NOAA Technical Memorandum OMPA-15

DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

NEW YORK SLUDGE TRACKING EXPERIMENT

STAX-1

John R. Proni
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Ronald L. Sellers
Donald J. Walter

Boulder, Colorado
January 1982

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UNITED STATES
DEPARTMENT OF COMMERCE
Malcolm Baldrige,
Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
John V. Byrne,
Administrator

Office of Marine
Pollution Assessment
R.L. Swanson,
Director

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Abstract

Sewage sludge in the ocean has been detected using a modified 200 KHz acoustic echo sounder. The three-dimensional distribution of suspended material and its rate of diffusion have been determined after digital processing of data. Increased biological activity is apparently associated with the presence of sewage sludge. The detection of internal waves in 30 m of water is reported.

Introduction

The short-term fate of sewage sludge dumped in the ocean is largely unknown due to the lack of real-time tracking techniques. Chemical sampling suffers from the inherent time lag between the time the sample is taken and the time the analysis is complete, the lack of knowledge as to where in the sludge cloud the chemical sample was gathered or, in fact, whether the sample came from the sludge cloud and not the adjacent waters. Shipboard measurements with a light beam transmissometer, whether towed or lowered, provide measurements along a horizontal or vertical line and require extensive sampling of the sludge cloud to provide a reasonably complete three-dimensional concentration map. The time required for such extensive sampling is probably long compared to the interval in which significant changes take place in a sludge cloud. This report describes the first use of a modified 200 KHz acoustic echo sounder detecting sludge dumped into the ocean, monitoring the sewage cloud over a period of several hours.

Objective

Guidance from meetings with the Physical Oceanography Laboratory, the Marine Geology and Geophysics Laboratory, and the MESA New York Bight Office helped determine the following objectives for the Sludge Tracking

Acoustic Experiment (STAX-1):

1. Show that sewage sludge dumped in the ocean is detectable acoustically.
2. Show that the space-time evolution of a sewage sludge dump may be followed by acoustic profiling.
3. Make estimates of particle concentration throughout the detectable sewage waste cloud.
4. Show that real-time acoustic profiling is a feasible guide for water sampling in the sludge dump area.
5. Make estimates of the residence time of the sludge material in the water column.

Field Method

In September 1975, as part of NOAA's New York Bight Project, a three-day pilot sludge tracking experiment was conducted aboard the NOAA ship George B. Kelez in the New York Bight sewage sludge area. An 80-watt, 200 KHz acoustic echo sounder with the receiver modified to give 100 db maximum gain and a 1 kilowatt, 20 KHz Lodar echo sounder were operated continuously throughout the three-day period. The detected signal from each system was tape recorded in analog form for later digitization and computer analysis. Paper strip chart recorders provided real-time data output from both systems. The transducer for each system was mounted in a streamlined towbody and towed at 2 m depth on opposite sides of the ship. The 200 KHz system had a beamwidth of 20°, and the 20 KHz had a beamwidth of 12° X 18°. Occasional water samples were obtained by conventional hydro-cast within and outside the sludge cloud. Particle size analysis for all water samples within one hour of capture was provided by a Coulter counter mounted on a vibration isolation-table, and profiles with expendable bathythermographs (XBT) and a lowered conductivity-temperature depth sensor were obtained. The water column was well mixed down to 18 m, with a 4°C (19-15°C) thermocline to the bottom at 25 m.

The Environmental Protection Agency prohibited all sewage sludge dumping for a 48-hour period so that an acoustic background survey could be made and water samples taken within the sludge dump area. During the next 24-hours (1000 EDST, 22 September to 1000 EDST, 23 September) the dumping was limited to specific ships, and the actual dumping was directed by the Kelez. After 1000 EDST, 23 September, conventional dumping procedures were resumed.

The first dump in the controlled period (from the Owls Head Sewage Treatment Plant) was made from 1045 to 1111 EDST in a 3 km line from west to east in the sludge dump area. The Kelez traversed the length of the dump several times by making a zigzag track at alternating 45° angles to the tanker's straight line dump. This fresh line dump was clearly visible on the paper recorder output of both 200 KHz and 20 KHz systems (fig. 15) and produced detectable acoustic return above background level throughout the water column (23 m), implying that some portion of the sludge sank to the bottom in 20 minutes or less. After one hour the sludge was no longer directly detectable by the 20 KHz system, although it was indirectly detectable in that the system displayed the presence of many large point scatterers in the same regions where the 200 KHz system was still detecting sludge directly. It is assumed that the large point scatterers are fish or other types of highly mobile marine biota. Possible reasons for their presence will be discussed below. This line dump was tracked for an hour and forty minutes with good signal on the 200 KHz system when the Kelez departed for another dumping event. When this line dump was 4 hours old, it was traversed again and was still detectable.

At 1450 EDST in the controlled period, a sewage tanker dumped its entire contents (from Nassau County Bay Park Sewage Treatment Plant) at one location. Many transects of this dump were made over a period of two and a half hours. During this time the dump mass was observed to move slightly northward with the upper portion becoming displaced further to the north relative to the lower portion, indicating the presence of a current shear (winds were from 170° at 6 knots). As with the morning line dump, the 20 KHz system no longer gave detectable acoustic return from the sludge after approximately 1 hour, although the higher concentration of point scatterers, thought to be fish, was present during the entire tracking period.

Additional sludge dumps were tracked after dark on 23 September, but the background acoustic scattering throughout the water column was significantly increased, presumably due to nocturnal migration of unidentified biota from the bottom. This made detection and tracking of sludge for periods of greater than 2 hours impossible. The increased background scattering level was evident on the 200 KHz system in the form of continuous signal amplitude. The 20 KHz system showed the water column to have become densely populated with point scatterers of the same sort observed in the regions of sludge earlier in the day.

The nature of the objects responsible for the high concentration of point scatterers observed in the sludge cloud on the 20 KHz records is not known. Point scatterers observed were not concentrated at the dumpsite before introduction of sewage, but congregated rapidly, usually within 10 minutes after the dump. However, it seems reasonable to speculate that the point scatterers, because of their apparent high mobility and affinity for the nutrient-rich sewage cloud, are either marine biota or are vertically transported aggregates formed by flocculation of sewage particles when they are introduced into the water column. A continuous layer with a high concentration of point scatterers was also observed to "rise" from the bottom in an area to the west of the dumpsite soon after sunset. Such behavior of point scattering objects is reminiscent of the response of the deep scattering layer to the day-night light cycle.

The basic quantity measured in this experiment is the magnitude of the received acoustic signal at the face of the acoustic transducer. Using certain reasonable assumptions, which are stated below, estimates have been made of the acoustic scattering strength per unit volume. A fundamental assumption is that the acoustic scattering strength per unit volume is related (perhaps proportional) to particle concentration. This kind of assumption is often made in optical studies of particle concentration. In the present paper, it is assumed that the acoustic scattering strength per unit volume is an indicator, but at present a poorly defined one, of sewage particle concentration. Portions of the acoustic records from the 20 KHz and 200 KHz systems shown in figures 2 through 7 illustrate the clarity with which sewage sludge was detected. Figures 2, 3, and 4 are passes over the 1045 EDST line dump. Figures 5, 6, and 7 are passes over the 1450 EDST spot dump. Figure 1 is a map showing part of the ship track over the spot dump and indicating the sludge cloud boundaries.

Laboratory Methods

The Ocean Acoustics Laboratory has the capability of digitizing acoustic data (analog tape recording) on the PDP 11/40 computer system. Figure 8 is a computer plot of unprocessed acoustic return as a function of depth (bottom occurs at 23.5 m) in the line sewage dump. The strip chart record corresponding to this profile is shown in figure 3 at 1200 m distance (200 KHz system). Plots of scattering strength per unit volume as a function of time from the data recorded on magnetic tape were obtained from digitized portions of the 200 KHz data from the sludge event. Averages of successive ten-second time intervals yield profiles of acoustic return which are reasonably noise-free and represent a sampling interval of approximately 20 m along the ship's track. Since the acoustic beam is essentially conical, the intensity of the transmitted pulse and subsequent echo decreases as the square of the depth of the acoustic reflector. Therefore, it is necessary to multiply the ten-second averaged profiles by the square of the depth to give profiles of actual scattering strength per unit volume as a function of depth. To estimate how much scattering was due to the sludge alone, the profile of averaged scattering strength per unit volume just outside the sludge dump was subtracted from each averaged profile obtained along the ship's track within the dump region. For each transect of a dump region, the value of net scattering strength per unit volume due to sludge can be estimated at a prescribed depth plotted as a function of distance through the sludge clouds.

The scattering strength at 14 m depth for 3 crossings of the morning line dump calculated as described above is shown in figure 16. The progressive displacement of the scattering curves in figure 16 along the abscissa represents the southerly drift of the sludge cloud during the tracking period. The result of the profile in figure 8, after being processed, is shown in figure 9 (the large signal excursion at the bottom of these profiles is an artifact of the processing and should be disregarded). The profile in figure 9 is a relative measure of particle concentration increases near the bottom whereas the signal manifested on the strip chart and in figure 8 decreased in intensity toward the bottom.

A sequence of profiles, processed as above, has been made for each of three passes through the same portion of the 1045 EDST line dump. The value of each of these profiles was noted at two particular depths and plotted as a function of horizontal position on the transect through the sludge cloud. The results of the transects, spaced approximately 30 minutes apart, are shown in figures 10, 11, and 12. In these figures the distance scales serve only to show the horizontal dependence of particle concentration and do not relate to each other because the entire sludge cloud was moving southward and was found at a different location on each transect. Appendix E is a collection of these profiles. A negative particle concentration implies only that the signal at that position and depth deviated below the average background level outside the cloud.* It is encouraging to note that the ratio of the peak concentrations, figures 10 to 11, and figures 11 to 12, are nearly the same as would be expected for equal time intervals along a diffusion process.

In addition, the time dependence of the width of the sludge cloud is not inconsistent with diffusion rates of dye streaks in the ocean as discussed by Bowden et al. (1974).

It should be mentioned that three observations, believed to be new, were made. The first is that the 20 KHz system shows biological activity, probably feeding, increased rapidly in the region of the sewage sludge cloud immediately after the dump. This activity persisted until the sludge had become very dilute. The second, shown in figure 13, is an internal wave packet seen on the 20 KHz system at 1200 m "distance" and 20 m depth. Apparently internal waves propagate into quite shallow water from the outer shelf or are generated nearshore by some mechanism. The third, shown in figure 14 (20 KHz system), is the occurrence at sunset

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*A particle concentration of zero (zero difference from background) corresponds to 0.7 milligrams/liter suspended material. Peak concentration in figures 10 and 11 are a few milligrams/liter. Water sampling was performed only once in the sludge due to fear of health hazard without specialized expertise.

of a phenomenon similar to the rise of the well-known acoustic scattering layer. As seen in figure 14, the water column fills with fish (or other type of biota) rising into the water column from the shelf bottom.

Summary

Sewage sludge dumped in the ocean is acoustically detectable for several hours using commercially available equipment with a moderate amount of modification. The signal-to-noise ratio is higher during daylight, presumably due to the lower level of biological activity in the water column. The space-time evolution of a sludge dump can be followed by making regular traverses of the dump area, and the relative three-dimensional distribution of suspended material can be determined with digital processing. It is clear that chemical sampling for research or monitoring purposes could be accurately guided in real-time using acoustic tracking, because the sludge boundaries are easily discernible from the qualitative paper strip chart record alone. Estimates of the local horizontal diffusivity representing mixing and diffusive processes less than 100 m in scale may also be made.

Acknowledgments

The valuable assistance of the following persons is hereby acknowledged: Mr. Peter Anderson, EPA Region II, who made possible the controlled dumping; Capt. E.R. Hanson, Supervisor of Marine Operations, New York Department of Water Resources; Mr. E.F. Albers, Modern Transport Company; Mr. Peter Frank, General Marine Transport Company, for the participation of their dumping vessels in this experiment; Dr. Donald Hansen, Cdr. Lawrence Swanson, Mr. Hal Stanford, NOAA, who provided substantial discussions on experiment design and Ms. Deborah Revette for the timely software required for data processing.

Reference

Bowden, K.F., D.P. Kravel, and R.E. Lewis, 1974. In Advances in Geophysics, H.E. Landsberg and J. van Mieghem (Eds.), Academic Press, New York, Vol. 18-A, p. 319.

FIGURE CAPTIONS

Figure 1 Ship Track over the 1450 EDST dump with sludge cloud boundaries indicated.

Figure 2 20 KHz and 200 KHz acoustic echographs from passes made from 1100 to 1120 EDST over the 1045 EDST line dump.

Figure 3 Same as figure 2, but for passes made from 1130 EDST to 1150 EDST.

Figure 4 Same as figure 2, but for passes made from 1140 EDST to 1200 EDST.

Figure 5 20 KHz and 200 KHz acoustic echographs from passes made from 1500 EDST to 1520 EDST over the 1450 EDST "spot" dump.

Figure 6 Same as figure 5, but for passes made from 1535 EDST to 1555 EDST.

Figure 7 Same as figure 6, but for passes made from 1625 EDST to 1645 EDST.

Figure 8 A computer plot of unprocessed acoustic return as a function of depth in the 1045 EDST sewage line dump. Bottom occurs at 23.5 m.

Figure 9 Computer plot of data shown in figure 8 after processing.

Figure 10 Graph showing particle concentration (processed acoustic return) as a function of horizontal position for the 1108 EDST pass in the 1045 EDST line dump.

Figure 11 Same as figure 10, but for the 1138 EDST pass.

Figure 12 Same as figure 11, but for the 1212 EDST pass.

Figure 13 An internal wave packet as seen on the 20 KHz acoustic echograph circa 1200 m distance.

Figure 14 The evening rise of the biological scattering layer as seen on the 20 KHz acoustic system.

Figure 15 A comparison of 20 KHz and 200 KHz system responses to the 1045 EDST line dump, during passes at 1108 EDST, 1138 EDST, and 1212 EDST, respectively.

Figure 16 Data from figures 10, 11, and 12, projected along a north-south line to show both dispersion and drift of the 1045 EDST line dump.

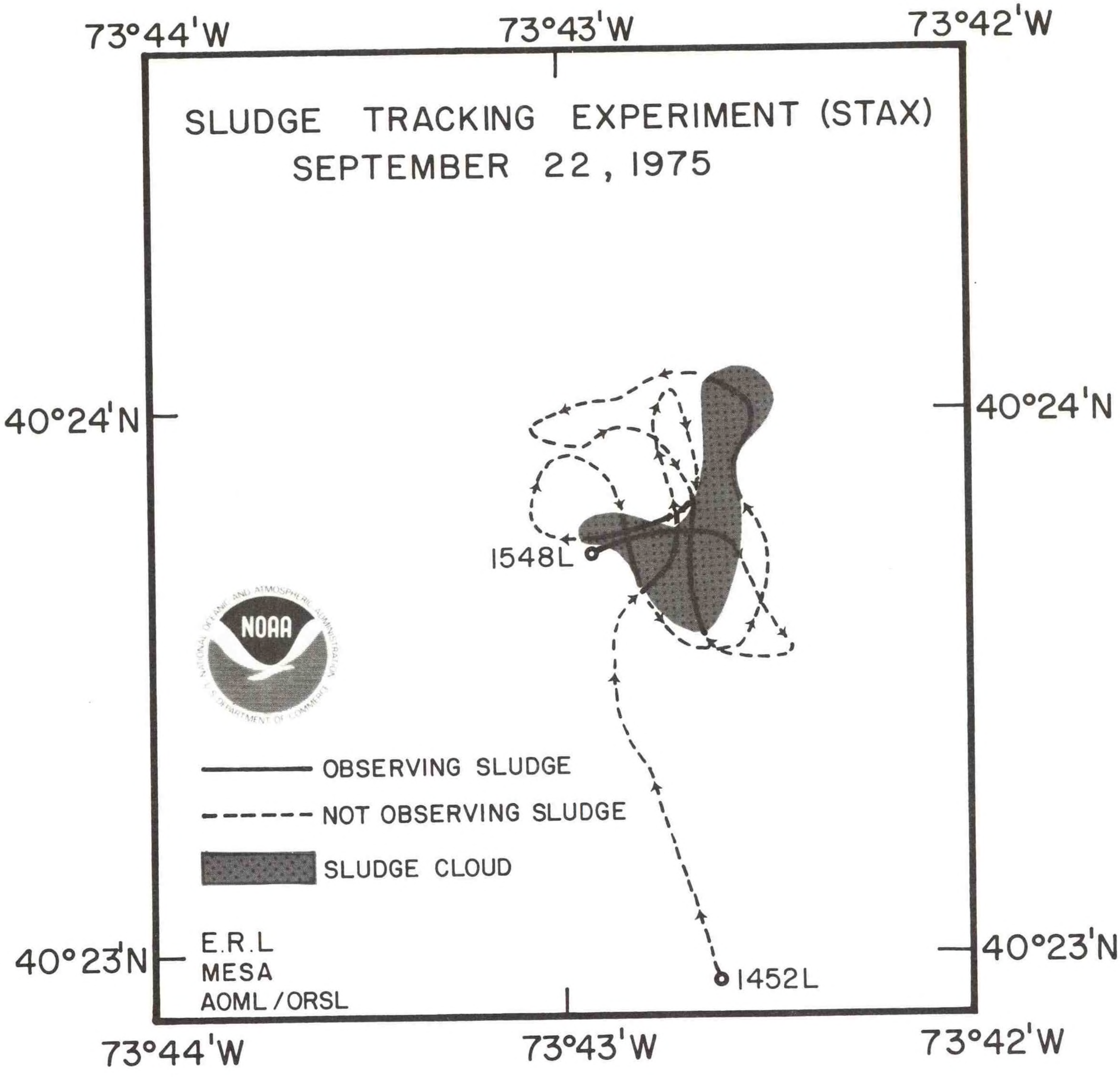


Figure 1. Ship Track over the 1450 EDST dump with sludge cloud boundaries indicated.

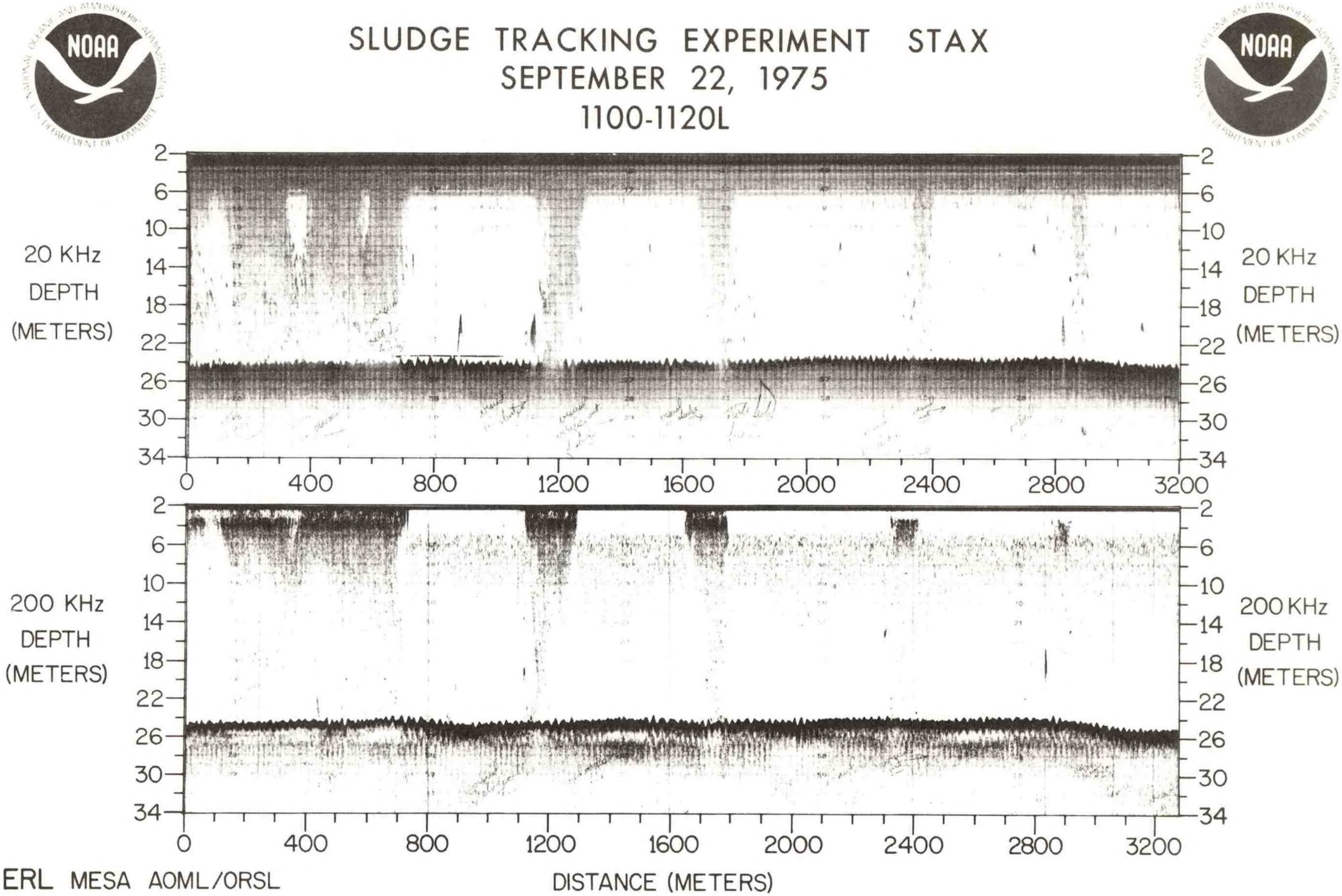


Figure 2. 20 KHz and 200 KHz acoustic echographs from passes made from 1100 to 1120 EDST over the 1045 EDST line dump.

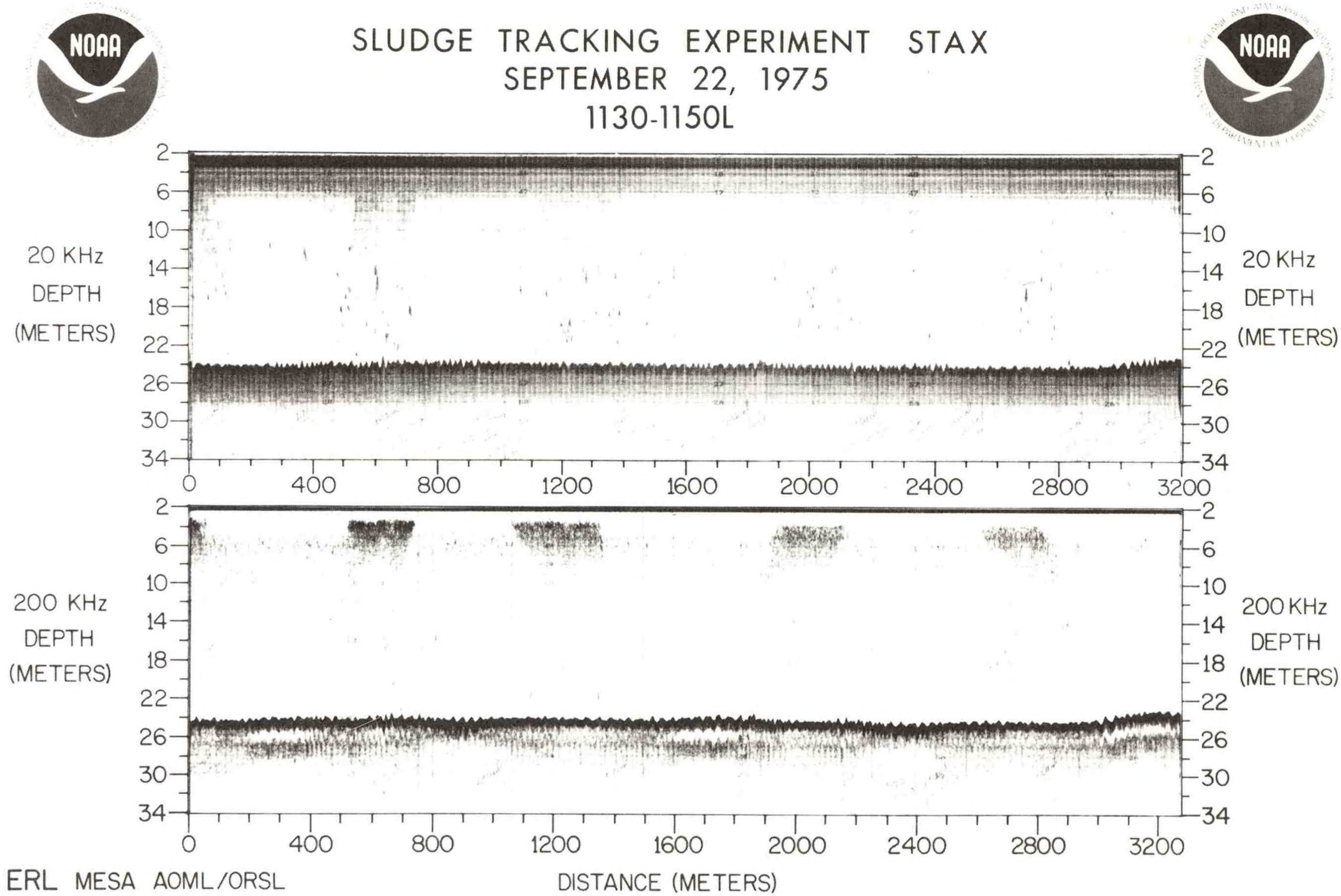


Figure 3. 20 KHz and 200 KHz acoustic echographs from passes made from 1130 to 1150 EDST line dump.

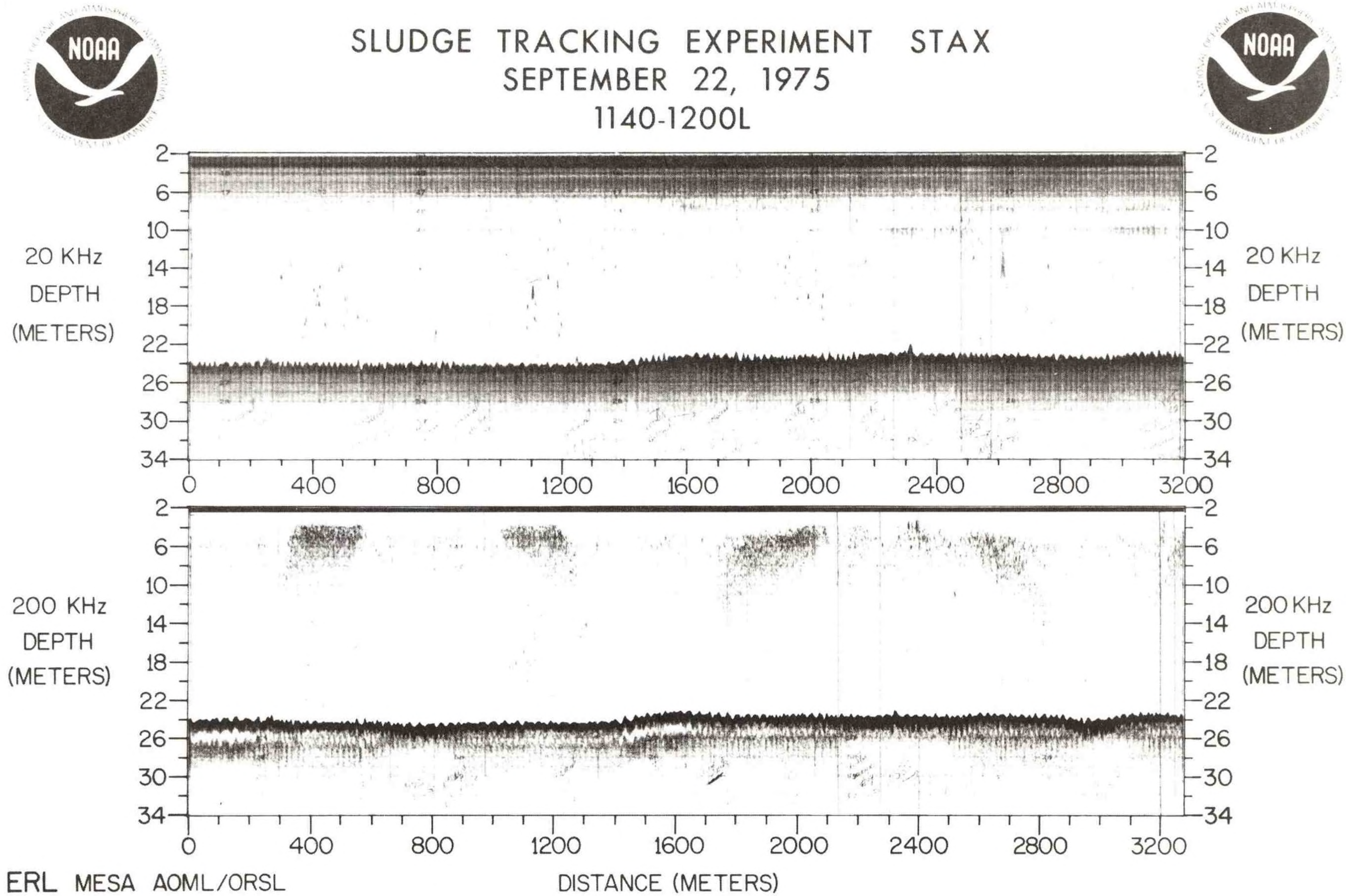


Figure 4. 20 KHz and 200 KHz acoustic echographs from passes made from 1140 to 1200 EDST line dump.

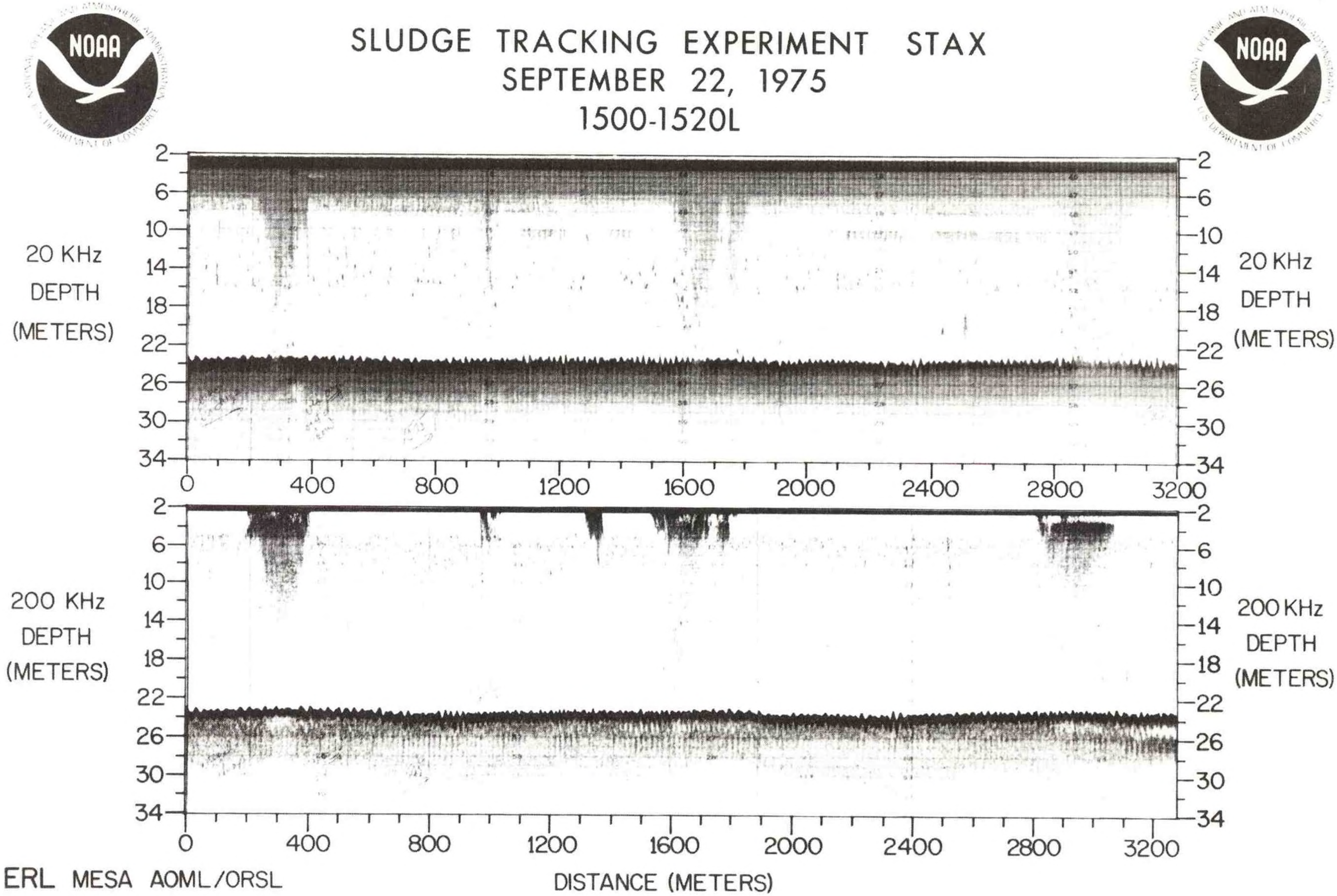


Figure 5. 20 KHz and 200 KHz acoustic echographs from passes made from 1500 to 1520 EDST over the 1450 EDST "spot" dump.

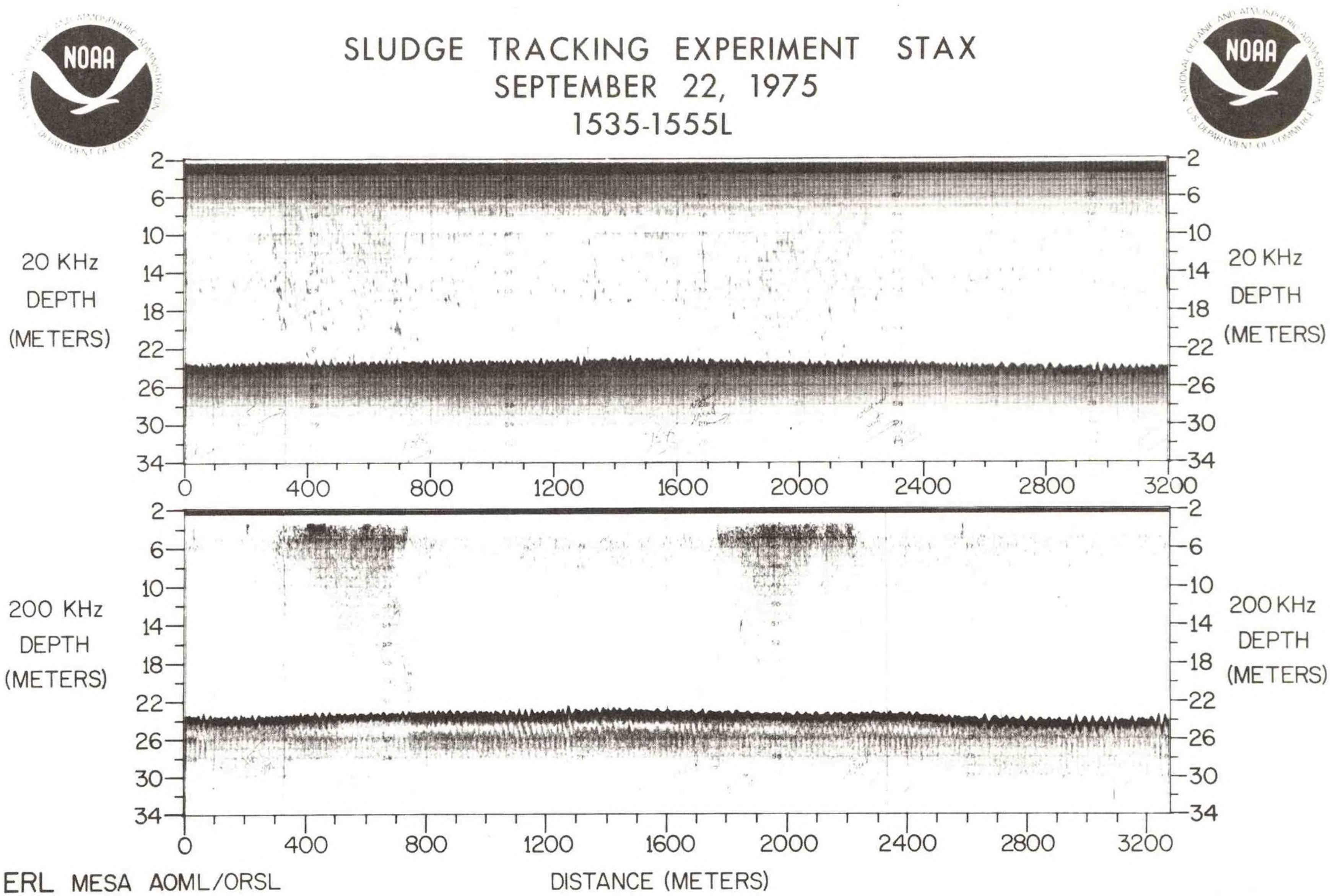


Figure 6. 20 KHz and 200 KHz acoustic echographs from passes made from 1535 to 1555 EDST over the 1450 EDST "spot" dump.

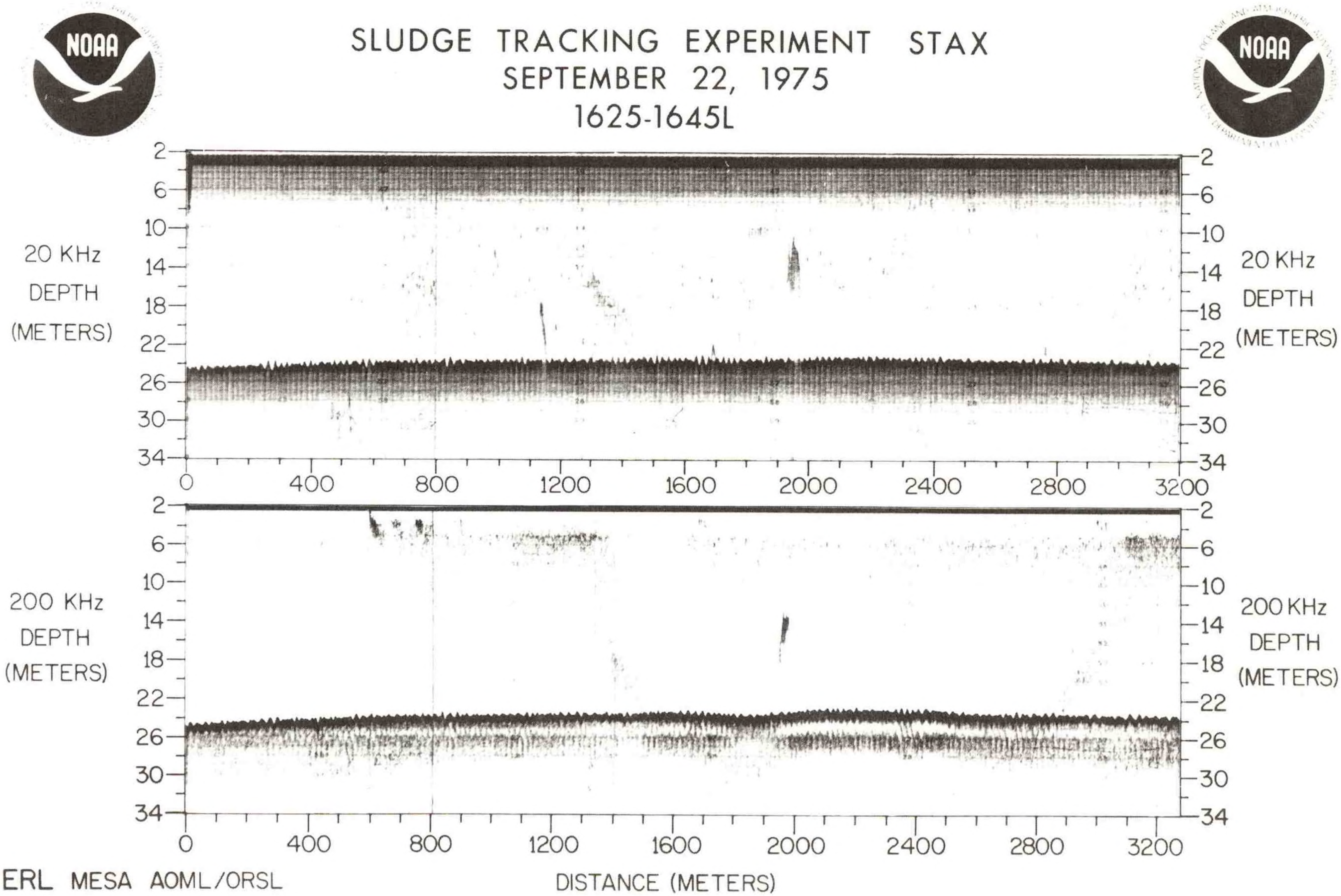


Figure 7. 20 KHz and 200 KHz acoustic echographs from passes made from 1625 to 1645 EDST over the 1450 EDST "spot" dump.

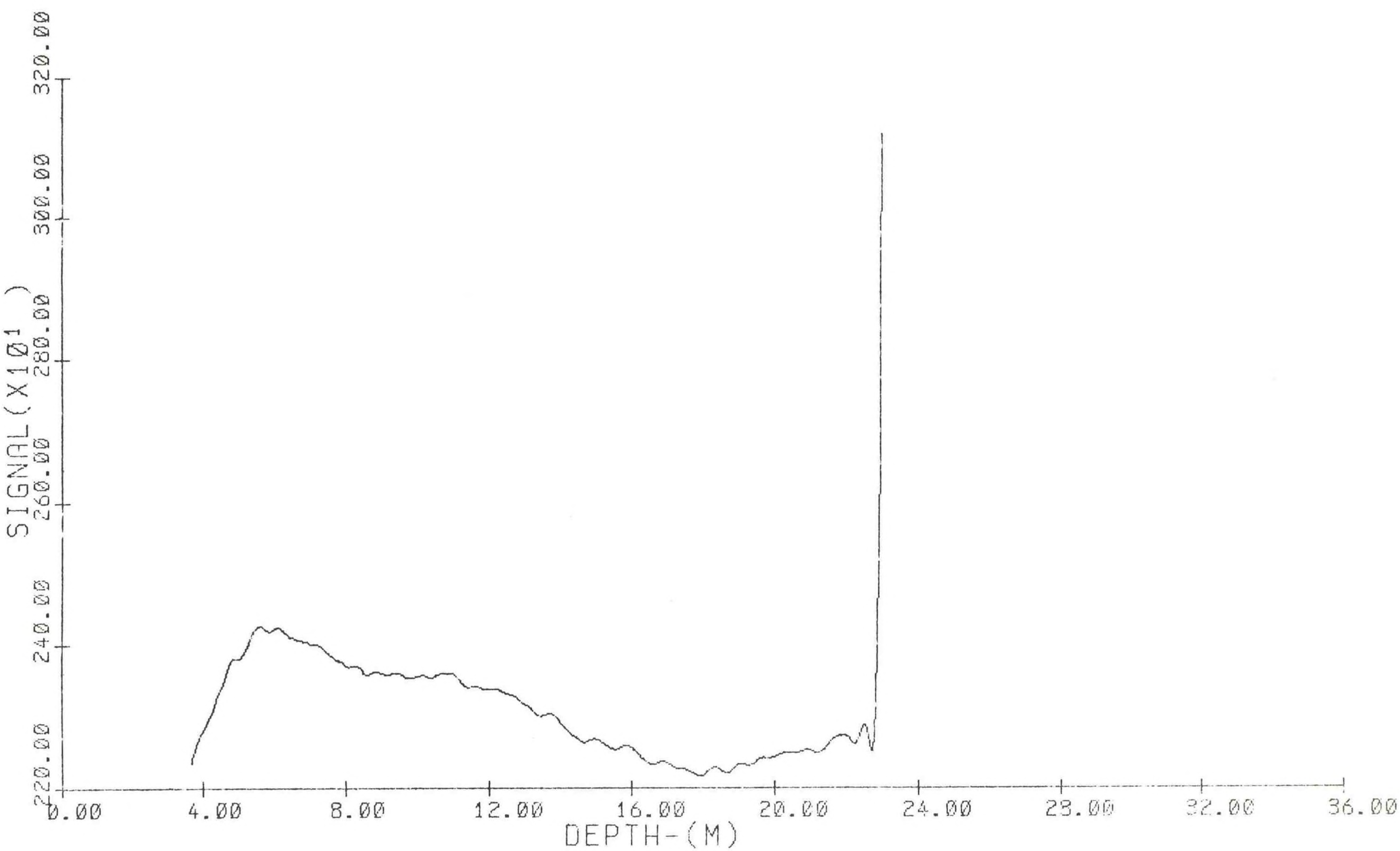


Figure 8. A computer plot of unprocessed acoustic return as a function of depth in the 1045 EDST sewage line dump. Bottom occurs at 23.5 m.

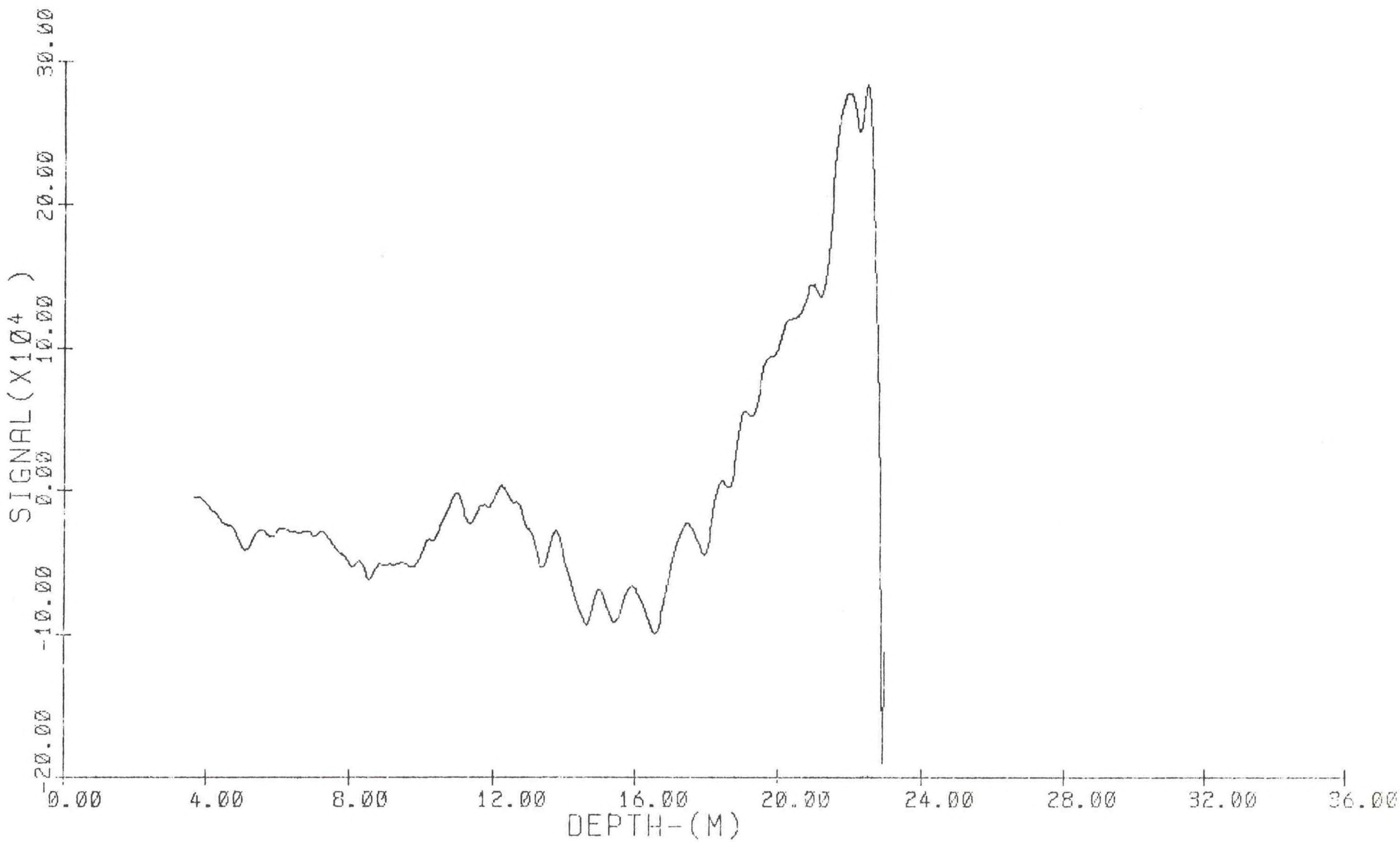


Figure 9. Computer plot of data shown in figure 8 after processing.

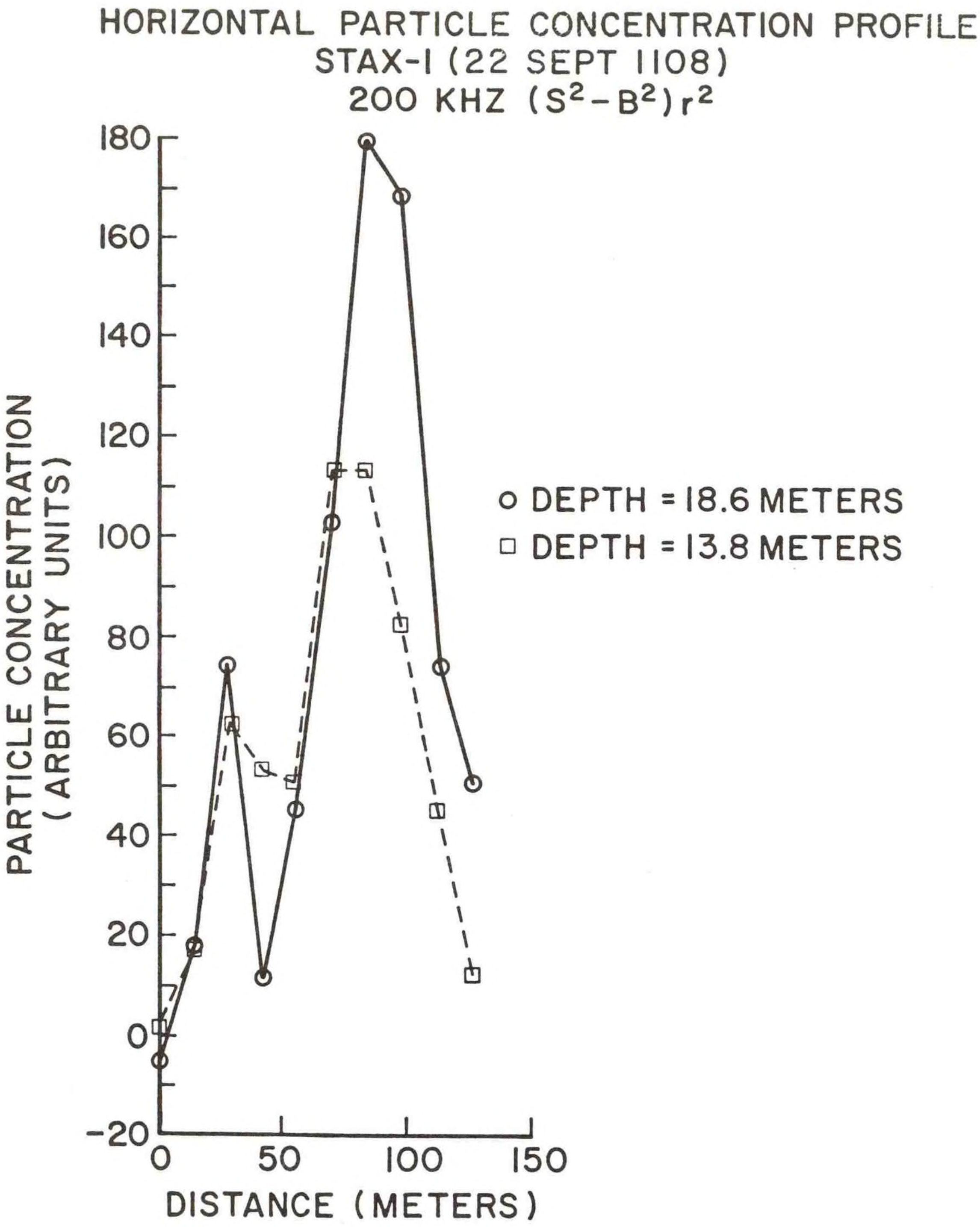


Figure 10. Graph showing particle concentration (processed acoustic return) as a function of horizontal position for the 1108 EDST pass in the 1045 EDST line dump.

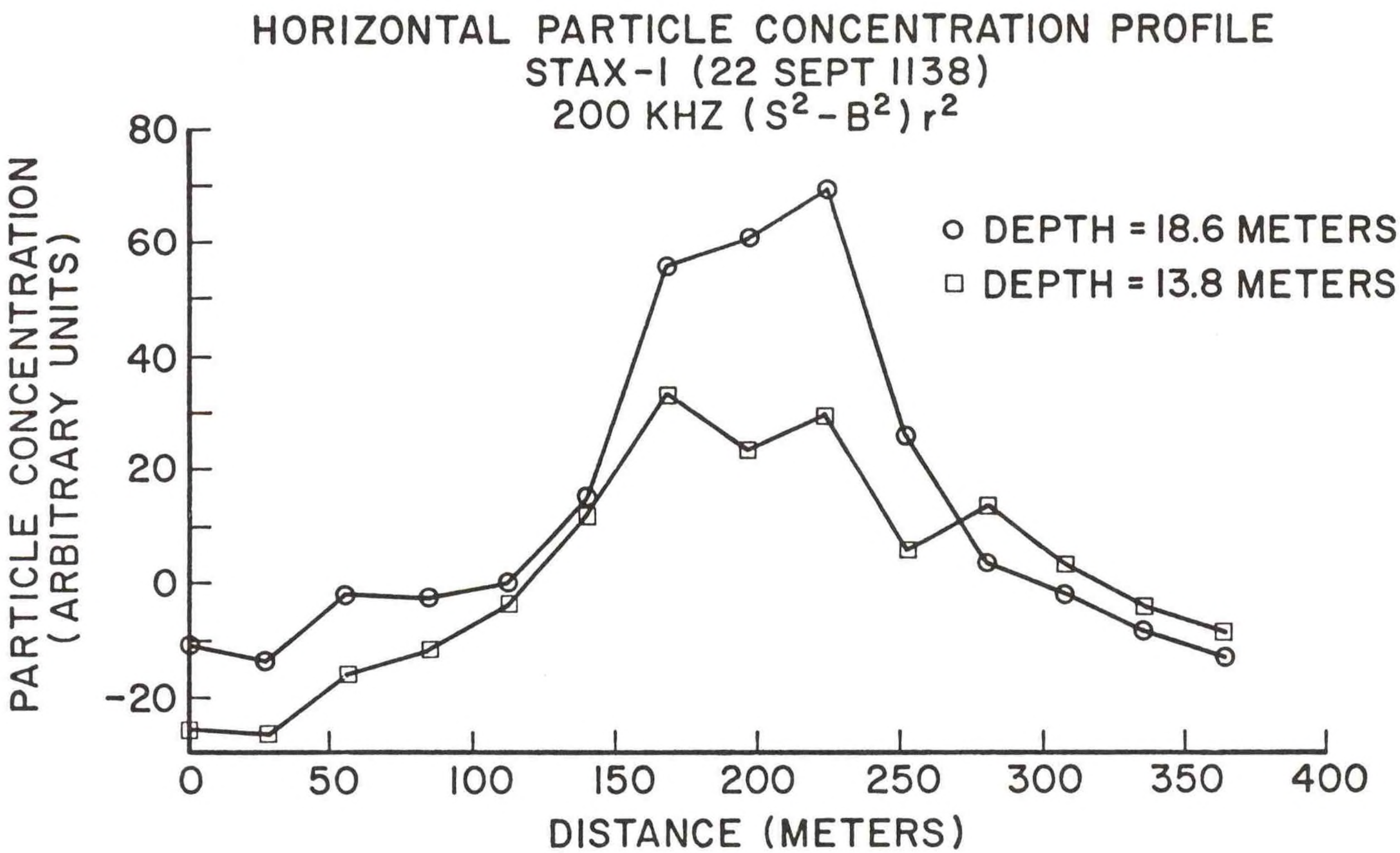


Figure 11. Graph showing particle concentration (processed acoustic return) as a function of horizontal position for the 1138 EDST pass in the 1045 EDST line dump.

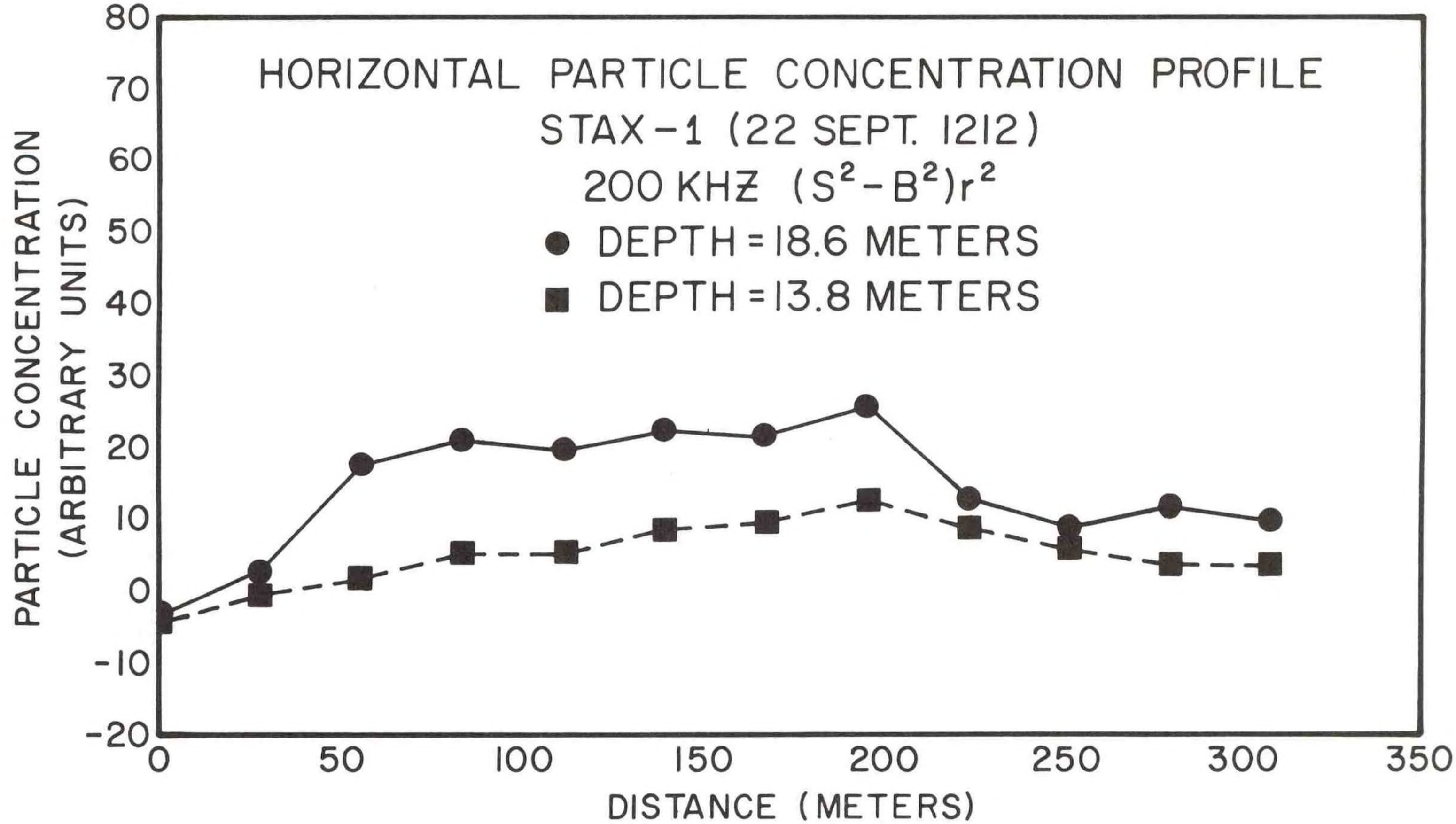


Figure 12. Graph showing particle concentration (processed acoustic return) as a function of horizontal position for the 1212 EDST pass in the 1045 EDST line dump.

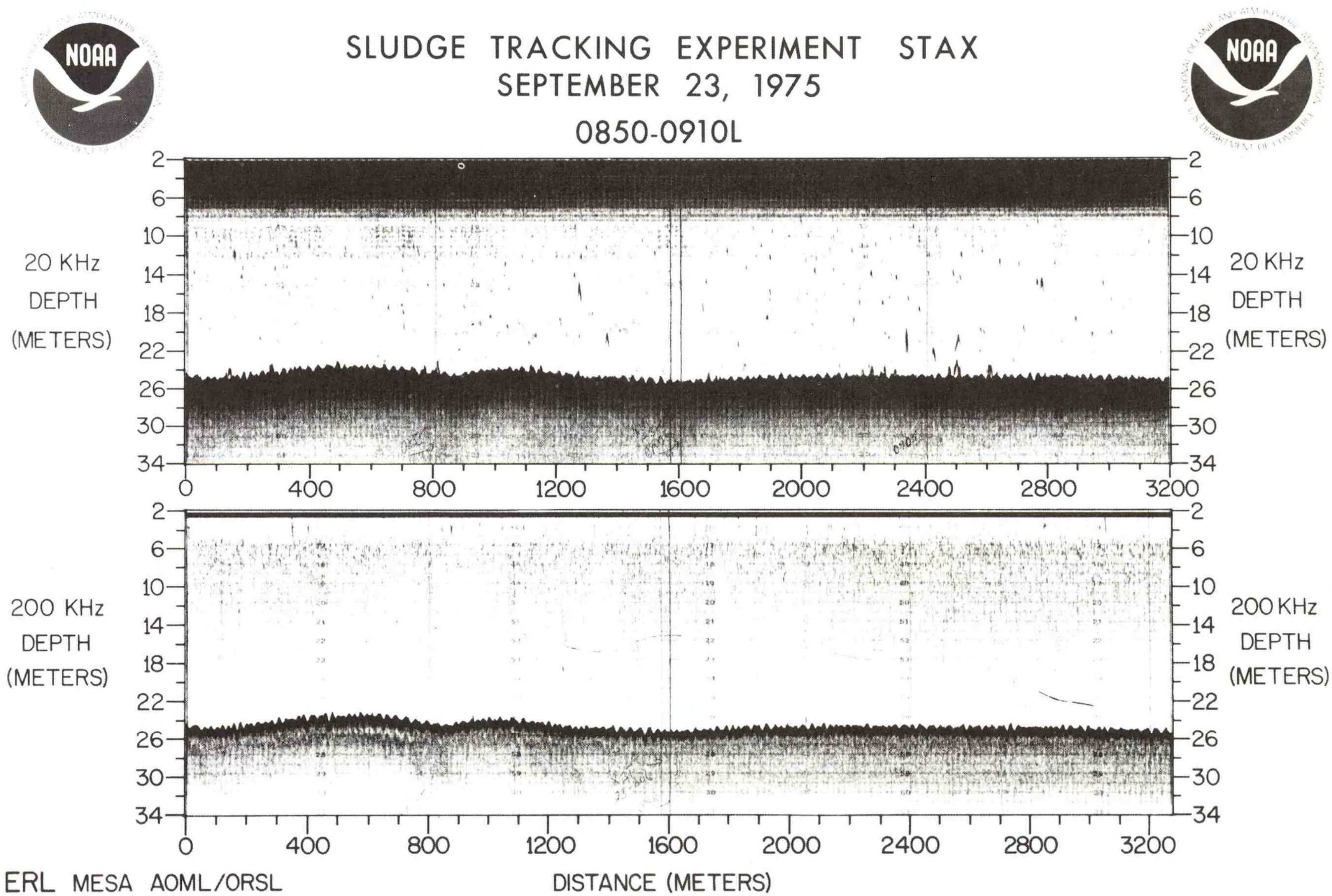


Figure 13. An internal wave packet as seen on the 20 KHz acoustic echograph circa 1200 m distance.

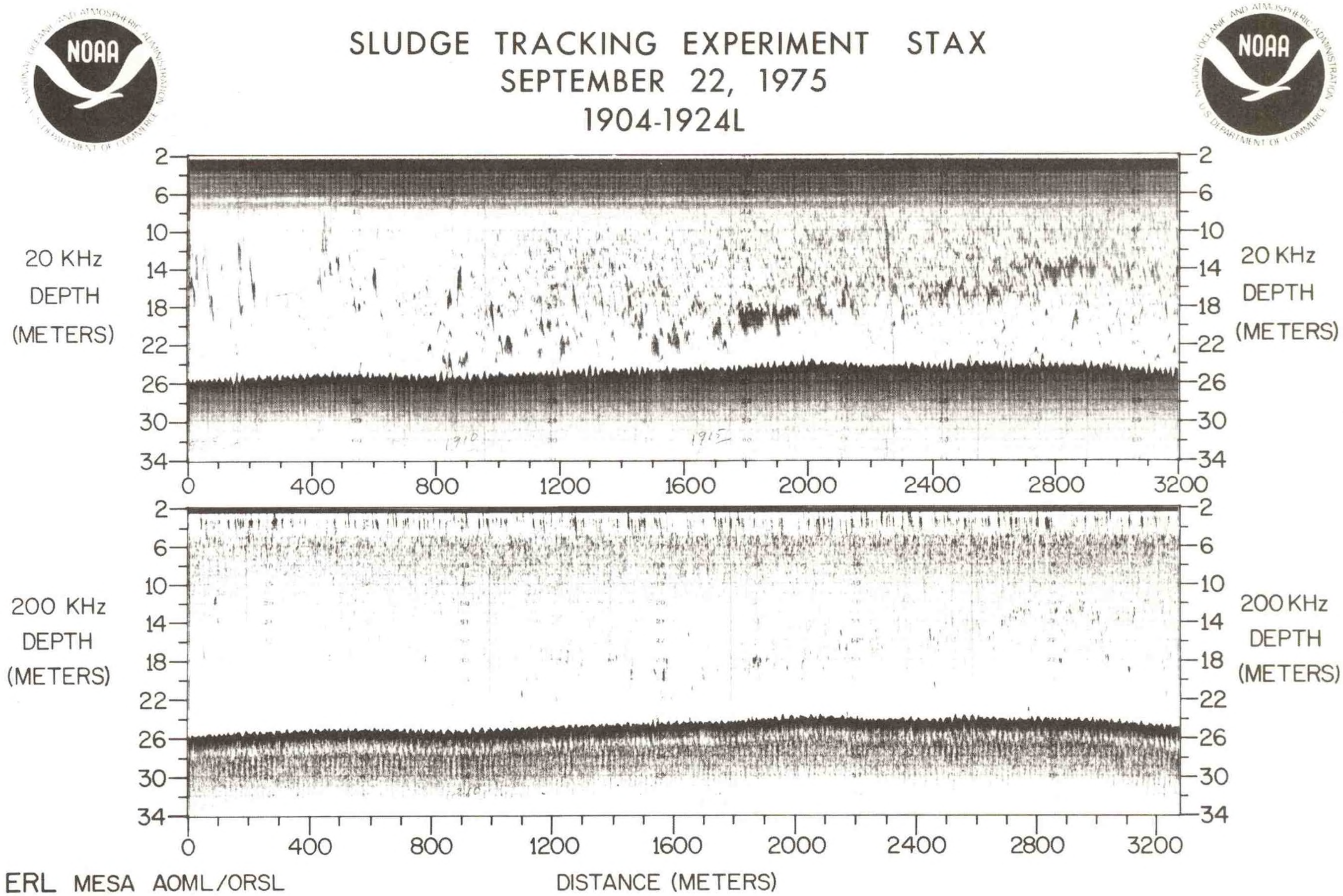


Figure 14. The evening rise of the biological scattering layer as seen on the 20 KHz acoustic system.

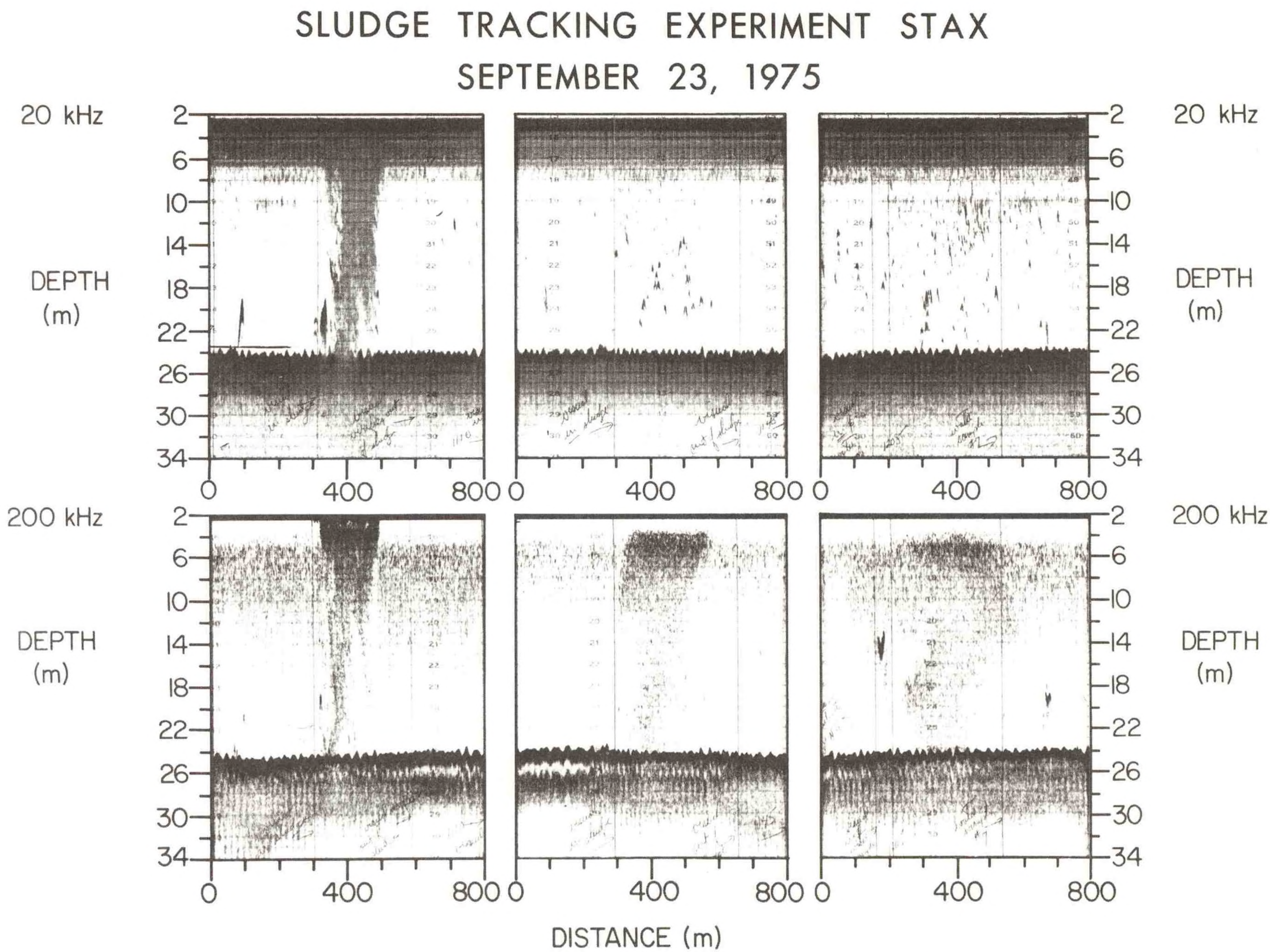


Figure 15. A comparison of 20 KHz and 200 KHz system responses to the 1045 EDST line dump, during passes at 1108, 1138, and 1212 EDST, respectively.

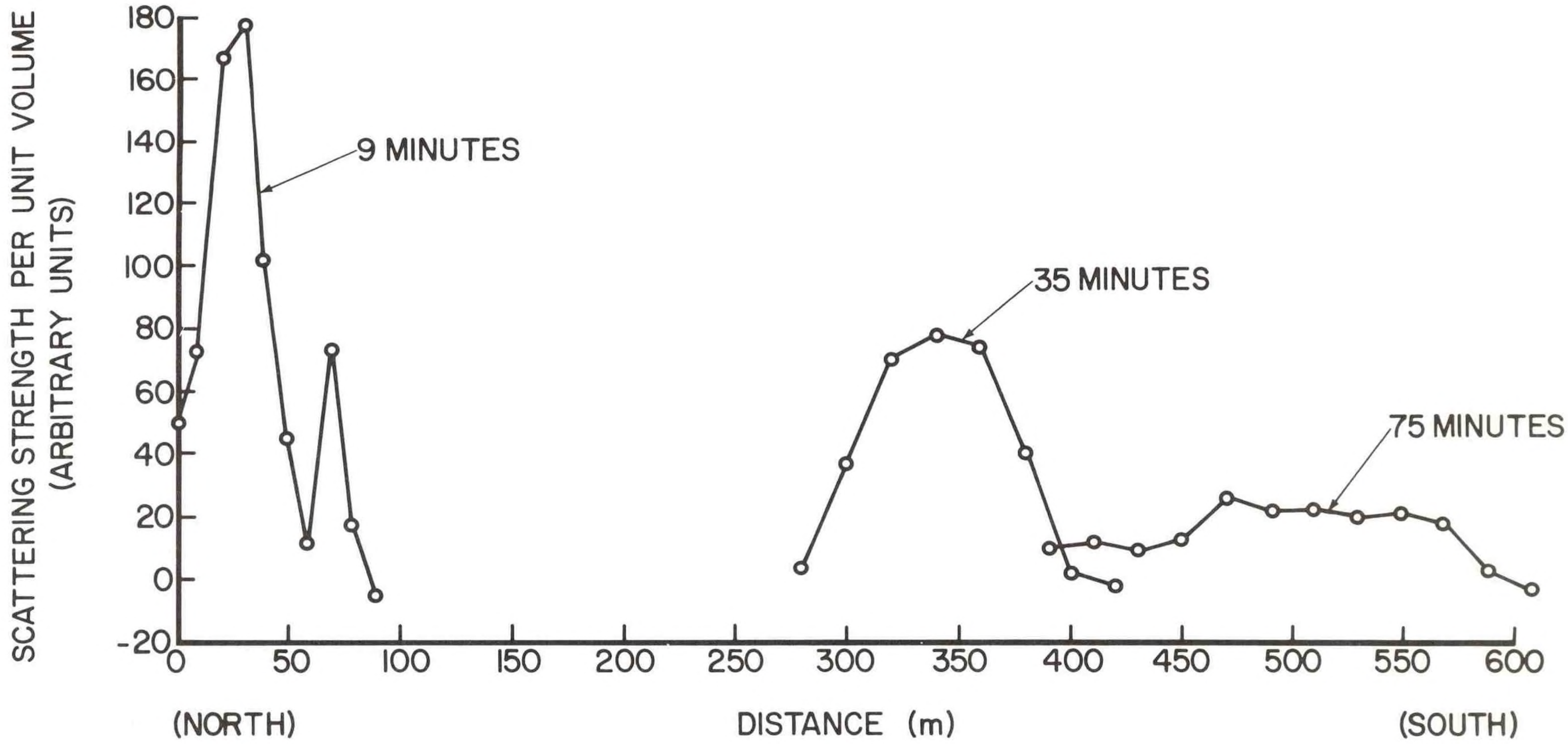
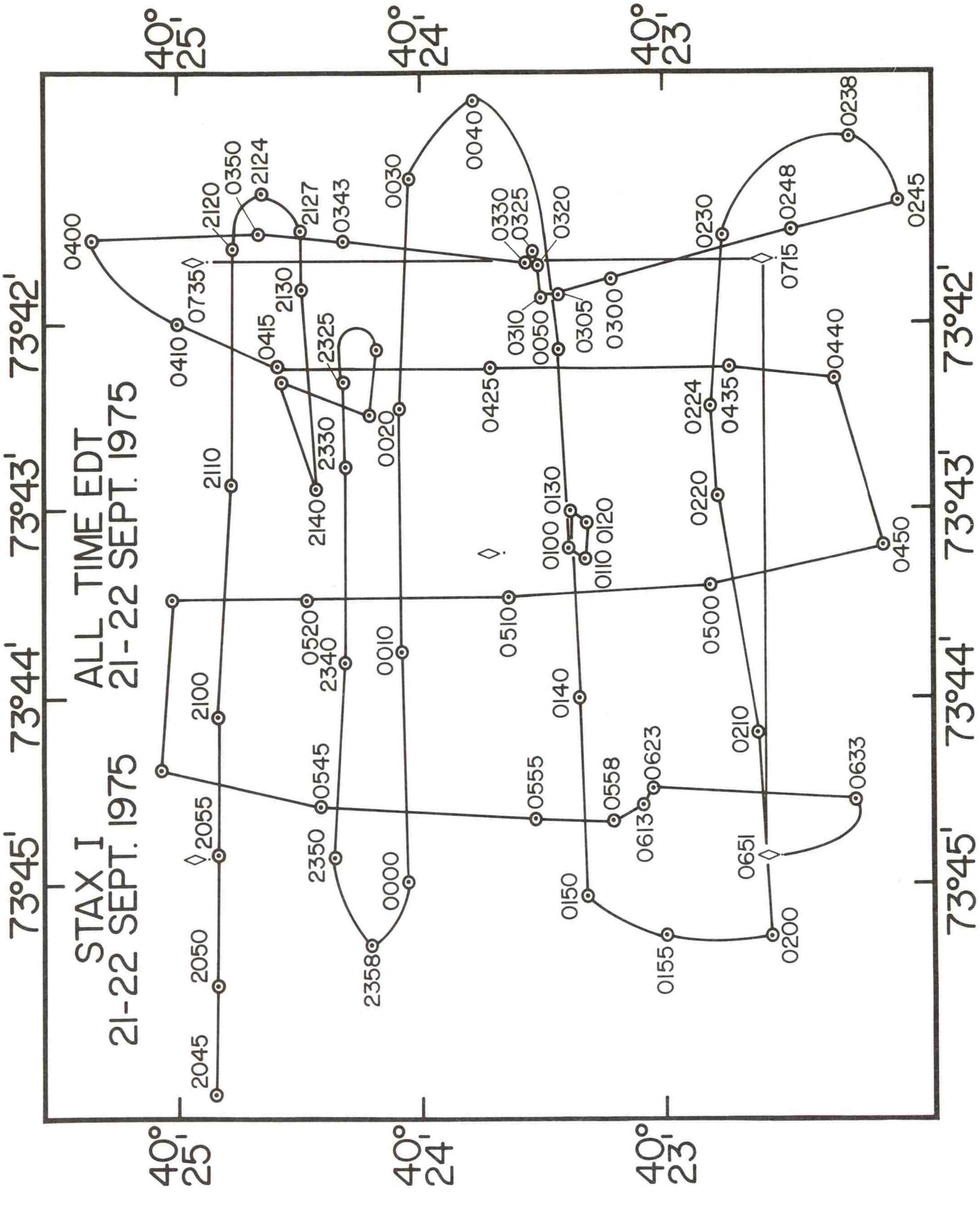


Figure 16. Data from figures 10, 11, and 12, projected along a north-south line to show both dispersion and drift of the 1045 EDST line dump.

Appendix A

SHIP TRACK


STAX I
21-22 SEPT. 1975
ALL TIME EDT
21-22 SEPT. 1975
73°45'
73°44'
73°43'
73°42'
40° 25'
40° 24'
40° 23'
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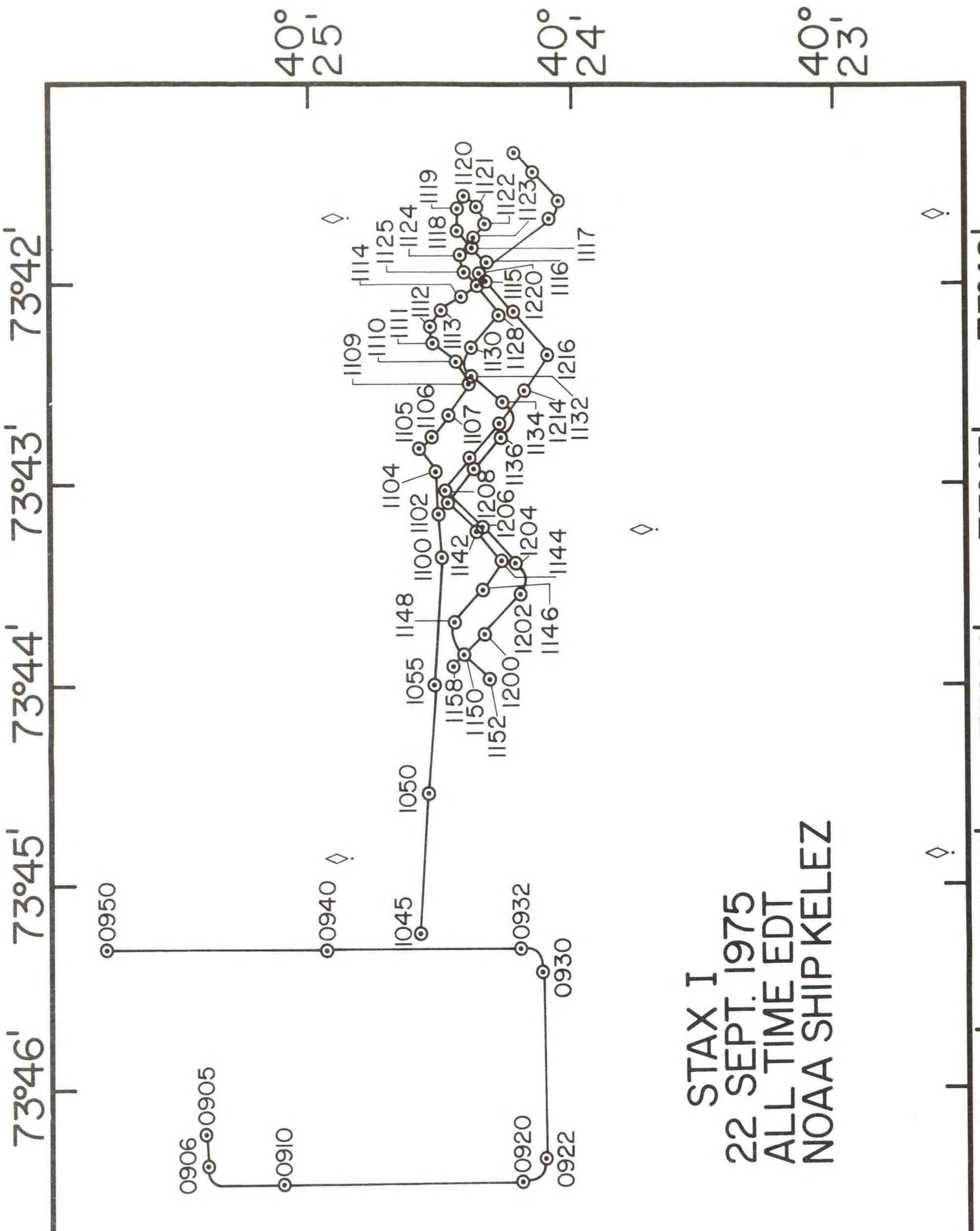
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22 SEPT. 1975
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NOAA SHIP KELEZ
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73°43'
73°42'
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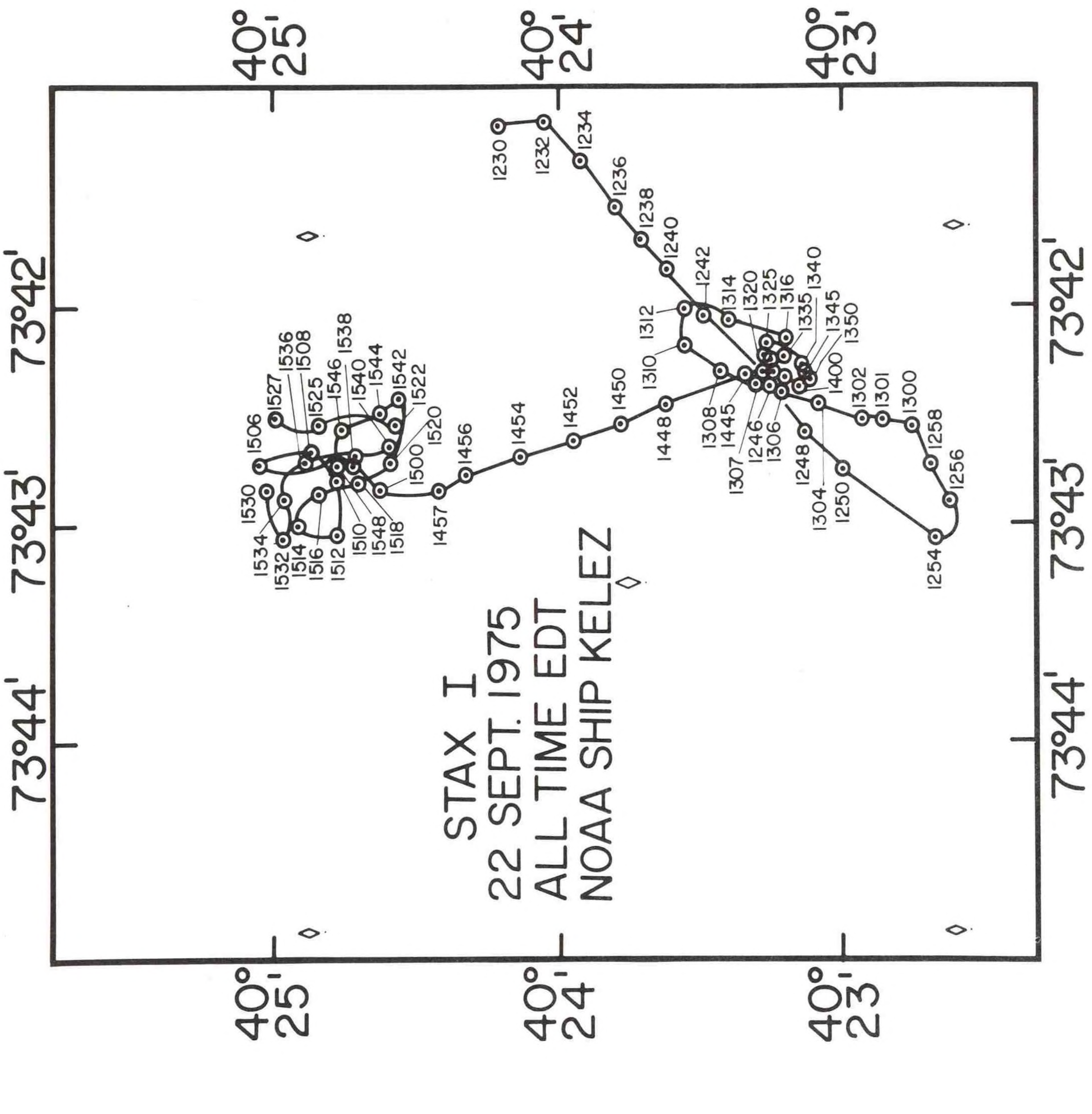
40° 24'
40° 23'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ALL TIME EDT
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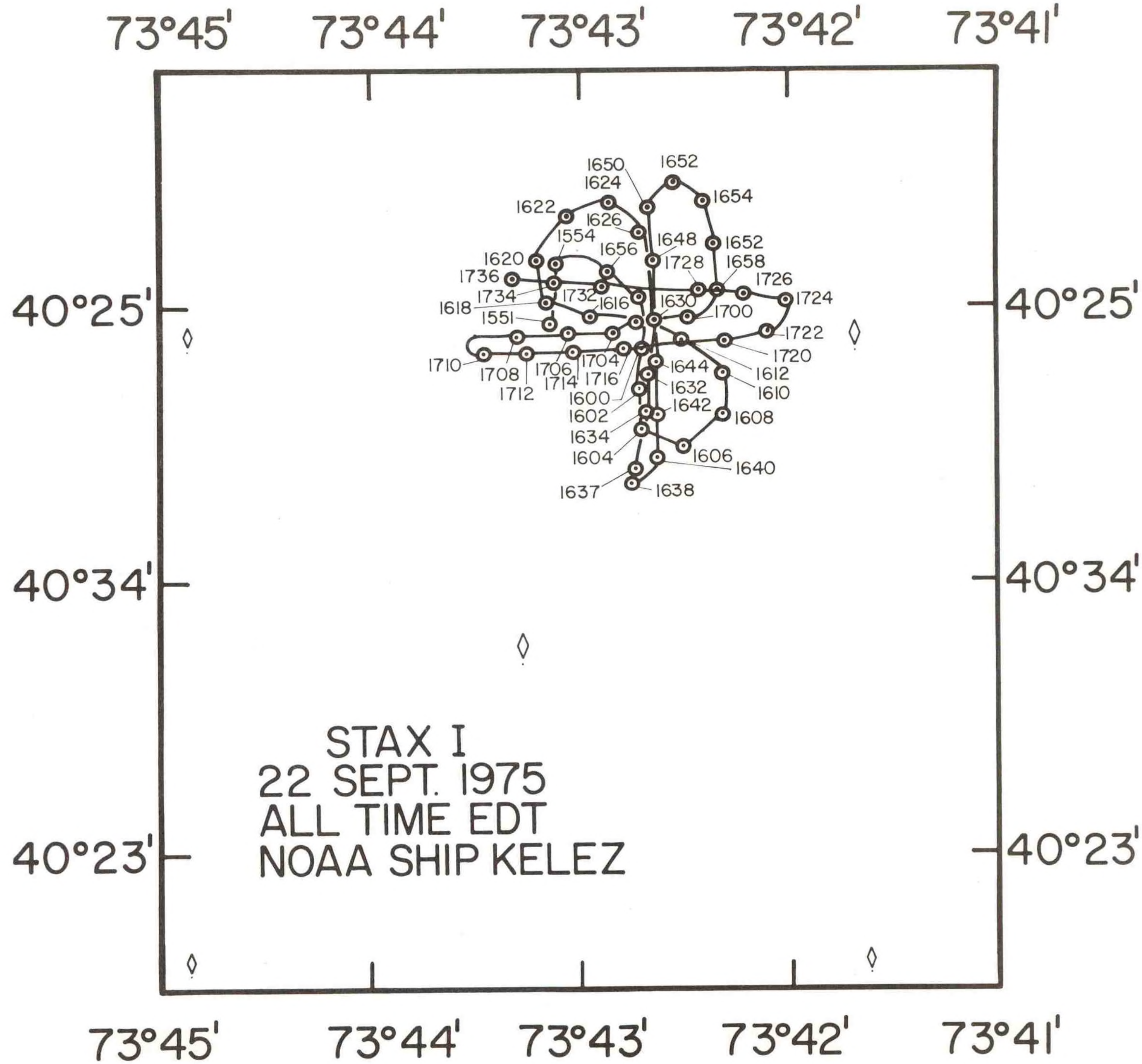
40° 23'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ALL TIME EDT
NOAA SHIP KELEZ
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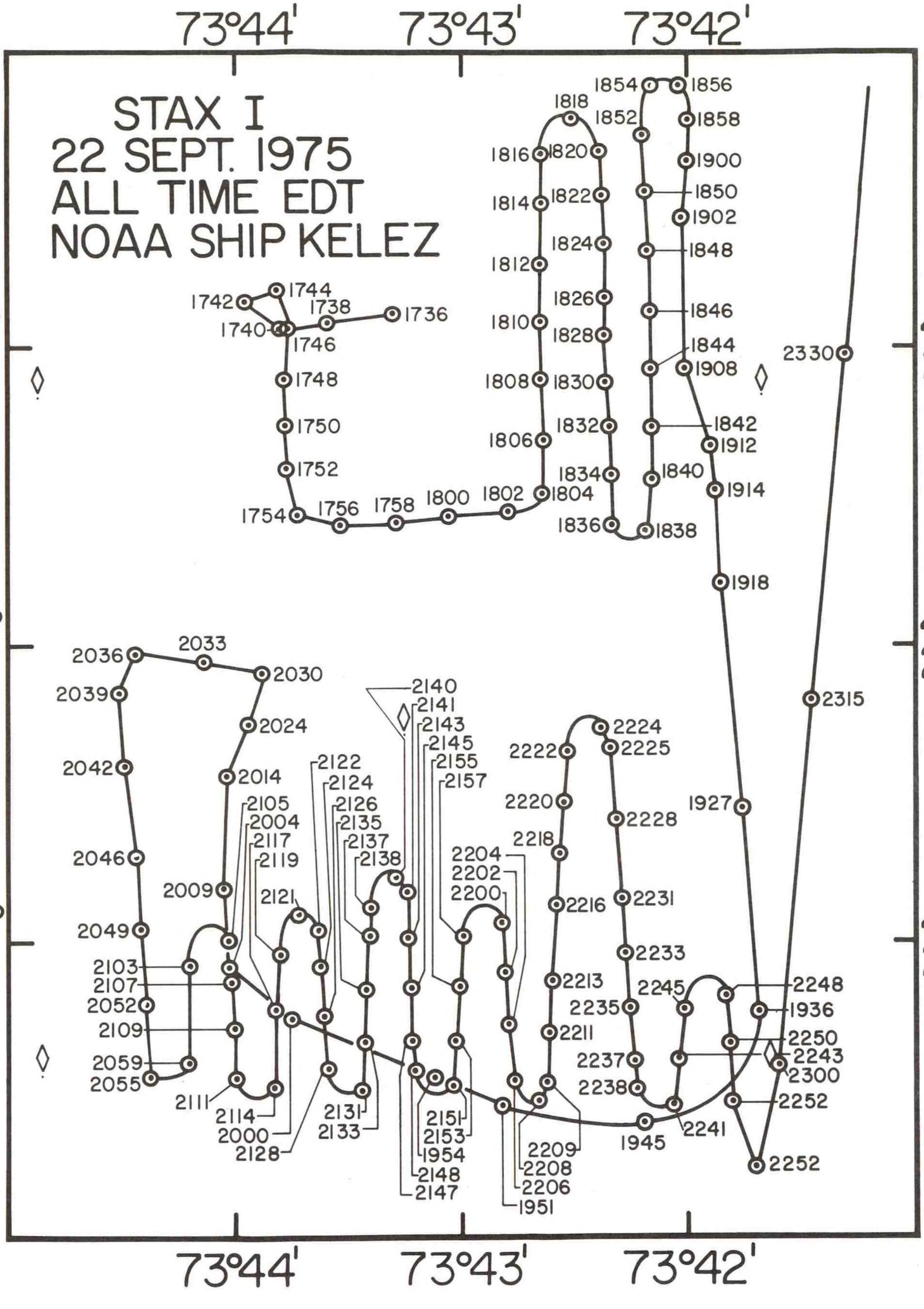
STAX I
22 SEPT. 1975
ALL TIME EDT
NOAA SHIP KELEZ
73°44'
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40° 23'
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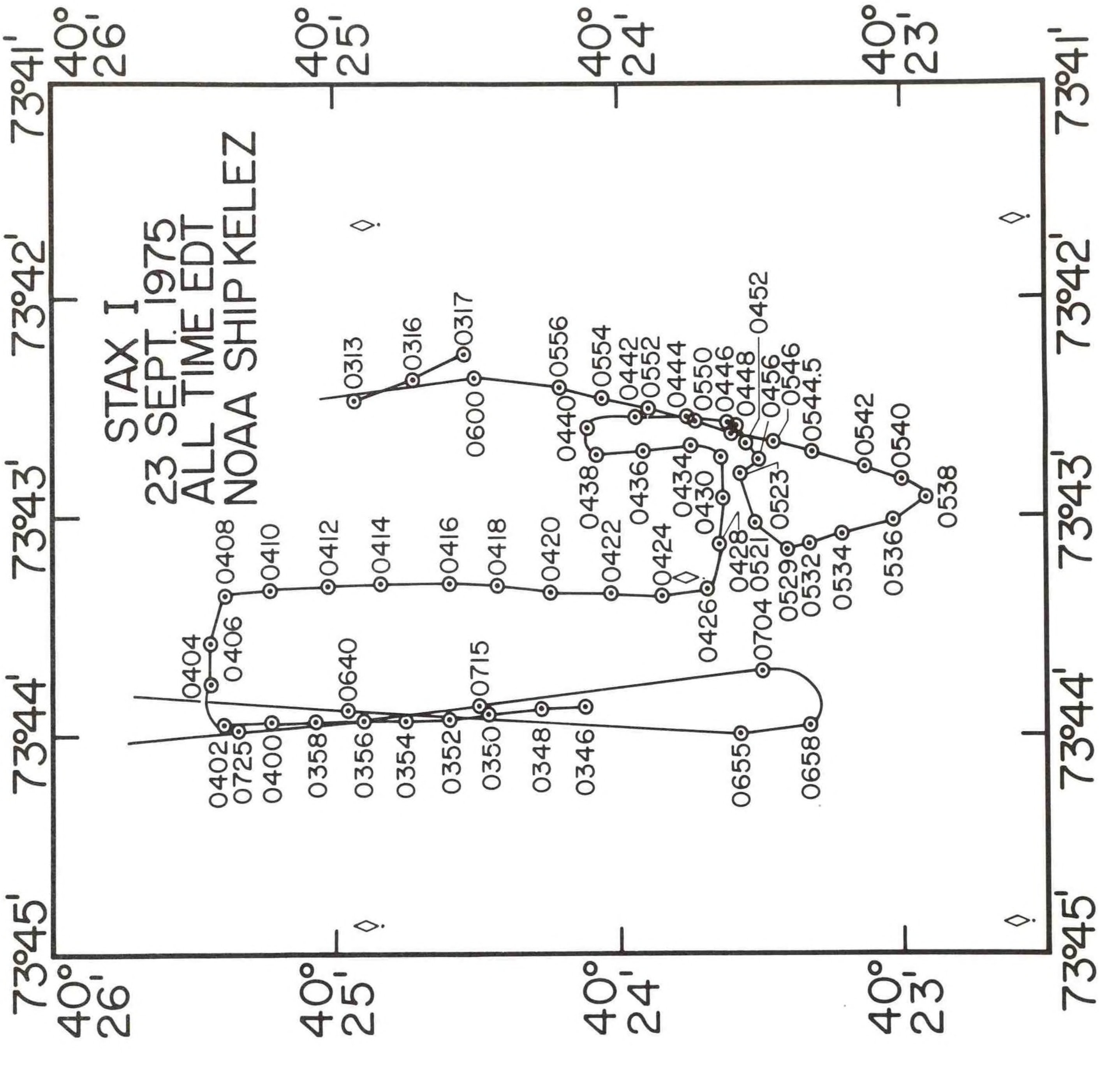
STAX I
23 SEPT. 1975
ALL TIME EDT
NOAA SHIP KELEZ
73°41'
73°42'
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0704
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0725
0400
0358
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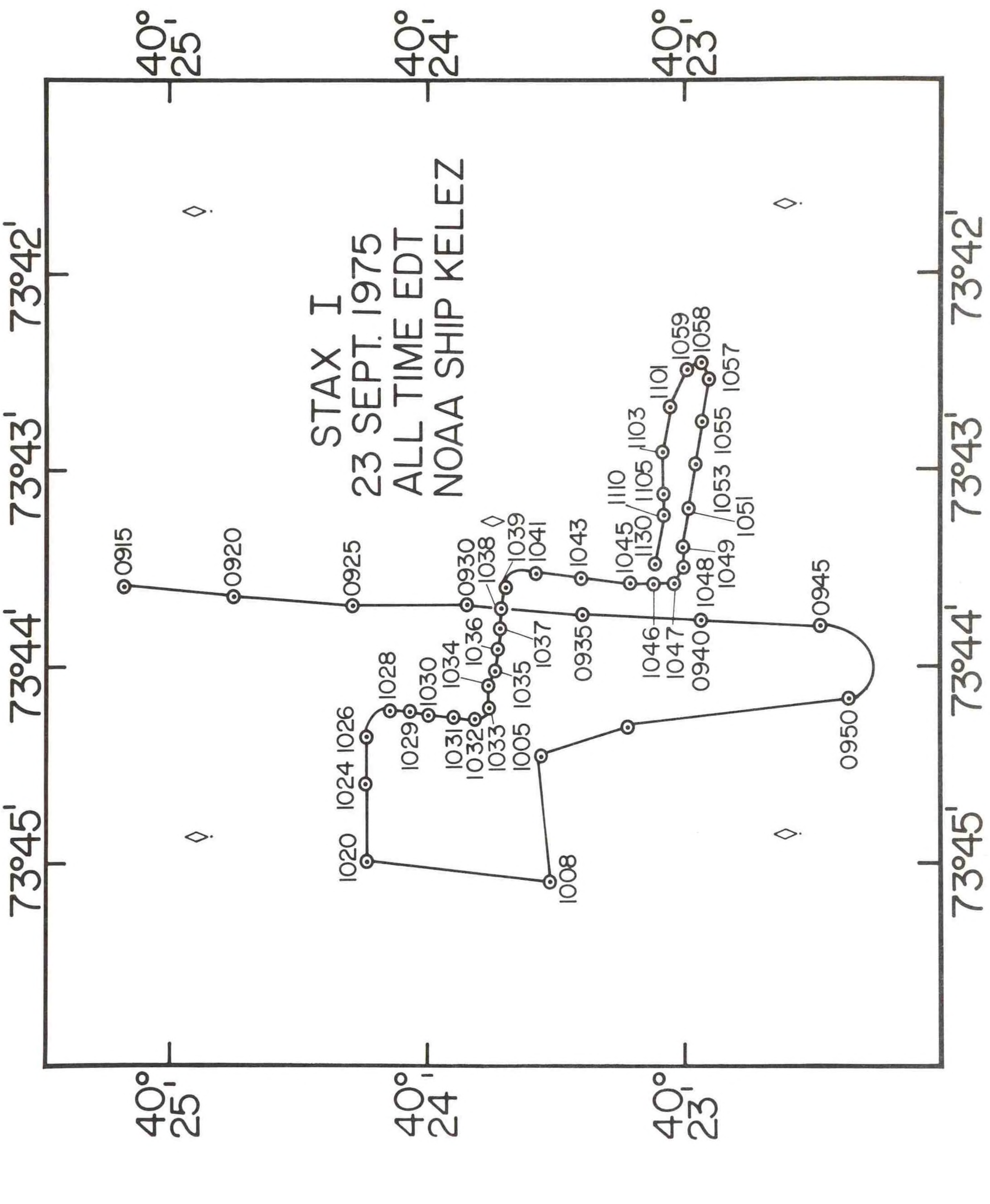
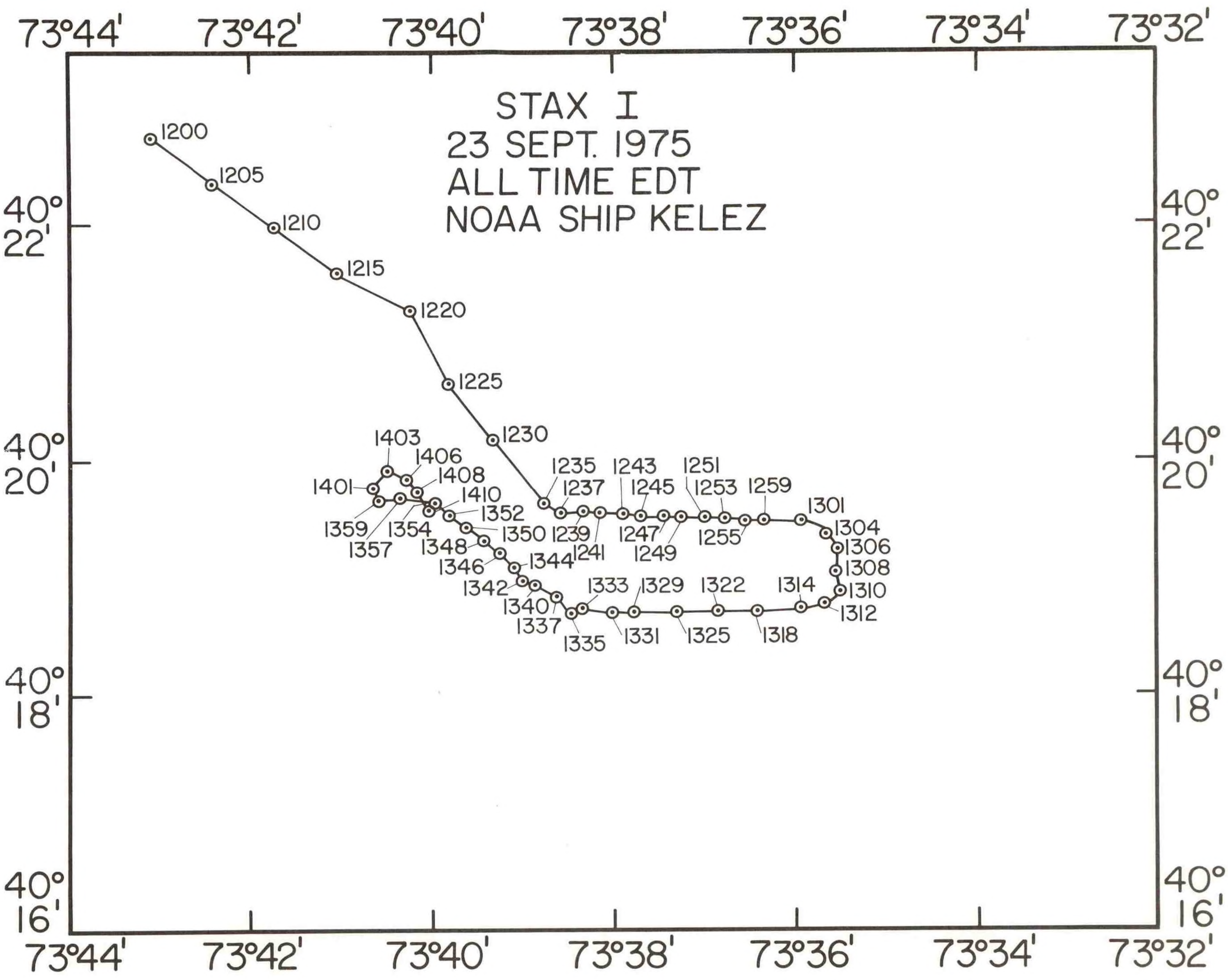
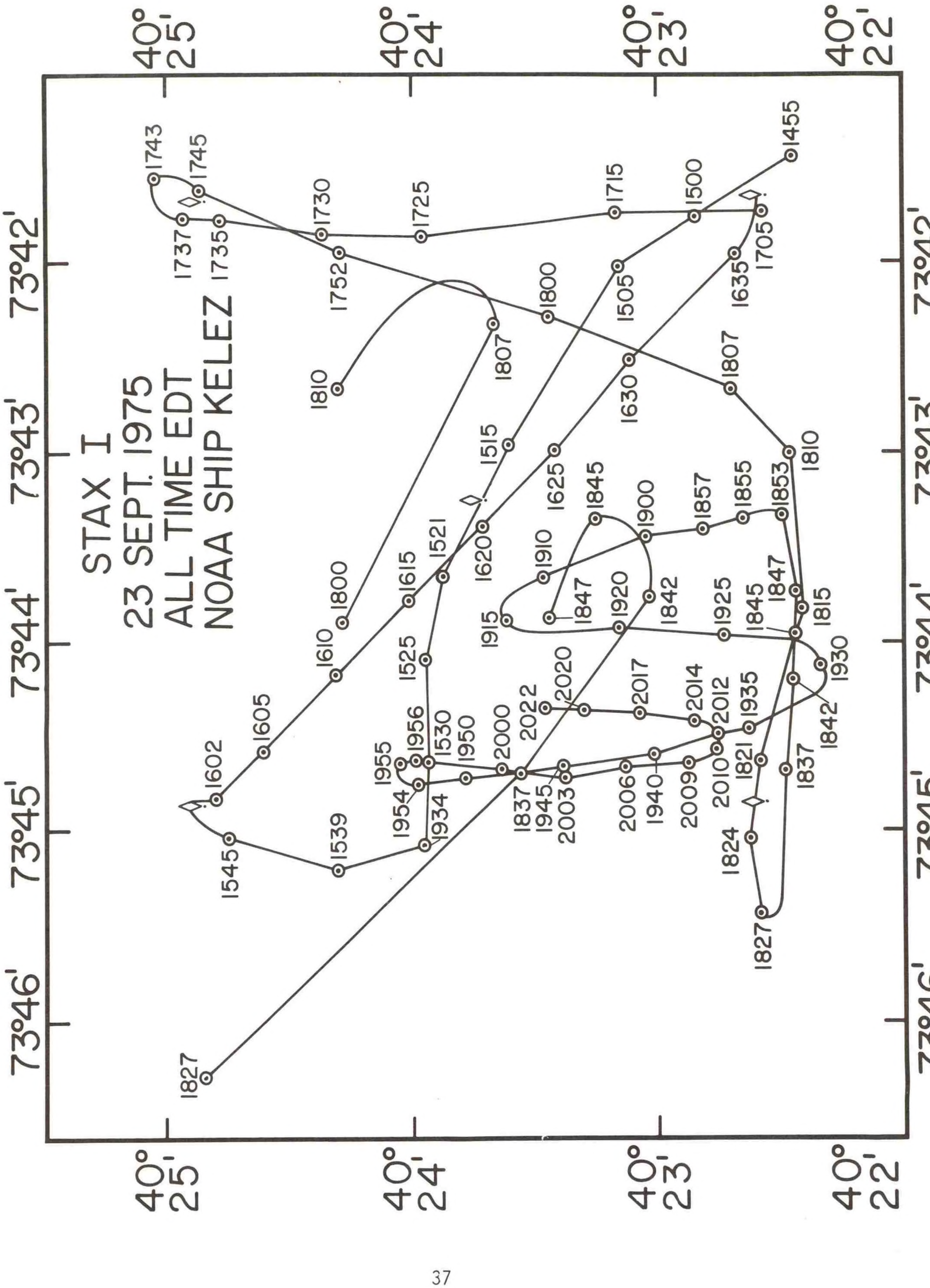
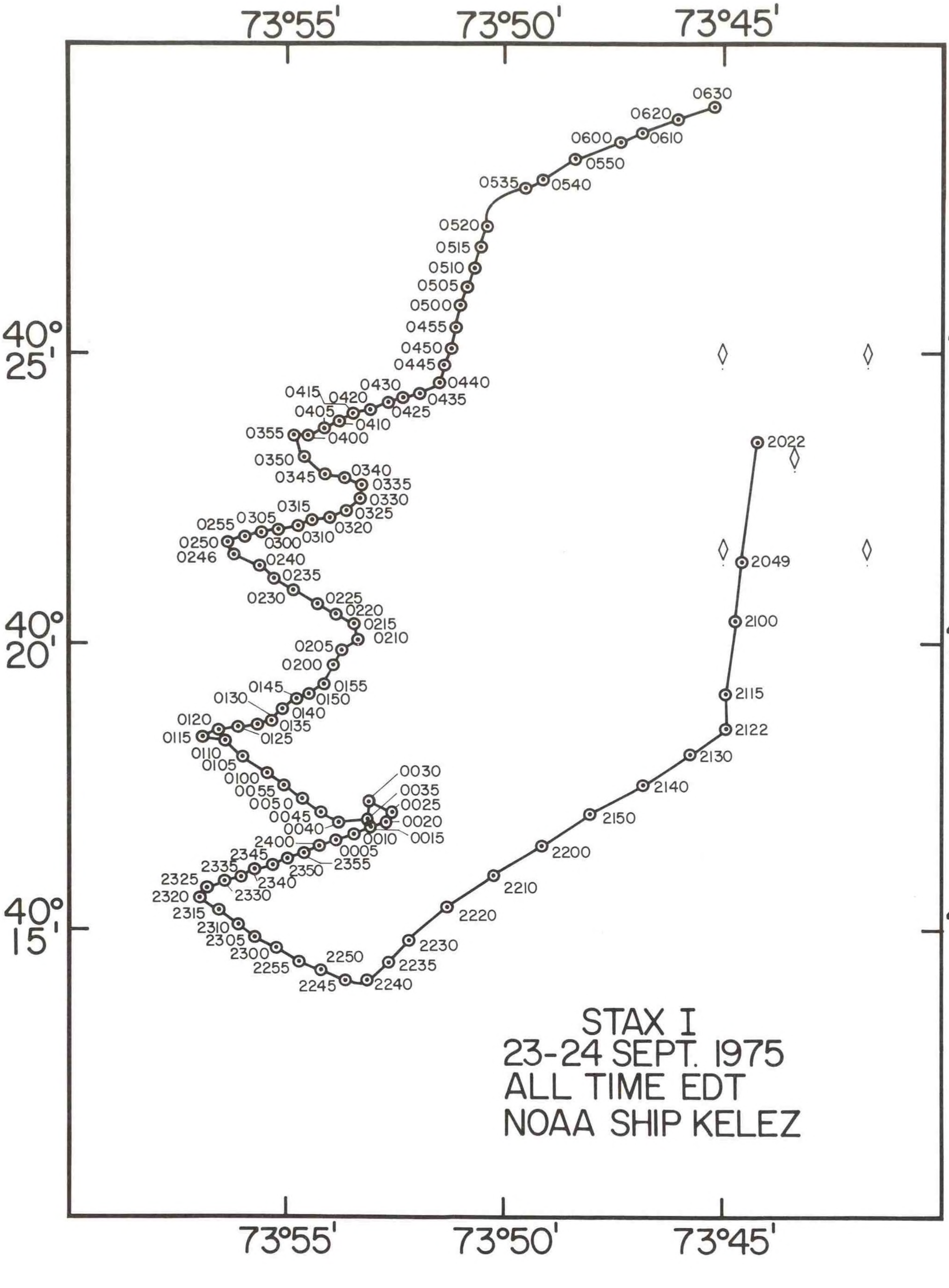
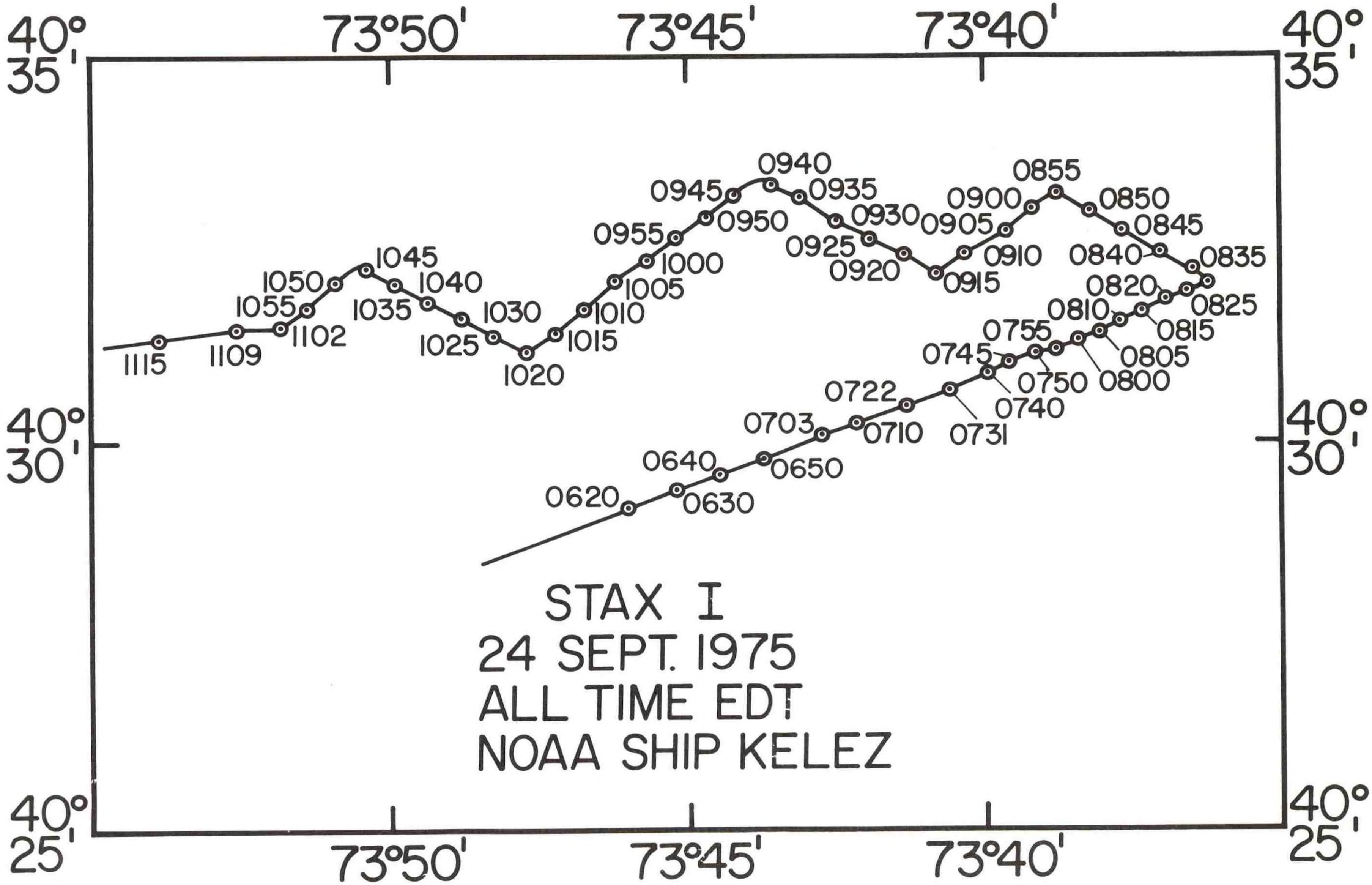
0350
0348
0346
0655
0658


STAX I
23 SEPT. 1975
ALL TIME EDT
NOAA SHIP KELEZ
40° 25'
40° 24'
40° 23'
73°42'
73°43'
73°44'
73°45'
0915
0920
0925
0930
0935
0940
0945
0950
1005
1008
1020
1024
1026
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1041
1043
1045
1046
1047
1048
1049
1051
1053
1055
1057
1058
1059
1101
1103
1105
1110
1130


STAX I
23 SEPT. 1975
ALL TIME EDT
NOAA SHIP KELEZ
73°44'
73°42'
73°40'
73°38'
73°36'
73°34'
73°32'
40° 22'
40° 20'
40° 18'
40° 16'
1200
1205
1210
1215
1220
1225
1230
1235
1237
1239
1241
1243
1245
1247
1249
1251
1253
1255
1259
1301
1304
1306
1308
1310
1312
1314
1318
1322
1325
1329
1331
1333
1335
1337
1340
1342
1344
1346
1348
1350
1352
1354
1357
1359
1401
1403
1406
1408
1410


STAX I
23 SEPT. 1975
ALL TIME EDT
NOAA SHIP KELEZ
40° 25'
40° 24'
40° 23'
40° 22'
73°42'
73°43'
73°44'
73°45'
73°46'


73°55'
73°50'
73°45'
40° 25'
40° 20'
40° 15'
STAX I
23-24 SEPT. 1975
ALL TIME EDT
NOAA SHIP KELEZ


STAX I
24 SEPT. 1975
ALL TIME EDT
NOAA SHIP KELEZ
40° 35'
40° 30'
40° 25'
73°50'
73°45'
73°40'
0620
0630
0640
0650
0703
0710
0722
0731
0740
0745
0750
0755
0800
0805
0810
0815
0820
0825
0835
0840
0845
0850
0855
0900
0905
0910
0915
0920
0925
0930
0935
0940
0945
0950
0955
1000
1005
1010
1015
1020
1025
1030
1035
1040
1045
1050
1055
1102
1109
1115

Appendix B

COULTER DATA

Identification of the analysis reads as follows:

Cl - S = Cast 1 Surface

Cl - M = Cast 1 Midwater

Cl - B = Cast 1 Bottom

Cast 1	(21001)	2304 EDT	21 September 1975
Cast 2	(22001)	0117 EDT	22 September 1975
Cast 3	(22002)	0305 EDT	22 September 1975
Cast 4	(22003)	0558 EDT	22 September 1975
Cast 5	(22004)	1432 EDT	22 September 1975
Cast 6	(23001)	0510 EDT	22 September 1975

Mass/Unit volume is written on each coulter record for that sample.

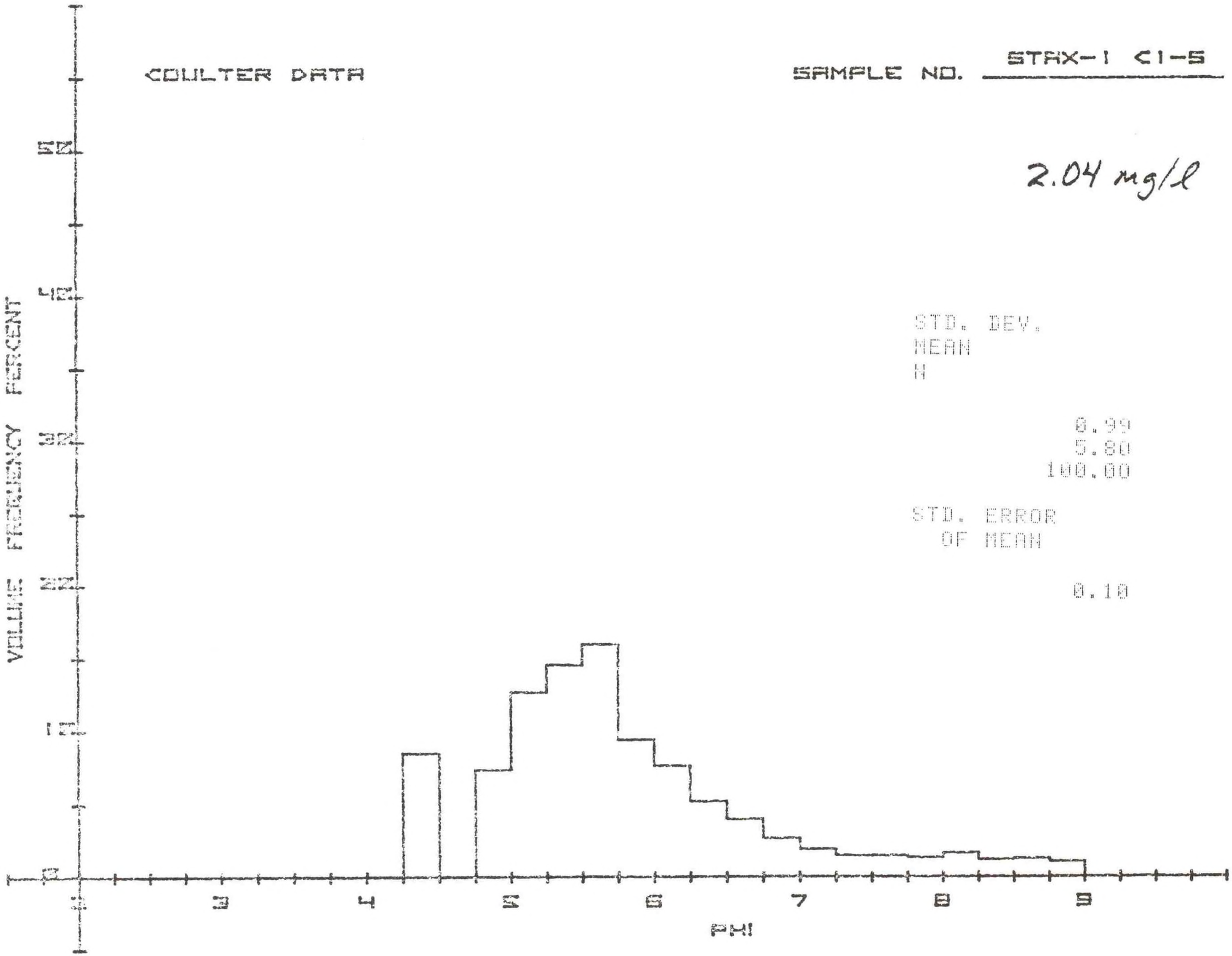
COULTER DATA

SAMPLE NO. STAX-1 <1-5

2.04 mg/l

STD. DEV. 0.99
MEAN 5.80
N 100.00

STD. ERROR OF MEAN 0.10



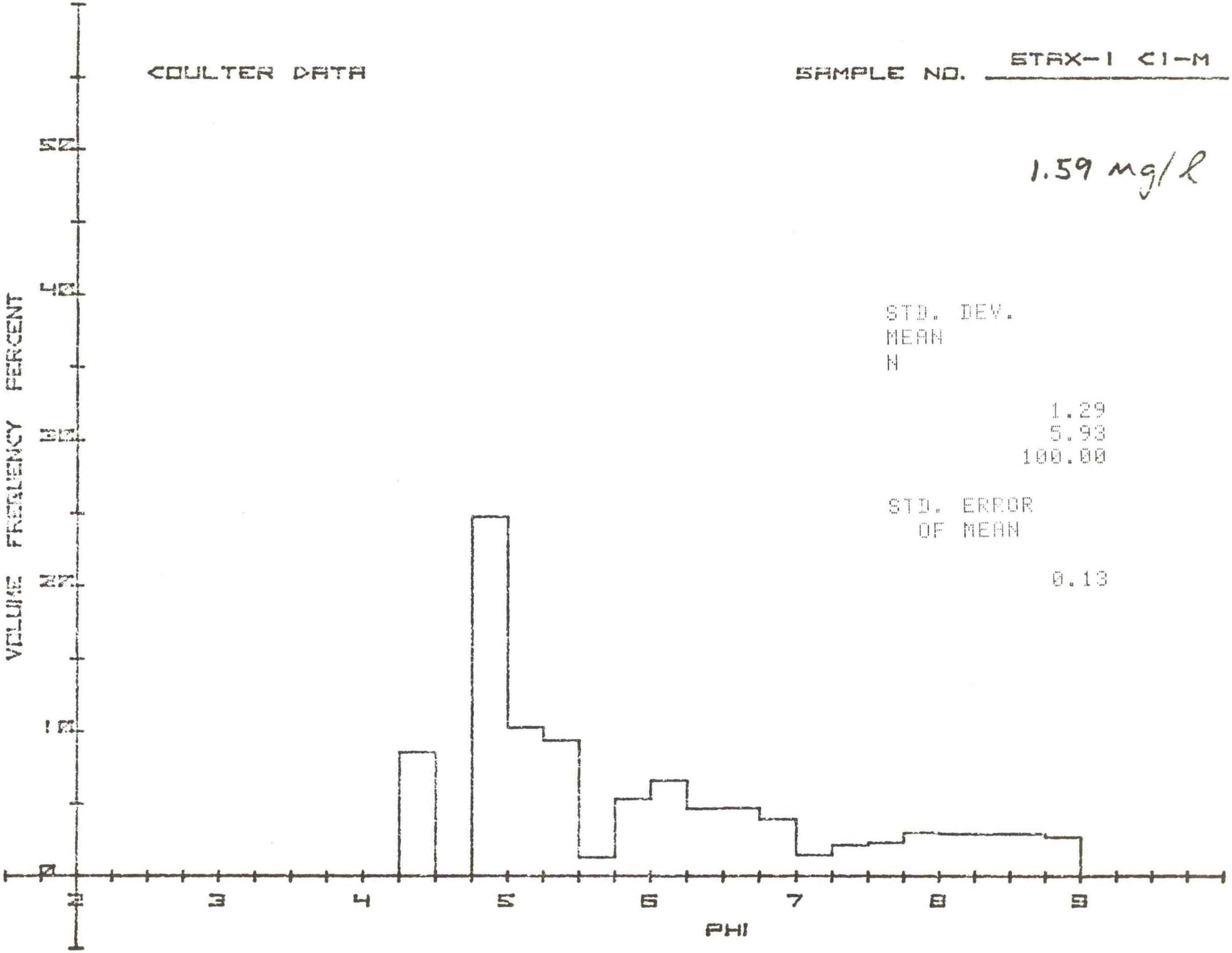
COULTER DATA

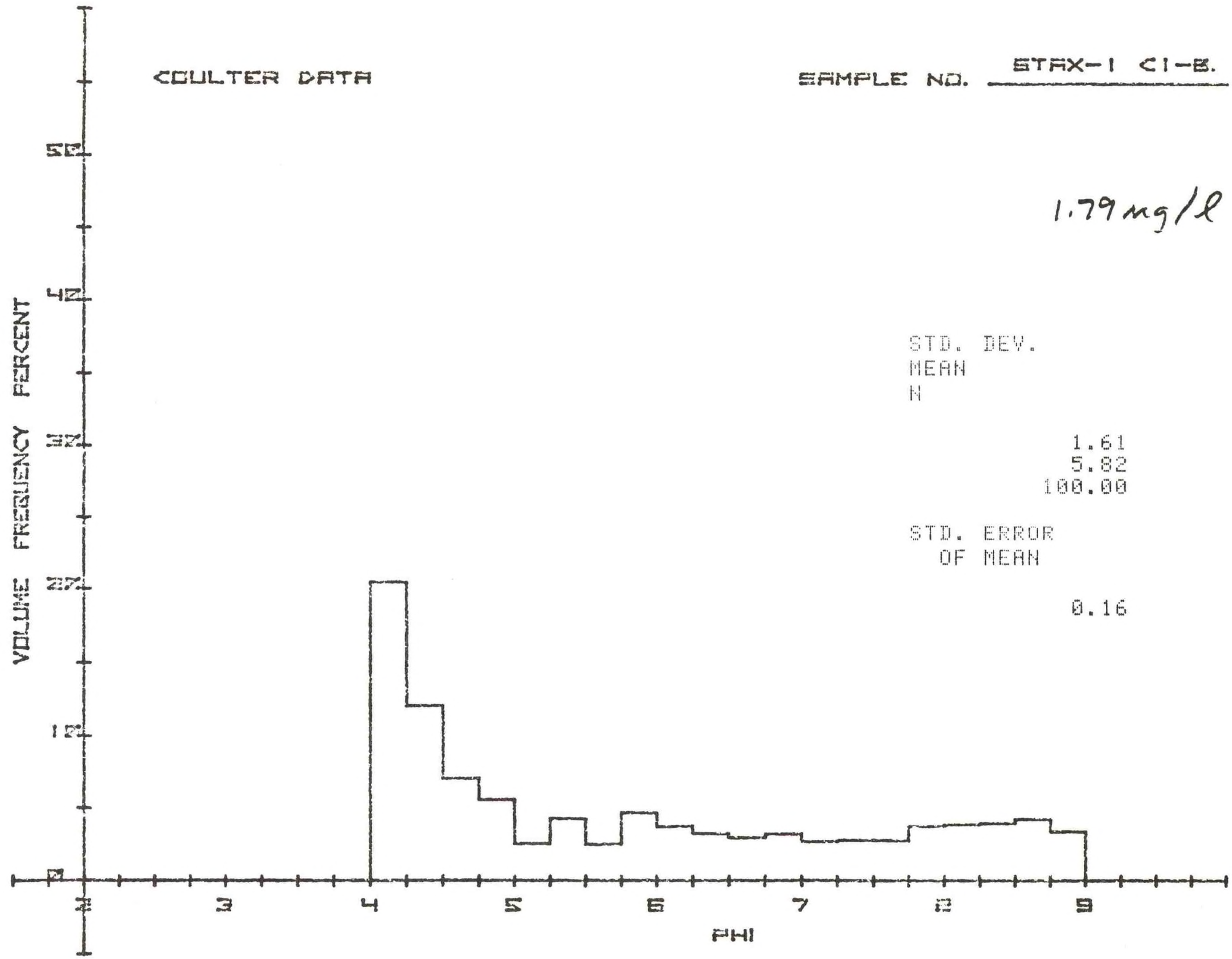
SAMPLE NO. STAX-1 C1-M

1.59 mg/l

STD. DEV. 1.29
MEAN 5.93
N 100.00

STD. ERROR OF MEAN 0.13



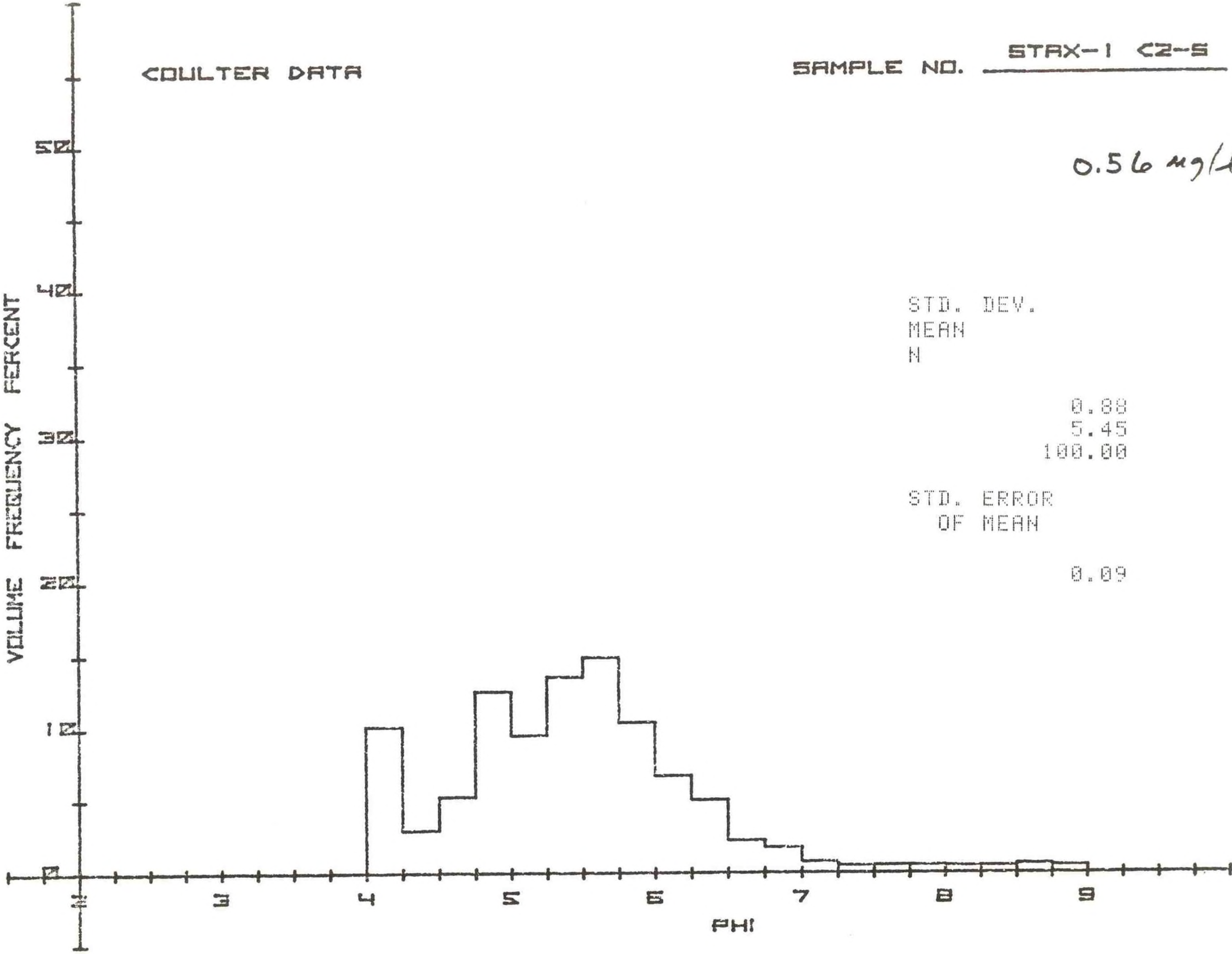

COULTER DATA
SAMPLE NO. STAX-1 C1-B.
1.79 mg/l
STD. DEV. 1.61
MEAN 5.82
N 100.00
STD. ERROR OF MEAN 0.16
VOLUME FREQUENCY PERCENT
PHI
2
3
4
5
6
7
8
9

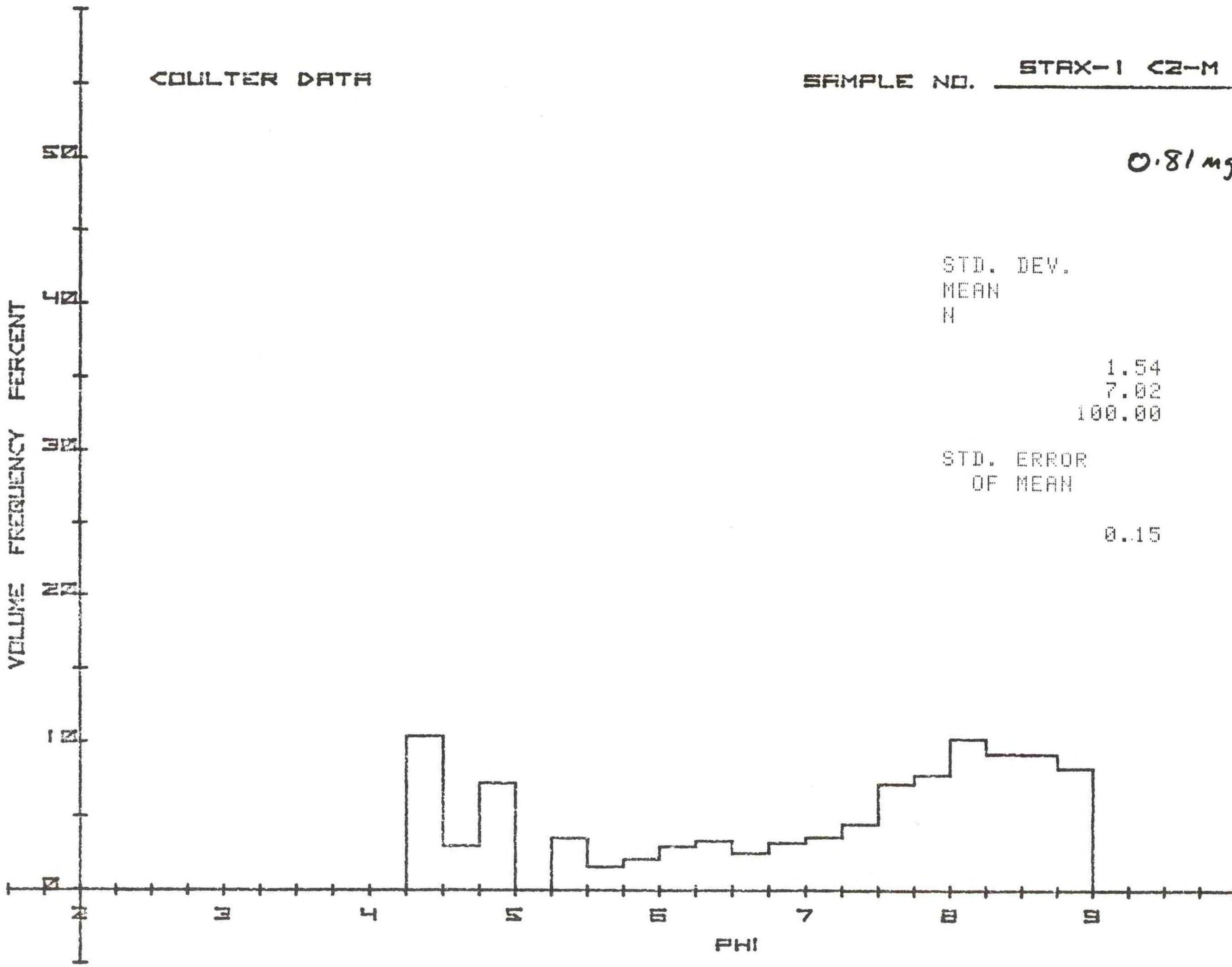
COULTER DATA

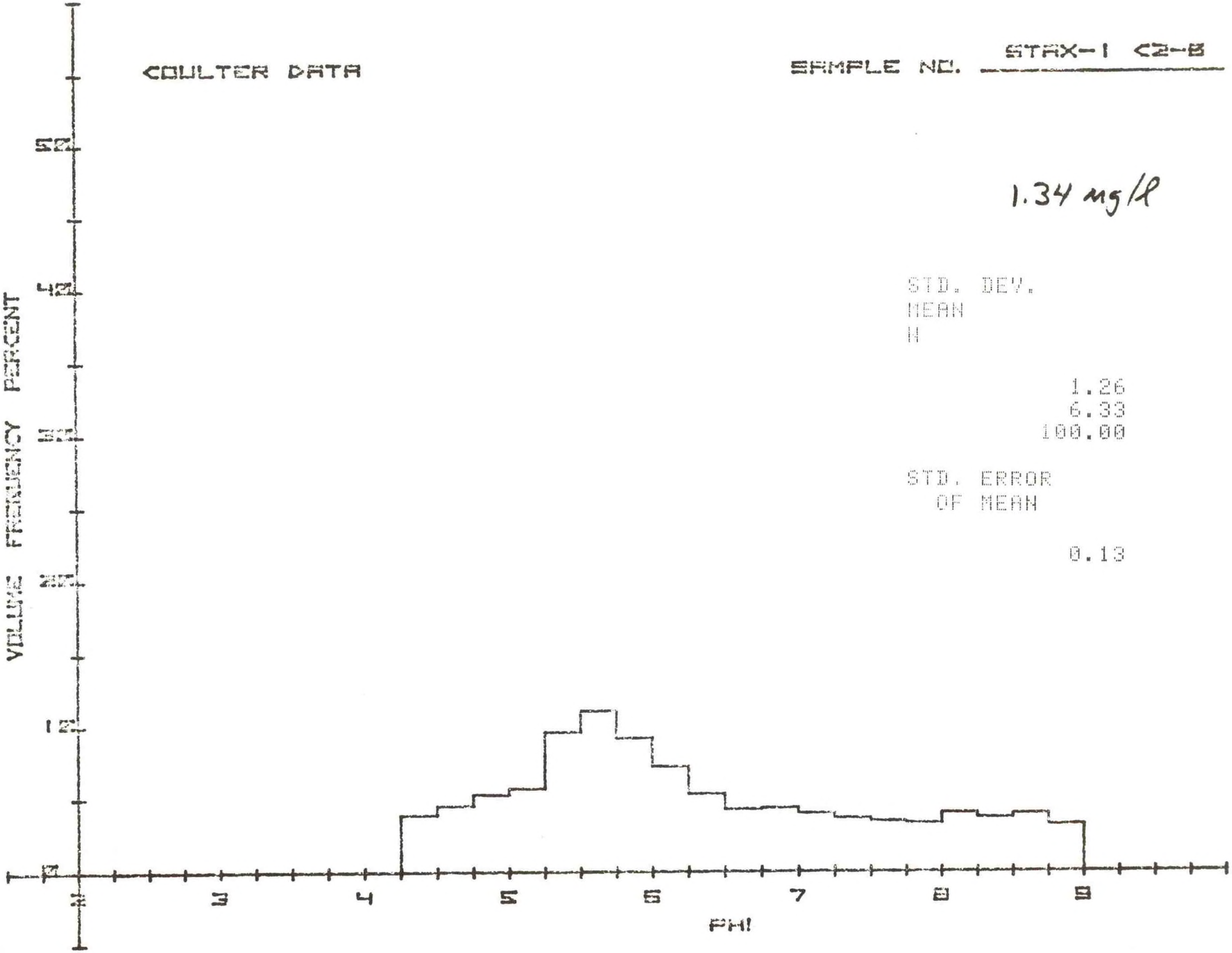
SAMPLE NO. STAX-1 C2-S

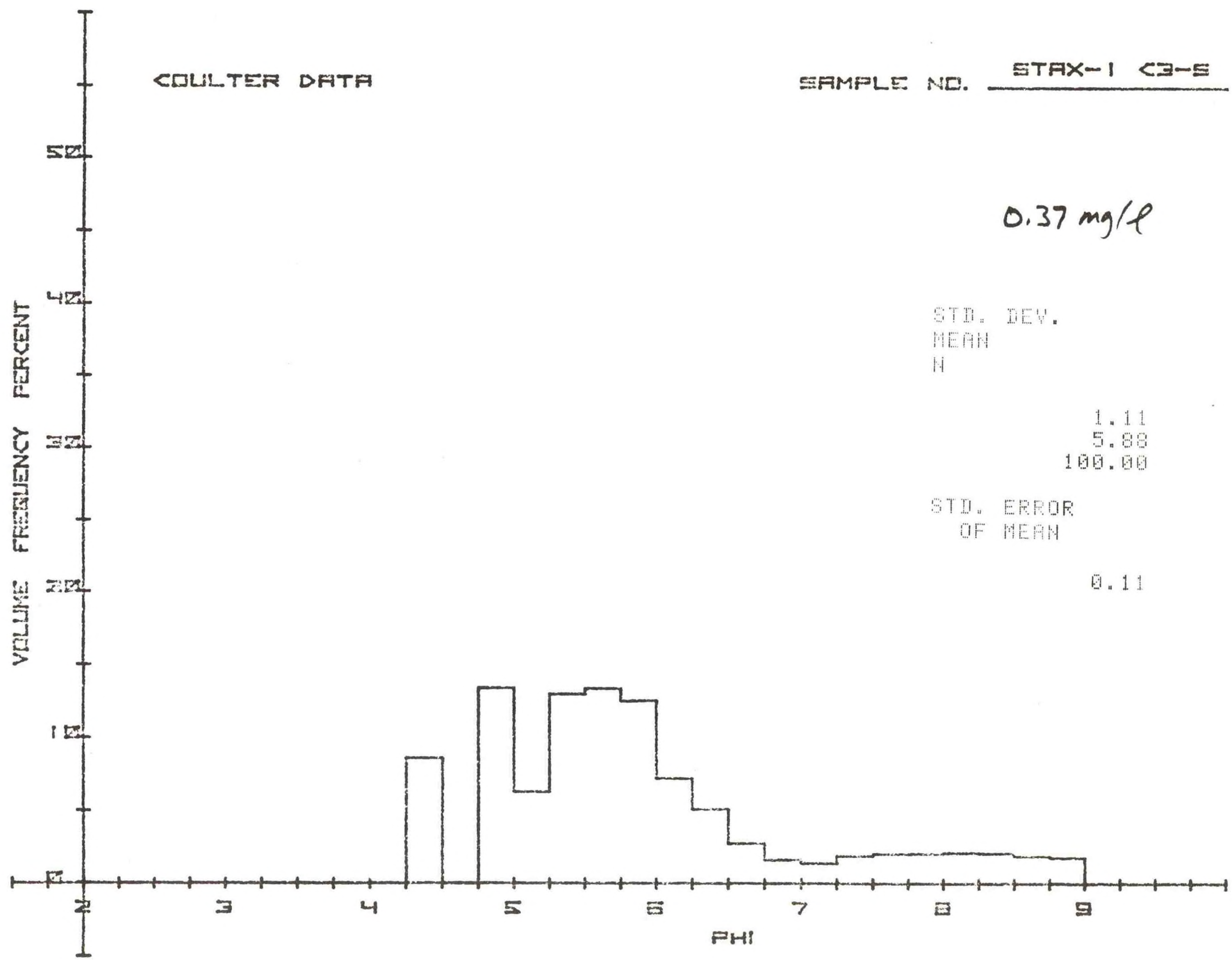
0.56 mg/l

STD. DEV.	0.88
MEAN	5.45
N	100.00
STD. ERROR OF MEAN	0.09




COULTER DATA
SAMPLE NO. STAX-1 C2-M
0.81 mg/l
STD. DEV. 1.54
MEAN 7.02
N 100.00
STD. ERROR OF MEAN 0.15
VOLUME FREQUENCY PERCENT
0
10
20
30
40
50
2
3
4
5
6
7
8
9
PHI


COULTER DATA
SAMPLE NO. STRAX-1 C2-B
1.34 mg/l
STD. DEV. 1.26
MEAN 6.33
N 100.00
STD. ERROR OF MEAN 0.13
VOLUME FREQUENCY PERCENT
50
40
30
20
10
0
2
3
4
5
6
7
8
9
PHI

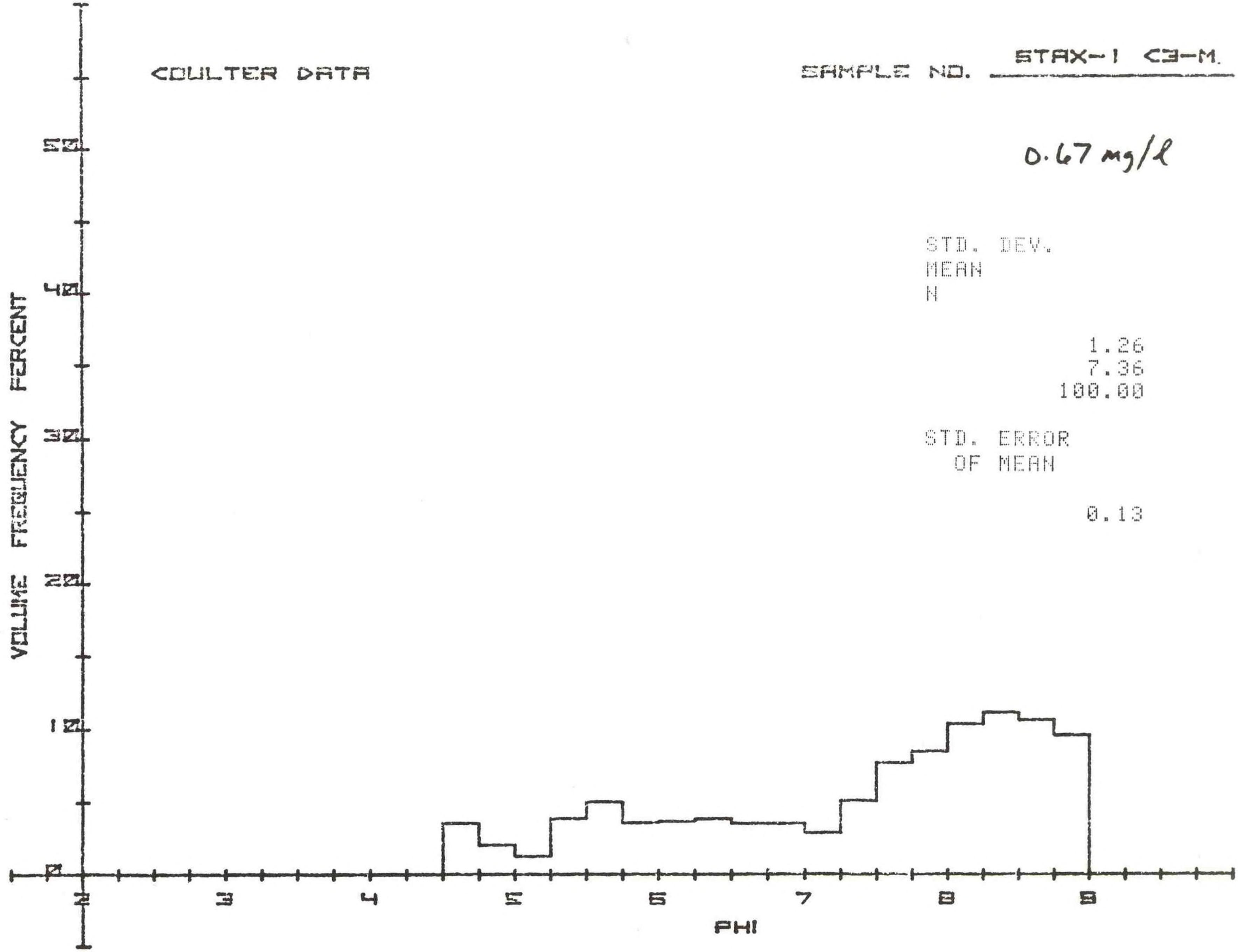

COULTER DATA
SAMPLE NO. STAX-1 C3-S
0.37 mg/l
STD. DEV. 1.11
MEAN 5.88
N 100.00
STD. ERROR OF MEAN 0.11
VOLUME FREQUENCY PERCENT
0
10
20
30
40
50
2
3
4
5
6
7
8
9
PHI

COULTER DATA

SAMPLE NO. STAX-1 C3-M.

0.67 mg/l

STD. DEV.	1.26
MEAN	7.36
N	100.00
STD. ERROR OF MEAN	0.13

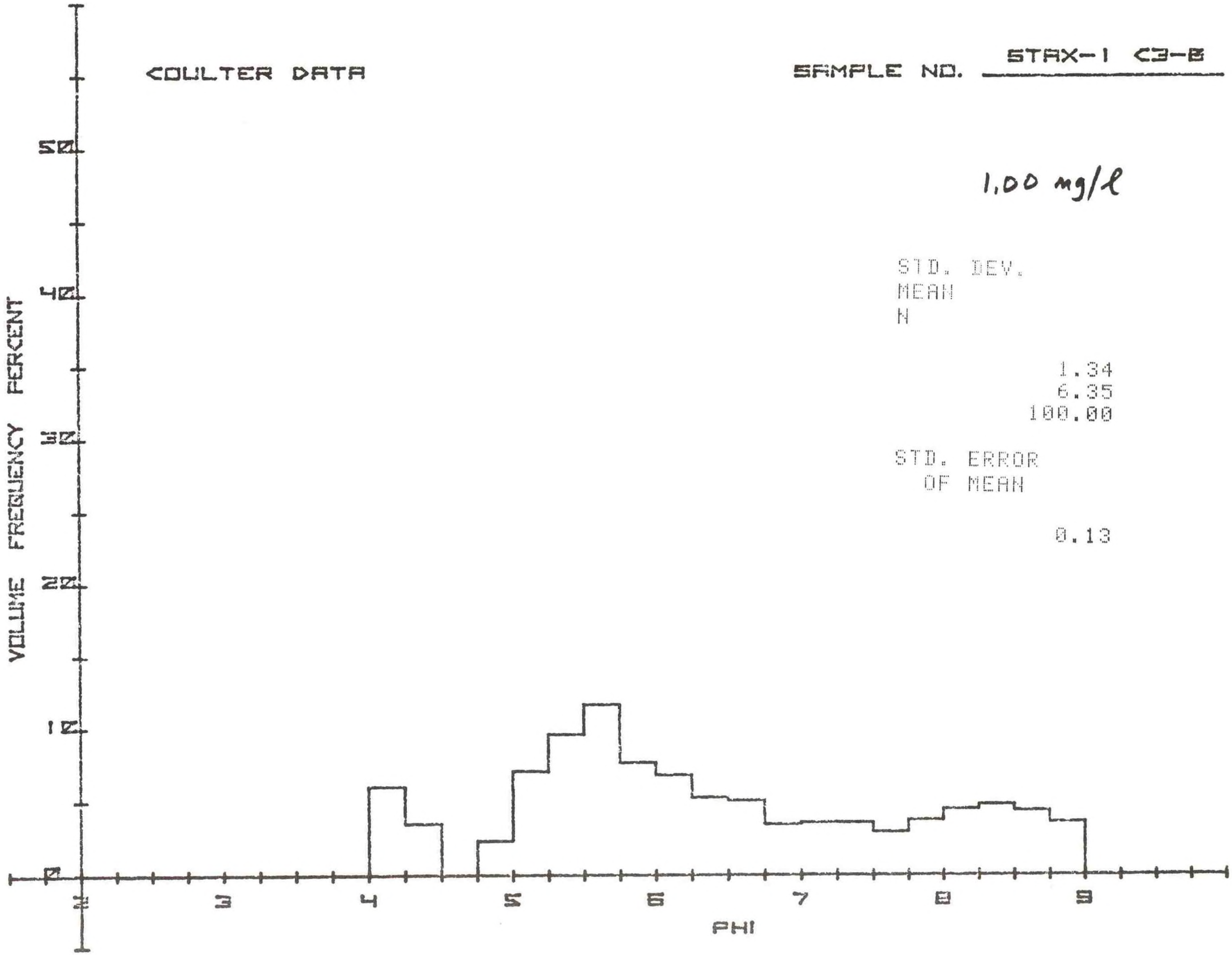


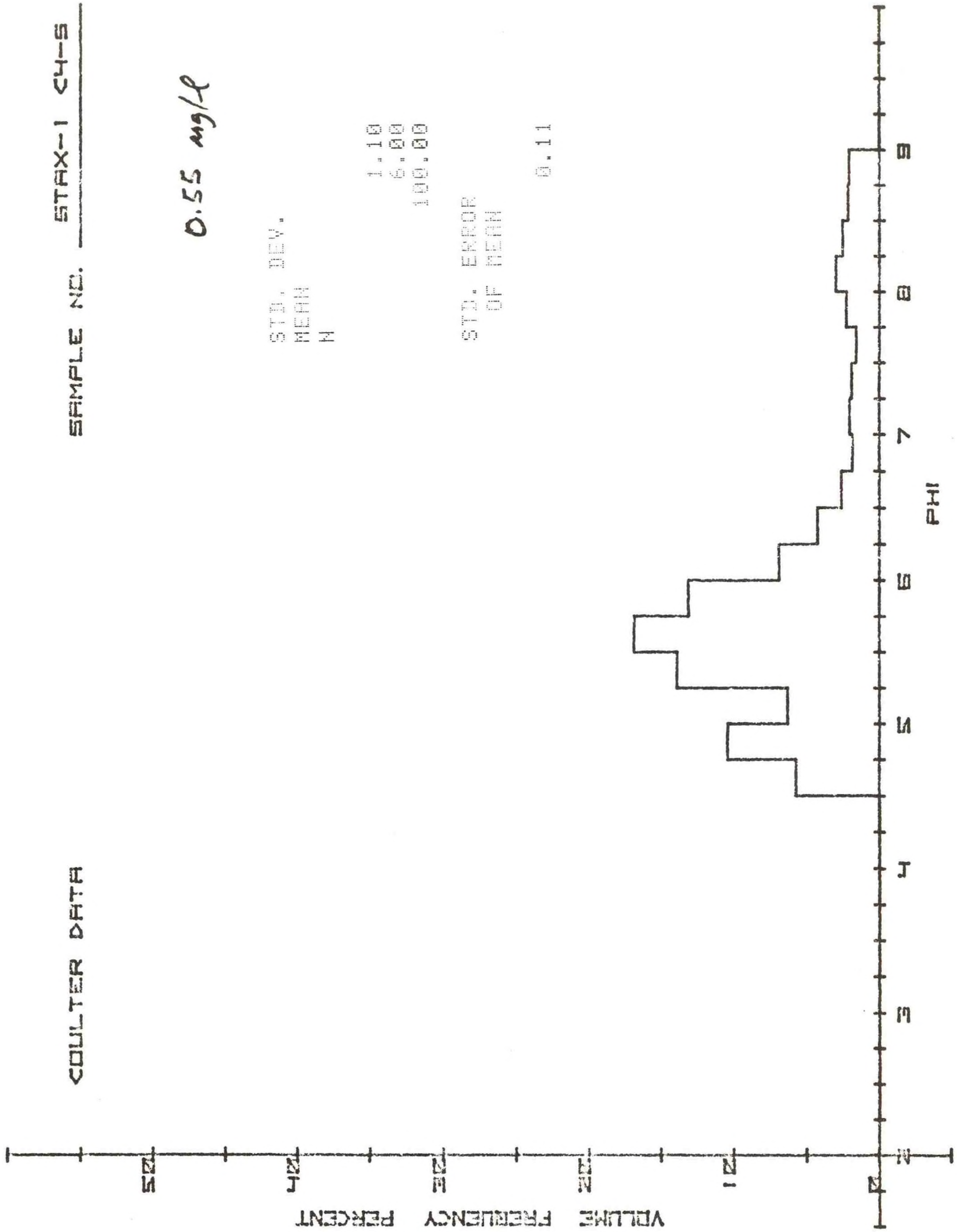
COULTER DATA

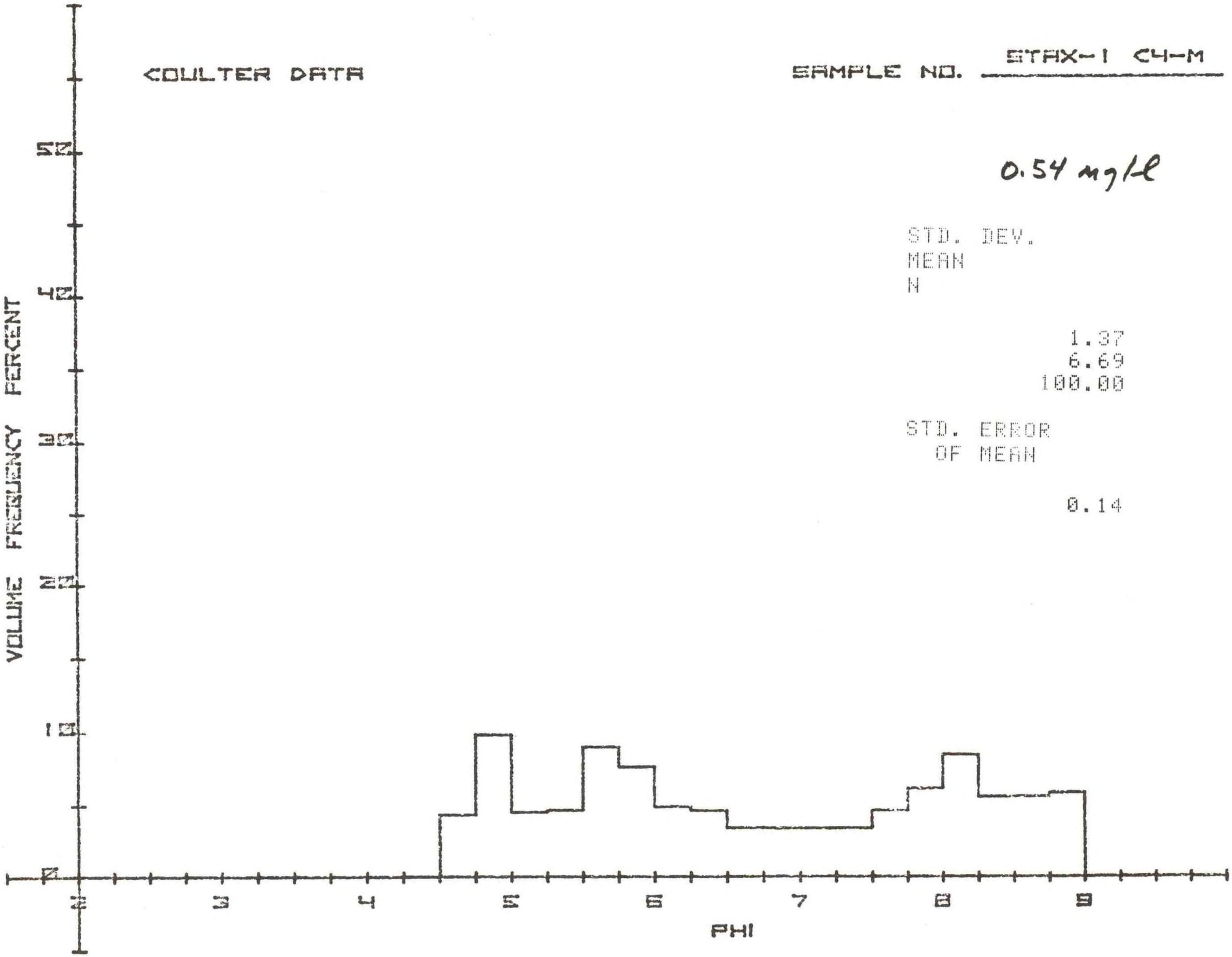
SAMPLE NO. STAX-1 C3-B

1,00 mg/l

STD. DEV.	1.34
MEAN	6.35
N	100.00
STD. ERROR OF MEAN	0.13




COULTER DATA
SAMPLE NO. STAX-1 C4-5
0.55 mg/l
STD. DEV. 1.10
MEAN 6.00
N 100.00
STD. ERROR OF MEAN 0.11
VOLUME FREQUENCY PERCENT
0
10
20
30
40
50
PHI
2
3
4
5
6
7
8
9

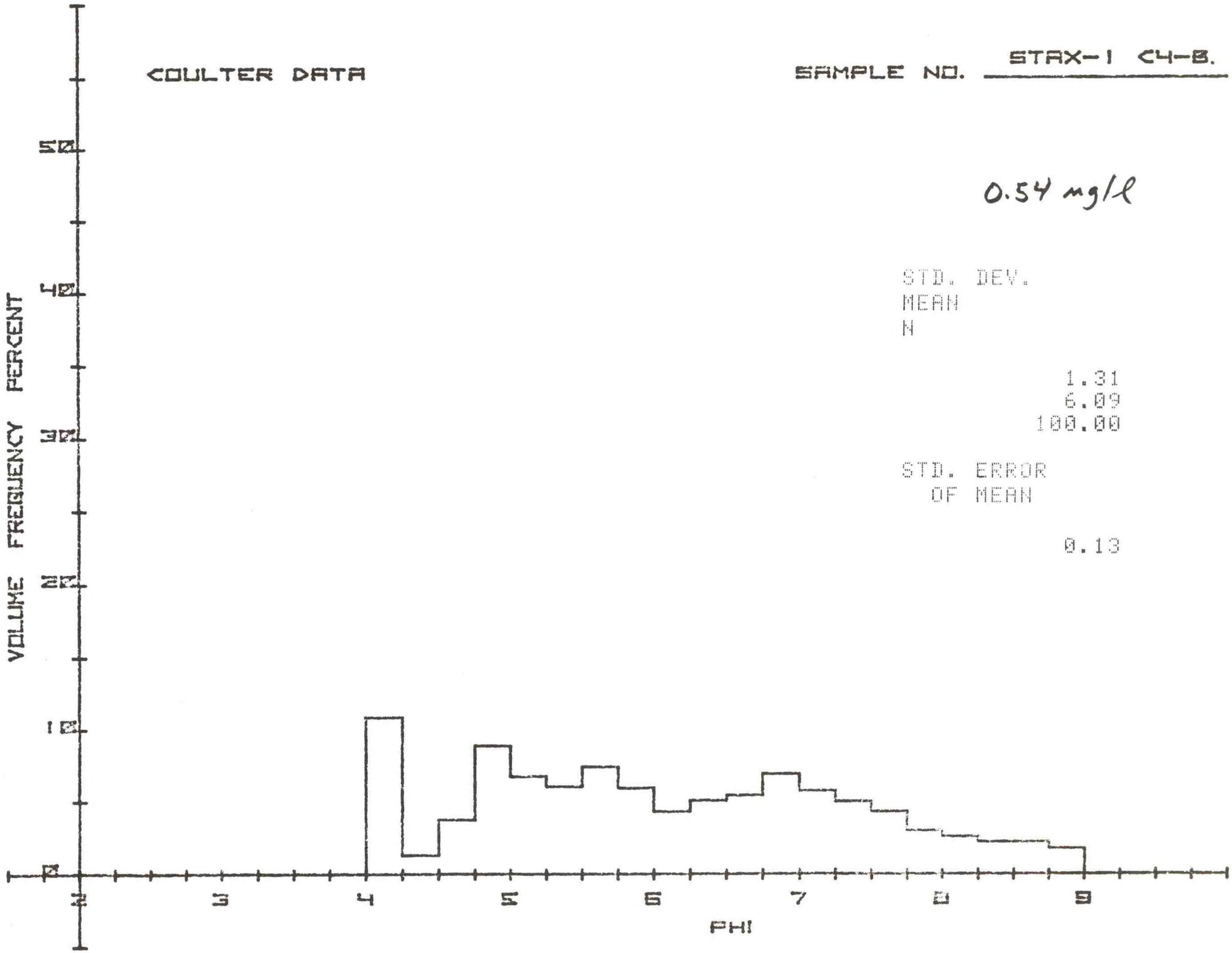

COULTER DATA
SAMPLE NO. STAX-1 C4-M
0.54 mg/l
STD. DEV. 1.37
MEAN 6.69
N 100.00
STD. ERROR OF MEAN 0.14
VOLUME FREQUENCY PERCENT
0
10
20
30
40
50
2
3
4
5
6
7
8
9
PHI

COULTER DATA

SAMPLE NO. STAX-1 C4-B.

0.54 mg/l

STD. DEV.	1.31
MEAN	6.09
N	100.00
STD. ERROR OF MEAN	0.13

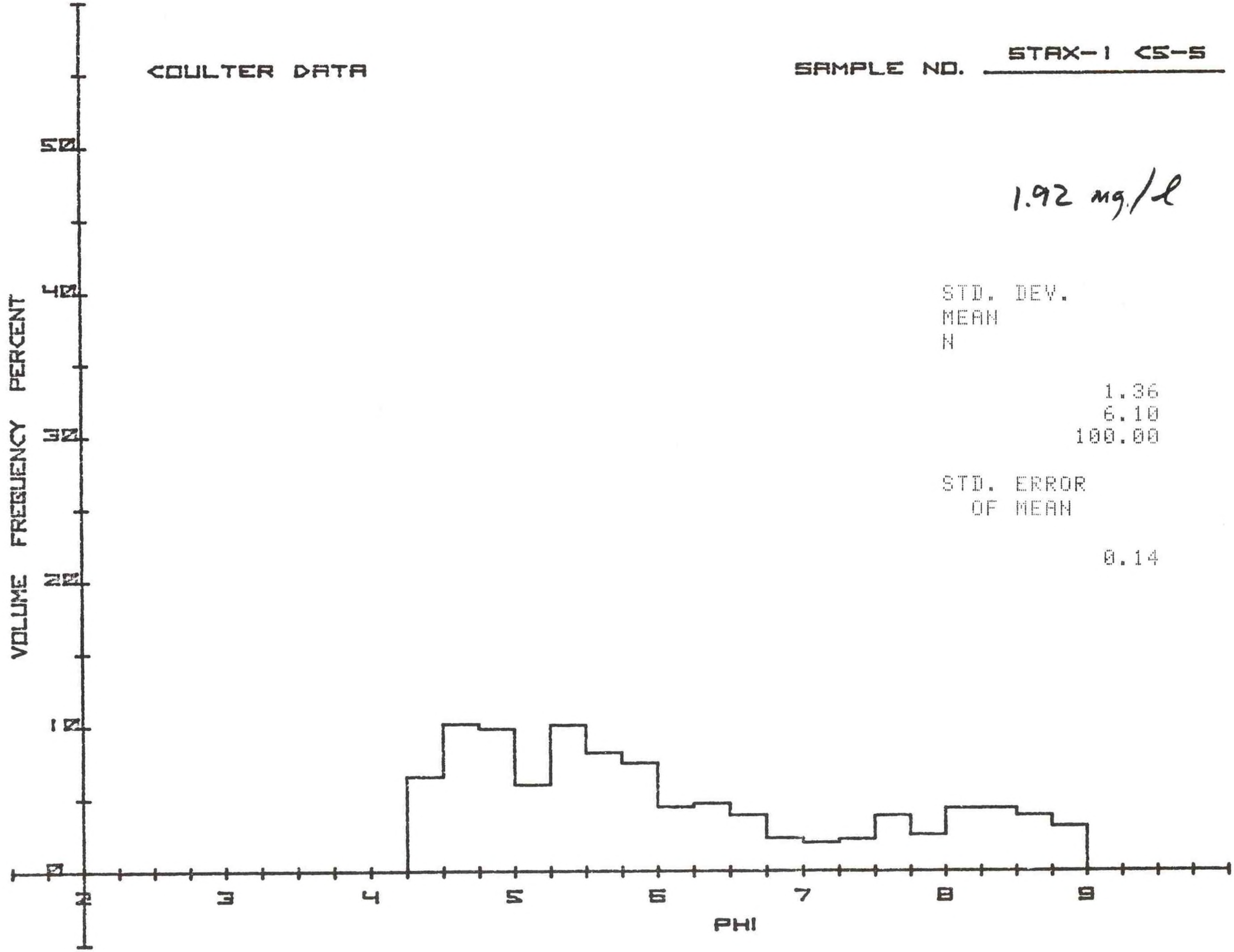


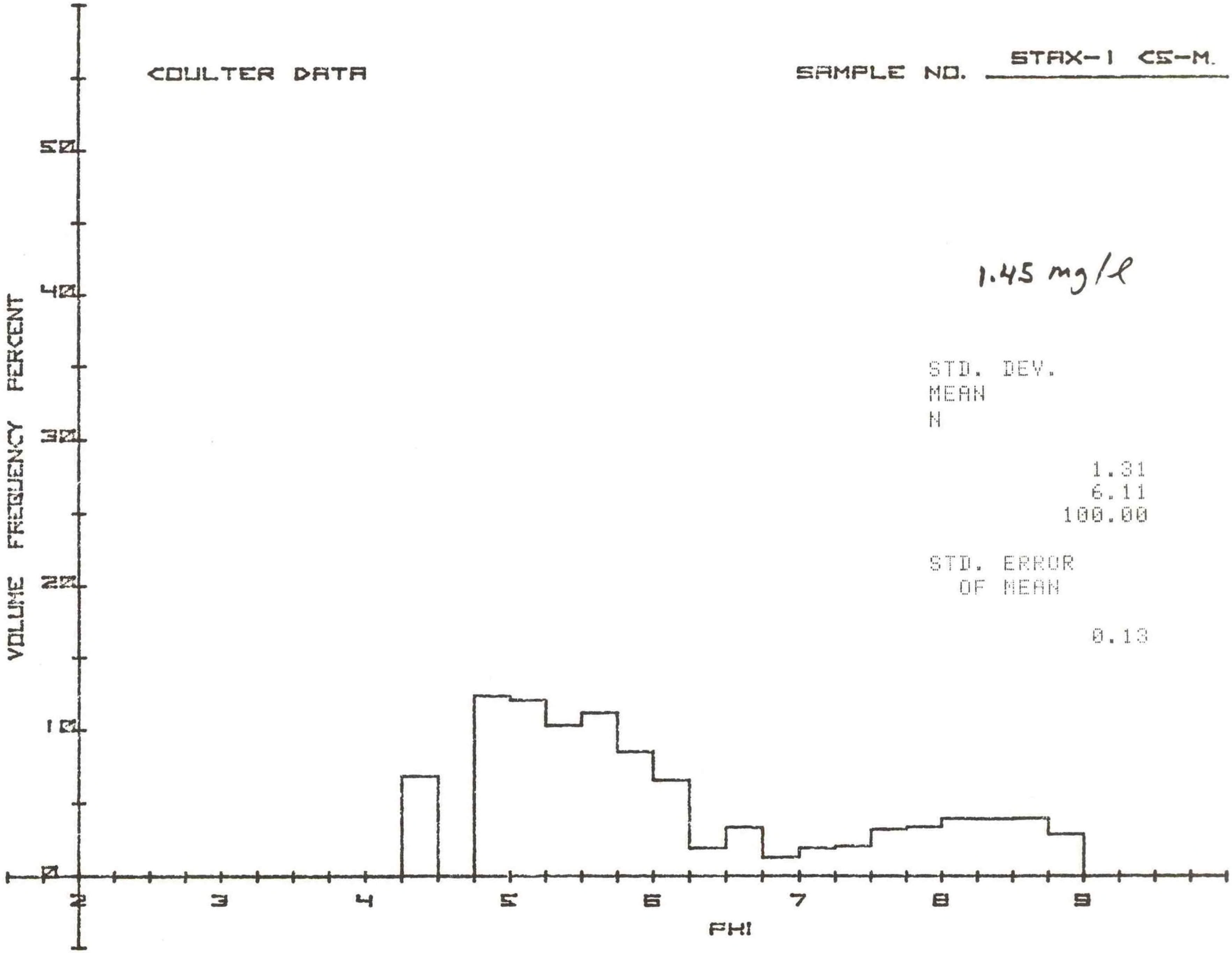
COULTER DATA

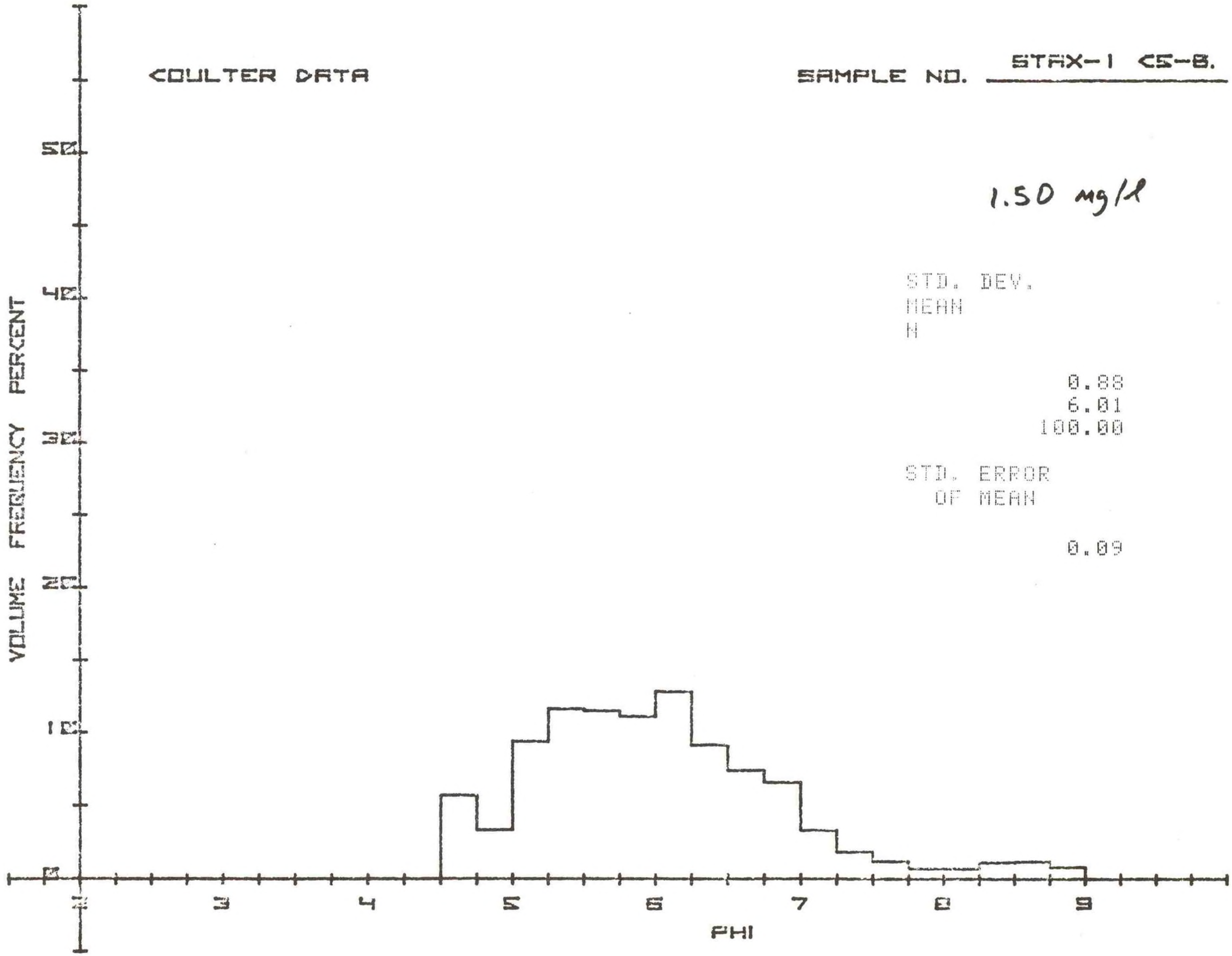
SAMPLE NO. STAX-1 <CS-5

1.92 mg./l

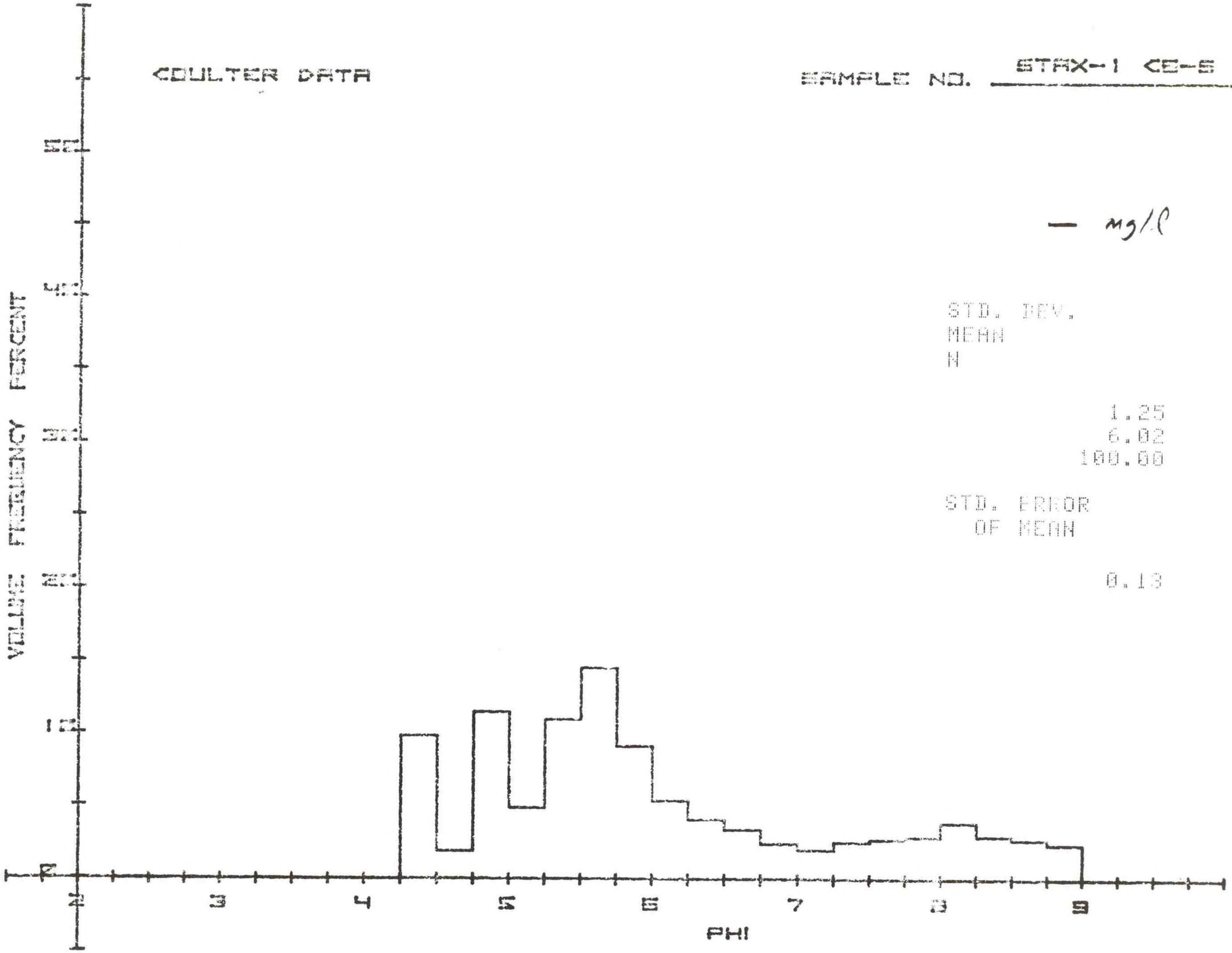
STD. DEV.	1.36
MEAN	6.10
N	100.00
STD. ERROR OF MEAN	0.14

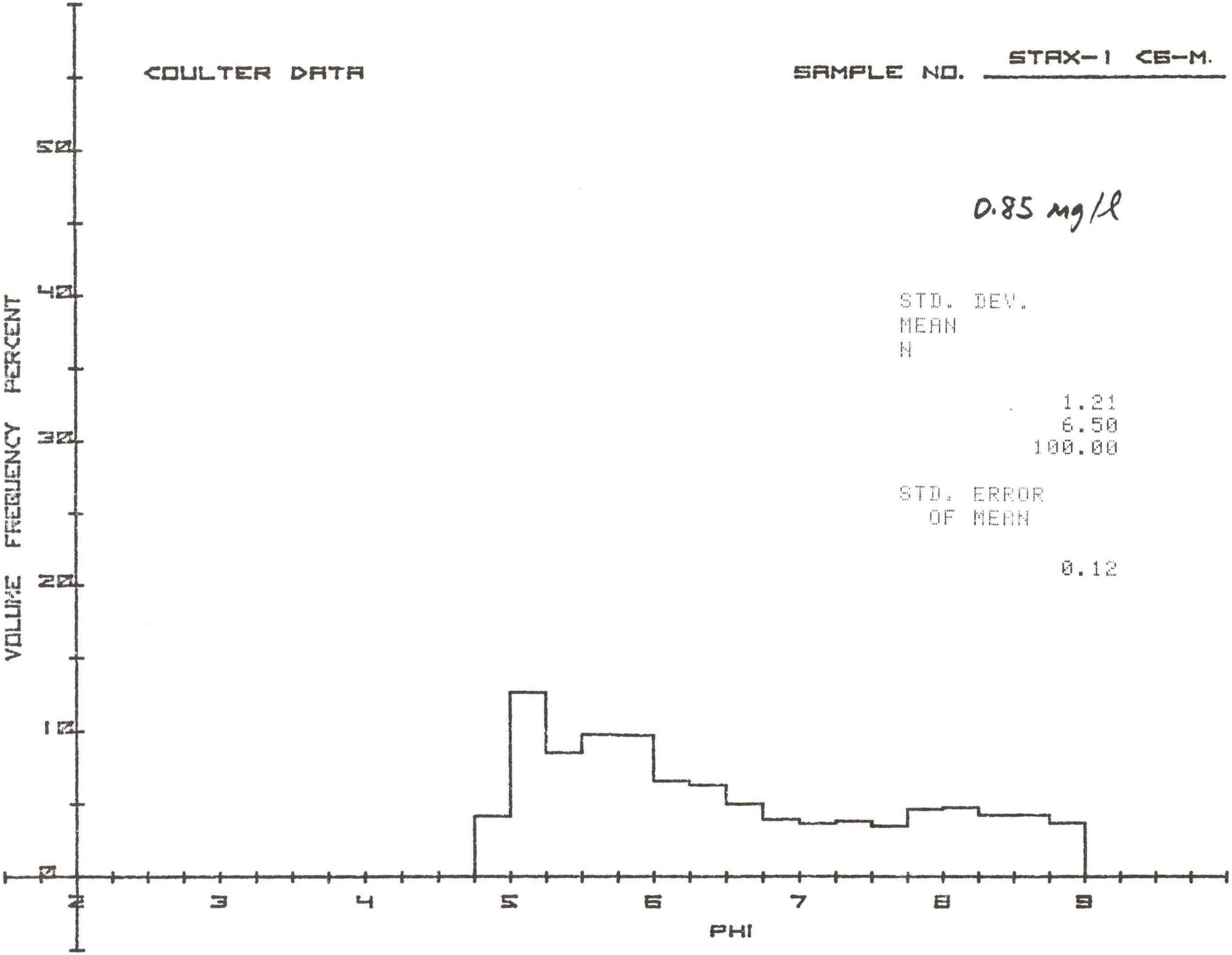


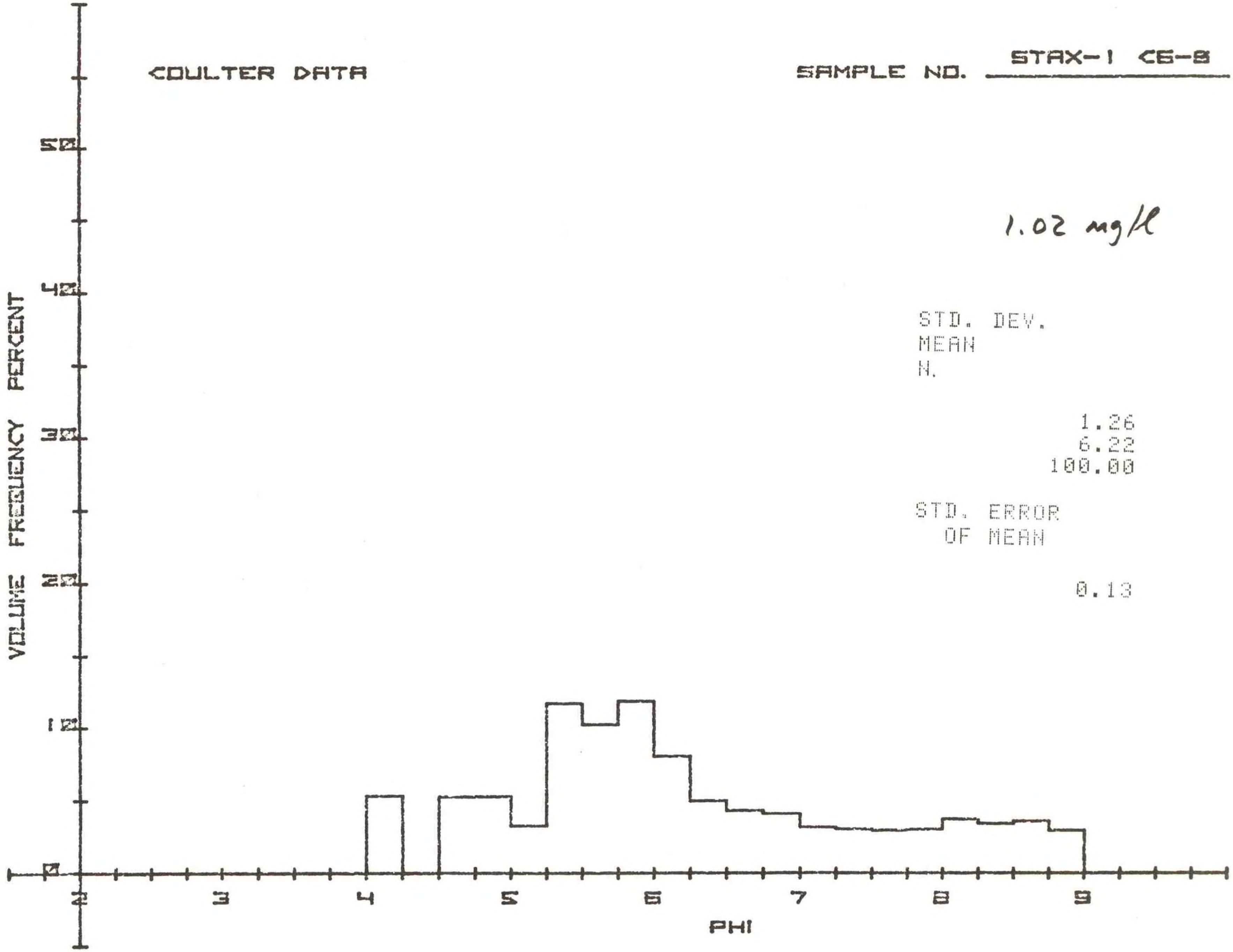

COULTER DATA
SAMPLE NO. STAX-1 CS-M.
1.45 mg/l
STD. DEV. 1.31
MEAN 6.11
N 100.00
STD. ERROR OF MEAN 0.13
VOLUME FREQUENCY PERCENT
0
10
20
30
40
50
2
3
4
5
6
7
8
9
PHI



<COULTER DATA
SAMPLE NO. STAX-1 <S-8.
1.50 mg/l
STD. DEV. 0.88
MEAN 6.01
N 100.00
STD. ERROR OF MEAN 0.09
VOLUME FREQUENCY PERCENT
50
40
30
20
10
0
2
3
4
5
6
7
8
9
PHI


COULTER DATA
SAMPLE NO. STAX-1 CE-5
— mg/l
STD. DEV. 1.25
MEAN 6.02
N 100.00
STD. ERROR OF MEAN 0.13
VOLUME FREQUENCY PERCENT
PHI
2
3
4
5
6
7
8
9
10
20
30
40
50


COULTER DATA
SAMPLE NO. STAX-1 C6-M.
0.85 mg/l
STD. DEV. 1.21
MEAN 6.50
N 100.00
STD. ERROR OF MEAN 0.12
VOLUME FREQUENCY PERCENT
0
10
20
30
40
50
2
3
4
5
6
7
8
9
PHI


COULTER DATA
SAMPLE NO. STAX-1 C6-8
1.02 mg/l
STD. DEV. 1.26
MEAN 6.22
N. 100.00
STD. ERROR OF MEAN 0.13
VOLUME FREQUENCY PERCENT
0
10
20
30
40
50
2
3
4
5
6
7
8
9
PHI

Appendix C

SLUDGE DATA SUMMARY

These data were provided by the United States Environmental Protection Agency, Region II, Edison, New Jersey.

SLUDGE DATA SUMMARY

	Sludge Origin				
	Middlesex Co. SA	Bergen Co. SA	NYC Owls Head STP	NYC Newtown Ck. STP	Gen. Marine Trans. Corp.
Volume (c.y.)	6650	3460	2370	3780	1904
Specific Gravity	1.089	1.039	1.057	1.021	1.010
Total Solids (%)	28.2	18.0	15.6	13.6	24.3
Suspended Solids (%)	16.8	17.8	4.9	8.4	3.2
pH (su)	5.2	5.7	7.4	7.7	7.1
Specific Conductance (umhos/cm)	5100	6500	9250	12000	4820
Mercury (mg/kg)	0.98	3.0	0.68	0.85	2.6
Cadmium (mg/kg)	39	11.6	4.4	24	5.0
Copper (mg/kg)	710	426	556	481	219
Lead (mg/kg)	950	186	266	910	79
Chromium (mg/kg)	188	816	106	414	39
Arsenic (mg/kg)	6	1.4	4	<1	<1
Nickel (mg/kg)	54	110	41	58	18

SLUDGE DATA SUMMARY (Cont)

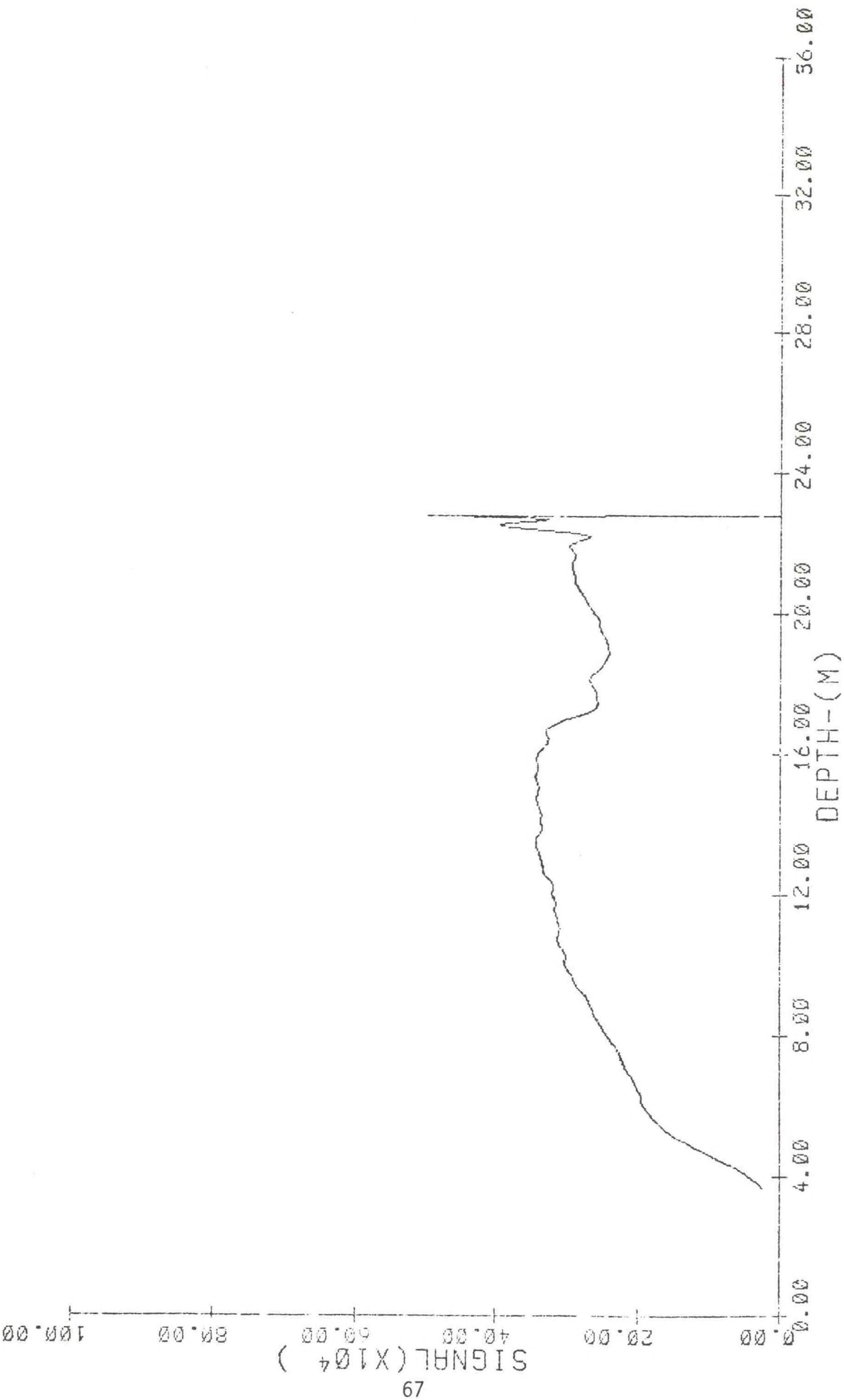
Transporter	Origin of Sludge	Date and Time of Dump	Barge/Vessel	Volume
Modern Trans. Co.	Middlesex Co. STP	9/23/75-0230	Lisa	6650
Modern Trans. Co.	Bergen Co. STP	9/22/75-2010	Raritan	3460
NYC-EPA	Newtown Ck. STP	9/22/75-1100	North River	3780
NYC-EPA	Owls Head STP	9/22/75-1010	Owls Head	2370
Gen. Marine Corp.	Nassau Co. Bay Park	9/22/75-1450	Susan Frank	1904

Appendix D

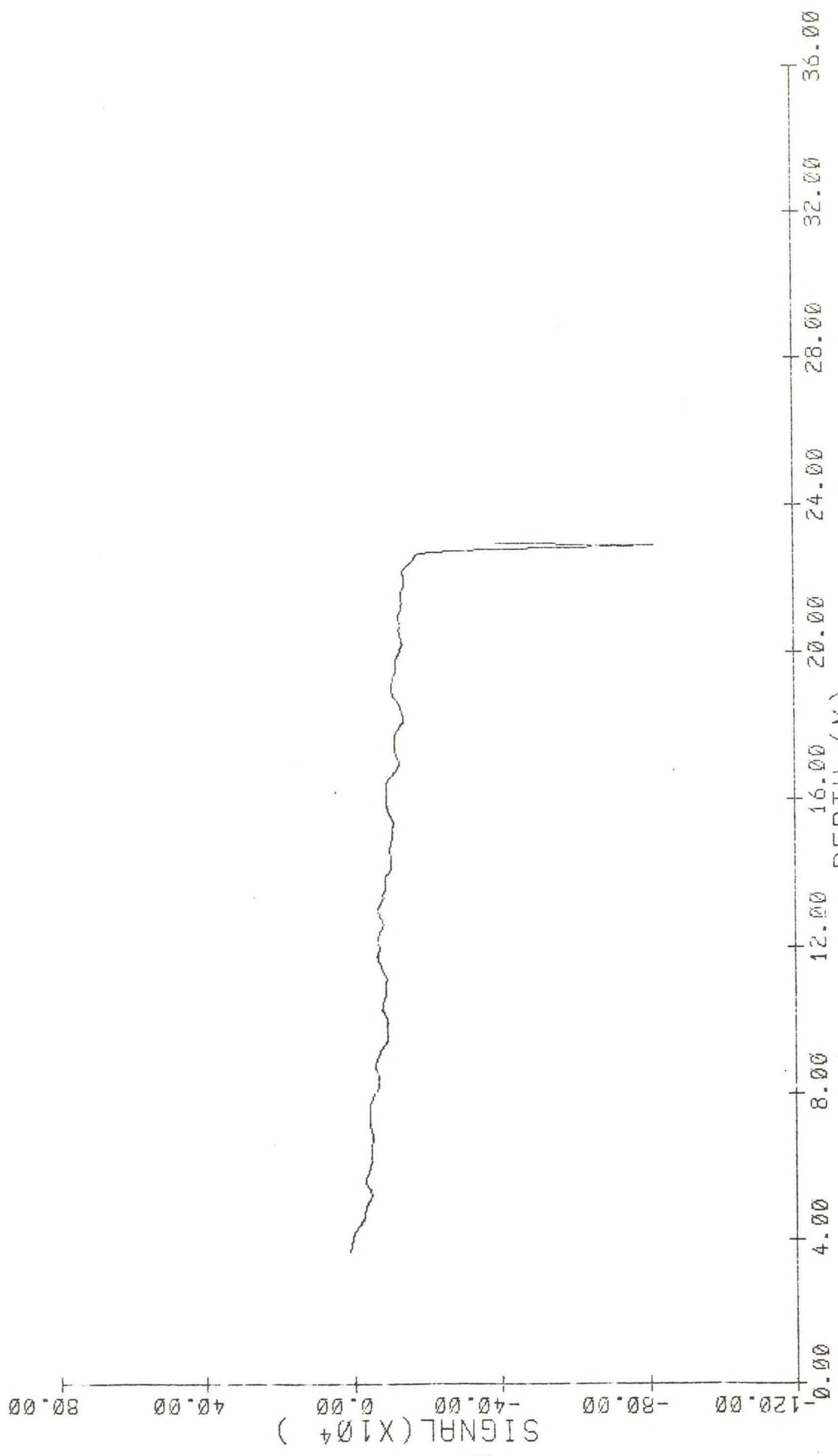
COMPUTER PROCESSED ACOUSTIC DATA

The plots that follow are:

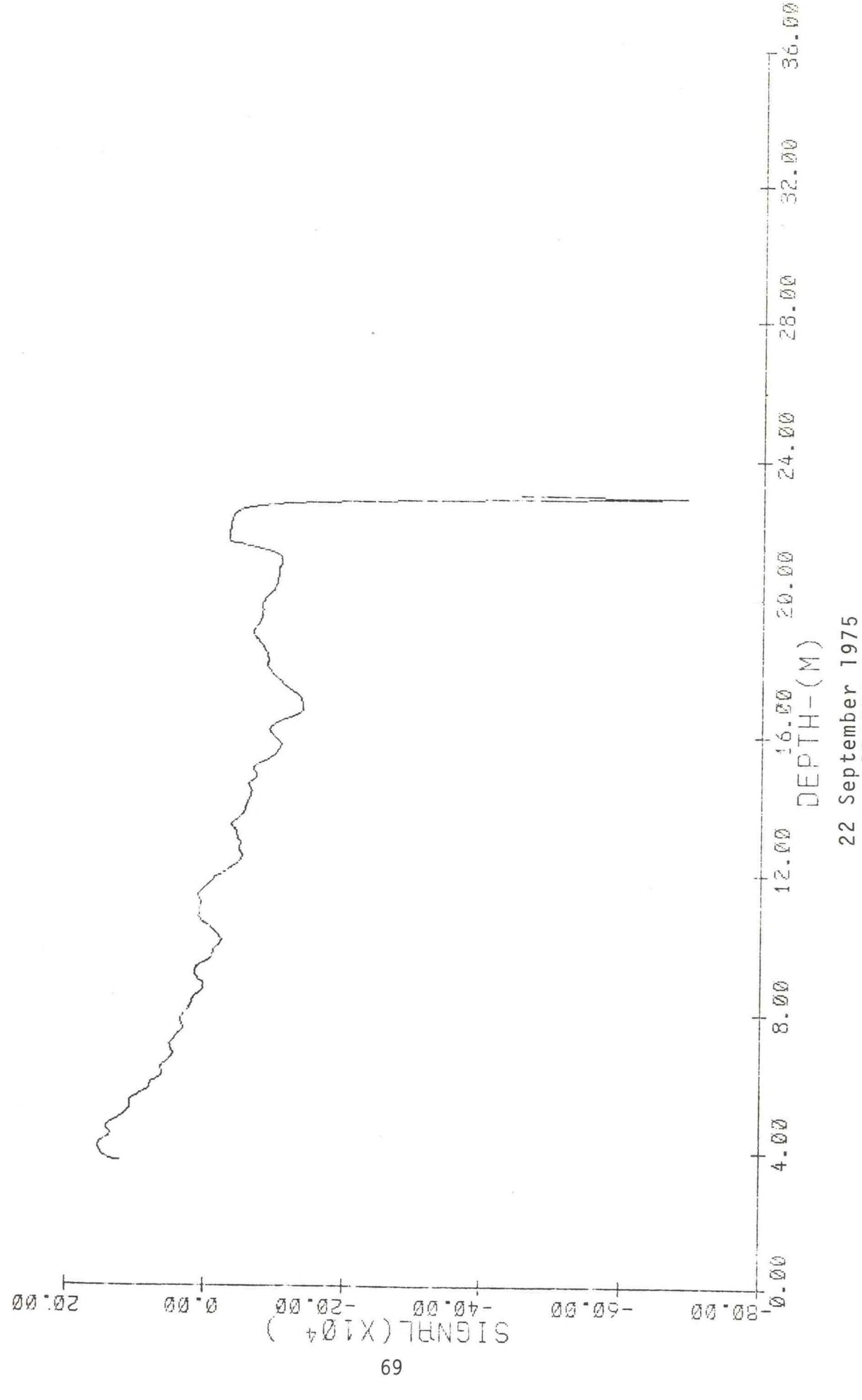
Scattering strength per unit volume (SIGNAL) as a function of time from the data recorded on magnetic tape from the 200 kHz device. The records are 15 second averages representing approximately twenty meters along the ship's track. To estimate how much scattering is done by the sewage sludge alone, the averaged scattering strength per unit volume from just outside the sludge dump was subtracted from each profile. This background signal is included as the last figure.

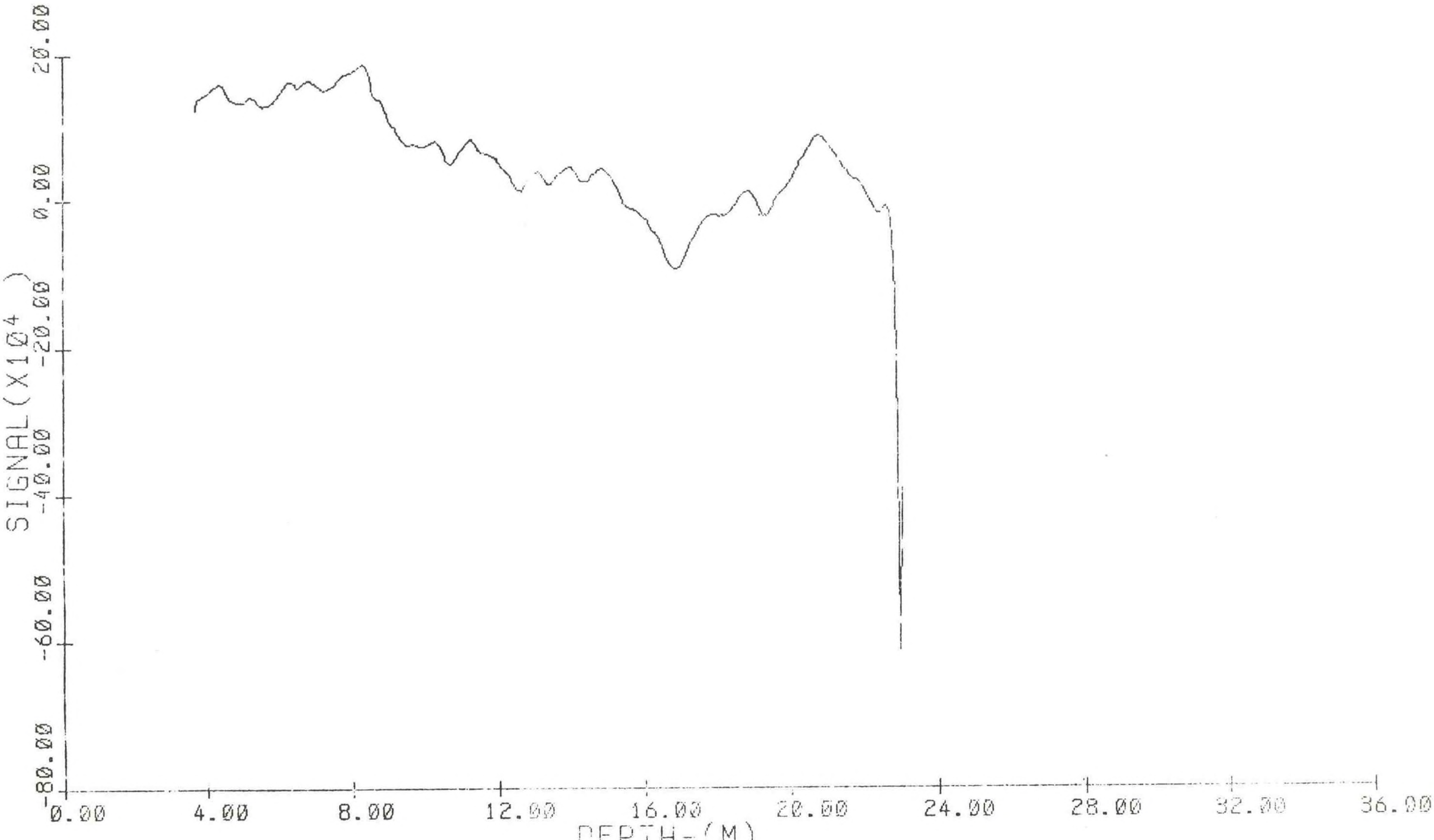


22 September 1975
113628-113501
EDT

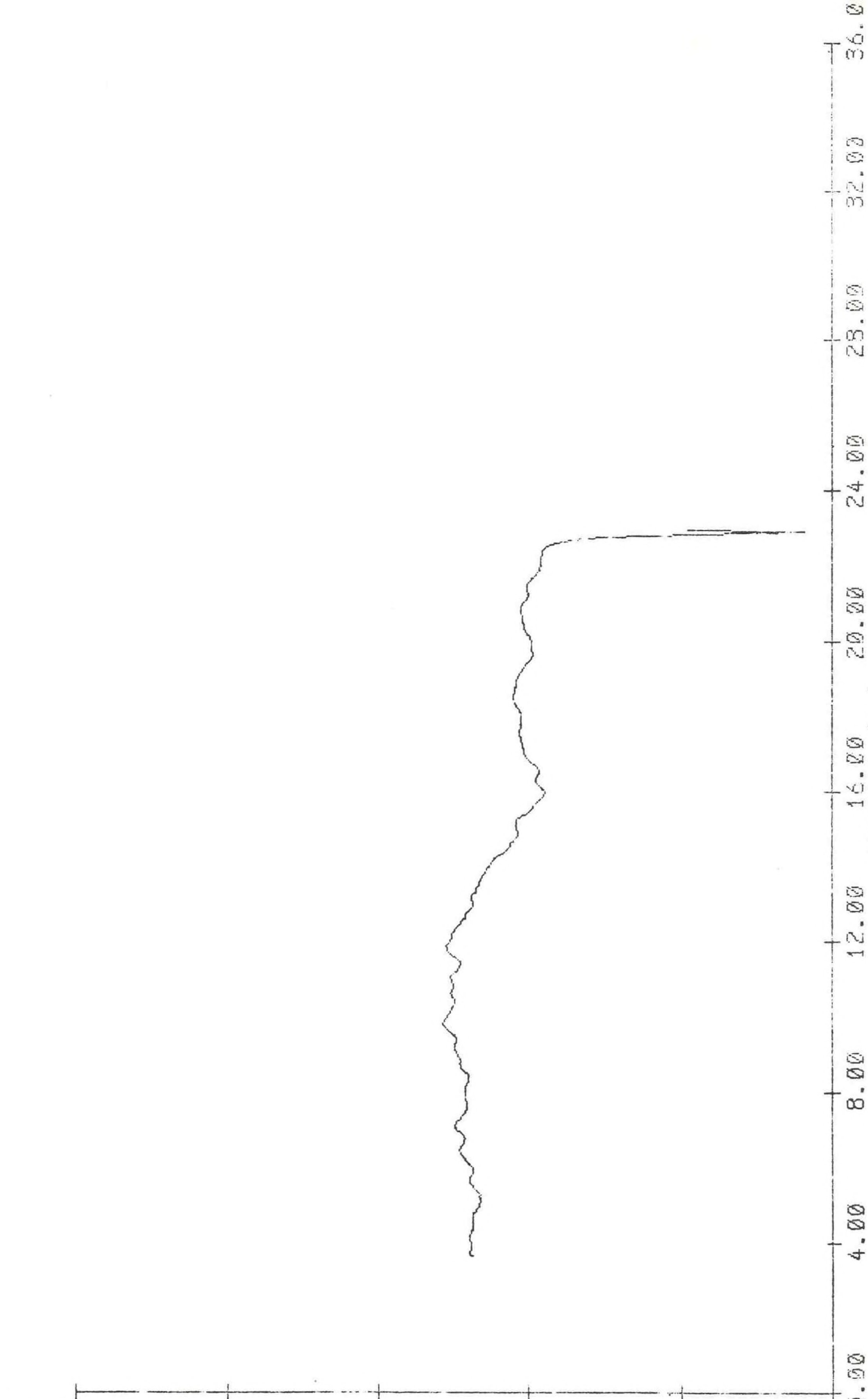


22 September 1975
113635
EDT

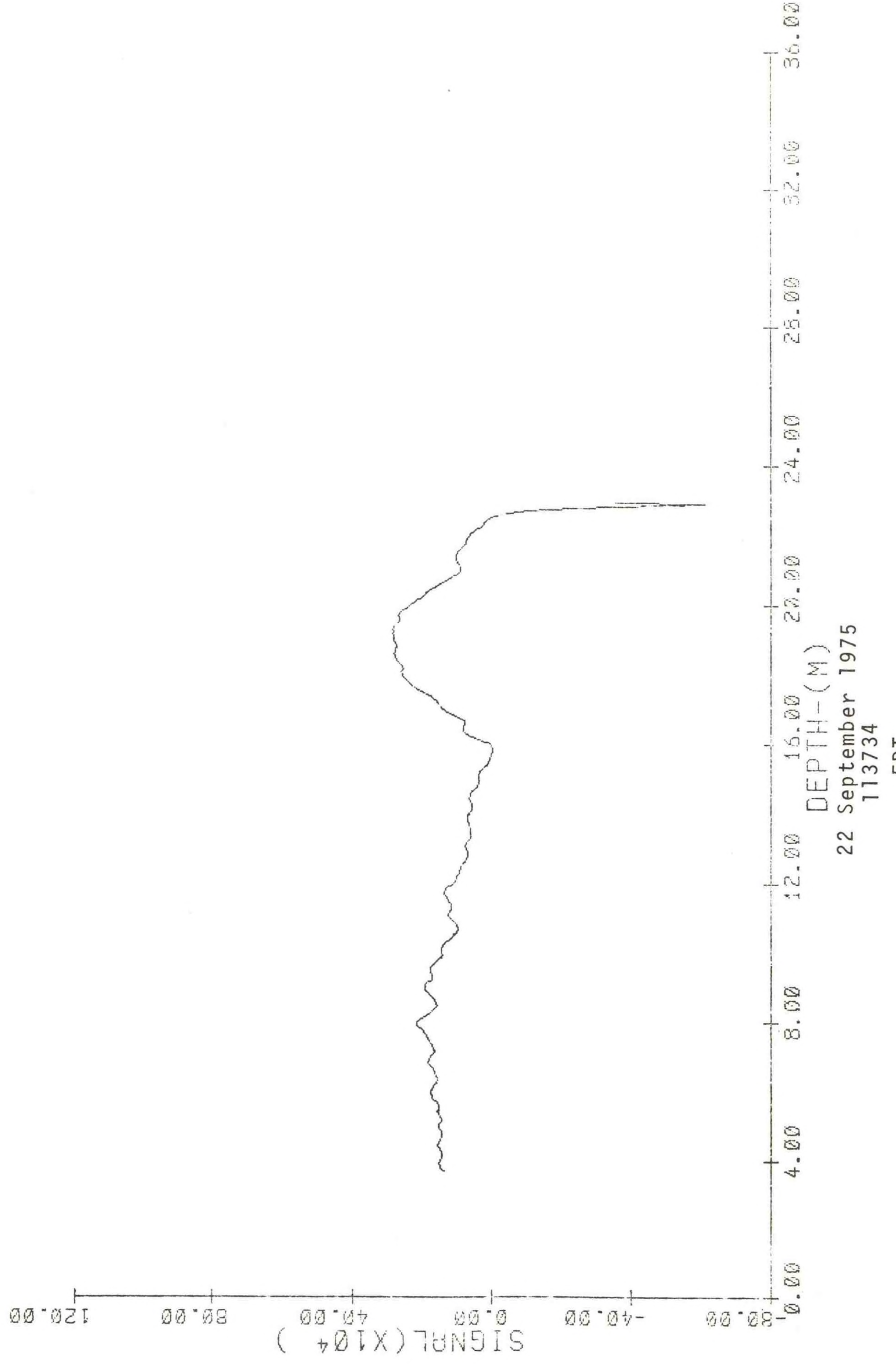

DEPTH-(M)
SIGNAL(X10^4)
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
36.00
20.00
0.00
-20.00
-40.00
-60.00
-80.00
22 September 1975
113651
EDT

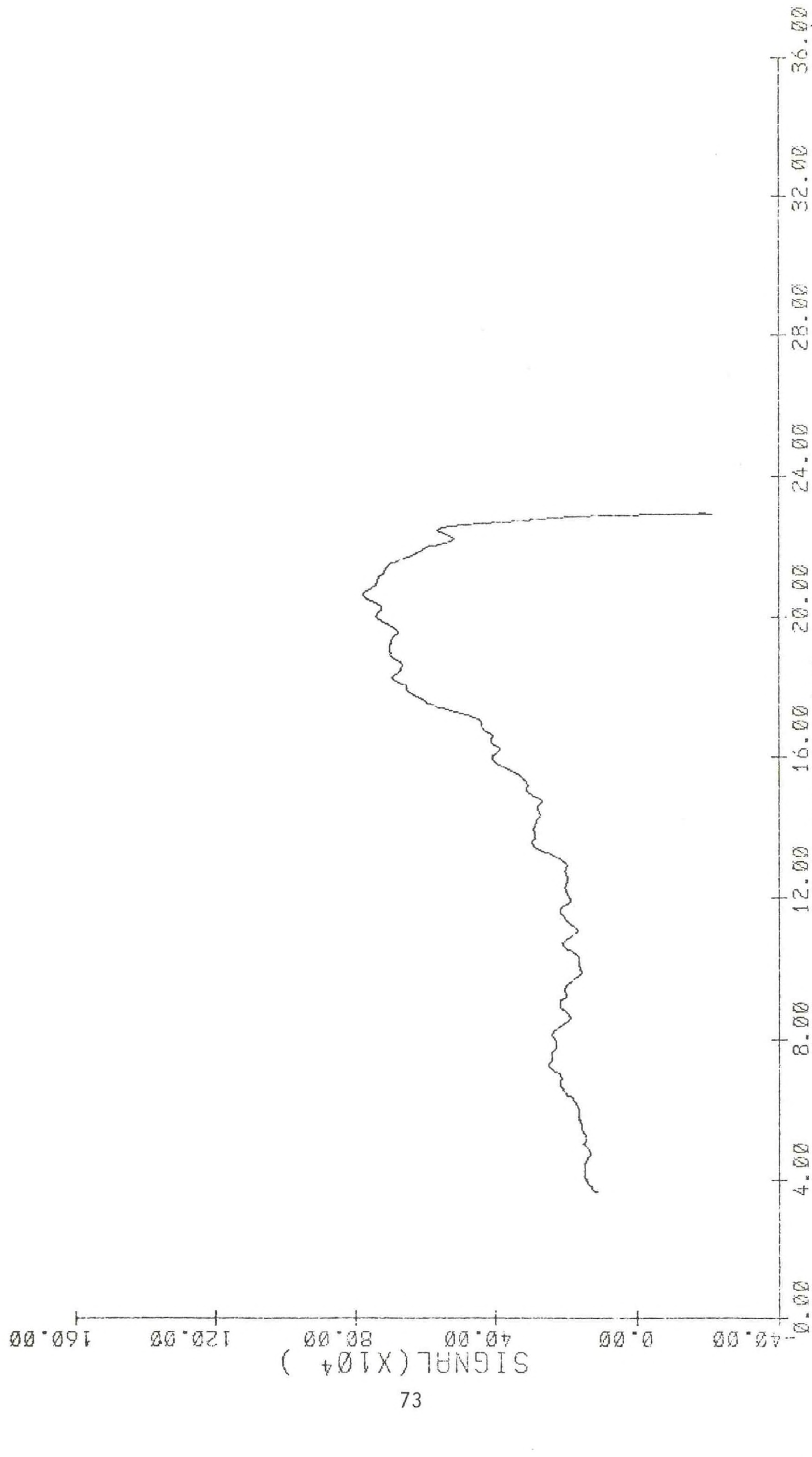


22 September 1975
113706
EDT

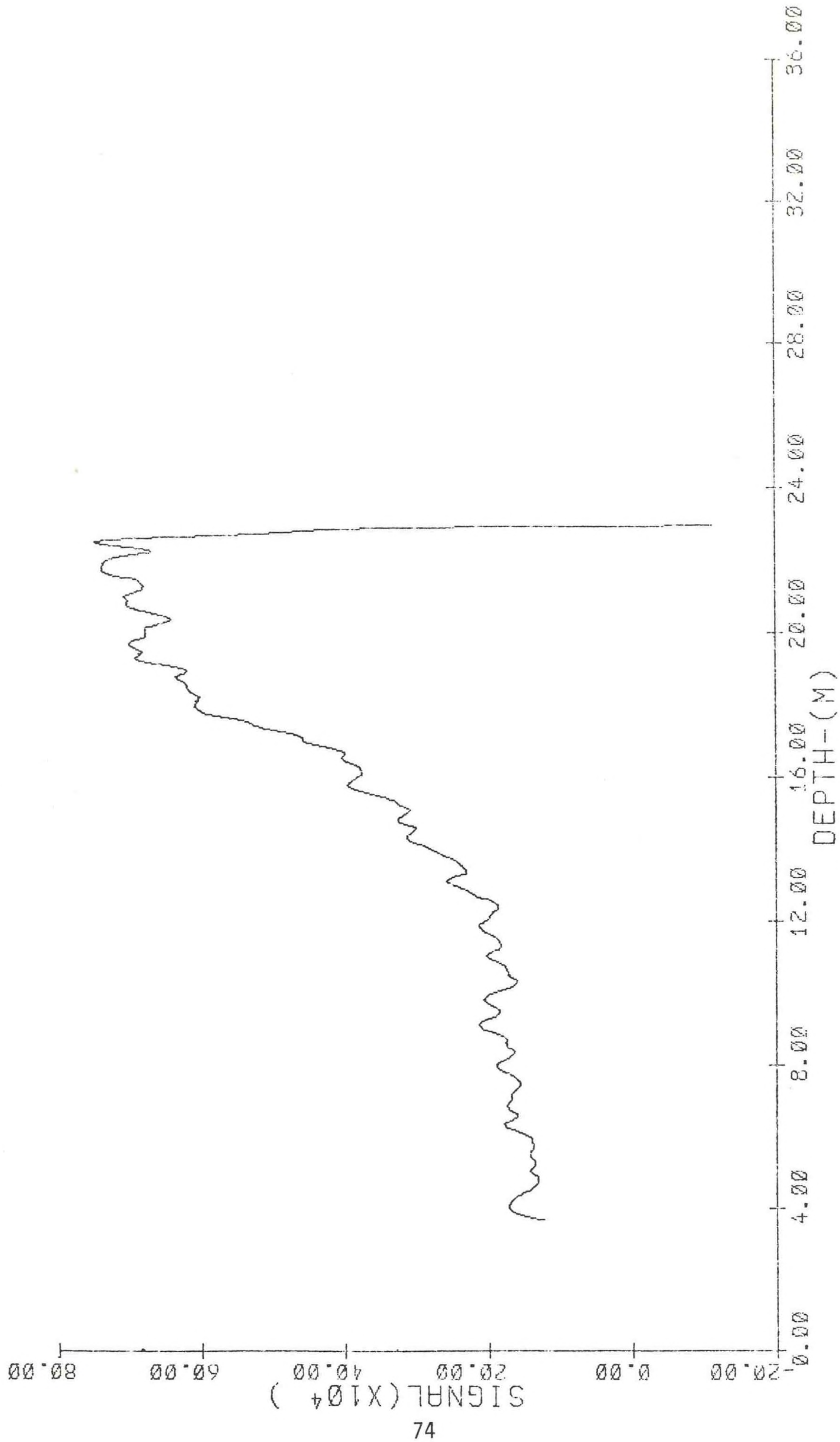


22 September 1975
113720
EDT

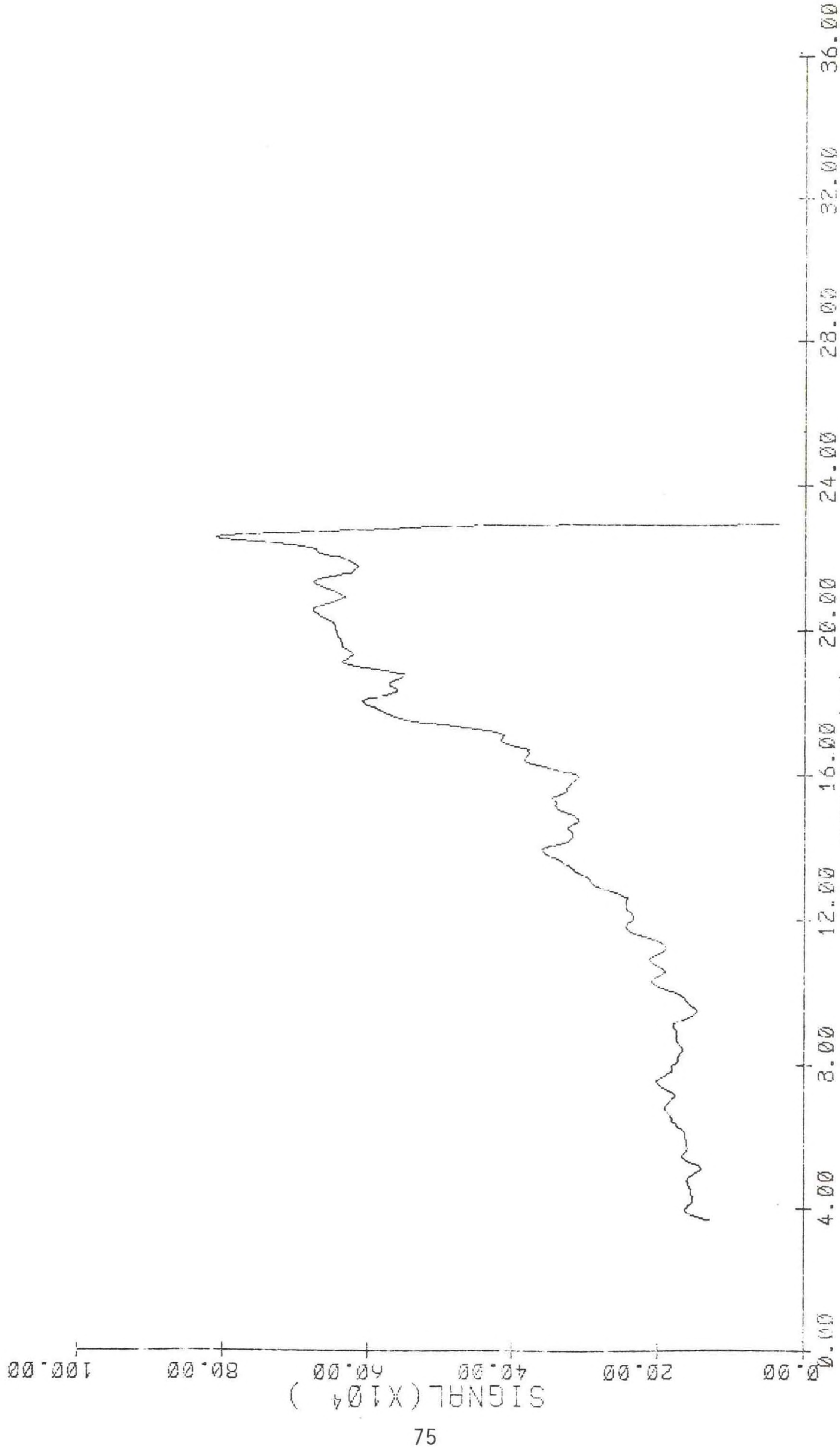

0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
36.00
DEPTH-(M)
22 September 1975
113734
EDT
-80.00
-40.00
0.00
40.00
80.00
120.00
SIGNAL(X10⁴)



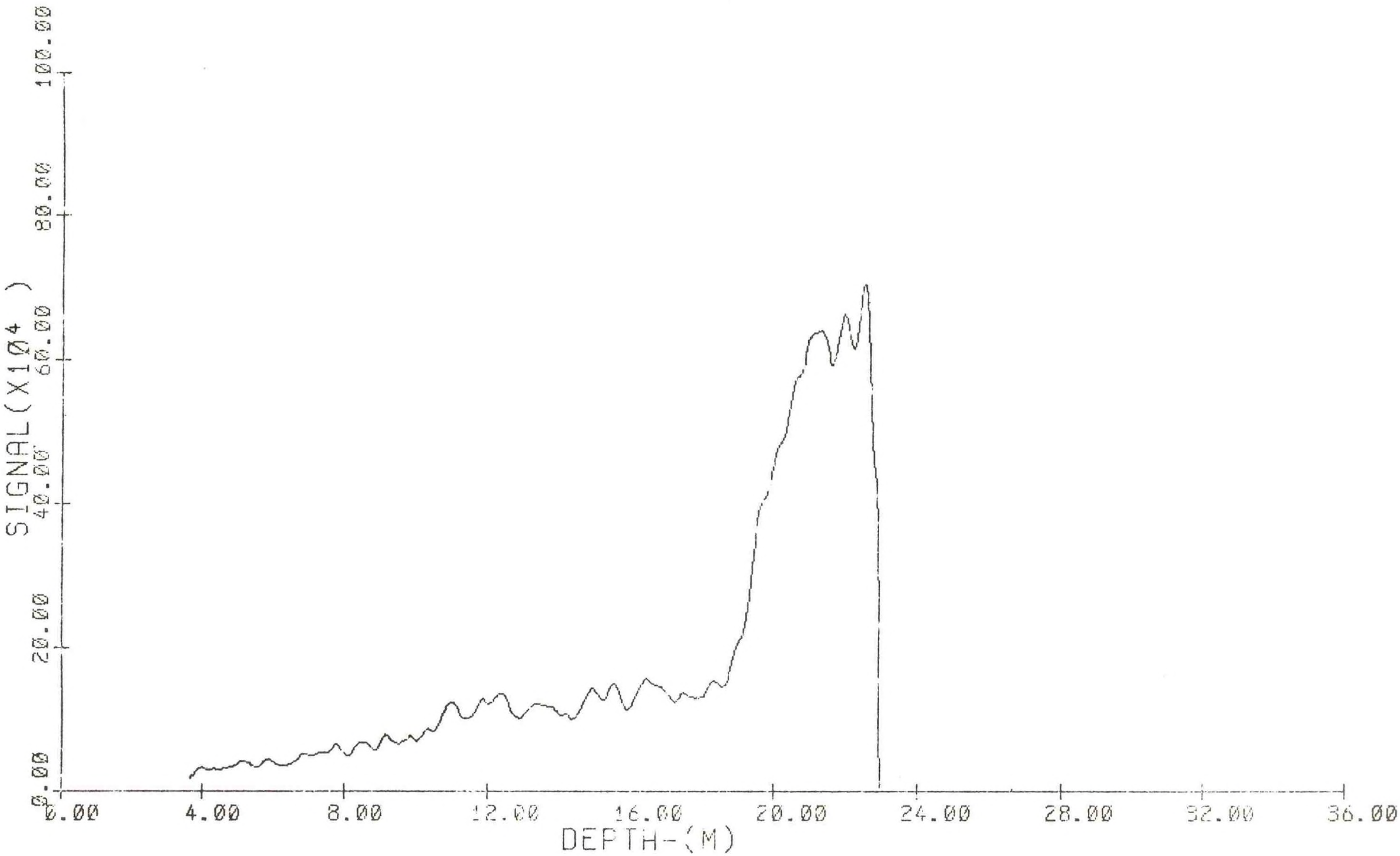
22 September 1975
1137:49 EDT



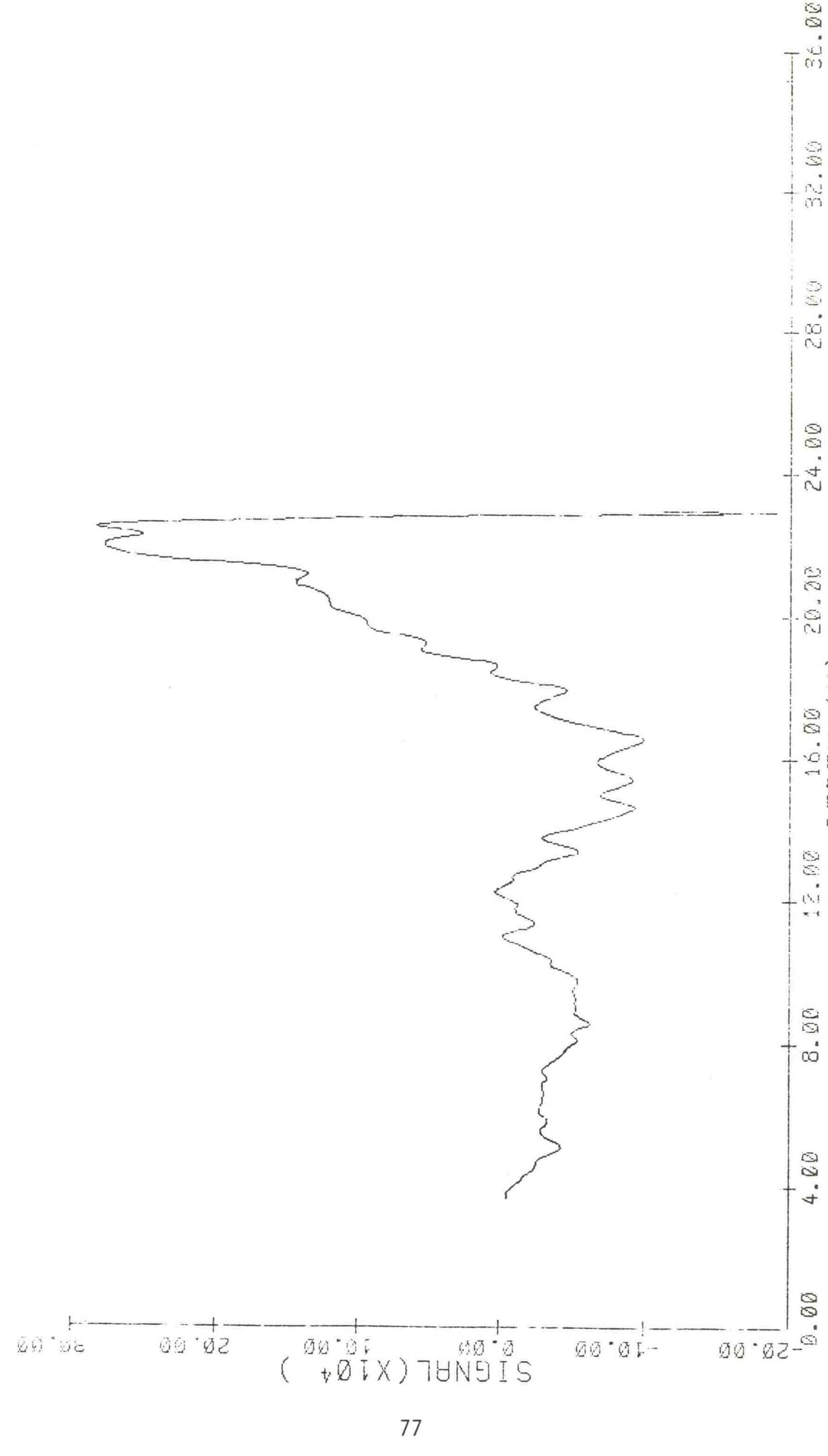
22 September 1975
1138:03 EDT



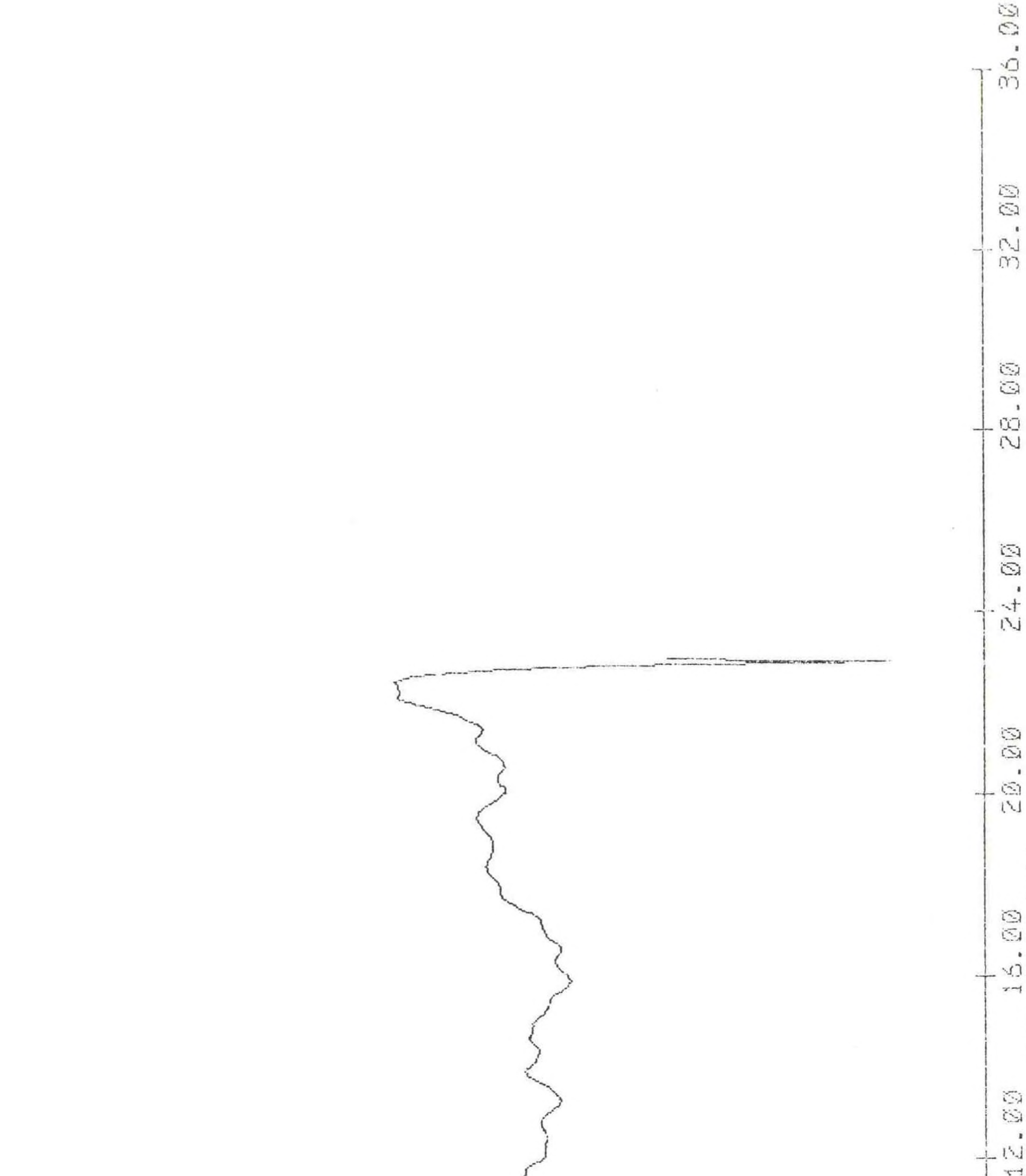
22 September 1975
113815
EDT



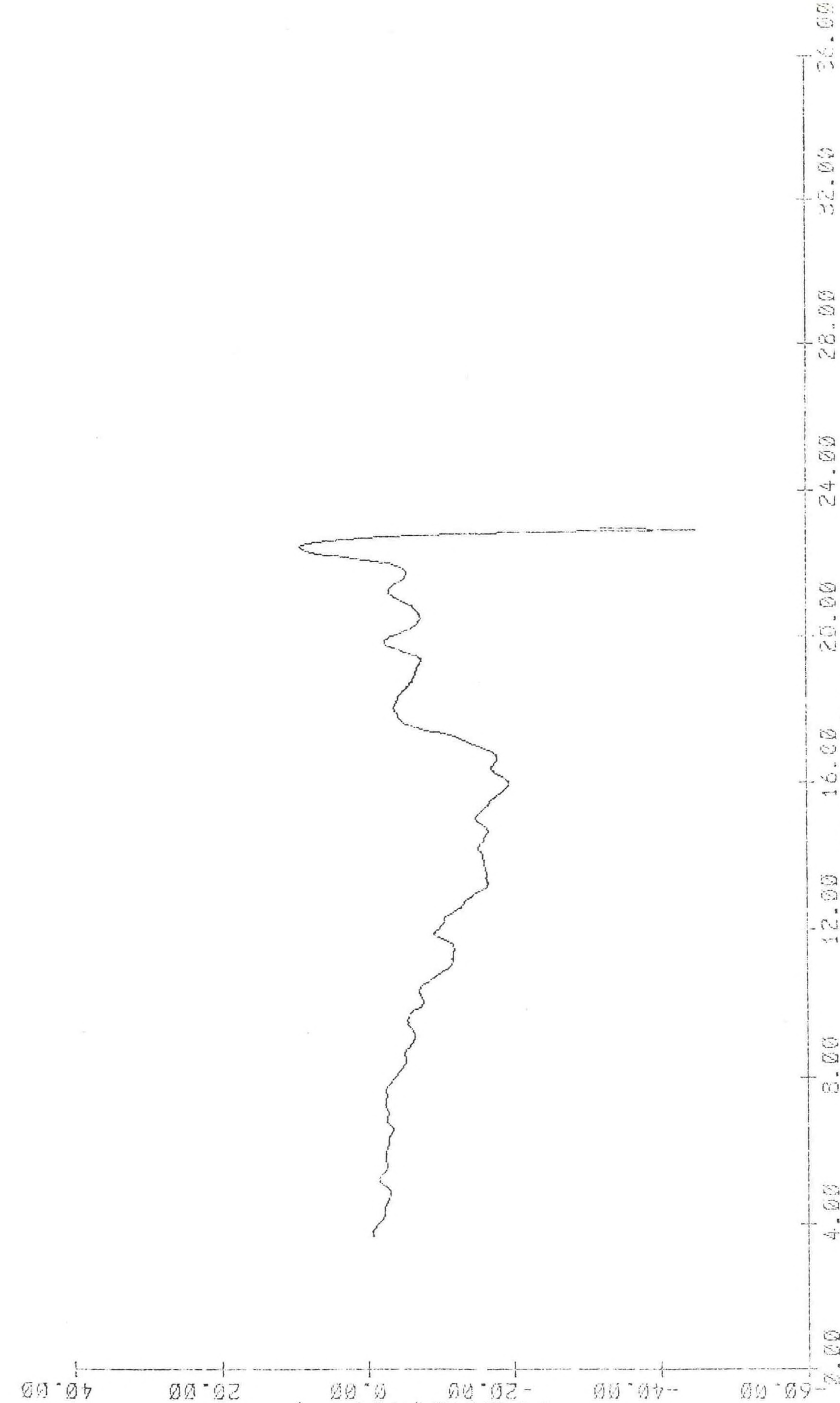
22 September 1975
113830
EDT



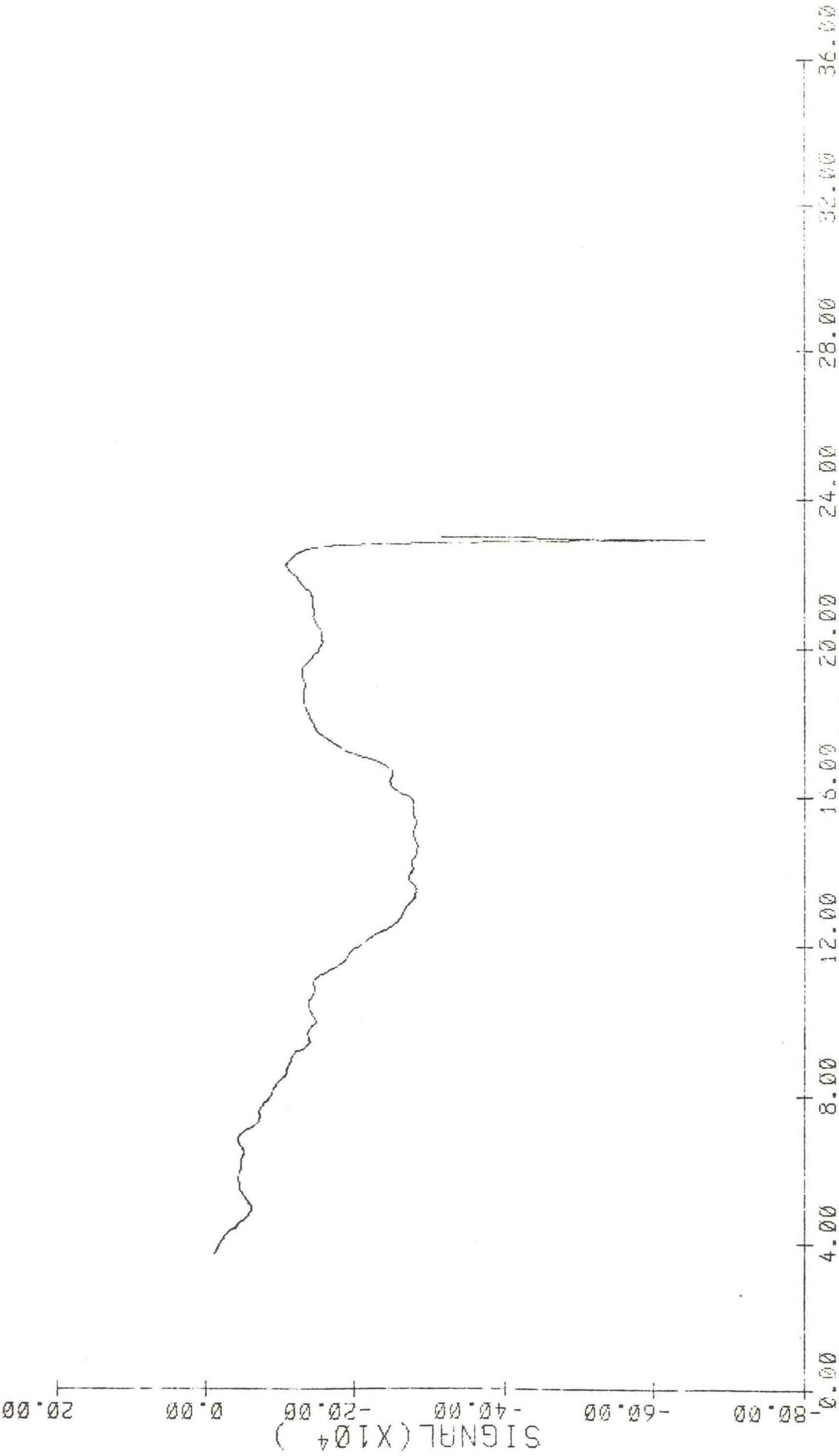
22 September 1975
113845
EDT



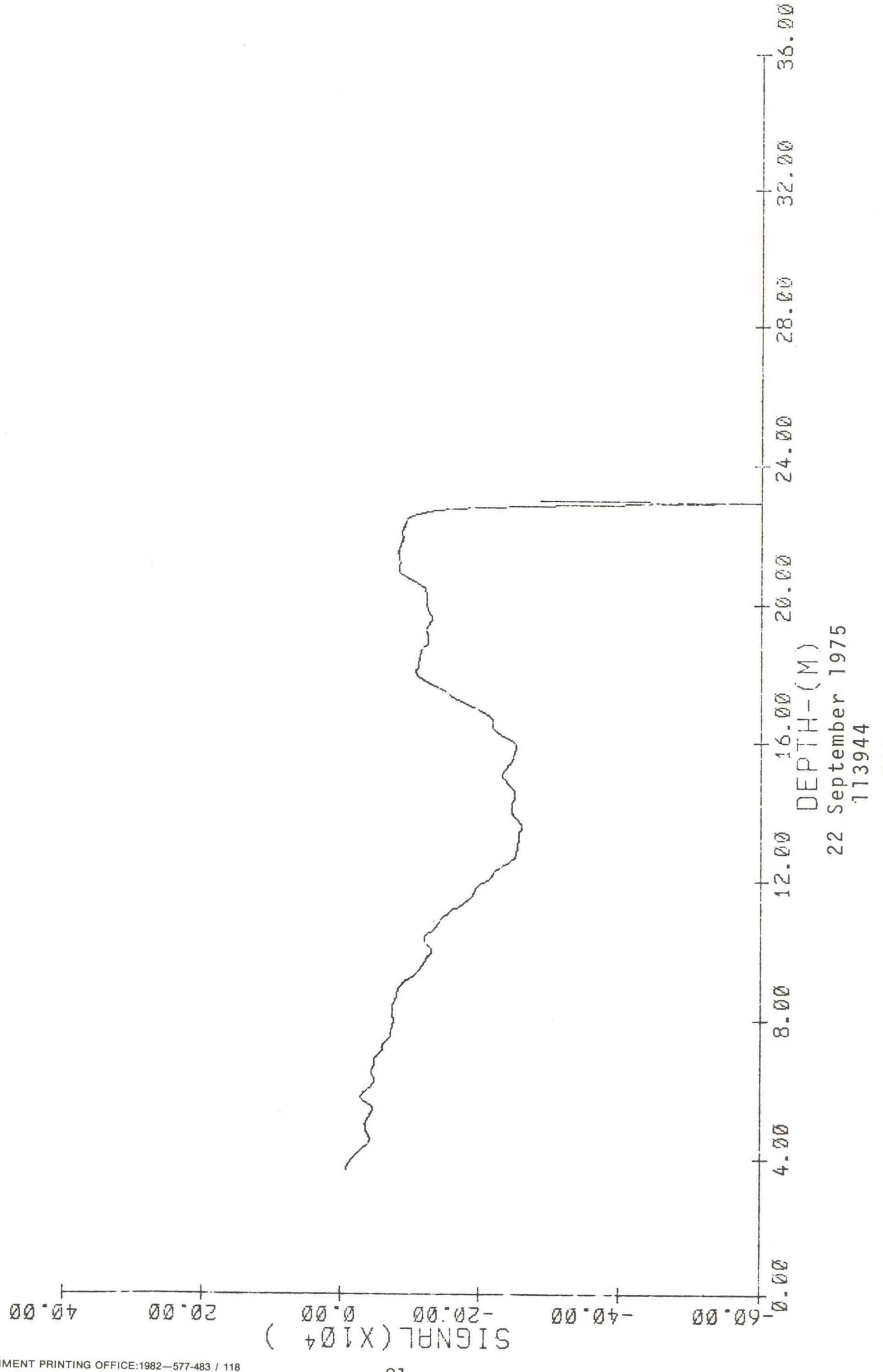
22 September 1975
1138:58 EDT



22 September 1975
1139:12 EDT



22 September 1975
113927
EDT



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