USING A DUAL FREQUENCY ECHO SOUNDER FOR THE DETERMINATION OF SUSPENDED SEDIMENT IN THE WATER COLUMN

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ABSTRACT

The presence of unconsolidated sediment in channels and ports has presented the hydrographic surveyor with a misleading image of the seafloor and created a constant source of conflict between the operator and dredging contractor. In 1985, a revolutionary new concept for defining the nautical bottom, navigable depth, by utilizing the material density was established in the Port of Zeebrugge. At about the same time, investigations by outside contractors put the density of the nautical bottom at about 1.20t/m ³ (Warnier etal 1998). This very soft layer, often layers, of material has not only been difficult to define but has been migratory in nature and in many cases, apparently random in occurrence. In an effort to better locate and delineate the presence of this flocculation, acoustic tests were undertaken over a known fluid mud area utilizing different frequencies.

A series of data acquisition lines utilizing different lower frequency transducers were run across the same predetermined paths to ascertain the images and data attainable. The lower frequencies of 12, 24, and 33 kHz were used with and without TVG settings active. The same lines were run with a density measuring device and bottom samples collected top provide a ground-truthing mechanism. The data was processed utilizing acoustic imaging software and was also processed with density imaging software. The various data sets were then compared to see if any correlation to material density, volume, and to nautical depth could be achieved.

Keywords: echo sounder**,** fluid mud, nautical depth, unconsolidated sediment,

INTRODUCTION

The Basics

Essentially, all echo sounders work in a similar manner. As in Figure 1, a pulse is transmitted from the transducer to the sea bottom and reflected back to the receive element of the transducer. The return echo is processed and the total travel time is converted to a range, then depth using a known sound velocity. Typical beam angles vary from 2.75° to 20º.

Each return signal corresponds to a location on the bottom. The return signals characteristics, frequency and amplitude, are dependent on conditions at that specific point. The quality of the return signal is not only a function of the transducer but also of the angle of incident and the reflective properties of the bottom material encountered.
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Figure 1-Echo Sounder Operation

The sound velocity is dependent the water temperature and salinity, that is the density and also any suspended sediment in the water column. The reflectivity is a function of the surface texture, the incident angle, and the density gradient, that is the degree of change in density between two mediums. This point of change shown in Figure 2 is referred to as a lutocline and significantly alters the sounding parameters (Mehta etal 1991). Occurrences of lutoclines in a fluid mud or varying unconsolidated material zones are common. These presences cause the acoustic signal to varying greatly.

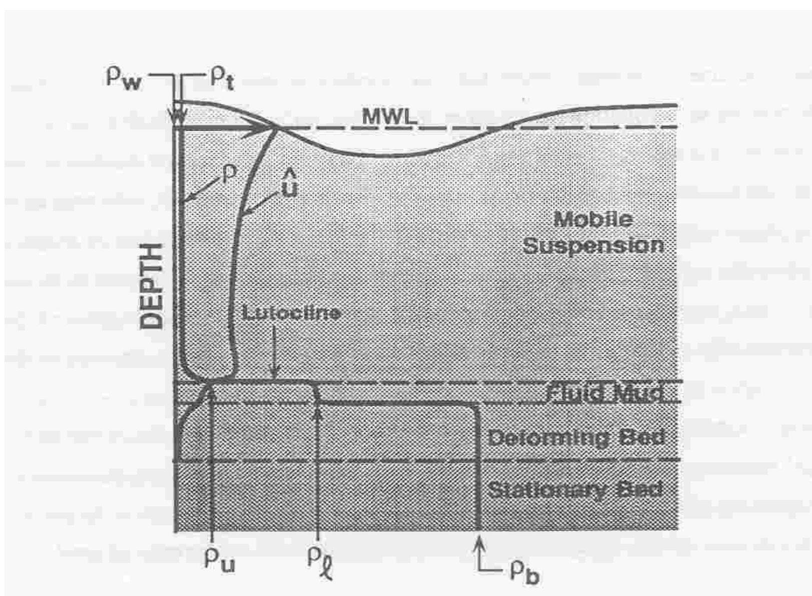

Figure 2 -Fluid Mud

In addition to the sound velocity, the sediment layers can also affect the signal transmission losses through the attenuation of the signal by the increased impedance and alteration of the signal path due to deflection. Based on the inconsistencies of the variables; “In unconsolidated (fluid mud) bottoms, “these records cannot be interpreted reliably unless other correlating information is developed” (US Army Corps of Engineers etal 2002).

Defining Suspended Sediment Utilizing Lower Frequencies

Due to the problems already described, a variety of software and hardware combinations have been applied in an effort to devise a readily usable technique for delineating the "navigable depth" in a real-time manner. In the past, a lead sounding line has often been employed to determine which of the multiple returns displayed on an echo sounder chart is the "true" bottom.

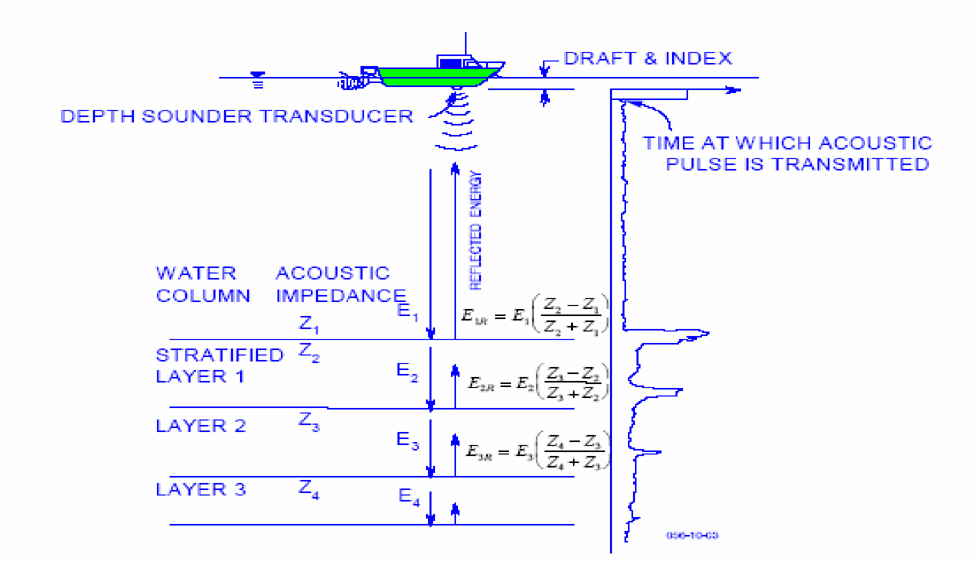

Figure 3 -Low Frequency Penetration

Based on the known characteristics of acoustic medium, the results of 12, 24, and 33 kHz survey data was compared with density gradient measuring software to determine if the correlating information needed could be confirmed using only the time based parameters contained in the echo sounder signal. All of the results were then compared to bottom samples used as a benchmark.

The area surveyed was chosen for the levels of suspended sediment present, up to nine feet. A survey grid was prepared and sets of data collected using the same line parameters. The resultant information was then compared to the actual bottom material for confirmation.

RESULTS

The data sets collected yielded a considerable insight into the effects of frequency on the imaging of soft and unconsolidated material, but when compared to the known sediment conditions, they lacked the resolution to provide accurate volume or density information about the unconsolidated layers in the water column. The dual frequency record below shows an area of significant unconsolidated sediment in the water column. The first image is at 200 kHz and is the top of the fluid mud. The second image represents the softer material.

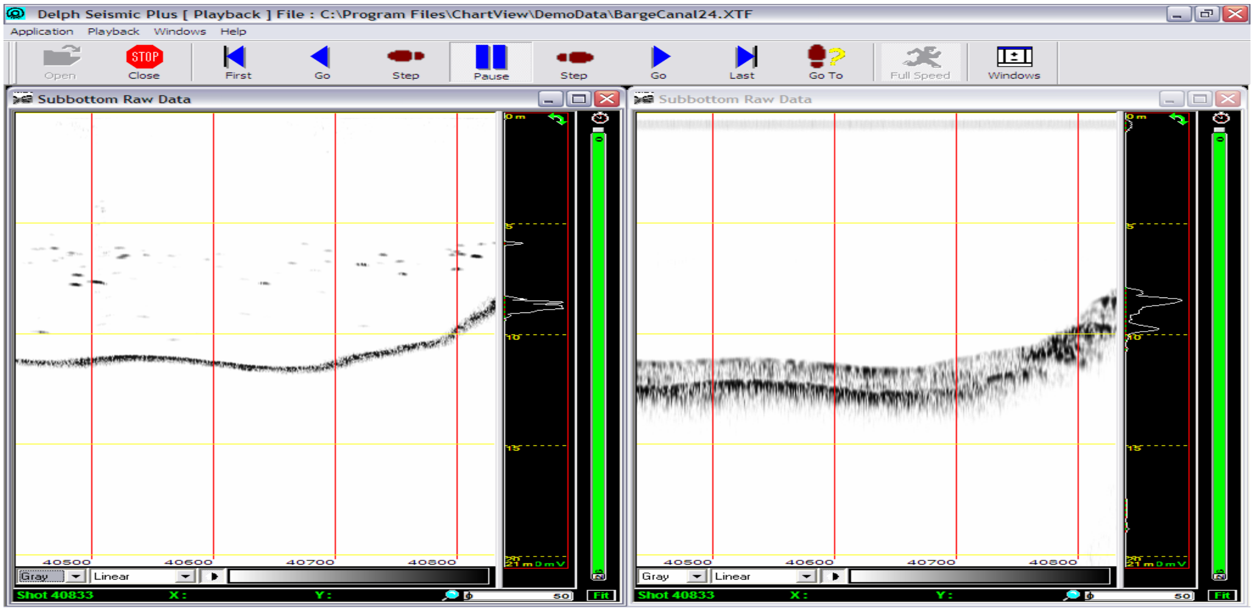

Figure 4 - 200/24 kHz record of Fluid Mud

The high frequency, 200 kHz, reflects from even a very soft material while the 24 kHz signal penetrates the softer sediments and provides a clear image of the unconsolidated layers as seen in Figure 4.

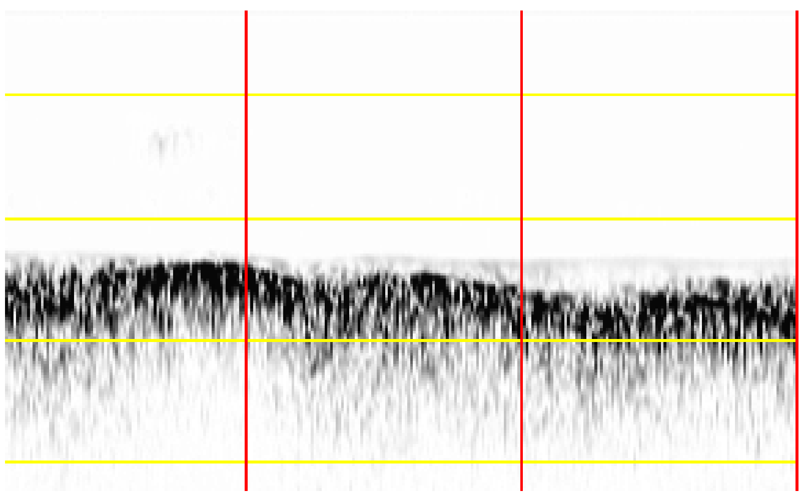

Figure 5-12 kHz Return

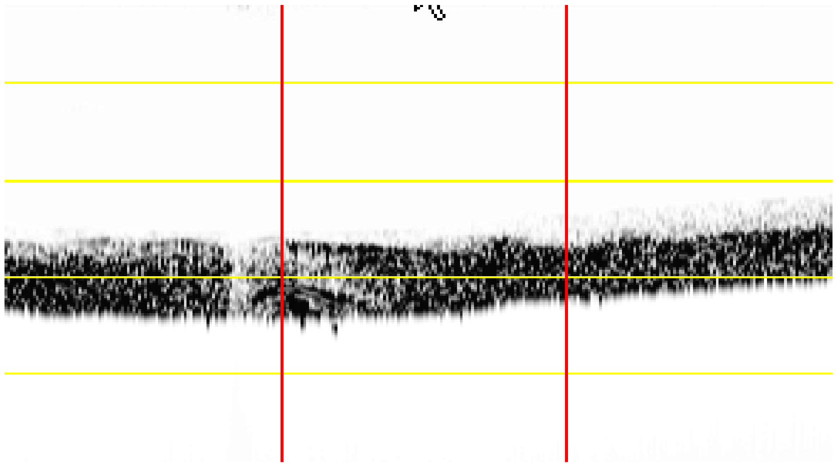

Figure 6- 24 kHz Return

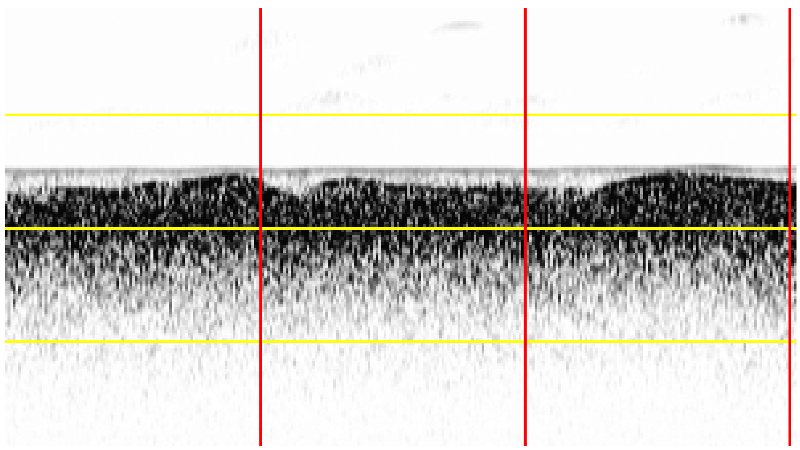

Figure 7 - 33 kHz Return

While the different frequencies provide significantly distinct images of the seafloor, none are necessarily adequate for the determination of navigable depth or even the precise measure of the suspended material above the bottom. In the examples above, Figures 5, 6, and 7, a typical fluid mud area is more closely examined using 12, 24, and 33 kHz signals. Due to the variances in the speed of sound, the precise depth of material indicated is in question.

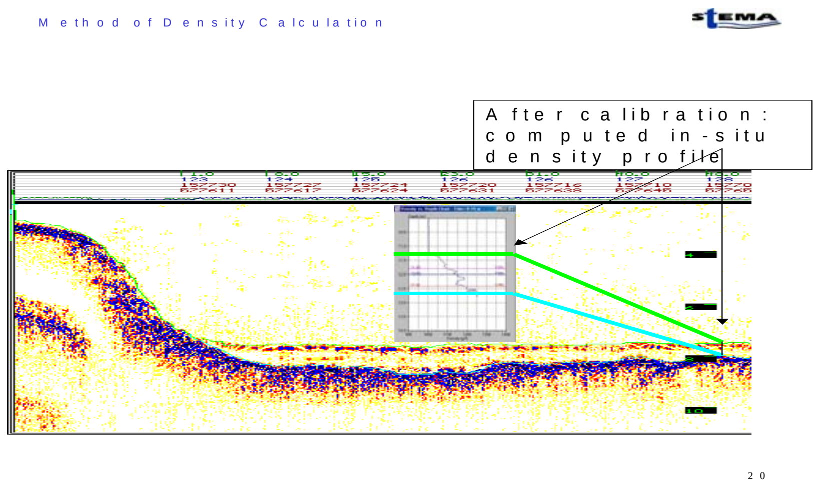

Figure 8-Navigable Depth in Fluid Mud

Density gradient systems can effectively provide the desired information after calibration. Figure 8 indicates the area within the fluid mud zone that a vessel can continue to navigate. In Figure 9, a typical system for determining the density of the unconsolidated sediment layer utilizing the echo sounder information is shown. [i]

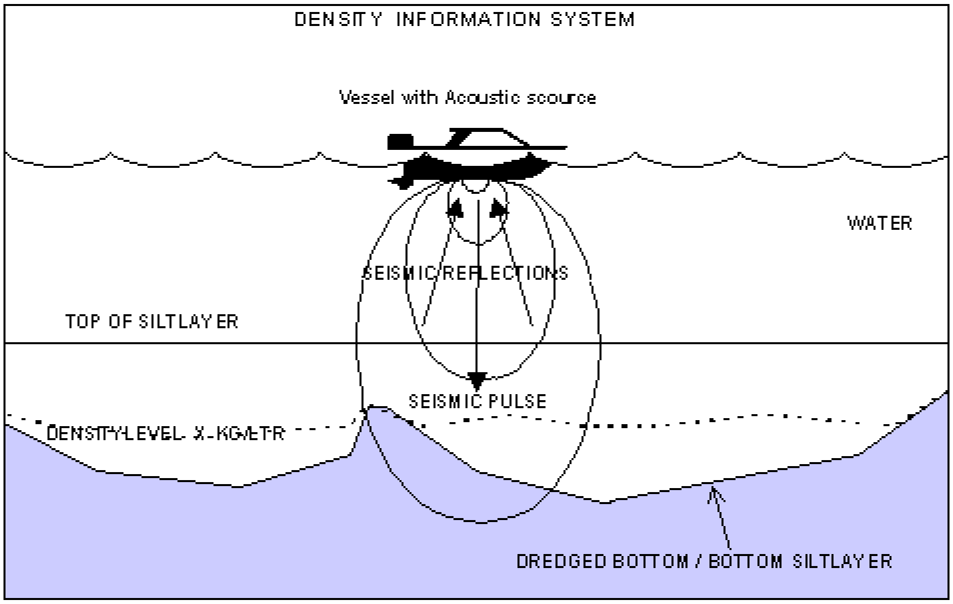

Figure 9-Acoustic Density System

CONCLUSIONS

Echo sounder systems are able to accurately and precisely define the consolidated materials of the bottom. Additionally, using two diverse frequencies can indicate the presence of soft or unconsolidated material in the water column. Based on lower frequency images, certain assumptions as to the depth and extent of the material may be assumed. This alone however is not adequate for the determination of navigable depth in fluid mud and additional information needs to be collected. The density and viscosity of the suspended material cannot be determined using a standard echo sounder.

Research and development of acoustic density systems, either combined with echo sounders, or stand alone needs to continue until a reliable and timely system can be deployed.

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