4. APPROACH

Our approach was to develop a simple analytical model, or framework, to characterize the effects of wind climate, fetch, initial site elevation, and tidal inundation on the inhibition of sediment deposition. We then used the analytical framework to evaluate empirical observations of site evolution. The wind wave analytical framework is described in Section 5 and the empirical study is described in Section 6. To assess the potential for lowering the internal peninsula crest elevations, we estimated the inundation frequency of the lowered peninsula configuration and estimated the amount of wave power that would be transmitted over the top of the peninsula while it was inundated. The peninsula height analysis is described in Section 7.

5. ANALYSIS OF WIND WAVE EFFECTS ON COHESIVE SEDIMENT DEPOSITION

For the wind-wave analysis, we used linear wave theory to complete the following tasks:

1. provide a conceptual analytical framework for understanding the effects of wave action on sediment inhibition; and

2. provide an estimate of the predicted effects of wave action on sedimentation inhibition at Hamilton following restoration.

5.1 Conceptual Analytical Framework

Section 3 discusses how subsided sites evolve into vegetated marshplains by progressively accumulating cohesive sediment until mudflats reach an elevation at which vegetation can establish. Wind wave action can stop or slow this process by inhibiting deposition and, if wave action is sufficiently high, scouring previously-deposited sediments. Water moves in response to each passing wave. If water velocities are sufficiently high, flocculated sediments tend to remain in suspension rather than depositing. There exists a critical threshold velocity at the bed above which no deposition occurs. The critical velocity is a function of sediment characteristics and varies widely. Bed velocities are a function of wave characteristics and water depth, with larger waves causing higher bed velocities. Wave characteristics are, in turn, functions of wind speed, fetch, and depth.

Figures 2 and 3 show the relationship between depth, fetch, and wind speed on calculated bed velocity. Figure 2 shows the effects of varying fetch for a constant wind speed; Figure 3 shows the effects of varying wind speed for a constant fetch. The figures show that bed velocity increases with fetch and wind speed. Bed velocity generally increases in shallow water, with the exception of very shallow water (less than approximately 0.5 feet). In very shallow water, wave heights quickly decrease with depth, and bed velocities decrease as well. The range of critical velocities above which no deposition occurs is also shown in Figures 2 and 3. These critical velocities correspond with the upper (0.33 ft/s) and lower (0.10 ft/s) values used in modeling cohesive sediment deposition for the Napa River Flood Management Project (PWA 1997). The calculations presented in Figures 2 and 3 are based on linear wave theory, using shallow water wave equations, and follow standard methods described in the USACE Shore Protection Manual (USACE 1984).

5.2 Estimated Effects of Wave Action on Sediment Inhibition at Hamilton

Figures 2 and 3 are based on linear wave theory for constant depths and wind speeds. In reality, depth changes over the course of the tidal cycle and wind speeds are varying. To estimate the effects of wind waves on deposition at Hamilton, we calculated expected bed velocities over a range of wind and depth conditions for a given bed elevation / fetch combination. We compared the calculated bed velocities with critical velocities to predict expected inhibition of deposition. For each bed elevation/fetch combination, we considered the expected frequency of various depths and winds to calculate a weighted average percent inhibition of deposition by wave action.

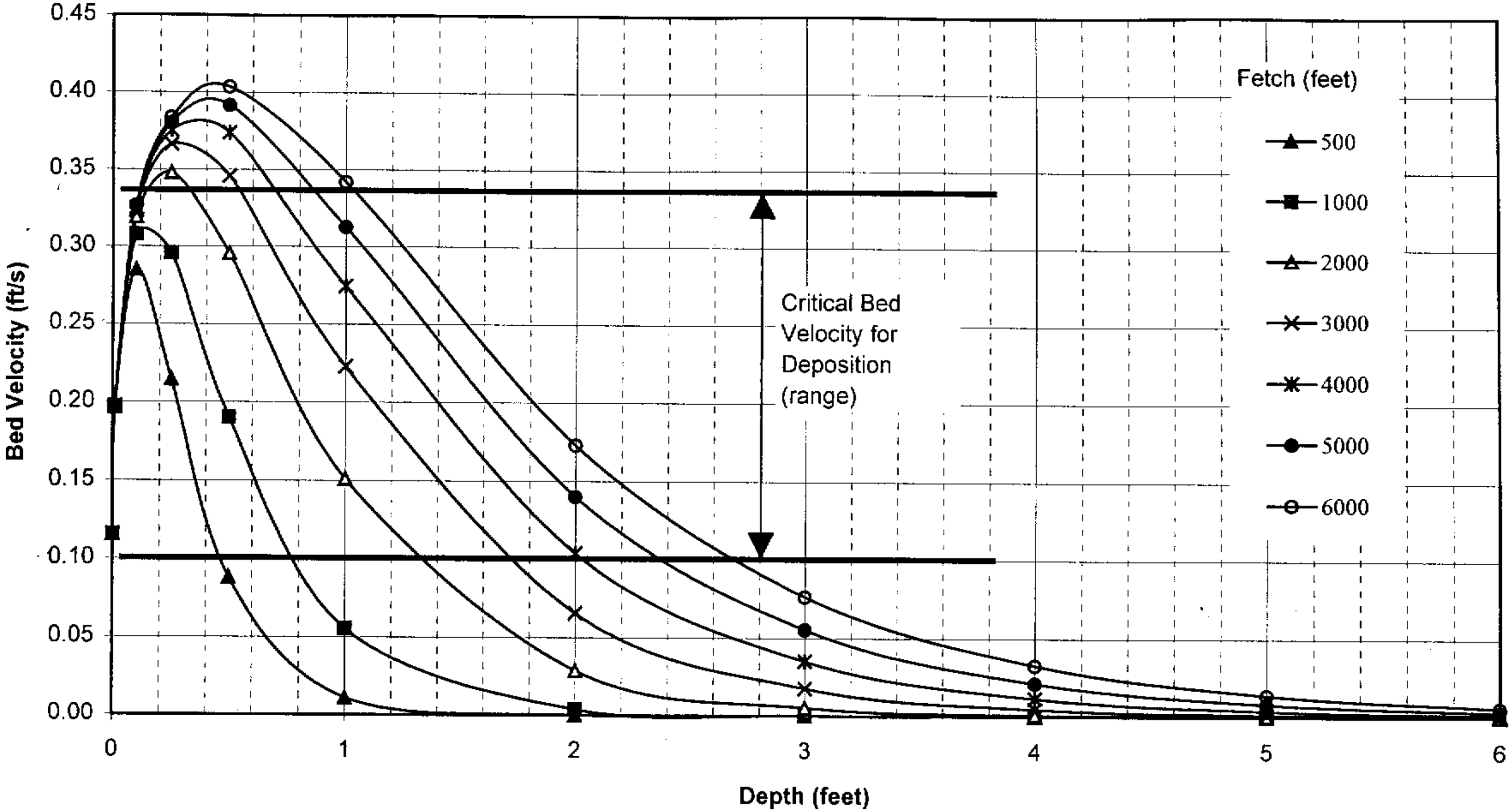
Figure 4 shows the effect of bed elevation and fetch on expected deposition at Hamilton for the weighted average wind climate and tide levels. Both high and low critical velocities are shown. Figure 4 shows that for bed elevations in the 0 to 1 foot NGVD range, just below the vegetation colonization elevation, wind waves are expected to inhibit deposition between 10% and 36% of the time for a 3000 foot fetch and between 18% to 44% of the time for a 6000 foot fetch. The calculated difference in inhibition between the 3000 and 6000-foot fetches is approximately 8% to 10% in the 0 to +1 foot NGVD bed elevation range. These differences reflect an assumption of weighted average wind conditions and other simplifying assumptions.

The differences between the 3000-foot and 6000-foot fetch conditions become much more significant when strong sea breezes or storm winds are considered. Longer fetches can have a larger relative effect during extreme wind events. Figure 5 shows the relationship between bed elevation, fetch, and critical velocity on expected deposition at Hamilton for wind speeds of 15.5 mph. Winds of this speed or higher occur approximately 11% of the time (DWR 1978). For storm wind conditions, reducing the fetch from 6000 to 3000 feet lowers wind wave deposition inhibition (i.e., raises deposition rates) by an average of 18% to 24% , and a maximum of 47%.

The effect of reducing fetch on minimizing scour is also expected to be more important in strong wind conditions. Although we did not simulate scour for this study, we expect scour to respond similarly to inhibition of deposition for changes in bed elevation, fetch, and wind speed. Any elevation loss due to scour must be regained through additional deposition if the site is to evolve to tidal marsh. Scour of cohesive sediments is caused by high bed velocities (higher than for inhibition of deposition) combined with other factors such as bioturbation of the mudflat. The critical velocity for scour in field conditions as compared to laboratory conditions is not well defined.

For the data presented in Figures 4 and 5, we used wind intensity-duration-frequency relationships to convert hourly wind data to equivalent shorter duration wind speeds. These corrected wind speeds were then used with fetch and depth as input variables to deep and shallow-water wave equations. The calculation process was automated using Matlab computer code. The frequency distribution of Hamilton hourly wind speeds was obtained from DWR (1978). Tidal inundation frequency is based on predicted tides at the Petaluma River Entrance.

Figure 6 provides a schematic of how wind-wave action slows long-term sedimentation. Although we have not considered the effects of suspended sediment concentration on deposition rates for this analysis, sedimentation rates are sensitive to suspended sediment concentrations. A doubling of the suspended sediment concentration will approximately double the rate of long-term sedimentation, while a halving of the suspended sediment concentration will approximately halve it.



Note: Assumes constant wind speed of 10 mph.
Source: PWA analysis.

figure 2

Bed Velocity as a Function of Depth and Fetch Length for a Constant Wind Speed

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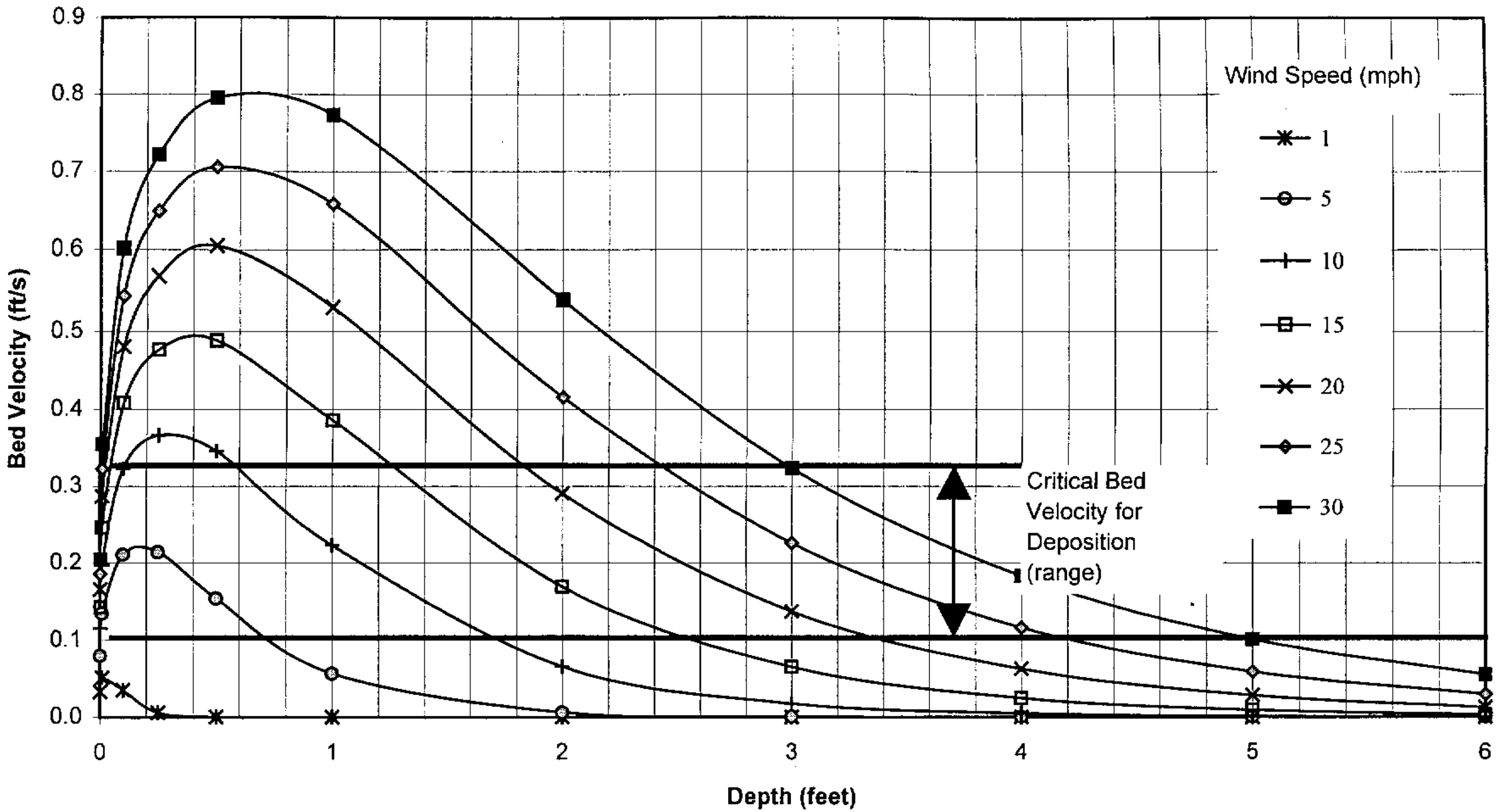
peninsula.xls Fig 2 2/23/99

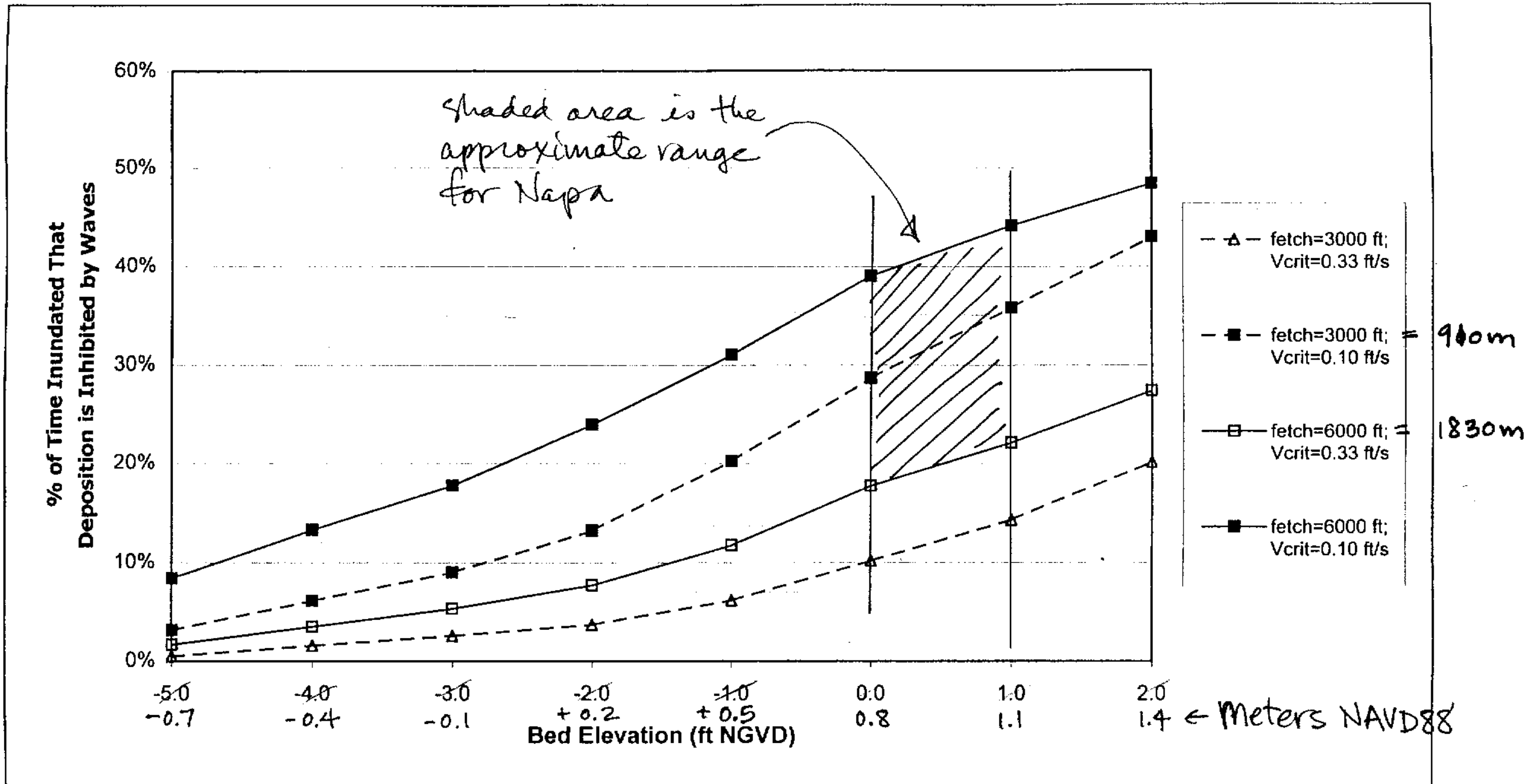


Note: Assumes constant fetch length of 3000 feet.
Source: PWA analysis.

figure 3

Bed Velocity as a Function of Depth and Wind Speed for a Constant Fetch Length

Philip Williams & Associates, Ltd. | PWA#: N1287



Vcrit = critical bed velocity above which deposition does not occur.
Note: Weighted average wind speeds and tide distribution.
Source: PWA Analysis.

figure 4

Effect of Bed Elevation, Fetch and Critical Velocity on Expected Deposition for Hamilton Conditions

Philip Williams & Associates, Ltd. | PWA#: 1287

Source: Williams & Orr 1999 (PWA # 1287)

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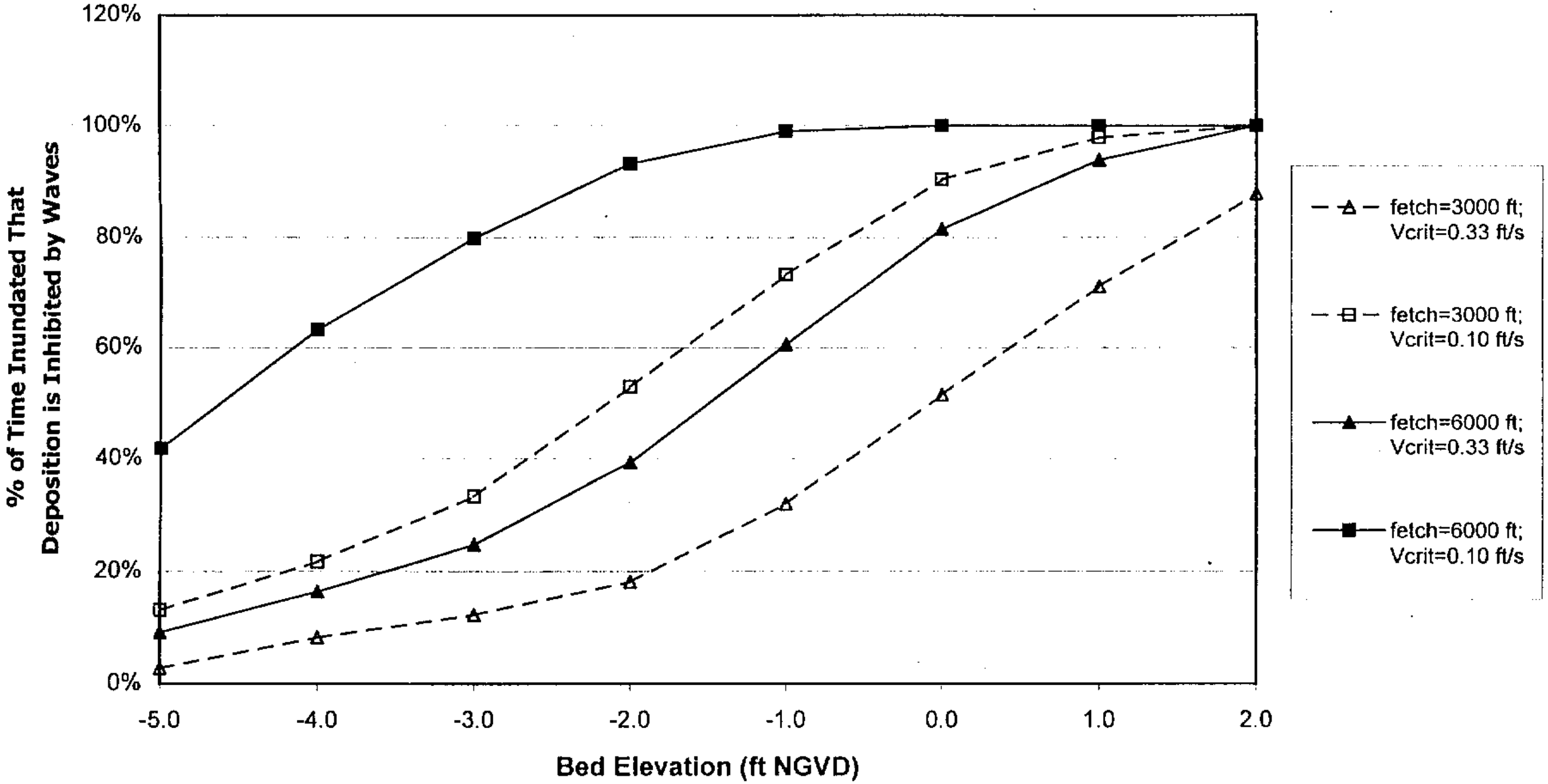

Vcrit = critical bed velocity above which deposition does not occur.
Note: Wind speed equals 15.5 mph (13.5 knots) (10% frequency of occurrence). → = 6.93 m/s
Weighted average tide distribution.
Source: PWA Analysis.

figure 5

Effect of Bed Elevation, Fetch and Critical Velocity on Expected Deposition for Hamilton Wind Storm Conditions

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