GEOLOGY OF NEW YORK HARBOR

Geological and Geophysical Methods of Characterizing the Stratigraphy for Dredging Contracts

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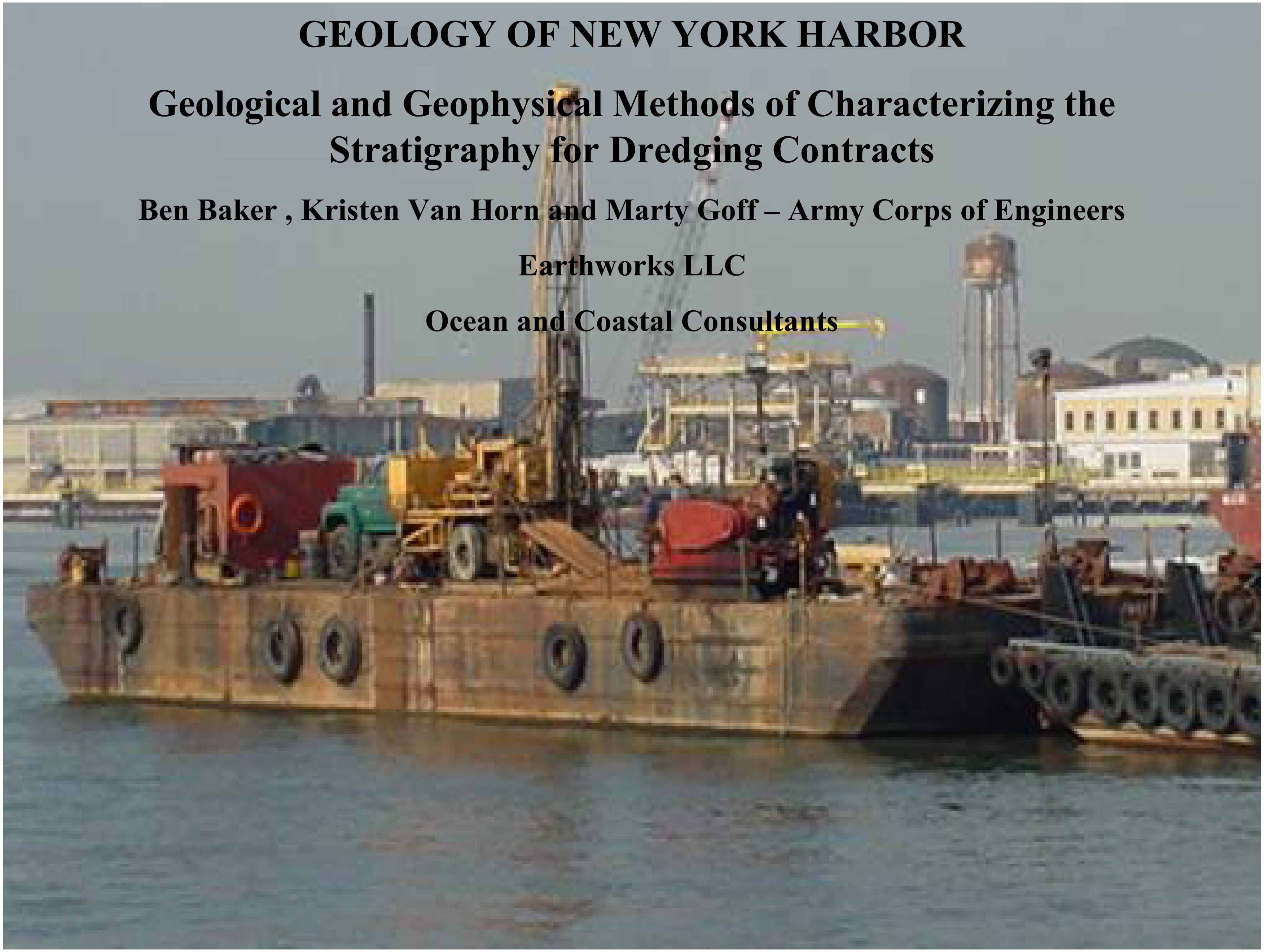
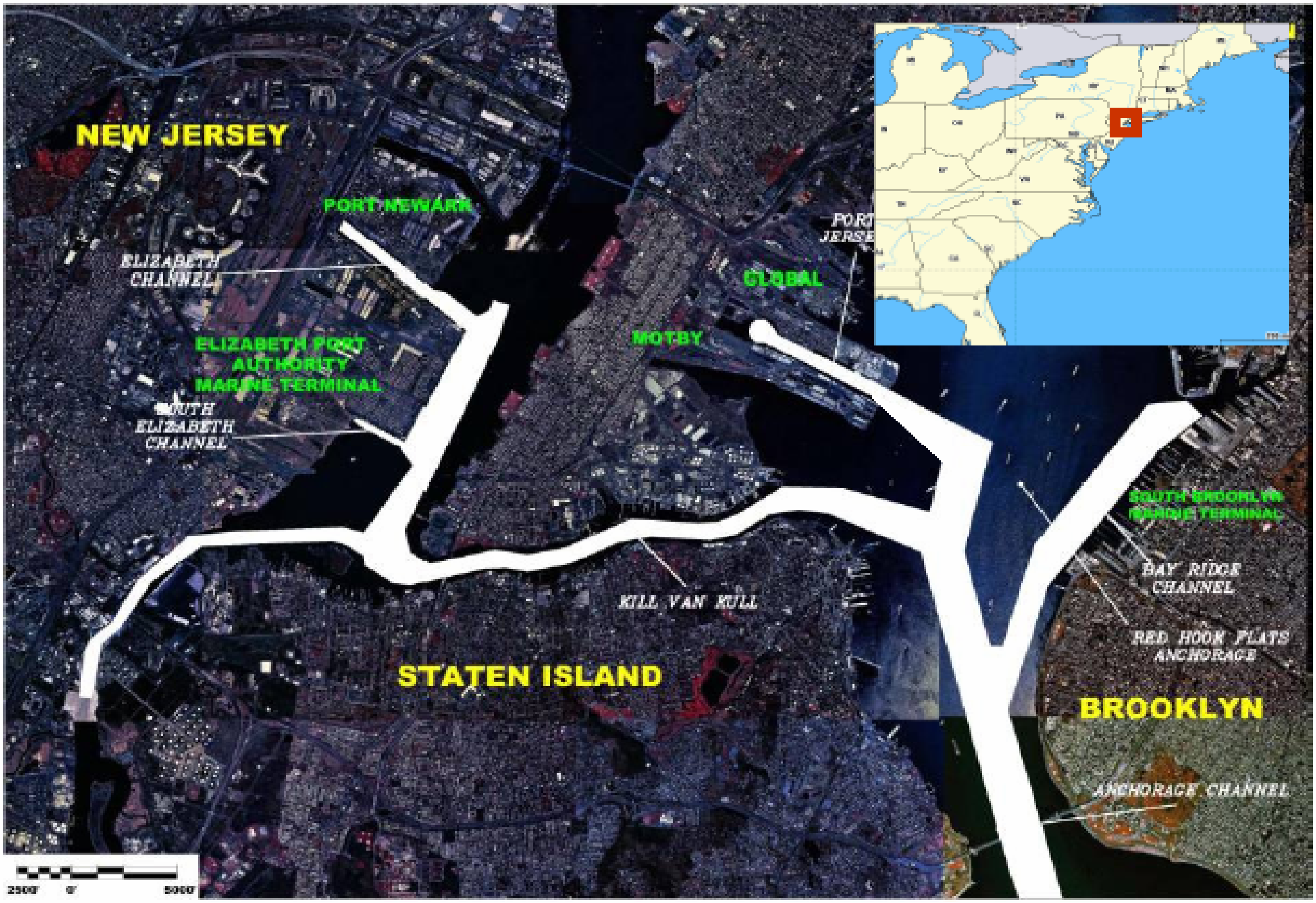


Project Background

- 3rd largest container port in the U.S.
- Largest port on North America's East Coast
- Largest petroleum port in the U.S.



Index Map showing the location of the –45' MLW Navigation Project.

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Geological and Geophysical Methods of Characterizing the Stratigraphy for Dredging Contracts

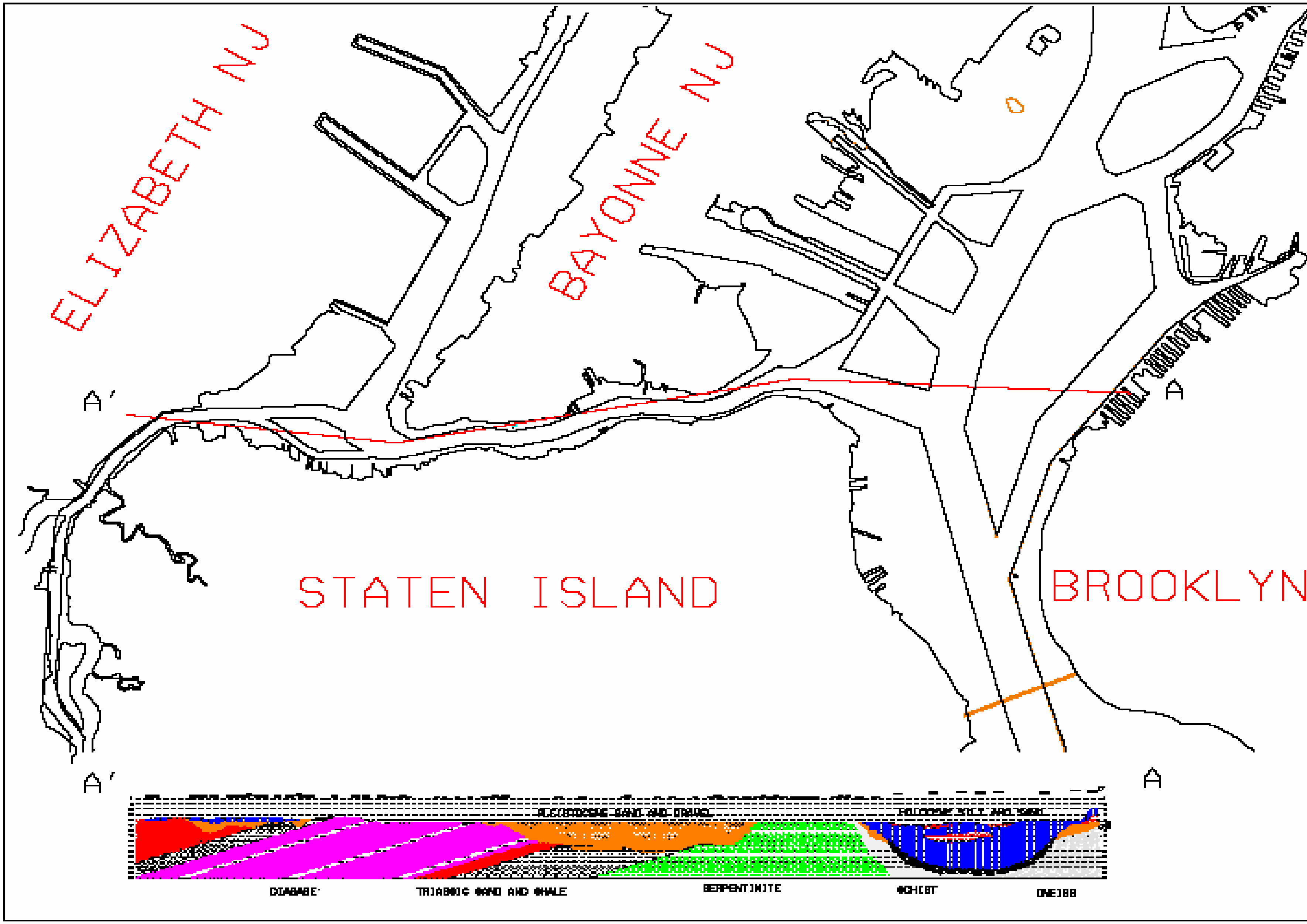
Geological Mapping (1,000+ SPT borings, vibracores and gravity cores)

- Cross-Sections and Profiles
- Subcrop (Slice) Maps
- Isopach (thickness) Maps
- Percent Sand Maps
- Specialty Maps such as Dredgeability

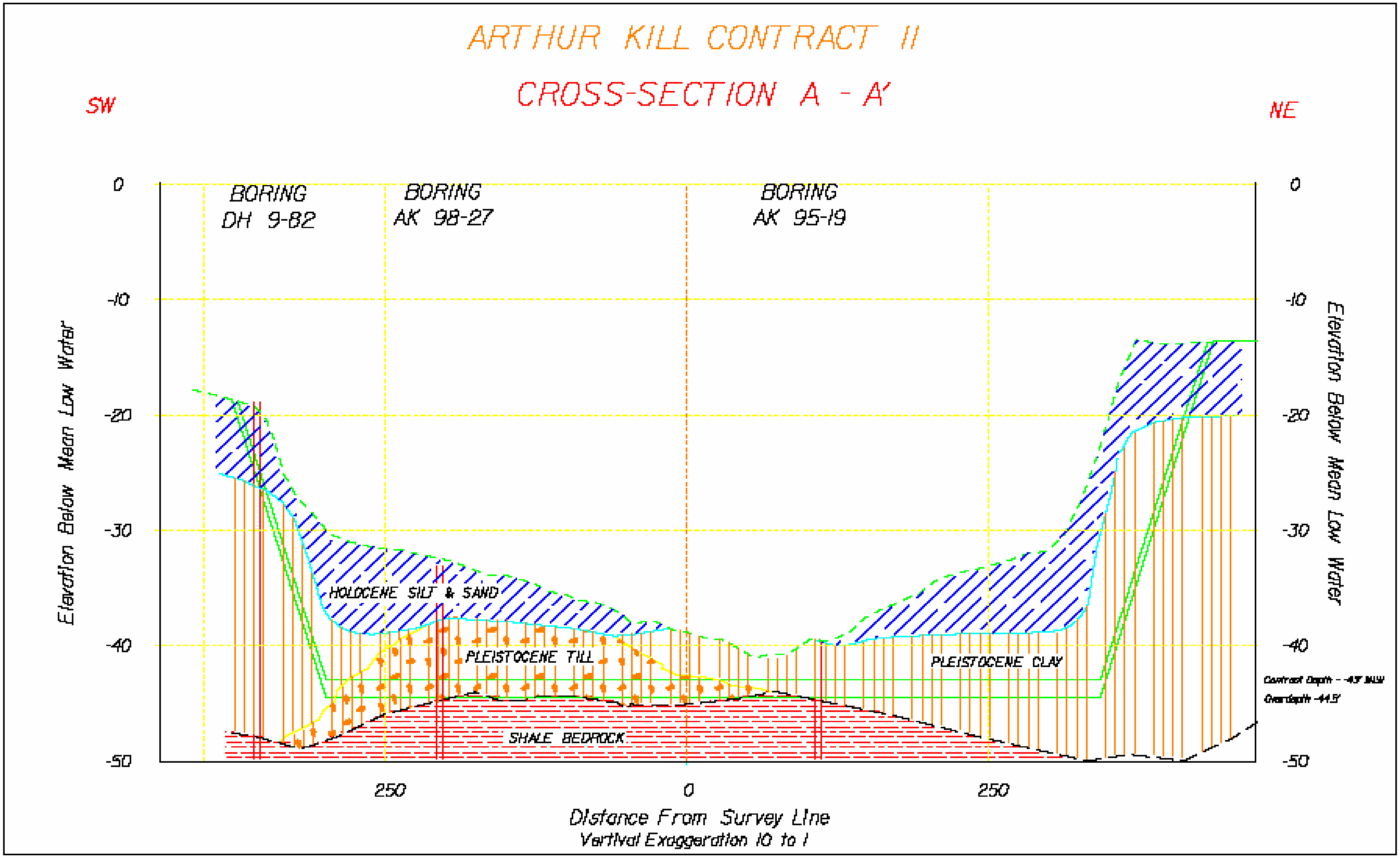
Geophysical Mapping Techniques

- Side Scan Sonar – Sediment Distribution and Channel Floor Anomalies
- Sub-bottom Profiles – Subsurface Structure and Stratigraphy
- Magnetometer – Buried utilities such as oil and gas pipelines
- Multi Channel Seismic – Velocity Mapping for Dredgeability of Rock
- Laser Induced Fluorescence – Identification of Contaminated Sediments

Location Map and Regional Stratigraphic Cross-Section

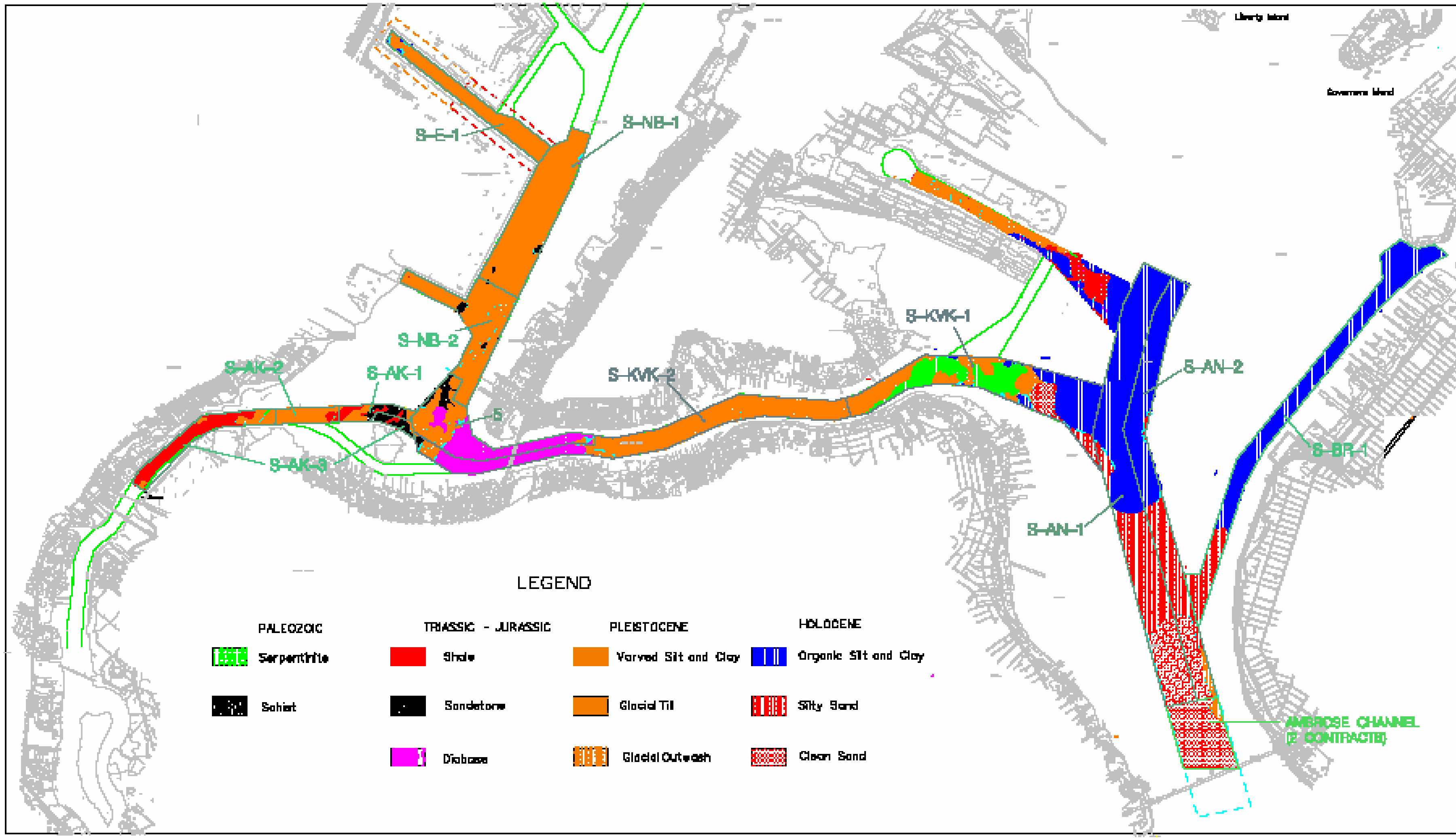


Typical Cross-Section – Dredging Prism and Materials



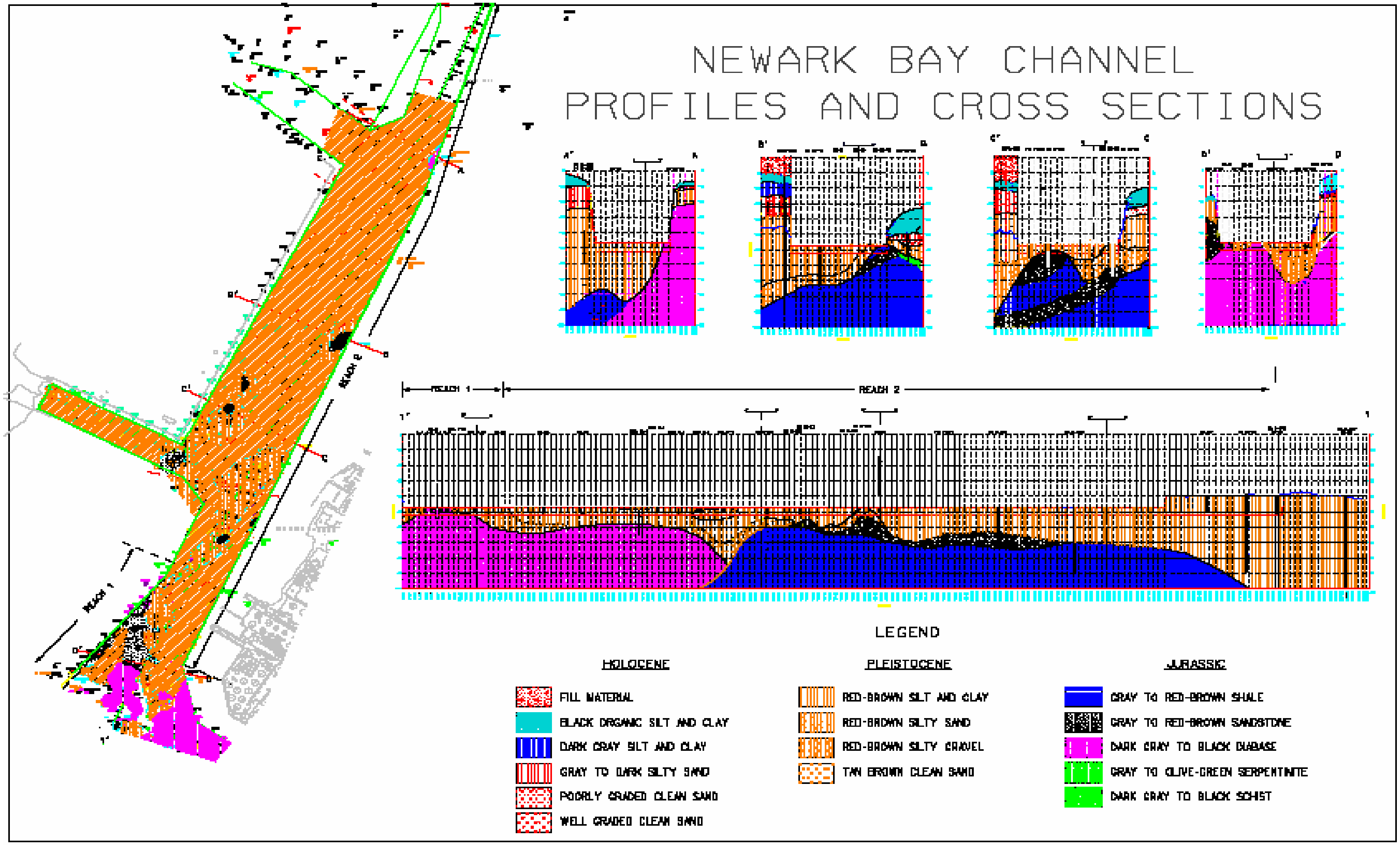
Subcrop (Slice) Maps on the following illustrations are constructed at the last after dredging project depth (43.5'MLW).

Subcrop of Materials Exposed along Channel Floor After Phase II



Most of the navigation channels to the west of the natural Hudson River Channel have been dredged to an elevation of –48.5’ MLW and Pleistocene or older materials are exposed along the channel floor. Existing topography often related to weathering properties of underlying material…Bayonne underlain by Diabase that is highly resistant to erosion.

Newark Bay - Detailed Subcrop, Proile and Cross-Sections

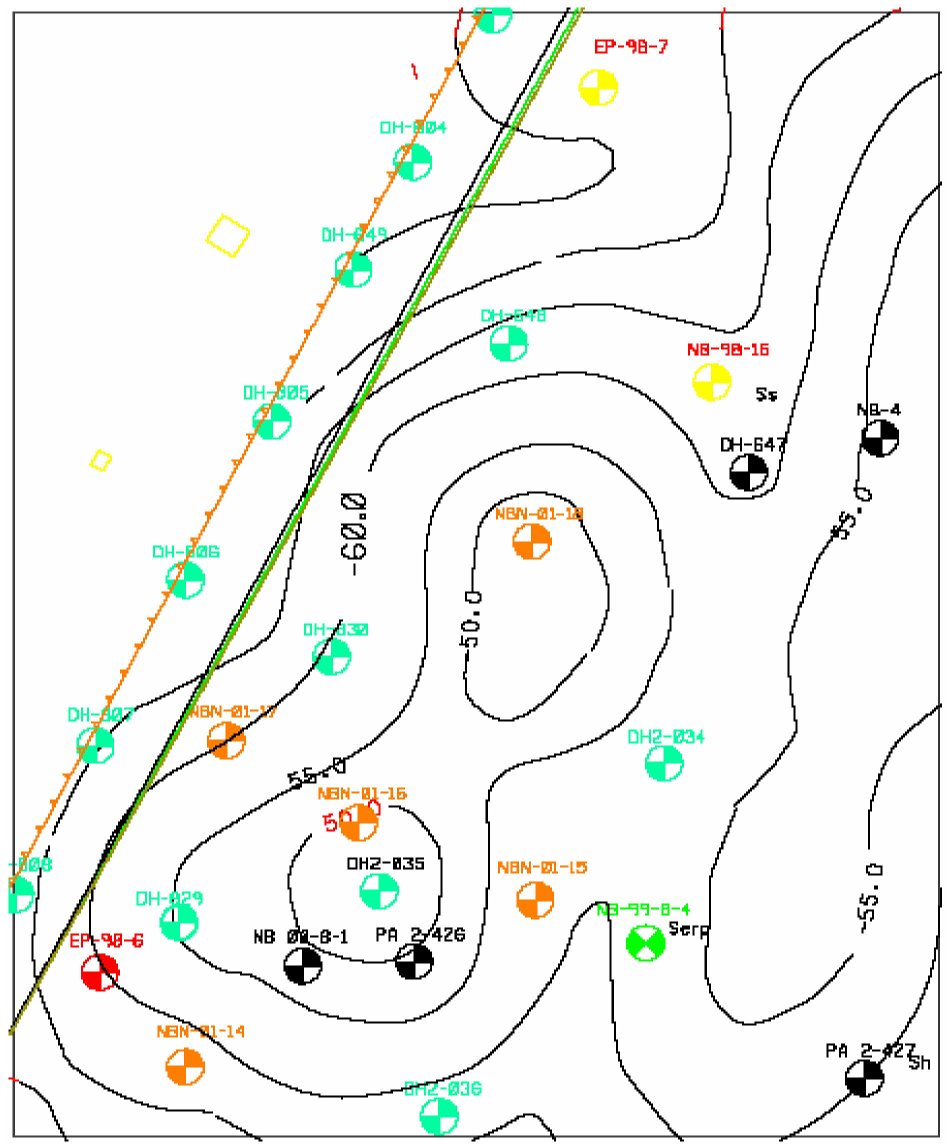


Subcrop maps are used to define soil and rock areas that may require different dredging equipment or in the case of rock may require blasting. The maps are also used to define ocean disposal test reaches such as for the Pleistocene sand and gravel (till) or varved silt and clay. After testing both of these units were eventually determined to be suitable for ocean disposal.

Newark Bay - Top of Rock Contour Map Before Dredging

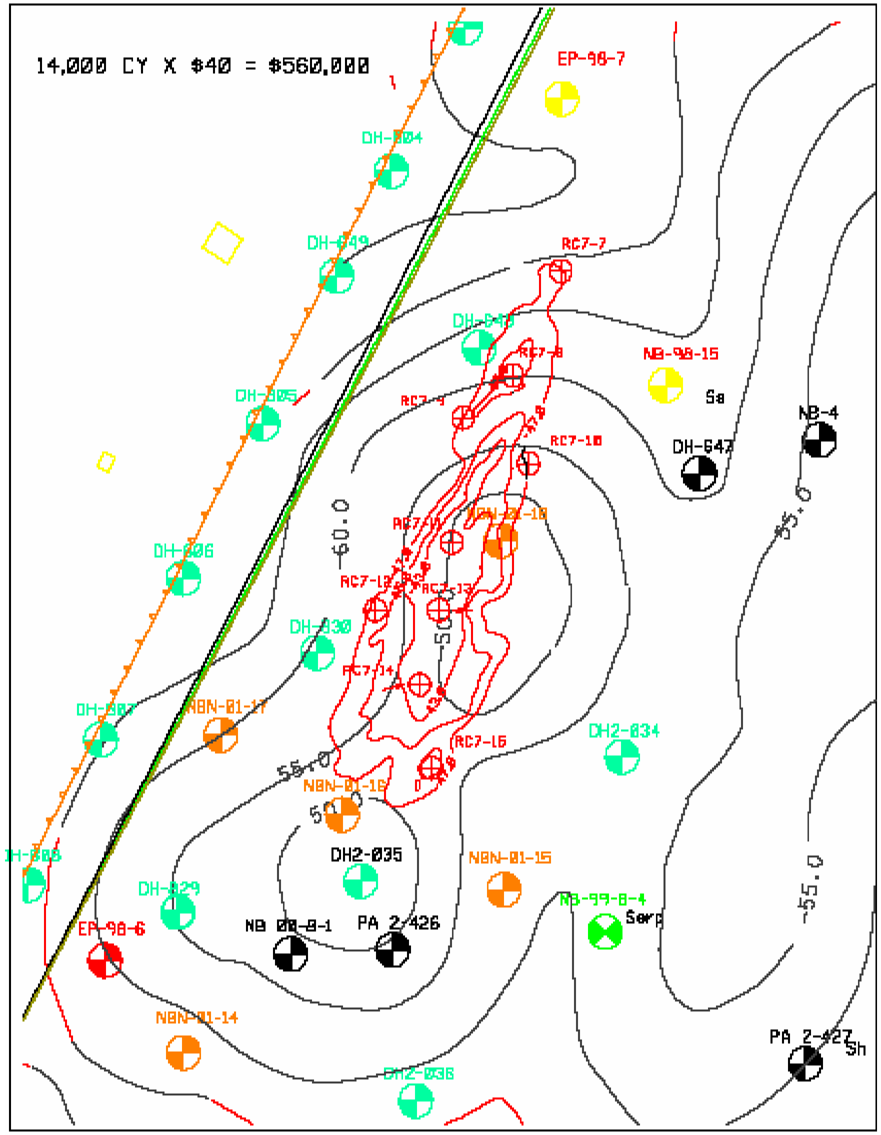
Case Study

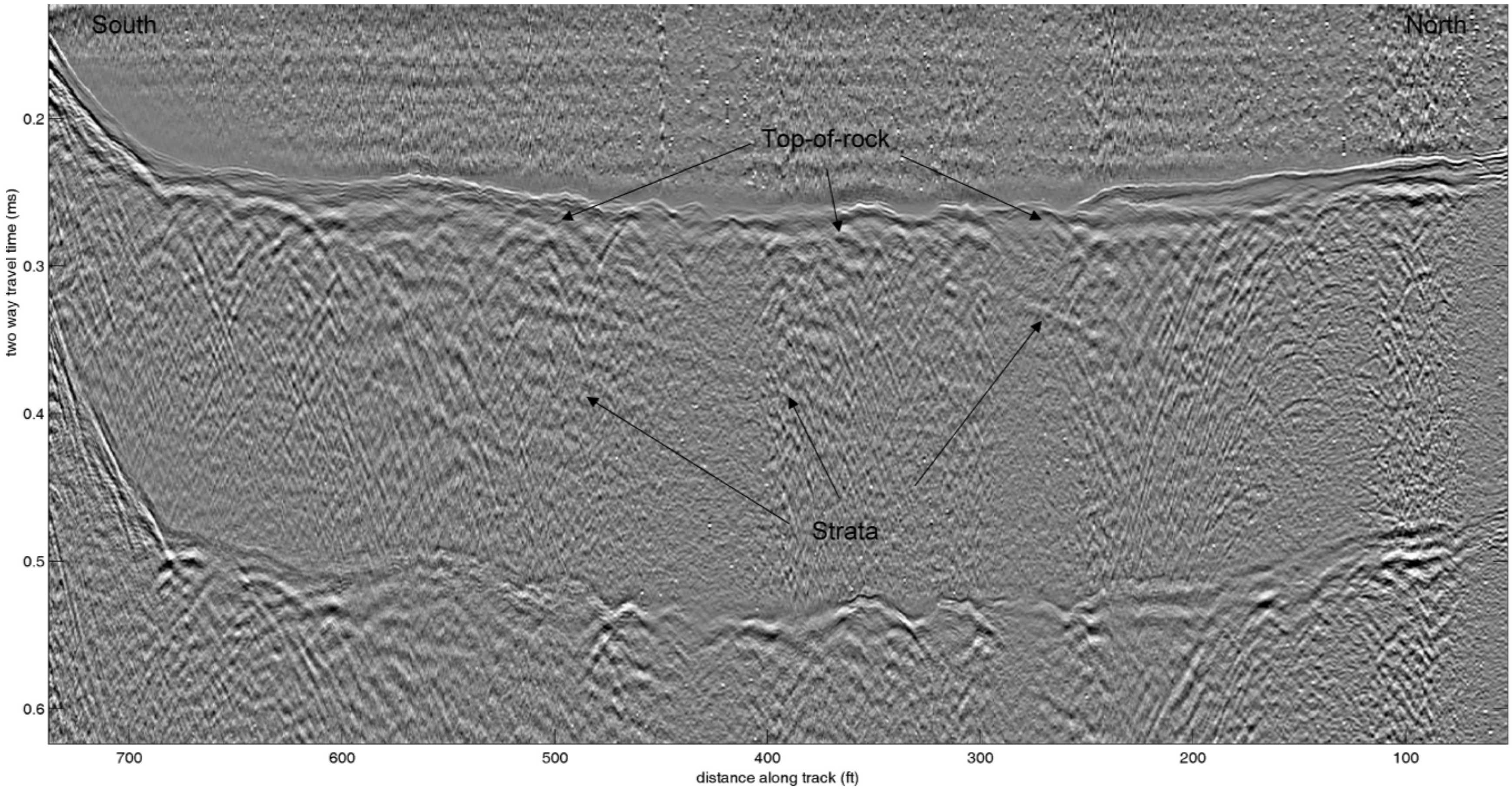
Required dredge depth in this contract was a minimum of -47 MLW. Top of rock based on borings indicated that rock was high but would probably not be encountered.



Rock Claim – Undetected Rock Ridge

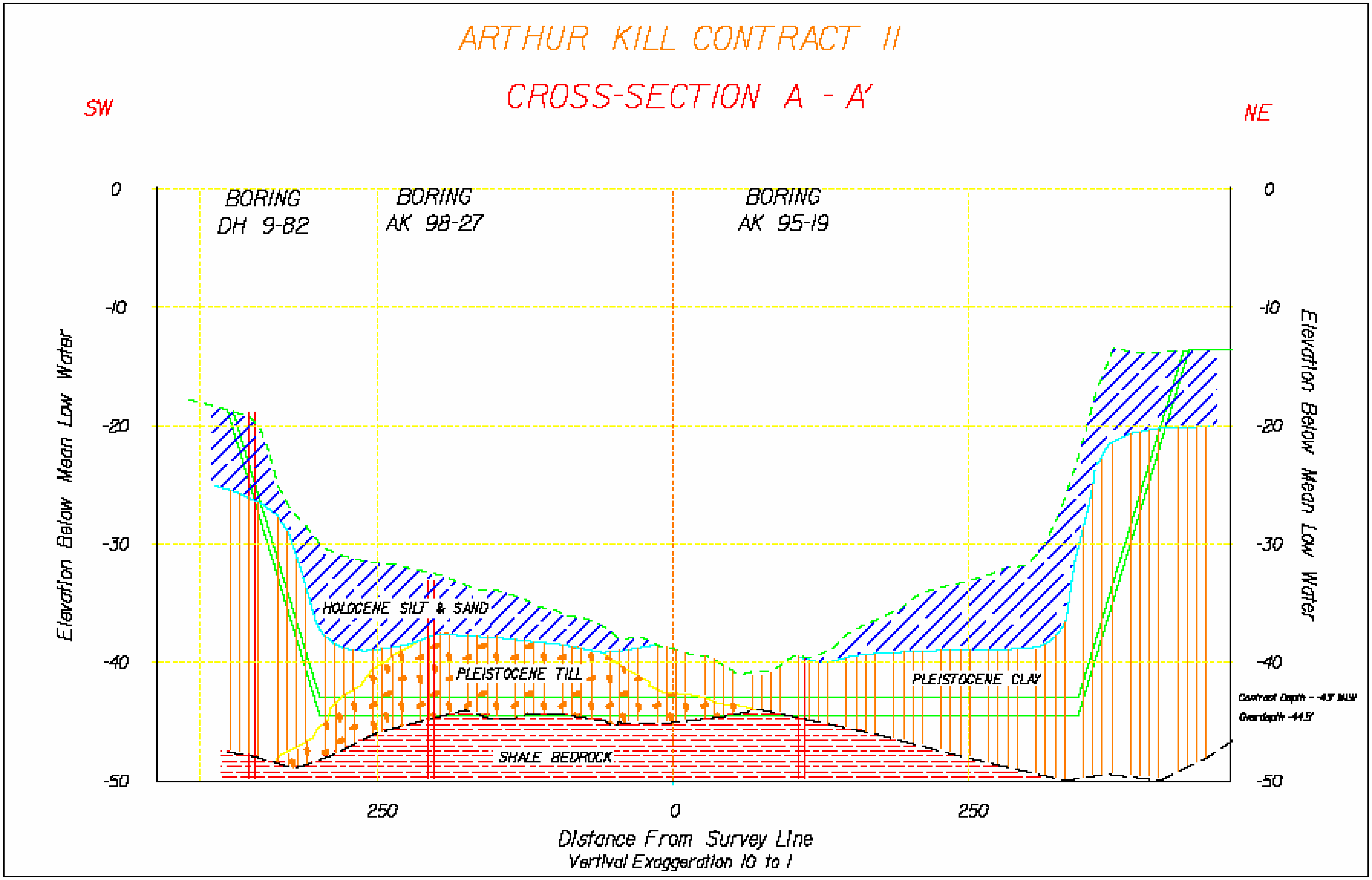
Dredging Contractor reported that rock was being encountered. Nine borings were acquired and verified that there was a narrow sandstone ridge that came up to an elevation of –43' MLW…. well within the dredging prism.





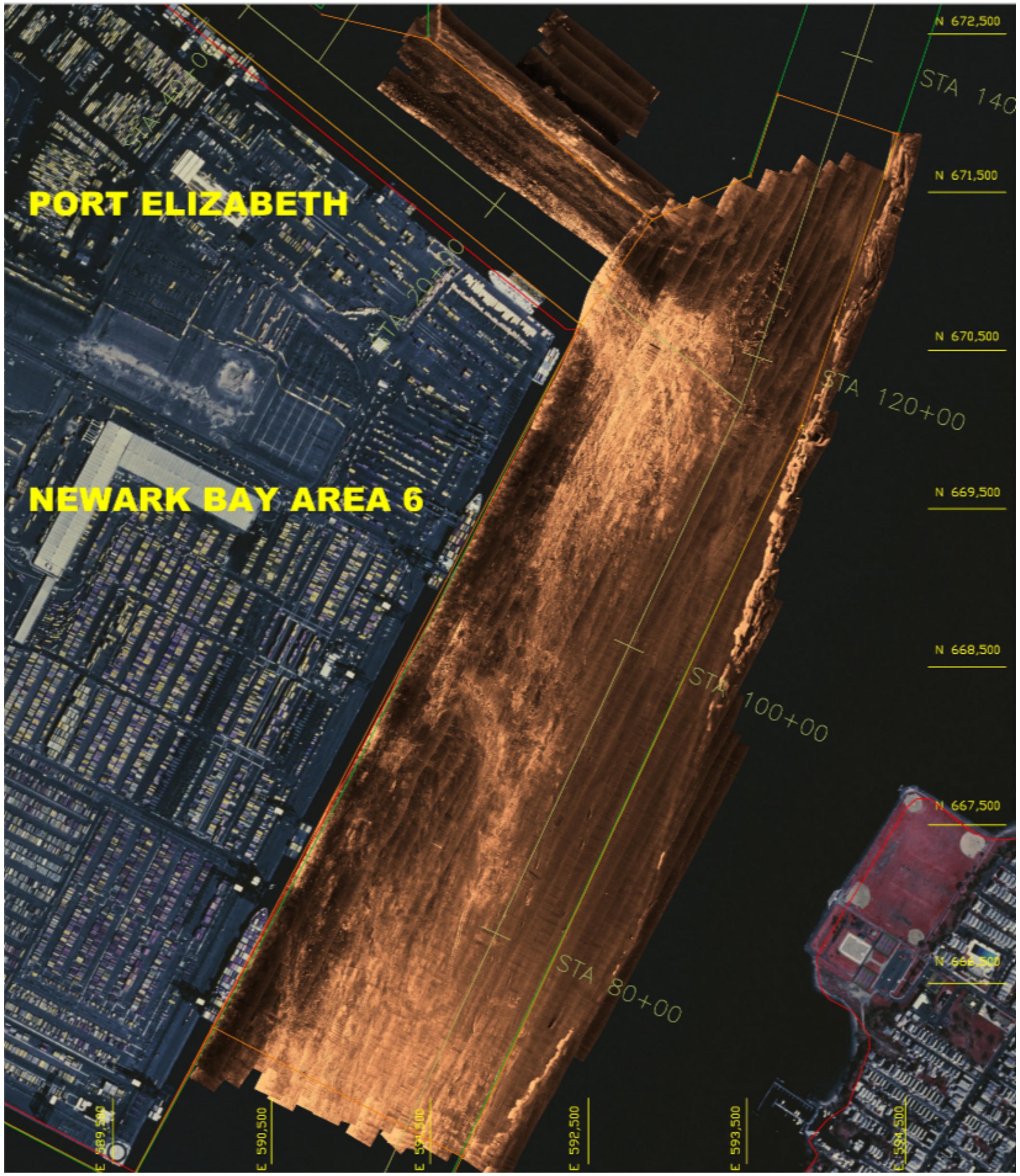
Sub-Bottom Profile-Arthur Kill Channel - Top of Rock

Dipping surfaces are probably shale/sandstone contacts. Sandstone is more resistant and forms ledges. Top of rock is not continuous event and requires interpretation between points. The ridge on the previous example is probably similar to the ones shown on this seismic section.

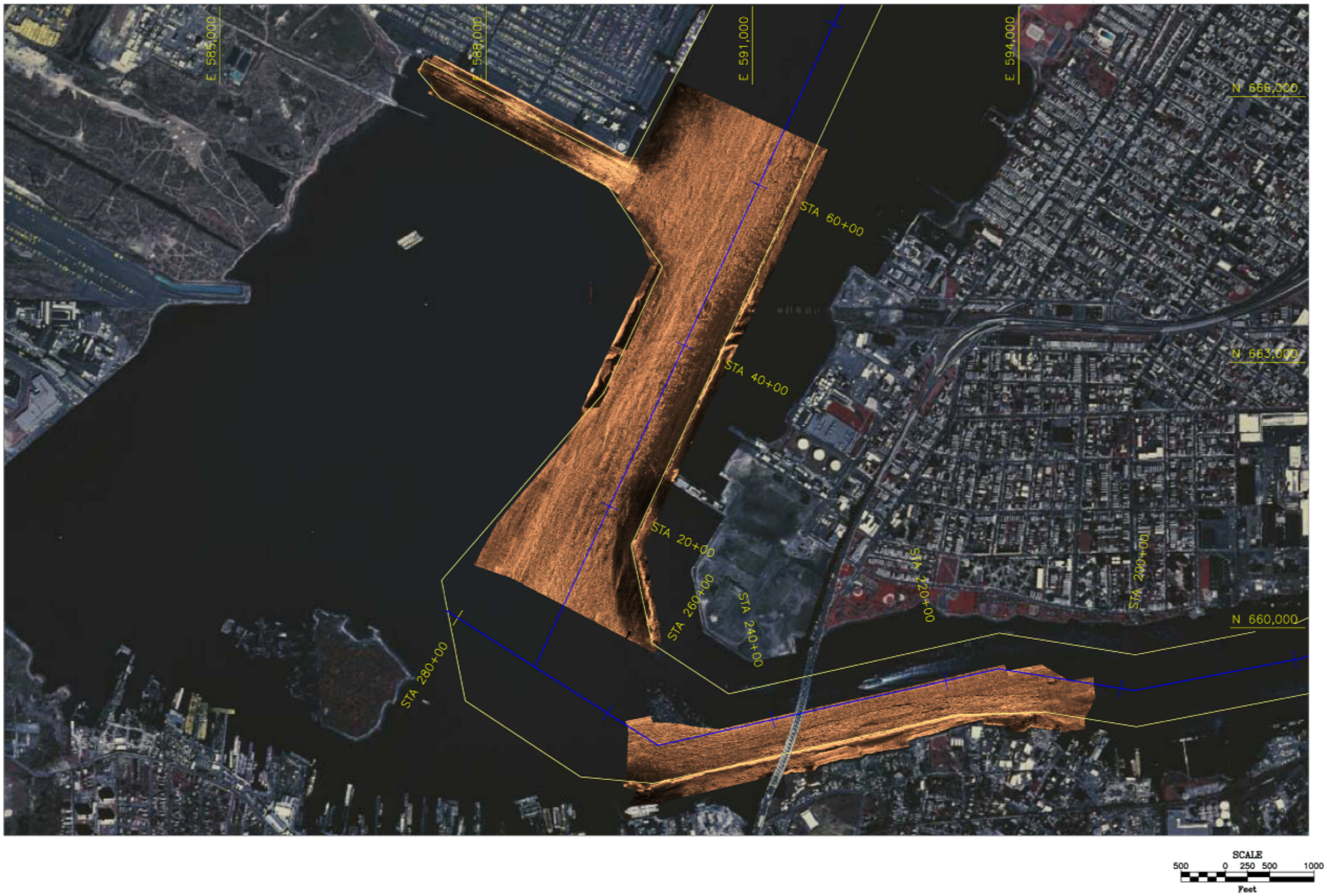


Cross-section showing distribution of materials prior to the last phase of dredging. Note the black silt shown on the following Side Scan Sonar Mosaics.

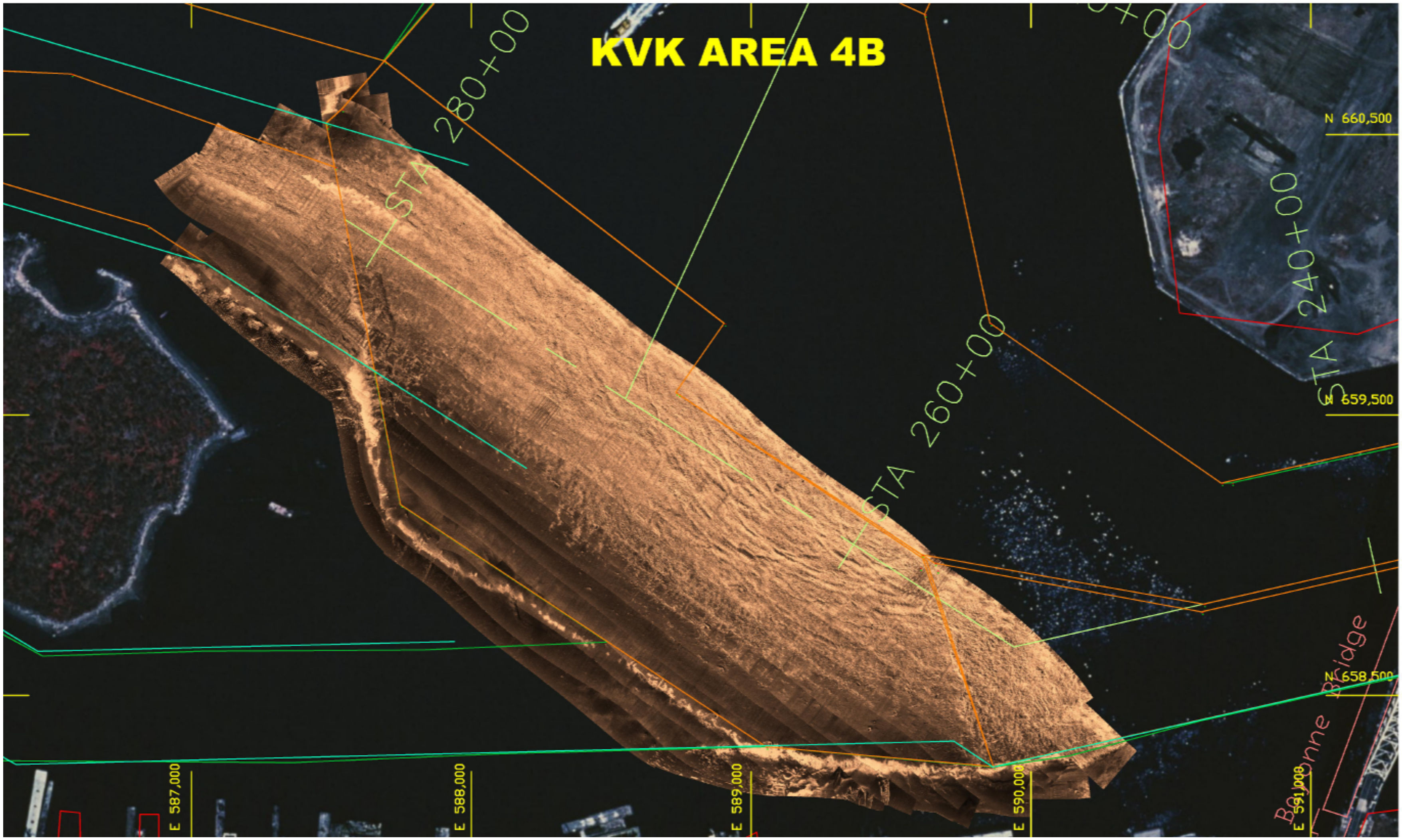
Side Scan Sonar Mosaic of Newark Bay - Black Silt Footprint



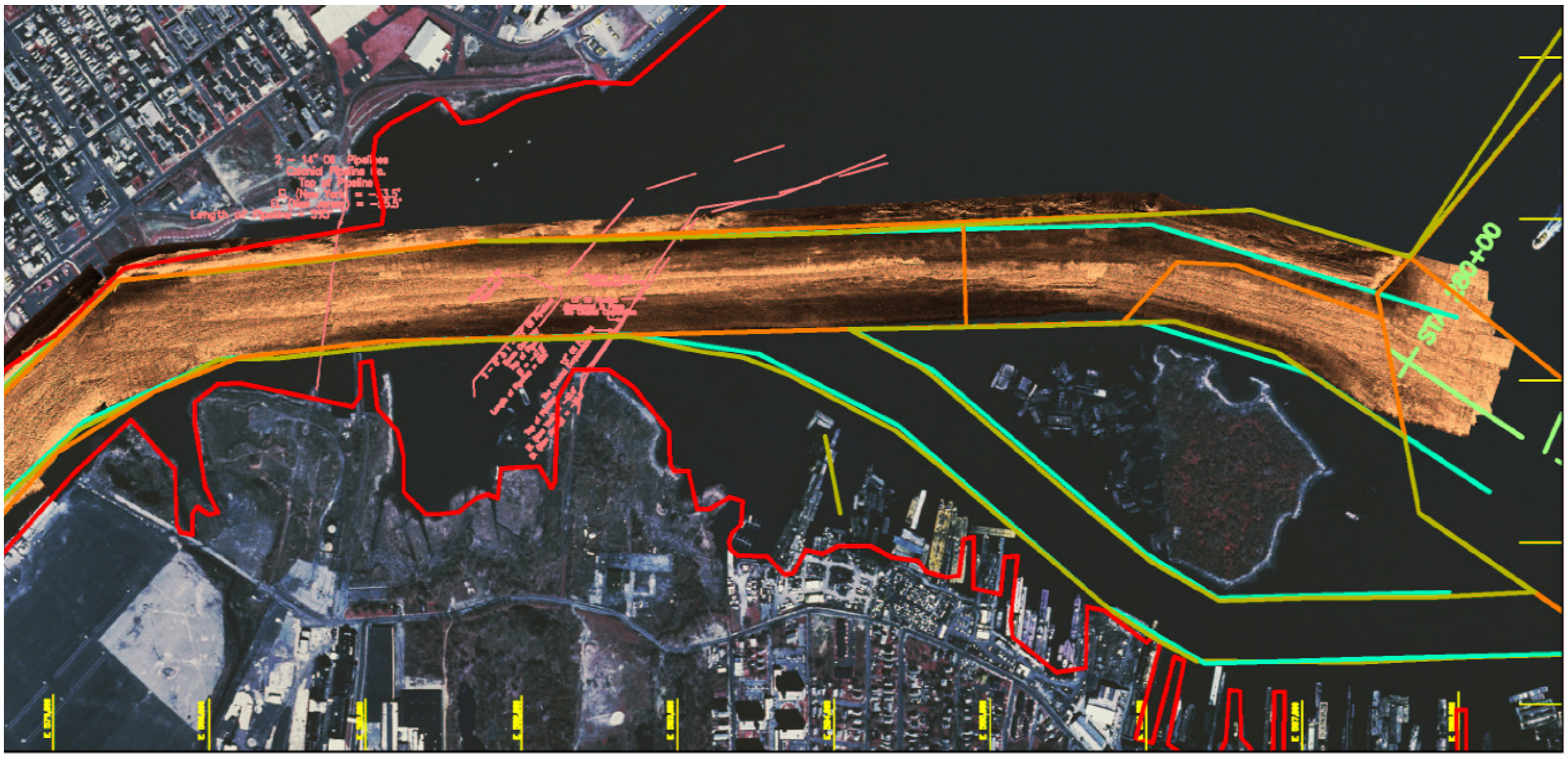
Side Scan Sonar Mosaic – Southern Newark Bay



Side Scan Image of Bergen Point Area (Kill Van Kull Channel)



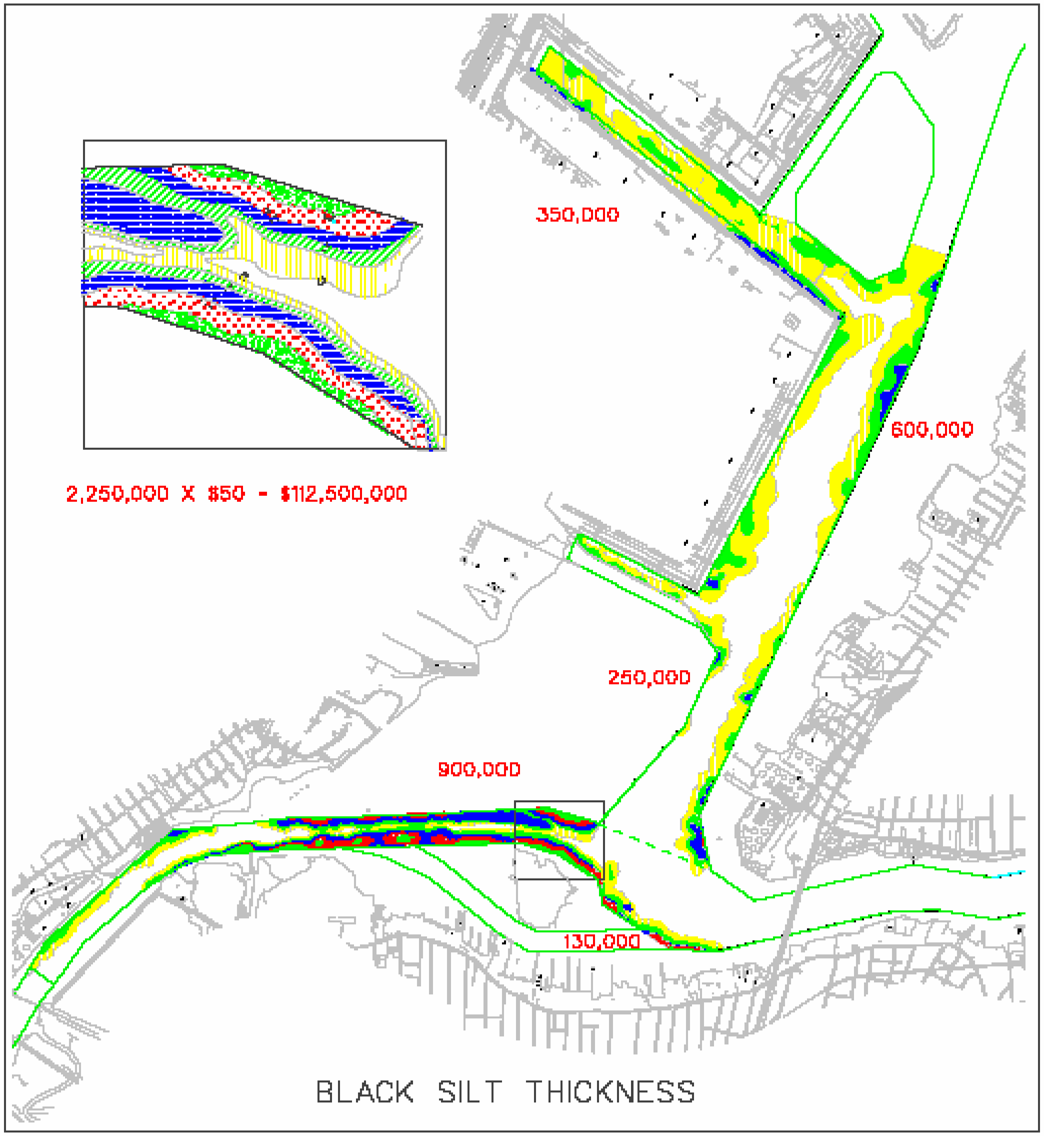
Side Scan Sonar Mosaic – Arthur Kill Channel



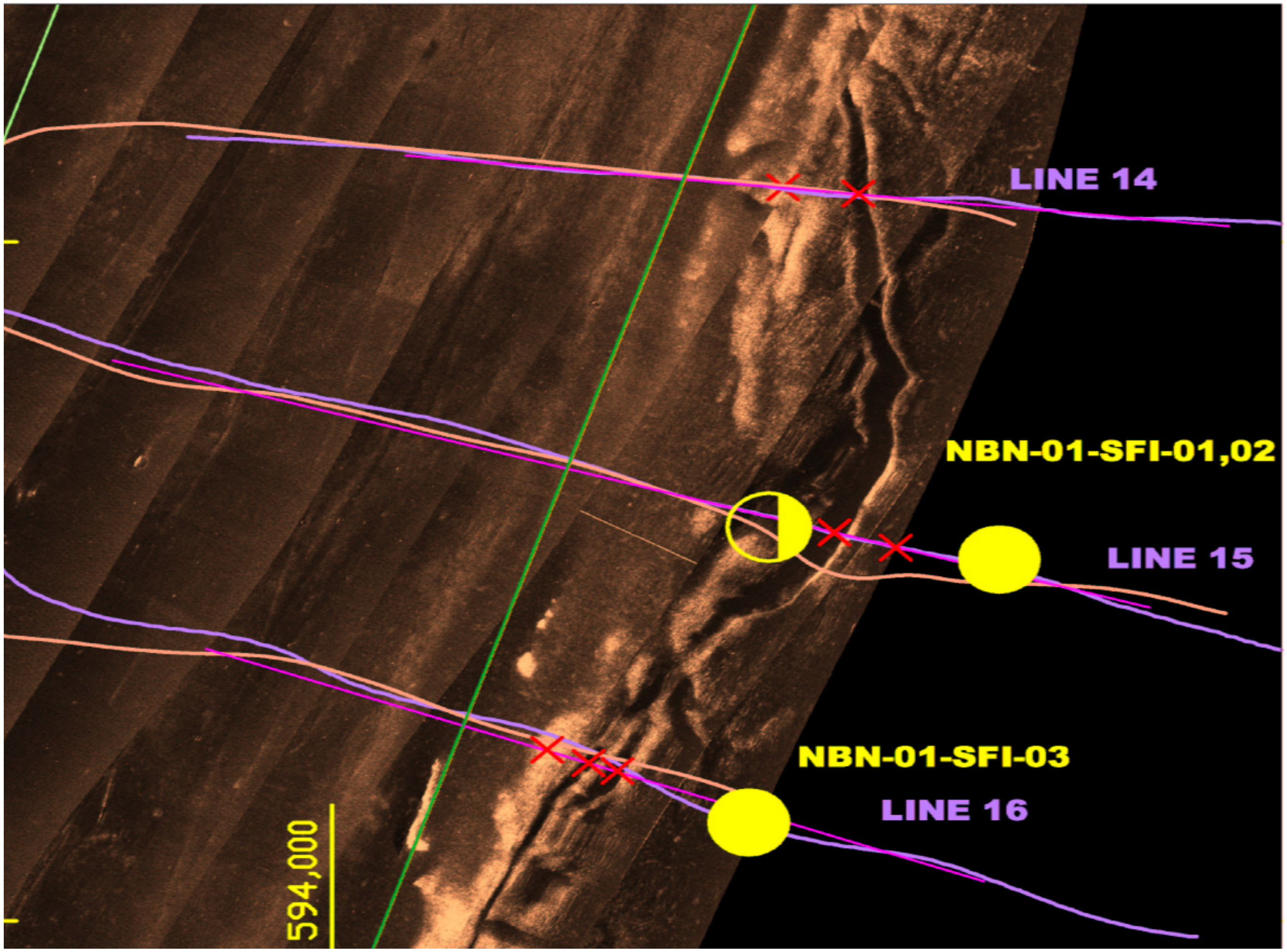
Gravity Core sometimes referred to as a dart that is used to collect soft samples such as the black silt. Can sample up to about seven feet. Have done as many as fifty samples in one day if the only consideration is thickness.

Black Silt Isopach (Thickness) Map
Contour Interval 2.5’

Volume estimates are determined from the area of each thickness band and the average thickness of the band. For instance the 2.5’ to 5.0’ band covers an area of 10,000 sf and has an average thickness of 3.75’ then the volume is 37,500 sf or 1388 cy.

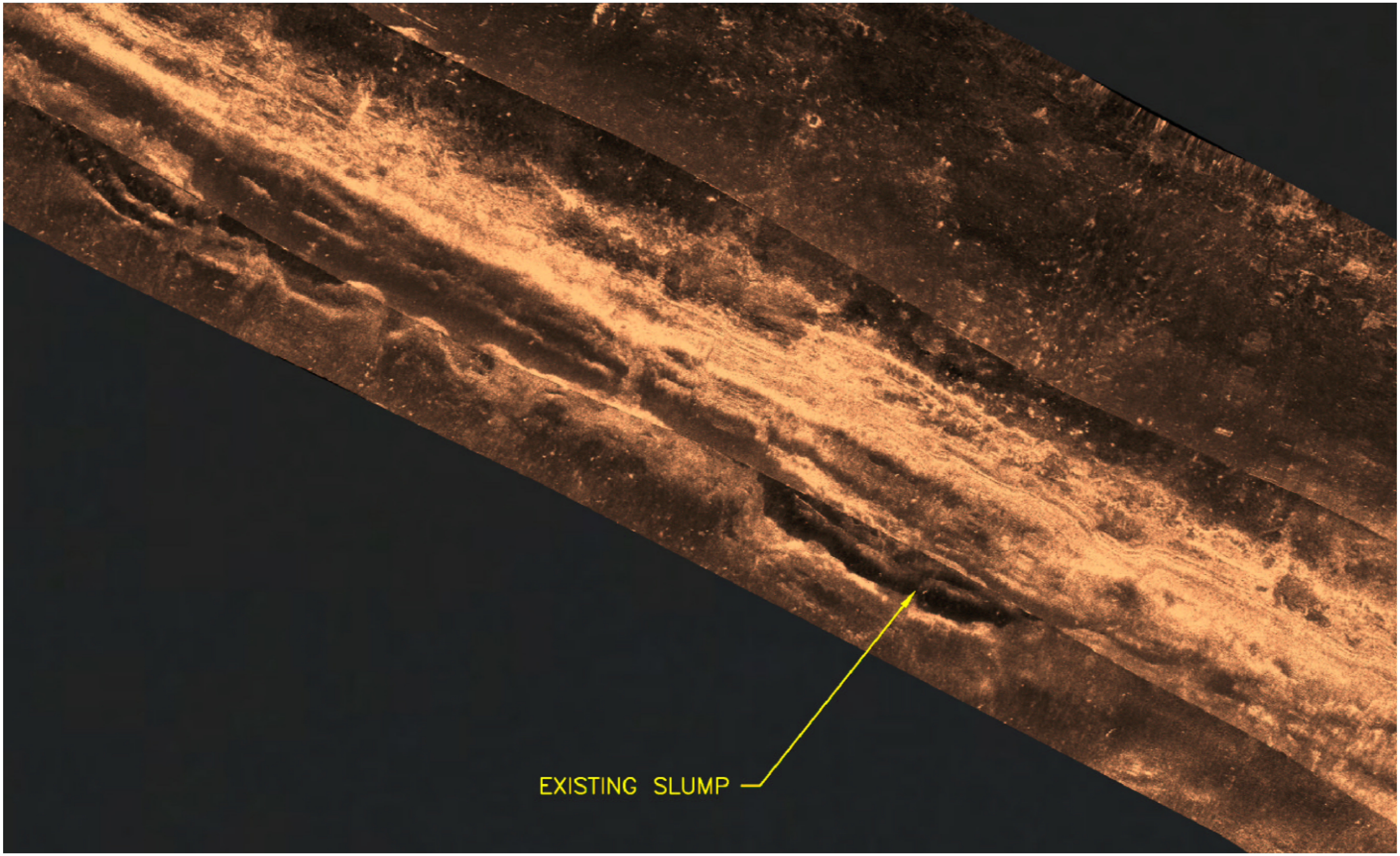


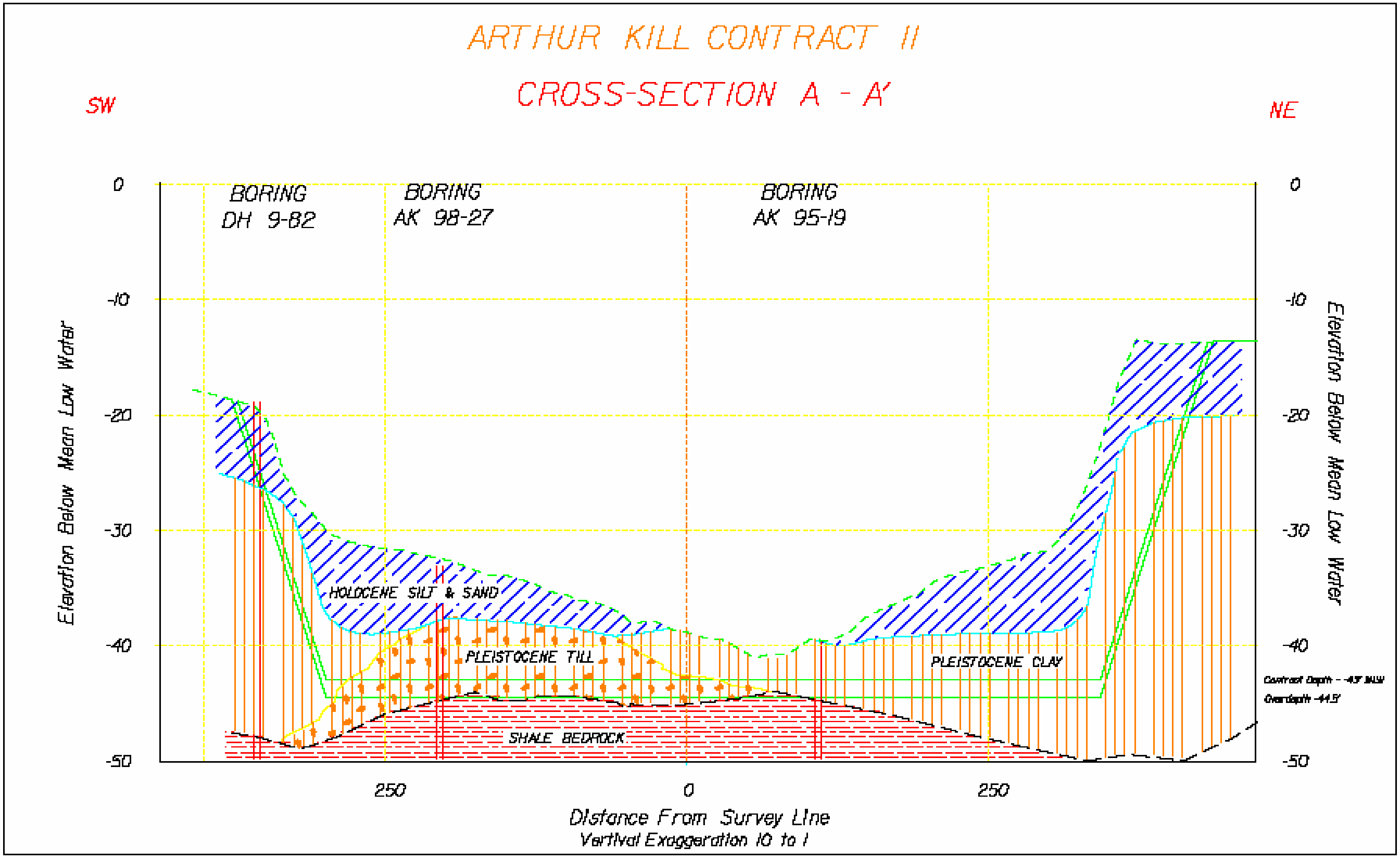
Side Scan Mosaic – Side Slope Slump Failure



Side Scan used to evaluate side slope and to detect slope or slump failures. These well define anomalies are most common in areas where there is a thick black silt layer overlying soft Pleistocene Silt and Clay.

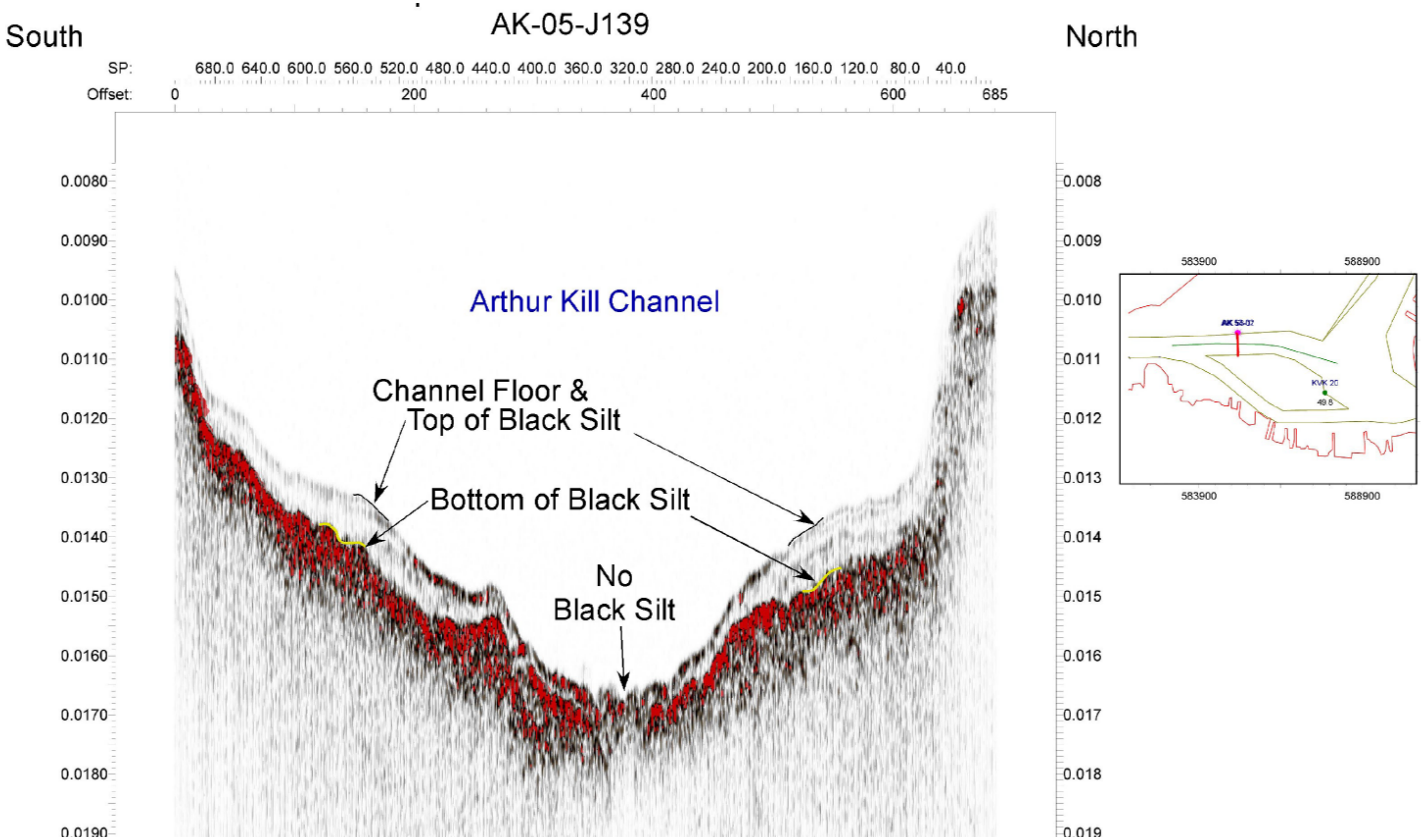
South Elizabeth Channel – Side Slope Slump Feature



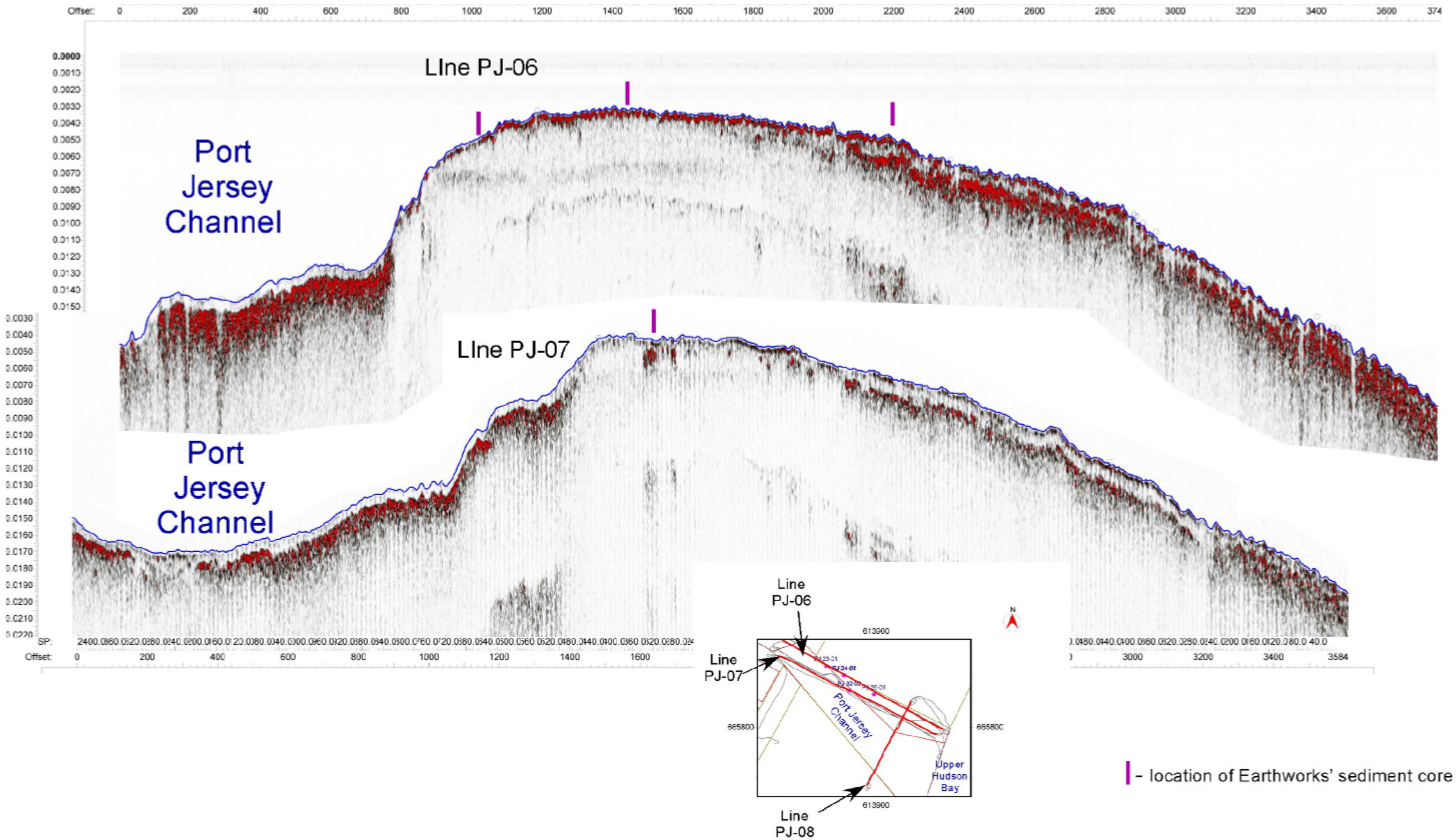


Typical cross-section showing distribution of black silt in eastern Arthur Kill. Note similarity to sub-bottom profile on following illustration.

Sub-Bottom Profile – Black Silt Thickness in Arthur Kill Channel



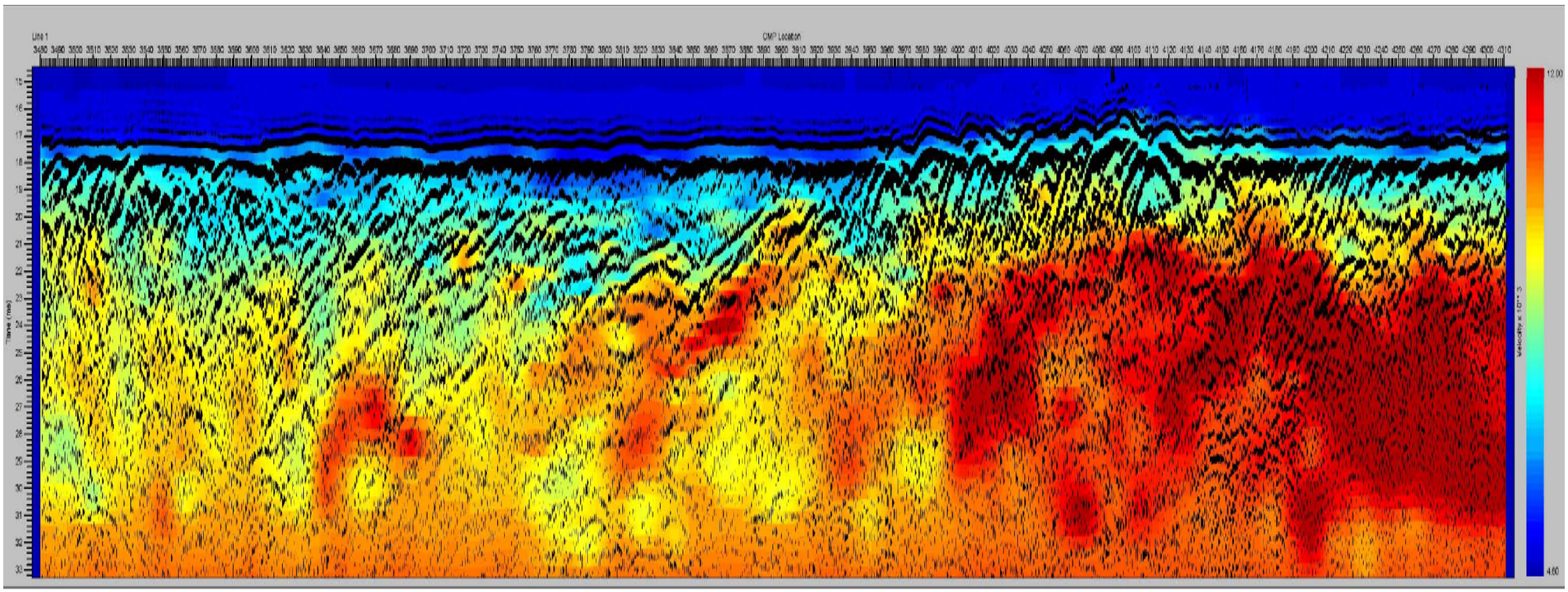
Black Silt Thickness – Port Jersey Channel and Flats



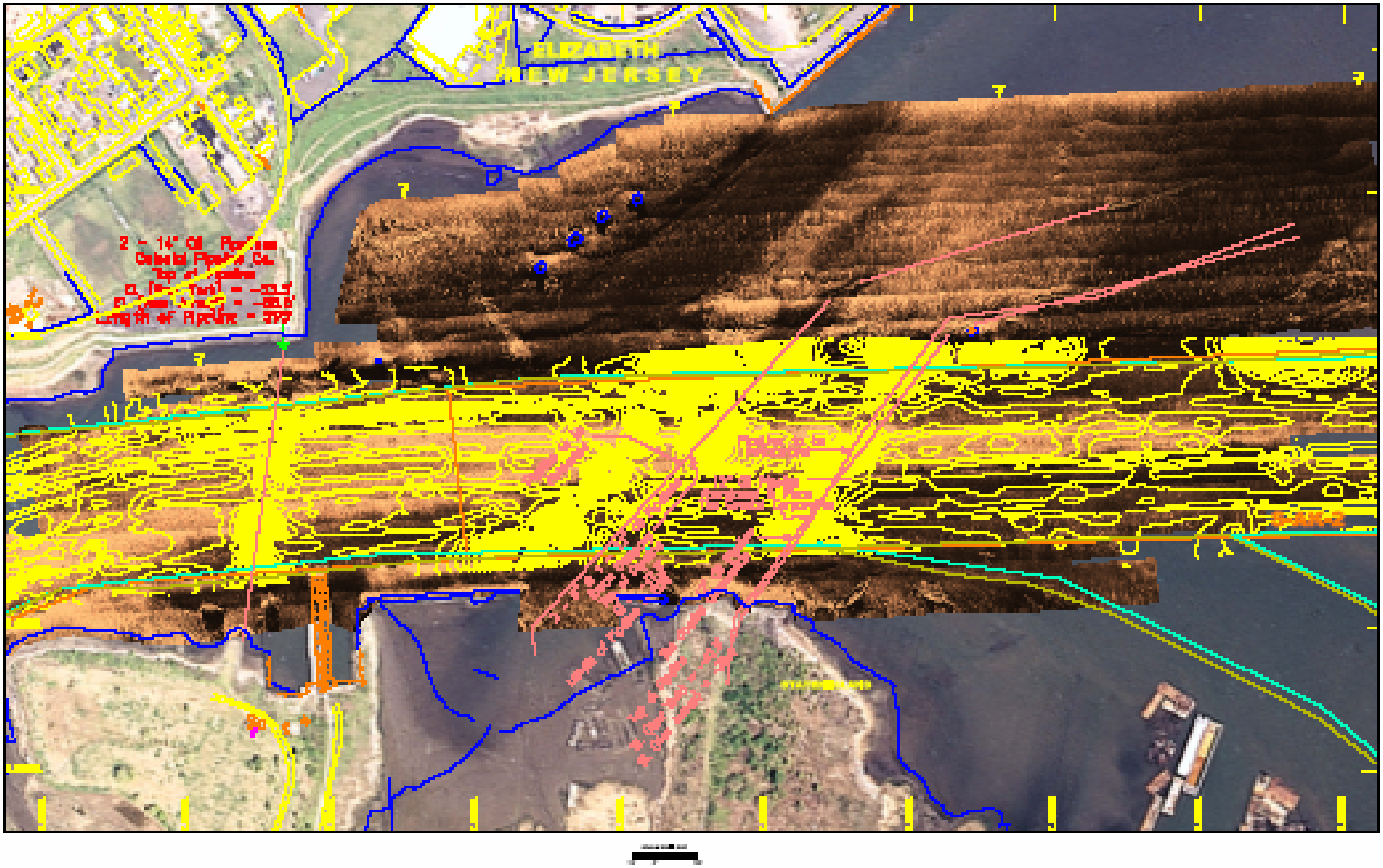
Two sub-bottom profiles shown on index map. Note the wedge of silt that thins as water depth decreases. These sections were used separate the silt into two ocean disposal test reaches.

Multi-Channel Seismic – Velocity Analysis to Determine Dredgeability of Rock

Less than7,000 fps is dredgeable with clamshell
7,000 to 10,000 fps is dredgeable with a excavator
Greater than 10,000 fps requires treatment such as blasting etc.



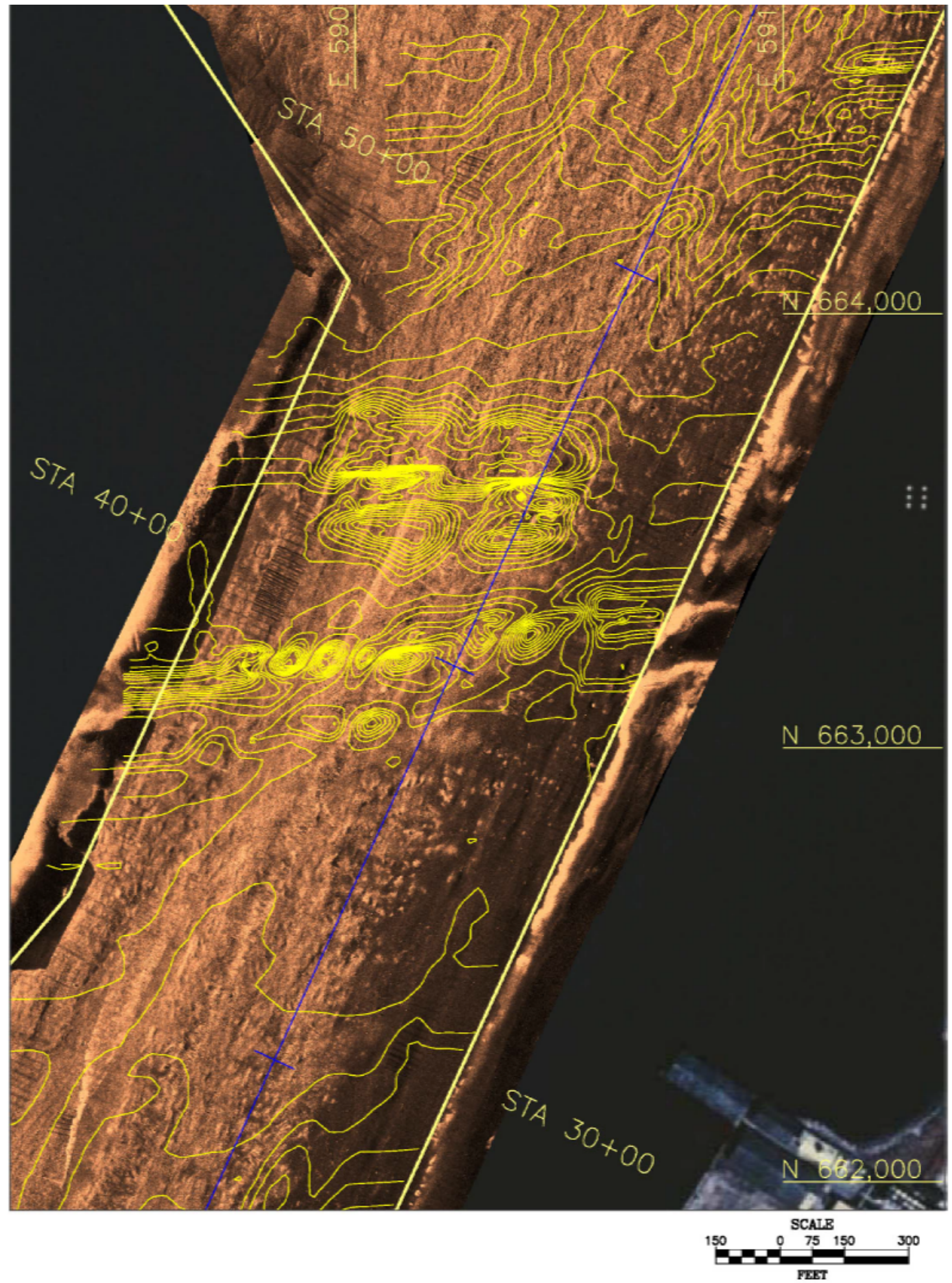
Magnetometer Survey – Arthur Kill Channel – O&G Pipelines



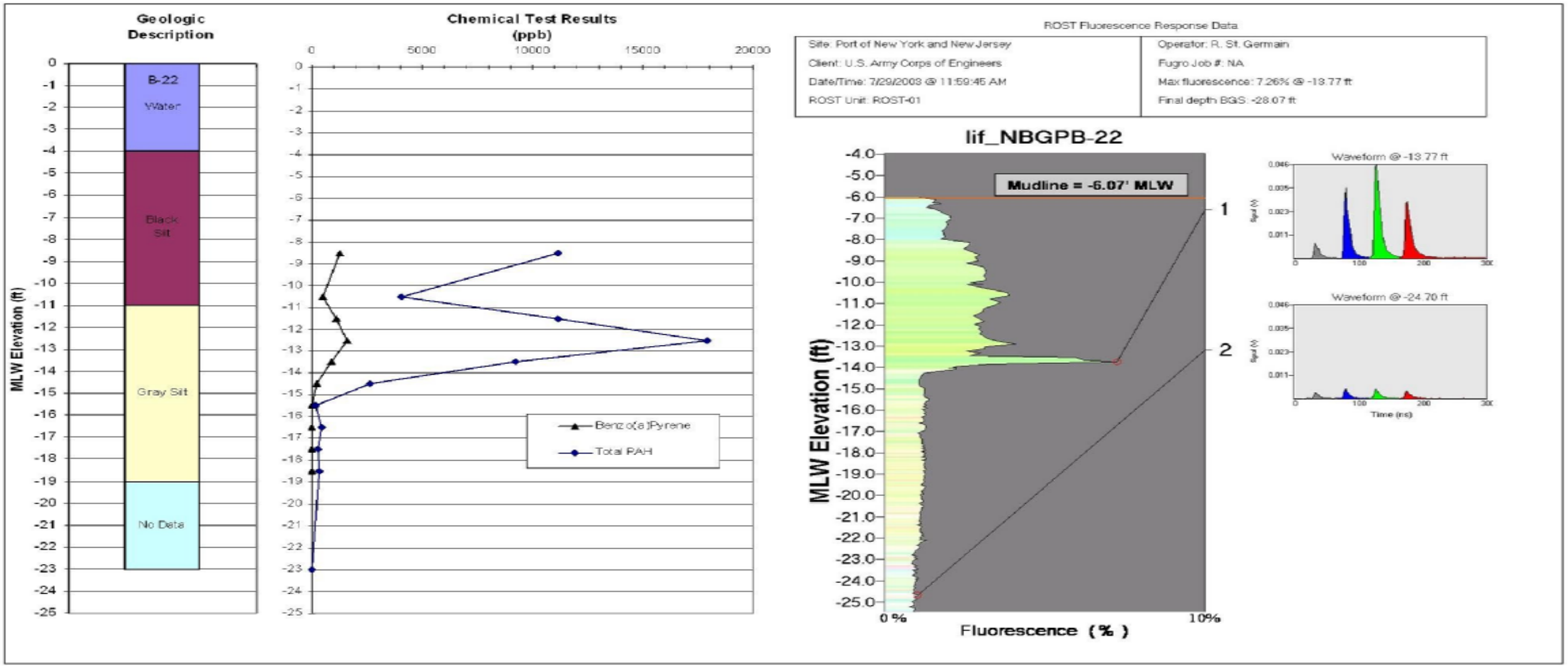
Magnetometer survey revealed the presence of a strong, linear anomaly to the west of known pipelines that was not documented.

Magnetometer Survey
Southern Newark Bay

Oil and Gas Pipelines and Old Railroad Structural Remnants



Laser Induced Fluorescence in Newark Bay – Comparison of Chemical Testing and LIF For Purpose of Identifying Upland Sediments



There are areas in the harbor where the black silt is more than twenty feet (20') thick. Contaminants generally occur in the upper few feet. Chemical testing can be used to break the silt into separate test reaches but chemical testing is expensive. If correlations such as this can be obtained it may be possible to obtain a relatively large number of points and map the layer more accurately and at a greatly reduced cost.

Comparison of LIF and Chemical Testing in Anchorage Channel – Identification of Upland Sediments