Tahera Diamond Corporation

JERICHO PROJECT
NORTH DAM
CONSTRUCTION SPECIFICATIONS

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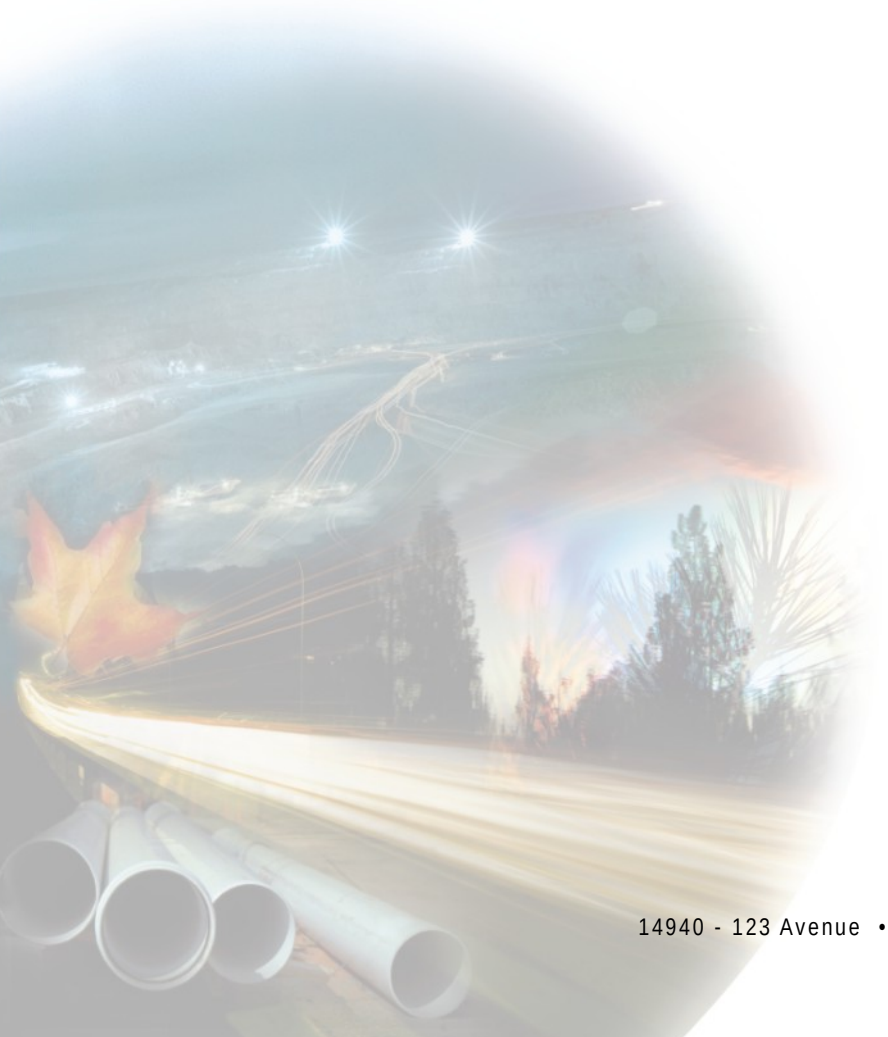

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SECTION 1001 GENERAL

1.0 GENERAL

Tahera Diamond Corporation is operating the Jericho Diamond Mine, Nunavut. The fine processed kimberlite from the mine operation is deposited in the Processed Kimberlite Containment Area (PKCA), which consists of several perimeter dams and cross-lake divider dykes. The proposed North Dam is one of the perimeter dams that are required based on the tailings/water management plan. The North Dam is a zoned rockfill frozen core dam used to retain water within the PKCA.

The structural body of the dam includes a till berm, frozen crushed rock core, rockfill shell, and transition zones. A key trench will be excavated beneath the core to ice-saturated soil or competent rock and backfilled with the core material to produce a well-bonded and impermeable mass. A second seepage barrier is provided by a geosynthetic clay liner on the upstream side of the core tied into the key trench.

Horizontal thermosyphon evaporator loops will be installed near the base of the core such that the frozen core and its permafrost foundation are sufficiently cold to act as an impervious barrier.

A grout curtain will be installed in the dam foundation below the key trench to cut off potential seepage paths through open joints or fractures.

Ground temperature cables will be installed in the key trench backfill and the core to monitor the thermal regime of the dam core and foundation as well as the thermal performance of the horizontal thermosyphons. Survey monitoring points will be installed along the dam crest to monitor dam deformations through its service life.

Most of the dam construction shall occur during the winter to meet the design intent.

2.0 DEFINITIONS OF TERMS USED

ASTM	the latest version of the referenced method presented by the American Society for Testing Materials.
Construction Drawings:	the design drawings as issued for construction of the dam.
Construction Specifications:	this document.
Contractor:	the general contractor responsible for constructing the dam.
Engineer:	EBA Engineering Consultants Ltd. (EBA) representative on site during dam construction or related activities.
GCL	Geosynthetic Clay Liner
Owner:	Tahera Diamonds Corporation (Tahera)
PK	Processed Kimberlite

Site: the area in which dam construction or related activity is occurring.

Unsuitable: not meeting the requirements stated herein or not receiving the Engineer's approval.

3.0 MATERIALS

The material zones referenced in these specifications are designated on the Construction Drawings. Estimated total in-place material quantities are listed in Table 1001.1. The quantities of material do not include any contingency for waste.

TABLE 1001.01: NORTH DAM MATERIAL QUANTITIES FOR CONSTRUCTION

Excavation/Material Type	Quantity [a]
Key Trench Excavation[b]	2,800 m^3
Run-of-Mine Shell Material (700 mm minus) (Material A)	18,600 m^3
Till Fill (300 mm minus) (Material B)	1,400 m^3
150 mm minus Transition Rockfill (Material C)	3,000 m^3
Coarse PK (20 mm minus) (Material D)	700 m^3
20 mm minus Core Material (Material E)	6,100 m^3
Geosynthetic Clay Liner (GCL)	2,600 m^2
Thermosyphon Evaporator Pipe	570 m
Thermosyphon Radiators (39 m^2 each)	4
Ground Temperature Cables[c]	8
Survey Monitoring Points[d]	6

Notes:

(a) Quantities are "in-place". Seaming allowance and contingencies must be added to GCL quantities to account for overlap, damaged sections, and/or waste during construction. It is recommended that 20% extra quantities be available on site. Bulking factors and contingencies must be added to fill quantities; 20% should be added to reported quantities for stockpile volumes. Quantities have been calculated based on 1 m contour data.

(b) The volume of key trench excavation has been calculated assuming a trench depth of 2 m over the valley and south abutment and 3 m over the north abutment. The depth and volume of key trench excavation depends on the conditions encountered. The required depth shall be determined during construction by the Engineer.

(c) See Drawing ND-8 for details.

(d) See Drawing ND-9 for details.

4.0 SITE CLEANUP

The Contractor shall remove all temporary structures and shall clean up the construction areas, borrow areas, and stockpile areas.

Waste materials shall be disposed properly according to applicable regulations and rules and approved by the Owner for on-site disposal.

SECTION 1003

SECTION 1003 WATER CONTROL

1.0 GENERAL

.1 Water control for construction of the North Dam is described in this section.

.2 The key trench and dam footprint areas shall be dewatered, as required, to allow for fill placement in a dry environment.

.3 Water control and dewatering is the responsibility of the Contractor.

2.0 COFFERDAMS

.1 Temporary cofferdams may be required to minimize water flow into the key trench excavation.

.2 Construction and design of the cofferdams is the responsibility of the contractor. The design and construction plan must be submitted to the Engineer prior to construction.

3.0 DEWATERING SUMP(S)

.1 Any inflow of ground water or surface run-off water into the key trench or dam footprint must be controlled using suitably placed and sized sumps and pumps.

.2 Water collected in the sumps must be discharged properly according to the Owner's direction and following applicable regulations or rules. Discharge of water must not cause erosion.

.3 Construction, operation and maintenance of the sump(s) and pump(s) are the responsibility of the Contractor.

SECTION 1004

SECTION 1004 FOUNDATION PREPARATION

1.0 GENERAL

.1 Foundation preparation for the dam is presented in this section. Construction of the grout curtain is described in Section 1012.

2.0 NON-KEY TRENCH FOUNDATIONS

.1 Surficial vegetation, organic soils, and/or loose, protruding boulders shall be removed from the area beneath the till berm, core and transition zones, as indicated on the Construction Drawings or as determined by the Engineer.

.2 All snow, ice or other debris shall be removed prior to fill placement.

.3 Ice-rich soils beneath the core and liner system or other soils deemed to be unsuitable by the Engineer must be removed.

.4 The prepared foundation surface shall be approved by the Engineer.

3.0 KEY TRENCH FOUNDATION

.1 The key trench must be excavated into ice-saturated, permanently frozen soil or competent rock as determined by the Engineer. The base of the excavation must have no natural or excavation related open voids or joints.

.2 Preliminary depths of the key trench excavation are shown on the Construction Drawings. The final depths of excavation will be determined in the field by the Engineer.

.3 Excavation of rock shall be conducted in a manner that avoids excessive fracturing of underlying rock.

.4 The key trench can be excavated using mechanical or drill and blast means. Drill and blast excavation may be limited by the Engineer if excessive cracking of rock or soil beneath the key trench occurs.

.5 Final cleaning of the key trench must be conducted with hand excavation, brooms and compressed air or other appropriate equipment such as rippers, jack hammers etc. to remove all loose, broken or altered material from the base of the key trench. Snow and ice must be removed from the key trench prior to fill placement.

.6 Ice-rich soils exposed on the upstream face of the key trench excavation shall be removed from areas underlying the liner system. Additional excavation beyond the limits of the key trench excavation may be required at the Engineer's discretion.

.7 Any inflow of water into the key trench excavation shall be controlled by sumps and pumps in a manner that minimizes thaw and erosion of the key trench base.

4.0 DRILLING AND BLASTING

.1 The Contractor is responsible for ensuring that blasting procedures used are within guidelines set by all regulatory bodies and authorities having jurisdiction on site.

.2 The Contractor must use excavation methods that minimize fracturing beyond excavation limits.

.3 Care must be taken in locating the drill holes, orienting the drills and during drilling so that accurate positioning and alignment of the drill holes is achieved.

.4 The method of excavation must produce a key trench base that is free of abrupt changes in elevation.

.5 Controlled blasting techniques must be used to satisfy the excavation requirements stated herein. The initial explosive type and quantity, blasting sequence and delay pattern must be flexible in order to meet these requirements.

.6 The Contractor shall submit complete details of any proposed blast to the Engineer. Submitted data shall include the following:

- the location, depth and area of the blast,
- the type, strength, quantity, column load and distribution of explosives to be used per hole, per day and per blast,
- the sequence and pattern of the delay, and
- the description and purpose of any special methods to be adopted.

.7 If, in a specific area, a plan that was previously adopted does not produce conditions in accordance with the requirements stated herein, the Contractor must submit a revised blasting plan to the Engineer before continuing with drilling and blasting in adjacent areas.

5.0 FOUNDATION APPROVAL

.1 The foundation must be inspected and approved by the Engineer before any fill material is placed.

SECTION 1005

SECTION 1005 FILL MATERIALS

1.0 GENERAL

.1 This section describes the material specifications for fill materials used in construction of the North Dam.

.2 Material quantities are presented in Section 1001.

2.0 REFERENCE STANDARDS

.1 ASTM C136 – Standard Test Method for Sieve Analysis of Fine and Coarse Aggregate.

3.0 MATERIAL SOURCES

.1 No material shall be borrowed or excavated without the Owner's prior approval.

.2 Pits and quarries must be maintained and managed in accordance with the requirements set out in the Owner's Land Use and Quarry Permits.

.3 The Contractor must process all materials to meet the gradations specified herein.

.4 Core material (20 mm minus) shall be obtained by processing material obtained from Jericho pit or other sources approved by the Owner, providing the final product meets the gradations specified herein. Processing will be required to achieve the specified gradation.

.5 The 20 mm minus material is to be used as the bedding material above and beneath the geosynthetic clay liner (GCL) within the key trench and below the GCL on the core slope.

.6 The coarse processed kimberlite (Coarse PK) from the plant is to be used as the bedding material over the core slope GCL, as indicated on the Construction Drawings.

.7 Transition (150 mm minus) material shall be obtained by processing material obtained from Jericho pit or other sources approved by the Owner, providing the final product meets the gradations specified herein. Processing will be required to achieve the specified gradation.

.8 Run-of-mine material (700 mm maximum size) shall be obtained from Jericho pit or other sources approved by the Owner, provided the final product meets the requirements stated herein. Specific quarrying and/or processing procedures may be required to meet the specified maximum size.

.9 Till shall be obtained from the Jericho waste dumps or other sources approved by the Owner.

.10 The parent rock from which all fill materials (except for the Coarse PK) are derived must be hard, durable rock. The rock in a potential quarry source must be approved

by the Engineer prior to quarrying. The Engineer may require acid base accounting, trial crushing, and durability tests prior to approving a quarry site.

.11 The parent rock sources for dam fill materials must be inspected by the Engineer throughout material processing and dam construction activities to ensure the requirements stated herein are being met.

4.0 MATERIAL SPECIFICATIONS

.1 20 mm Minus Material (Material E)

a. The fill material used in the key trench and frozen core shall be 20 mm minus crush hard rock with durable particles, be free of roots, topsoil or deleterious material and have a particle size distribution falling within the limits set forth in Table 1005.1.

TABLE 1005.1 : 20 MM MINUS MATERIAL PARTICLE SIZE DISTRIBUTION LIMITS

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

.2 Coarse PK (Material D)

a. Coarse processed kimberlite (Coarse PK) from the process plant can be used as the bedding material over the upper GCL above the key trench. Previous laboratory particle size analyses on the Coarse PK samples indicated that the Coarse PK can be classified as gravelly sand with a maximum particle size of 10 mm and negligible amount of fines smaller than 0.08 mm. The gradation of the Coarse PK may slightly vary with mine operation. The Coarse PK used for the dam construction should have a maximum particle size of less than 20 mm.

.3 150 mm Minus Material (Material C)

a. The 150 mm minus material used as transition between the core and shell materials must be free of roots, topsoil and other deleterious material and have a particle size distribution falling within the limits presented in Table 1005.2.

TABLE 1005.2 : 150 MM MATERIAL PARTICLE SIZE DISTRIBUTION LIMITS	
Particle Size (mm)	% Passing by Weight
150	100
100	75 - 100
50	40 - 70
20	20 – 50
10	0 - 30
5	0 - 10

.4 Run-of-Mine Material (Material A)

a. The run-of-mine material can have a wide variation in gradation with a maximum particle size of 700 mm. Rockfill particles must be hard, durable and angular.

b. The depth and spacing of blast drill holes as well as the weight and delay of charges shall be selected to produce run-of-mine rockfill material meeting the specification.

c. Any significant concentration of unsuitable materials must be removed and directed to a waste disposal area, other location approved by the Owner or, with the Engineer's approval, mixed with other materials to produce a material meeting specifications.

.5 Till Material (Material B)

a. The till material shall have a particle size distribution falling within the limits in Table 1005.3. Particles must be hard, durable and angular to sub-angular.

TABLE 1005.3 TILL MATERIAL PARTICLE SIZE DISTRIBUTION LIMITS	
Particle Size	% Passing by Weight
250	100
75	80 – 100
20	50 – 90
5	31 – 70
0.08	7 - 26

SECTION 1006

SECTION 1006 FILL PLACEMENT

1.0 GENERAL

.1 The placement methods for fill materials to be used in the construction of the dam are described in this section.

.2 Construction must be performed in accordance with the best modern practice and with equipment best adapted to the work being performed. Embankment materials must be placed so that each zone is homogeneous, free of stratifications, ice chunks, lenses or pockets, and layers of material with different texture or grading not conforming to the requirements stated herein.

.3 No embankment fill material shall be placed on any part of the foundation until it has been prepared as specified herein and approved by the Engineer. Placement of fill material must conform to the lines, grades and elevations shown on the Construction Drawings, as specified herein or as per the direction of the Engineer. Fill placement must be conducted in such a manner that mixing of fill materials with fill materials in adjacent zones is avoided.

.4 Embankment construction must not proceed when the work cannot be performed in accordance with the requirements of the Construction Specifications. Any part of the embankment that has been damaged by the action of rain, snow or any other cause must be removed and replaced with the appropriate material conforming to the requirements stated herein before succeeding layers are placed.

.5 Stockpiling, loading, transporting, dumping and spreading of all materials must be carried out in such a manner to avoid segregation or any other condition that does not meet the requirements stated herein. Segregated materials must be removed and replaced with materials meeting the requirements stated herein and receiving the Engineer's approval.

.6 The Contractor must remove all debris, vegetation or any other material not conforming to the requirements stated herein. The Contractor must dispose of these materials in an area approved by the Owner.

2.0 20 MM MINUS (FROZEN CORE AND KEY TRENCH BACKFILL)

.1 The key trench foundation must be cleared of all deleterious material as described in Section 1004. The foundation area must be inspected and approved by the Engineer before fill placement proceeds.

.2 Snow and ice must be removed from the base of the key trench excavation before fill can be placed in that area.

.3 Key trench and core material placement must be conducted when air temperatures will freeze a lift of key trench material within 24 hours of placement. Experience has shown that a 250 mm thick lift freezes back within 24 hours when air

temperatures are below –15°C. The time to freezeback will depend on the moisture content, wind speed, air temperature and solar radiation.

.4 The 20 mm minus material from the stockpile must be mixed with heated water using a method approved by the Engineer to create a homogeneous mix that is fully thawed and does not contain interstitial ice. The mix must not freeze until after it is placed and compacted in the key trench excavation. The temperature of the mix water required to meet the requirements stated herein may vary depending on the air temperature, wind speed and solar radiation.

.5 The 20 mm minus material for the core and trench backfill shall have a minimum average degree of saturation of 85% with no results falling below 80%. The moisture content shall be adjusted so that the material shall become nearly ice-saturated mass when frozen but no excessive water shall be available to form ice lenses. The established moisture content may be adjusted from time to time during construction based on results of the quality assurance tests.

.6 The 20 mm minus material placed in the key trench and core must be spread and levelled immediately upon placement. The material must not be reworked, disturbed or rutted after compaction.

.7 The 20 mm material placed in the key trench and core shall be compacted with a smooth drum vibratory compactor weighing not less than 10 tonnes. The material shall be compacted with at least six passes (back and forth being two passes) to achieve the maximum density possible at the placed moisture content. The number of passes may be adjusted at the Engineer's discretion to suit varying conditions.

.8 The lift thickness must be varied to achieve 100% freezeback prior to placement of the next lift. Freezeback is defined as a maximum temperature of –2°C. The lift thickness may be adjusted depending on the placed moisture content and climatic conditions and results of fill temperature monitoring. Individual lifts must have uniform thickness.

.9 The fill area must be cleared of snow, ice and loose material before a new lift is placed. The surface of each lift must be approved by the Engineer before it is covered by a subsequent lift.

.10 The first lift of key trench backfill will serve as a bedding layer between the GCL liner and the base of the key trench. Extra care should be taken by the Contractor to ensure the surface of the first lift before liner placement is as smooth and even as possible. Small batches of 20 mm minus material may be required to provide localized levelling and smoothing of the first lift surface to ensure the liner system has a level, even subgrade beneath it. Localized frozen high points on the surface of the first lift that the Engineer believes may cause puncture or stressing of the liner system must be removed without disturbing the surrounding lift surface.

.11 The Contractor must ensure that the integrity of the GCL liner system, temperature cables, and thermosyphon evaporator pipes buried in the fill are not compromised during construction. Precautions the Contractor may take to avoid damaging these components may include, but will not be limited to: avoiding vehicles travelling directly on these components without sufficient cover fill protection, avoiding turning tracked vehicles on the first two lifts of the cover fill, providing light plants in the work area to improve operator visibility, or using pylons to mark the lift/liner interface or any other sensitive areas.

.12 Any damage to the GCL liner, temperature cables, and thermosyphon evaporator pipes must be immediately reported to the Engineer. Repair work must commence as soon as possible. Fill placement must cease immediately in an area where the damage occurs until the repair work is completed. The fill surrounding the damaged area may have to be excavated, without causing any further damage, to permit repairs to be made. Excavation methods suitable for this task may vary depending on the degree of freezing that may have already taken place in the fill.

3.0 COARSE PK FOR LINER COVER

.1 The Coarse PK as the cover material over the GCL liner on the upstream slope and crest of the frozen core shall be placed as described in Section 1007.

4.0 TRANSITION 150 MM MINUS ROCKFILL MATERIAL

.1 The Transition 150 mm minus rockfill material must be placed in lifts not exceeding 400 mm thickness. The placement method used must ensure that segregation and nesting of coarse particles is avoided.

.2 The Transition 150 mm minus rockfill material must be compacted with a smooth drum vibratory compactor weighing not less than 10 tonnes. Moisture conditioning may be required prior to compaction. The Transition 150 mm minus rockfill material must be compacted with at least four passes of the compactor (back and forth being two passes). Rolling patterns must be used throughout construction to optimize the number of passes, amount of water added and vibration frequency for compacting the 150 mm minus rockfill material.

5.0 RUN-OF-MINE ROCKFILL

.1 The run-of-mine rockfill must be placed in lifts not exceeding 700 mm thickness. The placement method must ensure that segregation and nesting of coarse particles is avoided.

.2 The run-of-mine rockfill shall be compacted by ensuring that loaded haul truck traffic is routed over the entire surface of each lift. Particles greater than 700 mm diameter must be moved to the upstream or downstream face of the dam.

6.0 TILL MATERIAL

.1 The till material must be placed in lifts not exceeding 300 mm thickness. The placement method used must ensure that segregation and nesting of coarse particles is avoided. The till material should be placed and compacted under unfrozen conditions.

.2 The till material must be compacted with a smooth drum vibratory compactor weighing not less than 10 tonnes. Moisture conditioning may be required prior to compaction. The till material must be compacted with at least four passes of the compactor (back and forth being two passes). Rolling patterns must be used throughout construction to optimize the number of passes, amount of water added and vibration frequency for compacting the till material.

.3 The Contractor shall carry out proof roll tests on the till at the Engineer's request.

SECTION 1007

SECTION 1007 GEOSYNTHETIC CLAY LINER

1.0 GENERAL

.1 This section describes the product and installation specifications for the Geosynthetic Clay Liner (GCL) for the North Dam.

.2 The GCL shall be provided by the Owner and installed by the Contractor.

2.0 PRODUCT

.1 The GCL shall consist of sodium bentonite between two non-woven geotextiles which are bonded by needle-punching. The GCL shall be Bentomat DN, or approved equivalent. The product shall conform to the physical, mechanical and hydraulic properties listed in Table 1007.1.

.2 The GCL manufacturer shall provide to the Engineer, prior to the shipment of the materials, a signed manufacturing certification that the materials to be shipped to the site have test values which meet or exceed each property listed in Table 1007.1.

TABLE 1007.1: TECHNICAL SPECIFICATIONS FOR GEOSYNTHETIC CLAY LINER

Product Specifications				
Geotextile Property	Test Method	Standard[1]	Units	Value
Bentonite				
Swell Index	ASTM D5890	Minimum	mL/g	12
Mass/Area(1)	ASTM D5993	Minimum	kg/m^2	3.6
Fluid Loss	ASTM D5891	Maximum	ml	18
Finished GCL				
Index Flux(2)	ASTM D5887	Maximum	m^3/m^2/s	1 x 10^{-8}
Grab Strength(3)	ASTM D6768	MARV	N/cm	88
Peel Strength	ASTM D6496	Minimum	N/cm	6.1
Hydraulic Conductivity(2)	ASTM D5887	Maximum	cm/s	5 x 10^{-9}
Hydrated Internal Shear Strength(4)	ASTM D5321 ASTM D6243	Minimum	kPa	24 @ 10 kPa confining

Notes:

(1) Bentonite mass/area at 0 percent moisture content

(2) Index flux and permeability testing with deaired distilled/deionized water at 551 kPa (80 psi) cell pressure, 531 kPa (77 psi) headwater pressure and 517 kPa (75 psi)tailwater pressure.

(3) Minimum Average Roll Value (MARV)

(4) Peak values measured at 10 kPa (200 psf) normal stress for a specimen hydrated for 48 hours.

3.0 SHIPPING AND STORAGE

.1 Shipping shall conform to the requirements of the manufacturer and shall be carried out in a manner which shall protect the rolls from damage or water penetration during shipment.

.2 Storage of the GCL rolls on site shall be in a secure location that will minimize exposure. It is absolutely essential that the GCL rolls are protected from exposure to water.

4.0 INSTALLATION

.1 The bedding surface for the GCL shall be made smooth with all protrusions, and angular particles larger than 20 mm removed.

.2 The installation of the GCL shall not begin until a proper sub-base has been prepared and approved by the Engineer.

.3 The GCL shall be placed in the key trench in a manner that will prevent damage to the liner. The method of deployment shall be discussed with and approved by the Engineer.

.4 The GCL shall be temporarily anchored such that it does not move while backfilling.

.5 The GCL in the key trench shall be carefully covered with saturated 20 mm minus core material as described in Section 1005. The fill should be mixed and placed as described in Section 1006.

.6 The upstream slope of the core as the GCL subgrade should be uniformly compacted and graded and shall be free of loose material.

.7 The GCL panels should be placed perpendicular to the dam axis.

.8 GCL deployment shall not be carried out during any form of precipitation, or in periods of high wind.

.9 Uncovered edges of GCL panels shall be protected at the end of the working day with a waterproof sheet adequately secured with ballast.

5.0 LAPPING AND JOINING

.1 Unless shown otherwise on the construction drawings, the GCL shall have a minimum overlap of 500 mm.

.2 Each overlap should be treated with powdered bentonite or bentonite paste (mixed with 6 parts water to 1 part bentonite by weight), comprised of the same bentonite as used in the manufacture of the GCL. The bentonite shall be applied at the minimum rate of 0.4 kg/m of seam.

.3 All joints shall be placed such that the higher liner overlaps the lower liner.

6.0 GCL COVER MATERIAL

.1 Cover material refers to the material upstream and on top of the upper GCL placed on the upstream slope and over the crest of the frozen core.

.2 The cover material shall be Coarse PK and free of oversize particles greater than 20 mm, top soil, roots or other deleterious materials that may compromise the integrity of the liner system. The placement method used must ensure that segregation and nesting of coarse particles is avoided.

.3 The Contractor must ensure that the integrity of the GCL liner is not compromised during placement and compaction of the cover material. The cover material shall be placed such that it is pushed across the seams from the overlap roll to the underlap roll. Care shall be taken not to push aggregate between the seam overlap. The cover material should be pushed up-slope to minimize tension on the GCL when covering GCL on sloped areas.

.4 Equipment shall push the cover material ahead of the equipment, and never travel directly on the GCL. The cover material shall be placed with low ground pressure equipment. Care should be taken to avoid damaging the GCL by making sharp turns or pivots with equipment as well as sudden starts or stops.

.5 Precautions shall be taken to prevent damage to the GCL by restricting the use of heavy equipment over the liner. A minimum thickness of 500 to 900 mm of cover, as determined by the Engineer, shall be kept between heavy equipment and the GCL at all times, except when final-grading. No heavy vehicles should be driven directly on the GCL until the proper thickness of cover has been placed.

.6 The initial lift of the cover material shall be 300 mm in thickness and compacted to 90% of the maximum dry density (ASTM D698-91) or as specified by the Engineer to prevent damage to the GCL. The subsequent lifts should be placed in lifts not exceeding 300 mm in thickness and compacted to 95% of the maximum dry density (ASTM D698-91). The Coarse PK should be placed and compacted in unfrozen conditions. Moisture conditioning may be required to achieve the specified level of compaction.

7.0 DAMAGE

.1 The Contractor shall record all areas requiring repair due to damage during shipping, handling, or deployment, or manufacturing flaws and report to the Engineer. The method of repair to be used shall be approved by the Engineer.

.2 The Contractor shall immediately report to the Engineer all areas where the GCL is damaged or seen to be damaged during the GCL installation and cover fill placement. Repair work must commence as soon as possible. Fill placement must cease immediately in an area where the integrity of the GCL liner has been compromised. Excavation of fill surrounding the damaged GCL liner may have to be excavated, without further damaging the integrity of the liner, to permit repairs to be made.

Hand excavation must be used to expose damaged portions of the liner for repair. The method of repair to be used shall be approved by the Engineer.

.3 All repairs made by the placement of a patch of the same material over the damage shall extend at least 500 mm beyond the flaw or damage in every direction.

SECTION 1008

SECTION 1008 HORIZONTAL THERMOSYPHONS

1.0 GENERAL

.1 This section describes the product and installation specifications for horizontal thermosyphons to be installed in the North Dam.

2.0 MATERIALS (BY MANUFACTURER)

.1 Thermosyphons shall be two-phase, liquid-vapour type thermosyphons charged with carbon dioxide refrigerant.

.2 The thermosyphons shall be constructed with A53B Schedule 40 steel pipe.

.3 Radiators shall be 75 mm O.D. pipe with 32 mm high x 0.012 mm nominal thickness carbon steel fins. Fin density shall be four (4) rows of fins per 25 mm of pipe. Each horizontal thermosyphon loop shall be connected to a 39 m^2 radiator.

.4 Standard of Acceptance: Thermosyphons as manufactured by Arctic Foundations of Canada Inc., Winnipeg, Manitoba, or an approved equivalent.

.5 The heat extraction capacity of the thermosyphons shall, at a minimum, satisfy the empirical expression for overall heat transfer conductance of a 6.5 m^2 radiator, charged with carbon dioxide refrigerant, for an evaporator slope angle of 0 degrees above horizontal, as described in Haynes and Zarling (1988), "Thermosyphons and Foundation Design in cold Regions," Cold Regions Science Technology, vol. 15, pp. 251-259. The effective heat transfer conductance of the 39 m^2 radiator shall be at least six times the calculated heat transfer conductance of the 6.5 m^2 radiator.

.6 The evaporator and radiator sizes shall be as shown on the Construction Drawings or as approved by the Engineer.

.7 All welds shall meet ASME boiler and pressure vessel codes.

3.0 INSTALLATION

.1 The evaporator pipes shall be installed as specified on the Construction Drawings or as directed by the Engineer.

.2 The radiators shall be erected plumb.

.3 All piping shall be tested prior to burial as detailed in Section 1010. Evaporator pipe that has been damaged or accidentally kinked during installation shall be reported to the Engineer and replaced, at the discretion of the Engineer.

4.0 MONITORING

.1 The operation of the thermosyphons shall be monitored with a contact thermometer or an infrared surface temperature measuring device to verify operation. Operation is generally indicated by a thermosyphon temperature being a few degrees warmer

than the air temperature. Monitoring shall be carried out twice a month during the first three months in which the thermosyphons are expected to be operational. The thermosyphons will only be operational during the period when the air temperatures are colder than the ground temperatures.

.2 Performance of the thermosyphons shall be evaluated with ground temperature cables as shown on the Construction Drawings and as described in Section 1009 of this document.

5.0 WARRANTY

.1 The thermosyphons shall have a minimum five year manufacturer's warranty against reduction in heat transfer performance.

SECTION 1009

SECTION 1009 INSTRUMENTATION

1.0 GENERAL

.1 The required geotechnical instrumentation for monitoring the performance of the dam is presented in this section.

.2 The survey monuments as shown on the Construction Drawings shall be supplied and installed by the Contractor.

.3 Ground temperature cables, casings, and data logger housings will be supplied and installed by the Engineer with the Contractor's assistance when needed. The holes for installation of the vertical ground temperature cables shall be drilled by the Contractor.

.4 The Contractor shall be responsible for providing protection for all instruments installed before construction of the dam is complete. The method of protection must be approved by the Engineer. The Contractor may be held responsible (at the Engineer's discretion) for replacement or repair of instruments damaged during construction.

2.0 INSTRUMENTATION REQUIREMENTS

.1 Ground temperature cables must be installed as shown on the Construction Drawings to measure ground temperature during construction and operation of the dam. Ground temperature cables will be provided by the Engineer.

.2 Data logger housings for the ground temperature cables will be provided by the Contractor as shown on the Construction Drawings.

.3 Single bead ground temperature cables will be used to monitor the freeze back of individual lifts of the key trench backfill. These instruments will be provided by the Engineer.

.4 Survey monuments shall be supplied by the Contractor.

3.0 GROUND TEMPERATURE CABLE INSTALLATION

.1 Horizontal ground temperature cables must be installed during construction. Vertical ground temperature cables must be installed after the completion of the shell fill on the dam crest during construction. The locations and orientation of the ground temperature cables are shown on the Construction Drawings.

.2 Drillholes for vertical ground temperature cable installation must be 100 mm ID or greater. Drillholes must be drilled in the presence of the Engineer to the depths shown on the Construction Drawings. Schedule 40 PVC 50 mm ID pipe, or approved equivalent, with a watertight end cap, must be placed in the hole prior to casing removal.

.3 The inside and outside of the PVC pipe must be backfilled with sand such that there are no air voids around the pipe or ground temperature cable.

.4 Horizontal ground temperature cables passing through the 150 mm minus rockfill material and the run-of-mine material must be placed in a steel pipe of sufficient strength to resist crushing upon placement of fill material. A 0.3 m thick layer of 20 mm minus material should be placed over the steel pipe within these zones. The portion of the cable over the downstream dam slope should also be protected in a steel pipe.

.5 The location of the installed instruments must be surveyed to 100 mm horizontal and 20 mm vertical accuracy.

4.0 SURVEY MONUMENTS

.1 Survey monuments shall be supplied and installed by the Contractor as shown on the Construction Drawings to monitor the dam deformations during the dam service life. The installation may be directed or inspected by the Engineer.

SECTION 1010

SECTION 1010 QUALITY ASSURANCE

1.0 GENERAL

.1 The quality assurance testing required by the Engineer is described in this section.

.2 The quality testing will be conducted by the Engineer.

2.0 FILL TESTING REQUIREMENTS

.1 20 mm minus material

a. Quality control testing must be performed during the crushing operation when the 20 mm minus material is being processed. The tests and testing frequency required during processing of the 20 mm minus material are presented in Table 1010.1. Additional testing may be required at the discretion of the Engineer.

TABLE 1010.1: REQUIRED TESTING AND FREQUENCY DURING PROCESSING OF 20 MM MINUS MATERIAL

Test	Test Frequency
Particle Size Analysis	One per 500 m^3 produced
Maximum Density	One per 1000 m^3 produced

b. Additional sieve analysis testing may be conducted by the Engineer on samples collected from the dam fill to verify that the placed gradation meets the gradation requirements stated herein.

c. The compacted density of the 20 mm minus material used as core and key trench fill must be evaluated by coring samples for lab testing and in situ compaction testing with a nuclear densometer. Samples of the placed fill will be obtained using a concrete coring rig. The core sample will be used to determine if the lift of key trench backfill is completely frozen and to determine the soil properties. The testing frequency may be adjusted as determined by the Engineer. The required tests and testing frequency for the core and key trench fill is presented in Table 1010.2. Additional testing may be required at the discretion of the Engineer.

TABLE 1010.2: REQUIRED CORE AND KEY TRENCH BACKFILL TESTING AND FREQUENCY		
Test	Test Frequency of Mixed Material	Test Frequency for Placed Material
Mixture Density	One per 500 m^3	-
Moisture Content	One per 250 m^3	4 per lift or 2 per day
Placed Bulk Density	-	4 per lift or 2 per day
Degree of Saturation	-	4 per lift or 2 per day
Particle Size Analysis	One per two days	
Specific Gravity	One per two days	

.2 Coarse PK for liner cover

a. At lease one particle size analysis and one maximum density should be conducted for the Coarse PK material used for the liner cover. Additional testing may be required at the discretion of the Engineer.

b. The in situ density and moisture content of the compacted Coarse PK shall be measured using a nuclear densometer. Samples of the cover material may be taken from the lift surface for additional testing at the discretion of the Engineer. The required tests and testing frequency for the compacted cover material is presented in Table 1010.3.

TABLE 1010.3: REQUIRED LINER COVER FILL TESTING AND FREQUENCY	
Test	Test Frequency for Placed Material
Placed Moisture Content	2 per lift or 2 per day
Placed Dry Density	2 per lift or 2 per day

.3 Transition 150 mm minus rockfill material

a. Samples of the Transition 150 mm minus material will be evaluated from time to time during processing and placement to ensure that the produced and placed gradation meets the specification stated herein. Additional testing may be conducted at the discretion of the Engineer.

.4 Fill Testing Methods

a. Mixture density of core and key trench backfill shall be determined by using a concrete yield bucket as specified in CSA Can 3-A23.2-M90 or approved equivalent.

b. Samples of placed core and key trench fill must be taken once freezeback is completed by means of a concrete coring machine. The core must extend through the lower contact of the lift. All cored samples must be evenly distributed over the lift surface. All holes must be thoroughly washed with clean water to remove any remaining drilling fluid and backfilled with saturated 20 mm minus material immediately after extraction of the core.

c. Each cored sample of core key trench fill shall be split in half longitudinally and transversely and then examined and photographed by the Engineer. The bonding between layers, ice-saturation and ice bonding will be evaluated.

d. Moisture content is defined as the ratio of the weight of water to the weight of dry soil. Moisture content testing must be conducted according to ASTM D2216.

e. The method of determining bulk density of the cored key trench material will depend on the quality of the sample. The sample volume can be determined from the dimensions if the core has uniform dimensions. The Engineer will rely on in situ measurements of core and key trench fill density with a nuclear densometer if core recovery is poor or if the recovered cores are non-uniform.

f. The degree of saturation for cored samples will be determined, when possible, from the measured moisture content, bulk density and measured specific gravity.

g. Specific gravity shall be determined using the flask method according to ASTM D854.

SECTION 1011

SECTION 1011 ADFREEZE PILES

1.0 GENERAL

.1 Adfreeze steel pipe piles are required to support the thermosyphon radiators. Locations of the thermosyphon radiators and details of the pile installation are shown on the Construction Drawings or as directed by the Engineer. The product and installation specifications for the piles are described in this section.

2.0 INSTALLATION

.1 A minimum 100 mm nominal Schedule 40 pipe is recommended. The pile installation holes shall be drilled to a diameter at least 100 mm larger than the outside diameter of the pipe.

.2 The pile shall penetrate a minimum of 6.0 m below grade.

.3 Holes shall be cut on opposite sides of the pile to ensure the sand slurry fills the annulus between the steel pipe pile and the wall of the borehole. The holes also provide a mechanical interlock between the frozen sand backfill and the steel which contributes to the specified allowable bond strength. The holes shall be spaced at 525 mm and be approximately 50 mm wide by 100 mm long, as shown on the Construction Drawings. No holes shall be placed within the top 2 m of the pile embedment.

.4 After drilling, the hole shall be free of water, mud, slough and any other deleterious material. This procedure is very important for obtaining a suitable bond between the slurry and the pile, and between the slurry and the permafrost or rock. Loose material and oil and grease shall be completely cleaned off the pile immediately before installation. These operations shall be monitored by the Engineer.

.5 It is recommended that the pile be placed in the hole first and slurry placed down the centre of the pile. The slurry shall consist of approximately 15% to 35% water by volume. The water content shall be moist enough to attain a workable and fully saturated mixture but shall be minimized to facilitate freezeback. A pencil vibrator or a pile vibrator shall be used to densify the slurry.

.6 Aggregate used for slurry shall consist of mineral soils conforming to the following gradation limits listed in Table 1011.1.

TABLE 1011.1 TYPICAL GRADATION OF SLURRY SAND FOR BACKFILL	
Sieve Size (mm)	% Passing by Weight
10	100
5	85-100
2	60-100
0.63	20-65
0.08	0-15

.7 Water used for slurry production shall be fresh potable water. The temperature of the slurry when placed shall not exceed 10ºC to minimize permafrost disturbance and freezeback time.

.8 Accurate records of slurry volumes placed down the hole shall be kept. This is to identify that there are no voids between the pile and the side of the hole.

SECTION 1012

SECTION 1012 CURTAIN GROUTING

1.0 GENERAL

.1 This section describes the curtain grouting program for the North Dam. The work includes supplying all labour, equipment, and materials for the program; designing cement grout mixes and additives; drilling, washing, and percolation testing of grout holes; mixing and injecting cement grout in grout holes; and recording all relevant data from percolation testing and grouting.

.2 The preliminary grout hole locations for the grouting program are shown on Construction Drawings. The Engineer may increase or decrease the scope of any part of the drilling and grouting program if necessary. Drilling, testing, and grouting shall be performed under the technical direction and supervision of the Engineer. The technical direction will include: location of grout holes, orientation and sequence of drilling and washing grout holes, sequence of grouting, selection of pumping rates and durations, and modifications and adjustments to the grouting procedures.

.3 The Contractor shall provide experienced operating and supervisor personnel for the grout program. Adjustments and modifications required by the Engineer shall be executed by the Contractor upon receipt of notice of the Engineer's requirements.

.4 The Contractor shall leave sufficient flexibility in developing his schedule for any adjustments that may be required by the Engineer during the work to ensure that the curtain grouting is continuous and complete and provides an impervious barrier beneath the Dam. This may include drilling, testing and grouting additional holes beyond the lines shown on the Drawings.

.5 The Engineer will provide inspection staff to monitor the grouting operations. The Contractor shall assist the Engineer in the collection and recording of all water testing and grouting data.

.6 Publications listed below form part of this Specification to the extent specified in this Section.

CAN3 A5 M88 Portland Cement

CAN3 A23.1-94 Concrete Materials and Methods of Concrete Construction.

ASTM C 404 93 Standard Specification for Aggregates for Masonry Grout

.7 All materials shall be handled, stored and protected from deterioration and contamination. Deteriorated or contaminated materials shall not be used.

2.0 MATERIALS

2.1 WATER

.1 Water used for drilling, washing, percolation testing, and as an ingredient of grout mixtures shall be fresh, clean and free from deleterious amounts of oil, silt, organic matter, alkali, acids, salts and other impurities and shall conform to the requirements of CSA Standard CAN3 A23.1 94. At the time of mixing, the temperature of water used in grout mixes shall be less than 25°C and greater than 10°C.

.2 Adequate water storage facilities shall be provided to ensure a continuous supply of water for washing drill holes and for the grouting operations, and to ensure that grouting operations will not be hindered by a temporary breakdown in the main supply line.

2.2 CEMENT

.1 Cement used in the grout mixes shall meet the requirements in accordance with CSA Standard CAN3 A5 M88.

.2 Cement containing lumps or foreign matter which the Engineer considers detrimental to the results of the grouting program shall be removed from the site by the Contractor. The temperature of the cement shall be at least 10°C when added to the grout mix.

.3 Each shipment of cement shall be stored so that it is protected from the weather and is readily distinguished from other shipments. To prevent undue aging of cement, cement shall be used in the chronological order in which it is delivered to the site. The cement shall not be older than 3 months upon delivery to the site.

2.3 SAND

.1 Sand used in the grout mix shall consist of clean, durable stone particles, shall be free from lumps of clay and foreign matter, shall have a moisture content of less than 3 percent of the dry weight and shall conform to CSA Standard CAN3 A23.1-94 with the following modified grading requirements:

TABLE 1012.1: PARTICLE SIZE DISTRIBUTION LIMITS FOR SAND USED IN GROUT MIX

Sieve Size (mm)	% Passing by Weight
2.5	100
1.25	95 – 100
0.63	60 – 85
0.32	30 – 50
0.16	10 – 30
0.08	0 – 5

2.4 ADDITIVES

.1 The mixing, handling, storing and rates of application of additives shall be in accordance with the manufacturers recommendations. The rates of application of additives shall be designed by the Contractor and approved by the Engineer.

.2 Retarding and expanding additives for cement and sand cement grouts shall be used only with the Engineer's prior approval.

.3 Accelerants may be required for the grout mixes due to the anticipated permafrost conditions at the site.

.4 Additives should be compatible with each other and the cement. When possible, they shall be obtained from the same manufacturer to ensure their compatibility.

2.5 BENTONITE

.1 Bentonite incorporated in grout mixes shall be of a type that disperses easily in water. It is recommended that the bentonite be pre-mixed with a known quantity of water and allowed to stabilize 24 hours prior to mixing with the grout. The Bentonite shall be bond bentonite (sodium montmorillonite bentonite) as manufactured by Black Hills Bentonite, Mills, Wyoming or equivalent.

3.0 GROUT MIXES

.1 Cement grout mixes shall be designed by the contractor and approved by the dam design team.

.2 Grout shall consist of a mixture of cement and water, additives, bentonite or sand when required. The proportions of materials in the grout mixes may be varied during the grouting program to suit the particular conditions encountered. When required, bentonite shall be between one and three percent by mass of the cement. Proportions of materials used in grout mixtures and any adjustments thereto during grouting operations shall be subject to prior written approval by the Engineer.

.3 At least 30 days prior to the start of the grouting program and at such other times requested by the Engineer, the Contractor shall arrange or perform tests on the grout mixes with actual materials proposed for use in this grouting program in a qualified testing laboratory to establish the consistencies of mixes, practical mixing ratios, initial and final setting times, the optimum quantities of sand, bentonite, silica fume or other admixtures, compatibility of additives with grout mix ingredients, and such other properties as may affect the quality of the grout.

.4 The proposed grout mix designs and the results of the laboratory testing shall be submitted to the Engineer for review and approval at least 15 working days prior to the start of the grouting program.

.5 An initial water-cement ratio of 3:1 by weight had been used in curtain grouting in bedrock for some dams in Canada and may be adopted as an initial water-cement ratio for the current grout program. In case of excess grout take under this initial ratio, the water-cement ratio may be gradually lowered down to 2:1, 1:1, 0.8:1 or 0.5:1 by weight or sanded grout mix is used where viscosity in-place is desired.

.6 The grout mixes should meet the requirements that the grout can be reasonably cured under ground temperatures of -2˚C to -5˚C but without generating excess heat during setting stage. The excess heat may thaw the existing ice-filled joints that could exist in the bedrock.

.7 A non-sanded grout mix shall be used for grouting narrow cracks and fractures in the rock which are unable to accept a viscous sanded grout. A sanded grout mix shall be used in grouting up large open seams, cracks, and other voids where viscosity in place is desired or in topping up the grout holes after grouting.

4.0 DRILLING, TESTING AND GROUTING EQUIPMENT

.1 The Contractor shall provide all drilling, washing and grouting equipment including drill rig, mixers, agitators, water pumps, grout pumps, pipes, grout lines, grout flow meters, valves, pressure gauges, tools and spare parts necessary to drill grout holes and inject a continuous supply of grout into grout holes. Grout plants shall be mobile, self-contained units.

.2 Details of the drilling and grouting equipment and the layout of the grouting plant shall be submitted to the Engineer for review at least 15 days prior to shipment to the site.

.3 Either percussion or diamond rotary drill rig can be used for drilling all grout holes. Drilling equipment should be able to drill inclined holes and set casings in the overburden soils and shallow bedrock. Drilling equipment shall be equipped for continuous washing of the holes with water after drilling.

.4 The water pumps shall have a maximum output of not less than 1 L/s and shall be capable of maintaining constant pressure. If the water for the grouting operations is not directly from a pond or lake, a water storage tank sufficient to supply all of the pumps for a period of one hour shall be used.

.5 Grout materials shall be mixed with a high speed, high shear mixer. Facilities shall be provided at the mixer for the accurate measurement of grout materials so that mix proportions can be controlled. A sufficient number of mixers should be available, ready for immediate use, to produce grout at the rates required by the hole or holes being grouted and without interruption due to mixer breakdown.

.6 Grout materials shall be maintained in suspension in an agitator equipped with screens to remove hardened grout. Screen openings shall be 6.4 mm (1/4 inches).

Agitators shall be equipped with baffles to reduce vortex formation and shall be provided with adequately marked dip sticks or graduations for measuring the volume of their contents.

.7 Each grout plant shall be provided with acceptable storage for adequate supplies of cement, additives and other materials so that grouting can be carried on without interruption. Each plant shall have a suitable housing for protection against rain and frost and, if required, shall have direct radio or telephone communications with personnel at the point of grout injection.

.8 Grout pumps shall be of the helical rotor-progressive cavity type and shall be capable of pumping at least 1 L/s of grout having a water-cement ratio of 0.5:1 at a maximum discharge pressure of 400 kPa. The pump shall be located at a distance not greater than 50 m from the hole being grouted.

.9 Valves in contact with grout shall be diaphragm and/or plug cock valves each equipped with its own hand-wheel control.

.10 Grouting headers shall be provided for feeding grout into grout holes. A grout header shall include a supply connection, a connection with a valve to a grout hole, and a return line with a valve. A single hose with a maximum length of 15 m shall connect the header to a tremie pipe for grouting the hole.

.11 One pressure gauge and one grout flow meter (or recorder) shall be installed between the valve to the hole and the tremie pipe to measure the grout injection pressure and total grout take and grout flow rate with time. The grout flow meter (or recorder) shall be capable of measuring flows in the range of 0.001 L/s to 1 L/s and recording or plotting the flow rates and/or volumes of grout pumped into each hole versus time.

.12 The tremie pipe shall be 25 mm (1 inch) diameter steel pipes, each 1.5 m (or 3.0 m) long, end threaded for easy assembling to form up to a 15 m long pipe. Extra pipes shall be available for replacing damaged pipes.

.13 The gauges, meters, hoses, valves, joints and couplings shall be capable of withstanding pressures double those required for the grouting program.

5.0 DRILLING

.1 All grout holes shall be drilled and washed using percussion drills with a 76 mm (3 inch) diameter. All holes shall be located and drilled in the orientation and to the depths shown on the Construction Drawings, or as required by the Engineer. The holes shall be inclined 20 degrees to the vertical towards the north abutment along the dam axis to maximize the intersection of the holes with horizontal and vertical joint sets, as indicated on the Construction Drawings.

.2 Primary grout holes shall be drilled and grouted first followed by the secondary holes drilled and grouted. The tertiary grout holes will be drilled and grouted after all primary and secondary holes have been grouted. Grout holes shall not be drilled within 10 m of another grout hole which is being grouted, or which has been grouted in the previous 24 hours.

.3 Curtain grout holes drilled through the top overburden soils shall have short casings installed 0.15 m (6 inches) into rock and protruding at least 0.15 m (6 inches) above the ground surface to prevent the entry of foreign materials. Casings may be installed in advance of drilling.

.4 The orientation of each hole drilled shall be measured. Grout holes that deviate more than three degrees from the required orientation or direction may be filled with grout tremmied from the bottom and abandoned. Such abandoned holes may be redrilled and grouted later as required by the Engineer at no additional cost to the Owner.

.5 After drilling, any hole that becomes clogged or obstructed before the start of grouting such that the tremie pipe can not reach the hole bottom shall be cleaned out in a manner acceptable to the Engineer, or the hole shall be redrilled as required by the Engineer.

.6 Grease, rod dope, drilling mud, or other lubricants shall not be used on drill rods as an aid to drilling.

6.0 WASHING AND PERCOLATION TESTING

.1 Grout holes shall be washed with fresh water after the holes are drilled to their final depth and prior to percolation testing. Holes shall be washed out with water injected through a wash pipe at the bottom of the holes until clear water returns to the surface.

.2 A percolation test will be conducted for each grout hole prior to grouting to estimate overall permeability of the bedrock and detect any major open joints or fracture zones in the bedrock. The casing installed through the overburden zone in the hole should be in place during the percolation test. The procedures for a percolation test are as follows:

a. Fill the hole with the water supply hose to a water level close to the top of the casing or to the original ground surface such that the water level can be clearly seen. Record the water level or elevation;

b. Measure and record water levels in the hole at 1, 2, 5, 10, 20, 30, 40, 50, and 60 minutes after pumping water into the hole is stopped;

c. If the water level in the hole drops to more than 2.0 m below the original ground surface in 10 minutes, Steps a and b shall be repeated.

7.0 GROUT MIXING AND PREPARATION FOR GROUTING

.1 Grout materials including water shall be protected from freezing and shall be at a temperature between 10°C and 25°C, throughout the mixing and agitation period up to the time of injection. The grout plant and the work area around the drill hole shall be covered and heated as necessary. Temperature sensors shall be placed at the locations required by the Engineer to monitor temperature conditions. The construction schedule may require that some grouting be done during winter conditions.

.2 Grout shall be mixed in batches of suitable volume and in such a way as to enable the water cement ratio and the composition of grout suspensions to be changed to ensure continuous flow and minimum wastage. Grouts shall be mixed for a minimum of 5 minutes before injection.

.3 The required volume of the grout for a given grout hole can be roughly estimated based on the percolation test results of the hole, hole total length, and hole diameter. The volume of the mixed grout can be adjusted accordingly to limit the grout waste. All grout which cannot be injected within one hour of mixing shall be wasted at no cost to the Owner.

.4 In general, grout injection shall be started using a grout mix with an initial high water-cement ratio such as 3:1 by mass. This mix shall be maintained or thickened, depending on the percolation results prior to grouting and the rate of grout take during grouting. Changes to the grout mix may be required by the Engineer at the grout plant. The criteria may be adjusted by the Engineer during the grouting program based on experience gained at the beginning of the program.

8.0 GROUTING

.1 Gravity grouting or tremie grouting method is proposed for the grouting program for the North Dam. The gravity grouting method consists of drilling a hole to a final depth, washing the hole to clear cuttings, testing bedrock overall water permeability, lowering a grout tremie pipe to the bottom of the hole, and injecting the grout through the pipe such that the grout is pushed from the hole bottom up to the ground surface or the top of the casing and then maintained at this level for a specified period of time. The maximum grouting pressure for this method is approximately equal to the total weight of the grout column above the location to be grouted. This grouting method is generally effective for cases where relatively large, open voids exist and will take grout freely.

.2 Grouting of the grout holes shown on the Construction Drawings shall commence with the primary grout holes. Following the completion of the primary grout holes, the secondary grout holes shown on the Construction Drawings shall be drilled at split spacing and grouted. A two-line grout curtain is proposed for the north

abutment where both the cores and the percolation test results indicated the existence of open joints and/or fracture zones.

.3 A single-line grout curtain is proposed over the valley and south abutment to detect any major open joints and/or fracture zones. A two-line grout curtain similar to that proposed for the north abutment may be required in some areas along the valley and south abutment if major open joints and/or fracture zones are detected in these areas during the percolation testing and grouting of the primary or secondary holes along the first grout curtain line. If the stabilized water level(s) in one or more grout hole(s) is more than 2.0 m below the original ground surface during the percolation testing, the second grout curtain line will be required within 6 m of the hole(s). This preliminary criterion for establishing the need for the second grout curtain line may be adjusted by the Engineer during the early stage of the grouting program based on site observations. The design team should be informed if the grout take in a particular hole is greater than twice the calculated volume of the drilled hole.

.4 Tertiary grout holes will be drilled between the two grout curtain lines to verify the effectiveness of the grout curtain after the completion of the secondary grout holes. Additional grout holes shall be drilled at split spacing around the hole(s) and then grouted to refusal if the stabilized water level in a tertiary grout hole is more than 3.0 m in the north abutment or 2.0 m in the valley and south abutment area below the original ground surface during a percolation test. This preliminary criterion for the need for additional grouting may be adjusted by the Engineer during the early stage of the grouting program based on site observations. Other criteria, such as those based on grout take, may be adopted during the construction stage based on actual field behaviour.

.5 In general, a grout mix with an initial high water-cement ratio such as 3:1 by mass shall be used for initial grouting of all holes. The grout will be pumped down a hole through a tremie pipe and pushed up from the hole bottom to the ground surface or the top of the casing and then maintained at this level for a minimum period of 10 minutes. Grouting using the same grout mix shall be continued until refusal if the rate of the grout take in a grout hole decreases with time during the initial 10-minute period.

.6 The water-cement ratio shall be gradually decreased and successively thicker mixes used if the grout absorption does not decrease appreciably during the initial grouting period. Each successive mix shall be injected for a minimum 10-minute period. Grouting using the same grout mix shall be continued to refusal if the grout absorption decreases during the 10-minutes period.

.7 In areas of high grout absorption, sand may be required to be added to the mix. The proportion of sand shall not exceed 2 parts sand to 1 part cement by mass, and all sand mixes and neat cement mixes with a water cement ratio less than 2:1 by mass shall include an approved fluidizer additive.

.8 If the grout absorption of a hole being grouted is so high that it is found impossible to push the grout to the ground surface after pumping a reasonable volume of grout at the minimum workable water cement ratio, the pumping shall be stopped temporarily and intermittent grouting performed, allowing sufficient time between injection for the grout placed to stiffen. If this procedure is not successful, grouting shall be discontinued, the grout allowed to set, and additional drilling and grouting shall be done in this hole or in adjacent holes until the desired resistance is built up.

.9 Injection of grout into a hole shall be in one continuous operation until the specified refusal criteria have been achieved and the grout hole has been backfilled. In case of breakdown of grouting equipment during the grouting of a hole, the grout tremie pipe should be removed from the hole prior to the setting of the grout and flushed to avoid blockage of the pipe. As required by the Engineer, the grouting operation may be resumed later or the hole may be re-drilled and re-grouted for the hole.

.10 The casing for a grout hole shall be removed during the late stage of grouting prior to setting of the grout inside of the casing. After grouting, each hole shall be backfilled to the original ground elevation by injection of a grout. Additional grout shall be added to compensate for any settlement of the initially injected grout.

.11 Surface grout leaks for grout holes at higher elevations in the dam abutments shall be sealed to prevent an excessive seepage of grout. An ample supply of premixed quick setting cement or mortar shall be available at the work site at all times. Should sealing not be feasible, grouting shall be discontinued, the grout allowed to set, and additional drilling and grouting shall be done in this hole or in adjacent holes until the desired resistance is built up.

.12 The rate of grout take with time and the total grout take for each grout hole should be recorded and documented. The records should be available to the Engineer during the grouting stage and served as a basis for making prompt decisions and adjustments.

9.0 QUALITY CONTROL

.1 All work for drilling, percolation testing and grouting of grout holes shall be done in the presence of the Engineer. The Contractor shall provide experienced operating personnel for each drilling rig and grouting plant in operation.

.2 Gauges and meters shall be cleaned and calibrated at start of the grouting program and periodically during each shift as necessary.

.3 Drilling, percolation testing and grouting records will be kept by the Contractor. The records will include, but not be limited to, project name; owner; name and signature of individual supervising the grouting and record keeping; date(s) and time(s) of all grouting; location and ID# of hole; orientation, azimuth and depth of hole; diameter of hole; water testing results; water/cement ratio and changes and

time of change of water cement/ratio; number of bags of cement injected in hole and wasted; grout pressure, changes in pressure and time of change; time and duration of injection; volume of sand or bentonite added, litres of water added to mix; and any other changes in procedures, pressures, rate of grout take, total grout take, mix or equipment that has direct effect on grouting operations. Completed and signed copies of grouting records will be submitted to the Engineer 24 hours after completion of grouting.

.4 When required by the Engineer, the grouting data shall be plotted by the Contractor immediately and continuously as the data are measured. The data can be plotted in tabular and graphical form. These field plots may be used by the Engineer to evaluate the grouting operation and to adjust the required procedures where necessary.

.5 The drilling and grouting records shall be signed by the Contractor and the Engineer after each shift.

.6 Whenever requested by the Engineer, the Contractor shall provide grout trial batches to verify the quality of grout to be placed.

10.0 CLEAN UP

.1 All grouting areas shall be kept free of water, grout, sludge, oil or any deleterious material regardless of origin so that none of these materials drain onto any part of the work areas completed or under construction. At all times during the progress of the grouting program, all open drill holes shall be protected.

.2 Upon completion of grouting, all grout supply connections shall be removed from the work area.

.3 Prior to final acceptance of the work, waste materials from the grouting operations shall be disposed properly according to applicable regulations, when required, with approval from the Owner, for on-site disposal.

.4 Each grout hole shall be clearly marked and numbered by the Contractor upon completion of the grout hole.