## CHAPTER 136

# EFFECT OF LONG PERIOD WAVES ON HYDROGRAPHIC SURVEYS

by

Orville T Magoon
Coastal Engineering Branch, U S Army Engineer Division,
South Pacific, 630 Sansome Street, San Francisco, California 94111

and

William O Sarlin
Chief, Technical Service Branch, U S Army Engineer District,
San Francisco, 100 McAllister Street, San Francisco, California 94102

## ABSTRACT

In conjunction with routine hydrographic surveys at Santa Cruz Harbor, California, bottom elevation discrepancies were observed which were not associated with positional errors It was suspected that these errors were associated with long period wave activity, common at this particular location on the Pacific Coast

The existing practice for obtaining hydrographic soundings is by use of floating craft using either echo sounding techniques or a "lead line" Both of the above techniques utilize the instantaneous water surface at the survey boat as a datum reference Normally the water surface elevation is determined by use of a water level recorder

Based on the analysis of 50 repetitions of a well monumented cross section in Santa Cruz Harbor, it was concluded that long period waves affect the results of hydrographic surveys by slowly varying the datum plane In the case of Santa Cruz Harbor, the maximum error due to this effect would be about ± 1 5 feet

## INTRODUCTION

Santa Cruz Harbor is located at the northerly end of Monterey Bay, California, about 65 nautical miles south of the entrance to San Francisco Bay, as shown in Figure 1 and Photo 1 The hydrography of the general coastal area and of Monterey Bay are shown on charts published by the United States Coast and Geodetic Survey, Nos 5402 and 5403 respectively In connection with studies of Monterey Harbor, located at the southerly end of Monterey Bay, and at Santa Cruz Harbor it has been shown that Monterey Bay and Santa Cruz Harbor are subject to pronounced seiching Individual maximum trough to crest heights of over three feet have been observed Nominal periods associated with these seiches vary from 80 seconds to over 10 minutes with oscillations of about 3 minutes in period being most evident

During the analyses of surveys made in the vicinity of Santa Cruz Harbor, an unexplained ambiguity in the sounding depths became apparent Although the cause of these ambiguities was unknown, it was hypothesized that they were caused by shifts in the sounding datum by long period waves Water level changes caused by these long period waves had previously been observed at Santa Cruz Harbor on numerous occasions by the authors These long wave oscillations of Monterey Bay and Santa Cruz Harbor are discussed by Wilson(1), Grauzinis(2), and Lynch(3) The existing practice for obtaining hydrographic survey information is by use of floating craft and either echo sounding techniques or by lead line The above techniques both utilize the instantaneous water surface at the survey boat as a datum reference. Generally a recording tide gage mounted on a 4" pipe well with a suitable orifice, a float, and recorder, are used in determining the instantaneous water surface Attenuated long period fluctuations in the water surface may be observed in the resulting marigram trace Discussion of tide gage attenuation is discussed by Cross(4) These long period undulations vary spacially both in period and height, however, it appears that their presence, but not their relative magnitude, may be determined by conventional portable tide gages Only the relatively flat bottom areas of the channel were used for purposes of this study and, therefore, the side slope areas are not involved

SURVEY TECHNIQUE

In order to measure the effects of long period waves on hydrographic surveys, a test project was started at Santa Cruz Harbor by establishing a "repetitive line" and this line is indicated on Figure 2 Cross-section surveys were taken along this line using an aluminum hydrographic boat with a length of 14 feet, a beam of 62 inches, a draft of approximately 12 inches The boat was equipped with a conventional tag-line reel with a cable marked at one foot intervals and a "Raytheon" fathometer, Model DE 119D, operating at a frequency of 200 kilo Hertz Leadline soundings were then taken with an eight pound lead to verify fathometer soundings A typical method used for hydrographic surveys is shown in Figure 3

Fifty (50) measurements of the repetitive lines were taken on 21-22 March 1968 Initially, ten (10) cross-sections were taken of the repetitive line on 20 March 1968, however, these lines were discarded from this

Numbers in parentheses indicate listed references at end of text study because they were considered practice lines for the crew to become accustomed to the survey techniques The tide was recorded continuously during the survey period with an automatic tide recorder mounted on a 4-inch pipe attached to a dock Tide corrections were applied to the fathometer soundings in order to correct the water depths The boat was controlled in the forward motion by a tag line calibrated at one (1) foot intervals with the zero end attached to a baseline on shore The side motion of the boat was controlled by an instrumentman with a transit on shore, giving signals to the boat operator for keeping the boat precisely on line The marigrams shown on Figures 4 and 5 are taken from a previous project and are included for typical data Figure 4 shows a typical record with an open end well, Figure 5 shows a typical record with a damped well

Then the plotted lines of soundings were superimposed on a chart to compare the results A sampling of these lines is shown on Figures 6, 7 and 8 These plottings indicate a data envelope of the echo sounding measurements of about one foot As the survey boat was traversing the reference line with closely controlled position, the sounding variations are then due to the datum changes as produced by the long period waves

These soundings are believed to be accurate since the location of the boat was controlled very carefully with an instrumentman on shore for the left and right directions or side motion of the boat The distances of the boat from the shore baseline were read on the tag line which was calibrated in feet Soundings were read to the closest tenth of a foot on the fathograms

## DISCUSSION

The effect of long period waves on hydrographic surveys has been demonstrated at Santa Cruz Harbor, and the effect of these waves at other locations along the Northern California Coast is believed to be of similar magnitude An effective monitor appears to be a recording tide gage located at an anti-nodal position in the survey area with a suitable orifice that would filter out short period waves A direct correction for the long wave effect could be obtained by use of a datum other than the water surface However, consideration of these techniques is beyond the scope of this study

In adjusting the soundings to account for the effect of tides, care must be taken to filter out the long wave excursions on the applicable marigrams In Santa Cruz Harbor, water elevations at locations away from the tide gage may be experiencing different water level elevations than at the tide gage In the extreme case, the water level at the tide gage could represent a maximum or peak on a wave and at the survey boat location in the harbor could represent a minimum or trough If the instantaneous water elevation is used at both the tide gage and at the survey boat, the sounding error will equal plus or minus the long period wave height

In the reduction of hydrographic sounding data, the water surface at the survey boat location is taken as a temporary datum This datum, is, of course, influenced by any water level fluctuations In the case presented in this paper, the actual fluctuation is considered to be due to long waves alone This is shown diagrammatically in Figure 9A, where the total long wave height is taken as "H" and it is further assumed that a recording gage and also the survey boat are located at anti-nodal positions in a standing wave situation Under these conditions, and with the recording tide gage operating correctly, a mean line may be drawn through the tide gage record (obviously the tide gage record may be damped mechanically or electrically) In this example, the maximum error due to the long wave effect will be equal to ±H/2 When the survey boat is at position A, the water level at the gage is A', but the average gage reading will be A'' Similarly, when the survey boat is at position B, the water level at the gage is B', and the average gage reading will be B'' If the actual water surfaces at both the survey boat and the gage are used, then the situation shown in Figure 9B results In this case, when the survey boat is at position C, the water level and the tide gage datum are at position C' Similarly, when the survey boat is at position D, the water surface and tide gage datum are at position D' In this instance, the maximum error will be ±H or twice the error as resulting in Case A, above

In a real harbor, the situation becomes much more complex due to the inability to describe the instantaneous water surface elevation at the gage and survey boat In instances where long waves are known to have occurred during surveys, it is suggested that a note be added to the survey information and resulting charts to indicate the situation

## CONCLUSIONS

Based on the results of this study, it is concluded that long period waves affect the results of hydrographic surveys by slowly varying the datum plane in a manner that cannot be corrected by existing techniques Experience at Santa Cruz Harbor indicates that long period waves reach heights slightly in excess of 3 feet and thus during times of occurrence of such waves, the maximum expected error in hydrographic surveys would be approximately equal to 1/2 this value or about ±1-1/2 feet due to this effect if the tide gage record has been properly reduced Incorrect reduction of the tide gage record may result in the sounding error equal to plus or minus the long wave height, or in this example ±3 feet

## ACKNOWLEDGEMENT

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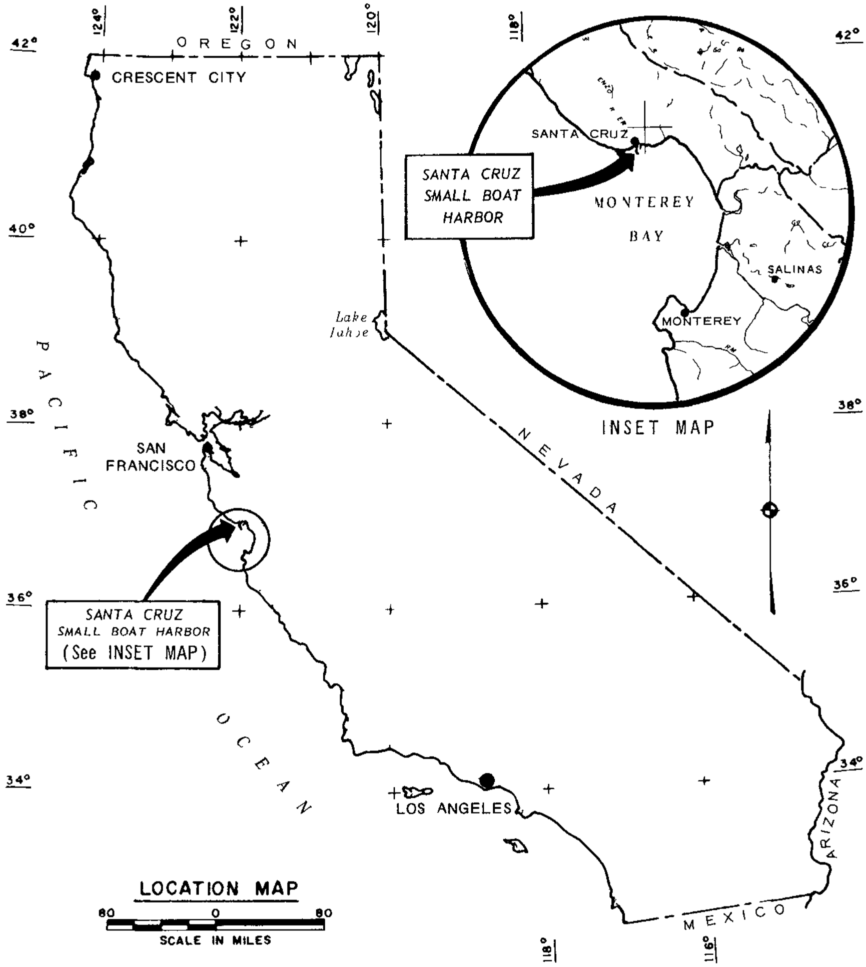
REFERENCES

1 Wilson, Basil W , Hendrickson, James A , and Kilmer, Robert E , "Feasibility Study for a Surge Action Model of Monterey Harbor, California," prepared for U S Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi, under Contract No DA 22-079-CIVENG-65-10, October 1965 Science Engineering Associates, a Division of Kaman Aircraft Corporation, San Marino, California

2 Grauzinis, V J , "An Analysis of Seiche Conditions in Santa Cruz Harbor, California, and Some Implications for the Proposed Harbor Extension," for U S Army Engineer District, San Francisco, Corps of Engineers, Contract No DACW07-68-C-0034, March 1968

3 Lynch, Thomas John, "Long Wave Study of Monterey Bay," Thesis at United States Naval Postgraduate School, September 1970

4 Cross, Ralph H , "Non-Linear Wave Effects on Tide Gages," Hydraulic Engineering Laboratory, College of Engineering, University of California, Berkeley, May 1967




SANTA CRUZ HARBOR

FIGURE 1

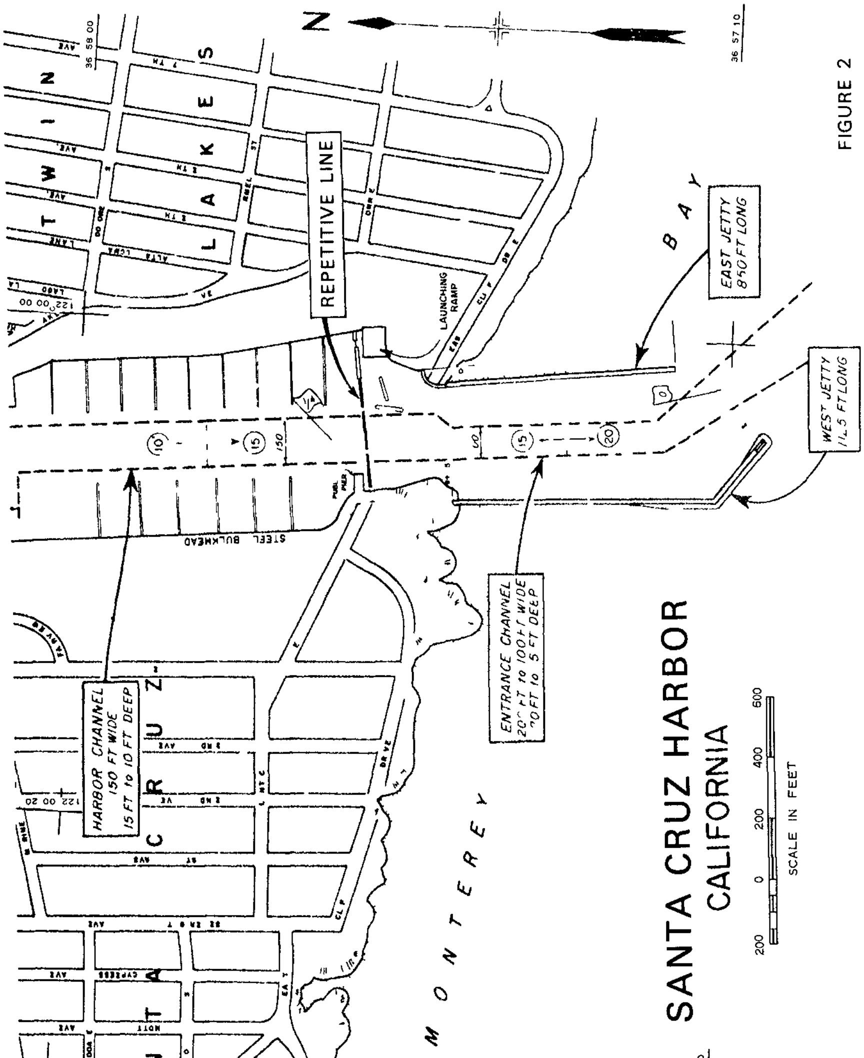

SANTA CRUZ HARBOR
CALIFORNIA
REPETITIVE LINE
EAST JETTY
850 FT LONG
WEST JETTY
1125 FT LONG
ENTRANCE CHANNEL
HARBOR CHANNEL
150 FT WIDE
15 FT TO 10 FT DEEP
LAUNCHING RAMP
STEEL BULKHEAD
FUEL PIER
TWIN LAKES
SANTA CRUZ
MONTEREY BAY
SCALE IN FEET
200 0 200 400 600

FIGURE 2

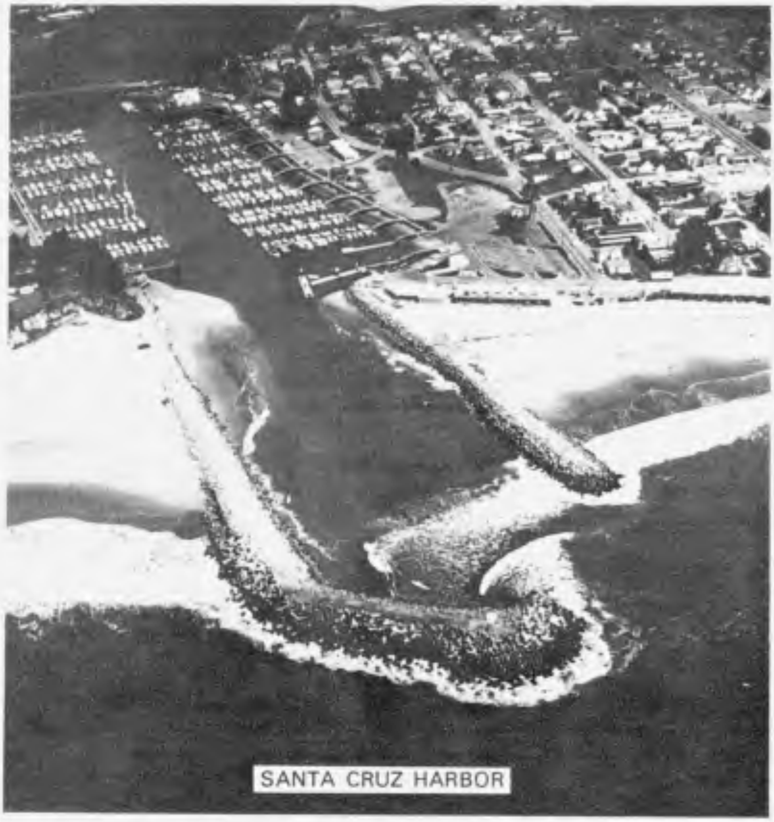



PHOTO 1

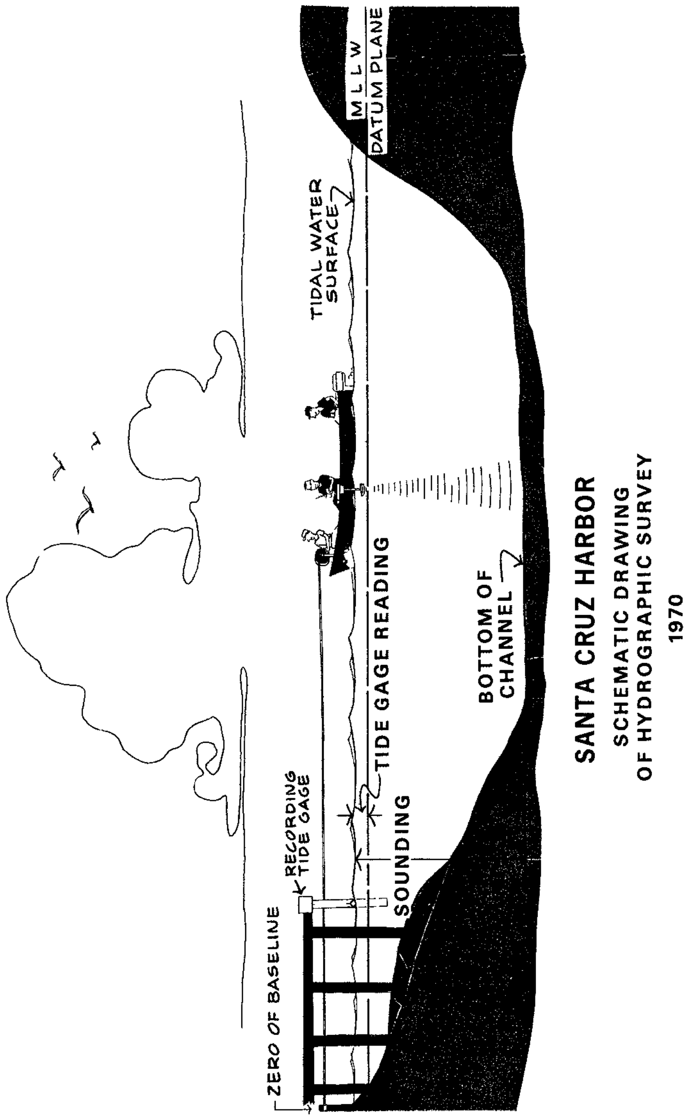

M L L W
DATUM PLANE
TIDAL WATER SURFACE
TIDE GAGE READING
RECORDING TIDE GAGE
SOUNDING
ZERO OF BASELINE
BOTTOM OF CHANNEL
SANTA CRUZ HARBOR
SCHEMATIC DRAWING
OF HYDROGRAPHIC SURVEY
1970

FIGURE 3

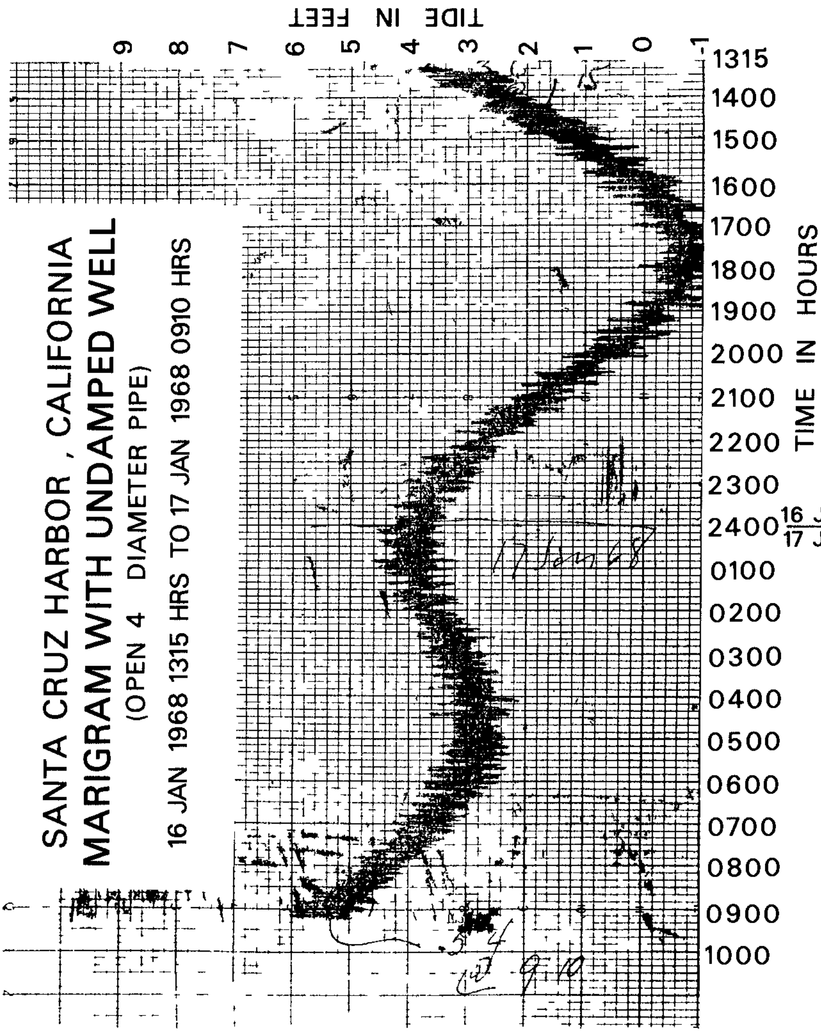

SANTA CRUZ HARBOR , CALIFORNIA
MARIGRAM WITH UNDAMPED WELL
(OPEN 4 DIAMETER PIPE)
16 JAN 1968 1315 HRS TO 17 JAN 1968 0910 HRS
TIDE IN FEET
9 8 7 6 5 4 3 2 1 0 -1
TIME IN HOURS
1315
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
16 JAN
17 JAN
0100
0200
0300
0400
0500
0600
0700
0800
0900
1000

FIGURE 4

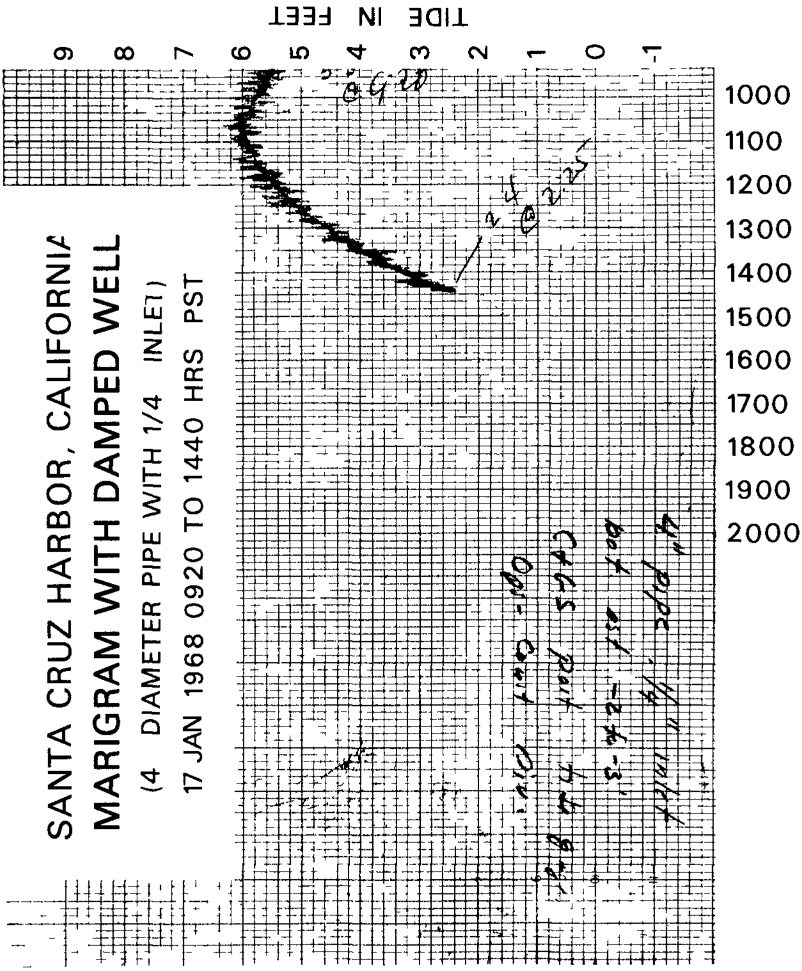

SANTA CRUZ HARBOR, CALIFORNIA
MARIGRAM WITH DAMPED WELL
(4 DIAMETER PIPE WITH 1/4 INLET)
17 JAN 1968 0920 TO 1440 HRS PST
TIDE IN FEET
9
8
7
6
5
4
3
2
1
0
-1
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
TIME IN HOURS

FIGURE 5

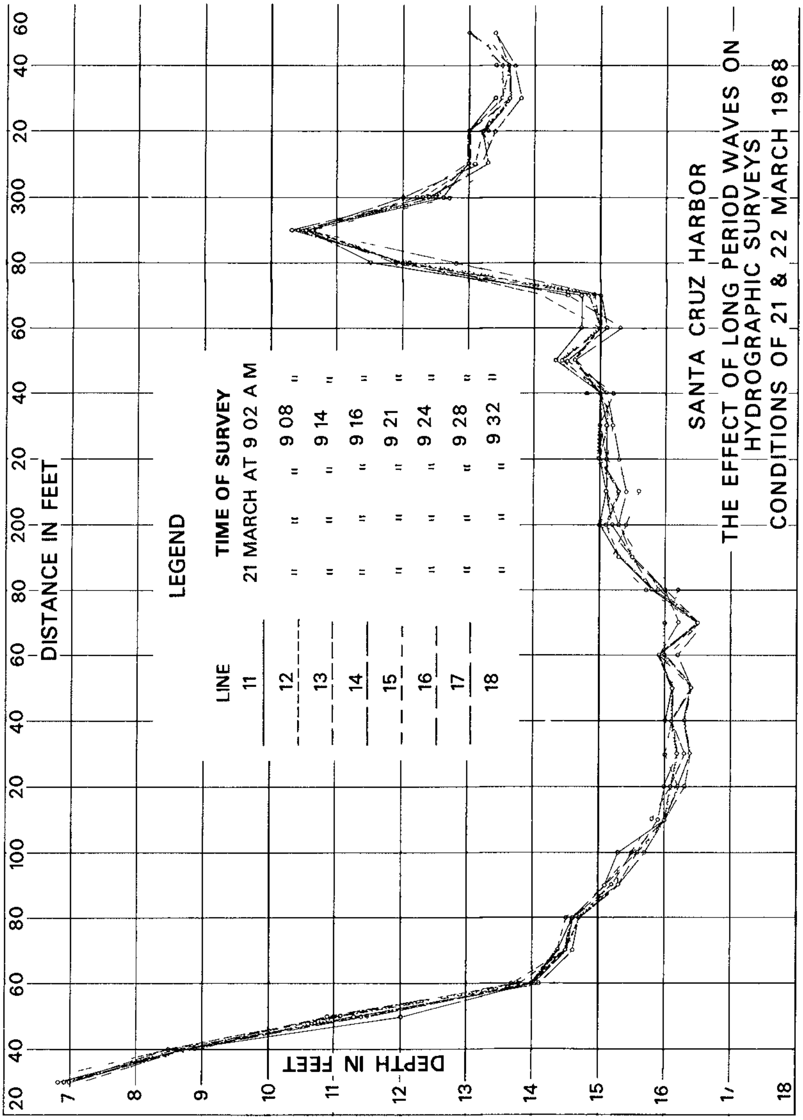
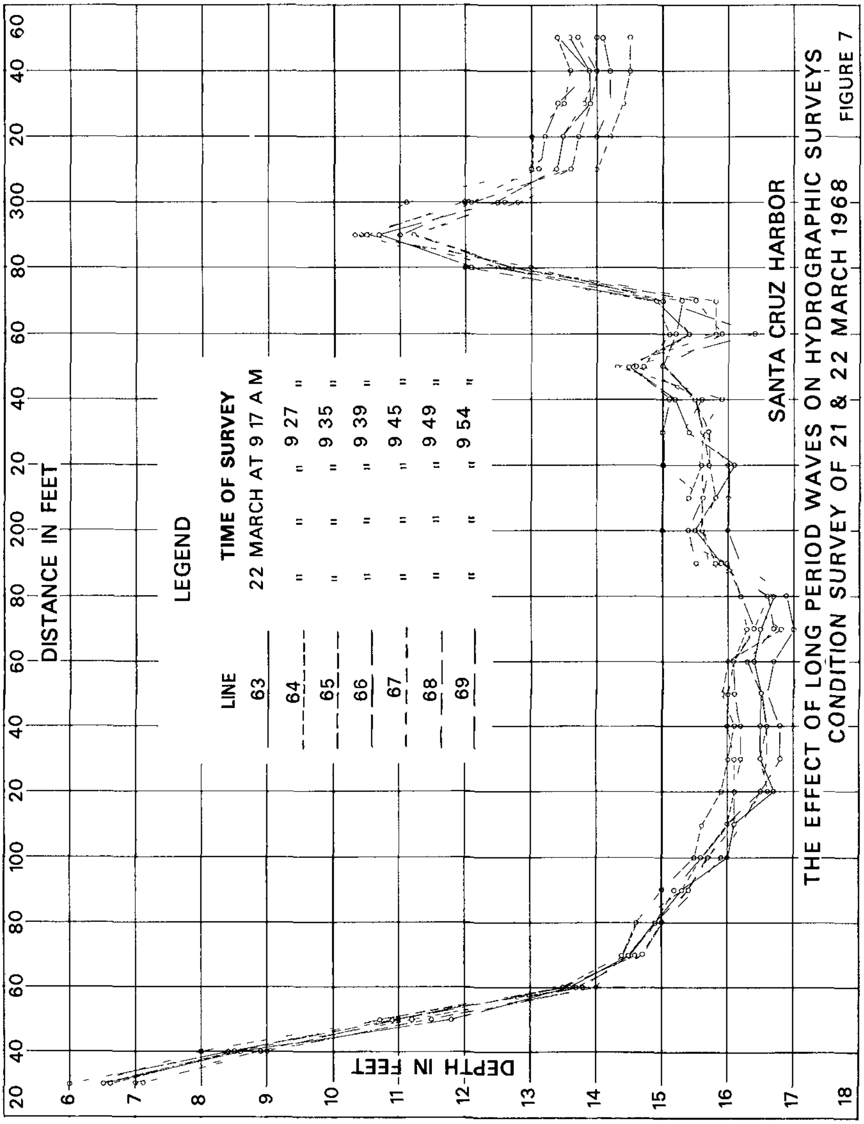

DISTANCE IN FEET
20
40
60
80
100
20
40
60
80
200
20
40
60
80
300
20
40
60
DEPTH IN FEET
7
8
9
10
11
12
13
14
15
16
17
18
LEGEND
LINE
11
12
13
14
15
16
17
18
TIME OF SURVEY
21 MARCH AT 9 02 A M
" " " " 9 08 "
" " " " 9 14 "
" " " " 9 16 "
" " " " 9 21 "
" " " " 9 24 "
" " " " 9 28 "
" " " " 9 32 "
SANTA CRUZ HARBOR
THE EFFECT OF LONG PERIOD WAVES ON
HYDROGRAPHIC SURVEYS
CONDITIONS OF 21 & 22 MARCH 1968

FIGURE 6




THE EFFECT OF LONG PERIOD WAVES ON HYDROGRAPHIC SURVEYS
CONDITION SURVEY OF 21 & 22 MARCH 1968

FIGURE 7

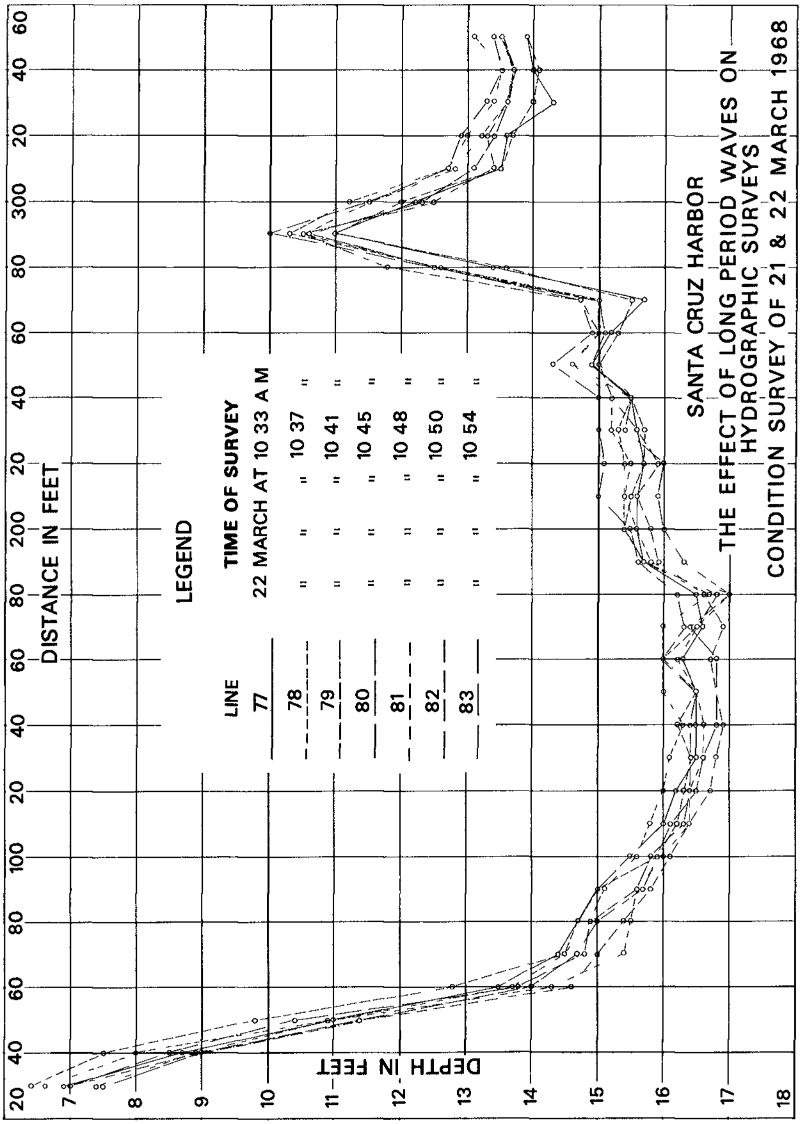
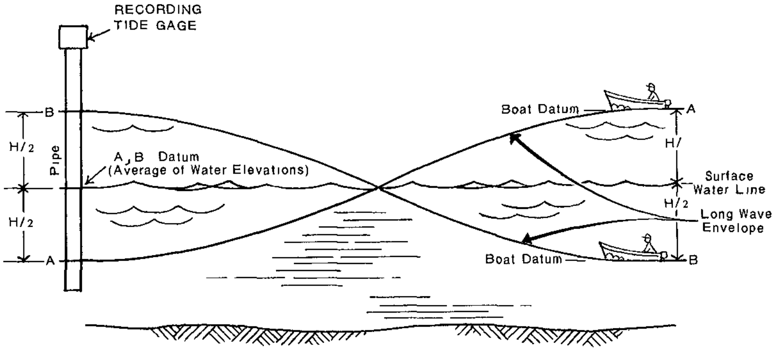

DISTANCE IN FEET
DEPTH IN FEET
LEGEND
LINE
TIME OF SURVEY
77 22 MARCH AT 10 33 A M
78 10 37
79 10 41
80 10 45
81 10 48
82 10 50
83 10 54
SANTA CRUZ HARBOR
THE EFFECT OF LONG PERIOD WAVES ON
HYDROGRAPHIC SURVEYS
CONDITION SURVEY OF 21 & 22 MARCH 1968

FIGURE 8

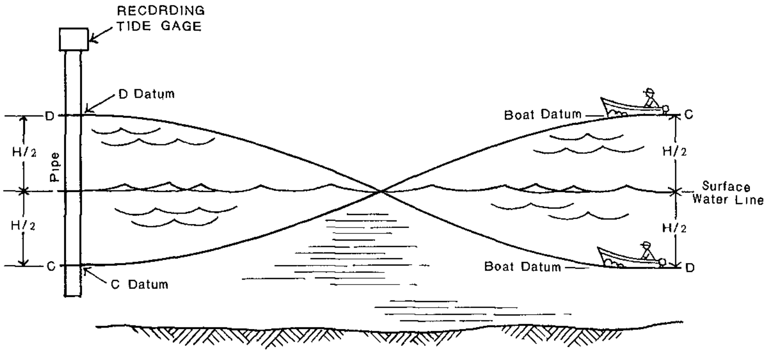
# SANTA CRUZ HARBOR




## (A) NORMAL METHOD OF SOUNDING REDUCTION FOR TIDES

Max Error= ± H/2

FIGURE 9A




## (B) INCORRECT METHOD OF SOUNDING REDUCTION FOR TIDES

Max Error=±H

H=Long Period Wave Height

FIGURE 9B