Knight Piésold CONSULTING

MEMORANDUM

To:	**ANGLOGOLD ASHANTI AUSTRALIA**	**Date:**	16th January 2009
Attn:	Belinda Bastow	**Our Ref:**	PE801-00083sdmM9001
		KP File Ref.:	PE801-83 EMEM-KP019
cc:	Massoud Massoudi	**From:**	Brett Stevenson

RE: TROPICANA PROJECT – TSF SEEPAGE ASSESSMENT

As requested, please find herein an assessment of the likely seepage rates during operation from the proposed tailings storage facility at Tropicana.

1. TSF Design Summary

The current tailings storage facility design is summarised as follows:

- The TSF will comprise of two cells operated concurrently.
- The embankments will be developed by downstream construction methods.
- The basin area will have composite soil and HDPE geomembrane liner. The HDPE geomembrane area will be located below the typical operating supernatant pond extents.
- Tailings will be discharged into the facility by sub-aerial deposition methods, using spigots at regularly spaced intervals, from all embankments to locate the supernatant pond centrally in each cell.
- A basin underdrainage system is included to reduce seepage and improve the geotechnical stability of the TSF. The underdrainage system drains by gravity to a collection sump located at the lowest point in the TSF basin for each cell and is pumped back into the supernatant pond for reuse.
- Based on the guidelines provided by the Department for Water (Water Quality Protection Note WQPN 27, February 2006), seepage rates from an engineered soil lined facility should not exceed 1 kL/ha/day.

2. Insitu foundation conditions

The foundation conditions under the TSF will comprise of:

- Aeolian sand.
- Calcrete.
- Transported sandy gravels / gravely sand.

All insitu foundation materials are expected to have relatively high permeabilities. The permeability of the Calcrete and transported sandy gravels is estimated to be a minimum of two to three orders of magnitude higher than that of the tailings / lining systems and therefore, seepage rates from the facility will be governed by the engineered lining system installed within the facility.

The performance of the facility, specifically regarding seepage, is not expected to vary whether the foundation material is the Calcrete or sandy gravel / gravelly sands (ie: location is not critical).

3. Design measures to reduce seepage

The engineered seepage control system will consist of the following components:

i. TSF Basin Composite Lining

A composite basin liner will be provided in the TSF comprising:

- 1.5 mm HDPE geomembrane liner (covering 20% of the basin area in each cell) overlying;
- A low permeability soil layer of either scarified, conditioned and recompacted in situ soils and / or imported fill (covering 100% of the basin area of the cell);

ii. Basin Underdrainage Collection System.

The underdrainage collection system will be constructed throughout the basin area and is designed to reduce the phreatic surface on the basin liner. One of the benefits of the underdrainage system is that it reduces seepage through the basin and through the embankment.

The underdrainage system will consist of two drainage networks, namely collector drains and branch drains. Collector drains and branch drains will be placed in both soil and geomembrane liner areas.

In the soil liner areas, the main collector drains will be constructed along the main valley, and will be underlain by the soil liner in all areas (minimum thickness 200 mm). The drains will consist of 160 mm diameter draincoil pipes located at 25 m centres, embedded within a 300 mm sand layer covered with 300 mm of erosion protection material. Branch drains will consist of 100 mm diameter draincoil pipes surrounded with sand and wrapped in geotextile. The drains will be covered with a 150 mm thickness layer of erosion protection material. The branch drains will feed directly into the collector drains.

In HDPE geomembrane lined areas, branch drains will be located on top of the geomembrane liner and will consist of 100 mm diameter draincoil pipes located at 25 m centres surrounded with sand and wrapped in geotextile.

4. Seepage Assessment

4.1 Background

Based on the current TSF design and location, a seepage assessment was undertaken for the TSF to quantify the following aspects:

- Estimate the steady state seepage rate from the TSF.
- Estimate the effect of the basin underdrainage system and the HDPE geomembrane on the phreatic surface within the TSF.

For this assessment and based on available information, all insitu soils below the TSF were designated to exhibit a permeability at least two orders of magnitude higher than the TSF basin lining systems and therefore do not impact at all on the rate of seepage from the facility.

A seepage model was created in the analysis program Seep/W. The underdrainage system drains, soil liner and HDPE geomembrane liner were included in the model.

4.2 Sub-surface Profiles

The subsurface conditions and layer thickness for the section were based on the subsurface profiles presented in KP Report Ref. PE801-00083/03 (issued as Rev A, September 2008), and summarised in Table 4.1.

Table 4.1: Indicative Soil Profile – non paleochannel areas

Depth to Base (m)	Thickness (m)*	Description
0.2 – 1.2	0.2 – 1.2	Surface sand material (Aeolian)
0.9+ – 2.1+	0.0 – 1.6+	Sub-surface gravel material (transported)
3.0 – 18.0	0.5 – 8.0	Calcrete (calcareous cement) material (Residual)
4.0 – 37.0+	1.0 – 19.0+	Saprolite material (Residual)

*NB – Thickness of calcrete and saprolite material based on inspection of air core spoil piles.

The depth of sandy gravel present in the paleochannel was inferred from the internal Anglogold memorandum 'Tailings Dam Paleochannel Interpretation' (17 October 2008), provided by Anglogold in January 2009.

4.3 Material Parameters

A plan of the adopted TSF configuration is presented as Figure 1. Typical basin cross sections are shown on Figure 2. The resulting seepage model is presented as Figure 3.

The material types and parameters used in the model are summarised in Table 4.2.

Table 4.2: Seepage Modelling - Material Parameters

Material Type	Estimated Permeability k (m/s)
Embankment:	
Embankment Zone A – Low Permeability	1×10^{-8}
Embankment Zone C – Structural Fill	5×10^{-7}
Tailings mass:	
Vertical direction	2×10^{-7}
Horizontal direction	2×10^{-6}
Basin liner:	
HDPE Geomembrane (effective)	1×10^{-12}
Sand Protection Layer	1×10^{-3}
Low permeability soil liner / subgrade	1×10^{-8}
Foundation:	
Surface Aeolian Sand	1×10^{-5}
Sub-surface Gravel	5×10^{-3}
Calcrete	1×10^{-5}
Saprolite	1×10^{-8}

4.4 Scenarios Modelled

Two scenarios were modelled, both representing the final TSF.

- Scenario 1 – Average pond extents (minimum operating volume), underdrainage system fully operational. This is intended to reflect the expected operational conditions.

- Scenario 2 – Wet pond extents resulting from a 1 in 100 year return interval storm event, underdrainage system fully operational.

The following boundary conditions were assumed in the analysis:

- The supernatant pond is represented by a constant head boundary condition, where the head is equal to the elevation of the pond surface;

- The exposed beach consists of a constant flux input equivalent to the water infiltration due to freshly deposited tailings in an active cell;

- Either side of the model comprised nodes set to model infinite elements. In physical terms, water can seep through the soil layers to an infinite distance to either side of the model;

- Drainage systems were modelled as a series of free draining points (or zero pressure nodes). These nodes were placed at the design underdrainage spacing.

4.5 Modelling Results

The results of each of the design cases are outlined below:

- Scenario 1 was modelled with the basin underdrainage system operational, with average operating supernatant pond extents. The phreatic surface in the TSF is located well within the HDPE liner extents and as a result low rates of seepage are forecast. The estimated rate of seepage from the TSF is in the order of 213 kL/day equivalent to 0.76 kL/ha/day for a total TSF size of 280 Ha.

- Scenario 2 was modelled with the basin underdrainage system operational, with the supernatant pond extents resulting from a 1 in 100 return average return interval storm event. The phreatic surface remains within the HDPE liner extents. The estimated rate of seepage from the TSF is in the order of 214 kL/d or an equivalent of 0.77 kL/ha/day.

Table 4.3: Seepage Modelling – Estimated Seepage Flows

Scenario	Seepage From TSF ($m^3/s/m^2$)		Total Seepage from TSF (kL/day)	Figure
	HDPE Lined Area	Soil Liner Area		
1 – Average conditions	2.21×10^{-10}	4.94×10^{-9}	215	4
2 – Wet conditions	2.59×10^{-10}	4.93×10^{-9}	217	5

5. Conclusions

Based on the assessment, the following conclusions are made:

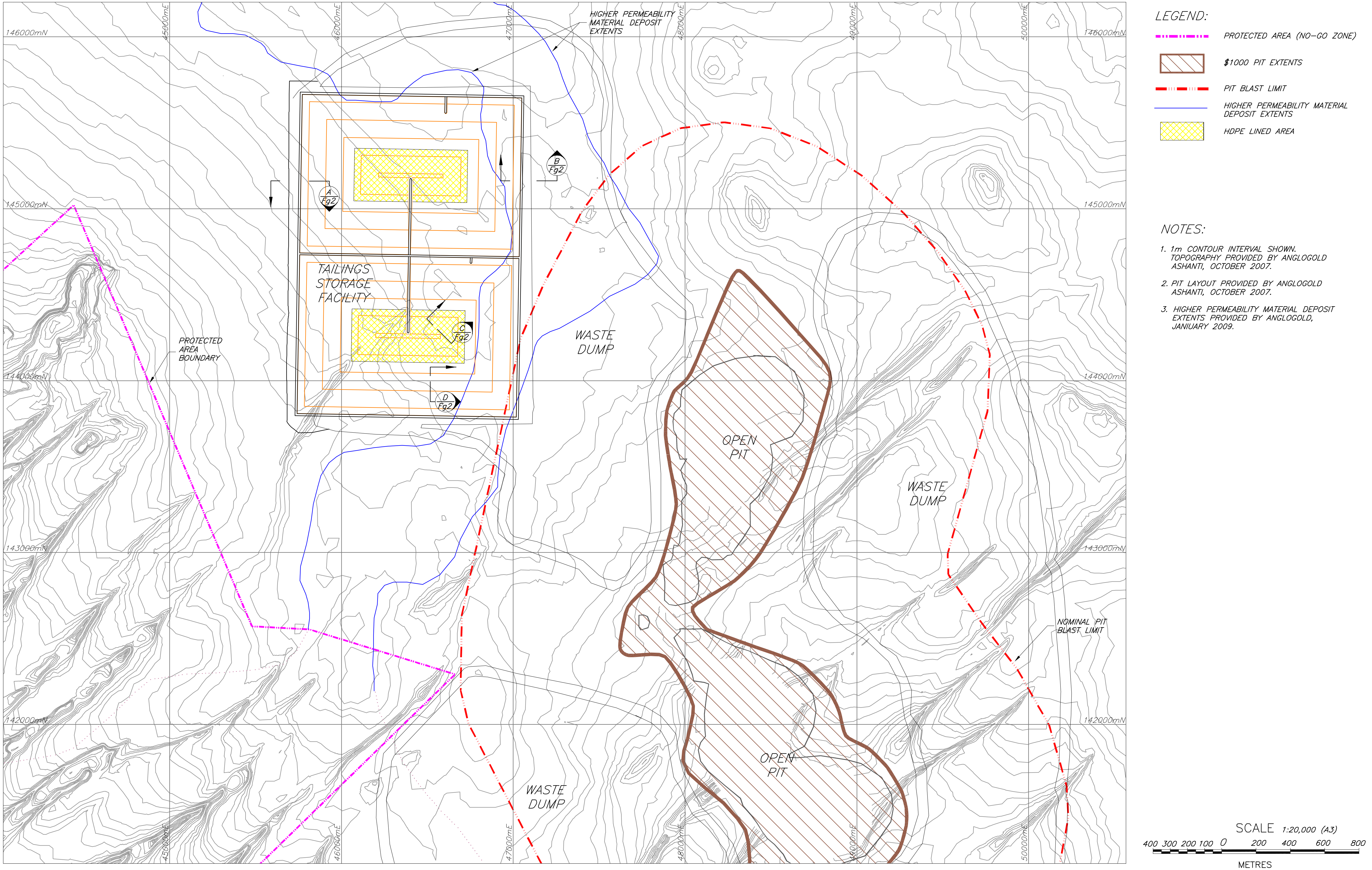
1. Seepage rate from the facility is not considered a significant issue.
2. The location of the facility, whether founded on Calcrete or the transported sandy gravel (paleochannel) has no impact on the rate of seepage from the facility, provided the pond extents remain within the HDPE liner extents.
3. Seepage rates under normal operating conditions are estimated to be below guideline limits as set by the Department of Water.
4. Seepage rates during extreme wet conditions continue to remain below the guideline limits.
5. Operation of the facility will need to be in strict accordance with the operating guidelines to ensure the pond does not exceed the HDPE liner extents and is returned to average operating conditions as quickly as possible.
6. Additional seepage control measures within the TSF basin are not considered necessary.
7. Monitoring and contingency plans currently nominated for the TSF remain valid.

We trust this is sufficient information for your current requirements. If you have any questions, please contact us.

Yours sincerely,
KNIGHT PIÉSOLD PTY LTD

BRETT STEVENSON
Associate Director

FIGURES



NOTES:

1. 1m CONTOUR INTERVAL SHOWN. TOPOGRAPHY PROVIDED BY ANGLOGOLD ASHANTI, OCTOBER 2007.
2. PIT LAYOUT PROVIDED BY ANGLOGOLD ASHANTI, OCTOBER 2007.
3. HIGHER PERMEABILITY MATERIAL DEPOSIT EXTENTS PROVIDED BY ANGLOGOLD, JANUARY 2009.

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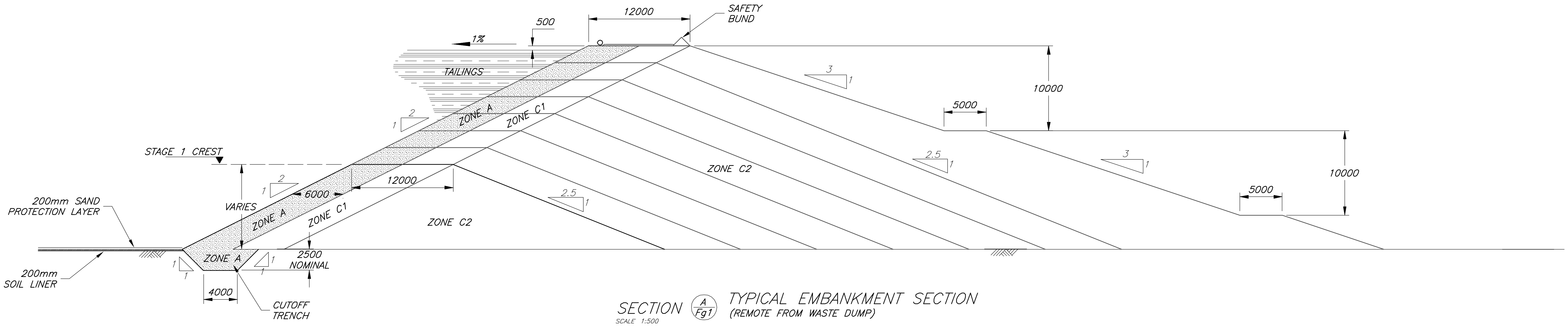
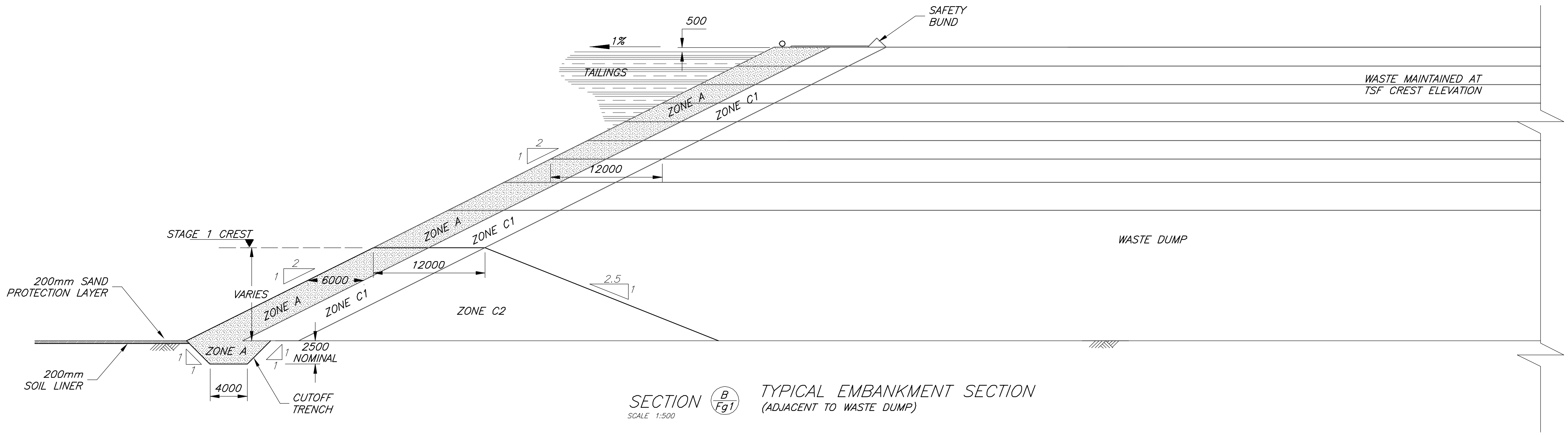
TROPICANA GOLD PROJECT
TAILINGS STORAGE FACILITY SEEPAGE MODELLING
FINAL GENERAL ARRANGEMENT

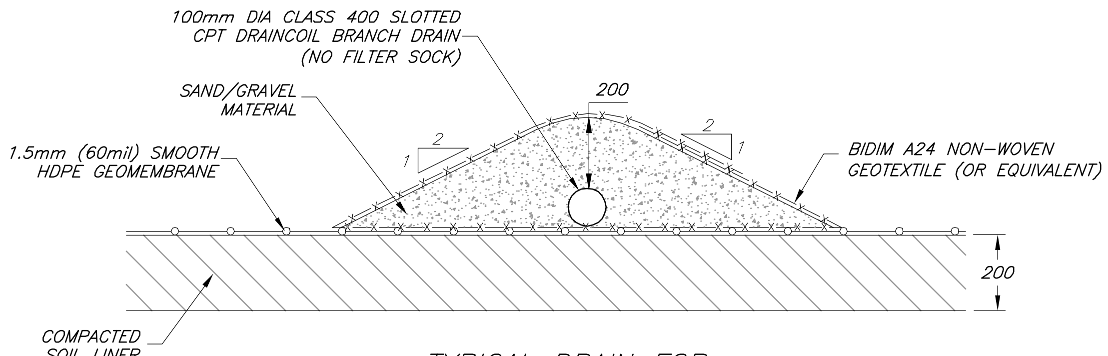
Ref: PE801-83-EMEM-KP019
Figure 1
Rev: 0



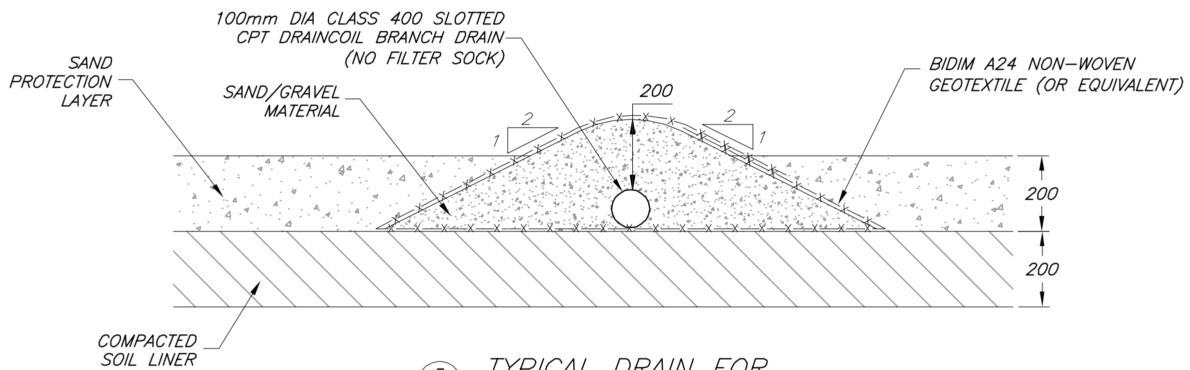
SECTION A/Fg1 TYPICAL EMBANKMENT SECTION
SCALE 1:500
(REMOTE FROM WASTE DUMP)



SECTION B/Fg1 TYPICAL EMBANKMENT SECTION
SCALE 1:500
(ADJACENT TO WASTE DUMP)



SECTION C/Fg1 TYPICAL DRAIN FOR GEOMEMBRANE LINER AREA
SCALE 1:20



SECTION D/Fg1 TYPICAL DRAIN FOR SOIL LINED AREA
SCALE 1:20

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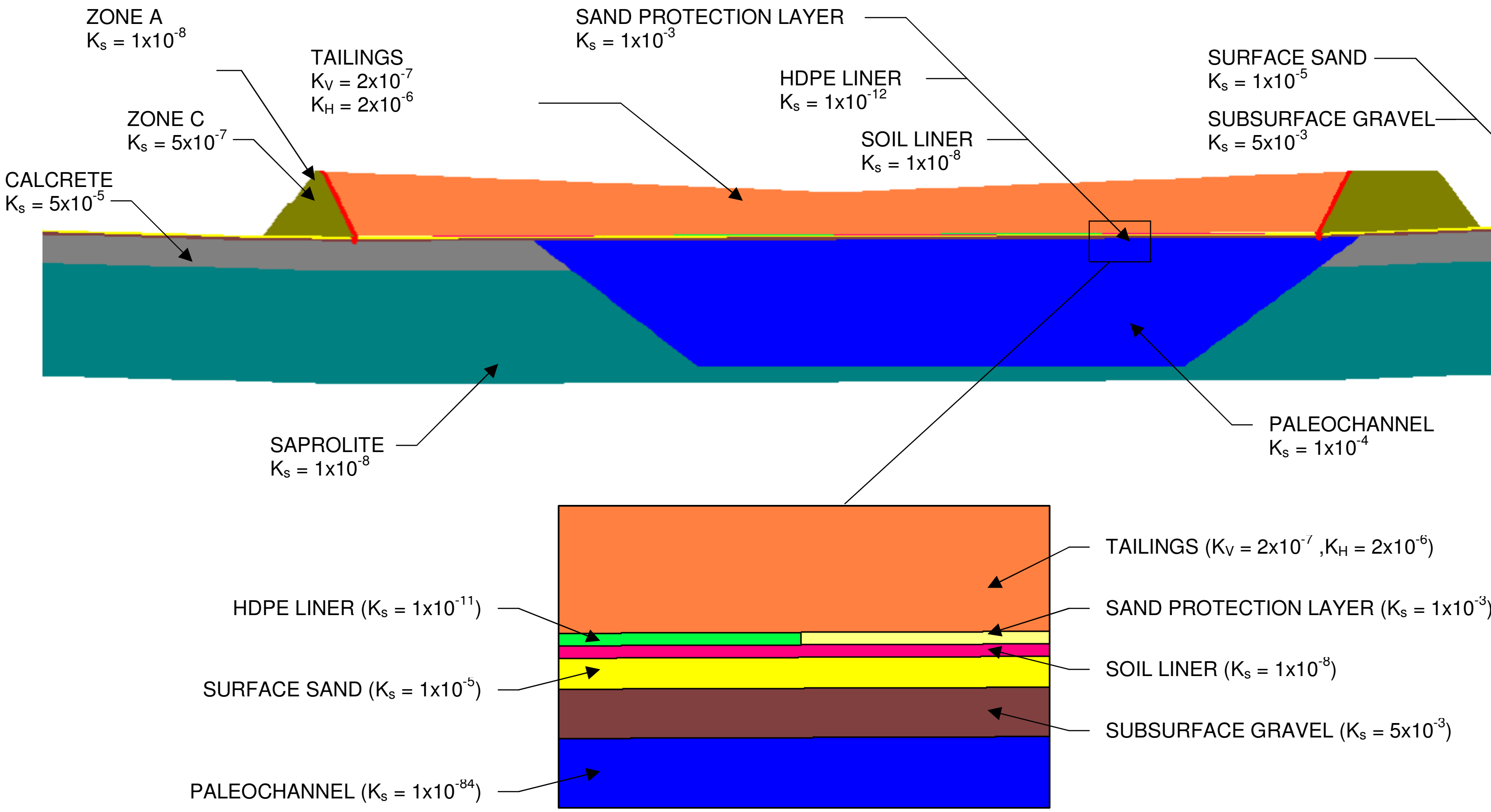
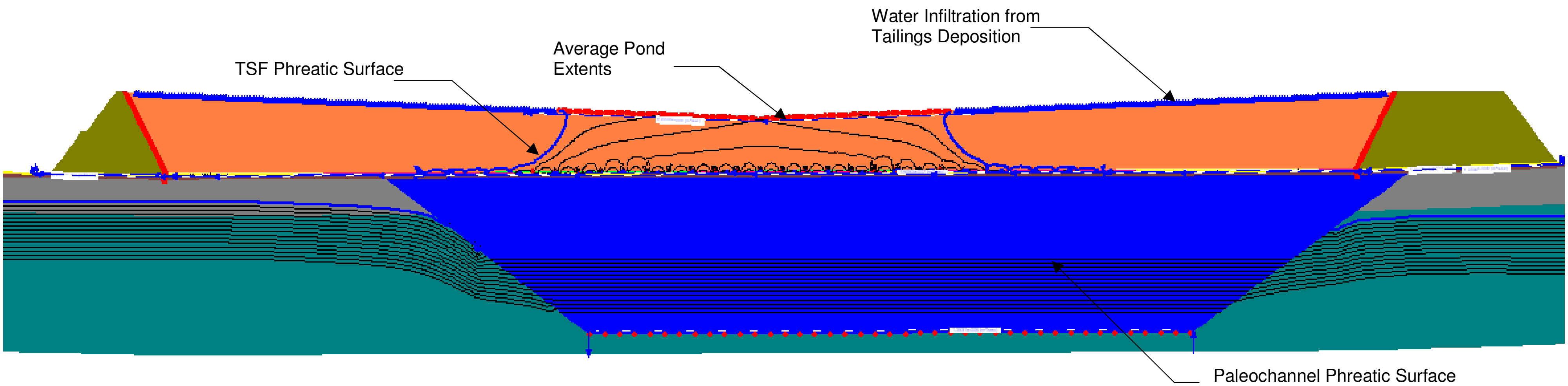
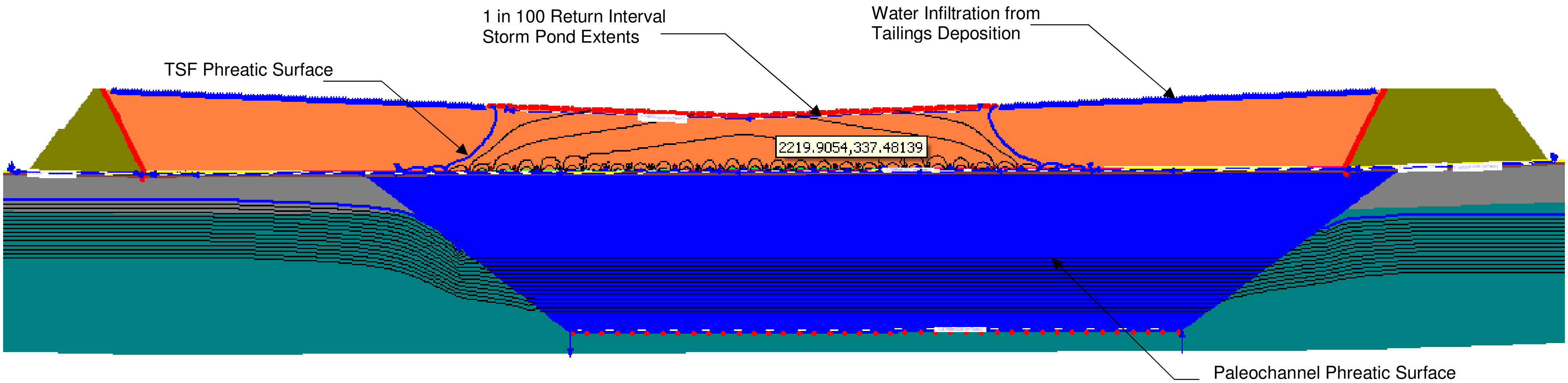
TROPICANA GOLD PROJECT
TAILINGS STORAGE FACILITY SEEPAGE MODELLING
TYPICAL EMBANKMENT SECTIONS

Ref: PE801-83-EMEM-KP019
Figure 2
Rev: 0



ZONE A
$K_s = 1x10^{-8}$
TAILINGS
$K_V = 2x10^{-7}$
$K_H = 2x10^{-6}$
ZONE C
$K_s = 5x10^{-7}$
CALCRETE
$K_s = 5x10^{-5}$
SAND PROTECTION LAYER
$K_s = 1x10^{-3}$
HDPE LINER
$K_s = 1x10^{-12}$
SOIL LINER
$K_s = 1x10^{-8}$
SURFACE SAND
$K_s = 1x10^{-5}$
SUBSURFACE GRAVEL
$K_s = 5x10^{-3}$
SAPROLITE
$K_s = 1x10^{-8}$
PALEOCHANNEL
$K_s = 1x10^{-4}$
TAILINGS ($K_V = 2x10^{-7}$,$K_H = 2x10^{-6}$)
HDPE LINER ($K_s = 1x10^{-11}$)
SAND PROTECTION LAYER ($K_s = 1x10^{-3}$)
SOIL LINER ($K_s = 1x10^{-8}$)
SURFACE SAND ($K_s = 1x10^{-5}$)
SUBSURFACE GRAVEL ($K_s = 5x10^{-3}$)
PALEOCHANNEL ($K_s = 1x10^{-84}$)


Water Infiltration from
Tailings Deposition
Average Pond
Extents
TSF Phreatic Surface
Paleochannel Phreatic Surface



1 in 100 Return Interval
Storm Pond Extents
Water Infiltration from
Tailings Deposition
TSF Phreatic Surface
2219.9054,337.48139
Paleochannel Phreatic Surface