APPENDIX D: PRELIMINARY GEOLOGICAL ASSESSMENT

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PRELIMINARY GEOLOGIC AND GEOTECHNICAL ASSESSMENT REPORT

Aleknagik to Koliganek Road Feasibility Study

DILLINGHAM CENSUS AREA, ALASKA

SHANNON & WILSON

April 2026

Shannon & Wilson No: 112571-001

Submitted To: Bristol Engineering Services Company, LLC
111 W. 16th Avenue, 3rd Floor
Anchorage, Alaska 99501
Attn: Jackie Hebnes, PE

Subject: PRELIMINARY GEOLOGIC AND GEOTECHNICAL ASSESSMENT REPORT, ALEKNAGIK TO KOLIGANEK ROAD FEASIBILITY STUDY, DILLINGHAM CENSUS AREA, ALASKA

Shannon & Wilson prepared this report and participated in this project as a consultant to Bristol Engineering Services Company, LLC. Our scope of services was specified in our proposal dated December 5, 2023 and authorization to proceed was received via Task Order Subcontract 32250060-01 on March 28, 2025. This report presents the results of a preliminary geologic/geotechnical assessment conducted by Shannon & Wilson, Inc. to support Bristol's feasibility study for developing overland routes between the communities of Aleknagik, Ekwok, New Stuyahok, and Koliganek, Alaska. This preliminary assessment report was prepared by the undersigned.

We appreciate the opportunity to be of service to you on this project. If you have questions concerning this report, or we may be of further service, please contact us.

Sincerely,

SHANNON & WILSON

Digitally signed by
Ryan Collins
Date: 4/7/26 08:16 AM

Ryan Collins, CPG
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RDC/KJG:KLB/rdc



Kyle Brennan, PE
Vice President

EXECUTIVE SUMMARY

This report presents the results of our Preliminary Geological and Geotechnical Assessment for the Aleknagik to Koliganek Road Feasibility Study. The preliminary assessment provides a foundational understanding of the geotechnical and geologic conditions in the project area and is intended to inform early-stage planning and corridor development. This assessment was entirely based on a review of existing documents and research and generally includes:

- A description of the physical conditions in the areas including climate, topography, vegetation and permafrost and seasonal frost characteristics,
- a description of the regional geology and seismicity along with more detailed descriptions of the local geology,
- a description of the general potential geologic hazards in the project area,
- a description of generalized anticipated subsurface conditions,
- and preliminary geotechnical considerations and data gap commentary.

The study area spans approximately 2,100 square miles within the western portion of the Nushagak lowlands, a region characterized by rolling terrain, extensive bogs, glacially influenced soils, and isolated permafrost. The western edge of the study area is bordered by the Wood River Mountains and Wood-Tikchik State Park. The Nushagak River, which delineates the eastern boundary of the project area, flows south through the lowland area and drains most of the lowlands into Bristol Bay.

The project area includes numerous rivers and drainages, boggy areas, rolling hills, locally mountainous terrain, and isolated permafrost soils. As such primary geologic hazards in the study area related to the development of new roadway corridors include soft and compressible soils, erosion, flooding, landslides, seasonal frost effects, and thaw unstable permafrost. Other potential hazards include seismically induced hazards such as liquefaction and lateral spreading, and ashfall from distant volcanos in the Aleutian-Alaska Range.

Geotechnical design considerations for roadway projects generally include site preparation and embankment development, addressing potential slope stability and settlement issues, establishing cut and fill slopes, development of roadway structural sections, bridge and culvert foundations, and retaining walls and other structures. As such, the corridor selection and development process should consider geotechnical factors that may adversely affect project feasibility, constructability, cost, and long-term performance. These factors

include but may not be limited to identifying and avoiding areas that likely contain challenging soil conditions such as wetland areas, boggy terrain, estuarine and tidal deposit areas, and unstable permafrost areas, to the extent possible. Substantial volumes of fill material will be required for roadway construction, and while suitable borrow materials are expected to be available throughout the region, their quality and distribution are likely to vary. Therefore, routes with a higher potential for suitable material sources in proximity to the project may be preferrable.

Existing geotechnical data in the project area is limited and primarily focused on currently developed areas. To support future design phases, a phased investigation approach is recommended, including additional geologic and geotechnical assessments, detailed terrain and landform mapping, field reconnaissance, and subsurface explorations such as borings, test pits, and geophysical surveys. These efforts will be essential for refining corridor alignments, evaluating geohazards, and ensuring the feasibility and resilience of the proposed roadway infrastructure.

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Important Information

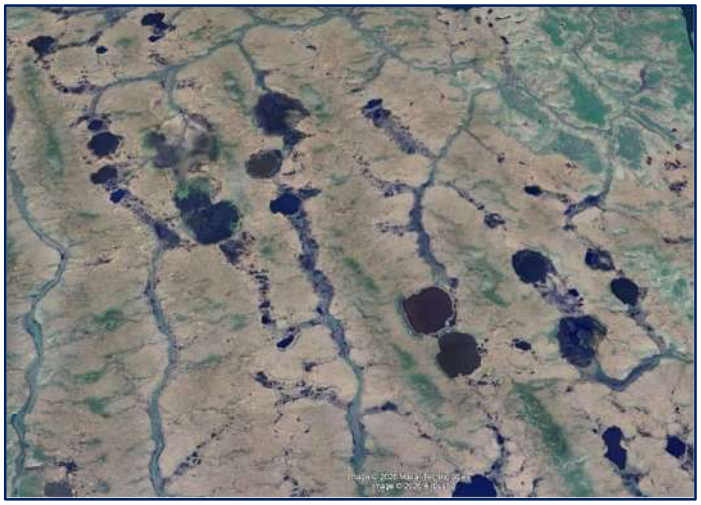
1 INTRODUCTION

This report presents the results of preliminary geotechnical and geologic studies by Shannon & Wilson, Inc. (S&W) to support Bristol's preliminary design and feasibility studies for potential roadway corridors connecting the villages of Aleknagik, Portage Creek, Ekwok, New Stuyahok and Koliganek, Alaska. To accomplish this, we gathered and reviewed geologic and geotechnical information from previous studies by S&W and others in the project area. Data was gathered from publicly available sources, tribal entities, as well as our in-house project database. This review is intended for use by the project design engineering staff, Bristol, and their representatives. The information included herein is intended to provide a generalized baseline of information in support of developing an understanding of possible conditions that may be encountered in the project area. We assume the information will be used to support preliminary corridor/route selection alternatives that will be identified for further investigations. We also assume that conditions described herein will be verified by additional studies, including reconnaissance and site/project specific explorations, to provide the basis of project design.

2 SITE DESCRIPTION

The proposed study area encompasses approximately 2,100-square miles, roughly bound by the Nushagak River on the south and east, Wood River and Wood-Tikchik State Park on the West, and the northern boundary of Township 5 South, Seward Meridian just north of Napotoli creek on the north. The project area is situated within the Nushagak lowlands which are generally characterized by low rolling hills, flat floodplains of the Nushagak and Wood Rivers along with low-lying muskeg swamps, oxbow lakes, and scattered thermokarsts (see Exhibit 2-1). The topography across the area mostly consists of relatively small rolling hills, mounds, and other topographic features, varying from about 100 to 500 feet in elevation. The Muklung Hills and Okstukuk Hills, located

Exhibit 2-1: Example of Potential Thermokarst/Thaw Ponds in the Nushagak Lowlands

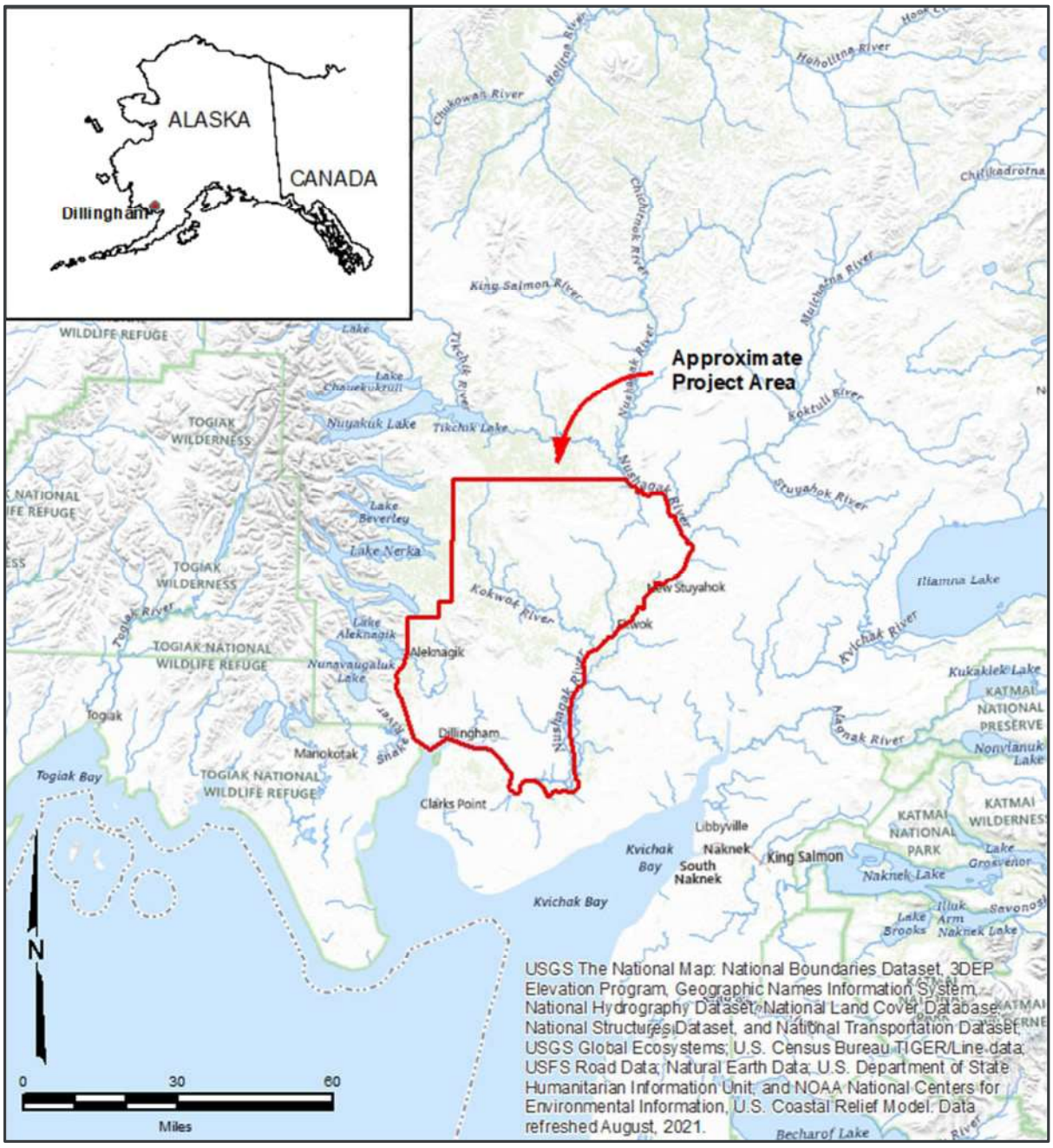


From Google Earth. Image Date 6/15/2024

near the west-central portion of the project area, and Kemuk Mountain in the northwestern portion of the area, have elevations ranging between approximately 1,700 to 2,300 feet above sea level. The Wood River (Ahklun) Mountains, a more extensive mountain range located west of the project area, delineates the transition zone between the tundra covered lowlands of the Nushagak River valley and mountainous areas to the west of the project. Numerous, large, landlocked fjord finger lakes carved by past glacial activity occupy the east-facing valleys of these mountains. A vicinity map showing the general project location is presented in Exhibit 2-2 below. Topographic and shaded relief maps showing prominent physical features of the project vicinity are included in Figure 1.

The project area is largely undeveloped except for the communities of Aleknagik, Portage Creek, Ekwok, New Stuyahok and Koliganek, located in the Dillingham Census area. Ekwok, Portage Creek, New Stuyahok and Koliganek located on Nushagak River are accessible by air, water, and, in the winter, over land. Infrastructure in these communities typically includes single-story houses and buildings, gravel roads, and gravel airstrips. The existing roadway network in these areas is relatively sparse and generally limited to areas within several miles of the communities. Most roadways are developed as rural gravel roads with limited drainage and maintenance. Aleknagik is connected to Dillingham via an approximately 18-mile long, two-laned, paved roadway which represents the longest and most modern roadway in the area. An existing bridge structure crosses the Wood River near the northern end of the route to provide access to Aleknagik.

Exhibit 2-2: Vicinity Map



3 PROJECT DESCRIPTION

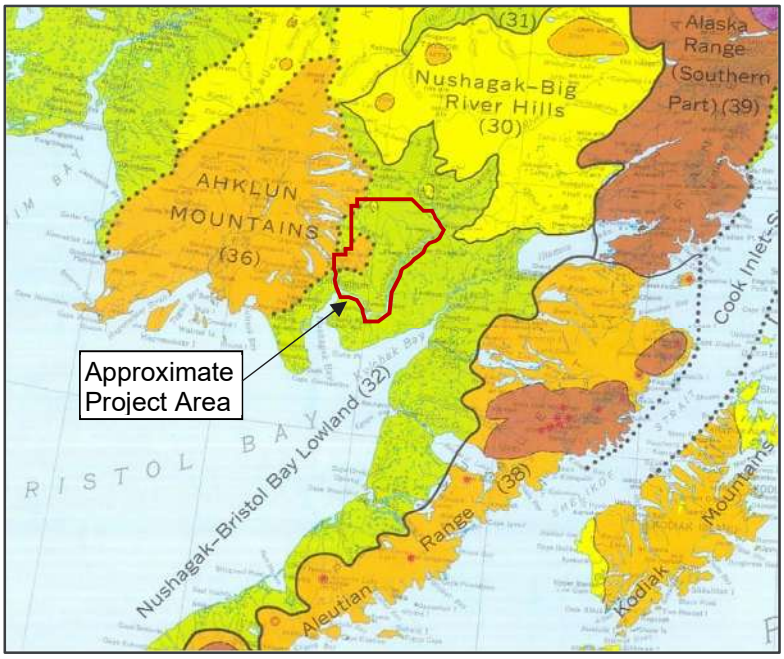
The overall goal of the project is to evaluate the feasibility of connecting the towns and villages of Aleknagik, Ekwok, Portage Creek, New Stuyahok and Koliganek by overland routes (roads). We understand the purpose of this study is to gather and examine existing geologic and geotechnical data in the proposed project area. These results will be used by

the design team to develop and evaluate potential roadway corridors and preliminary planning studies. We envision potential roadway options would generally be designed as a two-laned, rural roadway with a gravel surface. Drainage and crossings for smaller streams will likely be handled with corrugated pipe culverts less than about 4 feet in diameter to the extent possible. Larger diameter pipe culverts, pipe arch culverts, bridges, and other types of structures may be needed to provide crossings for larger drainages and fish passage.

4 GEOLOGIC SETTING AND CLIMATE

According to the U.S. Geological Survey (USGS) quadrangle maps, the majority of the project lies within the Dillingham 1:250,000 quadrangle, except for south of 59 degrees North latitude, which is within the Naknek and Nushagak Bay 1:250,000 quadrangles. In 1965, the USGS published a paper, *Physiographic Divisions of Alaska* (Wahrhaftig, 1965) that divides Alaska into 12 physiographic provinces and 60 smaller subdivisions to provide rough boundaries for and broadly describe the topography, geography, and landform geomorphology that can be used to gain a general understanding of complex underlying geologic processes that combine to form the landscape comprising these areas. The project area is primarily located within the Nushagak-Bristol Bay Lowland physiographic division defined by Wahrhaftig (1965), except for the Muklung Hills and Aleknagik area, which Wahrhaftig combined with the Ahklun Mountains physiographic division, presumably due to topographic similarities with the latter. Wahrhaftig generally describes the Nushagak-Bristol Bay Lowlands as a moraine and outwash-mantled area underlain by hundreds of feet of outwash and morainal soil deposits that thin to a feather edge along the base of the surrounding mountains.

Exhibit 4-1: Physiographic Divisions of Southwest Alaska



Taken from Wahrhaftig, 1965.

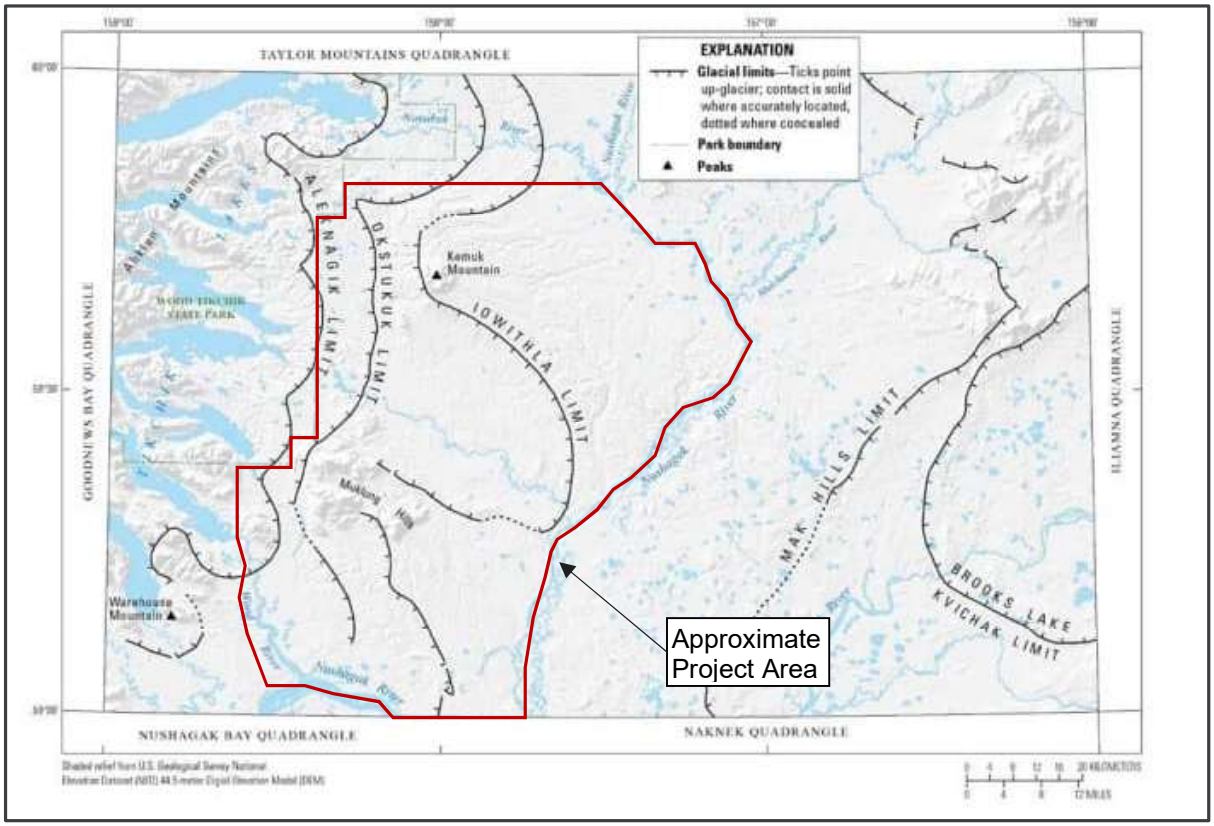
The lowland is drained by the Nushagak River which flows approximately 280 miles from the Alaska Range north of the project area to Nushagak Bay and defined the eastern project limits. Numerous smaller rivers and streams, flowing eastward from the higher elevation areas in the western portion of the project area, cross the project area and flow into the Nushagak River. The largest of these drainages are the Kokwok River, Iowithla River, Muklung River, Klutuk Creek, and Napotoli Creek. The Wood River provides the primary drainage for the finger lakes to the west of the project area through a series of rivers and streams that connect the lakes. Other drainages in the area include creeks and streams from moraine-dammed and kettle lakes, thaw ponds, bogs and marshes. Many morainal, kettle, and thaw lakes of various sizes dot the project area.

This section describes the general geologic setting, including regional geology, tectonics and seismicity, and other site characteristics that may be pertinent to project design, such as climatology, seasonal frost, perennially frozen ground (ie. permafrost), and vegetation.

4.1 Regional Geology

The geology of the area is dominated by earlier cycles of regional tectonic movement, and later glacial, glaciofluvial, and eolian activity. Massive ice sheets and extensive glaciation during the Pleistocene Epoch (~10,000 to 1.6 million years ago), and older, once buried the region and provided the processes that formed and shaped the lowland areas to their current state. During the late Wisconsin, glaciers assigned to the Aleknagik and older Okstukuk advances flowed eastward from the Wood River Mountains. These glaciations were preceded by the early-Wisconsin Iowithla glaciation (Wilson, 2018). Older glaciations (likely early Pleistocene) advanced from the Alaska Range to the east and from the Wood River Mountains to the west to cover most of the Nushagak Lowlands and the project area. Exhibit 4-2 indicates the approximate limits of the most recent glaciations in the project area.

Exhibit 4-2: Limits of mid to late-Pleistocene Glacial Advances



Taken from Wilson, 2018.

Surficial geology in the project area is dominated by glacial deposits or their outwash, including morainal deposits, drift sheets, and various glaciofluvial sands, gravels, silts, and outwash (Wilson, 2015; Mertie, 1938). Recent deposits of colluvium and alluvium are present locally near stream channels. Windblown deposits of eolian sand and loess are likely and may occupy significant swaths of land or smaller isolated pockets. Surficial deposits of silt, organic soils, organics (peat and moss) are also present in localized areas and may be up to tens of feet thick. Deposits within and adjacent to the Nushagak River likely consists of well sorted and bedded sand and gravel, with localized pockets of fine-grained soil in floodplains or slow moving, current or former backwater areas. Tidal and estuarine deposits exist closer to Nushagak Bay and may extend some distance up the Wood and Nushagak Rivers. An uplifted marine terrace is mapped northeast of the Wood River and may comprise extensive deposits of fine-grained soils and organics.

Bedrock is probably relatively deep (possibly hundreds of feet) across most of the project area but is exposed at the surface at Marsh Mountain (just east of Aleknagik), the Muklung Hills, Okstukuk Hills, and Kemuk Mountain. Based on available mapping, the north side of the Muklung Hills, the Okstukuk Hills, and Kemuk Mountain are composed of intrusive granitic rock of Tertiary age. Rock types include granite, quartz monzonite, granodiorite,

and quartz diorite (Mertie, 1938). Bedrock at Marsh Mountain and the southern portion of the Muklung Hills is comprised of Cretaceous-age marine sedimentary rocks including graywacke, slate, and argillite. These rocks are mapped as part of the Kulukak Subterrane of the Togiak lithotectonic terrane [large crustal blocks that have been accreted to the North American plate through ongoing tectonic motion] that comprise the Wood River Mountains further west (Decker, et al. 1994). A few kilometers east of Kemuk Mountain, a large mafic and ultramafic complex buried under 75 to 150 feet of unconsolidated, largely glacial deposits was discovered during an airborne geophysical investigation in 1959 (Berg and Cobb, 1967). Geologic maps of the project area showing generalized surficial geology and more detailed geology are included as Figures 2 and 3.

4.2 Tectonics and Seismicity

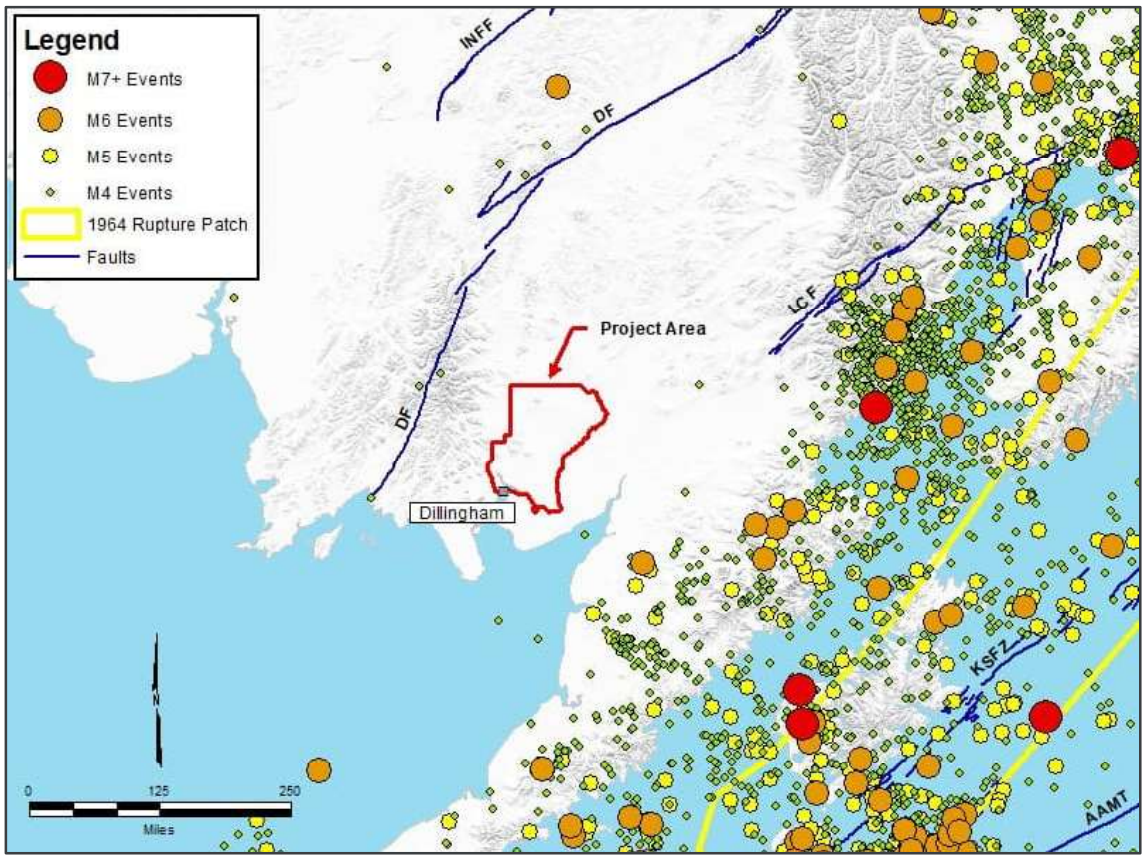
Alaska experiences approximately 22,000 earthquakes of any given magnitude per year, which accounts for 52 percent of the earthquakes in the United States (AEIC no date). The tectonics and seismicity of southern Alaska are the result of ongoing north-northwest movement between two lithospheric plates; the Pacific Plate moves about 5 to 6 centimeters per year (cm/yr) northwestward relative to the North American Plate. This movement results in a subduction zone (Aleutian-Alaska Megathrust) where the Pacific Plate dives beneath the North American Plate. Active seismicity in southwestern Alaska generally appears to occur as shallow earthquakes associated with random crustal faulting in the North American Plate, as well as along the Togiak fault to the west. Large seismic events related to deep earthquakes associated with the subduction zone (inter- and intraplate events) to the east may be felt in the project area but will likely have relatively mild effects on the project design or performance.

Based on our data review, no active mapped faults exist within the project area. The closest active faults to the project area are the Togiak Fault (the western most extension of the Denali-Fairweather fault system), which is located approximately 45 miles west, and the Lake Clark Fault, located approximately 85 miles northeast of the project area. Other historically active (but currently thought to be inactive) faults near the project area include the Mulchatna Fault, located along the Mulchatna River northeast of the project area, and Bruin Bay Fault, located approximately 80 to 120 miles southeast of the project area. Recent observations and studies of seismicity in the area of the Bruin Bay Fault suggest some movement may still occur along the fault (AEIC, 2025) to accommodate large scale crustal movements, though the fault is not considered active in the traditional sense.

According to the USGS Search Earthquake Catalog (https://earthquake.usgs.gov/earthquakes/search/, accessed 9/25/2025) the largest recorded earthquakes near the project area in the past 117 years include a magnitude (M) 6.6 near King Salmon on May 1, 1990, a

M 7.1 event near Pedro Bay, Alaska on January 24, 2016, and a M 6.8 event near Kohkanok, Alaska on July 12, 1912. Additionally, the M 9.2 Great Alaska Earthquake on March 28, 1964 originating from a large rupture along the Aleutian Alaska Megathrust in southcentral Alaska was likely felt in the project area. Exhibit 4-3 presents the locations of the major Quaternary faults and recent earthquakes in the southwestern Alaska region.

Exhibit 4-3: Recent Seismicity and Faulting



Faults: LCF – Lake Clark Fault, DF – Denali Fault, INFF – Iditarod-Nixon Fork Fault, KSFZ – Kodiak Shelf Fault Zone, AAMT – Alaska Aleutians Megathrust. Earthquakes from USGS Earthquake Catalog, 1908-2025, magnitude 4+. Map developed from GIS data provided by the State of Alaska, USGS, and Natural Earth.

4.3 Climate

The project area is located in a transitional climate zone with long, cold winters and shorter, warm summers. Climate data provided by the Western Region Climate Center for Dillingham, which is the only long-term climate monitoring station in the project area, is summarized in Exhibit 4-3 below. Based on the climate data, average annual precipitation is about 25 inches, mostly falling as rain from May to October. The average annual temperature is about 34 degrees Fahrenheit (WRCC, 2009). The design freezing index is about 3,500 degree days, while the design thawing index is about 3,500 degree days (Hartman, 1984).

Exhibit 4-4: Climate Data for Dillingham

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (˚F)	22.1	23.0	29.3	38.2	50.3	58.7	62.5	60.6	53.9	39.7	28.7	20.7	**40.6**
Average Min. Temperature (˚F)	10.1	9.8	14.9	24.6	34.9	43.2	47.4	46.6	40.3	26.5	16.7	8.1	**26.9**
Average Total Precipitation (in.)	1.79	1.35	1.49	1.01	1.47	1.93	2.79	3.92	3.47	2.21	2.19	1.87	**25.48**
Average Total Snowfall (in.)	17.1	11.2	13.2	5.4	0.3	0.0	0.0	0.0	0.1	2.1	15.5	18.1	**82.9**
Average Snow Depth (in)	17	18	18	12	1	0	0	0	0	0	4	12	**7**

NOTES:

1 Climate data for Dillingham, from Western Regional Climate Center, February 1, 1951 to May 31, 2005

˚F = degrees Fahrenheit

in. = inches

Based on modeling conducted by the Scenarios Network for Alaska & Arctic Planning (SNAP) at the University of Alaska Fairbanks, the annual average temperature in the project area is anticipated to rise over the next 30 years. Modeled temperature increases vary by location and based on the modeled assumptions for global emissions. In general, anticipated increase in mean annual temperature may be on the order of 5 to 10 degrees Fahrenheit over historical mean annual temperatures for data prior to 2009.

4.4 Local Vegetation

Except for along significant rivers and streams, tree cover is sparse and primary vegetation consists of tundra moss and grasses with dense patches of alder, willow, and other scrub brush scattered throughout. Low-lying and poorly-drained areas do not appear to support much tree or brush growth and are covered by extensive areas of muskeg (sphagnum or other peat moss) deposits or bogs. Tree cover, primarily spruce, poplar, and birch, exists along major drainage valleys and toward the western hills. Other groundcover consists of lichens, grasses and wildflowers.

5 LITERATURE RESEARCH

As part of this study, we reviewed information from United States Department of Agriculture/Natural Resources Conservation Service (USDA/NRCS) Soil Survey, Alaska Department of Transportation and Public Facilities (DOT&PF), Bristol Bay Native

Corporation (BBNC), and our in-house database for subsurface and geological information in the project area. Given the size and sparse development within the project area, available subsurface geotechnical information was generally limited to projects within the local villages. Soils information for remote portions of the project area were limited and generally obtained from the NRCS Web Soil Survey (WSS) and reconnaissance level geologic mapping by the USGS.

5.1 Web Soil Survey

One of the most comprehensive literature resources available for the majority of the project area was the NRCS WSS. The NRCS WSS provides soil maps for a variety of uses, including planning projects. Surface soil conditions are generally determined by soil survey scientists using satellite imagery, high altitude aerial photography, and field visits for confirmation. Original mapping was conducted for the soils included from the ground surface down to a depth of about 6 feet and lateral extents were defined using a 1:63,400 scale from aerial photos taken between 1999 and 2003. We were unable to determine the timing or level of detail of soil surveys conducted in the project area. More detailed technical information about the data compilation is available on the USDA/NRCS website or by contacting the local or regional USDA soil scientist. Soil survey data for the project area are intended for generalized planning and should not be used for design.

For purposes of this study, two soil data maps from the WSS database were focused on: Hydric Soils and Ground Temperature Regime. Maps were constructed for each of the soils using spatial data provided by the NRCS and ArcMap 10.8 and are included in Figure 4. The hydric soil map may be useful for evaluating the potential for poorly-drained and boggy areas that could affect project design and constructability. Ground temperature regime was selected to show potential permafrost areas. Note soil boundaries included on Figure 4 describe the probability of the surface soils in that area comprising the mapped soil parameter (hydric or permafrost potential). Additionally, we believe that the soils and soil conditions classified and divided in this database, and shown on Figure 4, are too generalized for any purpose other than preliminary planning of potential roadway corridors.

Because of the geologic history of the project area and likely limited field confirmation of the soil types, property's and characteristics for engineering design, only rough generalizations can be made about soil trends in the area. It is our opinion that the USDA/NRCS survey is adequate for the purposes (i.e. route selection, preliminary planning, and exploration plan development) of this project; however, a rigorous field effort, including geologic reconnaissance, mapping, and subsurface exploration should be conducted to confirm

surface and subsurface conditions, support roadway alignment development, and to advance project designs.

5.2 Geotechnical Records Review

We searched the DOT&PF online geotechnical report database, our in-house database, and contacted the BBNC land department for existing geotechnical information in the project area. The information collected during the review was used to assist in our general understanding of potential soil conditions in specific locations but is typically too detailed for the purpose of this report. Therefore, we only loosely discuss the results of reviewed reports herein; however, the information may be useful for more detailed evaluations once project alignments and routes are selected. Following are the reports we compiled and reviewed separated by area.

Aleknagik Area

- Geotechnical Report, Centerline Investigation, Aleknagik Wood River Bridge Design (1902), July 2011, Alaska Department of Transportation and Public Facilities, Central Region Materials Section, 186 p.
- Engineering Geology and Soil Report, Centerline Soils, Aleknagik Materials Investigation, October 1981, Alaska Department of Transportation and Public Facilities, Central Region Materials Section, 54 p.

Ekwok Area

- Geology Report, Ekwok Airport Rehabilitation, Project No. 55377, July 2004, Alaska Department of Transportation and Public Facilities, Central Region Materials, 91 p.
- Engineering Geology and Soil Report, Ekwok Materials Investigation, May 1983, Alaska Department of Transportation and Public Facilities, Central Region Materials Section, 24 p.

New Stuyahok Area

- Geotechnical Report, Wind Generator Foundations, New Stuyahok, Alaska, December 2005, Shannon & Wilson, Inc., 30 p.
- Geotechnical Report, New K-12 School, New Stuyahok, Alaska, March 2005, Shannon & Wilson, Inc., 47 p.
- Geotechnical Report, New AVEC Fuel Tanks, New Stuyahok, Alaska, March 2005, Shannon & Wilson, Inc., 26 p.
- Geology Data Report, New Stuyahok Airport Relocation Phase II, March 2004, Alaska Department of Transportation and Public Facilities, 246 p.

Koliganek Area

- Koliganek Materials Investigation, Runway and Borrow Investigation, September 12, 1972, State of Alaska Division of Aviation, 34 p.
- Engineering Geology and Soil Report, New Koliganek, June 1973, State of Alaska Division of Aviation, 14 p.
- Final Koliganek Geotechnical Report, New Koliganek [Koliganek BIA Road Project], February 2003, Bristol Environmental and Engineering Services Corporation, 43 p.
- Geotechnical Report, Koliganek Airport Reconstruction, Project #59276, August 2011, Alaska Department of Transportation and Public Facilities, Central Region Materials Section, 90 p.
- Geotechnical Recommendations, Koliganek Airport Reconstruction, Project No. 59276, June 2010, Alaska Department of Transportation and Public Facilities, Central Region Materials Section, 33 p.
- Geotechnical Report, New Koliganek Relocation, AIP 3-02-0192-02\59941, March 1994, Alaska Department of Transportation and Public Facilities, Central Region Materials Section, 37 p.
- Geotechnical Engineering Report, Water Treatment Plant, Koliganek, Alaska, September 2024, Shannon & Wilson, Inc., 49 p.

6 GEOLOGIC AND GEOTECHNICAL HAZARDS

The project area includes numerous rivers and drainages, boggy areas, rolling hills, steep mountainous terrain, and isolated permafrost soils. This diverse geologic terrain poses numerous hazards to potential roadway projects including erosion, flooding, landslides, and thaw unstable soils. Eruptions from of distant volcanos in the Aleutian-Alaska Range to the east could also bring ashfall to the area under the right conditions. In addition to these hazards, moderate seismic hazard exists in the region primarily related to distant seismic sources and random crustal seismicity. While relatively low in comparison to the seismic hazards of southcentral Alaska, this seismicity contributes additional hazards related to ground displacement and potential liquefaction of susceptible soils (loose saturated sands, some gravels, and non-plastic silts). The sections below describe these hazards and potential new or exacerbated hazards related to development of new roadways, or due to changes in climate.

6.1 Seasonal Frost and Perennially Frozen Soils

With average wintertime temperatures well below freezing, seasonal frost penetration into the subsurface is expected. The thickness of the "active layer," or that portion of the ground

at or near the surface which undergoes an annual freeze-thaw cycle, is largely dependent upon the location, ground cover, subsurface conditions, depth to groundwater and seasonal snow depth. Frost penetrates most deeply beneath well-drained road surfaces that are kept clear of snow and particularly around large diameter drainage structures that allow cold air to circulate beneath the road surface. At these locations, we estimate that seasonal frost may penetrate up to 8 to 12 feet below the ground surface. Away from the road surfaces and in areas where there is significant organic cover and lack of snow removal, we estimate that frost penetration is likely shallower, on the order of 4 to 6 feet.

Hazards related to seasonal frost generally include frost heaves, loss of subgrade support during spring thaw, and drainage issues. For roadways, loss of subgrade support is typically mitigated by using non-frost susceptible fill materials in the structural section and maintaining adequate drainage.

Exhibit 6-1: Example of Effects from Thawing Permafrost on Roadway



Photo showing thaw pond and roadway damage along the Parks Highway caused by thawing and settlement of ice-rich permafrost. Photo Credit: Shannon & Wilson, 2020.

According to the Permafrost Characteristics of Alaska (PCA) map by the University of Alaska Fairbanks Institute of Northern Engineering (Jorgenson, et al. 2008), the project area is located in an area of 'isolated' and absent permafrost. Permafrost is defined as ground that has remained at a temperature of 32° F or colder for two or more years. The PCA map defines isolated permafrost as having a permafrost distribution of less than 10 percent.

Isolated areas of permafrost may exist in the project area. Figure 4 was generated using soil data provided by the NRCS WSS Ground Temperature regime to highlight potential areas where permafrost may be present. Note the data provided by the WSS is primarily based on interpretations of aerial photographs by others and may not represent actual conditions. Therefore, permafrost distribution within the shaded areas on the figure showing potential permafrost may vary significantly over relatively short distances or permafrost may not be present at all. Similarly, permafrost may be present in areas where the WSS data suggest thawed soils should exist. In general, the data suggest that permafrost prevalence and occurrence may be increased in the eastern portion of the project area.

In general, the thawing of permafrost soils beneath roadways results in a loss of subgrade support, and settlement as ice lenses and/or massive ice thaw. The magnitude of the strength loss and rate/magnitude of settlement is dependent upon the volumetric ice content, the rate and depth of thaw, the ability for the thawed soil to drain, the compressibility of the organic and mineral soils, and the loading applied above the thaw front. The rate of thaw is dependent upon the climatic conditions, ground cover, and the thermal properties of the mineral and organic soil and ice mass.

6.2 Seismically Induced Hazards

Seismically induced hazards generally include faulting and ground rupture, lateral spreading, and liquefaction. Following are generalized risk assessments for these hazards related to design and construction of roads, bridges, and related structures that could be considered for this project.

6.2.1 Faulting

Faulting or ground rupture is simply a surface expression of displacement along an active fault zone after an earthquake event. In our opinion, there is a low potential for ground rupture associated with surface faulting over much of the project area. Ground rupture usually occurs in areas with relatively thin deposits of soil (less than 100 feet over bedrock) and project area is likely underlain by significantly thicker soil deposits than that. Additionally, there are no mapped active faults within the project limits based on our data review.

6.2.2 Liquefaction

Liquefaction triggering is estimated by comparing the liquefaction resistance properties of a soil deposit to the seismic demand placed on the soil layer by a given earthquake. The seismic load or demand placed on the soils required to cause liquefaction is a function of the intensity and duration of ground shaking. The duration of ground shaking is related to earthquake magnitude, and the intensity depends on magnitude, distance from the earthquake, and site response characteristics. The intensity of ground shaking is described by a shear stress normalized to an effective overburden pressure, referred to as the cyclic stress ratio (CSR). Generally the shear stress and CSR are estimated as a function of the peak horizontal ground acceleration, overburden stress, and a stress reduction coefficient, which accounts for a variation in the stress level or acceleration with depth. Typically, soil liquefaction results in sand boils on the ground surface, differential surface subsidence, differential settlement of structures, and/or punching failures of foundation elements.

Exhibit 6-2: Example of Embankment Failure due to Seismic Effects



Damage to roadway embankment along Vine Road in Wasilla, Alaska after November 30, 2018 earthquake. Photo Credit: Adrian Bender/USGS (2018)

We believe that soil liquefaction under a design earthquake event could be a moderate risk factor in the final design of this project especially in low-lying, poorly drained areas where sandy alluvium or outwash is present. Liquefiable soils may be present and should be designed for in areas with loose to medium dense, saturated granular soils with typically less than 20 percent fines.

6.2.3 Lateral Spreading

Lateral spreading is a phenomenon that can occur in loose to dense, saturated sandy and/or gravelly soils beneath even very gently sloping ground surfaces and on level ground near slopes (i.e. free face) such as riverbanks or lakes. Lateral spreading results from the softening and weakening of liquefied soil; it differs from flow sliding in that it occurs in soils whose residual strength does not exceed the shear stresses required for static equilibrium.

As a result, lateral spreading deformations generally occur during the period of earthquake ground shaking; the deformations develop in an incremental manner.

For this project, we believe that the potential for lateral spreading is relatively low due to the seismic environment. Lateral spreading risk is greatest along bluff lines near major streams and around natural or man-made slope features where shallow (less than 5 feet deep) groundwater conditions occur. To address lateral spreading, designs should consider the subsurface conditions, structure placement (relative to slopes) and shallow slope angles near sensitive structures or site features.

6.3 Erosion and Flooding

Numerous rivers and drainages provide drainage throughout the project area. Erosion is a potential concern any time a roadway embankment crosses a drainage or is adjacent to a river. In addition to natural drainages, damage from erosion also occurs from surface water draining off the roadway and related drainage improvements.

Flooding hazards may also exist in association with rivers, streams, and other drainages. Typically, flooding hazards are most prevalent during periods of high precipitation, or runoff from snow melt. Ice damming of larger rivers and streams can also result in widespread flooding of adjacent low-lying areas and flood plains. Flooding and erosion hazard areas should be evaluated and considered during selection of potential roadway corridors.

6.4 Volcanism

The project is located northwest of a chain of volcanoes that stretch from the Aleutian Islands and up the Alaska Peninsula. The nearest volcanoes the project are in Katmai National Park area, about 120 miles southeast of the project area. Given the right conditions, pyroclastic flows, lahars, and ballistics showers can extend tens of miles from the eruption point. Though it is unlikely that such conditions would spread to this project area as a result of volcanism, the site could experience light ashfall during a major volcanic event of any of the nearby, active volcanoes (Mulliken, et al. 2018). These active volcanoes are monitored on a continual basis by the Alaska Volcano Observatory.

7 ANTICIPATED SUBSURFACE CONDITIONS

In general, we believe that much of the soil in the project area, as well as the interpreted landforms, are controlled by past glacial and glaciofluvial processes as well as recent alluvial processes. Much of the Nushagak Lowlands is within areas mapped as glacial

outwash, glacial drift, and glacial moraine deposits. Soils in drift and moraine areas may be highly variable, ranging from predominantly fine-grained to coarse and gravelly. Typical drift soils comprise a tightly packed, relatively equal distribution of fines, sand, and gravel. These types of soil deposits typically have very low permeability and are relatively dense. Given the age of the some of the deposits, reworking and erosion near the surface may affect these properties in the shallow horizons. Outwash deposits typically comprise relatively well-drained sands and gravels associated with typical, large scale, glacial outwash features. The presence of permafrost may affect permeability and drainage characteristics. In areas of relatively flat topography, where groundwater levels are relatively shallow, isolated depressions within this environment readily form lakes, ponds, and bogs. These features may also provide ideal environments for the accumulation of fine grained, lake or shallow marine sediments (depending on their age). Organic soils and peat of various thickness are also likely present across the project area.

Windblown deposits of sand and loess may blanket significant portions of the project area. These deposits are typically formed as glaciers retreat when the ground surface is relatively barren. Loess deposits are typically relatively thin, and are probably less than 5 to 10 feet thick, where present. Sands dunes and stabilized sand dunes may be relatively thick depending on the size of the dune. Active deposition of these types of deposits is likely minimal in the project area due to vegetative cover, however, localized areas of active dunes are possible.

More detailed discussions regarding anticipated subsurface conditions in the project area are included in the following subsections. Certain conditions that may affect corridor development and selection are shown on the generalized engineering geology map included in Figure 5.

7.1 Organic Soils

Based on our review of existing information and aerial photographs and our general understanding of the environment, we believe that most of the ground surface in the project area is covered with some thickness of organic soils. It is likely that the only places that are not covered by organic soils are stream bottoms, steep or actively eroding stream banks, some higher elevation uplands, or man-made cut features (areas of disturbed ground). Organic soils can consist of a variety of materials from thin organic mats comprising grass and tundra moss to thick fibrous deposits of peat. Organic soils can also include soft, fine-grained lacustrine or shallow marine deposits that contain decayed organic matter intermixed with mineral soils (organic silts/clays). In general, organic materials are not suitable for use in developing embankments and, as a general rule, are not typically suitable for subgrade support of new embankments.

The distribution of organic soils is, in our opinion, strongly correlated to landforms and topography. We anticipate that the thickest organic deposits will be found in the low-lying bog areas that are evident on aerial photography and noted as "hydric" soils in Figure 4. In general, boggy areas in the project area appear to range in size from relatively small and isolated pockets occupying local topographic depressions to expansive, larger, bog features such as those found around the Kokwok River in the central portion of the project area. It is difficult to estimate the thickness of a peat deposit by surface features without the benefit of subsurface explorations, however experience suggests that peat deposits along the selected corridors could range from 5 to 20 feet deep. We expect that shallower peat thicknesses will likely be experienced on the margins of peat bogs or on smaller, less expansive bog features. Note that organic silts and clays can be found beneath bog features, but are not always necessary for bog development.

Other, thinner organic deposits can be expected along most potential road corridors in the form of organic mats. An organic mat is defined as a mass of tree, brush, moss, and grass root material that forms on the ground surface. This is typically comprised of mostly living organic material near the ground surface, but often grades to more decayed material mixed with sand and silt (much like topsoil) 1 to 2 feet below the ground surface. Experience in Southwestern Alaska suggests that such organic mat deposits persist on elevated, well-drained ground and could range in thickness from 1 to 3 feet.

7.2 Mineral Soils

Given the glacially and alluvially influenced depositional environment of the project area, the mineral soil conditions along the proposed corridors are likely variable. We believe that mineral soils in the upland areas within the project boundary likely consist of complexly interbedded silt, sand, and gravel with occasional cobbles and boulders. Given the depositional environment, it is difficult to anticipate the distribution of these different soil types without the benefit of subsurface explorations. Although we believe the soils in the upland areas will vary significantly, we believe the average condition will yield soils that will be "embankable" for roadway construction. If they exist, fine-grained mineral soils that may be susceptible to consolidation under embankment loading will most likely be isolated in low-lying areas beneath peat deposits. Note, a significant area of potential fine-grained soils is identified on the geologic map around the Kokwok River (see Figure 3 and 5).

7.3 Groundwater Conditions

Groundwater conditions in the project area will vary significantly. We suspect that groundwater levels within boggy areas or "hydric" soils identified on Figure 4 will be at or near (within several feet) the ground surface. Depending on the gradation and topography

of the upland areas, groundwater could also be near the ground surface or relatively deep (greater than 50 feet). It is important to note that in glacial soils that contain interbedded gravel, sand, and silt; areas of perched water or confined zones of water may be encountered in excavations. These areas can consist of saturated layers of sand sandwiched between layers of impermeable silt and when exposed can create significant amounts of water seepage. Typically, these zones drain themselves dry over a period of time, but may be difficult to handle or control while they are draining.

7.4 Permafrost

Because the project lies within a zone of isolated permafrost (which covers most of Southwestern Alaska) and much of the area is undeveloped, we believe that permafrost soils could be encountered along proposed road corridors. Experience suggests that permafrost soils in this region of the State are usually ice rich and associated with fine-grained soils that have natural temperatures that are usually at or just below the freezing point of water. Based on our data review, it appears that isolated masses of permafrost have been encountered during subsurface explorations in the Koliganek and New Stuyahok areas. Explorations we reviewed in other areas did not encounter permafrost, but likely exist in localized masses.

If permafrost is encountered in this project, we believe that it will be prone to more rapid thawing once the ground surface and natural temperature regimes are disturbed and significant settlement could occur as these soils thaw. It is our opinion that permafrost soils are most likely to be encountered in low-lying boggy areas, away from major river drainages, where the natural ground cover consists of thick layers of surface organics or peat. Permafrost soils may also be more likely when the above conditions are located on the north or east of a topographic high. Based on the Ground Temperature Regime data from the NRCS WSS, included in Figure 4, permafrost occurrence may be more prevalent in the eastern portion of the project area.

7.5 Existing Geotechnical Conditions for Select Locations

The following subsections include generalized descriptions of subsurface conditions encountered in various geotechnical reports we reviewed. The descriptions are intended to provide a generalized understanding of subsurface conditions in areas where previous explorations were conducted. As previously discussed, existing geotechnical information was limited to projects within or close to existing developed areas. The documents we reviewed for each of these areas are listed in Section 5.2. Note, because the purpose of this report is to develop a generalized understanding of geologic conditions across the project area, we have excluded the reviewed documents from this report for brevity.

7.5.1 Aleknagik

Explorations conducted by the DOT&PF in the airport area and road improvements near Aleknagik suggest the typical soil profile in this area consists of 1 to 2 feet of organics underlain by an extensive layer of windblown silt (e.g., loess) several feet thick and silty, glacially derived soils with varying amounts of sand and gravel. Soils exhibiting clay-like behavior were encountered in some explorations, primarily in low-lying areas. Groundwater may be shallow in some places and appears to be related to water levels in Lake Aleknagik and the Wood River but may exist in perched zones on top of fine-grained soils. Low-lying and poorly-drained marshy areas with shallow or perched groundwater and thick deposits of organic soils are scattered throughout the area but are generally not extensive. Bedrock was encountered in several borings we reviewed at depths as shallow as 9 feet.

7.5.2 Ekwok

Subsurface explorations conducted by DOT&PF for an airport improvement project and by Shannon & Wilson for a health clinic project near the airport gravel pit suggest the typical soil profile consists of 1 to 2 feet of organic soils overlying 5 to 10 feet of silt and sandy silt and then relatively clean sand and gravels. Groundwater was typically encountered within about 10 to 15 feet of the ground surface. No permafrost was reported in the explorations we reviewed.

7.5.3 New Stuyahok

Explorations by DOT&PF and others in the New Stuyahok areas generally encountered silty soils with various amounts of sand. In some explorations, sand and gravel content in the silty soils was noted to increase with depth. Permafrost was encountered intermittently in explorations conducted by the DOT&PF east of the townsite for the airport relocation project (DOT&PF, 2004). Layers of relatively clean sand and gravel were occasionally encountered and appear to be more prevalent north of the townsite and in gravel bars on the Nushagak River.

7.5.4 Koliganek

Subsurface information we reviewed near Koliganek largely consisted of reports by DOT&PF for relocation of the airport and subsequent improvements. In general, the soil profile in the airport area consisted of 1 to 2 feet of organic soils overlying interbedded silts and sands and varying amounts of gravel. Permafrost was encountered sporadically at depths as shallow as 12 inches where organic soils were still intact. According to DOT&PF reports, specific areas at the airport have reportedly experienced differential ground

settlements on the order of 1 to 2 feet, likely due to thawing of ice-rich permafrost. Sources of clean borrow material for construction are reportedly limited with primary source being an island on the Nushagak River about 1.5 miles east of the town.

8 PRELIMINARY GEOTECHNICAL CONSIDERATIONS

Geotechnical considerations for roadway projects generally include site preparation and embankment development, establishing cut and fill slopes, development of roadway structural sections, bridge and culvert foundations, and retaining walls. Other factors such as slope stability, addressing potential settlements, geohazards, and constructability should also be considered. Generalized geotechnical considerations for corridor development and selection, borrow source availability, and additional data needs are discussed below. Note that the considerations below are based on desktop studies only and are only intended to support initial planning, development of potential roadway corridors, and conceptual level engineering design.

8.1 Corridor Development and Selection

Geotechnical factors that could influence corridor development and selection largely include identifying areas that could negatively influence the performance, constructability, and cost of developing new roadways and associated improvements. Based on our current understanding of the anticipated site conditions in the project area, such factors may include avoiding wetland areas, which generally support thick deposits of organic soils, have shallow groundwater and surface water, and may present increased challenges for developing foundations at bridge and culvert crossings. Availability of suitable borrow materials is typically more limited in these areas which would increase hauling distances and affect construction costs. Significant areas of poorly-drained, boggy terrain and estuarine deposits that could affect design and construction of roads and drainage crossing structures are shown on Figure 5. In our opinion, new road alignments should generally avoid these areas to the extent practicable; however, collecting more detailed information in these areas may be useful for evaluating the effects these conditions will have on design of potential projects. Areas with increased prevalence of hydric soils, Figure 4, may have similar conditions and should be further evaluated during the corridor development and selection process.

Isolated pockets of permafrost may exist in the project area. Based on the NRCS soil data, permafrost potential may be higher in the eastern portion of the project area, see Figures 4 and 5. General hazards related to permafrost are discussed in Section 6.1. The presence of permafrost can affect long term performance of road embankments but will have the most

significant effect on designing suitable foundations for bridges and culverts. Permafrost areas with sloping ground can also effect cut slope stability.

8.2 Borrow Sources

Significant amounts of fill will be needed to construct new embankments and develop the structural section and surface course for new roadways. As such, we envision new borrow sources will need to be developed along the roadway corridor as construction progresses. Soils containing less than about 20 to 25 percent fines are generally suitable for embankment construction, depending on the actual gradation of the material and contractors means and methods. Based on our understanding of the likely geologic conditions in the project area, we anticipate that borrow materials suitable for roadway construction will be available across much of the project area but the type, gradation, and distribution of suitable materials will likely be highly variable. Units identified as alluvial deposits and glacial outwash on the detailed geologic map, Figure 3, are most likely to produce higher quality aggregate materials and structural fill for construction compared to other types of deposits. Based on the information we reviewed, gravel bars along the Nushagak River have also been utilized for borrow materials near some of the existing villages. Other drainages and abandoned channel deposits may contain minable quantities of relatively clean borrow material. Depending on the gradation properties, these materials may be suitable for development of embankments and structural sections. Glacial drift and moraine deposits comprise a wide variety of materials ranging from silts and clays to relatively clean sand and gravel and may yield suitable materials for general embankment development and structural section development. Granitic and sedimentary bedrock from the hilly areas described earlier in this report and shown the geologic maps in Figures 2, 3, and 5, may be useful for generating surface coarse materials as well as large stones for rip rap or armor rock. The type and quality of the roadway fill and stone products will need to be verified during project design and construction.

8.3 Data Gap Analysis and Other Geotechnical Considerations

Based on our desktop data review, it is apparent that there is limited geotechnical data available over most of the project area. The existing geotechnical reports and documents we reviewed were typically associated with projects in the subject village areas. These reports provided some insight into potential conditions that may exist in the village areas but are only sufficient to gain a general understanding of conditions in a specific location. Geologic maps and NRCS WSS data provided more comprehensive coverage but appear to have been largely generated from interpretations made from aerial photographs and limited reconnaissance. While these types of data provide general insights, more detailed information is needed to support advancement of project designs.

Future efforts to support preliminary and final designs will require significant geotechnical and geological studies. A phased approach may be appropriate for collecting information at various milestones during project development. During the initial phases of corridor development and selection, additional geologic assessments may be useful and should be performed to refine our understanding of the surface and subsurface conditions along potential corridors identified. These efforts should include more detailed terrane and landform mapping using recent aerial photographs, lidar/topographic studies, etc., and field reconnaissance to confirm the interpretations, observe surficial site conditions, and inform development of exploration plans and estimates. Subsurface explorations will be needed for final design, and may be beneficial for evaluating conditions along potential roadway route alternatives, depending on preliminary design requirements and the results of more detailed desktop geologic assessments and reconnaissance efforts. At a minimum, we envision explorations will be needed to support design of embankments, bridges, large diameter culverts, and to identify potential material sites. These explorations will likely consist primarily of geotechnical borings, however, other methods such as test pits, hand probes, and possibly geophysical methods could provide useful information depending on the project requirements and should be considered. The type and quantity of explorations should be determined during future project phases.

9 CLOSURE AND LIMITATIONS

This report was prepared for the exclusive use of our client, Bristol, and their representatives for evaluating the site as it relates to the geotechnical aspects discussed herein. The conclusions and interpretation contained in this report are based on site conditions as they were presented in the reviewed existing information. Subsurface conditions in the project area are expected to be highly variable and additional studies will be needed to further develop our understanding of the conditions in the project area.

If there is a substantial lapse of time between the submittal of this report and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, it is recommended that this report be reviewed to determine the applicability of the conclusions considering the changed conditions and time lapse. Unanticipated soil conditions are commonly encountered and cannot fully be determined by reviewing existing information, conducting surface reconnaissance, or taking soil samples or advancing test holes. Please read the Important Information section at the back of this report to reduce your project risks.

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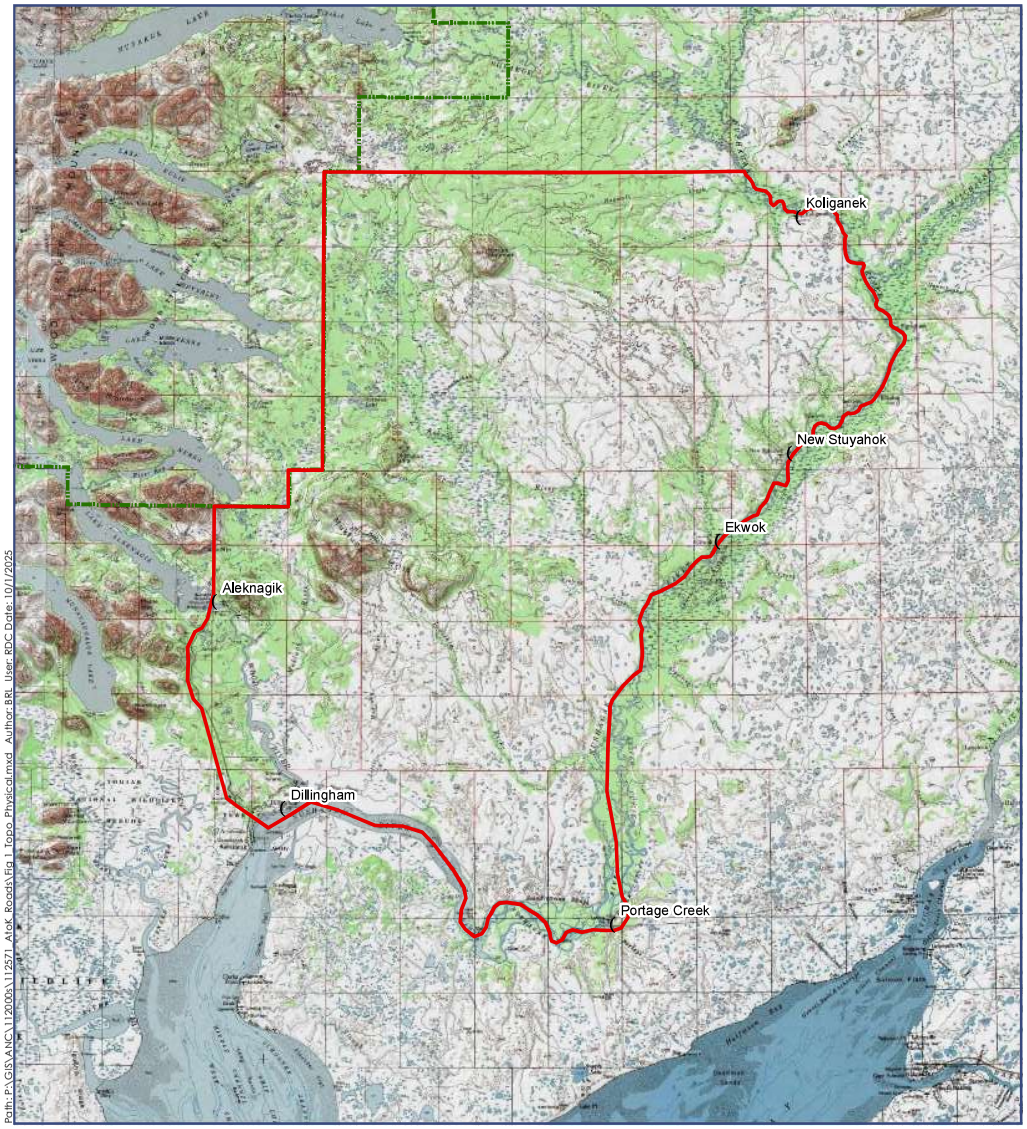

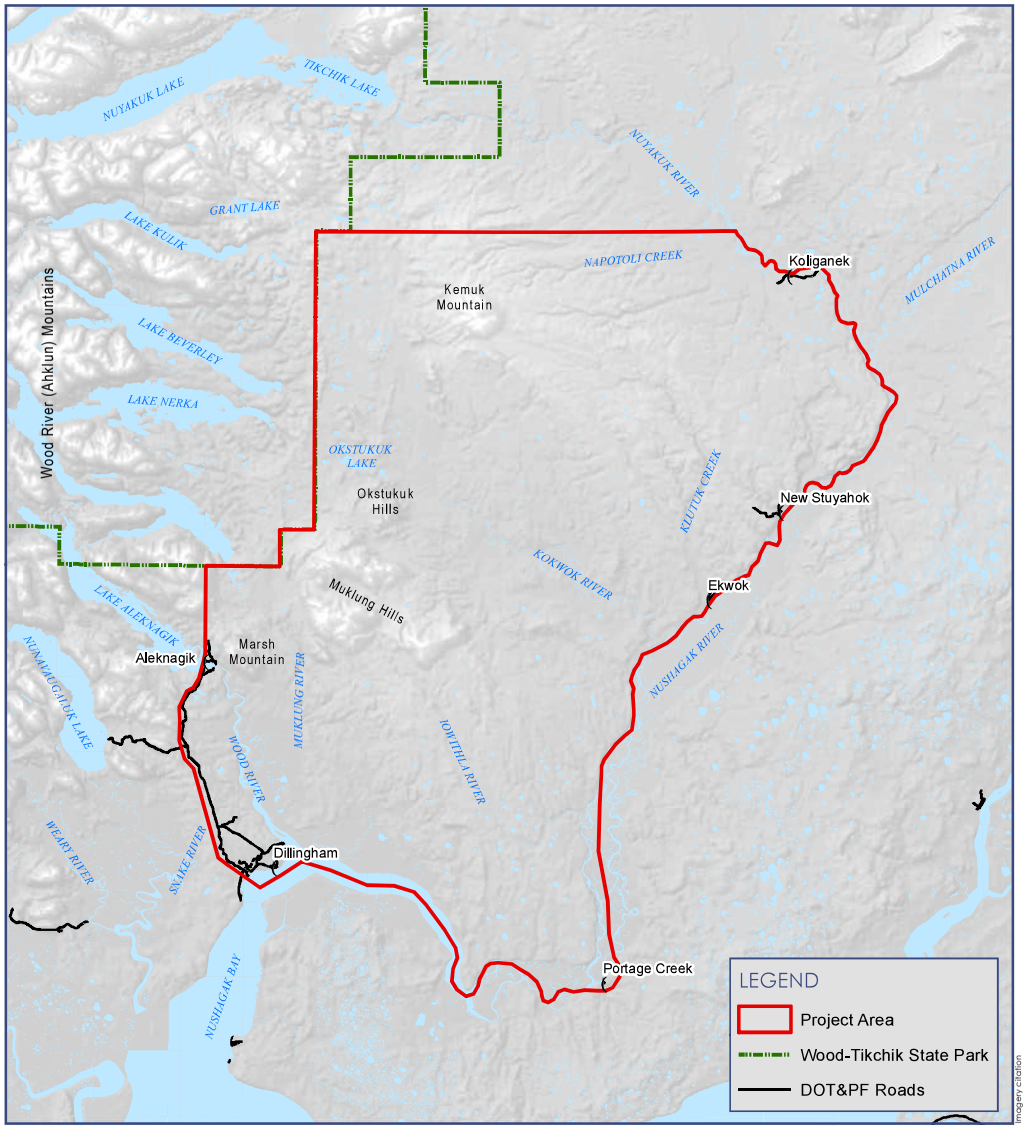

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Imagery citation

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Notes:
1. Project area boundary should be considered approximate.
2. Topographic map provided by arcgisonline.com. Copyright: ©2013 National Geographic Society, i-cubed.
3. Shaded relief map provided by State of Alaska Geoportal Map Service, https://geoportal.alaska.gov/arcgis/services
4. Spatial data layers for roads, hydrology, and communities provided by the State of Alaska DNR and DOT&PF

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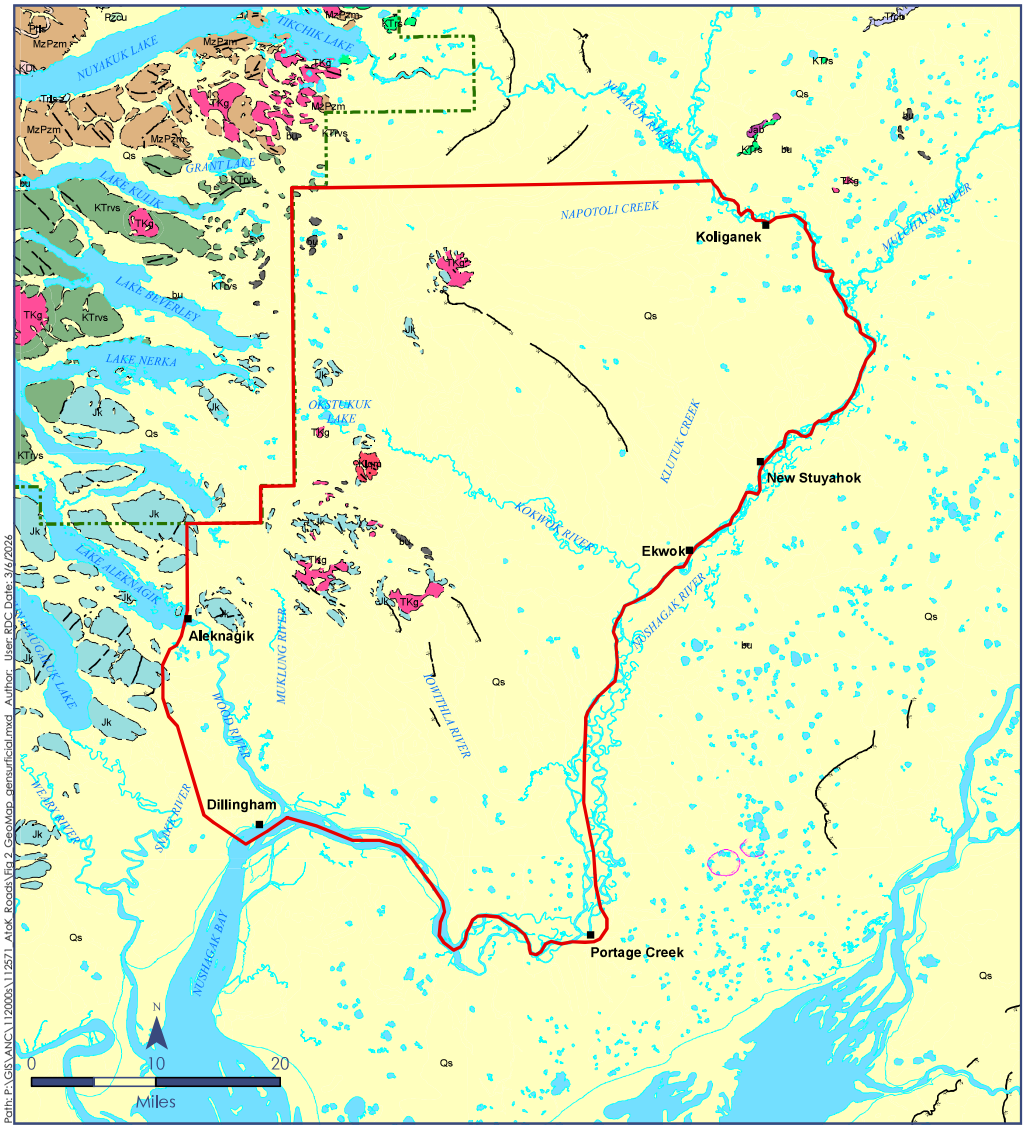
TOPOGRAPHIC AND PHYSICAL MAPS

Figure 1



Legend

Map Unit Descriptions

- bu — Bedrock of unknown type
- KTrs — Volcanic and sedmentary rocks (Gemuk Group)
- TrIs — Carbonates and assoicated rocks (Triassic)
- Pzcu — Black chert (lower Paleozoic, Devonian or older)
- KDt — Togiak-Tikchik Complex, undivided (Mesozoic to Devonian)
- KTrvs — Volcanic and sedimentary rocks of southwest Alaska (Cretaceous to Triassic?)
- Jk — Graywacke of Kulukak Bay of Hoare and Coonrad (1978) (Upper to Middle Jurassic)
- PIls — Limestone of southwest Alaska (Togiak-Tikchik Complex) (Permian)
- Trcb — Cottonwood Bay and Chilikradrotna Greenstones (Late Triassic, Norian?)
- Jab — Andesite and basalt (Jurassic)
- MzPzm — Southwest Alaska mélange (Mesozoic and Paleozoic)
- Klqm — Quartz monzonite and monzonite (Late Cretaceous)
- TKg — Felsic granitic rocks (Tertiary, Paleocene, or Late Cretaceous, Maastrichtian)
- Qs — Unconsolidated surficial deposits, undivided (Quaternary)
- Water

Explanation of Map Symbols

- Project Area
- Wood-Tikchik State Park
- Communities
- Stratigraphic contact or intrusive contact, location certain
- Stratigraphic contact or intrusive contact, location approximate
- Stratigraphic contact or intrusive contact, location inferred, queried
- Normal fault, location certain
- Normal fault, location approximate
- Normal fault, location inferred, queried
- Shoreline or riverbank
- Caldera or crater rim
- Internal contact
- Moraine limit having tics on right from origin
- Fault, sense of displacement uncertain, location certain
- Concealed contact
- Concealed normal fault
- Concealed fault of uncertain displacement

Notes:
1. Project area boundary should be considered approximate.
2. Map adapted from Geologic Map of Alaska (Wilson, et. al., 2015) and provided spatial data. Locations and nature of faults and other geologic contacts were mapped by Wilson, et. al. (2015).

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GENERALIZED SURFICIAL GEOLOGY MAP

Figure 2

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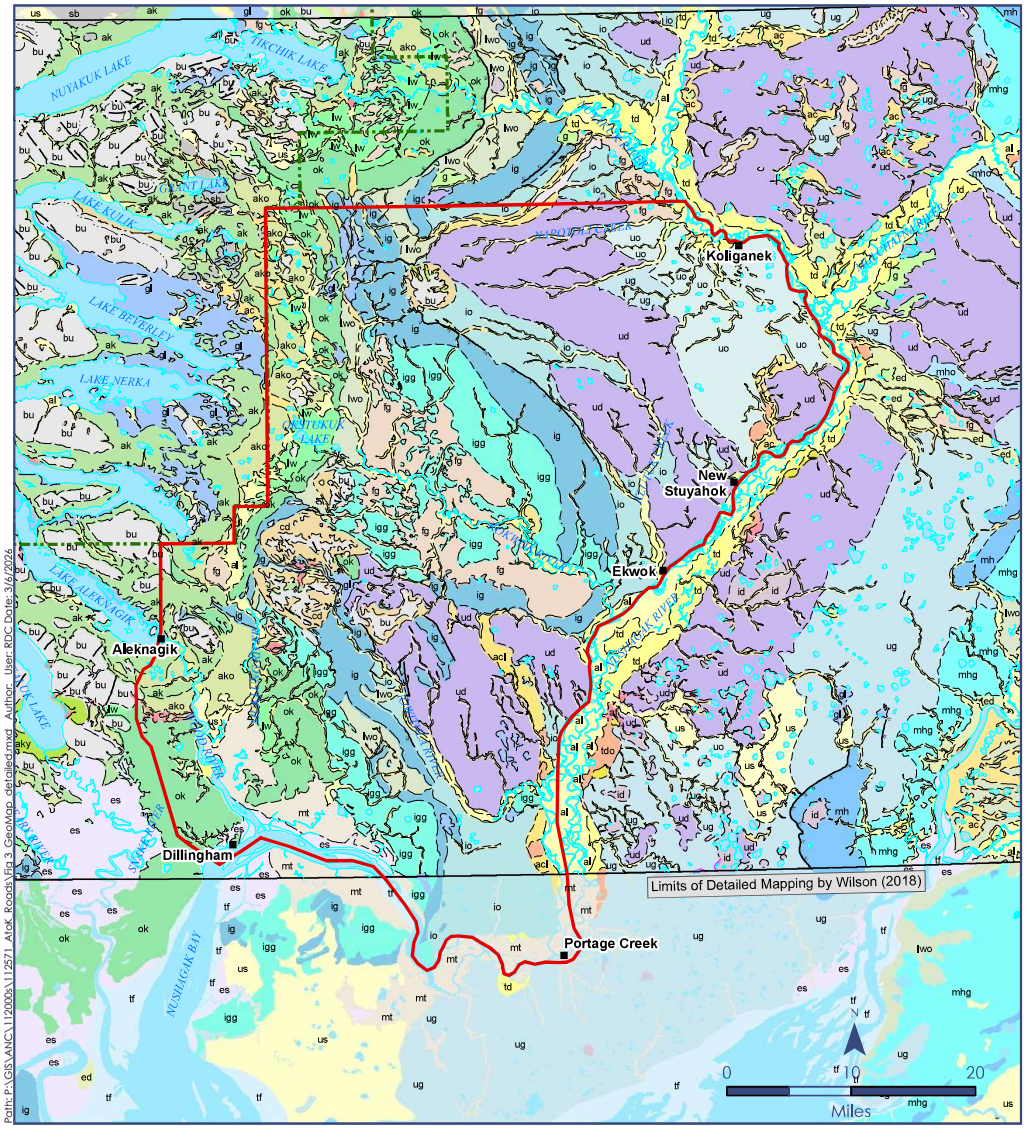

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LIST OF MAP UNITS

[See Description of Map Units (in pamphlet) for complete unit descriptions.]

UNCONSOLIDATED DEPOSITS

- us — Surficial deposits, undivided (Quaternary)—Locally subdivided into:
- tf — Modern tidal flat deposits (Holocene)
- sf — Solifluction deposits (Holocene)
- es — Estuarine deposits (Holocene)
- mt — Marine terrace deposits (Holocene? and Pleistocene)
- ls — Landslide deposits (Holocene)
- cd — Colluvial deposits (Holocene)
- ed — Eolian deposits (Quaternary)
- b — Beach deposits (Quaternary)
- ld — Lacustrine deposits (Quaternary)
- fg — Fine-grained deposits (Quaternary)

ALLUVIAL DEPOSITS

Alluvial deposits—Subdivided into:

- al — Flood-plain deposits (Holocene)
- af — Alluvial fan and talus deposits (Holocene)
- td — Terrace deposits (Quaternary)
- tdo — Older terrace deposits (Quaternary)
- ac — Abandoned channel deposits (Pleistocene)
- acl — Abandoned channel deposits, lake drainage (Quaternary)
- il — Inferred levee deposits (Pleistocene)

GLACIAL DEPOSITS

- g — Glacial deposits, undivided (Quaternary)—Where possible, subdivided into:
- gc — Glacial deposits in cirques (Holocene or late Wisconsin?)
- gl — Glaciolacustrine deposits (late Pleistocene)
- ak — Drift, Aleknagik glaciation (late Pleistocene)—Locally subdivided into:
- aky — Youngest advance, Aleknagik glaciation
- ako — Outwash, Aleknagik glaciation
- ok — Drift, Okstukuk glaciation (late Pleistocene)
- bk — Drift, Brooks Lake glaciation, Kvichak advance (late Pleistocene)
- lw — Ground moraine (late Pleistocene)
- lwo — Outwash (late Pleistocene)
- lg — Drift, Iowithla glaciation (Pleistocene)—Locally subdivided into:
- lgg — Ground moraine, Iowithla glaciation
- lo — Outwash, Iowithla glaciation
- lgd — Drumlins, Iowithla glaciation
- mh — Drift, Mak Hill glaciation (Pleistocene)—Locally subdivided into:
- mhg — Ground moraine, Mak Hill glaciation
- mho — Outwash, Mak Hill glaciation
- mhd — Drumlins, Mak Hill glaciation
- ek — Esker deposits (Pleistocene)
- ud — Drift, unnamed glaciations (early Pleistocene)—Locally subdivided into:
- ug — Ground moraine, unnamed glaciations
- uo — Outwash, unnamed glaciations

BEDROCK

- sb — Scoured bedrock
- Bedrock, undivided

EXPLANATION OF MAP SYMBOLS

- Contact—Long-dashed where location is approximate; short-dashed where location is inferred; dotted where location is concealed
- Internal contact—Separates areas of glacially scoured bedrock from bedrock that does not appear to have been overridden during the last glacial maximum
- Fault—Solid where location is certain; long-dashed where location is approximate; short-dashed where location is inferred; dotted where location is concealed
- Caldera or crater rim—Solid where location is certain
- Moraine—End, recessional, and lateral moraine limit; hachures point to ice
- Park boundary
- Community
- Peak
- Survey monument

* Legend taken from Wilson (2018)

Notes:

1. Project area boundary should be considered approximate.
2. Map adapted from Surficial Geologic Map of the Dillingham Quadrangle, Southwestern Alaska (Wilson, 2018) and provided spatial data. Map units outside the Dillingham quadrangle were interpreted and adapted from the Geologic Map of Alaska (Wilson, et. al., 2015)
3. Locations and nature of faults and other geologic contacts were mapped by Wilson (2018).
4. See respective publication for detailed map unit descriptions.

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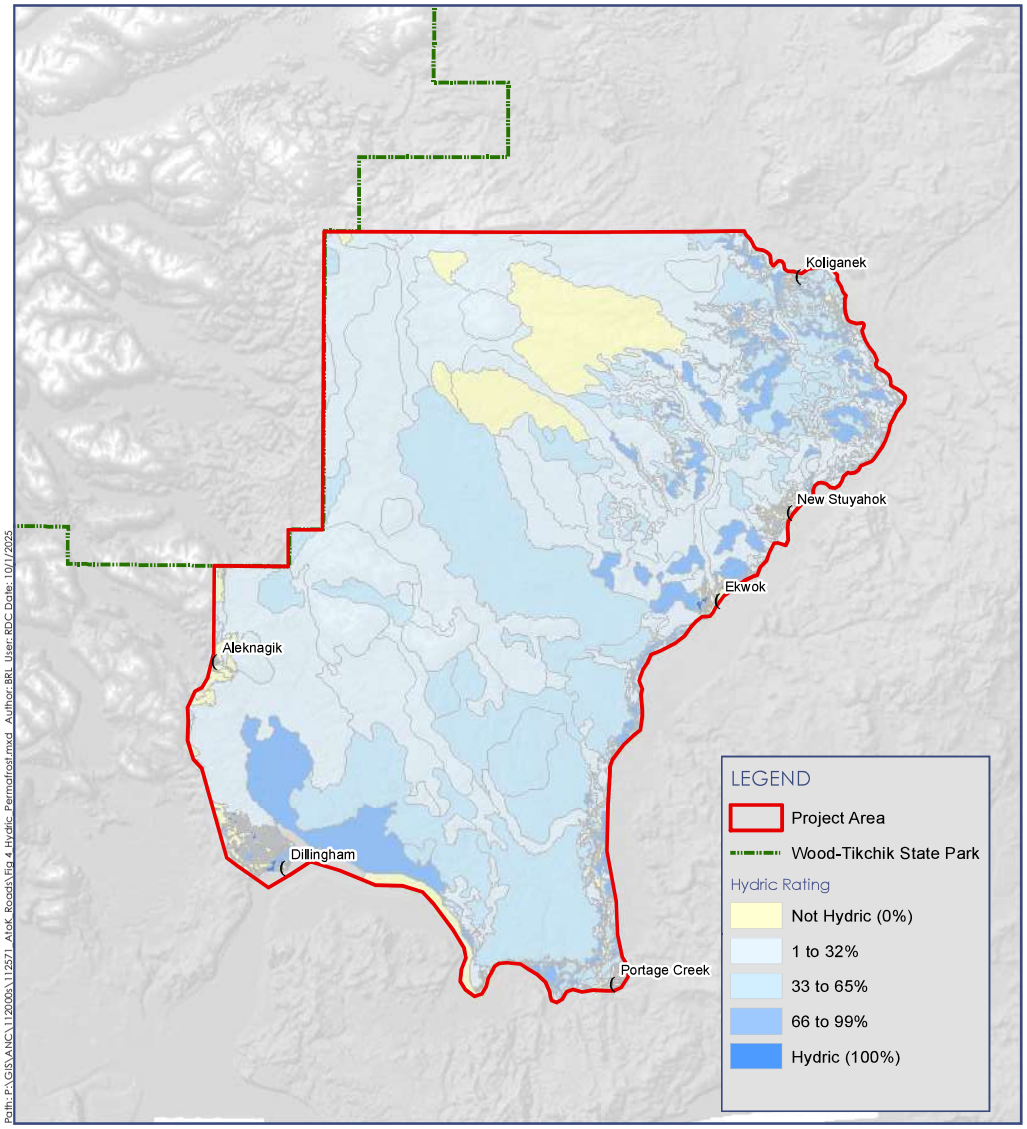
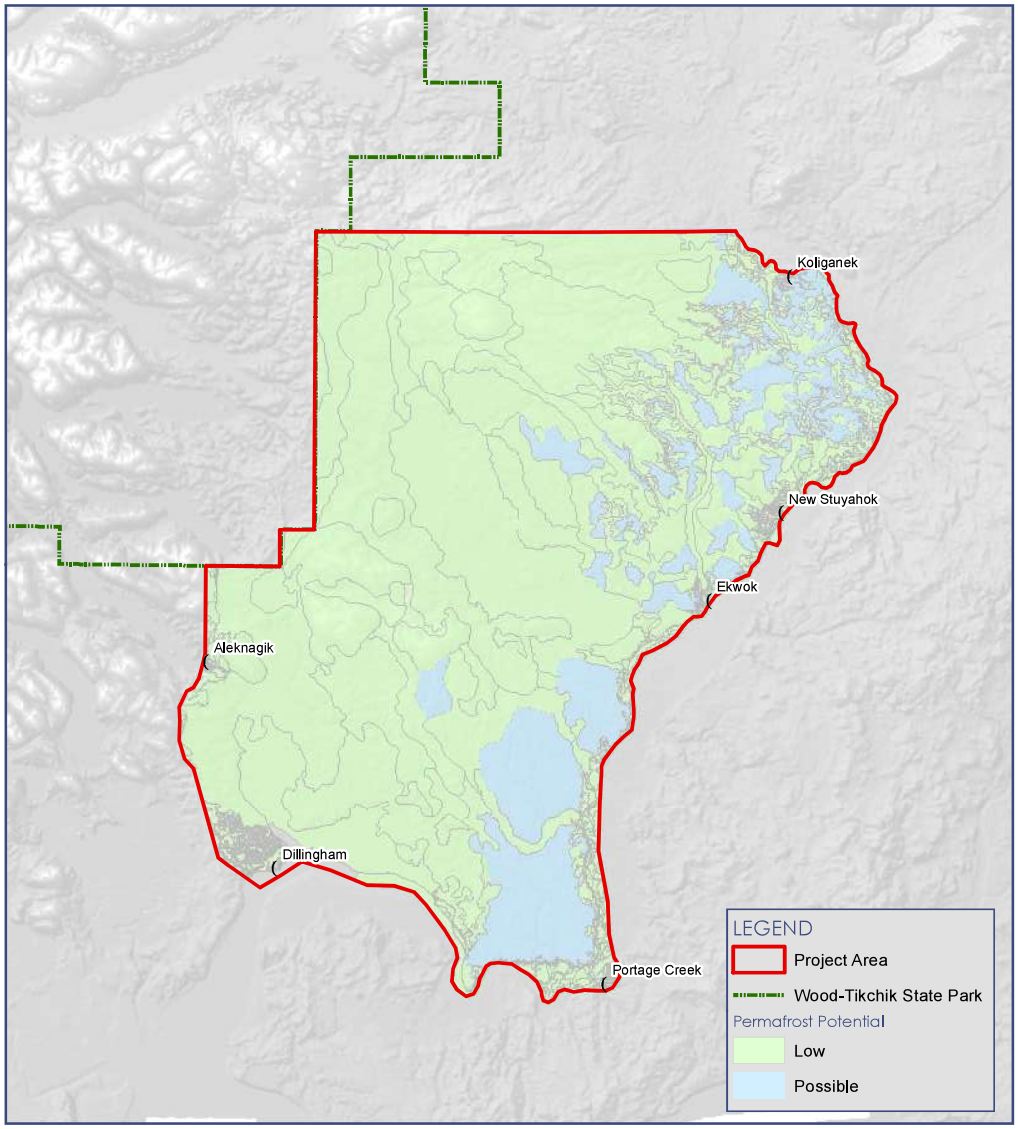
DETAILED GEOLOGIC MAP

Figure 3





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0 10 20
Miles

Notes:
1. Project area boundary should be considered approximate.
2. Hydric soil rating and permafrost potential were generated using gSSURGO spatial data and the ArcMap Soil Data Development toolbox provided by the USDA NRCS. Soil conditions and boundaries indicated were established using relationships developed by the NRCS. Shannon & Wilson made no attempt to modify the original data or related queries. Data was downloaded and accessed September 2025.
3. See NRCS Web Soil Survey for additional information regarding soil data acquistion and development.

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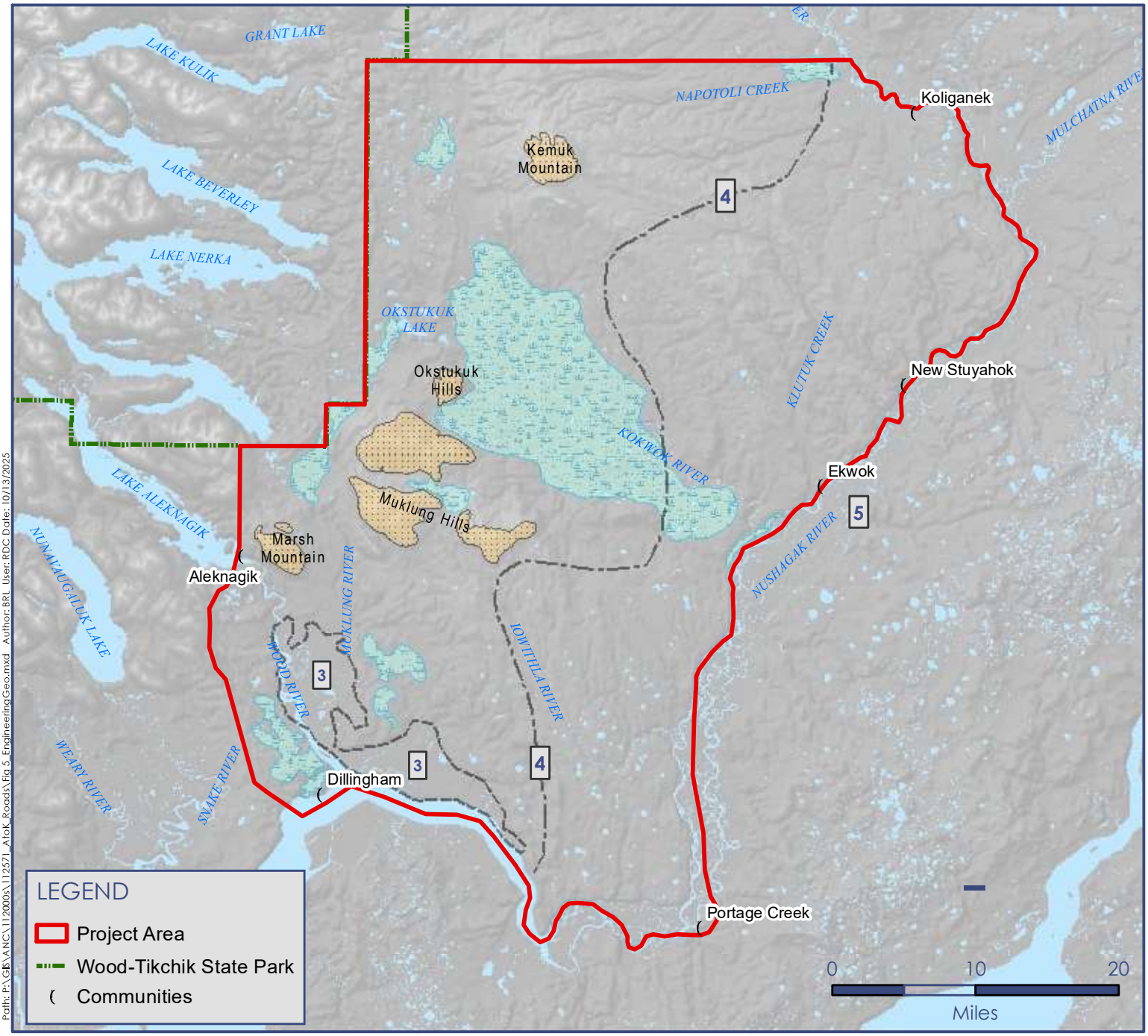
HYDRIC AND PERMAFROST SOILS

Figure 4



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Explanation of Engineering Geology Interpretations

1. Areas with likely shallow bedrock resources.
2. Significant boggy areas with extensive deposits of thick organic soils and peat likely. May be underlain by soft and/or compressible fine-grained soils. Likely poorly-drained and wet.
3. Marine terrace, estuarian, and tidal deposit area. May contain thick soft and/or compressible soils and organics.
4. Area east of line indicates potentially increased permafrost prevalence based on NRCS soil data.
5. Gravel bars and floodplains along the Nushagak River and other drainages may contain sand and gravel borrow suitable for development of roadway embankments, structural sections, and crushed aggregate materials.

Notes:

1. Limits of project area should be considered approximate.
2. Outlined areas are intended to show major areas that may contain the indicated conditions. Limits should be considered approximate and smaller features with similar characteristics likely exist in other areas.

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GENERALIZED ENGINEERING GEOLOGY

Figure 5

IMPORTANT INFORMATION

Important Information

About Your Geotechnical/Environmental Report

IMPORTANT INFORMATION

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors that were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining

IMPORTANT INFORMATION

your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary, because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims

IMPORTANT INFORMATION

being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports, and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland