W00731

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service

DESCRIPTIVE REPORT

Type of Survey:	Reconnaissance
Registry Number:	W00731

LOCALITY

State(s):	Alaska
General Locality:	Kotzebue Sound
Sub-locality:	Kotzebue, Kivalina and Deering

2022

CHIEF OF PARTY
Ryan Cross

LIBRARY & ARCHIVES

Date:

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

REGISTRY NUMBER:

HYDROGRAPHIC TITLE SHEET

W00731

INSTRUCTIONS: The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office.

State(s):	**Alaska**
General Locality:	**Kotzebue Sound**
Sub-Locality:	**Kotzebue, Kivalina and Deering**
Scale:	**20000**
Dates of Survey:	**07/13/2022 to 08/11/2022**
Instructions Dated:	**N/A**
Project Number:	**ESD-AHB-24**
Field Unit:	**eTrac**
Chief of Party:	**Ryan Cross**
Soundings by:	**R2Sonic 2024 (MBES)**
Imagery by:	**EdgeTech 4205 (SSS)** **R2Sonic 2024 (MBES Backscatter)**
Verification by:	**Atlantic Hydrographic Branch**
Soundings Acquired in:	**meters at Mean Lower Low Water**

Remarks:

Any revisions to the Descriptive Report (DR) applied during office processing are shown in red italic text. The DR is maintained as a field unit product, therefore all information and recommendations within this report are considered preliminary unless otherwise noted. The final disposition of survey data is represented in the NOAA nautical chart products. All pertinent records for this survey are archived at the National Centers for Environmental Information (NCEI) and can be retrieved via https://www.ncei.noaa.gov/. Products created during office processing were generated in NAD83 UTM 3N, MLLW. All references to other horizontal or vertical datums in this report are applicable to the processed hydrographic data provided by the field unit.

DESCRIPTIVE REPORT MEMO

November 28, 2023

MEMORANDUM FOR: Atlantic Hydrographic Branch

FROM: Report prepared by AHB on behalf of field unit
Ryan Cross
Chief of Party, eTrac

SUBJECT: Submission of Survey W00731

General Communication Inc. (GCI) contracted eTrac Inc. (eTrac) to conduct geophysical and geotechnical surveys along the submarine cable routes of the Maniilaq Fiber Project (MFP). MFP is envisioned as two separate non-powered (unrepeatered) submarine fiber optic cables to bring high-speed connectivity from Kotzebue to the rural communities of Kivalina and Deering. The Kotzebue to Kivalina cable route is approximately 175 km long and includes a branching unit (BU) and a 15 km spur to a landing at the Red Dog Mine port. The Kotzebue to Deering cable route is approximately 98 km in length.

The External Source Data team created three grids based on geographic area from 7 submitted .xyz files.

All soundings were reduced to Mean Lower Low Water using VDatum. The horizontal datum for this project is North American Datum of 1983 (NAD 83). The projection used for this project is Universal Transverse Mercator (UTM) Zone 3.

All survey systems and methods utilized during this survey were as described in GCI Maniilaq Fiber Project Survey Report, attached to this memo.

All data were reviewed for DTONs and none were identified in this survey.

eTrac acquired the data outlined in this report. Additional documentation from the data provider may be attached to this report.

This survey does meet charting specifications and is adequate to supersede prior data.

GCI Maniilaq Fiber Project

Survey Report

DRAFT

20 September 2022

V1.3

Submitted to:

GCI

Attn. Bruce Rein
2550 Denali St.
Anchorage, AK 99503

Submitted by:

eTrac
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1 INTRODUCTION

General Communication Inc. (GCI) contracted eTrac Inc. (eTrac) to conduct geophysical and geotechnical surveys along the submarine cable routes of the Maniilaq Fiber Project (MFP).

MFP is envisioned as two separate non-powered (unrepeatered) submarine fiber optic cables to bring high-speed connectivity from Kotzebue to the rural communities of Kivalina and Deering. The Kotzebue to Kivalina cable route is approximately 175 km long and includes a branching unit (BU) and a 15 km spur to a landing at the Red Dog Mine port. The Kotzebue to Deering cable route is approximately 98 km in length (Figure 1-1).

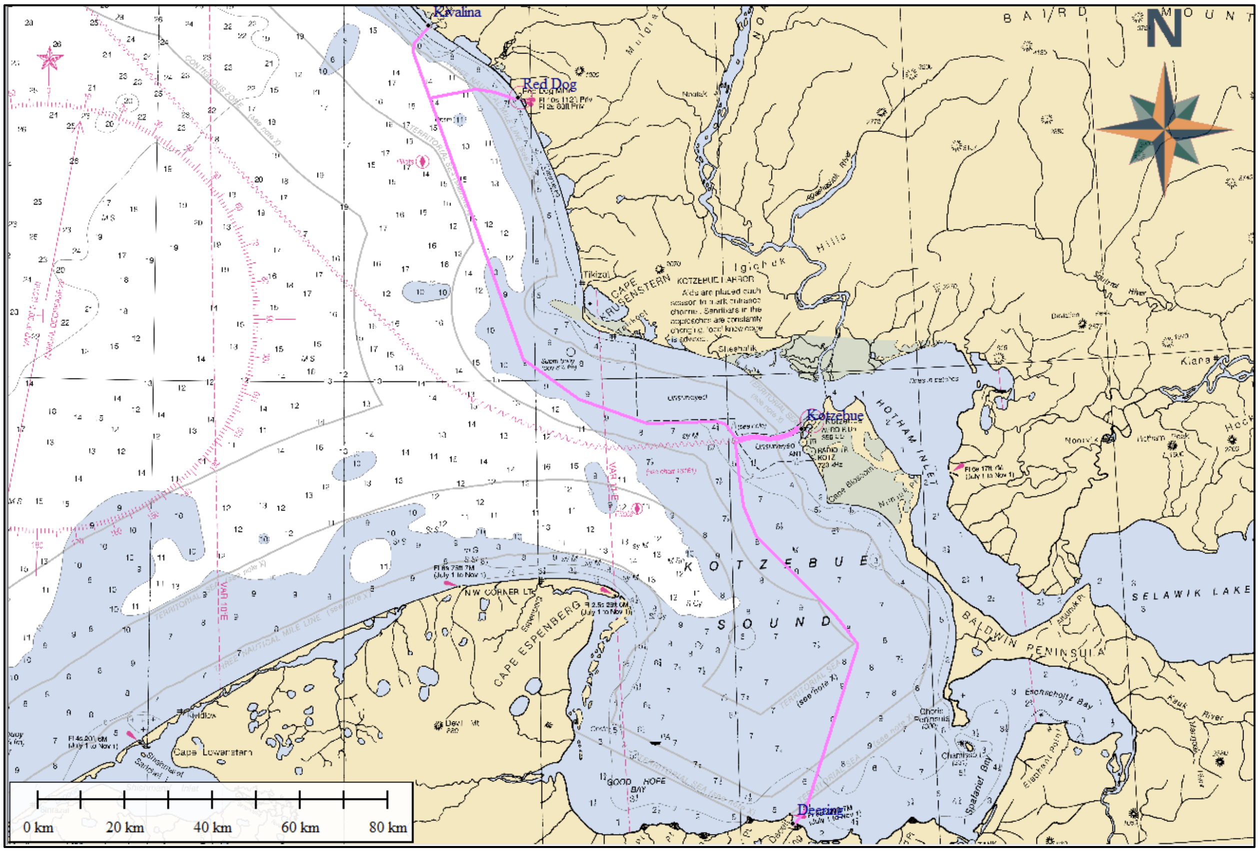


Figure 1-1 Maniilaq Fiber System Cable Routes and Landing Sites.

This report summarizes the geophysical and geotechnical survey operations, data processing and provides and interpretation of the geophysical and geotechnical results. Extensive research for the MFP route selection was provided to GCI in a separate report entitled "*GCI Maniilaq fiber Project Desktop Study 2022 V1.3*". This report should be read in conjunction with the DTS.

2 MOBILIZATION, TESTING, AND DEMOBILIZATION

2.1 Pre-mobilization and Vessel Transit to Site

Project mobilization started with staging and testing equipment at eTrac's office in Wasilla, AK. All equipment and supplies were then shipped to Kotzebue, AK in the week prior to onsite mobilization. eTrac's survey vessel, the *R/V Thunder* concluded survey work in the vicinity of Cape Newenham in early July, the vessel then returned to Bethell and prepared for the transit to Kotzebue. The *R/V Thunder* departed Bethel on July 4th at 5pm and arrived in Nome on July 7th at 1:30am. The vessel departed Nome on July 8th at 4am and arrived in Kotzebue on July 9th at 7:30am (Figure 2-1).

Figure 2-1. R/V Thunder transit path from Bethell to Kotzebue.

Figure 2-2. R/V Thunder in Kotzebue, AK

2.2 On-Site Geophysical Survey Mobilization and Testing

Onsite geophysical mobilization began on July 12th. The positioning system and multibeam echosounder (MBE) were already installed from the previous project, however the multibeam was removed and reinstalled to add a bracket for the sub-bottom profiler (SBP). Assembled or installed during the geophysical mobilization were the sub-bottom profiler, side scan sonar (SSS), magnetometer (MAG), cable counter, side scan sonar winch, and moving vessel profiler (MVP). A spare side scan sonar and spare magnetometer were also tested and staged on the vessel.

Also mobilized onto the vessel was a RAID array server, a SSS & MAG survey acquisition station and an onboard data processing station.

Once installed all offsets of sensors from the central reference point were measured. The inertial motion unit (IMU), which was installed close to the center of rotation, was selected as the vessel reference point for all sensors. Offsets shown in Table 2-1 were then entered into the acquisition software.

Table 2-1. R/V Thunder Survey Device Offsets

	X (Fwd) m	Y (Stbd) m	Z (down) m
IMU RP to R2 Sonic AC	**-0.682**	**-4.117**	**2.866**
IMU RP to Innomar AC	**-0.864**	**-4.602**	**2.888**
IMU to Approx. Center of Vessel Rotation	**0.000**	**-0.850**	**1.000**
IMU to Primary Ant	**7.970**	**1.027**	**-3.600**
Ant baseline Pri. to Sec. (Measured)	**0.000**	**-3.750**	**0.000**
Ant baseline Pri. to Sec. (GAMS results)	**-0.041**	**-3.757**	**-0.052**

Sensors were integrated with position and timing messages and computers were networked to the server for data transfer and storage.

System testing included the following individual procedures:

- MBE:
    - Data collection to evaluate signal to noise ratio and adjust instrument settings
    - Patch test to evaluate angular misalignment between the IMU and sonar head
    - Data collection over NOAA bathymetric data to evaluate surface feature alignment.
- SBP:
    - Data collection to optimize settings and evaluate sub-surface signal penetration and resolution.
- SSS:
    - Rub test on deck to check functionality
    - Data collection to evaluate data quality and feature alignment with bathymetric data.
- Magnetometer:
    - Rotation of sensor for high latitude operation. Application of pressure sensor and altimeter scalar and bias.
    - Data collection over quintillion cable to evaluate signal response and target alignment.
- Cable Counter:
    - Sheave calibration and preset determination.
- MVP:
    - Testing of operation and confirmation of sound velocity reading with surface probe.

Systems were also operated simultaneously to evaluate signal crosstalk. A combination of triggering and frequency shifting was utilized to minimize acoustic interference between systems.

Although technically part of the geotechnical program, the grab sampler was mobilized on July 21st during weather standby to allow sampling in Zone 1 when geophysical survey operations were not possible in other areas.

2.3 On-Site Geotechnical Survey Mobilization

On August 3rd the *R/V Thunder* was mobilized for geotechnical survey with a Piston Core. At the same time the geophysical systems were partially demobilized. The positioning system and multibeam system remained in place as there were a few small gaps in the bathymetric data that would be filled during the geotechnical campaign.

Geotechnical mobilization on the R/V Thunder consisted of clearing the deck of all geophysical survey equipment, assembling the piston core, trimming core liners to length, building a launch and recovery guide on deck, and setting up a core analysis station.

The piston core was then tested at one of the nearest stations in Zone 1. After a few cycles of launching and recovering the corer to improve the efficiency and safety of operations, geotechnical mobilization was considered complete.

Figure 2-3. Piston Core and core liners ready for mobilization.

2.4 Demobilization

Demobilization of the geotechnical kit and the remaining geophysical components commenced on Aug 12th. All equipment was removed from the vessel and shipped to Anchorage or beyond. The R/V *Thunder* was prepared for transit. Due to weather conditions in the Bering Strait the R/V *Thunder* did not depart Kotzebue until Aug 18th.

2.5 Xtratuff Mob and Demob

Near the entrance to the Kotzebue Channel there is a shoal that could not be safely surveyed from the *R/V Thunder.* Therefore, a local vessel of opportunity was required. The local vessel was the *Xtratuff*, an aluminum landing craft with twin 225HP outboards. The *Xtratuff* was mobilized for bathymetric survey on Aug 10th and was demobilized on August 17th.

Figure 2-4. Xtratuff mobilized for shallow water bathymetric survey.

3 SURVEY OPERATIONS

3.1 Geophysical Survey Equipment

3.1.1 POSITIONING

On the *R/V Thunder* an Applanix POS MV V5 Inertial Navigation System (INS) with real time Marinestar G4+ corrections provided positioning and heading. The POS MV inertial motion unit (IMU) supplied angular measurements of pitch, roll, yaw as well as heave.

On the *Xtratuff* a R2Sonic I2NS INS was utilized.

3.1.2 MBE

Survey operations utilized a pole mounted R2Sonic 2024 on the *R/V Thunder*. The 2024 was operated at a frequency of 350kHz, with 256 beams per ping. The R2Sonic recorded bathymetric data as well as echo intensity (backscatter data). An R2Sonic 2020 was utilized on the *Xtratuff.*

3.1.3 SBP

An Innomar Compact parametric sub-bottom profiler was utilized for sub-bottom imaging. The Innomar low frequency was set to 12kHz.

3.1.4 SSS

The side scan sonar was an EdgeTech 4205 tri-frequency and was operated at a range of 75m. The low (~120kHz) and mid (~410kHz) frequencies were recorded. Only the mid frequency side scan sonar records were processed.

3.1.5 MAG

The Geometrics G882 magnetometer was towed in tandem aft of the side scan sonar. Magnetometer data was only acquired at the Quintillion cable crossing and on route centerlines in the vicinity of established lightering zones.

3.1.6 SOUND VELOCITY

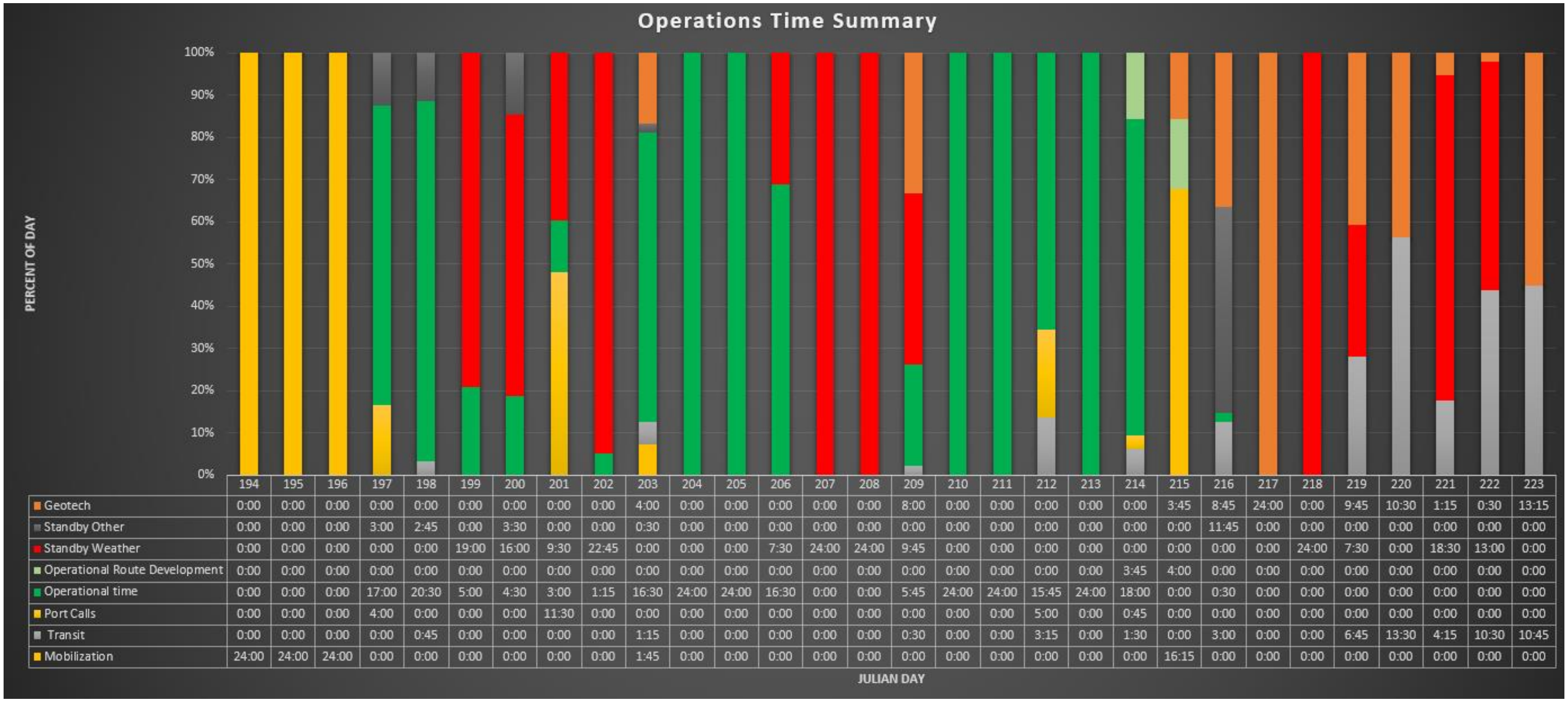
Sound velocity was measured with an AML MVP or AML Base-X using direct speed of sound sensors.

3.2 Geotechnical Survey Equipment

The geotechnical survey equipment consisted of a MSI Piston Corer configured with a 2-meter barrel and a vanveen style grab sampler.

3.3 Vessel Time Summary

Records of operations started on the first day of mobilization, July 13th or Julian Day 194. Records are based on UTC time and end on the last day of survey operations (Aug 11, 2022, or JD223). A summary of time utilization is presented in Figure 3-1. For details regarding operations on each day please see the Daily Progress Reports.



	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208
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■ Standby Other	0:00	0:00	0:00	3:00	2:45	0:00	3:30	0:00	0:00	0:30	0:00	0:00	0:00	0:00	0:00
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🟩 Operational Route Development	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00
🟩 Operational time	0:00	0:00	0:00	17:00	20:30	5:00	4:30	3:00	1:15	16:30	24:00	24:00	16:30	0:00	0:00
🟨 Port Calls	0:00	0:00	0:00	4:00	0:00	0:00	0:00	11:30	0:00	0:00	0:00	0:00	0:00	0:00	0:00
■ Transit	0:00	0:00	0:00	0:00	0:45	0:00	0:00	0:00	0:00	1:15	0:00	0:00	0:00	0:00	0:00
🟨 Mobilization	24:00	24:00	24:00	0:00	0:00	0:00	0:00	0:00	0:00	1:45	0:00	0:00	0:00	0:00	0:00

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🟧 Geotech	8:00	0:00	0:00	0:00	0:00	0:00	3:45	8:45	24:00	0:00	9:45	10:30	1:15	0:30	13:15
■ Standby Other	0:00	0:00	0:00	0:00	0:00	0:00	0:00	11:45	0:00	0:00	0:00	0:00	0:00	0:00	0:00
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■ Transit	0:30	0:00	0:00	3:15	0:00	1:30	0:00	3:00	0:00	0:00	6:45	13:30	4:15	10:30	10:45
🟨 Mobilization	0:00	0:00	0:00	0:00	0:00	0:00	16:15	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00

Figure 3-1. Time summary analysis for each task based on UTC days starting on the first day of mobilization.

3.4 Shore Side Support

In addition to offshore survey operations, a shore side office was set up for data processing and logistical support (Figure 3-2). At the shore side office, a second RAID array data server hosted a shore side copy of the raw and processed data. A hydrographic data processor and geophysicist processed and evaluated data providing a second level of QC, and preliminary interpretation.

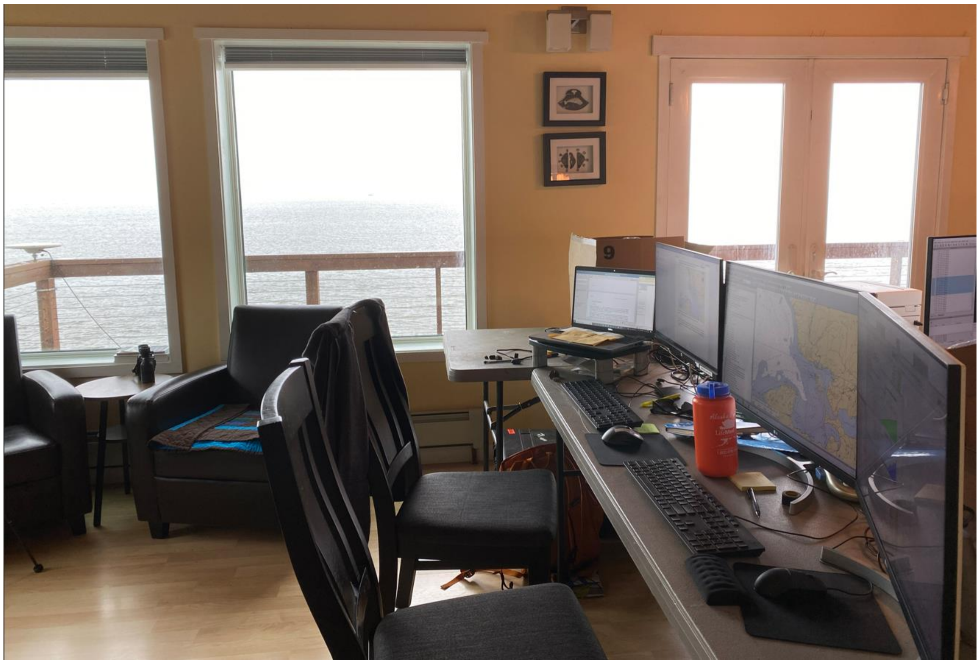


Figure 3-2. Data processing and analysis workstations at the shoreside support office.

3.5 GNSS Base station and shift to MLLW

Recorded navigation files were post processed using POSPac MMS. GNSS observations from UNAVCO Station AB18 were utilized. Station AB18 is a continuously operating station located near Kotzebue and part of the Network of the Americas (NOTA). AB18 records 15 second observations utilizing a Septentrio PolarRx5 receiver with a Trimble Choke Ring antenna.

The post processed navigation was applied to the bathymetric data. The bathymetric data was vertically shifted from the recorded ellipsoid heights to the Mean Lower Low Water (MLLW) tidal datum using a WGS84 ellipsoid to MLLW separation model provided by NOAA's office of Coast Surveys. Sub-bottom records were also vertically corrected to MLLW based on the postprocessed bathymetric data.

4 GEOPHSICAL DATA PROCESSING

4.1 SSS Data Processing

Side scan sonar data was processed in Chesapeake Technologies SonarWiz7. .XTF files were converted to CSF files for processing. Bottom tracking and gain corrections, nadir filtering and display range editing was performed to optimize the image quality. A series of mosaic tiles with a 1m resolution was exported for each zone.

A pycnocline resulted in refraction and unacceptable noise in the outer ranges of the SSS data (Figure 4-1). A change in sound velocity of up to 20 m/s occurs at the pycnocline. To mitigate this refraction and loss of signal the side scan sonar was flown below the pycnocline when possible. Further mitigation was applied in post processing by reducing the displayed range of each side scan sonar image to build a mosaic.

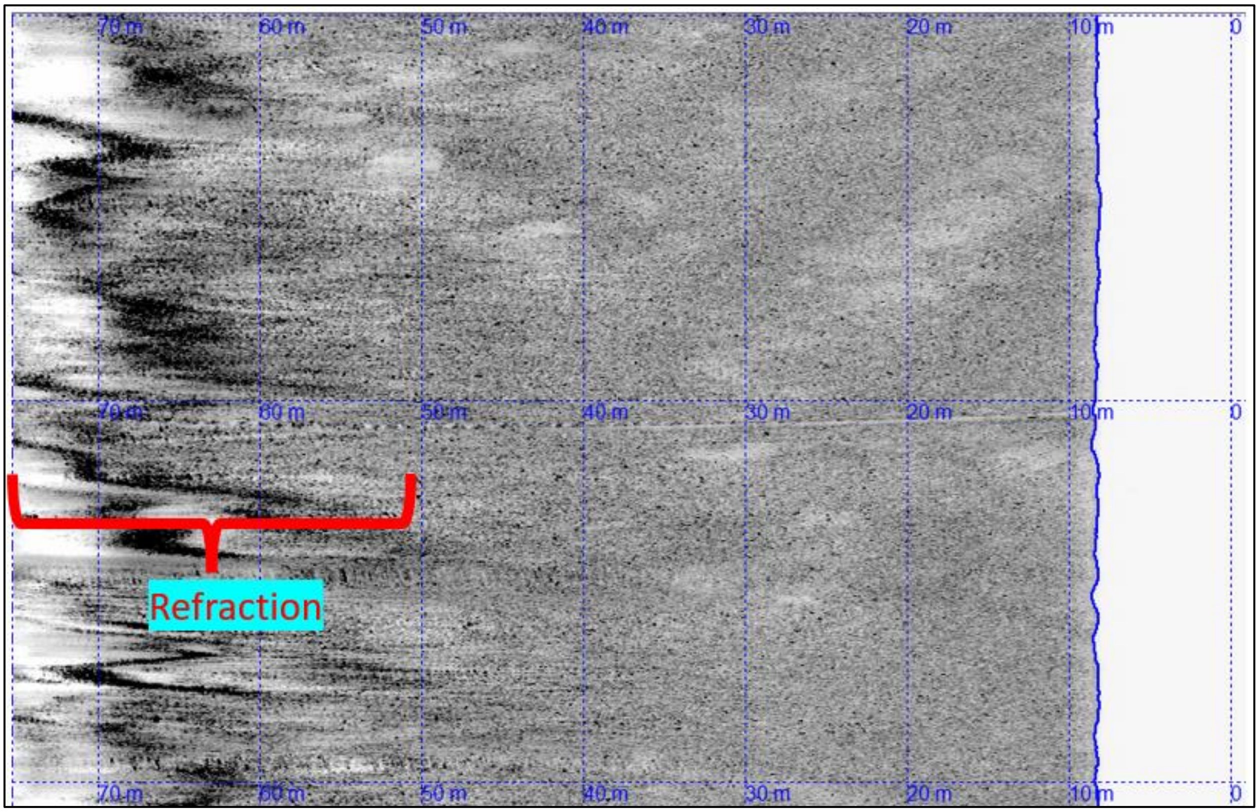


Figure 4-1. Example side scan image where seafloor reflection is lost beyond 50 meters due to refraction of the sound waves as they traverse the pycnocline.

The side scan data detected surface sediment variations, which was used in conjunction with multibeam backscatter and geotechnical samples to analyze the distribution of surface sediments. An example of the side scan sonar mosaic from Zone 2 is shown in Figure 4-2.

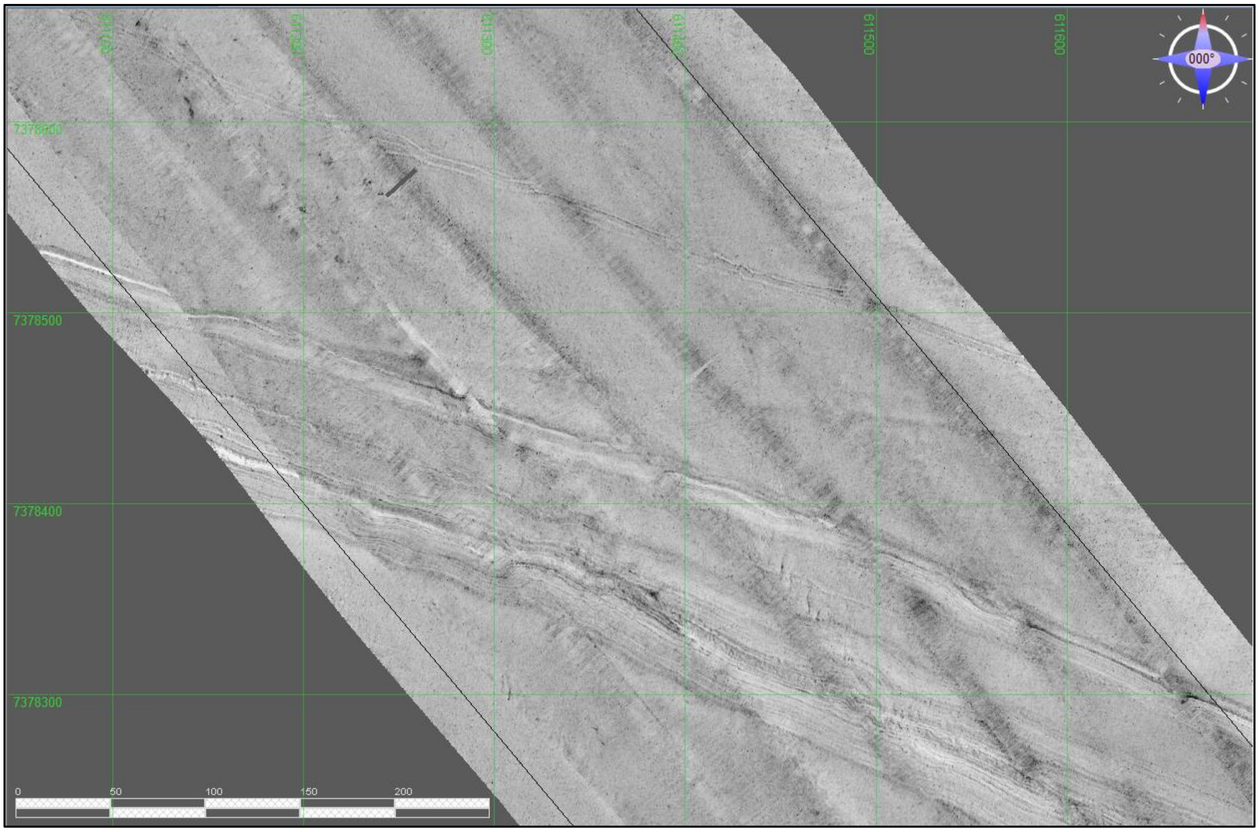


Figure 4-2. Zone 2 side scan sonar mosaic

4.2 **SBP Data Processing**

Sub-bottom data was processed in Chesapeake Technologies SonarWiz7. .raw files from the Innomar were converted to .SGY. In SonarWiz the .SGY files were converted to .CSF for editing. In SonarWiz the centerline files were bottom tracked and then gain corrected before blanking the water column and datum correcting the sub-bottom data to the bathymetric surface. Piston core locations were added in SonarWiz for planning and then interpretation and integration of the geophysical and geotechnical results. Final datum corrected sub-bottom centerline profiles were exported as .SGY files.

4.3 **MAG Data Processing**

Magnetometer data was processed in SonarWiz. .CSF files that were written in real-time during acquisition were examined in SonarWiz. Magnetic field strength anomalies were then selected using the magnetometer editor and anomaly selection tools in SonarWiz. Magnetometer data was exported from SonarWiz as ascii text X,Y,Gamma.

5 SURVEY RESULTS AND INTERPRETATIONS

The results of the geophysical and geotechnical survey are organized by Zones and then discussed with references to route kilometer markers along the Kotzebue to Deering (K-D), Kotzebue to Kivalina (K-K), or Branching Unit to Red Dog (BU-RD) routes.

The geophysical and geotechnical results allow for an integrated interpretation of the geological and geophysical properties of the route. Therefore, rather than present the results in the order they were collected (geophysical and then geotechnical) the results are presented in a more integrated way using multiple data sets to draw conclusions. Within each zone the results are generally presented with the most quantitative and factual results first, such as bathymetry and sediment properties. This is followed by an integrated interpretation of surficial and sub-surface sediments and their properties.

Bathymetry and Seafloor Features: Using the results of the multibeam echosounder water depths along the route relative to MLLW are presented. The multibeam bathymetry and side scan sonar imagery where it is applicable are then used to analyze the seafloor morphological features.

Geotechnical Results: The factual findings of the geotechnical sampling are presented to allow integration with the geophysical data in the following sections. This includes the quantitative results of core sample recovery, shear strength, and compressive strength along with the qualitative results of the descriptive sediment logs.

Surface Sediments: Using the results of the side scan sonar and backscatter from the multibeam sonar the acoustic intensity of seafloor reflections and that relationship to seafloor sediment characteristics and surface sediment samples is presented.

Sub-surface Stratigraphy: The results of the sub-bottom profiler data are integrated with the coring data to discuss the sub-surface stratigraphy.

Magnetometer Anomalies: The results of the magnetometer data if acquired in that zone are discussed. Note that the cable crossing in Zone 1 is discussed separately in Section 5.7.

Six zones subdivide the MFP project area and are shown in Figure 5-1. Note that Zone 1 contains both the K-K route and the K-D route. Therefore, in Zone 1 both routes are discussed in parallel. Similarly, Zone 6 contains both the northern extent of the K-K route and the BU-RD route.

This report is meant to be read in conjunction with the DTS and viewed in conjunction with the North-Up and Alignment Charts or GIS database. The following sections are meant to be read in order as common features are discussed in detail when first encountered and then mentioned without further explanation in later sections.

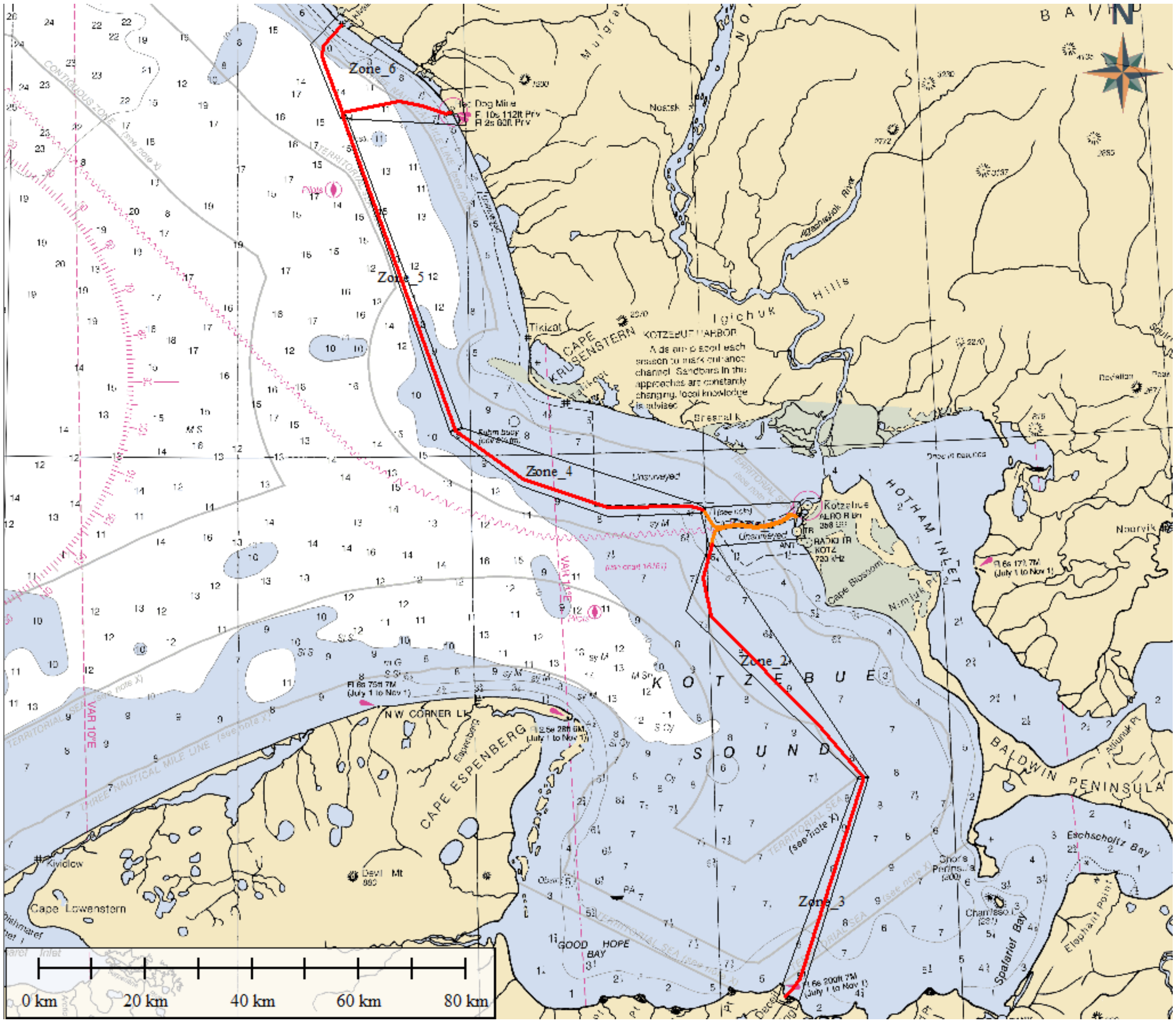


Figure 5-1. MFP Survey Zones.

5.1 Zone 1: K-K KP 0.0 to 18.5 & K-D KP 0.0 to 20.0

Zone 1 starts at the Kotzebue BMH and encompasses the narrow and shallow channel that stretches 15 km to the west. The west end of Zone 1 is defined by the 8 m depth contour and the start of Zone 2 for the K-D route and Zone 4 for the K-K route. Much of Zone 1 is very shallow and includes the Kotzebue landing and the Kotzebue channel shoal where water depths are less than 3 meters.

5.1.1 BATHYMETRY AND SEAFLOOR FEATURES

The bathymetry data coverage in Zone 1 starts at about 400 meters from shore where water depths are just 1.6 m (MLLW) At KP 0.5 water depths are 3 m and the survey area covers a 150 m corridor along both routes to KP 18.5 where depths reach 8 meters. Between KP 13.7 and KP 15.8 water depths are less than 3 m and were acquired from separate shallow draft vessel of opportunity (Figure 5-2, and Figure 5-3). Water depths in the channel range from less than 3 to 9.5 m with an average depth of approximately 7 m. Outside of the shoal water depths increase from 3 to 8 m over approximately 3 km.

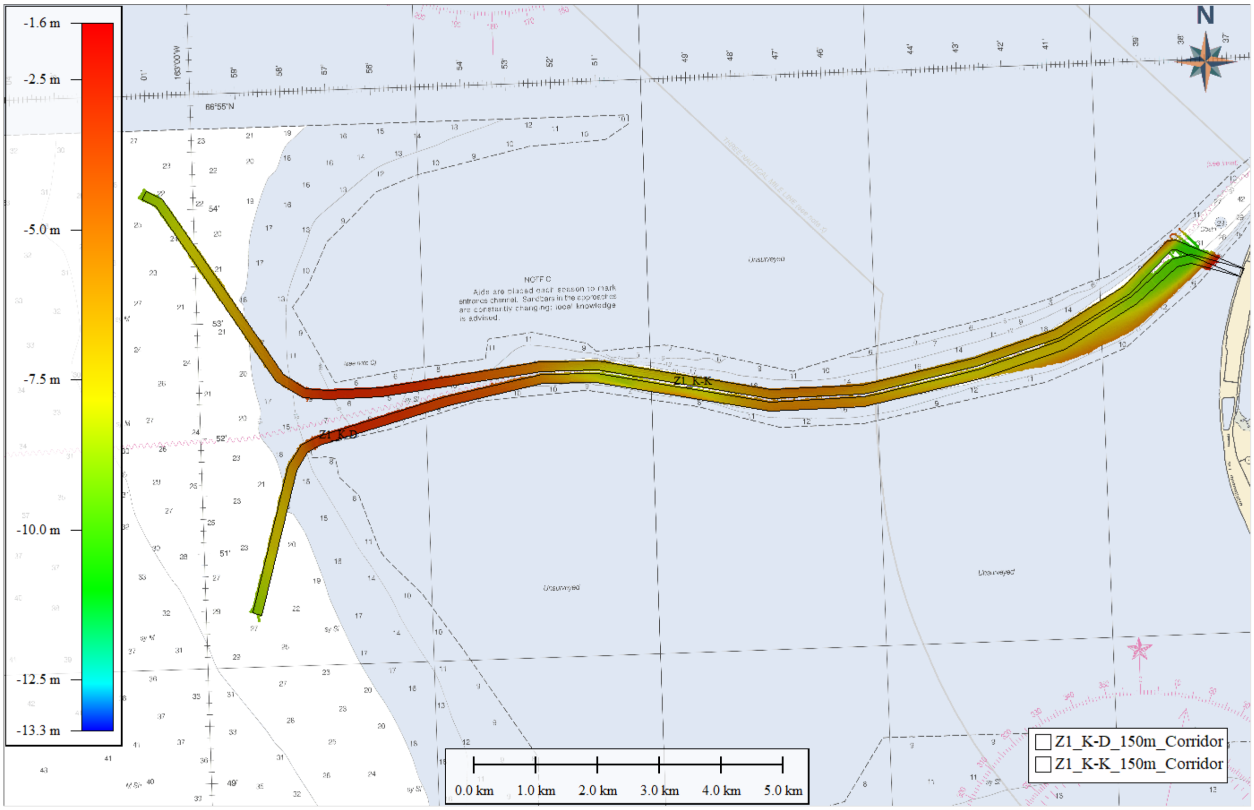


Figure 5-2. Zone 1 Bathymetry covering both the K-K and K-D routes

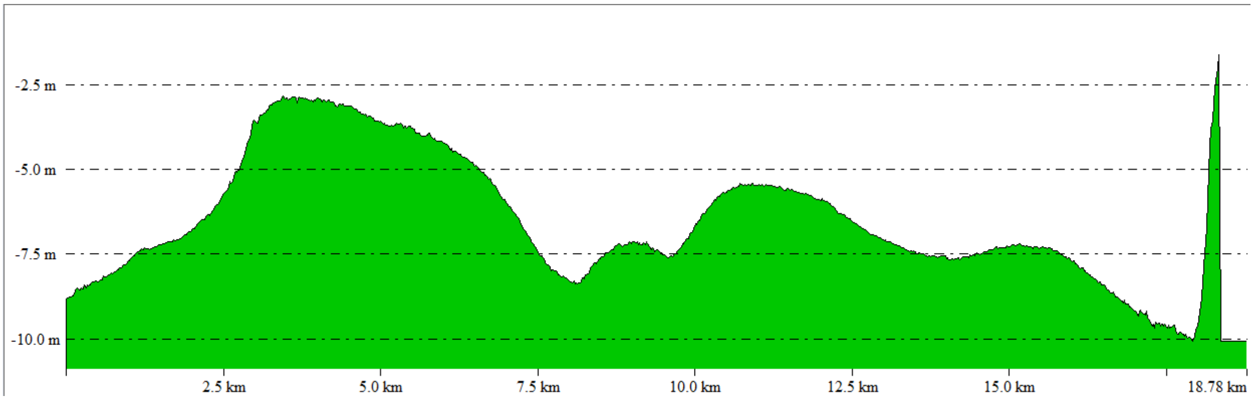


Figure 5-3. Zone 1 K-D bathymetric profile (West of Zone 1 on the left, East end on the right).

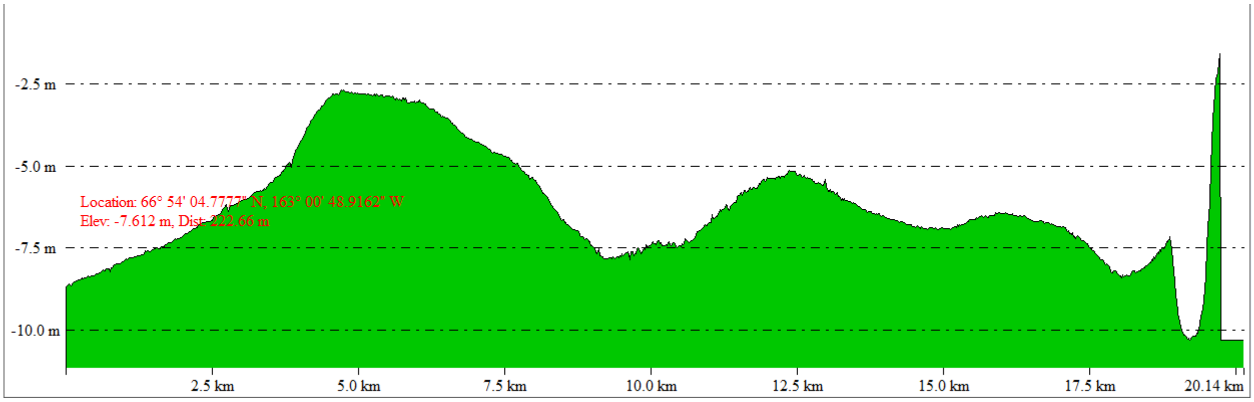
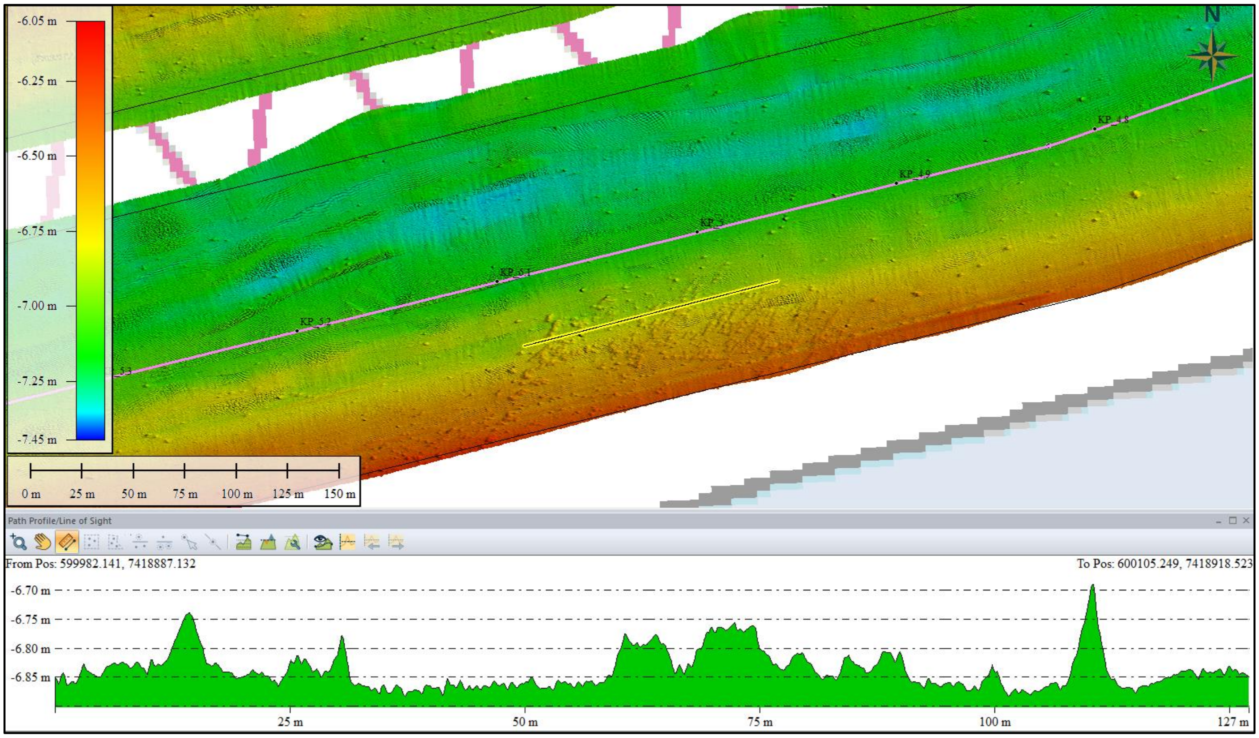


Figure 5-4. Zone 1 K-D bathymetric profile (West of Zone 1 on the left, East end on the right).

Between KP 0.5 and KP 6.0 the seafloor is scoured with abundant mounds or hummock-like features. These mound features vary in length from 1 to 12 m with heights above the surrounding seabed of 0.1 to 0.2 m (Figure 5-5). These features are the result of differential erosion of the seabed by the currents in the channel. Scouring occurs around more erosion resistant seabed soils. Many of the mounds are asymmetrical with additional seabed scour down current of the features.

The seafloor is most scoured in the deepest part of the channel. There is no evidence to suggest the composition of these mounds are rock or a different sediment type than the surrounding seabed. Based on the bathymetric data more than 1500 mounds were digitized (Figure 5-6).



From Pos: 599982.141, 7418887.132

To Pos: 600105.249, 7418918.523

Figure 5-5. Example of seafloor mound features in Zone 1.

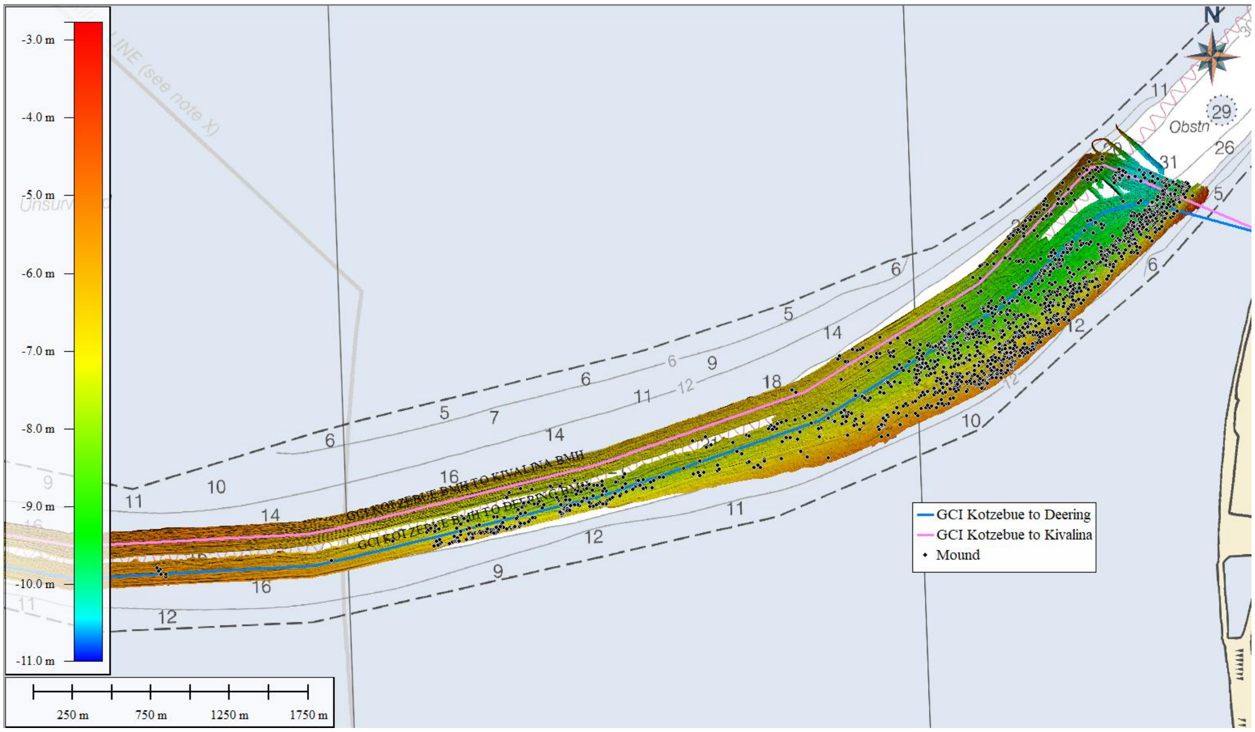
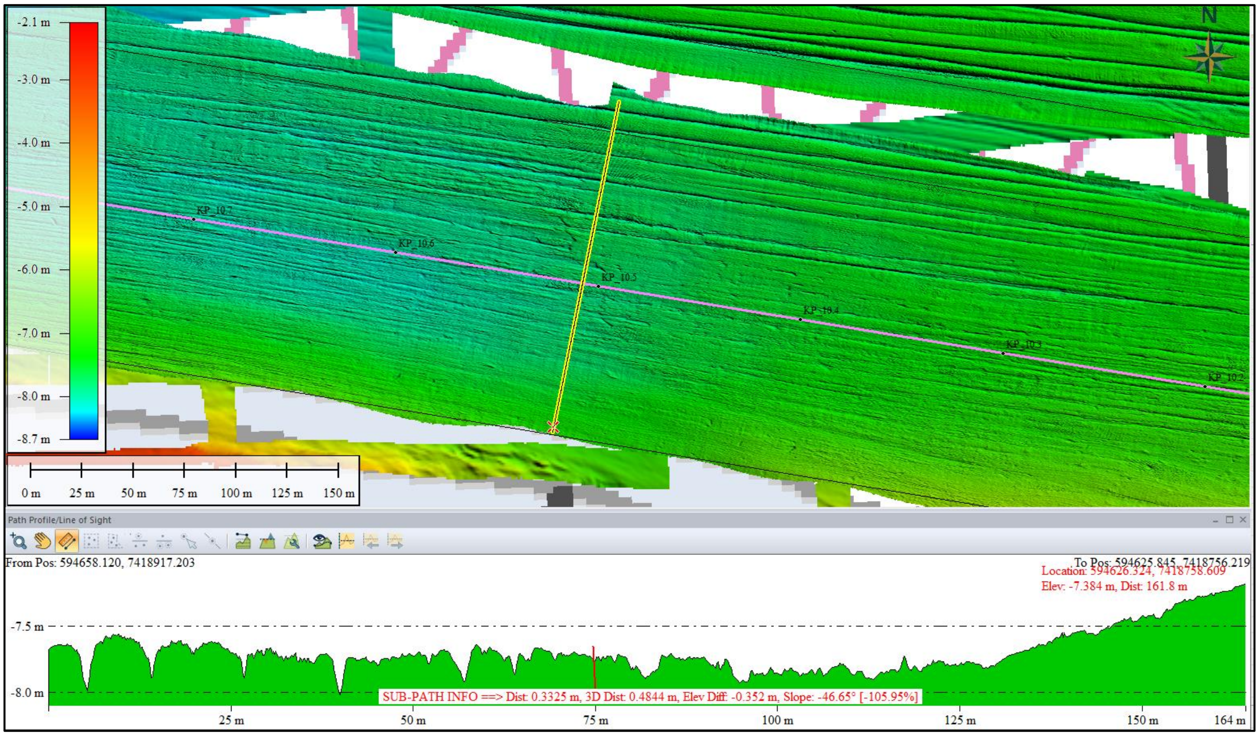


Figure 5-6. Digitized mounds in Zone 1

Between KP 6 and KP 8 the seabed is relatively flat and mostly featureless with only a handful of small scour holes and mounds. Water depths here are 5.5 to 6 meters.

From KP 8 to KP 11 water depths increase from 6 to 8 plus meters. Here the seafloor is dominated by seabed striations that follow the gentle curve of the channel. These striations occur across the width of the survey corridor (Figure 5-7). Scours are up to 0.4 m deep. Based on bathymetric data acquired by NOAA in 2011 the seafloor striations change slowly over time. Some striations remain unchanged while others have appeared, disappeared or shifted. These striations are likely the result of seabed scour by water or possibly water laden with broken river and lake ice. The scours in the channel are different than the ice scours seen outside of the channel which are the result of ice keels gouging into the seabed at a discrete point in time.



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To Pos: 594625.845, 7418756.219

Location: 594626.324, 7418758.609

Elev: -7.384 m, Dist: 161.8 m

SUB-PATH INFO ==> Dist: 0.3325 m, 3D Dist: 0.4844 m, Elev Diff: -0.352 m, Slope: -46.65° [-105.95%]

Figure 5-7. Zone 1 seafloor striations

Between KP 11.3 and KP 11.6 the striations end abruptly with a cluster of scour holes and other elongated seafloor scours (Figure 5-8). These scours are presumably caused by ice, water flow, or both as the channel begins to shoal. These scour holes are generally a few meters across and 10 to 20 cm deep. In Zone 1 more than 560 scour hole features were digitized from the bathymetric data with nearly 400 in this 0.5 km long section.

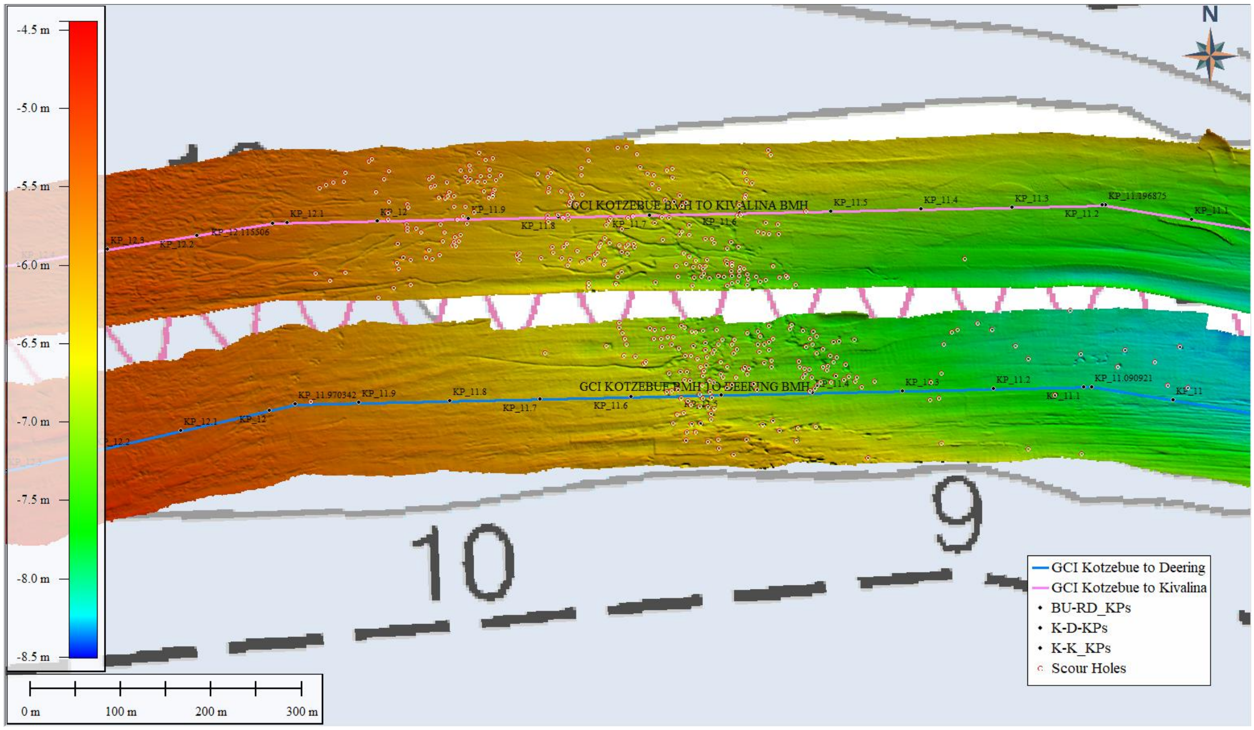


Figure 5-8. Seabed scours at the west end of the striations just east of the Kotzebue channel entrance shoal.

From KP 11.6 to KP 13.7 the seabed shoals to 3.0 meters with little to no surface features.

From KP 13.7 to 15.8 water depths are less than 3 meters and were surveyed with a local vessel of opportunity. In water depths less than 3.2 meter, near KP 15, 8 scour holes were identified. These scours are up to 40 m in diameter and up to 0.6 meters deep (Figure 5-9).

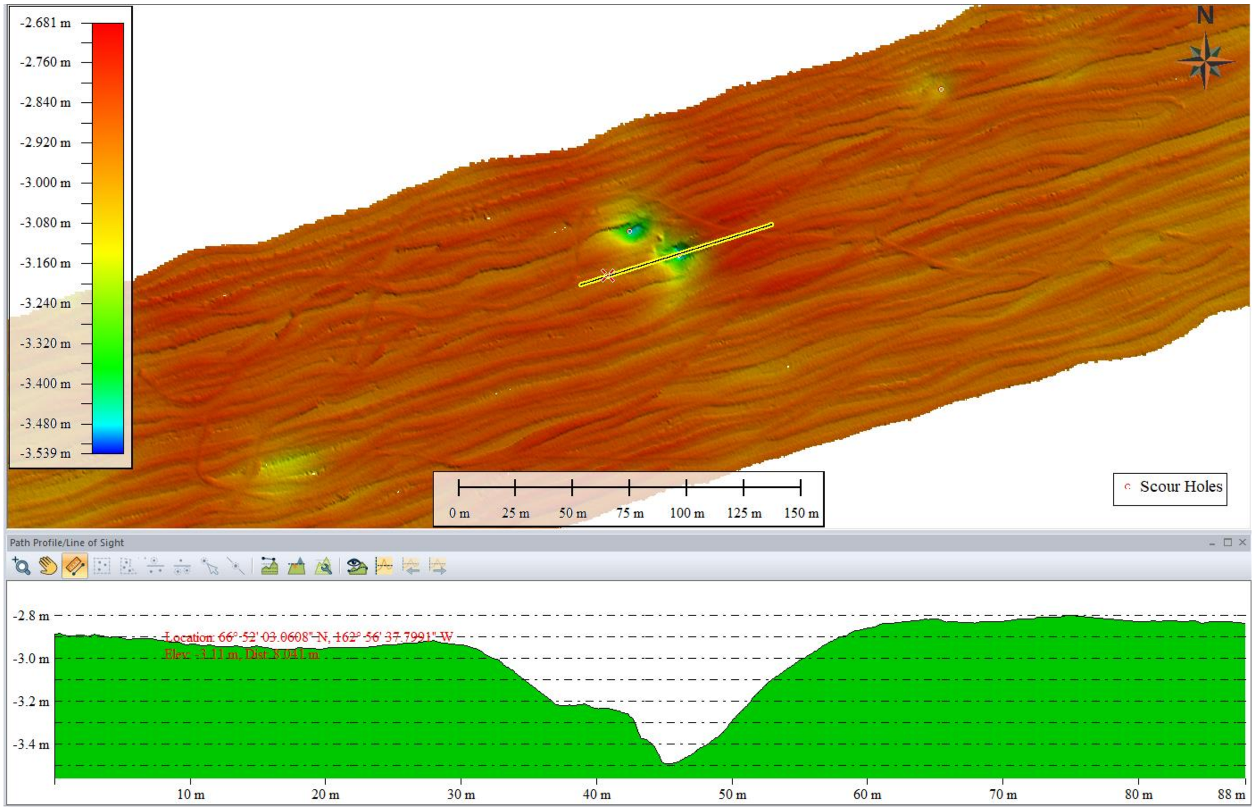
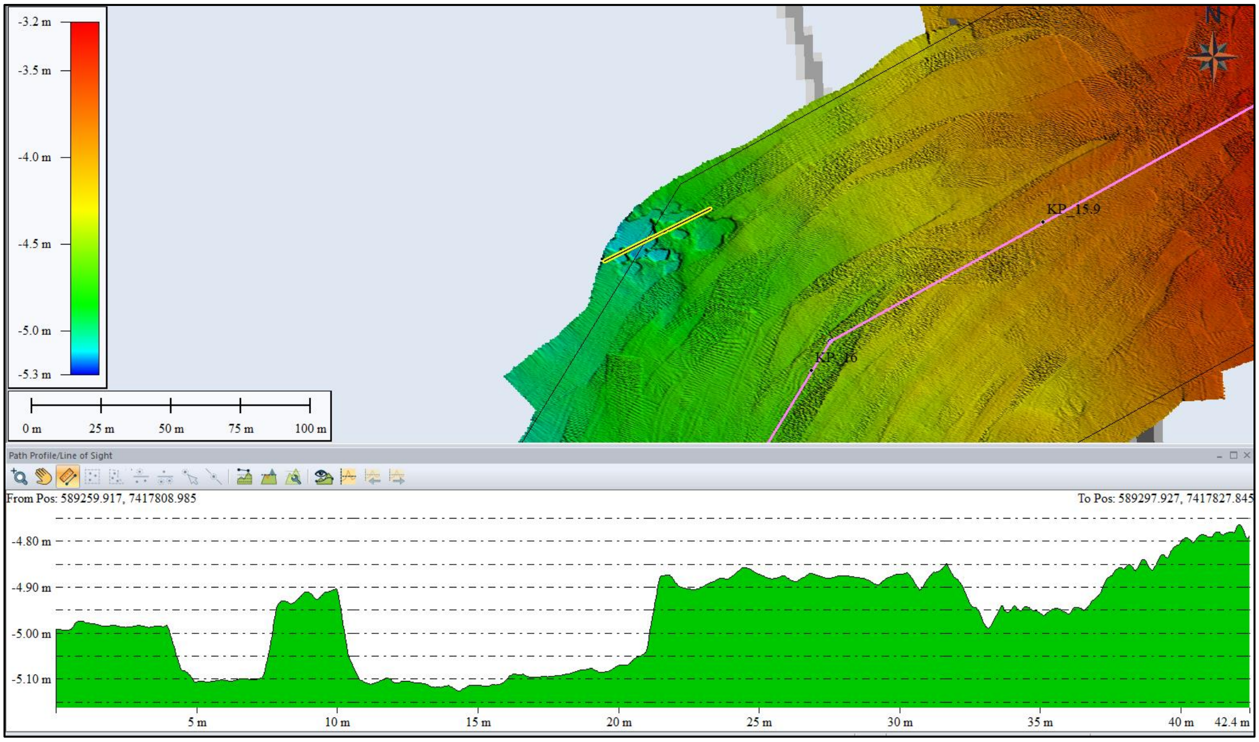


Figure 5-9. Example of scour hole in shallow waters of Zone 2.

At K-D KP 16.0 and 100 m northwest of the route a pattern of larger but shallower semicircular seafloor scour depressions are observed (Figure 5-10).



From Pos: 589259.917, 7417808.985

To Pos: 589297.927, 7417827.845

Figure 5-10. Seabed scours located west of the Kotzebue entrance channel shoal.

Given the proximity of these scours are on or adjacent to the channel entrance, is seems probable that the scouring is related to the high-volume water discharge from the channel.

Along the K-D route the first ice keel scour is encountered at KP 16.6 in a water depth of 6.5 meters. Between KP 17.0 and KP 17.1 a unique pattern of scouring and seabed topography is present west of the route center line. A 10-meter diameter 0.3 m deep scour hole is adjacent to NNW by SSW linear scours. The scoured surface appears slightly elevated above the surrounding seafloor.

Along the K-D route between KP17 and the end of Zone 1 at KP 18.5 there are occasional narrow, isolated unremarkable ice scours with depths of no more than 0.1 meters.

New ice scours that were not present in the 2011 NOAA data are observed in the MFP 2022 bathymetric data. Also, some ice scours observed in the NOAA data from 2011 are no longer present in the 2022 MFP data and appear to have been infilled. This indicates that seafloor ice scouring is active and that scours observed in the 2022 bathymetric data reflect the current regime of ice scouring along the route (Figure 5-11).

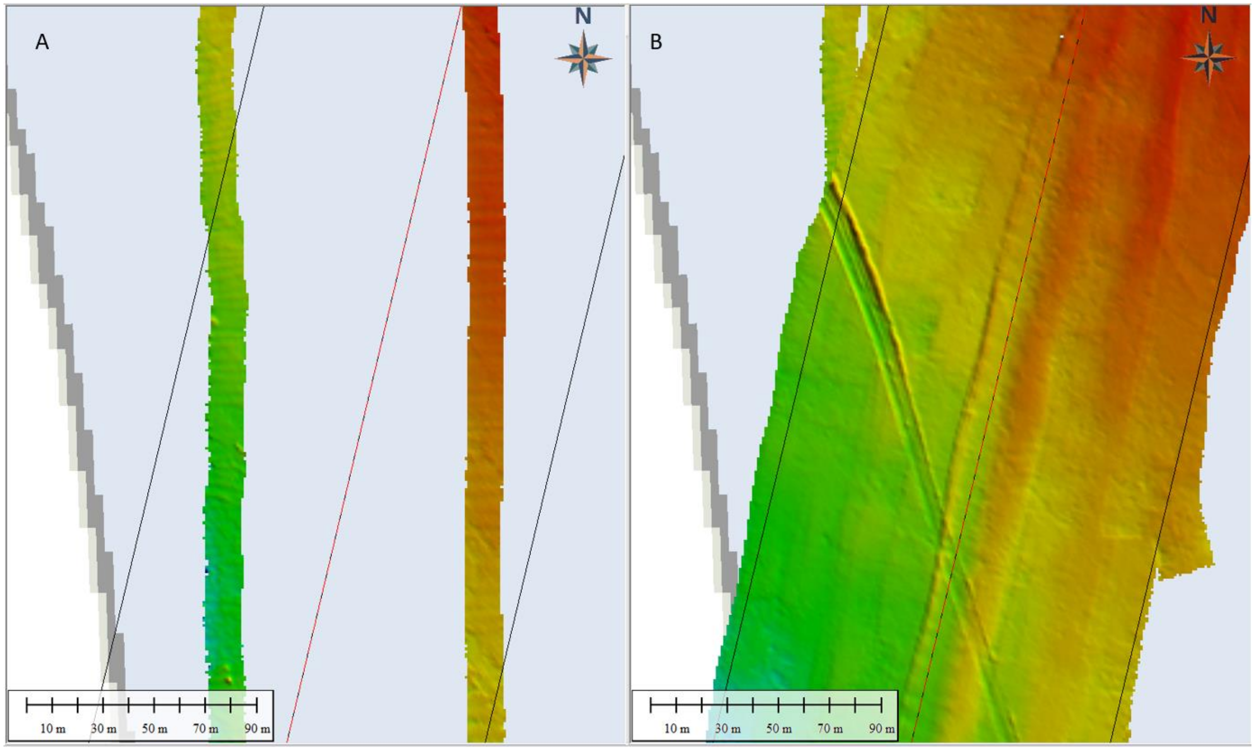


Figure 5-11. A: NOAA data from 2011, B: MFP data from 2022 of the same area showing a new ice scour.

Along the K-K route the first ice keel scour is encountered at KP 16.3 in a water depth of 5.1 meters. This north-south oriented ice scour has a sharp western boundary while the eastern boundary appears to be filling with prograding sediments from the Kotzebue Channel.

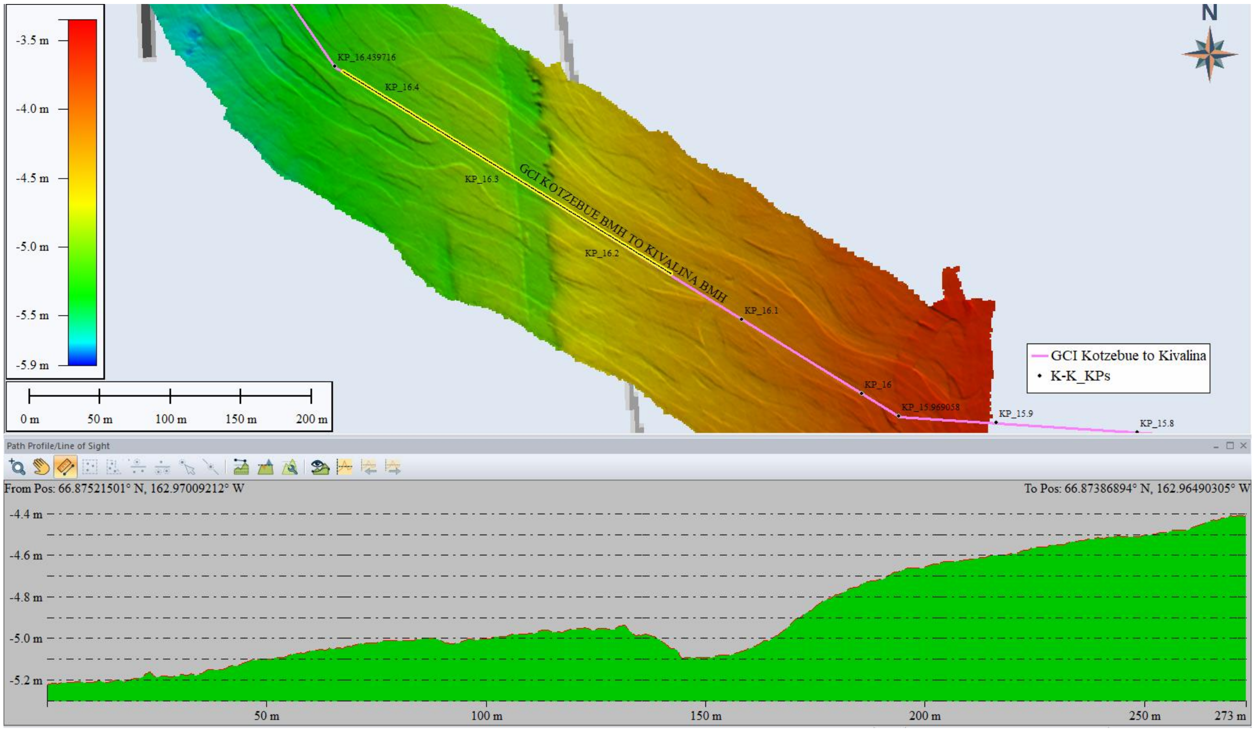


Figure 5-12. Ice keel scour in shallow water along the K-K route infilling with prograding sediments from the Kotzebue Channel.

From the ice scour at KP 16.3 to the western end of the K-K route in Zone 1 at KP 20 water depths increase gradually from 5 to 8 meters with only a few additional ice scours between KP 19 and 20.

5.1.1 GEOTECHNICAL RESULTS

45 grab samples and 8 piston cores were collected in Zone 1 (Figure 5-13). Inside of the Kotzebue Channel the seabed sediment is predominantly composed of wet, soft to very soft clay and silty clay. Most samples were noted as having high plasticity and medium or low dilatancy. Near the shoal, fine sand was observed in one grab sample. Note that no geotechnical data was collected in water depths less than 3 m. Outside of the channel the predominant surface sediment is silt based on both the grab samples and surface sediments of the cores. Additional details are provided in Table 5-1 and Table 5-2.

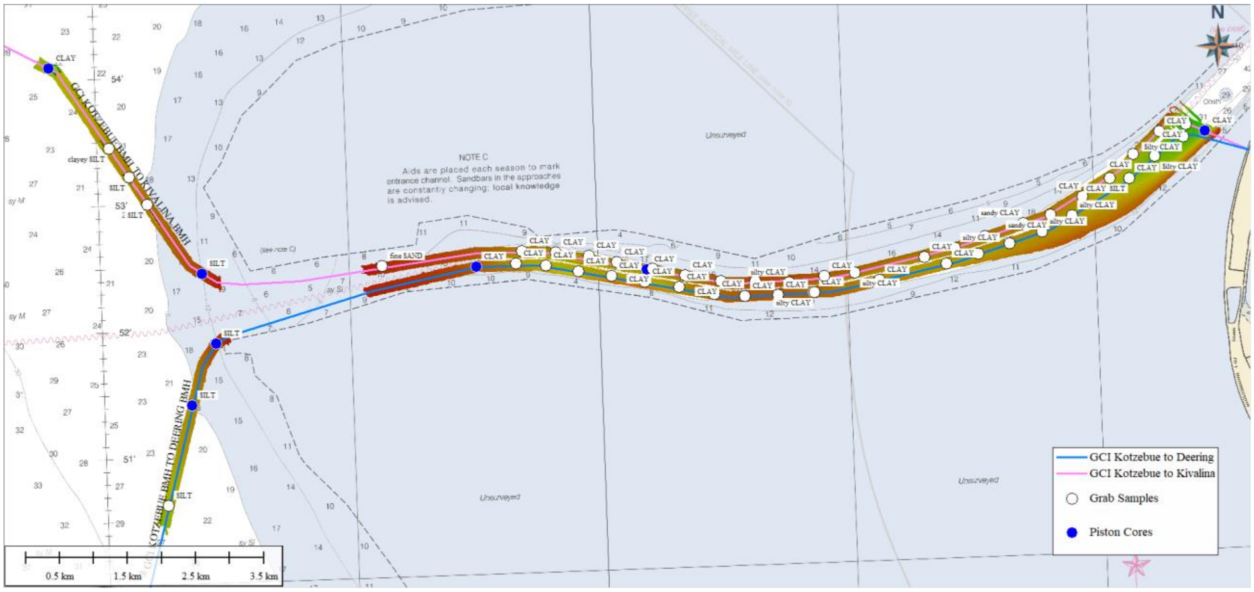


Figure 5-13. Zone 1 Geotech stations

Table 5-1. Zone 1 Grab Sample Descriptions

STATION	DESCRIPTION
GS_K-D_1000	Wet, silty CLAY, low plasticity, slow dilatancy, fine sand pockets, trace shells <1cm, trace organics.
GS_K-D_1500	Wet, silty, CLAY, low plasticity, slow dilatancy, trace organics.
GS_K-D_2000	SILT, few fine sand pockets, trace organics, trace shells <1cm
GS_K-D_3000	Wet, silty CLAY with some silt pockets, trace shells, trace organics.
GS_K-D_3500	Silty CLAY with fine sand pockets, trace shells, trace organic
GS_K-D_4000	Moist, silty CLAY, medium dilatancy, medium plasticity, pockets of fine sand, trace shells, trace organics.
GS_K-D_4500	Soft, wet, silty CLAY, high plasticity, low dilatancy, trace organics, trace shell fragments.
GS_K-D_5000	Wet, CLAY, high plasticity, low dilatancy, trace shell fragments, trace organics.
GS_K-D_6000	Wet, soft, CLAY, high plasticity, low dilatancy, trace shell fragments, trace organics.
GS_K-D_6500	Wet, soft, CLAY, high plasticity, low dilatancy, trace shell fragments, trace organics, trace silt.
GS_K-D_7000	Moist, medium stiff, silty CLAY, medium plasticity, medium dilatancy, trace organics.
GS_K-D_7500	Wet, soft, CLAY, high plasticity, low dilatancy, minor amounts of silt, trace organics.
GS_K-D_8000	Wet, soft, CLAY, high plasticity, low dilatancy, trace organics.
GS_K-D_8500	Wet, soft, CLAY, high plasticity, low dilatancy, trace organics.
GS_K-D_9000	Wet, very soft, CLAY, high plasticity, low dilatancy, trace silty pockets.
GS_K-D_9500	Wet, very soft, CLAY, high plasticity, low dilatancy, trace organics.
GS_K-D_10000	Wet, very soft, CLAY, high plasticity, low dilatancy, minor amounts of organics.
GS_K-D_10500	Wet, very soft, CLAY, high plasticity, low dilatancy, trace organics.
GS_K-D_11000	Wet, soft, CLAY high plasticity, low dilatancy, few organics.
GS_K-D_11500	Wet, soft, CLAY high plasticity, low dilatancy, few organics, trace silt.
GS_K-D_18500	SILT, trace organics.

GS_K-K_1000	Wet, soft, CLAY, high plasticity, low dilatancy, few pockets of fine sand, trace organics.
GS_K-K_1500	Wet, medium stiffness, CLAY, high plasticity, low dilatancy, pockets of fine sand, trace shells and organics.
GS_K-K_2000	Wet, medium stiffness, CLAY, high plasticity, low dilatancy, some fine sand pockets, few organics, trace shells.
GS_K-K_2500	Wet, soft, CLAY, med plasticity, low dilatancy, few fine sand layers, trace shells.
GS_K-K_3000	Moist, medium soft, CLAY, high plasticity, medium dilatancy, few fine sand, minor amounts of organics.
GS_K-K_3500	Wet, soft, sandy CLAY, high plasticity, low dilatancy, trace organics.
GS_K-K_4000	Moist, sandy CLAY, medium plasticity, medium dilatancy, some organics, trace shells <1cm.
GS_K-K_4500	Wet, soft, sandy CLAY, high plasticity, medium dilatancy, abundant organics (shells) 1-2cm
GS_K-K_5000	Wet, soft, silty CLAY, high plasticity, low dilatancy, some organics (sticks) and shells 1-3cm, few fine sand layers.
GS_K-K_5500	Wet, soft, CLAY, high plasticity, low dilatancy, some fine sand pockets, trace organics.
GS_K-K_6500	Wet, soft, silty CLAY, high plasticity, low dilatancy, pockets of fine sand, trace organics
GS_K-K_7000	Wet, soft, CLAY, medium plasticity, medium dilatancy, some silt and fine sand, trace organics.
GS_K-K_7500	Wet, soft, silty CLAY, high plasticity, low dilatancy, trace fine sand, trace organics.
GS_K-K_8000	Wet, soft, CLAY, medium plasticity, medium dilatancy, few organics, trace fine sand.
GS_K-K_8500	Wet, soft, CLAY, high plasticity, low dilatancy, abundant black organics.
GS_K-K_9000	Wet, soft, CLAY, high plasticity, low dilatancy, abundant organics, minor amounts of fine sand.
GS_K-K_9500	Wet, soft, CLAY, high plasticity, medium dilatancy, some organics, trace shells <1cm.
GS_K-K_10000	Wet, soft, CLAY, high plasticity, low dilatancy, trace organics.
GS_K-K_10500	Wet, soft, CLAY, high plasticity, medium dilatancy, few black organics throughout, trace shells <1cm.
GS_K-K_11000	Wet, soft, CLAY, high plasticity, low dilatancy, fine organic material throughout, trace silt, trace shells <1cm.
GS_K-K_11500	Wet, soft, CLAY, high plasticity, low dilatancy, trace organics, trace silt.
GS_K-K_13500	Fine SAND, micaceous, trace fine shell fragments < 2mm.
GS_K-K_17500	SILT, trace organics.
GS_K-K_18000	SILT, pockets of soft clay, trace organics.
GS_K-K_18500	Clayey SILT, moderate amounts of fibrous organics throughout.

Table 5-2. Zone 1 sediment core descriptions

STATION	**SED. DESCRIPTION 1**	**SED. DESCRIPTION 2**	**SED. DESCRIPTION 3**	**SED. DESCRIPTION 4**	**SED. DESCRIPTION 5**
PC_K-D_2000	Wet silty CLAY with trace organics (bivalves) muddy silt lenses, trace fine sand lenses, low plasticity trace dropstones (sub angular) up to 2 cm.				
PC_K-D_7000	0-25cm Wet, very soft, CLAY, high plasticity, low dilatancy, minor amounts of silt.	25-43cm Wet, soft, silty CLAY, high plasticity, low	44-48cm Firm, SILT, trace amounts of clay.	48-68cm Soft, silty CLAY, high plasticity, low	68-89cm Dense, fine SAND, poorly graded.

		dilatancy		dilatancy.	
PC_K-D_12000	0-32cm Wet, soft to medium stiff, silty CLAY, medium plasticity, low dilatancy, high mica content.				
PC_K-D_16000	0-33cm Dense SILT.				
PC_K-D_17000	0-94cm SILT, firm, well graded.				
PC_K-K_700	0-20cm Wet, very soft, CLAY, low dilatancy, high plasticity, minor amounts of silt.	20-58cm Moist, soft, CLAY, high plasticity, medium dilatancy, increasing silt content moving towards lower contact.	58-59cm fine SAND lens with 0.5-1cm subrounded clasts.	59-153cm Moist, medium stiff, silty CLAY, low plasticity high dilatancy.	0-20cm CLAY, low dilatancy, high plasticity, minor amounts of silt.
PC_K-K_9600	0-49cm Very soft transitioning to soft, wet, CLAY, high plasticity, no dilatancy.	49-60cm SILT, lower contact @ 59-60cm abundant shell hash <1cm.	60-84cm Moist, medium stiff, silty CLAY		0-49cm Soft, wet, CLAY, high plasticity, no dilatancy.
PC_K-K_16200	0-30cm Very soft, clayey SILT, poorly graded, weakly cemented.	30-43 Medium stiff SILT, poorly graded, weakly cemented.	43-48cm Wet, medium stiff, CLAY, high plasticity, low dilatancy	48-67cm Wet, very soft, CLAY, high plasticity, low dilatancy.	0-30cm Very soft, clayey SILT, poorly graded, weakly cemented.

Based on the 7 core samples, Zone 1 is composed of clay, silty clay, clayey silt, silt, silty sand, and fine sand. Coarser sediments are likely to be encountered in immediate proximity to the beach. Sediment property descriptions in Zone 1 ranged from very soft to stiff. Based on 15 torvane tests the sediment is predominantly (87% of observations) very soft with an undrained shear strength of less than 0.2 kg/cm^2. The remaining 13% of observations were soft soil with and undrained shear strength of 0.2 to 0.41 kg/cm^2 (Figure 5-14). Based on 16 torvane tests the unconfined cohesive strength ranges from 0.03 to 2.25 kg/cm^2 (Figure 5-15).

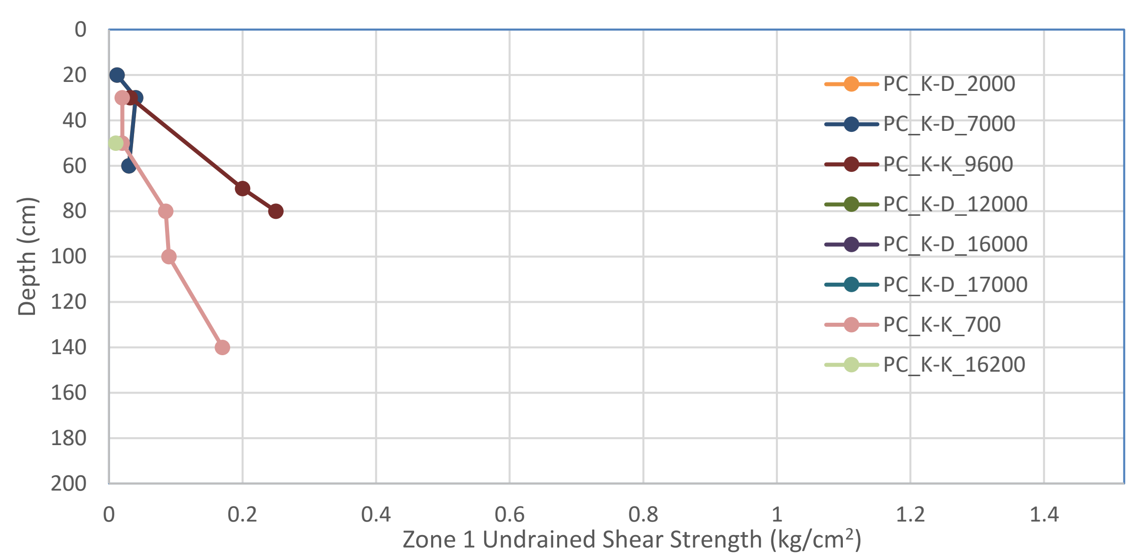


Figure 5-14. Zone 1 Undrained shear strength measurements

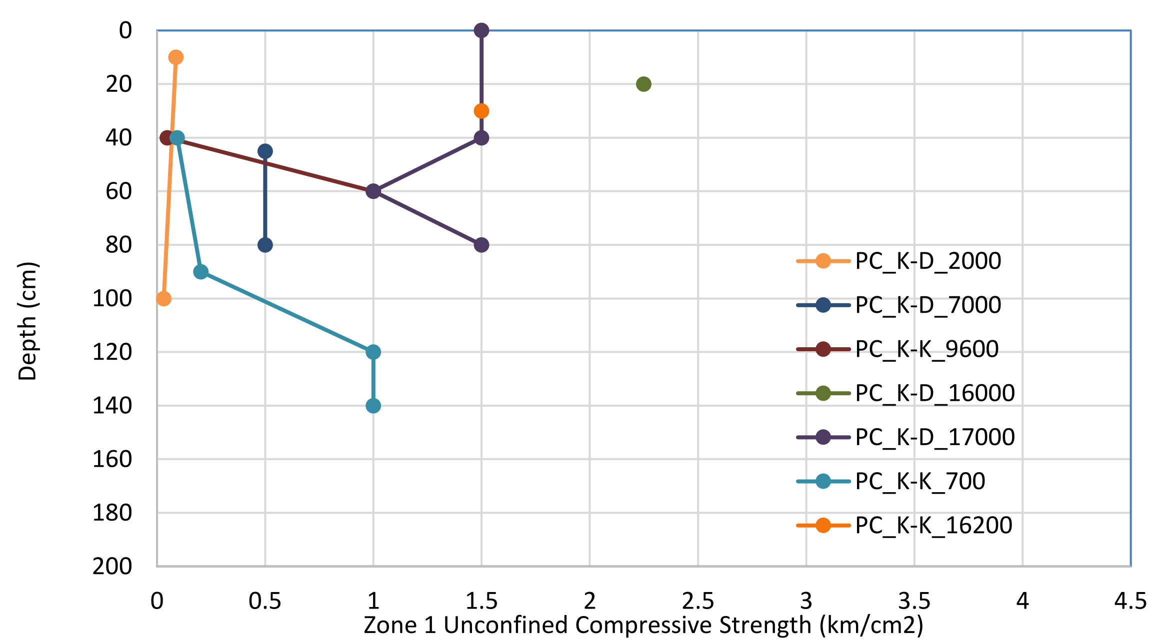


Figure 5-15. Zone 1 Unconfined compressive strength measurements

Table 5-3 shows the relationship between the numeric values of shear strength and compressive strength and the descriptive term of soil property. Figure 5-16 shows the distribution of soil types in Zone 1 based on the geotechnical tests.

Table 5-3. Shear Strength and Compressive Strength Classification Bins

Soil Property Descriptive Term	**Undrained Shear Strength (Kg/cm^2)**	**Unconfined Compressive Strength (Kg/cm^2)**
Very Soft	< 0.2	< 0.25
Soft	0.2 to 0.41	0.25 to 0.5
Firm	0.41 to 0.76	0.5 to 1
Stiff	0.76 to 1.52	1 to 2
Very Stiff	>1.52	2 to 4
Hard		>4

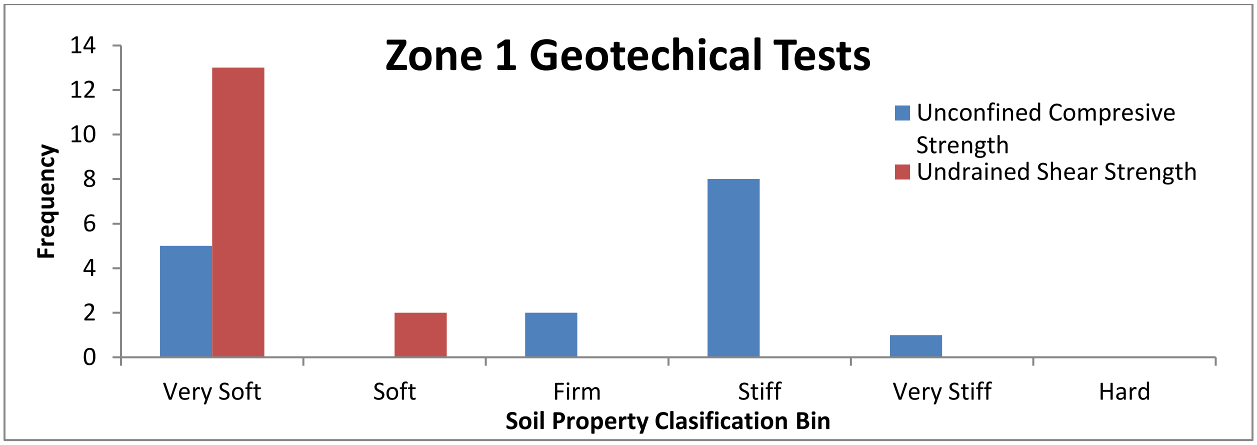


Figure 5-16. Zone 1 soil properties based on geotechnical tests

Note that out of the 8 cores acquired in zone 1 only two cores recovered more than 1 meter of sediment. The maximum recovery was 153 cm with an average recovery of 84 cm. Therefore, stiffer sediments may be encountered at depth that were not sampled in coring and do not present differently in the acoustic records.

5.1.2 SURFACE SEDIMENTS

Based on the multibeam backscatter and geotechnical results the surface sediments inside the channel from the beginning of data collection at KP 0.5 to the shoal is clay and silty clay. From KP 12 across the shoal the surface sediment is fine sand. Outside of the shoal from KP 15 to the western end of Zone 1 the surface sediment is silt or clayey silt.

5.1.3 SUB-SURFACE STRATIGRAPHY

Where water depths were sufficient, sub-bottom profiler data was acquired along the center line of Zone 1. Horizontal stratigraphy is seen throughout zone 1 the only notable stratigraphic structure is a 3-meter deep paleochannel near the east end of the route where it crosses the modern channel. Sediments in the paleochannel onlap on both margins (Figure 5-17).

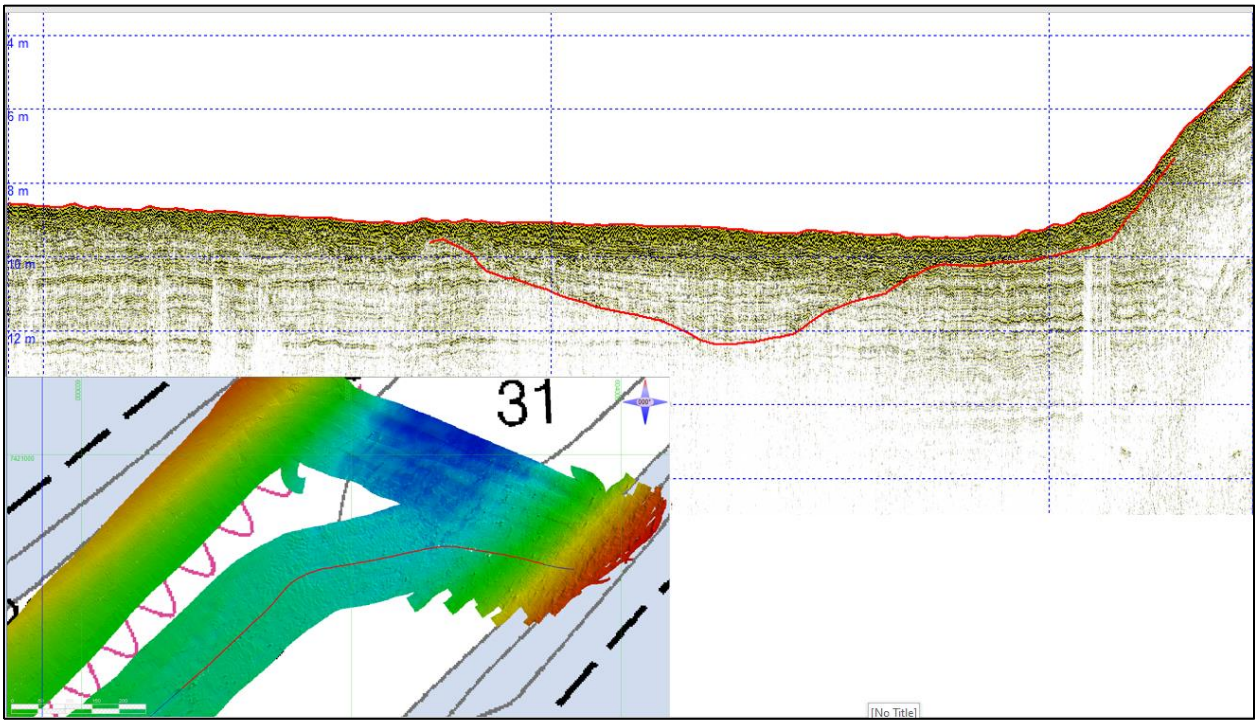


Figure 5-17. paleo-channel near eastern margin of zone 1.

From KP 0.5 to KP 7 there is a contiguous near-horizontal bedding that follows the channel surface to a depth of 2 m or greater. A core sample collected at KP 2.0 recovered 1.2 meters of very soft, wet silty clay with muddy silt lenses, and trace fine sand lenses (Figure 5-18).

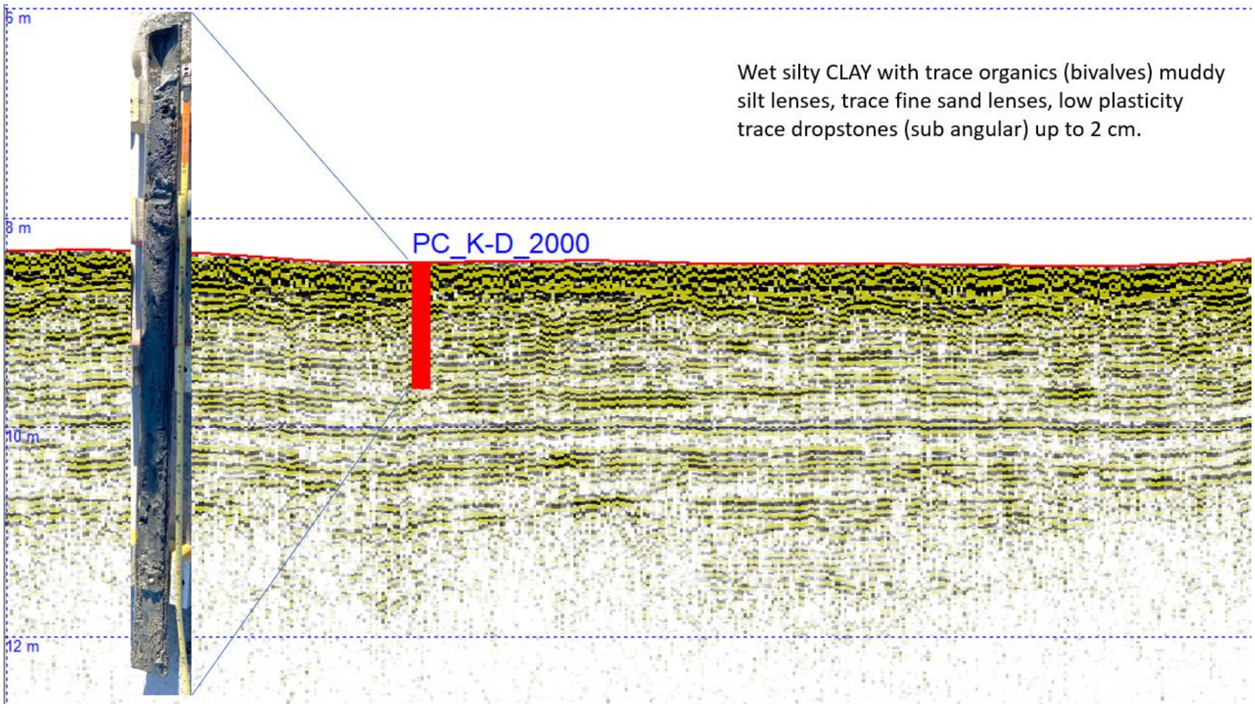


Figure 5-18. Sub-bottom and core records from K-D_2000

From KP 7 to KP 13 the sub-bottom profile signal attenuates quicker providing 1 to 2 meters of depth record. Three cores were acquired in this area. At K-D_7000, 89 cm were recovered with the upper 43 cm composed of soft clay and silty clay, overlaying firm silt and dense, poorly graded fine sand. At K-D_9600 there was a similar recovery of 84 cm with the upper 49 cm composed of soft clay overlaying dense silt and medium stiff silty clay. At K-D_12000, 32 cm were recovered of soft to medium stiff silty clay.

Outside of the channel in Zone 1 along the K-D route the stratigraphy is less continuous, possibly due to frequent seabed ice scouring or increased wave action that would mix or homogenize recent seabed deposits. Along this section of the K-D route two cores were recovered. At K-D_16000, 33 cm of very dense silt were recovered with an unconfined compressive strength value of 2.5 kg/cm^2 (very stiff). At K-D_17000, 94 cm of firm well graded silt was recovered with an unconfined compressive strength ranged from 1 to 1.5 kg/cm^2 (stiff) (Figure 5-19).

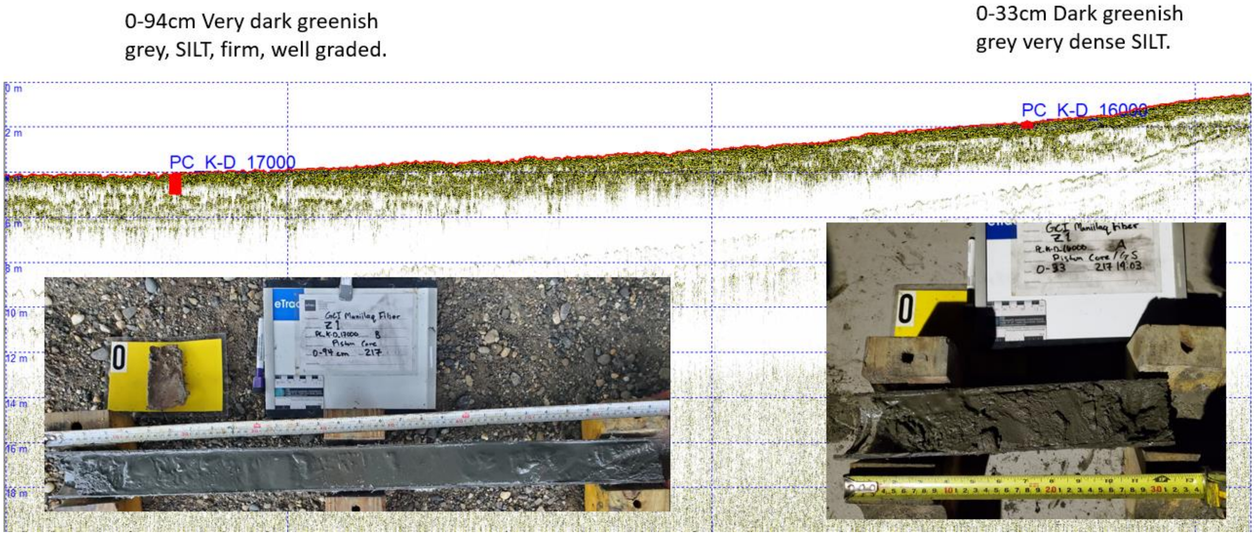
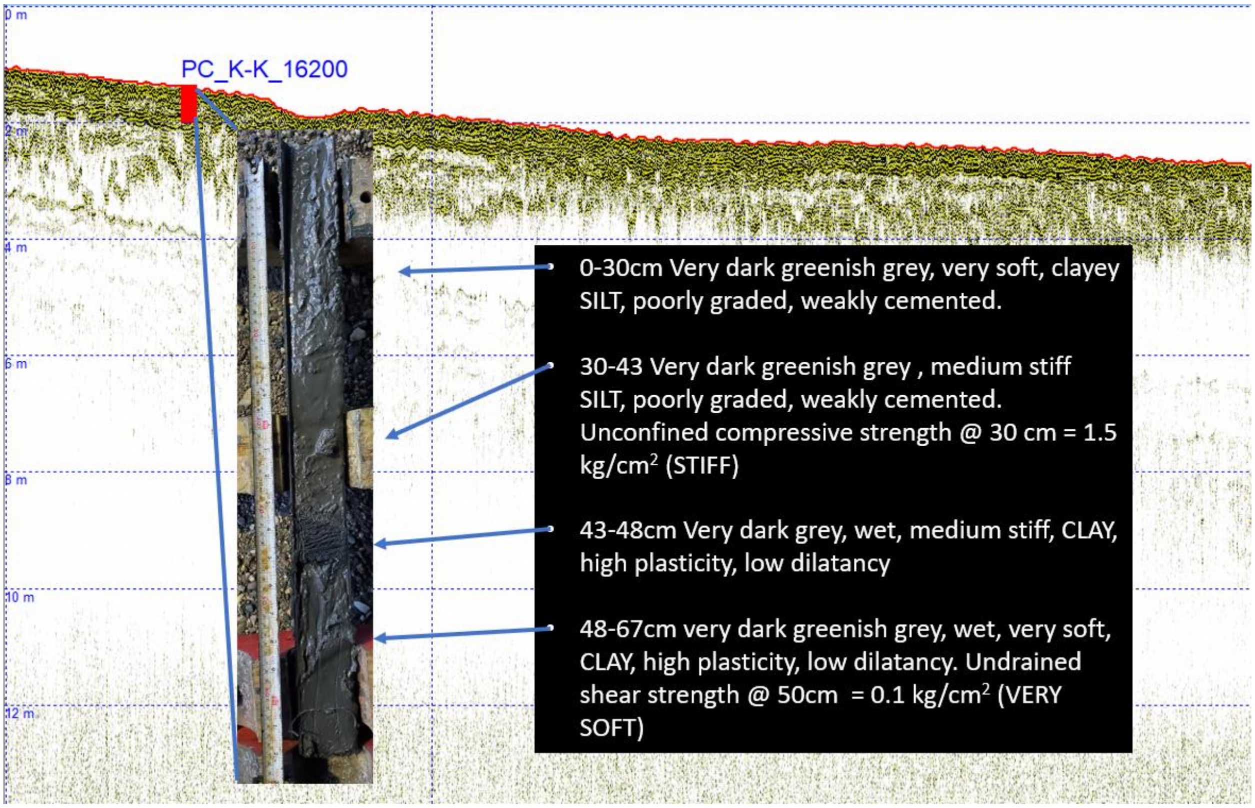


Figure 5-19. Sub-bottom profile and coring results for Zone 1 K-D_16000 and K-D_17000

Outside of the channel in Zone 1 along the K-K route the upper couple of meters of sediment stratigraphy is less pronounced, based on the sub-bottom profile the sediments are almost homogeneous in places, again this is possibly due to frequent seabed ice scouring or wave energy that would mix recent sediment deposits. At K-K_16200 a 67 cm core composed of clayey silt, silt and clay was recovered (Figure 5-20). The minimal recovery at K-D 12000 K-D 16000 and K-K 16200 is likely related to the stiff to very stiff sediments encountered.



- 0-30cm Very dark greenish grey, very soft, clayey SILT, poorly graded, weakly cemented.
- 30-43 Very dark greenish grey , medium stiff SILT, poorly graded, weakly cemented. Unconfined compressive strength @ 30 cm = 1.5 kg/cm^2 (STIFF)
- 43-48cm Very dark grey, wet, medium stiff, CLAY, high plasticity, low dilatancy
- 48-67cm very dark greenish grey, wet, very soft, CLAY, high plasticity, low dilatancy. Undrained shear strength @ 50cm = 0.1 kg/cm^2 (VERY SOFT)

Figure 5-20. Sub-bottom profile and coring results of Zone 1 K-K 16200.

5.1.1 MAGNETIC ANOMALIES

Magnetometer data was not acquired along the cable route in zone 1. For results on the Quintillion cable crossing see Section 5.7.

5.1.2 SUMMARY

Zone 1 presents unique challenges to the MFP routes. These challenges include shallow water, strong currents, a narrow channel, one cable crossing and cable routes in close proximity to and existing fiber cable. In the geophysical data we identified hundreds of seafloor features (mounds, scour holes, and other elongated scours), however these low relieve features do not appear that they will be problematic to the installation of the cable or present a hazard to the installed cable.

Very soft to stiff sediments have been identified within the channel with one observation of very stiff sediment outside of the channel shoal. Based on soil properties and empirical evidence from the Quintillion fiber cable, cable burial to a depth of 1 m or greater should be achievable.

5.2 Zone 2 (K-D KP 18.5 to KP 73.8)

5.2.1 BATHYMETRY AND SEAFLOOR FEATURES

The bathymetry data in Zone 3 covers a 300-meter-wide corridor along the entire length (Figure 5-21).

Surveyed depths in Zone 3 range from 2.7 m to 16.3 meters below MLLW. Most of Zone 2 lays within the flat bottom basin of Kotzebue Sound with water depths of 14.5 to 15.5 meters below MLLW (Figure 5-22).

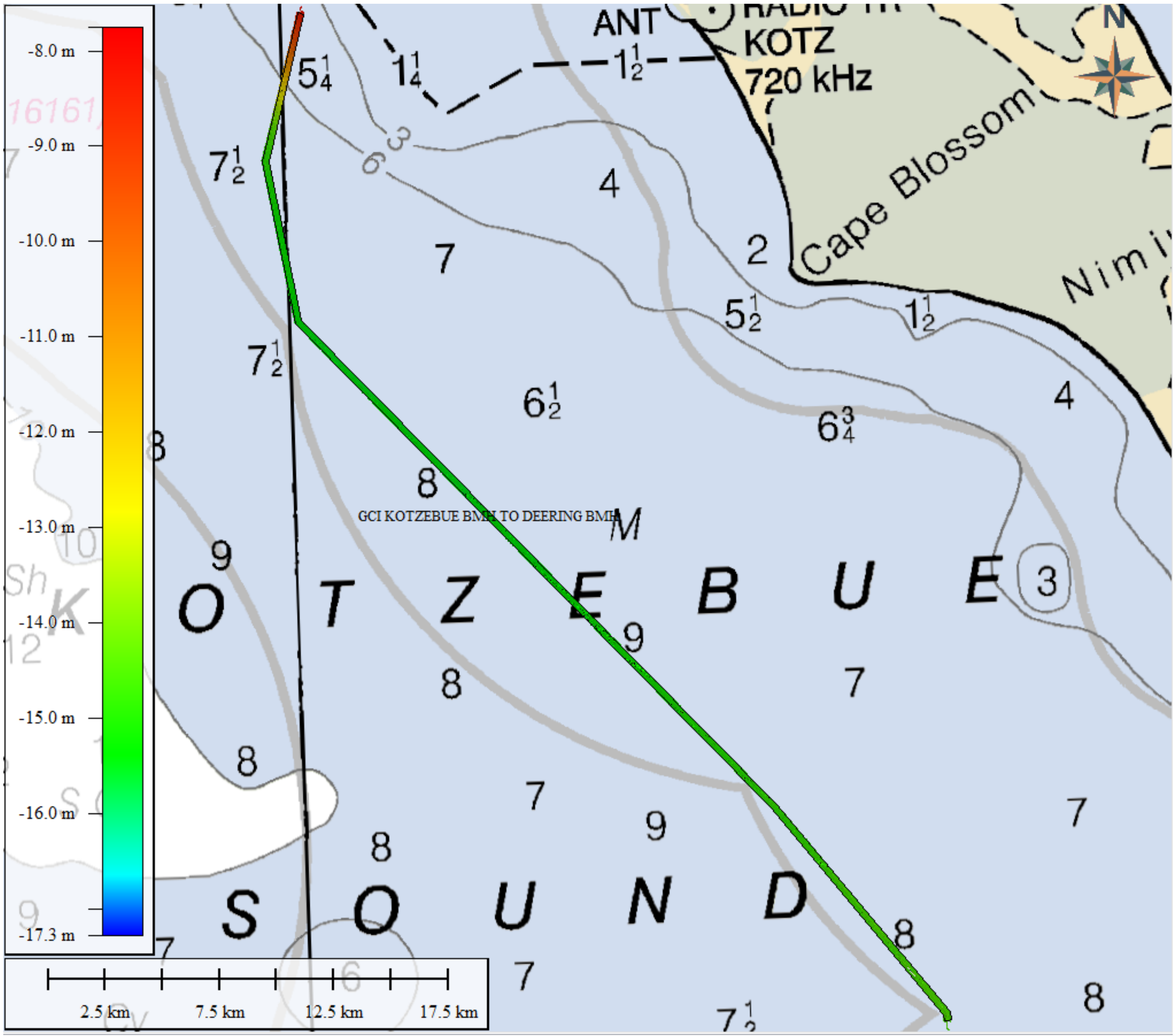


Figure 5-21. Zone 2 bathymetry coverage

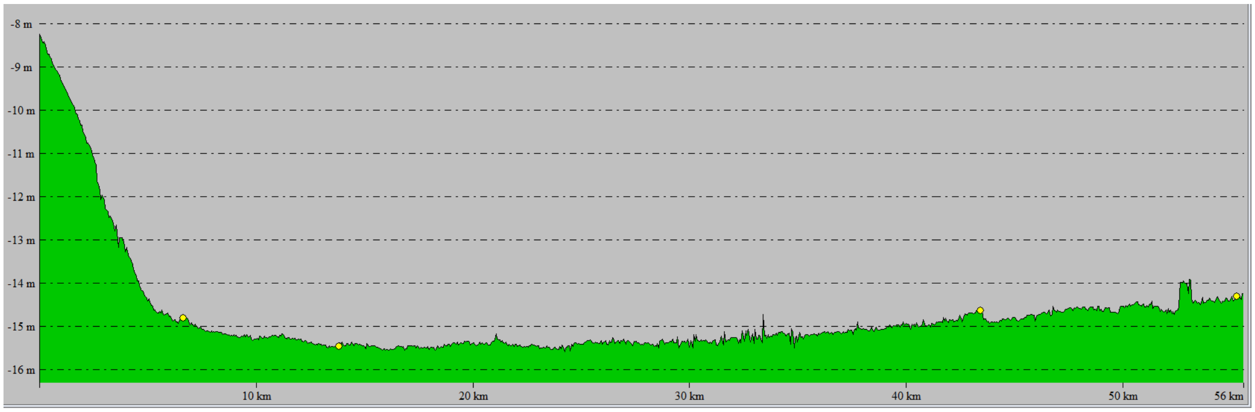


Figure 5-22. Zone 2 bathymetric profile

Ice scouring is common in all water depths throughout Zone 2. Nearly 400 scours were digitized in Zone 2 (Figure 5-23). Most ice scours are oriented northwest-southeast however there are numerous exceptions. The widest and most extensive scouring in Zone 2 is located between K1 42 and KP 61 (Figure 5-24).

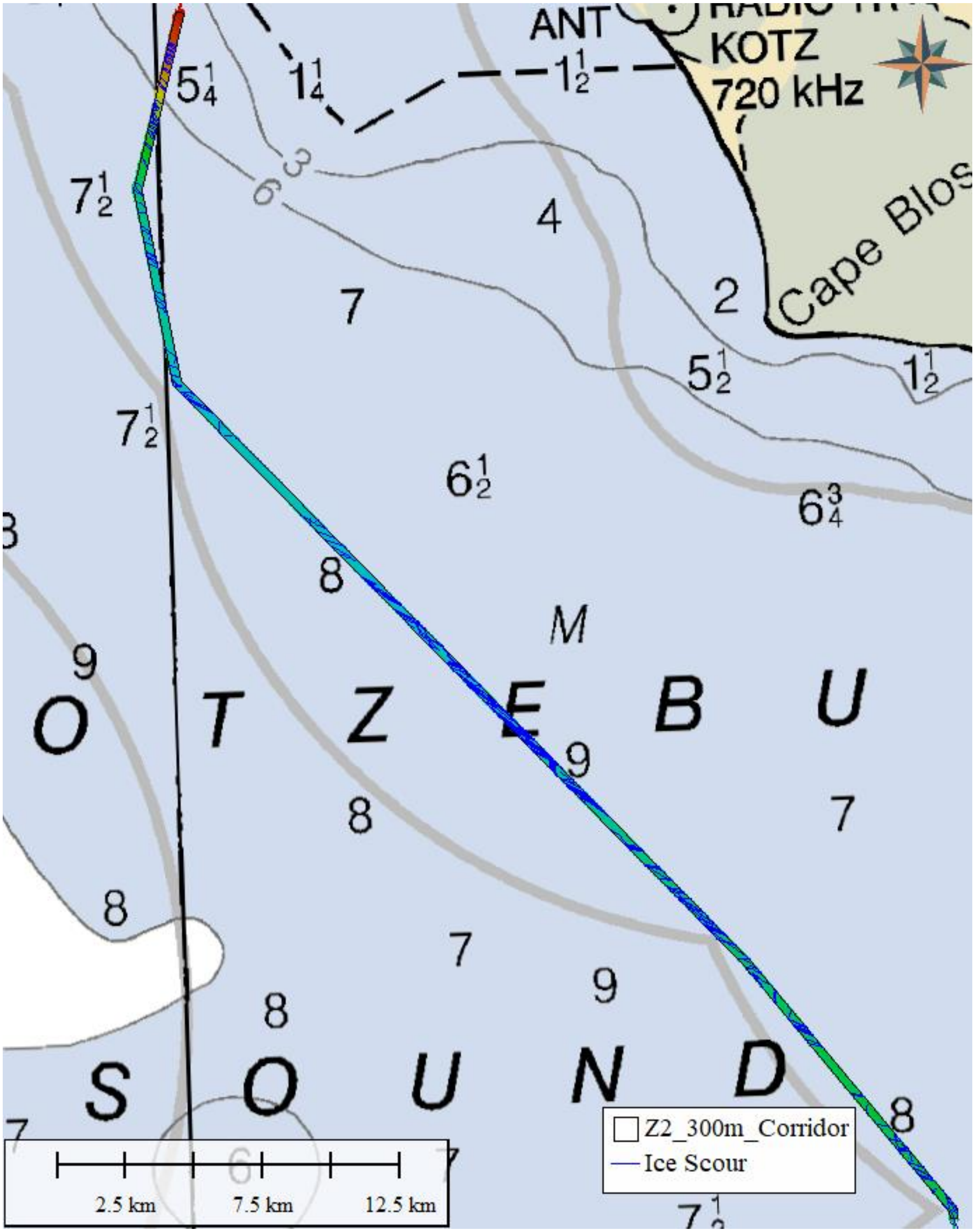


Figure 5-23. Zone 2 Ice Scours

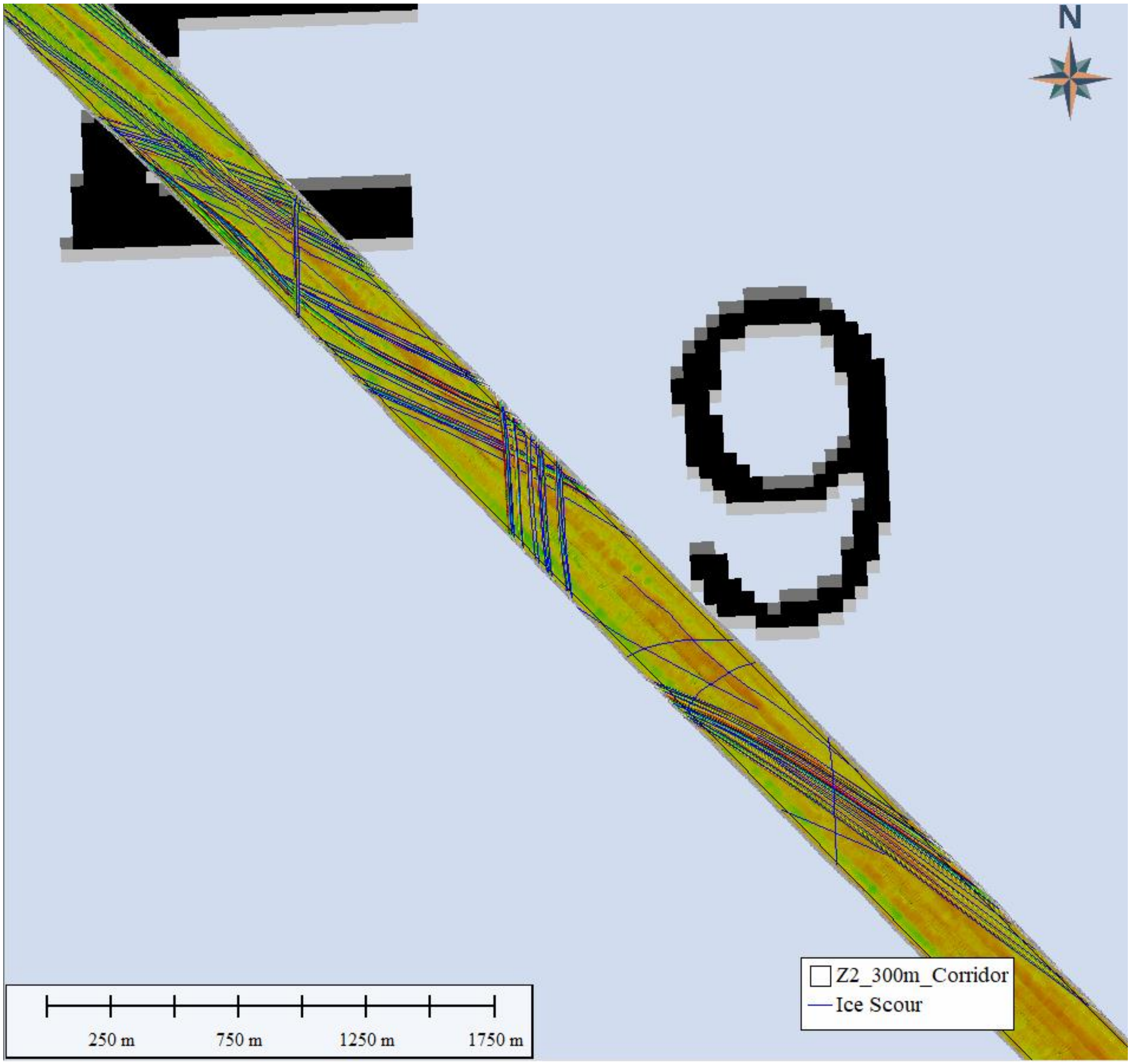
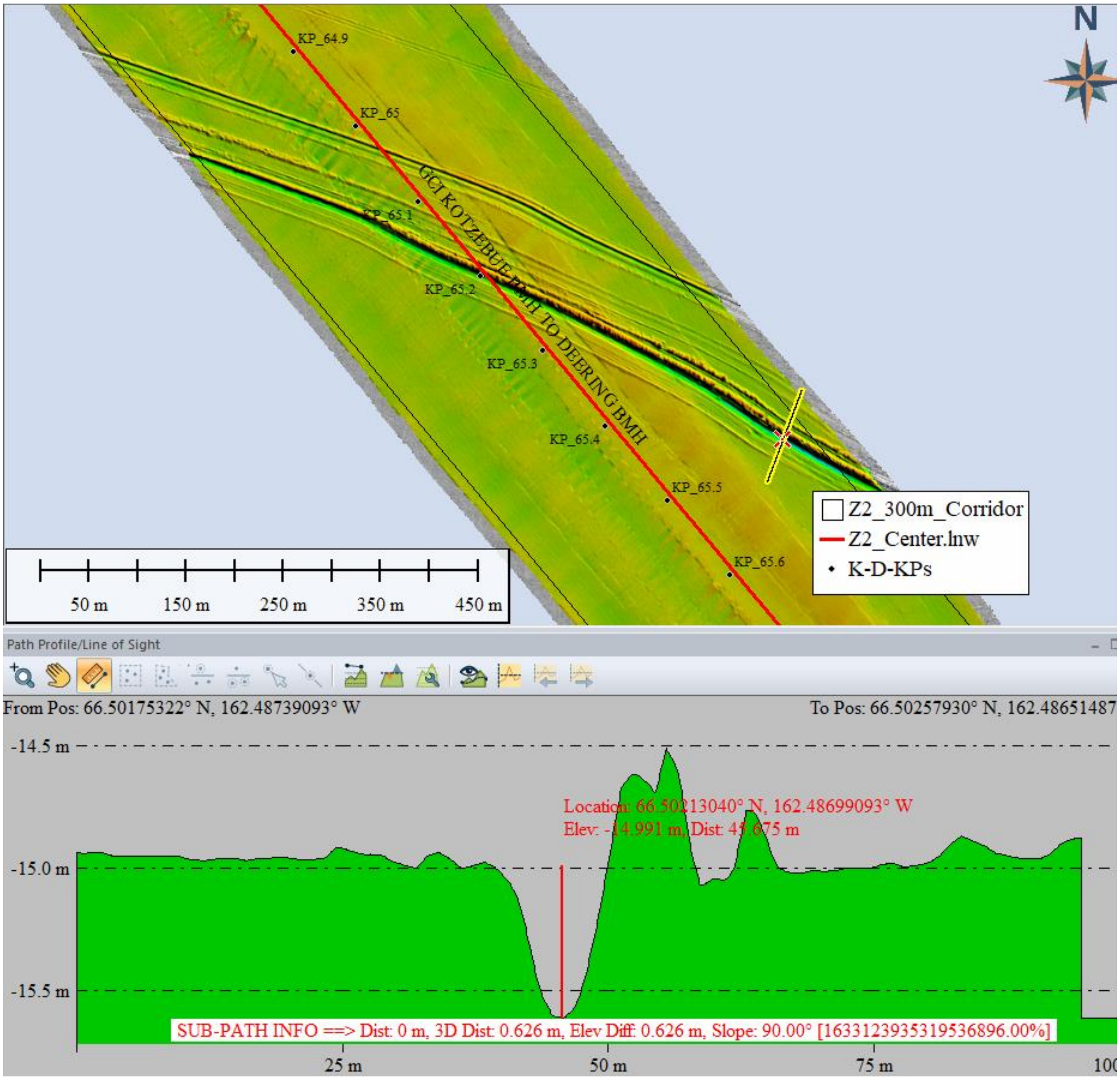


Figure 5-24. Ice scour concentration between KP 42 and KP 61 on the K-D route.

Typical ice scour depths are 0.1 to 0.2 m below the surrounding seabed. Furrows are typically of equal or slightly greater height above the surrounding seabed. However, the maximum scour depth observed in Zone 2 was 0.6 m (Figure 5-25) and the maximum furrow height observed was 0.6 m.



From Pos: 66.50175322° N, 162.48739093° W

To Pos: 66.50257930° N, 162.48651487

Location: 66.50213040° N, 162.48699093° W
Elev: -14.991 m, Dist: 45.675 m

SUB-PATH INFO ==> Dist: 0 m, 3D Dist: 0.626 m, Elev Diff: 0.626 m, Slope: 90.00° [1633123935319536896.00%]

Figure 5-25. Deep ice scour example from Zone 2 near KP 65.5.

5.2.2 GEOTECHNICAL RESULTS

1 grab sample and 8 piston cores were collected in Zone 2 (Figure 5-13). The seabed sediment is composed of clay, silty clay, clayey silt, and silt. Beneath the surface, clay continues to be the most predominate sediment type (Table 5-4).

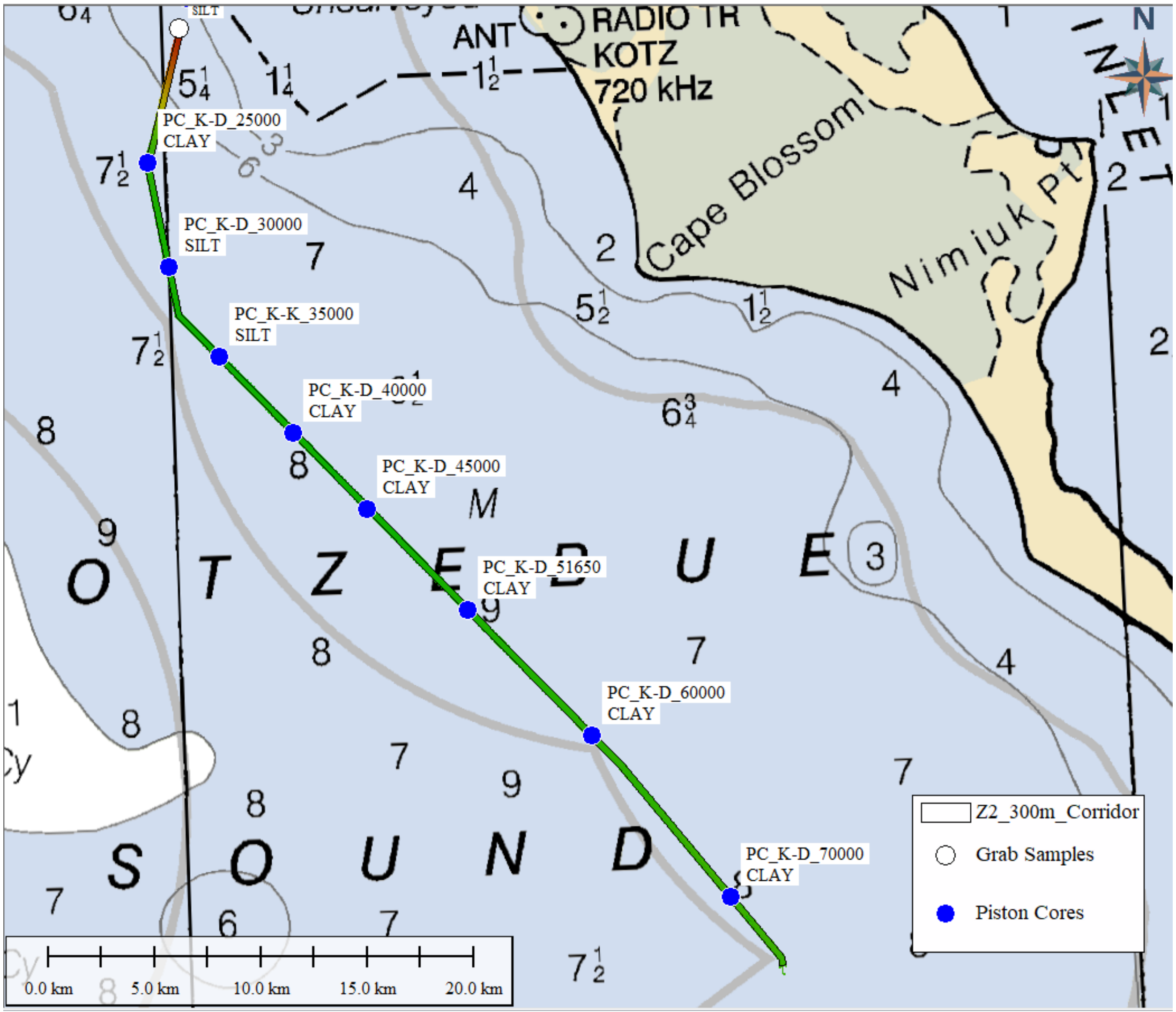


Figure 5-26. Zone 2 Geotechnical stations and surface sediments

Table 5-4. Zone 2 sediment core descriptions.

STATION	SED. DESCRIPTION 1	SED. DESCRIPTION 2	SED. DESCRIPTION 3	SED. DESCRIPTION 4
PC_K-D_25000	0-5cm Wet, very soft, CLAY, high plasticity, low dilatancy.	5-67cm Medium stiff, moist to dry, CLAY, low plasticity, high dilatancy. Fine sand layer @ 45cm, 0.5cm thick		
PC_K-D_30000	0-24cm Stiff, clayey SILT.	24-53cm Wet, firm, silty CLAY, low plasticity, high, dilatancy. Lenses of		

		soft black clay @ 33 and 43 cm ~1-2 cm thick.		
PC_K-D_35000	0-5cm Medium stiff, wet, silty CLAY.	5-39cm Wet, medium stiff, CLAY, black organic streaks @ 5-24 cm, high plasticity, medium dilatancy.	39-65 Wet, soft, CLAY, few fine sand pockets.	
PC_K-D_40000	0-9cm Wet, soft, silty CLAY, high plasticity, low dilatancy.	9-14cm ORGANIC, irregular upper and lower contacts, no organic odor.	14-19cm Loose, clayey SILT, high mica content.	19-48cm Moist, soft, silty CLAY, low plasticity, high dilatancy, high mica content.
PC_K-D_45000	0-15cm tiff, moist, silty CLAY, low plasticity, high dilatancy, occasional black organic streaking, trace shell fragments.			
PC_K-D_51650	0-10cm Clayey SILT, dense, interbedded with dark greenish grey silty CLAY, moist, high plasticity, medium dilatancy.			
PC_K-D_60000	0-2cm soft wet loose CLAY, low plasticity	2-12cm medium plasticity CLAY	12-30cm moist medium firm CLAY	30-70cm firm CLAY
PC_K-D_70000	0-52cm Moist, medium stiff, CLAY, high plasticity, medium dilatancy.	52-113cm Dark greenish grey, firm, silty CLAY, high mica content.	113-153cm Wet, very soft, CLAY, high plasticity, low, dilatancy	

Measurements of shear strength and compressive strength were acquired in all cores with the exception of K-D_45000 and K-D_51650 due to the minimal recovery.

Based on 19 shear strength tests in Zone 2 the sediment is predominantly (89% of test results) very soft to soft with only two measurements barely falling into the firm category at 0.43 kg/cm^2 and 0.45 kg/cm^2 (Figure 5-27). Based on 20 unconfined compressive strength tests the sediment is very soft to very stiff. Firm to stiff clay was measured in 5 of the 6 cores analyzed. Only one core (K-D 30000) was very stiff clay with a measured value of 3.5 (kg/cm^2) at a depth of 40cm (Figure 5-28).

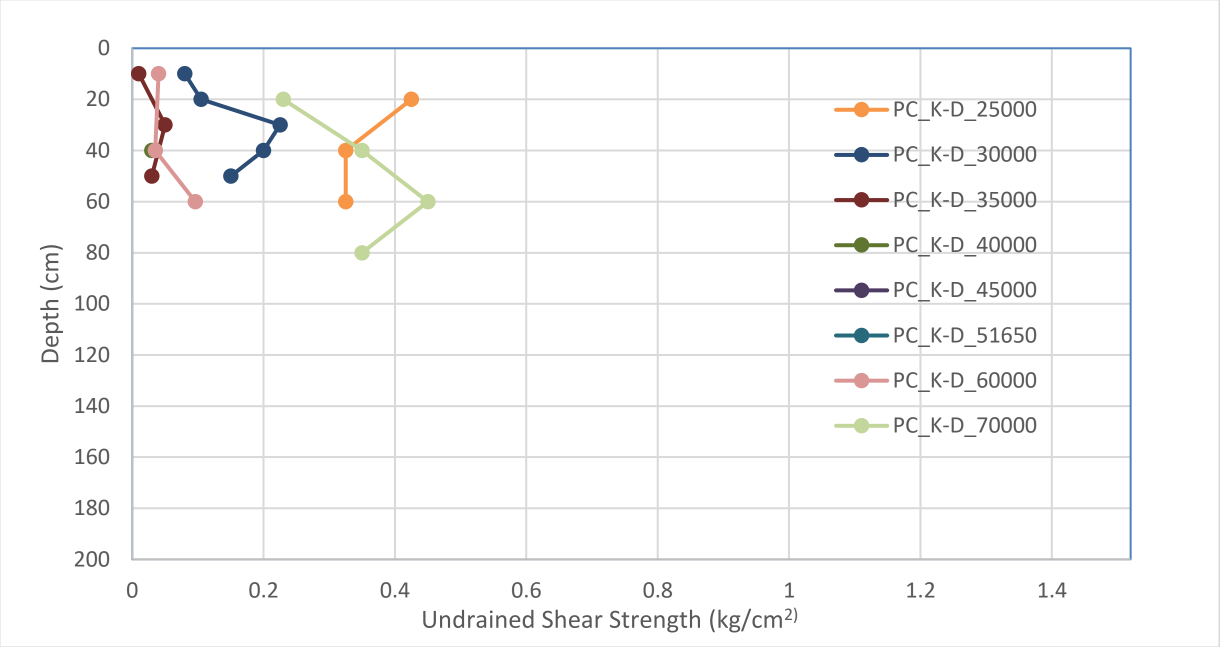


Figure 5-27. Zone 2 Undrained shear strength measurements

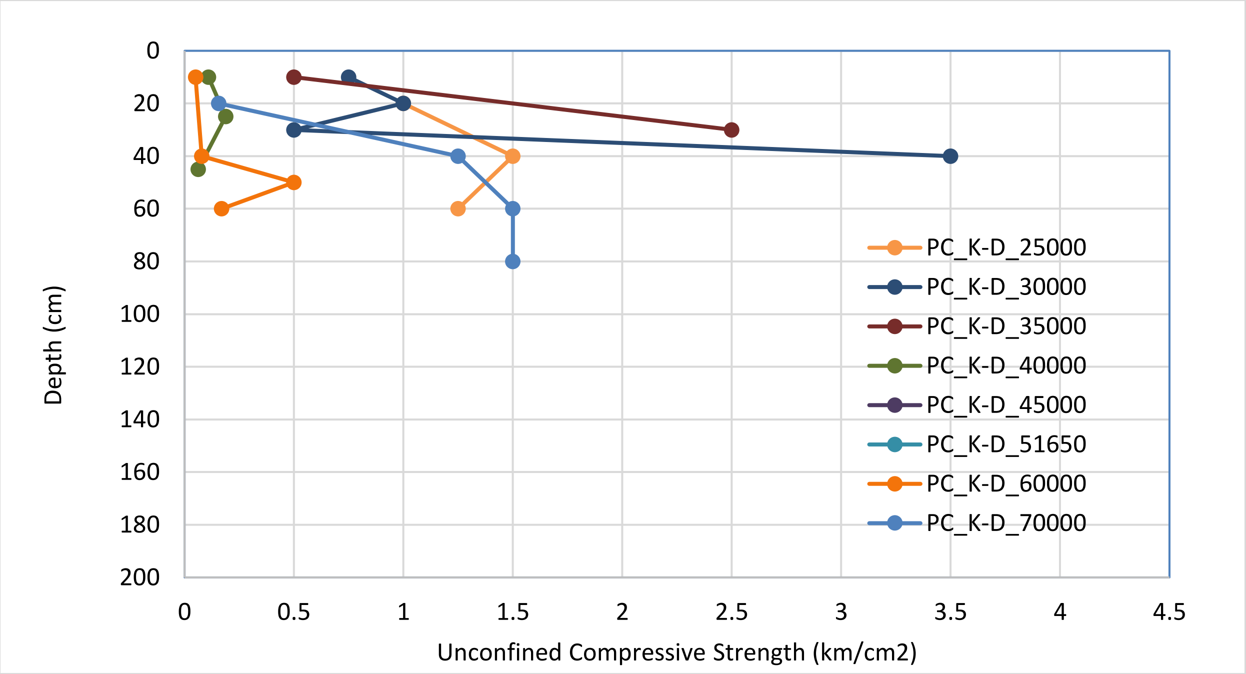


Figure 5-28. Zone 2 Unconfined compressive strength measurements

Based on the relationship between the descriptive soil property terminology and numeric values of shear strength and compressive strength shown in Table 5-3, Figure 5-29 shows the distribution of soil types in Zone 2 based on the geotechnical tests.

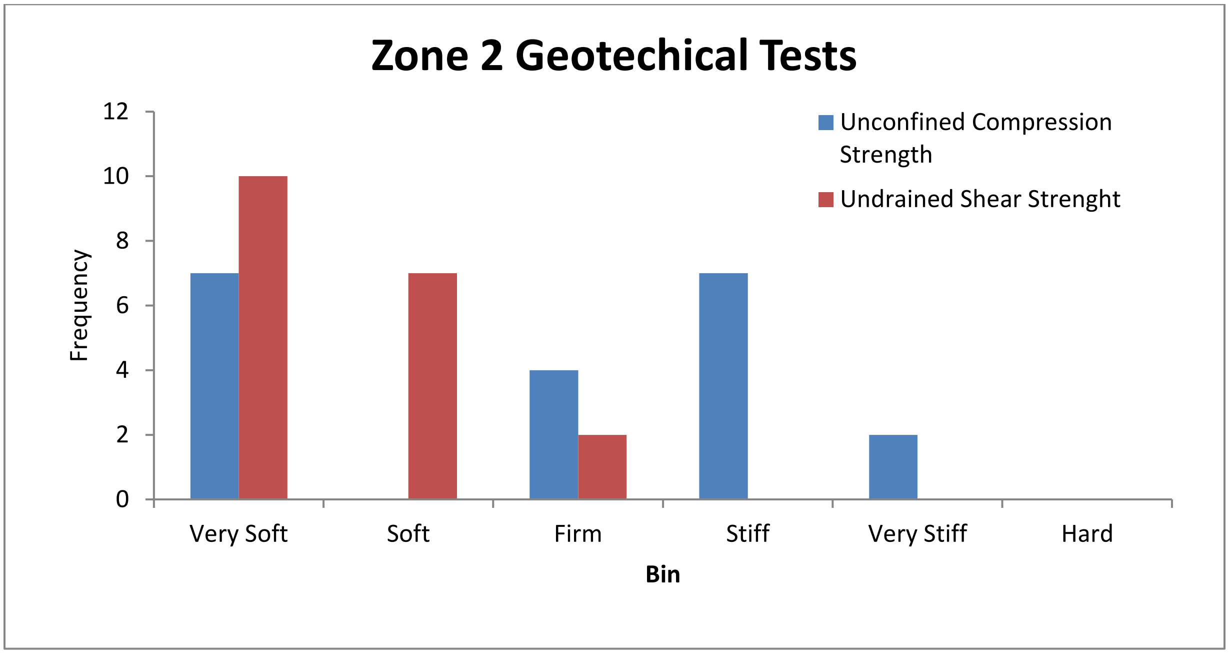


Figure 5-29. Zone 2 soil properties based on geotechnical tests

Note that out of the 8 cores acquired in zone 2 only one core recovered more than 1 meter of sediment. The maximum recovery was 153 cm with an average recovery of 60 cm. Therefore, stiffer sediments may be encountered at depth that were not sampled in coring and do not present differently in the acoustic records.

5.2.3 SURFACE SEDIMENTS

Based on the side scan sonar imagery, multibeam backscatter, and geotechnical results the surface sediments throughout Zone 2 are clay and silty clay. Variations in the side scan sonar reflection intensity are associated with ice scours. Furrows normally present a higher intensity reflection however this is likely due to the angle of incidence and rugosity as opposed to a change in the sediment properties. Reduced reflection intensity is observed within larger flat bottomed ice scours. This indicates the scours are trapping finer grained sediments (clay) (Figure 5-30).

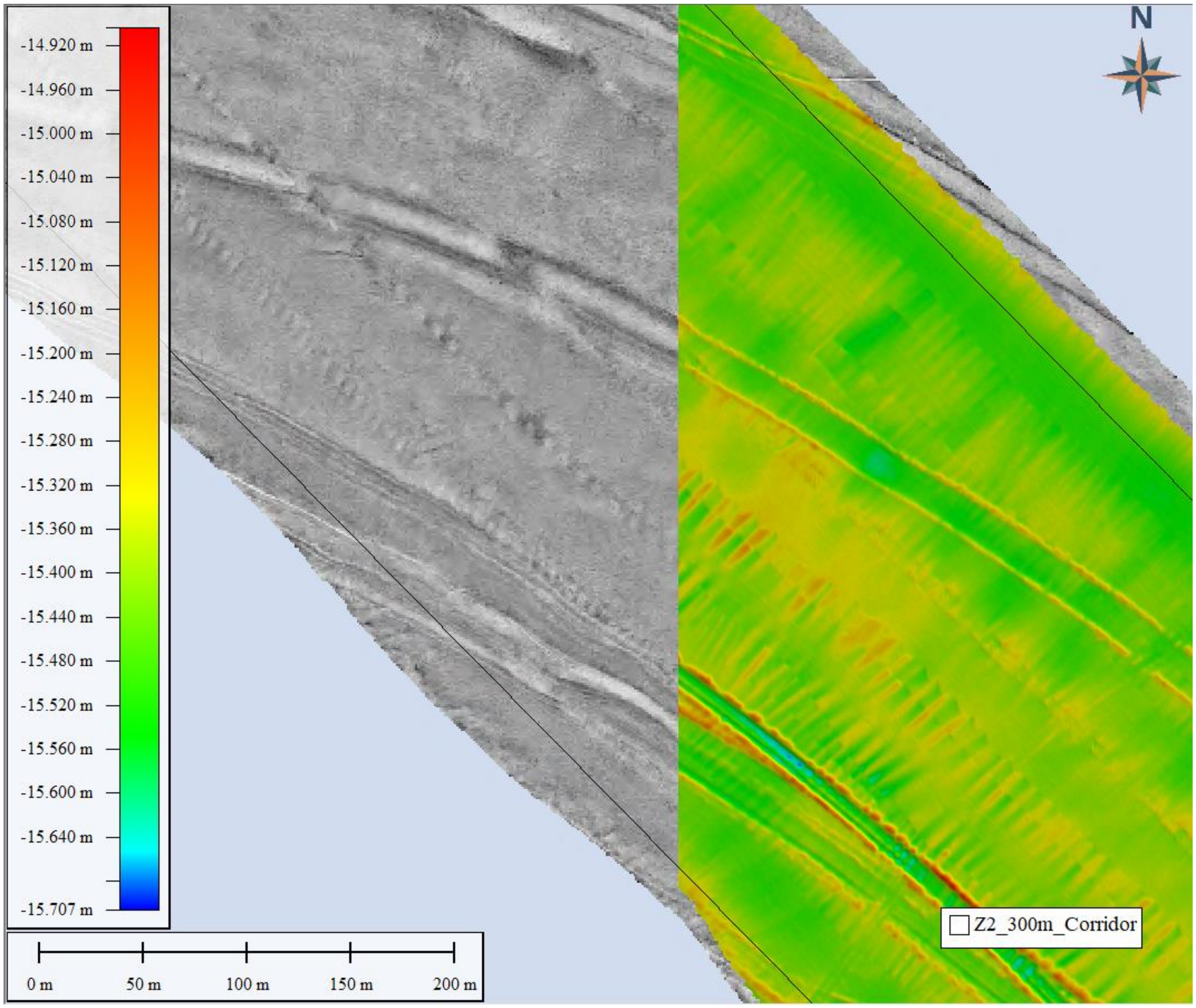


Figure 5-30. Example of side scan sonar reflection intensity variation in ice scours.

From KP 23 to KP 40 much of the seafloor has a mottled appearance. This texture has a southeast-northwest bias and is therefore likely related to old ice scours that have been reworked by wave action. The actual cause of the reflection intensity variability is likely changes in sediment grain size clay vs. silt (Figure 5-31).

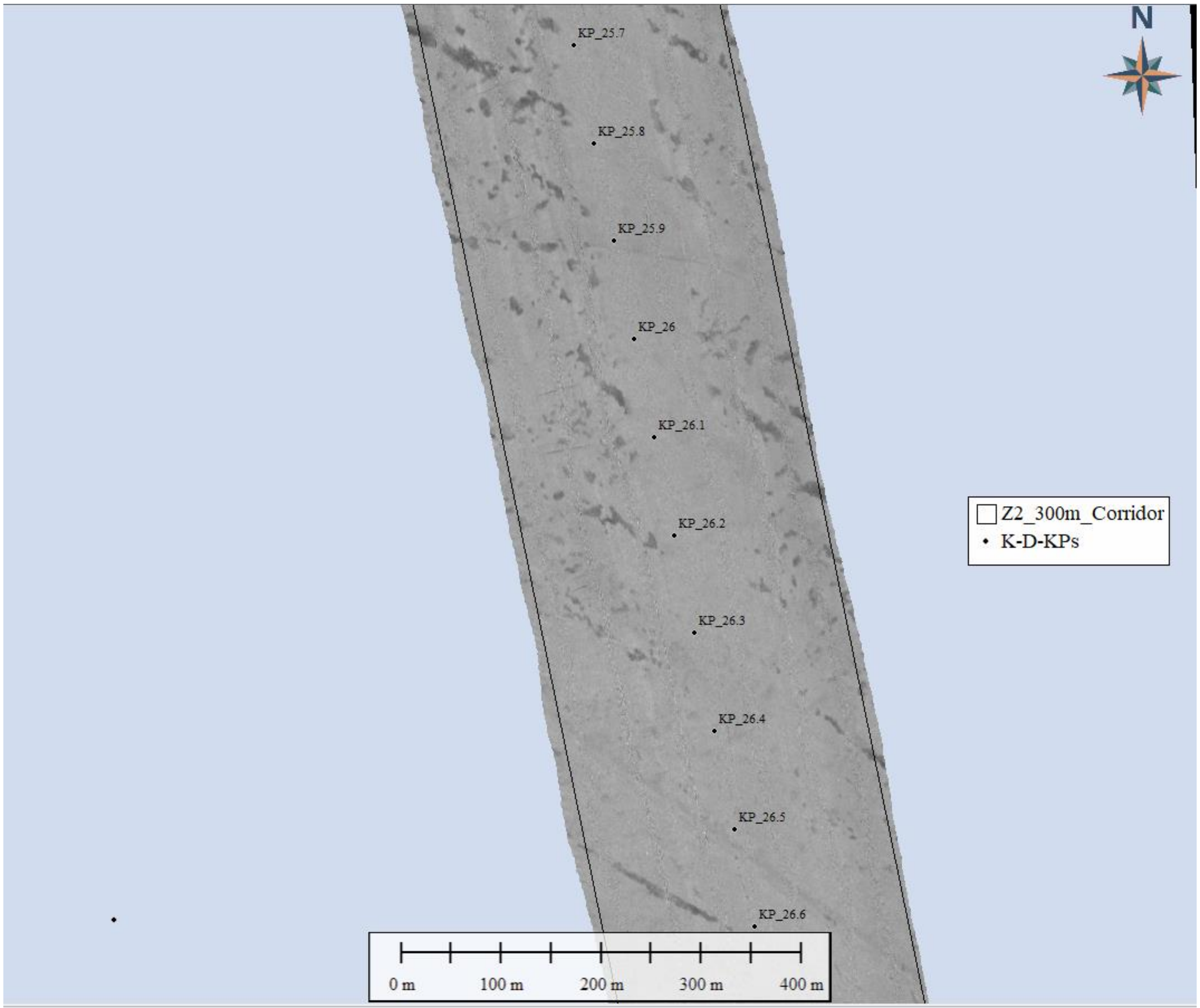


Figure 5-31. Example from Zone 2 of mottled texture in the backscatter imagery.

Between KP 42.1 and 42.6 there is a small rise of about 0.5 m in elevation along the southwest side of the survey corridor. This rise is apparent in the multibeam backscatter imagery and appears consist of courser material (likely silt or sandy silt) than the surrounding surface sediments (silty clay and clayey silt) (Figure 5-32)

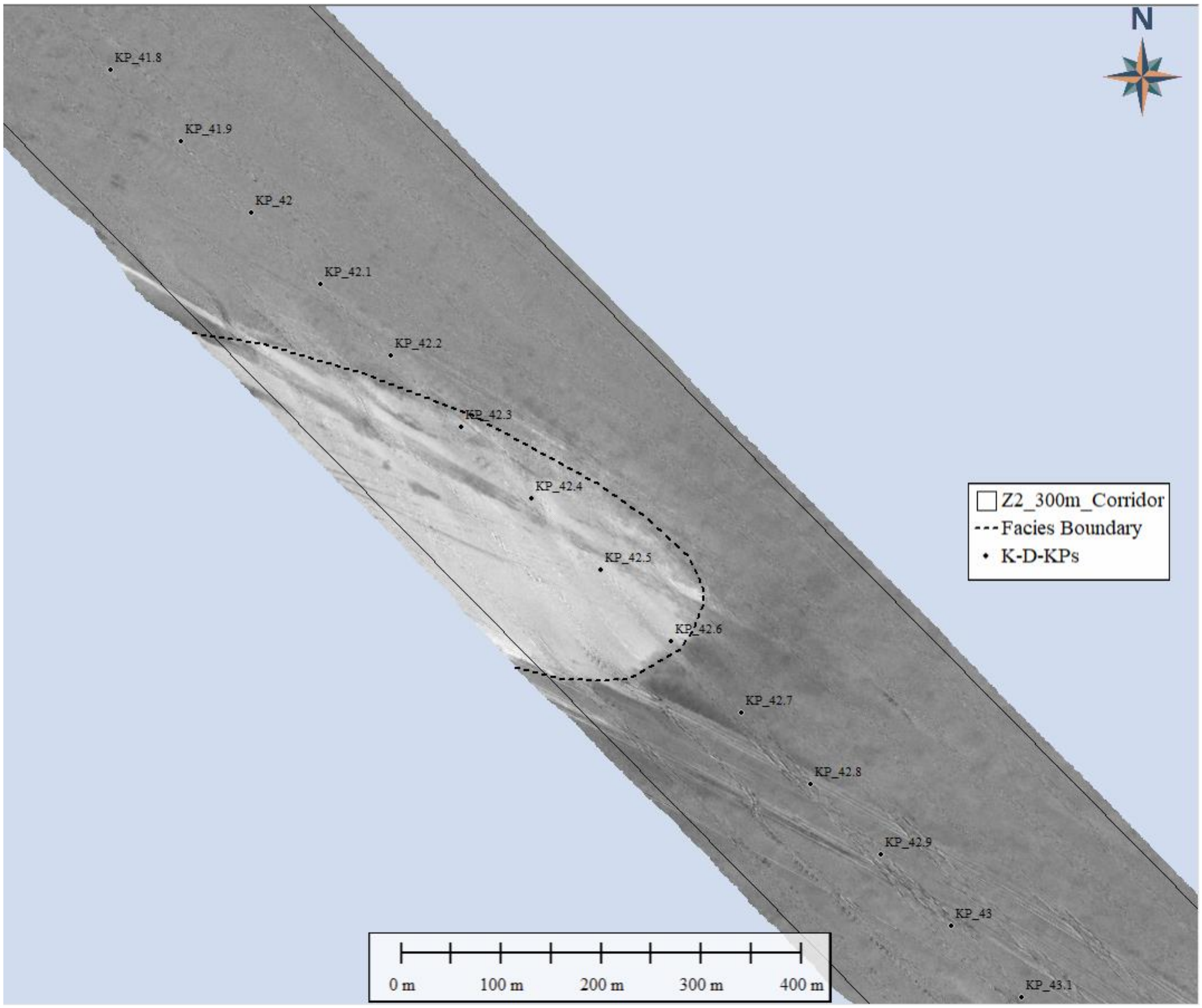


Figure 5-32. Area of increased backscatter reflection intensity.

5.2.4 SUB-SURFACE STRATIGRAPHY

Sub-bottom penetration of 2 m or greater was achieved throughout Zone 2. Acoustic penetration of up to 11 m was observed.

Five examples of sub-bottom profiles along the centerline of Zone 2 are shown in Figure 5-33. Image A shows a near surface unconformity and relatively deep acoustic penetration, semi-horizontal reflections, and variable acoustic blanking. Image B shows dipping bedding, downlap, and surface ice gouging. Image C shows rapid signal attenuation in a sediment with no internal horizons. Image D shows moderate signal attenuation in sediments with horizontal bedding. Lastly, image E shows a mix of horizontal and dipping beds over a zone of low amplitude reflection terminating on a reflector at depth.

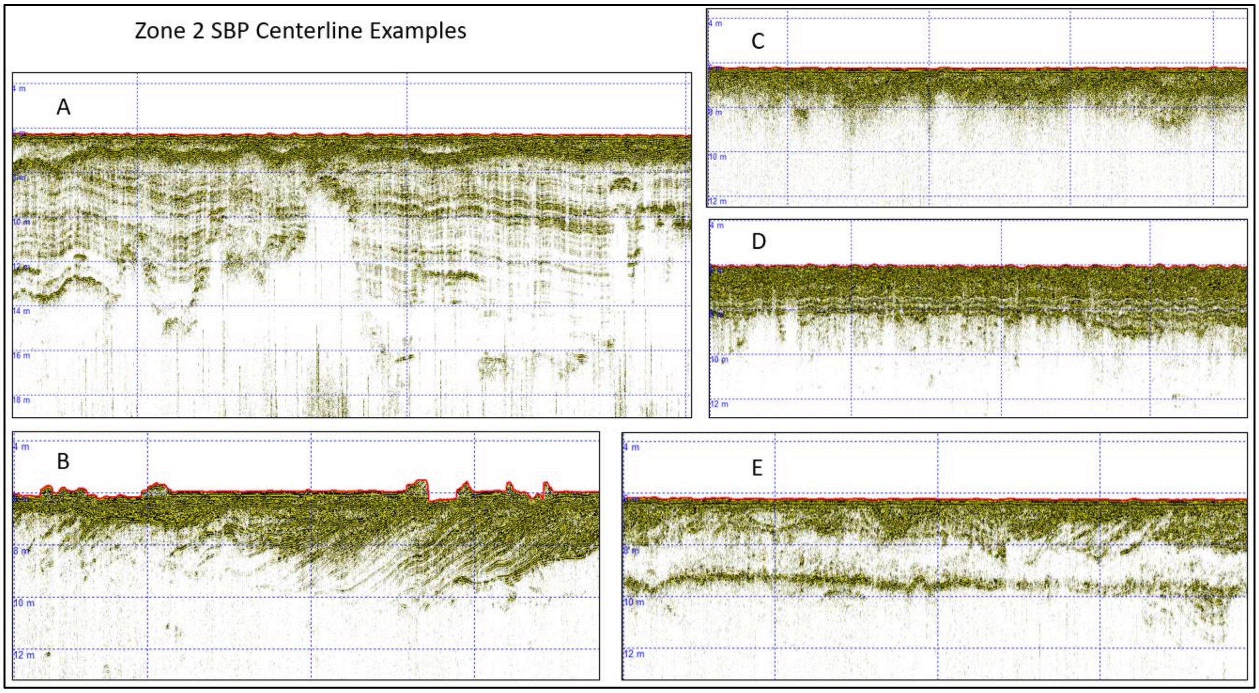
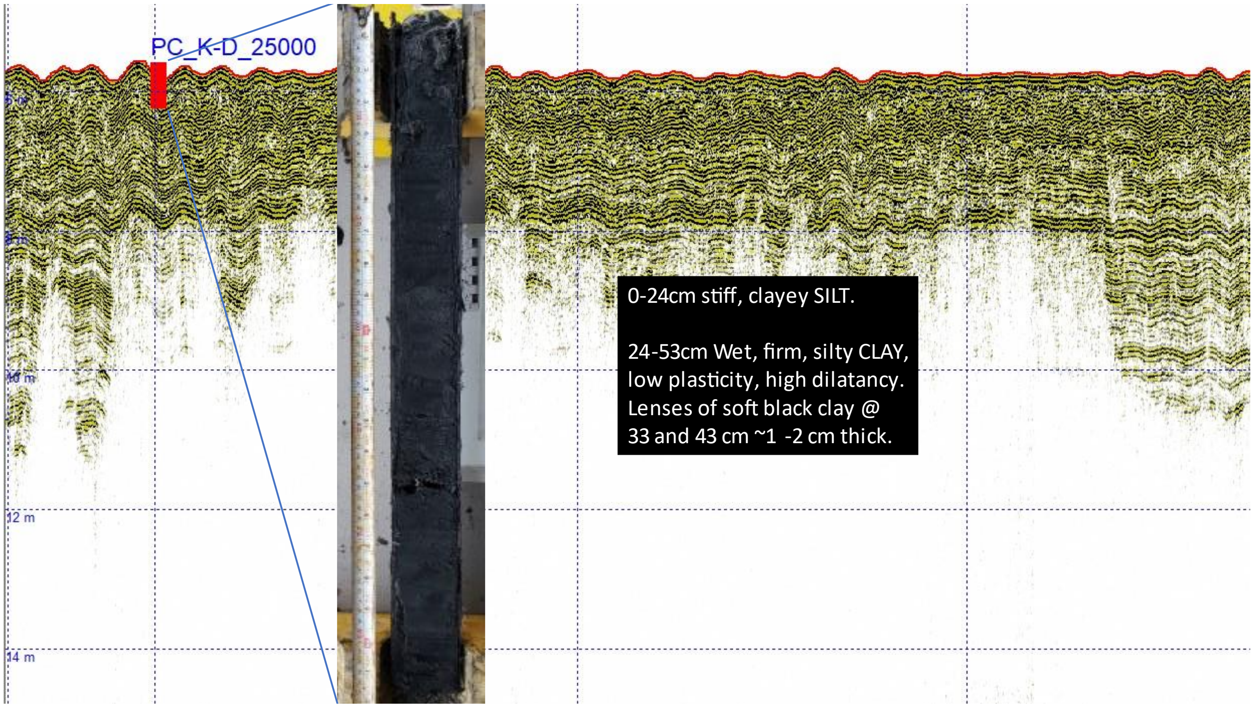


Figure 5-33. Zone 2 sub-bottom profile examples

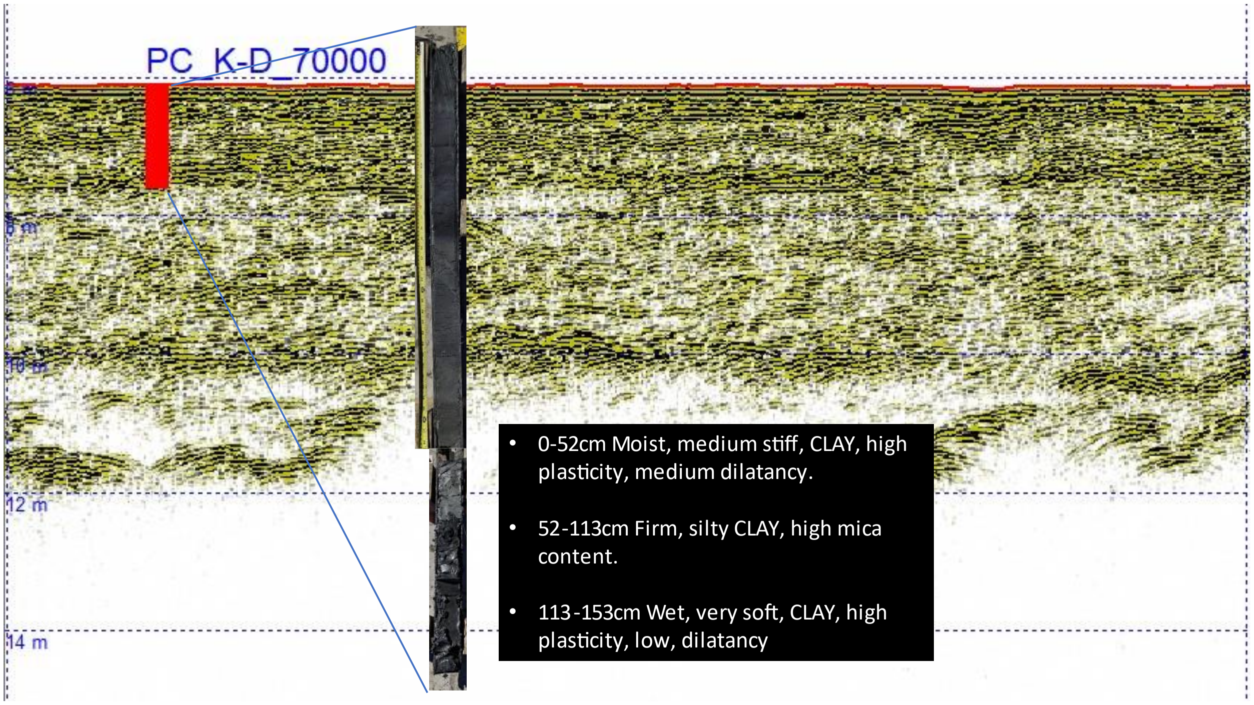
Throughout Zone 2 the pattern of sub-surface reflections varies between the spectrum of examples shown in Figure 5-33. There is no distinguishable spatial relationship or relation to water depth. The stratigraphy seen throughout Zone 2 is consistent with a low energy marine depositional environment and the variations in acoustic reflectivity represent small changes in sediment grainsize or density. There are no significant stratigraphic horizons within the sub-bottom profiles that are expected to impact the cable installation. Therefore, no internal horizons have been digitized. However, the sub-bottom records have been carefully reviewed for geophysical anomalies or inconsistencies from locations ground truthed with core samples. Figure 5-34 and Figure 5-35 provide examples of sub-bottom profiles with overlayed core samples within Zone 2.



0-24cm stiff, clayey SILT.

24-53cm Wet, firm, silty CLAY, low plasticity, high dilatancy. Lenses of soft black clay @ 33 and 43 cm ~1 -2 cm thick.

Figure 5-34. Sub-bottom and core records from K-D_25000



- 0-52cm Moist, medium stiff, CLAY, high plasticity, medium dilatancy.
- 52-113cm Firm, silty CLAY, high mica content.
- 113-153cm Wet, very soft, CLAY, high plasticity, low, dilatancy

Figure 5-35. Sub-bottom and core records from K-D_70000

There are no indications of outcropping or sub-cropping bedrock or glacial till within the proposed burial depth.

5.2.1 MAGNETIC ANOMALIES

Magnetometer data was acquired along the centerline of zone 2. Of particular interest was the lightering area at the north end of Zone 2. 1 magnetic anomaly was detected in Zone 2; however, its broad monopole response indicates the ferrous target is deep, laterally offset or the anomaly may be geologic in nature.

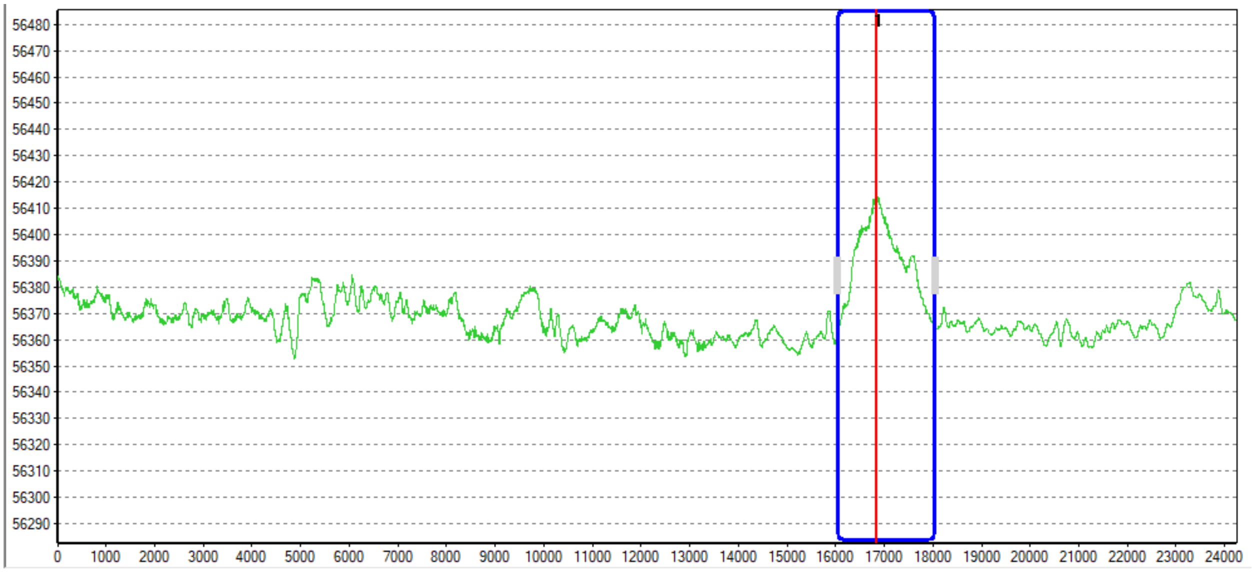


Figure 5-36. Zone 2 magnetic anomaly

5.2.2 SUMMARY

Seafloor ice scours are a common seafloor feature throughout Zone 2. Clay is the predominate sediment type throughout Zone 2. Stiff and even very stiff clay is likely to be encountered during cable installation. Sub-bottom records did not reveal any stratigraphic horizons of sub-cropping features of concern.

5.3 Zone 3 (K-D KP 73.8 to KP 117.7)

5.3.1 BATHYMETRY AND SEAFLOOR FEATURES

The bathymetry data in Zone 3 covers a 300-meter-wide corridor until KP 115.1 where water depths are less than 8 meters. From KP 115.3 to KP 117.2 a 150-meter-wide corridor was surveyed to within 400 meters of the shore at Deering (Figure 5-39).

Surveyed depths in Zone 3 range from 3.7 m to 15.2 meters below MLLW. The majority of Zone 3 lays within the flat bottom basin of Kotzebue Sound with water depths of 14.25 to 15 meter below MLLW (Figure 5-37 and Figure 5-38).

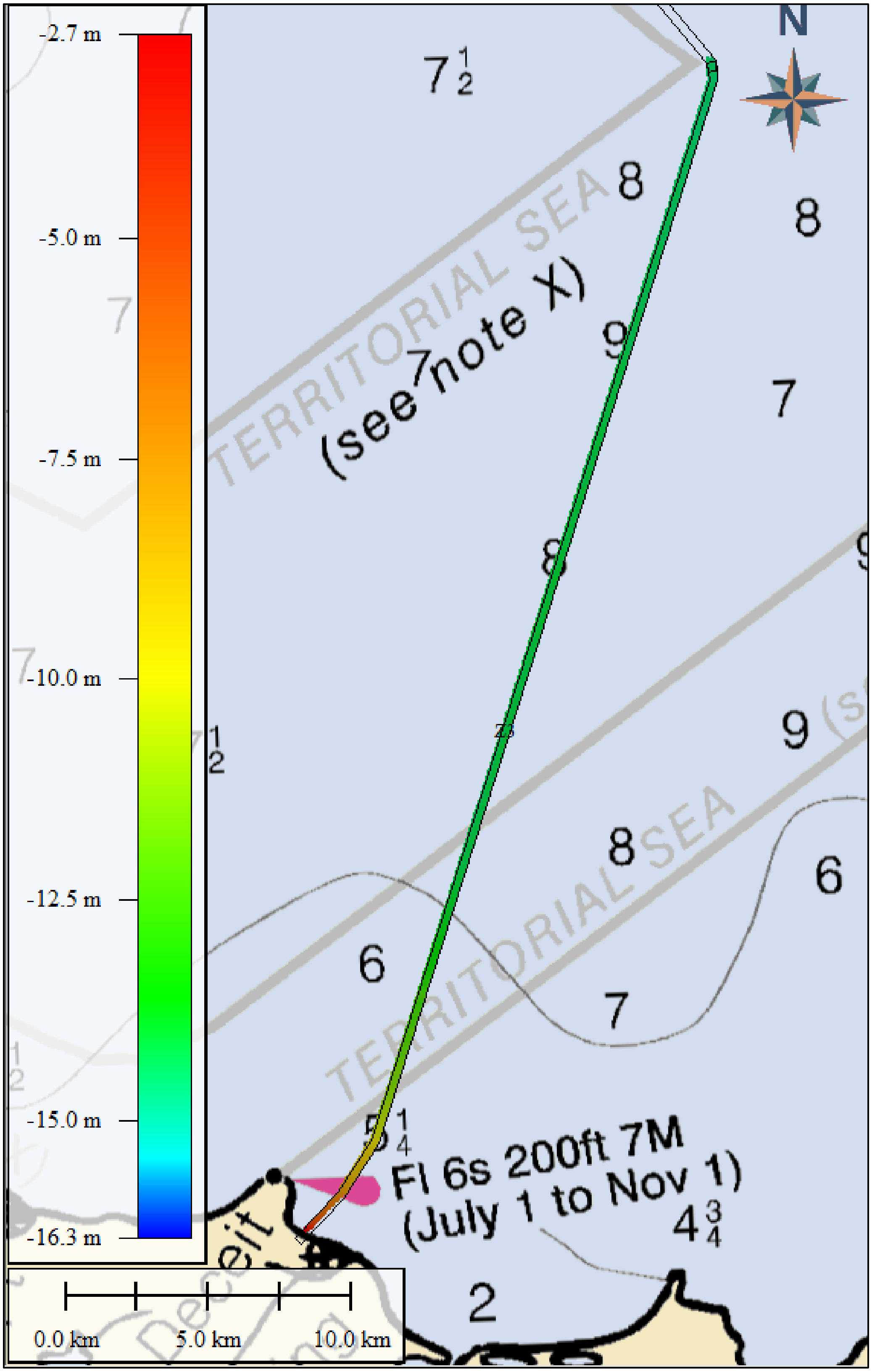


Figure 5-37. Zone 3 Bathymetry coverage

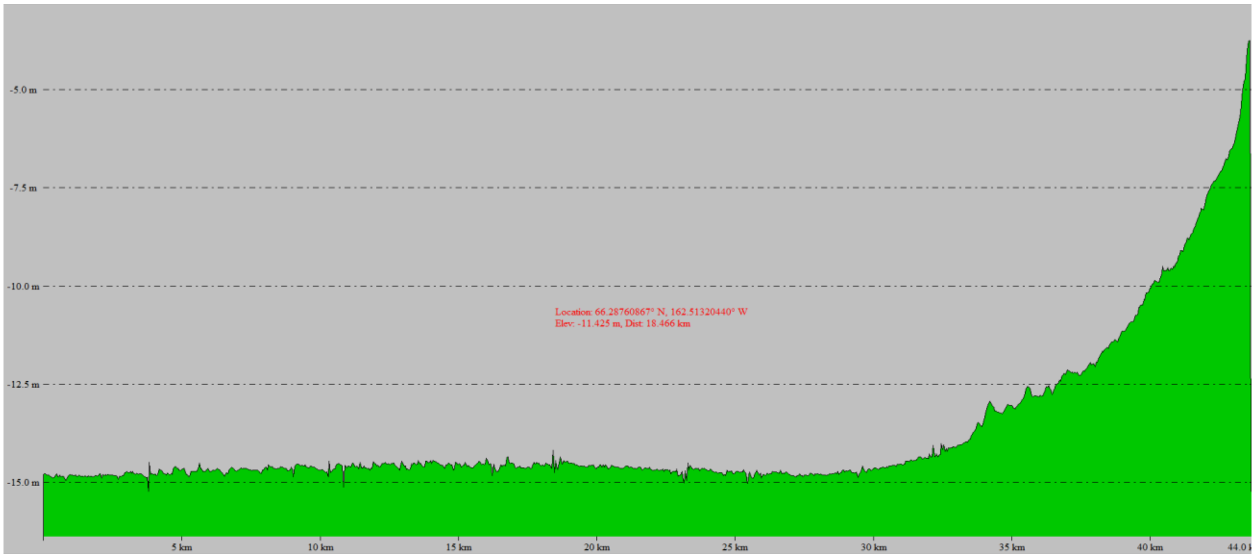


Figure 5-38. Zone 3 Bathymetric profile

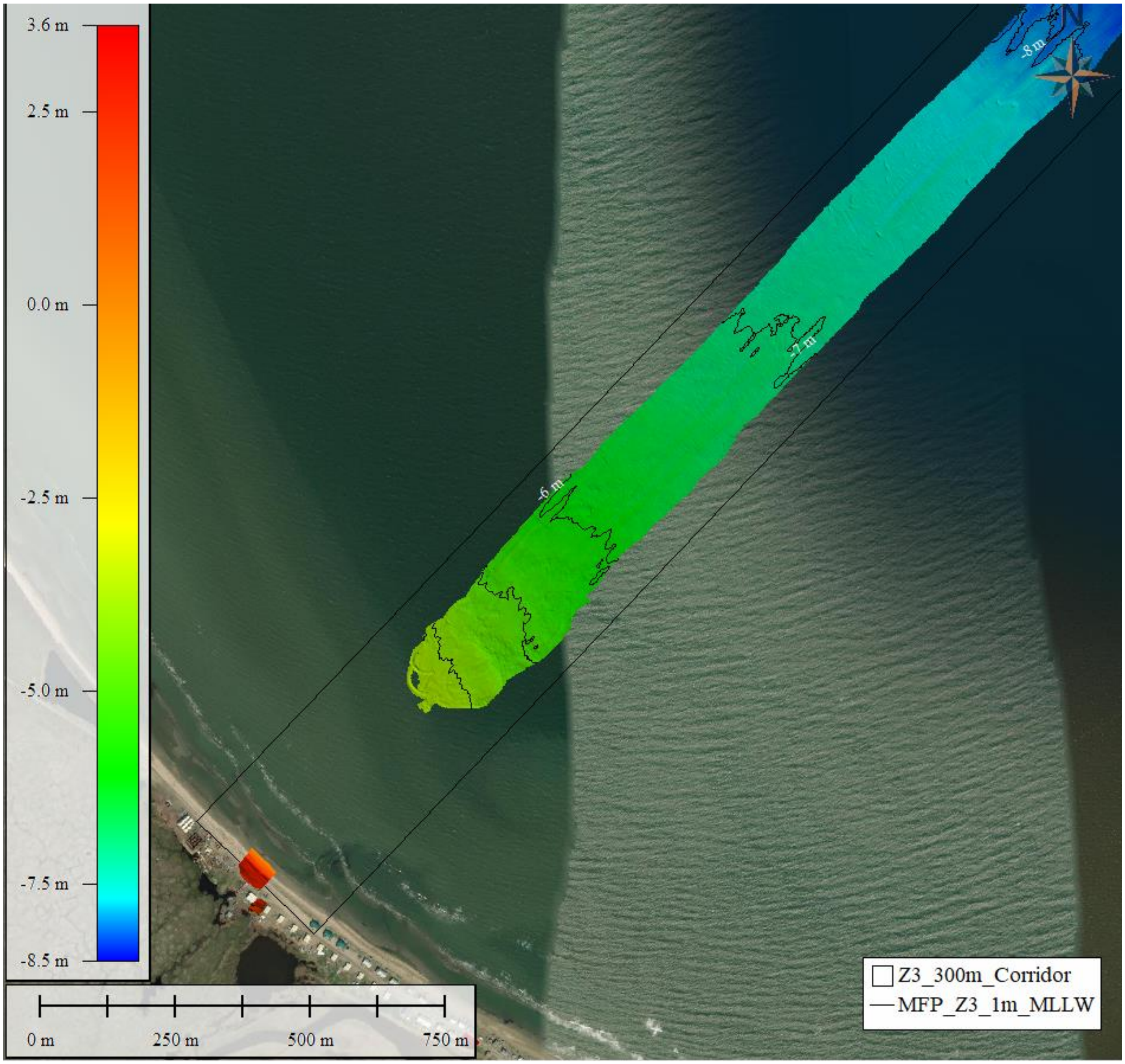


Figure 5-39. Nearshore bathymetry at Deering, AK

Ice scouring is prolific throughout zone 3. Hundreds of ice scours cross the survey corridor. Younger, fresher scours can be distinguished from older scours by the sharpness of features and cross cutting relations. For example, in Figure 5-40 scour C is cut by scour B while scour B is cut by scour A, thus C is the oldest scour while A is the youngest. Scour A has sharp features and lumpy furrows while scour C is infilled and has well rounded furrows.

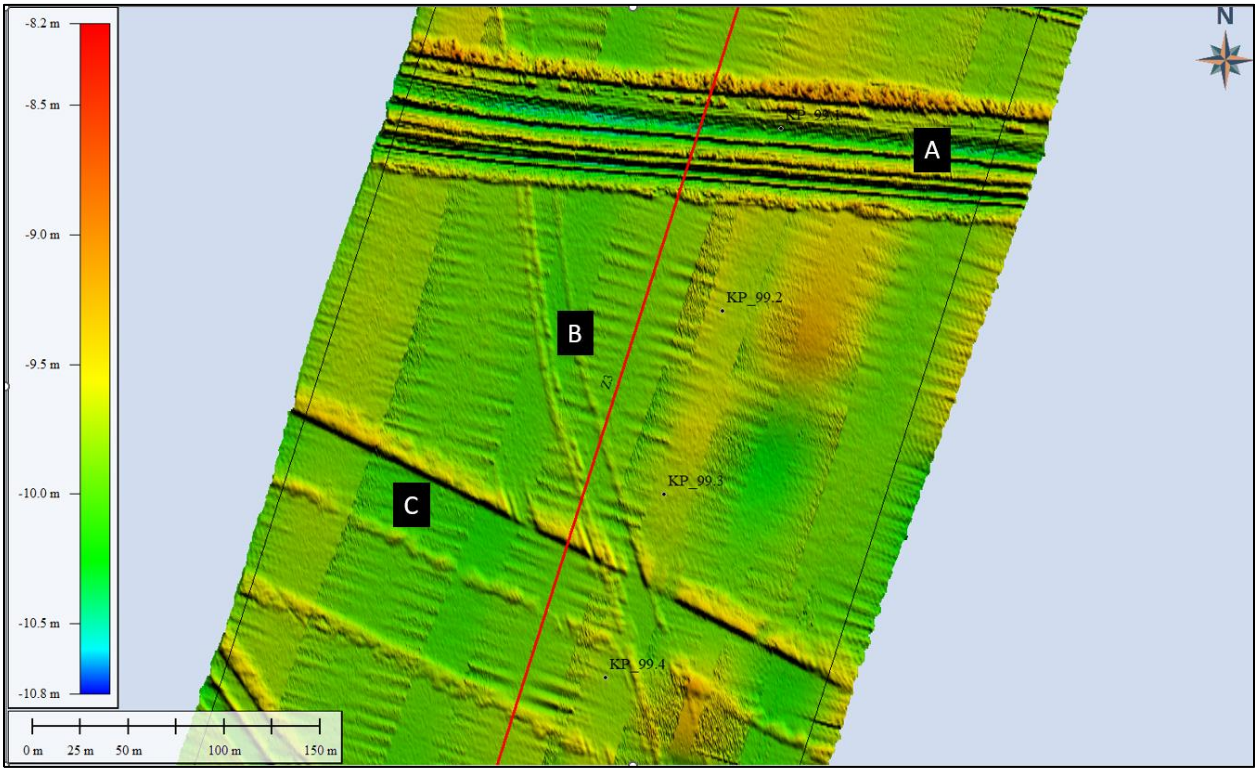


Figure 5-40. Example of ice scours showing cross cutting relations from Zone 3.

Nearly 1200 ice scours were digitized in Zone 3 (Figure 5-41). Most ice scours are oriented between east-west and southeast-northwest however there are numerous exceptions.

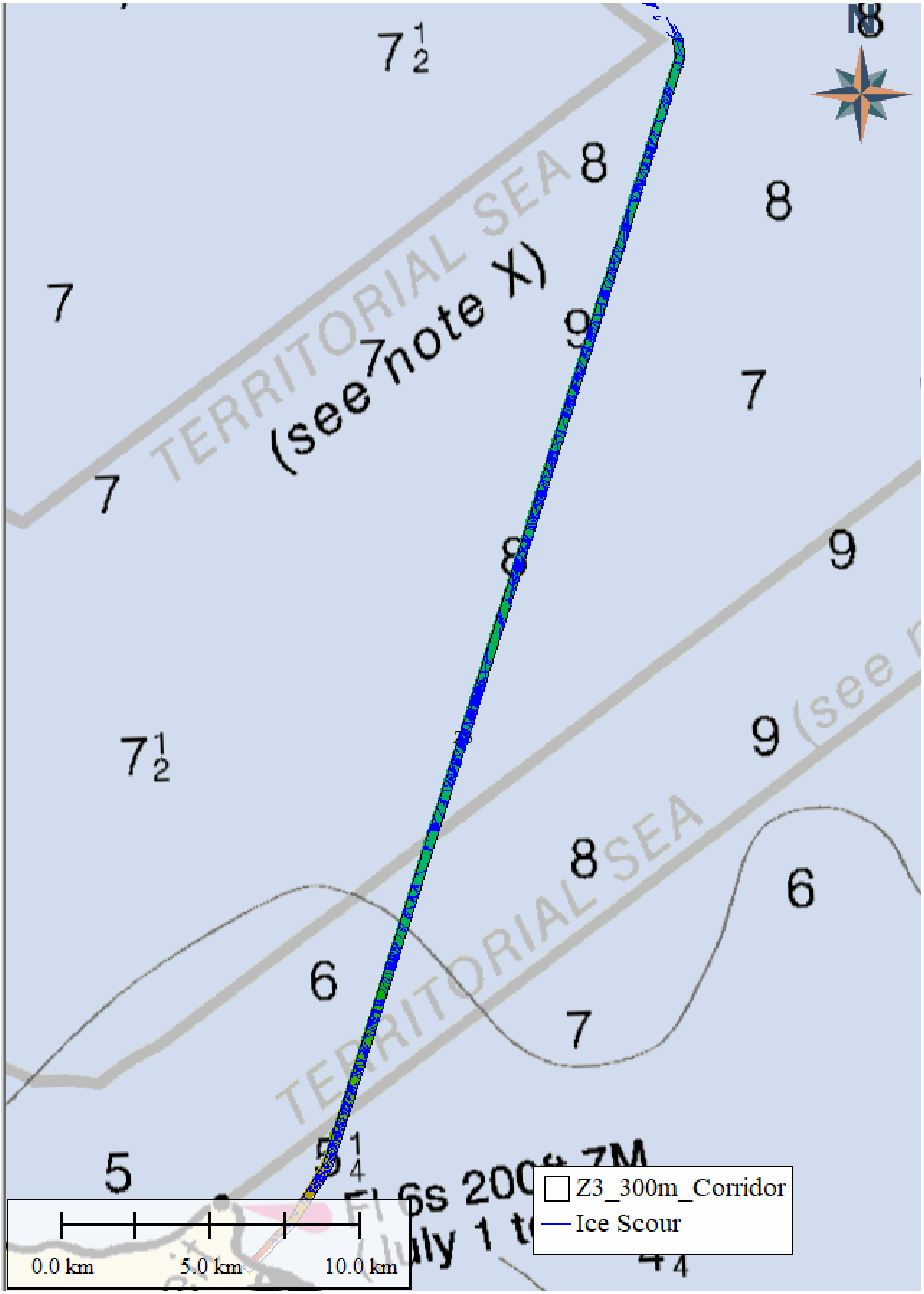

Z3_300m_Corridor
Ice Scour
0.0 km
5.0 km
10.0 km
TERRITORIAL SEA
(see note X)
Fl 6s 200ft 7M
July 1 to
N

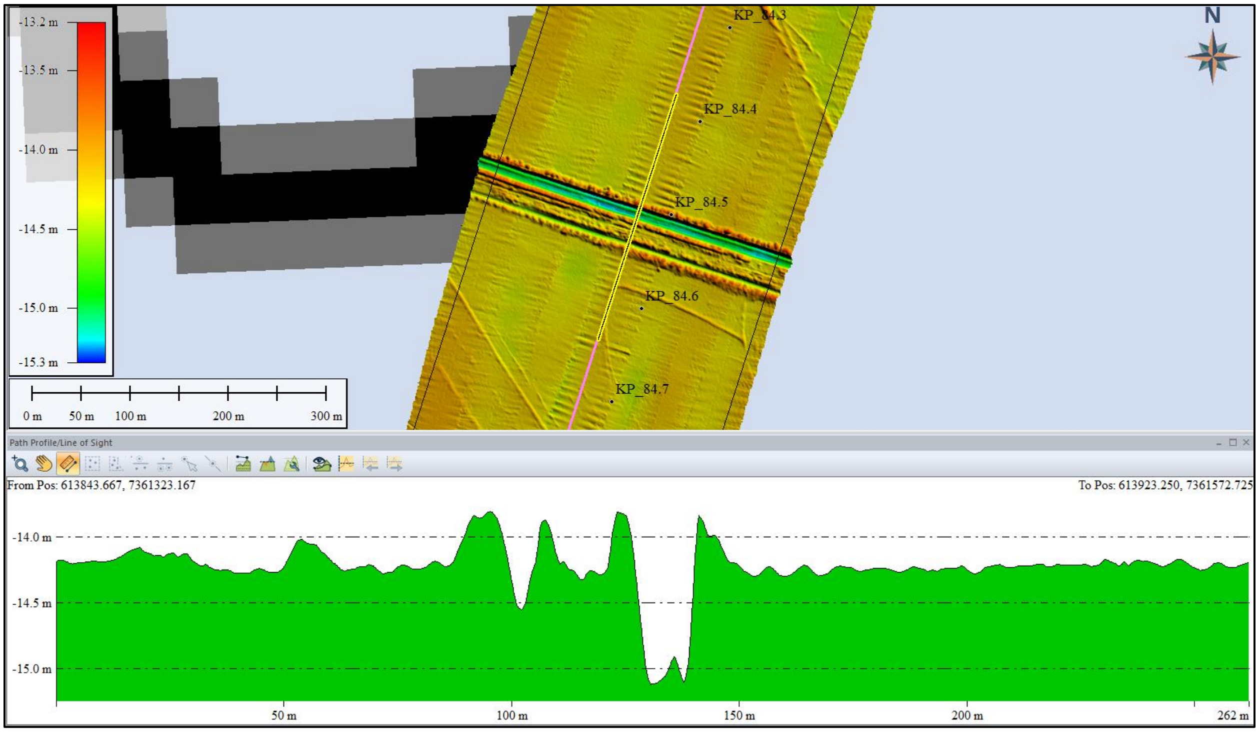
Figure 5-41. Zone 3 Ice Scours

A sub-set of the younger looking scours in Zone 3 were examined by measuring their width, bearing, max furrow height and max scour depth (Table 5-5)

Table 5-5. Zone 3 Ice Scour Analysis

Zone 3 scours	**Average (m)**	**Maximum (m)**
Width between furrows	22	176
Scour Depth below adjacent seafloor	0.31	0.85
Furrow Height above adjacent seafloor	0.29	0.84

The deepest scour identified is shown in Figure 5-42 and the widest scour is shown in Figure 5-43.



From Pos: 613843.667, 7361323.167

To Pos: 613923.250, 7361572.725

Figure 5-42. 0.84-meter-deep ice scour in Zone 3

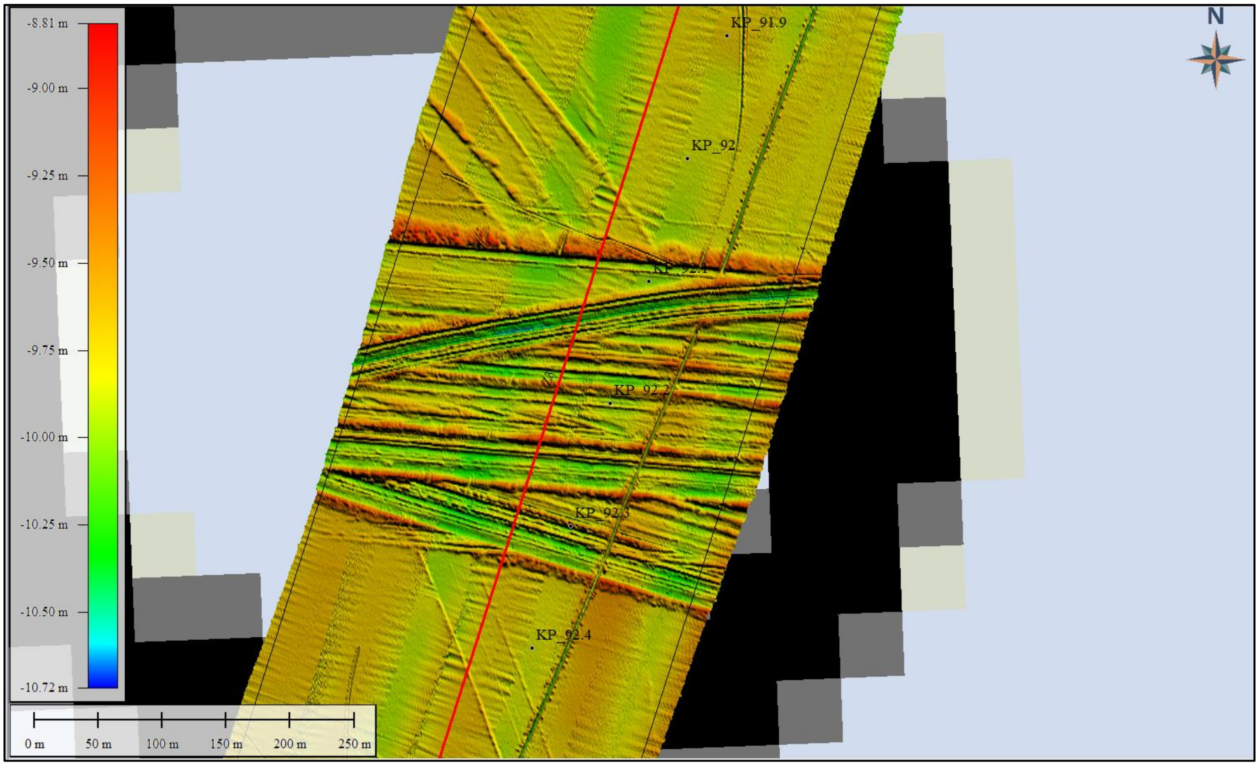


Figure 5-43. 176 m wide ice scour in Zone 3.

5.3.2 GEOTECHNICAL RESULTS

1 grab sample and 6 piston cores were collected in Zone 3 (Figure 5-44). Across the Kotzebue Sound Basin from the northern boundary of Zone 3 at KP 74 to KP 113 the seabed surface sediment is composed of wet soft clay and silty clay. Between KP 113 and the southern terminus of the route at Deering (KP 118) the surface sediments become courser and included clayey sand, coarse sand, and sandy gravel.

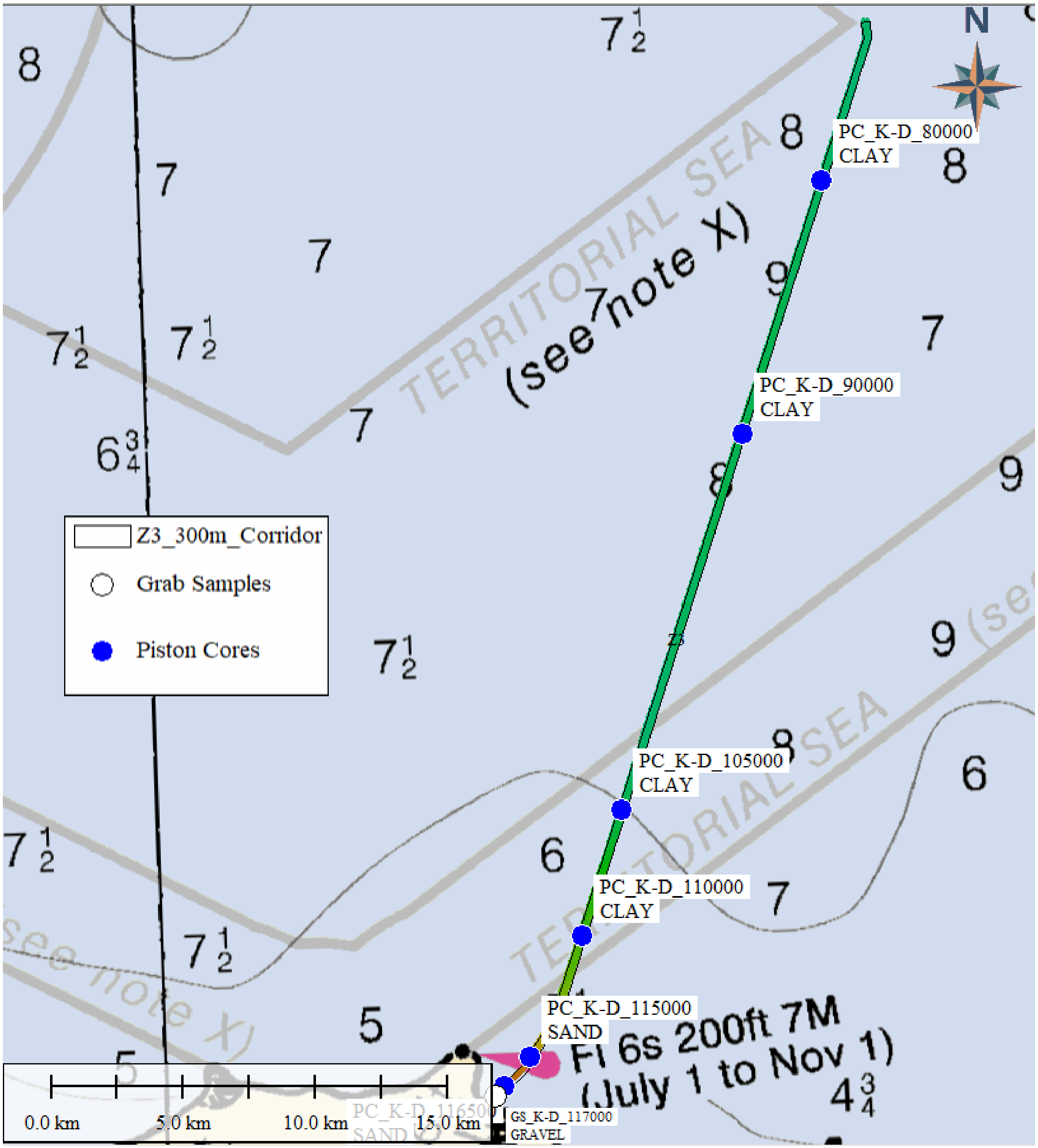


Figure 5-44. Zone 3 Geotechnical stations and surface sediments

Beneath the surface, clay, silty clay and clayey silt constitute of the sediments along the basin floor. As the seafloor slopes up towards the landing at Deering, sand and sandy gravel are encountered and resulted piston core refusal beyond 26 cm. Sediment core descriptions are provided in (Table 5-6).

Table 5-6. Zone 3 sediment core descriptions

STATION	SED. DESCRIPTION 1	SED. DESCRIPTION 2	SED. DESCRIPTION 3	SED. DESCRIPTION 4
PC_K-D_80000	0-5cm Wet, soft, CLAY, high plasticity, low dilatancy.	5-169cm Stiff transitioning to stiff, CLAY, lighter colored dark greenish grey laminations throughout.		
PC_K-D_90000	0-157cm Moist, CLAY, soft transitioning to very stiff moving down-hole. Lenses of shell fragments up to 1cm @ 103-106, trace shell fragments throughout.			
PC_K-D_105000	0-16cm Soft, wet, CLAY, high plasticity, medium dilatancy.	16-132cm Moist, stiff, CLAY, transitioning to stiff clay moving down-hole.		
PC_K-D_110000	0-86cm Moist, soft transitioning to medium stiff, silty CLAY, low plasticity, high dilatancy, high mica content, dark brownish grey organic banding throughout with trace shell fragments.			
PC_K-D_115000	0-9cm Loose, medium grained SAND, subangular-angular, abundant subrounded, fine gravel clasts, minor organic content.	9-20cm Clayey SILT, up to 50% light brown organics.	20-37cm Clayey SILT, very firm, increasing organic content moving towards lower contact. Up to 50% light brown organic content in lower 10cm.	37-74cm Moist, very stiff, silty CLAY, low plasticity, fast dilatancy, minor organic content.
PC_K-D_116500	0-26cm Loose, poorly graded, clayey med to coarse SAND, subangular to angular with moderate subangular fine gravel clasts.			

Measurements of shear strength and compressive strength were acquired in all cores apart from K-D_116500 where shear strength measurements were not applicable due to the grain size.

25 shear strength tests in were performed on cores from zone 3. 24% of measurements revealed very soft sediment, 60% tested as soft sediment and 16% tested as firm sediment with a maximum shear strength of 0.53 kg/cm^2 (Figure 5-45). Based on 26 unconfined compressive strength tests the sediment is very soft to hard. Two cores contained firm sediments and two additional cores contained stiff sediments. In only one core (K-D 90000) was hard clay identified with a value of 4.0 (kg/cm^2) at a depth of 80cm (Figure 5-46).

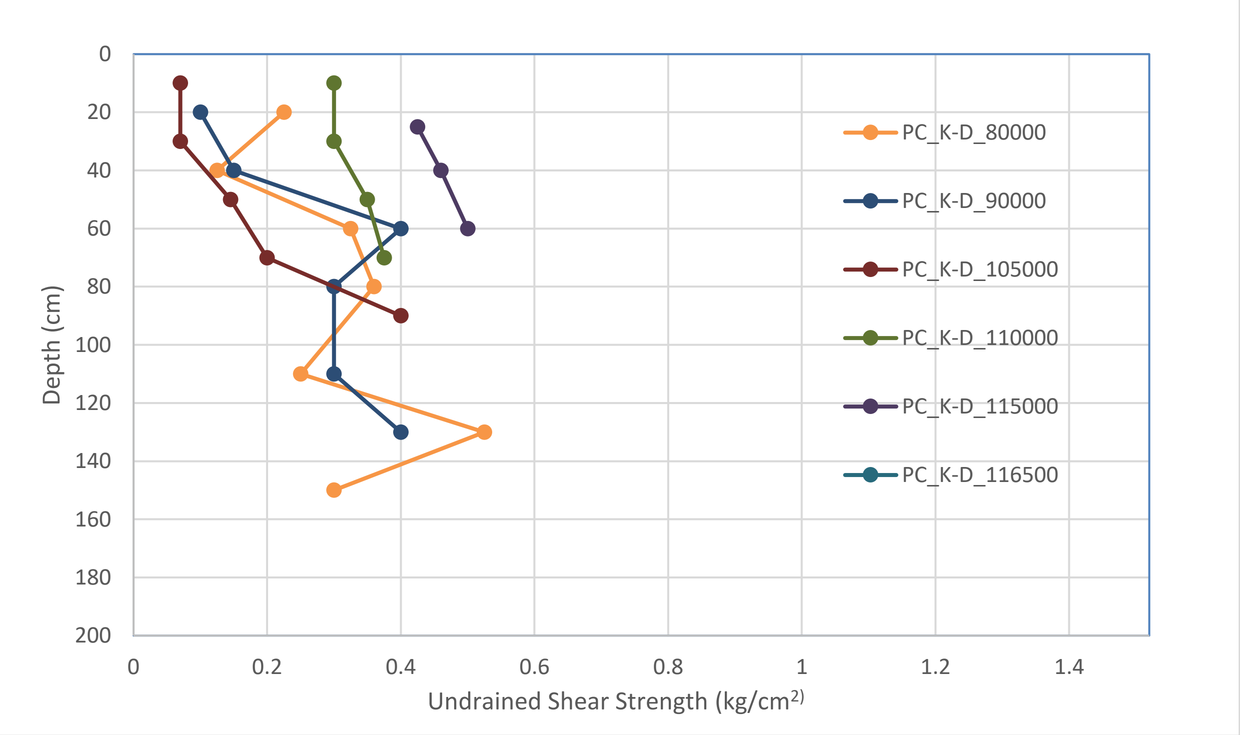


Figure 5-45. Zone 3 Undrained shear strength measurements

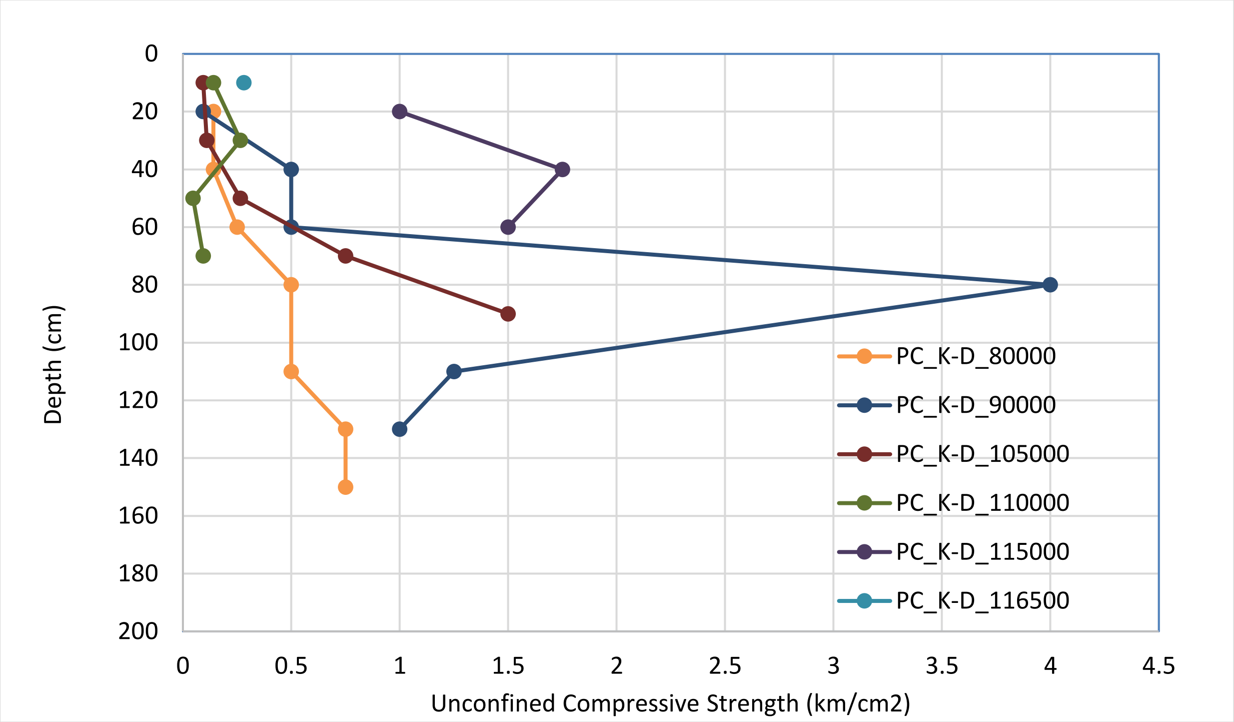


Figure 5-46. Zone 3 Unconfined compressive strength.

Based on the relationship between the descriptive soil property terminology and numeric values of shear strength and compressive strength shown in Table 5-3, Figure 5-47 shows the distribution of soil types in Zone 3 based on the geotechnical tests.

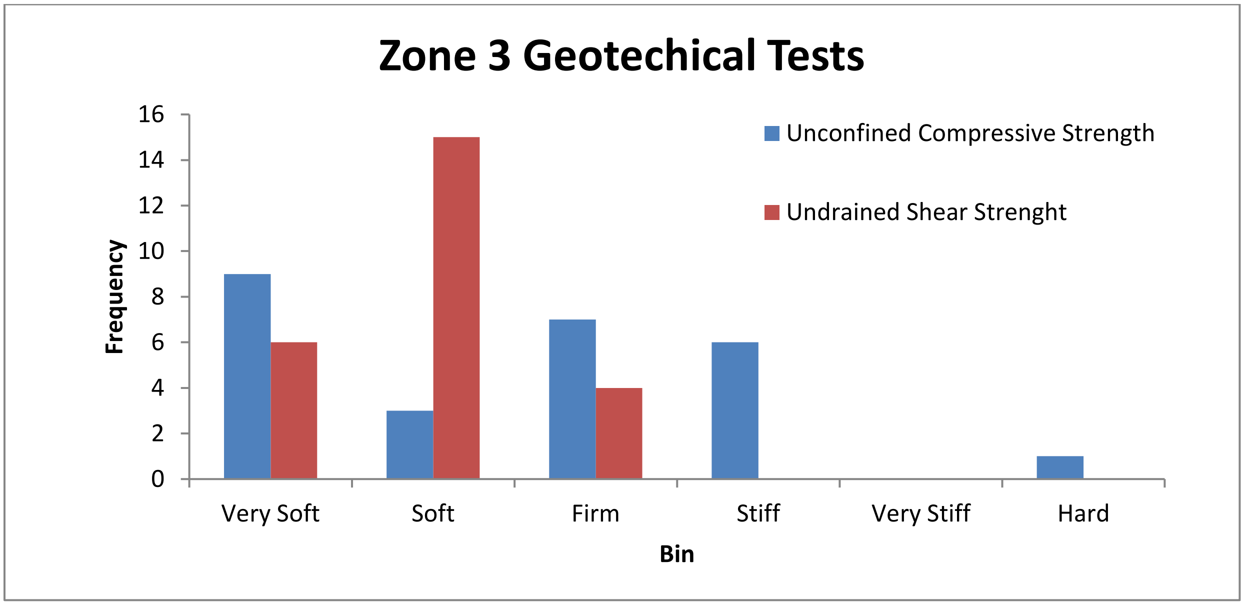


Figure 5-47. Zone 3 soil properties based on geotechnical tests

Note that out of the 6 cores acquired in Zone 3 only three cores recovered more than 1 meter of sediment. The maximum recovery was 169 cm with an average recovery of 107 cm. Therefore, stiffer sediments may be encountered at depth that were not sampled in coring and do not present differently in the acoustic records.

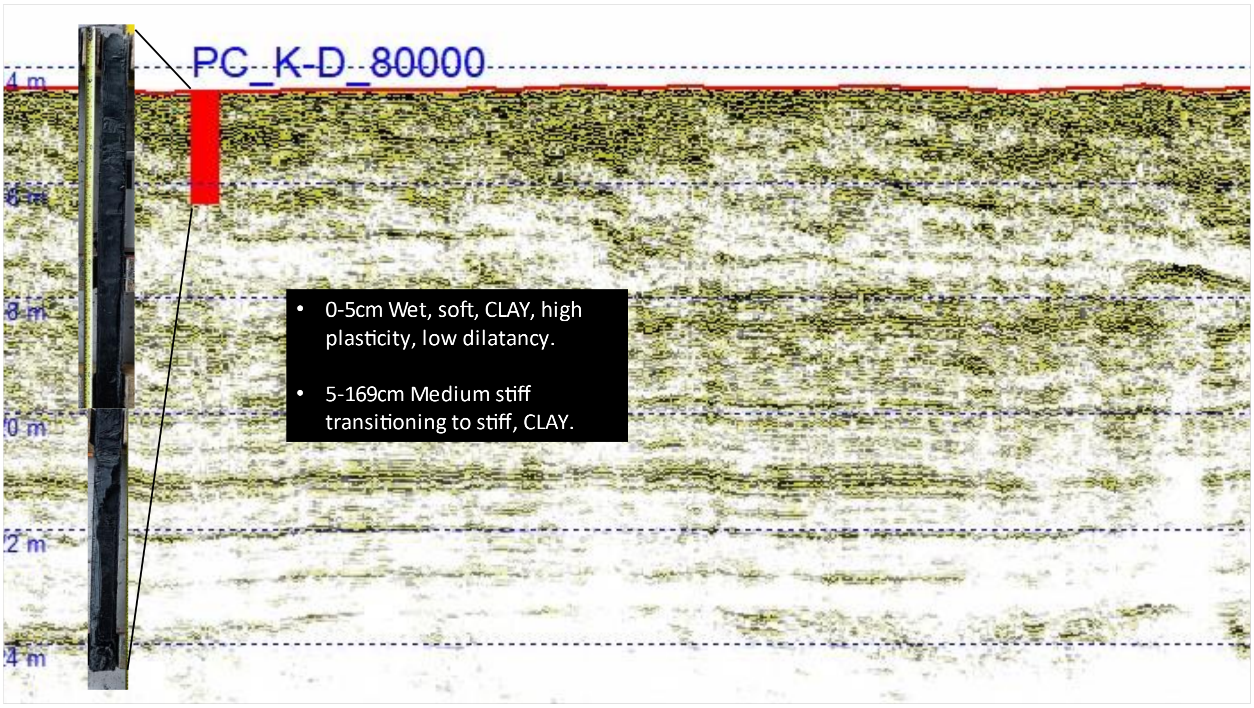
5.3.3 SURFACE SEDIMENTS

Based on the side scan sonar imagery, multibeam backscatter, and geotechnical results the surface sediments throughout Zone 3 are clay and silty clay with the exception of the southern and shallowest most 5 km of the route where the sediments are clayey sand, and sandy gravel. As discussed in Section 5.2.3, based on the side scan sonar reflectivity seafloor depression or gouges caused by ice scours trap finer grained sediments than the surrounding seafloor

5.3.4 SUB-SURFACE STRATIGRAPHY

Sub-bottom penetration of greater than 2 m was achieved throughout Zone 3. Acoustic penetration of up to 11 m was obtained across much of the basin. Signal penetration decreased with decreasing depth and increasing sediment grain size near the southern end of the route.

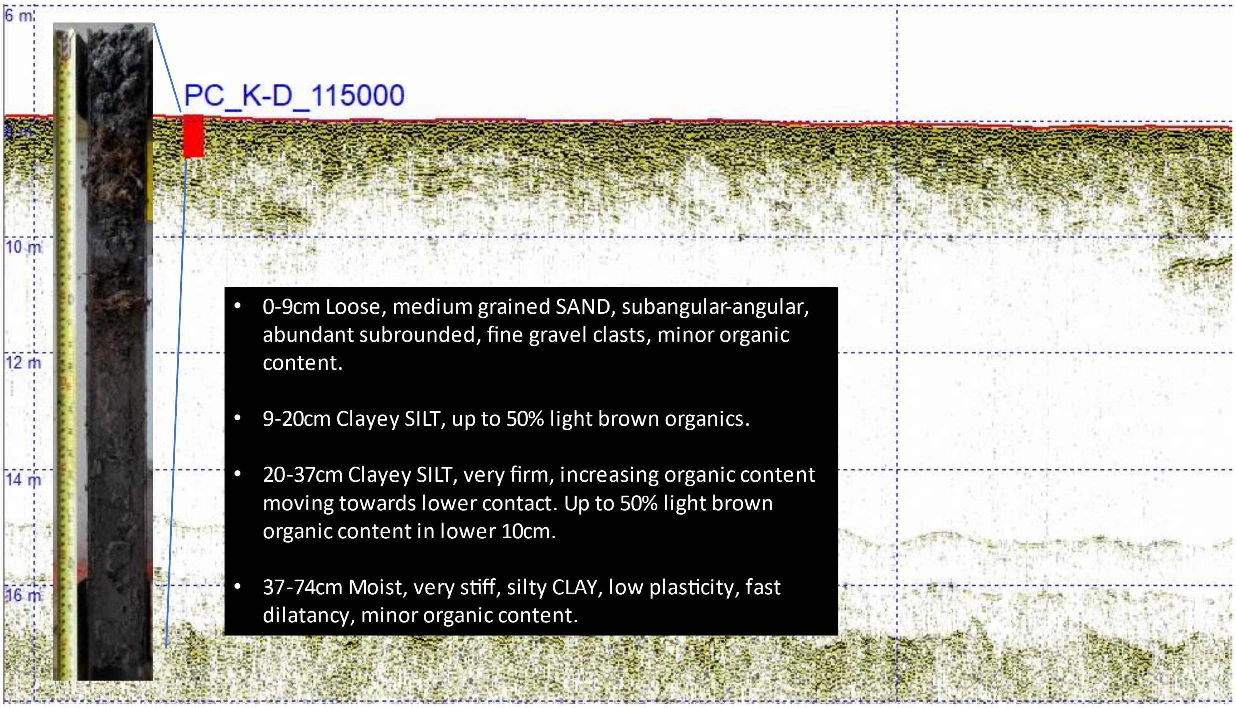
A typical example of a sub-bottom profile from KP 73.8 to KP 107.7 is shown in Figure 5-48. In Figure 5-48 the upper 2.5 meters show a discontinues pattern of reflections. From 3.5 meter to the signal extinction the record shows a horizontal continuous stratigraphy with minor variations in acoustic reflectivity. This pattern of deep thick horizontal sediments is contiguous across the basin where water depths are consistently about 14 to 15 m deep. Based on cores at KP 80, KP 90, and KP 105 the upper sediment is composed of stiff clay



- 0-5cm Wet, soft, CLAY, high plasticity, low dilatancy.
- 5-169cm Medium stiff transitioning to stiff, CLAY.

Figure 5-48. Zone 3, Sub-bottom profile example at PC_K-D_80000 within the basin of Kotzebue Sound.

Starting at 107.7 water depths begin to decrease and grain size increases. A core sample at K-D_110000 in 12.5 meters of water achieved 86 cm of penetration and found stiff silty clay with organic banding. By the time we reach the next core sample at K-D_115000 water depths are 8.7 meters. Here the sub-bottom record is reduced to approximately 2 meters. Fine sand with find gravel clasts overlays clayey silt and silty clay (Figure 5-49). Based on this stratigraphy it would seem coarse grained material is being transported downslope via wave action or ice rafting from the shore near Deering.



- 0-9cm Loose, medium grained SAND, subangular-angular, abundant subrounded, fine gravel clasts, minor organic content.
- 9-20cm Clayey SILT, up to 50% light brown organics.
- 20-37cm Clayey SILT, very firm, increasing organic content moving towards lower contact. Up to 50% light brown organic content in lower 10cm.
- 37-74cm Moist, very stiff, silty CLAY, low plasticity, fast dilatancy, minor organic content.

Figure 5-49. Zone 3, Sub-bottom profile at PC_K-D_11500.

A final core was acquired at KP 116.5 in 6.7 meters of water. The acquired sediment was clayey medium to coarse sand with fine gravel. Given these grain sizes it is not surprising that the sub-bottom penetration here was no greater than 2 meters.

At K-P 117 which is 680 meters from shore and has a water depth of 5 m MLLW a final grab sample was acquired containing subangular sandy gravel.

5.3.5 MAGNETIC ANOMALIES

No magnetometer data was acquired in Zone 3.

5.3.6 SUMMARY

Seafloor ice scours are prolific throughout Zone 3 and show evidence of gouging greater than 0.8 meters into the seabed. Clay is the predominate sediment type throughout the deeper waters of Zone 3. Firm, stiff, and occasionally hard clay is likely to be encountered during cable installation. The installer can expect to encounter sand and gravel over the last 3 km of the route near Deering. Sub-bottom records did not reveal any stratigraphic horizons of sub-cropping features of concern.

5.4 Zone 4 (K-K KP 18.5 to 70.3)

5.4.1 BATHYMETRY AND SEAFLOOR FEATURES

The bathymetry data in Zone 4 covers a 300-meter-wide corridor. Surveyed depths in Zone 4 range from 8.4 m to 26.1 meters below MLLW. From KP 18.5 to KP 35 water depths gradually increase from 8.4 to 15 m. From KP 35 to KP 56 the seabed is nearly flat with water depths increasing by only 2 meters. From KP 56 to KP 70 water depths increase from 15 to 26 meters. (Figure 5-50 and Figure 5-51).

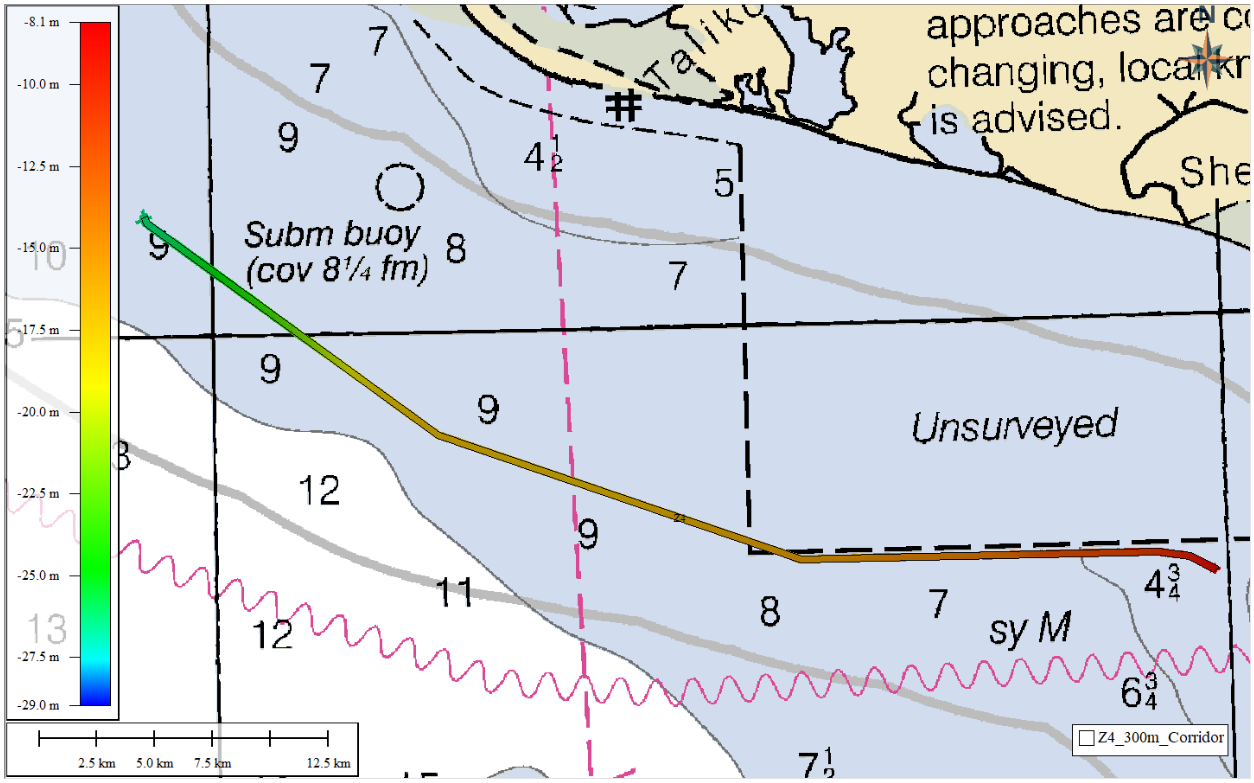


Figure 5-50. Zone 4 Bathymetry coverage

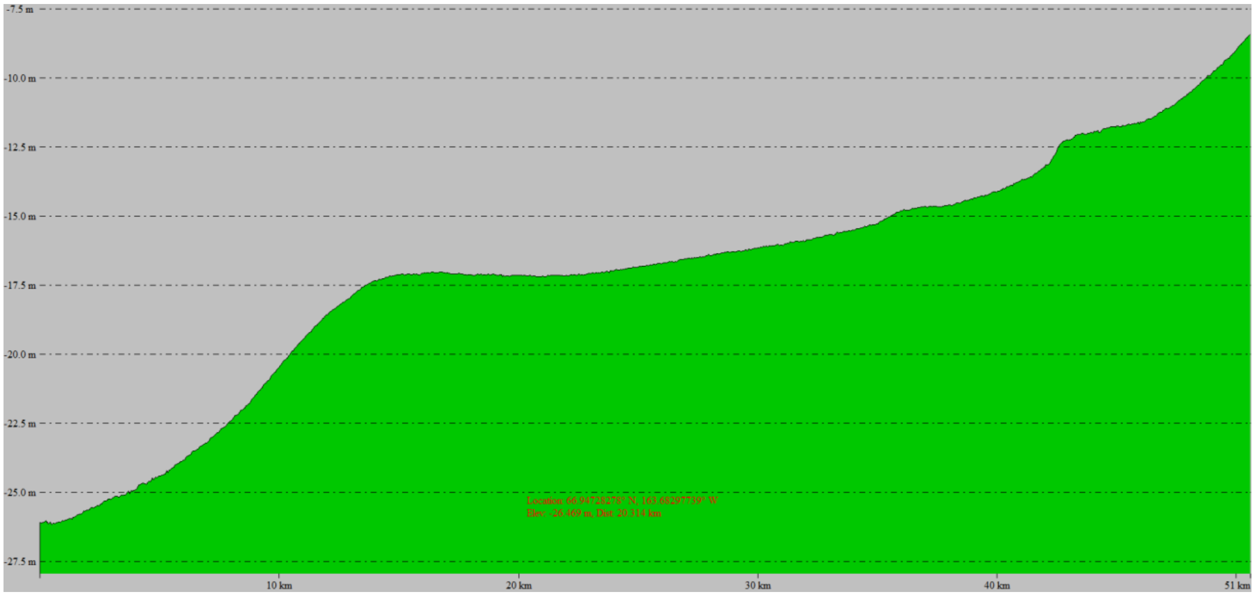


Figure 5-51. Zone 4 Bathymetric profile

In Zone 4 seabed ice scouring is observed in water depths ranging from 8.5 to 23.5 meters. Scouring is most common in the eastern third of Zone 4 where water depths range from 8.5 to 16 meters. 236 scours were digitized in Zone 4 (Figure 5-52). Most ice scours are oriented north-northwest by south-southeast expect in water depths between 17 and 23 meters where ice scours are frequently oriented northeast southwest. The ice scours in Zone 4 are not as wide and deep as the scours in the central and lower parts of Kotzebue Sound (Zones 2 and 3) rarely exceeding 0.1 m in scour depth. There are a few hypotheses to consider. One hypothesis is that there is simply less scouring, and the ice keels exert less force on the seabed in this region. Another hypothesis is that the seabed sediment is harder which prevents deep gouging, however the geotechnical data does not support this hypothesis. A third hypothesis is that there is increased wave energy in Zone 4 compared to Zones 2 and 3 resulting in ice scours that are more quickly infilled, and furrows eroded. This last hypothesis is supported by the subdued appearance of scours with the exception of scours in water depths greater than 21 meters.

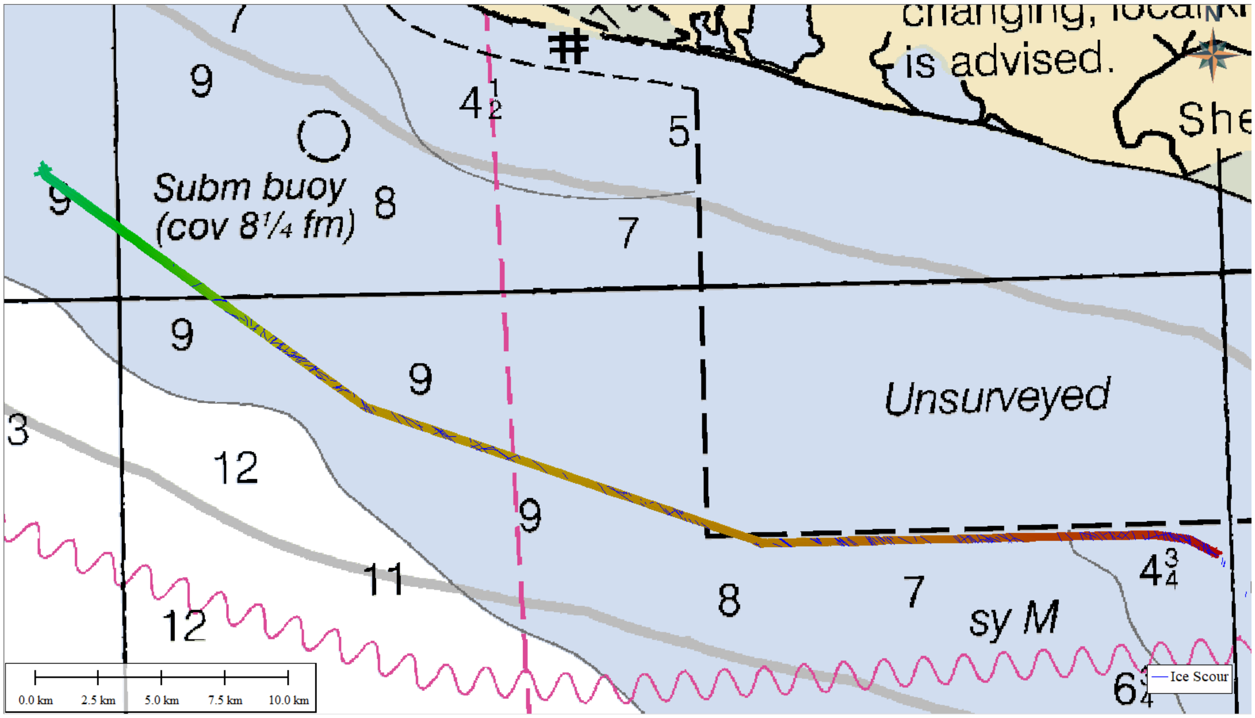


Figure 5-52. Zone 4 Ice Scours

5.4.1 GEOTECHNICAL RESULTS

6 piston cores were collected in Zone 4 (Figure 5-53). The seabed surface sediment composition ranges from very soft clay to fine sand, to clayey silt, to firm clay.

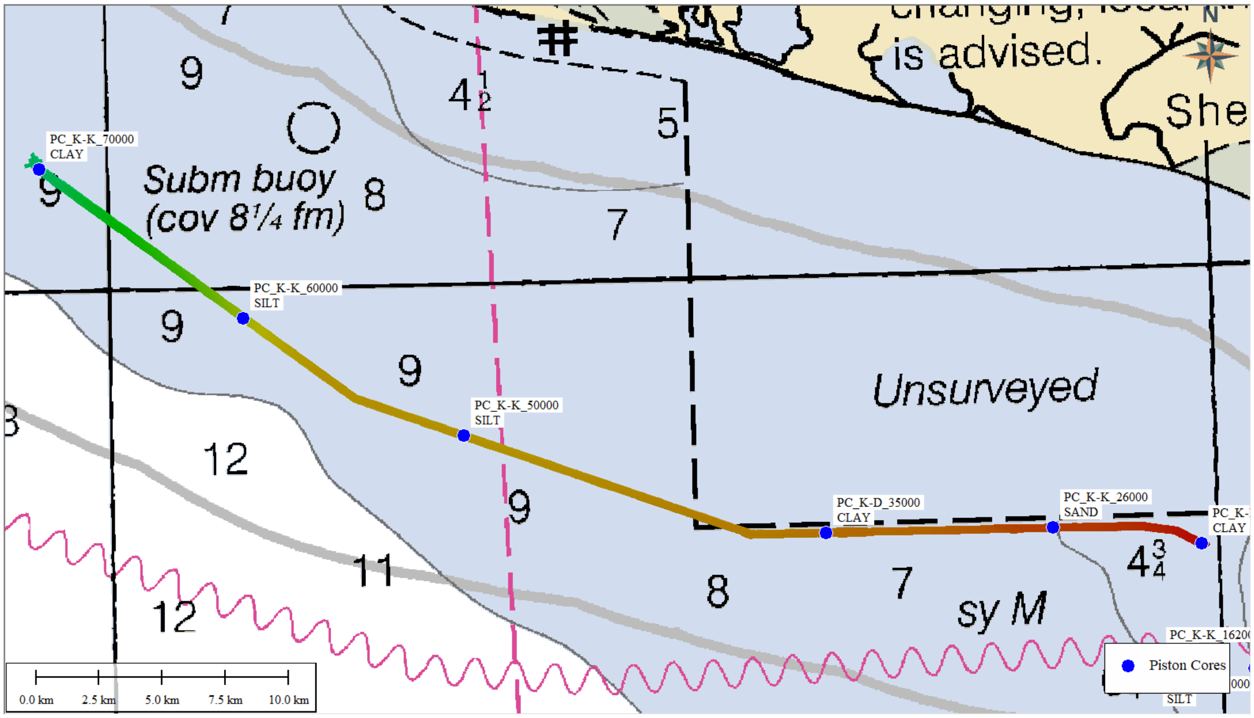


Figure 5-53. Zone 4 Geotechnical stations and surface sediments

Beneath the surface, clay, clayey silt, and fine sand constitute the sediments. Sediment core descriptions are provided in (Table 5-7).

Table 5-7. Zone 4 sediment core descriptions

STATION	SED. DESCRIPTION 1	SED. DESCRIPTION 2
PC_K-K_20000	0-10cm GLEY1 4/10Y Dark greenish grey, wet, very soft, CLAY, high plasticity, low dilatancy, trace silt	10-82 GLEY 1 3/5GY Very dark greenish grey, moist, soft, CLAY, medium, plasticity, medium dilatancy.
PC_K-K_26000	0-30cm GLEY1 4/10Y Dark greenish grey, very dense, poorly sorted, fine SAND, trace shell fragments 1cm.	
PC_K-K_35000	0-75cm GLEY 1 3/5GY, very day greenish grey, sandy SILT, firm, poorly graded, pocket of medium firm fine sand (25-42cm), light greenish grey	
PC_K-K_50000	0-34cm GLEY1 4/N Dark grey, medium dense, clayey SILT, high mica content.	
PC_K-K_60000	0-20cm Piston Core/Grab Sample: GLEY1 4/N Dark grey, very dense, SILT, high mica content.	
PC_K-K_70000	0-50cm GLEY 3/1 very dark grey med firm CLAY. High plasticity, medium dilatancy.	50-140 cm GLEY 2.5/1 bluish black. Firm sticky CLAY. High plasticity.

Shear strength tests in Zone 4 were performed on cores K-K_20000 at the east end of Zone 4 and K-K_70000 at the west end of Zone 4. All measurements of shear strength revealed very soft to soft sediment (Figure 5-54). Based on 12 unconfined compressive strength tests the sediment is very soft to stiff. However only cores K-K_35000 and K-K_50000 have measurements of 1 kg/cm^2 barely falling into the stiff category (Figure 5-55).

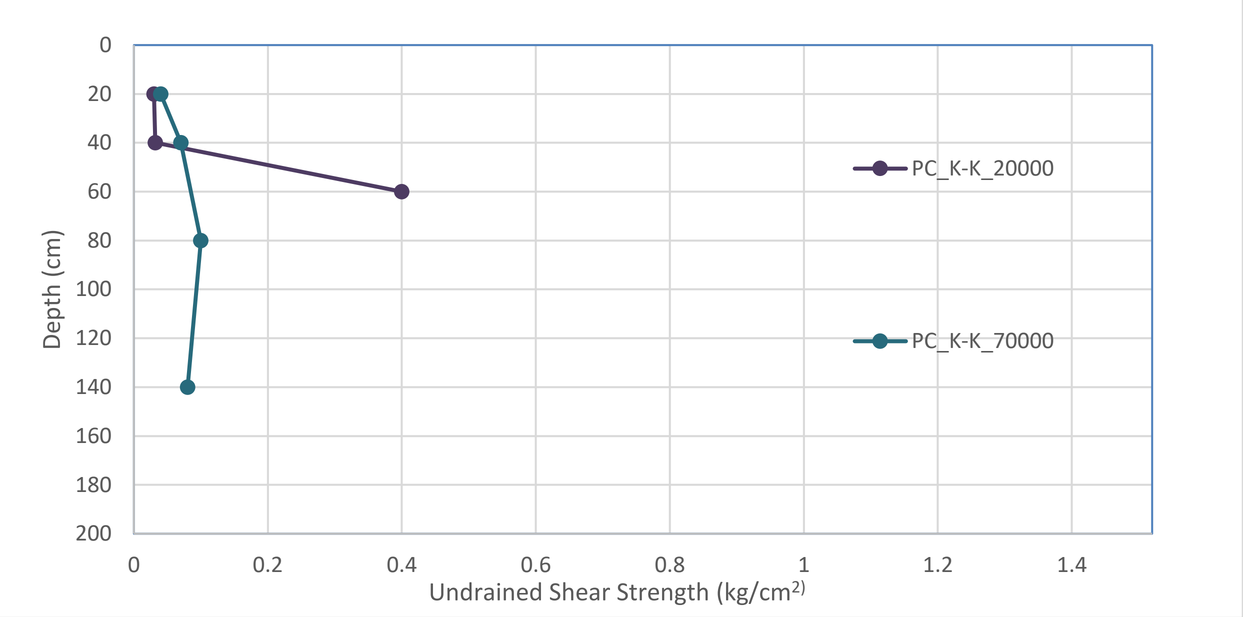


Figure 5-54. Zone 4 Undrained shear strength

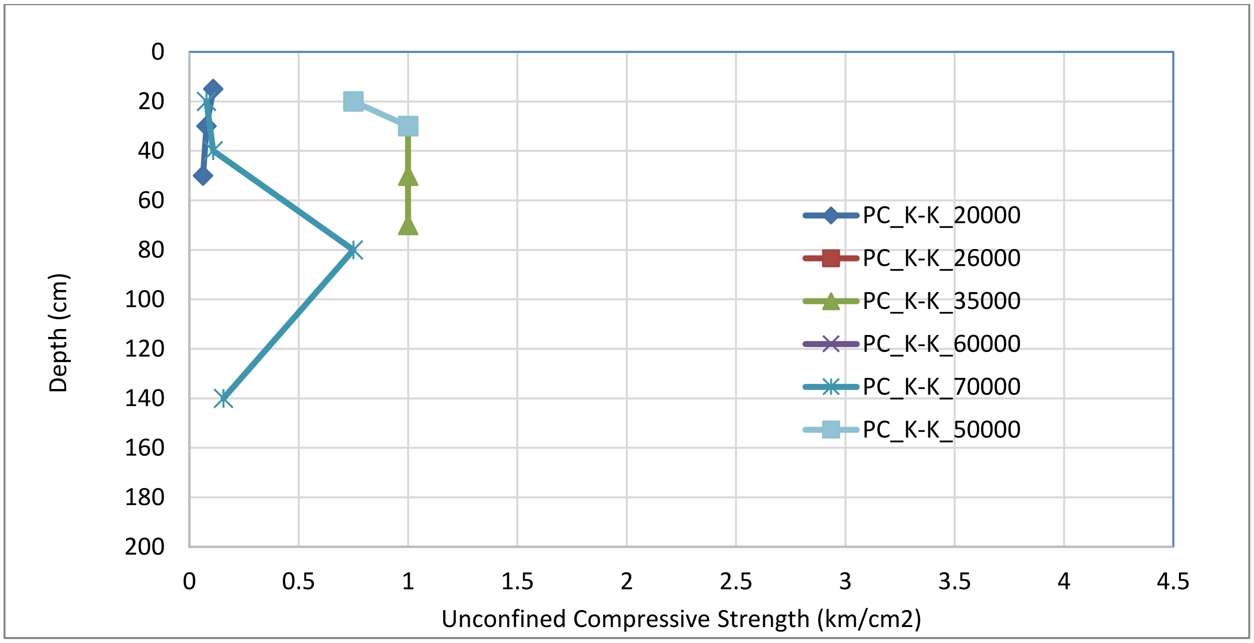


Figure 5-55. Zone 4 Unconfined compressive strength

Based on the relationship between the descriptive soil property terminology and numeric values of shear strength and compressive strength shown in Table 5-3, Figure 5-56 shows the distribution of soil types in Zone 4 based on the geotechnical tests.

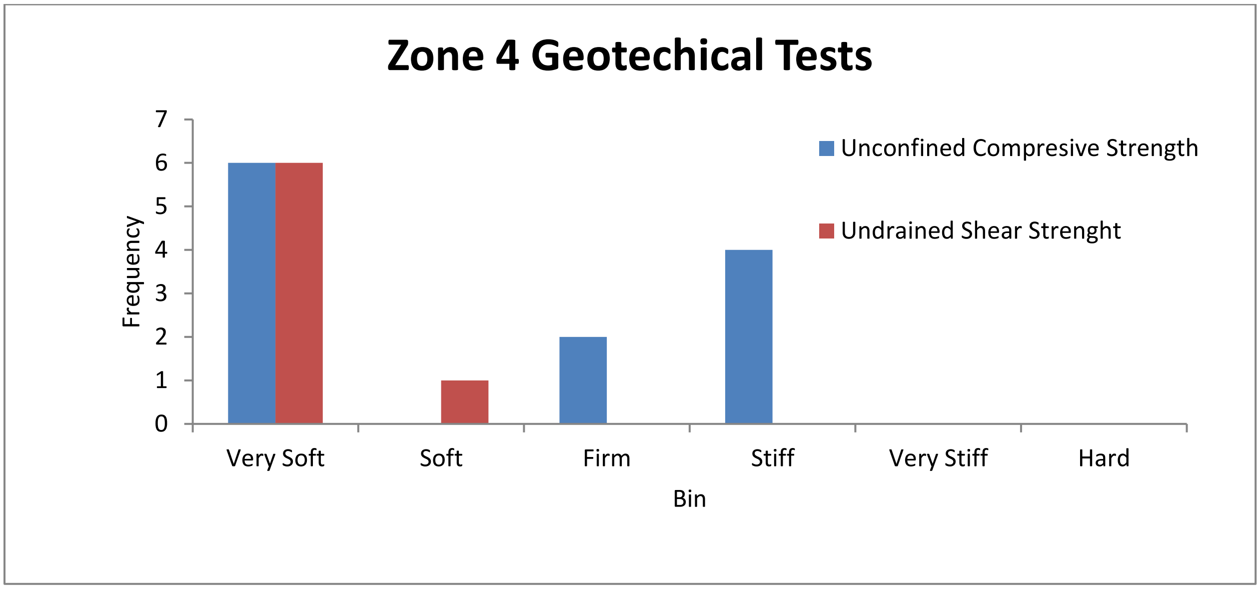


Figure 5-56. Zone 4 soil properties based on geotechnical tests

Note that out of the 6 cores acquired in Zone 4 only one core recovered more than 1 meter of sediment. The maximum recovery was 164 cm with an average recovery of 67cm. Therefore, stiffer sediments may be encountered at depth that were not sampled in coring and do not present differently in the acoustic records.

5.4.1 SURFACE SEDIMENTS

Based on the side scan sonar imagery, multibeam backscatter, and geotechnical results the surface sediments throughout Zone 4 are clay, clayey silt, silt, sandy silt and find sand. From KP 18.5 to 43 there are small pockets of sand, silt and clay some of which make visible the ice scours (Figure 5-57). West of KP 43 the seafloor is uniformly composed of clayey silt, which gradually transitions to clay as water depths level out at 26 meters at the western end of Zone 4 (KP 70).

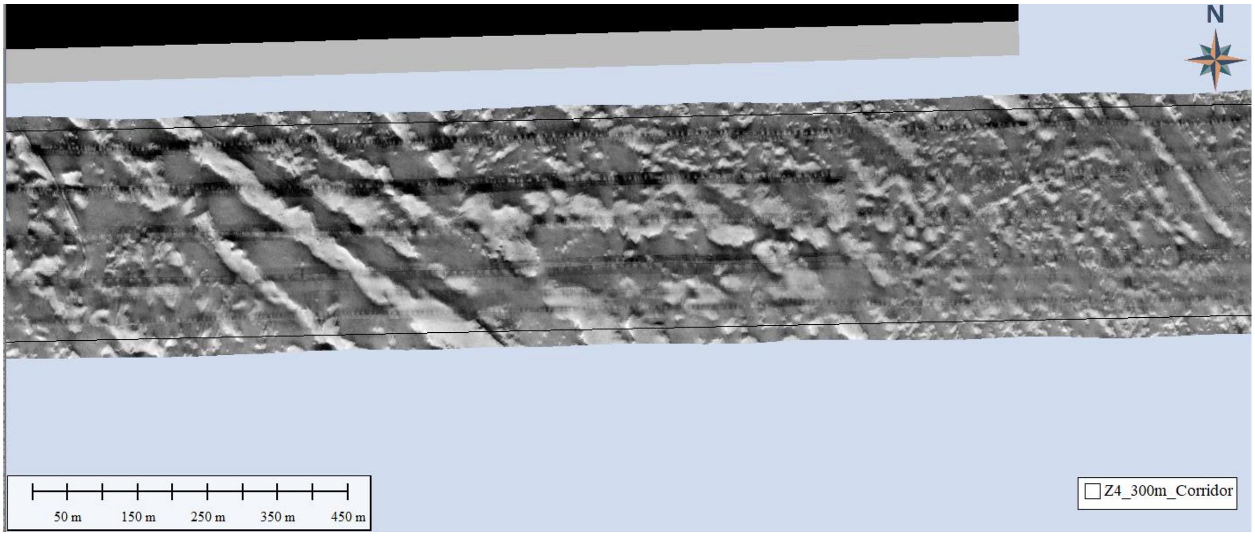
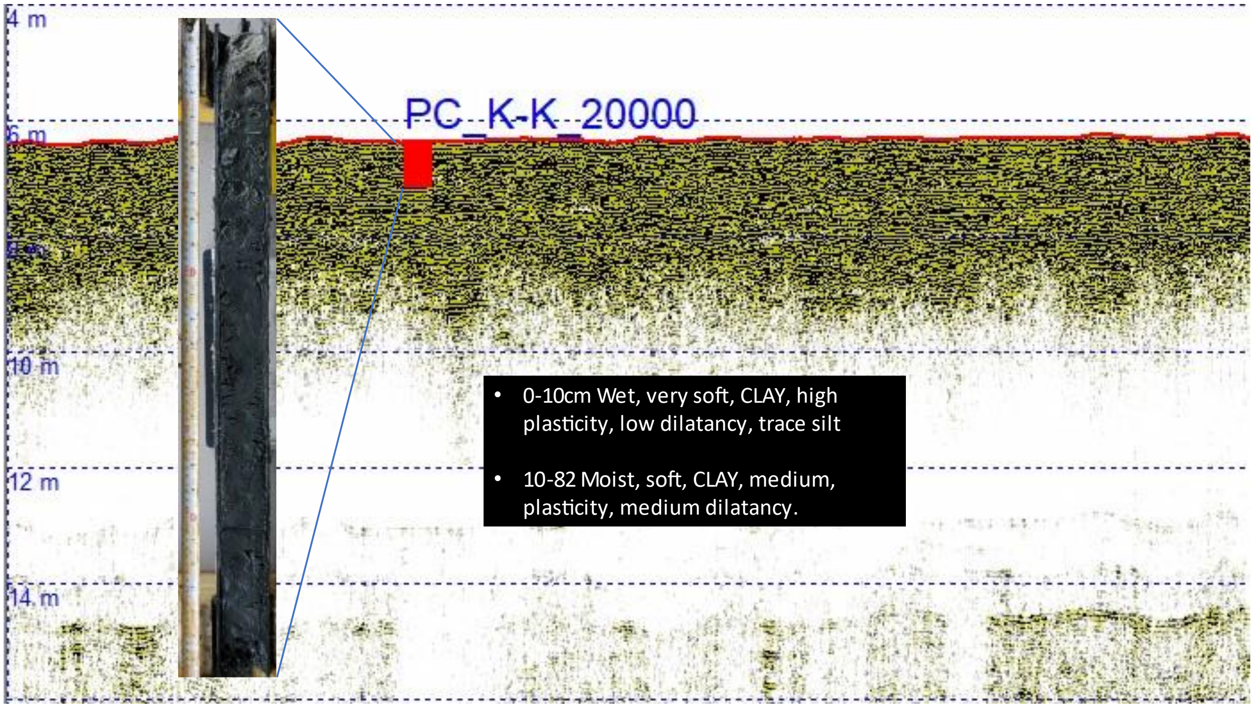


Figure 5-57. Small pockets of fine sand, silt, and clay near KP 34 in Zone 4.

5.4.1 SUB-SURFACE STRATIGRAPHY

Sub-bottom penetration of greater than 2 m was achieved throughout Zone 4. Acoustic penetration of up to 11 m was obtained. In general, acoustic signal penetration decreased with decreasing depth and likely indicates increased sediment grain size near the eastern end of Zone 4. That said, in just 11 meters water depth signal penetration occasionally extents to 9 meters below the seabed indicating a stratigraphy primarily composed of clay.

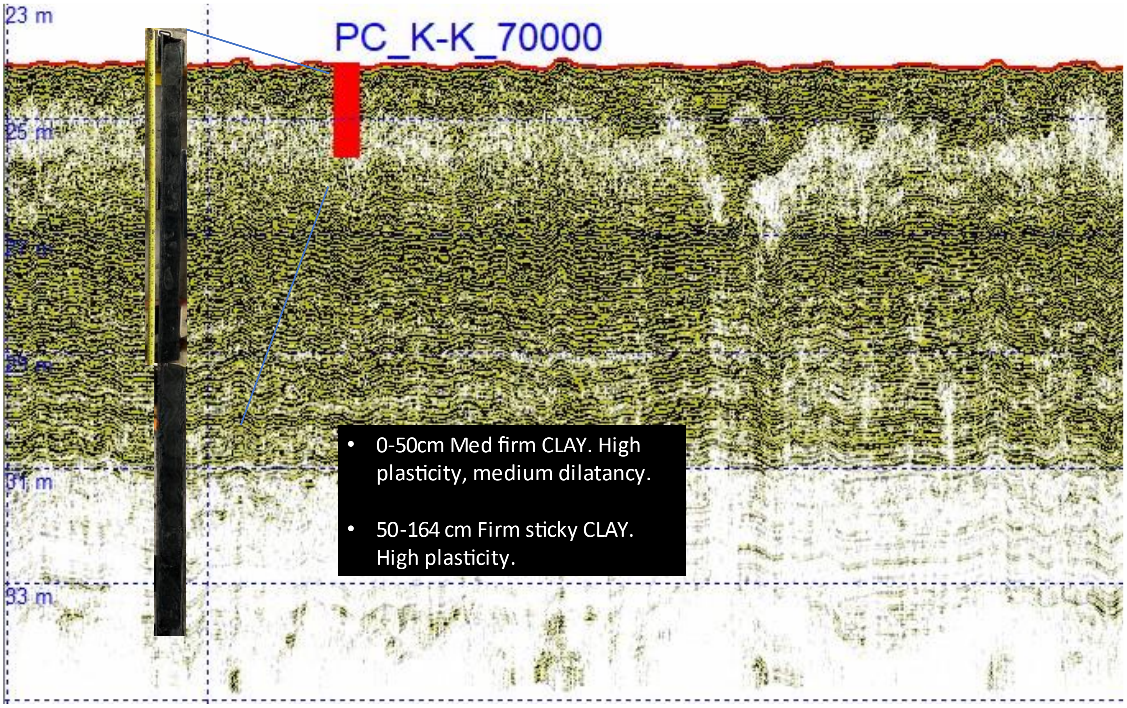
A typical example of a sub-bottom profile from KP 18.5 and KP 53 is shown in Figure 5-58. In Figure 5-58 shows discontinues reflections with the signal gradually attenuating at approximately 4 meters below the seabed.



- 0-10cm Wet, very soft, CLAY, high plasticity, low dilatancy, trace silt
- 10-82 Moist, soft, CLAY, medium, plasticity, medium dilatancy.

Figure 5-58. Zone 4, Sub-bottom profile example at PC_K-K_20000.

Figure 5-59 shows a typical sub-bottom profile with core sample for the western and deeper sections of Zone 4 from KP 53 to KP 70.



- 0-50cm Med firm CLAY. High plasticity, medium dilatancy.
- 50-164 cm Firm sticky CLAY. High plasticity.

Figure 5-59. Zone 4, Sub-bottom profile at PC_K-K_70000.

5.4.1 MAGNETIC ANOMALIES

Magnetometer data was acquired along the centerline of Zone 4. No magnetic field strength anomalies were detected.

5.4.1 SUMMARY

Seafloor ice scours are common in water depths less than 17 m, however, scours in this region appear lightly incised. The installer can expect to encounter soft clay and some areas of firm to stiff clay along with clay silt and find sand. Sub-bottom records did not reveal any stratigraphic horizons of sub-cropping features of concern.

5.5 **Zone 5 (K-K KP 70.3 to 132.9)**

5.5.1 BATHYMETRY AND SEAFLOOR FEATURES

The bathymetry data in Zone 5 covers a 300-meter-wide corridor. Surveyed depths in Zone 5 range from 21.2 m to 27.7 meters below MLLW. From KP 85 to KP 95 there is undulating terrain before gradually sloping from the shoalest point of Zone 5 near KP 95 to the deepest point at KP 120. The undulating terrain and shoal point may be associated with a western extent of the Cape Krusenstern Shoal. (Figure 5-60 and Figure 5-61).

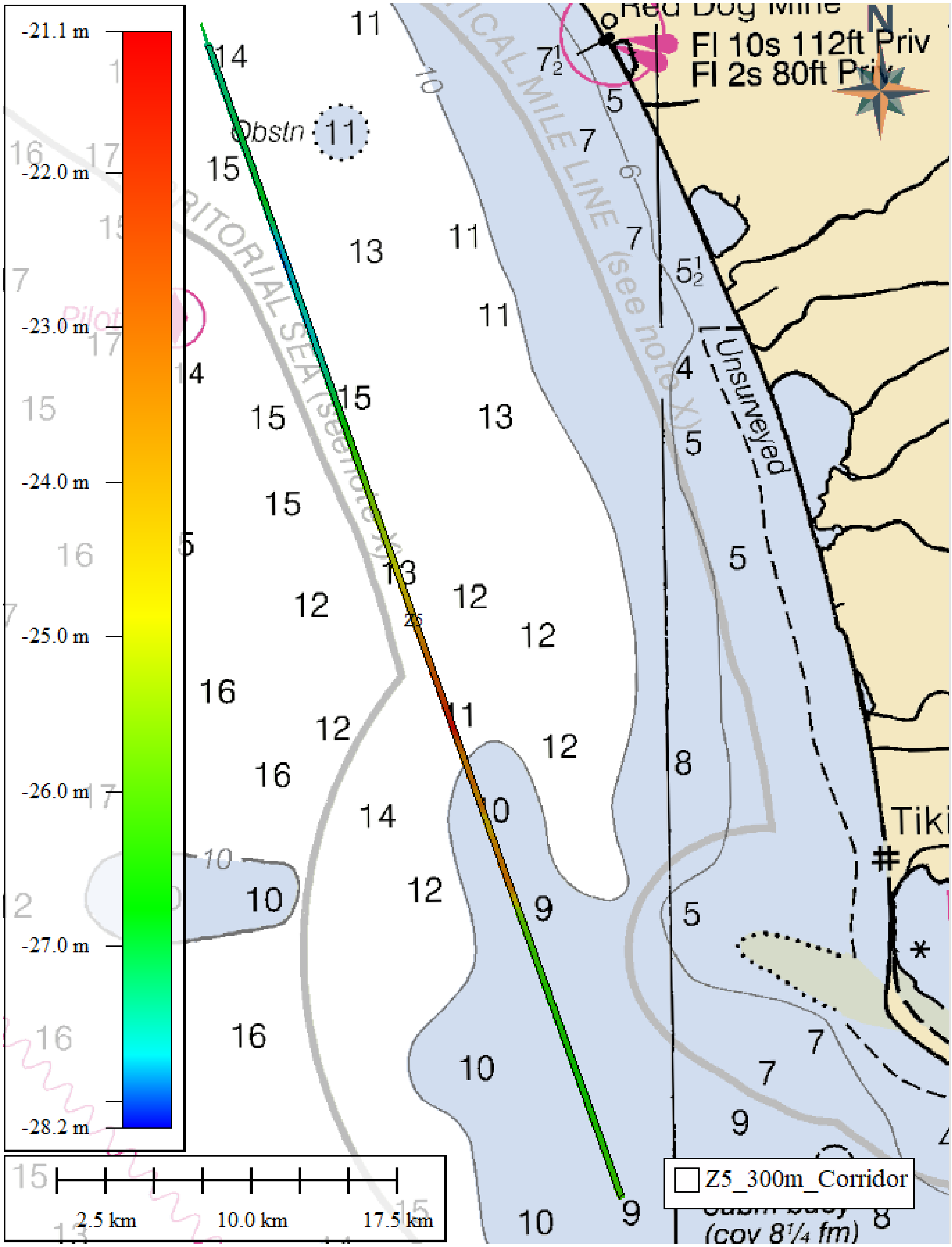


Figure 5-60. Zone 5 Bathymetry coverage

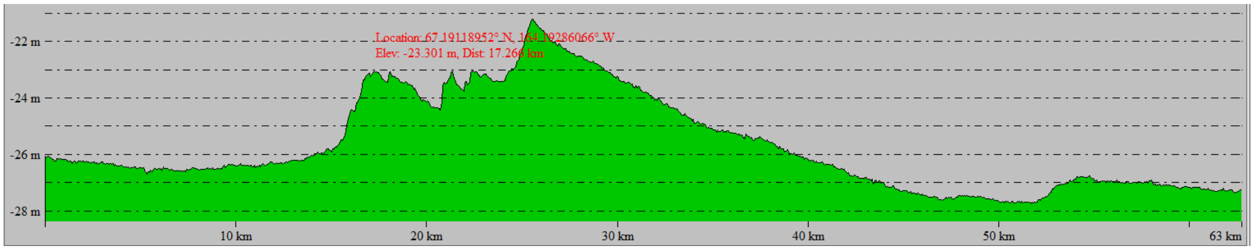


Figure 5-61. Zone 5 Bathymetric profile

In Zone 5 seabed ice scouring is observed at all water depths. Scouring is most common in the shoalest waters between KP 84 and KP102 where water depths are less than 25 meters. 74 scours were digitized in Zone 5 (Figure 5-62).

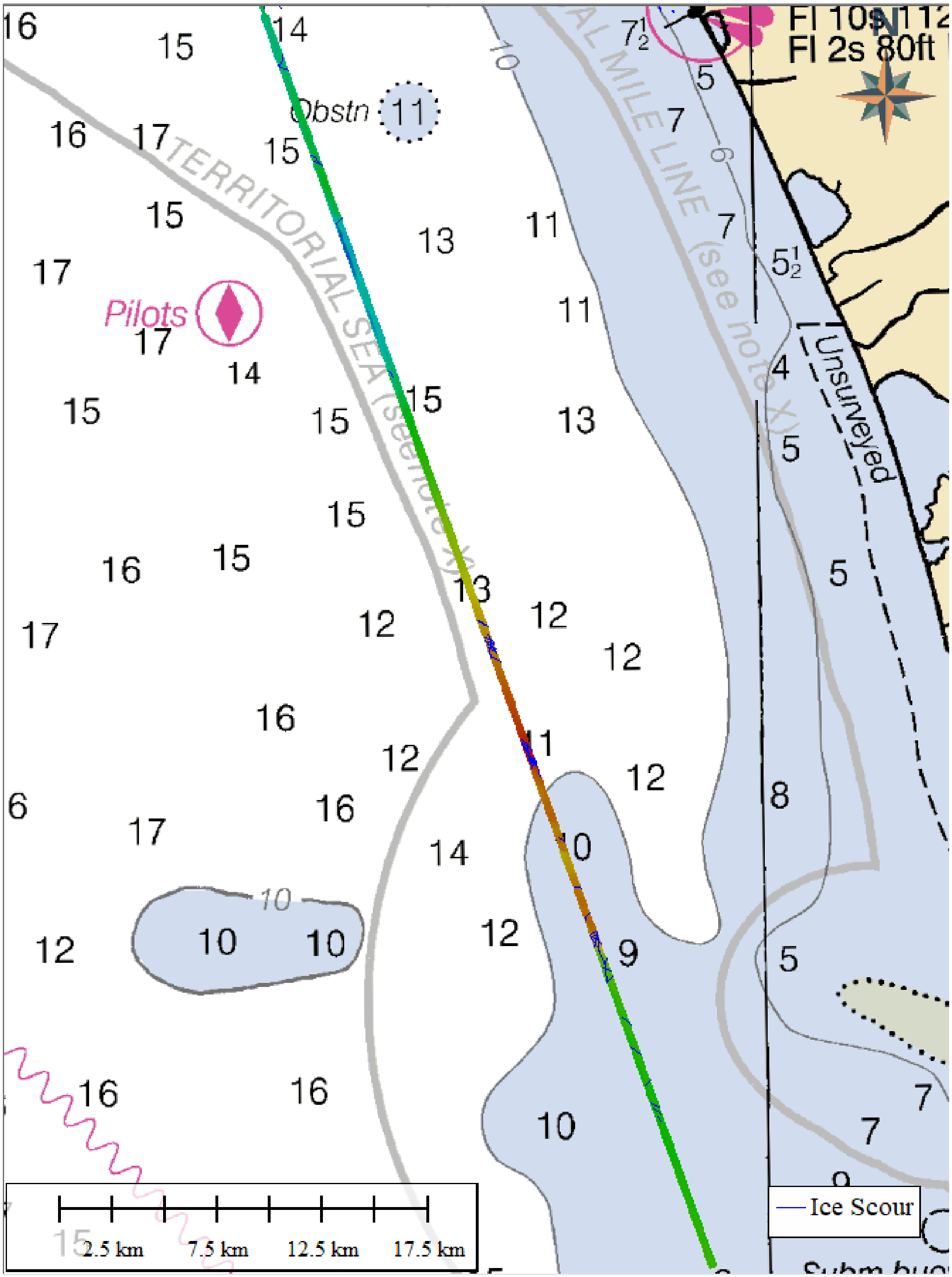
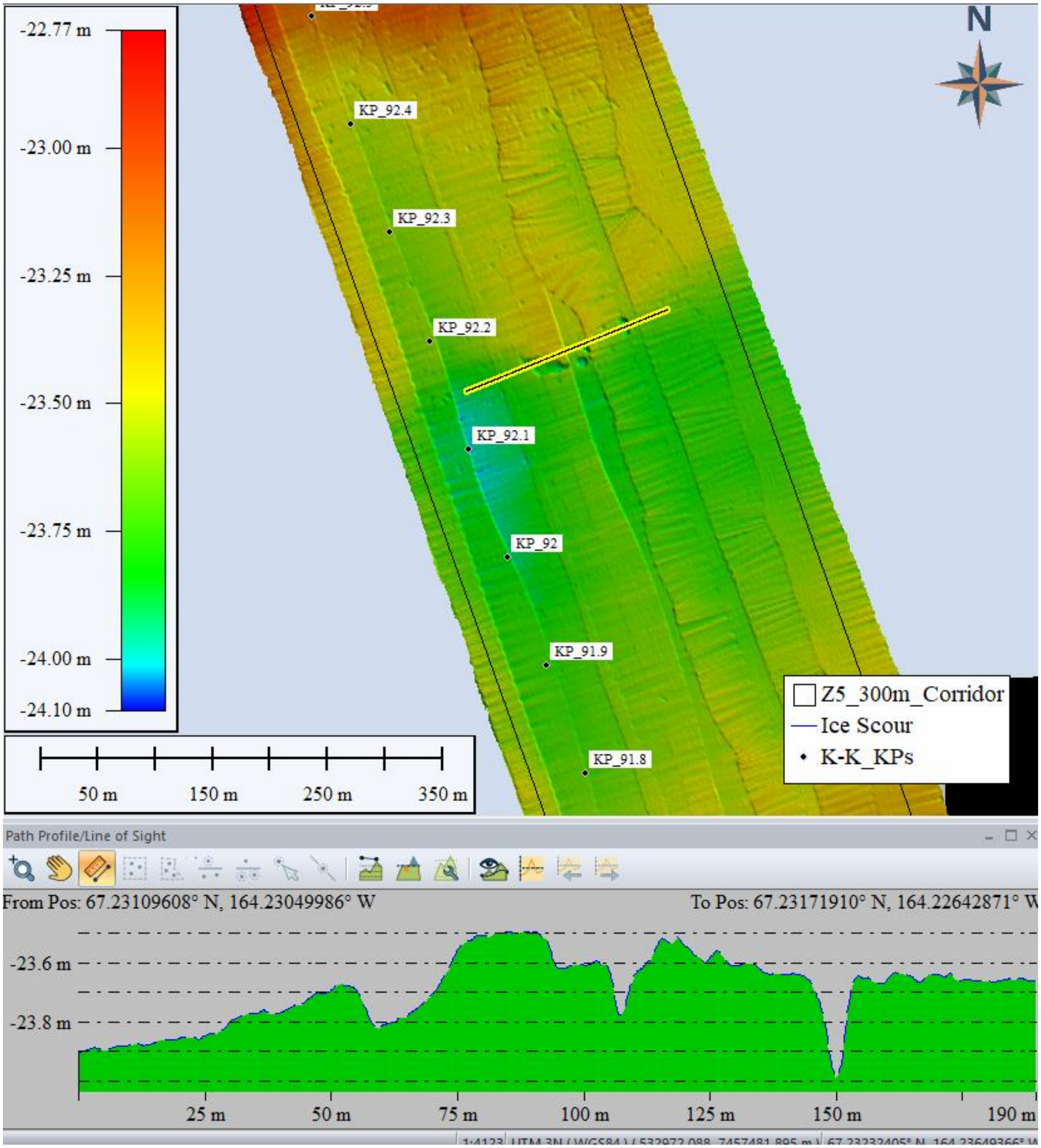


Figure 5-62. Zone 5 Ice Scours

Between KP 92.1 and 92.2 there are a few depressions up to 0.35 meters deep and up to 40 meters across (Figure 5-63). The origin of these depressions is unknown although presumably it is caused by some type of ice related scouring.



From Pos: 67.23109608° N, 164.23049986° W

To Pos: 67.23171910° N, 164.22642871° W

1:4123 UTM 3N (WGS84) (532972.088, 7457481.895 m) 67.23232405° N, 164.23649366° W

Figure 5-63. Zone 5, Seafloor depressions near KP 92.1

Between KP 94.5 and KP 95.5 in water depths between 23 and 21 meters deep, there is a zone of seabed scouring consisting of linear scours and depressions. Scour depths are less than 0.2 meters (Figure 5-64).

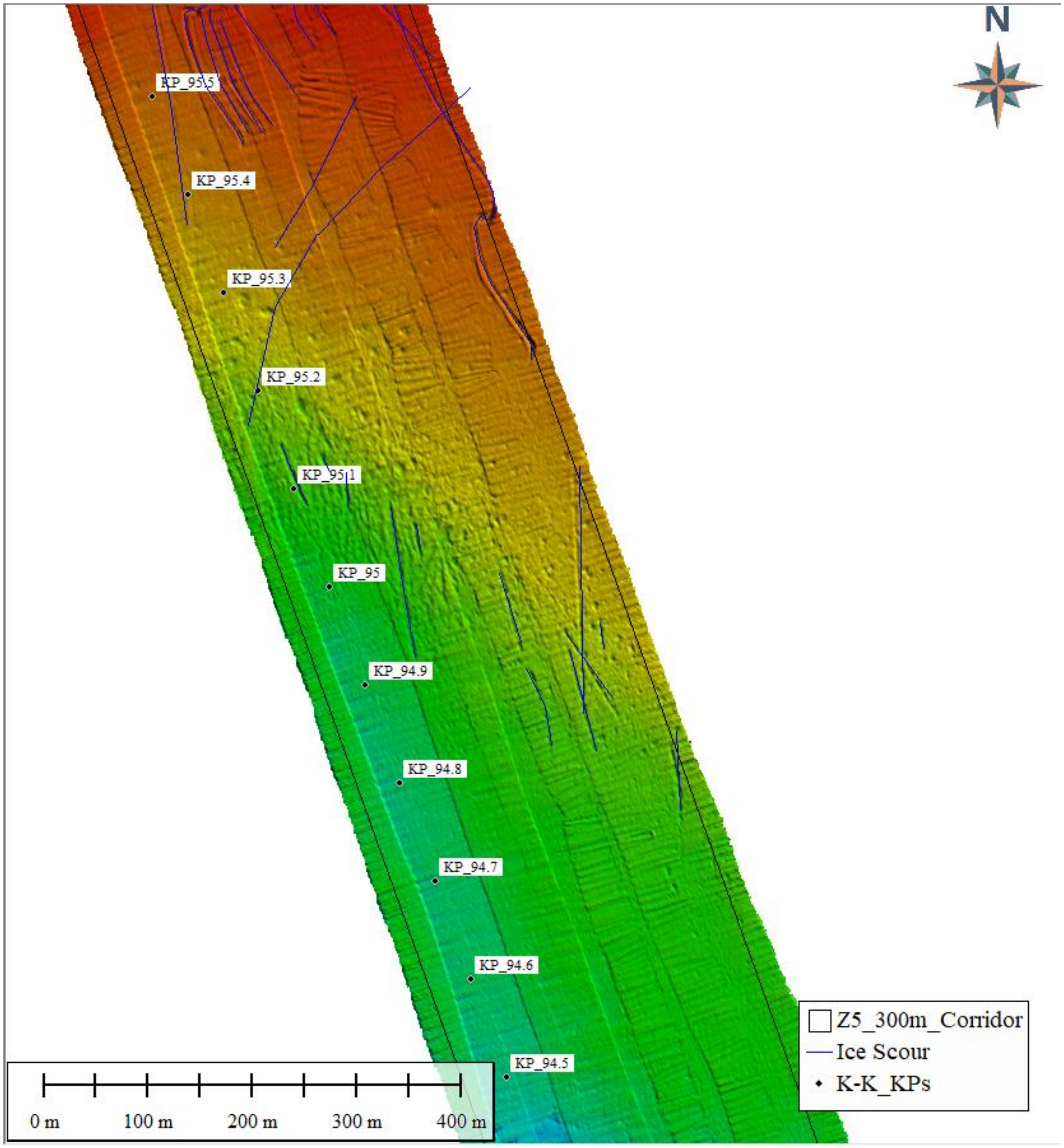


Figure 5-64. Zone 5 Scour area between KP 94.5 and 95.5

5.5.1 GEOTECHNICAL RESULTS

8 piston cores were collected in Zone 5 (Figure 5-65). The seabed surface sediment composition ranges from clay to silty fine sand.

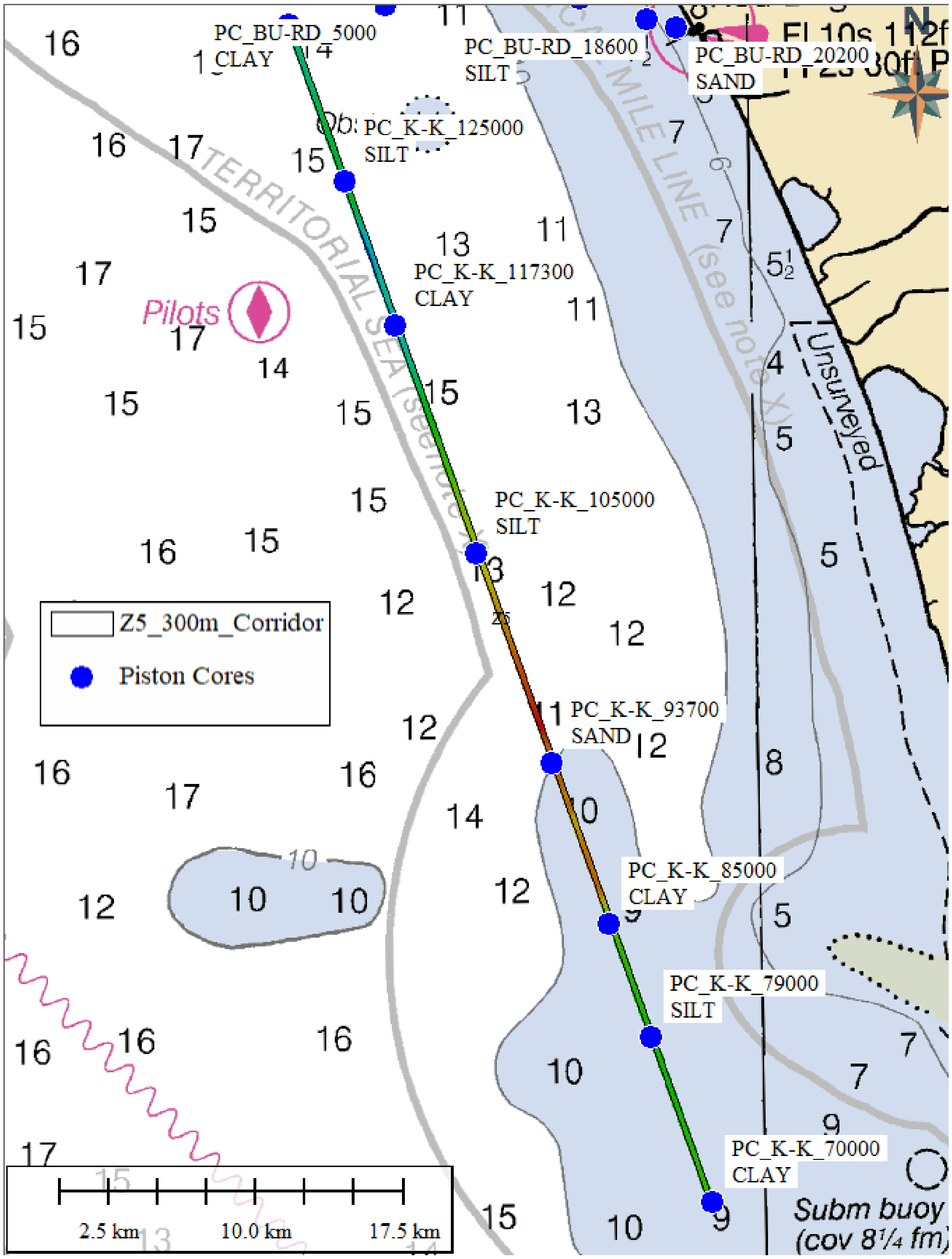


Figure 5-65. Zone 5 Geotechnical stations and surface sediments

Beneath the surface, clay, silty clay, clayey silt, sandy silt, and fine sand constitutes the sediments. Sediment core descriptions are provided in (Table 5-8).

Table 5-8. Zone 5 sediment core descriptions

STATION	SED. DESCRIPTION 1	SED. DESCRIPTION 2	SED. DESCRIPTION 3	SED. DESCRIPTION 4	SED. DESCRIPTION 5
PC_K-K_79000	0-24cm Firm SILT, 32-45cm: CLAY, 45-83cm sandy SILT.	24-32cm Black, moist, soft, CLAY, med plasticity, high dilatancy, minor silt content.	32-45 Moist, stiff to very stiff, CLAY, low plasticity, high dilatancy, black organic streaking towards lower contact.	45-83cm Firm, sandy SILT.	
PC_K-K_85000	0-75cm Stiff-very stiff moving down-hole, CLAY, medium plasticity, high dilatancy, minor amount of black organic streaking <0.5cm wide throughout.				
PC_K-K_93700	0-15cm Loose, silty fine SAND, trace shell fragments <0.5cm.	15-44cm Very dense, SILT, high mica content.			
PC_K-K_105000	0-11cm Clayey SILT, 5cm subrounded fine gravel clast, trace shell hash <1cm	11-35cm Moist, soft, CLAY, medium plasticity, high dilatancy, increasing organic content moving down-hole.	35-38cm Lens of organic material, strong organic odor.	38-67cm Very wet, very soft, CLAY, high plasticity, no dilatancy. (Too soft to perform torvane)	67-68cm Fine SAND. May have settled from upper clay unit after recovery.
PC_K-K_117300	0-15cm Very dense, micaceous, silty CLAY.				
PC_K-K_125000	0-20cm Medium dense SILT.	20-41cm Clayey SILT, subangular fine			

		gravel clasts at lower contact.			

Shear strength tests in Zone 5 were performed on cores K-K_79000, KK_85000, and K-K_105000. Measurements of shear strength revealed very soft to firm sediment (Figure 5-66). Based on 14 unconfined compressive strength tests the sediment is very soft to hard. However, hard sediment was only found in K-K_93700 (Figure 5-67).

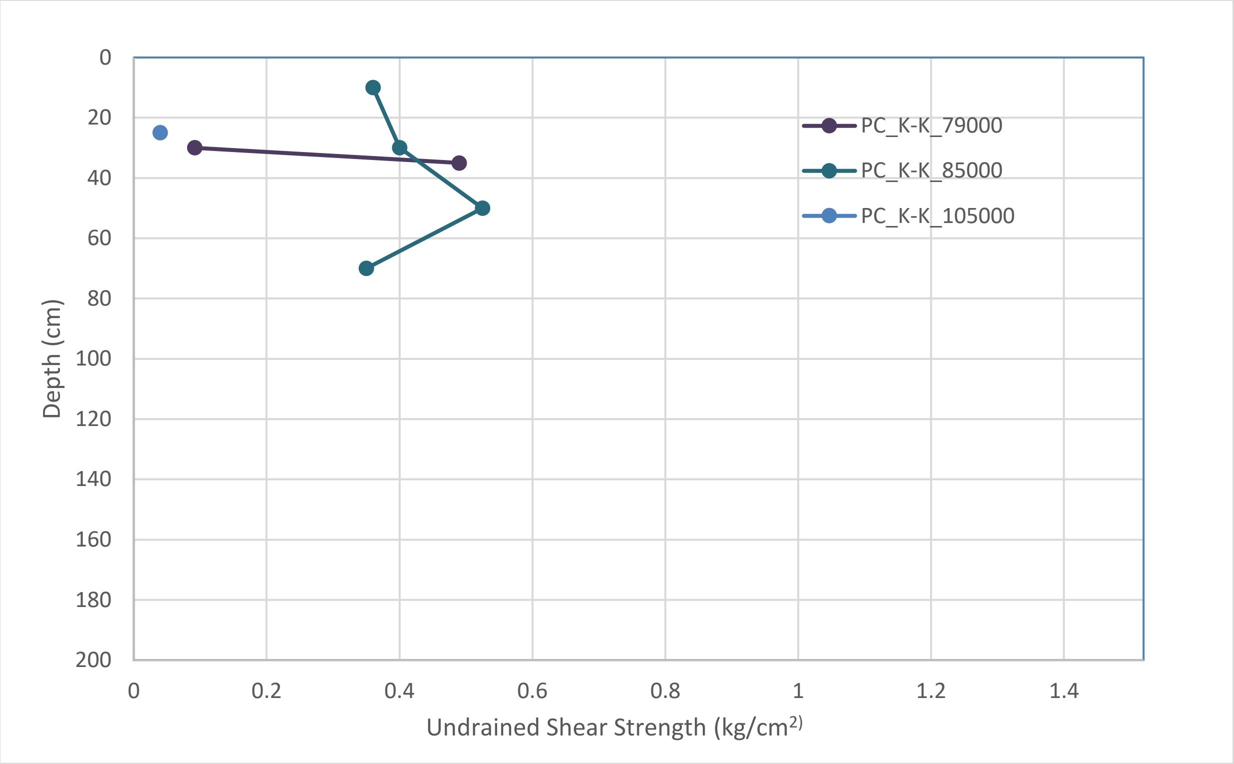


Figure 5-66. Zone 5 Undrained shear strength

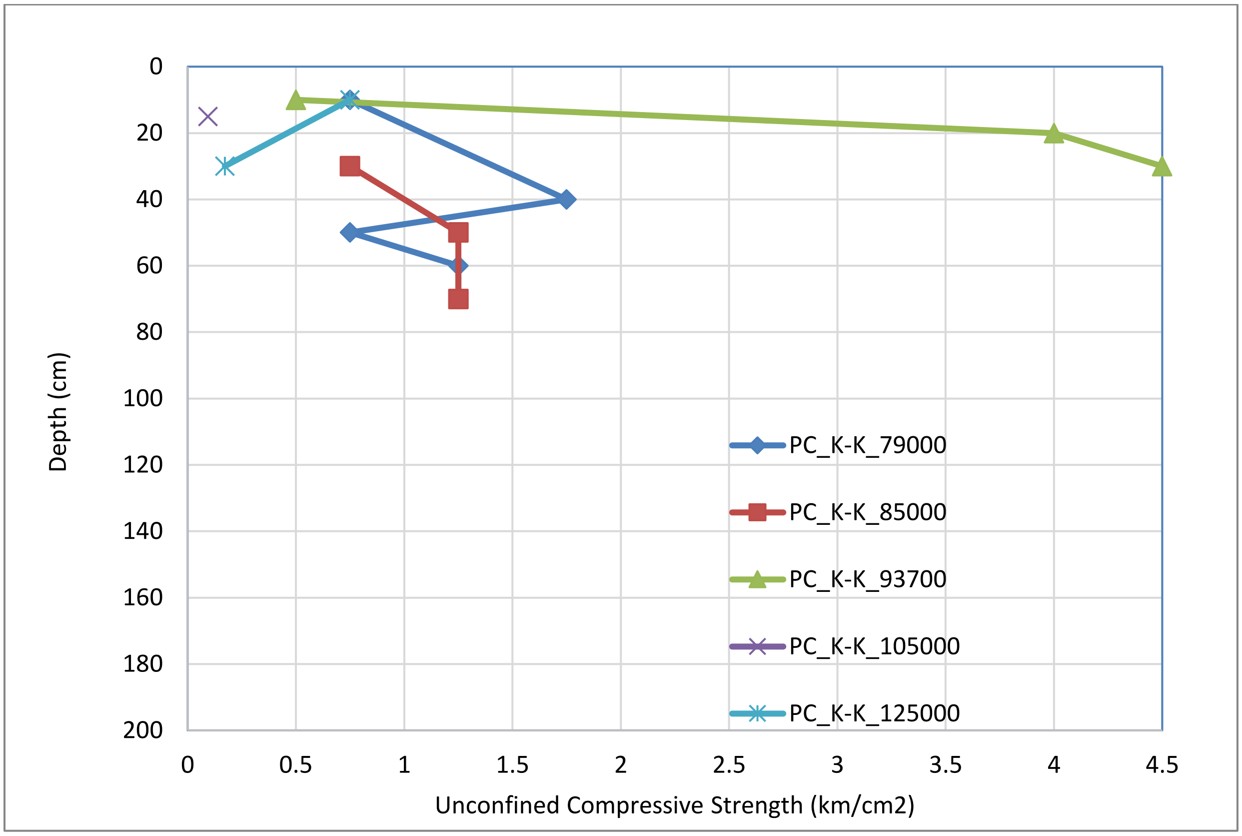


Figure 5-67. Zone 5 Unconfined compressive strength

Based on the relationship between the descriptive soil property terminology and numeric values of shear strength and compressive strength shown in Table 5-3, Figure 5-68 shows the distribution of soil types in Zone 5 based on the geotechnical tests.

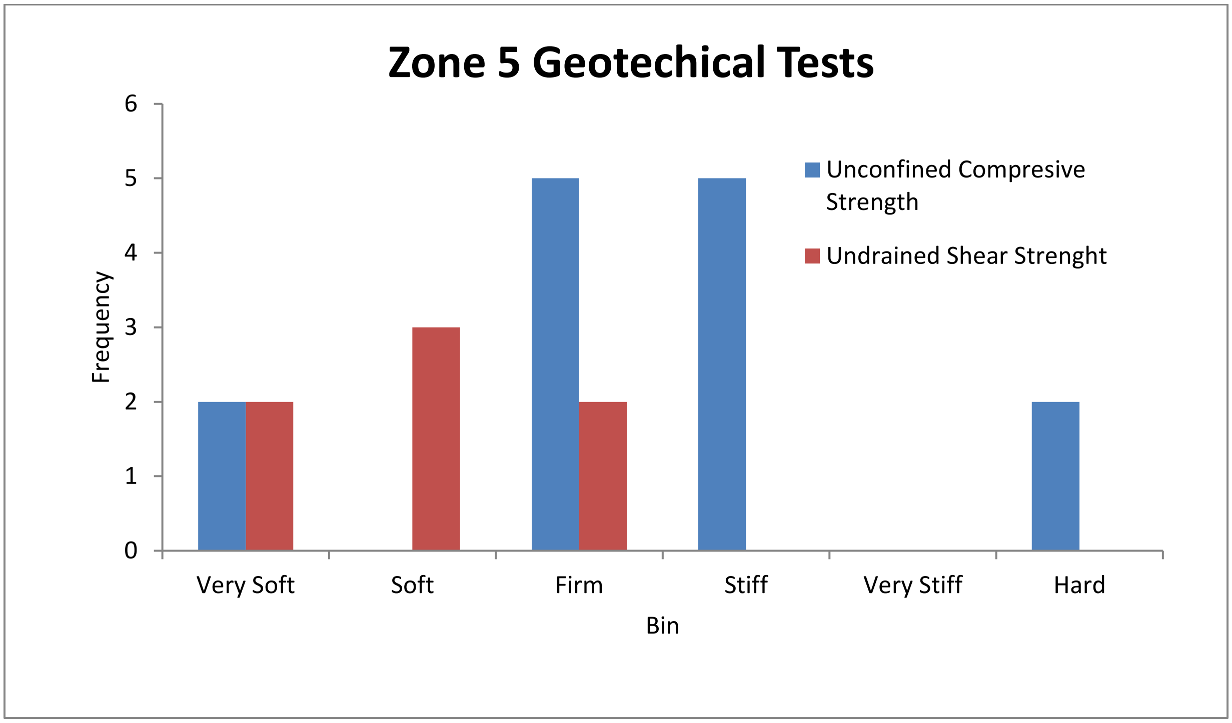


Figure 5-68. Zone 5 soil properties based on geotechnical tests

Note that out of the 6 cores acquired in Zone 5 none of the cores recovered more than 1 meter of sediment. The maximum recovery was 83 cm with an average recovery of 54cm. Therefore, stiffer sediments may be encountered at depth that were not sampled in coring and do not present differently in the acoustic records. This is particularly true for cores such as K-K_93700 where hard sediment was recovered from the bottom of the core at a depth of 44 cm.

5.5.1 SURFACE SEDIMENTS

Based on the side scan sonar imagery, multibeam backscatter, and geotechnical results the surface sediments throughout Zone 5 are clay, silty clay, silt, and silty sand. From KP 122 to 123 and from KP 132.6 to 132.9 there are small pockets of fine sand noticeable in the SSS reflection imagery (Figure 5-69).

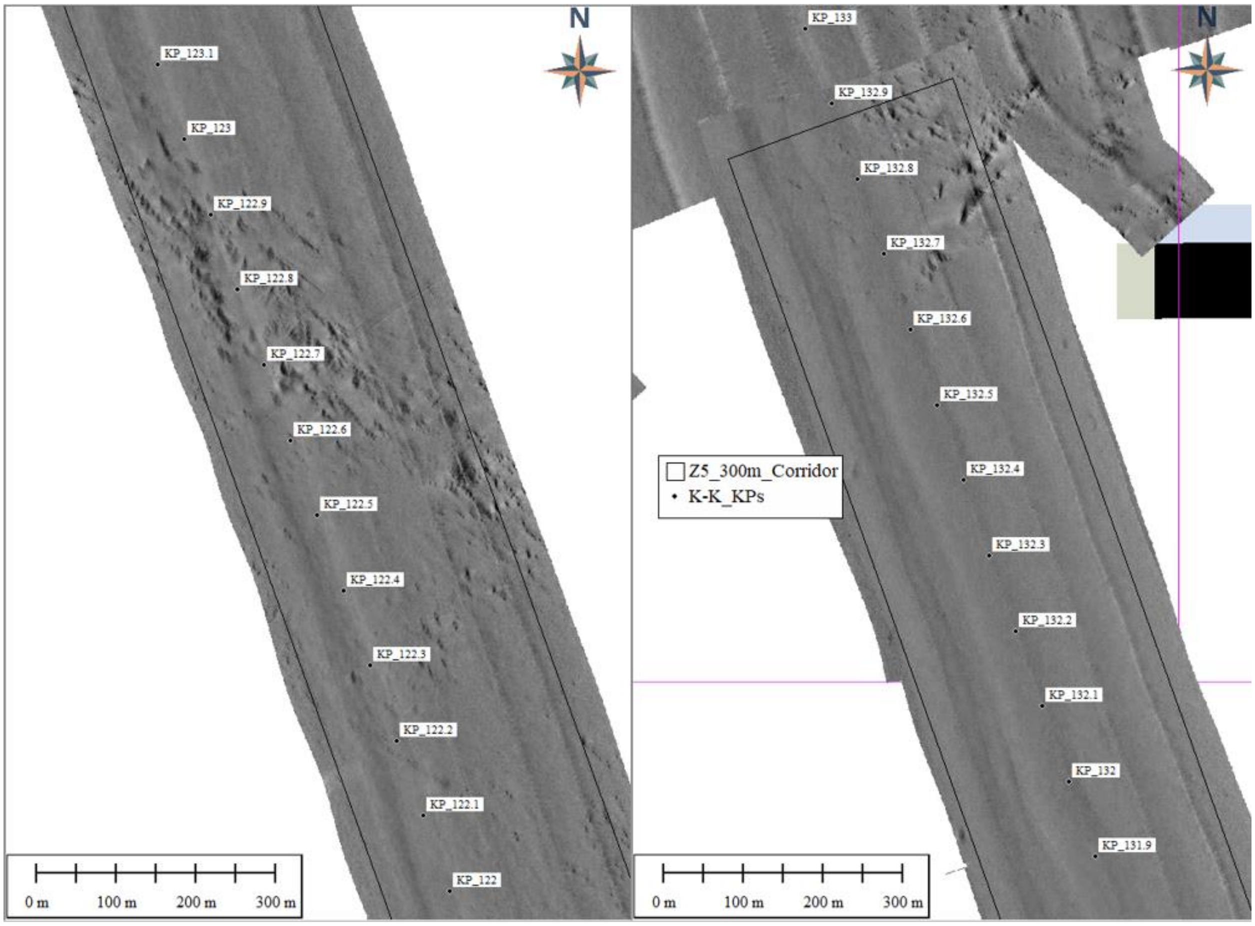
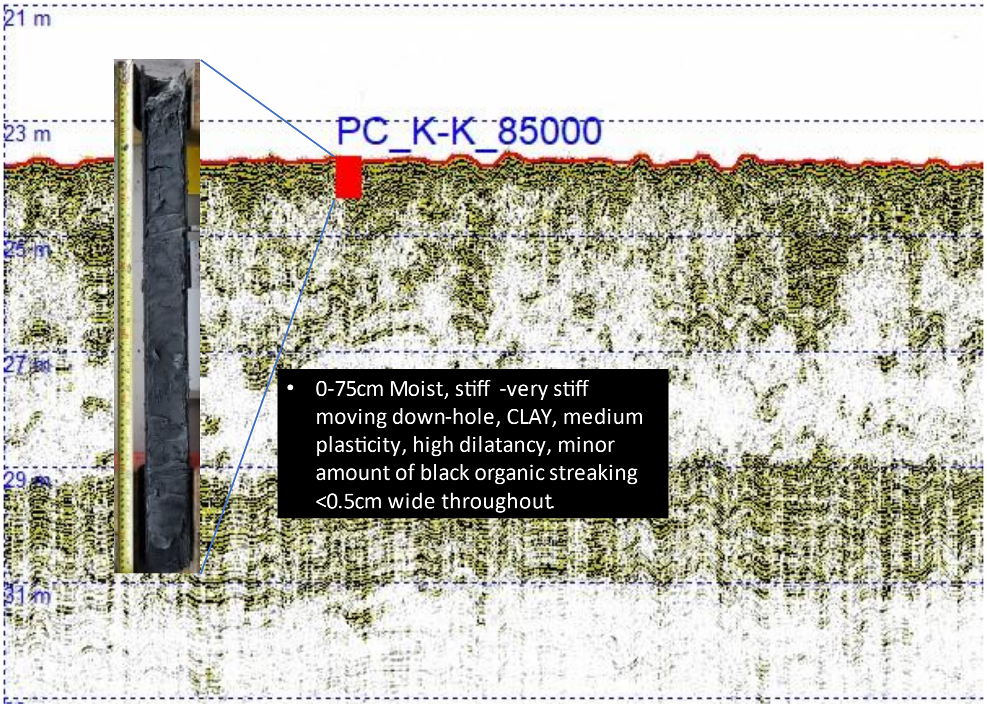


Figure 5-69. Two zones of small pockets of fine sand in Zone 5.

5.5.1 SUB-SURFACE STRATIGRAPHY

Sub-bottom penetration of greater than 2 m was achieved throughout Zone 5. Acoustic penetration of up to 9 m was obtained. From KP 70 to KP 92 the stratigraphy is characterized by horizontally bedded stiff and hard clay that results in relatively deep acoustic signal penetration (Figure 5-59 and Figure 5-70). Within this zone of deep clay deposits there is an anomaly in the stratigraphy at KP 79 where a 1 km long sub-surface, dome shaped horizon attenuates the signal and results in sub-bottom penetration reduced to as little as 2 meters. Based on the reflection characteristics and geotechnical sampling this dome shaped feature is a silty or sand palo-dune feature such as the morphological seafloor feature seen further north in Zone 5 between KP 84 and KP 100 (Figure 5-71).



- 0-75cm Moist, stiff -very stiff moving down-hole, CLAY, medium plasticity, high dilatancy, minor amount of black organic streaking <0.5cm wide throughout

Figure 5-70. Zone 5, Sub-bottom profile example at PC K-K_85000

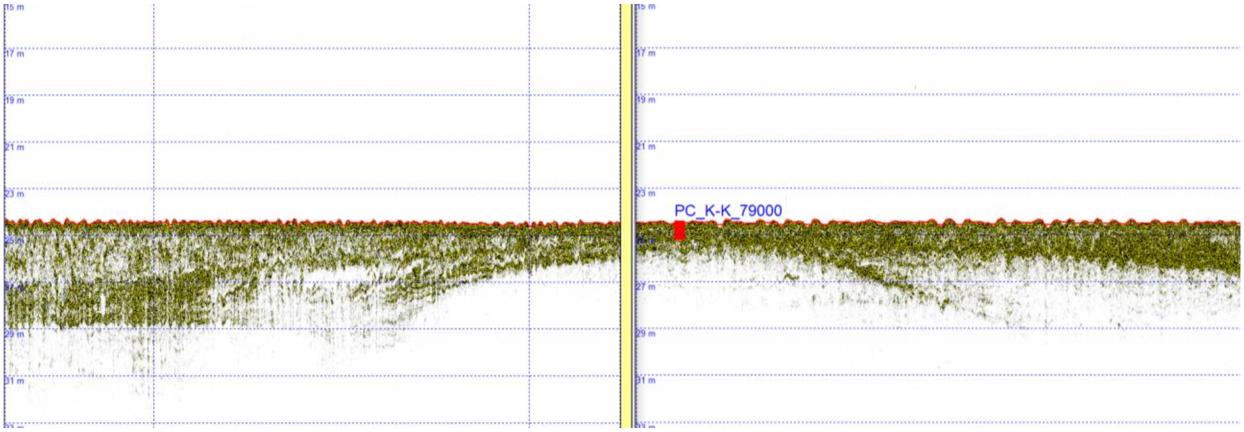
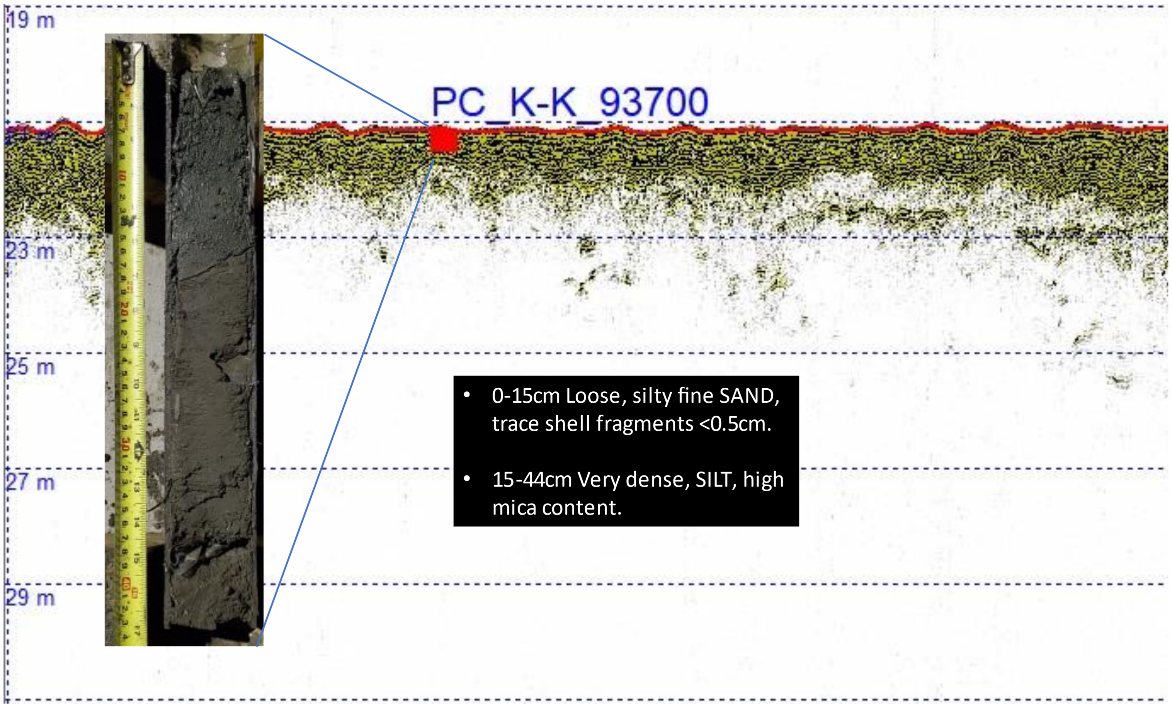


Figure 5-71. Dome shaped subsurface horizon near KP 79

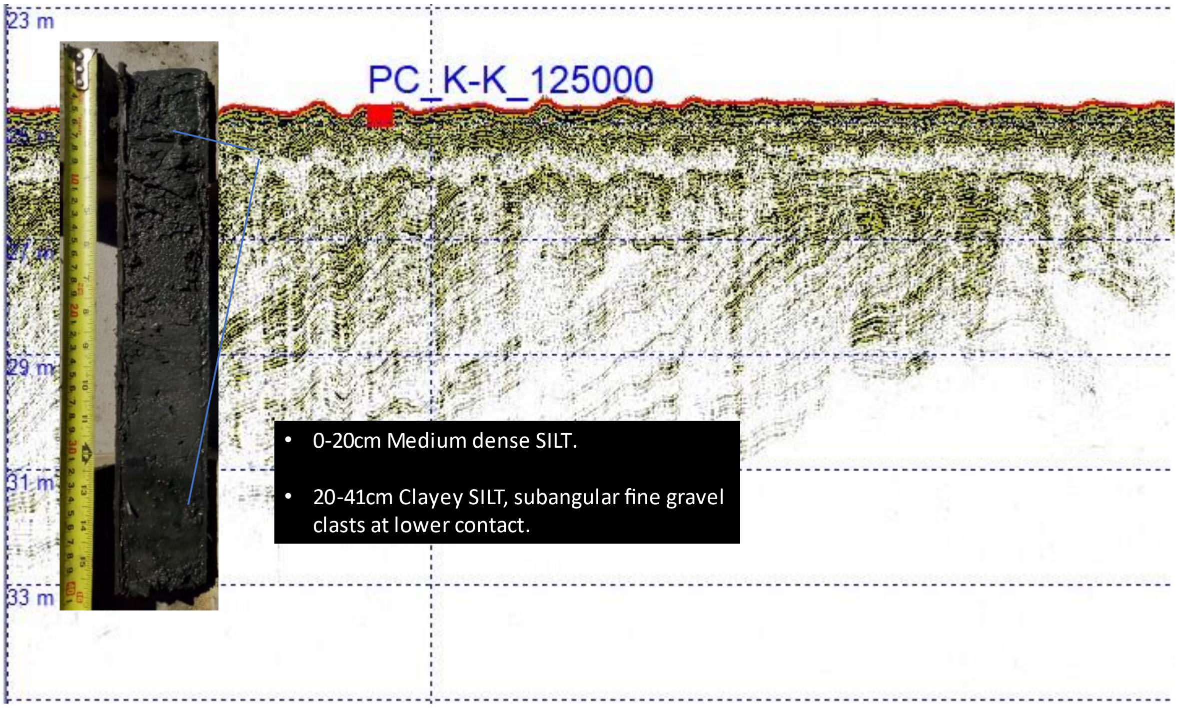
From KP 93 to 96 the sub-bottom record is predominantly homogenous and quickly attenuating due to a surface veneer of unknown thickness of silt and find sand possibly related to the Cape Krusenstern Shoal and observed in piston core sample K-K_93700 (Figure 5-72).



- 0-15cm Loose, silty fine SAND, trace shell fragments <0.5cm.
- 15-44cm Very dense, SILT, high mica content.

Figure 5-72. Zone 5, Sub-bottom profile example at PC_K-K_93700.

Beyond KP 96 to the north end of Zone 5 at KP 133 the stratigraphy can be generally characterized as soft clay to silt with some inclusions of fine sand, fine gravel, organic horizons and trace shell hash. These deposits often overlay dipping beds which are presumably from dune deposits composed of silt and silty clay based on a lack of rapid signal attenuation (Figure 5-72)



- 0-20cm Medium dense SILT.
- 20-41cm Clayey SILT, subangular fine gravel clasts at lower contact.

Figure 5-73. Zone 5, Sub-bottom profile example at PC_K-K_12500.

5.5.1 MAGNETIC ANOMALIES

Magnetometer data was acquired along the centerline of Zone 5. No magnetic field strength anomalies were detected.

5.5.1 SUMMARY

While seafloor ice scours are present in Zone 5, they are far less frequent due to greater water depths. The installer can expect to encounter stiff to hard clay south of the shoal at KP 96. North of the shoal the seabed is composed of a mix of soft clay to very dense silt. Sub-bottom records did not reveal any stratigraphic horizons or sub-cropping features of concern.

5.6 Zone 6 (K-K KP 132.9 to 152 & BU-RD 0 to 21)

5.6.1 BATHYMETRY AND SEAFLOOR FEATURES

The bathymetry data in Zone 6 covers a 300-meter-wide corridor in water depths greater than 8 m and a 150 m swath in water depths 8 m to 3 m (Figure 5-74). Surveyed depths in Zone 6 along the Kotzebue to Kivalina Route range from 3 to 27.8 meters below MLLW with bathymetric data coverage within 165 m of shore (Figure 5-75 & Figure 5-77). Surveyed depths in Zone 6 along the Branching Unit to Red Dog Route range from 3 to 27.2 meters below MLLW with bathymetric data coverage within 32 meters of shore (Figure 5-76 & Figure 5-78).

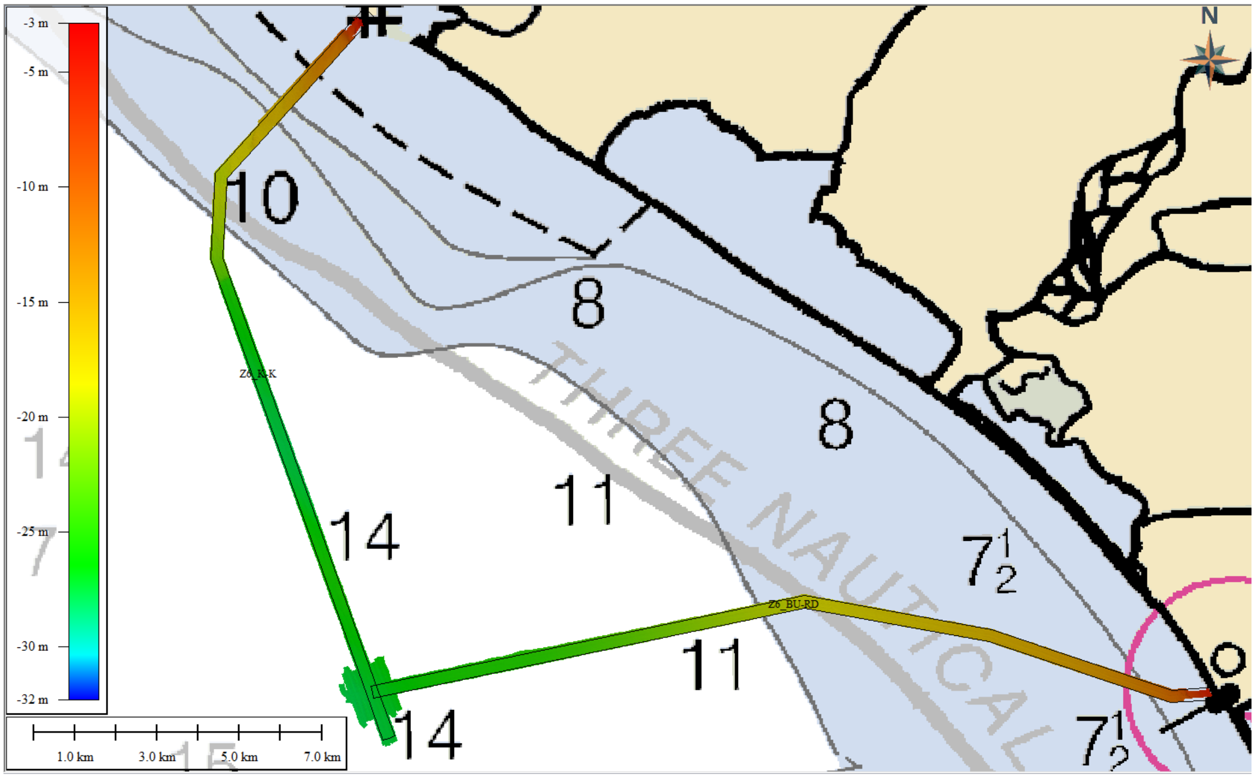


Figure 5-74. Zone 6 Bathymetry coverage

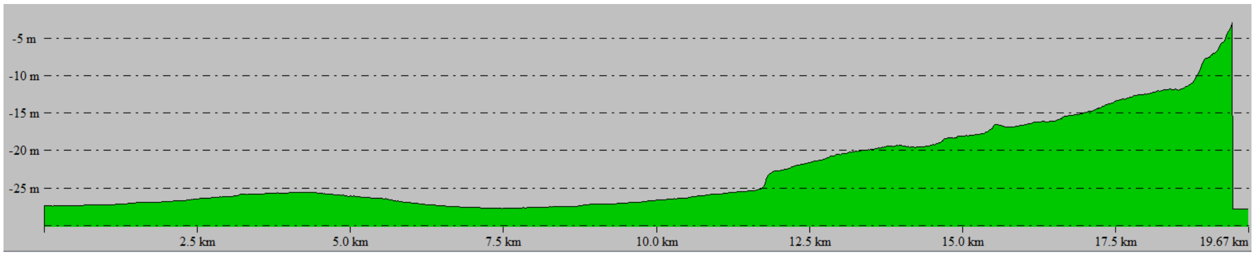


Figure 5-75. Zone 6 K-K Bathymetric profile

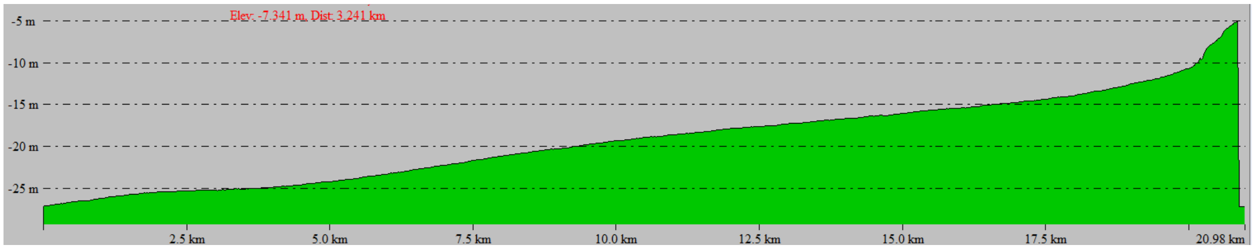


Figure 5-76. Zone 6 BU-RD Bathymetric profile

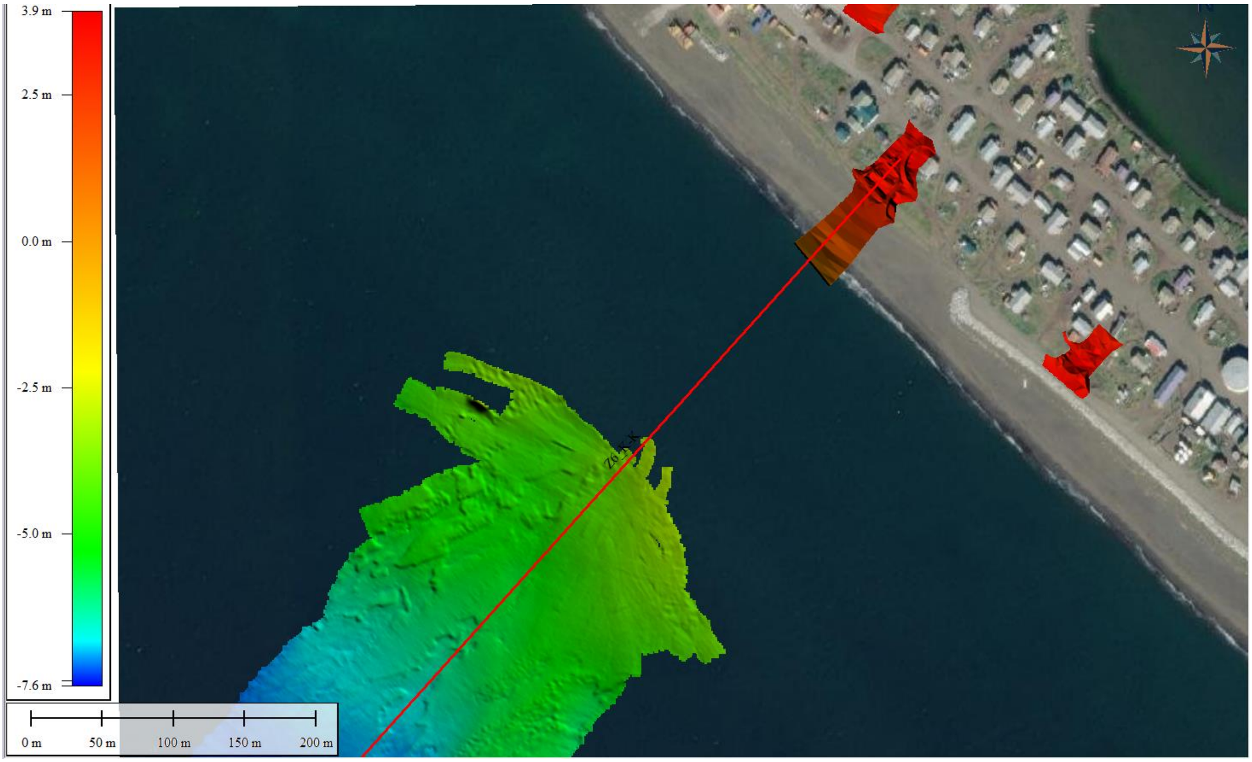


Figure 5-77. Nearshore bathymetry at Kivalina, AK

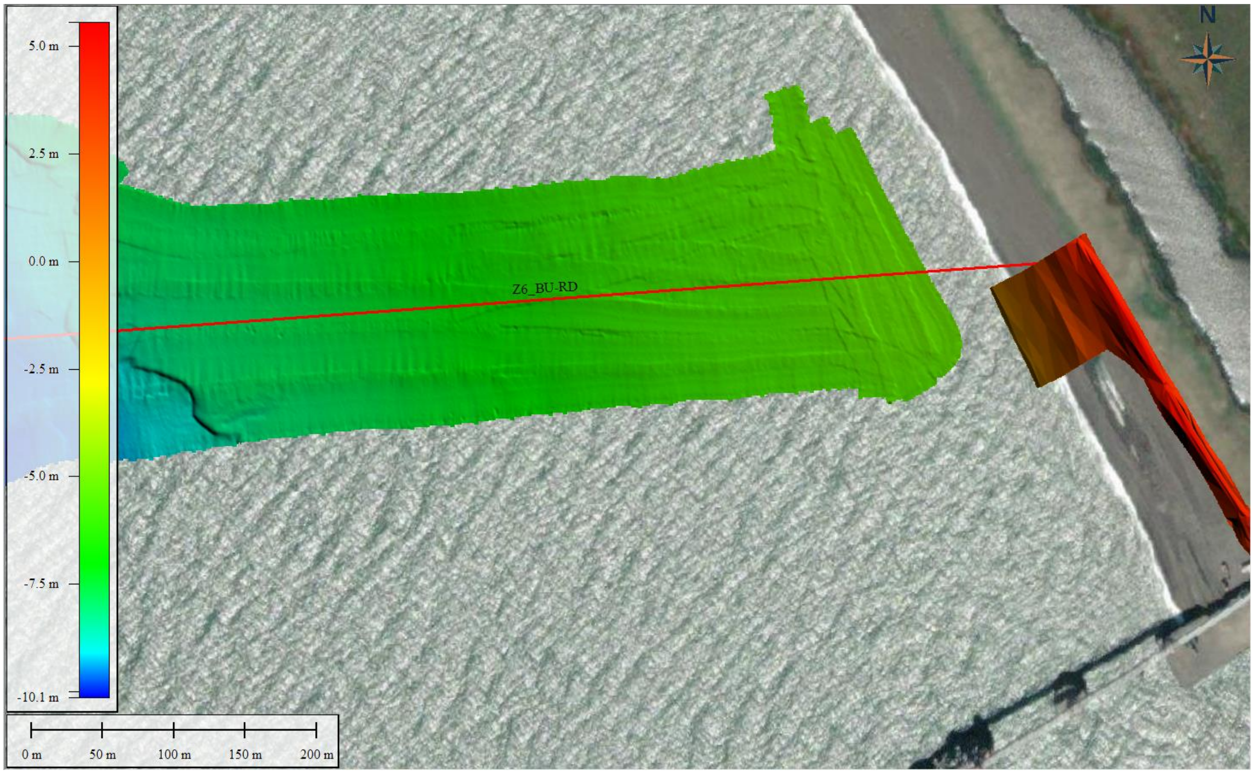


Figure 5-78. Nearshore bathymetry at Red Dog, AK

Seafloor ice scours are present at all water depths in Zone 6 and common in water depths less than 22 m. 296 ice scours were digitized in Zone 6 (Figure 5-79). The predominate ice scour orientation is between northwest-southeast and north-south. Ice scours are relatively shallow with most scours incised less than 0.1 m. 14 mounds caused by ice shove have been identified and are up to 0.9 meters tall and up to 1000 m^2 in area (Figure 5-80).

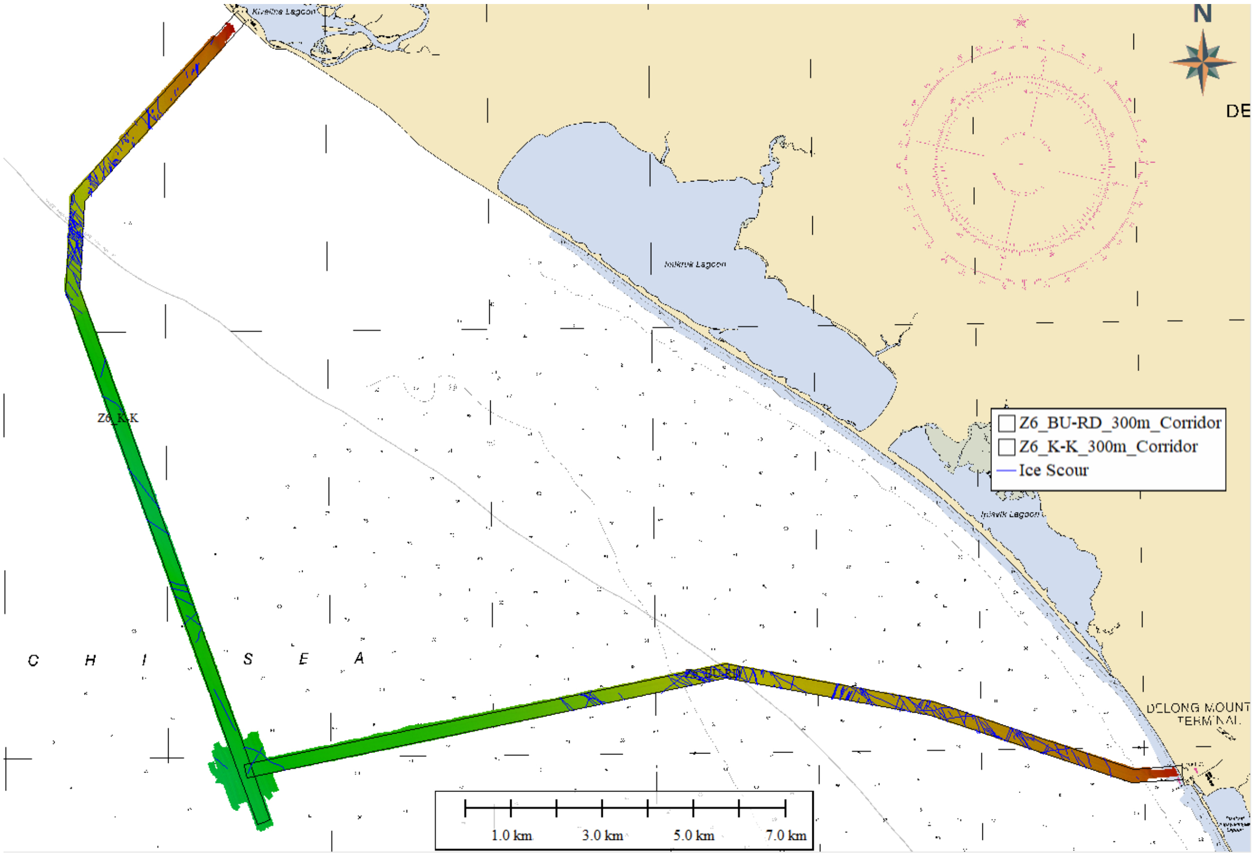


Figure 5-79. Zone 6 ice scours.

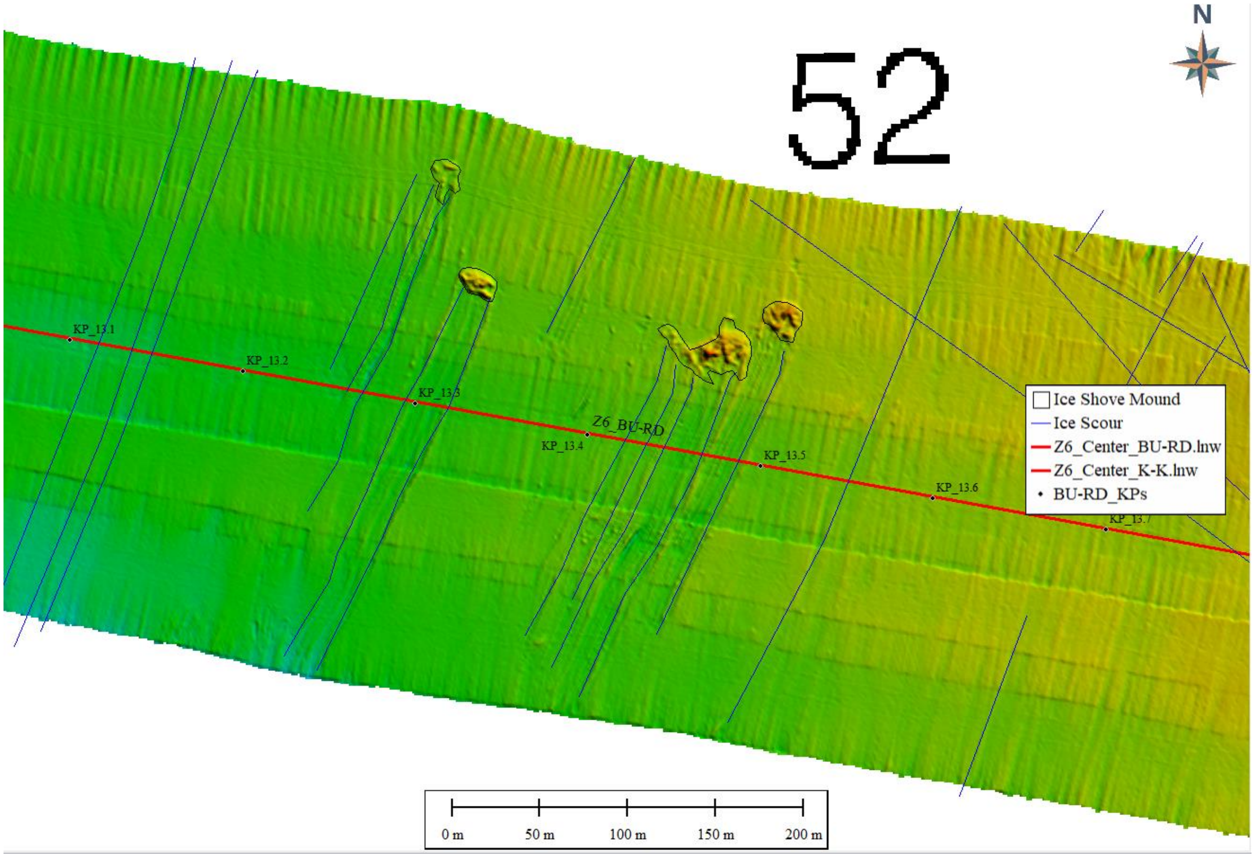


Figure 5-80. Example of ice shove mounds near KP 13.5 on the BU-RD route.

The only other geomorphological feature observed in Zone 6 are the beach parallel prograding sandbar features seen in 8 to 10 m water depths near the Red Dog landing and at Kivalina (Figure 5-81). These bars mark the depth at which wave energy starts to interact with the seafloor. Inshore of the bar near Kivalina the seabed is marked with shallow scours 0.1 to 0.2 m in depth (Figure 5-82).

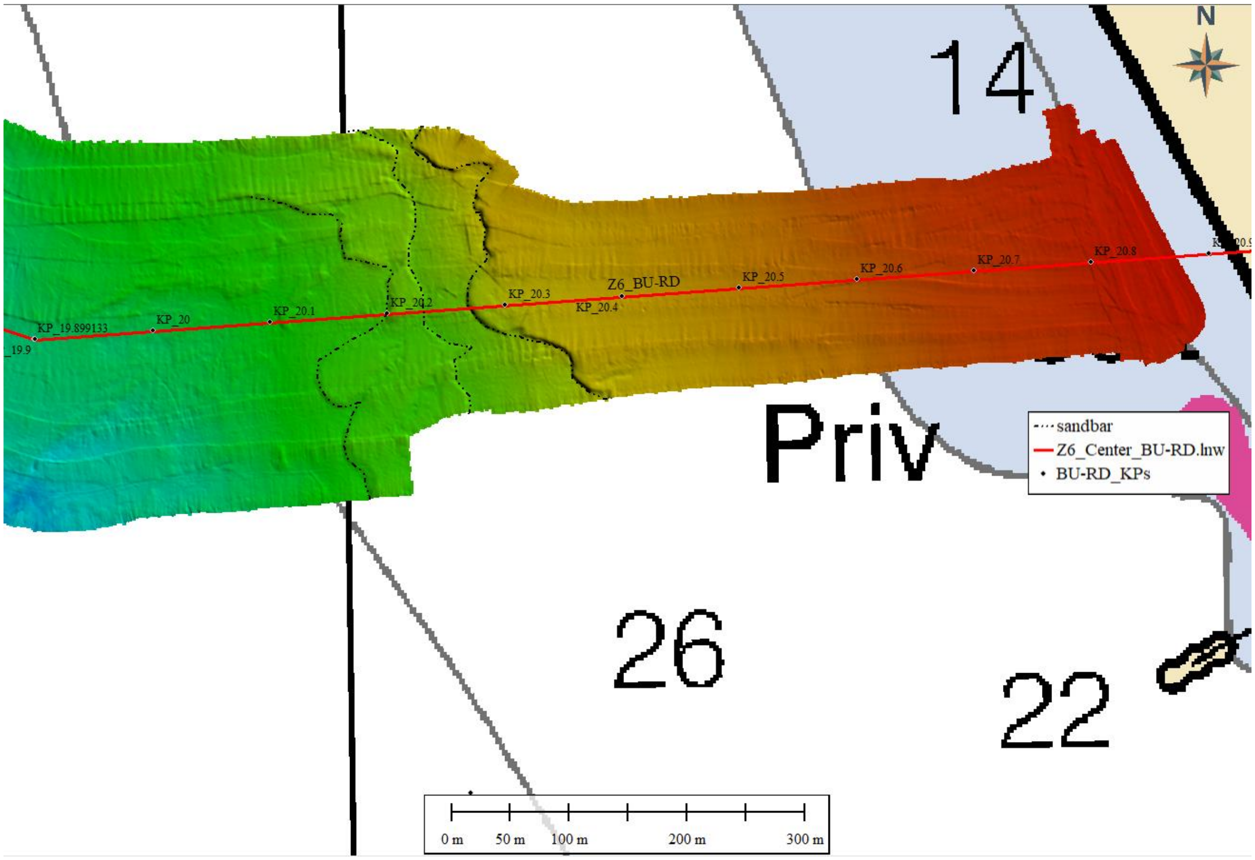


Figure 5-81. Sandbars near the Red Dog landing.

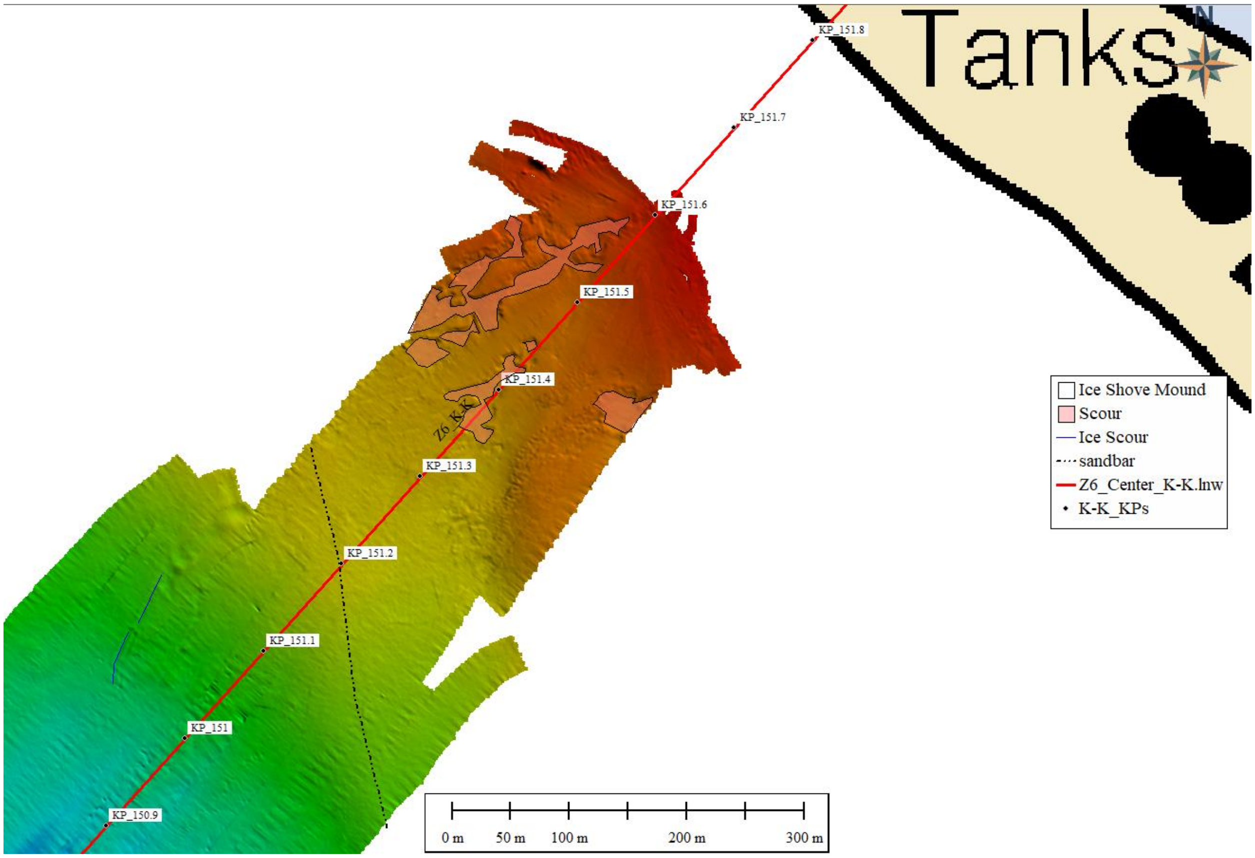


Figure 5-82. Sandbar and scour at the Kivalina Landing.

5.6.1 GEOTECHNICAL RESULTS

9 piston cores and two grab samples were collected in Zone 6 (Figure 5-83). The seabed surface sediment composition ranges from silty clay to fine gravel.

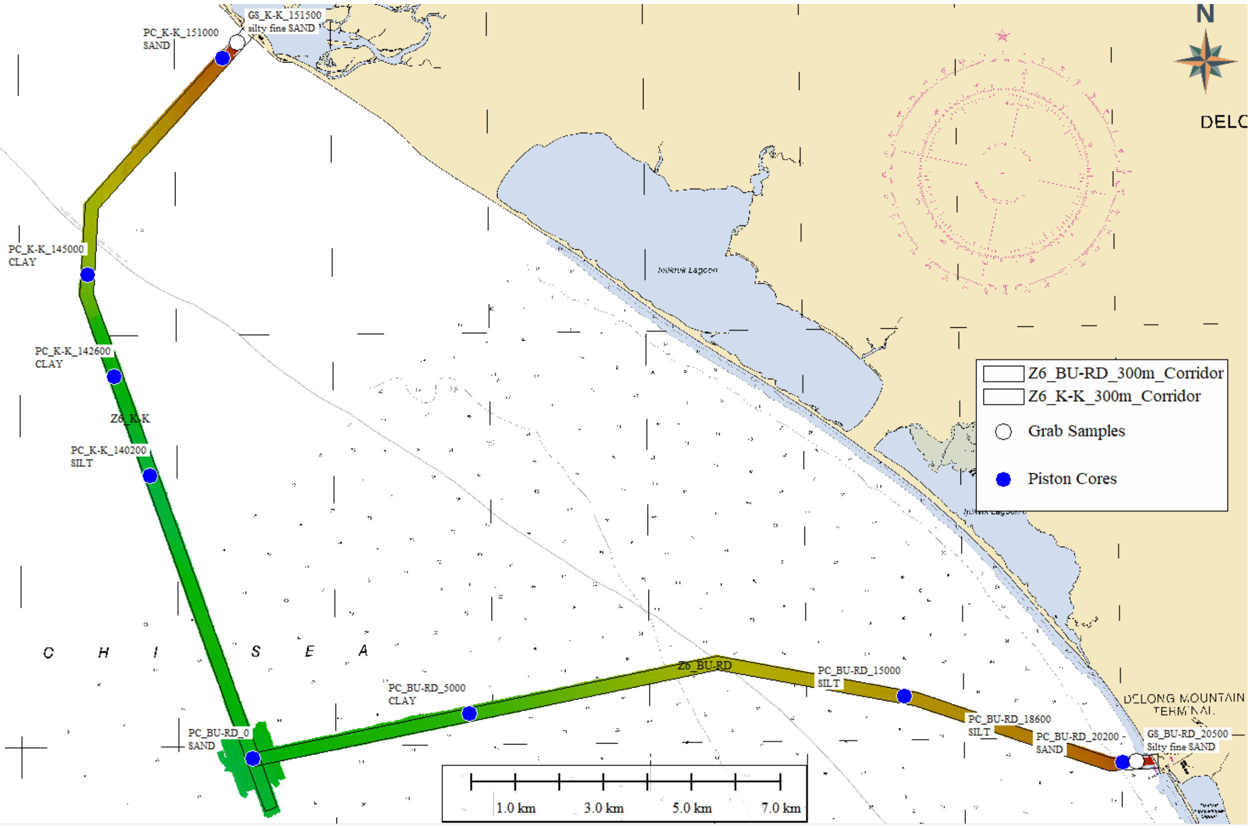


Figure 5-83. Zone 6 Geotechnical stations and surface sediments

Beneath the surface the sediment consists of clay to gravel. Grain size increases with decreasing depth. Sediment core descriptions are provided in (Table 5-9).

Table 5-9. Zone 6 sediment core descriptions

STATION	SED. DESCRIPTION 1	SED. DESCRIPTION 2	SED. DESCRIPTION 3	SED. DESCRIPTION 4	SED. DESCRIPTION 5
PC_BU-RD_0	0-17cm medium dense, fine SAND.	17-25cm Moist, soft, sandy CLAY, medium plasticity, medium dilatancy.	25-43cm Medium dense, clayey SILT, small pocket of soft clay at lower contact.	43-89cm Dense, silty fine SAND, minor amounts of elongated, subangular clast at upper contact ~1cm	89-97cm Medium dense, silty fine SAND, minor amounts of elongated subrounded clasts 1-2cm.
PC_BU-RD_5000	0-90cm Moist, soft to medium stiff, silty CLAY,	90-102cm Wet, very soft, CLAY, high plasticity, low			

	medium plasticity, medium dilatancy.	dilatancy, intact organics (bivalve and worms).			
PC_BU-RD_15000	0-32cm Medium stiff to stiff, clayey SILT, high mica content.	32-35cm Coarse sand with silty matrix, subangular clasts 0.5-1cm.			
PC_BU-RD_18600	0-11cm Dense, SILT.	11-27cm Soft silty CLAY, medium plasticity, high dilatancy, subangular coarse sand at lower contact.	27-70cm Fine to coarse SAND with fine gravel at lower contact. Fining upwards sequence, poorly sorted, subrounded to subangular.		
PC_BU-RD_20200	0-12cm Soft clayey fine SAND, subrounded coarse sand clasts 1-3cm.	12-55cm Moist, soft to medium stiff CLAY, transition to black CLAY moving down-hole, medium plasticity, high dilatancy.			
PC_K-K_140200	0-32cm Clayey SILT, interbedded with black clayey silt, high mica content.	32-45cm Soft, sticky CLAY, low plasticity, high dilatancy, high mica content.	45-124cm Moist, stiff to very stiff, silty CLAY, low plasticity, high dilatancy, high mica content.	124-133cm Moist, soft, silty CLAY, low plasticity, high dilatancy, high mica content.	
PC_K-K_142600	0-22cm Moist, soft, silty CLAY, trace shell fragments.	22-62cm Stiff to very stiff, silty CLAY.			
PC_K-K_145000	0-12cm Very wet, very soft, CLAY, high plasticity, high dilatancy.	12-39cm Clayey matrix, medium - coarse SAND, subrounded - subangular, well sorted, few coarse gravel clasts ~			

		5cm, elongated, subangular to subrounded.			
PC_K-K_151000	0-15cm Coarse SAND to fine GRAVEL, well sorted, subrounded to angular, minor shell fragments.				

Shear strength tests in Zone 6 were performed on most cores. 15 measurements of shear strength revealed very soft to stiff sediment (Figure 5-84). Based on 21 unconfined compressive strength tests the sediment is very soft to hard. However, hard sediment was only found in K-K_142600 at a depth of 50 cm (Figure 5-85).

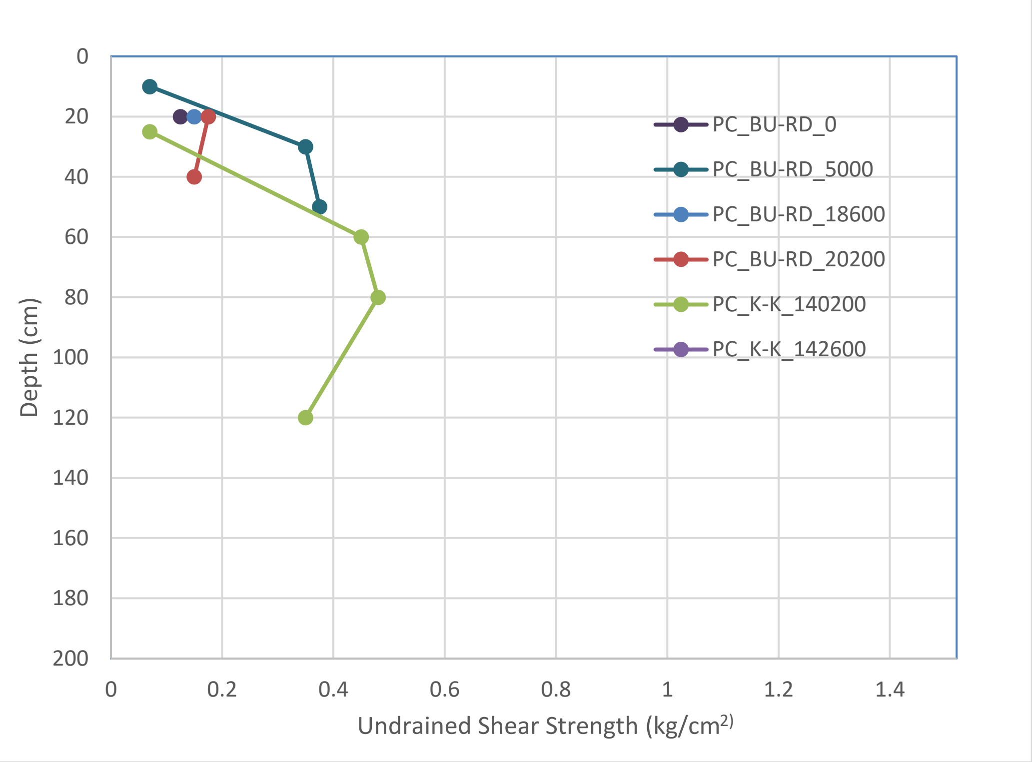


Figure 5-84. Zone 6 Undrained shear strength

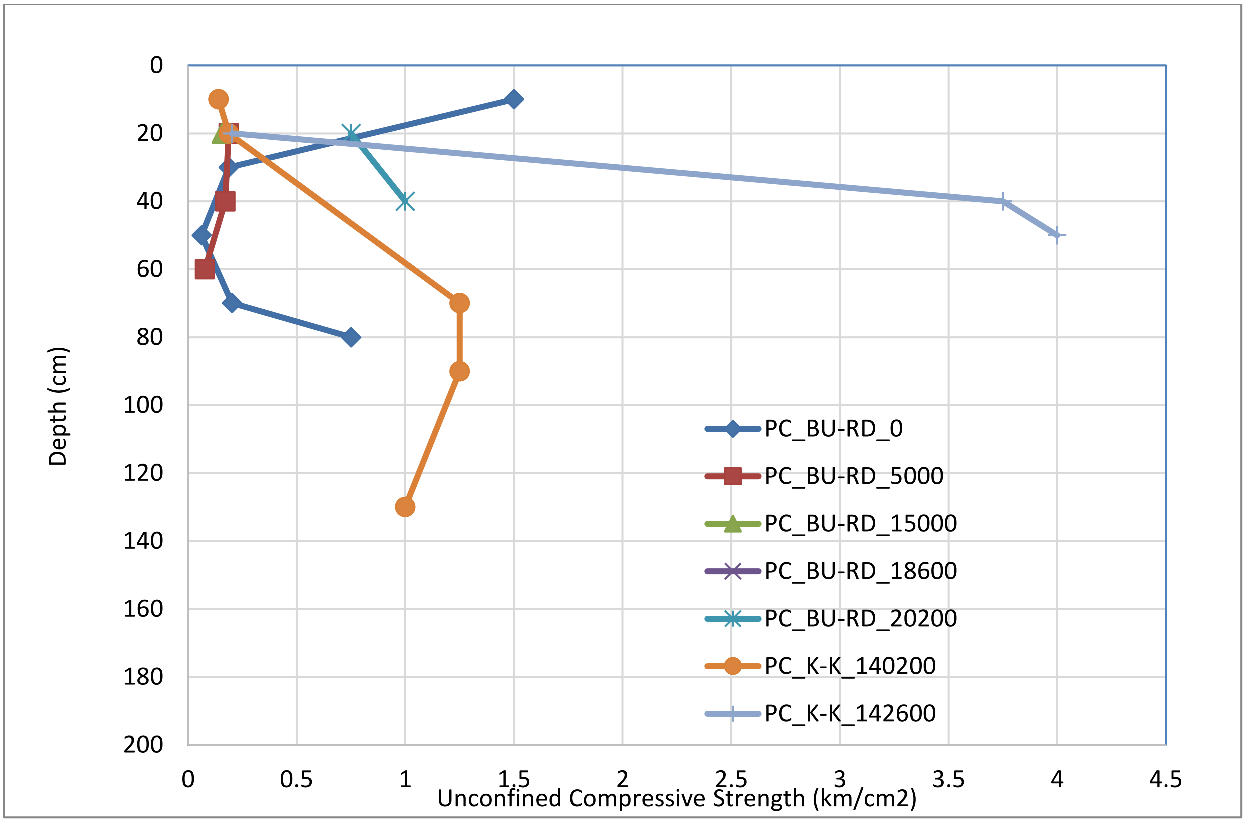


Figure 5-85. Zone 6 Unconfined compressive strength

Based on the relationship between the descriptive soil property terminology and numeric values of shear strength and compressive strength shown in Table 5-3, Figure 5-86 shows the distribution of soil types in Zone 6 based on the geotechnical tests.

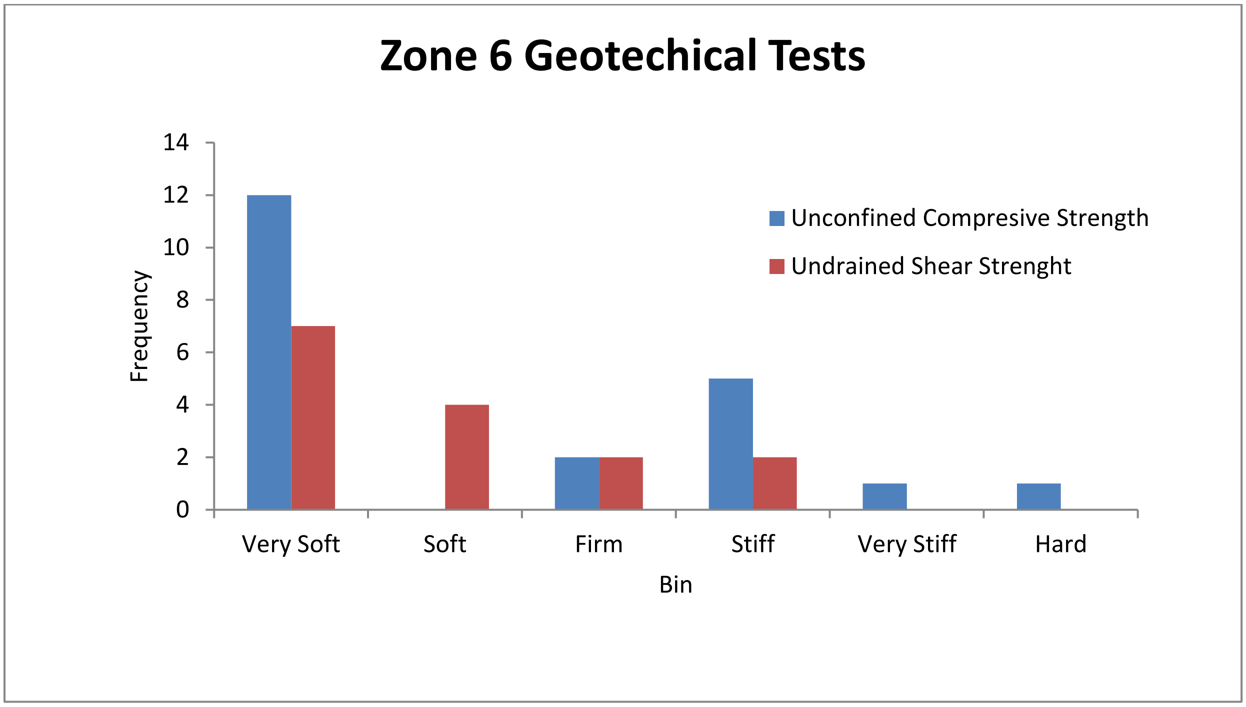


Figure 5-86. Zone 6 soil properties based on geotechnical tests

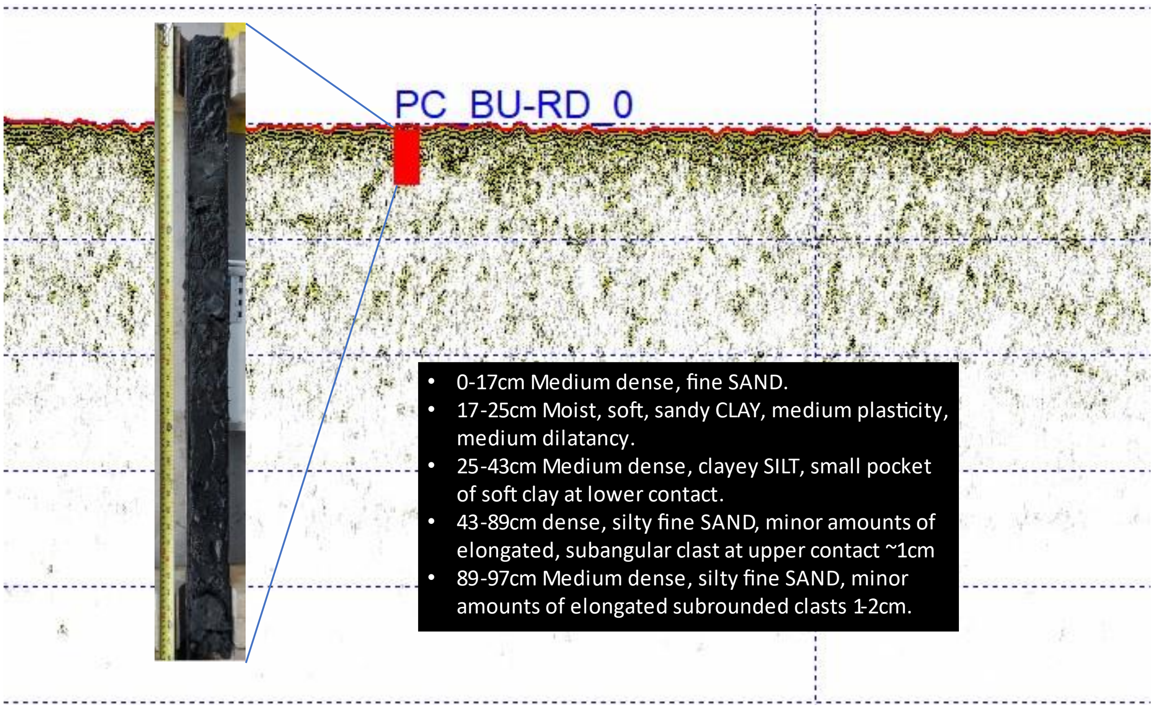
Note that out of the 9 cores acquired in Zone 6 only 2 cores recovered more than 1 meter of sediment. The maximum recovery was 133 cm with an average recovery of 67cm. Therefore, stiffer sediments may be encountered at depth that were not sampled in coring and do not present differently in the acoustic records. This is particularly true for cores such as K-K_142600 where hard sediment was recovered from the bottom of the core at a depth of 50 cm.

5.6.1 SURFACE SEDIMENTS

Based on the side scan sonar imagery, multibeam backscatter, and geotechnical results the surface sediments in Zone 5 range from clay to fine gravel. As with other zones the primary surface sediment is clay, however areas of seabed disturbance due to ice scouring or wave energy near shore show a mix of sand and clay pockets.

5.6.1 SUB-SURFACE STRATIGRAPHY

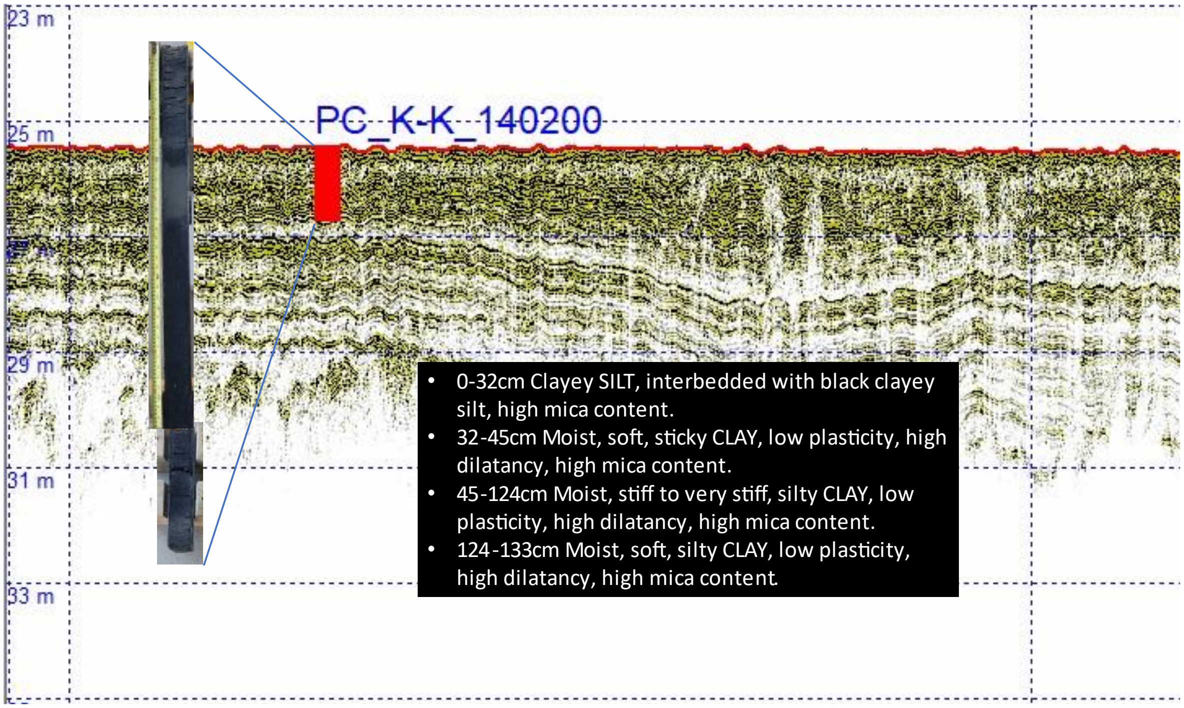
From K-K KP 133 through the branching unit at 133.4 to 134.7 the sub-bottom sediments are composed of a mix of clay, silt and fine sand are well represented by piston core taken at the branching unit (Figure 5-87). In this area, the dense fine sand in the upper 17 cm has a compressive strength of 1.5 kg/cm^2 (Stiff), but all other tests showed very soft to firm sediments.



- 0-17cm Medium dense, fine SAND.
- 17-25cm Moist, soft, sandy CLAY, medium plasticity, medium dilatancy.
- 25-43cm Medium dense, clayey SILT, small pocket of soft clay at lower contact.
- 43-89cm dense, silty fine SAND, minor amounts of elongated, subangular clast at upper contact ~1cm
- 89-97cm Medium dense, silty fine SAND, minor amounts of elongated subrounded clasts 1-2cm.

Figure 5-87 Zone 6, Sub-bottom profile example at PC_BU-RD_0

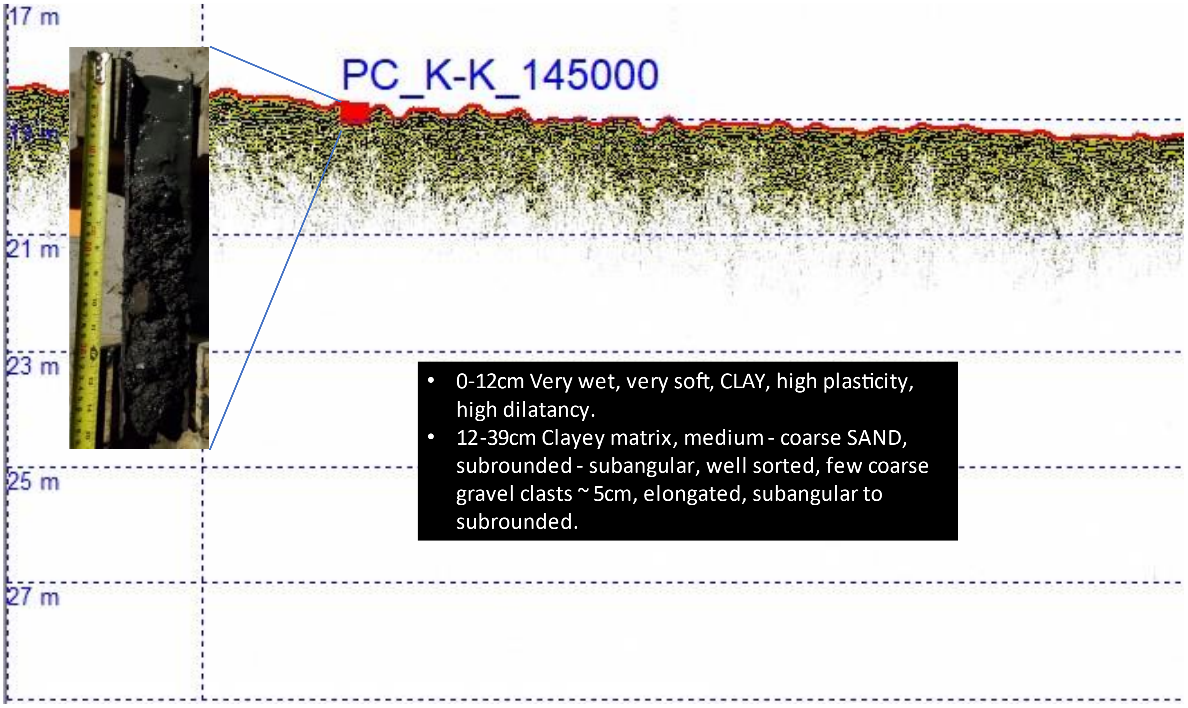
Starting at KP K-K 134.7 the seabed composition changes to a thick sequency of clay to clayey silt that was sampled at KP_K-K_140200 (Figure 5-88)



- 0-32cm Clayey SILT, interbedded with black clayey silt, high mica content.
- 32-45cm Moist, soft, sticky CLAY, low plasticity, high dilatancy, high mica content.
- 45-124cm Moist, stiff to very stiff, silty CLAY, low plasticity, high dilatancy, high mica content.
- 124-133cm Moist, soft, silty CLAY, low plasticity, high dilatancy, high mica content.

Figure 5-88. Sub-bottom profile example at PC_K-K_140200

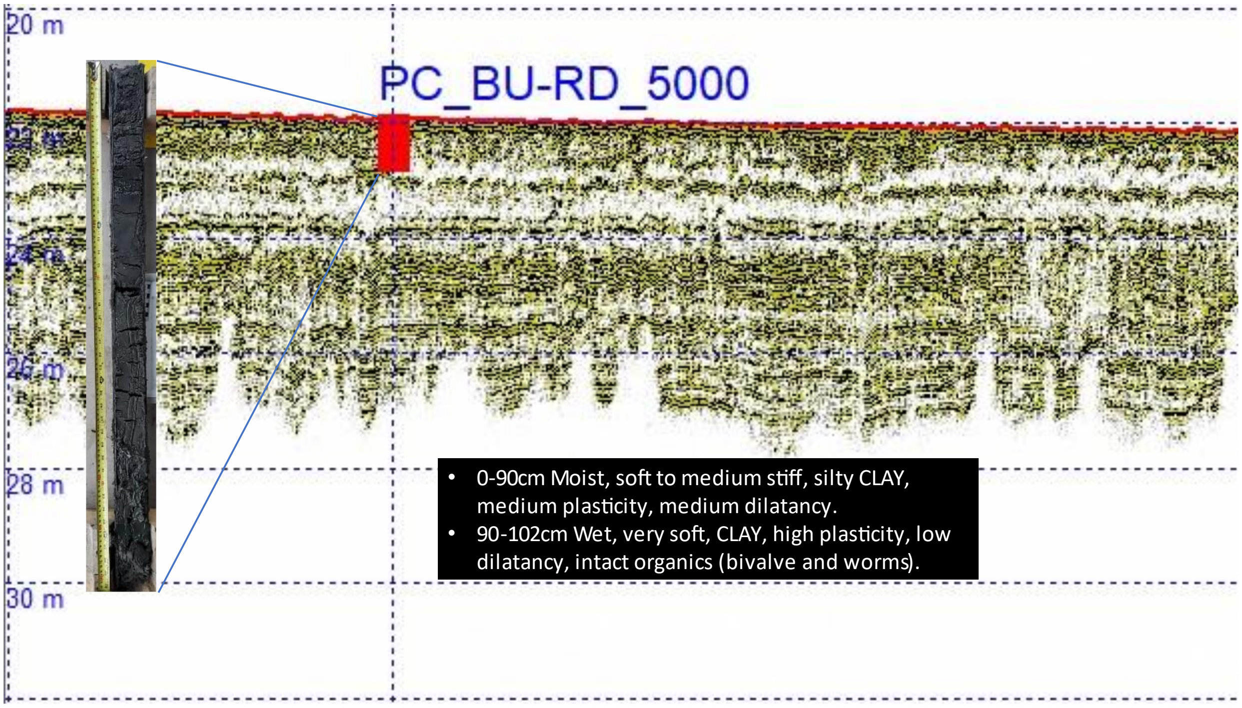
At KP K-K 142 the thick clay horizon thins to a veneer approximately 1m in thickness and appears to overlay a siltier or sandier horizon. At KP K-K 144 a sudden elevation change of approximately 2.5 meters marks the boundary of a seabed sediment facies change. Starting at K-K 144 coarse sand with gravel and a clayey matrix extends to the beach at KP 152 (Figure 5-89).



- 0-12cm Very wet, very soft, CLAY, high plasticity, high dilatancy.
- 12-39cm Clayey matrix, medium - coarse SAND, subrounded - subangular, well sorted, few coarse gravel clasts ~ 5cm, elongated, subangular to subrounded.

Figure 5-89. Sub-bottom profile example at PC_K-K_151000

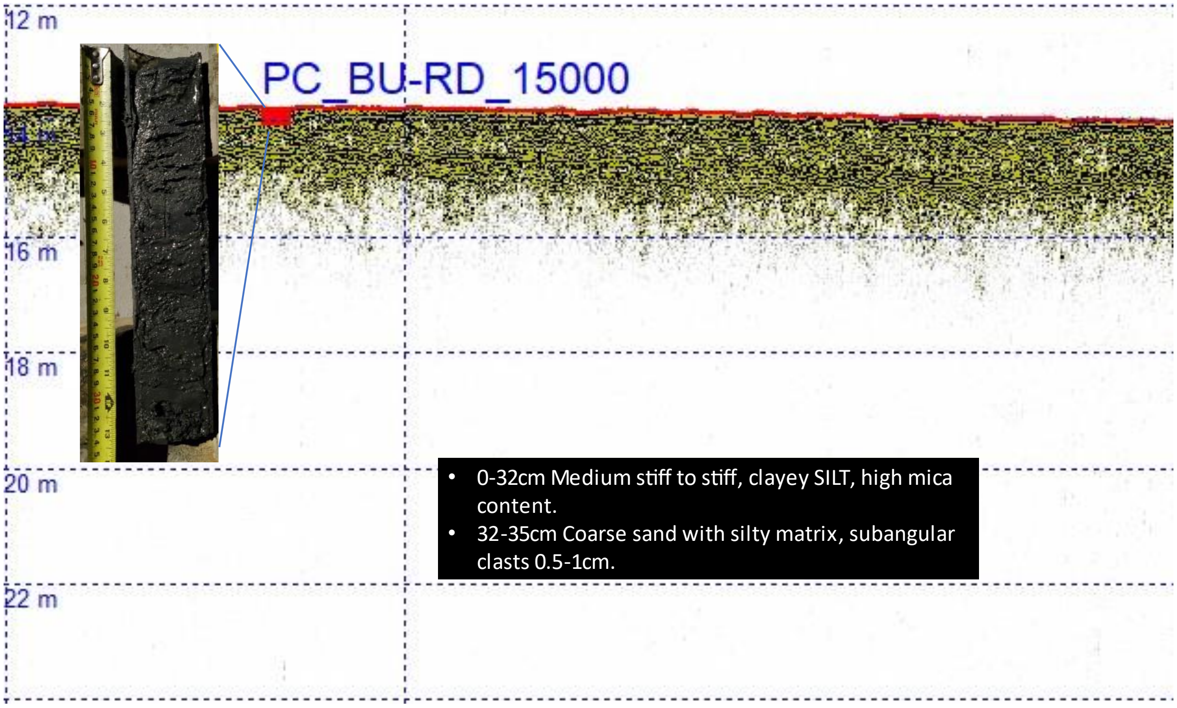
Going back to KP 0 on the BU-RD route we start with the sediment described in the first paragraph of this section and shown in Figure 5-87. Along this BU-RD route this seabed stratigraphic regium continues to KP 2.6 before plunging under an onlapping sequence of clean clay and silty clay, represented by the core at BU-RD_5000 (Figure 5-90).



- 0-90cm Moist, soft to medium stiff, silty CLAY, medium plasticity, medium dilatancy.
- 90-102cm Wet, very soft, CLAY, high plasticity, low dilatancy, intact organics (bivalve and worms).

Figure 5-90. Sub-bottom profile example at PC_BU-RD_5000

This sequence of thick, clean clay continues until tapering out between KP 13 and KP 15, exposing silt and sand which was sampled at PC_BU-RD_15000 (Figure 5-91). The clay sequence then thickens again through KP 16 and tapers out a final time near KP 18. At PC_BU-RD_18600 A thin horizon of clay is still present however the predominate sediment type is now coarse sand and gravel. The coarser sediment type is reflected in the rapid sub-bottom signal attenuation. Sand at the seabed surface continues to the landing at Red Dog with one additional piston core sample at KP 20.2 and one additional grab sample at KP 20.5.



- 0-32cm Medium stiff to stiff, clayey SILT, high mica content.
- 32-35cm Coarse sand with silty matrix, subangular clasts 0.5-1cm.

Figure 5-91. Sub-bottom profile example at PC_BU-RD_15000

5.6.1 MAGNETIC ANOMALIES

Magnetometer data was acquired along the centerline of the BU-RD segment of Zone 6. No magnetic field strength anomalies were detected.

5.6.1 SUMMARY

Seafloor ice scours are present in Zone 6, particularly in water depths less than 22 m. Some ice scours terminate at sediment mounds that have been pushed up by ice keels. In Zone 6 sediment grainsizes range from clay to gravel and the compressive strength is also widely ranging from very soft to hard. Sub-bottom records did not reveal any stratigraphic horizons or sub-cropping features of concern.

5.7 Quintillion Cable Crossing

Between KP 1 and KP 3.5 Magnetometer and sub-bottom data was acquired on survey lines oriented perpendicular to the Quintillion cable. The location of the Quintillion fiber optic cable was confirmed to align with the RPL provided by Quintillion based on 11 magnetic field strength anomalies Figure 5-92.

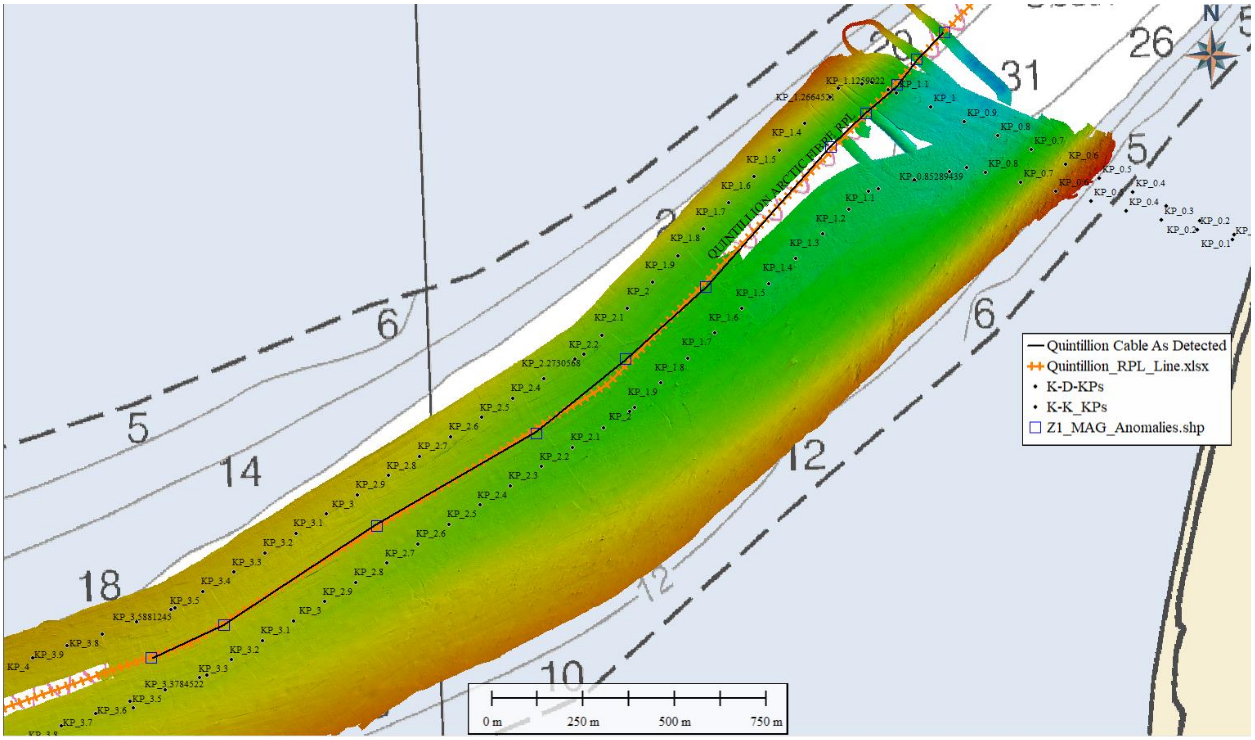


Figure 5-92. Magnetometer anomalies, confirm the location and depth of the buried Quintillion cable.

In only one sub-bottom profile was the Quintillion cable was identified by a hyperbolic reflection at a depth of 1 meter below the surface Figure 5-93.

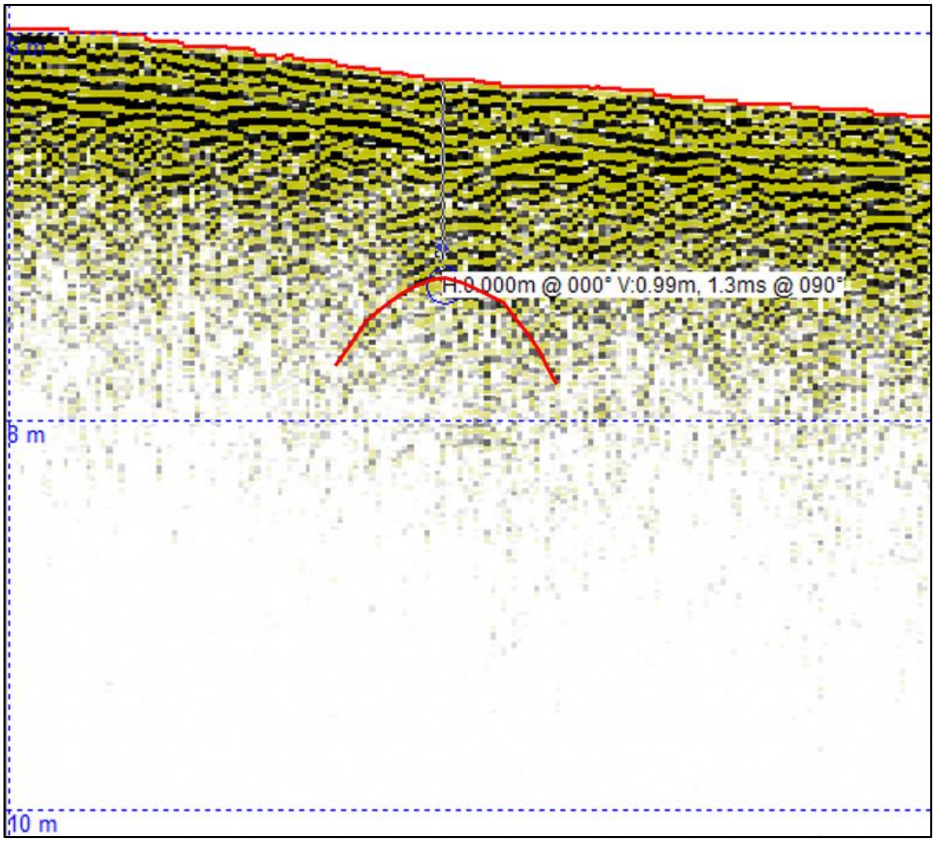


Figure 5-93. Hyperbolic reflection in a sub-bottom profile from the buried quintillion cable.