Planning of Dredging Operations utilizing deposited Siltation Vertical and Horizontal Sediment Mapping

Part Two – Sediment Geoacoustic Backscatter metrics used to compute Geotechnical Parameters

Part Two – Introduction

This second part of the Dredge Planning paper is intended for scientists, engineers, and other technical readers who want to understand the underlying geoacoustic metrics used to compute geotechnical (i.e. Wet Bulk Density, Porosity, etc.) parameters as were shown on the maps in Part One.

For decades it has been known that a relationship exists between acoustic reflectivity and sediment type; with the greatest reflection occurring from sandy or rocky sea bottoms and the poorest reflection from muddy bottoms; Albers (1965), Breslau (1965). However, in those years, researchers were limited by measuring equipment as only linear acoustic devices and wide beamwidth echo sounding transducers were available. In addition to the lack of acoustic instruments which could provide highly calibrated signals, signal processing algorithms and resulting software were limited.

Still, research yielded important relationships between acoustic backscatter and geotechnical parameters. Morgan (1964), Hamilton (1956), Sutton (1957) and Shumway (1960) all independently developed regression equations relating acoustic Reflection Coefficient to Sediment Porosity. Figure 1 plots their results and indicates a 99 percent confidence (correlation coefficient).

Unabara's machine learning algorithm incorporates field tested first and second order equations based upon over 8000 sediment parameter datasets from throughout the world. In addition, the learning ability of the algorithm allows users to finely ground-truth/calibrate the Hydro-2F system to specific survey areas.

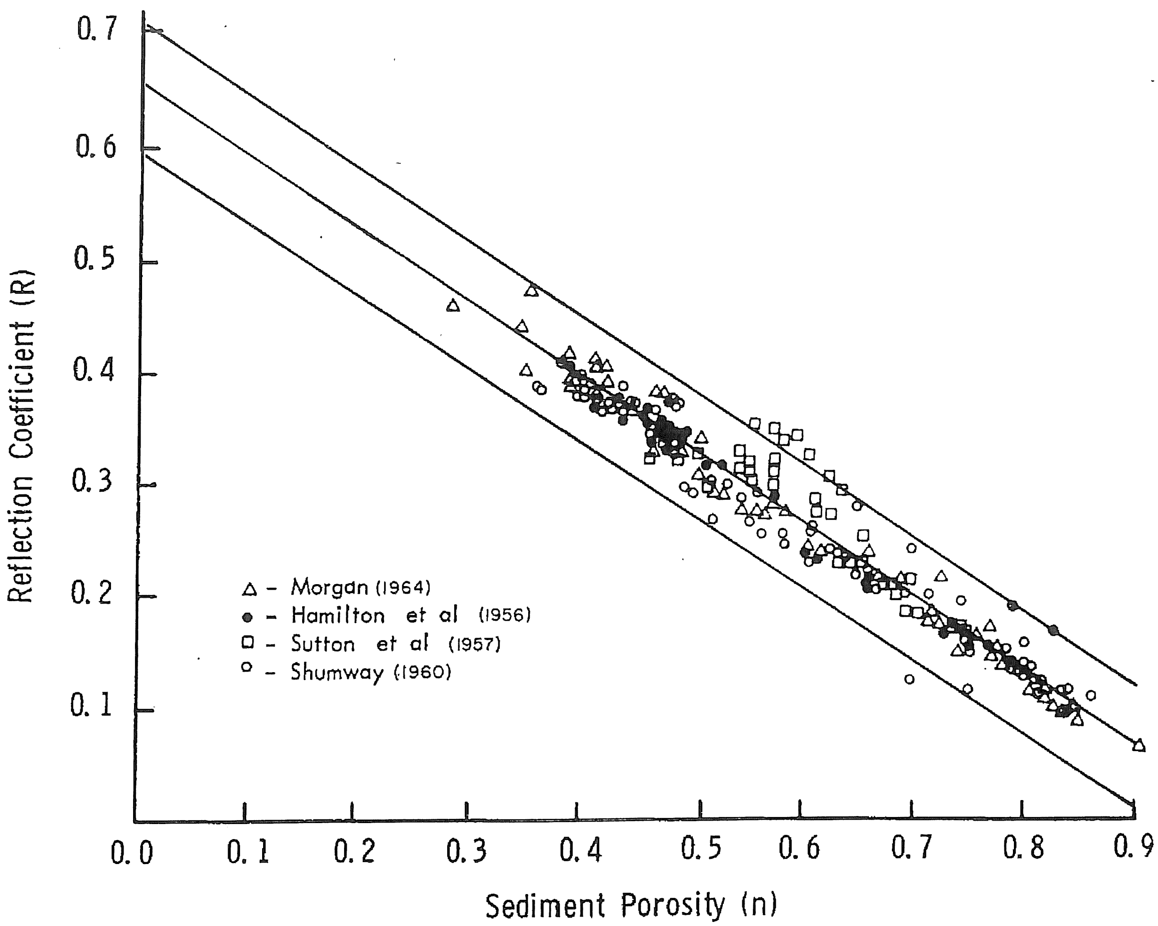
Nafe and Drake (1963) established the relationship between porosity and wet bulk density of a sediment as:

$$ps = pwn + psol (1 - n)$$

where:

ps = wet bulk density
pw = density of water
psol = density of solid material in sediment
n = sediment porosity

Based upon more recent research by Unabara and others, Unabara's proprietary algorithm very accurately predicts Wet Bulk Density, Porosity, and other geotechnical parameters.



0.7
0.6
0.5
0.4
0.3
0.2
0.1
Reflection Coefficient (R)
△ - Morgan (1964)
● - Hamilton et al (1956)
□ - Sutton et al (1957)
○ - Shumway (1960)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Sediment Porosity (n)

Bottom Contrasting™

In some cases, the user may desire to simply know how many different sediment types exist in a given area and where the types are distributed (geoposition wise). This can easily be done by comparison of acoustic bottom losses of the surficial sediment layer horizontally over the survey area; likewise, he may see different consolidated bottom types by comparing acoustic bottom losses (expressed in decibels) over the area. The poorest acoustic reflection will come from the areas (i.e. muddy bottom) of maximum bottom loss while the highest reflection will come from the areas (i.e. sand, rock) of minimum bottom loss. MAP I shows the distribution of surficial bottom types of differing acoustic bottom losses. If he elects, the user may take grab samples or core samples at various geopositions to define what bottom losses correlate to what sediment types. While this is not needed in many cases because wet bulk density and porosity are already mapped (see Part One), the user has the option of ground-truthing on his own.

MAP J provides the bottom losses for the consolidated sediment layer. MAP K & L show the reflectivity expressed in percentage. A "perfect reflector" (bottom), if one were possible, would result in a value of 100%. So, as bottom loss increases, the reflection % decreases.

Importance of Horizontal Spatial Resolution

Conventional analog echo sounder sonar systems utilize linear transmitters with wide beamwidth acoustic transducers; 12, 24, 28 KHz. transducers may have a main beamwidth of perhaps 22 to 30 degrees. These type of transducers also typically have side-lobes beyond the main beam. In shallow water depths, in addition to the main beam, energy from the side-lobes ensonify the sea floor. In a 10 foot water depth, the diameter of the total area ensonified, at the low frequencies (12, 24, 28 KHz.) would be a six to eight foot circle. Depth and backscattering information is thus averaged over a wide area thus missing many of the horizontal details of the sea floor.

In contrast to the ensonified area mentioned above, the Unabara Hydro-2F Multi-Frequency Synthetic Beam Bathymetric & Sea Floor Sonar has a very narrow beamwidth of only about 10% of a linear sonar, thus the ensonified diameter at the 10 foot depth is only about 6 inches. This small 6 inch target area, along with a much higher ping rate than conventional linear sonars, allows the detection and display of very fine details in the sea floor. Whether the user is seeking to see very small changes in the sediment type distribution or wanting to find small bridge scour holes in the water bottom, the Hydro-2F provides the needed spatial resolution.

List of References

Albers, V.M., 1965, Underwater Acoustics Handbook II, The Pennsylvania State University Press.

Breslau, L., 1965, Classification of Sea Floor Sediments with a ship-borne acoustical system: Symposium “Le Petrole et La Mer”, Monoco, V. 132, p. 1-9.

Hamilton, E.L., Shumway, G., Menard, H.W., and Shipek, C.J., 1956. Acoustic and other Physical Properties of Shallow Water Sediment off San Diego; J. Acoustical Society of America, V. 28, p. 1-15.

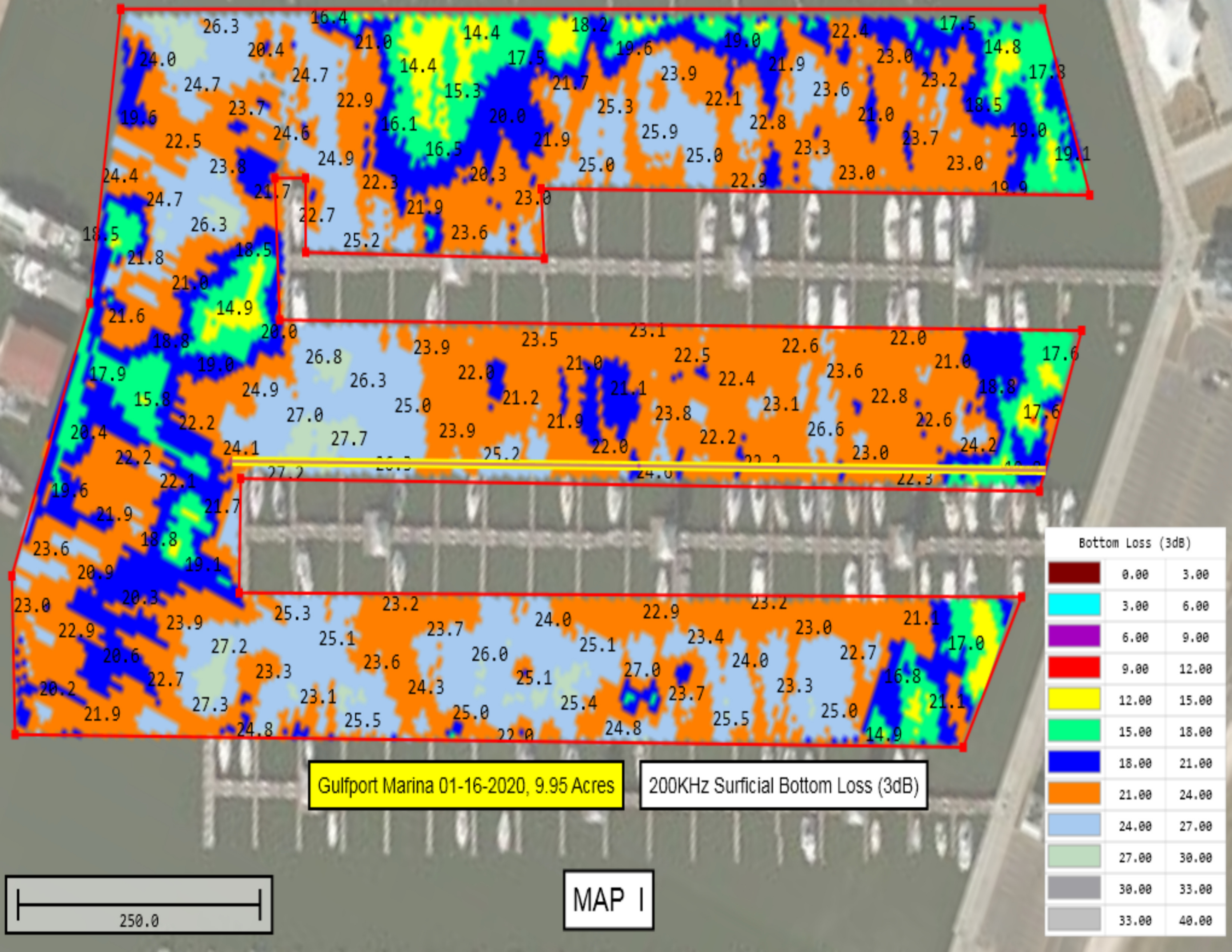
Morgan, N.A., 1964 Geophysical Studies in Lake Erie by Shallow Marine Seismic Methods, Ph.D. dissertation, University of Toronto, Canada.

Shumway, G., 1960, Sound, Speed and Absorption Studies of Marine Sediments by a Resonance Method, Part I: Geophysics, V. 25, p 451 – 467.

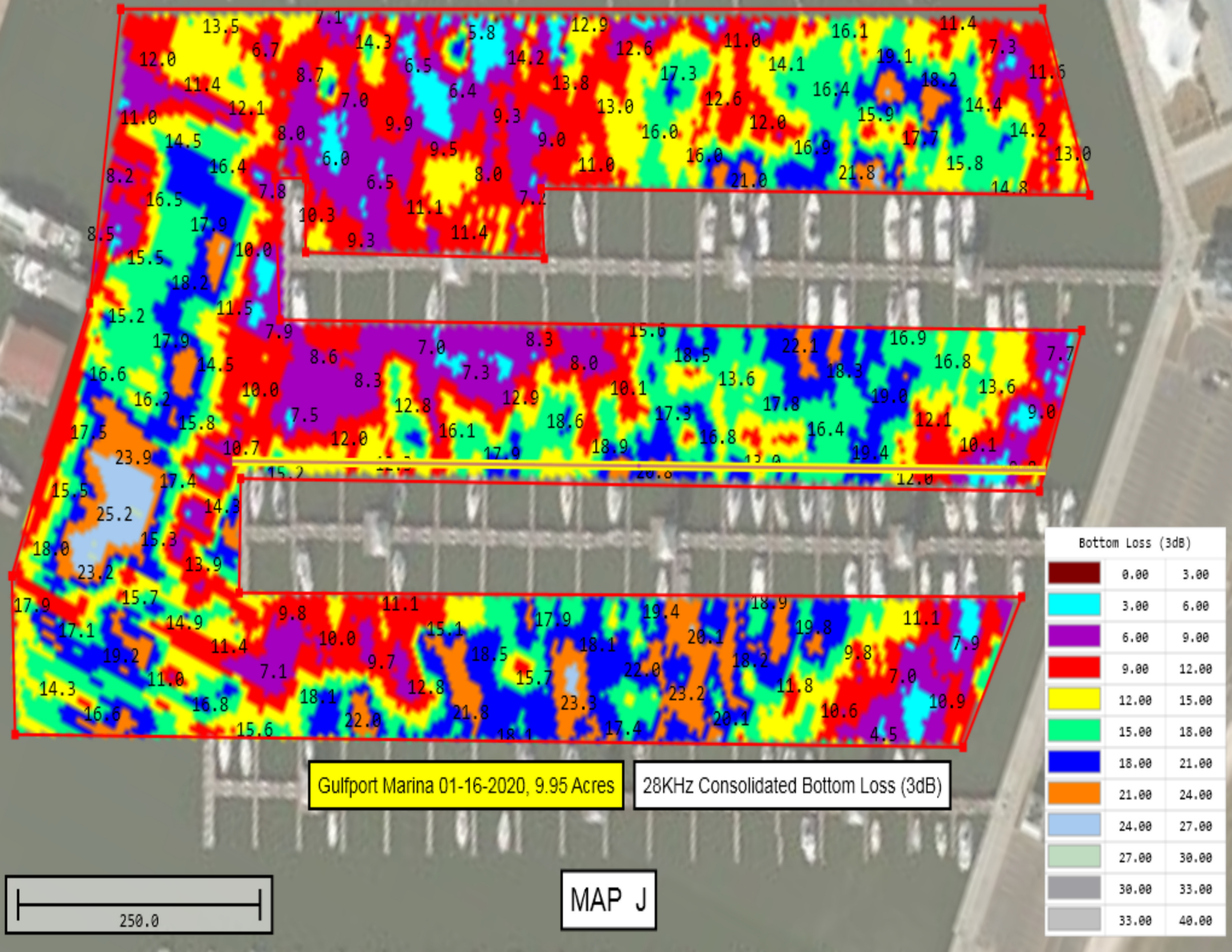
Sutton, G.F., Berckhemer, H., and Nafe, J.E., 1957, Physical Analysis of Deep Sea Sediments: Geophysics, V. 22, No. 4, p. 779 – 812.

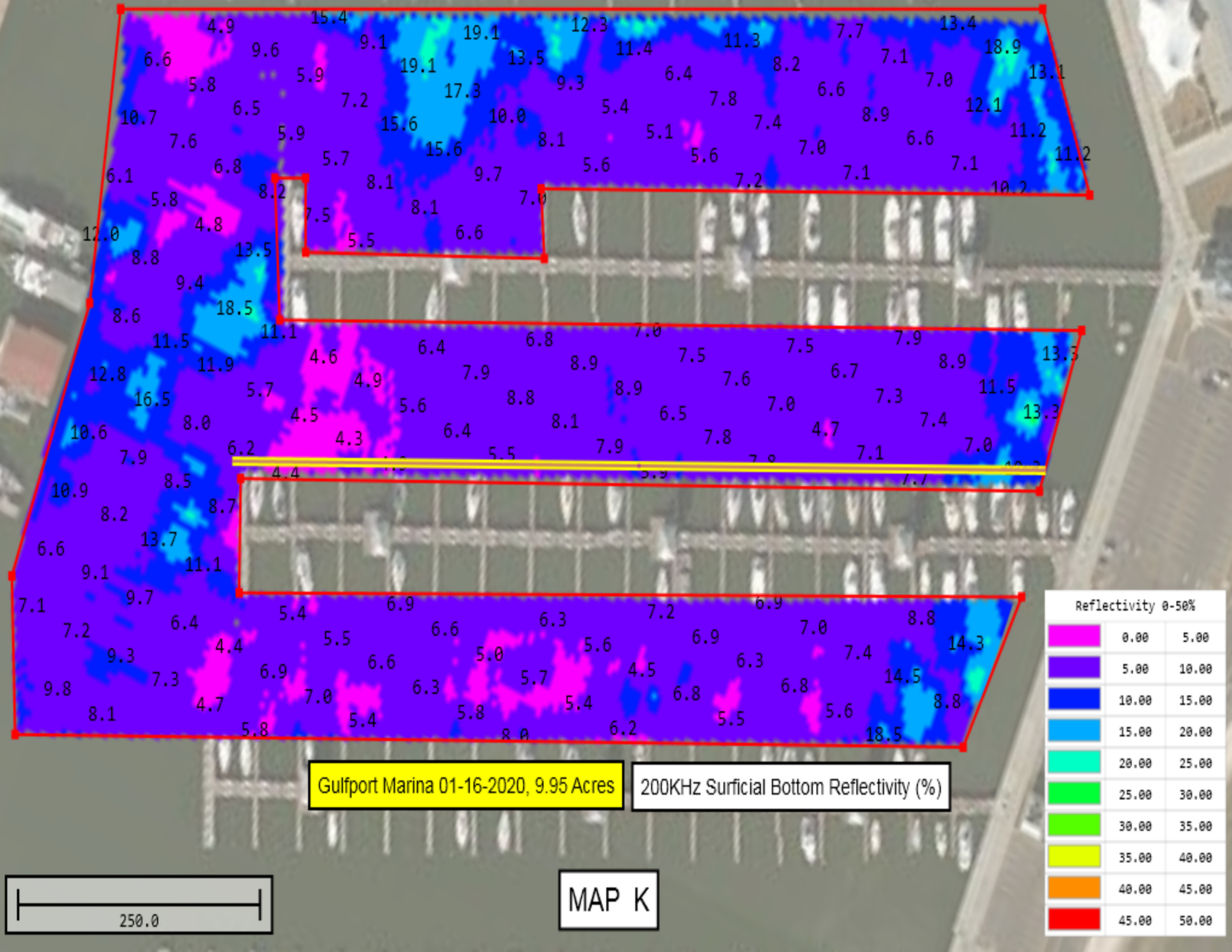
Nafe, J.E. and Drake, C.L., 1963, Physical Properties of Marine Sediments; The Sea, V.3, p. 794-815: New York, John Wiley & Sons.

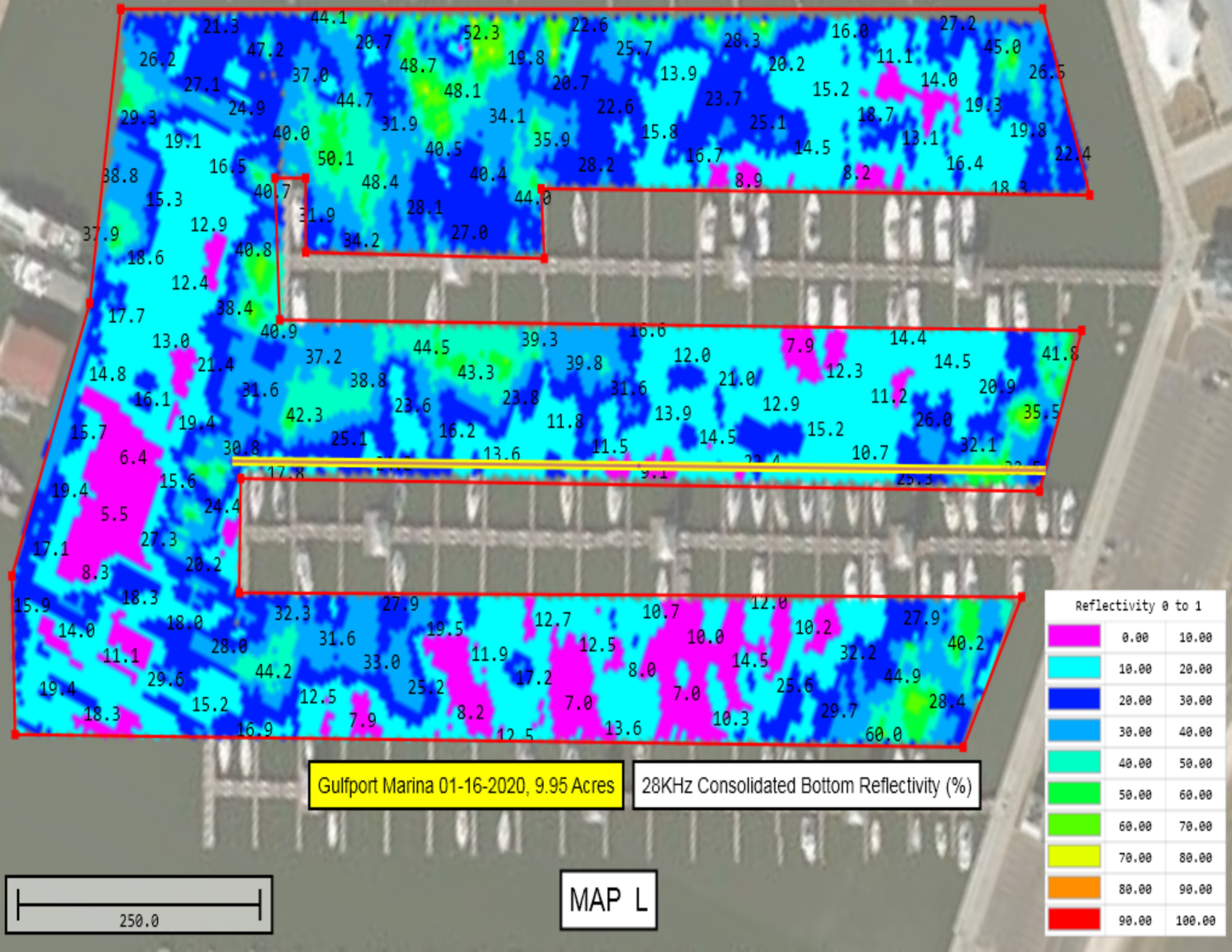
For additional reading request Unabara’s Publication TDOCS-2020-4:
Overview: Acoustic Characteristics of Sea Bottom Sediments



Gulfport Marina 01-16-2020, 9.95 Acres
200KHz Surficial Bottom Loss (3dB)
MAP I
250.0
Bottom Loss (3dB)
0.00 3.00
3.00 6.00
6.00 9.00
9.00 12.00
12.00 15.00
15.00 18.00
18.00 21.00
21.00 24.00
24.00 27.00
27.00 30.00
30.00 33.00
33.00 40.00


Bottom Loss (3dB)
0.00 3.00
3.00 6.00
6.00 9.00
9.00 12.00
12.00 15.00
15.00 18.00
18.00 21.00
21.00 24.00
24.00 27.00
27.00 30.00
30.00 33.00
33.00 40.00
Gulfport Marina 01-16-2020, 9.95 Acres
28KHz Consolidated Bottom Loss (3dB)
MAP J
250.0


Gulfport Marina 01-16-2020, 9.95 Acres
200KHz Surficial Bottom Reflectivity (%)
MAP K
250.0
Reflectivity 0-50%
0.00 5.00
5.00 10.00
10.00 15.00
15.00 20.00
20.00 25.00
25.00 30.00
30.00 35.00
35.00 40.00
40.00 45.00
45.00 50.00


Gulfport Marina 01-16-2020, 9.95 Acres
28KHz Consolidated Bottom Reflectivity (%)
MAP L
250.0
Reflectivity 0 to 1
0.00 10.00
10.00 20.00
20.00 30.00
30.00 40.00
40.00 50.00
50.00 60.00
60.00 70.00
70.00 80.00
80.00 90.00
90.00 100.00