US Army Corps of Engineers
Alaska District

Geotechnical Feasibility Appendix

Akutan Harbor Navigational Improvement

Akun Island, Alaska

Alaska District, Pacific Ocean Division

07 February 2024
Status: ATR Review Submittal

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS, ALASKA DISTRICT
P.O. BOX 6898
JBER, AK 99506-0898

CEPOA-ECG-M 07 February 2024

MEMORANDUM FOR

Civil Works Project Management (CEPOA-PM-C), CPT Matthew Ripperger

SUBJECT: Geotechnical Feasibility Appendix for the Akutan Harbor Navigational Improvements Feasibility Study, Akun Island, Alaska.

1. Enclosed is the Geotechnical Feasibility Appendix for the Akutan Harbor Navigational Improvements feasibility study located on Akun Island, Alaska. Included with this appendix are discussions of the anticipated subsurface conditions, preliminary geotechnical evaluation, and the geophysical survey for the proposed project.

2. Questions should be addressed to Justin Miller at 907-753-2577 or Amy Steiner at 907-753-2800.

JUSTIN M. MILLER, P.E.
Civil Engineer
CEPOA-ECG-M

AMY L. STEINER, P.E.
Chief, Geotechnical and
Materials Section
CEPOA-ECG-M

JOHN J. RAJEK, P.E.
Chief, Geotechnical and
Engineering Services Branch
CEPOA-ECG

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1 Introduction

The purpose of this report is to perform a desktop review of historical geotechnical information, document the anticipated subsurface geotechnical conditions, provide analyses of anticipated site conditions as they pertain to the project described herein, and to introduce a preliminary geotechnical design and construction criteria for the Akutan Harbor Navigational Improvements located on Akun Island, Alaska. Information and assumptions in this report were developed through site visits and geophysical survey data. The information presented is intended for use by design engineers and planners to evaluate the feasibility of proposed project. Information in this report is not intended for use in construction contract documents. An extensive exploration program and a more detailed engineering analysis are needed before the final geotechnical recommendations for the design and construction of the proposed project can be made.

2 Location and Project Description

The Native Village of Akutan is located on Akutan Island on the north side of Akutan Harbor. The Akutan Airport is located about six miles east on Akun Island (Figure 2-1). Akutan Island and Akun Island are located in southwestern Alaska and is part of the Fox Islands subgroup of the Aleutian Islands. The Native Village of Akutan is serviced by the airport on Akun Island. Passengers and light freight are transported from Akun Island to the Native Village of Akutan via helicopter. The Fox Islands subgroup is the easternmost subgroup of the Aleutian chain and the one closest to mainland Alaska. Akun Island lies immediately northeast of Akutan. The project location and vicinity map is provided in Attachment A-1 to this report.

Figure 2-1. Project Location and Vicinity Map

A marine link between the Native Village of Akutan and Akutan Airport is being considered during this study. Marine facilities including a seaplane base, helicopter pad, small boat harbor, city dock, and ferry dock are located at the Native Village of Akutan. The only marine facilities located on Akun Island is a concrete hovercraft pad along the coast west of the runway. Access to the small boat harbor in the Native Village of Akutan is limited to relatively small vessels and is overcrowded. An additional harbor is located approximately 2 miles east of the city at the head of Akutan Harbor. This harbor was constructed in 2012 and serves as a harbor of refuge for the commercial fishing fleet but has no road access to the Native Village of Akutan.

The proposed harbor would be sized to accommodate a design vessel with a length of 58 feet and a draft of 8 feet. A rubble mound breakwater would protect a 120 foot by 120 foot turning basin. Both the entrance channel and turning basin would have a dredge depth of -13.0 feet. Blasting is anticipated for construction of the turning basin or entrance channel in the proposed location of the tentatively selected plan (TSP). The entrance channel would have a minimum width of 60 feet to a maximum width of 120 feet when turning around the nose of the breakwater. Proposed service facilities required would include a pile-supported dock, turning dolphins, uplands with an area of approximately 0.15 acres for loading/unloading freight from dock, and a 12-foot-wide road connecting the harbor areas with the infrastructure. The proposed harbor layout (TSP) is discussed in Section 6 and shown in Figure 6-2.

3 Previous Geotechnical Investigations

In 2005, Duane Miller and Associates (DMA) conducted a geotechnical exploration to support a Master Planning Study for the Akutan Airport. In 2008, the Alaska Department of Transportation and Public Facilities (ADOT&PF) conducted a geotechnical investigation and NORCAL Geophysical Consultants (NORCAL) conducted a seismic survey to support an airport improvement project. The airport project included the construction of a 4,500-foot paved and lighted runway with auxiliary buildings on Akun Island, along with a hovercraft landing ramp and pad facility in Surf Bay and an approximately 3,000-foot access road connecting the airport apron to the hovercraft ramp and pad facility (ADOT&PF 2008). The hovercraft landing ramp is located near the southeast corner of the proposed ramp for this project. The locations of the test borings performed by ADOT are shown in Figure 3-1. The location of the test borings performed by DMA are shown in Figure 3-2.

An offshore geophysical survey was conducted by WSP Golder in August 2022 to investigate the thicknesses of sediment over bedrock within the area of proposed navigation improvements. General site conditions within the project area are expected to consist of a variable thickness of unconsolidated sediment overlying a harder layer interpreted to be bedrock. At some locations, the geophysical data also shows the presence of an intermediate strength layer below the sub-bottom elevation that could be weathered bedrock. Weak surficial sediment was not encountered, which is consistent with the relatively high-energy environment in Surf Bay. Cross-sections and plan view drawings displaying inferred sediment thicknesses and bedrock elevations are provided in the WSP Golder report titled Geophysical Survey Report Akutan Harbor Navigational Improvements dated January 2023. The historical reports discussed in this section are included as an Annex to this report.

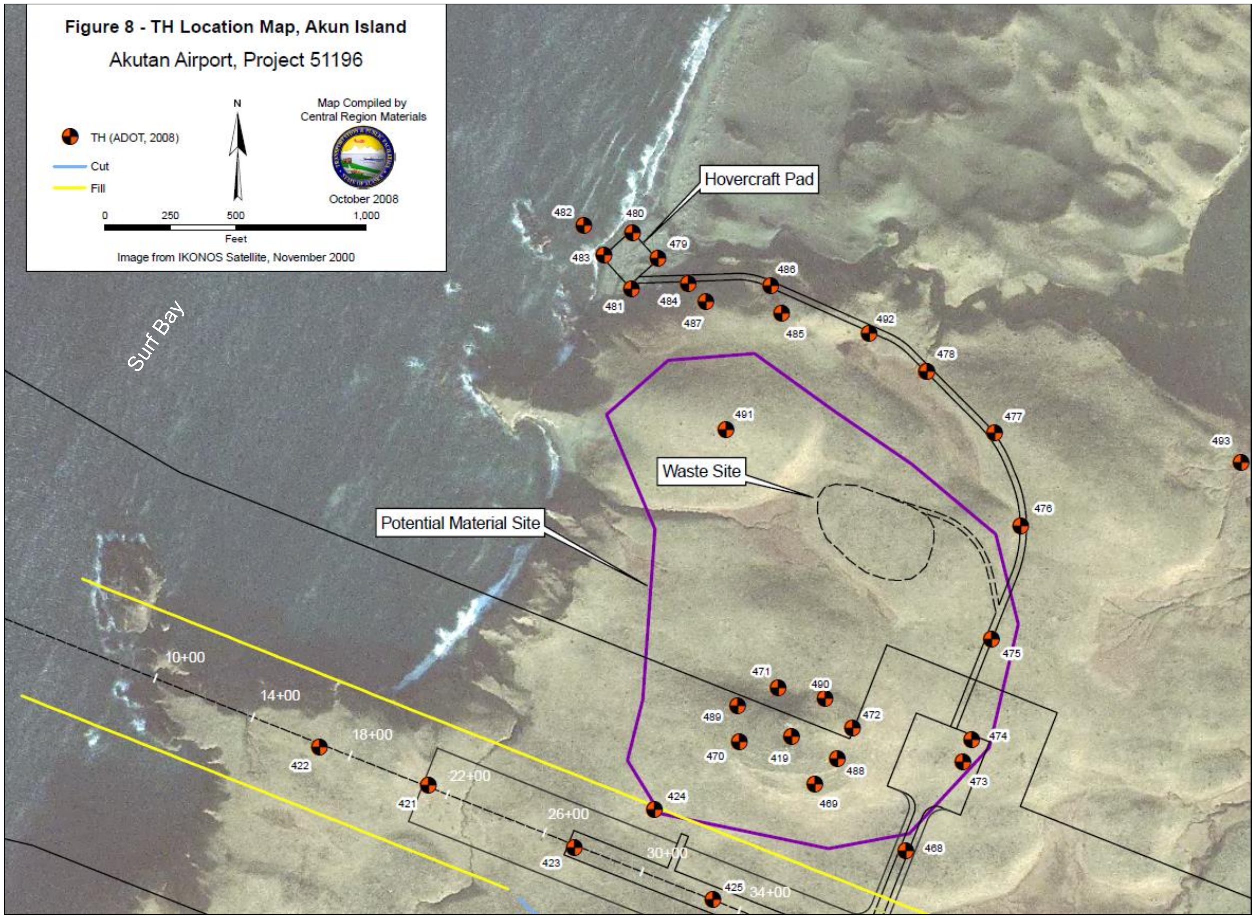

Figure 3-1. Historical Test Boring Locations (ADOT, 2008)

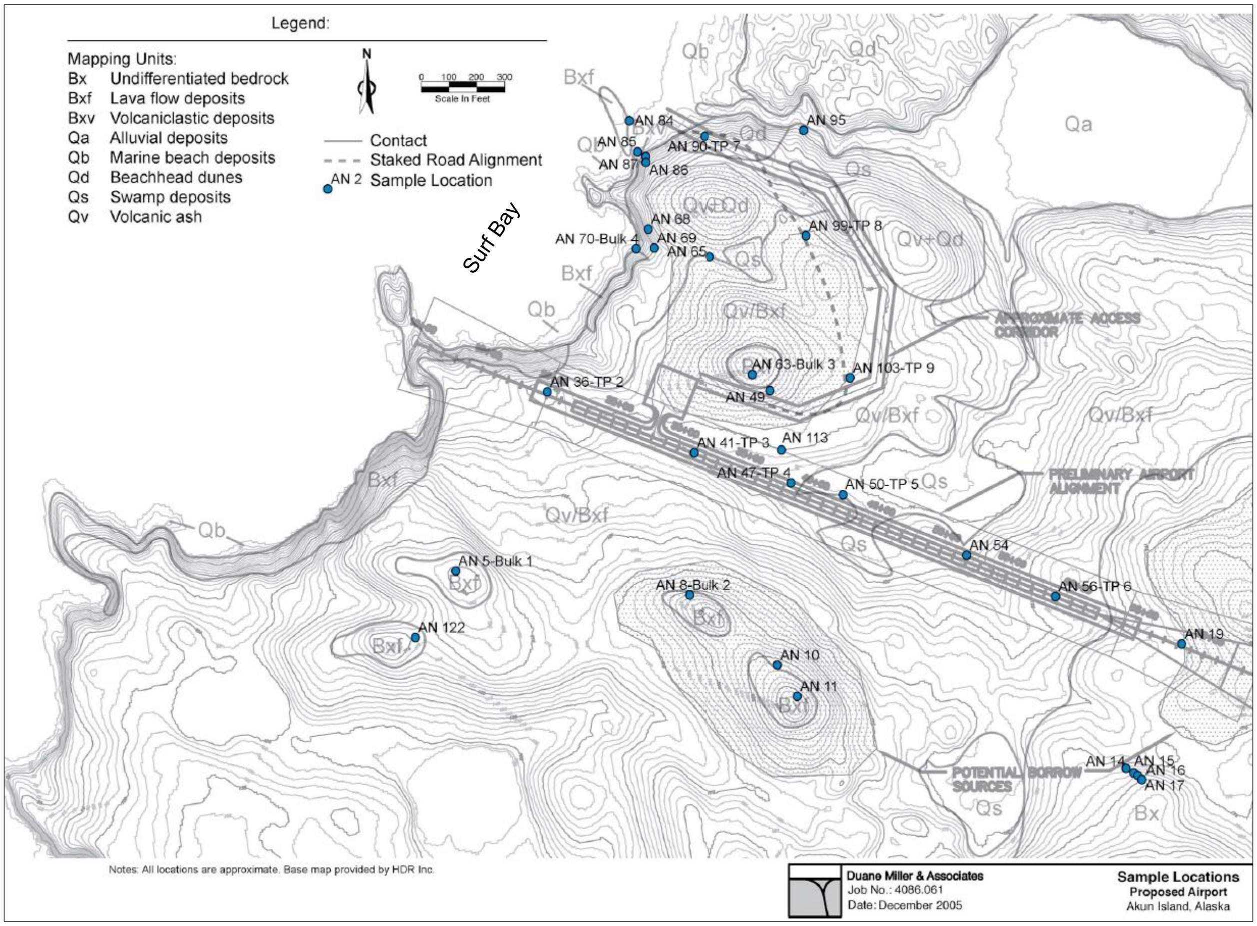

Figure 3-2. Historical Test Boring Locations (DMA, 2005)

4 Regional Geology

The Aleutian Islands are a volcanic island arc extending southwest from the Alaska Peninsula. These islands separate the Bering Sea from the Pacific Ocean. The Aleutian Island arc is situated along the Aleutian subduction zone where the oceanic Pacific Plate is subducted beneath the continental North American plate. This results in a volcanic arc and high rates of seismicity. During the Pleistocene epoch, glaciation blanketed the Aleutian chain. At present, the Aleutian Islands often consist of steep volcanic slopes that descend directly into the sea and glacier-carved fjords. Glacial and volcanic deposits are commonly found concurrently in the Aleutian Island surficial geology, including glacial deposits in valley bottoms and ridge tops, and modern pyroclastic deposits such as air-fall ash and ash-flow tuff.

Akun Island is located approximately six miles east of the City of Akutan and approximately 35 miles northeast of Dutch Harbor and Unalaska. The Akutan Volcano, one of the most active volcanoes in the Aleutian Arc, sits on the western half of Akutan Island, and Mt. Gilbert Volcano is located approximately five miles north of the project site on Akun Island. Mt. Gilbert is a stratovolcano with massive basalt flows and thick pyroclastic deposits from modern and ancestral volcanic activity. Volcaniclastic debris flows and lahar deposits are found at the base of the volcanic slopes and in local valley bottoms. The identified geologic units in the vicinity of the proposed harbor location of Akun Island are shown in Figure 4-1.

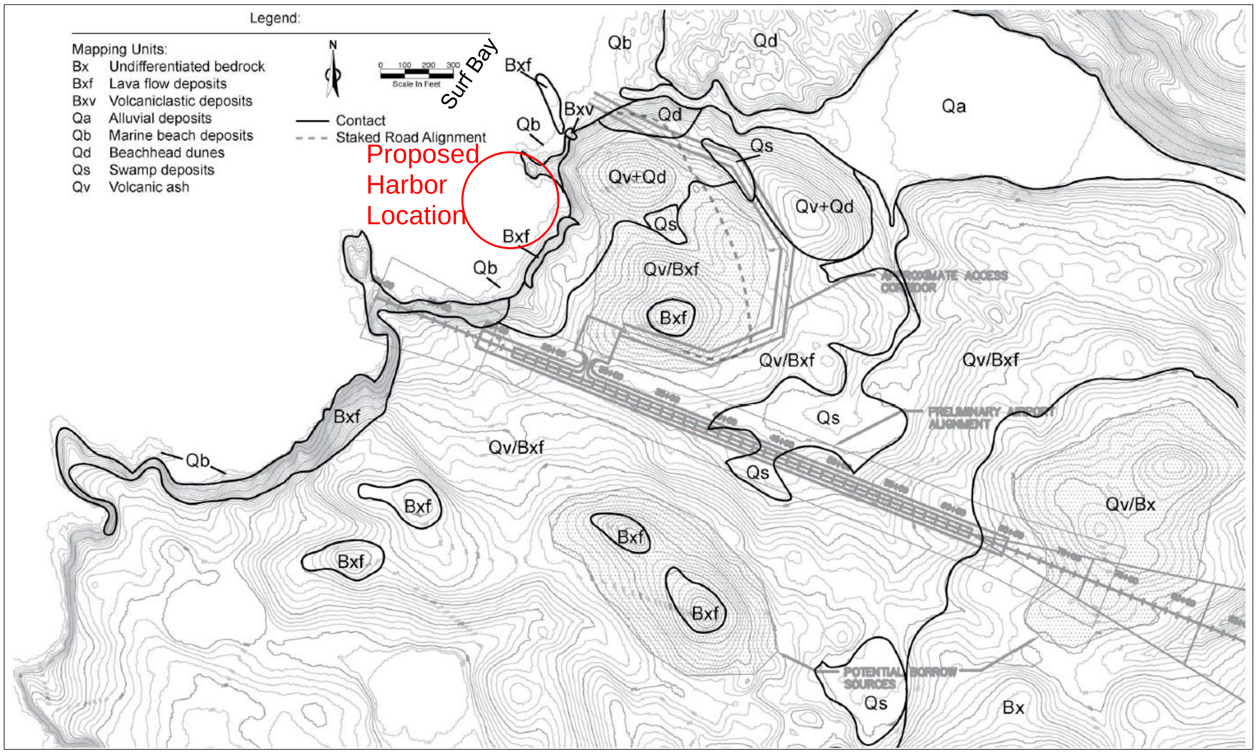

Figure 4-1. Geologic Map of Akutan and Akun Islands (DMA, 2005)

5 Geotechnical Design Considerations

It is anticipated that rubble mound breakwaters can be constructed for the planned project. It is important that prudent consideration be given to certain subsurface conditions and construction aspects including deleterious foundation soils, stability, seismic concerns, and settlement. This engineering analysis is based on historical geotechnical information and the 2022 geophysical survey. The following sections are based on anticipated conditions and must be reevaluated following a formal subsurface site investigation.

5.1 Anticipated Soil Profile

Based on the available historical information and the result of the geophysical survey, it is anticipated that the soils near the proposed breakwaters in the area of the tentatively selected plan (TSP) consists of 5 to 10 feet of unconsolidated marine sediments (gravels and sands) overlying igneous bedrock. Anticipated subsurface stratigraphy in the area of the alternatives is presented in the attached Geophysical Survey Report prepared by Golder Associates dated January 10, 2023. The anticipated soil profile must be confirmed by a geotechnical drilling program.

5.2 Anticipated In Situ Soil Properties

The soil properties used to design the revetment profile are summarized in Table 5-1. Typical unit weights from Table 5-2 (Coduto, 2001) and effective internal friction angles were estimated in accordance with Table 3-1 of EM 1110-1-1905, *Bearing Capacity of Soils* (1992). The soil properties in Table 5-1 are assumed soil properties and will need to be reevaluated following a formal subsurface site investigation.

Table 5-1. Anticipated Design Foundation Soil Properties

Interpreted Geology	[1]Physical Properties	Unified Soil Classification Symbol	[2]Dry Unit Weight (pcf)	[2]Internal Friction Angle (degrees)
Unconsolidated sediment	Loose to Medium Dense	GW - SW	100 – 120 (110)	29 - 30 (29)
Basalt	Hard / Unweathered	Bedrock	140 – 160 (150)	38 - 55 (48)

[1] Physical properties are assumed and should be considered approximate.
[2] Ranges of applicable values are presented, recommended value is shown in parentheses

5.3 Preliminary Breakwater Cross-Section

The preliminary cross-section for the breakwater is shown in Figure 5-1. During the engineering analyses, each soil layer was assumed to be homogeneous, fully saturated, and uniform in composition.

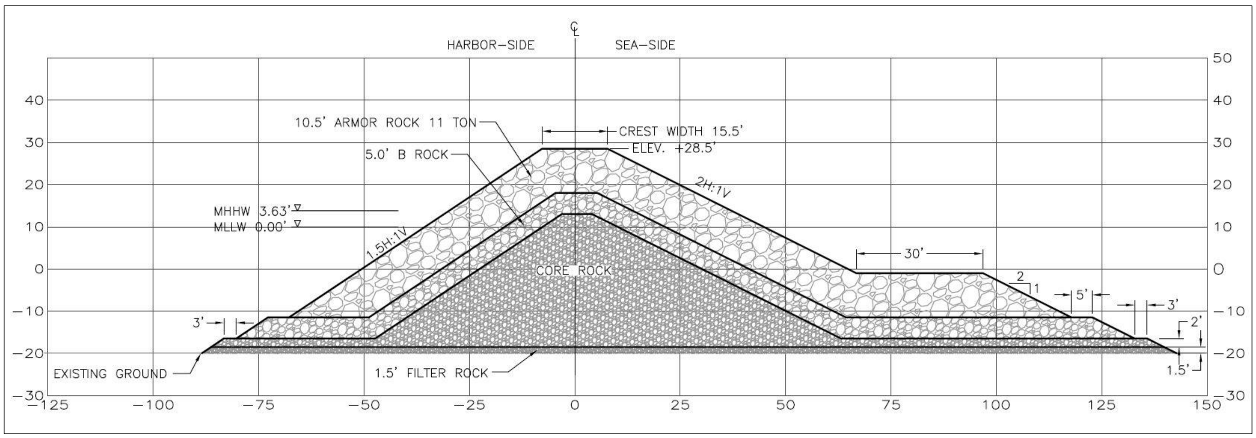

Figure 5-1. Preliminary Breakwater Cross-Section

5.4 Design Factors of Safety

Appropriate factors of safety must be to ensure adequate performance of the project throughout its design life. Three important considerations in determining appropriate factors of safety include: uncertainties in the conditions being analyzed, the consequences of failure, and the acceptable performance. Table 5-2 provides applicable factors of safety and source documents, which include procedures for performing the analysis.

Table 5-2. Applicable Factors of Safety

Reference	Analysis Condition	Minimum Factor of Safety
EM 1110-1-1905	Bearing Capacity	2.5
EM-1110-2-1902	Slope Stability, End of Construction	1.3
EM-1110-2-1902	Slope Stability, Long Term	1.5
EM-1110-2-1902	Slope Stability, Earthquake Loading	>1.0

5.5 Rubble-Mound Breakwater Engineering Properties

It is anticipated that the proposed breakwaters will be constructed using three different rock materials: armor rock (A Rock), intermediate rock (B Rock), and core rock. Assumed engineering properties of the breakwater materials are shown in Table 5-3.

Table 5-3. Assumed Breakwater Embankment Fill Properties

Breakwater Unit	[1]Dry Unit Weight (pcf)	[1]Internal Friction Angle (degrees)
A-Rock	95 – 115 (107)	40 - 55 (45)
B-Rock	95 – 115 (107)	40 – 55 (45)
Core Rock	95 – 115 (107)	40 - 55 (45)
[1] Ranges of applicable values are presented, recommended value is shown in parentheses		

5.6 Tide Conditions

The tides at Akutan are generally diurnal with two highs and two lows occurring daily. Tide levels, referenced to Mean Lower Low Water (MLLW), are shown in Table 5-4. Water level data is from the National Oceanic and Atmospheric Administration (NOAA) online database.

Table 5-4. Tidal data for the Akutan Harbor Navigation Improvements Referenced to MLLW

Tide	* Elevation (feet)
Mean Higher High Water (MHHW)	+3.73
Mean High Water (MHW)	+3.42
Mean Tide Level	+2.16
Mean Low Water (MLW)	+0.89
Mean Lower Low Water (MLLW)	0.00
* Source: NOAA National Ocean Surface	

5.7 Earthquake Ground Motions

Akun Island, Alaska is located in a region of high seismicity. Per the UFC 3-220-01 Geotechnical Engineering Section 2-1, the criteria for minimum factor of safety for liquefaction of risk category I & II structures is greater than or equal to 1.0, and for risk category III & IV structures greater than or equal to 1.1. Site-modified seismic ground motion parameters values used for this analysis are provided in Table 5-5. The values provided are based on mapped values from the American Society of Civil Engineers (ASCE) Minimum Design Loads for Buildings and Other Structures (ASCE 7-16) and UFC 3-301-01 Structural Engineering.

Table 5-5. Probabilistic Ground Motions (g) for Akun Island

Parameter	2% in 50 yr	5% in 50 yr	10% in 50 yr
PGA	0.59	0.46	0.36
0.2s SA	1.29	0.99	0.78
1.0s SA	0.52	0.39	0.31
PGA – Peak Ground Acceleration SA – Spectral Acceleration			

6 Alternatives

The study team evaluated three navigation improvement alternatives (Alternatives 1 through 3) in the process of recommending a TSP. The three alternatives considered are shown in the list below and described is the following sections.

- Alternative 1: Harbor Southwest of Unnamed Point (without blasting)
- Alternative 2 (TSP): Harbor South of Unnamed Point (with blasting)
- Alternative 3: Harbor Located South of Unnamed point (with blasting)

6.1 Alternative 1: Harbor Southwest of Unnamed Point (without blasting)

The harbor for Alternative 1 would be sized to accommodate a design vessel with a length of 58 feet and a draft of 8 feet. The 715-foot-long rubble mound breakwater would protect a 120 foot by 120 foot turning basin. Both the entrance channel and turning basin would have a dredge depth of -13.0 feet MLLW. It is anticipated that blasting would not be required for the turning basin or entrance channel in this location. The entrance channel would have a minimum width of 60 feet to a maximum width of 120 feet when turning around the nose of the breakwater. Local service facilities required would include a 560 foot long by 12-foot-wide pile-supported dock, turning dolphins, uplands with an area of approximately 0.15 acres for loading/unloading freight from dock, and a 1,100 foot long by 12-foot-wide road connecting the harbor areas with the existing pad to the south of the hotel. The proposed layout of Alternative 1 is shown in Figure 6-1.

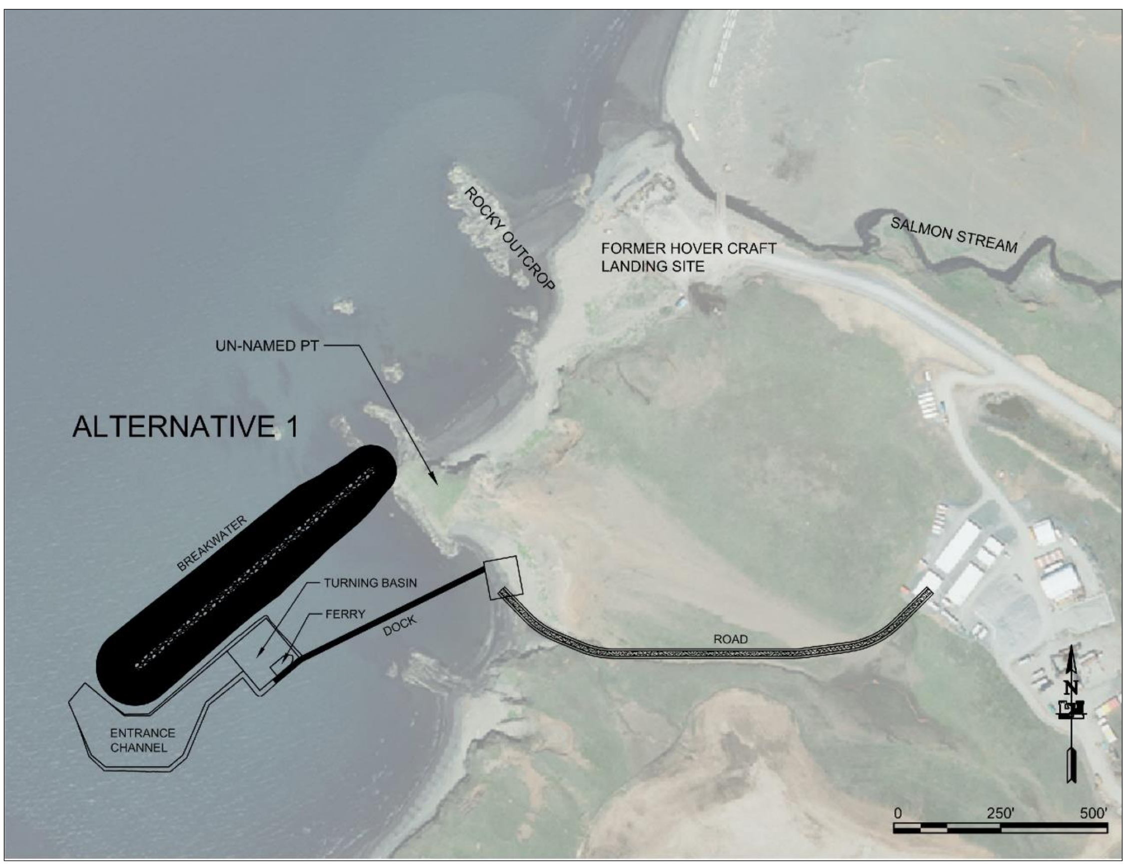

Figure 6-1. Alternative 1: Harbor Southwest of Unnamed Point (without blasting)

6.2 Alternative 2: Harbor South of Unnamed Point (with blasting) (Tentatively Selected Plan)

The harbor for Alternative 2 would be sized to accommodate a design vessel with a length of 58 feet and a draft of 8 feet. The 450-foot-long rubble mound breakwater would protect a 120 foot by 120 foot turning basin. Both the entrance channel and turning basin would have a dredge depth of -13.0 feet MLLW. It is anticipated that blasting would be required for the turning basin or entrance channel in this location. The entrance channel would have a minimum width of 60 feet to a maximum width of 120 feet when turning around the nose of the breakwater. Local service facilities required would include a 290 foot long by 12-foot-wide pile-supported dock, turning dolphins, uplands with an area of approximately 0.15 acres for loading/unloading freight from dock, and a 1,100 foot long by 12-foot-wide road connecting the harbor areas with the existing pad to the south of the hotel. The proposed layout of Alternative 2 is shown in Figure 6-2.

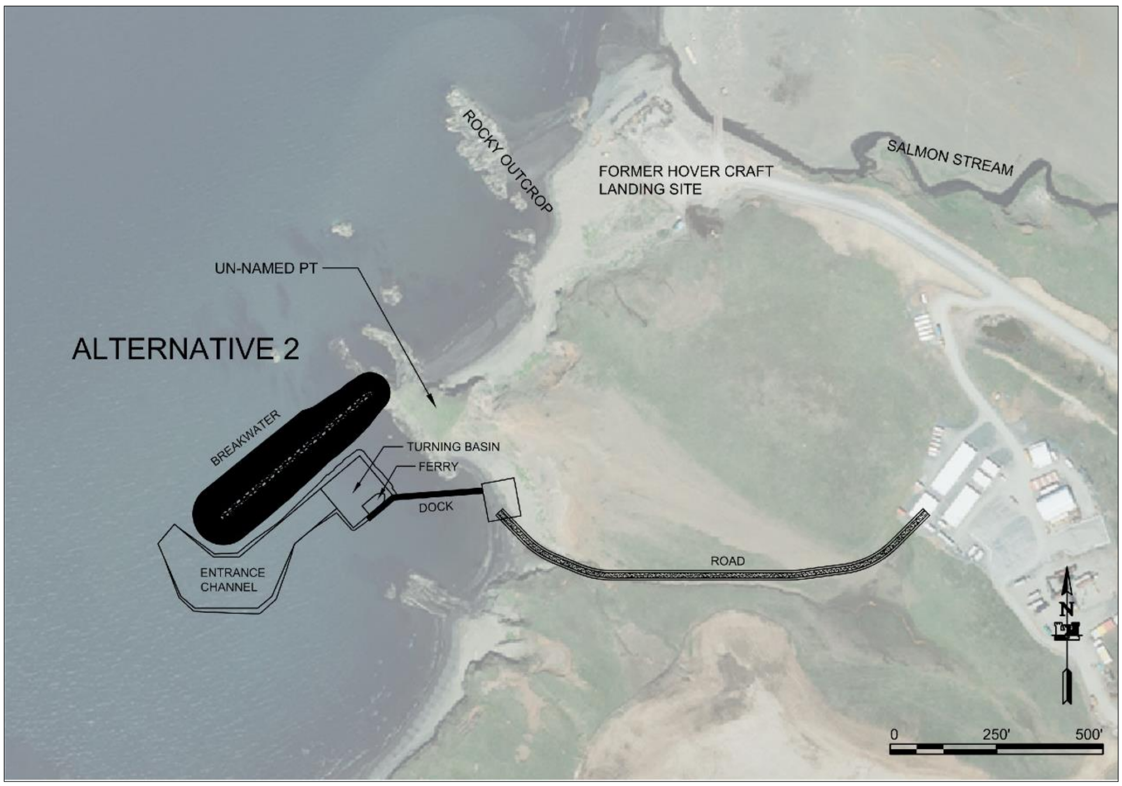

Figure 6-2. Alternative 2: Harbor South of Unnamed Point (with blasting)

6.3 Alternative 3: Harbor Located South of Unnamed point (with blasting)

The harbor for Alternative 3 would be sized to accommodate a design vessel with a length of 58 feet and a draft of 8 feet. The 400-foot-long rubble mound breakwater would protect a 120 foot by 120 foot turning basin. Both the entrance channel and turning basin would have a dredge depth of -13.0 feet MLLW. It is anticipated that blasting would be required for the turning basin or entrance channel in this location. The entrance channel would have a minimum width of 60 feet to a maximum width of 120 feet when turning around the nose of the breakwater. Local service facilities required would include a 325 foot long by 12-foot-wide pile-supported dock, turning dolphins, uplands at the existing hovercraft pad for loading/unloading freight from dock, and a 270 foot long by 12-foot-wide road connecting the existing hovercraft pad. The proposed layout of Alternative 3 is shown in Figure 6-3.

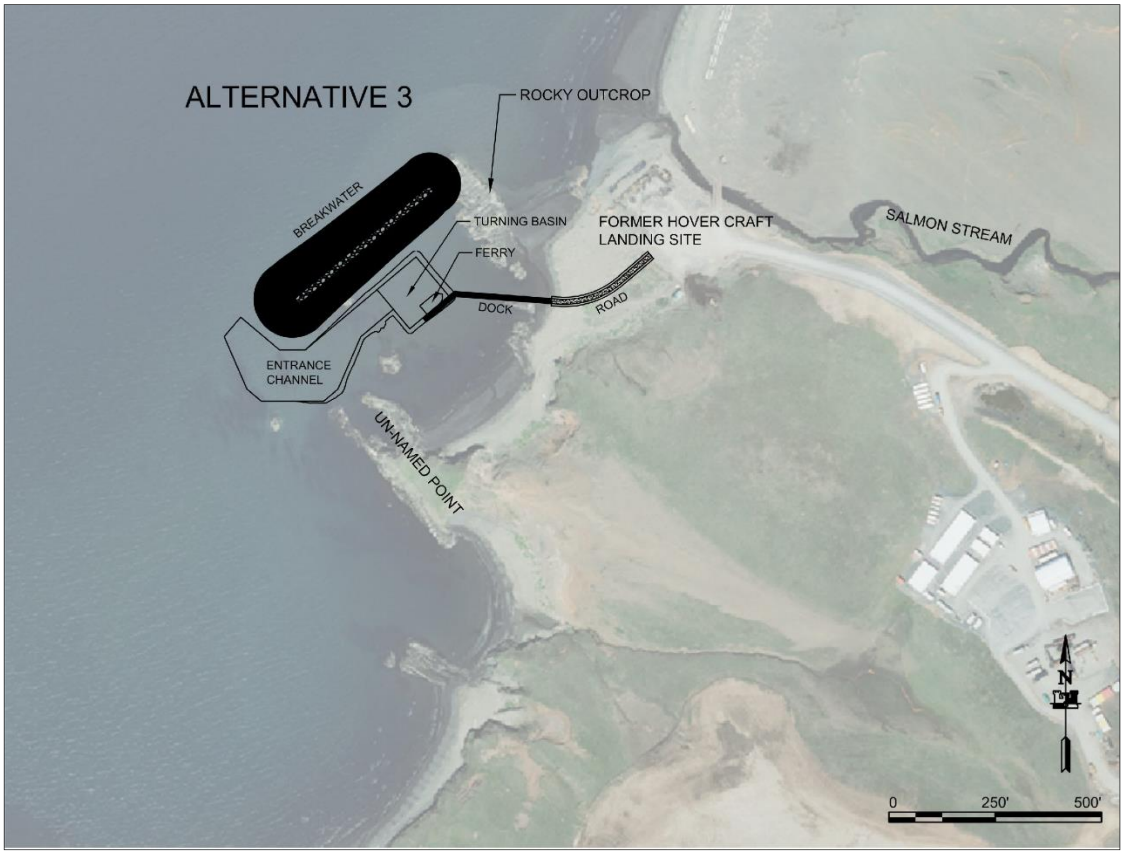

Figure 6-3. Alternative 3: Harbor Located South of Unnamed point (with blasting)

7 Preliminary Geotechnical Analysis of Alternatives

The following sections are based on information gathered during site visits, review of the geophysical survey and historical geotechnical reports, and assumptions on the subsurface conditions. These sections are for the feasibility analysis of alternatives only and are not adequate for a formal design. A formal subsurface site investigation needs to be performed in order to evaluate and validate the assumptions.

7.1 Bearing Capacity Analysis

A preliminary bearing capacity analysis was performed using the Meyerhoff's general bearing capacity equation in accordance with EM 1110-1-1905 *Bearing Capacity of Soils* (1992). For this analysis, the in-situ soil was assumed to be in a drained condition. The foundation soils unit weight (γ), assumed unit weight of seawater, internal friction angle (φ), and width (B) are assumed to be 110 pcf, 64 pcf, 29 degrees, and 250 feet respectively. The ultimate bearing capacity is as follows:

$$Q_u = \frac{1}{2}\gamma' B N_\gamma = \frac{1}{2} \cdot (110pcf - 64pcf) \cdot 250ft \cdot 10.4 = 59.8ksf$$

Based on the calculated ultimate bearing capacity of the soils at 59.8 ksf, the allowable bearing capacity, Q_a, is shown in the equation below.

$$Q_a = \frac{Q_u}{FS} = \frac{59.8ksf}{2.5} = 23.9ksf$$

The loaded area is essentially flat with very little relief. Therefore, no eccentric loading is assumed. For the most conservative factor of safety, a completely dry revetment over a completely saturated subgrade was used when calculating the embankment loading. Calculation of the embankment loading is:

$$Q_{embankment} = 107pcf \cdot (50ft - 20ft) + 20ft \cdot (107pcf - 64pcf) = 4.1ksf$$

The equation below shows the estimated Factor of Safety for the proposed breakwaters:

$$FS_{bearing\ capacity} = \frac{Q_u}{Q} = \frac{59.8ksf}{4.1ksf} = 14.6$$

Based on the assumptions used in the preliminary analysis, the proposed breakwaters have a factor of safety greater than 2.5 with regards to a bearing capacity failure.

7.2 Slope Stability Analysis

The following is a preliminary slope stability analysis using chart solutions for embankment slopes provided in Appendix E of EM 1110-2-1902 *Slope Stability* (2003). All influenced foundation soils are assumed to be free draining. Therefore, the stability verification applies only to the Long Term and End of Construction cases. Only the most critical condition was analyzed to verify the stability analysis.

Since the embankment and foundation material are assumed cohesionless and $\varphi > 0°$, the dimensionless parameter, $I_{c\varphi}$, is infinite and the slope stability charts for infinite slopes were used for verification.

In accordance with Figure E-7:

1) The pore pressure ratio, r_u, is assumed to be 0, since both the embankment material and foundation soil are assumed free draining:

$$r_u = 0$$

2) Parameters A and B were determined from Figure E-7:

$$A = 1$$

$$B = 2.1$$

3) The Factor of Safety was calculated as follows:

$$FS = A\frac{tan\varphi'}{tan\beta} + B\frac{c'}{\gamma H} = (1)\frac{\tan(45°)}{\tan(33.3°)} + (2.1)\frac{0}{107pcf * 50ft} = 1.5$$

Based on the assumptions used in the preliminary analysis, the proposed structures have a factor of safety greater than or equal to the minimum requirement of 1.5 for long term stability with regards to a slope stability failure.

7.3 Settlement Analysis

The magnitude of settlements that can be expected within the revetment depend on the applied loads, the density of the foundation soils, and the care with which the revetment materials are placed. Settlement can be immediate (cohesionless soils) or time-dependent (cohesive soils), or a combination of both for soils exhibiting intermediate cohesionless/cohesive characteristics. It is anticipated that the soils directly underlying the project site consist of cohesionless soils, therefore the majority of the settlement is expected to be immediate as load is applied, a small amount of time-dependent settlement is expected. The recommended depth of analysis is a minimum of four times the width of the embankment, or to the depth of an incompressible soil.

The settlement analysis was conducted to a depth of 30 feet below mudline using the Schmertmann Approximation specified in EM 1110-1-1904, Engineering and Design Settlement Analysis (1990). The total maximum settlement at the center of the breakwater is expected to be on the order of 6 inches. Most of this settlement is expected to occur as the fill is being placed and completely settled by the end of the construction.

Differential settlements will be gradual due to the anticipated load distribution and should be highest near the top of the breakwater, where the load is greatest. Rock armored breakwaters are sufficiently flexible such that their stiffness is not considered in this analysis. Total and differential settlements within the embankment may be substantially higher if the fill is poorly placed.

7.4 Dredging Considerations

Mechanical dredging in combination with heavy ripping and/or drilling and blasting will be required to remove material from the proposed entrance channel and mooring basin. Currently, the alternatives have a planned dredge depth of -13 feet MLLW. Blasting Subject Matter Experts must be consulted during the preconstruction engineering and design (PED) phase of the project.

Anticipated dredging conditions consist of approximately 5 to 10 feet of loose to medium dense unconsolidated sediment at the surface transitioning into bedrock at varying depths. Based in the information presented in the 2003 Geophysical Report by WSP Golder, it is anticipated that the depth of bedrock ranges from approximately -5 feet MLLW along the eastern portion of the proposed entrance channel to -20 feet MLLW along the western portion of the proposed entrance channel. The sediment material can be mechanically dredged by clamshell or long-reach excavator. For estimating purposes, we anticipate dense sediments, weathered bedrock, or bedrock will be encountered within the dredge prism. The type of equipment required to remove dense sediments or weathered bedrock could consist of but is not limited to an excavator-mounted pneumatic or hydraulic rock breaker, rock ripper, xcentric ripper, rock ripping bucket, cutter head methods, or grinding. After dense sediment or weathered bedrock is loosened or ripped, it can be mechanically dredged by clamshell or long-reach excavator. Bedrock and hard materials are expected to require drilling and controlled blasting before it can be mechanically dredged. The means and methods of dredging will not be dictated by the Government and left up to the Contractor.

8 Future Geotechnical Site Investigation Recommendations

It is recommended that a geotechnical site investigation consisting of drilling between 15 and 20 test borings below the proposed rubble-mound breakwaters, entrance channel, and maneuvering basin as well as 5 test borings for the access road be conducted during the preconstruction engineering and design (PED) phase of the project. Test borings will extend a minimum of 10 feet below the proposed dredge depths and 10 feet below the proposed cut depth of the access road. Laboratory testing of the sediment material could consists of gradations, Atterberg limits, moisture content, one dimensional consolidation, and triaxial compression. Laboratory testing of the encountered rock could include recovery, rock quality designation (RQD), unit weight, unconfined compression test (USC), tensile testing, Mohs hardness, and CERCHAR Abrasively Index (CAI). The main goal of a geotechnical site investigation would be to properly characterize proposed dredge material, allow further evaluation and recommendations of the suitability of breakwater foundation material, and identify any geological conditions that would require special considerations during PED. Geotechnical information would also be used to establish the basis for accurate dredging cost estimates, as actual dredge material properties are unknown at the time of writing.

9 References

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ANNEX

HISTORICAL GEOTECHNICAL REPORTS

Final Report – Geophysical Survey Report, Akutan Harbor Navigational Improvements, WSP Golder (10 January 2023) 95 Sheets

REPORT

Final Report - Geophysical Survey Report Akutan Harbor Navigational Improvements

Contract W911KB21D0001

Submitted to:

Mr. Justin Miller

US Army Corps of Engineers - Alaska District
PO BOX 6898
JBER, ALASKA 99506

Submitted by:

Golder Associates USA Inc.

1400 W Benson Blvd, Suite 420, Anchorage, Alaska 99503

+1 907 344 6001

31405083.004

January 10, 2023

Distribution List

Justin Miller - justin.m.miller@usace.army.mil

Amy Steiner - amy.l.steiner@usace.army.mil

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TABLES

IMAGES (IN TEXT)

FIGURES (ATTACHED)

APPENDICES

1.0 INTRODUCTION

Golder Associates USA Inc. (Golder, a member of WSP) is pleased to present the results of our nearshore marine geophysical survey for the Akutan Harbor Navigational Improvements Project. The project site is located on the southwestern shoreline of Akun Island, approximately 35 miles east of Dutch Harbor and Unalaska and six miles east of the City of Akutan, Alaska (Figure 1). The project area is located at the west end of the Akutan Airport and spans approximately 2,500 feet along the southern end of Surf Bay, flanked on either side by narrow headlands of volcanic rock as shown in Figure 2. Proposed improvements include construction of a 550-foot rubble breakwater to protect a roughly 5-acre basin that will have a minimum depth of 20 feet below mean lower low water (MLLW).

The Akutan Navigational Improvements Project includes evaluating the feasibility of installing a breakwater wall at one of two locations to increase navigation capabilities for small and medium size vessels connecting the City of Akutan and the Akutan Airport on Akun Island. The presence of rock along portions of the shoreline, and just offshore, indicate possible shallow depth to bedrock within the project area.

1.1 Project Understanding

The US Army Corps of Engineers – Alaska District (USACE) is selecting a preferred location for navigational improvement and developing the design for the project. Golder understands the placement of future navigational improvements may depend on sub-surface geologic conditions. Specifications for the type or placement of project features can be refined by understanding the thickness and lateral extent of the subsurface stratigraphy, particularly soft sediment, and the depth to the top of bedrock.

1.2 Scope of Work

The scope of work consisted of conducting a shallow marine geophysical investigation to define subsurface conditions needed for project design. The marine geophysical data were acquired on a grid with pre-planned survey track lines that ran parallel and perpendicular to the shoreline. Details of the survey methods are presented in Section 3.0.

2.0 BACKGROUND DATA REVIEW

In 2005, Duane Miller and Associates (DMA) conducted a geotechnical exploration to support a Master Planning Study for the Akutan Airport. In 2008, the Alaska Department of Transportation and Public Facilities (ADOT&PF) conducted a geotechnical investigation and NORCAL Geophysical Consultants (NORCAL) conducted a seismic survey to support an airport improvement project. The data from these projects were reviewed as part of the background data review phase of this project and select excerpts from these reports are included in Appendix A. Golder was also provided with bathymetric contours collected in 2015 (presented as Government Furnished Item, GFI-3) in PDF, XML, and DWG formats.

The airport project included the construction of a 4,500-foot paved and lighted runway with auxiliary buildings on Akun Island, along with a hovercraft landing ramp and pad facility in Surf Bay and an approximately 3,000-foot access road connecting the airport apron to the hovercraft ramp and pad facility (ADOT&PF 2008). The hovercraft landing ramp is located near the southeast corner of the proposed ramp for this project. The borehole logs from this location (ADOT&PF 2008) are included in Appendix A.

2.1 Regional Geologic Setting

The site is located within the Aleutian Islands, a volcanic island arc extending southwest from the Alaska Peninsula that separates the Bering Sea from the Pacific Ocean. The Aleutian Island arc is situated along the

Aleutian subduction zone where the oceanic Pacific Plate is subducted beneath the continental North American plate, which results in a volcanic arc and high rates of seismicity. During the Pleistocene epoch, glaciation blanketed the Aleutian chain. At present, the Aleutian Islands often consist of steep volcanic slopes that descend directly into the sea and glacier-carved fjords. Glacial and volcanic deposits are commonly found concurrently in the Aleutian Island surficial geology, including glacial deposits in valley bottoms and ridge tops, and modern pyroclastic deposits such as air-fall ash and ash-flow tuff.

Akun Island is located approximately six miles east of the City of Akutan and approximately 35 miles northeast of Dutch Harbor and Unalaska. The Akutan Volcano, one of the most active volcanoes in the Aleutian Arc, sits on the western half of Akutan Island, and Mt. Gilbert Volcano is located approximately five miles north of the project site on Akun Island. Mt. Gilbert is a stratovolcano with massive basalt flows and thick pyroclastic deposits from modern and ancestral volcanic activity. Volcaniclastic debris flows and lahar deposits are found at the base of the volcanic slopes and in local valley bottoms (DMA 2005).

2.2 Local Site Conditions

The project site is located at the south end of Surf Bay, where the beach is partially protected from the open ocean by a small andesite ridge. The beach gently slopes uphill from the ocean to the east to beach cliffs, which are composed of interbedded beach sand and ash deposits (DMA 2005). Borehole logs supporting the construction of the hovercraft landing ramp (Figure 2), located near the northeast corner of the project area, indicate interbedded gravel and sand overlying bedrock at depths ranging from 19 feet to more than 30 feet below ground surface (Appendix A, ADOT&PF 2008). Photographs from the project area in 2005 are included in Appendix A (DMA 2005).

3.0 GEOPHYSICAL SURVEY METHODS

The offshore geophysical survey was conducted within the project areas of Akun Island on August 24 to August 27, 2022, by Fern Webb, Senior Marine Geophysicist from Golder's office in Vancouver, Canada. A marine mammal observer (MMO; Matt Ferguson, USACE) was provided by USACE to observe and notify/stop work if any potential conflicts with wildlife and our survey efforts arise, and Inocencio Roman was present as a USACE observer.

The instruments used for the marine survey included a high frequency (5kHz) sub-bottom profiler (SBP) to identify and map the thickness of fine-grained sediment, and a bubble pulser (BP) low-frequency (0.4-1.2kHz) seismic reflection system to map the thickness of coarse-grained sediment and to determine the depth to the top of interpreted bedrock and/or acoustically hard reflectors. A side scan sonar (SSS) survey was also conducted to characterize seabed surficial materials and differentiate between areas of exposed bedrock versus overburden sediment cover.

Table 1 below summarizes the geophysical instruments used for this investigation, and a schematic of the instrument setup is shown in Image 1 below.

Table 1: Geophysical Survey Instrumentation

Equipment	System	Application
GPS	Trimble Ag132 Differential GPS	Real-time position information
High Frequency Sub-Bottom Profiler	Datasonic Model SBT-2200 (3.5 to 12 kHz) with GeoAcoustics T135 transducer	Identify and map thickness of fine-grained sediment deposits
Low Frequency Seismic Reflection System	Datasonic SPR-1200	Identify and map thickness of coarse-grained sediment and depth to top of acoustically hard layer and/or bedrock
Side Scan Sonar	Imagenex Yellowfin	Side Scan Sonar seafloor coverage

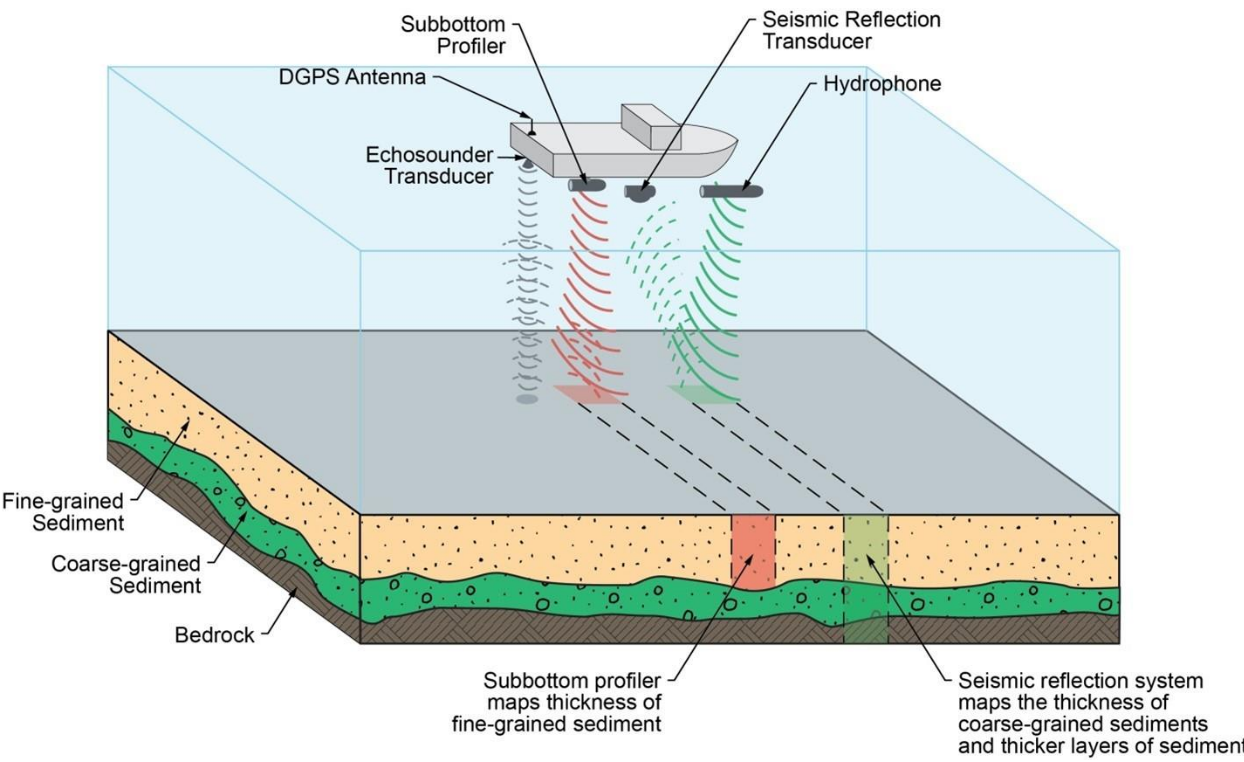


Image 1: Example Survey Instrumentation Schematic. Side Scan Sonar towfish is not shown.

3.1 Survey Vessel

The geophysical, navigational, and hydrographic instruments were installed on the charter vessel ‘Miss Alyssa’, owned and operated by Captain Jimmer MacDonald of Dutch Harbor (Image 2). The vessel was operated by Captain MacDonald during the survey. The sub-bottom profiler (SBP) transducer was mounted off the starboard side on a pole mount. The bubble pulser (BP) transducer was mounted on a pole-mount on the port side of the vessel. Two hydrophone receivers for the BP were deployed, one from the bow of the vessel and one from the starboard corner of the stern. The side scan sonar (SSS) was deployed from the center of the stern. The GPS antenna used for positioning of geophysical data was installed on the roof of the cabin. The relative location of all sensors was measured and recorded for incorporation into the processing of the acquired data.

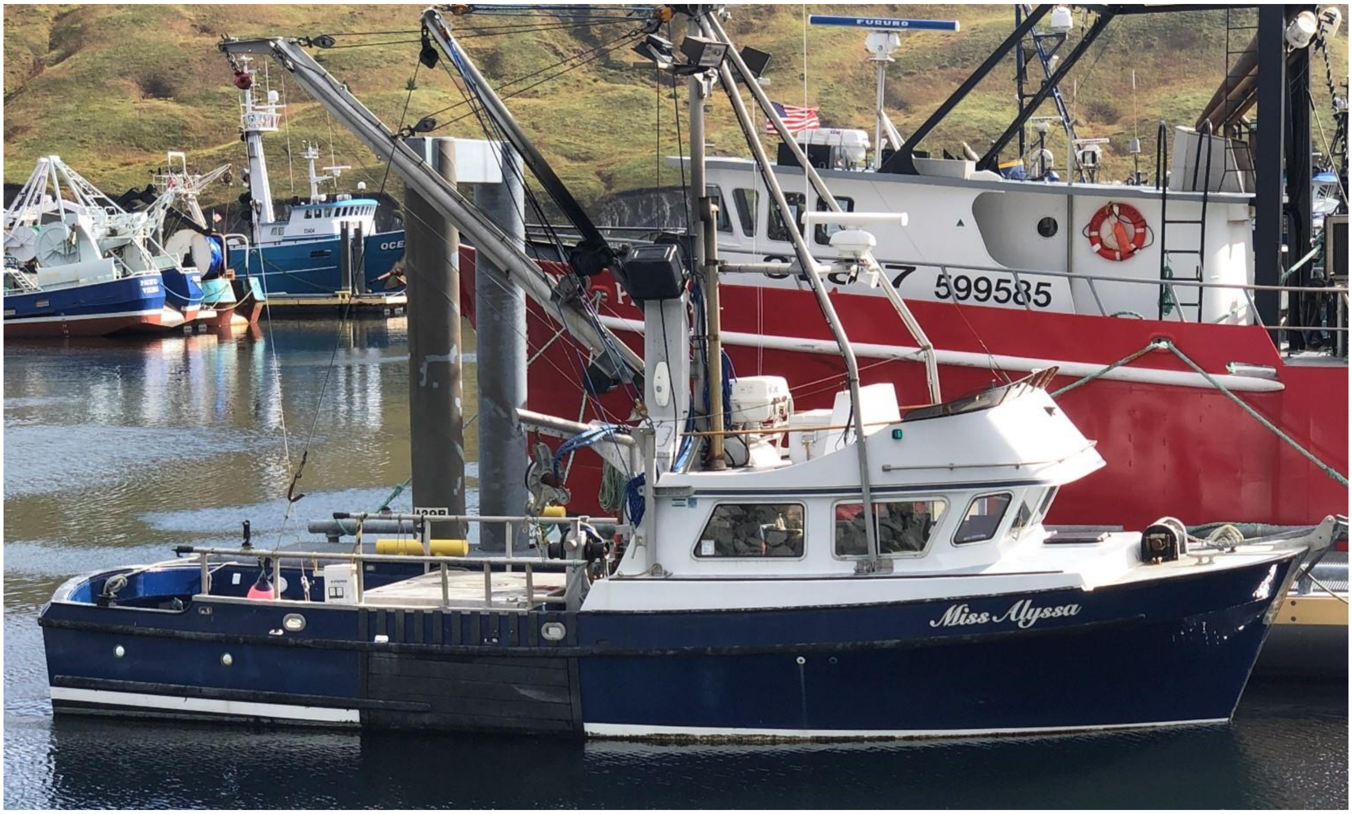


Image 2: Survey Vessel Miss Alyssa

3.2 Navigation

The position of the survey vessel was determined with a differential global positioning system (DGPS). All position data were collected in NAD83, and projected into Alaska State Plane Zone 10, US Survey Feet. Navigation data were acquired with a Trimble AG132 Differential GPS system interfaced to an acquisition computer running HYPACK 2018 software, an industry standard navigation software package. The position of the survey vessel was displayed in real-time on a monitor located at the helm in front of the survey vessel operator. This monitor also displayed additional navigation parameters, such as distance down line and distance offline, water depth, vessel speed, and heading. This information enabled the vessel operator to pilot the boat along pre-plotted survey transects displayed on the monitor, in addition to viewing the location of completed transects.

3.3 Sub-Bottom Profiler System

A Datasonic Model SBT-2200 sub-bottom profiler (SBP) system, coupled with a 3.5 kHz transducer, was used to identify and determine the thickness of surficial deposits of fine-grained sediment. The system uses a single transducer to send and receive acoustic pulses directed at the seafloor. The acoustic pulses can penetrate tens of feet in homogeneous fine-grained sediment but are not able to penetrate dense sand or coarse-grained material. The reflections from the seabed and sub-bottom layers are displayed in real-time as a profile or vertical cross section on the digital acquisition system monitor.

3.4 Seismic Reflection System

A Datasonic SPR-1200 low-frequency seismic reflection profiling system, referred to as a bubble pulser (BP), was used to acquire information on the thickness of dense and coarse-grained, unconsolidated sediment and to detect the top of interpreted acoustic basement or bedrock. The data from this system was acquired simultaneously with the sub-bottom profiler data and displayed in real-time using the Chesapeake digital acquisition system. The digital acquisition system was interfaced with the navigation system to provide real-time position information on the acquired data.

3.5 Side Scan Sonar System

An Imagenex Yellowfin digital side scan sonar (SSS), operating at 330 kHz was used for this survey. The SSS towfish was deployed off the stern of the boat. Data were set to collect a 200 feet per side for a swath width of 400 feet. The data were recorded using the Imagenex Yellowfin acquisition software.

4.0 GEOPHYSICAL DATA PROCESSING AND ANALYSIS

The geophysical data processing and analysis for each geophysical method employed is described in the following sections.

4.1 Seismic Reflection Data

The geophysical SBP data (high and low frequency) were processed using the Geosuite Allworks marine seismic reflection processing software (Geo Marine Survey Systems, B.V.).

The SBP profiles showed only scattering of the acoustic pulse in the near-seabed, which we interpret to indicate that there are no fine-grained sediments at the seabed. This result is expected given the high-energy ocean wave and storm environment of Surf Bay. A comparison of the seismic reflection data results is provided in Figure 3.

In contrast to the higher-frequency SBP data, the lower-frequency BP data provided good subsurface penetration with a maximum penetration of approximately 50 feet below the seabed. Therefore, the low-frequency data was prioritized for processing and interpretation of sub-bottom stratigraphy.

Raw data profiles were imported in SEG-Y format into the seismic data processing software and translated to the project coordinate system. The available multibeam datasets were imported to the software as surface features which Geosuite automatically slices along the track line of each file to project a reference surface into the display of each data profile. The profile data were adjusted for local tide variations (NOAA Station 9462711). Additional processing steps included static corrections for instrument offsets, and filters and gain adjustments to improve the appearance of the acoustic reflections and aid interpretation. Data profiles were reviewed iteratively to identify and pick the first prominent acoustic horizon. The software allows for display of line intersections with picked horizons, which ensures that the sub-bottom interpretation is consistent from profile to profile.

The picked horizon is interpreted to be the base of the unconsolidated sediment and the top of rock and/or acoustically hard material. However, we note that this horizon may not be the acoustic basement since several reflectors can be seen deeper on some of the seismic reflection data. These deeper reflectors do not generally correlate well from profile to profile. We interpret these reflections to possibly result from a variety of out-of-plane features and intermittent internal structures within the heterogenous harder volcanic deposits and flows.

Unconsolidated sediment thickness is determined by multiplying the compressional velocity of sound through sediment by the two-way travel time for an acoustic pulse to travel from the seabed to the top of the underlying interpreted consolidated and/or course-grained sediment or rock. For this work, a nominal value of 5,000 feet per second (fps), was used for the compressional velocity of the unconsolidated sediment overlying the top of interpreted bedrock.

The profile interpretation and picking procedure generated a database of sediment thickness and depth to an acoustically hard sub-bottom reflector, interpreted as top of bedrock, with corresponding map coordinate for each pick.

4.2 Side Scan Sonar Data

Side scan sonar data were processed using the Hypack Sidescan Targeting and Mosaicking module. Raw SSS in Imagenex *.872 format was converted to Hypack *.HSX format and imported to the processing module. The SSS images were reviewed in swath format to identify and locate targets of interest and rendered as georeferenced mosaics in geotif format to confirm data coverage and positioning of features relative to other datasets. Examples of the SSS imagery are provided in Figure 4 and discussed further in section 5.1.

5.0 GEOPHYSICAL SURVEY RESULTS

5.1 Background Data

Several sources of background geospatial data were available to provide a baseline interpretation of the seabed conditions at the Surf Bay site. These included multibeam bathymetry sourced from NOAA, high-resolution aerial imagery, and the results of a hydrographic survey completed for USACE by Stantec in 2015. These data are compiled and presented in Figure 5, Panel A.

The background data were interpreted alongside the SSS images to identify seabed features. Interpreted features of the seabed are provided as polygons in Figure 5, Panel B. Of specific interest was defining the boundaries of bedrock outcrops. Additional seabed features identified and mapped were zones of sand waves, and a zone of irregular seabed between approximately 28 feet and 38 feet below MLLW with several distinctive elongated divots in the north corner of the survey area. The seabed in the project area is generally planar sloping between approximately 2.5% to 5%. The basalt rock exposures which form the prominent headlands are angular and irregular with localized slopes and facets with angles exceeding 55%. This contrast in geomorphology was used to aid the interpretation of the boundary between the unconsolidated sand and the submerged bedrock.

5.2 Seismic Reflection Survey Results

A complete set of interpreted seismic reflection profiles is provided in Appendix B. Each profile is shown alongside a track line map highlighting the specific positioning of that line. The profiles are all presented with a common horizontal and vertical scale as indicated by the fiducial markers.

Figure 6 shows the locations of the seismic reflection track lines for the field data, the bathymetric contours, and the location of the interpreted bedrock outcrops. The locations of geologic cross sections are overlain on the map along with the proposed breakwater and navigation channel locations. The dashed pink line indicates the inshore limit of safe operation for the survey vessel. The safe operation limit was assessed by Captain MacDonald at the time of survey with consideration of the prevailing wind and wave conditions compared to the limitations of vessel draft and maneuverability. The -20 feet MLLW bathymetric contour is highlighted in yellow.

An isopach map of the unconsolidated sediment, interpreted to be coarse sands and gravels, is presented in Figure 7. The isopach map was generated by interpolation between the seismic reflection profiles using the Kriging algorithm (Golden Software Surfer18). Areas of the seabed interpreted to be exposed bedrock were included as inputs to the interpolation scheme as fixed isopach values of 0 feet. This approach extended the interpolation of sediment thickness shoreward of the limit of operation. Due to limited access into the cove at the southern extent of the project area, the sediment isopach could not be shown in this location.

A surface model of the elevation of the hard sub-bottom reflector was created as the subtraction of the sediment isopach from the seabed surface. The contours of elevation of this horizon are provided in Figure 8. The contour corresponding to -20 feet MLLW is highlighted in blue.

The maximum unconsolidated sediment thickness is found at the north corner of the area of interest where the northern breakwater option intersects the 55 feet contour of the isopach map. Under most of the area covered by the two breakwater and channel options, the unconsolidated sediment is expected to be between 0 feet and 25 feet in thickness with significant areas of exposed bedrock.

Interpreted geologic cross sections were generated for nine (9) alignments within the study area for this project. These cross-sections were created by slicing the seabed surface and the hard sub-bottom elevation surface model along the prescribed alignments defined by the coordinates listed in Table 2.

The locations of these alignments are shown in Figure 2, Figure 6, Figure 7, and Figure 8.

Table 2: Prescribed Cross Section Coordinates

Cross Section ID	Start Easting	Start Northing	End Easting	End Northing
1-1'	5498637	1309734	5499037	1309434
2-2'	5498817	1309974	5499217	1309674
3-3'	5498988	1310201	5499388	1309901
4-4'	5498839	1310671	5499239	1310370
5-5'	5499002	1310922	5499499	1310549
6-6'	5499098	1311100	5499377	1310887
A-A'	5498857	1309444	5499319	1310059
B-B'	5498657	1309594	5499479	1310689
C-C'	5498957	1310336	5499179	1311102
	NAD83 State Plane Alaska Zone 10 - Feet			

The interpreted geological cross sections are provided in Figure 9 to Figure 14. The vertical datum is MLLW and the horizontal scaling is in chainage feet. The cross sections have been vertically exaggerated at an approximately 2:1 ratio.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The project area lies between Daryl’s Point on the west and an existing hovercraft landing area on the west. Two 550-foot-long rubble mound breakwaters are being evaluated by USACE, along with a dredge channel to access an approximate 5-acre basin that will be dredged to -20 feet MLLW. Figure 15 and Figure 16 show the simplified seabed bathymetry and simplified elevation contours of hard sub-bottom (respectively) to indicate the overlap of proposed structures with the -20 feet MLLW elevation of the seabed and the interpreted bedrock surface. Water depths are expected to range 0 feet MLLW at rock outcrops to about -22 feet MLLW. Unconsolidated sediment along the channel and basin area or bedrock will underlie the breakwater sites as discussed below.

- **Breakwater Option 1 (east)**. Interpreted subsurface conditions shown in Figure 7 range from bedrock outcrop on the western end to as much as 60 feet of unconsolidated sediment on the eastern end. In the channel, the thickness of unconsolidated sediment is interpreted to vary from 0 feet to about 45 feet at the entrance to the channel. More than half of the channel and basin area has material interpreted to be bedrock at elevations above the -20-foot MLLW dredge depth.
- **Breakwater Option 2 (west)**. Interpreted subsurface conditions shown in Figure 7 range from bedrock outcrop on the eastern end to as much as 20 feet of unconsolidated sediment on the western end. In the channel, the thickness of unconsolidated sediment is interpreted to vary from 0 feet to about 35 feet at the entrance to the channel. Most of the basin and about 30% of the channel will require dredging in material interpreted to be bedrock at elevations above the -20-foot MLLW dredge depth.

General site conditions within the project area are expected to consist of a variable thickness of unconsolidated sediment overlying a harder layer interpreted to be bedrock. At some locations, the geophysical data also shows the presence of an intermediate strength layer below the sub-bottom elevation that could be weathered bedrock. Weak surficial sediment was not encountered, which is consistent with the relatively high energy environment in Surf Bay.

- **Unconsolidated Sediment**. The unconsolidated sediment is expected to consist of primarily sand along with layers of fine gravel also present (DMA 2005, ADOT&PF 2008) that is expected to have a similar gradation to the marine beach and beached dune deposits found along the shoreline, as shown in Image 3 (below, also included in Appendix A). Borehole data from ADOT&PF (2008) at the hovercraft landing area indicated layers of sand interbedded with more gravelly material, which is expected to be loose at depth based on the heave noted during drilling. In addition, laboratory testing reported in DMA (2005) indicated that the dune sand had a friction angle of 29°, which is consistent with relatively loose material. Consequently, given the high seismicity and depositional environment, unconsolidated sediment should be considered liquifiable unless site specific geotechnical data shows otherwise.

  The marine geophysical survey results presented here show the interpreted depth to the base of unconsolidated sediment varies at the site, with the thickest sediments located at the north corner of the survey area. Beneath the proposed options for the breakwater and channel footprints, the unconsolidated sediment over interpreted bedrock ranges from 0 feet (bedrock outcrop) to 55 feet. Based on the acoustic signature, the seabed was interpreted to be coarse sands and gravels and/or volcanic bedrock in all surveyed areas. The high frequency seismic reflection profiling showed no evidence of softer sediments at the seabed. Because the seismic reflection method does not yield conclusive sediment type identification of unconsolidated material, it is recommended that an intrusive investigation (jet probing or drilling) be conducted over the potential footprint(s) of any navigational improvement structures to provide the geotechnical information necessary to further the design of any navigational improvements on Akun Island, for example estimates of rippability of the seabed material.

- **Bedrock**. Bedrock mapped along the shoreline (Image 3 below, also included in Appendix A) is inferred to extend offshore, primarily as lava flow material, but including zones of undifferentiated bedrock or volcanoclastic material consisting of debris flow and lahar deposits. Methods of excavating bedrock can be correlated to seismic shear wave velocity for planning purposes. NORCAL (2008) reported that most of the areas surveyed indicated seismic velocities of 8,000 to 12,000 feet/second. Therefore, it should be assumed that blasting will be required during excavation of bedrock within the channel and basin areas.

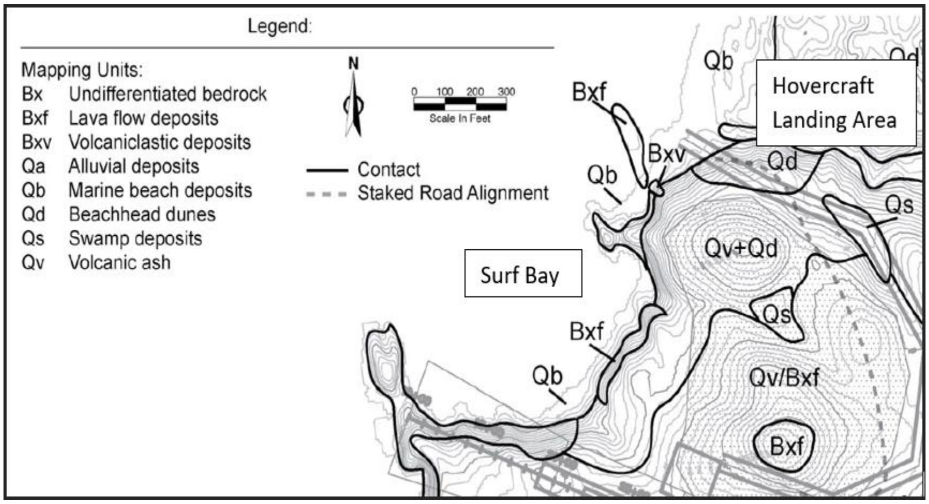


Image 3: Surficial geology at Surf Bay (excerpted from DMA 2005, Plate 1)

7.0 LIMITATIONS

This report has been prepared exclusively for the USACE for use in design of the proposed navigational improvements. If there are significant changes in the nature, design, or location of the facilities, we should be notified so that we may review our conclusions and recommendations considering the proposed changes and provide a written modification or verification of the changes.

There are possible variations in subsurface conditions between explorations and with time. Therefore, inspection and testing by a qualified geotechnical engineer should be included during construction to provide corrective recommendations adapted to the conditions revealed during the work. In addition, a contingency for unanticipated conditions should be included in the construction budget and schedule.

Golder geophysical services were conducted in a manner consistent with the level of care and skill ordinarily exercised by other members of the geophysical community currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services. Side scan sonar, sub-bottom, and seismic reflection profiling are remote sensing geophysical methods that may not detect all surface or subsurface features of interest or concern. Furthermore, it is possible that interpreted subsurfaces may, upon intrusive sampling, prove to have been misinterpreted and or a different material type than that observed onshore. The geotechnical work program followed the standard of care expected of professionals undertaking similar work in the State of Alaska under similar conditions. No warranty expressed or implied is made.

Thank you for the opportunity to assist the USACE with the Akutan Navigational Improvements Project. If you have questions, please contact Jessica Feenstra (907-865-2533) or Mark Musial (907-865-2511).

Golder Associates USA Inc.

Jessica Feenstra
Senior Project Geophysicist/Geologist

Mark Musial. PE
Vice President

DAE/FW/JPF/MRM

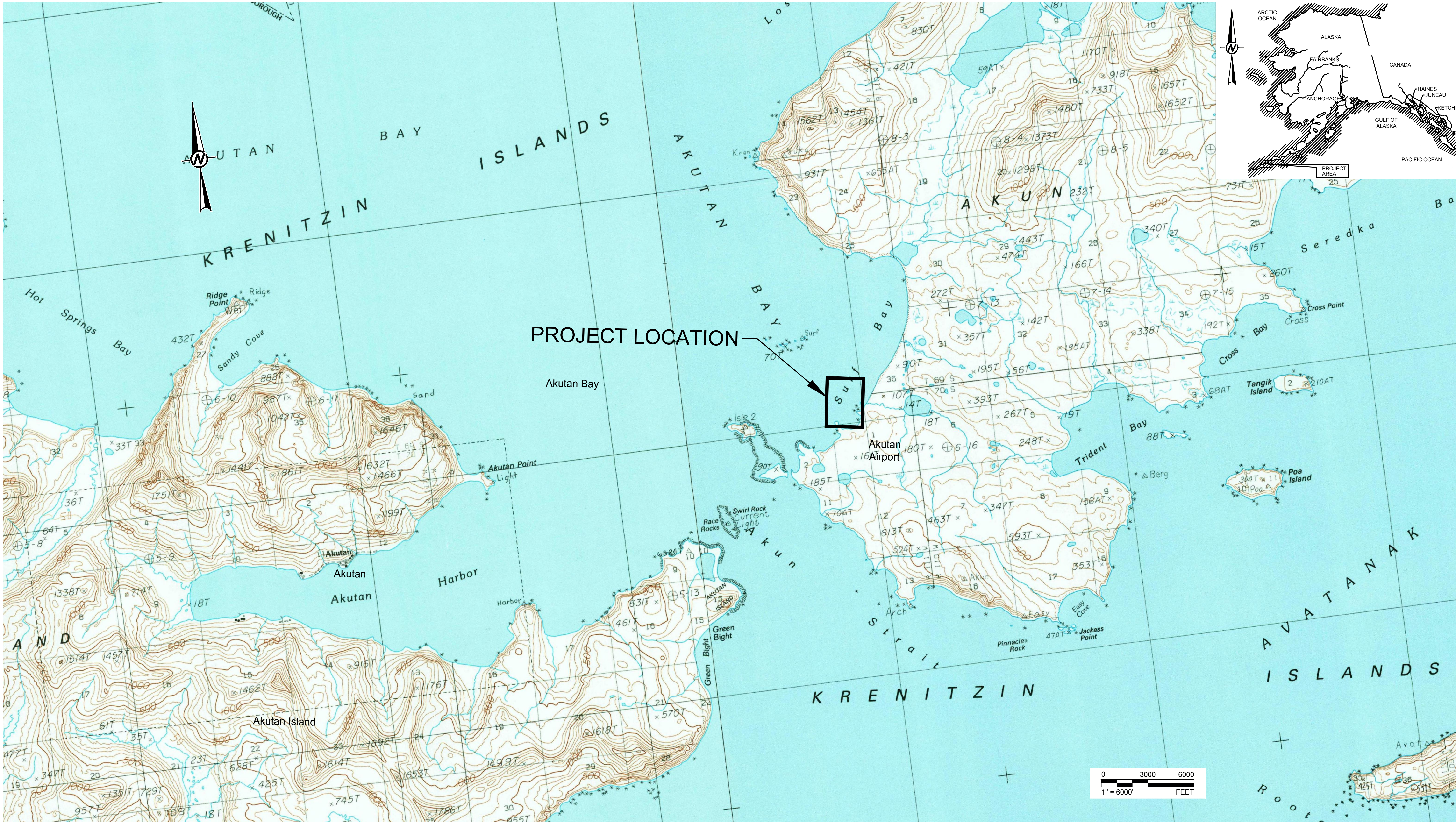
8.0 REFERENCES

ADOT&PF (Alaska Department of Transportation and Public Facilities) 2008. Geotechnical Report, Akutan Airport. Project No. 51196. Prepared by ADOT&PF Central Regions Materials, Anchorage, AK.

DMA (Duane Miller and Associates) 2005. Geotechnical Exploration, Akutan Airport Master Plan, Akun Island, AK, DMA Job No. 4086.061. Prepared for HDR Engineering, Inc., December 9, 2005.

NORCAL 2008. Seismic Survey, Akutan Airport Relocation Project, Akutan and Akun Islands, AK, NORCAL Job No. 08-368.06. Prepared for DMA, October 13, 2008.

FIGURES



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CONSULTANT WSP GOLDER	YYYY-MM-DD	2024-01-10	TITLE **VICINITY MAP**
	DESIGNED	-	
	PREPARED	APG	
	REVIEWED	JPF	
	APPROVED	MRM	PROJECT NO. 31405083.004 · PHASE 001 · REV. 0 · FIGURE 1

Path: \\Anchorage\Public\Geomatics\USACE\Akutan\99_PROJ\31405083.004 USACE Akutan Harbor Geophysical Survey\01\40_PROD\ | File Name: 31405083.004.001.dwg | Last Edited By: agarrigus Date: 2023-01-10 Time:11:03:50 AM | Printed By: AGarrigus Date: 2023-01-10 Time:3:31:53 PM
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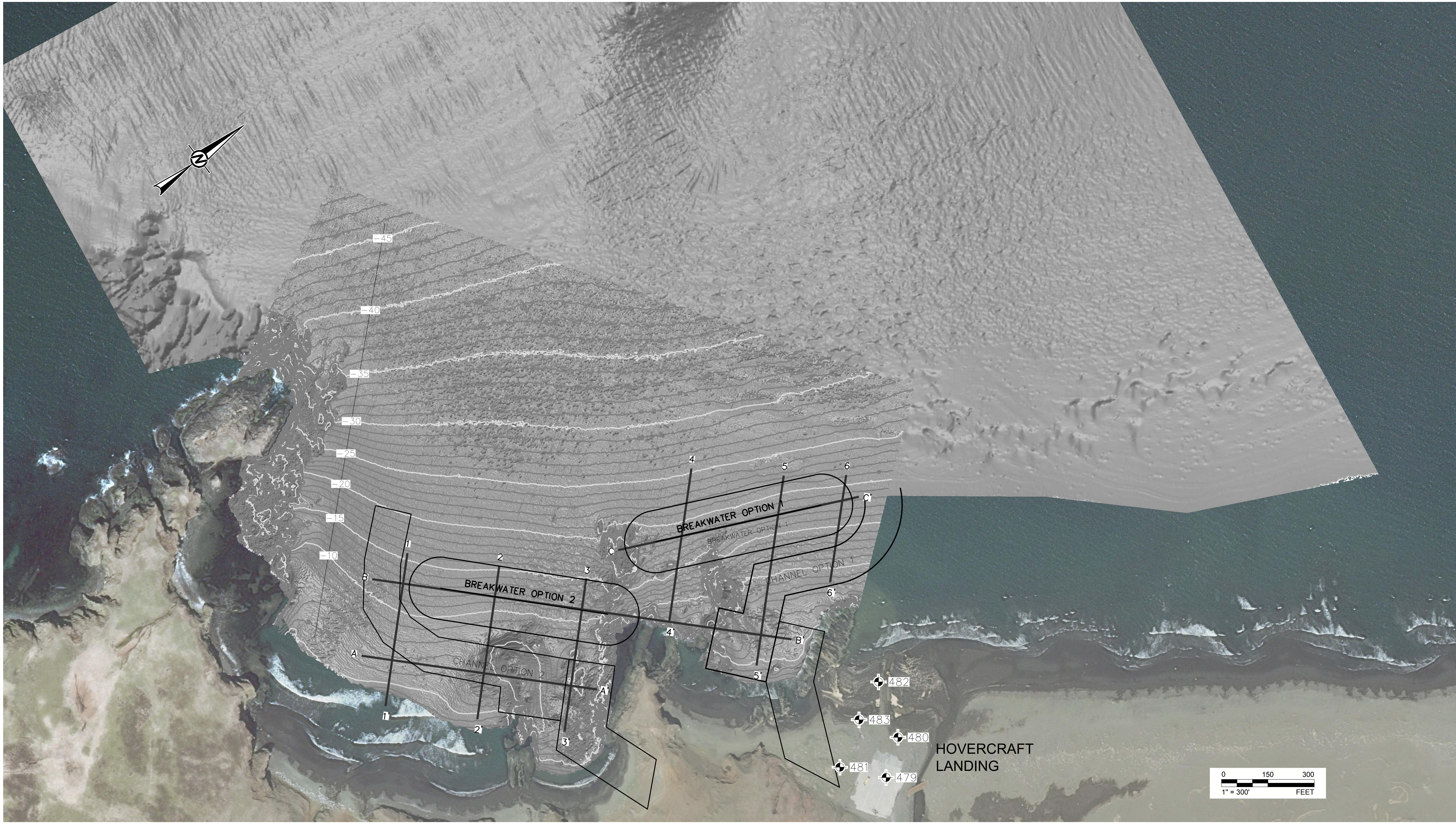

LEGEND

1 RFI TRANSECTS AND ID

BOREHOLE (ADOT&PF, 2008)

REFERENCE(S)

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2. SHADED RELIEF IMAGE DEVELOPED FROM TWO SOURCES. (1) BATHYMETRIC DATA FILE FROM SURVEY H12360 AND DISTRIBUTED BY NOAA. DATE OF SURVEY WAS JULY 24 TO AUGUST 24 2011. (2). HYDRO SURFACE PROVIDED IN LANDXML FORMAT FILE, AKUN TOPO 2015.XML ACQUIRED BY STANTEC IN 2015 AND PROVIDED BY U.S. ARMY CORPS OF ENGINEERS - ALASKA DIVISION ON SEPT 23. VERTICAL DATUM IS MLLW (FEET).
3. AERIAL IMAGERY FROM WORLD IMAGERY LAYER DISTRIBUTED BY ESRI.

CLIENT
U.S. ARMY CORPS OF ENGINEERS - ALASKA DISTRICT

CONSULTANT

WSP GOLDER

YYYY-MM-DD	2023-01-10
DESIGNED	-
PREPARED	APG
REVIEWED	JPF
APPROVED	MRM

PROJECT
AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT

AKUTAN, ALASKA

TITLE
GEOPHYSICAL INVESTIGATION MAP

PROJECT NO.	PHASE	REV.	FIGURE
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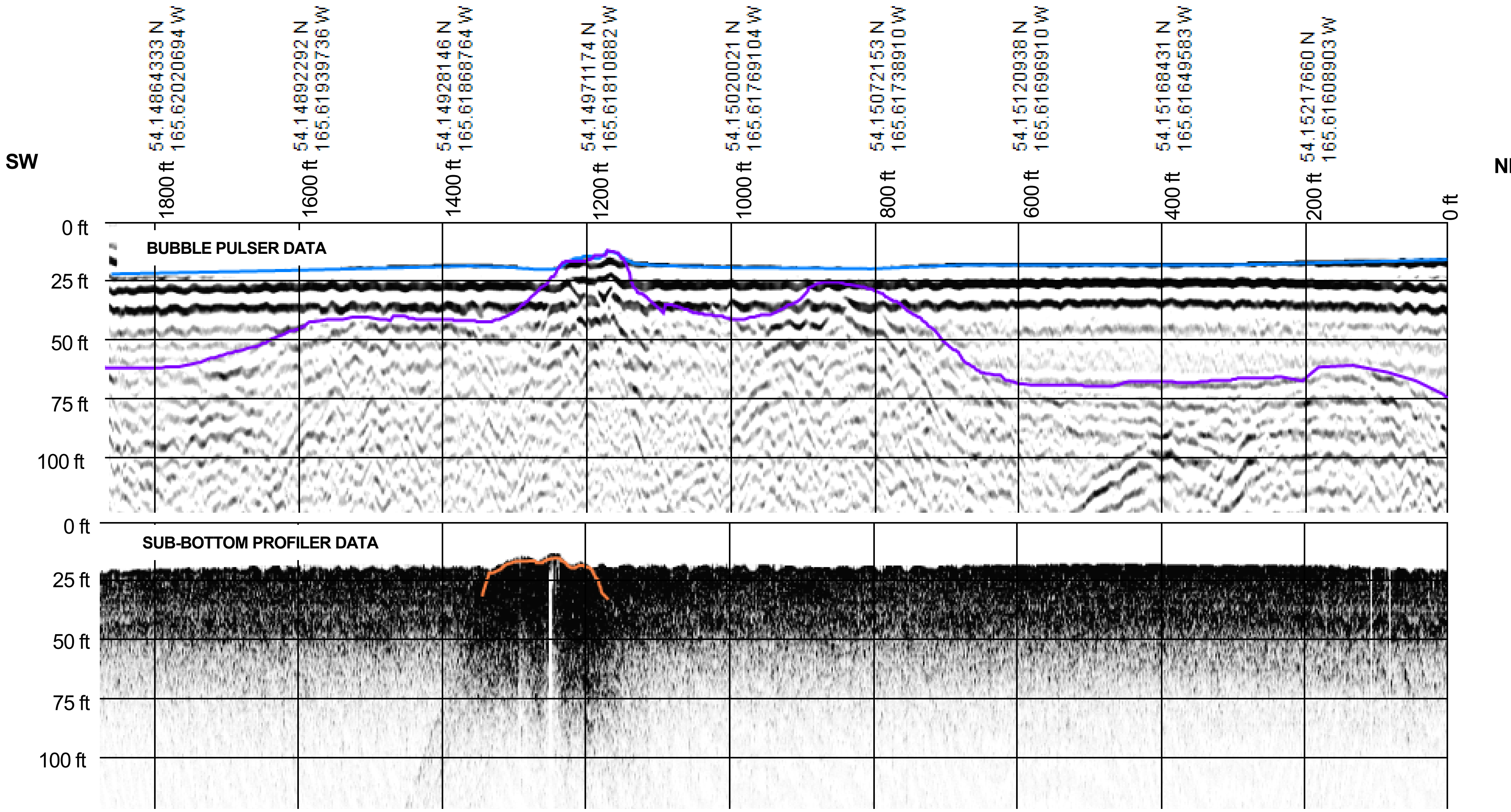

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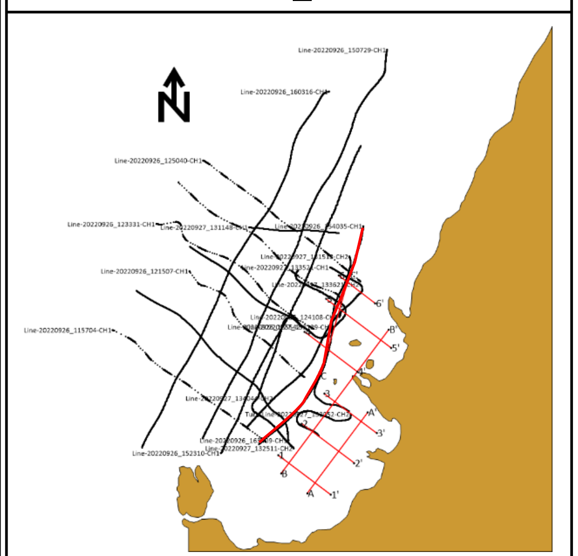

LEGEND

- SEABED REFLECTION
- INTERPRETED HARD SUB-BOTTOM REFLECTOR (BP)
- INTERPRETED HARD SUB-BOTTOM REFLECTOR (SBP)

NOTES

1) SUB-BOTTOM DEPTHS BASED ON A SEISMIC VELOCITY OF 5000FT/MS
2) DEPTHS RELATIVE TO MLLW
3) SEISMIC PROFILES POSITIONED USING DIFFERENTIAL GPS

CLIENT
U.S. ARMY CORPS OF ENGINEERS – ALASKA DISTRICT

PROJECT
AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT
AKUTAN, ALASKA

CONSULTANT

WSP GOLDER

YYYY-MM-DD	2023-01-10
PREPARED	FMW
DESIGNED	FMW
REVIEWED	JPF
APPROVED	MRM

TITLE
SEISMIC REFLECTION DATA COMPARISON

PROJECT NO.	REV.	FIGURE
31405083.004	0	3

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25 mm
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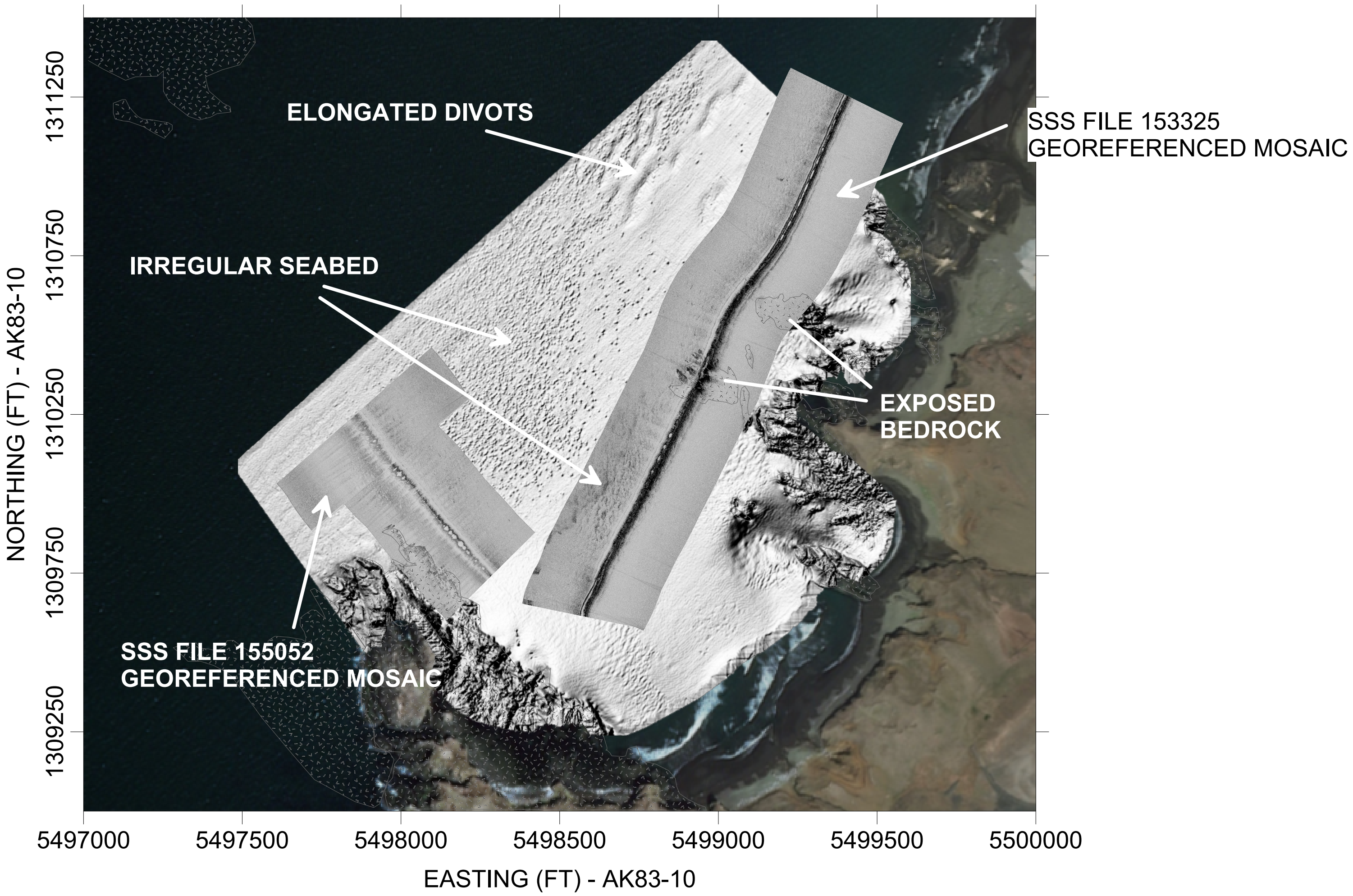
GEOREFERENCED SIDE SCAN SONAR MOSAICS



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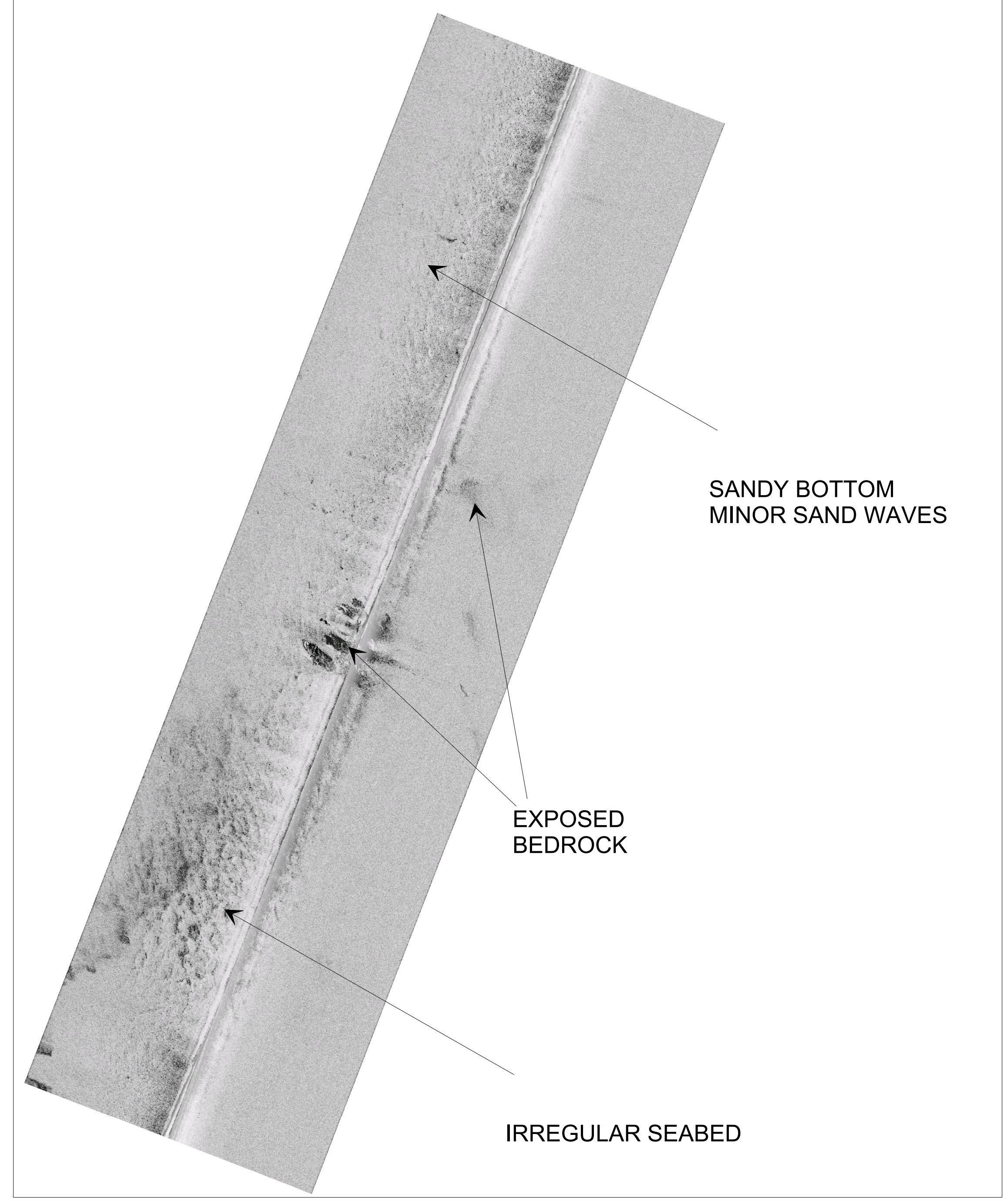

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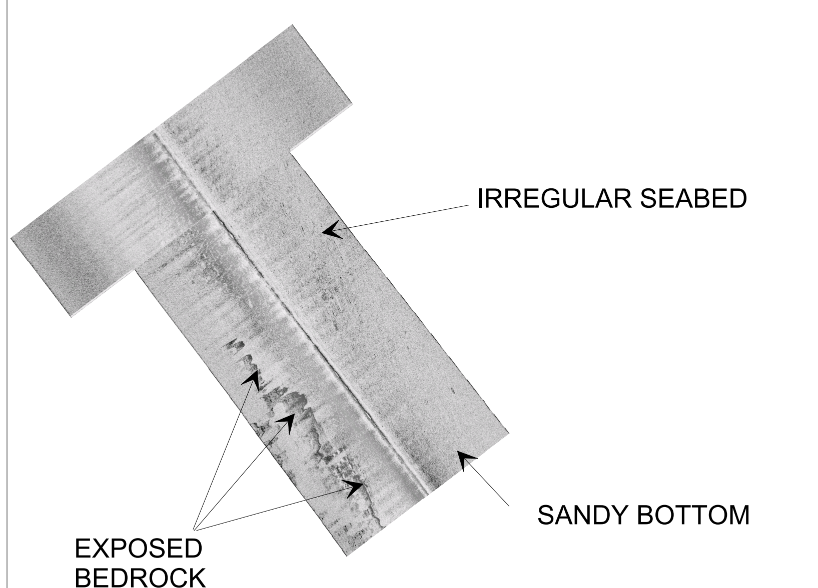


LEGEND

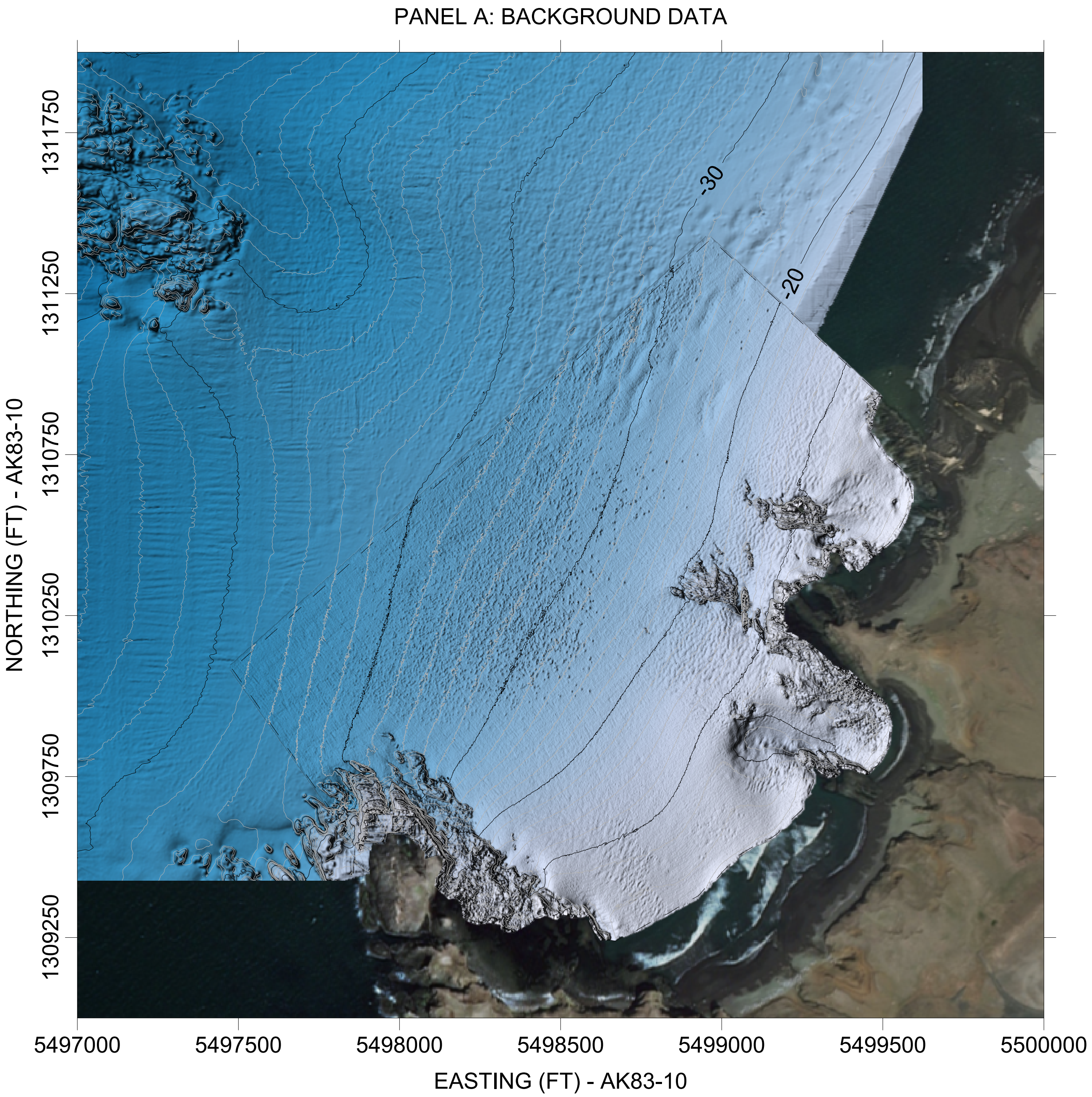
EXPOSED BEDROCK

NOTES

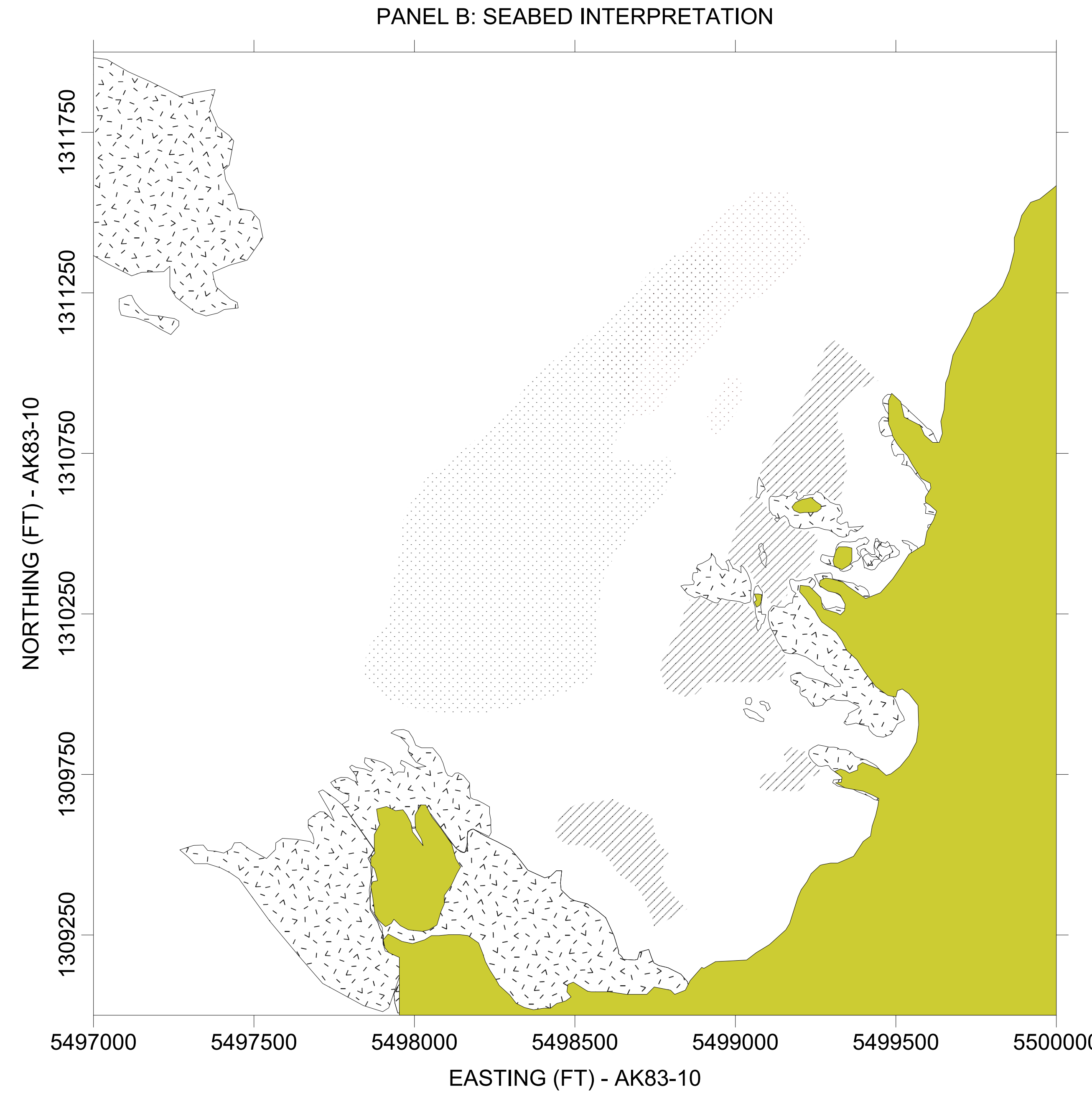
1) NOT ALL AVAILABLE SSS DATA IS PRESENTED

CLIENT U.S. ARMY CORPS OF ENGINEERS - ALASKA DISTRICT		PROJECT AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT AKUTAN, ALASKA	
CONSULTANT	YYYY-MM-DD: 2023-01-05	TITLE EXAMPLE SIDE SCAN SONAR INTERPRETATION	
WSP GOLDER	PREPARED: FMW		
	DESIGN: FMW		
	REVIEW: JPF		
	APPROVED: MRM	PROJECT No. 31405083.004 REV 0	FIGURE 4

PANEL A: BACKGROUND DATA



PANEL B: SEABED INTERPRETATION



SEABED DEPTH BELOW MLLW (FT)

-70 FT -60 FT -50 FT -40 FT -30 FT -20 FT -10 FT 0 FT

LEGEND

- EXPOSED BEDROCK
- SANDWAVES
- IRREGULAR SEABED (0.5 - 1ft amplitude)
- ELONGATED SEABED DIVOTS
- LIMIT OF 2015 MULTIBEAM DATA
- MAJOR BATHYMETRY CONTOUR (10 FT INTERVAL)
- MINOR BATHYMETRY CONTOUR (2 FT INTERVAL)

FEET

0 500 1000 1500 2000

CLIENT
U.S. ARMY CORPS OF ENGINEERS - ALASKA DISTRICT

PROJECT
AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT

AKUTAN, ALASKA

CONSULTANT

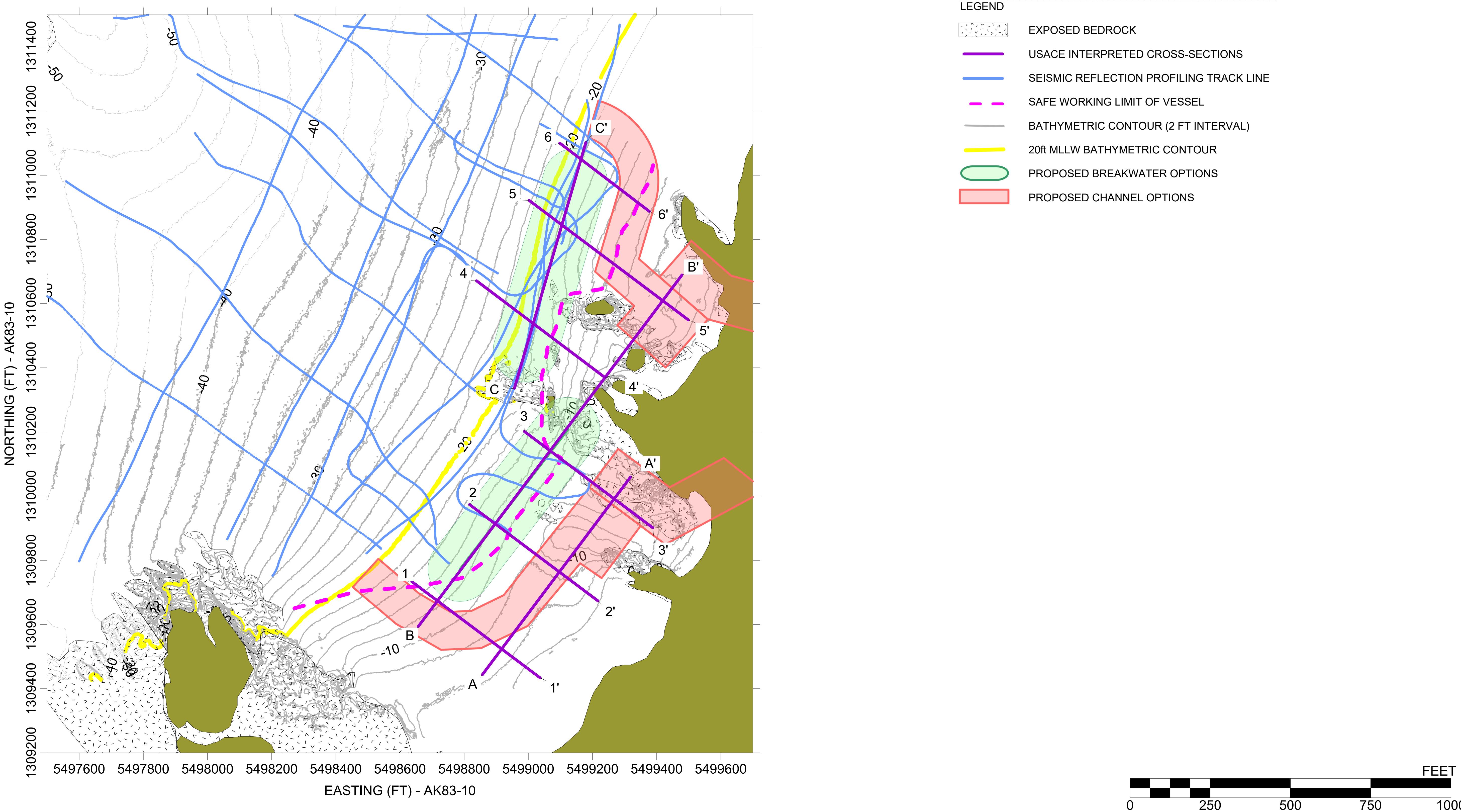
WSP GOLDER

YYYY-MM-DD	2023-01-05
PREPARED	FMW
DESIGN	FMW
REVIEW	JPF
APPROVED	MRM

TITLE
BACKGROUND DATA AND SEABED INTERPRETATION

PROJECT No.	REV	FIGURE
31405083.004	0	5

SEISMIC REFLECTION PROFILING COVERAGE



CLIENT
U.S. ARMY CORPS OF ENGINEERS - ALASKA DISTRICT

PROJECT
AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT

AKUTAN, ALASKA

CONSULTANT

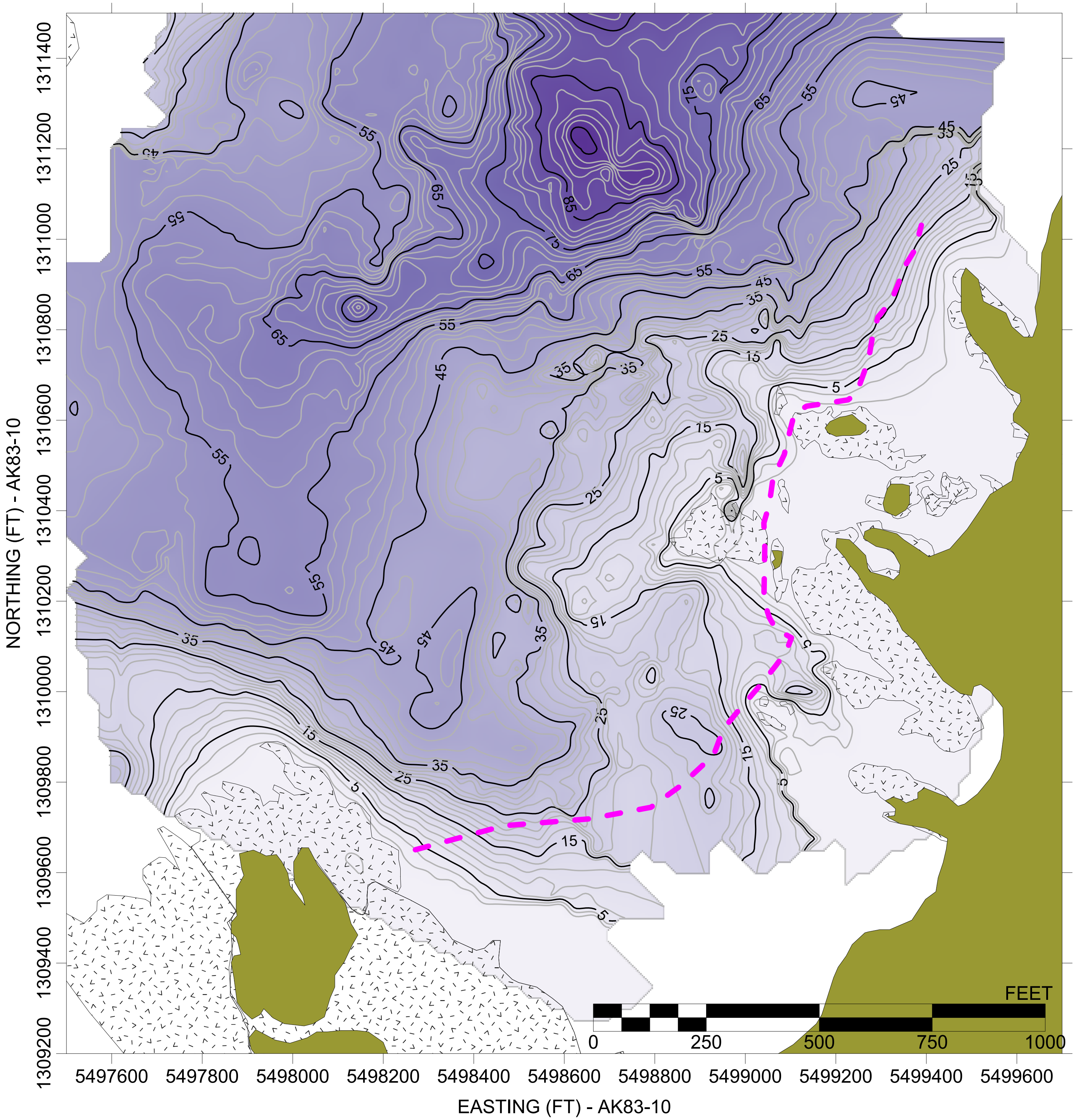
WSP GOLDER

YYYY-MM-DD	2023-01-05
PREPARED	FMW
DESIGN	FMW
REVIEW	JPF
APPROVED	MRM

TITLE
SEISMIC REFLECTION PROFILING COVERAGE

PROJECT No.	REV	FIGURE
31405083.004	0	6

UNCONSOLIDATED SEDIMENT ISOPACH



LEGEND

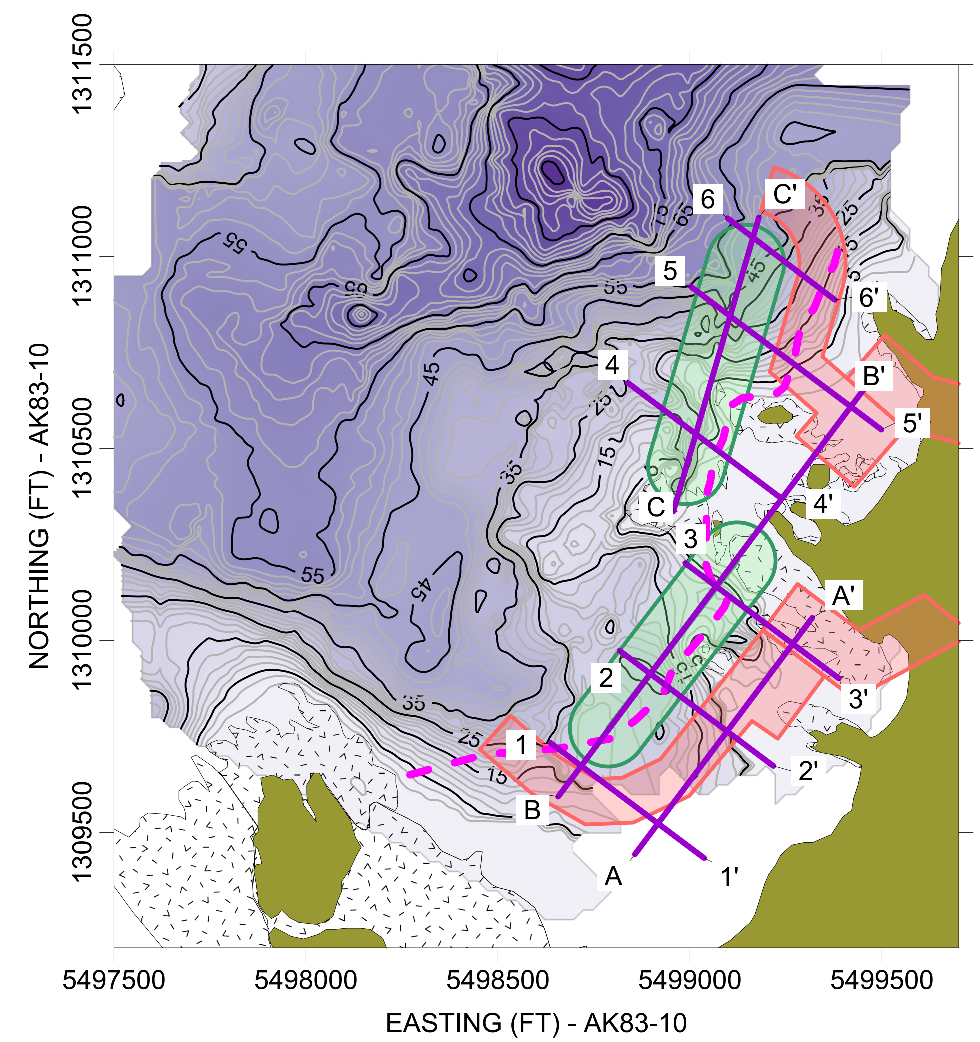
EXPOSED BEDROCK

USACE INTERPRETED CROSS-SECTIONS

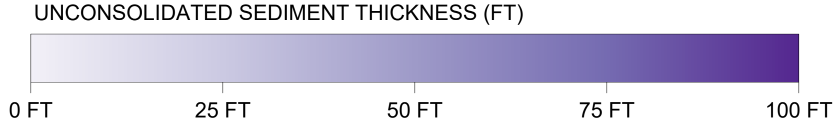
SAFE WORKING LIMIT OF VESSEL

PROPOSED BREAKWATER OPTIONS

PROPOSED CHANNEL OPTIONS

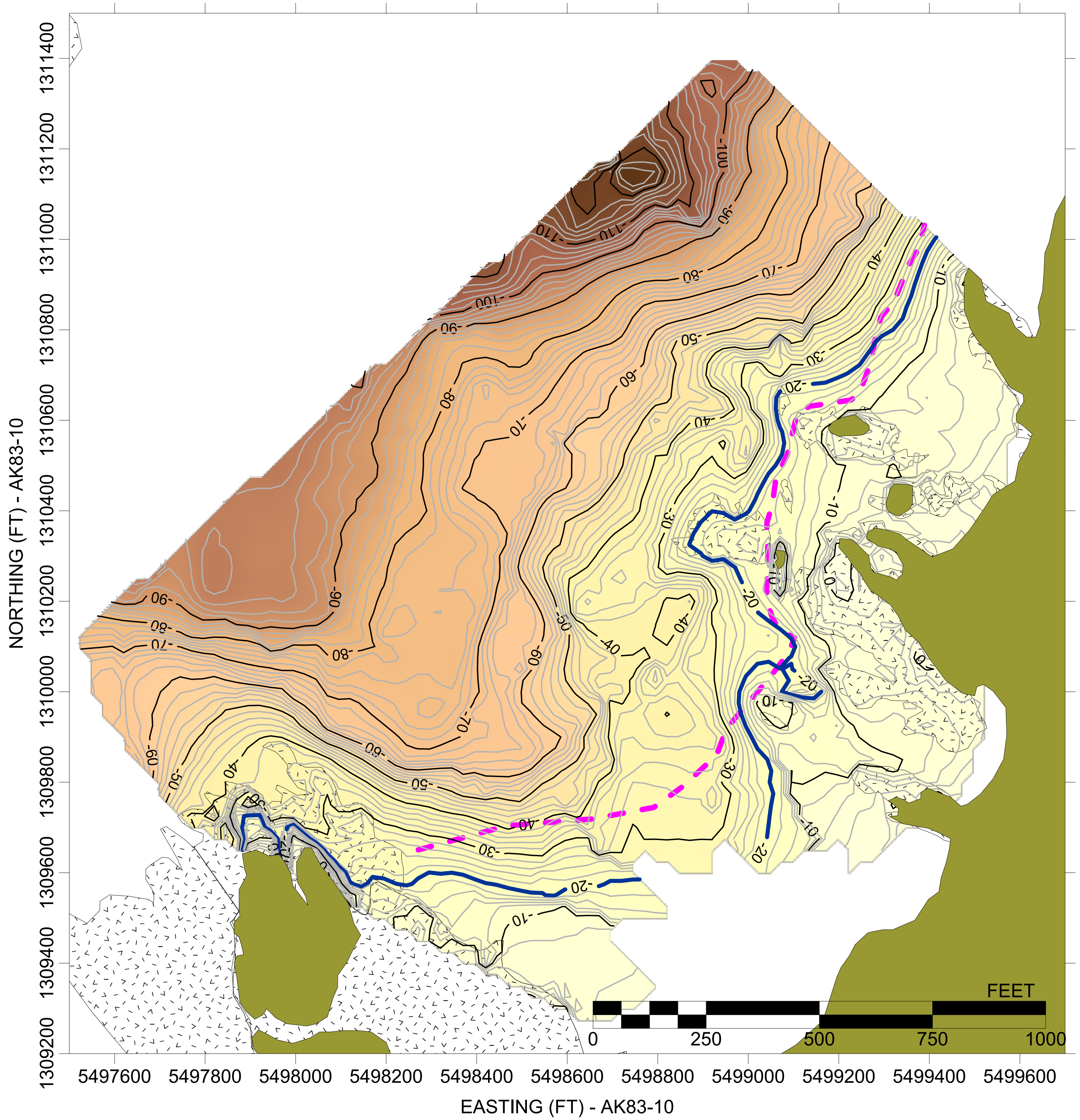


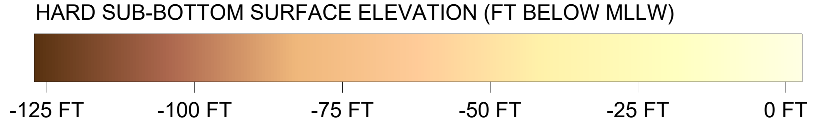
UNCONSOLIDATED SEDIMENT THICKNESS (FT)



CLIENT U.S. ARMY CORPS OF ENGINEERS - ALASKA DISTRICT		PROJECT AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT AKUTAN, ALASKA	
CONSULTANT WSP GOLDER	YYYY-MM-DD: 2023-01-05 PREPARED: FMW DESIGN: FMW REVIEW: JPF APPROVED: MRM	TITLE **ISOPACH MAP - UNCONSOLIDATED SEDIMENT**	
		PROJECT No. 31405083.004	REV 0 / FIGURE 7

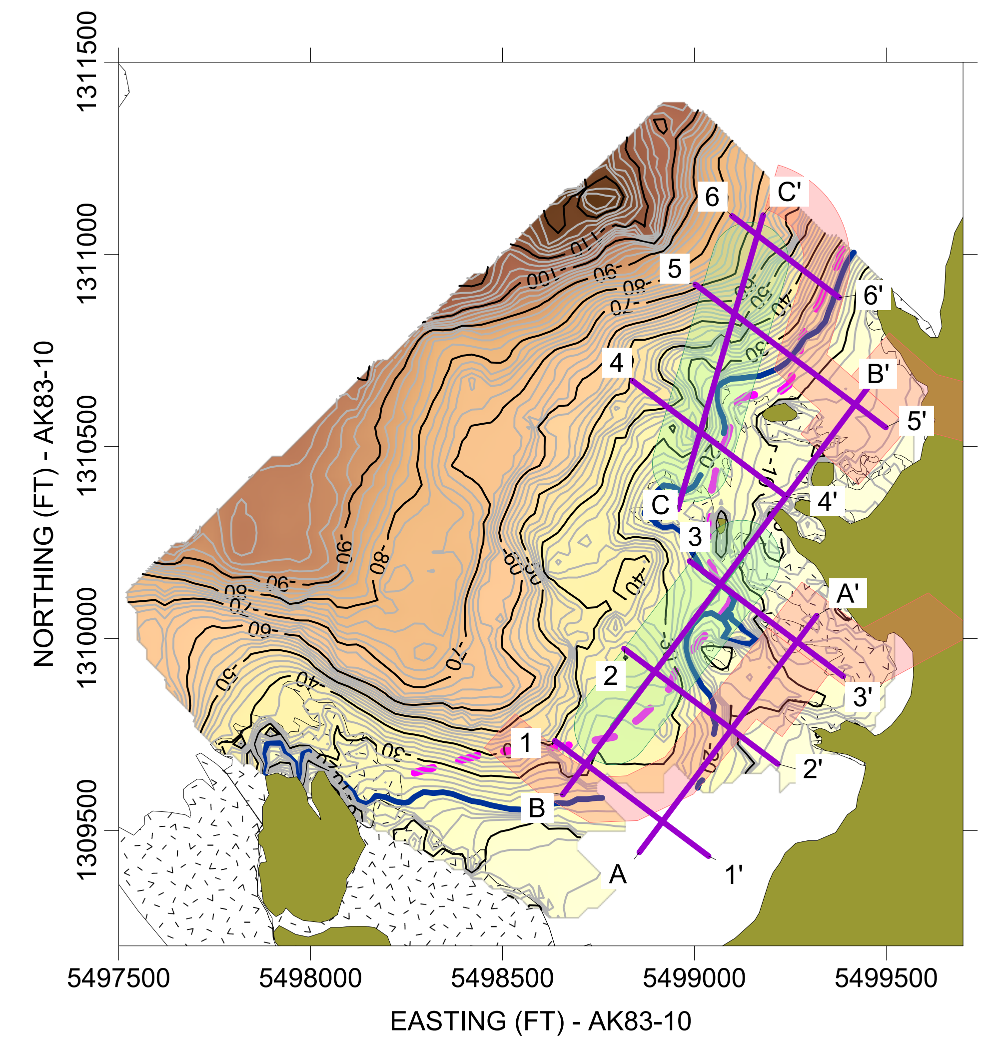
INTERPRETED HARD SUB-BOTTOM ELEVATION (FT BELOW MLLW)





LEGEND

- EXPOSED BEDROCK
- USACE INTERPRETED CROSS-SECTIONS
- SAFE WORKING LIMIT OF VESSEL
- 20 ft MLLW INTERPRETED BEDROCK ELEVATION
- PROPOSED BREAKWATER OPTIONS
- PROPOSED CHANNEL OPTIONS

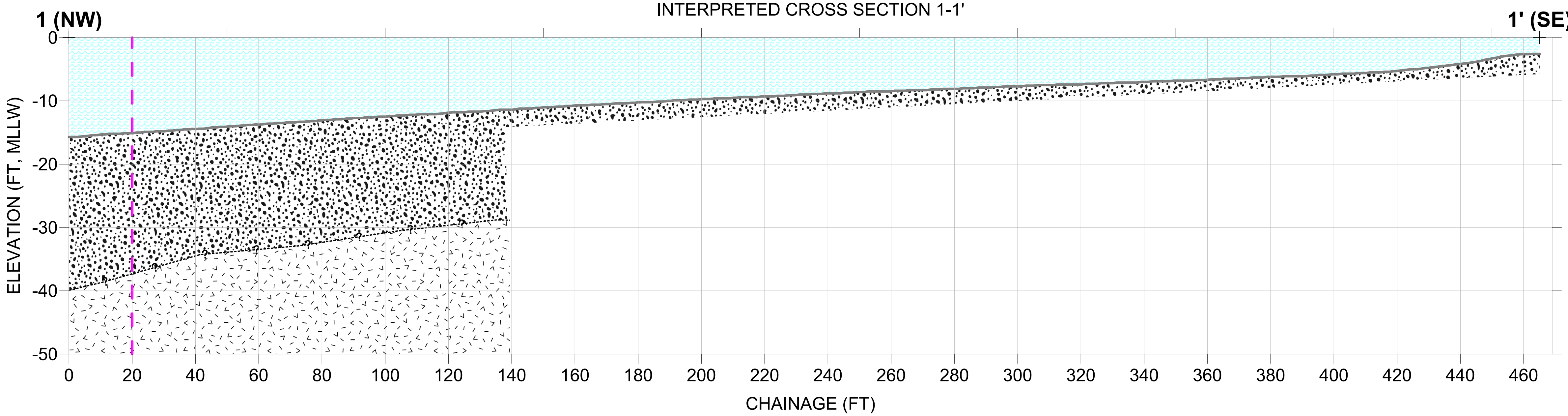


CLIENT U.S. ARMY CORPS OF ENGINEERS - ALASKA DISTRICT	PROJECT AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT AKUTAN, ALASKA
CONSULTANT WSP GOLDER	TITLE **ELEVATION CONTOUR MAP OF INTERPRETED HARD SUB-BOTTOM**

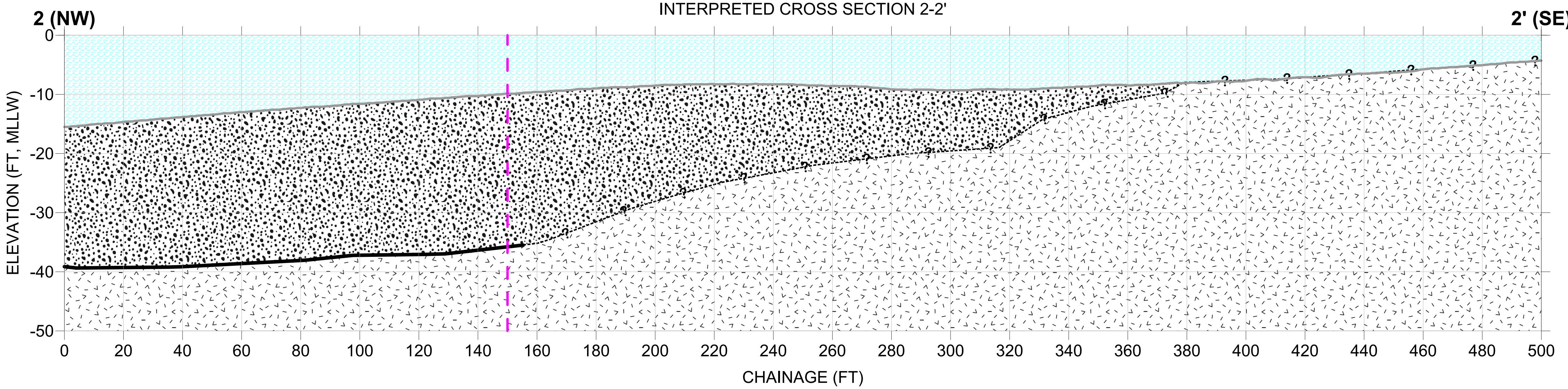
YYYY-MM-DD	2023-01-05
PREPARED	FMW
DESIGN	FMW
REVIEW	JPF
APPROVED	MRM

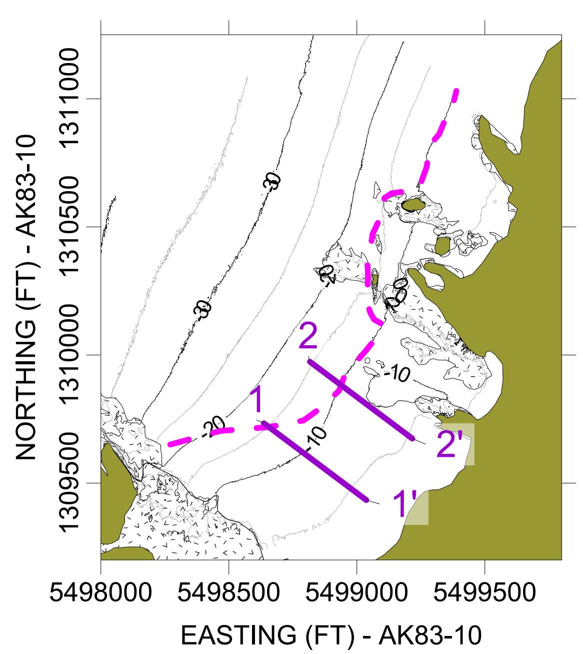
PROJECT No.	REV	FIGURE
31405083.004	0	8

INTERPRETED CROSS SECTION 1-1'



INTERPRETED CROSS SECTION 2-2'





LEGEND

- INTERPRETED SAND/GRAVEL SEABED
- INTERPRETED EXPOSED BEDROCK
- INTERPRETED SUB-BOTTOM BEDROCK
- INFERRED SUBBOTTOM BEDROCK - LIMITED DATA
- SAFE LIMIT OF SURVEY OPERATIONS
- WATER
- SAND/GRAVEL UNCONSOLIDATED
- IGNEOUS BEDROCK

CLIENT
U.S. ARMY CORPS OF ENGINEERS - ALASKA DISTRICT

PROJECT
AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT

AKUTAN, ALASKA

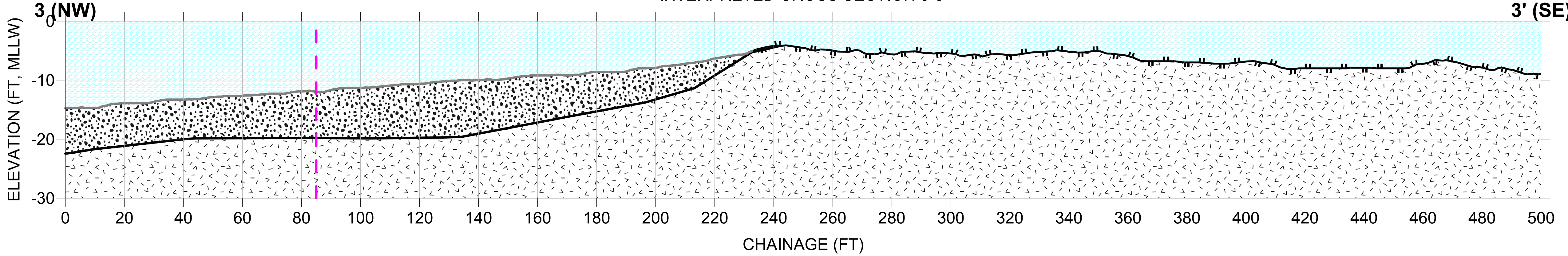
CONSULTANT

YYYY-MM-DD	2023-01-05
PREPARED	FMW
DESIGN	FMW
REVIEW	JPF
APPROVED	MRM

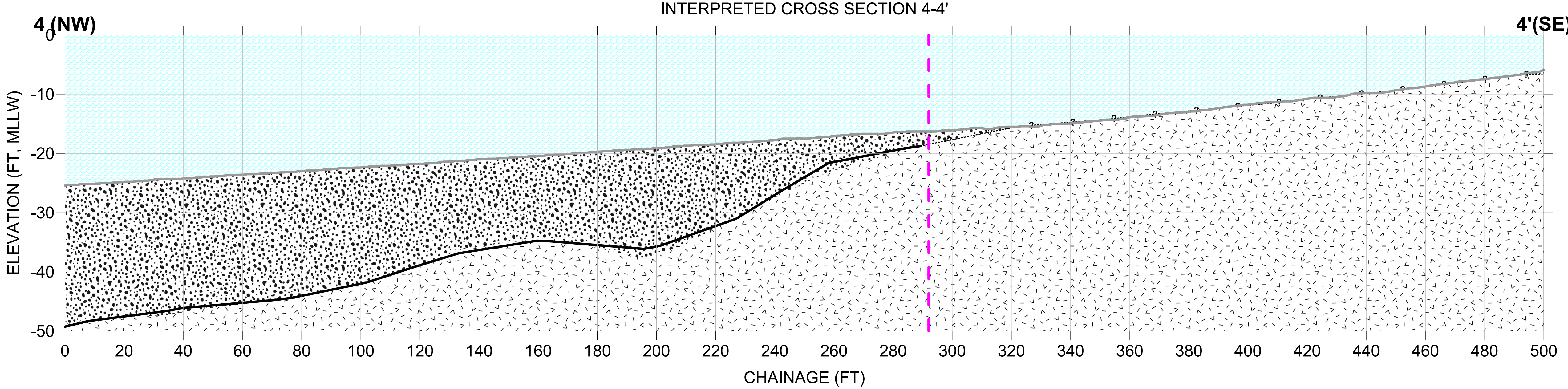
TITLE
CROSS SECTION 1-1'
CROSS SECTION 2-2'

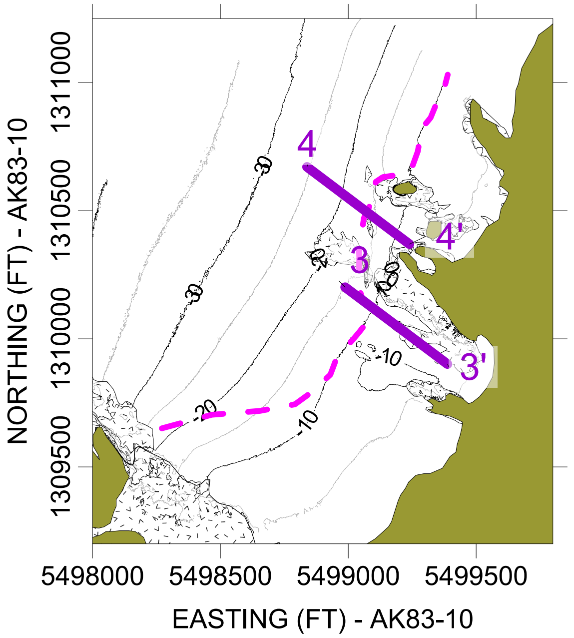
PROJECT No.	REV	FIGURE
31405083.004	0	9

INTERPRETED CROSS SECTION 3-3'



INTERPRETED CROSS SECTION 4-4'





LEGEND

- INTERPRETED SAND/GRAVEL SEABED
- INTERPRETED EXPOSED BEDROCK
- INTERPRETED SUB-BOTTOM BEDROCK
- INFERRED SUBBOTTOM BEDROCK - LIMITED DATA
- SAFE LIMIT OF SURVEY OPERATIONS
- WATER
- SAND/GRAVEL UNCONSOLIDATED
- IGNEOUS BEDROCK

CLIENT
U.S. ARMY CORPS OF ENGINEERS - ALASKA DISTRICT

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2023-01-05
PREPARED	FMW
DESIGN	FMW
REVIEW	JPF
APPROVED	MRM

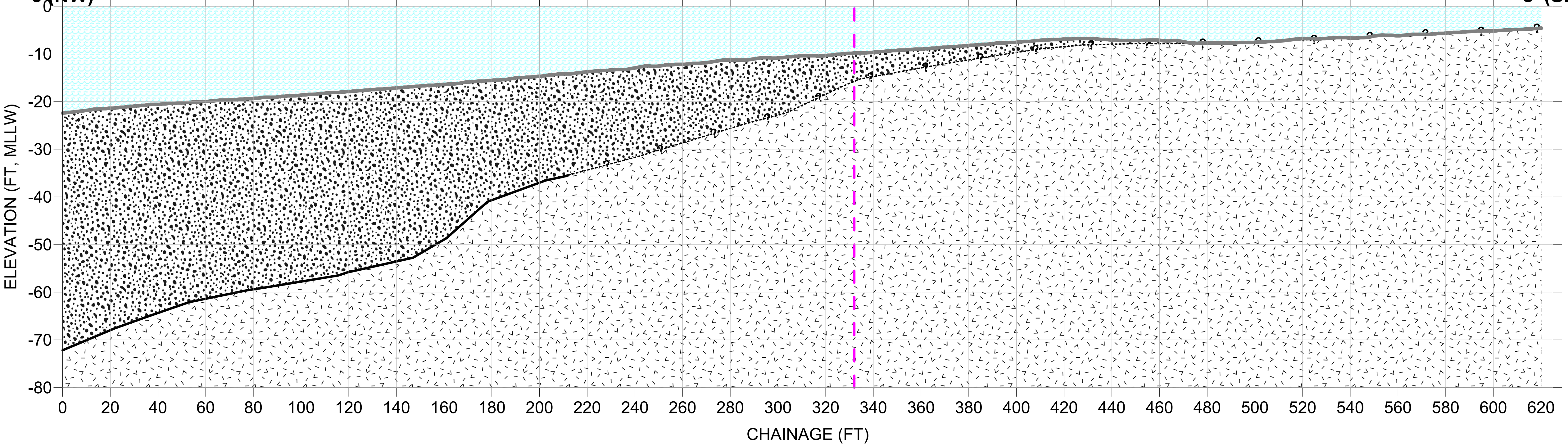
PROJECT
AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT

AKUTAN, ALASKA

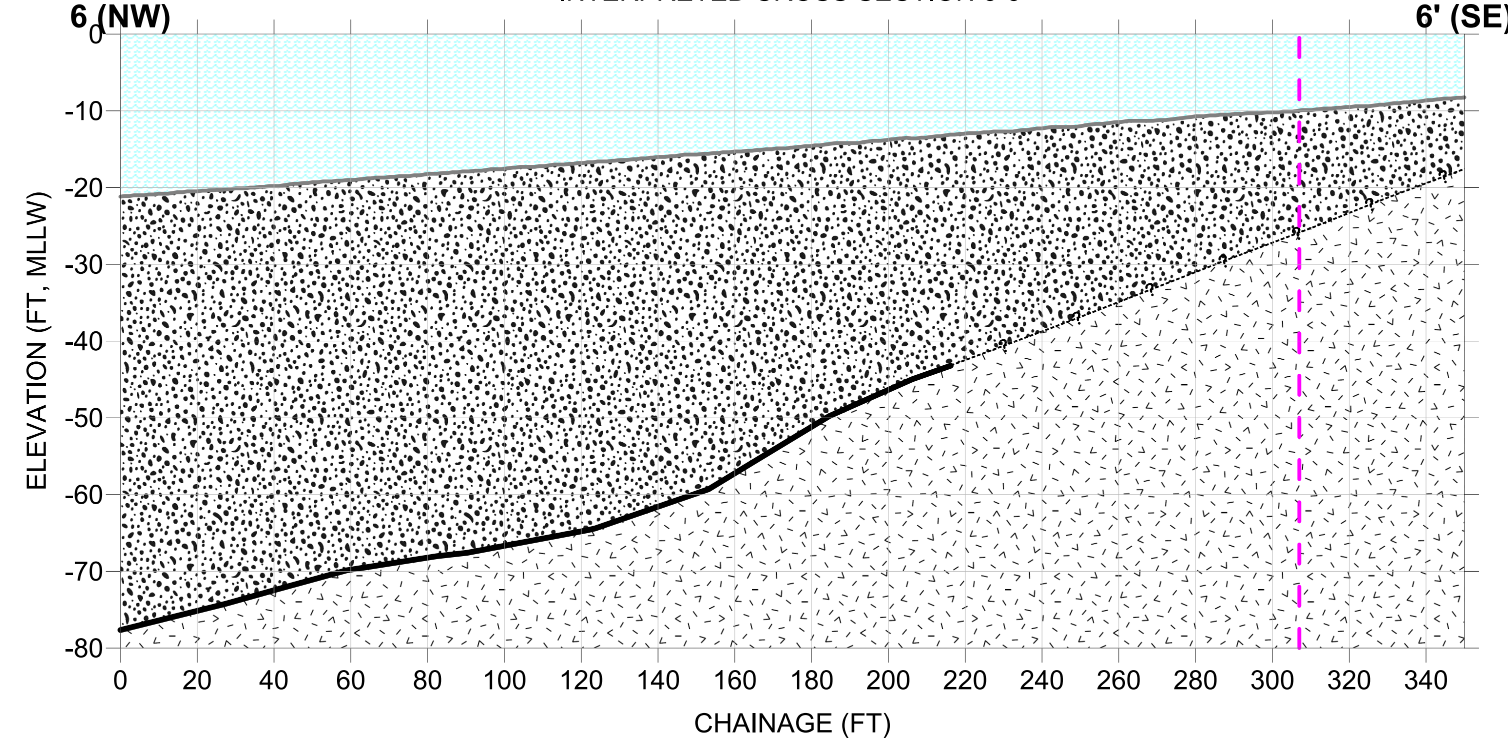
TITLE
CROSS SECTION 3-3'
CROSS SECTION 4-4'

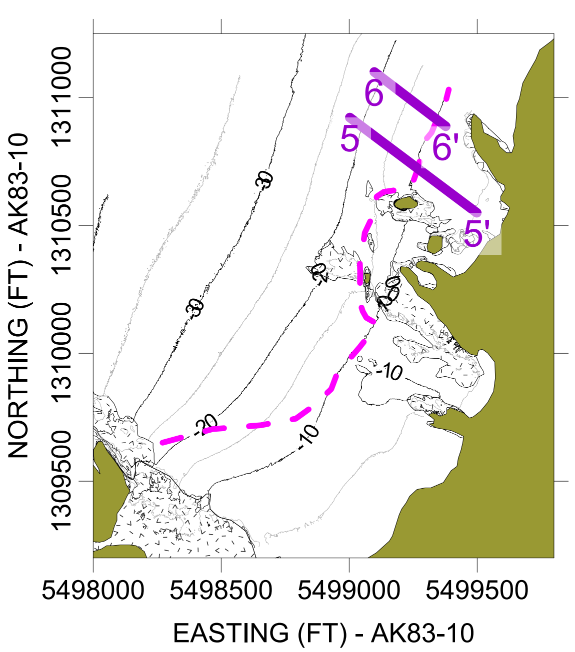
PROJECT No.	REV	FIGURE
31405083.004	0	10

INTERPRETED CROSS SECTION 5-5'



INTERPRETED CROSS SECTION 6-6'





LEGEND

- INTERPRETED SAND/GRAVEL SEABED
- INTERPRETED EXPOSED BEDROCK
- INTERPRETED SUB-BOTTOM BEDROCK
- INFERRED SUBBOTTOM BEDROCK - LIMITED DATA
- SAFE LIMIT OF SURVEY OPERATIONS
- WATER
- SAND/GRAVEL UNCONSOLIDATED
- IGNEOUS BEDROCK

CLIENT
U.S. ARMY CORPS OF ENGINEERS - ALASKA DISTRICT

PROJECT
AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT

AKUTAN, ALASKA

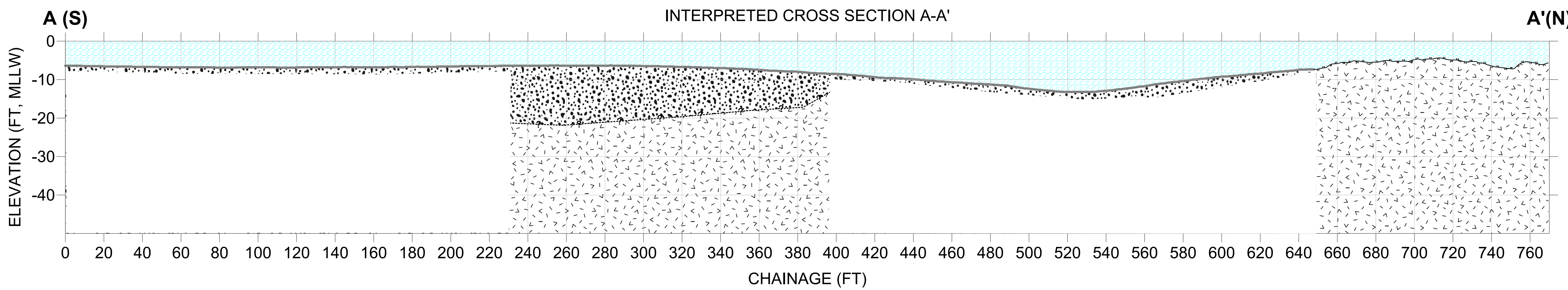
CONSULTANT

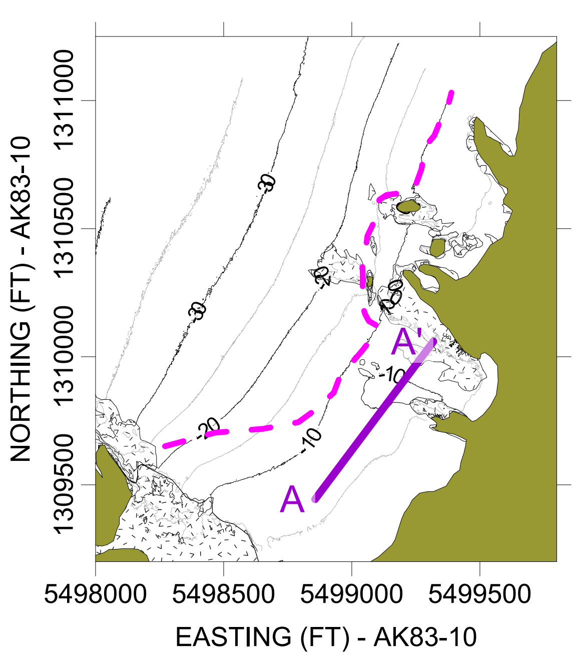
WSP GOLDER

YYYY-MM-DD	2023-01-05
PREPARED	FMW
DESIGN	FMW
REVIEW	JPF
APPROVED	MRM

TITLE
CROSS SECTION 5-5'
CROSS SECTION 6-6'

PROJECT No.	REV	FIGURE
31405083.004	0	11

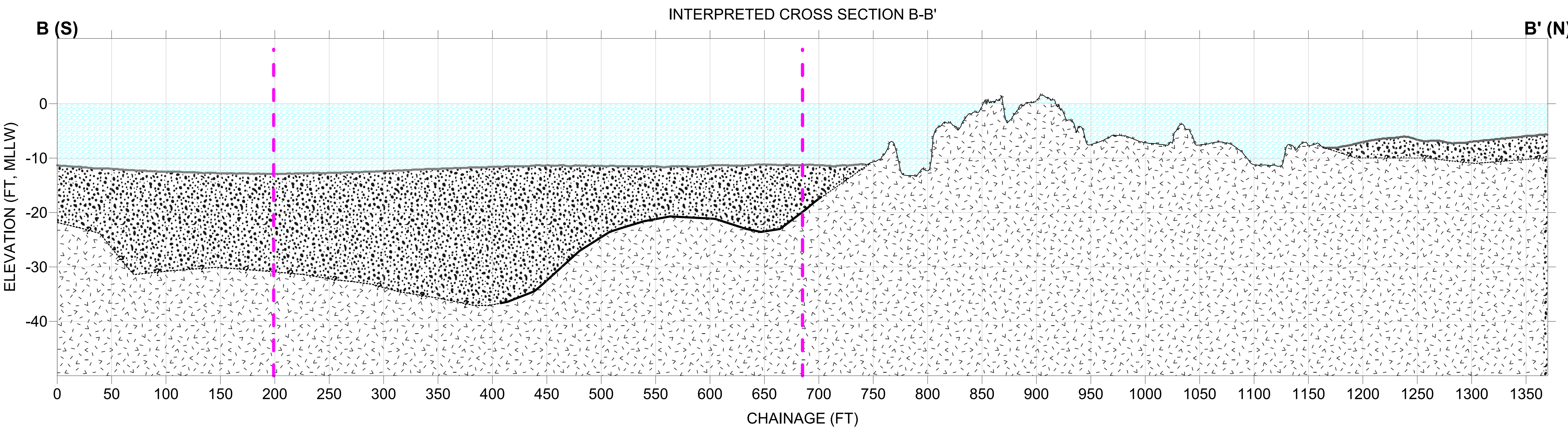


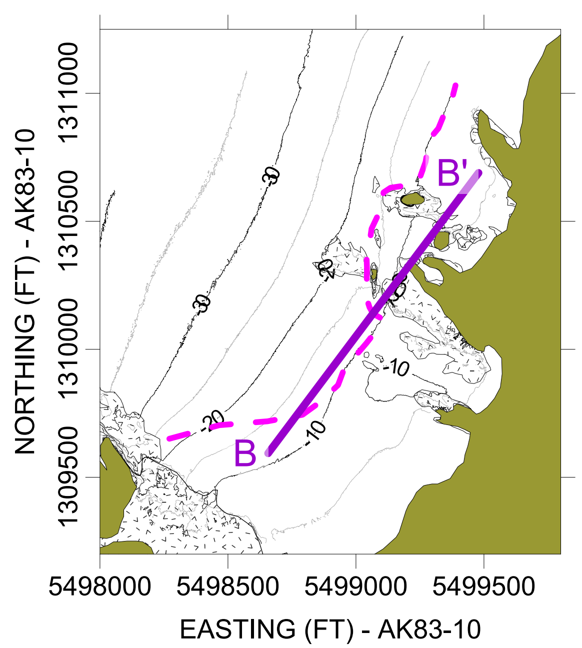


LEGEND

- INTERPRETED SAND/GRAVEL SEABED
- INTERPRETED EXPOSED BEDROCK
- INTERPRETED SUB-BOTTOM BEDROCK
- INFERRED SUBBOTTOM BEDROCK - LIMITED DATA
- SAFE LIMIT OF SURVEY OPERATIONS
- WATER
- SAND/GRAVEL UNCONSOLIDATED
- IGNEOUS BEDROCK

CLIENT U.S. ARMY CORPS OF ENGINEERS - ALASKA DISTRICT			PROJECT AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT AKUTAN, ALASKA
CONSULTANT WSP GOLDER	YYYY-MM-DD	2023-01-05	TITLE **CROSS SECTION A-A'**
	PREPARED	FMW	
	DESIGN	FMW	
	REVIEW	JPF	PROJECT No. 31405083.004 — REV 0 — FIGURE 12
	APPROVED	MRM	

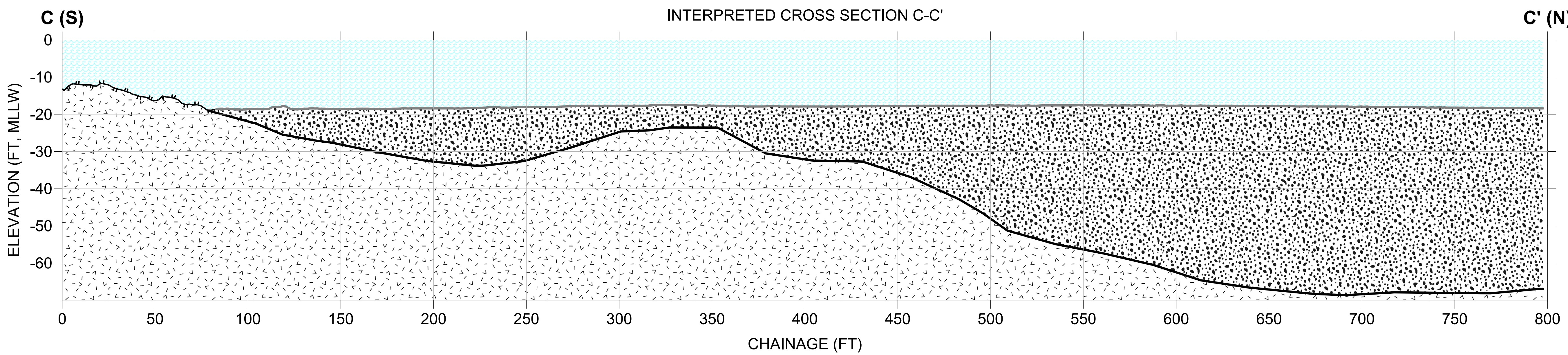


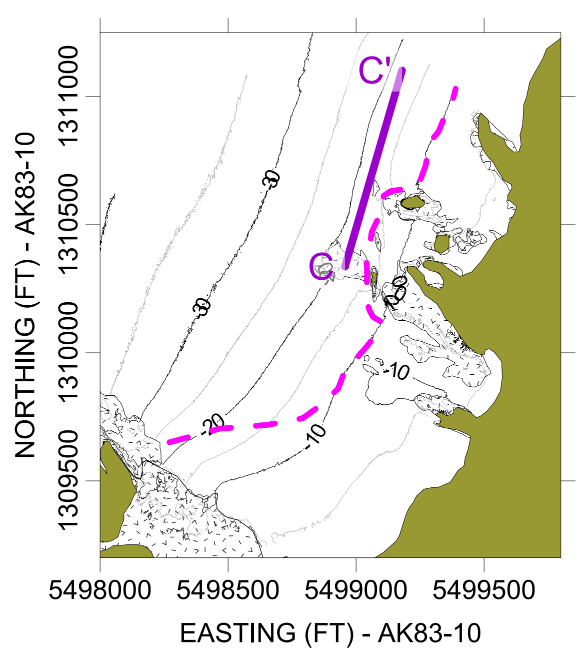


LEGEND

- INTERPRETED SAND/GRAVEL SEABED
- INTERPRETED EXPOSED BEDROCK
- INTERPRETED SUB-BOTTOM BEDROCK
- INFERRED SUBBOTTOM BEDROCK - LIMITED DATA
- SAFE LIMIT OF SURVEY OPERATIONS
- WATER
- SAND/GRAVEL UNCONSOLIDATED
- IGNEOUS BEDROCK

CLIENT	U.S. ARMY CORPS OF ENGINEERS - ALASKA DISTRICT	PROJECT	AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT AKUTAN, ALASKA
CONSULTANT	WSP GOLDER	TITLE	**CROSS SECTION B-B'**
YYYY-MM-DD	2023-01-05	PROJECT No.	31405083.004
PREPARED	FMW	REV	0
DESIGN	FMW	FIGURE	13
REVIEW	JPF		
APPROVED	MRM		





LEGEND

- INTERPRETED SAND/GRAVEL SEABED
- INTERPRETED EXPOSED BEDROCK
- INTERPRETED SUB-BOTTOM BEDROCK
- INFERRED SUBBOTTOM BEDROCK - LIMITED DATA
- SAFE LIMIT OF SURVEY OPERATIONS
- WATER
- SAND/GRAVEL UNCONSOLIDATED
- IGNEOUS BEDROCK

CLIENT
U.S. ARMY CORPS OF ENGINEERS - ALASKA DISTRICT

PROJECT
AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT

AKUTAN, ALASKA

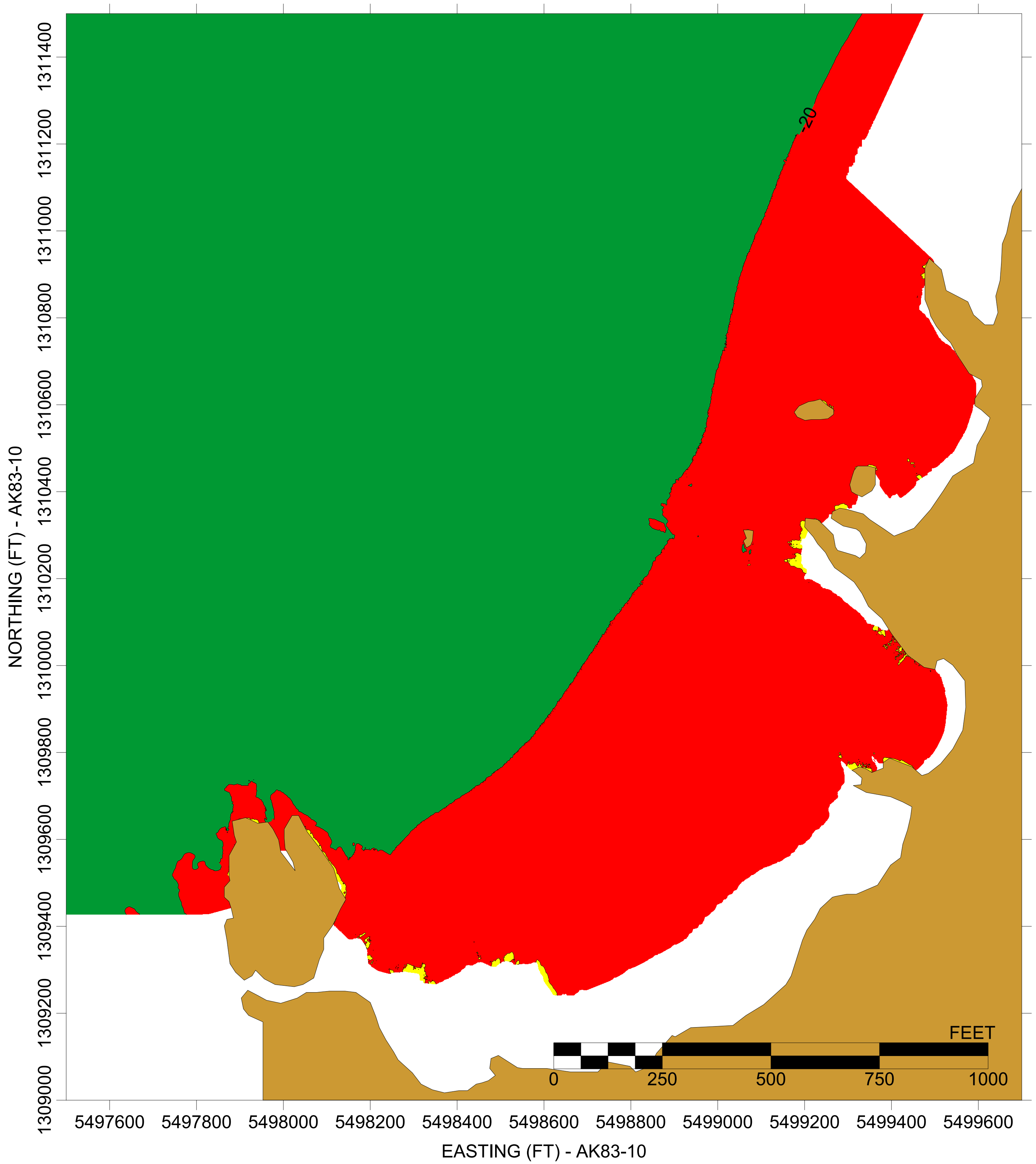
CONSULTANT

WSP GOLDER

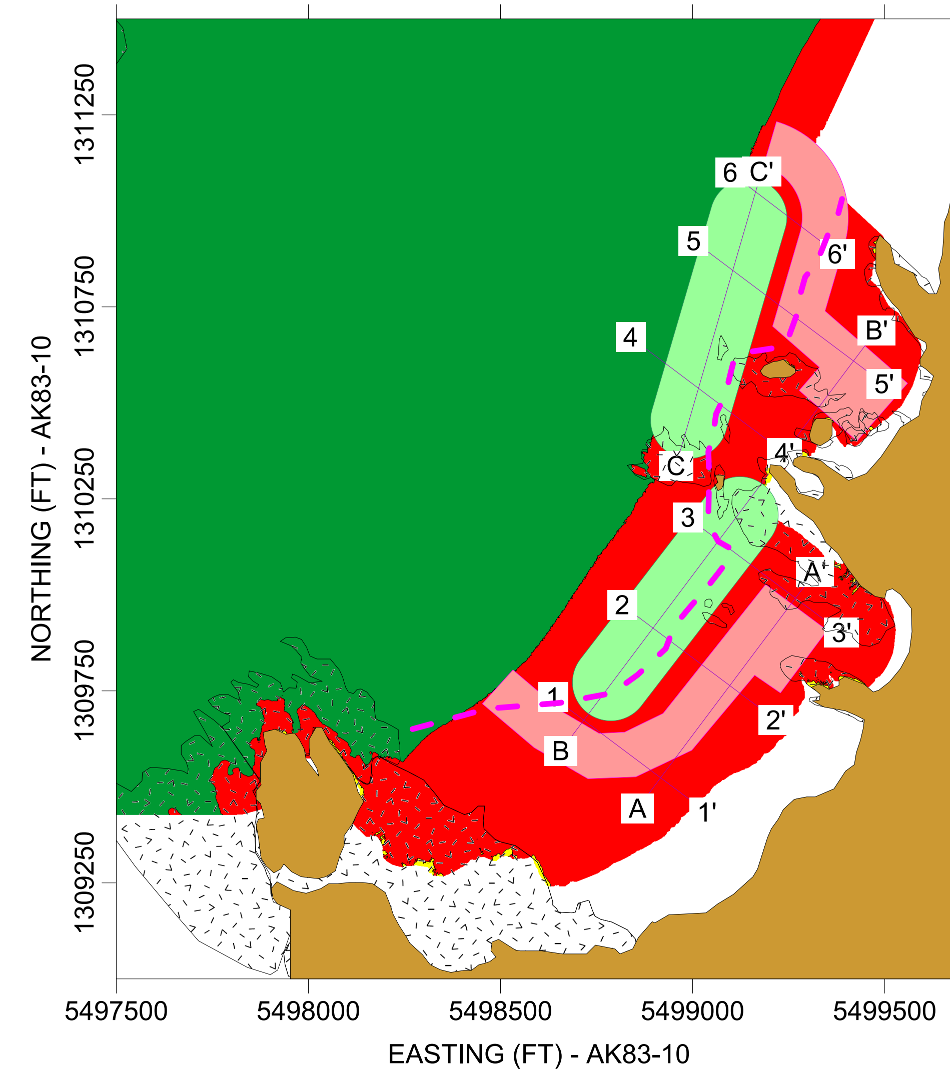
YYYY-MM-DD	2023-01-05
PREPARED	FMW
DESIGN	FMW
REVIEW	JPF
APPROVED	MRM

TITLE
CROSS SECTION C-C'

PROJECT No.	REV	FIGURE
31405083.004	0	14



SEABED DEPTH BELOW MLLW (FT)



LEGEND

- EXPOSED BEDROCK
- USACE INTERPRETED CROSS-SECTIONS
- SAFE WORKING LIMIT OF VESSEL
- PROPOSED BREAKWATER OPTIONS
- PROPOSED CHANNEL OPTIONS

CLIENT
U.S. ARMY CORPS OF ENGINEERS - ALASKA DISTRICT

PROJECT
AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT

AKUTAN, ALASKA

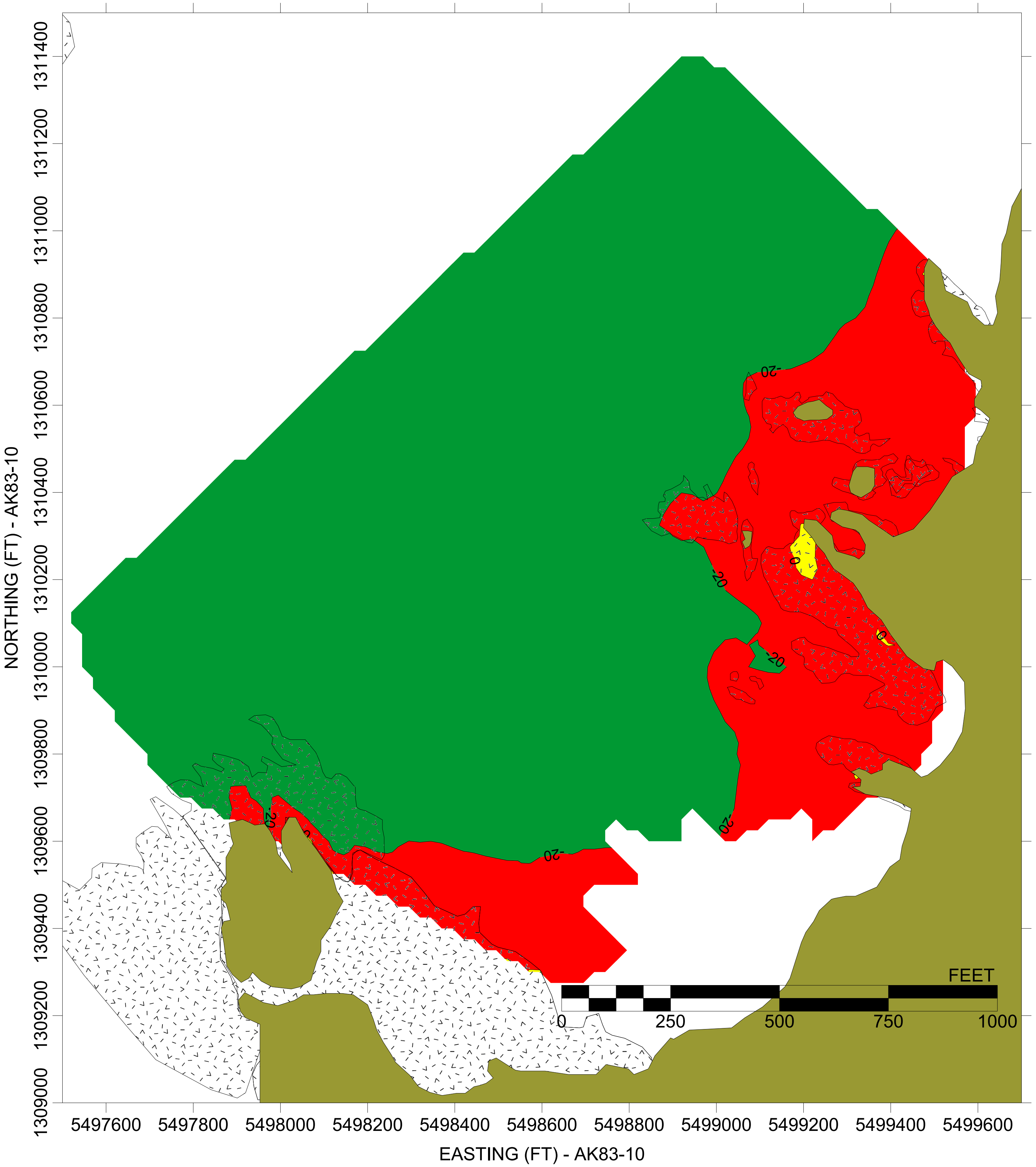
CONSULTANT

WSP GOLDER

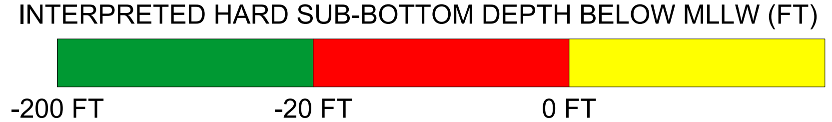
YYYY-MM-DD	2023-01-05
PREPARED	FMW
DESIGN	FMW
REVIEW	JPF
APPROVED	MRM

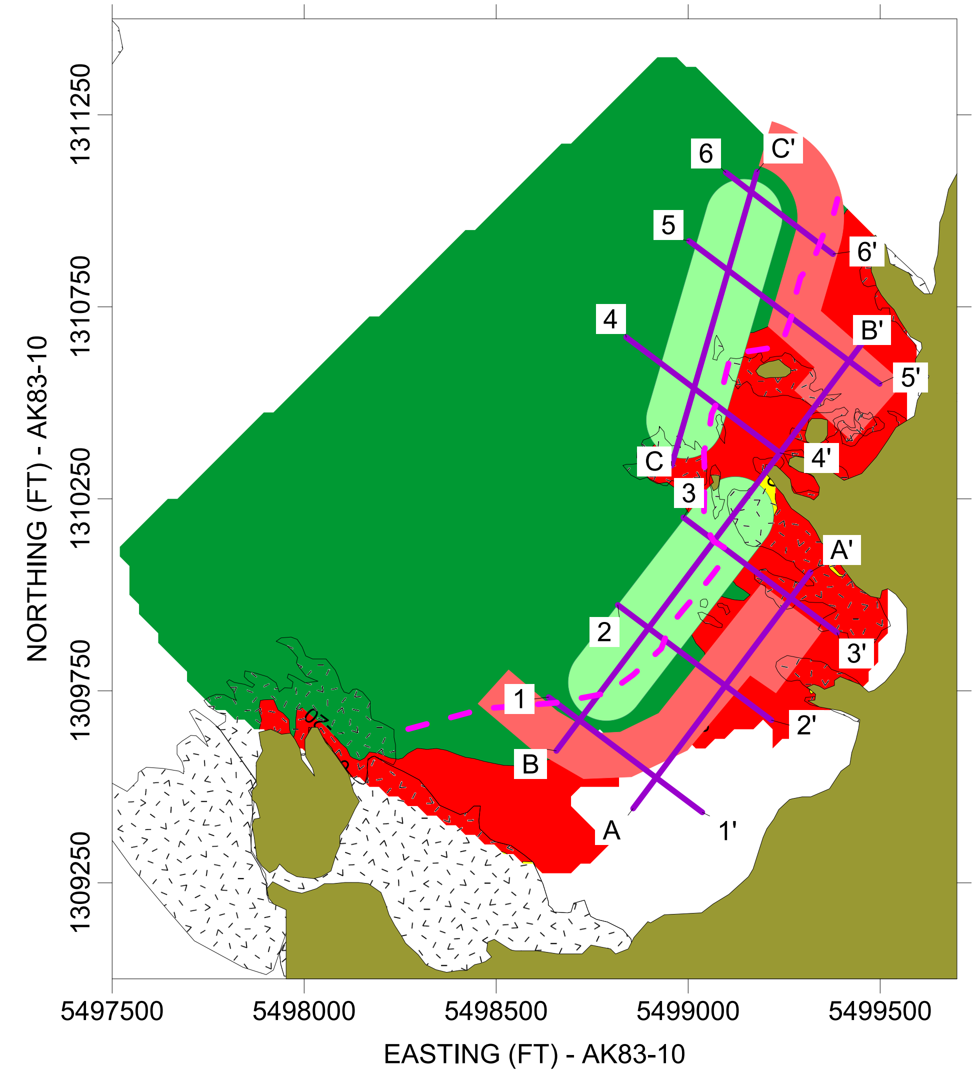
TITLE
SIMPLIFIED SEABED BATHYMETRY

PROJECT No.	REV	FIGURE
31405083.004	0	15



INTERPRETED HARD SUB-BOTTOM DEPTH BELOW MLLW (FT)





LEGEND

- EXPOSED BEDROCK
- USACE INTERPRETED CROSS-SECTIONS
- SAFE WORKING LIMIT OF VESSEL
- PROPOSED BREAKWATER OPTIONS
- PROPOSED CHANNEL OPTIONS

CLIENT	U.S. ARMY CORPS OF ENGINEERS - ALASKA DISTRICT
PROJECT	AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT AKUTAN, ALASKA
CONSULTANT	WSP GOLDER
YYYY-MM-DD	2023-01-05
PREPARED	FMW
DESIGN	FMW
REVIEW	JPF
APPROVED	MRM
TITLE	**SIMPLIFIED ELEVATION CONTOUR MAP OF HARD SUB-BOTTOM**
PROJECT No.	31405083.004
REV	0
FIGURE	16

APPENDIX A

Historic Reports

A report prepared for

HDR Engineering, Inc.
2525 C St., Suite 305
Anchorage, AK 99503

GEOTECHNICAL EXPLORATION
<u>Akutan Airport Master Plan</u>
Akun Island, Alaska

by

Duane L. Miller, P.E.
Civil Engineer 3696-E

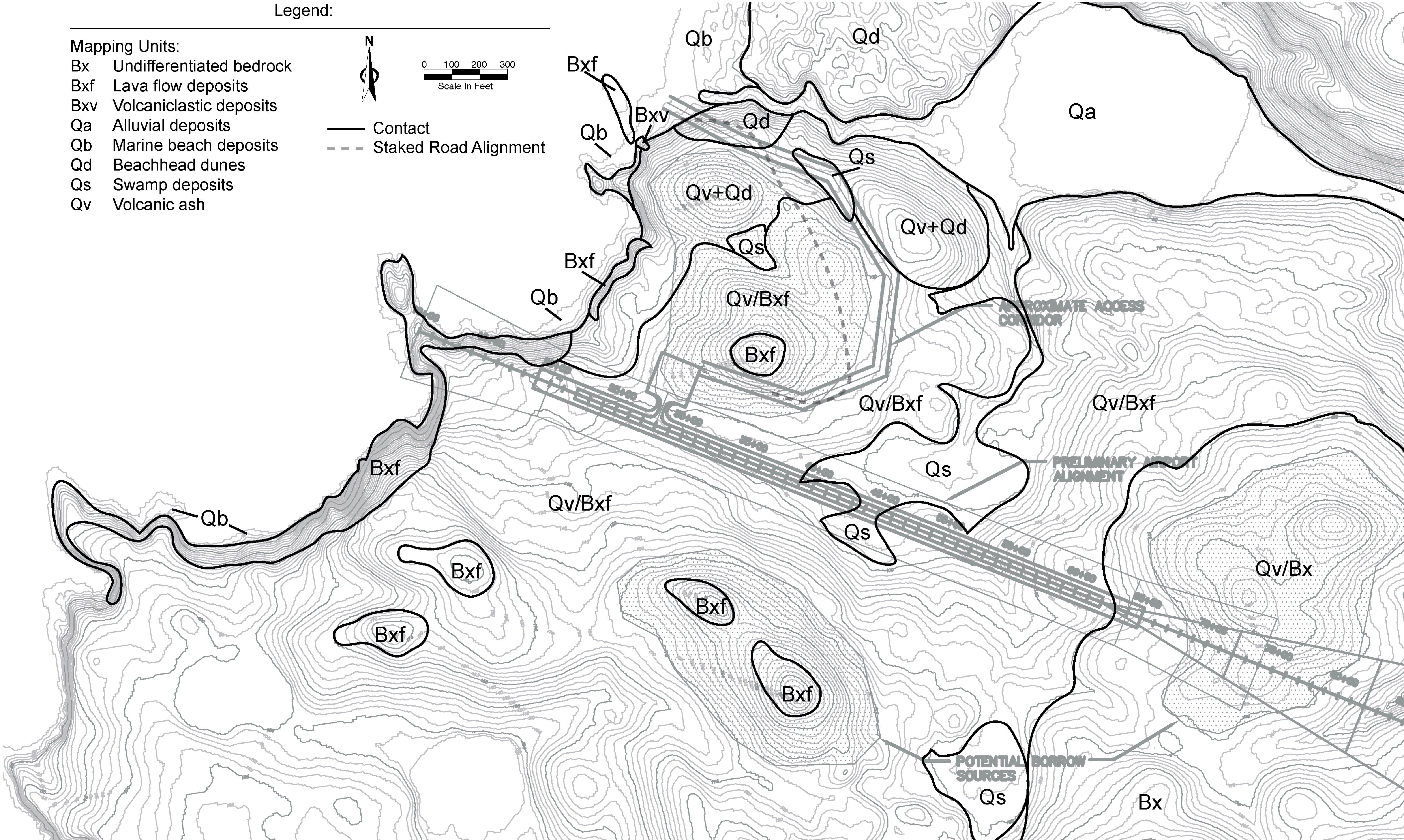
Walter T. Phillips, P.G.
Professional Geologist AA 0062

Susan Y. Wilson
Geologist

DM&A Job No. 4086.061

Duane Miller & Associates
5821 Arctic Blvd, Suite A
Anchorage, Alaska 99518
(907) 644-3200
FAX 644-0507

December 9, 2005



Notes: All locations are approximate. Base map provided by HDR Inc.

Duane Miller & Associates
Job No.: 4086.061
Date: December 2005

Project Map
Proposed Airport
Akun Island, Alaska

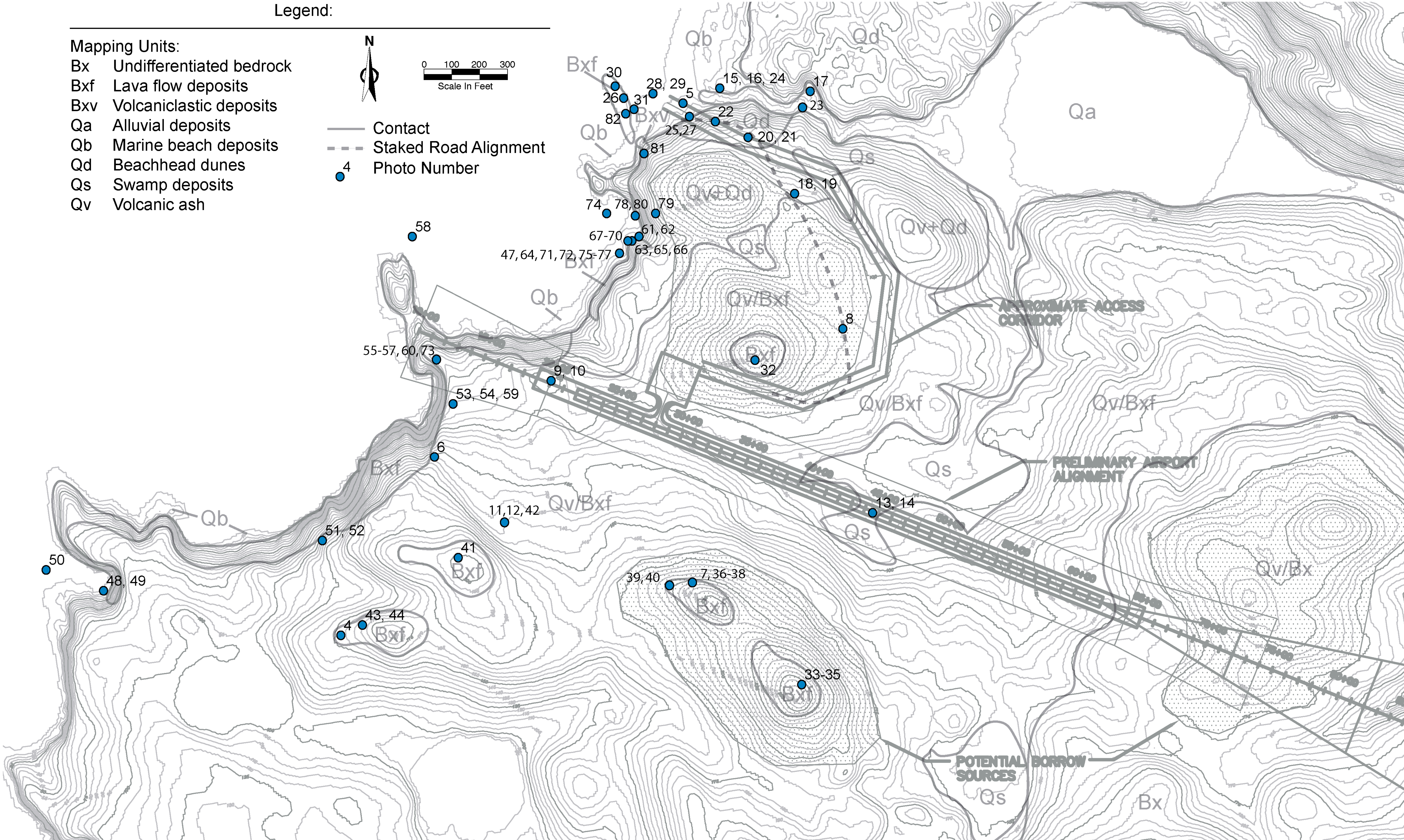
Plate
1

Legend:

Mapping Units:

Bx	Undifferentiated bedrock
Bxf	Lava flow deposits
Bxv	Volcaniclastic deposits
Qa	Alluvial deposits
Qb	Marine beach deposits
Qd	Beachhead dunes
Qs	Swamp deposits
Qv	Volcanic ash

Contact
Staked Road Alignment
4 Photo Number

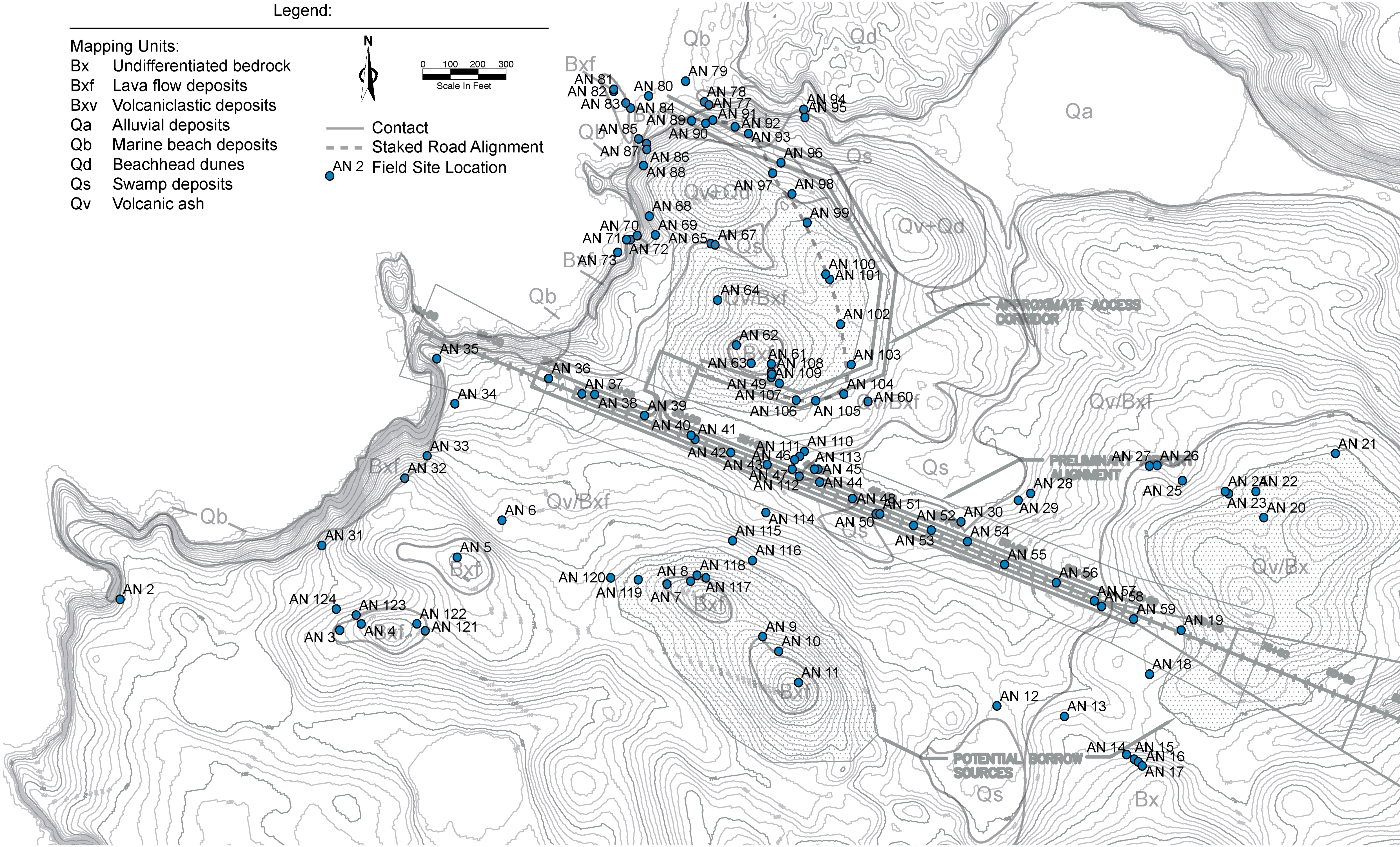


Notes: All locations are approximate. Base map provided by HDR Inc.

Duane Miller & Associates
Job No.: 4086.061
Date: December 2005

Photo Locations
Proposed Airport
Akun Island, Alaska

Plate
B1



Notes: All locations are approximate. Base map provided by HDR Inc.

Duane Miller & Associates
Job No.: 4086.061
Date: December 2005

Field Site Locations
Proposed Airport
Akun Island, Alaska

Plate
A1

PHOTO 25: The road alignment is located behind the lower building, near the stream. This photo was taken from the breakwater near the proposed landing site, field site AN 83.

PHOTO 26: Road alignment looking southwest towards breakwater. This photo was taken at field site AN 89 looking southwest toward the breakwater.

PHOTO 27: View of the landing area, panning from the east to the south at low tide, field site AN 80.

PHOTO 28: View of the landing area at low tide looking west from field site AN 80..

PHOTO 29: Western end of breakwater, with a view panning across the landing area from the western end of the breakwater at field site AN 81.

PHOTO 30: View across landing area to the north from field site AN 84.

Duane Miller & Associates Job No.: 4086.061 Date: December 2005	**SITE PHOTOGRAPHS** Proposed Airport Akun Island, Alaska	Plate B16

PHOTO 72: Sand outcrop viewed from field site AN 35.

PHOTO 73: Sand and ash are interbedded below the wind tower on coast. View looking east from sea.

PHOTO 74: Sand outcrop viewed from the cove, near field site AN 71.

PHOTO 75: A closer view of Photo 74. The contact between the overlying interbedded sand and ash, and basalt is clear.


PHOTO 76: A closer view of the basalt, from field site AN 71.

PHOTO 77: Interbedded sand and ash.

PHOTO 78: Interbeds of ash and sand at field site AN 68.

PHOTO 79: Closer view of the brecciated basalt and interbedded sand and ash.

PHOTO 80: A series of debris flows/lahars followed by a fluvial outwash at field site AN 86.

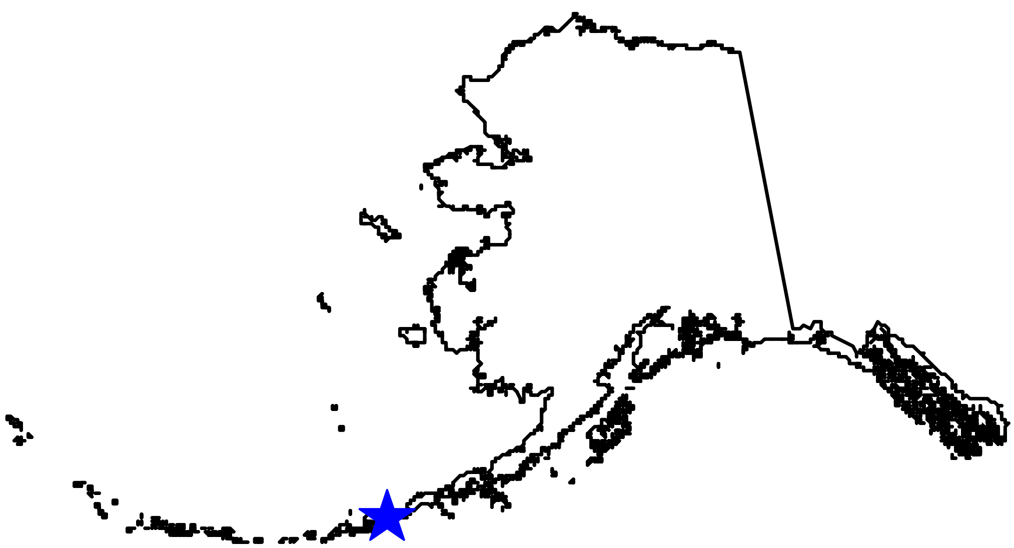
PHOTO 81: The outcrop shown above is visible to the left on this photo taken from the breakwater south of Surf Beach, field site AN 83.

GEOTECHNICAL REPORT

AKUTAN AIRPORT

PROJECT # 51196

NOVEMBER 2008



Prepared By
ALASKA DEPARTMENT OF TRANSPORTATION & PUBLIC FACILITIES
Central Region Materials
Anchorage, Alaska

ALASKA
Department of Transportation & Public Facilities

GEOTECHNICAL REPORT

AKUTAN AIRPORT

Project # 51196

November 2008

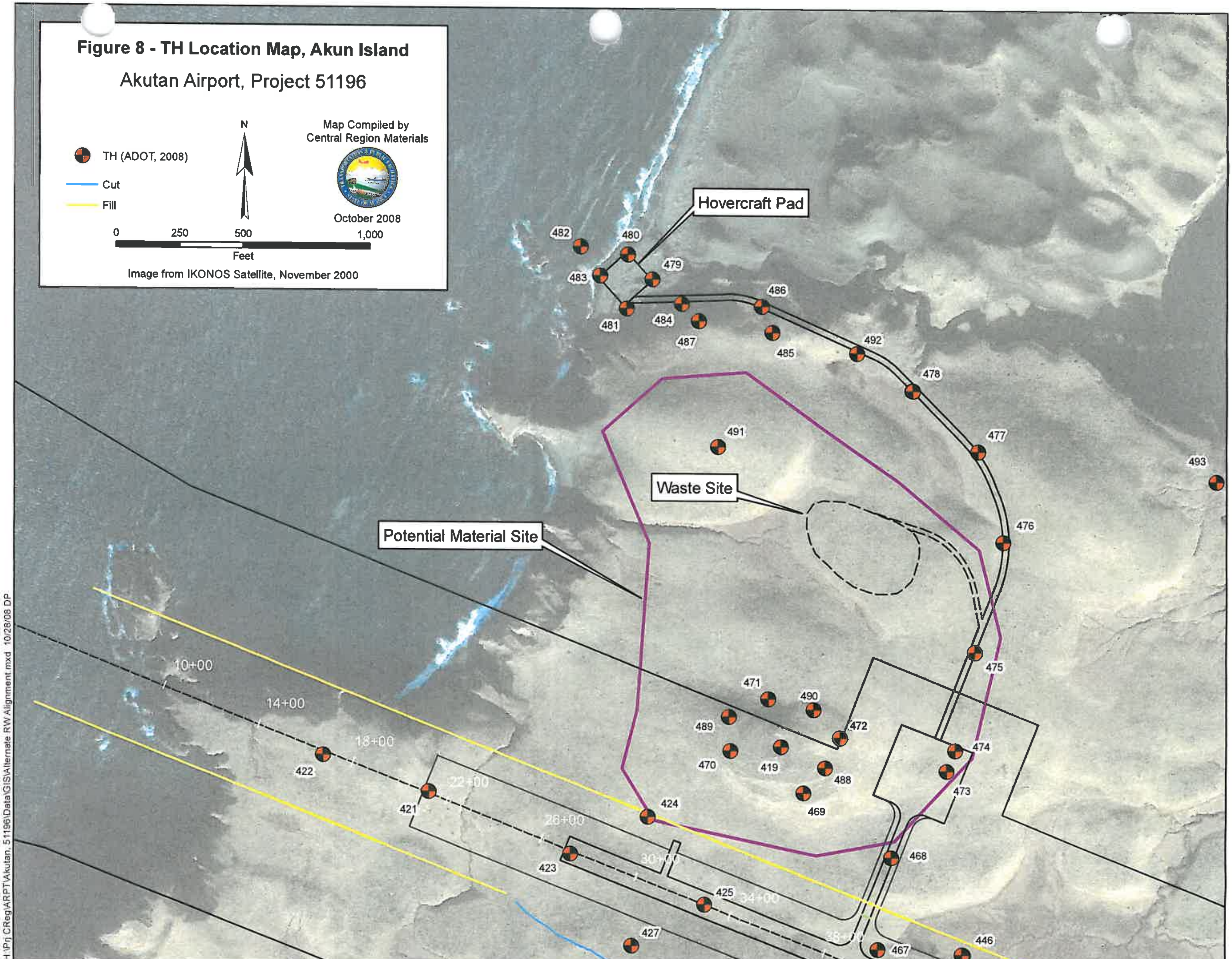
Prepared By:

Craig Boeckman, C.P.G.
Regional Geologist
Central Region Materials

Barry A. Benko, C.P.G.
Engineering Geologist
Central Region Materials

Approved By:

Newton Bingham, P.E.
Regional Materials Engineer
Central Region Materials



H:\Prj CReg\ARPT\Akutan, 51196\Data\GIS\Alternate RW Alignment.mxd 10/28/08 DP

LOG OF TEST HOLE

HOLE # 479

STATE OF ALASKA DOT&PF
Central Region Materials
Geology Section

PROJECT NUMBER :*51196*
PROJECT :*Akutan Development*
NORTHING : *1310743.46909*, ***EASTING :*** *5500017.71052*

Station / Location: *Akun Island*
Offset:
Elevation:

Equipment_Type: *CME 45 C*
Drilling Method: *Hollow-stem Auger, 6-5/8" OD*
Field Crew: *T. Johnson & C. Roach*

Total Depth: *26.5 feet*
Date: *7/24/2008 - 7/24/2008*
Geologist: *B.A. Benko*

Ground Water Data

Depth in (ft.)	5.5	
Time		
Date		
Symbol	▼	

Surface Veg: almost none, beach

Sample Data

Depth (Feet)	Sample Type	Number	Blow Count	N-Value	USCS Classification
5.5–7	SPT	BB336	2, 1, 6		GP
10–11.5	SPT	BB337(SNT)	5, 11, 17	28	SP
19.5–20.5	SPT	BB338(SNT)	10, 18		SP

SUBSURFACE MATERIAL

0.0	**SAND** (SP) dry, - est. <1% fines; uniformly graded; fine-grained sand; occasional organic strands 0 to 2 ft depth;
	BB336 Moisture=9.6%, Org=0.6%
5.8	**GRAVEL with Sand with Cobbles**(GP) Contains cobbles
8.5	**SAND** (SP) - est. <10% fines.
	No sample. 0.5 ft sand heave
20.0	@20-ft sample: 10% fine, rounded gravel clasts to 1/2 in. max size recovered; silt pockets created by decomposition of soft pebbles.
	No sample. 2.5 ft sand heave
26.3	**Bedrock**
26.5	BOH 26.5

☒ CME Auto Hammer ☐ Cathead Rope Method ☒ 140 lb. hammer with 30 in. drop ☐ 340 lb. hammer with 30 in. drop

A USCS LOG OF TEST HOLE AKUTAN - FINAL 401 THRU 494_REV11-17-08.GPJ 2006DATATEMPLATE.GDT 11/18/08

LOG OF TEST HOLE

HOLE # 480

STATE OF ALASKA DOT&PF
Central Region Materials
Geology Section

PROJECT NUMBER : 51196
PROJECT : Akutan Development
NORTHING : 1310838.71681, **EASTING :** 5499922.20965

Station / Location: Akun Island
Offset:
Elevation:

Equipment_Type: CME 45 C
Drilling Method: Hollow-stem Auger, 6-5/8" OD
Field Crew: T. Johnson & C. Roach

Total Depth: 30.0 feet
Date: 7/25/2008 - 7/25/2008
Geologist: B.A. Benko

Ground Water Data

Depth in (ft.)	5	
Time		
Date		
Symbol	▼	

Surface Veg: none (Beach)

Depth (Feet)	Sample Type	Number	Blow Count	N-Value	USCS Classification	Subsurface Material	Depth to boundary
0					SP	SAND (SP) dry	0.0
3	AUGER	BB339				BB339 p200=1%, Sa=68%, Gr=31%	
3.8					SP	SAND with Gravel(SP)	3.8
5–6.5	SPT	BB340 (SNT)	20 18 17	35			
7.0					GP	GRAVEL with Sand(GP) - cobbles present(?)	7.0
8.0					SP	SAND with Gravel(SP)	8.0
9.7					SP	SAND (SP)	9.7
10–11.5	SPT	'	3 12 23	35			
12.5					GP	GRAVEL (GP) - est. by drill reaction	12.5
13.0					SP	SAND (SP) - est. by drill reaction	13.0
14.0					GP	GRAVEL (GP) - est. by drill reaction	14.0
15.0					SP	SAND (SP)	15.0
15–16.5	SPT	'	6 15 27	42			
20						5 ft sand heave. No sample.	
25						0.5 ft sand heave. No sample.	
30					BOH 30	0.5 ft sand heave. No sample.	30.0

☒ CME Auto Hammer ☐ Cathead Rope Method ☒ 140 lb. hammer with 30 in. drop ☐ 340 lb. hammer with 30 in. drop

A USCS LOG OF TEST HOLE AKUTAN - FINAL 401 THRU 494_REV11-17-08.GPJ 2006DATATEMPLATE.GDT 11/18/08

LOG OF TEST HOLE

HOLE # 481

STATE OF ALASKA DOT&PF
Central Region Materials
Geology Section

PROJECT NUMBER : *51196*
PROJECT : *Akutan Development*
NORTHING : *1310627.74435*, **EASTING :** *5499916.79495*

Station / Location: *Akun Island*
Offset:
Elevation:

Equipment_Type: *CME 45 C*
Drilling Method: *Hollow-stem Auger, 6-5/8" OD*
Field Crew: *T. Johnson & C. Roach*

Total Depth: *20.0 feet*
Date: *7/25/2008 - 7/25/2008*
Geologist: *B.A. Benko*

Ground Water Data

Depth in (ft.)	5	
Time		
Date		
Symbol	▼	

Surface Veg: bare at TH location; adjacent mounds support lush cover Sawgrass, Lupines

Depth (Feet)	Sample Type	Number	Blow Count	Sample	Recovery	N-Value	USCS Classification	Frozen Zone	Soil Graphic	SUBSURFACE MATERIAL	Depth
0							SP			**SAND** (SP) dry, About 1% fines.	0.0
3							SP-SM			**SAND with Silt** (SP-SM) About 10% fines. Some silt layers	3.0
5 ▼	SPT	BB341(SNT)	1 2 2	X		4					
6							GP			**GRAVEL with Sand** (GP) Contains cobbles	6.0
9	SPT	BB342(SNT)	14 27 37	X							
9.5							GP-GM			**GRAVEL with Silt** (GP-GM) About 10% fines	9.5
13							SP			**SAND** (SP) About 3% fines. About 15% gravel.	13.0
15	SPT	'	4 9 18	X			SP			**SAND with Gravel** (SP)	15.0
19	SPT	'	3 25	X						**Bedrock**	19.0
20									BOH 20		20.0

☒ CME Auto Hammer ☐ Cathead Rope Method ☒ 140 lb. hammer with 30 in. drop ☐ 340 lb. hammer with 30 in. drop

A USCS LOG OF TEST HOLE AKUTAN - FINAL 401 THRU 494_REV11-17-08.GPJ 2006DATATEMPLATE.GDT 11/18/08

LOG OF TEST HOLE

HOLE # 482

STATE OF ALASKA DOT&PF
Central Region Materials
Geology Section

PROJECT NUMBER : *51196*
PROJECT : *Akutan Development*
NORTHING : *1310869.49599*, **EASTING :** *5499734.85721*

Station / Location: *Akun Island*
Offset:
Elevation:

Equipment_Type: *CME 45 C*
Drilling Method: *Hollow-stem Auger, 6-5/8" OD*
Field Crew: *T. Johnson & C. Roach*

Total Depth: *15.0 feet*
Date: *7/26/2008 - 7/26/2008*
Geologist: *B.A. Benko*

Ground Water Data

Depth in (ft.)	0.5	
Time		
Date		
Symbol	▼	

Surface Veg: Beach in Intertidal zone

Depth (Feet)	Sample Type	Number	Blow Count	Sample Recovery	N-Value	USCS Classification	Frozen Zone	Soil Graphic	SUBSURFACE MATERIAL	Depth
0						SP			**SAND** (SP) dry, About 1% fines.	0.0
4						GP			**GRAVEL with Sand**(GP)	4.0
5–6.5	SPT	BB343(SNT)	6 11 19		30					
7						SP			**SAND with Gravel**(SP)	7.0
10									No sample due to sand heave	
14									No sample due to sand heave	
15								BOH 15		15.0

☒ CME Auto Hammer ☐ Cathead Rope Method ☒ 140 lb. hammer with 30 in. drop ☐ 340 lb. hammer with 30 in. drop

A USCS LOG OF TEST HOLE AKUTAN - FINAL 401 THRU 494_REV11-17-08.GPJ 2006DATATEMPLATE.GDT 11/18/08

LOG OF TEST HOLE

HOLE # 483

STATE OF ALASKA DOT&PF
Central Region Materials
Geology Section

PROJECT NUMBER : *51196*
PROJECT : *Akutan Development*
NORTHING : *1310755.90838*, **EASTING :** *5499811.9088*

Station / Location: *Akun Island*
Offset:
Elevation:

Equipment_Type: *CME 45 C*
Drilling Method: *Hollow-stem Auger, 6-5/8" OD*
Field Crew: *T. Johnson & C. Roach*

Total Depth: *14.8 feet*
Date: *7/26/2008 - 7/26/2008*
Geologist: *B.A. Benko*

Ground Water Data

Depth in (ft.)	3	
Time		
Date		
Symbol	▼	

Surface Veg: none (Beach)

Sample Data

Depth (Feet)	Sample Type	Number	Blow Count	Sample	Recovery	N-Value	USCS Classification	Frozen Zone	Soil Graphic
0–1		BB346					SP		
3 ▼							GP		
5–6.5	SPT	BB344	11, 16, 16			32			
7							SP		
8.5							SP		
10–11.5	SPT	BB345(SNT)	9, 14, 19			33			
13.5–14.8	SPT	BB347(SNT)	5, 9, 22						BOH 14.8

SUBSURFACE MATERIAL

Depth (ft)	Description
0.0	**SAND** (SP) dry, About 1% fines. BB346 (1-8.5 ft), p200=1%, Sa=74%, Gr=25%
3.0	**GRAVEL with Sand**(GP) Contains cobbles. BB344 Moisture=8.3%, Org=0.9%
7.0	**SAND with Gravel**(SP)
8.5	**SAND** (SP)
14.8	

☒ CME Auto Hammer ☐ Cathead Rope Method ☒ 140 lb. hammer with 30 in. drop ☐ 340 lb. hammer with 30 in. drop

A USCS LOG OF TEST HOLE AKUTAN - FINAL 401 THRU 494_REV11-17-08.GPJ 2006DATATEMPLATE.GDT 11/18/08

October 13, 2008

Ms. Susan Wilson
Duane Miller Associates
5821 Arctic Boulevard, Suite A
Anchorage, Alaska 99518-1654

Subject: Seismic Survey
Akutan Airport Relocation Project, Akutan and Akun Islands, AK
NORCAL Job Number 08-368.06

Dear Ms. Wilson:

This report presents the findings of a seismic survey performed by NORCAL Geophysical Consultants, Inc. on the Aleutian Islands of Akutan and Akun. The survey was performed during the period of August 11 – 22, 2008 by NORCAL Professional Geophysicist Donald J. Kirker. Field assistance, background information, and logistical support, were provided by Jeremiah Drage of Duane Miller Associates (DMA). Blasting services were provided by Buck and Kevin Kuhn of Statewide Blasting and Perforating Service.

SITE DESCRIPTION

The Akutan Airport Relocation Project is a feasibility study for the construction of a proposed airport runway and hovercraft landing ramp. The airport runway will be located at the south end of Akun Island. The hovercraft landing ramp will be located at the west end of the village of Akutan on Akutan Island, as shown on Plate 1.

The seismic survey on Akun was conducted along 13 seismic lines at 7 sites, as determined by DMA. Eleven of the lines were distributed at six sites near the footprint of the proposed runway. They are designated as Sites 1 through 6 on Plate 1. The remaining 2 lines were located on top of a ridge northeast of the runway. This area is designated as Site 7. The terrain is characterized by slightly rolling hills to moderately steep slopes covered with tundra. Basalt outcrops are evident at the tops of most of the small hills and ridges. Surface elevations along the seismic lines range from approximately 98 feet to over 380 feet above msl.

The seismic survey on Akutan, as determined by DMA, was conducted along one line (Line 14) positioned above the proposed hovercraft landing ramp, as shown on Plate 1. The terrain consists of a steep slope covered with tundra. Surface elevations along the line range from approximately 154 feet to over 285 feet above mean sea level (msl). Surface depressions related to past slope failures are evident within the area.

The local geology on both islands consists of welded ash flows and basalt overlain by colluvium. The character of the basalt ranges from massive, unfractured rock to columnar jointed and highly weathered rock.

OBJECTIVE AND SCOPE OF WORK

The objective of the geophysical investigation is to delineate subsurface variations in the seismic properties that can be related to thickness of overburden and depth to bedrock. This information may also be used to assess the excavation characteristics (rippability) of the overburden and rock materials.

To achieve this objective we conducted high resolution 2D seismic refraction (SR) and 1-D multi-channel analysis of surface waves (MASW) surveys, as directed by DMA. As a result, SR was conducted along Lines 1 through 13 on Akun and Line 14 on Akutan. The MASW survey was conducted at Site 1 along Line 2 on Akun. The scope of work also consists of analyzing and interpreting the geophysical data and presenting the results in a written report.

FIELD INVESTIGATION

SEISMIC REFRACTION

Methodology

The SR method is used to determine the compressional wave velocity of subsurface materials. The seismic velocity of fill, sediments, and rock are dependent on physical properties such as compaction, density, hardness, and induration. However, other factors such as bedding, jointing, fracturing, and saturation also affect seismic velocity. Typically, low velocities are indicative of loose soil, poorly compacted fill material, poorly consolidated sediments, and deeply weathered and highly fractured rock. Moderate velocities are usually indicative of more consolidated sediments, compacted fill, and/or highly to moderately weathered, jointed, and fractured rock. High velocities are indicative of slightly weathered to unweathered rock with little fracturing.

Data Acquisition

Akun Island

We obtained seismic refraction data along Lines 1 through 13, as shown on Plate 1. The seismic lines varied in length from 240 to 725 feet and consisted of one or two spreads. A spread consisted of 3 shot points and 24-geophones distributed in a collinear array. Two of the shot points were placed 5 to 10 feet off of each end. The third was positioned in the center of the spread. The geophones were spaced at 10 to 20 foot intervals along each spread. Given this geometry, each spread measured 240 to 500 feet long. The specifications of the seismic lines with regard to length, number of spreads, geophones per spread, geophone separation, and number of shot points, are listed in Table A, below.

Table A: Seismic Line Specifications

Line No.	Site	Length (ft)	No. of Spreads	Geophones per Spread	Geophone Separation (ft)	Shot Points per Line
1	Site 1	470	1	24	20	3
2	Site 1	725	2	24	20 & 10	6
3	Site 2	480	1	24	20	3
4	Site 2	480	1	24	20	3
5	Site 3	492	1	24	20	3
6	Site 3	500	1	24	20	3
7	Site 4	480	1	24	20	3
8	Site 4	480	1	24	20	3
9	Site 5	480	1	24	20	3
10	Site 5	480	1	24	20	3
11	Site 6	480	1	24	20	3
12	Site 7	240	1	24	10	3
13	Site 7	320	1	24	20	3

Statewide Blasting and Perforating Service produced seismic energy at each shot point by using 1/3 lb. charges of binary explosives buried at depths of approximately 2 to 3 ft. The charges were detonated by instantaneous electric blasting caps initiated by a high voltage, capacitor discharge blaster, connected to the seismograph.

Akutan Island

We obtained seismic refraction data along Line 14, as shown on Plate 1. It measured 240 feet and consisted of one spread, comprising 3 shot points and 24-geophones distributed in a collinear array. Two of the shot points were placed 5 feet off of each end. The third was positioned in the center. The geophones were spaced at 10 foot intervals.

We produced seismic energy at each shot point using multiple impacts with an 8-pound sledge hammer against a metal plate placed on the ground surface. An accelerometer attached to the hammer transmitted an electrical pulse to the seismograph each time the plate was struck, triggering a recording event.

Equipment

The P-waves produced by the sledge hammer and explosives were detected by a collinear array of 24-Mark Products geophones with a natural frequency of 10-Hz. The geophones were connected by seismic spread cables to a Geometrics ***Geode*** 24-channel distributed array seismic system. The analog signals transmitted by the geophones were digitized by the ***Geodes*** 24-bit analog to digital converters, amplified, conditioned and processed, and then transmitted via a network cable to a Panasonic ***Toughbook*** field computer where the signals were displayed and recorded.

We used a Trimble global positioning system (GPS) with sub-meter accuracy to measure the geographical coordinates of each shot point and geophone. These positions were differentially corrected and exported for data analysis, using the US State Plane 1983, Alaska Zone 10, NAD 1983 (Aleutian Island) coordinates.

Data Analysis Procedures

Prior to the computer analysis, we determined the location and elevation of all shot points and geophone positions based on the GPS coordinates. The seismic data were then analyzed using the computer program ***Seisimager*** by Geometrics, Inc. This is an interactive program that is used to determine the shot point to geophone travel times, and to compute a 2D model based on those times. Once the travel times for a given line have been determined, the program uses those times, along with the shot point and geophone elevations and locations, to compute a preliminary 2D seismic model using a time-delay method. The program then uses a tomographic routine and ray-tracing procedure to compute synthetic travel-times according to the preliminary model. The program then compares the synthetic travel times with the measured travel times and adjusts the 2D model accordingly. Typically, it takes 10- to 20-iterations of this procedure to produce a 2D model that provides a close fit to the measured travel times. Once a satisfactory model is computed, the software contours the model velocities to produce a seismic velocity vs. depth and distance cross-section (profile). More detailed descriptions of the SR methodology, data acquisition, and data analysis procedures are provided in Appendix A.

MASW

Methodology

The MASW method is used to determine the seismic velocity of shear S-waves in subsurface materials. When seismic waves are generated at or near the ground surface, both body and surface waves are generated. Body waves consist of both compressional (P) and shear (S) waves. Surface waves, commonly referred to as ground roll in seismic surveys, account for more than two-thirds of the energy produced by vertical seismic energy sources. As a result, surface waves are the most prominent signal on multi-channel seismic records. In addition, surface waves have dispersion properties that body waves lack. That is, different wavelengths have different penetration depths and, therefore, propagate at different velocities. By analyzing the dispersion of surface waves it is possible to obtain a near-surface S-wave velocity profile. Since S-wave velocity is directly proportional to shear modulus, this provides a direct indication in the variation of stiffness (or rigidity) of subsurface materials.

Data Acquisition and Analysis Procedures

We collected the MASW data along Line 2 on Akun using roll-along techniques similar to those used in seismic reflection surveys. Our procedure was to distribute 48-geophones along the line at 10-ft intervals in a collinear array (spread). We then generated surface waves at shot points distributed at 20-ft intervals along the traverse. For each shot point, the signals from 24 contiguous geophones were selected using a roll box and were recorded using a 24-channel seismograph.

We began the survey with geophones 1 through 24 active, and the shot point positioned 20-ft from the first geophone. After recording the data (shot gather) we moved the shot point 20-ft along the line and used the roll box to activate geophones 3 through 26. We continued in this manner, moving both the shot point and the active 24-geophone array 20-ft at a time until the last 24 geophones in the array were active. We then picked up the first 24 geophones and moved them to the end of the array and continued the data acquisition to cover the total length of each profile. We used the same seismic sources and seismograph system as was used for the SR survey.

Upon completion of the MASW survey, we downloaded the seismic data to a lap-top computer. These data were used to produce a 2-D cross-section illustrating variations in Vs with depth and distance beneath the seismic line. It should be noted that the 2D cross-section does not cover the entire length of the geophone array. This is because the 1D Vs models comprising the section are plotted beneath the center of their respective 24-geophone arrays. As a result, there is no coverage beneath the outermost 12-geophones at either end of the line. Further descriptions of the MASW methodology, data acquisition, and analysis are provided in Appendix A.

RESULTS

The results of the SR and MASW surveys are presented by the seismic velocity profiles on Plates 2 through 10. The SR velocity profiles for Lines 1 through 14 are shown on Plate 2 through 10. The MASW profile for Line 2 is shown below the SR profile on Plate 3. On each profile the vertical axis represents elevation (above mean sea level) and the horizontal axis represents distance. The SR and MASW profiles depict the ground surface, and show color contours representing the range in compressional P-wave (Vp) and shear S-wave (Vs) velocities, respectively.

The SR velocity profiles (Plates 2 through 10) indicate average seismic velocities ranging from 500 to over 12,000 ft/s to depths of 50 to over 100 feet. With each seismic line, the contours indicate a gradual increase in velocity with depth. Typically, velocities at the low end of this range (500 to 3,000 ft/s) represent unconsolidated to semi-consolidated sediments such as surficial soils and colluvium. Velocities at the upper end of this range (8,000 to over 12,000 ft/s) typically represent more competent rock, such as unfractured basalt. Seismic velocities within the range of 3,000 to 8,000 ft/s are typical of consolidated colluvium and rock with varying degrees of fracturing and jointing. This is especially true along Line 3 (Site 2) where velocities of 4,000 to 6,000 ft/s were defined over outcropping columnar jointed basalt. In this case, the resulting velocities are probably reduced due to the columnar jointing of the rock.

The MASW velocity profile on the bottom half of Plate 3 indicates average S-wave velocities of 500 to 4,300 ft/s to depths of 95 to over 140 feet. The gradational color scale indicates that S-wave velocities increase gradually with depth. This profile does not show lower velocities at depth that would indicate less competent rock beneath a harder cap rock.

EXCAVATION CHARACTERISTICS

As stated previously, rock outcrops were observed throughout most of the area of investigation. The bedrock velocities range from about 3,000-ft/sec to over 12,000 ft/s, with most of the subsurface consisting of 8,000 to 12,000 ft/s material.

In the industry, velocity is commonly related to rippability. However, the information shown on the seismic velocity profiles should only be used as a general guide, as many other factors should also be considered. These factors include rock jointing and fracture patterns, the experience of the equipment operator, and the equipment and excavation methods selected. Also, the computed velocities measured along each profile are an average for each layer. Therefore, there may be localized zones within each layer where the velocities may be higher or lower than indicated. Since the accuracy of our findings is subject to these limitations, it should be noted that subsurface conditions may vary from those depicted in the final results. A more detailed discussion of the limitations with regard to the seismic refraction method is presented in Appendix A.

STANDARD OF CARE

The scope of NORCAL's services for this project consisted of using geophysical methods to create subsurface velocity profiles. The accuracy of our findings is subject to specific site conditions and limitations inherent to the techniques used. We performed our services in a manner consistent with the standard of care ordinarily exercised by members of the profession currently employing similar methods. No warranty, with respect to the performance of services or products delivered under this agreement, expressed or implied, is made by NORCAL.

We appreciate having the opportunity to provide you with this information.

Respectfully,

NORCAL Geophysical Consultants, Inc.

Donald J. Kirker

Donald J. Kirker
Geophysicist, GP-997

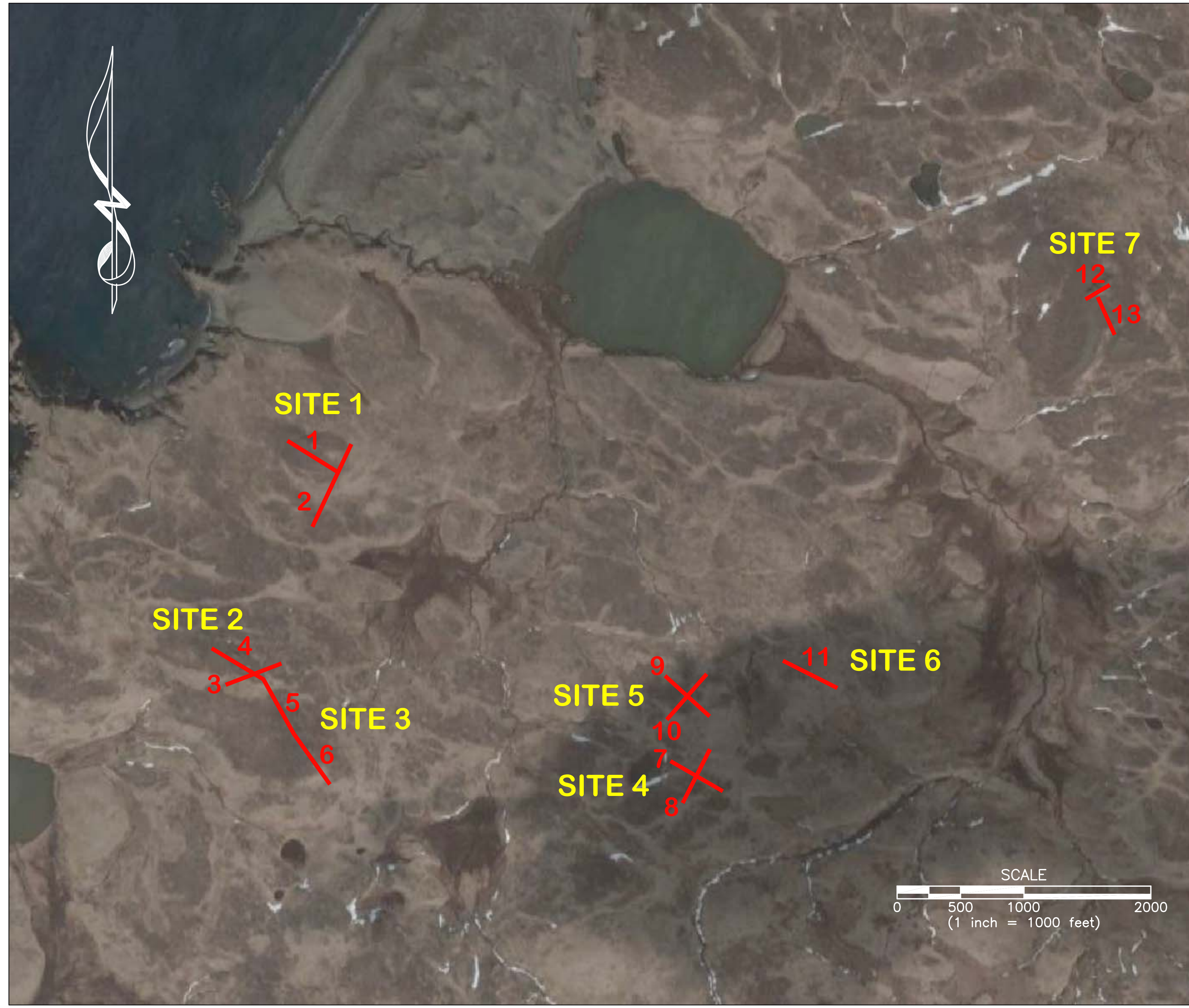
DJK/tt

Enclosures: Plates 1 through 10
Appendix A - Seismic Methods

VICINITY MAP

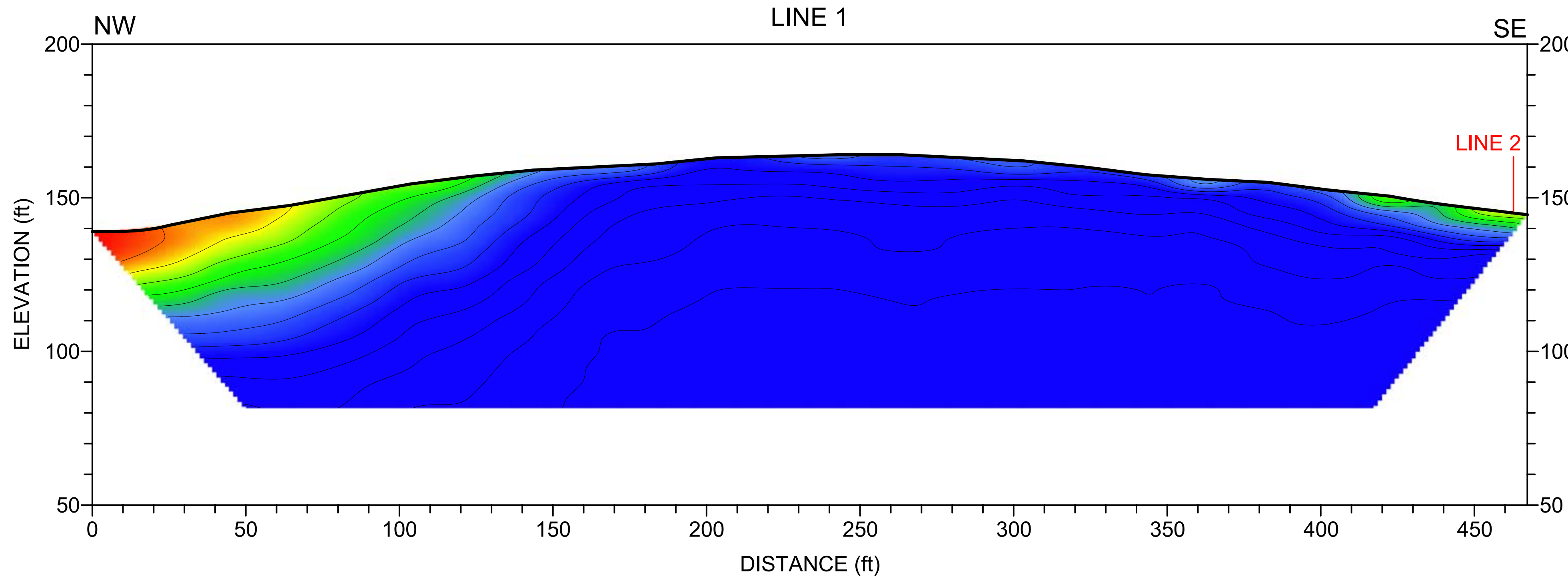
AKUTAN ISLAND

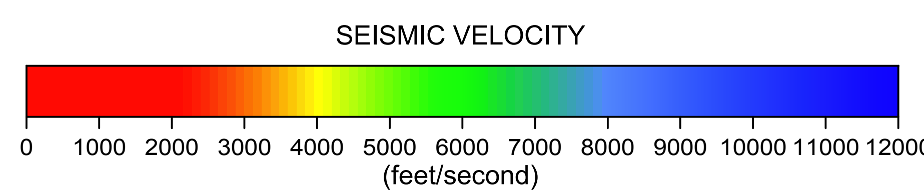
AKUN ISLAND

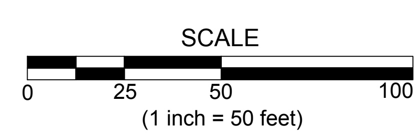


LEGEND	
—	SEISMIC REFRACTION PROFILE

NORCAL	SITE LOCATION MAPS SEISMIC REFRACTION SURVEY	
	LOCATION: AKUN & AKUTAN ISLANDS, ALASKA	
	CLIENT: DUANE MILLER & ASSOCIATES	PLATE
JOB #: 08-368.06	NORCAL GEOPHYSICAL CONSULTANTS INC.	1
DATE: SEP. 2008	DRAWN BY: G.RANDALL / APPROVED BY: DJK	

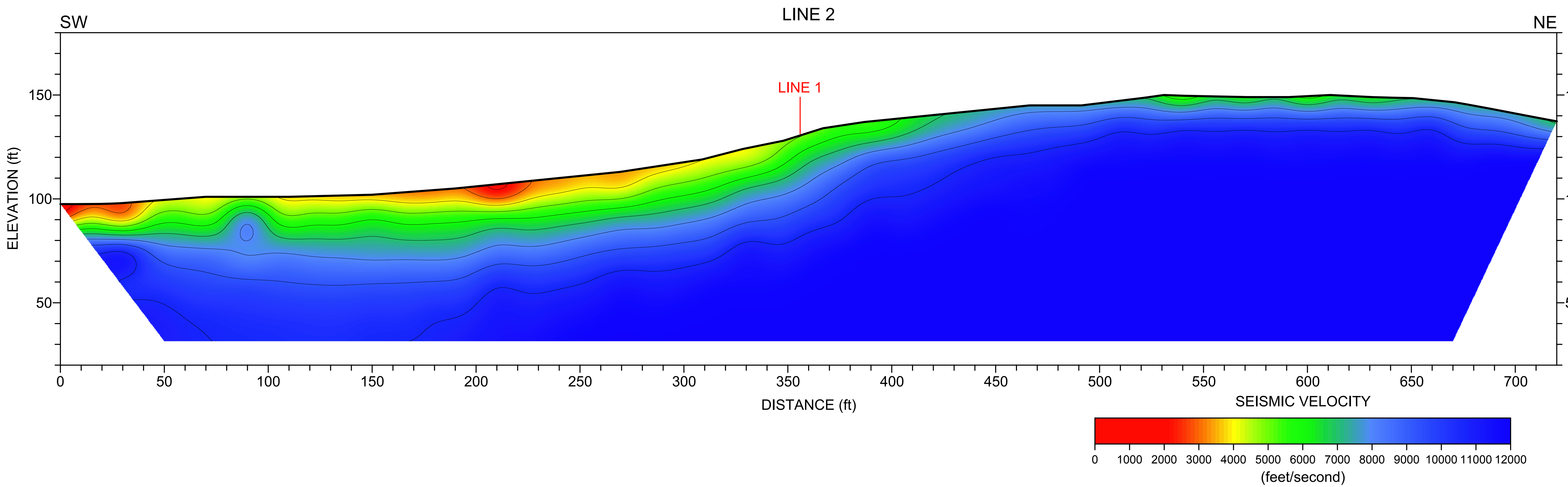


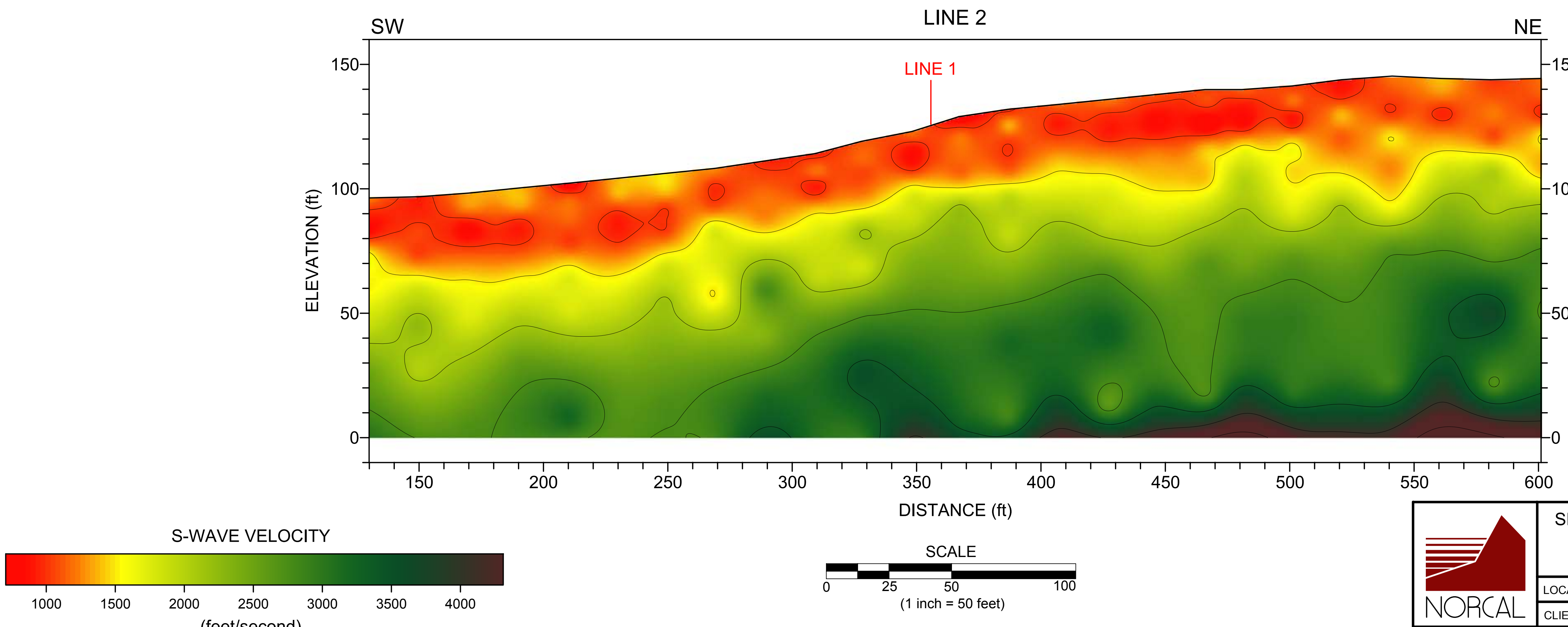




NORCAL

SEISMIC REFRACTION PROFILE LINE 1 AKUN ISLAND - SITE 1	
LOCATION: AKUN, ALASKA	
CLIENT: DUANE MILLER ASSOCIATES	PLATE 2
JOB #: 08-368.06	NORCAL GEOPHYSICAL CONSULTANTS INC.
DATE: SEPT. 2008	DRAWN BY: D. KIRKER · APPROVED BY: DJK





NORCAL

SEISMIC REFRACTION & MASW PROFILES
LINE 2
AKUN ISLAND - SITE 1

LOCATION: AKUN, ALASKA

CLIENT: DUANE MILLER ASSOCIATES

JOB #: 08-368.06

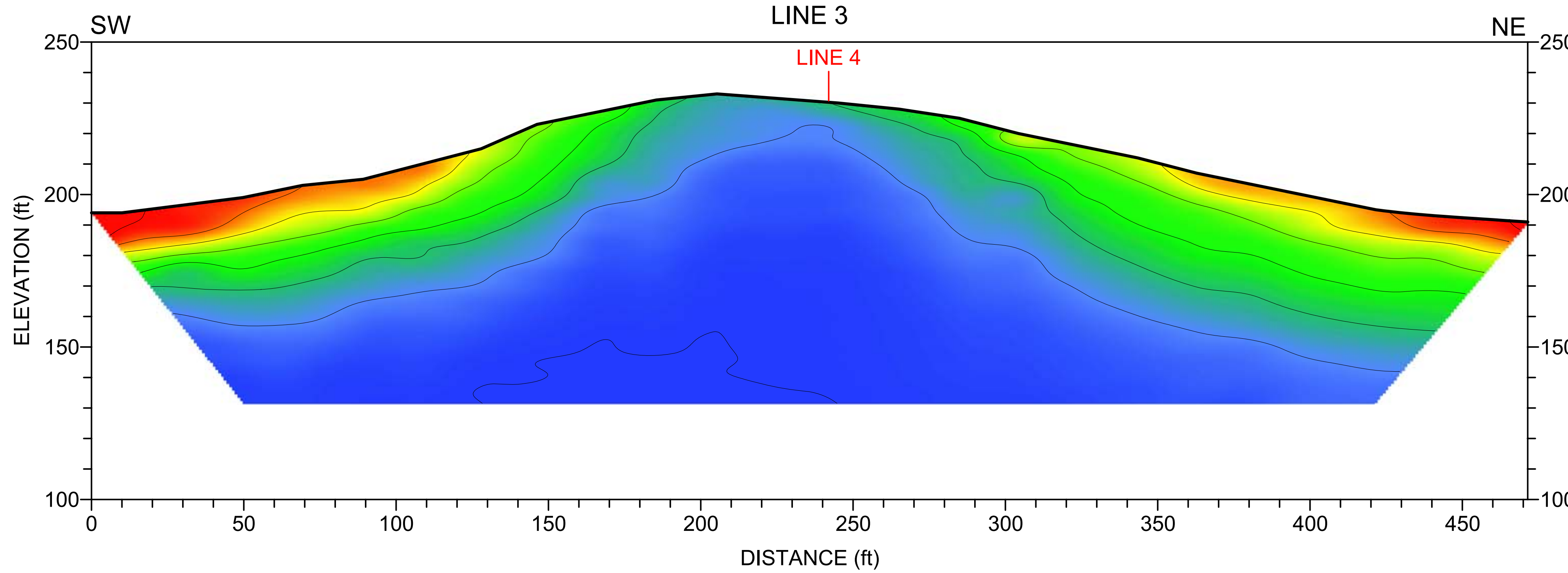
NORCAL GEOPHYSICAL CONSULTANTS INC.

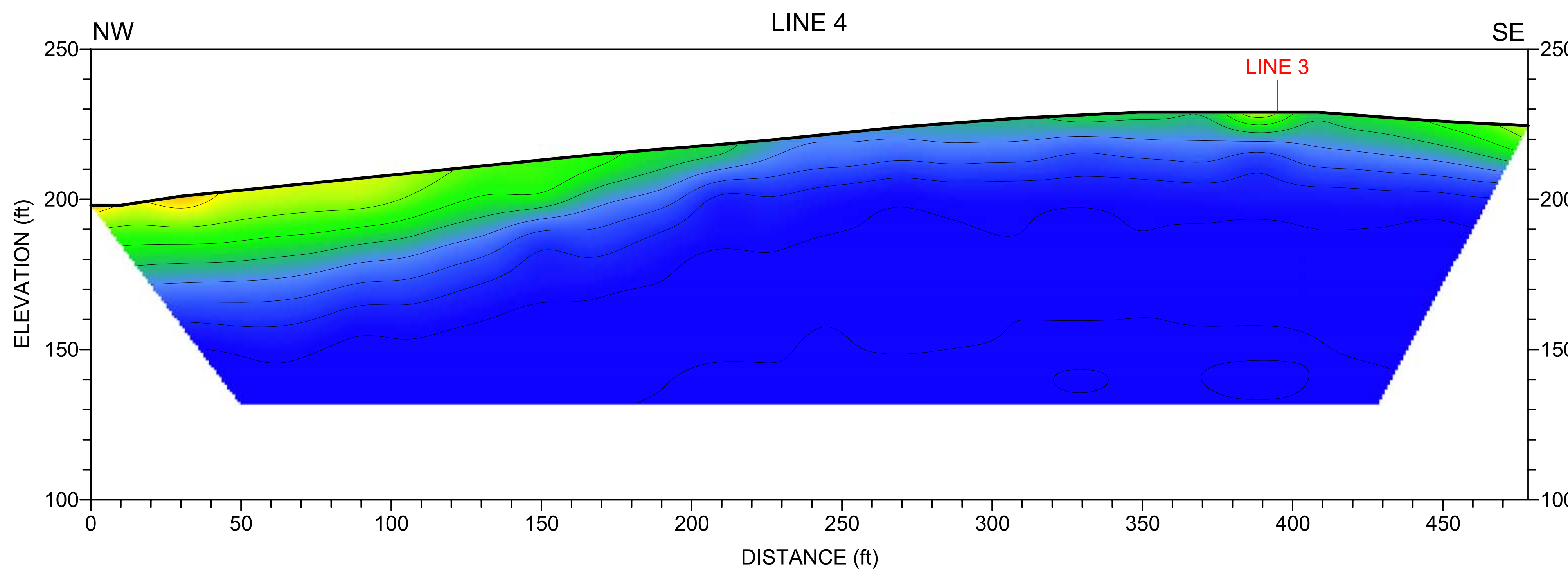
DATE: SEPT. 2008

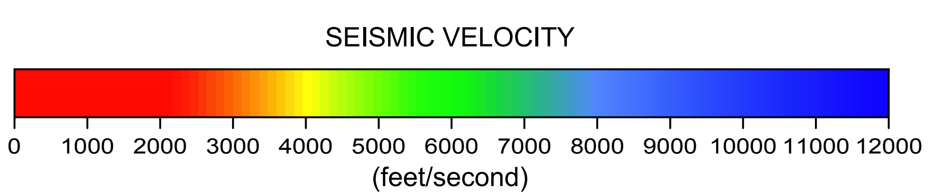
DRAWN BY: D. KIRKER

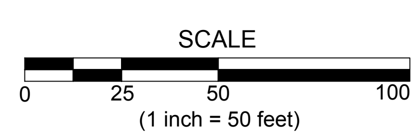
APPROVED BY: DJK

PLATE
3









NORCAL

SEISMIC REFRACTION PROFILE
LINES 3 & 4
AKUN ISLAND - SITE 2

LOCATION: AKUN, ALASKA

CLIENT: DUANE MILLER ASSOCIATES

NORCAL GEOPHYSICAL CONSULTANTS INC.

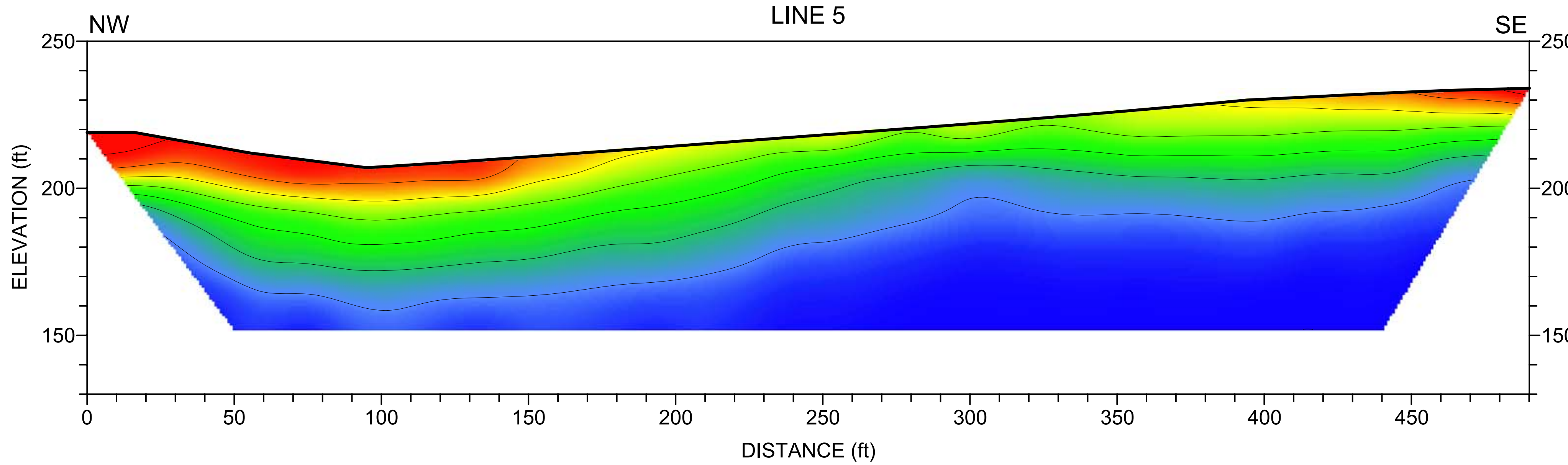
JOB #: 08-368.06

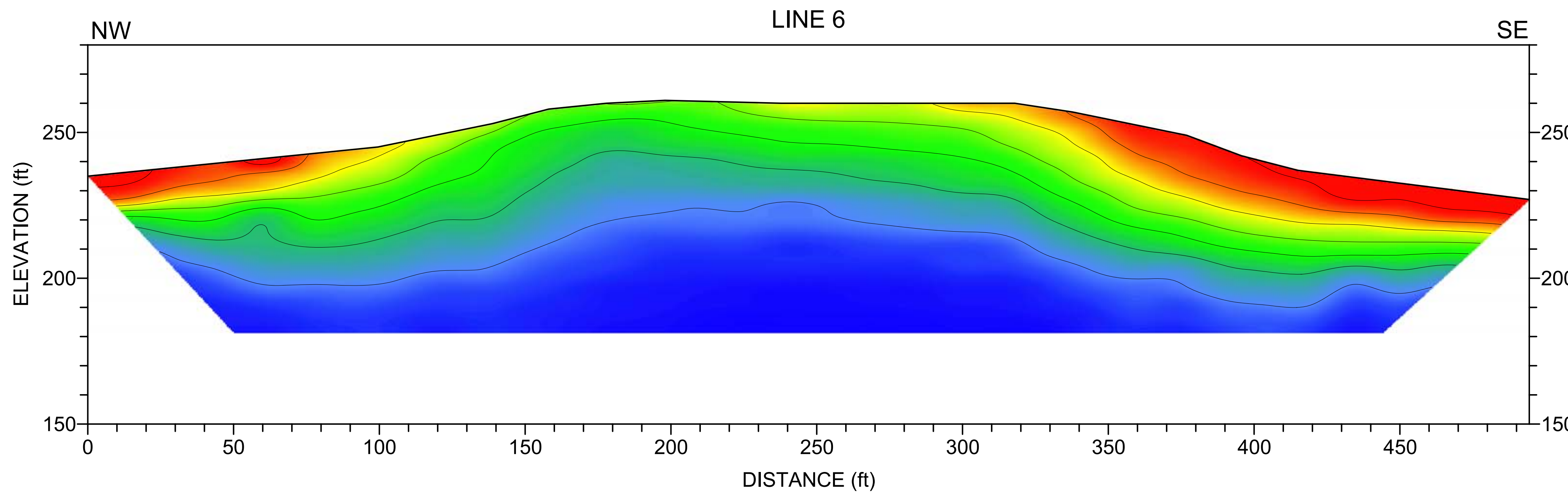
DATE: SEPT. 2008

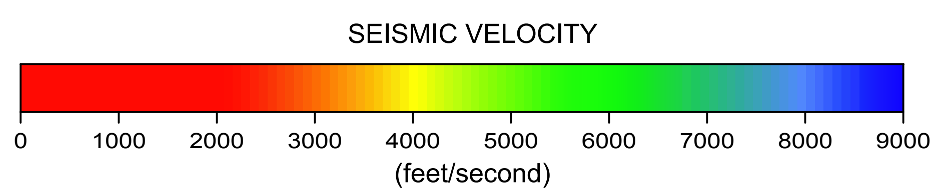
DRAWN BY: D. KIRKER

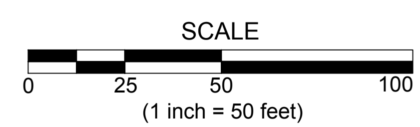
APPROVED BY: DJK

PLATE 4









NORCAL

SEISMIC REFRACTION PROFILE
LINES 5 & 6
AKUN ISLAND - SITE 3

LOCATION: AKUN, ALASKA

CLIENT: DUANE MILLER ASSOCIATES

JOB #: 08-368.06

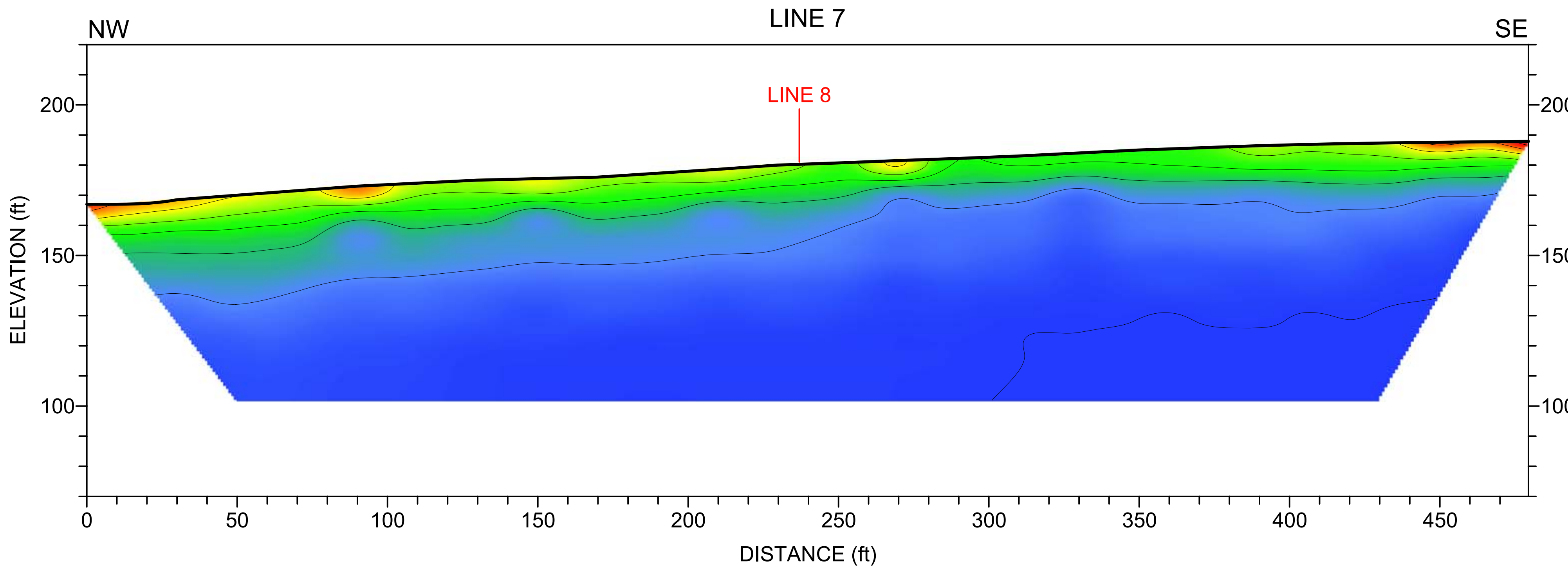
NORCAL GEOPHYSICAL CONSULTANTS INC.

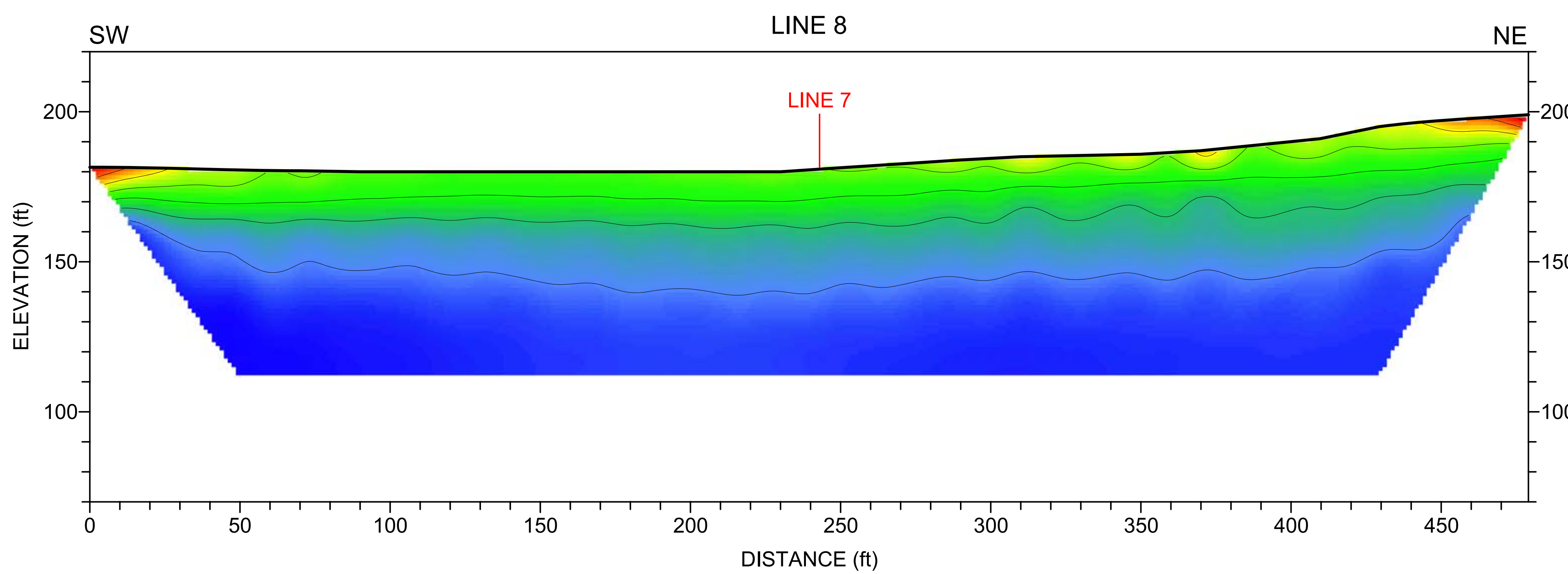
DATE: SEPT. 2008

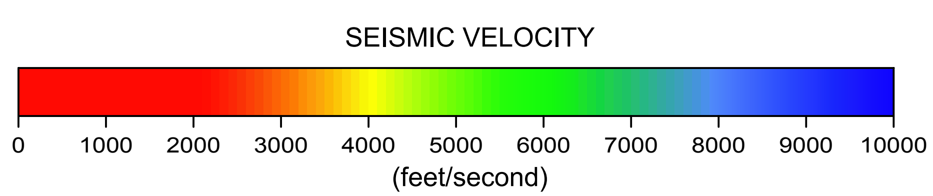
DRAWN BY: D. KIRKER

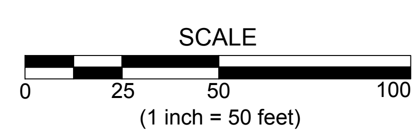
APPROVED BY: DJK

PLATE 5









NORCAL

SEISMIC REFRACTION PROFILE
LINE 7 & 8
AKUN ISLAND - SITE 4

LOCATION: AKUN, ALASKA

CLIENT: DUANE MILLER ASSOCIATES

JOB #: 08-368.06

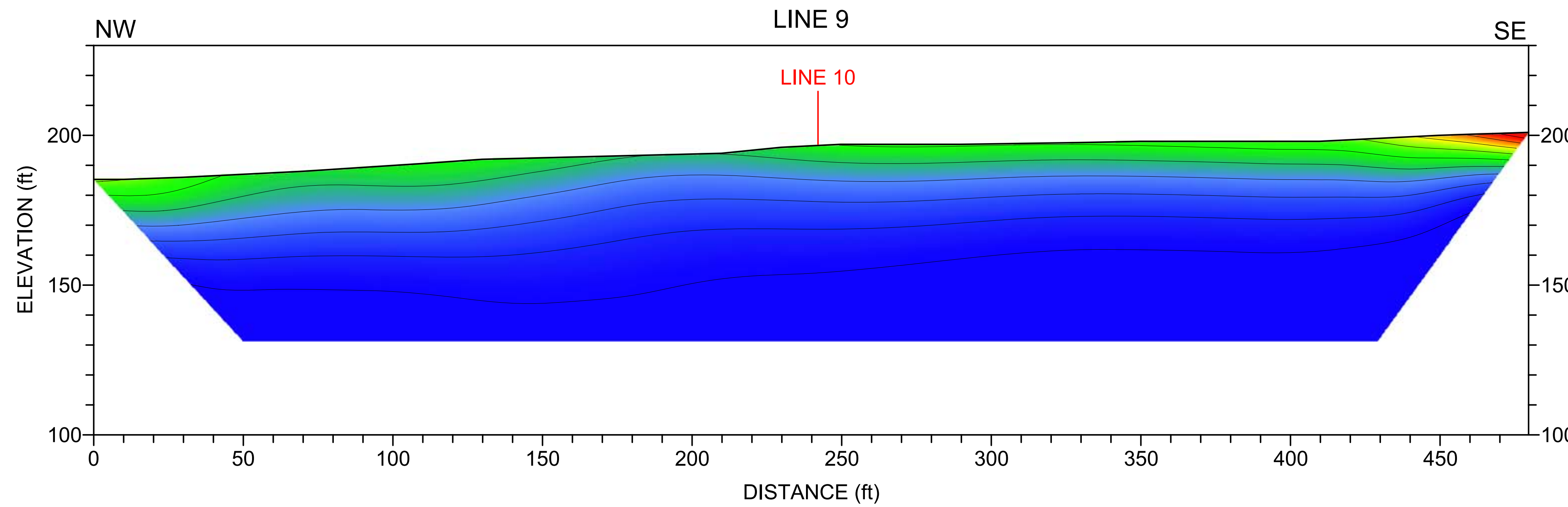
NORCAL GEOPHYSICAL CONSULTANTS INC.

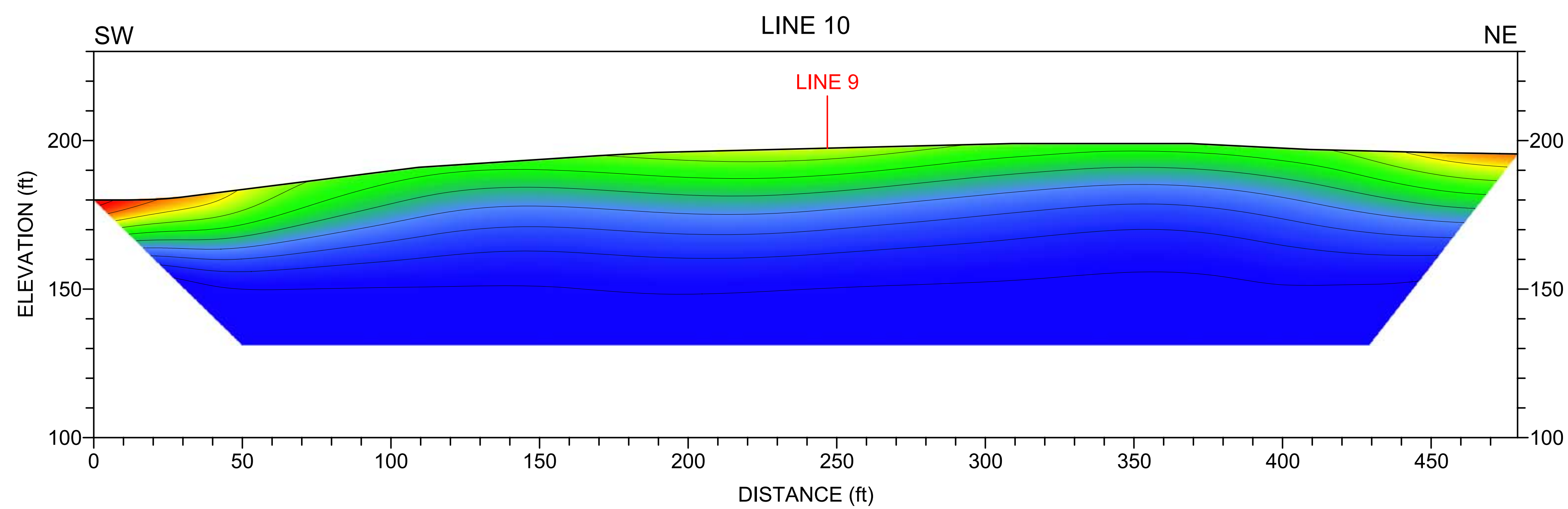
DATE: SEPT. 2008

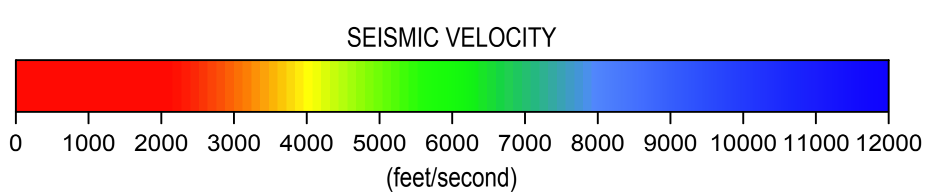
DRAWN BY: D. KIRKER

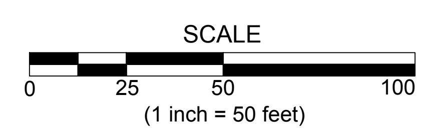
APPROVED BY: DJK

PLATE
6









NORCAL

SEISMIC REFRACTION PROFILE
LINE 9 & 10
AKUN ISLAND - SITE 5

LOCATION: AKUN, ALASKA

CLIENT: DUANE MILLER ASSOCIATES

JOB #: 08-368.06

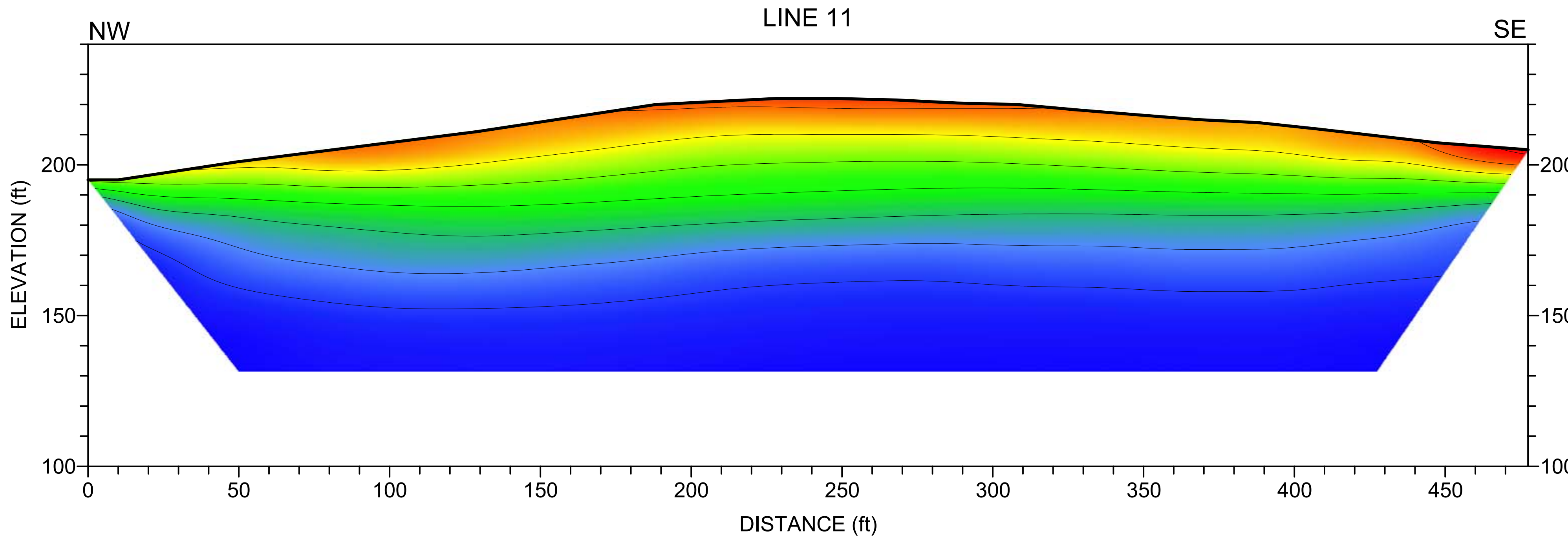
NORCAL GEOPHYSICAL CONSULTANTS INC.

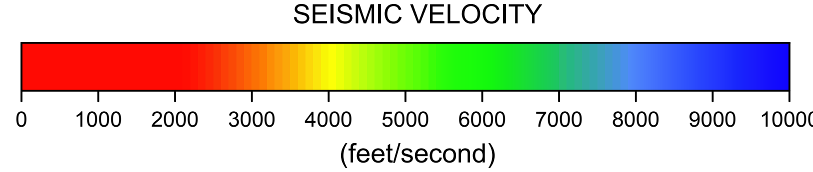
DATE: SEPT. 2008

DRAWN BY: D. KIRKER

APPROVED BY: DJK

PLATE
7



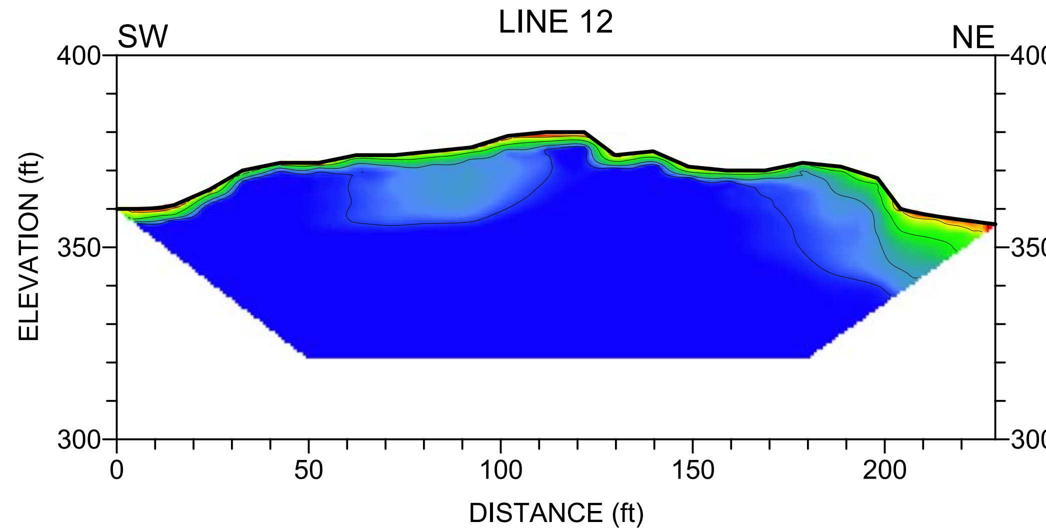


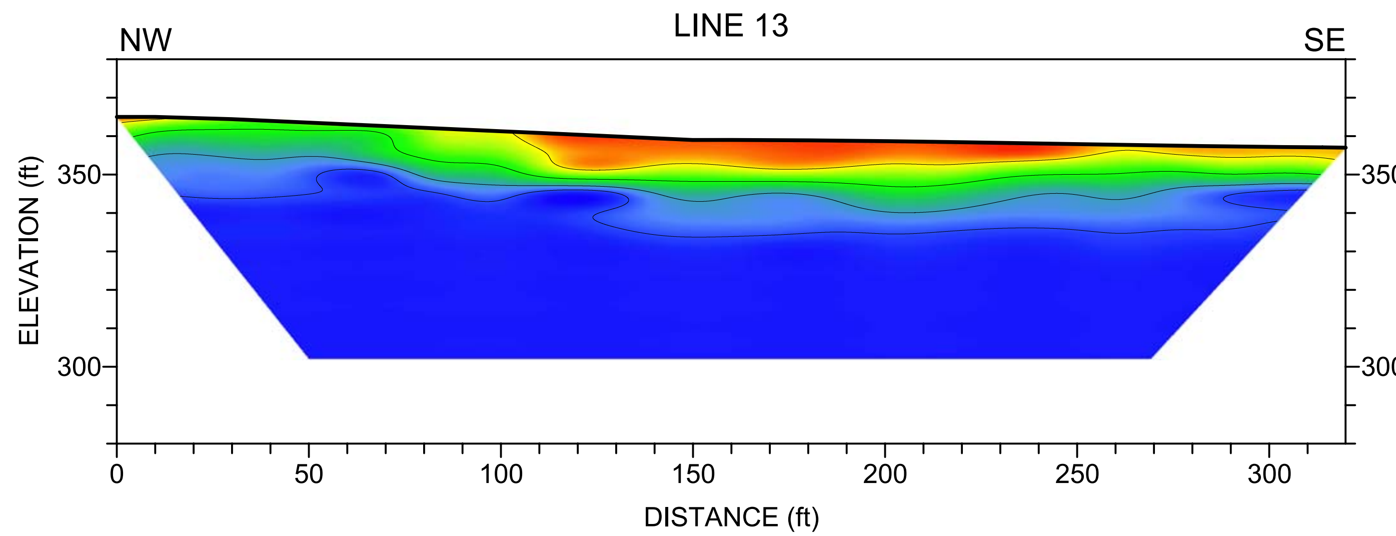
SCALE

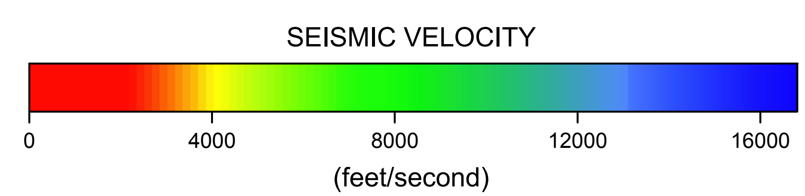
0 25 50 100

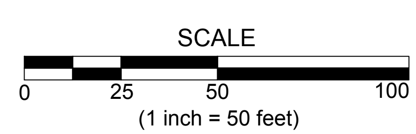
(1 inch = 50 feet)

NORCAL	SEISMIC REFRACTION PROFILE LINE 11 AKUN ISLAND - SITE 6	
	LOCATION: AKUN, ALASKA	
	CLIENT: DUANE MILLER ASSOCIATES	PLATE
JOB #: 08-368.06	NORCAL GEOPHYSICAL CONSULTANTS INC.	8
DATE: SEPT. 2008	DRAWN BY: D. KIRKER · APPROVED BY: DJK	



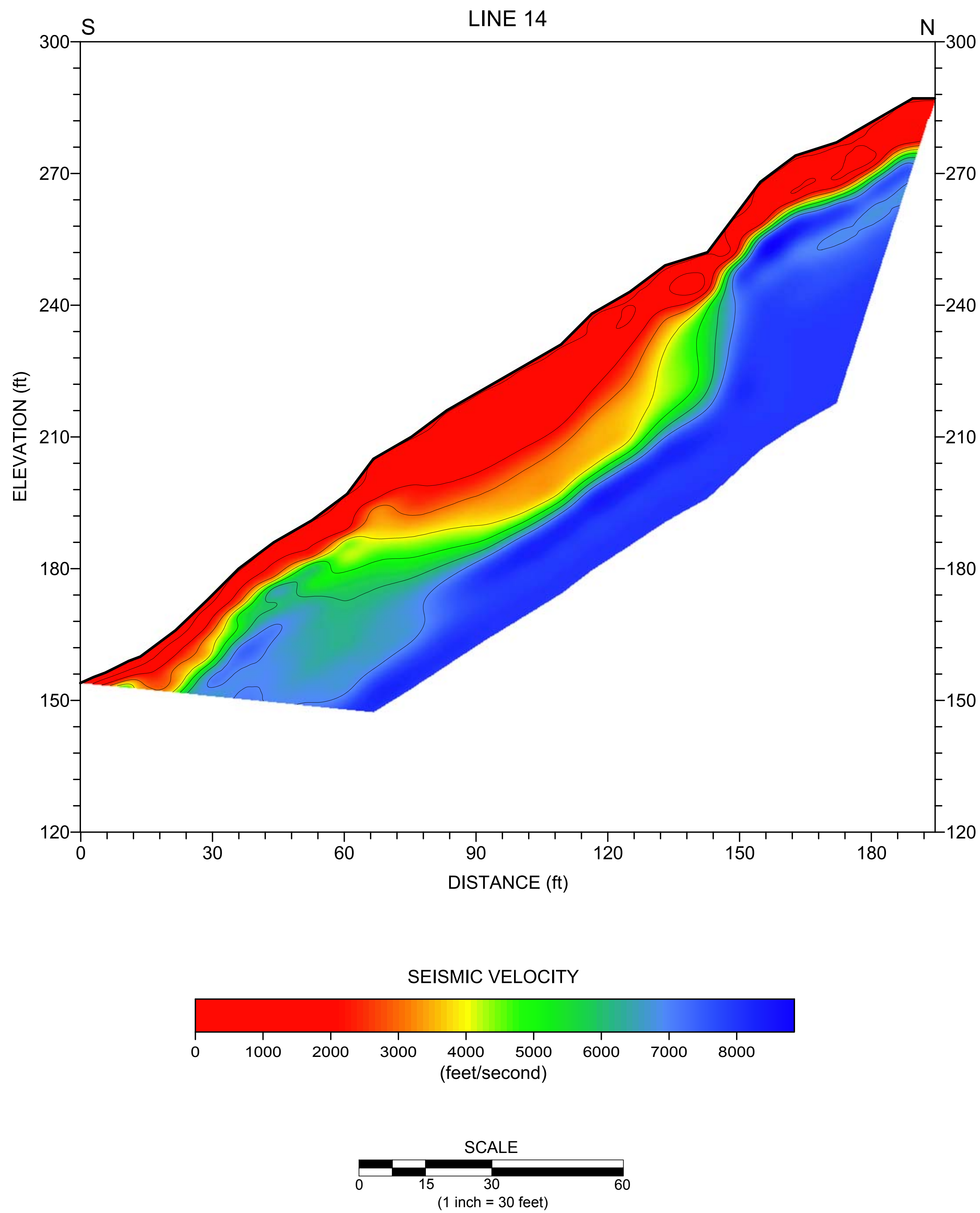






NORCAL	SEISMIC REFRACTION PROFILE LINES 12 & 13 AKUN ISLAND - SITE 7
	LOCATION: AKUN, ALASKA
	CLIENT: DUANE MILLER ASSOCIATES
JOB #: 08-368.06	NORCAL GEOPHYSICAL CONSULTANTS INC.
DATE: SEPT. 2008	DRAWN BY: D. KIRKER — APPROVED BY: DJK

PLATE 9



NORCAL

SEISMIC REFRACTION PROFILE
LINE 14
AKUTAN ISLAND

LOCATION: AKUTAN, ALASKA		
CLIENT: DUANE MILLER ASSOCIATES		PLATE 10
JOB #: 08-368.06	NORCAL GEOPHYSICAL CONSULTANTS INC.	
DATE: SEPT. 2008	DRAWN BY: D. KIRKER	APPROVED BY: DJK

Appendix A

SEISMIC SURVEYS

Appendix A

SEISMIC REFRACTION (SR)

Methodology

The seismic refraction method provides information regarding the seismic velocity structure of the subsurface. An impulsive (mechanical or explosive) source is used to produce compressional (P) wave seismic energy. The P-waves propagate into the earth and are refracted along interfaces caused by an increase in velocity. A portion of the P-wave energy is refracted back to the surface where it is detected by sensors (geophones) that are coupled to the ground surface in a collinear array (spread). The detected signals are recorded on a multi-channel seismograph and are analyzed to determine the shot point-to-geophone travel times. These data can be used along with the corresponding shot point-to-geophone distances to determine the depth, thickness, and velocity of subsurface seismic layers.

The seismic refraction technique is based on several assumptions. Paramount among these are:

1) that seismic velocity increases with depth, and,
2) that the velocity of each seismic layer is uniform over the length of the given spread.

In cases where these assumptions do not hold, the accuracy of the technique decreases. For example, if a low velocity layer occurs between two layers of higher velocity, the low velocity layer will not be detected and the depth to the underlying high velocity layer will be erroneously large. Also, if the velocity of a seismic layer varies laterally within a spread, those variations will be interpreted as fluctuations in the elevation of the underlying seismic layer.

Instrumentation

Data acquisition is initiated along each SR line by producing seismic energy using a mechanical source. Mechanical sources produce energy by impacting a metal strike plate on the ground surface with either a 12-16 pound sledge hammer or an accelerated weight drop. The resulting seismic wave forms are recorded using a Geometrics 24-channel engineering seismograph and Mark Products geophones with a natural frequency of 10 Hz. The data are recorded on hard copy records (seismograms) as well as on computer disks for future processing. The seismograms display the amount of time it takes for a compression (P) wave to travel from a given shot point to each geophone in a spread.

Data Analysis

The seismic data are downloaded to a computer and processed using the program ***Seisimager*** by Geometrics, Inc. This is an interactive program that is used to determine the shot point to geophone travel times, and to compute a 2D model based on those times. Once the travel times for a given line are determined, the programs time-term algorithms are used to compute a preliminary 2D seismic model. This model is then used as input for the programs tomographic routine. Using this procedure, the program divides the starting model into a network of cells and assigns velocities to those cells based on the starting model. The program then traces the refracted seismic travel paths through those cells and computes the associated travel times. It then compares the computed travel times with the measured times and adjusts the velocities of the appropriate cells to improve the fit. The software is programmed to continue this procedure for twenty iterations. Typically, at the end of the twenty iterations the travel times associated with the computed model match the observed travel times to an accuracy of one milli-second (mS) or better. Once a satisfactory model is computed, the software contours the model velocities to produce seismic velocity vs. depth and distance cross-sections (profiles).

Limitations

In general, there are limitations unique to the SR method. These limitations are primarily based on assumptions that are made by the data analysis routine. First, the data analysis routine assumes that the velocities along the length of each spread are uniform. If there are localized zones within each layer where the velocities are higher or lower than indicated, the analysis routine will interpret these zones as changes in the surface topography of the underlying layer. A zone of higher velocity material would be interpreted as a low in the surface of the underlying layer. Zones of lower velocity material would be interpreted as a high in the underlying layer.

Second, the data analysis routine assumes that the velocity of subsurface materials increase with depth. Therefore, if a layer exhibits velocities that are slower than those of the material above it, the slower layer will not be resolved. Also, a velocity layer may simply be too thin to be detected. Due to these and other limitations inherent to the SR method, the results of the SR survey should be considered only as approximations of the subsurface conditions. The actual conditions may vary locally.

1-D MULTI-CHANNEL ANALYSIS OF SURFACE WAVES (MASW)

Methodology

When seismic waves are generated at or near the ground surface, both body and surface waves are generated. Body waves consist of both compressional (P) and shear (S) waves. Surface waves (e.g., Rayleigh, Love, etc.) propagate at velocities that are proportional to shear wave velocity (Vs). If a vertical energy source is used, Rayleigh type surface waves are produced. These are commonly referred to as ground roll in seismic surveys. Rayleigh waves are retrograde elliptical and travel at approximately 0.9 times the velocity of S-waves.

MASW data are gathered in much the same way as high-resolution reflection data. Seismic energy - generated by vertical impacts on the ground surface - are detected by an array of closely spaced geophones. The primary differences are that the surface wave technique requires an energy source that is capable of producing ground roll and geophones that are capable of detecting low frequency (<10 Hz) signals.

Surface waves account for more than two-thirds of the energy produced by vertical seismic energy sources. As a result, surface waves are the most prominent signal on multi-channel seismic records. In addition, surface waves have dispersion properties that body waves lack. That is, different wavelengths have different penetration depths and, therefore, propagate at different velocities. By analyzing the dispersion of surface waves it is possible to obtain a near-surface S-wave velocity profile. Since S-wave velocity is directly proportional to shear modulus, this provides a direct indication in the variation of stiffness (or rigidity) of subsurface materials.

Data Acquisition

The spectral analysis of surface waves (SASW) is not a new technique. This method has been used by engineers and geophysicists for many years. However, the conventional method involves using two receivers (geophones) to record multiple impacts at a fixed point. The survey is initiated with the geophones at close proximity to the impact (shot) point. With succeeding impacts the geophones are moved further and further away. This is done so that the surface wave can be sampled at numerous locations. The data from all of the geophone locations are then analyzed to determine the variation in the velocity of the surface wave with respect to frequency. This results in what is referred to as a dispersion curve. With this technique, it may take several hours to obtain a dispersion curve at a single point.

Recent advances in computer software and processing techniques developed by researchers at the University of Kansas have made it possible to analyze surface waves using a large number of shot points and receivers. This is referred to as the multi-channel surface wave (MASW) technique. Dispersion curves at dozens of points distributed along a profile can now be obtained with MASW in the same amount of time it previously took to obtain a single dispersion curve using SASW. The surface wave data are gathered in much the same way as high resolution seismic reflection data. Seismic waves generated by vertical impacts on the ground surface are detected by an array of closely spaced geophones (spread). The energy source and the geophones are sequentially moved along a profile as the survey progresses.

Data Analysis

We analyze MASW data using the computer program ***Surfseis***, which was developed at the University of Kansas. The software analyzes the data by identifying the ground-roll portion of the seismic wave traces, computing the frequency and velocity of the wavelets, and constructing a dispersion curve representing the variation in surface wave velocity versus frequency. The program then inverts the dispersion curve to compute a one-dimensional (1D) layered model indicating shear-wave velocity (Vs) versus depth beneath the center of the geophone array for each shot gather. In all cases the MASW modeling was iterated until the dispersion curve generated from the S-wave velocity model closely matched that calculated from the shot gathers. The 1D models inverted from all four shot gathers were then entered into a spread sheet which computed average Vs versus depth values.

The inversion of the dispersion curve into a shear wave velocity profile is a non-unique process. By default, the software will produce a shear wave profile containing 10 distinct subsurface velocity intervals at various depths. To help resolve the non-uniqueness of the solution, the results from the P-wave refraction survey were used to guide the positioning of the layering in the S-wave velocity profile, particularly at shallow depths where MASW resolution is lacking. In most cases this suitably resolved the shallow velocity interfaces and resulted in a close fit between the modeled and observed dispersion curves. Typically, the MASW technique resolves velocity interfaces at greater depths than the refraction analysis given the 138-ft geophone spread length. Therefore, the models shown on Plates 2 through 11 and listed in Table 1, indicate Vs at greater depths than Vp. Furthermore, the MASW technique is capable of resolving velocity reversals (decrease in velocity with depth) that cannot be detected by the refraction method.

APPENDIX B

Interpreted Seismic Reflection Profiles – Field Data

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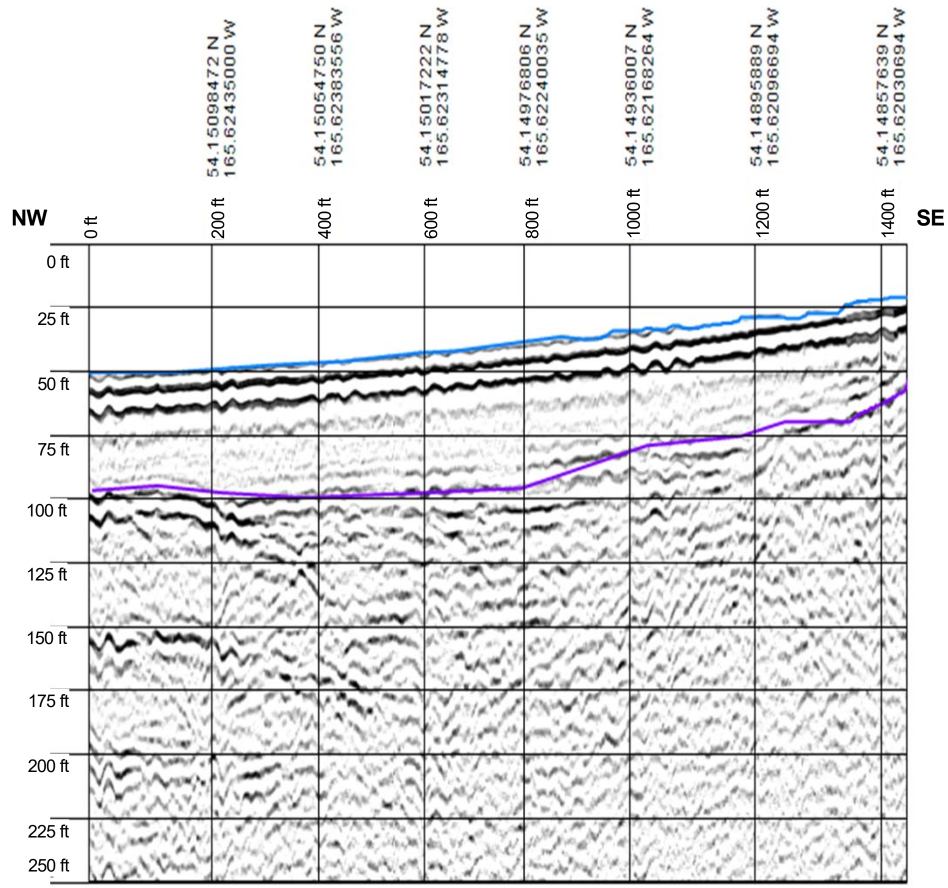

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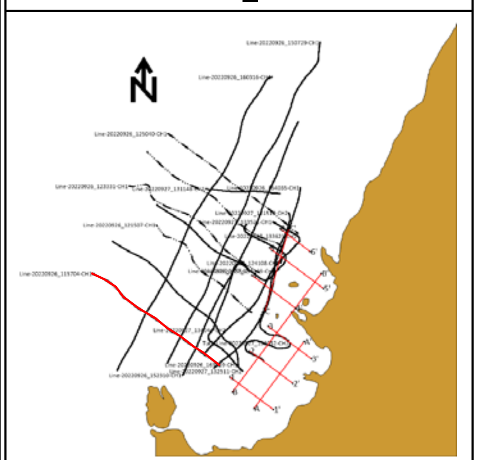


LEGEND

- SEABED REFLECTION
- INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

1) SUB-BOTTOM DEPTHS BASED ON A SEISMIC VELOCITY OF 5000FT/MS
2) DEPTHS RELATIVE TO MLLW
3) SEISMIC PROFILES POSITIONED USING DIFFERENTIAL GPS

CLIENT
U.S. ARMY CORPS OF ENGINEERS – ALASKA DISTRICT

PROJECT
AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT
AKUTAN, ALASKA

CONSULTANT
WSP GOLDER

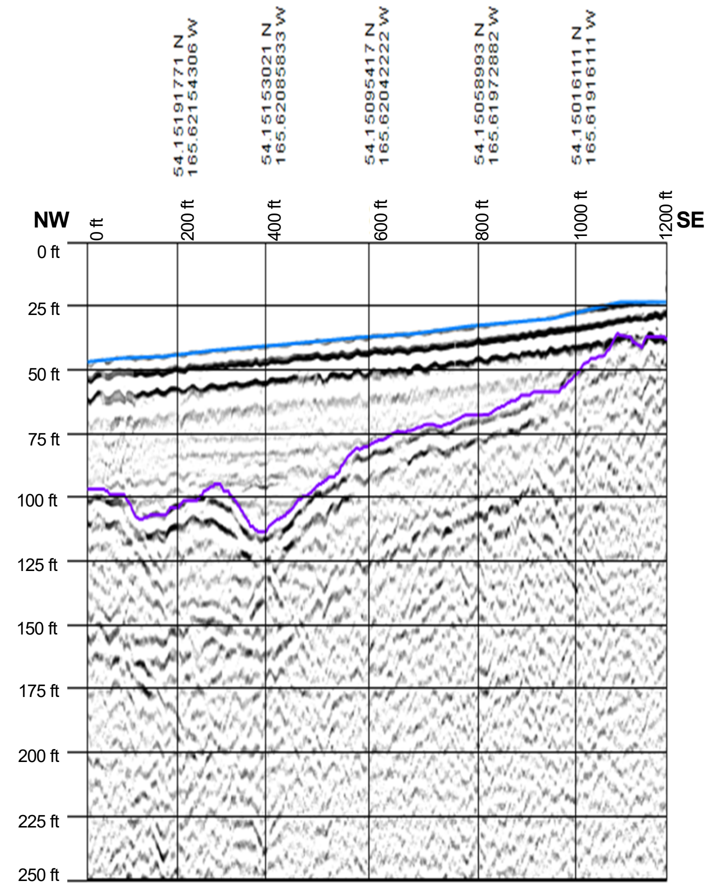
YYYY-MM-DD	2023-01-06
PREPARED	JRRD
DESIGNED	JRRD
REVIEWED	FMW
APPROVED	MRM

TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 1**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25 mm
0

Line-20220926_121507-CH1.png



Line-20220926_121507-CH1

LEGEND

SEABED REFLECTION

INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

1) SUB-BOTTOM DEPTHS BASED ON A SEISMIC VELOCITY OF 5000FT/MS
2) DEPTHS RELATIVE TO MLLW
3) SEISMIC PROFILES POSITIONED USING DIFFERENTIAL GPS

CLIENT
U.S. ARMY CORPS OF ENGINEERS – ALASKA DISTRICT

PROJECT
AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT
AKUTAN, ALASKA

CONSULTANT

WSP GOLDER

YYYY-MM-DD	2023-01-06
PREPARED	JRRD
DESIGNED	JRRD
REVIEWED	FMW
APPROVED	MRM

TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 2**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
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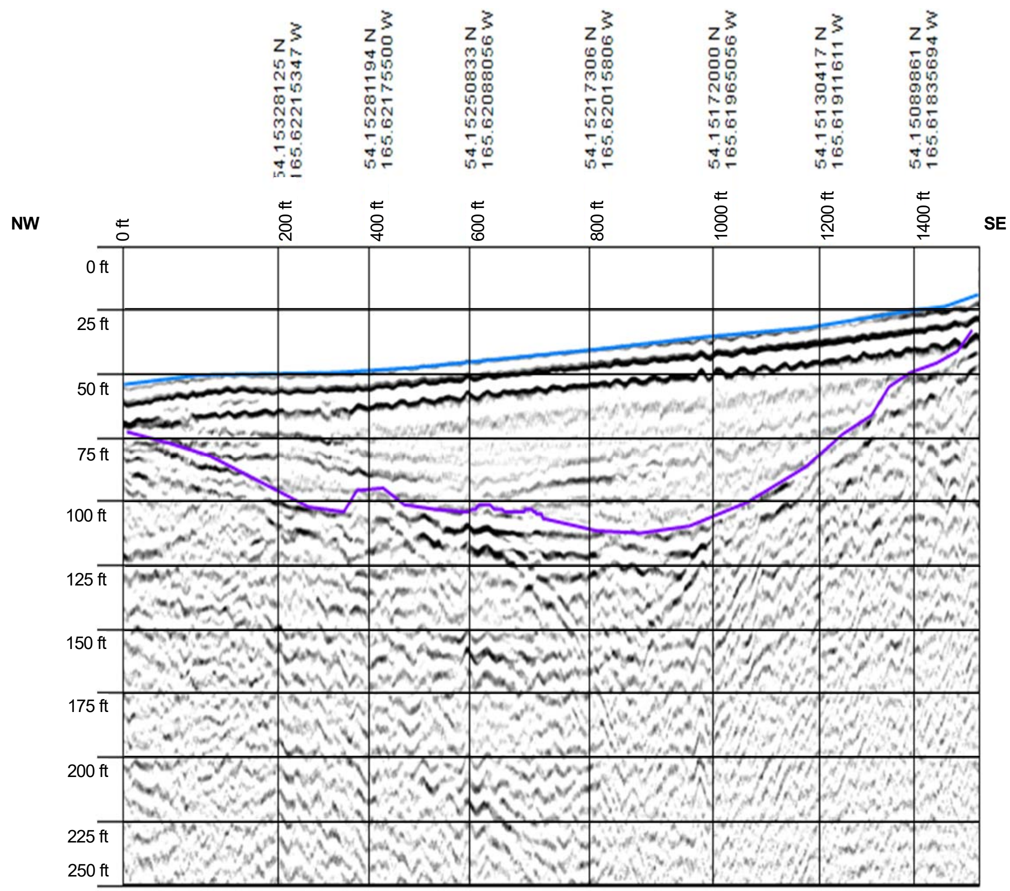

Line-20220926_123331-CH1

LEGEND

SEABED REFLECTION

INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

1) SUB-BOTTOM DEPTHS BASED ON A SEISMIC VELOCITY OF 5000FT/MS
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CONSULTANT	YYYY-MM-DD	2023-01-06
WSP GOLDER	PREPARED	JRRD
	DESIGNED	JRRD
	REVIEWED	FMW
	APPROVED	MRM

TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 3**

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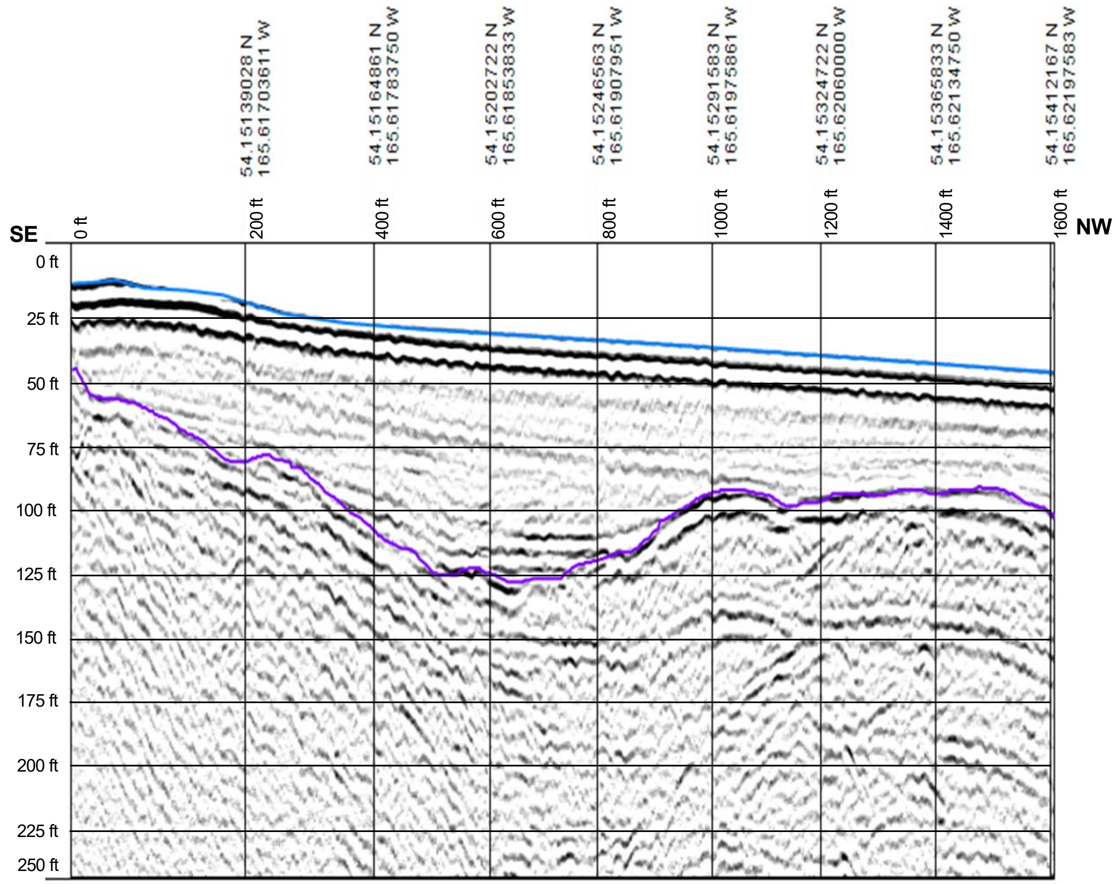

Line-20220926_124108-CH1

LEGEND

SEABED REFLECTION

INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

1) SUB-BOTTOM DEPTHS BASED ON A SEISMIC VELOCITY OF 5000FT/MS
2) DEPTHS RELATIVE TO MLLW
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CONSULTANT wsp GOLDER	TITLE **LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE**

YYYY-MM-DD	2023-01-06
PREPARED	JRRD
DESIGNED	JRRD
REVIEWED	FMW
APPROVED	MRM

PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 4**

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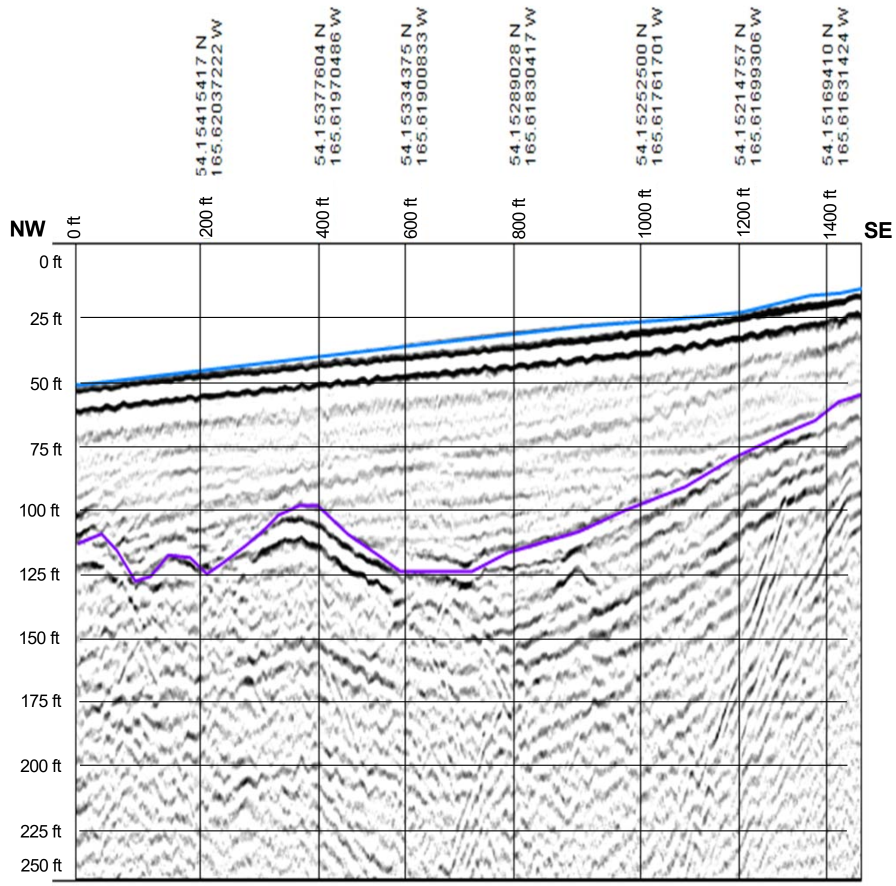

Line-20220926_125040-CH1

LEGEND

SEABED REFLECTION

INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

1) SUB-BOTTOM DEPTHS BASED ON A SEISMIC VELOCITY OF 5000FT/MS
2) DEPTHS RELATIVE TO MLLW
3) SEISMIC PROFILES POSITIONED USING DIFFERENTIAL GPS

CLIENT U.S. ARMY CORPS OF ENGINEERS – ALASKA DISTRICT	PROJECT AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT AKUTAN, ALASKA

CONSULTANT: WSP GOLDER

YYYY-MM-DD	2023-01-06
PREPARED	JRRD
DESIGNED	JRRD
REVIEWED	FMW
APPROVED	MRM

TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
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25 mm
0

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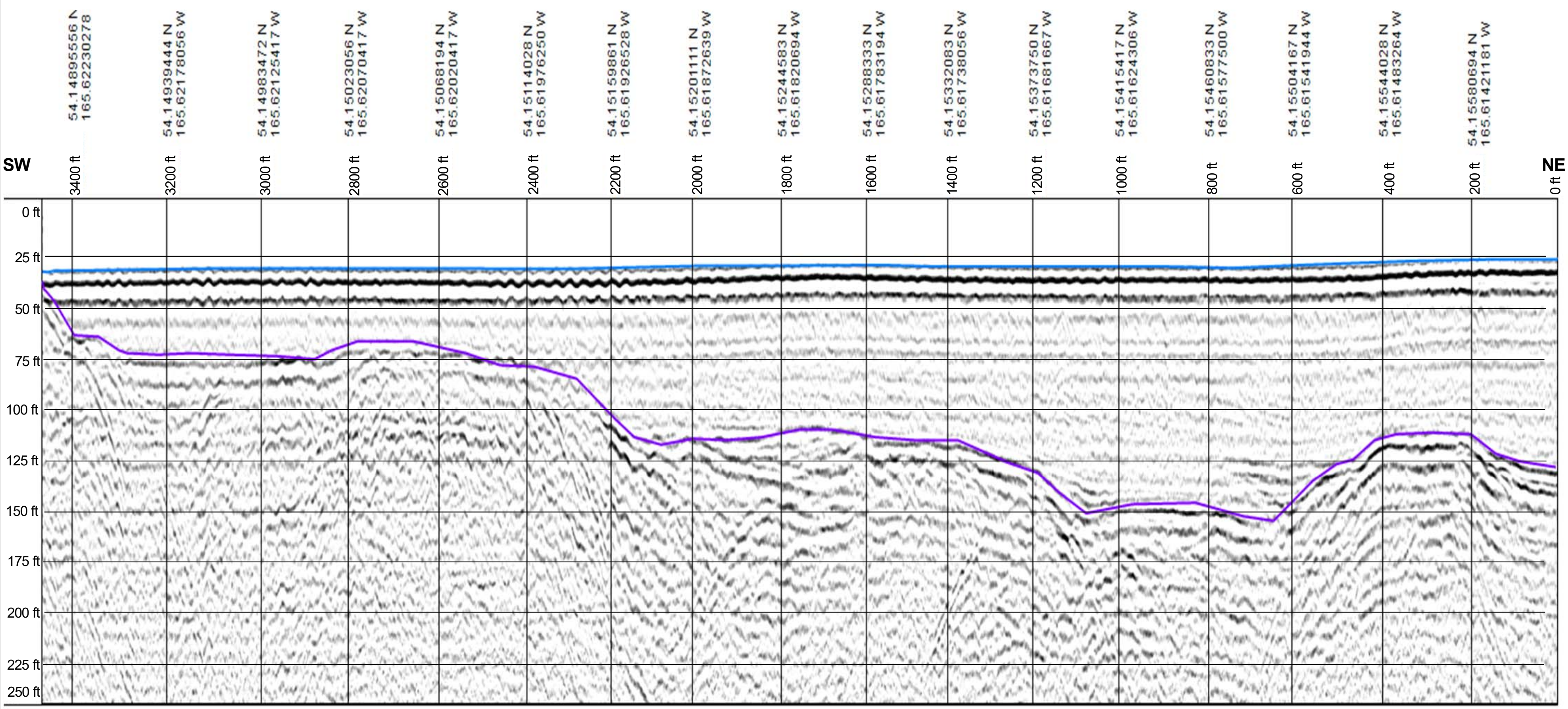

Line-20220926_150729-CH1

LEGEND

SEABED REFLECTION

INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

1) SUB-BOTTOM DEPTHS BASED ON A SEISMIC VELOCITY OF 5000FT/MS
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YYYY-MM-DD	2023-01-06
PREPARED	JRRD
DESIGNED	JRRD
REVIEWED	FMW
APPROVED	MRM

TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 6**

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25 mm
0

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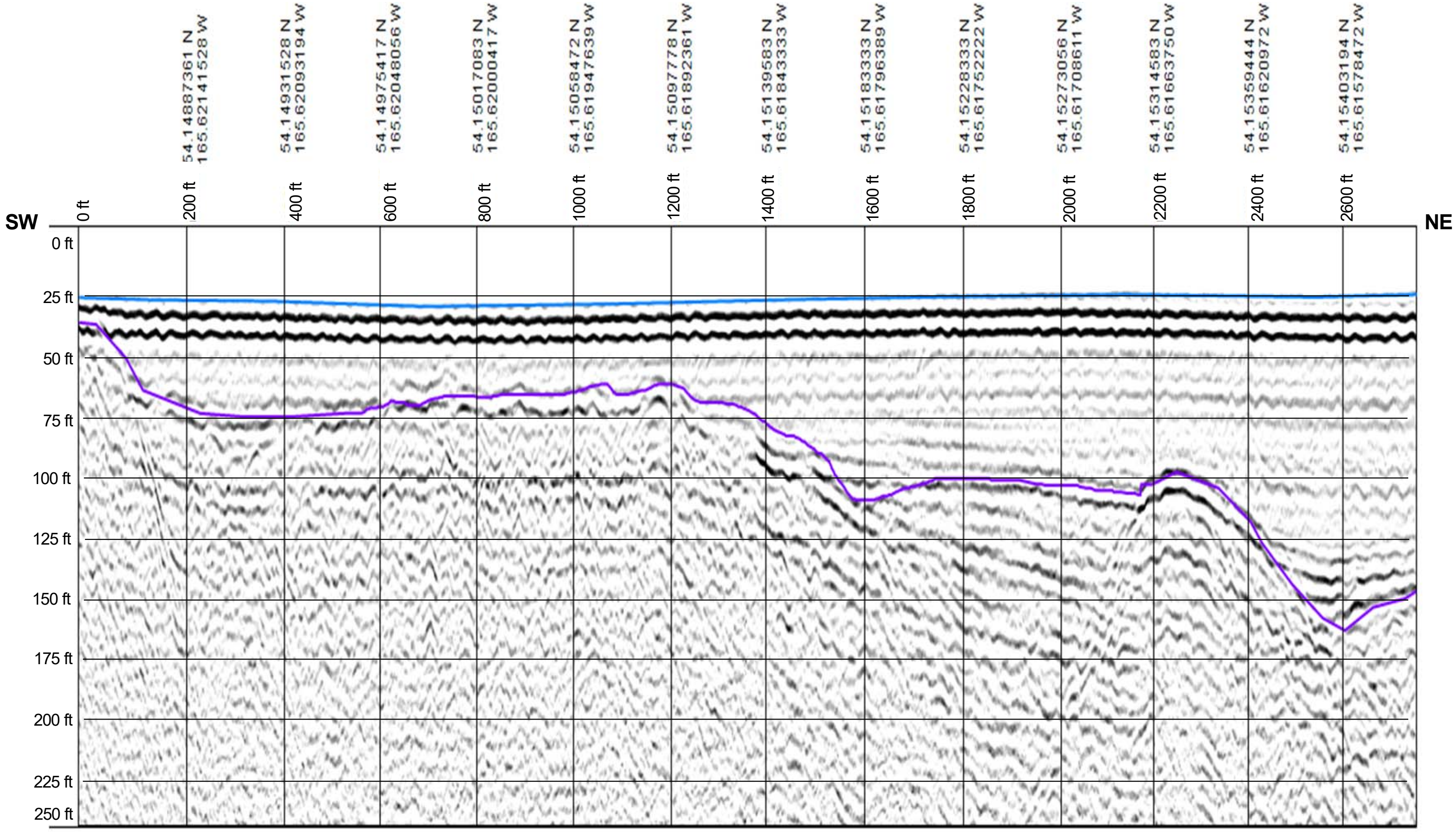

Line-20220926_152310-CH1

LEGEND

- SEABED REFLECTION
- INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

1) SUB-BOTTOM DEPTHS BASED ON A SEISMIC VELOCITY OF 5000FT/MS
2) DEPTHS RELATIVE TO MLLW
3) SEISMIC PROFILES POSITIONED USING DIFFERENTIAL GPS

CLIENT
U.S. ARMY CORPS OF ENGINEERS – ALASKA DISTRICT

PROJECT
AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT
AKUTAN, ALASKA

CONSULTANT

wsp GOLDER

YYYY-MM-DD	2023-01-06
PREPARED	JRRD
DESIGNED	JRRD
REVIEWED	FMW
APPROVED	MRM

TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
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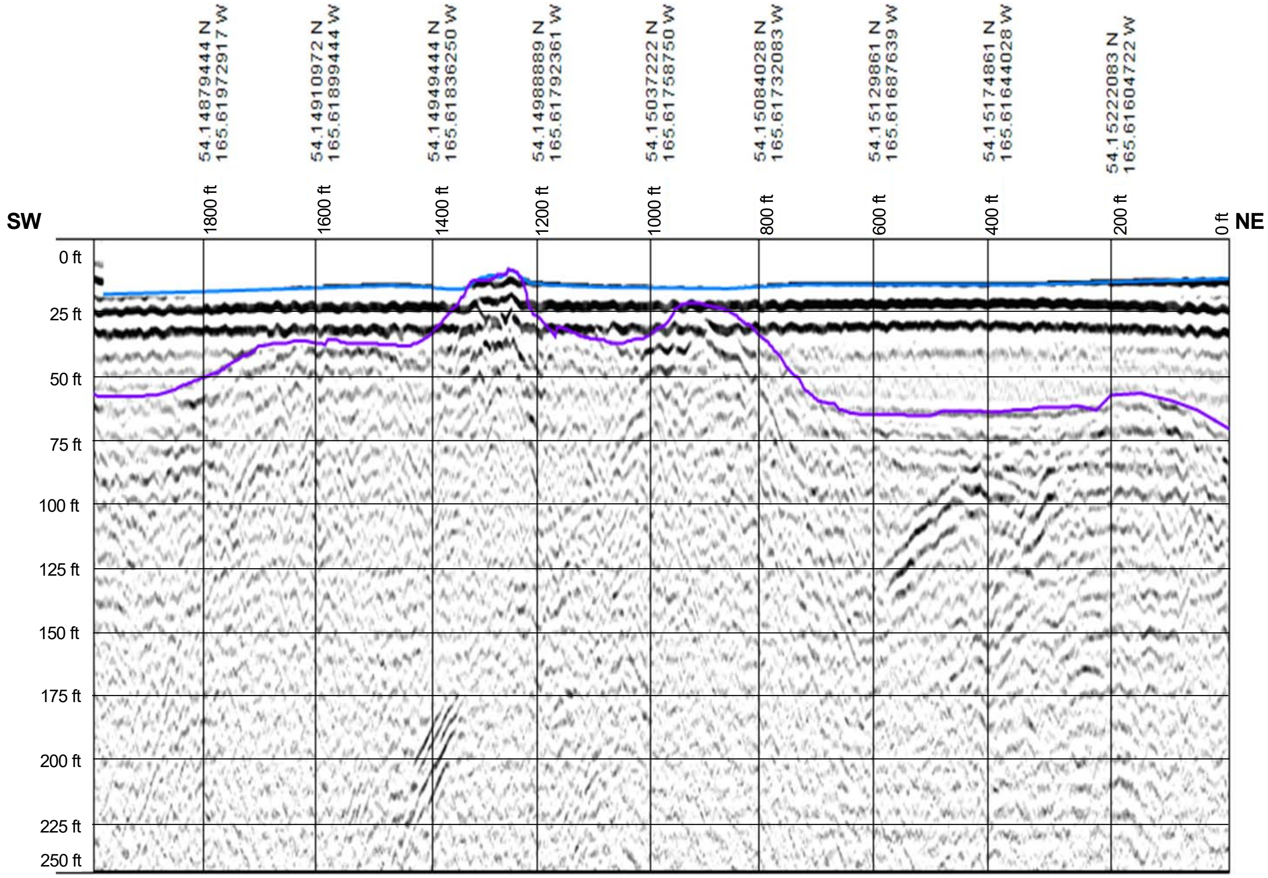

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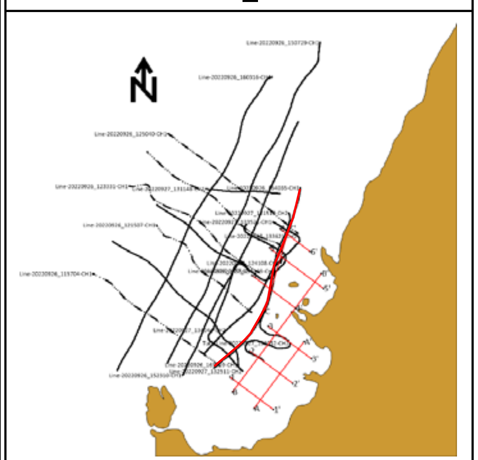

LEGEND

- SEABED REFLECTION
- INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

1) SUB-BOTTOM DEPTHS BASED ON A SEISMIC VELOCITY OF 5000FT/MS
2) DEPTHS RELATIVE TO MLLW
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CLIENT
U.S. ARMY CORPS OF ENGINEERS – ALASKA DISTRICT

PROJECT
AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT
AKUTAN, ALASKA

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2023-01-06
PREPARED	JRRD
DESIGNED	JRRD
REVIEWED	FMW
APPROVED	MRM

TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA
INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
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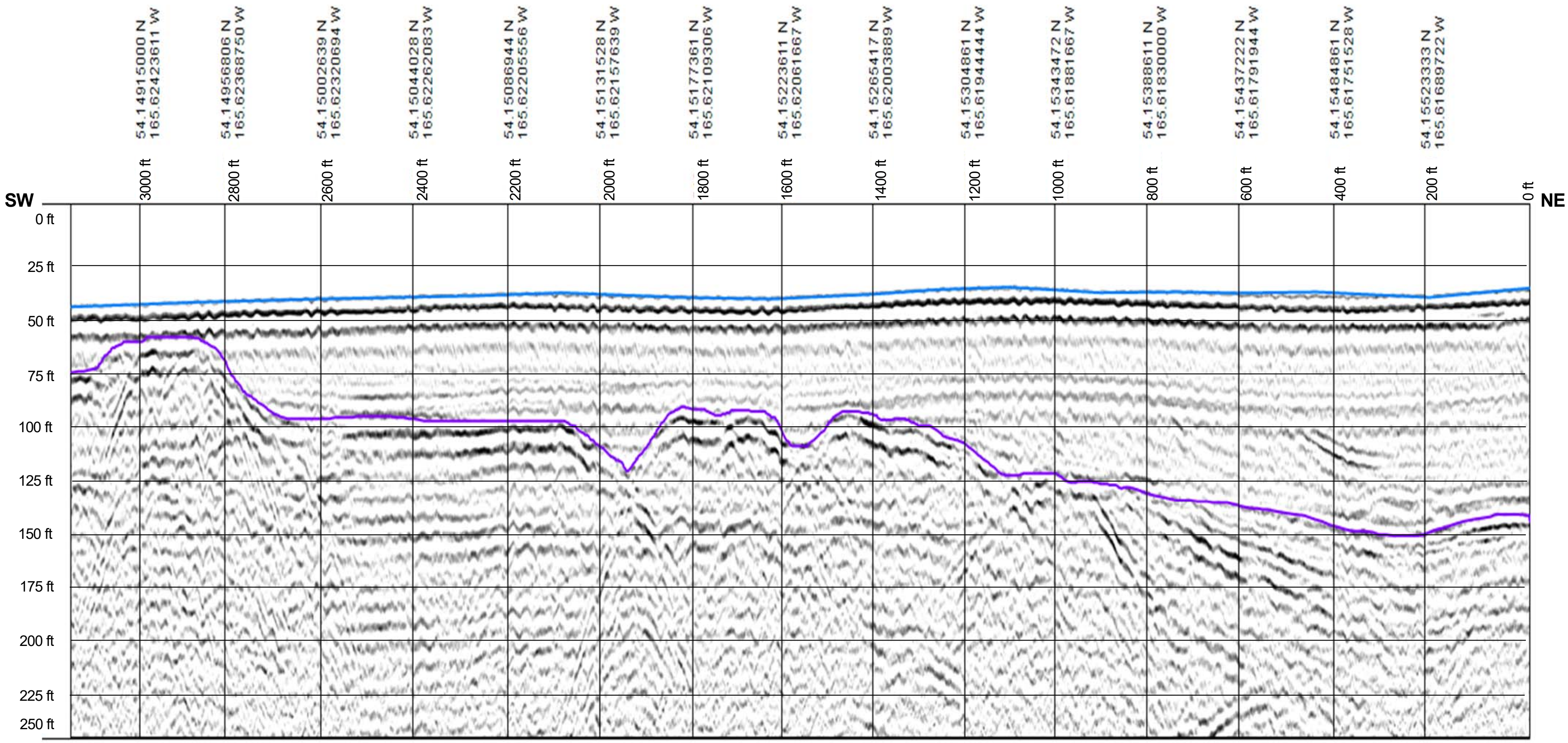

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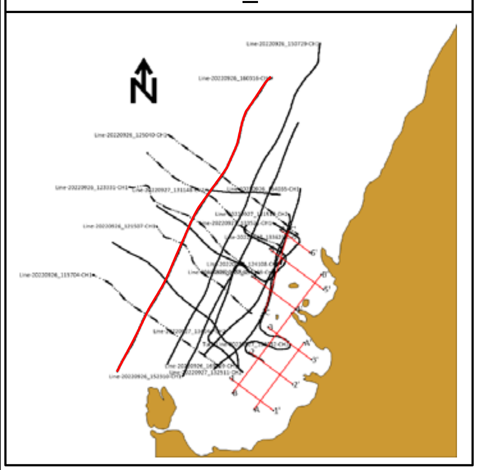


LEGEND

- SEABED REFLECTION
- INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

1) SUB-BOTTOM DEPTHS BASED ON A SEISMIC VELOCITY OF 5000FT/MS
2) DEPTHS RELATIVE TO MLLW
3) SEISMIC PROFILES POSITIONED USING DIFFERENTIAL GPS

CLIENT	PROJECT
U.S. ARMY CORPS OF ENGINEERS – ALASKA DISTRICT	AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT AKUTAN, ALASKA

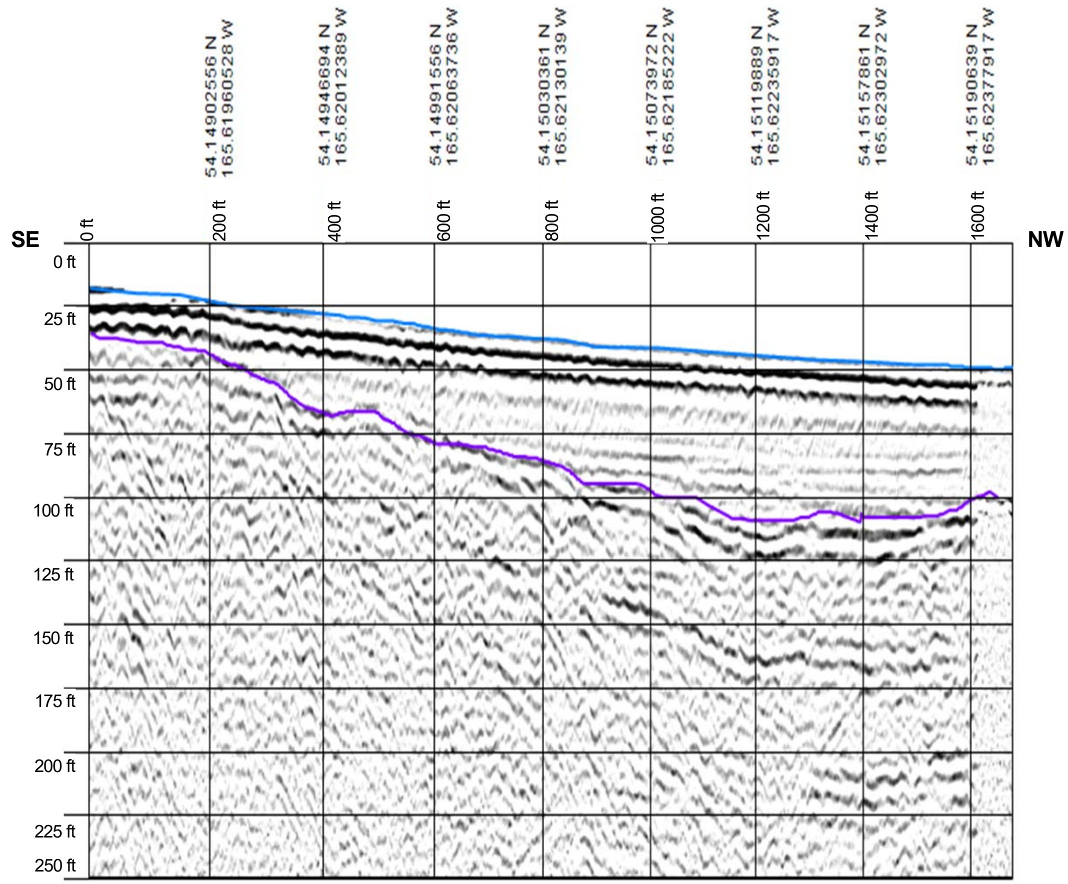
CONSULTANT		
WSP GOLDER	YYYY-MM-DD	2023-01-06
	PREPARED	JRRD
	DESIGNED	JRRD
	REVIEWED	FMW
	APPROVED	MRM

TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 9**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25 mm
0

Line-20220926_163409-CH1.png



Line-20220926_163409-CH1

LEGEND

SEABED REFLECTION

INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

1) SUB-BOTTOM DEPTHS BASED ON A SEISMIC VELOCITY OF 5000FT/MS
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CLIENT

U.S. ARMY CORPS OF ENGINEERS – ALASKA DISTRICT

PROJECT

AKUTAN HARBOR NAVIGATIONAL IMPROVEMENTS PROJECT
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WSP GOLDER

YYYY-MM-DD	2023-01-06
PREPARED	JRRD
DESIGNED	JRRD
REVIEWED	FMW
APPROVED	MRM

TITLE

LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA
INTERPRETED PROFILE

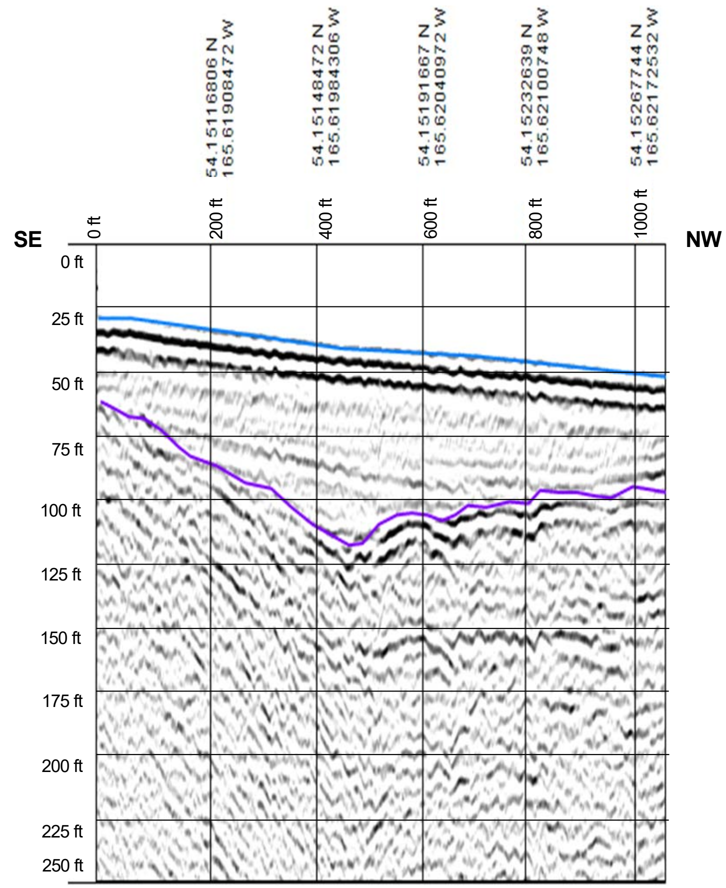
PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 10**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

25 mm

0

Line-20220926_165542.png



Line-20220926_165542

LEGEND

SEABED REFLECTION

INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

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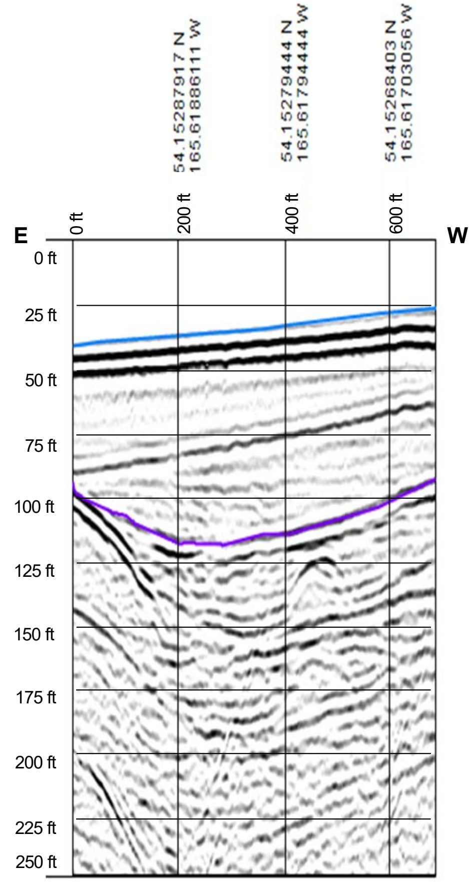
TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 11**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25 mm
0

Line-20220927_131148-CH1.png



Line-20220927_131148-CH1

LEGEND

SEABED REFLECTION

INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

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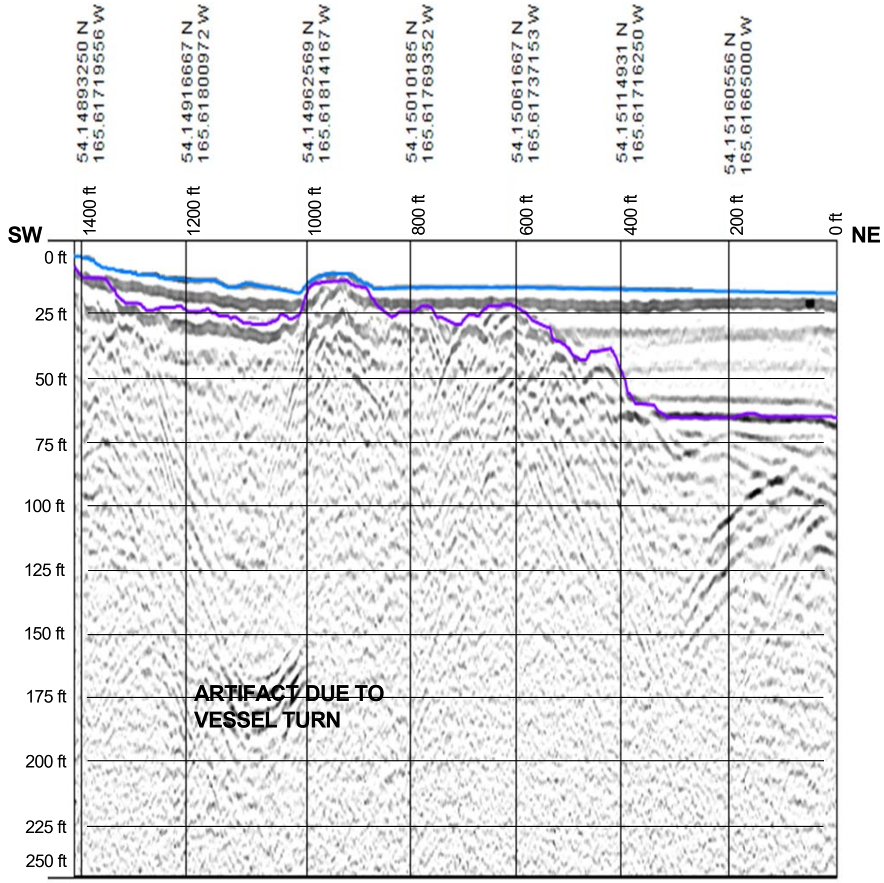
APPROVED	MRM

TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 12**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25 mm
0

Line-20220927_131518-CH2.png



Line-20220927_131518-CH2

LEGEND

SEABED REFLECTION

INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

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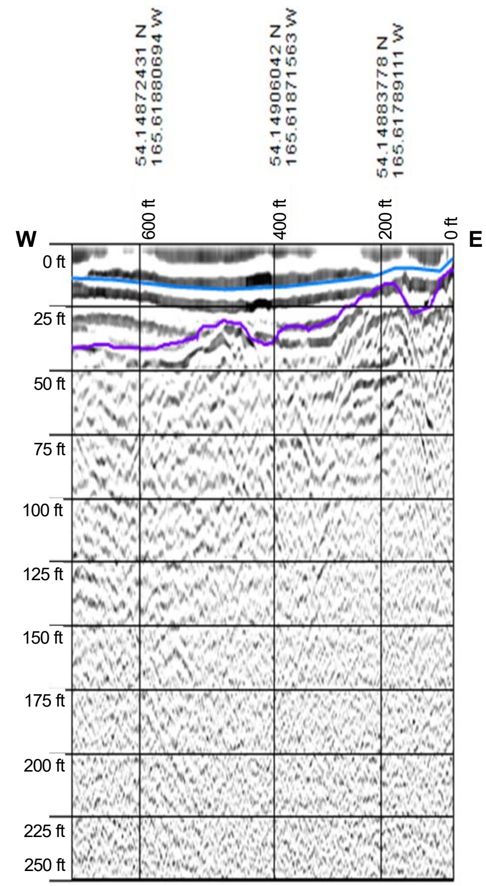
TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 13**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25 mm
0

Turn-Line-20220927_132052-CH2.png



Turn-Line-20220927_132052-CH2

LEGEND

SEABED REFLECTION

INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

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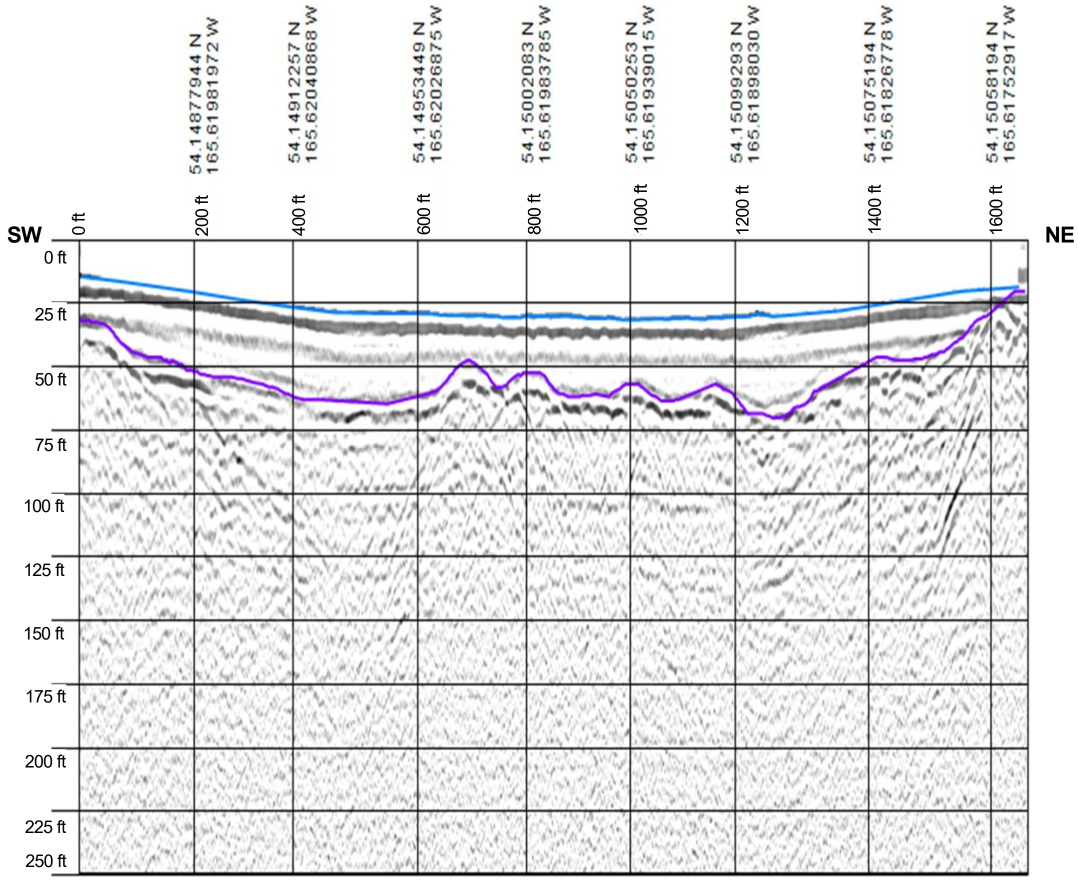
TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

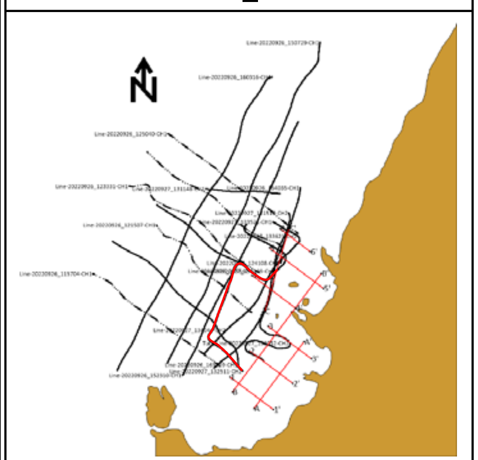
PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 14**

25 mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
0

Line-20220927_132511-CH2.png



Line-20220927_132511-CH2



LEGEND

SEABED REFLECTION

INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

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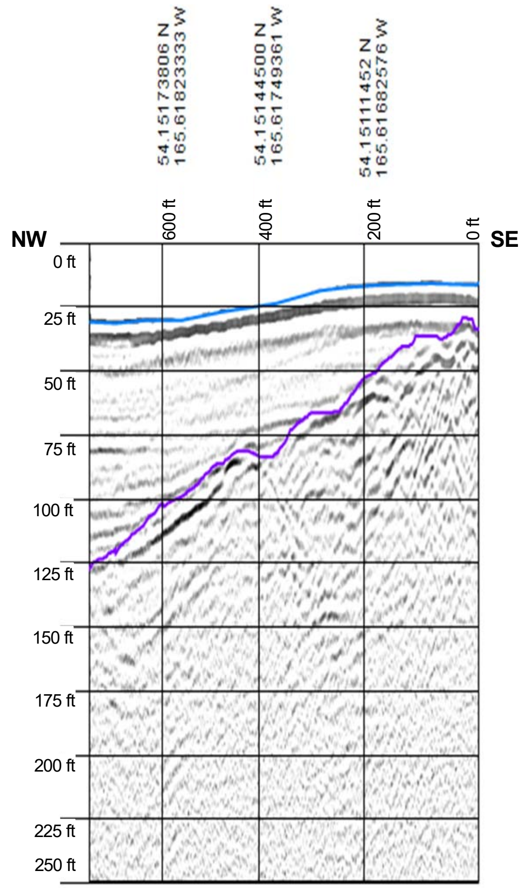
TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
31405083.004	0	B 15

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25 mm
0

Line-20220927_133129-CH2.png



Line-20220927_133129-CH2

LEGEND

- SEABED REFLECTION
- INTERPRETED HARD SUB-BOTTOM REFLECTOR

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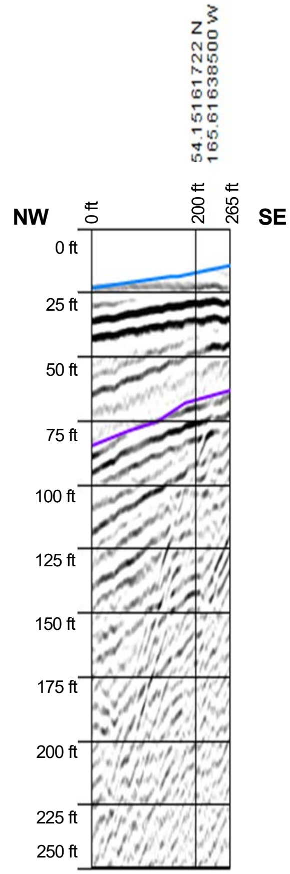
TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 16**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25 mm
0

Line-20220927_133521-CH1.png



Line-20220927_133521-CH1

LEGEND

SEABED REFLECTION

INTERPRETED HARD SUB-BOTTOM REFLECTOR

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wsp GOLDER

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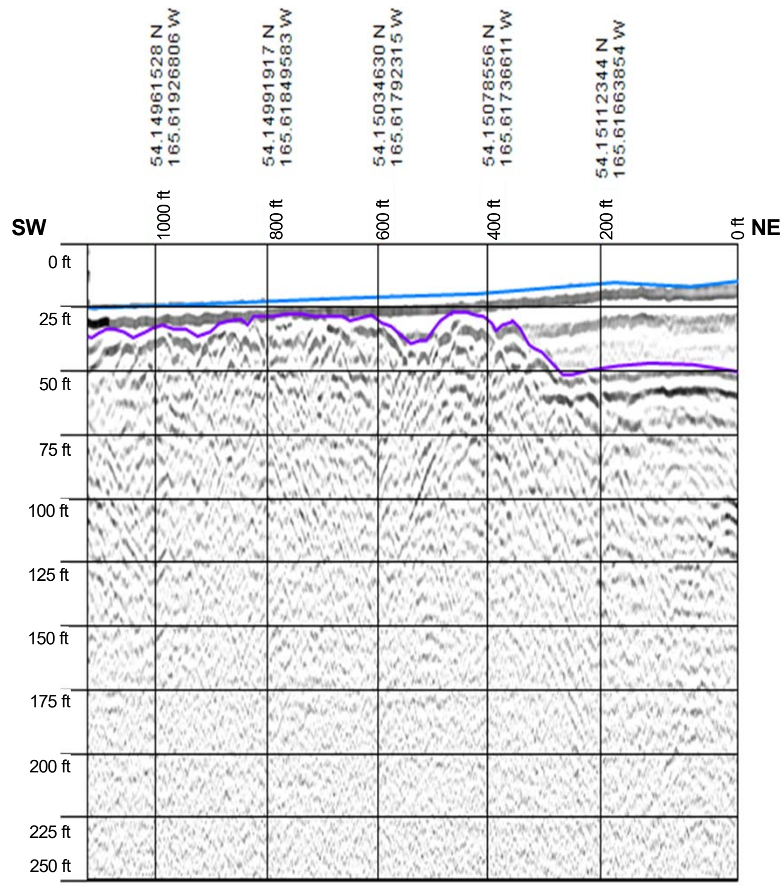
APPROVED	MRM

TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 17**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25 mm

Line-20220927_133621-CH2.png



Line-20220927_133621-CH2

LEGEND

SEABED REFLECTION

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AKUTAN, ALASKA

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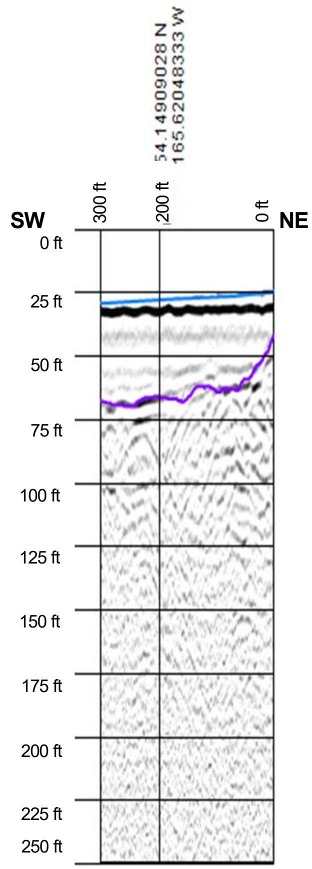
TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 18**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25 mm
0

Line-20220927_134044-CH2.png



Line-20220927_134044-CH2

LEGEND

- SEABED REFLECTION
- INTERPRETED HARD SUB-BOTTOM REFLECTOR

NOTES

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CLIENT
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PROJECT
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AKUTAN, ALASKA

CONSULTANT

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YYYY-MM-DD	2023-01-06
PREPARED	JRRD
DESIGNED	JRRD
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APPROVED	MRM

TITLE
LOW FREQUENCY SUB-BOTTOM PROFILING FIELD DATA INTERPRETED PROFILE

PROJECT NO.	REV.	FIGURE
31405083.004	**0**	**B 19**

25 mm
0
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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