NARRAGANSETT MARINE LABORATORY
University of Rhode Island
Kingston, Rhode Island

Reference No. 53-21

SEDIMENTATION PROJECT

AVERAGE MONTHLY SURFACE WAVE BOTTOM OSCILLATIONS OFF SOUTH BEACH, MARTHA'S VINEYARD

by
STEACY D. HICKS

Technical Report No. 2
May 1954

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Approved for Distribution Charles J. Fish
Director

TECHNICAL REPORT NO. 2

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ABSTRACT

Graphs are presented showing the maximum speeds and lengths of bottom oscillations due to surface waves as a function of depth for each month (except June) off South Beach, Martha's Vineyard. The calculations are based on the theory of waves of small amplitude. The data represent oscillations due to the average monthly significant waves.

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INTRODUCTION

The most important water movements off exposed coasts are due to waves, and long shore and rip currents. The purpose of this study was to determine the movements due to wave motion acting along the bottom in a specific area off an exposed coast; namely, South Beach, Martha's Vineyard. Since waves cause oscillatory motion along the bottom, this report is concerned with calculations of the lengths of these oscillations and the maximum speeds which particles attain in such an oscillation. This information is important, not only in its effects on objects resting on the bottom, but also in its effects on erosion, transportation and deposition of sediments.

DISCUSSION

Wave height and period observations from July 1946 to May 1947 (Seiwell 1948) and from January to April 1944 (Bigelow 1947) were used as representing average monthly conditions of waves in the vicinity of South Beach, Martha's Vineyard. Seiwell's observations were made with an underwater pressure recorder located about one and one-quarter miles south of Cuttyhunk Island in 75 feet of water; Bigelow's were surf observations at South Beach.

Deep water is defined as water of depth greater than 1/2 of the wave length, shallow water as water of depth less than 1/20 of the deep water wave length and intermediate water as water between 1/20 and 1/2 of the deep water wave length.

Both sets of observations were first reduced to their equivalent values in deep water using the plates in H.O. No. 234 and the Supplement to H.O. 234. The areas are in such close proximity that the same deep water waves approach both areas even though they have different values at the two observing places due to differences in depth and topography. Refraction was not considered, due to lack of sufficient observations and reliability (within the accuracy of the work) for calculations in such a complex topography as that existing from No Mans Land out to deep water.

The deep water heights and periods for March and April from the two sets were then averaged.

Using the plates from H.O. 234 (and Supplement), the heights and lengths for each month (except June) were deter-

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mined for depths of 20, 40, 60 and 80 feet. No refraction was considered, due to lack of observations. However, the waves approach from the south, generally, and the contours are approximately straight and parallel. No significant error should result from failure to apply corrections for refraction in this area for average monthly conditions.

In deep water the individual particles of water associated with progressive waves describe circles, the diameter of their orbits being equal to the wave height at the surface and decreasing exponentially with depth. For intermediate and shallow water waves, these orbits are flattened rather than being perfect circles. At any location in intermediate and shallow water, these orbits become more and more flattened with depth such that at the bottom the motion has no vertical component and merely oscillates back and forth.

The horizontal velocity component of particle motion, u, for intermediate water is given by the expression (Arthur 1951):

$$u = A\sigma \frac{\cosh k(z+h)}{\sinh kh} \cos(kx - \sigma t)$$

Where A is the amplitude $\left(\frac{\text{Height}, H}{2}\right)$

k, the wave number $\left(\frac{2\pi}{\text{Length}, L}\right)$

σ, the frequency $\left(\frac{2\pi}{\text{Period}, T}\right)$

h, the depth of water

and z, the depth of the particle. (positive upwards)

In shallow water:

$$u = \frac{A\sigma}{kh} \cos(kx - \sigma t)$$

For the maximum horizontal particle velocity at the bottom, these equations are:

$$u = \frac{H\pi}{T \sinh \frac{2\pi d}{L}} \quad \text{for intermediate water and}$$

$$u = \frac{HL}{2Td} \quad \text{for shallow water.}$$

Figure 1 presents the results. The maximum speed of oscillation is given as a function of depth for each month.

The equations for the orbital diameter of particle motion are:

$$D = -2A \frac{\cosh k(z+h)}{\sinh kh} \sin(kx - \sigma t)$$ for intermediate water and

$$D = -\frac{2A}{kh} \sin(kx - \sigma t)$$ for shallow.

These in turn reduce to:

$$D = \frac{H}{\sinh \frac{2\pi d}{L}}$$ (Intermediate) and

$$D = \frac{HL}{2\pi d}$$ (Shallow) for the length of the horizontal oscillation at the bottom. Figure 2 shows these lengths as a function of depth of water for each month.

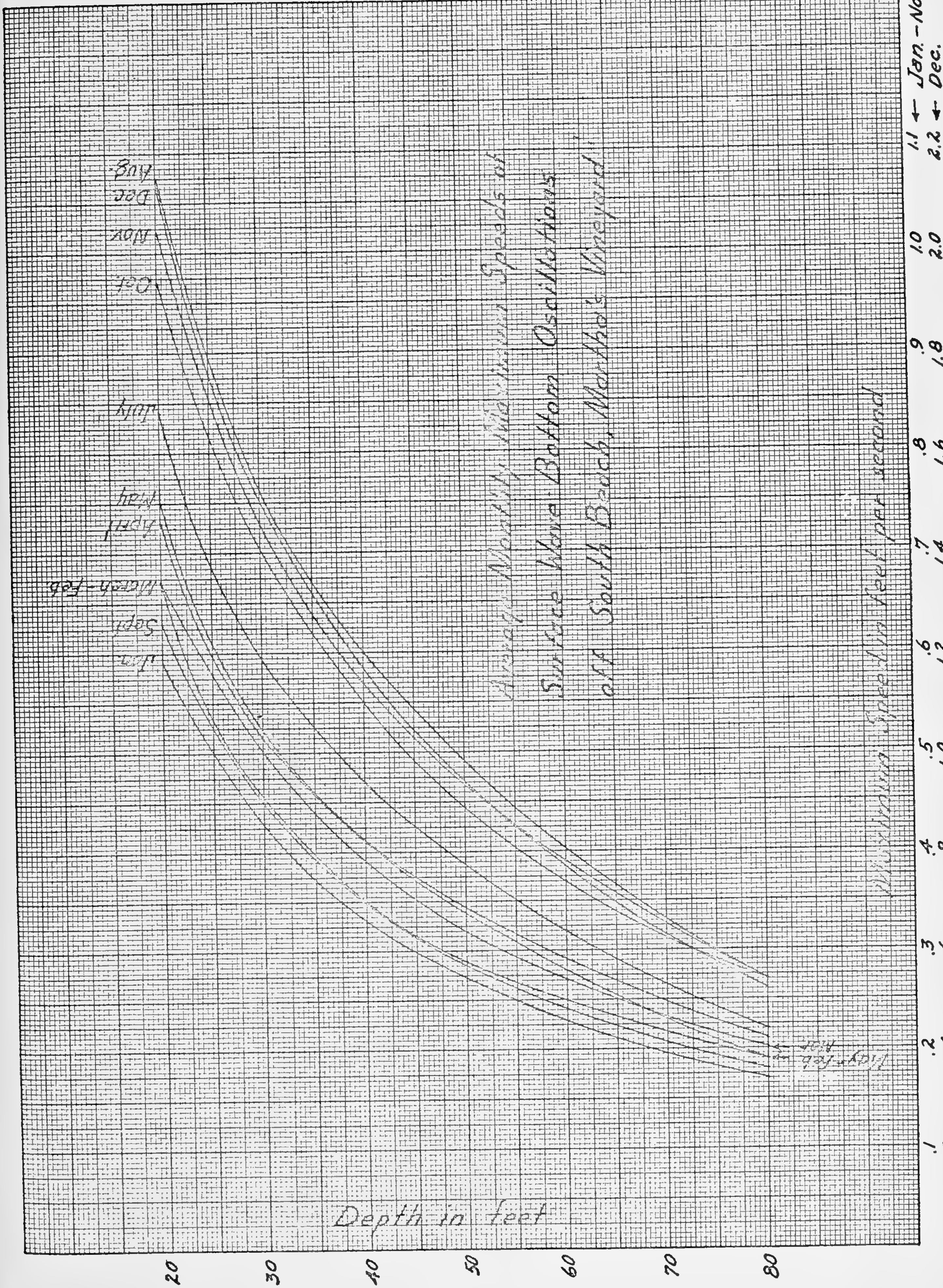
Table I gives the data from which the graphs (Fig. 1 and 2) were drawn. It should be pointed out that the calculations express the upper limits of conditions since Seiwell's wave meter was located in 75 feet of water and, therefore, did not record waves of less than 150 ft. in length. Bigelow's observations were of surf and were probably "significant waves" (Munk 1944). It is therefore logical to assume that these graphs (Fig. 1 and 2) present the results of the average monthly significant waves.

SUMMARY

Figures 1 and 2 show the maximum speeds and lengths of bottom oscillations due to surface waves as a function of the depth of water for each month (except June) off South Beach, Martha's Vineyard.

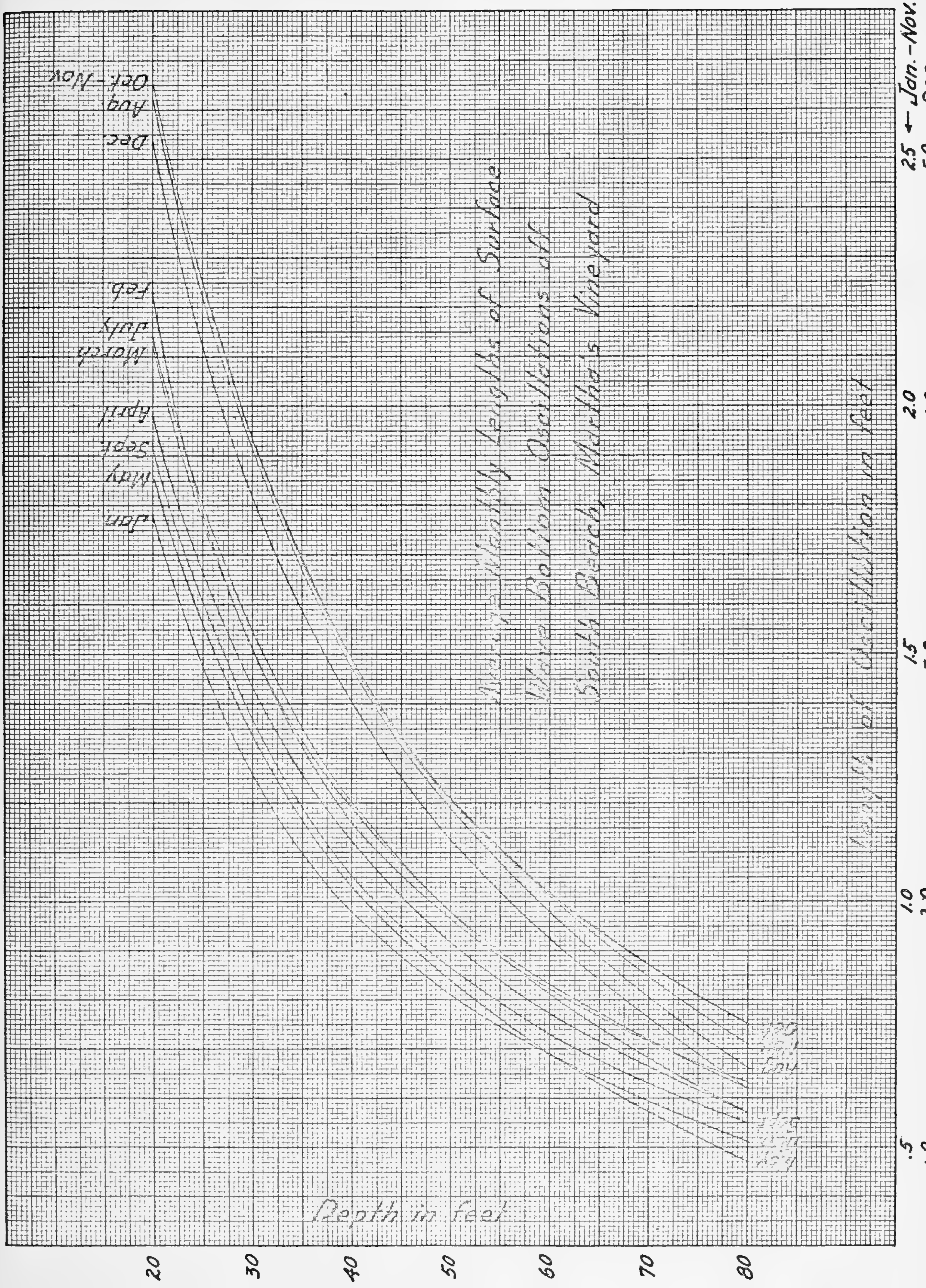
The calculations for December show large values of speed and length due to the very high wave height average reported by Seiwell. The average wave length for December was the lowest for the entire year, however, which leads to the conclusion that the condition was caused by one or more local storms during the month. The curves for December, therefore, probably give abnormally large values.

FIGURE 1



Average Monthly Maximum Speeds of
Surface Wave Bottom Oscillations
off South Beach, Martha's Vineyard
Maximum Speed in feet per second
Depth in feet
1.1 ← Jan.-Nov.
2.2 ← Dec.
Dec
Aug.
Nov
Oct
July
April
May
March-Feb
Sept
Jan.
20
30
40
50
60
70
80

FIGURE 2



Average Monthly Lengths of Surface
Wave Bottom Oscillations off
South Beach, Martha's Vineyard
Length of Oscillation in feet
Depth in feet
Oct.-Nov.
Aug.
Dec.
Feb.
July
March
April
Sept.
May
Jan.
2.5 ← Jan.-Nov.
5.0 ← Dec.
2.0
4.0
1.5
3.0
1.0
2.0
.5
1.0
20
30
40
50
60
70
80

TABLE I

	H_d	L_d	T	H (ft.)				L (ft.)				u (ft./sec.)				D (ft.)				H_b	d_b
Depth →				20'	40'	60'	80'	20'	40'	60'	80'	20'	40'	60'	80'	20'	40'	60'	80'		
Jan.	.95	452	9.4	.99	.89	.87	.87	226	307	357	388	.59	.33	.23	.17	1.78	.98	.69	.51	2.3	2.9
Feb.	.95	554	10.4	1.12	.91	.87	.87	250	349	407	449	.67	.35	.25	.19	2.23	1.16	.82	.63	2.4	3.1
Mar.	1.09	482	9.7	1.14	1.04	1.00	.99	234	318	371	405	.67	.39	.27	.20	2.12	1.19	.83	.62	2.5	3.2
Apr.	1.30	370	8.5	1.30	1.20	1.18	1.20	204	270	311	337	.73	.41	.29	.21	1.98	1.12	.77	.57	2.6	3.3
May	1.38	312	7.8	1.35	1.26	1.27	1.27	186	243	275	293	.75	.41	.28	.19	1.85	1.03	.69	.47	2.5	3.2
July	1.54	328	8.0	1.52	1.42	1.42	1.42	190	250	285	305	.84	.47	.32	.22	2.14	1.20	.81	.57	2.6	3.3
Aug.	2.02	304	7.7	1.96	1.84	1.86	186	182	239	269	286	1.07	.60	.40	.27	2.62	1.47	.98	.66	3.5	4.5
Sept.	1.01	462	9.5	11.05	.95	.92	.92	229	369	360	393	.63	.35	.24	.18	1.91	1.05	.73	.55	2.5	3.2
Oct.	1.69	379	8.6	1.71	1.55	1.54	1.55	207	277	315	341	.97	.55	.37	.27	2.65	1.49	1.02	.75	3.1	4.0
Nov.	1.83	344	8.2	1.82	1.68	1.66	1.68	196	258	296	316	1.02	.57	.39	.27	2.65	1.48	1.01	.71	3.2	4.1
Dec.	4.08	288	7.5	3.91	3.71	3.75	3.79	177	230	259	274	2.13	1.17	.77	.52	5.07	2.80	1.85	1.24	5.5	7.0

H - Wave Height, ft.
L - Wave Length, ft.
T - Wave Period, sec.
u - Maximum Particle Velocity at Bottom, ft./sec.
D - Maximum Length of Bottom Oscillation, ft.
d - Depth, ft.
d subscript - Deep Water
b subscript - Breaking

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