Acoustical Hydrographic Cross Section of the Gulfport, MS. Ship Channel

(using Unabara's Hydro-2F™ Multi-Frequency Synthetic Beam Bathymetric & Sea Floor Sonar)
With examples of the prediction of Geotechnical Sediment Characteristics using Geoacoustic Sea Floor Backscattering Information Processing

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SURVEY AREA

The Gulfport Harbor Navigation Channel has long been recognized as a problem area related to soft (or liquid) mud. This channel varies between 200 feet to 300 feet in width and has a design nautical (navigable) depth of about 36 feet. This 11 mile channel traverses Mississippi Sound from just south of Ship Island to Gulfport. At the shore end of the channel is a ship turning basin whose depth is maintained at about 36 to 38 feet. The basin is in an area of rapid sedimentation due to its morphology and location relative to circulation. Tidal currents near the basin are nearly parallel to the coastline causing an eddy in the basin. Much of the new incoming sediment load is kept in suspension causing high turbidity throughout the water column. Required frequent dredging further adds to the sediment load (mud, etc.).

EQUIPMENT & METHODS

A portable Unabara Hydro-2F™ Sonar was installed on a survey launch together with associated RTK GPS and Windows Notebook PC. In addition to the Hydro-2F™'s PC-based Control & Display software, Hydromagic™ (Eye4Software B.V., The Netherlands) Mapping and Dredge Monitoring PC software was employed for generating illustrations shown in Charts A thru K. In a similar manner digital data outputs from the Hydro-2F™ may be used with HYPACK™, Caris™, and other mapping programs.

For this paper, the multi-color display mode of the Hydromagic™ was used to illustrate the functionality of the Hydro-2F™. It should be noted that Hydromagic™ can also generate isobaths (depth) contour lines or provide tabular XYZ format data. Data may also be exported as AutoCad™ DXF or Google™ KML files. Sonar derived information may be overlayed with existing grid maps and/or satellite photographic maps to provide both video and hard-copy augmented reality maps.

Prediction of geotechnical sediment values presented on the charts herein are based upon Unabara's proprietary algorithm with first and second order parameters derived from Reflection Coefficients. Previous research of Reflection Coefficient significance were published by Akal (1972), Hamilton (1970), Tegowski (2005), and others.

Note that while GPS geoposition reference lines normally overlay illustrations and contour maps, such has been removed from Charts A thru K to eliminate clutter.

Data used for this paper was obtained using 230 Khz. for the "high" frequency and 12 Khz. for the "low" frequency. (For the low frequency, the user can also select 10 Khz., 18 Khz., 24 Khz., 28 Khz., or 30 Khz.). During the survey, real-time, depths derived from each of the two frequencies, sea bottom reflectivity and loss, and other information is viewable to the user via the main "dashboard" display on the PC.

EXPLANATION OF CROSS SECTION CHARTS

About 1.5 miles south of Gulfport, a series of survey lines were run, each running directly across the ship channel. Depth and acoustic backscatter parameters, along with GPS position, was recorded for both acoustic frequencies.

The attached eleven charts are mostly self-explanatory. Some annotation has been added for the purpose of clarification. Since the survey lines extend somewhat past the main ship channel path on both sides, the locations of the “red” and “green” channel markers have been marked on each figure.

CHART A shows the Depth values as measured by the high frequency. The sea bottom here represents the initial bottom detected by the high frequency echo. This is referred to as “surficial sediment” as it is the first detectable layer at the bottom of the water column. You will note that the majority of the width of the ship channel has a surficial bottom depth of about 30 to 34 feet. Outside of the channel, the depth shallows quickly to about 14 to 11 feet, then to about 10 to 11 feet.

CHART B shows Bottom Loss for the surficial soft sea bottom (as determined by the 230 Khz. frequency). Note that the highest bottom loss values lie in the soft/liquid mud areas of the actual ship channel.

CHART C shows the actual Reflectivity for the surficial sediments shown on Chart B.

CHART D shows the predicted Porosity values for the surficial sea bottom on Chart B based directly upon Reflection Coefficients as suggested by Breslau (1965), Faas (1969), and later by others.

CHART E shows the predicted Bulk Densities for the surficial sea bottom on Chart B. Over the years, numerous researchers have established the relationship between porosity and the bulk (wet) density of a sediment. This relationship was summarized by Nafe and Drake (1963).

CHART F shows the Depth values as measured by the low frequency. This low frequency penetrates the surficial sediment bottom and does not return an echo until it detects a difference in acoustic impedance representing a “hard” consolidated bottom layer. In this figure, the actual deepest consolidated bottom depth in the ship channel is about 37 feet. The space between in the “two bottoms” is filled with soft/liquid of undetermined density. *Once the location and depth range of the soft/liquid mud is determined acoustically, it is prudent to vertically profile this depth range (soft/liquid mud layer thickness) using a rheometric instrument. This will establish at what depth in the liquid layer the density reaches a value which is not safe for a ship to pass thru.*

CHART G shows Bottom Loss for the consolidated layer of mud (as determined by the 12 Khz. frequency) which lies below the soft/liquid mud layer. Bottom loss values for areas outside of the channel markers are also shown.

CHART H shows the actual Reflectivity for the consolidated sediments shown on Chart F.

CHART I shows the predicted Porosity values for the consolidated sediments on Chart F.

CHART J shows the predicted Bulk Densities for the consolidated sediments on Chart F.

CHART K compares the depths of the surficial bottom with that lower bottom layer as determined by the low frequency. The colors and corresponding values in feet represent areas of differing soft or liquid (mud) sediment thickness. You will note that in the center of the ship channel the soft/liquid layer is about 4 feet thick. Interesting is that outside of the channel markers, on both sides of the channel, there is 0 to 1 foot of difference between the two bottoms. This is because the areas shown as bright red to yellow have a sand and silty sand composition. This can easily be proven by ground truthing; or, Reflection Coefficient can be calculated from bottom loss; and Reflection Coefficient is directly proportional to Porosity; and, lastly, bulk density and average grain size can be predicted from Porosity.

Special Note: Shortly before this survey was performed, the USACE had dredged portions of the ship channel. Historical evidence indicates that at various times between dredging operations the layer of liquid mud in the channel was greater than measured in this survey.

List of References

Akai, T., (1972) The relationship between the physical properties of underwater sediments that affect bottom reflection. Marine Geology, Vol. 13, p. 251-266

Breslau, L. (1965) Classification of sea floor sediments with a ship-borne acoustical system; Symposium “Le Petrole et La Mer,” Monaco, Vol. 132, p. 1-9

Faas, R.W. (1969) Analysis of the relationship between acoustic reflectivity and sediment porosity. Geophysics, Vol. 34, No. 4, p. 546-553

Hamilton, E.L., (1970) Reflection coefficients and bottom losses at normal incidence computed from Pacific sediment properties. Geophysics, Vol. 35, No. 6, p. 995-1004

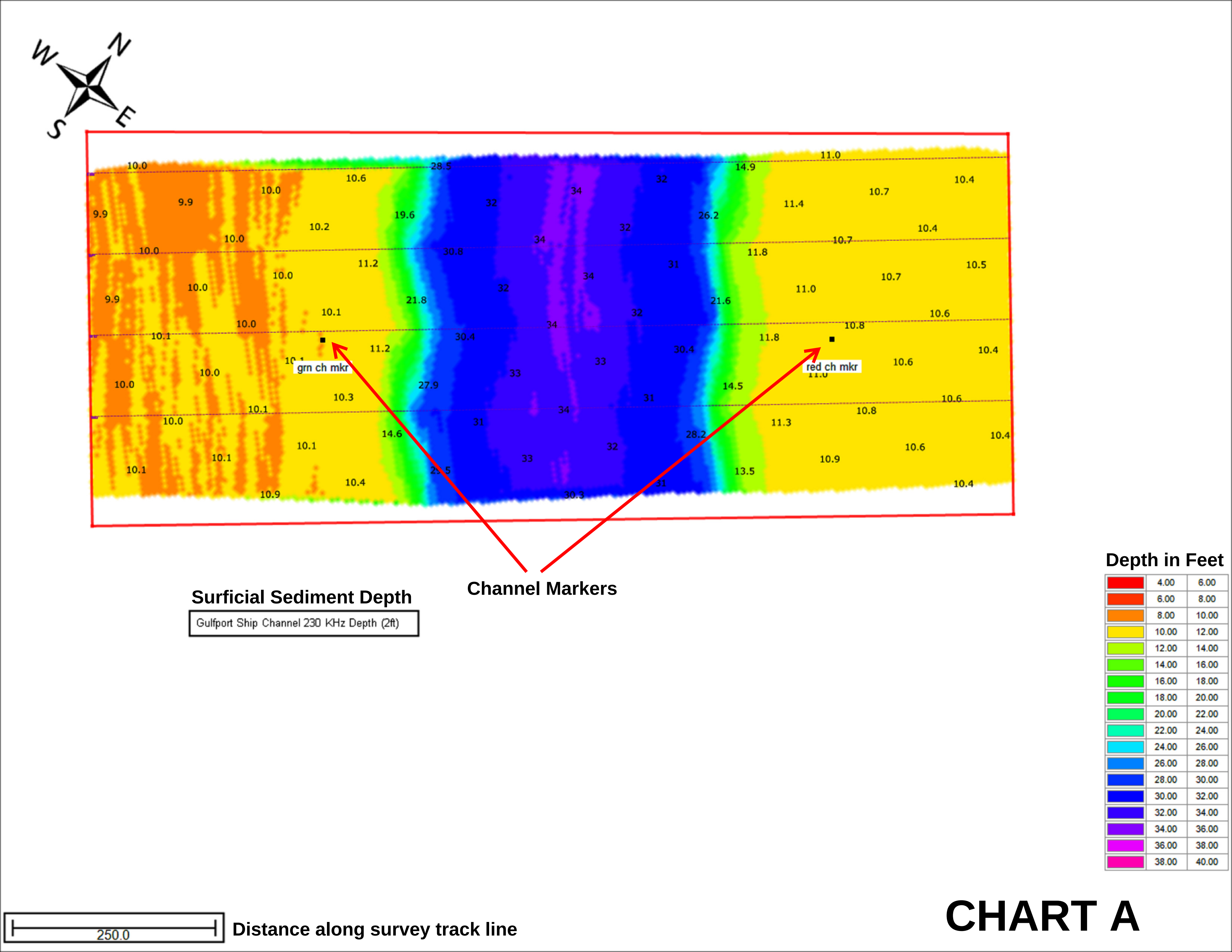
Nafe, J.E. and Drake, C.L. (1963) Physical properties of marine sediments; The Sea, Vol. 3, p. 794-815; New York, John Wiley & Sons.

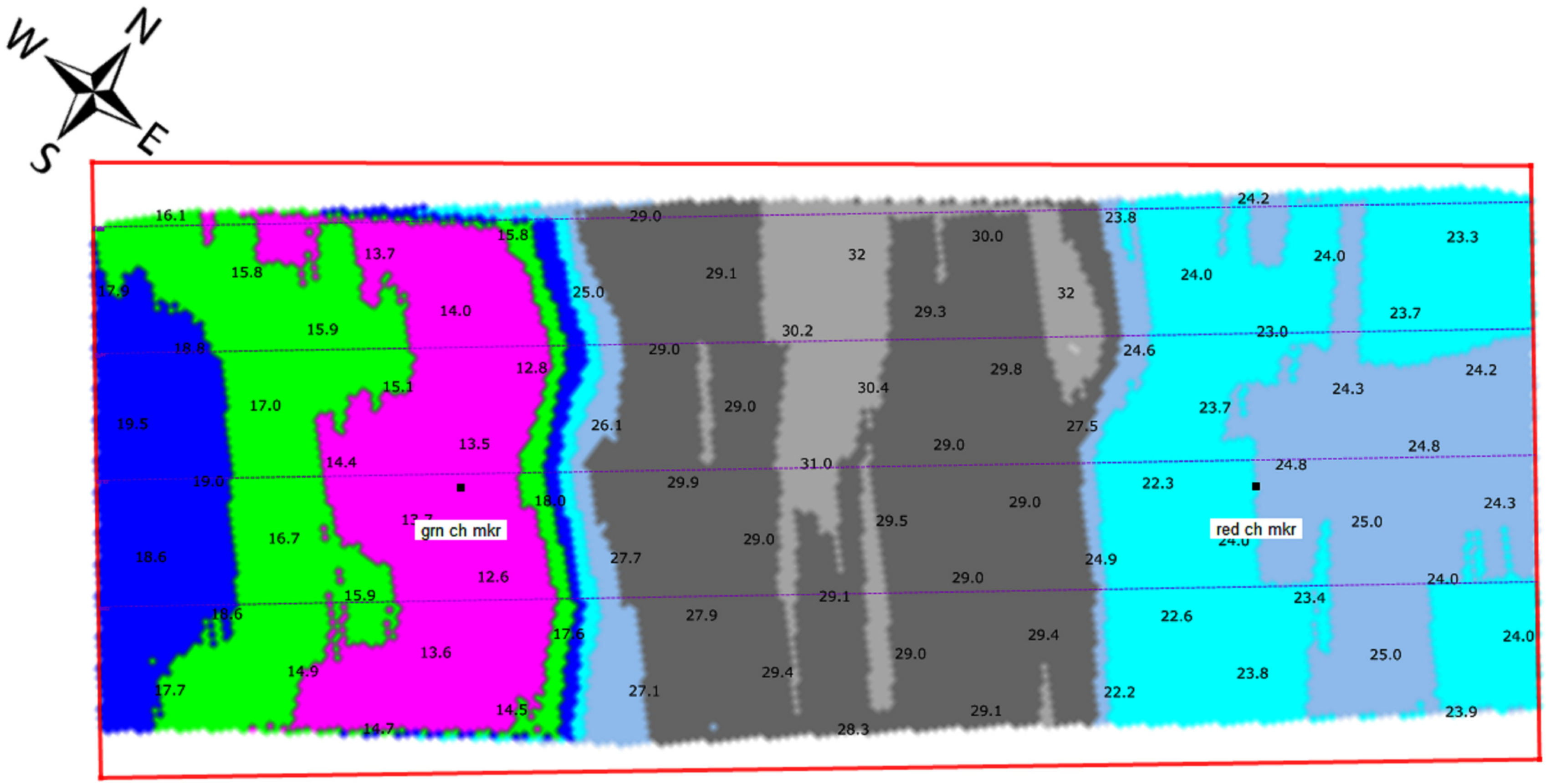
Tegowski, J. (2005) Acoustical classification of the bottom sediments of the southern Baltic Sea. Quaternary International, Vol. 130, p. 153-161.

For a comprehensive reference as an aid to understanding the terms and principles mentioned herein, we suggest the book:

<u>*High-Frequency Seafloor Acoustics*</u>
Authors: Darrell R. Jackson, University of Washington, Seattle, Washington
Michael D. Richardson, Naval Research Laboratory, Stennis Space Center, MS
E-Book: e-ISBN-13: 978-0-387-36945-7 Library of Congress Control # 200692906 © 2007

CHARTS A thru K


W
N
S
E
grn ch mkr
red ch mkr
Channel Markers
Surficial Sediment Depth
Gulfport Ship Channel 230 KHz Depth (2ft)
Depth in Feet
4.00 6.00
6.00 8.00
8.00 10.00
10.00 12.00
12.00 14.00
14.00 16.00
16.00 18.00
18.00 20.00
20.00 22.00
22.00 24.00
24.00 26.00
26.00 28.00
28.00 30.00
30.00 32.00
32.00 34.00
34.00 36.00
36.00 38.00
38.00 40.00
250.0
Distance along survey track line
CHART A



Surficial Acoustic Bottom Loss

Gulfport Ship Channel 230 KHz Bottom Loss (3db)

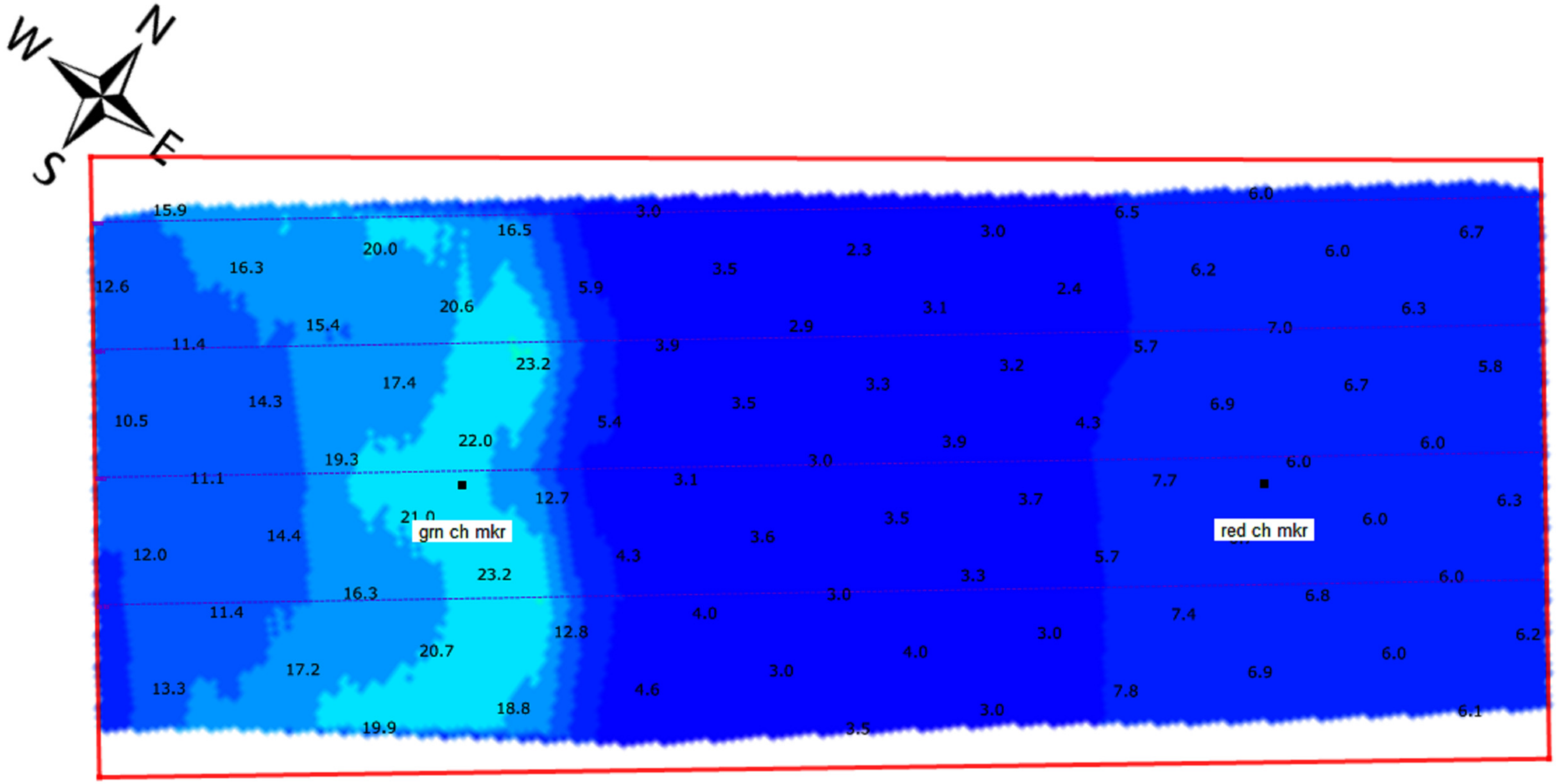
Bottom Loss		
	0.00	3.00
	3.00	6.00
	6.00	9.00
	9.00	12.00
	12.00	15.00
	15.00	18.00
	18.00	21.00
	21.00	24.00
	24.00	27.00
	27.00	30.00
	30.00	33.00
	33.00	40.00

Lower Acoustic Loss

Higher Acoustic Loss

250.0 **Distance along survey track line**

CHART B



Surficial Sediment Reflectivity

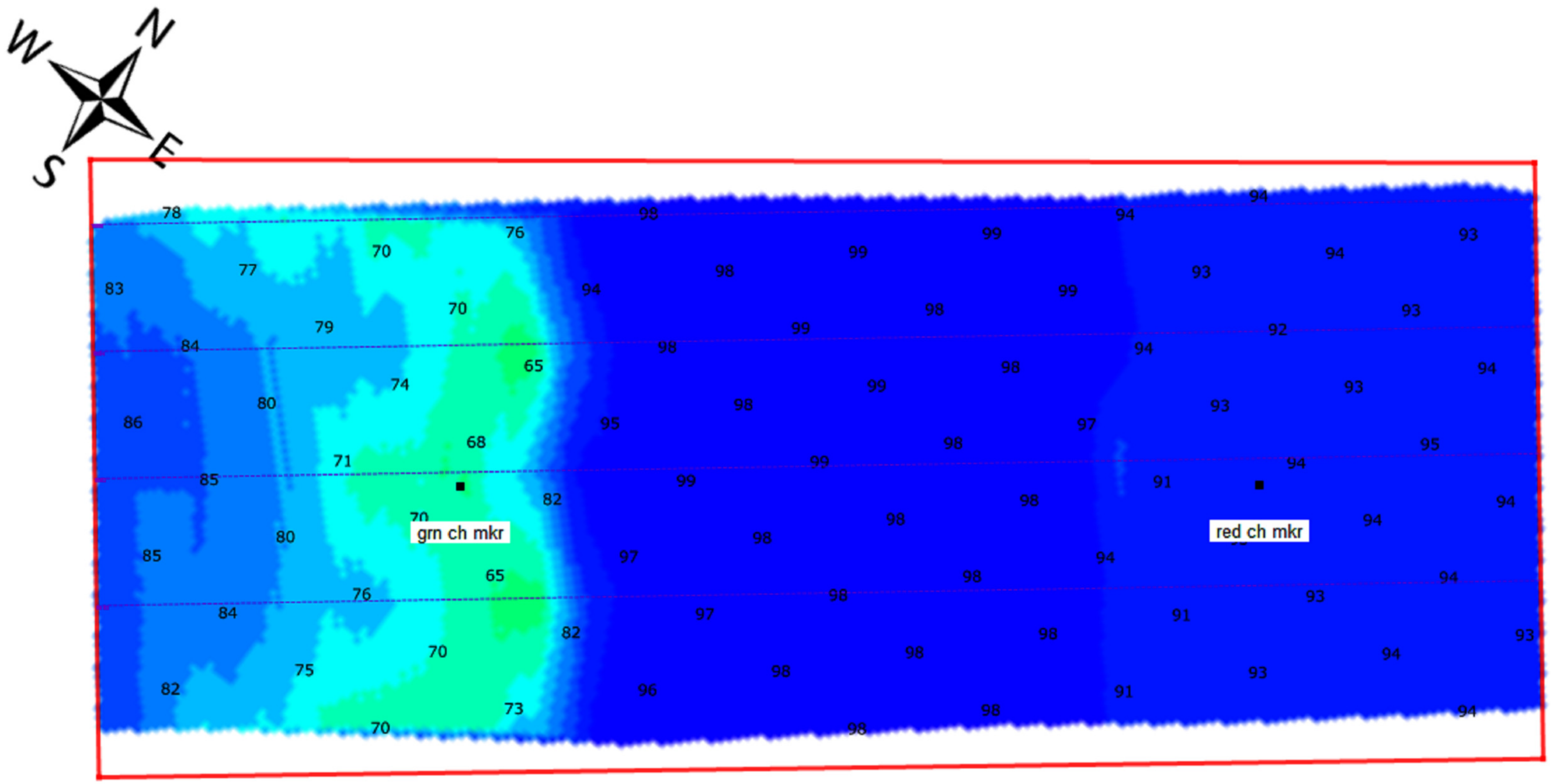
Gulfport Ship Channel 230 KHz Bottom Reflectivity (%)

Bottom Reflectivity

	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
	50.00	55.00
	55.00	60.00
	60.00	65.00
	65.00	70.00
	70.00	75.00
	75.00	80.00
	80.00	85.00
	85.00	90.00

250.0 **Distance along survey track line**

CHART C



Surficial Sediment Porosity

Gulfport Ship Channel 230 KHz Bottom Porosity (%)

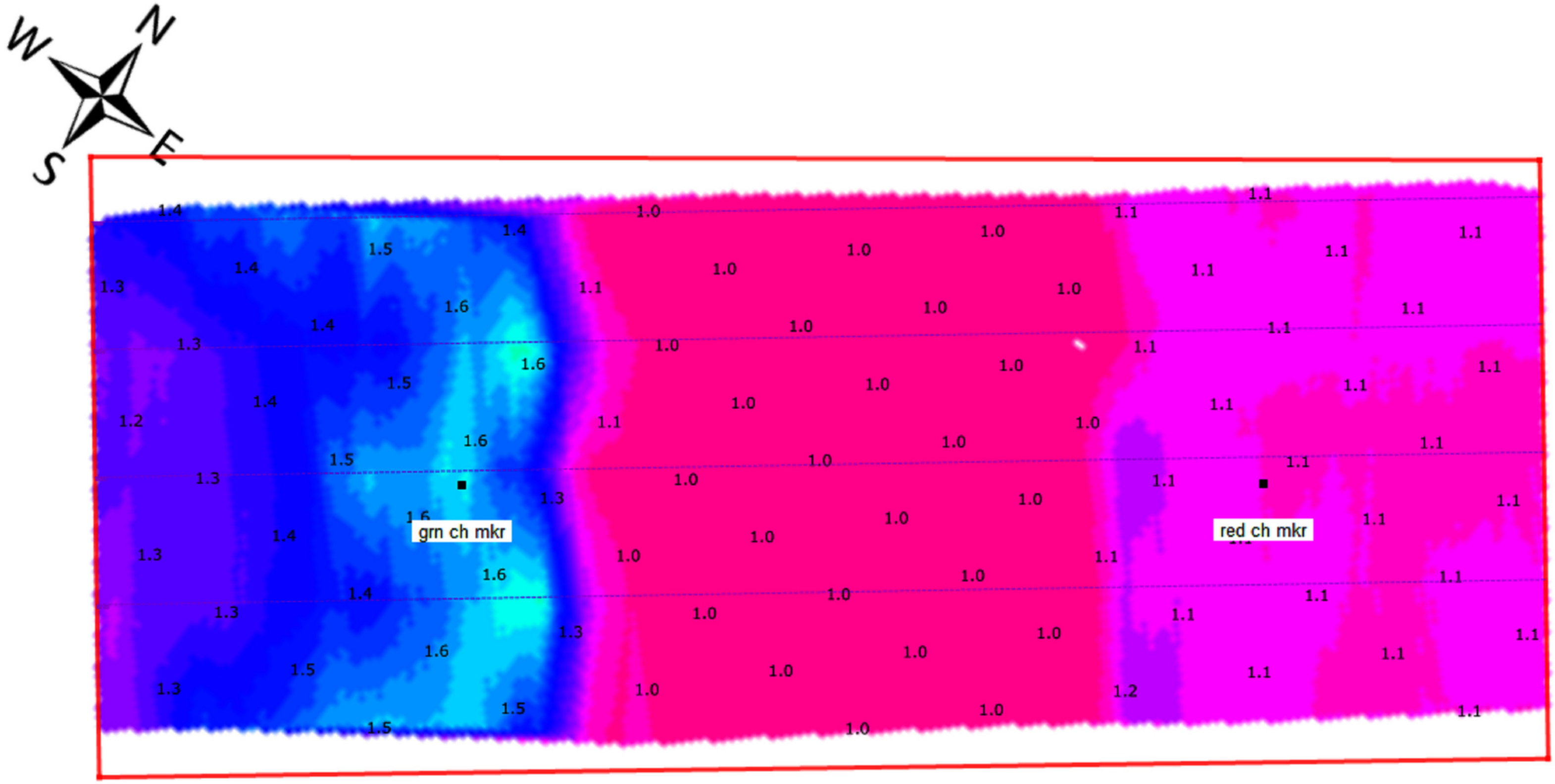
Porosity(%)

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
50.00	55.00
55.00	60.00
60.00	65.00
65.00	70.00
70.00	75.00
75.00	80.00
80.00	85.00
85.00	90.00
90.00	95.00
95.00	100.00

250.0

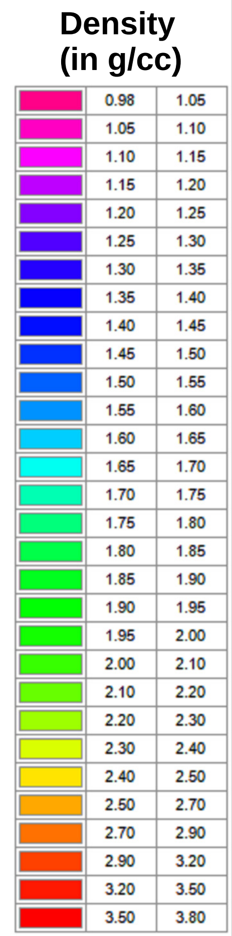
Depth along survey track line

CHART D



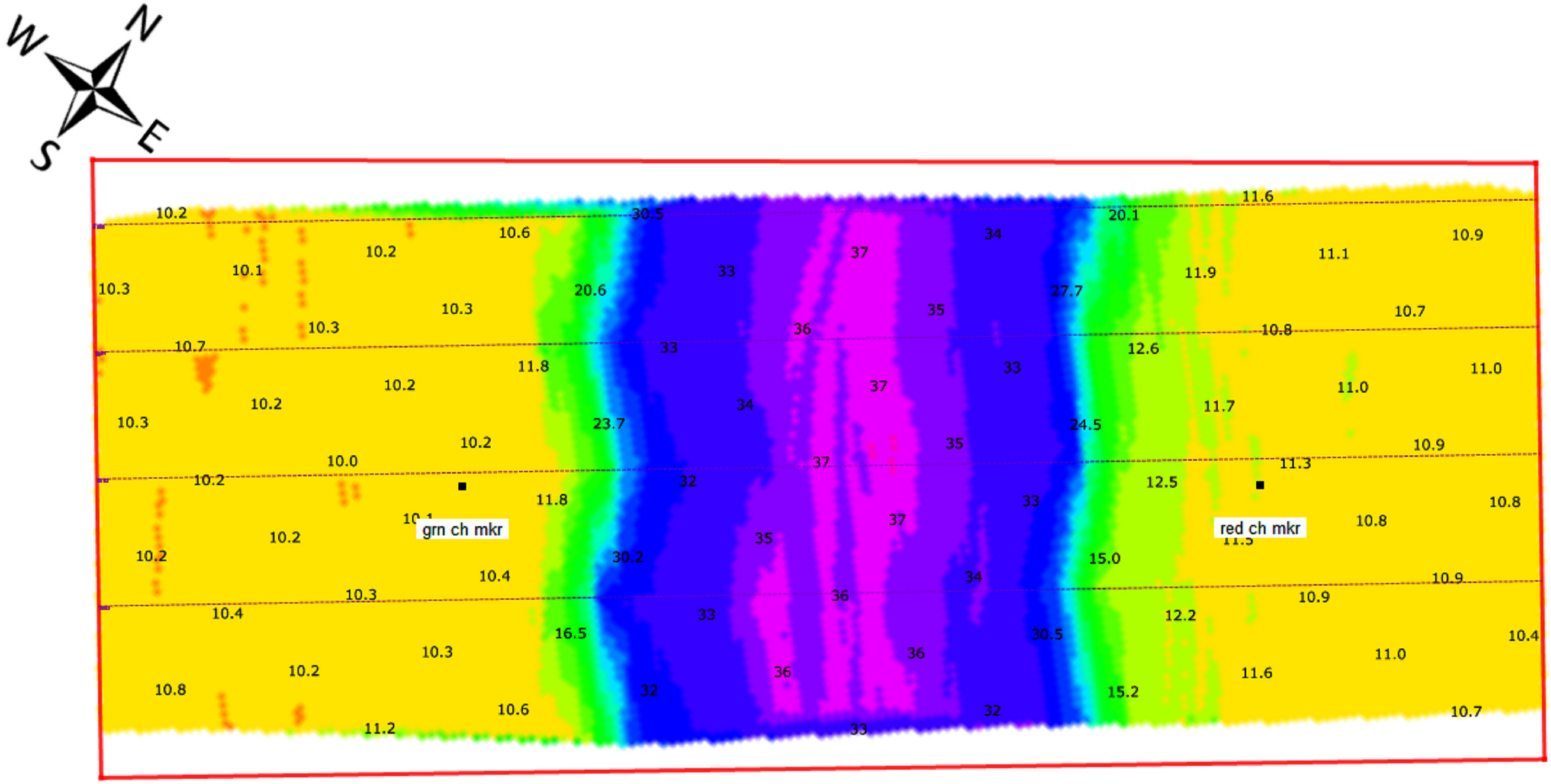
Surficial Sediment Density

Gulfport Ship Channel 230 KHz Bottom Density (g-cc)



250.0 **Distance along survey track line**

CHART E

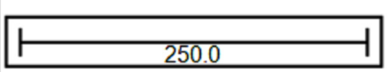


Consolidated (Hard) Sediment Depth

Gulfport Ship Channel 12 KHz Depth (2ft)

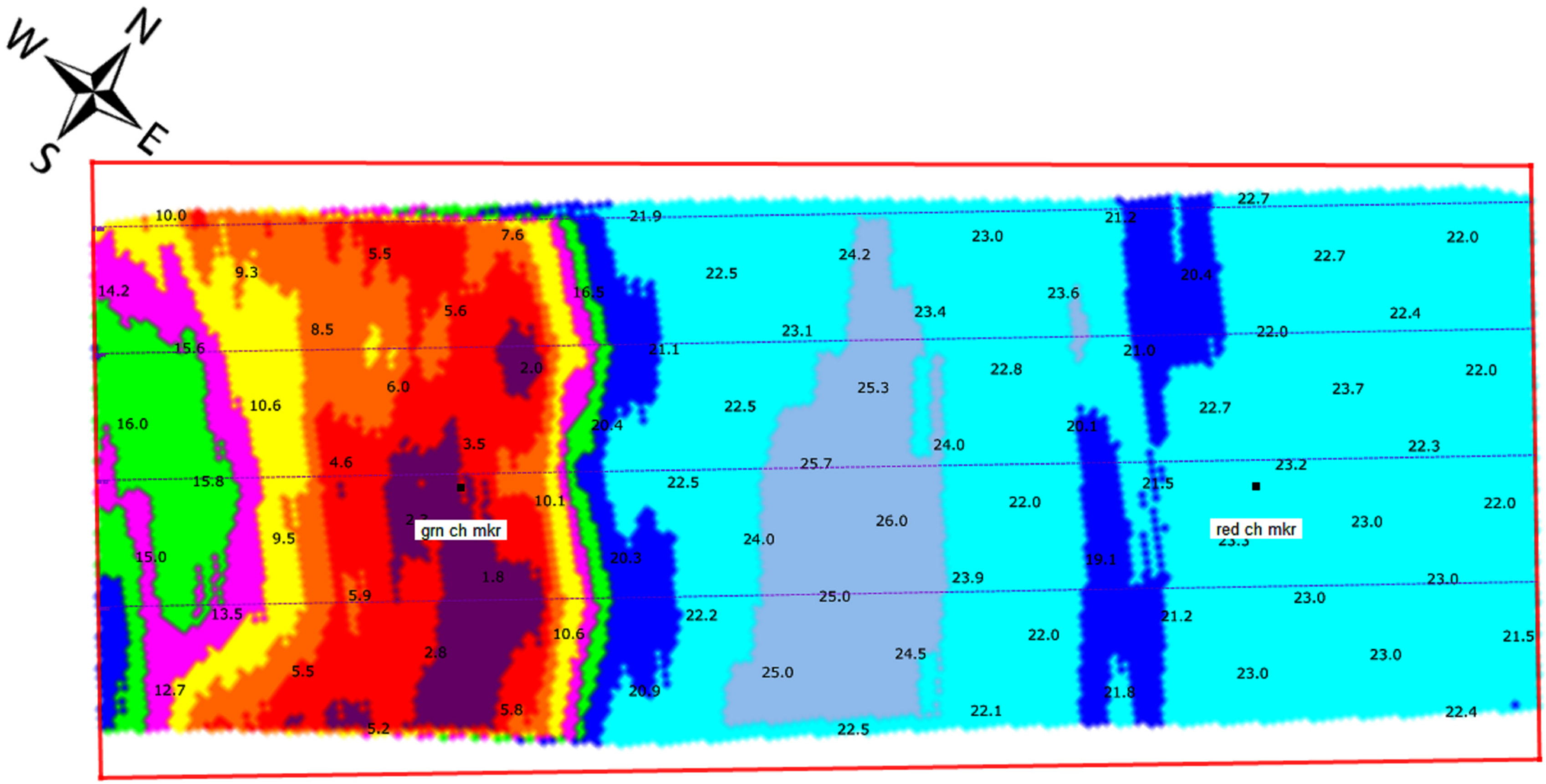
Depth in Feet

	4.00	6.00
	6.00	8.00
	8.00	10.00
	10.00	12.00
	12.00	14.00
	14.00	16.00
	16.00	18.00
	18.00	20.00
	20.00	22.00
	22.00	24.00
	24.00	26.00
	26.00	28.00
	28.00	30.00
	30.00	32.00
	32.00	34.00
	34.00	36.00
	36.00	38.00
	38.00	40.00



Distance along survey track line

CHART F



Consolidated Sediment Acoustic Bottom Loss

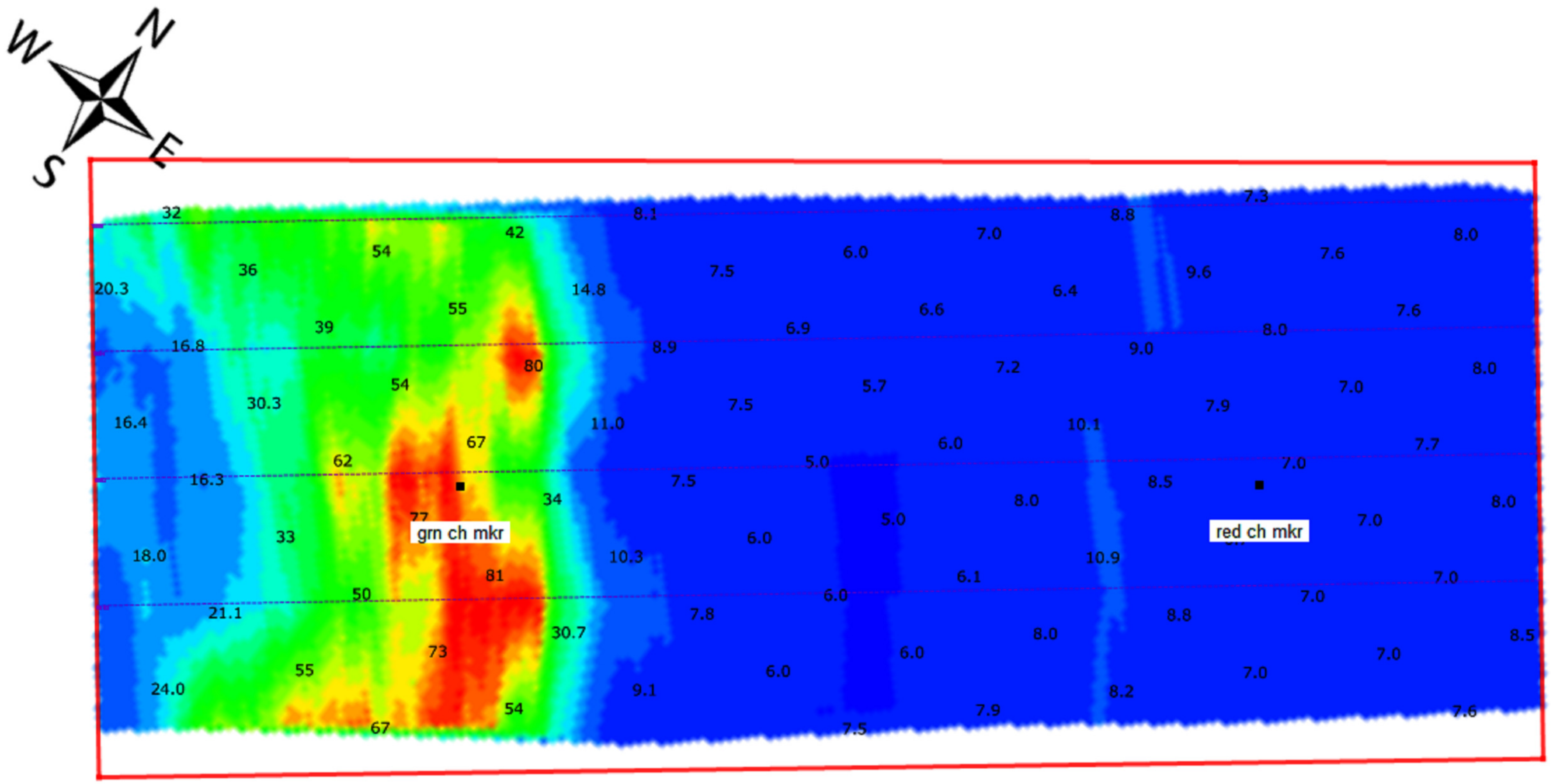
Gulfport Ship Channel 12 KHz Bottom Loss (3db)

Bottom Loss

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

250.0 **Distance along survey track line**

CHART G



Consolidated Sediment Reflectivity

Gulfport Ship Channel 12 KHz Bottom Reflectivity (%)

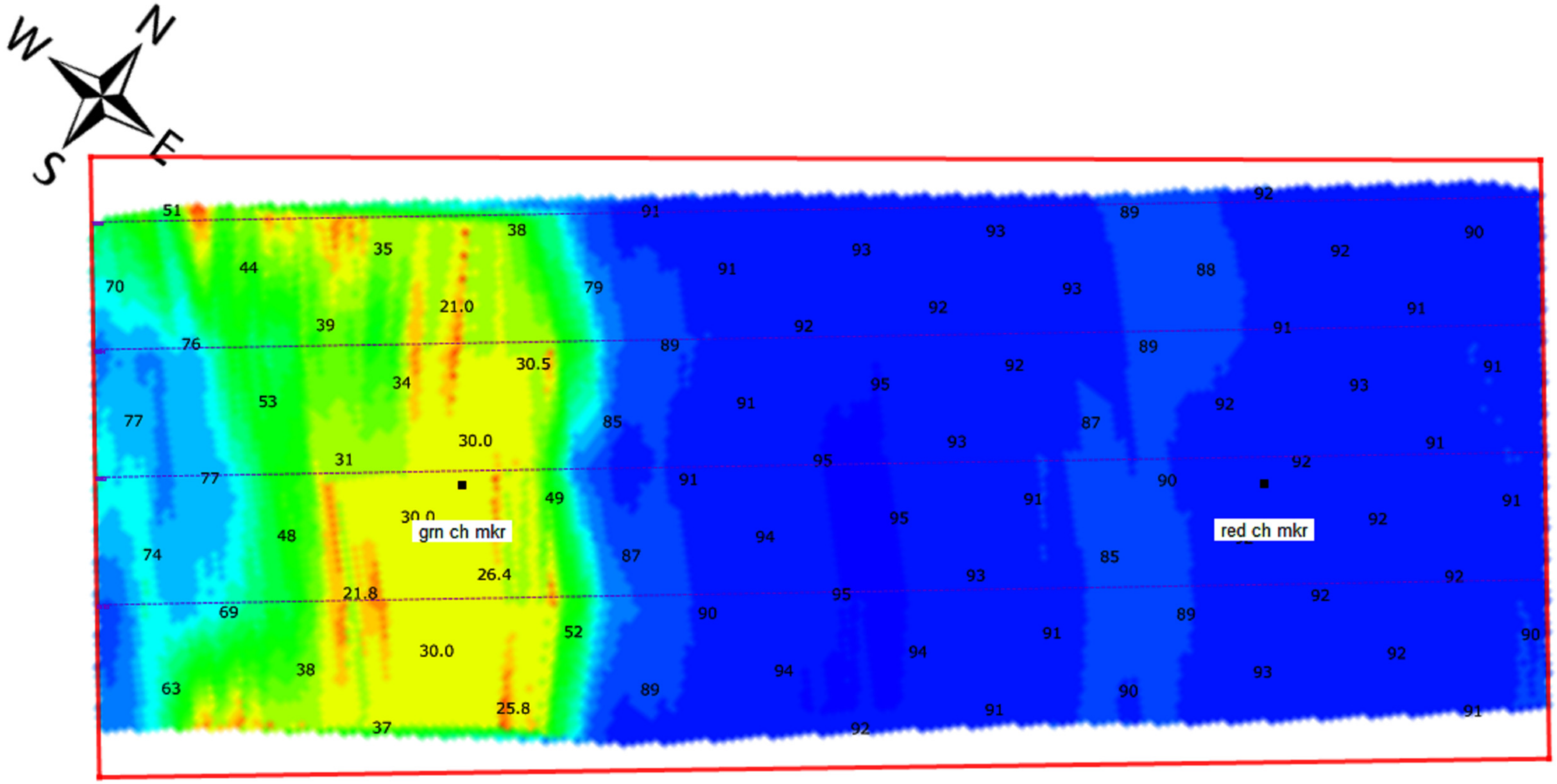
Bottom Reflectivity

	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
	50.00	55.00
	55.00	60.00
	60.00	65.00
	65.00	70.00
	70.00	75.00
	75.00	80.00
	80.00	85.00
	85.00	90.00

250.0

Distance along survey track line

CHART H



Consolidated Sediment Porosity

Gulfport Ship Channel 12 KHz Bottom Porosity (%)

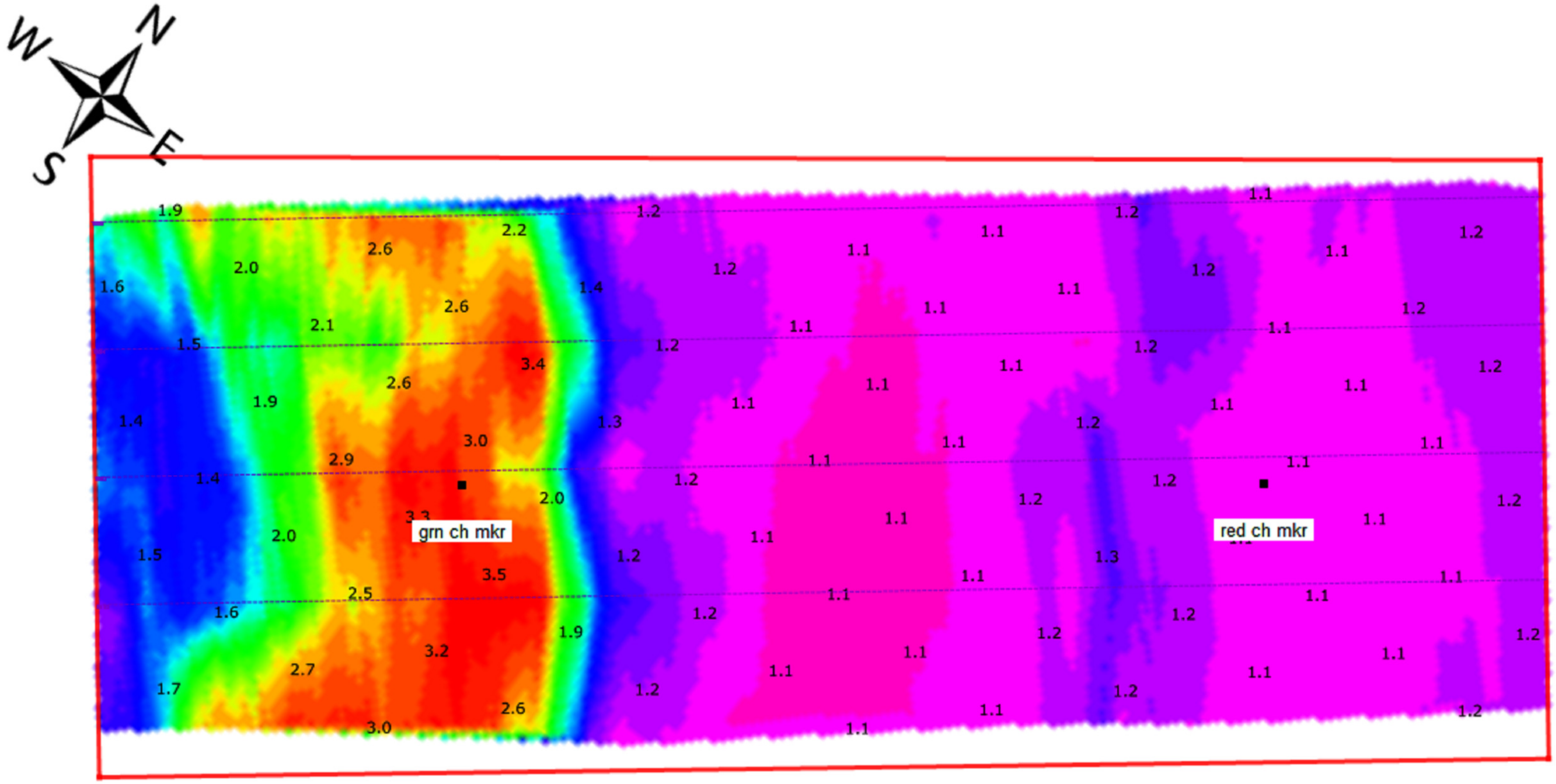
Porosity(%)

	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
	50.00	55.00
	55.00	60.00
	60.00	65.00
	65.00	70.00
	70.00	75.00
	75.00	80.00
	80.00	85.00
	85.00	90.00
	90.00	95.00
	95.00	100.00

250.0

Distance along survey track line

CHART I



Density (in g/cc)

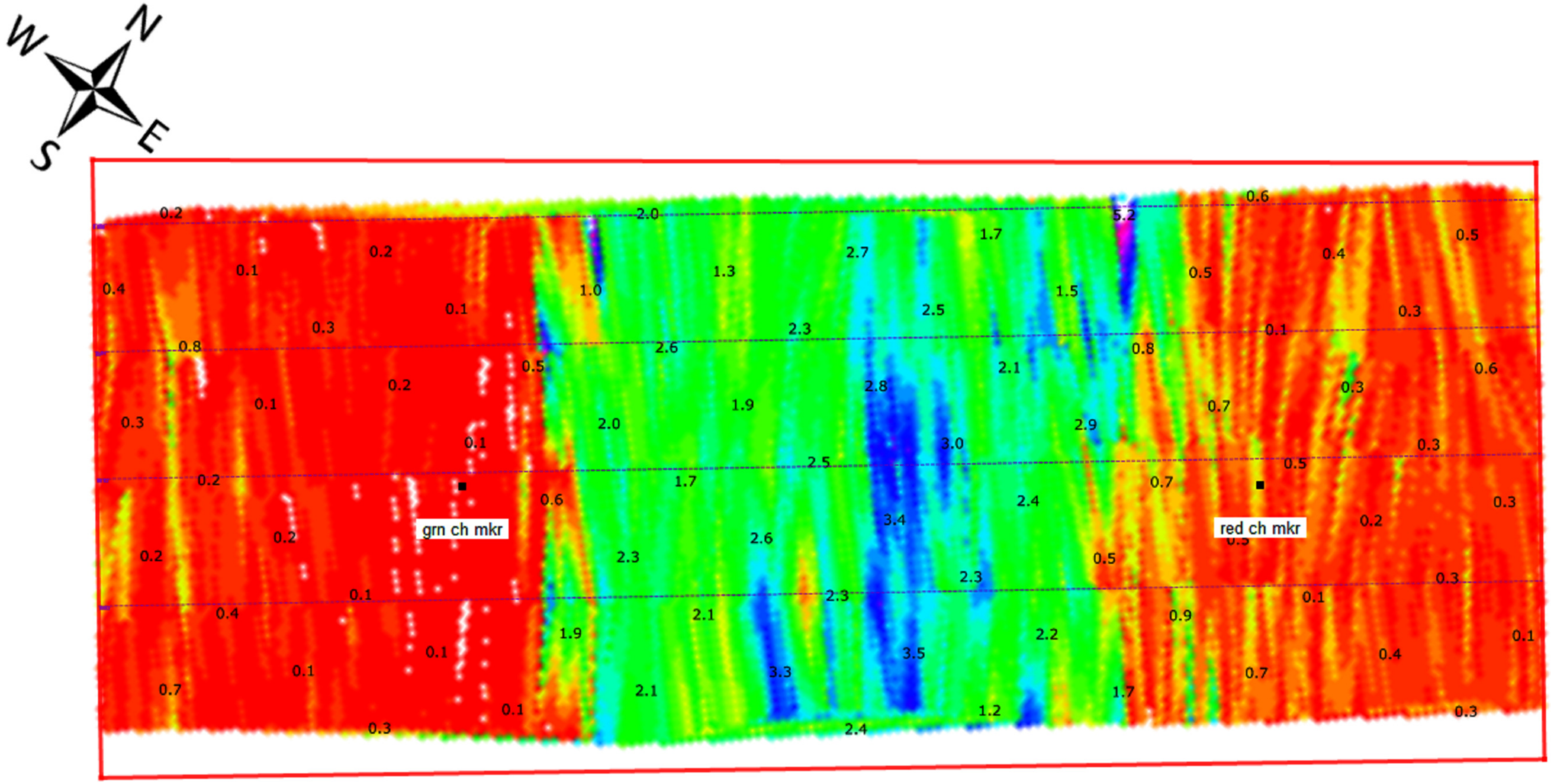
0.98	1.05
1.05	1.10
1.10	1.15
1.15	1.20
1.20	1.25
1.25	1.30
1.30	1.35
1.35	1.40
1.40	1.45
1.45	1.50
1.50	1.55
1.55	1.60
1.60	1.65
1.65	1.70
1.70	1.75
1.75	1.80
1.80	1.85
1.85	1.90
1.90	1.95
1.95	2.00
2.00	2.10
2.10	2.20
2.20	2.30
2.30	2.40
2.40	2.50
2.50	2.70
2.70	2.90
2.90	3.20
3.20	3.50
3.50	3.80

Consolidated Sediment Density

Gulfport Ship Channel 12 KHz Bottom Density (g-cc)

CHART J

250.0 **Distance along survey track line**



Gulfport Ship Channel LF-HF Mud Layer Thickness (0.25ft)

Thickness (in Feet)

	0.00	0.25
	0.25	0.50
	0.50	0.75
	0.75	1.00
	1.00	1.25
	1.25	1.50
	1.50	1.75
	1.75	2.00
	2.00	2.25
	2.25	2.50
	2.50	2.75
	2.75	3.00
	3.00	3.25
	3.25	3.50
	3.50	3.75
	3.75	4.00
	4.00	4.25
	4.25	4.50
	4.50	4.75
	4.75	5.00

250.0 **Distance along survey track line**

CHART K