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Alexander Project

Alexander Shaft Waste Rock Dump Design

SLR Project No.: 750.01080.00007

Report No.: Doc. no.01

Revision No. 0

July 2016

Anglo American Inyosi Coal (Pty) Ltd

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ALEXANDER SHAFT WASTE ROCK DUMP DESIGN

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ACRONYMS AND ABBREVIATIONS

Below a list of acronyms and abbreviations used in this report.

Acronyms / Abbreviations	**Definition**
DDF	Depth – duration - frequency
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
GN R. 632	Government Notice, Regulation 632
LCT	Leachable Concentration Threshold
MAP	Mean Annual Precipitation
MPRDA	Mineral and Petroleum Resource Development Act
PCD	Pollution Control Dam
S - Pan	Symonds Pan
TCT	Total Concentration Threshold
WRD	Waste Rock Dump

ALEXANDER SHAFT WASTE ROCK DUMP DESIGN

1 INTRODUCTION

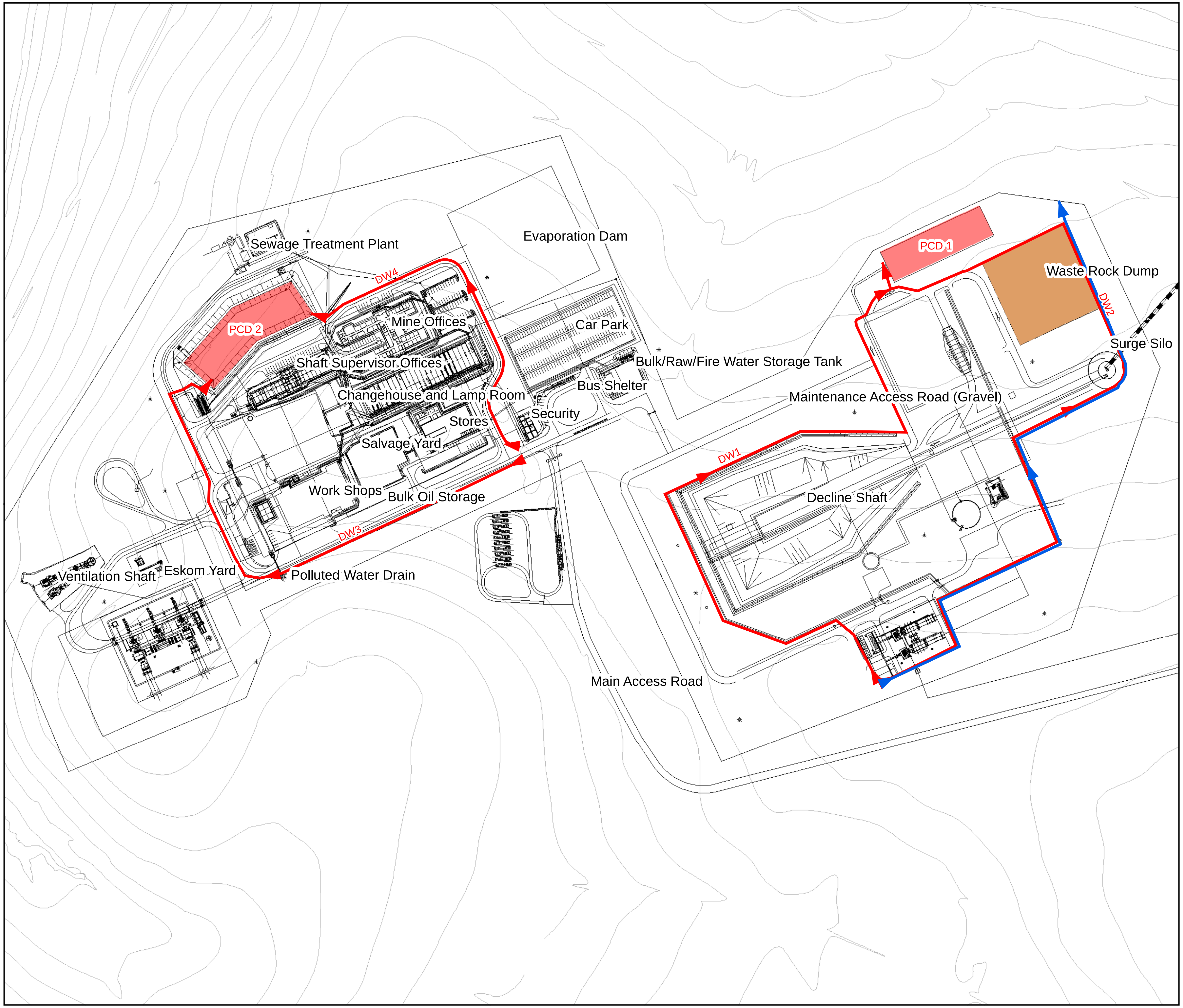
A Mining Right Application in terms of the Mineral and Petroleum Resource Development Act, 2002 (MPRDA, Act No. 28 of 2002), as amended has been lodged to secure the Alexander mining right.

As part of obtaining the Mining Right it is necessary to apply for a Waste Management Licence under the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008) for the proposed waste rock dump (WRD). Approximately 11 300 m^3 of overburden material will be removed when sinking the mineshafts (decline and vertical), with bulking this will result in around 20 000 m^3 of waste rock to be stockpiled adjacent to the shaft, which at closure will be used to backfill the shaft. For the location of the WRD in the Alexander Shaft complex see Figure 1.

In applying for a Waste Management Licence for the WRD the requirements of the following regulations need to be satisfied:

- Regulations Regarding the Planning and Management of Residue Stockpiles and Residue Deposits from a Prospecting, Mining, Exploration or Production Operation, 2015 (GN R.632)
- Waste Classification and Management Regulations, 2013 (GN R.634)
- National Norms and Standards for the Assessment of Waste for Landfill Disposal, 2013 (GN R. 635)
- National Norms and Standards for Disposal of Waste to Landfill, 2013 (GN R.636)

This report demonstrates how, by taking a risk based approach, the design of the WRD will comply with these regulations.



Legend

- Clean Stormwater Channels
- Dirty Stormwater Channels
- Pollution Control Dam (PCD)
- Waste Rock Dump (WRD)
- Shaft Complex
- Conveyor Route
- 1m Contours

0 50 100 200

Meters

Projection: Transverse Mercator
Datum: Cape, LO29

Anglo American Inyosi Coal (Pty) Ltd

Figure 1

Alexander Project Shaft Complex Layout

SLR

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2 DESIGN INFORMATION

2.1 SITE SELECTION

The WRD is to be located within the Alexander shaft complex boundary. The selection of the Alexander shaft location is described Section 7 of the EIA/EMP report. The location has been assessed against the following criteria.

- Minimize overburden and optimise the mine access point
- As coal will be transported to the existing processing site by conveyor, limiting the length of the conveyor was an important criteria
- Access to the shaft location
- Impact on surface water resources including wetlands and water courses
- The ground water regime
- Soils and land use / productivity
- Impact on sensitive flora and fauna

The location of the WRD within the shaft complex was selected based on the following criteria.

- Proximity to the shaft entrance to minimize haulage distances
- Outside of any zone of influence affecting the shaft entrance cut slope stability
- Up gradient of the shaft complex pollution control dam (PCD), such that any dirty water can easily be directed to the PCD.

The selected location of the WRD is shown on Figure 1.

2.2 WASTE ROCK PROPERTIES

The likely waste rock properties have been inferred from information on similar coal mining operations in the region.

2.2.1 WASTE ROCK PHYSICAL PROPERTIES

Waste rock will be generated as a result of the sinking of the Alexander mine shaft. The shaft will be sunk approximately 68 m below ground level at an angle of 13 degrees, resulting in a total length of 300 m. This will require approximately 11 300 m^3 of overburden material to be removed and stockpiled at the site. The geological units typical of the area, through which the shaft is likely to pass, are as follows.

- Soft overburden (transported residual soils – clays and silts)
- Sandstone and silt stone (non to slightly carbonaceous)
- Carbonaceous lithological units (siltstone and shale)
- Coal seams

In sinking the shaft, softer material will be excavated while harder material will need to be blasted before excavation. Selective mining will be undertaken, whereby carbonaceous material is to be separated from the waste rock and transported to the Goedehoop processing plant. The remaining overburden will be transported to the waste rock dump by dumpers and end tipped.

From geotechnical studies carried out at the Kriel and Elders Collieries the following general soil properties are anticipated to occur at the Alexander site:

- The surface soils will typically be 5 metres thick and comprise of transported residual soils. These soils can be described as clayey silty sands with the residual soils being either completely weathered sandstones or shales. Depending on the topographic and location of wetlands the following soils types are expected be encountered, clayey sand, clay of intermediate plasticity, and clayey silts.
- Below the surface soils it is anticipated to find sandstone with inter-bedded siltstone, which will be partially weathered.

Typical properties of the expected waste rock materials are given in Table 1 below.

TABLE 1: TYPICAL WASTE ROCK PROPERTIES

Rock Type	Density (kg/m^3)	Friction Angle (Degrees)
Sandstone	2 000 – 2 300	35
Shale	1 900 – 2 200	35

2.2.2 WASTE ROCK GEOCHEMICAL CLASSIFICATION

The report 'Alexander Coal Project, Preliminary Geochemical Assessment, 2016' discusses the likely geochemical properties of the waste rock without the availability of site specific geochemical information. In terms of GN R.634 this report gives the following guidance on the waste type classification.

"It is unlikely that the overburden will be a Type 4 waste, as it is unlikely for both leachable concentrations and total concentrations of all elements to be below the relevant threshold limits (LCT0 and TCT0). It is also unlikely that overburden will be a Type 0 waste, as it is unlikely that leachable concentrations will be above the LCT3 or total concentrations will be above the TCT2."

2.3 SITE GEOTECHNICAL RISKS

The following geotechnical risks are associated with the soils in the region.

- Collapsible soils may occur with an associated risk of differential settlement. The transported and possibly the residual soils may exhibit a collapsible grain structure. This occurs in any open textured silty or sandy soil, with a high void ratio (low dry density, i.e. <1500kg/m^3), and a relatively high shear strength at a low moisture content, due to colloidal or other coatings around individual grains. This is common in transported soils and in areas where quartz rich rocks (i.e. granite or felspathic sandstone) have undergone chemical weathering to produce intensely leached residual soils. Collapse settlement will not occur in soils with a collapsible grain structure below the water table.

- Expansive clays may also occur, causing foundation damage due to continual heave and shrinkage. Soils in which variations in moisture content result in volumetric change, i.e. swell or shrinkage of the soil skeleton are defined as expansive soils. These soils are expected to occur near wetlands and rivers. These soils are the most commonly occurring of the problematic soils in Southern Africa

If the soils are found to be collapsible these soils are to be removed or re-engineered by rip and re-compaction beneath starter embankments. Expansive clays found beneath heavy loads are to be removed and suitable material (such as G5/6) is to be placed in engineered layers, and compacted to specification.

2.4 CLIMATE

2.4.1 REGIONAL CLIMATE

The proposed Alexander Project is located in the Mpumalanga Highveld region where the climate is characterised as generally dry. Summers are warm to hot with an average daily high temperature of approximately 27˚C (with occasional extremes up to 35˚C). Winters are mild to cold with an average daily high of approximately 15˚C (with occasional extreme minima as low as -10˚C). Frost and mist are frequently experienced during the winter months on the Mpumalanga Highveld.

The majority of precipitation is experienced during the summer months, mostly in the form of afternoon thundershowers. Mean annual precipitation (MAP) is 707 mm, with 85% of the annual rainfall occurring between October and March. Mean annual evaporation (MAE) in the region is approximately 1600 mm.

2.4.2 RAINFALL

The South African Weather Service rain gauge 0478292_W (Langsloot) is used for the site surface water study, 'Alexander Project, Surface Water Study for the EIA, 2016'. The gauge is 17.7 km form the site, at an elevation of 1 580 mamsl, and has a 78 year record length. Average monthly rainfall depths for the rainfall record are given in Table 2.

TABLE 2: AVERAGE MONTHLY RAINFALL (GAUGE 0478292_W - LANGSLOOT)

Month	Average Rainfall (mm)
January	119.4
February	86.9
March	76.9
April	37.2
May	19.5
June	6.5
July	5.6
August	9.3
September	21.1
October	75.2
November	106.9
December	108.4
Total	**673.0**

The storm rainfall depth – duration - frequency (DDF) curves, as presented in the surface water study, are given in Table 3 below.

2.4.3 EVAPORATION

Evaporation data is based on records from Rietfontein (B1E004) Symonds Pan having 23 years (1981 – 2003) of monthly records were available. A pan coefficient is used to convert S-pan evaporation to evaporation from open water such as a dam or pond, as presented in Table 4 below.

TABLE 3: STORM DEPTH-DURATION-FREQUENCY CURVES FOR PROJECT SITE

Duration	Rainfall Depth (mm)						
	1:2 year	1:5 year	1:10 year	1:20 year	1:50 year	1:100 year	1:200 year
5 minutes	9	12.1	14.3	16.6	19.7	22.2	24.9
10 minutes	13	17.4	20.6	23.9	28.4	32	35.8
15 minutes	16.1	21.6	25.5	29.5	35.1	39.5	44.2
30 minutes	20.6	27.7	32.7	37.9	45	50.7	56.7
45 minutes	23.9	32	37.8	43.8	52	58.7	65.6
1 hour	26.5	35.5	42	48.6	57.7	65	72.8
1.5 hours	30.6	41.1	48.5	56.2	66.8	75.2	84.2
2 hours	33.9	45.6	53.8	62.3	74	83.4	93.3
4 hours	40.7	54.7	64.6	74.8	88.9	100.1	112
6 hours	45.3	60.8	71.9	83.2	98.9	111.4	124.7
8 hours	48.9	65.6	77.5	89.8	106.7	120.2	134.5
10 hours	51.9	69.6	82.2	95.2	113.1	127.5	142.6
12 hours	54.4	73	86.3	99.9	118.7	133.7	149.6
16 hours	58.7	78.8	93.1	107.7	128	144.3	161.4
20 hours	62.3	83.5	98.7	114.3	135.8	153	171.2
24 hours	65.3	87.7	103.6	119.9	142.4	160.5	179.6

TABLE 4: MONTHLY AVERAGE EVAPORATION (GAUGE B1E004 – RIETFONTEIN)

Month	S-Pan Evaporation (mm)	Pan Coefficient1	Open Water Evaporation (mm)
January	201.9	0.84	169.6
February	171.9	0.88	151.3
March	157.9	0.88	139.0
April	129.9	0.88	114.3
May	114.3	0.87	99.5
June	91.0	0.85	77.3
July	103.1	0.83	85.6
August	132.6	0.81	107.4
September	173.9	0.81	140.8
October	192.2	0.81	155.6
November	192.0	0.82	157.4
December	194.6	0.83	161.5
Total	**1855.3**	**N/A**	**1559.4**

3 WASTE ROCK DUMP DESIGN

3.1 OPERATION OF WRD

The WRD will be formed over a period of approximately two years, during the sinking of the Alexander mine shafts, and will remain in place for the 35 - year life of mine. Topsoil cross the footprint of the WRD will be stockpiled along with top soil stripped from the rest of the shaft complex. At mine closure the overburden material stockpiled in the WRD will be used to backfill the shafts. The WRD footprint will be cleared of any waste rock and infrastructure before the topsoil is replaced and re-vegetated.

3.2 WRD GEOMETRY

Considering the typical grading curve of the extracted overburden material, and its associated void ratio, a bulking factor of 1.77 has been assumed. Assuming minimal compaction occurs in the placement of the overburden material, it can then be estimated that 11 300 m^3 of in situ material take up a volume of 20 000 m^3 in the WRD.

The following constraints were considered in defining the geometry of the WRD.

- Minimize the WRD footprint area to:
    - limit the area of land impacted,
    - and to minimize rainfall infiltration volumes.
- An adequate area for dumpers to operate on the top of the WRD at its full height.
- Side slopes to be at a slack enough gradient for dumpers to drive up during construction, as well as to allow the placement of a soil cover.
- Height of WRD to be minimized to:
    - limit loading on foundation soils,
    - and to minimize the length of the side slopes so as to limit storm water runoff velocities and therefore erosion potential.

By limiting the height of the WRD to 5 m and the side slope gradient to 1v:4h, results in a footprint area of 6 889 m^2 (83 m by 83 m square).

3.3 SLOPE STABILITY

Due to the WRD's low height, and the proposed 1v:4h side slope gradients, slope stability is not envisioned to pose a design challenge. At the detailed design stage a slope stability analysis will be undertaken to demonstrate a minimum factor of safety of 1.5 is achieved, as required by the GN R.632. This analysis will take account of;

- findings of a site geotechnical investigation,
- sampled waste rock properties and,

- any proposed containment barrier design.

3.4 INFILTRATION AND SEEPAGE

Rainfall infiltration and seepage rates are important to understand, as any contaminants that may be present in the waste rock can only be mobilized by the movement of water through the waste rock matrix. A modelling exercise was undertaken to understand both seepage rates into the ground beneath the WRD and that decanting from any underdrainage system, being described in detail under Appendix A. The modelling was undertaken for a WRD having both no cover as well as a soil cover, and for a range of containment barrier permeabilities (Scenarios A to F).

The parameters used in modelling the WRD are as follows.

- WRD Area of 0.69 ha
- Waste Rock void ratio of 39% (homogenous well-graded gravel)
- The WRD is taken to be located on a 1v:70h slope
- The WRD is schematised in plan, as a segment (1/3) of a circle, with the horizontal seepage face being the associated arc
- The WRD is taken to have a 300mm thick clay containment barrier (liner)
- The model was run with the 78-year historic rainfall record (deterministic simulation).

The results for a WRD having no cover are presented in Table 5 and Figure 2 below. The associated average total annual infiltration depth was 230 mm and the average annual runoff depth was 64.5 mm.

The results for a WRD with a soil cover, as described in Section 3.6, are presented in Table 6 and Figure 3 below. The associated average total annual infiltration depth was 25.9 mm and the average annual runoff depth was 31.6 mm.

TABLE 5: RANGE OF RESULTS FOR THE 78-YEAR HISTORIC RAINFALL RECORD (NO COVER)

Scenario	Vertical Permeability (m/s) - liner	Horizontal Permeability (m/s) – waste rock or drains	Average Daily Pressure Head on Liner (m)	Average Daily Vertical Seepage (m^3)	Average Daily Horizontal Seepage (m^3)
A	$1x10^{-10}$	1	0.0019	0.0001	4.34
B	$1x10^{-10}$	$1x10^{-2}$	0.0038	0.019	4.32
C	$1x10^{-10}$	$1x10^{-4}$	0.261	0.111	4.22
D	$1x10^{-9}$	$1x10^{-4}$	0.213	1.02	3.32
E	$1x10^{-7}$	$1x10^{-4}$	0.0033	4.3	0.035
F	$1x10^{-6}$	$1x10^{-4}$	0.0019	4.33	0.004

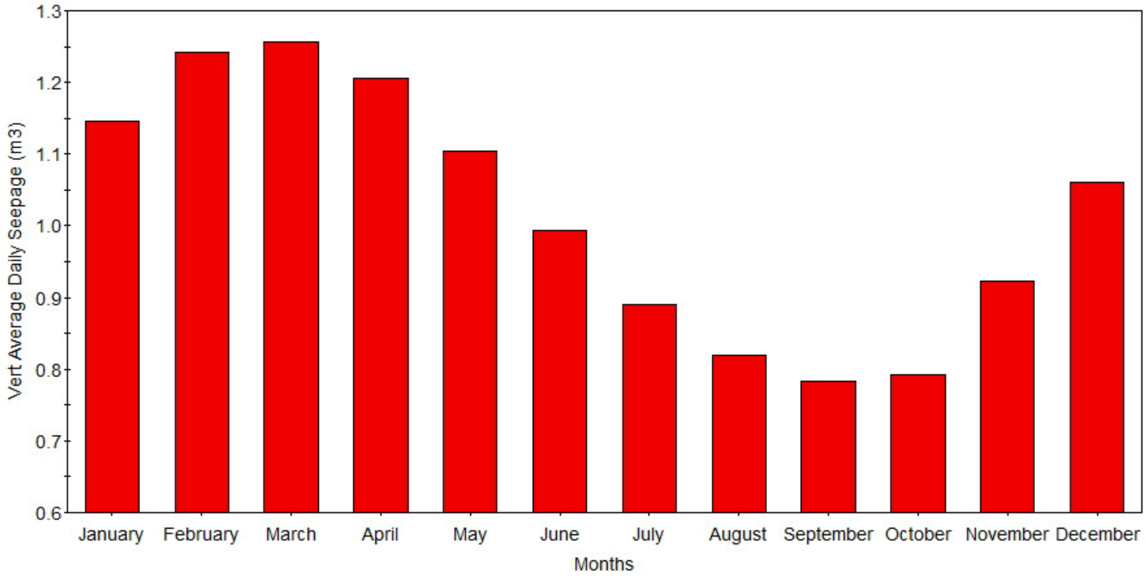


FIGURE 2: AVERAGE DAILY VERTICAL SEEPAGE BY MONTH FOR SCENARIO D (NO COVER)

TABLE 6: RANGE OF RESULTS FOR THE 78-YEAR HISTORIC RAINFALL RECORD (WITH SOIL COVER)

Scenario	Vertical Permeability (m/s) - liner	Horizontal Permeability (m/s) – waste rock or drains	Average Daily Pressure Head on Liner (m)	Average Daily Vertical Seepage (m^3)	Average Daily Horizontal Seepage (m^3)
A	$1x10^{-10}$	1	0.0002	0.29×10^{-5}	0.49
B	$1x10^{-10}$	$1x10^{-2}$	0.0004	0.002	0.49
C	$1x10^{-10}$	$1x10^{-4}$	0.035	0.05	0.44
D	$1x10^{-9}$	$1x10^{-4}$	0.02	0.24	0.25
E	$1x10^{-7}$	$1x10^{-4}$	0.0004	0.49	0.0044
F	$1x10^{-6}$	$1x10^{-4}$	0.0002	0.50	0.0004

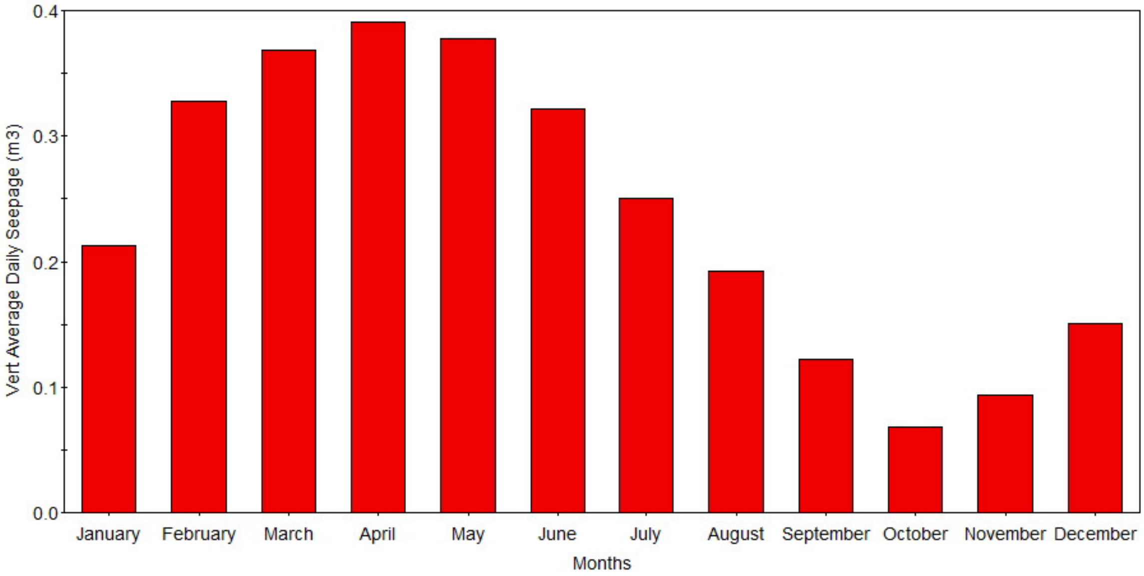


FIGURE 3: AVERAGE DAILY VERTICAL SEEPAGE BY MONTH FOR SCENARIO D (WITH SOIL COVER)

3.5 STORM WATER RUNOFF

Peak storm water discharges have been calculated for the proposed 0.689 ha WRD for both the no cover and soil cover options. In both cases, the total area of the WRD was used in the calculations, along with a nominal time of concentration of 15 minutes. This gives the 1:50 annual exceedance probability critical storm intensity as 140 mm/h (Table 3). The Rational method runoff coefficients were built up using Table 3.7 of the SANRAL Drainage Manual as shown in Table 7.

TABLE 7: BUILD UP OF RATIONAL METHOD RUNOFF COEFFICIENTS

	No Cover	Soil Cover
Surface Slope	0.16 (Hilly)	0.16 (Hilly)
Permeability	0.04 (Very permeable - Gravel)	0.16 (Semi Permeable – Silty Clay)
Vegetation	0.28 (No vegetation)	0.21 (Grasslands)
Total Base Coefficient	0.48	0.53
Return Period Adjustment Factor	0.83 (1:50 – Flat / Permeable)	0.83 (1:50 – Flat / Permeable)
Runoff Coefficient	0.4	0.43

Using the Rational method with a runoff coefficient of 0.4 gives the peak discharge, having a 1:50 annual exceedance probability as 0.11 m^3/s.

With a vegetated soil cover over the waste rock the surface runoff from the WRD can be argued to be clean, and can therefore be discharged directly to the environment. However during the construction of the waste rock dump, and before the soil cover has been installed, storm water runoff will need to be directed to the adjacent PCD via impermeable channels. A silt trap will be required to limit the sediment load on the PCD.

It is proposed that the drainage channels be concrete lined such that their integrity can be maintained over the 35 year life of mine. With the low 1:50 peak discharge rate the channel size will be governed by what is practical to construct rather than flow constraints.

The Alexander Shaft Complex storm water management plan is discussed in more detail under the report 'Alexander Project, Surface Water Study for the EIA, 2016'.

3.6 COVER TO WRD

As the WRD will not be operational over the 35 year life of mine it would benefit from a soil cover. There are two approaches to designing a soil cover.

- **A water shedding, low permeability cover**: This would consist of a low permeability clay capping layer over the waste rock. There would be limited infiltration and the majority of storm water would runoff the WRD. This cover type is used where it is important to minimize the migration of contaminates in the waste to the surface by plant uptake. It does however result in a more artificial surface that generates excessive surface water runoff, making it more difficult to establish vegetation and control erosion.
- **A store and release cover**: This would consist of a thick layer of soil, into which most of the rainfall will infiltrate and be held in storage, until it is removed by evapotranspiration. Vegetating the cover with deep rooting grass species and shrubs will maximise the evapotranspiration potential. A layer of coarser material is normally provided beneath the cover to break the capillary rise, which would otherwise draw contaminated water up into the soil cover from the waste below. During extended wet periods the soil cover's water storage capacity will be exceeded and the excess water will infiltrate into the waste rock. This design results in a cover that replicates natural soil process, thereby limiting surface water runoff and facilitating the establishment of indigenous plant species. However some infiltration into the waste rock will have to be accepted.

The following advantages and disadvantages of using a store and release cover have been identified.

Advantages of using a cover:

- Results in an 80% reduction in the annual average rainfall infiltration and a 50% reduction in annual average surface runoff, as demonstrated in Section 3.4 above.
- May allow surface runoff to be treated as clean, allowing it to be discharged to the environment. This will save on drainage infrastructure, including the silt trap, as well as reduce the volumes of dirty water to be managed.
- Prevents windblown dust and erosion of the waste rock.
- Removes the need to manage erosion of the exposed waste rock surface.
- Restricts the flow of oxygen to the waste rock thereby limiting the acid generation potential.
- Due to being vegetated it is aesthetically pleasing.
- It is a durable solution as it does not rely on geosynthetics, which can be damaged, or clay which can desiccate.

Disadvantages of a cover:

- Double handling of material as the surface soils will need to be stockpiled temporarily before being used to construct the cover.
- There may be some ongoing maintenance required – e.g. maintaining the vegetative cover and irrigation during the dry season.

As the advantages outweigh the disadvantages, it is recommended that a store and release cover is included in the WRD design.

It is proposed that the cover will be approximately 0.5 m to 1 m thick, and be constructed from the top soil overburden excavated in sinking the shaft. A review of the typical surface soils in the area indicates that there will be a suitable depth of soft soils available to use as a soil cover. To prevent fines being washed into the open matrix of the waste rock a filter layer will be required beneath the soil cover. This could be formed from a well graded gravel or sand material, or a geotextile equivalent, such as a non-woven filter fabric like Bidim. The cover should be vegetated with a deep rooting grass species that can thrive in well drained soils.

It is not recommended that an impermeable barrier, such a HDPE or clay, be provided below the soil cover. Such a barrier will not only create a preferential slip plane but will also result in a saturated soil matrix during extended wet periods, thereby increasing the risk of erosion on the WRD side slopes. The reduction in the already small infiltration rate is outweighed by the additional cost and erosion risk.

3.7 CONTAINMENT BARRIER

Without the availability of site specific geochemical information the waste rock has been assessed as either, Type 3, Type 2 or Type 1 waste, see Section 2.2.2 of this report. Based on the waste type classification alone, either a Class C, B or A containment barrier would be required. However, by taking a risk based approach, whereby the overall impact on the water environment and likely receptors is considered, a Class D containment barrier may also be justifiable

The containment barrier classes required by GN R.634 are given in Table 8 below. The licence applicant has committed to selecting one of these barrier systems during the detailed design of the WRD, informed by an analysis of site specific samples and the overall risk to the ground water environment.

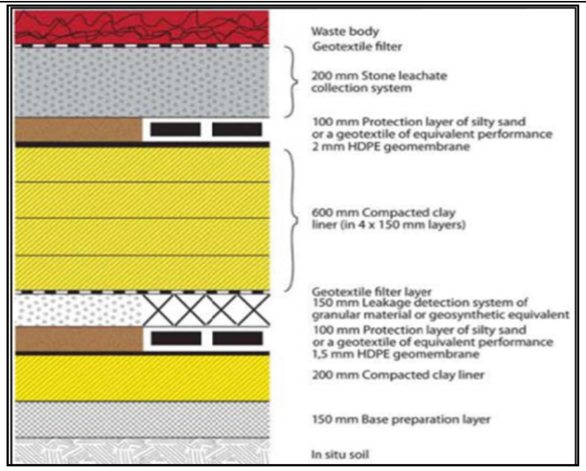
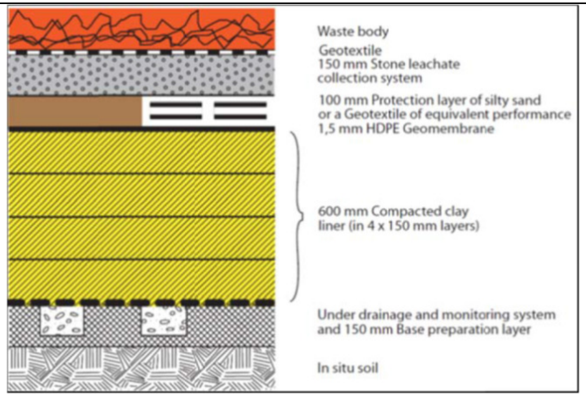
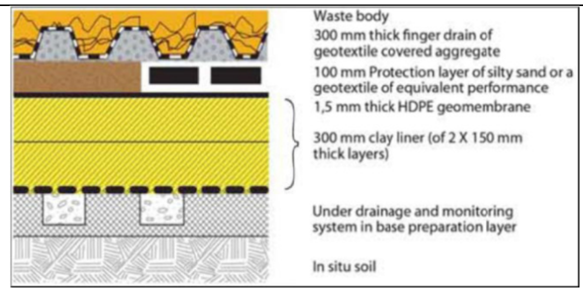
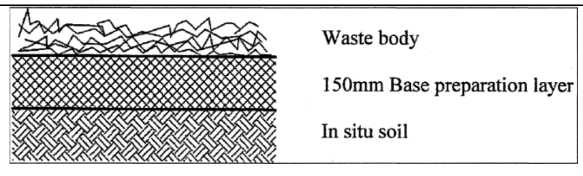
The risk posed by seepage from the WRD needs to be assessed in the context of the;

- quantity of seepage reporting to the ground water table over the 35 year life of the WRD (with the use of a soil cover),
- the levels of the identified chemical elements in the natural ground water regime,
- and the overall movement of ground water and its impact on local receptors.

At this stage there is not enough site specific information to commit to the use of a specific class of barrier system. As part of the detailed design the following will need to be considered in the design of the containment barrier system.

- The residual seepage volumes through the selected barrier system and their impact on the natural groundwater environment.
- The effect of settlement on the integrity of the barrier system.
- A protective layer to prevent the barrier system being damaged by the dumping of waste rock.
- An effective underdrainage system to collect seepage and direct it to the adjacent PCD.
- A preliminary quality assurance plan for the construction of the barrier system.

TABLE 8: LANDFILL DISPOSAL REQUIREMENTS DETAILED IN THE NATIONAL NORMS AND STANDARDS FOR DISPOSAL OF WASTE TO LANDFILL (GN R. 636)

Waste Type	Listed Wastes	Landfill Disposal requirements	Landfill Design specifications
Type 0	None	The disposal of Type 0 waste is not allowed to landfill. These wastes must be treated before being reassessed for landfill disposal.	n/a
Type 1	NA	Type 1 waste may only be disposed of at a Class A Landfill.	
Type 2	Domestic Waste. Business waste not containing hazardous waste or hazardous chemicals. Non-infectious animal carcasses. Garden Waste.	Type 2 waste may only be disposed of at a Class B Landfill.	
Type 3	Post-consumer packaging. Waste tyres.	Type 3 waste may only be disposed of at a Class C Landfill	
Type 4	Building and demolition waste not containing hazardous waste or hazardous chemicals. Excavated earth material not containing hazardous waste or hazardous chemicals.	Type 4 waste may only be disposed of at a Class D Landfill	

3.8 SECURITY

As the WRD is to be located within the boundary of the Alexander shaft complex there will be no need for a specific security fence or controlled access points. There will be no significant health and safety risks posed by the WRD that warrant controlled access. The waste rock is not toxic and there are no deep excavations or falling hazards associated with the WRD. Therefore the zone of influence in terms of section 73 of GN R.527 (Mineral and Petroleum Development Regulations) is assumed to be ~ 50 m.

3.9 OPERATION AND MAINTENANCE

A preliminary operation and maintenance manual will be produced with the detailed design of the WRD. It is envisioned that no operational tasks will be required and only limited maintenance undertaken over the 35 year life of the WRD. Possible maintenance tasks that could be required include;

- maintenance of any vegetation,
- repair of any surface erosion due to storm water runoff,
- clearing debris from storm water channels and removal of sediment from the silt trap,
- and rodding underdrainage pipes if a containment barrier is required.

3.10 DECOMMISSIONING AND CLOSURE

The following tasks will be undertaken at decommissioning and closure of the WRD.

- The top soil cover will be removed and temporarily stockpiled separately before being used to complete the mine shaft backfill.
- The waste rock will be used to backfill the mine shaft.
- Any containment barrier system will be removed and disposed of.

3.11 IMPACT MANAGEMENT

At detailed design and EIA/EMP report will be prepared to address the following.

- Assess the potential mitigated impacts of the waste rock dump on water resources over the life of the mine.
- Design a monitoring system to assess impacts over the life of the mining operation. As the impact of the WRD will be small in comparison with the overall mining operation, the monitoring system used will be that for the overall mining operation. The following will be considered in the design of such a monitoring system.
    - Location of monitoring points and monitoring protocol.
    - Reporting frequency and procedure.

- Environmental quality objectives.
- Dealing with non-conformances.

4 ASSUMPTIONS AND LIMITATION

The following information was not available in time for the submission of the mining right application.

- Waste rock material chemical characterisation
- Physical properties of the waste rock material
- Geotechnical properties of the soils underlying the proposed WRD location

This report therefore serves to present a conceptual design of the WRD, using parameters and assumption taken from a review of the available information applicable to coal mines in the region. These limitations will be addressed prior to project construction as part of the final design process.

5 CONCLUSION AND RECOMMENDATIONS

In support of an application to obtain a Waste Management Licence for the Alexander Mine a design has been presented for the WRD. With a volume of 20 000 m^3, and a footprint area of 6 889 m^2 (83 m by 83 m), the WRD is a minor part of the overall mine infrastructure. It will remain in place over the 35 year life of mine, after which the waste rock will be used to backfill the shaft, and the site rehabilitated.

As the WRD will be dormant for the majority of the life of mine it is proposed to install a vegetated soil cover once the WRD has been constructed. It has been shown that the soil cover will limit infiltration of rain water into the waste rock and will allow storm water runoff to be classified as clean. Restricting the infiltration of rain water into the waste rock is important as it is the mechanism by which contaminants are mobilised and enter the ground water. Not only will the soil cover control infiltration, it will also limit the migration of oxygen into the waste rock, thereby reducing the acid generating potential. The soil cover will have the added benefits of controlling soil erosion on the WRD and preventing the generation of windblown dust. Slope stability risks will be mitigated by specifying shallow side slopes to the WRD.

As required by GN R.632 the applicant will undertake a chemical characterisation of the overburden material at the detailed design stage. This will be used to select the required class of containment barrier in accordance with GN R.636. The selection of the containment barrier will also consider the risk posed by seepage from the WRD in the context of;

- quantity of seepage reporting to the ground water table over the 35 year life of the WRD,
- the levels of the identified chemical elements in the natural ground water regime, and
- the overall movement of ground water and its impact on local receptors.

Ryan Sweetman	**Ryan Sweetman**	**Alistair James**
(Report Author)	**(Project Manager)**	**(Project Reviewer)**

REFERENCES

- Regulations Regarding the Planning and Management of Residue Stockpiles and Residue Deposits from a Prospecting, Mining, Exploration or Production Operation, 2015 (GN R.632)
- Waste Classification and Management Regulations, 2013 (GN R.634)
- National Norms and Standards for the Assessment of Waste for Landfill Disposal, 2013 (GN R. 635)
- National Norms and Standards for Disposal of Waste to Landfill, 2013 (GN R.636)
- Mineral and Petroleum Development Regulations, 2004 (GN R.527)
- Alexander Project, Surface Water Study for the EIA, Ref. 750.01080.00005_Report 01, June 2016
- Alexander Coal Project, Preliminary Geochemical Assessment, Ref. 750.01080.00006_Report 01, June 2016
- SANRAL Drainage Manual, 6th Edition

APPENDIX A: WASTE ROCK DUMP SEEPAGE MODEL

Project Reference: 750.01080.00007

File Ref. Alexander Shaft WRD Seepage Model_Rev_02

27th July 2016

PROJECT: Alexander Shaft Waste Rock Dump

CLIENT: Anglo American Inyosi Coal (Pty) Ltd

TECHNICAL NOTE 01 – DRAFT REV.01

TN01 – WASTE ROCK DUMP SEEPAGE MODEL

1. INTRODUCTION

It is necessary to apply for a Waste Management Licence for a Waste Rock Dump (WRD) under the National Environmental Management: Waste Act, 2008. The design and management of a WRD is legislated by the Regulations Regarding the Planning and Management of Residual Stockpiles and Residue Deposits from a Prospecting, Mining, Exploration or Production Operation. These regulations require a pollution containment barrier (PCB) system to be selected in accordance with the:

- National Norms and Standards for the Assessment of Waste for Landfill Disposal, 2013;
- and the National Norms and Standards for Disposal of Waste to Landfill, 2013.

The resulting seepage rate and quality of the water emanating from the WRD needs to be estimated, such that the residual impacts on the water resource can be assessed over the full life cycle of the WRD.

Seepage from a WRD comprises of both horizontal and vertical components. The vertical component is the residual seepage through the PCB system, while the horizontal component is that which daylights at the toe of the WRD. The more effective the PCB system the greater the horizontal component will be.

The seepage itself is driven by water collecting at the base of the WRD, supplied by rainfall infiltrating into the WRD. The seepage rate is therefore governed by the percentage of rainfall that infiltrates into the WRD. The nature of the WRD surface will therefore govern the resulting infiltration rate.

A model was developed in GoldSim to improve the understanding of the infiltration and resulting horizontal and vertical seepage rates from a WRD.

2. MODEL SCHEMATISATION

The model comprises of two main modules, that which generates the infiltration and that which controls the resulting water volume stored at the base of the RWD, and hence the seepage. The volume of water stored at the base of the WRD is schematised as a segment of a cone, the edge of which corresponds to the seepage face at the toe of the WRD, Figure 1 and Figure 5 below. For a WRD on a horizontal plane surface the seepage face length will approximate to a full circle, while where the WRD is constructed on a sloping plane the seepage face will be at the down slope side of the WRD and approximate to an arc.

To schematise the water stored at the base of the WRD as a segment of a cone the WRD itself is schematised as a segment of a circle in plan, Figure 1 below. The associated circle radius is calculated such that the segment of the circle has the same area as the WRD. The two modules of the model are described in detail in the following sections.

The model is dynamic, in that it simulates daily seepage volumes over a defined timeframe. In this case, the timeframe is the duration of a 78-year daily rainfall record from 1914 to 1992. The continuous rainfall record used in the model was taken from the South Africa Weather Services (SAWS) station 0478292_W at Langsloot, located approximately 17.7 km from the project site.

Table 1: Average monthly rainfall (Gauge 0478292_W - langsloot)

Month	Average Rainfall (mm)
January	119.4
February	86.9
March	76.9
April	37.2
May	19.5
June	6.5
July	5.6
August	9.3
September	21.1
October	75.2
November	106.9
December	108.4
Total	**673.0**

For the purposes of the modelling exercise, the WRD material is assumed to be a homogenous well-graded gravel with no cover. The WRD is also modelled with a soil cover to demonstrate the effect on seepage and runoff volumes.

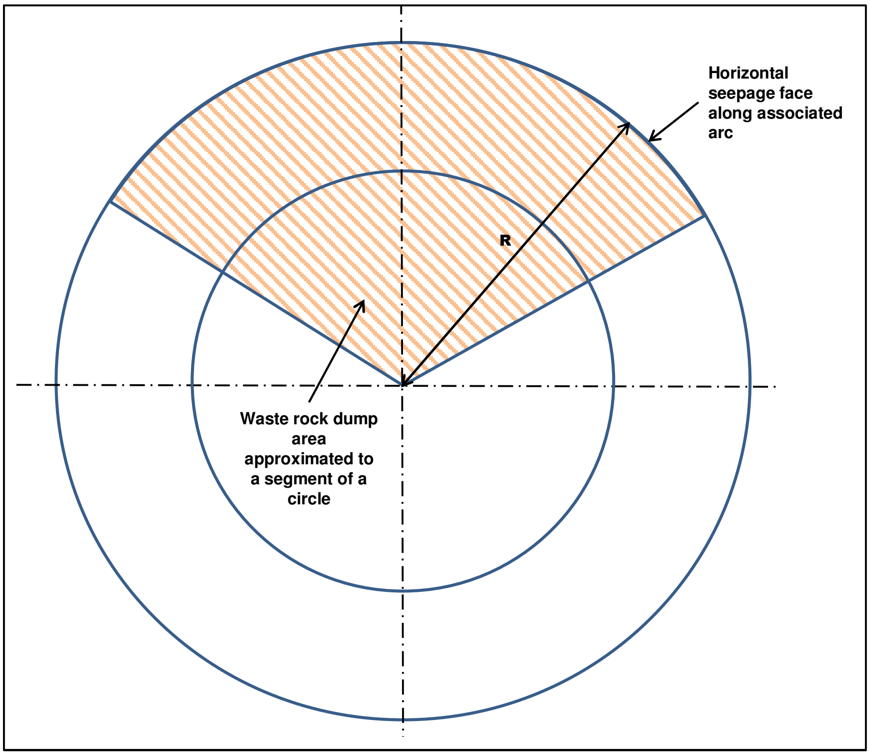


Figure 1 Plan on WRD as Represented in the Model

3. INFILTRATION MODULE

The infiltration into the WRD is calculated by considering the soil moisture budget in the surface layer of the WRD subject to evapotranspiration. The soil moisture budgeting routine is taken from the FAO Irrigation and Drainage Paper No.56, Crop Evapotranspiration (guidelines for computing crop water requirements) and is schematised in Figure 2 below.

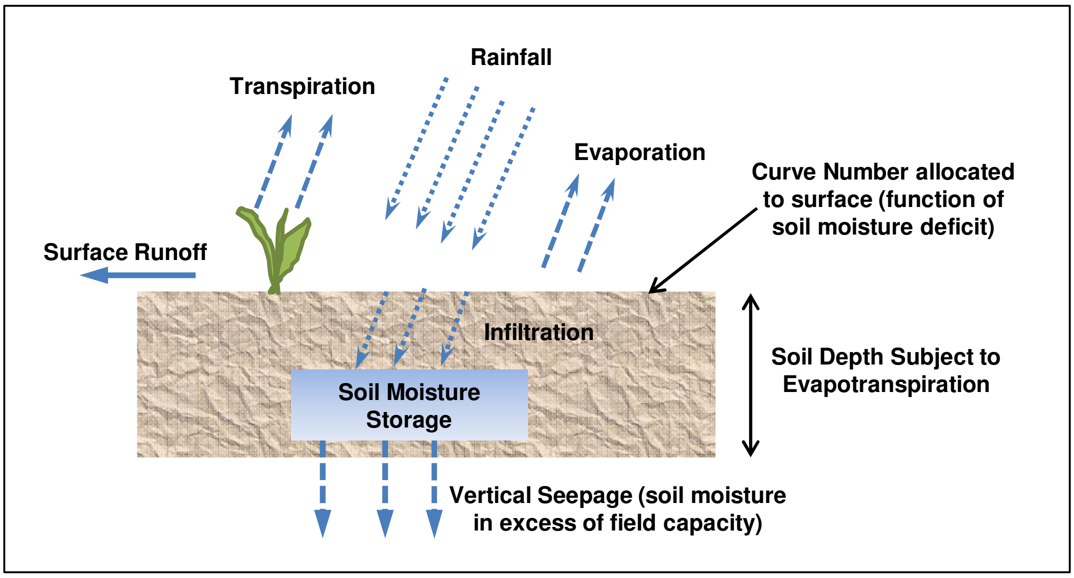


Figure 2 Schematic of Soil Moisture Budget

The portion of the rainfall that becomes direct surface runoff is calculated using the United States Soil Conservation Service (SCS) Method. The SCS method is a simplification of the rainfall infiltration process that occur during a storm event, requiring the allocation of a Curve Number (CN) to a catchment, which is a representation of the catchment's moisture deficit at the onset of the storm. The CN(II) value allocated to the catchment is representative of a moisture deficit when the soil moisture is 50% of the moisture associated with the plant wilting point.

The CN(II) value is selected from a table of values provided in the United States National Engineering Handbook, Part 630. These values are given for different land uses and soil types. As it has been assumed that the WRD material is gravel, and that there is no engineered cover, the 'Hydrologic Soil Group A' was selected for the surface of the WRD. This is the most permeable of the soil groups having the lowest runoff potential. The surface of the WRD is taken to be bare of vegetation and so the land use class is taken to be that of a gravel road. Combining the soil group with the land use class results in a CN(II) value of 76.

The CN value is varied throughout the simulation with the change is soil moisture deficit, using the Hawkins equation as presented in the SCS-Based Design Runoff Report, WRC Project No. 155, 1987. The CN value is limited to an upper CN(III) value, associated with a saturated soil, and a lower CN(I) value, associated with the minimum soil moisture content

That portion of the rainfall that does not become direct surface runoff is taken to infiltrate into the surface layer and contributes to the soil moisture storage. The soil moisture is depleted by both evaporation, and transpiration where there is vegetation present. The soil depth subject to transpiration is taken to be the rooting depth of the surface vegetation, while soil depth subject to evaporation is taken to be a nominal 100 mm in depth (as recommended in FAO Irrigation and Drainage Paper No.56). As there is no vegetation present on the WRD, the soil depth considered for moisture budgeting purposes is therefore 100 mm. The soil suction head will be of this order as the WRD material is taken to be gravel. Once the soil moisture reaches field capacity any additional infiltration is lost as vertical seepage into the WRD.

The soil water characteristics for different soil types (USA Soil Texture Classification) are given in FAO Irrigation and Drainage Paper No.56 – Table 19. The soil type that most closely matches the properties of gravel was taken to be 'sand', for which the soil water characteristics are given in Table 2 below. The averages of the values provided were used in the model to represent the gravel surface of the WRD.

Table 2 Soil Water Characteristics for Sand

	Lower Value	Upper Value	Average Value
Field Capacity – FC (m^3/m^3)	0.07	0.17	0.12
Wilting Point - WP (m^3/m^3)	0.02	0.07	0.045
Minimum Moisture (m^3/m^3) - 0.5 x WP	0.01	0.035	0.023
Readily Evaporable Water (mm) – 100 mm soil depth	2	7	4.5

To demonstrate the impact on infiltration of a vegetated soil cover the model was also run with the following parameters for calculating the soil moisture budget.

- A 500 mm thick loam soil cover having the average value soil water characteristics presented in Table 3.
- Grass having a basal crop evapotranspiration coefficient of 1, a moisture stress parameter of 0.6, a 300 mm rooting depth and 100% coverage.
- A CN-II value of 71 (Hydrological Soil Group C with a grass surface protected from grazing).

Table 3 Soil Water Characteristics for Silty Clay

	Lower Value	Upper Value	Average Value
Field Capacity – FC (m^3/m^3)	0.3	0.42	0.36
Wilting Point - WP (m^3/m^3)	0.17	0.29	0.23
Minimum Moisture (m^3/m^3) - 0.5 x WP	0.085	0.145	0.115
Readily Evaporable Water (mm) – 100 mm soil depth	8	12	10

The FAO Irrigation and Drainage Paper No.56 moisture budgeting routine requires the definition of the reference evapotranspiration (ET_0), to which factors are applied to give the evapotranspiration at any given time step in the model. There are many methods given for estimating the applicable ET_0, however the simplest is the application of a factor to the Class A-Pan evaporation based on the site's climate, as determined by Table 5 in the FAO Irrigation and Drainage Paper No.56. This gives a pan coefficient of approximately 0.7, which is also that typically used to convert Class A-Pan evaporation to that for open water in South Africa.

In the Alexander Surface Water Study the average monthly S-Pan values are provided for the site from the Rietfontein (B1E004) Symonds Pan, Table 4 below. Surface Water Resources of South

Africa 1990 - Volume 1 Appendices. WRC Report 298/1.1/94 provides monthly coefficients to convert S-Pan values to open water evaporation. As the A-Pan coefficient calculated above is not applicable to S-Pan values, and as the S-Pan coefficients vary by month, it was decided to take the open water evaporation values given in Table 4 as being representative of ET_0.

Table 4 Average Monthly Open Water Evaporation Depths Applicable to the Site

Month	S-Pan Evaporation (mm)	Pan Coefficient	Open Water Evaporation (mm)
January	201.9	0.84	169.6
February	171.9	0.88	151.3
March	157.9	0.88	139.0
April	129.9	0.88	114.3
May	114.3	0.87	99.5
June	91.0	0.85	77.3
July	103.1	0.83	85.6
August	132.6	0.81	107.4
September	173.9	0.81	140.8
October	192.2	0.81	155.6
November	192.0	0.82	157.4
December	194.6	0.83	161.5
Total	**1855.3**	**N/A**	**1559.4**

4. SEEPAGE MODULE

The model seepage module is schematised in Figure 5 below. Infiltration into the WRD is taken to pass through a depth of unsaturated waste rock material before eventually entering a zone of saturated material at the base of the WRD. The average time taken for infiltration to reach the zone of saturated material is a function of the height of the WRD, as well as the unsaturated hydraulic conductivity of the waste rock material. To approximate this travel time the option is provided to delay the contribution of the seepage to the saturated zone. The travel time was estimated as a nominal 7 days, from consideration of unsaturated seepage velocities.

As described in Section 2 above the saturated zone is represented as the segment of a cone in the model. The radius of the cone is fixed by the radius of the segment of a circle used to represent the WRD in plan, Figure 1 above. The height of the cone is governed by the volume of water in the saturated zone at each time step and the void ratio of the waste rock material. For the purpose of this model, the void ratio of the waste rock material is taken to be 39%. The resulting slope of the cone surface is taken to be the hydraulic gradient for the calculation of horizontal seepage.

Vertical seepage occurs through the PCB, which in this case is taken to be a clay liner. It is assumed that the soil below the clay liner is orders of magnitude more permeable than the clay liner and so there is negligible pressure head remaining once the seepage has passed through the clay. This allows the simplification of assuming zero pressure head at the base of the clay liner. The head driving seepage through the liner is then taken to be the elevation head across the liner (liner thickness) and the pressure head imposed by the saturated zone above the clay liner. The pressure head in the saturated zone is taken to be half of the height of the cone used to represent the saturated zone (the average height of the cone). The daily vertical seepage is therefore a function of the pressure head, liner thickness, clay saturated hydraulic conductivity and area of the WRD.

The horizontal seepage from the saturated zone is taken to be driven by the hydraulic gradient from the centre of the cone to the edge. This gradient is taken to be the slope of the cone surface. The area over which the horizontal seepage is applied is taken to be the height of the cone, at half the radius from the centre, multiplied by the associated arc. This is a simplification of what would in reality be a more complex pieziometric head profile, being relatively flat across the majority of the WRD with a steep parabolic drawdown curve nearer the seepage face.

There is the option in the model to slope the surface of the clay liner from the centre of the cone segment to the edge. This will increase the hydraulic gradient acting on the horizontal seepage by adding elevation head to the total driving head. In the model the required surface slope is entered as a horizontal distance for a 1 m drop in elevation, from which the elevation head at the centre of the cone segment is calculated. The storage cone segment volume and geometry are not altered because:

- as long as the cone segment height and radius remain the same the volume will be the same as that with a horizontal base;
- and the resulting reduction in height of the cone surface above the clay liner is very small for the practical maximum slopes that would be applied to the clay liner (5% reduction for a 1v:3h slope).

5. RESULTS

The WRD model gives an indication of the average seepage volumes that can be expected for pollution containment barrier (PCB) systems of differing performance. The resulting seepage volumes can be used as input to more detailed contaminant transport models. The following results have been generated using the WRD model to give an indication of the degree of seepage that can be expected for a range of different PCB permeability's. The common WRD parameters used in the model are as follows.

- WRD Area of 0.69 ha
- Waste Rock void ratio of 39% (homogenous well-graded gravel)
- The WRD is taken to be located on a 1v:70h slope
- The WRD is schematised in plan as a segment (1/3) of a circle with the seepage face being the associated arc
- The clay liner is taken to be 300mm thick

The model was run with the 78-year historic rainfall record (deterministic).

5.1. DETERMINISTIC RESULTS

The results for a WRD having no cover are presented in Table 5 and Figure 3 below. The associated average total annual infiltration depth was 230 mm and the average annual runoff depth was 64.5 mm.

The results for a WRD with a soil cover, as described in Section 3, are presented in Table 6 and Figure 4 below. The associated average total annual infiltration depth was 25.9 mm and the average annual runoff depth was 31.6 mm.

Table 5: Range of Results for the 78-year Historic Rainfall Record (no cover)

	Vertical Permeability (m/s) - liner	Horizontal Permeability (m/s) – waste rock or drains	Average Daily Pressure Head on Liner (m)	Average Daily Vertical Seepage (m^3)	Average Daily Horizontal Seepage (m^3)
A	$1x10^{-10}$	1	0.0019	0.0001	4.34
B	$1x10^{-10}$	$1x10^{-2}$	0.0038	0.019	4.32
C	$1x10^{-10}$	$1x10^{-4}$	0.261	0.111	4.22
D	$1x10^{-9}$	$1x10^{-4}$	0.213	1.02	3.32
E	$1x10^{-7}$	$1x10^{-4}$	0.0033	4.3	0.035
F	$1x10^{-6}$	$1x10^{-4}$	0.0019	4.33	0.004

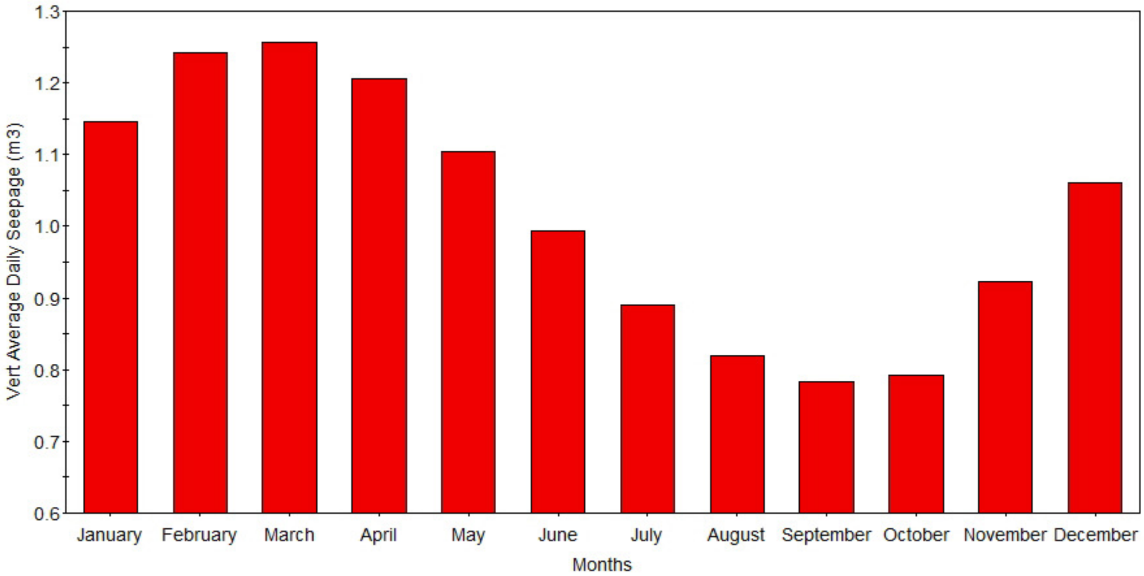


Figure 3: Average Daily Vertical Seepage by Month for Scenario D (no cover)

Table 6: Range of Results for the 78-year Historic Rainfall Record (with soil cover)

	Vertical Permeability (m/s) - liner	Horizontal Permeability (m/s) – waste rock or drains	Average Daily Pressure Head on Liner (m)	Average Daily Vertical Seepage (m^3)	Average Daily Horizontal Seepage (m^3)
A	$1x10^{-10}$	1	0.0002	0.29×10^{-5}	0.49
B	$1x10^{-10}$	$1x10^{-2}$	0.0004	0.002	0.49
C	$1x10^{-10}$	$1x10^{-4}$	0.035	0.05	0.44
D	$1x10^{-9}$	$1x10^{-4}$	0.02	0.24	0.25
E	$1x10^{-7}$	$1x10^{-4}$	0.0004	0.49	0.0044
F	$1x10^{-6}$	$1x10^{-4}$	0.0002	0.50	0.0004

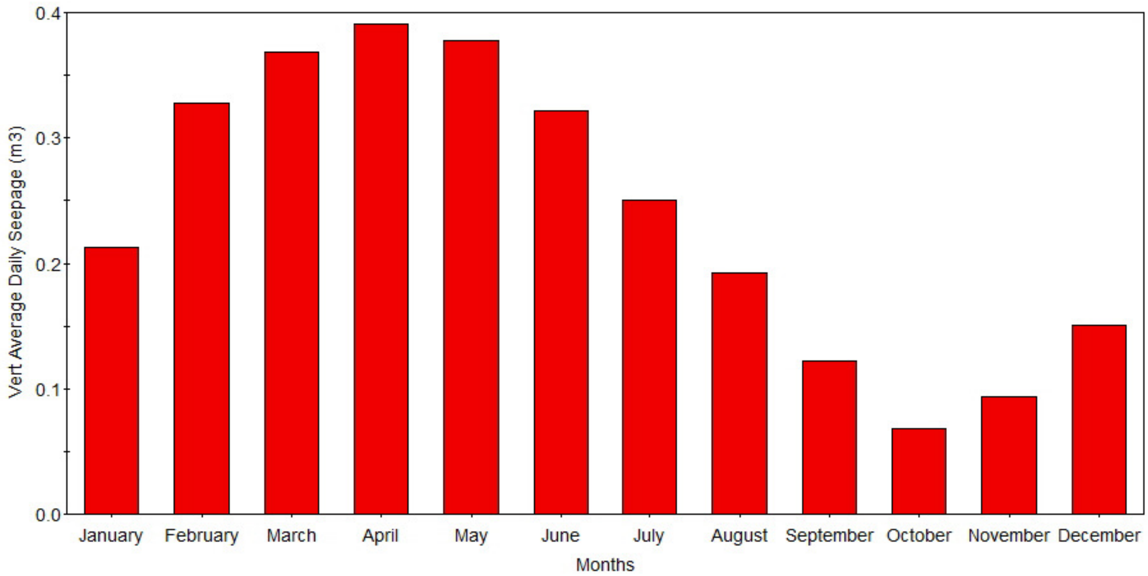


Figure 4: Average Daily Vertical Seepage by Month for Scenario D (with soil cover)

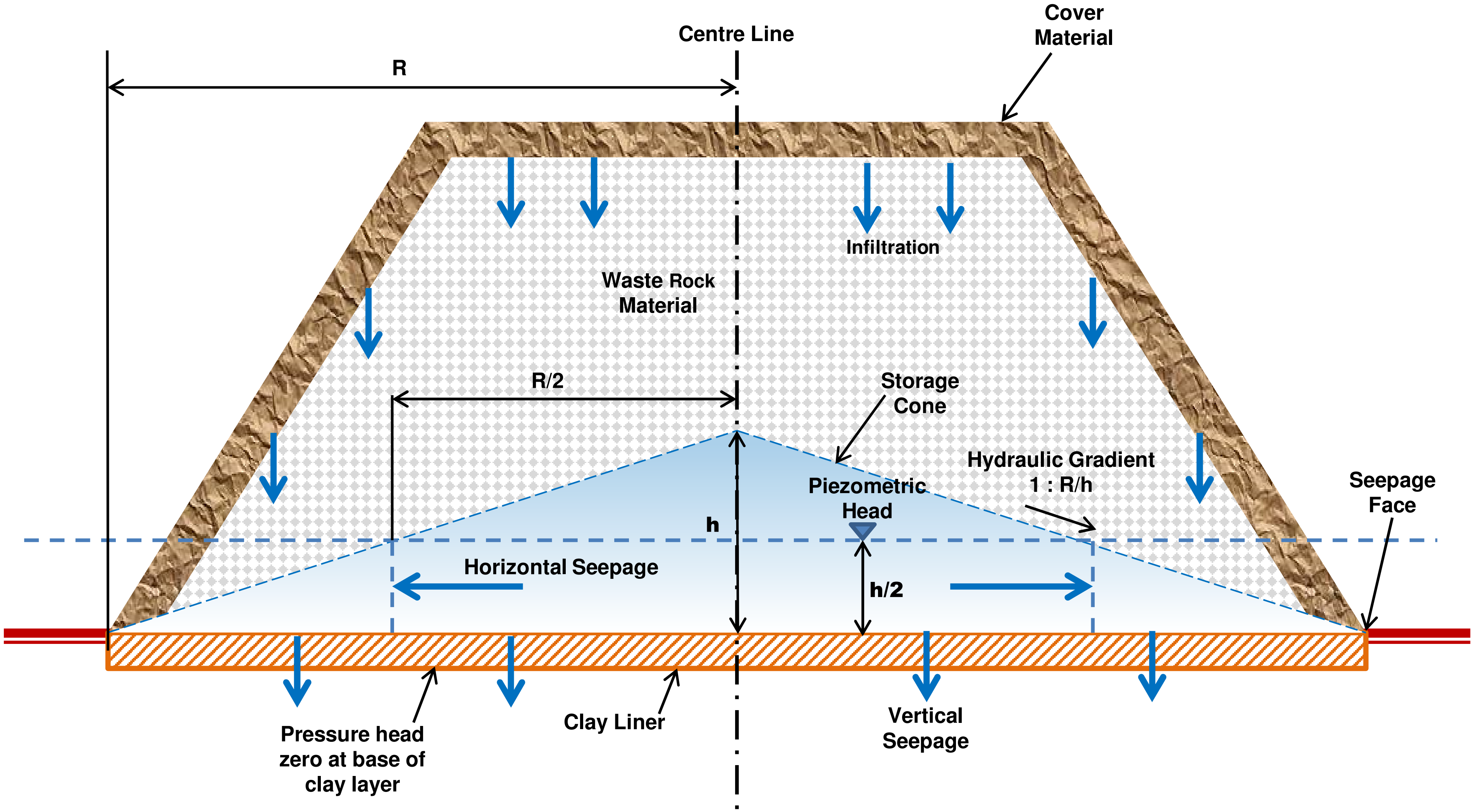


Figure 5 Schematisation of WRD Seepage Model

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