

**Knik Arm Tunnel Feasibility Study**  
**PSA No. 25251013**  
**Program No. HSHWY00029**  
**Geotechnical Data Summary**

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## 1 INTRODUCTION

This report summarizes the available desktop information pertaining to the geotechnical conditions in the project area for the Knik Arm Tunnel Feasibility Study. The report utilizes previously completed geotechnical investigation and analyses provided by Alaska DOT&PF (DOT&PF) in and around the 21,000-foot wide channel. The purpose of this Geotechnical Data Summary report is to provide an overview of the geotechnical investigations completed to-date.

Since information and data is currently only available in PDF document format, no summary statistics of the data itself are provided in this report. This report is intended to serve as an inventory summary of what data is available, with a discussion of anticipated general data gaps. No interpretations or analyses have been performed in the development of this summary report.

### 1.1 Prior Studies

Geotechnical studies related to the Knik Arm Crossing (KAC) have been performed previously, beginning in the early 1970s. The most recent geotechnical studies were conducted between 2004 and 2007. These studies have primarily focused on the feasibility and conceptual design of a bridge crossing. These studies are briefly discussed below:

Prior to the early 2000s, there are four known geotechnical studies performed north of Cairn Point to evaluate various alignment crossings. These studies are Dames & Moore, 1970, Alaska Department of Highways, 1970, Shannon & Wilson, 1971, and Harding Lawson Associates (HLA), 1984. These reports have not been provided or made available by DOT&PF, and are presumed to be limited in extent based on narratives in more recent reports.

In 2003, Parsons Brinckerhoff Construction Services, Inc./HDR Alaska, Inc. published a feasibility study for the Knik Arm Crossing evaluating both bridge and tunnel alternatives. The technological feasibility assessment relied on the existing geotechnical investigation data to-date, and revealed broad gaps in geotechnical information. Geologic profiles and estimated ranges of geotechnical parameters for each of the soil units are derived from the previous studies and reported in this feasibility study.

In the early 2000s, a number of additional geotechnical investigations were conducted, focusing on the bridge alternative. In 2003, Shannon & Wilson conducted a field reconnaissance of a proposed new Alaska Railroad Corporation rail corridor extending from Port MacKenzie north to either Wasilla or Houston, Alaska. This study focused on near-surface geotechnical conditions, primarily outside of the study area for this tunnel feasibility study.

In 2004, Golder Associates performed an overwater geophysical survey with the purpose of mapping the thickness and characteristics of unconsolidated sediments overlying bedrock in the corridor being considered for a bridge crossing. Seismic refraction was performed to interpret subsurface features or

boundaries, sediment thickness and depth to subsurface reflectors. A bathymetry survey was also conducted to map the seafloor.

A 2004 preliminary geotechnical report developed by Shannon & Wilson incorporates the Golder geophysical survey as well as field explorations and testing, surface reconnaissance and laboratory testing for the preliminary engineering analysis of the bridge pile foundations. The study provides an updated geological section as well as a preliminary ground response analysis of the site, a brief liquefaction evaluation, and a preliminary embankment stability evaluation.

The most recent geotechnical investigations in the Knik Arm Crossing corridor were conducted in 2007. The Geotechnical Data Report, Knik Arm Crossing (Shannon & Wilson 2007a), included an off-shore boring program, supported by cone penetration tests (CPT), shear wave measurements and in situ pressuremeter testing. Two on-shore borings were also completed to characterize the East and West shoreline soils. Site and regional tectonics and seismicity are also discussed in detail.

The Geotechnical Engineering Report, Knik Arm Crossing, Mat-Su Access Route (Shannon & Wilson, 2007b) presents the results of the geotechnical study for a road corridor accessing the west side of KAC. This study characterizes the general near-surface ground conditions along the approximately 13-mile alignment.

The Knik Arm Crossing Geotechnical Memorandum (Shannon & Wilson 2007c) summarizes the regional geology and geologic units present in the channel and on the shorelines. This memorandum also includes historical site investigation data that has not been provided in previous reports.

## **1.2 Current Scope of Work**

As a part of the overall Knik Arm Tunnel Feasibility Study (PSA No. 25251013) scope, DOT&PF has requested a written report and tables summarizing the available desktop information of geotechnical conditions in the project area, based on a review of all previously completed geotechnical investigations and analyses provided by DOT&PF. As the existing geotechnical data is provided in multiple PDF reports, without any digital data files available, the first step is to compile an inventory of data collected to date, which is summarized in this report.

A compiled inventory of data collected to date includes field reconnaissance notes, the number and location of borings and CPTs, in situ tests, laboratory tests and geophysical surveys. Key relevant interpretations provided by others, such as geological profiles, are also documented. Anticipated data gaps based on (1) borehole sample locations and (2) typical geotechnical parameters relevant to soft ground tunneling are identified.

## **1.3 Report Organization**

This summary report is organized into 5 main sections. Section 1 consists of general information regarding the project, prior studies, current scope of work, and the authorization and limitations of

this report. Section 2 describes the site and project. Section 3 provides a detailed inventory review of the type and quantity of data published in each of the historical geotechnical studies. Section 4 discusses the general geotechnical data required for tunnel feasibility assessments and design and mentions perceived data gaps based on the available data. In closing, Section 5 presents the conclusions of this initial desktop review, and provides recommendations for further analysis and investigations.

#### **1.4 Authorization**

This work was performed in general accordance with our Subconsultant Agreement with Stantec Consulting Services Inc. with subsequent amendments aimed at completing an expanded work scope. Stantec and the project representatives from the DOT&PF approved the general scope of the geotechnical work for this report in the Statement of Services of the Prime contract (PSA No. 25251013).

#### **1.5 Limitations**

The historical geotechnical site investigation data provided by DOT&PF was only made available in PDF format. A statistical summary of geotechnical parameters requires that the data be digitized in a data table format. Without the digitized data, this summary report is limited to an inventory of the type and quantity of data available. No analysis or interpretation of the data is provided in this initial report. Any interpretive statements or claims attributed to other parties in this report do not necessarily reflect the views of Emprise Concepts or the project team.

## **2 SITE DESCRIPTION**

The Knik Arm Crossing aims to connect the west and east shore of Knik Arm, along with the development of vehicle access corridor along a two mile stretch of undeveloped shoreline near the Port of Anchorage and an upland connection to existing roads north of Port MacKenzie.

### **2.1 Site Description**

The Knik Arm is an extension of the upper Cook Inlet north of Anchorage, Alaska. Anchorage, located in Southcentral Alaska, is the largest city in the state and accounts for roughly 40% of the state's population. Major transportation hubs for people and goods include the Port of Anchorage and the Ted Stevens Anchorage International Airport. Knik Arm is an approximately 34 mile long and 1.5- to 5-mile wide body of water that is oriented northeast by southwest. A vicinity map is provided on Figure 1.

Knik Arm is part of a glacial and tectonically active landscape and is influenced by glacial rivers like the Knik and Matanuska Rivers, which bring large sediment loads. It is characterized by strong currents, deep water and large tides. Extreme weather in the form of strong winds, winter storms and sea ice are common. Tides are large and range between approximately Elevation +34.1 feet (MLLW Datum) at high tide and -6.1 feet at low tide to a total maximum change of 40.2 feet. Visibility under

water is generally limited to a few feet or less due to the presence of glacial silt. These potentially hazardous conditions make the construction of a highway bridge across the channel one of the more challenging projects in Alaska, which justifies a detailed feasibility study of a tunnel alternative.

A site map, showing the proposed location of the KAC and the study area boundary, is provided on Figure 2. The east side crossing is about one mile north of Cairn Point, and the west side about one mile north of the existing Port MacKenzie Dock. The water crossing distance for this alignment is about 2 ¼ miles (about 11,900 feet).

## **2.2 Project Description**

The purpose of the KAC is to provide an alternative transportation corridor to the Glenn Highway, connecting Anchorage with the Matanuska-Susitna Valley and points north and east. A geologic map of the project area is provided on Figure 3. Thorough geologic descriptions and geologic maps of the project area have been provided in previous KAC studies, particularly in the 2007 Shannon & Wilson Knik Arm Crossing Geotechnical Memorandum. Thorough discussions of the tectonics and seismicity of the project area are also provided in the Shannon & Wilson memo and other previous KAC studies.

This report is part of a larger tunnel feasibility study being undertaken to address potential safety, mobility, and economic benefits associated with the proposed tunnel as an alternative to the existing Glenn Highway. The anticipated rise in commuter and freight traffic between Anchorage and the Matanuska-Susitna Borough, as well as the disruptions from seismic activity, bridge impacts, and construction increasing in recent years, underscores the need for alternative transportation corridors to strengthen the overall network.

## **3 EXISTING GEOTECHNICAL DATA**

DOT&PF-provided PDF reports and memorandums were reviewed for existing geotechnical data. The following sections provide a description of each document found to contain existing geotechnical data and a summary of the type and quantity of available geotechnical data. A list of unavailable documents likely containing additional geotechnical data that were referenced in the DOT&PF-provided documents was developed during our review and is presented at the end of this Section. Table 1 presents a summary of all DOT&PF documents that were reviewed as part of this scope of work.

Knik Arm Tunnel Feasibility Study  
 Geotechnical Data Summary  
 4/15/2025

Table 1: Summary of Documents Reviewed

Document Title	File Name	Year	Contains Geotechnical Data/Information
Engineering Feasibility and Cost Estimate Update - Issues and Corridor Alignment	20030131 KAC Feasibility Vol 1 Parsons.pdf	2003	No
Engineering Feasibility and Cost Estimate Update - Technology Update	20030131 KAC Feasibility Vol 2 Parsons.pdf	2003	Yes
Engineering Feasibility and Cost Estimate Update - Schedule, Cost, Contracting, and Finance	20030131 KAC Feasibility Vol 3 Parsons.pdf	2003	No
Reconnaissance Geotechnical Report, Mat-Su Rail Corridor	APPENDIX G GEOTECHNICAL REPORT.pdf	2003	Yes
Preliminary Geotechnical Report - Knik Arm Bridge Project	200402 KAC Prel Geotech Report Shannonwilson.pdf	2004	Yes
Knik Arm Crossing Engineering Feasibility and Cost Estimate Update	200405 KAC Cost Estimate Update Parsons.pdf	2004	No
Knik Arm Geophysical Investigation	Knik Arm Geophysical Investigation.pdf	2004	Yes
Geotechnical Exploration Plan	200601 KAC Geotech Plan Shannonwilson.pdf	2006	No
Cost Estimate Review Study	200606 KAC Cost Estimate Review PBSJ.pdf	2006	No
Geotechnical Data Report, Knik Arm Crossing	200703 KAC Geotech Data Report Shannonwilson.pdf	2007	Yes
Geotechnical Engineering Report - Knik Arm Crossing	200703 KAC Pt Mac Geotech PND.pdf	2007	Yes
Review of Draft DEIS Cost Estimate	200706 KAC EIS Estimate Review Rise.pdf	2007	No
Knik Arm Crossing Approach Roads	20070529 KAC Approach Roads PND.pdf	2007	No
Construction Cost Estimate Update of the Main Span	20070711 KAC Estimate Update TYLin.pdf	2007	No
Knik Arm Crossing Geotechnical Memorandum	FINAL March 2007 Memo.pdf	2007	Yes
Knik Arm Crossing Cost Estimate Review	200905 KAC Cost Review FHWA.pdf	2009	No
Report of Drivability & 47" Dia. Pile Design	20090131 KAC Foundation Gerwik.pdf	2009	No
Ambient Noise Measurements near the Proposed Knik Arm Crossing Site during May and July 2010	201102 KAC Ambient Noise HDR.pdf	2010	No
Knik Arm Crossing Development Concepts	20100323 KAC Development Concepts PND.pdf	2010	No
Capital Expenditure Report	201102 KAC Capital Expenditure Report.pdf	2011	No
Noise Measurements of an Oscillator System for Drilled Shafts	201103 KAC Noise Report Oscillator HDR.pdf	2011	No
Design Designation	20110324 KAC Design Designations.pdf	2011	No
Right-Of-Way Map	20130114 KAC Right of Way Map Government Hill.pdf	2013	No

### **3.1 Knik Arm Crossing Engineering Feasibility and Cost Estimate Update, Volume 2 Technology Update, Parsons 2003**

Parsons prepared an update to the engineering feasibility and cost update for the KAC in 2003. The purpose of this project was to provide a preliminary examination of historical and current planning, engineering, and cost factors for the purpose of updating the engineering feasibility and cost estimate components of the KAC project. This update was presented in three (3) volumes. Although this update does not contain geotechnical site investigation or geotechnical laboratory testing data, Volume 2 contains a thorough review and evaluation of available geotechnical data within the KAC project area prior to 2003. Volume 2 contains the following elements that may be of geotechnical interest for the Knik Arm Tunnel Feasibility Study:

- A discussion of subsurface conditions within the Knik Arm at the location of the proposed bridge crossing (as of 2003), including:
  - A geologic cross section along the proposed bridge crossing (see Figure 4).
  - Seven (7) stratigraphic soil units with preliminary geotechnical design parameters (unit weight, undrained shear strength, angle of internal friction, and deep foundation design parameters; see Figure 5).
- A discussion of soil conditions near Ship Creek and Government Hill, along the South Approach (Anchorage Connector) to the 2003 KAC crossing alignment.
- A discussion of abutment and highway embankment considerations, including discussions related to the following areas/components of the 2003 KAC:
  - Bridge over Ship Creek
  - Government Hill Landslide
  - Cut-and-Cover Tunnel through Government Hill
  - Port of Anchorage
  - Shoreline Embankment
  - Abutment Bluffs
  - Highway Pavement Section
- A discussion of **Tunnel Technology and Alternatives** focusing on the feasibility of immersed tube and bored tunnels.

### **3.2 Reconnaissance Geotechnical Report, Mat-Su Rail Corridor, Shannon & Wilson, 2003**

This report presents the results of a field reconnaissance and baseline geotechnical engineering study performed by Shannon & Wilson in 2003 to support the development of a new Alaska Railroad Corporation corridor extending from Port MacKenzie, AK to Willow, AK or Houston, AK. This report does not contain any geotechnical site investigation or geotechnical laboratory testing data, but does contain a discussion of the soil types present along the western side of the Knik Arm. The discussion provided in this report is based upon literature review and three field reconnaissance visits performed in May 2002, November 2002, and January 2003.

### **3.3 Preliminary Geotechnical Report, Knik Arm Bridge Project, Shannon & Wilson, Feb. 2004**

Shannon & Wilson performed a preliminary geotechnical site investigation and laboratory testing program in support of the KAC Bridge Project and prepared a preliminary geotechnical report for the DOT&PF in 2004. The purpose of the geotechnical site investigation and associated laboratory testing was to define the subsurface conditions across a proposed crossing location and to estimate conceptual level pile sizes, capacities, and embedment lengths for bridge piers. The geotechnical site investigation took place between July and October 2003. This report contains geotechnical site investigation information from the following:

- 16 borings performed as part of the 2003 site investigation with depths between 26.5 ft and 242.5 ft.
- 3 historic borings completed by others (Harding Lawson Associates, 1984) with depths between 38.5 and 109.5 ft.
- 2 historic borings completed by Shannon & Wilson in 1996 and 2003, with depths between 21.5 and 72 ft.
- 247 Standard Penetration Test (SPT) samples
- 70 thin-walled tube (i.e.: Shelby tube) samples
- 16 soil core samples
- 5 additional soil samples with unknown sampling methods
- 2 Cone Penetration Tests (CPTs) with depths between 106.95 ft and 224.17 ft.
- 1 downhole shear wave velocity survey
- Surficial reconnaissance of the bluffs on the east and west shores of the Knik Arm near the proposed crossing location.
- Geophysical surveys consisting of seismic reflection and bathymetry (see Section 3.4 for details).

This report contains geotechnical information from the following geotechnical laboratory tests:

- 275 moisture content
- 35 grain size analysis
- 53 fines fraction
- 76 Atterberg limits
- 113 pocket penetrometer
- 13 unconsolidated-undrained (UU) triaxial shear
- 30 unconfined compression (UCS)
- 5 1D consolidation
- 37 unit weight (determined through UU, UCS, and consolidation testing)

Shannon & Wilson utilized the data collected from the geotechnical site investigation and laboratory testing program to develop a new geologic cross section along the proposed crossing location (see Figure 6), and a geologic cross section along the eastern shoreline of the Knik Arm (see Figure 7). This cross section contained four basic geologic units within the channel crossing, in descending order as follows:

1. Recent Channel Marine Deposits
2. Glacial Till or Moraine Deposits
3. Glacial Lake Clays or Marine/Alluvial Sands
  - a. Glacial Lake Clays
  - b. Alluvial Sands
4. Possible Knik Tills

Geotechnical pile design parameters were presented for 10 borings drilled through the Knik Arm channel crossing (Figure 8). Additional geotechnical analyses that may be of interest for the Knik Arm Tunnel Feasibility Study include a site-specific ground response analysis, soil liquefaction analysis, embankment stability analysis, and recommendations for future geotechnical studies and testing.

### **3.4 Knik Arm Geophysical Investigation, Golder Associates, Feb. 2004**

In support of Shannon & Wilson's 2004 geotechnical site investigation and laboratory testing program for the KAC Bridge Project, Golder Associates (Golder) performed a marine geophysical investigation across the Knik Arm for the purpose of: i) mapping the thickness and characteristics of the unconsolidated sediments within the Knik Arm at the proposed crossing location using seismic reflection; and ii) mapping the depth of water in the Knik Arm surrounding the proposed crossing location using a single-channel precision echosounder. Golder stated that the seismic reflection data was difficult to interpret, which was not unexpected considering the complex depositional environment within the Knik Arm. Golder utilized the seismic reflection data in conjunction with the data from the Shannon & Wilson 2004 geotechnical borings to develop several geologic cross sections surrounding the proposed crossing location. The locations of these sections are shown on Figure 9. The cross sections are shown on Figure 10 through Figure 14.

### **3.5 Geotechnical Data Report, Knik Arm Crossing, Shannon & Wilson, March 2007**

Shannon & Wilson performed a second geotechnical site investigation and laboratory testing program in support of the KAC Bridge Project and prepared a geotechnical data report for the DOT&PF in 2007. The purpose of the geotechnical site investigation, field testing, and laboratory testing was to collect geotechnical data along the conceptual alignment for the Knik Arm Crossing structure (the bridge) and abutments. The geotechnical site investigation involved drilling 19 overwater borings between August and October 2006. An additional on-shore boring was drilled on the western shore of the Knik Arm in December, 2005. The report also includes a log for an on-shore boring on the eastern shore of the Knik Arm that was drilled as part of the geotechnical site investigation discussed

in Section 3.3. This report contains new geotechnical site investigation information from the following:

- 20 borings performed as part of the 2005-2006 site investigation with depths between 20 ft and 270.5 ft.
- 504 Standard Penetration Test (SPT) samples
- 45 thin-walled tube (i.e.: Shelby tube) samples
- 16 soil core samples
- 1 bulk soil sample
- 5 Cone Penetration Tests (CPTs) with depths between 39.29 ft and 145.83 ft.
- 2 downhole shear wave velocity surveys
- 2 downhole pressuremeter profiles

This report contains geotechnical information from the following geotechnical laboratory tests:

- 538 moisture content
- 26 grain size analysis
- 67 fines fraction
- 66 Atterberg limits
- 187 pocket penetrometer
- 129 torvane
- 7 unconsolidated-undrained (UU) triaxial shear
- 26 unconfined compression (UCS)
- 3 1D consolidation
- 25 unit weight (determined through UU, UCS, and consolidation testing)

Shannon & Wilson utilized the data collected from the geotechnical site investigation and laboratory testing program to verify the four basic geologic units within the channel crossing that were identified in their 2004 preliminary geotechnical report (Recent Channel Marine Deposits, Glacial Till or Moraine Deposits, Glacial Lake Clays or Marine/Alluvial Sands, and Possible Knik Tills). They also characterized the east and west shoreline soils as consisting of predominantly Glacial Lake Clays and Glacial Till. A revised geologic cross section was not provided with this geotechnical data report.

### **3.6 Geotechnical Engineering Report, Knik Arm Crossing, Mat-Su Access Route, Shannon & Wilson, March 2007**

Shannon & Wilson performed a geotechnical site investigation and laboratory testing program in support of developing a road corridor for accessing the west side of the Knik Arm Crossing and prepared a geotechnical engineering report for the DOT&PF in 2007. The purpose of the geotechnical site investigation, field testing, and laboratory testing was to characterize the general subsurface

conditions along the alignment and support preliminary engineering recommendations. The geotechnical site investigation was performed in 2006 and involved drilling 93 borings along the alignment, and an additional seven (7) borings to evaluate the potential of a localized gravel borrow source at several proposed quarry locations along or near the proposed alignment. Most of the geotechnical borings presented in this geotechnical engineering report are outside of the Knik Arm Tunnel Feasibility study boundary. That said, these borings should be acknowledged and inventoried since construction of a tunnel will still require development of a road corridor for accessing the west side of the Knik Arm. This report contains new geotechnical site investigation information from the following:

- 100 borings performed as part of the 2006 site investigation with depths between 15 ft and 72.6 ft.
- 593 Standard Penetration Test (SPT) samples
- 1 thin-walled tube (i.e.: Shelby tube) samples
- 55 bulk soil sample

It should be noted that the location information for the borings in this report is referenced to the stationing of the proposed road alignment. We currently do not have access to the CAD data/stationing linework, and boring locations are unable to be determined at this time. This report contains geotechnical information from the following geotechnical laboratory tests:

- 440 moisture content
- 92 grain size analysis
- 10 Atterberg limits
- 24 pocket penetrometer
- 19 torvane

In general, Shannon & Wilson reported encountering subsurface soils consisting of existing fill, granular native soils, fine grained native soils, and peat/organic rich soils along the proposed west access route alignment. This geotechnical engineering report also contains recommendations related to ground clearing/stripping, existing roadway preparation, organic subgrade preparation, excavation considerations, embankment construction, widening existing embankments, permanent cut and fill slopes, pavement design, structural fills and compaction, geosynthetics, and drainage.

### **3.7 Knik Arm Crossing Geotechnical Memorandum, Shannon & Wilson, March 2007**

Shannon & Wilson prepared a Geotechnical Memorandum for the Knik Arm Crossing project and submitted this memo to DOT&PF, Knik Arm Bridge and Toll Authority, and the Federal Highway Administration in March 2007. The memo presented the results of a review and evaluation of available geotechnical data in support of engineering studies for the proposed KAC. The purpose of the review and evaluation of available geotechnical data was to provide baseline foundation recommendations

along the proposed bridge approach corridors on the east (Anchorage) and west (Matanuska-Susitna) sides of the Knik Arm to aid the design team in evaluating environmental impacts associated with construction of the KAC bridge and approaches. This memo compiled data from several historic studies, performed both by Shannon & Wilson and others. This memo contains new geotechnical site investigation information from the following:

- 34 historical borings performed by Shannon & Wilson or others, including:
  - Five (5) borings performed on the Matanuska-Susitna side of the KAC with depths between 31.5 ft and 226.7 ft.
  - Seven (7) borings performed near the Port of Anchorage with depths between 21.5 ft and 51.5 ft.
  - 12 borings performed at the “Ingra/Gambell Couplet/1<sup>st</sup> Ave. Slide” with depths between 21.5 ft and 169.9 ft. The “Ingra/Gambell Couplet” is located on the north end of Downtown Anchorage and is bounded by E 3<sup>rd</sup> Ave to the south, Ship Creek to the north, Ingra St. to the east, and Cordova St. to the west.
  - Eight (8) borings performed at the Government Hill Slide location with depths between 45 ft and 233.2 ft.
- 206 Standard Penetration Test (SPT) samples
- 42 thin-walled tube (i.e.: Shelby tube) samples
- 14 bulk soil sample
- 807 additional soil samples with unknown sampling methods

This memo contains geotechnical information from the following geotechnical laboratory tests:

- 809 moisture content
- 15 grain size analysis
- 7 fines fraction
- 540 Atterberg limits
- 57 pocket penetrometer
- 3 torvane
- 735 lab vane
  - Undrained shear strength data on 735 samples and sensitivity data on 626 samples

This memo also provides a discussion of subsurface material types on the Matanuska-Susitna side of the KAC, within the KAC, and on the Anchorage side of the KAC. Geotechnical recommendations include pile capacity and design, soil liquefaction, and highway embankment considerations for the approaches to the KAC that would be constructed through the Government Hill Landslide, Port of Anchorage, and along the East Shoreline/Bluffs. A cut and cover tunnel through Government Hill is also discussed.

### 3.8 Other documents referenced but not available

Several, predominantly older, documents were found in the references of the documents reviewed and discussed in this memo that may contain additional geotechnical information. These documents are listed below, in chronological order from oldest to newest:

- Alaska Department of Highways Materials Section, 1968, Foundation Report, Anchorage Port Access Via Duct, Bridge No. 455, Anchorage, Alaska, April, F-042-1(23).
- Dames & Moore, 1970, Report of Seismic Reflection Survey, Proposed Knik Arm Highway Crossing for the State of Alaska Department of Highways, December.
- Shannon & Wilson, Inc., 1971, Geologic and Engineering Reconnaissance, Proposed Knik Arm Crossing, Anchorage, Alaska, August.
- Kelley, J., 1981, from Harding Lawson Associates, 1984, Geologic and Geotechnical Considerations, Knik Arm Crossing, Anchorage, Alaska, HLA Job No. 9620,016.08, November.
- Slemmons, 1982, from Harding Lawson Associates, 1984, Geologic and Geotechnical Considerations, Knik Arm Crossing, Anchorage, Alaska, HLA Job No. 9620,016.08, November
- Harding Lawson Associates, 1984, Geologic and Geotechnical Considerations, Knik Arm Crossing, Anchorage, Alaska, HLA Job No. 9620,016.08, November.
- URS Corporation. 2005. Draft Technical Memorandum, Seabed Movement of Knik Arm, Anchorage, Alaska, for Knik Arm Bridge and Toll Authority and ADOT&PF, Anchorage.
- HDR Alaska, Inc. and PND Inc. 2006. Knik Arm Crossing Seismic Studies Technical Memorandum. Draft report prepared for Knik Arm Bridge and Toll Authority, ADOT&PF, and FHWA.

### 3.9 Summary

Table 2 through Table 6 presents a summary of all geotechnical data available within the DOT&PF-provided documents. Existing geotechnical data locations are shown on Figure 15 through Figure 18. Recall that borings presented in *Geotechnical Engineering Report, Knik Arm Crossing, Mat-Su Access Route, Shannon & Wilson, March 2007* (see Section 3.6) are currently unable to be accurately located and are not shown on these figures.

Table 2: Geotechnical Data Summary - Site Investigation

Document Title	Prepared By	Year	Location(s)	Borings [No.]	Boring Depth, min [ft]	Boring Depth, max [ft]	CPTs [No.]	CPT Depth, min [ft]	CPT Depth, max [ft]	Test Pits [No.]	Test Pit Depth, min [ft]	Test Pit Depth, max [ft]	Surficial Reconnaissance	Geophysics
Engineering Feasibility and Cost Estimate Update - Technology Update, Volume 2	Parsons	2003	Crossing	--	--	--	--	--	--	--	--	--	--	--
Reconnaissance Geotechnical Report, Mat-Su Rail Corridor	Shannon & Wilson	2003	West Access	--	--	--	--	--	--	--	--	--	Yes	--
Preliminary Geotechnical Report - Knik Arm Bridge Project	Shannon & Wilson	2004	Crossing	21	21.5	242.5	2	106.95	224.17	--	--	--	Yes	Yes <sup>1</sup>
Knik Arm Geophysical Investigation	Golder	2004	Crossing	--	--	--	--	--	--	--	--	--	--	Yes
Geotechnical Data Report - Knik Arm Crossing	Shannon & Wilson	2007	Crossing	20	20	270.5	5	39.29	145.83	--	--	--	--	--
Geotechnical Engineering Report - Knik Arm Crossing, Mat-Su Access Route	Shannon & Wilson	2007	West Access	100	15	72.6	--	--	--	--	--	--	--	--
Knik Arm Crossing Geotechnical Memorandum	Shannon & Wilson	2007	West Access East Access	34	21.5	226.7	--	--	--	1	24.5	24.5	--	--

Notes: 1) Report discusses seismic reflection and bathymetry surveys performed by Golder and presented under the Knik Arm Geophysical Investigation, Golder Associates, Feb. 2004 report.

Table 3: Geotechnical Data Summary - Sampling

Document Title	Prepared By	Year	Location(s)	SPT [No.] <sup>1</sup>	Thin-Walled Tube [No.]	Grab/Bulk [No.]	Soil Core [No.]	Unknown [No.]
Engineering Feasibility and Cost Estimate Update - Technology Update, Volume 2	Parsons	2003	Crossing	--	--	--	--	--
Reconnaissance Geotechnical Report, Mat-Su Rail Corridor	Shannon & Wilson	2003	West Access	--	--	--	--	--
Preliminary Geotechnical Report - Knik Arm Bridge Project	Shannon & Wilson	2004	Crossing	247	70	--	16	5
Knik Arm Geophysical Investigation	Golder	2004	Crossing	--	--	--	--	--
Geotechnical Data Report - Knik Arm Crossing	Shannon & Wilson	2007	Crossing	504	45	1	49	--
Geotechnical Engineering Report - Knik Arm Crossing, Mat-Su Access Route	Shannon & Wilson	2007	West Access	593	1	55	--	--
Knik Arm Crossing Geotechnical Memorandum	Shannon & Wilson	2007	West Access East Access	206	42	14	--	807

Notes: 1) SPT category includes conventional SPT and 3-inch OD SPT.

Table 4: Geotechnical Data Summary – In-Situ Testing

Document Title	Prepared By	Year	Location(s)	Downhole Shear Wave Velocity [No.]	Pressuremeter [No.]
Engineering Feasibility and Cost Estimate Update - Technology Update, Volume 2	Parsons	2003	Crossing	--	--
Reconnaissance Geotechnical Report, Mat-Su Rail Corridor	Shannon & Wilson	2003	West Access	--	--
Preliminary Geotechnical Report - Knik Arm Bridge Project	Shannon & Wilson	2004	Crossing	1	--
Knik Arm Geophysical Investigation	Golder	2004	Crossing	--	--
Geotechnical Data Report - Knik Arm Crossing	Shannon & Wilson	2007	Crossing	2	2
Geotechnical Engineering Report - Knik Arm Crossing, Mat-Su Access Route	Shannon & Wilson	2007	West Access	--	--
Knik Arm Crossing Geotechnical Memorandum	Shannon & Wilson	2007	West Access East Access	--	--

Table 5: Geotechnical Data Summary – Laboratory Testing, Index Tests

Document Title	Prepared By	Year	Location(s)	Moisture Content [No.]	Density/Unit Weight [No.]	Grain Size Analysis [No.]	Fines Fraction [No.]	Atterberg Limits [No.]
Engineering Feasibility and Cost Estimate Update - Technology Update, Volume 2	Parsons	2003	Crossing	--	--	--	--	--
Reconnaissance Geotechnical Report, Mat-Su Rail Corridor	Shannon & Wilson	2003	West Access	--	--	--	--	--
Preliminary Geotechnical Report - Knik Arm Bridge Project	Shannon & Wilson	2004	Crossing	275	37	35	53	76
Knik Arm Geophysical Investigation	Golder	2004	Crossing	--	--	--	--	--
Geotechnical Data Report - Knik Arm Crossing	Shannon & Wilson	2007	Crossing	538	25	26	67	66
Geotechnical Engineering Report - Knik Arm Crossing, Mat-Su Access Route	Shannon & Wilson	2007	West Access	440	--	92	--	10
Knik Arm Crossing Geotechnical Memorandum	Shannon & Wilson	2007	West Access East Access	809	--	15	7	540

Table 6: Geotechnical Data Summary – Laboratory Testing, Shear Strength and Consolidation Tests

Document Title	Prepared By	Year	Location(s)	Pocket Penetrometer [No.]	Torvane [No.]	Lab Vane [No.]	Clay Sensitivity [No.]	Unconfined Compression Test [No.]	Triaxial UU [No.]	Consolidation [No.]
Engineering Feasibility and Cost Estimate Update - Technology Update, Volume 2	Parsons	2003	Crossing	--	--	--	--	--	--	--
Reconnaissance Geotechnical Report, Mat-Su Rail Corridor	Shannon & Wilson	2003	West Access	--	--	--	--	--	--	--
Preliminary Geotechnical Report - Knik Arm Bridge Project	Shannon & Wilson	2004	Crossing	113	--	--	--	30	13	5
Knik Arm Geophysical Investigation	Golder	2004	Crossing	--	--	--	--	--	--	--
Geotechnical Data Report - Knik Arm Crossing	Shannon & Wilson	2007	Crossing	187	129	--	--	26	7	3
Geotechnical Engineering Report - Knik Arm Crossing, Mat-Su Access Route	Shannon & Wilson	2007	West Access	24	19	--	--	--	--	--
Knik Arm Crossing Geotechnical Memorandum	Shannon & Wilson	2007	West Access East Access	57	3	735	626	--	--	--

#### 4 GEOTECHNICAL DATA GAPS

Previous KAC geotechnical investigations and reports primarily focused on the geotechnical site characterization for the purpose of constructing a bridge crossing. It is anticipated that much of the existing data will be useful for this Tunnel Feasibility Study. However, there are some additional geotechnical parameters and site characteristics that are critical to tunnel construction.

Tunneling in soft ground / soil requires a comprehensive understanding of the geological and geotechnical conditions to adequately select the best tunneling technology, develop resilient and sustainable designs, and implement suitable construction means and methods. A combination of laboratory and in situ tests are typically employed to classify the soils and estimate their behavior, determine the strength and compressibility of the soils, and understand the hydraulic properties of the groundwater. Tables 7 and 8 present the in-situ and laboratory tests, respectively, that are typical of a site investigation program for the construction of a tunnel in soil.

Table 7: Standard in-situ tests, their purpose and importance to tunnel construction in soil.

Test	Purpose	Why It Matters for Tunneling
<b>Cone Penetration Test (CPT/CPTu)</b>	Determines soil stratigraphy, strength, and pore pressure	High-resolution profiling for identifying soft clays and sandy layers prone to deformation and water inflow.
<b>Standard Penetration Test (SPT)</b>	Assess relative density and strength of soil	Evaluation of soil strength and identifying weak or loose soils that may cause instability.
<b>Vane Shear Test</b>	Measure of undrained shear strength in clays	Critical for predicting potential squeezing, settlement, or face stability issues.
<b>Pressuremeter Test (PMT)</b>	Assess in situ stress-strain behavior	Estimation of deformation and required support pressure, especially in cohesive or silty soils.
<b>Dilatometer Test (DMT)</b>	Measures stiffness, strength, and stress history	Characterizing soil behavior under stress changes due to tunneling.
<b>Piezometers / Water Level Monitoring</b>	Monitor groundwater levels	Anticipating water ingress risks and evaluating the need for dewatering or face pressure management.
<b>Packer Tests</b>	Measures water flow in boreholes	Identifies zones with high water flow that may require special sealing or drainage during construction.
<b>Seismic Testing (CPT, Crosshole, Downhole)</b>	Measure shear wave velocity	Stiffness profiling and predicting tunnel-induced ground response.

Table 8: Standard laboratory tests, their purpose and importance to tunnel construction in soil.

Test	Purpose	Why It Matters for Tunneling
<b>Moisture Content</b>	Measure natural water content	Soil consistency. High water content may suggest instability or flow potential.
<b>Atterberg Limits (LL, PL, PI)</b>	Define soil plasticity and behavior	Indicates how sticky or soft soils become when wet—important for understanding workability and risk of ground deformation.
<b>Grain Size Distribution</b>	Classify soil and identify proportion of gravel, sand, and fines	Identifies soil types that affect machine choice, face stability, and settlement risk.
<b>Unit Weight / Density</b>	Define mass and weight characteristics of the soil	Important for stress calculations and estimating loads on tunnel lining.
<b>Specific Gravity</b>	Measures density of soil particles	Input for void ratio, porosity, and determining soil behavior under pressure.
<b>Unconfined Compression Test (UCS)</b>	Measure undrained shear strength of cohesive soils	Assessing face stability, support pressure, and short-term stand-up time in soft clays.
<b>Triaxial Shear Test (UU, CU, CD)</b>	Measure shear strength under different drainage paths.	Assessing face stability, support design, and ground deformation modeling.
<b>Direct Shear Test</b>	Determine shear strength of coarse-grained soils	Assess risks of ground movement and soil-liner interface shear strength.
<b>Oedometer (1D Consolidation)</b>	Measure soil compressibility	Predicting ground settlement due to tunneling or dewatering.
<b>Permeability Tests</b>	Measure rate of water flow through soil	Informs the risk of water entering the tunnel and guides waterproofing and dewatering decisions.
<b>Organic Content / pH Testing</b>	Identify organic soils or corrosive environments	Assess potential for corrosive environment degrading tunnel linings and TBM components.
<b>Abrasion</b>	Evaluates how abrasive soil particles are.	Indicates potential wear on tunneling machine tools— affects cost and maintenance planning.
<b>Soil Conditioning Tests (EPB)</b>	Tests how soil reacts to additives like foam.	Helps ensure the soil stays stable and flows well during machine tunneling.
<b>Filtration Index / Marsh Viscosity (Slurry)</b>	Tests how slurries behave under pressure.	Helps design the fluid system for slurry machines, ensuring the tunnel face stays stable.

Upon initial review, the following tests could provide added value to this feasibility study and would, at a minimum, be recommended to be performed before finalizing any tunnel design:

- Cone Penetration Test (CPT): Only a limited number of CPTs have been performed in previous geotechnical studies. The complex stratigraphy and potentially variable pore pressure

conditions under the Knik Arm warrant additional CPT tests to improve soil profiling and to better understand pore pressure conditions.

- Pressuremeter Test (PMT): Understanding the in situ stress-strain behavior will aid in the estimation of required support pressures and liner loads in determining feasible tunneling technologies.
- Packer Tests and/or Permeability Tests: An understanding of the groundwater behavior beneath the Knik Arm is critical for assessing appropriate tunnel boring machine configuration and tunnel liner design, including waterproofing requirements. Previous geotechnical studies do not evaluate groundwater behavior.
- Organic Content / pH Testing: Previous geotechnical studies do not address the presence of organics in the soil that may cause degradation of tunnel linings and tunnel boring machine components. It should be verified whether soils in the area may contain any organic material.
- Abrasion: Machine and cutter tool wear due to soil abrasivity will have significant implications on cost and maintenance estimates. Laboratory tests to evaluate the soil abrasivity will aid the evaluation of necessary intervention and maintenance requirements.

Additional site investigations may also be required between existing borings and/or at greater depths, depending on the alignment alternatives developed. For example, the vertical alignment of the tunnel may extend below the depth of existing borings. In addition, conceptual designs of the tunnel portals on the Anchorage and Port MacKenzie sides of KAC may require further geotechnical investigations to adequately assess the ground conditions. This will be further evaluated as the Conceptual Alternative Report is developed.

## **5 CONCLUSIONS AND RECOMMENDATIONS**

Previous geotechnical investigations and reports have focused on a bridge crossing for the KAC. The historical geotechnical data has been provided in the form of PDF reports. A tunnel feasibility evaluation requires a statistical analysis of the geotechnical data focusing on tunnel crossing. Therefore, digitizing the historical data from PDFs to data tables is required.

Typical tunnel engineering practice groups soils into Engineering Soil Units (ESUs) based on similar engineering behavior, making them more useful for design, risk assessment, and construction planning than traditional classification systems (e.g., USCS). It is recommended that an ESU system be adopted for the purpose of characterizing the geotechnical conditions when assessing tunnel feasibility. Furthermore, the last geological cross section was developed at the conclusion of the 2004 geotechnical investigations. The subsequent investigations contain significantly more information about the subsurface conditions, and it is recommended that a new geological section be developed for this feasibility study.

Additional geotechnical investigations and tests will enhance the tunnel feasibility assessment, particularly regarding groundwater behavior, in situ pressures, and corrosive/abrasive properties. As

the Conceptual Alternatives Report is developed, the necessity for additional geotechnical investigation will be evaluated, and recommendations for additional investigations and tests will be provided.

## 6 REFERENCES

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**Shannon & Wilson, Inc., 1971**, Geologic and Engineering Reconnaissance, Proposed Knik Arm Crossing, Anchorage, Alaska, August.

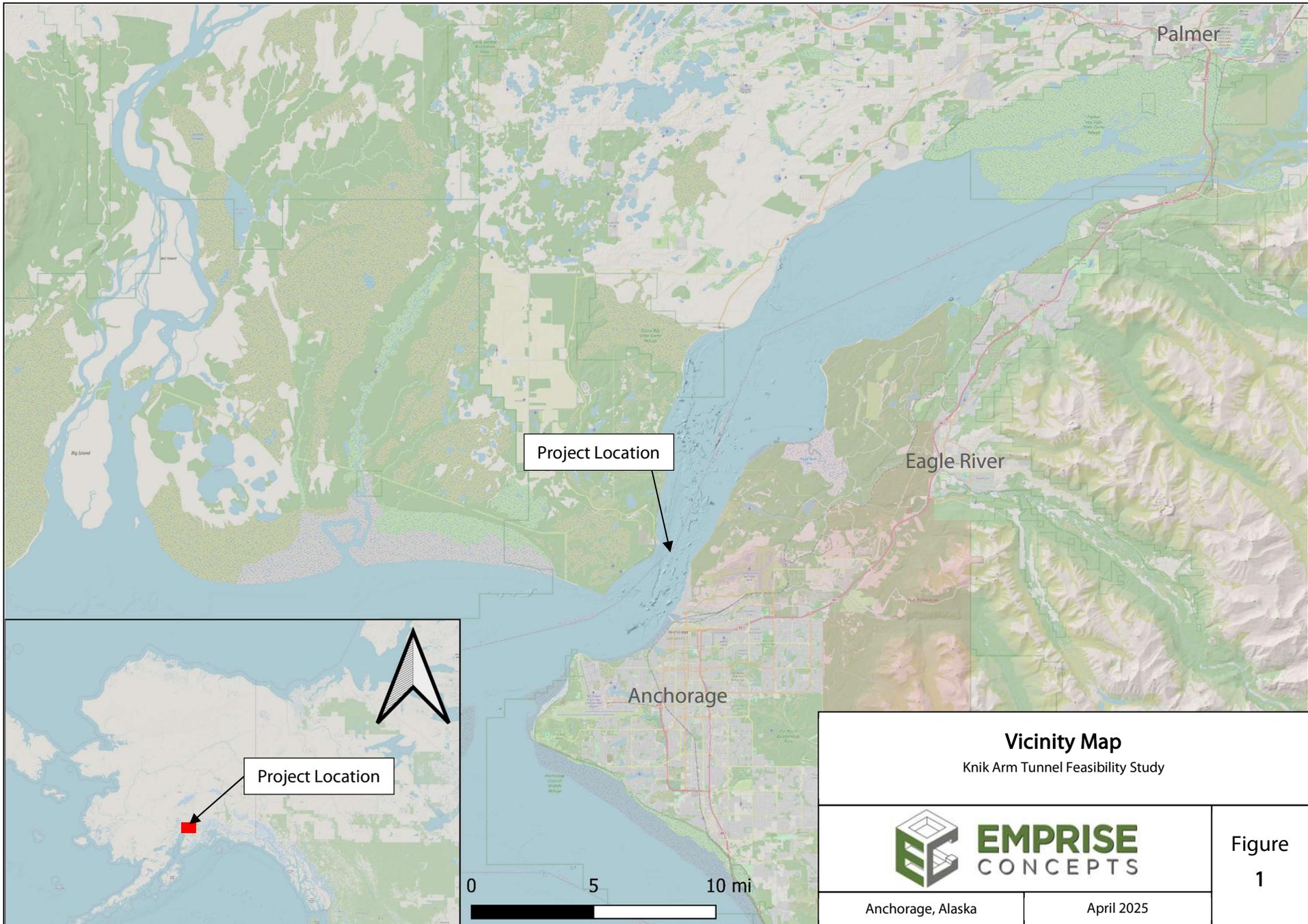
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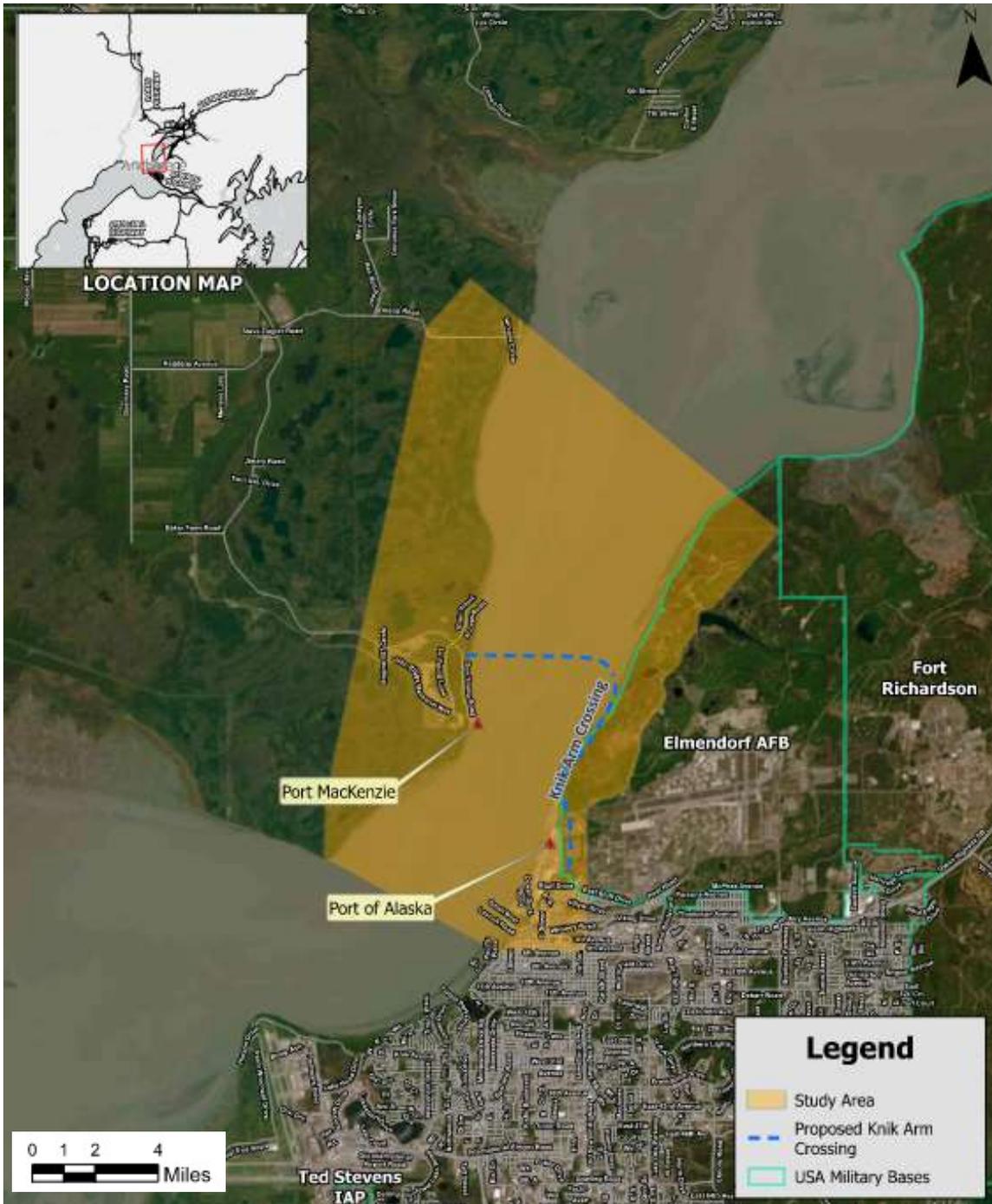
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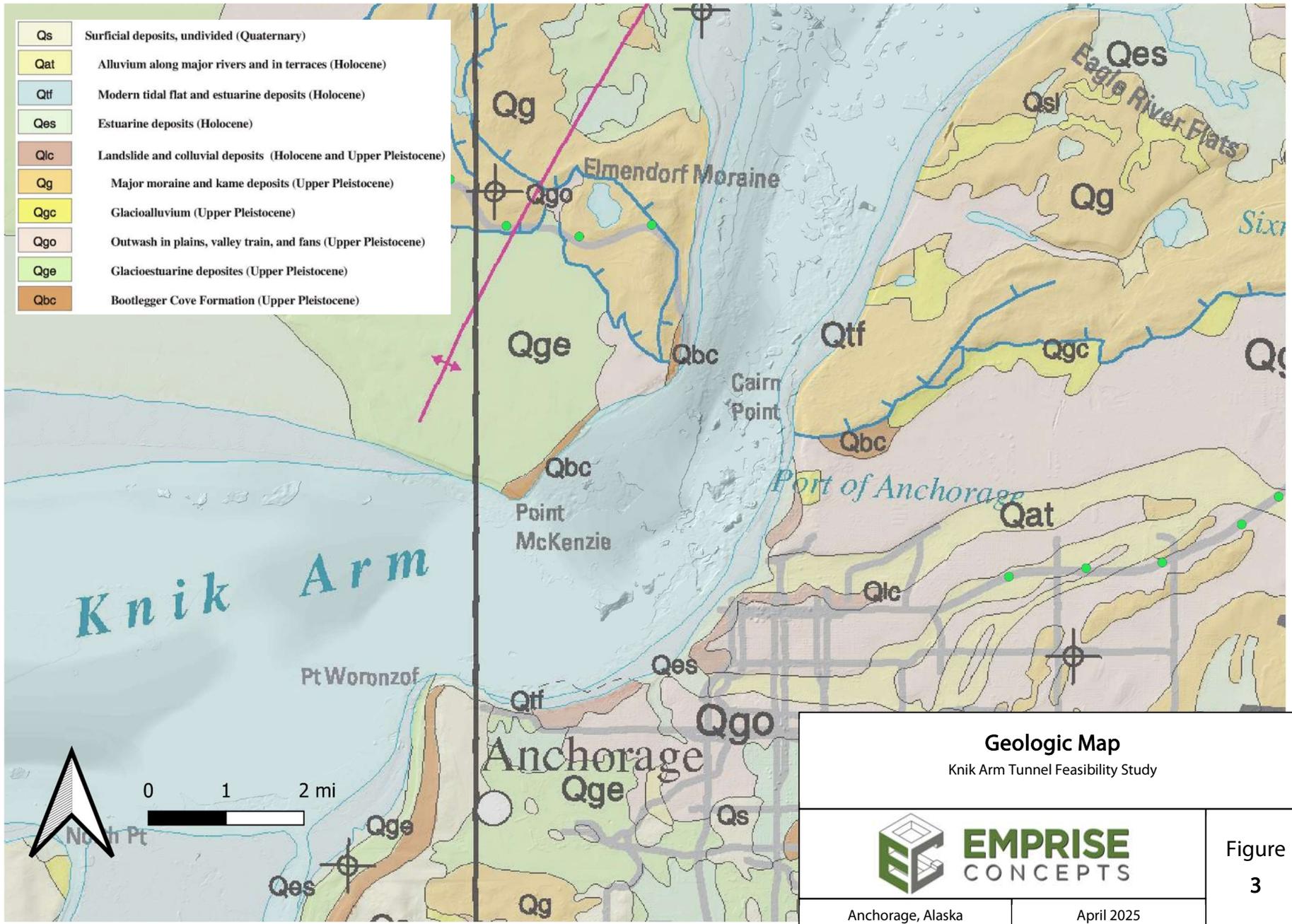
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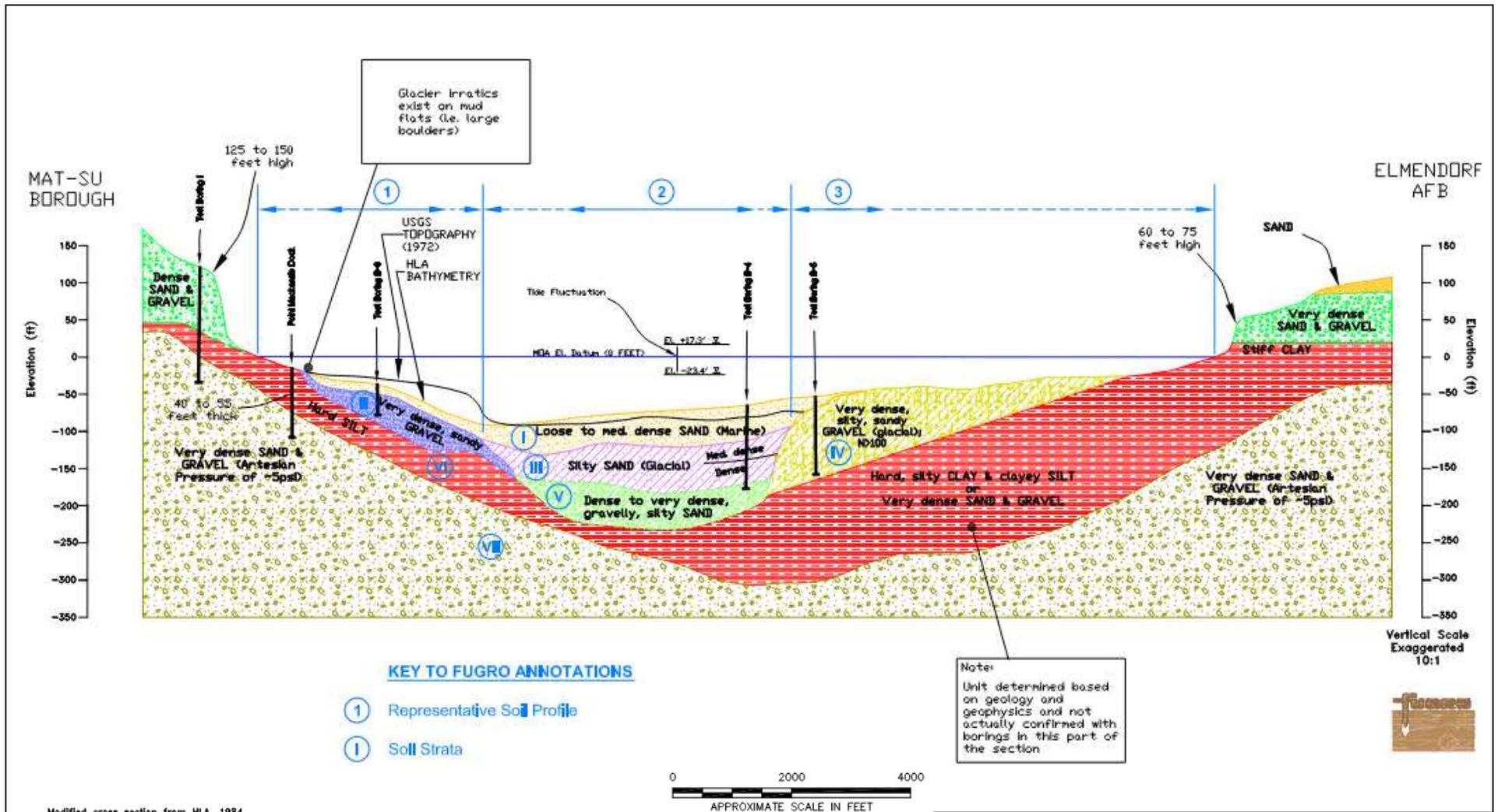


<p><b>Site Map</b></p> <p>Knik Arm Tunnel Feasibility Study</p>	
	
Anchorage, Alaska	April 2025
<p>Figure 2</p>	

- Qs Surficial deposits, undivided (Quaternary)
- Qat Alluvium along major rivers and in terraces (Holocene)
- Qtf Modern tidal flat and estuarine deposits (Holocene)
- Qes Estuarine deposits (Holocene)
- Qlc Landslide and colluvial deposits (Holocene and Upper Pleistocene)
- Qg Major moraine and kame deposits (Upper Pleistocene)
- Qgc Glacioalluvium (Upper Pleistocene)
- Qgo Outwash in plains, valley train, and fans (Upper Pleistocene)
- Qge Glacioestuarine deposits (Upper Pleistocene)
- Qbc Bootlegger Cove Formation (Upper Pleistocene)



<p><b>Geologic Map</b> Knik Arm Tunnel Feasibility Study</p>	
	<p>Figure 3</p>
<p>Anchorage, Alaska</p>	<p>April 2025</p>



Modified cross section from HLA, 1984

### Parsons 2003: Geologic Cross Section

Knik Arm Tunnel Feasibility Study



Figure 4

Anchorage, Alaska

April 2025

**Table 2-1. Geotechnical Design Parameters: Profile 1  
(Based on Boring B-6 and Cross Section)**

[Note: Elevation = approximately -40 feet]

Unit	Description	Depth (feet)	Submerged Unit Weight, $\gamma'$ (pcf)	Undrained Shear Strength, $S_u$ (ksf)	Angle of Internal Friction, $\phi'$ (degrees)	Soil-Pile Friction Angle, $\delta$ (degrees)	Limiting Skin Friction, $F_{max}$ (kips/ft <sup>2</sup> )	Bearing Capacity Factor, $N_Q$	Limiting Unit End Bearing, $Q_{max}$ (kips/ft <sup>2</sup> )
I	Loose to Medium Dense Sand	0 - 13	55	-	25	20	1.4	12	60
II	Very Dense Sandy Gravel	13 - 37	65	-	40	35	2.4	50	250
VI	Hard Silt	37 - 82	60	4.0	-	-	-	-	-
VII	Very Dense Sand and Gravel	82 - 300	65	-	40	35	2.4	50	250

**Table 2-2. Geotechnical Design Parameters: Profile 2  
(Based on Boring B-4 and Cross Section)**

[Note: Elevation = approximately -65 feet]

Unit	Description	Depth (feet)	Submerged Unit Weight, $\gamma'$ (pcf)	Undrained Shear Strength, $S_u$ (ksf)	Angle of Internal Friction, $\phi'$ (degrees)	Soil-Pile Friction Angle, $\delta$ (degrees)	Limiting Skin Friction, $F_{max}$ (kips/ft <sup>2</sup> )	Bearing Capacity Factor, $N_Q$	Limiting Unit End Bearing, $Q_{max}$ (kips/ft <sup>2</sup> )
I	Loose to Medium Dense Sand	0 - 26	55	-	25	20	1.4	12	60
IIIA	Medium Dense Silty Sand	26 - 70	60	-	25	20	1.4	12	60
IIIB	Dense Silty Sand	70 - 87	60	-	30	25	1.7	20	100
V	Dense to Very Dense Gravelly Silty Sand	87 - 137	65	-	35	30	2.0	40	200
VII	Very Dense Sand and Gravel	137 - 300	65	-	40	35	2.4	50	250

**Table 2-3. Geotechnical Design Parameters: Profile 3  
(Based on Boring B-5 and Cross Section)**

[Note: Elevation = approximately -50 feet]

Unit	Description	Depth (feet)	Submerged Unit Weight, $\gamma'$ (pcf)	Undrained Shear Strength, $S_u$ (ksf)	Angle of Internal Friction, $\phi'$ (degrees)	Soil-Pile Friction Angle, $\delta$ (degrees)	Limiting Skin Friction, $F_{max}$ (kips/ft <sup>2</sup> )	Bearing Capacity Factor, $N_Q$	Limiting Unit End Bearing, $Q_{max}$ (kips/ft <sup>2</sup> )
I	Loose to Medium Dense Sand	0 - 10	55	-	25	20	1.4	12	60
IV	Very Dense Silty Sandy Gravel	10 - 107	65	-	35	30	2.0	40	200
VI	<b>Profile 3A</b> Hard Silty Clay and Clayey Silt	107 - 240	60	4.0	-	-	-	-	-
	<b>Profile 3B</b> Very Dense Sand and Gravel	107 - 240	65	-	40	35	2.4	40	250
VII	Very Dense Sand and Gravel	240 - 300	65	-	40	35	2.4	50	250

**Parsons 2003: Geotechnical Design Parameters**

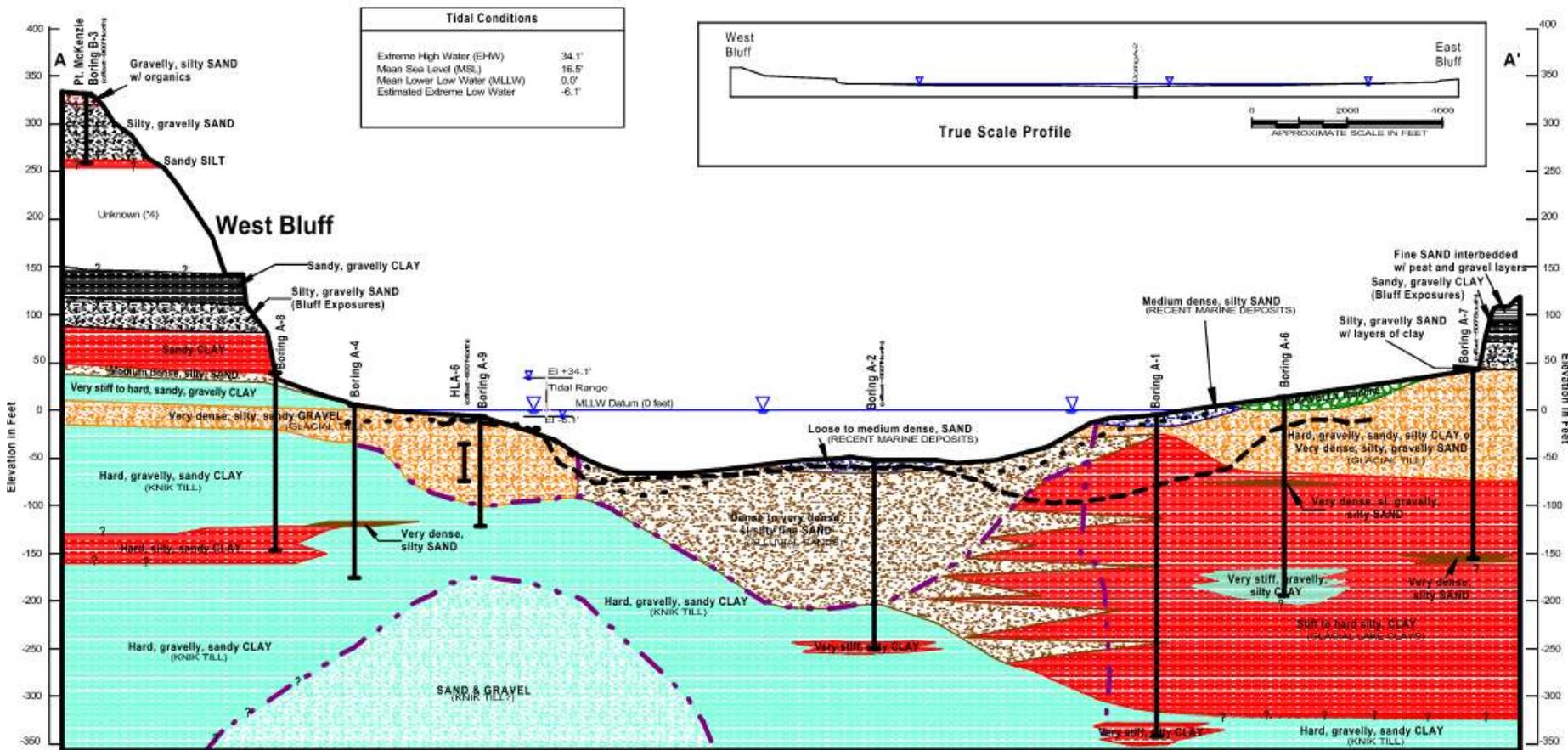
Knik Arm Tunnel Feasibility Study



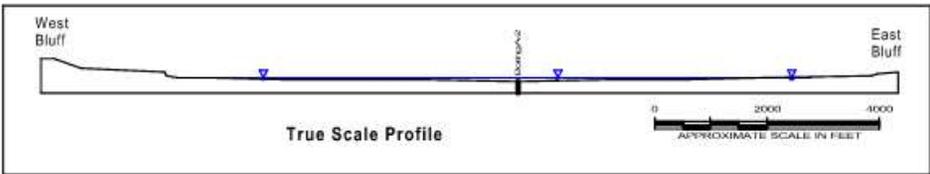
Figure  
5

Anchorage, Alaska

April 2025



Tidal Conditions	
Extreme High Water (EHW)	34.1'
Mean Sea Level (MSL)	16.5'
Mean Lower Low Water (MLLW)	0.0'
Estimated Extreme Low Water	-6.1'



**LEGEND**

- CLAY
- GRAVEL
- Till-like Material
- SAND
- Recent marine SAND
- Gravelly SAND
- Interbedded layers of fine SAND, peat and gravel
- SAND & GRAVEL (based on Geophysical Survey)
- Water Level, 0' Elevation
- (Knik Till) Geologic Unit referred to in text
- Surface Contours by Shannon & Wilson, Inc, 2003
- Surface Contours by Golder Associates, 2004
- Surface Contours by NOAA, 2001 -See Figure 2
- Geophysical Reflector Boundary (Golder, 2004) -Adjusted to match boring contacts

1. Project Datum: MLLW
2. The profile is generalized from materials encountered in borings and interpreted from geophysical surveys and variations between the profile and actual conditions may exist.
3. See Figure 1 for location of profile.
4. Soil Conditions in this depth zone are unknown because they are not visible in the bluff exposures nor were they penetrated with borings.

**Shannon & Wilson, 2004: KAC Geologic Cross Section**

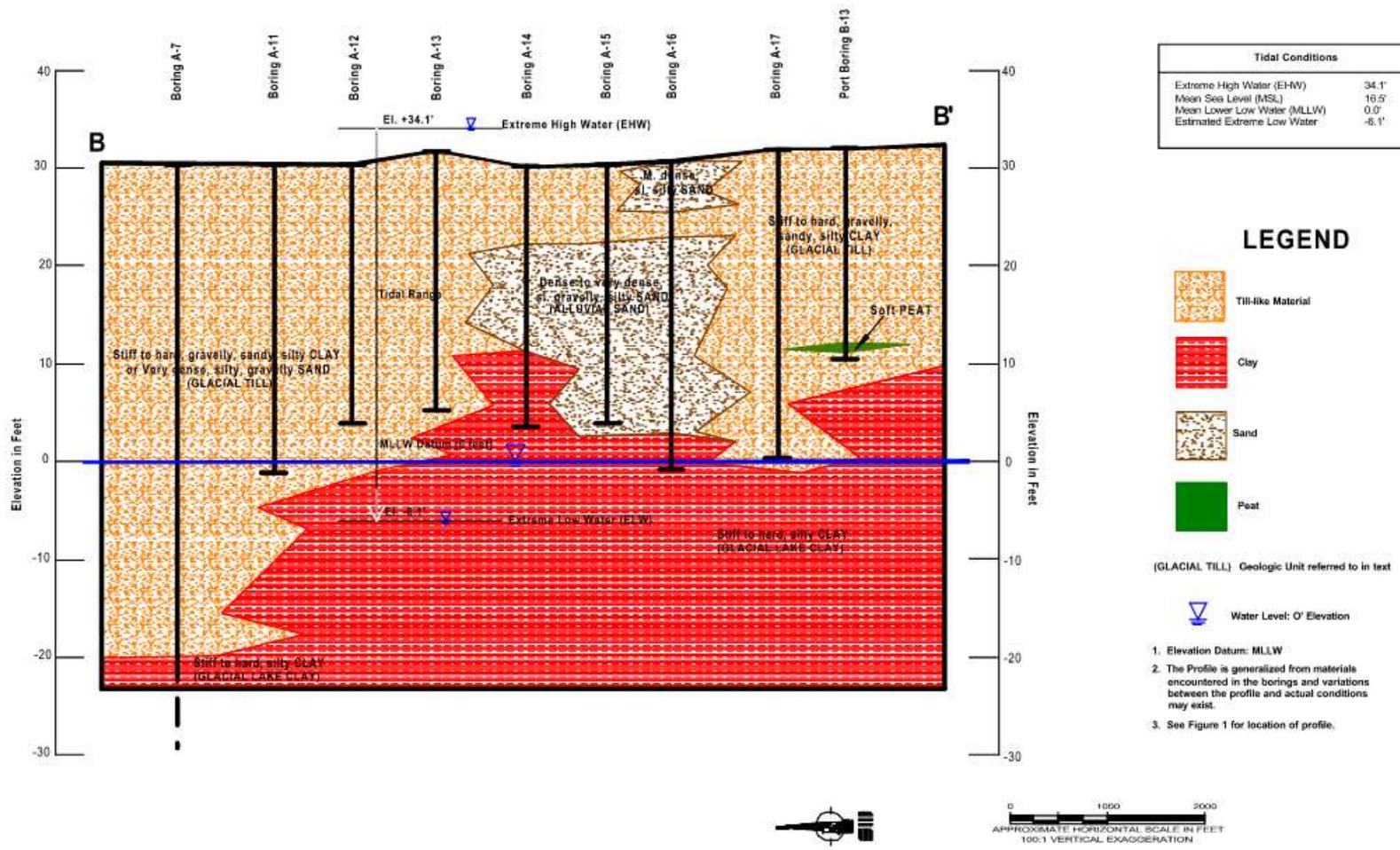
Knik Arm Tunnel Feasibility Study



Figure 6

Anchorage, Alaska

April 2025



**Shannon & Wilson, 2004: East Shoreline Geologic Cross Section**  
 Knik Arm Tunnel Feasibility Study



Figure  
7

Anchorage, Alaska

April 2025

Source: Preliminary Geotechnical Report, Knik Arm Bridge Project, Shannon & Wilson, Feb. 2004

Profile Matching Conditions in Boring A-1							
Description	Depth Below Mudline (feet)	Submerged Unit Weight, $\gamma$ (pcf)	Undrained Shear Strength, $S_u$ (ksf)	Soil-Pile Friction Angle, $\phi$ (degrees)	Limiting Skin Friction, $F_{s,lim}$ (kips/ft <sup>2</sup> )	Bearing Capacity Factor, $N_c$	Limiting Unit End Bearing, $Q_{u,lim}$ (kips/ft <sup>2</sup> )
Medium dense, silty sand	0 - 12	82.6		17.5	1.2	10	50.0
Stiff to hard, silty CLAY	12 - 61	69	3.2		1.6		28.8
Stiff to very stiff, silty clay	61 - 104	65	2.0		1.0		18.0
Very stiff, silty CLAY	104 - 145	64	2.9		1.45		26.1
Very stiff to hard, silty clay	145 - 159	64	4.0		2.0		36.0
Very stiff silty clay	159 - 226	66	2.2		1.1		19.8
Stiff silty clay	226 - 240	67	1.0		.75		9.0
Very stiff to hard silty clay	240 - 270	77	4.0		2.0		36.0
Stiff to very stiff silty clay	270 - 312	68	3.4		1.7		30.6
Hard, gravelly silty clay	312 - 337	74	4.7		2.35		42.3
Profile Matching Conditions in Boring A-2							
Description	Depth Below Mudline (feet)	Submerged Unit Weight, $\gamma$ (pcf)	Undrained Shear Strength, $S_u$ (ksf)	Soil-Pile Friction Angle, $\phi$ (degrees)	Limiting Skin Friction, $F_{s,lim}$ (kips/ft <sup>2</sup> )	Bearing Capacity Factor, $N_c$	Limiting Unit End Bearing, $Q_{u,lim}$ (kips/ft <sup>2</sup> )
Loose sand	0 - 20	58		0	.60	5	25
Medium dense, slightly silty, fine sand	20 - 65	60		0	1.2	10	50
Medium dense to very dense silty sand	65 - 100	66		25	1.7	2	100
Very dense, slightly silty to clean sand	100 - 142	70		30	2.0	40	200
Very dense silty sand and gravel	142 - 156	73		35	2.4	50	250
Very stiff to hard silty clay	156 - 182	63.5	3.7		1.85		33.3
Hard slightly sandy silty clay	182 - 191	66		30	2.0	40	200
Very stiff silty clay	191 - 198	63.5	2.5		1.25		22.5
Profile Matching Conditions in Boring A-4							
Description	Depth Below Mudline (feet)	Submerged Unit Weight, $\gamma$ (pcf)	Undrained Shear Strength, $S_u$ (ksf)	Soil-Pile Friction Angle, $\phi$ (degrees)	Limiting Skin Friction, $F_{s,lim}$ (kips/ft <sup>2</sup> )	Bearing Capacity Factor, $N_c$	Limiting Unit End Bearing, $Q_{u,lim}$ (kips/ft <sup>2</sup> )
Dense to very dense silty sand and gravel	0 - 40	78		35	2.4	50	250
Hard gravelly silty clay	40 - 123	65	5		2.5		45
Very dense silty sand	123 - 128	63		30	2.0	40	200
Hard, sandy silty clay	128 - 144	66	5		2.5		45
Hard slightly gravelly silty clay	144 - 200	66	6		3.0		54

Profile Matching Conditions in Boring A-5							
Description	Depth Below Mudline (feet)	Submerged Unit Weight, $\gamma$ (pcf)	Undrained Shear Strength, $S_u$ (ksf)	Soil-Pile Friction Angle, $\phi$ (degrees)	Limiting Skin Friction, $F_{s,lim}$ (kips/ft <sup>2</sup> )	Bearing Capacity Factor, $N_c$	Limiting Unit End Bearing, $Q_{u,lim}$ (kips/ft <sup>2</sup> )
Very stiff to hard clay with sand	0 - 25	65	3.5		1.75		31.5
Very stiff dense clay and sand	25 - 125	68	3.0		1.75		27.0
Very dense and hard sand and clay	125 - 160	66		30	2.00	35	100.0
Profile Matching Conditions in Boring A-6							
Description	Depth Below Mudline (feet)	Submerged Unit Weight, $\gamma$ (pcf)	Undrained Shear Strength, $S_u$ (ksf)	Soil-Pile Friction Angle, $\phi$ (degrees)	Limiting Skin Friction, $F_{s,lim}$ (kips/ft <sup>2</sup> )	Bearing Capacity Factor, $N_c$	Limiting Unit End Bearing, $Q_{u,lim}$ (kips/ft <sup>2</sup> )
Very stiff sandy gravelly silty clay	0 - 45	65	3.3		1.85		29.7
Very dense sandy gravel and cobbles	48 - 65	78		35	2.4	50	200
Very dense, gravelly silty SAND	65 - 80	68		32	2.1	40	200
Very stiff to hard sandy, silty clay	80 - 87	67	3.0		1.5		27
Dense to very dense slightly gravelly silty SAND	87 - 93	68		30	2.1	40	200
Very stiff to hard slightly sand silty clay	93 - 135	67	3.5		1.75		31.5
Very stiff to hard slightly sandy silty clay	135 - 181	68	3.3		1.65		29.7
Hard, gravelly silty clay	181 - 210	76	5.0		2.5		45
Profile Matching Conditions in Boring A-7							
Description	Depth Below Mudline (feet)	Submerged Unit Weight, $\gamma$ (pcf)	Undrained Shear Strength, $S_u$ (ksf)	Soil-Pile Friction Angle, $\phi$ (degrees)	Limiting Skin Friction, $F_{s,lim}$ (kips/ft <sup>2</sup> )	Bearing Capacity Factor, $N_c$	Limiting Unit End Bearing, $Q_{u,lim}$ (kips/ft <sup>2</sup> )
Very dense, silty SAND, gravel and cobbles	0 - 117	78		36	2.5	48	230
Hard, silty clay	117 - 193	66	5		2.5		45
Dense, silty SAND	193 - 220	72		30	2.0	40	200
Profile Matching Conditions in Boring A-8							
Description	Depth Below Mudline (feet)	Submerged Unit Weight, $\gamma$ (pcf)	Undrained Shear Strength, $S_u$ (ksf)	Soil-Pile Friction Angle, $\phi$ (degrees)	Limiting Skin Friction, $F_{s,lim}$ (kips/ft <sup>2</sup> )	Bearing Capacity Factor, $N_c$	Limiting Unit End Bearing, $Q_{u,lim}$ (kips/ft <sup>2</sup> )
Medium dense, silty sand	0 - 10	58		15	1.0	8	40
Very stiff to hard, sandy gravelly clay	10 - 36	65	3.5		1.75		31.5
Very dense, slightly gravelly slightly silty SAND	36 - 61	66		32	2.2	42	210
Hard, gravelly sandy, silty Clay	61 - 162	78	5.0		2.5		60
Hard, slightly sandy silty clay	162 - 220	73	4.4		2.2		39.6

Profile Matching Conditions in Boring A-9							
Description	Depth Below Mudline (feet)	Submerged Unit Weight, $\gamma$ (pcf)	Undrained Shear Strength, $S_u$ (ksf)	Soil-Pile Friction Angle, $\phi$ (degrees)	Limiting Skin Friction, $F_{s,lim}$ (kips/ft <sup>2</sup> )	Bearing Capacity Factor, $N_c$	Limiting Unit End Bearing, $Q_{u,lim}$ (kips/ft <sup>2</sup> )
Very dense slightly silty, gravelly sand	0 - 17	68		35	2.4	50	250
Very dense, sandy gravel	17 - 50	76		38	3.0	80	280
Very dense, silty, gravelly sand	50 - 95	68		35	2.4	50	250
Hard, slightly gravelly sandy clay	95 - 140	70	4.0		2.0		360
Profile Matching Conditions in Boring A-10							
Description	Depth Below Mudline (feet)	Submerged Unit Weight, $\gamma$ (pcf)	Undrained Shear Strength, $S_u$ (ksf)	Soil-Pile Friction Angle, $\phi$ (degrees)	Limiting Skin Friction, $F_{s,lim}$ (kips/ft <sup>2</sup> )	Bearing Capacity Factor, $N_c$	Limiting Unit End Bearing, $Q_{u,lim}$ (kips/ft <sup>2</sup> )
Loose to medium dense, fine sand	0 - 43	63		15	1	8	40
Dense to very dense fine sand	43 - 126	67		30	2	40	200
Medium dense, silty fine sand	126 - 150	77		35	2.4	50	250
Hard, sandy, silty Clay	150 - 190	65	5		2.5		45
Very dense, silty, sandy gravel	190 - 210	78		35	2.4	50	250
Hard, slightly sand gravelly clay	210 - 240	70	6		3.0		65

# Shannon & Wilson, 2004: Geotechnical Pile Design Parameters

Knik Arm Tunnel Feasibility Study



Figure 8

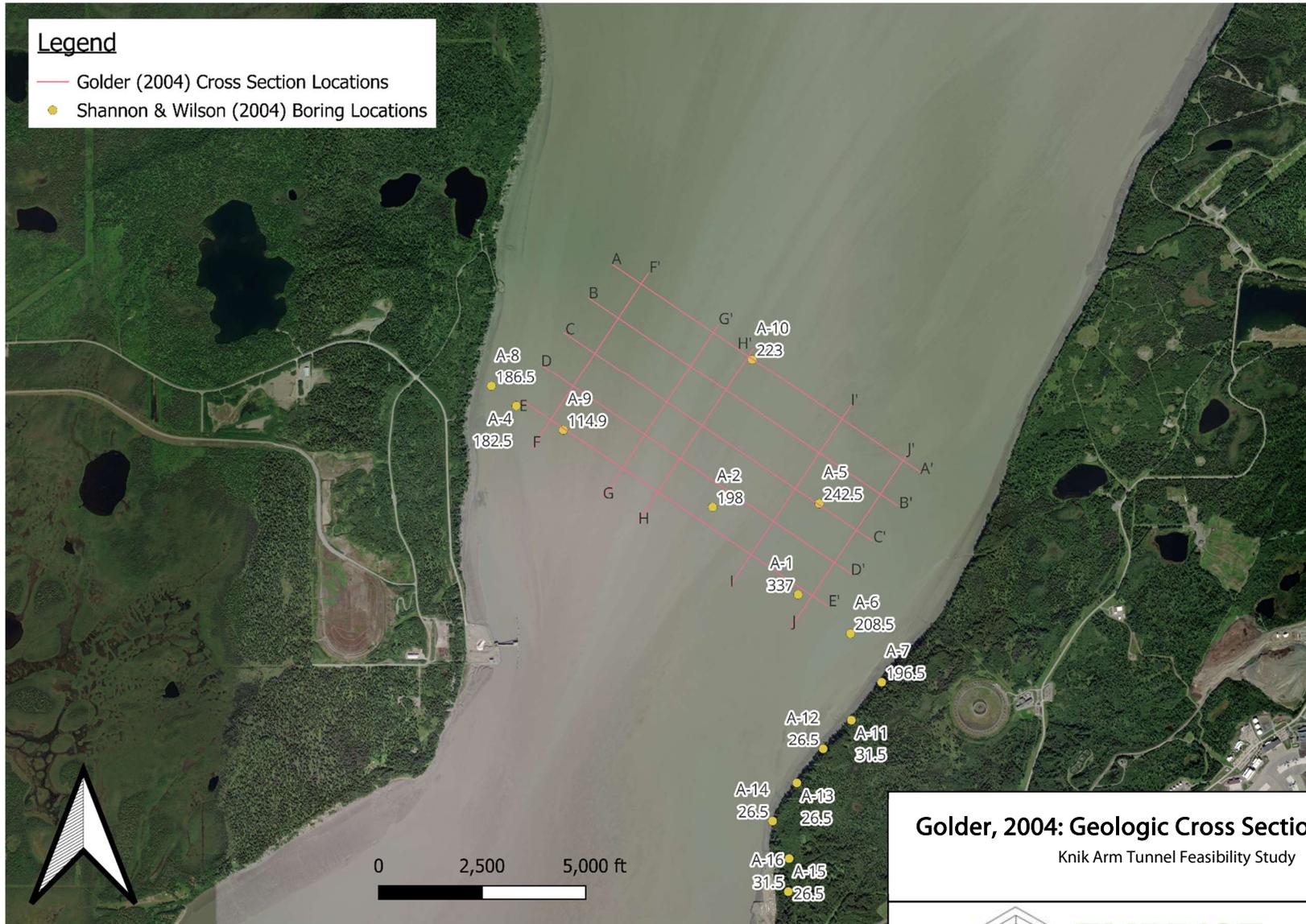
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Source: Preliminary Geotechnical Report, Knik Arm Bridge Project, Shannon & Wilson, Feb. 2004

**Legend**

- Golder (2004) Cross Section Locations
- Shannon & Wilson (2004) Boring Locations



**Golder, 2004: Geologic Cross Section Locations**

Knik Arm Tunnel Feasibility Study



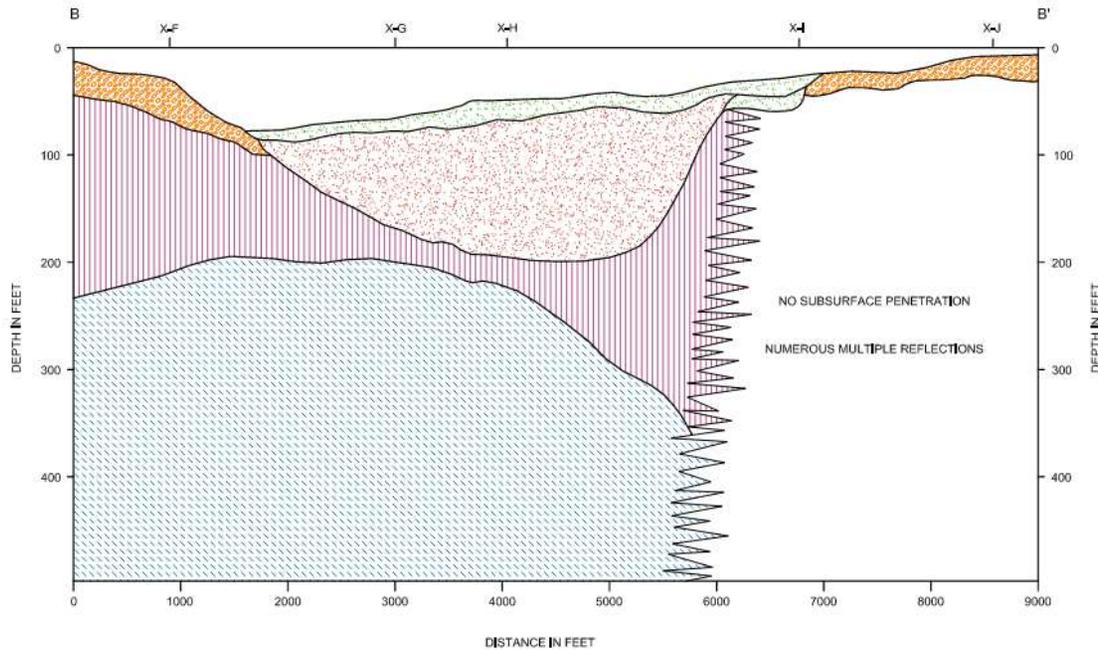
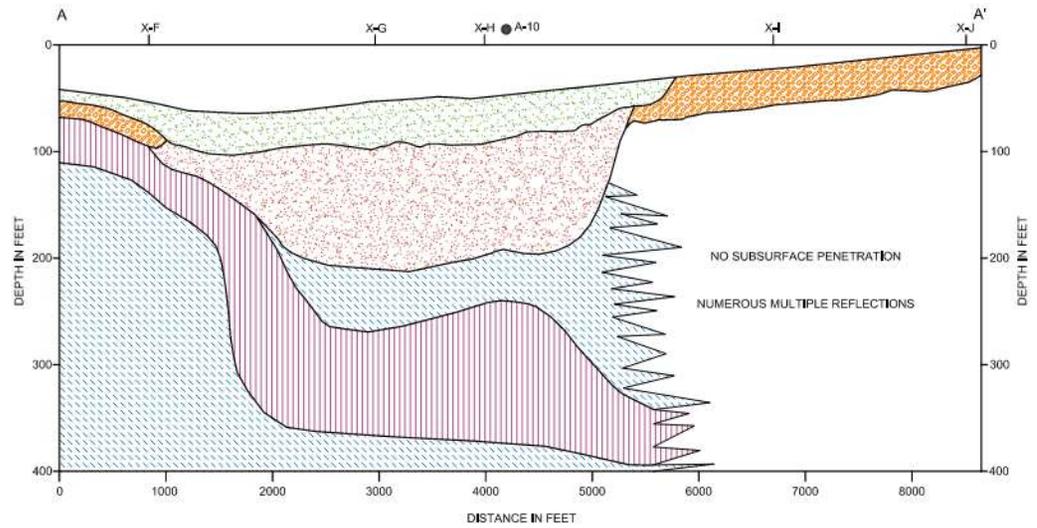
Anchorage, Alaska

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Figure  
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**LEGEND**

-  Recent Marine SAND
-  Till-Like Material Silty, Gravelly SAND
-  Dense Silty SAND
-  Hard, Gravelly Sandy CLAY
-  Silty CLAY
-  Sand and Gravel
-  Cobbles and Boulders
- X-A INTERSECTION OF LINES



**Golder, 2004: Geologic Cross Sections  
A-A' and B-B'**

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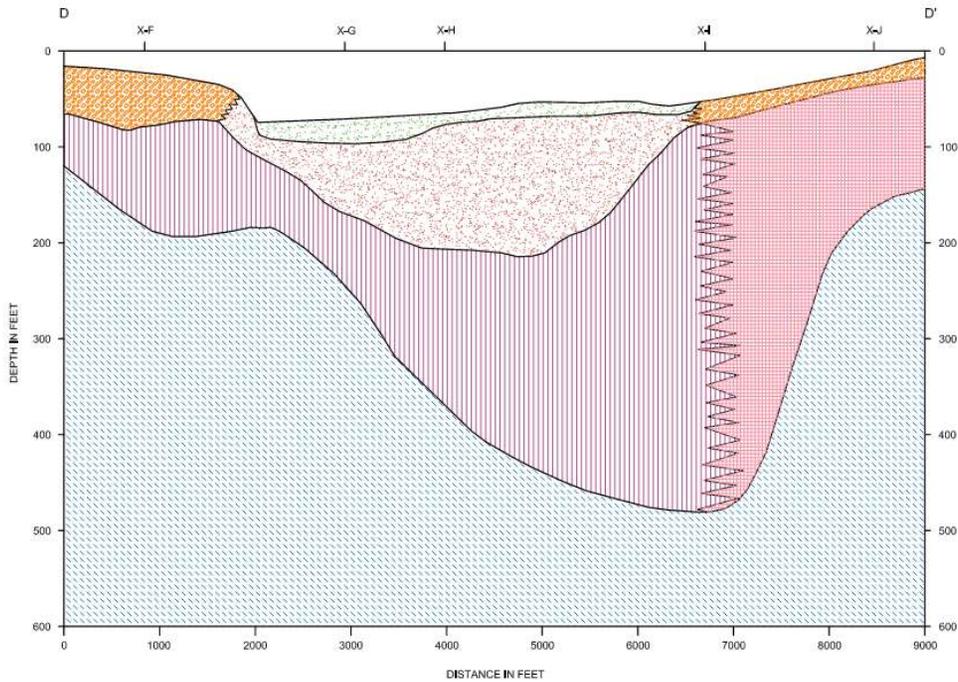
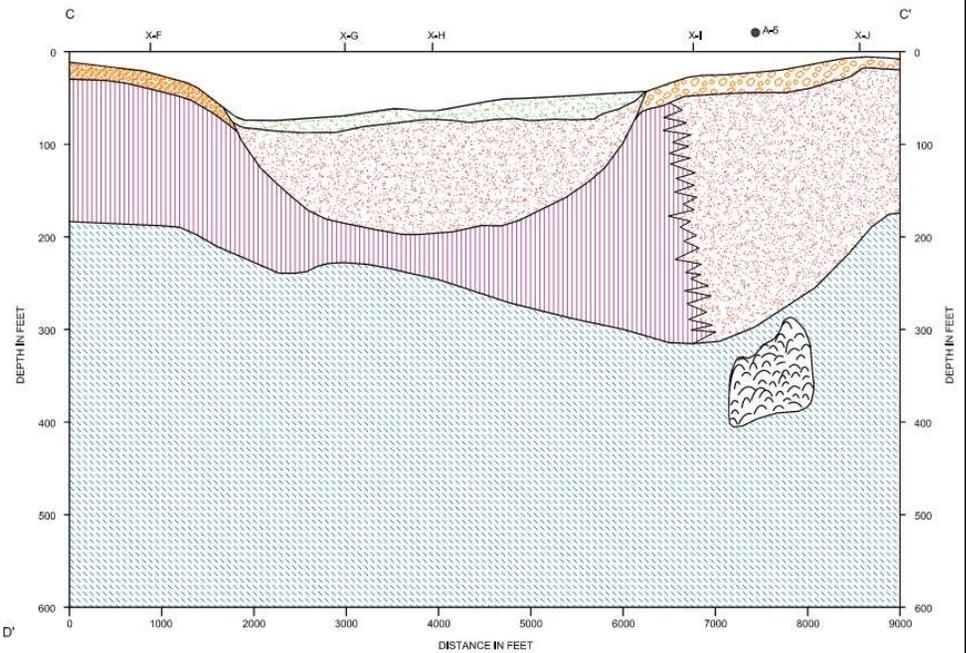
Figure  
10

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**LEGEND**

-  Recent Marine SAND
-  Till-Like Material Silty, Gravelly SAND
-  Dense Silty SAND
-  Hard, Gravelly Sandy CLAY
-  Silty CLAY
-  Sand and Gravel
-  Cobbles and Boulders
- X-A INTERSECTION OF LINES



**Golder, 2004: Geologic Cross Sections  
C-C' and D-D'**

Knik Arm Tunnel Feasibility Study



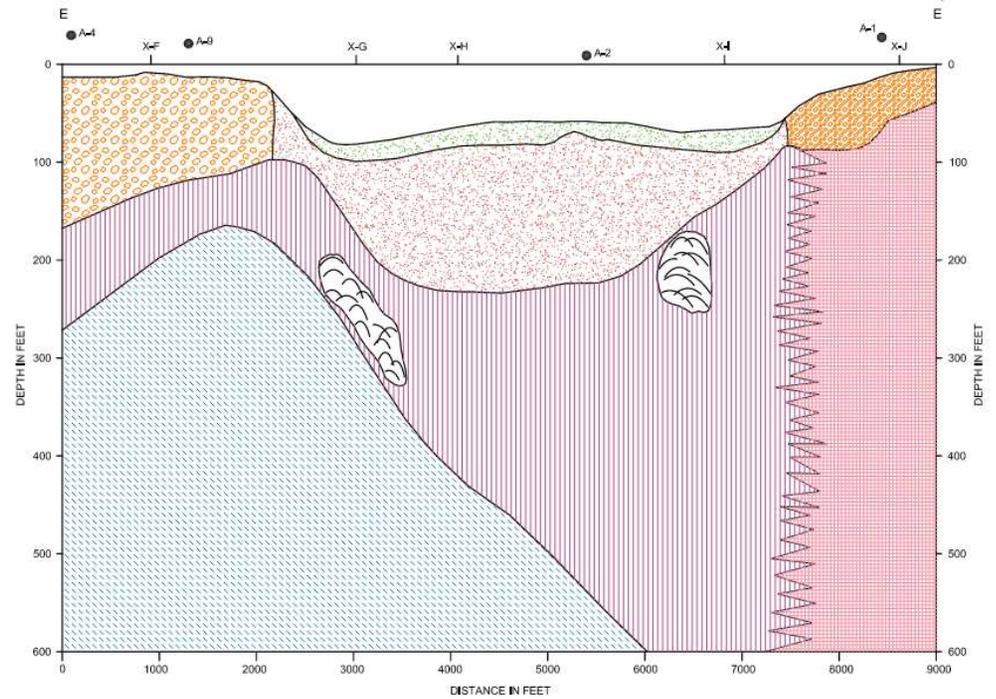
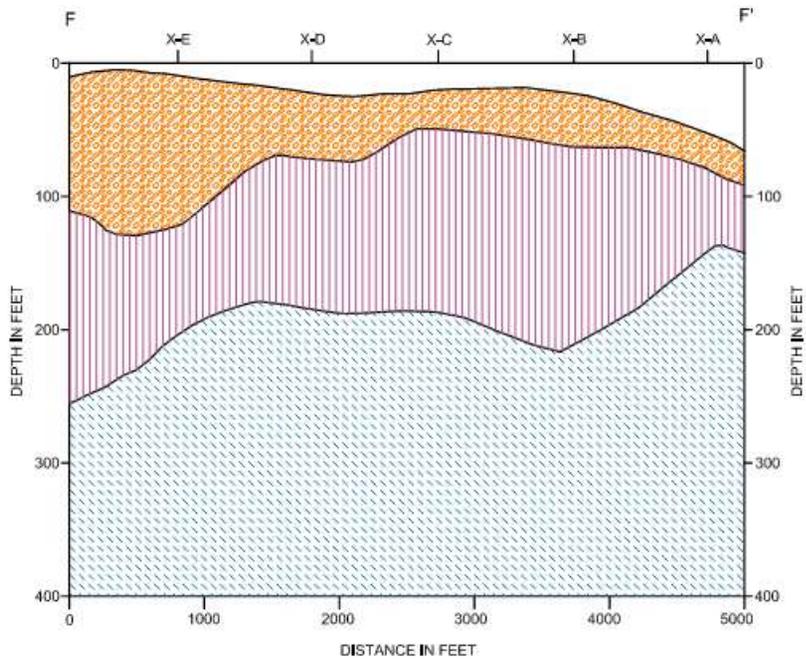
Figure  
**11**

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**LEGEND**

-  Recent Marine SAND
-  Till-Like Material Silty, Gravelly SAND
-  Dense Silty SAND
-  Hard, Gravelly Sandy CLAY
-  Silty CLAY
-  Sand and Gravel
-  Cobbles and Boulders
- X-A INTERSECTION OF LINES



**Golder, 2004: Geologic Cross Sections  
E-E' and F-F'**

Knik Arm Tunnel Feasibility Study



Figure  
12

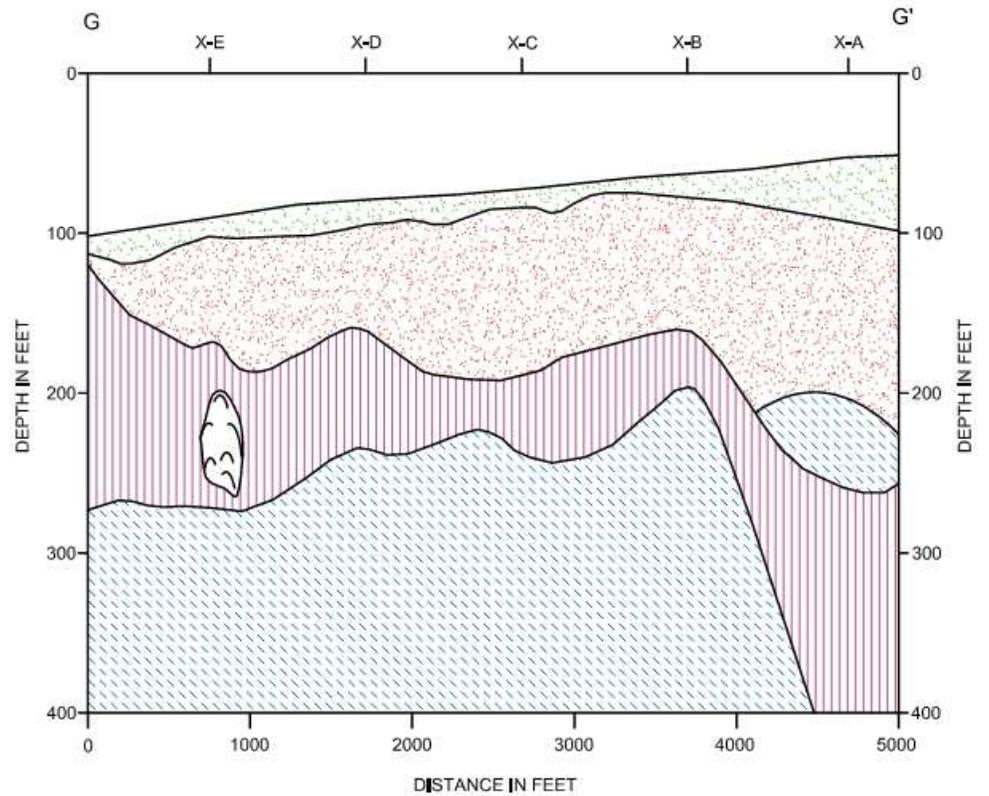
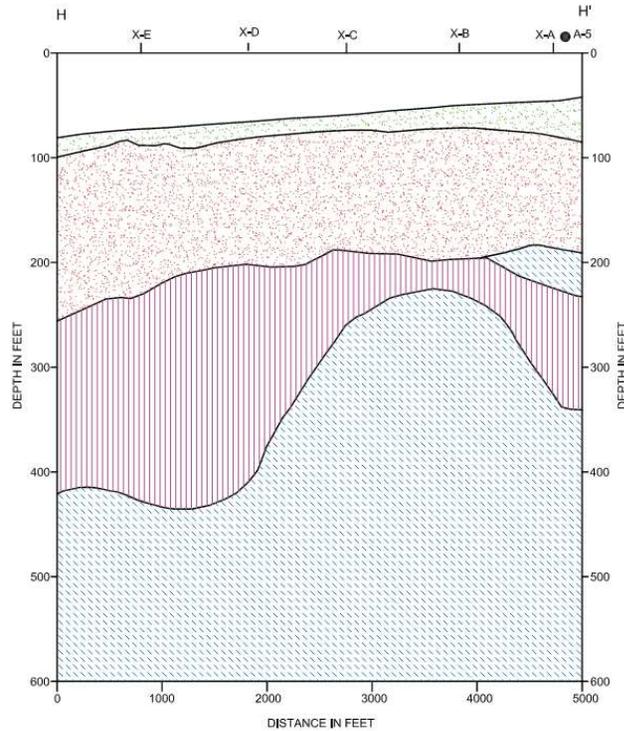
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**LEGEND**

-  Recent Marine SAND
-  Till-Like Material Silty, Gravelly SAND
-  Dense Silty SAND
-  Hard, Gravelly Sandy CLAY
-  Silty CLAY
-  Sand and Gravel
-  Cobbles and Boulders

X-A INTERSECTION OF LINES



**Golder, 2004: Geologic Cross Sections  
G-G' and H-H'**

Knik Arm Tunnel Feasibility Study



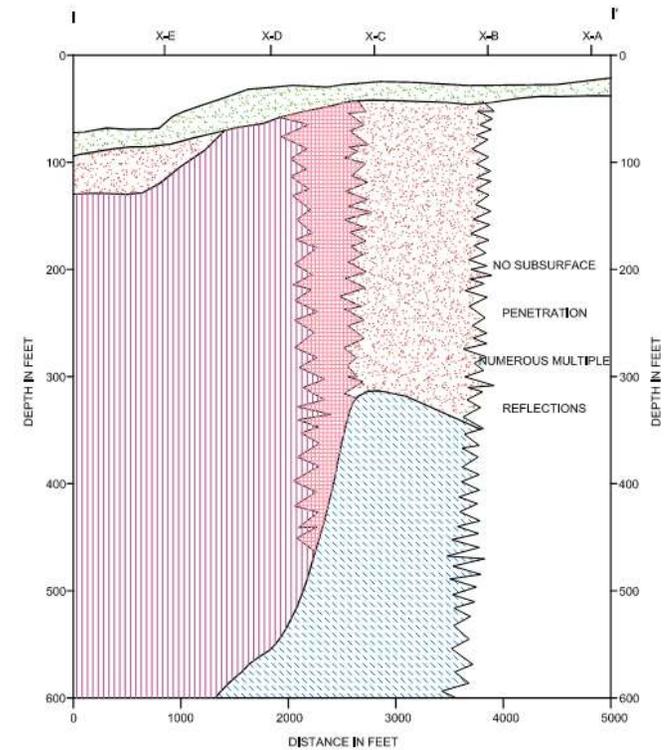
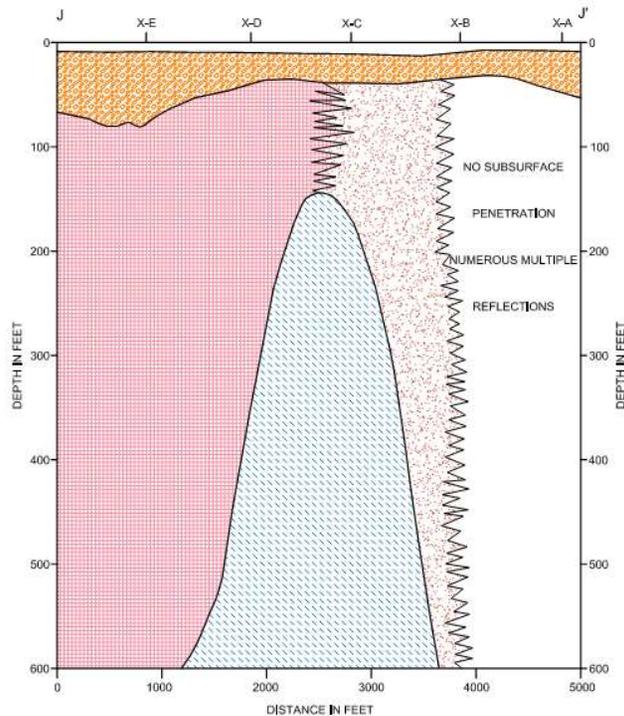
Figure  
**13**

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**LEGEND**

-  Recent Marine SAND
-  Till-Like Material Silty, Gravelly SAND
-  Dense Silty SAND
-  Hard, Gravelly Sandy CLAY
-  Silty CLAY
-  Sand and Gravel
-  Cobbles and Boulders
- X-A INTERSECTION OF LINES



**Golder, 2004: Geologic Cross Sections  
I-I' and H-H'**

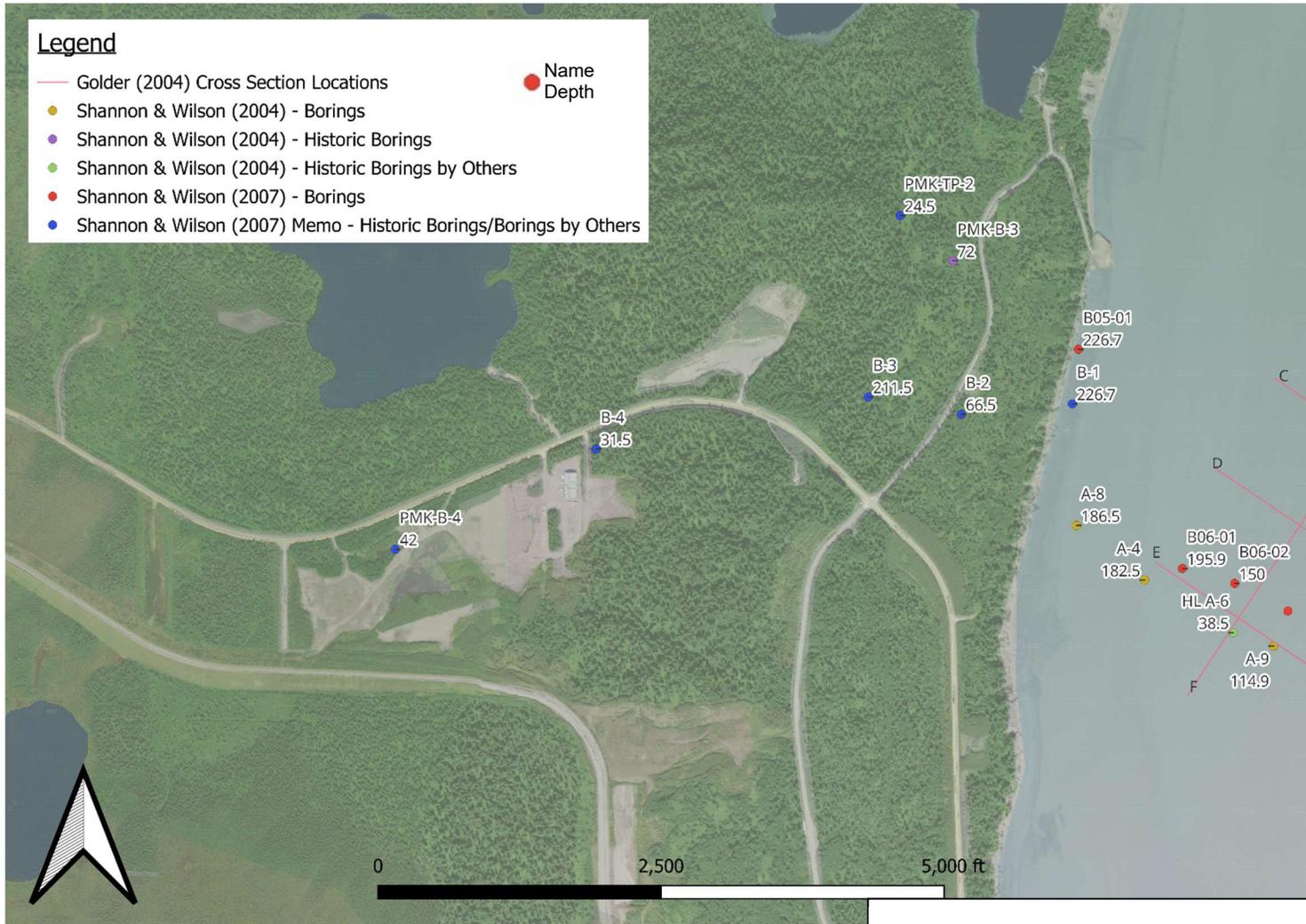
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Figure  
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**Existing Geotechnical Data Locations  
Matanuska-Susitna Side**

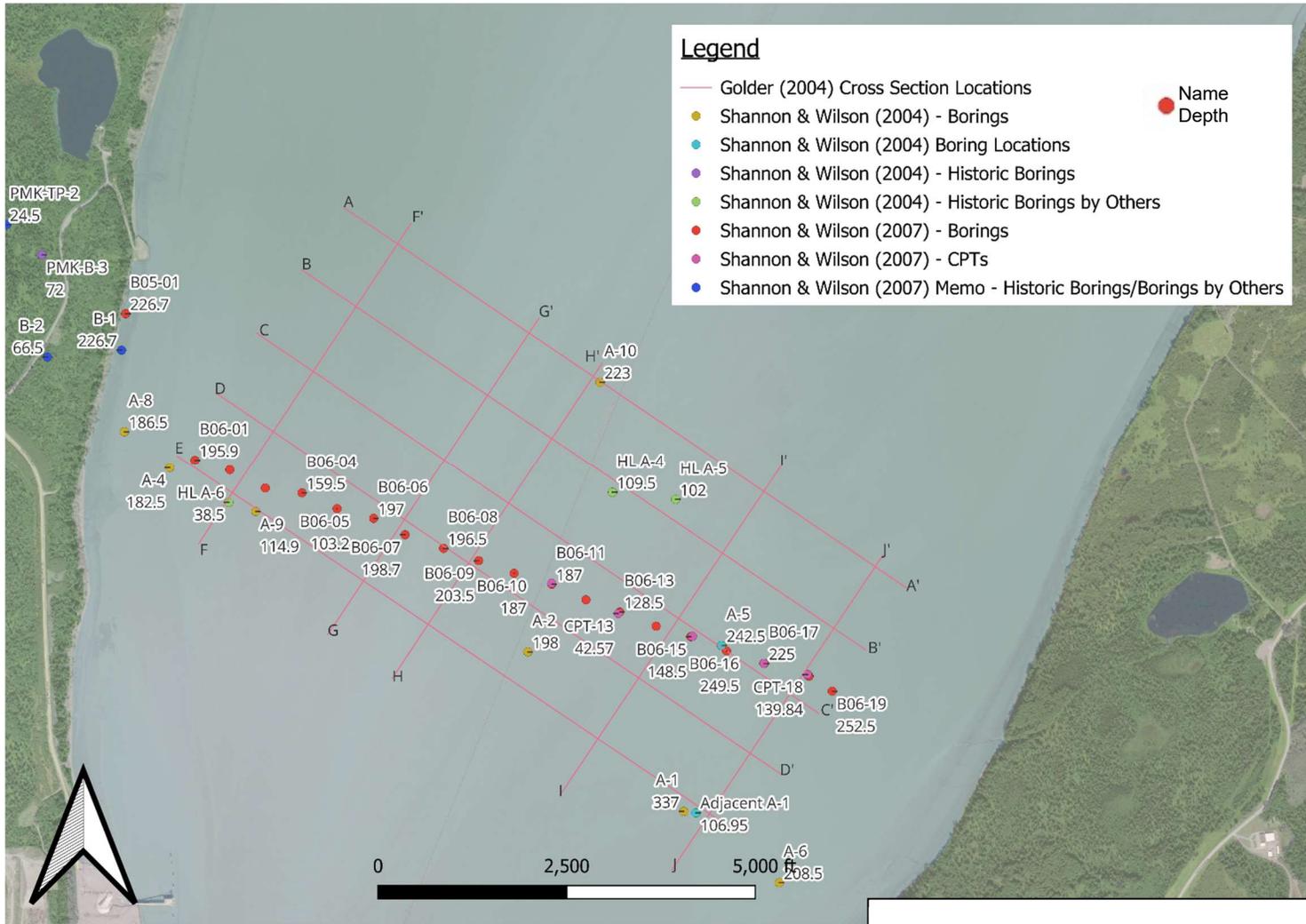
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Figure  
15



**Existing Geotechnical Data Locations**  
**Knik Arm Crossing**  
Knik Arm Tunnel Feasibility Study



**Figure**  
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**Existing Geotechnical Data Locations  
East Bluffs**  
Knik Arm Tunnel Feasibility Study



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Figure  
17



**Existing Geotechnical Data Locations  
Anchorage Side**  
Knik Arm Tunnel Feasibility Study



Figure  
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