Tahera Diamond Corporation

JERICHO PROJECT
WEST DAM
DESIGN REPORT

1100060.004

September 2005

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APPENDICES

1.0 INTRODUCTION

Tahera Diamond Corporation is presently developing the Jericho Diamond Mine, Nunavut, located approximately 420 km northeast of Yellowknife. Processed kimberlite will be deposited in a small lake as described in the report titled "Design of the Processed Kimberlite Containment Area" (SRK, 2004). The Processed Kimberlite Containment Area (PKCA) consists of several perimeter dams and cross-lake divider dykes as shown in Drawing WD-1.

Fine Processed Kimberlite solids (fine PK) will be beached in the eastern portion of the PKCA between the East Dams and the Divider Dykes. Water will filter through the divider dykes into the western portion of the PKCA. The water level in the facility is ultimately controlled by the West Dam located at the west end of the PKCA. The western portion of the PKCA will perform as a 'polishing pond' to facilitate the settlement of any remaining suspended solids so that excess water can be discharged to Stream C3 during the spring, summer and fall. Further details of the PKCA operation will be described under separate cover in a PKCA management plan that is currently being prepared.

This document describes the design and construction of the PKCA West Dam. The available site geotechnical data is summarized and the design basis for the dam is presented. Reduced size construction drawings are presented in Appendix A of this report. Construction specifications are presented in a separate document.

2.0 DESIGN INTENT

The design criteria for the West Dam is as follows:

- The dam should retain water within the PKCA
- The dam will remain physically stable during the operational life of the mine.
- The dam will not be required after mine abandonment

2.1 DAM SITING AND ALIGNMENT SELECTION

The dam is located at the west end of Long Lake as shown on Drawing WD-1. The dam is between Long Lake and a small pond immediately west of Long Lake.

2.2 FOUNDATION CONDITIONS

The estimated surficial geology the West Dam is shown in Drawing WD-2 (Thurber 2003).

The south abutment consists of a relatively steep bedrock slope. The center of the dam and south abutment is a gentle slope covered with a mantle of organics. The dam overlies the outlet of Long Lake. There is a small intermittent stream that flows from Long Lake to a small pond west of Long Lake.

Five boreholes were drilled at the West Dam in 2000 and 2003. (BH-03-07, BH-03-08, 00SRKGeotech2, 00SRKGeotech3 and 00SRKGeotech8). The boreholes encountered a thin organic layer (approximately 0.1 to 0.15 m thick) overlying till, (to depths ranging from 4.6 to 8.8 m), overlying granite bedrock.

Borehole BH-03-07 (SRK 2003) drilled adjacent to the outlet of Long Lake encountered thin organics (0.1 m) overlying 5 m of till consisting of cobbles and boulders with sand and gravel matrix. Frozen ground was encountered at a depth of 3 m with visible stratified ice lenses at a depth of 4.0 m. The moisture content of the frozen till was 14%, which could be indicative of a soil with some excess ice content. Granite bedrock was encountered at a depth of 5.2 m.

Borehole BH-03-08 (SRK 2003) drilled in the southern abutment adjacent to the outlet of Long Lake encountered thin organics (0.1 m) overlying 5.4 m of till consisting of cobbles and boulders with sand and gravel matrix. Frozen ground was encountered at a depth of 2 m with stratified ice lenses up to 6 mm thick between 2.0 and 3.3 m. Soil between 3.3 m and 5.5 m had no excess ice and was well bonded with a moisture content of approximately 10%. Granite bedrock was encountered at a depth of 5.5 m. The top 2 m of the bedrock was weathered with clay gouge.

Ground temperatures were measured in Borehole BH-03-08. Temperatures in September 2003 ranged from –6 to -7°C at depths between 10 m and 15 m.

2.3 LAKE LEVEL PROJECTIONS

The natural water level in Long Lake is approximately 515.4 m. The maximum allowable water level during operation of the PKCA will be 523 m. The water level in the PKCA will be governed by the West Dam with pumping to maintain the water level, below the maximum level. The water levels are intended to be kept as close as possible to the natural level (515.4 m) by pumping the clean water out of the facility on a seasonal basis. The water level will initially be lowered approximately 2 m below the natural water level before fine PK is deposited into the PKCA.

3.0 DESIGN CROSS-SECTIONS

The planned layouts and typical cross-section of the West Dam are presented in Drawings WD-3 and WD-4.

The nature of the foundation soils is such that it is desirable to maintain them in a frozen condition rather than necessitating a massive excavation below the embankment. Consequently, a frozen core earth dam on a permafrost foundation will be utilized.

An effective frozen core dam requires that the central core and foundation remain frozen year around to act as an impervious barrier against seepage. The core and foundation must be nearly saturated with ice to produce a well-bonded and impermeable mass, and the permafrost must be sustained. A secondary seepage barrier is provided by a geosynthetic liner on the upstream face of the frozen core. Similar designs have been developed by EBA for the EKATI Diamond Mine.

The upstream shell primarily consists of rockfill. A small till zone has been placed at lower elevations to reduce convective water movement through the open graded rockfill. The downstream shell of the dam will be constructed of rockfill. This will provide a strong material and will have minimal settlement. The rockfill shells are designed to be constructed with 3.0H:1V outside slopes.

4.0 SLOPE STABILITY

4.1 ANALYSIS METHODOLOGY

Limit equilibrium analyses have been carried out to determine the factors of safety for slope stability during construction and operation of the intermediate dykes. All analyses were conducted using the commercial, two-dimensional, slope stability computer program, SLOPE-W. The factors of safety have been computed using the Morgenstern - Price Method.

The dam is designed to meet Canadian Dam Association guidelines (CDA, 1999). The design criteria for computed minimum factors of safety are given in Table 1.

TABLE 1: SLOPE STABILITY DESIGN CRITERIA

Loading Conditions	Minimum Factor of Safety	Slope
Static loading, full reservoir	1.5	Downstream and Upstream
Full or partial rapid drawdown	1.2 to 1.3	Upstream
Earthquake, full reservoir	1.1	Downstream and Upstream

The stability analyses were carried out for the deepest dyke cross-section, which is the worst case for evaluating dam stability.

4.2 MATERIAL PROPERTIES

The material properties chosen for the embankment and foundation materials in the stability analysis are presented in Table 2. The properties for granular materials were selected based on experience with similar materials used and encountered by EBA in dam designs at other sites across the Arctic. The analyses have been carried out assuming unfrozen embankment fill, therefore strength increase associated with frozen embankment fill will add additional safety to the design.

TABLE 2: MATERIAL PROPERTIES USED IN STABILITY ANALYSES			
Material	Angle of Internal Friction (°)	Cohesion (kPa)	Unit Weight (kN/m³)
Run-of-Mine	42	--	20
200 mm Minus Material	35	--	21
20 mm Minus Material	32	--	20
GCL Liner	8.7	11.3	20
Till – effective stress	32	--	20
Till - total stress (upstream)	0	50	19
Till - total stress (downstream)	0	63	19

The friction angle presented in Table 2 for the run-of-mine material is conservative for shallow depths where confining stresses are low.

The foundation till soils have been analyzed for both undrained thawed effective strength parameters and long term frozen total stress parameters. The undrained frozen strength has been estimated by a relationship (Johnson, 1981) for the lower limit of the 50 year shear strength of an ice rich soil. The relationship is as follows:

$$C = 35 + 28T$$

Where:

T = Temperature in °C below freezing (with positive sign).

C = Long term strength (kPa)

A temperature of –0.5 °C has been assumed for the upstream conditions, and –1.0 °C has been assumed for downstream conditions. The estimated strength from this relationship is considered to be conservative given that the foundation soils have relatively low excess ice contents.

The GCL liner has been analyzed assuming it has a "large–displacement" strength envelope. It has been assumed that the GCL liner is a needle-punched non-woven, nonwoven product with strength parameters as listed and summarized by Zornberg et al, 2005. Designing with "large-displacement" strengths are conservative, as the liner must undergo movement which subjects the liner to a stress higher than its peak strength.

4.3 PORE WATER PRESSURE CONDITIONS

4.3.1 Rockfill

The pore water pressures assigned to the rockfill on the upstream side of the core corresponded to the maximum pond elevation for the static and seismic full reservoir stability analyses. The rockfill is expected to drain during rapid draw down situations.

Pore water pressures assigned to the downstream rockfill equalled the original ground elevation. The dam core is not expected to leak significant volumes of water and, furthermore, the rockfill is free draining and will not sustain a significant water level within itself.

4.3.2 Till

The pore water pressures assigned to the till berm in the upstream side of the dam corresponded to the maximum pond elevation for the static and seismic full reservoir stability analyses. Pore pressures were conservatively assumed to remain at the original level during rapid drawdown situations.

4.3.3 Liner System

The pore water pressures assigned to the GCL liner correspond to the maximum pond levels for the static, seismic, and rapid drawdown stability analyses.

4.3.4 Foundation Till

It was assumed that negligible excess pore water pressures would be generated due to thaw of the till under the upstream or downstream portions of the dams. This is considered to be appropriate for the following reasons:

- thaw will progress relatively slowly into the foundation, and
- the till is non-plastic and has a significant sand and gravel content, which increases permeability.

Given these conditions, the thaw consolidation parameter (Morgenstern and Nixon, 1971) will be low, indicating that excess pore water pressures generated in the till during thaw will be negligible. Furthermore, the permeability of the coarse-grained till is expected to prevent the build-up of excess pore water pressures during rapid drawdown.

4.4 SEISMICITY

The project area lies in a region of low seismicity, but magnitude 4+ earthquakes have recently occurred within a similar part of the shield. NRCan (NRCan 2003a and NRCan 2003b) recommends that a probabilistic approach should be adopted to estimate the peak ground accelerations (PGA); particularly the new proposed National Building Code of Canada (NBCC) PGA values.

The CDA indicates that the usual minimum criterion for the design earthquake for a dam, which coincides with the "low" consequence category, would be an earthquake with an annual exceedance with return periods of 100 to 1,000 years. NRCan (2003a and 2003b) indicates that the 1,000-year event has a peak acceleration of 0.016 g. However, in conjunction with proposed changes to the NBCC, NRCan indicates that performance of the dams be designed for an earthquake with a 2,475 year return period which has a peak ground acceleration of 0.06 g. This has been adopted as the design earthquake.

4.5 ANALYSES RESULTS

Table 3 summarizes the factors of safety under static, rapid drawdown and seismic conditions for different failure surfaces on the upstream and downstream slopes.

TABLE 3: SUMMARY OF STABILITY ANALYSIS RESULTS

Slip Surface	Case (Foundation Strength)	Factor Safety		
		Static	Static, Rapid Drawdown of Reservoir	Seismic
Upstream	Effective Stress	1.9	1.6	1.4
Upstream	Total Stress	2.0	1.4	1.4
Downstream	Effective Stress	2.2	2.2	1.8
Downstream	Total Stress	1.7	1.7	1.4

The computed minimum factors of safety exceed the design criteria of 1.5, 1.2 and 1.1 for static, rapid drawdown and seismic loading conditions, respectively, in accordance with the CDA, Dam Safety Guidelines (CDA 1999).

5.0 CREEP

The foundation soils consist of sand and gravel till with some excess ice as discussed in Section 2.2. The ice contents in the foundation soil are relatively low. There is the possibility of some creep of the dam foundation; however it is difficult to accurately assess the creep magnitude. It is EBA's opinion that the risk of creep movement is low given the foundation properties.

The dam has been designed with an upstream berm to reduce the shear stresses in the foundation near the dam core. The upstream berm also serves as a location to install slope inclinometers if required in the future.

Creep is a slow, long-term process. It is recommended that the dam be monitored for movements and remedial measures be employed if significant creep movement is observed.

6.0 SETTLEMENT

A portion of the dam is founded on till that has a low ice content. A small amount of settlement would occur if the till thaws.

It is anticipated that the water level in the PKCA will be maintained at a low level thereby minimizing foundation thaw and settlement; however, if the water is maintained at a high elevation for an extended period; some foundation thaw and settlement may occur. Settlement should be less than 20 cm based on ice contents observed in the boreholes.

A berm will be constructed on the upstream slope of the dam. The berm maintains the water further from the dam core; which in turn maintains the zone of potential thaw and settlement away from the core and liner. The upstream rockfill shell and till berm will be flexible and will tolerate some settlement and distortion.

All dam fill materials must be properly compacted to reduce post construction settlements. Compaction of rockfill in dams with sloping upstream water retention membranes is commonplace. Several dam construction case histories illustrating compaction of rockfill are presented in Cooke et al (1985). CDA, Dam Safety Guidelines further state that membrane faced rockfill dams should be constructed using compacted thin lifts (CDA, 1999).

7.0 THERMAL PERFORMANCE

Thermal analysis carried out during the preliminary design (SRK 2004) indicated satisfactory thermal behaviour of the dam under extreme conditions of water impoundment over the life of the dam. Additional thermal analyses carried out by EBA confirm adequate dam performance.

The thermal behaviour is a function of the foundation temperatures and temperature of the frozen core at the end of construction. The temperature of the dam foundation will be further evaluated during construction, using ground temperature cables. The temperature of the core will be measured as the dam is being constructed.

Percolation testing will also be carried out in the boreholes drilled in the base of the key trench after it is excavated. These will provide additional information regarding the characteristics of the foundation soils that will also be used to determine the requirements for thermosyphons.

The thermal analysis will be re-evaluated if the temperature data warrants. Horizontal pipes for thermosyphons will be installed within the dam core, as shown in Drawing WD-9. This will enable thermosyphons to be easily retrofitted into the dam if required.

8.0 WORST CASE FAILURE SCENARIO

The combination of a frozen core and a liner within a rockfill shell provides a low probability of a sudden release of impounded water due to slope instability or massive seepage loss. Nevertheless, the environmental impact of a hypothetical worst-case failure scenario must be considered in the event that the dam fails.

The dam foundation and core are expected to be frozen at the end of construction. The risk of seepage through the foundation is considered to be very low. There is a low risk of seepage through the bedrock abutments if the bedrock fractures are not ice filled. Further characterization of the bedrock abutments will be carried out during construction through falling head tests (percolation tests) and visual observations in the key trench. It is EBA's opinion that if seepage were to occur through the bedrock, it would be a manageable quantity and would be pumped back to the PKCA.

Seepage from the West Dam would flow to a small pond just downstream of the West Dam, and then west via Stream C3 to Lake C3 and then north by northeast to Carat Lake.

In the event seepage occurs through the dam, the water level in the PKCA should be kept as low as practically possible. Seepage should be collected in the pond downstream of the West Dam and pumped back to the PKCA if necessary. If required, a seepage collection dam could be constructed downstream of the pond west of the PKCA.

9.0 MATERIAL PROPERTIES

The following provides a summary of the materials that will be used to construct the dam. Specifications for the material gradations and placement requirements are presented in the West Dam Construction Specifications.

9.1 SLOPE PROTECTION

The upstream slope of the West Dam may be subject to wave action. The fetch length between the West Dam and Divider Dyke is 750 m.

The calculated wave height is 0.5 m for the maximum sustained wind of 74 kph. Rip-rap with a minimum average particle size (D50) of 300 mm is required to protect the dam against wave action.

It is proposed that the upstream dam shell will be run-of-mine rock with a maximum particle size of 700 mm. It is anticipated that the run of mine will have an average particle size larger than the minimum requirements for rip-rap and therefore will be suitable slope protection.

9.2 RUN-OF-MINE ROCKFILL

The upstream and downstream shell materials will be run-of-mine granitic rock with a maximum particle size of 700 mm. The material shall be placed in lifts of a maximum of 700 mm. Any boulder larger than 700 mm can be wasted to the outside downstream edge of the dam.

9.3 TILL

A small till berm will be constructed within the upstream shell. The natural till deposits on site vary from sand and gravel with some cobbles and boulders to silty sand and gravel with cobbles and boulders. The till for the West Dam should be a silty sandy till with some cobbles. Particles larger than 250 mm should be removed from each lift of material to allow for compaction of the till. The large particles can be wasted on the outsides of the till berm.

9.4 20 MM MINUS CORE

A 20 mm minus crushed granite will be used to construct the frozen core. The material must have a minimum of 4% particle sizes smaller than 80 microns.

9.5 GEOCOMPOSITE CLAY LINER

A geocomposite clay liner (GCL) will be placed on the upstream side of the frozen core and within the key trench. The recommended GCL consists of two non-woven geotextiles encapsulating a layer of bentonite. The GCL will be needle punched to provide adequate shear strength.

9.6 LINER BEDDING

Bedding material must be placed on either side of the GCL. The bedding material can consist of 20 mm minus crush material, or 40 mm minus esker material with sub rounded particles.

9.7 TRANSITION MATERIAL

A 200 mm minus transition material is required between the liner bedding material and the rockfill material and also between the core and the rockfill. The transition material must meet filter criteria for the liner bedding and the rockfill as follows:

- D15 of the transition < 5 * D85 of the filter
- D15 of the rockfill < 5 * D85 of the transition

9.8 QUANTITIES

Table 4 presents the in-place quantities of material required for each zone of the West Dam if constructed as per design geometry. The quantities of material do not include any contingency for waste.

TABLE 4: DAM MATERIAL QUANTITIES [redacted]					
Structure	Geocomposite Clay Liner (GCL) (m²)	Fill Material Type			
		20 mm minus (m^3)	Transition (m^3)	Rockfill Shell (m^3)	Till (m^3)
West Dam	6100	17,000	7,600	52,000	3,100

Note: Quantities are "in-place". Seaming allowance and contingencies must be added to GCL quantities. 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.

10.0 CONSTRUCTION PLAN [redacted]

10.1 GENERAL

Construction of the dam will be conducted in accordance with the Construction Specifications and Construction Drawings. The Construction Specifications are in a separate document that accompanies this report. The Construction Drawings have also been issued as a separate document package. A set of construction drawings (reduced in size) are included, for ease of reference, with this report. The Construction Specifications and Construction Drawings must be among the governing documents used for construction planning and supervision, and ultimate construction of the dams.

10.2 CONSTRUCTION REQUIREMENTS

The Construction Specifications present the details regarding foundation preparation, fill materials, fill placement, the geomembrane liner system, instrumentation and quality assurance program. It is anticipated that the contractor chosen to conduct the work will develop a construction plan.

10.3 SCHEDULE

The requirements for construction of the dam dictates that fill placement occur in cold weather conditions. Core and key trench construction (backfill, liner system) must take place during the months when air temperatures are below -15°C. The following generalized schedule for dam construction is suggested for construction planning purposes:

- October to November: Preparation for Construction - Develop material sources, construct temporary warming shed at dam location, excavate, process and separately stockpile 20 mm minus and 200 mm minus material, preparation of foundation upstream and downstream of key trench, placement of the upstream till berm (coffer dam), key trench excavation and percolation testing in the base of the key trench.

- November to December: Dam Construction - GCL placement in the key trench, installation of ground temperature cables, placement of 20 mm minus in key trench, thermosyphon pipe installation, and core construction.
- January to April: On going Dam Construction - GCL placement, transition and run of mine placement and demobilization and site cleanup.

Successful construction of the key trench is of paramount importance in meeting the design intent of the dam. Cold weather construction will require careful preparation and attention to equipment selection and maintenance on the part of the contractor.

10.4 FOUNDATION PREPARATION

The footprint under the upstream till berm, 20 mm minus and transition zones must be grubbed to remove boulders and loose, fractured bedrock.

The key trench must be excavated into permafrost so that the GCL liner system is keyed into permanently frozen ground. The width and depth of the key trench will vary along the axis of each dam. The minimum depth of excavation is shown on the Construction Drawings. The actual depth of excavation will be determined on site during key trench excavation, as the key trench must extend into ice-saturated permafrost soil or rock. The key trench within bedrock areas will be excavated using drill and blast techniques with removal of material by excavators and/or front end loaders. Loose frozen soil, fractured boulders and fractured bedrock, as well as protruding frozen ground, boulders or bedrock, must be removed to provide a relatively smooth key trench base. Additional excavation (blasting or mechanical) may be required to achieve a relatively smooth base.

The key trench within till areas can be excavated just after initial freeze up using conventional excavation methods. Placement of the liner and key trench backfill must immediately follow key trench excavation.

Groundwater may be encountered during key trench excavation. Any inflow of ground water into the excavation must be controlled using sumps and pumps and be discharged into the PKCA.

10.5 MOISTURE CONDITIONING OF EMBANKMENT MATERIALS

Granular material used for construction of the core, key trench, liner bedding and transition zones within the dam cross-sections will be processed from rock developed from mining operations. Processing will be required to achieve the specified gradations. Separate stockpiles of the different granular materials must be developed prior to the start of construction. The processed materials must be stockpiled as dry as possible to prevent any ice bonding of particles within the stockpile.

The 20 mm minus material used for the core and key trench must be placed in a semi-slurry condition. Water must be added to the 20 mm minus material to bring the moisture content to about 2% above the optimum water content as determined by ASTM 698 (by mass). The water must be heated to prevent freezing before placement in the key trench.

10.6 MATERIAL PLACEMENT

10.6.1 Core and Key Trench Fill

Air temperatures during key trench and core construction shall be –15°C or colder. The moisture conditioned 20 mm minus material for the key trench and core fill must be trucked to the dam site and be placed and compacted before freezing occurs.

The first lift of 20 mm minus material placed in the key trench must be placed at a moisture content of 12% or greater with an average degree of saturation no less than 85% and with no individual value falling below 80%. The first lift of key trench backfill will act as a bedding layer between the liner and the base of the key trench as well as a seepage barrier beneath the liner system.

The remainder of the 20 mm minus material placed in the key trench will have a moisture content of at least 2% in excess of the optimum moisture content determined from test method ASTM D698-91. Compaction will be achieved by construction equipment traffic used to spread the material and a 10 tonne (minimum weight) vibratory, smooth drum compactor. When required, the moisture content of the key trench backfill must be regulated so that excessive water is not available to form ice lenses.

The core and key trench fill must be spread in lifts thin enough to freeze completely before the next lift is placed. A lift thickness of 250 mm should be sufficient to permit daily freezing during cold weather (<-15°C) placement. However, parameters such as mixing water content, surface cleaning and lift thickness should be optimized by controlled experimentation early in the construction season. These parameters may need to be periodically changed to suit varied weather conditions.

10.6.2 GCL Liner System

The GCL liner must be placed on smoothed bedding material and covered with bedding material. The liner panels must be overlapped 500 mm, and moisture conditioned bentonite paste placed along the seams.

10.6.3 Run-of-Mine Material

The run-of-mine rockfill material must be placed in lifts no thicker than 700 mm. Compaction of this material will be achieved by routing heavy equipment (bulldozers, haul trucks) evenly over each lift.

Run-of-mine material must be placed in a manner that will not cause segregation or nesting of coarse particles. The effectiveness of the construction technique will be evaluated in the field by the site engineer and changes to the construction procedure will be made as required. Boulders greater than 700 mm size should be bladed out of the fill and be wasted on the outside slope.

10.6.4 200 mm Minus Transition Material

The 200 mm minus material must be placed in lifts not exceeding 400 mm in thickness. This material must be placed in a manner that will not cause segregation and/or nesting of coarse particles.

Compaction will be achieved by at least four passes with a smooth drum vibratory roller weighing 10 tonnes or more. It is anticipated that the number of passes, vibration frequency and volume of water required will be checked periodically throughout construction using a proof roll. The number of passes, vibration frequency and volume of water added should correspond to the point when deflection is not visible.

10.6.5 Liner Bedding Material

The liner bedding material must be placed in the superstructure of the dams in lifts not exceeding 300 mm in thickness in such a manner that will not cause segregation and/or nesting of coarse particles. This material must be moisture conditioned, as required, and compacted to a minimum of 95% of the maximum dry density determined by test method ASTM D698-91 prior to placing a subsequent lift.

10.7 QUALITY ASSURANCE

The construction quality assurance program must be structured so that construction-sensitive features of the design are achieved. The elements of the program will include:

- Careful surveying to establish material quantities on a daily basis and allow preparation of as-built drawings.
- Specific quality control approvals at critical times such as key trench excavation, key trench backfill and superstructure fill placement.
- Monitoring and field testing of fill materials.
- Monitoring of fill mixing procedures.
- Specific approval of construction procedures for moisture conditioning and placement of all embankment materials.
- Daily field testing of the key trench and core fill to show complete lift freezeback and uniform distribution of moisture and density parameters.
- Observation and approval of contractors' proposed material placement sequences and preparation of surfaces below each lift placement.
- Periodic processing and evaluation of temperature data collected from ground temperature cables installed in the fill as part of long-term monitoring.
- Observation of GCL liner installation to ensure that design requirements are met.
- Defined procedures for reporting with identified responsibilities for decision-making during construction.

- Specific requirements and testing frequencies for the Quality Assurance process during construction are set out in the Construction Specifications.

11.0 LONG-TERM MONITORING

11.1 PURPOSE

Performance monitoring is an integral part of the operation of any water retention structure. This section describes a recommended monitoring program for the construction and operation for the West Dam.

The proposed monitoring program will serve the following three functions:

- Monitor the thermal regime of the dams,
- Monitor movements of the dam, and
- Satisfy regulatory requirements for dam performance monitoring.

Each of the components of the monitoring program is detailed in the following sections. The recommended instrumentation program for the West Dam is presented in the Construction Drawings.

11.2 THERMAL MONITORING

Horizontal ground temperature cables will be installed in the key trench backfill of the dam. The layout of the horizontal ground temperature cables within the key trench geometry is presented in the Construction Drawing WD-7. Vertical ground temperature cables will also be placed within the dam.

11.3 SURVEY MONITORING

Survey monitoring points will be installed along the crest of the dam as shown in Construction Drawing WD-8. They will be used to monitor settlement or horizontal movements of the dam through its service lives.

Survey monitoring points shall consist of either wooden survey stakes and/or iron bars embedded 300 mm into 20 mm material or "Hilti" bolts installed in the top of boulders where run-of-mine material exists at the dam crests. The actual survey point will be the top of the survey stake/iron bar and/or "Hilti" bolt.

The survey monitoring points should be installed and surveyed immediately upon completion of dam construction. The survey point elevations and coordinates should be surveyed on a monthly basis for the first two years of operation. Survey data should be reviewed by a geotechnical engineer until deformations are minor or at least until after the second filling of the reservoir.

12.0 ANNUAL INSPECTION

An annual site inspection will be conducted by the design team to document the performance of each of the dams in the PKCA. These visits should take place at the end of summer when maximum annual thaw has developed. It would be preferable to conduct the visits when the reservoir is empty to permit inspection of the upstream slope and toe of the dams.

The specific tasks conducted during these visits include:

- Inspection of the upstream and downstream slopes for any sign of distress,
- Inspection of the dam crests for any sign of transverse cracking, and
- Inspection of the abutments and downstream toes for any evidence of seepage.

13.0 CLOSURE

The recommendations and design provided herein are based on our review of the information described in Section 2.0. It is recommended that site preparation and observation of the fill placement for the embankments shall be monitored by qualified personnel under the direction of an EBA geotechnical engineer. Construction changes which may or may not be required to field-fit the design should be approved by a qualified geotechnical engineer.

This report has been prepared in accordance with generally accepted geotechnical engineering practices. No other warranty is made, either express or implied. Reference should be made to EBA's Geotechnical General Conditions, attached to this report, for further limitations.

EBA trusts that this report satisfied your present requirements. Should you require any additional information, please contact us.

Respectfully submitted,
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APPENDIX

APPENDIX A CONSTRUCTION DRAWINGS