Fishing Harbor, Nakuek, AK

PART V

SHIP MOTIONS

Hopper dredge at Port Canaveral, FL

CHAPTER TWO HUNDRED FIFTEEN

Surges and Waves Generated by Ships in a Constricted Channel

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Introduction

A study of surges and waves was initiated because of serious bank erosion along the Sabine-Neches Waterway, located in East Texas. The Waterway provides ship access from the Gulf of Mexico to Port Arthur and Beaumont. The design water depth in the ship channel is 12.12 m (40 ft). The 1978 tonnage of ships using the waterway was 69,740,900 tons (1). The highway on the east bank of the Waterway between Port Arthur and Mesquite Pt. leading to Louisiana had to be relocated several times because of bank erosion. The erosion was thought to be principally caused by ship traffic generating surges and waves.

The main purpose of the study was to:

1. evaluate the magnitude of surges and waves generated by ships using the Waterway,

2. evaluate bank erosion potential, and

3. evaluate and recommend the most economical structural measures to prevent further bank erosion.

The results of this first part of the study are reported in this paper.

Literature Review

The literature on waves and surges created by ships in dredged navigational channels is rather limited, but occurrences of such phenomena have been observed in many countries. The most severe problem occurs in an artificial channel dredged in a shallow inlet or a tidal estuary. Large ships passing through such a confined deep channel cause a significant initial drop in water level and a resulting surge as the ships proceed along the channel. The waves generated by such ships are relatively small as compared with the magnitude of the generated surge. Small, high-speed vessels generate only insignificant surges, but may create relatively high waves.

Lee and Bowers (5) conducted tests for the Panama Canal and made extensive drawdown measurements for a wide range of channel depths,

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widths, and ship speeds. Helm and Woltinger (4) stated that the speed of the return flow (surge) provides an indication of the magnitude of the soil erosion problem.

Gelencser (3) confirmed the occurrence of drawdown created by ships in the St. Lawrence Seaway.

Dand and White (2) reported on the studies conducted in the Suez Canal and indicated that one of the disadvantages of a horizontal berm at the western side of the Canal is the generation of surge waves. A dimensionless plot of the vessels Froude Number, as a function of the blockage ratio, was developed to indicate the possibility of creating a drawdown at the berm.

Balanin, et al. (1) and Van de Kaa (8) also addressed the problem of the drawdown that occurs with ship's passage. Maynard (7) conducted field studies on the Sacramento River Deep Water Ship Channel concerning riprap protection in navigation channels.

Generation of Surges and Waves

In an artificially-dredged channel, in otherwise shallow water, a large ship displaces a large volume of water which must then follow in the opposite direction to the ship's movement along both sides of the ship (Figure 1). This causes a surge which moves perpendicularly to the bank at a high velocity, thus causing bank erosion (Figure 2). Surges as high as 3.3 m (10 ft) have been observed during the passage of large vessels moving at a relatively high speed. In addition, bow and stern waves are generated by the vessels, but these are of small magnitude as compared with generated surges. Small work boats and tugs generate only insignificant surges but generate waves which may be of the order of 1 to 1.2 m (3 to 4 ft) when travelling at high speed.

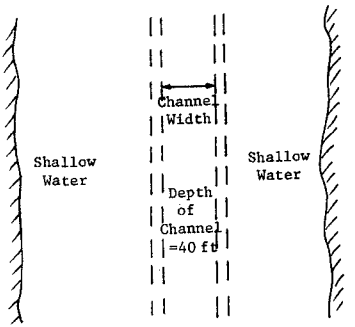

Figure 1. Dredged Ship Channel

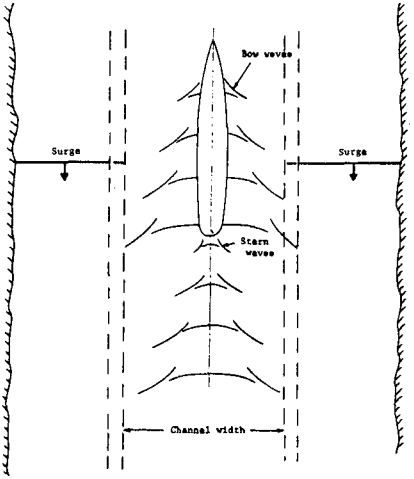

Figure 2. Waves and Surges Generated by a Ship in a Constricted Channel

Field Measurements

Field measurements of ship's speed, draft, generated waves and surges were taken with a video tape recorder, movie camera and pressure transducers installed at several locations along the banks of the Waterway. Pressure transducers were installed in about 2.1 to 2.4 m (7 to 8 ft) of water and connected to a recorder on land.

Transducers, approximately 6.4 cm (2.5 inches) diameter at the base and 18.5 cm (7.25 inches) long, were constructed of stainless steel. The transducers were connected to an electronic recorder which traced the water level as a function of time. Since the recorders were powered by batteries, they were only turned on when a vessel passed through the Waterway.

A typical recorded surge trace by a deep-draft vessel is shown in Figure 4 and a typical recorded wave trace is shown in Figure 5. A sample surge trace as a function of time is shown in Figure 5 for a 4.7 m (15.5 ft) draft vessel moving at 9.77 knots. It will be noted that surging continued for several minutes (the recorder was turned off after 5 minutes.). In some cases, surging was observed for 20 minutes or more.

Data Analysis

Surge height for a range of ship drafts

The surge height as a function of Froude Number for a range of ship drafts is shown in Figures 6 and 7. The surge height is shown in

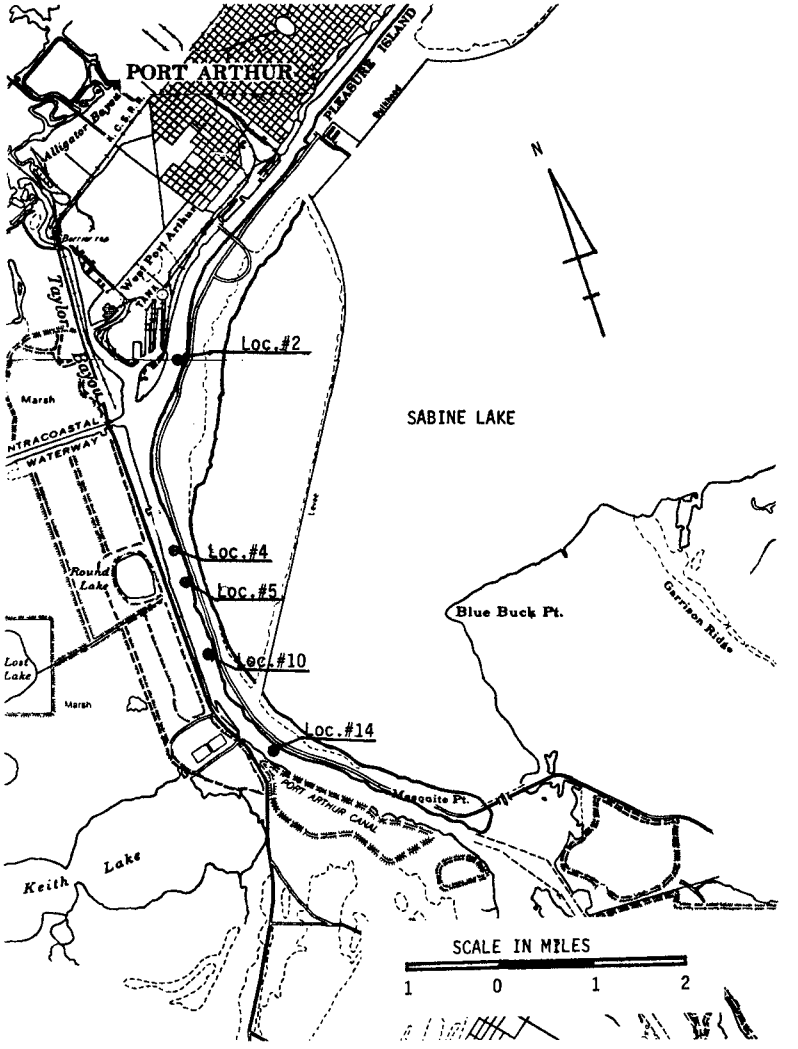

Figure 3. Sabine-Neches Waterway between Port Arthur and Mesquite Pt. (Texas)

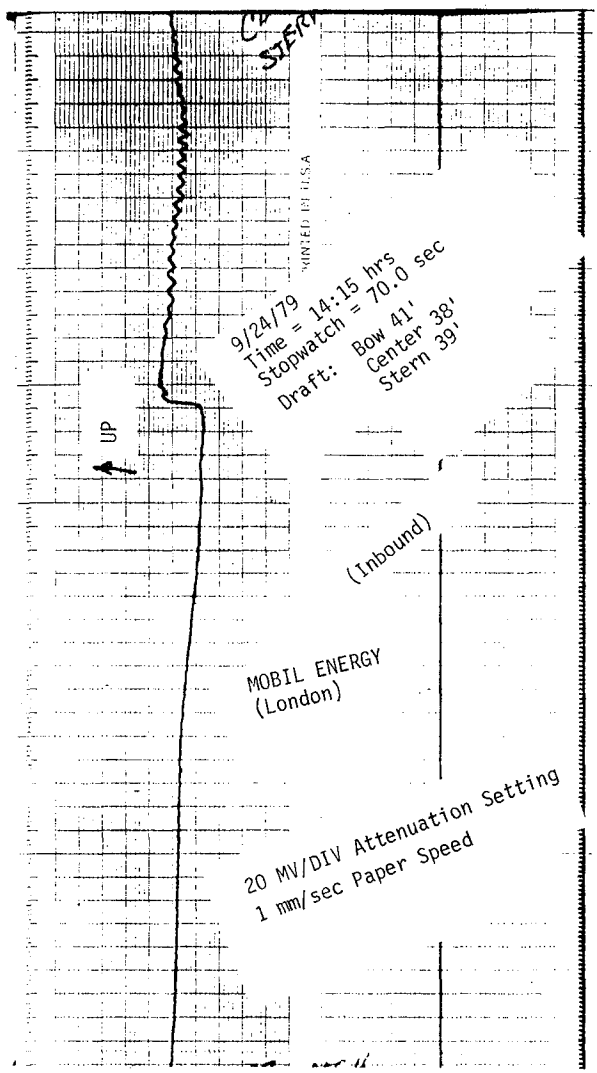

Figure 4. Typical Recorder Trace of Surge Due to Passage of a Ship

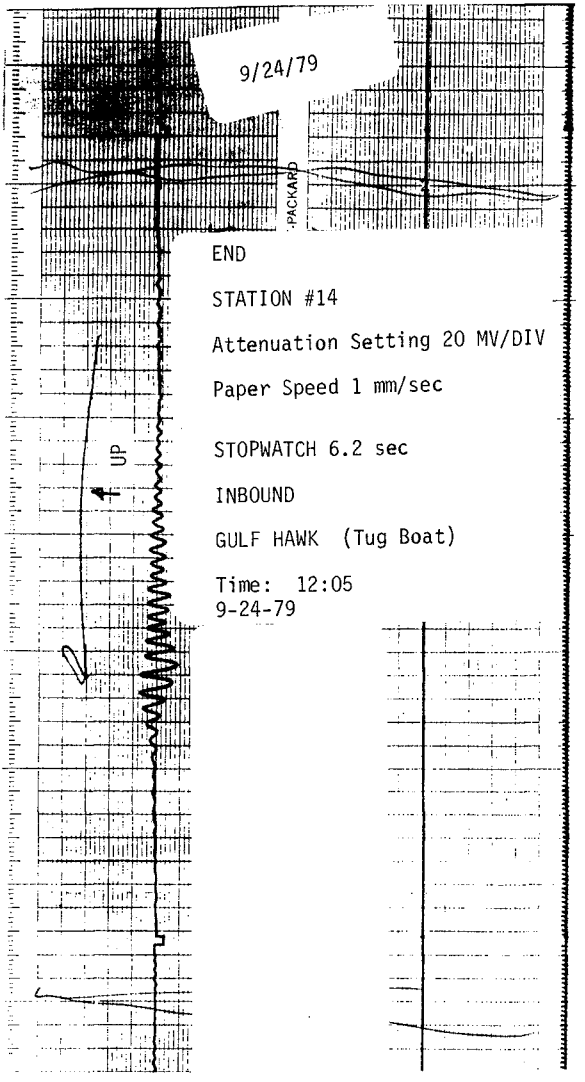

Figure 5. Typical Recorder Trace of Waves from Wake Due to Passage of a Tug Boat

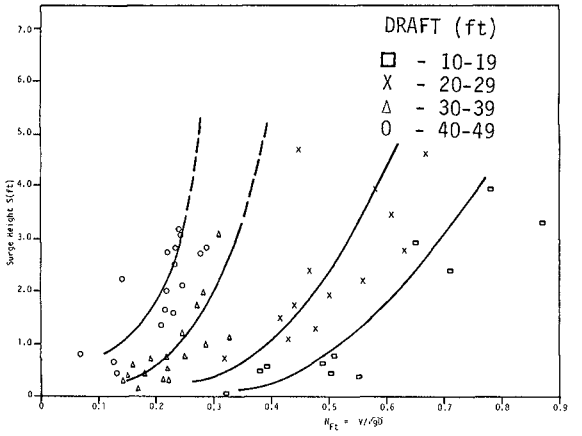

Figure 6. Surge Height Vs. Froude Number at Location #2 for Inbound Ships (Equal Draft)

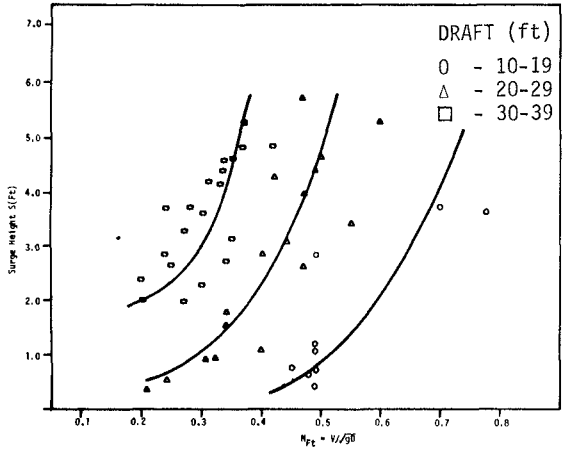

Figure 7. Surge Height Vs. Froude Number at Location #2 for Outbound Ships (Equal Draft)

feet (1 ft = 0.3048 m) and the Froude number is defined as

$$\frac{V}{\sqrt{gD}}$$

where

V = vessel's speed,
g = acceleration due to gravity, and
D = vessel's draft.

The vessel's draft is also shown in feet.

Figure 6 represents the data for inbound ships at location No. 2 (see Figure 3 for actual location) and Figure 7 shows similar information for outbound ships. The lines are drawn for ships of equal draft ranges. It is quite clear from the figures that the surge height is a function of the Froude Number and the ship's draft. The surge height increases rapidly with the Froude Number.

Surge height for a range of ship speeds

The surge height as a function of Froude Number for a range of ship speeds is shown in Figures 8 and 9 for outbound ships.

Surge height for a range of ship drafts and observed ship speeds

Figure 10 presents the surge height measurements for outbound ships at location No. 2 as a function of ship's speed, and Figure 11 presents the surge height measurements for inbound ships at location No. 14.

Surge height/length of ship (B.P.) for a range of ship drafts

Figures 12 through 14 present the surge height data in a dimensionless form (surge height/length of ship between perpendiculars) as a function of Froude Number for two locations, No. 2 and No. 14. Figures 12 and 13 are for location No. 2 for inbound and outbound ships respectively and Figure 14 is for location No. 14.

Occurrences of surge heights

Figure 15 presents the number of surge height occurrences measured at location No. 2, and Figure 16 shows the number of occurrences of ship-generated wave heights measured at location No. 14. Figure 15 presents the data for deep-draft vessels and Figure 16 is for small vessels moving at low speeds.

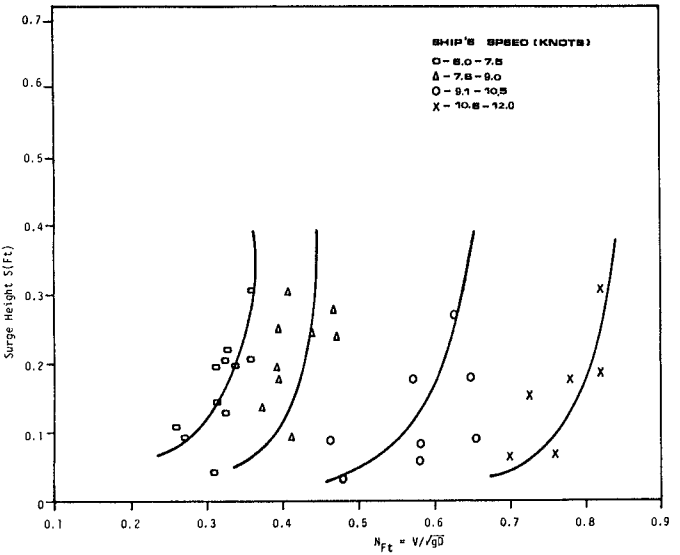

Figure 8. Surge Height Vs. Froude Number at Location #14 for Inbound Ships (Equal Speed)

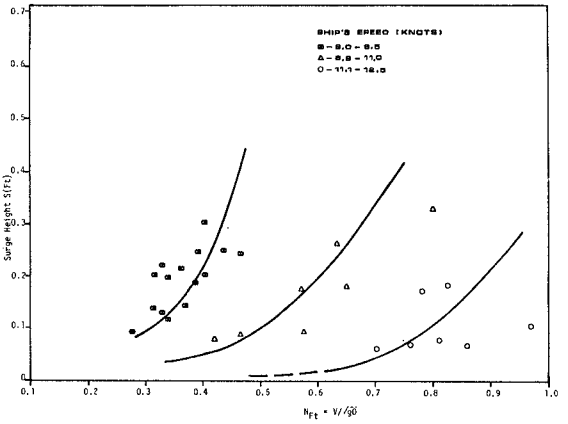

Figure 9. Surge Height Vs. Froude Number at Location #14 for Outbound Ships (Equal Speed)

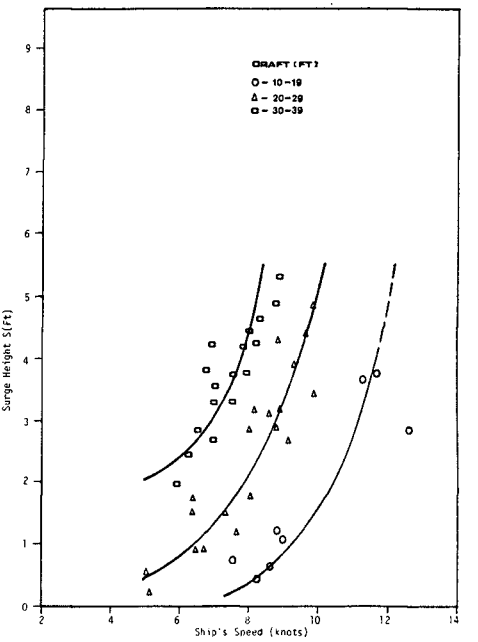

Figure 10. Surge Height Vs. Ship's Speed at Location #2 for Outbound Ships (Equal Draft)

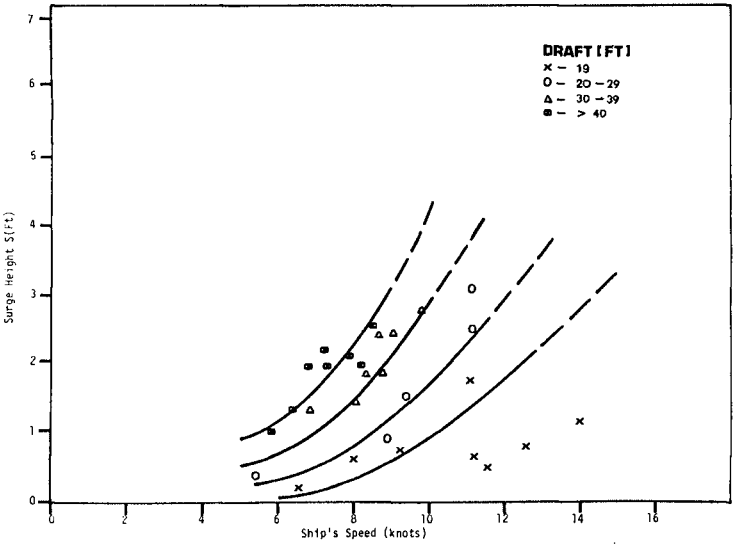

Figure 11. Surge Height Vs. Ship's Speed at Location #2 for Outbound Ships (Equal Draft)

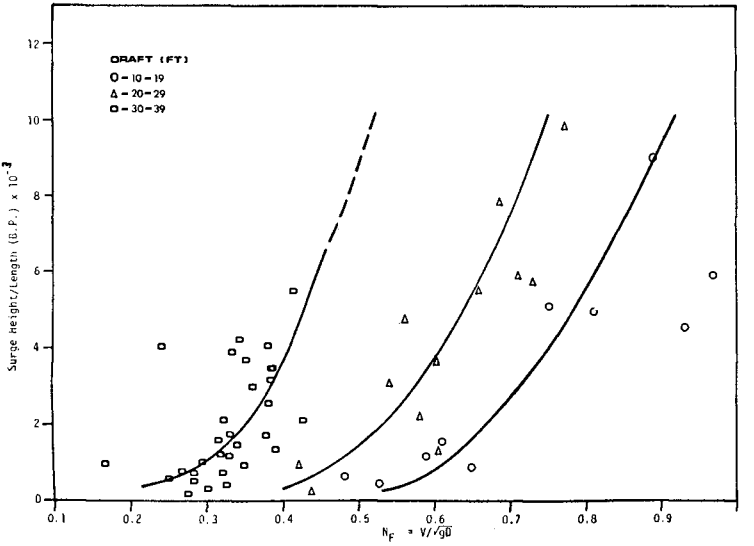

Figure 12. Surge Height/Length of Ship (B.P.) Vs. Froude Number at Location #2 for Inbound Ships

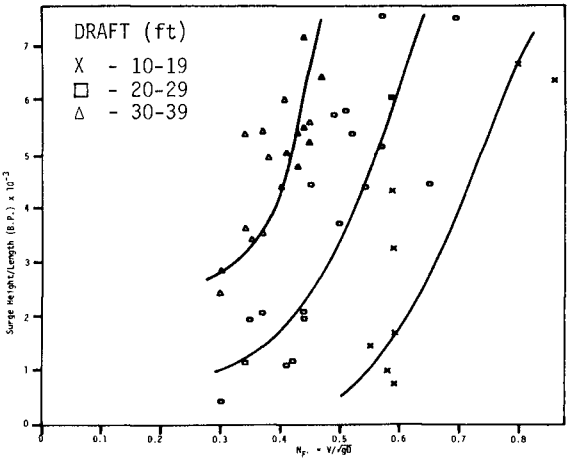

Figure 13. Surge Height/Length of Ship (B.P.) Vs. Froude Number at Location #2 for Outbound Ships

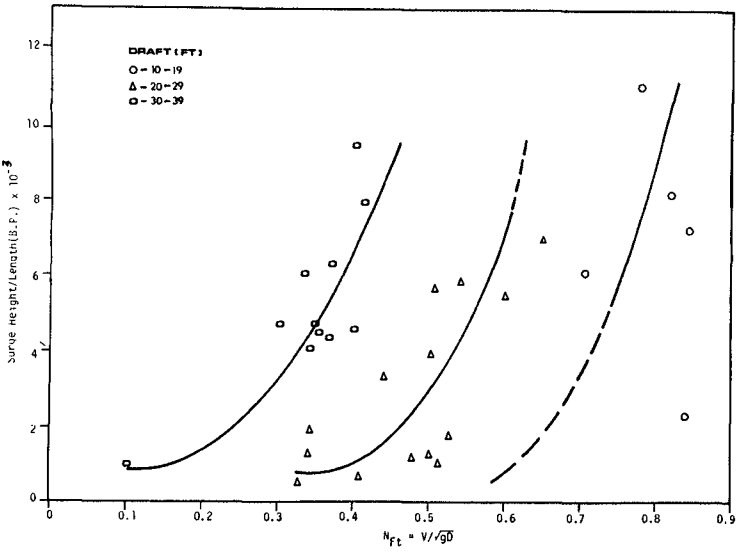

Figure 14. Surge Height/Length of Ship (B.P.) Vs. Froude Number at Location #14 for Outbound Ships (Equal Draft)

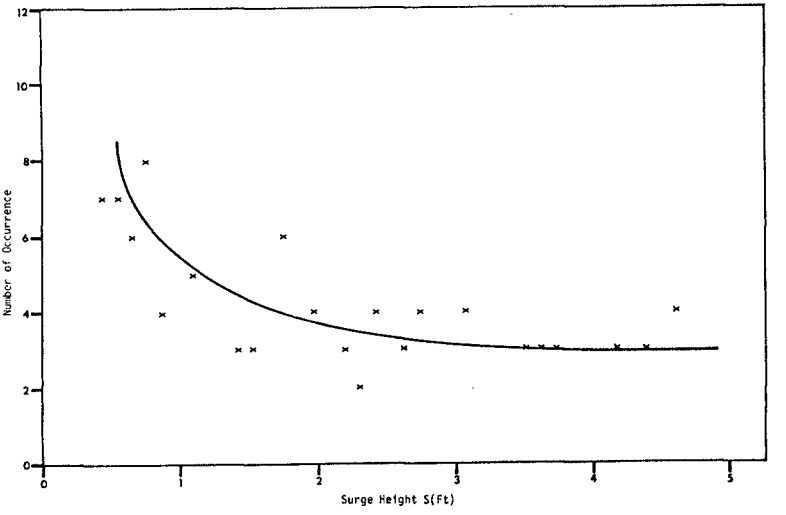

Figure 15. Number of Occurrence Vs. Surge Height at Location #2

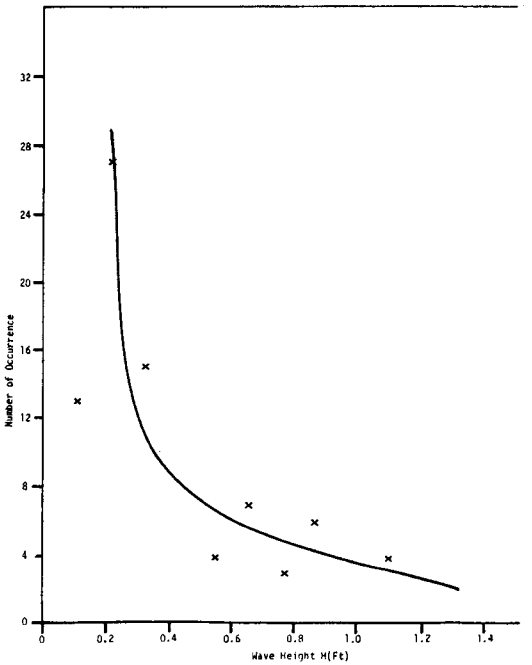

Figure 16. Number of Occurrence Vs. Wave Height at Location #14

Conclusions

1. Considerable surges and waves generated by ships were observed in the Sabine-Neches Waterway. Such surges and waves are the principal cause of bank erosion along the Waterway.

2. The surge height generated by large vessels in a dredged channel, in an otherwise shallow estuary or inlet, is a function of ship's draft and ship's speed. In general, the greater the ship's draft and ship's speed, the greater the generated surge and drawdown.

3. The waves generated by small vessels are principally a function of ship's speed.

4. The surge height generated by large vessels is considerably higher than the waves generated by such vessels.

5. The wave heights generated by small vessels are very large in comparison with surges generated by such vessels. In fact, the surges generated by small vessels can be considered insignificant.

Acknowledgment

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Appendix - References

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