February 9, 2018 1402344

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RE: GEOTECHNICAL FINDINGS AND RECOMMENDATIONS, TOGIAK TO TWIN HILLS INTERTIE PROJECT, TOGIAK, ALASKA

Dear Karl:

Golder Associates Inc. (Golder) is pleased to present our summary geotechnical findings and engineering recommendations for the Togiak-Twin Hills intertie project. The Togiak-Twin Hills intertie project consists of a proposed five mile long overhead transmission line between the two communities. The general alignment is provided in Figure 1. CRW Engineering Group LLC (CRW) was contracted by the project owner, Alaska Energy Authority (AEA), to provide planning and engineering services for the intertie project. CRW subcontracted Gray Stassel Engineering Inc. (GSE) to develop the powerline and Togiak River crossing conductor geometry and pole loads. CRW subcontracted Golder to perform a limited geotechnical exploration reconnaissance along the proposed intertie alignment. The data from the limited geotechnical reconnaissance effort combined with our interpretation of the geology along the proposed alignment were used to develop our recommendations.

Our services were performed in general accordance with our proposal to CRW dated March 14, 2014 and LOA 64 dated August 23, 2016. We coordinated with CRW and GSE during the course of our work.

1.0 INTRODUCTION AND PROJECT UNDERSTANDING

An overhead electric power transmission line is proposed between the communities of Togiak and Twin Hills, Alaska. The transmission line alignment is approximately five miles in length and crosses several drainages including the Togiak River and surrounding flood plain. We understand the system will consist of three conductors plus a neutral. A typical span length between the power poles will be approximately 275 feet over moist tundra and flood plain areas. Over the Togiak River a span of approximately 1,200 feet will be required. We understand timber power poles are planned to support the conductors. For the overland powerline alignment, driven H-piles are preferred to support the timber poles although direct set poles may be used in some areas near Twin Hills. Guy anchors are expected at select pole locations along the overland powerline alignment. Larger dimensioned helical pile groups are expected to support the timber poles for the Togiak River crossing. Multiple guys will also be required for the Togiak River crossing poles.

Due to a variety of project constraints, mobilization of a geotechnical drilling subcontractor for the field investigations was not authorized by AEA. Accordingly, we have based our geotechnical recommendations for the driven H-pile, larger dimensioned helical piles and guy anchor foundations for the timber poles on a limited shallow subsurface field assessment and our interpretation of the geologic depositional environmental along the general intertie alignment. All users of this submittal should understand and accept the limitations inherent with the authorized geotechnical field program.

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2.0 SCOPE OF WORK-FOR GEOTECHNICAL EXPLORATION

Our scope of services for the intertie project consisted of:

- Reviewing historic geotechnical and geologic reports near the proposed development area.
- Reviewing aerial imagery of the area along the planned intertie alignment.
- Review the preliminary Togiak River crossing conductor geometry and loads developed by CRW and GSE.
- Advancing small diameter probes by hand to characterize near surface soils.
- Advancing a series of shallow test holes along the powerline alignment using a hand-held Hilti hammer drill to aid in characterizing shallow, near surface soil conditions.
- Advancing small diameter steel rods deeper than shallow test holes or hand probes using a Hilti hammer drill to infer subsurface soil conditions.
- Based on the reviewed documents, imagery and the field findings, develop our opinion of the geotechnical conditions along portions of the proposed alignment, in particular along the planned Togiak River crossing.
- Based on inferred or estimated geotechnical conditions, develop geotechnical recommendations for the intertie line poles, guys and Togiak River crossing.

3.0 REVIEW OF EXISTING GEOTECHNICAL DATA

Golder has conducted geotechnical investigations in Togiak and Twin Hills since the 1990’s for a variety of infrastructure projects. Most of our in-house geotechnical data is not located along the Togiak-Twin Hills intertie alignment. Key elements from our review of historic geotechnical data near the proposed intertie are summarized below:

- **Togiak Heights Sewer Upgrades, Golder, 2013** – Golder performed a geotechnical exploration for a proposed sewer utility upgrade in the general area of the sewer utility along the road section of Bayview Drive, north-south through the Togiak Heights Subdivision. The geotechnical exploration consisted of advancing six geotechnical test pits to depths between 7.5 and 10.5 feet below the ground surface at the time of the field effort (bgs). The conditions of the test pits were generally similar and consisted of a thin veneer of organic material, typically one foot thick, over mineral silt to depths of 3.5 to 7 feet, over sand and gravel to the depths explored. Groundwater was observed in one test pit at approximately 3 feet bgs. No permafrost was encountered in the test pits.
- **Togiak Teacher Housing, Duane Miller Associates LLC (DMA), 2009** – DMA performed a geotechnical exploration for a proposed teacher housing structure in Togiak near the existing school. The geotechnical exploration consisted of advancing six test pits to depths between 6 and 11.5 feet bgs. The test pits were excavated on an existing gravel pad that was approximately 3 feet thick. Below the gravel fill, a mixture of silty sand and silty gravel with cobbles was encountered to the depths explored in each test pit. Groundwater was observed in three of the test pits between 6 and 7 feet bgs. Frozen soil, characterized as remnant seasonal frost, was encountered between 4 and 10 feet bgs in five of the test pits without encountering permafrost.
- **Various Geotechnical Reports, DMA/Golder** – DMA has performed various geotechnical explorations within Togiak for water, sewer, fuel and dock improvements. In general, the soils encountered consisted of loose sand and gravel without encountering permafrost. Groundwater was generally encountered at an average of approximately 5 feet bgs.

- **Twin Hills Housing Project, DMA, 1999** – Eleven test pits were advanced to depths between 6.5 to 10.5 bgs. The test pits were located approximately 250 feet west of the runway on the top of a ridge extending downhill to the west. The organic layer was generally less than one foot thick, but organic silt was found as deep as 4 feet bgs. The organic silt was underlain by silt and gravelly silt at many of the locations. The sand and gravel was mostly found at depths less than 6 feet and continued to depth. No permafrost was present in the area.
- **Geotechnical Investigation for the Design of Airport Improvements, Twin Hills, DMA, 1994** - Fifteen test pits were advanced to depths between 4 to 9 feet in the vicinity of the airport. An additional eleven test pits were advanced at the proposed borrow source two miles south on Beach Road. The test pits at the airport encountered fill over 1 to 2 feet of organic material, over silty gravel. Many of the test pits encountered refusal on tightly nested volcanic boulders. At the borrow site, the test pits encountered 1 to 1.5 feet of organic material over gravelly sand and sandy gravel. No permafrost was encountered in any of the test pits.

4.0 GENERALIZED SITE CONDITIONS

4.1 Regional Setting and Geology

The community of Togiak is situated on the western shore of Togiak Bay in the Ahklun Mountains Physiographic Province, approximately 70 miles west of Dillingham. The community is located on a series of beach lines near the mouth of the Togiak River. The hills in the Togiak area are composed primarily of sedimentary and meta-sedimentary rocks of Cretaceous age. Small outcrops of granitic stocks are present in the area and Quaternary lava flows are present to the east of the village. In the Togiak River valley some volcanic rocks may be interbedded with the sedimentary deposits. The bedrock may have weathered in-place and locally derived rock and granular soil colluvial deposits should be expected on the lower slopes.[1]

The community of Twin Hills is situated approximately four air miles to the east of Togiak and is located along a distributary of the Togiak River that forms the southeastern part of Togiak Bay. The village is located south, across the river, from two meta-volcanic hills that rise between 300 and 400 feet above the surrounding area.

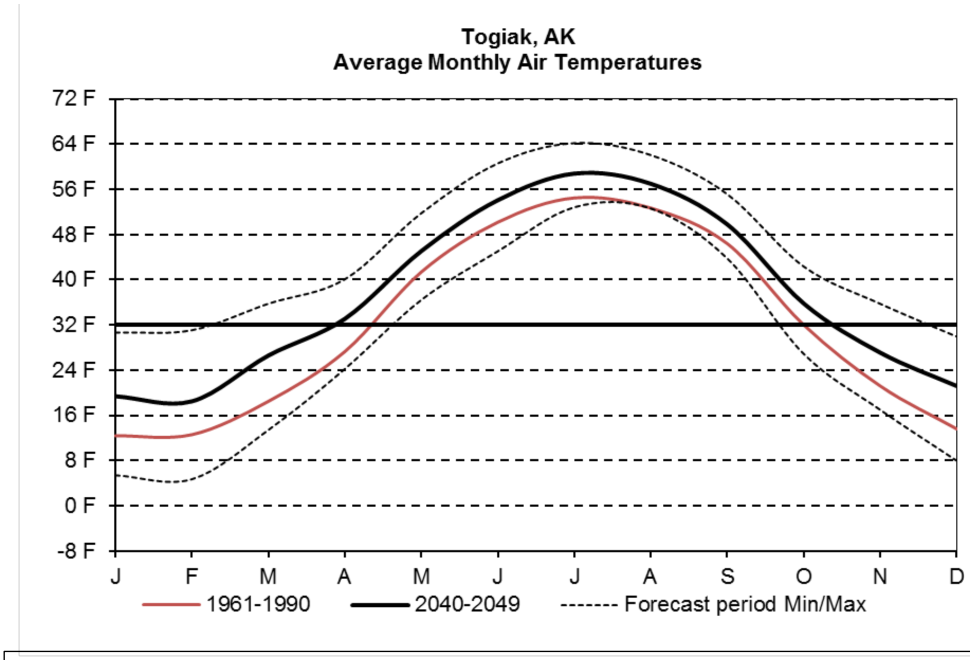
The general Togiak and Twin Hills area has been mapped by US Geologic Survey (USGS) as a zone underlain by isolated masses of permafrost.[2] However, permafrost was not encountered in the shallow subsurface data reviewed within the intertie corridor between Togiak and Twin Hills.

4.2 Climate

Situated on the coast, Togiak is strongly influenced by a maritime climate. Summers are cool and moist and winters are moderate and windy. In summer, prevailing winds are generally from the south. The prevailing winds for the remaining months of the year are from the north. The strong winter winds observed in the Dillingham area can result in snow drifting that insulates the underlying ground.

[1] Warhartig, Clyde (1965). *Physiographic Divisions of Alaska*. Washington: GPO.
[2] Ferrians, O.J., Jr., (1965), Permafrost map of Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map 445, 1 sheet, scale 1:2,500,000.

To estimate forecasted air temperature changes in this area, we relied on the University of Alaska Fairbanks Scenarios for Alaska & Arctic Planning (SNAP) group data, aggregated on a monthly basis. The SNAP group has developed forecast air temperatures based on an average of five Global Circulation Models (GCM) they consider most applicable to Alaska. From these data, the SNAP group provides minimum, mean and maximum air temperature data for specific locations. For our analysis at this site, we relied on 1960-1991 historic air temperature data based on PRISM downscaling methods and forecast air temperature data for the 2040-2049 period based on a Representative Concentration Pathway (RCP) of 6.0 watts/m^2. Summary air temperatures, freeze and thaw indices are provided below for the proposed development area.



Period		Average Air Temperature	Freeze Index	Thaw Index
1961-1990	Mean	31.9 F	2,600 F-days	2,700 F-days
2040-2049	5 Model Mean	37.2 F	1,410 F-days	3,360 F-days
2040-2049	Maximum	45.0 F	120 F-days	4,900 F-days
2040-2049	Minimum	27.6 F	3,730 F-days	2,180 F-days
Maximum: Warmest Values from all 5 GCM Models				
Minimum: Coldest Values from all 5 GCM Models				
DESIGN (AVE 5 MODEL AVE AND MAX)			2,570 F-days	4,130 F-days

Based on our review of forecast air temperatures, average annual air temperature and air thaw index should be expected to increase throughout the project's estimated 30 to 40-year service life. The air freeze index is expected to decrease over the project's service life. While a general warming is expected, shorter-term variations in average air temperatures should be expected.

5.0 FIELD EXPLORATION PROGRAM

Prior to performing the field exploration, the Native Village of Togiak was contacted by Golder to coordinate local utility locates. The field program consisted of site reconnaissance and shallow subsurface explorations. The field exploration was conducted between October 10 and 13, 2014 by Golder Engineer Nick Moran and CRW Engineer Andy Horazdovsky. A project specific Health and Safety plan was developed by Golder for the field program.

The crew was stationed in Togiak and mobilized to the sites by an R44 helicopter operated by Pollux Aviation. The R44 transported the two-person field crew and sling loading the field investigation equipment between the visited sites.

5.1 Shallow Subsurface Exploration

The shallow subsurface exploration program consisted of the following tasks:

- Advancing hand probes along the intertie alignment to infer near surface soil conditions, in particular the thickness and extent of organic material.
- Drilling and sampling shallow test holes along the power line alignment using a hand-held Hilti hammer drill to characterize near surface soil conditions.
- Advancing steel rods beyond the shallow test holes or hand probe depths using a Hilti hammer drill to infer soil density and consistency at depth. Soil sampling was not possible with this effort.

The hand probes consisted of advancing a slender steel rod, approximately ½-inch diameter, into the ground surface. The hand probes were assembled in 5-foot sections with a total length of 10 feet. Hand probes were advanced at each location along the alignment to infer shallow subsurface soil conditions. A noted variation in probe resistance was inferred to represent the approximate thickness of soft soils or organics.

The test holes were advanced by a hand-held Hilti hammer drill (Hilti TE-70 ATC) to depths of 6 to 8 feet below the existing ground surface. The hammer drill was powered by portable generators and required a two-person crew to safely operate. At nearly all test hole locations, it was not possible to recover representative soil samples at depth due to shallow groundwater infilling the drill hole. However, we were able to collect surface soil samples from areas of exposed river bed on either side of the Togiak River.

Small diameter (3/8-inch) steel rods were advanced with the Hilti hammer (percussion) drill at six locations along the proposed alignment and one location along the proposed alternate alignment. The rods were advanced at the general locations presented in Figure 1. The locations are labeled Organic Depth 1 through Organic Depth 7 for this report. The rods were advanced to nominal depths ranging from 15 to 39 feet bgs in an effort to infer general subsurface material conditions by the steel rod advancement rates and behavior.

6.0 LABORATORY TESTING

Recovered near-surface soil samples from exposed areas near the Togiak River were retained in double-sealed, polyethylene bags and shipped to Golder's geotechnical laboratory in Anchorage for further analysis. In the laboratory, the soil samples were reviewed to confirm field visual classifications and select samples were tested for soil index properties. Laboratory tests were conducted in general accordance with ASTM International geotechnical laboratory test procedures. Laboratory testing included:

- Soil moisture content
- Particle size distribution

- Atterberg Limits (soil plasticity)

Laboratory data are summarized in Appendix A.

7.0 GENERALIZED SUBSURFACE CONDITIONS

Based on laboratory testing and the field investigation effort, the inferred subsurface conditions consist of organic material overlying non-to low plastic silt that is expected to extend below the estimated foundation embedment depths. Due to the lack of subsurface soil sampling along the alignment outside portions of the Twin Hills area, subsurface conditions have been inferred to be primarily saturated mineral silt below nominal 5 foot thick surface organic silt layer. Saturated mineral silt is expected to be encountered below the surface organic layer to below the proposed powerline pole foundation depths. For use in axial and lateral capacity modeling we have assumed the silt will exhibit non-plastic behavior similar to a non-cohesive, loose, saturated fine sand. Based on the area depositional environment, the mineral silt may have organics either as intermixed zones or as distinct layers. Sequences of peat or highly organic silt can be present throughout the area within the expected foundation depths.

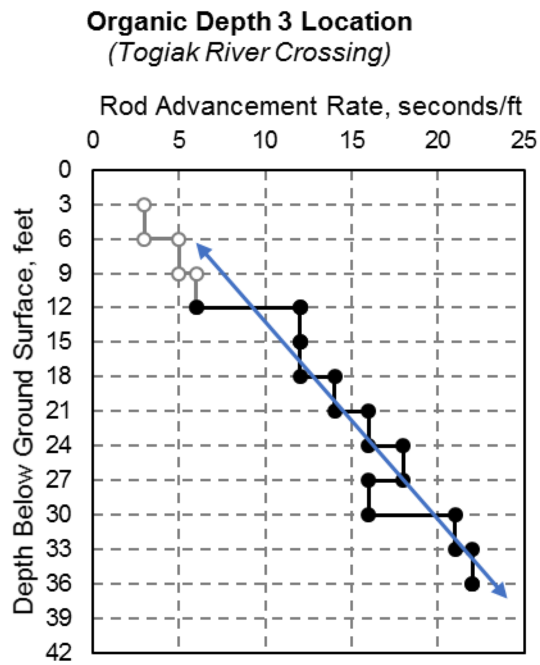
In general, rapid rod advancement with depth at a relatively consistent rate may infer the presence of organic material, or very soft or loose mineral soil conditions. Rod advancement with increasing resistance and slowing rates may infer mineral soils that may develop shear strength with depth. Refusal of rod advancement may indicate denser soil, rock or potentially frozen soil. Table 1 below summarizes the advancement rates of the steel rods at select locations along the powerline alignment. The rods were advanced by hand to about 3 feet bgs so advancement rates for this section were not recorded.

In general, the advancement rates presented in Table 1 indicate loose soils to the depths explored. At depths greater than 20 feet, collection of subsurface information is limited due to the exploration methods employed. At six of the seven locations, rod advancement was stopped prior to refusal because the depth of loose materials encountered indicated direct set type foundations would not be suitable for the poles. Rod refusal was only encountered at the Organic Depth 1 location, which was advanced nearest the bedrock outcropping near Twin Hills. The rod refusal was inferred to be on larger dimension aggregate or bedrock of undetermined weathering.

Table 1: Steel Rod Advancement Rates

Depth (feet)	Drive Rates (seconds/foot)						
	Organic Depth 1 Location	Organic Depth 2 Location	Organic Depth 3 Location	Organic Depth 4 Location	Organic Depth 5 Location	Organic Depth 6 Location	Organic Depth 7 Location
0-3	-	-	-	-	-	-	-
3-6	2	4	3	1	2	5	2
6-9	8	6	5	6	5	3	5
9-12	17	10	6	7	7	3	11
12-15	52- Refusal	14	12	17	14	6	15
15-18		10	12	18	23	10	24
18-21		14	14	20	19	12	
21-24		17	16	26	20	12	
24-27			18	10	13	23	
27-30			16				
30-33			21				
33-36			22				
36-39			22				

The deepest rod advanced was at the Organic Depth 3 location, near the east bank of the Togiak River. The rod was advanced to 39 feet bgs and rod advancement was stopped prior to rod refusal. The steel rods were advanced at this location to help collect information for the larger span over the river. The following plot summarizes the rod advancement rates at the Togiak River crossing. As noted in the plot, a generally increasing rod advancement rate was recorded starting around 10 to 12 feet bgs inferring relatively similar subsurface conditions with depth. However, the rod advancement rates are considered relatively rapid indicating looser soils.



8.0 DISCUSSION

We have based our geotechnical recommendations for the intertie project on the results of our limited site-specific geotechnical exploration effort and our interpretation of the geology along the proposed alignment. Subsurface conditions have been inferred based on rod advancement rates and our interpretation of the regional geology and the geologic depositional environmental along the intertie alignment.

Beneath a thin surface organic mat and about 5 to 10 feet of organic silt, we have assumed a mineral silt will be present that extends below proposed foundation depths. Groundwater will be encountered about 5 feet bgs except along the upland areas near Twin Hills. Limitations of the exploration methods did not allow for subsurface data to be collected to adequately determine the geotechnical engineering properties of the soil. Therefore, generally conservative soil engineering property values have been assumed for our analysis. For use in analysis of axial and lateral capacity of the pile foundations, we have assumed the loose, saturated silt will exhibit non-plastic behavior. We have also assumed minimal axial strength will develop in the initial 5 to 10 feet bgs except along the upland areas near Twin Hills.

GSE has developed line pole and Togiak River crossing loads. For the line poles, a nominal lateral force transverse to the conductor axis of about 2,000 pounds is expected at the conductor elevation, approximately 35 feet above surrounding grade. For geotechnical purposes, we have assumed this lateral force will result in an 80 kip-foot moment near the base of the timber pole. The conductors will balance lateral forces parallel to the conduct axis, except at pole line tangent points. At pole line tangent points, guys will be installed to resists lateral (tension) forces.

For the Togiak River crossing, GSE estimates each conductor will develop a nominal 16.6-kip tension force along each guy anchor for guy orientation 45 degrees from vertical. The river crossing is expected to require 60-foot tall timber poles with one conductor per pole (4 poles total along each side of the Togiak River crossing). The timber pole arrays along on each side of the river crossing will include above grade cross bracing.

To aid with constructability, we understand AEA desires H-pile geometry for all timber line poles, except at areas for possible direct set timber poles near Twin Hills. We have based our geotechnical recommendations on HP10x57 driven pile foundations with round timber pole attached to the above grade portion of the H-pile for the line poles. We have assumed a nominal 4 to 5 foot long H-pile section will remain above grade to timber pole attachment. All line pole piles will be installed vertical.

Along portions of the intertie route near Twin Hills, shallow bedrock is anticipated that may permit direct-set timber poles. If direct-set timber poles are used, they should be installed butt down. Compact granular backfill is recommended for all direct set timber poles.

At the Togiak River crossing, batter oriented larger riser diameter helical pile groups are planned under each timber pole. Multiple helical piles are anticipated to support each Togiak River crossing pole. The timber poles for the Togiak River Crossing will be cross braced.

In all locations, helical piers (screw piles) are planned for guy anchorages with all guys (line and river crossing poles) oriented 45 degrees from vertical. At all guy locations, the helical pier and the guy cable should be oriented in direct alignment to avoid developing a moment at the helical pier/guy cable connection.

Due to the limited subsurface information, construction observation will be critical to the performance of the foundation systems, particularly at the river crossing. Construction observation and field testing at select locations during pole foundation installation will provide shorter response times to address unanticipated or unexpected conditions encountered during pile and guy foundation installation. In order to maintain the required minimum clear space between the conductors and the Togiak River, we understand the river crossing foundations have a lower tolerance for axial and lateral movement relative to the line pole foundations. Pile axial capacity and estimates of long-term foundation lateral capacity and axial settlement should be verified by load testing select helical piles during the river crossing pole foundation construction.

9.0 GEOTECHNICAL RECOMMENDATIONS AND CONSIDERATIONS

Based on discussions with the design team, we understand the proposed foundation piles along the line pole alignment are estimated to have a maximum moment of 80 kip-foot per pile at the ground surface. However, the structural loads may be refined as the project design develops. Therefore, our foundation recommendations should be reviewed by us as the design and structural loading criteria are refined.

9.1 Frost Uplift Design Forces – All Pole Locations

At all intertie foundation locations, we have estimated seasonal frost may extend approximately 3 feet below ground surface. We have assumed frost breaks (i.e., polyethylene sheeting, grease, etc.) are not practical along the driven H-pile sections. For our analysis, we have assumed a seasonal frost uplift stress of approximately 30 pounds per square inch (psi) can develop along the H-pile box perimeter through the seasonal frost zone of along the outside perimeter of the helical piles and piers.

9.2 Line Pole Axial Capacity

We anticipate the line poles will be lightly axially compression loaded and seasonal frost forces may govern the minimum H-pile embedment depth. To resist seasonal frost forces acting on driven H-piles, we recommend a minimum embedment depth of 50 feet below grade. We have applied a factor of safety of 1.3 against frost heave for our analysis.

Driven H-piles embedded at least 50 feet below grade are expected to develop an allowable axial compression capacity of 15-kips. We applied a factor of safety of 3 to develop our estimated allowable axial compression loads for driven H-piles in the non-cohesive mineral silt soil. Further site investigation using geotechnical drilling and sampling methods or compressive load testing on installed piles can be considered to refine the allowable axial compression capacity analysis, which may reduce minimum pile embedment depth.

9.3 Line Pole Lateral Resistance

For the H-pile foundations, lateral capacity and deflections were estimated based on methods developed by Matlock and Reese for vertical piles installed in non-cohesive soil. In our analyses, we used a moment of 80 kip-foot applied at the ground surface. We also assumed the H-pile will be installed with the pile strong axis oriented normal to the conductor axis. Due to the expected higher organic content soils near the ground surface, we have assumed minimal lateral resistance will develop until five feet below existing ground surface. For our lateral analysis, we have assumed the general soil profile and soil properties summarized in Table 2.

Table 2: Lateral Soil Profile

Depth of Layer Below Ground Surface (feet)	Effective Unit Weight (lbs/ft^3)	Undrained Cohesion (lbs/ft^2)	Friction Angle (degrees)	Horizontal Modulus of Subgrade Reaction (lbs/in^3)
5 to 100	50	0	28	15

Based on the anticipated soils, lateral displacements for line pole H-piles on the order of 2 to 3-inches may develop at the ground surface. If this displacement is not acceptable, one method to increase lateral resistance is to include a steel plate on the piles embedded below the seasonal frost depth. To develop passive soil resistance to augment the H-pile lateral resistance, a steel plate on the order of 3 feet wide by 2 feet high orientated parallel to the conductor axis can be fixed to the pile during installation, but prior to final target embedment. The basal corners of the plate may be tapered for installation ease, but we should review the plate geometry as the design advances. The structural engineer should determine the steel plate thickness and connection to the H-pile for the anticipated loads.

We estimate a steel plate of this dimension seated into the underlying mineral silts, estimated to be between 6 to 8 feet below grade, can develop passive soil resistance to balance the moment developed at the base of the timber pole. This assumes the steel plate will be seated in saturated mineral silt. The H-piles augmented with the steel plate as discussed above are estimated to result in a lateral displacement normal to the conductor axis of less than 1-inch at the ground level. If thicker sequences of looser soil are inferred in the shallow subsurface materials, additional steel plates may be considered to increase lateral resistance. If additional steel plates are used, they should be oriented vertically below the primary plate noted above. We can provide additional design considerations for the lateral resistance augmentation methods as the project design develops.

All potential contractors should be advised of this steel plate option to verify their H-pile installation means and methods can embed the steel piles and plates to the desired depths. It is essential the steel plates do not terminate in the zone of seasonal frost penetration.

9.4 River Crossing Helical Piles

We understand the Togiak River span will be on the order of 1,200 feet. GSE estimates each conductor will develop a 16.6-kips tension load along a single guy attached to each timber pole. GSE estimates this guy tension will provide for the minimum required conductor clearance over the Togiak River. Base reactions for each timber pole at the river crossing are estimated to be no greater than 40-kips axial compression. Along each side of the river, the timber pole arrays will be guyed using orientations both parallel and normal to the conductor axis. Also, the timber poles along each bank of the river will be cross braced above grade. If so, a minimum moment and shear is expected to be generated at the base of the timber poles.

We recommend each timber pole for the Togiak River crossing be founded on larger riser diameter helical piles. The minimum 10-inch riser diameter, schedule 40 helical pile is recommended, or as advised by the structural engineer. Each helical pile should be shop fabricated with three helices, 24-inch, 22-inch and 20-inch diameter helices with the smallest dimensioned helix located along the distal end of the helical pile. A 6-inch helix pitch is advised with the leading edge of each helix prepared for the expected subsurface conditions. A three-helix diameter interhelix separation recommended. Helix plates should be at least ¾-inch thick, or as recommended by the structural engineer and helical pile manufacturer for the anticipated installation torques and axial loads. All helices must be designed and fabricated to track in a geometrically identical fashion.

For the Togiak River crossing timber poles, at least three (3) helical piles are advised under each timber pole. Each helical pile should be installed axisymmetric to the timber pole centerline. The uppermost helix should be embedded at least 25 feet below finish grade. All three helical piles should be structurally connected to a common pile cap. A larger diameter steel shell may be attached to the pile cap for installation of the timber pole.

The helical piles should be installed at a radially symmetric outward batter from the timber pole centerline. A maximum nominal 1H:8V (horizontal:vertical) batter can be used. Provided each helical pile is installed with a radially outward batter, the centerlines for the three helical piles installed under a common pile should be at least 30-inches apart at the pile cap to reduce the potential for group interactions. If vertical helical pile installation geometries are being considered, a larger centerline separation may be required to reduce potential group effects. We should be contacted if vertical installation geometries for the helical piles are being considered.

Due to expected use of multiple guy anchors at the river crossing, the axial compression loads developed on the helical piles are considered sustained loads. Based on our hand probes near the river crossing, soft or loose soils may be present to considerable depth. Additional helical pile riser pipe should be provided with the base bid in the event deeper embedment is necessary to achieve the required axial resistance. The helical pile installation means and methods may require field splicing riser sections. If so, the structural engineer's recommendations for field splice welds must be followed. All pipe rise field spices must result in continuous alignment with the lead helical pile section centerline.

The helical piles should be provided with corrosion protection suitable for the environment and expected service life. We recommend hot dip galvanizing for all helical piles unless otherwise specified by the design team. Depending on the contractor's installation means and methods, the helical pile risers may have penetrations to aid with installation. If so, the penetration zone should be removed or flush welded to completely seal the preparation using appropriate corrosion protection as recommended by the structural engineer.

Each helical pile should be installed using a hydraulic drive head capable of safely achieving the require installation torques with an appropriate margin of safety. For planning, each helical pile should develop an installation torque of at least 35,000 foot-pounds as averaged over the final five (5) feet of embedment is recommended.

Based on inferred subsurface conditions, a nominal 10-inch riser diameter, triple helix pile discussed above with the uppermost helix embedded at least 25 feet below grade at the river crossing should be expected to develop an allowable axial capacity of 20-kips per pile with an estimated factor of safety of 2.

Pile installation should be monitored by a geotechnical engineer experienced with larger dimensioned helical pile installation. Axial capacity and estimated axial settlement should be determined on at least one pile along each river bank using a load/settlement axial compression test procedure. We can provide recommendations for this static test method with the design team as the project design advances.

9.5 Guy Anchors

We understand the helical piers are preferred for all guy anchors. Guy anchors should be founded on helical piers (screw piles) with a minimum geometry of nominal 2-7/8-inch diameter, schedule 40 pipe risers with triple 12-10-8 inch diameter helices. Hot dip galvanizing is recommended for all helical piers. The helices can be manufactured with a 3-inch pitch with the smallest diameter helix along the distal end of the helical pier. The uppermost helix should be installed at least 15 vertical feet below existing grade and develop a minimum 3,000 foot-pounds of torque as averaged over the final three feet of embedment. Note, a minimum 15-foot vertical embedment will require at least 22 feet of embedment along the shaft for a 45° batter installation. Deeper helical pier embedment may be required to achieve the minimum recommended installation torque thus additional riser sections should be provided to accommodate variable subsurface conditions.

A 3,000 foot-pound installation torque should provide for an approximate allowable tension capacity of 18-kips for each helical pier embedded in the saturated mineral silt expected at this site. Due to the uncertainty in subsurface conditions, select helical anchors at each critical load site should be axially tension load tested to the design load plus a factor of safety of at least two (2). Deeper helical pier embedment or use of multiple helical piers for each guy cable should be included with the project design. Guys for the river crossing may require a larger riser shaft and helix diameter, embedment depths or multiple helical piers per guy, particularly if multiple guys are planned for a timber pole. Select river crossing guy anchors should also be tension load and creep tested since they are considered critical load systems. We can provide recommendations for helical pier tension load testing as the design advances.

9.6 Construction Considerations

The loose, saturated states of the surface and near surface soils along the alignment will exhibit low bearing capacities and the potential to rut under traffic loads. Access along the alignment may require surface frost adequate to support the planned construction equipment. Even in the winter months, low ground pressure equipment, rig mats and possibly temporarily hardened construction access may be needed. It is our understanding that the Togiak River does not completely freeze over in the winter and weather conditions may not be conducive for building ice for construction equipment access.

Surface frost may require thawing or predrilling to advance the helical pile and piers. If predrilling through surface frost is used, the predrill diameter should not exceed the riser shaft outside diameter.

Due to the limits of the geotechnical exploration, it is possible the piles may not behave as anticipated during construction. If the piles meet refusal before reaching design installation depths, or if inadequate resistance is encountered at the design installation depth, Golder should be consulted in a timely manner to determine foundation design modifications. For these reasons, a cost and schedule contingency should be included for the construction of the transmission intertie.

9.7 Driven Pile Installation Considerations

Piles should be driven plumb to within 1/8-inch per foot, or as specified by the design team. Piles should be within 3 inches of the design locations or as recommended by the design team. Other issues related to the pile installation for design team consideration include:

- **Hammer/Pile System Acceptance and Driving Criteria**: The selected pile hammer energy should achieve the minimum recommended embedment with the attached vertical steel plates without damaging the pile system. A wave equation analysis should be performed as part of the contractor hammer submittal. Compressive driving stresses should not exceed 90-percent of the pile steel yield strength. A maximum blow count for the particular pile and hammer energy should be determined prior to starting work. We can provide further guidance regarding pile driving criteria.
- **Pile Installation Inspection**: We recommend that a qualified technician or engineer be present during production driving to observe and record pile installation practices. Complete driving logs should be maintained for all piles as part of the permanent as-built record. Complete logs should include: blows per foot, hammer type and size, date and time of installation, hammer stroke and hammer setting, and note any issues encountered during pile installation. A Saximeter (or similar) instrumentation is recommended to record pile blow counts and hammer stroke during installation. The plans and specifications for the pile installation should be reviewed for conformance with the geotechnical engineering recommendations prior to finalizing the design documents.
- **Pile Capacity Determination**: A tension load test preformed in accordance with ASTM D3689 is recommended on at least one line H-pile to verify capacity against seasonal frost forces. Load testing may either be conducted through the owner’s representative or the contractor, and should be specified as part of the bid documents. Alternatively, PDA testing designed and conducted to determine axial compression and uplift capacity may be considered in lieu of static load testing for driven line piles depending on the contractor’s selected pile installation means and methods. If PDA analysis is not applicable based on the contractor’s pile installation means and methods, a static compression load test in accordance with ASTM D1143 is recommended on select line piles to determine axial compression capacity.

9.8 Helical Piles and Piers Installation

Helical piles and guy anchor helical piers must be installed in accordance with the manufacturer’s installation recommendations. If installed incorrectly, the helices can significantly disturb the soil fabric around the helices. The disturbed soil surrounding the helices or at the ground surface may result in significantly reduced axial and lateral capacity as well as increased helical pile/pier movements. Helical pile/pier installation recommendations include the following guidelines.

- **Installation Guidelines:** The helices must be advanced in a continuous manner that allows the helix to “screw” into the soil matrix, rather than “auger” through the soil matrix, which can result in disturbed soils around the helices. The rate of advancement should be 3 to 5 rotations per minute (rpm). Apply uniform down pressure to maintain a penetration rate identical to the helix pitch. The rate of rotation and magnitude of down pressure may require adjustment during installation.
- **Helical Pier/Guy Cable Geometry:** The helical piers should be installed in direct line with guy cable orientation to avoid developing moments at the helical pier/guy cable connection.
- **Helical Pile and Pier Installation Inspection:** A calibrated torque indicator is required during installation. The maximum applied torque should not exceed the values developed by the helical pile/pier manufacturer. The manufacturer’s maximum allowable

installation torque should not be exceeded prior to attaining the minimum recommended embedment depth. If the maximum allowable torque value is reached prior to attaining the specified termination depth, the helical pile/pier should be removed by back rotation and a pilot hole should be advanced to termination depth and then the helical pier re-installed at least 5 feet into virgin soil.

- **Helical Pier Capacity Determination:** We recommend a helical pier tension load test be conducted on select guy anchors. A tensile load test (ASTM D3689) is recommended to confirm capacity of the helical piers. The static load test should be conducted to 200 percent of the design tension load. Helical piers along line pile guys for tension load testing should be determined in consultation with the design team. At least one guy at each side of the Togiak River crossing will also require tension testing to refine the correlation between installation torque and tension capacity. For the river crossing helical piers we also advise measuring displacements during the load test. At the river crossing, a minimum 60-minute sustained tension load test with displacement measurements to determine creep movement is recommended. We can assist the design team with helical pier tension load testing as the project design develops.
- **Lateral Capacity:** During helical pier installation, the surficial soils surrounding the helical pier may be disturbed and leave a small gap between the riser shaft and the soil. We recommend that the installed piles be inspected and the soil surrounding the pile be compacted with vibratory roller equipment if a gap of ¼-inch or more is observed along the pile riser shaft.
- **Togiak River Helical Pile Axial Compressive Load and Settlement Determination**: We recommend at least two static compressive load test be conducted on select Togiak River crossing helical piles to determine axial capacity and estimated settlement of the river crossing timber pole foundation. The static load test should be conducted in accordance with ASTM D1143 on at least one helical pile installed along each side of the river. Additional load testing may be warranted if differing subsurface conditions are inferred during foundation installation. Please note that axial load testing on batter oriented helical piles may require specialized testing procedures. It may be easier to conduct axial load testing on a vertically installed test helical pile of identical geometry as the production helical piles. If desired, we can assist the design team and contractor with the helical pile load test program.

10.0 USE OF REPORT

This report has been prepared for the use of CRW for the design of the planned power line intertie between the villages of Togiak and Twin Hills, Alaska. If there are significant changes in the nature, design, or location of the facilities, we should be notified so that we may review our conclusions and recommendations in light of the proposed changes and provide a written modification or verification of the changes.

There are possible variations in subsurface conditions between the shallow explorations and also with time. Therefore, inspection and testing by a qualified geotechnical engineer should be included during construction to provide corrective recommendations adapted to the conditions revealed during the work.

Unanticipated soil conditions are commonly encountered and cannot fully be determined by a limited number of explorations or soil samples. Such unexpected conditions frequently result in additional project costs in order to build the project as designed. Therefore, a contingency for unanticipated conditions should be included in the construction budget and schedule.

The work program followed the standard of care expected of professionals undertaking similar work in Alaska under similar conditions. No warranty expressed or implied is made.

11.0 CLOSING

We appreciate the opportunity to provide work on this report. We are available to provide additional recommendations or comments as necessary. Please contact us at 907-865-25371 if you have questions or comments.

Sincerely,

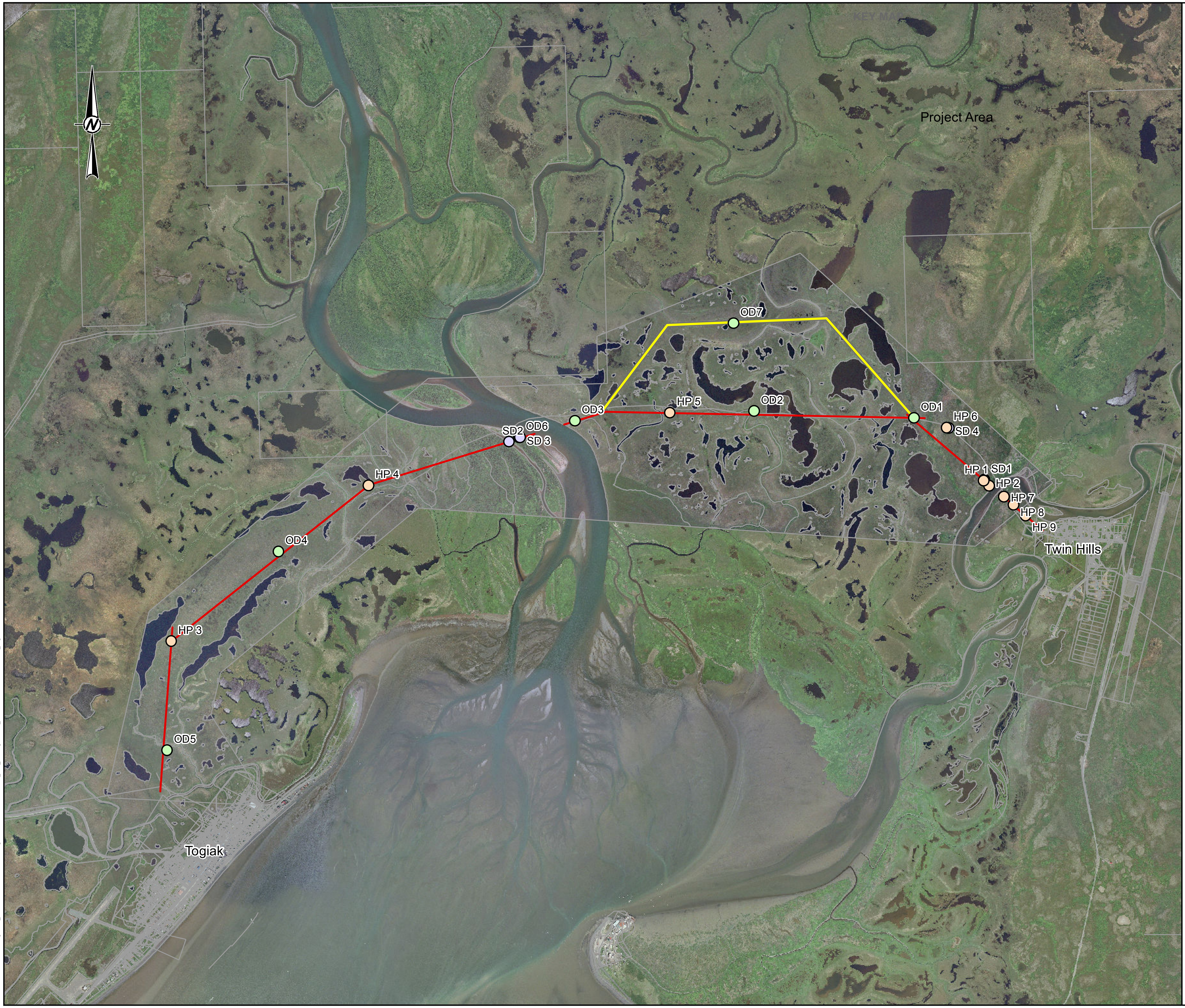
GOLDER ASSOCIATES INC.

Ryan Campbell
Project Engineering Geologist

Richard A. Mitchells, PE
Principal and Senior Geotechnical Engineer

Attachments: Figure 1: Field Investigation Points
Appendix A: Laboratory Data

FIGURES



LEGEND

Field Investigation

Name

- HP-Hand Probe
- OD-Organic Depth
- SH-Shallow Drill Hole
- Proposed Intertie Route
- Alternative Alignment

2,000 1,000 0 2,000

FEET

REFERENCE

1. AERIAL IMAGERY PROVIDED BY CRW
2. PROPOSED ALIGNMENT PROVIDED BY CRW

CLIENT
CRW ENGINEERING GROUP LLC
ANCHORAGE, AK

PROJECT
TOGIAK TO TWIN HILLS INTERTIE

TITLE
FIELD INVESTIGATION POINTS

CONSULTANT

Golder Associates

YYYY-MM-DD	2014-12-23
PREPARED	APG
DESIGN	RLC
REVIEW	RLC
APPROVED	RAM

PROJECT No.	CONTROL	Rev.	FIGURE
1402344		1	1

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

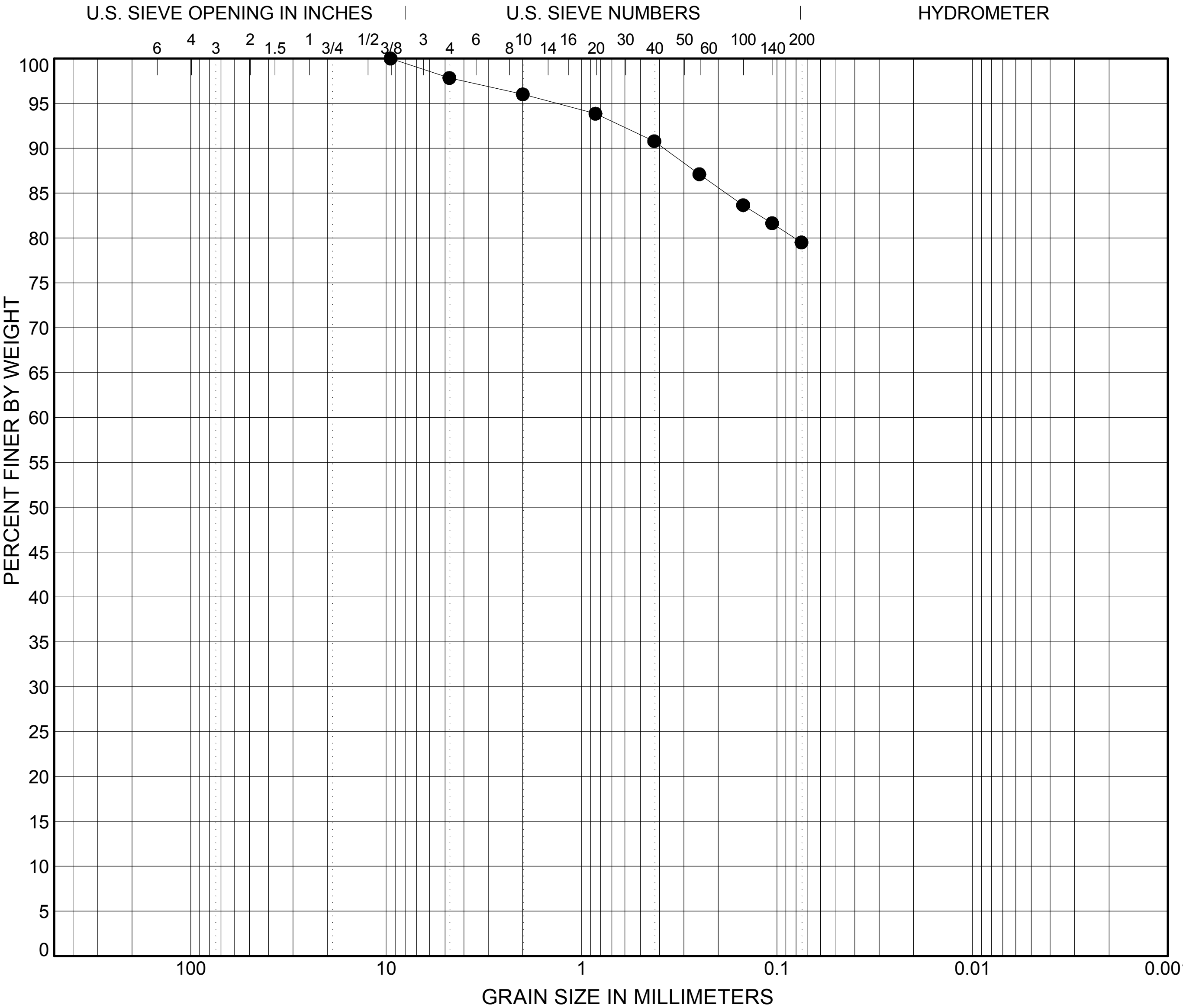
APPENDIX A
LABORATORY DATA

Golder Associates

FIGURE A-1: SUMMARY OF PARTICLE SIZE DISTRIBUTION RESULTS

Reference(s)
ASTM D422
ASTM D6913

Client:	CRW	**Project No.:**	1402344		
Project:	Togiak/Twin Hills Intertie	**QA/QC By:**	J. Randazzo	**Date:**	11/18/2014
Location:	Togiak, Alaska	**Reviewed By:**	H. Weston	**Date:**	11/18/2014



	Sample Location	Sample Number	Depth (ft)	USCS Classification	Cc	Cu	% Gravel	% Sand	% Fines	% < 0.02 mm
●	OD 3	S1	0.0	elastic silt with sand (MH)	-	-	2	18	79.5	

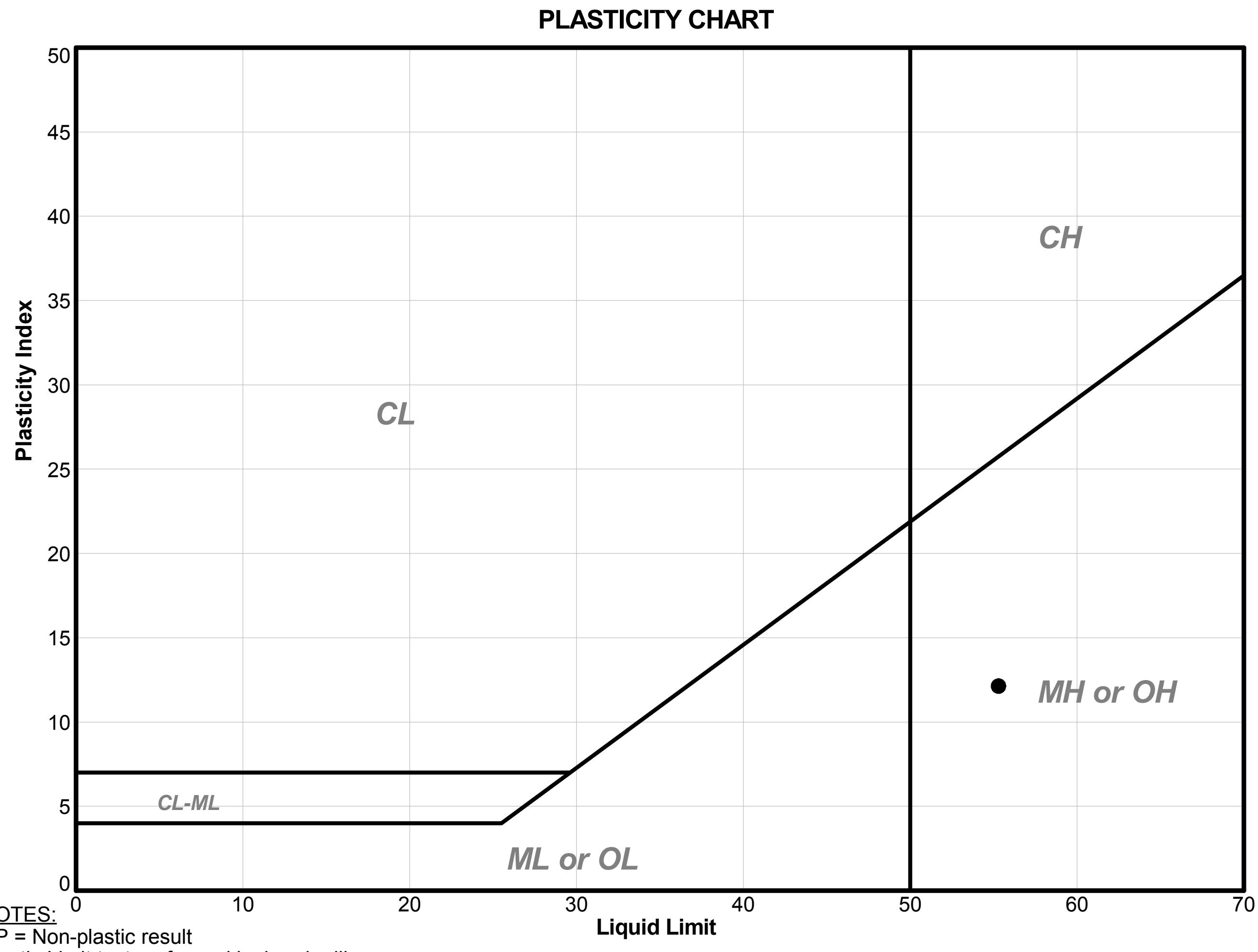
CRW TOGAIK TWIN HILLS INTERTIE.GPJ LIBRARY-ANC(10-11-17).GLB [ANC LAB GRAIN SIZE] ttrosper 2/8/18

Golder Associates

FIGURE A-2: LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX

Reference(s)
ASTM D4318

Client:	CRW	**Project No.:**	1402344		
Project:	Togiak/Twin Hills Intertie	**QA/QC By:**	J. Randazzo	**Date:**	11/18/2014
Location:	Togiak, Alaska	**Reviewed By:**	H. Weston	**Date:**	11/18/2014



NOTES:
NP = Non-plastic result
Plastic Limit test performed by hand rolling
Liquid Limit test performed using mechanical device

	Sample Location	Sample Number	Depth (ft)	Bottom (ft)	Passing #40 Sieve (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index	USCS	Natural Moisture Content (%)
●	OD 3	S1	0.0	1.0	91	55	43	12	MH	53

CRW TOGAIK TWIN HILLS INTERTIE.GPJ LIBRARY-ANC(10-11-17).GLB [ANC LAB ATTERBERG CASAGRANDE MULTI (10)] ttrosper 2/8/18