SCIENCE APPLICATIONS, INC.

DRAFT

EVALUATION OF THE
EFFECTIVENESS OF DREDGING
ON THE
KENNEBEC RIVER, ME

CONTRIBUTION #42

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DRAFT

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New England Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254

Submitted by:

Robin Robertson
Robert W. Morton
Science Applications, Inc.
Ocean Science & Technology Division
P.O. Box 509
One Washington Street
Newport, RI 02840
(401) 847-4210

SAI

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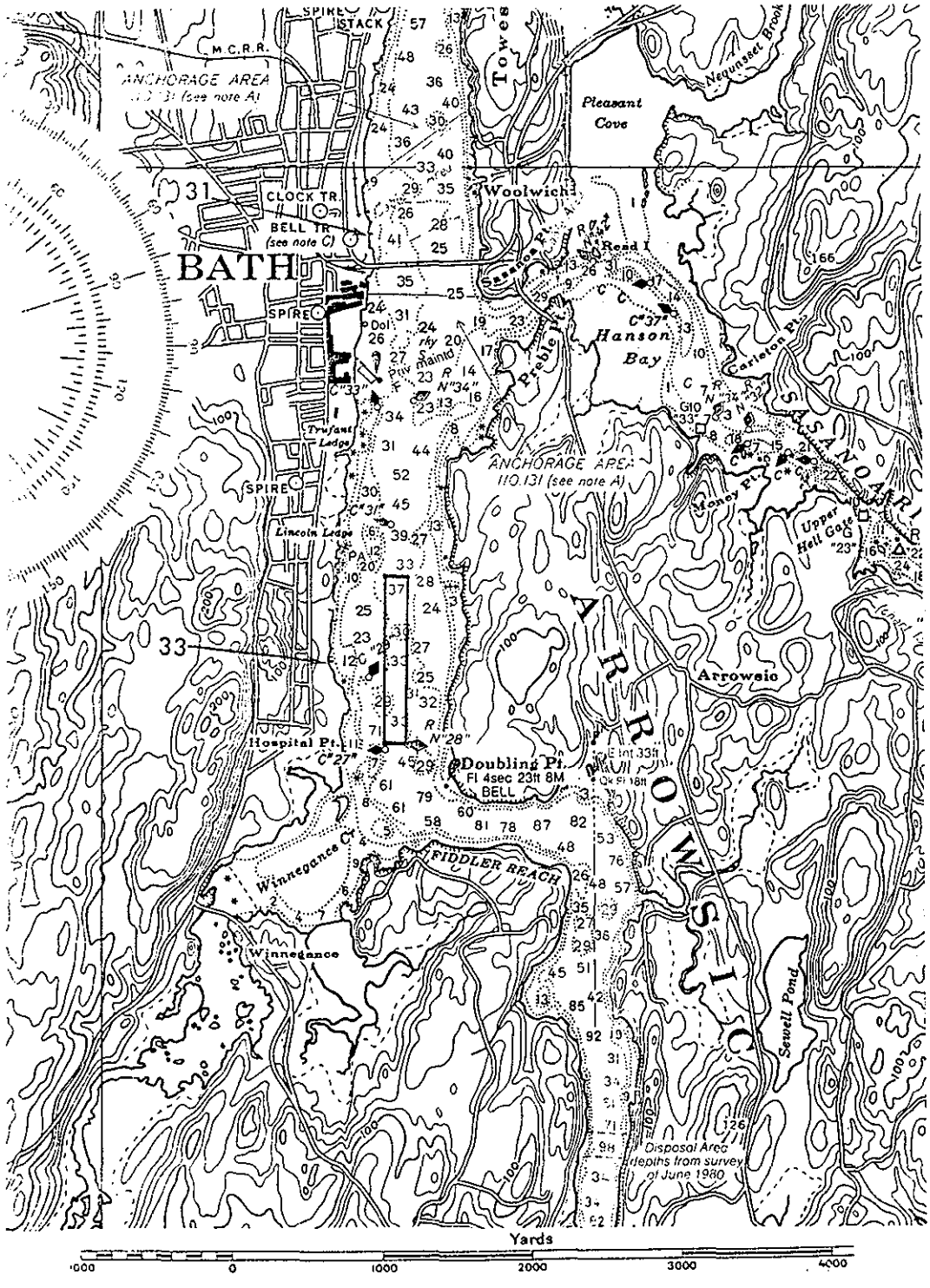
1.0 INTRODUCTION

The New England Division of the Corps of Engineers has been dredging the Kennebec River, south of Bath, Maine, over a period of years to ensure safe passage for ships entering and leaving the Bath Iron Works Shipyard. One section of the river, shown in Figure 1-1, is characterized by large sand waves which are constantly in motion, and therefore, it is important to determine whether the dredging activities conducted by the Corps in this region are effectively deepening the river in a semi-permanent manner or whether the sand immediately returns to the same equilibrium depth which existed before dredging.

In order to assess this situation, the New England Division conducted a series of replicate bathymetric surveys from January, 1980 through March, 1982. During this period, dredging of the study area took place in October, 1981. This report presents a comparison of all the surveys, through development of depth and volume difference measurements, to evaluate the effect of dredging relative to natural variation.

2.0 METHODS

The ten replicate bathymetric surveys were obtained from an area located approximately two nautical miles downstream of the Bath Iron Works on the Kennebec River (Fig. 1-1) and consisted of six parallel lanes oriented in a north-south direction, spaced approximately 30 meters apart. Although not all lines on all surveys were of equal distance, they averaged 1265 meters in length and were profiled on each of the following



KENNEBEC RIVER SURVEY AREA

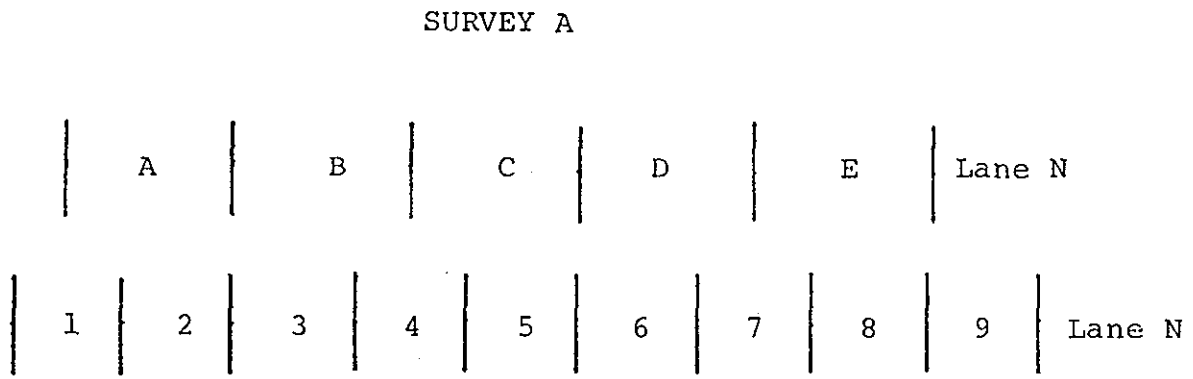
FIGURE 1-1

dates over a two year period:

- January 30, 1980
- June 11, 1980
- September 29, 1980
- November 14, 1980
- December 2, 1980
- October 5, 1981
- November 2, 1981
- December 14, 1981
- February 3, 1982
- March 4, 1982

Each of the ten surveys was digitized, recording depth as a function of distance north of an east-west line marking the southern border of the survey area. Since both the lane length and the distance between depth measurements varied, both between and within surveys, a re-gridding scheme was developed so that comparison of depth between two surveys was always made at the same location. The regridding was accomplished by the computer according to the scheme presented in Figure 2-1. The survey with the widest spacing between points was designated as the baseline and data from the more densely spaced survey were weighted according to the percentage overlap with the baseline depth locations. This gridding only took place in areas where lanes overlapped, consequently, in all cases, the volume difference was computed on the shortest of the two survey lanes being compared.

The volume differences were developed by integrating the depth curve to obtain the area from mean low water to the measured bottom over the lane length covered by both surveys. The integrated values from the later survey were then subtracted from the values for the first survey and multiplied by the lane width to determine the volume difference between surveys. Since the volume of water was measured, a negative change in volume



SURVEY A Points	SURVEY B Points used to calculate the corresponding value (weight)
A	1(33%), 2(67%)
B	3(67%), 4(33%)
C	4(33%), 5(67%)
D	6(67%), 7(33%)
E	7(33%), 8(67%)

Figure 2-1. Survey Regridding Scheme

meant an accretion to the bottom and a positive change meant erosion. Consequently, the result was multiplied by (-1) to obtain the volume change in sediment.

Because the length of the survey lines and the time between surveys varied substantially, a normalized volume difference was computed for each pair of surveys analyzed. This normalized difference was calculated by dividing the measured volume difference by the effective lane length (in meters), the lane width (in meters), and the number of days between surveys. The normalized result thus represents the average daily volume change over one square meter of the bottom.

3.0 RESULTS

Eleven survey pairs were analyzed for depth profile comparison and calculation of volume difference. Dredging of an estimated 41,000m^3 of material was accomplished during the period from October 5 to November 2, 1981. Those surveys completed before dredging took place are presented in Table 3-1a and those following dredging in Table 3-1b. Depth profiles for all surveys studied are presented in Appendix A, comparisons of those profiles are shown in Appendix B, and volume difference data on a lane by lane basis are presented in Appendix C.

Examination of Table 3-1a indicates a relatively active bottom with losses and gains of sediment volume sometimes in excess of that dredged. When examined in terms of daily volume change, there is also a substantial difference in the rate of accretion or erosion of sediment with a maximum ranging from plus to minus 3.7×10^{-3} $m^3/m^2/day$, while at other times, the

Table 3-1a. Pre-Dredging Changes in Volume and Normalized Depth Differences on the Kennebec River.

Survey	Volume Difference (m^3)	Normalized Volume Differences ($x10^{-3} m^3/m^2/day$)
January 30, 1980 to June 11, 1980	59,000	3.6
June 11, 1980 to September 29, 1980	12,000	0.9
September 29, 1980 to November 14, 1980	-27,000	-3.7
November 14, 1980 to December 2, 1980	-10,000	-0.3
December 2, 1980 to October 5, 1981	-40,000	-0.6

Note: Negative volume differences denote a loss of sediment volume from the first survey to the second.

$$\text{Normalized Volume Difference} = \frac{\text{Volume Difference}}{\text{Effective Lane Length} * \text{Lane Width} * \text{Number of Days}}$$

Table 3-1b. Post-Dredging Changes in Volume and Normalized Depth Differences on the Kennebec River.

Survey	Volume Difference (m^3)	Normalized Volume Differences ($x10^{-3} m^3/m^2/day$)
October 5, 1981 to November 2, 1981 dredging occurred	-64,000	-11.0
November 2, 1981 to December 14, 1981	2,500	0.3
December 14, 1981 to February 3, 1982	51,000	5.6
February 3, 1982 to March 4, 1982	-50,500	-9.6
November 2, 1981 to March 4, 1982	2,500	0.1
December 14, 1981 to March 4, 1982	-1,500	0.0

Note: Negative volume differences denote a loss of sediment from the first survey to the second.

$$\text{Normalized Volume Difference} = \frac{\text{Volume Difference}}{\text{Effective Lane Length} * \text{Lane Width} * \text{Number of Days}}$$

mean rate is less than 1 x 10^{-3} $m^3/m^2/day$.

A chart of the total volume change measured as a function of time is presented in Figure 3-1. The high variability of the pre-dredging period is readily apparent, however, it is important to note that over nearly a two year period from January 1980 to October 1981, the absolute volume change was quite small, indicating the site was close to equilibrium.

The effect of dredging is readily apparent in Figure 3-1 and Table 3-1b. Although the estimated dredge volume was only 41,000m^3, the survey difference technique showed a net loss of 64,000m^3. The depth profiles for the October 5 and November 2, 1981 surveys (Figs. 3-2a,b,c) show clearly the results of dredging at the site. Lane #1, which is located west of the dredge site, shows little change, while all of the others show a substantial increase in depth, and no shoals above the 10 meter isobath designated as the dredging depth. The excess loss of material above the dredging estimate is most likely due to resuspension and transport of material during the dredging operation, but may also be influenced by a continual loss of sediment from the survey area beyond the boundaries of the dredging operation.

The impact of dredging is also apparent in the normalized volume difference, (11 x $10^{-3}m^3/m^2/day$) where the rate of loss was nearly three times greater than the maximum observed during any non-dredging period (3.7 x 10^{-3} $m^3/m^2/day$), and 25 times greater than typical ambient values observed before and after dredging (5 x 10^{-4} $m^3/m^2/day$).

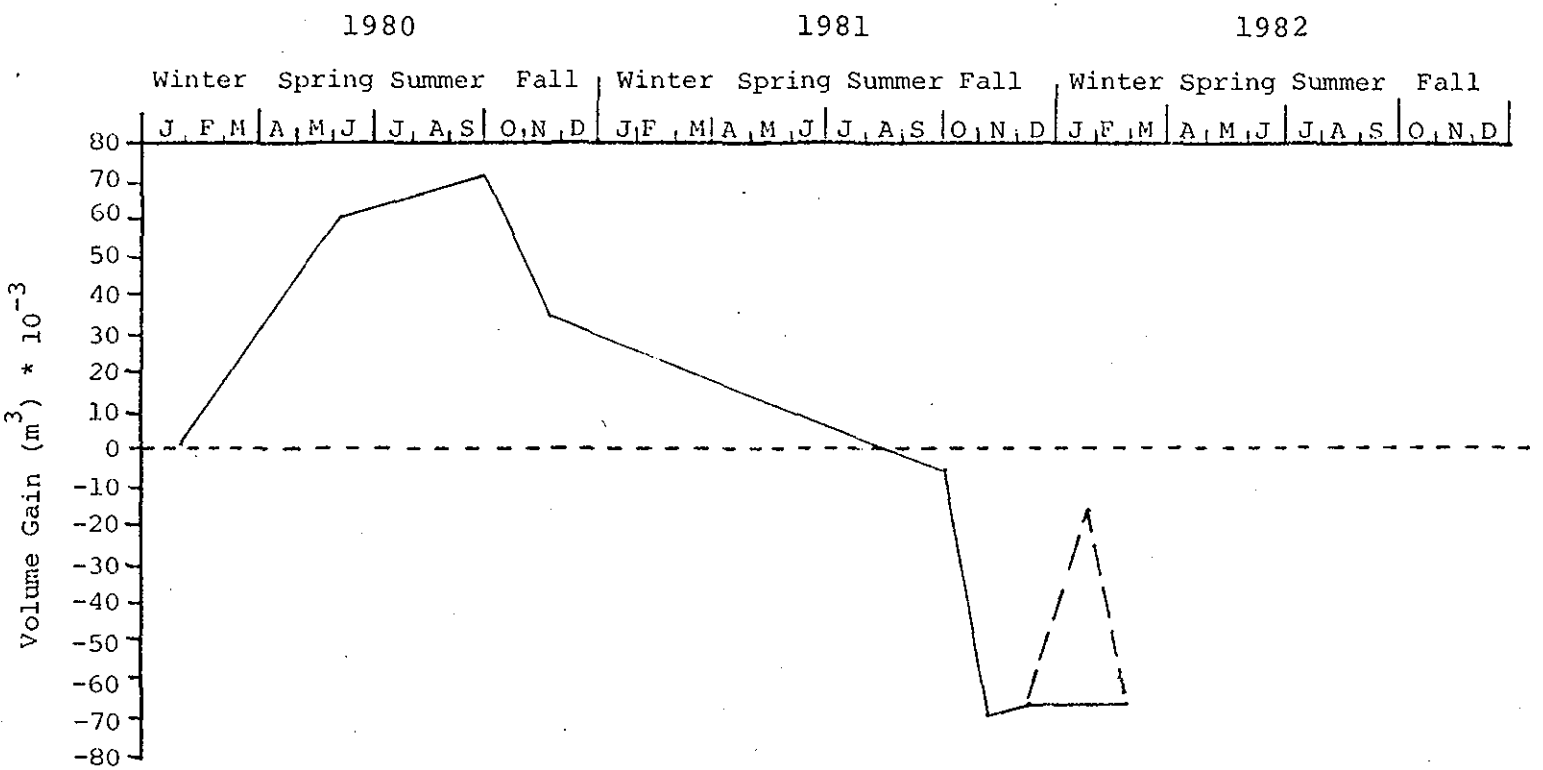


Figure 3-1. Total Volume Change with Time.

DEPTH DIFFERENCES BETWEEN PRE- AND POST-DREDGING SURVEYS, OCTOBER 5, 1981 AND NOVEMBER 2, 1981

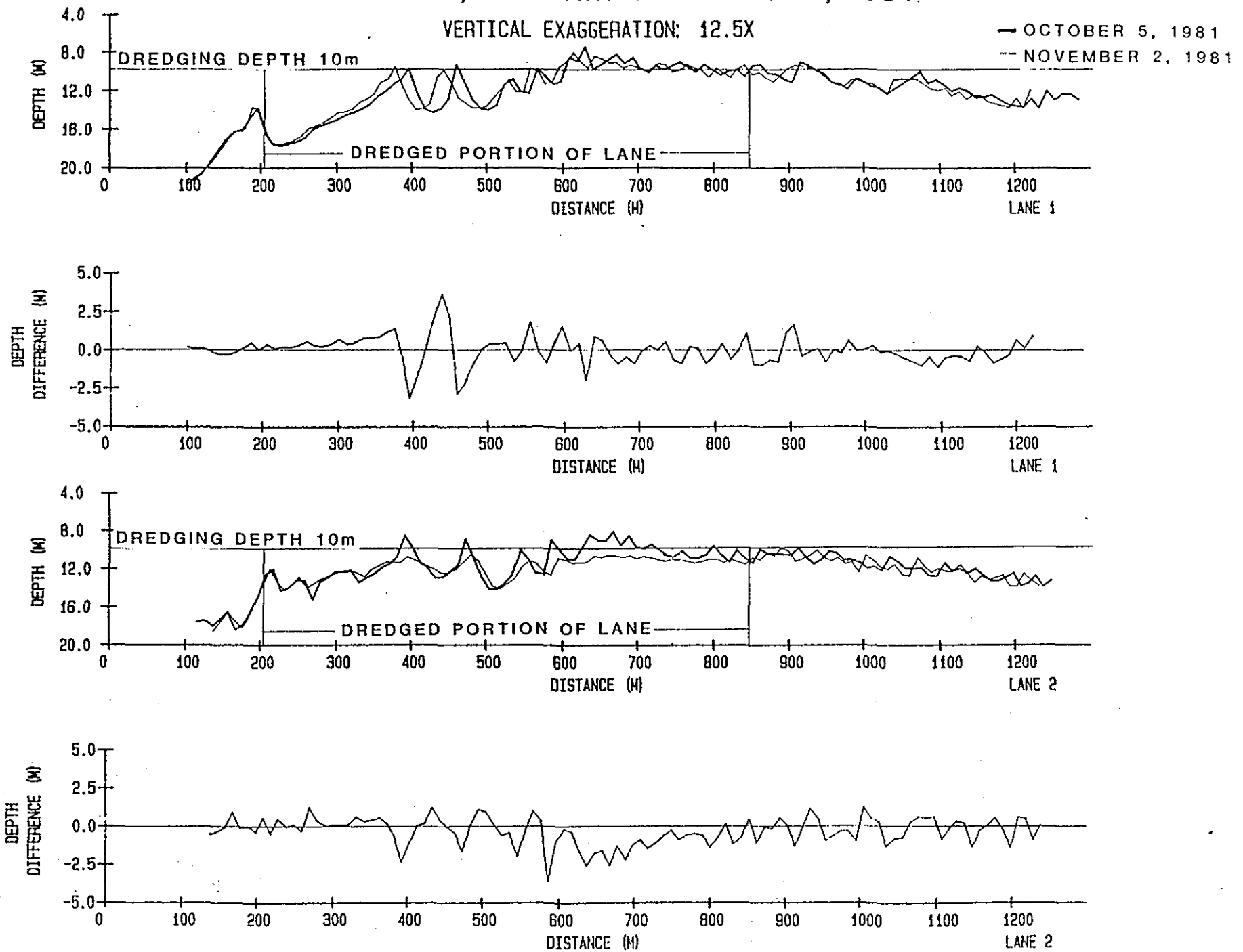


Figure 3-2a

DEPTH DIFFERENCES BETWEEN PRE- AND POST-DREDGING SURVEYS, OCTOBER 5, 1981 AND NOVEMBER 2, 1981

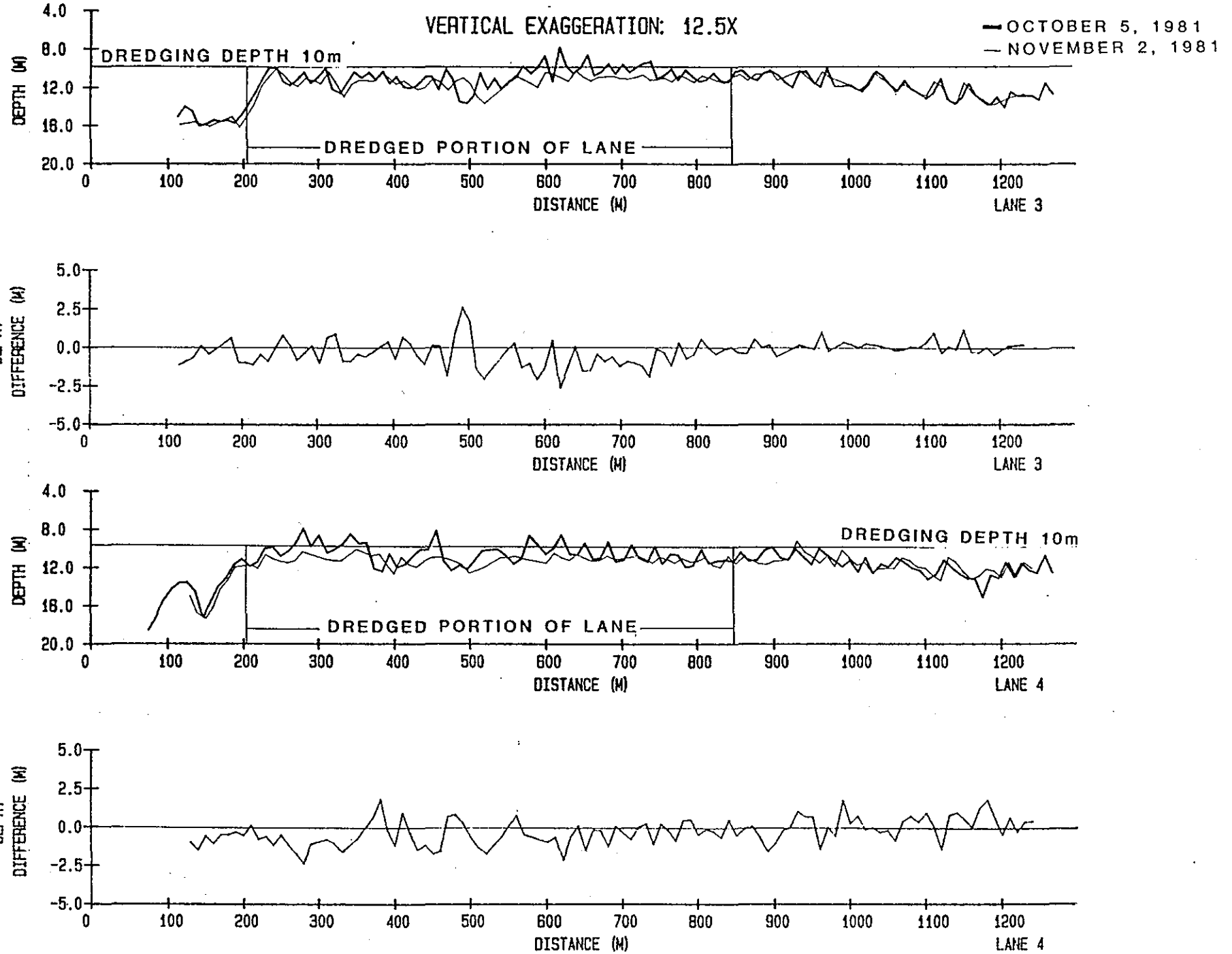


Figure 3-2b

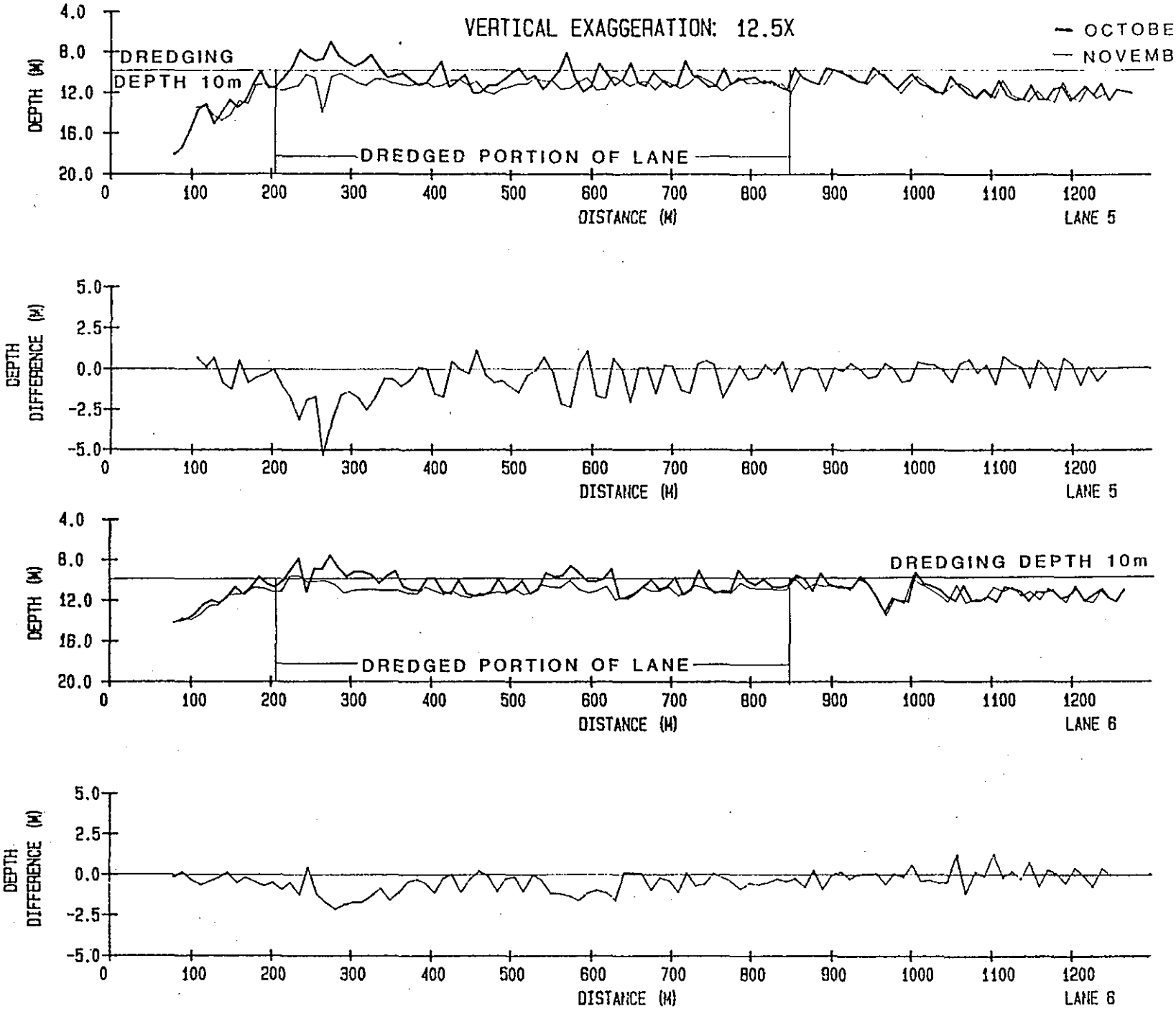

DEPTH DIFFERENCES BETWEEN PRE- AND POST-DREDGING SURVEYS,
OCTOBER 5, 1981 AND NOVEMBER 2, 1981
VERTICAL EXAGGERATION: 12.5X
OCTOBER 5, 1981
NOVEMBER 2, 1981
DREDGING
DEPTH 10m
DREDGED PORTION OF LANE
DEPTH (M)
DISTANCE (M)
LANE 5
DEPTH DIFFERENCE (M)
DISTANCE (M)
LANE 5
DREDGING DEPTH 10m
DREDGED PORTION OF LANE
DEPTH (M)
DISTANCE (M)
LANE 6
DEPTH DIFFERENCE (M)
DISTANCE (M)
LANE 6

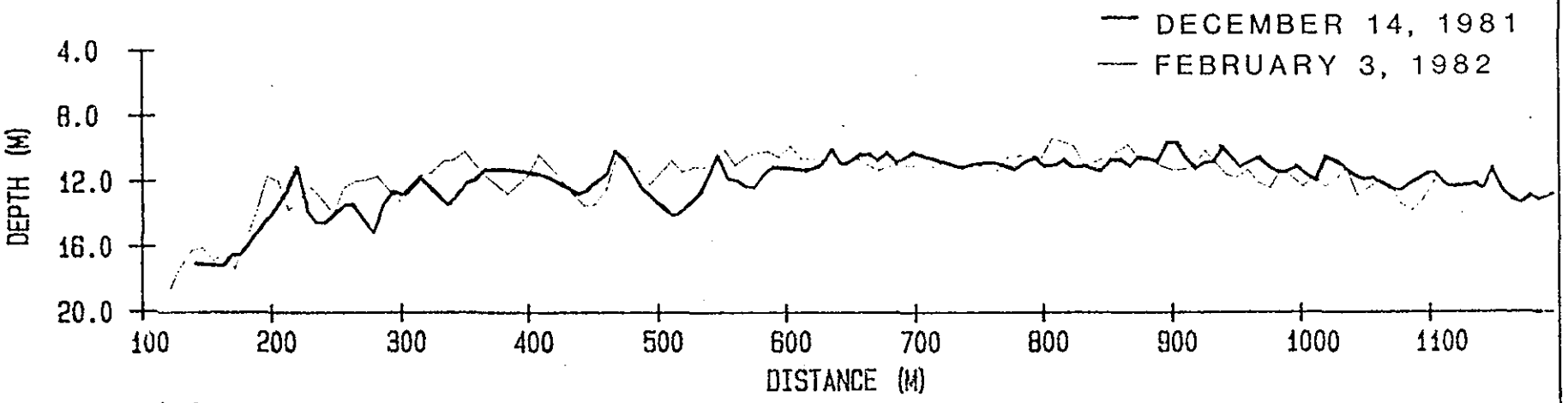
Figure 3-2c

Following dredging, the bottom appears to have remained stable, although some doubt is placed on this stability by the survey conducted on February 3, 1982 (shown by the dotted line on Figure 3-1). This survey indicated an accretion of 51,000m^3 from December to February, followed by a nearly identical loss from February to March. Comparison of the December/February and December/March data (Figs. 3-3 a&b) reveals that the depth profiles in February were substantially different from December (3-3a), while those from March (3-3b) were very similar, and that the volume difference from December to March was quite small.

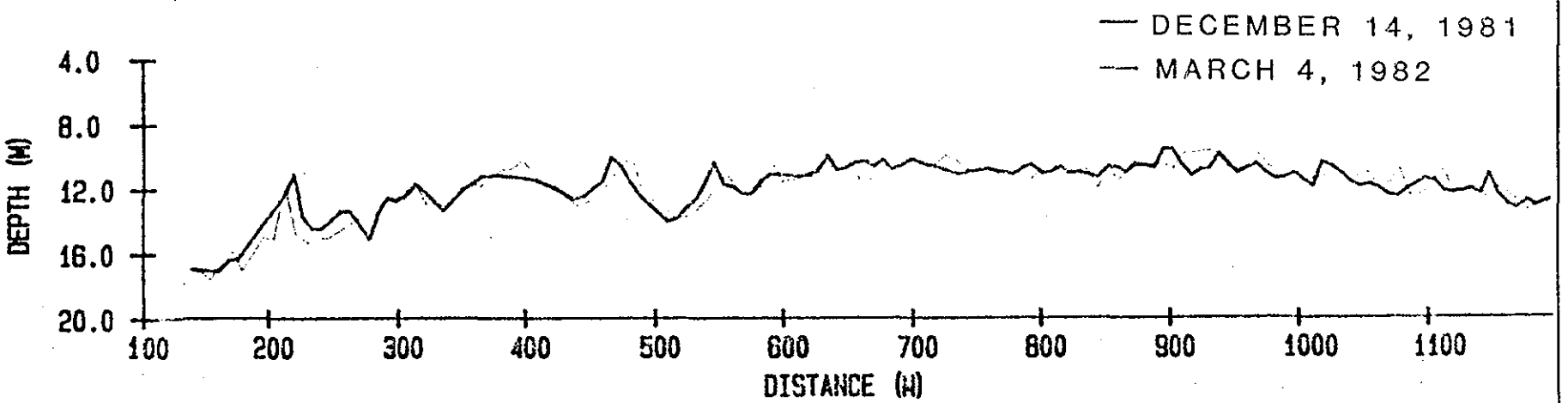
Considering the configuration of the bottom in February, the continuous forces acting on the sand waves, and the total volume of sediment involved, it would be highly unlikely for the bottom topography in March to reform identical to that observed in December. A more logical explanation would be some sort of measurement error or offset in the February survey and very little change in bottom conditions from December through March. Consequently, the February survey should be neglected when considering the results of this study.

If this is done, then the changes following dredging are very small, and although only four months were examined, there was very little indication of renewed shoaling and a return to the original equilibrium condition. Most of the changes that do occur are confined to lane #1, which was not included in the dredging area (Figs. 3-4a,b,c).

Although they do not contain a substantial volume of sediment, there are several shoals, particularly in Lanes 4, 5 and 6 that extend slightly above the 10 meter isobath which means



a) lane 2 of December 14, 1981 and February 3, 1982



b) lane 2 of December 14, 1981 and March 4, 1982

Figure 3-3. Comparison between Depth Profile Pairs for
a) December 14, 1981 and February 3, 1982 and
b) December 14, 1981 and March 4, 1982

DEPTH DIFFERENCES BETWEEN DECEMBER 14, 1981 AND MARCH 4, 1982

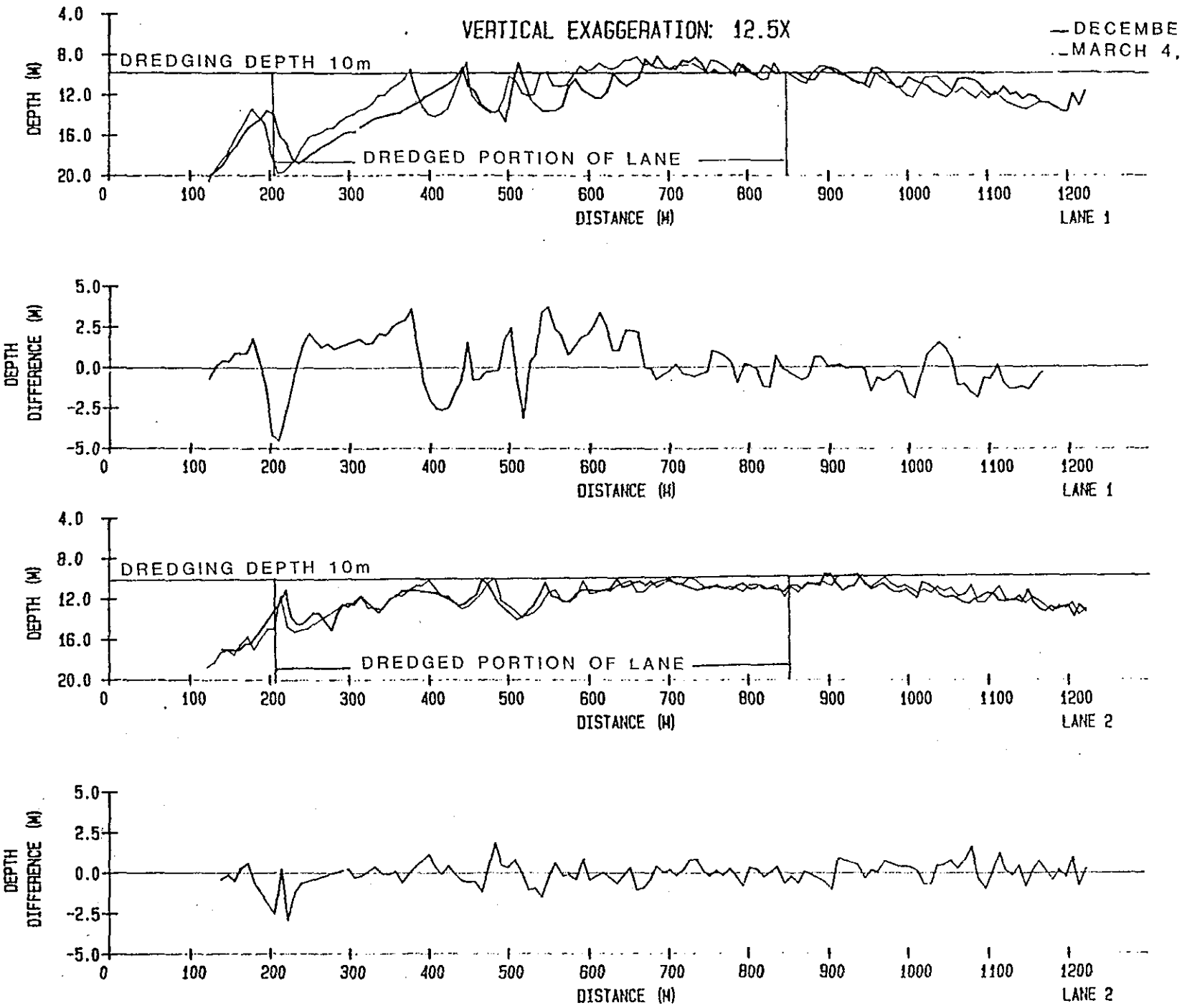


Figure 3-4a

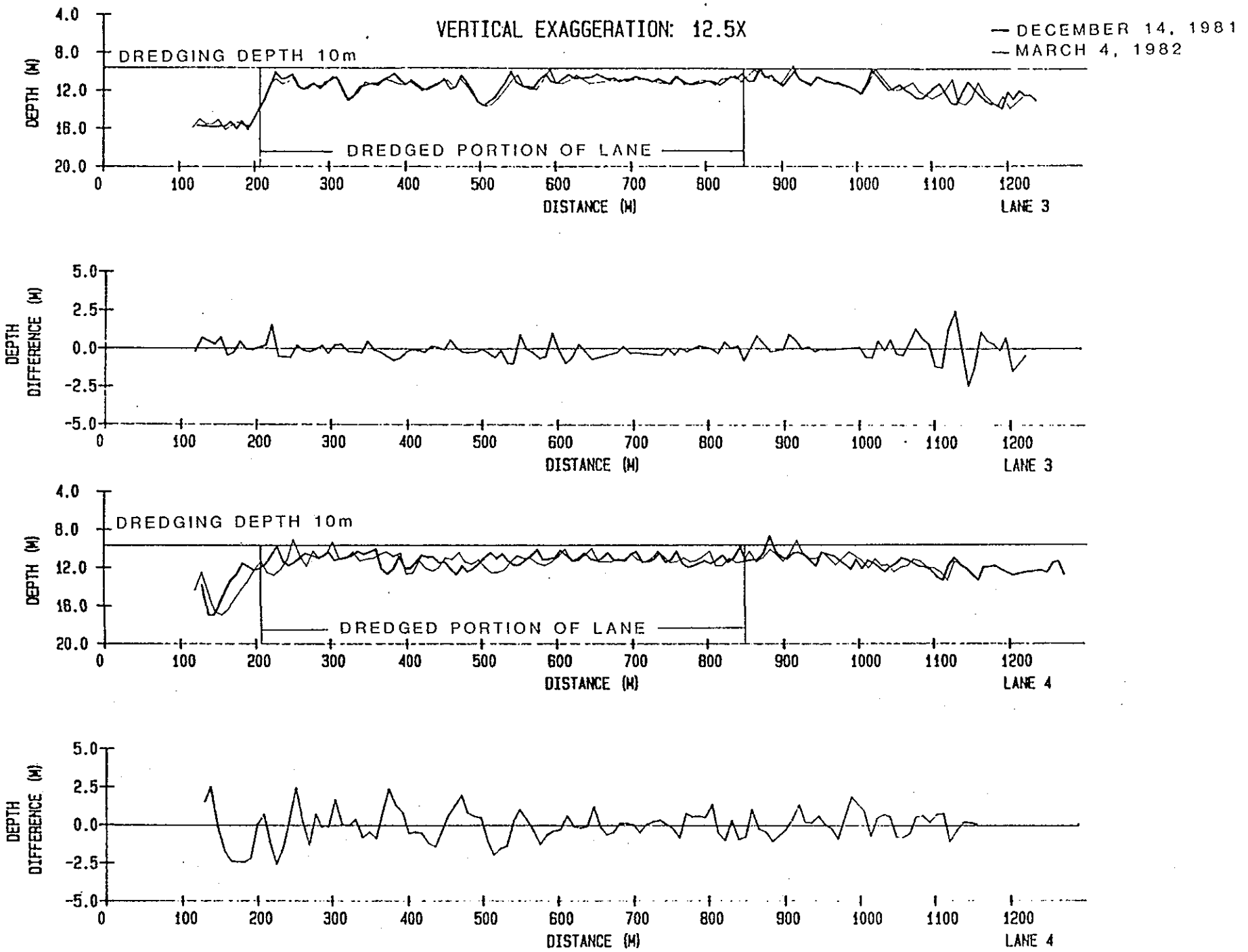

DEPTH DIFFERENCES BETWEEN DECEMBER 14, 1981 AND MARCH 4, 1982
VERTICAL EXAGGERATION: 12.5X
DECEMBER 14, 1981
MARCH 4, 1982
DREDGING DEPTH 10m
DREDGED PORTION OF LANE
DEPTH (M)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
DISTANCE (M)
LANE 3
DEPTH DIFFERENCE (M)
5.0
2.5
0.0
-2.5
-5.0
LANE 4

Figure 3-4b

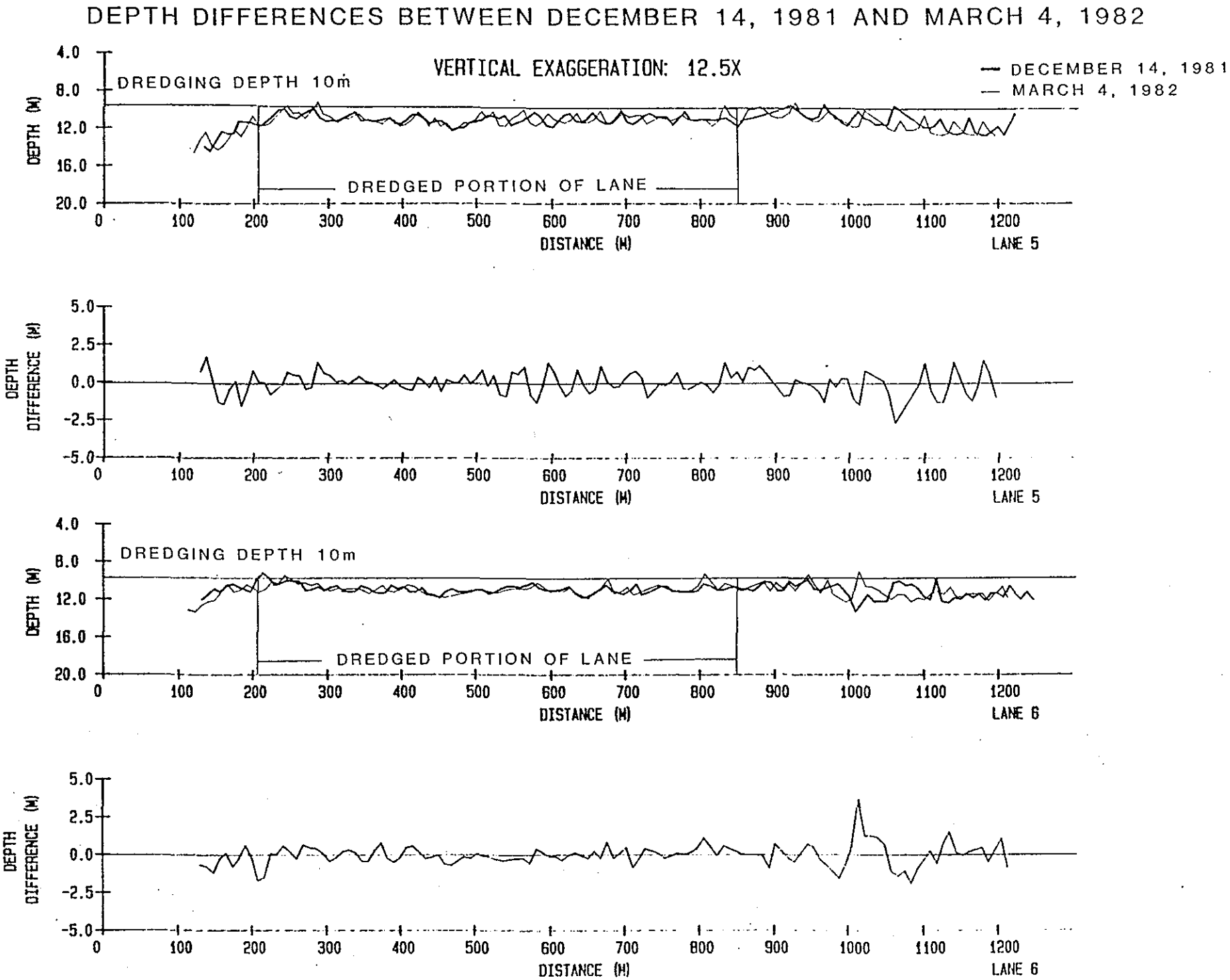

DEPTH DIFFERENCES BETWEEN DECEMBER 14, 1981 AND MARCH 4, 1982
VERTICAL EXAGGERATION: 12.5X
DECEMBER 14, 1981
MARCH 4, 1982
DREDGING DEPTH 10m
DREDGED PORTION OF LANE
DEPTH (M)
DEPTH DIFFERENCE (M)
DISTANCE (M)
LANE 5
LANE 6

Figure 3-4c

that even though no substantial accretion of sediment has occurred, the formation of sand waves can cause shoaling in a relatively short time.

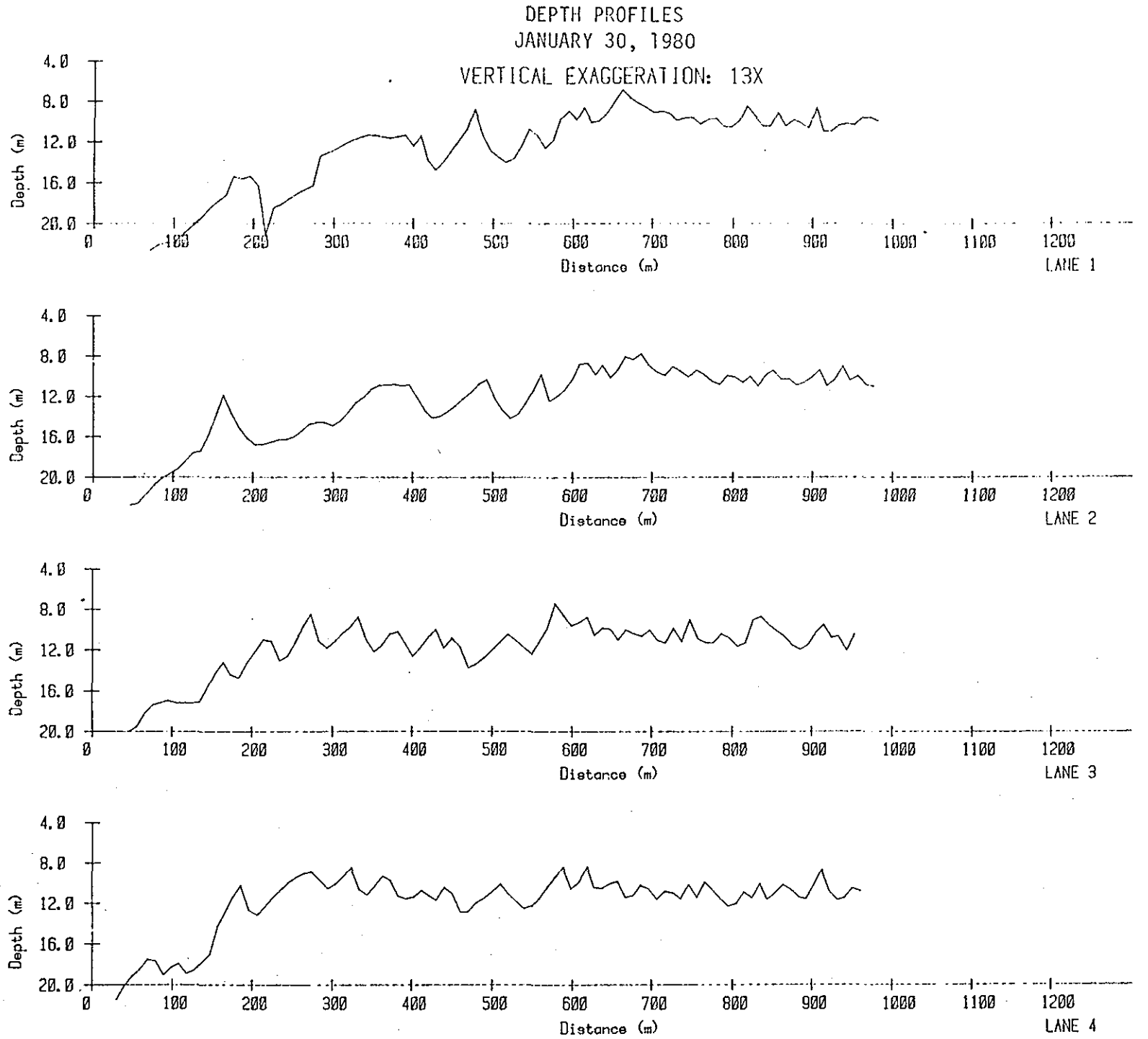
4.0 SUMMARY

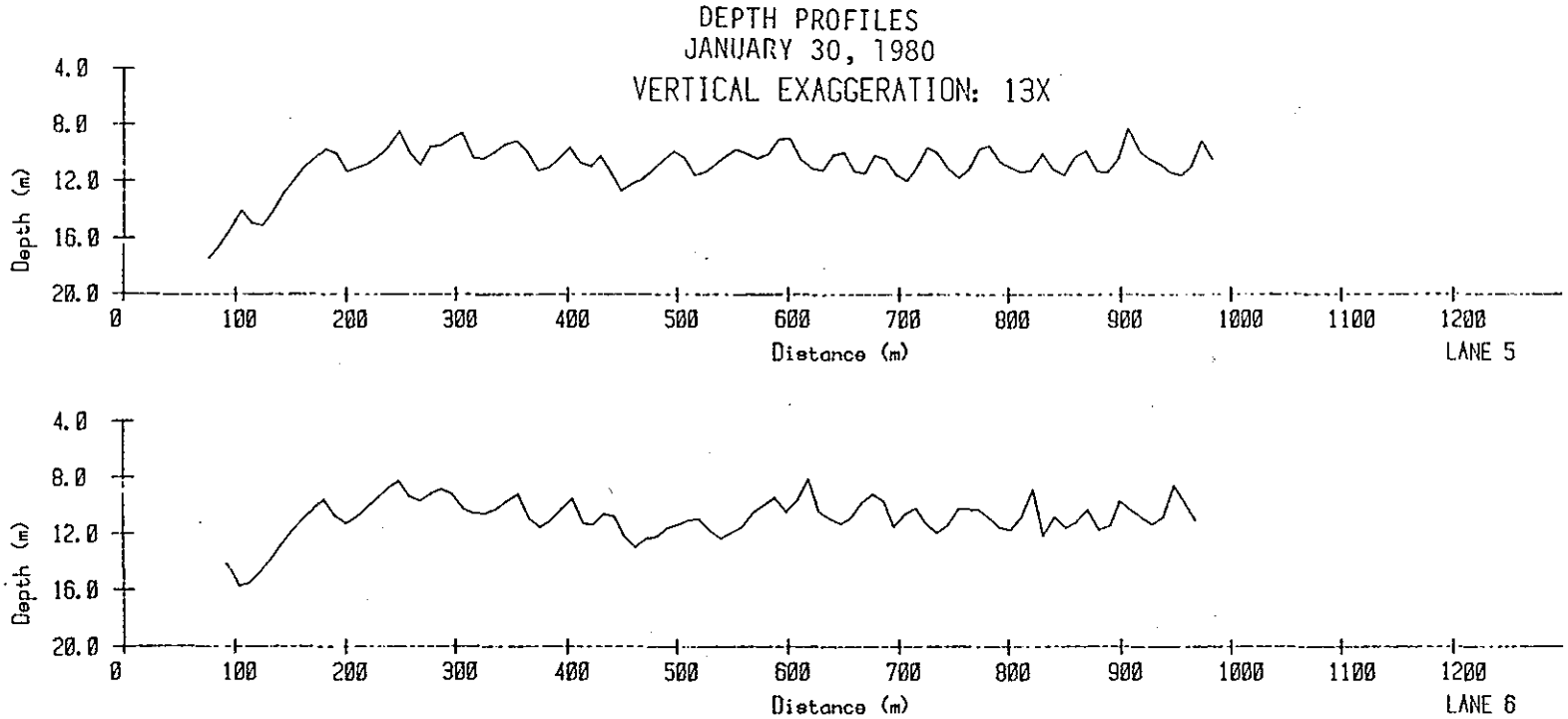
Based on comparisons of the ten hydrographic surveys conducted on the Kennebec River, it is apparent that the dredging site is extremely dynamic and subject to significant changes in bottom topography. In spite of this variability, the dredging operation conducted during October, 1981 did have a significant and lasting impact on the area. During the four months following dredging, there was no significant deposition or return to original equilibrium conditions and it appears that the 10 meter minimum depth will be maintained.

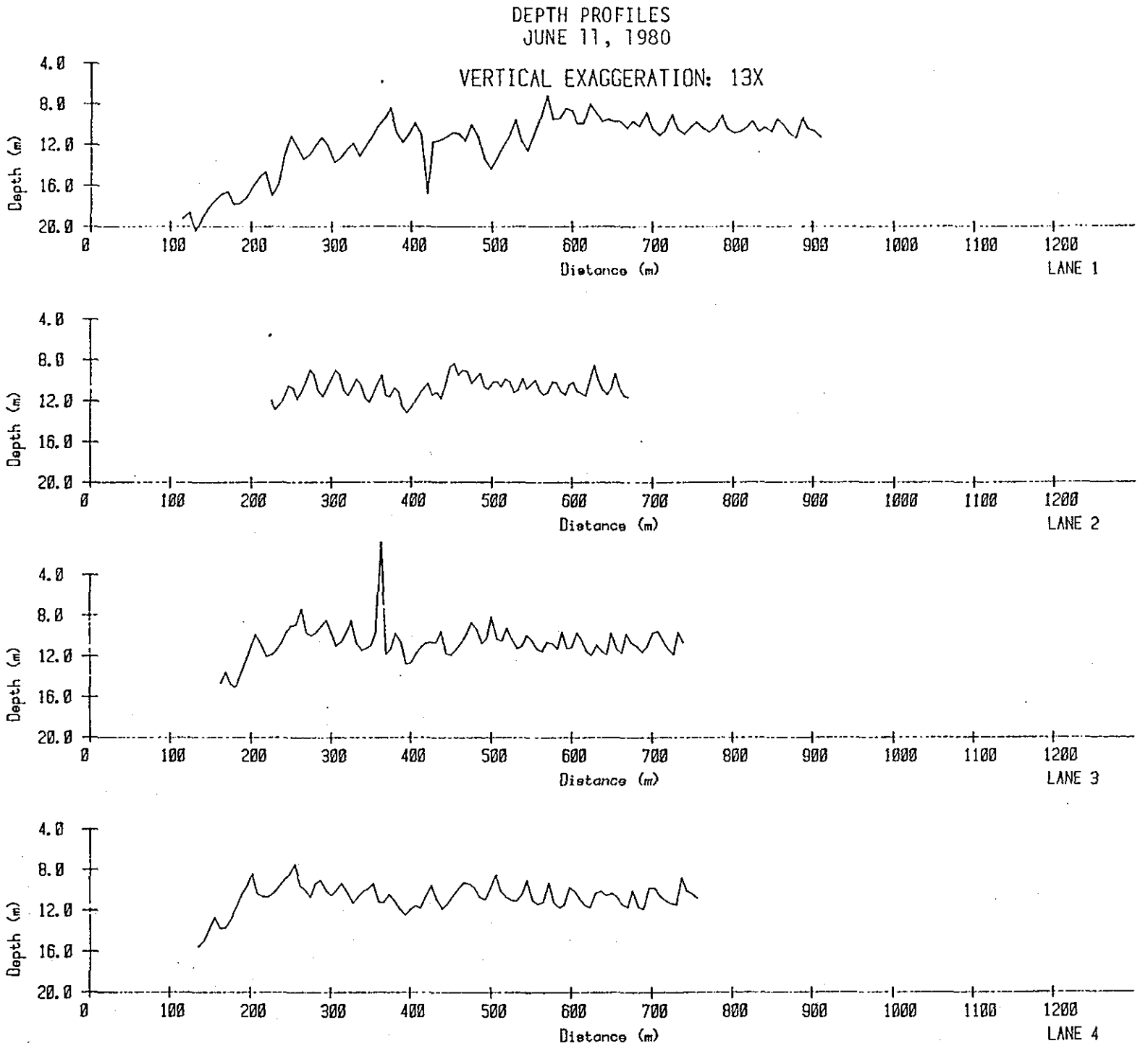
This generally positive result must be tempered, however, by the observation of several small shoal areas in the March, 1982 survey extending above the 10m isobath. Although this shoaling was relatively minor, future surveys may show an increase in the number and extent of these features. Assuming the 10 meter depth specification includes some safety margin, these shoals should not present a hazard to navigation, however, future dredging specifications might require a slightly deeper depth to insure safe passage. Because of this potential for shoaling, it is recommended that additional surveys be conducted on a periodic basis.

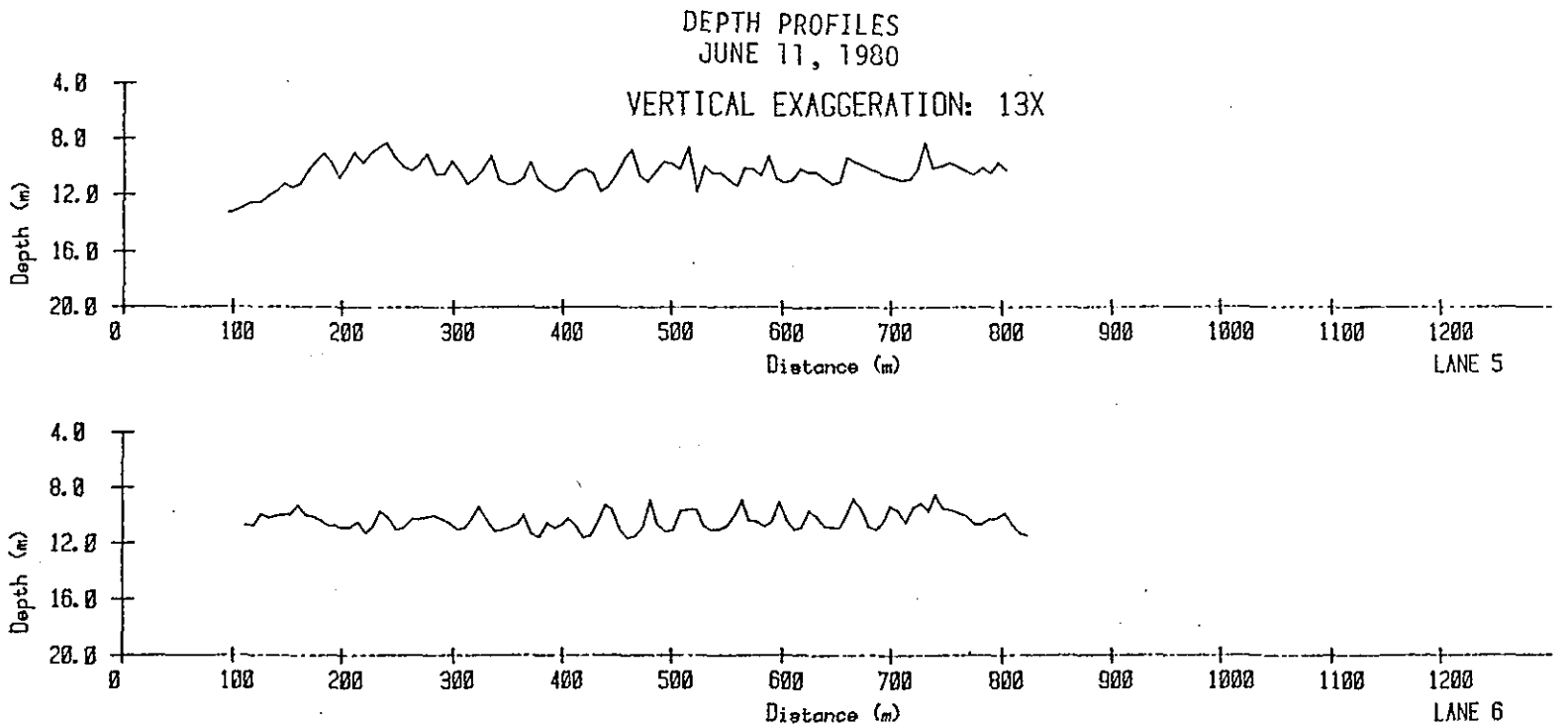
APPENDIX A

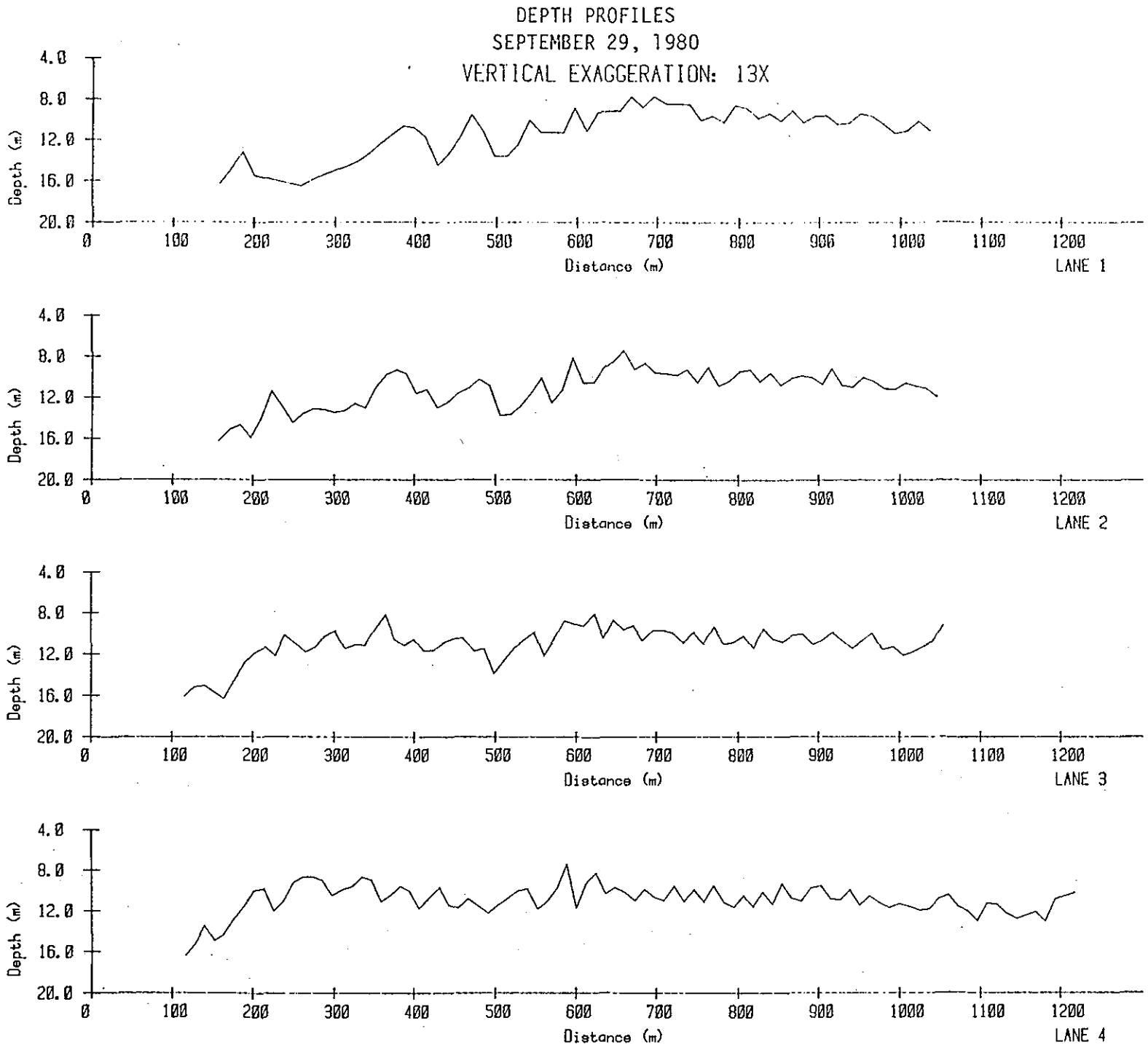
DEPTH PROFILES
KENNEBEC RIVER SURVEYS

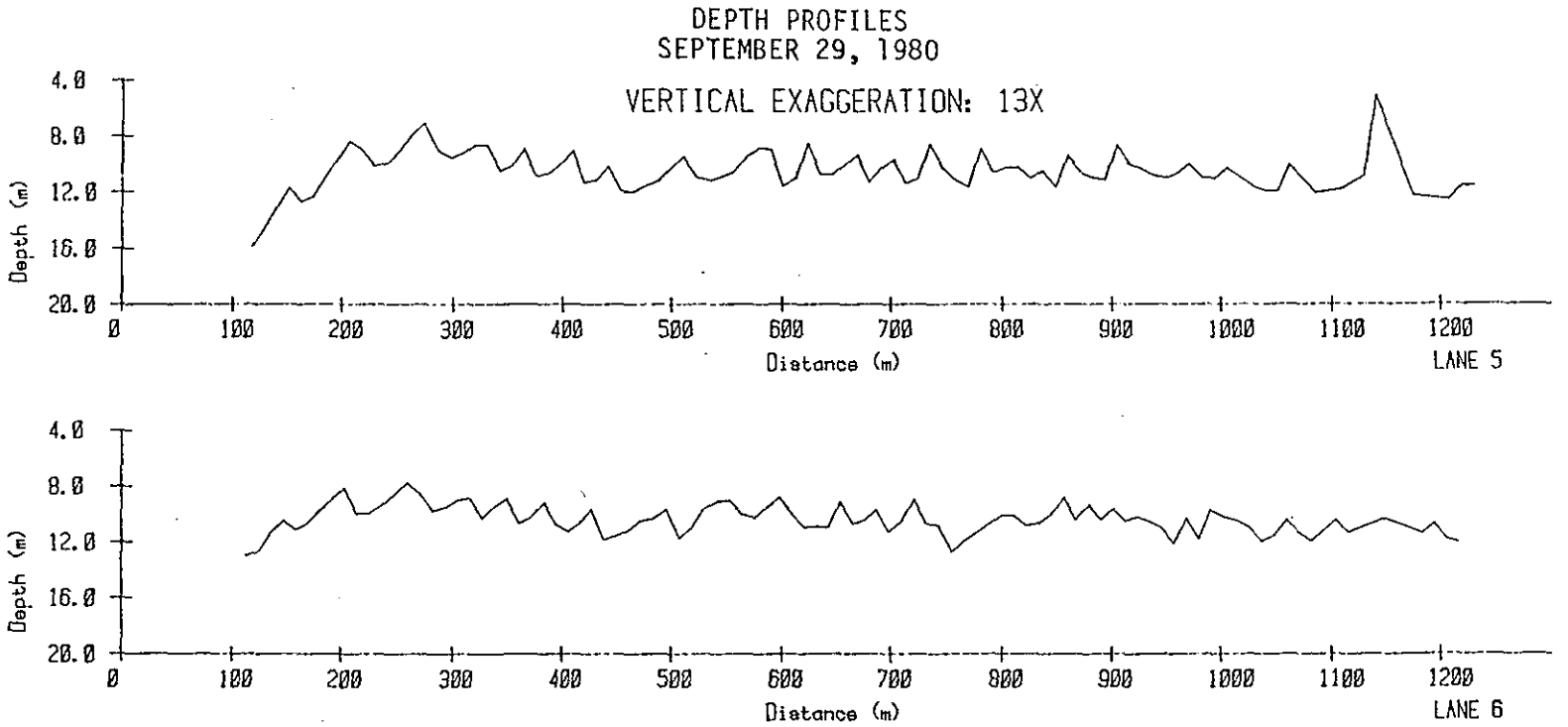

DEPTH PROFILES
JANUARY 30, 1980
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 1
LANE 2
LANE 3
LANE 4

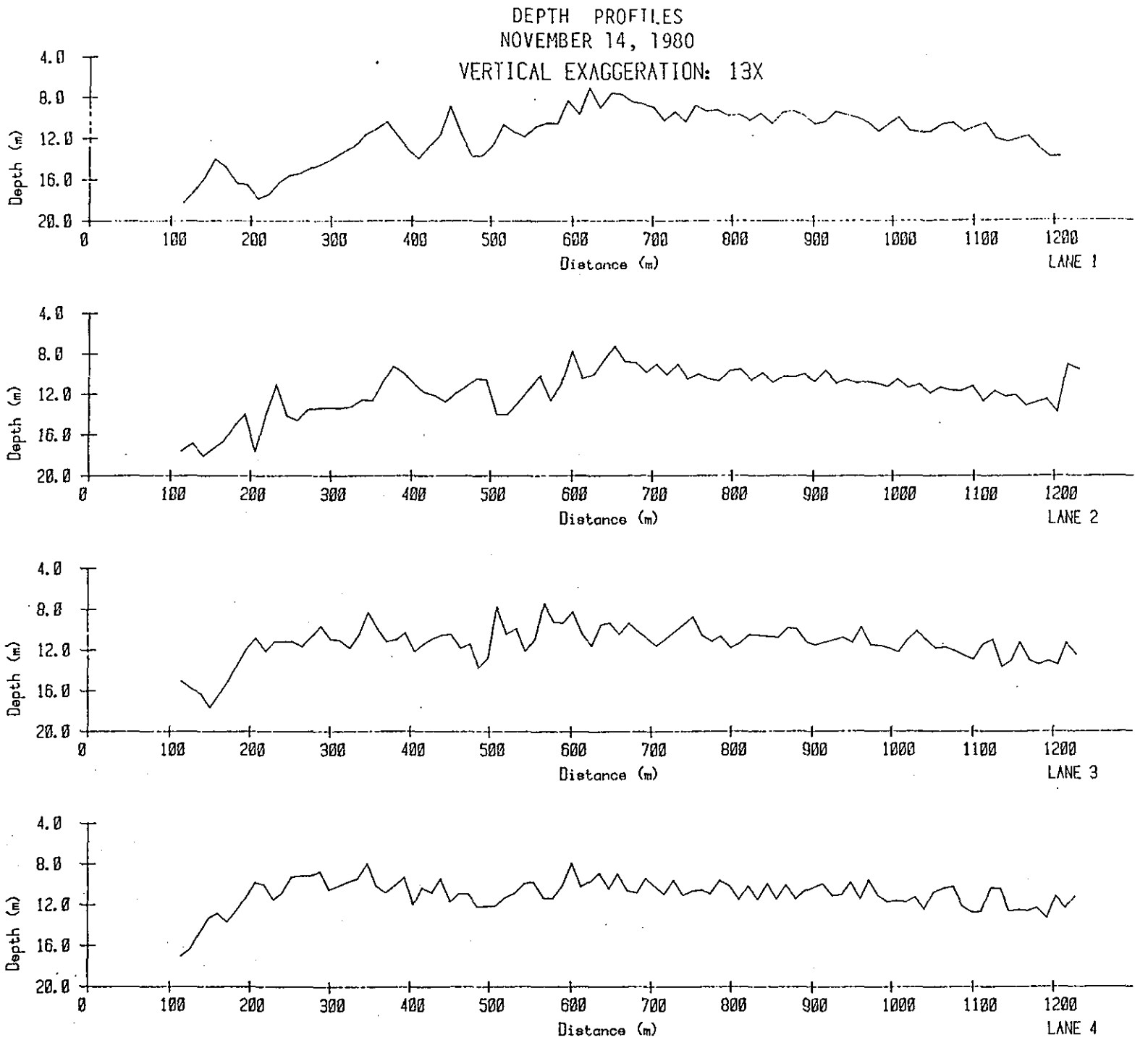

DEPTH PROFILES
JANUARY 30, 1980
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 5
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 6

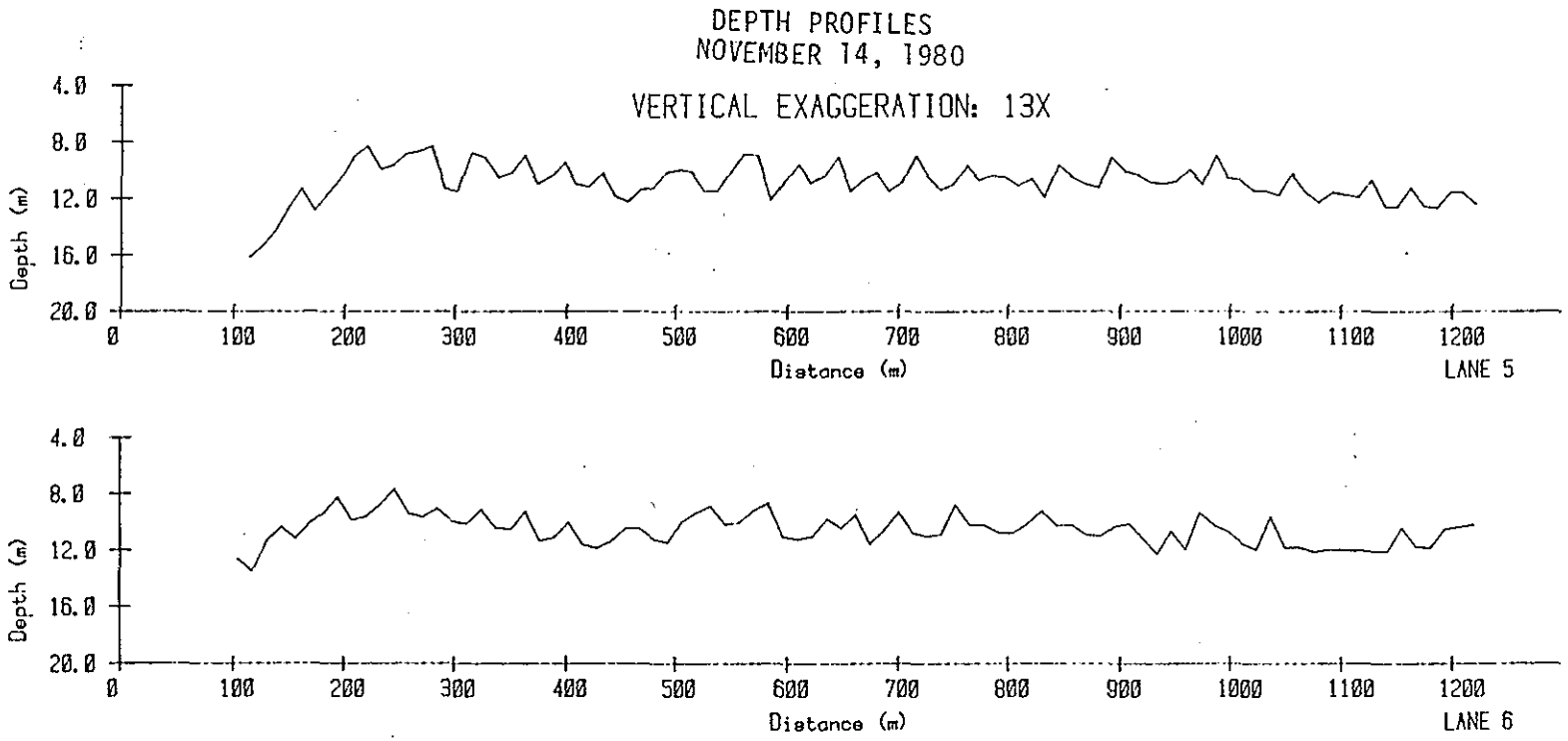

DEPTH PROFILES
JUNE 11, 1980
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 1
LANE 2
LANE 3
LANE 4


DEPTH PROFILES
JUNE 11, 1980
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 5
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 6

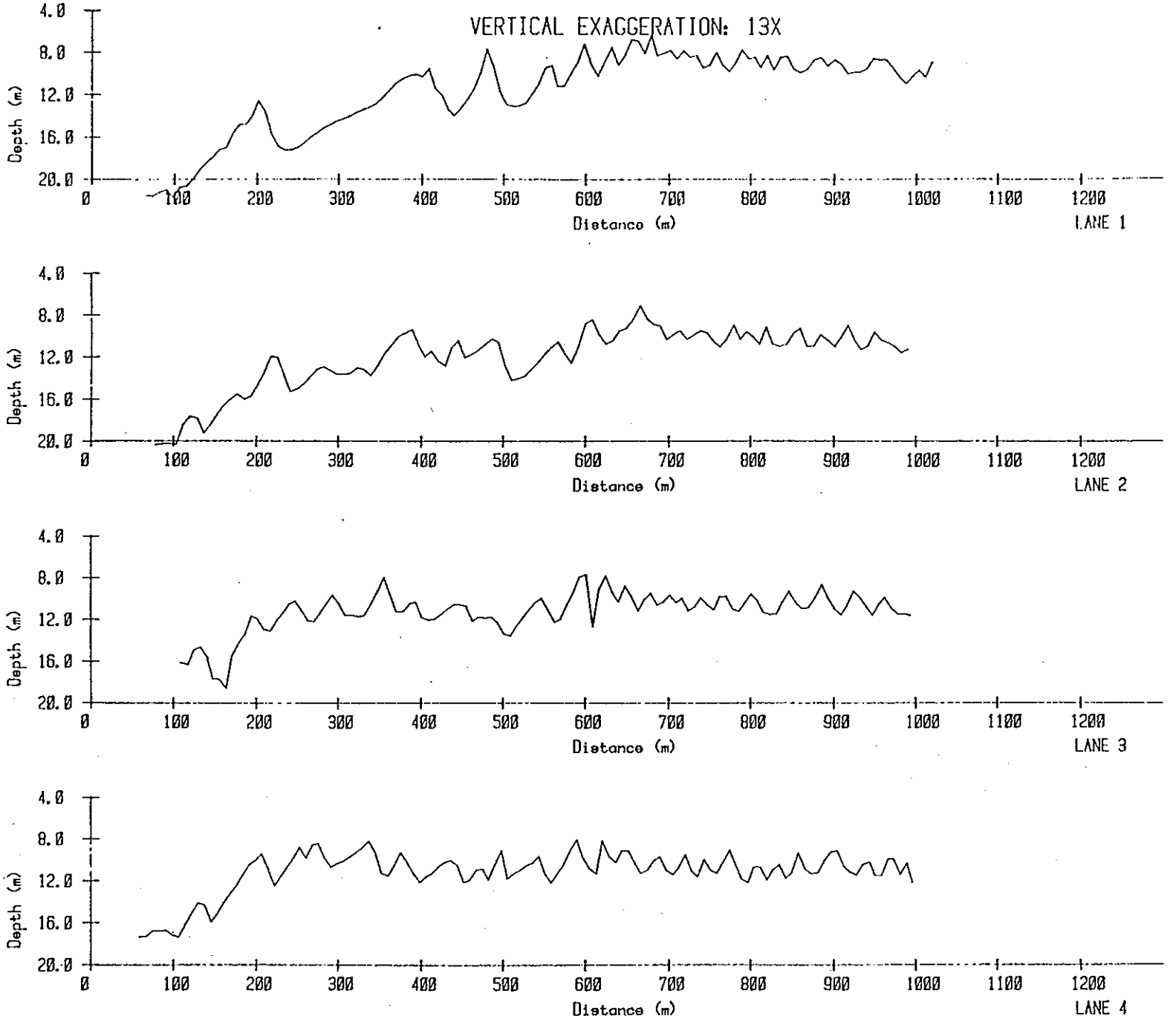

DEPTH PROFILES
SEPTEMBER 29, 1980
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 1
LANE 2
LANE 3
LANE 4

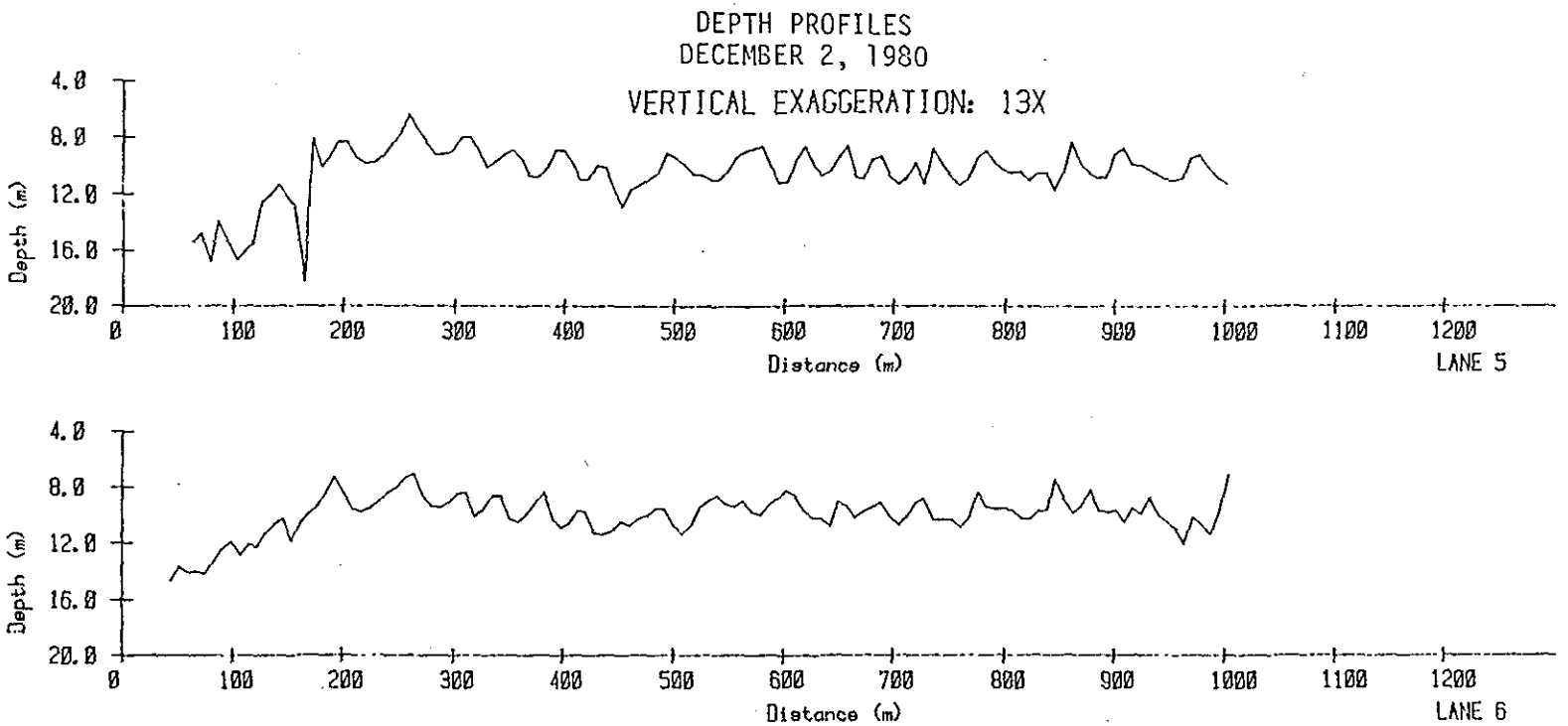

DEPTH PROFILES
SEPTEMBER 29, 1980
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 5
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 6


DEPTH PROFILES
NOVEMBER 14, 1980
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 1
LANE 2
LANE 3
LANE 4


DEPTH PROFILES
NOVEMBER 14, 1980
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 5
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 6

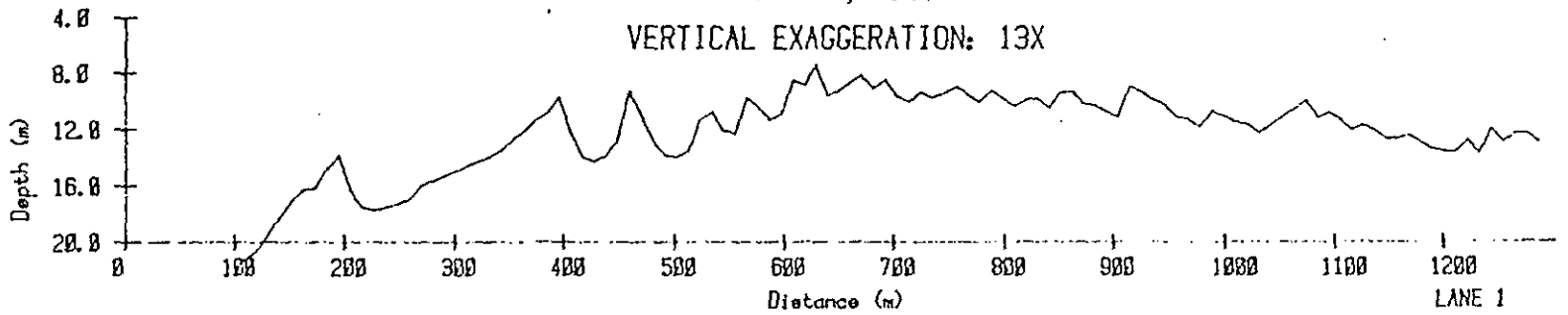
DEPTH PROFILES
DECEMBER 2, 1980

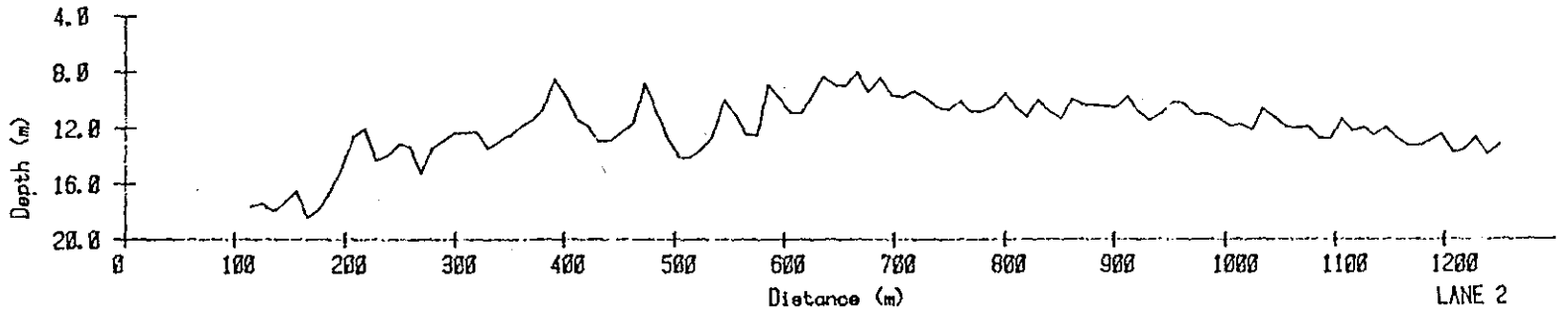


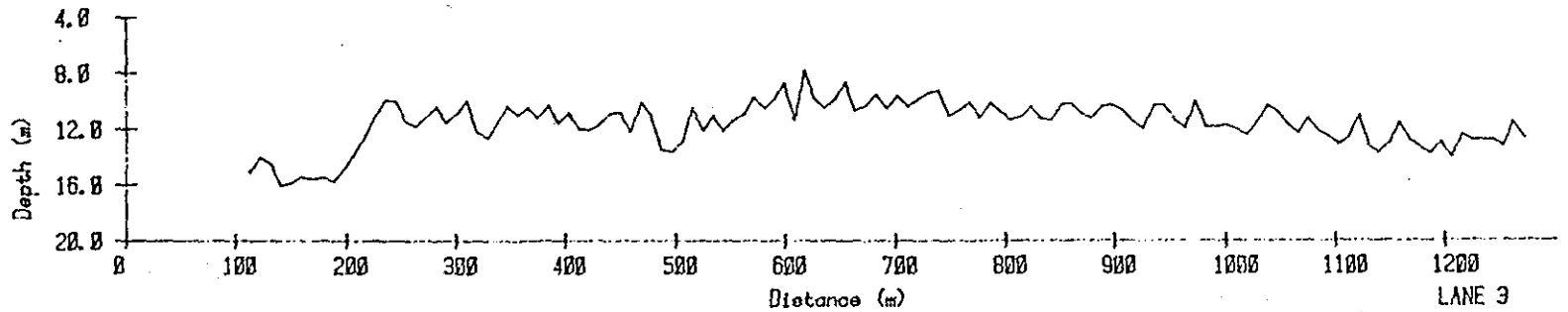

DEPTH PROFILES
DECEMBER 2, 1980
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 5
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 6

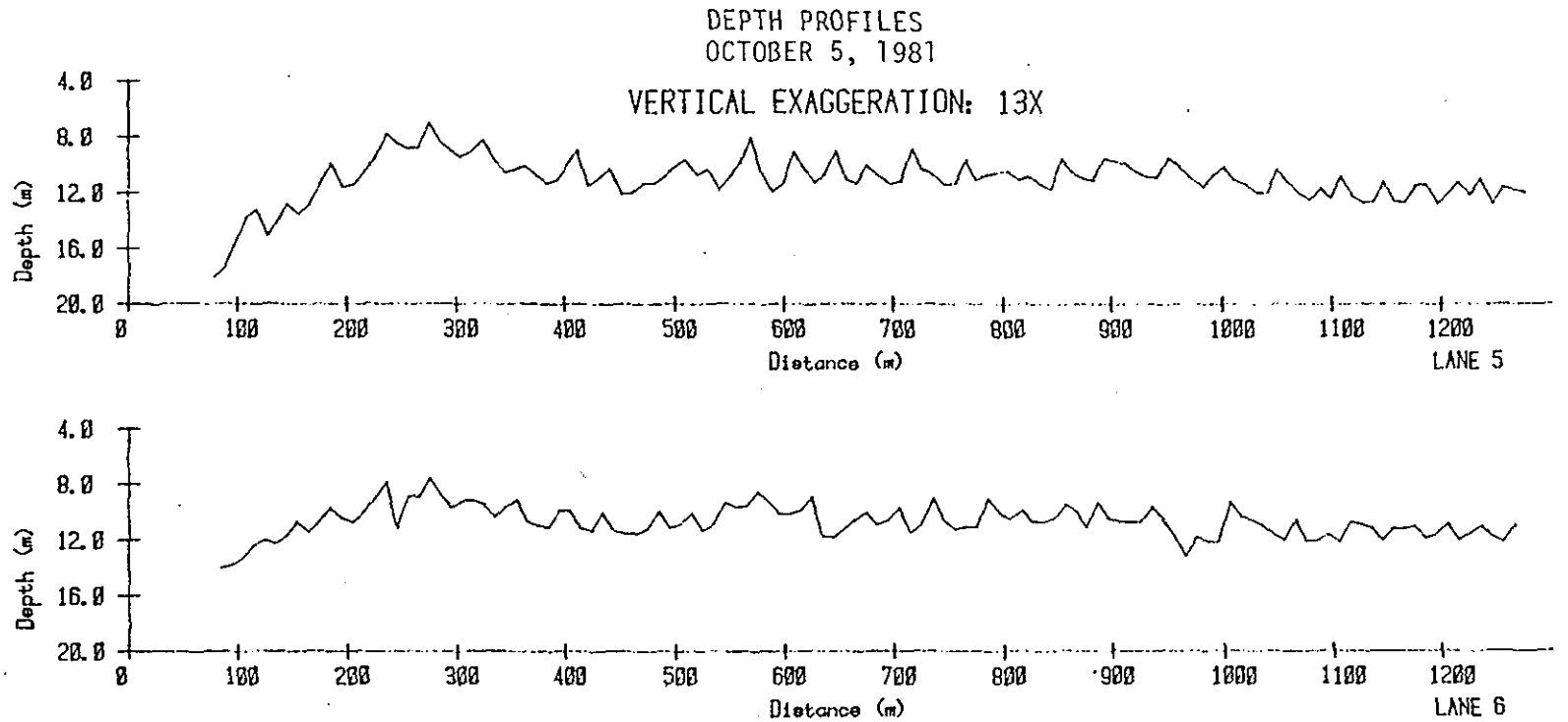
DEPTH PROFILES
OCTOBER 5, 1981

VERTICAL EXAGGERATION: 13X



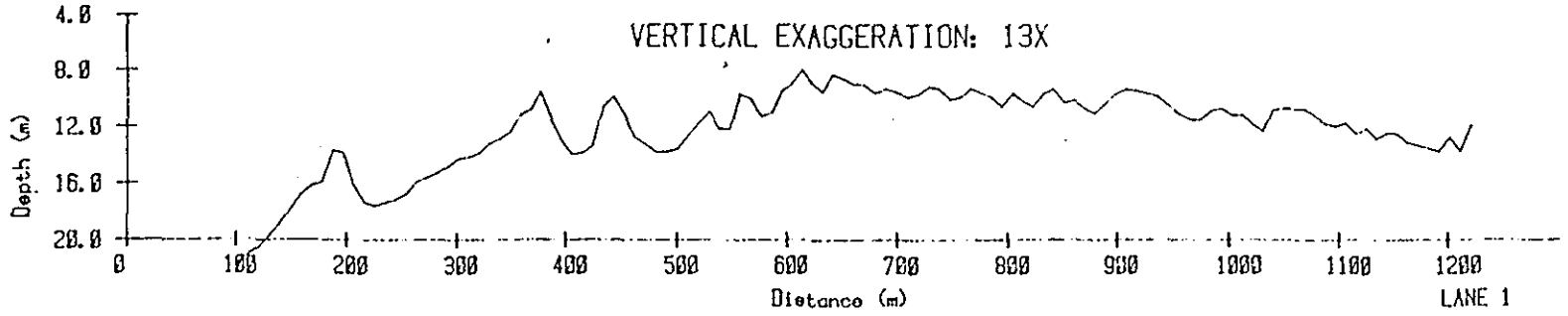


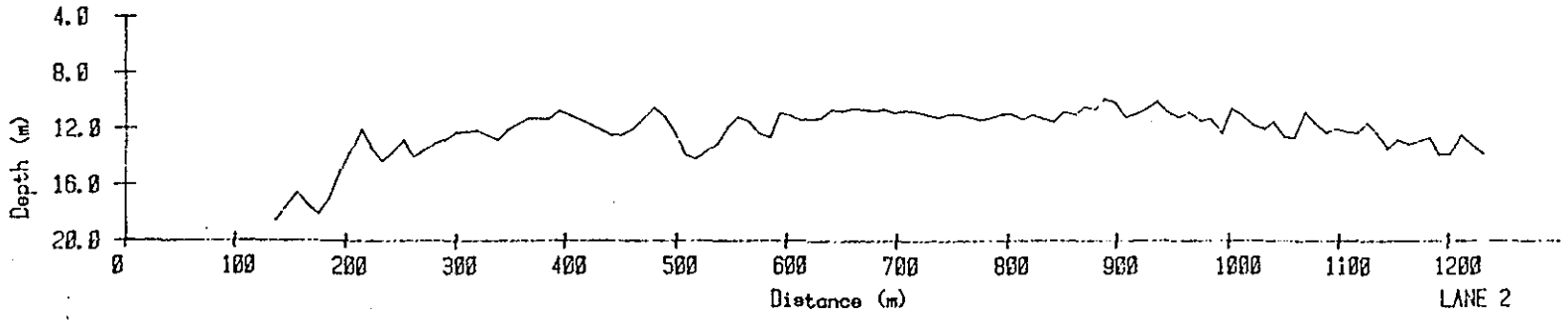


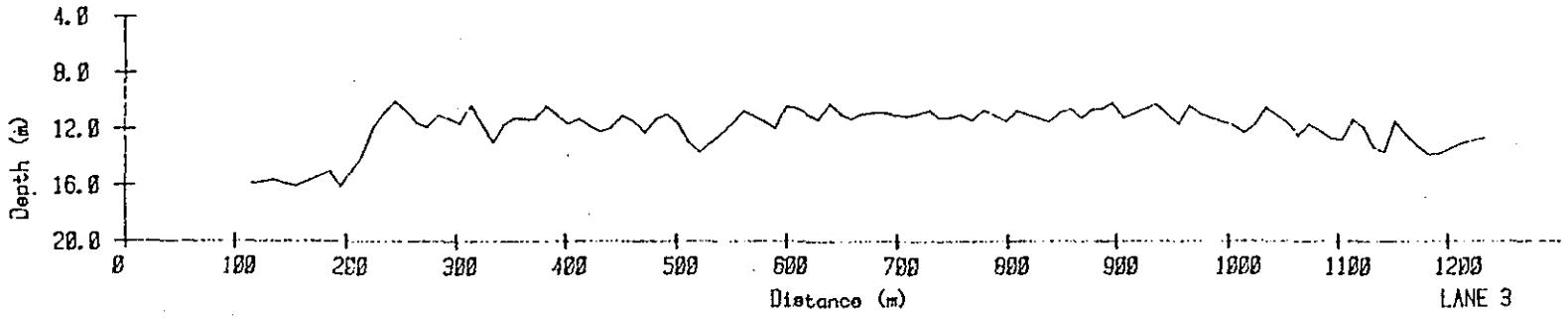

DEPTH PROFILES
OCTOBER 5, 1981
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 5
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 6

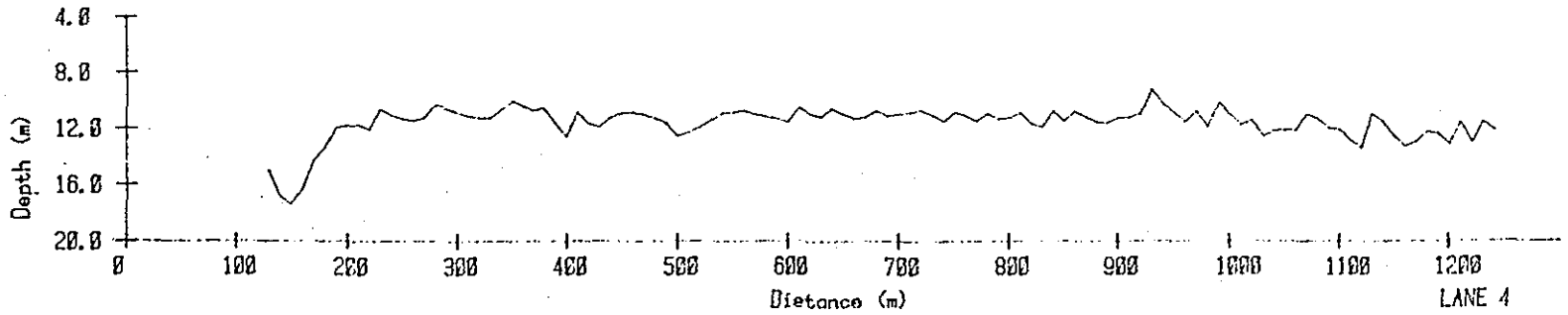
DEPTH PROFILES
NOVEMBER 2, 1981

VERTICAL EXAGGERATION: 13X



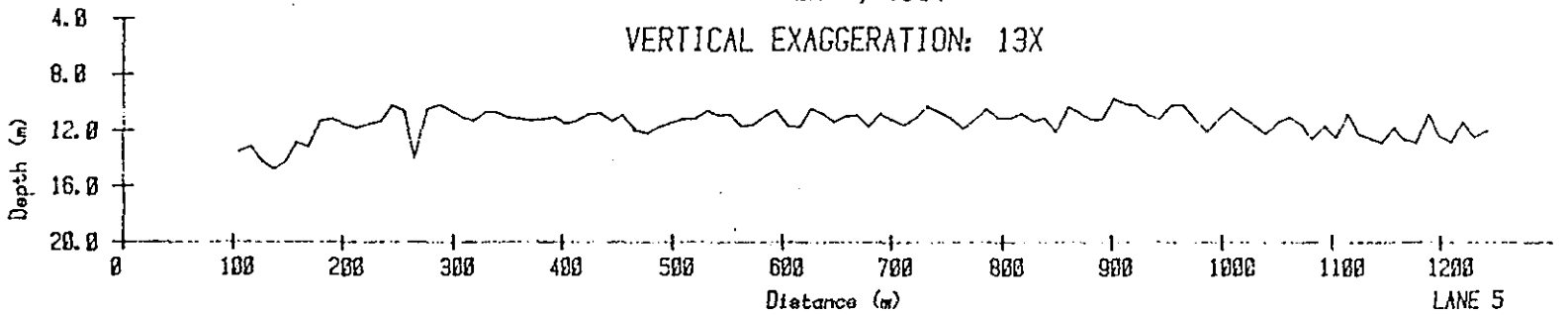


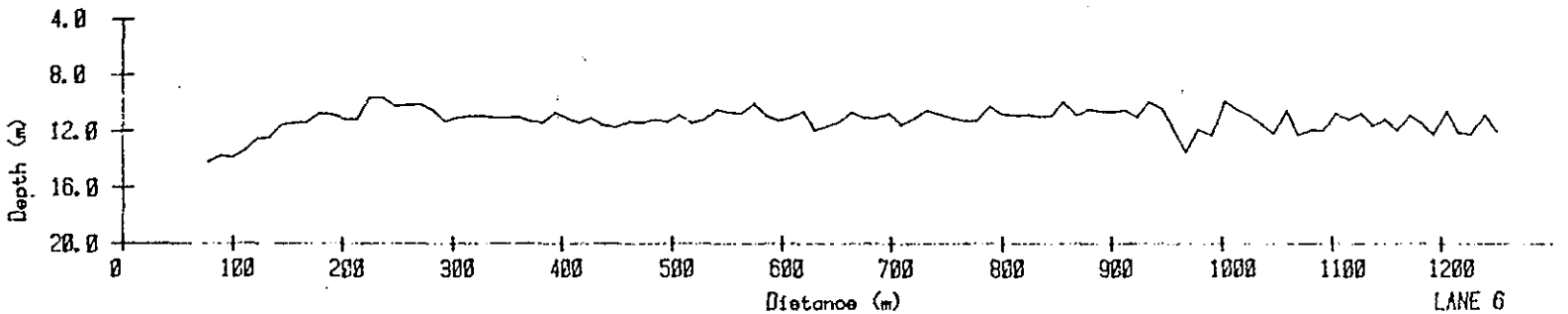


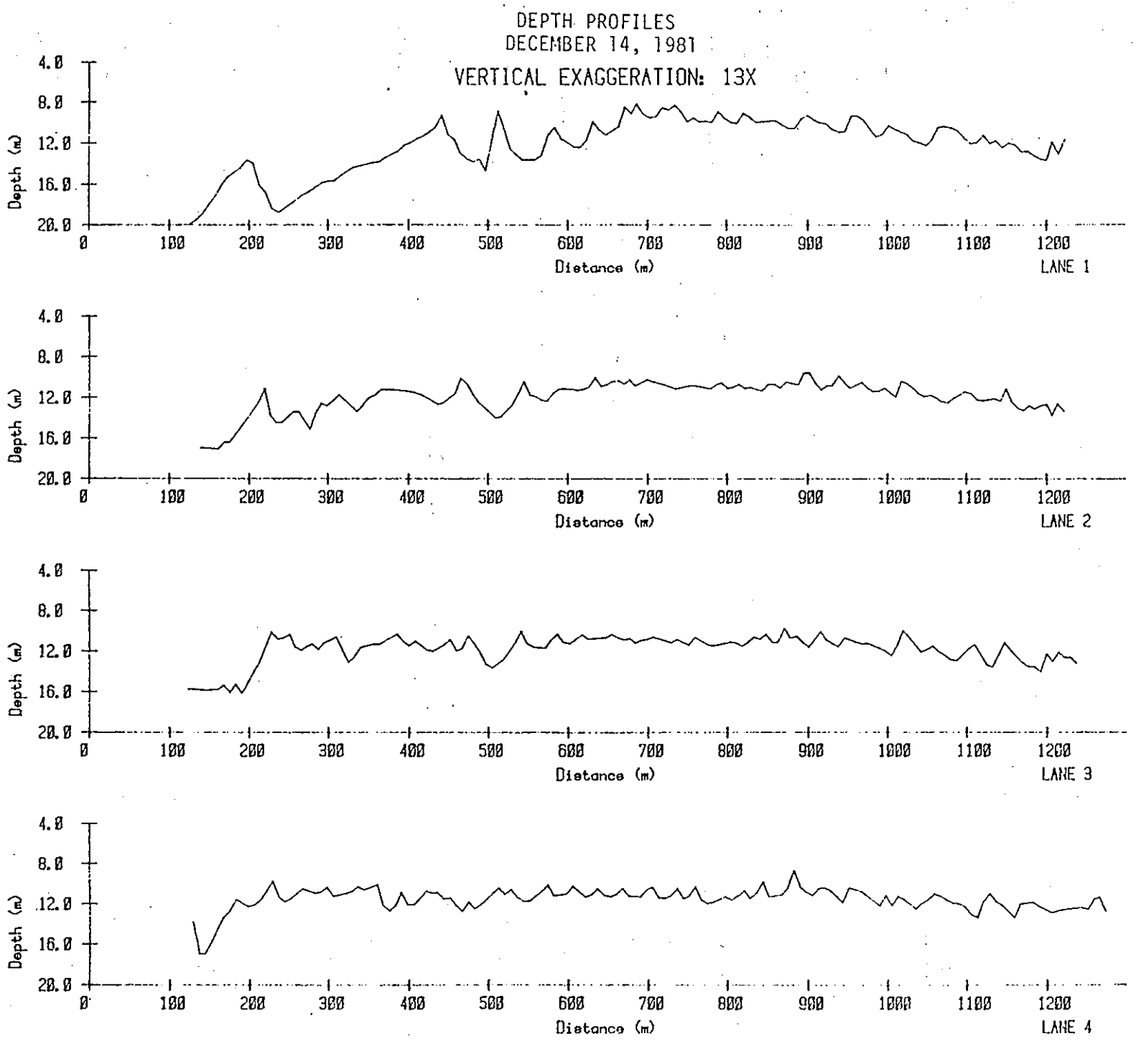


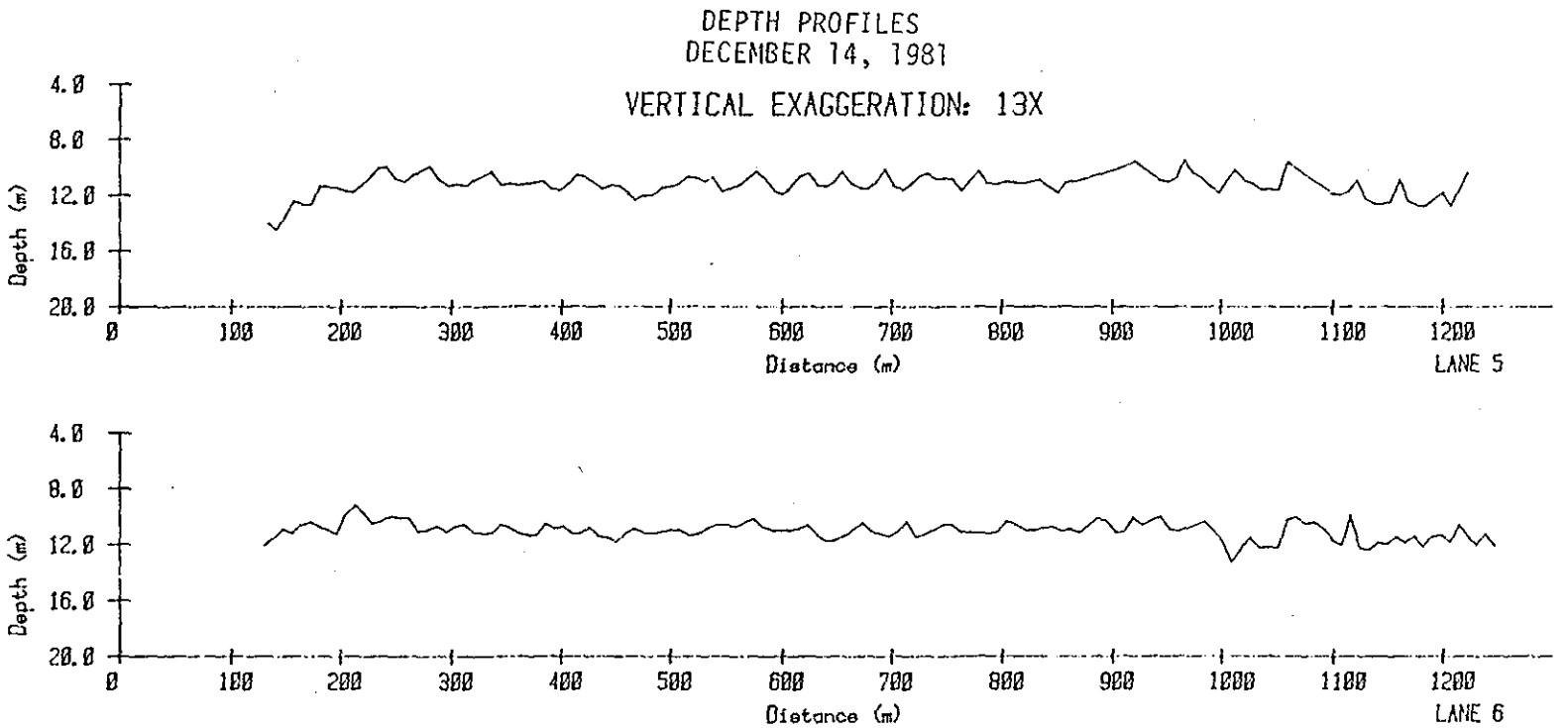
DEPTH PROFILES
NOVEMBER 2, 1981

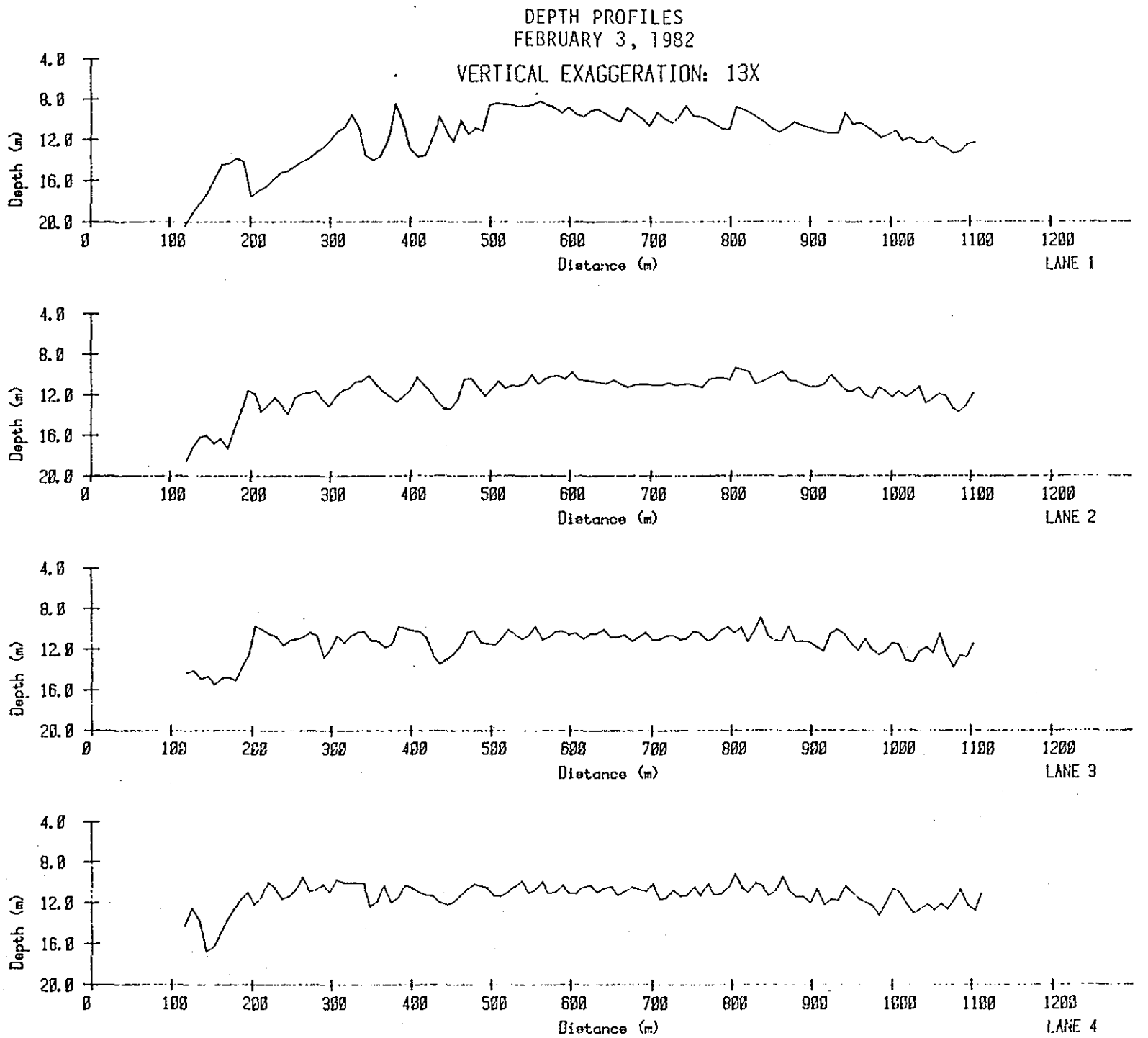
VERTICAL EXAGGERATION: 13X

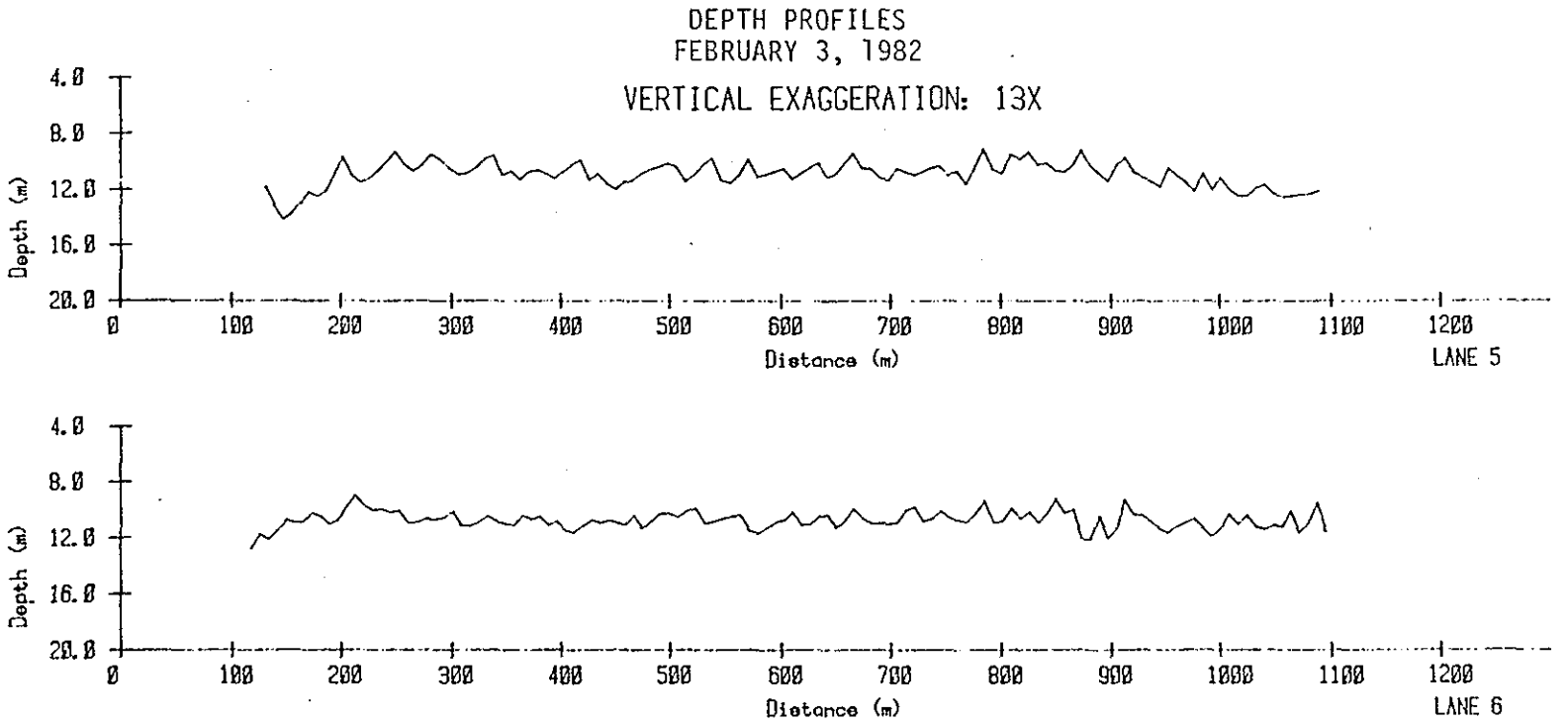





DEPTH PROFILES
DECEMBER 14, 1981
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 1
LANE 2
LANE 3
LANE 4

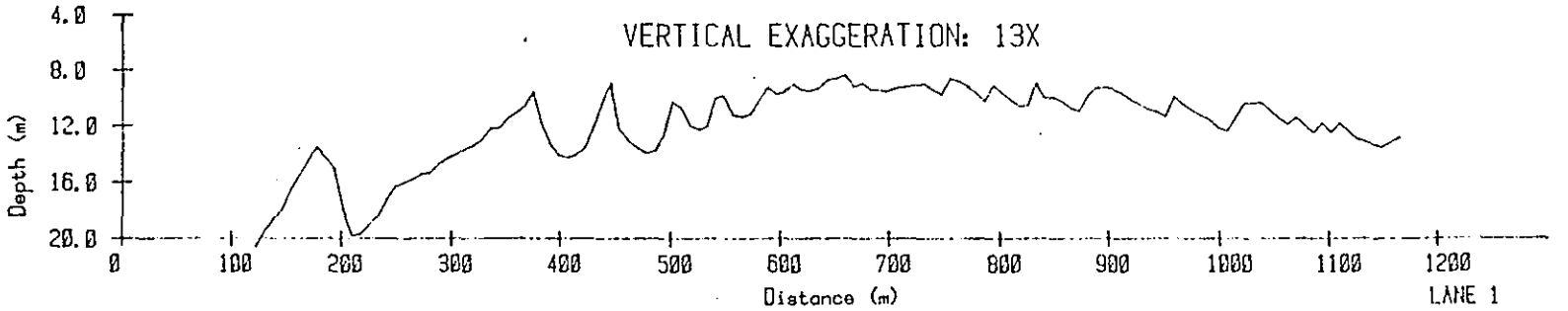

DEPTH PROFILES
DECEMBER 14, 1981
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 5
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 6

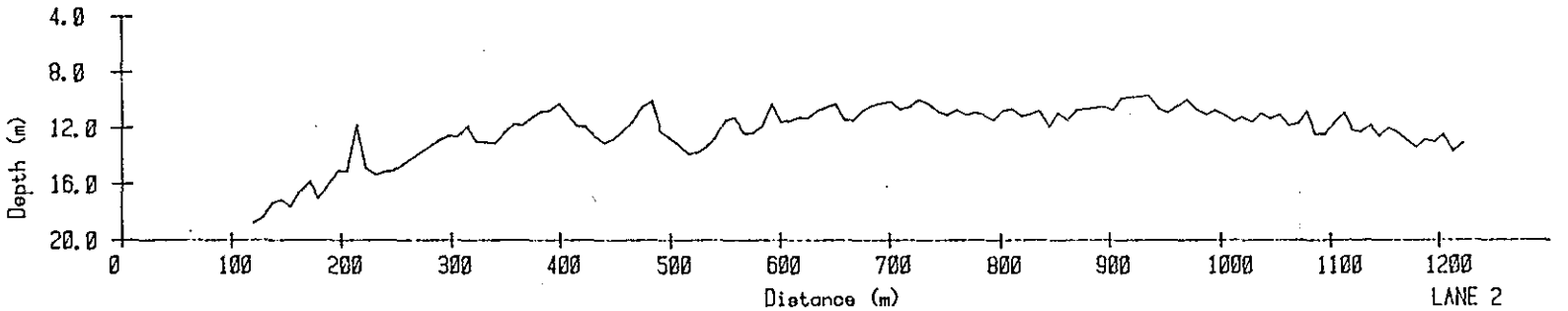

DEPTH PROFILES
FEBRUARY 3, 1982
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 1
LANE 2
LANE 3
LANE 4

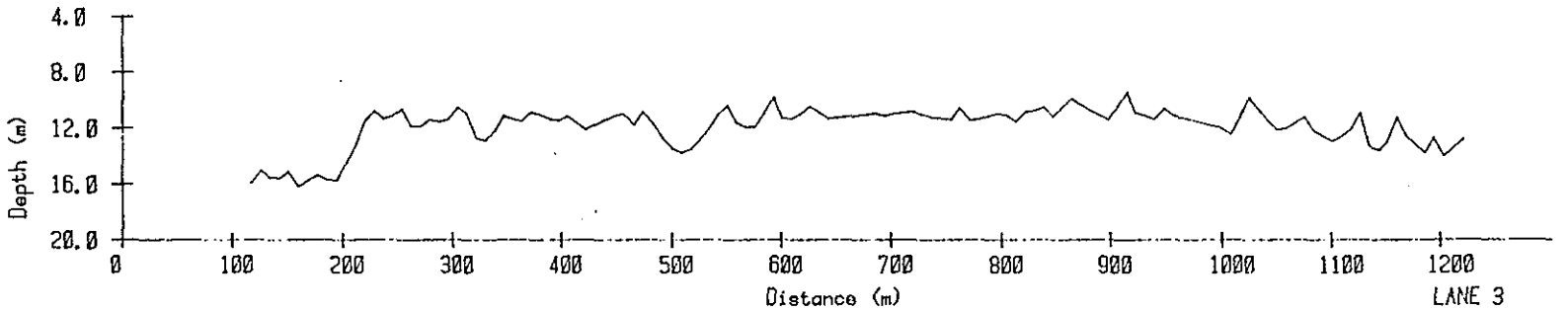

DEPTH PROFILES
FEBRUARY 3, 1982
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 5
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 6

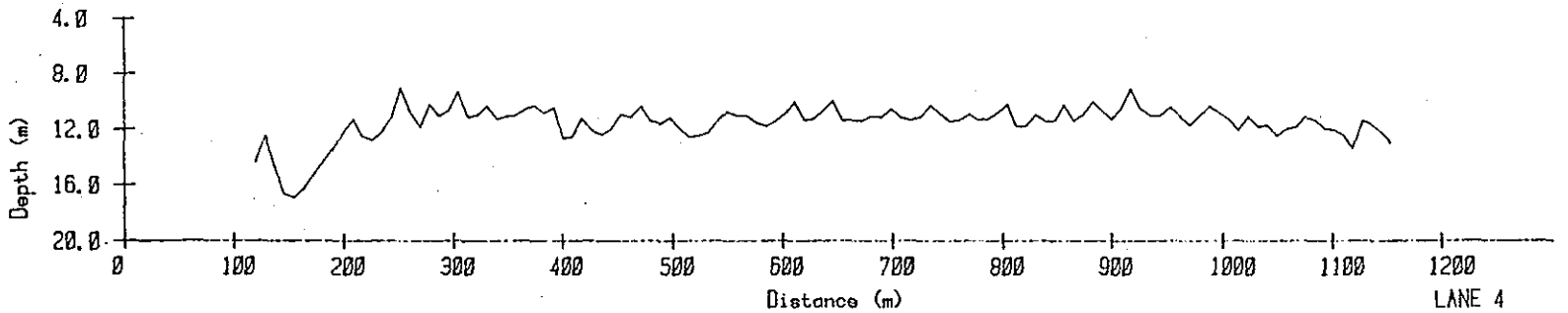
DEPTH PROFILES
MARCH 4, 1982

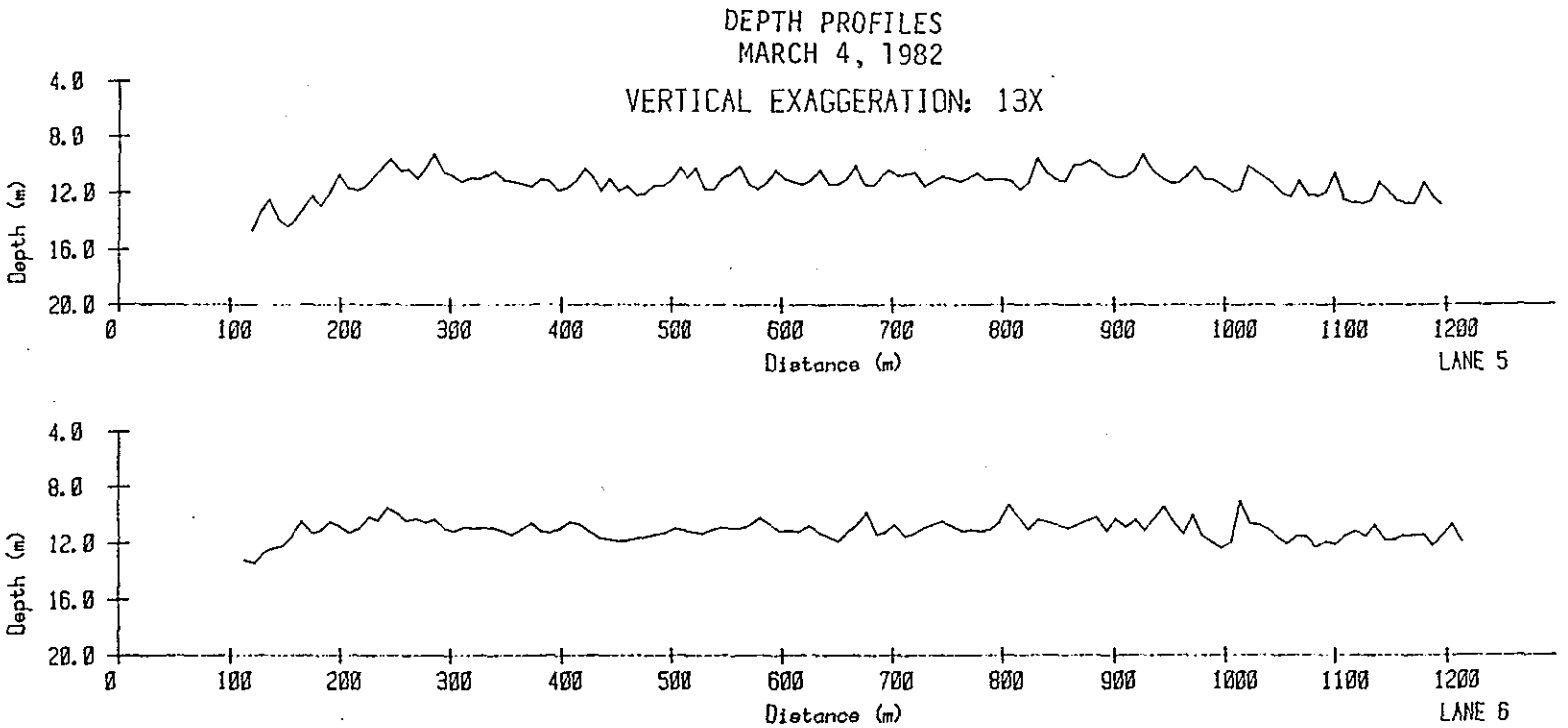
VERTICAL EXAGGERATION: 13X







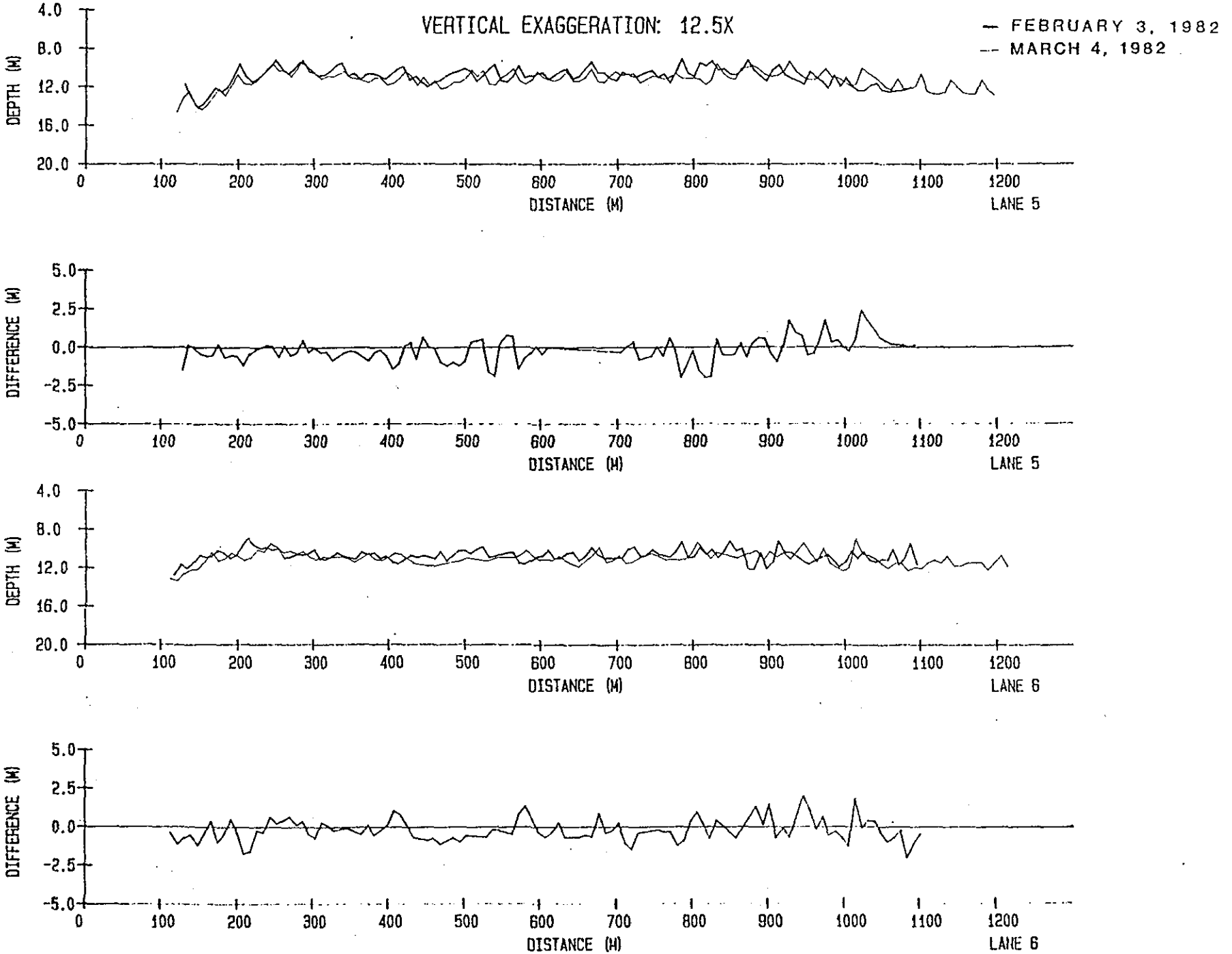


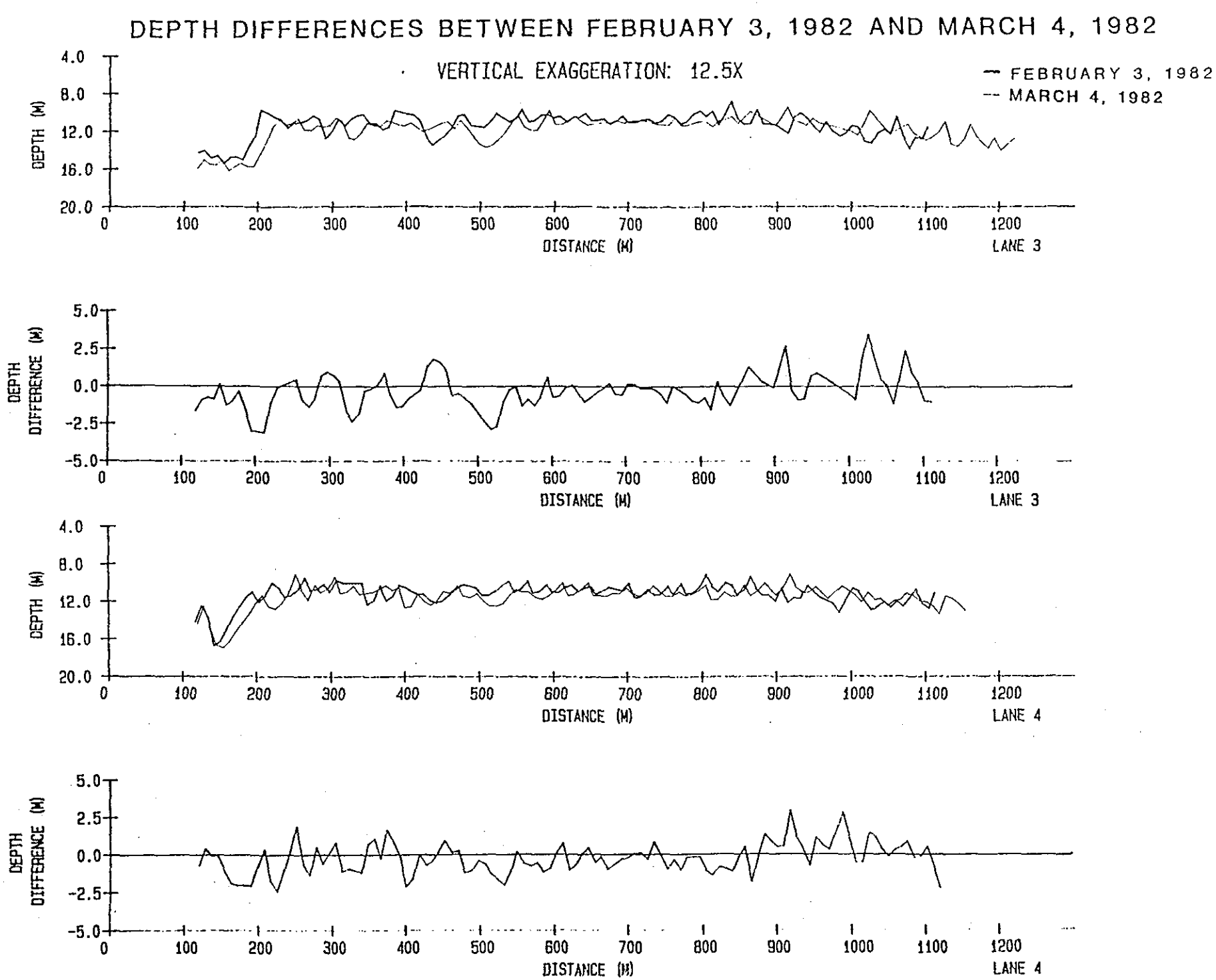

DEPTH PROFILES
MARCH 4, 1982
VERTICAL EXAGGERATION: 13X
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 5
Depth (m)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance (m)
LANE 6

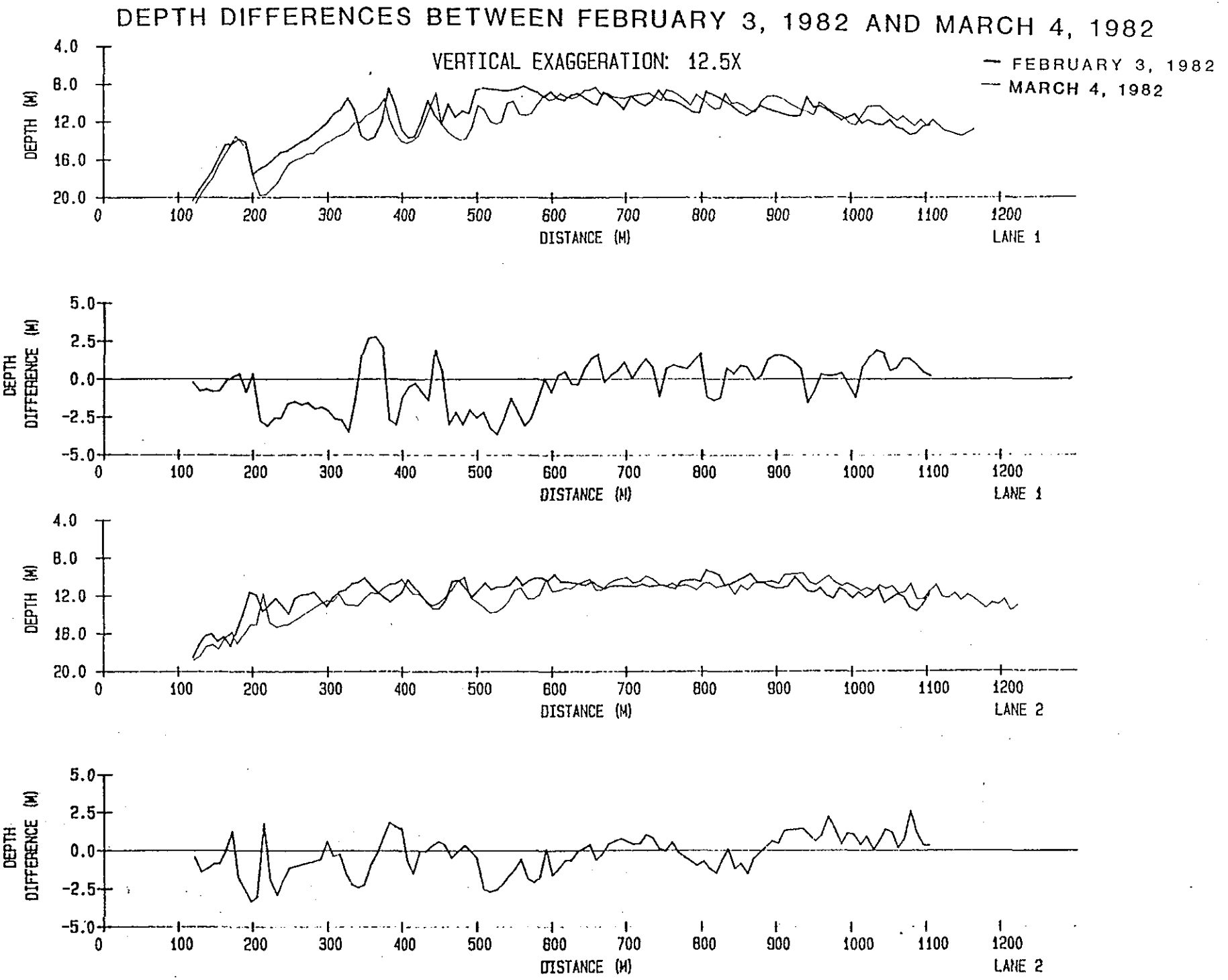
APPENDIX B

DEPTH PROFILE COMPARISONS
KENNEBEC RIVER SURVEYS

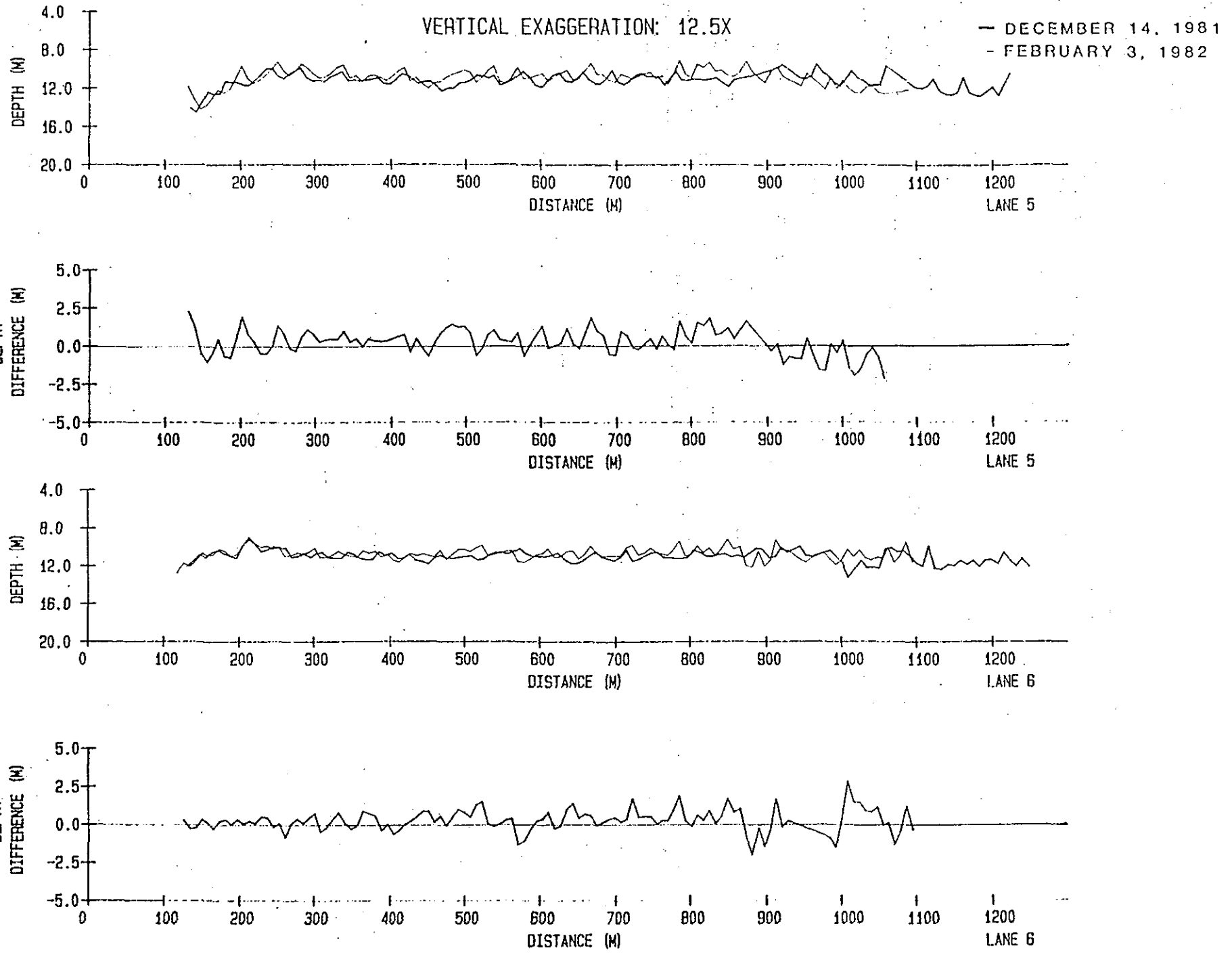
DEPTH DIFFERENCES BETWEEN FEBRUARY 3, 1982 AND MARCH 4, 1982



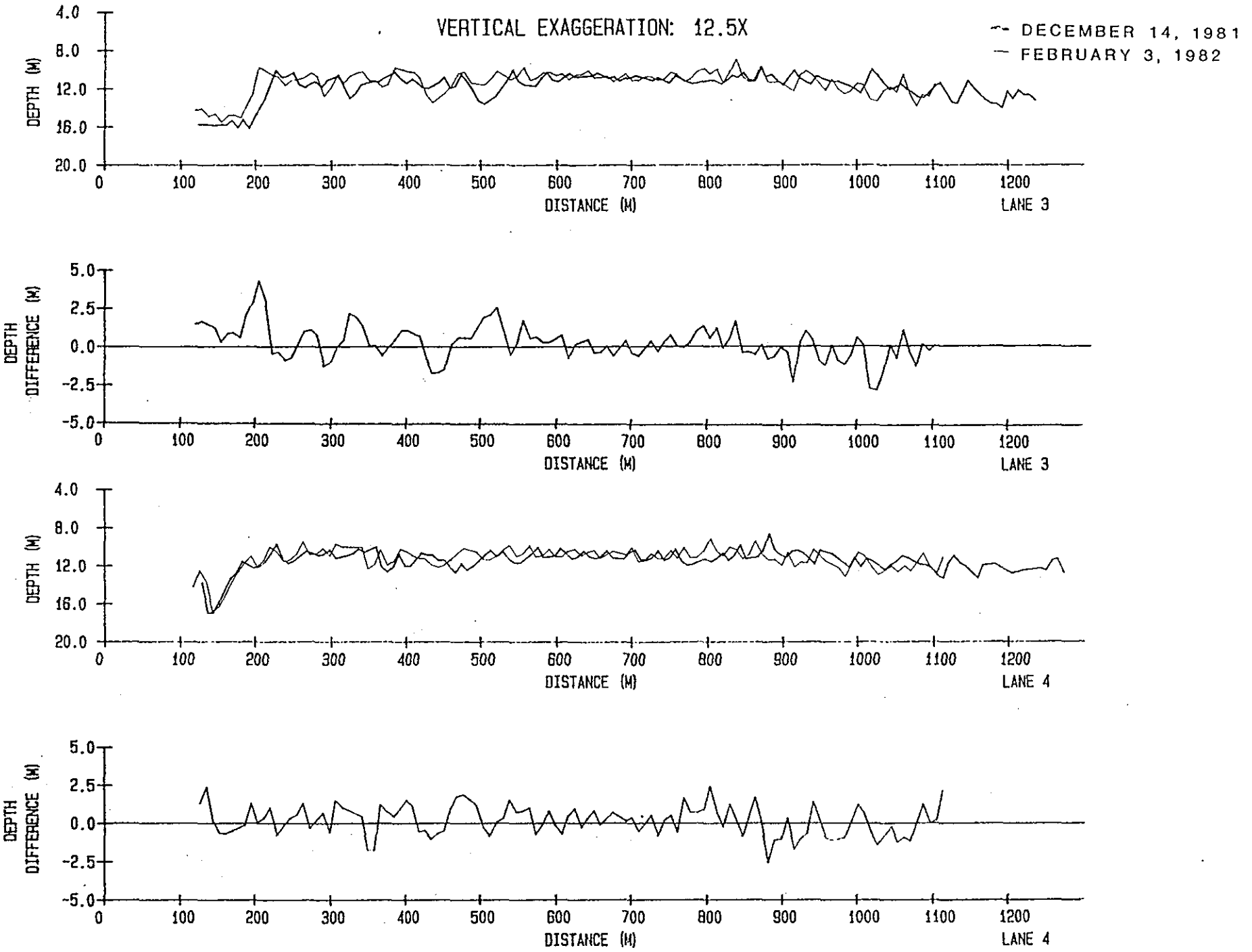

DEPTH DIFFERENCES BETWEEN FEBRUARY 3, 1982 AND MARCH 4, 1982
VERTICAL EXAGGERATION: 12.5X
FEBRUARY 3, 1982
MARCH 4, 1982
DEPTH (M)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
DISTANCE (M)
LANE 3
DEPTH DIFFERENCE (M)
5.0
2.5
0.0
-2.5
-5.0
DISTANCE (M)
LANE 3
DEPTH (M)
DISTANCE (M)
LANE 4
DEPTH DIFFERENCE (M)
DISTANCE (M)
LANE 4


DEPTH DIFFERENCES BETWEEN FEBRUARY 3, 1982 AND MARCH 4, 1982
VERTICAL EXAGGERATION: 12.5X
FEBRUARY 3, 1982
MARCH 4, 1982
DEPTH (M)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
DISTANCE (M)
LANE 1
DEPTH DIFFERENCE (M)
5.0
2.5
0.0
-2.5
-5.0
DISTANCE (M)
LANE 1
DEPTH (M)
4.0
8.0
12.0
16.0
20.0
DISTANCE (M)
LANE 2
DEPTH DIFFERENCE (M)
5.0
2.5
0.0
-2.5
-5.0
DISTANCE (M)
LANE 2

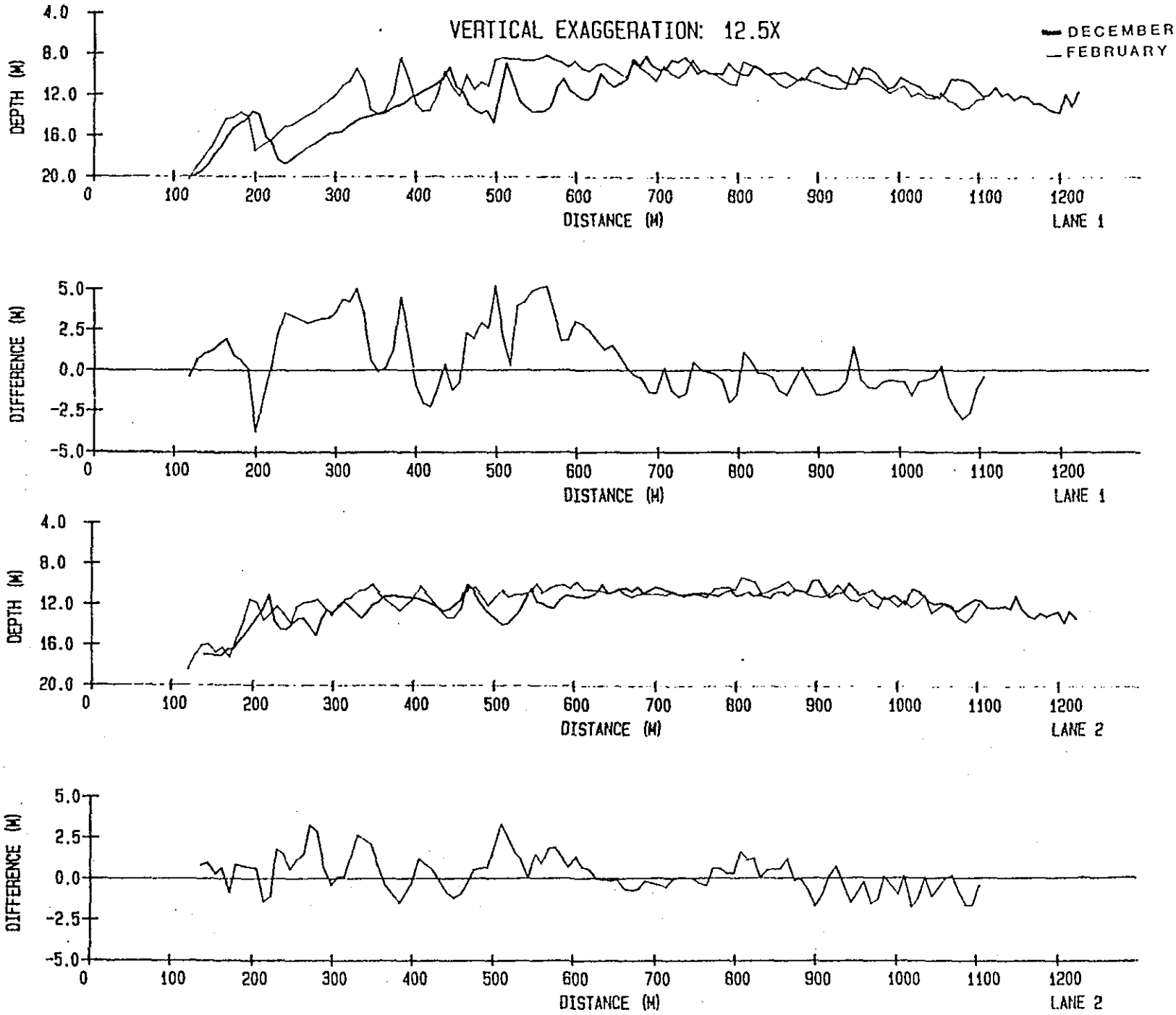
DEPTH DIFFERENCES BETWEEN DECEMBER 14, 1981 AND FEBRUARY 3, 1982



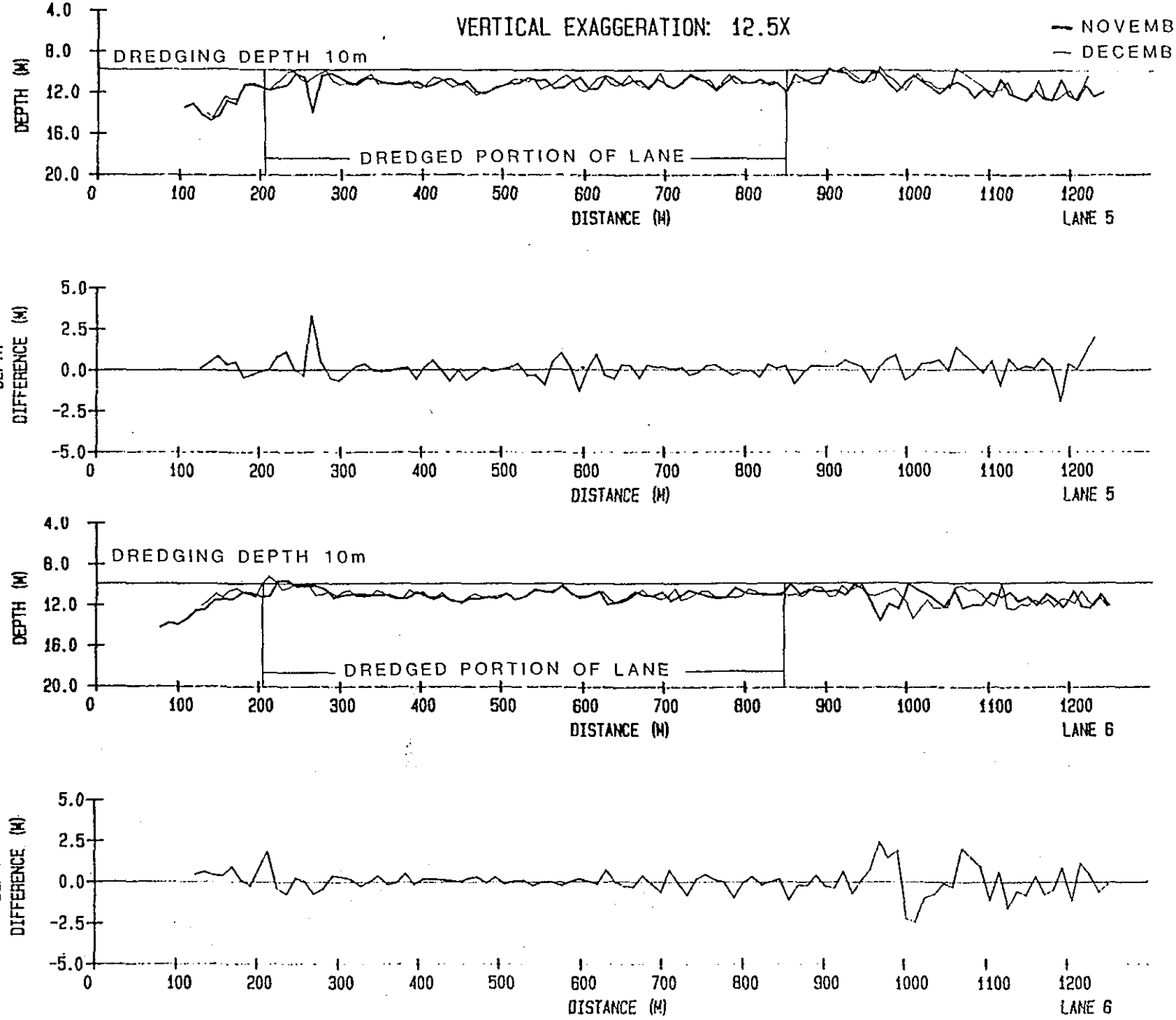
DEPTH DIFFERENCES BETWEEN DECEMBER 14, 1981 AND FEBRUARY 3, 1982



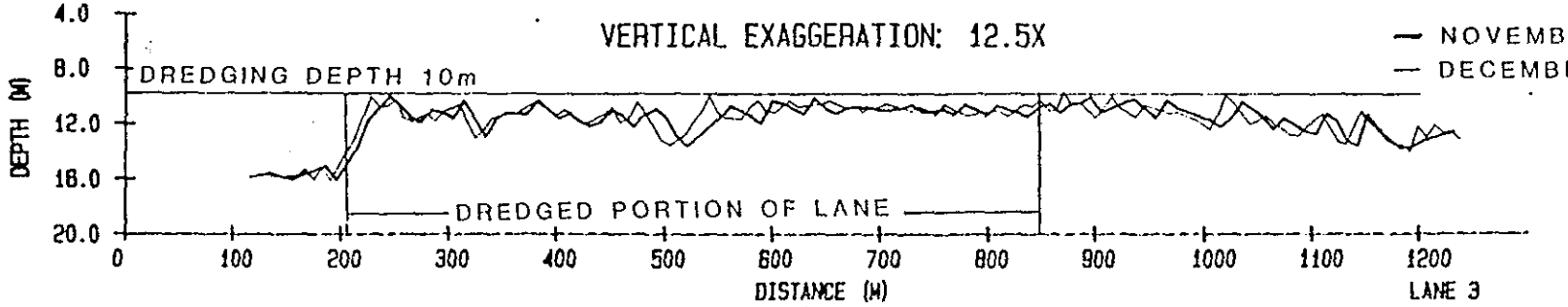
DEPTH DIFFERENCES BETWEEN DECEMBER 14, 1981 AND FEBRUARY 3, 1982

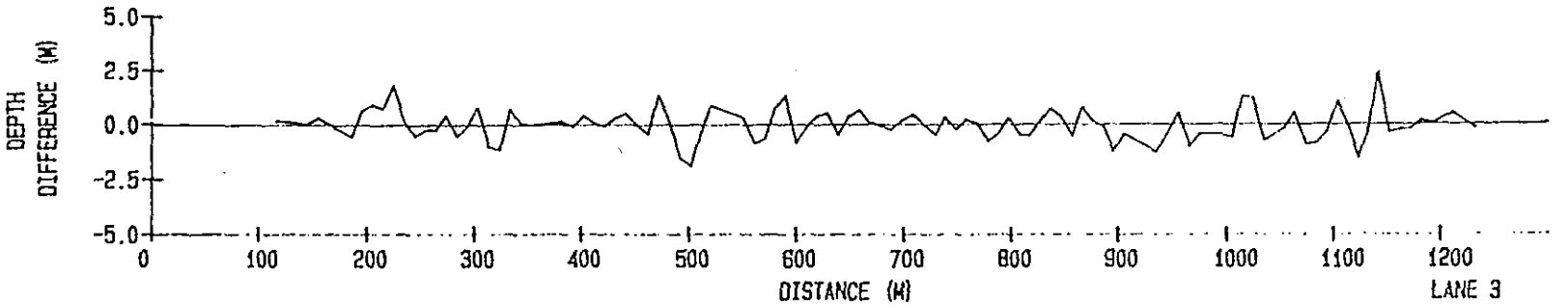


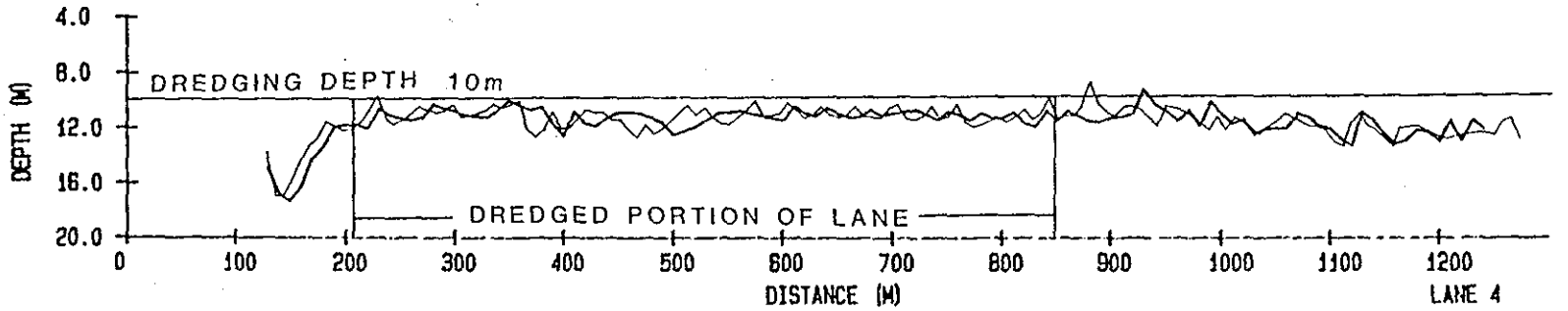
DEPTH DIFFERENCES BETWEEN NOVEMBER 2, 1981 AND DECEMBER 14, 1981

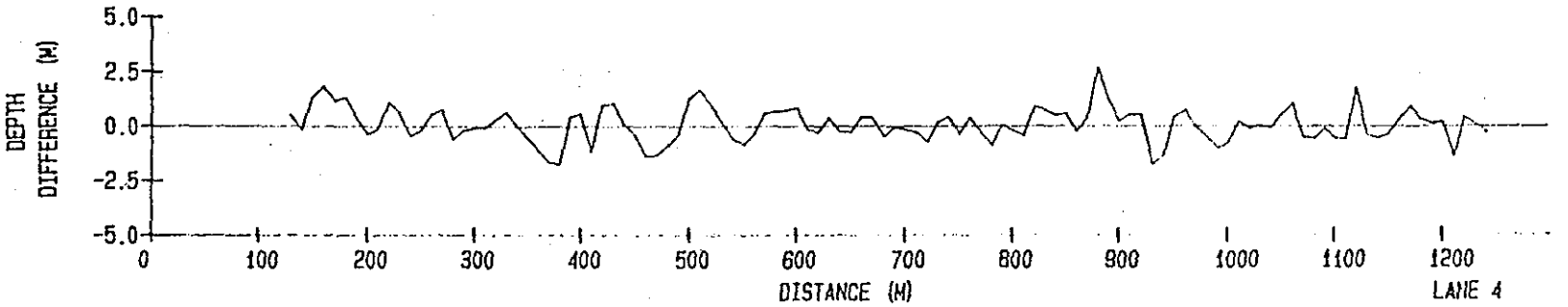


DEPTH DIFFERENCES BETWEEN NOVEMBER 2, 1981 AND DECEMBER 14, 1981

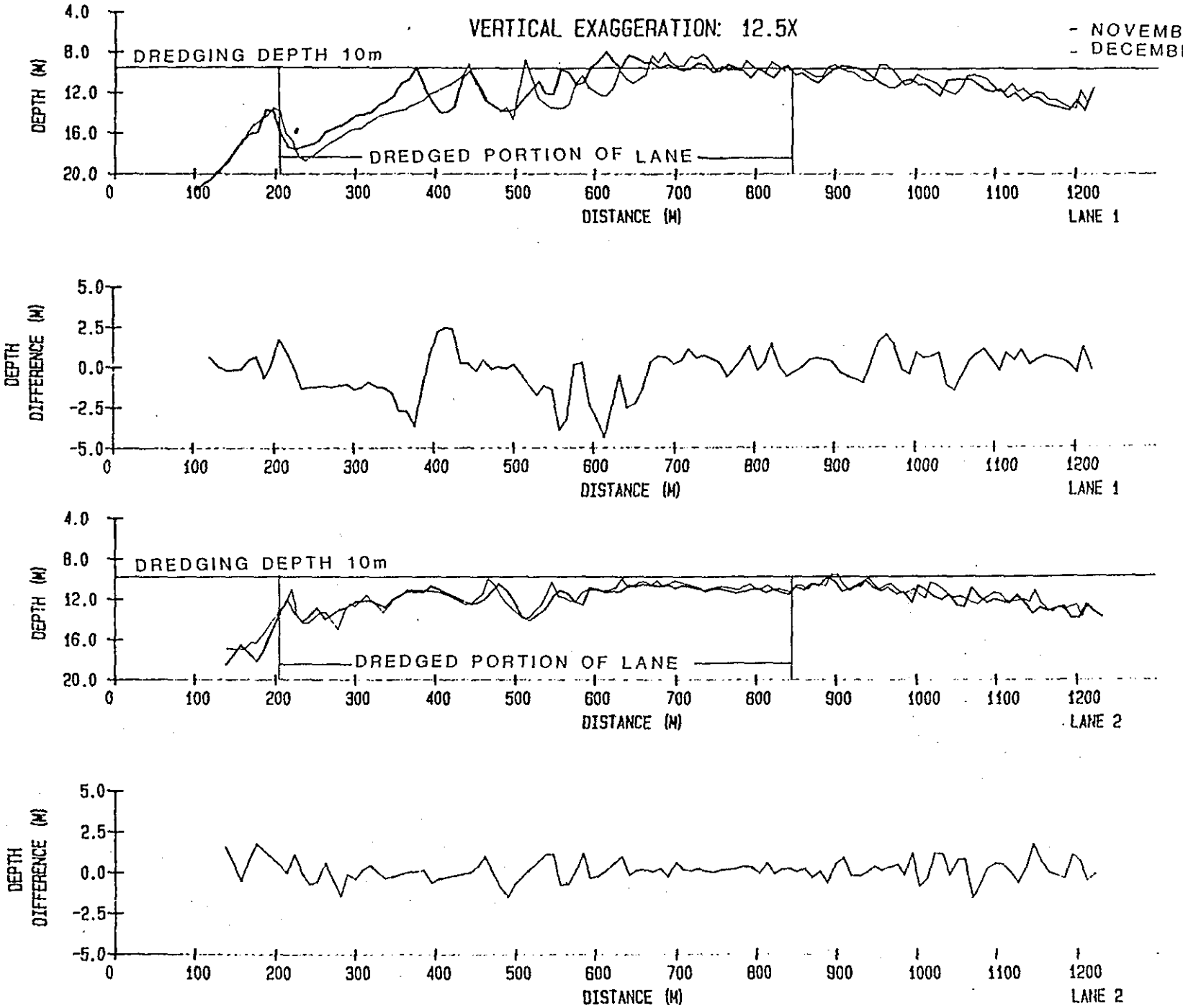




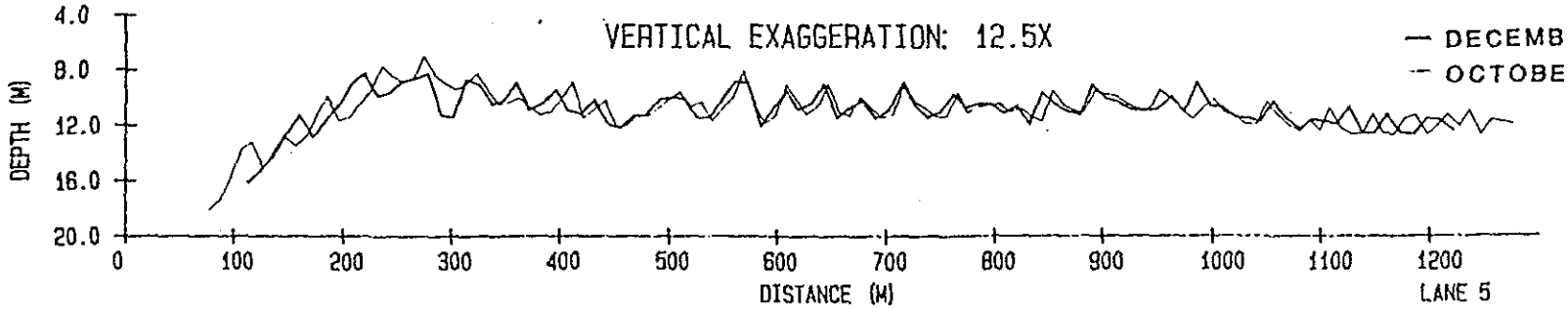


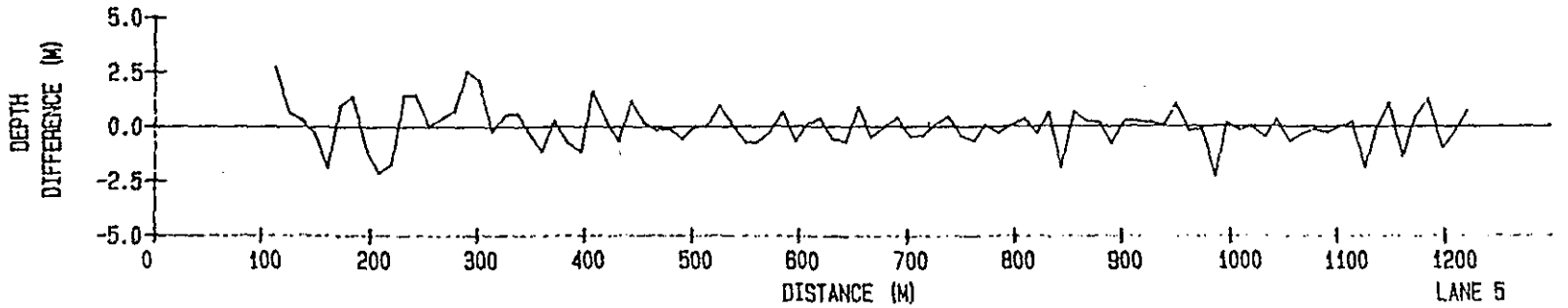


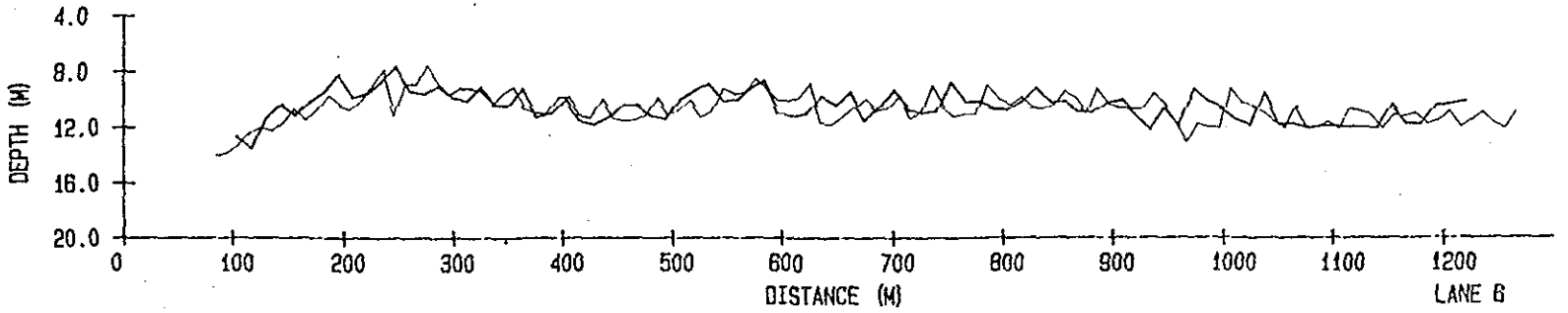
DEPTH DIFFERENCES BETWEEN NOVEMBER 2, 1981 AND DECEMBER 14, 1981

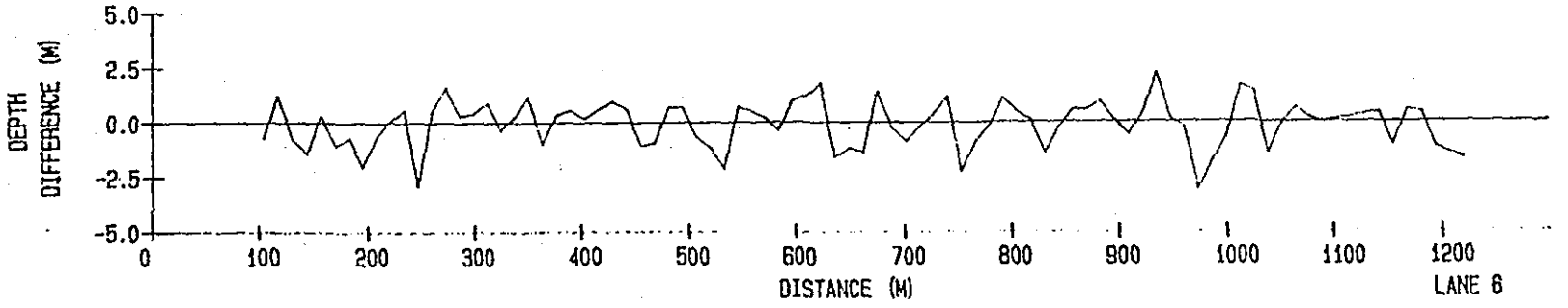


DEPTH DIFFERENCES BETWEEN DECEMBER 2, 1980 AND OCTOBER 5, 1981

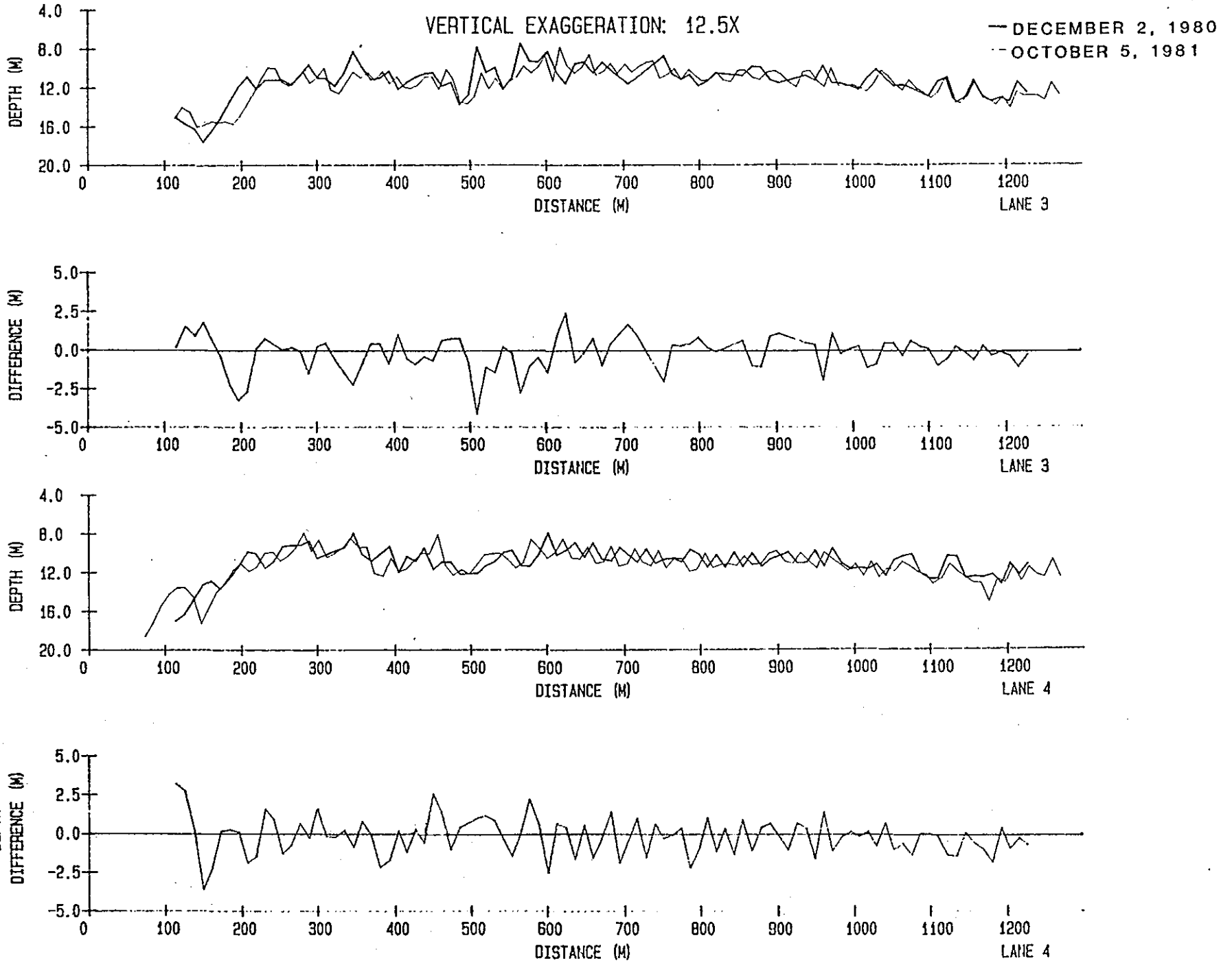




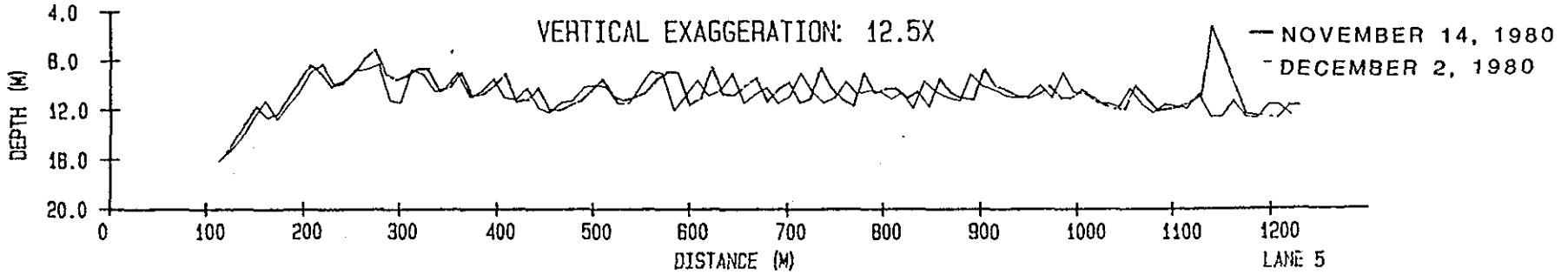


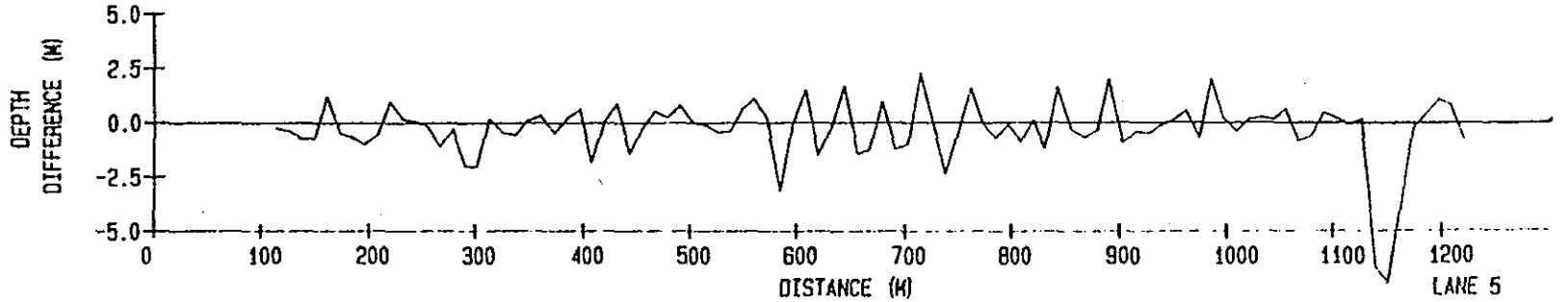


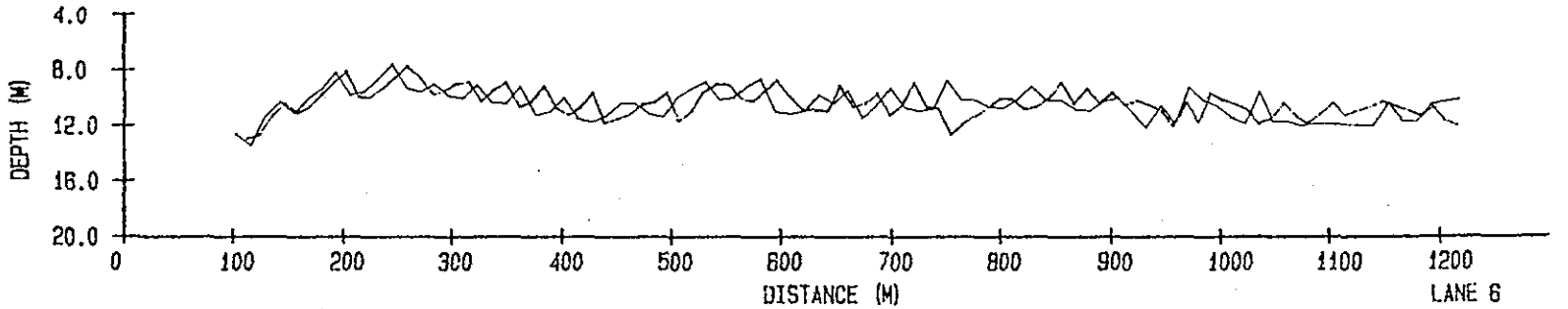
DEPTH DIFFERENCES BETWEEN DECEMBER 2, 1980 AND OCTOBER 5, 1981

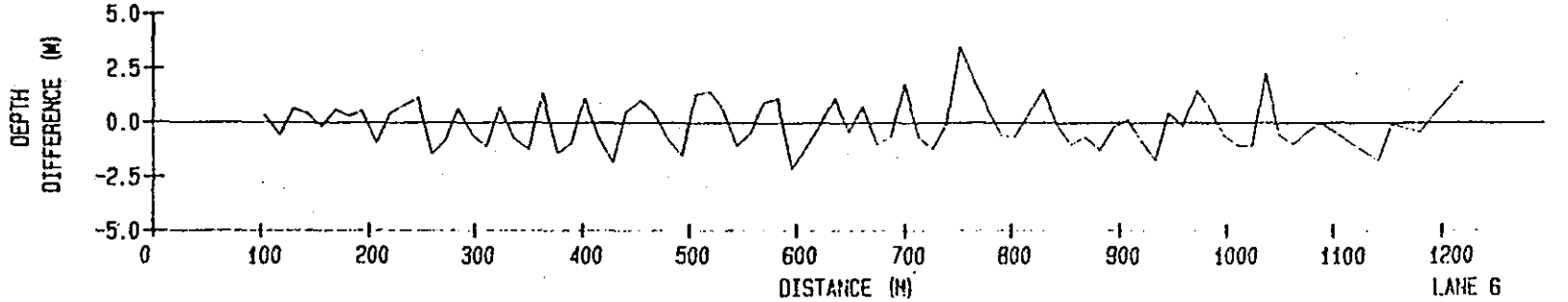


DEPTH DIFFERENCES BETWEEN NOVEMBER 14, 1980 AND DECEMBER 2, 1980

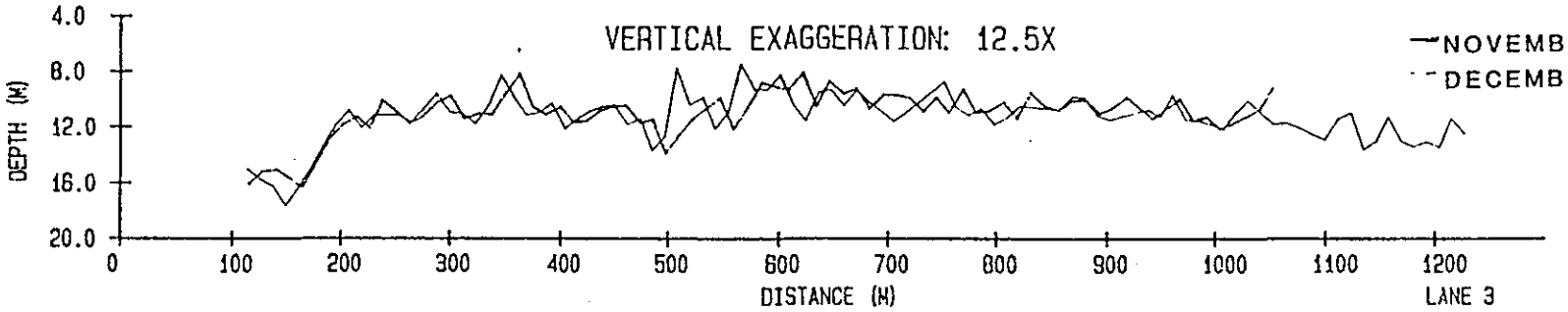


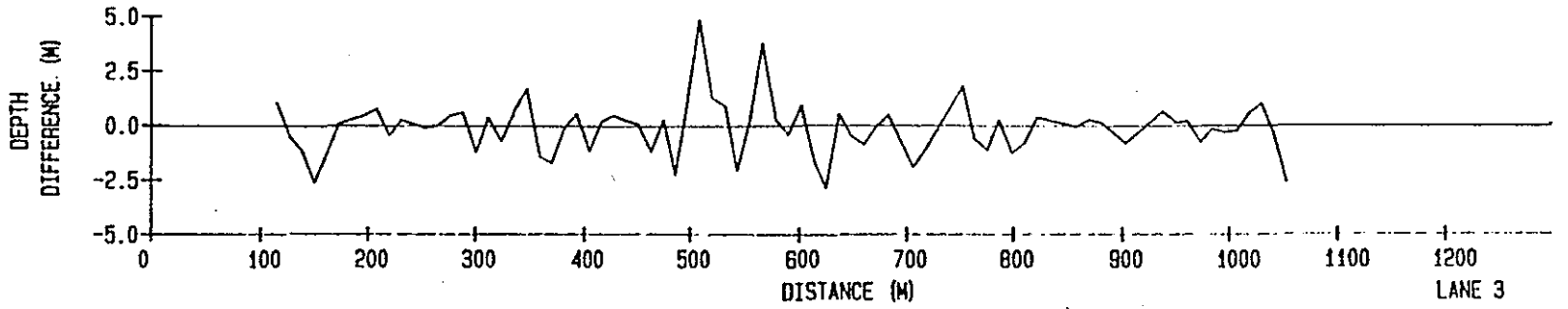


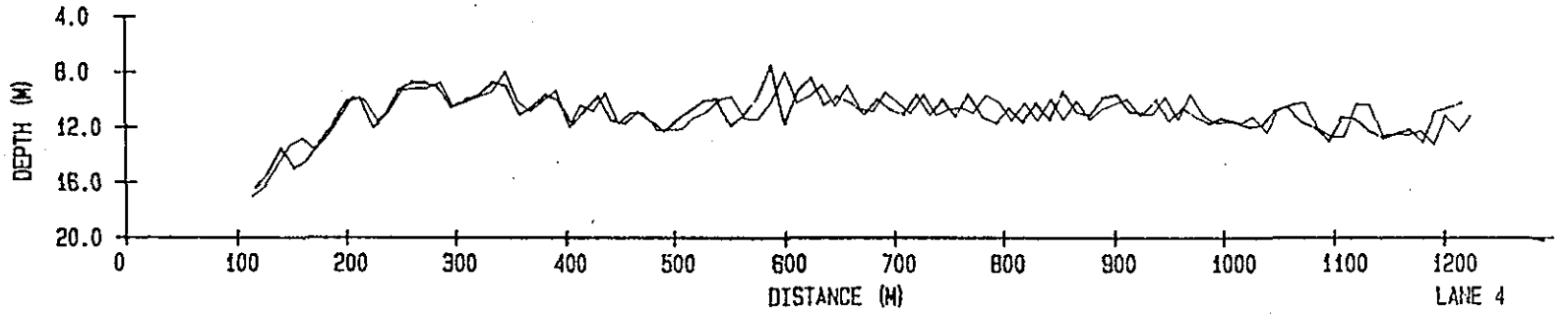


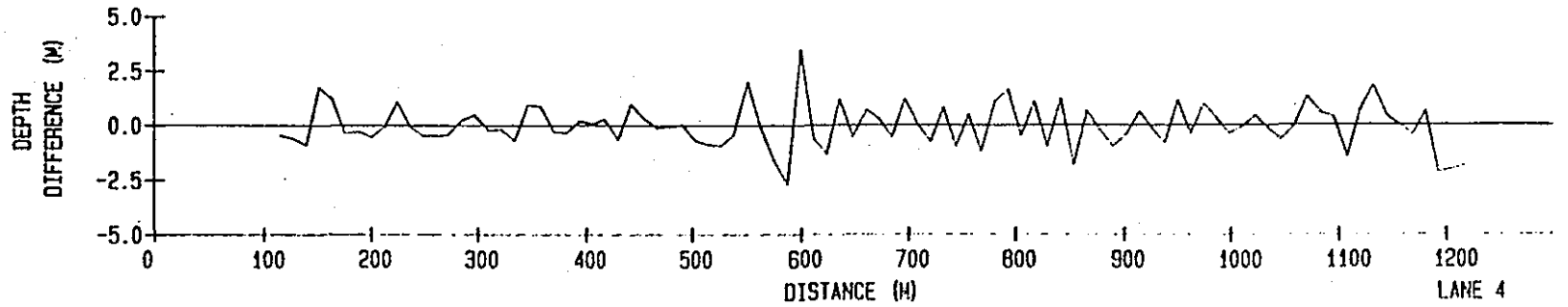


DEPTH DIFFERENCES BETWEEN NOVEMBER 14, 1980 AND DECEMBER 2, 1980

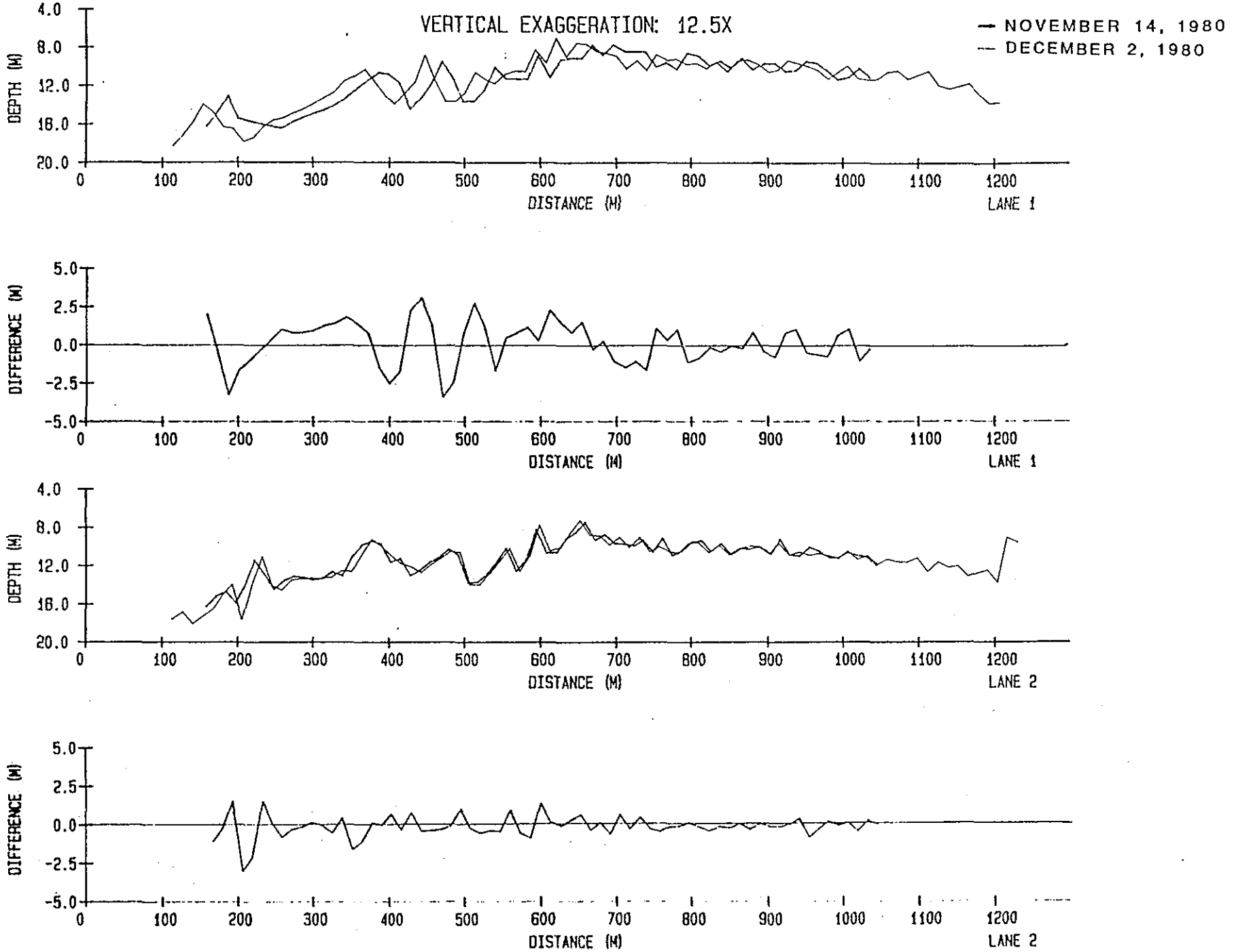




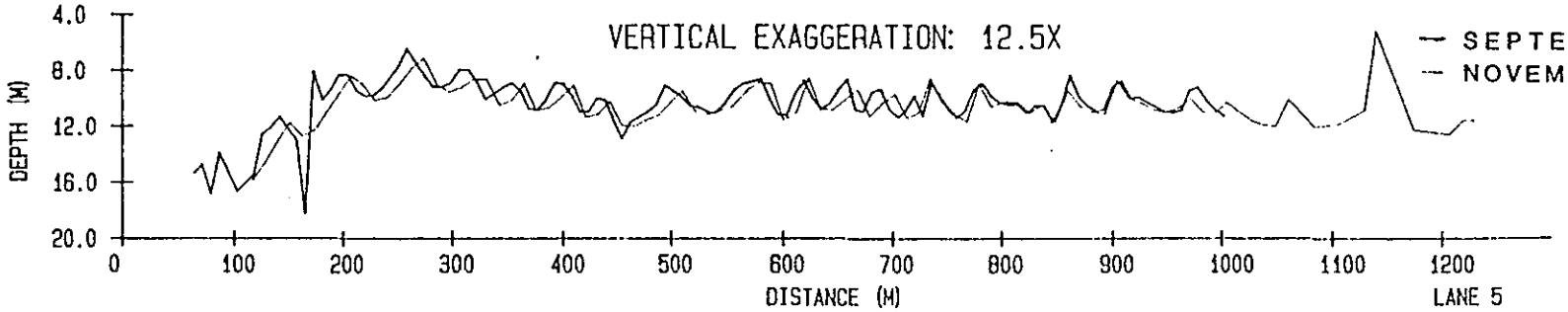


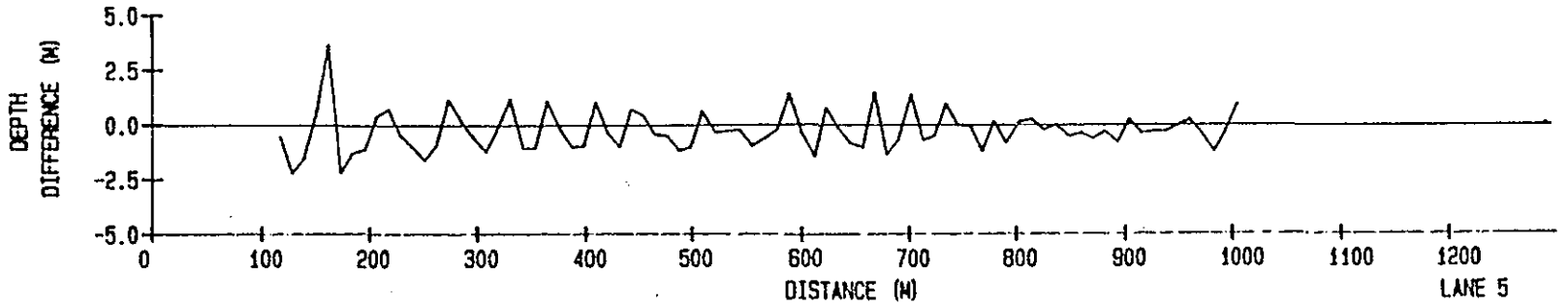


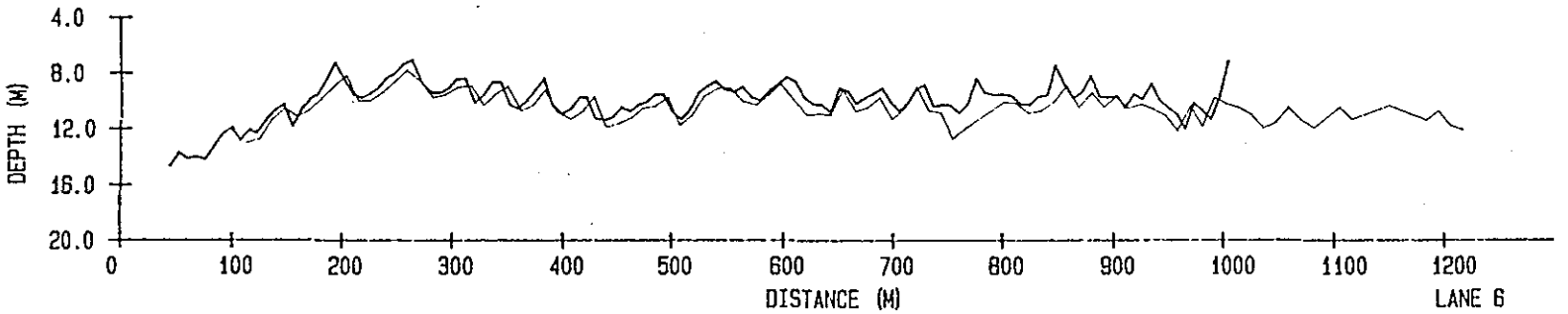
DEPTH DIFFERENCES BETWEEN NOVEMBER 14, 1980 AND DECEMBER 2, 1980

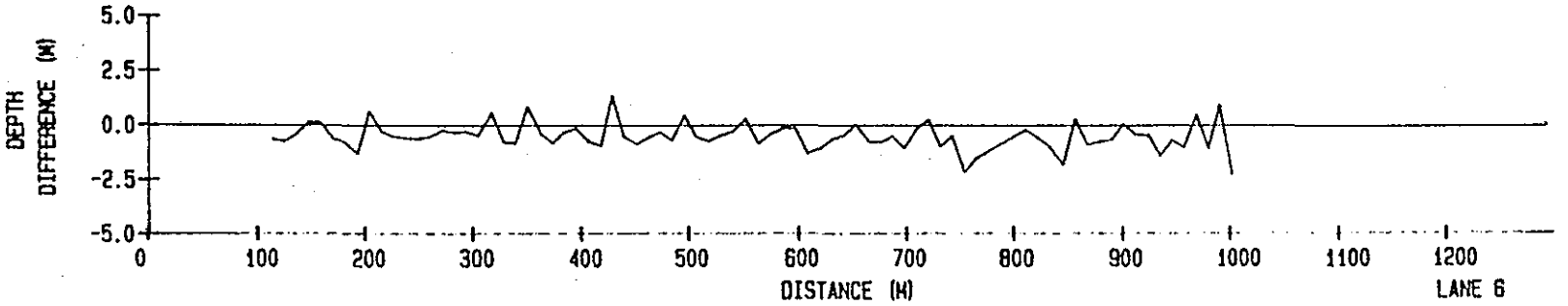


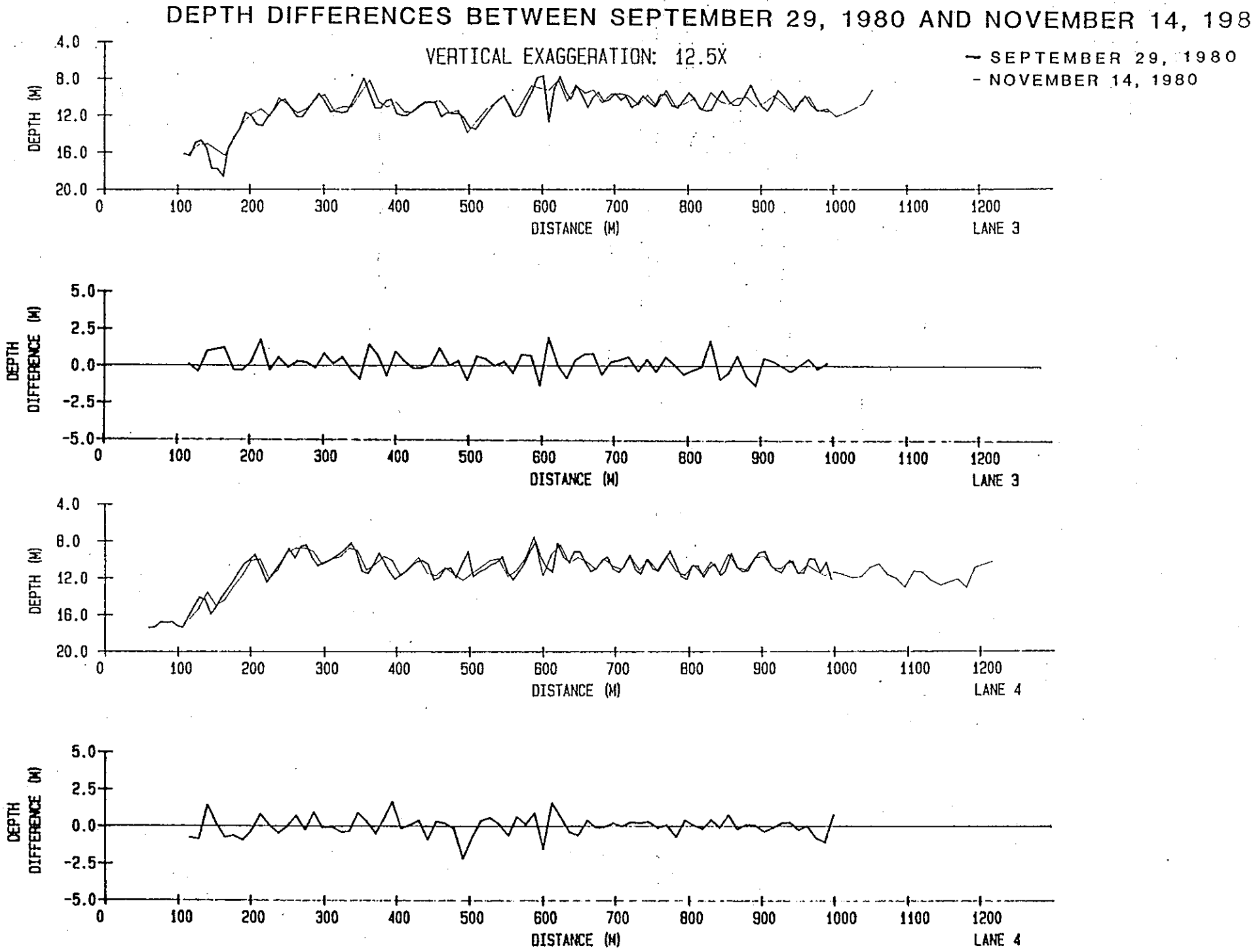
DEPTH DIFFERENCES BETWEEN SEPTEMBER 29, 1980 AND NOVEMBER 14, 1980

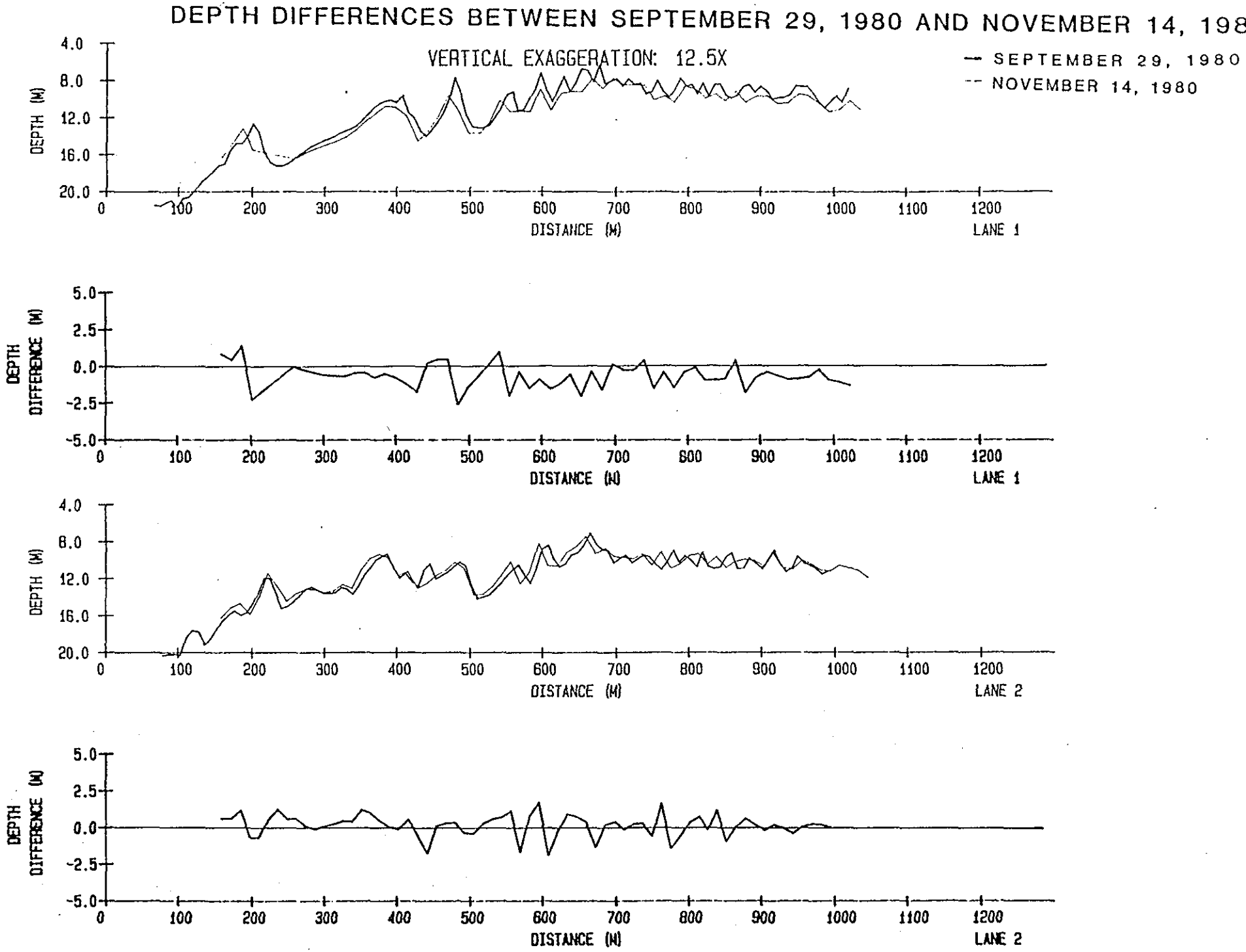









DEPTH DIFFERENCES BETWEEN SEPTEMBER 29, 1980 AND NOVEMBER 14, 198
VERTICAL EXAGGERATION: 12.5X
SEPTEMBER 29, 1980
NOVEMBER 14, 1980
DEPTH (M)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
DISTANCE (M)
LANE 3
DEPTH DIFFERENCE (M)
5.0
2.5
0.0
-2.5
-5.0
DISTANCE (M)
LANE 3
DEPTH (M)
DISTANCE (M)
LANE 4
DEPTH DIFFERENCE (M)
DISTANCE (M)
LANE 4


DEPTH DIFFERENCES BETWEEN SEPTEMBER 29, 1980 AND NOVEMBER 14, 198
VERTICAL EXAGGERATION: 12.5X
SEPTEMBER 29, 1980
NOVEMBER 14, 1980
DEPTH (M)
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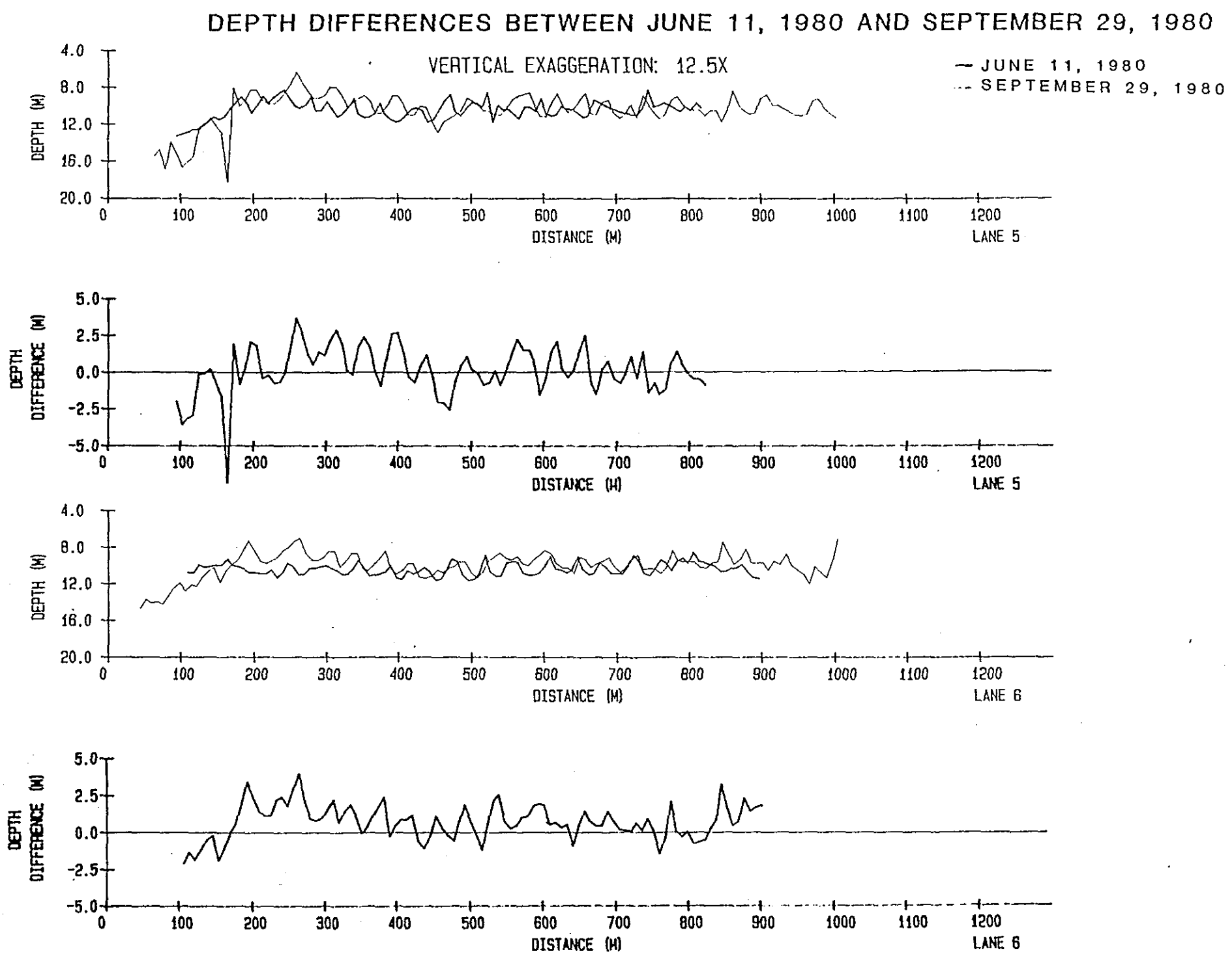
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
DISTANCE (M)
LANE 1
DEPTH DIFFERENCE (M)
5.0
2.5
0.0
-2.5
-5.0
DISTANCE (M)
LANE 1
DEPTH (M)
DISTANCE (M)
LANE 2
DEPTH DIFFERENCE (M)
DISTANCE (M)
LANE 2


DEPTH DIFFERENCES BETWEEN JUNE 11, 1980 AND SEPTEMBER 29, 1980
VERTICAL EXAGGERATION: 12.5X
JUNE 11, 1980
SEPTEMBER 29, 1980
DEPTH (M)
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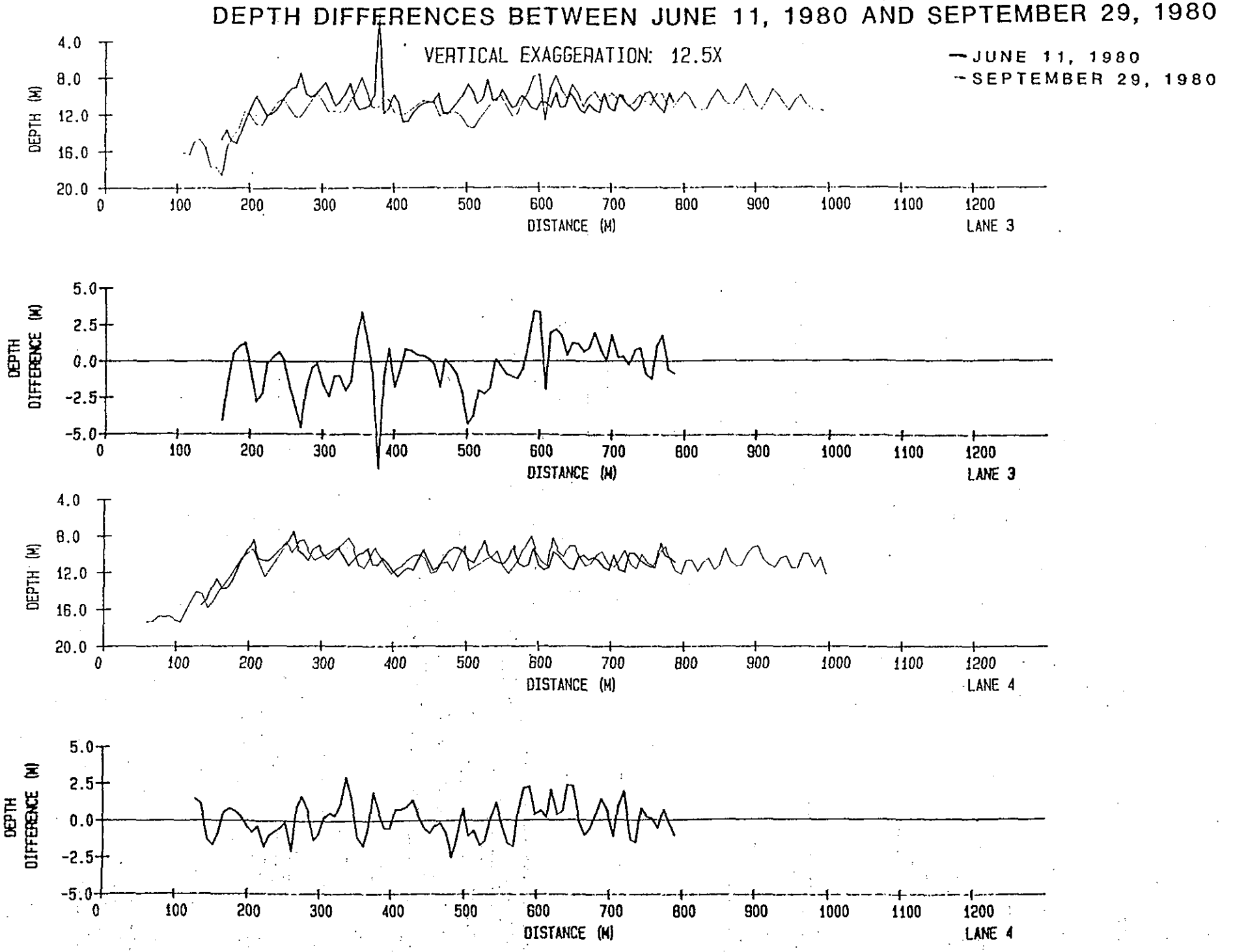
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
DISTANCE (M)
LANE 5
DEPTH DIFFERENCE (M)
5.0
2.5
0.0
-2.5
-5.0
DISTANCE (M)
LANE 5
DEPTH (M)
DISTANCE (M)
LANE 6
DEPTH DIFFERENCE (M)
DISTANCE (M)
LANE 6


DEPTH DIFFERENCES BETWEEN JUNE 11, 1980 AND SEPTEMBER 29, 1980
VERTICAL EXAGGERATION: 12.5X
JUNE 11, 1980
SEPTEMBER 29, 1980
DEPTH (M)
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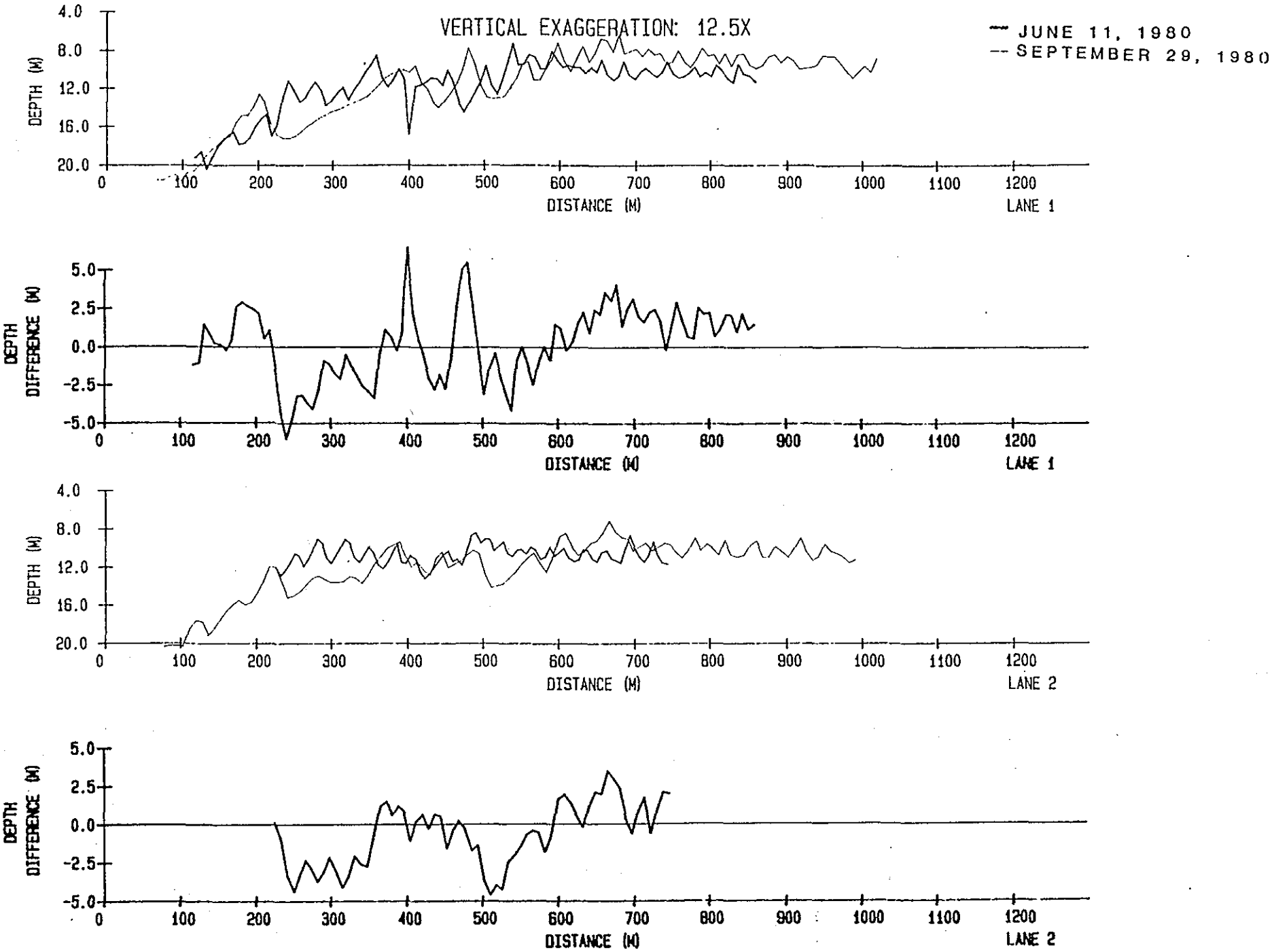
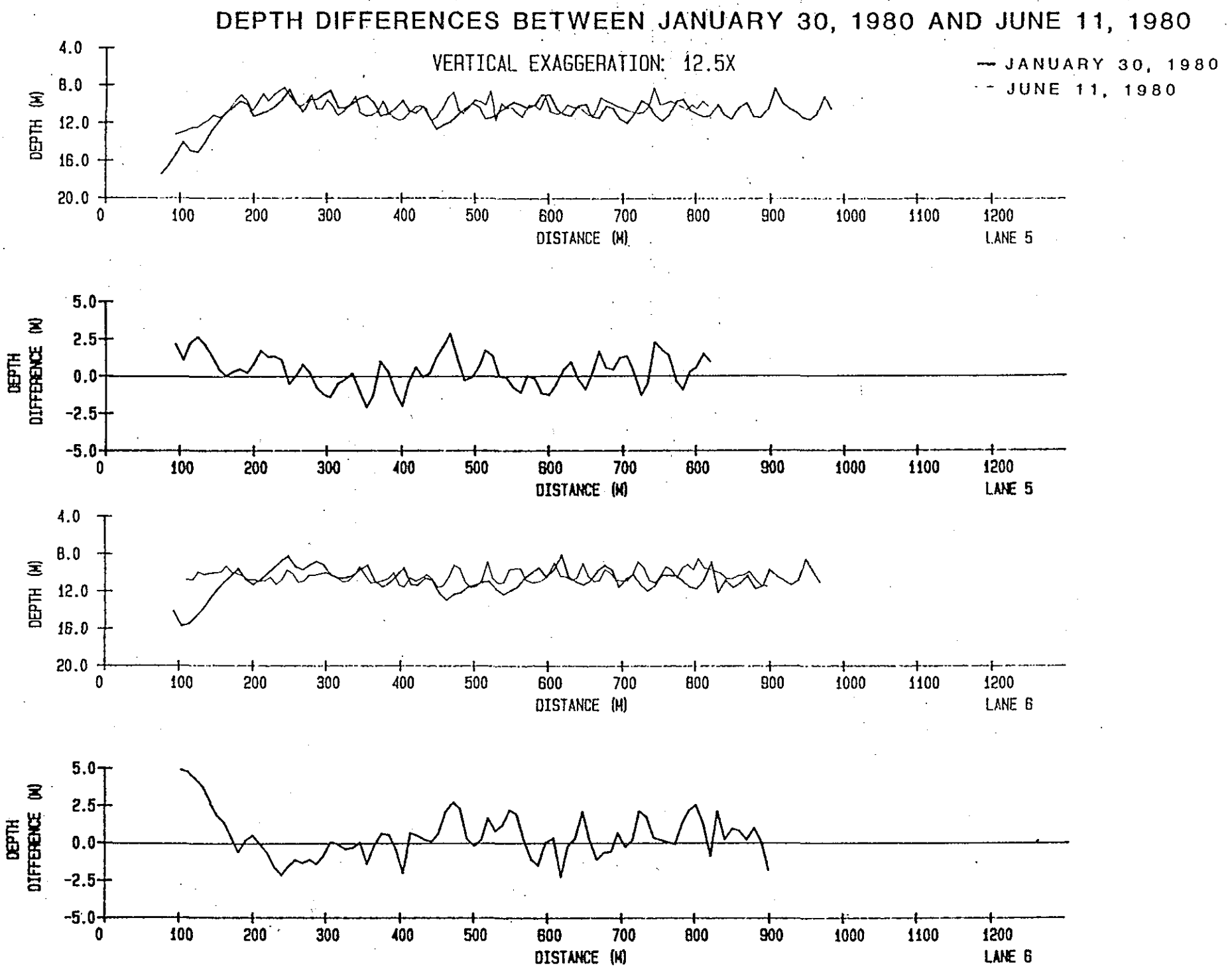
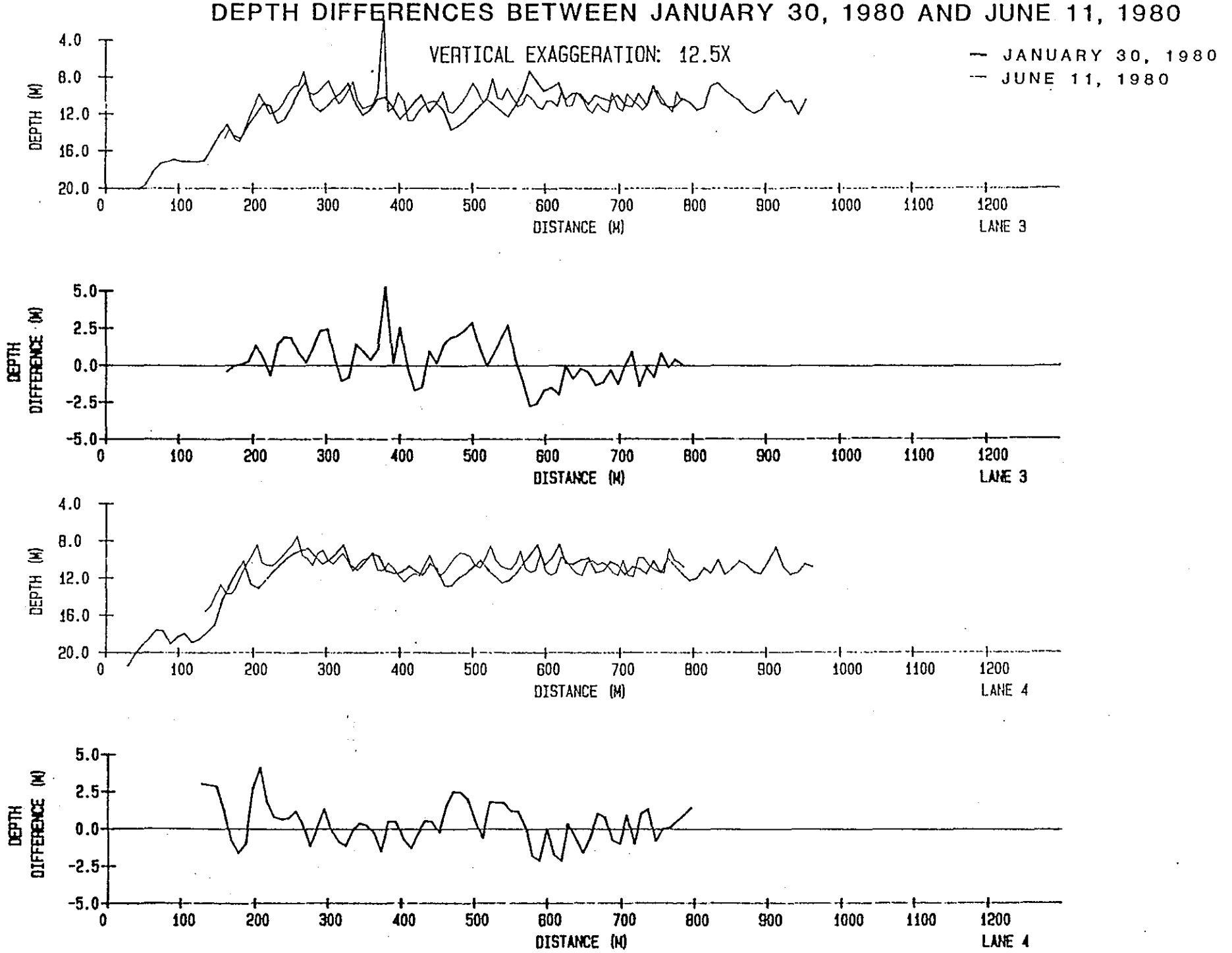
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
DISTANCE (M)
LANE 3
DEPTH DIFFERENCE (M)
5.0
2.5
0.0
-2.5
-5.0
DISTANCE (M)
LANE 3
DEPTH (M)
DISTANCE (M)
LANE 4
DEPTH DIFFERENCE (M)
DISTANCE (M)
LANE 4

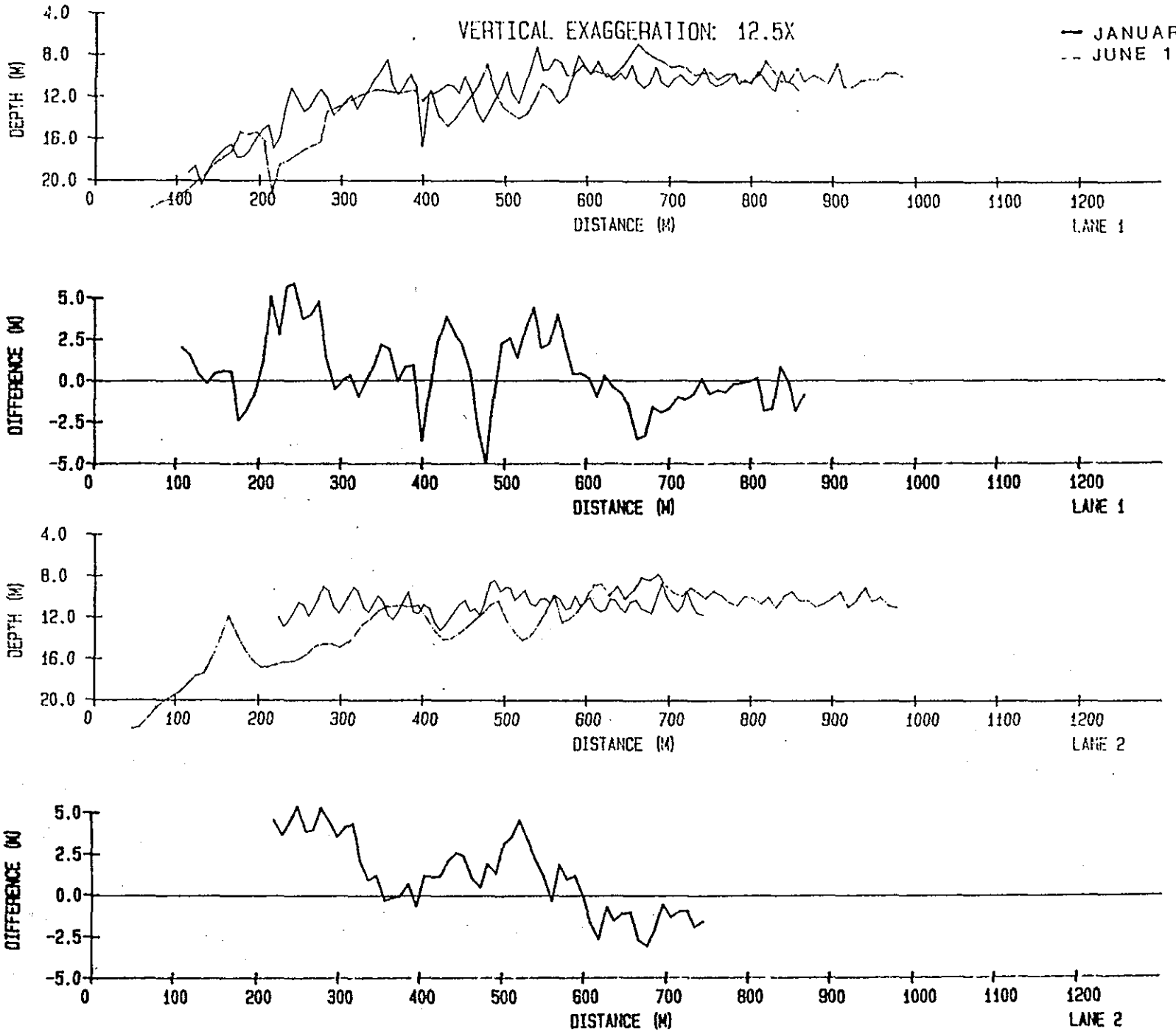
DEPTH DIFFERENCES BETWEEN JUNE 11, 1980 AND SEPTEMBER 29, 1980




DEPTH DIFFERENCES BETWEEN JANUARY 30, 1980 AND JUNE 11, 1980
VERTICAL EXAGGERATION: 12.5X
JANUARY 30, 1980
JUNE 11, 1980
DEPTH (M)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
DISTANCE (M)
LANE 5
DEPTH DIFFERENCE (M)
5.0
2.5
0.0
-2.5
-5.0
DISTANCE (M)
LANE 5
DEPTH (M)
DISTANCE (M)
LANE 6
DEPTH DIFFERENCE (M)
DISTANCE (M)
LANE 6


DEPTH DIFFERENCES BETWEEN JANUARY 30, 1980 AND JUNE 11, 1980
VERTICAL EXAGGERATION: 12.5X
JANUARY 30, 1980
JUNE 11, 1980
DEPTH (M)
4.0
8.0
12.0
16.0
20.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
DISTANCE (M)
LANE 3
DEPTH DIFFERENCE (M)
5.0
2.5
0.0
-2.5
-5.0
DISTANCE (M)
LANE 3
DEPTH (M)
DISTANCE (M)
LANE 4
DEPTH DIFFERENCE (M)
DISTANCE (M)
LANE 4

DEPTH DIFFERENCES BETWEEN JANUARY 30, 1980 AND JUNE 11, 1980



APPENDIX C

VOLUME DIFFERENCE DATA
KENNEBEC RIVER SURVEYS

APPENDIX C-1

Effective Lane Lengths for Comparison of Kennebec River Surveys

Survey	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	All Lanes
January 30, 1980 to June 11, 1980	760	505	625	670	730	800	4090
June 11, 1980 to September 29, 1980	745	525	630	660	725	765	4050
September 29, 1980 to November 14, 1980	865	840	880	885	890	890	5250
November 14, 1980 to December 2, 1980	855	885	940	1105	1110	1120	6015
December 2, 1980 to October 5, 1981	1095	1120	1120	1115	1110	1120	6680
October 5, 1981 to November 2, 1981 dredging occurred	1125	1105	1125	1125	1140	1175	6795

APPENDIX C-1 (CONT.)

Survey	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	All Lanes
November 2, 1981 to December 14, 1981	1105	1090	1120	1115	1110	1135	6675
December 14, 1981 to February 3, 1982	990	995	970	985	990	975	5905
February 3, 1982 to March 4, 1982	990	985	1000	1005	965	995	5940
December 2, 1980 to March 4, 1982	1045	1090	1105	1030	1070	1090	6430
November 2, 1981 to March 4, 1982	1045	1085	1100	1035	1085	1105	6455

Note: Effective lane length is defined as the length over which data were available from both surveys.

APPENDIX C-2

NUMBER OF DAYS BETWEEN SURVEYS

January 30, 1980 - June 11, 1980	133 days
June 11, 1980 - September 29, 1980	110 days
September 29, 1980 - November 14, 1980	15 days
November 14, 1980 - December 2, 1980	19 days
December 2, 1980 - October 5, 1981	307 days
October 5, 1981 - November 2, 1981	28 days
November 2, 1981 - December 14, 1981	43 days
December 14, 1981 - February 3, 1982	51 days
February 3, 1982 - March 4, 1982	29 days
December 14, 1981 - March 4, 1982	80 days

APPENDIX C-3

Total Volume Differences Between Surveys on the Kennebec River

Survey	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	All Lanes
January 30, 1980 to June 11, 1980	12,000	18,500	3,500	6,000	8,000	11,000	59,000
June 11, 1980 to September 29, 1980	4,000	-11,000	-5,500	1,000	6,000	17,500	12,000
September 29, 1980 to November 14, 1980	-16,000	4,000	6,000	500	-7,500	-14,000	-27,000
November 14, 1980 to December 2, 1980	3,000	-3,500	-3,000	500	-4,500	-2,500	-10,000
December 2, 1980 to October 5, 1981	-14,500	-8,500	-8,000	-7,500	1,500	-3,000	-40,000
October 5, 1981 to November 2, 1981 dredging occurred	500	-10,500	-9,500	-10,500	-17,500	-17,000	-64,00

APPENDIX C-3 (CONT.)

Survey	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	All Lanes
November 2, 1981 to December 14, 1981	-8,000	4,000	500	2,000	2,500	1,500	2,500
December 14, 1981 to February 3, 1982	19,500	6,000	8,500	4,500	6,000	7,000	51,000
February 3, 1982 to March 4, 1982	-11,500	-8,000	-10,000	-8,000	-6,000	-7,000	-50,500
December 14, 1981 to March 4, 1982	7,000	-2,000	-1,000	-3,000	-1,500	-1,000	-1,500
November 2, 1981 to March 4, 1982	-1,000	3,500	-500	500	-500	500	2,500

Note: Negative volume differences denote a loss of sediment from the first survey to the second.

APPENDIX C-4

Normalized Volume Differences Between Surveys on the Kennebec River

Survey	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	All Lanes
January 30, 1980 to June 11, 1980	3.9	9.1	2.4	2.3	2.6	2.8	3.6
June 11, 1980 to September 29, 1980	1.6	-6.2	-2.5	0.5	2.6	6.8	0.9
September 29, 1980 to November 14, 1980	-13.2	3.4	4.8	0.5	-6.0	-11.4	-3.7
November 14, 1980 to December 2, 1980	6.3	-7.2	-5.9	0.9	-7.8	-3.7	-0.3
December 2, 1980 to October 5, 1981	-1.4	-0.8	-0.8	-0.7	0.1	-0.3	-0.6
October 5, 1981 to November 2, 1981 dredging occurred	0.5	-11.0	-9.9	-10.9	-18.0	-17.0	-11.0

APPENDIX C-4 (CONT.)

Survey	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	All Lanes
November 2, 1981 to December 14, 1981	-5.4	2.8	0.3	1.4	1.6	1.0	0.3
December 14, 1981 to February 3, 1982	12.5	3.8	5.6	2.9	3.9	4.6	5.6
February 3, 1982 to March 4, 1982	-12.9	-9.0	-11.3	-9.0	-6.9	-7.8	-9.6
December 14, 1981 to March 4, 1982	2.7	-0.7	-0.4	-1.3	-0.6	-0.4	0.0
November 2, 1981 to	-0.3	0.9	-0.1	0.1	-0.1	0.1	0.1

Note: Negative normalized volume differences denote a loss of sediment from the first survey to the second.

$$\text{Normalized Volume Difference} = \frac{\text{Total Volume Difference}}{\text{Effective Lane Length} * \text{Lane Width} * \text{Number of Days}}$$