SOILWATER CONSULTANTS

MULGA ROCK URANIUM PROJECT TAILINGS STORAGE FACILITY SEEPAGE ANALYSIS

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Revision Code*

A - Report issued for internal review

B - Draft report issued for client review

C - Final report issued to client

LIMITATIONS

The sole purpose of this report and the associated services performed by Soil Water Consultants (SWC) was to undertake preliminary seepage analysis for the proposed Tailings Storage Facilities (TSF) to be constructed and utilised at the Mulga Rock Uranium Project (MRUP). This work was conducted in accordance with the Scope of Work presented to Vimy Resources ('the Client'). SWC performed the services in a manner consistent with the normal level of care and expertise exercised by members of the earth sciences profession. Subject to the Scope of Work, the TSF seepage analysis was confined to MRUP. No extrapolation of the results and recommendations reported in this study should be made to areas external to this project area. In preparing this study, SWC has relied on relevant published reports and guidelines, and information provided by the Client. All information is presumed accurate and SWC has not attempted to verify the accuracy or completeness of such information. While normal assessments of data reliability have been made, SWC assumes no responsibility or liability for errors in this information. All conclusions and recommendations are the professional opinions of SWC personnel. SWC is not engaged in reporting for the purpose of advertising, sales, promoting or endorsement of any client interests. No warranties, expressed or implied, are made with respect to the data reported or to the findings, observations and conclusions expressed in this report. All data, findings, observations and conclusions are based solely upon site conditions at the time of the investigation and information provided by the Client. This report has been prepared on behalf of and for the exclusive use of the Client, its representatives and advisors. SWC accepts no liability or responsibility for the use of this report by any third party.

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1 INTRODUCTION

1.1 SCOPE OF THE DOCUMENT

This document reports the results of preliminary seepage analysis undertaken on the proposed above-ground and in-pit Tailings Storage Facilities (TSFs) to be constructed and operated at the Mulga Rock Uranium Project (MRUP). This information is needed to fulfil the requirements of the Environmental Protection Authority (EPA) approved Environmental Scoping Document (ESD), and represents a preliminary environmental risk assessment for these proposed landforms. This report should be read in conjunction with the Tailings Disposal Study (GHD, 2015a), Groundwater Assessment of Tailings and Process Water Disposal to Princess Pit (GHD, 2015b) and the Physicochemical Summary of Tailings to be generated from the MRUP (SWC, 2015).

1.2 DESCRIPTION OF THE MULGA ROCK URANIUM PROJECT

The Mulga Rock Uranium Project (MRUP) lies approximately 240km east-north-east of Kalgoorlie-Boulder in the Shire of Menzies (Figure 1.1). The area is remote, located on the western flank of the Great Victoria Desert, comprising series of large, generally parallel sand dunes, with inter-dunal swales and broad flat plains.

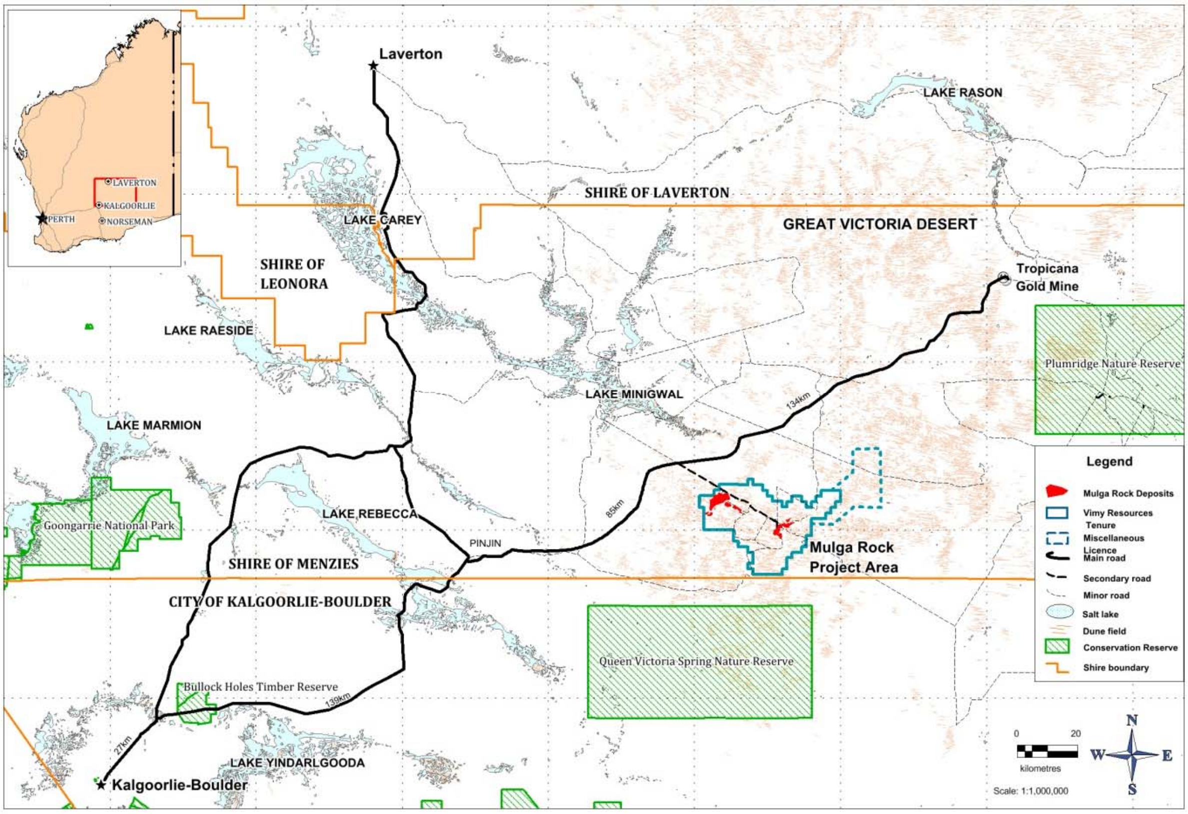

Figure 1.1: Location of MRUP.

The MRUP covers approximately 102,000 hectares on granted mining tenure (primarily M39/1080 and M39/1081) within Unallocated Crown Land (UCL). It includes two distinct mining centres, Mulga Rock East (MRE) comprising the Princess and Ambassador Resources and Mulga Rock West (MRW) comprising the Emperor and Shogun Resources, which are approximately 20km apart (Figure 1.2). Mining will commence at MRE which will include the location of the metallurgical processing plant. Up to 4.5 Million tonnes per annum (Mtpa) of ore will be mined and processed to produce, on average, 1,360 tonnes of uranium oxide concentrate (UOC) per year over the life of the Project. The anticipated Life-of-Mine (LOM) is up to 16 years, based on the current identified resources.

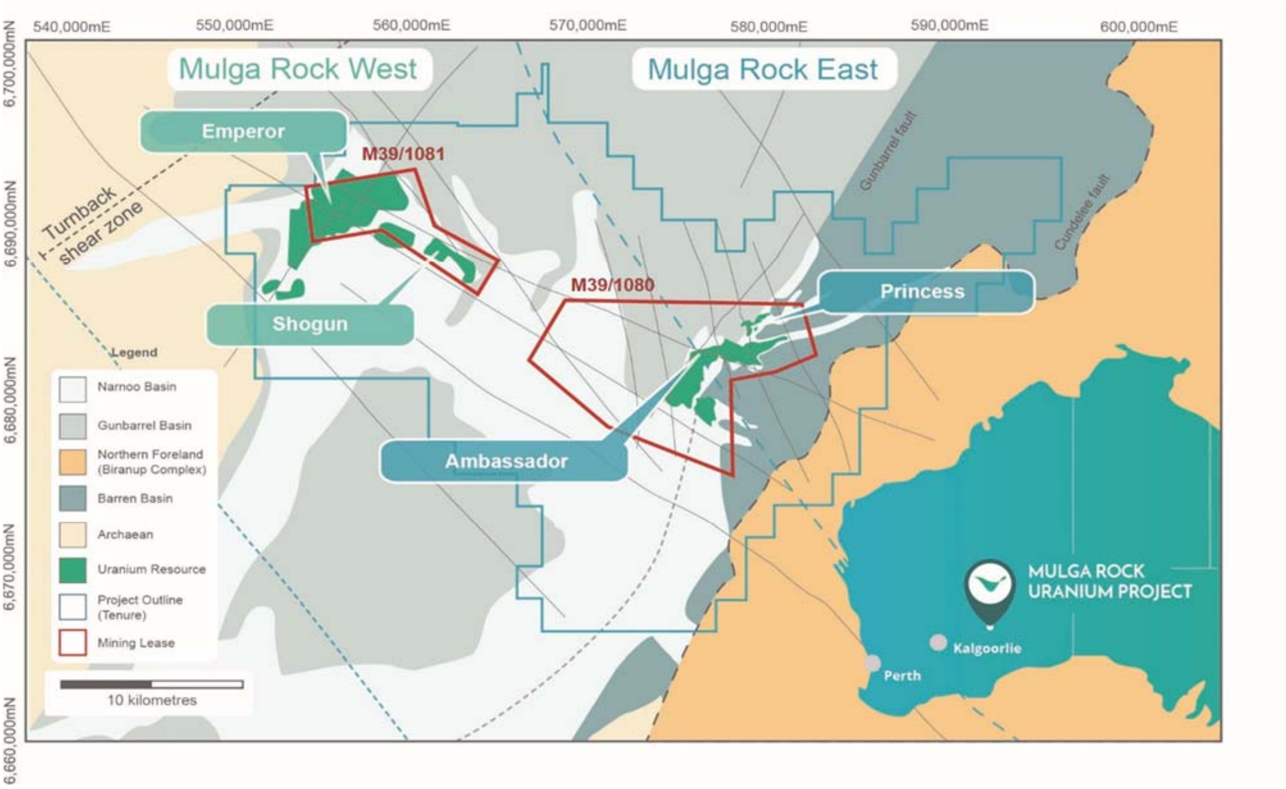

Figure 1.2: MRUP mining centres and associated resources.

The MRUP has been extensively drilled with 2,383 aircore and RC holes completed within the resources for a total combined depth of 146,844 metres. In addition, 531 diamond holes have been completed across the project for total 22,042 metres of core. The Resources are well defined and has essentially been closed out in most directions. Resource estimates from September 2015 are provided in Table 1.1.

The mineralogy of the MRUP is complex, with over 50 minerals of interest being recognised, in addition to the common rock-forming minerals (Douglas *et al.*, 1996). The bulk of the uranium mineralisation occurs as diffuse lateral concentrations of uranium absorbed to organic carbonaceous material and ultra-fine grains of uraninite [UO_2], along with very minor amounts of brannerite [$(U^{4+},Ca)(Ti,Fe^{3+})2O_6$] and coffinite [$U(SiO4)_{1-x}(OH)_{4x}$]. Uranium mineralisation is too fine to be resolved by scanning electron microscopy (SEM) and is disseminated evenly throughout the organic rich sediments (Douglas *et al.*, 1996). The MRUP will mine and treat ore with an average grade of 600 ppm U_3O_8 .

Table 1.1: The MRUP Mineral Resource Estimate as of September 2015.

Deposit / Resource	Classification	Cut-off Grade (ppm U_3O_8)[4]	Tonnes (Mt)[3]	U_3O_8 (ppm)[4]	U_3O_8 (Mlb)
Mulga Rock East					
Princess	Indicated	150	1.3	690	1.9
Princess	Inferred	150	2.5	380	2.1
Ambassador	Indicated	150	13.2	750	21.7
Ambassador	Inferred	150	16.1	460	16.3
Sub-Total			33.1	580	42.0
Mulga Rock West					
Emperor	Inferred	150	28.4	450	28.1
Shogun	Inferred	150	4.1	550	4.9
Sub-Total			32.5	460	33.0
Total Resource			65.6	520	75.0

The Mulga Rock East Deposit also contains a base metal (BM) resource. An inventory for each base metal has been established that extends beyond the uranium resource. Base metals will be recovered as part of the processing of the uranium ore, but economic extraction of BM independently of uranium is unlikely at this time. Therefore the BM Resource estimate in Table 1.2 represents only the BM inventory coinciding with the boundaries of uranium resource even though there is additional BM mineralisation outside the uranium domains. The Princess and Ambassador BM Resources are provided in Table 1.2. Scandium also coincides with the uranium resource across the MRE deposit and is also reported (Table 1.2).

Previous explorers did not assay for BM during previous drilling at the MRW Deposit (Emperor and Shogun), and therefore no BM resource estimation can be determined for that Deposit at this stage. Future drilling at MRW will address this, however the geology is very similar and if similar BM are present as occurs at MRE, Vimy expects to determine a BM resource at MRW based on the same assumptions, and that the BM flow-sheet developed for MRE will apply equally.

An illustration of the proposed MRUP process flowsheet is provided in Figure 1.3. Run-of-mine (ROM) ore is beneficiated within the mining area via a semi-mobile beneficiation plant. Given the high content of barren silca-rich sand within the mineralised sediments, removal of this sand prior to leaching is an important step for reducing throughput into the main uranium process plant. The beneficiation process uses gravity separation to separate the light uranium-bearing organic matter from the heavy course-grained silica-rich sands and gravels. This process removes approximately 50% of mass for only a minimal loss of uranium. The silica sand will be blended back into the pit void with the overburden.

The final beneficiated slurry, which has been subsequently upgraded in uranium, is pumped to the main process plant for further treatment. From here, the ore is milled and then enters an acid leach circuit where the final leach discharge is pumped to a resin-in-pulp (RIP) circuit to recover the uranium in solution. The RIP circuit is simple and analogous to a gold carbon-in-pulp circuit, with resin used instead of activated carbon.

Uranium is then stripped from the resin to produce a uranium yellowcake concentrate which is packaged into steel drums for export. The slurry from the uranium RIP circuit is barren of recoverable uranium but is further processed, following neutralisation, to produce separate copper-zinc and nickel-cobalt mixed sulphide concentrates which will be packaged for subsequent sale.

Table 1.2: MRUP Base Metal Mineral Resource Estimate as from September 2015.

Deposit / Resource	Tonnes (Mt)	Cu (ppm)[1]	Zn (ppm)[1]	Ni (ppm)[1]	Co (ppm)[1]	Sc (ppm)[1]
Mulga Rock East – tonnes and grade						
Princess - Indicated	1.3	750	1280	440	210	60
Princess - Inferred	2.5	270	500	250	140	20
Ambassador - Indicated	13.0	340	1350	600	250	30
Ambassador - Inferred	15.1	170	320	300	160	20
Total	**31.9**	**270**	**790**	**420**	**200**	**25**

Deposit / Resource	Classification	Cu (kt)	Zn (kt)	Ni (kt)	Co (kt)	Sc (kt)
Mulga Rock East – contained metal						
Princess	Indicated	0.9	1.6	0.6	0.3	0.07
Princess	Inferred	0.7	1.3	0.6	0.4	0.04
Ambassador	Indicated	4.4	17.5	7.8	3.3	0.4
Ambassador	Inferred	2.6	4.8	4.6	2.4	0.3
Total		**8.6**	**25.2**	**13.6**	**6.4**	**0.81**

1 Note that the base metal resource is contained wholly within the uranium resource. It is reported using the same cut-off grade of 200ppm U_3O_8 with no additional base metal or scandium grade cut-offs applied.

1.3 CONCEPTUAL HYDROGEOCHEMICAL SITE MODEL

The MRUP has regular geology across all deposits and consists of carbonaceous clastic sediments, associated with a paleochannel and its tributaries, containing accumulations of uranium and base metal. The carbonaceous lacustrine and estuarine sediments have been strongly oxidised to a depth of 25-45 metres with the uranium and base metals being enriched in horizontal zones just below the reduction-oxidation ("redox") boundary. The distribution of the enriched uranium, and other metals and metalloids, is strongly associated with the distribution of the organic-rich carbonaceous sediments, as the uranium is strongly bound to the organic matter through complex ion exchange and/or functional group assemblages (i.e. the positively charged uranyl ion binding with the negatively charged carboxylate anion: UO_2^{2+} + R-COO^- ; Douglas *et al.*, 1996). This organic-rich layer effectively acts as a Passive or Permeable Reactive Barrier (PRB) stripping uranium and other solutes from the groundwater as it passes through this material. The uranium mineralisation varies in thickness from 1.5m to 12m in MRW and up to 32m at MRE below the redox boundary. The ground water table is typically 2-5 metres below the redox boundary.

Strong density stratification exists with the palaeochannel aquifer, with TDS varying from around 60 – 70 g/L within the basal highly transmissive (i.e. 10 – 140 m/day) sands to 40 – 50 g/L within the central lower permeable (i.e. 0.2 – 9 m/day) portion of the paleovalley. Within the orebody the salinity varies from 25 – 35 g/L sodium chloride, with these predominately finer textured, organic rich sediments having a much reduced permeability of only 0.02 – 0.7 m/day.

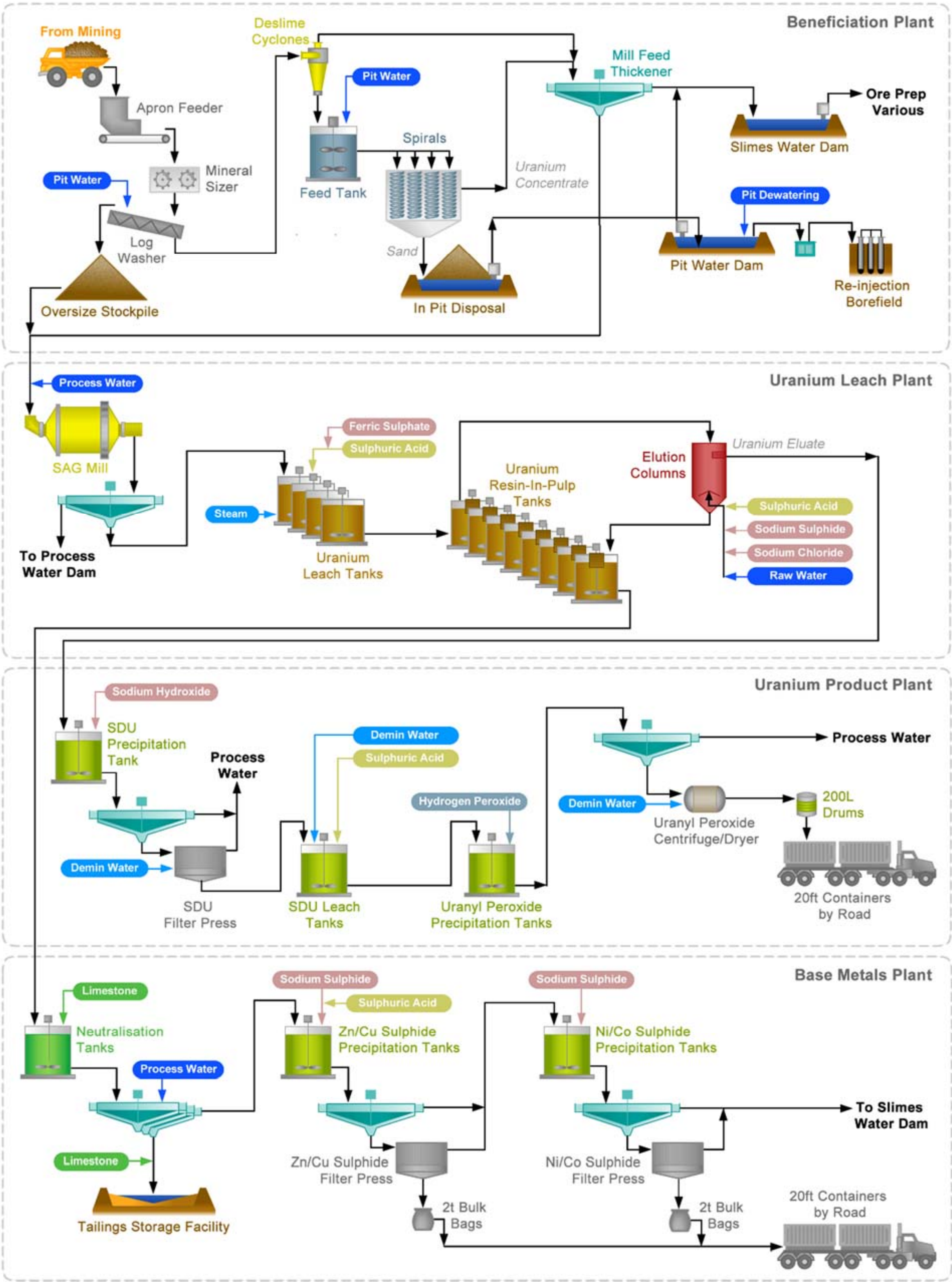

Figure 1.3: Illustration of MRUP proposed process flowsheet.

The reactivity of the sediment shows a strong decreasing trend with depth, coinciding with the reduction in organic matter from 10 – 50% C_{total} (Total Carbon) in the orebody to 0.5 – 2% within the basal sands.

Hydraulic gradients within the paleodrainage channel are very small (i.e. <0.001; Rockwater, 2015) and subsequently groundwater movement within and into or out of the aquifer is sluggish and inconsequential (i.e. it represents a very slow meandering oxbow section of the larger Ponton Creek palechannel located some 65 km to the south (Rockwater, 2015)

1.4 TAILINGS STORAGE FACILITIES (TSFS)

At the MRUP three TSFs are likely to be constructed and operated during the Life of Mine (LoM). The TSFs will consist of one above ground and two in-pit facilities located in the Princess and northern portion of the Ambassador East Deposit. A map showing the proposed location of the TSFs is provided in Figure 1.5. Details of the TSFs and their proposed operation are provided below:

Above-ground TSF

- Total footprint area: 106 ha
- Number of tailings cells: 2
- Tailings cell area: 41 ha each (53ha each including embankment walls)
- Life cycle: 3 years (18 months of initial deposition + 18 months of contingency storage)
- Annual production of dry tailings: 1,273,000 t
- Maximum height of tailings: 10 m
- Number of lifts: 1
- Deposition type: Subaqueous
- Deposition method: Perimeter spigots
- Solids content: 40%
- Decant: No
- Underdrainage system: Yes

In-pit TSF

- Total footprint area/tailings cell area: 237 ha (65 ha – Princess Pit; 172 ha Ambassador East
- Life cycle: ~8 years Princess TSF and ~8 years Ambassador East TSF
- Annual production of dry tailings: 1,273,000 t
- Maximum height of tailings material: approximately 30 m
- Deposition type: Subaqueous
- Deposition method: Perimeter spigots
- Solids content: 40%
- Decant: No
- Underdrainage system: Yes – base of TSF open to underlying aquifer to facilitate draining

Figure 1.4 shows a long section illustration of the of the in-pit tailings facilities at different phases of operation of the MRUP through to final site closure.

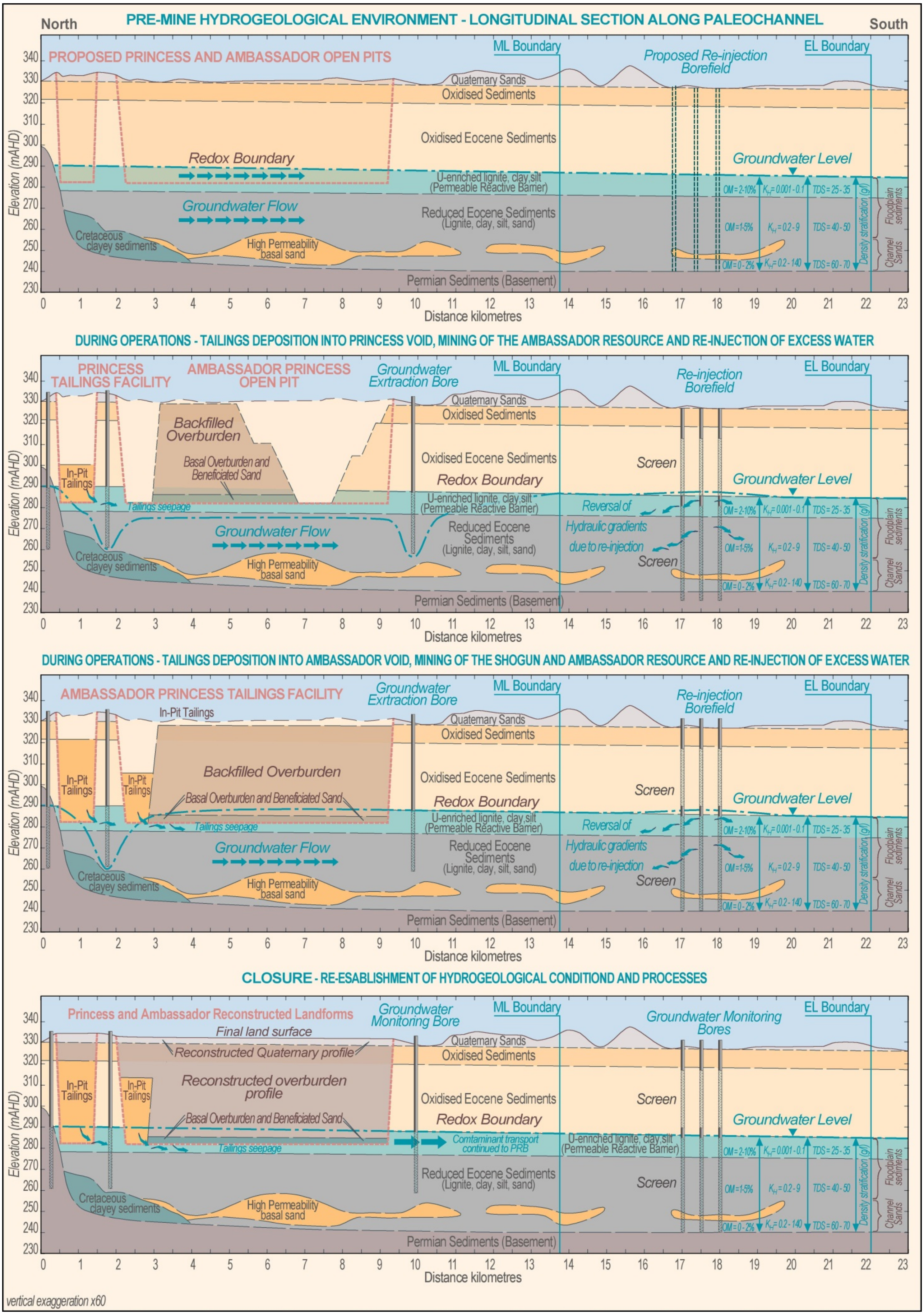

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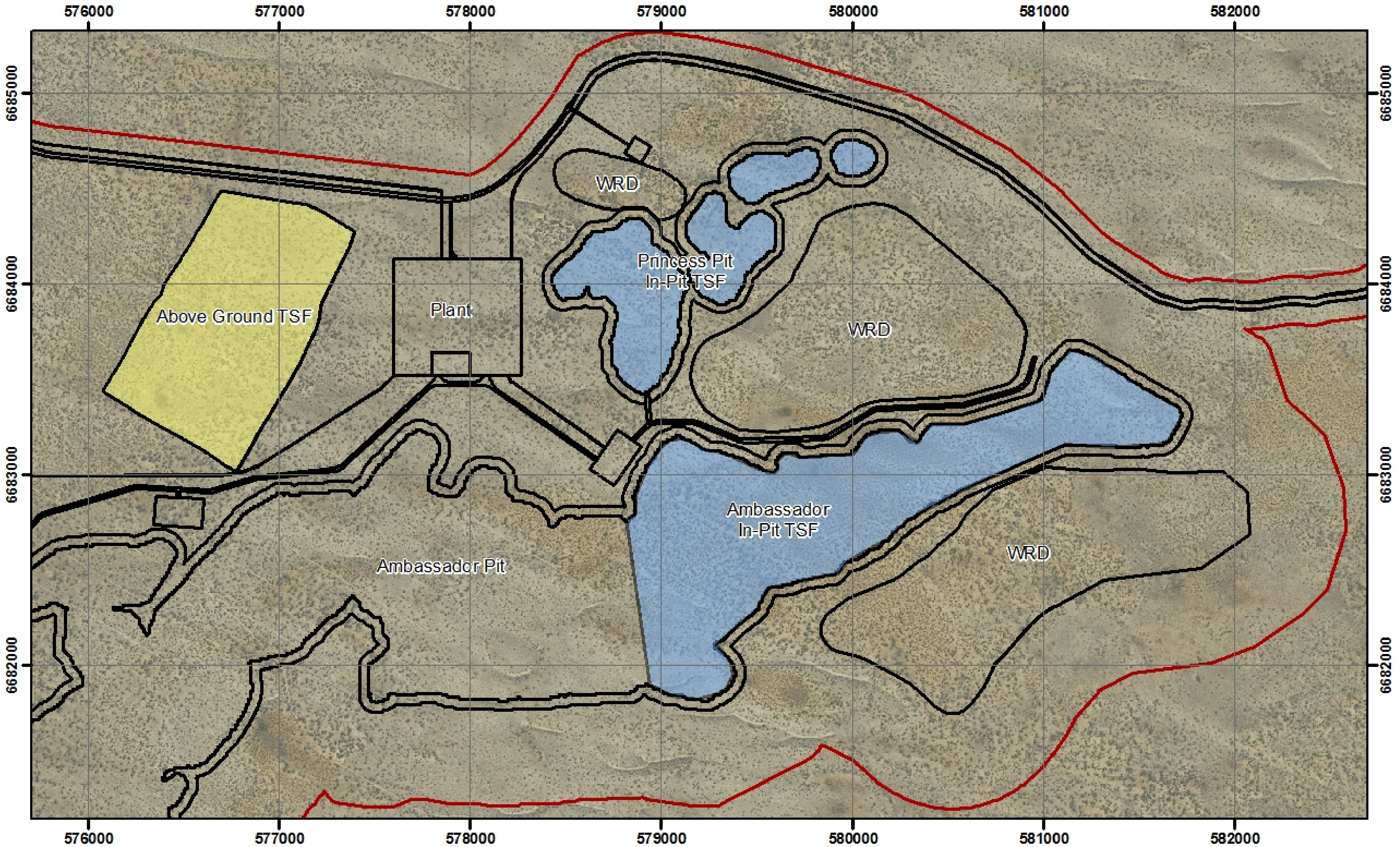
Figure 1.4: Conceptual hydrogeochemical site model for the MRUP



VIMY RESOURCES	Figure 1.5: Proposed location of the above-ground and in-pit TSFs at MRUP
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1.5 TAILINGS PHYSICOCHEMICAL AND HYDRAULIC PROPERTIES

The physicochemical and hydraulic properties of the tailings have been documented by SWC (2015). In summary, the tailings have a similar geochemical composition as the ore material, albeit lower in uranium and base metals, and have an appreciably higher fine (silt + clay) fraction, in response to both beneficiation, and removal of sand, and grinding to a target of P80 < 150 μm during processing. The report findings are summarised as follows:

- Tailings generated from the metallurgical plant will have a dominant clay texture and high carbon content (~40% total carbon) and thus it's permeability under both saturated and unsaturated conditions will be limiting to seepage;
- Metallurgical processing removes the majority of Co, Cu, Ni, Zn and U, with the remaining metals and metalloids being strongly bound to the mineral surfaces or within the crystal mineral structure, and thus not readily available for leaching.
- ASLP testwork showed that only Co, Cu, Mn, Ni, Pb and Zn had the potential to mobilise from the tailings, with all other solutes retained in or on the solid-phase.
- Tailings seepage will likely have a lower salinity than the receiving groundwater environment and therefore density stratification will ensure that any tailings seepage plume is forced through the carbonaceous PRB likely removing the excessive solutes and equilibrating the tailings water to that of the surrounding groundwater; hence the risk of impact from tailings seepage is considered small.
- The potential for the tailings to oxidise and generate Acid and Metalliferous Drainage (AMD) is limited by the following:
  - High Carbon content - tailings generated will likely contain around 40% Total Carbon, with the majority of this, given the pH of the tailings, to be organic C. Microbial decomposition of the organic material will result in a continual consumption of available oxygen favouring reducing (Eh) conditions below the approximate ~600-700 mV (SHE) needed to oxidise Ferrous (Fe^{2+}) to Ferric (Fe^{3+}), which has the potential to oxidise sulphides.
  - Inherent buffering capacity – although the pH of the tailings would suggest no readily available acid neutralisation capacity (ANC) is present (i.e. no carbonates present), microbial decomposition of the organic matter, under depleted oxygen and sulphur reducing conditions, will produce biogenic alkalinity which will assist in neutralising the released acidity.
  - Limited oxygen diffusion into clayey tailings at field capacity - the tailings are relatively clayey, and based on the fine particle size distribution are expected to have a high field capacity of around 30% (v/v), and a corresponding air-filled porosity of only 10% (v/v). Under these conditions the oxygen diffusion rate is expected to be low (< 8.0×10^{-7} m/s) and limiting to sulphide oxidation (i.e. to completely oxidise the 1.64% Total S, assuming it is all sulphidic, approximately 30 g of oxygen/kg of soil is needed). Based on the very oxygen diffusion rates at field capacity in the clayey tailings, insufficient oxygen will be available to fully oxidise the sulphides.
  - Low permeability of the tailings following draining – as shown by the predicted Hydraulic Conductivity Function (HCF) for the tailings the permeability of the tailings is expected to decrease sharply as the tailings consolidated and drains. At field capacity the permeability of the tailings is expected to be around 1.0×10^{-1} cm/d (equivalent to 1.1×10^{-8} m/s; Note: the DoW Clay Liner criteria is 1.0×10^{-9} m/s). Consequently, the transport and seepage of any oxidation reaction products (i.e. AMD) from the base of the TSF, once it is at field capacity, will be limited.
- Based on the above information the potential for the tailings to generate AMD is limited, and it is only over very long time scales (i.e. > 10,000 years), when the above protective mechanisms cease operating (i.e. when all of the

organic matter is consumed), that AMD is expected to occur; albeit the actual sulphide content of the tailings is relatively low.

2 MODELLING APPROACH

Modelling of the proposed seepage likely to be generated from both the above-ground and in-pit TSFs was undertaken using HYDRUS 2D/3D, which is considered best practice software for modelling variably saturated water flow as it explicitly solves the Richards' equation. Modelling of the TSFs was undertaken in the following two phases:

i. Operational phase of tailings deposition – in this phase (modelled period 10 years) tailings exists as a slurry with excess liquor (i.e. the tailings has not consolidated), resulting essentially in a large dam filled with water; and
ii. Consolidation or drying phase – in this phase all excess liquor has been removed, either by underdrainage, seepage or evaporation, and the tailings material consolidates or dries overtime resulting in less water being available for seepage (i.e. reduction in hydraulic heads) and lower permeability of the tailings restricting the movement of seepage.

2.1 MODEL SETUP

The model setup for the above-ground TSF and the in-pit TSF is shown in Figure 2.1. For the Operational Phase of tailings deposition, excess water conditions were achieved using a constant head upper boundary set at 0 kPa for a 10 year period. Using this approach positive pressure heads were maintained throughout the modelled period, with maximum head values of 5 – 10 m being exerted within the basal tailings profile. In order to prevent the model from crashing, due to rate limiting permeability, the tailings in the operational phase was assigned a 'Sand' texture with a very large saturated hydraulic conductivity of 5,000 cm/d, to maximise the volume of water with the TSF (overlying the clay liner) and ensure that downward movement of water, to the clay liner, was not limited by the material. For the consolidation phase, actual tailings texture data was used as this will strongly influence the release characteristics and permeability of the tailings as it drains to saturation and ultimately to field capacity.

For both models the free drainage boundary was set at the base of the Oxidised Eocene sediments, which is 40 m below the base of the above-ground TSF, and coincident with the base of the in-pit TSF (Figure 2.1). The location of this boundary also corresponds with the watertable, and therefore modelled free drainage will effectively equate to the volume of seepage that is likely to enter the groundwater system.

Seepage boundaries were positioned immediately above the clay liner in the above-ground TSF, to simulate an underdrainage system, and on the downstream side of the *in-situ* materials to prevent the build-up of hydraulic pressures along the model boundary.

All other boundaries were set as No Flux.

2.2 PARAMETERISATION

The hydraulic parameters of the tailings and the deeper overburden materials (i.e. Miocene and Oxidised Eocene) were not available at the time this investigation. Hydraulic parameters were therefore derived from the Rosetta Lite Hydraulic Estimation Software, built into the HYDRUS Package, based on (where available) measured physical properties, including particle size distribution and bulk density. The predicted hydraulic properties used for all modelled materials are provided in Table 2.1.

Table 2.1: Hydraulic properties of the materials modelled in this project

Material	Texture	θr (cm³/cm³)	θs (cm³/cm³)	α (1/cm)	n (-)	Ks (cm/day)
Tailings						
(i) Operational phase	Sand	0.001	0.43	0.145	2.68	5,000
(ii) Consolidation phase	Sandy Loam	0.078	0.43	0.036	1.56	24.96
Clay liner	Clay	0.0982	0.4588	0.015	1.2529	0.00864† 0.1‡
Calcrete	Silty Loam	0.0645	0.4387	0.0051	1.6626	18.26
Miocene sediments	Loamy Sand	0.0387	0.387	0.0267	1.4484	38.25
Oxidised Eocene sediment	Clayey Sand	0.1169	0.3854	0.0334	1.2067	11.35

Notes: †Equivalent to the DoW (2013) Clay Liner criteria of 10^{-9} m/s; ‡Higher permeability modelled (i.e. 10^{-8} m/s) to simulate a 'leaky' clay liner in the above-ground TSF.

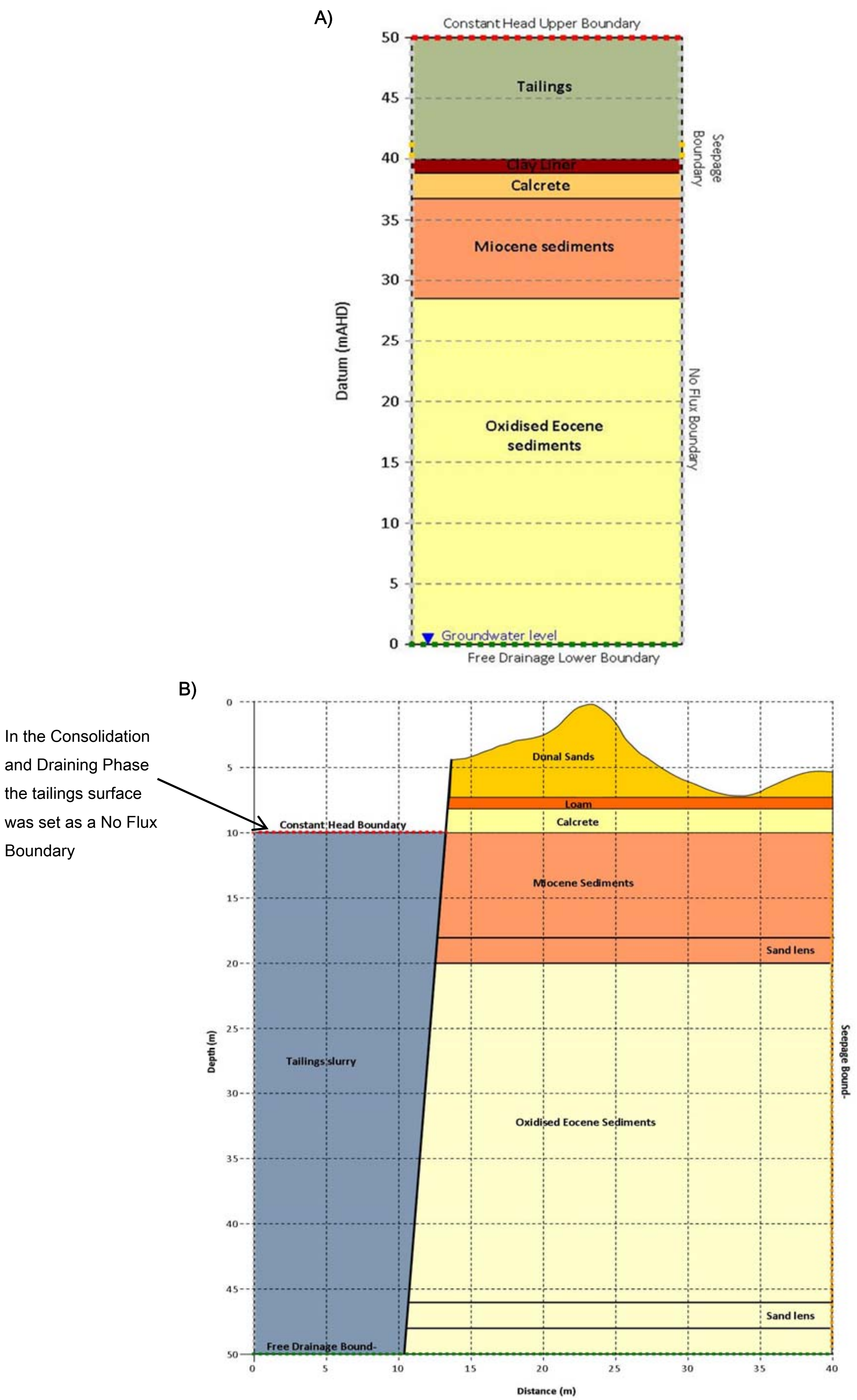
Based on the above hydraulic parameters, the derived Soil Water Characteristic Curve (SWCC) and Hydraulic Conductivity Function (HCF) for the materials modelled are presented Figure 2.2.

Preliminary physical and geotechnical testwork was conducted on several clay materials from the basal portion of the Oxidised Eocene to determine their suitability for use as a clay liner. The measured parameters of these clays are provided in Table 2.2, whilst the morphological properties of the basal clay layer are shown in Plate 2.1. Initial permeability testing shows that this material has a saturated hydraulic conductivity (Ksat) value of < 10^{-9} m/s, meeting the DoW (2013) seepage criteria for clay liners.

Table 2.2: Preliminary physical and geotechnical testwork on the basal kaolinitic clay zone

Parameter	NBS 0002	NBS 0005	NBS 0003	NBS 0008
Gravimetric Moisture (%)	27.15	40.20	36.57	35.56
Bulk Density (g/cm³)	1.68	1.50	1.44	1.46
Particle Density (g/cm³)	2.51	2.50	2.40	2.39
Total Porosity (%)	32.97	41.10	39.92	38.69
Air-Filled Porosity (AFP (%)	5.82	0.90	3.35	3.14
Liquid Limit	31.00	34.38	44.54	40.28
Plastic Limit	23.85	27.87	30.63	25.66
Plasticity Index	7.16	6.52	13.91	14.62
MBDD (g/cm³)	1.71	1.54	1.56	1.68
Optimal Moisture Content (%; g/g)	17.11	18.09	16.22	13.82
Ksat at 95% MBDD (m/s)	< 10^{-9}	< 10^{-9}	< 10^{-9}	< 10^{-9}

Plate 2.1: Deeper portion of the Oxidised Eocene sediment showing basal kaolinitic clay layer (Black Box) above the orebody at a depth of around 40 m



VIMY RESOURCES	Figure 2.1: Model setup for A) Above-ground TSF and B) In-pit TSF	soilwater GROUP
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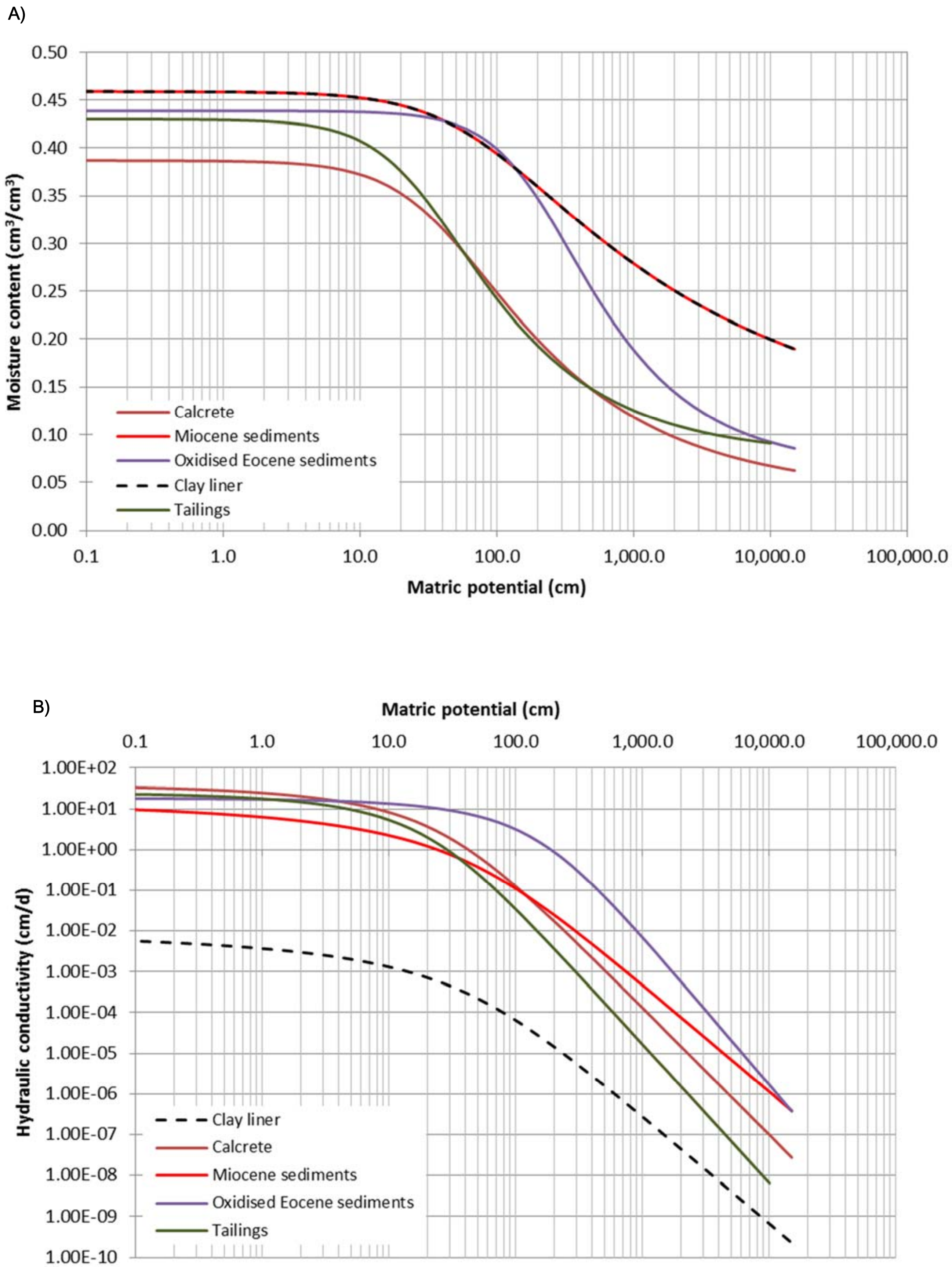
A)



VIMY RESOURCES	Figure 2.2: Predicted A) SWCC and B) HCF for the modelled materials	soilwater GROUP
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3 MODEL RESULTS

3.1 ABOVE-GROUND TSF

3.1.1 OPERATIONAL PHASE OF TSF

The Operational Phase of the above-ground TSF was modelled for a 10 year period (over three times longer than then actual life of the TSF). The cumulative drainage leaving the base of the modelled profile, and reaching the groundwater, is shown in Figure 3.1A. After 10 years only 27 cm of drainage to the underlying watertable occurs, which equates to a yearly average of 2.7 cm/year. This value is below the DoW (2013) allowable seepage through a clay liner which is 3.15 cm/year. The area of the active tailings cells in the TSF (Figure 1.5) is approximately 41 ha each cell, and thus the volume of deep drainage below the TSF, and reaching the groundwater at 40 m depth, equates to 22.1 ML (Note: at an allowable seepage rate of 10^{-9} m/s this volume of water equates to 26.2 ML). It is important to acknowledge that the aquifer system underlying the above-ground TSF has a thickness of approximately 10 m, and thus over the same active total cell area (i.e. 82 ha), and assuming a 50% porosity, the aquifer contains 41 GL of groundwater. The modelled seepage of only 22.1 ML/year therefore equates to < 0.5% of the total aquifer volume. Given this low volume of seepage reaching the groundwater, no observable change in groundwater quality will likely occur in response the Operational Phase of the above-ground TSF.

To model the case of a 'leaky' clay liner, the permeability of the modelled liner was increased by an order of magnitude to 0.1 cm/d (equivalent to 10^{-8} m/s). In this situation a total of 165 cm of deep drainage is expected, averaging 16.5 cm/year (Figure 3.1A). This seepage rate equates to a seepage volume of 135.3 ML/year, which is <1% of the aquifer volume underlying the TSF.

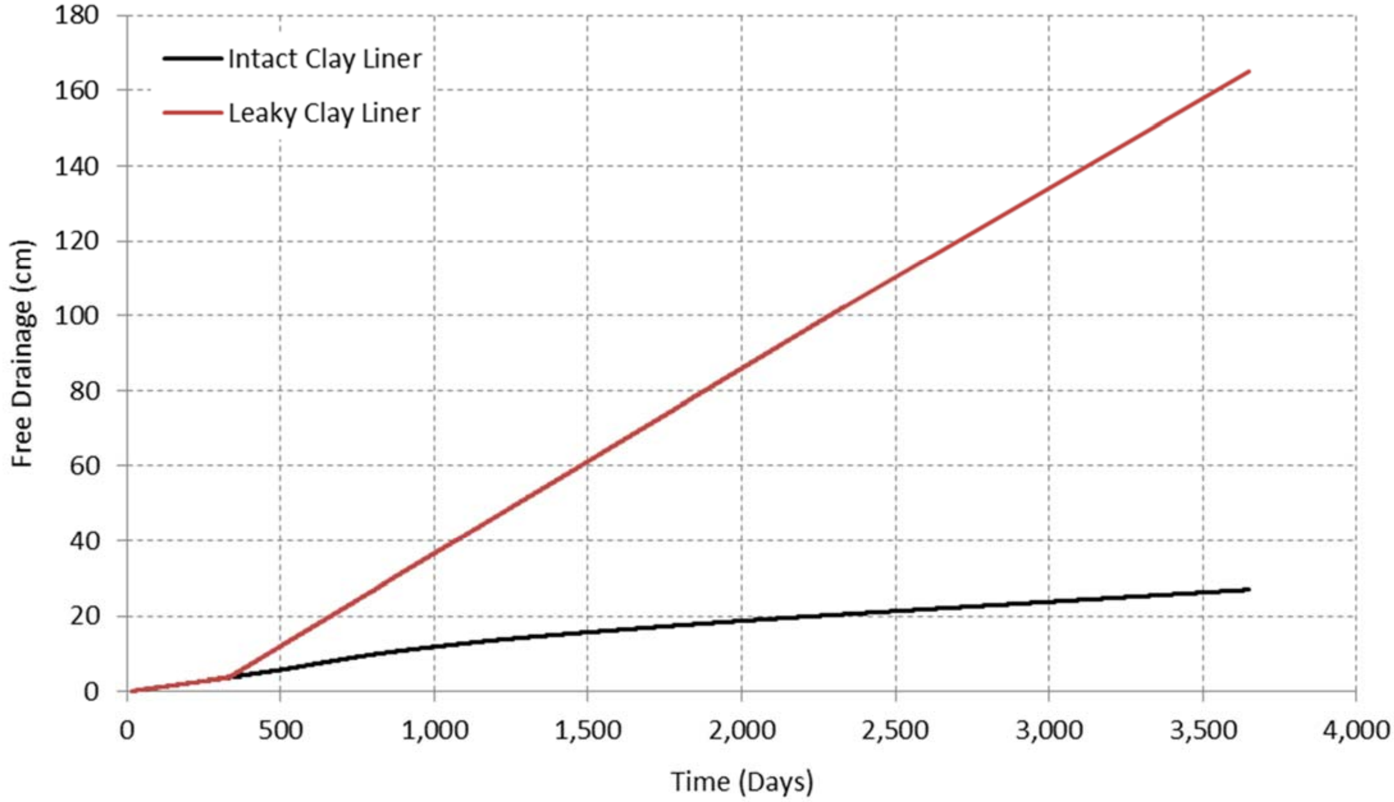
Modelled soil moisture profiles for the Operational Phase of the above ground TSF are provided in Figure 3.2.

3.1.2 CONSOLIDATION AND DRYING PHASE

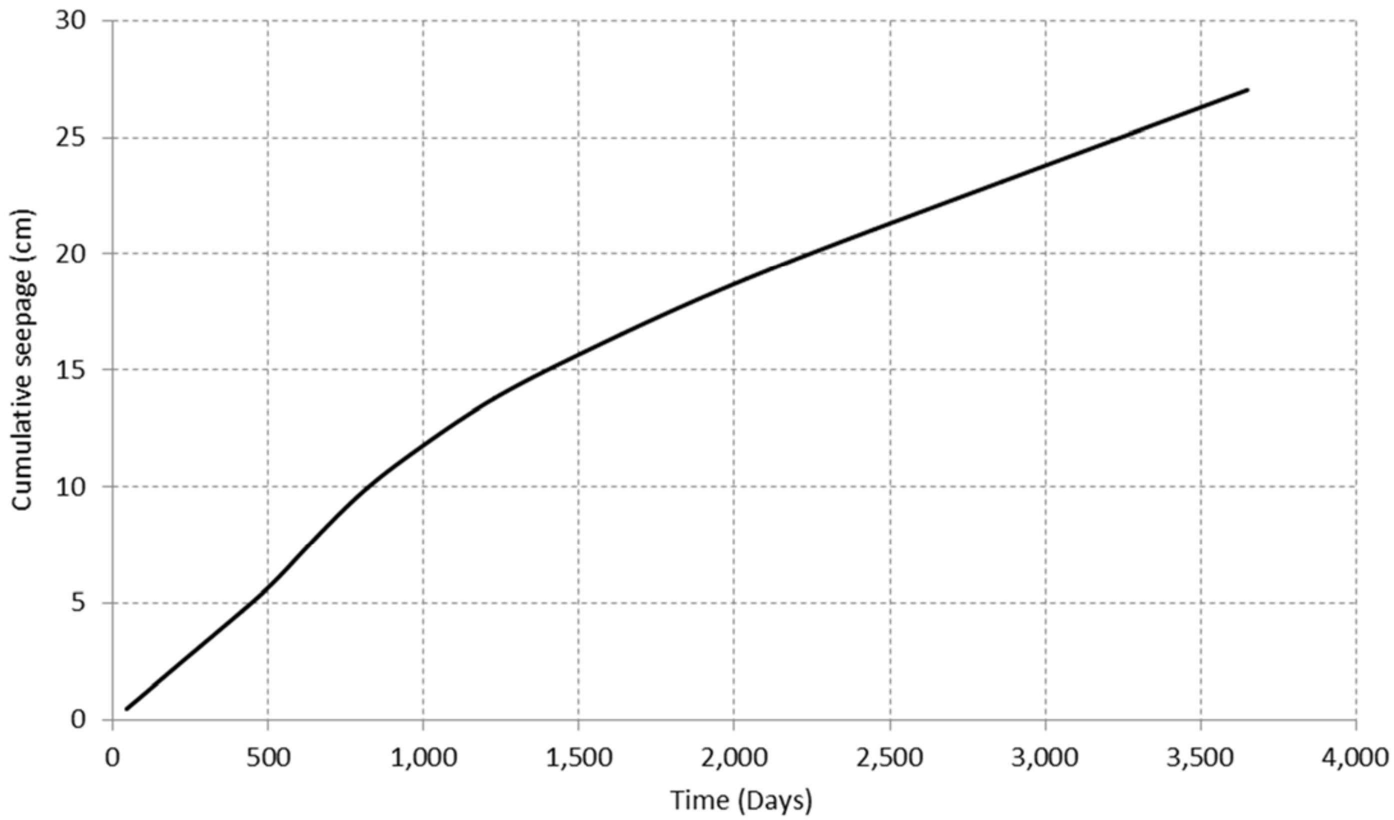
In the Consolidation and Drying Phase of the above-ground TSF all excess tailings liquor has been removed, either by underdrainage, evaporation or seepage, and thus the tailings material exists in a saturated state with a matric suction of 0 kPa (or -0.1 kPa for modelling purposes). Seepage from the tailings only occurs for 1,521 days (approximately 4.2 years) after which time the tailings have effectively drained to field capacity or beyond and thus minor further seepage will occur (Figure 3.1B). The continued seepage beyond 1,521 days, and to the modelled limit of 3,650 days, is due to the draining of the deep unsaturated soil profile. After 1,521 days a total of 16 cm of seepage has reached the watertable, equating to 131.2 ML of seepage from the active tailings cells (< 1% of the total aquifer volume underlying the TSF). After the tailings have drained, the seepage rate intercepting the water table drops to 1.8 cm/year, which is 14.8 ML/year or < 0.1% of the aquifer volume under the TSF.

Modelled soil moisture profiles for the Consolidation Phase of the above ground TSF are provided in Figure 3.3.

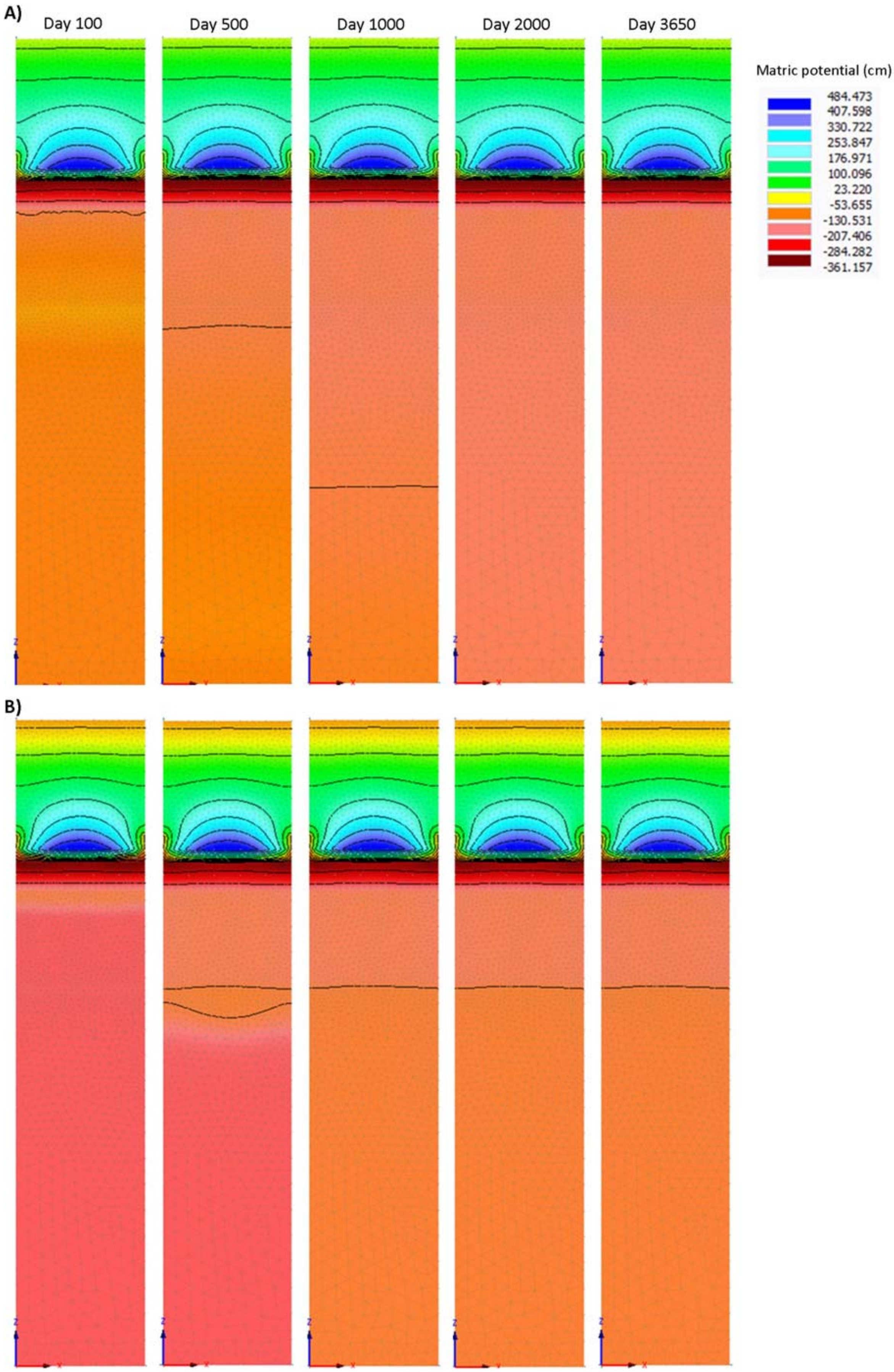
A)



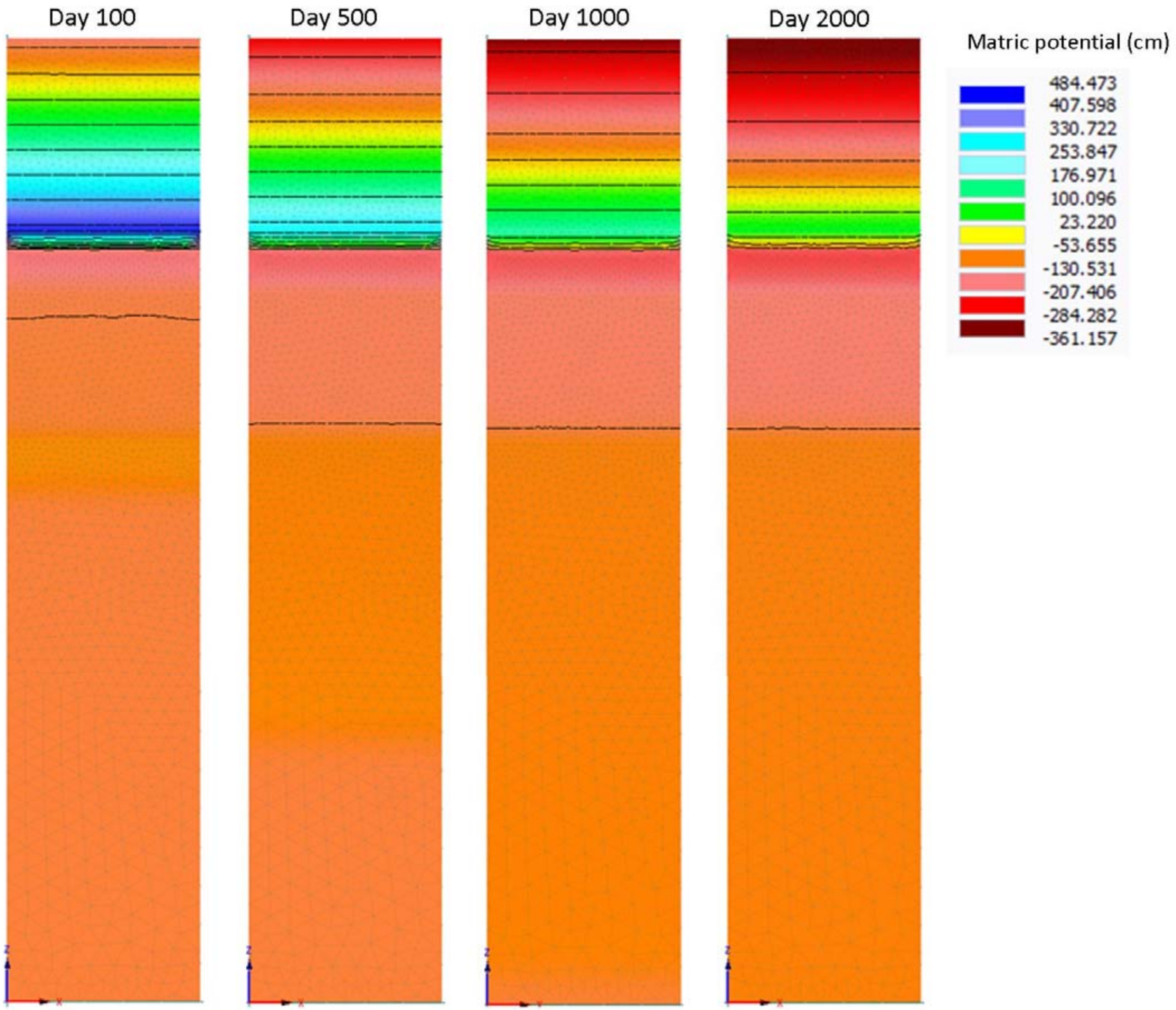
B)



VIMY RESOURCES	Figure 3.1: Predicted cumulative seepage during the A) Operational Phase and B) Consolidation Phase	soilwater GROUP
MULGA ROCK URANIUM PROJECT TAILINGS STORAGE FACILITY SEEPAGE ANALYSIS		



VIMY RESOURCES	Figure 3.2: Modelled soil moisture profiles for A) Intact clay liner and B) Leaky clay liner	soilwater GROUP
MULGA ROCK URANIUM PROJECT TAILINGS STORAGE FACILITY SEEPAGE ANALYSIS		



VIMY RESOURCES	Figure 3.3: Modelled soil moisture profiles for the above-ground TSF during the consolidation and draining phase
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soilwater GROUP

3.2 IN-PIT TSF

For the in-pit TSF, seepage to the watertable is expected and is required to consolidate and drain the tailings. The impact of this seepage on groundwater quality, and the fate and transport of the tailings plume within the paleodrainage channel, has been modelled by GHD (2015b). The GHD report concludes that negligible impacts on groundwater quality are expected and that solute concentrations are expected to remain within background concentrations over the long-term (i.e. 10,000 years). It is important to note that any seepage derived from the tailings will be appreciably less saline than the paleoaquifer (See Section 1.3; Figure 1.4) and thus density stratification will ensure that any tailings seepage is constrained to the upper portion of the groundwater, which due to the carbonaceous material acts like a Passive or Permeable Reactive Barrier (PRB) and a sink for most solutes contained within the seepage water.

Based on the above, the purpose of modelling the in-pit TSF was to ensure that lateral movement of tailings seepage was constrained to the TSF, and that no impact on the surrounding environment[1], and in particular the deep rooted vegetation, is likely to occur. The emphasis of this modelling was therefore on the lateral movement of tailings seepage into the side walls of the in-pit TSF and through the deep unsaturated sediments.

3.2.1 OPERATIONAL PHASE OF IN-PIT TSF

As described in Section 3.1.1, the tailings within the Operational Phase exists as a slurry with an initial solids content of 40%, which may increase to only 50 – 60% during active deposition. Consequently, the in-pit TSF is effectively a large 'bath tub' or dam containing tailings liquor. Representative modelled soil moisture profiles during the Operational Phase are provided in Figure 3.4.

The modelling predicts that tailings seepage will penetrate through the pit walls and extend slowly into the surrounding *in situ* unsaturated materials. After 4 years of tailings deposition the seepage is expected to extend a maximum distance of 10 m from pit wall, within the upper portion of the *in situ* profile (Figure 3.4). It can be seen that the infiltration of seepage occurs preferentially along the sand lens, wetting up the underlying upper Eocene sediments. Within the Miocene or 'Biologically Active Zone', infiltration only occurs approximately 2.5 m into the side wall of the in-pit TSF.

At depth penetration into the basal sand lens occurs to a distance of around 25 m from the pit wall, and this is expected given the high hydraulic (pore) pressures likely to be experienced in the basal portion of the TSF.

At 10 years after the commencement of tailings deposition the infiltration of the seepage will likely only extend to 20 – 30 m within the upper portion of the Oxidised Eocene (i.e. associated with the sand lens), whilst at depth the high pressure heads will likely force and cause the seepage to infiltrate over 40 m (and possibly to 100 m) into the side wall. Where sand lens are absence seepage into the side wall will only extend around 10 m from the TSF.

The limited lateral infiltration of seepage water into the side walls of the in-pit TSF is primarily due to the very low hydraulic conductivity of the *in situ* sediments in an unsaturated condition. As described in the HCF (Figure 2.2B) the permeability of the sediments, at field capacity (i.e. 100 cm matric suction) is around 0.1 cm/d (equivalent to 10^{-8} m/s). The permeability

[1] Observations of rooting profiles of native tree species shows that roots are constrained to the Quaternary and Miocene sediments, and do not extend beyond the the Miocene/Oxidised Eocene contact. The Quaternary and Miocene sediments are therefore coined the 'Biologically Active Zone'.

of the ‘dry’ or unsaturated sediments surrounding the TSF becomes rate limiting and subsequently ‘seals the side walls of the TSF prevent excessive lateral movement of seepage.

3.2.2 Consolidation and Drying Phase

Once the in-pit tailings has drainage sufficiently so that the majority of the excess tailings water has been removed either by seepage to the underlying aquifer or evaporation, the potential for lateral infiltration into the side walls of the TSF and through the *in situ* materials is diminished due to the rate limited permeability of the material in an unsaturated condition. Vertical seepage will therefore dominate and negligible lateral seepage will likely occur; as shown in Figure 3.5.

The moisture profile figures show that after one year (Day 365) the tailings has drained to field capacity (i.e. -100 cm matric potential) to around 15 m depth and just after 2.5 years (Day 1000) it has completely drained, with all tailings existing at field capacity. It must be noted that the upper tailings surface in this model was set to a No Flux and therefore no additional water inputs by rainfall or reduced water losses by surface crusting, in response to evaporation, will occur. By setting the upper tailings surface to an Atmospheric Boundary the tailings material will likely hold more water (i.e. at suctions < 100 cm; field capacity) for a longer period of time than identified in this investigation. Recent drilling work undertaken by SWC in several legacy gold mine TSFs has shown that the tailings at depths of > 5 m generally retain appreciable moisture, at levels above field capacity; hence moisture levels to -40 cm matric potential can be expected to remain in the MRUP in-pit TSF for considerably longer than modelled in this investigation (i.e.10 – 20 years). Although this is the case, the low permeability of the surrounding ‘drier’ *in situ* materials will still limit lateral seepage and vertical seepage will remain dominant over the life of the in-pit TSF.

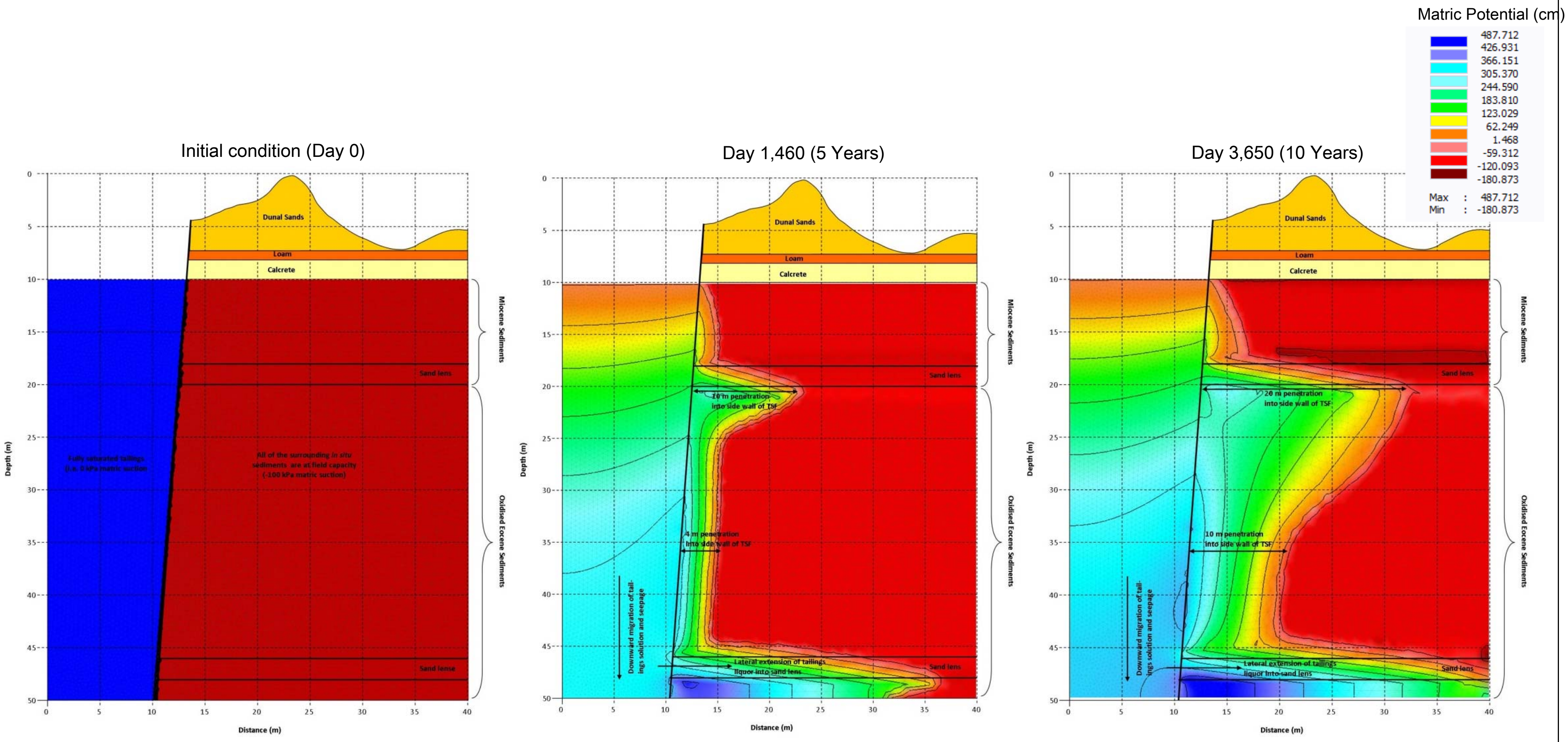

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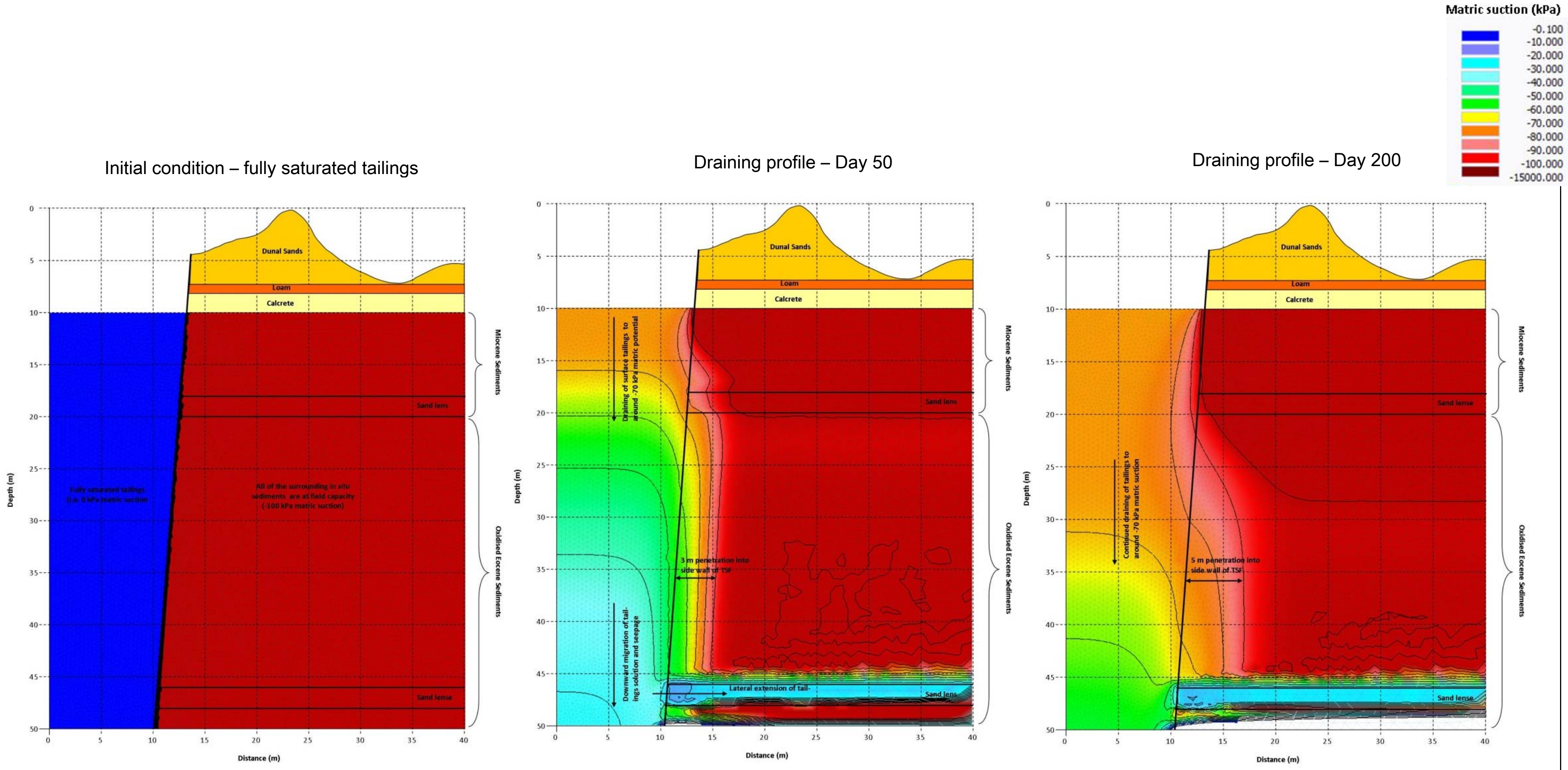
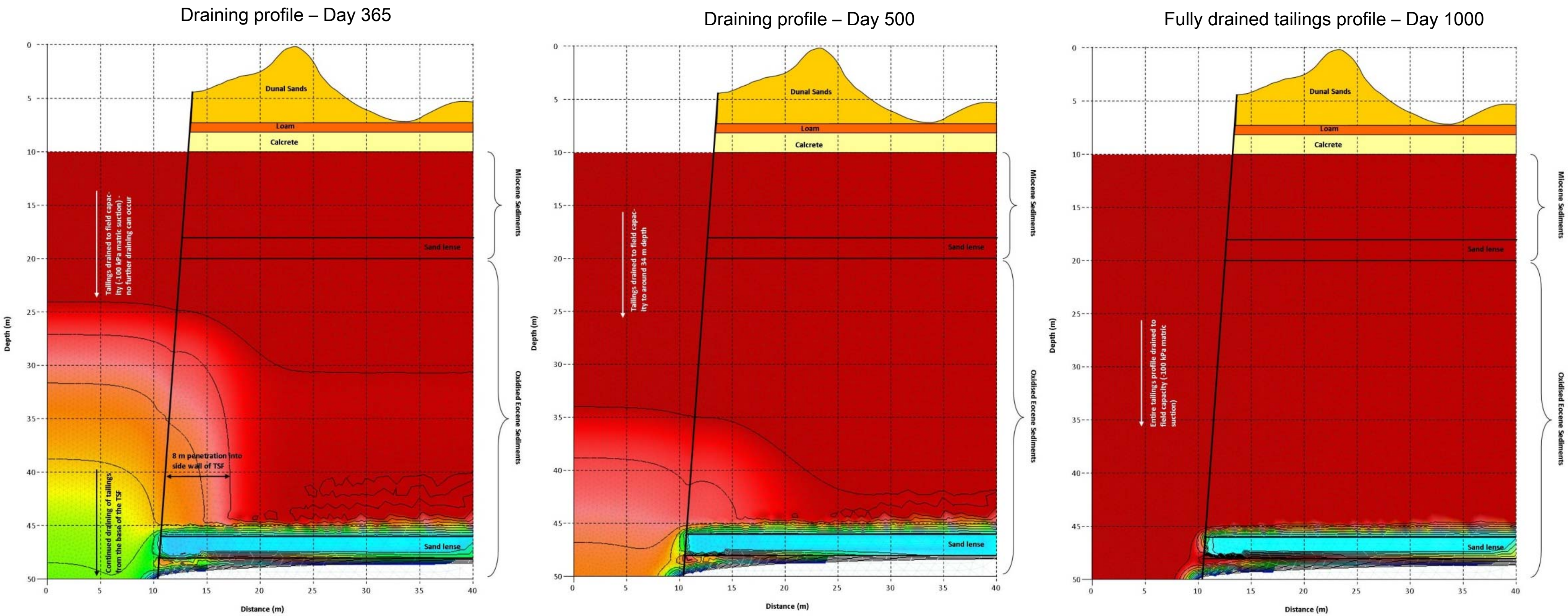
Figure 3.4: Modelled soil moisture profiles for the in-pit TSF over a 10 year active deposition period

soilwater GROUP



VIMY RESOURCES	Figure 3.5: Modelled soil moisture profiles for the in-pit TSF over a 10 year consolidation and draining phase	soilwater GROUP
MULGA ROCK URANIUM PROJECT TAILINGS STORAGE FACILITY SEEPAGE ANALYSIS		



VIMY RESOURCES	*Figure 3.5 continued…*	soilwater GROUP
MULGA ROCK URANIUM PROJECT TAILINGS STORAGE FACILITY SEEPAGE ANALYSIS		

4 CONCLUSIONS AND RECOMMENDATIONS

Based on the seepage analysis results obtained in this investigation, the potential risks of the above-ground and in-pit TSF to the surrounding environment are considered low, and no adverse environmental impacts are expected to occur in response their operation or post-closure development. The results show that the potential for lateral seepage of tailings liquor into the surrounding unsaturated sediments is small due to their very low permeability at moisture levels at or approaching field capacity (i.e. the *in situ* soils have an existing inherent permeability that approaches the clay liner criteria set by the DoW, 2013). Vertical movement of seepage is therefore the dominant process, and the extent of lateral seepage into the 'Biologically Active Zone' (i.e. the rooting zone of the native vegetation) is restricted to within 5 m of the in-pit TSF walls.

Seepage below the proposed above-ground TSF will likely occur and seepage water is expected to reach the underlying watertable overtime. Model results predict that the quantity of seepage water intersecting the watertable is likely to be around 2.7 cm/year, which equates to <0.5% of the total aquifer volume beneath the above-ground TSF. Any tailings seepage entering the aquifer system is not expected to impact on the quality of the aquifer, as their properties are similar (SWC, 2015). Table 4.1 shows a comparison of existing groundwater and tailings ASLP test leachates. These results show negligible impact on the ground water beneath or downstream of the surface TSF.

It is important to note that the expected tailings seepage will be less saline than the receiving groundwater system and thus density stratification will constrain the seepage to the upper carbonaceous material which acts as a Passive or Permeable Reactive Barrier (PRB) filtering solutes from the aquifer. This is currently evident by the underlying sediments to the main orebody containing elevated levels of uranium and radionuclides pointing to ongoing fixation by the organic matter. Based on this process, solute and transport modelling undertaken by GHD (2015), clearly identifies that no change in groundwater quality above background concentrations occurs in response to tailings seepage.

Table 4.1: Composition of groundwater underlying the above-ground TSF and expected tailings seepage (SWC, 2015)

Analyte	Groundwater (Site)		Tailings Seepage (ASLP)
	Average	Maximum	Average
pH	4.91	8.05	4 - 4.5
TDS (mg/L)	41846	146900	16850
ORP_Field	100	335	336.5
Cl (mg/L)	23945	75620	2950
F (mg/L)	0.5	0.8	1.85
Al (mg/L)	0.9	2	6
As (mg/L)	0.03	0.03	<0.10
Ba (mg/L)	0.045	0.155	0.05
Be (mg/L)	0.013	0.02	<0.01
Ca (mg/L)	483	1185	9
Cd (mg/L)	0.034	0.319	0.195
Co (mg/L)	0.47	4.00	2.1
Cr (mg/L)	0.015	0.077	0.075
Cu (mg/L)	0.372	2.800	4.6

Analyte	Groundwater (Site)		Tailings Seepage (ASLP)
	Average	Maximum	Average
Fe (mg/L)	17	190	8.5
K (mg/L)	362	935	0.5
Mg (mg/L)	1368	3995	6.5
Mn (mg/L)	0.94	3.10	0.09
Mo (mg/L)	0.018	0.035	<0.01
Na (mg/L)	14098	45000	87
Ni (mg/L)	0.29	3.80	6.30
Pb (mg/L)	0.15	3.10	7.25
Sb (mg/L)	0.010	0.015	<0.02
Se (mg/L)	0.039	0.100	<0.1
Si (mg/L)	16	53	<0.01
Sr (mg/L)	6.62	11.80	<0.01
Th (mg/L)	1.00	10.00	<0.01
Tl (mg/L)	0.0005	0.0005	0.23
U (mg/L)	0.02	0.068	0.08
V (mg/L)	0.005	0.009	0.19
Zn (mg/L)	0.96	13.00	7.10

It is important to reiterate that at no point, during the operational or consolidation phases, does the unsaturated soil profile underlying the above-ground TSF approach saturation; hence limiting the application of seepage recovery bores to capture the tailings plume (i.e. seepage recovery bores can only operate when the underlying materials are saturated). As can be seen in Figure 3.2 and Figure 3.3, moisture levels only exceed field capacity by a small margin (i.e. filling of the mesopores; 30 – 75 µm diameter), which results in the observed seepage. The unsaturated zone hydraulic conductivity of the *in situ* materials at field capacity is around 0.1 cm/d (10^{-8} m/s), and thus this provides an upper limit to the extent and volume of seepage that may intersect the underlying groundwater system.

The tailings cell design and predicted seepage from the TSF will not impact surface vegetation.

4.1 RECOMMENDATIONS

The seepage modelling undertaken in this study is highly conservative as it does not take into account the consolidation behaviour of the tailings, it assumes hydraulic parameters likely higher than actually exist, and does not factor in structural barriers occurring within the sedimentary profile which will impede seepage movement. Consequently, the modelling was performed under ‘wetter’ conditions (i.e. considerably more water draining from the TSFs) and higher flow rates, likely resulting in an overestimate of the seepage that is to be expected. To obtain better estimates of seepage rates for both the above-ground and in-pit TSFs, the following is recommended:

- Investigate methods to maximise the settling performance and consolidation of the tailings as this will:
  - Remove excess water contained within the TSFs and therefore reduce the overall volume of tailings liquor available for seepage;
  - Reduce the overall permeability of the tailings, according to the HCF, and

  - Maximise the capacity of the TSFs, therefore reducing their overall size and limit the magnitude of potential seepage,
- Quantify the hydraulic parameters of the tailings during and after consolidation, and of the surrounding *in situ* sediments as this will better constrain the rate of seepage movement through these materials.
- Incorporate structural features of the surrounding *in situ* sediments (i.e. hardpan layers) to more accurately predict seepage away from the TSFs.

Although the above recommendations are made, given the conservative nature of this study, they are unlikely to alter the accuracy of the overall findings of this report.

5 REFERENCES

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