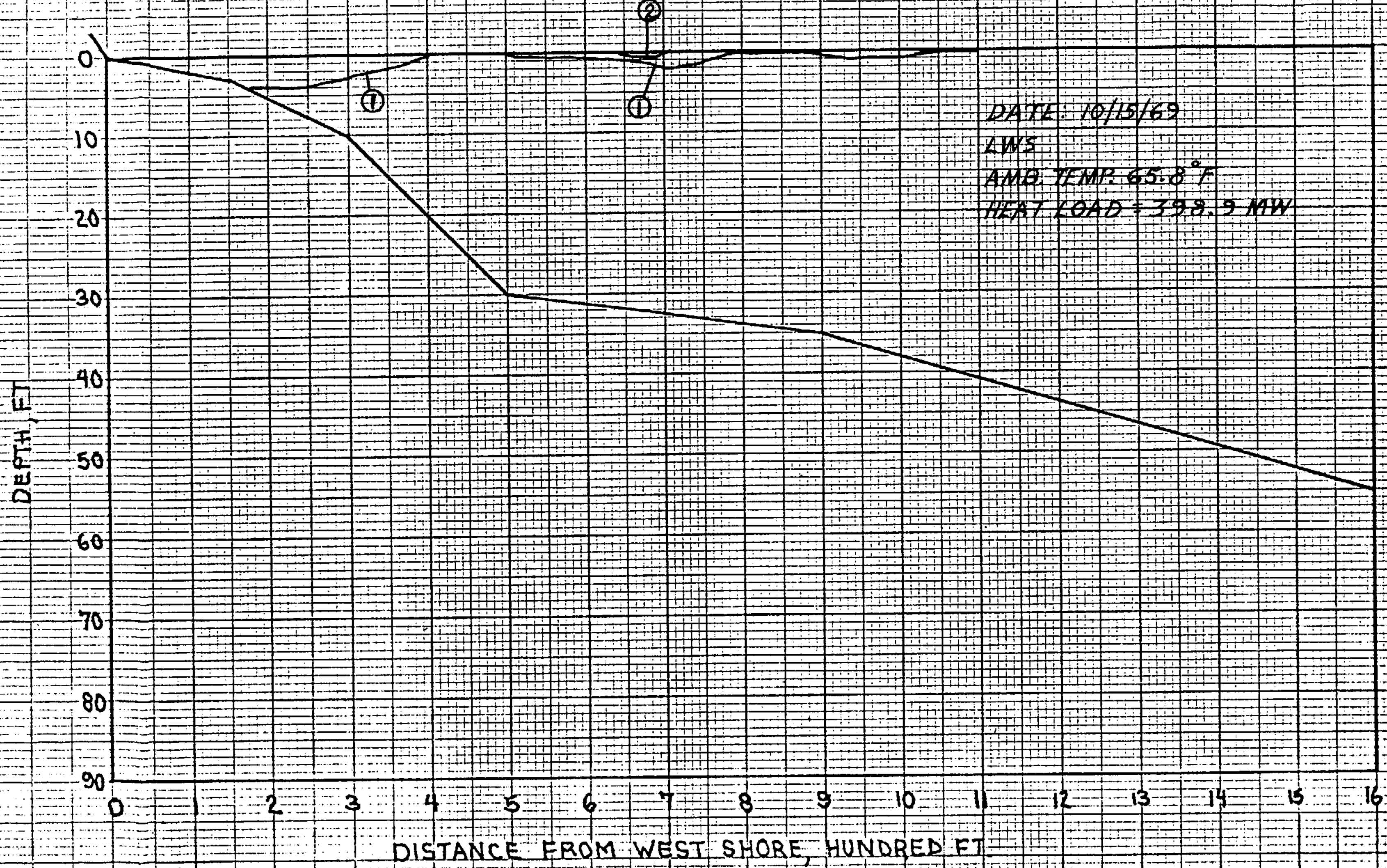


FIGURE B-156

HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)

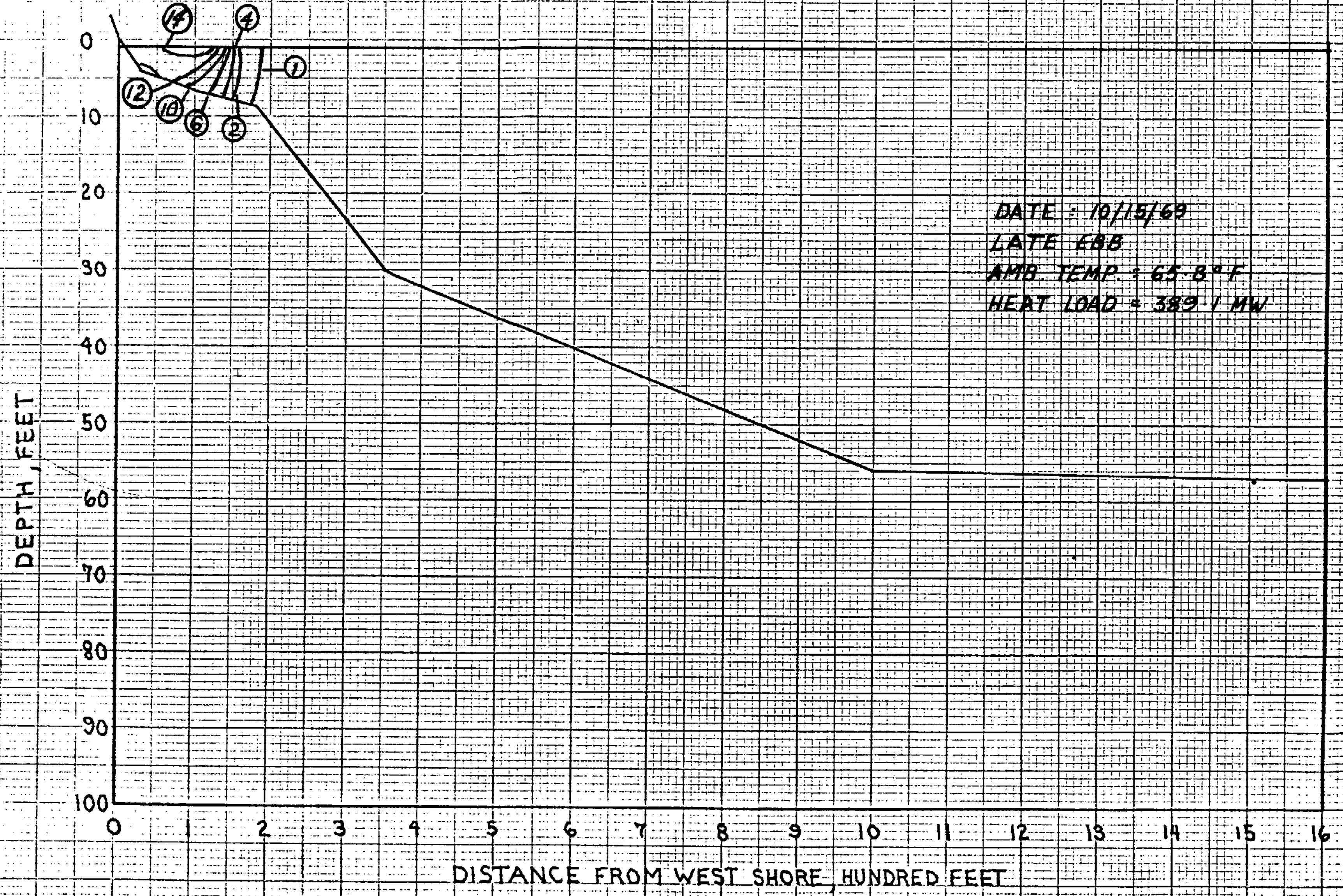
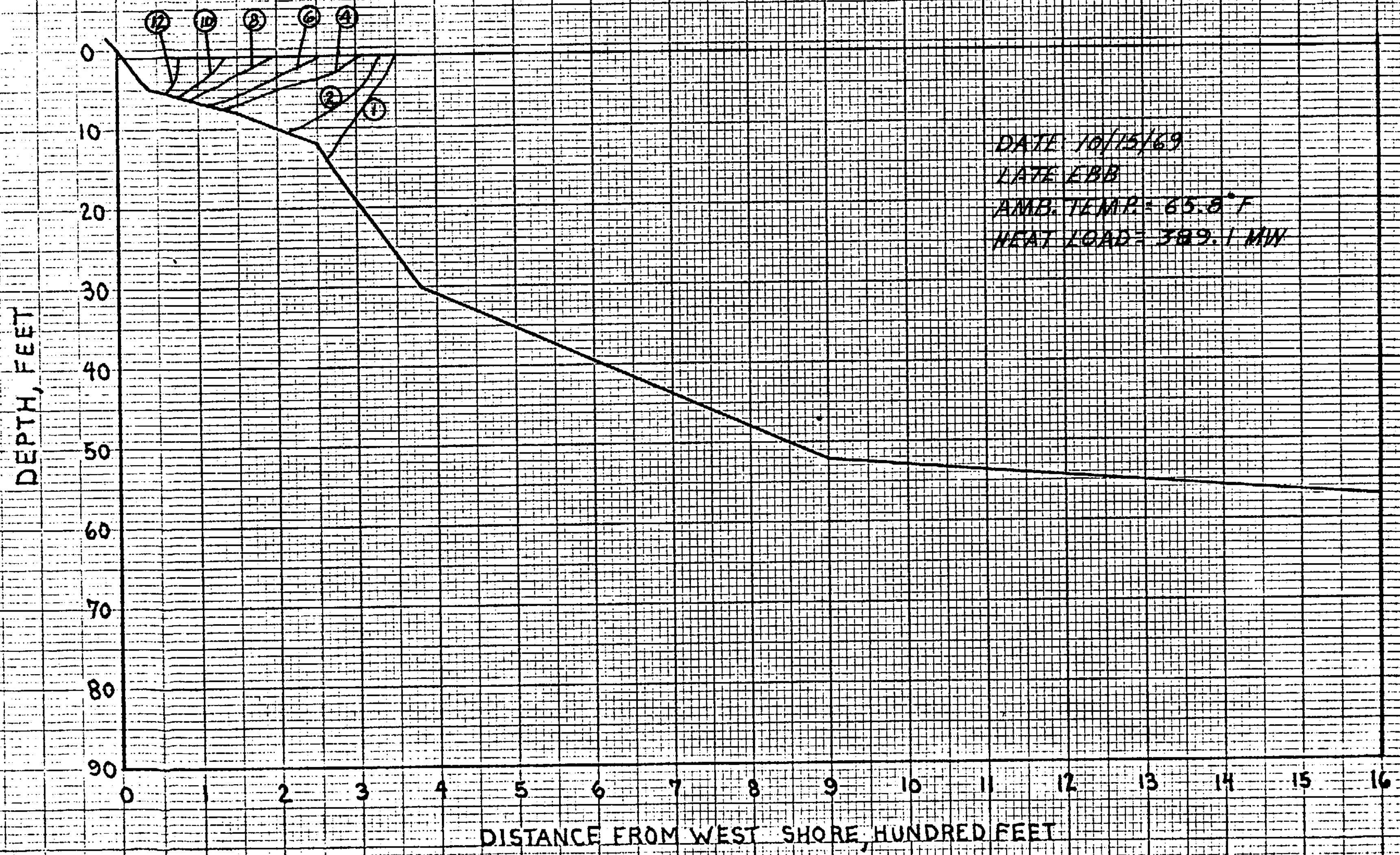


FIGURE B-157

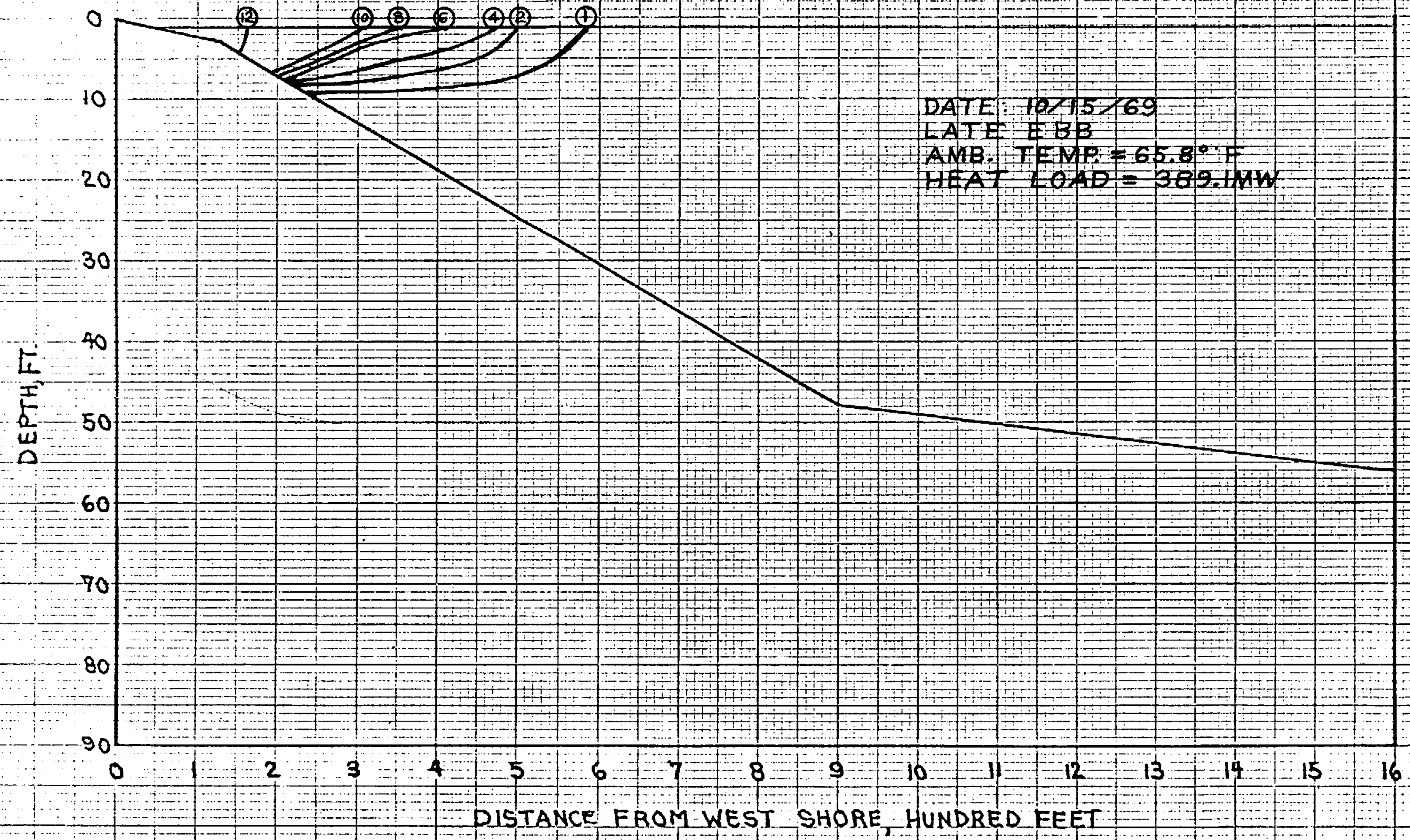
HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)



DATE 10/15/69
LATE EBB
AMB. TEMP.= 65.8°F
HEAT LOAD= 389.1 MW

FIGURE B-158

HUDSON RIVER AT DANSKAMMER
800 FT. DOWNSTREAM FROM DISCHARGE (S-S-3)

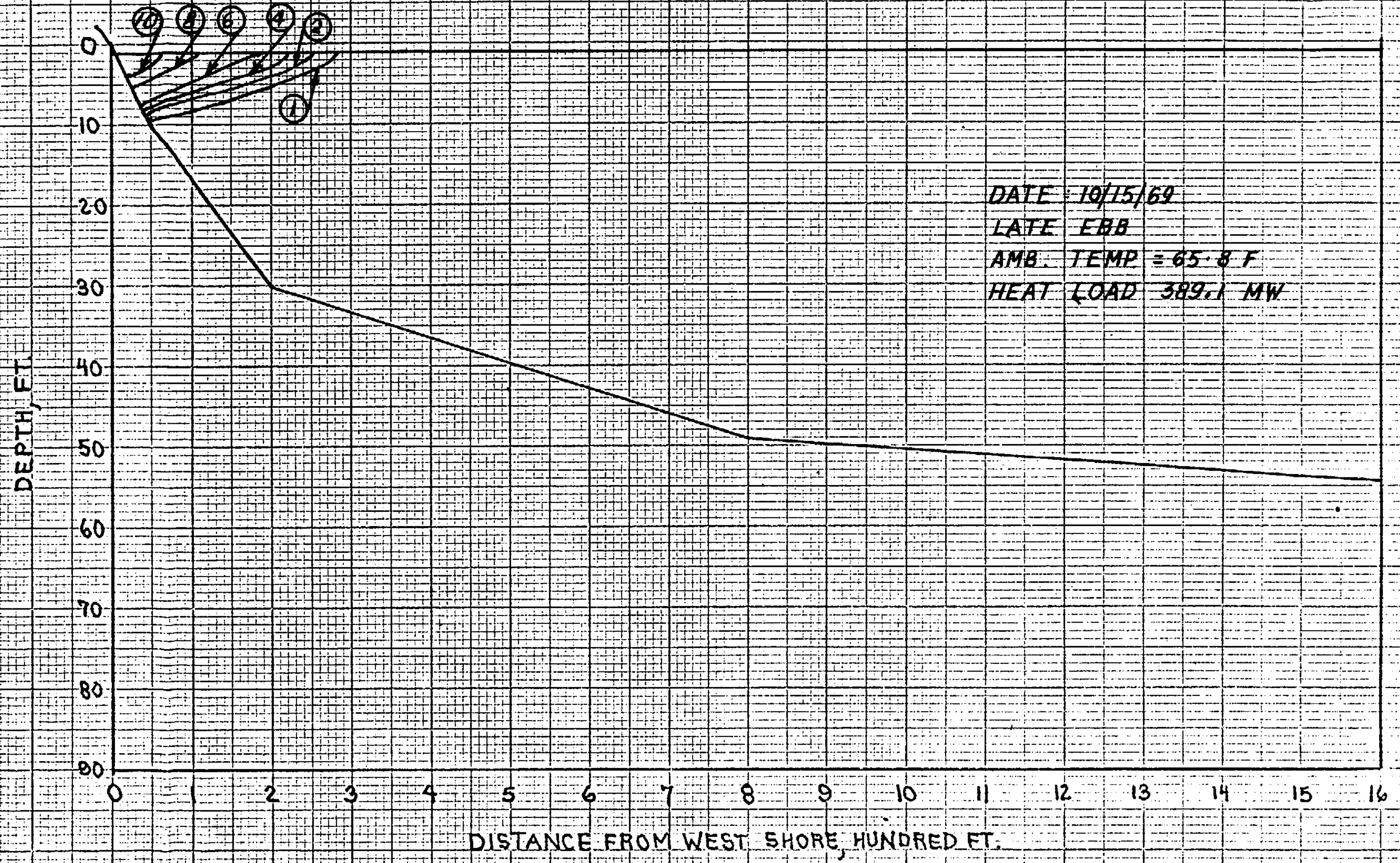


DATE: 10/15/69
LATE EBB
AMB. TEMP. = 65.8° F
HEAT LOAD = 389.1MW

FIGURE B-159

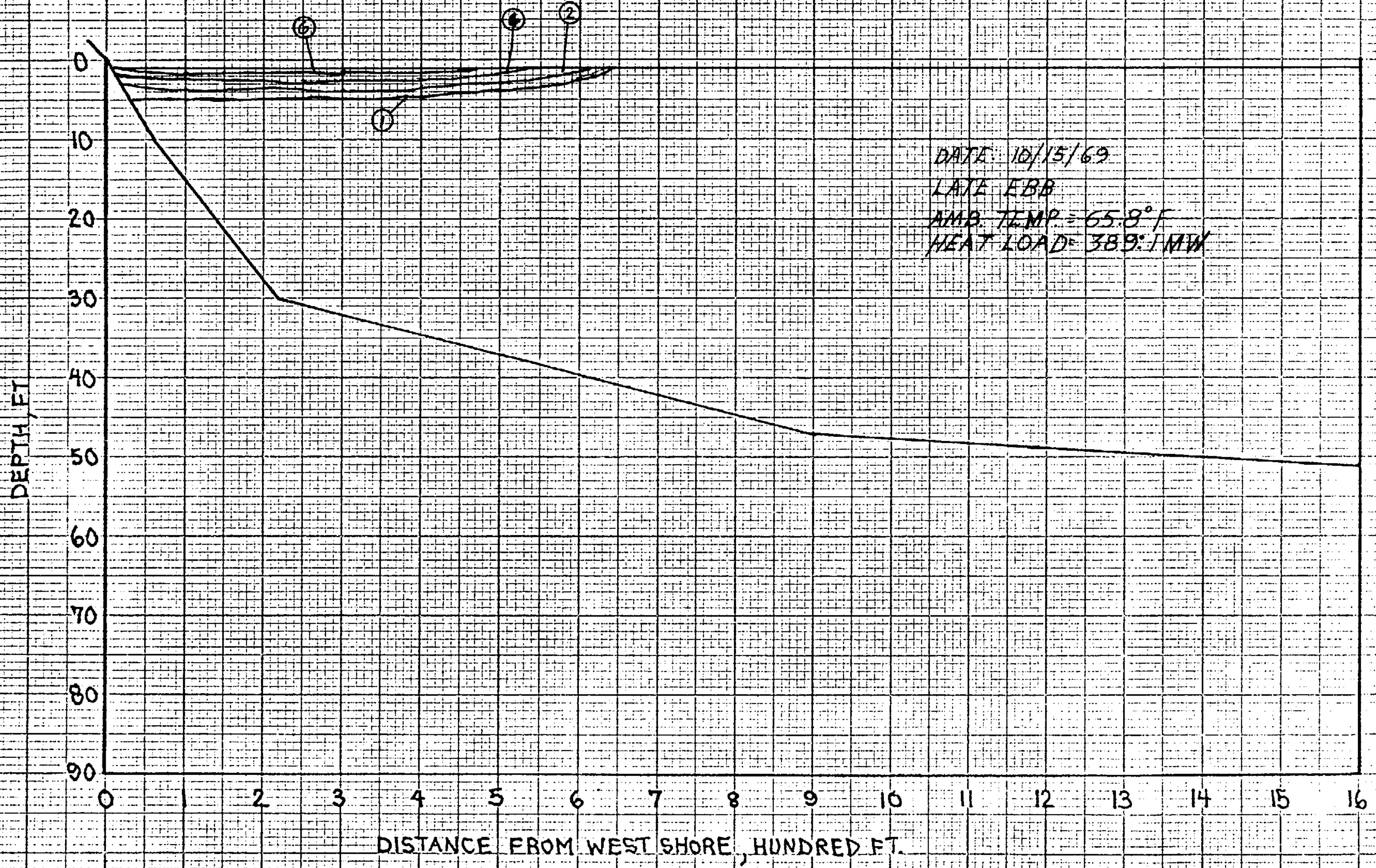
FIGURE B-160

HUDSON RIVER AT DANSKAMMER
1300 FT. DOWNSTREAM FROM DISCHARGE (I-I)



DATE 10/15/69
LATE EBB
AMB. TEMP = 65.8 F
HEAT LOAD 389.1 MW

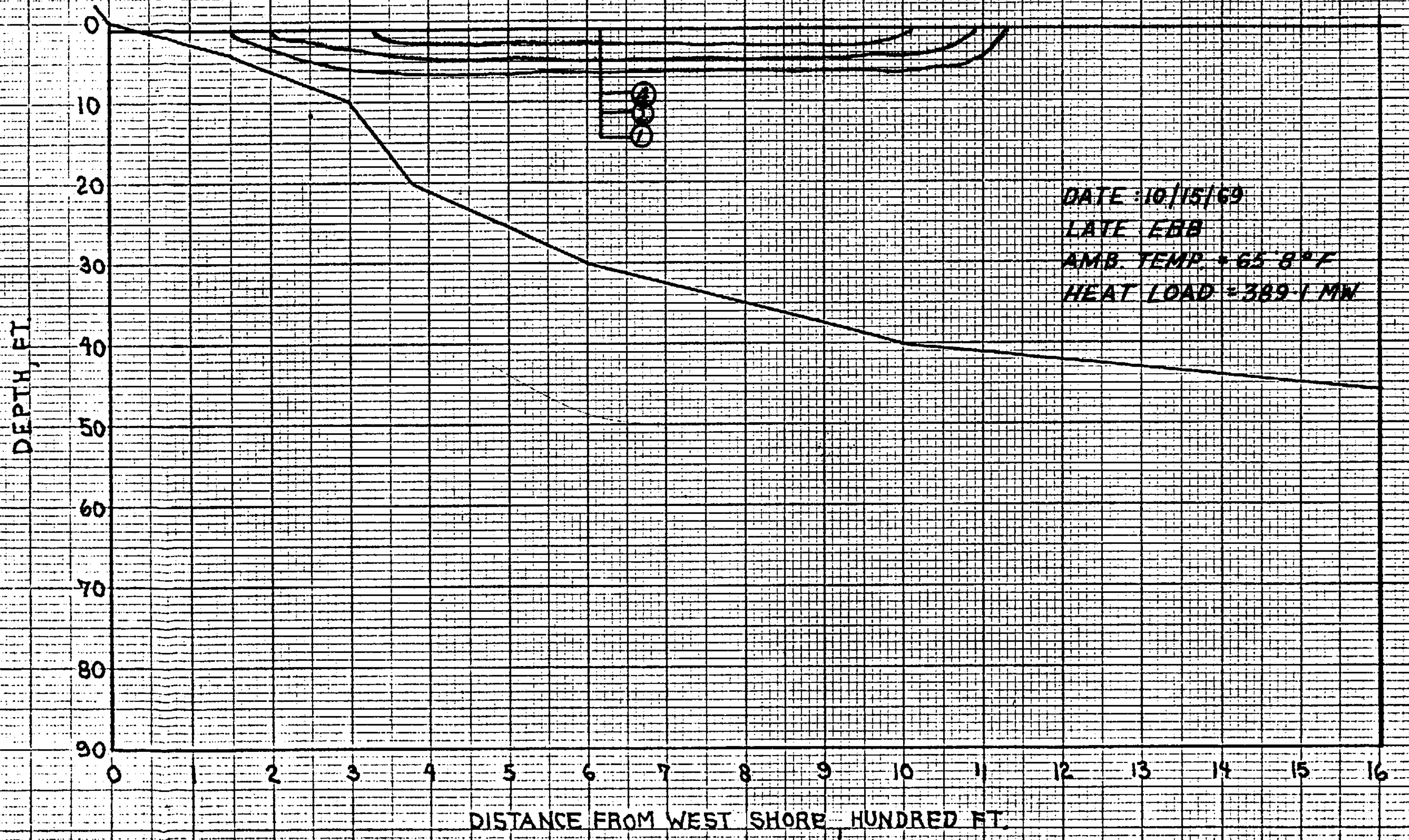
HUDSON RIVER AT DANSKAMMER
2450 FT DOWNSTREAM FROM DISCHARGE



DATE: 10/15/69
LATE EBB
AMB. TEMP = 65.8°F
HEAT LOAD: 389.1 MW

FIGURE B-161

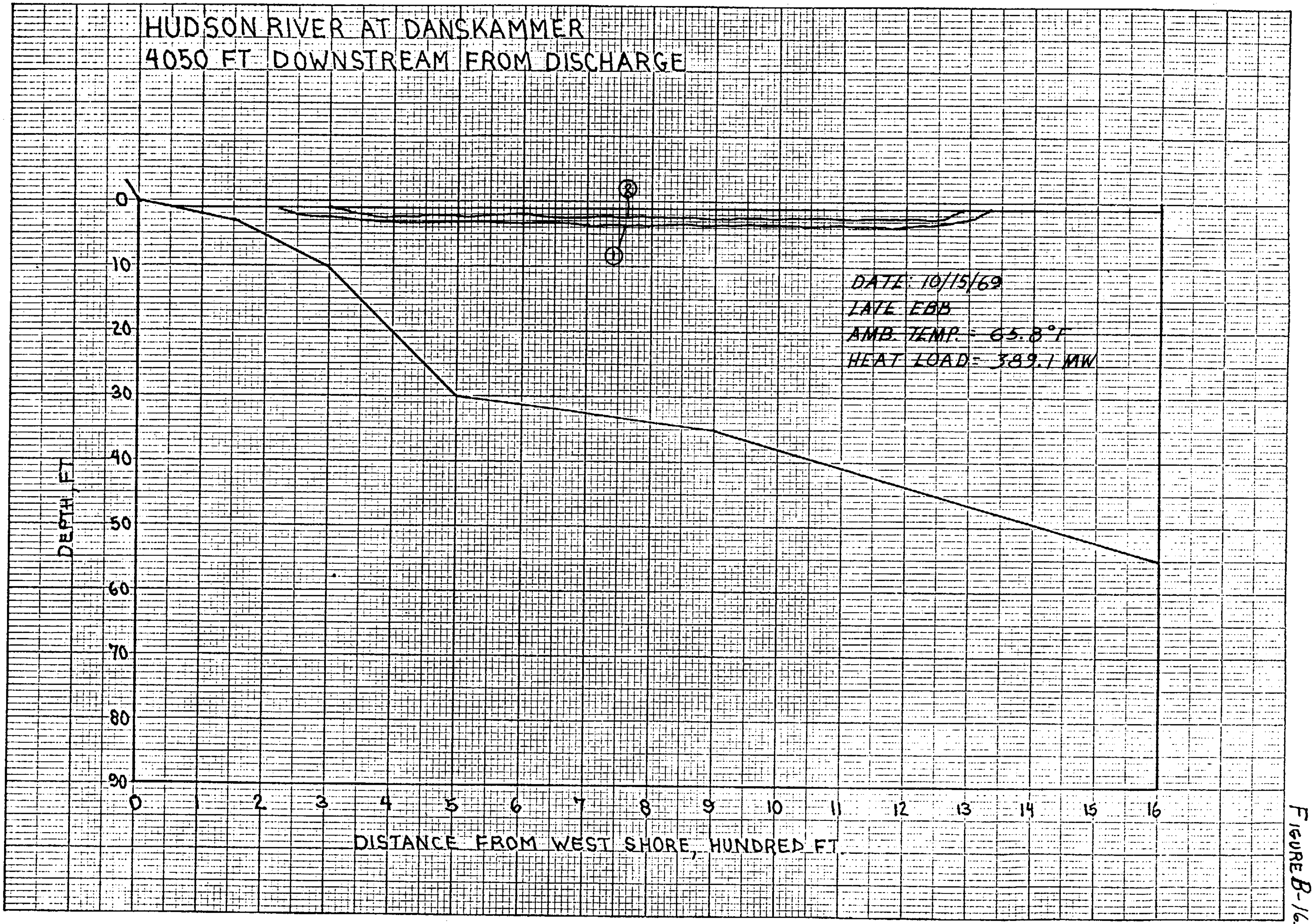
HUDSON RIVER AT DANSKAMMER
3000 FT. DOWNSTREAM FROM DISCHARGE (S-S-4)



DATE: 10/15/69
LATE EBB
AMB. TEMP. = 65.8°F
HEAT LOAD = 389.1 MW

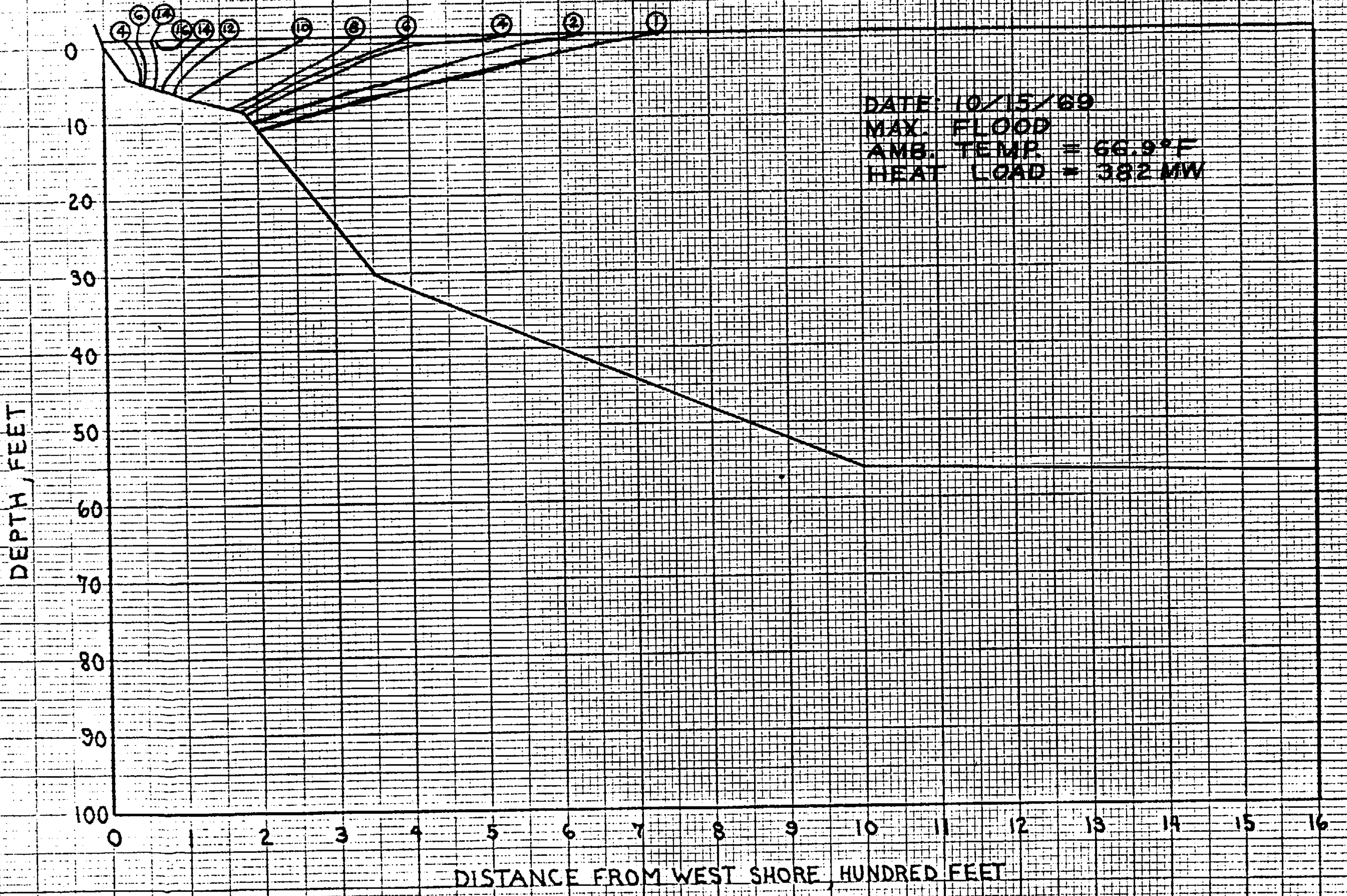
FIGURE B-162

FIGURE B-163



HUDSON RIVER AT DANSKAMMER
4050 FT DOWNSTREAM FROM DISCHARGE

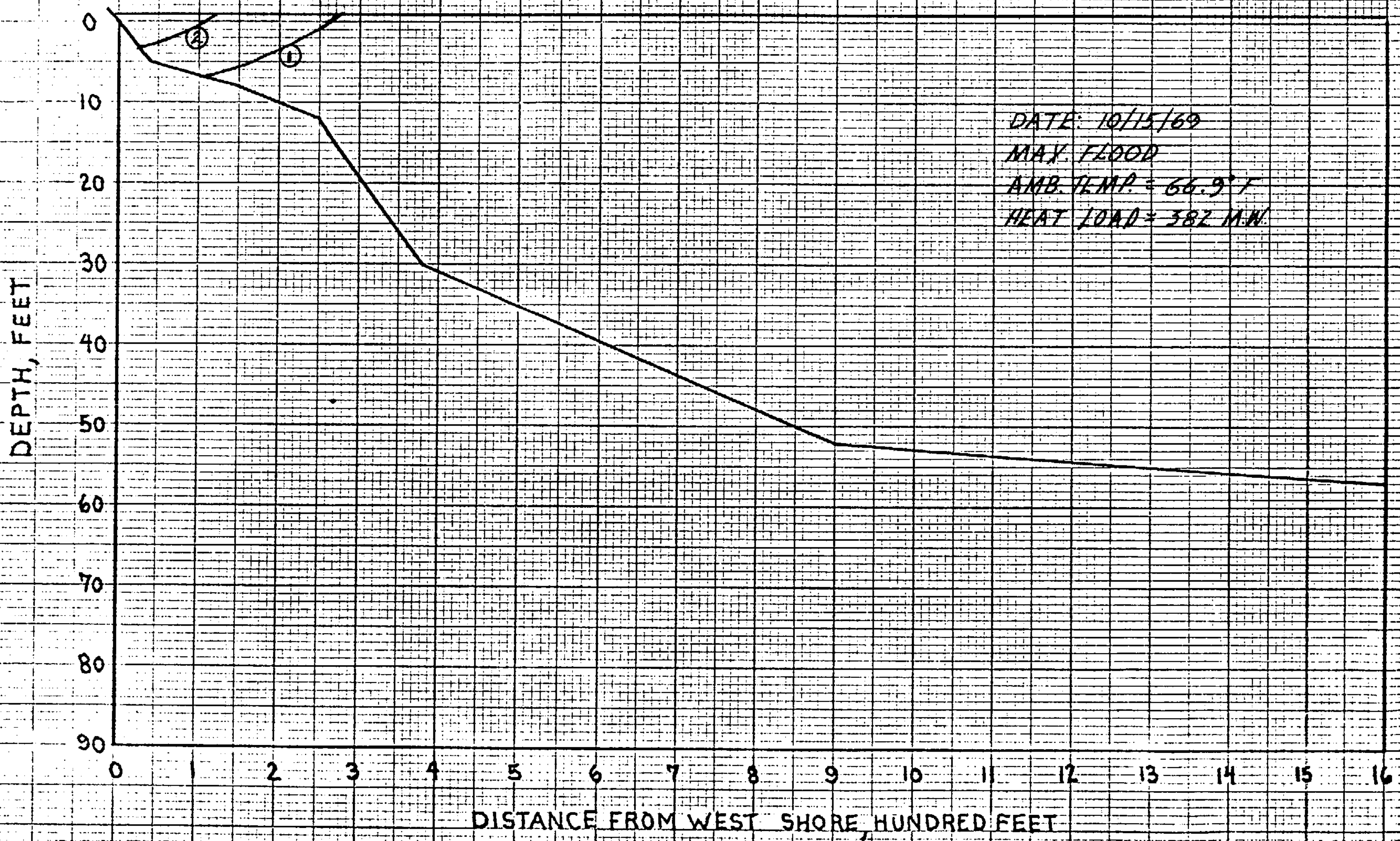
HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 50 FEET DOWNSTREAM FROM DISCHARGE (S-S-1)



DATE: 10/15/69
MAX. FLOOD
AMB. TEMP. = 66.9°F
HEAT LOAD = 382 MW

FIGURE B-164

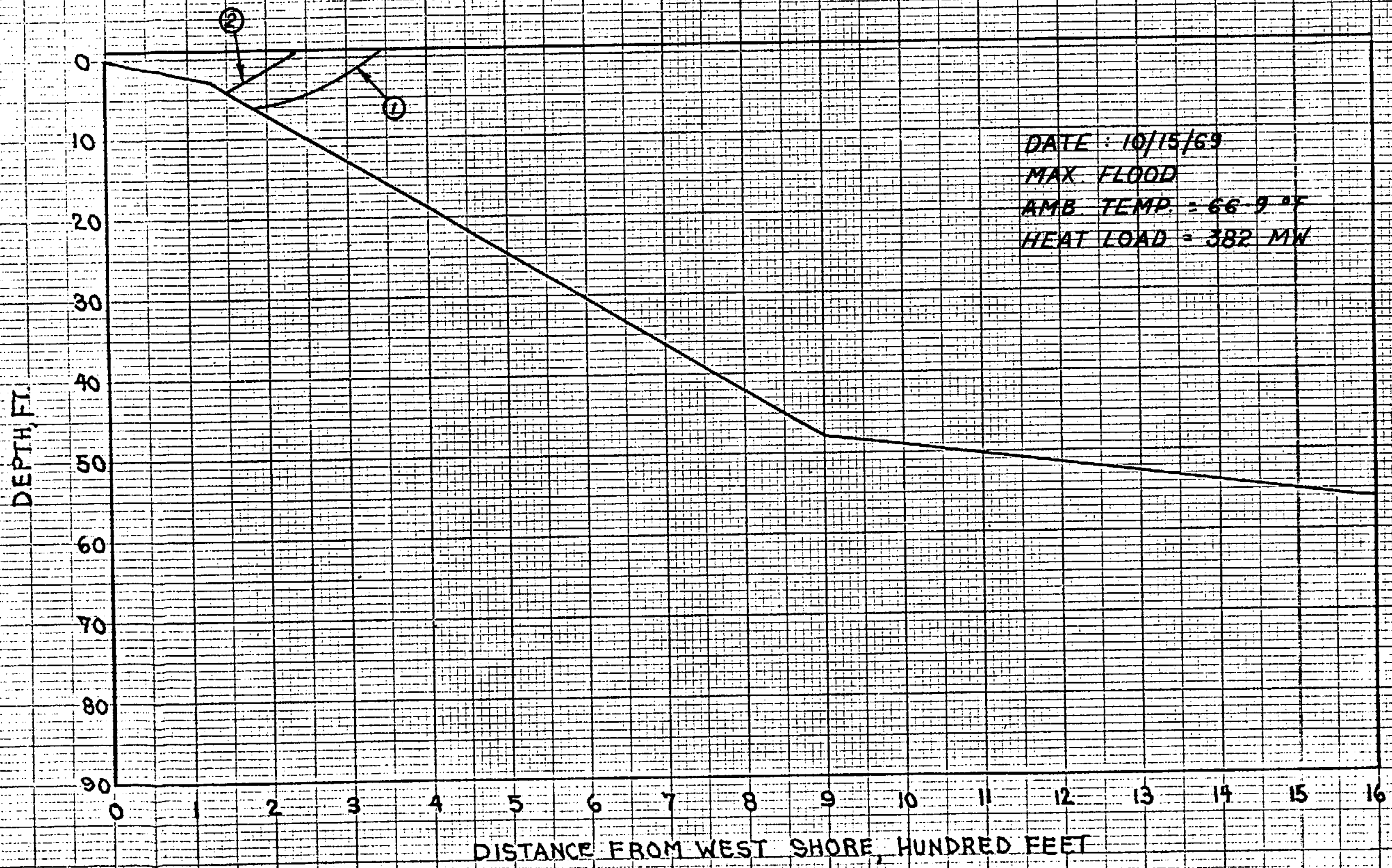
HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 390 FEET DOWNSTREAM FROM DISCHARGE (S-S-2)



DATE: 10/15/69
MAX FLOOD
AMB. TEMP. = 66.9° F
HEAT LOAD = 382 MW

FIGURE B-165

HUDSON RIVER AT DANSKAMMER
800 FT. DOWNSTREAM FROM DISCHARGE (S-S-3)

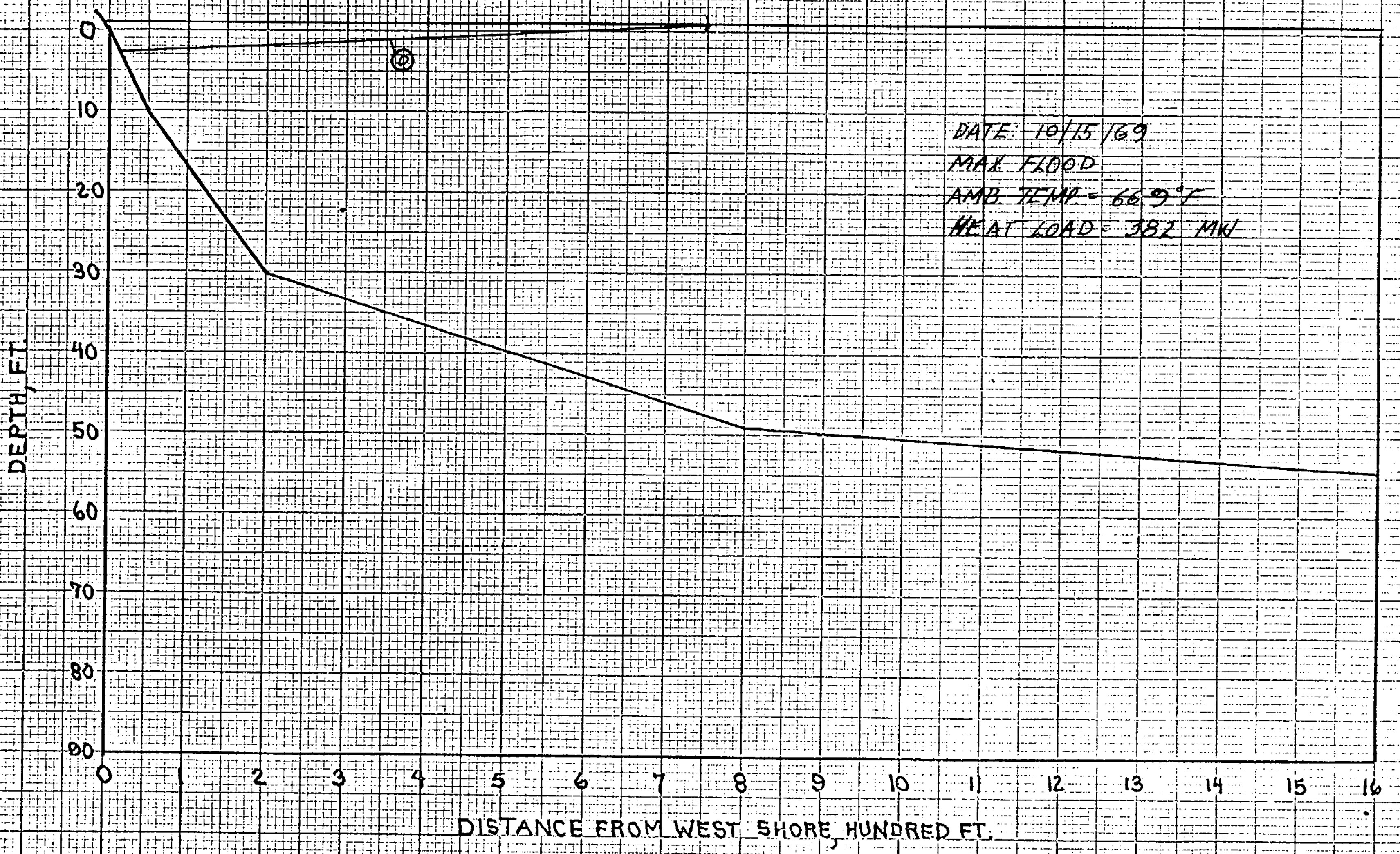


DATE : 10/15/69
MAX FLOOD
AMB TEMP = 66.9 °F
HEAT LOAD = 382 MW

FIGURE B-166

FIGURE B-167

HUDSON RIVER AT DANSKAMMER
1300 FT. DOWNSTREAM FROM DISCHARGE (I - I)



APPENDIX C

VARIABLE THERMAL STRATIFICATION FACTOR MATHEMATICAL MODEL

BY JPL DATE 12-1-69

QUIRK, LAWLER & MATUSKY ENGINEERS
ENVIRONMENTAL SCIENCE & ENGINEERING CONSULTANTS
505 FIFTH AVENUE
NEW YORK, NEW YORK 10017

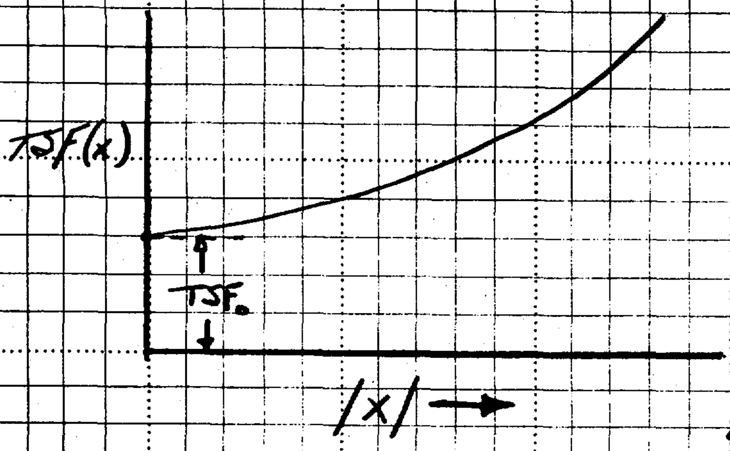
SHEET NO. 1 OF

CHKD. BY DATE

JOB NO. 176-0

SUBJECT OVERALL ~~RIVER~~ THERMAL MODEL

CASE I: ONE-D, DISPERSION VIA E, INCREASING TSF



$TSF = TSF_0 \, e^{a|x|}$

where a is positive

$\Delta \bar{T}_s = TSF \cdot \Delta \bar{T}$

$\Delta \bar{T}_s = 0$ @ $x = \pm \infty$

$\Delta \bar{T} = 0$ @ $x = \pm \infty$

$TSF \rightarrow \infty$ @ $x = \pm \infty$

Say $\Delta \bar{T} = \Delta \bar{T}_0 \, \mathrm{Exp}\, b|x|$

where b is negative

to obtain $\Delta \bar{T}_s = 0$ @ $x = \pm \infty$

$|b| > |a|$

FOR REACH I (upstream)

$$E \frac{d^2 \Delta \bar{T}_I}{dx^2} - U \frac{d \Delta \bar{T}_I}{dx} - K e^{-ax} \cdot \Delta \bar{T}_I = 0$$

FOR REACH II (downstream)

$$E \frac{d^2 \Delta \bar{T}_{II}}{dx} - U \frac{d \Delta \bar{T}_{II}}{dx} - K e^{ax} \cdot \Delta \bar{T}_{II} = 0$$

THE BOUNDARY CONDITIONS ARE:

1. $\Delta \bar{T}_I = 0$ @ $x = -\infty$
2. $\Delta \bar{T}_{II} = 0$ @ $x = +\infty$
3. $\Delta \bar{T}_I = \Delta \bar{T}_{II}$ @ $x = 0$
4. $H = \rho C_p E A \left[\frac{d \Delta \bar{T}_I}{dx} - \frac{d \Delta \bar{T}_{II}}{dx} \right]$ @ $x = 0$

$$K = \frac{\bar{K} \cdot TSF_0}{\rho C_p D}$$

BY JPL DATE 12-1-69 SHEET NO. 2 OF
CHKD. BY DATE JOB NO. 176-0
SUBJECT OVERALL RIVER THERMAL MODEL
CASE I

SOLUTION OF DIFFERENTIAL EQUATION

$$E\frac{d^2T}{dx^2} - U\frac{dT}{dx} - Ke^{ax}\cdot T = 0$$

in which $T = \Delta\bar{T}$, either reach I or reach II

a = negative for reach I

positive for reach II

Note: $|a|$ does not have to be the same for both I & II.

E & U do, otherwise BC # 4 would be different

a of course is constant in each reach

Let $e^{ax} = \tau$, $x = a^{-1}\ln\tau$, $\frac{d\tau}{dx} = ae^{ax} = a\tau$

- $$\frac{dT}{dx} = \frac{dT}{d\tau}\cdot\frac{d\tau}{dx}$$
$$= \frac{dT}{d\tau}\cdot a\tau$$

- $$\frac{d^2T}{dx^2} = \frac{d}{dx}\left(\frac{dT}{dx}\right) = \left[\frac{d}{d\tau}\left(\frac{dT}{d\tau}\cdot a\tau\right)\right]\frac{d\tau}{dx}$$
$$= a\tau\left[a\tau\cdot\frac{d^2T}{d\tau^2} + a\frac{dT}{d\tau}\right]$$
$$= a^2\tau^2\frac{d^2T}{d\tau^2} + a^2\tau\frac{dT}{d\tau}$$

THE ODE BECOMES:

$$Ea^2\tau^2\frac{d^2T}{d\tau^2} + Ea^2\tau\frac{dT}{d\tau} - Ua\tau\frac{dT}{d\tau} - K\tau\cdot T = 0$$

BY ________ DATE ________ SHEET NO. 3 OF ________

CHKD. BY ________ DATE ________ JOB NO. ________

SUBJECT ________

CHECK

$$\frac{d}{dx}\left[E\frac{dT}{dx} - UT\right] - Ke^{ax}\cdot T = 0$$

$$\left\{\frac{d}{dr}\left[\quad '' \quad\right]\right\}\frac{dr}{dx} - Kr\cdot T = 0$$

$$\left\{\frac{d}{dr}\left[E\frac{dT}{dr}\cdot ar - U\cdot T\right]\right\}ar - '' = 0$$

$$Ea^2r^2\frac{d^2T}{dr^2} + Ea^2r\frac{dT}{dr} - Uar\frac{dT}{dr} - Kr\cdot T = 0 \quad \text{ok}$$

REARRANGE TO STANDARD FORM (Hildebrand, p. 156)

$$\left(\frac{1}{Ea^2}\right)$$

$$r^2\frac{d^2T}{dr^2} + r\left(1 - \frac{U}{Ea}\right)\frac{dT}{dr} - \left(\frac{K}{Ea^2}\right)r\cdot T = 0$$

UNIT CHECK: $\frac{U}{Ea}\,[=]\,\frac{FT/SEC}{(FT^2/SEC)\cdot FT^{-1}}$ = dimensionless

$$\frac{K}{Ea^2}\,[=]\,\frac{DAY^{-1}}{MILE^2/DAY\cdot MILE^{-2}} = \;'' \quad \text{ok}$$

CHECK AGAINST EQUA. DEVELOPED IN '64 FOR EXP. AREA

$$\frac{E}{A}\frac{d}{dx}\left[A\frac{dL}{dx} - \frac{Q}{E}L\right] - KL = 0\,, \quad A = A_0e^{ax}$$

a is always positive

$$E\left\{\frac{d}{dr}\left[r\frac{dL}{dr}\cdot(ar) - \frac{U_0}{E}L\right]\right\}ar - KrL = 0 \qquad r = e^{ax}$$

$$\frac{dr}{dx} = ar$$

This is not similar to the above. r appears to the 2nd power in the first term here, whereas above it only appears to the first power in the analogous term.

Solution via Hildebrand (p 157)

General Bessel Equa	Thermal Application
x	r
y	T or better, use θ where $\theta = \frac{\Delta T}{\Delta T_0}$
a	$\left(1 - \frac{U}{Ea}\right)$
b	-0
r	$\neq \infty$
c	0
d	$-\frac{K}{Ea^2}$
s	$1/2$

$$\theta = r^{\left(\frac{U}{2Ea}\right)} Z_p\left(\frac{\sqrt{\frac{-K}{Ea^2}}}{1/2} r^{1/2}\right)$$

in which $p = \frac{1}{1/2}\sqrt{\left(\frac{U}{2Ea}\right)^2} = \frac{U}{Ea}$

∴, since $\frac{\sqrt{d}}{s}$ is imaginary, Z_p are I_p & K_p or I_{-p}

Form of the General Solution

$$\theta = C_1 r^{N_1} I_p \sqrt{N_2 r} + C_2 r^{N_1} K_p \sqrt{N_2 r}$$

in which $N_1 = \frac{U}{2Ea}$, $N_2 = \frac{4K}{Ea^2}$, $p = \frac{U}{Ea}$

See footnote, Hildebrand, p 156 re sign of p. In this case p can be taken as non-negative

SUBSTITUTION OF the Boundary Conditions

1. $\Delta \bar{T}_I = 0$ @ $X = -\infty$

$\Theta_I = 0$ @ $r = e^{ax} = \infty$ a & x both negative

2. $\Delta \bar{T}_{II} = 0$ @ $X = +\infty$

$\Theta_{II} = 0$ @ $r = e^{ax} = \infty$ a & x both positive

3. $\Delta \bar{T}_I = \Delta \bar{T}_{II}$ @ $x = 0$

$\Theta_I = \Theta_{II}$ @ $r = 1$

4. $$H = \rho C_p E A \left[\frac{d\Delta\bar{T}_I}{dx} - \frac{d\Delta\bar{T}_{II}}{dx} \right]_{x=0}$$

$$\frac{H}{\rho C_p E A} = \Delta\bar{T}_0 \left[\frac{d\Theta_I}{dr} \cdot \frac{dr}{dx} - \frac{d\Theta_{II}}{dr} \cdot \frac{dr}{dx} \right]_{r=1}$$

$$= \Delta\bar{T}_0 \left[\left(\frac{d}{dx}\left(e^{ax}\right) \right) \frac{d\Theta_I}{dr} - \left(\frac{d}{dx}\left(e^{ax}\right) \right) \frac{d\Theta_{II}}{dx} \right]_{r=1}$$

$$= \Delta\bar{T}_0 \left[r \cdot a_I \frac{d\Theta_I}{dr} - r\, a_{II} \frac{d\Theta_{II}}{dr} \right]_{r=1}$$

$$\frac{1}{\Delta T_0} \left[\frac{H}{\rho C_p E A} \right] = a_I \frac{d\Theta_I}{dr} - a_{II} \frac{d\Theta_{II}}{dr}$$

Note: a_I & $\frac{d\Theta_I}{dr}$ are both negative, so product is positive

a_{II} is positive, $d\Theta_{II}/dr$ is negative, so neg. prod is positive

$\frac{d\Theta_I}{dr}$, $\frac{d\Theta_{II}}{dr}$ are both neg., since r varies from unity to infinity for both, and Θ_I & Θ_{II} both decrease from $r=1$ to zero @ $r = \infty$

SUBJECT REDUCTION OF BC # 4 to dimensionless form

LET $f_1 = a_I / a_{II}$, $f_2 = a_{II}/a_{II} = \underline{1}$

$$\frac{1}{a_{II} \cdot \Delta T_0}\left(\frac{H}{\rho C_p E A}\right) = f_1 \frac{d\Theta_I}{d\tau} - \frac{d\Theta_{II}}{d\tau}$$

CHECK UNITS OF LEFT SIDE

$$\frac{1}{\frac{1}{\cancel{FT}} \times \cancel{{}^\circ F}}\left(\frac{\cancel{BTU/DAY}}{\cancel{\#/CF} \cdot \cancel{\frac{BTU}{\#\text{-}{}^\circ F}} \cdot \cancel{\frac{SF}{DAY}} \cdot SF}\right) \Rightarrow \text{DIMENSIONLESS} \quad \boxed{ok}$$

Now ΔT_0 is as yet undefined, appearing so far as the undefined, constant characteristic temp rise.

LET $\Delta T_0 = \dfrac{H}{\rho C_p a_{II} E A}$

The fourth BC then becomes:

$$1 = f_1 \frac{d\Theta_I}{d\tau} - \frac{d\Theta_{II}}{d\tau} \quad @ \ \tau = 1$$

Note: f_1 is always negative & may take on any finite, non ~~zero~~ value.

BC #1

$$\Theta_I = 0 = C_1(\infty)^{-|N_1|} I_{|2N_1|}\sqrt{+\infty} + C_2(\infty)^{-|N_1|} K_{|2N_1|}\sqrt{+\infty}$$

$$= C_1\cdot(0)\cdot(\infty) + C_2\cdot(0)\cdot(0)$$

ASYMPTOTIC BEHAVIOR OF FIRST TERM:

$$\rho^{-\frac{U}{2Ea_I}}\cdot I_{\left|\frac{U}{Ea_I}\right|}\sqrt{\frac{4K}{Ea_I^2}\rho} \quad \text{as } \rho\to\infty$$

as $\rho\to\infty$

$$= \rho^{\frac{U}{2Ea_I}}\cdot\frac{C^{\sqrt{\frac{4K}{Ea_I^2}\rho}}}{\sqrt{2\pi\sqrt{\frac{4K}{Ea_I^2}\rho}}} \quad \text{in which } a_I \text{ is neg.}$$

$$= \frac{C^{\text{POSITIVE } \rho}}{\text{COEFF}\cdot\rho^{\text{POSITIVE BUT SINGLE VALUED \& FINITE}}} = \infty \quad \text{as } \rho\to\infty$$

THEREFORE C_1 MUST EQUAL ZERO

BC #2

$$\Theta_{II} = 0 = \underbrace{C_3(\infty)^{+|N_1|} I_{|2N_1|}\sqrt{+\infty}} + C_4(\infty)^{+N_1} K_{|2N_1|}(\infty)$$

$$= C_3\cdot(\infty)\cdot(\infty) + C_4\cdot(\infty)\cdot(0)$$

C_4 must be [illegible]. C_4 is shown to be [illegible] on the next page, i.e. indeterminate is shown to go to zero

$$0 = C_4 \cdot r^{N_1} \cdot K_{/2N_1/}\sqrt{N_2 r} \quad \text{as } r \to \infty$$

as $r \to \infty$, $K_{/2N_1/}\sqrt{N_2 r} \to ?$

Hildebrand gives behavior OF K_p as follows

$$K_p(x) \to \frac{e^{-x}}{\sqrt{\frac{2}{\pi} x}}, \quad x \to \infty$$

or $r^{\frac{U}{2Ea_{II}}} \cdot \frac{e^{-\text{positive}}}{\sqrt{\frac{2}{\pi}\,\text{positive}}} \to 0$

Therefore, upon SUBST. of BC #1 & 2, we have:

$$\Theta_I = C_7\, r^{N_1} K_{2N_1}\sqrt{N_2 r}, \quad N_1 \text{ negative}$$

$$\Theta_{II} = C_4\, r^{N_1} K_{-2N_1}\sqrt{N_2 r}, \quad N_1 \text{ positive}$$

SUBSTITUTING BC #3, GET:

$$C_7 = C_4$$

Therefore, prior to use of BC #4, we have:

$$\left.\begin{matrix}\Theta_I \\ \Theta_{II}\end{matrix}\right\} = C \begin{cases} r^{-N_{1_1}} K_{/2N_{1_1}/}\sqrt{N_{2_1} r}, & N_{1_1} = \frac{U}{2Ea_I} \\ r^{N_{1_2}} K_{2N_{1_2}}\sqrt{N_{2_2} r}, & N_{1_2} = \frac{U}{2Ea_{II}} \end{cases}$$

$N_{2_1} = \frac{K}{Ea_I^2}$

$N_{2_2} = \frac{K}{Ea_{II}^2}$

Application of BC #4

$$1 = f_1 \frac{d\Theta_I}{dr} - \frac{d\Theta_{II}}{dr} \quad @ \; r = 1$$

$$\frac{d\Theta_I}{dr} = C\left[N_1 \cdot r^{N_1 - 1} K_{|2N_1|}\sqrt{N_2 r} + r^{N_1}\frac{d}{dr}\left(K_{|2N_1|}\sqrt{N_2 r}\right)\right.$$

NEED the derivative wrt r of $K_{|2N_1|}\sqrt{N_2 r}$

$$\frac{d\,K_p(\alpha r)^{1/2}}{dr} = \frac{d\,K_p(\alpha r)^{1/2}}{d(\alpha r)^{1/2}} \cdot \frac{d(\alpha r)^{1/2}}{dr}$$

$$= \left[-K_{p+1}(\alpha r)^{1/2} + \frac{p}{(\alpha r)^{1/2}} K_p(\alpha r)^{1/2}\right]\frac{(\alpha r)^{-1/2}}{2}\alpha$$ Hildebr. p. 152 eq. 110

Applied to the above, $p = |2N_1|$, $\alpha = N_2$,
when $r \to 1$, this becomes

$$\left[-K_{|2N_1|+1}(N_2)^{1/2} + \frac{|2N_1|}{\sqrt{N_2}} K_{|2N_1|}(N_2)^{1/2}\right]\frac{\sqrt{N_2}}{2}$$

absolute val. (since p is non-neg.

$$\left.\frac{d\Theta_I}{dr}\right\}_{r=1} = C\left[\underset{\text{numerically negative}}{N_1} \cdot K_{2N_1}\sqrt{N_2} - \frac{\sqrt{N_2}}{2} K_{|2N_1|+1}\sqrt{N_2} + |N_1| K_{2N_1}\sqrt{N_2}\right]$$

$N_1 = \frac{U}{2Ea_I}$, neg.

~~For $\frac{d\Theta_{II}}{dr}$, Hildebrand p 15?, eq 110 yields the more tractable form~~

$$\frac{d\left(K_p(\alpha r)^{1/2}\right)}{dr} = \frac{(\alpha r)^{-1/2}\alpha}{2}\left[K_{p+1}(\alpha r)^{1/2} - \frac{p}{(\alpha r)^{1/2}} K_p(\alpha r)^{1/2}\right], \quad p = -2N_{1_{II}}, \; \alpha = N_{2_{II}}$$

$$\left.\frac{d\Theta_{II}}{dr}\right\}_{r=1} = C\left[\underset{\text{positive}}{N_1} \cdot K_{2N_{1_{II}}}\sqrt{N_{2_{II}}} + \frac{\sqrt{N_{2_{II}}}}{2} K_{2N_{1_{II}}+1}(\sqrt{N_2}) - \frac{2N_{1_{II}}\sqrt{N_2}}{\sqrt{N_{2_{II}}}\,2} K_{2N_{1_{II}}}(\sqrt{N_2})\right]$$

$N_1 = U/2Ea_{II}$

$$1 = C\left[-f_1\frac{\sqrt{N_{2_1}}}{2}\cdot K_{2N_1+1}(\sqrt{N_{2_1}}) - \left[\left(K_{-2N_2+1}(\sqrt{N_{2_2}})\right)\frac{\sqrt{N_{2_2}}}{2}\right]\right]$$

$$C = 2\left[-f_1\sqrt{N_{2_1}}\cdot K_{2N_1+1}(\sqrt{N_{2_1}}) + \sqrt{N_{2_2}}\,K_{-2N_2-1}(\sqrt{N_{2_2}})\right]^{-1}$$

& PROBLEM IS SOLVED

For simple case of $a_I = -a_{II}$, $f_1 = -1$

$N_{2_1} = N_{22}$, $N_1 = -N_2$ Let $N_1 = -N_1$

$N_{12} = N_1$

$N_{2_1} = N_{22} = N_2$

C THEN IS GIVEN:

$$C = \frac{2}{\sqrt{N_2}}\underbrace{\left[+K_{2N_1+1}(\sqrt{N_2}) + K_{2N_1-1}(\sqrt{N_2})\right]}_{= \left[-2\frac{dK_{2N_1}(\sqrt{N_2})}{d\sqrt{N_2}}\right]^{-1}}$$

raised to -1 power

Hildebrand, p152, eq 112a

$$C = -\left\{\sqrt{N_2}\frac{dK_{2N_1}(\sqrt{N_2})}{d\sqrt{N_2}}\right\}^{-1}$$

as N_2 inc, K decr.
deriv. is neg. [illegible]
OK

SOLUTION

$$\Theta_I = \frac{2\,\tau^{-N_1} K_{2N_1} \sqrt{N_2 \tau}}{\sqrt{N_2}\left[K_{2N_1+1}(\sqrt{N_2}) + K_{2N_1-1}(\sqrt{N_2})\right]}$$

N_1 in exponent must remain negative because τ in reach I is $\exp(ax)$ where a is negative

$$\tau^{N_1} = e^{aN_1x} = e^{\frac{u}{2E}x}$$

where x is neg

$$\Theta_{II} = \frac{2\,\tau^{N_1} K_{2N_1} \sqrt{N_2 \tau}}{\sqrt{N_2}\left[K_{2N_1+1}(\sqrt{N_2}) + K_{2N_1-1}(\sqrt{N_2})\right]}$$

AT POINT OF DISCHARGE

$$\Theta_I = \Theta_{II} = \frac{2\,K_{2N_1} \sqrt{N_2}}{\sqrt{N_2}\left[K_{2N_1+1}\sqrt{N_2} + K_{2N_1-1}\sqrt{N_2}\right]}$$

Typical Case

$N_1 = \frac{U}{2E|a|}$ for order of BF

$N_2 = \frac{4K}{Ea^2}$

$\Theta = \frac{\Delta T}{\Delta T_0}$, $\Delta T_0 = \frac{H}{\rho C_p |a| E A}$

Roseton - see Notes of 3/5/69 - Book I, Job # 176-0

$E = 6$ sq mi/day

$U = 0.44$ mi/day

Calc of a

TSF @ Dansk discharge = 10.1 (400' below discharge)

" " Roseton intake = 19.5 (2700' " ")

$\ln \frac{TSF_1}{TSF_2} = ax$, $a = \frac{2.3 \log\left(\frac{19.5}{10.1}\right)}{\frac{2700}{5280}} = \frac{2.3 \times 0.286}{0.51} = 1.29 \text{ mi}^{-1}$

$N_1 = \frac{0.44}{2 \times 6 \times 1.29} = 0.0284$

Thus, for the Rapid Growth Rates & Low velocities, Character of our problem, it appears that the order of the BF approaches zero. At $r = 1$, $K_0(r^{1/2})$ & $K_1(r^{1/2})$ are rather close, & get closer as $r \rightarrow$ (see Wylie - p419) - if $\sqrt{N_2}$ is fract, stan diff. will be greater @ $r=1$, but N_1 is so close to zero, approx as zero order appears to be excellent. Note $K_p = K_{-p}$ (see def.)

about 0.5 & 0.65 respect

B

Solution as zero order BF i.e. $N_1 \to 0$
velocity effect negl.

$$\Theta_{I,II} = \frac{-K_0\sqrt{N_2 r}}{\left[\sqrt{N_2}\,\frac{d}{d\sqrt{N_2}}\left\{K_0\sqrt{N_2}\right\}\right]}$$

$$= \frac{K_0\sqrt{N_2 r}}{\sqrt{N_2}\,K_1\sqrt{N_2}}$$

$N_2 = \frac{4K}{Eq^2}$ / $K = \frac{\bar{K}\cdot TSF_0}{\rho C_p D} = \frac{150\times 10.1}{62.4\times 30}$

$= 0.81\ day^{-1}$

$= \frac{4\times 0.81}{6\times 1.29\times 1.29} = 0.324$ $\sqrt{N_2} =$

should this soln = unity ? check identities

$\Theta_I @ r=1 = \frac{K_0\sqrt{N_2}}{\sqrt{N_2}K_1\sqrt{N_2}} = \frac{K_0(0.57)}{0.57K_1(0.57)} = \frac{\overset{0.82}{\cancel{0.83}}}{0.57\times \underset{1.41}{\cancel{1.37}}}$

$= \cancel{1.06}\ 1.02$

$\Delta T_0 = \frac{H}{\rho C_p q E A}$ $H = 1.72\times 10^{11}$
$A = 150{,}000\ SF$

$= \frac{1.72\times 10^{11}}{62.4\times 1.29\times 6\times 15\times 10^5 \times 5280\ \frac{FT}{mile}}$ ② ⑤ 4 $= \frac{1.72\times 10^{11}}{0.624\times 1.29\times 6\times 1.5\times 0.528\times 10^{11}}$

0.46

$= 0.45\,°F$

$\Delta\bar{T}\}_{x=0} = \overset{1.02}{\cancel{1.06}}\times 0.45 = \cancel{0.48}$

$\Delta\bar{T}_S\}_{x=0} = \overset{0.46}{\cancel{0.48}}\times 10.1 = \overset{4.6}{\cancel{4.8}}\,°F$

256F

$\frac{BTU/DAY}{\#/CF \times \frac{BTU}{\#\text{-}°F}\times\frac{1}{mile}\times\frac{mile^2}{Day}\times °F\times\frac{FT}{mile}} = °F$ ok

Comparable result for static TSF

If TSF = 10.1, $\frac{4K'E}{u^2} = 14.85 \times \frac{10.1}{1.5} = 100$

$\Delta \bar{T} = 2.0 \times \frac{4}{10} = 0.8°F$ vs 0.48 by growth function

- Growth function will also show rapid downstream decay
- Integrate over $-\infty$ to $+\infty$ to show complete loss
- Do for expanding area of E (both exp.) (Check functions first)
- Use NNTF approach w/wo an E for high tidal & NTF – in both cases use Expanding TSF.

BY ________ DATE ________ SHEET NO. 15 OF ________

CHKD. BY ________ DATE ________ JOB NO. ________

SUBJECT

CHECK SOLUTION IN ODE, BC & OVERALL INTEGRAL

1. Integration of total Region

$$H = \int_{-\infty}^{\infty} \bar{K} \cdot TSF \cdot \Delta \bar{T} \cdot B \, dx$$

$$= \int_{-\infty}^{\infty} e^{ax} \cdot \Delta \bar{T} \, dx \left[\bar{K} \cdot TSF_0 \cdot B \right] \qquad a e^{ax} dx = d\eta$$

$$= \left\{ \Delta T_0 \int_{-\infty}^{1} \Theta_I(\eta) \frac{d\eta}{a_I} + \Delta T_0 \int_{1}^{\infty} \Theta_{II}(\eta) \frac{d\eta}{a_{II}} \right\} \left[\bar{K} \cdot TSF_0 \cdot B \right]$$

For symmetric case $\frac{U}{2aE} \to 0$ (U negligible)

$$\frac{H a}{\bar{K} \cdot TSF_0 \cdot B \cdot \Delta T_0} = 2 \int_1^{\infty} \frac{K_0 \sqrt{N_2 \eta}}{\sqrt{N_2}\, K_1 \sqrt{N_2}} \, d\eta$$

$$\int_1^{\infty} K_0 \sqrt{N_2 \eta} \, d\eta = \frac{H \cdot a \cdot \sqrt{N_2} \cdot K_1 \sqrt{N_2}}{2 \bar{K} \cdot TSF_0 \cdot B \cdot \Delta T_0}$$

$d(\sqrt{\eta})^2$
$= 2\sqrt{\eta}\, d\sqrt{\eta}$
when $\eta = 1, \infty$
$\sqrt{\eta} = 1, \infty$
$\sqrt{N_2 \eta} = \sqrt{N_2}, \infty$

$$\int_1^{\infty} 2\sqrt{\eta}\, K_0 \sqrt{N_2 \eta} \, d\sqrt{\eta} = \text{''}$$

$$\frac{2}{N_2} \int_{\sqrt{N_2}}^{\infty} \sqrt{N_2 \eta}\, K_0 \sqrt{N_2 \eta} \, d\sqrt{N_2 \eta} = \text{''}$$

$$\int_{\sqrt{N_2}}^{\infty} \sqrt{N_2 \eta} \cdot K_0 \sqrt{N_2 \eta} \, d\sqrt{N_2 \eta} = \frac{H \cdot a \cdot N_2^{3/2} \cdot K_1 \sqrt{N_2}}{4 \bar{K} \cdot TSF_0 \cdot B \cdot \frac{H}{\rho C_p a E A}}$$

$$\Delta T_0 = \frac{H}{\rho C_p a E A}$$

Since $N_r = \frac{4K}{Eq^2}$, $K = \frac{\bar{K}\,TSF_0}{\rho C_p D}$, Right side becomes:

B·D

$$\frac{\cancel{H\cdot a\cdot\left(\frac{4K}{Eq^2}\right)\left(\frac{\bar{K}\,TBF_0}{\rho C_p D}\right)}\sqrt{N_r}\,K_1\sqrt{N_r}\,\cancel{\left(\rho C_p a_1 K H\right)}}{\cancel{4\bar{K}\cdot TSF_0\cdot B\cdot H}} = \sqrt{N_r}\,K_1\sqrt{N_r}$$

Proof therefore Requires that we show:

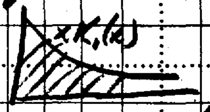
$$\int_{\sqrt{N_r}}^{\infty}\sqrt{N_r\rho}\cdot K_0\sqrt{N_r\rho}\;d\sqrt{N_r\rho} = \sqrt{N_r}\,K_1\sqrt{N_r}$$

Using analogy for $\int J_p(\alpha x)$ (p 178, H) (Prob OK, see p 153 eq 114 - same form for J & K

$$\int_{x_1}^{\infty} x\,K_0(x)\,dx = \Big[x\,K_1(x)\Big]_{x_1}^{\infty} = \Big[\sqrt{N_r\rho}\,K_1\sqrt{N_r\rho}\Big]_{\sqrt{N_r}}^{\infty}$$

$$\left[\overset{\to 0}{\infty\cdot 0} - \sqrt{N_r}\,K_1\sqrt{N_r}\right] \neq \sqrt{N_r}\,K_1\sqrt{N_r}$$

All ok except sign - analogy prob. correct except for sign - must be since



area under this curve would be pos.

Yes - sign is reversed - see 11.3.27, p 484, HMF

2. CHECK solution in ODE: Use Zero-order Soln.

$$\Theta_I = \Theta_{II} = \frac{K_0\sqrt{N_2\tau}}{\sqrt{N_2}\,K_1\sqrt{N_2}}$$

Use ODE in X so check will include transform check

$$E\frac{d^2\overline{\Delta T}}{dx^2} - \frac{U\,d\overline{\Delta T}}{dx} - Ke^{ax}\cdot\overline{\Delta T} = 0$$

For this case, U = 0

$$E\cdot\cancel{\Delta T_0}\frac{d^2\Theta}{dx^2} - Ke^{ax}\cdot\cancel{\Delta T_0}\cdot\Theta = 0$$

LET $\tau = e^{ax}$, $K_0\sqrt{N_2\tau} = K_0\sqrt{N_2}\,e^{\frac{ax}{2}}$

$$E\frac{d^2\left[K_0\left(\sqrt{N_2}e^{\frac{ax}{2}}\right)\right]}{dx^2} - Ke^{ax}K_0\left(\sqrt{N_2}e^{\frac{ax}{2}}\right) = 0$$

$$E\frac{d}{dx}\left[\frac{d}{d\sqrt{N_2}e^{\frac{ax}{2}}}K_0\left(\sqrt{N_2}e^{\frac{ax}{2}}\right)\frac{d\sqrt{N_2}e^{\frac{ax}{2}}}{dx}\right] - Ke^{ax}K_0\left(\sqrt{N_2}e^{\frac{ax}{2}}\right) = 0$$

$$E\frac{d}{dx}\left[-K_1\left(\sqrt{N_2}e^{\frac{ax}{2}}\right)\cdot\sqrt{N_2}\,e^{\frac{ax}{2}}\cdot\frac{a}{2}\right] - \text{''}$$

$e^{\frac{ax}{2}}$ −

$$-E\left[\left(-K_0\left(\sqrt{N_2}e^{\frac{ax}{2}}\right) - \frac{1}{\sqrt{N_2}e^{\frac{ax}{2}}}K_1\left(\sqrt{N_2}e^{\frac{ax}{2}}\right)\right)N_2e^{ax}\cdot\frac{a^2}{4} + K_1\left(\sqrt{N_2}e^{\frac{ax}{2}}\right)\cdot\sqrt{N_2}\frac{a^2}{4}\right.$$

or

$$\left(\left(K_0\sqrt{N_2\tau} + \frac{K_1\sqrt{N_2\tau}}{\sqrt{N_2\tau}}\right)N_2\tau + K_1\sqrt{N_2\tau}\cdot\sqrt{N_2\tau}\right) + \left(\frac{4K}{Ea^2}\right)\left(K_0\sqrt{N_2\tau}\right)\tau = 0$$

cancels

$N_2\tau K_0\sqrt{N_2\tau} - N_2\tau K_0\sqrt{N_2\tau} = 0$ OK

3. Check Solution in BC

always positive, both reaches

$$\Theta_{I,II} = \frac{K_0 \sqrt{N_2 r}}{\sqrt{N_2} K_1 \sqrt{N_2}} = 0 \ @ \ r = +\infty$$

BC 1 & 2 OK

BC #3 ok by inspection

$$BC \#4: \quad 1 = -\frac{d\Theta_I}{dr} - \frac{d\Theta_{II}}{dr}\Bigg\}_{@ r = 1} = -2\frac{d\Theta_{II}}{dr}$$

$$\frac{d\Theta}{dr} = \frac{d\Theta}{d\sqrt{N_2 r}} \cdot \frac{d\sqrt{N_2 r}}{dr}$$

$$= \left(\frac{1}{\sqrt{N_2} K_1 \sqrt{N_2}}\right)\left(-K_1 \sqrt{N_2 r}\right) \frac{\sqrt{N_2}}{2} r^{-1/2}$$

$$@ r = 1 \rightarrow -\frac{1}{2}$$

$$\text{SUBST in BC:} \quad 1 = -2\left(-\frac{1}{2}\right) = 1 \ \boxed{\text{OK}}$$

Everything checks for zero order solution - if future use is to be made of non-zero order soln. check it also, although it should be right since zero order soln. was obtained from general order solution (could however have had an error which might have been dropped out, or compensated for, in going to zero order case.

CAN the SURFACE temperature RISE as x increases

$$\Delta\bar{T} = \Delta T_0 \cdot \Theta(\tau)$$, a monotonic, decreasing funct. of $\tau\,(\propto x)$

$$\Delta\bar{T}_s = TSF \cdot \Delta T_0 \cdot \Theta(\tau)$$

$$= TSF_0 \cdot \Delta T_0 \cdot \tau\,\Theta(\tau)$$

$$\Theta_s = \frac{\Delta\bar{T}_s}{TSF_0 \cdot \Delta T_0} = \tau\,\Theta(\tau)$$

is this function monotonic

$$\Theta_s = \frac{\tau\; K_0\sqrt{N_2\tau}}{\sqrt{N_2}\,K_1\sqrt{N_2}} = \frac{\overbrace{(\sqrt{N_2\tau})^2 K_0\sqrt{N_2\tau}}}{N_2^{3/2}\,K_1\sqrt{N_2}}$$

LET $(\sqrt{N_2\tau})^2 K_0\sqrt{N_2\tau} = \xi^2 K_0\,\xi$

$$\frac{d\;\xi^2 K_0\xi}{d\xi} = 2\xi K_0\xi - \xi^2 K_1\xi = 0$$

$$\xi\left(2K_0\xi - \xi K_1\xi\right) = 0$$

One extremum @ $\xi = 0$. But τ never equals 0, so this solution is extraneous to the bounds of this problem.

$$2K_0(\xi) - \xi K_1(\xi) = 0$$

[i.e. - provided ~~TSF~~ is growing in both directions

Extremum @ $\xi = \dfrac{2K_0(\xi)}{K_1(\xi)}$

Behavior of 2nd term. (negative, as shown below → MAXIMUM

$$\frac{d}{d\xi}\left[\frac{d}{d\xi}\left(\xi^2 K_0\xi\right)\right] = 2K_0\xi - 2\xi K_1\xi - 2\xi K_1\xi - \xi^2\frac{d}{d\xi}K_1\xi$$

$$= 2K_0(\xi) - 4\xi K_1\xi - \xi^2\left(K_0\xi - \xi^{-1}K_1\xi\right);$$ evaluate @ $\xi = \dfrac{2K_0(\xi)}{K_1(\xi)}$

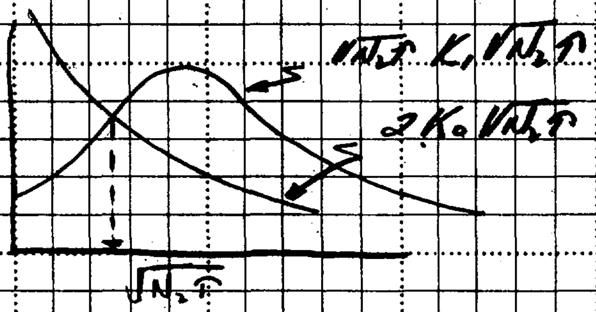
$$= 2K_0 - 8\frac{K_0}{\cancel{K_1}}\cancel{K_1} - \frac{4K_0^3}{K_1^2} + 2\frac{K_0}{\cancel{K_1}}\cancel{K_1} = -4K_0 - \frac{4K_0^3}{K_1^2}$$ = negative

Value of ΔT_3 at maximum

$$\Theta_{3_{Max}} = \frac{(\sqrt{N_2 T})^2 K_0 \sqrt{N_2 T}}{N_x^{3/2} \cdot K_1 \sqrt{N_x}} \quad \Bigg\} \quad \sqrt{N_2 T} = \frac{2K_0 \sqrt{N_2 T}}{K_1 \sqrt{N_2 T}}$$

To find value of $\Theta_{3_{Max}}$, solve:

$$(\sqrt{N_2 T}) K_1 \sqrt{N_2 T} = 2K_0 \sqrt{N_2 T}$$



SUBJECT

INVESTIGATE EXTREMUM CASE, USING ASYMPTOTIC EXP, SMALL ARG.

$$\xi = \frac{2K_0(\xi)}{K_1(\xi)} = \frac{-2\ln\xi}{2^0(0)!\,\xi^{-1}}$$

$$= -2\xi\ln\xi$$

But ξ must be < 1 for signs to agree.

Thus $\sqrt{N_0}\,P_{CRIT} < 1$

Furthermore, ξ values cancel & get

$$\ln\xi = -0.5$$

$$\xi = \text{Exp}(-0.5) = 0.607, \text{ say } 0.6$$

TOO INACCURATE — see below

Check Table of Bessel Functions for more

X	e^x	$e^x K_0 x$	$2K_0 x$	$e^x K_1 x$	$K_1 x$	$\left(\frac{2K_0 x}{K_1 x}\right)x$
0.6	1.822	1.417	1.556	2.374	1.303	1.195
0.5	1.648	1.524	1.852	2.731	1.658	1.118
0.4	1.492	1.663	2.23	3.259	2.182	1.022
0.3	1.350	1.853	2.75	4.125	3.055	0.904

[illegible] 1/2 not really

must approach unity for either

Linear interpol. $\frac{1.02-1.00}{1.02-0.9}\times 0.1 = \frac{.02}{.12}\times 0.1 = 0.0167 = 0.3833$

But stay on upside, so use 0.385

Use $\xi_{crit} = 0.385$

$\sqrt{N_2 \tau_{crit}} = 0.385$

$\tau_{crit} = 0.148 / N_2$

For this problem, $N_2 = 0.324$, $\tau_{crit} = 0.374$

Since $\tau_{crit} < 1$, Function is monotonic throughout bounds of problem

Physics of Prob. are such that observed TSF values, used to calc a, will yield a's, which, when taken with K & E, will yield N_2 values > 1.21 & τ_{crit} will be less than unity

RECALCULATE $K_1(\sqrt{N_2})$ using HMF, p. 417

$\sqrt{N_2}$	$\exp\sqrt{N_2}$	$e^{\sqrt{N_2}} K_1 \sqrt{N_2}$	$K_1 \sqrt{N_2}$
0.6	1.822	2.374	1.303
0.5	1.648	2.731	1.658

Diff = 0.355

Linear interpolation: $\frac{0.03}{0.10} \times 0.355 = 0.1065$

$K_1(0.57) = 1.303 + 0.106 = 1.41$ vs 1.37 used prev.

For $K_0(0.57)$, from pg 21, $(0.926 - 0.778)\frac{0.03}{0.10} + 0.778 = 0.822$ vs 0.83 used prev.

$\frac{778}{0.148}$ 0.044 $\frac{0.044}{0.822}$

SUBJECT ____

ROSETON PROBLEM

$$\Delta \bar{T} = \Delta T_0 \left[\sqrt{N_2} \cdot K_1 \sqrt{N_2}\right]^{-1} K_0 \sqrt{N_2 T}$$

$$= \left[\frac{0.45}{0.57 \times 1.41}\right] K_0(0.57\,T^{1/2}) = 0.56\,K_0(0.57\,T^{1/2})$$

$$\Delta \bar{T}_S = TSF_0 \cdot T \cdot \Delta \bar{T}$$ p 417, HMF

$$= 10.1 \cdot T \cdot \Delta \bar{T}$$ $K_0(\sqrt{N_2 T})$

① X (miles)		② 1.27x C (T)	③ $0.57T^{1/2}$ ($\sqrt{N_2T}$)	④ $C^{③}$	⑤ ④·K_0(③)	⑥ ⑤/④	⑦ 0.56 ⑥	⑧ 10.1 ②·⑦
0	1095	1.00	0.57	1.77	SEE pg 22	0.822	0.46	4.64
0.865	.486	3.06	1.0	2.72	1.144	0.421	0.236	7.3
1.15	.646	4.42	1.2	3.32	1.057	0.319	0.179	8.0
			1.3	3.67	1.021	0.278		
1.38	.778	6.00	1.4	4.05	0.988	0.244	0.136	8.2
1.93	1.086	12.2	2.0	7.4	0.842	0.114	0.064	7.9
1.49	0.839	6.9	1.5	4.48	0.958	0.214	0.12	8.34
1.59	0.895	7.85	1.6	4.95	0.931	0.188	0.105	8.30
2.28	[illegible]	19.2	2.5	[illegible]	[illegible]	[illegible]	0.035	6.8
2.80	1.575	37.6	3.5	33	0.649	0.0197	0.011	4.2
3.36	1.887	77	5.0	148	0.548	0.0037	0.002	1.6
4.42	2.486	306	10.0	22,000	0.392	0.0000178	[illegible]	0.03

@ 8°F AVG, t max of 16, 80% ≥ 4°F (Surf. disch)

@ 8°F " ξ max of 8 or 9 80% ≥ 4 (sub. disch ← But [illegible] be [illegible] for this.

Next - develop explanation of how TSI charts ([illegible]) and graphs (a) for various outfall [illegible] - as worked in [illegible] purpose.

$\frac{2K_0(\bar{x})}{\bar{x}K_1(\bar{x})}$	$\bar{x}$	$e^{\bar{x}}$	$e^{\bar{x}}K_0\bar{x}$	$2K_0\bar{x}$	$e^{\bar{x}}K_1\bar{x}$	$K_1\bar{x}$	$\frac{2K_0\bar{x}}{K_1\bar{x}}$
1.22	1.2	3.32	1.057	0.635	1.443	0.435	1.46
1.15	1.3	3.67	1.021	0.555	1.367	0.373	1.49
1.09	1.4	4.06	0.988	0.487	1.301	0.321	1.52
1.027	1.5	4.48	0.958	0.428	1.243	0.278	1.54
0.975	1.6	4.95	0.931	0.377	1.192	0.241	1.56
0.93	1.7	5.47	0.906	0.331	1.146	0.209	1.58
0.89	1.8	6.05	0.883	0.292	1.105	0.183	1.60
0.85	1.9	6.69	0.861	0.258	1.067	0.160	1.61
0.81	2.0	7.39	0.842	0.228	1.033	0.140	1.63

Linear interpolation between 1.5 & 1.6

$$\left.\begin{array}{l}(1.027-0.975) = 0.052 \\ 1.001-0.975 = 0.025\end{array}\right\} \quad \frac{0.025}{0.052}\times 0.1 = 0.048$$

$$\bar{x}_{\text{critical}} = 1.6-0.048 = 1.552$$

$$r_{\text{critical}} = \frac{(\bar{x}_{\text{crit}})^2}{N_2} = \frac{2.4}{N_2}$$

For this problem, $r_c = \frac{2.4}{0.324} = 7.4$

BY ________ DATE ________

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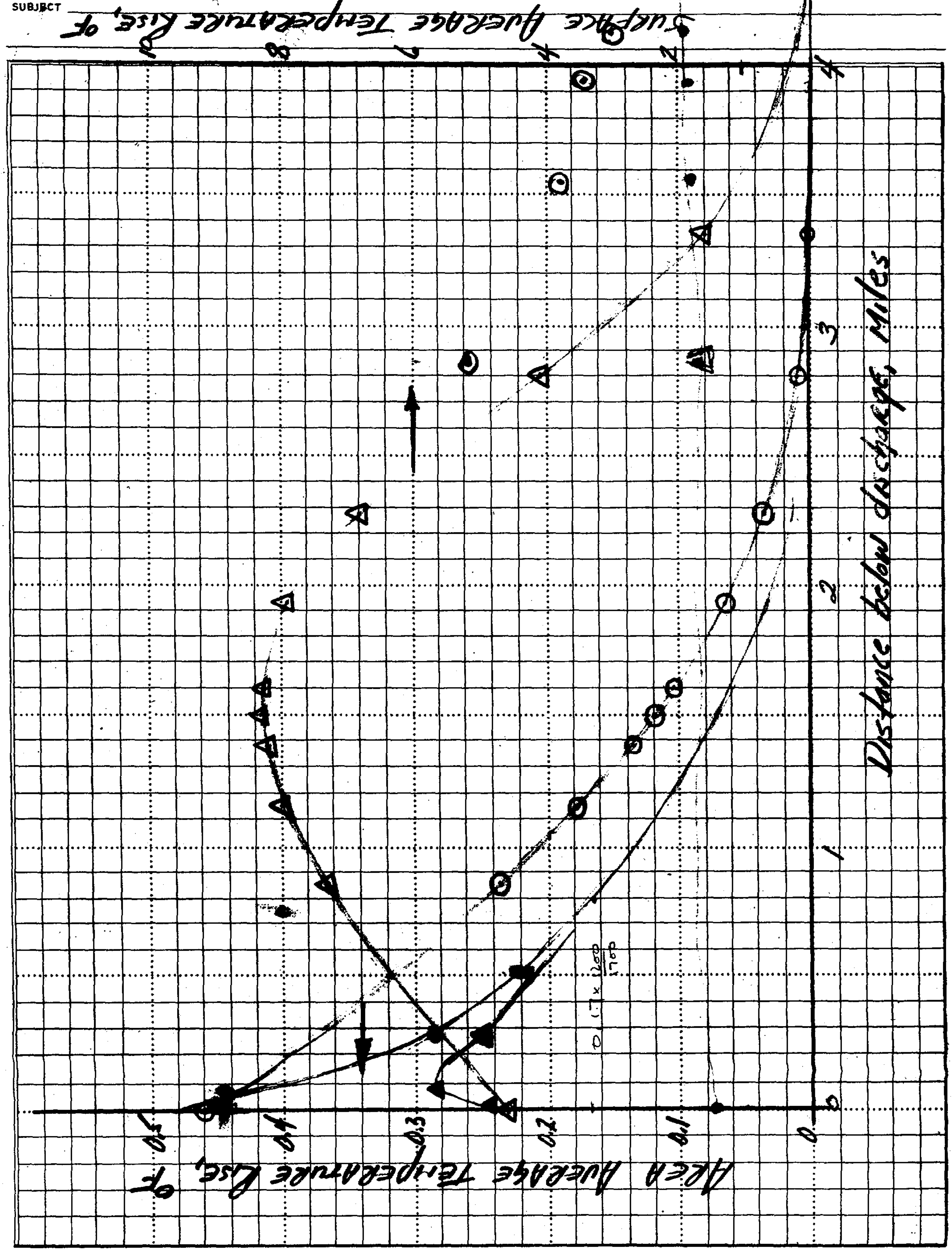
SHEET NO. 25 OF ________

JOB NO. ________

SUBJECT ________



APPENDIX D

THEORETICAL ANALYSIS OF SUBMERGED JET DISCHARGE

THEORETICAL ANALYSIS OF SUBMERGED JET DISCHARGE

A. Introduction

The characteristics of any hydraulic phenomenon, such as a hydraulic jump or a submerged jet, may be analyzed by application of the fundamentals of fluid flow. The applicable principles of fluid flow include:

1. The principle of conservation of mass, from which the equation of continuity is developed;

2. The principle of kinetic energy, from which certain flow equations are derived; and

3. The principle of momentum, from which equations describing dynamic forces exerted by flowing fluids may be established.

In the case of a jet submerged in a quiescent body of liquid of the same density, the pressure distribution is assumed to be hydrostatic, and, if drag forces are neglected, the momentum flux in the direction of the expanding jet remains constant. Assumption of a particular velocity function (such as the Gaussian frequency distribution) then permits evaluation of the rate of jet expansion and the accompanying distribution of the turbulence characteristics.

The following description of the fate of a submerged jet of heated effluent may help to clarify the complex inter-relationship between the different principles outlined above.

B. Description of the Problem

When a jet of heated effluent is discharged into a receiving water body at some depth below its surface, it rises, as a plume, to the surface, and then spreads laterally and longitudinally at the free surface. This rising behavior is caused by both initial vertical momentum flux (which is present unless the jet is directed horizontally), and the net buoyant force due to the lower density of the jet. The initial vertical momentum flux is due to the fact that the jet has a higher vertical velocity than the surrounding river water. The buoyant force is caused by the difference in density between the heated effluent and the surrounding ambient river water.

Reduction in temperature occurs by entrainment of the river water into the jet as the jet of heated liquid works its way toward the surface. This dilution proceeds until the relative velocity between the jet and surrounding water is reduced to zero. This phenomenon is called initial jet dilution. Further dilution occurs by turbulent transport mechanisms.

The relative motion between the plume and the river water develops shear stresses. Turbulence is generated and mixing takes place first around the periphery of the column and finally throughout the whole column. This results in a continual growth in jet size, a decrease in jet temperature, and an increase in density of the heated jet as it nears the surface.

Entrainment of horizontal momentum possessed by the river itself, as the jet entrains the river water, causes the plume to move upstream or downstream depending upon river flow direction.

In estuaries, the introduced heat is ultimately lost to the atmosphere and flushed from the estuary in the seaward directed flow of the surface layers.

The purpose of this theoretical analysis was to develop a mathematical model and computer program, suitable for the prediction of the coordinates of the axis of the jet, and, at any point on this axis, for the prediction of jet size, velocity, dilution, density and temperature. Model inputs include port size, initial jet velocity, jet orientation, discharge water salinity, maximum plant temperature rise, river ambient temperature, river water salinity and river runoff and/or tidal velocity.

C. Formulation of the Mathematical Model

In this section the basic equations for a circular jet discharging into a river are developed in terms of the known above mentioned design parameters.

The problem is formulated based upon the following assumptions:

1. Initial jet momentum is conserved, i.e., dragforce is neglected and the jet, at any point, will contain this momentum as originally distributed in the three dimensional system, as well as any momentum picked up from the river itself.
2. The jet is axially symmetric along its entire length.
3. Jet expansion continues indefinitely.
4. Boundary effects are neglected and an infinite source of water is available for dilution.

The first assumption has been adopted in submerged discharge analysis by many investigators. Field and laboratory measurements have shown the second assumption is valid in most practical cases, at least until the river bottom or surface begins to interfere. The effects of drag force and boundary interference are discussed in Chapters III and IV, under verification and application of the model.

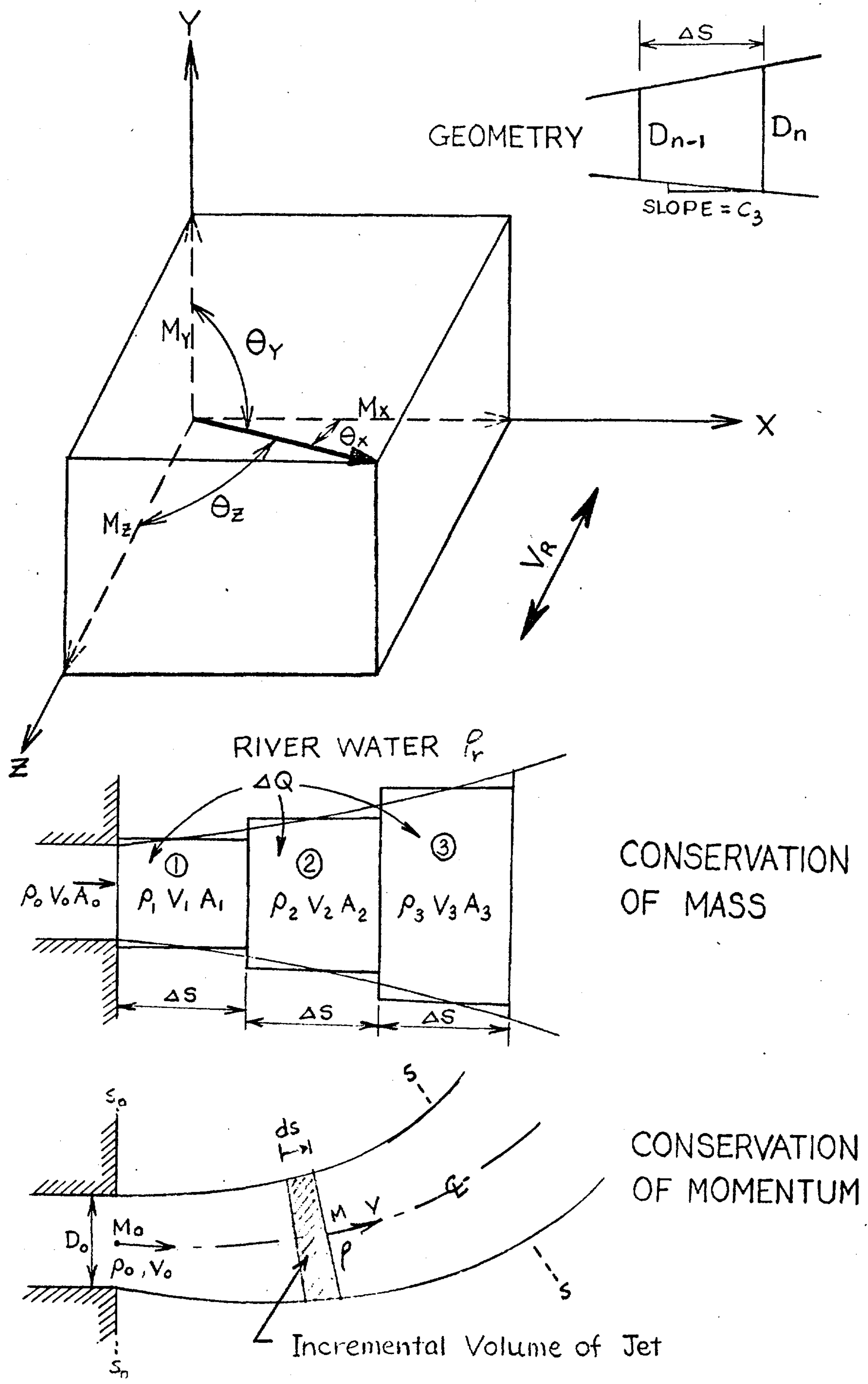
Figure 1 shows the coordinate system chosen for the analysis. The "x" axis is horizontal, perpendicular to the longitudinal axis of the river (this is the "z" axis), and values of "x" increase positively as one moves away from the outfall (x=0) laterally into the river.

The "y" axis begins at the outfall (y=0) and moves vertically upward toward the river's surface. Values of "y" increase positively as one moves vertically upward.

The "z" axis begins at the outfall (z=0). Values of "z" increase positively as one moves downstream along the river's longitudinal axis, which, of course, is normal to the lateral, or "x" axis, of the river. In tidal rivers, the river itself possesses a positive "z" momentum during ebb, and a negative "z" momentum during flood.

FIGURE 1

SUBMERGED DISCHARGE MODEL DEVELOPMENT



The momentum in the lateral or "x" direction is considered to be constant. This implies that the buoyant forces, produced by differences in the mass density of the effluent and the receiving waters, will cause the plume of diluted effluent to surface before the lateral momentum is diminished by the effect of viscous or frictional resistance.

Vertical or "y" momentum, at any reference point in the plume, is equal to any initial vertical momentum from the outfall, plus the total buoyant force occurring at the point. Notice that this recognizes the addition of momentum to the system, as the jet becomes exposed to the influence of the river.

Momentum in the longitudinal direction is equal to the component of initial momentum in this direction, plus the added amount due to the exchange of momentum from the receiving waters entrained into the jet plume. This recognizes that the entrained river water is part of the river's flow and , as such, possesses a "z" velocity and, therefore, a "z" momentum.

The origin of this coordinate system (x=0,y=0,z=0) is actually the vena contracta of the jet as it emerges from the submerged outfall. For sharp edged ports or slots, this will be slightly beyond the opening itself (and slightly below, if the jet is directed downward at some angle from the horizontal). For rounded openings, the center of the opening is the origin of the coordinate system.

1. Development of the Momentum Equations

Consider the flow path shown in Figure 1 in which sections s_o and s are normal to the centerline of the jet at the outfall and at any arbitrary section beyond the outfall, respectively.

Adopt the following nomenclature:

A_o = Cross-sectional area of the vena contracta

A = Cross-sectional area of the jet at any point x,y,z

C_3 = Slope of the jet boundary

x = Lateral distance from point of discharge

y = Vertical distance from point of discharge

z = Longitudinal distance from point of discharge

s = Length along centerline of jet from point of discharge

D_o = Diameter of the jet's vena contracta

D = Diameter of the jet at any point x,y,z

v_o = Initial average jet velocity = Q_o/A_o

v = Average jet velocity at any point x,y,z = Q/A

v_r = Average river or tidal velocity (positive = downstream)

ρ_o = Mass density of effluent

ρ = Jet mass density at any point x,y,z

ρ_r = River mass density

M_o = Initial jet momentum = $\rho_o A_o v_o^2$

M = Total jet momentum at any point x,y,z

M_x, M_y, M_z = $M\text{Cos } \theta_x, \theta_y, \theta_z$

$\theta x, \theta_y, \theta_z$ = Direction of angles between a tangent to the centerline of the jet at any point x,y,z and the x,y,z axes

Q_o = Effluent flow rate

Q = Flow rate of the jet at any point

V_n = Incremental volume of jet over an incremental distance Δs

Momentum balances are written for the three directions using the control volume approach. This is particularly suitable for the system under study, since the discharge is continuous, and for this study, assumed to be operating at steady state.

We are dealing, therefore, with rates of momentum flow, i.e., the momentum per unit time flowing past an inlet or outlet section of the jet volume chosen for analysis, and the basic equation is developed by inventorying the momentum as it flows in and out of this volume, and is produced by development of buoyant forces, lost due to viscous drag, or added along the length of the volume element due to entrainment of river water possessing a momentum of its own.

This inventory equation is written on each of x,y, and z momentum over the jet volume between the sections s_o and s as follows:

$$\begin{matrix}\text{Rate of} \\ \text{Momentum Input}\end{matrix} - \begin{matrix}\text{Rate of} \\ \text{Momentum Output}\end{matrix} + \begin{matrix}\text{Forces Acting on Jet and} \\ \text{Momentum Flow Gained or Lost}\end{matrix}$$

$$= \begin{matrix}\text{Time Rate of Accumulation of} \\ \text{Momentum within Jet}\end{matrix} \qquad \text{..........(1)}$$

For the steady state condition, the only one investigated here, the right side of Equation 1 is identically zero.

Consider "x" momentum. Since drag is neglected, the third term in Equation 1 is zero and the momentum equation in the "x" direction is written as follows:

$$M_{x_0} - M_x\}_s = 0$$

or

$$\rho V^2 A \cos\theta_x = \rho_0 V_0^2 A_0 \cos\theta_0 \qquad \text{..........(2)}$$

Consider "y" direction. In the "y" direction, the vertical momentum flux (flow) increases due to the net buoyant effect. Application of Equation 1 to "y" momentum over the volume between 0 and s yields:

$$M_0 \cos\theta_{Y_0} - M\cos\theta_Y + \int_0^s (\rho - \rho_r) g A\, ds = 0$$

or

$$M\cos\theta_Y = M_0 \cos\theta_{Y_0} + \int_0^s (\rho - \rho_r) g A\, ds \qquad \text{..........(3)}$$

Consider "z" momentum. In the "z" direction, the rate of change of momentum flux along the jet is equal to the rate of entrainment of river momentum flux, which is inherently "z" directed. Since the jet entrains river water, and since this water has a "z" velocity, which we assume will not be lost or decreased, the "z" balance must include the introduction of river "z" momentum into the jet.

The magnitude of this rate of momentum introduction will be the product of the entrained mass flow, $\rho_r dQ$, times the river velocity, v_r. Application of Equation 1 to "z" momentum, over the jet volume between s_o and s then yields:

$$M_o \cos\theta_{z_o} - M\cos\theta_z + \int_o^s \rho_r V_r \frac{dQ}{ds}\, ds$$

$\underline{\underline{or}}$

$$M\cos\theta_z = M_o \cos\theta_{z_o} + \int_o^s \rho_r V_r \frac{dQ}{ds}\, ds \qquad \ldots\ldots\ldots\ldots (4)$$

We are in the process of developing a system of simultaneous equations to provide a unique solution for a number of unknowns ($\rho, v, A, \theta_x, \theta_y, \theta_z$). The unknown ρ, which appears in the integral in Equation 3, and dQ/ds, or $\frac{d(vA)}{ds}$, which appears in the integral in Equation 4, are complex functions of s, i.e., of location. Analytical solutions of this eventual system of equations, therefore, will be virtually impossible to obtain.

A numerical technique, suitable for high speed digital computation, will be used to solve the equations. The development of this solution begins by breaking the jet plume into a finite number of sections, each of length Δs, along its centerline (see Figure 1).

Equations 3 and 4, describing the balance of "y" and "z" momentum over the jet lengths, are rewritten for incorporation into the numerical solution technique as follows:

$$M_n \cos\theta_{y_n} = M_o \cos\theta_{y_o} + \sum_{i=1}^{n} (\rho_r - \bar{\rho}_i) g V_i$$

or

$$M_n \cos\theta_{y_n} = M_{n-1} \cos\theta_{y_{n-1}} + (\rho_r - \bar{\rho}_n) g V_n \qquad \text{..........(5)}$$

$$M_n \cos\theta_{z_n} = M_o \cos\theta_{z_o} + \sum_{i=1}^{n} \rho_r V_r \Delta Q_i$$

or

$$M_n \cos\theta_{z_n} = M_{n-1} \cos\theta_{z_{n-1}} + \rho_r V_r \Delta Q_n \qquad \text{..........(6)}$$

The following definitions apply:

M_n = the momentum flowing out of the segment n. This is equal to the product of the density, velocity and cross-sectional area of the jet at the downstream end of the volume segment V_n.

$\cos\theta y_n$ = the "y" direction cosine of the tangent to the jet centerline at the downstream end of the segment V_n. $\cos\theta z_n$ is defined similarly.

V_n = the volume of any jet segment n. This is equal to the average cross-sectional area of the segment, A_n, times the segment length Δs.

ΔQ_n = the incremental river flow entrained into the segment n. The total jet flow leaving the segment at its downstream end includes this flow, all previously entrained river flows, $\sum_{i=1}^{n-1} \Delta Q_i$, and the jet flow, Q_o.

The final momentum relationship, which will be necessary to provide sufficient equations to obtain a unique solution, is written by recognizing that the total momentum at any point is the vector sum of the momentum in the x,y and z directions. This is written:

$$\bar{M} = \bar{M}_x \mathbin{+\!\!\!\!\rightarrow} \bar{M}_Y \mathbin{+\!\!\!\!\rightarrow} \bar{M}_z \qquad \text{..........(7)}$$

or, in terms of the scalars which appear in the individual component equations:

$$M^2 = M_x^2 + M_Y^2 + M_z^2 \qquad \text{..........(8)}$$

Since each component momentum scalar can be written in terms of the product of M and the pertinent direction cosine, Equation 8 just requires that the sum of the direction cosines equal unity. Thus, we have:

$$M_n = \rho_n V_n^2 A_n \qquad \text{..........(9)}$$

and

$$\cos^2\theta_{x_n} + \cos^2\theta_{Y_n} + \cos^2\theta_{z_n} = 1 \qquad \text{..........(10)}$$

The following definitions apply:

ρ_n = mass density of the jet, at the downstream end of the segment V_n

v_n = average jet velocity, at the downstream end of the segment V_n

A_n = cross-sectional area of the jet, at the downstream end of the segment V_n

Note that the average segment density and area, $\overline{\rho}_n, \overline{A}_n$, which appear in the previous set of definitions, are hatted to distinguish them from ρ_n and A_n.

We have now developed five independent equations, namely equations 2,5,6,9 and 10. Observation of these equations show that ten unknown variables have been generated, namely the total momentum M_n, the three direction cosines $\theta_x, \theta_y, \theta_z$, the geometric quantities A_n and V_n, the mass quantities ρ_n and $\overline{\rho}_n$, and the flow quantities v_n and ΔQ_n.

Thus, we will have to develop at least five more equations, and more if any new unknown variables are introduced. The following sections consider the geometric and flow relationships available to do this.

2. Development of Geometric Relationships

Extensive literature on the expansion of submerged jets shows that the slope of the jet boundary generally is in the range of 1 to 4 to 1 to 6. Actually, most authors recognize a core flow, or zone of establishment, in which the boundary increases at a slower rate, say 1 to 6 to 1 to 10, for a distance of about six port diameters, followed by a zone of established flow where the expansion rate is of the order of 1 to 5. (1), (2), (3)

This fact has been utilized as a key element in the solution of the present problem. We have insufficient field data to establish empirical expansion coefficients for the Hudson River, but have recognized that any jet will show a volume expansion. The expansion coefficients, or slopes, used, therefore, have been taken from the literature. Evaluation of the sensitivity of the results to choice of slope has been made and shows that this approach is an acceptable one.

The slope of the jet cone, relative to the jet centerline, is assumed to be fixed and is given by the coefficient C_3. The diameter of the downstream end of any jet segment V_n is written:

$$D_n = D_{n-1} + 2 C_3 \Delta S \qquad \text{..........(11)}$$

In the programmed solution of this problem, the existence of two zones of different slopes is recognized. C_3 is replaced by C_1 in the zone of establishment, which is stated to exist for a total distance S_2. In the established zone, instead of using the value of C_1, C_3 in Equation 11, is replaced by a larger constant, designated C_2.

Equation 11 introduces one more equation, but at the same time one more unknown variable. D_n, of course, can be computed directly from Equation 11 without recourse to other equations, but this calculation removes Equation 11 from further use and we still need five more equations (11 variables, 6 equations at this point).

Once the jet diameter D_n is known, however, geometric relationships for A_n and V_n can be introduced, and we will have two more equations without introducing any addition unknowns.

The area A_n, is given simply:

$$A_n = \frac{\pi}{4} D_n^2 \qquad \text{..........(12)}$$

Each segment of the expanding jet is the frustum of a cone, the volume of which is written:

$$V_n = \frac{\pi}{12} \Delta S \left[D_n^2 + (D_n - 2C_3 \Delta S) D_n + (D_n - 2C_3 \Delta S)^2 \right] \text{..........(13)}$$

We now have 11 variables and eight independent equations. One additional geometric relationship can be developed.

If we consider the case of a constant density, constant temperature system, relative velocity is the only difference between the jet and the surrounding medium. In this case the volume of any segment V_n is equal to the volume of the preceding segment plus the volume of river water introduced by entrainment. This is written:

$$V_n = V_{n-1} + (V_n - V_{n-1}) \qquad \text{..........(14)}$$

This, of course, is trivial for the constant density case and new information is not provided. For the case of discharge of a fluid of one density into a fluid of another density, but at the same temperature, the mass occupied by the volume segment V_n, can be obtained in terms of the mass occupied by the previous volume, V_{n-1}, and the mass introduced by entrainment of river water. This is written:

$$\bar{\rho}_n V_n = \bar{\rho}_{n-1} V_{n-1} + \rho_r (V_n - V_{n-1}) \qquad \text{..........(15)}$$

In other words, the mass in the segment n is equal to whatever is in segment n-1 plus that which is added by entrainment of river water. This incremental mass, of course, must equal the river density times the volume increment, $V_n - V_{n-1}$. This equation provides additional information for a constant temperature system.

For our case, since temperature and density both vary, the mass relationship will still hold, but it cannot be expressed as simply as is done in Equation 15. V_n must reflect a certain shrinkage, due to the fact that the average temperature within V_n is not as high as that within V_{n-1}. In other words, were a volume of average density $\bar{\rho}_{n-1}$ and average temperature T_{n-1} mixed with a volume of average density ρ_r and average temperature $\bar{T}_r$, which is cooler than $\bar{T}_{n-1}$, the resultant volume would be smaller and the density larger than would occur if both temperatures were equal. Thus, Equation 15 is incorrect since $(V_n - V_{n-1})$ no longer represents the exact volume of entrained water.

Recognizing the temperature effect on the density, the equation of state for water is then introduced to provide additional information on density. This is written:

$$\bar{\rho}_n = f(\bar{T}_n) \quad \text{..........(16)}$$

This function appears in the programmed solution as a least squares polynomial fit of tabulated density-temperature relationships for waters of various salinities. Actually, the program incorporates the entire density-temperature-salinity relationship, as well as an equation of continuity on salinity, so that it may be used in situations in which the effluent salinity is different than the river salinity.

Equation 16 introduces one more unknown variable, $\bar{T}_n$, as well as one more equation, so that three equations are still needed. We know, however, that a heat balance will eventually be introduced, even if the equation of state had not been, since a knowledge of T_n is one of the solution objectives.

Equation 16 was introduced at this point because an alternative approach, and in fact our original approach, is to use Equation 15.

This approach, however, introduces substantial error in the location of the surface boil, because the buoyant forces, which control the upward movement of the jet, are, of course, strongly influenced by the jet density.

Actually, Equation 15 is quite useful and does appear in the programmed solution. A trial and error solution technique has been used and Equation 15 is employed to obtain an initial estimate of jet density. This estimate then becomes the point of departure into the trial and error solution.

It should be noted that there is a slight anamoly in the solution, since the jet slope is held constant and was originally defined as a measure of the entrained water. The incremental volume in segment V_n, i.e., V_n-V_{n-1}, now represents the entrained volume less the temperature-induced shrinkage which has occurred. The volume change due to the temperature effect is insignificant, however, and there need be no further concern on this point.

Recognition of the temperature-induced effect was necessary because of its effect on density. Although equally small, the change appears in the $(\rho_r-\rho)$ buoyancy term, where small changes in ρ cause large changes in $(\rho_r-\rho)$, since ρ is numerically very close to ρ_r.

We now have nine equations and twelve unknown variables. Continuity and energy relationships are now developed to provide additional information.

3. Development of the Continuity Relationship

Application of the inventory equation for mass, similar to that given by Equation 1 for momentum, gives:

$$\rho_o V_o A_o - \rho V A \Big\}_s + \int_0^s \rho_r \frac{dQ}{ds} ds = 0$$

or

$$\rho V A \Big\}_s = \rho_o V_o A_o + \int_0^s \rho_r \frac{dQ}{ds} ds \qquad \text{..........(17)}$$

Using the segmented approach, Equation 17 is rewritten:

$$\rho_n V_n A_n = \rho_o V_o A_o + \sum_{i=1}^{n} \rho_r \Delta Q_i$$

or, since the river density is usually assumed to be constant,

$$\rho_n V_n A_n = \rho_o V_o A_o + \rho_r Q_r$$

or, in terms of the characteristics of the previous segment

$$\rho_n V_n A_n = \rho_{n-1} V_{n-1} A_{n-1} + \rho_r \Delta Q_n \qquad \text{..........(18)}$$

No new unknown variables have been introduced, so we now have a total of ten equations and twelve unknown variables. A heat balance over the jet will provide an eleventh equation, as shown next.

4. Development of the Heat Balance

An inventory of thermal energy over the jet is written in accordance with the principles of Equation 1 as follows:

$$\rho_o V_o A_o C_{p_o} \Delta T_o - \rho V A C_p \Delta T \Big\}_s + \int_0^s \rho_r C_{p_r} \Delta T_r \frac{d\Phi}{ds} ds = 0$$

or

$$\rho V A C_p \Delta T \Big\}_s = \rho_o V_o A_o C_{p_o} \Delta T_o + \int_0^s \rho_r C_{p_r} \Delta T_r \frac{d\Phi}{ds} ds \quad \text{........(19)}$$

In Equation 19, $C\rho_o$,$C\rho_r$ and $C\rho$ are the heat capacities of the effluent, river and diluted jet waters, respectively. These vary only slightly with temperature, and from this point forward are considered to be constant and equal, with a value of 1.0 BTU/#/^{o}F.

Heat losses have been neglected. Previous work has shown that only negligible losses occur in the near vicinity of a heated discharge. Loss along the submerged boundary of the jet is totally insignificant, and even at the surface, significant heat transfer to the atmosphere does not occur until the surface area affected by the heated water is much larger than that associated with the jet. In other words, atmospheric heat transfer does not become significant within the zone of initial dilution.

In segmented form, Equation 19 may be written:

$$\rho_n V_n A_n \Delta T_n = \rho_o V_o A_o \Delta T_o + \sum_{i=1}^{n} \rho_r \Delta T_r \Delta Q_i$$

or

$$\rho_n V_n A_n \Delta T_n = \rho_o V_o A_o \Delta T_o + \rho_r \Delta T_r Q_r$$

or

$$\rho_n V_n A_n \Delta T_n = \rho_{n-1} V_{n-1} A_{n-1} \Delta T_{n-1} + \rho_r \Delta T_r \Delta Q_n \quad \text{..........(20)}$$

Any reference temperature may be chosen to define the datum for the various ΔT. In this work, T_r, the river ambient temperature, has always been held constant. If T_r is chosen as the datum, the terms in Equations 19 and 20 containing ΔT_r vanish, and the heat balance becomes simply:

$$\rho_n V_n A_n \Delta T_n = \rho_o V_o A_o \Delta T_o$$

or

$$\rho_n V_n A_n \Delta T_n = \rho_{n-1} V_{n-1} A_{n-1} \Delta T_{n-1} \quad \text{..........(21)}$$

Notice that the ratio, $\Delta T_n/\Delta T_o$, is just equal to the flow dilution factor, $\rho_n v_n A_n/\rho_o v_o A_o$. This factor is included in the computer output printout and, as will be shown, is used as a primary control in the interpretation of results.

Equation 21 introduces a new unknown variable, T_n (ΔT_n, of course, is just equal to $T_n - T_r$), so we now have eleven equations and thirteen unknowns.

5. Nature of Average Density and Temperature, ρ_n and $\overline{T}_n$

Two of these unknown quantities are $\overline{T}_n$ and $\overline{\rho}_n$, the average temperature and density in the jet segment V_n. These must bear some relation to the segment outlet temperature and density, T_n and ρ_n. These quantities only arise because the numerical solution technique requires that the segment volume be finite.

As this volume becomes increasingly small, $\overline{\rho}_n \rightarrow \rho_n$, and $\overline{T}_n \rightarrow T_n$; in the limit, the defining equations are differential equations, not difference equations, and $\overline{\rho}_n$, which appears in the equation for "y" momentum, does not appear at all, being, for point behavior, identical to ρ. The average temperature $\overline{T}_n$, of course, appeared upon introduction of the equation of state for $\overline{\rho}_n$. The point temperature value, T, would be required to evaluate the point density, ρ.

The computer solution employed is an iterative technique and requires relatively small segment lengths for rapid convergence. For small segment lengths, $\overline{\rho}_n \approx \rho_n$ and $\overline{T}_n \approx T_n$, and, for this model, have been set identically equal to the segment outlet density and temperature, ρ_n and T_n.

6. Model Development Summary

At this point, we have succeeded in introducing sufficient equations to permit a unique solution, given numerical values of the input parameters $(\rho_o, T_o, v_o, A_o, \theta x_o, \theta y_o, \theta z_o, \rho_r, v_r, T_r)$.

The eleven unknown variables are $D_n, A_n, V_n, \rho_n, v_n, T_n, \Delta Q_n, M_n, \theta x_n, \theta y_n, \theta z_n$.

The solution proceeds by solving for the various outlet section variables for the first segment, n=1, in which the inlet section variables (the n-1 subscripted variables in the various equations) are the known parameters in the jet's vena contracta $(\rho_o, T_o, v_o, D_o, A_o, \theta x_o, \theta y_o, \theta z_o)$. These results then become input for segment 2 and the equations are now solved for the outlet variables ρ_2, T_2,

v_2, etc. This procedure is usually continued until $v_n = v_r$, although, in interpreting results, a number of controls have been instituted, as will be discussed in latter sections.

In the actual solution technique, D_n,A_n and V_n are obtained immediately from Equations 11,12 and 13. The remaining eight variables, ρ_n,v_n,T_n,ΔQ_n,M_n,θx_n,θy_n and θz_n, are obtained by a trial and error solution of the eight simultaneous equations, 2,5,6,9,10,16,18 and 21.

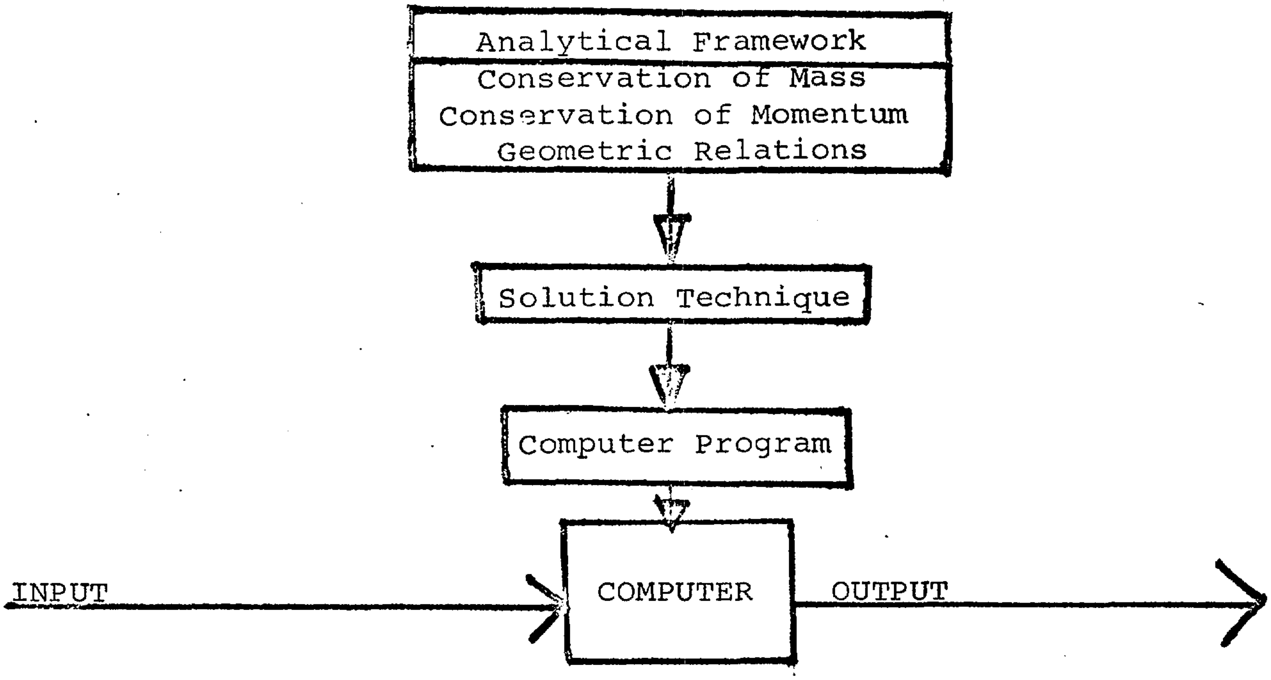
D. Submerged Discharge Computer Program

The foregoing procedure has been programed in Fortran IV for solution on RAPIDATA time-sharing facilities. Chart I is a schematic diagram of the relation of the model, the solution technique, the program and computer input and output.

Plate I is a listing of the input or data file for the program, and includes a description of each item of input data and its location in the data file. This facilitates use of the program by personnel previously unfamiliar with it. The main program is THOUT3, standing for the third modification of our thermal outfall routine. The data file is designated THOUTA.

CHART "1"

SUBMERGED DISCHARGE ANALYSIS
FLOW SHEET



- .Port size
- .Jet initial velocity
- .Depth of submergence
- .Orientation of port
- .Maximum temperature of heated liquid
- .Mass density of effluent
- .Port coefficients
- .Ambient temperature
- .River velocity
- .Mass density of river water

- .Path of jet
- .Jet velocity
- .Jet size
- .Mass density of jet

- .Dilution ratio
- .Jet temperature

PLATE I

SUBMERGED OUTFALL INPUT DATA FILE

```
OLD
NAME: THOUTA

READY
LIST


THOUTA     13:58    RDS2  OCTOBER 10, 1969

1000    1,100
3000    .1,.16,.2,62.,12.,.05
4000    10.,2.9,.7071,.0,.7071
5000    .96,.04,90.,90.
6000    92.,72.,2.,2.
10000   THE SEQUENCE OF PARAMETER DEFINITIONS WHICH FOLLOWS IS THE
10100   SAME AS THE SEQUENCE OF DATA WHICH APPEARS ABOVE.
10200   NRUNS   (# OF INDEPENDENT RUNS),KT(KT*DS=PRINTOUT INTERVAL)
10300   DS      (INCREMENT ALONG JET CENTERLINE)(FT)
10400   C1      JET SLOPE WITHIN CORE FLOW
10500   C2      JET SLOPE BEYOND CORE FLOW (AFTER S2)
10600   S2      LENGTH OVER WHICH C1 IS APPLICABLE (FT)
10700   YLIM    DISTANCE OF SURFACE FROM INITIAL JET CENTERLINE (FT)
10800   DDQ1    INITIAL INCREMENT OF FLOW ADDED TO JET
10900   DO      INITIAL DIAMETER OR JET (PORT DIAMETER)(FT)
11000   VO      INITIAL JET VELOCITY (FT/SEC)
11100   COSX    ANGLE THE JET CENTERLINE MAKES WITH +XAXIS (LATERAL)
11200   COSY    ANGLE THE JET CENTERLINE MAKES WITH +YAXIS (VERTICAL)
11300   COSZ    ANGLE THE JET CENTERLINE MAKES WITH +ZAXIS (LONGITUDINAL)
11400   VTMAX   MAXIMUM VELOCITY (TIDAL)(FT/SEC)
11500   VRIV    RIVER VELOCITY (FT/SEC)
11600   ANGT    ANGLE INCREMENT ADDED TO INITIAL ANGLE FOR MULTI-ANGLE RUNS
11700   ANG     INITIAL STARTING ANGLE (S'NE CURVE)(DEG)
11800   TO      INITIAL JET TEMPERATURE (F)
11900   TRIV    INITIAL RIVER TEMPERATURE (F)
12000   SALO    INITIAL SALINITY OF JET (PPT)
12100   SALR    INITIAL SALINITY OF RIVER (PPT)




BYE
OFF AT 14:01
```

Numerical values of the jet slope and port coefficients (1) used in the program (line 3000 in THOUTA) are summarized below:

Coefficient	Circular Port	Slot
Diameter, D_o	D_o	$4A_o/\pi$
Jet Slope, C_3		
Zone of flow establishment, C_1	0.16	0.15
Zone of established flow, C_2	0.20	0.25
Length of zone of flow establishment, S_2	6.2 D_o	5.3 X width

Plate II is a listing of the main program THOUT3. This program is reasonably general and can be used to evaluate a large number of submerged outfall situations.

For example, between lines 1440C and 1680C, the river velocity at any phase of the tide is computed, given the runoff velocity and the maximum tidal velocity. The computer is then directed to print results at any desired number of equally spaced time increments over the full tidal cycle.

Between lines 1800C and 2102C, the density is given as a function of temperature and salinity. Coefficients employed were obtained previously by a least squares polynomial fit of density-temperature-

PLATE II

1 OF 5

SUBMERGED OUTFALL PROGRAM LISTING

```
OLD
NAME: THOUT3

READY
LIST


THOUT3     13:41    RDS2  OCTOBER 10, 1969

1000         INTEGER OF1,OF2,DENCT
1020         CALL OPENF(1,"THOUTA")
1022         CALL OPENF(2,"THOUTO")
1040         IF1=1
1060         OF1=66
1062         OF2=2
1080    102  FORMAT(1H ,5F10.2,F10.4//)
1100    111  FORMAT(1H ,8X,2HDS,8X,2HC1,8X,2HC2,8X,2HS2,
1120&        6X,4HYLIM,6X,4HDDQI/)
1140    112  FORMAT(1H ,8X,2HD0,8X,2HV0,6X,4HCOSX,
1160&        6X,4HCOSY,6X,4HCOSZ/)
1180    192  FORMAT(1H ,17HTOO MANY CUTS....,I4,3X,6HDDQ = ,F10.5)
1200         READ(IF1,) NRUNS,KT
1220         NR=0
1230         DTOL=1.E-05
1240         PI=3.14159265
1260         PI1=PI/180.
1280         TOL=0.3
1281         ITOLI=1000
1282         CUT=2.
1283         NCUTS=50
1284         JRHO=1
1286         RHOTR=1.E-2
1288         TBOUND=10.
1292         JSURFT=0
1300    200  READ(IF1,)DS,C1,C2,S2,YLIM,DDQI
1320         READ(IF1,)DO,VO,COSX,COSY,COSZ
1340         READ(IF1,)VTMAX,VRIV,ANGT,ANG
1360         READ(IF1,)TO,TRIV,SALO,SALR
1380         TANG=360.
1420C
1440C        TIDAL RIVER VELOCITY FUNCTION
1460C
1480   1091  VR=VRIV+VTMAX*SIN(ANG*PI1)
1500         WRITE(OF1,312)
1520    312  FORMAT(1H ,7X,3HANG,8X,2HVR/)
1540    311  FORMAT(1H ,2F10.2//)
1560         WRITE(OF1,311)ANG,VR
1580         DQ=0.
1600         DDQ=DDQI
1620         ITOL=ITOLI
1640         I=0
1660         J=0
1680C
1700C        TEMPERATURE CONVERSION
1720C
1740         CO=(5./9.)*(TO-32.)
1760         CR=(5./9.)*(TRIV-32.)
1780C
1800C        LEAST-SQUARES EVALUATION OF MASS DENSITY FROM TEMP.
1820C
1840         COF1=9.991638E-01
1860         COF2=7.736451SE-04
1880         COF3=-7.6762273E-07
```

2 OF 5

```
1920        DROSR=COF1+COF2*SALR+COF3*SALR**2.
1940        F1=1.0000512
1960        F2=3.5764685E-05
2000        F3=-6.8972574E-06
2020        F4=2.8117132E-08
2040        DENO=F1+F2*CO +F3*CO**2. +F4*CO**3.
2060        DENR=F1 +F2*CR +F3*CR**2. +F4*CR**3.
2080        RHOO=1.93869627*(DENO+DROSO-.9991)
2100        RHOR=1.93869627*(DENR+DROSR-.9991)
2101C
2102C       END OF MASS DENSITY EVALUATION
2103C
2104C
2105C       VARIOUS INITIAL VALUES
2106C
2120        A0=.7854*D0*D0
2121        VOL=A0*DS
2140        OMENO=RHOO*A0*V0*V0
2160        XMO=OMENO*COSX
2180        YMO=OMENO*COSY
2200        ZMO=OMENO*COSZ
2220        DMOM=0.
2240        RMOM=ZMO
2260        BOUY=0.
2280        B=0.
2300        S=0.
2320        X=0.
2340        Y=0.
2360        K=0
2380        Z=0.
2400        D=D0
2420        V=V0
2440        A=A0
2460        RHO=RHOO
2470        TEMP2=T0
2472        SAL2=SALO
2480   113  FORMAT(1H ,8X,2HT0,6X,4HTRIV,6X,4HSALO,6X,4HSALR/)
2500C
2520C       PRINT OUT INPUT DATA
2540C
2560        WRITE(OF1,111)
2580        WRITE(OF1,102)DS,C1,C2,S2,YLIM,DDQI
2600        WRITE(OF1,112)
2620        WRITE(OF1,155)D0,V0,COSX,COSY,COSZ
2640   155  FORMAT(1H ,5F10.2//)
2660        WRITE(OF1,113)
2680        WRITE(OF1,158)T0,TRIV,SALO,SALR
2700   158  FORMAT(1H ,4F10.2////)
2710        WRITE(OF1,500)
2720        WRITE(OF1,501)
2722        WRITE(OF2,816)
2724   816  FORMAT(////,1H ,7X,1HS,5X,1HD,4X,9HDIRECTION,
2726&       8H COSINES,4X,21HRADIUS PROJECTIONS ON)
2728        WRITE(OF2,817)
2730   817  FORMAT(1H ,15X,2(2X,6HX-AXIS,2X,6HY-AXIS,2X,6HZ-AXIS)/)
2740C
2760C       MAJOR LOOP TO INCREMENT JET CENTER LINE DISTANCE
2780C
2800     1  S=S+DS
2802        TEMP1=TEMP2
2804        SAL1=SAL2
2820        A1=A
2840        RHO1=RHO
2860        V1=V
```

```
2940    20 C3=C1
2960       GO TO 23
2980    21 C3=C2
3000    23 DD=C3*2.*DS
3020       D=D+DD
3040       A=.7854*D*D
3060       VOL=.2618*DS*(D*D+D1*D+D1*D1)
3080       RMOM=RMOM+DMOM
3100       B=32.2*(RHOR-RHO)*VOL
3120       BOUY=BOUY+B
3140       RHO=(RHO1*VOL1+RHOR*(VOL-VOL1))/VOL
3160       YM=YMO+BOUY
3180       XM=XMO
3200C
3220C      TRIAL AND ERROR SOLUTION FOR ENTRAINED FLOW RATE INCR.
3240C
3260    70 DQ=DQ+DDQ
3280       I=I+1
3281       JJ=1
3282  2050 TEMP2=(RHO1*TEMP1*V1*A1+RHOR*DQ*TRIV)/((V1*A1+DQ)*RHO)
3283       TC2=(5./9.)*(TEMP2-32.)
3284       SAL2=(SAL1*V1*A1*RHO1+SALR*DQ*RHOR)/((V1*A1+DQ)*RHO)
3285       RHOC=F1+F2*TC2+F3*TC2**2+F4*TC2**3
3286       DRO=COF1+COF2*SAL2+COF3*SAL2**2
3287       RHOC=1.9386927*(RHOC+DRO-.9991)
3288       IF(ABS(RHOC-RHO)-RHOTL)2000,2000,2010
3289  2010 IF(JJ-JRHO)2030,2020,2020
3290  2030 JJ=JJ+1
3291       RHO=RHOC
3292       GO TO 2050
3293  2020 WRITE(OF1,2021)RHO,RHOC,TEMP2
3294  2021 FORMAT(1H ,5HRHO= ,E15.9,6HRHOC= ,E15.9,8HTEMP2 = ,E15.9,///)
3295       GO TO 910
3296  2000 RHO=RHOC
3300       DMOM=RHOR*VR*DQ
3320       ZM=RMOM+DMOM
3340       TM=SQRT(XM*XM+YM*YM+ZM*ZM)
3360       V=SQRT(TM/(RHO*A))
3380       DQC=(RHO*V*A-RHO1*V1*A1)/RHOR
3400       T=ABS(DQ-DQC)
3420       IF(T-TOL)40,40,50
3440    50 IF(I-ITOL)70,70,51
3460    51 IF(J-NCUTS)52,191,191
3480    52 DQ=0.
3500       DDQ=DDQ/CUT
3520       ITOL=ITOLI*DDQI/DDQ
3540       I=0
3560       J=J+1
3580       GO TO 70
3660    40 I=0
3680       DDQ=DDQ*CUT
3700       J=J-1
3720       ITOL=ITOLI*DDQI/DDQ
3721C
3722C      END OF TRIAL AND ERROR LOOP
3723C
3740C
3760C      COMPUTATION OF ANGLES AND DIST. FOR JET CENTERLINE.
3780C
3782C      ANGX,ANGY,ANGZ..ARE DIRECTIONAL COSINES OF MOMENTUM
3784C      VECTOR AND POSITIVE (+) X,Y AND Z AXIS RESPECTIVELY.
3786C
3800       ANGX=XM/TM
3820       ANGY=YM/TM
```

```
3842      SANGX=SQRT(1.-ANGX**2)
3844      SANGY=SQRT(1.-ANGY**2)
3846      SANGZ=SQRT(1.-ANGZ**2)
3860      DX=ANGX*DS
3880      DY=ANGY*DS
3900      DZ=ANGZ*DS
3902      PROJRX=SANGX*(D/2.)
3904      PROJRY=SANGY*(D/2.)
3906      PROJRZ=SANGZ*(D/2.)
3920      X=X +DX
3940      Y=Y+DY
3960      Z=Z+DZ
3980      K=K+1
4000      DIL=A*V*RHO/(A0*V0*RHO0)
4001C
4002C     EVALUATION OF AVERAGE JET TEMPERATURE
4003C
4020      TDIL=T0/DIL+(1.-(1./DIL))*TRIV
4040      F5=-1.5383679E+05
4060      F6=3.1249029E+05
4080      F7=-1.5864127E+05
4110      SALJ=(SALR*(A*V -A0*V0) +SAL0*A0*V0)/(A*V)
4111      DEN=RH0/1.93869627
4115      TEST=F5+F6*DEN+F7*DEN**2.
4116      DTEST=1.E-02
4120      TEST1=TEST-TBOUND
4125      DENCT=1
4130      DEN1=COF1+COF2*SALJ +COF3*SALJ**2.
4140  410 DEN2=F1+F2*TEST1 +F3*TEST1**2. +F4*TEST1**3.
4150      RHOT=1.93869627*(DEN2 +DEN1 -0.9991)
4160      DIF=ABS(RHOT-RHO)
4170      IF(DIF -DTOL)400,400,401
4180  401 IF(TEST1-TEST-TBOUND)405,405,406
4190  405 TEST1=TEST1 +DTEST
4200      GO TO 410
4210  406 DTEST=DTEST/2.
4212      DENCT=DENCT+1
4214      IF(DENCT-10)422,422,972
4220  422 TEST1=TEST-1.
4230      GO TO 410
4240  400 TRHOF=(9./5.)*TEST1 +32.
4241      IF(JSURFT)800,800,810
4242  800 YTEMP=Y+(D/2.)*SANGY
4244      IF(YLIM-YTEMP)802,802,810
4246  802 JSURFT=1
4248      WRITE(OF1,803)
4249      WRITE(OF2,803)
4250  803 FORMAT(//,1H ,26HAT NEXT LINE OF OUTPUT JET,
4251&     20H INTERSECTED SURFACE//)
4252      WRITE(OF1,100)S,X,Y,Z,D,V,TDIL,TRHOF,DIL
4254      WRITE(OF2,815)S,D,ANGX,ANGY,ANGZ,PROJRX,PROJRY,PROJRZ
4256  815 FORMAT(1H ,F8.1,F7.1,3F8.5,3F8.1/)
4258  810 CONTINUE
4460      IF(K-KT)622,623,910
4480  623 CONTINUE
4500  500 FORMAT(1H ,7X,1HS,7X,1HX,7X,1HY,7X,1HZ,6X,1HD,5X,1HV,
4520&     2X,4HTEMP,2X,4HTEMP,6X,3HDIL/1H ,49X,2HBY,4X,2HBY)
4540  501 FORMAT(1H ,48X,3HDIL,3X,3HDEN/)
4600      WRITE(OF1,100)S,X,Y,Z,D,V,TDIL,TRHOF,DIL
4605      WRITE(OF1,101)TEMP2,SAL2,RHO
4606      WRITE(OF2,815)S,D,ANGX,ANGY,ANGZ,PROJRX,PROJRY,PROJRZ
4610  101 FORMAT(/,3HT= ,F12.3,3HS= ,F12.2,5HRHO= ,F12.3)
4620  100 FORMAT(1H ,4F8.1,1F7.1,3F6.1,F9.2/)
4640      K=0
4650  622 CONTINUE
```

PLATE II 5 OF 5

```
4700   901 ANG=ANG+ANGT
4720       IF(ANG-TANG)1091,900,900
4740   191 WRITE(OF1,192)J,DDJ
4760   900 NR=NR+1
4780       IF(NR-NRUNS)200,910,910
4790   972 WRITE(OF1,973)DENCT
4795   973 FORMAT(1H ,///15H DENCT > LIMIT ,I10)
4800   910 CALL EXIT
4820       END
```

salinity tables. These relationships are used later on in the program in solving for density.

Between lines 2520C and 2730 the computer is instructed to printout basic input data, so that output can be readily interpreted by the engineer, in terms of the input or controlling system parameters.

The program then proceeds through an iterative solution of the previously developed equations, segment by segment.

Plates III and IV are typical solution printouts. Plate III includes the input data, identified in Plate I, and basic output information. The first four output items, s,x,y and z, locate the position of any point on the jet centerline, which is a distance s from the origin along the centerline, in terms of its x,y and z coordinates. Units, which will be included in a printout revision, are FT. for each of these four variables.

"D" is jet diameter in FT., measured normal to a tangent to the centerline at the point x,y,z. "v" is average jet velocity, across the jet section, normal to the centerline tangent at x,y,z.

RUN

SUBMERGED OUTFALL PROGRAM PRINTOUT

PLATE III

```
THOUT3     12:49    RDS2  OCTOBER 2, 1969

        ANG         VR

       90.00       1.00

         DS         C1         C2         S2        YLIM       DDQI

        0.10       0.15       0.25      79.50      20.00     0.0500

         DO         VO       COSX       COSY       COSZ

        8.75      10.00       1.00       0.00       0.00

         TO       TRIV       SALO       SALR

       96.00      79.00       2.00       2.00


        S        X        Y        Z        D       V  TEMP   TEMP        DIL
                                                          BY     BY
     (FT.)    (FT.)    (FT.)    (FT.)    (FT)  FT/SEC  DIL    DEN

      10.0     10.0      0.1      0.2     11.7    7.4  91.7   91.8       1.34

 T=        91.770S=         2.00RHO=          1.931
      20.0     20.0      0.2      0.7     14.7    5.9  89.1   89.2       1.69

 T=        89.243S=         2.00RHO=          1.932
      30.0     29.9      0.6      1.5     17.7    4.9  87.3   87.6       2.04

 T=        87.561S=         2.00RHO=          1.933
      40.0     39.9      1.1      2.7     20.7    4.2  86.1   86.3       2.39

 T=        86.362S=         2.00RHO=          1.933
      50.0     49.7      1.8      4.1     23.7    3.7  85.2   85.5       2.74

 T=        85.464S=         2.00RHO=          1.934
      60.0     59.5      2.7      5.9     26.7    3.3  84.5   84.8       3.10

 T=        84.767S=         2.00RHO=          1.934
      70.0     69.2      3.9      8.0     29.7    3.0  83.9   84.2       3.46

 T=        84.210S=         2.00RHO=          1.934
      80.0     78.8      5.4     10.4     32.8    2.7  83.4   83.7       3.85

 T=        83.736S=         2.00RHO=          1.934
      90.0     88.2      7.2     13.3     37.8    2.4  82.8   83.0       4.49
```

```
LIST
```

SUBMERGED OUTFALL PROGRAM PRINTOUT (ADDITIONAL)

```
THOUTO     17:07    RDS2   OCTOBER 13, 1969
```

PLATE IV

```
00010
00020
00030
00040
00050          S        D     DIRECTION COSINES      RADIUS PROJECTIONS ON
00060                        X-AXIS  Y-AXIS  Z-AXIS  X-AXIS  Y-AXIS  Z-AXIS
00070
00080       10.0     11.7 0.99994 0.01092 0.00000       0.1     5.9     5.9
00090
00100       20.0     14.7 0.99969 0.02478 0.00000       0.2     7.4     7.4
00110
00120       30.0     17.7 0.99914 0.04157 0.00000       0.4     8.9     8.9
00130
00140       40.0     20.7 0.99812 0.06128 0.00000       0.6    10.4    10.4
00150
00160       50.0     23.7 0.99648 0.08387 0.00000       1.0    11.8    11.9
00170
00180       60.0     26.7 0.99401 0.10927 0.00000       1.5    13.3    13.4
00190
00200
00210
00220  AT NEXT LINE OF OUTPUT JET INTERSECTED SURFACE
00230
00240
00250       67.4     29.0 0.99154 0.12983 0.00000       1.9    14.4    14.5
00260
00270       70.0     29.7 0.99052 0.13740 0.00000       2.0    14.7    14.9
00280
00290       80.0     32.8 0.98577 0.16809 0.00000       2.8    16.2    16.4
00300
00310       90.0     37.8 0.97938 0.20202 0.00000       3.8    18.5    18.9
00320
00330      100.0     42.8 0.97090 0.23950 0.00000       5.1    20.8    21.4
00340
00350      110.0     47.8 0.95998 0.28008 0.00000       6.7    23.0    23.9
00360
00370      120.0     52.8 0.94634 0.32319 0.00000       8.5    25.0    26.4
00380





PPP
```

"TEMP BY DIL" is the calculation of the jet temperature using Equation 21. To check the numerical consistency of the program, temperature is also computed (after the solution is complete) using Equation 18 and the program solution value of ρ. This value is "TEMP BY DEN . Differences are virtually always less than $1^{o}F$ apart.

"TEMP BY DIL" is the correct value of jet temperature at any point. There will generally be a small difference between the two values, due to the trial and error nature of the solution. Temperature computed by Equation 21, which computes "TEMP BY DIL", is less sensitive to density errors than is temperature computed by Equation 18, and is the choice to set the jet temperature value.

"DIL" is the jet dilution factor, $\rho Q/\rho_o Q_o$. The second line of output data includes jet temperature, salinity and density for the x,y,z above it. Temperature is merely a repeat of "TEMP BY DEN" to greater precision and is included to identify the line with the line above.

Plate IV is additional printout, which includes the "S" and "D" for identification with output data on Plate III, and gives the direction cosines and the projection of the radius on each of the three cordinate axes. This information is used in computing the size of the jet isotherms, particularly as they appear at the surface.

Central Hudson Gas & Electric Corporation
Consolidated Edison Company of New York, Inc.
Niagara Mohawk Power Corporation

EFFECT OF ROSETON PLANT COOLING WATER DISCHARGE ON HUDSON RIVER TEMPERATURE DISTRIBUTION AND ECOLOGY

December, 1969

A Report Prepared Jointly by:

Quirk, Lawler & Matusky Engineers
Environmental Science & Engineering Consultants
505 Fifth Avenue
New York, New York 10017

and

Oceanographic Analysts, Inc.
4 Washington Square Village
New York, New York 10012

QUIRK, LAWLER & MATUSKY ENGINEERS
ENVIRONMENTAL SCIENCE & ENGINEERING CONSULTANTS
505 FIFTH AVENUE
NEW YORK, NEW YORK 10017
212 867-0080

WATER RESOURCES DEVELOPMENT
WATER POLLUTION CONTROL
AIR POLLUTION CONTROL
SOLID WASTES DISPOSAL

SYSTEMS ANALYSIS & DESIGN

COMPUTER FACILITIES
PILOT PLANT FACILITIES
ANALYTICAL LABORATORIES

THOMAS P. QUIRK
JOHN P. LAWLER
FELIX E. MATUSKY

WILLIAM A. PARSONS
LEONARD J. EDER
ROBERT A. NORRIS
VINCENT J. BOCCHINO

December 15, 1969

File: 176-0

Mr. Henry L. Walker
Vice President
Central Hudson Gas & Electric Corporation
284 South Avenue
Poughkeepsie, New York 12602

Dear Mr. Walker:

In accordance with your authorization, we are submitting our report on the evaluation of the effect of the Roseton Plant cooling water discharge on Hudson River temperatures and ecology.

The study was conducted jointly by: Quirk, Lawler & Matusky Engineers (QL&M) under the direction of Dr. John P. Lawler and Oceanographic Analysts, Inc. (OAI) under the direction of Dr. Alfred Perlmutter.

Mr. Karim A. Abood of QL&M acted as the project engineer. He coordinated the field work and wrote this report.

Quirk, Lawler and Matusky Engineers conducted the field work and evaluated the engineering measurements to predict the effect of the Roseton plant and to determine compliance with the Thermal Discharge Criteria and the size of the heated zone.

Oceanographic Analysts, Inc. performed the ecological sampling and laboratory work and evaluated the effect of the heated discharge on the area's ecology.

For your convenience, we have preceded this report with a summary of findings, conclusions and recommendations.

Very truly yours,

Dr. Alfred Perlmutter

Dr. Alfred Perlmutter
OCEANOGRAPHIC ANALYSTS, INC.

Dr. John P. Lawler
QUIRK, LAWLER & MATUSKY ENGINEERS

TABLE OF CONTENTS

QUIRK, LAWLER & MATUSKY ENGINEERS

OCEANOGRAPHIC ANALYSTS, INC.

QUIRK, LAWLER & MATUSKY ENGINEERS

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

1. Central Hudson Gas & Electric Corporation is planning to build a 1200 MWE fossil-fueled electric generating station at Roseton in the town of Newburgh, Orange County, New York.

   At rated capacity, the heated discharge will raise the temperature of the 650,000 gpm cooling water flow by 17°F.

   This cooling water will be withdrawn from the Hudson River, circulated through the condensers, and then returned to the river downstream of the intake structure.

   The outfall will consist of a 12 foot diameter underwater pipe terminating in an end section and provided with eight horizontal discharge ports. The port section will be parallel with the river's shore and the jets normal to the river's longitudinal axis. The upstream port will be located at about 500 feet downstream of the intake. The effluent will be discharged through these ports at 20 feet below the mean water elevation.

   A multi-port sheet piling design was originally proposed and discussed with the New York State Department of Health personnel. However, during the course of additional detailed studies of this design, a modification to a multi-port underwater pipe design was found to be necessary. Several structural, esthetic and economic factors led to this modification.

   For the purpose of illustrating the merits and mechanics of a submerged type of outfall and since a considerable effort was expended on the original design, we have chosen to retain the detailed evaluation of the sheet piling design in this report.

   The results of the evaluation of both designs are documented in Chapter IV.

2. Central Hudson is required by the New York State Department of Health (NYSDH) to evaluate the effect of the Roseton thermal discharge on Hudson River temperature and ecology, prior to NYSDH action on an application for a permit to construct facilities to discharge warmed water to the Hudson River.

   A program of engineering and biological surveys in the river in the vicinity of (1) the existing 500 MWE Danskammer plant, located about ½ mile north of Roseton and on the river's west bank, and (2) the proposed Roseton plant, commenced in April, 1969.

Engineering field measurements included temperature, dissolved oxygen, and salinity. Biological sampling included trapping fish in fyke nets, seining fish in the very shallow, near shore waters of a cove, into which the Danskammer heated water is discharged, and collection of bottom sediments. The results of that study are presented in this report.

3. A conservative mathematical model has been developed to estimate the expected effect of the proposed plant. This model is an improvement on previous thermal models, in that it recognizes that thermal stratification increases, as distance from the plane of discharge increases.

The first stage computation associated with this model predicts the average temperature rise across any cross-section of the river, above or below the river cross-section, over which the heated liquid is discharged. We recognize that temperature rises are actually distributed over the river decreasing from a maximum value at the point of discharge, to zero as one moves toward the other side of the river, toward its bottom, or upstream or downstream of the plane of discharge. The area-averaged temperature rise, $\Delta\overline{T}$, however, provides a convenient means of characterizing the overall effect of the heated discharge on the river, and is a necessary first stage in a three stage development of the temperature rise distribution.

Also part of the first stage computation, is the prediction of the average temperature rise across the surface of any cross-section. This parameter is designated the surface average temperature rise, and is written $\Delta\overline{T}_S$. Due to the lower density of the heated liquid, it will always rise toward the surface, and the surface average temperature rise, for a given cross-section, will always be greater than the area-averaged temperature rise for that section.

These two parameters describe, rather completely, the overall effect of a heated discharge on the temperature rise across any section of the river. The ratio, $\Delta\overline{T}_S/\Delta\overline{T}$, has been coined the thermal stratification factor (TSF) and is equal to the ratio of the mean depth of the river section, D, to the mean thickness of the heated layer, D_H. In other words, the effect of a thermal discharge can be considered to be represented by an elevated temperature, $\Delta\overline{T}_S$, located at the surface of the river in a layer, D_H thick. The river water below this layer is unaffected by the heated temperature; i.e., does not suffer a temperature rise.

A comparison of model predicted values of $\Delta\overline{T}$ and $\Delta\overline{T}_S$ with field observations of the same, for the generating, hydrological and meteorological conditions at Danskammer this summer, is shown in Figure S-1. The agreement at the plane of heated liquid discharge is rather good. Furthermore, the shape of the distribution of these parameters along the river's longitudinal axis agrees with the qualitatively observed decay of these values with distance. The measured values, however, clearly decrease much more rapidly than do the predicted values, and for this reason, this model is considered to be a rather conservative description of the effect of a heated discharge on river temperature rises.

4. This model was utilized to predict the overall temperature rises which can be expected in the presence of a 1200 MWE waste heat load from Roseton.

Thermal stratification decreases when a submerged discharge is used, due to the introduction of the heated liquid well below the surface and to the intense mixing which is caused by the high velocity jets. The TSF for the Roseton discharge is expected to vary between 1.5 and 2.0.

Figure S-2 shows the predictions for the area-average and surface-average temperature rises caused by the Roseton discharge as well as the measured temperature rises at Danskammer. As indicated earlier, the predicted distribution beyond the plane of discharge is very conservative. In the case of Danskammer, for example, Figure S-1 shows that the computed values are more than five times greater than their measured counterparts at a distance of one mile downstream of the discharge.

The maximum area-average temperature rise occurs at the plane of discharge. The critical section for the maximum surface-average temperature rise occurs some distance beyond the plane of discharge. Growth of the surface average temperature rise, however, is more than offset by continuous reduction in the thickness of the heated surface layer, as indicated by the continuous reduction in the area-averaged values. Danskammer measurements (Figure S-1) show this effect also, although much closer to the discharge than was predicted.

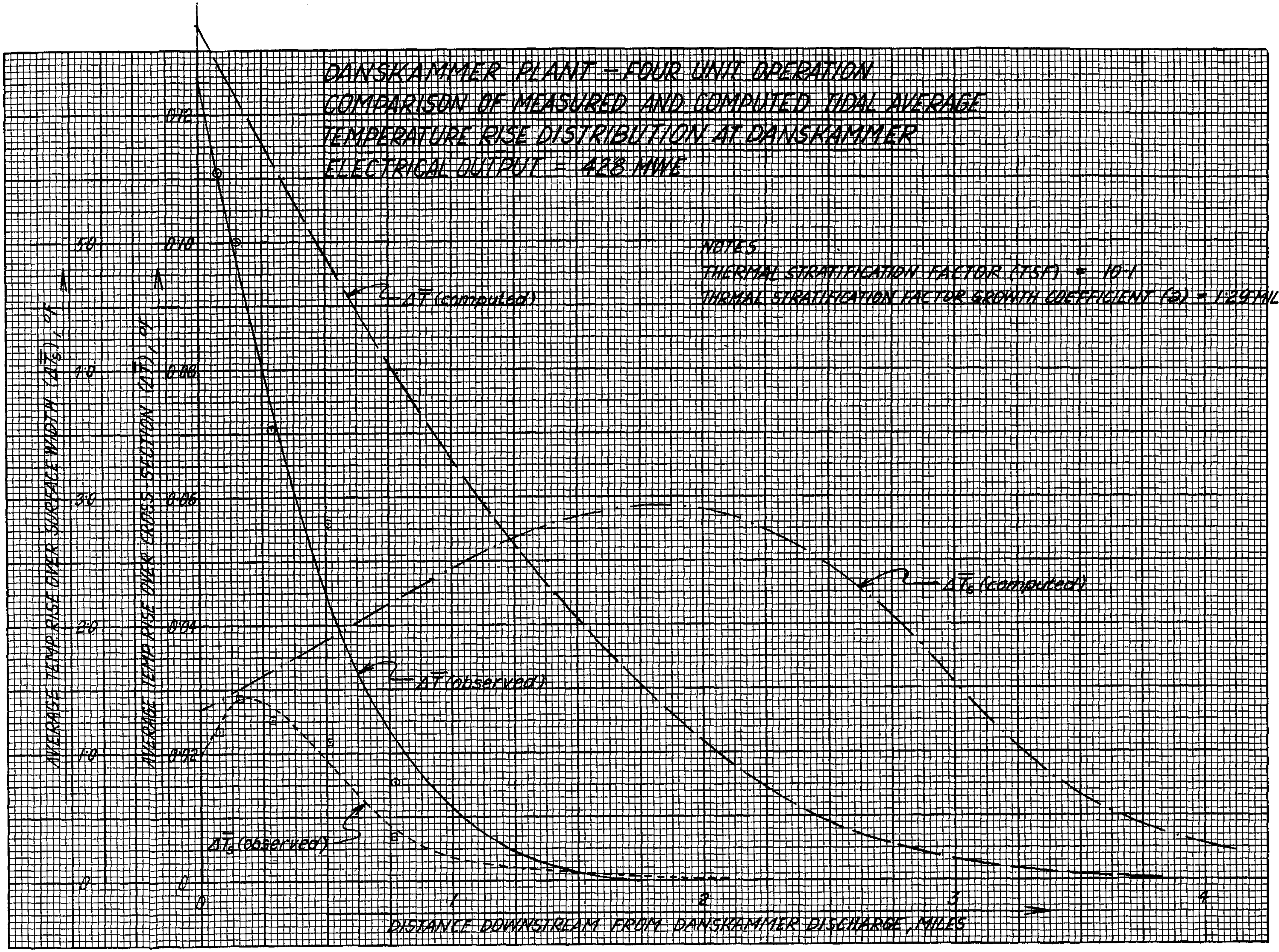

DANSKAMMER PLANT – FOUR UNIT OPERATION
COMPARISON OF MEASURED AND COMPUTED TIDAL AVERAGE
TEMPERATURE RISE DISTRIBUTION AT DANSKAMMER
ELECTRICAL OUTPUT = 428 MWE
NOTES
THERMAL STRATIFICATION FACTOR (TSF) = 10·1
THERMAL STRATIFICATION FACTOR GROWTH COEFFICIENT (a) = 1·29 MILE⁻¹
ΔT̄ (computed)
ΔT̄ (observed)
ΔT̄s (computed)
ΔT̄s (observed)
AVERAGE TEMP. RISE OVER SURFACE WIDTH (ΔT̄s), °F
AVERAGE TEMP. RISE OVER CROSS-SECTION (ΔT̄), °F
5·0
4·0
3·0
2·0
1·0
0
0·12
0·10
0·08
0·06
0·04
0·02
0
0
1
2
3
4
DISTANCE DOWNSTREAM FROM DANSKAMMER DISCHARGE, MILES

Figure S-1

ROSETON PLANT
AREA-AVERAGE AND SURFACE-AVERAGE TEMPERATURE RISE DISTRIBUTION
(RATED CAPACITY - SUBMERGED DISCHARGE AT ROSETON)

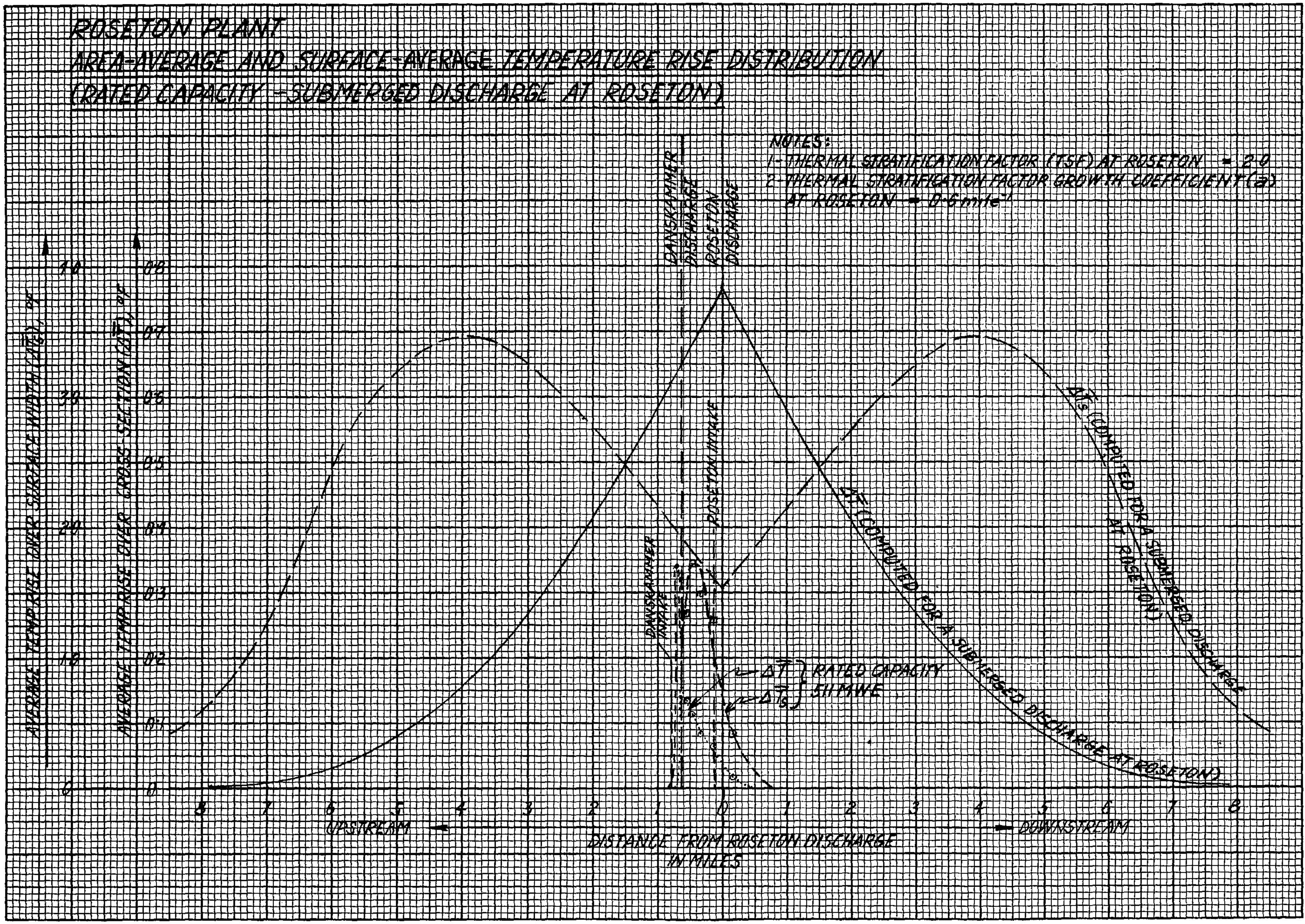


Figure S-2

The results shown in Figure S-2 are summarized in Table S-1. For a stratification factor of 2.0, the heated effect in the immediate vicinity of the discharge is represented by a 20 ft. thick layer of water raised 1.5°F above the ambient temperature. At a point some 4 miles below the discharge, the effect is contained in a layer less than 2 ft. thick, elevated by 3.4°F. Of course, comparison to the measured results indicates the actual maximum Roseton surface effect will occur much closer to the vicinity of the plant itself.

5. In accordance with the New York State Water Resource Commission's (NYSWRC) criteria on Thermal Discharges, specific attention was given to determining the zone of the river, within which temperatures may exceed 83°F or a 4°F temperature rise above ambient. The maximum ambient temperature observed during the survey was 77.5°F. A maximum summer ambient condition of 79°F has been established in previous studies. At this level, the 4°F rise criterion is equivalent to the 83°F criterion, and the prediction of the zone of the river, within which temperature rises exceeded 4°F, is the object of the "temperature" portion of this report.

   The maximum percentages of the cross-sectional area and surface width bounded by the 4°F isotherm are given in Table S-2. Two values, corresponding to the stratification levels discussed in item 4 above, are shown.

   Ranges of these parameters for the tidal average condition, as well as for the tidal phase for which each parameter reaches a maximum, are given in Table S-2.

   Figure S-3 shows the predictions for the percentage of surface width and cross-sectional area bounded by the 4°F isotherm for the tidal average as well as the critical tidal phase conditions. These were obtained using the conservative mathematical model and the rated capacity heat loads of both Danskammer and Roseton plants. The maximum percentage of either parameter is clearly less than the 4°F criterion.

   Figure S-4 shows the surface temperature isotherms obtained using the conservative mathematical model. The maximum temperature of 7°F is the maximum surface temperature expected to occur in the presence of the submerged outfall. The extension of this value some distance beyond the outfall in

TABLE S-1

SUMMARY OF OVERALL ELEVATED TEMPERATURE EFFECTS AT ROSETON

ELEVATED TEMPERATURE EFFECT	THERMAL STRATIFICATION	
	TSF = 1.5	TSF = 2.0
At the Discharge Section		
.Area Average Rise, $\Delta\overline{T}$, ^{o}F	0.94	0.77
.Surface Average Rise, $\Delta\overline{T}_s$, ^{o}F	1.4	1.5
.Mean Depth, D, Ft.	40.0	40.0
.Mean Depth, Heated Layer, D_H, Ft.	27.0	20.0
At the Section of Maximum Average Surface Temperature		
.Area Average Rise, $\Delta\overline{T}$, ^{o}F	0.27	0.16
.Surface Average Rise, $\Delta\overline{T}_s$, ^{o}F	3.0	3.4
.Mean Depth, D, Ft.	40.0	40.0
.Mean Depth, Heated Layer, D_H, Ft.	3.6	1.9

TABLE S-2

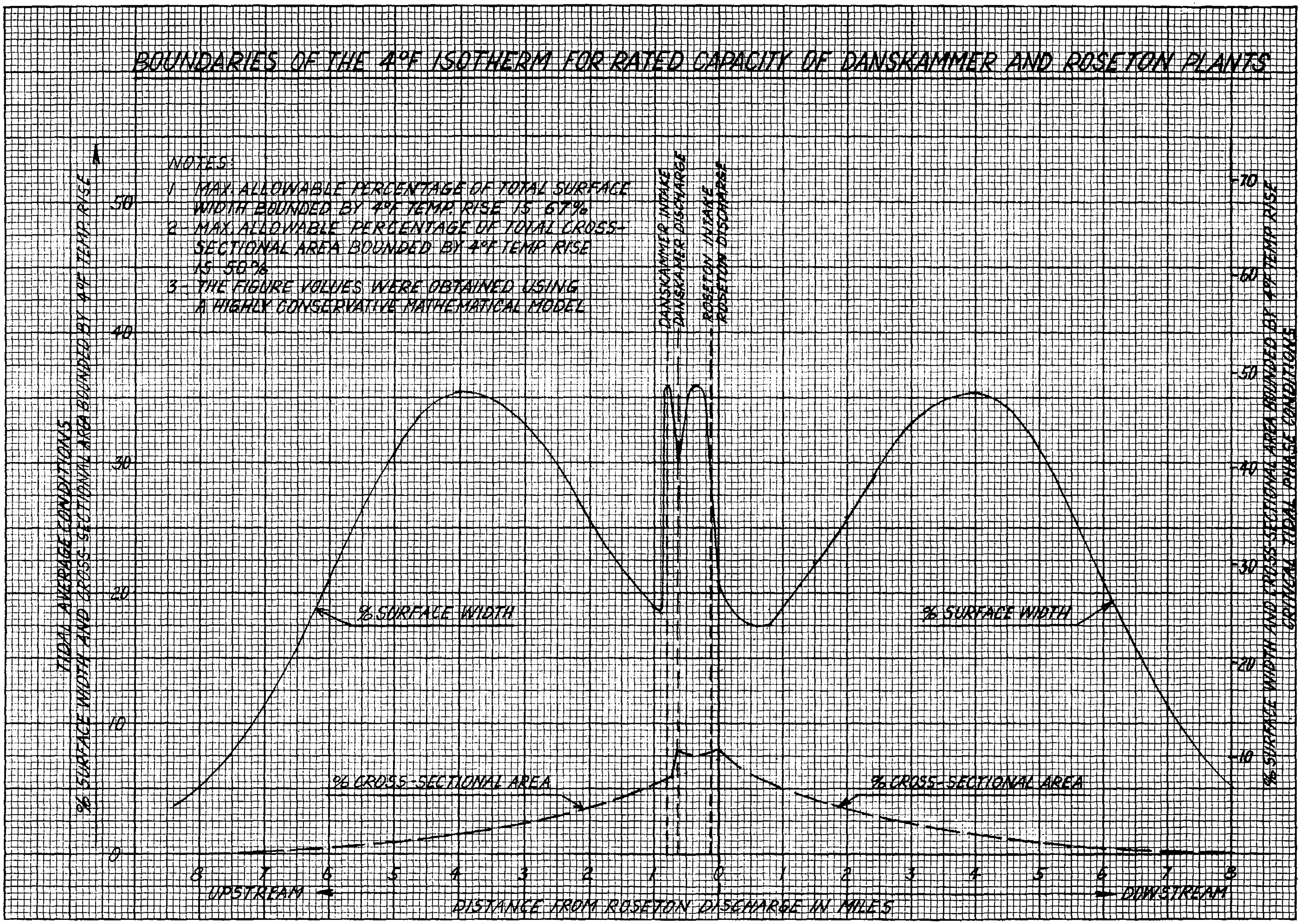
PORTION OF RIVER AT ROSETON AFFECTED BY TEMPERATURE RISES IN EXCESS OF 4°F FOR THE TIDAL AVERAGE AND THE CRITICAL TIDAL PHASE SUBMERGED DISCHARGE CONDITIONS

Parameter	EXPECTED RANGE[1]		Thermal Criteria
	Tidal Average	Critical Tidal Phase	
Maximum % Area	6-8	8-10	50
% Width at the Discharge	12-13	16-18	67
Maximum % Width	29-35	40-47	67

---

[1] These values were computed using a conservative mathematical model and a TSF_o of 1.5 and 2.0 and a TSF growth coefficient of 0.5 and 0.6/mile.

Figure S-3



BOUNDARIES OF THE 4°F ISOTHERM FOR RATED CAPACITY OF DANSKAMMER AND ROSETON PLANTS

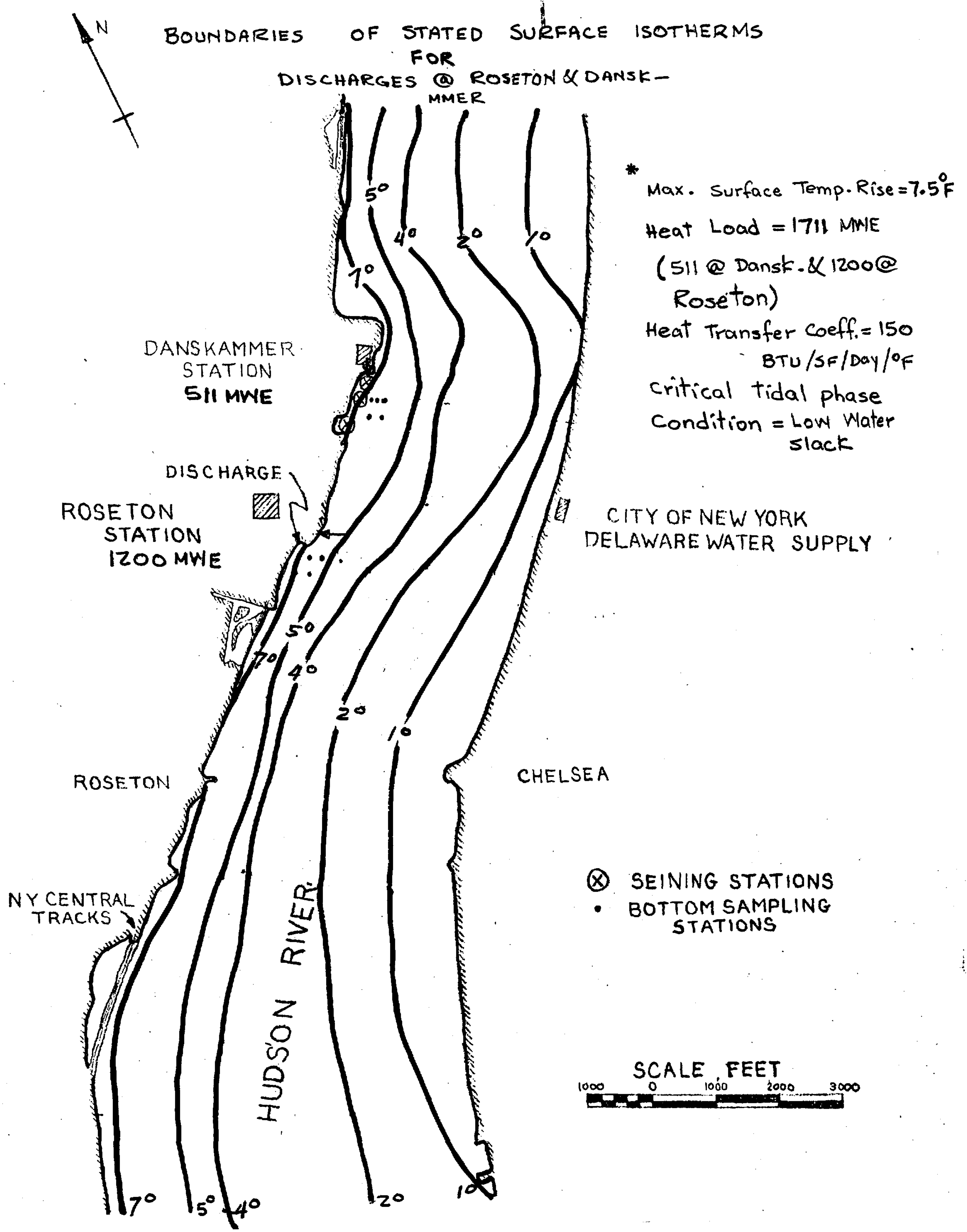
NOTES:

1 - MAX. ALLOWABLE PERCENTAGE OF TOTAL SURFACE WIDTH BOUNDED BY 4°F TEMP. RISE IS 67%
2 - MAX. ALLOWABLE PERCENTAGE OF TOTAL CROSS-SECTIONAL AREA BOUNDED BY 4°F TEMP. RISE IS 50%
3 - THE FIGURE VALUES WERE OBTAINED USING A HIGHLY CONSERVATIVE MATHEMATICAL MODEL

FIGURE S-4

CRITICAL SUMMER CONDITION*

BOUNDARIES OF STATED SURFACE ISOTHERMS FOR DISCHARGES @ ROSETON & DANSKAMMER



* Max. Surface Temp. Rise = 7.5°F

Heat Load = 1711 MWE

(511 @ Dansk. & 1200 @ Roseton)

Heat Transfer Coeff. = 150 BTU/SF/Day/°F

Critical tidal phase Condition = Low Water slack

Figure S-4 is considered to be conservative. We anticipate that the maximum rise beyond the immediate vicinity of the outfall will range between 3 and 5°F.

6. A mathematical model describing the behavior of a submerged jet in the Hudson River was developed and successfully programmed for computer solution. Previous applications of this model showed that the computed results agree reasonably well with measurements made in an undistorted Hudson River hydraulic model, and in the vicinity of the submerged outfall of Orange and Rockland Utilities' Lovett Unit #4, located at Tomkins Cove on the Hudson River's west bank.

   An outfall design consisting of a 12 foot underwater pipe and provided with four 5' diameter and four 4½' diameter ports, spaced 30' centers, submerged 20' below the water's surface, and discharging at about 15 ft/sec. normal to the river's longitudinal axis, was selected.

   Computed results for this design and for a condition of a maximum ambient temperature of 79°F, and a maximum condenser rise of 18°F, showed that the maximum surface temperature rise can be expected to be 6°F.

7. The measured Danskammer temperature distribution, the computed overall effect, and the submerged outfall design support the following conclusions:

   1. The effect of the Danskammer discharge on the Roseton intake is negligible. The observed area-average temperature rise at the proposed location of the intake is less than .05°F. Elevated surface temperatures are prevented from influencing intake temperature by the presence of a 5 ft. skimmer wall.

   2. The effect of the Roseton discharge on the Danskammer and Roseton intakes will be very small. Table S-1 and Figure S-2, which represent the conservative mathematical model, show that the area-average temperature rise in the vicinity of these intakes is less than 1°F. The submerged discharge model shows that there will be no effect at these locations.

A plant temperature rise of 18°F above ambient, reflecting a 1°F rise at the intake, and the 17°F maximum condenser ΔT, has been used in this report, so that any slight intake effect has been accounted for.

3. There will be no measurable effect caused by rated capacity operation of the Roseton plant on the New York City water supply pumping station at Chelsea. This station is located on the opposite shore of the river, some 4000 ft. north east of Roseton, and its intake is located close to the river's bottom.

4. All the NYSWRC thermal discharge criteria for estuaries will be met.

SUMMARY OF BIOLOGICAL STUDIES

A. Abundance of Bottom Organisms

The bottom organisms are more abundant in the area influenced by the heated effluent from the Danskammer Power Station than in the adjacent area where the proposed Roseton Power Station will be located.

B. Relative Abundance of Fishes and It's Relationship to Water Temperatures

The abundance of various predominant species of fish in the Hudson River is closely associated with habitat preference. Increased water temperatures, even as high as 91 degrees F., do not appear to influence abundance.

Whether abundance is maintained by a constantly emigrating and immigrating population, or a stationary one able to effectively adjust to the higher water temperatures, or both, is not known. Preliminary holding experiments suggest that these fish can live in water temperatures in the low 90's without apparent ill effect, for varying periods of time, depending on the species.

C. Distribution of Larval Fish

Concentrations of fish larvae obtained in the Cornwall area from late April through mid-July, 1968 by Northeast Biologists were analyzed to determine the effect of the Roseton intake on fish larvae. Consideration of channel and shoal geometry from Danskammer Point to Cornwall, and of the types of fish species taken all along this reach indicates that the Cornwall data is indicative of the distribution of fish larvae in the Danskammer-Roseton area.

The maximum Roseton intake flow is 1,460 cfs, or 1% of the average tidal flow in the Hudson at this point. The cross-sectional area between the west bank and the 30 ft. depth contour on the west side of the river's channel is 4% of the river's cross-section. This 30 ft. contour represents a conservative estimate of the boundary of the zone in the river in the vicinity of Roseton, within which intake water is withdrawn.

Since the tidal excursion is 4 miles, waters will be withdrawn from the zone between Marlboro on the north and Newburgh on the south. These represent outer boundaries, and most of the waters withdrawn by the plant are within a very small region in the near vicinity of the plant.

Based on the Cornwall data, the percentages of larvae within this zone of the river, which can be expected to be located west of the river channel's western 30 ft. depth contour are 11% of striped bass larvae, 12% of white perch larvae, and 15% of the larvae of remaining species.

These percentages were based on a schematic representation of the river's cross-section, in which the 30 ft. contour bounded 7%, rather than the actual 4% of the river's cross-section. Therefore, the percentages of larvae given above are about 75% higher than estimates based on actual cross-section data.

Only a very small fraction of the larvae estimated above to exist with the 30 ft. contour will be influenced by the plant intake. Comparing the fraction of the river's cross-section bounded by the 30 ft. contour (4%) to the fraction of the average tidal flow withdrawn by the plant (1%) suggests that most of the water will be withdrawn from a zone well within this bounding contour.

Secondly, as shown on Figure 19, the larvae tend to concentrate at the surface and bottom.

The intake is provided with a skimmer wall to a point about 5 feet below normal low water level. This wall will effectively block the withdrawal of the surface fish larvae in this area.

The slope of the modified river bottom running out to deep water in the area of the intake and the low velocities at the bottom layer will reduce the withdrawal of fish larvae in this area.

D. Effect on Chelsea Pumping Station

The QL&M studies have shown that there will be no measurable temperature effect due to the Roseton plant on the Chelsea intake. In the absence of elevated temperatures at this point, the Roseton plant will have no influence on the river biology in the vicinity of the Chelsea intake. Furthermore, Item C above shows clearly that the Roseton intake will not influence the eastern shore biology.

I. INTRODUCTION

Central Hudson Gas & Electric Corporation, with its principal office in Poughkeepsie, New York, is planning to build a 1200 MW electric generating plant at Roseton. The site is located near Roseton in the Town of Newburgh, Orange County, New York. The property lies along the west bank of the Hudson River, some 65 river miles above New York City Harbor. The site is situated directly south of and adjacent to the Danskammer Point Generating Station of Central Hudson.

Central Hudson, Consolidated Edison and Niagara Mohawk will own the plant as tenants in common. Central Hudson, on behalf of the tenants in common, will arrange for, supervise and effectuate the design and construction of the plant. Upon its completion Central Hudson will also operate and maintain the plant.

The plant will have an aggregate generating capability of 1200 MW, consisting of two 600 MW units, the first of which is expected to be ready for commercial operation by November 1, 1972, and the second by May 1, 1973.

The plant will be a steam electric fossil-fueled generating station. Spent steam will be condensed for reuse by circulating cooling water through the system to remove the waste heat from the spent steam. The cooling water will be withdrawn from the Hudson River, circulated through condensers, and then returned to the river downstream from the intake structure. Maximum cooling water flow is 656,000 gallons per minute.

Should the plant be operated at its maximum capacity, the waste heat will raise the temperature of the cooling water flow by 17°F. The outfall will consist of a 12 foot diameter underwater pipe terminating in an end section and provided with eight horizontal discharge ports. The port section will be parallel with the river's shore and perpendicular to the river's longitudinal axis. The upstream port will be located at about 500 feet downstream of the intake. The effluent will be discharged through these ports at 20 ft. below the mean water elevation.

The New York State Department of Health, by virtue of the New York State Public Health Law, is empowered to review and issue permits to construct and operate facilities which discharge wastes into the waters of the State. In reviewing applications for permits to discharge heated liquids, the State Department of Health engages the State Department of Conservation as a consultant.

The State Department of Health restricts permission to discharge wastes to situations where said discharges will not impair the best usage of the receiving waters or any other State waters into which the receiving waters may flow.

New thermal discharges are evaluated in accordance with the guidelines and provisions set forth in "Criteria Governing Thermal Discharges (Heated Liquids)" adopted by the New York State Water Resources Commission on July 25, 1969.

For estuaries, these criteria state the following:

> "The water temperature at the surface of an estuary shall not be raised to more than 90°F at any point provided further, at least 50 percent of the cross-sectional area and/or volume of the flow of the estuary including a minimum of 1/3 of the surface as measured from water edge to water edge at any stage of tide, shall not be raised to more than 4°F over the temperature that existed before the addition of heat of artificial origin or a maximum of 83°F, whichever is less. However, during July through September if the water temperature at the surface of an estuary before the addition of heat of artificial origin

> is more than 83°F, an increase in temperature not to exceed 1.5°F, at any point of the estuarine passageway as delineated above, may be permitted."

A meeting in April, 1969 was held between Health Department staff personnel and Central Hudson Gas & Electric Corporation, to discuss procedures to be followed for the evaluation of the discharge effect prior to formal submission of an application. During this meeting Central Hudson described the proposed Roseton circulating water system. Central Hudson consultants presented a preliminary description of the expected temperature effects, including those of both Danskammer and Roseton plants. These effects were based on some field measurements and a conservative analytical mathematical model. A discussion of the biological factors involved in the thermal discharge and intake problems were also outlined.

At this meeting, the State Department of Health requested Central Hudson to present the following:

1. A prediction of the maximum temperature expected to occur at Roseton and the size of the heated zone.

2. Separate evaluation of the Danskammer plant effects.

3. A prediction of the mixing characteristics in the area.

4. A listing prepared from existing records, of striped bass, white perch and "other" species for the reach of river under study.

5. A tabulation of bottom organisms in the vicinity of the existing Danskammer discharge and the proposed Roseton discharge for spring, summer and fall conditions.

A program of temperature and bottom organism surveys in the vicinity of Danskammer plant and the proposed Roseton plant was then instituted. Five ecological stations were established in the cove immediately south of the existing plant and an additional five sampling stations were located in the cove south of the Roseton plant.

Temperature measurements were made on five occasions during the period April 17 through August 13, 1969. Bottom samples were taken at two week intervals at all of the ten ecological stations on six occasions during the period May 7 through August 13, 1969.

These results showed that relatively small portions of the River's surface were subjected to temperature rises in excess of 4°F.

Surface temperature rises of no more than 10°F were found in the vicinity of the proposed intake. However, no temperature rises were seen in this area at five feet below the surface. The ecological surveys showed that the productivity of the bottom at both sites was satisfactory. The productivity, however, was somewhat poorer at Roseton.

These results were then presented to the State Department of Health in August, 1969. At this meeting, Dr. Alfred Perlmutter proposed an ecological study of the area to determine the ability of fish and other life forms to live in areas of elevated temperature.

This ecological study would include the trapping of fish in fyke nets, the seining of fish in the very shallow waters of the Danskammer cove, and the collection of bottom sediments, as well as the observation of aquatic vegetation.

Measurements during this period of biological testing would also include additional information to support the biological sampling; i.e., temperatures obtained coincident with biological sampling, other physical and chemical water tests to describe environmental conditions such as salinity and dissolved oxygen, observation of prevailing meteorological conditions and conduct of sampling during all tidal and intertidal stages.

The State Department of Health accepted this program and requested additional temperature surveys in the vicinity of Danskammer to support the mathematical models of temperature distribution and to be used in predicting the temperature effect of the Roseton plant cooling water discharge on Hudson River temperature distribution.

The purpose of this report is to present the results of this study. Results of the original ecological and thermal surveys are also included.

The report is formated as follows:

1. A discussion of the measured temperature data and a statistical analysis of these measurements are given in Chapter II. Results of physical measurements other than temperature are also presented in Chapter II.

2. A detailed description of the field survey procedures employed for the temperature and ecological surveys is given in Appendix A.

3. All of the temperature and engineering measurements are presented in Appendix B. This Appendix is in the form of a separate volume.

4. Prediction of the effect of Roseton plant cooling water discharge on Hudson River temperature distribution and a comparison of this effect to the estuary criteria of the New York Water Resources Commission's Thermal Discharge Criteria are given in Chapter III. Details of the theoretical model used for this purpose are presented in Appendix C.

5. Evaluation of the proposed Roseton submerged discharge design is presented in Chapter IV.

6. Theoretical analysis of submerged jet discharge and a set of computer printouts of Roseton plant submerged discharge are given in Appendices D and E, respectively.

7. Chapter V presents the results of the ecological program outlined earlier.

The engineering and ecological program measurements and results presented in this report were conducted by Quirk, Lawler & Matusky Engineers and Oceanographic Analysts, Inc., respectively.

Quirk, Lawler & Matusky temperature measurements are used in

Chapters II and III to predict the effect of Roseton discharge and determine compliance with the Thermal Discharge Criteria and the size of the heated zone, and in Chapter V to assist Oceanographic Analysts in their evaluation of the effect of the heated discharge on the area's ecology.

II. PRESENTATION AND ANALYSIS OF DANSKAMMER PLANT ENGINEERING MEASUREMENTS

A. Presentation of Temperature Measurements

A program of temperature surveys was instituted on July 8, 1969 and continued for more than three months. A preliminary surface temperature survey was conducted on April 17, 1969.

The original ecological program, consisting of bottom sample collection only, started on May 7 and continued until October 22, 1969.

On August 13, 1969 a combined thermal-ecological program was initiated on a regular weekly basis. Ecological sampling at three seining and ten bottom sample stations and temperature measurements in the vicinity of Danskammer and Roseton plants were made once a week throughout the daylight hours on Wednesdays, for an eleven week period ending on October 22, 1969. Figure 1 shows the locations of the two plants, as well as the ecological stations and the critical temperature section at Danskammer.

Table 1 lists all the temperature and ecological survey days and

FIGURE

LOCATION MAP
ROSETON POWER PLANT

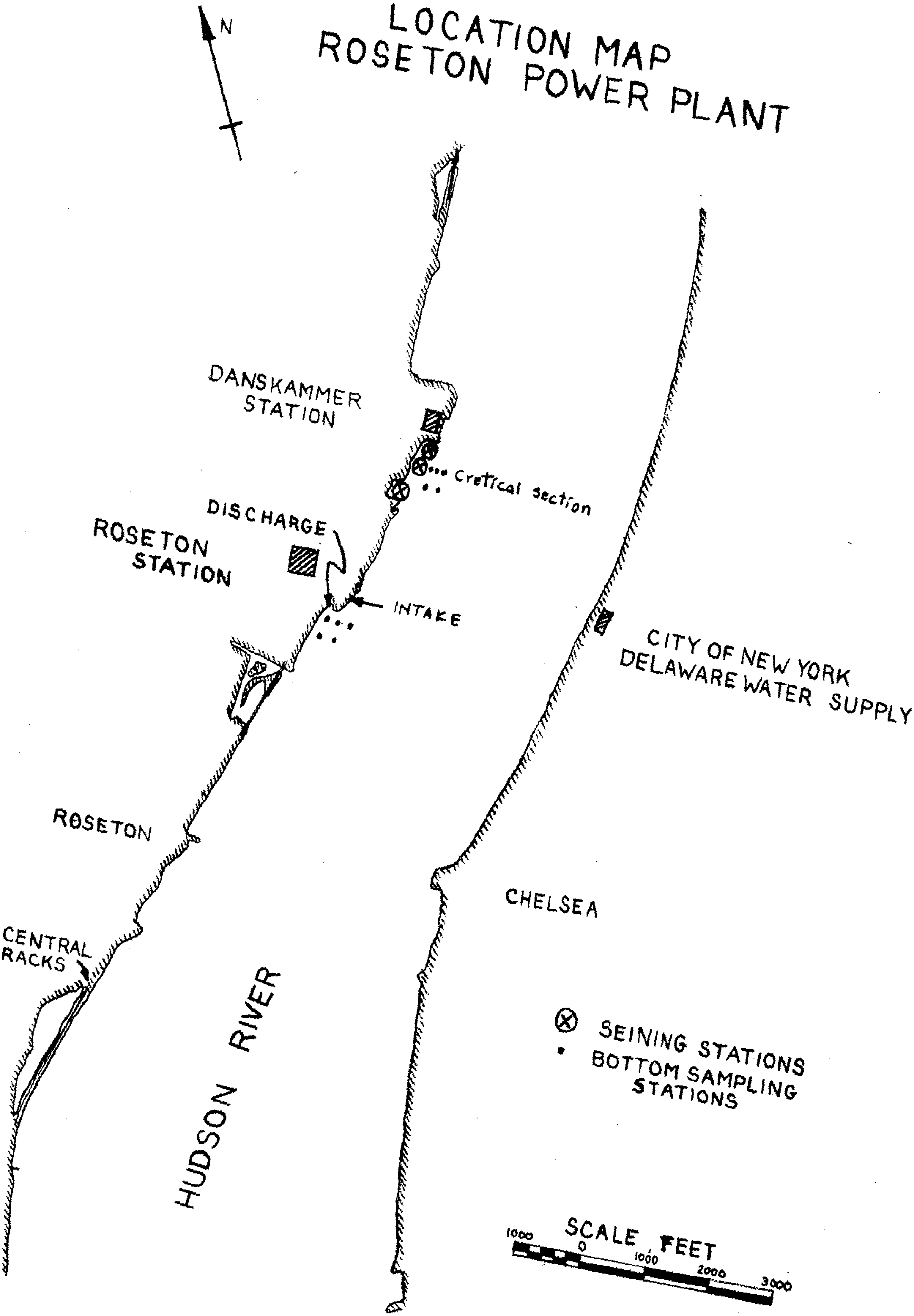


TABLE 1

DANSKAMMER PLANT THERMAL & ECOLOGICAL SURVEYS

Date	Tidal Phase	Average Range of Electrical Output During Temperature Runs, MWE	Remarks
4/17/69	EF,MF,EE,ME LE	-	Preliminary Temperature Surveys
5/ 7/69	-	-	Ecological Survey (Bottom Samples only)
6/ 4/69	-	-	Ecological Survey (Bottom Samples only)
6/18/69	-	-	Ecological Survey (Bottom Samples only)
7/ 2/69	-	-	Ecological Survey (Bottom Samples only)
7/16/69	-	-	Ecological Survey (Bottom Samples only)
7/18/69	LE,LWS,MF	492 - 504	Temperature Surveys
7/25/69	-	-	Depth Measurement
7/30/69	EF,LF,HWS	428 - 441	Temperature Survey
8/ 6/69	HWS,ME,LWS	455 - 494	Temperature Survey
8/13/69	MF,HWS,ME (EF)	461 - 470	Temperature & Ecological Survey
8/20/69	ME,LWS (ME)	424 - 463	Temperature & Ecological Survey
8/25/69	-	-	Ecological Survey (Control Experiment)

TABLE 1 (CONTINUED)

DANSKAMMER PLANT THERMAL & ECOLOGICAL SURVEYS

Date	Tidal Phase	Average Range of Electrical Output During Temperature Runs, MWE	Remarks
8/27/69	-	-	Ecological Survey (Control Experiment)
9/ 3/69	(ME)	-	Ecological Survey
9/ 4/69	-	-	Ecological Survey (Control Experiment)
9/10/69	MF,HWS,ME (LE)	393 - 434	Temperature & Ecological Survey
9/17/69	LWS,MF (LWS)	487.4 - 496.2	Temperature & Ecological Survey
9/24/69	MF,HWS (MF)	354.3 - 406	Temperature & Ecological Survey
10/ 1/69	LE,LWS,MF (LE)	435 - 458	Temperature & Ecological Survey
10/ 8/69	MF,HWS,ME (HWS)	258 - 267.6	Temperature & Ecological Survey
10/15/69	LE,LWS,MF (LWS)	382 - 399	Temperature & Ecological Survey
10/22/69	(LF)	360 - 370	Ecological Survey

Total Runs of Temperature Survey : 35
Total Runs for Maximum Flood : 9
Total Runs for High Water Slack : 6
Total Runs for Maximum Ebb : 6
Total Runs for Low Water Slack : 6
Total Runs of Ecological Survey : 18

the corresponding tidal current conditions.

During the survey period (April 17 through October 22, 1969) there were 35 and 18 actual temperature and ecological runs, respectively. These runs reflect behavior corresponding to four specific tidal phases and several electrical output ranges. Twelve, thirteen, six and five temperature runs were conducted during ebb, flood, low water slack and high water slack conditions, respectively.

Danskammer plant output, which controls heat load, ranged from 258 to 504 MWE during the survey period.

A detailed description of the field survey procedures employed for the temperature and ecological surveys is given in Appendix A.

Temperature survey results are presented as 15 separate sets in Appendix B, each set representing one day's effort. Each set consists of the following:

1. A table delineating the portion of Hudson River subjected to temperature rises in excess of $4^{O}F$. The effect is expressed in terms of river surface

width and cross-sectional area at the section of maximum severity as well as river surface area and longitudinal extent enclosed by temperature rises in excess of 4^{O}F.

2. Two or three figures showing the plant operating data and tidal characteristics that prevailed during each run. These figures depict the variation in the tidal current, plant electrical output, intake and discharge temperatures and maximum plant temperature rise during the survey hours.

   The plant operating data were taken from the plant records. Differences of up to several degrees between these records and QL&M survey readings of the discharge and intake temperatures were observed on several occasions. In general, the recorded temperatures were higher than their survey counterparts. This is due to the fact that the recorded temperatures were measured at just one point by less frequently calibrated instruments. Recorder temperatures are included, however, since they are more numerous and show temperature behavior at the plant throughout each survey run.

3. Two to three isothermal maps showing the surface temperature distribution for the individual tidal phases. The corresponding meteorological conditions (wind speed and direction, sky cover, daily average temperature, daily precipitation, dew point, barometric pressure and average temperature during the run); tidal conditions (tidal current and stage); plant operating data (heat load, cooling water flow, intake and discharge temperatures); and the river ambient temperature used in the data reduction are shown on each isothermal map.

   On some of these maps, the actual raw temperature measurements and the traverses followed during the run are also shown.

   Temperature measurements coincidental with ecological surveys are shown on the corresponding isothermal maps. These measurements include the surface as well as the cross-sectional temperature readings at the three seining stations.

4. Several river cross-sections depicting the temperature distribution across the section of maximum severity,

> as well as other sections in the vicinity, for the various tidal phases.
>
> For the Danskammer plant, the section of maximum severity is usually located some 400 ft. south of the discharge. This is also the location of the second seining station. This location is shown on the plant layout in Figure 1.
>
> These cross-sections represent only part of the total river cross-section. Temperature rises beyond the cutoff point were not measurable and, therefore, the remainder of the river cross-section was not plotted.

The surface area and longitudinal extent parameters were introduced for the purpose of determining the size of the zone in the River's surface subjected to rises in excess of $4^{\circ}F$. This information was specifically requested by the New York State Departments of Health and Conservation.

Three typical isothermal maps and cross-sections for the maximum flood and high water slack and maximum ebb of August 13, 1969 are shown in Figures 2 through 7. These measurements reflect

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HUDSON RIVER AT DANSKAMMER
CROSS-SECTION 180 FEET DOWNSTREAM FROM DISCHARGE

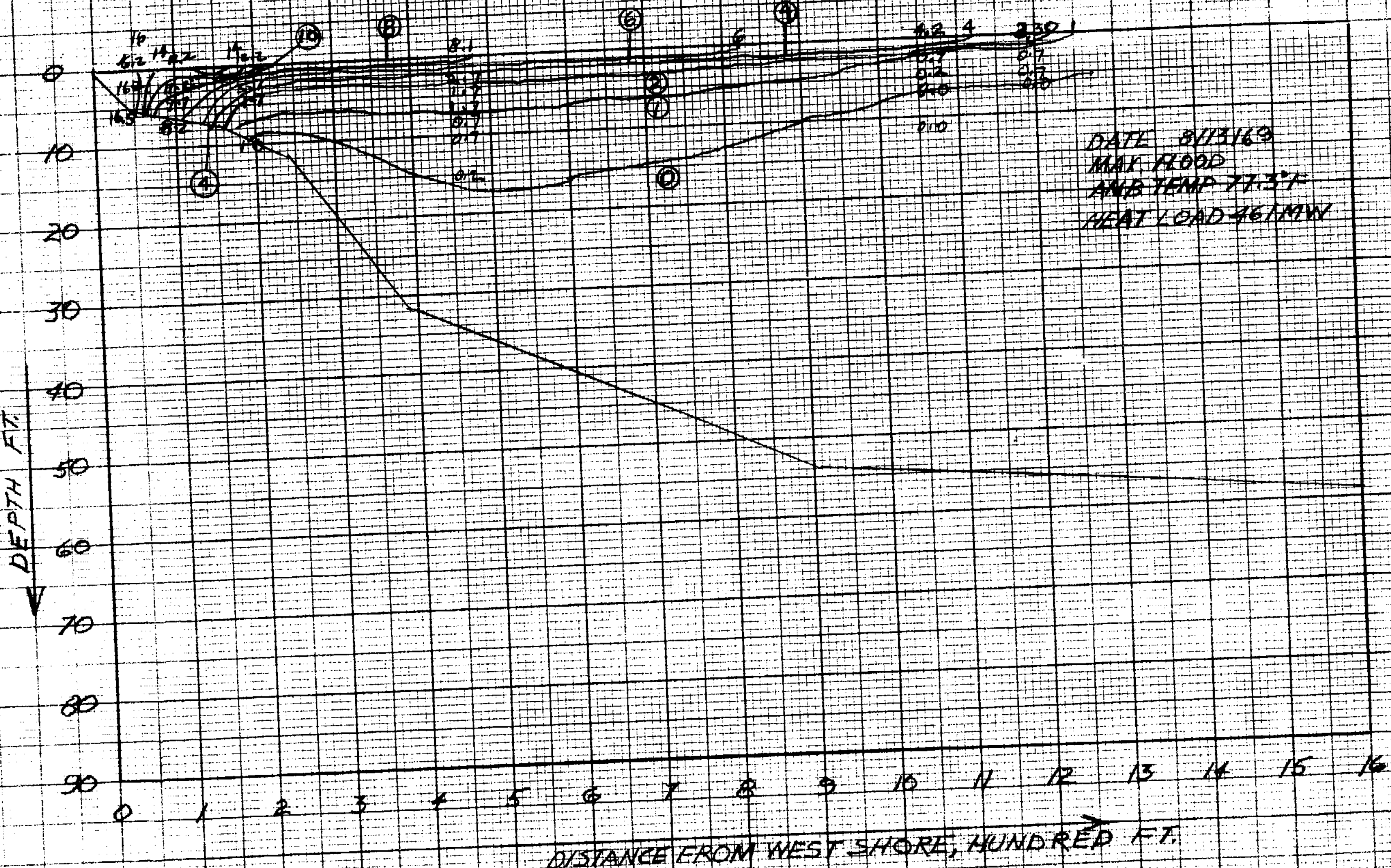

FIGURE 3

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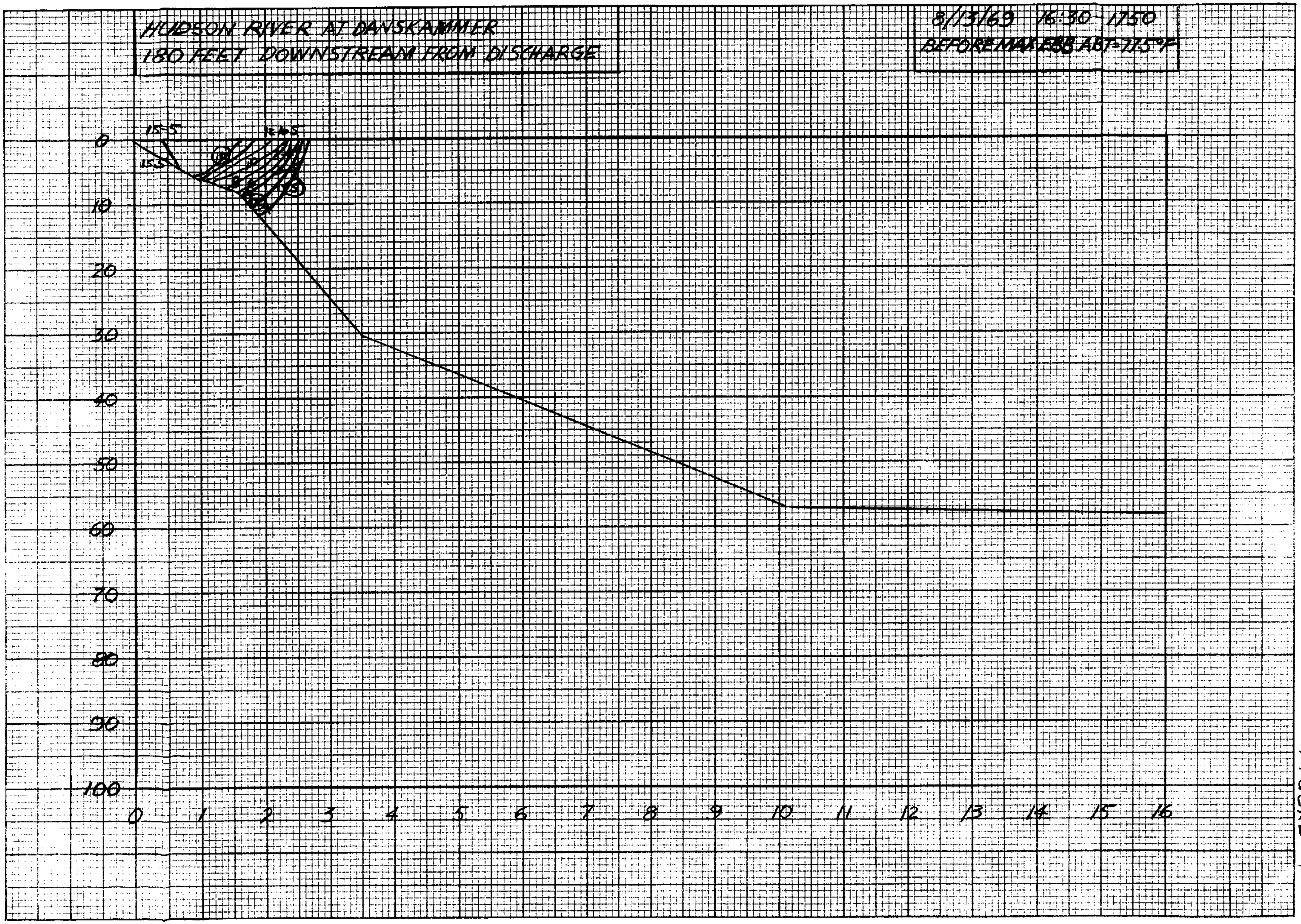

HUDSON RIVER AT DANSKAMMER
180 FEET DOWNSTREAM FROM DISCHARGE

8/13/69 16:30 1750
BEFORE MAX EBB ABT=77.5°F

FIGURE 7

the temperature distribution resulting from a four unit operating heat load of some 740 MWE. The actual raw temperature data and the criss-cross traverses followed during the survey are also shown.

Although shown as typical, these three runs actually represent the most severe observed condition for river surface area, cross-sectional area and surface width subjected to temperature rises in excess of 4°F temperature rise, during the period 7/18 through 10/15/69.

Table 2 lists the most severe observations for the 4°F surface width and cross-sectional area, as well as for the 4°F surface width and longitudinal extent, for each of the four tidal phases (flood, ebb, highwater slack & low water slack). These table values reflect the effect of four unit operation on Hudson River temperature distribution. Details of these sixteen conditions are presented in Appendix B on the figures whose numbers are shown in Table 2.

The surface width and cross-sectional area parameters were used to delineate Danskammer plant effects with respect to New

TABLE 2

HUDSON RIVER AT DANSKAMMER

LIST OF THERMAL CONDITIONS OF MAXIMUM SEVERITY OBSERVED AT THE CRITICAL SECTION DURING THE PERIOD 7/18 THROUGH 10/15/69

		CONDITION OF MAXIMUM SEVERITY IN TERMS OF PORTION OF RIVER SUBJECTED TO TEMPERATURE RISES EQUAL TO OR GREATER THAN 4°F EXPRESSED AS			
Tidal Phase	Description	% Width	% Cross-Sectional Area	Surface Area, Acres	Longitudinal Extent, Ft.
Maximum Flood	Figure # (Appendix A)	B-29	B-32	B-5	B-29
	Date of Occurrence	8/13/69	8/13/69	7/18/69	8/13/69
	Electrical Output, MWE	461	461	494	461
	Magnitude of Parameter	26.3	1.63	29.7	2205
High Water Slack	Figure # (Appendix A)	B-30	B-66	B-12	B-12
	Date of Occurrence	8/13/69	9/10/69	7/30/69	7/30/69
	Electrical Output, MWE	470	393	438	438
	Magnitude of Parameter	16.1	1.49	78	7750
Maximum Ebb	Figure # (Appendix A)	B-20	B-34	B-31	B-20
	Date of Occurrence	8/ 6/69	8/13/69	8/13/69	8/ 6/69
	Electrical Output, MWE	493	470	470	493
	Magnitude of Parameter	9.7	0.95	176	10,000
Low Water Slack	Figure # (Appendix A)	B-21	B-77	B-99	B-21
	Date of Occurrence	8/ 6/69	9/17/69	10/1/69	8/ 6/69
	Electrical Output, MWE	494	496	458	494
	Magnitude of Parameter	19	1.57	75.9	6000

York State Water Resources Commission criteria for thermal discharges.

Figure 8 depicts the average surface temperature distribution of the 31 temperature runs conducted during 7/18 through 10/15/69. This average condition was obtained by taking the lateral and longitudinal averages of the average specific tidal phases. The average profiles corresponding to each of the four specific tidal phases are shown in Figures 9 through 12.

Figure 8 may be interpreted as representing a tidal average condition for normal summer daylight four unit operation of Danskammer plant. The average plant output during the survey period was about 428 MWE.

Figure 8-a shows the portions of the cross-sectional area at the critical section encompassed by various temperature rises for the tidal average, normal summer operation condition.

Variation in the tidal average summer operation measurements with heat load is presented in the next Chapter.

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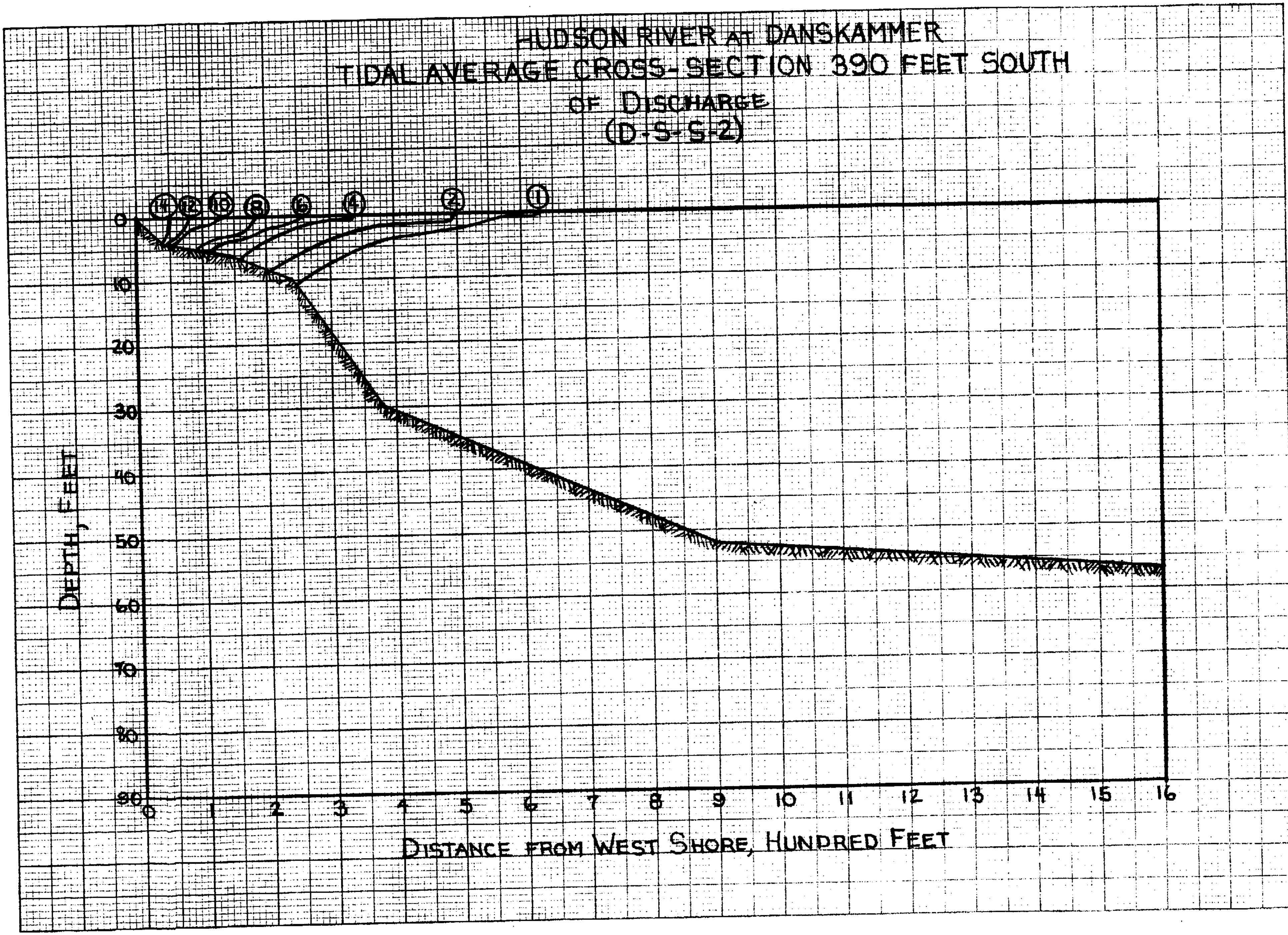


HUDSON RIVER AT DANSKAMMER
TIDAL AVERAGE CROSS-SECTION 390 FEET SOUTH
OF DISCHARGE
(D-S-S-2)

FIGURE 8-a

B. Statistical Analysis of Danskammer Plant Temperature Measurements

Tidal average behavior and the most severe observations for the $4^{o}F$ surface width and cross-sectional area, as well as for the surface area and longitudinal extent were presented in the previous section. These observations reflect the effect of the plant during a specific and occasional set of conditions.

A more practical and comprehensive evaluation of the plant's effect may be obtained by statistically analyzing all of the measured temperature effects for the observation period.

Such an approach is necessary for the purpose of determining the probability of occurrence of temperature effects resulting from any electrical output level and during any specific tidal phase. Statistical analysis results will also determine the probability of occurrence of the Danskammer effect used in predicting Roseton plant effect. Discussion of the latter purpose appears in Chapter III.

As in the previous section, four temperature parameters were used in the analysis. These include the river surface width, cross-sectional area, longitudinal extent and surface area subjected to temperature rises in excess of 4°F.

Since four tidal phases were taken into consideration, the duration of any observation is roughly equivalent to a three hour period.

The observed temperature data were grouped in two different ways. These include temperature effects corresponding to the following electrical output and tidal phase conditions that existed during the runs:

1. All electrical outputs and all tidal conditions.
2. All electrical outputs but evaluating the four tidal phases separately.

Evaluation of data collected during all observed tidal phases reflect the thermal effects during any three hour tidal phase condition. Analysis of those representing a specific tidal phase gives the effects over a duration of that specific three hour tidal phase.

The 1969 operation of Danskammer plant may be considered as representing a normal summer condition. The observed heat loads, however, were probably higher than normal due to a high electrical demand caused by failures of several power stations operated by other electrical companies during the survey period.

For convenience, these two conditions will be designated in this report as follows:

1. Normal summer operation during any three-hour tidal phase.
2. Normal summer operation over a duration of a specific three-hour tidal phase. Specific phases are ebb, flood, high water slack and low water slack.

The object of the statistical analysis is to present the probability distribution of temperature effects observed for these two conditions. However, the frequency of the appropriate loading and tidal phase condition itself must be established before presenting the distribution of the temperature effects, i.e., analyses of the several sets of observations made for each condition.

Since the measurements were made only in daylight hours and since heat loadings are always substantially lower at night, the two loading-phase conditions will be seen at best 50% of the time. This is due to the fact that there are roughly two three-hour tidal phases of a given kind in a 24 hour day. The daylight three-hour observations period represent the most sever conditions.

Also, since there are approximately four tidal phases during the daylight hours of a day, the probability of occurrence of any specific tidal phase in a survey day is 25%.

The probability of occurrence of the two loading-phase conditions may be determined from these frequencies as follows:

Condition 1 (all loads, all daylight tidal phases) = 50%

Condition 2 (all loads, specific daylight tidal phases)
= 50%X25% = 12.5%

Interpretation of the results of the data of these two conditions must, therefore, be related to the frequency of occurrence of both the values within one data group, i.e., temperature parameter, as well as the group itself, i.e., loading-phase condition.

Statistical evaluation of the data is presented, in terms of portion of river subjected to temperature rises in excess of 4°F, in the remaining part of this section.

1. Hudson River Surface Width at Danskammer Subjected to Temperature Rises in Excess of 4°F

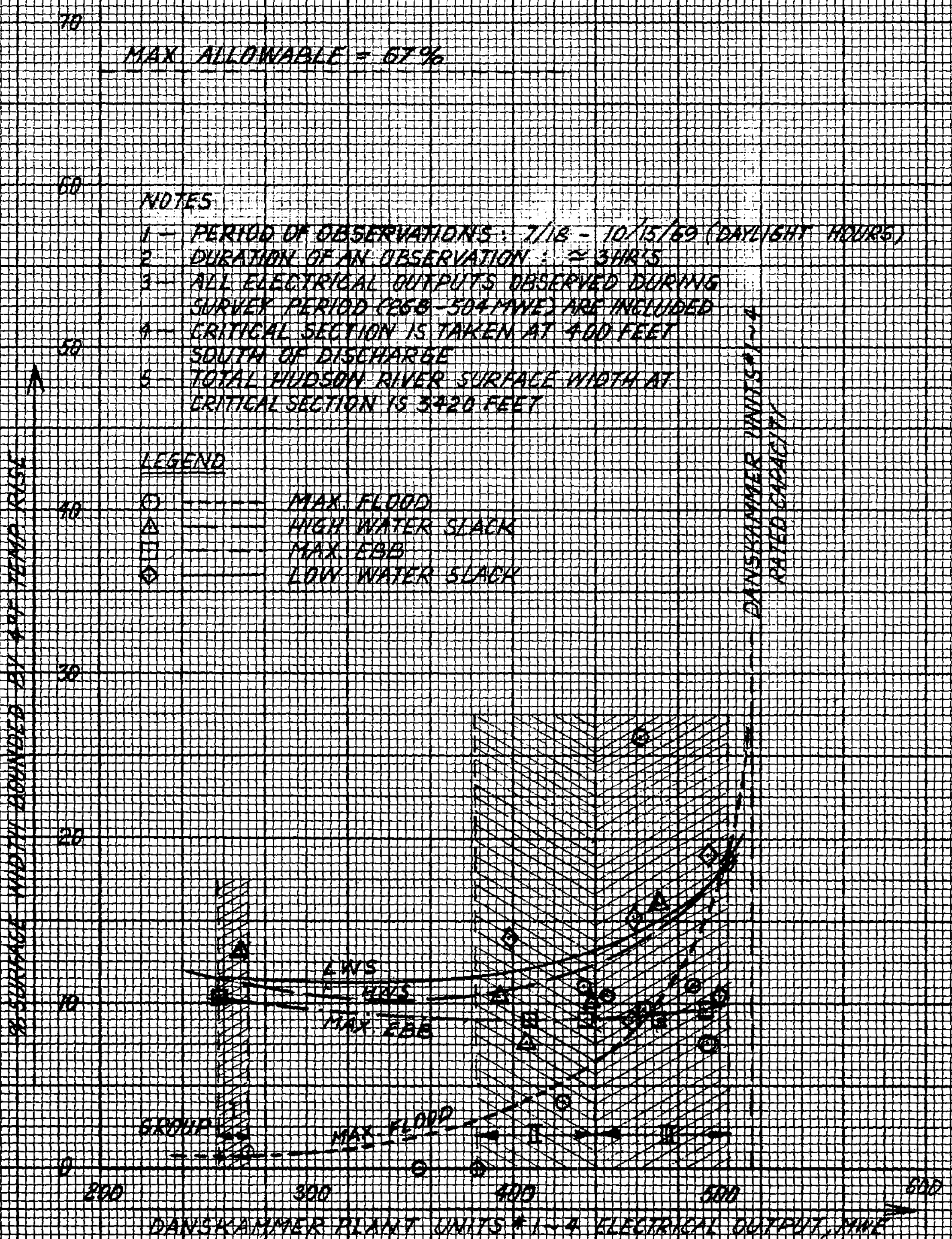
As indicated earlier, Danskammer plant temperature measurements showed that the maximum river width and cross-sectional area affected by temperature rises in excess of 4°F usually occurs at some 400 ft. south of the discharge. On a few occasions, however, a more critical surface section was observed downstream of this location. This may be due to the meteorological conditions which prevailed during some of the temperature runs, or may be the result of thermal stratification. Discussion of this latter supposition appears in Chapter III.

Figure 13 depicts the variation in percentage of total Hudson River width at the critical section enclosed by temperature rises equal to or greater than 4°F for all observed tidal conditions and heat loads. Values ranging from 0 to 26.3% of the total Hudson River surface width at Danskammer were observed.

The tidal average behavior is shown in Figure 14.

FIGURE 13

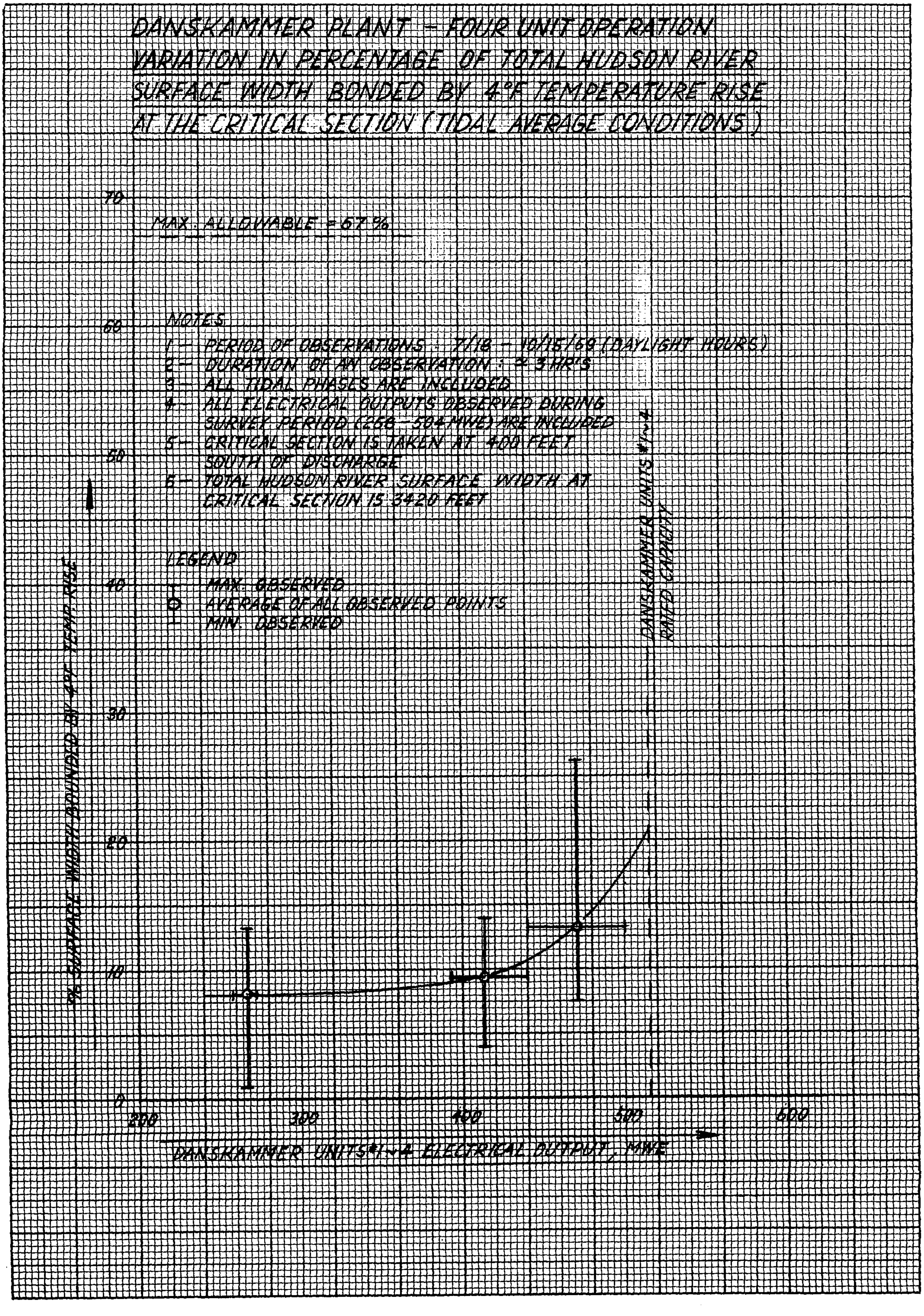
DANSKAMMER PLANT - FOUR UNIT OPEPERATION VARIATION IN PERCENTAGE OF TOTAL HUDSON RIVER SURFACE WIDTH BOUNDED BY 4°F TEMPERATURE RISE AT THE CRITICAL SECTION



NOTES

1 — PERIOD OF OBSERVATIONS : 7/18 - 10/15/69 (DAYLIGHT HOURS)
2 — DURATION OF AN OBSERVATION : ≃ 3HR'S
3 — ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (268 - 504 MWE) ARE INCLUDED
4 — CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
5 — TOTAL HUDSON RIVER SURFACE WIDTH AT CRITICAL SECTION IS 3420 FEET

FIGURE 14



DANSKAMMER PLANT – FOUR UNIT OPERATION
VARIATION IN PERCENTAGE OF TOTAL HUDSON RIVER SURFACE WIDTH BONDED BY 4°F TEMPERATURE RISE AT THE CRITICAL SECTION (TIDAL AVERAGE CONDITIONS)

MAX. ALLOWABLE = 67 %

NOTES
1 – PERIOD OF OBSERVATIONS : 7/18 – 10/15/69 (DAYLIGHT HOURS)
2 – DURATION OF AN OBSERVATION : ≃ 3 HR'S
3 – ALL TIDAL PHASES ARE INCLUDED
4 – ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (268 – 504 MWE) ARE INCLUDED
5 – CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
6 – TOTAL HUDSON RIVER SURFACE WIDTH AT CRITICAL SECTION IS 3420 FEET

Figure 15 shows the frequency of occurrence of percentage width bounded by 4°F temperature rise for the normal summer operation during any three-hour tidal phase condition.

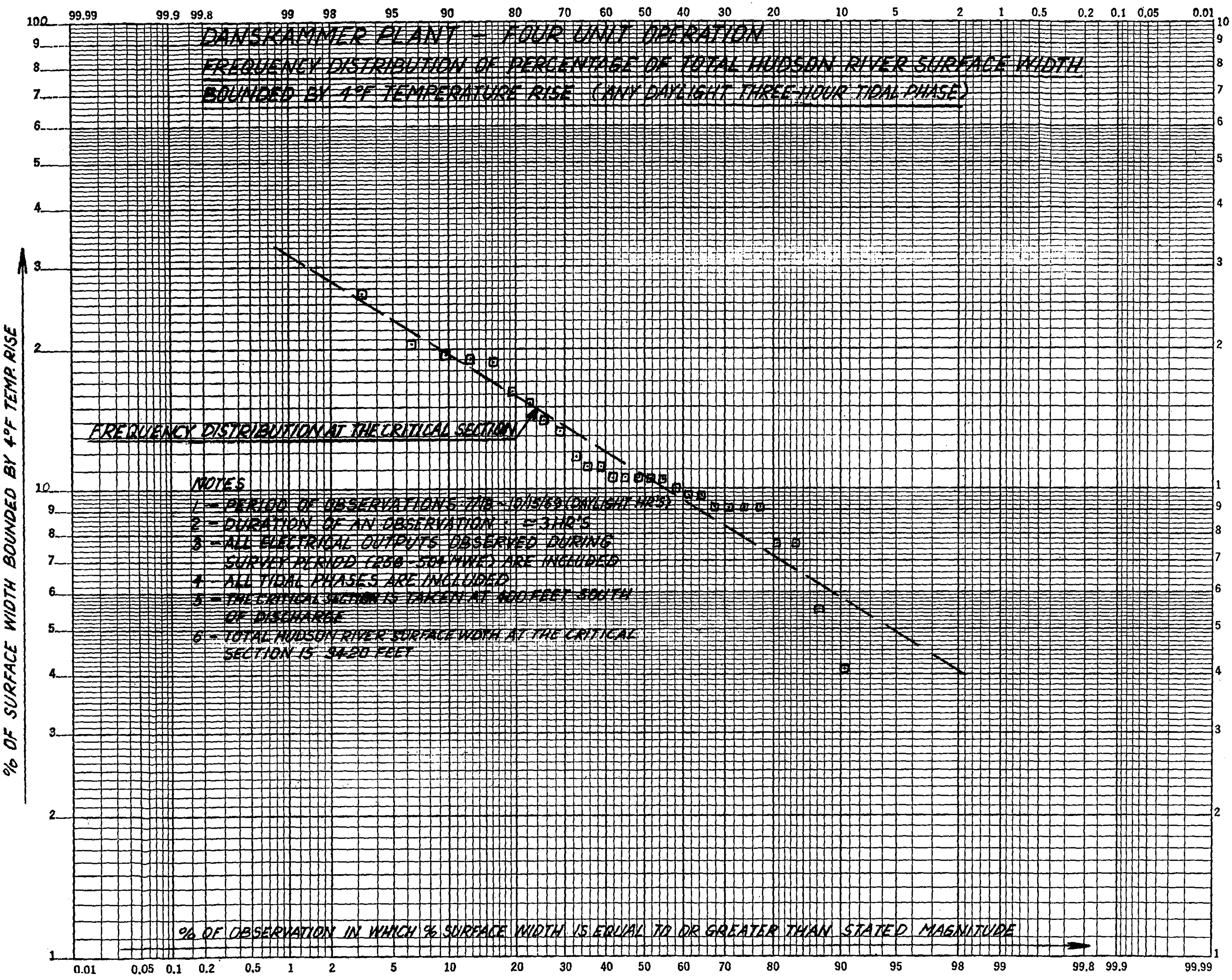
Figure 16 depicts the frequency distribution of 4°F surface width for the four daylight three-hour tidal phases.

As indicated earlier, the probability of occurrence of these two sets of data is 50 and 12.5% respectively.

The tidal cycle variation in surface width enclosed by 4°F temperature rise for a 50% frequency of occurrence was obtained from Figure 16 and is shown in Figure 17.

2. Hudson River Cross-Sectional Area at Danskammer Subjected To Temperature Rises in Excess of 4°F

The measured cross-sectional areas bounded by 4°F temperature rise at the critical section section are shown as a function of electrical output in Figure 18. Values ranging from 0 to 1.63% of the total river cross-sectional areas were observed. The tidal average behavior is shown in Figure 19.



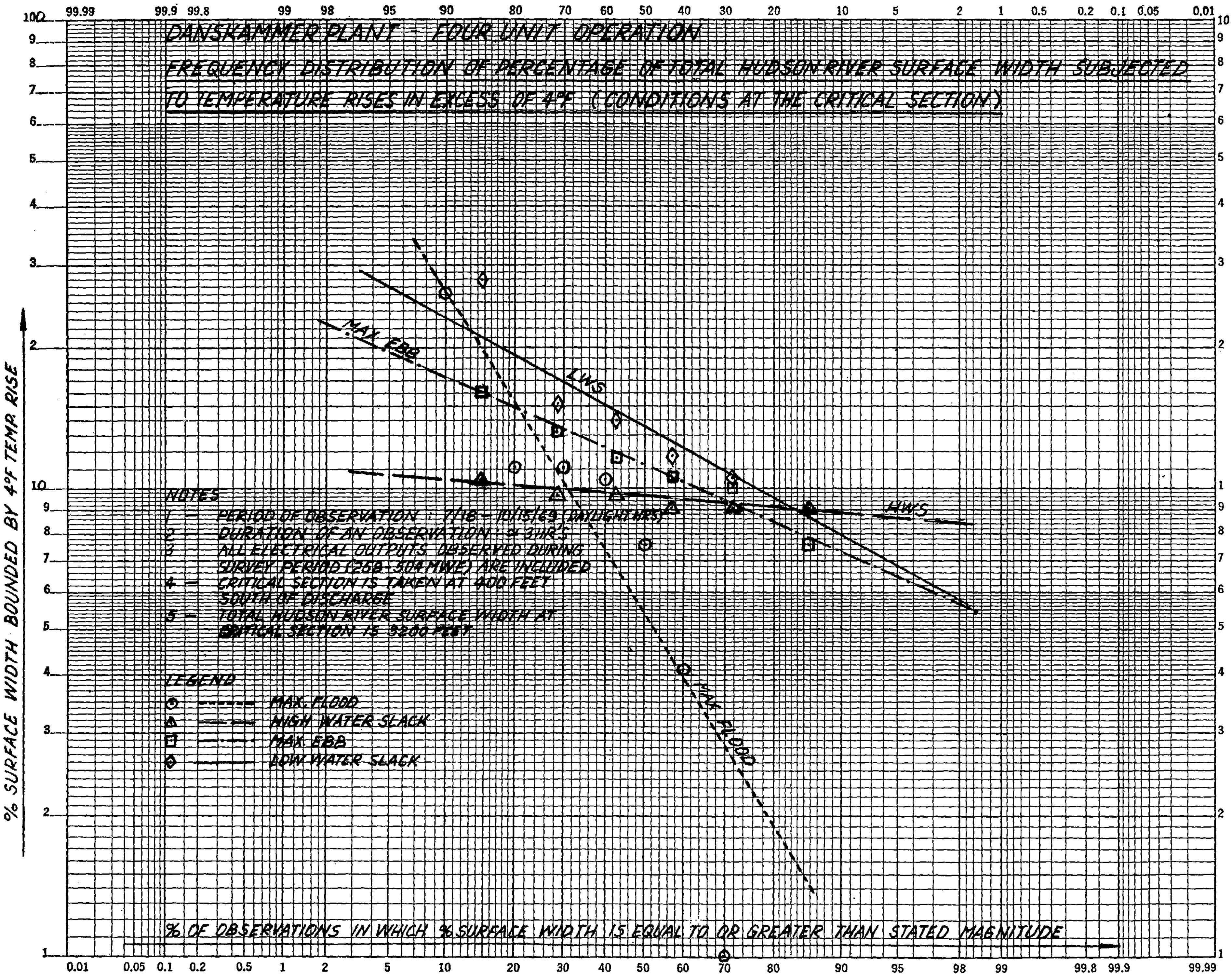
DANSKAMMER PLANT - FOUR UNIT OPERATION

FREQUENCY DISTRIBUTION OF PERCENTAGE OF TOTAL HUDSON RIVER SURFACE WIDTH BOUNDED BY 4°F TEMPERATURE RISE (ANY DAYLIGHT THREE HOUR TIDAL PHASE)

FREQUENCY DISTRIBUTION AT THE CRITICAL SECTION

NOTES
1 - PERIOD OF OBSERVATIONS: 7/18 - 10/15/69 (DAYLIGHT HR'S)
2 - DURATION OF AN OBSERVATION: ≈ 3 HR'S
3 - ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (250 - 504 MWE) ARE INCLUDED
4 - ALL TIDAL PHASES ARE INCLUDED
5 - THE CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
6 - TOTAL HUDSON RIVER SURFACE WIDTH AT THE CRITICAL SECTION IS 3420 FEET

FIGURE 15



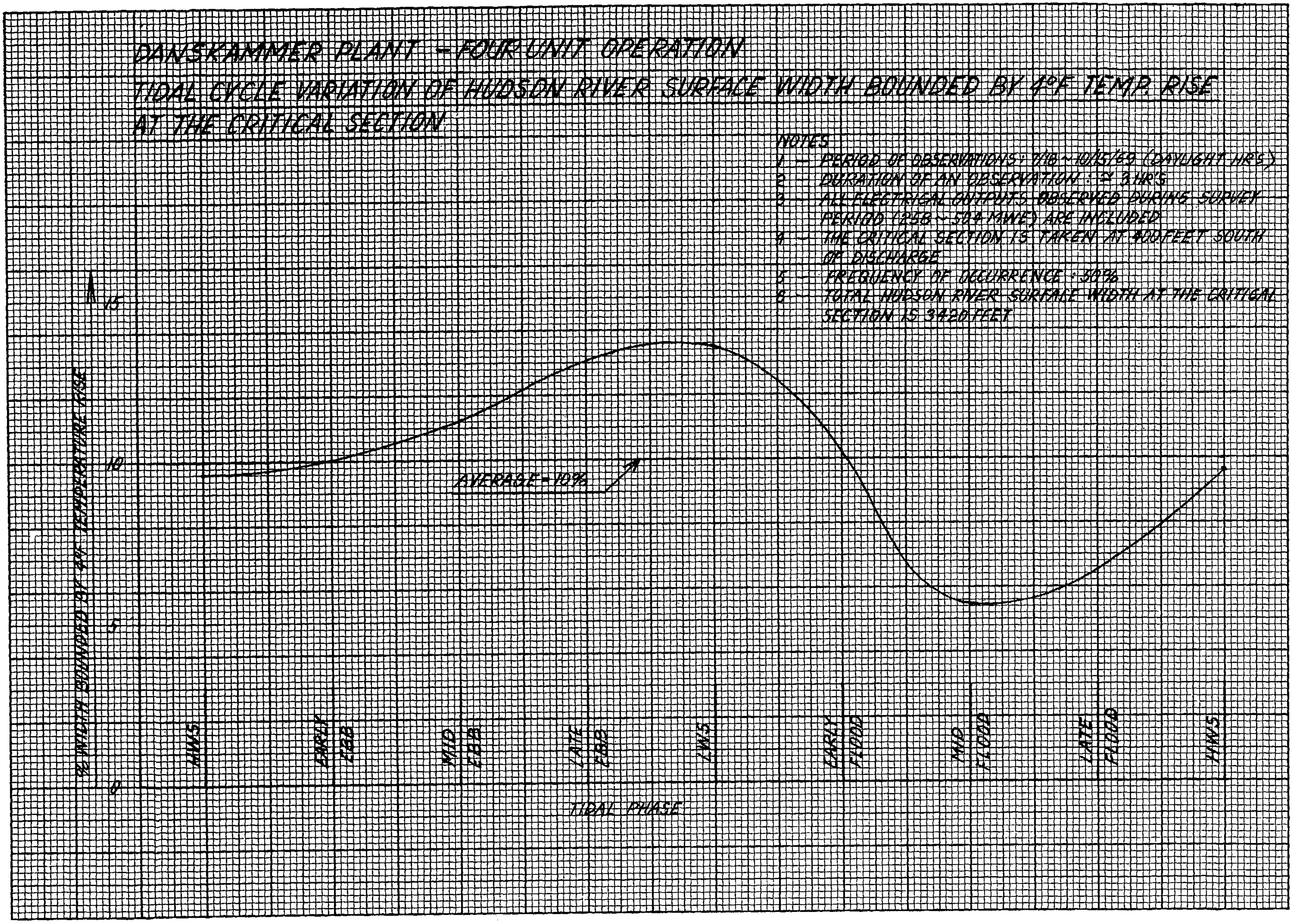
DANSKAMMER PLANT - FOUR UNIT OPERATION

FREQUENCY DISTRIBUTION OF PERCENTAGE OF TOTAL HUDSON RIVER SURFACE WIDTH SUBJECTED TO TEMPERATURE RISES IN EXCESS OF 4°F (CONDITIONS AT THE CRITICAL SECTION)

NOTES
1 — PERIOD OF OBSERVATION : 7/18 - 10/15/69 (DAYLIGHT HRS)
2 — DURATION OF AN OBSERVATION : ≈ 3 HR'S
3 — ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (268-504 MWE) ARE INCLUDED
4 — CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
5 — TOTAL HUDSON RIVER SURFACE WIDTH AT CRITICAL SECTION IS 3200 FEET

FIGURE 16

FIGURE 17

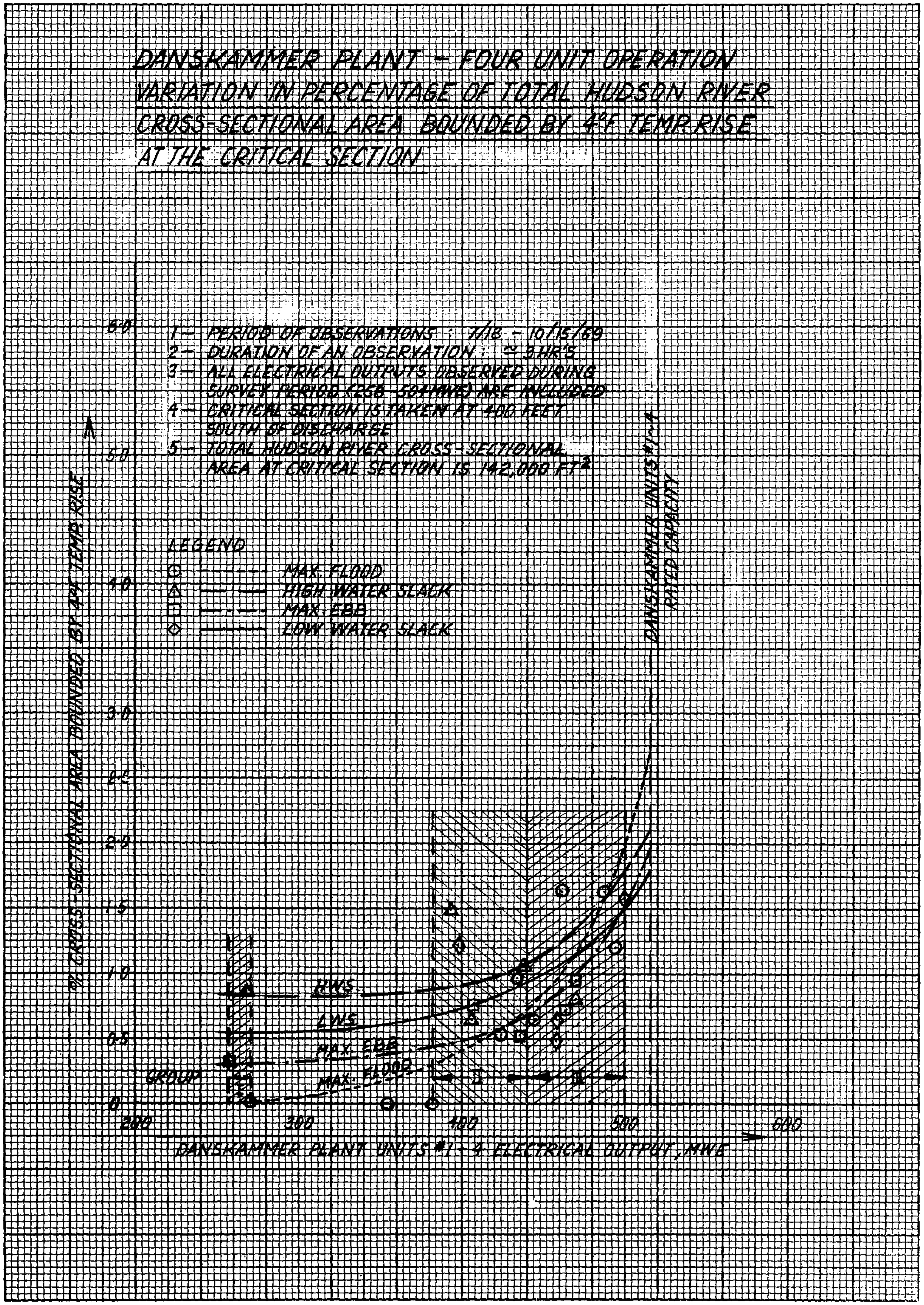


DANSKAMMER PLANT - FOUR UNIT OPERATION

TIDAL CYCLE VARIATION OF HUDSON RIVER SURFACE WIDTH BOUNDED BY 4°F TEMP. RISE AT THE CRITICAL SECTION

NOTES
1 — PERIOD OF OBSERVATIONS: 7/18 ~ 10/15/69 (DAYLIGHT HRS)
2 — DURATION OF AN OBSERVATION: ≃ 3 HR'S
3 — ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 ~ 504 MWE) ARE INCLUDED
4 — THE CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
5 — FREQUENCY OF OCCURRENCE: 50%
6 — TOTAL HUDSON RIVER SURFACE WIDTH AT THE CRITICAL SECTION IS 3420 FEET

FIGURE 18

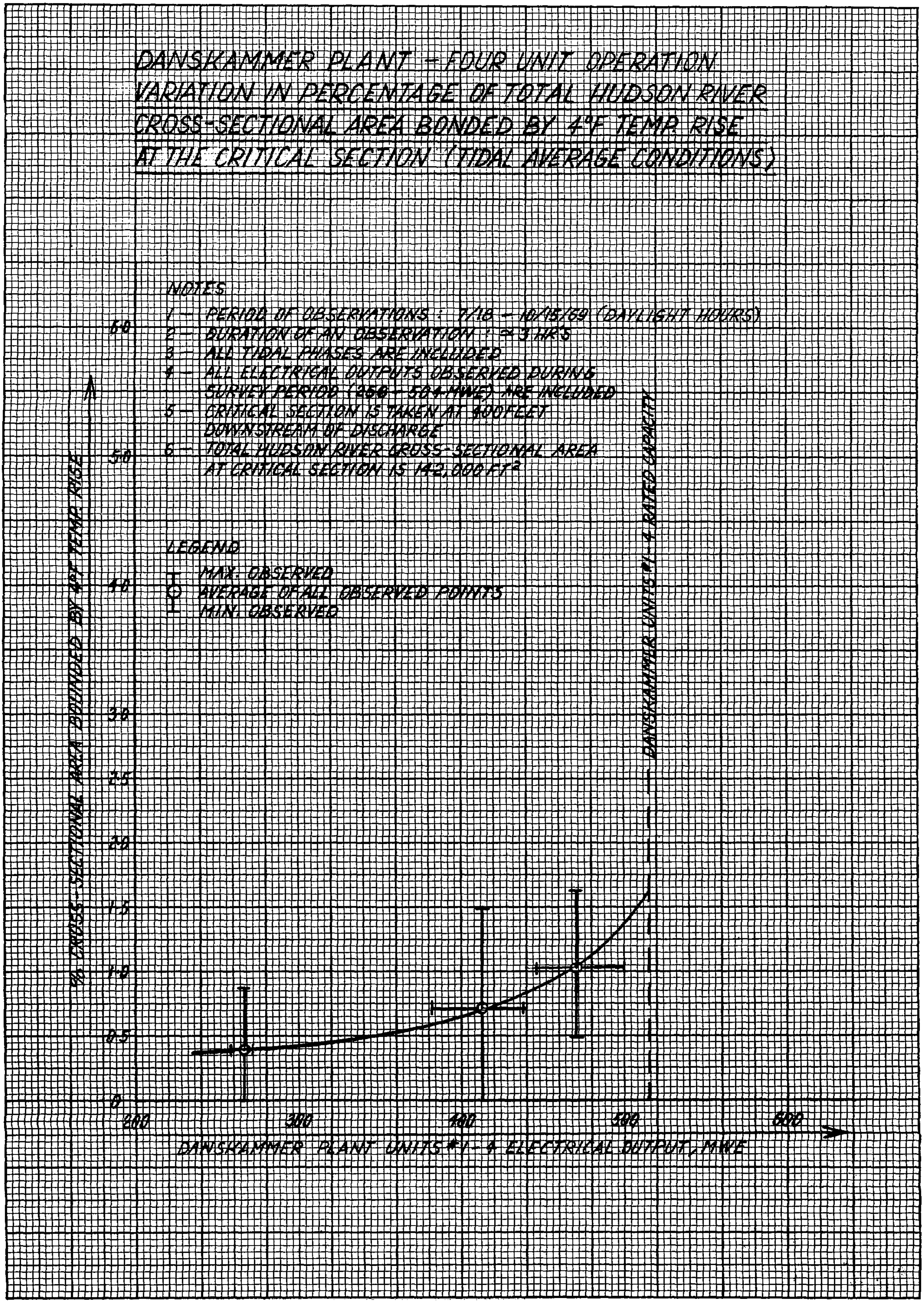


DANSKAMMER PLANT - FOUR UNIT OPERATION
VARIATION IN PERCENTAGE OF TOTAL HUDSON RIVER CROSS-SECTIONAL AREA BOUNDED BY 4°F TEMP. RISE AT THE CRITICAL SECTION

1 - PERIOD OF OBSERVATIONS : 7/18 - 10/15/69
2 - DURATION OF AN OBSERVATION : ≃ 3 HR'S
3 - ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (288 - 504 MWE) ARE INCLUDED
4 - CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
5 - TOTAL HUDSON RIVER CROSS - SECTIONAL AREA AT CRITICAL SECTION IS 142,000 FT²

FIGURE 19

DANSKAMMER PLANT - FOUR UNIT OPERATION VARIATION IN PERCENTAGE OF TOTAL HUDSON RIVER CROSS-SECTIONAL AREA BONDED BY 4°F TEMP. RISE AT THE CRITICAL SECTION (TIDAL AVERAGE CONDITIONS)



NOTES

1 — PERIOD OF OBSERVATIONS : 7/18 – 10/15/69 (DAYLIGHT HOURS)
2 — DURATION OF AN OBSERVATION : ≃ 3 HR'S
3 — ALL TIDAL PHASES ARE INCLUDED
4 — ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (250 – 504 MWE) ARE INCLUDED
5 — CRITICAL SECTION IS TAKEN AT 400 FEET DOWNSTREAM OF DISCHARGE
6 — TOTAL HUDSON RIVER CROSS-SECTIONAL AREA AT CRITICAL SECTION IS 142,000 FT²

LEGEND

MAX. OBSERVED
AVERAGE OF ALL OBSERVED POINTS
MIN. OBSERVED

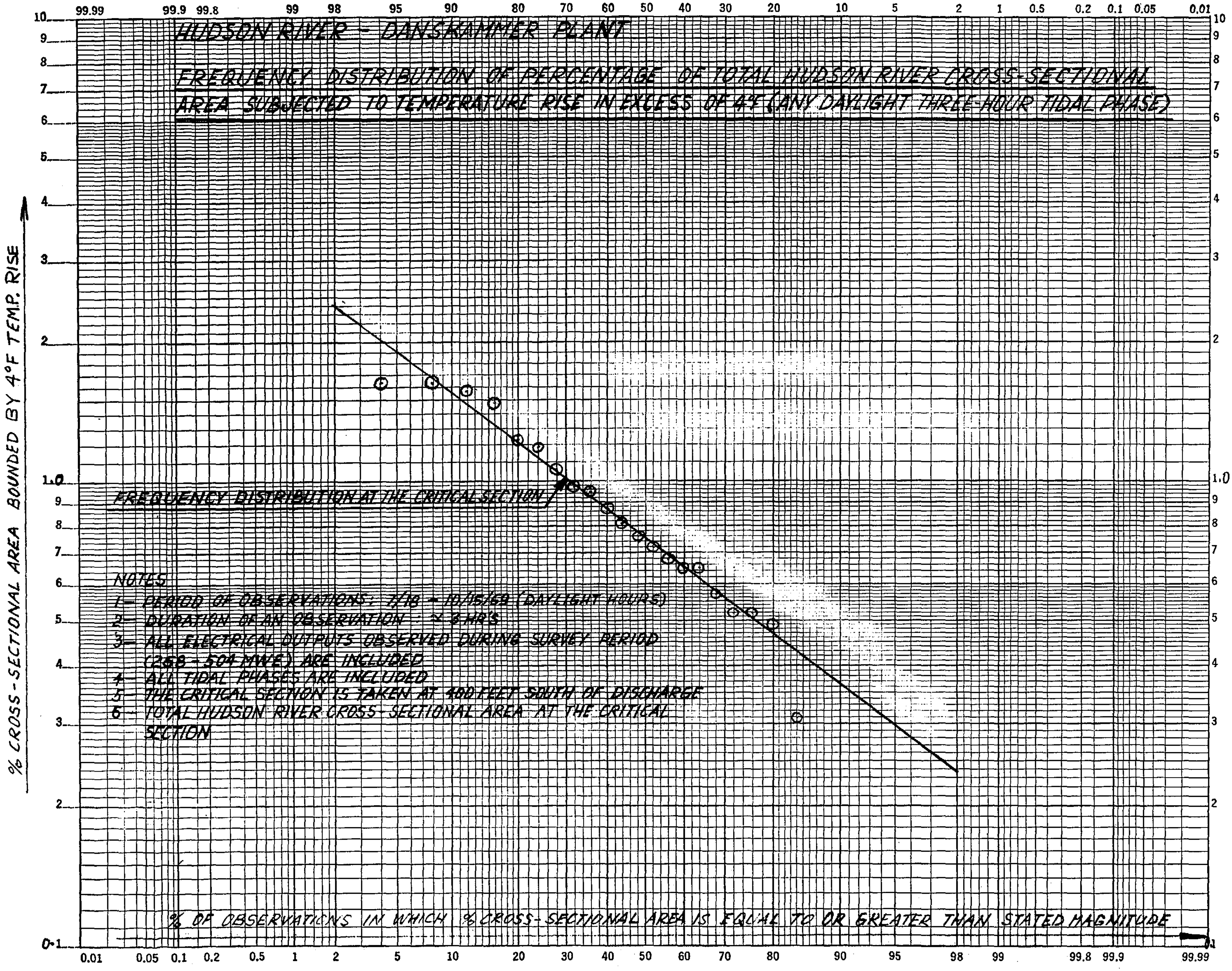
The cross-sectional area measurements were statistically analyzed in a manner similar to that used in evaluating the affected surface width presented in Item 2 above.

The results are presented in a graphical form and shown in Figures 20 through 22. Figures 20 and 21 depict the frequency distribution for the two loading-phase conditions. Variation over a period of one tidal cycle is shown in Figure 22 for a 50% probability of occurrence.

3. Hudson River Longitudinal Extent and Surface Area Subjected to Temperature Rises in Excess of 4°F

Figures 23 and 24 show the measured longitudinal extent and surface area enclosed by the 4°F isotherm, respectively. Values ranging from 900 ft. and 3 acres to 10,000 ft. and 176 acres were observed. The corresponding tidal average values are shown in Figures 25 and 26.

The frequency distribution of these two temperature parameters during any daylight three-hour tidal phase is shown in Figures 27 and 28. The probability functions for the specific tidal phases are shown in Figures 29 and 30, respectively.

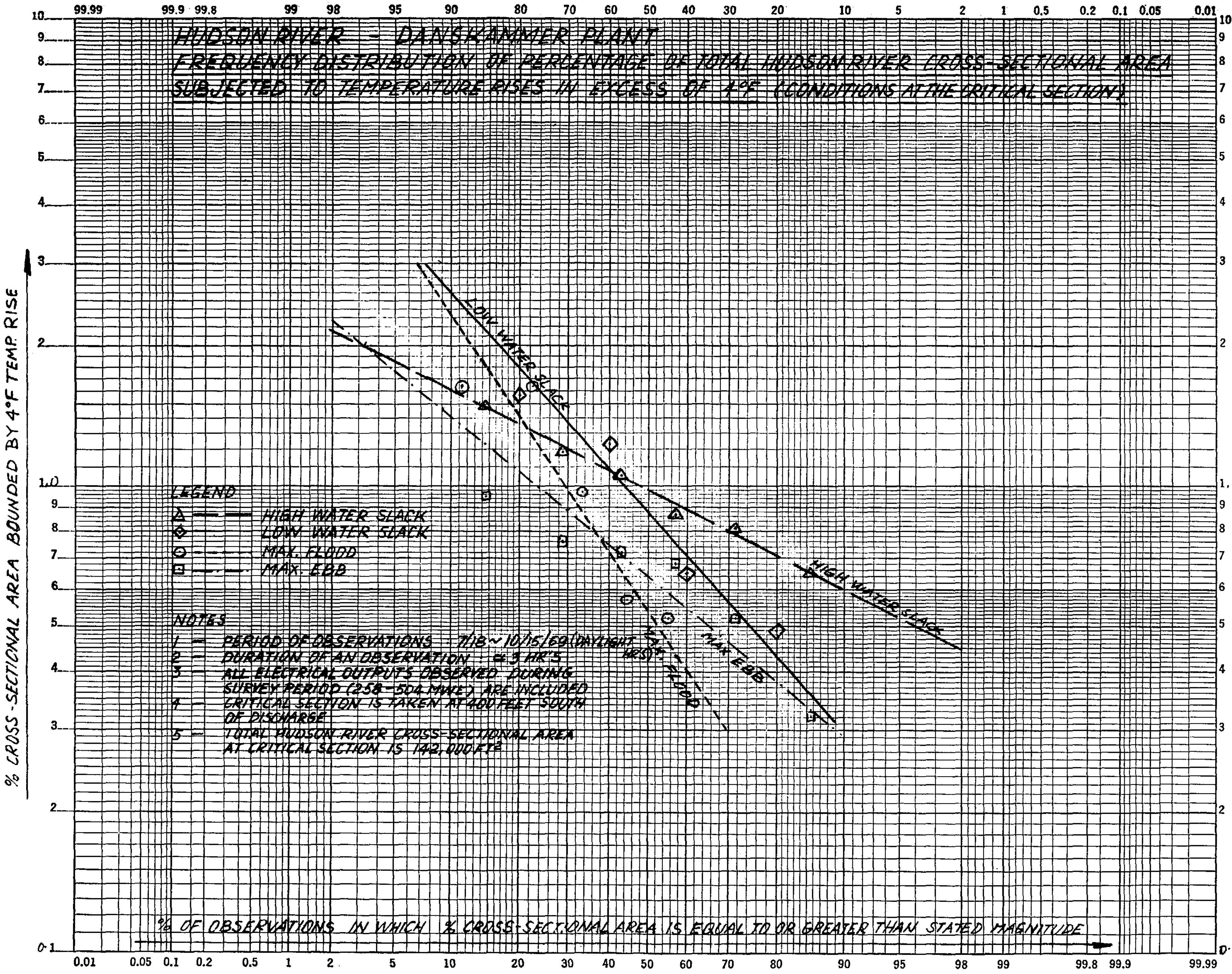


HUDSON RIVER - DANSKAMMER PLANT

FREQUENCY DISTRIBUTION OF PERCENTAGE OF TOTAL HUDSON RIVER CROSS-SECTIONAL AREA SUBJECTED TO TEMPERATURE RISE IN EXCESS OF 4°F (ANY DAYLIGHT THREE-HOUR TIDAL PHASE)

NOTES
1— PERIOD OF OBSERVATIONS: 7/18 - 10/15/69 (DAYLIGHT HOURS)
2— DURATION OF AN OBSERVATION : ≃ 3 HR'S
3— ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 - 504 MWE) ARE INCLUDED
4— ALL TIDAL PHASES ARE INCLUDED
5— THE CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
6 — TOTAL HUDSON RIVER CROSS-SECTIONAL AREA AT THE CRITICAL SECTION

FIGURE 20

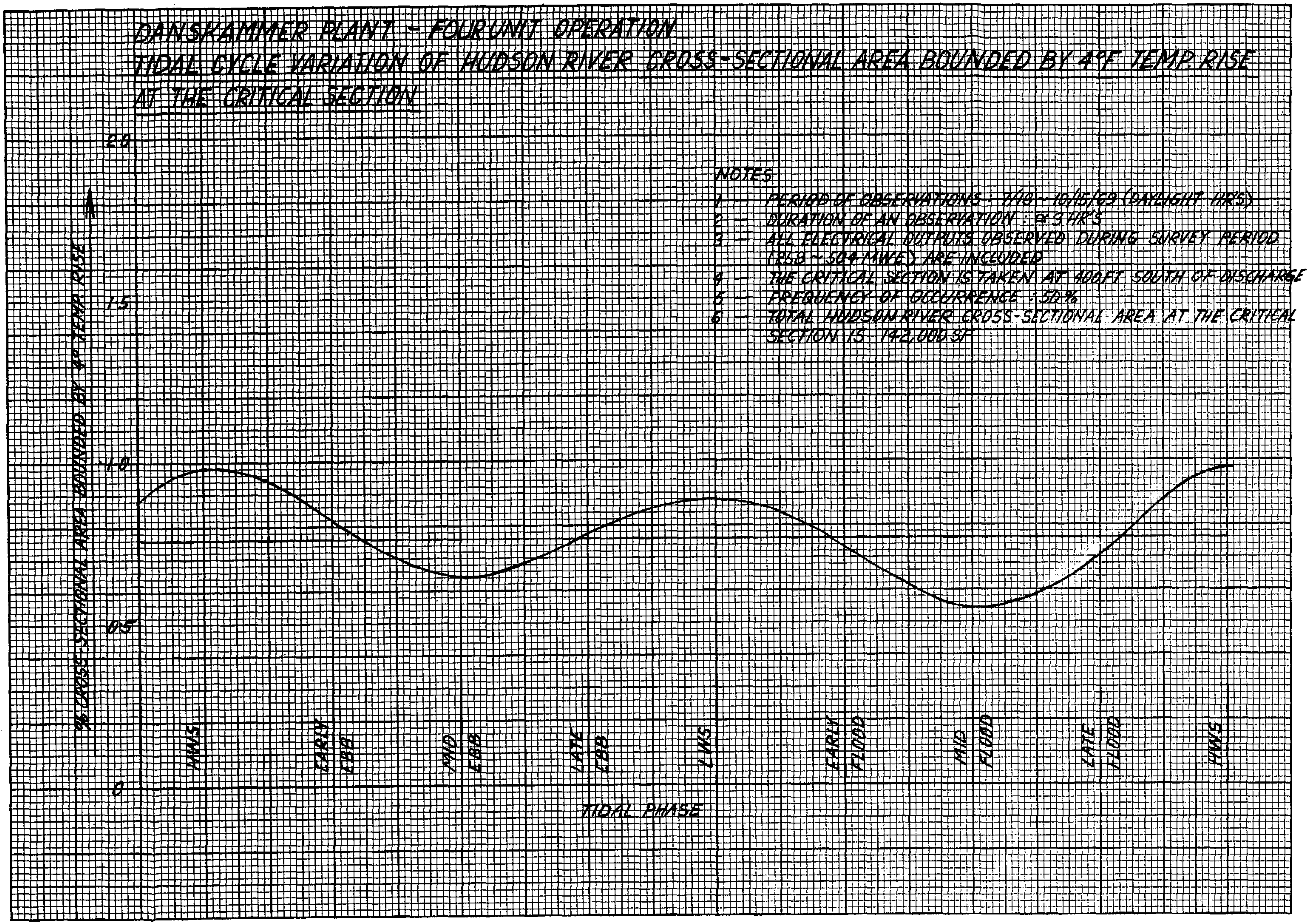


HUDSON RIVER - DANSKAMMER PLANT
FREQUENCY DISTRIBUTION OF PERCENTAGE OF TOTAL HUDSON RIVER CROSS-SECTIONAL AREA
SUBJECTED TO TEMPERATURE RISES IN EXCESS OF 4°F (CONDITIONS AT THE CRITICAL SECTION)

NOTES
1 — PERIOD OF OBSERVATIONS : 7/18 ~ 10/15/69 (DAYLIGHT HRS)
2 — DURATION OF AN OBSERVATION : ≅ 3 HR'S
3 — ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 - 504 MWE) ARE INCLUDED
4 — CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
5 — TOTAL HUDSON RIVER CROSS-SECTIONAL AREA AT CRITICAL SECTION IS 142,000 FT²

FIGURE 21

FIGURE 22

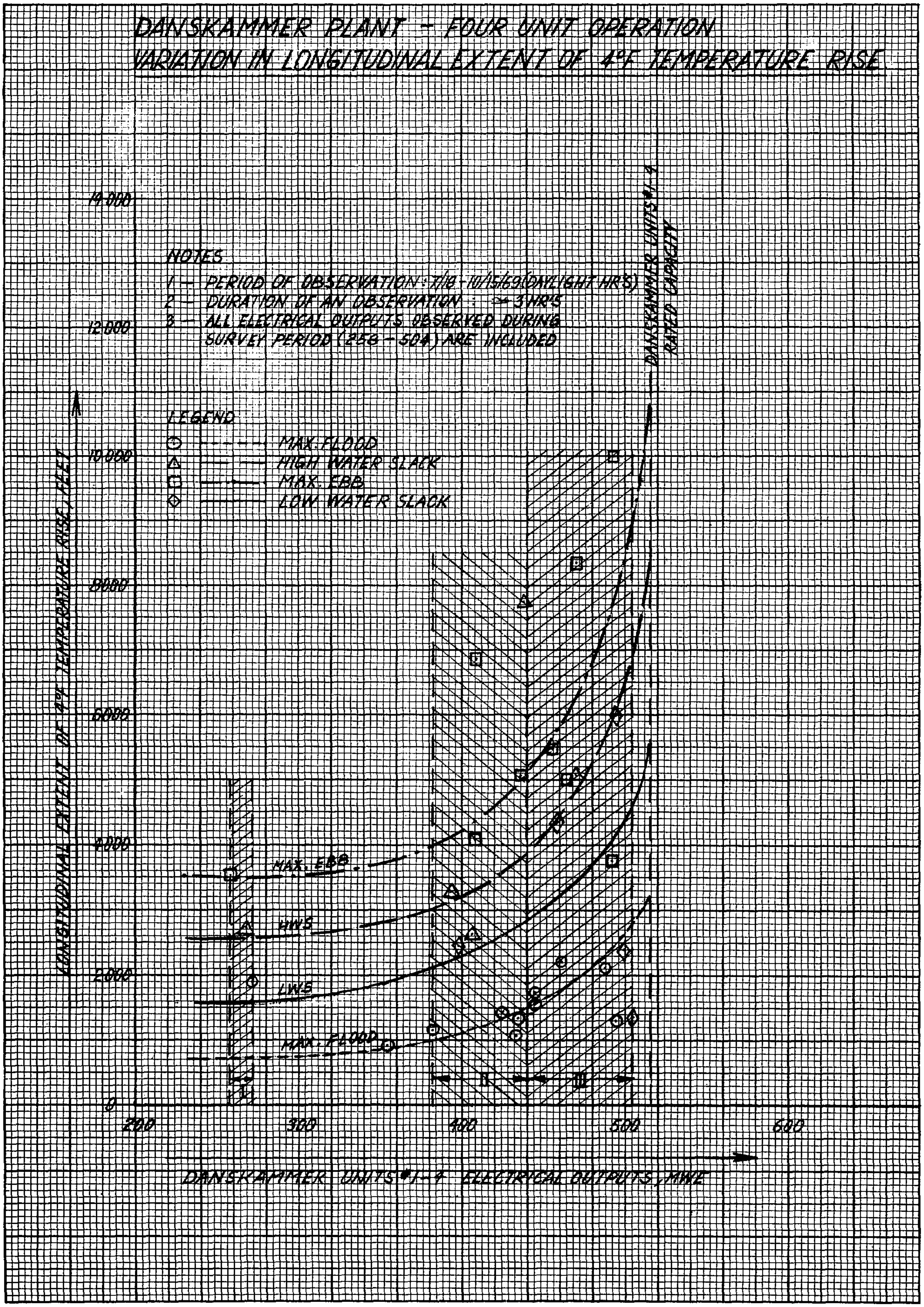


DANSKAMMER PLANT - FOURUNIT OPERATION
TIDAL CYCLE VARIATION OF HUDSON RIVER CROSS-SECTIONAL AREA BOUNDED BY 4°F TEMP. RISE
AT THE CRITICAL SECTION

NOTES

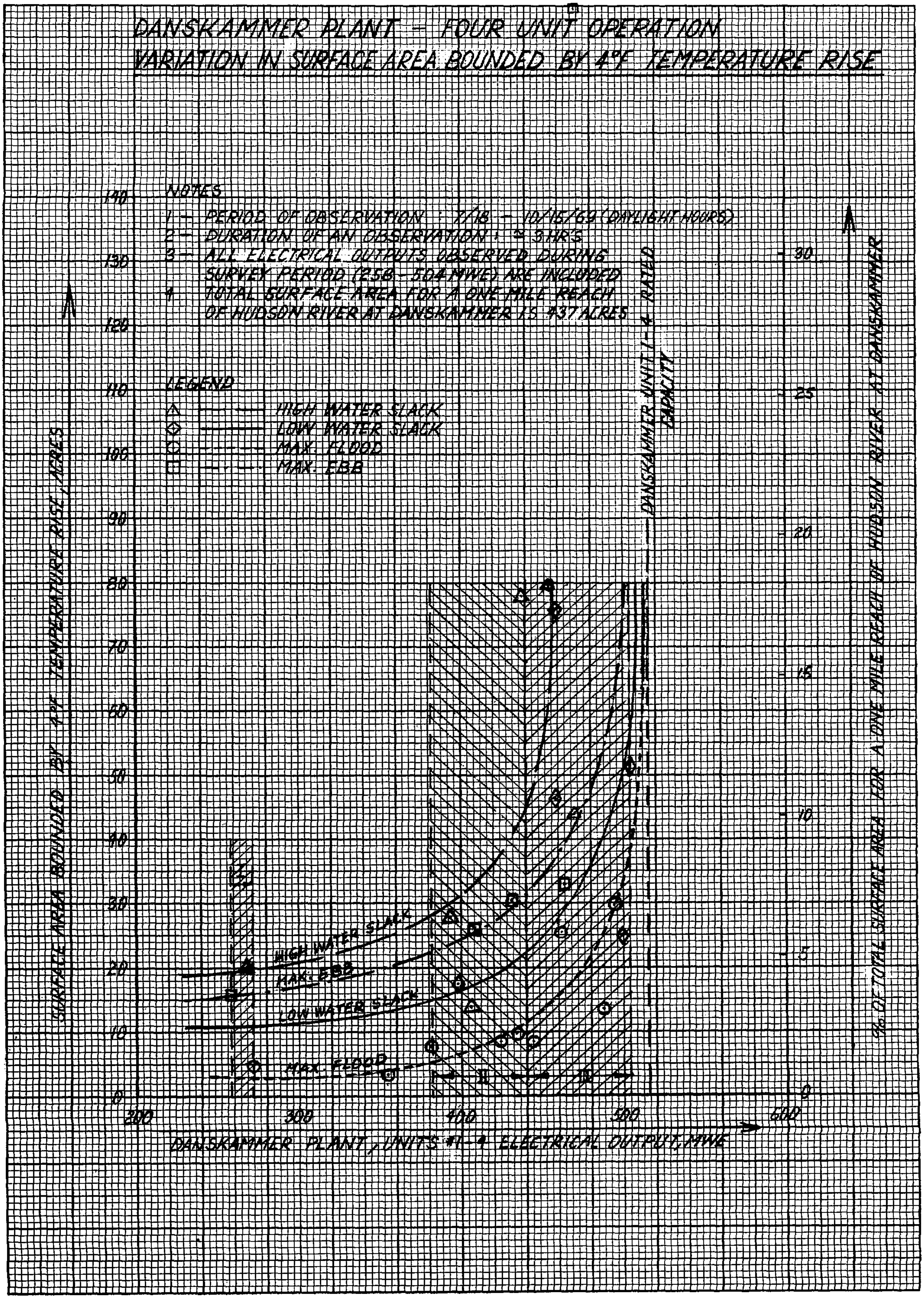
1 — PERIOD OF OBSERVATIONS : 7/10 ~ 10/15/69 (DAYLIGHT HR'S)
2 — DURATION OF AN OBSERVATION : ≅ 3 HR'S
3 — ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 ~ 504 MWE) ARE INCLUDED
4 — THE CRITICAL SECTION IS TAKEN AT 400FT SOUTH OF DISCHARGE
5 — FREQUENCY OF OCCURRENCE : 50%
6 — TOTAL HUDSON RIVER CROSS-SECTIONAL AREA AT THE CRITICAL SECTION IS 142,000 SF

FIGURE 23



DANSKAMMER PLANT – FOUR UNIT OPERATION
VARIATION IN LONGITUDINAL EXTENT OF 4°F TEMPERATURE RISE

FIGURE 24



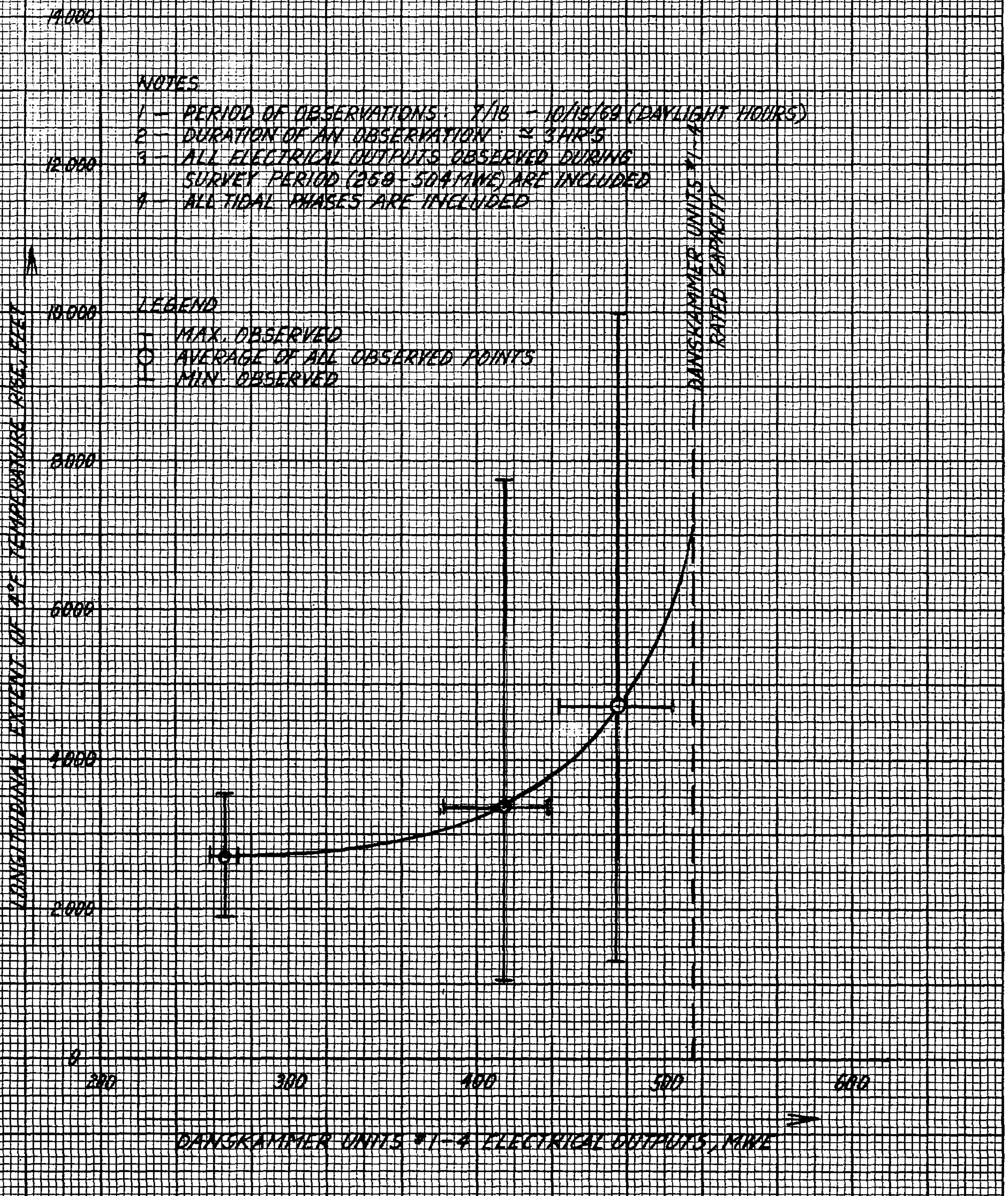
DANSKAMMER PLANT – FOUR UNIT OPERATION
VARIATION IN SURFACE AREA BOUNDED BY 4°F TEMPERATURE RISE

NOTES

1 – PERIOD OF OBSERVATION : 7/18 – 10/15/69 (DAYLIGHT HOURS)
2 – DURATION OF AN OBSERVATION : ≃ 3 HRS
3 – ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 - 504 MWE) ARE INCLUDED
4 TOTAL SURFACE AREA FOR A ONE MILE REACH OF HUDSON RIVER AT DANSKAMMER IS 437 ACRES

FIGURE 25

DANSKAMMER PLANT - FOUR UNITS OPERATION
VARIATION IN LONGITUDINAL EXTENT OF 4°F TEMPERATURE RISE (TIDAL AVERAGE CONDITIONS)

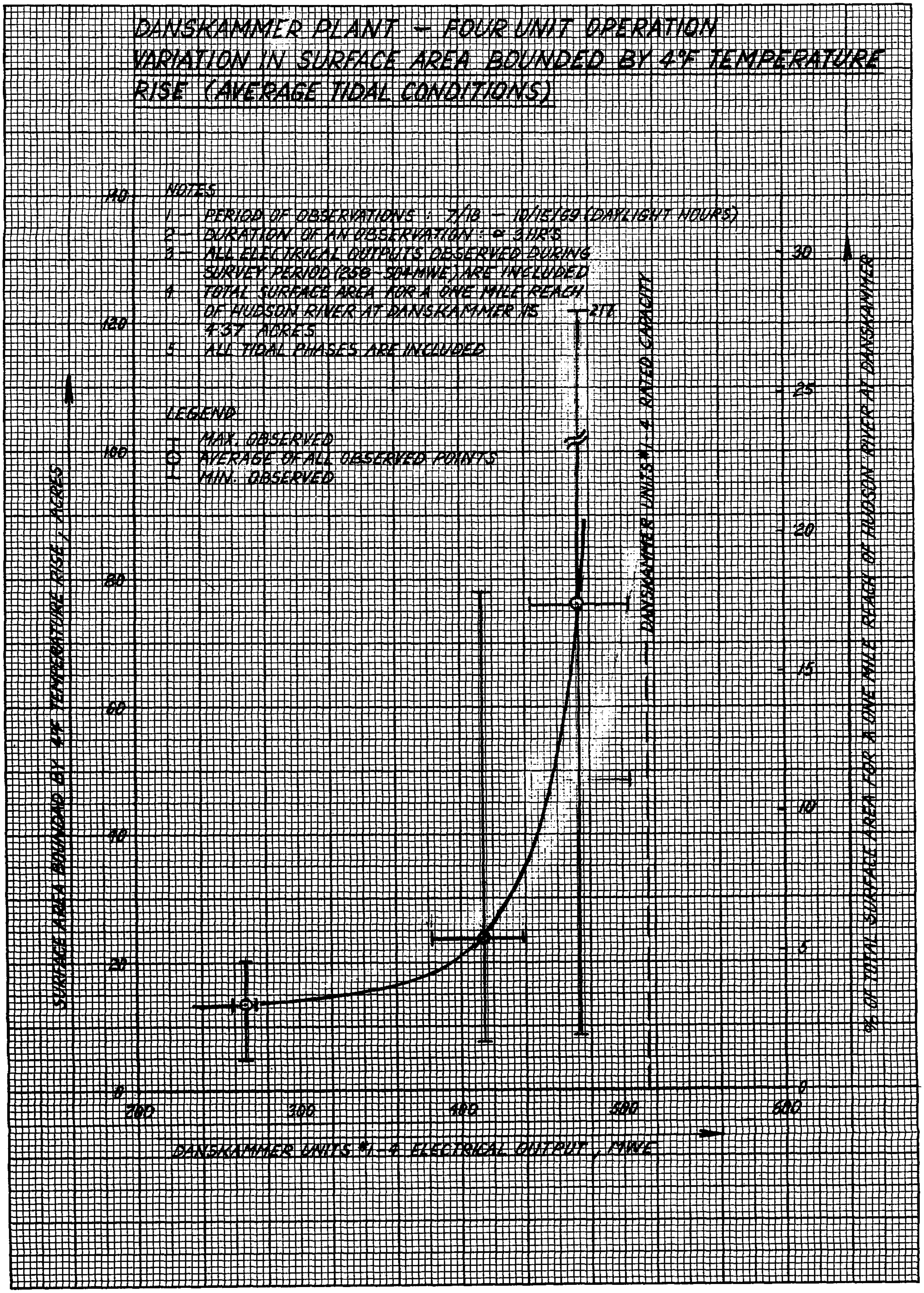


NOTES

1 — PERIOD OF OBSERVATIONS: 7/18 - 10/15/69 (DAYLIGHT HOURS)
2 — DURATION OF AN OBSERVATION: ≃ 3 HR'S
3 — ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (269-504 MWE) ARE INCLUDED
4 — ALL TIDAL PHASES ARE INCLUDED

LEGEND

FIGURE 26



DANSKAMMER PLANT — FOUR UNIT OPERATION
VARIATION IN SURFACE AREA BOUNDED BY 4°F TEMPERATURE RISE (AVERAGE TIDAL CONDITIONS)

NOTES
1 — PERIOD OF OBSERVATIONS : 7/18 — 10/15/69 (DAYLIGHT HOURS)
2 — DURATION OF AN OBSERVATION : ≈ 3 HRS
3 — ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 - 504 MWE) ARE INCLUDED
4 TOTAL SURFACE AREA FOR A ONE MILE REACH OF HUDSON RIVER AT DANSKAMMER IS 437 ACRES
5 ALL TIDAL PHASES ARE INCLUDED

LEGEND
MAX. OBSERVED
AVERAGE OF ALL OBSERVED POINTS
MIN. OBSERVED

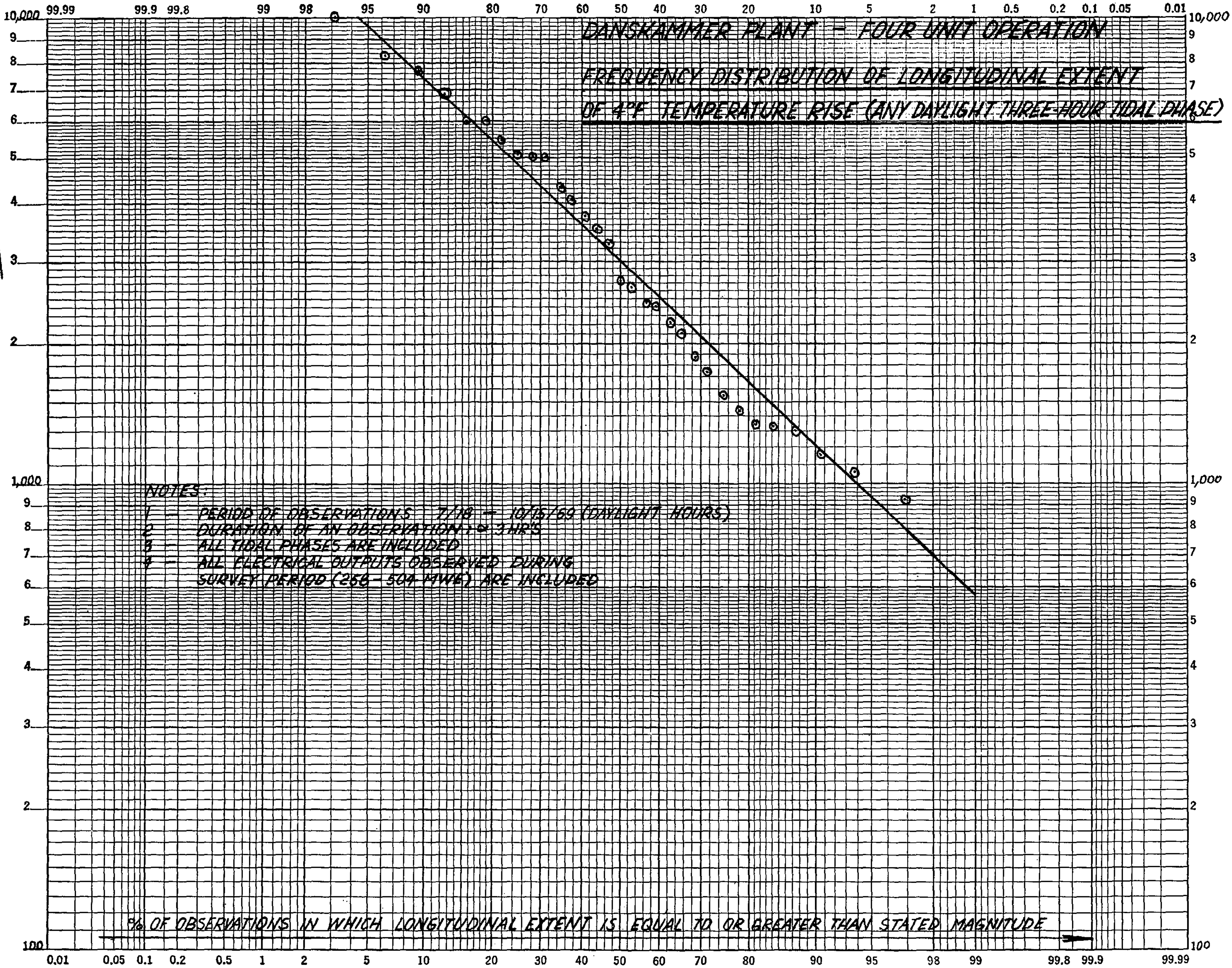


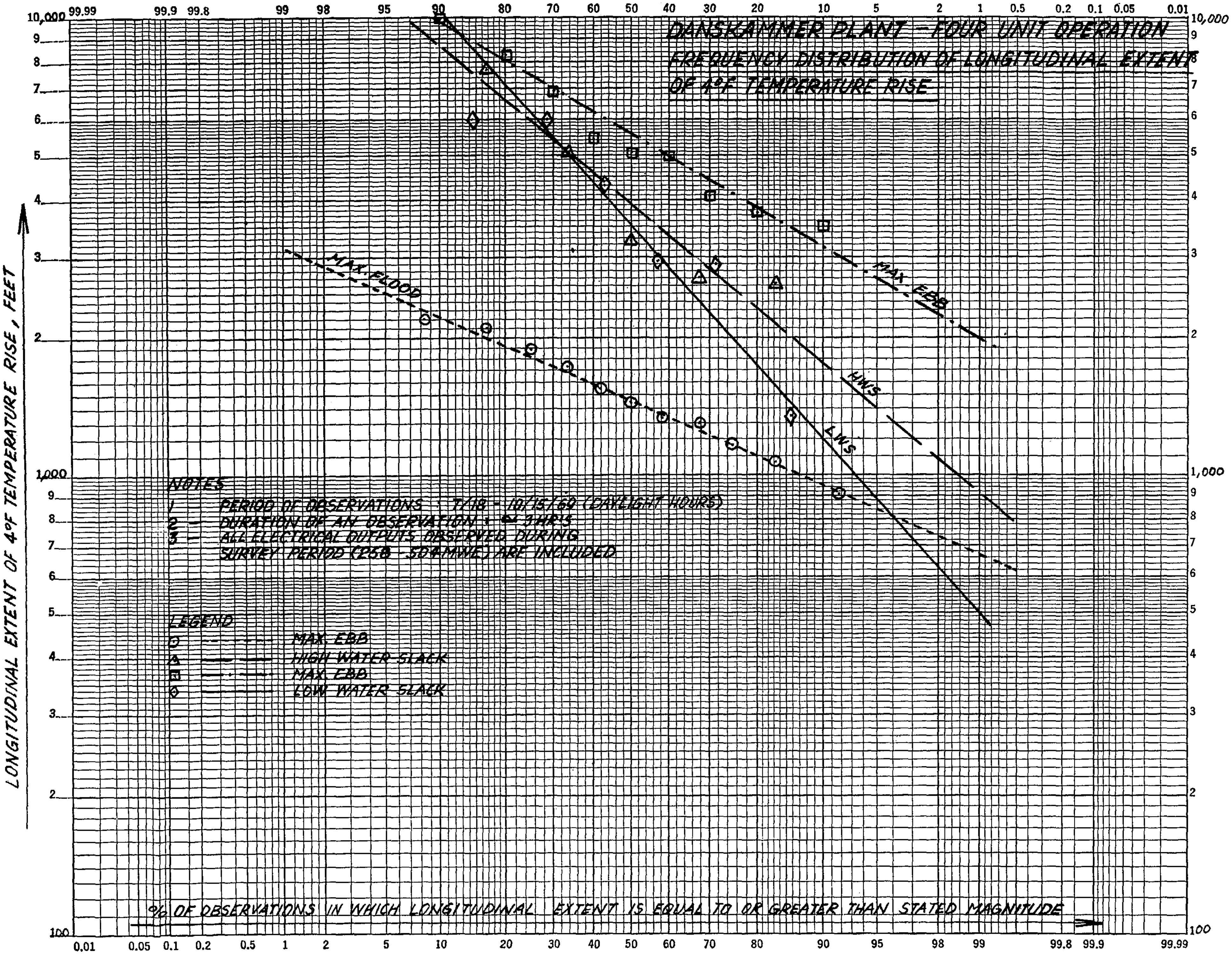
FIGURE 27

DANSKAMMER PLANT — FOUR UNIT OPERATION

FREQUENCY DISTRIBUTION OF LONGITUDINAL EXTENT OF 4°F TEMPERATURE RISE (ANY DAYLIGHT THREE-HOUR TIDAL PHASE)

NOTES:

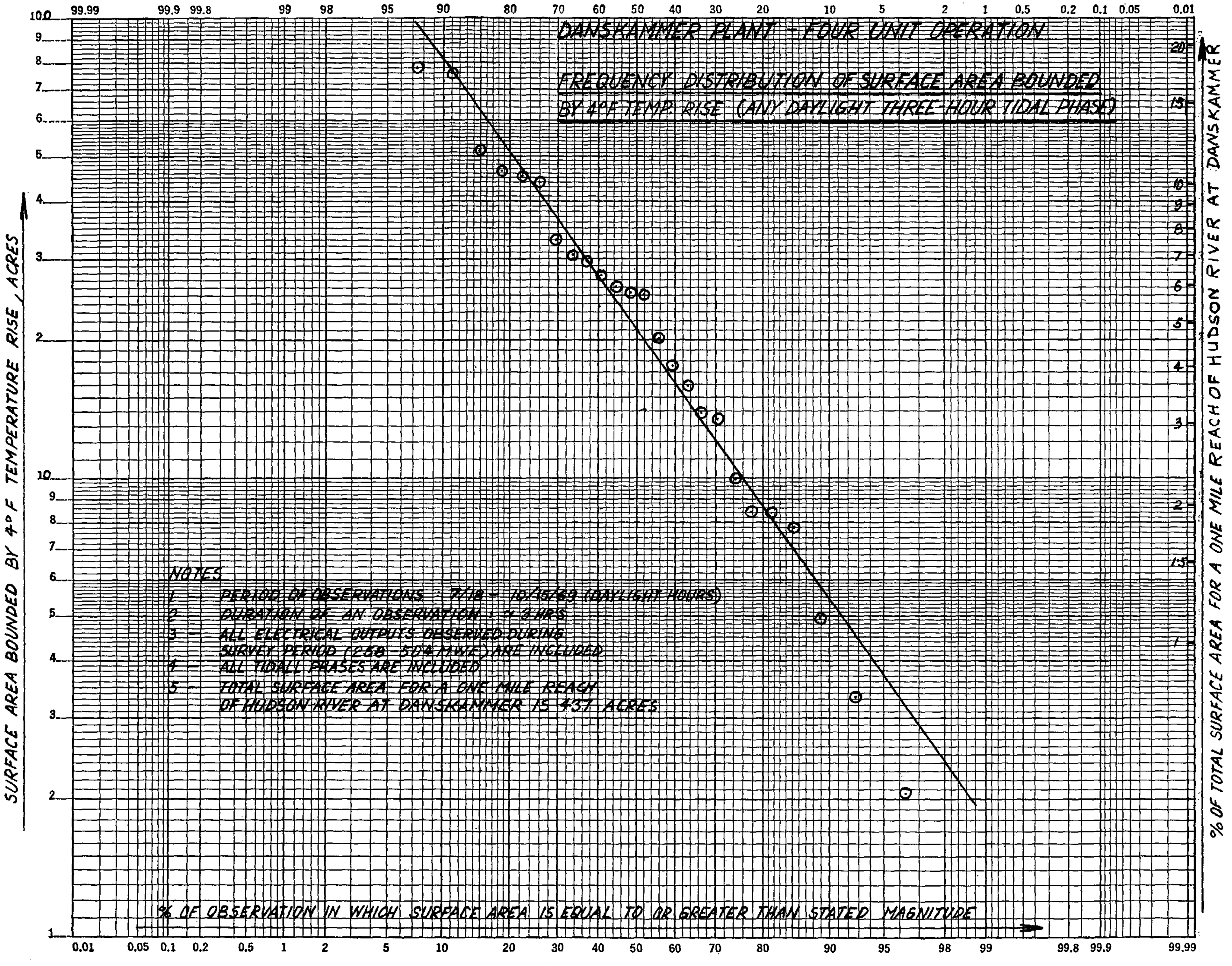
1 — PERIOD OF OBSERVATIONS 7/18 — 10/15/69 (DAYLIGHT HOURS)
2 — DURATION OF AN OBSERVATION: ≈ 3 HR'S
3 — ALL TIDAL PHASES ARE INCLUDED
4 — ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 - 504 MWE) ARE INCLUDED



DANSKAMMER PLANT – FOUR UNIT OPERATION
FREQUENCY DISTRIBUTION OF LONGITUDINAL EXTENT OF 4°F TEMPERATURE RISE

NOTES
1 — PERIOD OF OBSERVATIONS : 7/18 - 10/15/69 (DAYLIGHT HOURS)
2 — DURATION OF AN OBSERVATION : ≃ 3 HR'S
3 — ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 - 504 MWE) ARE INCLUDED

FIGURE 28

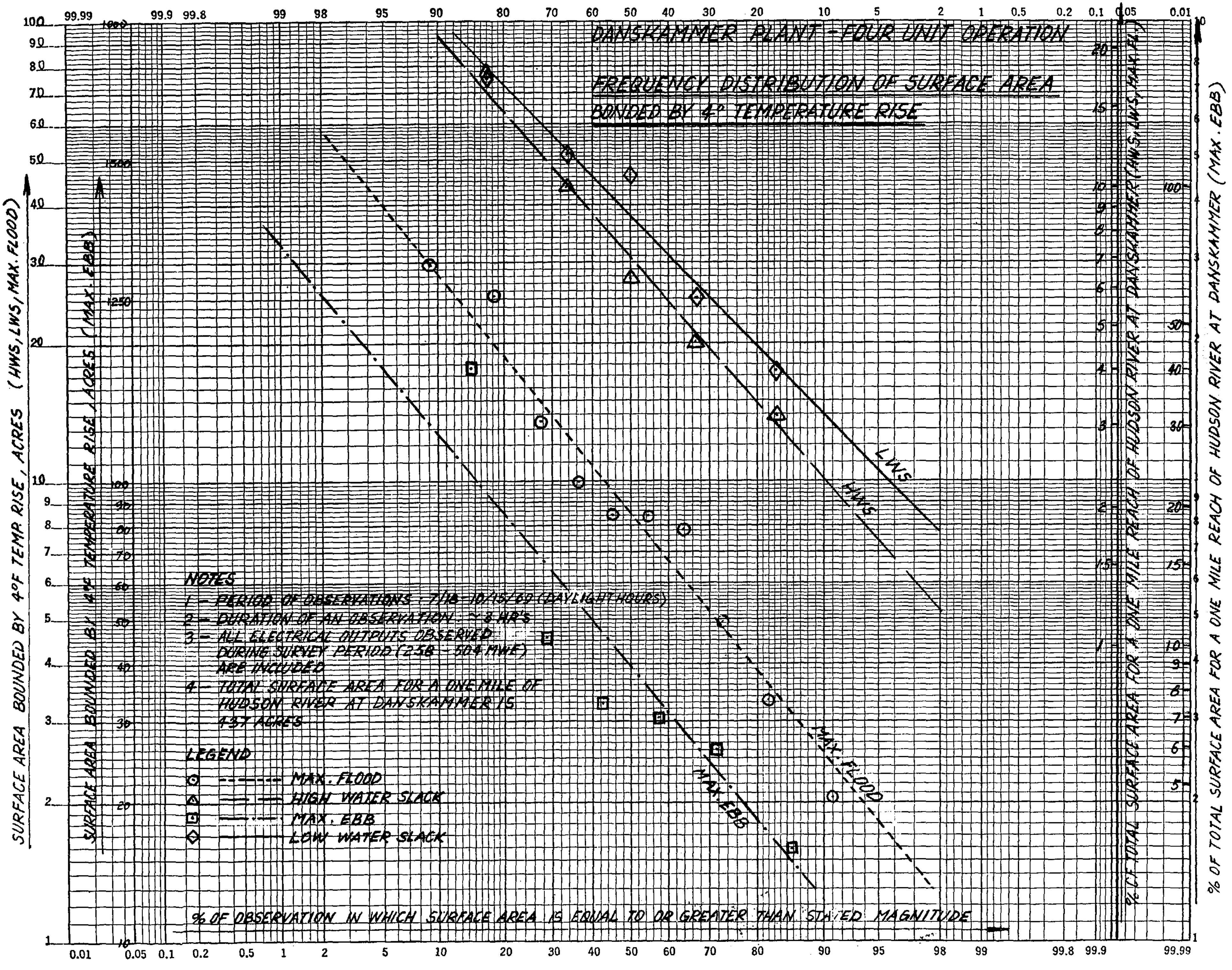


DANSKAMMER PLANT - FOUR UNIT OPERATION

FREQUENCY DISTRIBUTION OF SURFACE AREA BOUNDED BY 4°F TEMP. RISE (ANY DAYLIGHT THREE HOUR TIDAL PHASE)

NOTES
1 — PERIOD OF OBSERVATIONS : 7/18 - 10/15/69 (DAYLIGHT HOURS)
2 — DURATION OF AN OBSERVATION : ≈ 3 HRS
3 — ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 - 504 MWE) ARE INCLUDED
4 — ALL TIDALL PHASES ARE INCLUDED
5 — TOTAL SURFACE AREA FOR A ONE MILE REACH OF HUDSON RIVER AT DANSKAMMER IS 437 ACRES

FIGURE 29



DANSKAMMER PLANT - FOUR UNIT OPERATION

FREQUENCY DISTRIBUTION OF SURFACE AREA BONDED BY 4° TEMPERATURE RISE

NOTES

1 - PERIOD OF OBSERVATIONS - 7/18 - 10/15/69 (DAYLIGHT HOURS)

2 - DURATION OF AN OBSERVATION - ~ 3 HR'S

3 - ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 - 504 MWE) ARE INCLUDED

4 - TOTAL SURFACE AREA FOR A ONE MILE OF HUDSON RIVER AT DANSKAMMER IS 437 ACRES

LEGEND

⊙ - - - - - MAX. FLOOD

△ — — — HIGH WATER SLACK

⊡ — · — · MAX. EBB

◇ ———— LOW WATER SLACK

FIGURE 30

4. Summary of the Statistical Analysis of Danskammer Plant Temperature Measurements

The results of the frequency distribution of all four temperature parameters for the two loading-phase conditions for 10%, 50% and 90% probabilities of occurrence are summarized in Table 3.

The specific tidal phase values shown in the table correspond to that phase of the four tidal phases which exhibited the most severe effect.

Table 4 compares the ten percent probability of occurrence values to the range of observed effect as well as the maximum allowable values set by the New York State Water Resources Commission criteria for thermal discharges.

Notice that, except for the surface area parameter, the 10% probability of occurrence of specific tidal phase values are higher than the maximum observed values. The 10% probability value is considered to represent a rather remote happenstance.

Observations show clearly that the margin of compliance with the maximum limitations imposed by the Thermal Discharge Criteria is very great.

TABLE 3

STATISTICAL ANALYSIS OF DANSKAMMER PLANT TEMPERATURE EFFECT EXPRESSED IN TERMS OF PORTION OF RIVER AT DANSKAMMER AFFECTED BY TEMPERATURE RISES IN EXCESS OF 4°F (ALL OBSERVED HEAT LOADS)

	PROBABILITY OF OCCURRENCE					
	10%		50%		90%	
Temperature Parameter	Any 3 Hr. Tidal Phase	Critical Specific Tidal Phase	Any 3 Hr. Tidal Phase	Critical Specific Tidal Phase	Any 3 Hr Tidal Phase	Critical Specific Tidal Phase
Surface Width (%)	19.5	26.3	10.5	13.5	6.8	9
Cross-Sectional Area (%)	1.55	2.6	0.75	0.98	0.36	0.6
Longitudinal Extent (Ft)	7400	11,000	3000	5500	1200	3200
Surface Area (Acres)	80	130	21	40	5.5	12
Surface Area (%)	18	30	5	9	1.3	3

TABLE 4

DANSKAMMER PLANT, FOUR UNIT OPERATION

PORTION OF HUDSON RIVER AT DANSKAMMER EFFECTED BY TEMPERATURE RISES IN EXCESS OF 4°F

Temperature Parameter[1]	OBSERVED RANGE[2] Minimum	Maximum	10% PROBABILITY OF OCCURRENCE[3] Any 3 Hr.[5] Tidal Phase	Critical[6] Specific Tidal Phase	Maximum[4] Allowable
Surface Width (%)[7]	0	26.3	19.5	26.3	67
Cross-Sectional Area (%)[8]	0	1.63	1.55	2.6	50
Longitudinal Extent (Ft)	900	10,000	7400	11,000	
Surface Area (Acres)	3	176	80	130	
Surface Area (%)[9]	.68	40	18	30	

---

1. The critical section is taken at 400 ft. south of the discharge.
2. Period of observations = 7/18 - 10/15/69 (daylight hours). Duration of an observation = 3 hours.
3. The 10% probability of occurrence is for the three-hour period corresponding to the loading phase condition in question.
4. New York State Water Resources Commission Criteria for Thermal Discharges.
5. Probability of occurrence of this loading-phase condition is one out of two times.
6. Probability of occurrence of this loading-phase condition is one out of five times.
7. Total surface width at the critical section = 3420 ft.
8. Total cross-sectional area at the critical section = 142,000 sq.ft.
9. Total surface area for a one mile reach of river one-half mile upstream to one-half mile downstream of the discharge = 437 acres.

C. Other Environmental Measurements at Danskammer

These measurements were done in conjunction with the ecological surveys. They included physical and chemical water analysis as well as observation of prevailing meteorological conditions.

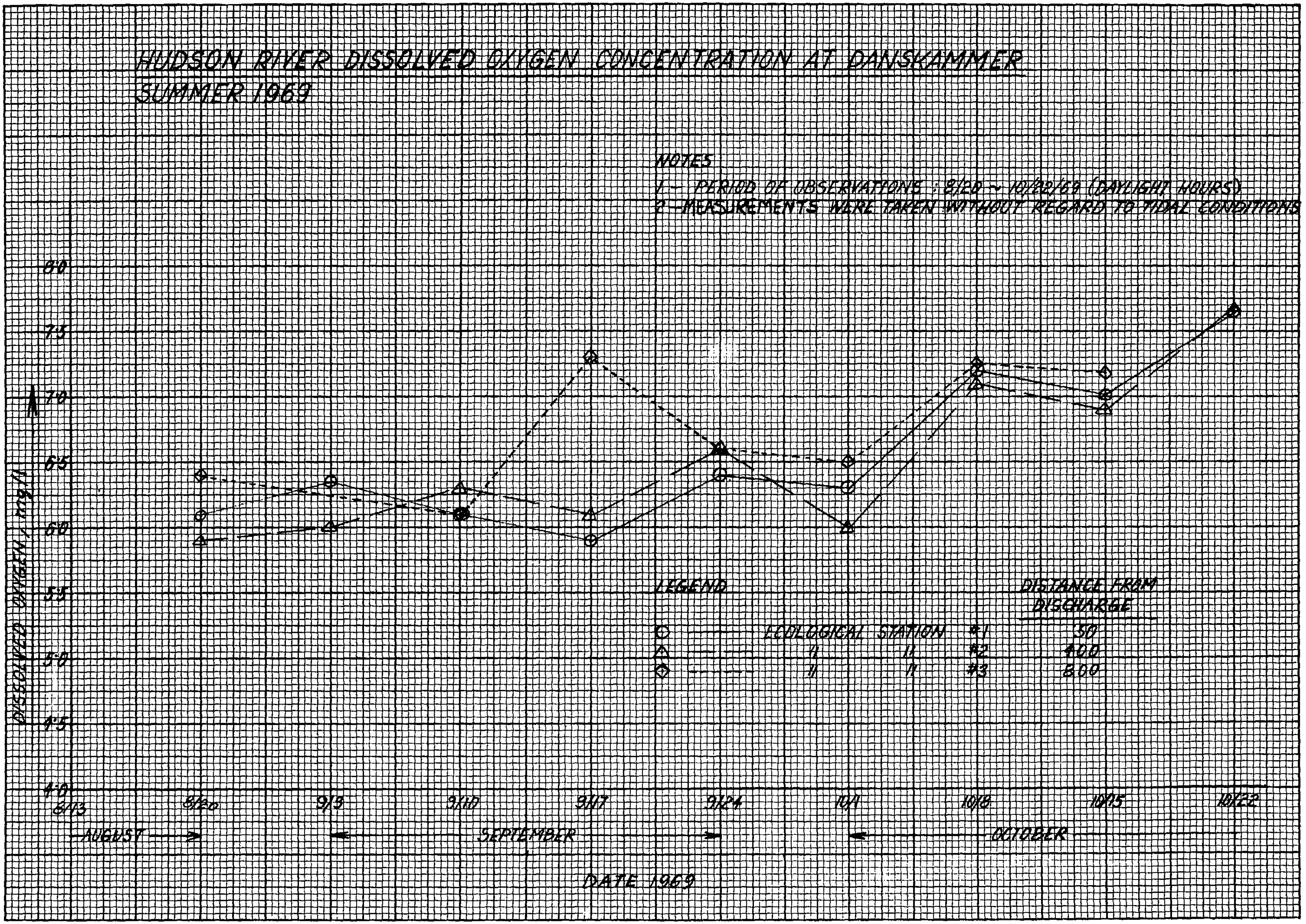
A minimum of six salinity and dissolved oxygen samples were collected at the seining stations during each ecological run. Tests and analytical determinations were made in accordance with "Standard Methods for the Examination of Water and Wastewater", 12th Edition.

Figures 31 and 32 show the dissolved oxygen and salinity measurements at the three seining stations during the ecological survey period. Figure 31 indicates that there was no consistent correlation between the dissolved oxygen measurements and their relative distance from the cooling water discharge.

Particular note should be taken of the minimum single value of dissolved oxygen of 5.9 ppm and the 25 sample DO average of 6.5 ppm, indicative of reasonably good water.

Figure 32 shows that, except for relatively few measurements, the

FIGURE 31



HUDSON RIVER DISSOLVED OXYGEN CONCENTRATION AT DANSKAMMER

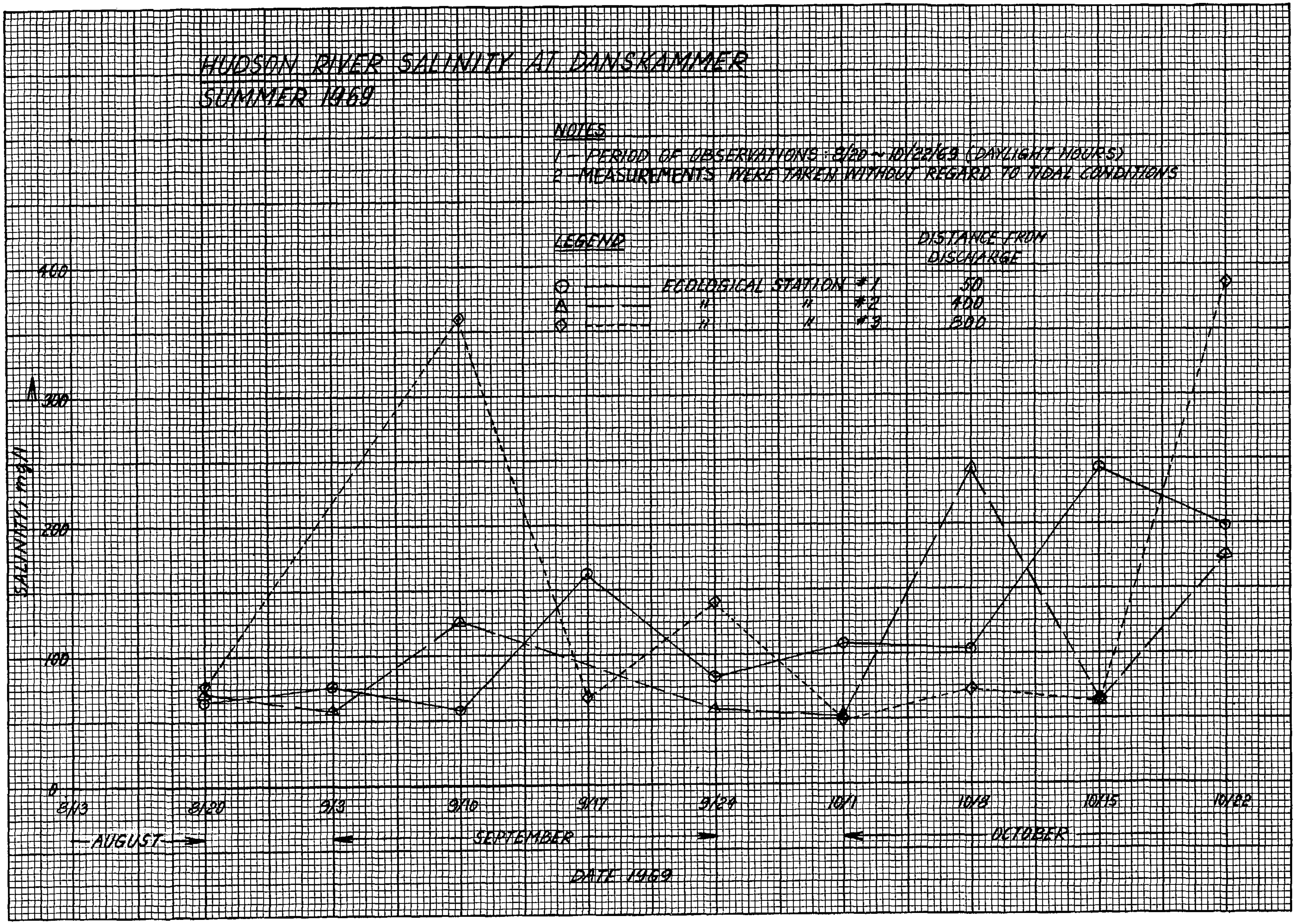
SUMMER 1969

NOTES

1 – PERIOD OF OBSERVATIONS : 8/20 ~ 10/22/69 (DAYLIGHT HOURS)

2 – MEASUREMENTS WERE TAKEN WITHOUT REGARD TO TIDAL CONDITIONS

FIGURE 32


HUDSON RIVER SALINITY AT DANSKAMMER
SUMMER 1969

NOTES
1 – PERIOD OF OBSERVATIONS: 8/20 ~ 10/22/69 (DAYLIGHT HOURS)
2 – MEASUREMENTS WERE TAKEN WITHOUT REGARD TO TIDAL CONDITIONS

salinity was essentially the same at all stations. Values ranging from 50 ppm to 380 ppm with an average slightly higher than 100 ppm were observed. These measurements indicate the absence of a significant ocean-derived salt concentration in the area during the survey period.

The average salinity and dissolved oxygen in the cove south of Danskammer discharge, as well as the observed river ambient temperature and Hudson River fresh water flow at Green Island, are shown in Figure 33.

The ambient temperature of the Hudson at Lovett ranged from 63°F in late October to 77.5°F in mid-August.

Figure 34 summarizes the surface weather conditions that prevailed during the survey period. More detailed meteorological data are given on all of the isothermal maps in Appendix B.

The wind speed and direction are probably the major two meteorological parameters that affect the river temperature distribution. The unusual behavior of some of the measured isotherms may be explained by these two parameters. The wind direction is shown on all of the temperature maps in Appendix B.

LARGE
DOCUMENT

LARGE DOCUMENT

The meteorological data were obtained from Stewart Air Force Base in Newburgh, some three miles south of Danskammer. These measurements agreed very well with the meteorological field observations in the vicinity of Danskammer.

Table 5 summarizes all of the engineering measurements during the survey period.

TABLE 5

SUMMARY OF ENGINEERING MEASUREMENTS AT DANSKAMMER

SUMMER 1969

Parameter	Units	OBSERVED VALUES		Average
		Minimum	Maximum	
Salinity	ppm	50	387	120
Dissolved Oxygen	ppm	5.9	7.68	6.5
Ambient Water Temperature	^oF	63.0	77.3	73.5
Fresh Water Flow	cfs	2700	11,000	7000
Air Temperature	^oF	56.5	86	75.5
Dew Point	^oF	45	72	57
Barometric Pressure	in Hg.	29.22	29.65	29.48

III. PREDICTION OF THE EFFECT OF ROSETON PLANT COOLING WATER DISCHARGE ON HUDSON RIVER TEMPERATURE DISTRIBUTION

The purpose of this chapter is to predict the effect of the Roseton plant on Hudson River temperature distribution and to compare the expected resultant distribution against the Thermal Criteria of the New York State Water Resources Commission.

Tidal average results of Danskammer measurements are given first, followed by presentation of an analytical model describing temperature distribution from a heated effluent. Evaluation of applicability of the model in light of these measurements is then given. The Danskammer measurements are then combined with the model predictions for Roseton discharge to delineate expected temperature effects at Roseton.

A. Tidal Average Results of Danskammer Measurements

Field measurements of Hudson River temperatures in the vicinity of the Danskammer plant were presented and analyzed in the previous chapter. Temperature rise isotherms across the section at Danskammer were constructed for four tidal phases. Three electrical output groupings as well as an overall average electrical output during the survey period were considered.

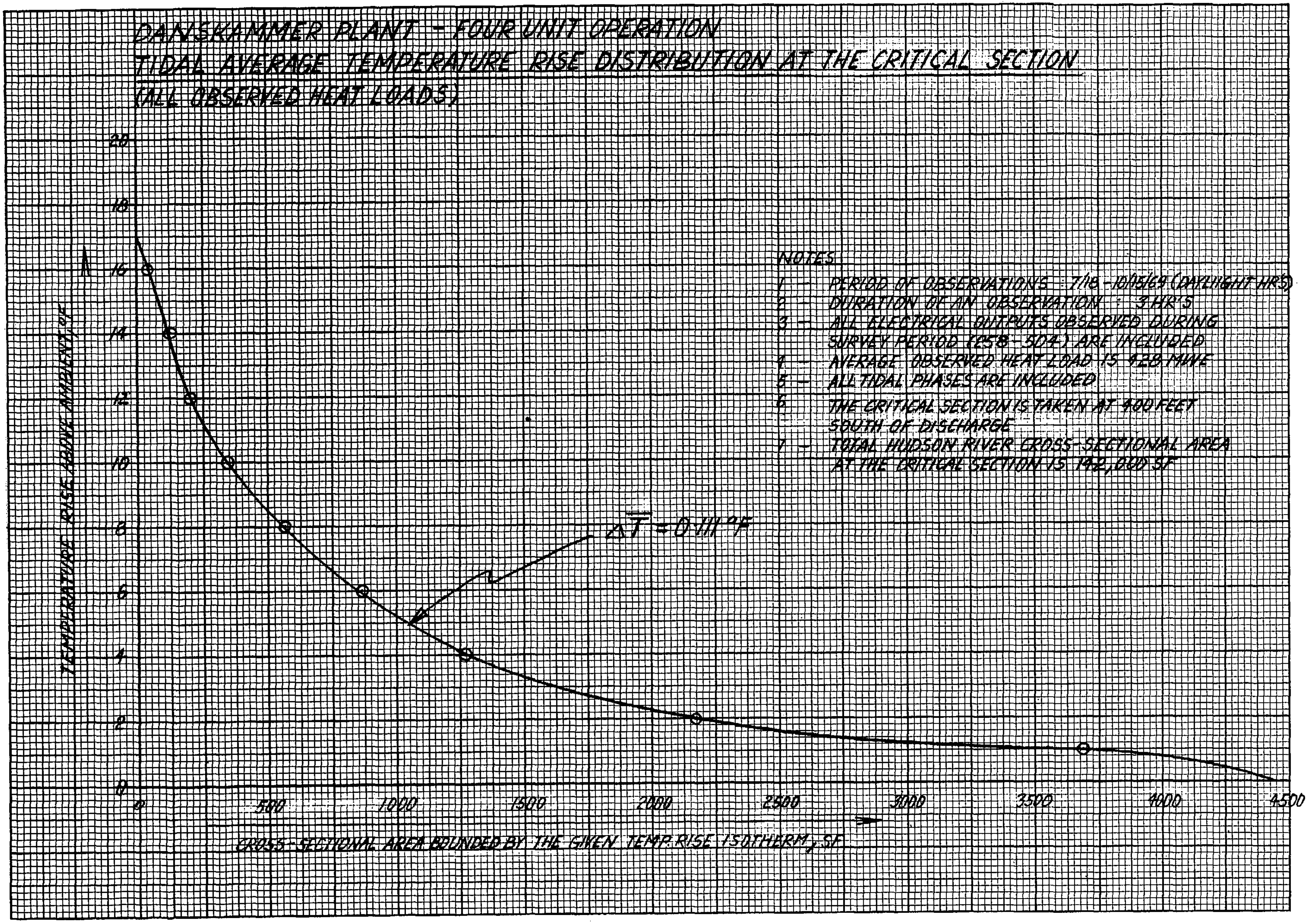
The tidal cycle averages of these measurements are presented in this chapter. These values are necessary for the purpose of determining the overall effect on the river and the applicability of the mathematical model used for Roseton prediction.

The plots of the tidal average temperature rise isotherms at the Danskammer section versus cross-sectional area enclosed by each isotherm are shown in Figures 35 through 38. Figure 35 depicts the variation corresponding to all heat loads that existed during the survey period. These loads ranged from 258 to 504 MWE with an overall average of 428 MWE.

The tidal average temperatures corresponding to the three individual heat load groups are given in Figures 36 through 38.

The average temperatures over the entire cross-section are also shown on these figures. This parameter was obtained by computing the area under the curve in these figures and dividing this result by the total cross-sectional area at Danskammer of 142,000 sq.ft.

FIGURE 35

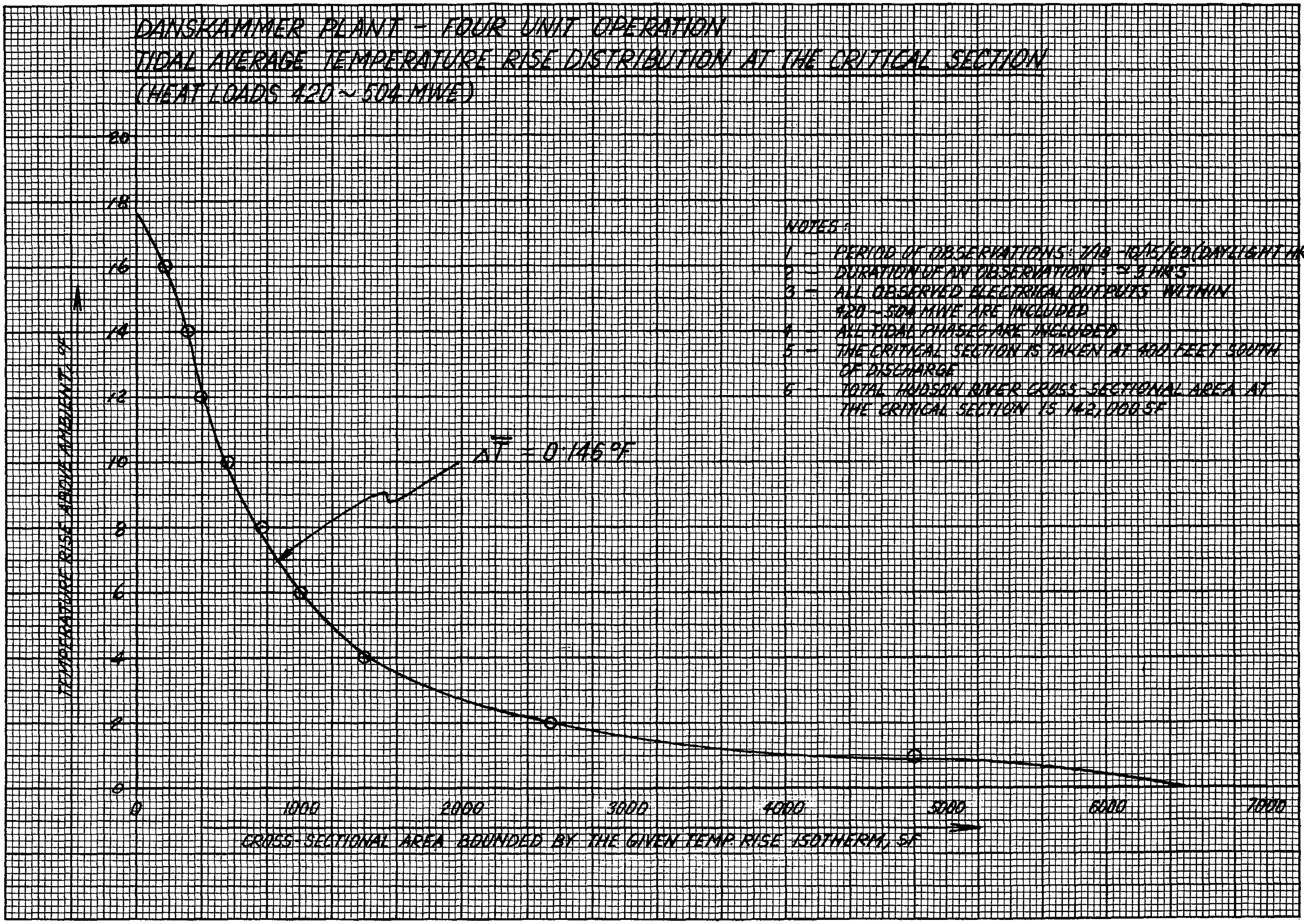


DANSKAMMER PLANT - FOUR UNIT OPERATION
TIDAL AVERAGE TEMPERATURE RISE DISTRIBUTION AT THE CRITICAL SECTION
(ALL OBSERVED HEAT LOADS)

NOTES

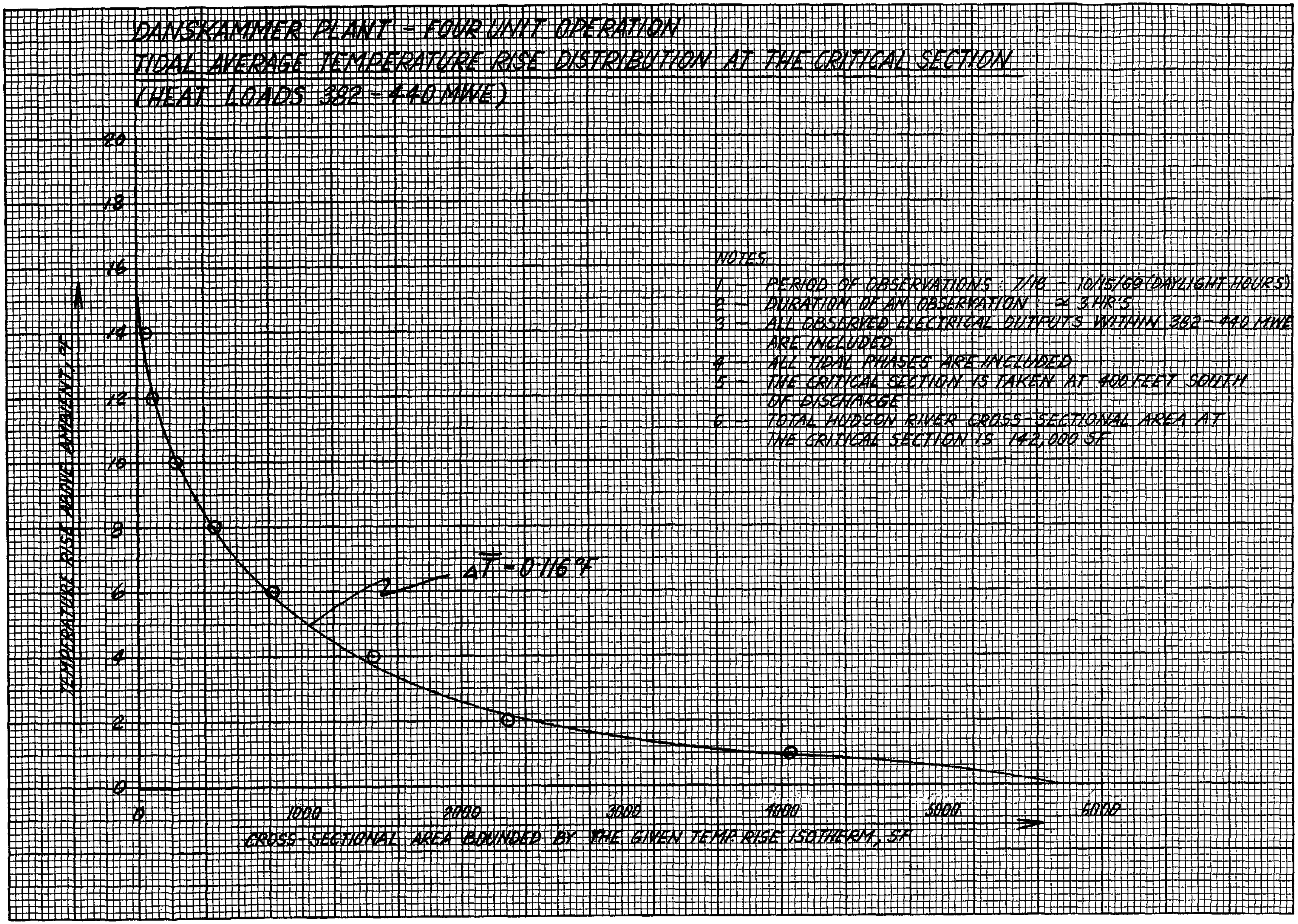
1 - PERIOD OF OBSERVATIONS : 7/18 - 10/15/69 (DAYLIGHT HRS)
2 - DURATION OF AN OBSERVATION : 3 HR'S
3 - ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 - 504) ARE INCLUDED
4 - AVERAGE OBSERVED HEAT LOAD IS 928 MWE
5 - ALL TIDAL PHASES ARE INCLUDED
6 - THE CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
7 - TOTAL HUDSON RIVER CROSS-SECTIONAL AREA AT THE CRITICAL SECTION IS 142,000 SF

FIGURE 36



DANSKAMMER PLANT - FOUR UNIT OPERATION
TIDAL AVERAGE TEMPERATURE RISE DISTRIBUTION AT THE CRITICAL SECTION
(HEAT LOADS 420 ~ 504 MWE)

NOTES:
1 - PERIOD OF OBSERVATIONS: 7/18 - 10/15/69 (DAYLIGHT HR'S)
2 - DURATION OF AN OBSERVATION : ≃ 3 HR'S
3 - ALL OBSERVED ELECTRICAL OUTPUTS WITHIN 420 ~ 504 MWE ARE INCLUDED
4 - ALL TIDAL PHASES ARE INCLUDED
5 - THE CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
6 - TOTAL HUDSON RIVER CROSS-SECTIONAL AREA AT THE CRITICAL SECTION IS 142,000 SF



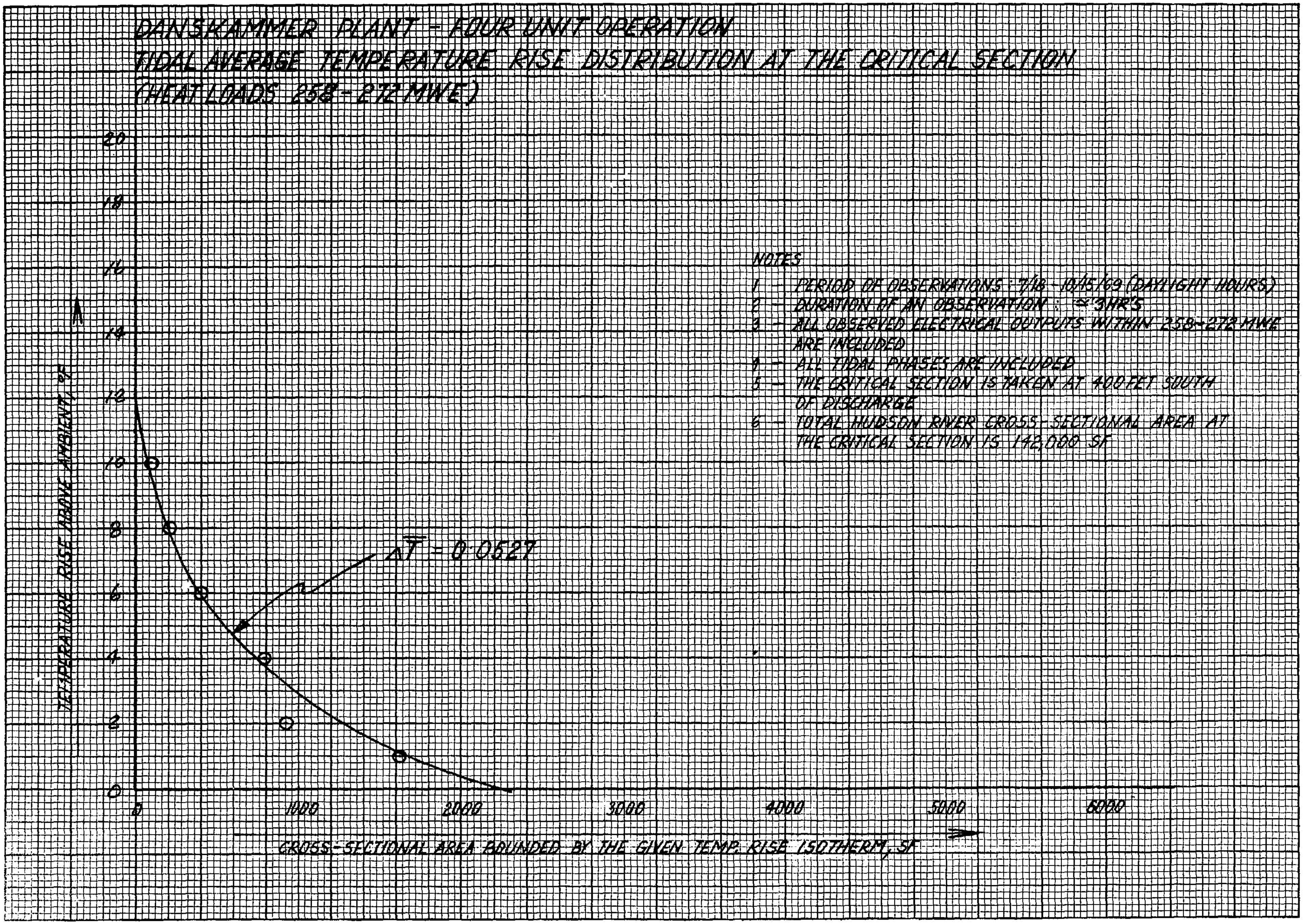
DANSKAMMER PLANT - FOUR UNIT OPERATION
TIDAL AVERAGE TEMPERATURE RISE DISTRIBUTION AT THE CRITICAL SECTION
(HEAT LOADS 382 - 440 MWE)

NOTES

1 - PERIOD OF OBSERVATIONS: 7/18 - 10/15/69 (DAYLIGHT HOURS)
2 - DURATION OF AN OBSERVATION: ≃ 3 HR'S
3 - ALL OBSERVED ELECTRICAL OUTPUTS WITHIN 382 - 440 MWE ARE INCLUDED
4 - ALL TIDAL PHASES ARE INCLUDED
5 - THE CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
6 - TOTAL HUDSON RIVER CROSS-SECTIONAL AREA AT THE CRITICAL SECTION IS 142,000 SF

FIGURE 37

FIGURE 38



DANSKAMMER PLANT - FOUR UNIT OPERATION
TIDAL AVERAGE TEMPERATURE RISE DISTRIBUTION AT THE CRITICAL SECTION
(HEAT LOADS 258-272 MWE)

NOTES

1 — PERIOD OF OBSERVATIONS : 7/18 - 10/15/69 (DAYLIGHT HOURS)
2 — DURATION OF AN OBSERVATION : ≃ 3HR'S
3 — ALL OBSERVED ELECTRICAL OUTPUTS WITHIN 258-272 MWE ARE INCLUDED
4 — ALL TIDAL PHASES ARE INCLUDED
5 — THE CRITICAL SECTION IS TAKEN AT 400 FET SOUTH OF DISCHARGE
6 — TOTAL HUDSON RIVER CROSS-SECTIONAL AREA AT THE CRITICAL SECTION IS 142,000 SF

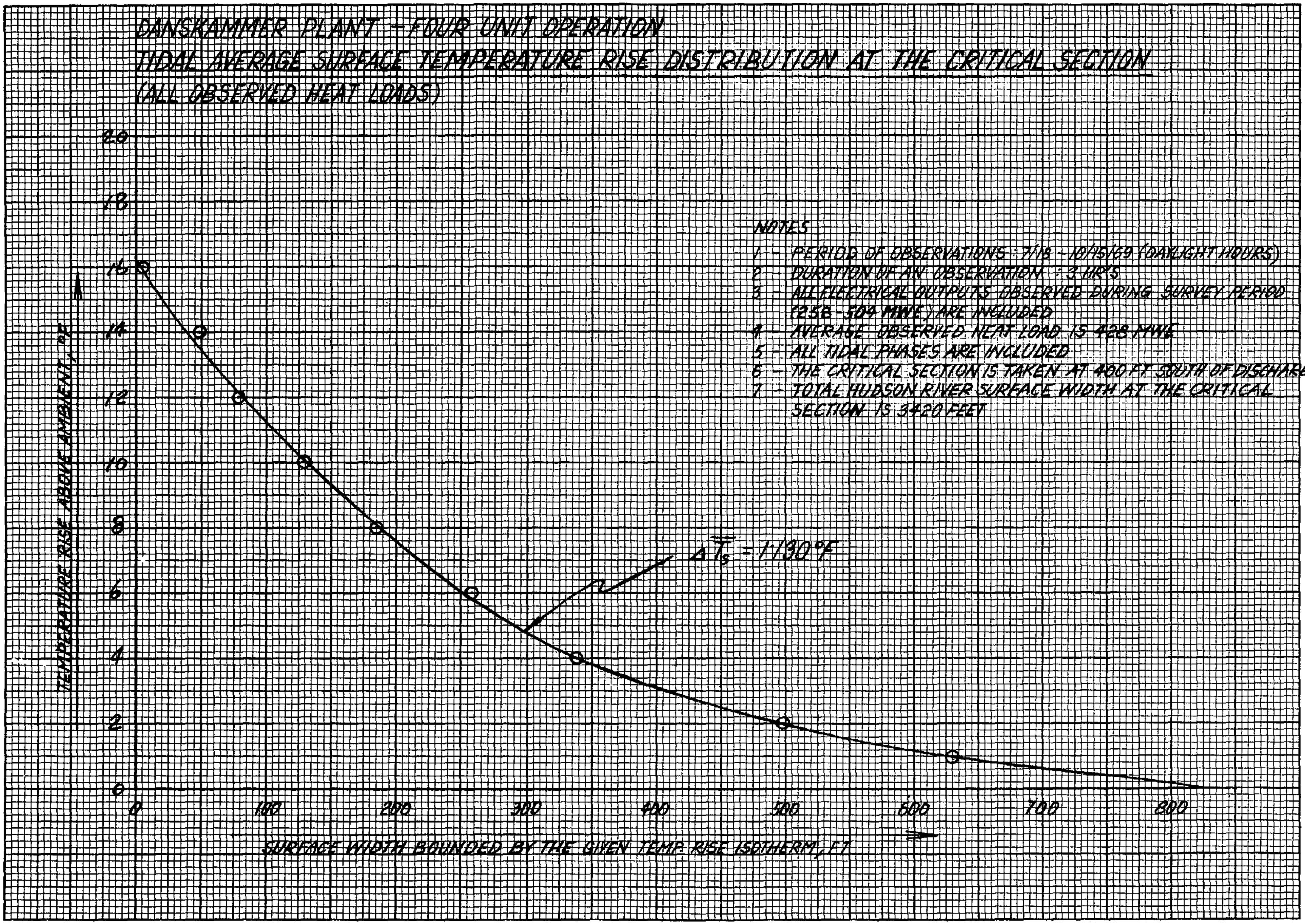
The tidal average surface widths bounded by all temperature rise isotherms were computed in a similar manner. The results for all observed heat loads and the three individual heat load groups are given in Figures 39 through 42, respectively.

The variation of the average temperature rise over the entire cross-section and surface width at the critical section with heat load is shown in Figures 43 and tabulated in Table 6.

The average width, cross-sectional area, longitudinal extent and surface area bounded by temperature rises in excess of $4^{o}F$ are also given in Table 6.

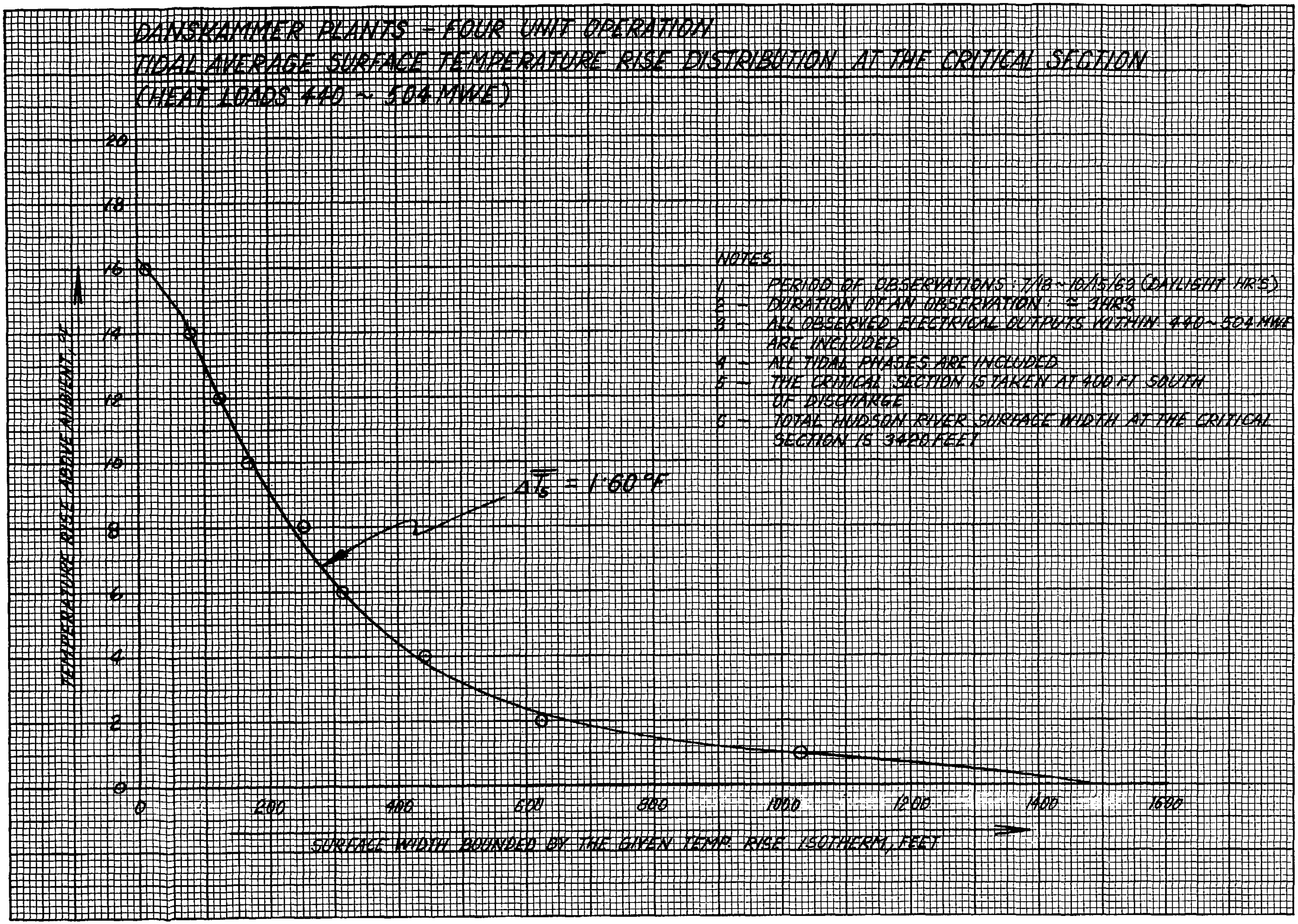
The statistical analysis of Chapter II indicates that the $4^{o}F$ temperature rise parameter values appearing under all observed heat loads have a frequency of occurrence ranging from 22% for the surface area to 55% for the width. The frequency of the area and longitudinal extent parameters is 38 and 36% respectively. The overall average is about 38%. In other words, values equal to or greater than those of Table 6 are expected to occur 38% of the time. The 38% probability is for any three-hour daylight tidal phase period. This period itself occurs only 50% of the time. The

DANSKAMMER PLANT – FOUR UNIT OPERATION
TIDAL AVERAGE SURFACE TEMPERATURE RISE DISTRIBUTION AT THE CRITICAL SECTION
(ALL OBSERVED HEAT LOADS)



NOTES
1 – PERIOD OF OBSERVATIONS: 7/18 – 10/15/69 (DAYLIGHT HOURS)
2 – DURATION OF AN OBSERVATION: 3 HR'S
3 – ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 – 504 MWE) ARE INCLUDED
4 – AVERAGE OBSERVED HEAT LOAD IS 428 MWE
5 – ALL TIDAL PHASES ARE INCLUDED
6 – THE CRITICAL SECTION IS TAKEN AT 400 FT SOUTH OF DISCHARGE
7 – TOTAL HUDSON RIVER SURFACE WIDTH AT THE CRITICAL SECTION IS 3420 FEET

FIGURE 39



DANSKAMMER PLANTS - FOUR UNIT OPERATION
TIDAL AVERAGE SURFACE TEMPERATURE RISE DISTRIBUTION AT THE CRITICAL SECTION
(HEAT LOADS 440 ~ 504 MWE)

NOTES

1 — PERIOD OF OBSERVATIONS: 7/18 ~ 10/15/69 (DAYLIGHT HR'S)
2 — DURATION OF AN OBSERVATION: ≃ 3HR'S
3 — ALL OBSERVED ELECTRICAL OUTPUTS WITHIN 440 ~ 504 MWE ARE INCLUDED
4 — ALL TIDAL PHASES ARE INCLUDED
5 — THE CRITICAL SECTION IS TAKEN AT 400 FT SOUTH OF DISCHARGE
6 — TOTAL HUDSON RIVER SURFACE WIDTH AT THE CRITICAL SECTION IS 3420 FEET

FIGURE 40

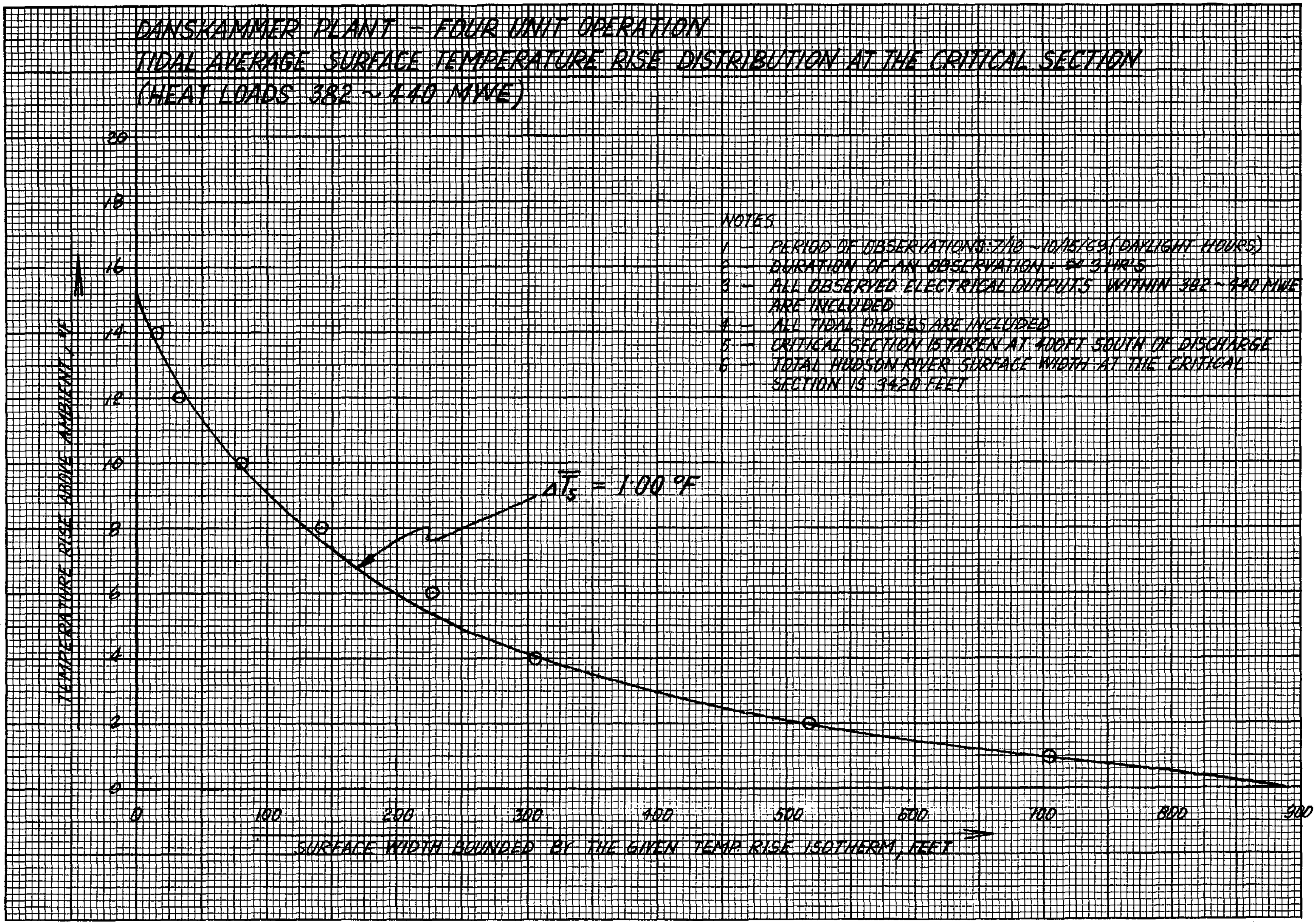


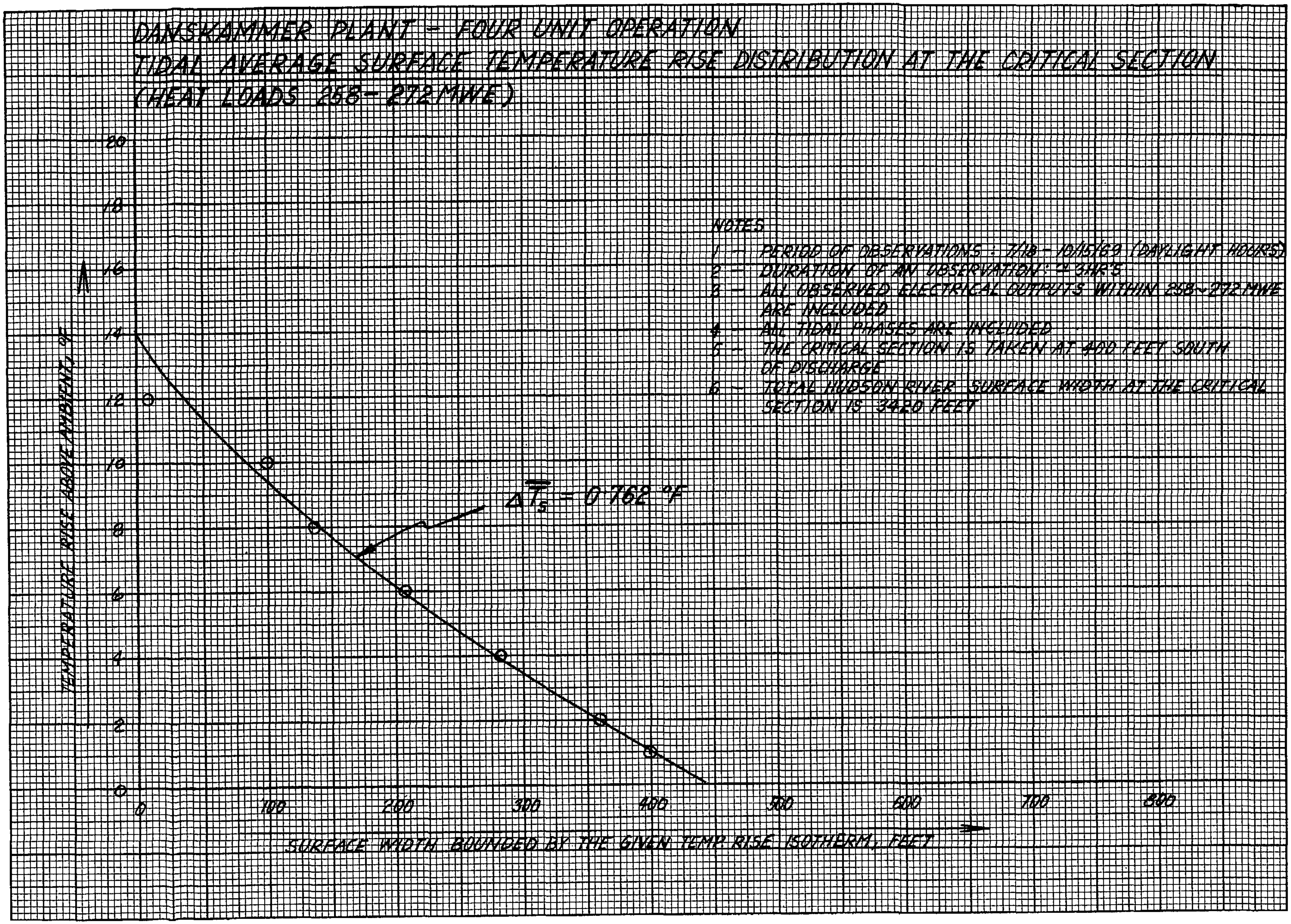
FIGURE 41

DANSKAMMER PLANT - FOUR UNIT OPERATION
TIDAL AVERAGE SURFACE TEMPERATURE RISE DISTRIBUTION AT THE CRITICAL SECTION
(HEAT LOADS 382 ~ 440 MWE)

NOTES

1 — PERIOD OF OBSERVATIONS: 7/18 ~ 10/15/69 (DAYLIGHT HOURS)
2 — DURATION OF AN OBSERVATION : ≈ 3 HR'S
3 — ALL OBSERVED ELECTRICAL OUTPUTS WITHIN 382 ~ 440 MWE ARE INCLUDED
4 — ALL TIDAL PHASES ARE INCLUDED
5 — CRITICAL SECTION IS TAKEN AT 400 FT SOUTH OF DISCHARGE
6 — TOTAL HUDSON RIVER SURFACE WIDTH AT THE CRITICAL SECTION IS 3420 FEET

FIGURE 42

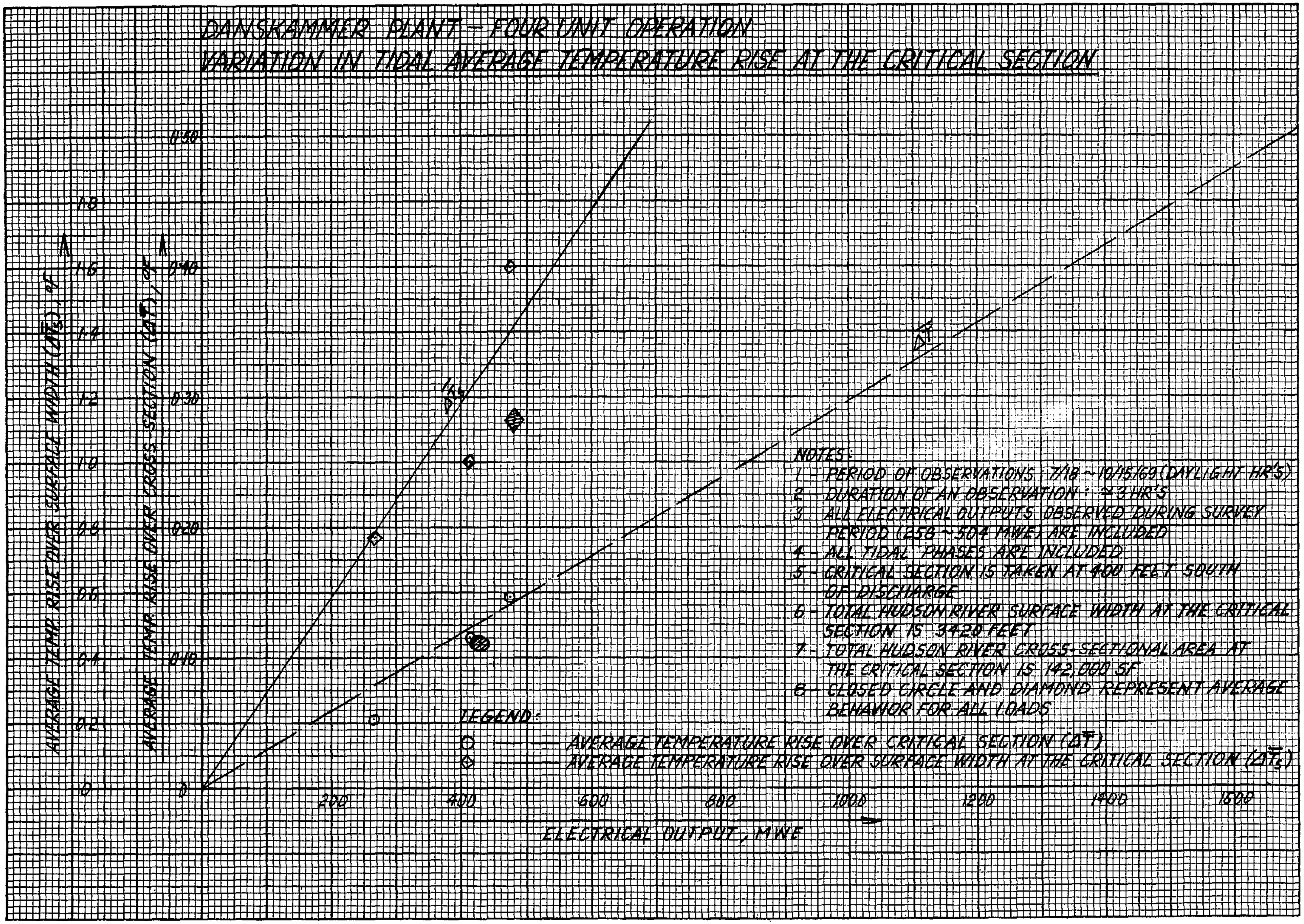


DANSKAMMER PLANT – FOUR UNIT OPERATION
TIDAL AVERAGE SURFACE TEMPERATURE RISE DISTRIBUTION AT THE CRITICAL SECTION
(HEAT LOADS 258 – 272 MWE)

NOTES
1 – PERIOD OF OBSERVATIONS : 7/18 – 10/15/69 (DAYLIGHT HOURS)
2 – DURATION OF AN OBSERVATION: ≈ 3HR'S
3 – ALL OBSERVED ELECTRICAL OUTPUTS WITHIN 258~272 MWE ARE INCLUDED
4 – ALL TIDAL PHASES ARE INCLUDED
5 – THE CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
6 – TOTAL HUDSON RIVER SURFACE WIDTH AT THE CRITICAL SECTION IS 3420 FEET

FIGURE 43

DANSKAMMER PLANT – FOUR UNIT OPERATION
VARIATION IN TIDAL AVERAGE TEMPERATURE RISE AT THE CRITICAL SECTION



NOTES:
1 – PERIOD OF OBSERVATIONS: 7/18 ~ 10/15/69 (DAYLIGHT HR'S)
2 – DURATION OF AN OBSERVATION: ≈ 3 HR'S
3 – ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 ~ 504 MWE) ARE INCLUDED
4 – ALL TIDAL PHASES ARE INCLUDED
5 – CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
6 – TOTAL HUDSON RIVER SURFACE WIDTH AT THE CRITICAL SECTION IS 3420 FEET
7 – TOTAL HUDSON RIVER CROSS-SECTIONAL AREA AT THE CRITICAL SECTION IS 142,000 SF
8 – CLOSED CIRCLE AND DIAMOND REPRESENT AVERAGE BEHAVIOR FOR ALL LOADS

LEGEND:
○ ——— AVERAGE TEMPERATURE RISE OVER CRITICAL SECTION ($\overline{\Delta T}$)
◇ ——— AVERAGE TEMPERATURE RISE OVER SURFACE WIDTH AT THE CRITICAL SECTION ($\overline{\Delta T_s}$)

TABLE 6

DANSKAMMER PLANT, FOUR UNIT OPERATION

VARIATION IN TIDAL AVERAGE TEMPERATURE EFFECT DUE TO CHANGES IN HEAT LOAD

Temperature Parameter	All Observed Heat Loads (MWE)	LOAD RANGE (MWE)		
		(258-272)*	(382-440)	(440-504)
Average Heat Load (MWE)	428	266	413	473
$\Delta\overline{T}$	.111	.0527	.116	.146
$\Delta\overline{T}_s$	1.13	.768	1.00	1.60
TSF	10.1	14.6	9.5	11.0
4° Width (%)	10.0	8.2	9.05	12.9
4° Area (%)	0.9	0.52	0.956	1.0
4° Longitudinal Extent (Ft)	3941	2708	3888	4718
4° Surface Area (Acres)	48.5	15.2	23.9	76.2

* Based upon few measurements.

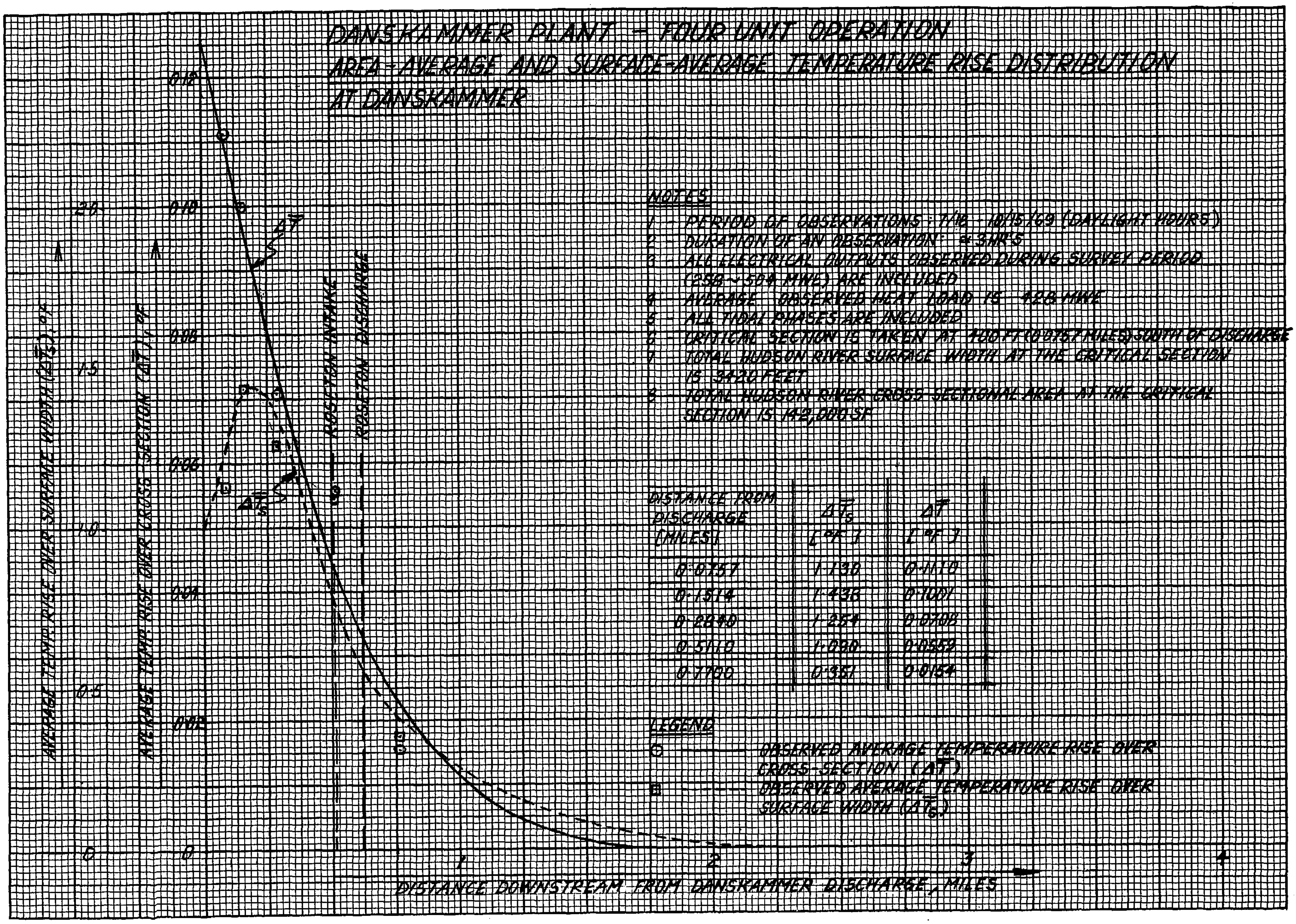
probability of occurrence of these values is, therefore, very small. Hence, the use of the table values in the computation is considered to be conservative.

The tidal average temperature rises over the cross-sectional area and surface width at several locations downstream of the Danskammer discharge were computed in a similar fashion. The results are shown in Figure 44.

Notice that the area average temperature rise decreases rapidly from about 0.12°F at the Danskammer discharge to about .05°F at the Roseton intake. Notice also that the tidal average surface temperature rise increases just from about 1°F at the discharge to just less than 1.5°F some 800 ft. downstream of the discharge, and then decreases to about 1.1°F at the Roseton intake.

Downstream of this location, both parameters decrease rapidly and approach zero some two miles below the discharge.

Due to the Danskammer discharge orientation only a very small portion of the River upstream of the discharge experiences measurable temperature rises.



DANSKAMMER PLANT – FOUR UNIT OPERATION
AREA-AVERAGE AND SURFACE-AVERAGE TEMPERATURE RISE DISTRIBUTION AT DANSKAMMER

NOTES

1 – PERIOD OF OBSERVATIONS : 7/18 - 10/15/69 (DAYLIGHT HOURS)
2 – DURATION OF AN OBSERVATION: ≈ 3HRS
3 – ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 ~ 504 MWE) ARE INCLUDED
4 – AVERAGE OBSERVED HEAT LOAD IS 428 MWE
5 – ALL TIDAL PHASES ARE INCLUDED
6 – CRITICAL SECTION IS TAKEN AT 400 FT (0.0757 MILES) SOUTH OF DISCHARGE
7 – TOTAL HUDSON RIVER SURFACE WIDTH AT THE CRITICAL SECTION IS 3420 FEET
8 – TOTAL HUDSON RIVER CROSS SECTIONAL AREA AT THE CRITICAL SECTION IS 142,000 SF

DISTANCE FROM DISCHARGE [MILES]	$\Delta\overline{T}_s$ [°F]	$\Delta\overline{T}$ [°F]
0.0757	1.130	0.1110
0.1514	1.436	0.1001
0.2840	1.254	0.0708
0.5110	1.030	0.0552
0.7700	0.351	0.0154

LEGEND

⊙ ———	OBSERVED AVERAGE TEMPERATURE RISE OVER CROSS-SECTION ($\Delta\overline{T}$)
⊞ – – –	OBSERVED AVERAGE TEMPERATURE RISE OVER SURFACE WIDTH ($\Delta\overline{T}_s$)

FIGURE 44

The measured thermal stratification factor (surface average temperature rise/area average temperature rise) is shown in Figure 45. Values ranging from about 10 at the discharge to 20 at the Roseton intake were observed. These high values indicate that the elevated temperatures caused by the Danskammer surface discharge concentrate at the surface as the heated effluent moves away from the plane of discharge.

B. Development of the Mathematical Temperature Model

An early model[1] developed to describe the decay of the tidal-smoothed, area averaged temperature rise, as one moves away from the plane of discharge of the heated liquid, recognized the role played by stratification of the thermal effluent as it entered the water course.

In this model, the parameter utilized to describe this phenomenon arose quite naturally in the development of the defining differential equation; i.e., the ratio of the surface average temperature rise to the area averaged temperature rise appear in the derivation

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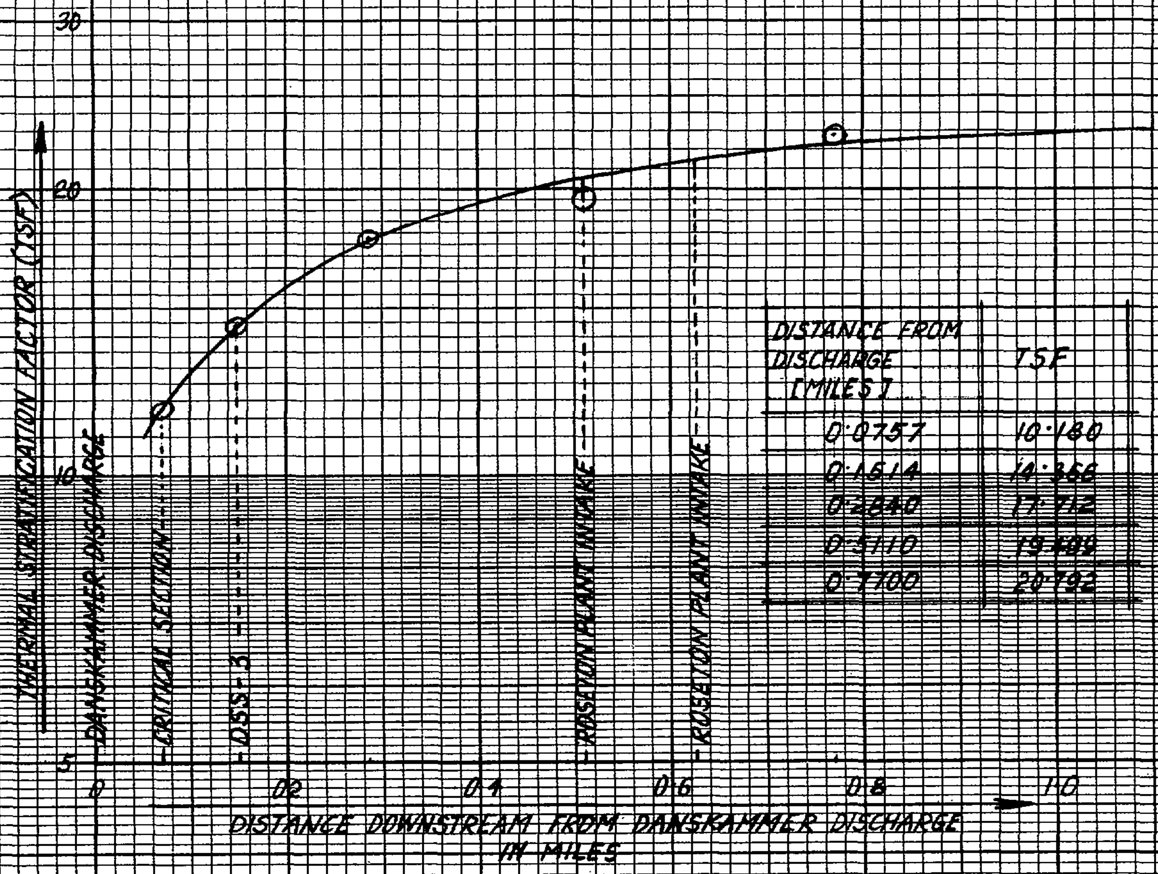
[1] Quirk, Lawler & Matusky Engineers, report to Consolidated Edison, "Effect of Indian Point Cooling Water Discharge on Hudson River Temperature Distribution", January, 1968.

DANSKAMMER PLANT - FOUR UNIT OPERATION
VARIATION IN HUDSON RIVER THERMAL STRATIFICATION FACTOR AT DANSKAMMER



DISTANCE FROM DISCHARGE [MILES]	TSF
0·0757	10·180
0·1614	14·368
0·2840	17·712
0·5110	19·409
0·7700	20·792

NOTES

1 - PERIOD OF OBSERVATIONS : 7/18 - 10/15/69
2 - DURATION OF AN OBSERVATION : ≈ 3 HRS
3 - ALL ELECTRICAL OUTPUTS OBSERVED DURING SURVEY PERIOD (258 ~ 504 MWE) ARE INCLUDED
4 - AVERAGE OBSERVED HEAT LOAD IS 428 MWE
5 - ALL TIDAL PHASES ARE INCLUDED
6 - CRITICAL SECTION IS TAKEN AT 400 FT (0·0757 MILES) SOUTH OF DISCARGE
7 - TOTAL HUDSON RIVER SURFACE WIDTH AT THE CRITICAL SECTION IS 3420 FT
8 - TOTAL HUDSON RIVER CROSS SECTIONAL AREA AT THE CRITICAL SECTION IS 142,000 SF

of the defining equation and was termed the thermal stratification factor or TSF.

In previous work, the TSF was assumed to be constant, and the numerical value assigned was obtained from temperature measurements made at the plane of discharge. However, observations at several existing power plant sites show that this parameter increases as one moves away from the plane of discharge. In particular, this occurred at Danskammer, as shown in Figure 45, which appears after page 32.

Theoretically, this increase in the TSF should be expected, because the surface should be the last zone to see elevated temperature rises before complete elimination of all residual excess heat. In other words, the heated surface layer becomes thinner as distance from the plant increases, with the higher temperature continuing to exist in the upper zones of this layer.

The model used in this study to predict the overall temperature effect takes this growth of the TSF into account. Following the development given in Appendix A of Reference 1, the steady state defining differential equation for tidal-smoothed area averaged temperature rise in an estuary whose area, dispersion coefficient, fresh water flow and heat transfer coefficient are constant, is:

$$E\frac{d^2\Delta\bar{T}}{dx^2} - U\frac{d\Delta\bar{T}}{dx} - K'\cdot TSF(x)\cdot\Delta\bar{T} = 0 \qquad .....(1)$$

in which:

$\Delta\bar{T}$ = tidal-smoothed, area averaged temperature rise, $^{\circ}F$

x = distance from point of discharge, miles (position downstream)

E = longitudinal dispersion coefficient, $mile^2/day$

U = 16.4 (Q/A), freshwater velocity, mile/day

Q = freshwater runoff, CFS

A = river cross-sectional area, SF

K' = $\bar{K}/\rho C_p D$, temperature exchange coefficient, day^{-1}

$\bar{K}$ = heat transfer coefficient, BTU/SF/Day/$^{\circ}F$

ρ = density of water, #/cu. ft.

C_ρ = heat capacity of water, BTU/#/$^{\circ}F$

D = A/B, mean depth of River, Ft.

B = River surface width, Ft.

TSF(x) = $\overline{\Delta T_s}/\overline{\Delta T}$, thermal stratification factor, dimensionless and a function of distance x.

For this study, TSF(x) has been assumed to be an exponential growth function of distance and is given:

$$TSF = TSF_o \cdot e^{ax} \qquad \ldots\ldots(2)$$

in which:

TSF_o = thermal stratification factor at x=0

a = TSF growth coefficient, mile^{-1}

The product (ax) is assumed to be positive whether operating in the reach upstream of the discharge (negative x) or in the downstream positive reach. Figure 45 shows that the growing Danskammer TSF is not exactly correlated by the exponential function. This fact, and its effect on the model's ability to reproduce measured effects, is discussed in greater detail in the next section of this chapter.

The estuary is assumed to be an infinite receiver, which implies that the values of the system parameters (A,E,U,K) do not change before the elevated temperature effect becomes negligible. This assumption is conservative.

The model is developed in detail in Appendix C. After obtaining a broadly applicable solution for different values of (a) in the upstream (I) and downstream (II) reaches, it is shown that, for the case of equal values of (a) in both reaches, which is expected to apply for the transverse directed submerged discharge, freshwater velocity has little effect and the solution for the downstream reach is:

$$\theta_{II}(\tau) = \frac{K_o(\sqrt{N_2 \tau})}{\sqrt{N_2}\, K_1(\sqrt{N_2})} \quad \text{.....(3)}$$

in which:

N_2 = K/Ea^2, dimensionless

K = $K' \cdot TSF_o$

K' = $\overline{K}/\rho C_p D\ ax$

τ = e^{ax}

K_o = Modified Bessel Function of the Second Kind of order zero

K_1 = Modified Bessel Function of the Second Kind of order one

$\theta_{II}(\uparrow)$ = $\Delta\overline{T}/\Delta T_o$

ΔT_o = $H/\rho C_p aEA$

H = heat load to River, BTU/Day

The solution in the upstream reach, for these conditions, is identical to Equation 3.

C. Evaluation of Mathematical Model Results Using Danskammer Temperature Measurements

The solution presented in the previous section was used to determine the tidal average temperature rise distribution caused by four unit operation at Danskammer for the conditions of the 1969 survey. Values of the parameters for the study area are summarized below:

Electrical output$_{(H)}$ = 428 MWE (average of all observed loads)

Heat Load at 38% Effluent, 15% other losses = .428X10" BTU/Day

Thermal Stratification Factor at the Discharge (TSF_o) = 10.1 (taken from Figure 45)

River Cross-Sectional Area (A) = 142,000 sq.ft.

River Mean Depth (D) = 41.5 ft.

Dispersion Coefficient (E) = 6 sq. miles/day

Heat Transfer Coefficient ( ) = 150 BTU/SF/day/^{o}F

Mass density (ρ) = 62.4 lb./ft.^{3}

Heat capacity (C_ρ) = 1 BTU/lb/^{o}F

TSF growth coefficient (a) = 1.29/mile

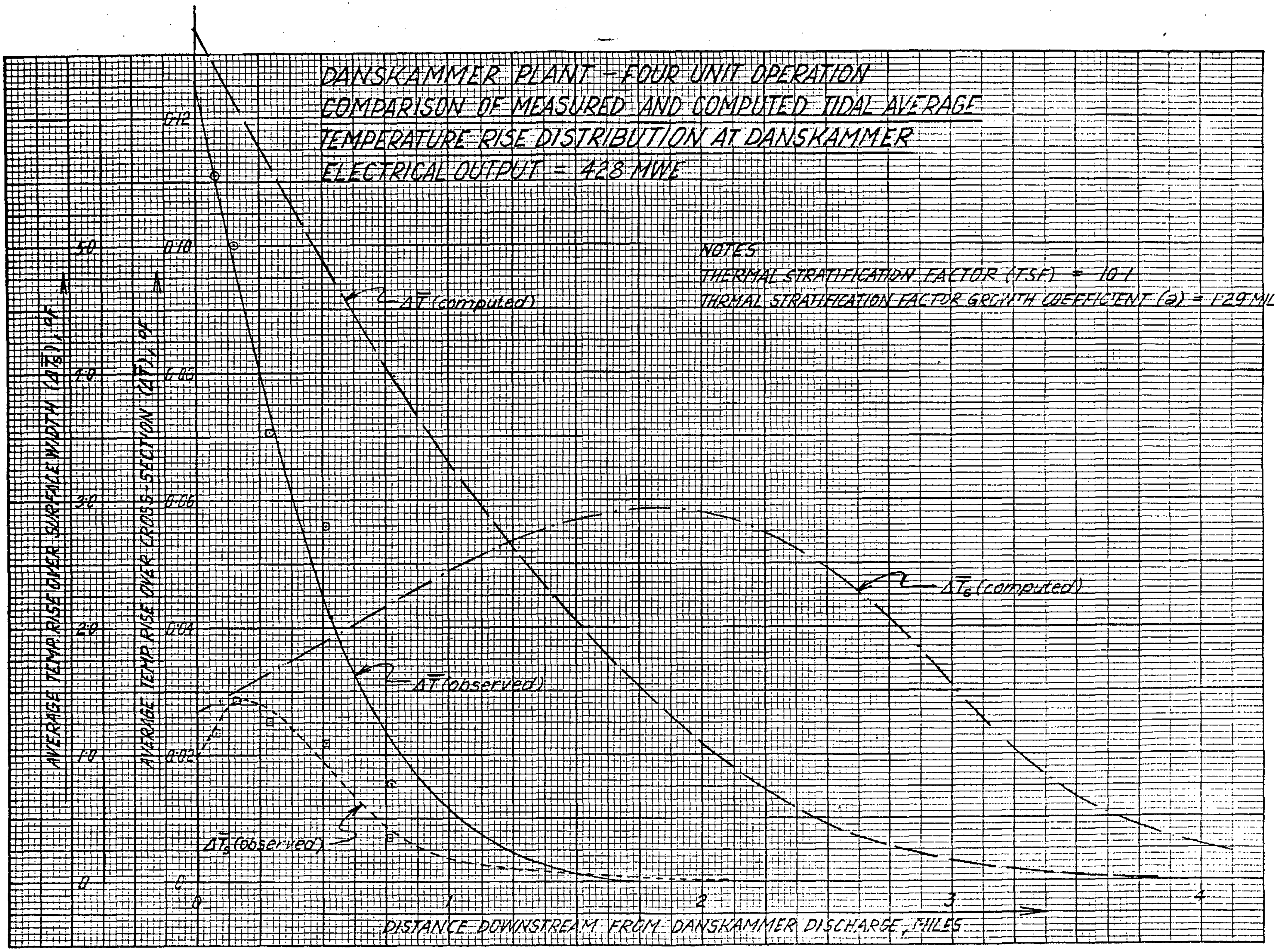
The rate of increase of the thermal stratification factor (a) used in the computation represents an average value over a distance of one half mile downstream of the discharge.

Model results for these conditions are compared to river temperature measurements in the vicinity of Danskammer in Figure 46. The predicted rises at the plane 400 ft. below the Danskammer discharge are very close to their measured counterparts. The computed area average temperature rise and surface average temperature rise at this point are 15% and 20% higher than the measured values, respectively.

The close agreement between the measured and observed temperature rise parameters may also be interpreted as representing an additional support for the selection of the ambient temperature used in the analysis.

The agreement between the computed and measured shape of these two functions is also good.

FIGURE 46



DANSKAMMER PLANT - FOUR UNIT OPERATION
COMPARISON OF MEASURED AND COMPUTED TIDAL AVERAGE
TEMPERATURE RISE DISTRIBUTION AT DANSKAMMER
ELECTRICAL OUTPUT = 428 MWE

NOTES
THERMAL STRATIFICATION FACTOR (TSF) = 10·1
THRMAL STRATIFICATION FACTOR GROWTH COEFFICIENT (a) = 1·29 MILE^{-1}

The computed results beyond the plane of discharge are much higher than the measured values. Therefore, the model results are considered to be very conservative. The following comments apply to the disagreement between the measured and computed results:

1. The computed values are based on a constant value of the TSF growth coefficient (a=1.29/mile). Figure 45, however, shows that this value is not constant. Actually, it decreases from 6.56/mile at the discharge to .85/mile at the Roseton intake.

   Had lower (a) values been used in computing temperature behavior below the plane of discharge, the area average rise would be larger and the surface average rise smaller. The reverse would be true, if higher (a) values were used.

   Measured (a) values are higher than the 1.29 mile^{-1} value used in the computation in a zone extending from the discharge to some 1500 ft. downstream, and are lower than 1.29 mile^{-1} beyond this point.

   The use of measured (a) values would therefore, lower the computed area average rises in the first 1500 ft. and cause an increase beyond this location. In other words, the computed area average results would be closer to their measured counterparts in the vicinity of the discharge but more conservative than shown in Figure 46 beyond this point.

2. The model assumes symmetrical temperature distribution downstream and upstream of the discharge. This assumption is valid only when the discharge plane is perpendicular to the river flow direction and the effect of freshwater flow is not significant. Danskammer discharge direction, however, is the same as that of ebb flow and the river portion upstream of the discharge sees insignificant temperature rises.

   Inclusion of this observation in the model would force all the model heat into the downstream reach, and would cause the computed downstream temperature rises to be larger than those shown in Figure 46.

3. The computations were based on a constant river cross-sectional area and mean depth. However, the area increases and the mean depth decreases in the downstream

direction, meaning that substantially more surface area is available for heat transfer since the area average temperature rise is inversely proportional to the area and directly proportional to the square root of the mean depth, the changes in downstream geometry would result in a lower computed result. This would tend to give better agreement between the model and the measurements.

For example, changing the cross-sectional area and depth from 142,000 sq. ft and 41.5 ft., which strictly applies only at Danskammer, to the 150,000 sq.ft. and 28 ft. values which exist one mile downstream, would cause a decrease in area and surface average temperature rise from 0.065 $^{\circ}$F and 2.5°F to about 0.03°F and 1.2°F, respectively. The corresponding measured parameters are .004°F and .6°F, respectively.

These results indicate that even if the effects of changes in geometry, discharge orientation and TSF growth coefficient were taken into consideration, the model would still give very conservative results.

The following points may explain the reason for the very rapid measured decay of the area and surface average temperature rises with distance away from Danskammer:

1. Rapid dispersal and dilution of the heated effluent in the vicinity of the plant caused by very high local dispersion coefficient. Measured temperature distribution within the first mile above and below the plane of discharge indicates that the effective thermal dispersion coefficient is much higher than the conventional one-dimensional coefficient used in the calculations.

2. Very high heat transfer coefficients. The coefficient used in this study was developed from lake studies. However, in estuaries, due to generally higher wind speed, the surface heat transfer coefficient is probably higher. This observation is supported by the fact that reaeration coefficients in estuaries are generally somewhat higher than those in lakes.

3. Heat losses to river bottom and other boundaries. These losses were not taken into consideration in this study.

D. Prediction of the Effect of Roseton Plant Discharge

The purpose of this section is to determine, for the condition of the Roseton plant loading, the effect of Roseton cooling water discharge on river temperatures, using the sectional and surface average temperatures obtained via the mathematical model presented above.

Comparison of Danskammer measurements with the computed results showed that the mathematical model behavior of both the area and surface temperature rises, across the plane of discharge, gives a reasonably accurate description of the actual behavior of these parameters. Also, the model values beyond the plane of discharge are highly conservative.

This model was utilized to predict the effect which can be expected in the presence of 1200 MWE waste heat load from Roseton.

Five different thermal stratification factor functions were used in the computations. Values of thermal stratification factors at the discharge (TSF_O) and TSF growth coefficients (a) ranging from 10.1 and 1.29 to 1.5 and .5 were considered. The upper limit represents a surface discharge at Roseton similar to Danskammer and the lower one is indicative of a thoroughly mixed submerged discharge. The three intermediate conditions represent several ranges of stratification for both surface and submerged discharges.

These five conditions and the corresponding model results are summarized in Table 7. The first three and the last two may be taken as representing surface and submerged discharges with different mixing intensities.

The surface discharge conditions were considered for comparison purposes only. The value of TSF of 1.0 would be obtained if the heated discharge were completely mixed across the plane of discharge. This value represents a minimum which will only be approached. The fact that the Roseton discharge is to be submerged, and is twice the flow of the existing Danskammer discharge is expected to drive the stratification factor down from 10.1 of 428 MWE Danskammer surface discharge to values between 1.5 and 2.5.

The percentages of cross-sectional area and surface width expected to be bounded by temperature rises in excess of 4°F are also given in Table 7, and are shown in Figure 47. These values were obtained by using the generalized solution for exponential decay

TABLE 7

TIDAL AVERAGE

AREA-AVERAGE AND SURFACE-AVERAGE TEMPERATURE RISE AND PORTION OF RIVER AFFECTED BY RISES IN EXCESS OF 4°F ISOTHERM FOR CONDITIONS OF MAXIMUM SEVERITY AT ROSETON

CONDITIONS

Heat Load = 1.2 X 10^{11} BTU/Day, Maximum Plant Temperature Rise = 18°F (Including 1°F to Account for Recirculation and Danskammer Effect)

Dispersion Coefficient = 6 Square Miles/Day

Heat Transfer Coefficient = 150 BTU/Sq.Ft./Day/°F

Cross-Sectional Area = 150,000 Square Feet.

Surface Width = 3750 Feet

Mean Depth = 40 Feet

TABLE 7 (CONTINUED)

TIDAL AVERAGE

AREA-AVERAGE AND SURFACE-AVERAGE TEMPERATURE RISE AND PORTION OF RIVER AFFECTED BY RISES IN EXCESS OF 4°F ISOTHERM FOR CONDITIONS OF MAXIMUM SEVERITY AT ROSETON

				SURFACE-AVERAGE TEMPERATURE RISE, °F		PORTION OF RIVER BOUNDED BY 4°F TEMPERATURE RISE		
						% Area	% Width	
Condition	TSF[1] at the Discharge	TSF Growth Coefficient (a), mile^{-1}	Maximum Area-Average Temperature Rise, °F	at the Discharge	at the Sections of Maximum Surface Effect		at the Discharge	at the Sections of Maximum Surface Effect
Surface Discharge								
1	10.1	1.29	.351	3.55	7.66	2	37	100
2	5.0	1.00	.461	2.30	5.60	2.6	21	99
3	3.0	0.75	.613	1.84	4.3	4	15	50
Submerged Discharge								
4	2.0	0.60	.766	1.53	3.45	6	13	35
5	1.5	0.5	.936	1.41	3.00	8	12	29

[1] TSF = Thermal Stratification Factor

ROSETON PLANT
VARIATION IN SURFACE-AVERAGE AND AREA-AVERAGE TEMPERATURE RISES WITH THERMAL STRATIFICATION FACTOR AT ROSETON

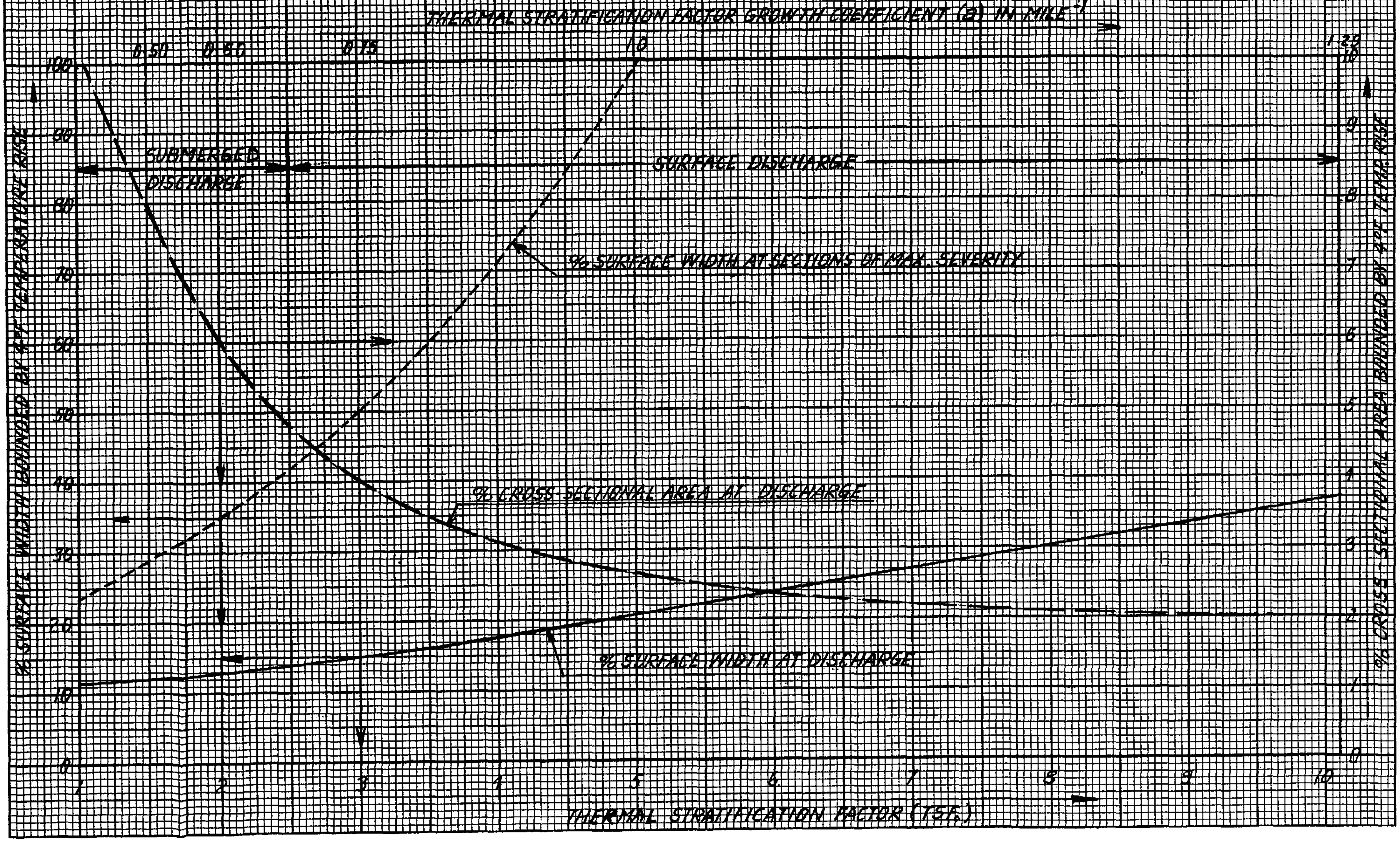


FIGURE 47

models developed previously.[2]

The use of the exponential decay models in this case is supported by the Danskammer measurements of 1969. Figures 35 through 42 indicate that the area-average and the surface-average temperature rises followed exponential functions. Two typical correlations of the measured temperature rises for all observed heat loads, shown in Figures 35 and 39, with the exponential relationship, are shown in Figures 48 and 49.

The area and surface temperature rise curves in Figure 47 were developed using a maximum plant temperature rise of 18°F and a surface rise of 7.5°F. The plant temperature rise is 17°F. One degree was added to account for the effect of the Danskammer plant and recirculation. These effects, however, are far less than 1°F as will be shown in Chapter IV.

The maximum surface temperature rise was computed using a dilution ratio of 3.55 and a surface temperature distribution following

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[2] Quirk, Lawler & Matusky Engineers, "Effect of Indian Point Cooling Water Discharge on Hudson River Temperature Distribution", February, 1969, Figure 24.

DANSKAMMER PLANT - FOUR UNIT OPERATION
EXPONENTIAL DECAY COEFFICIENT FOR CROSS-SECTIONAL AREA ENCLOSED BY TEMPERATURE RISES IN EXCESS OF 4°F

NOTES
1 - PERIOD OF OBSERVATIONS : 7/18 ~ 10/15/69 (DAYLIGHT HOURS)
2 - DURATION OF AN OBSERVATION : ≃ 3 HR'S
3 - ALL ELECT. OUTPUTS OBSERVED DURING SURVEY PERIOD (264 - 504 MWE) ARE INCLUDED
4 - ALL TIDAL PHASES ARE INCLUDED
5 - CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
6 - TOTAL HUDSON RIVER CROSS-SECTIONAL AREA AT THE CRITICAL SECTION IS 142,000 SF
7 - THESE POINTS WERE TAKEN FROM FIG. 35

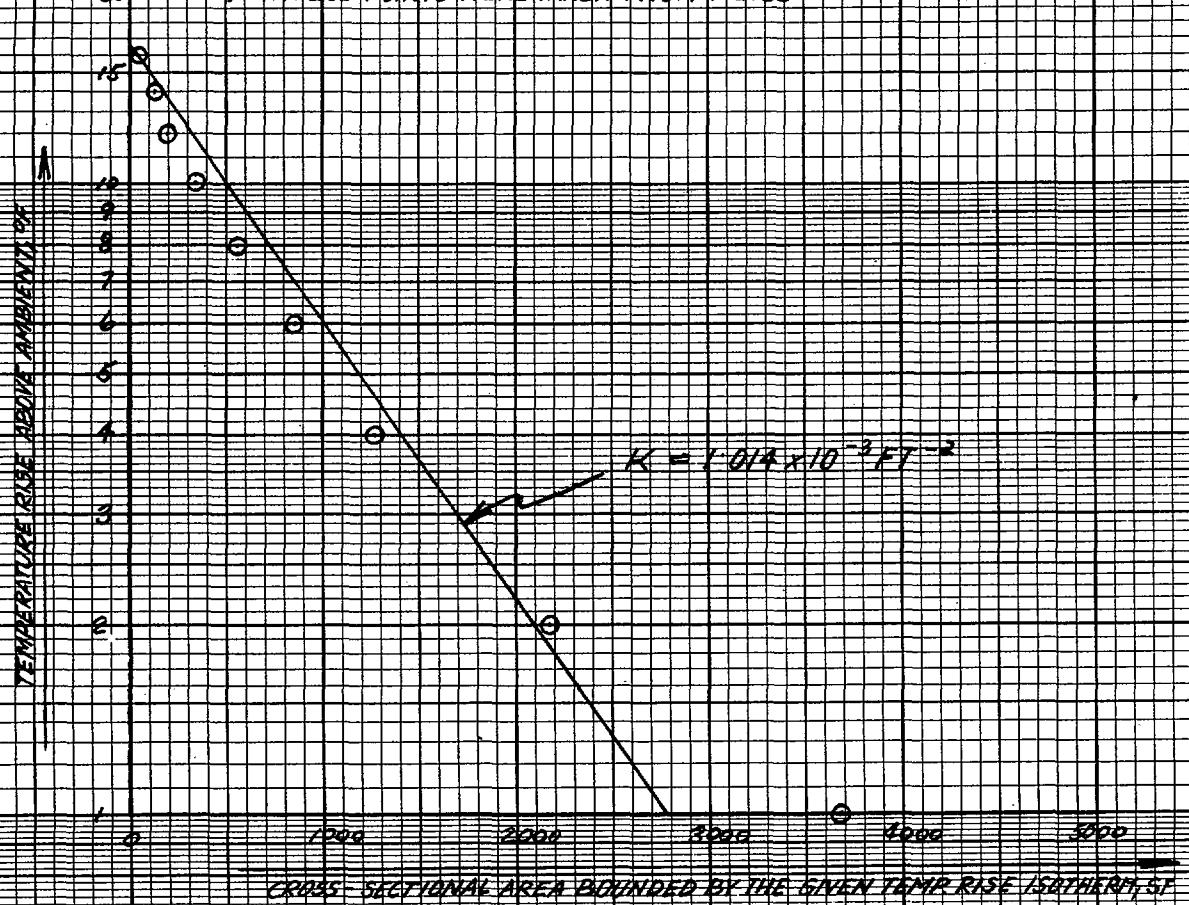
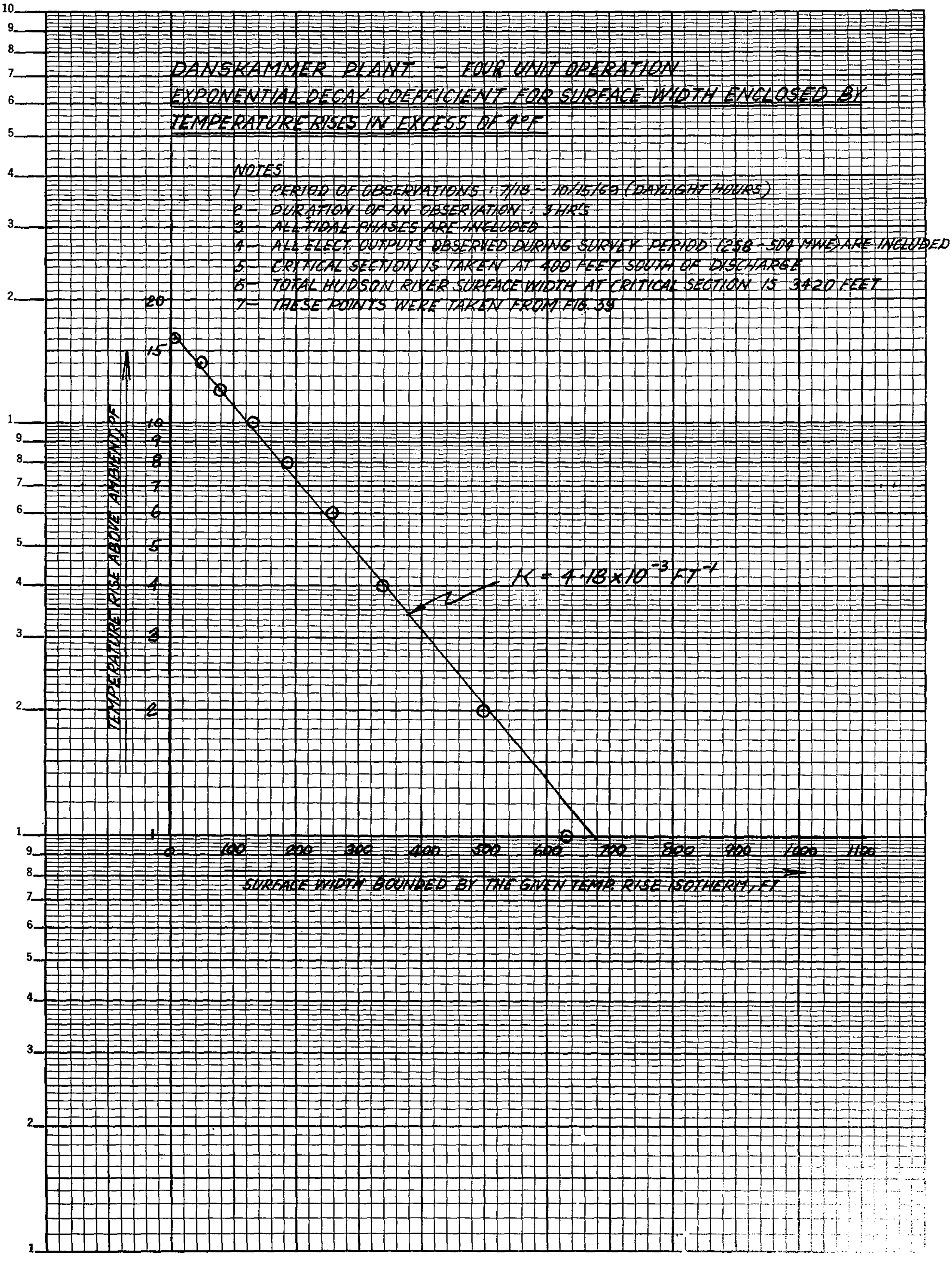


FIGURE 49



DANSKAMMER PLANT – FOUR UNIT OPERATION

EXPONENTIAL DECAY COEFFICIENT FOR SURFACE WIDTH ENCLOSED BY TEMPERATURE RISES IN EXCESS OF 4°F

NOTES

1 – PERIOD OF OBSERVATIONS : 7/18 ~ 10/15/69 (DAYLIGHT HOURS)
2 – DURATION OF AN OBSERVATION : 3 HR'S
3 – ALL TIDAL PHASES ARE INCLUDED
4 – ALL ELECT. OUTPUTS OBSERVED DURING SURVEY PERIOD (258 - 504 MWE) ARE INCLUDED
5 – CRITICAL SECTION IS TAKEN AT 400 FEET SOUTH OF DISCHARGE
6 – TOTAL HUDSON RIVER SURFACE WIDTH AT CRITICAL SECTION IS 3420 FEET
7 – THESE POINTS WERE TAKEN FROM FIG. 39

$K = 4.18 \times 10^{-3}\ FT^{-1}$

a cosine function. This dilution ratio value represents the minimum expected dilution associated with the planned submerged discharge. Further discussion of this value is presented in Chapter IV.

These values indicate that on the tidal average basis only 6 to 8 and 12 to 13% of the total cross-sectional area and surface width at Roseton, respectively are expected to see temperature rises in excess of 4°F. These values are considerably lower than the 4°F upper limit of the thermal criteria.

As indicated earlier, the maximum surface temperature rise occurs at a plane located above or below the plane of discharge. The submerged discharge results show that at these sections, some 29 to 35% of the surface width will experience temperature rises in excess of 4°F.

All of these values correspond to tidal average conditions. The tidal cycle variation observed at Danskammer, however, showed that the 4°F surface width and area corresponding to the critical tidal phase conditions are about 35% higher than the tidal average effects. The observed tidal cycle variation in these parameters is presented in Figures 17 and 22. The use of this ratio and the tidal average results indicate that some 8 to 10 and 40 to 47% of the total cross-sectional area and surface width, respectively are expected to be subjected to rises in excess of 4°F during the critical tidal phases.

The tidal average and critical tidal phase effects for the submerged discharge conditions are summarized and compared to the New York State Water Resources Commission Criteria for Thermal Discharges in Table 8.

Were a surface discharge planned for Roseton plant, no more than 3 and 37% of the cross-sectional area and surface width, respectively, at the discharge, would be enclosed by temperature rises in excess of 4°F. However, computed percentage of surface width would range from 50 to 100%.

Figures 50 and 51 show the decay of the area-average and surface-average temperature rise with distance below the plane of discharge at Roseton, respectively. All five conditions are presented. It must be realized that these values are very conservative since the model was not adjusted to account for variation in geometry and thermal stratification factor function.

TABLE 8

PORTION OF RIVER AT ROSETON AFFECTED BY TEMPERATURE RISES IN EXCESS OF 4°F FOR THE TIDAL AVERAGE AND THE CRITICAL TIDAL PHASE SUBMERGED DISCHARGE CONDITIONS

Parameter	EXPECTED RANGE[1] Tidal Average	EXPECTED RANGE[1] Critical Tidal Phase	Thermal Criteria
Maximum % Area	6-8	8-10	50
% Width at the Discharge	12-13	16-18	67
Maximum % Width	29-35	40-47	67

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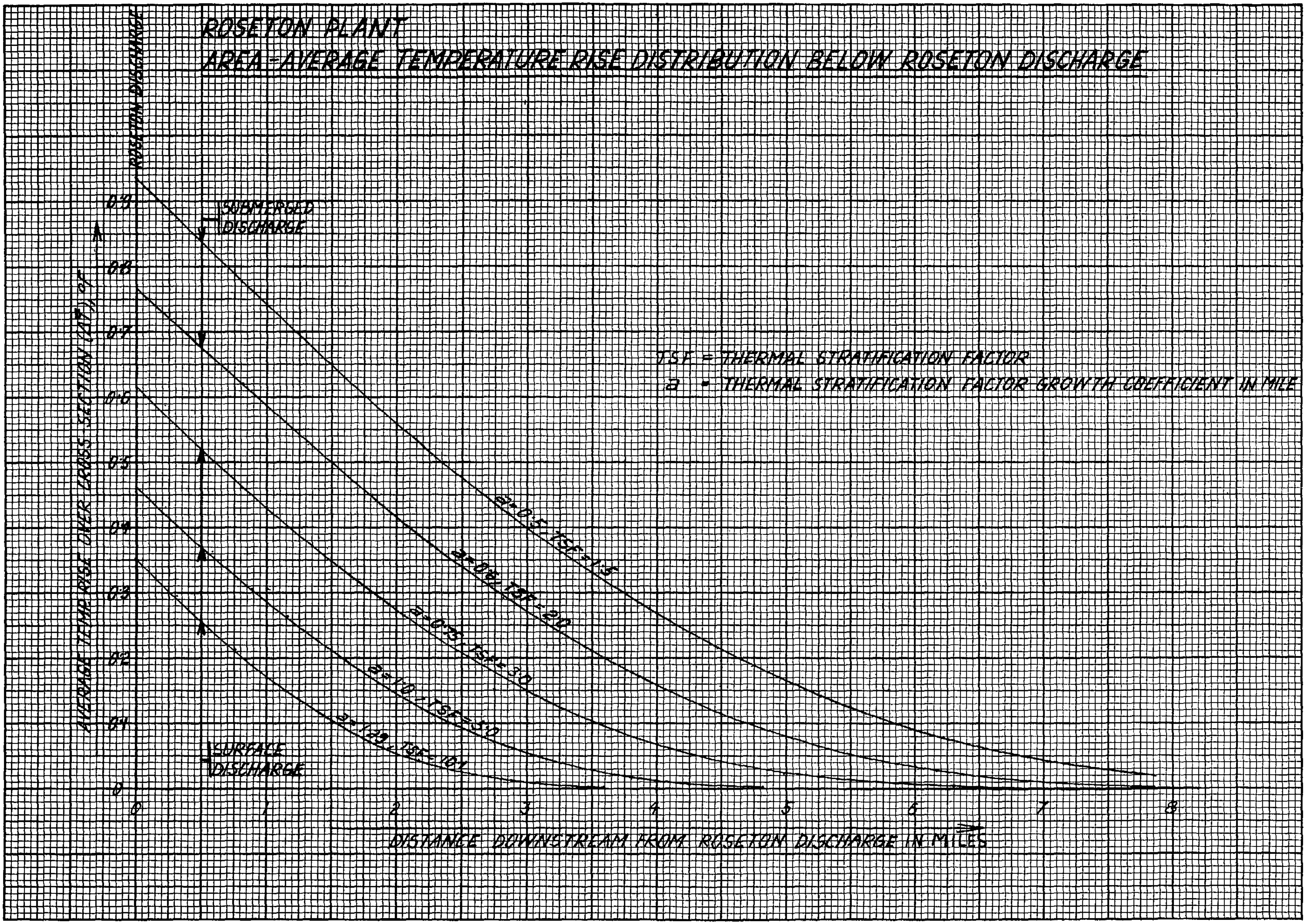
[1] These values were computed using a conservative mathematical model and a TSF_o of 1.5 and 2.0 and a TSF growth coefficient of 0.5 and 0.6/mile.

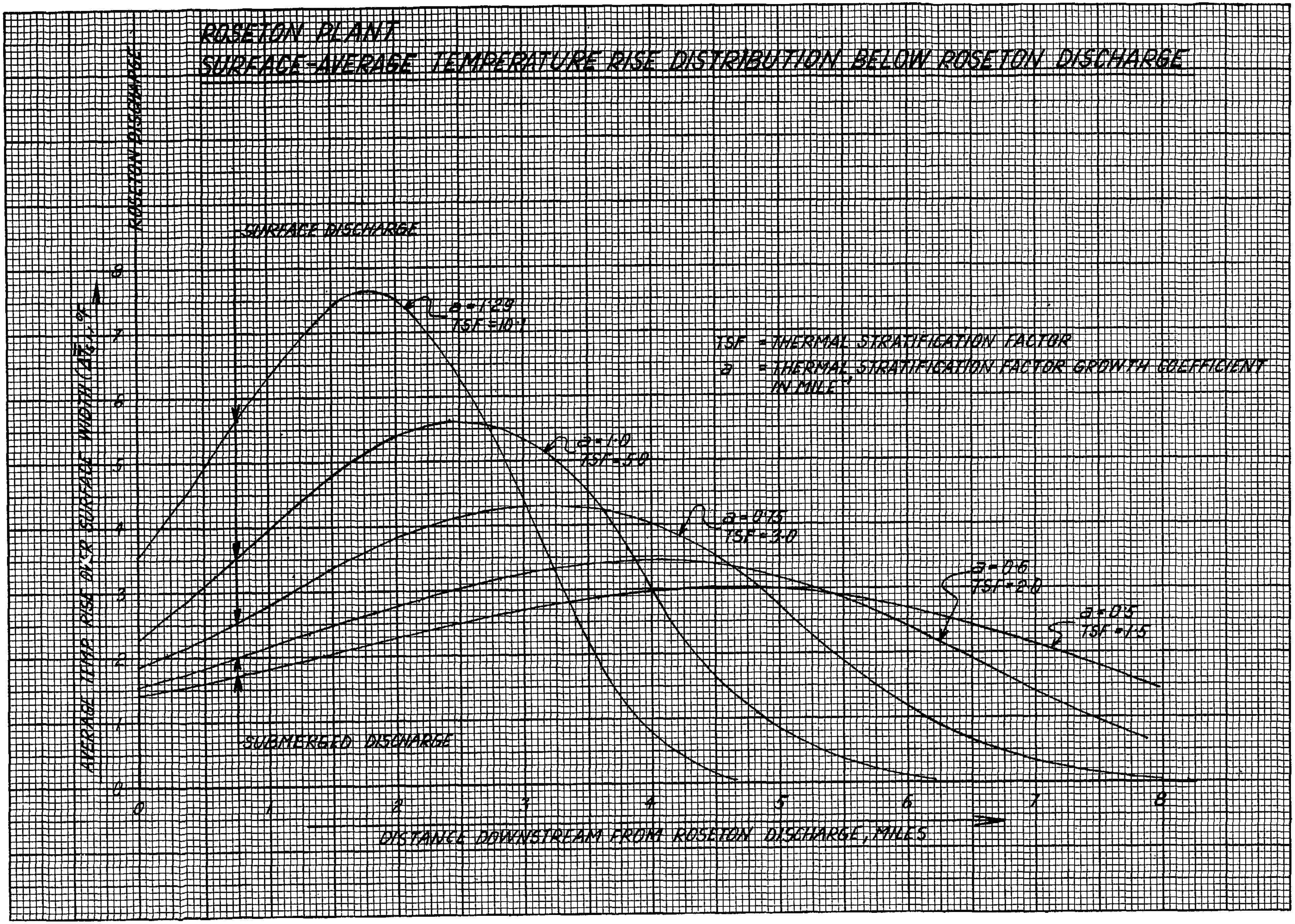


ROSETON PLANT

AREA-AVERAGE TEMPERATURE RISE DISTRIBUTION BELOW ROSETON DISCHARGE

FIGURE 50

FIGURE 51


ROSETON PLANT
SURFACE-AVERAGE TEMPERATURE RISE DISTRIBUTION BELOW ROSETON DISCHARGE

TSF = THERMAL STRATIFICATION FACTOR
a = THERMAL STRATIFICATION FACTOR GROWTH COEFFICIENT IN MILE^{-1}

Figures 52 and 53 superimpose the Danskammer rated capacity effect on a surface discharge and the planned submerged discharge at Roseton.

The effect of the proposed submerged discharge on the Danskammer and Roseton intakes is not expected to be significant. The highly conservative model results show that maximum area-average temperature rise at these locations will be on the order of 1.5°F. This effect was taken into consideration in the computations by increasing the condenser temperature rise by 1°F. In reality, however, much lower rises will be seen at these locations. Further discussion of this effect is given in Chapter IV.

Figure 53-a shows the predictions for the percentage of surface width and cross-sectional area bounded by the 4°F isotherm. These represent the effect of rated capacity operation at Roseton as well as at Danskammer. The values were obtained using the conservative model.

ROSETON PLANT
AREA-AVERAGE AND SURFACE-AVERAGE TEMPERATURE RISE DISTRIBUTION
(RATED CAPACITY - SURFACE DISCHARGE AT ROSETON)

NOTES:
1 - THERMAL STRATIFICATION FACTOR (TSF) AT ROSETON = 10·1
2 - THERMAL STRATIFICATION FACTOR GROWTH COEFFICIENT (a) AT ROSETON = 1·29 mile^{-1}

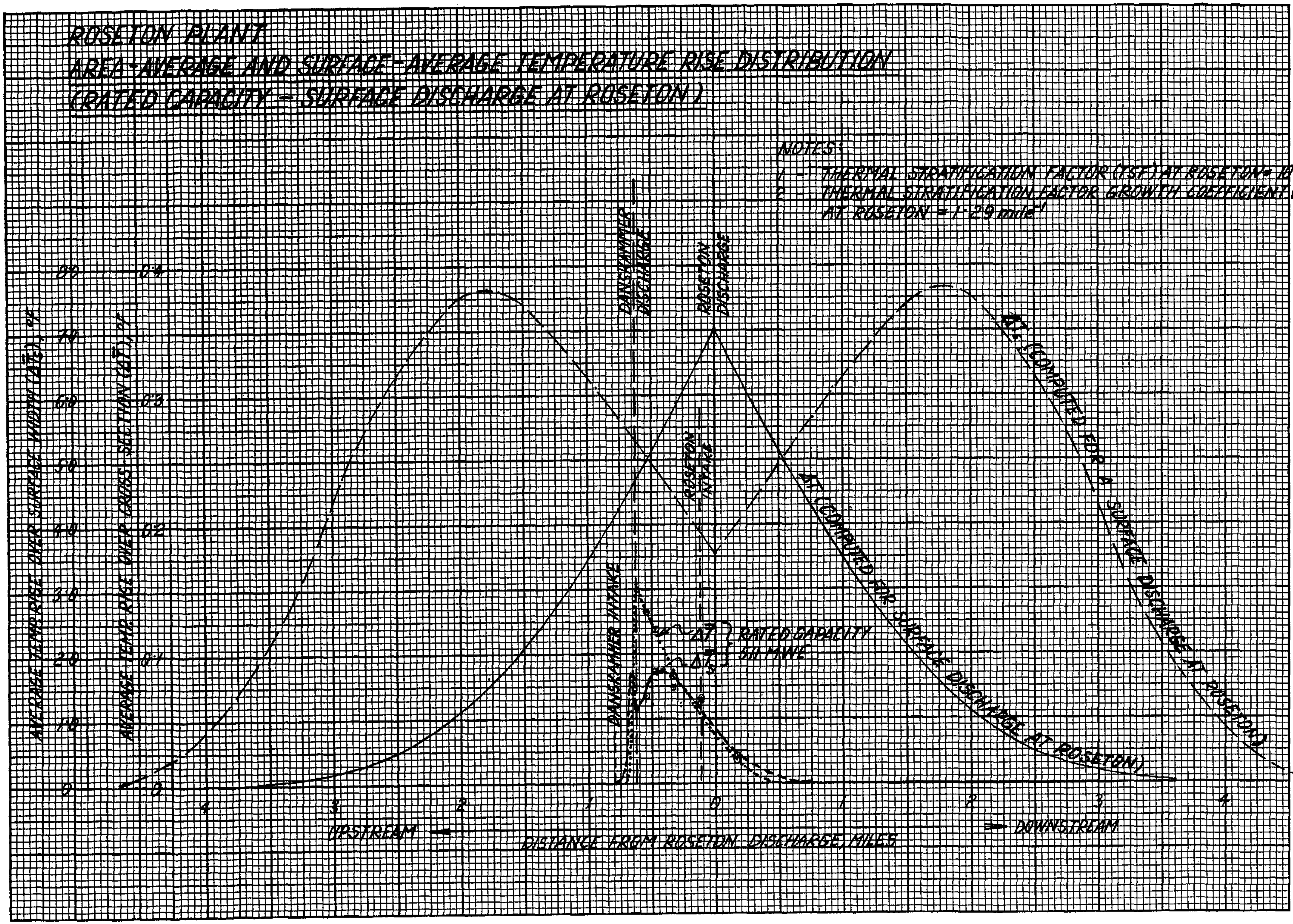
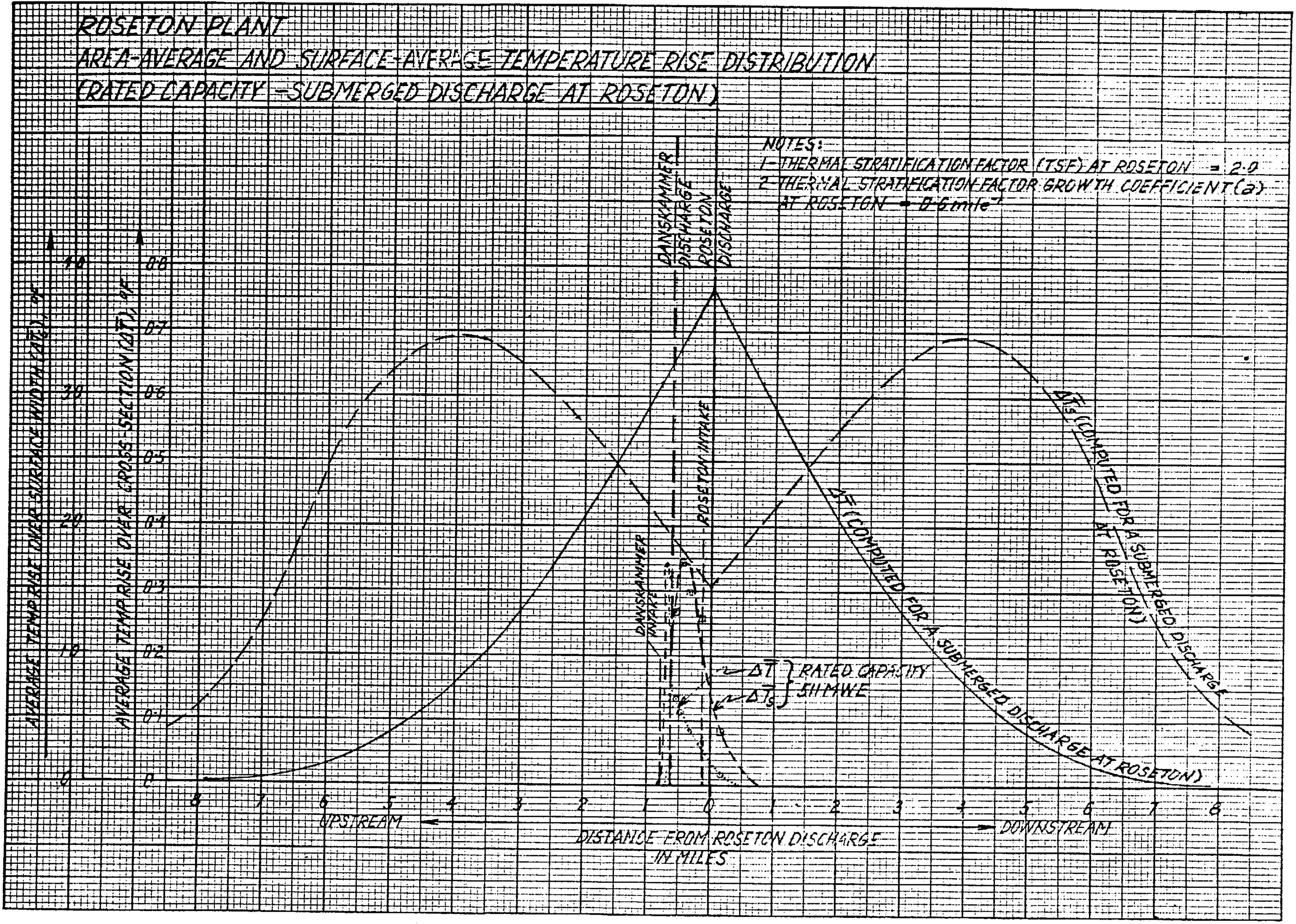


FIGURE 52

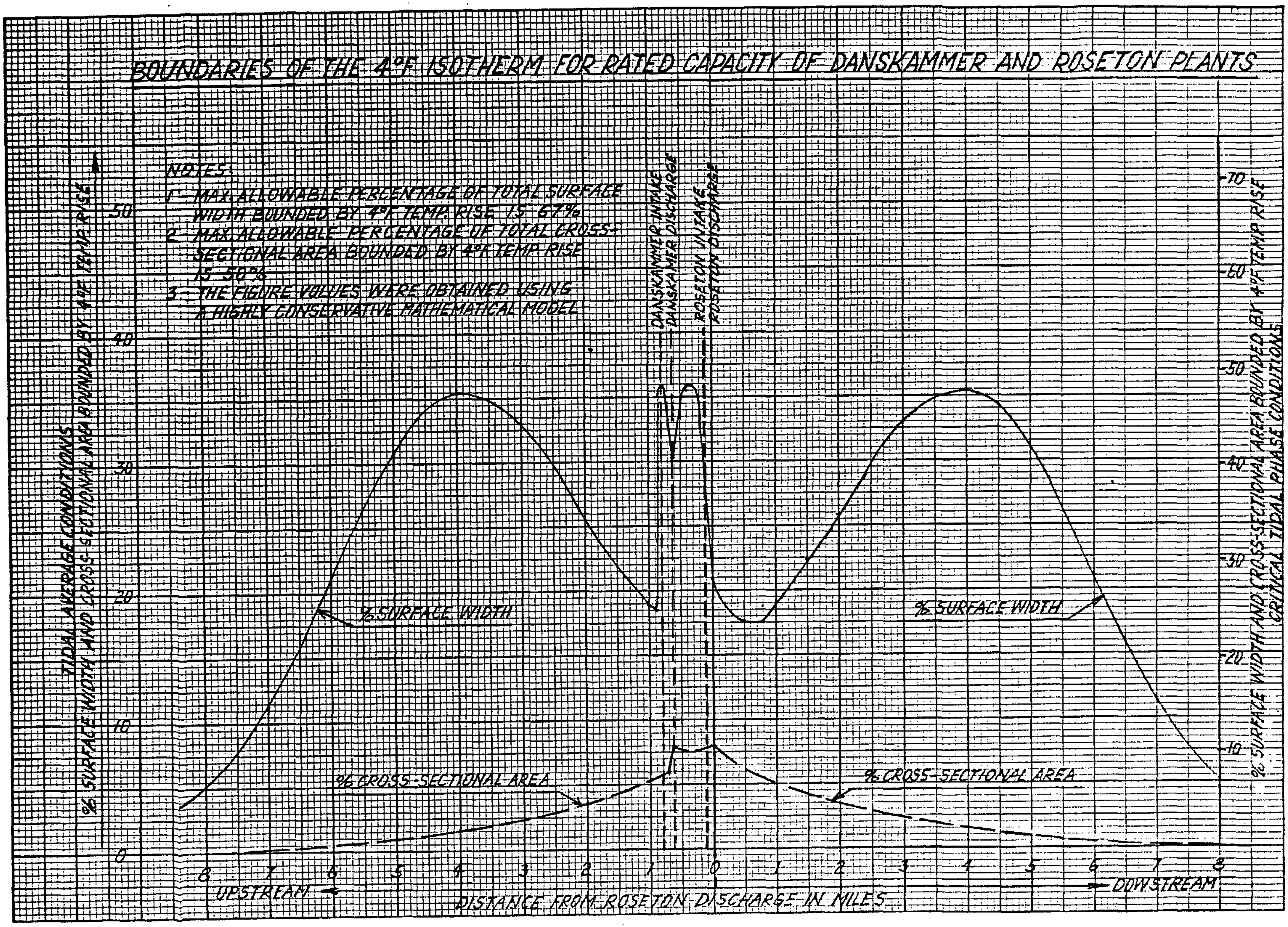
FIGURE 53



ROSETON PLANT
AREA-AVERAGE AND SURFACE-AVERAGE TEMPERATURE RISE DISTRIBUTION
(RATED CAPACITY - SUBMERGED DISCHARGE AT ROSETON)

NOTES:
1 - THERMAL STRATIFICATION FACTOR (TSF) AT ROSETON = 2.0
2 - THERMAL STRATIFICATION FACTOR GROWTH COEFFICIENT (a) AT ROSETON = 0.6 mile⁻¹

FIGURE 53A



BOUNDARIES OF THE 4°F ISOTHERM FOR RATED CAPACITY OF DANSKAMMER AND ROSETON PLANTS

NOTES:
1 - MAX. ALLOWABLE PERCENTAGE OF TOTAL SURFACE WIDTH BOUNDED BY 4°F TEMP. RISE IS 67%
2 - MAX. ALLOWABLE PERCENTAGE OF TOTAL CROSS-SECTIONAL AREA BOUNDED BY 4°F TEMP. RISE IS 50%
3 - THE FIGURE VALUES WERE OBTAINED USING A HIGHLY CONSERVATIVE MATHEMATICAL MODEL

IV. EVALUATION OF ROSETON PLANT SUBMERGED DISCHARGE

A. Introduction

Submerged outlets in the effluent pipe from the Roseton plant are planned for discharging the heated liquid to the River. This type of outfall was selected to insure that the thermal criterion of a 90°F maximum surface water temperature at any point in the River's surface be met at all times. The submerged outfall, by comparison to a surface discharge, will also reduce the percentage of the surface width subjected to temperature rises greater than 4°F.

A mathematical model describing the behavior of a submerged jet in an estuary was developed and successfully programmed for computer solution.

Detailed description of this hydraulic phenomenon and formulation of the mathematical model and computer program are presented in Appendix D.

Basically, the model consists of a set of twelve simultaneous equations describing the principles of the fluid mechanics of submerged jets, and incorporates the effects of plant intake temperature, density and salinity, plant outfall temperature, density, salinity and flow, outfall geometry including port size, shape, edging, orientation, and submergence, and river velocity (both runoff and tidal), tidal phase, and ambient temperature, density and salinity.

Initial jet momentum, induced buoyancy, and entrained river flow and momentum are the major controlling mechanisms accounted for. Drag force and the influence of the river surface and bottom on the expanding jet are not included. However, a procedure for adjusting computed results to account for the boundary and drag effects not included in the mathematical model was developed.

Computer output includes the path of the expanding jet, and at any port along this path, the jet diameter, velocity, density, temperature and dilution factor. Stops are included to indicate when the jet boundary reaches the river surface or bottom and when interference between adjacent jets in a multiple-port design occurs.

Previous applications of this program[3] showed that computed results agreed reasonably well with measurements made in Hudson River undistorted hydraulic model, and in the vicinity of the submerged outfall of Orange and Rockland Utilities' Lovett Unit #4, located at Tomkins Cove on the Hudson River's west bank, less than two miles south of Indian Point.

This mathematical model was used to determine the most efficient design and expected effect of Roseton submerged outfall. Results of this evaluation are documented below.

B. Roseton Submerged Discharge Design

The effect of various submerged outfall designs and depths of submergence was studied in detail.

An outfall design consisting of five slots, located along the river side of the sheet piling of a holding pond at a depth of 20 ft. below the water's surface, and discharging at 15 ft/sec. normal to the river's longitudinal axis was evaluated in detail. This

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[3] Quirk, Lawler & Matusky Engineers, "Effect of Submerged Discharge of Indian Point Cooling Water on Hudson River Temperature Distribution", October, 1969.

outfall configuration, originally discussed with New York State authorities, was based on existing hydraulic model and analytical studies for the Indian Point discharge.

However, during the course of additional detailed studies of this design, a modification from the multi-port sheet piling configuration to a multi-port underwater pipe design was found to be necessary.

Several factors led to this modification. The foundation conditions at Roseton were found to differ substantially from those at Indian Point site and the sheet piling design presented serious difficulties. At Roseton, depth to firm foundation material averages above 100 ft. from the river surface which complicates the sheet piling design. In addition, it was determined that the land side would require sheet piling as well as the water side to protect the railroad embankment.

Large diameter internally braced circular cells were investigated, but did not offer appreciable construction advantages.

An underwater discharge pipe supported on piles and extending out into the river's deeper waters was determined to be considerably less costly. The modified outfall consists of eight circular ports submerged 20 ft. below the water's surface and discharging at 15 ft./sec. normal to the river's longitudinal axis. This configuration was selected after extensive theoretical evaluation of several designs and was found to be more effective in dispersing the heated effluent than the sheet piling design.

In addition, the disturbance to the river's bottom during construction will be reduced and the bottom ultimately taken up by the completed facility will be substantially less. Moreover, the discharge pipe will not appear above the river's surface at all and is thus esthetically far more pleasing than the originally proposed sheet piling design.

For the purpose of illustrating the merits and mechanics of a submerged type of outfall and since an extensive effort was put into the evaluation of the sheet piling design prior to its modification, we have chosen to retain the detailed evaluation of this design.

The results of the theoretical evaluation of the underwater pipe outlet design are documented first. Following this is a description of the sheet piling design and a summary of its effectiveness.

C. Evaluation of the Selected Underwater Pipe Outlet

A detailed study of flow distribution from the outlet ports for several combinations of port sizes favored the selection of the following design:

Effective length of discharge pipe (distance between centerlines of the first and last port) = 210'

Depth of centerline submergence below mean water elevation = 20'

Number of ports = 8

Port size = four 5' diameter and four 4½' diameter

Orientation of ports = 0°, 90°, 90° with lateral, longitudinal and vertical axes, respectively.

Port spacing (centerline to centerline) = 30'

Flow distribution through the ports is tabulated* below.

Port Number	Port Size, ft.	Flow through Port, cfs	Initial Jet Velocity, fps
1 upstream jet	4.5	208.2	17.5
2	4.5	191.5	16.1
3	4.5	177.2	14.9
4	4.5	165.6	13.9
5	5.0	192.2	13.1
6	5.0	181.4	12.3
7	5.0	174.1	11.8
8 downstream jet	5.0	169.8	11.5

---

*Computed by Burns & Roe, Inc., Letter of February 11, 1970.

Details of this design are shown in Figure 54.

A previously developed[4] mathematical model describing the behavior of a submerged jet was used to evaluate the selected design.

The evaluation was based upon the following parameters:

Maximum effluent temperature rise = 18°F

Ambient temperature = 79°F

Maximum discharge temperature = 97°F

Net river velocity	(ebb)	=	1 fps
	(flood)	=	-.9 fps
	(slack)	=	.05 fps

River salinity = 100 ppm

As explained below, these parameters represent a summer condition of maximum severity and were used because summer conditions are considered by many to constitute the critical biological condition.

Expected capacity operation of two units at Roseton will result in a 17°F temperature rise in the 656,000 gpm cooling water flow. All results used in the computations are based on continuous, year round operation at 18°F and 656,000 gpm and represent a severe

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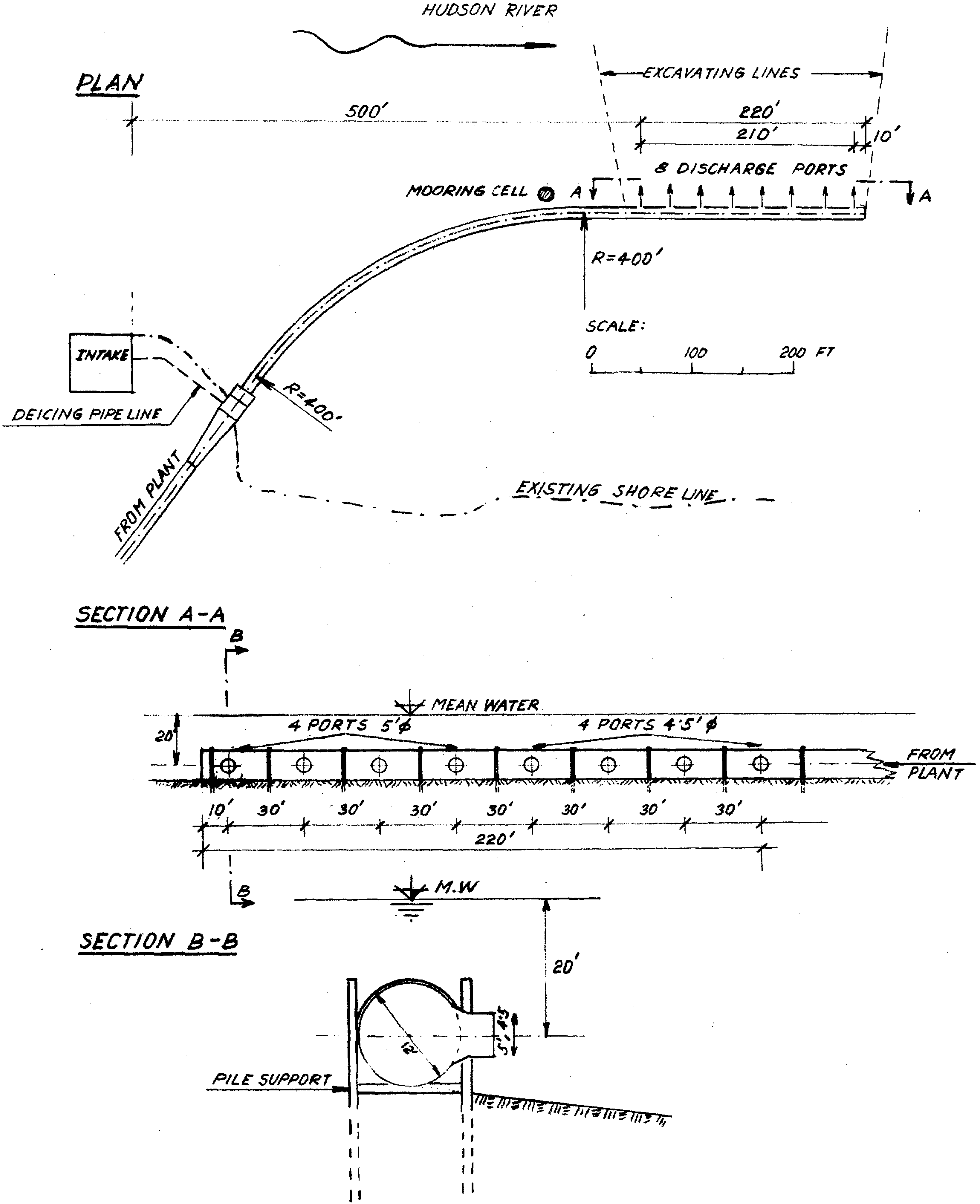
[4] Quirk, Lawler & Matusky Engineers, "Effect of Submerged Discharge of Indian Point Cooling Water on Hudson River Temperature Distribution", October, 1969.

FIGURE 54

ROSETON PLANT - SUBMERGED DISCHARGE DESIGN *



* THE DESIGN IS TAKEN FROM BURNS & ROE, INC. DRAWING OF 3/13/70

loading condition. This heat load is 6% higher than that associated with the maximum possible 2 unit electrical output (stretch rating). Planned operation, however, is lower than this value.

The use of temperature rise of 18°F will also account for the temperature rises that will be caused by Danskammer plant operation and seen at Roseton intake. This effect, however, is for less than 1°F. Danskammer measurements, presented in the previous chapter, showed that temperature rises caused by the Danskammer plant are only seen in the upper five feet of water. These measurements also showed that no more than an area average temperature rise of about .05°F is seen at the Roseton intake.

As will be shown later, the effect of the Roseton discharge on the intake is negligible. Roseton intake facility, however, will include a skimmer wall extending to 4.5 ft. below the water surface and is designed to withdraw water from this elevation to 26 ft. below mean low water elevation.

Taking a hypothetical case in which no skimmer wall is used, and the measured surface average temperature rise of 1.1°F is experienced by an upper layer of five feet in thickness, the theoretical effect of Danskammer operation on Roseton intake may then be computed as follows:

Net intake temperature rise = (temperature rise of upper layer X depth of upper layer + temperature rise of lower layer X depth of lower layer)/total depth of intake.

$$= (1^{\circ}X5'+0^{\circ}X20')/25' = 0.2^{\circ}F$$

This hypothetical value is only 20% of that used in the computation. The use of plant temperature rise of 18°F, therefore, represents the most severe condition that can be expected.

The maximum river water ambient temperature used in this evaluation is 79°F. This value is considered to be the highest ambient water temperature that will be seen by the intake at any time. Ambient water temperature does not reach this value every year. For example, the maximum ambient water temperature observed in the vicinity of Roseton last summer occurred in August and was 77.5°F.

The net river velocities of 1.0 fps during ebb, -.9 fps during flood and .05 fps during slack conditions used in the computation represent a long term summer time average for the vicinity of Roseton.

A salinity of 100 ppm was used so that no advantage is taken of the high salinity-induced mixing associated with high ocean-derived salinity concentrations.

Computer printouts for this critical summer condition corresponding to ebb phase for the 5' diameter and 4½' diameter jets are shown in Plates I and II respectively.

Figures 55 and 56 depict the details of the computed lateral, vertical and longitudinal location of the 5' diameter jets for ebb phase conditions. The corresponding locations of the 4½' diameter jets are shown in Figures 57 and 58.

The jet boundaries shown in these figures represent the vertical and longitudinal projections of the computed jet sizes at different locations. The computed jet velocities and dilution ratios are shown in Figures 56 and 58. Stops indicating when the jet's upper boundary and centerline reach the river's surface, and when interference between adjacent jets occurs are also located on Figures 55 through 58.

In order to minimize the interference between the lower boundary of the jets and the bottom of the river, the area bounded by

ROSETON PLANT SUBMERGED DISCHARGE (5'ϕ)
MOST SEVERE SUMMER CONDITIONS
EBB TIDE

PLATE I
SHEET 1 OF 3

```
THOUTC    16:40   RDS2  MARCH 18, 1970

      ANG        VR

     90.00      1.00

      DS         C1         C2         C3        YLIM       DDCI

     0.10       0.16       0.20       31.[illegible]     20.00      0.0500

      DO         VO        COSX       COSY       COSZ

     5.00      12.18      1.00       0.00       0.00

      TO        TRIV       SALO       SALR

    97.00      79.00      0.10       0.10


      S          X          Y          Z          D        V   TEMP  TEMP          DIL
                                                                BY    BY
                                                               DIL   DEN

    10.0      10.0       0.0        0.0        3.2      7.4  90.0  89.7         1.[illegible]4

T=         89.758S=            0.10RHO=              1.929
    20.0      20.0       0.2        1.1       11.4      5.4  36.9  36.6         2.29

T=         86.630S=            0.10RHO=              1.930
    30.0      29.9       0.5        2.5       14.6      4.2  35.1  34.9         2.94

T=         84.900S=            0.10RHO=              1.931
    40.0      39.7       0.9        4.4       13.5      3.0  33.3  3[illegible].6         3.76

T=         83.613S=            0.10RHO=              1.931
    50.0      49.3       1.6        7.0       22.5      2.8  32.9  32.8         4.62

T=         82.774S=            0.10RHO=              1.932
    60.0      53.7       2.4       10.2       26.5      2.4  32.3  32.2         5.50
```

At next line of output, jet interference occurs

```
T=         82.197S=            0.10RHO=              1.932
    70.0      57.9       3.6       13.9       30.5      2.1  31.8  31.8         6.41

T=         81.777S=            0.10RHO=              1.93[illegible]
```

PLATE I
SHEET 2 OF 3

```
AT NEXT LINE [illegible] OUTPUT JET INTERSECTED SURFACE
```

i.e.) Upper boundary reaches surface

```
      74.0     71.6      4.1     15.5    32.1    2.0  81.7  81.6      6.79

      80.0     76.9      5.0     18.1    34.5    1.9  81.4  81.4      7.37

T=         81.447S=         0.10RHO=          1.932
      90.0     85.5      6.7     22.9    38.5    1.7  81.1  81.1      8.39

T=         81.153S=         0.10RHO=          1.932
     100.0     93.8      8.7     28.1    42.5    1.6  80.9  80.9      9.46

T=         80.924S=         0.10RHO=          1.932
     110.0    101.7     10.9     33.8    46.5    1.5  80.7  80.7     10.61

T=         80.727S=         0.10RHO=          1.932
     120.0    109.0     13.4     39.9    50.5    1.4  80.5  80.5     11.84

T=         80.556S=         0.10RHO=          1.932
     130.0    116.3     16.2     46.2    54.5    1.3  80.4  80.4     13.15

T=         80.409S=         0.10RHO=          1.932
```

PLATE I
SHEET 3 OF 3

```
READY
LISTNH
00010
00020
00030
00040
00050          S        D     DIRECTION COSINES     RADIUS PROJECTIONS ON
00060                         X-AXIS  Y-AXIS  Z-AXIS  X-AXIS  Y-AXIS  Z-AXIS
00070
00080        10.0     8.2 0.99346 0.06859 0.05479      0.2     4.1     4.1
00090
00100        20.0    11.4 0.99380 0.02057 0.10929      0.6     5.7     5.7
00110
00120        30.0    14.6 0.98602 0.08573 0.16277      1.2     7.3     7.2
00130
00140        40.0    18.5 0.97253 0.15405 0.22620      2.2     9.9     9.0
00150
00160        50.0    22.5 0.95470 0.17563 0.28779      3.4    11.2    10.7
00170
00180        60.0    26.5 0.93026 0.10002 0.34553      4.8    13.2    12.4
00190      At next line of output, jet interference occurs
00200        70.0    30.5 0.90320 0.16175 0.39333      6.7    15.1    14.8
00210
00220
00230
00240  AT NEXT LINE OF OUTPUT JET INTERSECTED SURFACE
00250      i.e.) Upper boundary reaches surface
00260
00270        74.0    32.1 0.89749 0.10799 0.41890      7.1    15.9    14.6
00280
00290        80.0    34.5 0.87971 0.15514 0.44950      8.2    17.1    15.4
00300
00310        90.0    38.5 0.84531 0.13047 0.50179     10.3    18.9    16.7
00320
00330       100.0    42.5 0.80960 0.21163 0.54750     12.5    20.8    17.3
00340
00350       110.0    46.5 0.77126 0.23862 0.59010     14.8    22.6    18.3
00360
00370       120.0    50.5 0.73034 0.26349 0.60944     17.0    24.4    19.6
00380
00390       130.0    54.5 0.69007 0.28616 0.66477     19.7    26.1
```

DYE

```
OFF AT 17:58
```

PLATE II
SHEET 1 OF 3

ROSETON PLANT SUBMERGED DISCHARGE (4·5'ϕ)
MOST SEVERE SUMMER CONDITIONS
EBB TIDE

```
THOUT3     10:20    RDS2   FEBRUARY 24, 1970

          ANG         VR

        90.00        1.00

           DS         C1          C2          S2        YLIM        DDGI

         0.10       0.16        0.20       27.90       20.00      0.0500

           DO         VO        COSX        COSY        COSZ

         4.50      15.60        1.00        0.00        0.00

           TO       TRIV        SALO        SALR

        97.00      79.00        0.10        0.10


         S          X          Y          Z         D       V   TEMP   TEMP         DIL
                                                                  BY     BY
                                                                 DIL    DEN
STAT

RUNNING

      10.0      10.0       0.0        0.2      7.7     9.1   89.5   90.0         1.71


T=         90.032S=          0.10RHO=          1.929
STAT

RUNNING

      20.0      20.0       0.1        0.8     10.9     6.4   86.4   87.0         2.43


T=          87.053S=         0.10RHO=          1.930
      30.0      29.9       0.3        1.9     14.3     4.9   84.6   85.2         3.19


T=          85.245S=         0.10RHO=          1.931
      40.0      39.8       0.6        3.5     18.3     3.9   83.4   83.8         4.10


T=          83.783S=         0.10RHO=          1.931
      50.0      49.5       1.1        5.6     22.3     3.2   82.6   82.9         5.04


T=          82.868S=         0.10RHO=          1.932
      60.0      59.1       1.8        8.4     26.3     2.7   82.0   82.2         5.99
```

PLATE II
SHEET 2 OF 3

At next line of output, jet interference occurs

```
T=        82.245S=          0.10RHO=          1.932
      70.0     68.5      2.6     11.6     30.3     2.4   81.6   81.8      6.98

T=        81.795S=          0.10RHO=          1.932

 AT NEXT LINE OF OUTPUT JET INTERSECTED SURFACE
```

i.e., Upper boundary reaches surface

```
      77.7     75.6      3.5     14.5     33.3     2.2   81.3   81.5      7.76

      80.0     77.7      3.7     15.4     34.3     2.1   81.3   81.4      8.00

T=        81.456S=          0.10RHO=          1.932
      90.0     86.7      5.0     19.6     38.3     1.9   81.0   81.2      9.05

T=        81.192S=          0.10RHO=          1.932
     100.0     95.4      6.6     24.3     42.3     1.8   80.8   80.9     10.16

T=        80.962S=          0.10RHO=          1.932
     110.0    103.8      8.4     29.4     46.3     1.7   80.6   80.7     11.33

T=        80.766S=          0.10RHO=          1.932
     120.0    111.9     10.4     34.9     50.3     1.6   80.4   80.6     12.55

T=        80.606S=          0.10RHO=          1.932
     130.0    119.7     12.7     40.7     54.3     1.5   80.3   80.4     13.86

T=        80.458S=          0.10RHO=          1.932
     140.0    127.1     15.2     47.0     58.3     1.4   80.2   80.3     15.23

T=        80.334S=          0.10RHO=          1.932
     150.0    134.2     17.8     53.5     62.3     1.4   80.1   80.2     16.69

T=        80.220S=          0.10RHO=          1.932
        ANG          VR

      180.00       0.05
```

PLATE II
SHEET 3 OF 3

```
        S        D     DIRECTION COSINES     RADIUS PROJECTIONS ON
                    X-AXIS  Y-AXIS  Z-AXIS  X-AXIS  Y-AXIS  Z-AXIS

      10.0      7.7 0.99912 0.00559 0.04156     0.2     3.8     3.8

      20.0     10.9 0.99647 0.01410 0.08277     0.5     5.4     5.4

      30.0     14.3 0.99147 0.02555 0.12779     0.9     7.1     7.1

      40.0     18.3 0.98145 0.03978 0.18754     1.8     9.1     9.0

      50.0     22.3 0.96784 0.05656 0.24514     2.8    11.1    10.8

      60.0     26.3 0.95094 0.07558 0.30001     4.1    13.1    12.5
```

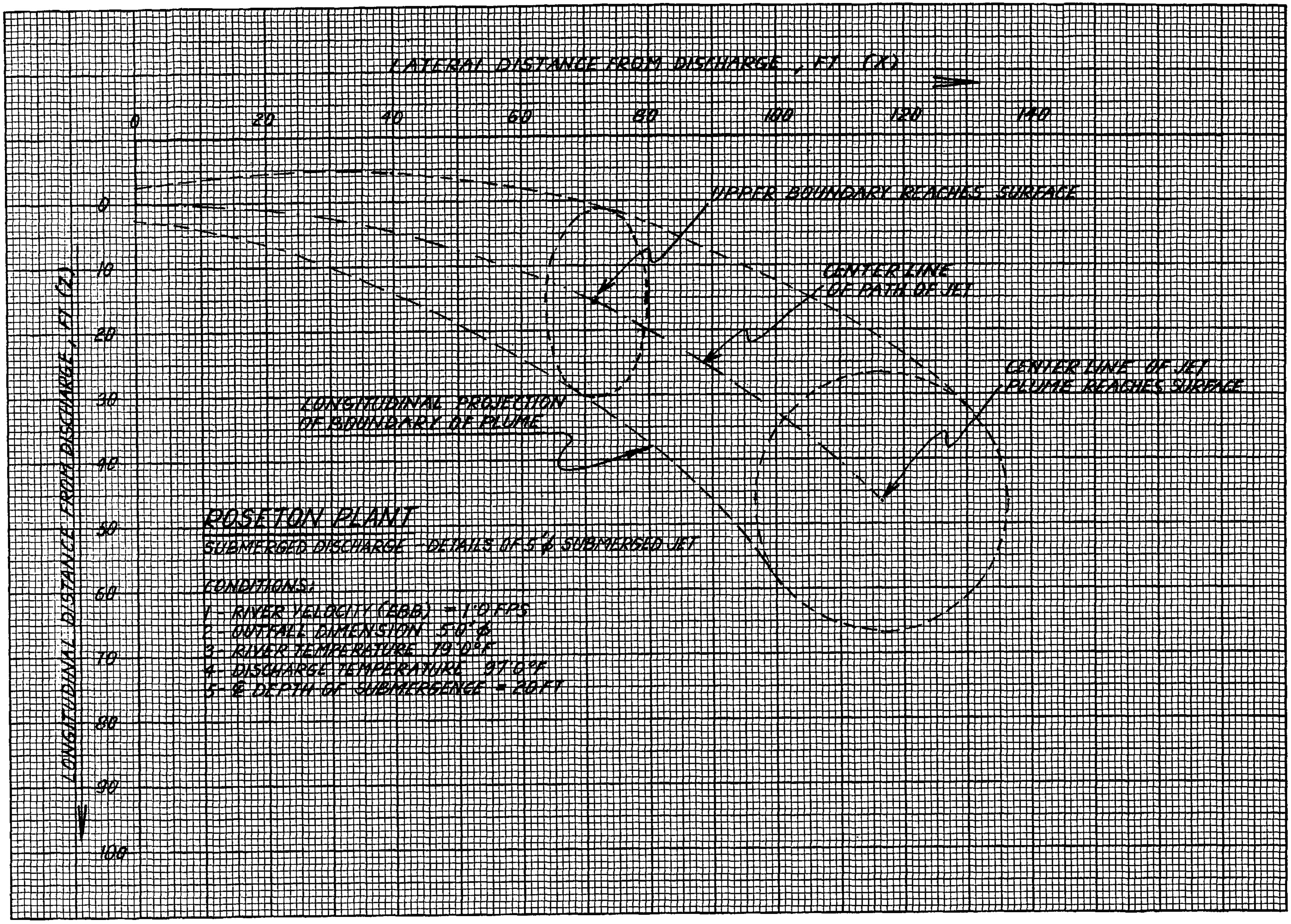
At next line of output, jet interference occurs

```
      70.0     30.3 0.93113 0.09653 0.35168     5.5    15.1    14.2



 AT NEXT LINE OF OUTPUT JET INTERSECTED SURFACE
```

i.e.) Upper boundary reaches surface

```
      77.7     33.3 0.91416 0.11376 0.38906     6.8    16.6    15.4

      80.0     34.3 0.90884 0.11907 0.39979     7.1    17.0    15.7

      90.0     38.3 0.88450 0.14290 0.44411     8.9    18.9    17.1

     100.0     42.3 0.85632 0.16719 0.48864    10.9    20.8    18.4

     110.0     46.3 0.82553 0.19123 0.53097    13.1    22.7    19.6

     120.0     50.3 0.79414 0.21504 0.56842    15.3    24.5    20.7

     130.0     54.3 0.75943 0.23730 0.60577    17.7    26.4    21.6

     140.0     58.3 0.72500 0.25844 0.63843    20.1    28.1    22.4

     150.0     62.3 0.68899 0.27743 0.66958    22.6    29.9    23.1
```

FIGURE 55



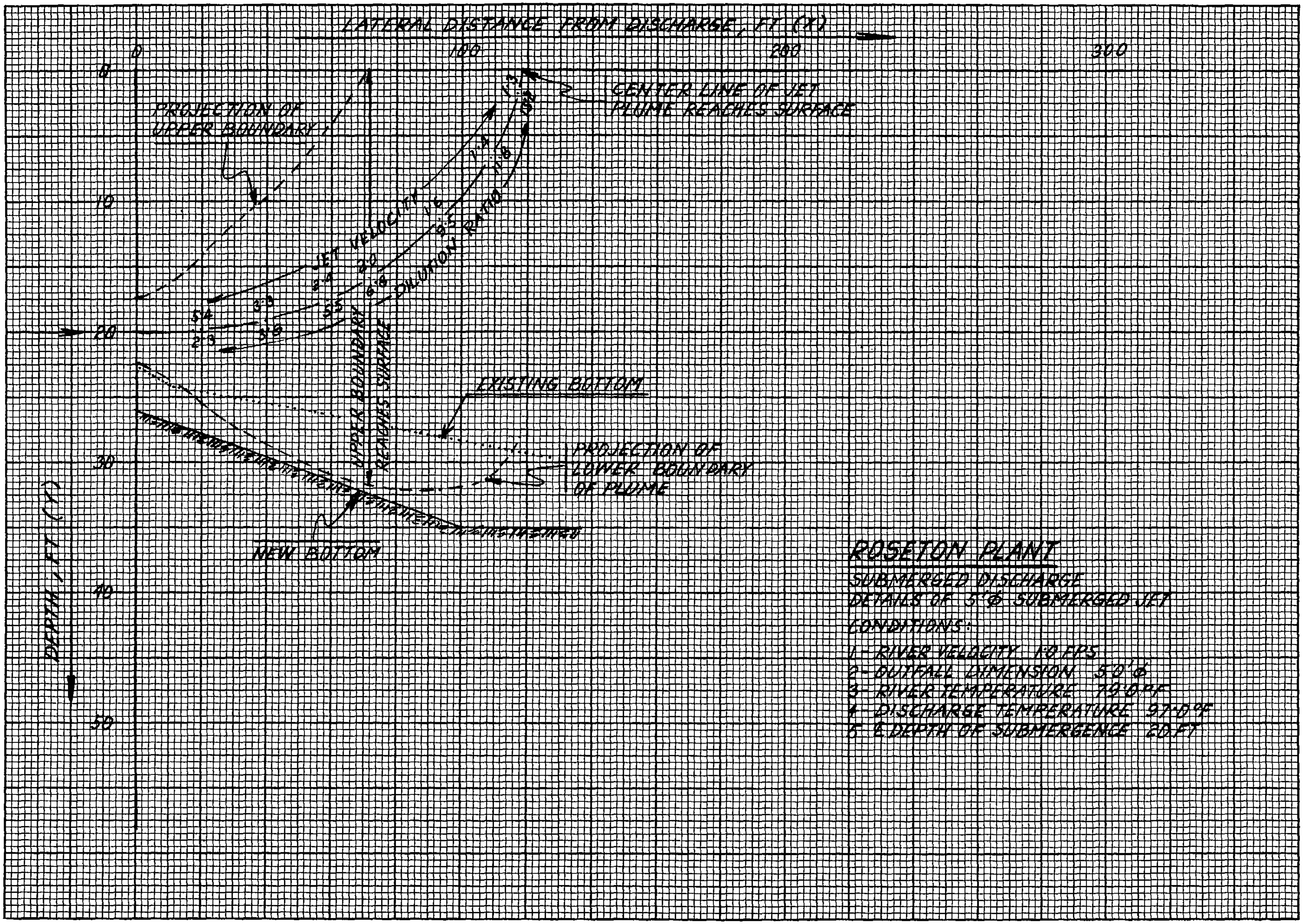
ROSETON PLANT

SUBMERGED DISCHARGE - DETAILS OF 5' ɸ SUBMERGED JET

CONDITIONS:

1 - RIVER VELOCITY (EBB) = 1.0 FPS
2 - OUTFALL DIMENSION 5.0' ɸ
3 - RIVER TEMPERATURE 79.0°F
4 - DISCHARGE TEMPERATURE 97.0°F
5 - ℄ DEPTH OF SUBMERGENCE = 20 FT

FIGURE 56



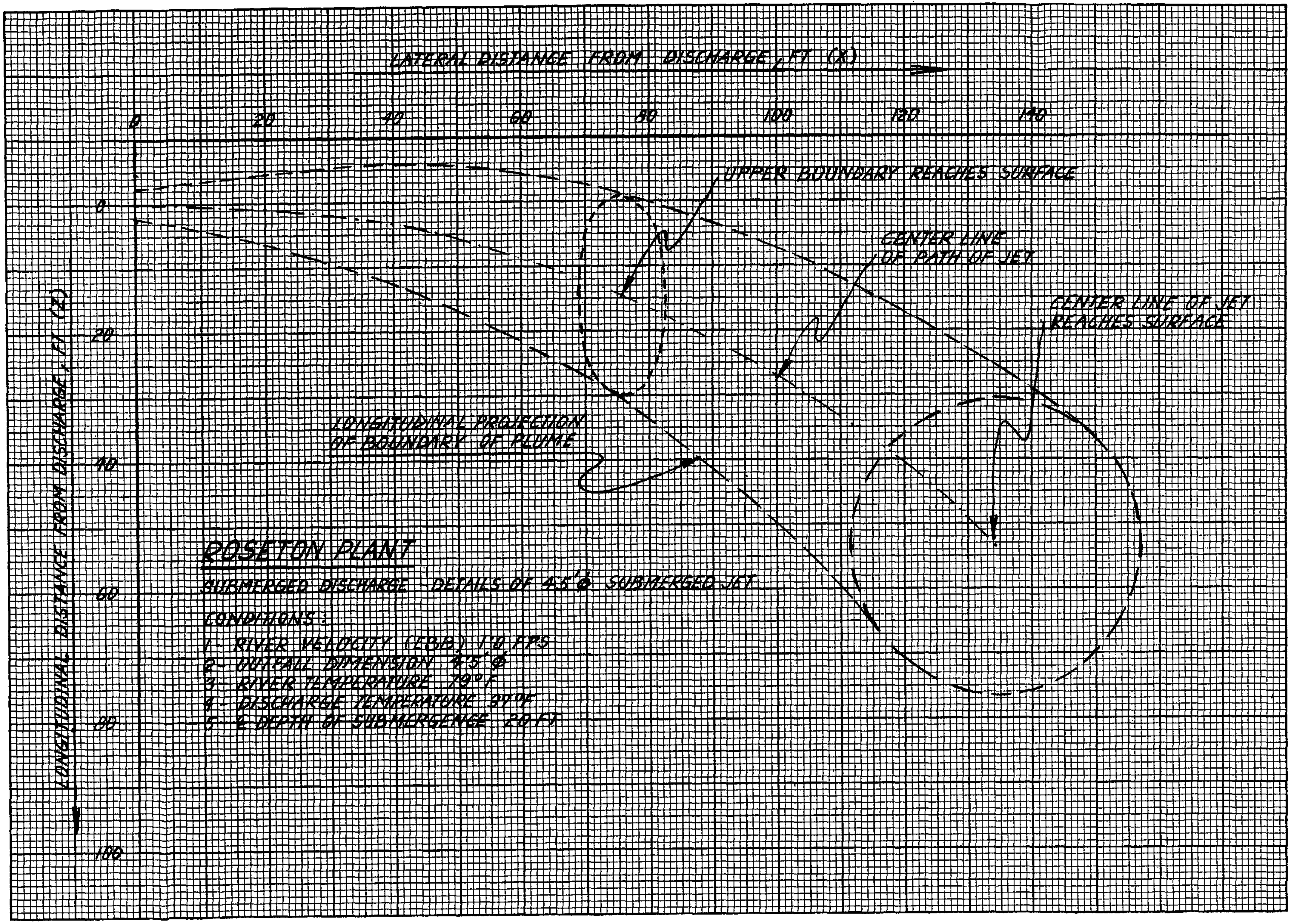
ROSETON PLANT

SUBMERGED DISCHARGE
DETAILS OF 5'Ø SUBMERGED JET

CONDITIONS:

1 - RIVER VELOCITY 1.0 FPS
2 - OUTFALL DIMENSION 5.0'Ø
3 - RIVER TEMPERATURE 79.0°F
4 - DISCHARGE TEMPERATURE 97.0°F
5 - ℄ DEPTH OF SUBMERGENCE 20 FT

FIGURE 57



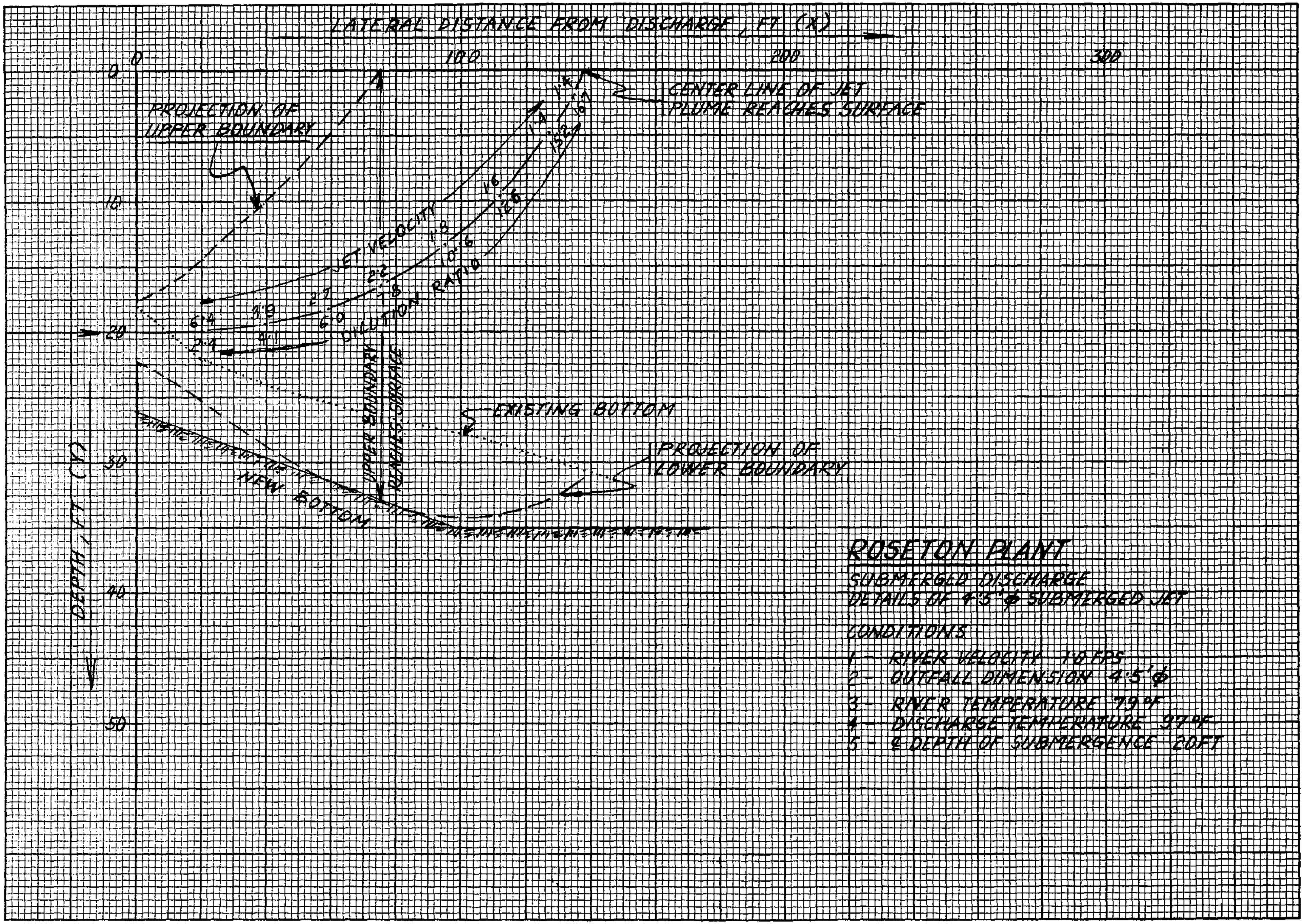
ROSETON PLANT

SUBMERGED DISCHARGE - DETAILS OF 4.5'Φ SUBMERGED JET

CONDITIONS:

1 - RIVER VELOCITY (EBB) 1.0 FPS
2 - OUTFALL DIMENSION 4.5'Φ
3 - RIVER TEMPERATURE 79°F
4 - DISCHARGE TEMPERATURE 97°F
5 - ℄ DEPTH OF SUBMERGENCE 20 FT

FIGURE 58



ROSETON PLANT

SUBMERGED DISCHARGE
DETAILS OF 4.5'Φ SUBMERGED JET

CONDITIONS
1 - RIVER VELOCITY 1.0 FPS
2 - OUTFALL DIMENSION 4.5'Φ
3 - RIVER TEMPERATURE 79°F
4 - DISCHARGE TEMPERATURE 97°F
5 - ℄ DEPTH OF SUBMERGENCE 20FT

dashed lines in Figure 54 will have to be dredged, during construction, to the depths shown in Figures 56 and 58.

Jet interference between adjacent jets occurs when the plume diameter exceeds center to center port spacing, which, in this design, is 30 feet. The upper boundary reaches the surface when the vertical projection of the jet's radius exceeds the difference between the depth of submergence and the vertical location of the jet. The lower boundary hits the river's bottom, when the vertical projection of the jet's radius is greater than the difference between the water depth and the vertical elevation of the jet's centerline. The centerline of the plume reaches the surface when the vertical location of the plume is equal to the depth of submergence to the port centerline. For convenience, these four locations will be referred to, in this report, as the interference, surface boundary, bottom boundary and centerline surface controls.

Dilution ratios for the two different jets, associated with these four controls, are summarized in Table 9. The values appearing under the bottom boundary control in the table were taken from the corresponding computer printout values. In terms of vertical distance, these values represent the characteristics at the location where the vertical projection of the jet's radius is

TABLE 9

SUMMARY OF DILUTION RATIOS ASSOCIATED WITH CONTROL LOCATIONS AT ROSETON (EBB CONDITIONS)

	Interference Control	BOUNDARY CONTROL Upper	BOUNDARY CONTROL Lower	Centerline Surface Control
Port Size: 5' diameter				
	6.41	6.79	7.32	14.80
Port Size: 4½' diameter				
	6.98	7.76	8.00	16.69

1. Location where jet interference occurs.
2. Location where upper boundary reaches the surface.
3. Location where lower boundary hits the river's bottom.
4. Location where jet centerline reaches the surface.

equal to the difference between a water depth of 35 ft. and the vertical elevation of the jet's centerline. Such location will usually occur at a lateral distance of some 50 to 80 ft. from the plane of discharge.

The jet interference control dilution ratios represent the absolute minimum expected dilution. On the other hand, the values associated with the centerline surface control, i.e., when the centerline of the plume reaches the surface, are indicative of the dilution ratios in cases where the influence of drag force and the river surface and bottom on the expanding jets are not significant. The values associated with the surface boundary and bottom controls represent two different intermediate ranges.

For the purpose of showing the most extreme effect of Roseton discharge, the minimum dilution ratios associated with the jet interference control were used in this study. In other words, the computations ignore any dilution occurring beyond the location where the adjacent jets interfere with each other at some 70' off the discharge pipe. In reality, however, entrainment of the river water into the individual jets will occur beyond this location, due to the availability of large volumes of ambient water in the remaining portion of the river's cross-section.

The program results show that the absolute minimum expected dilution ratio ranges from 6.37 to 6.98, depending upon the size of the port, for ebb conditions. The ratios associated with other tidal phases are essentially the same as the ebb values. A weighted average dilution ratio of the eight jets is:

$$6.5 = \frac{6.37 \text{ X } \frac{\pi}{4} \text{ X } 25 + 6.98 \text{ X } \frac{\pi}{4} \text{ X } 20.25}{(25 + 20.25)\ \frac{\pi}{4}}$$

The average surface temperature rise over the entire plume is then computed as follows:

$$\text{Average temperature rise} = \frac{\text{maximum plant temperature rise}}{\text{weighted average dilution ratio}}$$

$$= \frac{18}{6.5} = 2.78^{\circ}\text{F}$$

This value may be compared to the average surface temperature rise over the river's width of 3.5°F computed using the variable TSF model.

A series of temperature rise isotherms may be constructed using this temperature rise value and assuming an appropriate temperature distribution function across the plume's surface.

Figure 59 shows the relative locations of the eight jets. The locations where the upper boundary and the centerline of the individual jets reach the surface are also indicated on the figure. Since the jets are spaced on 30 ft. centers some interference between the jets is expected to occur. The computed size of the plume resulting from all of the jets is also shown.

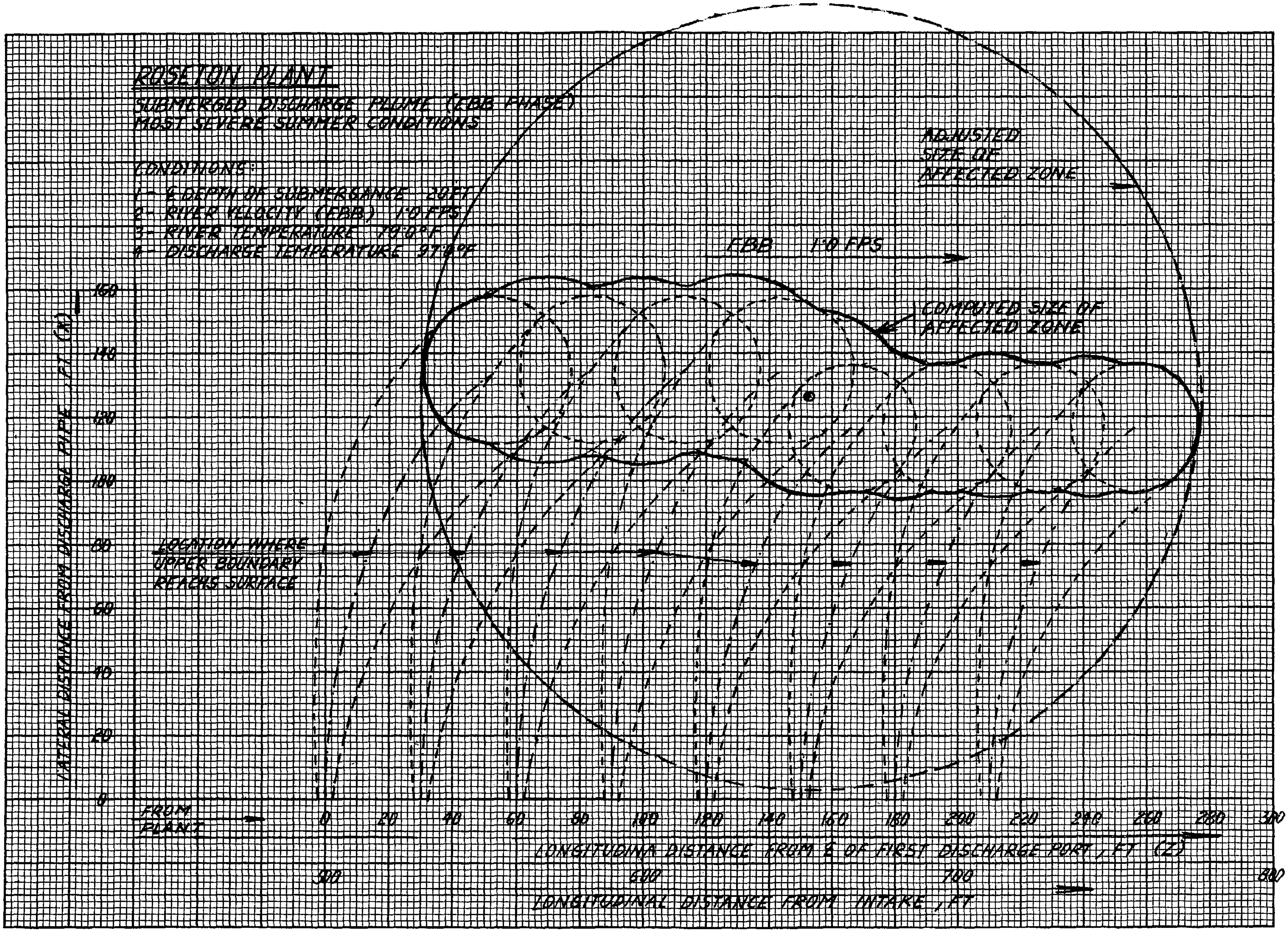
The theoretical size of the plume is very small due to the fact that the mathematical model does not take into account the boundary effects. A description of a procedure accounting for these effects follows:

1. Move the near shore extent of the surface area expected to be affected by temperature rises in excess of the jet boundary temperature back to the location where the upper boundary of the jets reaches the surface.

2. Assume that the shape of the affected zone is circular having a centroid equivalent to that of the theoretical area.

3. Assume that the radius of the affected area is equal to the maximum computed distance between the centroid and the theoretical boundary of the plume.

FIGURE 59


ROSETON PLANT
SUBMERGED DISCHARGE PLUME (EBB PHASE)
MOST SEVERE SUMMER CONDITIONS
CONDITIONS:
1 - ℄ DEPTH OF SUBMERGANCE 20FT
2 - RIVER VELOCITY (EBB) 1.0 FPS
3 - RIVER TEMPERATURE 79.0°F
4 - DISCHARGE TEMPERATURE 97.0°F
ADJUSTED SIZE OF AFFECTED ZONE
EBB 1.0 FPS
COMPUTED SIZE OF AFFECTED ZONE
LOCATION WHERE UPPER BOUNDARY REACHS SURFACE
LATERAL DISTANCE FROM DISCHARGE PIPE, FT (X)
160
140
120
100
80
60
40
20
0
FROM PLANT
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
LONGITUDINA DISTANCE FROM ℄ OF FIRST DISCHARGE PORT, FT (Z)
500
600
700
800
LONGITUDINAL DISTANCE FROM INTAKE, FT

The modified affected area is shown by a broken circle on Figure 59. Notice that this area encloses a zone greater than its computed counterpart.

The maximum surface temperature rise may be computed by assuming that the resultant plume is circular in shape and that the temperature distribution between the maximum value and an ambient temperature follows a cosine function, or:

$$\Delta T_{max} = (\Delta \overline{T}_s) \frac{\pi^2}{4(\pi-2)} = 2.78 \text{ X } 2.16 = 6^{o}F$$

Temperature rises higher than this computed value by about 1°F may be seen at the surface.

The computed longitudinal extent and lateral distance from shore bounded by the jet's plume indicate that the effect of the submerged discharge on the Roseton and the Danskammer intakes is expected to be negligible.

These predictions as well as the conservative variable TSF results also indicate that the effect of the Roseton discharge is not expected to be seen at the New York City pumping station at Chelsea, which is located on the opposite shore of the river some 4,000 ft. northeast of Roseton.

These results seem to be on the liberal side when compared to the prediction of the variable TSF model presented in Chapter III. The following comments apply to the disagreement between the results of these models:

1. The variable TSF model gives very conservative results beyond the plane of discharge. In the case of Danskammer, for example, the computed results are more than five times greater than their measured counterparts at a distance of one mile downstream of the discharge.

2. The submerged discharge model does not take into account the effect of drag force and the influence of the river surface and bottom on the expanding jet. Also, this model ignores the existence of a heated layer at the surface. The variable TSF model showed that there would be an upper layer having a thickness of no more than 20 ft. and an average surface temperature of about 1.5^{O}F at the plane of discharge. The thickness of this layer decreases radically as one moves away from the discharge. For example, the variable TSF model showed that the thickness of this layer would decrease to less than 2 ft. at a distance of about 4 miles away from the plant. The surface-average temperature rise at this location would be about 3.5^{O}F.

A behavior similar to this is to be expected since the elevated temperatures tend to concentrate at the surface as the heated effluent moves away from the discharge. The thickness of the elevated temperature layer decreases from a maximum at the plane of discharge to zero at some distance away where no temperature rise is seen at the surface.

These points indicate that the variable TSF model results represent a highly conservative picture of the expected effect. On the other hand, the effect may be expected to be somewhat greater than the submerged discharge model predictions.

D. Evaluation of the Original Sheet-piling Design

As indicated in item B above, the method of discharging the heated effluent has during the course of detailed studies been modified from the multi-port sheet piling design to an underwater pipe design.

Since the sheet piling design was originally discussed with several State authorities and since an extensive evaluation of that design was made, we have selected to include a summary of our evaluation in this report.

This design consists of five slots, submerged 20' below the water's surface, and discharging at 15 ft/sec normal to the river's longitudinal axis. Details of this design are shown in Figure 54-a and summarized below.

Effective length of discharge canal (between centerlines of the first and last port)	=	200 ft.
Depth of centerline submergence below mean low water elevation	=	20 ft.
Number of ports	=	5

Port dimensions = 3 - 6 ft. long and 3.5 ft. high
2 - 8.5 ft. long and 5 ft. high

Orientation of ports = $0^{\circ}, 90^{\circ}, 90^{\circ}$ with lateral, longitudinal and vertical axes, respectively.

Port spacing (centerline to centerline) = 50 ft.

Initial jet velocity = 15 fps

This design was theoretically evaluated on the basis of the same critical summer condition parameters used in evaluating the underwater pipe design. These parameters are listed in item C above.

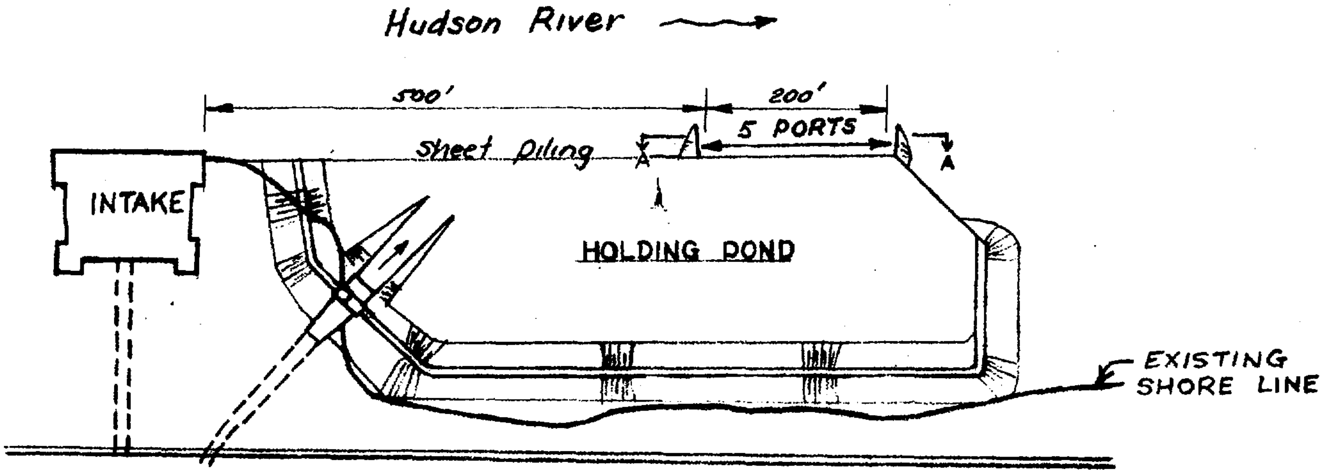
Computer printouts for this critical summer condition corresponding to ebb, slack and flood phases for the 5'X8.5' and 3.5X6' jets are shown in Plates I-a through VI-a, respectively.

Roseton Plant

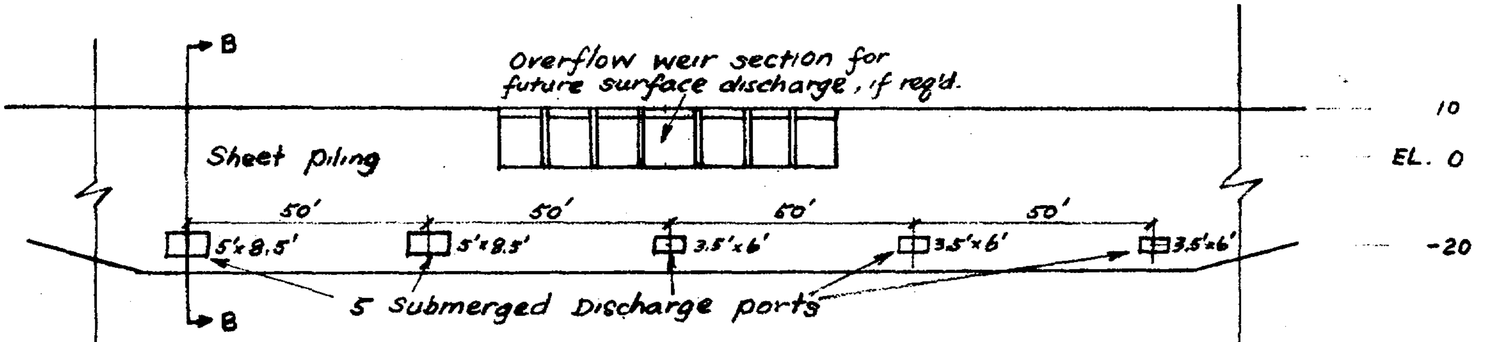
FIGURE 54-a

Circulating Water Intake and Discharge Details

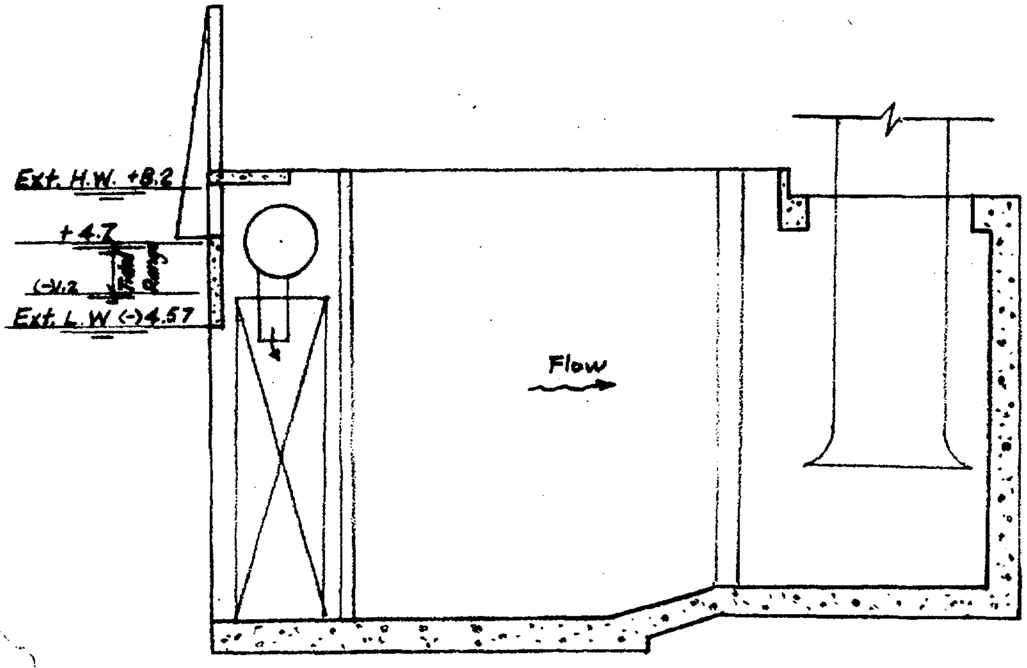
Preliminary Conceptional Design (Sheet Piling Design)



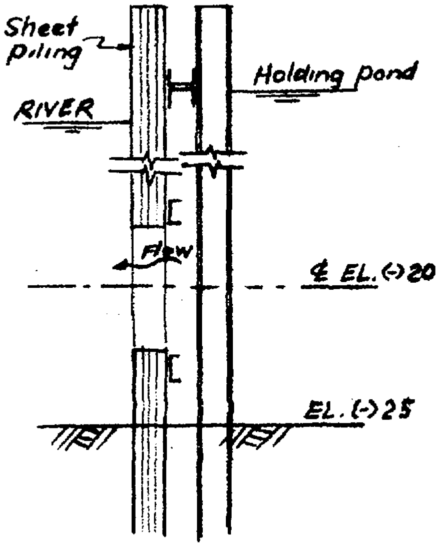
PLAN



SECTION A-A



INTAKE STRUCTURE



SECTION B-B

ROSETON PLANT SUBMERGED DISCHARGE (5'×8.5') PLATE I-

SHEET 1 OF 3

MOST SEVERE SUMMER CONDITION

EBB TIDE

(SHEET PILING DESIGN)

```
THOUTK     15:47   RDS2   DECEMBER 2, 1969

00010          ANG          VR
00020
00030        90.00         1.00
00040
00050
00060           DS           C1           C2           S2         YLIM         DDQI
00070
00080         0.10         0.15         0.25        45.00        20.00       0.0500
00090
00100
00110           DO           VO         COSX         COSY         COSZ
00120
00130         7.35        15.00         1.00         0.00         0.00
00140
00150
00160           TO         TRIV         SALO         SALR
00170
00180        97.00        79.00         0.10         0.10
00190
00200
00210
00220
00230          S       X       Y       Z       D      V   TEMP    TEMP          DIL
00240                                                     BY      BY
00250                                                      DIL     DEN
00260
00270       10.0    10.0     0.0     0.1    10.3   10.6   91.8    92.1          1.41
00280
00290
00300 T=        92.099S=        0.10RHO=           1.929
00310       20.0    20.0     0.1     0.5    13.3    8.3   88.9    89.3          1.82
00320
00330
00340 T=        89.352S=        0.10RHO=           1.929
00350       30.0    30.0     0.3     1.1    16.3    6.7   87.1    87.6          2.23
00360
00370
00380 T=        87.584S=        0.10RHO=           1.930
00390       40.0    39.9     0.5     2.0    19.3    5.7   85.8    86.3          2.64
00400
00410
00420 T=        86.348S=        0.10RHO=           1.930
00430       50.0    49.9     0.9     3.2    23.3    4.7   84.6    85.1          3.20
00440
00450
00460 T=        85.116S=        0.10RHO=           1.931
00470       60.0    59.7     1.4     4.8    28.3    3.9   83.6    84.0          3.90
00480
00490
00500 T=        84.027S=        0.10RHO=           1.931
00510       70.0    69.5     2.1     6.8    33.3    3.3   82.9    83.2          4.61
```

PLATE 1-a

SHEET 2 OF 3

```
00530
00540 T=        83.269S=           0.10RHO=          1.931
00550
00560
00570  AT NEXT LINE OF OUTPUT JET INTERSECTED SURFACE
00580
00590     i.e. Upper boundary of jet reached surface
00600      73.9      73.3        2.4        7.7     35.3     3.2   82.7   83.0        4.89
00610
00620      80.0      79.1        3.0        9.2     38.3     2.9   82.4   82.7        5.33
00630
00640
00650 T=        82.713S=           0.10RHO=          1.932
00660      90.0      88.7        4.0       12.1     43.3     2.6   82.0   82.3        6.08
00670
00680
00690 T=        82.270S=           0.10RHO=          1.932
00700     100.0      98.0        5.3       15.3     48.3     2.4   81.6   81.9        6.84
00710
00720
00730 T=        81.908S=           0.10RHO=          1.932
00740     110.0     107.2        6.8       19.0     53.3     2.2   81.4   81.6        7.63
00750
00760     At next line of output, jet interference occurs.
00770 T=        81.619S=           0.10RHO=          1.932
00780     120.0     116.2        8.6       23.0     58.3     2.0   81.1   81.3        8.44
00790
00800
00810 T=        81.369S=           0.10RHO=          1.932
00820     130.0     124.9       10.6       27.5     63.3     1.9   80.9   81.2        9.29
00830
00840
00850 T=        81.159S=           0.10RHO=          1.932
00860     140.0     133.4       12.8       32.2     68.3     1.8   80.8   81.0       10.18
00870
00880
00890 T=        80.973S=           0.10RHO=          1.932
00900     150.0     141.7       15.3       37.4     73.3     1.7   80.6   80.8       11.11
00910
00920
00930 T=        80.813S=           0.10RHO=          1.932
00940     160.0     149.6       18.0       42.8     78.3     1.6   80.5   80.7       12.08
00950
00960     Centerline of jet plume reaches surface.
00970 T=        80.671S=           0.10RHO=          1.932
00010
00020
00030
00040
00050         S         D     DIRECTION COSINES     RADIUS PROJECTIONS ON
00060                       X-AXIS  Y-AXIS  Z-AXIS  X-AXIS  Y-AXIS  Z-AXIS
00070
00080      10.0      10.3 0.99967 0.00536 0.02526      0.1      5.2      5.2
00090
00100      20.0      13.3 0.99865 0.01247 0.05042      0.3      6.7      6.7
00110
00120      30.0      16.3 0.99692 0.02135 0.07547      0.6      8.2      8.2
00130
00140      40.0      19.3 0.99444 0.03198 0.10037      1.0      9.7      9.6
00150
00160      50.0      23.3 0.98981 0.04442 0.13526      1.7     11.7     11.6
```

PLATE I-2

SHEET 3 OF 3

```
00170
00180      60.0    28.3 0.98196 0.05918 0.17959      2.7      14.2      13.9
00190
00200      70.0    33.3 0.97190 0.07626 0.22268      3.9      16.6      16.3
00210
00220
00230
00240  AT NEXT LINE OF OUTPUT JET INTERSECTED SURFACE
00250
```

i.e., Upper boundary of jet reaches surface.

```
00260
00270      73.9    35.3 0.96740 0.08352 0.23909      4.5      17.6      17.1
00280
00290      80.0    38.3 0.95971 0.09549 0.26426      5.4      19.1      18.5
00300
00310      90.0    43.3 0.94493 0.11654 0.30582      7.1      21.5      20.6
00320
00330     100.0    48.3 0.92753 0.13894 0.34697      9.0      23.9      22.7
00340
00350     110.0    53.3 0.90826 0.16245 0.38558     11.2      26.3      24.6
00360
```

At next line of output, jet interference occurs.

```
00370     120.0    58.3 0.88624 0.18651 0.42402     13.5      28.7      26.4
00380
00390     130.0    63.3 0.86260 0.21085 0.45984     16.0      31.0      28.1
00400
00410     140.0    68.3 0.83661 0.23486 0.49490     18.7      33.2      29.7
00420
00430     150.0    73.3 0.80931 0.25833 0.527:T@ 21.5     35.4      31.2
00440
00450     160.0    78.3 0.78077 0.28085 0.55815     24.5      37.6      32.5
00460
00470
00480
```

Centerline of jet plume reaches surface.

ROSETON PLANT SUBMERGED DISCHARGE (5'x8.5')

MOST SEVERE SUMMER CONDITION - SLACK TIDE

(SHEET PILING DESIGN)

PLATE II-2

SHEET 1 OF 2

```
00980          ANG          VR
00990
01000       180.00        0.05
01010
01020
01030           DS          C1          C2          S2        YLIM        DDQI
01040
01050         0.10        0.15        0.25       45.00       20.00      0.0500
01060
01070
01080           DO          VO        COSX        COSY        COSZ
01090
01100         7.35       15.00        1.00        0.00        0.00
01110
01120
01130           TO        TRIV        SALO        SALR
01140
01150        97.00       79.00        0.10        0.10
01160
01170
01180
01190
01200          S         X         Y         Z        D       V    TEMP    TEMP       DIL
01210                                                               BY      BY
01220                                                              DIL     DEN
01230
01240       10.0      10.0       0.0       0.0     10.3    10.6    91.8    92.1      1.41
01250
01260
01270 T=        92.099S=          0.10RHO=          1.929
01280       20.0      20.0       0.1       0.0     13.3     8.3    88.9    89.3      1.82
01290
01300
01310 T=        89.351S=          0.10RHO=          1.929
01320       30.0      30.0       0.3       0.1     16.3     6.7    87.1    87.6      2.23
01330
01340
01350 T=        87.582S=          0.10RHO=          1.930
01360       40.0      40.0       0.5       0.1     19.3     5.7    85.8    86.3      2.64
01370
01380
01390 T=        86.344S=          0.10RHO=          1.930
01400       50.0      50.0       0.9       0.2     23.3     4.7    84.7    85.1      3.18
01410
01420
01430 T=        85.109S=          0.10RHO=          1.931
01440       60.0      60.0       1.5       0.2     28.3     3.9    83.7    84.0      3.87
01450
01460
01470 T=        84.015S=          0.10RHO=          1.931
01480       70.0      69.9       2.1       0.3     33.3     3.3    83.0    83.2      4.55
01490
01500    At next line of output, upper boundary of jet reaches surface
01510 T=        83.252S=          0.10RHO=          1.931
01520       80.0      79.9       3.0       0.5     38.3     2.9    82.4    82.7      5.24
01530
01540
01550 T=        82.689S=          0.10RHO=          1.932
01560       90.0      89.8       4.1       0.6     43.3     2.5    82.0    82.3      5.93
01570
01580
01590 T=        82.258S=          0.10RHO=          1.932
```

PLATE II-a

SHEE 2 OF 2

```
01600     100.0     99.8      5.5       0.8    48.3   2.3  81.7  81.9      6.62
01610  At next line of output, jet interference occurs
01620
01630 T=       81.917S=          0.10RHO=          1.932
01640     110.0    109.6      7.1       1.0    53.3   2.1  81.5  81.6      7.33
01650
01660
01670 T=       81.641S=          0.10RHO=          1.932
01680     120.0    119.4      9.0       1.2    58.3   1.9  81.2  81.4      8.04
01690
01700
01710 T=       81.413S=          0.10RHO=          1.932
01720     130.0    129.2     11.2       1.4    63.3   1.8  81.1  81.2      8.76
01730
01740
01750 T=       81.222S=          0.10RHO=          1.932
01760     140.0    138.8     13.8       1.7    68.3   1.6  80.9  81.0      9.50
01770
01780
01790 T=       81.057S=          0.10RHO=          1.932
01800     150.0    148.4     16.7       2.0    73.3   1.5  80.8  80.9     10.25
01810
01820
01830 T=       80.905S=          0.10RHO=          1.932
01840     160.0    157.9     19.9       2.3    78.3   1.5  80.6  80.8     11.02
01850
01860  Centerline of jet plume reaches surface
01870 T=       80.775S=          0.10RHO=          1.932
00490
00500
00510        S        D    DIRECTION COSINES     RADIUS PROJECTIONS ON
00520                    X-AXIS  Y-AXIS  Z-AXIS  X-AXIS  Y-AXIS  Z-AXIS
00530
00540      10.0     10.3 0.99998 0.00536 0.00126      0.0      5.2      5.2
00550
00560      20.0     13.3 0.99992 0.01249 0.00252      0.1      6.7      6.7
00570
00580      30.0     16.3 0.99976 0.02141 0.00378      0.2      8.2      8.2
00590
00600      40.0     19.3 0.99947 0.03214 0.00504      0.3      9.7      9.7
00610
00620      50.0     23.3 0.99897 0.04481 0.00683      0.5     11.7     11.7
00630
00640      60.0     28.3 0.99815 0.06011 0.00913      0.9     14.1     14.2
00650
00660      70.0     33.3 0.99688 0.07812 0.01142      1.3     16.6     16.7
00670  At next line of output, upper boundary of jet reaches surface
00680      80.0     38.3 0.99502 0.09878 0.01370      1.9     19.1     19.2
00690
00700      90.0     43.3 0.99240 0.12202 0.01596      2.7     21.5     21.7
00710
00720     100.0     48.3 0.98886 0.14775 0.01819      3.6     23.9     24.2
00730  At next line of output, jet interference occurs
00740     110.0     53.3 0.98421 0.17583 0.02038      4.7     26.3     26.7
00750
00760     120.0     58.3 0.97827 0.20610 0.02251      6.0     28.5     29.2
00770
00780     130.0     63.3 0.97087 0.23834 0.02459      7.6     30.8     31.7
00790
00800     140.0     68.3 0.96184 0.27231 0.02662      9.4     32.9     34.2
00810
00820     150.0     73.3 0.95109 0.30756 0.02872     11.3     34.9     36.7
```

ROSETON SUBMERGED DISCHARGE (5'×8.5') PLATE III-a
MOST SEVERE SUMMER CONDITION SHEET 1 OF 3
FLOOD TIDE (SHEET PILING DESIGN)

```
THOUTK      11:03    RDS2  DECEMBER 11, 1969

00010          ANG         VR
00020
00030       270.00        -.90
00040
00050
00060           DS          C1          C2          S2         YLIM        DDQI
00070
00080         0.10        0.15        0.25       45.00        20.00      0.0500
00090
00100
00110           DO          VO        COSX        COSY         COSZ
00120
00130         7.35       15.00        1.00        0.00         0.00
00140
00150
00160           TO        TRIV        SALO        SALR
00170
00180        97.00       79.00        0.10        0.10
00190
00200
00210
00220
00230         S          X          Y          Z          D      V   TEMP   TEMP         DIL
00240                                                                 BY     BY
00250                                                                DIL    DEN
00260
00270       10.0       10.0        0.0        -.1       10.3   10.6   91.8   92.1        1.41
00280
00290
00300  T=       92.099S=          0.10RHO=           1.929
00310       20.0       20.0        0.1        -.5       13.3    8.3   88.9   89.3        1.82
00320
00330
00340  T=       89.352S=          0.10RHO=           1.929
00350       30.0       30.0        0.3       -1.0       16.3    6.7   87.1   87.6        2.23
00360
00370
00380  T=       87.584S=          0.10RHO=           1.930
00390       40.0       39.9        0.5       -1.8       19.3    5.7   85.8   86.3        2.64
00400
00410
00420  T=       86.348S=          0.10RHO=           1.930
00430       50.0       49.9        0.9       -2.9       23.3    4.7   84.6   85.1        3.19
00440
00450
00460  T=       85.115S=          0.10RHO=           1.931
00470       60.0       59.8        1.4       -4.3       28.3    3.9   83.6   84.0        3.89
00480
00490
00500  T=       84.025S=          0.10RHO=           1.931
00510       70.0       69.6        2.1       -6.1       33.3    3.3   82.9   83.2        4.60
00520
00530
00540  T=       83.266S=          0.10RHO=           1.931
00550
```

PLATE III-a

SHEET 2 OF 3

```
00560
00570  AT NEXT LINE OF OUTPUT JET INTERSECTED SURFACE
00580
00590  i.e., Upper boundary of jet reaches surface.
00600       73.9      73.4       2.4      -6.9     35.3     3.2   82.7   83.0       4.88
00610
00620       80.0      79.3       3.0      -8.3     38.3     2.9   82.4   82.7       5.32
00630
00640
00650 T=          82.708S=              0.10RHO=             1.932
00660       90.0      88.9       4.1     -10.9     43.3     2.6   82.0   82.3       6.05
00670
00680
00690 T=          82.282S=              0.10RHO=             1.932
00700      100.0      98.4       5.3     -13.8     48.3     2.4   81.6   81.9       6.80
00710
00720  At next line of output, interference of jet occurs
00730 T=          81.920S=              0.10RHO=             1.932
00740      110.0     107.7       6.9     -17.2     53.3     2.1   81.4   81.6       7.57
00750
00760
00770 T=          81.628S=              0.10RHO=             1.932
00780      120.0     116.8       8.7     -20.8     58.3     2.0   81.2   81.4       8.36
00790
00800
00810 T=          81.388S=              0.10RHO=             1.932
00820      130.0     125.7      10.7     -24.9     63.3     1.9   81.0   81.2       9.19
00830
00840
00850 T=          81.175S=              0.10RHO=             1.932
00860      140.0     134.4      13.0     -29.2     68.3     1.7   80.8   81.0      10.05
00870
00880
00890 T=          80.996S=              0.10RHO=             1.932
00900      150.0     142.9      15.5     -33.9     73.3     1.6   80.6   80.8      10.94
00910
00920
00930 T=          80.835S=              0.10RHO=             1.932
00940      160.0     151.1      18.3     -38.8     78.3     1.6   80.5   80.7      11.87
00950
00960  Centerline of jet plume reaches surface
00970 T=          80.694S=              0.10RHO=             1.932
```

PLATE III-a

SHEET 3 OF 3

```
THOUTO    11:10   RDS2  DECEMBER 11, 1969

00010
00020
00030
00040
00050        S        D     DIRECTION COSINES     RADIUS PROJECTIONS ON
00060                    X-AXIS  Y-AXIS  Z-AXIS  X-AXIS  Y-AXIS  Z-AXIS
00070
00080      10.0     10.3 0.99973 0.00536 -.02274     0.1     5.2     5.2
00090
00100      20.0     13.3 0.99889 0.01248 -.04539     0.3     6.7     6.7
00110
00120      30.0     16.3 0.99746 0.02136 -.06796     0.6     8.2     8.2
00130
00140      40.0     19.3 0.99539 0.03201 -.09042     0.9     9.7     9.6
00150
00160      50.0     23.3 0.99154 0.04449 -.12195     1.5    11.7    11.6
00170
00180      60.0     28.3 0.98498 0.05935 -.16213     2.4    14.2    14.0
00190
00200      70.0     33.3 0.97652 0.07661 -.20137     3.6    16.6    16.3
00210
00220
00230
00240   AT NEXT LINE OF OUTPUT JET INTERSECTED SURFACE
00250
00260   i.e., Upper boundary of jet reaches surface
00270      73.9     35.3 0.97270 0.08395 -.21636     4.1    17.6    17.2
00280
00290      80.0     38.3 0.96615 0.09609 -.23943     4.9    19.1    18.6
00300
00310      90.0     43.3 0.95391 0.11760 -.27609     6.5    21.5    20.8
00320
00330     100.0     48.3 0.93892 0.14071 -.31405     8.3    23.9    23.0
00340   At next line of output, interference of jet occurs
00350     110.0     53.3 0.92200 0.16507 -.35025    10.3    26.3    25.0
00360
00370     120.0     58.3 0.90327 0.19041 -.38451    12.5    28.6    26.9
00380
00390     130.0     63.3 0.88198 0.21613 -.41882    14.9    30.9    28.8
00400
00410     140.0     68.3 0.85928 0.24204 -.45062    17.5    33.2    30.5
00420
00430     150.0     73.3 0.83445 0.26751 -.48179    20.2    35.3    32.1
00440
00450     160.0     78.3 0.80837 0.29235 -.51095    23.1    37.5    33.7
00460   Centerline of jet plume reaches surface.
00470
00480
```

ROSETON PLANT SUBMERGED DISCHARGE (3.5'×6') PLATE IV-a
MOST SEVERE SUMMER CONDITION SHEET 1 OF 3
EBB TIDE (SHEET PILING DESIGN)

```
THOUTK      13:40    RDS2   DECEMBER 2, 1969

00010           ANG          VR
00020
00030         90.00        1.00
00040
00050
00060            DS          C1          C2          S2        YLIM        DDQI
00070
00080          0.10        0.15        0.25       31.80       20.00      0.0500
00090
00100
00110            DO          VO        COSX        COSY        COSZ
00120
00130          5.17       15.00        1.00        0.00        0.00
00140
00150
00160            TO        TRIV        SALO        SALR
00170
00180         97.00       79.00        0.10        0.10
00190
00200
00210
00220
00230           S       X        Y        Z       D      V   TEMP   TEMP       DIL
00240                                                           BY     BY
00250                                                          DIL    DEN
00260
00270       10.0    10.0      0.0      0.2     8.2    9.5   90.4   91.0      1.58
00280
00290
00300 T=        91.027S=          0.10RHO=           1.929
00310       20.0    20.0      0.1      0.7    11.2    6.9   87.3   88.1      2.16
00320
00330
00340 T=        88.148S=          0.10RHO=           1.930
00350       30.0    29.9      0.3      1.5    14.2    5.5   85.5   86.4      2.75
00360
00370
00380 T=        86.431S=          0.10RHO=           1.930
00390       40.0    39.9      0.6      2.8    18.8    4.1   83.9   84.5      3.67
00400
00410
00420 T=        84.563S=          0.10RHO=           1.931
00430       50.0    49.6      1.1      4.8    23.8    3.3   82.8   83.3      4.68
00440
00450
00460 T=        83.355S=          0.10RHO=           1.931
00470       60.0    59.3      1.8      7.3    28.8    2.8   82.2   82.6      5.71
00480
00490
00500 T=        82.578S=          0.10RHO=           1.932
00510       70.0    68.7      2.7     10.5    33.8    2.4   81.7   82.0      6.78
00520
00530
00540 T=        82.039S=          0.10RHO=           1.932
00550
```

PLATE IV-a
SHEET 2 OF 3

```
00560
00570  AT NEXT LINE OF OUTPUT JET INTERSECTED SURFACE
00580  i.e., Upper boundary of jet reaches surface
00590
00600       71.4      70.0        2.8      11.0      34.5    2.3  81.6  82.0       6.93
00610
00620       80.0      78.0        3.8      14.2      38.8    2.1  81.3  81.6       7.89
00630
00640
00650 T=        81.632S=             0.10RHO=            1.932
00660       90.0      86.9        5.2      18.5      43.8    1.9  81.0  81.3       9.05
00670
00680
00690 T=        81.298S=             0.10RHO=            1.932
00700      100.0      95.5        6.9      23.2      48.8    1.7  80.8  81.0      10.28
00710
00720
00730 T=        81.038S=             0.10RHO=            1.932
00740      110.0     103.8        8.8      28.5      53.8    1.6  80.6  80.8      11.58
00750
00760
00770 T=        80.813S=             0.10RHO=            1.932
00780      120.0     111.7       11.0      34.2      58.8    1.5  80.4  80.6      12.96
00790
00800
00810 T=        80.626S=             0.10RHO=            1.932
00820      130.0     119.2       13.4      40.3      63.8    1.4  80.2  80.5      14.44
00830
00840  At next line of output, jet interference occurs.
00850 T=        80.466S=             0.10RHO=            1.932
00860      140.0     126.4       16.0      46.8      68.8    1.4  80.1  80.3      16.01
00870
00880
00890 T=        80.326S=             0.10RHO=            1.932
00900      150.0     133.1       18.9      53.7      73.8    1.3  80.0  80.2      17.70
00910
00920  Centerline of jet plume reaches surface.
00930 T=        80.202S=             0.10RHO=            1.932
00030
00040
00050         S         D     DIRECTION COSINES      RADIUS PROJECTIONS ON
00060                       X-AXIS  Y-AXIS  Z-AXIS   X-AXIS   Y-AXIS   Z-AXIS
00070
00080       10.0       8.2 0.99940 0.00581 0.03410      0.1      4.1      4.1
00090
00100       20.0      11.2 0.99759 0.01431 0.06793      0.4      5.6      5.6
00110
00120       30.0      14.2 0.99451 0.02556 0.10152      0.7      7.1      7.0
00130
00140       40.0      18.8 0.98605 0.03978 0.16163      1.6      9.4      9.3
00150
00160       50.0      23.8 0.97255 0.05735 0.22552      2.8     11.9     11.6
00170
00180       60.0      28.8 0.95496 0.07792 0.28633      4.3     14.4     13.8
00190
00200       70.0      33.8 0.93372 0.10109 0.34342      6.1     16.8     15.9
00210
00220
```

PLATE IV-a
SHEET 3 OF 3

```
00230
00240  AT NEXT LINE OF OUTPUT JET INTERSECTED SURFACE
00250  i.e., Upper boundary of jet reaches surface
00260
00270      71.4    34.5 0.93049 0.10452 0.35109      6.3     17.2     16.2
00280
00290      80.0    38.8 0.90861 0.12629 0.39810      8.1     19.2     17.8
00300
00310      90.0    43.8 0.87879 0.15242 0.45222     10.5     21.6     19.5
00320
00330     100.0    48.8 0.84655 0.17904 0.50129     13.0     24.0     21.1
00340
00350     110.0    53.8 0.81046 0.20496 0.54877     15.8     26.3     22.5
00360
00370     120.0    58.8 0.77248 0.22976 0.59202     18.7     28.6     23.7
00380
00390     130.0    63.8 0.73315 0.25283 0.63132     21.7     30.9     24.7
00400  At next line of output, jet interference occurs
00410     140.0    68.8 0.69281 0.27358 0.66721     24.8     33.1     25.6
00420
00430     150.0    73.8 0.65217 0.29170 0.69970     28.0     35.3     26.4
00440  Centerline of jet plume reaches surface
00450
```

ROSETON PLANT SUBMERGED DISCHARGE (3.5'x6')
MOST SEVERE SUMMER CONDITION
SLACK TIDE (SHEET PILING DESIGN)

PLATE V-a
SHEET 1 OF 2

```
          ANG         VR

       180.00       0.05



           DS         C1          C2          S2        YLIM       DDQI

         0.10       0.15        0.25       31.80       20.00     0.0500


           DO         VO        COSX        COSY        COSZ

         5.17      15.00        1.00        0.00        0.00


           TO       TRIV        SALO        SALR

        97.00      79.00        0.10        0.10





           S          X          Y          Z        D        V  TEMP   TEMP         DIL
                                                                  BY     BY
                                                                 DIL    DEN

        10.0       10.0        0.0        0.0      8.2      9.5  90.4   91.0        1.58


  T=        91.027S=          0.10RHO=              1.929
        20.0       20.0        0.1        0.0     11.2      6.9  87.3   88.1        2.16


  T=        88.146S=          0.10RHO=              1.930
        30.0       30.0        0.3        0.1     14.2      5.5  85.6   86.4        2.74


  T=        86.427S=          0.10RHO=              1.930
        40.0       40.0        0.7        0.1     18.8      4.1  83.9   84.5        3.64


  T=        84.553S=          0.10RHO=              1.931
        50.0       50.0        1.1        0.2     23.8      3.3  82.9   83.3        4.62


  T=        83.336S=          0.10RHO=              1.931
        60.0       60.0        1.8        0.4     28.8      2.7  82.2   82.5        5.59


  T=        82.551S=          0.10RHO=              1.932
        70.0       69.9        2.8        0.5     33.8      2.3  81.7   82.0        6.57
```

At next line of output, upper boundary reaches surface.

```
  T=        82.003S=          0.10RHO=              1.932
        80.0       79.8        4.0        0.7     38.8      2.0  81.4   81.6        7.55


  T=        81.600S=          0.10RHO=              1.932
        90.0       89.7        5.5        1.0     43.8      1.8  81.1   81.3        8.55
```

PLATE V-a
SHEET 2 OF 2

```
01540
01550 T=        81.291S=            0.10RHO=            1.932
01560     100.0     99.5        7.4        1.2     48.8    1.6   80.9   81.0        9.56
01570  At next line of output, jet interfence occurs.
01580
01590 T=        81.048S=            0.10RHO=            1.932
01600     110.0    109.3        9.7        1.5     53.8    1.5   80.7   80.8       10.59
01610
01620
01630 T=        80.851S=            0.10RHO=            1.932
01640     120.0    118.9       12.3        1.9     58.8    1.3   80.5   80.7       11.64
01650
01660
01670 T=        80.689S=            0.10RHO=            1.932
01680     130.0    128.4       15.4        2.2     63.8    1.2   80.4   80.5       12.72
01690
01700
01710 T=        80.554S=            0.10RHO=            1.932
01720     140.0    137.8       18.9        2.6     68.8    1.2   80.3   80.4       13.84
01730
01740  Centerline of jet plume reaches surface
01750 T=        80.431S=            0.10RHO=            1.932
00470
00480
00490          S         D     DIRECTION COSINES      RADIUS PROJECTIONS ON
00500                       X-AXIS  Y-AXIS  Z-AXIS   X-AXIS  Y-AXIS  Z-AXIS
00510
00520       10.0       8.2 0.99998 0.00581 0.00171      0.0     4.1     4.1
00530
00540       20.0      11.2 0.99989 0.01434 0.00340      0.1     5.6     5.6
00550
00560       30.0      14.2 0.99966 0.02569 0.00510      0.2     7.1     7.1
00570
00580       40.0      18.8 0.99915 0.04028 0.00819      0.4     9.4     9.4
00590
00600       50.0      23.8 0.99820 0.05878 0.01157      0.7    11.9    11.9
00610
00620       60.0      28.8 0.99659 0.08111 0.01494      1.2    14.4    14.4
00630
00640       70.0      33.8 0.99407 0.10715 0.01828      1.8    16.8    16.9
00650  At next line of output, upper boundary reaches surface.
00660       80.0      38.8 0.99037 0.13676 0.02158      2.7    19.2    19.4
00670
00680       90.0      43.8 0.98518 0.16972 0.02481      3.8    21.6    21.9
00690
00700      100.0      48.8 0.97820 0.20575 0.02796      5.1    23.9    24.4
00710  At next line of output, jet interference occurs
00720      110.0      53.8 0.96915 0.24450 0.03100      6.6    26.1    26.9
00730
00740      120.0      58.8 0.95777 0.28553 0.03389      8.5    28.2    29.4
00750
00760      130.0      63.8 0.94385 0.32835 .0
       Centerline of jet plume reaches surface.
```

ROSETON PLANT SUBMERGED DISCHARGE (3.5'×6')　PLATE VI-2
MOST SEVERE SUMMER CONDITION　SHEET 1 OF 3
FLOOD TIDE　(SHEET PILING DESIGN)

```
THOUTK      09:59    RDS2   DECEMBER 11, 1969

00010          ANG           VR
00020
00030       270.00         -.90
00040
00050
00060           DS           C1           C2           S2         YLIM         DDQI
00070
00080         0.10         0.15         0.25        31.80        20.00       0.0500
00090
00100
00110           DO           VO         COSX         COSY         COSZ
00120
00130         5.17        15.00         1.00         0.00         0.00
00140
00150
00160           TO         TRIV         SALO         SALR
00170
00180        97.00        79.00         0.10         0.10
00190
00200
00210
00220
00230            S          X          Y          Z        D       V   TEMP    TEMP        DIL
00240                                                                   BY      BY
00250                                                                  DIL     DEN
00260
00270         10.0       10.0        0.0        -.2      8.2     9.5   90.4    91.0       1.58
00280
00290
00300 T=        91.027S=              0.10RHO=             1.929
00310         20.0       20.0        0.1        -.6     11.2     6.9   87.3    88.1       2.16
00320
00330
00340 T=        88.147S=              0.10RHO=             1.930
00350         30.0       30.0        0.3       -1.4     14.2     5.5   85.5    86.4       2.75
00360
00370
00380 T=        86.430S=              0.10RHO=             1.930
00390         40.0       39.9        0.6       -2.5     18.8     4.1   83.9    84.5       3.66
00400
00410
00420 T=        84.561S=              0.10RHO=             1.931
00430         50.0       49.7        1.1       -4.3     23.8     3.3   82.9    83.3       4.66
00440
00450
00460 T=        83.351S=              0.10RHO=             1.931
00470         60.0       59.4        1.8       -6.6     28.8     2.7   82.2    82.6       5.69
00480
00490
00500 T=        82.573S=              0.10RHO=             1.932
00510         70.0       68.9        2.7       -9.5     33.8     2.4   81.7    82.0       6.74
00520
00530
00540 T=        82.032S=              0.10RHO=             1.932
00550
```

PLATE VI-
SHEET 2 OF 3

```
00560
00570  AT NEXT LINE OF OUTPUT JET INTERSECTED SURFACE
00580
00590  i.e., Upper boundary of jet reaches surface.
00600      71.4     70.3      2.9    -9.9    34.5    2.3   81.6   82.0      6.89
00610
00620      80.0     78.3      3.9   -12.9    38.8    2.1   81.3   81.6      7.82
00630
00640
00650  T=        81.636S=          0.10RHO=          1.932
00660      90.0     87.4      5.3   -16.7    43.8    1.9   81.0   81.3      8.96
00670
00680
00690  T=        81.310S=          0.10RHO=          1.932
00700     100.0     96.2      7.0   -21.1    48.8    1.7   80.8   81.0     10.14
00710
00720
00730  T=        81.049S=          0.10RHO=          1.932
00740     110.0    104.8      9.0   -25.9    53.8    1.6   80.6   80.8     11.39
00750
00760
00770  T=        80.833S=          0.10RHO=          1.932
00780     120.0    113.0     11.2   -31.1    58.8    1.5   80.4   80.6     12.70
00790
00800  At next line of output, interference of jet occurs.
00810  T=        80.649S=          0.10RHO=          1.932
00820     130.0    120.8     13.8   -36.8    63.8    1.4   80.3   80.5     14.10
00830
00840
00850  T=        80.489S=          0.10RHO=          1.932
00860     140.0    128.3     16.6   -42.8    68.8    1.3   80.2   80.3     15.59
00870
00880
00890  T=        80.352S=          0.10RHO=          1.932
00900     150.0    135.5     19.6   -49.1    73.8    1.3   80.0   80.2     17.17
00910
00920   Centerline of jet plume reaches surface.
00930  T=        80.232S=          0.10RHO=          1.932
```

PLATE VI-2
SHEET 3 OF 3

```
         S         D     DIRECTION COSINES     RADIUS PROJECTIONS ON
                        X-AXIS  Y-AXIS  Z-AXIS  X-AXIS  Y-AXIS  Z-AXIS

       10.0      8.2 0.99951 0.00581 -.03069       0.1      4.1      4.1

       20.0     11.2 0.99802 0.01432 -.06117       0.4      5.6      5.6

       30.0     14.2 0.99548 0.02559 -.09145       0.7      7.1      7.1

       40.0     18.8 0.98851 0.03987 -.14583       1.4      9.4      9.3

       50.0     23.8 0.97728 0.05761 -.20395       2.5     11.9     11.7

       60.0     28.8 0.96248 0.07850 -.25973       3.9     14.4     13.9

       70.0     33.8 0.94437 0.10216 -.31261       5.6     16.8     16.1



   AT NEXT LINE OF OUTPUT JET INTERSECTED SURFACE
```

i.e., Upper boundary of jet reaches surface

```
       71.4     34.5 0.94159 0.10567 -.31975       5.8     17.2     16.3

       80.0     38.8 0.92328 0.12819 -.36210       7.5     19.2     18.1

       90.0     43.8 0.89785 0.15575 -.41184       9.6     21.6     20.0

      100.0     48.8 0.86937 0.18404 -.45860      12.1     24.0     21.7

      110.0     53.8 0.83809 0.21245 -.50246      14.7     26.3     23.3

      120.0     58.8 0.80424 0.24009 -.54365      17.5     28.5     24.7
```

At next line of output, interference of jet occurs

```
      130.0     63.8 0.76825 0.26635 -.58211      20.4     30.8     25.9

      140.0     68.8 0.73129 0.29082 -.61696      23.5     32.9     27.1

      150.0     73.8 0.69361 0.31298 -.64880      26.6     35.1     28.1
```

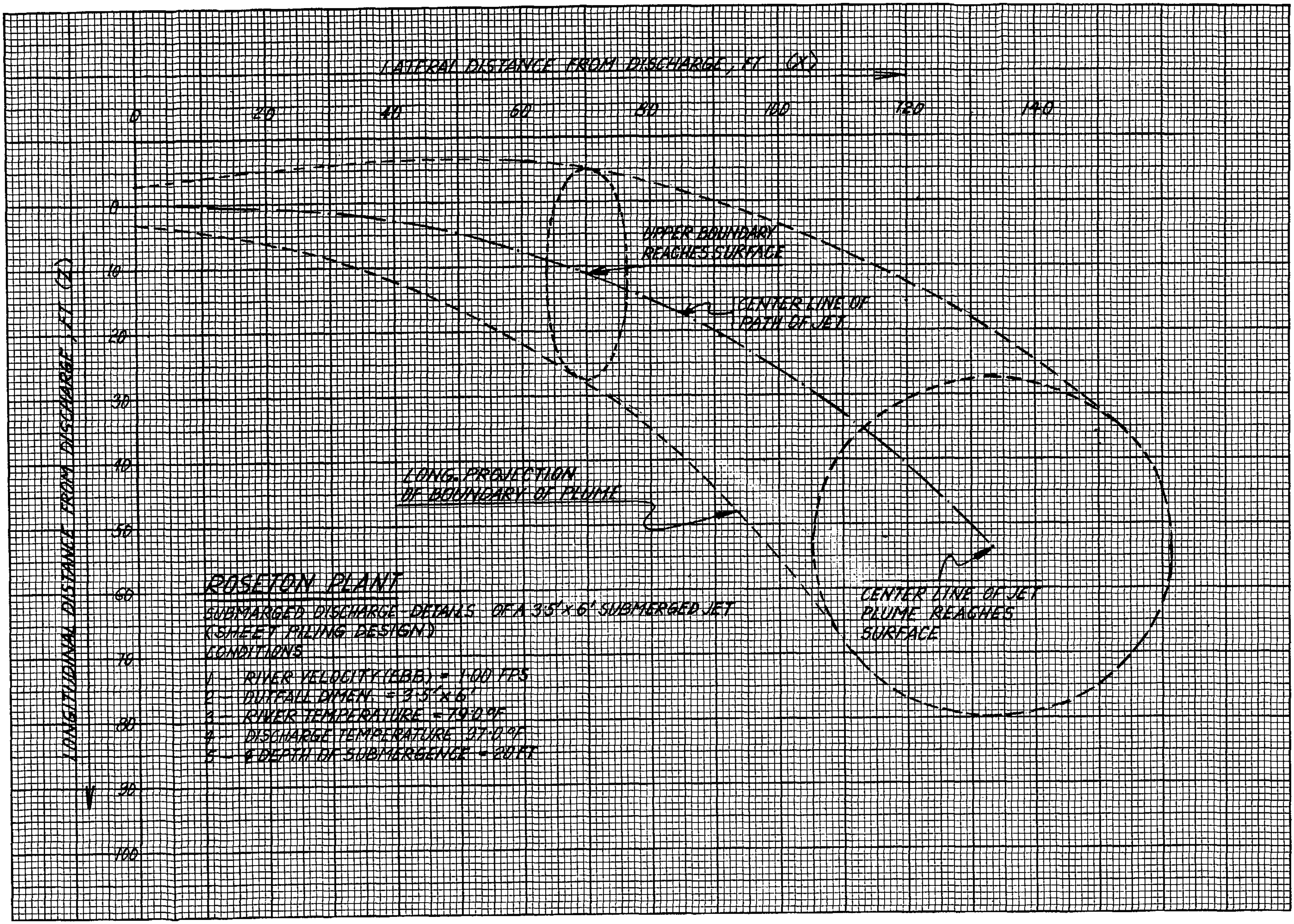
Centerline of jet plume reaches surface.

Figures 55-a and 56-a depict the details of the computed lateral, vertical and longitudinal location of the 5'X8.5' jets for ebb phase conditions. The corresponding locations of the 3.5'X6' are shown in Figures 57-a and 58-a.

The jet boundaries shown in these figures represent the vertical and longitudinal projections of the computed jet sizes at different locations. The computed jet velocities and dilution ratios are shown in Figures 56-a and 58-a. Stops indicating when the jet's upper boundary and centerline reach the river's surface, and when interference between adjacent jets occurs are also located on Figures 55-a through 58-a. Figure 59-a shows the relative locations of the five jets.

Jet interference between adjacent jets occurs when the plume diameter exceeds center to center port spacing, which, in this design, is 50 feet. The upper boundary reaches the surface when the vertical projection of the jet's radius exceeds the difference between the depth of submergence and the vertical location of the jet. The lower boundary hits the river's bottom, when the vertical projection of the jet's radius is greater than the difference between the water depth and the vertical elevation of the jet's centerline. The centerline of the plume reaches the surface

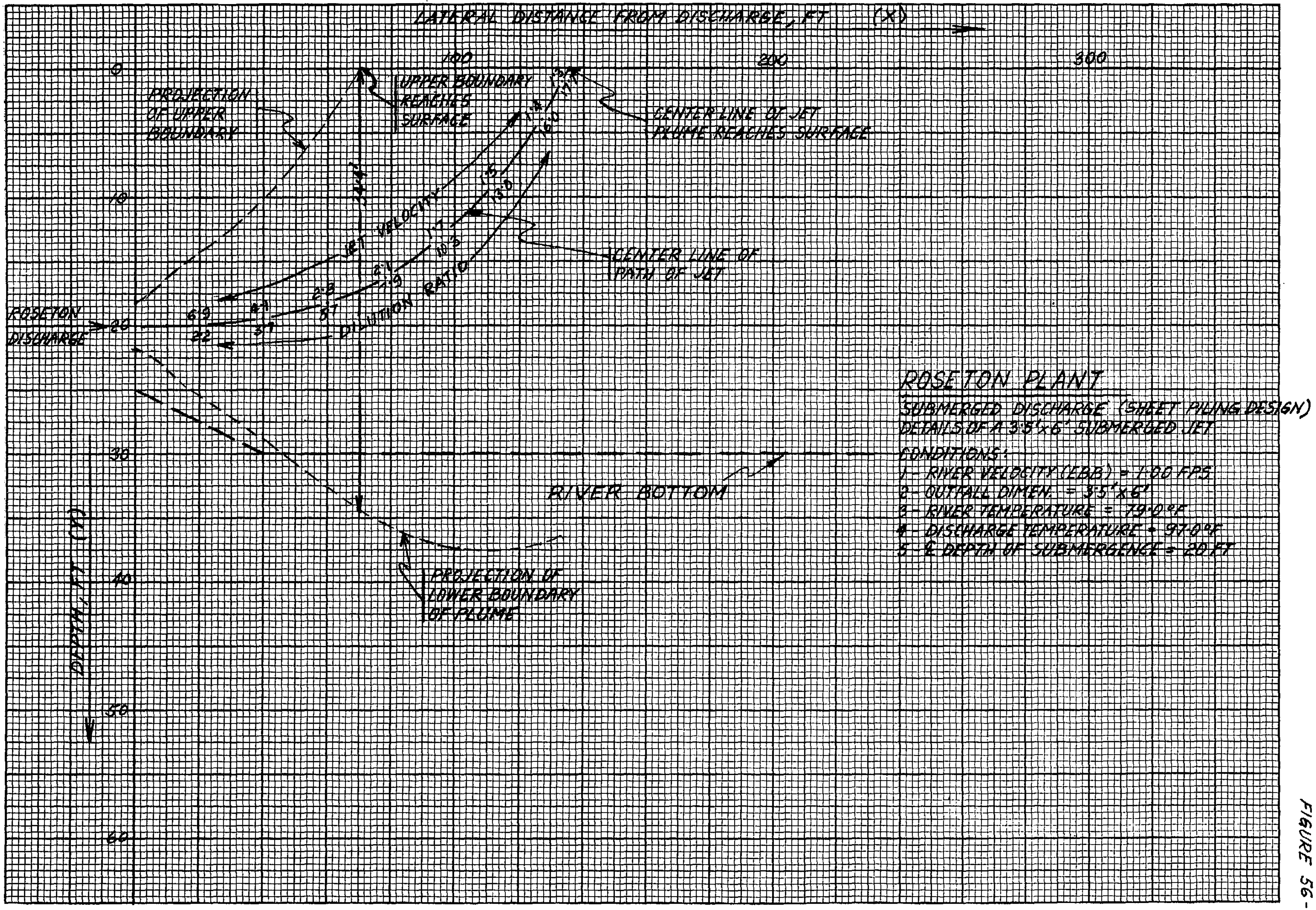
FIGURE 55-a



ROSETON PLANT

SUBMARGED DISCHARGE DETAILS OF A 3.5' x 6' SUBMERGED JET
(SHEET PILING DESIGN)
CONDITIONS

1 — RIVER VELOCITY (EBB) = 1.00 FPS
2 — OUTFALL DIMEN. = 3.5' x 6'
3 — RIVER TEMPERATURE = 79.0 °F
4 — DISCHARGE TEMPERATURE 97.0 °F
5 — ℄ DEPTH OF SUBMERGENCE = 20 FT



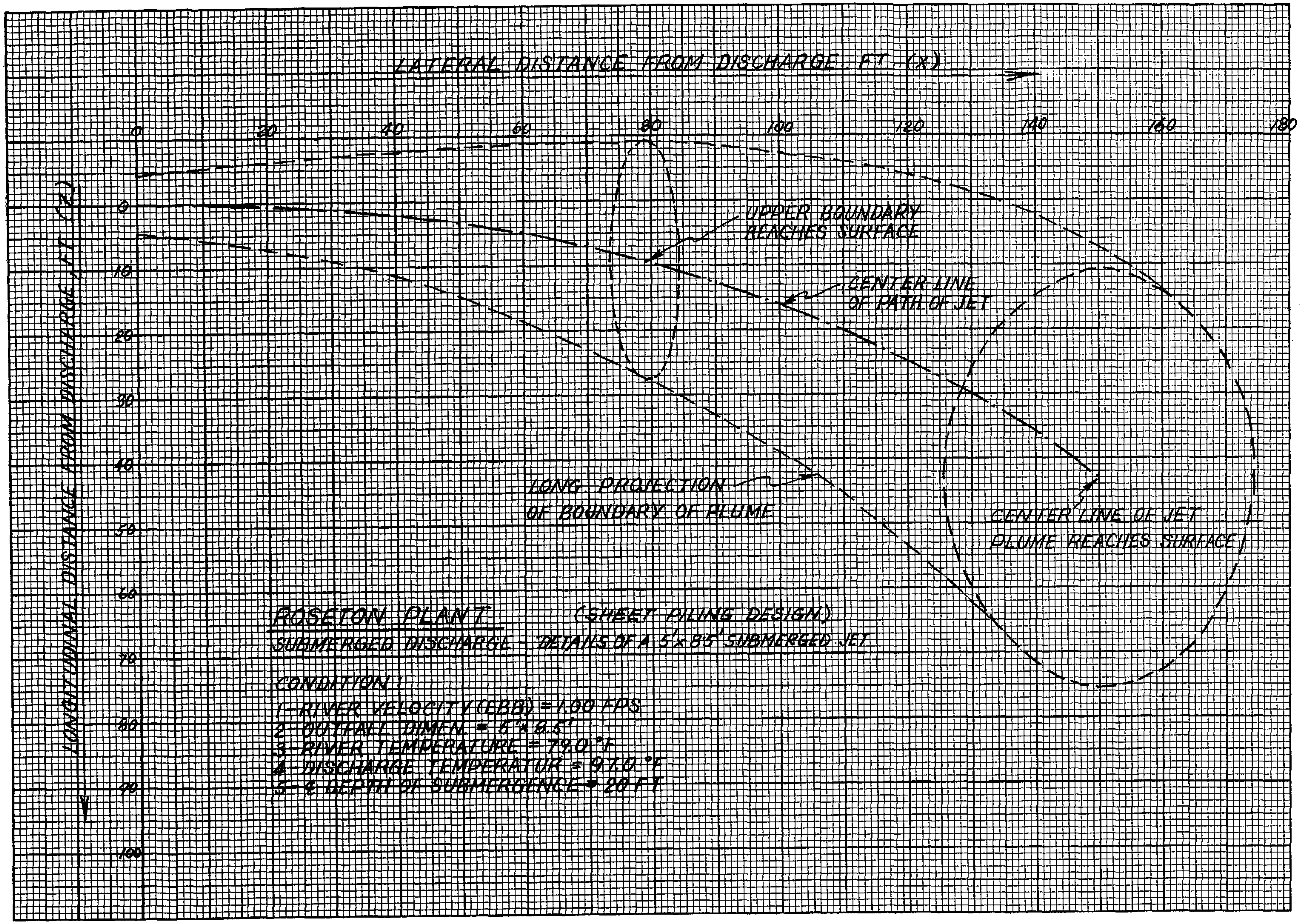
ROSETON PLANT

SUBMERGED DISCHARGE (SHEET PILING DESIGN)
DETAILS OF A 3.5'x6' SUBMERGED JET

CONDITIONS:
1 - RIVER VELOCITY (EBB) = 1.00 FPS
2 - OUTFALL DIMEN. = 3.5'x6'
3 - RIVER TEMPERATURE = 79.0°F
4 - DISCHARGE TEMPERATURE = 97.0°F
5 - ℄ DEPTH OF SUBMERGENCE = 20 FT

FIGURE 56-2

FIGURE 57-a



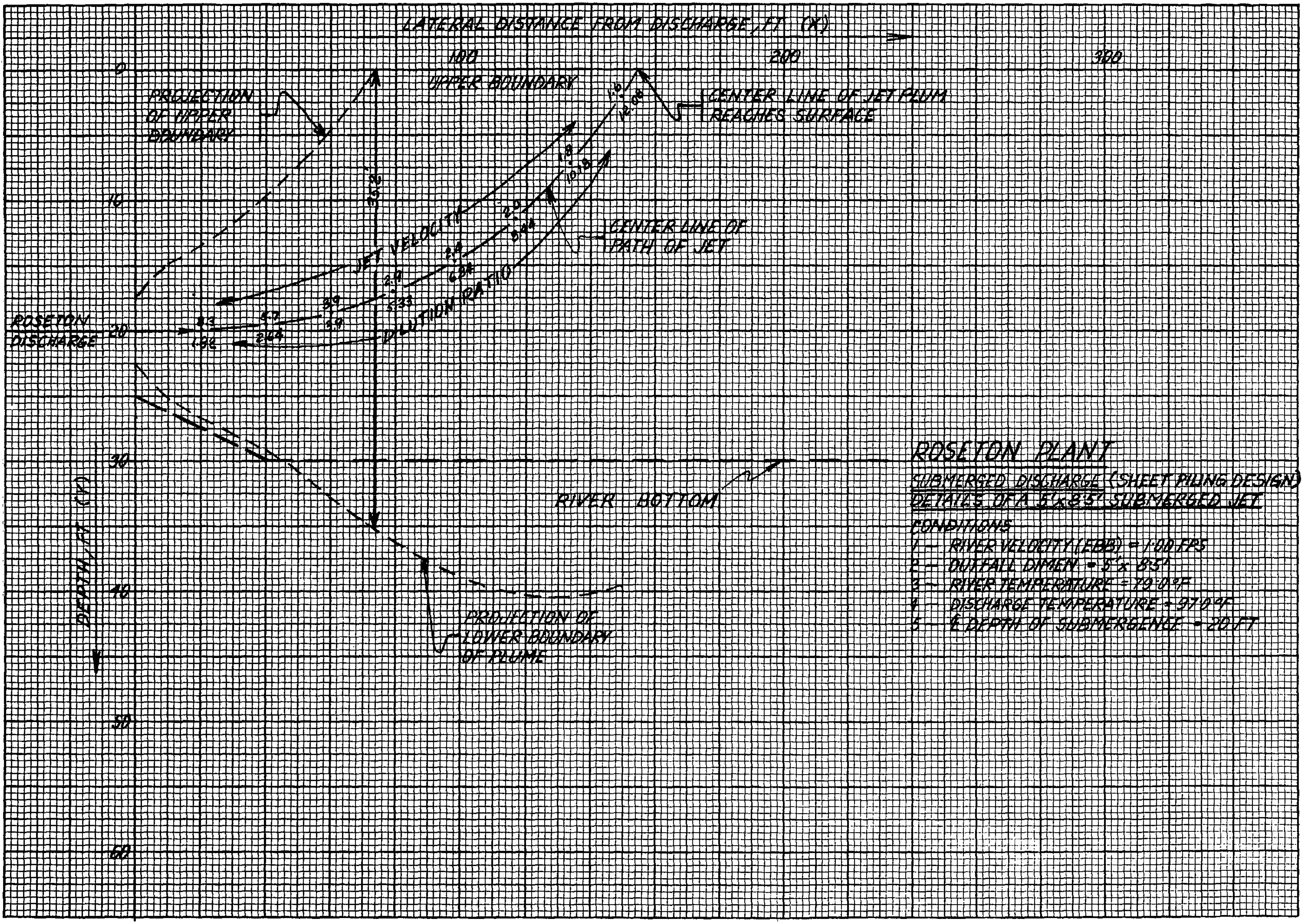
ROSETON PLANT (SHEET PILING DESIGN)

SUBMERGED DISCHARGE - DETAILS OF A 5'x 85' SUBMERGED JET

CONDITION:

1-RIVER VELOCITY (EBB) = 1.00 FPS
2-OUTFALL DIMEN. = 5'x 8.5'
3-RIVER TEMPERATURE = 79.0 °F
4-DISCHARGE TEMPERATUR = 97.0 °F
5-℄ DEPTH OF SUBMERGENCE = 20 FT

FIGURE 58-2



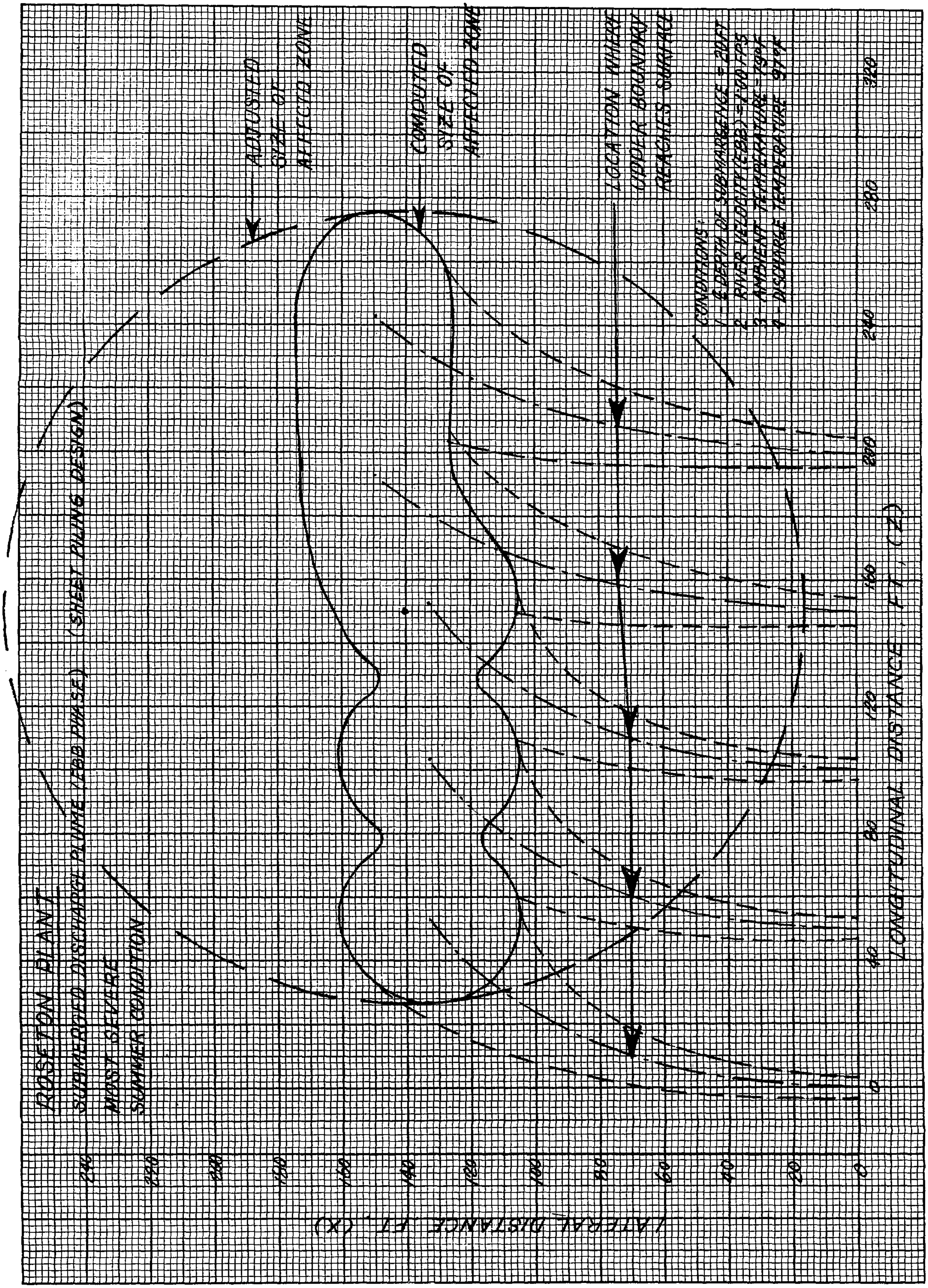
ROSETON PLANT

SUBMERGED DISCHARGE (SHEET PILING DESIGN)

DETAILS OF A 5'x8.5' SUBMERGED JET

CONDITIONS
1 — RIVER VELOCITY (EBB) = 1.00 FPS
2 — OUTFALL DIMEN = 5' x 8.5'
3 — RIVER TEMPERATURE = 79.0°F
4 — DISCHARGE TEMPERATURE = 97.0°F
5 — ℄ DEPTH OF SUBMERGENCE = 20 FT

FIGURE 59-2


ROSETON PLANT
SUBMERGED DISCHARGE PLUME (EBB PHASE) (SHEET PILING DESIGN)
MOST SEVERE
SUMMER CONDITION
ADJUSTED SIZE OF AFFECTED ZONE
COMPUTED SIZE OF AFFECTED ZONE
LOCATION WHERE UPPER BOUNDARY REACHES SURFACE
CONDITIONS:
1 ℄ DEPTH OF SUBMERGENCE = 20FT
2 RIVER VELOCITY(EBB) = 1.00 FPS
3 AMBIENT TEMPERATURE - 79°F
4 DISCHARGE TEMPERATURE 97°F
LATERAL DISTANCE, FT. (X)
240
220
200
180
160
140
120
100
80
60
40
20
0
LONGITUDINAL DISTANCE, FT. (Z)
0
40
80
120
160
200
240
280
320

when the vertical location of the plume is equal to the depth of submergence to the port centerline. For convenience, these four locations will be referred to, in this report, as the interference, surface boundary, bottom boundary and centerline surface controls.

Dilution ratios for the two different jets, associated with these four controls, are summarized in Table 9-a. The values appearing under the bottom boundary control in the table were taken from the corresponding computer printout values. In terms of vertical distance, these values represent the characteristics at the location where the vertical projection of the jet's radius is equal to the difference between a water depth of 30 ft. and the vertical elevation of the jet's centerline. Such location will usually occur at a lateral distance of some 40 to 50 ft. from the plane of discharge.

The bottom boundary control dilution ratios represent the absolute minimum expected dilution. On the other hand, the values associated with the centerline surface control, i.e., when the centerline of the plume reaches the surface, indicative of the dilution ratios in cases where the influence of drag force and the river surface and bottom on the expanding jets are not significant.

TABLE 9-a

SUMMARY OF DILUTION RATIOS ASSOCIATED WITH CONTROL LOCATIONS AT ROSETON

Tidal Phase	Interference Control	BOUNDARY CONTROL Upper	BOUNDARY CONTROL Lower	Centerline Surface Control
Port Size : 5' X 8.5'				
Ebb	8.44	4.89	2.92	12.08
Slack	7.33	5.24	2.91	11.02
Flood	7.57	4.88	2.915	11.87
Port Size : 3.5' X 6'				
Ebb	16.01	6.93	4.175	17.7
Slack	10.59	7.55	4.13	13.8
Flood	14.10	6.89	4.16	17.17

1. Location where jet interference occurs.
2. Location where upper boundary reaches the surface.
3. Location where lower boundary hits the River's bottom.
4. Location where jet centerline reaches the surface.

The values associated with the surface boundary and interference controls represent two different intermediate ranges.

For the purpose of showing the most extreme effect of Roseton discharge, the minimum dilution ratios associated with the bottom boundary control were used in this study. In other words, the computations ignore any dilution occurring beyond the location where the lower boundary of the jets hits the river's bottom at some 40' to 50' offshore. In reality, however, entrainment of the river water into the individual jets will occur beyond this location, due to the availability of large volumes of ambient water in the remaining portion of the river's cross-section.

The program results show that the absolute minimum expected dilution ratio ranges from 2.91 to 4.14 depending upon the size of the port and the tidal phase. A weighted average dilution ratio of the five jets is:

$$3.55 \simeq \left(\frac{2.91 X 2 X 8.5 X 5 + 4.14 X 3 X 6 X 3.5}{2 X 8.5 X 5 + 3 X 6 X 3.5} \right)$$

The average surface temperature rise over the entire plume is then computed as follows:

$$\text{Average surface temperature rise} = \frac{\text{maximum plant temperature rise}}{\text{weighted average dilution ratio}}$$

$$= \frac{18}{3.55} = 5.08^{\circ}$$

The corresponding maximum surface temperature rise above the river ambient temperature is therefore 7.8°F (5.08 X $\pi/2$).

These values are somewhat higher than those corresponding to the underwater pipe scheme, i.e., 5.08°F vs. 2.78°F and 7.8°F vs. 6°F. Therefore, the selected submerged discharge design is a more effective design in dispersing the heated plant discharge than the sheet piling.

The higher dilution ratio associated with the underwater pipe resulted from the use of smaller part sizes (4-1/2 ft diameter & 5 ft diameter parts versus 3.5 ft x 6 ft & 5 ft x 8.5 ft slots), a larger number of openings (8 versus 5) and a more efficient velocity distribution.

The river bottom shown in Figures 56-a and 58-a was based upon the USC&GS soundings. A local survey of the river bottom in the vicinity of Roseton showed smaller depths. Dredging will be required as shown previously and results in less lower boundary control and a corresponding higher available dilution ratio, than was employed in the analysis of the sheet piling design.

CHAPTER V

ECOLOGICAL STUDIES RELATED TO THE PROPOSED GENERATING STATION AT ROSETON, NEW YORK

by

OCEANOGRAPHIC ANALYSTS, INC.
Alfred Perlmutter, Sc.D.

ECOLOGICAL STUDIES RELATED TO THE PROPOSED GENERATING STATION AT ROSETON, NEW YORK.

I. INTRODUCTION

Ecological studies of the waters in the vicinity of the proposed generating station at Roseton, N.Y. were started on May 7, 1969 and continued through October 22 of that year. The direction of the program was influenced by the presence of the existing Danskammer fossil fuel plant, a few thousand feet north of the proposed station. The heated discharge from this plant has been going into the river for many years. Consequently, a study of the waters adjacent to the Danskammer plant, could be useful in predicting the possible effects of the thermal effluent of the proposed Roseton station, on the ecology. At both sites, there is an "indentation" of the shoreline to the south, in which the heated discharge water tends to accumulate, particularly at the ebb tide.

Initially, the investigation was limited to a comparison of the abundance of bottom organisms in these "indentation" areas between the two sites. It was soon recognized that fish were abundant in the "indentation" area at the Danskammer station, and in close cooperation with Quirk, Lawler and Matusky studies were designed to obtain information on the relationship of the various fish species to the heated effluent. Simultaneously with these field studies, another study was conducted in the laboratory on data collected by Northeast Biologists on the distribution of larval fishes in the Hudson River, to project, if possible, the effect of the new plant on the larval fish population.

Procedures and methods, and results, are given below for each of the three major aspects of the investigation; namely, (1) Abundance of Bottom Organisms (2) Relative Abundance of Fishes and It's Relationship to Water Temperatures (3) Distribution of Larval Fishes.

II. ABUNDANCE OF BOTTOM ORGANISMS

A. Procedures and Methods

1. Location of Sampling Stations

Five sampling stations were established in the "indentation" immediately south of the existing Danskammer Power Station (Figure 1) and an additional five sampling stations were established in the indentation immediately south of the proposed Roseton Power Station (Figure 2).

2. Depth of Water at Stations

Bottom samples were taken at depths ranging from 5 to 42 feet at Danskammer (Tables 1, 1a, 1b) and 3 to 27 feet at Roseton (Tables 2, 2a, 2b).

3. Methods of Sampling and Analysis

Bottom samples were collected with a messenger operated Birge-Ekman Dredge (5 kg. in weight, 15 cm. cube dredge box). A 400 cc. sample was removed from the dredge and preserved in 4% formalin. In the laboratory, the biota in each sample was sorted and classified. The depth of the water and the surface water temperature (degrees C.) were recorded for each collection.

4. Sampling Period and Sample Number

Sampling began on May 7, 1969 and continued through October 22, 1969. During May, June and July samples were taken on Wednesdays at two week intervals, on May 7, 21; June 4, 18; and July 2, 16 and 30. During the remainder of the season, they were taken weekly, each Wednesday, on August 13, 20, 27; September 3, 10, 17, 24; and October 1, 8, 15 and 22.

B. Results

The data collected in the "indentation" of the Danskammer Power

Station and the proposed Roseton Power Station are summarized in Tables 1, 1a, 1b and 2, 2a, 2b and in Figures 3, 4 and 5. During the entire period at Danskammer eight types of organisms were collected including Annelids, Chironomid larvae, Polychaetes, Nematodes, Hirudinea, Copepods, Isopods and Amphipods. In addition invertebrate eggs were also present. In contrast, at Roseton, only three types of organisms were taken; Annelids, Chironomid larvae and Polychaetes.

Annelids predominated at Danskammer and Roseton but were always far more abundant at Danskammer. The total number of Annelids taken from the five bottom stations at Danskammer on May 7, May 21, June 4 and June 18 was 23, 34, 78 and 88 respectively compared to 0, 19, 25 and 39 taken from the five bottom stations at Roseton on the same dates. On July 2, 16 and 30, and Aug. 13, 20 and 27; 75, 42, 69, 33, 14 and 40 were taken from the five bottom stations at Danskammer compared to 18, 29, 5, 20, 7 and 11 taken from the five bottom stations at Roseton the same days. On Sept. 3, 10, 17 and 24, and Oct. 1, 8, 15 and 22; 38, 27, 23, 35, 25, 9, 23 and 10 were taken from the five bottom stations at Danskammer compared to 15, 13, 17, 9, 4, 6, 4 and 3 taken from the five bottom stations at Roseton on the same days.

Both at Danskammer and Roseton the abundance of Annelids increased in early May, reached a peak in June and started to decline in July.

Chironomid larvae and Polychaetes, the two other groups of organisms common to both Danskammer and Roseton, were far less abundant than the Annelids. The Chironomid larvae were most abundant at Danskammer. Peak abundance in both areas was in late May and early June. Erratic occurrence at low levels of abundance was characteristic of the Chironomid larvae during the remaining period and this was also true of the Polychaetes, throughout the entire study period.

The bottom at both Danskammer and Roseton consists of a loose, sticky clay intermixed with silt. There was no discernable difference in this material between the two areas which might explain the relatively poor productivity of the bottom at Roseton compared to Danskammer.

C. Conclusions

In summary, in so far as the bottom organisms are concerned, these are more abundant in the area influenced by the heated effluent from the Danskammer Power Station than in an adjacent area where the proposed Roseton Power Station will be located.

III. RELATIVE ABUNDANCE OF FISHES AND IT'S RELATIONSHIP TO WATER TEMPERATURES

A. Procedures and Methods (Seine Samples)

1. Location and Description of Seining Stations

Three seining stations were established in the "indentation" immediately south of the existing Danskammer Power Station (Figure 1). Seine Station 1, was closest to the outfall structure. Seine Station 3 was furthest from the outfall structure in the "indentation" area. Seine Station 2 was between the other two stations but closer to Seine Station 1 than Seine Station 3. The position of each station was determined to a large extent by its accessibility to a seine net. Seine Station 1, was a shoal beach which gradually sloped into the deeper outfall channel. The bottom appeared to be mostly sand, gravel and small stones. At intermediate and low tides the net collected in an area from the edge of the outfall channel to the shore. Seine Station 2 was located off an area of cement spoil and consisted of a very small beach which abruptly descended into deeper water. The beach itself was made up of sand, gravel and small stones but at its edges, as it descended abruptly, the bottom became muddy and rooted aquatic plants, particularly Potamogeton were abundant. Seining was only effective in the area from the shore to the edge of the rooted aquatic plants. Seine Station 3 was in a small cove in the "indentation" area. This was a shoal and the bottom was a viscous soft mud.

Additional seine sites were sought in the "indentation" area at Roseton site. Here, the shore is rimmed with the remains of old, wooden bulkheads and docks and the water deepens rapidly immediately offshore of these structures. Consequently, no seine samples could be obtained in this area.

2. Methods of Physical and Chemical Data Procurement and Analysis

These are described in detail in the accompanying report of Quirk, Lawler and Matusky (p. A1 to A9) and will not be discussed here.

3. Methods for Procurement and Analysis of Data on Fish

Fish were sampled at the three stations using a 50 foot nylon seine with the following specifications. The mesh size was 3/8 inch; the top and bottom lines were of 1/4 inch polypropyline. The top line had plastic floats (2-1/2 inches in diameter and 1-1/4 inches thick) every 15 inches, while the bottom line had a No. 9 oblong lead every 15 inches. Centrally located in the body of the net was a pocket, of the same material as the rest of the net, which was 4 by 4 feet at its attachment and extended back for 6 feet.

The net was set in prescribed areas at each seine station according to a fixed procedure. It was pulled out into the water perpendicular to the shore for its entire length, if possible, or until a depth of four feet was reached. This was the maximum depth at which a man in waders could operate the net without getting wet. The net was then pulled out into the water perpendicular to the shore for its entire length. At this position, it was stretched parallel to the shore and then hauled to the beach. The product of the distance from the shore where the net was set and the length of the net was taken as the area seined.

Fishing sampling was undertaken at all four stations once a week, each Wednesday from Aug. 13 to Oct. 22, 1969. Usually only one set of the net was made at each station on a sampling day. However, on some days, a series of sequential seine samples were taken at the same station, particularly at Seine Stations 1 and 2. The fish were preserved in 4 percent formalin and brought to the laboratory for study.

At the laboratory each fish sample was sorted by species. The standard length (tip of snout to end of vertebral column) of all fish was measured by means of dividers and a steel rule. Measurements were to the nearest .1 mm. Since each seine haul was taken in a designated area following a prescribed procedure the number of fish captured in the known area seined can be taken as a measure of relative abundance. Since the area seined at each haul could not always be the same, resulting in variable units of measure of relative abundance, the unit of measure of relative abundance was arbitrarily set at the number of fish per 5000 square feet of area seined and each seine set adjusted to this unit.

B. Procedures and Methods (Holding Experiments)

This experiment was run on September 4, 1969 after arrangement with the plant management at Danskammer to adjust their flow of discharge water to obtain a maximal thermal effect. Three fyke nets each approximately 4' high, 4' wide and 10' long were anchored in 5' of water close to the discharge canal of the Danskammer Power Station. The fish used were collected at Seine Station 2 using the 50' seine described above. The water temperature at this station at the time of collection of the fish was 91 degrees F. After each seine haul the fish were stored in a plastic tub until a sufficient number could be taken to warrant the experiment. The fish were held in the tub for 1 hour. At the end of this time the water temperature had fallen to 84 degrees. Inactive and injured fish were discarded and each species of the remaining fish was divided into three equal or near equal lots by transferring each lot to a plastic bucket.

A single lot of each species was poured from a bucket into each of the three fyke nets and the mouth and bag openings closed. The number and size composition of each species of fish introduced into each fyke is summarized in Tables 13 and 14. Included are white perch, striped bass, pumpkinseed, bluegill, golden shiner (Fyke 1 only), spottail shiner, goldfish, banded killifish and brown bullhead.

The fish were introduced into Fyke 1 at 12:22, into Fyke 2 at 12:30 and into Fyke 3 at 12:38. They were removed 1 hour later from Fyke 1, 2½ hours later from Fyke 2 and 4 hours later from Fyke 3. The fish removed from each fyke were placed in buckets of water and then transferred to a holding tub and their condition observed. During the period in which the fish were retained in the fykes, a continuous recorder connected to a thermister set at a depth of 3' in the region of the fykes showed a temperature range of 92.4 to 93.0 degrees F. Periodic check of the temperature at the surface and bottom in the vicinity of the fykes with a thermometer indicated that these were the same.

C. Results

1. Physical and Chemical Aspects

a. Water Temperature

Data on water temperature at the seining sites at the time the fish were sampled are summarized in Table 3. Only water temperatures at depths of four feet or less are given since these were the effective seining depths. Computed differences in temperature between the surface and bottom water and the maximum and minimum rise in temperature of these layers of water over the ambient are given in Table 4. Differences in temperature between the surface and the bottom layers of water at the seining sites ranged from 0.1 to 6.4 at Seine Station 1, 0.0 to 4.2 at Seine Station 2 and 0.0 to 7.1 at Seine Station 3. Large temperature differentials between the surface and bottom layers of water at Seine Stations 1 and 2 appear to occur mostly at flood tides and are apparently caused by retention of some of the heated effluent at the surface of the "indentation" area. At ebb tides there appear to be a good mixing of the heated effluent and river waters. During the sampling period the maximum rise in water temperature over ambient water temperature at Seine Station 1 ranged from 6.5 to 15.2 degrees F, at Seine Station 2, from 0.6 to 14.2 and at Seine Station 3, from 0.8 to 12.5. The average surface temperature was highest at Seine Station 1 (89.1 and 77.8 in Periods 1 and 2) next highest at Seine Station 2 (88.4 and 74.6 in Periods 1 and 2) and lowest at Seine Station 3 (85.6 and 74.0 in Periods 1 and 2). During the period August 13 to September 17 when water temperatures in the Danskammer "indentation" were mostly over 83 degrees F. the surface and bottom at the time fish samples were taken at Stations 1 and 2 were approximately the same. It should be noted that during this period fish at these two seining sites were in water ranging in temperature from 85.9 to 91.0 degrees.

b. Salinity

There appears to be no significant difference among the seining stations in the salinity of the water (Table 3). Salinity readings (mg/l) were relatively low at all stations ranging from 50 to 360.

c. Dissolved Oxygen

Dissolved oxygen was always adequate at all seine stations and no significant difference in this parameter could be discerned among the stations (Table 3).

2. Biological Aspects

a. Species Composition of the Fish Catch

(1) Relative Abundance

A total of 20 species of fishes were captured by the seine. A list of these fishes including the common and scientific names are given in Table 19. Information on relative abundance of each species of fish is summarized in Tables 5 to 7. In these tables, the catch of all species per single set of the haul seine is enumerated in terms of an adjusted catch per 5000 square feet of seine area. Each table summarizes the data for a single seine station (Table 5, Seine Station 1; Table 6, Seine Station 2; Table 7, Seine Station 3). Examination of the data shows that 9 species of fishes predominate in the waters at Danskammer. These are the white perch, striped bass, brown bullhead, spottail shiner, golden shiner, goldfish, banded killifish, Jonny darter and pumpkinseed. In the period Aug. 13 to Sept. 17 they were 96.89%, 96.60% and 92.10% of all the fish taken at Seine Stations 1, 2 and 3 respectively. In the period Sept. 24 to Oct. 22 they were 98.01%, 94.84% and 38.06% of all the fish caught at Seine Stations 1, 2 and 3 respectively (Tables 5-7, Figures 6-7).

The average number of all fish and of each of the nine predominant species of fish caught per individual set of the haul seine (adjusted to number per 5000 sq. ft. of seine area) during the periods Aug. 13 to Sept. 17 and Sept. 24 to Oct. 22 is shown in Table 8 and Figures 6 and 7. Looking first at Period 1, Aug. 13 to Sept. 17, (Figure 6), the abundance of all fish was highest at Seine Station 1 (181.7) almost as high at Seine Station 2 (165.0) and was lowest at Seine Station 3 where the abundance was about 50% less (97.1). Looking at the individual species, the white perch was most abundant at Station 1 (67.1), somewhat less abundant at Station 2 (50.0) and at a considerably lower level of abundance at Station 3 (7.4). Striped bass was far more abundant at Station 1 than at Station 2 (47.8 and 8.6 respectively) and was not present at Station 3. Brown bullhead were present in moderate amounts at Stations 1 and 2 (15.5 and 9.8) and rare at Station 3 (1.7). Spottail shiner were most common at Station 2 (23.4), less common at Station 3 (10.3) and uncommon at Station 1 (2.2). Golden shiner were fairly abundant at Station 2 (37.2) and uncommon at Stations 1 and 3 (3.6 and 4.6). Goldfish were present in moderate numbers at Stations 1 and 3 (15.3 and 16.3) but less common at Station 2 (5.4). Banded killifish were very abundant at Station 3 (45.4), only half as abundant at Station 2 (20.4) and uncommon at Station 1 (3.6). Johnny darter were present in moderate numbers at Station 1 (18.4) were less common at Station 2 (6.2) and uncommon at Station 3 (1.7). Pumpkinseed were not abundant at any stations but were most numberous at Station 1 (8.2) compared to 4.0 and 2.0 at Stations 2 and 3 respectively.

In Period 2, Sept. 24 to Oct. 22, (Figure 7), the abundance of all species was again highest at Seine Station 1 (810.2) and far greater than the abundance at Stations 2 and 3 (171.0 and 156.0). White perch were very abundant at Station 1 (256.6) abundant to a much lesser extent at Station 2 (54.7) and only moderately abundant at

Station 3 (17.6). Striped bass were very abundant at Station 1 (495.6) abundant to a much lesser extent at Station 2 (58.8) and not present as in the previous period at Station 3. Brown bullhead was only present in low numbers at all stations (0.4, 3.5 and 4.0 at Stations 1, 2 and 3). Spottail shiner as in the previous month were moderately abundant at Station 2 (23.7) and uncommon at Stations 1 and 3 (3.2 and 5.2). Golden shiner were uncommon at all stations (0.2, 4.7, 2.0 at Stations 1, 2, 3 respectively). This was also true for the goldfish at Station 1 and 2 (2.0 and 0.5). They were somewhat more prevalent at Station 3 (7.8). Banded killifish were uncommon at Station 1 (1.2), not taken at Station 2 and were in moderate numbers at Station 3 (13.0). Johnny darter were present in moderate numbers at Stations 1 and 2 (7.8 and 5.2) but uncommon at Station 3 (1.0). Pumpkinseed were moderately abundant at Station 1 (27.4) but less so at Stations 2 and 3 (11.0 and 8.8). As has been indicated above, during this period (Sept. 24 to Oct. 22), the nine predominant species made up only 38.06% of the fish caught at Station 3. Much of the remaining portion of the catch was made up of blueback herring and to a lesser extent of alewife and mummichog (Table 7).

2. Relationship of Relative Abundance of Predominant Species of Fish to Water Temperature

The relationship of the relative abundance of each of the nine predominant species to water temperature is indicated from data contained in Tables 3-8.

a. White Perch

Regardless of water temperature fewer white perch were present at Station 3 than at the other two stations. They were more abundant at Station 1 than at Station 2 although differences in water temperature between these two stations are slight. The greater abundance of white perch at Station 1 might be attributed to its preference for a sand-gravel-stone bottom as a habitat. Such a habitat is most extensive at Station 1, less so at Station 2 and almost nonexistent at Station 3. Most fish were in the young-of-the-year age group (0+) as indicated by length frequency data (Table 9).

b. Striped Bass

Again regardless of water temperature, striped bass were much more abundant at Station 1 than at Station 2 and were not present at all at Station 3. As with the white perch, the striped bass prefers a hard bottom and this is most available at Station 1. Fish were mostly in the 0+ age group (Table 9).

c. Brown Bullhead

The brown bullhead appeared to be most abundant at Stations 1 and 2 at the season of the year when the water was warmest. Since this species prefers a muddy bottom its high abundance at Stations 1 and 2, where the bottom is predominantly hard, might be attributed in part to the attraction by the warmer water. The fish were all in the 0+ age group (Table 9).

d. Spottail Shiner

Spottail shiner were much more abundant at Station 2 than the other stations and no relationship to water temperature was apparent. It is likely that the deeper water immediately off the collecting beach, with its mud bottom and emergent plants, is a favorite habitat of this species, and that this population wanders into the limited beach area where it is vulnerable to the seine. Most of the fish taken were apparently in the 0+ year class (Table 9).

e. Golden Shiner

There was no obvious relationship between golden shiner abundance and water temperature. This was a relatively uncommon species in the "indentation" area and was taken only in quantity during August at Station 2. These fish belonged to the 1+ or older age groups and probably wandered into the limited beach seining area from the deeper, weedier, habitat immediately offshore. During the same period, the fish at the other stations were mainly in the 0+ age group (Table 9).

f. Goldfish

No obvious relationship was observed between the abundance of this species and water temperature. During the period of highest water temperatures (Aug. 13-Sept. 17) goldfish were most abundant at Station 1 and 3. In the period of lower water temperatures, the abundance dropped at all stations but to a lesser extent at Station 3. Station 3, which had the greatest overall abundance of goldfish during the entire study, is a shallow, mud flat, a habitat favored by this species. Age groups found included 0+ and older fishes (Table 9).

g. Banded Killifish

Again the relationship of the abundance of this species to water temperature was not apparent. This banded killifish was found most abundantly at Station 3 throughout the study period and was fairly abundant at Station 1, during the interval Aug. 13-Sept. 17. In the Hudson River, this species has been found most commonly in places with muddy bottoms. It's abundance pattern at Danskammer is therefore most likely attributable to habitat preference. The sizes of fish taken are shown in Table 9.

h. Johnny Darter

Abundance of the Johnny darter was greatest at Station 1 and diminished progressively at Stations 2 and 3. It is not likely that the increase in abundance is associated with an increase in water temperature. Rather such an increase in abundance would be expected as a result of habitat preference. The Johnny darter, lacks a gas bladder and consequently, is primarily a bottom inhabitant. It is most commonly found on firm, sandy bottoms. Such a bottom is most available at Station 1 and becomes progressively less available at Stations 2 and 3. The size of fish caught are shown in Table 9.

e. Pumpkinseed

The pumpkinseed, like the Johnny darter, favors a habitat having a firm bottom. The abundance of this species at the three stations follows a pattern similar to that of the Johnny darter and also appears to be related to the availability of preferred habitat. The sizes of fish taken, both 0+ and older age groups, are shown in Table 9.

To complete the picture on the fish taken by seine, the sizes of the other fish present in the catch at the various stations are summarized in Tables 10-12.

b. Fish Viability Related to Water Temperature

Results from the holding experiments are summarized in Tables 13 and 14. In Fyke 1, after the fish had been held in water ranging from 92.4-93.0 degrees F for 1 hour, 3 of the 10 white perch were dead; the sole bluegill was dead; and 1 of the small pumpkinseed and 2 of the small banded killifish were missing. These could have died and been eaten or since they were small killed and eaten by the larger fish. In Fyke 2, after the fish had been held for 2½ hours in the same temperatures of water, 2 of the 9 white perch were dead, and 4 of the banded killifish were missing. In Fyke 3, after the fish had been held for 4 hours in the same temperatures of water, 4 of the 9 white perch were dead; the sole small striped bass used was dead; 2 of the 4 pumpkinseed were missing; the sole spottail shiner was missing; of the initial 6 banded killifish, 1 was dead and 3 missing; 1 of the 4 brown bullheads was dead.

Observation of the living fish in a holding tank for a period of one hour after removal from the net showed a residual mortality in three of the nine species. This residual mortality was most apparent in the white perch and to a lesser extent in the banded killifish and spottail shiner. Whether the residual mortality in these species was due to their retention in the heated water or handling is difficult to say. It was noticed that those fish which were dying in the holding tank were severely scaled, probably by the webbing of the fyke net. The remainder of the fish, which were active and moved, normally, showed no scaling.

D. Conclusions

In summary, the above data would indicate that the abundance of various predominant species of fish in the Hudson River is closely associated with habitat preference. Increased water temperatures, even as high as 91 degrees F, does not appear to influence abundance.

Whether abundance is maintained by a constantly, emigrating and immigrating population, or a stationary one able to effectively adjust to the higher water temperatures, or both, is not known. Preliminary holding experiments suggest that these fish can live in water temperatures in the low 90's without apparent ill effect, for varying periods of time, depending on the species.

IV. DISTRIBUTION OF LARVAL FISHES

A. Similarity of the Danskammer-Roseton Area and the Cornwall Area

The stretch of river extending from the Danskammer-Roseton area to the Cornwall area is fairly uniform, and consists of rather extensive shoals on the East side of the river, a relatively narrow shoal area on the West side of the river, and a channel reaching depths down to 80' (Figure 8). Species of fish taken at Cornwall are the same as those taken at the Danskammer-Roseton area. At both places, either at the existing or proposed power station sites on the western shore, there is little shoal area compared to the extensive shoals on the opposite eastern shore.

Consequently, it might be expected that information obtained on the distribution of fish larvae at Cornwall would be indicative of the distribution in the Danskammer-Roseton area. Examination of all data obtained by Northeast Biologists during the period 1965-1968, showed that the 1968 data were most suitable for such a study. Following is an analysis of these data to show comparative larval concentrations at various depth contours in terms of striped bass, white perch and all other species combined.

B. Data Analysis

The average numbers of larvae along a depth contour presented in the next three items (C,D&E), Tables 15 through 18, and Figures 9 through 19 were based on a simple arithmetic average of the magnitudes of the observations at that location.

The percentages of larvae in the area from the western shore to a given depth contour were computed by dividing the sum of contour averages within that area to the sum of all contour averages. This averaging technique gives an equal weight to the contour averages rather than to the individual observations.

A more representative percentage giving equal weight to all of the observations may be obtained by dividing the sum of the individual values within the area of interest to the sum of all of the observations within the cross-section.

The following example may help to clarify the difference between the two averaging techniques:

The per cent of miscellaneous fish larvae found in the area from the western shore to the 30' contour at Cornwall during May 16-31, 1968 is 20.7 using the contour average method (see Table 16 and

Figure 10). Using the weighted average method, this value becomes 16.4%.

Due to its simplicity the contour average method was used to present the percentages corresponding to the different contour locations. These results are presented in items C through E. The weighted average method was used to compute the percentages of the larvae that were found in the area bounded by the west shore and the 30' contour only. These results are given in item F.

C. Concentration of Miscellaneous Fish Larvae Related to Depth Contours

The results of the study of the concentration of miscellaneous fish larvae (all larvae exclusive of striped bass and white perch) in relation to depth contours are summarized in Tables 15-18 and Figures 9-18. These larvae were most numerous from mid-May to mid-June with the average number for all depths along a depth contour, ranging from 8.7 to 34.9 larvae per 1000 cu. ft. of water. During this period, of all the miscellaneous larvae present across the whole stretch of the river, less than 21% were found in the area from the western shore to the 30 foot contour and less than 28% to the 45 foot contour. Of the larvae in the area from the western shore to the 30 foot contour, from 52% to 67% were at the surface and 17% to 48% were at the bottom (Figures 15-16).

D. Concentration of White Perch Larvae Related to Depth Contours

The results of the study of the concentration of white perch larvae in relation to depth contours are summarized in Tables 15-18. White perch larvae were most abundant from mid-May to mid-June with the average number for all depths along a depth contour ranging from 0.8 to 5.0 larvae per 1000 cu. ft. of water. During this period of all the white perch larvae present across the whole stretch of the river, less than 13% were found in the area from the western shore to the 30 foot contour and less than 20% to the 45 foot contour. Of the white perch larvae in the area from the western shore to the 30 foot contour, 23% to 50% were at the surface and 34% to 70% were at the bottom.

E. Concentration of Striped Bass Larvae Related to Depth Contours

The results of the study of the concentration of striped bass larvae in relation to depth contours are summarized in Tables 15-18. Striped bass larvae were most abundant from mid-May to mid-June with the average number for all depths along a depth contour ranging from 1.1 to 19.4 larvae per 1000 cu. ft. of water. During this period of all the striped bass larvae present across the whole width of the river, less than 19% were found in the area from the western shore to the 30 foot contour and less than 34% to the 45 foot contour. Of the striped bass larvae in the area from the western shore to the 30 foot contour, 9% to 30% were at the surface and 65% to 75% were at the bottom.

F. Conclusions

Concentrations of fish larvae obtained in the Cornwall area from late April thru mid-July, 1968 by Northeast Biologists were analyzed to determine the effect of the Roseton intake on fish larvae. Consideration of channel and shoal geometry from Danskammer Point to Cornwall, and of the types of fish species taken all along this reach indicates that the Cornwall data is indicative of the distribution of fish larvae in the Danskammer-Roseton area.

The maximum Roseton intake flow is 1,460 cfs, or 1% of the average tidal flow in the Hudson at this point. The cross-sectional area between the west bank and the 30 ft. depth contour on the west side of the river's channel is 4% of the river's cross-section. This 30 ft. contour represents a conservative estimate of the boundary of the zone in the river in the vicinity of Roseton, within which intake water is withdrawn.

Since the tidal excursion is 4 miles, waters will be withdrawn from the zone between Marlboro on the north and Newburgh on the south. These represent outer boundaries, and most of the waters withdrawn by the plant are within a very small region in the near vicinity of the plant.

Based on the Cornwall data, the percentages of larvae within this zone of the river, which can be expected to be located west of the river channel's western 30 ft. depth contour are 11% of striped bass larvae, 12% of white perch larvae, and 15% of the larvae of remaining species. These percentages were computed using the weighted average method described in item B above.

These percentages were based on a schematic representation of the river's cross-section, in which the 30 ft. contour bounded 7%, rather than the actual 4% of the river's cross-section. Therefore, the percentages of larvae given above are about 75% higher than estimates based on actual cross-section data.

Only a very small fraction of the larvae estimated above to exist with the 30 ft. contour will be influenced by the plant intake. Comparing the fraction of the river's cross-section bounded by the 30 ft. contour (4%) to the fraction of the average tidal flow withdrawn by the plant (1%) suggests that most of the water will be withdrawn from a zone well within this bounding contour.

Secondly, as shown on Figure 19, the larvae tend to concentrate at the surface and bottom.

The intake is provided with a skimmer wall to a point about 5 feet below normal low water level. This wall will effectively block the withdrawal of the surface fish larvae in this area.

The slope of the modified river bottom running out to deep water in the area of the intake and the low velocities at the bottom layer will reduce the withdrawal of fish larvae in this area.

Table 1 Abundance 1/ of Bottom Organisms in the Vicinity of the Danskammer Power Station; May-June 1969

Station	Date	Time	Depth	Surface Temp. (Cent.)	Annelids	Chironomid Larvae	Nematodes	Polychaetes	Copepods	Invertebrate Eggs	Hirudinea
1	May 7	10:35	5	25.0	2	3	—	1	—	1	—
2	"	9:48	10	24.0	21	—	—	—	—	—	—
3	"	11:00	33	24.0	—	1	—	—	1	—	—
4	"	12:20	10	21.0	—	—	—	—	—	—	—
5	"	12:07	33	20.0	—	—	—	—	—	—	—
Total	"				23	4	—	1	1	1	—
1	May 21	9:00	5	29.0	8	2	—	—	—	—	—
2	"	9:09	11	23.0	2	—	—	—	—	—	—
3	"	9:18	38	2/	9	5	—	—	—	—	—
4	"	9:27	13	2/	11	2	—	—	—	—	—
5	"	9:40	37	2/	4	3	1	—	—	—	—
Total	"				34	12	1	—	—	—	—
1	June 4	8:38	7	29.0	17	1	—	—	—	—	—
2	"	8:46	10	28.0	31	6	—	—	—	—	—
3	"	9:02	28	23.0	4	7	—	—	—	—	—
4	"	9:13	14	27.0	19	—	—	—	—	—	—
5	"	9:19	42	21.0	7	1	—	—	—	—	—
Total	"				78	15	—	—	—	—	—
1	June 18	9:47	5	26.0	6	—	—	—	—	—	—
2	"	9:56	9	25.5	5	—	—	—	—	—	—
3	"	10:02	38	24.0	13	—	—	4	—	—	—
4	"	10:10	11	27.0	52	—	—	—	—	—	—
5	"	10:15	30	25.0	12	—	—	—	—	—	—
Total	"				88	—	—	4	—	—	—

1/ Number per 400 cc. sample of bottom.

2/ Instrument inoperative.

Table 1a Station; Abundance 1/ of Bottom Organisms in the Vicinity of the Danskammer July-August 1969.

Station	Date	Time	Depth (ft.)	Surface Temp. Cent.	Annelids	Polychaetes	Chironomid Larvae	Hirudineans	Isopods
1	July 2	8:40	5	30.5	16	-	-	-	-
2	"	8:52	12	28.0	6	-	-	-	-
3	"	9:30	30	27.0	13	-	-	-	-
4	"	9:50	18	30.5	31	-	1	-	-
5	"	9:40	34	27.0	9	-	1	-	-
Total					75	-	2	-	-
1	July 16	8:50	6	31.0	10	-	1	-	-
2	"	8:58	9	28.0	3	-	-	-	-
3	"	9:08	31	27.0	2	-	-	-	-
4	"	9:15	15	30.0	12	-	1	1	-
5	"	9:21	29	28.0	15	1	1	-	-
Total					42	1	3	1	-
1	July 30	9:14	6	31.0	9	-	-	-	-
2	"	9:23	9	30.0	4	1	-	-	-
3	"	9:28	32	27.0	23	-	-	1	-
4	"	9:44	15	30.0	33	-	-	-	-
5	"	9:53	32	29.0	0	-	-	-	-
Total					69	1	-	1	-
1	Aug. 13	11:45	6	30.0	13	-	-	-	-
2	"	11:50	10	28.0	7	-	-	-	-
3	"	12:10	32	28.5	1	-	-	-	-
4	"	12:15	10	31.0	11	1	1	-	-
5	"	12:25	31	27.5	1	1	-	-	-
Total					33	2	1	-	-
1	Aug. 20	8:45	5	31.0	3	-	-	-	-
2	"	8:50	9	28.0	6	-	-	-	-
3	"	8:55	30	25.0	1	-	-	-	-
4	"	9:00	15	29.0	3	-	-	-	-
5	"	9:10	30	25.0	1	1	-	-	1
Total					14	1	-	-	1
1	Aug. 27	10:40	6	32.0	19	-	-	-	-
2	"	10:50	10	28.0	5	1	-	-	-
3	"	10:55	35	25.0	4	-	-	-	-
4	"	11:00	10	24.0	4	-	-	-	-
5	"	11:10	29	24.0	8	-	-	-	-
Total					40	1	-	-	-

1/ Number per 400 cc. sample of bottom.

Table 1b Abundance 1/ of Bottom Organisms in the Vicinity of the Danskammer Station: September - October 1969

Station	Date	Time	Depth (ft.)	Surface Temp. Cent.	Annelids	Poly-chaetes	Chiron-omid Larvae	Isopods	Amphipods
1	Sept. 3	8.55	5	32.0	14	–	–	–	–
2	"	9.02	10	26.5	8	–	–	–	–
3	"	9:05	35	26.0	1	–	–	–	–
4	"	9:10	15	32.0	9	–	–	–	–
5	"	9:13	35	26.0	6	1	–	–	–
Total					38	1	–	–	–
1	Sept. 10	8:45	5	28.0	4	–	–	1	–
2	"	8:47	9	26.5	12	–	1	–	–
3	"	8.51	28	25.0	5	–	–	–	–
4	"	8:55	10	27.5	4	–	–	–	–
5	"	9:00	29	26.0	2	–	–	1	–
Total	"				27	–	1	2	–
1	Sept. 17	10:35	6	30.0	7	–	–	–	–
2	"	10:10	10	27.0	3	–	–	–	–
3	"	10:20	35	26.0	5	–	–	–	–
4	"	10:40	10	29.0	2	–	–	–	–
5	"	10:45	30	26.0	6	–	–	–	–
Total					23	–	–	–	–
1	Sept. 24	9:00	9	23.0	5	–	–	–	–
2	"	9:08	11	21.0	9	–	–	–	–
3	"	9:15	25	22.0	5	–	–	–	–
4	"	9:30	14	22.0	5	–	–	–	–
5	"	9:35	31	22.0	11	–	–	2	–
Total	"				35	–	–	2	–
1	Oct. 1	11:35	5	27.0	14	2	–	–	–
2	"	11:43	10	26.0	8	–	2	–	–
3	"	11:52	34	22.0	–	–	–	5	–
4	"	12:00	13	26.0	2	–	–	–	–
5	"	12:07	31	23.0	1	–	–	–	1
Total	"				25	2	2	5	1
1	Oct. 8	10:48	7	19.0	3	–	–	–	–
2	"	11:03	10	19.0	1	–	–	–	3
3	"	11:08	32	20.0	1	–	–	–	1
4	"	11:17	14	20.0	4	–	–	–	–
5	"	11:23	35	19.0	–	–	–	–	–
Total	"				9	–	–	–	4
1	Oct. 15	10:50	5	23.0	5	–	–	–	–
2	"	11:00	6	21:5	6	–	–	–	–
3	"	11:10	33	20.0	1	1	–	–	–
4	"	11:20	15	21.5	11	–	1	–	–
5	"	11:35	41	20.0	–	–	2	–	–
Total	"				23	1	3	–	–
1	Oct.22	11:25	10	16.0	2	–	–	–	–
2	"	11:35	16	16.0	3	–	–	–	–
3	"	11:40	41	16.0	1	–	–	1	–
4	"	11:50	21	16.0	2	–	2	–	–
5	"	11:55	40	16.0	2	–	2	–	–
Total	"				10	–	4	1	–

1/ Number per 400 cc sample of bottom.

Table 2 Abundance 1/ of Bottom Organisms in the Vicinity of the Proposed Roseton Power Station; May-June 1969.

Station	Date	Time	Depth (ft)	Surface Temp. (Cent.)	Annelids	Chironomid Larvae	Polychaetes
1	May 7	12:37	10	14.0	—	—	—
2	"	12:50	25	14.0	—	—	—
3	"	13:31	29	14.0	—	—	—
4	"	13:58	18	14.5	—	—	—
5	"	13:38	26	14.0	—	—	—
Total	"				—	—	—
1	May 21	9:50	12	2/	—	—	—
2	"	9:58	17	2/	1	1	—
3	"	10:03	25	2/	8	5	—
4	"	10:08	16	2/	10	—	—
5	"	10:15	23	2/	—	—	—
Total	"				19	6	—
1	June 4	9:39	5	20.0	14	1	—
2	"	9:46	17	20.0	6	2	—
3	"	9:52	25	21.0	5	—	—
4	"	10:00	14	20.0	—	—	—
5	"	10:13	15	20.0	—	—	—
Total	"				25	3	—
1	June 18	10:27	5	22.0	—	—	1
2	"	10:32	14	22.0	18	1	—
3	"	10:37	24	22.0	21	—	—
4	"	10:42	9	21.5	—	1	—
5	"	10:47	17	21.5	—	—	—
Total	"				39	2	1

1/ Number per 400 cc. sample of bottom.

2/ Instrument inoperative.

Table 2a Abundance 1/ of Bottom Organisms in the Vicinity of the Proposed Roseton Power Station; July-August 1969.

Station	Date	Time	Depth (ft.)	Surface Temp. Cent.	Annelids	Polychaetes	Chironomid Larvae
1	July 2	10:10	4	25	1	-	-
2	"	10:05	6	25	-	-	-
3	"	9:58	20	25	7	-	-
4	"	10:20	10	25	2	-	1
5	"	10:25	20	25	8	-	1
Total					18		2
1	July 16	9:37	3	24	4	1	1
2	"	9:44	5	24	9	1	-
3	"	9:50	20	25	16	1	2
4	"	9:57	10	25	-	-	-
5	"	10:04	16	25	-	-	-
Total					29	3	3
1	July 30	10:05	5	25	1	-	-
2	"	10:30	6	25	1	-	-
3	"	10:40	22	25	3	-	-
4	"	10:45	10	25	-	-	-
5	"	10:52	20	25	-	-	-
Total					5	-	-
1	Aug. 13	12:30	6	26	2	-	-
2	"	12:40	17	26	7	-	-
3	"	12:50	24	27	8	-	-
4	"	13:00	10	26	-	-	-
5	"	13:10	25	25.5	3	-	-
Total					20	-	-
1	Aug. 20	9:30	5	25	-	-	-
2	"	9:15	13	25	3	-	-
3	"	9:25	26	26	4	-	-
4	"	9:35	13	25	-	1	-
5	"	9:45	27	26	-	-	-
Total					7	1	-
1	Aug. 27	11:20	6	24	1	-	-
2	"	11:25	15	24	2	-	-
3	"	11:30	24	24	8	-	-
4	"	11:40	10	24	-	-	-
5	"	11:35	26	24	-	-	-
Total					11	-	-

1/ Number per 400 cc. sample of bottom

Table 2b Abundance 1/ of Bottom Organisms in the Vicinity of the Proposed Roseton Power Station; Sept.-Oct. 1969.

Station	Date	Time	Depth (ft.)	Surface Temp. Cent.	Annelids	Polychaetes	Chironomid Larvae
1	Sept. 3	9:22	9	25.0	6	–	–
2	"	9:25	23	25.5	4	–	–
3	"	9:28	26	25.0	5	–	1
4	"	9:32	15	25.0	–	–	–
5	"	9:34	25	25.5	–	–	–
Total	"				15	–	1
1	Sept. 10	9:05	5	23.5	7	–	–
2	"	9:08	15	23.0	3	–	–
3	"	9:12	23	23.5	2	–	–
4	"	9:16	15	23.0	0	–	–
5	"	9:18	25	23.5	1	–	–
Total	"				13	–	–
1	Sept. 17	10:50	3	24.0	4	–	–
2	"	10:55	8	24.0	2	–	–
3	"	11:00	22	24.0	5	–	–
4	"	11:10	9	25.0	3	–	–
5	"	11:15	20	25.0	3	–	–
Total					17	–	–
1	Sept. 24	9:50	6	22.0	2	–	–
2	"	10:00	16	22.0	5	–	–
3	"	10:05	26	21.0	1	–	1
4	"	10:10	11	21.0	1	–	–
5	"	10:17	25	21.0	–	–	–
Total	"				9	–	1
1	Oct. 1	12:18	4	21.0	–	–	–
2	"	12:24	14	21.0	2	–	–
3	"	12:30	25	21.0	1	–	–
4	"	12:37	10	21.0	1	–	–
5	"	12:42	20	21.0	–	–	–
Total	"				4	–	–
1	Oct. 8	11:35	6	19.0	1	–	–
2	"	11:41	9	19.0	–	–	–
3	"	11:47	22	19.0	5	–	–
4	"	11:55	10	19.0	–	–	1
5	"	12:00	21	19.0	–	1	1
Total	"				6	1	2
1	Oct. 15	11:45	5	18.5	–	–	1
2	"	11:50	7	18.5	–	–	–
3	"	12:00	20	18.5	3	–	–
4	"	12:05	10	18.5	–	–	–
5	"	12:10	25	18.5	1	–	2
Total	"				4	–	3
1	Oct. 22	12:08	8	16.0	–	–	–
2	"	12:12	20	16.0	1	–	2
3	"	12:17	30	16.0	2	–	–
4	"	12:25	12	16.0	–	–	1
5	"	12:30	20	16.0	–	–	–
Total	"				3	–	3

1/ Number per 400 cc. sample of bottom.

Table 3 Physical Data: Danskammer, August - October 1969.1/

Date	Time	Tidal Cycle	Ambient Temp (F)	Station	Temperature (Fahrenheit) Surface	Depth in Feet 1	2	3	4	D.O. (mg/l)	Salinity (mg/l)
8/13	10:00- 11:30	Early Flood	77.3	1	89.4	89.02/	–	–	–	–	–
"	"	"	"	2	89.0	–	–	–	–	–	–
"	"	"	"	3	88.0	–	–	–	–	–	–
8/20	9:30- 11:30	Max. Ebb	76.0	1	91.2	91.1	91.0	91.02/	–	6.1	65
"	"	"	"	2	90.0	90.0	89.0	–	–	5.9	72
"	"	"	"	3	88.5	89.0	83.5	–	82.2	6.4	76
9/3	9:30	Max. Ebb	76.0	1	90.2	90.5	90.52/	–	–	6.4	76
"	11:20	"	"	2	90.2	90.0	89.5	–	–	6.0	58
"	11:43	"	"	3	87.0	87.02/	–	–	–	–	–
9/10	9:30- 11:00	Late Ebb	76.0	1	88.0	88.0	88.0	88.0	88.8	6.1	58
"	"	"	"	2	86.1	86.1	86.1	86.0	86.0	6.3	126
"	"	"	"	3	83.1	80.8	78.0	77.0	76.93/	6.1	360
9/17	11:35- 12:50	Low Slack	75.0	1	86.5	86.4	86.4	86.4	86.4	5.9	162
"	"	"	"	2	86.5	86.5	86.4	86.1	85.9	6.1	–
"	"	"	"	3	81.5	81.2	80.22/	–	–	7.3	67
9/24	10:25- 11:30	Max. Flood	72.4	1	78.9	77.4	76.8	75.0	73.5	6.4	83
"	"	"	"	2	73.0	73.0	73.0	73.0	72.9	6.6	58
"	"	"	"	3	73.2	73.2	73.0	73.1	73.1	6.6	140
10/1	9:40- 10:40	Late Ebb	70.0	1	83.2	83.4	83.0	82.82/	–	6.3	108
"	"	"	"	2	82.5	82.5	82.5	82.12/	–	6.0	52
"	"	"	"	3	82.5	81.8	81.2	81.22/	–	6.5	50
10/8	11:40- 12:40	High Slack	67.5	1	80.3	80.3	79.5	79.2	78.5	7.2	104
"	"	"	"	2	79.0	78.1	76.4	75.4	74.8	7.1	243
"	"	"	"	3	75.5	73.6	70.0	68.6	68.42/	7.2	73
10/15	10:40- 11:45	Low Slack	65.8	1	76.9	76.7	76.7	76.5	76.42/	7.0	243
"	"	"	"	2	75.9	75.9	75.8	75.6	75.2	6.9	65
"	"	"	"	3	75.6	75.6	75.5	75.5	–	7.2	65
10/22	10:06	Max. Flood	61.04/	1	69.6	69.0	68.0	63.5	63.2	7.6	–
"	10:25	Late Flood	"	2	62.8	62.8	62.8	62.82/	–	7.7	–
"	10:35	"	"	3	63.0	63.0	63.02/	–	–	–	–

1/ Collected by Quirk, Lawler and Matusky

2/ Bottom

3/ Bottom; depth 3.5 feet.

4/ Estimated

Table 4 Changes in Water Temperature: Danskammer, August-October 1969

		TEMPERATURE					
Date	Station	Surface	Bottom	Ambient	Difference Between Surface and Bottom	Rise Over Ambient Maximum	Minimum
8/13	1	89.4	89.0	77.3	0.4	12.1	11.7
"	2	89.0	—	"	—	11.7	—
"	3	88.0	—	"	—	10.7	—
8/20	1	91.2	91.0	76.0	0.2	15.2	15.0
"	2	90.0	89.0	"	1.0	14.0	13.0
"	3	88.5	82.2	"	6.3	12.5	6.2
9/3	1	90.2	90.5	76.0	0.3	14.5	14.2
"	2	90.2	89.5	"	0.7	14.2	13.5
"	3	87.0	87.0	"	0.0	11.0	11.0
9/10	1	88.0	88.8	76.0	0.8	12.8	12.0
"	2	86.1	86.0	"	0.1	10.1	10.0
"	3	83.1	76.9	"	6.2	7.1	0.9
9/17	1	86.5	86.4	75.0	0.1	11.5	11.4
"	2	86.5	85.9	"	0.6	11.5	10.9
"	3	81.5	80.2	"	1.3	6.5	5.2
9/24	1	78.9	73.5	72.4	5.4	6.5	1.1
"	2	73.0	72.9	"	0.1	0.6	0.5
"	3	73.2	73.1	"	0.1	0.8	0.7
10/1	1	83.2	82.8	70.0	0.4	13.2	12.8
"	2	82.5	82.1	"	0.4	12.5	12.1
"	3	82.5	81.2	"	1.3	12.5	11.2
10/8	1	80.3	78.5	67.5	1.8	12.8	11.0
"	2	79.0	74.8	"	4.2	11.5	7.3
"	3	75.5	68.4	"	7.1	8.0	0.9
10/15	1	76.9	76.4	65.8	0.5	11.1	10.6
"	2	75.9	75.2	"	0.7	10.1	9.4
"	3	75.6	75.5	"	0.1	8.8	8.7
10/22	1	69.6	63.2	61.0	6.4	8.6	2.2
"	2	62.8	62.8	"	0.0	1.8	1.8
"	3	63.0	63.0	"	0.0	2.0	2.0

Table 5 Number of Each Species of Fish Caught Per Set of the Haul Seine 1/: Danskammer

Station 1, August-October 1969,

Date	8/13	8/13	8/13	8/13	8/13	8/13	8/20	8/27	9/3	9/10	9/17	Total	
Time	9:25	9:30	17:35	17:50	18:00	18:05	10:15	9:35	12:10	9:45	9:35		
High Tide	13:10	13:10	13:10	13:10	13:10	13:10	18:10	12:42	18:24	12:10	16:30	No.	%
Temp 2/	89	89	94	94	94	94	91	89	90	88	86		
Area Seined	1500	1500	1500	1750	1750	1750	1500	2000	2000	1250	1250		
White Perch	186	200	40	20	18	8	100	44	10	28	84	738	35.79
Striped Bass	24	56	—	—	2	—	20	2	2	244	176	526	25.51
Brown Bullhead	44	60	6	8	6	22	16	—	—	—	8	170	8.24
Spottail Shiner	—	—	—	—	2	2	—	—	—	—	20	24	1.16
Golden Shiner	—	—	—	—	—	—	30	10	—	—	—	40	1.94
Goldfish	20	6	—	18	6	32	64	4	10	—	8	168	8.15
Banded Killifish	—	—	—	—	—	—	6	4	22	—	8	40	1.94
Johnny Darter	14	30	24	26	28	8	40	4	24	—	4	202	9.80
Pumpkinseed	—	4	4	2	—	—	—	—	—	—	80	90	4.36
Bluegill	4	10	—	—	—	—	—	—	—	—	4	18	0.87
White Catfish	—	—	—	8	—	6	4	—	—	—	—	18	0.87
Eel	—	—	—	—	—	6	4	—	2	4	8	24	1.16
Alewife	—	—	—	—	—	—	—	2	—	—	—	2	.10
Blueback Herring	—	—	—	—	—	—	—	—	—	—	—	—	—
Carp	—	—	—	—	—	—	—	—	—	—	—	—	—
Largemouth Bass	—	—	—	—	—	—	—	—	—	—	—	—	—
Fourspine Stickleback	—	—	—	—	—	—	—	—	—	—	4	4	.19
Crevalle Jack	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	292	366	74	82	62	84	284	70	70	276	404	2064	100.08

1/ In terms of number of fish per 5000 square feet of area seined.
2/ At surface of water in degrees Fahrenheit.

Table 5 (continued) Number of Each Species of Fish Caught Per Set of the Haul Seine 1/:

Station 1, August-October 1969.

Date	9/24	9/24	9/24	10/1	10/1	10/8	10/15	10/15	10/22	10/22	Total	
Time	15:17	15:29	15:37	9:45	13:30	9:55	9:25	9:35	9:15	9:30		
High Water	11:35	11:35	11:35	16:55	16:55	10:50	15:20	15:20	9:48	9:48		
Temp 2/	82	82	82	83	81	80	77	77	70	70		
Area Seined	1250	1250	1250	2250	1250	2500	1250	1250	250	500	No.	%
White Perch	16	24	28	144	1052	18	88	76	—	1120	2566	31.66
Striped Bass	92	4	8	300	956	36	152	28	1080	2300	4956	61.16
Brown Bullhead	—	—	—	—	4	—	—	—	—	—	4	0.05
Spottail Shiner	—	—	—	—	—	—	28	4	—	—	32	0.39
Golden Shiner	—	—	—	2	—	—	—	—	—	—	2	0.02
Goldfish	—	—	—	12	4	—	—	4	—	—	20	0.25
Banded Killifish	—	—	—	—	—	—	12	—	—	—	12	0.15
Johnny Darter	—	—	—	14	16	—	12	36	—	—	78	0.96
Pumpkinseed	24	12	52	22	40	—	32	12	—	80	274	3.37
Bluegill	4	—	4	2	8	—	—	—	—	—	18	0.22
White Catfish	—	—	—	—	—	2	—	4	—	—	6	0.07
Eel	—	—	—	12	—	—	—	8	—	—	20	0.25
Alewife	—	—	—	—	—	—	—	—	—	—	—	—
Blueback Herring	—	—	—	—	—	—	20	24	—	—	44	0.54
Carp	4	—	4	2	—	—	—	—	—	—	10	0.12
Largemouth Bass	—	—	—	—	—	—	—	—	40	—	40	0.49
Fourspine Stickleback	—	—	—	—	—	—	—	—	—	—	—	—
Crevalle Jack	—	—	—	4	16	—	—	—	—	—	20	0.25
Total	40	40	96	514	2096	56	344	196	1120	3500	8102	99.95

1/ In terms of number of fish per 5000 square feet of area seined.
2/ At Surface of water in degrees Fahrenheit.

Table 6 Number of Each Species of Fish Caught Per Set of the Haul Seine 1/: Danskammer

Station 2, Aug.-Oct. 1969.

Date	8/13	8/13	8/13	8/13	8/13	8/20	8/27	9/3	9/10	9/17		
Time	10:00	10:05	10:15	10:30	17:30	10:50	9:20	11:30	10:45	9:00	Total	
High Water	13:10	13:10	13:10	13:10	13:10	18:10	12:42	18:24	12:10	16:30		
Temp. 2/	89	89	89	89	90	90	88	90	86	86	No.	%
Area	1750	1750	1750	1750	1250	625	1250	1250	1000	1200		
White Perch	12	40	12	22	48	104	72	16	120	54	500	29.27
Striped Bass	—	2	—	2	—	—	4	4	20	54	86	5.04
Brown Bullhead	—	14	—	—	64	8	8	—	—	4	98	5.74
Spottail Shiner	2	18	6	8	100	88	—	8	—	4	234	13.70
Golden Shiner	66	66	82	66	4	56	8	—	20	4	372	21.78
Goldfish	—	2	—	—	—	—	16	12	4	20	54	3.16
Banded Killifish	—	2	—	2	—	72	4	124	—	—	204	11.94
Johnny Darter	—	—	—	6	12	24	12	4	—	4	62	3.63
Pumpkinseed	—	—	—	—	12	—	4	4	—	20	40	2.34
Bluegill	2	—	—	—	—	—	8	—	—	—	10	0.59
White Catfish	—	—	—	—	8	8	—	—	—	—	16	0.94
Eel	—	—	—	—	—	—	8	8	—	4	20	1.17
Alewife	—	—	—	—	—	—	4	4	—	—	8	0.47
Shad	—	—	—	—	—	—	—	—	—	—	—	—
Largemouth Bass	—	—	—	—	—	—	—	—	—	—	—	—
Crevalle Jack	—	—	—	—	—	—	—	—	4	—	4	0.23
Total	82	144	100	106	248	360	148	184	168	168	1708	100.00

1/ In terms of number of fish per 5000 square feet of area seined.
2/ At surface of water in degrees Fahrenheit.

Table 6 (continued) Number of Each Species of Fish Caught Per Set of the Haul Seine 1/

Danskammer Station 2, Aug.-Oct. 1969.

Date	9/24	9/24	9/24	10/1	10/8	10/15	10/22	10/22	Total	
Time	14:37	14:52	14:58	10:20	9:35	9:00	9:00	10:00		
High Water	11:35	11:35	11:35	16:55	10:50	15:20	9:48	9:48		
Temp.2/	82	82	82	82	79	76	63	63		
Area Seined	1250	1250	1250	1000	600	800	600	150	No.	%
White Perch	104	164	100	40	16	6	8	-	438	32.02
Striped Bass	8	8	8	4	126	-	116	200	470	34.36
Brown Bullhead	8	12	4	4	-	-	-	-	28	2.05
Spottail Shiner	-	-	-	-	8	-	16	166	190	13.89
Golden Shiner	-	4	-	14	-	12	8	-	38	2.78
Goldfish	-	-	-	4	-	-	-	-	4	0.29
Banded Killifish	-	-	-	-	-	-	-	-	-	-
Johnny Darter	4	-	-	-	-	38	-	-	42	3.07
Pumpkinseed	4	12	12	14	-	12	-	34	88	6.43
Bluegill	4	4	4	-	-	-	-	-	12	0.88
White Catfish	-	-	-	-	-	-	-	-	-	-
Eel	4	-	-	-	-	-	-	-	4	0.29
Alewife	-	-	-	-	-	-	-	-	-	-
Shad	-	-	-	-	-	-	8	34	42	3.07
Largemouth Bass	4	-	-	-	-	-	-	-	4	0.29
Crevalle Jack	-	-	4	4	-	-	-	-	8	0.58
Total	140	204	132	84	150	68	156	434	1368	100.00

1/ In terms of number of fish per 5000 square feet of area seined.
2/ At surface of water in degrees Fahrenheit.

Table 7: Number of Each Species of Fish Caught per Set of the Haul Seine 1/: Danskammer Station 3, Aug.-Oct. 1969.

								Total	
								No.	%
Date	8/13	8/13	8/20	8/27	9/3	9/10	9/17		
Time	10:40	16:30	11:20	10:20	11:55	11:00	9:50		
High Water	13:10	13:10	18:10	12:42	18:24	12:10	16:30		
Temp. 2/	88	90	88	85	87	83	81		
Area Seined	2500	2500	1250	2500	2500	2500	1250		
White Perch	20	2	8	2	–	8	12	52	7.65
Brown Bullhead	2	4	–	2	–	4	–	12	1.77
Spottail Shiner	40	8	16	–	–	–	8	72	10.59
Golden Shiner	–	2	4	2	24	–	–	32	4.71
Goldfish	18	26	16	42	–	–	12	114	16.77
Banded Killifish	44	20	52	4	78	8	112	318	46.78
Johnny Darter	–	–	4	2	2	–	4	12	1.77
Pumpkinseed	–	–	–	2	–	4	8	14	2.06
Eel	–	–	–	2	–	–	–	2	0.29
Alewife	–	–	–	–	–	4	–	4	0.59
Blueback Herring	–	–	–	–	–	–	–	–	–
Mummichog	–	–	–	–	14	–	24	38	5.60
Crevalle Jack	–	–	–	–	–	2	8	10	1.47
Total	124	62	100	58	118	30	188	680	100.05

1/ In terms of number of fish per 5000 square feet of area seined.

2/ At surface water in degrees Fahrenheit.

Table 7 (continued) Number of Each Species of Fish Caught per Set of the Haul Seine 1/:

Danskammer Station 3, Aug.-Oct. 1969.

						Total	
Date	9/24	10/1	10/8	10/15	10/22		
Time	14:15	11:05	10:15	10:20	10:30		
High Water	11:35	16:55	10:50	15:20	9:48		
Temp 2/	79	82	75	76	63	No.	%
Area Seined	3750	3500	2500	2500	1250		
White Perch	9	21	42	12	4	88	11.28
Brown Bullhead	13	1	6	–	–	20	2.56
Spottail Shiner	3	3	–	4	16	26	3.33
Golden Shiner	–	–	2	–	8	10	1.28
Goldfish	4	33	–	2	–	39	5.00
Banded Killifish	–	9	–	56	–	65	8.33
Johnny Darter	–	5	–	–	–	5	0.64
Pumpkinseed	13	5	18	8	–	44	5.64
Eel	3	–	–	–	8	11	1.41
Alewife	3	–	60	2	8	73	9.36
Blueback Herring	–	–	2	8	328	338	43.33
Mummichog	–	19	–	42	–	61	7.82
Crevalle Jack	–	–	–	–	–	–	–
Total	48	96	130	134	372	780	99.98

1/ In terms of number of fish per 5000 square feet of area seined.
2/ At surface of water in degrees Fahrenheit.

Table 8 Average Number of Each of Nine Major Species of Fish Caught Per Daily Set of the Haul Seine, Danskammer, August-October 1969 1/

	Station 1		Station 2		Station 3	
Species	8/13-9/17 2/	9/24-10/22 3/	8/13-9/17 3/	9/24-10/22 4/	8/13-9/17 5/	9/24-10/22 6/
White Perch	67.1	256.6	50.0	54.7	7.4	17.6
Striped Bass	47.8	495.6	8.6	58.8	—	—
Brown Bullhead	15.5	0.4	9.8	3.5	1.7	4.0
Spottail Shiner	2.2	3.2	23.4	23.7	10.3	5.2
Golden Shiner	3.6	0.2	37.2	4.7	4.6	2.0
Goldfish	15.3	2.0	5.4	0.5	16.3	7.8
Banded Killifish	3.6	1.2	20.4	—	45.4	13.0
Johnny Darter	18.4	7.8	6.2	5.2	1.7	1.0
Pumpkinseed	8.2	27.4	4.0	11.0	2.0	8.8
Total 9 Species	181.7	794.4	165.0	162.1	89.4	59.4
Grand Total	187.6	810.2	170.8	171.0	97.1	156.0

1/ In terms of number of fish per 5000 square feet of area seined.

2/ Based on 11 samples.

3/ Based on 10 samples.

4/ Based on 8 samples.

5/ Based on 7 samples.

6/ Based on 5 samples.

Table 9 Length Frequencies of Major Species of Fishes Caught by Haul Seine: Danskammer, August 13-October 22, 1969.

	White Perch						Striped Bass						Brown Bullhead					
	8/13-9/17			9/24-10/22			8/13-9/17			9/24-10/22			8/13-9/17			9/24-10/22		
	Station			Station			Station			Station			Station			Station		
Length (mm)	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
20-24	5	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
25-29	16	11	4	—	—	—	5	—	—	—	—	—	—	—	—	—	—	—
30-34	36	20	2	—	—	—	6	1	—	—	—	—	—	—	1	—	—	—
35-39	49	24	5	2	—	—	3	—	—	—	—	—	2	6	—	—	—	—
40-44	43	16	4	5	—	2	3	—	—	—	—	—	2	—	—	—	—	—
45-49	41	16	1	8	3	9	3	—	—	—	—	—	14	8	1	—	—	—
50-54	4	16	1	18	17	8	1	2	—	2	—	—	18	6	2	—	—	—
55-59	10	8	3	80	30	18	12	4	—	10	4	—	9	1	—	—	—	—
60-64	4	1	1	150	28	5	22	7	—	48	8	—	5	3	1	—	—	2
65-69	2	—	—	106	13	8	27	3	—	110	14	—	2	1	1	—	—	3
70-74	1	—	—	26	1	—	21	1	—	136	8	—	1	—	—	—	2	5
75-79	1	—	—	9	1	—	22	1	—	111	5	—	—	—	—	—	3	2
80-84	6	—	—	—	—	—	7	—	—	91	2	—	—	—	—	—	2	1
85-89	4	—	—	1	—	—	5	2	—	47	1	—	—	—	—	1	—	1
90-94	—	—	—	1	2	—	—	—	—	15	—	—	—	—	—	—	—	—
95-99	—	1	—	12	4	—	—	—	—	17	—	—	—	—	—	—	—	—
100-104	—	—	—	12	2	—	—	—	—	5	—	—	—	—	—	—	—	—
105-109	2	—	—	11	1	—	—	—	—	3	—	—	—	—	—	—	—	—
110-114	—	—	—	5	1	—	—	—	—	3	—	—	—	—	—	—	—	—
115-119	—	—	—	2	1	—	—	—	—	4	—	—	—	—	—	—	—	—
120-124	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
125-129	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
130-134	—	—	—	1	—	—	—	—	—	3	—	—	—	—	—	—	—	—
205-209	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	224	114	21	451	104	50	138	21	—	605	42	—	53	25	6	1	7	14

Table 9 (continued) Length Frequencies of Major Species of Fishes Caught by Haul Seine: Danskammer, August 13-October 22, 1969.

	Spottail Shiner						Golden Shiner						Goldfish					
	8/13-9/17			9/24-10/22			8/13-9/17			9/24-10/22			8/13-9/17			9/24-10/22		
Length	Station			Station			Station			Station			Station			Station		
(mm)	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
25-29	1	3	4	—	—	—	—	1	2	—	—	—	4	—	—	—	—	—
30-34	1	11	16	—	—	—	1	6	6	—	—	—	14	—	5	—	—	—
35-39	—	19	9	—	—	—	11	3	5	—	2	—	22	—	9	—	—	—
40-44	1	9	1	—	—	1	—	2	1	—	1	—	5	—	18	—	—	—
45-49	1	7	—	—	—	—	—	—	1	—	1	—	7	1	5	—	—	—
50-54	2	1	—	2	—	2	—	—	—	—	—	—	1	2	5	3	—	2
55-59	1	1	—	4	—	4	—	—	—	—	1	—	—	1	3	—	—	1
60-64	—	—	—	2	—	—	—	1	—	—	—	—	—	2	—	2	—	4
65-69	—	—	—	—	—	3	1	1	—	—	—	1	—	6	3	—	1	10
70-74	—	—	—	—	1	1	—	1	—	—	1	—	—	1	2	1	—	6
75-79	—	—	—	—	2	—	—	8	—	—	—	—	—	1	—	1	—	1
80-84	—	—	—	—	3	—	—	12	—	—	—	—	—	—	—	—	—	1
85-89	—	—	—	—	2	—	—	21	—	—	—	—	—	—	—	—	—	1
90-94	—	—	—	—	—	—	—	18	—	—	—	—	—	—	—	—	—	1
95-99	—	—	—	—	—	—	—	16	—	—	1	1	—	—	—	—	—	—
100-104	—	—	—	—	—	—	—	11	—	—	—	—	—	—	—	—	—	—
105-109	—	—	—	—	—	—	—	10	—	—	—	—	—	—	—	—	—	—
110-114	—	—	—	—	—	—	—	2	—	—	—	1	—	—	—	—	—	—
140-144	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
215-219	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Total No.	7	51	30	8	8	11	13	113	15	1	7	3	54	14	50	7	1	27

Table 9 (continued) Length Frequencies of Major Species of Fishes Caught by Haul Seine: Danskammer, August 13-October 22, 1969.

	Banded Killifish						Johnny Darter						Pumpkinseed					
	8/13-9/17			9/14-10/22			8/13-9/17			9/24-10/22			8/13-9/17			9/24-10/22		
	Station			Station			Station			Station			Station			Station		
Length (mm)	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
20-24	—	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
25-29	2	5	20	—	—	—	8	1	—	—	—	—	1	—	—	1	—	1
30-34	4	8	27	—	—	2	27	5	1	—	—	—	5	3	—	11	—	3
35-39	3	11	31	—	—	2	25	6	1	—	—	—	6	3	3	13	1	4
40-44	4	10	17	—	—	16	4	1	2	15	2	—	3	—	1	9	2	4
45-49	2	4	14	—	—	4	1	—	—	5	2	—	1	—	1	7	3	4
50-54	—	2	2	—	—	5	—	—	—	1	3	1	4	—	—	2	4	1
55-59	—	1	2	1	—	3	—	—	—	1	—	2	—	—	—	1	1	2
60-64	—	—	2	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—
65-69	—	1	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
70-74	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
75-79	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—	1	—	—
80-84	—	—	—	—	—	—	—	—	—	—	—	—	1	2	1	—	—	2
85-89	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	3	—	4
90-94	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—
95-99	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
100-104	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	1
105-109	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
110-114	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—
115-119	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—
120-124	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—
125-129	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—
130-134	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
135-139	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
140-144	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Total No.	15	43	118	3	—	34	67	13	4	22	7	3	23	10	5	57	13	26

Table 10 Length of Miscellaneous Fishes Caught by Haul Seine at Danskammer Station 1: August 13-October 22, 1969.

Length (mm)	Bluegill		White Catfish		Eel		Alewife	Blueback Herring	Carp	Largemouth Bass	Fourspine Stickleback	Crevalle Jack
	A1/	B2/	A	B	A	B	A	B	B	B	A	B
25-29	–	–	–	–	–	–	–	–	–	–	1	–
30-34	–	–	–	–	–	–	–	1	–	–	–	–
35-39	–	–	1	–	–	–	–	1	–	–	–	–
40-44	–	–	–	–	–	–	–	3	–	–	–	–
45-49	–	–	1	–	–	–	–	5	–	–	–	–
50-54	–	–	1	–	–	–	–	1	–	–	–	–
55-59	–	–	–	–	–	–	1	–	–	–	–	–
60-64	–	–	–	1	–	–	–	–	–	–	–	–
65-69	–	–	–	–	–	–	–	–	–	–	–	–
70-74	–	–	–	1	–	–	–	–	–	–	–	–
75-79	–	–	–	–	–	–	–	–	–	–	–	–
80-84	2	–	–	–	–	–	–	–	–	–	–	–
85-89	2	1	–	–	–	–	–	–	–	1	–	2
90-94	–	1	2	–	–	–	–	–	–	–	–	3
95-99	–	–	–	–	–	–	–	–	–	–	–	1
100-104	–	–	–	–	–	–	–	–	–	–	–	–
105-109	–	–	1	–	–	–	–	–	–	–	–	–
110-114	1	–	–	–	1	–	–	–	–	–	–	–
125-129	–	–	–	–	–	1	–	–	–	–	–	–
130-134	–	1	–	–	–	–	–	–	–	–	–	–
135-139	–	–	–	–	–	1	–	–	–	–	–	–
140-144	–	2	–	–	–	–	–	–	–	–	–	–
145-149	–	–	–	–	1	–	–	–	–	–	–	–
150-154	–	–	–	–	1	–	–	–	–	–	–	–
165-169	–	–	–	–	–	1	–	–	–	–	–	–
190-194	–	–	–	–	–	1	–	–	–	–	–	–
195-199	–	–	–	–	–	–	–	–	–	–	–	–
200-204	–	–	–	–	1	–	–	–	–	–	–	–
250-254	–	–	–	–	1	–	–	–	–	–	–	–
260-264	–	–	–	–	–	–	–	–	1	–	–	–
320-324	–	–	–	–	1	1	–	–	–	–	–	–
360-364	–	–	–	–	–	1	–	–	–	–	–	–
390-394	–	–	–	–	–	–	–	–	1	–	–	–
395-399	–	–	–	–	–	1	–	–	–	–	–	–
440-444	–	–	–	–	1	–	–	–	–	–	–	–
520-524	–	–	–	–	–	–	–	–	1	–	–	–
Total	5	5	6	2	7	7	1	11	3	1	1	6

1/ Period, Aug. 13-Sept. 17.
2/ Period, Sept. 24-Oct. 22.

Table 11 Lengths of Miscellaneous Fishes Caught by Haul Seine at Danskammer Station 2: Aug. 13-Oct. 22, 1969.

	Bluegill		White Catfish	Eel		Alewife	Shad	Largemouth Bass	Crevalle Jack	
Length	A1/	B2/	A	A	B	A	B	B	A	B
50-54	–	–	–	–	–	1	–	–	–	–
55-59	–	–	1	–	–	–	–	–	–	1
60-64	–	–	–	–	–	1	–	–	–	–
65-69	–	–	–	–	–	–	–	–	–	–
70-74	–	–	–	–	–	–	–	–	–	–
75-79	–	–	–	–	–	–	–	–	–	1
80-84	2	–	–	–	–	–	–	–	–	–
85-89	1	–	–	–	–	–	–	–	–	–
90-94	–	–	–	–	–	–	2	–	–	–
95-99	–	–	1	–	–	–	–	–	1	–
100-104	–	–	1	–	–	–	–	–	–	–
105-109	–	–	–	–	–	–	–	–	–	–
110-114	–	–	–	1	–	–	–	–	–	–
115-119	–	–	–	–	–	–	–	–	–	–
120-124	–	1	–	–	–	–	–	–	–	–
125-129	–	1	–	1	–	–	–	–	–	–
130-134	–	–	–	1	–	–	–	–	–	–
135-139	–	–	–	–	–	–	–	–	–	–
140-144	–	1	–	–	–	–	–	–	–	–
145-149	–	–	–	1	–	–	–	–	–	–
150-154	–	–	–	–	–	–	–	–	–	–
155-159	–	–	–	–	–	–	–	1	–	–
160-164	–	–	–	–	–	–	–	–	–	–
165-169	–	–	–	1	–	–	–	–	–	–
170-174	–	–	–	–	–	–	–	–	–	–
175-179	–	–	–	–	1	–	–	–	–	–
Total	3	3	3	5	1	2	2	1	1	2

1/ Period, Aug. 13-Sept. 17.

2/ Period, Sept. 24-Oct. 22.

Table 12 Length of Miscellaneous Fishes Caught by Haul Seine at Danskammer Station 3: Aug. 13-Oct. 22, 1969

	Eel		Alewife		Blueback Herring	Crevalle Jack	Mummichog	
Length	A1/	B2/	A	B	B	A	A	B
30-34	-	-	-	-	4	-	-	-
35-39	-	-	-	-	13	1	4	-
40-44	-	-	-	-	25	-	4	1
45-49	-	-	-	-	26	-	4	8
50-54	-	-	-	5	12	1	1	17
55-59	-	-	1	11	7	-	-	7
60-64	-	-	1	13	-	1	-	-
65-69	-	-	-	5	-	-	-	1
130-134	-	1	-	-	-	-	-	-
135-139	-	-	-	-	-	-	-	-
140-144	-	-	-	-	-	-	-	-
145-149	-	1	-	-	-	-	-	-
150-154	-	-	-	-	-	-	-	-
155-159	-	1	-	-	-	-	-	-
160-164	-	-	-	-	-	-	-	-
165-169	-	-	-	-	-	-	-	-
170-174	-	-	-	-	-	-	-	-
175-179	-	-	-	-	-	-	-	-
180-184	-	1	-	-	-	-	-	-
325-329	1	-	-	-	-	-	-	-
330-334	-	-	-	-	-	-	-	-
335-339	-	1	-	-	-	-	-	-
Total	1	5	2	34	87	3	13	34

1/ Period, Aug. 13-Sept. 17.

2/ Period, Sept. 24-Oct. 22.

Table 13 Fish Holding Experiment at Outfall of Danskammer Power Station, September 4, 1969.

	Fyke 1				Fyke 2				Fyke 3			
	Alive		Dead	Missing	Alive		Dead	Missing	Alive		Dead	Missing
	0-hr	1-hr	1-hr	+1-hr	0-hr	2.5 hrs	2.5 hrs	2.5 hrs	0-hr	4-hrs	4-hrs	4-hrs
White Perch	10	7	3	_	9	7	2	_	9	5	4	_
Striped Bass	1	1	_	_	1	1	_	_	1	0	1	_
Pumpkin-seed	4	3	_	1	4	4	_	_	4	2	_	2
Bluegill	1	0	1	_	1	1	_	_	1	1	_	_
Golden Shiner	1	1	_	_	_	_	_	_	_	_	_	_
Spottail Shiner	1	1	_	_	1	1	_	_	1	_	_	1
Goldfish	4	4	_	_	4	4	_	_	4	4	_	_
Banded Killifish	6	4	_	2	6	2	_	4	6	2	1	3
Brown Bullhead	4	4	_	_	4	4	_	_	4	3	_	1

Table 14 Lengths of Fish Used in Holding Experiment at Outfall of Danskammer Power Station, September 4, 1969. 1/

Length	White Perch			Striped Bass			Pumpkin-seed			Bluegill			Golden Shiner			Spottail Shiner			Goldfish			Banded Killi-fish			Brown Bull-head		
	Fyke			Fyke			Fyke			Fyke			Fyke			Fyke			Fyke			Fyke			Fyke		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
30-34	_	1	_	_	_	_	_	1	_	_	_	_	_			_	_	_	_	_	_	_	_	_	_	_	_
35-39	1	_	1	_	_	1	_	1	1	_	_	_	_			_	_	_	_	_	_	_	_	_	_	_	_
40-44	1	4	2	_	_	_	1	1	_	_	_	_	_			_	1	_	_	1	1	_	_	_	_	_	_
45-49	2	2	1	_	_	_	_	_	_	_	_	_	_			_	_	_	_	_	_	4	_	1	_	_	_
50-54	3	2	3	_	_	_	1	_	_	_	_	_	_			_	_	_	1	_	1	_	2	1	_	_	1
55-59	3	_	2	_	_	_	_	_	_	_	_	_	_			_	_	_	2	_	_	_	_	1	2	_	_
60-64	_	_	_	_	_	_	_	_	_	_	_	_	_			_	_	_	1	1	1	_	_	_	_	_	_
65-69	_	_	_	_	1	_	_	_	_	_	_	_	_			_	_	_	_	1	_	_	_	_	1	2	2
70-74	_	_	_	_	_	_	_	_	_	_	_	_	_			1	_	_	_	1	_	_	_	_	1	2	_
75-79	_	_	_	1	_	_	_	1	1	_	_	_	_			_	_	_	_	_	1	_	_	_	_	_	_
80-84	_	_	_	_	_	_	_	_	_	_	1	_	_			_	_	_	_	_	_	_	_	_	_	_	_
85-89	_	_	_	_	_	_	_	_	_	_	_	_	_			_	_	_	_	_	_	_	_	_	_	_	_
90-94	_	_	_	_	_	_	_	_	_	_	_	_	_			_	_	_	_	_	_	_	_	_	_	_	_
95-99	_	_	_	_	_	_	_	_	_	_	_	1	_			_	_	_	_	_	_	_	_	_	_	_	_
100-104	_	_	_	_	_	_	_	_	_	_	_	_	_			_	_	_	_	_	_	_	_	_	_	_	_
105-109	_	_	_	_	_	_	_	_	_	_	_	_	1			_	_	_	_	_	_	_	_	_	_	_	_
110-114	_	_	_	_	_	_	1	_	_	_	_	_	_			_	_	_	_	_	_	_	_	_	_	_	_
150-154	_	_	_	_	_	_	_	_	_	1	_	_	_			_	_	_	_	_	_	_	_	_	_	_	_
Total	10	9	9	1	1	1	3	4	2	1	1	1	1			1	1	0	4	4	4	4	2	3	4	4	3

1/ Standard lengths of fish found in the nets at the end of the experiment.

Table 15 Distribution of Fish Larvae at Various Depths of Water in the Vicinity of Cornwall: April 23-May 15, 1968.

		Number			Percent			Cumulative Percent		
	Contour	S.B1/	W.P	Oth.	S.B.	W. P.	Oth.	S. B.	W. P.	Oth.
Average all Depths	W15	0.2	0.3	4.4	4.1	4.0	11.4	4.1	4.0	11.4
	W30	0.3	0.3	3.1	4.6	4.5	8.0	8.7	8.5	19.4
	W45	0.4	0.3	1.9	7.7	4.4	4.9	16.3	12.9	24.3
	W60	0.8	0.3	2.2	13.8	4.8	5.7	30.1	17.7	30.0
	C75	0.3	0.4	1.8	5.8	5.3	4.7	35.9	23.0	34.6
	E60	0.9	0.5	2.4	15.8	7.0	6.2	51.7	30.0	40.8
	E45	0.9	0.8	6.5	15.6	11.1	16.8	67.3	41.1	57.6
	E30	0.4	1.9	2.0	7.7	26.2	5.2	75.0	67.3	62.8
	E15	0.9	1.1	6.2	16.0	14.7	16.0	91.0	81.9	78.8
	E5	0.5	1.3	8.2	9.0	18.1	21.2	100.0	100.0	100.0
								S. B.2/	W. P.2/	Oth.2/
Surface	W15	0.0	0.1	3.6	4.2	20.7	40.9	0.2	0.8	4.7
	W30	0.1	0.3	4.5	25.9	31.3	47.9	1.4	2.2	8.5
	W45	0.0	0.4	2.2	4.4	30.2	29.3	1.7	3.6	9.9
	W60	0.0	0.3	2.8	6.2	19.4	25.0	2.6	4.5	11.3
	C75	0.1	0.8	3.5	2.1	32.1	33.0	2.7	6.2	12.9
	E60	0.0	0.2	2.5	5.4	6.3	20.5	3.5	6.6	14.2
	E45	0.0	0.7	14.2	1.1	20.7	55.0	3.7	8.9	23.4
	E30	0.0	2.1	1.7	6.7	37.4	28.3	4.2	18.7	24.9
	E15	0.3	1.0	6.6	31.9	46.7	53.2	9.3	25.5	33.4
	E5	0.5	1.3	8.2	100.0	100.0	100.0	18.3	43.6	54.6
								S. B.2/	W. P.2/	Oth.2/
Bottom	W15	0.2	0.5	5.2	95.8	79.3	59.1	3.9	3.2	6.7
	W30	0.2	0.4	2.8	63.0	45.5	29.8	6.8	5.2	9.1
	W45	0.3	0.6	2.5	73.3	44.2	33.3	12.4	7.1	10.8
	W60	0.3	0.6	2.1	43.2	32.6	18.8	18.4	8.7	11.8
	C75	0.1	0.5	1.6	23.5	21.1	15.1	19.7	9.8	12.5
	E60	0.5	1.3	2.3	53.8	49.8	18.9	28.2	13.3	13.7
	E45	0.6	1.4	4.7	65.2	43.3	18.2	38.4	18.1	16.8
	E30	0.3	2.4	2.5	73.3	41.6	41.7	49.6	29.0	18.9
	E15	0.6	1.1	5.8	68.1	53.3	46.8	60.5	36.8	26.4
	E5	—	—	—	—	—	—	—	—	—

1/ S. B., striped bass; W. P., white perch; Oth., other species.

2/ As components of the average-of-all-depths, cumulative percentage.

Table 16 Distribution of Fish Larvae at Various Depths of Water in the Vicinity of Cornwall: May 16-May 31, 1968.

		Number			Percent			Cumulative Percent		
	Contour	S.B[1]	W.P	Oth.	S.B.	W. P.	Oth.	S. B.	W. P.	Oth.
Average All Depths	W15	2.2	1.6	21.1	2.1	6.7	10.8	2.1	6.7	10.8
	W30	10.4	1.4	19.6	9.7	5.8	10.0	11.8	12.5	20.7
	W45	15.2	1.6	13.6	14.2	6.7	6.9	26.1	19.2	27.7
	W60	16.8	1.4	14.9	15.8	5.5	7.6	41.9	24.8	35.3
	C75	19.4	1.4	15.7	18.1	5.5	8.0	60.0	30.3	43.3
	E60	13.4	1.9	16.3	12.5	7.8	8.3	72.5	38.1	51.6
	E45	12.9	2.2	14.9	12.1	9.1	7.6	84.6	47.2	59.2
	E30	9.9	3.2	17.2	9.2	12.9	8.8	93.8	60.2	68.0
	E15	4.7	4.7	34.9	4.4	19.4	17.8	98.2	79.5	85.8
	E5	1.9	5.0	27.9	1.8	20.4	14.2	100.0	100.0	100.0
					S.B	W. P.	Oth.	S. B.	W. P.	Oth.[2]
Surface	W15	0.7	1.0	22.1	30.0	30.0	52.4	0.6	2.0	5.6
	W30	1.3	1.0	36.9	12.7	23.2	62.8	1.9	3.4	11.9
	W45	1.8	1.2	18.4	11.9	17.7	33.8	3.6	4.6	14.2
	W60	1.4	1.1	33.7	8.2	16.2	45.3	4.8	5.4	17.7
	C75	1.3	1.0	29.3	6.9	12.2	31.1	6.1	6.1	20.2
	E60	1.0	2.1	35.3	7.2	21.7	43.2	7.0	7.8	23.8
	E45	2.0	2.0	21.2	15.2	22.5	35.6	8.8	9.9	26.5
	E30	0.7	1.8	20.3	6.8	19.2	39.4	9.5	12.3	29.9
	E15	1.0	3.3	46.8	22.4	35.3	67.2	10.4	19.1	41.9
	E5	1.9	5.0	27.9	100.0	100.0	100.0	12.3	39.6	56.1
					S.B.	W. P.	Oth.	S. B.	W. P.	Oth.[2]
Bottom	W15	1.6	2.3	20.0	70.0	70.0	47.6	1.5	4.7	5.1
	W30	7.5	2.2	12.5	72.0	51.4	21.3	8.5	7.7	7.2
	W45	8.6	2.9	14.4	56.5	44.7	26.4	16.5	10.7	9.1
	W60	7.7	2.3	14.0	46.0	33.5	18.8	23.8	12.5	10.5
	C75	8.2	3.5	21.6	42.1	43.4	23.0	31.4	14.9	12.3
	E60	6.4	3.7	16.4	48.1	38.6	20.1	37.4	17.9	14.0
	E45	7.0	4.2	21.3	54.1	46.9	35.7	43.9	22.2	16.7
	E30	6.5	5.2	16.1	65.8	54.6	31.3	50.0	29.3	19.5
	E15	3.6	6.1	22.8	77.6	64.7	32.8	53.4	41.9	25.3
	E5	—	—	—	—	—	—	—	—	—

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[1] S. B., striped bass; W. P., white perch; Oth., other species.

[2] As components of the average-of-all- depths, cumulative percent.

Table 17 Distribution of Fish Larvae at Various Depths of Water in the Vicinity of Cornwall: June 1-June 15, 1968.

		Number			Percent			Cumulative Percent		
	Contour	S.B[1/]	W.P	Oth.	S.B.	W. P.	Oth.	S. B.	W. P.	Oth.
Average All Depths	W15	7.6	1.0	15.7	7.2	5.3	10.5	7.2	5.3	10.5
	W30	12.8	1.1	15.6	12.2	5.8	10.4	19.5	11.1	20.9
	W45	15.3	0.8	8.7	14.6	4.3	5.8	34.1	15.4	26.7
	W60	16.9	0.9	9.3	16.1	4.8	6.2	50.2	20.2	32.9
	C75	18.7	1.0	12.7	17.9	5.7	8.5	68.1	25.9	41.3
	E60	10.6	1.1	10.6	10.1	6.0	7.1	78.2	31.9	48.4
	E45	9.7	1.5	12.1	9.2	8.1	8.1	87.4	40.0	56.5
	E30	7.9	2.1	20.6	7.5	11.9	13.7	94.9	51.8	70.2
	E15	4.2	4.4	24.3	4.0	24.2	16.2	99.0	76.0	86.4
	E5	1.1	4.3	20.3	1.0	24.0	13.5	100.0	100.0	100.0
					S.B.	W. P.	Oth.	S. B.[2/]	W. P.[2/]	Oth.[2/]
Surface	W15	1.9	1.0	21.0	25.2	49.7	66.7	1.8	2.6	7.0
	W30	1.2	1.4	29.4	9.3	44.9	62.8	3.0	5.2	13.5
	W45	1.0	1.0	19.1	6.6	31.4	55.2	3.9	6.6	16.7
	W60	1.2	1.4	24.4	7.3	32.6	52.6	5.1	8.1	20.0
	C75	1.2	1.8	37.0	6.7	29.0	48.5	6.3	9.8	24.1
	E60	0.5	1.7	35.4	4.5	31.7	66.5	6.7	11.7	28.8
	E45	1.4	1.8	25.4	14.5	30.3	52.6	8.1	14.2	33.0
	E30	1.2	2.7	44.8	15.7	42.6	72.6	9.3	19.2	43.0
	E15	0.7	2.7	34.2	16.3	31.2	70.2	9.9	26.8	54.4
	E5	1.1	4.3	20.3	100.0	100.0	100.0	11.0	50.7	67.9
					S.B.	W. P.	Oth.	S. B.[2/]	W. P.[2/]	Oth.[2/]
Bottom	W15	5.7	1.0	10.5	74.8	50.3	33.3	5.4	2.7	3.5
	W30	8.3	1.1	7.9	64.7	33.9	16.9	13.3	4.6	5.2
	W45	7.4	1.1	7.8	48.2	34.0	22.5	20.4	6.1	6.6
	W60	6.2	0.7	7.3	36.7	16.5	15.7	26.3	6.9	7.5
	C75	4.8	1.7	10.1	25.8	26.7	13.2	30.9	8.4	8.7
	E60	3.1	0.9	5.4	29.2	16.9	10.1	33.8	9.4	9.4
	E45	3.5	1.9	8.5	36.0	32.0	17.6	37.1	12.0	10.8
	E30	5.1	2.8	13.0	64.0	43.6	21.1	42.0	17.2	13.7
	E15	3.5	6.0	14.5	83.7	68.8	29.8	45.3	33.8	18.5
	E5	—	—	—	—	—	—	—	—	—

1/ S. B., striped bass; W. P., white perch; Oth., other species.

2/ As components of the average-of-all-depths, cumulative percent.

Table 18 Distribution of Fish Larvae at Various Depths of Water in the Vicinity of Cornwall: June 15-June 30, 1968.

		Number			Percent			Cumulative Percent		
	Contour	S.B1/	W.P	Oth.	S.B.	W. P.	Oth.	S. B.	W. P.	Oth.
Average All Depths	W15	3.8	1.7	6.7	9.0	15.9	11.1	9.0	15.9	11.1
	W30	6.7	0.8	4.7	16.1	7.0	7.8	25.1	22.9	19.0
	W45	4.4	0.8	4.1	10.5	7.3	6.8	35.7	30.2	25.8
	W60	5.0	0.6	3.2	12.0	5.1	5.3	47.6	35.4	31.1
	C75	5.0	0.4	1.7	12.0	3.5	2.8	59.6	38.9	33.9
	E60	4.0	0.8	3.7	9.5	7.7	6.2	69.2	46.6	40.1
	E45	4.7	1.1	4.8	11.2	9.7	8.0	80.4	56.3	48.1
	E30	4.2	1.3	5.6	10.1	12.0	9.3	90.5	68.4	57.4
	E15	3.3	2.0	10.4	7.9	18.1	17.3	98.4	86.5	74.7
	E5	0.7	1.5	15.2	1.6	13.5	25.3	100.0	100.0	100.0
								S. B.2/	W. P.2/	Oth.2/
Surface	W15	0.3	2.1	5.3	7.4	60.2	39.6	0.7	9.6	4.4
	W30	0.9	0.9	7.5	12.8	38.9	53.2	2.7	12.3	8.6
	W45	1.2	1.6	11.2	28.0	50.0	68.3	5.7	16.0	13.2
	W60	0.4	0.8	7.1	8.4	28.5	44.1	6.8	17.4	15.6
	C75	1.0	0.7	3.3	19.7	29.7	32.4	9.0	18.5	16.5
	E60	1.3	1.3	10.5	33.9	29.9	56.2	12.3	20.8	20.0
	E45	0.6	1.1	9.5	13.2	26.7	49.2	13.7	23.4	23.9
	E30	0.7	1.3	10.5	15.6	32.4	62.1	15.3	27.3	29.7
	E15	0.5	1.5	11.0	16.7	37.2	53.1	16.6	34.0	38.9
	E5	0.7	1.5	15.2	100.0	100.0	100.0	18.2	47.5	64.2
								S. B.2/	W. P.2/	Oth.2/
Bottom	W15	3.5	1.4	8.1	92.6	39.8	60.4	8.4	6.3	6.7
	W30	5.0	0.9	4.3	74.9	38.0	30.5	20.4	9.0	9.1
	W45	1.4	0.5	2.1	31.1	14.0	12.8	23.7	10.0	10.0
	W60	1.6	0.6	3.6	32.8	22.4	22.4	27.6	11.2	11.2
	C75	0.9	0.3	1.5	18.1	14.0	14.7	29.8	11.2	11.6
	E60	0.9	1.0	3.8	22.1	22.5	20.3	31.9	12.9	12.9
	E45	1.8	0.9	4.4	37.7	20.1	22.8	36.1	14.9	14.7
	E30	3.0	1.7	4.2	70.4	43.9	24.9	43.2	20.2	17.0
	E15	2.7	2.5	9.7	83.3	62.8	46.9	49.8	31.6	25.1
	E5	—	—	—	—	—	—	—	—	—

1/ S. B., striped bass; W. P., white perch; oth., other.

2/ As components of the average-of-all-depths, cumulative percent.

Table 19 Common and Scientific Names of Fish Species Taken at Danskammer, Aug.-Oct. 1969.

Blueback Herring	*Alosa aestivalis*
Alewife	*Alosa pseudoharengus*
American Shad	*Alosa sapidissima*
Goldfish	*Carassius auratus*
Carp	*Cyprinus carpio*
Golden Shiner	*Notemigonus crysoleucas*
Spottail Shiner	*Notropis hudsonius*
White Catfish	*Ictalurus catus*
Brown Bullhead	*Ictalurus nebulosus*
American Eel	*Anguilla rostrata*
Banded Killifish	*Fundulus diaphanus*
Mummichog	*Fundulus heteroclitus*
Fourspine Stickleback	*Apeltes quadracus*
White Perch	*Roccus americanus*
Striped Bass	*Roccus saxatilis*
Pumpkinseed	*Lepomis gibbosus*
Crevalle Jack	*Caranx hippos*
Johnny Darter	*Etheostoma nigrum*
Largemouth Bass	*Micropterus salmoides*
Bluegill	*Lepomis macrochirus*

Figure 1 Diagram Showing Location of Bottom Sampling Stations at the Danskammer Power Station.

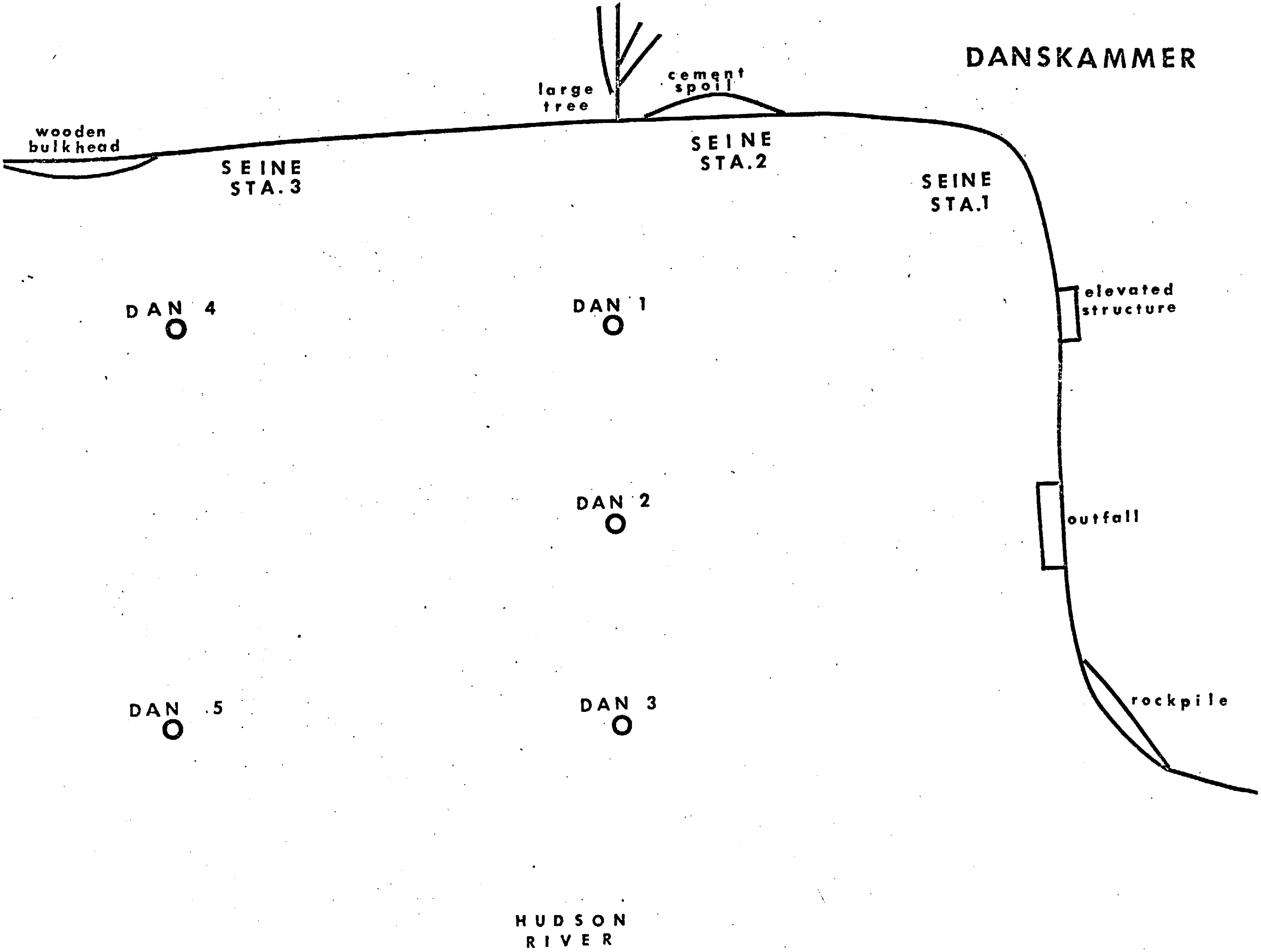

DANSKAMMER
large tree
cement spoil
wooden bulkhead
SEINE STA. 3
SEINE STA.2
SEINE STA.1
elevated structure
DAN 4
DAN 1
DAN 2
outfall
DAN 5
DAN 3
rockpile
HUDSON RIVER

Figure 2 Diagram Showing Location of Bottom Sampling Stations at the Proposed Roseton Power Station.

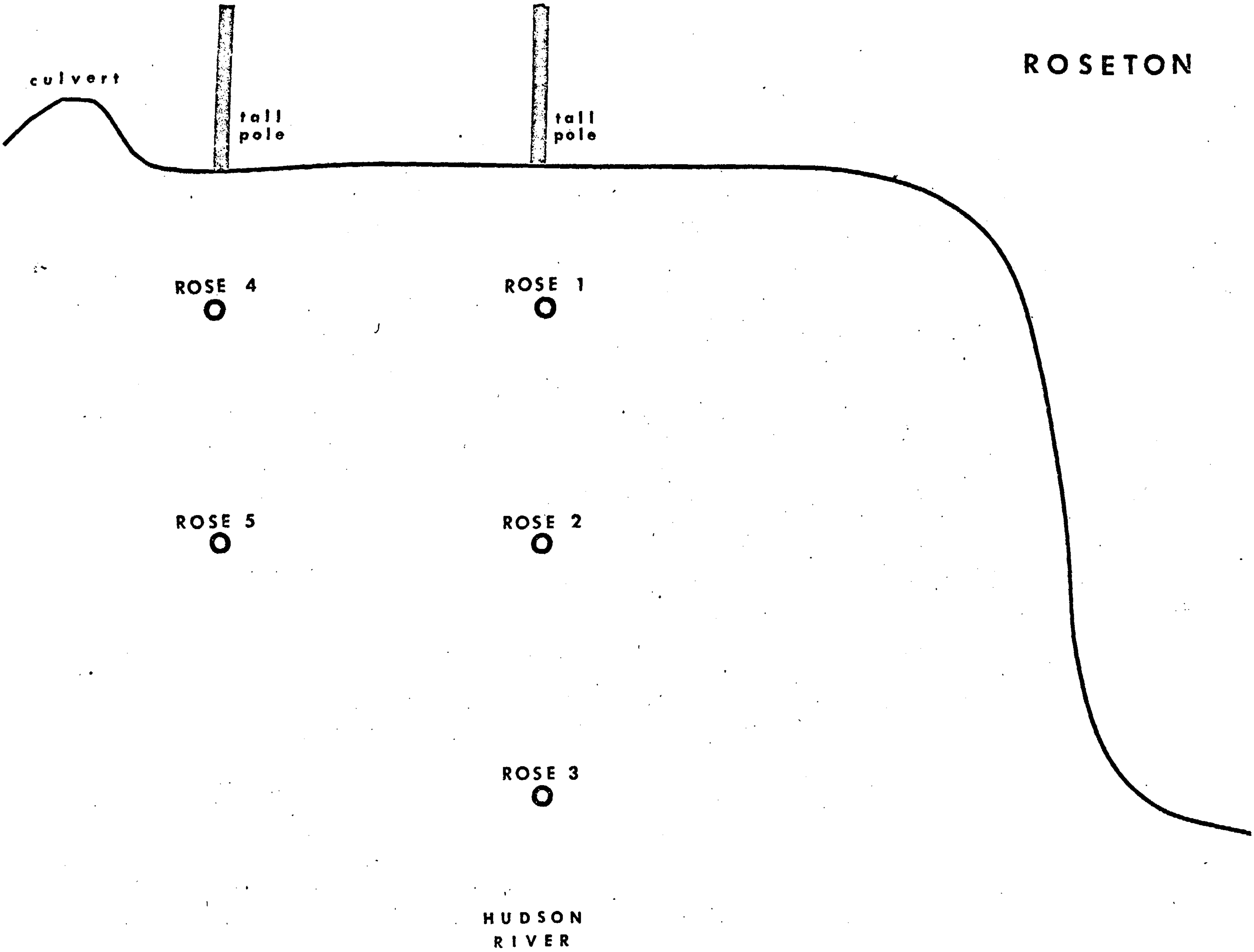

ROSETON
culvert
tall pole
tall pole
ROSE 4
ROSE 1
ROSE 5
ROSE 2
ROSE 3
HUDSON RIVER

Figure 3 Comparison of Relative Abundance of Bottom Organisms at the Danskammer Power Station and Proposed Roseton Power Station, May-June 1969.

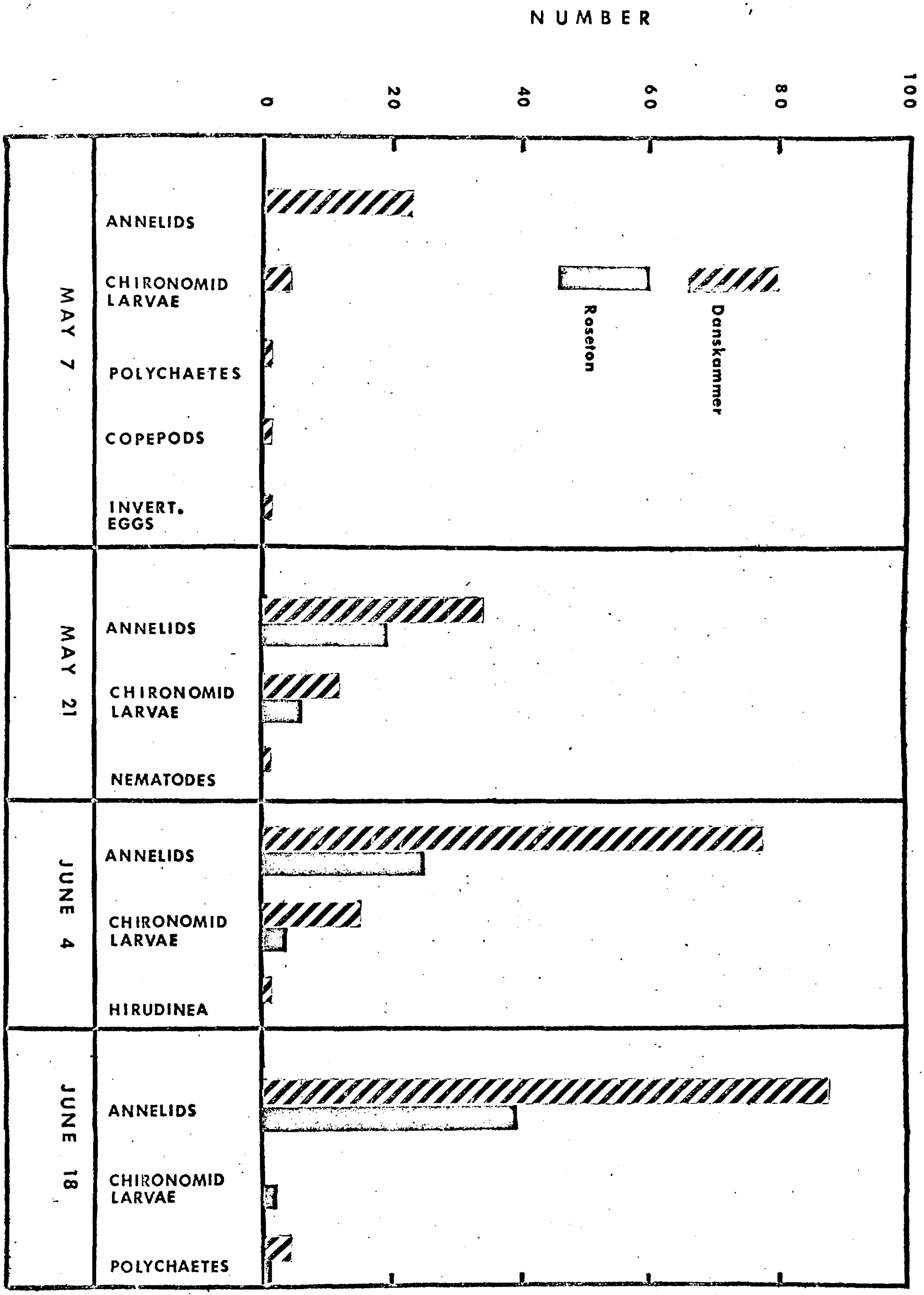

NUMBER
0
20
40
60
80
100
Roseton
Danskammer
MAY 7
ANNELIDS
CHIRONOMID LARVAE
POLYCHAETES
COPEPODS
INVERT. EGGS
MAY 21
ANNELIDS
CHIRONOMID LARVAE
NEMATODES
JUNE 4
ANNELIDS
CHIRONOMID LARVAE
HIRUDINEA
JUNE 18
ANNELIDS
CHIRONOMID LARVAE
POLYCHAETES

Figure 4. Comparison of Relative Abundance of Bottom Organisms at the Danskammer Power Station and the Proposed Roseton Power Station, July-August 1969.

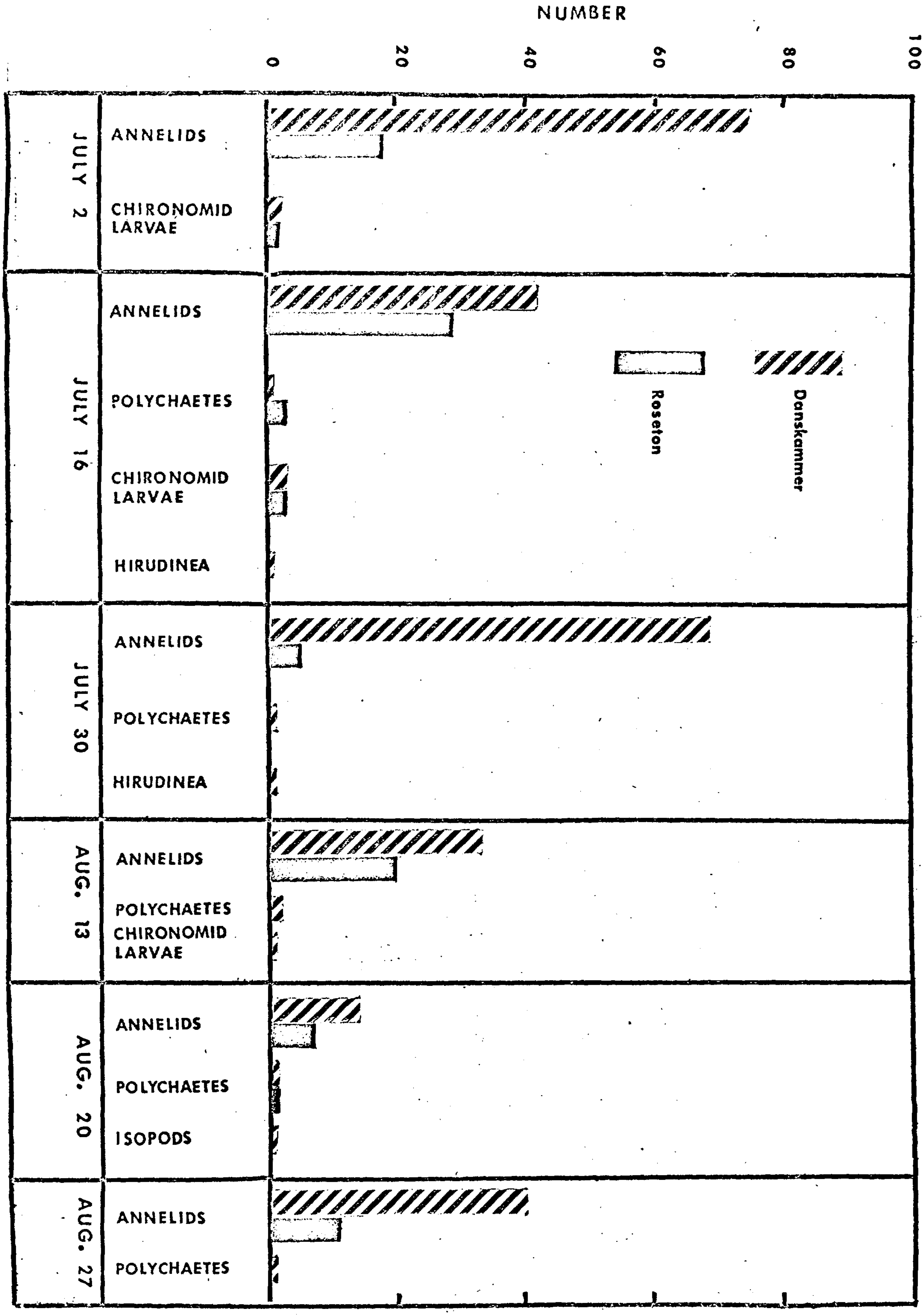

NUMBER
0
20
40
60
80
100
JULY 2
ANNELIDS
CHIRONOMID LARVAE
JULY 16
ANNELIDS
POLYCHAETES
CHIRONOMID LARVAE
HIRUDINEA
JULY 30
ANNELIDS
POLYCHAETES
HIRUDINEA
AUG. 13
ANNELIDS
POLYCHAETES
CHIRONOMID LARVAE
AUG. 20
ANNELIDS
POLYCHAETES
ISOPODS
AUG. 27
ANNELIDS
POLYCHAETES
Roseton
Danskammer

Figure 5 Comparison of Relative Abundance of Bottom Organisms at the Danskammer Power Station and Proposed Roseton Power Station, Sept. and Oct. 1969.

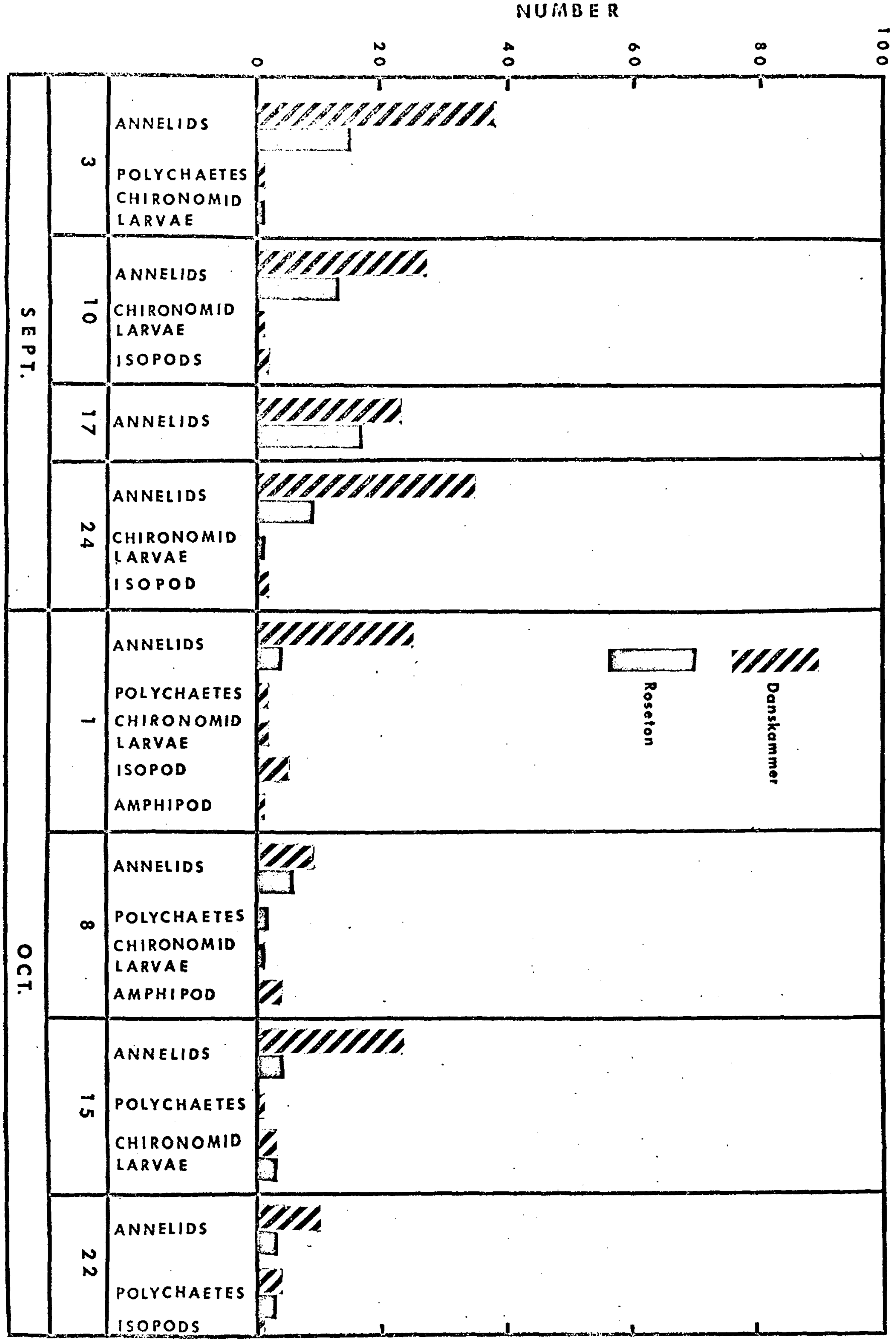

NUMBER
0
20
40
60
80
100
SEPT.
3
ANNELIDS
POLYCHAETES
CHIRONOMID LARVAE
10
ANNELIDS
CHIRONOMID LARVAE
ISOPODS
17
ANNELIDS
24
ANNELIDS
CHIRONOMID LARVAE
ISOPOD
OCT.
1
ANNELIDS
POLYCHAETES
CHIRONOMID LARVAE
ISOPOD
AMPHIPOD
8
ANNELIDS
POLYCHAETES
CHIRONOMID LARVAE
AMPHIPOD
15
ANNELIDS
POLYCHAETES
CHIRONOMID LARVAE
22
ANNELIDS
POLYCHAETES
ISOPODS
Roseton
Danskammer

Figure 6 Average Number of Each of Nine Major Species of Fish Caught Per Daily Set of the Haul Seine, Danskammer, Aug. 13-Sept. 17, 1969. (In terms of number of fish per 5000 sq. ft. of area seined).

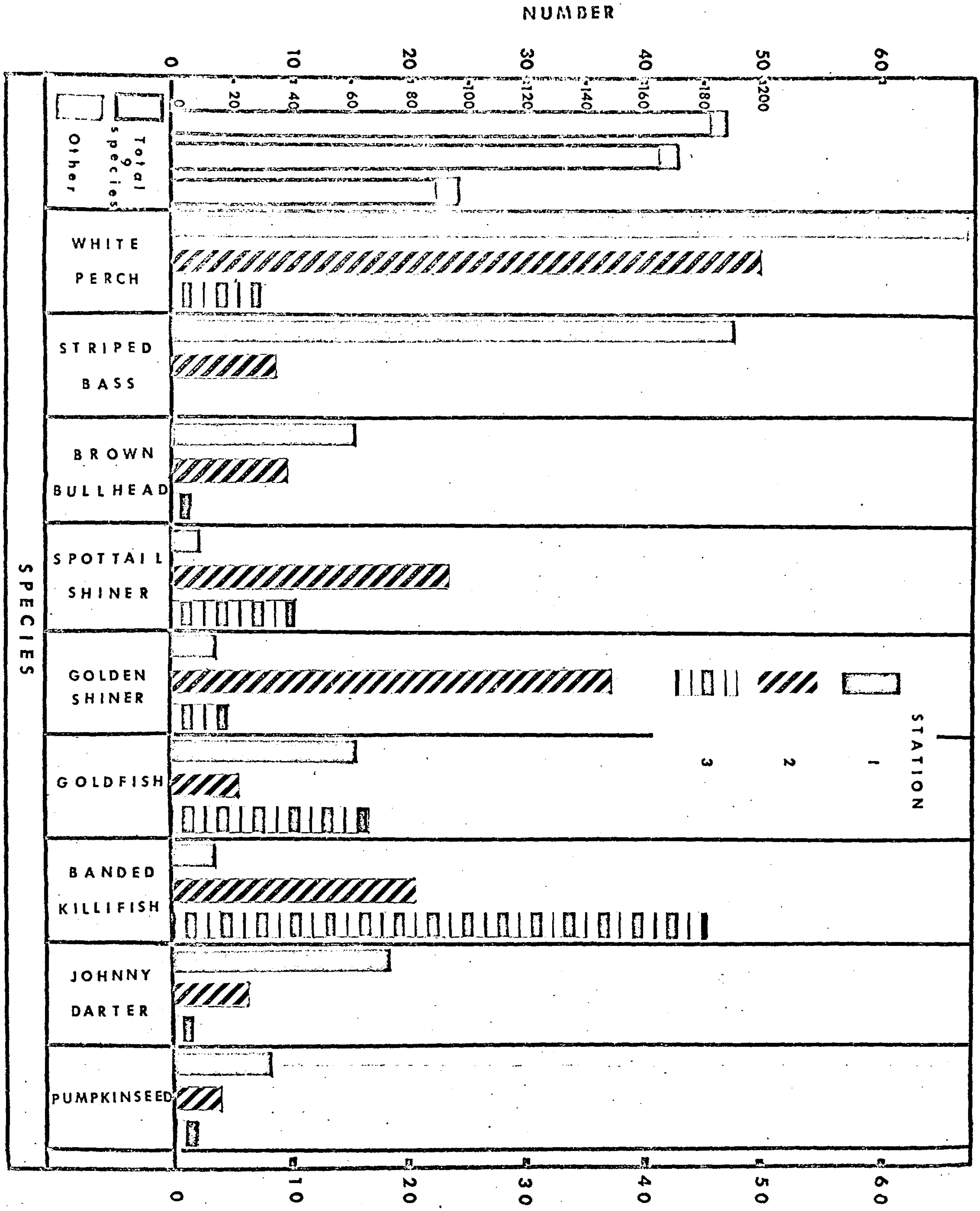
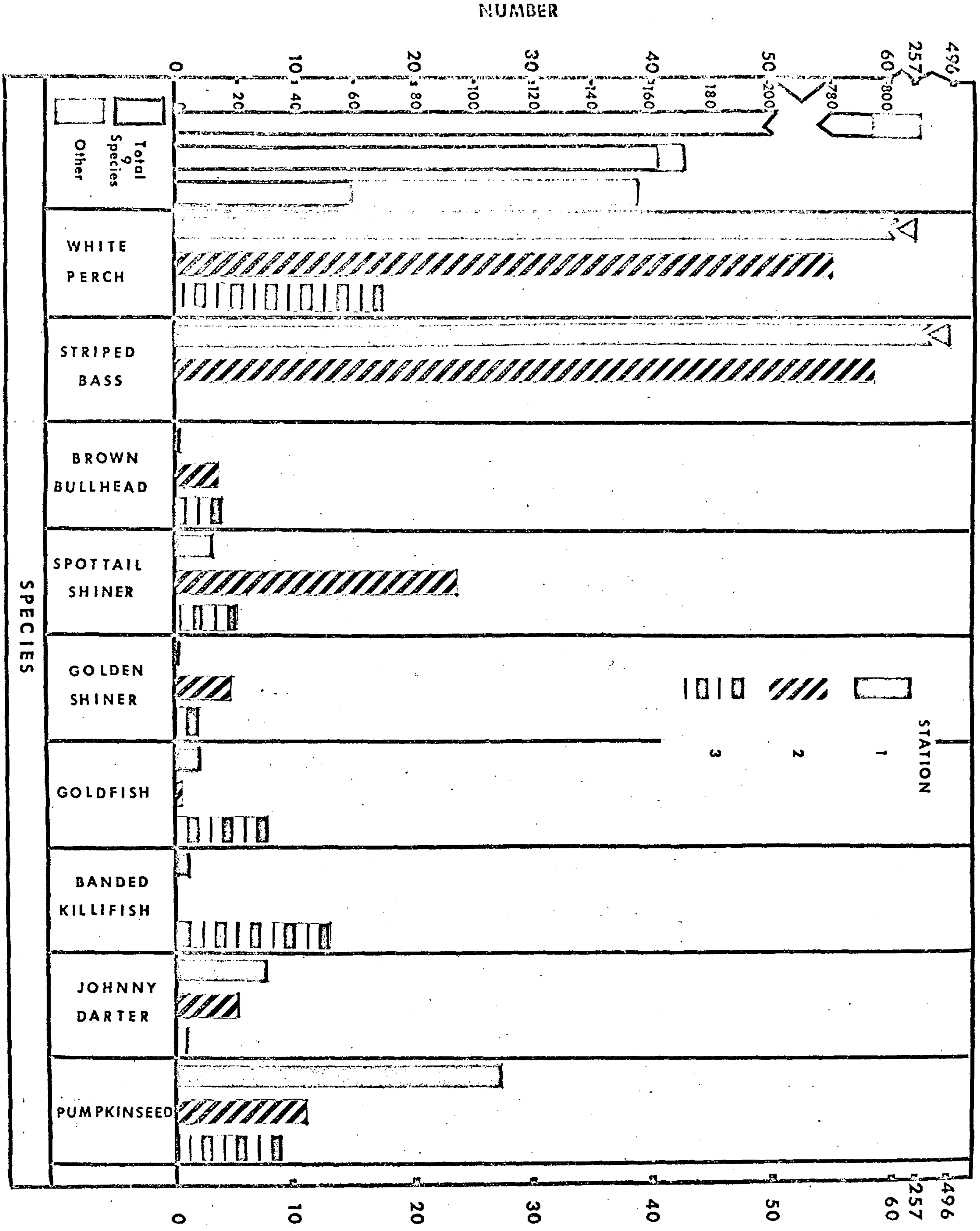

NUMBER
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
160
180
200
Total 9 species
Other
WHITE PERCH
STRIPED BASS
BROWN BULLHEAD
SPOTTAIL SHINER
GOLDEN SHINER
GOLDFISH
BANDED KILLIFISH
JOHNNY DARTER
PUMPKINSEED
SPECIES
STATION
1
2
3
0
10
20
30
40
50
60

Figure 7 Average Number of Each of Nine Major Species of Fish Caught Per Daily Set of the Haul Seine, Danskammer, Sept. 24-Oct. 22, 1969. (In terms of number of fish per 5000 sq. ft. of area seined).


NUMBER
0
10
20
30
40
50
60
257
496
20
40
60
80
100
120
140
160
180
200
780
800
Total 9 Species
Other
WHITE PERCH
STRIPED BASS
BROWN BULLHEAD
SPOTTAIL SHINER
GOLDEN SHINER
GOLDFISH
BANDED KILLIFISH
JOHNNY DARTER
PUMPKINSEED
SPECIES
STATION
1
2
3

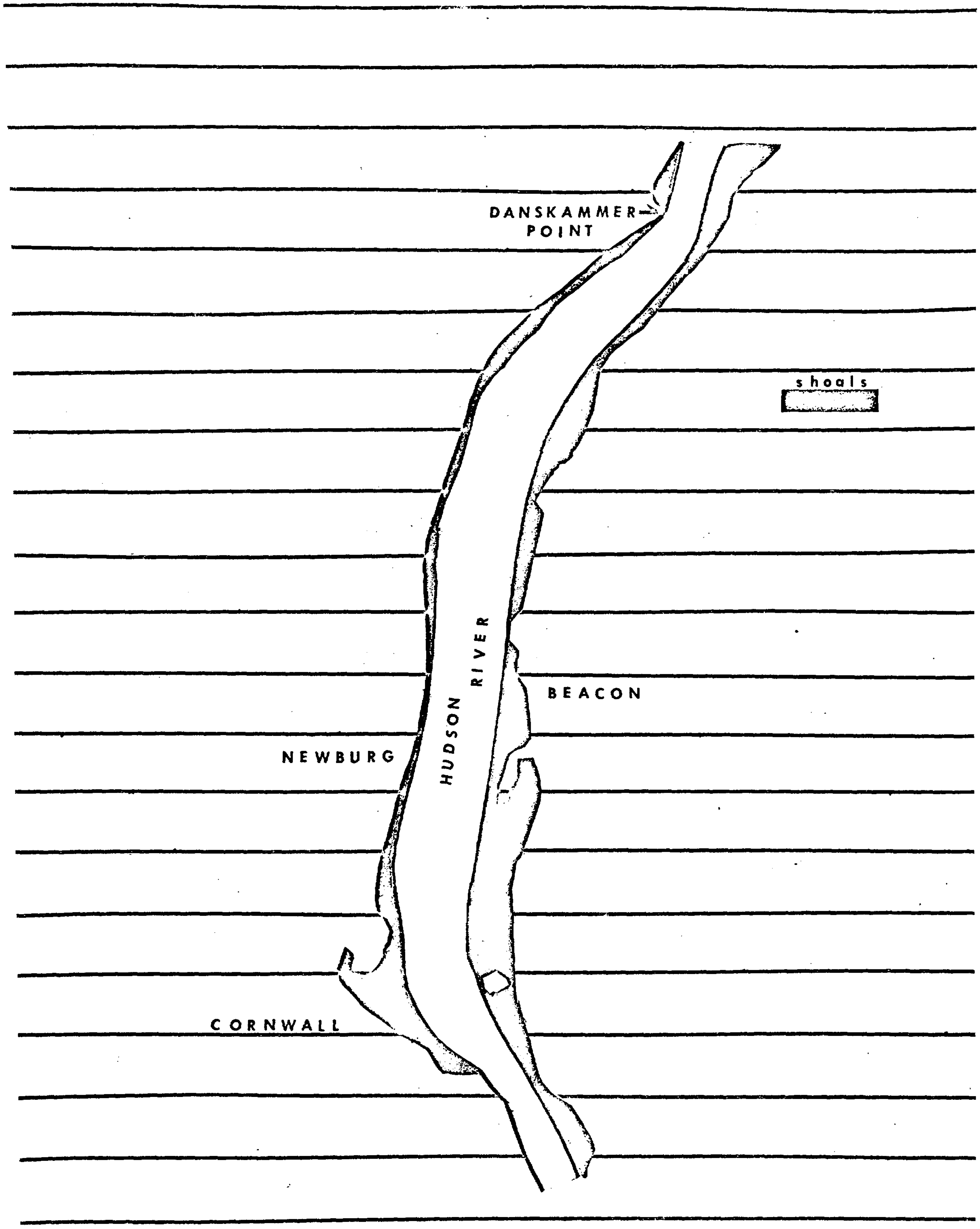

DANSKAMMER POINT
shoals
HUDSON RIVER
BEACON
NEWBURG
CORNWALL

Figure 9 Number of Larvae of Miscellaneous Species (Exclusive of Striped Bass and White Perch) per 1000 Cu. Ft. of Water at Various Depth Contours: Hudson River at Cornwall, April 25-May 15, 1968.

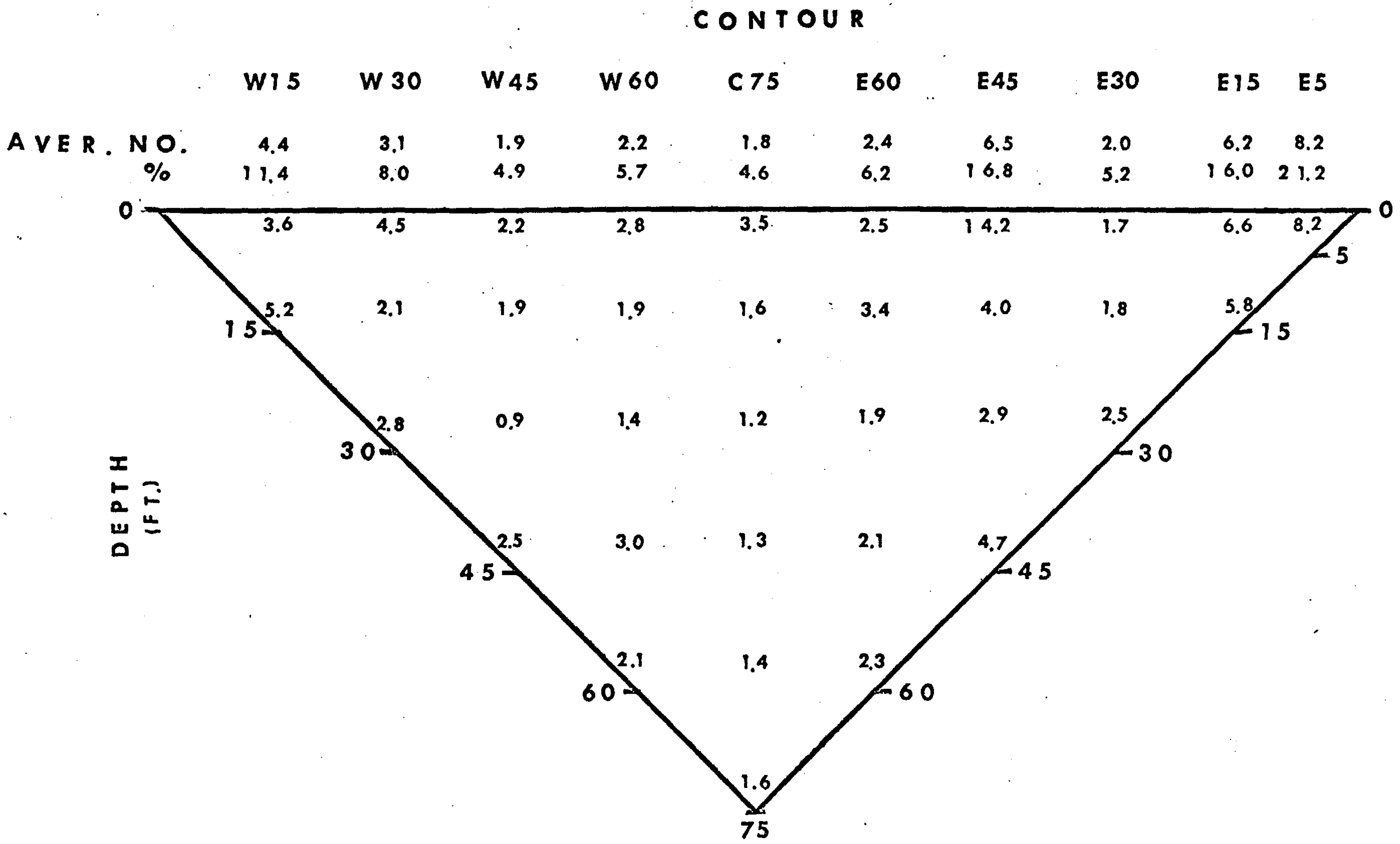

CONTOUR
W15 W30 W45 W60 C75 E60 E45 E30 E15 E5
AVER. NO. 4.4 3.1 1.9 2.2 1.8 2.4 6.5 2.0 6.2 8.2
% 11.4 8.0 4.9 5.7 4.6 6.2 16.8 5.2 16.0 21.2
0
0
3.6 4.5 2.2 2.8 3.5 2.5 14.2 1.7 6.6 8.2
5
5.2 2.1 1.9 1.9 1.6 3.4 4.0 1.8 5.8
15
15
2.8 0.9 1.4 1.2 1.9 2.9 2.5
30
30
DEPTH (FT.)
2.5 3.0 1.3 2.1 4.7
45
45
2.1 1.4 2.3
60
60
1.6
75

Figure 10 Number of Larvae of Miscellaneous Species (Exclusive of Striped Bass and White Perch) per 1000 Cu. Ft. of Water at Various Depth Contours: Hudson River at Cornwall, May 16-May 31, 1968.

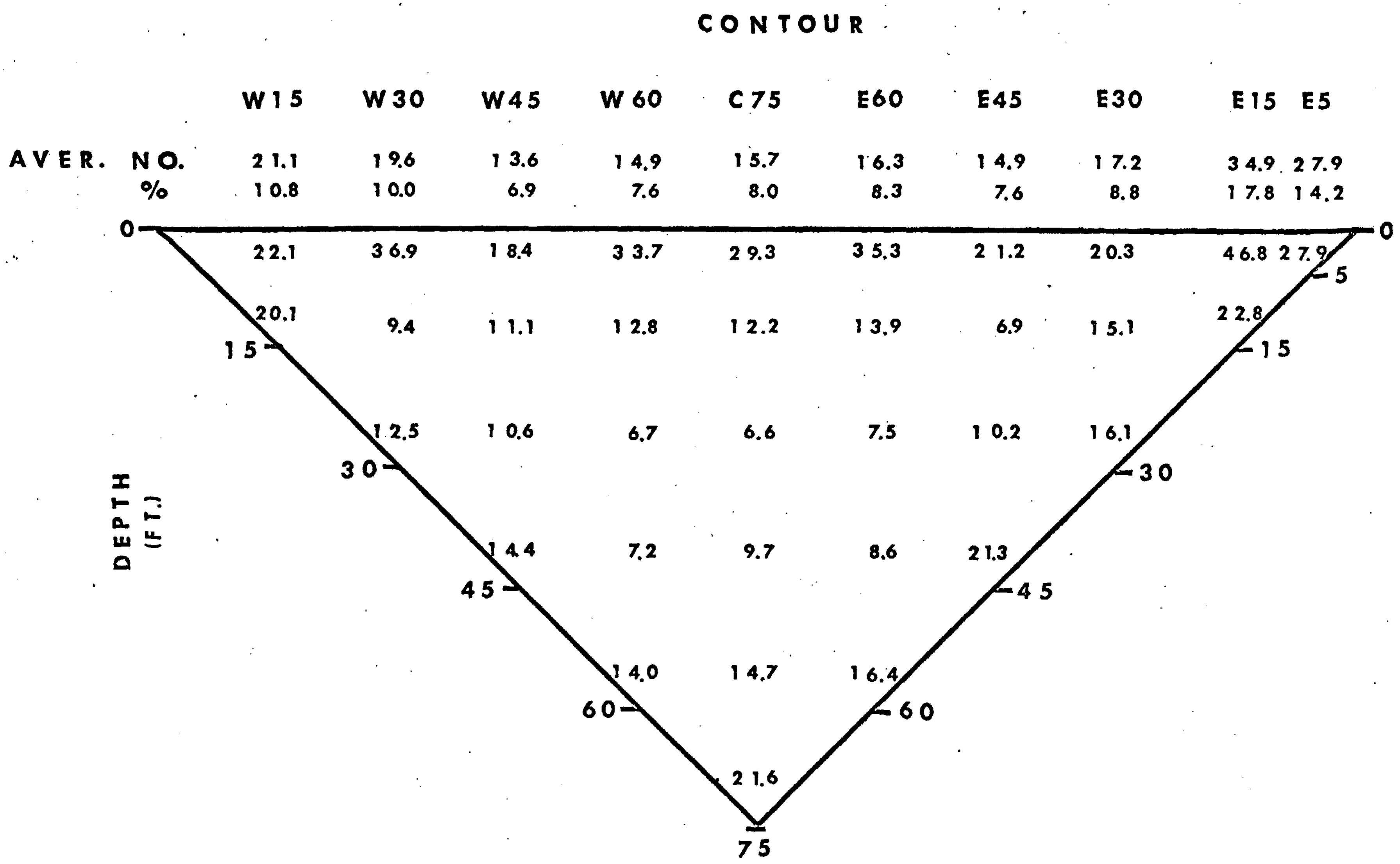

CONTOUR
W15
W30
W45
W 60
C 75
E60
E45
E30
E15
E5
AVER. NO.
21.1
19.6
13.6
14.9
15.7
16.3
14.9
17.2
34.9
27.9
%
10.8
10.0
6.9
7.6
8.0
8.3
7.6
8.8
17.8
14.2
0
0
22.1
36.9
18.4
33.7
29.3
35.3
21.2
20.3
46.8
27.9
5
20.1
9.4
11.1
12.8
12.2
13.9
6.9
15.1
22.8
15
15
12.5
10.6
6.7
6.6
7.5
10.2
16.1
30
30
DEPTH (FT.)
14.4
7.2
9.7
8.6
21.3
45
45
14.0
14.7
16.4
60
60
21.6
75

Figure 11 Number of Larvae of Miscellaneous Species (Exclusive of Striped Bass and White Perch) per 1000 Cu. Ft. of Water at Various Depth Contours: Hudson River at Cornwall, June 1-June 15, 1968.

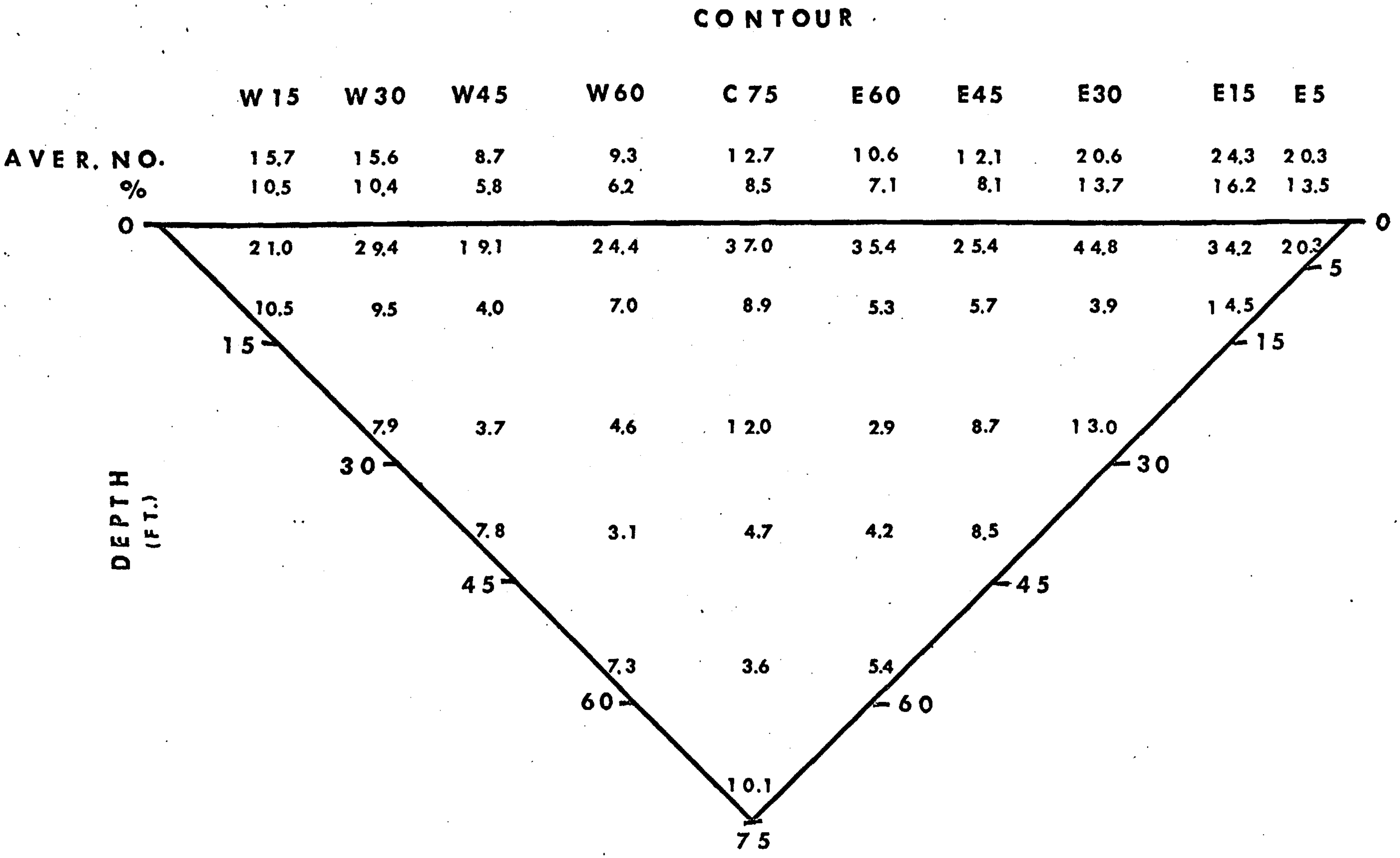

CONTOUR
W 15
W 30
W45
W60
C 75
E60
E45
E30
E15
E5
AVER. NO.
%
15.7
15.6
8.7
9.3
12.7
10.6
12.1
20.6
24.3
20.3
10.5
10.4
5.8
6.2
8.5
7.1
8.1
13.7
16.2
13.5
0
0
21.0
29.4
19.1
24.4
37.0
35.4
25.4
44.8
34.2
20.3
5
10.5
9.5
4.0
7.0
8.9
5.3
5.7
3.9
14.5
15
15
7.9
3.7
4.6
12.0
2.9
8.7
13.0
30
30
DEPTH
(FT.)
7.8
3.1
4.7
4.2
8.5
45
45
7.3
3.6
5.4
60
60
10.1
75

Figure 12 Number of Larvae of Miscellaneous Species (Exclusive of Striped Bass and White Perch) per 1000 Cu. Ft. of Water at Various Depth Contours: Hudson River at Cornwall, June 16-June 30, 1968.

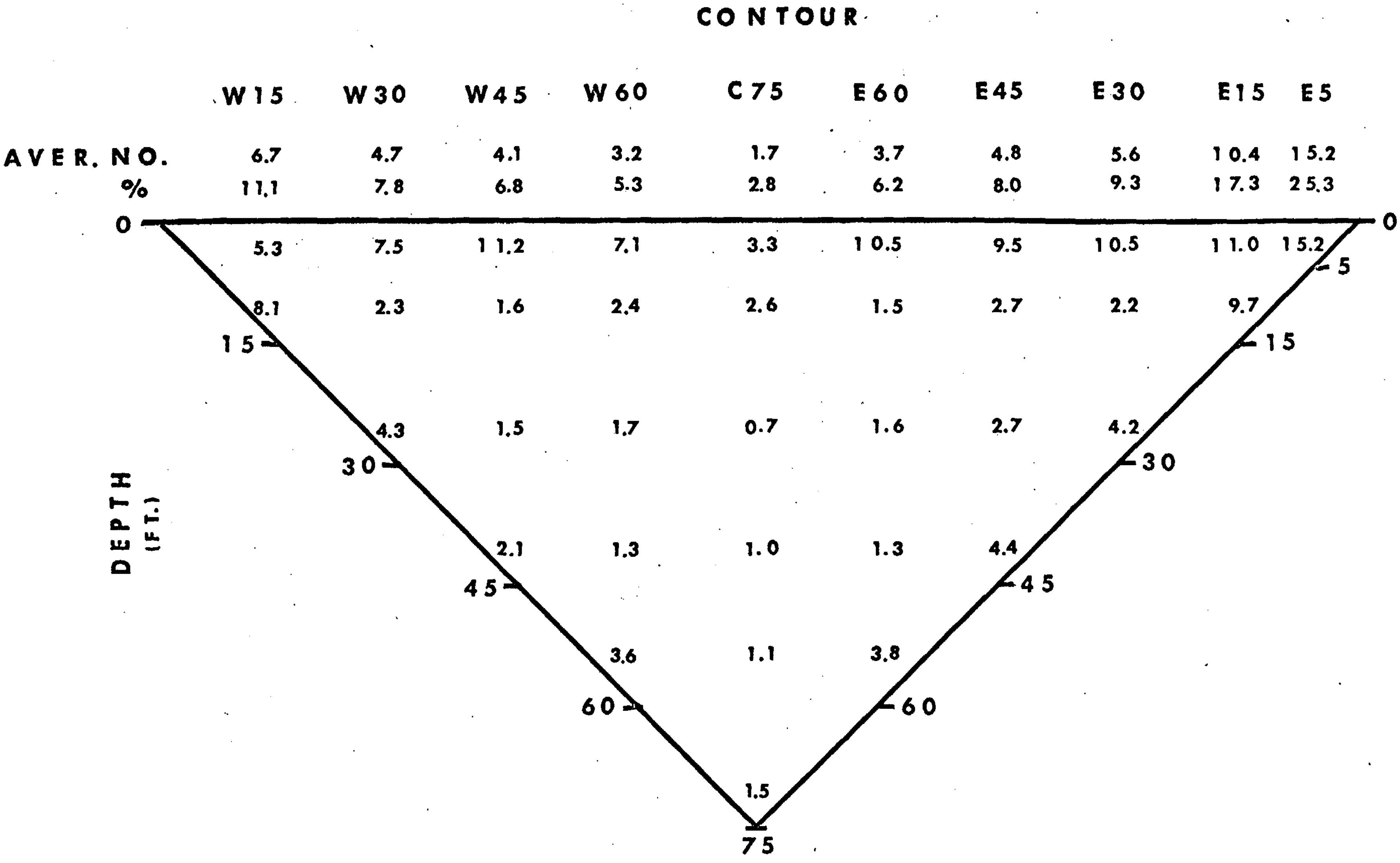

CONTOUR
W15
W30
W45
W60
C75
E60
E45
E30
E15
E5
AVER. NO.
6.7
4.7
4.1
3.2
1.7
3.7
4.8
5.6
10.4
15.2
%
11.1
7.8
6.8
5.3
2.8
6.2
8.0
9.3
17.3
25.3
0
0
5.3
7.5
11.2
7.1
3.3
10.5
9.5
10.5
11.0
15.2
5
8.1
2.3
1.6
2.4
2.6
1.5
2.7
2.2
9.7
15
15
4.3
1.5
1.7
0.7
1.6
2.7
4.2
30
30
DEPTH (FT.)
2.1
1.3
1.0
1.3
4.4
45
45
3.6
1.1
3.8
60
60
1.5
75

Figure 13 Number of Larvae of Miscellaneous Species (Exclusive of Striped Bass and White Perch) per 1000 Cu. Ft. of Water at Various Depth Contours: Hudson River at Cornwall, July 1-July 15, 1968.

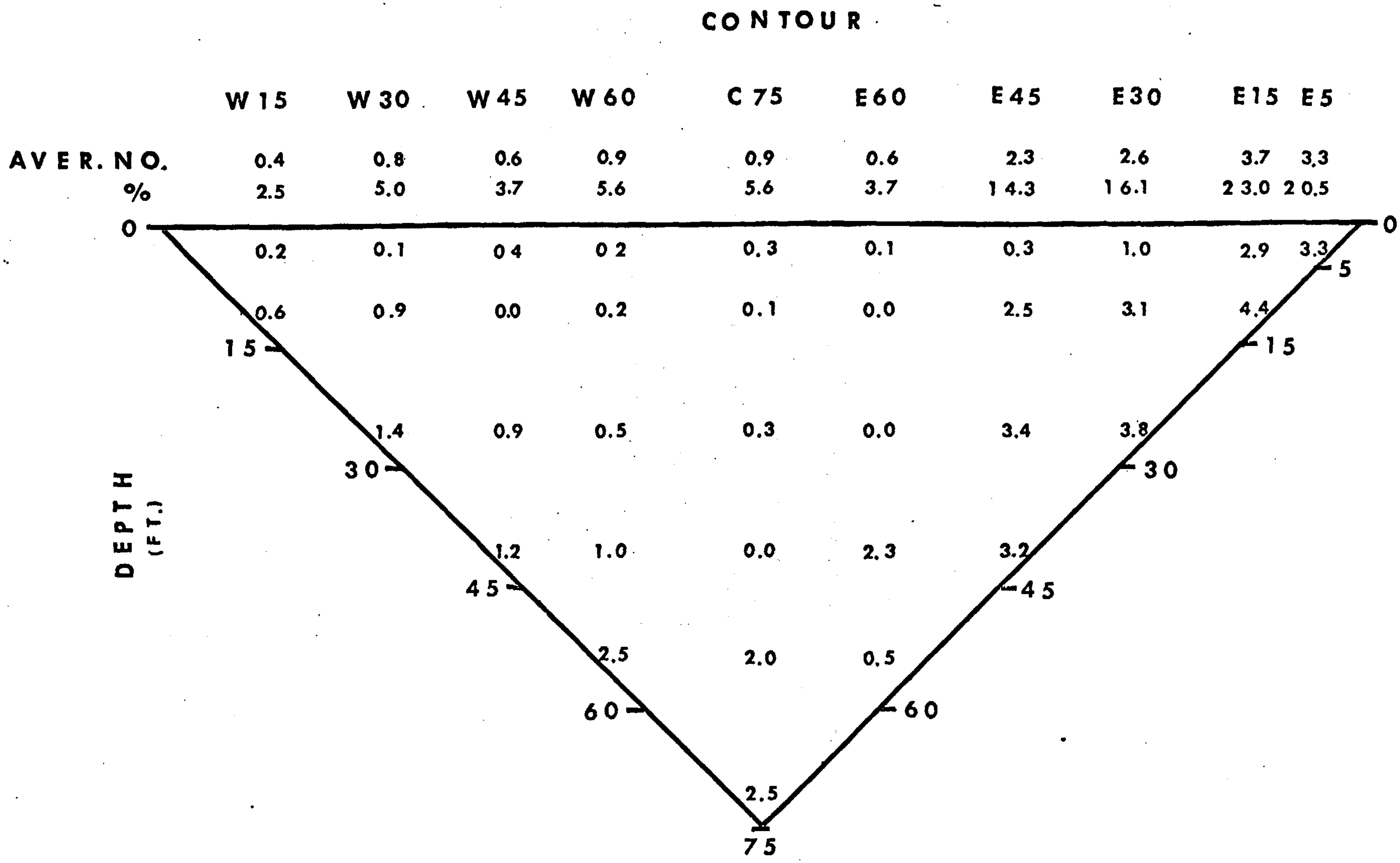

CONTOUR
W 15
W 30
W 45
W 60
C 75
E 60
E 45
E 30
E 15
E 5
AVER. NO.
%
0.4
0.8
0.6
0.9
0.9
0.6
2.3
2.6
3.7
3.3
2.5
5.0
3.7
5.6
5.6
3.7
14.3
16.1
23.0
20.5
0
0
0.2
0.1
0 4
0 2
0. 3
0.1
0.3
1.0
2.9
3.3
5
0.6
0.9
0.0
0.2
0. 1
0.0
2.5
3.1
4.4
15
15
1.4
0.9
0.5
0.3
0.0
3.4
3.8
30
30
DEPTH
(FT.)
1.2
1.0
0.0
2. 3
3.2
45
45
2.5
2.0
0. 5
60
60
2.5
75

Figure 14 Cumulative Percentage Distribution of Larvae of Miscellaneous Species (Exclusive of Striped Bass and White Perch) from the Western Shore of the Hudson River to Various Depth Contours: Cornwall, April 23-May 15, 1968.

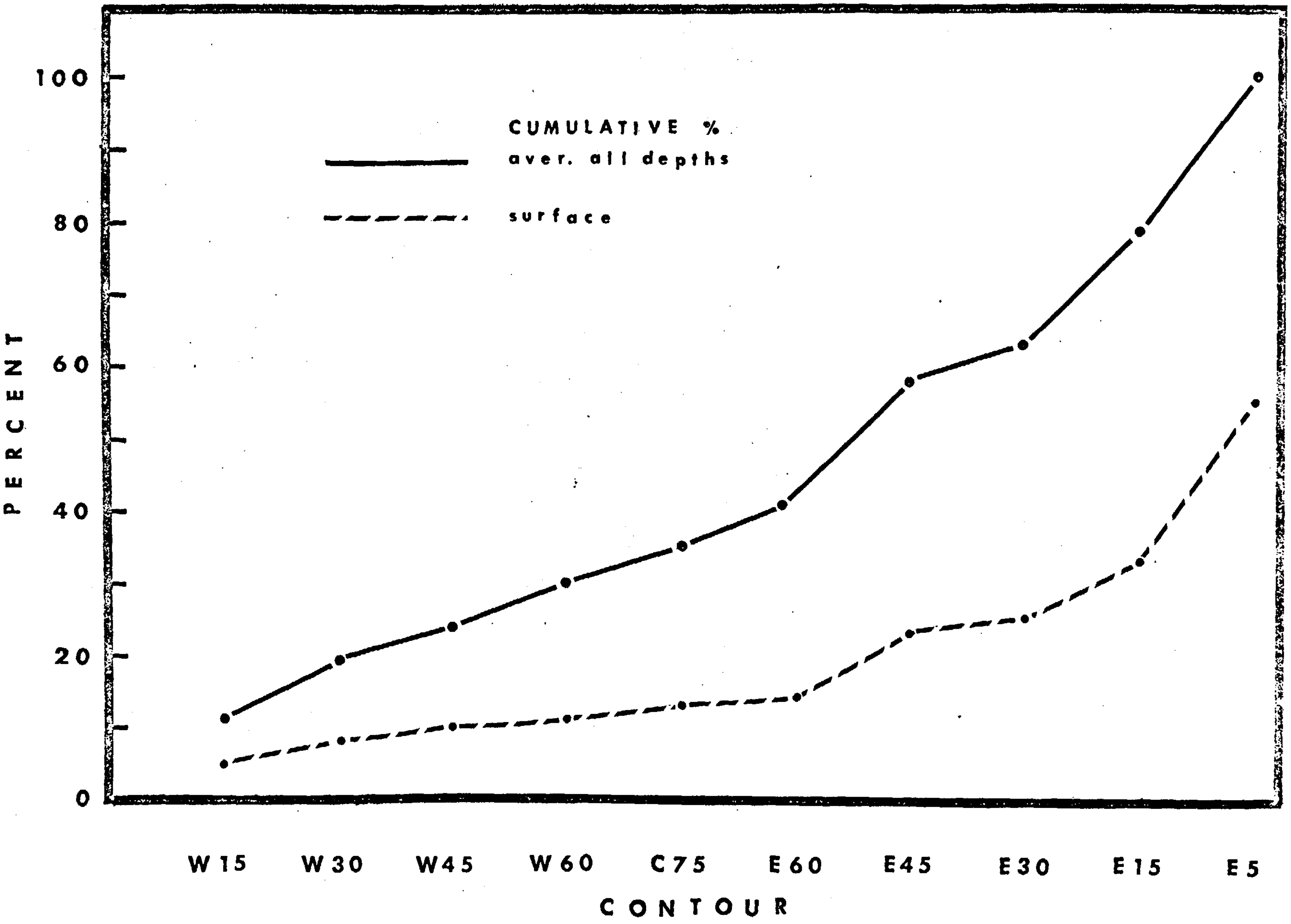

CUMULATIVE %
aver. all depths
surface
PERCENT
100
80
60
40
20
0
W 15
W 30
W 45
W 60
C 75
E 60
E 45
E 30
E 15
E 5
CONTOUR

Figure 15 Cumulative Percentage Distribution of Larvae of Miscellaneous Species (Exclusive of Striped Bass and White Perch) from the Western Shore of the Hudson River to - Various Depth Contours: Cornwall, May 16-May 31, 1968.

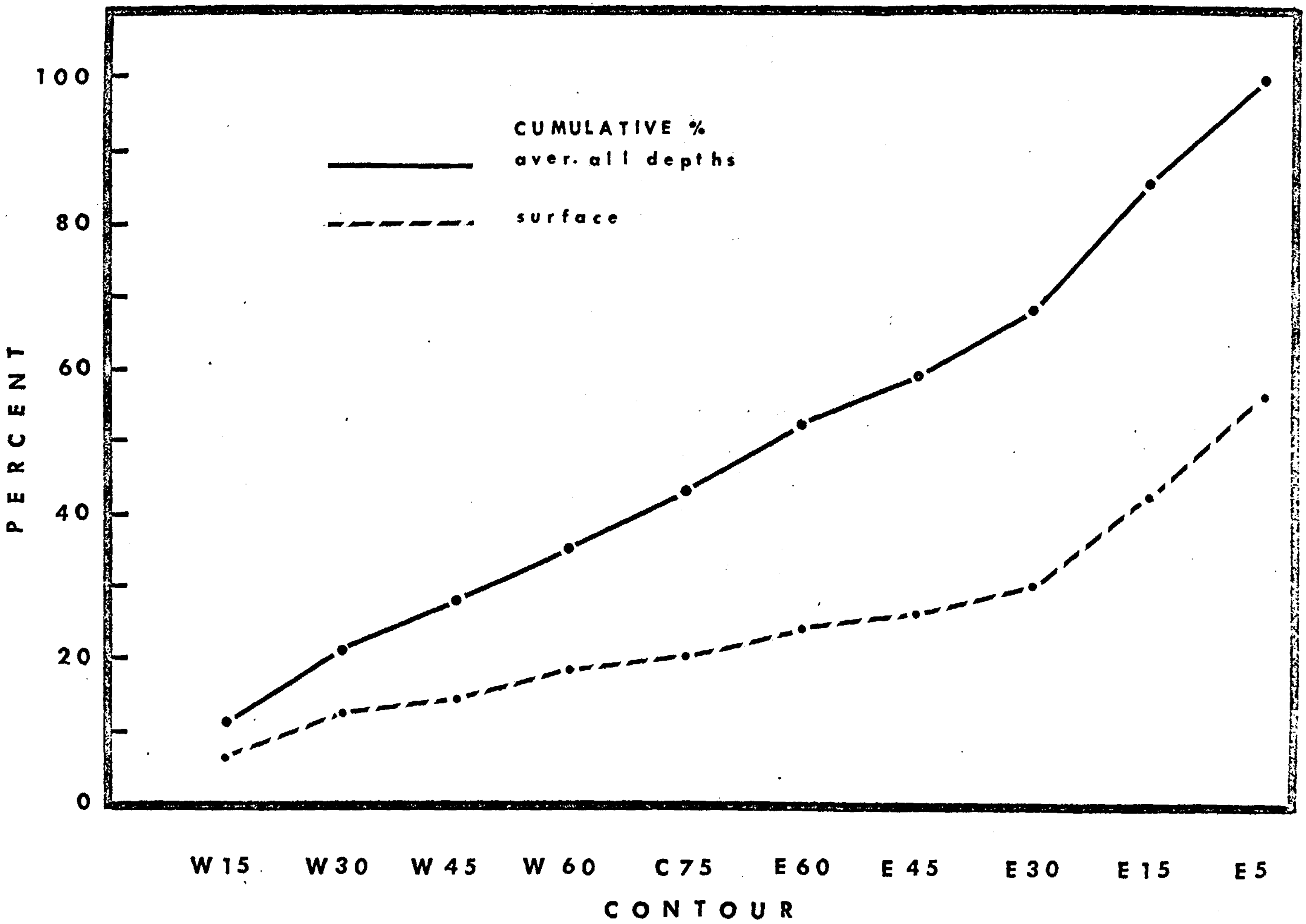

CUMULATIVE %
aver. all depths
surface
100
80
60
40
20
0
PERCENT
W15
W30
W45
W 60
C75
E60
E45
E30
E15
E5
CONTOUR

Figure 16 Cumulative Percentage Distribution of Larvae of Miscellaneous Species (Exclusive of Striped Bass and White Perch) from the Western Shore of the Hudson River to Various Depth Contours: Cornwall, June 1-June 15, 1968.

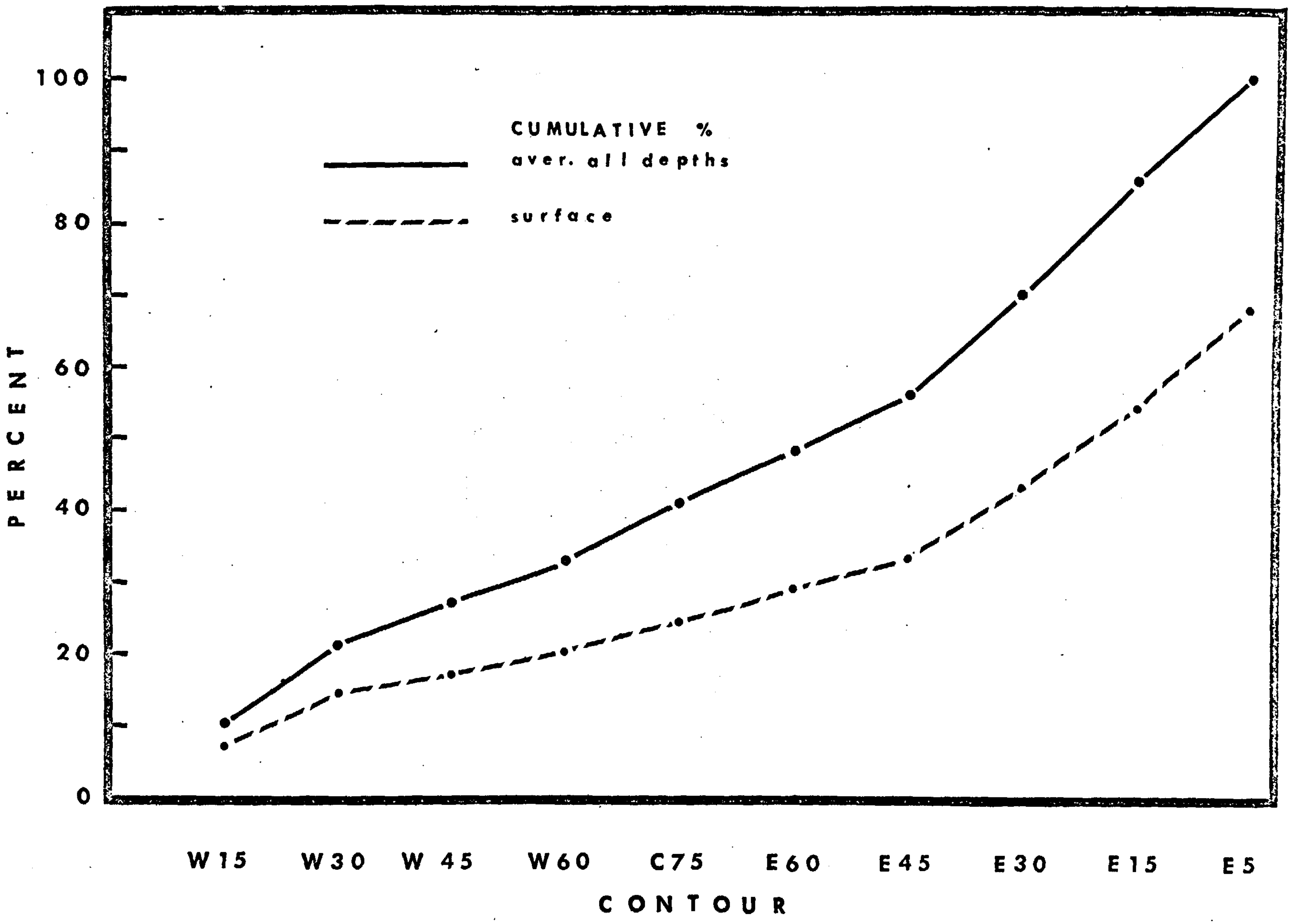

CUMULATIVE %
aver. all depths
surface
100
80
60
40
20
0
PERCENT
W15
W30
W 45
W60
C75
E60
E45
E30
E15
E5
CONTOUR

Figure 17 Cumulative Percentage Distribution of Larvae of Miscellaneous Species (Exclusive of Striped Bass and White Perch) from the Western Shore of the Hudson River to-Various Depth Contours: Cornwall, June 16-June 30, 1968.

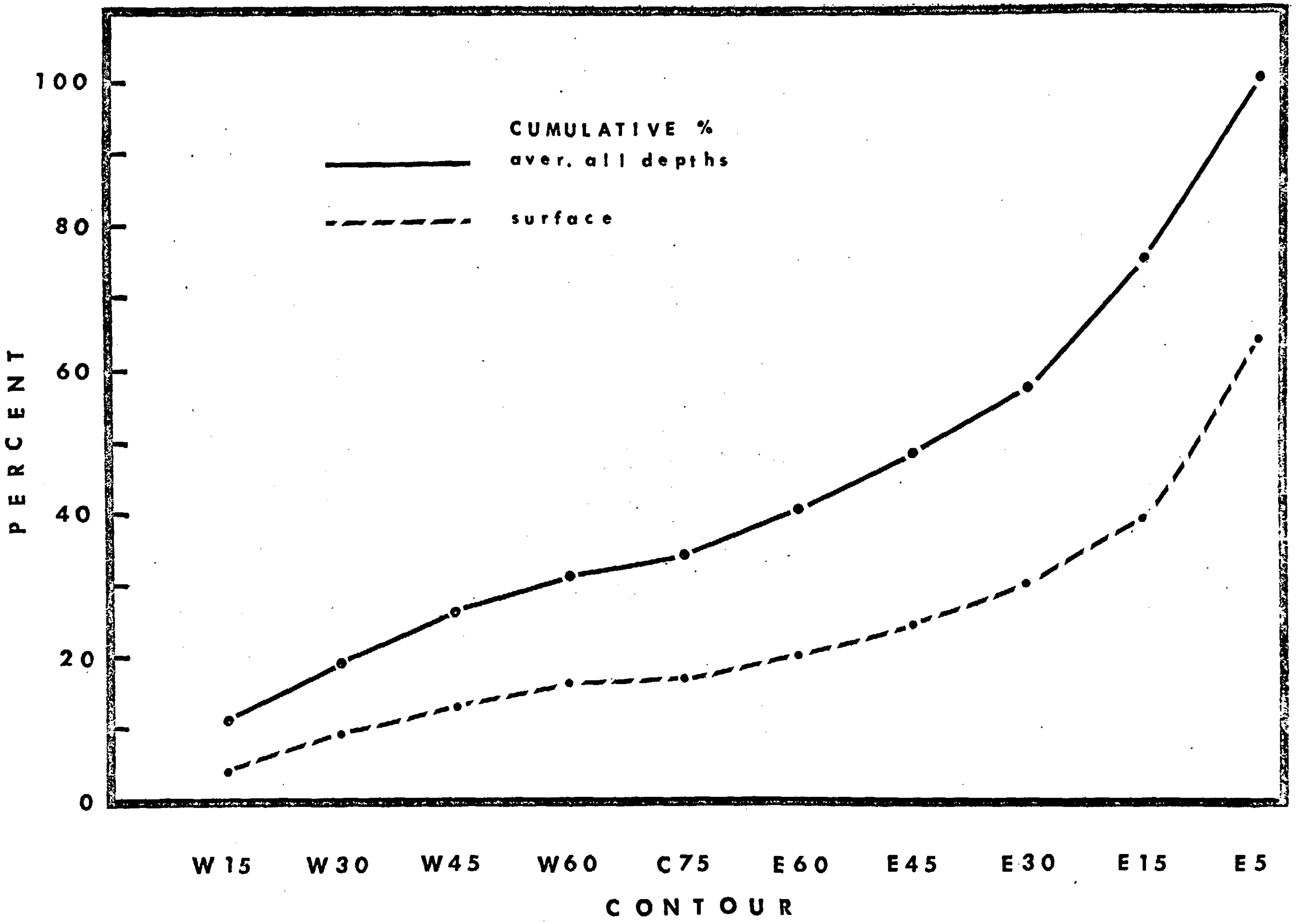
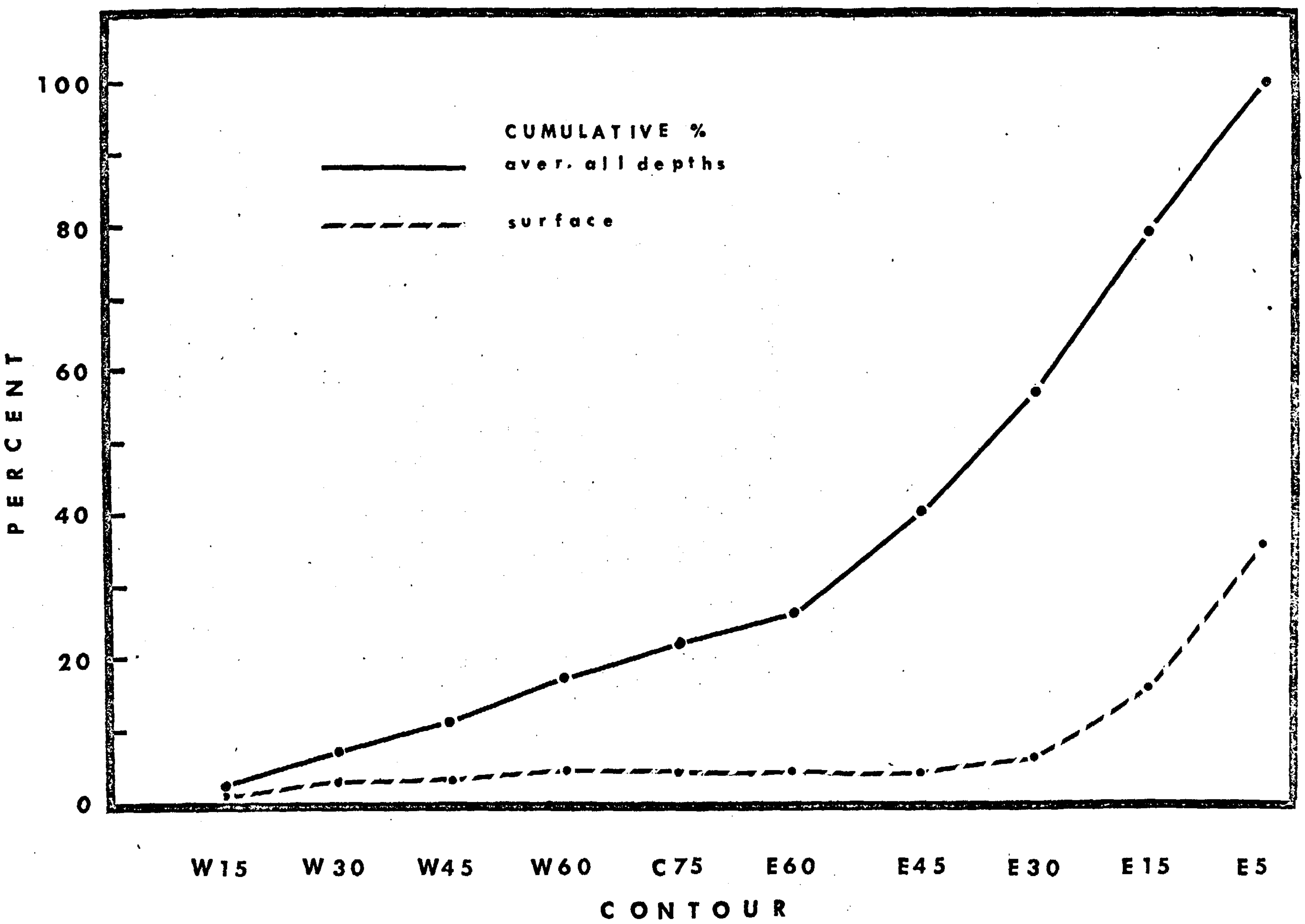
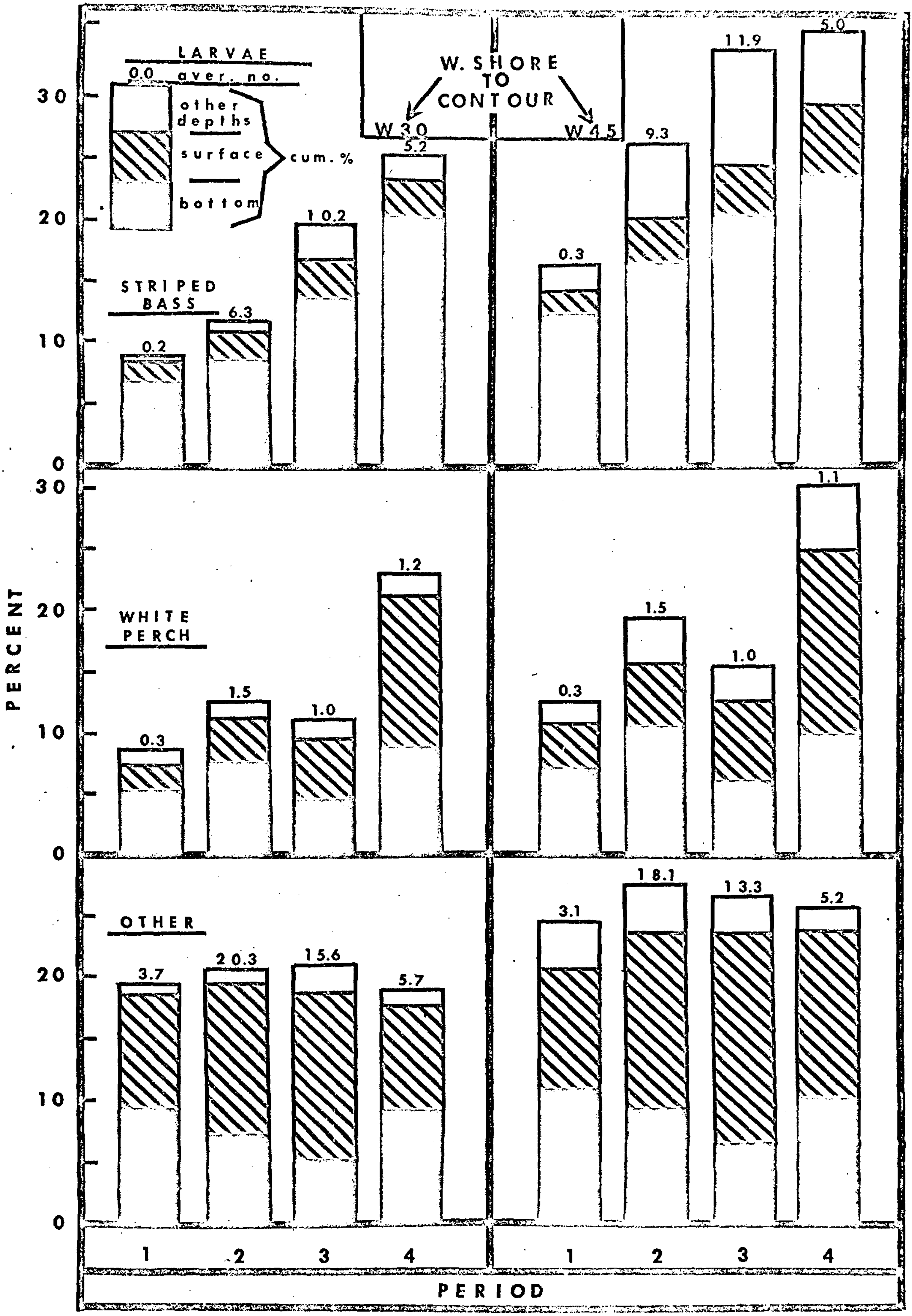

CUMULATIVE %
aver. all depths
surface
PERCENT
100
80
60
40
20
0
W 15
W 30
W 45
W 60
C 75
E 60
E 45
E 30
E 15
E 5
CONTOUR

Figure 18 Cumulative Percentage Distribution of Larvae of Miscellaneous Species (Exclusive of Striped Bass and White Perch) from the Western Shore of the Hudson River to-Various Depth Contours: Cornwall, July 1, July 15, 1968.



CUMULATIVE %
aver. all depths
surface
PERCENT
0
20
40
60
80
100
W15
W30
W45
W60
C75
E60
E45
E30
E15
E5
CONTOUR

Figure 19 Cumulative Percentage Distribution of Larvae of Striped Bass, White Perch and Other Species from the Western Shore of the Hudson River to the West 30 and West 45 Depth Contours Showing Relative Concentrations at the Surface, Bottom and the Remaining Combined Intermediate Depths.


LARVAE
0.0 aver. no.
other depths
surface
bottom
cum. %
W. SHORE TO CONTOUR
W30
W45
STRIPED BASS
WHITE PERCH
OTHER
PERCENT
0
10
20
30
PERIOD
1
2
3
4
0.2
6.3
10.2
5.2
0.3
9.3
11.9
5.0
0.3
1.5
1.0
1.2
0.3
1.5
1.0
1.1
3.7
20.3
15.6
5.7
3.1
18.1
13.3
5.2

SEISMIC SURVEY
WATER TEMPERATURE AND DEPTH MEASUREMENTS
ROSETON GENERATION SITE
NEWBURGH, NEW YORK
for
CENTRAL HUDSON GAS & ELECTRIC CORPORATION

WESTON GEOPHYSICAL ENGINEERS, INC.
WESTON, MASSACHUSETTS

WESTON GEOPHYSICAL ENGINEERS, INC.
POST OFFICE BOX 306
WESTON, MASSACHUSETTS 02193
AREA CODE 617 899-0060

July 19, 1968

Central Hudson Gas & Electric Corporation
Poughkeepsie, New York

Gentlemen:

A seismic survey, water temperature and depth measurements were conducted at the Roseton Generation Site of the Central Hudson Gas & Electric Corporation, Newburgh, New York during June 1968.

Preliminary data have been submitted. This is a formal, complete presentation of our findings.

Very truly yours,

WESTON GEOPHYSICAL ENGINEERS, INC.

Edward A Levine

for Richard J. Holt

RJH:jh

SEISMIC SURVEY

WATER TEMPERATURE AND DEPTH MEASUREMENTS

ROSETON GENERATION SITE

NEWBURGH, NEW YORK

INTRODUCTION

Field work including a seismic survey at the Central Hudson Gas & Electric Corporation, Roseton Generation Site, Newburgh, New York as well as bathythermograph and water depth measurements in the adjacent Hudson River, was completed during June 1968.

The seismic measurements were made by means of a multi-detector (twelve trace), seismic refraction system. For best results, the length of the seismic cable and the geophone interval were chosen in relation to the bedrock depths.

The bathythermograph measurements were made using an instrument containing a thermometer and a pressure sensor which when lowered into the water provided a graph of temperature versus water depth.

PURPOSE AND LOCATION

The purpose of the seismic refraction survey was to establish depths to bedrock in a portion of the site as generally outlined by

Mr. Stuart Laidlaw of the Central Hudson Gas & Electric Corporation. The seismic lines were oriented in the field to avoid significant topographic changes produced by excavation in the clay pit area of the Jova Brick Works.

The purpose of the bathythermograph survey was to determine water temperatures in the area of the Hudson River adjacent to the site. Measurements were made at the time of incoming and outgoing tides between the site and the discharge area of the Central Hudson Gas & Electric Corporation's Danskammer Station which is located less than one half mile north of the site.

The locations of the seismic lines and bathythermograph readings are shown on plan maps included with this report. Locations of field data as well as topography were provided by Hayward and Pakan Associates.

RESULTS

Seismic Survey

The results of the seismic survey are shown on the profile sections of this report. The velocity with which the seismic wave travels through the various layers as well as the thickness of the layers and depth to bedrock are given.

Tentative identifications of materials can be made based on seismic velocities and field observations but positive identification should be made by borings. The velocity range of 1,600 to 2,400 ft./sec. is indicative of an unsaturated loose overburden material such as the clays and silts existing at the site area. Along Line A, overburden velocities were as high as 3,000 ft./sec., which is probably an average of overburden material consisting of strata unsaturated, partially saturated and/or saturated. The seismic velocities of 4,700 to 5,000 ft./sec. are indicative of water saturated overburden material, probably clays and silts.

The seismic velocity of 16,000 ft./sec. is indicative of a competent bedrock.

An attempt was made to obtain seismic data in the area between the buildings of the Jova Brick Works and the Hudson River. Good data could not be obtained because of large amounts of fill material and the influence of building foundations. Some seismic information was obtained along the river's edge but the data was poor and indicated that the minimum thickness of overburden was fifty feet.

Bathythermograph Survey

The results of the bathythermograph survey are shown in the form of temperature versus water depth curves included in this report. The horizontal line shown on these curves at 0 depth represents the adjustment of the bathythermograph to the surface water temperatures. The distribution of surface water temperatures at the time of outgoing tides corresponds with visual surface effects.

Water Depth

The results of the water depth survey are shown in the form of a bottom contour map included with this report. The contours respresent elevations of the Hudson River bottom with mean sea level as a datum.

RECOMMENDATIONS

When the final site of the power plant is selected, it is recommended that some borings be taken for positive identification of overburden materials and correlation with the seismic data.

LARGE
DOCUMENT

LARGE
DOCUMENT

LARGE DOCUMENT

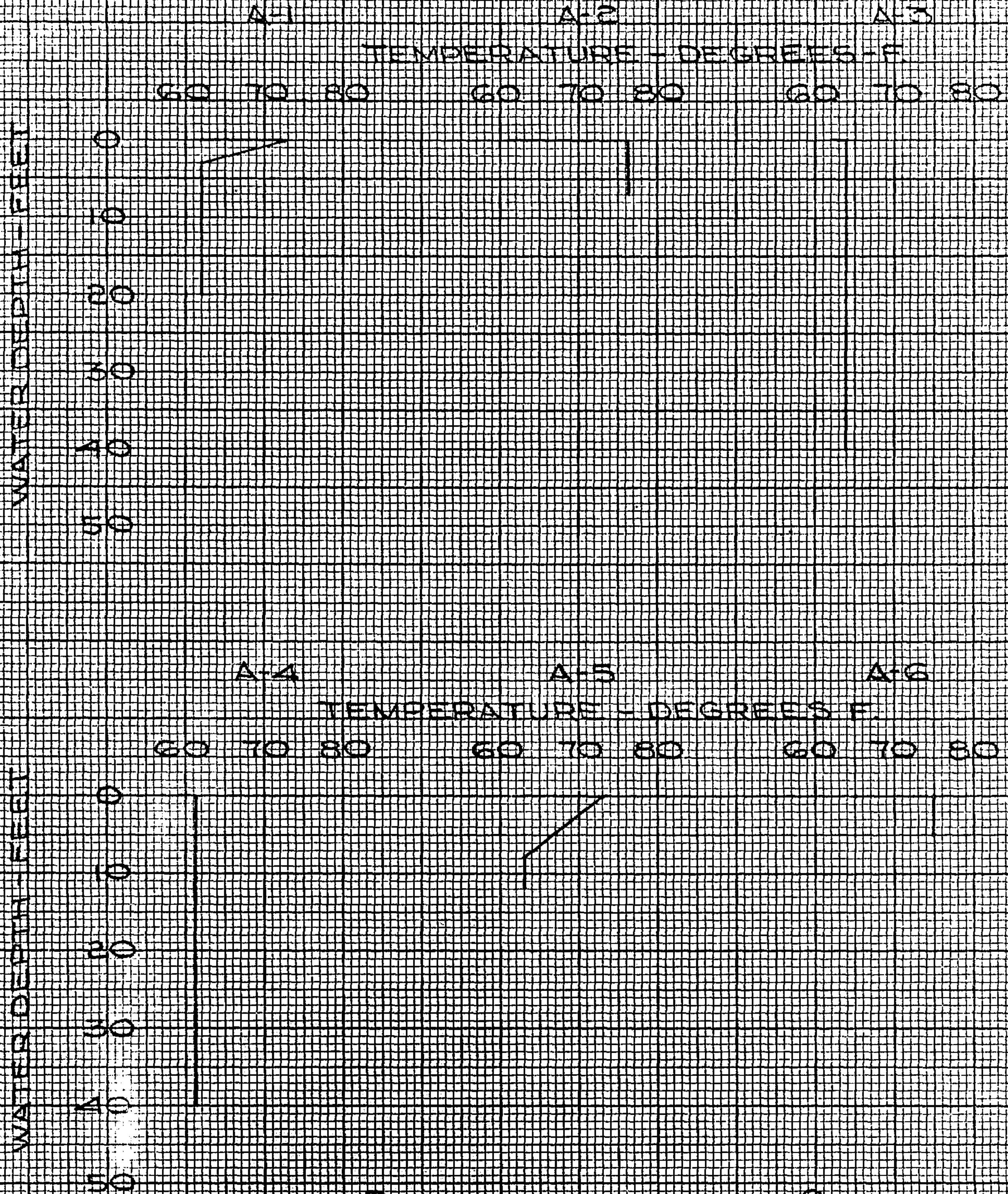
LARGE
DOCUMENT

LARGE
DOCUMENT

LARGE
DOCUMENT

BATHYTHERMOGRAPH MEASUREMENTS

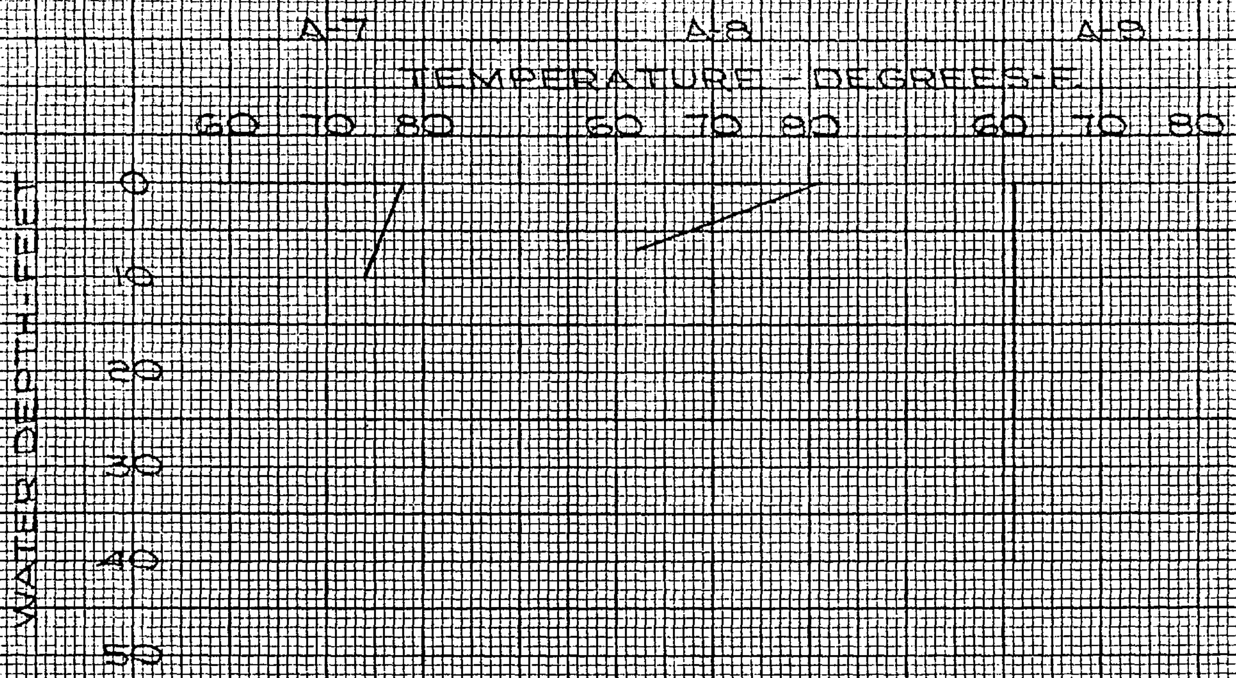
6/4/68 - 9:30 to 11:00 AM
OUTGOING TIDE

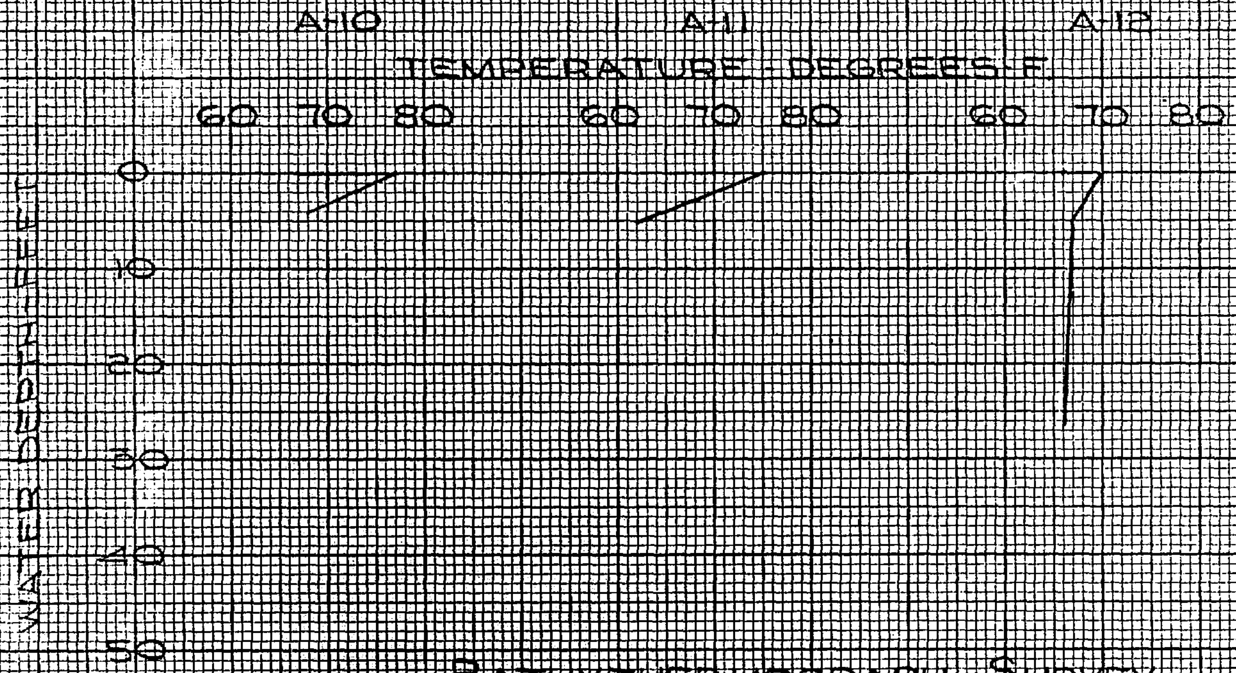


BATHYTHERMOGRAPH SURVEY
NEWBURGH, NEW YORK
by
WESTON GEOPHYSICAL ENGINEERS, INC.

6/4/68 - 9:30 to 11:00 A.M.

OUTGOING TIDE

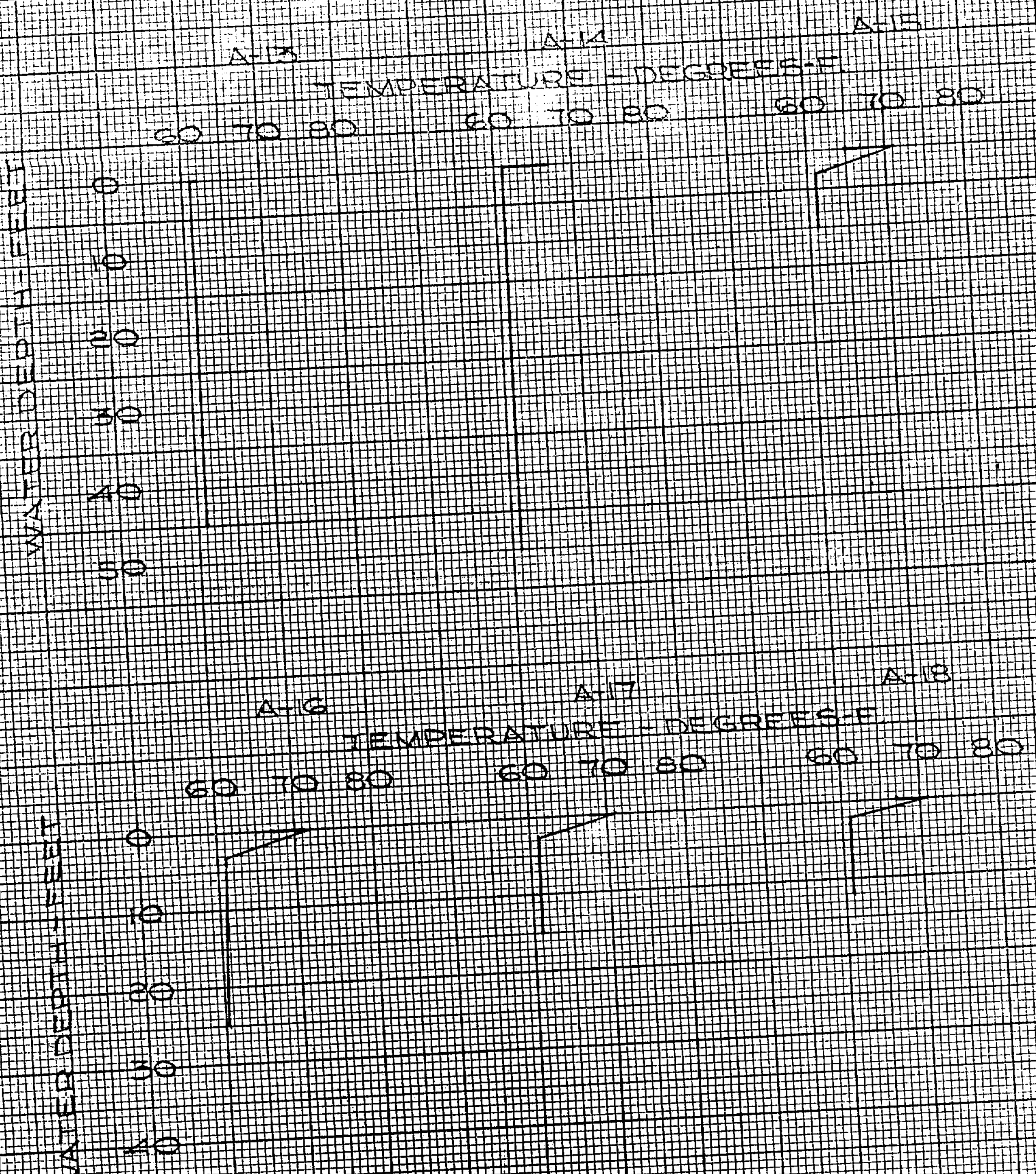




BATHYTHERMOGRAPH SURVEY
NEWBURGH, NEW YORK
by
WESTON GEOPHYSICAL ENGINEERS, INC.

5/4/68 - 9:30 to 11:00 A.M.

OUTGOING TIDE



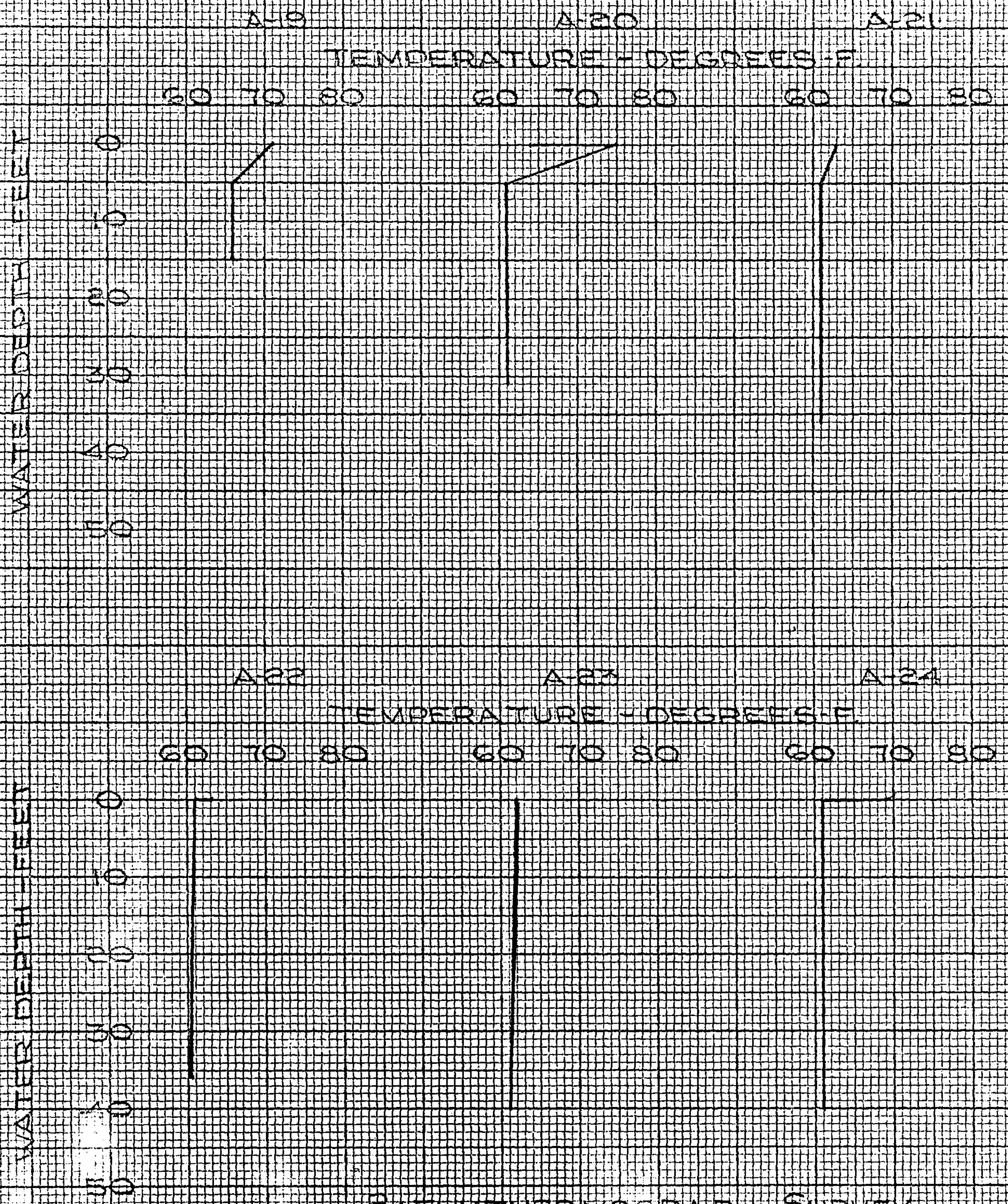
BATHYTHERMOGRAPH SURVEY

NEWBURGH, NEW YORK

by

WESTON GEOPHYSICAL ENGINEERS, INC.

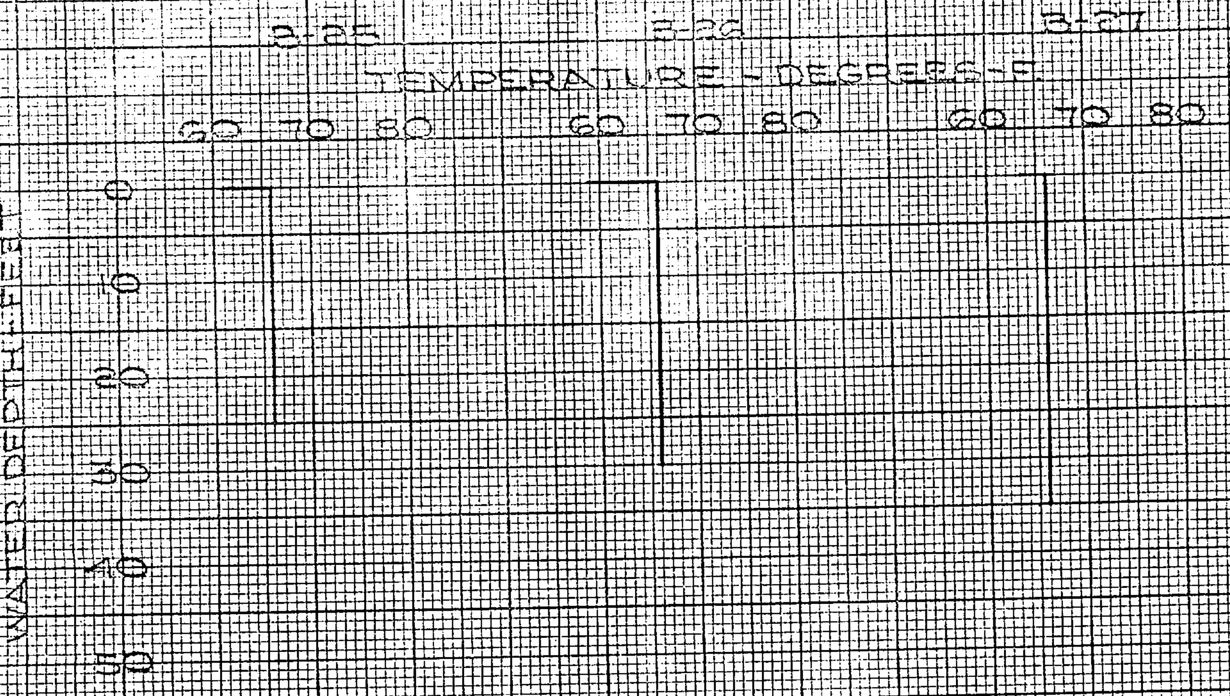
6/4/68 - 8:30 to 11:00 AM
OUTGOING TIDE



BATHYTHERMOGRAPH SURVEY
NEWBURGH, NEW YORK
by
WESTON GEOPHYSICAL ENGINEERS, INC.

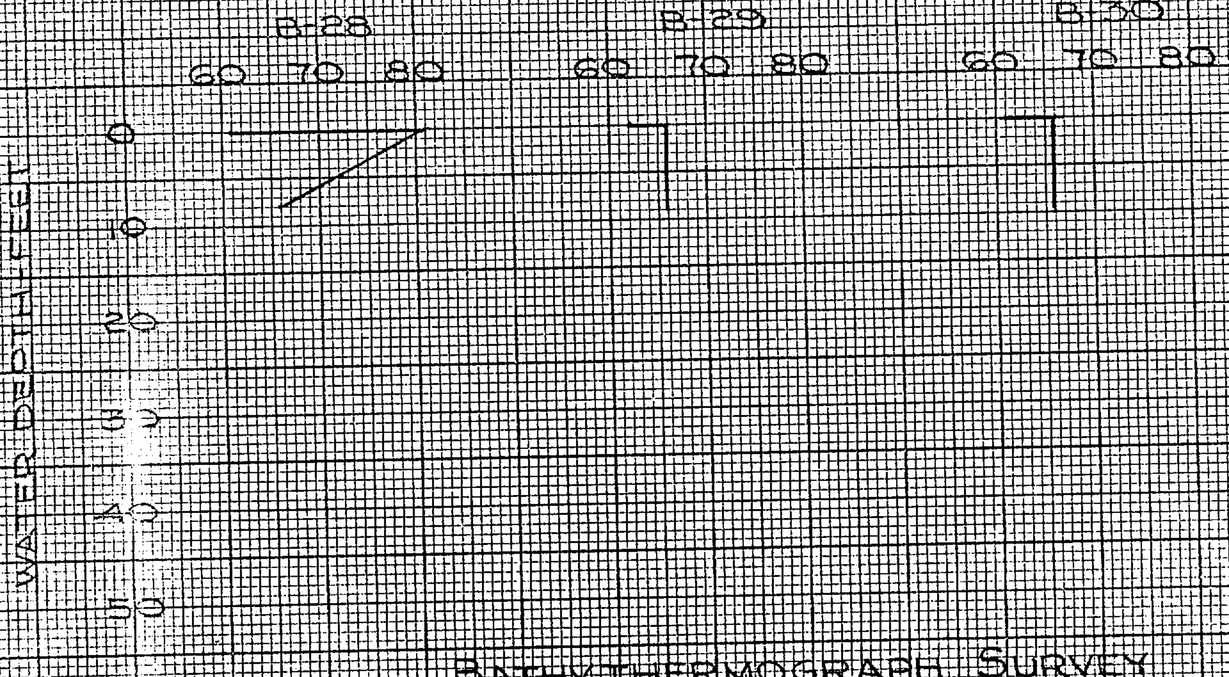
6/11/68 - 11:00 to 11:15 A.M.

INCOMING TIDE



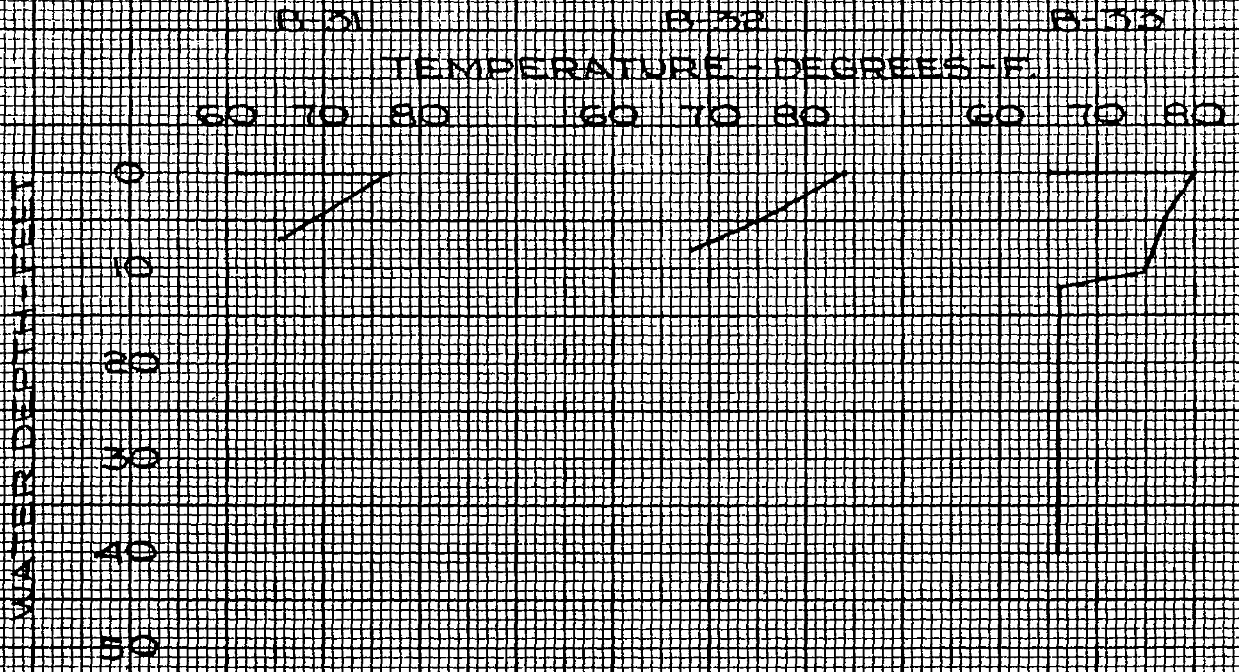
6/11/68 - 12:00 to 12:30 P.M.

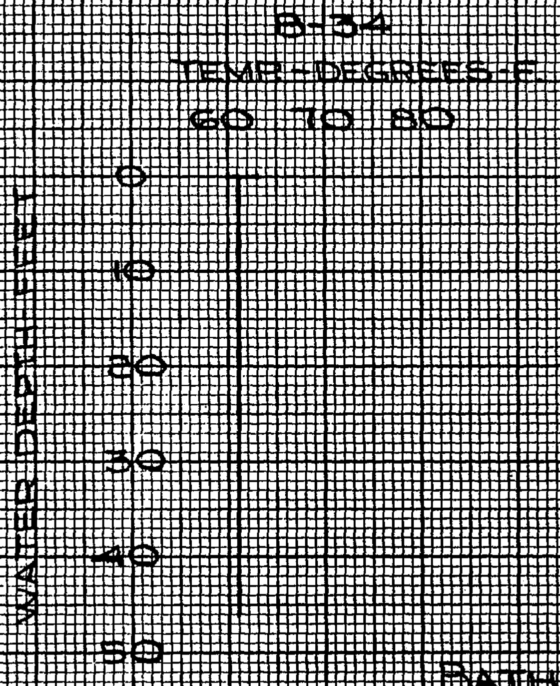
INCOMING TIDE



BATHYTHERMOGRAPH SURVEY
NEWBURGH, NEW YORK
by
WESTON GEOPHYSICAL ENGINEERS, INC

6/11/68 - 12:00 to 12:30 P.M.
INCOMING TIDE





BATHYTHERMOGRAPH SURVEY
NEWBURGH, NEW YORK
by
WESTON GEOPHYSICAL ENGINEERS, INC.