DRP-5-06
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Dredging Research Technical Notes

Length and End Slope Considerations, Interim Design Guidance Update for Nearshore Berm Construction

Purpose

This note updates length and end slope considerations presented in *Dredging Research Technical Notes* DRP-5-02, "Interim Design Guidance For Nearshore Berm Construction" (McLellan, Kraus, and Burke 1990). Presented are preliminary results of a numerical analysis applied to generic berm configurations, which highlight berm effects on the local wave climate. Dredging Research Program (DRP) monitoring and modeling work units will continue to update this guidance as the data base and predictive techniques are improved.

Background

The US Army Corps of Engineers has long been a proponent of the beneficial use of dredged material. Such uses include creation of bird habitats, aquatic habitats, wetlands, and placement of beach fills. In recent years, the concept of placing dredged material in shallow water in the form of shore-parallel berms gained acceptance as a means of enhancing the beach profile. Benefits of a berm to the nearshore zone include providing material to the littoral system and reducing erosive wave action on the beach landward of the berm. *Dredging Research Technical Notes* DRP-5-01 (McLellan 1990) summarized 10 ongoing and completed nearshore berm projects, and DRP-5-02 (McLellan, Kraus, and Burke 1990) provided interim guidance for siting and designing fine- to medium-sand nearshore berms constructed with dredged material. Technical Notes DRP-5-02 also emphasized that nearshore berms should be considered engineered structures, and cited empirical observations and preliminary analytical work to aid in their design.

This note contains a summary of literature pertaining to end slopes and berm lengths, a description of the numerical model used for analysis, berm geometries, tested conditions, preliminary study results, and design guidance.

Additional Information

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Berm End Slope and Length Design Considerations

Available information on nearshore berms indicates the potential for wave focusing due to end effects at nearshore berm terminal points (Zwamborn, Fromme, and Fitzpatrick 1970, Frisch 1979, and McLellan, Kraus, and Burke 1990). End effects are due to wave shoaling, wave refraction, and bottom diffraction in regions of drastically variant topography, resulting in increased wave heights and altered wave direction in the lee of berm ends. These phenomena depend on the depth change at the berm, wave height, period, and direction. Ebersole (1971) linked changes in wave refraction to possible changes in shoreline evolution. Frisch (1979) used a wave refraction model to investigate seabed anomalies. He noted that with steepening end slopes relative increases in wave crest curvature occur around a seabed anomaly. Additionally, the length of the affected shoreline increases with increased end slope steepness. Zwamborn, Fromme, and Fitzpatrick (1970) reported wave refraction problems associated with end slopes during construction of a berm at Durban, South Africa. The construction plan was changed to have milder end slopes, 1V (vertical) on 150H (horizontal) to minimize these refraction effects.

Frisch (1979) used a wave refraction computer model to compare a submerged conical-shaped feature with an elongated oval-shaped feature having the same side slopes, similar to a possible nearshore berm design template. The oval resembled a cone that had been symmetrically cut perpendicular to the shoreline and stretched, elongating the center so that the major axis (parallel to the shoreline) was four times the minor axis. The wave refraction patterns of the oval shape were similar to a cone separated at the middle and stretched apart, the cone being the lower limit of the oval shape. The ends of the oval shape refracted waves toward the center of the shoreline, suggesting converging longshore transport. The cone shape refracted waves through a caustic zone, resulting in a diverging longshore transport. These model test results suggest that an oval shape could provide protection to a length of shoreline, and a cone could potentially cause erosion. The feature placement distance offshore is a major factor contributing to shoreline changes. All features in the Frisch study were placed far enough offshore that the waves passed through the caustic zone before reaching the beach.

Nearshore berms should be of sufficient length to avoid focusing of waves at a location seaward of the shoreline. If a conical shape can cause localized erosion and an elongated oval shape has the potential to provide protection to the same region, the minimum length required of the feature's shore parallel axis to achieve beneficial effects can be optimized. McLellan, Kraus, and Burke (1990) investigated nearshore berm projects which are being monitored and found that existing berms as short as 2.5 times the wave length are not exhibiting wave-focusing effects. A limited numerical model study was conducted to provide additional insights regarding the question of minimum berm lengths.

Numerical Analysis

The numerical wave model used in this study was the **R**egional **C**oastal **P**rocess **WAVE** (RCPWAVE) model. RCPWAVE estimates the characteristics of linear, monochromatic waves as they propagate over arbitrary bathymetry. Aspects of linear wave theory represented in the governing equations used by RCPWAVE include refraction, shoaling, diffraction due to a very irregular bathymetry, and wave breaking. Finite-difference approximations of the governing equations are solved to predict wave propagation outside the surf zone (U.S. Army Engineer Waterways Experiment Station 1986) (*Coastal Engineering Technical Notes* CETN-I-42). For more detailed information regarding RCPWAVE, see Technical Report CERC-86-4 (Ebersole, Cialone, and Prater 1986).

The equation for equilibrium beach profiles,

$$h(y) = Ay^{2/3}$$

where

h = water depth
y = distance from shoreline
A = sediment dependent scale parameter

(Dean 1990), and a grain size D_{50} = 0.2 mm, were used for the profile on which the test berms for the RCPWAVE analysis would be placed. A generic berm configuration was created using the Silver Strand, California, berm as a guide (Juhnke, Mitchell, and Piszker 1990). At Silver Strand, the berm was placed in the region between the -9 and -39 ft mean lower low water (mllw) contours, with maximum berm elevation reaching -10 ft mllw (Burke, McLellan, and Clausner 1991). The test berms for this study were placed at the -18 ft mllw contour (Figure 1), slightly off the calculated midpoint between the two Silver Strand contours. A crest relief of 6 ft was chosen to

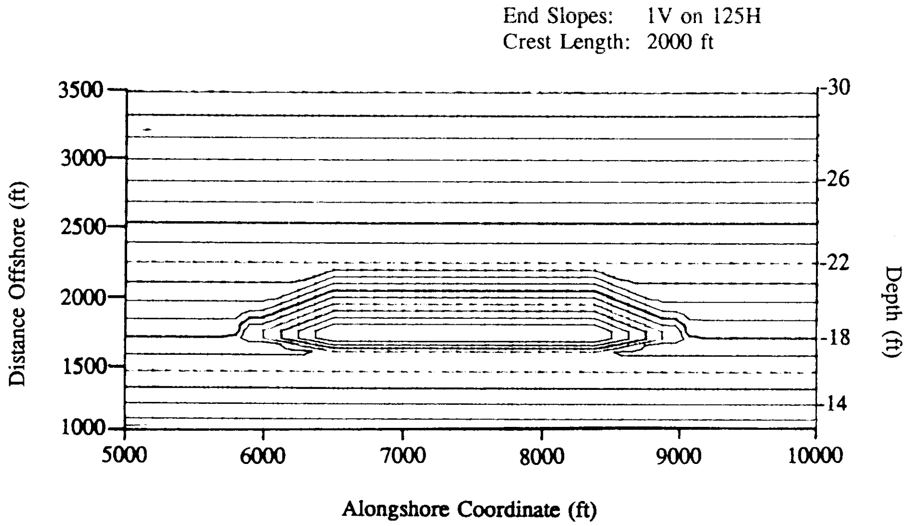

Figure 1. Berm placed shore-parallel on the -18 ft mllw contour with 6-ft relief

allow 12 ft of water over the crest, ensuring that hopper dredge minimum draft requirements could be met. Table 1 shows berm crest length and wave conditions tested. A 0 deg wave angle corresponds to a wave arriving perpendicular to the beach.

Table 1
Berm Crest Length and Wave Conditions

Crest Length, ft	Wave Angle, deg	Wave Period, sec
800	0, 22.5, 45	4, 6, 8, 10, 12, 14, 16, 20
1000	0, ±22.5, ±45	4, 6, 8, 10, 12, 14, 16, 20
1100	0, 22.5, 45	4, 6, 8, 10, 12, 14, 16, 20
1200	0, 22.5, 45	4, 6, 8, 10, 12, 14, 16, 20
1300	0, 22.5, 45	4, 6, 8, 10, 12, 14, 16, 20
1400	0, 22.5, 45	4, 6, 8, 10, 12, 14, 16, 20
1500	0, ±22.5, ±45	4, 6, 8, 10, 12, 14, 16, 20
1600	0, 22.5, 45	4, 6, 8, 10, 12, 14, 16, 20
1700	0, 22.5, 45	4, 6, 8, 10, 12, 14, 16, 20
1900	0, 22.5, 45	4, 6, 8, 10, 12, 14, 16, 20
2000	0, ±22.5, ±45	4, 6, 8, 10, 12, 14, 16, 20
2200	0, 22.5, 45	4, 6, 8, 10, 12, 14, 16, 20
2400	0, 22.5, 45	4, 6, 8, 10, 12, 14, 16, 20
3000	0, 22.5, 45	4, 6, 8, 10, 12, 14, 16, 20

The associated slopes for each berm crest length are listed in Table 2. Unit wave height was input to the model, and relative wave height in the lee of the berm was the criterion used in evaluating the various berm geometries.

Table 2
Berm Slopes and Crest Lengths

End Slope	Inshore Slope	Offshore Slope	Crest Length, ft
1V on 30H	1V on 25H	1V on 50H	2,000
1V on 50H	"	"	2,000
1V on 75H	"	"	2,000
1V on 100H	"	"	1,000
1V on 100H	"	"	1,300
1V on 100H	"	"	1,400
1V on 100H	"	"	1,500
1V on 100H	"	"	2,000
1V on 125H	"	"	800
1V on 125H	"	"	1,100
1V on 125H	"	"	1,200
1V on 125H	"	"	1,300
1V on 125H	"	"	1,600
1V on 125H	"	"	1,700
1V on 125H	"	"	1,900
1V on 125H	"	"	2,000
1V on 125H	"	"	2,200
1V on 125H	"	"	2,400
1V on 125H	"	"	3,000
1V on 150H	"	"	2,000

Using a crest length of 2,000 ft, end slopes of 1V on 30H, 1V on 50H, 1V on 75H, 1V on 125H, and 1V on 150H were tested to compare end effects of steeper slopes versus milder slopes. Steeper end slopes exhibited end effects across a narrower region parallel to the shoreline than did the milder end slopes, but the severity of the effects was greater than that of the milder slopes (higher wave heights in the lee of the berm ends). Also, longer period waves resulted in greater wave heights due to shoaling as depths decrease. Figure 2 shows wave height plots of the 0 deg wave angle at the -12 ft mllw contour for a 1V on 30H slope and 1V on 150H slope. To reduce the number of variables, a constant end slope was selected for further testing. Comparison of all slopes indicated that gentler

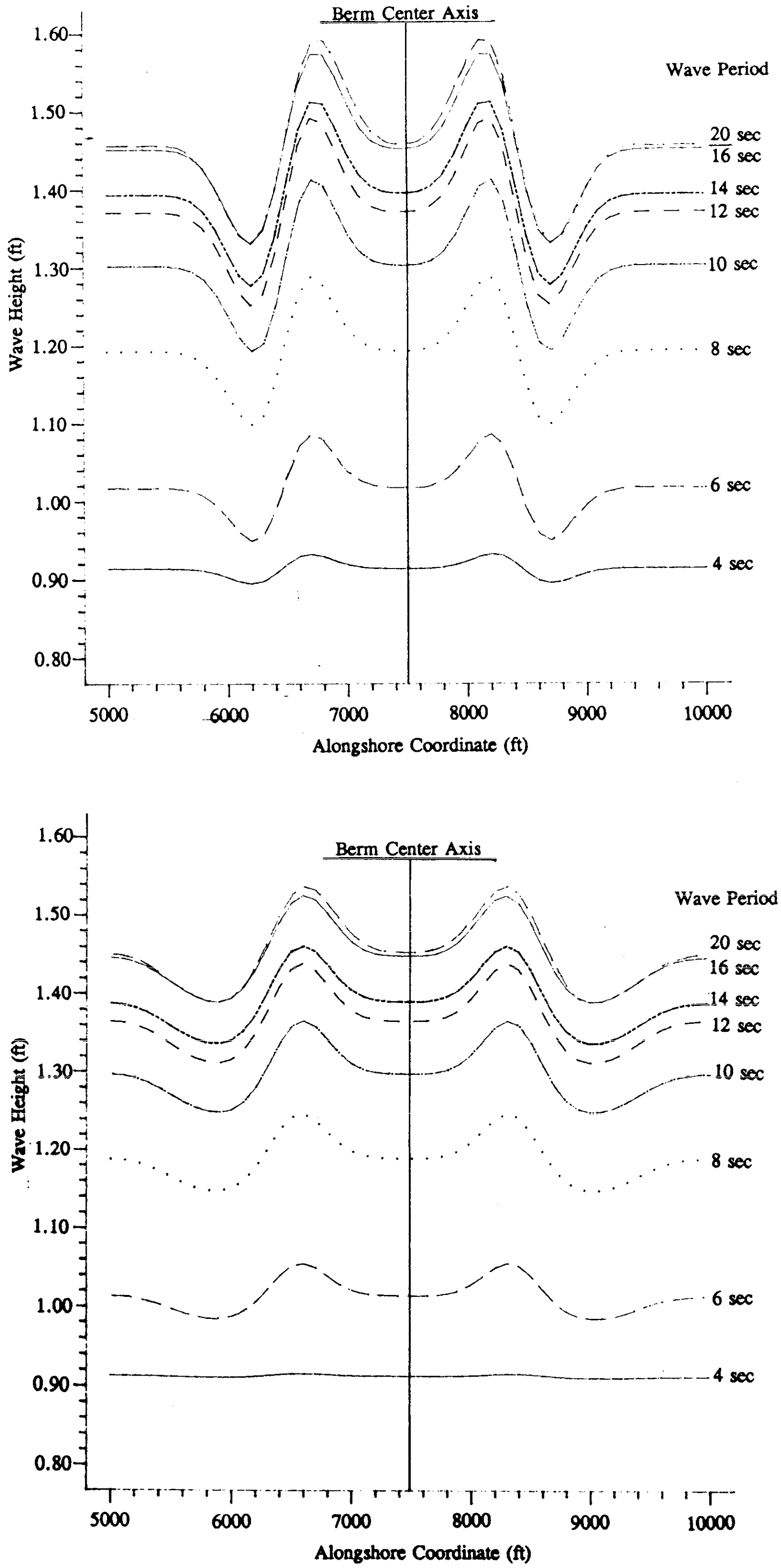

Figure 2. Wave heights calculated at -12 ft mllw contour with end slopes of 1V on 30H (top) and 1V on 150H (bottom) and crest length of 2,000 ft

slopes optimize berm design by reducing end effects. Since only minimal differences were determined between the 1V on 125H and 1V on 150H end slopes, the 1V on 125H was selected for further testing.

Wave heights in the lee of the berm parallel to the axis of the center of the berm were calculated at the -12 ft mllw contour ($H1_{12}$) for crest lengths of 800, 1,200, 1,700, 1,900, 2,000, 2,200, and 2,400 ft, and at the -16 ft mllw contour ($H1_{16}$) for crest lengths of 800, 1,100, 1,300, 1,600, 1,700, 2,000, 2,200, 2,400, and 3,000 ft. When $H1_{12}$ and $H1_{16}$ were equivalent to the resultant wave height outside of the region of influence of the berm (Figure 3) and the value at the center axis settled to a constant number (Figure 4), the berm was deemed not to exhibit wave focusing. Deep-water unit wave steepness also was calculated for each wave period, wave angle, and crest length. For the conditions tested, it was found that a berm 1,600 ft long or longer exhibited no end effect along the center axis of the berm at the -16 ft mllw contour. Berms of crest length equal to or greater than 2,000 ft displayed no wave focusing along the center axis at the -12 ft mllw contour.

To incorporate berm relief change, additional berms of 10 ft (8-ft water column over berm crest) and 2 ft (16-ft water column over berm crest) were tested. The same bathymetry grid was used, with only the berm's relief and crest length being varied. Wave heights were calculated at the -16 ft mllw contour using crest lengths of 800, 1,100, 1,300, 1,600, 1,700, and 2,000 ft with wave periods of 8, 12, and 20 sec, a wave angle of 22.5 deg, and end slopes of 1V on 125H. Even though the wave heights were greater on the shallower berms, wave focusing at the -16 ft mllw contour did not exist on berms 1,600 ft and longer for any berm reliefs.

Conclusions

Further testing will explore more berm geometries. Berm end effects and lengths will continue to be investigated, along with berm heights, distance offshore, and depth of placement. However, based on these limited numerical analyses, nearshore berms with 1V on 125H end slopes, 1V on 25H inshore slopes, 1V on 50H offshore slopes, and crest lengths equal or greater than 2,000 ft will not cause wave focusing for the wave conditions tested (that is, nonbreaking waves).

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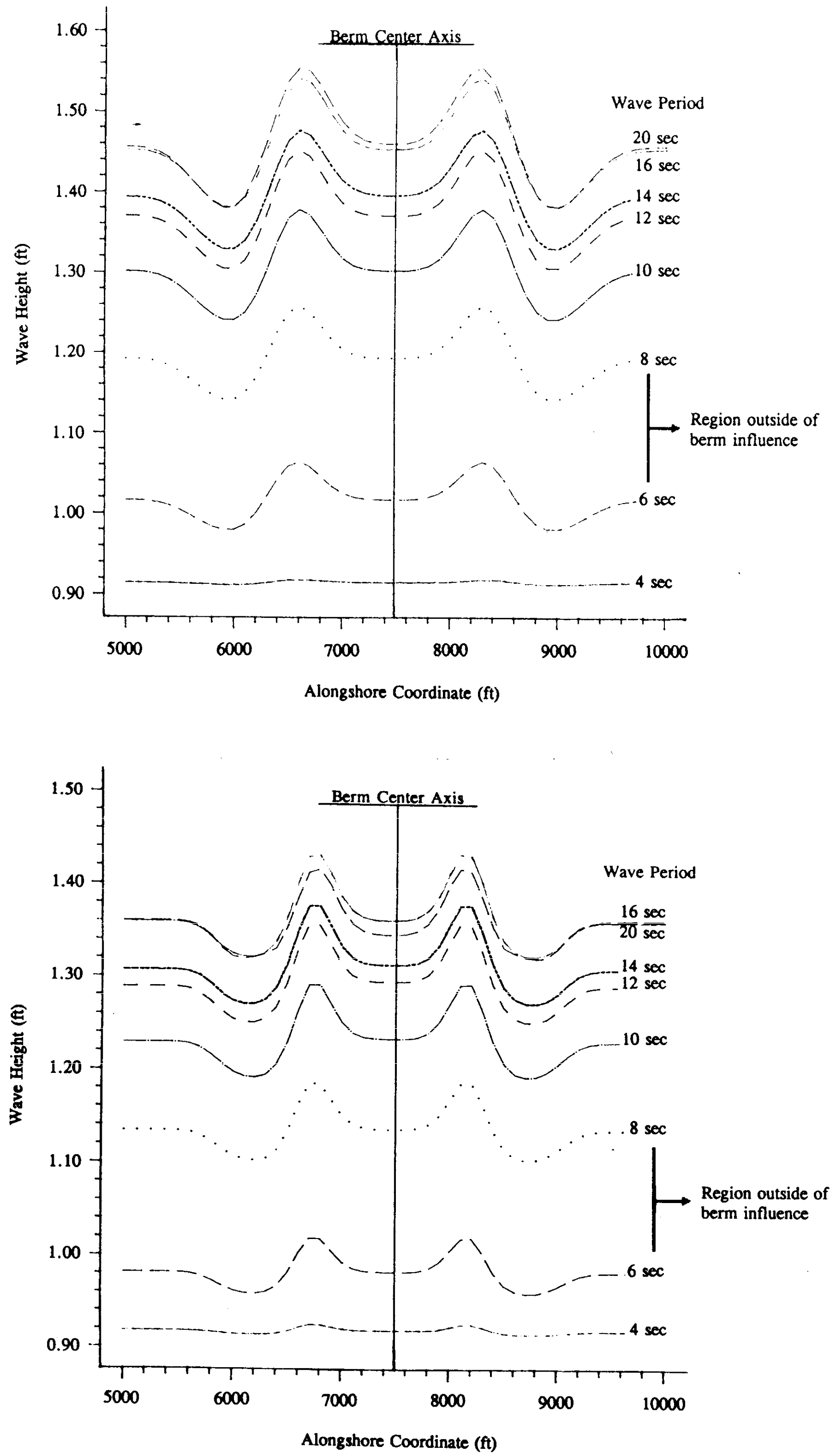
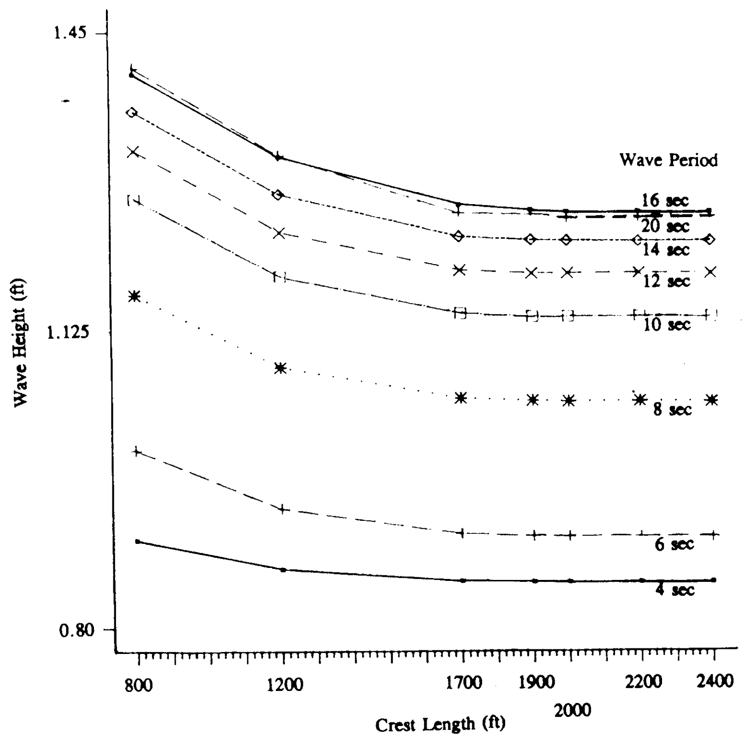


Figure 3. Plots showing wave heights in lee of berm are equivalent to wave heights outside of berm influence at the -12 ft mllw (top) and -16 ft mllw (bottom) contours; wave heights are compared along center axis and at the edge of the numerical model grid; side slope is 1V on 125H, and crest length is 2,000 ft



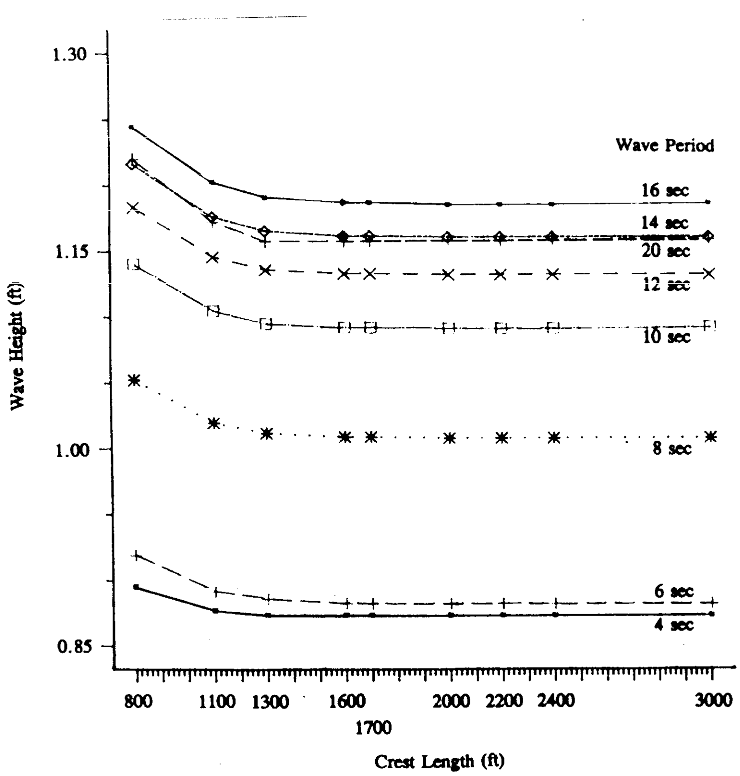


Figure 4. Plots showing berm center axis wave heights settling to constant number at the -12 ft mllw (top) and -16 ft mllw (bottom) contours

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