Attachment #4 – Dam Safety Review Reports

- PKC (2010)
- A154 (2013)
- A418 (2012)
Diavik Diamond Mine – PKC Facility
Dam Safety Review

Lac de Gras, Northwest Territories

Submitted to:

Diavik Diamond Mines Inc.
Yellowknife, NWT

Submitted by:

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IMPORTANT NOTICE

This report was prepared exclusively for Diavik Diamond Mines Inc. by AMEC Earth & Environmental Limited, a wholly owned subsidiary of AMEC Americas. The quality of information, conclusions and estimates contained herein is consistent with the level of effort involved in AMEC services and based on: i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions and qualifications set forth in this report. This report is intended to be used by Diavik Diamond Mines Inc. only, subject to the terms and conditions of its contract with AMEC. Any other use of, or reliance on, this report by any third party is at that party's sole risk.
CONCLUSIONS AND RECOMMENDATIONS

This report comprises a dam safety review (DSR) for the four dams comprising containment for the processed kimberlite containment (PKC) facility at the Diavik Diamond Mine at Lac de Gras, Northwest Territories. Mr. T. Martin, P.Eng., P.Geo. of AMEC Earth & Environmental (AMEC) was engaged by Diavik Diamond Mines Inc. (DDMI) to undertake the review. The DSR was undertaken in line with the Canadian Dam Association (CDA) guidelines\(^1\), which provide a standardized framework for the conduct and documentation of DSR’s. Mr. Martin visited the Diavik Diamond Mine from September 7-13, 2009 inclusive. During that visit, an inspection of the PKC facility dams was undertaken, as well as various other ponds that are documented in a separate report. Documentation pertaining to the design, construction, third party reviews, annual inspections, and operations, maintenance, and surveillance were made available and reviewed. Subsequent to the site visit, additional review of project documentation was undertaken. This report documents the DSR, understood to be the first conducted for the PKC facility dams.

Conclusions drawn from this DSR are as follows.

1. The PKC facility perimeter dams are stable. Design stability analyses for the East Dam, which is partially underlain by ice-rich soils, indicate acceptable stability even under thawing conditions.

2. The “High” consequence classification for the four PKC facility perimeter dams remains appropriate under the CDA (2007) guidelines.

3. The Maximum Design Earthquake (MDE) and the Inflow Design Flood (IDF) adopted for the design of the PKC facility perimeter dams remain appropriate.

4. The design, construction, and construction QA/QC were carried out generally to a good standard, although construction defects associated with the Stage 5 construction of the dams, specifically the North Dam, became apparent and, where identified, have been rectified. There remains some residual risk of additional construction defects, associated with the upstream liner, and the cutoff trench, manifesting themselves at the North Dam. The South Dam has yet to impound fine PK or a significant water pond.

5. Residual risk associated with potential construction defects within the North Dam (or the South Dam can be managed via effective fine PK spigotting and beach development practices. Wide, above-water beaches separating the perimeter dams from the water pond should be a focus of the operation of the facility. Changes to site water management capabilities, which allow DDMI to avoid the need to store a substantial volume of water in the PKC facility, should facilitate this.

6. Ongoing raising of the dams involves an interface between the contractor and the mine forces. It is important that this interface be effectively managed to reduce the potential for construction defects going forward. In particular, the waste rock delivered for construction of the dam shells must not be so coarse as to create potential filter compatibility issues with transition and bedding materials subsequently placed to accommodate liner construction.

7. The effective construction of the dams, and their safety, depend to a large extent on the manner in which the PKC facility is operated. It was a conflict between operational and construction requirements in terms of water management that contributed in large part to the

\(^1\) Canadian Dam Association (2007). “Dam Safety Guidelines”.

Stage 5 construction defects within portions of the North Dam that were subsequently identified and rectified. Such potential conflicts going forward should be identified and avoided in advance.

8. Seepage through and below the dams has for the most part been minor and manageable, the exception being the seepage in late 2008 and early 2009 associated with the subsequently-rectified North Dam defects. Nominal seepage of several litres/sec does not pose a dam safety risk.

9. The involvement of the DGRB is beneficial to the safety of the dams and should continue through to decommissioning of the PKC facility.

10. Diavik’s stewardship of the operation, maintenance, and surveillance of the PKC facility is carried out to good standards, although the need for improved communication between the various groups involved became apparent as a result of the difficulties in the Stage 5 construction that contributed to the North Dam construction defects. It is understood that DDMI has subsequently struck a “PKC committee” to facilitate improved communication, a good step given the dependence of the safety of the facility, and the quality of the ongoing dam construction, on the manner in which the facility is operated.

11. The OMS manual and the ERP document, as issued in April 2010, are of a high standard and meet all requirements for such documents. DDMI personnel having responsibility for various aspects of the PKC facility must become well-familiarized with the pertinent sections of these documents.

12. Pertinent documentation for the PKC facility and its associated dams is well-catalogued and readily accessible on site.

13. The instrumentation and monitoring system within the dams is adequate, and should be reviewed by the facility designer (Golder Associates) on an annual basis as part of the designer’s annual facility inspections and reviews.

14. Instrumentation data is promptly plotted and interpreted by DDMI geotechnical technicians. DDMI technicians also carry out very effective monitoring of seepage conditions, locations, and flows. This data too is plotted. DDMI personnel responsible for those aspects of the PKC facility pertinent to dam safety are knowledgeable and display appropriate diligence in the stewardship of the facility.

Recommendations arising from this DSR are as follows.

1. Appendix V of the OMS Manual (DDMI, 2010) includes a risk assessment undertaken in April 2008. Given the issues associated with the seepage issues in late 2008 and 2009, the North Dam construction defects (subsequently repaired), the accumulation of ice within the East and West Dams (and associated seepage breakout from higher elevations), and plans to discharge fine PK slurry from the North and South Dams, it is recommended that the risk assessment be revisited and updated.

2. The adequacy of the instrumentation used for monitoring the PKC facility dams should continue to be reviewed by the facility designer on a regular basis, and modifications to the monitoring system could be a potential outcome from an updated risk assessment. Threshold criteria for temperature data, the rate of change of temperature data, and monitored seepage rates should also be considered and, if judged applicable, incorporated within the OMS manual.

3. The next DSR is recommended to be carried out in 2015.
1.0 PROCESSED KIMBERLITE CONTAINMENT FACILITY - BACKGROUND

The Processed Kimberlite Containment (PKC) Facility provides permanent storage for by-products that result from processing the kimberlite ore at the Diavik Diamond Mine, located on East Island, a 17 km² island in Lac de Gras, NWT, approximately 300 km northeast of Yellowknife (64°30' North, 110°20' West). The PKC Facility is located in a valley running approximately east to west across East Island. The by-products of the ore processing are referred to as processed kimberlite (PK). PK is delivered to the PKC facility in two streams:

- **Fine PK** (minus 1 mm size material), discharged into the impoundment in slurry form. The fine PK slurry is discharged from the East and West Dams, and from the North and South Spigot Roads that separate the central portion of the PKC facility (which includes the process water reclaim pond area) from the north and south cells, which are to store the coarse PK.

- **Coarse PK** (1 mm to 6 mm size material), hauled to the facility via trucks in a largely dewatered state. Under the original design for the PKC facility, which envisioned the PK split (by dry weight) to be 2 parts fine PK to 1 part coarse PK, was to be stored within the north and south cells. However, it appears that the actual split is closer 7 parts fine PK to 1 part coarse PK.

The coarse PK is largely dewatered, and is transported to the PKC facility via trucks. The Coarse PK is trucked from the Process Plant to the PKC Facility and the Fine PK is transported as a low-density slurry via insulated, heat traced HDPE pipeline to spigot discharge points positioned around the perimeter of the facility.

The PKC facility was originally impounded by dams to the east and west, but with increasing height is now also contained by dams along its north and south perimeters. The upstream faces of these dams are lined with a geomembrane. For the starter East and West Dams, the face liner extends partially below the actual embankment in order to achieve a cutoff to frozen ground. For the South and North Dams, the liner is tied into a key trench at, or slightly upstream of, the upstream toes of these dams. The design of the PKC facility is thus intended to minimize seepage.

Figures 1.1 through 1.3 provide aerial views (from 2008) of the PKC facility. Note that the North and South Cells are separated from the Central Cell (which receives fine PK slurry discharge) via waste rock berms that provide access for pipelines and discharge of fine PK into the cell. These berms are referred to as the North and South Spigot Roads. Process water is reclaimed from the PKC facility to the process plant, from the Central Cell. Subaerial fine PK beaches serve to prevent excessive flow of free water from the reclaim pond area, through the North and South Spigot Roads, into the North and South Cells. Figures 1.4 and 1.5 respectively show an overall plan of the Diavik site, and a plan of the Phase 5 configuration of the PKC facility, per Golder (2007c).

The PKC facility is operated as a closed system in terms of water management, meaning there is no release of untreated water to the environment. Contact water (i.e. water considered to have been affected by mining operations) is routed to the North Inlet Pond, for subsequent treatment via the North Inlet Water Treatment Plant (NIWTP) for discharge to Lac de Gras. Seepage from the PKC facility is collected in a series of ponds, formed in low areas and
contained by lined dams. Collected seepage and runoff is either pumped back to the PKC facility, or is pumped to the North Inlet Pond. Seepage and runoff collection ponds pertinent to the PKC facility are as follows:

- Pond No. 4 downstream of West Dam;
- Pond No. 3 (old clarification pond) downstream of the northern portion of the West Dam, and downstream of the western portion of the North Cell;
- Pond No. 5 downstream of East Dam;
- Pond No. 1 downstream of the eastern portion of the North Cell; and
- Pond 7 downstream of the South Dam.

![Figure 1.1: Aerial View of PKC Facility (2008), Looking South](image-url)
Figure 1.2: Aerial View of PKC Facility (2008), Looking East

Figure 1.3: Aerial View of PKC Facility (2008), Looking Southeast
Figure 1.5: Phase 5 Plan Configuration of PKC Facility

Figure 1.6: Aerial View of PKC Facility (2009)

Note reduced extent of water pond relative to 2008 aerial views
2.0 DESIGN & CONSTRUCTION OF PKC FACILITY

2.1 Background

The PKC Facility is planned to be constructed in phases throughout the life of the facility. Phase 5 construction to crest El. 460 m is currently underway with a planned completion date in 2010.

The PKC Facility was initially designed by Nishi-Khon/SNC-Lavalin Ltd. (NKSL). Design details are provided in NKSL (1999a) and NKSL (2001a), the latter representing an update of the 1999 design report. The first three phases of the PKC Facility involved construction of the main valley sections of the East and West Dams, which were constructed per the design in these NKSL reports.

In 2005, Golder prepared design drawings for Phase 4 construction of the PKC Facility, which was carried out in 2006. Golder provided a design report for the Phase 5 configuration of the PKC facility in 2007, along with construction drawings and specifications for the Phase 5 raise of the dams, which was essentially complete as of the site September 2009 site visit undertaken for the purposes of this DSR.

A listing of the design and as-built reports issued for the PKC facility is provided in Tables 2.1 and 2.2 respectively. Table 2.2 also summarizes the construction history of the PKC facility.

Table 2.1: PKC Facility Design Reports

<table>
<thead>
<tr>
<th>Date</th>
<th>Author</th>
<th>Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999a</td>
<td>NKSL</td>
<td>Processed Kimberlite Containment Facility Design Report, No. 4200-41EG-1003</td>
</tr>
<tr>
<td>2001a</td>
<td>NKSL</td>
<td>Processed Kimberlite Containment Facility, Updated Design Report</td>
</tr>
</tbody>
</table>

The containment dams for the PKC facility are comprised primarily of run-of-mine waste rock, competent granodioritic rock from the two open pits, and quarried granodiorite for the East and West Dam starter dam sections. The upstream faces of the dams are lined with geomembrane, with the intent of minimizing seepage. The geomembrane is separated from the run-of-mine rockfill by transition and bedding materials. The geomembrane is extended with each stage of dam raising. For the starter sections of the East and West Dams, which were constructed in part over ice-rich soils within the valley oriented east-west, the geomembrane was extended for some distance below the starter embankment, such that the cutoff of the geomembrane into native soils would be sufficiently far from the warming influence of the PKC facility impoundment so as to remain frozen. With this approach, the design objective was therefore to key the geomembrane into material that would remain frozen and, thus essentially impervious to seepage flow.
<table>
<thead>
<tr>
<th>Phase</th>
<th>Construction Dates</th>
<th>Field Supervision / QA</th>
<th>Contractor</th>
<th>Crest Elevation (m)</th>
<th>Reference Documents</th>
</tr>
</thead>
</table>

For the Phases 2 and 3 raises of the Phase 1 starter dams, the geomembrane liner (HDPE) was raised up the face of the dams, which were raised via downstream construction. With the crest raising, the lateral extent of the dams expanded along the abutments. For these extensions, the geomembrane liner, rather than being extended below the dams as per the starter dams configuration, was keyed into excavated cutoff trenches at the toe of the extended dams, at locations that would not be outside of the zone of warming influence resulting from fine PK slurry discharge.

Containment for the PK along the north and south was provided by the north and south spigot roads, constructed of waste rock. These waste rock berms are internal structures that serve three functions:

- Provide access for the PK slurry pipelines for perimeter discharge into the PKC facility, and for the reclaim water pipeline.
- Provide access to the floating reclaim barge used to reclaim process water from the PKC facility.
- Provide containment for the fine PK discharged into the facility, with the north and south cells reserved (under original design) for coarse PK.
The Phase 4 dam raise design and construction involved a revised construction method and a new liner type. In a departure from the Phase 1, 2 and 3 dam sections, bituminous liner (nonwoven geotextile impregnated with bitumen) was installed instead of HDPE liner. The basis for the change was to select a liner type suitable for installation during cold weather, and a material that could tolerate coarser cover and bedding zones (compared to HDPE) without puncture. The bituminous geomembrane liner was bonded to the existing HDPE geomembrane from the Phase 3 raise onwards.

For the Phases 4 and 5 dam raises, the perimeter dams were raised or constructed by first placing a wide downstream rockfill shell section, for both the East and West Dams, and for the North and South Dams. This was followed by re-sloping of the upstream face to achieve a 3H:1V face to support placement of the upstream liner system. Where the dams were extended beyond the Phase 3 abutment limits, the new geomembrane liner was installed into a cutoff trench that was either excavated into bedrock or ice-poor till foundation at the upstream toe of the dams. As-built details of the Phase 4 construction can be found in Golder (2007b).

The Phase 5 design was for the raising of all four dams to crest Ei. 460 m Golder (2007c).

2.2 Dams Design

2.2.1 General

The designs of the dams vary based on whether they contain Fine or Coarse PK and, geometry constraints. The PKC Dams are constructed with an upstream liner system over a sequence of bedding materials, supported by a wide rockfill shell. The liner extends into cut-off trenches upstream of the rockfill, and is covered with fine-grained materials for protection. The cut-off trenches are excavated into ice-poor till or bedrock, and are backfilled with relatively low permeability fill to limit seepage below the dam.

Table 2.3 summarizes the PKC Dam stationing associated with the four dams, and associated PK material containment per the original design.

<table>
<thead>
<tr>
<th>PKC Dam Phase 5 Reference Line Stationing</th>
<th>Dam</th>
<th>PK Containment (per original design)</th>
</tr>
</thead>
<tbody>
<tr>
<td>From</td>
<td>To</td>
<td></td>
</tr>
<tr>
<td>0+000</td>
<td>1+800</td>
<td>South</td>
</tr>
<tr>
<td>1+800</td>
<td>2+700</td>
<td>East</td>
</tr>
<tr>
<td>2+700</td>
<td>3+100</td>
<td>East</td>
</tr>
<tr>
<td>3+100</td>
<td>4+200</td>
<td>North</td>
</tr>
<tr>
<td>4+200</td>
<td>4+600</td>
<td>North</td>
</tr>
<tr>
<td>4+600</td>
<td>5+532 (0+000)</td>
<td>West</td>
</tr>
</tbody>
</table>

Given the actual versus anticipated split between fine and coarse PK, and as described in the current version of the OMS manual (Rev. 1) for the PKC facility (DDMI, 2010), it is now planned to discharge fine PK slurry from around the entire perimeter of the PKC facility.
For each phase of construction of the dams, quality assurance and quality control (QA/QC) has been provided, by NKSL for Phases 1 through 3, and by Golder Associates for Phases 4 and 5. As-built reports are available to document each of the Phases 1 through 4 construction campaigns, prepared in each case by the consulting firm responsible for the QA/QC. No as-built reporting is as of yet available for the Phase 5 construction scope as outlined in the Golder (2007c) design report.

2.2.2 East Dam

The main valley section of the East Dam to crest elevation 440 m was constructed during Phases 1 to 3 with a rockfill embankment, an upstream HDPE liner at a slope of 2.5H:1V, and transition and liner bedding zones. The HDPE liner was anchored in the cut-off trench at the upstream toe of the dam. In two areas the downstream rockfill shell is founded on up to 6 m of ice rich soil overlying bedrock.

Raising the East Dam to crest elevation 450 m, completed during Phases 4 and the 2008 component of Phase 5, comprised rockfill shell placement and installation of the upstream bituminous liner system at a 3H:1V slope to El 450 m, and 1.5H:1V to El. 460 m.

The Phase 4 lateral extensions of the East Dam to the north and south were generally founded on ice poor soils over bedrock with some small areas of ice rich soil over bedrock. The liner was covered in the cut-off trenches with compacted select till. Phase 5 did not require extension of the cut-off trench.

2.2.3 West Dam

The upstream foundation of the West Dam was originally unfrozen silty sand. This talik was associated with a small inland lake that was pumped out prior to Phase 1 construction. The downstream foundation comprised generally ice poor frozen soil overlying bedrock at about 6 m depth.

The Phase 1 West Dam cut-off trench was as previously discussed located in the downstream section of the dam to key into the original frozen foundation area of the dam. The cutoff trench for the Phases 2 and 3 raises was located at the upstream toe of the abutment extensions.

During Phases 1 to 3, the main valley section of the West Dam was constructed with a rockfill shell and an upstream HDPE liner system installed at a slope of 2.5H:1V, to El. 440 m.

The Phase 4 raise of the main valley section of the West Dam to El. 445 m and extensions of the dam to the north and south were constructed with a rockfill shell and an upstream bituminous liner system at a slope of 3H:1V. The bituminous liner was joined to the existing HDPE liner at El. 440 m along the main valley section or, anchored with compacted select till into the cut-off trench along the upstream toe of extensions of the dam along the abutments.

In order to reduce the incursion of the downstream shell of the West Dam into Pond 4, the Phase 5 upstream slope of the West Dam was designed at 1.5H:1V, steeper than for the other dams. Future raises of the West Dam are planned with the same upstream liner slope of 1.5H:1V. The steeper upstream slope reduces the overall width of the West Dam, and reduces the amount the downstream toe must be advanced downstream into the Pond 4 area.
2.2.4 North Dam

The North Dam is generally founded on bedrock or thin soils overlying bedrock, although some sections of ice-rich soils were encountered during the cutoff trench excavations at its upstream toe. The cutoff trench excavation was extended through the ice-rich soils. The downstream rockfill shell of the western portion of the North Dam was shaped from the existing waste rock pile.

The eastern portion of the North Dam retains Coarse PK and separates the North Coarse PK Storage from the North Country Rock Pile. The western section of the North Dam, extending from the North Spigot Road to the West Dam retains Fine PK and separates the PKC Facility from Pond 3 and eventually the portion of the North Country Rock Pile containing Type III (potentially reactive) waste rock.

The original PKC Facility design (NKSL, 1999a and 2001a) presented a North Dam section in which a rockfill shell (comprised of Type I waste rock, non-reactive) was placed with an upstream till low permeability zone to separate the PK from the Type III waste rock in the North Country Rock Pile. The actual development of the North Country Rock Pile allowed for a modified design approach for the North Dam, with placement of Type III waste rock as the downstream rockfill shell for the section of the North Dam adjacent to the Type III portion of the North Country Rock Pile.

The North Dam was constructed with the upstream bituminous liner system installed at a slope of 3H:1V. The bulk of the North Dam was constructed essentially as a waste rock pile, with the waste rock designed to be placed in 5 m lifts, the intent of which was to impart some degree of compaction to the rockfill, and to reduce segregation, a particularly important objective given the eventual regarding and placement of bedding material for liner support and protection. The placement of the bulk rockfill for the North and South Dams was undertaken by the DDMI mine fleet, direct hauling waste rock from the open pits, and was not subjected to QA/QC apart from occasional visual inspection.

A cutoff trench was excavated along the full length of the North Dam and connected to the West and East Dam cutoff trenches at either end. The cutoff trench was backfilled with compacted select till. A “key-in” trench was excavated within the compacted till in the cut-off trench. The bituminous liner was anchored into this till-backfilled trench with compacted, bentonite-modified, processed sand and gravel backfill. The cutoff trench for the North Dam was tied into the trench terminations at the East and West Dams. Similarly, the liner on the North Dam was connected to the liners on the East and West Dams.

The North Dam includes a section of till at its intersection with the West Dam (referred to as the “till-plug”). Till placed on the upstream face of the West Dam will extend through the North Dam rockfill. The Golder (2007c) design report for Phase 5 indicates that bituminous liner was to be installed within the till section and anchored in the cutoff trench, thus achieving full geomembrane (HDPE + bituminous liner) of the facility, anchored into the dam crests, and into the cutoff trenches keyed into foundation till or bedrock.

2.2.5 South Dam

The South Dam is generally founded on bedrock or thin soils overlying bedrock. It does not appear that ice-rich soils were encountered along the alignment of the cutoff trench for this dam,
contrary to the experience in some areas of the cutoff trench along the North Dam. The cutoff trench was been excavated along the full length of the South Dam and was connected to the West and East Dam cutoff trenches at either end.

The South Dam was constructed with a rockfill shell (Type I) by the DDMI mine fleet, with the specification that the rock be placed in 5 m lifts (as per the design requirement for the North Dam). The upstream bituminous liner system was installed on the upstream face at a slope of 3H:1V. The liner was anchored into the cut-off trench with compacted, select till backfill and, connected to the liners on the East and West Dams.

2.2.6 North and South Spigot Roads

The north and south internal spigot roads support the Fine PK pipelines and spigots, and the reclaim water pipelines, and provide separation between the fine PK (central cell) and coarse PK (north and south cells) storage areas. The south spigot road will be abandoned when the Fine PK pipelines are relocated to the South Dam during Phase 5 construction. The spigot roads have been constructed using rockfill; however, future raises of the north spigot road may be undertaken using coarse PK.

These roads are required for operational purposes, are internal structures, and for the final configuration of the PKC facility represent redundant structures.

2.3 Flood Management and Emergency Spillway

An emergency spillway is provided for each PKC dam raise. The spillway is designed to convey the routed outflow from a 24-hour duration probable maximum precipitation (PMP) event. The spillway freeboard requirement is 1.5 m while passing the 24 hr PMP, meaning that the peak pond level during a PMP event would be at least 1.5 m below the crest of the lowest point along the PKC facility perimeter dams. The 24-hour PMP therefore represents the Inflow Design Flood (IDF) for the PKC facility, which is the event for which emergency discharge to the environment is acceptable, but overtopping and failure of the containment dams is not.

The Environmental Design Flood (EDF) represents the event that is to be fully contained within a facility with no release. Thus, while the IDF must be managed via a combination of storage and flood routing, the EDF must be stored. The EDF for the PKC facility is the 1 in 500 year return period spring runoff inflow (1 million m³).

Given that the PKC facility is self-contained (i.e. the runoff catchment is limited to the aerial extent of the facility itself), the safety of the PKC facility in terms of large runoff inflow events is not dependent on any runoff diversion facilities.

The spillway for the Phase 5 dam crest at El. 460 m is to be constructed through the West Dam to the north of the corner between the West and South Dams. At the time of the September 2009 DSR site visit, the spillway was not in place. However, given the storage capacity available in the north and south cells, this was judged acceptable as a temporary measure, although contingency plans should be in place to deal with the large excess of water post-event, and flood storage capacity within the PKC facility must be closely tracked such that the spillway is in place once required.
The design spillway section is trapezoidal with a base width of 2.0 m, a depth of 2.0 m, and side-slopes of 2H: 1V. The spillway bed profile is flat across the crest of the dam. A section of the spillway invert and side-slopes will be lined with bituminous liner. The spillway liner will be joined to the liner placed on the West Dam slope and is to extend to the downstream dam toe to provide a continuous barrier to infiltration of spillway discharge flows into the coarse waste rock downstream shell of the dam. The liner will be anchored at the top of the spillway side-slopes under a layer of rockfill.

A 150 mm minus granular material protective cover is included in the design over the spillway liner to provide thermal protection to the liner material. The granular cover is sacrificial material that would be expected to be washed away in the spillway design event.

The downstream face of the West Dam is to be locally flattened to 3H:1V, with the spillway constructed across the flattened slope. At the toe of the 3H:1V slope, the spillway will discharge into a natural drainage course downstream of the dam toe.

2.4 PK Management and Beach Development

2.4.1 Coarse PK

Coarse PK is to be directed to the north and south cells. However, due to the actual versus projected split between coarse and fine PK, and the use of coarse PK as a construction material within the PKC facility dams, to date in fact there has been very limited placement of coarse PK within the north and south cells. Golder (2007c) described ongoing PK deposition planning that considered use of the north cell for all coarse PK, and discharge of fine PK into the south cell, rather than coarse PK as per the original design.

Thermal modeling was undertaken by Golder (2007c) as part of the Phase 5 design, for a two-dimensional section for each of the East, West, and South Dams, all of which were assumed to be separated from the water pond by a spigotted beach of fine PK.

No thermal analysis was undertaken for the North Dam, which in turn was, per original design, to be separated from the water pond by a wide section of coarse PK. As discussed subsequently in this report, a water pond has periodically been in direct contact with the lower elevations of the North Dam, and coincident with such periods, there have been significant episodes of seepage reporting to downstream water collection ponds, accompanied by localized internal erosion below and possibly within the liner cutoff trench. It is therefore not clear at present that the design expectation, of a frozen seepage cutoff trench at the toe of the North Dam, which is predicted on the basis of Golder’s 2007 thermal analyses for the East, West, and South Dams thermal analyses, is being realized.

Current plans call for the discharge of fine PK slurry from the North and South Dams. This represents a significant improvement, in terms of seepage reduction, relative to the original plans calling for coarse PK against these dams. With minimal hydraulic head loss through coarse PK owing to its high hydraulic conductivity, there would have been very high gradients acting across the liner cutoff trench at the toes of the dams. Spigotted beaches of fine PK would limit the rate of seepage to any defects, and reduce hydraulic gradients that could drive internal erosion. However, given the observed degree of segregation that occurs on the spigotted fine PK beaches, substantial beach widths would be required to achieve the seepage reduction benefits of the fine PK beaches.
2.4.2 Fine PK

The presence of spigotted, above-water beaches of fine PK represents a design requirement for the East and West Dams, and, per the Golder (2007c) report, and the OMS Manual (DDMI, 2010), also now represents a design requirement for the North and South Dams as indicated above.

The fine PK slurry undergoes a significant degree of hydraulic segregation when discharged, with the coarser sizes being deposited relatively close to the discharge location (which is shifted regularly in order to achieve uniform beach development to the degree practical), and the finer sizes being deposited near and within the reclaim pond. The material deposited near and within the pond contains considerable clay content, and as a result is much more compressible, and much less hydraulically conductive, than the coarser material deposited nearer the discharge locations. Further, given the challenges of operating the PKC facility in the long winter season, particularly with respect to the reclaim water pond, ice has become entrained within the fine PK deposit (as well as frozen PK), more so below the subaerial beaches, with likely decreasing ice and frozen PK closer to the water pond (a source of heat). Owing to the challenges of maintaining uniform spigotting and beach widths in front of the dams, the relative position of the reclaim pond within the facility tends to shift on a regular basis. As a result, certain areas of the deposit likely comprise interfingered and layered sequences of the coarser (sand, silt sizes) fraction of the fine PK and finer (silt/clay) fraction, along with layers of ice.

Because of the significant degree of hydraulic segregation within the spigotted fine PK, the coarser fraction of the fine PK that is deposited nearest the discharge locations (i.e. nearest the dams) is of relatively high hydraulic conductivity. This is of significance because this coarser fraction of the fine PK can conduct seepage flow to any liner or foundation defects at a rapid rate, relative to that which would be expected should the fine PK not undergo hydraulic segregation on the beaches. In the presence of defects within the liner and/or the foundation cutoff, which would be localized in nature, the rate of seepage flow could be such that, given the heat flux, freezing could be locally prevented. Therefore, while idealized two-dimensional thermal analyses as conducted by NKSL in the original design report, and by Golder (2007b) in the Phase 5 design report, do indicate frozen conditions, and therefore, by inference, essentially zero seepage, localized and persistent seepage, owing to liner and/or foundation defects, can exist and, on the basis of monitoring data discussed subsequently herein, clearly do exist. The presence of the fine PK beaches separating the East, West, and South Dams serve to limit the seepage, but has to date proven insufficient to eliminate it.

2.5 Additional documents reviewed

Other reports pertinent to this DSR, not listed in Tables 2.1 or 2.2, are listed in Table 2.4.
### Table 2.4: Additional Review Documentation

<table>
<thead>
<tr>
<th>Title</th>
<th>Author</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Documents relating to operation of the PKC Facility</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PKC Facility Operation Plan*, Prepared for Diavik Diamond Mines Inc.</td>
<td>NKSL</td>
<td>2001b</td>
</tr>
<tr>
<td>Water Management Plan Version 5</td>
<td>DDMI</td>
<td>2007</td>
</tr>
<tr>
<td><strong>Documents relating to PK management, deposition planning, and life-of-mine planning</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Documents relating to geotechnical/geophysical site investigations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geotechnical Investigation, Diavik Diamond Project, Feasibility Study, NWT</td>
<td>EBA</td>
<td>1998</td>
</tr>
<tr>
<td>1999 Geotechnical Investigation, Diavik Diamond Project, Feasibility Study, NWT</td>
<td>EBA</td>
<td>1999</td>
</tr>
<tr>
<td><strong>Documents relating to closure and reclamation planning</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interim Closure and Reclamation Plan Version 2, RPT 197.</td>
<td>DDMI</td>
<td>2006</td>
</tr>
<tr>
<td><strong>Diavik Geotechnical Review Board reports</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.0 PROJECT ORGANIZATION

For any significant dam project, particularly one with a “High” consequence classification and with the design, construction, and operational complexities of the PKC facility, a sound organizational structure, staffed by knowledgeable and motivated personnel, is essential. DDMI has clearly defined roles and responsibilities for the PKC facility as given in Section 2 of the OMS Manual (DDMI, 2010). Within this section are defined:

- Roles, responsibilities, and corresponding level of authority; and
- Recommended minimum knowledge (of the PKC facility) for all involved personnel and roles.

DDMI retains a Geotechnical Review Board (GRB), comprised of three eminent geotechnical engineering experts. The GRB meets typically twice annually and provides independent, expert third party advice to DDMI on geotechnical issues at site, specifically the water retaining dykes, the open pits, and in recent years, certain aspects pertaining to the PKC facility. The involvement of the GRB in the PKC facility has expanded in recent years, to the benefit of the stewardship and safety of this facility.

The organization and stewardship of the project are in conformance with good practice and CDA guidelines, along with guidelines proposed by the Mining Association of Canada (MAC) for the stewardship of tailings facilities, and OMS manuals for tailings facilities (MAC, 1998, 2003).
4.0 SURVEILLANCE & GENERAL TRENDS IN DAMS PERFORMANCE

4.1 Visual Surveillance

The visual surveillance program for the PKC facility is described in detail in Section 8 of the OMS manual (DDMI, 2010), and comprises four types of inspections:

- Daily and Weekly Inspection – carried out by both geotechnical and process plant operations personnel to assess operating status of the various elements. The process plant group typically performs 2 inspections per shift;
- Annual Inspection - carried out by a qualified Engineer (the designer, first NKSL, and more recently Golder Associates) to verify that the facilities are functioning as intended; and,
- Dam Safety Review – carried out by third party engineer every 5 years (this report represents the first DSR for the PKC facility).

Visual inspections of the PKC Facility structures (PKC dams and collection pond dams) are the responsibility of the Technical Services and Site Services groups. The Technical services groups’ focus is on geotechnical aspects and dam safety. The Site Service groups’ focus is on Collection Pond water level management (i.e. pumping) and access.

The weekly PKC Facility structure inspections are carried out as part of the Geotechnical Personnel’s weekly duties, and are documented on standard visual inspection forms and maintained on file. These weekly inspections are undertaken by DDMI’s Geotechnical Technicians. The Senior Specialist, Earthworks also performs quarterly control inspections to confirm the inspections performed by the Technicians. The scope of these inspections includes:

- PKC pond elevation (recorded daily);
- Seepage;
- Widths of above water beaches, and areas deficient of beach;
- Inspection of general condition of the PKC dams and the downstream collection pond dams;
- Inspection of spillways; and
- Observed seepage, cracking, or other abnormal conditions.

The annual inspections are carried out by a representative of the consulting design firm (Golder Associates for the last several years) familiar with the design and on-going operation of the PKC Facility. These annual inspection reports (which include a review of operations, and instrumentation) are required to be submitted to the Water Board as part of water license compliance. The objective of the annual inspection is to confirm the inspections carried out by the DDMI personnel and to carry out a detailed review of the conditions of the facilities and facility operation. This detailed review includes a comprehensive review of the instrumentation installed for monitoring of the facility, and a comparison of annual observations to longer term trends.
4.2 Instrumentation

Instrumentation installed to monitor the performance of the PKC facility perimeter dams includes (per the OMS manual, refer to Tables 8-2 through 8-4):

- 33 (operational) thermistor strings in the PKC Dams and PK beaches, and 12 operational thermistor strings in the Ponds 3, 4 and 5 Dams. The reading schedule for the thermistors is twice monthly.

- 1 operational vibrating wire piezometer in the North Dam downstream of the liner on the near Stn. 4+000 m (a number of vibrating wire piezometers were installed within the fine PK beaches but these have since been abandoned). The piezometer is read twice monthly.

- 1 inclinometer in the East Dam (one more planned for installation), read twice monthly.

The most updated site plan showing the installed instrumentation within the PKC facility dams is Golder Associates Drawing no. 14000-41D1-5037 (from Golder, 2007c).

Presentation of instrumentation data is done via plots versus time (and versus depth in the case of thermistors), as is appropriate to facilitate prompt and effective interpretation and reporting of results. Interpretation is carried out by DDMI Geotechnical Technicians knowledgeable about the instrumentation, the PKC facility design and performance criteria, and the significance of nominal and anomalous instrumentation readings, which are outlined in the OMS manual, as are actions to be taken in the event of anomalous readings.

4.3 Seepage Monitoring

Collection Ponds No. 4 and 5 and the areas downstream of PKC East and West Dams respectively are inspected daily. Flows from both are measured via flow meters on the sump discharge pipelines. Ice build up in the ponds is also monitored.

Seepage from the PKC facility reporting to Pond 3, via the West and/or the North Dam, is difficult to identify and quantify.

With the expansion of the PKC facility to include the North Dam, seepage from the PKC facility also reports to Pond 1, and as such DDMI has instituted similar measures for estimating seepage inflows to this pond.

Besides monitoring of the seepage ponds, DDMI personnel in their visual inspections make note of any new wet spots along the perimeter dam toes that are potentially indicative of seepage. Identified locations are then regularly monitored and, as circumstances required, DDMI has installed ditching and additional sump pump stations to manage these seepage flows.

Observation reports commenting on the seepage conditions are prepared as needed by the Lead Geotechnician and distributed to the Senior Specialist, Earthworks, Manager Technical Services, Water Management Coordinator, and Golder Associates (design consultant).

The frequency of the flow monitoring and reporting is dependent on the seepage that is observed. During the warm periods of the year when seepage is often relatively high (due in part to snowmelt infiltration through the waste rock comprising the perimeter dams, and thawing
of ice within the rockfills), monitoring is completed daily and observation reports are prepared on a near weekly frequency. When seepage flows from the PKC Dams increase more than 25%, if new seeps are located or if any seepage is observed downstream of the Collection Pond Dams, monitoring is increased and additional observation reports are provided.

Water downstream of the PKC and Collection Ponds is monitored for conductivity and/or turbidity to provide indication as to whether it is run-off or PKC seepage or meteoric water.

4.4 Performance Trends

4.4.1 Thermistors Monitoring

Thermistors are installed within the foundations and the rockfill shells of the East and West Dams. Thermistors are also installed below the liner (within the liner bedding), and on the downstream side of the toe cutoff trench, at various locations along the toe of the North Dam. The data are summarized as follows.

East Dam

- Areas of ice-rich soils below the starter dam remain at sub-zero temperatures, although there does appear to be a slight warming trend in the cutoff trench (about 0.5°C per year) at the thermistor locations.

- While the base of the rockfill reads sub-zero temperatures, at somewhat higher elevations (i.e. from about El. 424 m to 431 m), temperatures consistently about zero indicate an accumulation of water, which due to phase change from liquid to solid to liquid exhibits a consistent temperature (latent heat effect). This condition is common in cold regions and is referred to as the zero curtain effect.

Although the foundation thermistors indicate sub-zero temperatures as per the design intent (and consistent with 2-dimensional thermal modeling), seepage is clearly occurring through the East Dam as evidenced by flows reporting year-round to downstream collection ponds. The maintenance of a frozen condition within ice-rich soils below the dam is important from a stability perspective, as thaw could induce lower mobilized shear strengths, along with excess pore pressures. However, stability analyses for the East Dam considered the potential for such developments and predicted the dam would retain adequate stability under such conditions. The methodology and analysis of the results are judged valid.

West Dam

- Thermistors installed within the foundation below the West Dam indicate frozen conditions.

- The cutoff trench, installed into permafrost downstream of the talik, remains frozen at the thermistor locations.

- There is a slight warming trend in the more upstream of the thermistors. The more downstream of the thermistors are indicating greater seasonal variation.

- The zero curtain effect is occurring within the rockfill shell of the West Dam, as is the case for the East Dam.
It is important to note that the designs of the East and West Dams in terms of thermal performance were based on thermal analyses that yielded predictions of ground temperatures in response to the construction and operation of the PKC facility. Such analyses were carried out as part of the original design of the PKC facility by NKSL (2001a) and Golder (2007c). In general the NKSL analyses predicted colder temperatures in the dam foundations than have actually been monitored via thermistors. The subsequent Golder analyses were conducted with the benefit of having the thermistor data to calibrate against, and so yielded predicted ground temperatures more in line with those suggested by the thermistor data. To date, it does not appear that threshold levels for thermistor-monitored temperatures have been established, neither in terms of absolute temperatures, nor in terms of trends over time (i.e. rate of change of temperatures). The establishment of such levels should be considered by the facility designer and incorporated into the instrumentation surveillance program. The implications of the build-up of ice within the rockfill shells of the East and West Dams should also be considered in terms of future thermal conditions in the foundations.

**North Dam**
Thermistors were installed in 2008 within the liner trench backfill (downstream of the liner) along the upstream toe of the North Dam. The shallow thermistors within the active layer show seasonal fluctuation between frozen and thawed conditions while deeper thermistors below the active layer within the cutoff trench have shown consistently frozen conditions except at one known location where thawed conditions exist owing to seepage.

**South Dam**
Thermistors were installed in 2007 within the liner trench backfill (downstream of the liner) along the upstream toe of the South Dam. Prior to the deposition of fine PK slurry against this dam, the thermistors have indicated seasonal fluctuations between thawed and frozen conditions.

**4.4.2 Seepage**

**4.4.2.1 East and West Dams**

While frozen conditions are indicated in the foundation of the East Dam, seepage through both these dams has been occurring since the initial years of operation. It appears that seepage rates had generally been minor (< 5 litres/sec per dam, with seasonal variation, and variability dependent on beach widths, of between 1-5 litres/sec) although with a gradual increasing trend.

The accumulation of water/ice within the rockfill shell of the West Dam and the East Dam has occurred coincident with the daylighting of seepage discharge from higher elevations along the contact between the dam toe and natural ground. It appears likely that the seepage breakout at progressively higher elevations is the result of the expansion of the extent of the water/ice within the rockfill shell as additional water from seepage and infiltration accumulates. It is understood that, with the onset of seasonal warming, the rate of seepage increases sharply, which may be due to a sudden release of water “dammed” by ice that thaws with the onset of warmer air temperatures. It is understood that DDMI have managed to successfully contain these flows, along with snowmelt, within the seepage capture and collection system. In recent years this has involved the construction of additional sump stations (e.g. Ray’s Sump, Barry’s Sump), essentially “chasing” the seepage breakout points to higher elevations. It is also understood that, over the past year, DDMI has installed pump wells through the rockfill shells, with the intent
of proactively pumping out the ice-dammed water as opposed to allowing the water to discharge and handling it reactively.

4.4.2.2 Seepage Conditions in 2008 and 2009

In 2008 and 2009, seepage rates to Pond 1 trended notably higher, coincident with the initial construction of the North Dam, and impounding of water in the North Cell. Construction of the North Dam liner system was completed in the spring 2008. During the fall of 2008 the pond elevation in the North Cell was to the point that there was ponded water to just below the limit of the CPK cover placed over the North Dam liner. Seepage was noted from the waste rock pile into Pond 1, with the inflow initially estimated to be approximately 5 to 7 litres per second (L/s), increasing to approximately 15 L/s in late November and then reducing to approximately 10 L/s by mid-December 2008. Seepage into Pond 1 stopped or froze after the North Cell pond was pumped down in early January 2009.

In 2009, with water again ponding in the North Cell, seepage rates to Pond 1 increased from 5 litres/sec April 6, 2009, to 15 litres/sec May 4, 2009, to about 60 litres/sec in July 2009. Prior to this incident, seepage rates had been gradually increasing, and the additional seepages had been appearing at higher elevations along the abutments of the West and East Dams.

The increased seepage from late 2008 through mid 2009 was successfully contained and managed by DDMI, with no release to the environment. Subsequent to this timeframe, and observations of settlement and liner defects near the toe cutoff trench along portions of the North Dam, repairs to the affected portions of the North Dam, believed to have represented the principal pathways for the anomalous seepage, were undertaken in 2009.

At the time the increased seepages occurred, up to several meters depth of water was ponded directly against the North Dam, with no intervening coarse or fine PK. These observations clearly demonstrated that the North and South Dams, with shallow toe seepage cutoffs, if in direct contact with a significant water pond, with no intervening beach of fine PK, are susceptible to substantial seepage, which can in turn could provide sufficient heat flux as to thaw any ice-rich soils that would serve to further exacerbate seepage conditions. Further, given high seepage gradients under such conditions, the potential for internal erosion exists where there are filter incompatible materials below and downstream of the toe cutoff trenches. Besides the repair works already undertaken, it is planned to discharge fine PK into the North Cell and provide separation between the dam and the water pond.

4.4.3 Deformation Monitoring

There has never been any meaningful deformation monument survey data.
5.0 CONSEQUENCE CLASSIFICATION REVIEW

The CDA guidelines provide a system for rating dams in terms of the incremental consequences of a potential failure. The CDA’s consequence classification system, per its 2007 Dam Safety Guidelines, is given in Table 5.1.

The design criteria adopted for the PKC facility dams were selected on the basis of a “High” consequence rating for the structure, based on the consequence classification scheme within the 1999 edition of the CDA guidelines. The design criteria adopted on that basis are given in Table 5.2. Also provided in Table 5.2 are the review comments for this DSR on the appropriateness of the consequence classification and the design criteria. In summary, the consequence classification and the design criteria remain appropriate and no updates are required. It is further noted that the design criteria adopted for the dike would suffice even under an “Extreme” classification under the 2007 guidelines’ classification system.
### Table 5.1: 2007 CDA Dam Classification Guidelines

<table>
<thead>
<tr>
<th>Dam Class</th>
<th>Population at Risk [note 1]</th>
<th>Incremental Losses</th>
<th>Infrastructure and Economics</th>
</tr>
</thead>
</table>
| Low       | None                         | 0                  | Minimal short-term loss  
No long-term loss | Low economic losses; area contains limited infrastructure or services |
| Significant | Temporary only               | Unspecified        | No significant loss or 
deterioration of fish or wildlife habitat  
Loss of marginal habitat only  
Restoration or compensation in kind highly possible | Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes |
| High      | Permanent                    | 10 or fewer        | Significant loss or 
deterioration of important fish or wildlife habitat  
Restoration or compensation in kind highly possible | High economic losses affecting infrastructure, public transportation, and commercial facilities |
| Very High | Permanent                    | 100 or fewer       | Significant loss or 
deterioration of critical fish or wildlife habitat  
Restoration or compensation in kind possible but impractical | Very high economic losses affecting important infrastructure or services (e.g. highway, industrial facility, storage facilities for dangerous substances) |
| Extreme   | Permanent                    | More than 100      | Major loss of critical fish or 
wildlife habitat  
Restoration or compensation in kind impossible | Extreme losses affecting critical infrastructure or services (e.g. hospital, major industrial complex, major storage facilities for dangerous substances) |

**Note 1.** Definitions for population at risk:
- **None** – There is no identifiable population at risk, so there is no possibility of loss of life other than through unforeseeable misadventure.
- **Temporary** – People are only temporarily in the dam-breach inundation zone (e.g. seasonal cottage use, passing through on transportation routes, participating in recreational activities).
- **Permanent** – The population at risk is ordinarily located in the dam-breach inundation zone (e.g. as permanent residents); three consequence classes (high, very high, extreme) are proposed to allow for more detailed estimates of potential loss of life (to assist in decision-making if the appropriate analysis is carried out).

**Note 2.** Implications for loss of life:
- **Unspecified** – The appropriate level of safety required at a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions. A higher class could be appropriate, depending on the requirements. However, the design flood requirement, for example, might not be higher if the temporary population is not likely to be present during the flood season.
## Table 5.2: Consequence Classification & Design Criteria

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Criterion</th>
<th>Comments</th>
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</thead>
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<tr>
<td>Consequence classification (CDA, 2007)</td>
<td>High</td>
<td>Appropriate, no need for revision.</td>
</tr>
<tr>
<td>Design Earthquake</td>
<td>MDE = 1 in 10,000 (probabilistically derived), yielding PGA = 0.023g.</td>
<td>Adequate, no need for revision. Immaterial to design and performance of the PKC dams given low regional seismicity.</td>
</tr>
<tr>
<td>Inflow Design Flood</td>
<td>Probable Maximum Flood (24-hour PMP), with 1.5 m freeboard above peak routed pond level</td>
<td>Adequate, no need for revision.</td>
</tr>
</tbody>
</table>
| Limit equilibrium factor of safety against embankment failure | ≥ 1.3 for short term, static loading conditions  
≥ 1.5 for steady state, static loading conditions  
≥ 1.1 for pseudo-static (steady state plus seismic coefficient) | Adequate.                                                               |
6.0 PKC DAMS INSPECTION

The dams were inspected by Mr. T. Martin of AMEC on Wednesday, September 10 and 11, 2009. The inspections were carried out in the company of Messrs. E. Thiesburger (Senior Earthworks Specialist) and D. Guigon (Lead Geotechnical Technician) of DDMI. The weather was dry, with high overcast and good visibility. Selected photographs taken during the inspection are provided in Appendix A. The dams were inspected from the crests, the downstream toes (East and West Dams) and the upstream toes (North and South Dams). The dams appeared stable and in good condition, with no indications of instability. Liner and cutoff trench repairs were in progress for the North Dam, which at the time of the inspection was not impounding water. There was minimal water in the South Cell, and none impounded by the South Dam. Seepage through the East and West Dams was observed at Ponds 5 and 4 respectively. Inflow was also noted in Pond 1 and the various small sumps installed by DDMI in response to seepage breakout at higher elevations along the PKC impoundment perimeter. A wide beach had been established upstream of the West Dam, while a narrower beach width had been established upstream of the East Dam, where beaching was active at the time of the site visit. Additional observations are provided in the photograph annotations.
7.0 OPERATIONS, MAINTENANCE AND SURVEILLANCE MANUAL

The OMS manual for the PKC facility was updated by DDMI in early 2010. The OMS manual is a comprehensive document meeting the requirements and guidelines outlined by CDA (2007) and MAC (2003).

The Emergency Response Plan (ERP) for the PKC facility dams is incorporated within the OMS manual. The plan appears comprehensive.

Given that the updated manual was issued in April 2010, effort should be made to ensure that all responsible parties become familiar with the manual and their own particular responsibilities as outlined in the manual.
8.0 COMPLIANCE WITH PREVIOUS REVIEWS

This is the first DSR undertaken for the PKC facility. However, the design, construction, and ongoing operation and surveillance receives the benefit of regular third party review via the 3-member Diavik Geotechnical Review Board (DGRB). The design and initial construction of the PKC facility was undertaken with no involvement from the DGRB. The DGRB typically meets twice per year, and the involvement of the DGRB in the ongoing design, construction and operation of the PKC facility dams is clearly to the benefit of the safety of these dams.
9.0 KEY ISSUES IDENTIFIED

Key issues identified in the course of this DSR are as follows:

1. There have been a number of depressions observed within the lining of the North Dam face. It appears, on the basis of investigations and subsequent repairs completed, that these depressions were the result of melting of snow/ice that had been incorporated into the rockfill placed, or re-sloped, over the winter months. Given observations of large rock sizes on the upstream face of the dam (see photos in Appendix A), there is also the potential for such settlements as a result of loss of material within the dam itself, although provided the liner remains intact the likelihood for this would be substantially reduced.

2. The seepage issues associated with the North Dam, and the subsequent investigations and repairs, indicated the potential for filter incompatibility of materials immediately downstream of the liner within the cutoff trench, owing to the placement of portal muck and till with a high rock content within and downstream of the cutoff trench backfill. The repairs dealt with most of this issue, however the placement of portal muck to the downstream of the cutoff trench (to replace excavated ice-rich soils) remains a potential vulnerability in terms of internal erosion induced by seepage below the liner. The issues associated with the cutoff trench construction of the North Dam were primarily the result of water control problems within the North Cell, which necessitated design and construction method modifications, one of which included the placement of portal muck. The water control problems in turn were the result of operational constraints incompatible with ongoing construction.

3. The high seepages, and the potential for internal erosion, clearly demonstrated that a significant water pond in direct contact with the North Dam must be avoided. Further, the original plan to place coarse PK against this dam, given the high hydraulic conductivity of the coarse PK, would be little different than a significant water pond in direct contact with the dam. However, DDMI now plans to discharge fine PK from both the North and the South Dams. This, together with the investigations and repairs undertaken for the North Dam, is judged a positive and necessary means of reducing the likelihood of future episodes of high seepage rates. Wide, above-water beaches of fine PK to separate the North and South Dams from the water pond will serve to reduce seepage gradients at the toe cutoff trenches.

4. While the maintenance of wide above-water beaches provides an effective means of managing these risks, control over the areal extent and position of the water pond will be required. Owing to the high degree of hydraulic segregation that occurs within the spigotted fine PK, relatively coarse, free-draining material settles out near the discharge points. This material is generally clean sand, of high hydraulic conductivity. It will therefore be necessary to maintain beaches of sufficient width such that the water pond is in contact with the finer fraction of the fine PK that settles out at greater distance from the spigot locations. The separation of the water pond from the perimeter dams via material of low hydraulic conductivity will reduce both seepage gradients and the rate at which seepage can flow to any potential construction defects and/or preferential seepage pathways below the lined dams.
5. Recent water management changes implemented at the site now permit the drawing of process water directly from the North Inlet Pond, rather than only from the PKC impoundment. This is expected to afford the PKC facility operators greater flexibility in terms of water management within the PKC facility, in particular the ability to maintain a water pond of much lesser extent. This should serve to reduce the potential for conflicting water management objectives between the operators of the PKC facility, and the constructors. This will also facilitate the maintenance of wide, above-water beaches that will serve to reduce the likelihood for manifestation of potential construction defects. Wide above-water beaches would also increase the likelihood of freezing of the fine PK.

6. Although much repair work has been undertaken for the North Dam, there is some residual risk associated with remaining potential construction defects within the North Dam, particularly with regards to the potential for internal erosion within the cutoff trench. This risk can be largely mitigated by the maintenance of above-water fine PK beaches as discussed above. During initial fine PK discharge into the North (and South) Cell, it will likely not be possible to maintain above-water beach along the entire length of the dam, so water control will be important to reduce ponding against the dam, and the potentially high initial seepage rates that would result. The use of localized sumps may be of benefit during initial fine PK discharge.

7. The accumulation of a zone of frozen water within the East and West Dams does not pose any kind of dam safety concern, but has proven, and will continue to be, an operational inconvenience owing to the appearance of seepage discharge zones at higher elevations along the dam abutments. The installation of pump wells by DDMI to proactively pump out water, as opposed to reacting to it via extension of the seepage collection system, is likely to alleviate the operational inconvenience.

The four dams are considered stable against embankment failure. There are no indications of instability. The seepage issues discussed herein affect the performance of the PKC facility in terms of the seepage capture and reclaim measures required to manage the issues, but do not, with appropriate operating practices, pose a risk to the physical stability of the dams. Continued monitoring and evaluation of seepage and thermal conditions will be required going forward to confirm that this remains the case.

Conclusions and recommendations arising from this DSR are presented at the beginning of the report.
10.0 REPORT CLOSURE

The assistance of Messrs. Eric Thiesburger and Dan Guigon of DDMI is gratefully acknowledged in the undertaking of this DSR.

Recommendations presented herein are based on a geotechnical evaluation of the findings of the site inspection, and upon review of the reports noted. If conditions other than those reported are noted during subsequent phases of the project, AMEC should be notified and be given the opportunity to review and revise the current recommendations, if necessary.

This report has been prepared for the exclusive use of Diavik Diamond Mines Inc, for specific application to the area within this report. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. AMEC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report. It has been prepared in accordance with generally accepted soil and foundation engineering practices. No other warranty, expressed or implied, is made.

Respectfully submitted,

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REFERENCES


AMEC File: VM00503
PKC DSR report_FINAL_Oct2010.docx


APPENDIX A

Site Inspection Photographs
Aerial view of the North Cell of the PKC facility, July 2009. Note the extent of the water pond, in contact with the toe of the North Dam.
July 2009 – looking east to west over the PKC facility. Note the large extent of the water pond in the central cell (yellow arrow), and the extent of ponded water in the North Cell (red arrow).
East Dam, July 2009. North Cell in the background, behind which is the waste rock pile. Note well developed beach upstream of the East Dam.
Downstream face of East Dam, with Seepage Collection Pond 5 (yellow arrow) and Pond 1 (red arrow).
July 2009 - Looking west-northwest at downstream face of East Dam. Central Cell to the left, North Cell to the right, and North Dam in the background. Pond 5 indicated by yellow arrow.
July 2009 – Pond 1 in the foreground (red arrow), Pond 5 in the background (yellow arrow).
August 2009 – upstream face of West Dam. Note narrow beach width towards the north abutment.
August 2009 – repair works underway at the toe of the North Dam.
August 2009 – Norfh Cell largely dewatered to facilitate repairs.
July 2009 – South Dam downstream face, looking northeast. South Cell indicated by yellow arrow, Central Cell by red arrow.
July 2009 - Downstream face of West Dam, with Pond 4 (yellow arrow) in the foreground.
July 2009 - Looking east to west over the PKC facility. South Cell to the left (yellow arrow), Central Cell. And North Cell to the right (red arrow). East Dam and Pond 5 in the foreground. Note well developed beach against the East Dam, with much less beach width against the West Dam.
September 2009 – Repair work in progress in the cutoff trench at the toe of the North Dam.
September 2009 – Reclaim water barge in the PKC impoundment water pond.

September 2009 - Panorama of the central cell, from North Dam west of North Barge Road.
September 2009 – waste rock on the face of the South Dam, above a section of slope where the transition fill was placed and shaped. Note the large rock sizes, prior to regrading and subsequent placement of the transition zone.
September 2009 – North Dam, large waste rock sizes immediately above the lined portion of the dam (liner covered in coarse PK). Liner not completely covered with coarse PK – “fingers” of coarse PK ballast placed to hold the liner down.
September 2009 – panorama from the crest of the West Dam, looking towards the North Cell.
September 2009 - Coarse PK being pushed upslope over the liner for protective cover (North Cell).
September 2009 – Downstream of the West Dam. Pond 4 Dam (left), and downstream face of the West Dam (right). Note haul truck on crest of West Dam – dumping to advance downstream shell of the dam.
September 2009 – Wet area (due to seepage) at downstream toe of East Dam.
September 2009 – Seepage return pump station – Pond 5.
September 2009 – Typical arrangement inside seepage collection sumps.
September 2009 – Downstream face of the East Dam (to left), and Pond 5 (yellow arrow).
APPENDIX B

As-Built Dam Sections