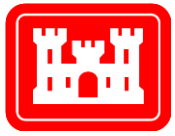


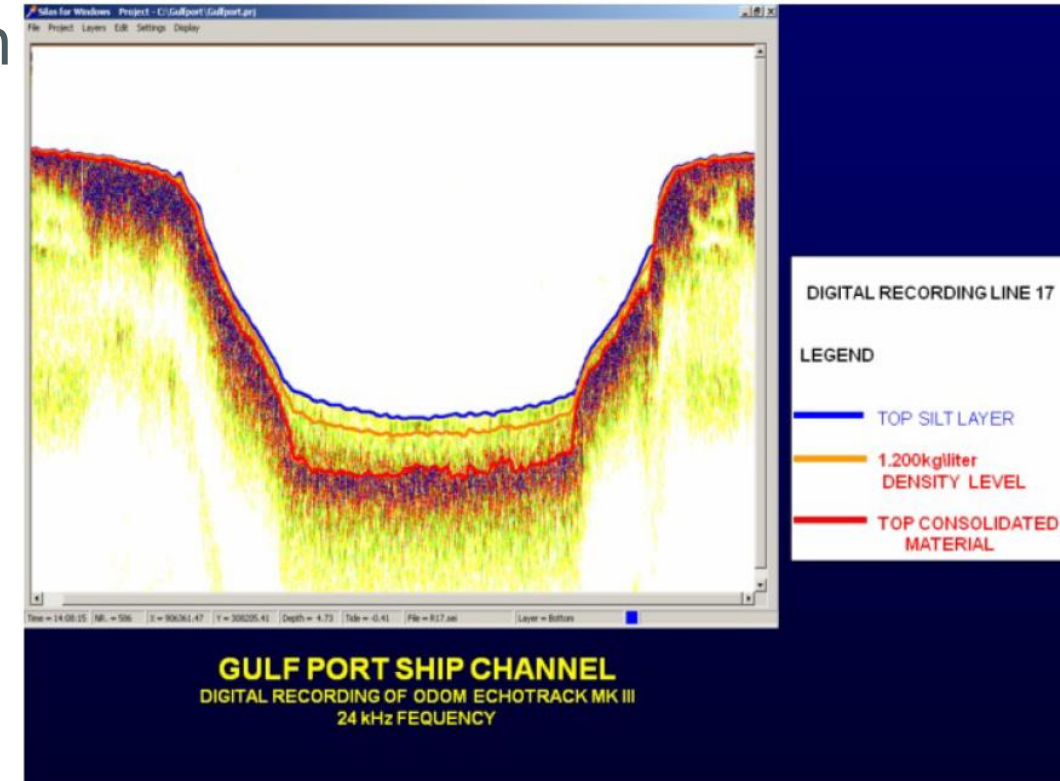
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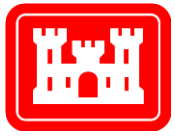
## Layered Media Detection WEDA Pacific Chapter Waikiki, Oct. '25



- Rheology – Parameters for the characterization of fluid mud
- Fluff – Fluid Mud – Suspended Sediments – Layered Media
- Material Density - Viscosity
- Lutocline – HF-kHz layer
- Separation – Media Density
- Navigable Bottom:  $\sim 1200 \text{ grams/litre} = 1.2 \text{ T/m}^3 = 1.2 \text{ kg/liter} = \text{generally accepted density}$
- CATZOC



EM 1110-2-5025

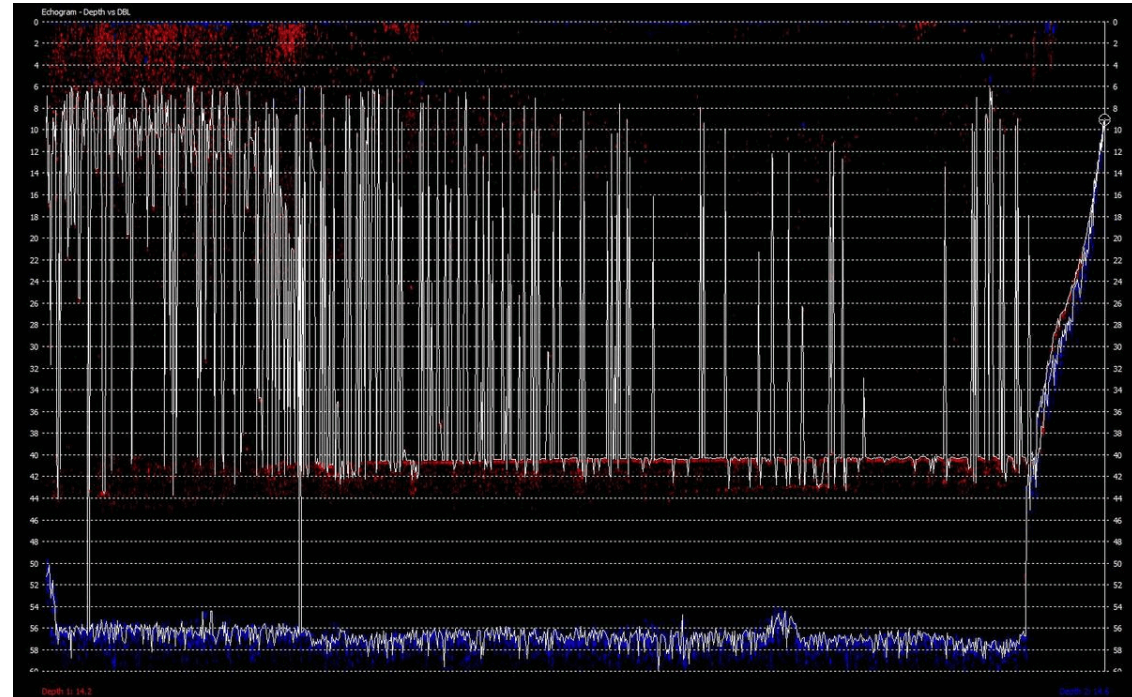


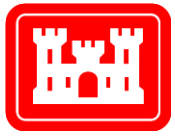
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# NAVIGATION SURFACE DETERMINATION

## ■ Current Methods

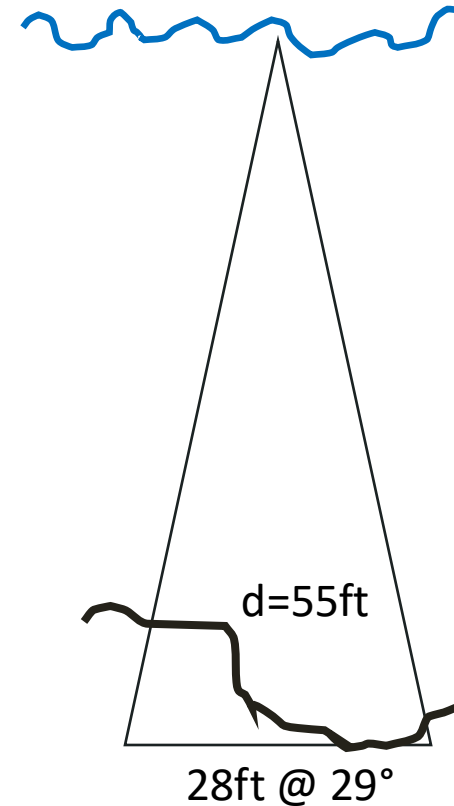
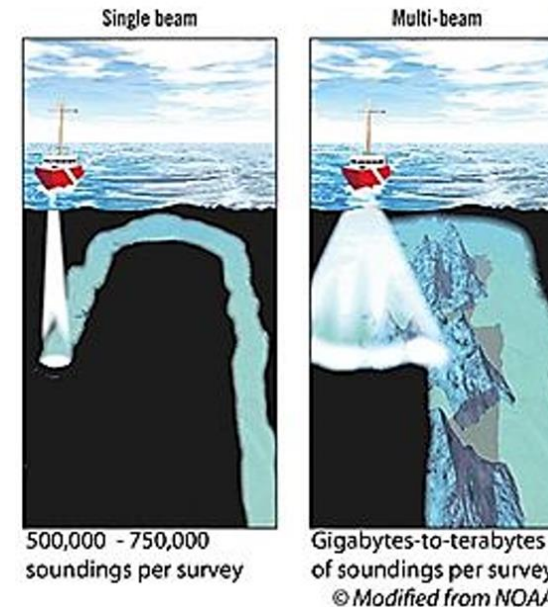
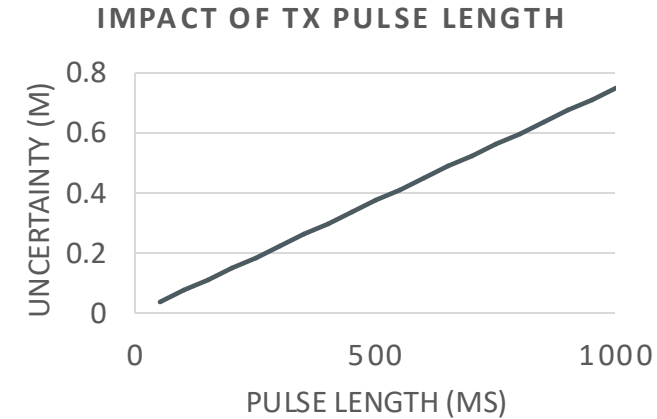
- Singlebeam such as Knudsen MiniSounder 200kHz / 28kHz (eg USACE, Savannah District)
  - 200ft cross-sections
  - New Work includes longitudinal
  - 3D RTK
- 
- CATZOC B (SB cross lines)
  - Wide footprint
  - Subjective data processing
  - Depths get more shallow over time





# PROBLEM STATEMENT

- What / where is the bottom
- Subjective solutions
  - Shotgun 24kHz, **28kHz**, 30kHz, 50kHz
    - What is pulse length??
    - > Beam angle = wide footprints = low resolution
    - What is the ideal/common operable frequency?
    - Widely spaced cross sections (what lies between?)
- CATZOC B → Ax
- Dredge contracts/payments (volume 'estimates')
- Dredge effort reporting





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# CATZOC LEVEL UNDERKEEL CLEARANCE REGIONS

| ENC ZOC symbols |  | 6 Stars = A1 |
|-----------------|--|--------------|
|                 |  | 5 Stars = A2 |
|                 |  | 4 Stars = B  |
|                 |  | 3 Stars = C  |
|                 |  | 2 Stars = D  |
|                 |  | U            |

| ZOC Category (note 1) | Position Accuracy (note 2)            | Depth Accuracy (note 3) |              | Seafloor Coverage                                                                                                  | Typical Survey Characteristics (note 5)                                                                                                                                                         |
|-----------------------|---------------------------------------|-------------------------|--------------|--------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A1                    | $\pm 5 \text{ m} + 5\% \text{ depth}$ | $= 0.50 + 1\%d$         |              | Full area search undertaken. Significant seafloor features detected (note 4) and depths measured.                  | Controlled, systematic survey (note 6) high position and depth accuracy achieved using DGPS and a multi-beam, channel or mechanical sweep system.                                               |
|                       |                                       | Depth (m)               | Accuracy (m) |                                                                                                                    |                                                                                                                                                                                                 |
|                       |                                       | 10                      | $\pm 0.6$    |                                                                                                                    |                                                                                                                                                                                                 |
|                       |                                       | 30                      | $\pm 0.8$    |                                                                                                                    |                                                                                                                                                                                                 |
|                       |                                       | 100                     | $\pm 1.5$    |                                                                                                                    |                                                                                                                                                                                                 |
|                       |                                       | 1000                    | $\pm 10.5$   |                                                                                                                    |                                                                                                                                                                                                 |
| A2                    | $\pm 20 \text{ m}$                    | $= 1.00 + 2\%d$         |              | Full area search undertaken. Significant seafloor features detected (note 4) and depths measured.                  | Controlled, systematic survey (note 6) achieving position and depth accuracy less than ZOC A1 and using a modern survey echo-sounder (note 7) and a sonar or mechanical sweep system.           |
|                       |                                       | Depth (m)               | Accuracy (m) |                                                                                                                    |                                                                                                                                                                                                 |
|                       |                                       | 10                      | $\pm 1.2$    |                                                                                                                    |                                                                                                                                                                                                 |
|                       |                                       | 30                      | $\pm 1.6$    |                                                                                                                    |                                                                                                                                                                                                 |
|                       |                                       | 100                     | $\pm 3.0$    |                                                                                                                    |                                                                                                                                                                                                 |
|                       |                                       | 1000                    | $\pm 21.0$   |                                                                                                                    |                                                                                                                                                                                                 |
| B                     | $\pm 50 \text{ m}$                    | $= 1.00 + 2\%d$         |              | Full area search not achieved; uncharted features, hazardous to surface navigation are not expected but may exist. | Controlled, systematic survey (note 6) achieving similar depth but lesser position accuracies than ZOCA2, using a modern survey echo-sounder (note 5), but no sonar or mechanical sweep system. |
|                       |                                       | Depth (m)               | Accuracy (m) |                                                                                                                    |                                                                                                                                                                                                 |
|                       |                                       | 10                      | $\pm 1.2$    |                                                                                                                    |                                                                                                                                                                                                 |
|                       |                                       | 30                      | $\pm 1.6$    |                                                                                                                    |                                                                                                                                                                                                 |
|                       |                                       | 100                     | $\pm 3.0$    |                                                                                                                    |                                                                                                                                                                                                 |
|                       |                                       | 1000                    | $\pm 21.0$   |                                                                                                                    |                                                                                                                                                                                                 |

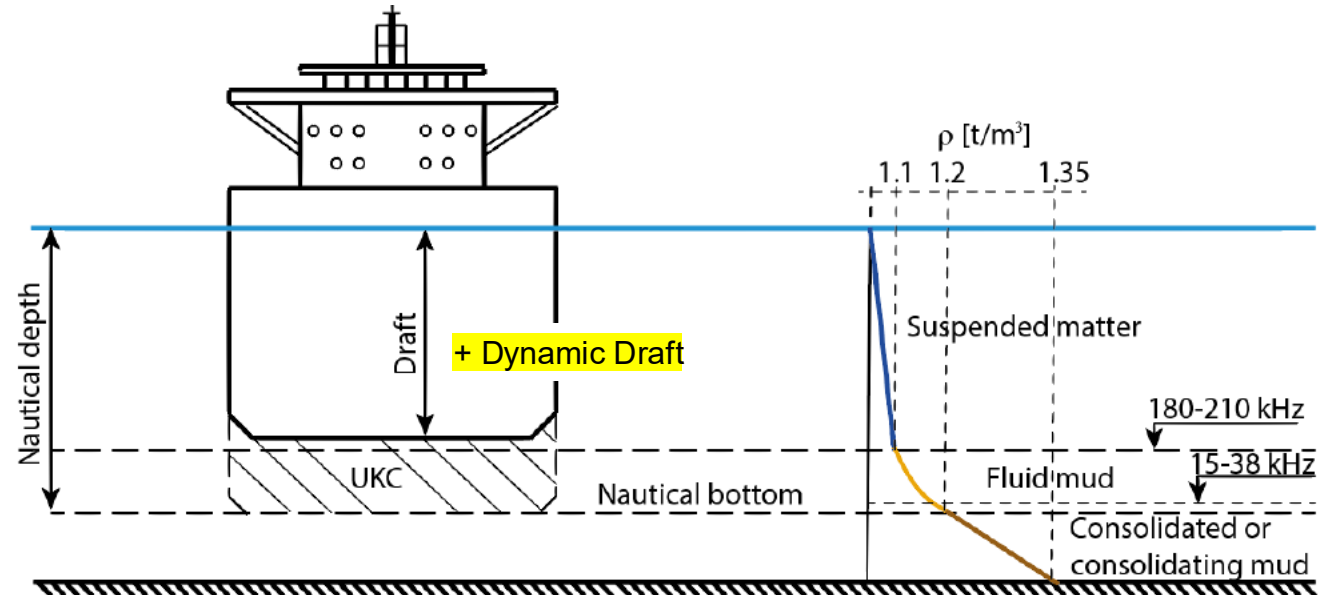


Figure 1: The nautical bottom concept, which was developed at the density limit of 1.2 t/m<sup>3</sup>. Adapted from from Nederlof, L. (1978).

**HOW NAVIGABLE ARE FLUID MUD LAYERS?**  
*PIANC-World Congress Panama City, Panama 2018, Kirichek, et al*

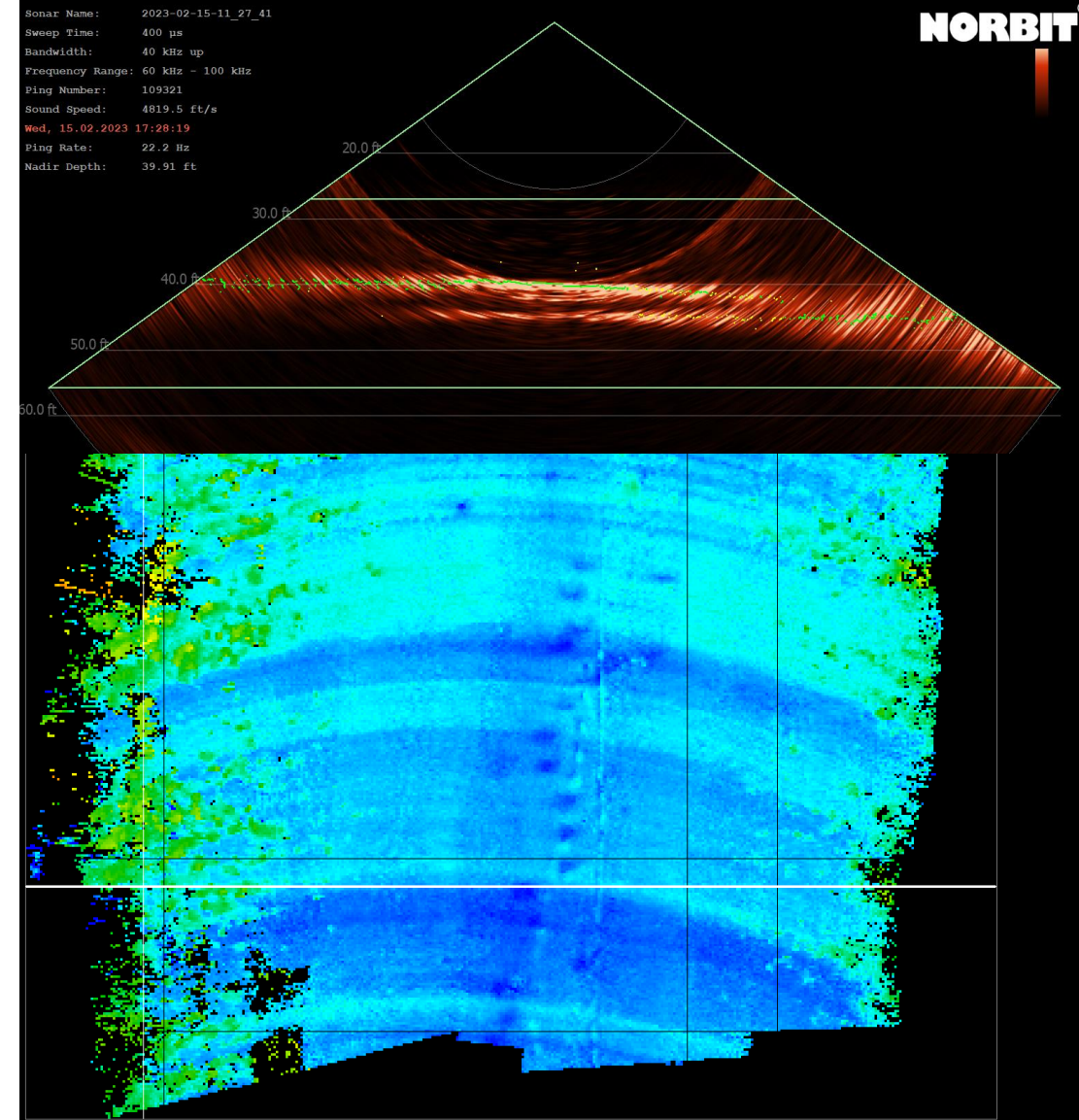
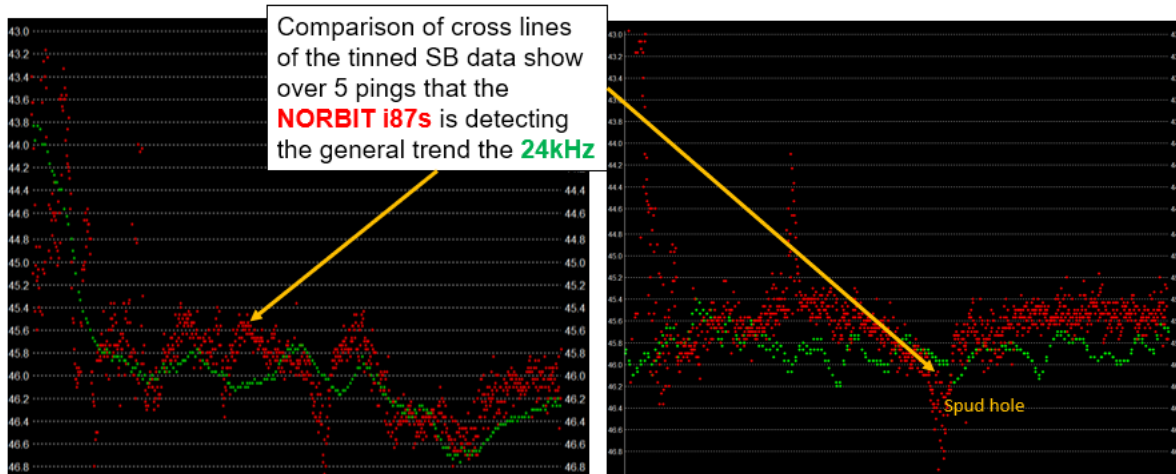


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# ORIGINS & PROOF OF CONCEPT – USACE NOLA



SBES and MBES Cross Sections over Sheet 11

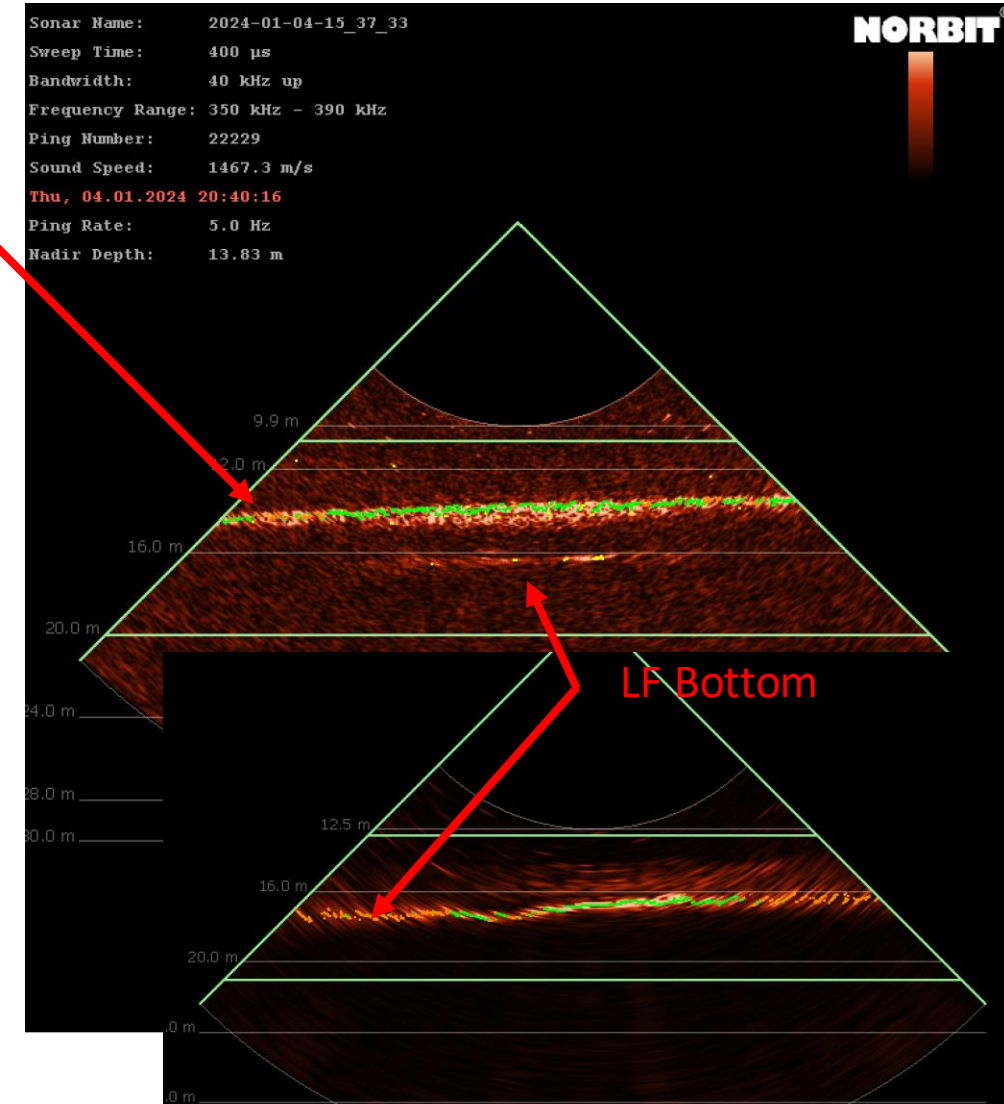
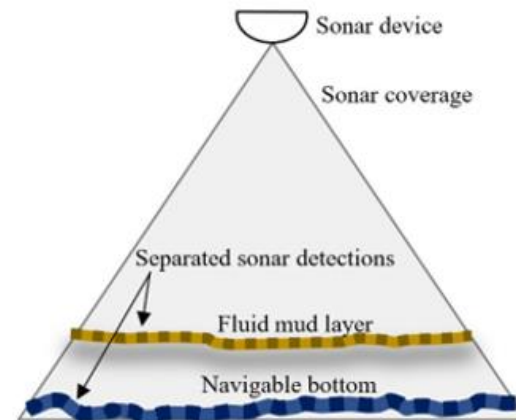
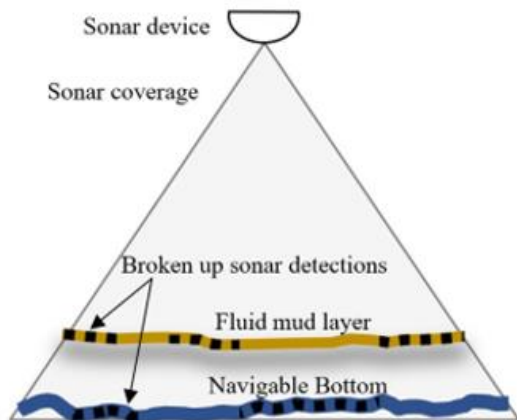




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# LMD – HOW IT WORKS

- The water-fluid mud interface, the “lutocline” is detected using HF
- The lutocline is a base determination for further signal processing to help the sonar find the navigable bottom.
- The lower frequency bottom is detected
- Both layers are exported

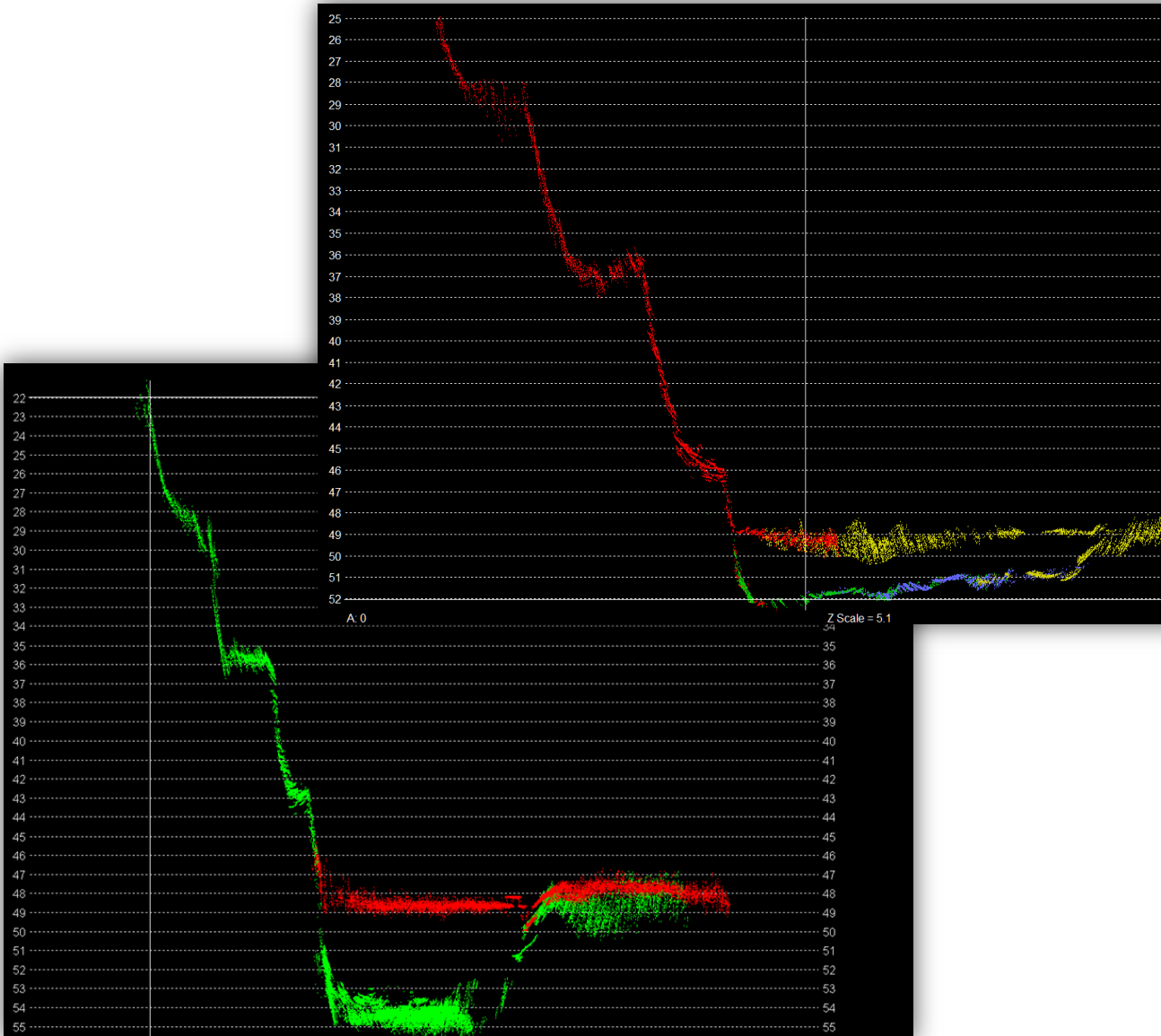
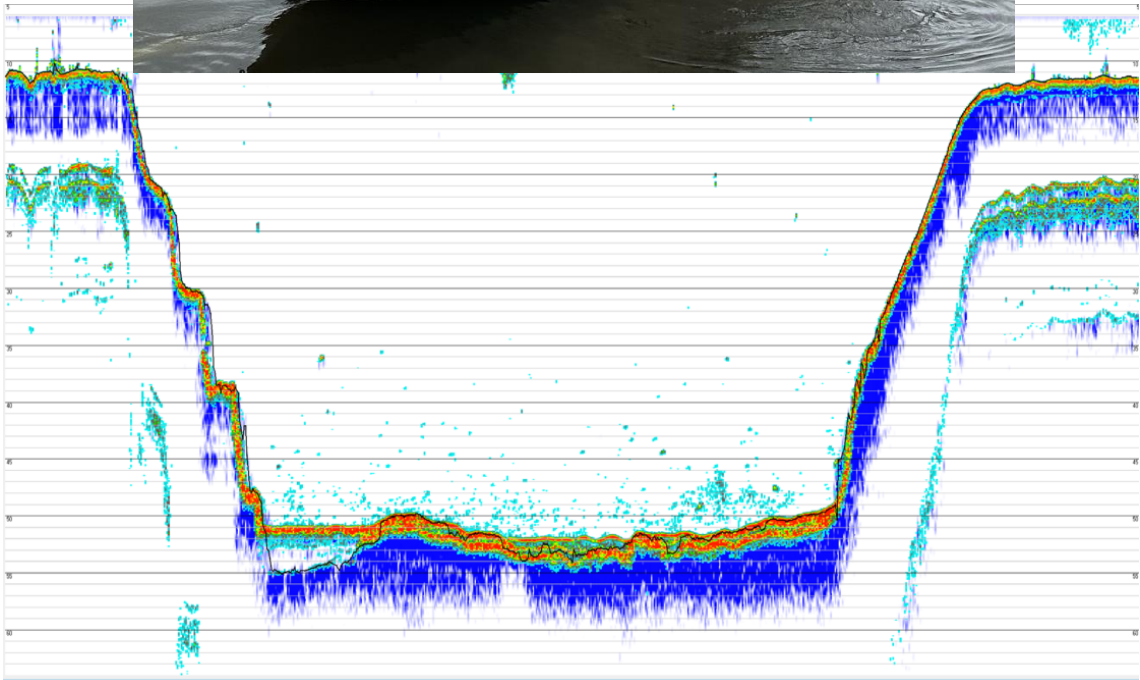


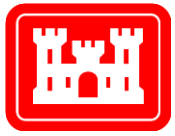


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# REFINEMENT – ST Hudson/GBA





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# TEAMED APPROACH



- USACE ERDC – Vicksburg
  - Rheotune
  - Odom CV300 200kHz & 24kHz
  - Ball valve sampler



- USACE ERDC – Vicksburg
  - R2Sonic 2026
  - Edgetech Sub-bottom profiler



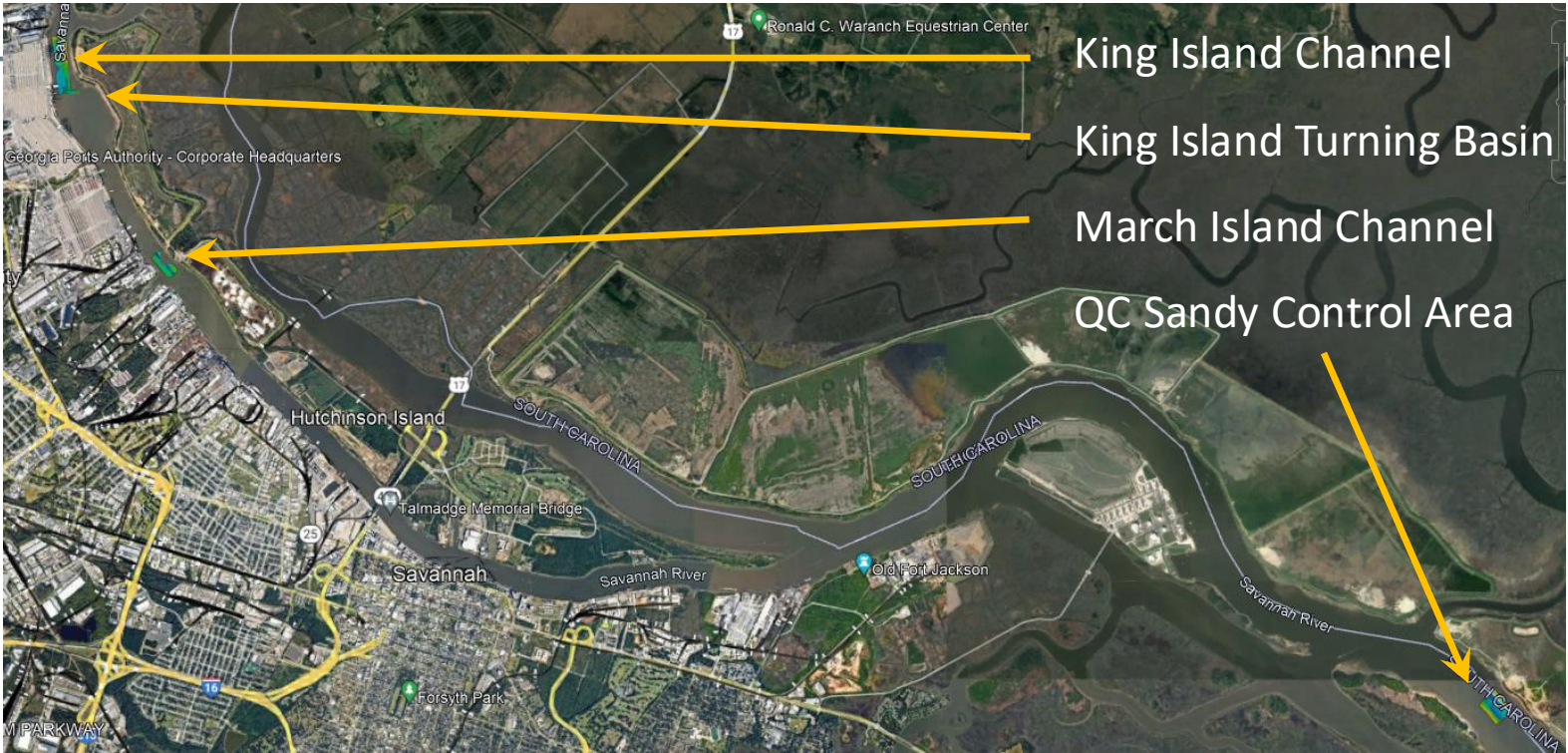
- USACE Savannah District – SV Maze
  - NORBIT Winghead i87s
  - Layered Media Detection
- USACE Savannah District – SV Gannet
  - Knudsen MiniSounder 200kHz & 28kHz



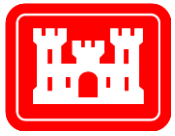
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# SAVANNAH RIVER



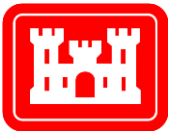
| Area                           | i87s      | Knudsen   | Odom      | SBP               |
|--------------------------------|-----------|-----------|-----------|-------------------|
| King Island Channel            | 90/370kHz | 28/200kHz | 24/200kHz | 3-16kHz & 3-12kHz |
| King Island Turning Basin      | 90/370kHz | 28/200kHz | 24/200kHz | 3-16kHz & 3-12kHz |
| Marsh Island Channel           | 90/370kHz | 28/200kHz | 24/200kHz | 3-16kHz & 3-12kHz |
| QC Control Area (sandy bottom) | 90/370kHz | 28/200kHz | 24/200kHz | 3-16kHz & 3-12kHz |



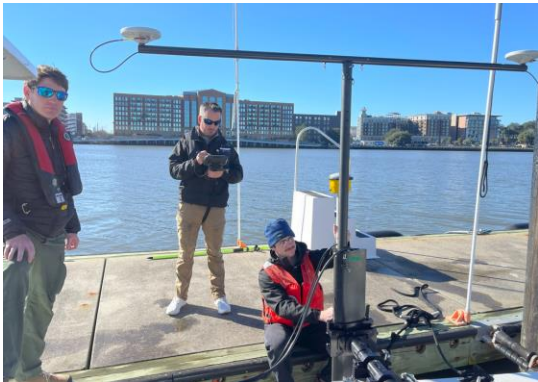
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# LMD VALIDATION – USACE SAVANNAH DISTRICT

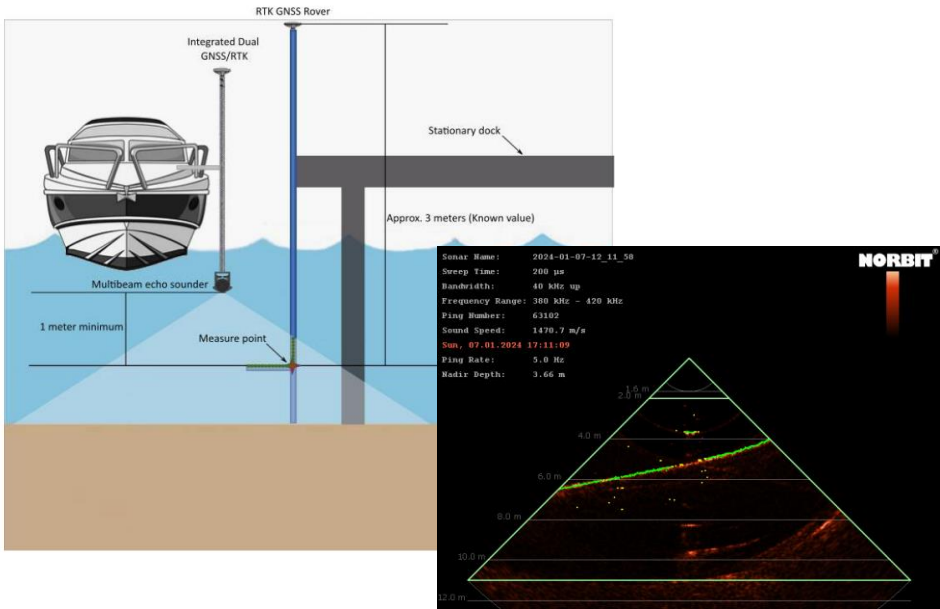


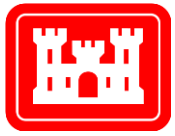


- Objectivity:
  - Plate Check MBES
  - Plate Check SBES (ERDC)
  - MBES mapping of Sandy Control area at start & end
  - SBES mapping of Sandy Control area at start & end
  - Comparison of MBES to SBES in Sandy Control
  - PPK of all MBES data
  - Common Hypack version and updates across platforms



| PLATE CHECK<br>400kHz (ft) | i87s   | Rover  | DIFFERENCE |
|----------------------------|--------|--------|------------|
| RTK                        | -18.23 | -18.24 | 0.01       |
| SB-PPK                     | -18.13 | -18.24 | 0.11       |





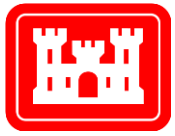
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# LMD TRIALS

## ERDC Activities

- Odom CV300 200/24kHz
  - R2Sonic 2026 at 90kHz
  - Samples at discrete depths
  - Rheotune samples
- 
- Awaiting data/results

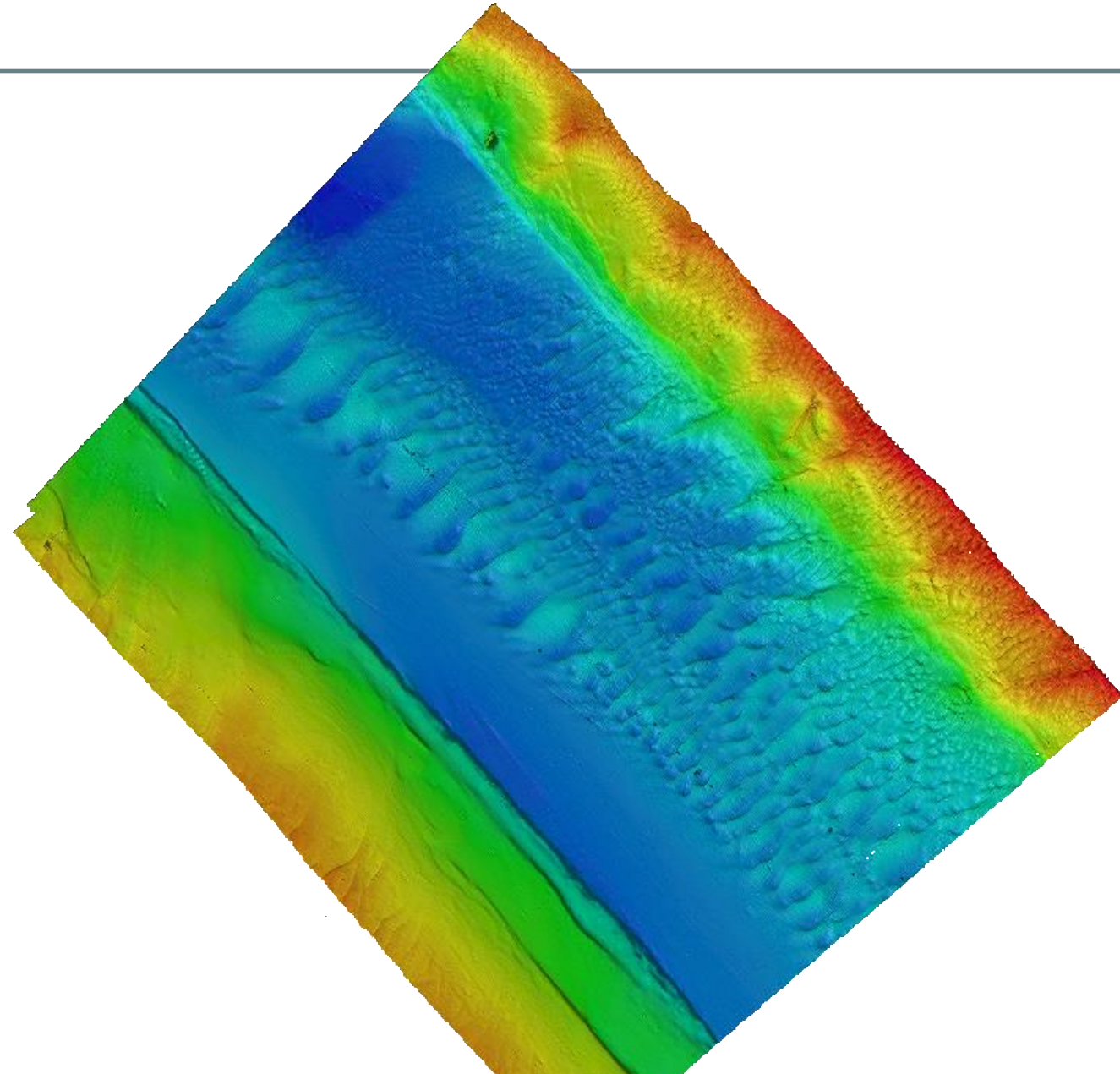
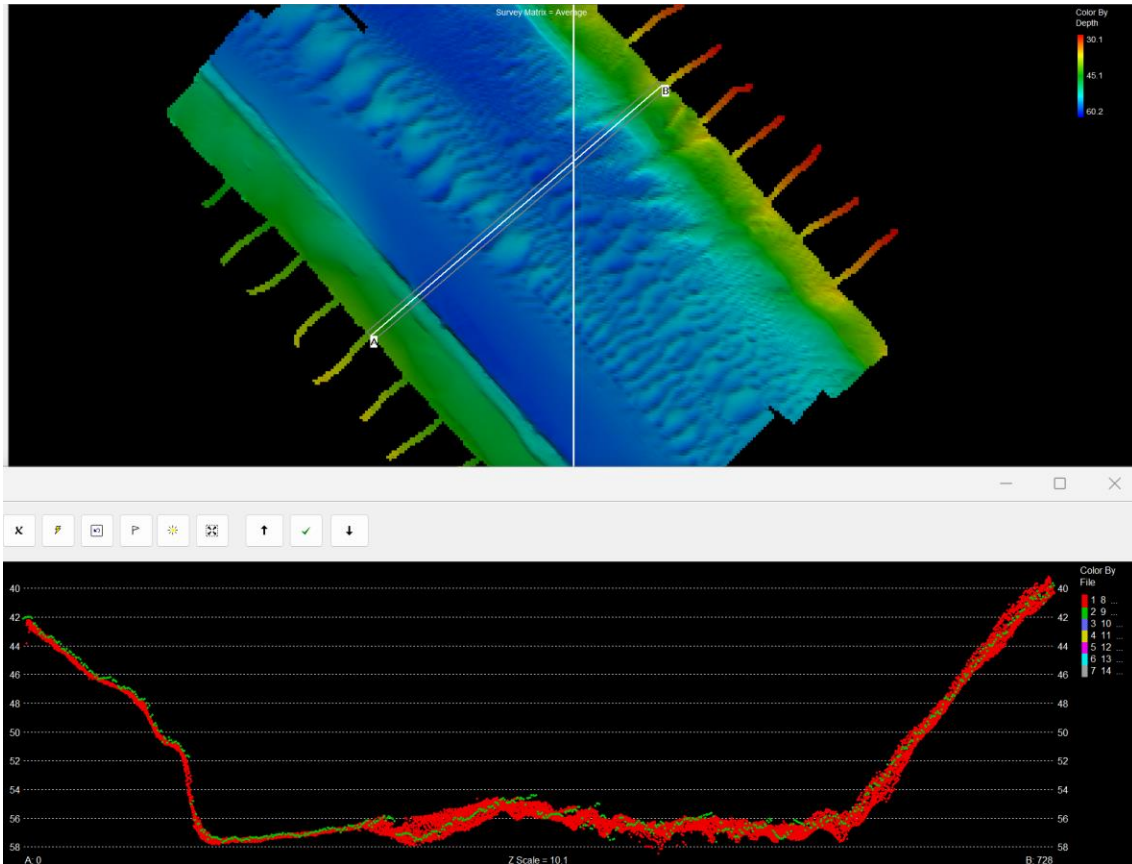


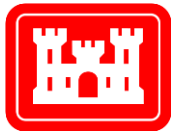


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# SANDY CONTROL AREA

- Winghead 100/400kHz FM

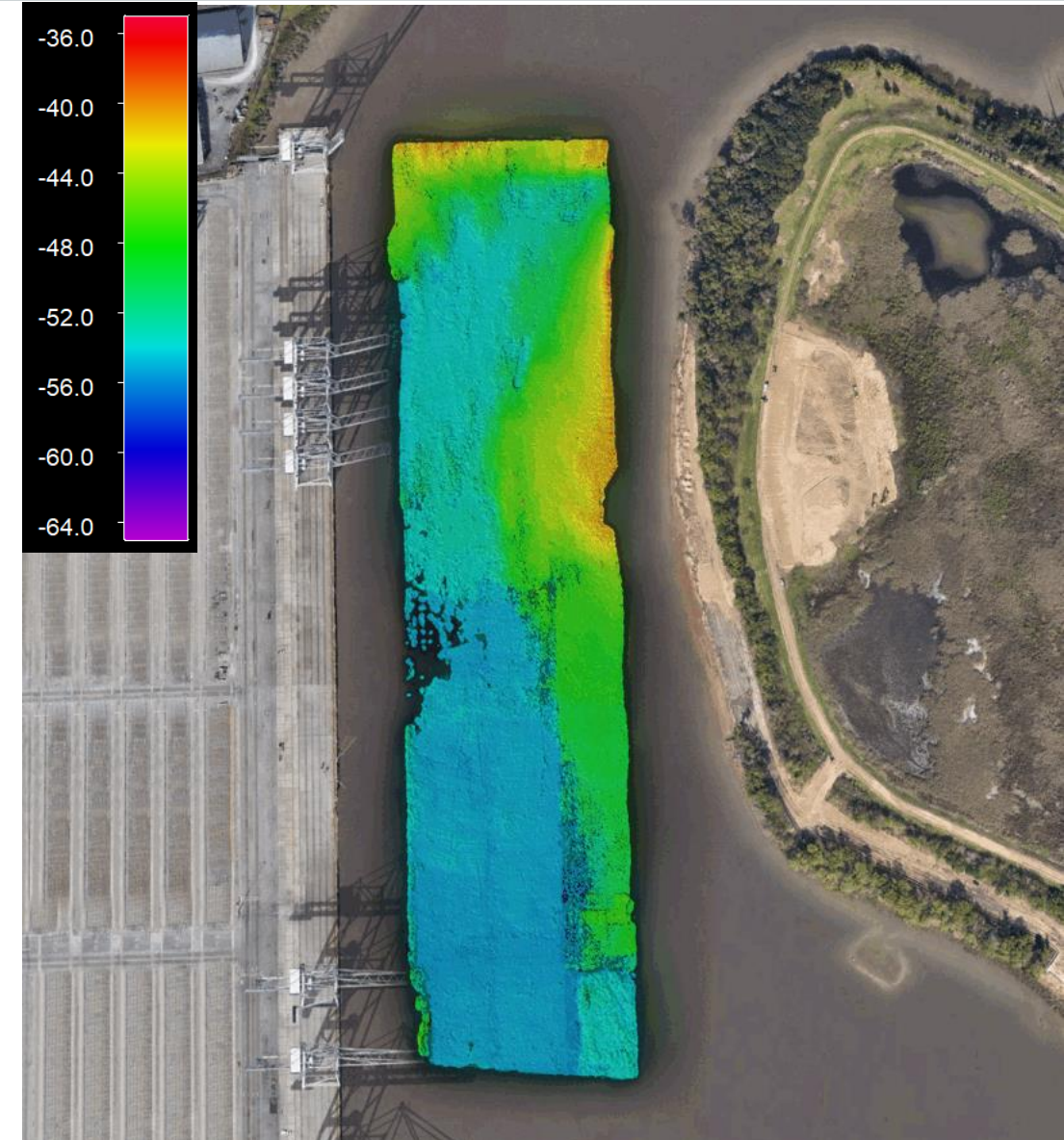
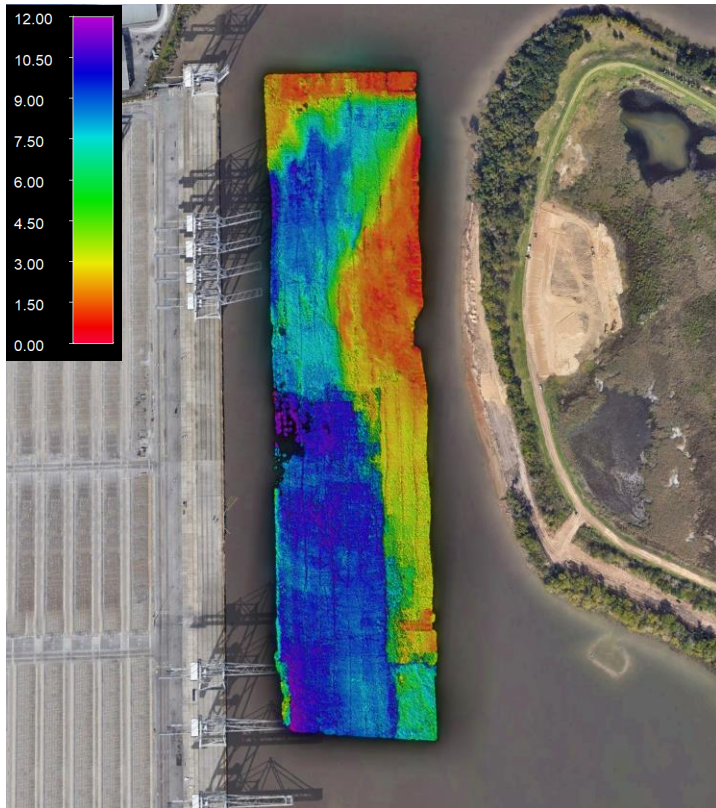




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# KINGS ISLAND CHANNEL

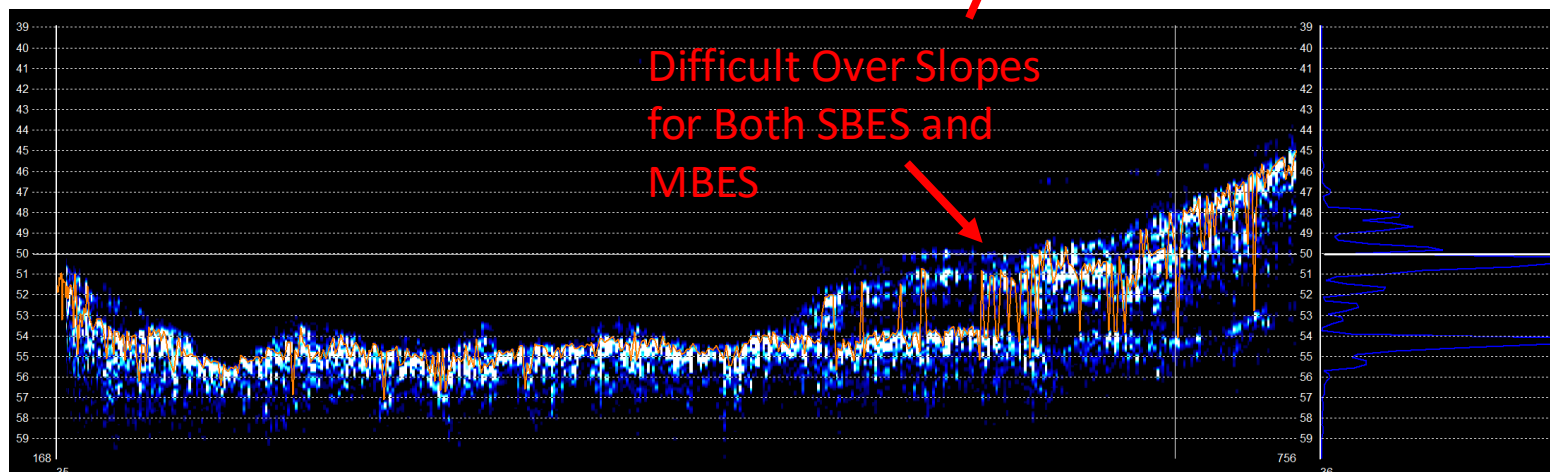
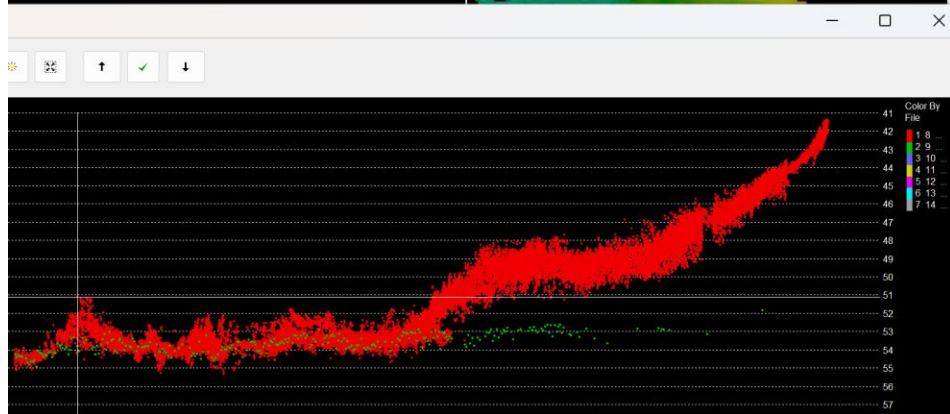
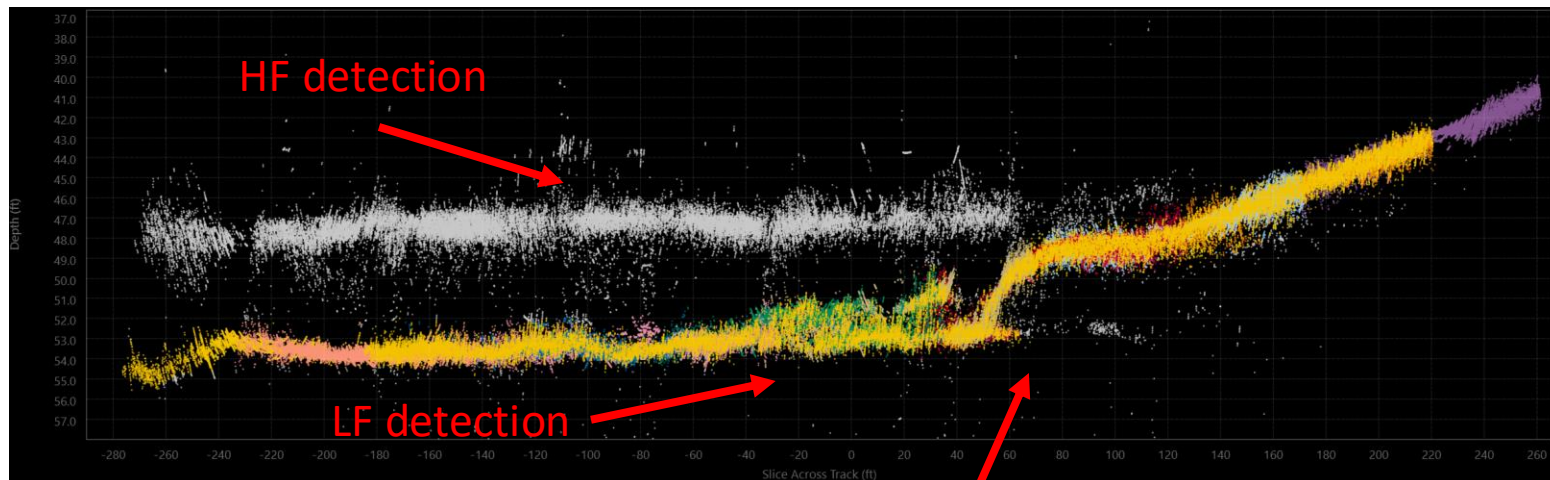
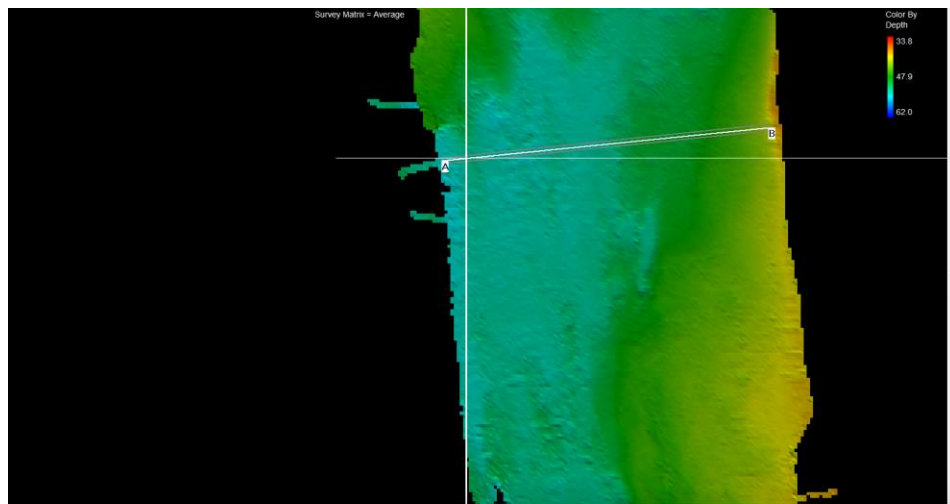
- Winghead high vs low frequency
- ~10-12ft penetration

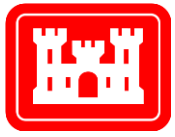




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# KINGS ISLAND CHANNEL

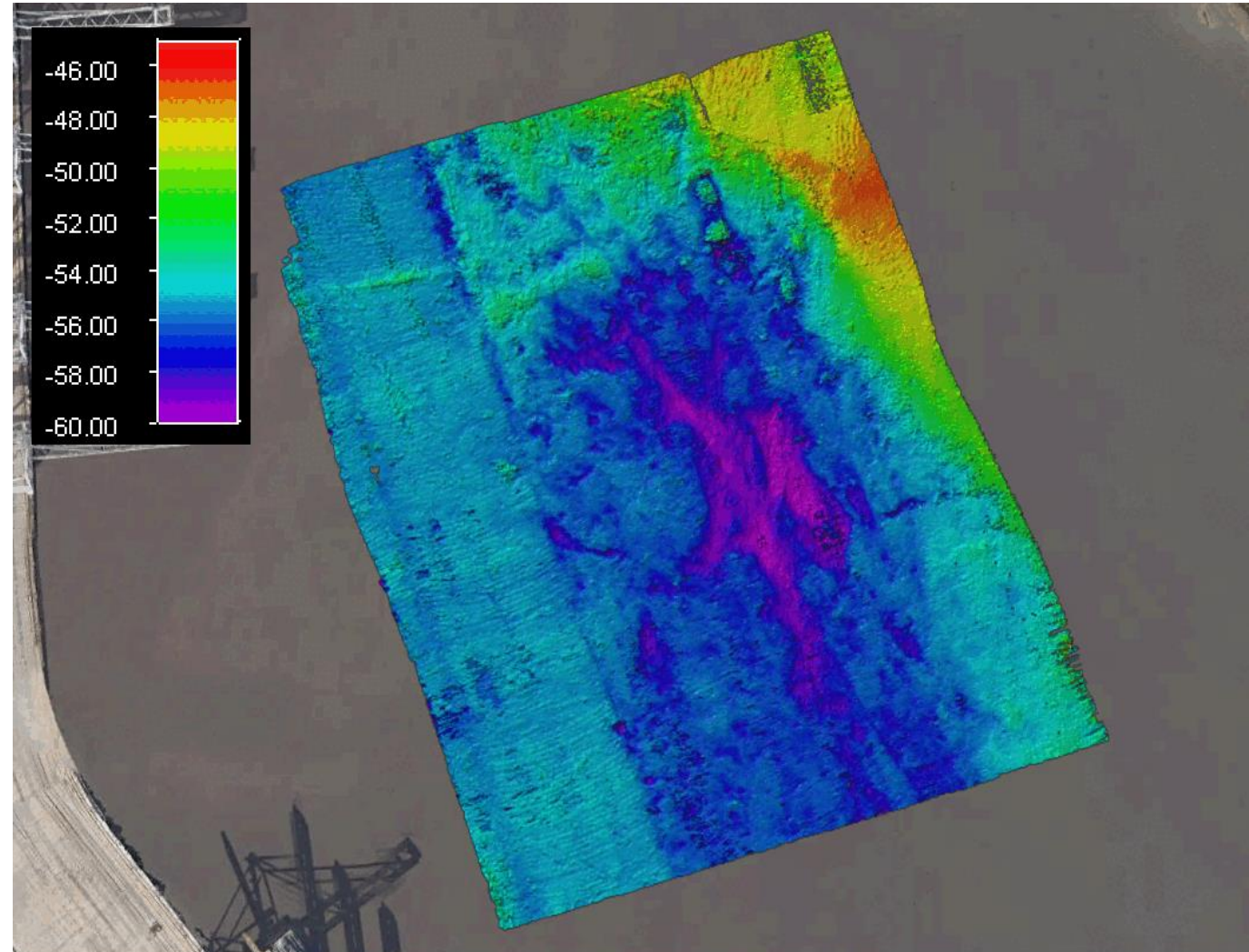
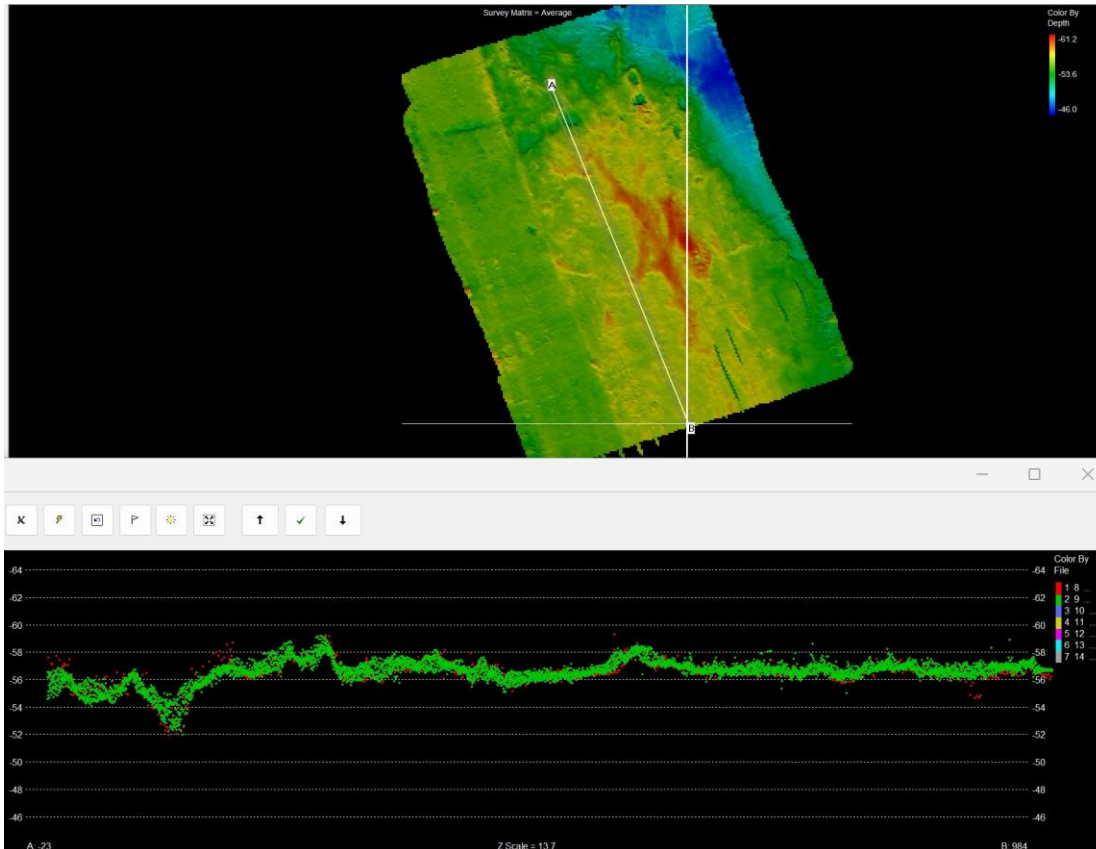


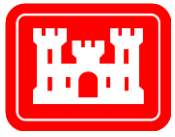


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# KINGS ISLAND TURNING BASIN

- Winghead high vs low frequency
- ~9-12ft penetration

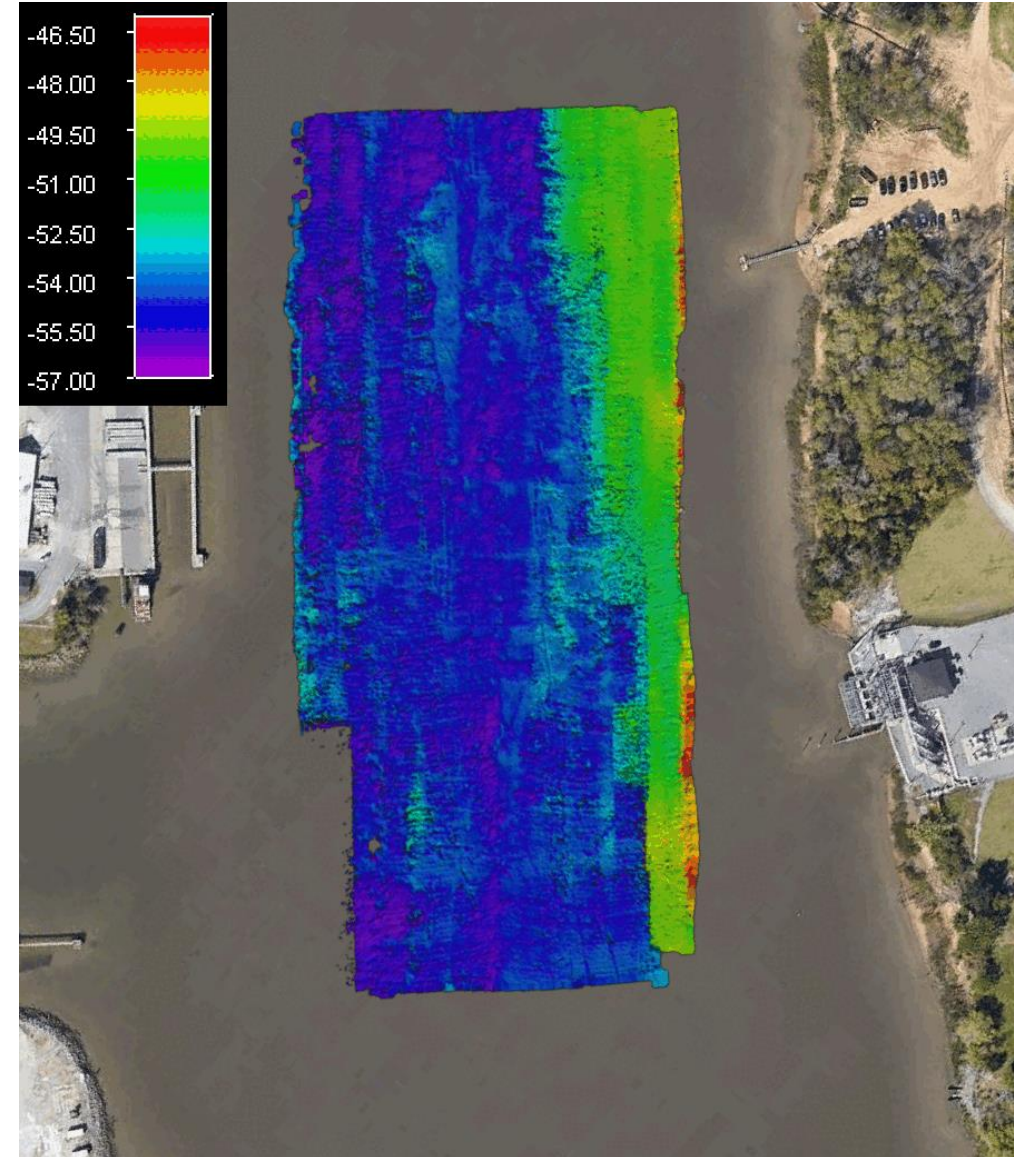
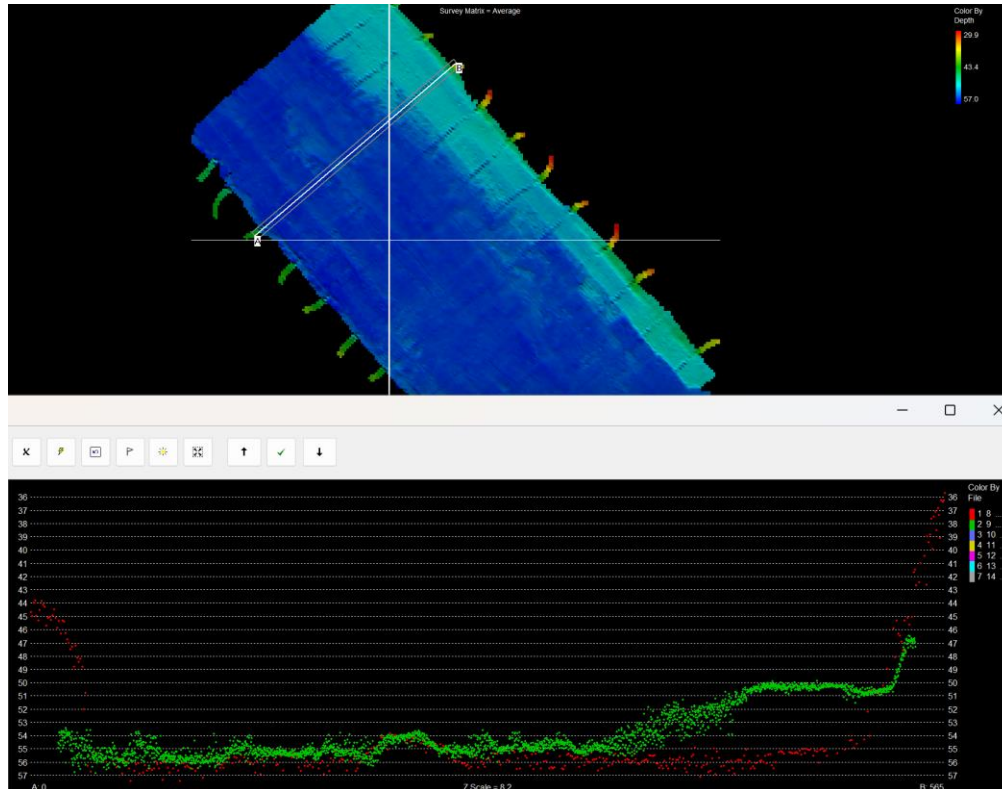




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# MARSH ISLAND CHANNEL

- Winghead high vs low frequency
- ~6ft penetration

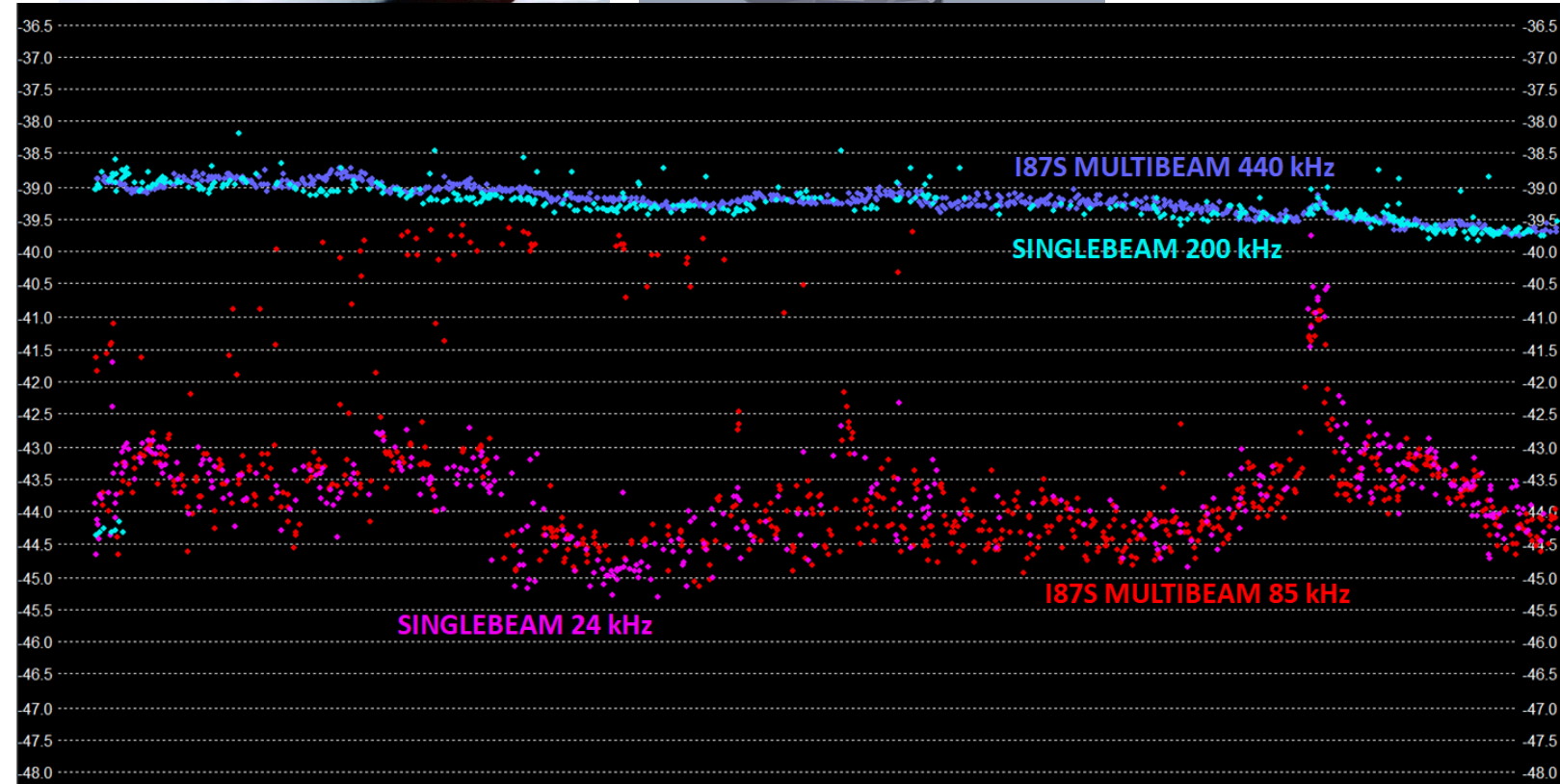
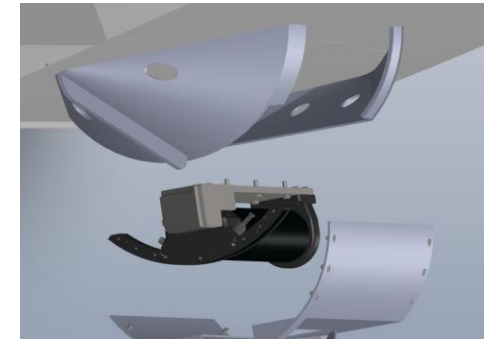




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# FURTHER WORK

- ✓ Singal Processing Refinement
- ✓ Tests in different environments
  - ✓ UK Ports:
    - ✓ Port Authority London
    - ✓ Bristol Ports
    - ✓ Port of Rotterdam
    - ✓ Port of Antwerpen
    - ✓ Sabine Pass
    - ✓ Port of Houston/Ship Channel
    - ✓ Savannah River
    - ✓ Calcasieu River
    - ✓ Papua New Guinea
    - Jacksonville
    - Manaus, Brazil
    - Uruguay River
    - Essequibo River, Guyana
- ✓ Learning in Mississippi Delta (USACE-NOLA)
- ✓ Integration & Processing Workflow with Hypack

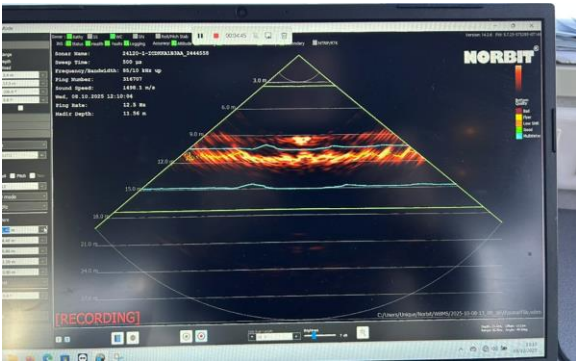
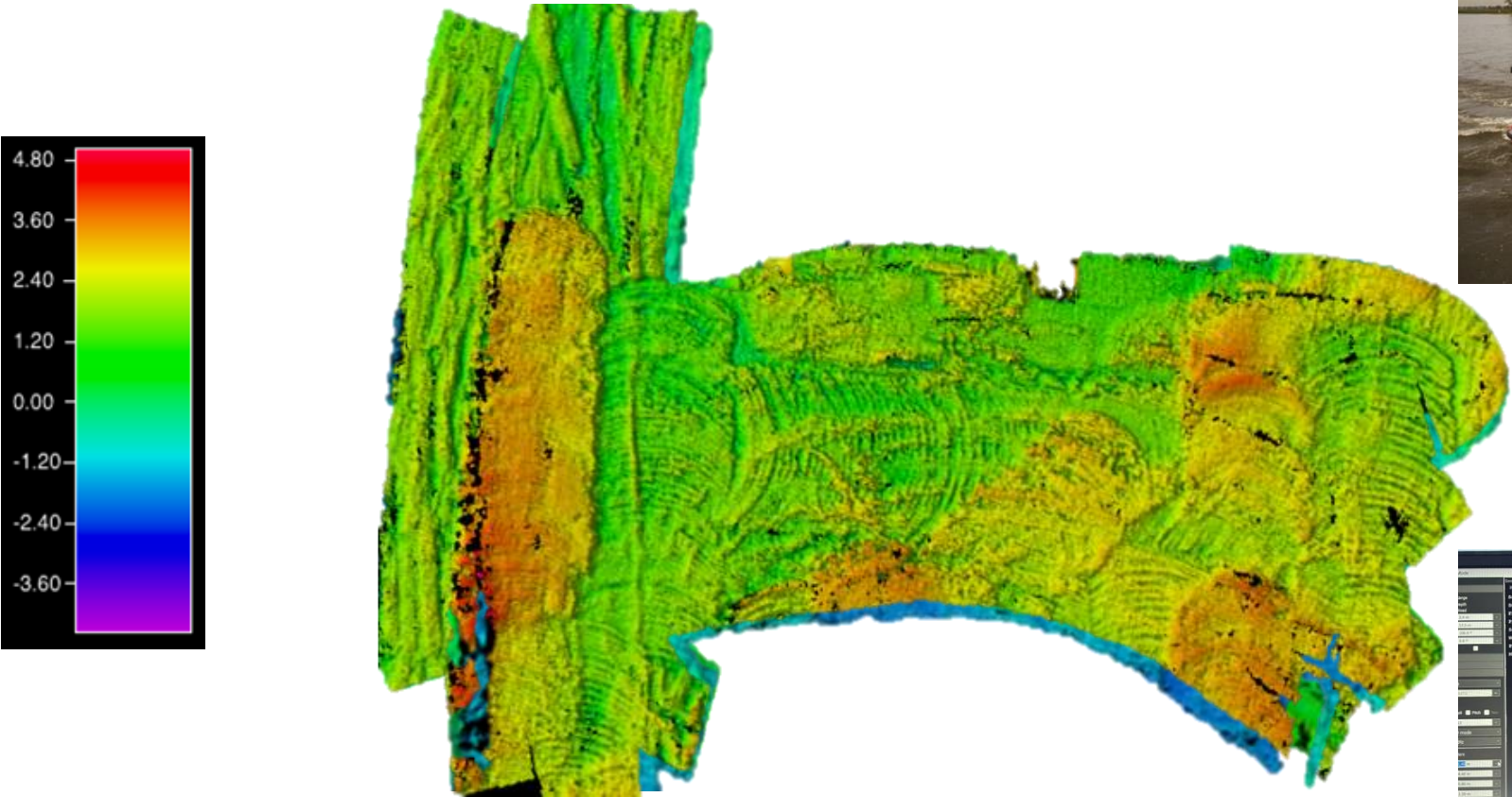


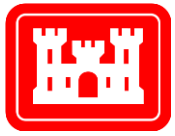


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# The Bristol Port Company

Dredge Removal (meters)

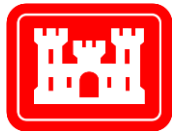




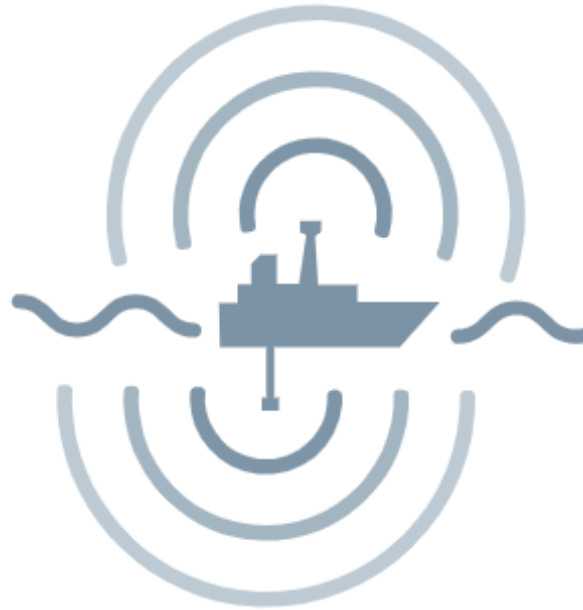
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# TAKE AWAY MESSAGE

- There IS a reasonable solution for fluid mud mapping and considering CATZOC A1/A2 classification.
- NORBIT Winghead LMD is:
  - An efficient 'wide' swath solution for fluid mud mapping.
  - Generally matches 28kHz singlebeam
  - Expected 'navigation surface' is less shoal than i87s LMD
  - A solution towards CATZOC A1/A2
  - Not a sub-bottom system!



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