DE BEERS CANADA

April 2012

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

Information Request Number: AANDC_23

Source: Aboriginal Affairs and Northern Development Canada (AANDC)

Subject: Borrow Materials – Quantities Available & Engineering Properties

EIS Section: Section 11.6: SON: Permafrost, Groundwater and Hydrogeology, Section 11.7: SON Vegetation, Annex D

Terms of Reference Section:

Preamble:

The stated objectives of the baseline program included:

- "… to complete a local and regional terrain (surficial material and landform) survey …" (De Beers 2010c, pg. D1-2) and
- "… to collect soil samples for laboratory analysis of … texture …" (De Beers 2010c, pg. D1-3)

Surficial materials are predominantly sandy, gravelly till with variable boulder content, which is described as a discontinuous veneer (<1 m thick) and occasionally thicker (1 to 4 m). Eskers are *"… of limited extent and unknown thickness."* (De Beers 2010c, pg. D5-3).

The till materials *"… commonly occur in association with other materials, especially with organic materials of peatlands."* (De Beers 2010c, esp. pgs. D5-5; also pg. D5-11 and Table D5.3-1).

"Permafrost features are common throughout the LSA. Piping, "boiling", and heaving of the active layer, thermokarst and thermo-erosion, and pingo development are of primary importance." (De Beers 2010c, pg D5-13 and Figures D7.3-1 to D7.3-7). Cryoturbation associated with these processes has the effect of mixing deleterious materials into the near-surface till deposits.

Field reconnaissance was undertaken to *"… verify the terrain units identified in the aerial photographs and assess the surficial soil composition."* (De Beers 2010c, pg. D7-10)

75 drill holes were completed to install 42 thermistors and, in part, *"… to retrieve good quality samples of … moraine, for boulder counts and geotechnical characterization."* (De Beers 2010c, pg. D7-4). *"Representative samples were tested for grain size distribution, hydrometer, and Atterberg limits tests."* (De Beers 2010c, pg. D7-5)

Interpretations as to erosion risk, acidification, sensitivity, and reclamation suitability (e.g. De Beers 2010e, Tables 11.7.I-9 and 11.7.I-11) and interpretations regarding performance of the materials as part of dyke and berm designs (EBA 2011a and b) are provided, yet none of the laboratory data are disclosed either as discrete test results or aggregate results. What are disclosed are generalized (e.g. De Beers 2010c, Table D7.2-6). These are inadequate to assess the suitability of the interpretations reported.

The construction quantities required (EBA 2011, Tables 6 and 7) are sizeable and it is unclear how much local borrow will be required until other "overburden" sources become available ((De Beers 2010b, pg. 3-32)

Request

1. The Proponent should provide the following:

    a) Grain size curves for all laboratory testing completed on borrow materials.

    b) Assessment of the percentage of inventoried borrow materials that will be useable when deleterious material content, recovery challenges (i.e. irregular bedrock surface configuration, wet nature of lake-bed sources, frozen condition of stock piles, etc.) are accounted for.

    c) If processing is required to eliminate deleterious materials (e.g. EBA 2011a, pg. 7) and/or to achieve suitable gradation (e.g. EBA 2011a, pgs. 7 to 9), where will this be located, what is the water-use requirement, and how will wash-water be managed?

d) Schedule as to where the materials will be recovered from (time and location) as required for construction of roads, air strip, pads, dykes, berms and for use in concrete aggregate.

e) Re-confirmation that a quarry and related processing will not be required for construction materials.

Response

a. The grain size curves for all laboratory tests completed on potential borrow materials can be found in Appendix AANDC_23-A, attached to this IR response. The borrow materials were evaluated for a previous study for the Project.

b. For the current project construction plan, there are no separate borrow or quarry sites for sourcing construction materials. The construction materials will be primarily obtained from pre-stripping of on-land portion of 5034 Pit for pre-production construction and from open pit mining operation for the remaining site construction activities. Preliminary yearly material balance indicates that the quantity of the materials from the pre-stripping and open pit operation will exceed the quantity of the construction materials required for site construction. The estimate of the available materials was obtained from the resource evaluation drilling and pit development plan and had accounted for deleterious material content and recovery challenges. When feasible, the materials (both overburden and rock) from construction cuts for the plant site and airstrip may be also used as site construction materials.

c. Where required, a crushing plant will be located adjacent to the source of mine rock. Crushing will be required to achieve the specific gradation from hard, durable, non-acid generating mine rock. Screening may be required for till fill material to remove boulder greater than 300 millimetre (mm). No water wash will be required.

d. The construction materials will be primarily obtained from pre-stripping of on-land portion of 5034 Pit for pre-production construction and from open pit mining operation for the remaining site construction activities. The schedule of the overburden extraction and utilization is presented in the Project Description Section 3, Table 3.7-1 in the 2012 EIS Supplement (De Beers 2012). The preliminary yearly material balance indicates that the quantity of the materials from the pre-stripping and open pit operation will exceed the quantity of the construction materials required for site construction. The material quantities and schedule for the dyke/berm construction is outlined in Appendix AANDC_23-B. The material required for the dyke/berm construction will come from pit mine rock, temporary stockpiles of crushed mine rock, temporary overburden stockpiles, mine rock piles, construction cuts, or coarse PK.

e. A separate quarry is not planned to be used for construction materials. It is planned that till overburden from pit development and crushed mine rock will be used for construction materials. Coarse processed kimberlite (PK) may be used as construction materials, subject to its availability and engineering properties.

References

De Beers. 2012. *Environmental Impact Statement Supplemental Information Submission for the Gahcho Kué Project*. Submitted to the Mackenzie Valley Environmental Impact Review Board. April 2012.

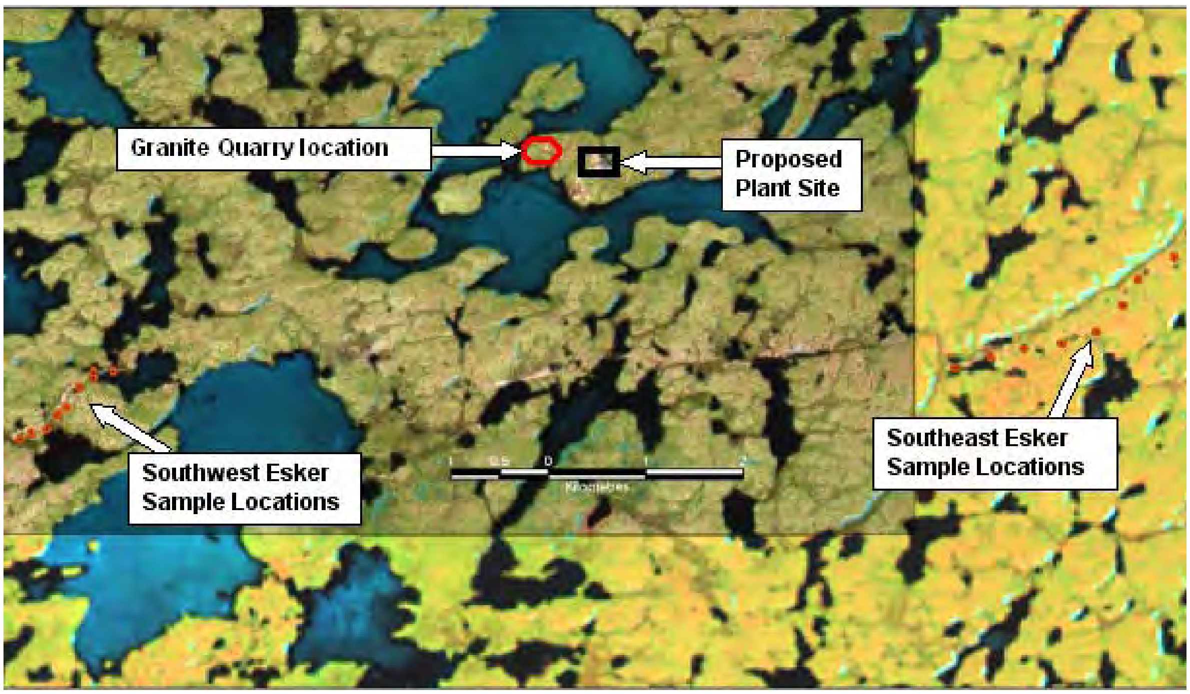
APPENDIX J

ESKERS AND QUARRY AGGREGATES EVALUATION

Development of the Gahcho Kué project will require a source of granular aggregate for concrete and filter materials for the construction of dykes. There are no suitable soils present in the immediate vicinity of Kennady Lake, therefore alternative borrow sources were identified for investigation. Two potential sources of aggregate were identified and sampled for testing in AMEC's laboratory in Edmonton. Samples were obtained from:

- Granitic country rock from the on-land portion of the 5034 Pit limit,
- Eskers located to the southeast and southwest of the Gahcho Kué Site

The relative locations of the borrow areas are illustrated in the figure below.



Granitic Country Rock

Core samples were obtained from the 5034 on-land drilling program carried out in early Spring of 2004, the core sampling procedures are presented in Appendix A. In total 9 composite samples were produced from core obtained from the following boreholes and respective depth intervals:

Sample #	Borehole #	Depth Interval (m)
1	MPV-04-199C	1-60
2	MPV-04-180C	1-41
3	MPV-04-180C	42-81
4	MPV-04-180C	82-126
5	MPV-04-145C	1-29
6	MPV-04-145C	30-57
7	MPV-04-145C	58-85
8	MPV-04-134C	1-23
9	MPV-04-134C	1-36

The core was crushed and then split into coarse and fine fractions. The fine and coarse fractions were subjected to a series of tests outlined by AMEC's Chief Materials Engineer (not all samples underwent every test) and are as follows:

- Sieve analysis of the fine and coarse aggregates (CSA-A23.2-2A).
- Amount of materials finer than 80 µm in aggregate (CSA-A23.2-5A).
- Relative density and absorption of fine and coarse aggregate (CSA-A23.2-6A,12A).
- Detailed petrographic analysis (ASTM-C295-90) (carried out in AMEC's Hamilton office).
- Soundness of aggregate by magnesium sulphate soundness test (CSA-A23.2-9A).
- Flat and elongated particles in coarse aggregate (CSA-A23.2-13A).
- Los Angeles abrasion resistance (CSA-A23.2-16A, 17A).
- Alkali-silica reactivity by accelerated expansion of mortar bars
  - (CSA-A23.2-25A) (a 16 day test)
  - If test 8 fails then perform length change due to alkali aggregate reaction in concrete prisms (CSA-A23.2-14A) (a 12 month test)

Complete testing results for the quarried country rock are presented in Appendix A. It is estimated that a pit developed in the area of the northeastern potion of the 5034 could yield 4.3 Mm^3 of granitic rock for processing

Samples of the granitic rock were also retrieved for acid base accounting (ABA) testing. Those results will be reported separately in the environmental baseline studies.

Esker Samples

Sand and gravel grab samples were gathered from two eskers located to the southwest and southeast of the Gahcho Kué site. An archaeologist accompanied the AMEC representative to identify and sites of interest, and to ensure sampling did not occur within a minimum of 30 metres of potential archaeological sites. In total 16 samples were obtained from the two eskers. Due to the limitations on the sampling procedures (only small grab samples were possible due to the remoteness of the site) the samples only provide a very limited indication of the material properties of the eskers. The 16 samples were sent to the AMEC Edmonton lab for grain size analysis. The volume of material available from the eskers was made from rough calculations (detailed survey was not available) in the field and are as follows:

- Esker 1 (SE) approximately 120,000 m^3
- Esker 2 (SW) approximately 75,000 m^3

Esker testing results and photographs are presented in Appendix C.

Discussion

All testing results were reviewed by AMEC's Chief Materials Engineer and are summarized as follows:

The samples appear to be of good quality for use in construction of concrete structures. Some processing will be required (screening and if necessary washing) to produce gradations conforming to the CSA A23.1 specifications

Specifically:

- Both the coarse and the fine aggregates display normal densities and low absorptions. This is beneficial for minimizing concrete creep and shrinkage
- Both the coarse and fine aggregates display sufficiently low values of mass loss in the Los Angeles Abrasion Test, to make them suitable for use in most concrete construction applications, including flatwork or pavements subjected to conventional vehicular induced traffic abrasion.
- Both the coarse and fine aggregates display very low values of mass loss in the magnesium sulphate soundness test, which is indicative of an aggregate which should have good frost resistance and resistance to degradation from chemical attack
- The coarse aggregates show generally good shape, as is indicated by the generally low amount of flat or elongated particles. This is beneficial for concrete consolidation and finishing.
- The aggregates show very low expansions in the CSA A23.2-25A accelerated mortar bar test for Alkali reactivity (AAR). This indicates that the concrete made with these aggregates should not suffer long-term degradation from AAR induced damage.

Gradation:

- The coarse aggregate fraction (>5mm) on average falls within the CSA A23.1 Table 5, Group 1, 20-5mm gradation envelope. There are, however some samples where the gradation falls outside of the fine side of the envelope. Blending during aggregate processing would be required to produce coarse aggregate with consistently suitable gradation.
- The fine aggregate fraction will require screening and also possibly washing to produce material which falls within the CSA A23.1 Table 4 FA1 gradation requirements for concrete sand. In particular there is an excess of material on the 0.16 and 0.08 sieves, which will need to be removed.
- Once the fine aggregate is processed, it is recommended that it be checked for freedom from deleterious organic impurities, using the CSA A23-A23.2-7A test.

The split between the coarse and fine aggregate fractions produced by the crushing of the core is unknown and will need to be evaluated in the field.

APPENDIX A

Core Sampling Procedures

<table>
<tr><th>Borehole Number</th><th>Collar Elev. (m)</th><th>Sampling Requirements</th><th>Sampling Interval/Frequency</th><th>Special Sample Handling Requirements</th><th>Samples Shipped to:</th></tr>
<tr><td>PG-1</td><td>416.77</td><td rowspan="4">Samples of the overburden granite (stop sampling once the borehole hits kimberlite) required for testing for suitability as a concrete aggregate source, both for plastic concrete (i.e. dykes cutoff wall) and for plant site concrete needs. Obtain samples to El. 380 m (i.e. about 25 m below Kennady Lake level).</td><td rowspan="4">Obtain about 2.5 kg of core (assuming granite overburden) at 5 m intervals in each borehole, down to El. 380 m. For about 125 m of drilling (above El. 380 m), this will yield about 60 kg of sample. Each sample should be bagged and labelled individually, with borehole number and depth indicated. Compositing of samples will be undertaken in the Materials Lab.</td><td rowspan="6">There is no requirement to prevent freeze/thaw of the samples. Nor is there any requirement to prevent changes in moisture content. Samples can be packed in boxes without need to minimize disturbance (i.e. core need not be kept upright).</td><td rowspan="6">AMEC Earth & Environmental Ltd., 4810 - 93rd Street, Edmonton, Alberta, T6E 5M4, phone: (780) 436-2152, Attention: Wayne Mah</td></tr>
<tr><td>PG-2</td><td>406.26</td></tr>
<tr><td>PG-10</td><td>412.97</td></tr>
<tr><td>ODS-17</td><td>405.14</td></tr>
<tr><td>D4-A-1T</td><td>405.57</td><td colspan="2" rowspan="2">As above, except these holes are angled and go only to 20 m depth. After geotechnical logging, retain 2.5 kg of core at 5 m intervals for each borehole, representing 10 kg of sample per abutment borehole.</td></tr>
<tr><td>D4-A-2T</td><td>404.26</td></tr>
<tr><td>D1-GB-01</td><td>404.22</td><td rowspan="17">4-inch diam. Core samples of lakebottom soft sediments (if can be sampled with Geobor apparatus) and till will be retrieved from these boreholes, drilled from the lake ice. The cores will be encased in plastic sleeve inserts within the coring apparatus, capped and sealed. <u>All</u> Geobor core retrieved from the boreholes will be required for shipping and logging/laboratory testing. Currently, assuming an average of 15 m of Geobor core (10 m in till, and 5 m into bedrock) per borehole, and 17 dyke boreholes, there will be about 255 m of Geobor S core retrieved during the program. NQ rock core retrieved from the boreholes will be geotechnically logged on site, and is not required for off-site testing.</td><td rowspan="17">Geobor S sampling will be continuous throughout the lakebottom tills, and 5 m into bedrock.</td><td rowspan="17">Geobor S core samples will come out of the ground unfrozen, and it is critical that they be maintained in that condition from retrieval through shipping off site. Upon retrieval from the core barrel, the ends of the plastic sleeve inserts containing the samples are to be capped, wrapped in saran wrap, and thoroughly sealed with duct tape to preserve the in situ moisture content of the samples. The core samples are to be shipped upright, and shall be packed in such a way that they undergo as little disturbance/jostling as possible during shipping.</td><td rowspan="17">AMEC Earth & Environmental Ltd., 4810 - 93rd Street, Edmonton, Alberta, T6E 5M4, phone: (780) 436-2152, Attention: Angela Kupper</td></tr>
<tr><td>D1-GB-02</td><td>404.2</td></tr>
<tr><td>D2-GB-05</td><td>404.31</td></tr>
<tr><td>D2-GB-06</td><td>404.26</td></tr>
<tr><td>D2-GB-07</td><td>404.6</td></tr>
<tr><td>D3-GB-01</td><td>404</td></tr>
<tr><td>D3-GB-02</td><td>404</td></tr>
<tr><td>D3-GB-03</td><td>404</td></tr>
<tr><td>D3-GB-04</td><td>404</td></tr>
<tr><td>D4-GB-01</td><td>404.23</td></tr>
<tr><td>D5-GB-01</td><td>404.44</td></tr>
<tr><td>D5-GB-02</td><td>404.5</td></tr>
<tr><td>D5-GB-03</td><td>405.35</td></tr>
<tr><td>D5-GB-04</td><td>404.34</td></tr>
<tr><td>D5-GB-05</td><td>404.8</td></tr>
<tr><td>D5-GB-06</td><td>404.26</td></tr>
<tr><td>D6-GB-01</td><td>404.16</td></tr>
</table>

APPENDIX B

Petrographic Report, Granite Samples, Grain Size Summary & Petrography Test Results

17 September 2004
File: VM00351

AMEC Earth & Environmental
2227 Douglas Road
Burnaby, British Columbia
V5C 5A9

Attention: Mr. Todd Martin, P.Eng.
Project Manager

Dear Sir;

RE: PETROGRAPHIC EXAMINATION OF PROPOSED CONCRETE AGGREGATE GAHCHO KUE' PRE-FEASIBILITY STUDY

1.0 INTRODUCTION

We are pleased to present the results of petrographic examinations carried out to assess the suitability of coarse and fine aggregate sampled from the overburden drilling program at Kennady Lake in the Northwest Territories for use as concrete aggregate. It is understood that this aggregate source has been proposed for a supply of concrete coarse and fine aggregate for the construction of mine site facilities for the Gahcho Kue' Diamond Project.

2.0 METHODOLOGY

A sample of the aggregate was received in our AMEC Hamilton, Ontario laboratory on 06 July 2004. Sampling details were not provided. The sample examined was separated into coarse and fine fractions and was labeled Sample 1. Nine samples were received in total.

Testing of the coarse and fine aggregate fractions included the following:

- ASTM C 295, ***Standard Guide for Petrographic Examination of Aggregates for Concrete;***
- CSA A23.2-15A, ***Petrographic Examination of Aggregates (Draft Version September 2003);***

3.0 RESULTS

3.1 Petrographic Examination - Coarse Aggregate

The coarse aggregate fraction comprised rock core crushed to a minus 20 mm sand and gravel.

One sieve fraction (-20 + 10 mm) was examined petrographically. This fraction was deemed representative of the entire coarse portion of the sample.

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The aggregate sample was composed almost entirely of an Alkali Granite (96.5 %) with the remaining 3.5 % consisting of individual grains of alkali feldspar (K-spar). A summary of the constituents and their quality is shown in Enclosure 1. The alkali granite was coarse grained with a rough texture. The feldspar grains were smooth-textured.

The alkali granite particles and feldspar grains were divided into individual quality classifications. The sample was found to consist of 88.9 % Good quality particles and 11.1 % Fair quality particles.

The Good quality particles were hard, unweathered, angular in shape and free of any surface coating or encrustations. Typically, the Fair quality particles are somewhat weathered and brittle (relatively low strength).

Based on the results of the petrographic observations, it is apparent that the coarse aggregate sample would be expected to display good performance in laboratory physical durability tests. The relatively high proportion (89 %) of Good quality material in the coarse aggregate fraction of the sample and lack of any Poor or Deleterious components indicates that the material would be acceptable for use in Portland cement concrete from a durability perspective.

Based on the procedure outlined in section 6.1.3 of CSA A23.2-15A, ***Petrographic Examination of Aggregates (draft version September 2003),*** the numerical quality indicator, or Petrographic Number (PN) determined for this aggregate is 122, which is indicative of a material of good physical-mechanical quality for use in concrete. According to the procedure, coarse aggregate for use in concrete pavement or flatwork should have a PN less than 125. Coarse aggregate proposed for use in concrete structures should have a PN less than 140.

Since this rock type is silicate-rich, this aggregate would have a high potential for being alkali-silica reactive. Appendix B of CSA A23.1, ***Alkali-Aggregate Reaction*** states in section B4.9 that…***Most of the reactive concrete aggregates are from sand and gravel deposits, containing variable amounts of sandstone, quartzite, chert, and volcanic, granitic, and metamorphic rocks.*** The coarse aggregate description for this sample is consistent with the comments presented in CSA A23.1-00 Appendix B and is indicative of an aggregate that has a high potential for deleterious expansion due to alkali-silica reactivity in Portland cement.

3.2 Petrographic Examination - Fine Aggregate Sample

As presented in Enclosure 2, the fine fraction of the sample was examined over the 2.5, 1.25, 0.630 and 0.315, 0.160 and 0.080 mm sieve sizes.

Enclosure 2 indicates that, compositionally, the fine aggregate is similar to the coarse aggregate sample in that it is composed entirely of alkali granite and its breakdown components which include individual grains of quartz, feldspar, amphibole and mica. These components display similar physical characteristics to their counterparts found in the coarse aggregate.

The fine aggregate was separated into 92.7 % Good quality particles, 3.0 % Fair quality and 4.3 % Poor quality particles. It should be noted that identification of the quality of fine aggregate is difficult due to the particle size. As such, separation of the particles into Good, Fair and Poor quality categories is based on mineralogical composition, and appearance/degree of fractured surfaces and weathering. The Good quality grains generally have rough surface texture, are angular and were observed to be of medium to high strength. The identification of Fair quality brittle alkali granite particles (3.0 % of the fine aggregate sample) is based on brittle or weathered particle appearance and the ability of the particle to resist probing with a metal needle. Poor quality mica and friable alkali granite particles (4.3 %) were observed to be of very low strength when probed, probably due to either inherent low strength and deep weathering.

The total proportion of Fair and Poor quality components in the fine aggregate accounts for 7.3 % overall. This proportion is considered relatively low and suggests, as with the coarse aggregate sample, that the sand would be durable with respect to physical/mechanical quality and acceptable for use in Portland cement concrete.

As with the coarse aggregate, the high proportion of silicate particles in the fine aggregate suggests a high potential for deleterious expansion due to alkali-silica reactivity in Portland cement concrete.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the petrographic examinations, the coarse and fine fractions of the aggregate sample appear suitable with respect to physical-mechanical quality for use in Portland cement concrete in their current as-received form. Physical durability testing should be conducted to verify the petrographic observations. Determination of deleterious substances or physical properties of the aggregate should be based on the CSA Test Methods detailed in CSA 23.1-00, Table 6, ***Limits for Deleterious Substances and Physical Properties of Aggregates.***

The petrographic observations indicated that the coarse and fine aggregates have a potential for deleterious expansion due to Alkali Silica Reactivity. As stated in CSA Standard Practice A23.2-27A, Figure 1 and according to Paragraph 2.3 of this standard practice, additional testing of these aggregates in Test Method CSA-A23.2-25A, ***Test Method for Detection of Alkali-Silica Reactive Aggregate by Accelerated Expansion of Mortar Bars,*** should be conducted.

We trust we have conducted this testing within our terms of reference. Should you have any questions, please contact our office

Yours truly,

AMEC Earth & Environmental

Reviewed by,

Ivan Severinsky, P.Geo
Senior Geologist

John Balinski, B.Sc.
Senior Materials Consultant

:is
Enclosures (2)

cc: Don Stefanyk, AMEC Edmonton

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CONCRETE AGGREGATE TEST REPORT

PROJECT: Gahcho Kue - Evaluation of Granite Overburden suitability for use as Aggregate
PROJECT No.: VM 00351
RECEIVING RECORD

Sample Description: Laboratory Crushed Core Samples
Sample Source: Group 1: Samples Nos. 04-AGG-199-01 to 60

RELATIVE DENSITY AND ABSORPTION OF COARSE AGGREGATE (CSA A23.2-12A

Bulk relative density(SSD): 2662 kg/m^3
Absorption : 0.35%

RELATIVE DENSITY AND ABSORPTION OF FINE AGGREGATE (CSA A23.2-6A

Bulk relative density(SSD): 2670 kg/m^3
Absorption : 0.28%

FLAT AND ELONGATED PARTICLES IN COARSE AGGREGATE (CSA A23.2-13A

Weighted Average: 4.8%

LOS ANGELES ABRASION OF COARSE AGGREGATE(CSA A23.2-16A

Material Grading: C
Loss at 500 Revolutions (%): 26.6%
Maximum Allowable by CSA A23.1-00: 50%

SOUNDNESS OF COARSE AGG. BY USE OF MAGNESIUM SULPHATE (CSA A23.2-9A

Weighted Average Loss: 0.38%
Maximum Allowable by CSA A23.1-00: 12%

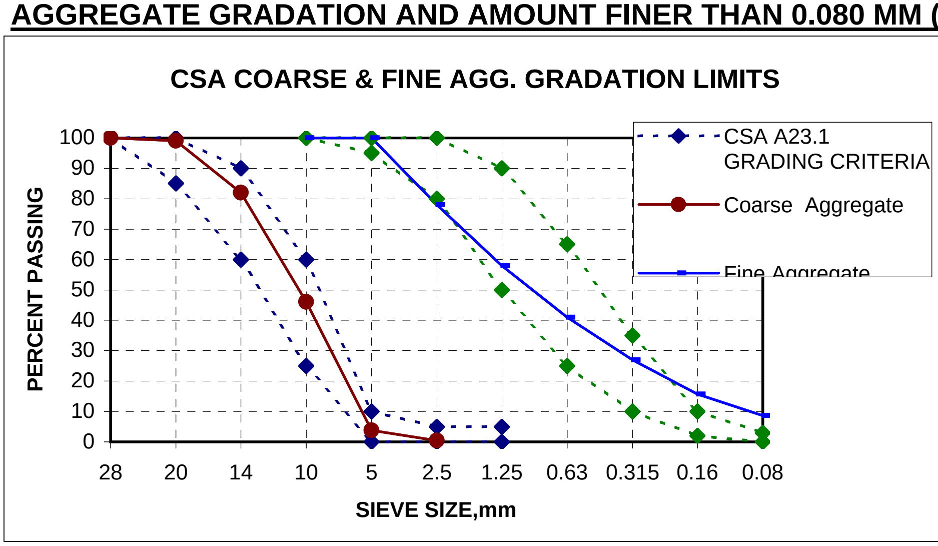
SOUNDNESS OF FINE AGGREGATE BY USE OF MAGNESIUM SULPHATE(CSA A23.2-9A

Weighted Average Loss: 2.0%
Maximum Allowable by CSA A23.1-00: 16%

ALKALI AGGREGATE REACTIVITY TEST(CSA A23.2-25a

Expansion (14 days): 0.04%
Maximum Allowable Expansion by CSA A23.2-28A: 0.10%

AGGREGATE GRADATION AND AMOUNT FINER THAN 0.080 MM (CSA A23.2-2A and 5A



Sieve Size (mm)	Coarse Aggregate	Fine Aggregate
28	100	
20	99	
14	82	
10	46	
5	4	100
2.5	0	78
1.25		58
0.63		41
0.315		27
0.16		16
0.08		8.6

CONCRETE AGGREGATE TEST REPORT

PROJECT: Gahcho Kue - Evaluation of Granite Overburden suitability for use as Aggregate
PROJECT No.: VM 00351

RECEIVING RECORD

Sample Description: Laboratory Crushed Core Samples
Sample Source: Group 2: Samples Nos. 04-AGG-180-001 to 041

RELATIVE DENSITY AND ABSORPTION OF COARSE AGGREGATE (CSA

Bulk relative density (SSD): 2646 kg/m^3
Absorption : 0.30%

RELATIVE DENSITY AND ABSORPTION OF FINE AGGREGATE (CSA

Bulk relative density (SSD): 2655 kg/m^3
Absorption : 0.32%

FLAT AND ELONGATED PARTICLES IN COARSE AGGREGATE (CSA A23.2 -13A

Weighted Average: 5.4%

LOS ANGELES ABRASION OF COARSE AGGREGATE (CSA A232.2-16A

Material Grading: C
Loss at 500 Revolutions (%): 25.6%
Maximum Allowable by CSA A23.1-00: 50%

SOUNDNESS OF COARSE AGG. BY USE OF MAGNESIUM SULPHATE (CSA A23.2-9A

Weighted Average Loss (5 cycles): 0.23%
Maximum Allowable by CSA A23.1-00: 12%

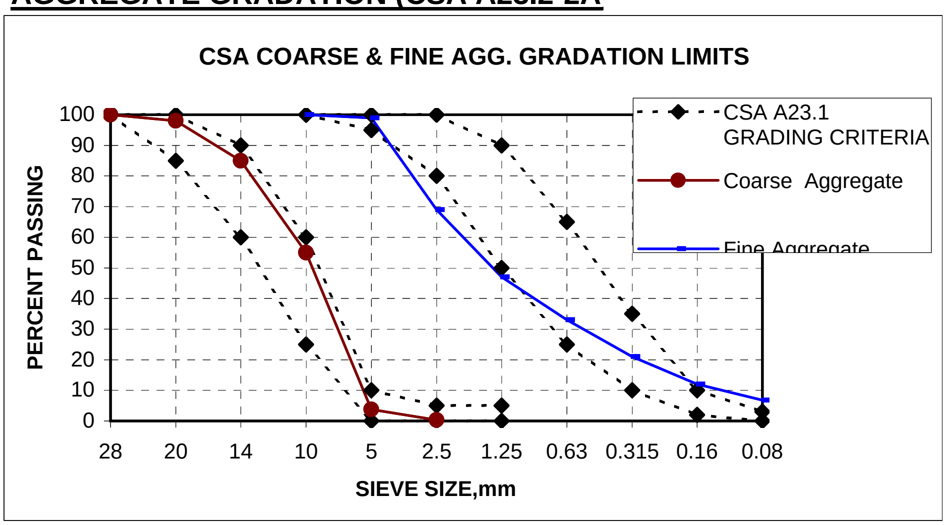
SOUNDNESS OF FINE AGGREGATE BY USE OF MAGNESIUM SULPHATE (CSA A23.2-9A

Weighted Average Loss (5 cycles): 1.3%
Maximum Allowable by CSA A23.1-00: 16%

ALKALI AGGREGATE REACTIVITY TEST(CSA A23.2-25a

Expansion (14 days): 0.04%
Maximum Allowable Expansion by CSA A23.2-28A: 0.10%

AGGREGATE GRADATION (CSA A23.2-2A



Sieve Size (mm)	Percent Passing Coarse Aggregate	Percent Passing Fine Aggregate
28	100	
20	98	
14	85	
10	55	100
5	4	99
2.5	0.3	69
1.25		47
0.63		33
0.315		21
0.16		12
0.08		6.8

CONCRETE AGGREGATE TEST REPORT

PROJECT: Gahcho Kue - Evaluation of Granite Overburden suitability for use as Aggregate
PROJECT No.: VM 00351

RECEIVING RECORD

Sample Description: Laboratory Crushed Core Samples
Sample Source: Group 3: Samples Nos. 04-AGG-180-042 to081

RELATIVE DENSITY AND ABSORPTION OF COARSE AGGREGATE (CSA

Bulk relative density (SSD): 2642 kg/m^3
Absorption : 0.28%

RELATIVE DENSITY AND ABSORPTION OF FINE AGGREGATE (CSA

Bulk relative density (SSD): 2657 kg/m^3
Absorption : 0.31%

FLAT AND ELONGATED PARTICLES IN COARSE AGGREGATE (CSA A23.2 -13A

Weighted Average: 4.0%

LOS ANGELES ABRASION OF COARSE AGGREGATE (CSA A232.2-16A

Material Grading: C
Loss at 500 Revolutions (%): 28.0%
Maximum Allowable by CSA A23.1-00: 50%

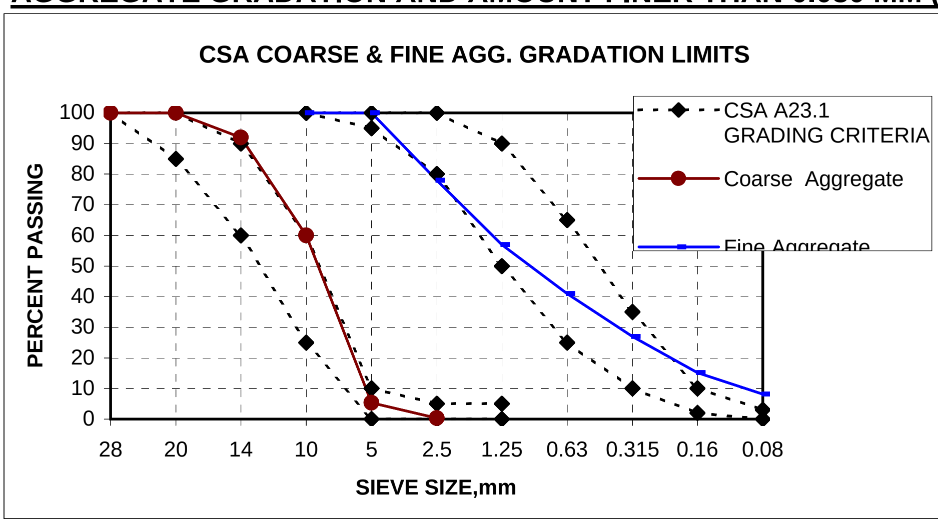
SOUNDNESS OF COARSE AGG. BY USE OF MAGNESIUM SULPHATE (CSA A23.2-9A

Weighted Average Loss (5 cycles): 0.23%
Maximum Allowable by CSA A23.1-00: 12%

SOUNDNESS OF FINE AGGREGATE BY USE OF MAGNESIUM SULPHATE (CSA A23.2-9A

Weighted Average Loss (5 cycles): 1.3%
Maximum Allowable by CSA A23.1-00: 16%

AGGREGATE GRADATION AND AMOUNT FINER THAN 0.080 MM (CSA A23.2-2A and 5A



Sieve Size (mm)	Percent Passing	
	Coarse Aggregate	Fine Aggregate
28	100	
20	100	
14	92	
10	60	100
5	5	100
2.5	0.3	78
1.25		57
0.63		41
0.315		27
0.16		15
0.08		8.2

CONCRETE AGGREGATE TEST REPORT

PROJECT: Gahcho Kue - Evaluation of Granite Overburden suitability for use as Aggregate
PROJECT No.: VM00351
RECEIVING RECORD

Sample Description:	Laboratory Crushed Core Samples
Sample Source:	Group 4: Samples Nos. 04-AGG-180-082 to 126

RELATIVE DENSITY AND ABSORPTION OF COARSE AGGREGATE (CSA

Bulk relative density (SSD):	2629 kg/m^3
Absorption :	0.30%

RELATIVE DENSITY AND ABSORPTION OF FINE AGGREGATE (CSA

Bulk relative density (SSD):	2646 kg/m^3
Absorption :	0.26%

FLAT AND ELONGATED PARTICLES IN COARSE AGGREGATE (CSA A23.2 -13A

Weighted Average:	2.5%

LOS ANGELES ABRASION OF COARSE AGGREGATE (CSA A232.2-16A

Material Grading:	C
Loss at 500 Revolutions (%):	28.0%
Maximum Allowable by CSA A23.1-00:	50%

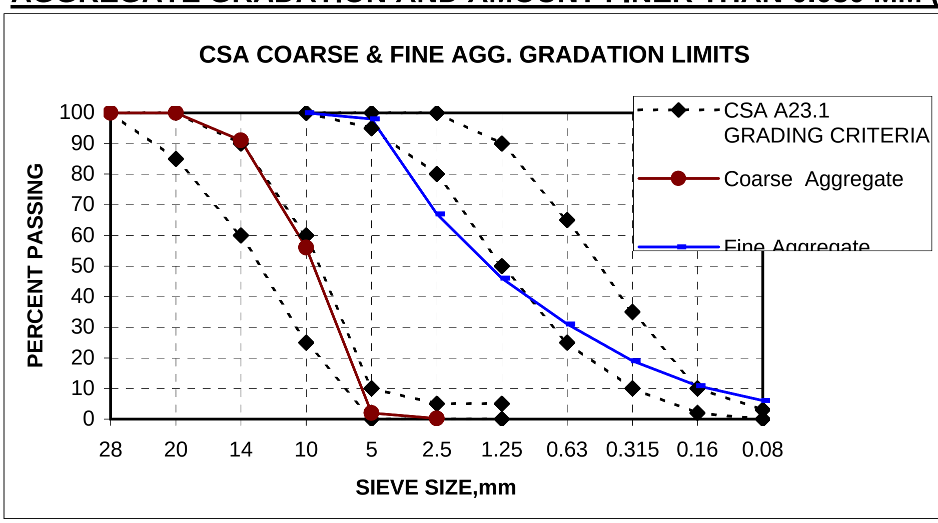
SOUNDNESS OF COARSE AGG. BY USE OF MAGNESIUM SULPHATE (CSA A23.2-9A

Weighted Average Loss (5 cycles):	0.39%
Maximum Allowable by CSA A23.1-00:	12%

SOUNDNESS OF FINE AGGREGATE BY USE OF MAGNESIUM SULPHATE (CSA A23.2-9A

Weighted Average Loss (5 cycles):	2.3%
Maximum Allowable by CSA A23.1-00:	16%

AGGREGATE GRADATION AND AMOUNT FINER THAN 0.080 MM (CSA A23.2-2A and 5A



Sieve Size (mm)	Percent Passing	
	Coarse Aggregate	Fine Aggregate
28	100	
20	100	
14	91	
10	56	100
5	2	98
2.5	0.2	67
1.25		46
0.63		31
0.315		19
0.16		11
0.08		6.1

CONCRETE AGGREGATE TEST REPORT

PROJECT: Gahcho Kue - Evaluation of Granite Overburden suitability for use as Aggregate
PROJECT No.: VM00351
RECEIVING RECORD

Sample Description:	Laboratory Crushed Core Samples
Sample Source:	Group 5: Samples Nos. 04-AGG-145-001 to 029

RELATIVE DENSITY AND ABSORPTION OF COARSE AGGREGATE (CSA

Bulk relative density (SSD):	2645 kg/m^3
Absorption :	0.30%

RELATIVE DENSITY AND ABSORPTION OF FINE AGGREGATE (CSA

Bulk relative density (SSD):	2647 kg/m^3
Absorption :	0.33%

FLAT AND ELONGATED PARTICLES IN COARSE AGGREGATE (CSA A23.2 -13A

Weighted Average:	2.6%

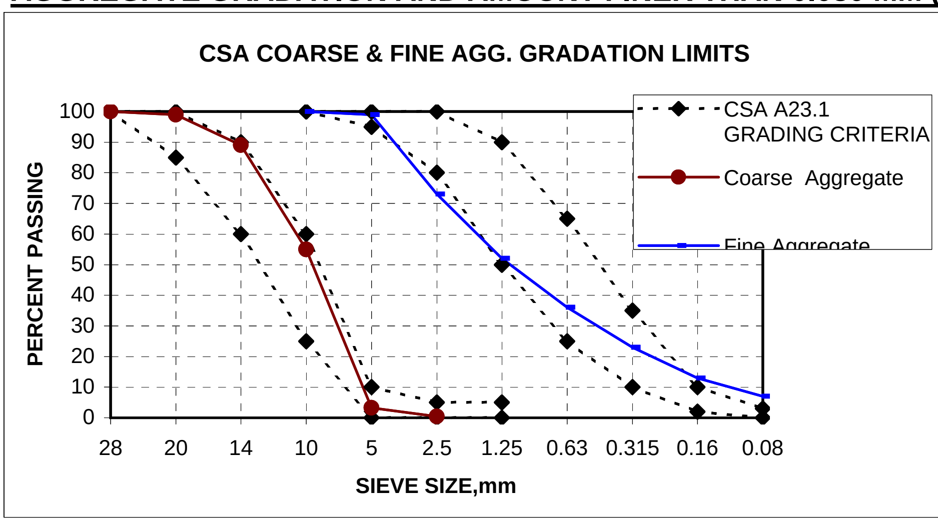
SOUNDNESS OF COARSE AGG. BY USE OF MAGNESIUM SULPHATE (CSA A23.2-9A

Weighted Average Loss (5 cycles):	0.37%
Maximum Allowable by CSA A23.1-00:	12%

SOUNDNESS OF FINE AGGREGATE BY USE OF MAGNESIUM SULPHATE (CSA A23.2-9A

Weighted Average Loss (5 cycles):	1.2%
Maximum Allowable by CSA A23.1-00:	16%

AGGREGATE GRADATION AND AMOUNT FINER THAN 0.080 MM (CSA A23.2-2A and 5A



Sieve Size (mm)	Percent Passing Coarse Aggregate	Percent Passing Fine Aggregate
28	100	
20	99	
14	89	
10	55	100
5	3	99
2.5	0	73
1.25		52
0.63		36
0.315		23
0.16		13
0.08		7.0

CONCRETE AGGREGATE TEST REPORT

PROJECT: Gahcho Kue - Evaluation of Granite Overburden suitability for use as Aggregate
PROJECT No.: VM 00351

RECEIVING RECORD

Sample Description: Laboratory Crushed Core Samples
Sample Source: Group 6: Samples Nos. 04-AGG-145-030 to 057

RELATIVE DENSITY AND ABSORPTION OF COARSE AGGREGATE (CSA

Bulk relative density (SSD): 2638 kg/m^3
Absorption : 0.38%

RELATIVE DENSITY AND ABSORPTION OF FINE AGGREGATE (CSA

Bulk relative density (SSD): 2644 kg/m^3
Absorption : 0.33%

FLAT AND ELONGATED PARTICLES IN COARSE AGGREGATE (CSA A23.2 -13A

Weighted Average: 3.7%

LOS ANGELES ABRASION OF COARSE AGGREGATE (CSA A232.2-16A

Composite Sample from Groups 6 and 7
Material Grading: C
Loss at 500 Revolutions (%): 27.3%
Maximum Allowable by CSA A23.1-00: 50%

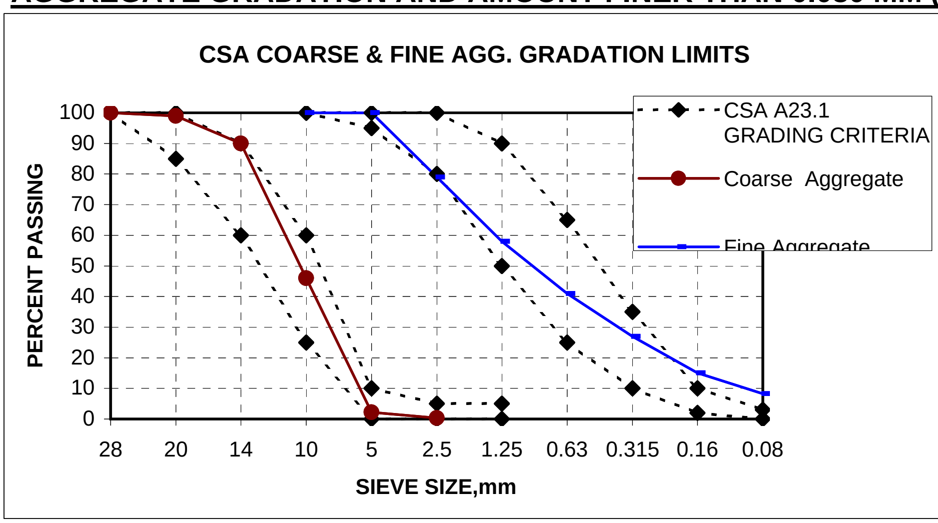
SOUNDNESS OF COARSE AGG. BY USE OF MAGNESIUM SULPHATE (CSA A23.2-9A

Weighted Average Loss (5 cycles): 0.52%
Maximum Allowable by CSA A23.1-00: 12%

SOUNDNESS OF FINE AGGREGATE BY USE OF MAGNESIUM SULPHATE (CSA A23.2-9A

Weighted Average Loss (5 cycles): 1.9%
Maximum Allowable by CSA A23.1-00: 16%

AGGREGATE GRADATION AND AMOUNT FINER THAN 0.080 MM (CSA A23.2-2A and 5A



Sieve Size (mm)	Percent Passing Coarse Aggregate	Percent Passing Fine Aggregate
28	100	
20	99	
14	90	
10	46	100
5	2	100
2.5	0	79
1.25		58
0.63		41
0.315		27
0.16		15
0.08		8.3

CONCRETE AGGREGATE TEST REPORT

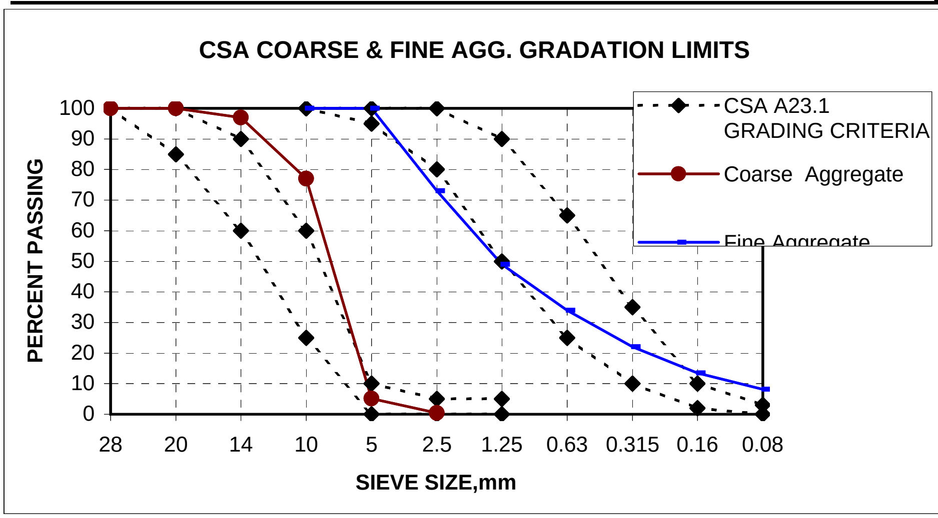
PROJECT: Gahcho Kue - Evaluation of Granite Overburden suitability for use as Aggregate
PROJECT No.: VM00351
RECEIVING RECORD

Sample Description: Laboratory Crushed Core Samples
Sample Source: Group 7: Samples Nos. 04-AGG-145-058 to 085

LOS ANGELES ABRASION OF COARSE AGGREGATE (CSA A232.2-16A

Composite Sample from Groups 6 and 7
Material Grading: C
Loss at 500 Revolutions (%): 27.3%
Maximum Allowable by CSA A23.1-00: 50%

AGGREGATE GRADATION AND AMOUNT FINER THAN 0.080 MM (CSA A23.2-2A and 5A



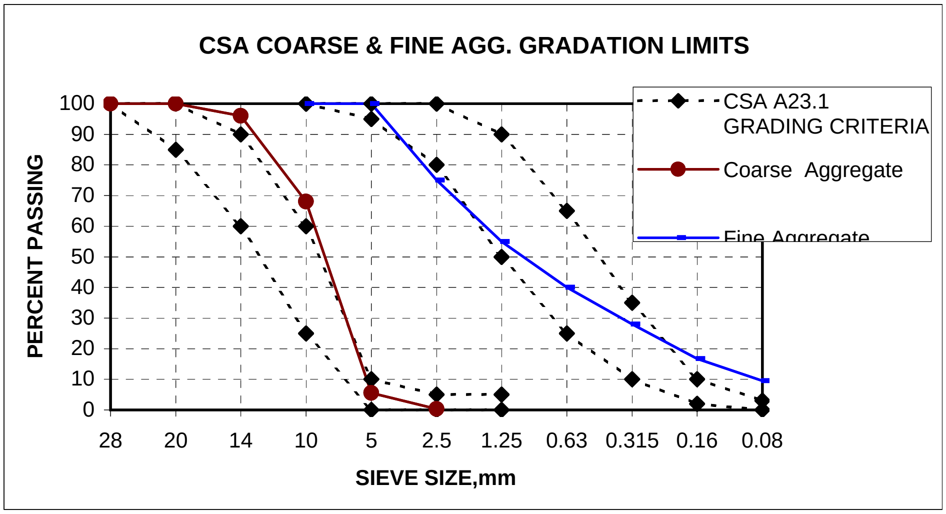
Sieve Size (mm)	Percent Passing	
	Coarse Aggregate	Fine Aggregate
28	100	
20	100	
14	97	
10	77	100
5	5	100
2.5	0	73
1.25		49
0.63		34
0.315		22
0.16		14
0.08		8.1

CONCRETE AGGREGATE TEST REPORT

PROJECT: Gahcho Kue - Evaluation of Granite Overburden suitability for use as Aggregate
PROJECT No.: VM00351
RECEIVING RECORD

Sample Description: Laboratory Crushed Core Samples
Sample Source: Group 8: Samples Nos. 04-AGG-134-001 to 023

AGGREGATE GRADATION AND AMOUNT FINER THAN 0.080 MM (CSA A23.2-2A and 5A



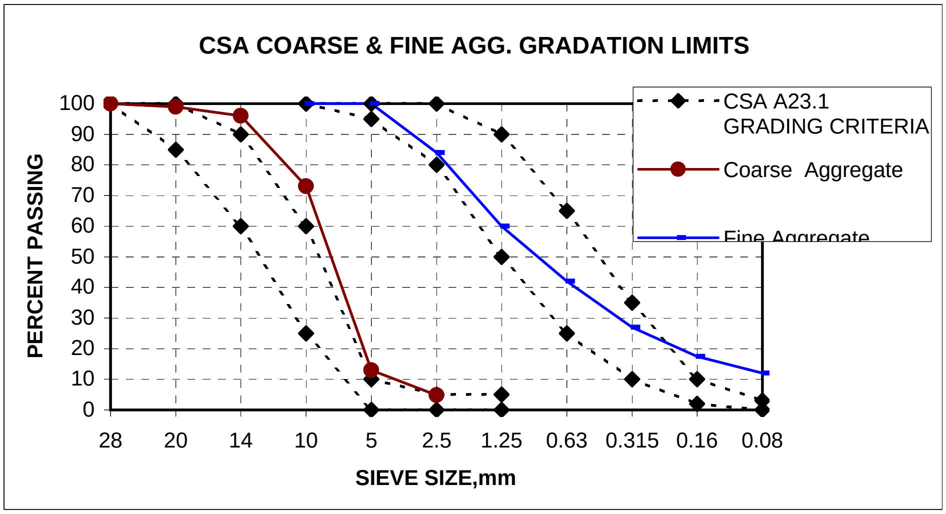
Sieve Size (mm)	Percent Passing	
	Coarse Aggregate	Fine Aggregate
28	100	
20	100	
14	96	
10	68	100
5	6	100
2.5	0.3	75
1.25		55
0.63		40
0.315		28
0.16		17
0.08		9.5

CONCRETE AGGREGATE TEST REPORT

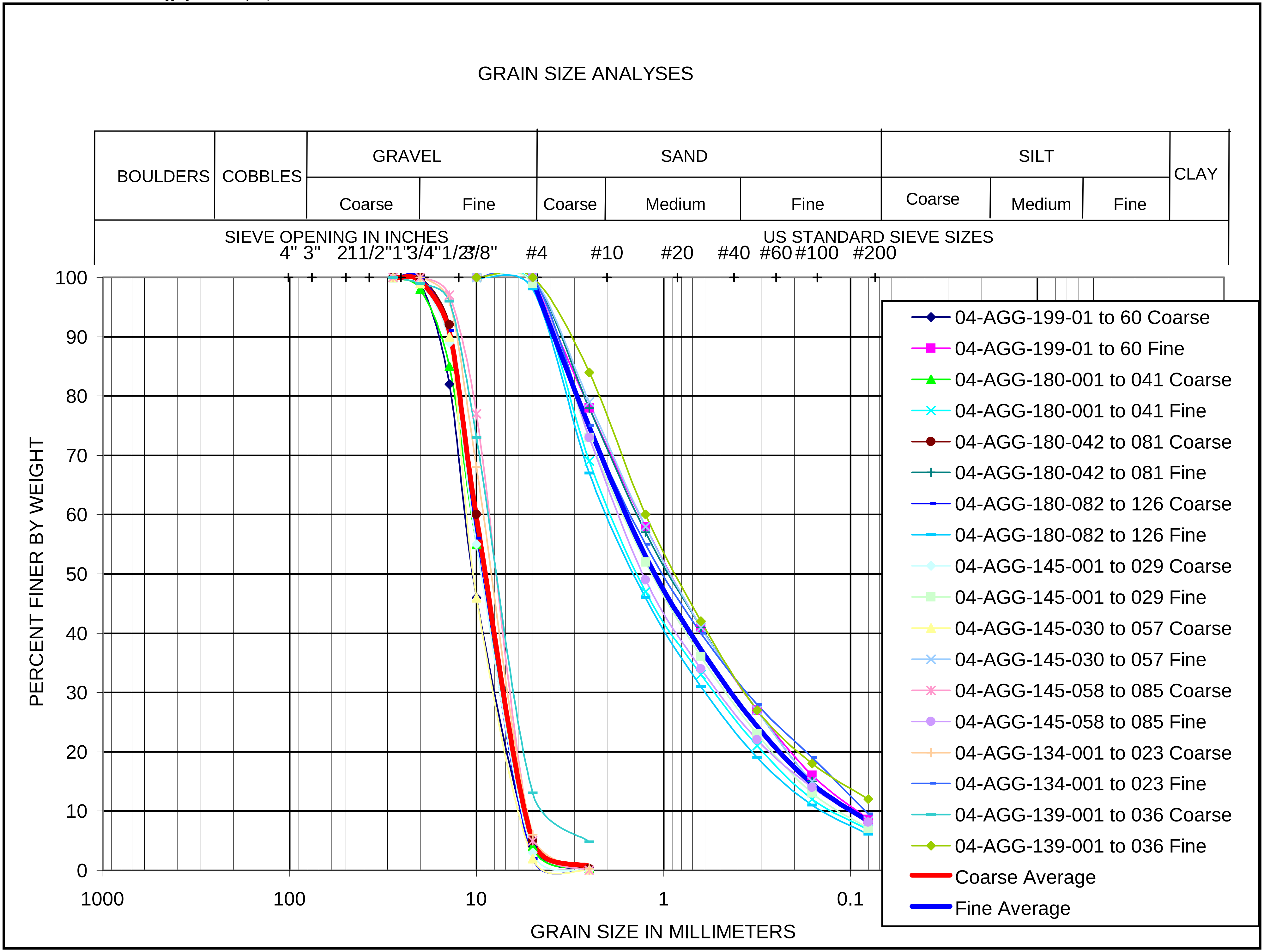
PROJECT: Gahcho Kue - Evaluation of Granite Overburden suitability for use as Aggregate
PROJECT No.: VM00351
RECEIVING RECORD

Sample Description: Laboratory Crushed Core Samples
Sample Source: Group 9: Samples Nos. 04-AGG-139-001 to 036

AGGREGATE GRADATION AND AMOUNT FINER THAN 0.080 MM (CSA A23.2-2A and 5A



Sieve Size (mm)	Percent Passing	
	Coarse Aggregate	Fine Aggregate
28	100	
20	99	
14	96	
10	73	100
5	13	100
2.5	4.8	84
1.25		60
0.63		42
0.315		27
0.16		18
0.08		12.0


GRAIN SIZE ANALYSES
BOULDERS
COBBLES
GRAVEL
Coarse
Fine
SAND
Coarse
Medium
Fine
SILT
Coarse
Medium
Fine
CLAY
SIEVE OPENING IN INCHES
US STANDARD SIEVE SIZES
4" 3" 2" 11/2" 1" 3/4" 1/2" 3/8" #4 #10 #20 #40 #60 #100 #200
PERCENT FINER BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
1000
100
10
1
0.1
GRAIN SIZE IN MILLIMETERS
04-AGG-199-01 to 60 Coarse
04-AGG-199-01 to 60 Fine
04-AGG-180-001 to 041 Coarse
04-AGG-180-001 to 041 Fine
04-AGG-180-042 to 081 Coarse
04-AGG-180-042 to 081 Fine
04-AGG-180-082 to 126 Coarse
04-AGG-180-082 to 126 Fine
04-AGG-145-001 to 029 Coarse
04-AGG-145-001 to 029 Fine
04-AGG-145-030 to 057 Coarse
04-AGG-145-030 to 057 Fine
04-AGG-145-058 to 085 Coarse
04-AGG-145-058 to 085 Fine
04-AGG-134-001 to 023 Coarse
04-AGG-134-001 to 023 Fine
04-AGG-139-001 to 036 Coarse
04-AGG-139-001 to 036 Fine
Coarse Average
Fine Average

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PETROGRAPHIC EXAMINATION OF COARSE AGGREGATE FOR CONCRETE
ASTM Designation: C295
CALCULATION OF RESULTS OF PARTICLE COUNTS

Project:	**VM00351**	**Source:**	**Gahcho Kue Pre-Feasibility Study**
Lab No.:	**S0321**	**Date:**	**September 15, 2004**
Client:	**AMEC E&C SERVICES LIMITED**	**Analyst:**	**Ivan Severinsky**

Composition of Fractions Retained on Sieves Shown Below

Individual Percentage Retained on Sieve — **20-10 mm**

Constituents	**No. of Particles**	**%**
Alkali granite, coarse grained, angular, subhedral grains, rough texture, hard	292	85.4
Alkali granite, coarse grained, angular, rough texture, brittle, subhedral grains	38	11.1
Alkali feldspar, angular, subhedral, some quartz present	12	3.5
Totals	342	100

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PETROGRAPHIC EXAMINATION OF COARSE AGGREGATE FOR CONCRETE

ASTM Designation: C295

CALCULATION OF RESULTS OF PARTICLE COUNTS

Project:	VM00351	**Source:**	**Gahcho Kue Pre-Feasibility Study**
Lab No.:	S0321	**Date:**	**September 15, 2004**
Client:	AMEC E&C SERVICES LIMITED	**Analyst:**	**Ivan Severinsky**

WEIGHTED PERCENTAGES OF CONSTITUENTS IN EACH SIEVE FRACTION

Constituents	20-10 mm	Weighted Composition of Sample
Alkali granite, coarse grained, angular, subhedral grains, rough texture, hard	85.4	85.4
Alkali granite, coarse grained, angular, rough texture, brittle, subhedral grains	11.1	11.1
Alkali feldspar, angular, subhedral, some quartz present	3.5	3.5
Total in sieve fraction (in %)	100.0	100.0
Total in sample, good aggregate		
Total in sample, fair aggregate		
Total in sample, poor aggregate		

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PETROGRAPHIC EXAMINATION OF COARSE AGGREGATE FOR CONCRETE
ASTM C-295
COMPOSITION AND CONDITION OF AGGREGATE SAMPLE

Project:	**VM00351**	**Source:**	**Gahcho Kue Pre-Feasibility Study**
Lab No.:	**S0321**	**Date:**	**September 15, 2004**
Client:	**AMEC E&C SERVICES LIMITED**	**Analyst:**	**Ivan Severinsky**

NUMBER OF PARTICLES IN PERCENT

	In Fractions Retained on Sieves shown Below	In Whole Sample			
CONSTITUENTS	**20-10 mm**	**Good**	**Fair**	**Poor**	**Totals**
Alkali granite, coarse grained, angular, subhedral grains, rough texture, hard		85.4			85.4
Alkali granite, coarse grained, angular, rough texture, brittle, subhedral grains			11.1		11.1
Alkali feldspar, angular, subhedral, some quartz present		3.5			3.5
Total					100
Weighted average, good		88.9%			
Weighted average, fair			11.1%		
Weighted average, poor					

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PETROGRAPHIC EXAMINATION OF FINE AGGREGATE FOR CONCRETE

ASTM Designation: C-295

COMPOSITION AND CONDITION OF AGGREGATE SAMPLE

Enclosure 2

Project:	**VM00351**	**Source:**	**Sample 1 (-5 mm)**
Lab No.:	**S231 - B, Fine Aggregate**	**Date:**	**14 September 2004**
Client:	**AMEC E & C Services Limited**	**Analyst:**	**Zlatko Brcic, B. Sc.**

AMOUNT, AS NUMBER OF PARTICLES IN PERCENT

CONSTITUENTS	In Fractions Retained on Sieves shown Below (%)						In Whole Sample (%)			
	2.5 mm	1.25 mm	630 µm	315 µm	160 µm	80 µm	Good	Fair	Poor	Totals
Alkali Granite, light coloured and reddish with biotite up to 10 %, medium hard	88.0	70.0	55.5	11.5	-	-	53.3			53.3
Alkali Granite, light coloured and reddish with biotite up to 15 %, brittle	3.5	5.0	5.0	-	-	-		3.0		3.0
Alkali Granite, light coloured and reddish with biotite up to 15 %, friable	1.0	1.0	-	-	-	-			0.5	0.5
Quartz, milky coloured and colourless, compact, high strength, hard	3.0	12.0	15.0	56.0	73.5	79.5	26.3			26.3
Quartz with Feldspar, colourless and reddish, medium strength	2.0	5.5	7.5	15.5	3.5	0.5	5.8			5.8
Feldspar, pink, white and yellow, compact, high strength	2.5	5.5	8.0	6.5	8.5	9.5	5.7			5.7
Amphibole Group, green to black, compact, hard	-	-	2.0	3.5	5.5	3.5	1.6			1.6
Mica Group, dark brown, black, low strength, soft	-	1.0	7.0	7.0	9.0	7.0			3.8	3.8
Total	100	100	100	100	100	100				100
Weighted average, good							92.7			
Weighted average, fair								3.0		
Weighted average, poor									4.3	

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PETROGRAPHIC EXAMINATION OF FINE AGGREGATE FOR CONCRETE

ASTM Designation: C295

CALCULATION OF RESULTS OF PARTICLE COUNTS

Table 2

Project:	**VM00351**	**Source:**	**Sample 1 (-5 mm)**
Lab No.:	**S231 - B, Fine Aggregate**	**Date:**	**14 September 2004**
Client:	**AMEC E & C Services Limited**	**Analyst:**	**Zlatko Brcic, B. Sc.**

WEIGHTED PERCENTAGES OF CONSTITUENTS IN EACH SIEVE FRACTION

Constituents	2.5 mm	1.25 mm	630 μm	315 μm	160 μm	80 μm	Weighted Composition of Sample
Alkali Granite, light coloured and reddish with biottite up to 10 %, medium hard, good	25.9	16.3	9.4	1.6	0.0	0.0	53.3
Alkali Granite, light coloured and reddish with biottite up to 15 %, brittle, fair	1.0	1.2	0.9	0.0	0.0	0.0	3.0
Alkali Granite, light coloured and reddish with biottite up to 15 %, friable, poor	0.3	0.2	0.0	0.0	0.0	0.0	0.5
Quartz, milky coloured and colourless, compact, high strength, hard, good	0.9	2.8	2.6	8.0	7.6	4.5	26.3
Quartz with Feldspar, colourless and reddish, medium strength, good	0.6	1.3	1.3	2.2	0.4	0.0	5.8
Feldspar, pink, white and yellov, compact, high strength, good	0.7	1.3	1.4	0.9	0.9	0.5	5.7
Amphibole Group, green to black colour, compact, hard, good	0.0	0.0	0.3	0.5	0.6	0.2	1.6
Mica Group, dark brown, black colour, low strength, soft, poor	0.0	0.2	1.2	1.0	0.9	0.4	3.8
Total in sieve fraction (in %)	29.4	23.3	17.0	14.3	10.3	5.7	100
Total in sample, good aggregate							
Total in sample, fair aggregate							
Total in sample, poor aggregate							

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PETROGRAPHIC EXAMINATION OF FINE AGGREGATE FOR CONCRETE

ASTM Designation: C295

CALCULATION OF RESULTS OF PARTICLE COUNTS

Table 1

Project:	**VM00351**	**Source:**	**Sample 1 (-5 mm)**
Lab No.:	**S231 - B, Fine Aggregate**	**Date:**	**14 September 2004**
Client:	**AMEC E & C Services Limited**	**Analyst:**	**Zlatko Brcic, B. Sc.**

Composition of Fractions Retained on Sieves Shown Below

Individual Percentage Retained on Sieve	**2.5 mm**		**1.25 mm**		**630 µm**		**315 µm**		**160 µm**		**80 µm**	
	29.4%		**23.3%**		**17.0%**		**14.3%**		**10.3%**		**5.7%**	
Constituents	**No. of Particles**	**%**	**No. of Particles**	**%**	**No. of Particles**	**%**	**No. of Particles**	**%**	**No. of Particles**	**%**	**No. of Particles**	**%**
Alkali Granite, light coloured and reddish with biotite up to 10 %, medium hard, good	176	88.0	140	70.0	111	55.5	23	11.5	-	-	-	-
Alkali Granite, light coloured and reddish with biotite up to 15 %, brittle, fair	7	3.5	10	5.0	10	5.0	-	-	-	-	-	-
Alkali Granite, light coloured and reddish with biotite up to 15 %, friable, poor	2	1.0	2	1.0	-	-	-	-	-	-	-	-
Quartz, milky coloured and colourless, compact, high strength, hard, good	6	3.0	24	12.0	30	15.0	112	56.0	147	73.5	159	79.5
Quartz with Feldspar, colourless and reddish, medium strength, good	4	2.0	11	5.5	15	7.5	31	15.5	7	3.5	1	0.5
Feldspar, pink, white and yellow, compact, high strength, good	5	2.5	11	5.5	16	8.0	13	6.5	17	8.5	19	9.5
Amphibole Group, green to black, compact, hard, good	-	-	-	-	4	2.0	7	3.5	11	5.5	7	3.5
Mica Group, dark brown, black, low strength, soft, poor	-	-	2	1.0	14	7.0	14	7.0	18	9.0	14	7.0
Totals	200	100	200	100	200	100	200	100	200	100	200	100

APPENDIX C

Photos & Sieve Analysis Reports

SA01

SA01

SA02

SA03

SA03

SA04

SA05

SA05

SA06

SA06

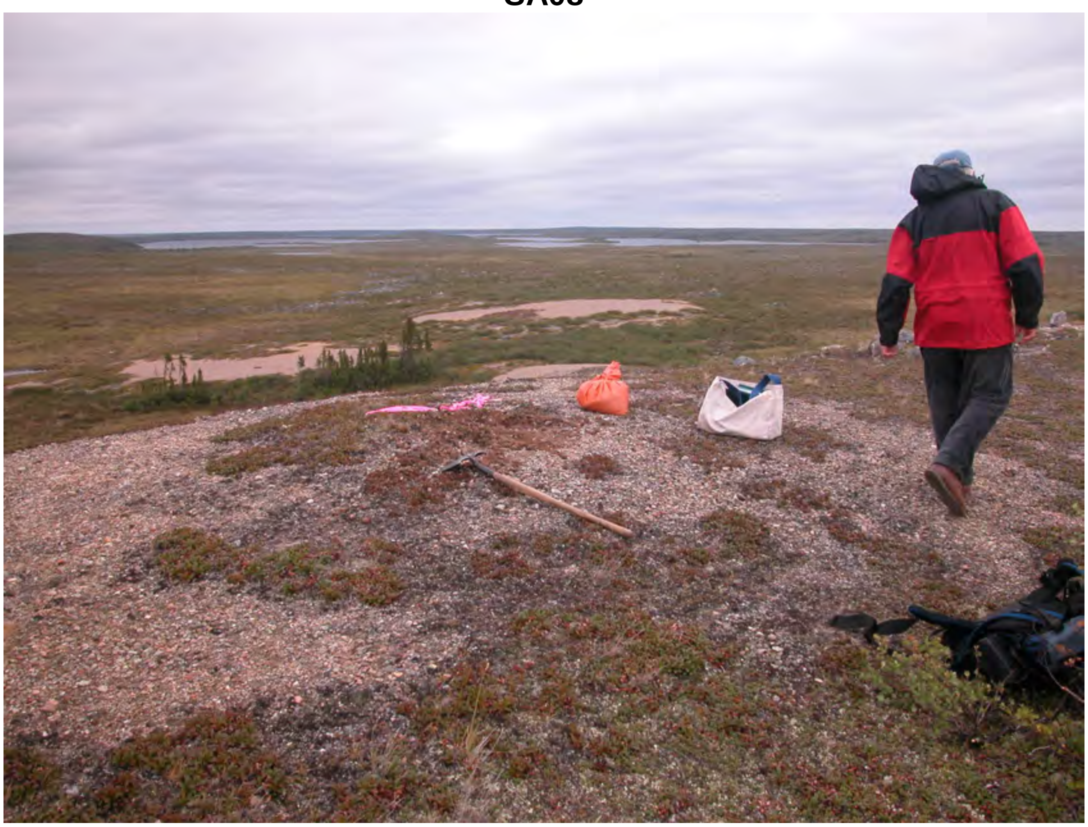

SA07


SA07

SA07

SA08

SA08



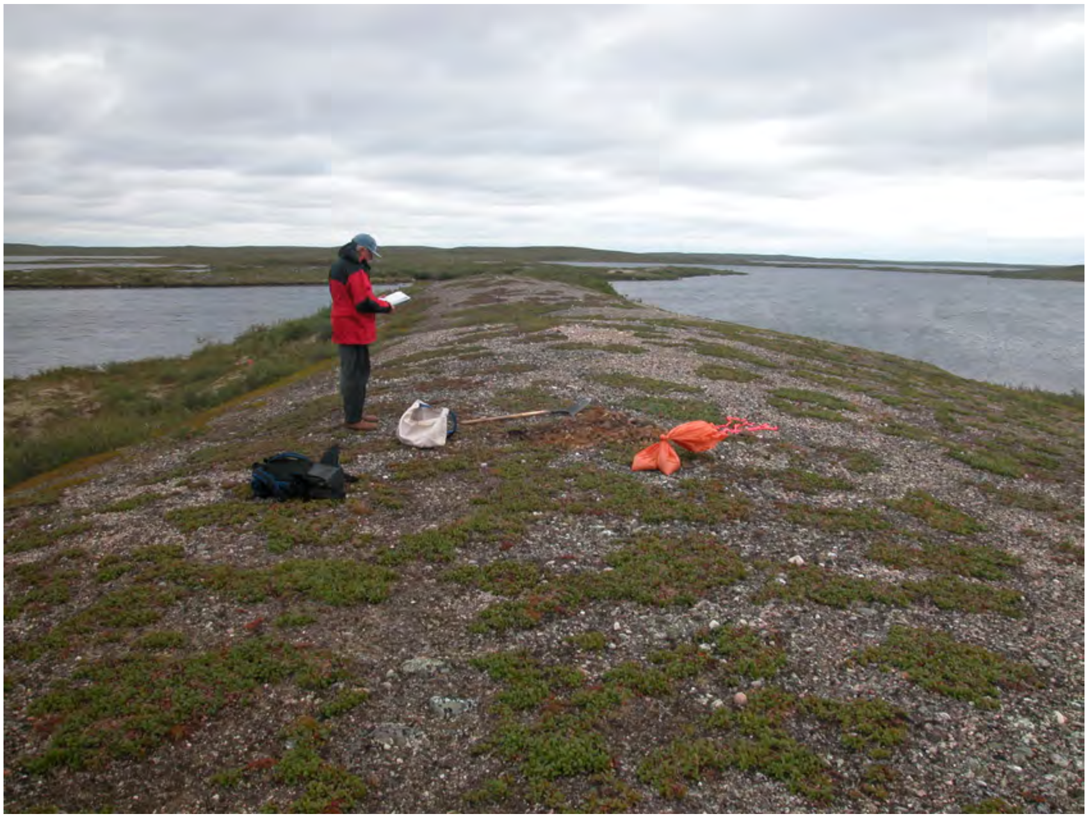
SA09

SA09

SA10

SA10

SA11



SA11

SA12

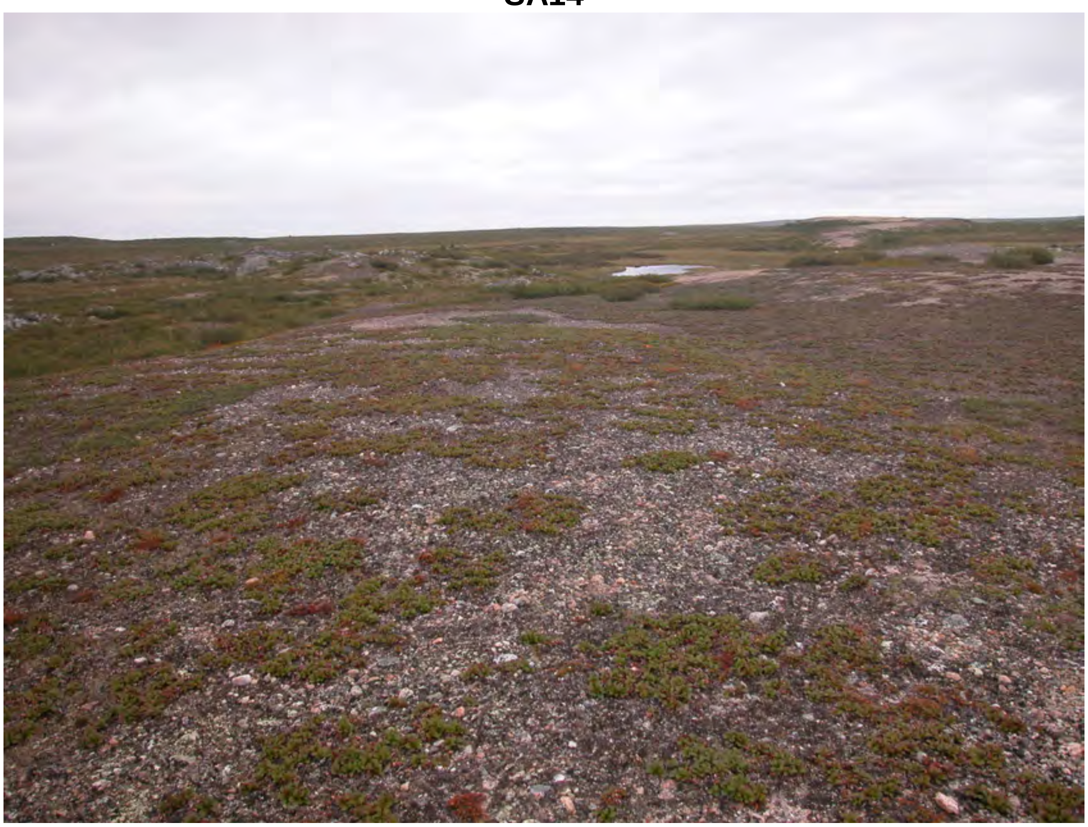
SA12

SA13

SA13

SA14

SA14



SA15

SA15

SA15

SA16

SA16

SIEVE ANALYSIS REPORT
CSA 23.1-80 SERIES

AMEC Earth & Environmental, A division of AMEC Americas Ltd.
4810 - 93 Street
Edmonton, AB T6E 5M4

amec

PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
C.C.

TO
AMEC-Burnaby BC

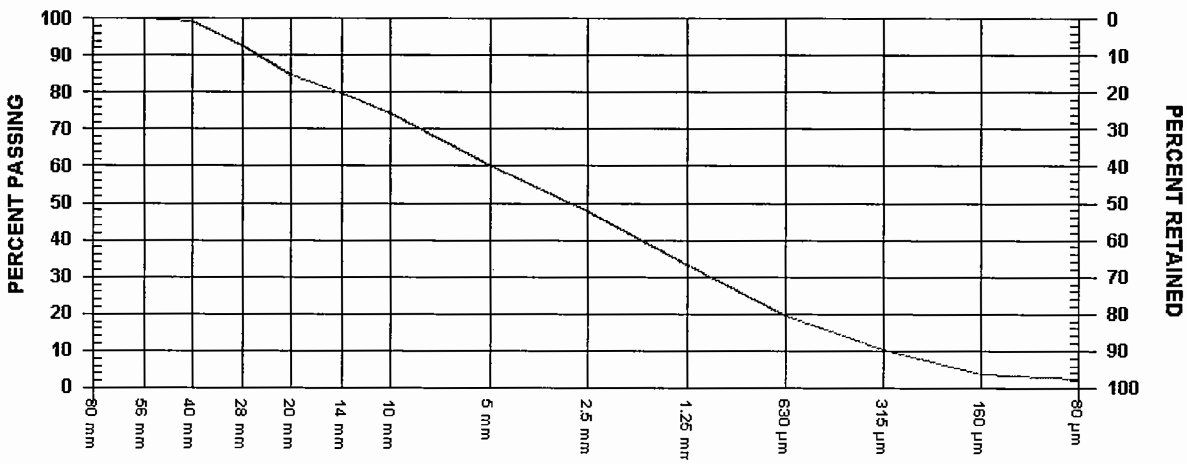
ATTN: Daryl Dufalt

PROJECT AMEC-Burnaby BC
Esker Sieves
CONTRACTOR

SIEVE TEST NO. 1
DATE TESTED 2004.Sep.24 DATE SAMPLED 2004.Sep.23

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES	PERCENT PASSING	GRADATION LIMITS
80 mm	100.0	
56 mm	100.0	
40 mm	99.1	
28 mm	92.4	
20 mm	84.8	
14 mm	79.7	
10 mm	74.4	

SAND SIZES AND FINES	PERCENT PASSING	GRADATION LIMITS
5 mm	60.4	
2.5 mm	47.8	
1.25 mm	33.1	
630 µm	19.3	
315 µm	10.2	
160 µm	3.8	
80 µm	2.3	

COMMENTS
A70, SA-1, 593654, 7033338

PER.
AMEC Earth & Environmental, A division of AMEC Americas Ltd.

 2004.Sep.27

Reporting of these test results constitutes a testing service only. Engineering interpretation or evaluation of test results is provided only on written request.

SIEVE ANALYSIS REPORT **AMEC Earth & Environmental, A division of AMEC Americas Ltd.**
CSA 23.1-80 SERIES
4810 - 93 Street
Edmonton, AB T6E 5M4

PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
C.C.

TO
AMEC-Burnaby BC

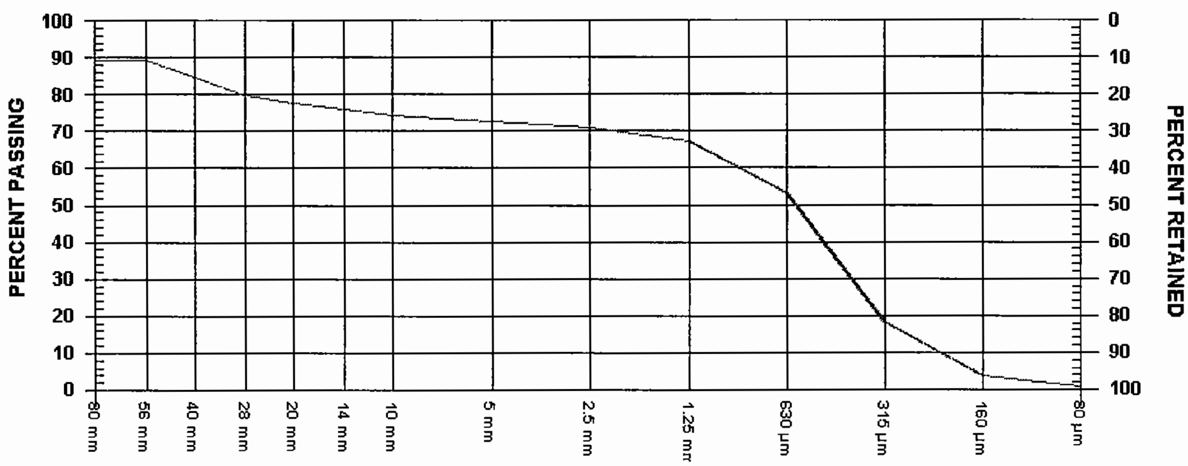
ATTN: Daryl Dufalt

PROJECT AMEC-Burnaby BC
Esker Sieves
CONTRACTOR

SIEVE TEST NO. 2
DATE TESTED 2004.Sep.24 DATE SAMPLED 2004.Sep.23

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES	PERCENT PASSING	GRADATION LIMITS
80 mm	89.3	
56 mm	89.3	
40 mm	84.5	
28 mm	79.8	
20 mm	77.6	
14 mm	75.9	
10 mm	74.4	

SAND SIZES AND FINES	PERCENT PASSING	GRADATION LIMITS
5 mm	72.6	
2.5 mm	70.9	
1.25 mm	67.2	
630 µm	53.1	
315 µm	18.3	
160 µm	3.6	
80 µm	0.7	

COMMENTS
A71, SA-2, 594017, 7033446

PER.
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 2004.Sep.27

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SIEVE ANALYSIS REPORT
CSA 23.1-80 SERIES

AMEC Earth & Environmental, A division of AMEC Americas Ltd.
4810 - 93 Street
Edmonton, AB T6E 5M4

PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
C.C.

TO AMEC-Burnaby BC

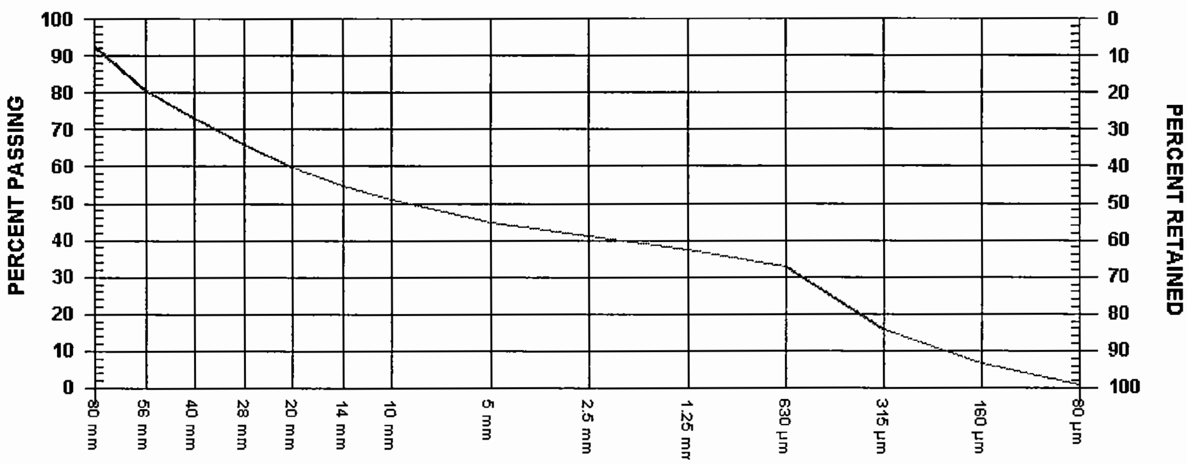
ATTN: Daryl Dufalt

PROJECT AMEC-Burnaby BC
Esker Sieves
CONTRACTOR

SIEVE TEST NO. 3 DATE TESTED 2004.Sep.24 DATE SAMPLED 2004.Sep.23

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES	PERCENT PASSING	GRADATION LIMITS
80 mm	92.6	
56 mm	80.4	
40 mm	73.0	
28 mm	66.2	
20 mm	59.9	
14 mm	54.7	
10 mm	50.9	

SAND SIZES AND FINES	PERCENT PASSING	GRADATION LIMITS
5 mm	45.0	
2.5 mm	40.9	
1.25 mm	37.2	
630 µm	32.7	
315 µm	15.7	
160 µm	6.7	
80 µm	1.0	

COMMENTS
A72, SA-3, 594364, 7033537

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SIEVE ANALYSIS REPORT CSA 23.1-80 SERIES **AMEC Earth & Environmental, A division of AMEC Americas Ltd.**

4810 - 93 Street
Edmonton, AB T6E 5M4

PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
C.C.

TO AMEC-Burnaby BC

ATTN: Daryl Dufalt

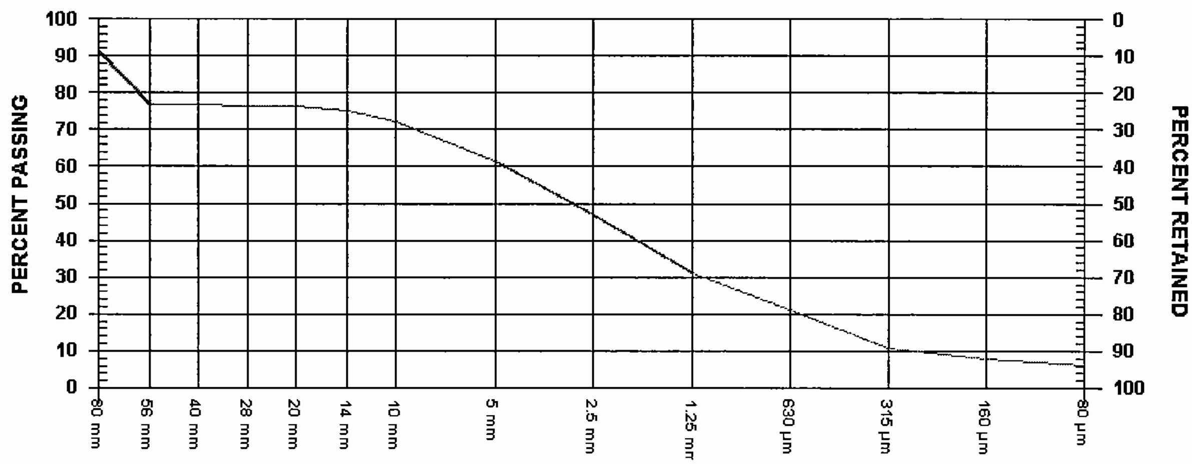
PROJECT AMEC-Burnaby BC
Esker Sieves
CONTRACTOR

SIEVE TEST NO. 4

DATE TESTED 2004.Sep.24 DATE SAMPLED 2004.Sep.23

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES	PERCENT PASSING	GRADATION LIMITS
80 mm	91.5	
56 mm	76.9	
40 mm	76.9	
28 mm	76.5	
20 mm	76.4	
14 mm	75.2	
10 mm	72.2	

SAND SIZES AND FINES	PERCENT PASSING	GRADATION LIMITS
5 mm	61.6	
2.5 mm	46.9	
1.25 mm	31.1	
630 µm	21.0	
315 µm	10.9	
160 µm	7.8	
80 µm	6.4	

COMMENTS
A73, SA-4, 594758, 7033590

PER.
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SIEVE ANALYSIS REPORT
CSA 23.1-80 SERIES

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PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
C.C.

TO AMEC-Burnaby BC

ATTN: Daryl Dufalt

PROJECT AMEC-Burnaby BC
Esker Sieves

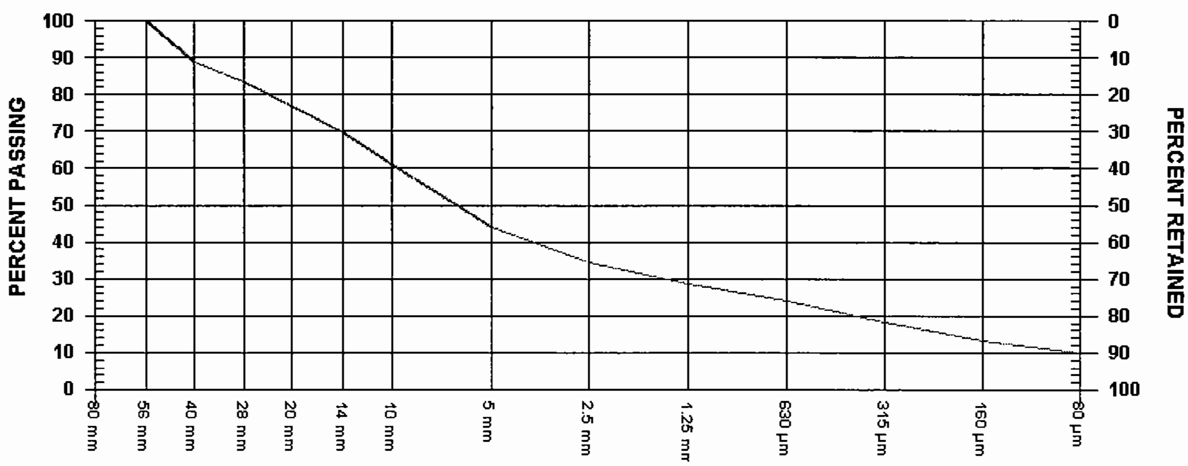
CONTRACTOR

SIEVE TEST NO. 5

DATE TESTED 2004.Sep.24 DATE SAMPLED 2004.Sep.23

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES	PERCENT PASSING	GRADATION LIMITS
80 mm	100.0	
56 mm	100.0	
40 mm	88.7	
28 mm	83.6	
20 mm	76.7	
14 mm	69.7	
10 mm	61.1	

SAND SIZES AND FINES	PERCENT PASSING	GRADATION LIMITS
5 mm	44.1	
2.5 mm	34.3	
1.25 mm	28.6	
630 µm	24.1	
315 µm	18.4	
160 µm	13.2	
80 µm	9.9	

COMMENTS
A74, SA-5, 595114, 7033710

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PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
C.C.

TO AMEC-Burnaby BC

ATTN: Daryl Dufalt

PROJECT AMEC-Burnaby BC
Esker Sieves

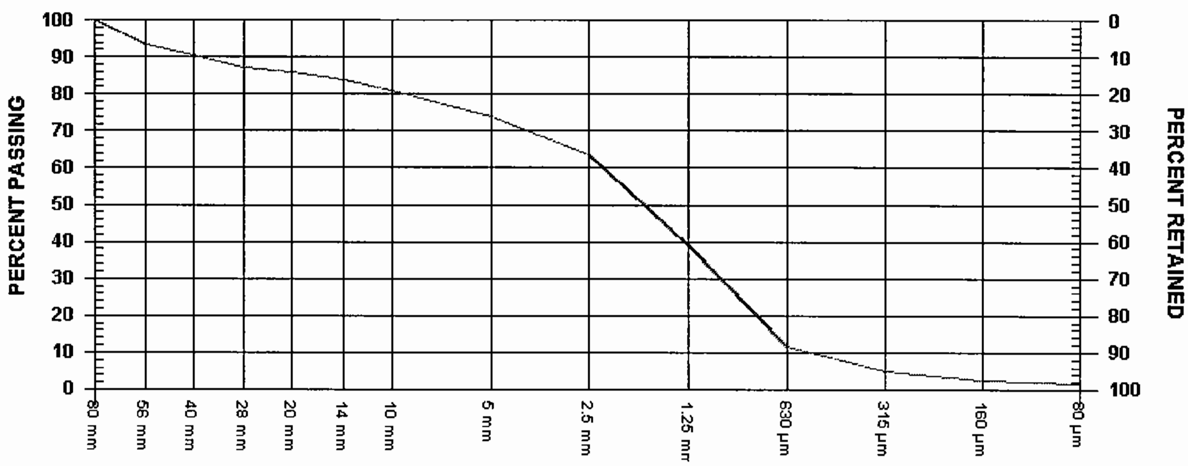
CONTRACTOR

SIEVE TEST NO. 6

DATE TESTED 2004.Sep.24 DATE SAMPLED 2004.Sep.23

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES	PERCENT PASSING	GRADATION LIMITS
80 mm	100.0	
56 mm	93.5	
40 mm	90.5	
28 mm	87.2	
20 mm	85.9	
14 mm	83.9	
10 mm	81.0	

SAND SIZES AND FINES	PERCENT PASSING	GRADATION LIMITS
5 mm	73.7	
2.5 mm	63.5	
1.25 mm	39.1	
630 µm	11.5	
315 µm	5.1	
160 µm	2.5	
80 µm	1.5	

COMMENTS
A75, SA-6, 595390, 7033985

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SIEVE ANALYSIS REPORT
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PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
C.C.

TO
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ATTN: Daryl Dufalt

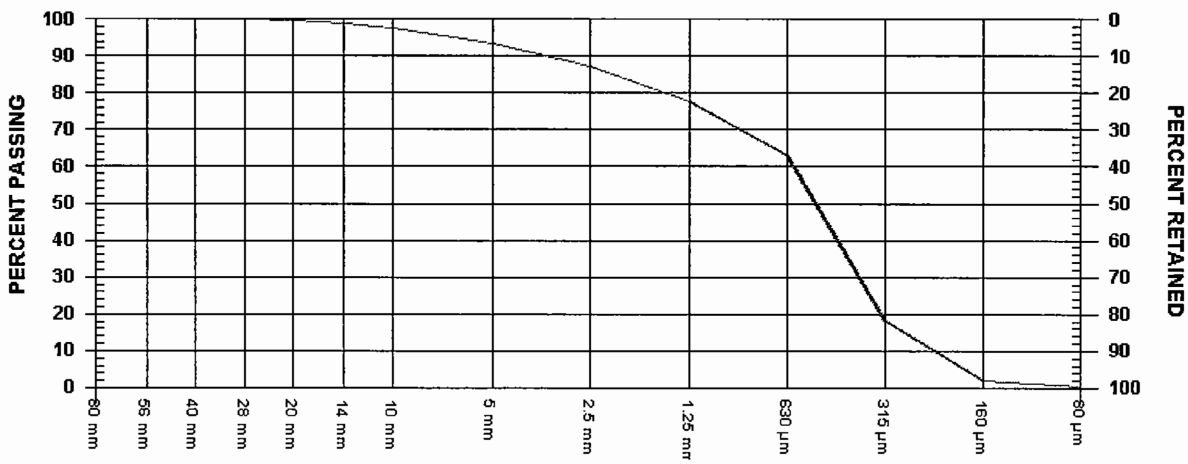
PROJECT AMEC-Burnaby BC
Esker Sieves
CONTRACTOR

SIEVE TEST NO. 7

DATE TESTED 2004.Sep.24 DATE SAMPLED 2004.Sep.23

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
80	mm	100.0	
56	mm	100.0	
40	mm	100.0	
28	mm	100.0	
20	mm	99.7	
14	mm	98.9	
10	mm	97.7	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
5	mm	93.4	
2.5	mm	87.2	
1.25	mm	77.5	
630	µm	63.3	
315	µm	18.1	
160	µm	1.9	
80	µm	0.4	

COMMENTS
A76, SA-7, 595544, 7034255

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SIEVE ANALYSIS REPORT
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PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
C.C.

TO
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ATTN: Daryl Dufalt

PROJECT AMEC-Burnaby BC
Esker Sieves
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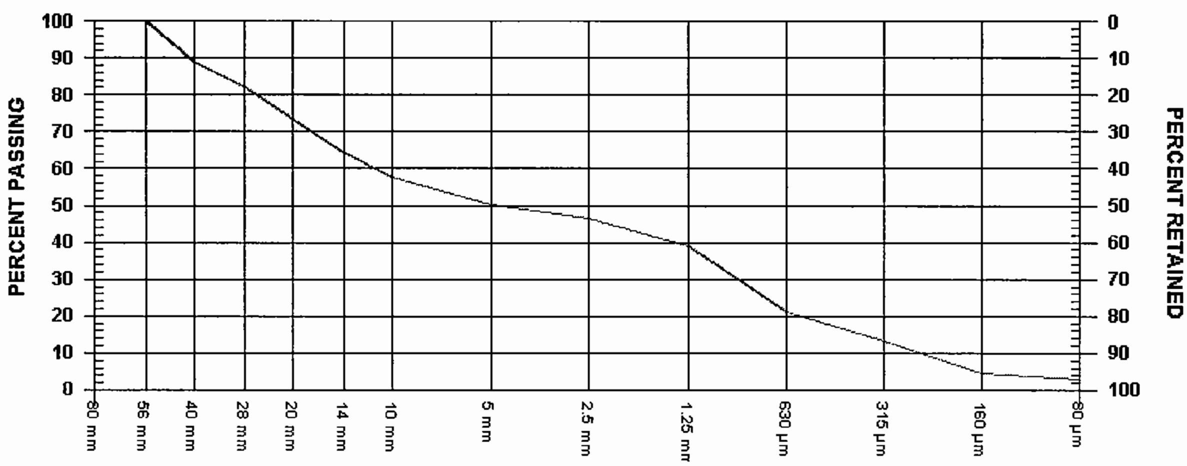
SIEVE TEST NO. 8

DATE TESTED 2004.Sep.24 DATE SAMPLED 2004.Sep.23

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES	PERCENT PASSING	GRADATION LIMITS
80 mm	100.0	
56 mm	100.0	
40 mm	89.0	
28 mm	82.3	
20 mm	73.5	
14 mm	64.5	
10 mm	57.8	

SAND SIZES AND FINES	PERCENT PASSING	GRADATION LIMITS
5 mm	50.2	
2.5 mm	46.5	
1.25 mm	38.9	
630 µm	21.3	
315 µm	13.4	
160 µm	4.7	
80 µm	3.0	

COMMENTS
A77, SA-8, 595918, 7034489

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 2004.Sep.27

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CLIENT AMEC-Burnaby BC
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ATTN: Daryl Dufalt

PROJECT AMEC-Burnaby BC
Esker Sieves

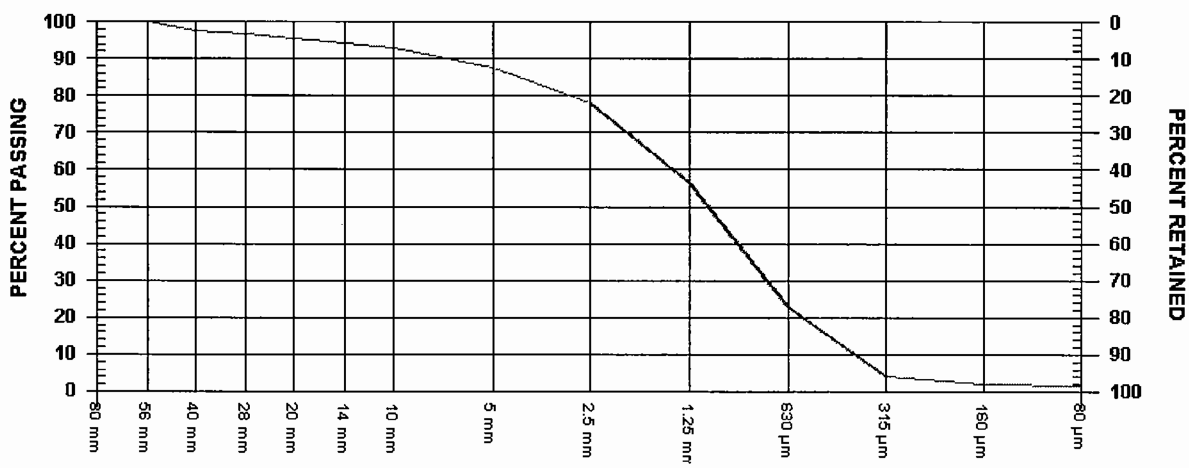
CONTRACTOR

SIEVE TEST NO. 9

DATE TESTED 2004.Sep.25 DATE SAMPLED 2004.Sep.24

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES	PERCENT PASSING	GRADATION LIMITS
80 mm	100.0	
56 mm	100.0	
40 mm	97.7	
28 mm	96.7	
20 mm	95.5	
14 mm	94.4	
10 mm	92.8	

SAND SIZES AND FINES	PERCENT PASSING	GRADATION LIMITS
5 mm	87.7	
2.5 mm	77.9	
1.25 mm	56.3	
630 µm	23.0	
315 µm	4.1	
160 µm	2.1	
80 µm	1.8	

COMMENTS
A78, SA-9, 584930, 7033301

PER.
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SIEVE ANALYSIS REPORT CSA 23.1-80 SERIES

AMEC Earth & Environmental, A division of AMEC Americas Ltd.
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PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
C.C.

TO
AMEC-Burnaby BC

ATTN: Daryl Dufalt

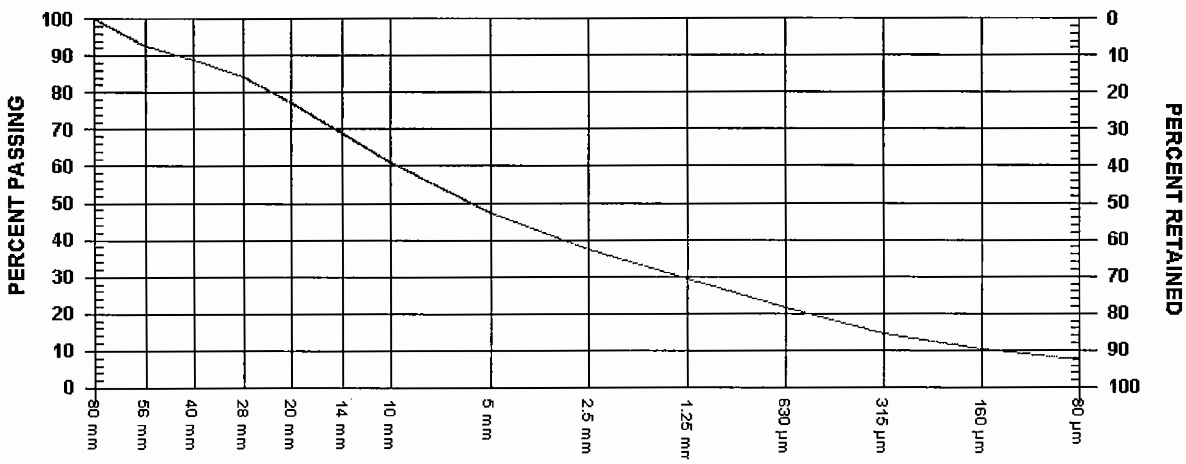
PROJECT AMEC-Burnaby BC
Esker Sieves
CONTRACTOR

SIEVE TEST NO. 10

DATE TESTED 2004.Sep.25 DATE SAMPLED 2004.Sep.24

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
80	mm	100.0	
56	mm	92.6	
40	mm	88.7	
28	mm	84.4	
20	mm	77.4	
14	mm	69.1	
10	mm	60.8	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
5	mm	47.3	
2.5	mm	37.4	
1.25	mm	29.5	
630	µm	21.6	
315	µm	14.4	
160	µm	10.4	
80	µm	7.6	

COMMENTS
A79, SA-10, 584730, 7033236

PER.
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SIEVE ANALYSIS REPORT
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4810 - 93 Street

Edmonton, AB T6E 5M4

PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
C.C.

TO
AMEC-Burnaby BC

ATTN: Daryl Dufalt

PROJECT AMEC-Burnaby BC
Esker Sieves

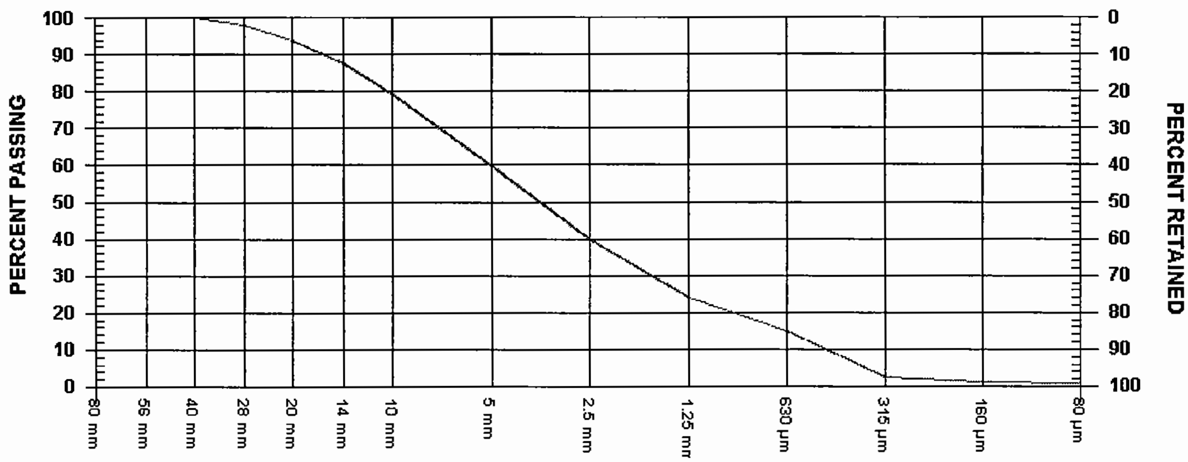
CONTRACTOR

SIEVE TEST NO. 11

DATE TESTED 2004.Sep.25 DATE SAMPLED 2004.Sep.24

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES	PERCENT PASSING	GRADATION LIMITS
80 mm	100.0	
56 mm	100.0	
40 mm	100.0	
28 mm	97.9	
20 mm	94.0	
14 mm	87.7	
10 mm	79.4	

SAND SIZES AND FINES	PERCENT PASSING	GRADATION LIMITS
5 mm	59.6	
2.5 mm	39.7	
1.25 mm	24.2	
630 µm	14.8	
315 µm	2.6	
160 µm	1.1	
80 µm	0.9	

COMMENTS
A80, SA-11, 584583, 7033140

PER.
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SIEVE ANALYSIS REPORT
CSA 23.1-80 SERIES

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4810 - 93 Street
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PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
C.C.

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ATTN: Daryl Dufalt

PROJECT AMEC-Burnaby BC
Esker Sieves

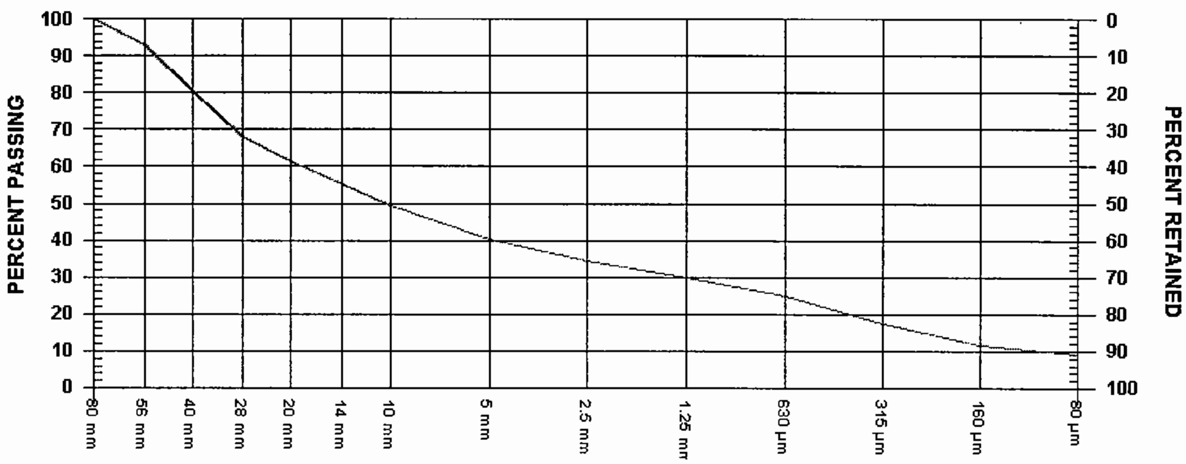
CONTRACTOR

SIEVE TEST NO. 12

DATE TESTED 2004.Sep.25 DATE SAMPLED 2004.Sep.24

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES	PERCENT PASSING	GRADATION LIMITS
80 mm	100.0	
56 mm	92.9	
40 mm	80.4	
28 mm	68.2	
20 mm	61.3	
14 mm	55.3	
10 mm	49.6	

SAND SIZES AND FINES	PERCENT PASSING	GRADATION LIMITS
5 mm	40.3	
2.5 mm	34.5	
1.25 mm	30.0	
630 µm	25.1	
315 µm	17.6	
160 µm	11.8	
80 µm	9.1	

COMMENTS
A81, SA-12, 584445, 7032926

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SIEVE ANALYSIS REPORT
CSA 23.1-80 SERIES

AMEC Earth & Environmental, A division of AMEC Americas Ltd.
4810 - 93 Street
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PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
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TO
AMEC-Burnaby BC

ATTN: Daryl Dufalt

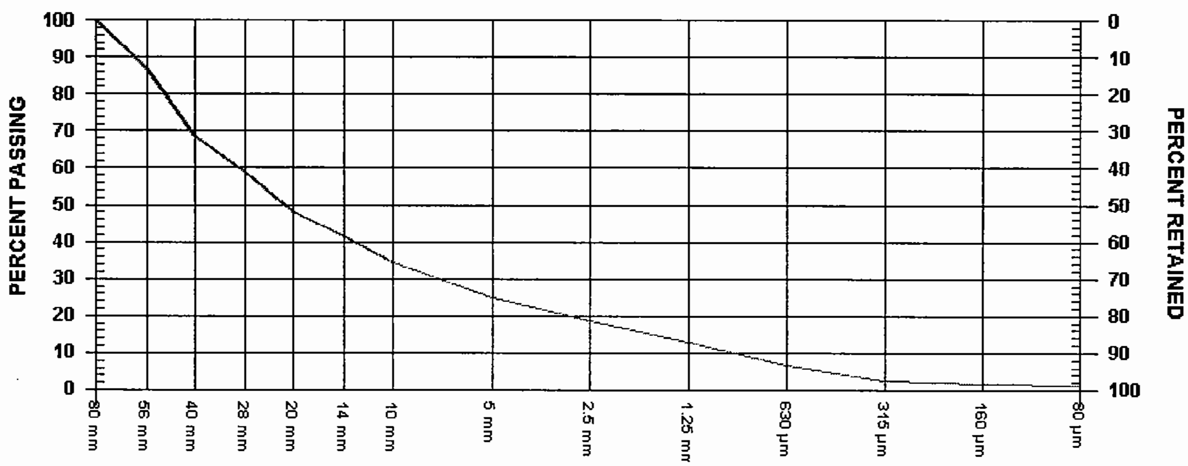
PROJECT AMEC-Burnaby BC
Esker Sieves
CONTRACTOR

SIEVE TEST NO. 13

DATE TESTED 2004.Sep.25 DATE SAMPLED 2004.Sep.24

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES	PERCENT PASSING	GRADATION LIMITS
80 mm	100.0	
56 mm	86.9	
40 mm	68.6	
28 mm	59.1	
20 mm	48.2	
14 mm	41.3	
10 mm	34.5	

SAND SIZES AND FINES	PERCENT PASSING	GRADATION LIMITS
5 mm	25.1	
2.5 mm	18.8	
1.25 mm	12.9	
630 µm	6.6	
315 µm	2.6	
160 µm	1.7	
80 µm	1.2	

COMMENTS
A82, SA-13, 584354, 7032852

PER.
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SIEVE ANALYSIS REPORT CSA 23.1-80 SERIES

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PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
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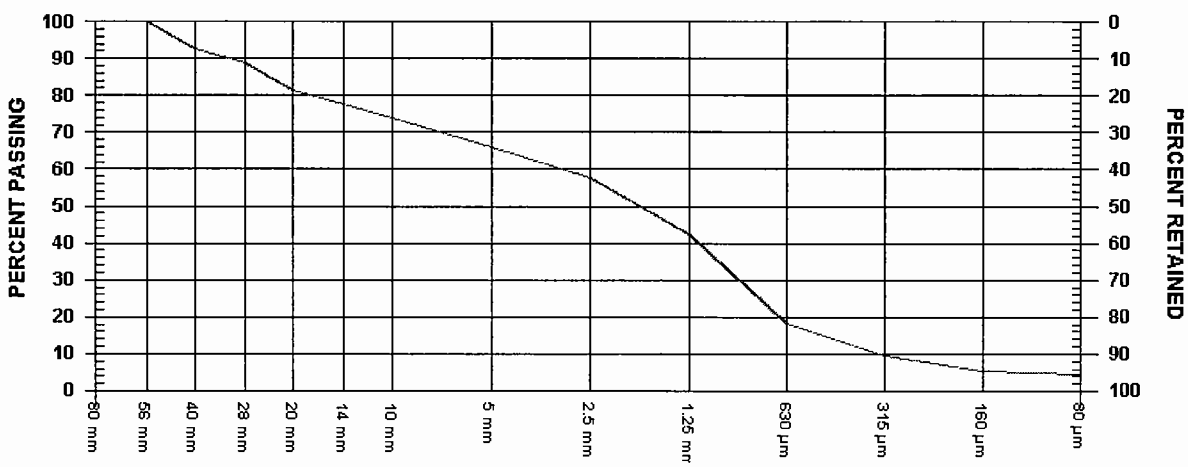
ATTN: Daryl Dufalt

PROJECT AMEC-Burnaby BC
Esker Sieves
CONTRACTOR

SIEVE TEST NO. 14 DATE TESTED 2004.Sep.25 DATE SAMPLED 2004.Sep.24

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES	PERCENT PASSING	GRADATION LIMITS
80 mm	100.0	
56 mm	100.0	
40 mm	92.6	
28 mm	88.9	
20 mm	81.5	
14 mm	77.7	
10 mm	73.7	

SAND SIZES AND FINES	PERCENT PASSING	GRADATION LIMITS
5 mm	66.1	
2.5 mm	57.8	
1.25 mm	42.4	
630 µm	18.4	
315 µm	9.7	
160 µm	5.5	
80 µm	4.5	

COMMENTS
A83, SA-14, 584247, 7032699

PER.
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 2004.Sep.27

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SIEVE ANALYSIS REPORT
CSA 23.1-80 SERIES

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PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
C.C.

TO AMEC-Burnaby BC

ATTN: Daryl Dufalt

PROJECT AMEC-Burnaby BC
Esker Sieves

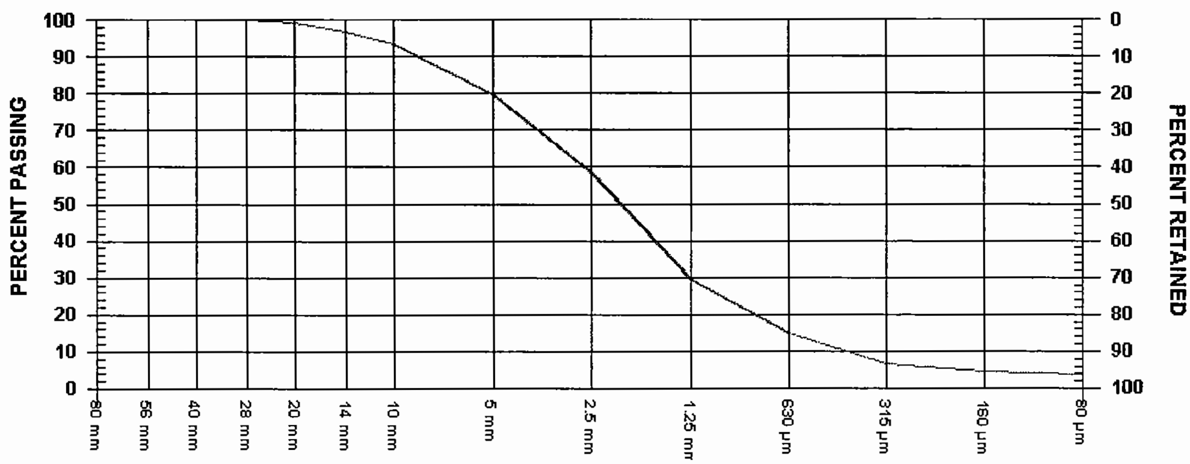
CONTRACTOR

SIEVE TEST NO. 15

DATE TESTED 2004.Sep.25 DATE SAMPLED 2004.Sep.24

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES	PERCENT PASSING	GRADATION LIMITS
80 mm	100.0	
56 mm	100.0	
40 mm	100.0	
28 mm	100.0	
20 mm	99.1	
14 mm	96.7	
10 mm	93.3	

SAND SIZES AND FINES	PERCENT PASSING	GRADATION LIMITS
5 mm	79.6	
2.5 mm	58.6	
1.25 mm	29.3	
630 µm	15.0	
315 µm	6.5	
160 µm	4.4	
80 µm	3.9	

COMMENTS
A84, SA-15, 584084, 7032660

PER.
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 2004.Sep.27

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SIEVE ANALYSIS REPORT
CSA 23.1-80 SERIES

AMEC Earth & Environmental, A division of AMEC Americas Ltd.
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amec

PROJECT NO. VM00351
CLIENT AMEC-Burnaby BC
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TO
AMEC-Burnaby BC

ATTN: Daryl Dufalt

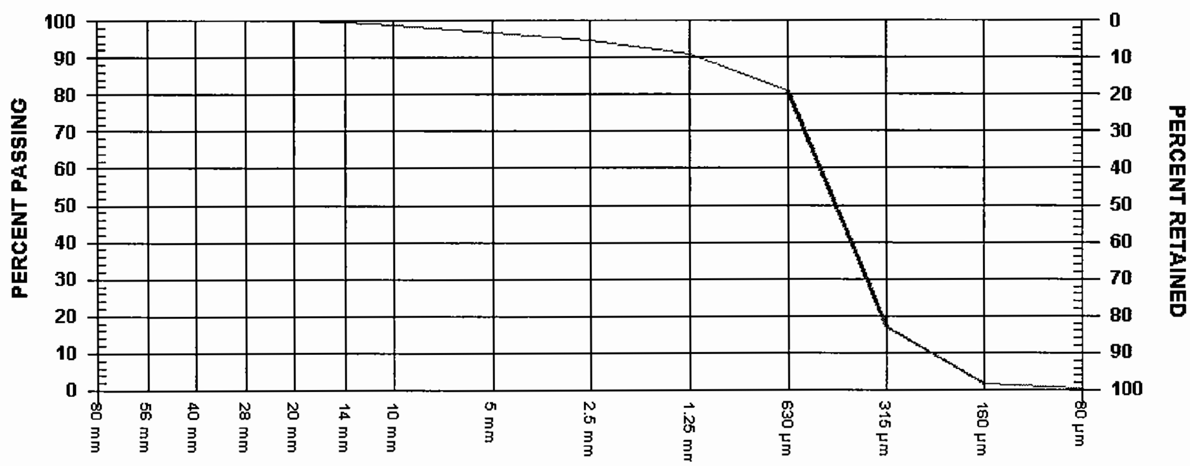
PROJECT AMEC-Burnaby BC
Esker Sieves
CONTRACTOR

SIEVE TEST NO. 16

DATE TESTED 2004.Sep.25 DATE SAMPLED 2004.Sep.24

SUPPLIER
SOURCE
SPECIFICATION
MATERIAL TYPE

SAMPLED BY
TESTED BY
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
80	mm	100.0	
56	mm	100.0	
40	mm	100.0	
28	mm	100.0	
20	mm	100.0	
14	mm	99.7	
10	mm	98.6	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
5	mm	96.6	
2.5	mm	94.5	
1.25	mm	90.9	
630	µm	81.1	
315	µm	17.1	
160	µm	1.7	
80	µm	0.4	

COMMENTS
A85, SA-16, 583966, 7032598

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TECHNICAL MEMO

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TO:	Andrew Williams, De Beers Veronica Chisholm, De Beers	**DATE:**	March 27, 2012
C:	Wayne Corso, JDS, Dan Johnson, JDS		
FROM:	Bill Horne, EBA Gordon Zhang, EBA, Hongwei Xia, EBA	**EBA FILE:**	E14101143
SUBJECT:	2012 Gahcho Kué EIS Supplement - Summary of Dyke Conceptual Design and Construction Material for Gahcho Kué Diamond Project, NWT, Canada		

1.0 INTRODUCTION

EBA Engineering Consultants Ltd. operating as EBA, A Tetra Tech Company (EBA) was retained by JDS Energy and Mining Inc. (JDS) to develop a waste and water management plan as a part of the project feasibility study for the Gahcho Kué Diamond Project. EBA completed the original waste and water management plan and submitted the report to JDS in September 2010 which included conceptual designs for dykes required for the Gahcho water and waste management.

Modifications to the waste and management plan were made as described in the 2012 EIS Supplement (De Beers 2012) Project Description. The mine waste and water management plan has been updated accordingly as well as the dyke conceptual designs. This memo is an update of EBA's previous dyke conceptual design and construction material summary memo (EBA 2011) to reflect the recent update on the mine waste and water management plan.

2.0 DYKE/BERM DESIGN AND CONSTRUCTION

2.1 Key Considerations

The key considerations for the dyke/berm design were as follows:

- Comply with the Canadian Dam Safety Guidelines;
- Minimize seepage through dykes while optimizing the construction efficiency;
- Maximize the use of mine waste materials produced during pit development;
- Minimize overall environmental footprints and effects;
- Facilitate an effective mine closure plan;
- Optimize the dyke construction sequences to reduce initial construction requirements during pre-operation stage and construction intensity during mine operation;

- Establish adequate setback from the open pit limits for mining safety and minimizing seepage into the open pits; and
- Incorporate mine site roads (including haul roads) into dykes, wherever practical.

2.2 Design Criteria

The following design criteria were adopted for the dyke design:

- All dykes were designated as Significant Dyke Class based on the recommendation of the Canadian Dam Safety Guidelines (CDA 2007)
- The Area 1 perimeter berms and water collection pond berms were designated as Low to Significant Dyke class
- Peak ground acceleration (PGA) of 0.06 g was adopted for the dyke design
- A minimum freeboard of 1.0 m was adopted for the dyke design
- The minimum factors of safety for dyke slopes meet or exceed the requirements in the Canadian Dam Association guidelines (CDA 2007).

2.3 Conceptual Level Dyke Design

A total of 14 dykes are required for the water and waste management during the mine operation. The locations of the dykes are shown in Figure 1, the overall layout of the mine site. The typical cross section for each dyke is presented in Figures 2 through 15.

2.3.1 Dyke A

The construction of Dyke A is required during early mine development before the initial lake dewatering and pit development. The dyke would be constructed in winter to satisfy the current mine construction plan. An existing water depth of about 2 m is anticipated along the main portion of Dyke A. Up to 6 m thick overburden till over bedrock was identified over the Dyke A area during the 2004 site investigation. Several boulders (up to 0.3 m) were recovered in the overburden zone from a borehole drilled in the main channel at the Dyke A location. A talik (unfrozen year-round) was identified within the main channel area during the site investigation. In consideration of the above information, a soil-bentonite slurry cutoff wall through a till fill zone placed over the overburden and the overburden to the bedrock surface has been adopted as the main seepage control measure for Dyke A. The cut-off wall will be protected by a downstream filter zone and a mine rock shell zone. The proposed dyke cross section is shown in Figure 2.

Dyke A will be breached to restore the original channel between Area 7 and Area 8 at the end of final mine closure after the water quality in the restored Kennady Lake in Areas 2 to 7 meets discharge criteria.

2.3.2 Dyke B

Dyke B is an 850 m long, internal water retention dyke between Areas 3 and 4 that will be constructed for draining Area 4 before mining the Tuzo Pit within the Area 4 basin. Dyke B will be constructed in Year 4 and early Year 5 when up to 11 m of water will be present above the lakebed along the Dyke B centreline. The overburden thickness along the dyke centreline is expected to be in a range from 1 m to 5 m.

Overburden materials from pit development will be available for Dyke B construction; therefore, a wide till core has been selected as the main seepage control measure for Dyke B. Several other options of seepage control measures, including sheet-pile wall, slurry cut-off wall, or jet grouting through dyke till fill and overburden foundation to bedrock surface, were also considered. Preliminary seepage analyses indicated that the magnitude of the seepage rates through the dyke and its foundation for those options would be similar to that for the dyke with a wide till core. The reason for the relatively low overall effectiveness of these advanced seepage control measures is that substantial seepage though fractured bedrock is predicted for all the cases. Without applying curtain grouting through the fractured bedrock zone beneath the dyke, the benefit gained from incorporating more advanced seepage control measures into Dyke B may not justify the anticipated high incremental cost.

Based on the above, Dyke B will be designed as a wide till core dam that excludes advanced seepage control measures and bedrock curtain grouting. The proposed dyke cross section is shown in Figure 3. This dyke design will maintain the seepage rate through the dyke in a manageable range. Seepage through the dyke will be collected in the water collection pond CP6 and the sumps in Tuzo Pit. The water will be either pumped back to Area 3 or directed to the process plant as a portion of reclaim water.

Dyke B will be constructed in two stages. The Stage 1 construction will include placing the upstream mine rock berm and downstream coarse PK berm in Year 4 when the projected water elevation in Areas 3 to 5 is below 419.5 m. The two berms will provide confinement to the wide till core materials to be placed in the water between the two berms. The upstream mine rock berm will also provide protection to the till core against wave action and potential slope instability through the core. The downstream coarse PK zone will provide downstream slope stability of the till core and partially serve as a filter zone to the till and overburden.

The till core will mainly serve as a low-permeable material to control the seepage through Dyke B. The overall permeability or hydraulic conductivity will depend on the source material properties, placement method, and in-place densities. Densification of a selected critical zone of the till core may be required to achieve the design intents. Depending on the till material gradation and placement method, particle segregation may occur during till placement. Special measures, such as using long-arm conveyer instead of truck end-dumping, may be required to reduce the potential particle segregation.

The till core dumped in the water will be relatively soft until any excess porewater pressure generated in the soil mass is dissipated and the consolidated is initiated; this is estimated to take several months. Trafficability of large construction equipment over the soft till will be an issue. This can be resolved before or during the early stage of the construction by conducting some field trafficability tests using selected construction equipment. Furthermore, the two Stage 1 construction berms may be used as solid bases for till placement from both the upstream and downstream sides inwards.

Dyke B will be lowered to a maximum crest elevation of 418.0 m at early mine closure and completely submerged under water when the Kennady Lake is restored to its original lake elevation of 420.7 m during the late stage of mine closure.

2.3.3 Dykes A1, D, E, F, and G

Dykes A1, D, E, F, and G are located away from major water bodies, so permafrost is expected to exist beneath the dyke footprints. Dyke A1 is a water diversion dyke to divert runoff water from the catchment area of Area 1 and to isolate the A watershed from Area 2. Dyke D is a water retention dyke to prevent water in Area 2 from flowing north into Lake N7 during the late stage of mine operation. Dyke E serves as a water diversion dyke initially and then a water retention dyke during the late stage of mine operation. Dyke F is a water diversion dyke to prevent water from the D watershed from flowing into Area 5 during mine operation. Dyke G is a water diversion dyke to prevent water from the E watershed from flowing into Area 6 during mine operation. The design concepts for these dykes are similar. The seepage control measures adopted for these structures include a liner keyed into competent frozen ground (saturated inorganic permafrost) or bedrock. The design intent was to protect the original permafrost foundation from thawing when possible and limit the seepage through these structures and their foundations. The till fill zone upstream of the liner provides thermal protection to the key trench and limits the seepage through the dyke that could result from a damaged liner. The mine rock shell provides the necessary overall stability and also serves as thermal cover to the dyke foundation around the key trench area. Proposed conceptual design cross sections for these dykes are shown in Figures 4 through 8.

Dykes A1 and D will remain in place after mine closure. Dykes E, F, and G will be breached to restore the original natural flow regimes during mine closure.

2.3.4 Dykes H, I and J

Dykes H, I, and J are internal water retention dykes between Area 5 and Area 6 (for Dykes H and I) and between Area 4 and Area 6 (for Dyke J). Two stages of construction will be adopted to limit the construction requirements during the early Stage 1 construction in Year -2 before pit development. The cofferdams for Dykes I and J will be placed under water during the early stage of the initial lake dewatering. The fills for the remaining Stage 1 construction for the dykes will be placed in dry conditions when the water level in Area 6 is further lowered to expose the lakebeds under the dyke footprints. A wide till core has been selected as a main water control measure to limit seepage through the dykes. The Stage 2 construction of the dykes will be completed before Year 3 when sufficient till is available from pit development and the projected maximum water level in Areas 3 to 5 remains below 419.5 m. Dyke cross sections are shown in Figures 9 through 11. Seepage through the dykes will be collected and pumped back to the source reservoir as required.

Dykes H and I will remain in place after mine closure. Dyke J will be lowered to a top crest elevation of 418.0 m to limit net fish habitat losses.

2.3.5 Dykes K, M and N

Dykes K, M, and N are internal water retention dykes and will be constructed in dry conditions. A wide till core has been selected as the main seepage control measure for these dykes. Dykes K and N will be constructed in two stages to meet the design intent and lower the overall construction cost. Dyke cross sections are shown in Figures 12, 14, and 15. The Stage 1 construction of Dyke N will serve as a portion of the haul road from the 5034 Pit to the south mine rock pile and will be constructed using overburden materials from the 5034 Pit. Similarly, the Stage 1 construction of Dyke K will serve as a portion of the haul road from the Hearne Pit to the west mine rock pile and will be constructed using overburden materials from the Hearne Pit. The Stage 2 construction will be completed in early Year 6 for Dyke K and in Year 9 for Dyke N. Dyke M will be completed before the Year 3 spring freshet. Seepage through the dykes will be collected and pumped back to the source cells as required.

Dykes K and N will be lowered to a maximum crest elevation of 418.0 m at early mine closure and completely submerged under water when the Kennady Lake is restored to its original lake elevation of 420.7 m during the late stage of mine closure. Dyke M can remain in place after mine closure.

2.3.6 Dyke L

Dyke L is a 1070 m long, curved filter dyke to retain the particles in the fine PK placed in Area 2 while allowing sufficient clean water passing through the dyke from Area 2 to Area 3. The dyke is designed based on past experience gained for similar filter dykes designed and construction managed by EBA at both the EKATI Diamond Mine and Jericho Diamond Mine. The dyke cross section is shown in Figure 13. The lower portion (below an elevation of about 419.5 m) of the dyke will be placed underwater with a maximum water depth of approximately 6.5 m. The mine rock benches within both the side slopes are required for slope stability. The dyke can be constructed in two stages to reduce early construction requirements. The Stage 1 construction to a crest elevation of 421.0 m will be in Year -1 before any fine PK is placed in Area 2. The remaining construction can be completed in Year 2.

A section (100 m width) of Dyke L crest close to the northwest abutment will be lowered down to an elevation of 421.0 m to create a contingency drainage path across the dyke after mine closure. The remaining portion of Dyke L will remain in place but will not retain water.

2.3.7 Area 1 Perimeter Berms

Three low berms are required at the low saddles along the west to south perimeter of Area 1 to retain water and provide some freeboard in Lake A1. The freeboard will prevent the water in the Lake A1 from flowing into Area 3 or Area 4 under an extreme precipitation event. The berms will be 2 to 3 m in height and constructed using available till materials and mine rock. A typical cross section of the berms is shown in Figure 16.

One of the berms will be breached to allow the excess water flowing from Area 1 into Area 3 after the water quality in the restored Kennady Lake in Areas 2 to 7 meets discharge criteria.

2.3.8 Water Collection Pond Berms

Four berms for water collection ponds CP3 to CP6 are required to limit surface runoff to flow into the active pits. A typical cross section of the berms is shown in Figure 16. The berms are designed to have a liner keyed into the key trench that is backfilled with selected till fill. The liner can be placed directly over the upstream surface of the berm slope and anchored into the fill immediately below the berm crest.

The berms for water collection ponds will not be requried after the end of mine life and will be completely submerged below water after the water elevation in Areas 4 and 6 is raised to above 418.0 m during mine closure.

2.4 Dyke Stability

Limited dyke slope stability analyses were conducted for Dyke L in this study. The design side-slopes for the remaining dykes and berms in this study were determined based on the findings from the stability analyses for Dyke L along with engineering judgement from previous engineering designs in the region and the mine rock pile stability analyses summarized in Appendix C of EBA's Water and Waste Management Report (EBA 2010). The design slopes are considered to be conservative and are expected to meet the design criteria

Detailed slope stability analyses with known soil properties of both the construction materials and foundation soils will be required to finalize and optimize the dyke/berm geometries in the final stage of designs for these dykes and berms.

2.5 Thermal Considerations

Permafrost is expected to exist beneath the majority of the footprint for each of Dykes A1, D, E, F, G, and M. These dykes, except for Dyke M, have been designed as zoned earth fill dykes with a liner keyed into the expected permafrost foundation to limit the seepage through the dyke and its foundation. No thermal analyses were conducted at this stage of study. Similar dykes have been successfully designed by EBA and constructed in other northern mines including EKATI and Jericho. The thermal behaviour of the dykes for this study was assessed based on the general site conditions at the Gahcho Kué project site and the experience gained from the dyke design for other northern mines. A minimum of 4 m thermal cover over the key trench area was adopted for Dykes A1, D, E, F, and G to maintain or delay thawing of the existing permafrost beneath the key trench.

A thermal cover of 3 m over the top of slurry cut-off wall in Dyke A was adopted to limit the freeze-thaw thermal effects on the wall.

Dykes A, E, F, and G are water diversion structures to limit water flowing into the internal water management ponds in the mine site area during mine operation. Any minor seepage through these dykes would be collected in the ponds and impose no or negligible negative effects on the surrounding environment. Dyke M is an internal dyke between Area 5 and Area 4. Any minor seepage through the dyke will be pumped back to its upstream side pond. Therefore, it is preferred, but not necessary, to maintain the existing permafrost beneath these dykes as long as the seepage rates through these dykes are manageable. A greater overall water storage capacity for the water management during mine operation is required when more water seeps through the diversion dykes. These dykes will be breached during mine closure or at the end of final mine closure.

Dykes A1 and D will remain in place after mine closure. It is expected that the permafrost could be maintained in the area beneath the key trench in these dykes over the relatively short period during the mine operation and early mine closure before the water quality in Area 2 to 7 meets the discharge criteria. The liner system together with permafrost foundation beneath the key trench will effectively cut off the seepage through the dykes. After the final mine closure when the water quality in Area 2 to 7 meets the discharge criteria, minor seepage through the dyke foundations would be acceptable; therefore, the presence of permafrost in the key trench area would be preferred but no longer a requirement.

The thermal designs in this study are experience-based and considered to be reasonable for the level of the current study and are expected to meet the general design criteria. Detailed thermal analyses with known site conditions and soil properties will be required to evaluate the thermal performance of the dykes and finalize the thermal designs during the next stage of study. The thermal analyses for these dykes must consider climate change (global warming) scenarios.

3.0 CONSTRUCTION MATERIALS AND QUANTITIES

3.1 Construction Materials

Eleven types of dyke/berm construction materials are proposed in this study, including mine rock fill, transition fill, liner bedding, till fill, till filter, road surface fill, rip-rap, fine PK filter, coarse PK, slurry cut-off wall material, and geomembrane liner. The general requirements for the materials are specified below for cost estimates only for the feasibility study. The requirements for each of the materials can vary slightly for a specific dyke or berm to meet specific design intents. The material specifications for construction will be developed in the final designs of the dykes and berms during the next stage of study.

Mine rock fill, used mainly for constructing the dyke/berm shell, can be sourced from selected run-of-mine mine rock from pit development or from rockfill quarry sites when required. The fill can have a wide variation in gradation, with a maximum particle size of 800 mm. The fill particles shall be angular and shall be derived from hard, durable, non-acid generating rock. The depth and spacing of drill holes and weight and delay of charge shall be selected to produce mine rock of specified size and quality.

Transition fill will mainly serve as a separator between mine rock fill and other finer materials such as liner bedding or till fill. It may need to meet filter design criteria under some applications. It can also be used as erosion protection and rip-rap bedding. The material shall be free of roots, organics, and other deleterious material and have a particle size distribution falling within the limits presented in Table 1. Processing will be required to achieve the specified gradation. The material can be processed from hard, durable, non-acid generating mine rock.

Table 1: Transition Fill Particle Size Distribution Limits

Particle Size (mm)	% Passing
150	100
100	75 – 100
50	40 – 70
20	20 – 50
10	0 – 30
5	0 – 10

Liner bedding fill will mainly serve as beddings placed above and below a geomembrane liner to protect the liner from damage during construction and under normal loading conditions. It may also be used to key the liner into the underlying permafrost foundation and to backfill the key trench. The required gradation will depend on the type of the liner to be protected and other specific applications. For construction planning purposes, gradation limits, as presented in Table 2, have been developed for the material. The maximum size of the particles could be larger if a more puncher-resistant liner, such as a bituminous geomembrane liner, is selected. The material can be processed from hard, durable, non-acid generating mine rock. Under certain applications, selected natural till or even coarse PK may be selected as potential alternatives to the specified liner bedding fill. This cost-saving opportunity can be investigated in the final designs of the dykes and berms.

Table 2: Liner Bedding Fill Particle Size Distribution Limits

Particle Size (mm)	% Passing
20	100
12.5	65 – 100
5	45 – 70
.63	15 – 35
.08	4 – 10

Till fill represents a wide range of natural overburden materials including inorganic till and even some lakebed sediments. An effective mixture of these two soil types may also be chosen. The major application of the till fill in this study is to serve as a low-permeable general fill to reduce seepage through dykes/berms and their foundations. The material shall be free of roots, organics, and other deleterious material. The material can have a wide variation in gradation with a maximum particle size of 300 mm and a fines (less than 0.08 mm) content of 10% to 40%. Selected till fill should be used to backfill the key trench over the liner for the water collection pond berms to form a low-permeable mass without damaging the liner. The overburden soils removed from the footprints of the three pits can be used as till fill material during the dyke and berm construction

Till filter is defined as a material that mainly protects the till fill from potential erosion/instability under seepage forces and hydraulic conditions. The material shall be free of roots, organics, and other deleterious material and have a particle size distribution falling within the limits presented in Table 3. Processing will be required to achieve the specified gradation. The material can be processed from hard, durable, non-acid generating mine rock.

Table 3: Till Filter Particle Size Distribution Limits

Particle Size (mm)	% Passing
38	100
20	75 – 100
12.5	50 – 100
5	35 – 60
.63	5 – 20
.08	0 – 5

Road surface fill will be used over either till fill or crushed rock to provide a stable foundation for the site roads. The fill should meet the requirements of site road designs, which are beyond the scope of this study.

The fill may have a tentative maximum particle size of 50 mm and a fines (less than 0.08 mm) content of less than 8%. The material can be processed from hard, durable, non-acid generating mine rock.

Rip-rap shall be used as erosion protection for Dyke L. The material shall be free of roots, organics and other deleterious material and have a particle size distribution falling within the limits presented in Table 4. Processing will be required to achieve the specified gradation. The material can be processed from hard, durable, non-acid generating rock that may otherwise go to the waste material storage sites.

Table 4: Rip-Rap Particle Size Distribution Limits

Particle Size (mm)	% Passing
300	100
150	75 – 100
50	25 – 65
25	10 – 40
5	0 – 15

Fine PK filter is defined as a filter material used in Dyke L to retain the majority of the fine PK particles but to have sufficient permeability for water to pass through. The material shall be free of roots, organics, and other deleterious material and have a particle size distribution falling within the limits presented in Table 5. Processing from hard, durable, non-acid generating rock will be required to achieve the specified gradation.

Table 5: Fine PK Filter Particle Size Distribution Limits

Particle Size (mm)	% Passing
20	100
12.5	85 – 100
5	65 – 80
1.25	43 – 55
0.63	32 – 45
0.315	23 – 33
0.16	16 – 26
0.08	10 – 18

Coarse PK from the process plant is planned to be used as a construction material for the construction of Dyke B. Its gradation has not been specified at this stage. It is expected to consist of predominantly sand-sized particles. The gradation, hydraulic conductivity, and durability of coarse PK should be investigated before coarse PK is selected as dyke construction material during the final design of the dykes and berms.

Slurry cut-off wall material for Dyke A will comprise either 50 mm minus crush rockfill with 6% bentonite (by weight) or sand and gravel with 6% bentonite.

Geomembrane Liner serves as a seepage barrier for each of Dykes A1, D, E, F, G, N14, E1, N18, and four water collection pond berms in this study. Generally, three types of the geomembrane liners are commercially available for this application. They are HDPE, polypropylene or bituminous geomembrane liners; each has its advantages and disadvantages. The bituminous geomembrane liner, Coletanche ES3 for Dykes A1, D, F, and G, and Coletanche ES2 for the remaining dykes and berms with liner, are selected for cost estimating purposes at this stage of design. If HDPE or polypropylene geomembrane liner is adopted, nonwoven geotextile cushion should be applied both above and below the geomembrane liner to protect the liner from damage during construction and normal operation. The final selection of the liner type will be made during the final design stage based on final design/construction requirements, construction season, and other considerations.

3.2 Construction Quantities

Tables 6 to 10 summarize the estimated material quantities for construction of dykes and berms for water and waste management. The material quantities are "in-place" and do not include material waste, bulking factors, liner seaming allowance, and contingencies. Seaming allowance and contingencies must be added to liner quantities to account for overlap, damaged sections, and/or waste during construction. Bulking factors and contingencies must be added to fill quantities. The volume of key trench excavation has been calculated assuming a trench depth of 2 m. The depth and volume of key trench excavation depend on the actual site conditions encountered.

Table 6: Construction Material Quantities for Dykes A, B, and L

Item	Unit	Dyke A	Dyke B		Dyke L	
			Stage 1 Construction	Stage 2 Construction	Stage 1 Construction	Stage 2 Construction
Mine Rock Fill	m^3	22,600	157,700	23,200	151,500	36,600
Transition Fill	m^3	N/A	N/A	18,400	19,800	9,900
Till Fill	m^3	2,500	N/A	835,400	N/A	N/A
Till Filter	m^3	1,300	N/A	18,400	N/A	N/A
Road Surface Fill	m^3	4,100	N/A	N/A	N/A	N/A
Rip Rap	m^3	N/A	N/A	7,200	12,200	8,800
Fine PK Filter	m^3	N/A	N/A	N/A	19,800	9,900
Coarse PK	m^3	N/A	133,500	50,200	N/A	N/A
Slurry Cut-off Wall Excavation	m^3	700	N/A	N/A	N/A	N/A
Slurry Cut-off Wall Backfill	m^3	700	N/A	N/A	N/A	N/A
Total Fill Volume	m^3	31,200	291,200	952,800	203,300	65,200

Table 7 Construction Material Quantities for Dykes A1, D, E, F, and G

Item	Unit	Dyke A1	Dyke D	Dyke E	Dyke F	Dyke G
Mine Rock Fill	m^3	19,000	7,200	18,800	11,300	17,100
Transition Fill	m^3	N/A	N/A	N/A	4,100	3,200
Liner Bedding	m^3	12,400	4,800	4,500	4,600	3,800
Till Fill	m^3	37,700	11,900	12,300	6,000	2,700
Till Filter	m^3	3,400	1,200	700	1,000	1,000
Road Surface Fill	m^3	4,200	2,300	2,700	1,300	3,000
Trench Excavation	m^3	14,000	5,900	4,200	4,600	5,900
Geomembrane Liner	m^2	16,400	5,300	4,100	4,400	4,100
Total Fill Volume	m^3	76,700	27,400	39,000	28,300	30,800

Table 8: Construction Material Quantities for Dykes H, I, J, K, M and N

Dyke	Construction Stage	Dyke Construction Material Volume (m^3)					
		Mine Rock Fill	Transition Fill	Till Fill	Till Filter	Road Surface Fill	Total Fill Volume
Dyke H	Stage 1	400	N/A	900	N/A	N/A	1,300
	Stage 2	4,400	N/A	13,900	900	2,600	21,800
Dyke I	Stage 1	1,700	1,500	19,200	500	N/A	22,900
	Stage 2	8,600	1,100	47,500	3,500	12,100	72,800
Dyke J	Stage 1	500	300	2,400	N/A	N/A	3,200
	Stage 2	1,300	N/A	5,000	400	1,200	7,900
Dyke K	Stage 1	N/A	N/A	75,900	N/A	10,100	86,000
	Stage 2	15,600	800	35,700	4,700	N/A	56,800
Dyke M	One stage	3,400	N/A	6,500	100	3,100	13,100
Dyke N	Stage 1	N/A	N/A	112,500	N/A	6,800	119,300
	Stage 2	23,400	900	57,700	6,400	N/A	88,400

Table 9: Construction Material Quantities for Water Collection Pond Berms for CP3 to CP 6

Item	Unit	Water Collection Pond Berm			
		CP3	CP4	CP5	CP6
Mine Rock Fill	m^3	5,400	500	3,000	8,500
Transition Fill	m^3	700	N/A	500	1,300
Liner Bedding Fill	m^3	1,800	300	800	2,000
Till Fill	m^3	3,800	700	1,300	3,500
Till Filter	m^3	500	100	200	600
Key Trench Excavation	m^3	4,600	900	1,400	3,800
Geomembrane Liner	m^2	4,100	600	1,400	3,600
Total Fill Volume	m^3	12,200	1,600	5,800	15,900

Table 10: Construction Material Quantities for Area 1 Perimeter Berms

Fine PK Management Berm	Berm Construction Material Volume (m^3)		
	Berm 1	Berm 2	Berm 3
Mine Rock Fill	2,300	1,100	1,900
Till Fill	7,500	4,000	6,500
Key Trench Excavation	2,500	1,500	2,400
Total Fill Volume	9,800	5,100	8,400

3.3 Construction Schedule

Table 11 presents the overall construction schedules for the dykes and berms required for the water and waste management.

Table 11 Summary of Dyke/Berm for Gahcho Kue Project, NWT

Name	Dyke/Berm Type	Approximate Construction Year	Maximum Design Operating Water Head at Dyke/Berm Centreline (m)	Total Length of Dyke/Berm (m)
Dyke A	Water retention /diversion dyke	Early Year -2 (before start of initial lake dewatering)	2.0	480
Dyke B	Internal water retention dyke	Year 4 to early Year 5	11.5	930
Dyke A1	Diversion/water retention dyke	Before Year -1 spring freshet	4.0	670
Dyke D	Water retention dyke	Before Year 2 spring freshet	2.0	240
Dyke E	Diversion dyke/water retention	Before Year 1 spring freshet	1.3	370
Dyke F	Diversion dyke	Before Year -1 spring freshet	3.0	290
Dyke G	Diversion dyke	Before Year -1 spring freshet	1.0	390
Dyke H	Internal water retention dyke	Stage 1 Construction in Year -2 ; full dyke (Stage 2) before Year 3	2.5	280
Dyke I	Internal water retention dyke	Stage 1 Construction in Year -2; full dyke (Stage 2) before Year 3	4.5	410
Dyke J	Internal water retention dyke	Stage 1 Construction in Year -2; full dyke (Stage 2) before Year 3	2.7	135
Dyke K	Internal water retention dyke	Stage 1 (haul road) construction in Year -1; full dyke (Stage 2) in Year 5 to early Year 6 (before Year 6 spring freshet)	7.7	340

Table 11 Summary of Dyke/Berm for Gahcho Kue Project, NWT

Name	Dyke/Berm Type	Approximate Construction Year	Maximum Design Operating Water Head at Dyke/Berm Centreline (m)	Total Length of Dyke/Berm (m)
Dyke L	Internal filter dyke	Stage 1 in Year -1 (before placing fine PK in Area 2) and full dyke (Stage 2) in Year 2	1.0	1065
Dyke M	Internal water retention dyke	Before Year 3 spring freshet	1.5	215
Dyke N	Internal water retention dyke	Stage 1 (haul road) construction in Year 4; full dyke (Stage 2) in Year 9	8.3	410
Area 1 Perimeter Berms	Internal water diversion berms	Year -1 or Early Year 1	1.0	680
Berms for Water Collection Ponds	Internal water retention berm	Road berm for CP2 in Year -1); berms for CP3 to CP5 in Year -1 and berm for CP6 in Year 5	3.0	1120

REFERENCES

CDA 2007. Dam Safety Guidelines. Canadian Dam Association, 2007, p.82.

EBA 2011. Summary of Dyke Design and Construction Material for Gahcho Kue Diamond Project, NWT, Canada. Technical memo submitted to De Beers Canada Lid. By EBA Engineering Consultants Ltd., December 13, 2011.