Execution of a Winter Geotechnical Drilling Program at Pond Inlet and Iqaluit, Baffin Island, Nunavut

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ABSTRACT

This paper presents the challenges overcome while successfully executing a winter geotechnical drilling program in Pond Inlet and Iqaluit in Nunavut, Canada in March/April 2017, supporting proposed port facilities to be built for these communities in the Canadian Arctic. Challenges included the logistics involved with mobilizing and demobilizing drilling equipment to the high Arctic, dealing with the extremely harsh weather, as well as having to plan and execute drilling on sea ice with a tidal range of over 11 m. The geotechnical drilling program focused on ground conditions underlying proposed deep sea port and small craft harbour sites at Iqaluit and a small craft harbour site in Pond Inlet, as well as sourcing suitable hard rock at both locations. This paper focuses primarily on Iqaluit whilst drawing upon key lessons learned from the works completed in Pond Inlet.

RÉSUMÉ

Cet article présente les défis à surmonter avec succès pendant l'exécution d'un programme de forage géotechnique d'hiver dans la région de Pond Inlet et Iqaluit au Nunavut de l'Arctique, le Canada en mars/avril 2017, en soutenant les installations portuaires proposé sera construit pour ces communautés dans l'Arctique canadien. Les défis comprenaient la logistique nécessaire à la mobilisation et la démobilisation des équipements de forage de l'Extrême-Arctique, traitant de la météo extrêmement dures, ainsi que d'avoir à planifier et exécuter des forages dans la glace de mer avec un marnage de plus de 11m. Le programme de forage géotechnique axée sur les conditions du sol sous-projet de port de haute mer et port pour petits bateaux sites à Iqaluit et d'un port pour petits bateaux à Pond Inlet site, ainsi que l'approvisionnement rock dur adapté aux deux endroits. Cet article se concentre principalement sur Iqaluit tout en s'appuyant sur les principales leçons tirées de l'œuvre achevée à Pond Inlet.

1 INTRODUCTION

Advisian (part of the WorleyParsons group of companies) was retained by the Government of Nunavut's Department of Community and Government Services (CGS) on behalf of the Department of Economic Development and Transportation (EDT) to provide consulting services for improvements to the marine infrastructure in Pond Inlet and Iqaluit. The overall scope of work included developing previous studies by WorleyParsons from a concept level through to detailed design and construction. This paper reviews the scope of work specific to the winter geotechnical investigation only. The winter scope of work comprised:

- Six (6) geotechnical boreholes drilled on sea ice in the footprint of the proposed deep sea port at Iqaluit;
- Four (4) geotechnical boreholes drilled on sea ice in the footprint of the proposed small craft harbour at Pond Inlet; and
- Two (2) geotechnical boreholes at a potential quarry site on land in Pond Inlet.

2 SITE CONDITIONS – IQALUIT

2.1 Location

Iqaluit, Nunavut is the hub of the eastern Arctic, located on the southern shores of Baffin Island in the Koojesse Inlet at the head of Frobisher Bay, in the Canadian Arctic as shown in Figure 1. Year-round access is by air, with Ottawa being the major direct link, as well as daily flights to other Arctic communities. Shipment of a range of items including fuel, construction equipment, house hold goods, food and other items is by sealift during summer to fall each year by marine carriers such as Nunavut Eastern Arctic Shipping (NEAS) and Desgagnes.

The Deep Sea Port (DSP) Study Area is comprised of prominent bedrock exposures that extend seaward from the upland, creating small embayments. Within the embayment areas, there are minor wave cut platforms with sloping cliff faces up to 45^0 coincident with rock defects.

The shoreline is characterized by whale-back outcrops. Sub-vertical to vertical cliffs and ravines traverse the area associated with variations in the rock type and structural defects. From the shoreline in the DSP Study Area, the surface extends seaward across low gradient tidal flats towards the deeper channels of the inlet. Boulders and cobbles are also present along the tidal flats.

2.2 Climate

Pond Inlet and Iqaluit experience long and extremely cold winters with daily average air temperatures ranging from -

9.7ºC October to -33.7ºC February at Pond Inlet and -3.7ºC October to -27.5ºC February at Iqaluit, (Environment Canada, 2010).

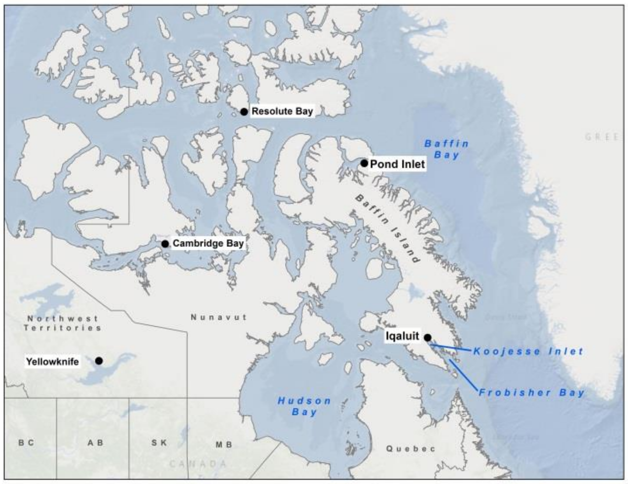

Figure 1. Location of Pond Inlet and Iqaluit, NU

2.3 Geological Setting

The Canadian Geoscience Map 64, Surficial Geology – Iqaluit, Nunavut (Allard et al. 2012), indicates the following geological conditions in the vicinity of the proposed marine infrastructure project:

- Marine Veneer (Mv): sand, silt and gravel; 0.5 to 2 m thick;
- Glacial Marine Delta (GMd): Sand, silt, boulders, and gravel; 2 to 20 m thick;
- Till Veneer (Tv): Diamicton; 0.5 to 2 m thick;more than 40% of area is till, less than 60% of areas is rock ledges and knobs, /and rubble;
- Till Blanket (Tb): Diamicton; 1 to 10 m thick;
- Bedrock (Pg): Monzogranite of Paleoproterozoic Cumberland Batholith.

2.4 Permafrost

Iqaluit is in the Continuous Permafrost Zone, defined as onshore ground temperature remains at or below 0°C for at least two consecutive years (Tarnocai and Bockheim, 2011). The ground may consist of one or more of the following: soil, rock, ice or organic material.

The permafrost of Baffin Island uplands has been estimated to be 400 to 700 m thick (Arluck, 2012) with a surface active layer that can vary widely from less than 1m in wet soils to greater than 5 m in rock outcrop.

Permafrost conditions in Iqaluit are highly variable spatially and with depth (LeBlanc et al., 2015). A generalized map shows that spatial distribution of ice rich permafrost near the shoreline deposits of the existing municipal breakwater is very complicated (refer to A Home Owners Guide to Permafrost in Nunavut, Government of Nunavut, 2013).

3 PROPOSED INFRASTRUCTURE

At the time of this paper, design was complete and construction had not yet commenced. A brief description of the planned upgrades covered by the winter geotechnical investigations is provided below.

3.1 Iqaluit Deep Sea Port

The general facility layout for the Deep Sea Port (DSP) will consist of the following components:

- Cellular sheet pile gravity dock structure including dredging to remove weak surface sediments and placement of a mattress and scour protection at the base of the cells.
- Earthfill causeway with a vehicle turning area to access the wharf, including slope protection.
- Sealift laydown area including slope protection. The laydown area is created by rock cutting at higher onshore grade and filling the lower near shore area; the rock cutting will be used to supply fill materials for the project, including the small craft harbour works. Cutting for the access road will also supply fill materials for the project.
- An auxiliary sealift ramp to permit offloading of multiple sealift vessels when required.
- Access road between the DSP laydown area and Akilliq Road at the Old Causeway.
- Shore moorings.

The upgrades to Akilliq Road were not originally included as part of the DSP development. In consultations with the City of Iqaluit at the Permitting Support stage, it was realized that the existing road does not fulfil the anticipated traffic from for the project. The road surface, drainage, width, grading and alignment are required to be upgraded. Figure 2 provides the location of the proposed developments.

Pond Inlet Small Craft harbour consists of a breakwater, dredged pocket and various mooring structures including a sheet pile bulkhead wall. A new hard rock quarry will be opened up to supply rock for the breakwaters.

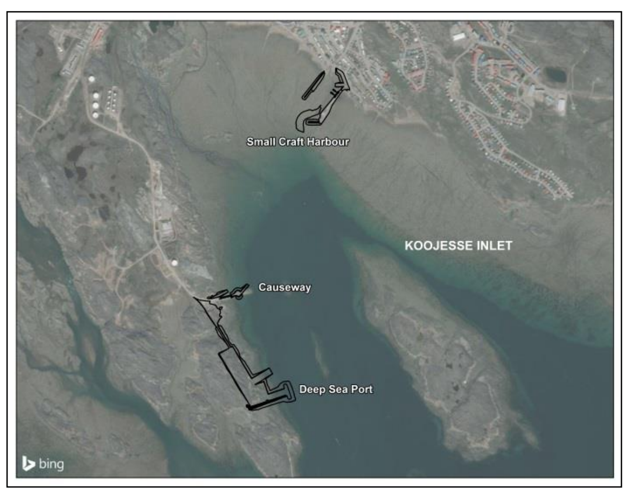

Figure 2. Proposed Small Craft Harbour and Deep Sea Port

4 PROJECT CHALLENGES, RISKS AND TEAM SELECTION

The primary geotechnical goals were to complete investigations at Pond Inlet and Iqaluit to define the soil and / or rock conditions underlying the proposed marine infrastructure, as well as source suitable rock for construction.

4.1 Challenges and Risks

Logistically from a weather perspective, it is preferable to undertake works from May to September where the daily average temperatures are significantly warmer. However, executing the work in summer would have necessitated mobilizing a barge and support vessels, which was cost prohibitive and would have resulted in a significant delay to the project execution plan. A winter investigation, drilling of the sea ice was selected.

The project teams experience and research of similar projects enabled an understanding of how challenging executing geotechnical investigations in the Arctic, especially during the winter months, can be. The key challenges and risks which were identified prior to executing the geotechnical investigation included:

- Assessment of risks associated with a lump sum contract;
- Selection of suitable contractor/s with experience of working on sea ice;
- Mobilizing / demobilizing equipment by air freighter;
- Weather conditions including snow storms and extreme cold temperatures and their impacts on health & safety as well as equipment performance and project delays;
- Working, travelling and moving equipment on sea ice;
- Large tidal range at the drill site (over 11 m);
- Remote work;
- Potential for encountering wildlife such as polar bears;
- Potential for equipment breakdowns and the limited local supplies available for making repairs;
- The need for community engagement and employment of local labour; and
- Predicting the unknown as best as possible.

Successful delivery of the project required partnering with a suitable drilling contractor, ice engineering consultant, local earthworks contractor as well as local logistical support and wildlife monitoring.

4.2 Contract

The overall project was priced based on a lump sum contract, which included the geotechnical scope of works. Working in the arctic is extremely challenging and it is essential that each stage of the project is carefully thought through. Recognizing that operations, climate and other items which are unforeseen will likely happen, and sufficient contingency is required to minimise the overall impact to the project budget and schedule.

4.3 Drilling Contractor

Selecting a geotechnical drilling contractor can be challenging. There are several companies that have experience executing projects in the Arctic, however, for this project, a contractor who had a proven track record working on sea ice as well as extreme tides needed to be identified.

Obtaining not only quotes, but also methodologies of how to execute such projects is key to identifying a suitable contractor. Selecting a contractor based on proven experience and a sound methodology for the project is the primary factor in selecting the contractor.

Logan Drilling Inc., based out of Nova Scotia, was selected. Logan had previous experience in the Arctic with Advisian at projects such as Nanisivik and Baffinland, as well as several projects in the Bay of Fundy, Nova Scotia, which demonstrated experience in three of the keys areas, extreme tides, Arctic climate and working on sea ice.

Each member of the drill crew had the necessary experience. Logan provided a specialist crew of five team members, which included an operations lead, two drillers and two helpers to cover 24-hour drilling operations. All five team members had experience working in similar conditions. As well as experience in drilling, one of the team members was a certified mechanic and another team member a certified carpenter which proved invaluable.

4.4 Ice Engineer

One of the key risks to this project was planning a drilling campaign that utilized the sea ice as a drilling platform with a tidal range of over 11m. However, working close to the shoreline with extreme tidal variations was not common practice with ice mechanics consultants.

NOR-EX Engineering Ltd, based out of Kamloops, British Columbia was selected to execute the scope of works.

4.5 Earthworks Contractor

Local earthworks moving contractors were selected for clearing of snow & access track construction across the sea ice, as well as moving the drill rig over the ice

In Pond Inlet, equipment and personnel were available from the CO-OP. In Iqaluit, R.L Hanson were selected primarily because they were the experienced in loading and unloading aircraft, and secondly based on their experience supporting events such as the snowmobile races (Toonik Tyme) which involves clearing access tracks for vehicles to drive on the sea ice each April.

4.6 Local Support

Local support is an important factor for the project. When planned for and executed correctly, the project should provide the community with valuable work opportunities and training. Providing good opportunities and leaving a positive impact on a community is fundamental to a project's success.

Qikiqtaaluk Business Development Corporation (Q-Corp) was engaged to provide local support including helpers and wildlife monitors and in Pond Inlet these services were also provided by Mittimatalik Hunters & Trappers Organization (HTO).

5 PROJECT EXECUTION

Prior to mobilizing drilling equipment for the winter geotechnical investigation, the author, operations manager from the drilling contractor and ice engineer conducted a site reconnaissance and ice assessment at Pond Inlet and Iqaluit in February 2017 to assess site access, confirm ice conditions and identify any key hazards / risks to the project.

5.1 Ice Reconnaissance

From planning meetings in Iqaluit during the earlier winter, it was observed that southeast storm winds in late fall 2016 had caused a significant rafting of ice onto the tidal beach area of Iqaluit at the normal access point. An ice reconnaissance survey was performed to assess the conditions and develop an access route through the ice rubble to the offshore level ice where the drilling would be undertaken.

Prior to mobilizing to site, the Ice Engineer was provided a proposed drill rig layout including dimensions and weights. The layout included the drill shack, water pump shack, drill rod baskets, generator and lights, heaters, pickup truck and loader. The total weight provided was approximately 29,110 kgs plus an additional weight of 12,730 kgs attributed to the pullback force of the drill rig which gave a total weight of 41,840 kgs.

Based on the weights and layout provided, a minimum ice thickness required ranged from 85 to 110 cm. The range of values related to the drill rig configuration, 85 cm included all weights excluding the loader and 110 cm included the loader.

The survey was performed by advancing ice augers through the sea ice using a 2” ice auger bit, and scanning of ice using ground penetrating radar (GPR), along access routes and within the footprint of proposed drill sites.

Figure 3. Ice Reconnaissance (Auger and GPR)

The data was reviewed to assess any anomalies such as cracks or zones of thinner ice from the GPR results, to target additional ice augured holes. It is noted that due to the very large tidal range in Iqaluit, the dates chosen to complete the survey were close to spring tides so the ice engineer could assess whether the large tidal variations affected ice integrity. GPR surveys completed during low tides were compared with the surveys high tides to check for any changes in ice integrity.

Results from the ice survey indicated that ice thickness in Iqaluit ranged from approximately 1.0 to 1.35m and in Pond Inlet 0.95 to 1.20m. These values are comparable to historic data collected in Iqaluit as shown on Figure 4.

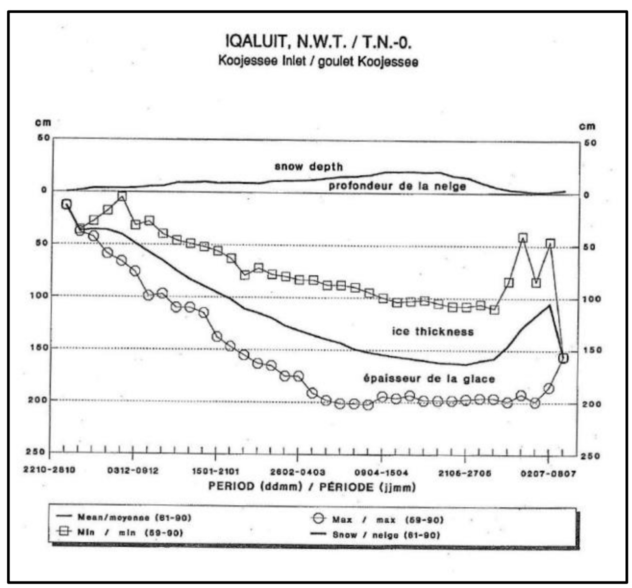

Figure 4.Iqaluit ice thickness data, excerpt from Ice Thickness Climatology 1961 to 1990 Normals.

Based on the results of the ice survey, the ice engineer provided several recommendations, including clearing and monitoring an ice pad in a radius of at least 25m from the drill hole as well as clearing and monitoring access routes to assess ice integrity and monitoring freeboard in the drill hole.

No major issues were identified in Iqaluit. A large tidal crack was evident close to the shoreline adjacent to the proposed borehole locations which corresponded to the low tide contour on the seabed, indicating that ice grounded at this location. The access route showed no major cracking other than the tidal flats which extend approximately 1000m from the shoreline. The tidal flats are strewn with boulders, so within this zone, multiple cracks parallel to the shoreline associated with the tide as well as radial cracking around boulders was evident. Pooling sea water was evident during high tides which corresponded to the spring tides. The mobilization of the drill rig from the sealift beach to the drill site was undertaken during low tides whilst the sea ice was grounded, avoiding ice stability problems near the fractures.

At Pond Inlet, it was known that a major storm event occurred at some time in the fall which broke up early ice in October and created a large area of ice pile-up near the harbour site. Whilst executing an initial ice survey in Pond Inlet it was discovered that the main target areas for proposed boreholes were obstructed by a large ice rubble field, running parallel to the beach. The zone of ice was approximately 50 m wide and over 1 km in length as shown in Figure 5. The combination of relatively shallow water and the variable keel depth suggested that ice was grounding out on the seabed with every tide cycle, causing continued fracture of the ice and ponding of water at low tide.

The ice reconnaissance team returned home to discuss the significance of the poor access with the design engineers and assess foundation concerns combined with site images to determine a course of action. A decision was made to conduct a second reconnaissance to assess what access could be achieved, albeit with the potential for reduced equipment weight limitations. Results of this second ice survey provided access routes which allowed borehole locations to be moved to within 50 metres offshore of the preferred locations compared to previous estimated locations some 250 metres offshore and in relatively deep water.

Figure 5. Rubblized ice in Pond Inlet

6 MOBILIZATION

The borehole drilling was conducted using a CME-55 drill rig weighing approximately 5,750 kgs. Drilling equipment and supplies were mobilized from Stewiacke, NS and flown into Iqaluit on a chartered flight operated by First Air.

The loading and unloading of the drilling equipment and supplies in Iqaluit was expedited by R.L Hanson. Upon arrival at Iqaluit, the drill crew constructed a timber framed and clad drill shack and water pump shack. The rig and shack were mounted on skids for dragging across the ice. The drill shack was large enough to fit the drill rig, tools, up to 4 personnel, mud tank and a small area for the geologist. A separate shack was required for the mud pump and other necessary items such as heaters, drill rods and casing were not able to fit inside the shack and were lifted to site separately. Figure 6 below shows the drill shack being constructed at the sealift beach which is located southeast of the airport and at the main access point to the ice.

Figure 6. Drill Rig Assembly at the sealift beach in Iqaluit

Once the drill shack was assembled, a loader towed the drill rig and water pump approximately 2 km to the proposed deep sea port area. Drill crews, geologists and local support were transported using a combination of skidoos and pick-up trucks.

6.1 Access Road and Pad Preparation

Prior to mobilizing the drill rig and associated equipment across the ice to the proposed deep sea port, the site access road was marked with wooden stakes and survey tape. Ice augers were advanced along the track to compare ice thicknesses with the GPR ice survey.

The access route which measured approximately 2 km in length was then cleared to 10 m width with a front end loader. The width of the access route was necessary in the event of a snow storm to provide sufficient width for vehicle access to / from the site and to enable monitoring of ice integrity along the surveyed route.

Pads were cleared at each borehole location to a minimum of 25m x 25m. Upon clearance of each pad location, each pad was inspected for potential cracks and / or other signs of weakness / potential hazards on a minimum twice daily basis.

Figure 7. Assembled shack being towed to deep sea port area

Figure 8. Road access and pad preparation

7 DRILLING METHODS AND SUBSURFACE CONDITIONS

The two proposed methods of drilling were water rotary and HQ Diamond drilling techniques. Both proposed drilling techniques require water as a drilling fluid. The skid mounted water pump, with mud tank and heater provided a continuous supply of drilling mud.

Snow was packed around the base of the drilling shack to reduce wind flow into the shack. Once setup, the driller augured an initial hole through the sea ice, dipped a measuring tape to the sea bed to record an initial water depth at the beginning of drilling. Due to a significant variation of the tide level during the drilling, the depth of in-situ tests including standard penetration test (SPT) and vane shear tests was determined by measuring water depth before each test from an augured ice hole adjacent to the borehole and compared against the initial depth measured at the beginning of the borehole through the sea ice.

Drilling operations were undertaken 24 hours per day for the duration of the drilling program. The ice conditions were frequently monitored at the drill locations and along the access routes from shoreline to the proposed drilling locations. The movement of sea ice was governed by tide as well as the sea floor, tidal cracking of sea ice was evident with low tide with the sea ice hinged where sea ice was grounded on the seafloor.

Due to the extreme temperatures it was essential that all equipment was heated. A total of three diesel heaters were used, two to heat the drill shack and one to heat the water pump. The author has previous experience in the higher Arctic of Eureka where the generator failed due to the extreme cold which meant the water lines froze, requiring drilling to stop while the lines were flushed of slush.

Inside the shack there was a driller, helper, geologist and wildlife monitor. Drilling was undertaken March 20 to March 30, 2017. Large tides were experienced during the investigation with the lowest recorded tide approximately 0.2 m Chart Datum (CD) and highest tide approximately 11.4 m CD. Six (6) boreholes were advanced from 5.2 to 11.2 metres below sea bed (mbsb) and seabed elevations ranged from approximately -1.7 to -19.5 m CD. The required length of drill pipe required ranged from approximately 19 to 41m below the sea ice in order to drill to the required depths to collect soil and rock samples.

Figure 9. Typical drilling setup at borehole locations

At completion of the drilling program, core boxes were transported to the accommodation, along with the soil samples stored in coolers. Soil samples were transferred from the drill shack to the pick-up truck to minimize the chance of samples freezing. Prior to demobilising from Iqaluit, all soil and rock samples were sent via air freight to a laboratory.

7.1 Subsurface Conditions

The geological subsurface materials encountered during the geotechnical investigation at Iqaluit generally agree with the soil and rock units described on the Surficial Geology Map of Iqaluit (Hodgson 2003). At the DSP, the conditions encountered typically consisted of intertidal sediments overlying marine / glaciomarine sediments, glacial sediments or directly onto bedrock.

- Intertidal Sediments (Unit 1) comprised of silty sand to sandy silt with varying amounts of clay and gravel; 0.8 to 4.3 m thick;
- Glaciomarine / Marine Sediments (Unit 2) comprised of clayey silt to silty clay with varying amounts of shells and shell fragments; 1.0 to 3.8 m thick;
- Glacial Sediments (Unit 3) comprised of Sandy Till to Till like material, predominantly silty sand to sandy silt with varying amounts of clay and gravel; 0.4 to 3.2 m thick; and
- Bedrock (Unit 4) comprised of Monzogranite; all boreholes terminated in this unit.

8 LESSONS LEARNED

Planning for and executing a geotechnical project in the Arctic will always present significant risks and challenges. For this project there were many variables out of the control of the contractor / consultant such as inclement weather, availability of local workers, contractors, equipment, accommodation as well as unforeseen conditions such as ice integrity and variable subsurface ground conditions.

For this project, key risks which were identified during project risk assessments were successfully mitigated by undertaking a site reconnaissance, hiring of a suitable drilling contractor, ice engineer, local workforce and earthworks contractors.

During the site reconnaissance, drilling plans were discussed and confirmed, local contractors and workers as well as local businesses such as accommodations and hardware supply stores engaged.

The selection of a competent drilling contractor and drill crew was key to the success of the project. The entire crew was experienced in Arctic drilling and included a qualified carpenter and mechanic whose skills were drawn upon several times, especially during the construction of the drill shack and in the event of mechanical breakdowns.

The crew was able to successfully mobilize equipment to Iqaluit and Pond Inlet, setup equipment and the shack in order to provide a safe working environment for the crew, whilst maintain 24 hr drilling operations. This was also the case with R.L Hanson and the CO-OP who provided the necessary personnel and heavy equipment in Pond Inlet and Iqaluit to clear access roads and drill pad locations as well as tow equipment in a safe and efficient manner.

Local labour proved to be instrumental, especially in Iqaluit whereby local knowledge of equipment, support vehicles as well as additional local labour kept the program running smoothly, as well as ensuring that key jobs and opportunities were kept locally including wildlife monitors, support vehicles, accommodation and food among others.

Key risks / challenges to the project which were unforeseen, included sea ice integrity in Pond Inlet, availability of earthworks contractor in Pond Inlet capable of ice preparation / snow clearing as well as loading / unloading the plane.

In addition, the level of effort required by the local earthworks contractors and quantities of equipment to build drill shacks was underestimated, organizing accommodation in both Iqaluit and Pond Inlet also proved to be challenging. Although frequent contact with the Co-op was made prior to mobilization, support equipment in Pond Inlet, as well as additional standby during mobilization of equipment from Iqaluit to Pond Inlet and demobilizing equipment from Pond Inlet proved to be more time consuming then planned.

Access to proposed drilling locations in Pond Inlet proved to be very challenging as ice integrity within the rubblized zone was significantly compromised and therefore the initial target location for boreholes had to be re-assessed. An additional ice survey was required in this area to look at alternative routes, identify no-go zones and finalize new drilling locations. Knowing the anticipated ice thickness (if available) for the project site is valuable and this information coupled with anticipated drill rig weights and drill site layouts provides the ice engineer with the preliminary information required before undertaking an ice survey.

The availability of personnel from the CO-OP did present a challenge in Pond Inlet (Pond Inlet is a very small community with limited support) and there was lost time associated with waiting for necessary personnel to support drilling operations. Thankfully certain members of the drill crew had heavy vehicle certificates and the CO-OP agreed for those personnel to operate equipment when members of the CO-OP where not available. The price and quantity of lumber as well as quantity of fuel was more than originally budgeted for.

Budgeting for adequate down time to account for delays due to inclement weather is very difficult in the Arctic. For this project a total of 7days was allocated. Due to delays associated with standby in mobilizing equipment and additional time taken to construct the drill shacks at both Pond Inlet and Iqaluit, as well as standby incurred due to complications with demobilizing equipment, a total of 21 standby days were incurred on the project.

The greatest budgetary challenge faced on the project was demobilizing the drill rig from Pond Inlet, the drill equipment had to be weighed but scales were not available in Pond Inlet, requiring scales and a crew to mobilize up to Pond Inlet.

9 RECOMMENDATIONS

A list of recommendations based on the lessons learned during this geotechnical investigation as well as experience gained from other relevant projects is provided below.

- The project manager and key field personnel should have relevant experience. The Arctic presents many challenges not faced in the south, having an understanding of what could go wrong is critical from a Health Safety and Environmental (HSE) and financial standpoint;

- Projects of this scale and complexity involve multiple disciplines. Ensure that each discipline is fully engaged and detailed scopes understood and integrated throughout each stage of the project to provide continuity and minimise potential conflicts;
- A risk workshop should be completed prior to finalizing work scopes with the aim to highlight the key risks / challenges and potential opportunities of the project;
- Engage key contractors (such as drilling, earthworks, ice engineer and airline) as early as possible to obtain clear and detailed work scopes and accurate quotations;
- A sufficient number of meetings between key contractors to discuss scope and schedule prior to issuing the proposal as well as prior to and during the investigation to minimize any potential misunderstanding / missed items which could have significant cost and or schedule implications;
- Prior to mobilizing to site, a sufficient HSE management plan and emergency response plan should be developed with input from key contractors, read by and signed by all field crew members to acknowledge that personnel understand the key hazards, control measures and emergency procedures;
- The financial risk should be shared between consultant and contractors in lump sum contracts;
- Adequate financial buffer added on to lump sum projects to aim to account for the unforeseen;
- For projects of a similar scale, complete a site reconnaissance with key project personnel as early as possible (at least 1 month prior to commencing fieldwork) in order to highlight any key changes in scope / potential hazards which can be discussed with the client and mitigated if necessary;
- The cost associated with local support, fuel, accommodation, consumables and other items sourced locally should be obtained prior to finalizing the proposal as these costs can vary from community to community.

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