DEW LINE CLEAN UP PROJECT
FOX-C (EKALUGAD FJORD)
DEW LINE SITE
2004 GEOTECHNICAL INVESTIGATION

Project No. 1100065.001

MARCH 2005

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Submitted To:

PUBLIC WORKS & GOVERNMENT SERVICES CANADA
EDMONTON, ALBERTA

Prepared by:

EBA ENGINEERING CONSULTANTS LTD.
EDMONTON, ALBERTA

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1.0 INTRODUCTION

1.1 General

EBA Engineering Consultants Ltd. (EBA) was retained by Public Works & Government Services Canada (PWGSC) on behalf of Indian and Northern Affairs Canada (INAC) to carry out a geotechnical investigation at the FOX-C (Ekalugad) DEW Line site (Figure 1). This site is located at 68° 42’ N, 68° 33’ W on the east coast of Baffin Island and on the south shore of Ekalugad Fjord, 195 km south of the community of Clyde River, Nunavut.

Details of EBA’s scope of work are provided in Section 1.2. The purpose of this investigation was to provide geotechnical and geophysical information pertaining to existing landfills and dumps, and proposed landfills, borrow sources, and access roads. This information will be used by others to develop design recommendations for the clean up of the FOX-C (Ekalugad) DEW Line site herein referred to as the FOX- C site.

Work that is being carried out by others in parallel to this geotechnical evaluation includes:

- An environmental sampling program and a hazardous and non-hazardous material waste audit by Earth Tech Inc.;
- A human health and ecological risk assessment for the site by Jacques Whitford; and
- The design of the comprehensive site remediation plan by UMA Engineering Ltd.

This report presents the data collected by EBA in 2004.

1.2 Scope of Work

EBA’s scope of work for the site visit was outlined as follows:

- Assess the condition of the access roads to the Upper Station Site, Beach Area, and the Lake Area Site, provide options for repairs and/or improvements.

- Identify, characterize and quantify gravel borrow sources for use as road repair material and landfill cover and/or construction material.

- Perform a geophysical survey (electromagnetic or ground penetrating radar) of known and suspected landfill locations to establish the areal limits of the landfills.

- Conduct a testpit program to confirm the geophysical survey defined boundaries established and presence of buried materials identified by the geophysical survey.

- Conduct a geotechnical assessment to determine suitable sites for new landfill construction at FOX-C.

- Complete a topographical survey of the site that identifies all key existing features, current and proposed landfill areas, testpit locations, and other sampling locations as identified by the other consultants on site.

EBA's scope of work does not include landfill design or remediation design; however, some preliminary concepts and recommendations are discussed in this report.

1.3 Site Visit

The geotechnical investigation was carried out between August 20 and September 1, 2004. EBA’s representative for the geophysical work was Mr. Brad Anshelm. Mr. Jason Berkers of EBA conducted the geotechnical investigation. Topographic surveys were carried out by Rick Wagar of UMA Engineering Ltd.

Geophysical surveys were carried out over areas known or suspected to contain buried debris. The geophysical survey involved using Geometrics G856 and G858 magnetometers to map the total magnetic field and vertical magnetic field gradients to delineate areas of ferrous debris. The Geometrics G858 cesium magnetometer has two vertically oriented sensors and a GPS positioning system and is used as the roving field unit. The Geometrics G856 proton precession magnetometer was used as a total magnetic field base station. Positioning for all surveys was accomplished using an integrated, real-time, sub-metre accuracy, differentially-corrected GPS system consisting of a base station unit with a UHF radio transmitter and a low magnetic signature roving unit with a UHF radio receiver. An overview of the operational theory behind these units and a description of the survey technique used at FOX-C are presented in Appendix A.

Shallow testpits were excavated at proposed new landfill locations and in potential granular borrow areas. A total of 48 testpits were excavated either by hand or using a John Deere 4600 tractor with a backhoe attachment. Soil samples were collected during the testpit program for laboratory index testing. The testpit logs are presented in Appendix B. Laboratory test results are presented in Appendix C.

The following sections provide observations of the local terrain, existing dumps and debris areas; collection of detailed geotechnical information at proposed new landfill locations and prospective borrow areas, and assessment of the condition of the existing access roads are provided in the following sections. Select photographs taken during the site visit are presented at the end of this report (see "Photographs" tab).

1.4 Previous Work

Since 1985, numerous environmental and risk assessments have been completed at the site, however, the existing landfills, locations of new engineered landfills and borrow sources have not been assessed. To EBA's knowledge, no geotechnical testpits or geotechnical testing soil samples have been undertaken prior to 2004.

2.0 SITE CONDITIONS

2.1 Site Description

The terrain at FOX-C consists of high rugged hills with exposed rock outcrops. Figure 1 shows the overall plan view of the layout of FOX C. Figures 2 through 13 provide larger scale plans of various areas of interest. The three primary areas of past activity at FOX-C include the Beach Area (Figure 13), the Lake Area (Figure 9), and the Upper Station (Figure 2). Beach Road, Lake Road and Station Road access the Beach Area, Lake Area and Upper Station, respectively. All three roads meet at the junction shown in Figure 1. The Beach Area is located on Qarmaralik Cove. Upper Station overlooks Ekalugad Fjord and is 770 m above sea level and about 3 flight kilometres southeast of the cove. The distance from the junction to Upper Station on the Station Road is about 5.9 kilometres and the distance from the junction and the Beach Area is about 2.2 km. Several road sections have become impassable since the site was abandoned in the 1960's.

The terrain and respective soil conditions at Fox-C are varied. Soil observed includes a clayey silt in the outwash valley located in the Beach Area, sand and gravel on parts of Lake Road, and boulders and weathered bedrock outcrop are dominant at the upper site.

The site is accessible by barge and by helicopter. An airstrip was never constructed at FOX-C due to the difficult terrain. The freshwater lake at the west end of Lake Road has been used as a landing strip in the winter.

2.2 Terrain

Baffin Island is part of the northeastern Canadian Shield and is underlain by granitic rock assemblages. The bedrock geology of this site is primarily granite and quartz monsonite. Permafrost is continuous and widespread in the Quaternary deposits which mantle Baffin Island.

Surficial geology units at higher site elevations, in the areas at referenced as Upper Station, Midstation and upper reaches of the Upper Station South comprise primarily bedrock and colluvium. At lower elevations surficial geology units include bedrock, moraines, alluvium, and beach sediments.

The Fox Charlie Glacier is situated some 1.5 km south of the upper site. One branch of the alpine glacier flows down to about 1 km south of the lower site. The whole icefield spreads from Ekalugad Fjord in the north to Kangok Fjord in the south.

2.3 Hydrology

Drainage systems associated with the fjords on the north coast of Baffin Island are generally short and steep.

High elevation development at FOX-C is located on a narrow summit and drainage divide.

Most of the development in the lower elevations is located between the ocean and a fresh water lake. The lake is mainly fed by melt water from the glacier, by snow melt, and by a larger lake situated approximately 2 km to the west. The lake itself is approximately 3 km long and 1 km wide and discharges into the ocean through a river approximately 1.5 km long.

2.4 Topography

The topography of Ekalugad Fjord is characterized by high rugged hills with numerous rock outcrops. The upper site is located on the summit of one of these hills which drops steeply on all its faces. The upper site is situated about 3 km from and 770 m above the beach area. The beach area is located on the south shore of the fjord in the lower reaches of an outwash valley.

3.0 OBSERVATIONS AND PRELIMINARY RECOMMENDATIONS OF EXISTING DUMPS

Five existing dumps were investigated during the 2004 site investigation program. Four dumps were reported in previous literature (Sinanni 2001) and are referenced as the Main Dump, the Garage Dump, the House Dump, and the Original Dump. The first three of these existing dump sites are located at the Upper Station. The Original Dump site is located at Upper Station South (approximately 750 m southeast of the Upper Station). The Midstation Dump was evaluated for the first time in 2004.

The five dumps and results of the respective geophysical surveys are described in Sections 3.1 through 3.5. Smaller debris areas assessed using geophysical survey are described in Section 4.0. EBA's investigation focused predominantly on areas of potential buried debris. A complete inventory of surface debris was completed by others.

3.1 Main Dump (Upper Station)

The Main Dump (Photos 1 and 2) is located 20 m northeast of a module train shown in Figures 2A and 2B. The dump contains barrels, domestic waste, miscellaneous metal and wood debris etc. scattered throughout the area. It appears that the material was disposed downslope from the edge of the summit. With the exception of two barrel cache locations, there is no specific dump area of concentrated debris.

Typically, the dump site terrain consists of bedrock controlled ridges, small plateaus and steep slopes throughout the area. Surface materials include boulders, rock outcrop and discontinuous areas of colluvial soils.

Drainage flows directly down the steep slope and eventually into the Ekalugad Fjord.

Results of the gradiometer survey at the Main Dump are presented on Figures 2B, 2C and 2D. Two distinct debris lobes were identified and named on the figures as Main Dump Lobes A and B. Both Lobe A and B are locations of surface debris barrel caches.

All other anomalies present on Figure 2B indicate areas of surface debris detected in the path of the geophysical survey. Not all of the surface debris present at the main dump is presented in the geophysical anomalies. Additional debris scattered throughout the area is shown in Figure 2A.

The collection of the debris at the Main Dump will be difficult due to the steep rocky terrain.

3.2 Garage Dump (Upper Station)

The Garage Dump is located south to southwest of the garage as shown in Figure 2A. The dump primarily contains barrels and miscellaneous metal and wooden debris, etc. that is scattered throughout the area. With the exception of one barrel cache, there is no specific area of concentrated debris. The debris is located on small pads and pathways between bedrock outcrops as shown in Photo 3 and 4.

Drainage from Garage Dump flows south approximately 1 km over relatively steep slope gradients to a glacier fed river. This river flows into the freshwater lake, which, in turn, discharges into the Ekalugad Fjord.

Results of the gradiometer survey at the Garage Dump are presented on Figures 2B, 2C and 2D. Two distinct debris lobes were identified and named on the figures as Garage Dump Lobes A and B. Both Lobe A and B are locations of surface debris. Lobe A contains heavy equipment tracks and other miscellaneous metal debris, while Lobe B is a barrel cache. All debris appears to be surface debris.

Not all of the surface debris present at the garage dump is presented in the geophysical survey figures. Additional surface debris is present throughout the area.

3.3 House Dump (Upper Station)

The House Dump (Photos 5 and 6) is located northeast of the remnants of the Inuit House shown in Figure 2A. The dump was hard to identify as it contains only a small amount of domestic waste, miscellaneous metal and wood debris and a couple of barrels that are scattered throughout the area. There is no specific dump area of concentrated debris.

The dump site terrain is comprised of a small pad area and bedrock outcrops. Drainage flows southwest down the steep slope and eventually into a glacier fed river approximately 1 km away. This river flows into the freshwater lake which, in turn, drains into the Ekalugad Fjord.

The results of the gradiometer survey are at the House Dump are presented on Figures 2B, 2C and 2D. One distinct debris lobe was identified and named House Dump Lobe A. Lobe A indicates an area of surface debris comprised of barrels. Lobe A along with all other surface debris in the area should be collected during clean up. No regrading will be required in the area.

The remnants of the Inuit House constitutes the majority of surface debris in the area which is located directly south of the House Dump.

3.4 Midstation Dump (Midstation)

The Midstation Dump (Photos 9 through 12) is located 350 m northeast of the Original Dump area along Station Road as shown in Figure 3A. Development at the site comprises a large laydown pad, an access road and Midstation Dump. The dump contains barrels, domestic waste, miscellaneous metal and wood debris, etc.

The local terrain comprises bedrock controlled ridges, small plateaus and steep slopes. A discontinuous veneer of soil exists with numerous boulders and rock outcrops. The laydown pad is in the saddle between two rock outcrops. The Midstation Dump is on a steep slope downgradient of the laydown pad. Drainage from the dump flows in the east direction into Ekalugad Fjord.

Drainage from the dump flows east down slopes that dip in the east direction and eventually into Ekalugad Fjord.

Results of the gradiometer survey at the Midstation Dump are presented on Figures 3A, 3C and 3D. Two distinct debris lobes were identified and named on the figures as Midstation Dump Lobes A and B, as shown. Lobe A contains surface debris consisting of barrel caches on the laydown pad area.

Lobe B is the location of the main dump area and contains barrels, domestic waste, miscellaneous metal and wood debris etc. There appears to be little soil mixed with the debris. Additional debris is scattered down the slope from Lobe B. The slope is very steep with numerous boulders and bedrock outcrops.

The geophysics survey indicates an anomaly in the south portion of Lobe B. This anomaly could be a result of surface debris; however, some buried debris may be present in the southern portion of Lobe B.

Consolidating and covering Lobe B in its present condition would be very difficult due to the steep slopes of the area. Construction safety would be a concern. It is recommended the debris be removed and placed in an engineered landfill. Collection of the debris will be difficult due to the steep rocky terrain.

Additional surface debris is present in the area between the pad area of Lobe A and Lobe B which was not surveyed with geophysics. This material should also be collected during clean up. Collection of the debris from this area is expected to be difficult due to the rocky terrain.

3.5 Original Dump (Upper Station South)

The Original Dump (Photos 7 and 8) is located along the Station Road as shown in Figure 4A. There is no specific area of concentrated debris. The dump contains barrels, domestic waste, miscellaneous metal and wood debris etc. that is scattered throughout the area.

Typically, the natural terrain is comprised of bedrock controlled ridges, small plateaus and steep slopes. Surface material comprised a discontinuous veneer of soils with widespread rock outcrop and boulders.

Drainage flows south down the slope into the glacier fed river to the freshwater lake which, in turn, discharges into a river that drains into the Ekalugad Fjord.

The results of the gradiometer survey at the Original Dump are presented on Figures 4A, 4B and 4C. One distinct debris lobe was identified and named on the figures as Original Dump Lobe A. Lobe A is a location of a barrel cache. Lobe A should be collected during clean up. No regrading will be required in the area.

Lobe A only presents a small fraction of the total amount of surface debris in the area. There is a large amount of scattered surface debris, and remnants of two Quonset huts and one storage shed in the area. All additional surface debris should also be collected during clean up. It is expected that collection of the debris at the Original Dump will be difficult due to the steep rocky terrain in which the material is scattered.

4.0 EXISTING DEBRIS AREAS

Debris areas investigated that are located separate from the dump areas were as follows:

- West Laydown Debris Area (Upper Station);
- Southwest Laydown Debris Area (Upper Station);
- Garage Debris Area (Upper Station);
- Main Tower Debris Area (Upper Station);
- East Laydown Debris Area (Upper Station);
- West Midstation Debris Area;
- East Midstation Debris Area;
- River Crossing Debris Area;
- Lake Debris Area;
- Borrow Debris Area; and
- Beach POL Debris Area.

The above noted debris areas were geophysically surveyed with the gradiometer. These areas are only a portion of the total surface debris on site. A complete inventory of surface debris on site was completed by others.

4.1 West Laydown Debris Area

The West Laydown Debris Area is located at the Upper Station site and includes two lobes (West Laydown Debris Area Lobe A and B) located west of the Garage as shown in Figure 2A and Photo 13. Geophysical survey results are presented in Figures 2B, 2C and 2D. Lobe A is an area of buried debris. The ground surface is relatively flat, and level within the remainder of the laydown area. There is little surface debris in the area. It is recommended that Lobe A be regraded with additional fill 0.7 m thick, provided that environmental assessments by others indicate there are no environmental concerns in the area. The recommended area of regraded fill is shown on Figure 2.

Lobe B is located on the east portion of the laydown area and consists of an area of surface debris consisting of construction debris and a truck.

4.2 Southwest Laydown Debris Area

The Southwest Debris Area is located at Upper Station and approximately 90 m southwest of the garage as shown in Figure 2A. The area was geophysically surveyed and the results are presented in Figure 2B, 2C and 2D. The debris area includes a single lobe of surface debris that consists of miscellaneous metal debris.

4.3 Garage Debris Area

The Garage Debris Area is located at the Upper Station and on the north and west side of the garage as shown in Figure 2A. The area was geophysically surveyed in 2004 and the results are presented in Figures 2B, 2C, and 2D. The debris area includes three lobes, Lobe A, B and C. Lobe A is located on the west side of the garage, while Lobe B is located east of the garage. Lobe A consists of a Bombadier vehicle and Lobe B consists of a bulldozer. This surface debris should be collected and hauled to a designated landfill. Lobe C is partially buried debris in the sideslope of the pad area southwest of the garage. A pallet of four barrels had been strapped together and used as fill during the construction of the pad area. Since these barrels will eventually fail, regrading the area is not recommended. This debris should be excavated during clean up.

4.4 Main Tower Debris Area

The Main Tower Debris Area is located at the Upper Station, approximately 70 m southeast of the module train as shown in Figure 2A. The area was geophysically surveyed in 2004. The debris area includes surface debris that consists of a large communication tower and miscellaneous metal debris.

4.5 East Laydown Debris Area

The East Laydown Debris Area (Figure 2A and Photo 14) is located at the Upper Station east of the Inuit House. The area is comprised of several pads and access roads. The area was geophysically surveyed as shown in Figures 2B, 2C and 2D. The debris area includes two lobes, East Laydown Debris Area Lobes A and B. Lobe A is a surface debris barrel cache, while Lobe B is primarily buried debris.

Lobe B is located on the north side of a pad area. The ground surface of the area is relatively flat and level with the pad. There are no visible signs of surface debris. It is recommended that Lobe B be regraded with fill 0.7 m thick, provided that environmental assessments by others indicate there are no environmental concerns in the area. A recommended area to be regraded is shown on Figure 2A.

4.6 West Midstation Debris Area

The West Midstation Debris Area is located on the north side of Station Road approximately 180 m southwest of the Midstation Dump area as shown in Figure 3A. The area consists of a laydown pad. The area was geophysically surveyed, as shown in Figures 3B, 3C and 3D. The debris area includes two lobes, West Midstation Debris Area Lobes A and B. Lobe A is located on the west side of the debris area. Lobe B is located on the east side of the debris area. Both Lobe A and Lobe B consist of barrel caches. All debris appears to be surface debris.

4.7 East Midstation Debris Area

The East Midstation Debris Area is located off the south side of Station Road approximately 70 m southwest of the Midstation Dump area as shown in Figure 3A. The area consists of a helipad location and pad area. The area was geophysically surveyed and the results are presented in Figures 3B, 3C and 3D. The debris area consists of a barrel cache. Several anomalies also are shown on the geophysical results. These anomalies are the result of individual surface barrels in the area.

Not all of the surface debris present in the area is presented in the geophysical survey figures. Additional surface debris is present throughout the area.

4.8 River Crossing Debris Area

The River Crossing Debris Area is located on Station Road approximately 500 m west of Borrow Area 1 as shown in Figure 6A. The area was geophysically surveyed and the results presented in Figures 6A, 6B, 6D. The debris is in four lobes, Lobe A through Lobe D. All four lobes consist of surface debris consisting of crushed barrels and miscellaneous metal debris.

4.9 Borrow Debris Area

The Borrow Debris Area (Figure 8A) is located on a ridge in a glacier river outwash. The area was geophysically surveyed and the results are presented in Figures 8A, 8B and 8C. The disturbed area was surveyed to determine if it contained buried debris. No anomalies or indication of buried debris were found in the area.

4.10 Lake Debris Area

The Lake Debris Area is located approximately 150 m east of the Lake as shown in Figure 9A. The area is a natural terrace and was used as a laydown area. The area was geophysically surveyed and the results are presented in Figures 9A, 9B, 9C. The debris is in four lobes, Lobe A through Lobe D. Lobe A and Lobe B are located on the north portion while Lobe C and Lobe D are located on the south. Lobe A consists of buried debris while the remaining three lobes consist of surface debris made up of construction equipment and miscellaneous metal debris. This surface debris should be collected during clean up.

The ground surface at Lobe A is relatively flat and is level with the surrounding area. There are no visible signs of surface debris in the immediate area. Provided that environmental assessments by others indicate there are no environmental concerns in the area, it is recommended that Lobe A be regraded with fill 0.7 m thick. The recommended area to be regraded is shown on Figure 9A.

4.11 Beach POL Debris Area

The Beach Debris Area (Figure 13A and Photos 15) is located at the POL tanks on the beach site of Ekalugad Fjord. The area was geophysically surveyed and includes two Lobes; Lobe A and Lobe B. Lobe A consists of buried debris while Lobe B consists of an area of miscellaneous surface metal debris.

Lobe A is located in the west sideslope of the POL pad. It is recommended that Lobe A be regraded with fill 0.7 m thick, provided that environmental assessments by others indicate there are no environmental concerns in the area. A regrade perimeter is shown in Figure 13A.

5.0 PROPOSED NEW LANDFILL LOCATIONS

At least one new landfill will be required for disposal of demolition debris, surface debris and excavated debris. A second landfill may be required to minimize haul distances. A soil disposal facility for contaminated soil or a landfarm for treatment of hydrocarbon contaminated soil may also be required at the site. Potential locations for these facilities were examined.

The location of these facilities is based on a variety of factors, including:

- size of the area available;
- acceptable soil and foundation conditions;
- surface drainage;
- topography;

- distance from natural water bodies or water courses; and
- ground conditions that could allow permafrost to function as a containment system.

The volume of contaminated soil and debris that have to be landfilled will dictate the size of the facilities and to a certain degree influence the areas chosen for construction of these new facilities. The volumes were unknown at the time of the report.

Four potential debris landfill locations, one soil disposal facility location were evaluated in 2004. Some of the areas are also suitable for landfarm locations as noted. The proposed locations are shown on Figures 1, 3, 9 and 11. Design considerations and parameters for the new landfills along with the proposed landfill locations are described in the following sections.

5.1 Debris Landfills

5.1.1 Design Considerations

Design considerations for Debris Landfills include the following.

Waste characterization - The waste material placed in new debris landfills should consist only of non-hazardous debris which includes treated and untreated wood, metal wastes from demolition and equipment disposal, empty crushed barrels, and concrete. Asbestos, when packaged according to regulations, is also considered non-hazardous.

Surface water run-on and run-off control - The final landfill surface must be graded to positively shed water so as to prevent ponding and infiltration. The landfill surface must not be so steep that it promotes erosion of the cover materials.

Leachate Control – It is understood that the proposed landfill material is inert waste; therefore, leachate needs to be controlled rather than eliminated completely. The following design factors will control the amount of leachate within the landfills:

- Only "Dry Waste" will be placed in the landfills;
- The short arctic summer limits the amount of time that water infiltration can occur;
- The compacted and graded cap material will promote surface run-off; and

- The proposed landfill sites have been located where natural overland runoff is minimal.

Frost Jacking - Frost jacking of debris occurs when; (1) fills contain debris subjected to seasonal freezing and thawing; (2) the mineral soils used for fill are frost susceptible (fine grained; and (3) there is access to free water. In order to prevent frost jacking, the landfill backfill material should be frost stable, and both groundwater and surface water must be controlled. Backfill material specifications that address these considerations are presented in Section 6.0.

Biological Odour and Methane Gas Control - Odour and gas generation are typical of most domestic landfills in the south and are the result of decomposition due to biological activity, fungi and bacteria. These are not considered to be significant factors in the design of demolition debris landfills at FOX-C for two reasons; firstly (1) the proportion of domestic waste to be landfilled will be insignificant in relation to the total volume of debris; and (2) the temperature of the waste and surrounding permafrost will limit decomposition and therefore the rate at which gas is generated.

Settlement of Landfill Surface - To reduce settlement and ground subsidence, the debris should be placed in 0.5 m thick lifts with a prescribed earth fill graded over each lift of debris to fill the voids. The earth fill should be a minimum of 0.15 m thick and worked into the underlying debris. Quality assurance testing should be carried out to determine the optimum debris lift thickness and to confirm that there are no large voids in the landfill.

5.1.2 Debris Landfill Design Parameters

The cover and berms may be constructed with appropriate granular borrow materials available at FOX-C. The intermediate fill should be a frost stable material. Recommended material specifications for the berm and cover and intermediate fill materials are presented in Section 6.0.

The landfills are generally constructed on grade to reduce constructability issues, and permafrost disturbance. The landfills should be constructed by first building containment berms around the perimeter of the landfill area. It is recommended that the containment berms have a maximum outside slope of 3H:1V and an inside slope of 1.5H:1V. The top of the berm should have a minimum width of 2.0 m. The available borrow materials at FOX-C for berm construction are erodible. It is therefore recommended that the surface of the berms be covered with a 0.5 m thick layer of gravel and cobbles.

To reduce settlement and ground subsidence, the debris should be placed in 0.5 m thick lifts with a prescribed non frost susceptible intermediate fill (see Section 6.0) graded over each lift of debris to fill the voids. The intermediate fill should be a minimum of 0.15 m thick and worked into the underlying debris. The maximum debris thickness (sum of all debris lifts) in the landfill should not exceed 3.0 m.

The landfill should be capped with a layer of fill compacted to 95% of the maximum density determined in the laboratory using standard effort (ASTM D698). The surface of the landfill should be graded to a slope between 2% and 4%. The landfill should be contoured to blend in with the surrounding terrain.

Most of the available fills for landfill covers are relatively pervious, however, using the available materials, landfill freezeback can be achieved using a thermally designed thickness of landfill cover. A freezeback design would significantly reduce the risk of moisture migration into and out of the landfill. Typically a landfill cap 1.0 m to 2.0 m thick is required. EBA can carry out the analysis for a freezeback cover design upon request.

Environmental assessment of the debris materials is being carried out by others. Provided the environmental risk of leachate products escaping the landfill is deemed acceptable, a cover thickness less than that required for complete freezeback can be used.

5.1.3 Potential New Debris Landfill Locations

During the 2004 investigation, four sites (Figure 1) were investigated as potential debris landfill sites. Debris Landfill Location 1 is located at the Midstation Dump. Locations 2 and 3 are located off Lake Road. Location 4 is located off of the Beach Road. The following sections describe each location in detail.

A fifth location for a landfill that may be contemplated is at Borrow Area 1, described in Section 6.2.1. A landfill at Borrow Area 1 would reduce the need to haul fills upslope to Midstation.

Potential Debris Landfill Location 1

A new landfill could be constructed on the existing pad area of the Midstation Dump and adjacent area, if required. The area is a relatively large and flat area which is accessed directly from the upper station road as shown on Figure 3 and Photo 9. The surface area of the existing pad is approximately 1800 m^2. The landfill could also be extended to the north if a larger area is required. The landfill could be constructed up against the mountain slope on the east side to blend into the natural topography of the area and reduce granular fill quantities. The landfill could also be extended to the west, but access to the Midstation Dump will have to be maintained until it is cleaned up.

The existing pad drains north, eventually into the Ekalugad Fjord.

The proposed area contains surface debris and some stained soil. The debris would have to be removed prior to landfill construction. The stained soil may impact landfill monitoring results. A thorough baseline sampling program is recommended.

Surface materials were dominantly boulders and bedrock outcrop, therefore, no testpits were excavated. Borrow sources for landfill are discussed in Section 6.0. The nearest borrow source (Borrow Area 1) is located downgradient of the site at a distance of approximately 2 km.

Potential Debris Landfill Location 2

Potential Debris Landfill Location 2 (Figure 9 and Photo 16) is situated in a terraced area north of the Lake Road roughly half way between Lake, Beach and Station Road Junction and the freshwater lake. There is presently a barrel cache located on the west portion of the site. The area has minor relief, from the northeast to the southwest side. The area is undisturbed and is accessed from the Lake road. The east landfill berm could be constructed into a natural slope and be blended into the natural topography of the area thus reducing granular fill quantities.

Three testpits (TP-32 to TP-34) were excavated in the proposed landfill area in 2004. All three testpits were terminated on frozen ground at a depth between 1.2 and 1.3 m. A damp to wet, fine to medium grained sand with trace to some silt and occasional cobbles was encountered in all the testpits. Moisture contents were 18.7% and 9.9%. The sand is overlain by 100 mm of organics. Several boulders were present at ground surface in the area. A small amount of ponded water was present on the ground surface in the vicinity of TP-32 during the investigation. Testpit logs are present in Appendix B and laboratory results are presented in Appendix C.

The proposed landfill site drains south toward the mouth of the glacier river into the freshwater lake. The freshwater lake discharges into Ekalugad Fjord.

Potential Demolition Debris Landfill Location 2 is a suitable location for debris landfill and/or soil disposal facility. Fill quantities can be reduced by taking advantage of the natural topography of the area.

Proposed Debris Landfill Location 3

Proposed Debris Landfill Location 3 (Figure 9 and Photo 17) is situated in a terraced area north of Lake road approximately 200 m east of the freshwater lake. The area is undisturbed and is accessed from Lake Road. The east landfill berm could be constructed into a natural slope, thus reducing the granular fill quantities.

Four testpits (TP-28 to TP-31) were excavated in the proposed landfill site in 2004. All four testpits met refusal on frozen ground at a depth between 1.2 and 1.4 m. The east portion of the area (TP-30 and TP-31) is comprised of fine to medium grained sand with some silt. This material is also present in the west portion of the site (TP-28 and TP-29) to a depth of 0.2 and 1.1 m, respectively. At Testpits TP-28 and TP-29 the underlying soils were sand and gravel with trace silt. The entire area is overlain by 100 to 200 mm of organics. Moisture contents for the fine to medium grained sand for the area were 3.1%, 10.3% and 10.2%. Testpit logs are present in Appendix B and laboratory results are presented in Appendix C.

The potential landfill site drains towards the freshwater lake approximately 200 m west, which then discharges to Ekalugad Fjord.

Proposed Demolition Debris Landfill Location 4

Proposed Debris Landfill Location 4 (Figure 11 and Photos 18 and 19) is a large relatively flat area on the west side of the Beach Road adjacent to Borrow Area 3. This area is also feasible as a Soil Disposal Facility or Landfarm. It is an undisturbed area that slopes towards the southwest. The area drains approximately 250 m southwest into a river which flows into Ekalugad Fjord.

Four testpits were excavated at the proposed site (TP-07 and TP-19 through TP-21). All testpits terminated in frozen ground with depths ranging between 1.0 and 1.2 m. The surficial soils ranged from fine to medium grained sand with some silt to sand and silt. The silty sand present in TP-20 is underlain by a layer of coarse-grained sand at 0.8 m to an undetermined depth. Moisture contents were 17.4%, 10.5%, 11.8% and 23.9%. Seepage was observed in all four testpits, with depth of seepage between 0.8 and 1.1 m. Testpit logs are presented in Appendix B and laboratory results are presented in Appendix C.

5.2 Soil Disposal Facility

5.2.1 Design Considerations

It is understood that there are soils on site that are contaminated with PCB's and heavy metals. Hazardous contaminated soil must be shipped off site. Non-hazardous contaminated soils can be landfilled on site using a lined containment system. The lined system should encapsulate the non hazardous contaminated soil and be covered with material so that it freezes back and remains in a frozen condition.

A leachate collection and monitoring system is not generally incorporated into high arctic landfills, as they do not function well in a permafrost environment. A combination of freezeback of the landfilled material and a geomembrane cover and base liner will result in little to no moisture migration into or out of the landfill.

Thermal analyses have not been carried out for the proposed developments. If a soil disposal facility is required at FOX-C it is recommended that a climate analysis and thermal analysis be carried out to determine the design parameters.

5.2.2 Potential Soil Disposal Facility Location 1

Soil Disposal Facility Location 1 was investigated for the specific purpose of a soil disposal facility. Other sites deemed suitable for a soil disposal facility include Landfill 2 and 4 (Section 5.1.3) provided these sites are not needed for landfill purposes.

Soil Disposal Facility Location 1 (Figure 11 and Photos 20) is a relatively flat area on the east side of Beach Road approximately 950 m south of the main beach area. The identified area is approximately 19,500 m^2. The area is undisturbed and slopes towards the northeast. The site drains to a creek which is 115 m away. The creek flows for approximately 850 m to the northwest and drains into Ekalugad Fjord. The west berm for Soil Disposal Facility Location 1 could be constructed into a natural slope, thereby reducing the granular fill quantities.

Four testpits were excavated in the area (TP-04, TP-12, TP-13 and TP-14). All testpits terminated in frozen ground at depths between 0.85 and 1.10 m. The surficial soils were predominantly clayey silt. Moisture contents were 19.8%, 24.3%, 22.7%, and 16.4%. Ice was present in the frozen soil in the base of TP-14 and stratified ice and soil (V_s = 20 to 40%) was present in two of the other testpits. Testpit logs and laboratory results are found in Appendix B and C, respectively.

Soil Disposal Facility Location 1 is considered an acceptable location disposal of non-hazardous contaminated soils; however, constructability issues may arise from the high natural moisture content of the material and the presence of ice rich permafrost. Excavation of active layer should be minimized to reduce the risk of thaw settlement of the underlying ice rich permafrost.

6.0 GRANULAR BORROW MATERIAL

An assortment of granular fill types are required for the construction of new landfills/soil disposal sites, remediation of existing debris areas, backfill of excavation areas and access road reconstruction. Characteristic particle distributions have been prescribed for six granular fill types for the following applications:

- Type 1 Granular Fill – coarse gravel, cobbles and boulders for erosion protection;
- Type 2 Granular Fill – gravel and sand for landfill cover;
- Type 3 Granular Fill – general fill for excavation backfill;
- Type 4 Granular Fill – silt and sand for landfill berms;
- Type 5 Granular Fill – sand for geomembrane bedding; and
- Type 6 Granular Fill – sand and gravel for intermediate landfill debris cover.

Section 6.1 describes the applications of these materials and characteristics of the above materials in more detail. Section 6.2 describes prospective borrow materials at FOX-C.

6.1 Granular Material Specifications

Type 1 Granular Fill is generally a well-graded gravel and cobbles with a trace of sand. It is typically used for erosion protection of landfills and as riprap for small drainage courses. The gradation requirements for Type 1 Granular Fill may vary significantly depending on the specific application. The gradation requirements should be evaluated once the specific application of Type 1 Granular Fill is known.

Type 2 Granular Fill is typically gravel and sand and is generally used for construction of landfill berms and covers and regrading requirements. Type 2 Granular Fill should have a particle size distribution within the limits presented on Table 1.

TABLE 1
TYPE 2 GRANULAR FILL
PARTICLE SIZE DISTRIBUTION LIMITS

Particle Size (mm)	% Passing
200	100
50	60 to 90
5	30 to 75
0.425	10 to 30
0.08	5 to 20

Type 3 Granular Fill is any sand and gravel material with a maximum particle size not exceeding 200 mm that is obtained from excavations or other approved sources. Type 3 is generally used for regrading, backfill of contaminated soil excavations and general site grading requirements. Type 2 Granular Fill is acceptable for Type 3 Granular Fill.

Type 4 Granular Fill is a non-saline, silt and sand material used for construction of containment berms and backfill of the key trench excavations for the Soil Disposal Facility. The water content of the Type 4 Granular Fill must be adjusted to achieve a minimum degree of saturation of 90%. It may be necessary to air-dry the material so that it can be placed and compacted according to the specifications. Type 4 Granular fill should have a particle size distribution within the limits presented on Table 2.

TABLE 2
TYPE 4 GRANULAR FILL
PARTICLE SIZE DISTRIBUTION LIMITS

Particle Size (mm)	% Passing
100	100
50	80 to 100
12.5	55 to 95
5	45 to 90
2	35 to 80
0.425	25 to 70
0.08	20 to 40

Type 5 Granular Fill is used as an embedment material for geosynthetic liners and should be comprised of rounded particles and free from angular particles, stones larger than 25 mm in diameter, waste or other deleterious materials. Type 5 Granular Fill should have a particle size distribution within the limits presented on Table 3.

TABLE 3
TYPE 5 GRANULAR FILL
PARTICLE SIZE DISTRIBUTION LIMITS

Particle Size (mm)	% Passing
25	100
12.5	75 to 100
5	50 to 100
2	30 to 60
0.425	10 to 40
0.08	0 to 8

Type 6 Granular Fill is generally used as an intermediate cover within landfills and is obtained from excavations or other sources generally consisting of gravel or sand in an unfrozen state and free of deleterious material. The maximum particle size of the material should be less than 150 mm with less than 8% of the material, by weight,

passing the 0.08 mm sieve. Some Type 2 and Type 3 Granular Fills, depending on the specific particle size distribution of the material, may be acceptable as Type 6 Granular Fill.

6.2 Granular Borrow Areas

Three existing borrow areas (Areas 1, 2, 3,) and four new Borrow Areas (Areas 4, 5, 6, and 7) were identified at the FOX-C site during the 2004 site investigation. The locations are shown in Figure 1. For new landfill and/or borrow pits, a 50 m setback between landfills and borrow areas is required.

Individual borrow areas are discussed in Section 6.2 and summarized in Section 6.3.

A John Deer 4600 tractor with a backhoe attachment was used to excavate testpits along Lake Road between Borrow Area 2 and Borrow Area 6. Due to impassable road conditions on Beach Road and Station Road, testpits were hand excavated. Soil samples were collected for laboratory index testing. Testpit logs are presented in Appendix B and laboratory test results are presented in Appendix C.

6.2.1 Proposed Borrow Area 1

Borrow Area 1 (Figures 1 and 5 and Photos 21 and 22) is located on the south side of Station Road approximately 1 flight km south of Midstation. The borrow area is predominantly sand and gravel with some silt and varying amounts of cobbles and boulders. A portion of the area has been depleted during previous borrow activities. The remaining undisturbed area has surface layer of boulders and cobbles.

A total of four shallow testpits were hand excavated in the area (TP-41 through TP-44). Testpit depths were between 0.3 and 0.6 m with two of the testpits meeting refusal on cobbles. Moisture contents were 7.7%, 7.6% and 9.3%. Testpit logs are presented in Appendix B, and laboratory results are presented in Appendix C. Particle size analysis size indicated the sample tested consisted of 36% gravel, 47% sand and 17% silt/clay. The sample contained 50 mm maximum particle sizes; however, particles up to 1.2 m are present in the borrow area. Refer to the testpit logs and photos for additional information.

With some sorting to remove boulders and oversize cobbles, the granular materials in Borrow Area 1 are considered suitable for Type 2 and Type 3 Granular Fill. Type 1 granular fill may be present in certain portions of the borrow area but no specific areas were identified during the investigation. The total identified area shown on Figure 5 is approximately 49,000 m^2. The disturbed area is approximately 26,000 m^2. An estimated volume of 49,000 m^3 would be available, assuming an average excavation thickness of 1.0 m. Additional material may be available at greater depth, but the material may be frozen and extraction would require a thaw and strip operation.

At the time of the 2004 investigation, ponded water was present in the disturbed portion of the borrow area. Control of surface drainage will be required during development as the borrow material will become difficult to work with if it becomes wet.

6.2.2 Proposed Borrow Area 2

Borrow Area 2 (Figures 1 and 10 and Photo 23) is located at the (Lake Road, Beach Road Station Road) Junction and contains a range of materials suitable for Type 1, Type 2, Type 3, Type 5, and Type 6 applications. Blending with fines from other sources would bed required to meet the Type 2 gradation. A stockpile of sand and gravel and a partially developed area has exposed fine to medium grained sand. It appears that the stockpile was area derived from the respective borrow site.

A total of four shallow testpits were excavated in the area with one on the top of the stockpile (TP-40) and three around the perimeter (TP-37 through TP-39). Testpit depths were between 1.15 and 1.8 m with all testpits meeting refusal on frozen ground. Testpit logs are presented in Appendix B. A sample of the material consisted of 36% gravel, 64% sand, and 0% silt/clay. Laboratory results are presented in Appendix C. The sample contained 25 mm maximum particle sizes; however, particles up to 200 mm are present in the borrow area. Refer to the testpit logs and photos for additional information.

The stockpile contains approximately 20,000 m^3 of material. The material at depth is frozen; therefore, extraction of the entire pile will require a thaw and strip operation.

A disturbed area located north of the stockpile exposes fine to medium grained sand suitable as Type 5 Granular Fill. The identified Type 5 area is approximately 7,300 m^2. An estimated volume of 7,300 m^3 may be available, assuming an excavation thickness of 1.0 m. Additional material would be available at greater depth, but the material may be frozen and extraction would require a thaw and strip operation.

6.2.3 Proposed Borrow Area 3

Borrow Area 3 (Figures 1 and 11) is an old borrow area located at the east side of Beach Road directly north of Potential Debris Landfill Location 4. The soils in the area are sands with trace of gravel to gravelly and trace silt to silty. Varying amounts of cobbles and boulders are present in both materials. A total of six testpits were excavated in the area (TP-05, TP-06, TP-15, TP-16, TP-17 and TP-18). One sample of material from the borrow area contained 6% gravel, 71% sand, and 23% silt/clay (Type 4), while another contained 25% gravel, 74% sand and 1% silt/clay (Type 5). Testpit logs are presented in Appendix B, and particle size distribution curves are presented in Appendix C.

Borrow Area 3 materials are considered suitable for Type 5 and/or Type 6 Granular Fill if carefully sorted. The identified area is approximately 13,000 m^2 in size. Assuming an average excavation thickness of 1.5 m, an estimated volume of 19,500 m^3 would be available. Additional material may be available at greater depth, but the material may be frozen and extraction would require a thaw and strip operation.

6.2.4 Proposed Borrow Area 4

Borrow Area 4 (Figure 12 and Photo 24) is located on the west side of Beach Road and approximately 600 m southwest of the Beach Area (Figure 1). Most of the proposed area is undisturbed; however, a barrel cache is present along the north perimeter.

Four testpits were excavated in the area (TP-02, TP-09, TP-10 and TP-11). All testpits were terminated in frozen ground at depths ranging between 0.7 and 1.2 m. The surficial soils are varied but include discontinuous clayey silts (Clay and Silt) and at depth included ICE+Soil (TP-11). Moisture contents select were determined to be 20.7%, 11.8%, 25.9%, 33.7% and 12.0%. No Moistures were carried out on the ICE+Soil. Testpit logs are presented in Appendix B and laboratory results are presented in Appendix C.

The material in Borrow 4 is finer grained than the Type 4 specification in Section 6.1. The material would be acceptable for Type 4 Granular Fill if the moisture content at the time of construction is adequate to produce a workable material. Drying and blending with a granular material may be required. Selective excavation with some sorting to remove boulders and cobbles greater than 100 mm diameter would also be required to make the material suitable for Type 4 Granular Fill. The identified area shown on Figure 12 is approximately 25,000 m^2. Assuming an average excavation thickness of 0.5 m, and a selective sourcing, an estimated volume of 8,000 m^3 of Type 4 Granular Fill would be available. Additional material may be available at greater depth or the area could be expanded to the south.

The feasibility of developing this borrow source will be influenced by the weather, management of the pit drainage and moisture content of the material. If the material becomes wet, rubber tired equipment may have difficulty accessing the borrow area. Tracked vehicles may be required. It may also be necessary to air dry the material or blend wet material with suitable dry material.

6.2.5 Proposed Borrow Area 5 (Proposed Debris Landfill Location)

Borrow Area 5 (Figure 9A and Photo 17) is a large relatively flat undisturbed area off Lake Road approximately 200 m east of the freshwater lake, as shown on Figure 9A and Photos 17. Potential Debris Landfill Location 3 is located within the area.

Four testpits (TP-28 to TP-31) were excavated to refusal on frozen material of 1.2 to 1.4 m depth. The entire area is overlain by 100 to 200 mm of organics. The east portion of the area (TP-30 and TP-31) is comprised of fine to medium grained sand with some silt. This material is also present in the west portion of the site, TP-28 and TP-29, to a depth of 0.2 and 1.1 m, respectively and is then underlain by sand and gravel with trace silt to the maximum depth of excavation. Moisture contents for the fine to medium grained sand found in the area were 3.1%, 10.3% and 10.2%. Testpit logs are present in Appendix B and laboratory results are presented in Appendix C.

The sand and gravel present in TP-28 and TP-29 is suitable for Type 2 and Type 3 Granular Fill; however, there appears to be limited quantities. The sand is suitable for Type 5 Granular Fill. The identified area shown on Figure 9 is approximately 10,500 m^2 in size. An estimated volume of 10,500 m^3 would be available, assuming an average excavation thickness of 1.0 m. Additional material may be available at greater depth, but the material may be frozen and extraction would require a thaw and strip operation.

6.2.6 Proposed Borrow Area 6

Borrow Area 6 (Figures 1 and 8) is a large relatively flat undisturbed area off Lake Road approximately 130 m east of the freshwater lake, as shown in Figures 1 and 8.

Six testpits (TP-22 through TP-27) were excavated to refusal at depths of 1.4 to 1.8 m. Typically, the area is comprised of 0 to 200 mm of fine to medium grained sand with some silt underlain by sand and gravel with trace silt to the maximum depth of excavation. TP-24 consisted of fine to medium grained sand with some silt to an undetermined depth. Particle size distribution analyses for two samples had gravel contents of 42% and 19%, sand contents of 55% and 78%, and silt/clay contents of 3% and 3%, respectively. Testpit logs are present in Appendix B and laboratory results are presented in Appendix C. The sample contained 25 mm maximum particle sizes; however, particles up to 250 mm are present in the borrow area.

The granular materials in Borrow Area 6 are considered suitable for Type 2, Type 3 and Type 6 Granular Fill. Blending with fines from other sources would be required to meet the Type 2 requirements. Type 1 and 5 Granular Fill may be available if the material was screened. Should any material be used as Type 2 or 3 Granular Fill, the use of a Type 1 Granular Fill cover may be required. The identified area shown on Figure 8 is approximately 20,000 m^2. Assuming an average excavation thickness of 1.0 m, an estimated volume of 20,000 m^3 would be available. Additional material may be available at greater depth, but the material may be frozen and extraction would require a thaw and strip operation. Additional material may also be available to the north as the topography is similar to that of Borrow Area 6; however, field confirmation is required.

6.2.7 Proposed Borrow Area 7

Borrow Area 7 (Figure 6 and Photos 25 through 28) is a large relatively flat, terraced area off Station Road approximately 350 m east of the junction of the access roads. The area is on the south side of the glacier fed river and is predominantly undisturbed.

No testpits were excavated in the area; however, the slopes of the terraced area were examined. The area is comprised of varying layers of sand and sand and gravel typical of an outwash area.

The granular materials in Borrow Area 7 are suitable for Type 2, Type 3 and Type 6 Granular Fill. Type 1 and 5 Granular Fill may be available if the material was screened. Should any material be used as Type 2 or 3 Granular Fill, the use of a Type 1 Granular Fill cover may be required. There is an old river channel present in the borrow area containing cobbles and gravel. This material would be suitable for Type 1 Granular Fill.

The identified area shown on Figure 8 is approximately 110,000 m^2 in size. Assuming an average excavation thickness of 1.0 m, an estimated volume of 110,000 m^3 would be available. Additional material is available to the west of the shown area, if required.

6.3 Summary of Granular Borrow Resources

All of the required Granular Borrow Types described in Section 6.0 were found at FOX-C. Table 4 summarizes the estimated borrow materials available at FOX-C. There is no requirement for crushing granular materials, but there may be a requirement for sorting and screening granular materials and blending materials to achieve the gradation requirements.

There is limited quantity of Type 1 material on the site.

Type 2 Granular Fill identified in Borrow Areas 2, 5, 6 and 7 is sandy and, therefore, easily eroded. Depending on the use of the Type 2 material, a cover layer of Type 1 Granular Fill may be required.

Type 4 Granular Fill was encountered in Borrow Area 4 within 0.5 m of the surface. At Borrow Area 4 the Type 4 Granular fill will become wetter with depth limiting the volume that can be removed. Developing the pit using proper drainage practices will be necessary. The material may have to be blended with granular fill to produce a workable material.

Type 5 and Type 6 Granular Fill were available in Borrow Areas 2, 3, 5, 6, and 7.

Most of the borrow sources are located at the west end of FOX-C in the vicinity of Lake Road and Beach Road.

Borrow Area 1 is approximately 2.5 km and 2.0 km distance by road (and down-gradient) from Upper Station and Midstation, respectively. The next closest borrow sources to these sites is Borrow Area 7 which is roughly 6 kilometres away (south of the Junction).

TABLE 4
SUMMARY OF FOX-C DEW LINE SITE GRANULAR BORROW SOURCES

Borrow Area	Available Granular Fill Type	Quantity Estimate			Comments
		Area (m^2)	Excavation Depth (m)	Volume (m^3)	
Borrow Area 1	Types 2 and 3	49,000	1.0	49,000	Partially Developed area and Undeveloped area.
Borrow Area 2	Types 2, 3 and 6	20,000	1.0	20,000	Partially Developed area
	Type 5	7,300 (Type 5)		7,300 (Type 5)	.
Borrow Area 3	Type 5 and 6	13,000	1.5	19,500	Partially Developed area
Borrow Area 4	Types 4	25,000	0.5	8,000	Undeveloped area.
Borrow Area 5	Types 5 and 6	10,500	1.0	10,500	Undeveloped area .
Borrow Area 6	Types 2, 3 and 6	21,500	1.0	21,500	Undeveloped area.
Borrow Area 7	Types 2, 3 and 6 Limited Type 1	110,000	1.0	110,000	Undeveloped area.

7.0 ACCESS ROAD EVALUATION

7.1 Beach Road

Beach Road (Figures 1, 10, 11, 12 and 13A and Photos 29 to 39) is approximately 2.2 km long. The existing road width (shoulder to shoulder) ranges from approximately 2.3 to 4.5 m and is typically 3 m.

The amount of regrading of the road surface prior to any significant vehicle traffic will depend on site development and the type of hauling equipment being used. With the exception of river crossings, the majority of road is still passable with a 4 x 4 pickup truck and with some fill placement and/or grading, it would be suitable for heavy equipment traffic. If two-way haul traffic is needed construction of pull out sections will be required.

All existing culverts on the Beach road were constructed out of 45 gallon barrels welded together. Breaks in the road where the road would be impassable by haul trucks exist at drainage crossings where the either culverts have failed (BR Crossings 1, 2 and 3) or where the road appears to have been washed out because no culverts were installed (BR Crossing 4).

The POL Tanks are located in the Beach Debris Area and mark the end of Beach Road. Between the POL tanks and BR Crossing 1, the road has been eroded by cross drainage. At this section the road embankment materials appear to have been derived by cut and fill. The local soils are fine-grained and highly erodible. The erosion is discontinuous over a distance of about 350 m along the road. Welded barrel culverts are present. Although water passes through the culverts, it appears to flow beneath the existing culverts. It is expected that under the weight of heavy equipment these culverts and road above them will fail. Culvert crossing should therefore should be upgraded. Where the road has been breached and eroded, fill will be required to resurface the road and provide a width passable by haul trucks. Most of the required fill may be salvaged locally and the remainder will need to be imported.

Between BR Crossing 1 and the Junction there are at least two additional culvert crossings that may require replacement as the existing culverts are no longer structurally sound. All existing culvert crossings should be assessed at the time of construction with the aid of heavy equipment.

Regular road maintenance during hauling will be required.

7.2 Lake Road

Lake Road is approximately 1.1 km long (Figure 1, Photos 41 and 42). The road surface width ranges from approximately 2.3 to 5.5 m and is typically 3 m. The road has been constructed from the granular material obtained from near the roadway. The soils range from sand to sand and gravel. No culvert crossings are present on the Lake Road. Generally the road is trafficable and in satisfactory condition for light traffic. Some grading is required over the extent of the roadway prior to any haul traffic. Approximate 240 m length of the road located on cross-sloped terrain requires reconstruction due erosion.

If two-way haul traffic is needed construction of pull out sections will be required. Regular grading during hauling will likely be required.

7.3 Station Road

Station Road from the Junction to the end of the road at the Upper Station is approximately 5.9 km long. The existing road surface width (shoulder to shoulder) between Kilometre 0 (Junction) and Kilometre 3.0 of Station Road ranges from approximately 2.5 to 5.5 m, but is typically 3 to 4 m. The general condition of the roadway to Kilometre 3.0 (approximately Crossing 2) is shown in Photos 49 to 54. A substantial amount of road structure remains that is in satisfactory condition for heavy equipment traffic, however, many sections will require varying amounts of surface preparation requiring fills resourced locally from the road right-of-way and/or from imported borrow. Road impasses in the first 3.0 kilometres include one failed road section, two river crossings (Crossing 1 and Crossing 2) and five washouts (Washouts 1 to 5).

From Kilometre 3.0 to the end of Station Road the road was constructed by placing fill over boulders and rock outcrops. The existing road surface width (shoulder to shoulder) throughout this section ranges from approximately 2.5 to 6.0 m, but is typically 4 to 6 m. The road conditions are shown in Photos 56 and 63. Approximately 1,000 m of the road located on cross sloped terrain requires resurfacing due to erosion and washouts. Construction of pull out sections may be required to facilitate two-way haul traffic.

Following are brief descriptions of impasses observed between the Junction and Kilometre 3.0 (Crossing 2).

Kilometre 0.1 Road Failure

A failed section of road (Figure 10 and Photo 43) approximately 140 m in length is located a distance about 100 m from the Junction (Station Road Kilometre 0). Failure at this road section appears to result from permafrost degradation coupled with deep erosion gullies across the road and undercutting by the glacier fed river.

Based on a visual assessment of the site it was deemed that for temporary access that it may be prudent to realign and build new road just upslope of the failed road section. A topographic survey was completed on the area to facilitate a redesign.

River Crossing 1

River Crossing 1 (Photos 48 and 49) was constructed in the 1960's using a culvert. The glacier fed river has washed out the crossing. Several options are available for reconstruction depending on the long term plan for the roadway and the specific use of the roadway. Construction of a properly sized culvert or a portable bridge are possibilities. Depending on the intended use of this road, it may be designed as a seasonal crossing to be removed each fall or as a longer term crossing.

River Crossing 2

River Crossing 2 (Photo 55) was also constructed in the 1960's using a culvert. The glacier fed river has washed out the crossing.

Several options are available for reconstruction depending on the long term plan for the roadway and the specific use of the roadway. Construction of a properly sized culvert or a portable bridge are possibilities. Depending on the intended use of this road, it may be designed as a seasonal crossing to be removed each fall or as a longer term crossing.

Washouts 1 through 5

Washouts (Figures 1, 6 and 7) have resulted from failed culverts and interference of the road with natural drainage paths. Washouts 1 through 5 are shown in Photos 44 to 47. The road at these sections is constructed out of sand and gravel or silt till obtained from the roadway right-of-way.

Washout No.	Length of Affected Road
1	Three existing culverts have been plugged, causing drainage to wash out the roadway at several locations. Approximately 80 m of affected roadway.
2	Approximately 60 m of affected roadway.
3	Approximately 100 m of affected roadway.
4	Roadway has been washed out in two main segments. A water course crosses the roadway. There is approximately 95 m of affected roadway.
5	Approximately 120 m of affected road.

Reconstruction would include installing culverts at the respective washouts and reconstructing the road and/or constructing armoured cross-ditches.

7.4 Road Repair Construction

Preliminary concepts for the Beach Road, Lake Road and Station Road repairs have been prepared based on a visual assessment of the road conditions. It has been assumed that the road will only be upgraded to support the short term clean up conditions. Annual maintenance will be required.

Final designs for all river crossings should be reviewed by a qualified hydrologist and should be in compliance with all Territorial and Federal regulations. It has been assumed that the flow during construction can be handled by several large culverts; however, culverts may not be able to handle the flow during peak freshet conditions. The culverts and crossing could be removed annually at the end of the construction to handle the flows of the following freshet. It is recommended that a hydrologic assessment be carried out to size the culverts and determine the need for annual removal.

7.4.1 Beach Road

The following work is required for the Beach Road:

- Regrade 350 m of road between the Beach POL tanks and BR Crossing 1.
  - Two existing culverts will require replacement
  - Minimal amounts of import fill required.
  - The existing fill materials will be salvaged and reused during the reconstruction.

- BR Crossings 1 and 2 are culvert locations that have been washed out.
  - The culverts will require replacement.
  - A hauling operation will be required to import fill material to each location.
  - It is assumed Borrow Area 2 would be utilized for fill material.
  - Development of this borrow source will be required.
  - It has been assumed that three articulated haul trucks and a loader will be utilized for the hauling operation and an excavator will be used to place the material. Approximately 250 m^3 and 170 m^3 of fill material will be required at Crossing 1 and 2, respectively.

- BR Crossing 3 is a segment of roadway that has been washed out from surface drainage.
  - A culvert should be installed in this location (or the area could be recontoured to promote drainage away from the roadway).
  - Approximately 170 m^3 of fill material from the roadway right of way or Borrow 3 will be used as fill material.

- BR Crossing 4 is a location where the existing culverts have been washed out.

  - A new culvert should be installed.
  - Approximately 250 m^3 of fill material will be required.
  - A hauling operation from Borrow Area 2 could be used.

7.4.2 Lake Road

Repairs to the Lake Road include repair of 240 m of road where minor washouts have occurred, and general grading along the remainder of the road. No import of fill from any of the prospective borrow sites is required for road repairs.

7.4.3 Station Road

Most of the hauling of debris and borrow on Station Road will be from Kilometre 3.0 onward. This will likely result in high two-way traffic between Kilometre 3.0 and the end of Station Road (Kilometre 5.9) whereas the use of first 3.0 kilometres of Station Road from the Junction to Kilometre 3.0 might be limited. Therefore, it may be feasible to upgrade the road in the first 3.0 kilometres so that it is suitable for seasonal temporary access sufficient to mobilize equipment to Kilometre 3.0 and provide a safe passage out in the event of an emergency. The following outlines the minimum requirements to make the road passable.

<u>General Repairs From Junction to Kilometre 3.0</u>

There are several segments that will require regrading in this section of roadway between River Crossing 1 and River Crossing 2 in addition to sections of road between impasses which are discussed below. The existing roadway surface can generally be regraded using fill material from upslope of the road.

General Repairs Kilometre 3.0 to End of Road (Upper Station)

The road between River Crossing 2 and the upper station site was typically constructed on a boulder and rock outcrop surface. The following work will be required:

- A combined total of approximately 1,000 m of road surface will require fill placement and grading.
- Approximately 1,800 m^3 of fill material imported from Borrow Area 1 will be required.

Kilometre 0.1 Road Failure

- A 140 m section of roadway from could be constructed upslope of the original road.
- The existing ground surface could be graded to provide a satisfactory road condition for the new alignment.
- An additional 180 m^3 of fill will be required for road construction.
- Two culvert installations would be required.

River Crossing 1

- Installation of two culverts, a boulder subbase and a surfacing course.
- The boulders can be sourced from Borrow Area 7.
- Surface course can be sourced from Borrow Area 2 or 7.
- Development of Borrow Area 7 will require dozer time to gain access and stockpile material for the hauling.
- Approximately 300 m^3 of fill material will be required.

River Crossing 2

- Installation of two culverts on a boulder subbase.
- The boulders to be used for the subbase along with the surface course can be sourced from the area or Borrow Area 1.
- The fill material can be sourced from Borrow Area 1.
- Development of Borrow Area 1 will require dozer time to gain access and stockpile material for the hauling.
- Approximately 500 m^3 of fill material will be required.

Washout 1

- There is approximately 80 m of affected roadway.
- The culverts will need to be replaced.
- The existing roadway surface can be regraded using fill material from upslope of the road
- Approximately 120 m^3 of fill material will be required.

Washout 2

- There is approximately 60 m of affected roadway.
- A culvert is recommended at this location.
- The existing roadway surface could be regraded using fill material cut from upslope of the road
- Approximately 100 m^3 of fill material will be required.

Washout 3

- There is approximately 100 m of affected roadway.
- The installation of a culvert is recommended at this location.
- The existing roadway surface could be regraded using fill material cut from upslope of the road
- Approximately 120 m^3 of fill material will be required.

Washout 4

- A watercourse crosses the roadway at this location.
- There is approximately 95 m of affected roadway.
- The installation of a culvert is recommended at this location.
- The existing roadway surface could be regraded using fill material cut from upslope of the road
- Approximately 400 m^3 of fill material will be required.

Washout 5

- There is approximately 120 m of affected roadway.
- A culvert should be installed at this location.
- The existing roadway surface could be regraded using fill material cut from upslope of the road
- Approximately 150 m^3 of fill material will be required.

It is estimated that the road repairs can be completed in approximately 25 working days. Camp, supervisory costs and project management costs should be added to the construction costs.

8.0 QUALITY ASSURANCE

Construction monitoring and quality control are essential for satisfactory performance of the concepts presented in this report. Inspection by a geotechnical engineer with arctic experience is recommended during construction so that the required density and moisture conditioning critical to the design are achieved.

Liner installation (if required) should be monitored by qualified construction quality assurance personnel. Supplied materials should be inspected and conform to specifications.

9.0 POST CONSTRUCTION MONITORING

A post-construction monitoring program is recommended for the landfills. New landfills and closure landfills should be monitored visually for any signs of settlement, erosion, and ponded water. It is recommended that they be inspected three years after construction is complete. The monitoring program for the Soil Disposal Facility landfill should be carried out during the period required for the facility to achieve thermal equilibrium. Three to five years duration is suggested initially, with the program suspended or substantially downgraded as acceptable performance is confirmed.

The monitoring program for landfills should consist of: visual monitoring; thermal monitoring; surface water or active layer water monitoring.

Suggested monitoring requirements are described in the following sections.

9.1 Visual Monitoring Program

A visual monitoring program should be carried out on an annual basis, by a Professional Engineer registered in NT who is familiar with the requirements of the landfill remediation design. The inspector should look for any signs of distress, including:

- signs of damage or potential damage from settlement, ponding, thermal instability, frost action, or erosion. The visual observations should be supported by simple elevation surveys and photography; and
- damage to the above-ground portions of groundwater monitoring devices or thermistors.

9.2 Thermal Monitoring

A thermal monitoring system should be implemented if freezeback designs are employed. A thermal/monitoring program would allow verification of predicted ground temperatures within the landfill structures. It is recommended that two ground temperature cables be installed within the central area of the landfill and two ground temperature cables be installed in the containment berms around the landfill. The cables should be installed in drill holes, inside a 25 mm diameter PVC casing, and backfilled with dry sand to eliminate air voids.

9.3 Ground Water or Surface Water Monitoring

Water quality should be monitored within 30 m of the facility. Monitoring should be carried out in existing surface waters or by using monitoring wells installed through the active layer. Samples of water should be obtained from the base of the active layer for testing at the end of the summer season. Baseline water quality data should be determined before any waste is placed in the facility. Representative background conditions should be measured approximately 200 m from the facility.

The results of monitoring during subsequent years should be analyzed and compared to the baseline data and monitoring data from previous years to identify any changes in water quality.

10.0 LIMITATIONS

This report pertains to the specific site and development described in Section 1.0. Isolated information should not be reproduced, transferred, or used outside the context of this report unless clearly referenced to the source. EBA Engineering Consultants Ltd. will not be responsible for unauthorized reuse or interpretation of information presented herein.

This report summarizes the data collected by EBA during the 2004 Geotechnical Investigation. It is recommended that EBA be given the opportunity to review or develop the details of the final design. It is also recommended that geotechnical, materials and environmental engineering field services, such as backfill and drainage measures and testing of soil density and gradation, be performed as construction proceeds to ensure that the design intent is met.

The design concepts presented in this report are based on analyses that demonstrate their feasibility. Certain assumptions pertaining to soil properties, active layer thickness and ground temperatures have been made based on regional knowledge of the terrain and engineering judgement. Engineering inspection during construction must be planned to observe and report site conditions such as active layer depth, soil texture and water content and groundwater conditions encountered during excavation. This data must be reviewed by the geotechnical engineer to confirm that the design intent will be met.

No thermal analysis has been completed to date for the design of a Soil Disposal Facility. Should a facility be required, further analyses are required for final design.

It should be noted that geological conditions are innately variable and are seldom spatially uniform. Stratigraphic information has been based on shallow testpits and surface exposures. In order to develop recommendations from this information, it is necessary to make assumptions concerning the stratigraphy. Adequate monitoring should be provided during construction to check that these assumptions are reasonable. Further conditions are presented in Appendix D, “Geotechnical Report – General Conditions.”

11.0 CLOSURE

This report has been prepared in accordance with generally accepted engineering practices and judgement has been used in developing recommendations. No other warrant is made, either expressed or implied.

Respectfully submitted,
EBA Engineering Consultants Ltd.

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 018
EBA ENGINEERING CONSULTANTS LTD.

Jason P.W. Berkers, P.Eng. (Yukon)
Project Engineer
Direct Line: (867) 668-2071 ext. 33
e-mail: jberkers@eba.ca

Reviewed by:

REGISTERED PROFESSIONAL ENGINEER
W.T. HORNE
LICENSEE
N.W.T.

W.T. Horne, P.Eng.
Senior Project Engineer, Circumpolar Regions
Direct Line: (780) 451-2130, ext. 276)
e-mail: bhorne@eba.ca

JPWB/WTH

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PHOTOGRAPHS

Photo 1
Main Dump looking west.

Photo 2
Main Dump looking east.

Photo 3
Garage Dump looking southwest, Lobe A in foreground.

Photo 4
Garage Dump looking north, Lobe B in foreground.

Photo 5
House Dump looking west, remnants of Inuit house on left, House Dump on right.

Photo 6
House Dump looking north.

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Original Dump looking southwest, west side of Station Road.

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Original Dump looking southwest, east side of Station Road.

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Midstation Dump Lobe A looking northwest, pad area.

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Midstation Dump looking north, Lobe B.

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Midstation Dump looking north, Lobe B in foreground.

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Midstation Dump looking east, toe of Lobe B.

Photo 13
West Laydown Debris Area looking east, Lobe A in foreground, Lobe B in background.

Photo 14
East Laydown Debris Area looking west, Lobe B in foreground.

Photo 15
Beach POL Debris Area looking northeast, Lobe A in background.

Photo 16
Potential Debris Landfill Location 2 looking northwest, barrel cache in background.

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Potential Debris Landfill Location 3 looking west.

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Potential Debris Landfill Location 4 looking west.

Photo 19
Potential Debris Landfill Location 4 looking southwest.

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Potential Soil Disposal Facility Location 1 looking northeast.

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Proposed Borrow Area 1 looking west.

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Proposed Borrow Area 1 looking north.

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Proposed Borrow Area 2 looking east.

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Proposed Borrow Area 7 looking east.

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Proposed Borrow Area 7 looking east, slope face.

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Proposed Borrow Area 7 looking northeast, slope face.

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Beach Road looking southwest.

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Beach Road looking southeast.

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Beach Road looking northeast at BR Crossing 1.

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Beach Road looking west at BR Crossing 3.

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Beach Road looking west at BR Crossing 4.

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Lake Road looking northeast, regrade area in background.

Photo 43
Station Road looking southeast. Road Failure Area,
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Station Road looking east, Washout 1.

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Station Road, Washout 3.

Photo 46b
Station Road looking east, Washout 4.

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Station Road looking east, Washout 5.

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Station Road looking north, north side of River Crossing 1.

Photo 49
Station Road looking south, River Crossing 1.

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Station Road looking east.

Photo 51
Station Road looking east.

Photo 52
Station Road looking east.

Photo 53
Station Road looking west.

Photo 54
Station Road looking north, south side of River Crossing 2.

Photo 55
Station Road looking south, north side of River Crossing 2.

Photo 56
Station Road looking north.

Photo 57
Station Road looking north.

Photo 58
Station Road looking east.

Photo 59
Station Road looking southwest.

Photo 60
Station Road looking northwest.

Photo 61
Station Road looking west.

Photo 62
Station Road looking west.

Photo 63
Station Road looking north.

FIGURES

(NOTE: Reduced scale drawings are included in this report. Full scale drawings can be provided by EBA upon request.)

APPENDIX A

GEOPHYSICAL SURVEY PROCEDURES

GEOPHYSICAL SURVEY PROCEDURES

A.1 Background

The objective of the geophysical program was to define the areal limits of known landfills, and to identify and delineate other locations with partially or completely buried debris in areas where suspicious activity has taken place. The geophysical data was recorded with complete spatial positioning information to enable both the results and coverage to be accurately documented for future reference. A number of geophysical techniques can be used including Magnetometer, Electromagnetic Induction tools, (EM31), Electromagnetic Transient (EM61) and Ground Penetrating Radar (GPR). All techniques have advantages and disadvantages and all techniques will be adversely affected by significant amounts of surface debris. Based on experience at other DEW Line sites a survey procedure using magnetometer systems was used At FOX-C. This choice was driven by three considerations:

1. It provided the most cost effective solution in terms of maximising the area surveyed within the field time constraints.
2. The data collected permitted an analysis of the data in the field and easy field confirmation of the results.
3. Based on experience at many DEW Line sites, all debris areas and landfills contain a proportion of ferrous material and therefore can be mapped successfully using magnetometers. The issue of surface debris was addressed by noting the distribution and magnitude of debris and compensating for its presence when interpreting the measured results.

A.2 Magnetic Survey Procedure

A Geometrics G-858 portable cesium magnetometer/gradiometer magnetic system (G-858) was used to map the aerial extent of the landfills and partially or completely covered debris areas. A Geometrics G-856 proton precession magnetometer was used to record diurnal variations in the background magnetic field strengths for total magnetic field strength corrections.

The G-858 is a single-person portable system that was used to measure total magnetic field strengths at two sensor locations on a continuous basis as a survey area was walked. Variations in the total magnetic field (anomalies) are typically indicative of buried metallic (ferrous) debris. The two sensors are vertically separated by approximately 1 m, and magnetic readings are taken at both sensors and compared. The difference between the two readings provides the magnetic gradient, which is proportional to the quantity, distance and orientation of the neighbouring ferrous metal. All magnetic data is collected with an integrated DGPS positioning system. Data is usually collected along parallel profile lines to ensure consistent areal coverage, but in situations where access is restricted, or in a more general reconnaissance mode, a randomly oriented line approach may be appropriate. GPS positioning data is collected and logged at the same time as the geophysical data and is differentially corrected in real time using a RTCM differential correction string obtained from an MSAT based satellite link. The position of the magnetic sensor is logged to submetre accuracies (x,y) once every second during data collection. By integrating the magnetic data collected with a sub-metre real time DGPS positioning system, it is possible to cover large areas quickly and provide detailed grids over anomalies determining their shape and distribution in the field immediately after data collection. This data is then used to mark the boundaries of any buried material for consideration in the environmental sampling program.

A.3 Geophysical Survey Methodology

The survey methodology consisted of several steps.

1. All known areas of concern were surveyed using the G-858 with line spacing of approximately 5 meters.
2. Areas where there was no possibility of buried debris (outcrop rock, undisturbed soil) were generally not surveyed. There were three exception to this and they were:

   a) Areas where it was important to document a “clean” zone surrounding landfill or debris areas for planning purposes.
   b) Areas where it was important to document that there was minimal debris (potential borrow locations for example).
   c) Areas where there was enough scattered surface debris over a large enough area to make mapping the location of the surficial debris using the magnetometer useful.

3. Magnetic base station data was collected using the G-856 at a nearby ‘clean’ area to allow the total magnetic field strength readings to be diurnally corrected.

4. The G-858 was used to walk the disturbed areas on site in reconnaissance mode to identify if there are further buried debris piles in areas showing surface disturbance. Any such areas found were surveyed in detail to define the extent of any buried material.

5. All geophysical data collected included integrated, real-time differentially corrected GPS positions with a sub-metre accuracy (x,y) to allow the location and contouring of the data in the field for evaluation and documentation.

6. The perimeter of any buried landfills and buried debris piles were marked using pin flags to facilitate environmental sampling.

A.4 Geophysical Data Presentation

The magnetometer data was processed and plotted as a colour contour map with UTM coordinates. Site plan information is integrated as a layer on the drawing.

On the colour contour map, anomalies appear as areas of high magnetic gradients either red (positive) or blue (negative), on a yellow background of limited or no response. There is no significance to whether the anomaly is red or blue. The red/blue colours simply represent the positive/negative gradient. Locations with high magnetic gradients will correspond to locations with ferrous debris and therefore the landfill or debris pile. The extent and intensity of the total magnetic field readings usually indicates whether one is looking at a small highly magnetic surface object or conversely a more massive, deeply buried object.

Interpreting the data is done by grouping the magnetic gradient anomalies (red or blue areas) into anomaly areas. Anomaly areas are groupings of individual magnetic responses that may be related based on knowledge of site conditions (buried concrete rubble with rebar, water wellhead, barbed wire fence), similarities in total field data, or by reviewing the final colour plots. These anomaly groupings are then compared against the total magnetic field readings for those locations in order to gauge their potential significance (quantity of ferrous material).

A.5 Magnetic Theory

The theory behind magnetic or gradiometer data at its simplest level involves taking a point measurement of the earth's total magnetic field strength at a specific location at an instant in time. The earth is surrounded by a magnetic field generated by the interaction of the molten core, convection currents within the core, and the earth's rotation. The field strength varies with time (diurnal variations). These variations are primarily caused by changes in the convection currents and the influence of solar activity, which is highest during periods of intense solar flaring (sunspot activity) and conversely lowest level when the sun is quiet. Usually, these variations are less than a few hundred gammas (nanoTesla, nT) in magnitude, but they are more pronounced at more northerly and southerly latitudes. Variations due to location on the earth's surface are solely a function of relative position with respect to the earth's magnetic poles. As the magnetic poles drift, so do the location readings. The earth's magnetic field varies by approximately 35,000 gammas from the magnetic poles to the equator.

Magnetic data is useful in locating objects such as buried steel and other ferrous objects since the earth's background magnetic field is distorted by the presence of magnetized rocks, soils and ferrous (iron) objects. This is because these objects also possess an induced field in the presence of the background field and the background and induced fields will combine to produce a resultant total field strength that is a summation of the two magnetic field vectors. Objects can be detected by subtracting the earth's background magnetic field from field data and contouring the remainder. In general, the effect from natural materials such as rocks and soils is small over small areas and is usually less than 1 gamma/m. Concentrated ferrous debris; however, can cause magnetic field distortions of up to 30,000 gammas/m.

A gradiometer differs from a magnetometer only in that two readings of the total magnetic field strength are taken at a specific location and time. The two readings are taken at slightly different positions; therefore, the difference between the two readings is a reflection of the magnetic gradient at that location. This reading is sensitive to near surface ferrous objects and gradient anomalies can, therefore, be interpreted as an indicator of potential targets. This difference is plotted as contours on a grid system and provides a visual representation of the location and distribution of magnetic gradient anomalies.

The G856 proton precession magnetometer takes advantage of the fact that molecules of hydrocarbon fluids behave as small magnets (dipoles) and; therefore, will align or polarize themselves with the lines of magnetic flux when exposed to a uniform magnetic field. In the sensor head this is achieved in a controlled fashion by means of an energized electric coil. When the uniform magnetic field is removed, the molecules will rotate (precess) from their polarized orientation in a circular fashion around the direction of the ambient or local magnetic field lines (similar to the way a spinning top will wobble in a circular fashion in the presence of a gravitation field). The rate at which this precession occurs is proportional to the intensity of the ambient field. By measuring the rate (frequency) of precession and applying a well known atomic constant (the gyromagnetic ratio of the proton), one can calculate the total magnetic field strength at a specific point in time.

By using this technique to measure total magnetic field strength, measurements can be made utilizing an instrument with no moving parts to an accuracy of 0.1 nT (gammas). The disadvantage of this method is that adequate time has to be allowed for the sensor system to energize (polarize the molecules) and then relax the field and take the reading. This requires a minimum reading rate of no faster than one reading every three seconds. As the sensor has to be stationary during this period it is difficult to collect data at a high enough rate for real-time evaluation of the data. In addition, the system stability and accuracy degrades in the presence of high magnetic gradients and background noise. If correctly tuned and setup; however, proton precession magnetometers are ideal for monitoring background magnetic readings at a static location.

A G858 cesium vapour magnetometer offers several advantages over the more traditional proton precession or flux-gate magnetometers, particularly for collecting field readings over large survey areas. These advantages include more stable readings in high field gradients, increased resolution (0.01 nT), and high sampling rates. This means that it is possible to use these devices as “real-time” detectors when seeking magnetic anomalies and it also allows data to be collected rapidly with high horizontal data resolutions while walking a site without having to stop at each reading location.

The theory behind how cesium vapour magnetometers work is based on quantum physics. Briefly, the sensor head measures the total magnetic field at a point in space at a reading interval of up to 10 times a second. It does this by shining circularly polarized light through a glass chamber (called an absorption cell) containing a small amount of cesium vapour in a partial vacuum. Cesium vapour is used because it only has one electron present in the atom’s outermost electron shell and this simplifies the excitation effect being measured. This electron can exist in nine different energy states in the presence of an external magnetic field. This effect is called Zeeman splitting. The energy differences from one Zeeman level to the next are approximately equal and are proportional to the strength of the ambient external magnetic field. By shining circularly polarized light generated by a cesium lamp through the absorption cell and measuring the Larmor frequency of an injected RF signal (called the H1 drive) required to reset photons within the absorption cell (so that they can absorb that light), one can measure their changes in energy and hence the ambient magnetic field strength. The constant of proportionality between the Larmor frequency and the ambient magnetic field strength is 3.498572 Hz/nT. This value is valid for the full range of typically encountered magnetic field values (20K nT to 90K nT).

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APPENDIX B

TESTPIT LOGS

MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

MAJOR DIVISION			GROUP SYMBOL	GRAPH SYMBOL	COLOUR CODE	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 200 SIEVE)	GRAVEL'S MORE THAN HALF COARSE GRAINS LARGER THAN NO. 4 SIEVE	CLEAN GRAVEL'S (LITTLE OR NO FINES)	GW		RED	WELL GRADED GRAVELS, LITTLE OR NO FINES	$C_u = \frac{D_{60}}{D_{10}} > 4 \quad C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$	
			GP		RED	POORLY GRADED GRAVELS, AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY GRAVEL'S (WITH SOME FINES)	GM		YELLOW	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12 %	ATTERBERG LIMITS BELOW "A" LINE OR P.I. LESS THAN 7
			GC		YELLOW	CLAYEY GRAVEL'S, GRAVEL-SAND-CLAY MIXTURES		ATTERBERG LIMITS BELOW "A" LINE P.I. MORE THAN 7
	SANDS MORE THAN HALF FINE GRAINS SMALLER THAN NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)	SW		RED	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_u = \frac{D_{60}}{D_{10}} > 6 \quad C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$	
			SP		RED	POORLY GRADED SANDS, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY SANDS (WITH SOME FINES)	SM		YELLOW	SILTY SANDS, SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12 %	ATTERBERG LIMITS BELOW "A" LINE OR P.I. LESS THAN 4
			SC		YELLOW	CLAYEY SANDS, SAND-CLAY MIXTURES		ATTERBERG LIMITS BELOW "A" LINE P.I. MORE THAN 7
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSES 200 SIEVE)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	$W_L < 50\%$	ML		GREEN	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (SEE BELOW)	
		$W_L < 50\%$	MH		BLUE	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS		
	CLAYS ABOVE "A" LINE ON PLASTICITY CHART NEGLIGIBLE ORGANIC CONTENT	$W_L < 30\%$	CL		GREEN	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELY, SANDY OR SILTY CLAYS, LEAN CLAYS		
		$30\% < W_L < 50\%$	CI		GREEN-BLUE	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS		
		$W_L > 50\%$	CH		BLUE	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS		
	ORGANIC SILTS & CLAYS BELOW "A" LINE ON CHART	$W_L < 50\%$	OL		GREEN	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	WHENEVER THE NATURE OF THE FINES CONTENT HAS NOT BEEN DETERMINED, IT IS DESIGNATED BY THE LETTER "F", E.G. SF IF A MIXTURE OF SAND WITH SILT OR CLAY	
		$W_L > 50\%$	OH		BLUE	ORGANIC CLAYS OF HIGH PLASTICITY		
HIGHLY ORGANIC SOILS			Pt		ORANGE	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOUR OR ODOR, AND OFTEN FIBROUS TEXTURE	

SPECIAL SYMBOLS

LIMESTONE		OILSAND	
SANDSTONE		SHALE	
SILTSTONE		FILL (UNDIFFERENTIATED)	

SOIL COMPONENTS

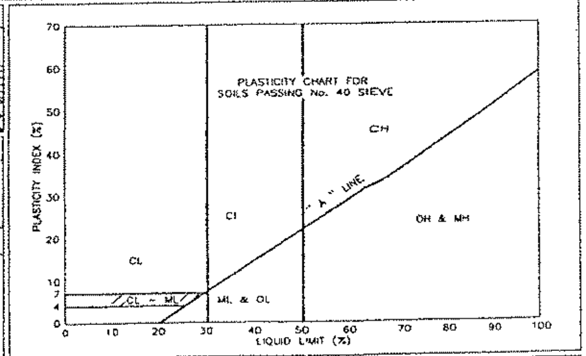
FRACTION		U.S. STANDARD SIEVE SIZE	
		PASSING	RETAINED
GRAVEL			
	COARSE	75mm	19mm
	FINE	19mm	4.75mm
SAND			
	COARSE	4.75mm	2.00mm
	MEDIUM	2.00mm	425μm
	FINE	425μm	75μm
SILT (NON PLASTIC)		75μm	2μm
CLAY (PLASTIC)		2μm	

DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS

PERCENT	DESCRIPTOR
50-35	'AND'
35-20	'Y' OR 'LY'
20-10	'SOME'
10-1	'TRACE'

OVERSIZED MATERIAL

ROUNDED OR SURROUNDED	NOT ROUNDED
COBBLES 75mm TO 200mm	ROCK FRAGMENTS > 75mm
BOULDERS > 200mm	ROCKS > 0.75 CUBIC METRE IN VOLUME



1. ALL SIEVE SIZES MENTIONED ON THIS CHART ARE U.S. STANDARD A.S.T.M. E.11
2. BOUNDARY CLASSIFICATIONS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE GIVEN COMBINED GROUP SYMBOLS, E.G. GW-GC IS A WELL GRADED GRAVEL SAND MIXTURE WITH CLAY BINDER BETWEEN 5 % AND 12%

GROUND ICE DESCRIPTION

ICE NOT VISIBLE

GROUP SYMBOLS	SYMBOLS	SUBGROUP DESCRIPTION	
N	Nf	Poorly-bonded or friable	
	Nbn	No excess ice, well-bonded	
	Nbe	Excess ice, well-bonded	

NOTE:
1. *Dual symbols are used to indicate borderline or mixed ice classifications*
2. *Visual estimates of ice contents indicated on borehole logs ± 5%*
3. *This system of ground ice description has been modified from NRC Technical Memo. 79, Guide to the Field Description of Permafrost for Engineering Purposes*

LEGEND
Soil ☐ Ice ■

VISIBLE ICE LESS THAN 50% BY VOLUME

GROUP SYMBOLS	SYMBOLS	SUBGROUP DESCRIPTION	
V	Vx	Individual ice crystals or inclusions	
	Vc	Ice coatings on particles	
	Vr	Random or irregularly oriented ice formations	
	Vs	Stratified or distinctly oriented ice formations	

VISIBLE ICE GREATER THAN 50% BY VOLUME

ICE	ICE + Soil Type	Ice with soil inclusions	
	ICE	Ice without soil inclusions (greater than 25 mm (1 in.) thick)	

FOX-C (EKALUGAD LAKE) DEW LINE SITE
2004 SITE INVESTIGATION
TESTPIT LOGS

Testpit	Depth (m)	Description
TP-01		Beach Area (POL tanks pad)
	0.0	SAND and GRAVEL – trace silt, medium to coarse grained sand, maximum aggregate size 50 mm, sub-angular to rounded, damp, brown (Sample at 0.2 – 0.3)
	0.8	SILT – sandy, gravelly, some clay, fine grained sand, grey, frozen
	0.83	END OF TESTPIT – REFUSAL ON PERMAFROST
TP-02		Borrow Area 4 (north portion)
	0.0	SILT – clayey, some gravel, trace fine sand, trace cobbles, occasional boulders, maximum aggregate size 250 mm, sub-angular to sub-rounded, damp, non-plastic, blocky, grey (Sample at 0.2 – 0.3, M.C. = 20.7%)
	0.6	SAND – silty, gravelly, some clay, trace cobbles, fine grained sand, maximum aggregate size 50 mm, subangular to rounded, damp grey/brown (Sample at 0.7 – 0.8, M.C. = 11.8%)
	1.2	END OF TESTPIT – REFUSAL ON PERMAFROST
TP-03		Beach Road (near Borrow Area 4, east side of road)
	0.0	SILT – clayey, some gravel, trace fine sand, trace cobbles, occasional boulders, sub-angular to sub-rounded, non-plastic, damp to wet, grey (Sample at 0.3 – 0.4)
	0.9	ICE and SILT – ice 50 – 60%
	0.9	END OF TESTPIT – REFUSAL ON PERMAFROST
TP-04		Tier II Facility Location 1 (west portion)
	0.0	SILT and SAND – some clay, some gravel, some cobbles, occasional boulders, subangular to rounded, damp, mottled tan/brown/grey (Sample at 0.3 – 0.4, M.C. = 19.8%)
	0.9	Permafrost – Vs at 20 – 30%
	0.9	END OF TESTPIT – REFUSAL ON PERMAFROST
TP-05		Borrow Area 3 (east portion)
	0.0	SAND – silty, some gravel, trace cobbles, fine to medium grained sand, subrounded to subangular, moist, mottled tan/brown/grey
	0.2	Becomes trace gravel (Sample at 0.5 – 0.6, Gravel = 6%, Sand = 71%, Silt/Clay = 23%, M.C. = 1.8%)
	1.4	Water infiltration at permafrost contact
	1.4	END OF TESTPIT – REFUSAL ON PERMAFROST

Testpit	Depth (m)	Description
TP-06		Borrow Area 3 (west portion)
	0.0	SAND – trace to some silt, some gravel, trace cobbles, medium grained sand, moist, tan/brown
	0.25	Becomes trace gravel
		(Sample at 0.4 – 0.5)
	1.4	END OF TESTPIT – REFUSAL ON PERMAFROST
TP-07		Borrow Area 3 (south portion)
	0.0	SAND – silty, some gravel, some cobbles, fine grained sand, subangular to rounded, damp, brown
	0.15	Becomes trace gravel
	1.1	Water content increases
		(Sample at 1.1 – 1.2)
	1.2	END OF TESTPIT – REFUSAL ON PERMAFROST
TP-08		Lake Road (south road edge)
	0.0	SAND – some silt to silty, fine to medium grained, moist, tan, gravel and cobbles at surface
		(Sample at 0.4 – 0.5)
	1.1	END OF TESTPIT – REFUSAL ON PERMAFROST
TP-09		Borrow Area 4 (middle portion)
	0.0	SILT – clayey, trace fine sand, trace gravel, low plasticity, damp, grey
		(Sample at 0.1 – 0.2, M.C. = 25.9%)
	0.5	Moisture content increases with depth
		(Sample at 0.7 – 0.8, M.C. = 33.7%)
	1.0	END OF TESTPIT – REFUSAL ON PERMAFROST
TP-10		Borrow Area 4 (south portion)
	0.0	SAND and SILT – gravelly, some clay, some cobbles, fine grained sand, subangular to rounded, maximum aggregate size 150 mm, non-plastic, damp to wet, non-plastic, grey/brown
		(Sample at 0.3 – 0.4, M.C. = 12.0%)
	1.0	END OF TESTPIT
		Boulders present up to 1.5 m dia., approximately 5% of surface
TP-11		Borrow Area 4 (south portion)
	0.0	SILT – clayey, gravelly, some cobbles, trace fine grained sand, maximum aggregate size 150 mm, subrounded to subangular, non-plastic, damp, grey
	0.3	Becomes trace gravel, trace cobbles, moisture content increases, plastic
	0.7	Permafrost - ICE and SOIL – 50%
	0.7	END OF TESTPIT – REFUSAL ON PERMAFROST

Testpit	Depth (m)	Description
TP-12		Tier II Facility Location 1 (south portion)
	0.0	SILT – clayey, trace cobbles, trace fine grained sand, maximum aggregate size 150 mm, subrounded to rounded, plastic, damp, grey/brown
		(Sample at 0.15 – 0.2, M.C. = 24.3%)
		(Sample at 0.5 – 0.6, M.C. = 22.7%)
	0.4	Moisture content increases
	0.7	Permafrost – Vs = 40%
	0.8	Vs = 20%
		(Sample at 0.8 – 0.85, M.C. = 40.2%)
	0.9	END OF TESTPIT – REFUSAL ON PERMAFROST
		Cobbles and Boulders on surface up to 0.5 m
TP-13		Tier II Facility Location 1 (east portion)
	0.0	SILT – clayey, trace gravel, trace cobbles, trace fine grained sand, plastic, damp to wet, grey/brown
	0.1	200 mm lense of fine grained sand, gravelly, come cobbles
	0.8	SAND – silty, some clay, fine grained sand, damp brown
		(Sample at 0.9 – 1.0, M.C. = 16.4%)
	1.1	END OF TESTPIT – REFUSAL ON PERMAFROST
		Cobbles and Boulders on surface up to 0.5 m
TP-14		Tier II Facility Location 1 (north portion)
	0.0	SILT – clayey, trace gravel, trace cobbles, trace fine grained sand, plastic, damp to wet, grey/brown
	0.75	Permafrost – ICE – 10 % soil
	0.8	ICE and SOIL – 50%
	0.85	END OF TESTPIT – REFUSAL ON PERMAFROST
		Cobbles and Boulders on surface up to 0.5 m
TP-15		Borrow Area 3 (north portion)
	0.0	SAND – silty, fine grained sand, damp tan, gravel and cobbles at surface
	0.15	SAND and SILT – fine grained sand, damp, grey
	0.25	SAND – gravelly, trace silt, well graded, maximum aggregate size 30 mm, subangular to subrounded, damp, orange/brown
	0.45	Becomes med to coarse grained, maximum aggregate size 75 mm, salt and pepper
		(Sample at 0.6 – 0.7, Gravel = 25%, Sand = 74%, Silt/Clay = 1%, M.C. = 1.2%)
	1.2	END OF TESTPIT
TP-16		Borrow Area 3 (north portion)
	0.0	SAND – gravelly, trace silt, well graded, maximum aggregate size 50 mm, subangular to subrounded, damp, tan/brown
	0.75	Becomes some silt, fine grained sand
	1.0	END OF TESTPIT

Testpit	Depth (m)	Description
TP-17		Borrow Area 3 (west portion)
	0.0	SAND – trace gravel, trace silt, medium grained, damp, brown, gravel and cobbles at surface
	1.2	END OF TESTPIT
TP-18		Borrow Area 3 (north portion)
	0.0	SAND – trace gravel, trace silt, medium grained, damp, brown, gravel and cobbles at surface
	0.5	SAND – some silt, fine to medium grained sand, damp, grey
	0.6	SAND – gravelly, trace silt, well graded, maximum aggregate size 75 mm, subrounded to subrounded, damp, tan
	1.2	END OF TESTPIT
TP-19		Borrow Area 3 (south portion)
	0.0	ORGANICS - rootmat
		SAND – some silt, trace gravel, fine to medium grained sand, damp, dark brown
	0.6	50 mm lenses of sand and gravel
	0.9	Water infiltration
		(Sample at 0.3 – 0.4, M.C. = 17.4%)
	1.2	END OF TESTPIT – REFUSAL ON PERMAFROST
TP-20		Borrow Area 3 (southwest portion)
	0.0	ORGANICS - rootmat
	0.02	SAND – silty, trace gravel, fine to medium grained sand, damp, mottled grey/tan/brown
		(Sample at 0.3 – 0.4, M.C. = 10.5%)
	0.8	SAND – trace gravel, trace silt, coarse grained, saturated, brown
	0.8	Water Infiltration
		(Sample at 0.9 – 1.0, M.C. = 11.8%)
	1.2	END OF TESTPIT – REFUSAL ON PERMAFROST
TP-21		Borrow Area 3 (southeast portion)
	0.0	ORGANICS - rootmat
	0.02	SAND and SILT – some clay, trace gravel, trace cobbles, fine to medium grained sand, damp to wet, mottled grey/tan/brown
	1.0	Water infiltration
		(Sample at 0.3 – 0.4, M.C. = 23.9%)
	1.0	END OF TESTPIT – REFUSAL ON PERMAFROST

Testpit	Depth (m)	Description
TP-22		Borrow Area 5 (south portion)
	0.0	SAND and GRAVEL – some cobbles, trace silt, well graded, maximum aggregate size 250 mm, subangular, to rounded, damp, brown
	0.4	Becomes med to coarse grained sand (Sample at 0.8 – 1.0, Gravel = 42%, Sand = 55%, Silt/Clay = 3%, M.C. = 6.1%)
	1.8	END OF TESTPIT - REFUSAL ON PERMAFROST
TP-23		Borrow Area 5 (centre portion)
	0.0	ORGANICS - rootmat
	0.02	SAND – some silt, fine to medium grained sand, dark brown
	0.2	SAND and GRAVEL – some cobbles, trace silt, well graded, maximum aggregate size 150 mm, subangular, to rounded, damp, brown
	0.4	Becomes med to coarse grained sand
	1.2	Water infiltration
	1.5	END OF TESTPIT - REFUSAL ON PERMAFROST
TP-24		Borrow Area 5 (centre portion)
	0.0	SAND – some silt, fine to medium grained sand, dark brown
	1.5	END OF TESTPIT - REFUSAL ON PERMAFROST
TP-25		Borrow Area 5 (northwest portion)
	0.0	SAND – some silt, fine to medium grained sand, dark brown
	0.2	SAND and GRAVEL – trace silt, well graded, maximum aggregate size 50 mm, subangular, to rounded, damp, brown
	1.0	Becomes med to coarse grained sand (Sample at 0.4 – 0.5)
	1.4	END OF TESTPIT - REFUSAL ON PERMAFROST
TP-26		Borrow Area 5 (west portion)
	0.0	SAND– some gravel, trace cobbles, trace silt, well graded, maximum aggregate size 200 mm, subangular, to rounded, damp, brown, varying layers of sand and gravel throughout testpit (Sample at 0.3 – 0.7, Gravel = 19%, Sand = 78%, Silt/Clay = 3%, M.C. = 3.9%)
	1.5	END OF TESTPIT - REFUSAL ON PERMAFROST
TP-27		Borrow Area 5 (southwest portion)
	0.0	SAND – some silt, fine to medium grained sand, dark brown
	0.15	SAND and GRAVEL – some cobbles, trace silt, well graded, maximum aggregate size 150 mm, subangular, to rounded, damp, brown
	0.6	400 mm layer of SAND – fine to medium grained
	1.5	END OF TESTPIT - REFUSAL ON PERMAFROST

Testpit	Depth (m)	Description
TP-28		Borrow Area 5 (north portion)
	0.0	ORGANICS - rootmat
	0.1	SAND – some silt, fine to medium grained sand, dark brown
	0.2	SAND and GRAVEL – trace silt, well graded, maximum aggregate size 50 mm, subangular, to rounded, damp, brown
	1.4	END OF TESTPIT - REFUSAL ON PERMAFROST
TP-29		Borrow Area 5 (east portion)
	0.0	ORGANICS - rootmat
	0.1	SAND – trace silt, fine to medium grained sand, dark brown
	0.2	Becomes medium grained (Sample at 0.3 – 0.5, M.C. = 3.1%)
	0.7	50 mm lense of Gravel – maximum aggregate size 50 mm
	1.1	SAND and GRAVEL – trace silt, medium grained sand, maximum aggregate size 75 mm, subangular, to rounded, damp, brown
	1.3	END OF TESTPIT - REFUSAL ON PERMAFROST
TP-30		Borrow Area 5 (east portion)
	0.0	ORGANICS - rootmat
	0.1	SAND – some silt, fine to medium grained sand, dark brown (Sample at 0.5 – 0.6, M.C. = 10.3%)
	1.2	END OF TESTPIT - REFUSAL ON PERMAFROST
TP-31		Borrow Area 5 (northeast portion)
	0.0	ORGANICS - rootmat
	0.2	SAND – some silt, fine to medium grained sand, dark brown (Sample at 0.3 – 0.4, M.C. = 10.2%)
	1.2	END OF TESTPIT - REFUSAL ON PERMAFROST
TP-32		NWH Landfill Location 2 (south portion)
	0.0	ORGANICS - rootlets
	0.1	SAND – some silt, trace cobbles, fine to medium grained sand, maximum aggregate size 250 mm, subrounded to rounded, damp, brown, rootlets to 300 mm
	0.3	Becomes dark brown
	1.0	Pockets of grey fine grained sand and silt (Sample at 0.4 – 0.5, M.C. = 18.7%)
	1.2	END OF TESTPIT – REFUSAL ON PERMAFROST
TP-33		NWH Landfill Location 2 (east portion)
	0.0	ORGANICS - rootlets
	0.1	SAND – some silt, trace cobbles, fine to medium grained sand, maximum aggregate size 250 mm, subrounded to rounded, damp, brown, rootlets to 300 mm
	0.35	Becomes dark brown
	1.3	END OF TESTPIT – REFUSAL ON PERMAFROST

Testpit	Depth (m)	Description
TP-34		NWH Landfill Location 2 (northwest portion)
	0.0	ORGANICS - rootlets
	0.1	SAND –trace silt, trace cobbles, occasional boulder up to 400 mm, fine to medium grained sand, subrounded to rounded, damp, brown
	1.0	Becomes coarser grained, grey (Sample at 0.15 – 0.25, M.C. = 9.9%)
	1.2	END OF TESTPIT – REFUSAL ON PERMAFROST Boulders present at the surface
TP-35		Lake Road (north side)
	0.0	SAND – some silt, fine grained, moist, tan, gravel and cobbles at surface
	1.0	END OF TESTPIT
TP-36		Lake Road (north side)
	0.0	SAND – some silt, fine grained, moist, tan, gravel and cobbles at surface
	1.1	END OF TESTPIT
TP-37		Borrow Area 2 (southwest portion)
	0.0	SAND and GRAVEL – some cobbles, trace silt, medium to coarse grained, maximum aggregate size 100 mm, sub angular to rounded, moist, brown Varying layers of finer and coarser material, brown
	1.2	END OF TESTPIT – REFUSAL ON PERMAFROST
TP-38		Borrow Area 2 (east portion)
	0.0	SAND and GRAVEL – some cobbles, trace silt, medium to coarse grained, maximum aggregate size 200 mm, sub angular to rounded, moist, brown
	0.4	SAND – trace silt, fine to medium grained, pockets of grey gravel and sand some silt, damp, varying orange/tan brown layers
	1.15	END OF TESTPIT – REFUSAL ON PERMAFROST
TP-39		Borrow Area 2 (north portion)
	0.0	SAND and GRAVEL – some cobbles, trace silt, medium to coarse grained, maximum aggregate size 200 mm, sub angular to rounded, moist, brown
	0.3	SAND – trace silt, fine to medium grained, pockets of grey gravel and sand some silt, damp, varying orange/tan brown layers
	1.0	100 mm lense of grey silt and sand
	1.1	SAND and GRAVEL – some cobbles, trace silt, coarse grained sand, maximum aggregate size 100 mm, sub angular to rounded, damp, grey
	1.5	END OF TESTPIT – REFUSAL ON PERMAFROST
TP-40		Borrow Area 2 (top of stockpile)
	0.0	SAND and GRAVEL – some cobbles, trace silt, coarse grained sand, maximum aggregate size 200 mm, sub angular to rounded, moist, grey (Sample at 0.3 – 1.0, Gravel = 33%, Sand = 64%, Silt/Clay = 0%, M.C. = 1.6%)
	1.8	END OF TESTPIT – REFUSAL ON PERMAFROST

Testpit	Depth (m)	Description
TP-41		Borrow Area 1 (east portion)
	0.0	SAND AND GRAVEL – some silt, some cobbles, trace clay, occasional boulders, well graded, subangular to subrounded, damp, brown (Sample at 0.0 – 0.3, Gravel = 36%, Sand = 47%, Silt/Clay = 17%, M.C. = 7.7%)
	0.3	END OF TESTPIT Boulders in area up to 1.2 m dia., approximately 30% oversize
TP-42		Borrow Area 1 (south portion)
	0.0	SAND AND GRAVEL – some silt, some cobbles, trace clay, occasional boulders, fine to medium grained sand, subangular to subrounded, damp, brown
	0.4	END OF TESTPIT – REFUSAL ON COBBLE Boulders in area up to 1.5 m dia., approximately 30% oversize
TP-43		Borrow Area 1 (southwest portion)
	0.0	SAND AND GRAVEL – some silt, some cobbles, trace clay, occasional boulders, fine to medium grained sand, subangular to subrounded, damp, brown
	0.6	(Sample at 0.2 – 0.6, M.C. = 7.6%) END OF TESTPIT Boulders in area up to 1.5 m dia., approximately 20% oversize
TP-44		Borrow Area 1 (west portion)
	0.0	SAND AND GRAVEL – silty, some cobbles, trace clay, occasional
	0.1	boulders, fine to medium grained sand, subangular to subrounded, damp, brown (Sample at 0.0 – 0.6)
	0.4	END OF TESTPIT – REFUSAL ON COBBLE Boulders in area up to 1.0 m dia., approximately 30% oversize
	1.2	
TP-45		Upper Station Road (upslope of south side)
	0.0	GRAVEL and SAND –silty, some cobble, some boulders, well graded, subangular to subrounded, damp to wet
	0.3	END OF TESTPIT Boulders up to 1.5 m dia.
TP-46		Upper Station Road (upslope of south side)
	0.0	SILT – sandy, gravelly, some clay, some cobble, some boulders, well graded, subangular to subrounded, low plasticity, wet, dark grey/brown
	0.3	END OF TESTPIT Boulders up to 1.5 m dia.

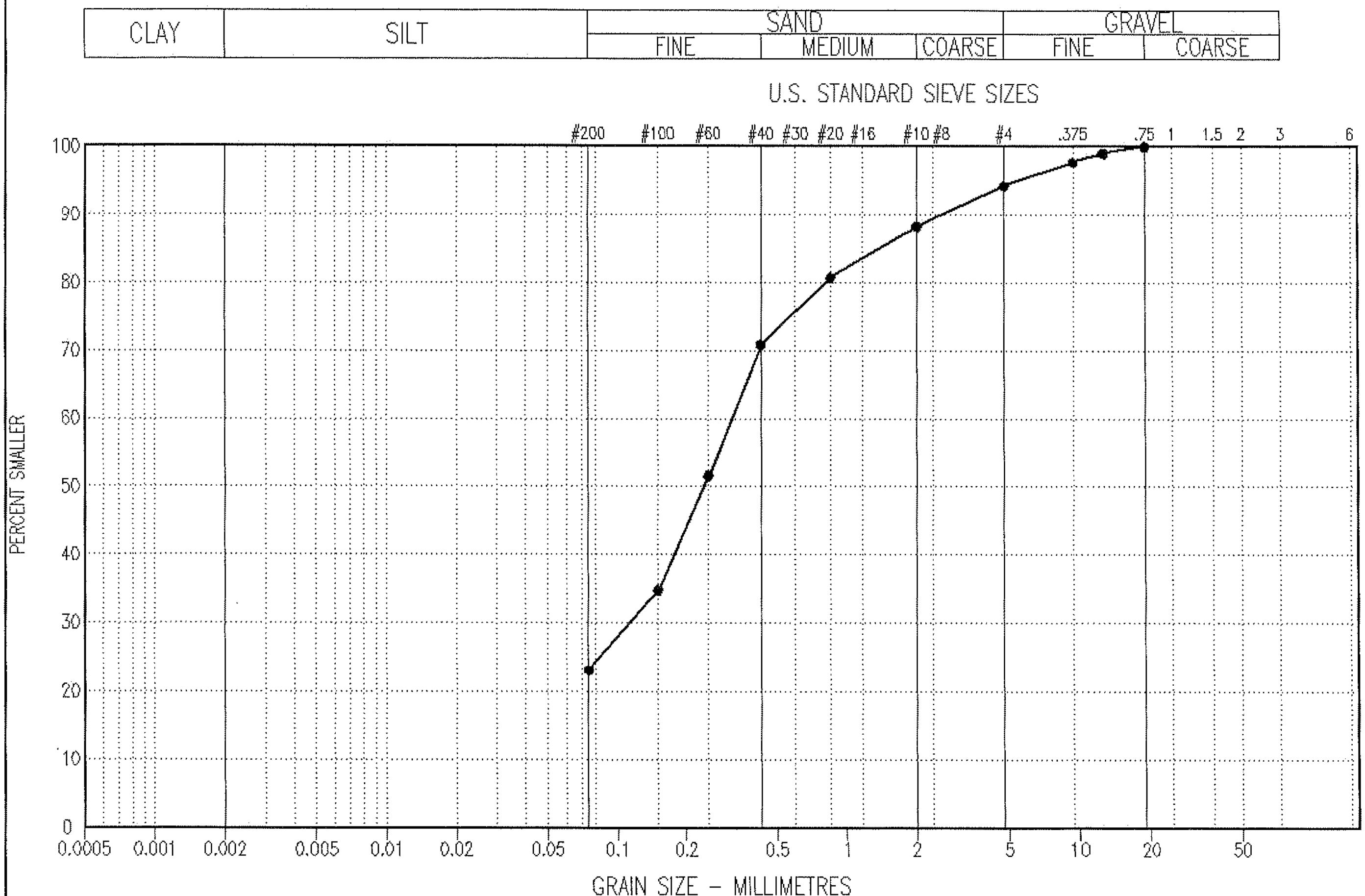
Testpit	Depth (m)	Description
TP-47		Upper Station Road (upslope of south side)
	0.0	GRAVEL and SAND –some silt, some cobble, some boulders, well graded, subangular to subrounded, wet
	0.3	END OF TESTPIT
		Boulders up to 2.5 m dia.
TP-48		Upper Station Road (upslope of south side)
	0.0	GRAVEL and SAND –some silt, some cobble, some boulders, well graded, subangular to subrounded, damp
	0.3	END OF TESTPIT
		Boulders up to 1.5 m dia.

APPENDIX C

GEOTECHNICAL LABORATORY ANALYSIS RESULTS

EBA Engineering

PARTICLE SIZE – ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION				Cu	Cc	U.S.C
			CLAY %	SILT %	SAND %	GRAVEL %			
●—●	TP-05	0.50 - 0.60	--- 23 ---		71	6	-	-	

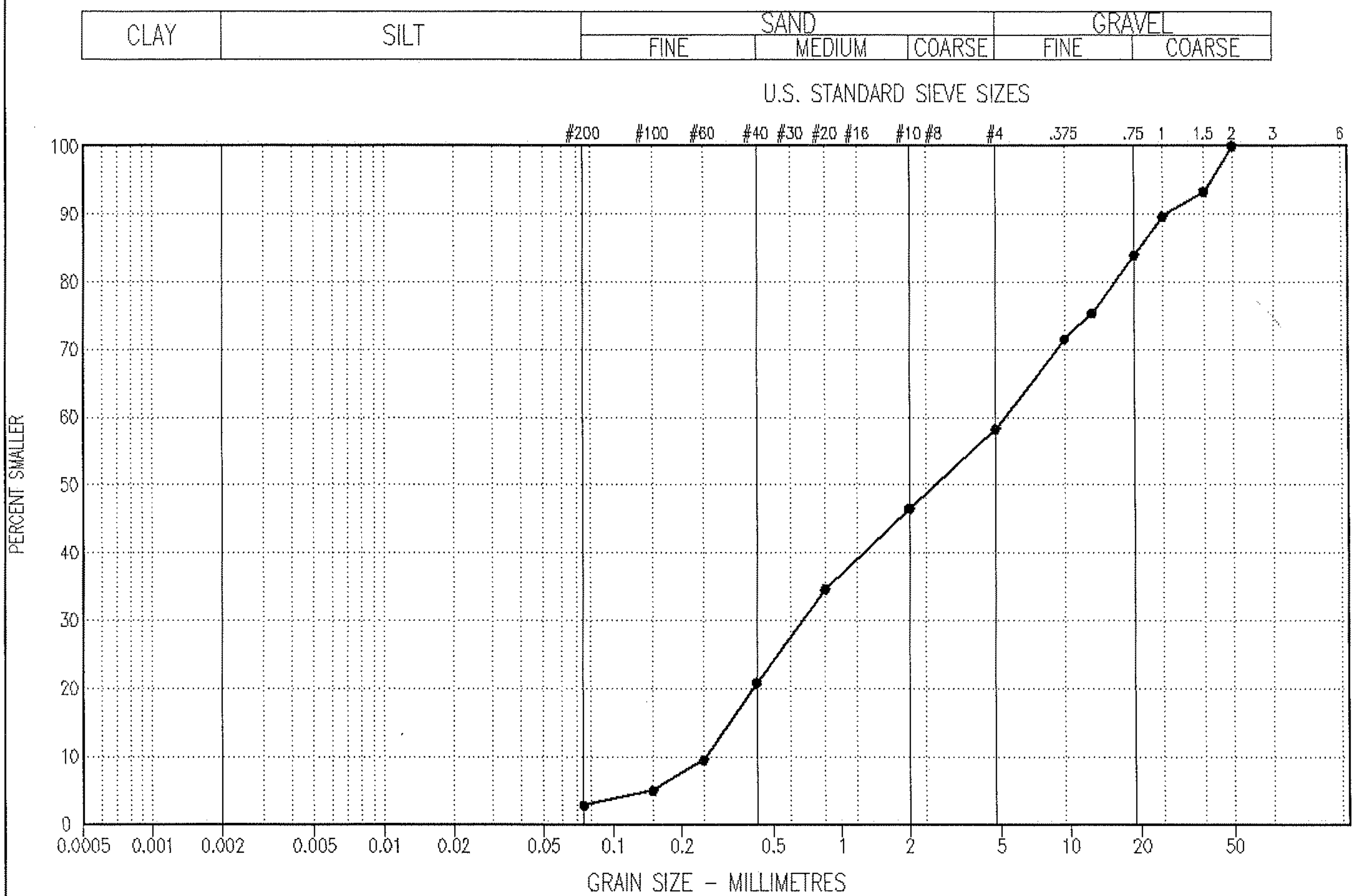
Note:
Trace cobbles in testpit.
Cobbles not included in sample.

Project: 0101-1100065.001 Date Tested: 04/09/21 BY: ZK

Tested in accordance with ASTM D422 unless otherwise noted.

EBA Engineering

PARTICLE SIZE - ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY %	SILT %	SAND %	GRAVEL %	Cu	Cc	U.S.C
•——•	TP-22	0.80 - 1.00	---	3 ---	55	42	20.8	0.4	SP

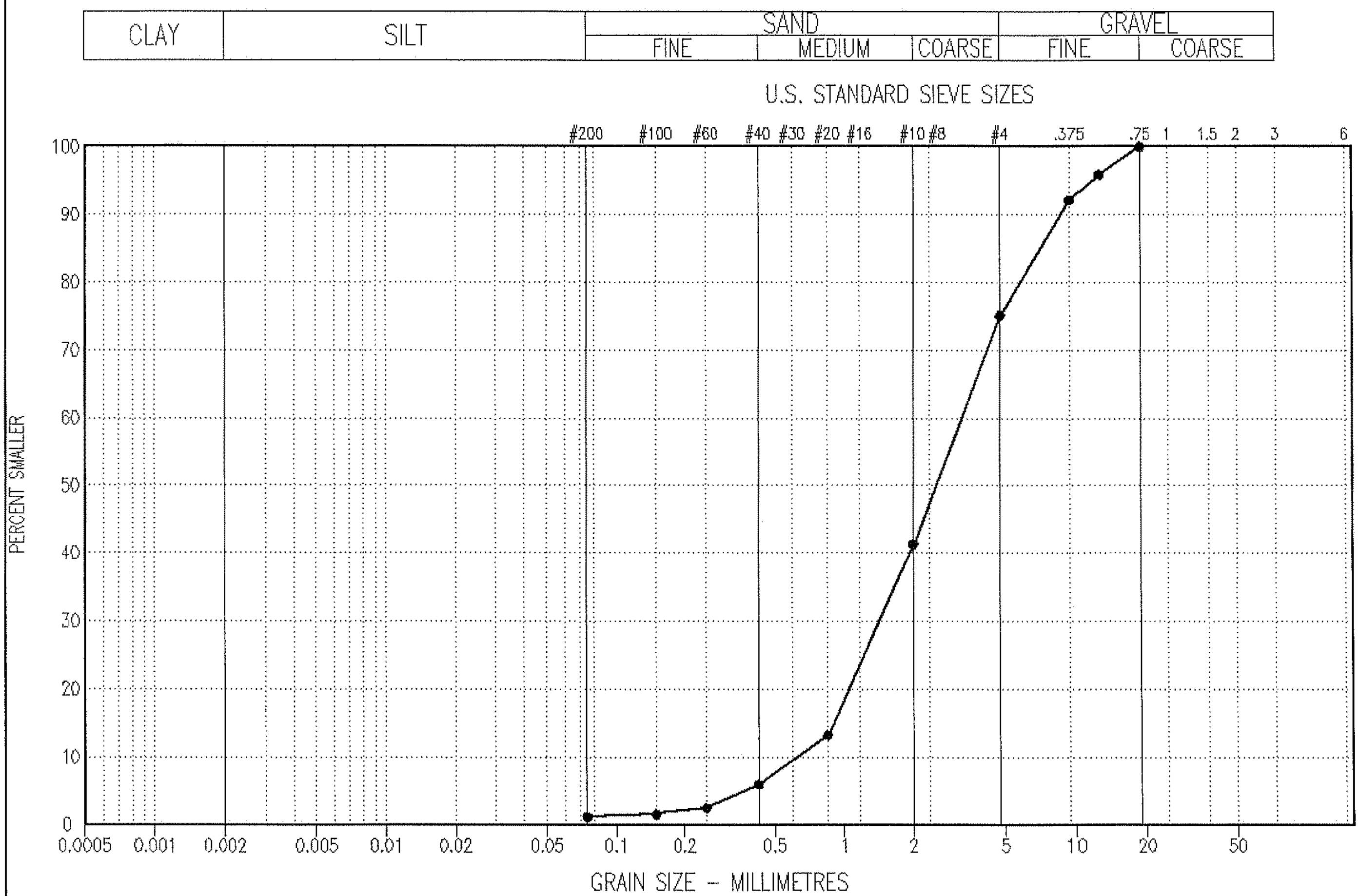
Note:
Some cobbles in testpit.
Cobbles not included in sample.

Project: 0101-1100065.001 Date Tested: 04/09/16 BY: ZK

Tested in accordance with ASTM D422 unless otherwise noted.

EBA Engineering

PARTICLE SIZE – ANALYSIS OF SOILS



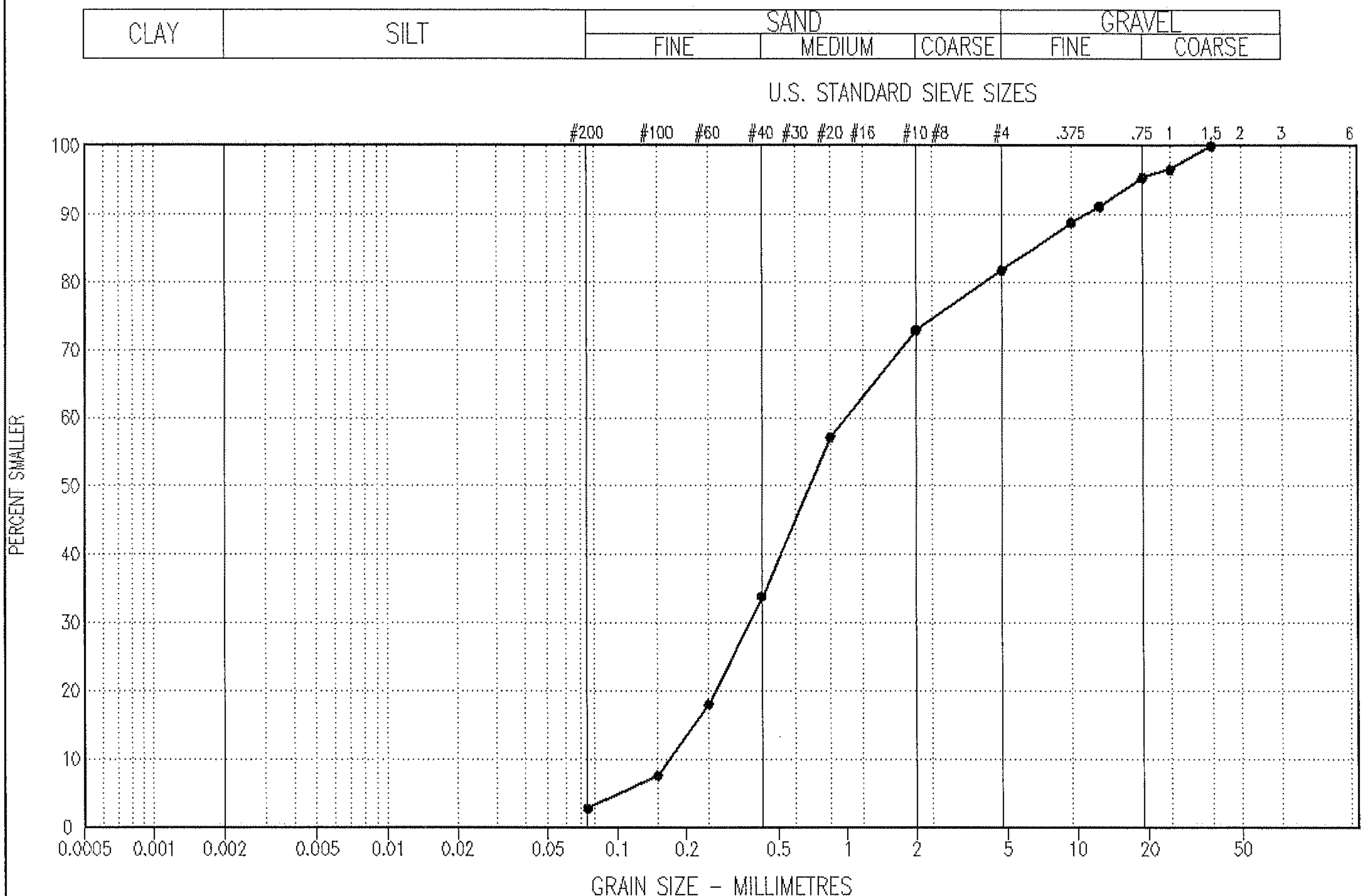
SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY %	SILT %	SAND %	GRAVEL %	Cu	Cc	U.S.C
●——●	TP-15	0.60 - 0.70	---	1 ---	74	25	5.3	1.0	SP

Note:
Trace cobbles in testpit.
Cobbles not included in sample.

Project: 0101-1100065.001 Date Tested: 04/09/21 BY: ZK

Tested in accordance with ASTM D422 unless otherwise noted.

PARTICLE SIZE - ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY %	SILT %	SAND %	GRAVEL %	Cu	Cc	U.S.C
●—●	TP-26	0.30 - 0.70	---	3 ---	78	19	6.1	0.8	SP

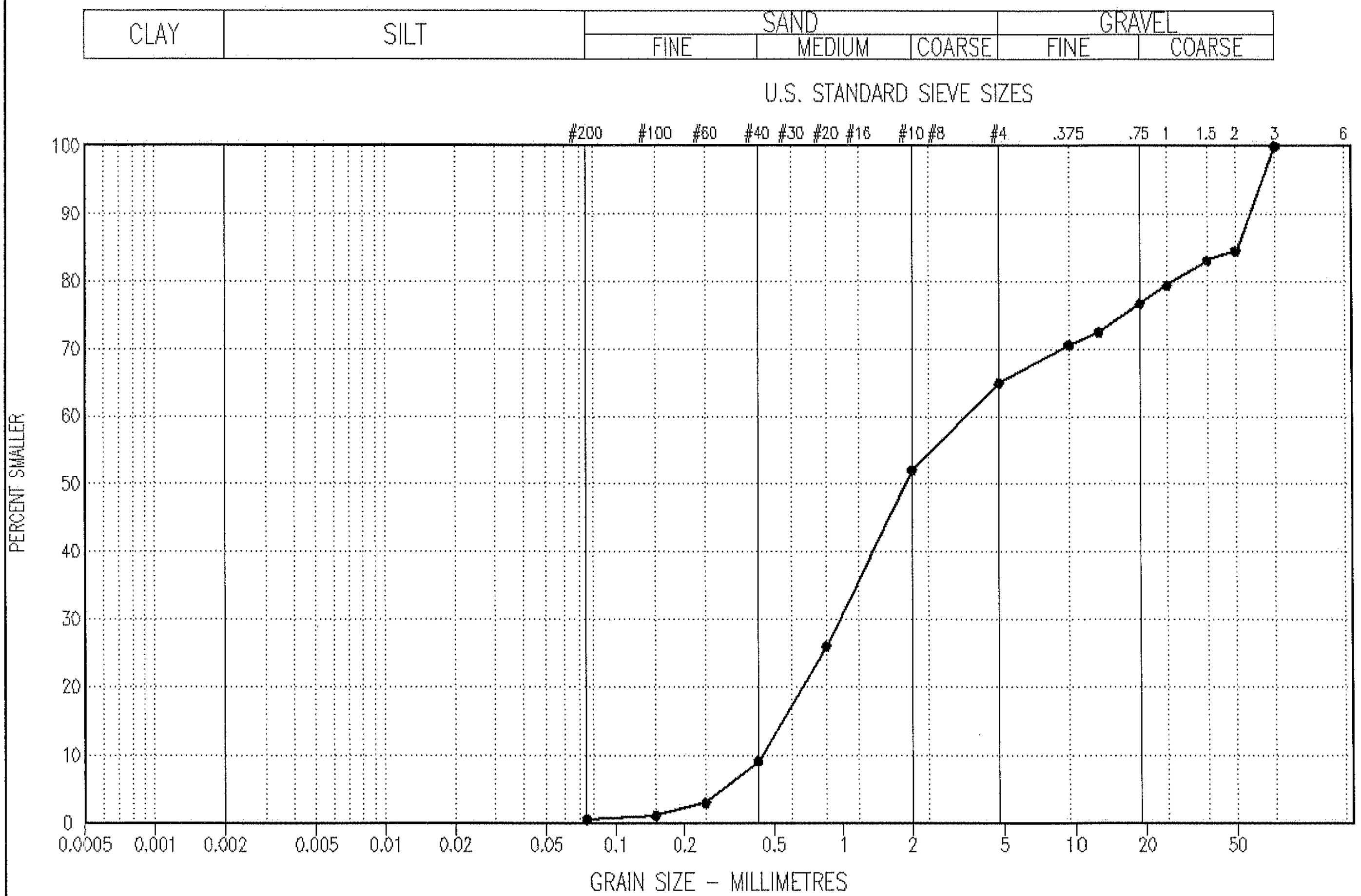
Note:
Trace cobbles in testpit.
Cobbles not included in sample.

Project: 0101-1100065.001 Date Tested: 04/09/16 BY: ZK

Tested in accordance with ASTM D422 unless otherwise noted.

EBA Engineering

PARTICLE SIZE - ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY %	SILT %	SAND %	GRAVEL %	Cu	Cc	U.S.C
●—●	TP-40	0.30 - 1.00	---	0 ---	64	36	8.3	0.6	SP

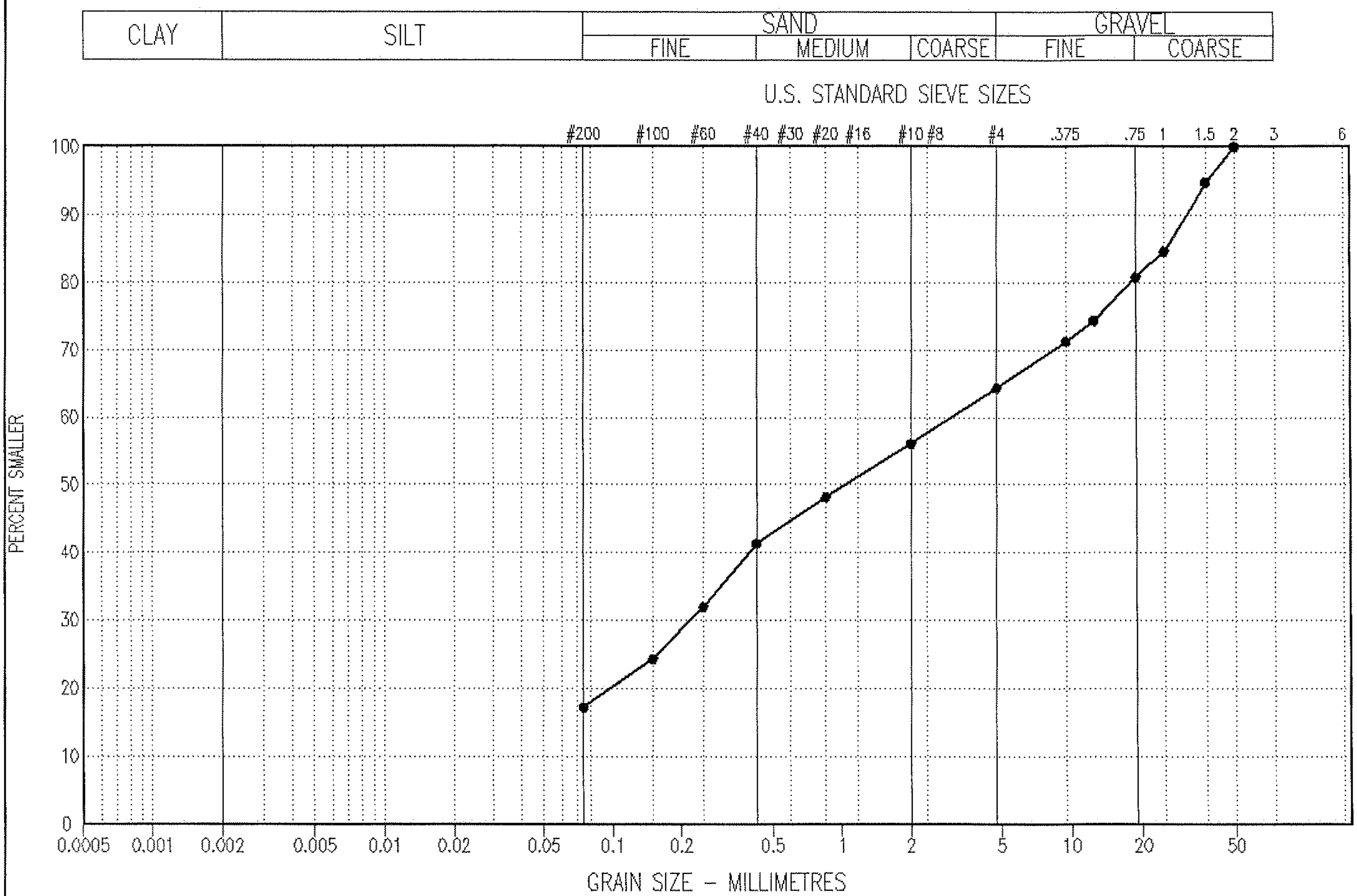
Note:
Some cobbles in testpit.
Cobbles not included in sample.

Project: 0101-1100065.001 Date Tested: 04/09/16 BY: ZK

Tested in accordance with ASTM D422 unless otherwise noted.

EBA Engineering

PARTICLE SIZE - ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY %	SILT %	SAND %	GRAVEL %	Cu	Cc	U.S.C
•——•	TP- 41	0.00 - 0.30	--- 17 ---		47	36	–	–	

Note:
Some cobbles in testpit.
Cobbles not included in sample.

Project: 0101-1100065.001 Date Tested: 04/09/16 BY: ZK

Tested in accordance with ASTM D422 unless otherwise noted.

APPENDIX D

GEOTECHNICAL REPORT
GENERAL CONDITIONS

This report incorporates and is subject to these "General Conditions."

1. USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of EBA's client. EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than EBA's client unless otherwise authorized in writing by EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of EBA. Additional copies of the report, if required, may be obtained upon request.

2. NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

3. LOGS OF TEST HOLES

The test hole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

4. STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

5. SURFACE WATER AND GROUNDWATER CONDITIONS

Surface and groundwater conditions mentioned in this report are those observed at the times recorded in the report. These conditions vary with geological detail between observation sites; annual, seasonal and special meteorologic conditions; and with development activity. Interpretation of water conditions from observations and records is judgmental and constitutes an evaluation of circumstances as influenced by geology, meteorology and development activity. Deviations from these observations may occur during the course of development activities.

6. PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

7. SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

8. INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

9. OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

10. DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

11. BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

12. SAMPLES

EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the client's expense upon written request, otherwise samples will be discarded.

13. STANDARD OF CARE

Services performed by EBA for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practising under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

14. ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

15. ALTERNATE REPORT FORMAT

Where EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed EBA's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by EBA shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by EBA shall be deemed to be the overall original for the Project.

The Client agrees that both electronic file and hard copy versions of EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EBA. The Client warrants that EBA's instruments of professional service will be used only and exactly as submitted by EBA.

The Client recognizes and agrees that electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.