Hydropedological Assessment for the Harmony Valley Tailings Storage Facility Project

Matjhabeng local municipality, Lejweleputswa District Municipality, Free State Province, South Africa

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Prepared by:

The Biodiversity Company

Cell: +27 81 319 1225

Fax : +27 86 527 1965

info@thebiodiversitycompany.com

www.thebiodiversitycompany.com

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Declaration	The Biodiversity Company and its associates operate as independent consultants under the auspice of the South African Council for Natural Scientific Professions. We declare that we have no affiliation with or vested financial interests in the proponent, other than for work performed under the Environmental Impact Assessment Regulations, Amended. We have no conflicting interests in the undertaking of this activity and have no interest in secondary developments resulting from the authorisation of this project. We have no vested interest in the project, other than providing a professional service within the constraints of the project (timing, time, and budget) based on the principals of science.

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1 Introduction

1.1 Background

The Biodiversity Company was appointed to conduct a specialist hydropedological level two (2) assessment for the Integrated Water Use License Application (IWULA) in support of the Water Use License (WUL) and Environmental Authorisation (EA) process related to the proposed Harmony Valley Tailings Storage Facility project, located in Welkom, Free State province. Harmony Gold Mining Company Limited (Harmony) own and operate a number of Gold Mines and Plants and currently deposit tailings onto the Free State South (FSS) 2 TSF, St. Helena 4 TSF, St. Helena 123 TSF, Dam 23 TSF, Brand D TSF and Target 1&2 TSF. The current planned Life of Mine (LOM) of the Free State Operations exceed the available deposition capacity of these TSFs, and Harmony is undertaking a feasibility assessment to construct the new TSFs with associated infrastructure. The hydropedological site assessments were conducted on the on the 21st to 22nd of July 2025. The hydropedological assessments were completed in fulfilment to obtain a Water Use Licence (WUL) authorisation for the consolidation for the Harmony Valley Tailings Storage Facility Project.

This report should be interpreted after taking into consideration the findings and recommendations provided by the specialist herein. Further, this report should inform and guide the Environmental Assessment Practitioner (EAP) and regulatory authorities, enabling informed decision making, as to the management of water resources in relation to the proposed project.

1.2 Project Description

Harmony holds an approved Mining Right (Ref: MR84). The Department of Mineral and Petroleum Resources (DMPR) has granted an amendment to the Environmental Authorisation in terms of the NEMA (Act No. 107 of 1998) and the EIA Regulations, 2014 (as amended). Harmony is currently in the process of applying for a Water Use Licence (WUL) for the proposed Valley TSF Project.

The construction phase of the project will require site establishment, site clearance, excavation, topsoil stripping and stockpiling, layering and compacting, prior to deposition of tailings at the site. The waste material solutes classify as a Type 3 waste. This requires a Class C liner system for the TSF and Return Water Dam (RWD).

The FSN1 RWD is an existing RWD. The FSN 1 RWD will be upgraded/ replaced with a new Lined RWD, to be known as the Valley RWD. The Valley RWD will have a total capacity of approximately 520 000 m^3.

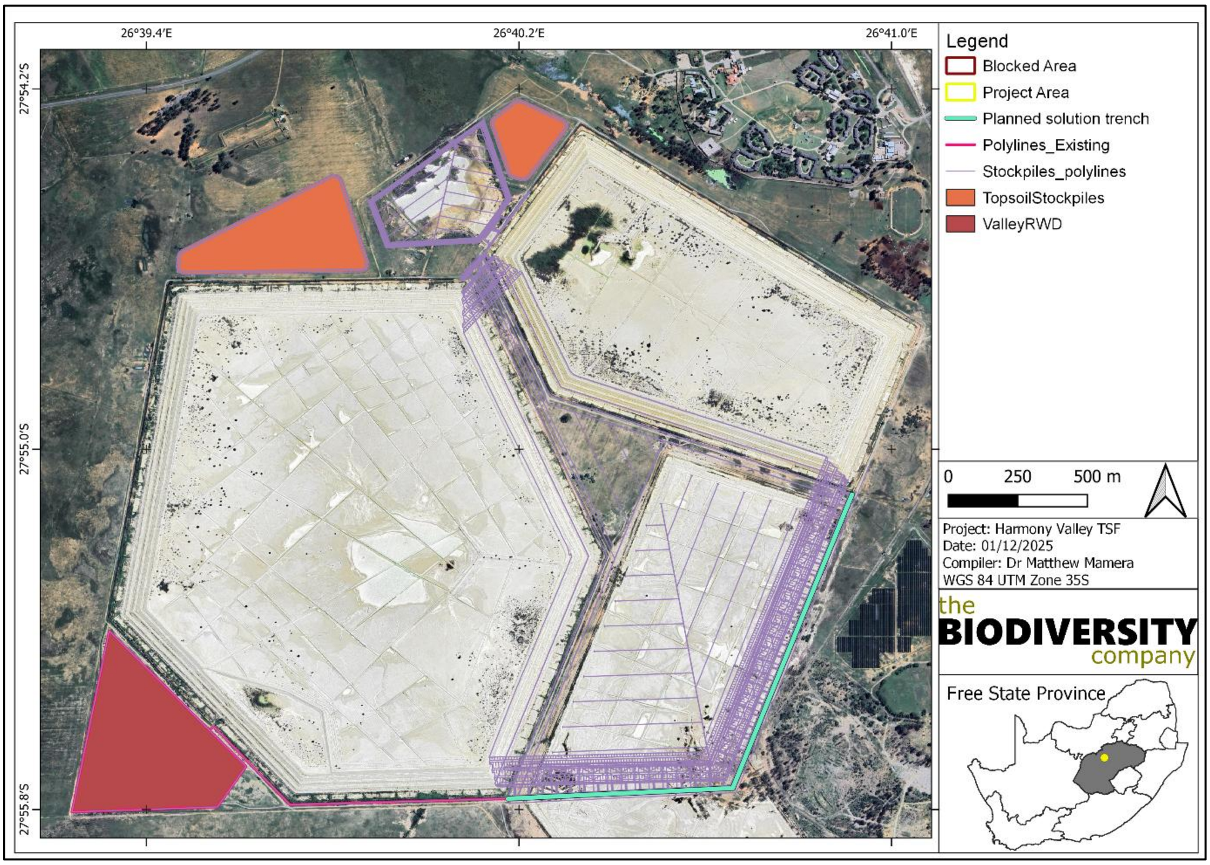

Figure 1-1 Map illustrating the proposed layout of the TSF

1.2.1 Project Area

The proposed Harmony Valley Tailings Storage Facility Project is located in Welkom town. The project is found within the Matjhabeng local municipality, Lejweleputswa District Municipality in the Free State Province. The project area is found approximately 2,7 km south of the R34 road, 2 km north of R710 regional road and 0-7 km west of the R30 regional road (Figure 1-2). The surrounding land use includes watercourses, agricultural activities (Crop and livestock), game farms and mining.

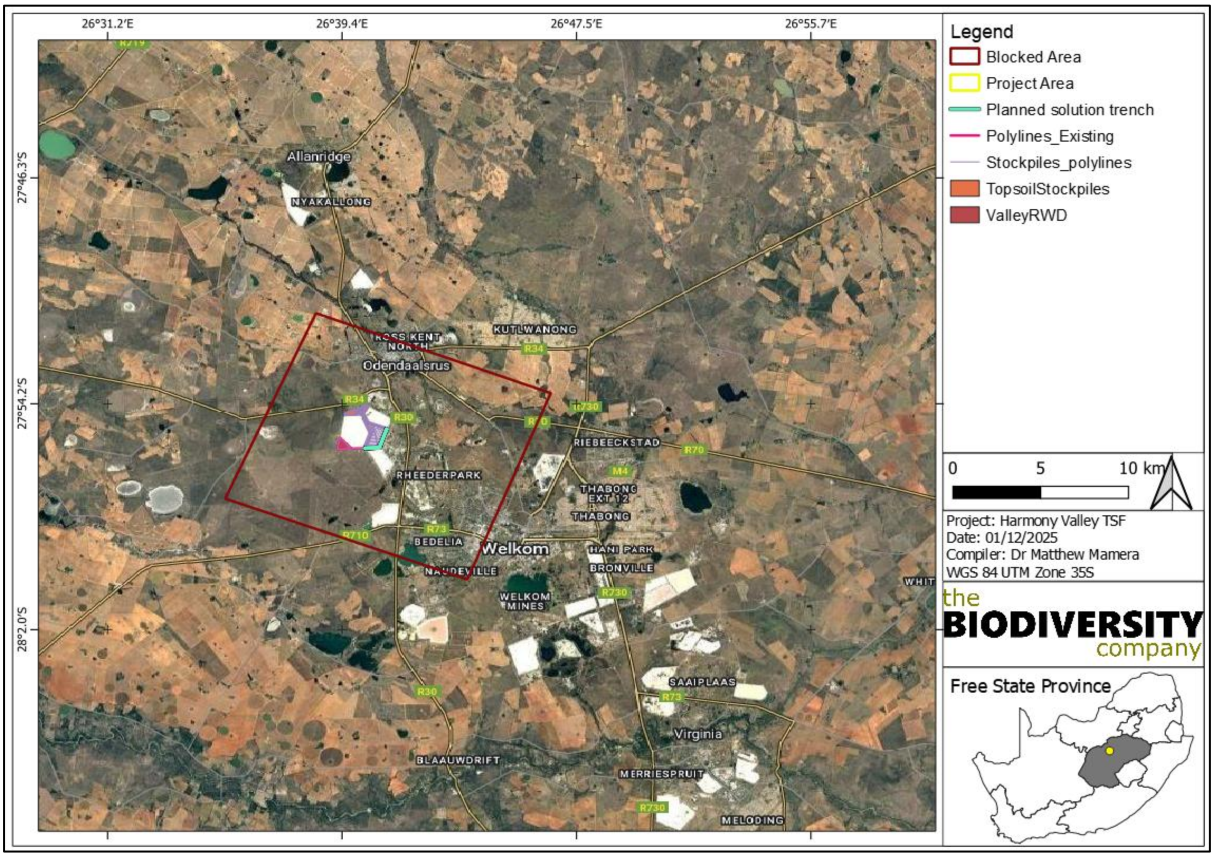

Figure 1-2 Spatial context of the proposed development

1.3 Scope of Work

The approach of this assessment is based on the protocols compiled by van Tol et al., (2021) and issued by the Department of Water and Sanitation (DWS). According to these protocols, the following two steps are required for this level of hydropedology assessment:

1. Identification of dominant hillslopes; and
2. Conceptualise hillslope hydrological responses.

For impact assessments associated with activities that pose significant threats on the interflow volumes of a landscape or activities that are expected to drastically change the dynamics of a landscape (i.e., open cast mining), four steps are required. For those activities that only include minor impacts (i.e., installation of a pipeline or infrastructure), only the first two steps are required. Therefore, considering the intensity of some of the proposed activities, only the first two steps will be relevant to this assessment.

TSF activities with existing activities and surface infrastructure or proposed activities like linear pipeline developments require a basic hydropedological assessment due to the risk level impacting local wetlands functions based on hydropedological hillslopes behaviour (see Appendix: Decision tree for when and the type of hydropedological assessment required).

1.4 Assumptions and Limitations

The following aspects were considered as limitations;

- Only the slopes affected by the project have been assessed;

- It has been assumed that the extent of the project area provided by the responsible party is accurate; and

- The GPS used for ground truthing is accurate to within five meters. Therefore, the observation soil site's delineation plotted digitally may be offset by at up to five meters to either side.

2 Literature Review

2.1 Hydropedological Flow Paths

Given that hydropedology is a relatively new field, a short literature review has been added on this interdisciplinary research field. This literature is an excerpt from van Tol et al., (2017).

Soil physical properties and hydrology play significant roles in the fundamentals of hydropedology. Physical properties including porosity, hydraulic conductivity, infiltration etc. determine micro preferential flow paths through a soil profile. The hydrology in turn is responsible for the formation of various morphological processes in soil, including mottling, colouration, and the accumulation of carbonate.

These processes are used to construct models illustrating sub-surface flow paths, storage, and interconnection between these flow paths. Hydropedology can therefore be used for a variety of functions. These functions include process-based modelling, digital soil mapping, pollution control management, impact of land use change on water resources, wetland protection, characterising ground and sub-surface flows as well as wetland protection and rehabilitation, of which the latter will be the main focus during this report (see Figure 2-1). The latter mentioned enables effective water resource management regarding wetlands and sub-surface flows in general.

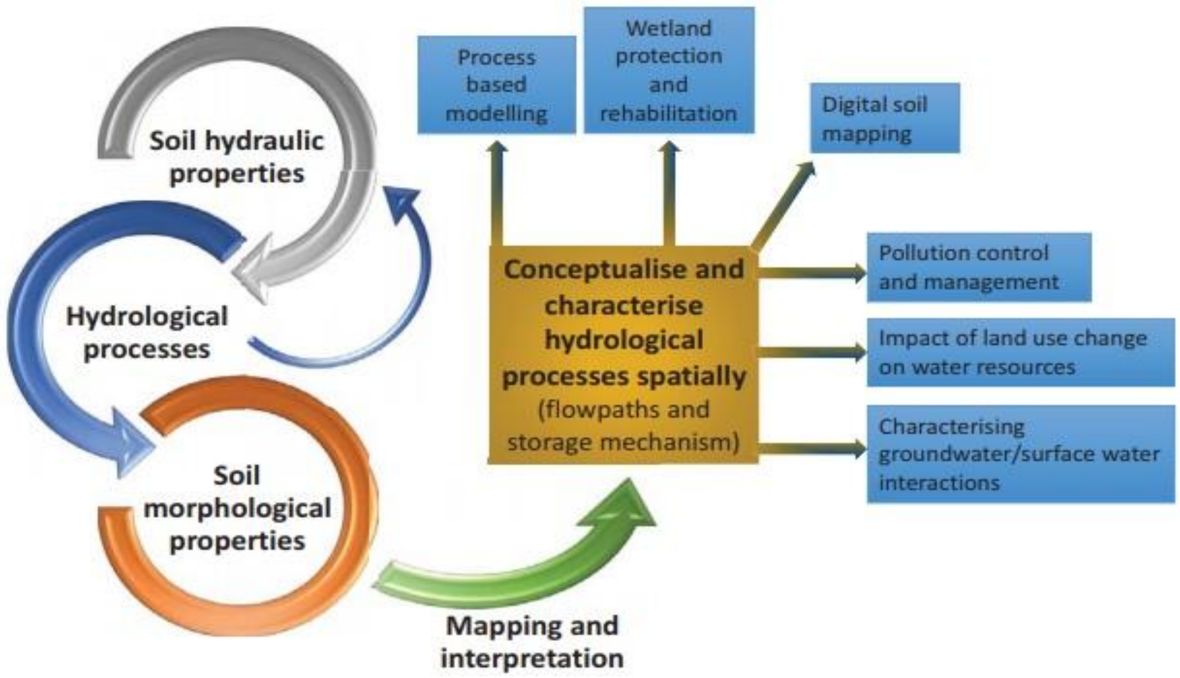

Figure 2-1 Illustration of the interactive nature of hydropedology and its potential applications (van Tol et al., 2017)

As can be seen in Figure 2-2, the hydropedological behaviour of soil types can differ significantly. Figure 2-2 (a) illustrates a typical red coloured soil (top- and sub-soil). This soil type will typically have a vertical flow path throughput the soil profile. Water will therefore infiltrate the topsoil and freely drain into the profile to such an extent that the water rapidly reaches the bedrock. After reaching this layer, water will penetrate the ground water source or be transported horizontally towards lower laying areas. This soil type is known as a recharge soil, given its ability to recharge ground and surface water sources.

Figure 2-2 (b) illustrates interflow soils. Lateral flows are dominant in this soil type and occurs due to differences in the hydraulic conductivity of soil horizons. The "sp" soil horizon restricts vertical movement and promotes lateral flows at the A/B interface. The lighter colour in this profile indicates leaching which is caused by lateral flows which often occurs on top of a bedrock layer due to the impermeable nature thereof. Mottles often occur above this impermeable layer due to fluctuating water levels, see the magnified illustration in Figure 2-2 (b-i).

Figure 2-2 (c) illustrates responsive soil. This hydropedological soil type is characterised (in this case) by a dark top-soil and a grey coloured sub-soil. Other indicators include mottling and gleying. These soil types are saturated for very long periods. Therefore, rainfall is unlikely to infiltrate this layer and would likely be carried off via overland flow and are mostly fed by lateral sub-surface flows. Shallow soils are equally responsive in the sense that the soil profile will rapidly be saturated during precipitation, after which rainfall will be carried off by means of overland flows.

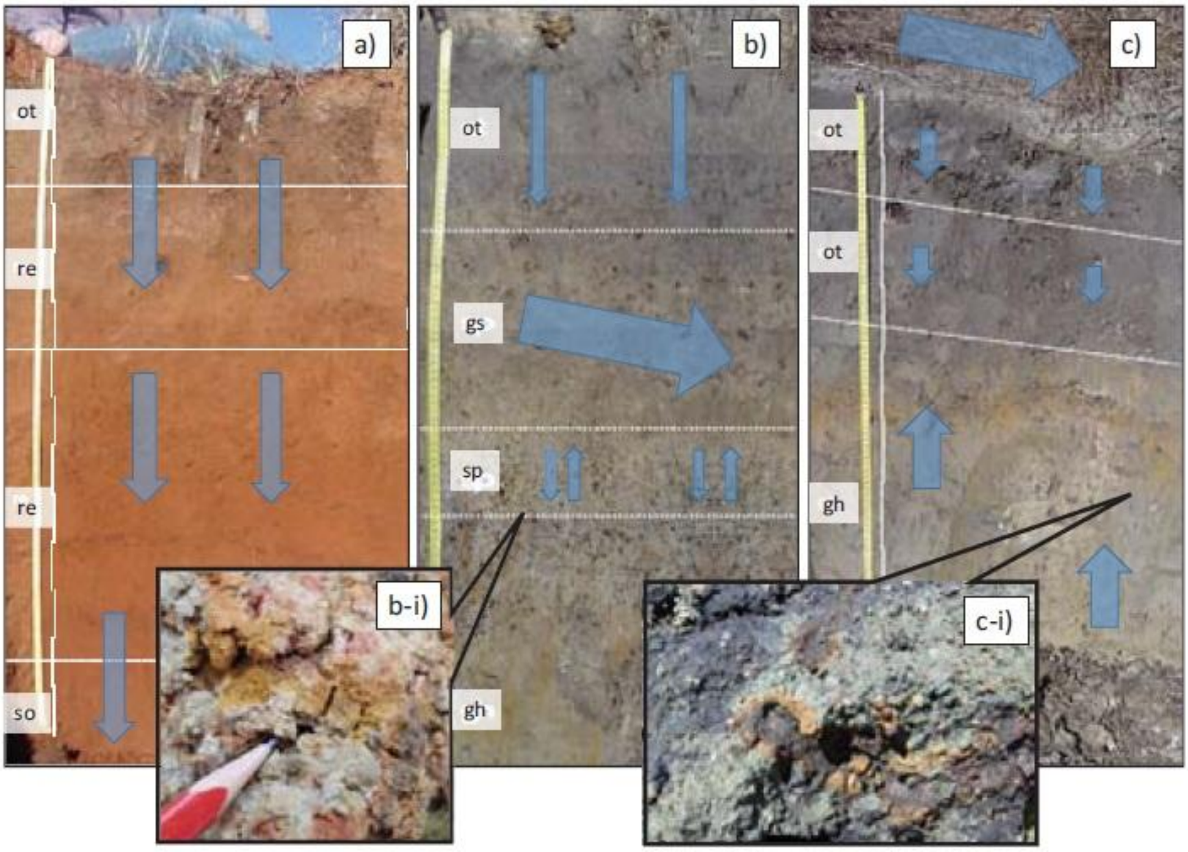

Figure 2-2 Illustration of different hydropedological soil types (van Tol et al., 2017)

A typical example of the hydropedological processes through a hillslope is illustrated in Figure 2-3. In this example, a recharge soil type is located at the upper reaches of the slope. Rainfall infiltrates this soil type and percolates vertically towards the bedrock. Water then, infiltrates into this bedrock given the permeability thereof and could now recharge groundwater or flow down-gradient towards soils in lower lying positions. The second soil type (the interflow zone) indicates lateral flows at the A/B interface and again at the soil/bedrock interface which feeds the responsive zone. The responsive zone is then simultaneously fed by lateral sub-surface flows and ground water recharge.

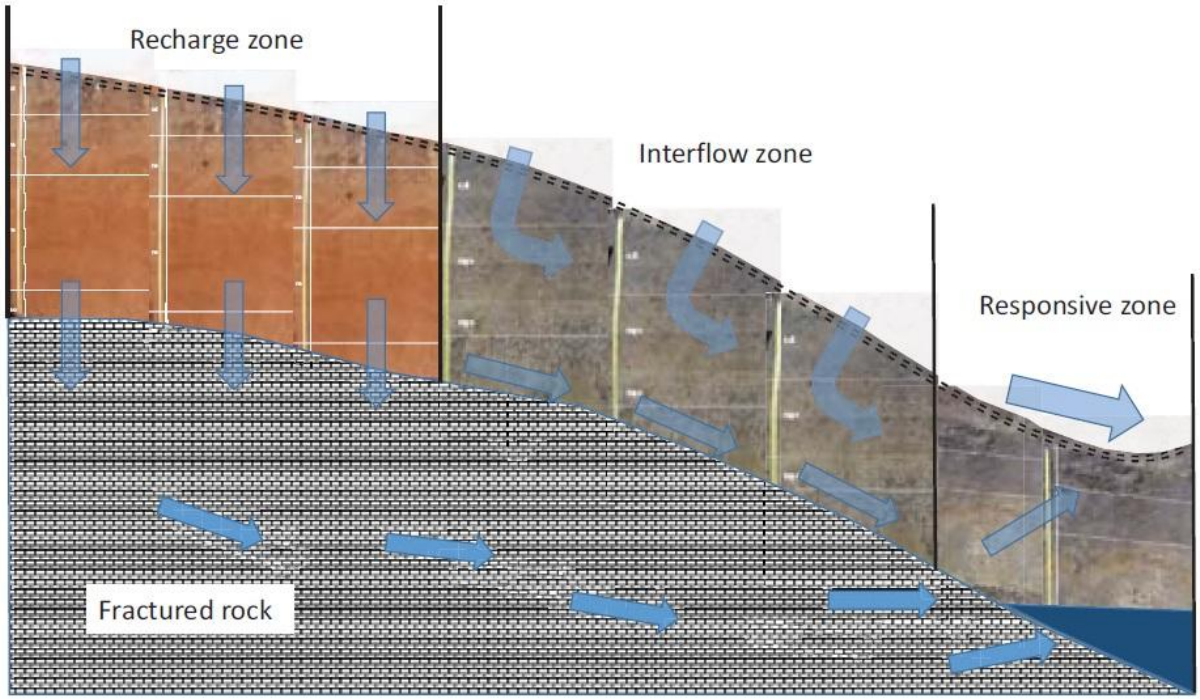

Figure 2-3 Illustration of different hydropedological soil types (van Tol et al., 2017)

The methodology of van Tol *et al.,* (2017) has since been updated to include a "stagnant" hydropedological type. According to van *Tol et al.,* (2019), four different hydropedological types exist, namely Recharge, Interflow, Responsive and Stagnating hydropedological types. These soil types are divided into seven subgroups depending on the morphology of the relevant soil form. The latest addition to this methodology, as mentioned, is known as a stagnating hydropedological type.

This soil type is characterised by restrictive movement of water through profiles (both laterally and vertically) and is dominated by evapotranspiration. The A- and B-horizon of such a soil type usually has a high permeability with morphological indicators indicating very little movement through the profile. Lime and iron concretions as well as cementation of silica are typical indicators of such a soil form.

3 Methodology

3.1 Desktop assessment

The following information sources were considered for the desktop assessment;

- Aerial imagery (Google Earth Pro);
- Land Type Data (Land Type Survey Staff, 1972 - 2006);
- Topographical river line data;
- Contour data (5 m); and
- Mucina & Rutherford (2006).

3.2 Field Procedure

The slopes within the project area have been assessed during the desktop assessment to identify possible transects (Figure 3-1) that will represent typical terrain and soil distribution patterns. These locations were then altered slightly during the survey depending on the extent of vegetation, slopes, access, and any features that will improve the accuracy of data acquired.

3.2.1 Identification of Soil Types and Hydrological Soil Types

Soil types have been identified according to the South African soil classification system (Soil Classification Working Group, 2018) after which the link between soil forms and hydropedological response were established (van Tol & Le Roux, 2019), and the soils regrouped into various hydropedological soil types as shown in Table 3-1 and the revised updated hydropedological soil types (van Tol and Bouwer, 2024) in Table 3-2.

Table 3-1 Hydrological soil types of the studied hillslopes (van Tol et al., 2019)

Hydrological soil type	Description	Subgroup	Symbol
Recharge	Soils without any morphological indication of saturation. Vertical flow through and out the profile into the underlying bedrock is the dominant flow direction. These soils can either be shallow on fractured rock with limited contribution to evapotranspiration or deep freely drained soils with significant contribution to evapotranspiration.	Shallow	
		Deep	
Interflow (a/b)	Duplex soils where the textural discontinuity facilitates build-up of water in the topsoil. Duration of drainable water depends on rate of ET, position in the hillslope (lateral addition/release) and slope (discharge in a predominantly lateral direction).	A/B	
Interflow (soil/bedrock)	Soils overlying relatively impermeable bedrock. Hydromorphic properties signify temporal build of water on the soil/bedrock interface and slow discharge in a predominantly lateral direction.	Soil/Bedrock	
Responsive (shallow)	Shallow soils overlying relatively impermeable bedrock. Limited storage capacity results in the generation of overland flow after rain events.	Shallow	
Responsive (saturated)	Soils with morphological evidence of long periods of saturation. These soils are close to saturation during rainy seasons and promote the generation of overland flow due to saturation excess.	Saturated	
Stagnating	In these soils outflow of water is limited or restricted. The A and/or B horizons are permeable but morphological indicators suggest that recharge and interflow are not dominant. These includes soils with carbonate accumulations in the subsoil, accumulation and cementation by silica, and precipitation of iron as concretions and layers. These soils are frequently observed in climate regions with a very high evapotranspiration demand. Although infiltration occurs readily, the dominant hydrological flow path in the soil is upward, driven by evapotranspiration.		

Table 3-2 Revised hydrological soil types of the representative hillslopes (van Tol et al and Bouwer, 2024)

Hydrological soil type	Description		Subgroup	Symbol
Recharge	Soils without any morphological indication of saturation. Vertical flow through and out the profile into the underlying bedrock is the dominant flow direction. These soils can either be shallow on fractured rock with limited contribution to evapotranspiration or deep freely drained soils with significant contribution to evapotranspiration.	These soils can either be shallow on fractured rock with limited contribution to evapotranspiration	Shallow	
		Deep freely drained soils which can contribute significantly to evapotranspiration	Deep	
		Soils with high clay contents and low conductivity	Slow	
Interflow	Three types of interflow soils occur, those where interflow is dominant at the A/B horizon interface, those where interflow is dominant at the soil/bedrock interface and those with morphological indicators of periodic saturation, but low hydraulic conductivities will limit significant flow through these soils.	This type occurs in duplex soils where the textural discontinuity facilitates build-up of water in the topsoil	shallow	
		Freely drained soils overly relatively impermeable bedrock. Hydromorphic properties signify periodic saturation associated with a water table at the soil bedrock/interface	Deep	
		Actual flow volumes and lateral transport is minimal as most of the water is either stagnant or evapotranspirated before it could make a significant contribution to streams or wetlands in lower lying positions.	Slow	
Responsive	Soils with morphological evidence of long periods of saturation. These soils are close to saturation during rainy seasons and promote the generation of overland flow due to saturation excess.	These soils 'respond' quickly to rain events and typically generate overland flow. These soils can either be shallow and overly relatively impermeable bedrock, with limited storage capacity which is quickly exceeded following a rain event	Shallow	
		They are soils with morphological indications of long periods of saturation. Since these soils are close to saturation during the rainy season additional precipitation will typically flow overland due to saturation excess	Wet	
		Soils with crusts or very low surface infiltration rates will promote overland flow due to infiltration excess, also known as Hortonian overland flow.	Hortonian	

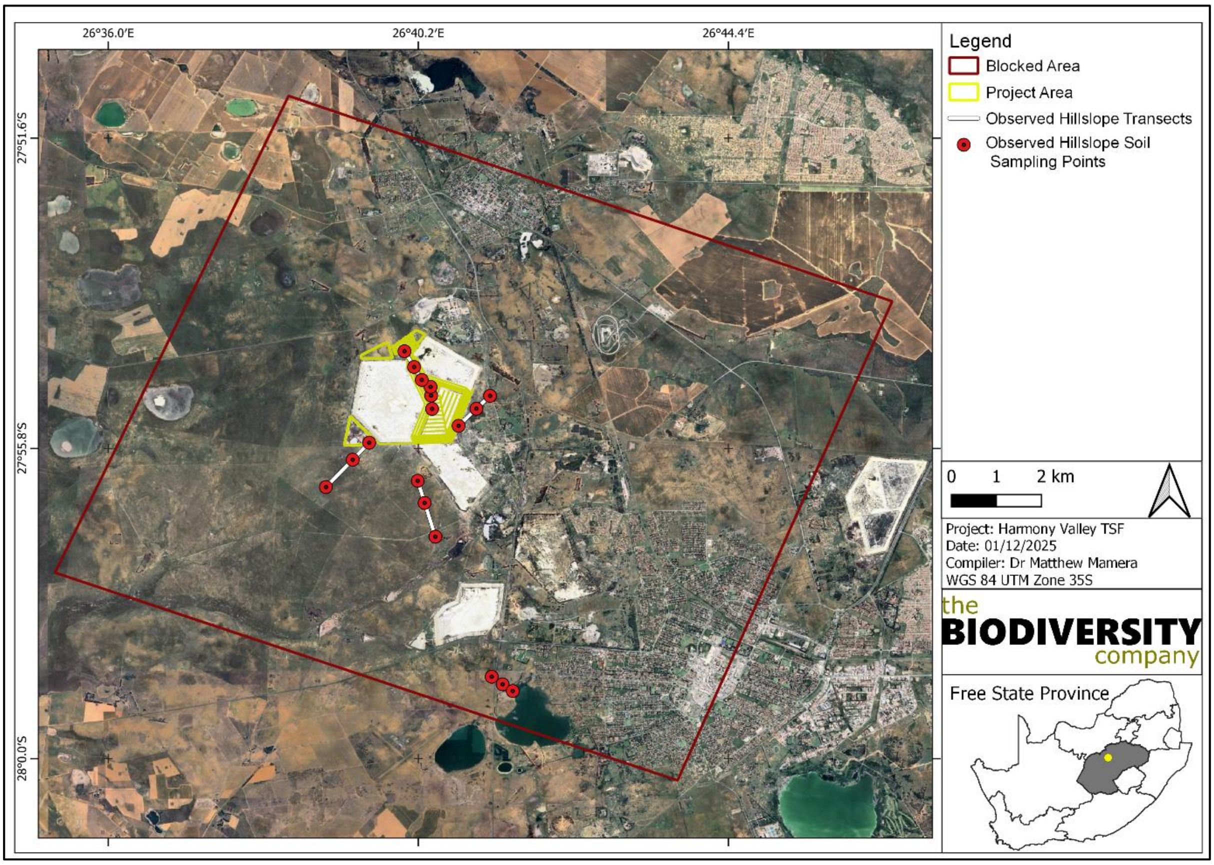

Figure 3-1 Transects and Observation Sites

4 Results and Discussions

4.1 Desktop Information

4.2 Climate

The project area falls within the Highveld Alluvial, Highveld salt Pans, Vaal-Vet Sandy Grassland and Western Free State Clay Grassland vegetation. The project area is characterised as a warm temperate climate, with high summer rainfalls which are concentrated from November to March, and severe frost occurrence in winter (37 days per year on average). The mean annual precipitation (MAP) is at 530 mm (Mucina & Rutherford, 2006: see below).

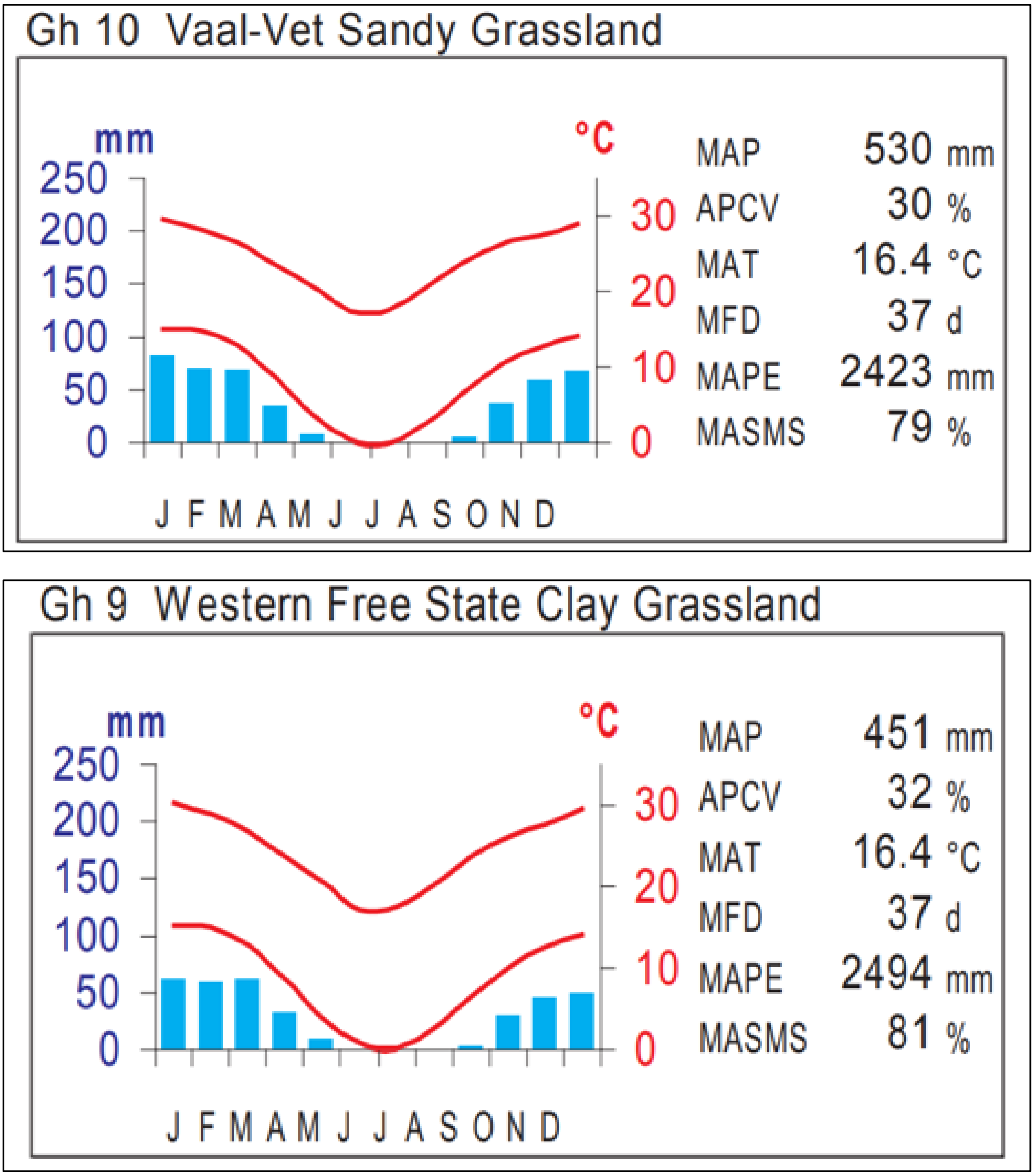

Figure 4-1 Summarised climate for the region (Mucina & Rutherford, 2006)

4.2.1 Vegetation

The Highveld Alluvial, Highveld salt Pans, Vaal-Vet Sandy Grassland and Western Free State Clay Grassland vegetation is widely distributed in the Free State and North-West provinces, extending through the central portion of the Vredefort Dome around Parys and Vredefort. The altitude of this vegetation types is between 1 340 meters above sea level (masl) to 1 520 meters above sea level (Mucina & Rutherford, 2006).

The landscape features include slightly undulating plains with mainly short, *Themeda triandra*-dominated grassland, though mostly grazed and often degraded. One of the most scenic landscapes of the Highveld, with the Vaal River cutting through the mountainous landscape (Savanna Biome) of the Vredefort Dome. Big boulders of granite are conspicuous in the area, creating microhabitats for a diversity of plants species (Mucina & Rutherford, 2006).

4.2.2 Geology & Soils

The geology of the area is characterised with Sandstone, shale, mudstone, sandstone, dolerite, and shale (Volksrust formation, Ecca and Beaufort group). Aeolian and possibly colluvial sand overlies the rock. Various soil types which occur in the landscape includes, the Hutton, Mispah and Avalon forms, representing plinthic soils. The landscape is associated with the Ba and Bc the land types.

According to the land type database (Land Type Survey Staff, 1972 - 2006), the project area is characterised by the Ae 40, Bd 20, and Dc 9 land type. The Ae 40 land type is mainly characterised with Hutton, Mispah, Katspruit and Rensburg soil forms with occurrence of other soils within the landscape. The Bd 20 land type is mainly characterised with Clovelly, Hutton, and Valsrivier soil forms with occurrence of other soils within the landscape. The Dc 9 land type is mainly characterised with Hutton, Swartland, and Willowbrook soil forms according to the Soil classification working group, (1991), with the occurrence of other soils and rocky areas within the landscape. The Bd land type commonly has plinthic catena: upland duplex and margalitic soils rare; Eutrophic, red soils not widespread. The Dc land types commonly have prismacutanic and pedocutanic diagnostic horizons. Other horizons associated to the landscape includes vertic, melanic and red structure diagnostic horizons. The relevant land types of terrain units for the Ae 40, Bd 20 and Dc 9 land types are presented below.

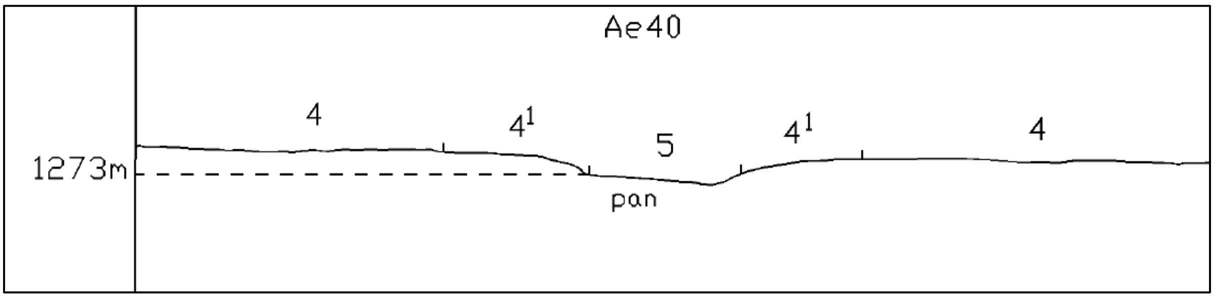

Figure 4-2 Illustration of land type Ae 40 terrain units (Land Type Survey Staff, 1972 - 2006)

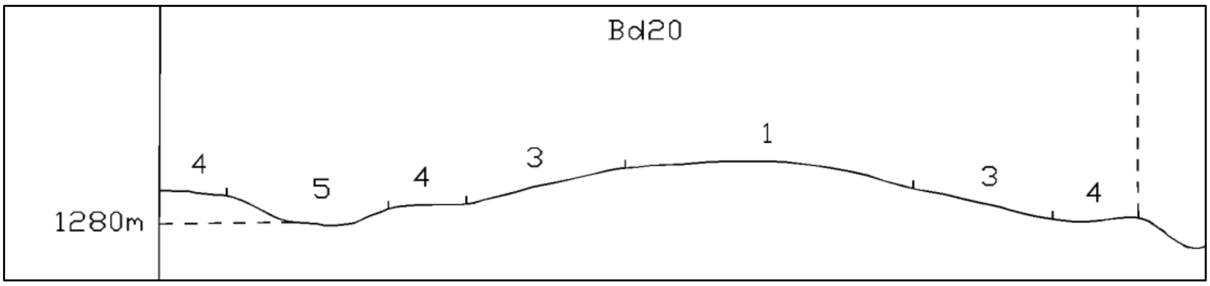

Figure 4-3 Illustration of land type Bd 20 terrain units (Land Type Survey Staff, 1972 - 2006)

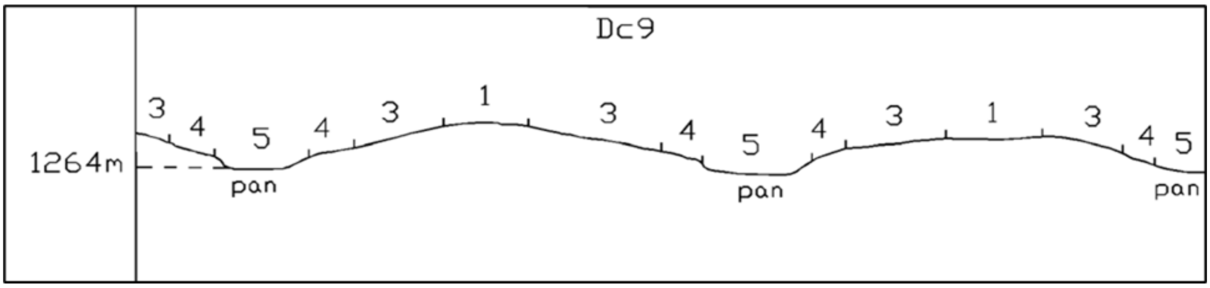

Figure 4-4 Illustration of land type Dc 9 terrain units (Land Type Survey Staff, 1972 - 2006)

Table 4-1 Soils expected at the respective terrain units within the Ae 40 land type (Land Type Survey Staff, 1972 – 2006)

Terrain Units					
4 (92%)		**4 (1) (4%)**		**5 (4%)**	
Hutton	89%	Mispah	50%	Katspruit, Rensburg	75%
Clovelly	6%	Swartland	25%	Swartland	25%
Avalon	3%	Oakleaf	25%		
Bainsvlei	2%				

Table 4-2 Soils expected at the respective terrain units within the Bd 20 land type (Land Type Survey Staff, 1972 – 2006)

Terrain Units							
1 (55%)		**3 (40%)**		**4 (3%)**		**5 (2%)**	
Clovelly	65%	Clovelly	45%	Hutton	60%	Valsrivier	55%
Avalon	30%	Hutton	25%	Valsrivier	18%	Arcadia, Rensburg	20%
Valsrivier	3%	Avalon	20%	Avalon	10%	Katspruit	15%
Katspruit	1%	Valsrivier	8%	Clovelly	5%	Oakleaf	10%
Arcadia, Rensburg	1%	Katspruit	1%	Oakleaf	5%		
		Arcadia, Rensburg	1%	Katspruit	1%		
				Arcadia, Rensburg	1%		

Table 4-3 Soils expected at the respective terrain units within the Dc 9 land type (Land Type Survey Staff, 1972 – 2006)

Terrain Units							
1 (10%)		**3 (27%)**		**4 (41%)**		**5 (22%)**	
Hutton	100%	Hutton	88%	Swartland	28%	Willowbrook	91%
		Clovelly	11%	Valsrivier	23%	Valsrivier	5%
		Oakleaf	11%	Sterkspruit	17%	Arcadia	2%
				Arcadia	4%	Sterkspruit	1%
				Estcourt	3%	Estcourt	1%
				Mispah	1%		

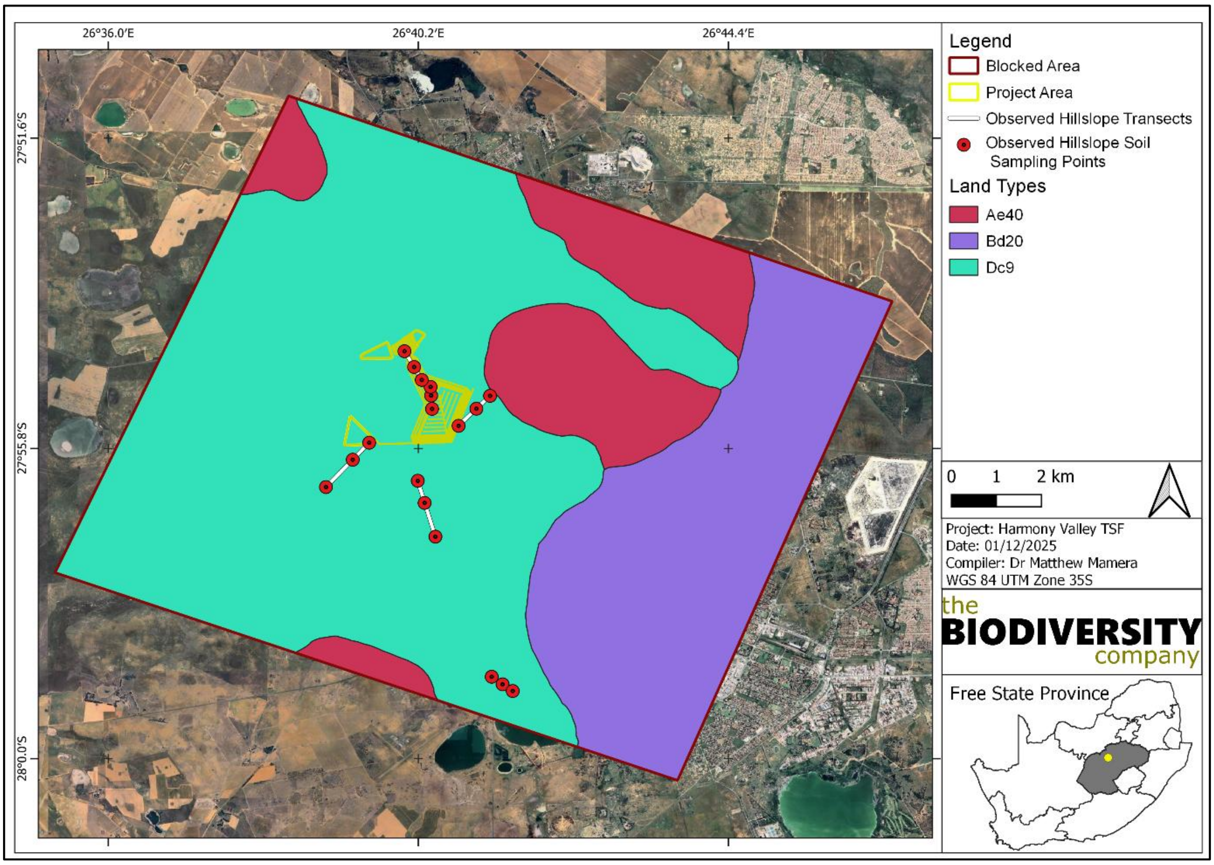

Figure 4-5 Land types present within the Harmony Valley Tailings Storage Facility project`s surroundings

4.3 Identified Soil Forms

The following soil forms were identified on-site whilst surveying the relevant transects;

- Ermelo (Orthic topsoil on top of a thick yellow brown apedal horizon);
- Avalon (Orthic topsoil on top of a yellow brown apedal horizon with a soft plinthic horizon below);
- Pinedene (Orthic topsoil on top of a yellow brown apedal horizon with a gleyic horizon below);
- Molopo (Orthic topsoil on top of a yellow brown apedal horizon, with a soft carbonate horizon below);
- Etosha (Orthic topsoil on top of a neocutanic horizon, with a soft carbonate horizon below);
- Swartland (Orthic topsoil on top of a pedocutanic horizon, with a lithic horizon);
- Katspruit (Orthic topsoil on top of a gleyic horizon); and
- Witbank (Transported technosols or material from mining activities).

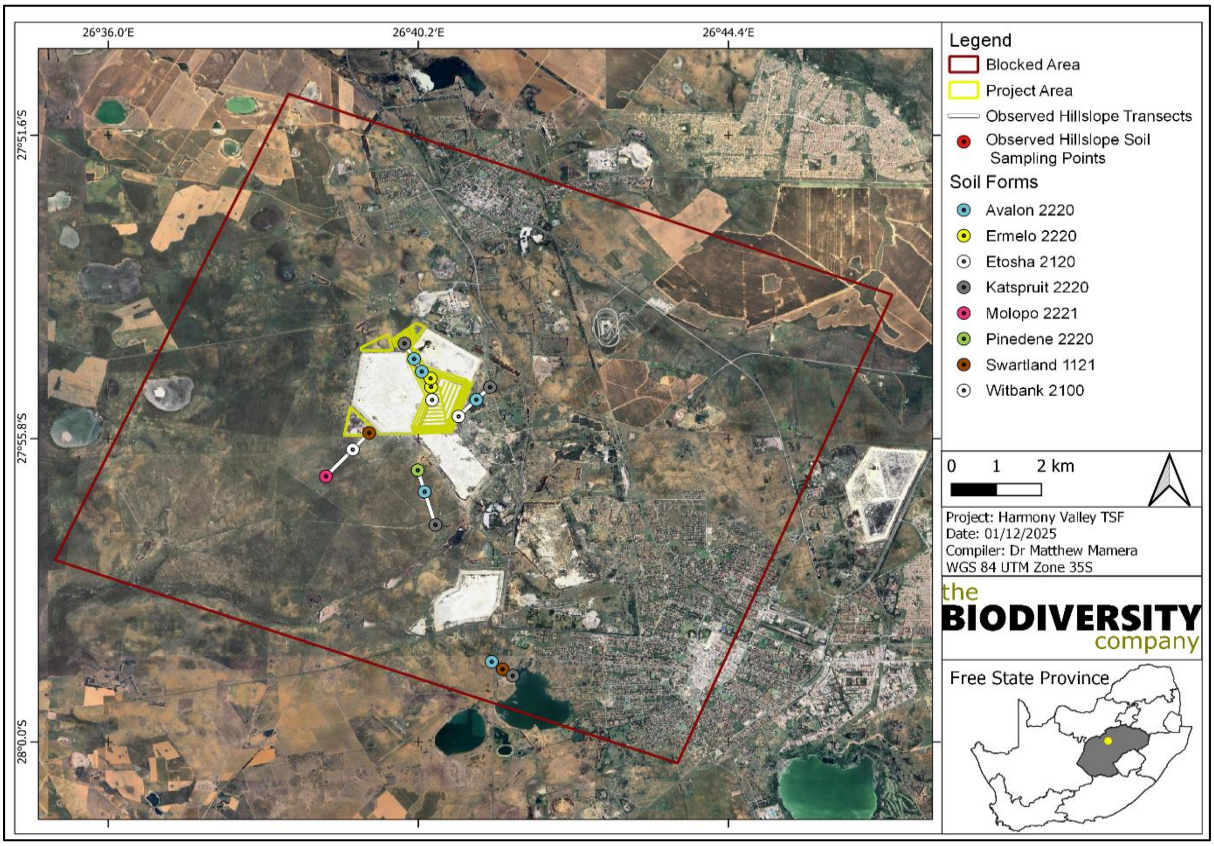

Figure 4-6 Soil forms and the respective soil families identified within representative hillslope transects

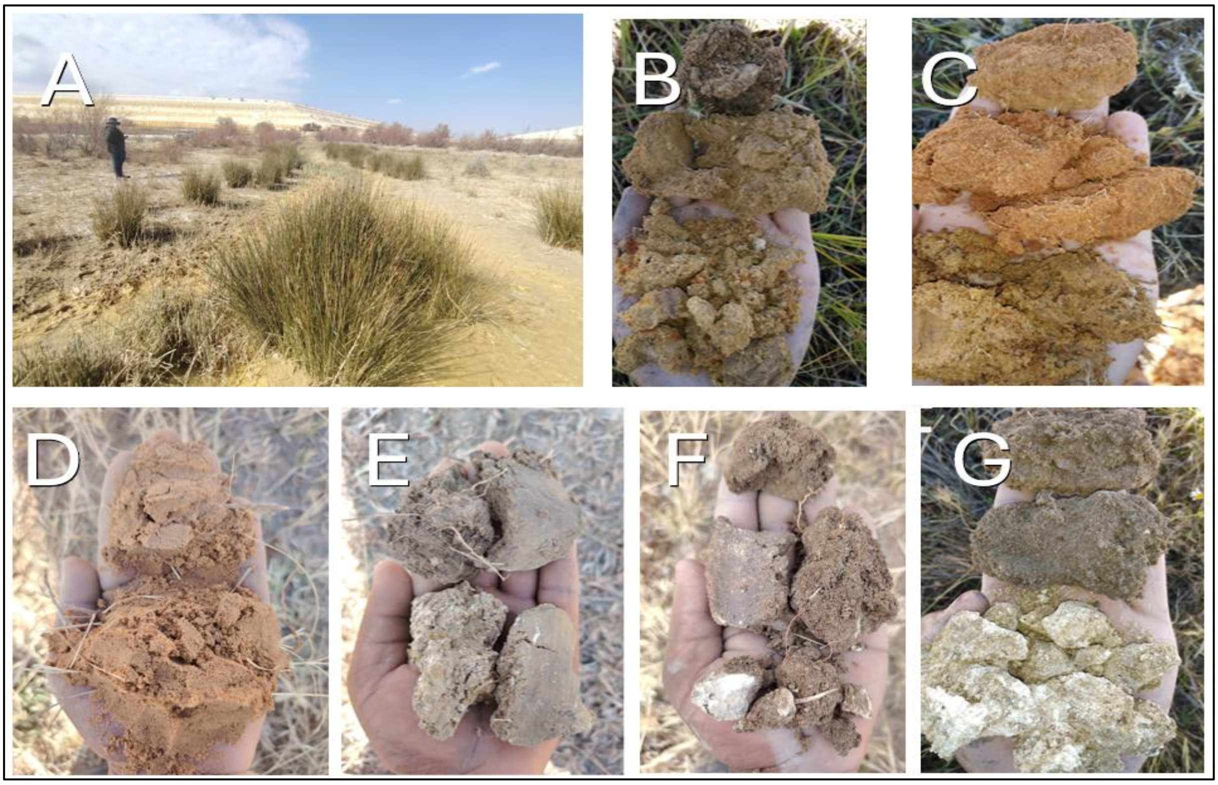

Figure 4-7 Diagnostic soil horizons identified on-site: A) Technosols. B-D) Orthic topsoil horizon with yellow brown apedal subsurface E-F) Pedocutanic subsurface horizon. G) Neocarbonate horizon with soft carbonate horizon.

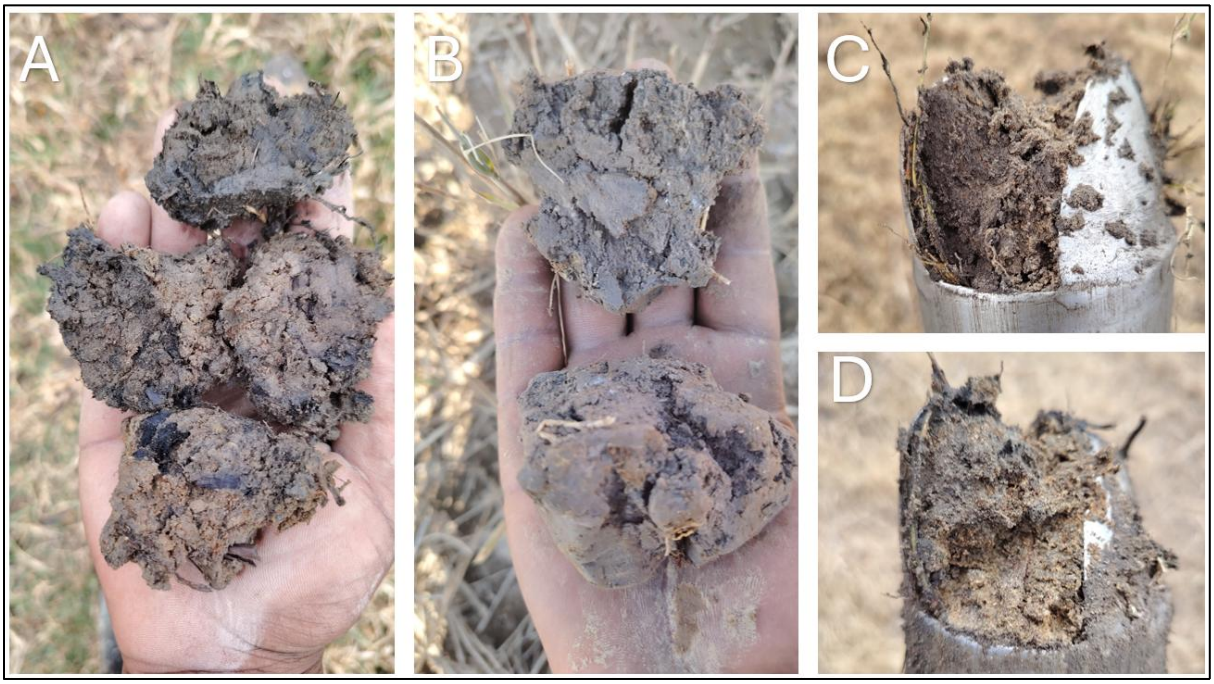

Figure 4-8 ***Diagnostic soil horizons identified on-site: A-D) Orthic topsoil with gley horizon.***

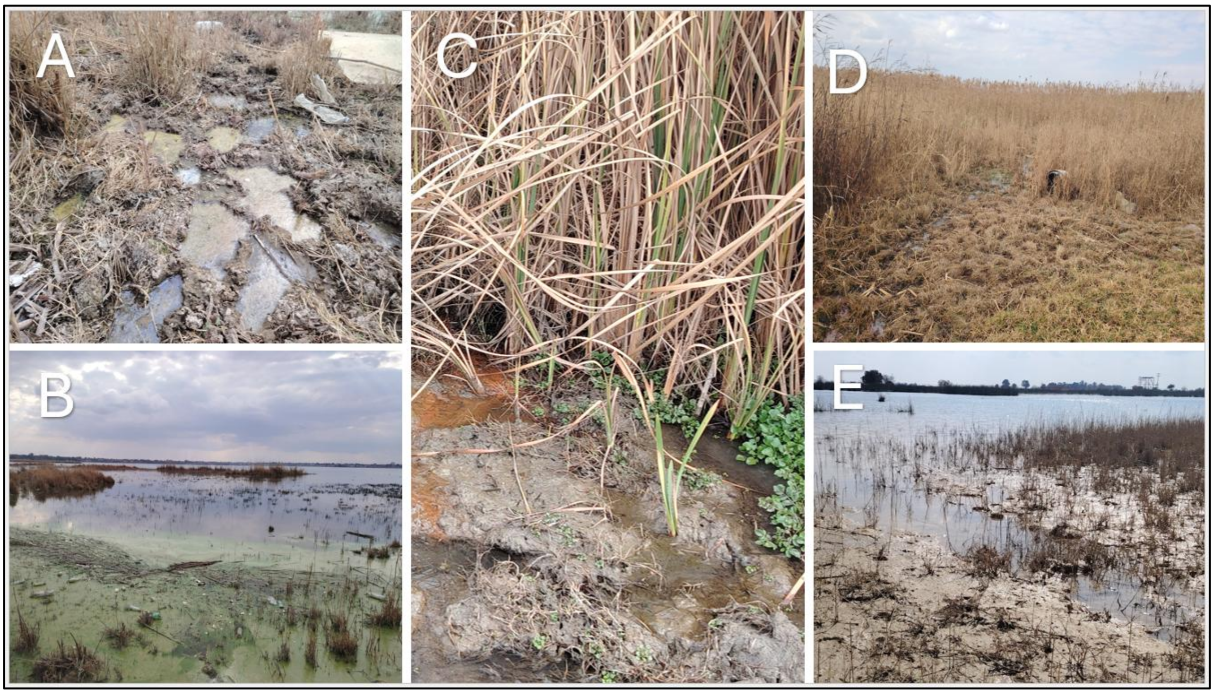

Figure 4-9 ***Diagnostic soil horizons identified on-site: A-E) Examples of surface return/overland flows and lateral flows pathways.***

4.4 Hillslope Hydrology

The survey was conducted to obtain information regarding the soil morphology to their respective soil family levels and hydropedological flow paths relevant to the hillslope by means of several representative transects (see Table 4-4). The hillslope hydrology of slopes intersected by the proposed Harmony Valley Tailings Storage Facility Project and associated infrastructure are characterised by their distinct hydropedological patterns. The majority of the slopes for the first distinctive hydropedological patterns are characterised by recharge (deep) and interflow (deep) (see Figure 4-10) hydropedological types. These patterns occur from the crest to the midslope transecting to interflow (deep) at the valley bottom merging to a watercourse. The majority of the slopes for the second and third distinctive hydropedological patterns are characterised by recharge (deep and slow) and responsive (shallow) (see Figure 4-10 to Figure 4-11) hydropedological types. These patterns occur from the crest to the midslope transecting to either recharge (deep) or recharge (slow) at the valley bottom merging to a watercourse.

The fourth and fifth distinctive hydropedological patterns are characterised with recharge (shallow and deep) and responsive (wet) (Figure 4-13 to Figure 4-14). These patterns occur from the crest to midslope transecting to responsive (wet) in the valley bottom section merging to the watercourse. The sixth distinctive hydropedological patterns are characterised with interflow (deep), recharge (slow) and responsive (wet) (Figure 4-12). These patterns throughout the hillslope (i.e. Interflow (slow and deep) from the crest to the midslope with a recharge (slow) type transecting to responsive (wet) in valley bottom section merging to the watercourse. Restrictions in the water flow occurs within the responsive soils due to the presence of a high clay content and partially or unfractured parent material (see Figure 4-12 to Figure 4-15).

Table 4-4 Identified hillslope dominant soil forms and hydropedological groups

Terrain Morphological Unit (TMU)							
1&2		3		4		5	
Soil form	Hydroped	Soil form	Hydroped	Soil form	Hydroped	Soil form	Hydroped
Witbank 2100	Responsive (Shallow)	Ermelo 2220	Recharge (deep)	Ermelo 2220	Recharge (deep)	Ermelo 2220	Recharge (deep)
Witbank 2100	Responsive (Shallow)	Avalon 2220	Interflow (Deep)	Avalon 2220	Interflow (Deep)	Katspruit 2220	Responsive (Wet)
Avalon 2220	Interflow (Deep)	Avalon 2220	Interflow (Deep)	Avalon 2220	Interflow (Deep)	Katspruit 2220	Responsive (Wet)
Molopo 2221	Recharge (Slow)	Etosha 2120	Recharge (Slow)	Etosha 2120	Recharge (Slow)	Swartland 1121	Recharge (Slow)
Pinedene 2220	Interflow (Slow)	Avalon 2220	Interflow (Deep)	Avalon 2220	Interflow (Deep)	Katspruit 2220	Responsive (Wet)
Avalon 2220	Interflow (Deep)	Swartland 1121	Recharge (Slow)	Swartland 1121	Recharge (Slow)	Katspruit 2220	Responsive (Wet)

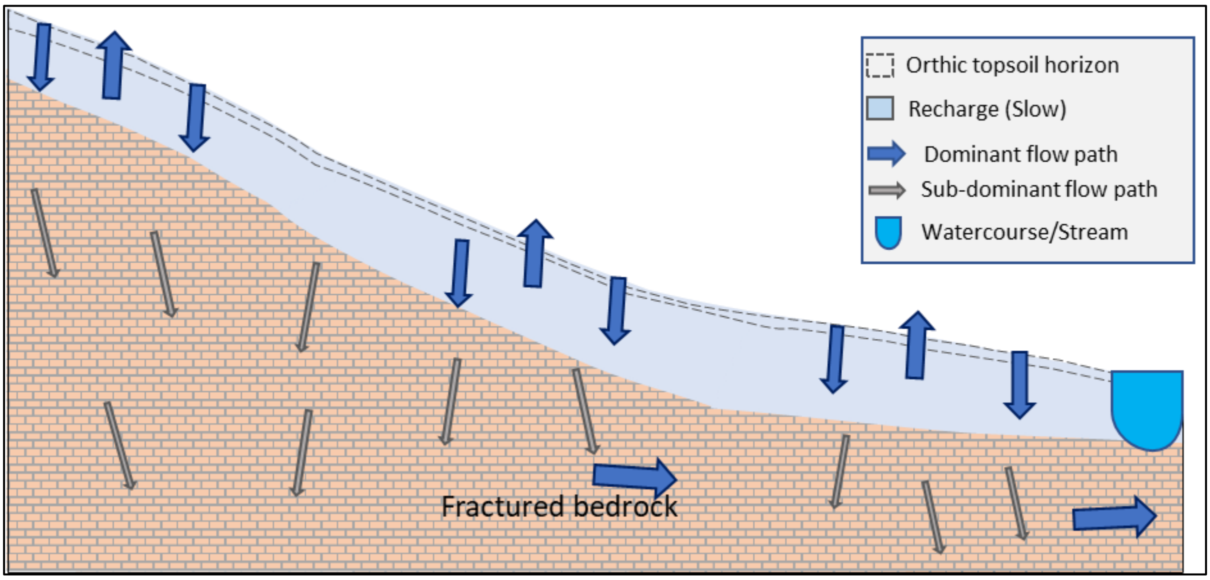

Figure 4-10 Hillslope hydrology one of six of the distinct hydropedological patterns prior to construction of the existing and proposed Harmony Valley Tailings Storage Facility Project and associated infrastructure

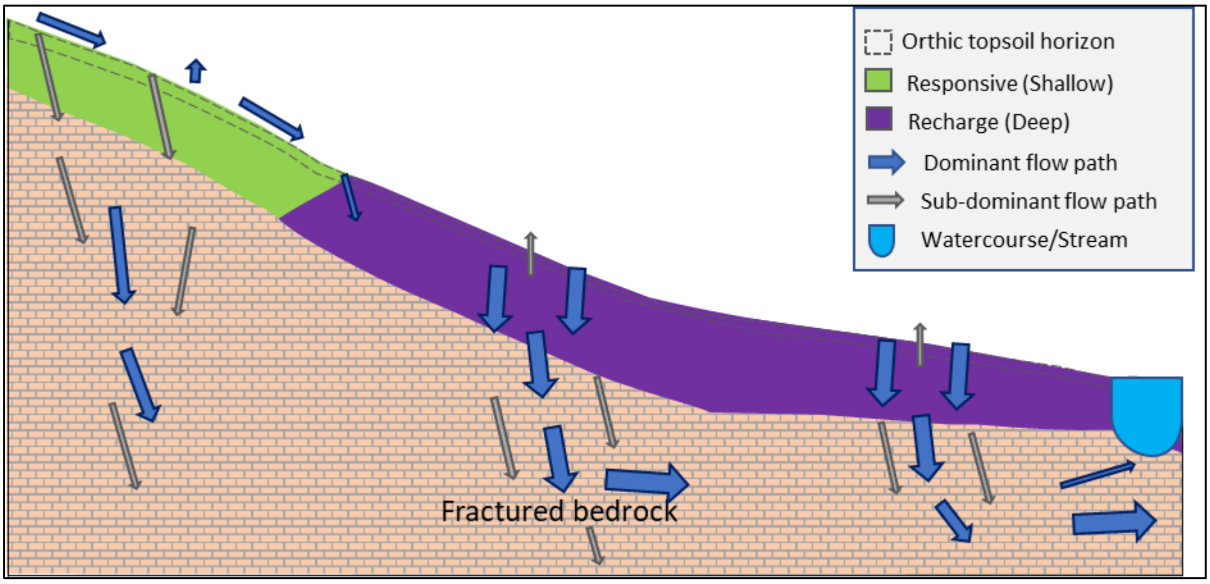

Figure 4-11 Hillslope hydrology two of six of the distinct hydropedological patterns prior to construction of the existing and proposed Harmony Valley Tailings Storage Facility Project and associated infrastructure

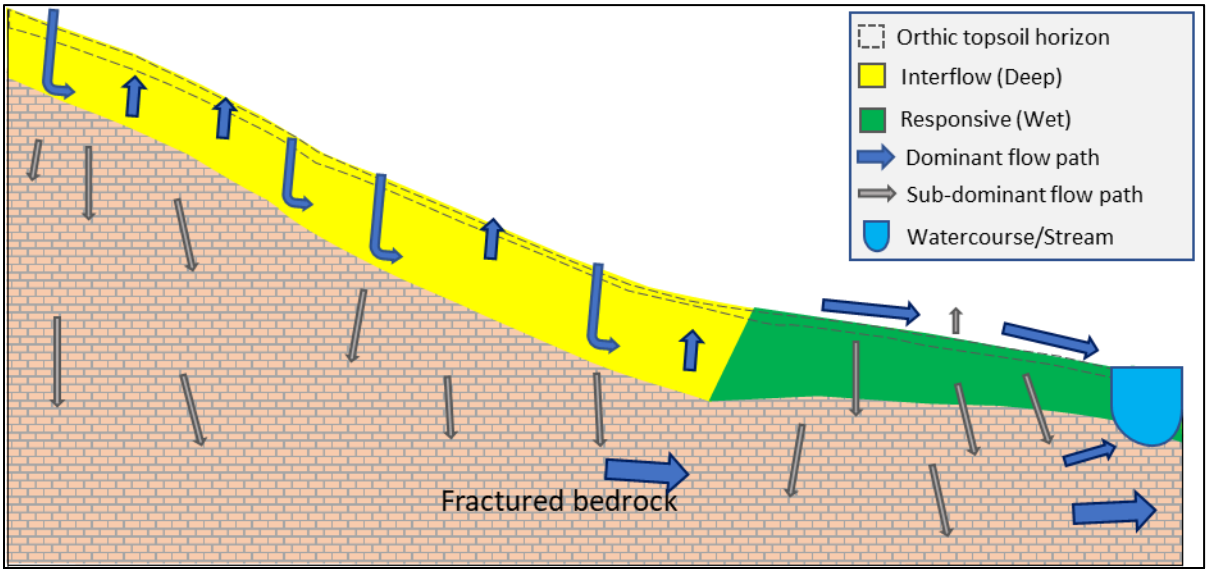

Figure 4-12 Hillslope hydrology three of six of the distinct hydropedological patterns prior to construction of the existing and proposed Harmony Valley Tailings Storage Facility Project and associated infrastructure

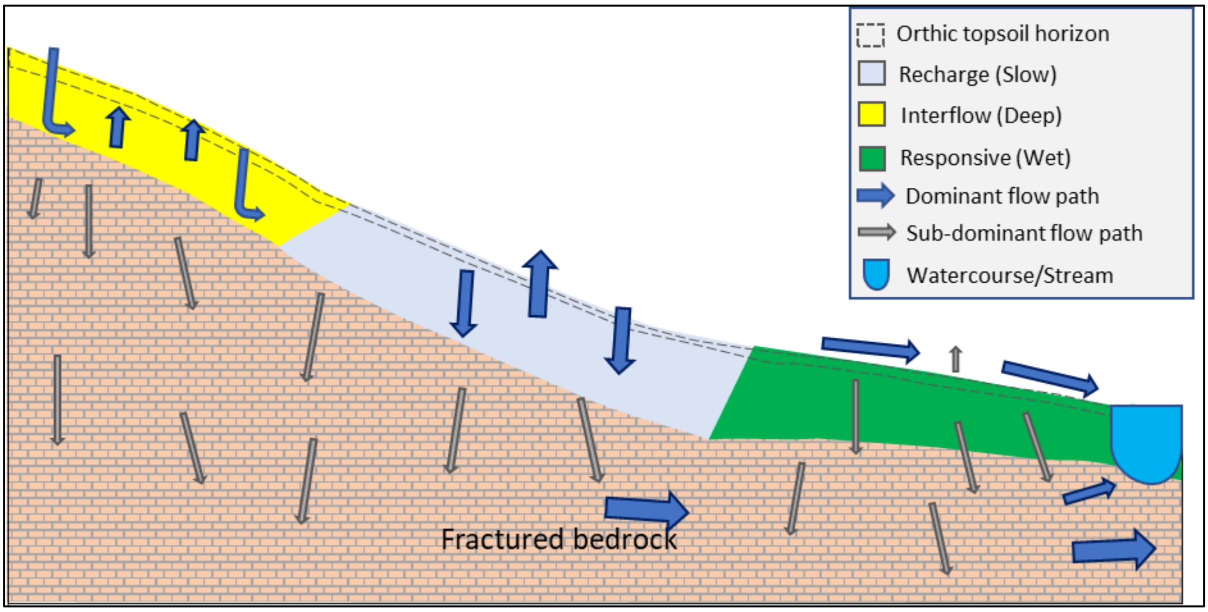

Figure 4-13 ***Hillslope hydrology four of six of the distinct hydropedological patterns prior to construction of the existing and proposed Harmony Valley Tailings Storage Facility Project and associated infrastructure***

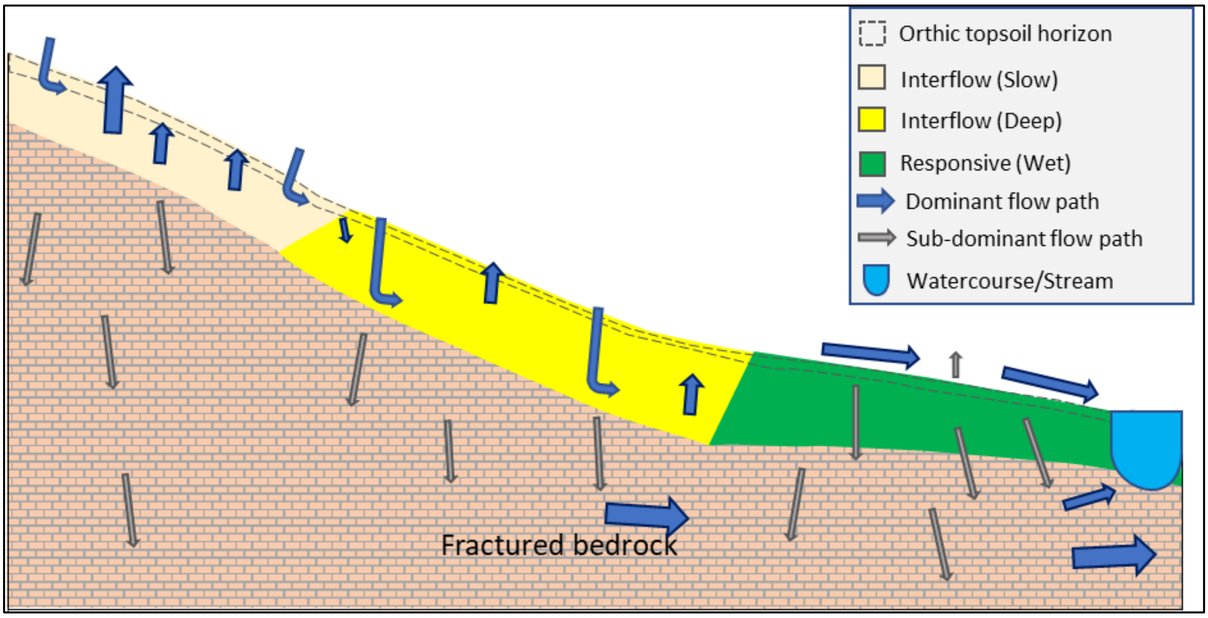

Figure 4-14 ***Hillslope hydrology five of six of the distinct hydropedological patterns prior to construction of the existing and proposed Harmony Valley Tailings Storage Facility Project and associated infrastructure***

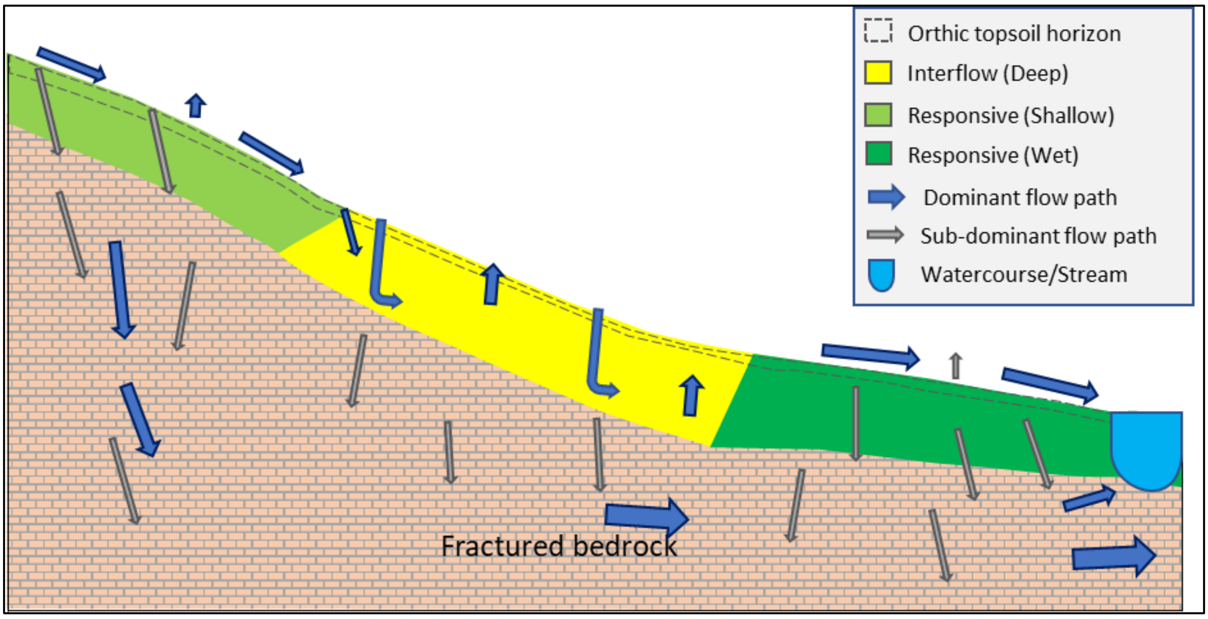

Figure 4-15 Hillslope hydrology six of six of the distinct hydropedological patterns prior to construction of the existing and proposed Harmony Valley Tailings Storage Facility Project and associated infrastructure

The deep Ermelo soils identified on-site are characterised with well drained profiles. The Ermelo soil forms consist of an orthic topsoil with a thick yellow brown apedal horizon below. Clear horizons of apedal horizons were evident and visible in the profile. These profiles are characterised by extremely high permeability soil hydraulic conductivity (Ks) rates, including the lower lithic horizon which can also be available below the B1 subsurface horizon in most cases. The Ae 4, Bd 20 and Dc 9 land types are commonly characterized with these soils from the crest to the lower midslope areas.

No signs of leaching or oxidation/reduction processes were identified throughout the soil profiles, which, together with the high Ks emphasises rapid vertical recharge of the groundwater storage as being the dominant flow path.

Some of the upper regions are characterised by interflow (Slow) hydropedological types. Flows in the interflow (Slow) decreases due to the presence of duplex soils or a bedrock layer, eventually becoming lateral flows in the topsoil towards wetlands and the watercourse. This can also result in surface stagnations. If the evaporative demand is higher most of the water is also lost through evaporation processes before reaching the lower wetlands or watercourses. The soils associated to these areas include, Iswepe soil forms with an albic B1 horizon with either a fractured or impermeable bedrock below.

Some of the midslope areas are characterized by recharge (Slow) hydropedological types. These soils commonly have high clay contents in the B1 horizon with low conductivity; volume of water flow is low due to the textural discontinuity resulting in surface stagnations. If the evaporative demand is higher most of the water is lost through evaporation processes. The soils associated to these areas include, Etosha, Molopo soil forms with a soft carbonate B2 horizon and Swartland soil forms with a pedocutanic B1 horizon.

Soft carbonate horizons are characterised with a weakly developed structure subsoil horizon composed of calcium and or magnesium carbonates to the extent that the morphology of this layer is dominated by carbonates with white to pale yellow colours. The layer is associated with lower slope positions in the terrain under arid to semi-arid climatic conditions (Soil Classification Working Group, 1991).

Pedocutanic horizons are well-developed, moderately strong subsoil horizon with distinct cutans on the ped surface. The texture of this horizon ranges from sandy clay loamy to dense clay soil, with a clear textural contrast from the sandy overlying horizon. A clear textural contrast between a sandier surface horizon and a higher clay upper subsurface horizon. Peds commonly exhibit brown to dark brown matrix colours while yellowish to brownish colour variation within ped interiors is permitted. Many red pedocutanic horizons derive their colouration from the underlying red to maroon shales and mudstones (Soil Classification Working Group, 2018).

Some of the midslope areas are characterized by interflow (deep) hydropedological types. These soils commonly have a low conductivity on the soil/bedrock interface; volume of water flow is low due to the textural discontinuity from the upper B2 horizon resulting in lateral flows. Presence of a semi-permeable or impermeable bedrock will cause lateral flows to change. Most of the water flows occur on the interface as lateral flows as due to restrictions in percolation of the parent material resulting in saturation conditions to overlying subsurface horizon. The soils associated to these areas include Avalon soil forms with a soft plinthic subsurface horizon.

Soft plinthic horizons have accumulations of iron (and in some cases manganese) as hydroxides and oxides with the presence of high chroma striations and concretions with black matrixes. This diagnostic horizon forms due to fluctuating levels of saturation. The iron and manganese concentration result in soft marks within the soil matrix which transform in concretions with high consistencies (Soil Classification Working Group, 1991).

The valley bottom regions are characterised by interflow (deep), recharge (slow or deep) and responsive (wet) hydropedological types. The Ae 4, Bd 20 and Dc 9 land types are commonly characterized with these soils in the footslope or valley bottom landscapes areas. The soil form relevant to the responsive (wet) hydropedological types, observation point is that of the Katspruit soil forms. The Katspruit soil forms are characterised by gley horizon as the subsoil, which is indicative of prolonged/permanently saturated soils which result in the formation of “responsive soils.” Responsive soils will be subject to overland/return flow during precipitation events (due to the naturally high-water content which will ensure rapid saturation). Between rainfall events, these soil forms will steadily feed watercourses and will lose moisture by means of Evapotranspiration (ET).

Gley horizons that are well developed and have homogenous dark to light grey colours with smooth transitions. Stagnant and reduced water over long periods is the main factor responsible for the formation of a gley horizon and could be characterised by green or blue tinges due to the presence of a mineral called Fougerite which includes sulphate and carbonate complexes. Even though grey colours are dominant, yellow, and/or red striations can be noticed throughout a gley horizon. The structure of a gley horizon mostly is characterised as strong pedal, with low hydraulic conductivities due to high clay content (clayey texture), although sandy gley horizons are also known to occur. The gley soil form commonly occurs at the toe of hillslopes (or benches) where lateral water inputs (sub-surface) are dominant and the underlaying geology is characterised by a low hydraulic conductivity. The gley horizon usually is second in diagnostic sequence in shallow profiles yet is known to be lower down in sequence and at greater depths (Soil Classification Working Group, 2018).

4.5 Conceptual Impact Prediction

The Harmony Valley Tailings Storage Facility Project and associated infrastructure will have acceptable impacts on the hydropedology behaviour of most relevant hillslopes, due to the position of the development area and associated infrastructure like the TSF, Return Water Dam (RWD) and associated pipelines (crest, lower and mid-slope).

The following hydrological flows are expected from the representative hillslopes;

1. In the upper crest areas (Figure 4-18), vertical flows are expected to remain dominate due the presence of recharge soils such as the recharge (slow) (Molopo soil forms). The presence of the TSF, RWD, pipelines, and other associated infrastructure will have minimal interception to the vertical flows;

2. The vertical flows will eventually become sub-dominate in the fracture or semi-permeable parent material; lateral flows will also occur towards the midslope areas. If the evaporation process is high some of the water will be lost especially on the available recharge shallow and slow from the topsoil layers.

3. In areas with recharge (slow) (Figure 4-16), interflow (slow) with Pinedene soils (Figure 4-20) and responsive (shallow) with Witbank soils (Figure 4-17 and Figure 4-21), overland flow or surface runoffs will occur following rainfall events which contributes towards the midslope and lower areas in the landscape.

4. In the midslope vertical flows are still prominent, even though presence of duplex soils (i.e. Swartland soil forms) in some areas will promote the percolation effect as most of the water is stored in these horizons. Lateral flows which are also sub-dominate will become prominent, contributing to the surface flows in the lower landscapes as overland flows (see Figure 4-18, Figure 4-20 and Figure 4-21). Some of these flows will be intercepted with the excavation drainage channels or pipelines or the existing and proposed TSF and RWD, which can result in the discontinuation of the flow paths. The draw-back effect can also occur towards the bedrock intercepted with such infrastructure. Such flows are expected to become vertical flows eventually recharging groundwater stores.

5. In the lower midslope to the valley bottom areas, transects with recharge soils will still behave as the overlying areas with dominate vertical flows, and also surface losses through evaporation (Figure 4-16, Figure 4-17 to Figure 4-18);

6. In the lower midslope and the valley bottoms with recharge (slow) hydropedological type (see Figure 4-16), with the Swartland (Recharge slow) will result in overland flows or lateral flows occurring between the soil/bedrock layer, recharging the watercourses or wetlands below. Lateral seeps from the proposed or existing TSF will also contribute on the surface flows towards the wetlands (artificial or natural) or watercourse. During the rainy periods, surface overland flows are prominent recharging the wetland areas. Some of the stagnant surface water flows can be lost through evaporation as percolation will be slow in these soils due to lower conductivity as the clay contents increase.

7. The other transects with the responsive (wet) hydropedological types (i.e. Katspruit soil forms) in the valley bottom (Figure 4-18 to Figure 4-21), are characterised with dominate surface overland flows or runoffs recharging wetlands and watercourses. These areas function as responsive receptors recharging the groundwater stores. The proposed development and the associated surface infrastructure should avoid these areas. Also, these areas have a high tendency to promote contaminates migrations towards available water resources.

8. In the landscape percolation effects can occur into either a fractured bedrock or semi-permeable layer, even though the effects are usually sub-dominate recharging the groundwater stores for the catchment.

The Harmony Valley Tailings Storage Facility Project and associated infrastructure located within the available recharge hydropedological type is not expected to affect the hillslope hydrology in any manner. Flow changes can occur in the lateral flows due to increased water regimes and underlying restrictive impermeable layers which can disconnect these lateral flows. Surface sealing due to increased compaction activities can also reduce such flows. These effects are however expected to have acceptable impact significance towards the total streamflow or total deductible water regime losses of sensitive receptors (downstream rivers and wetlands) and groundwater storage. Changes in water regime stores will occur, which requires good water regime management. Measures which can promote infiltration and reduce surface overland flows will result in the addition of the potential water regime losses back in the catchment.

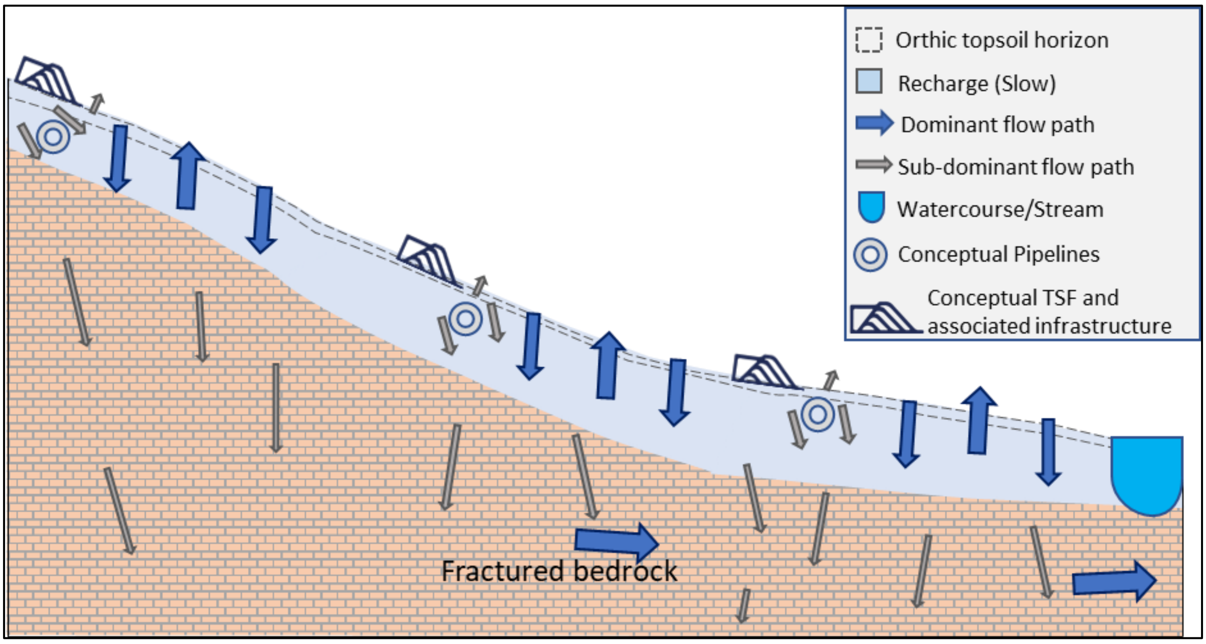

Figure 4-16 ***Hillslope hydrology one of six of the distinct hydropedological patterns after the construction of the Harmony Valley Tailings Storage Facility Project and associated infrastructure***

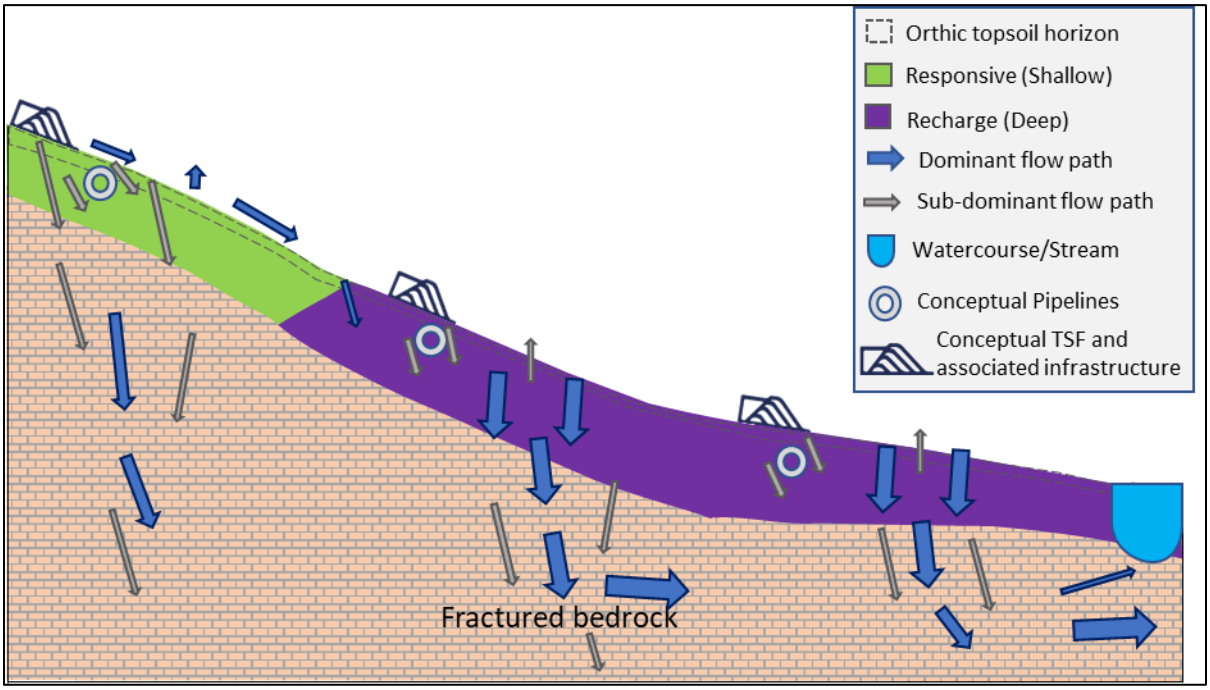

Figure 4-17 ***Hillslope hydrology two of six of the distinct hydropedological patterns after the construction of the Harmony Valley Tailings Storage Facility Project and associated infrastructure***

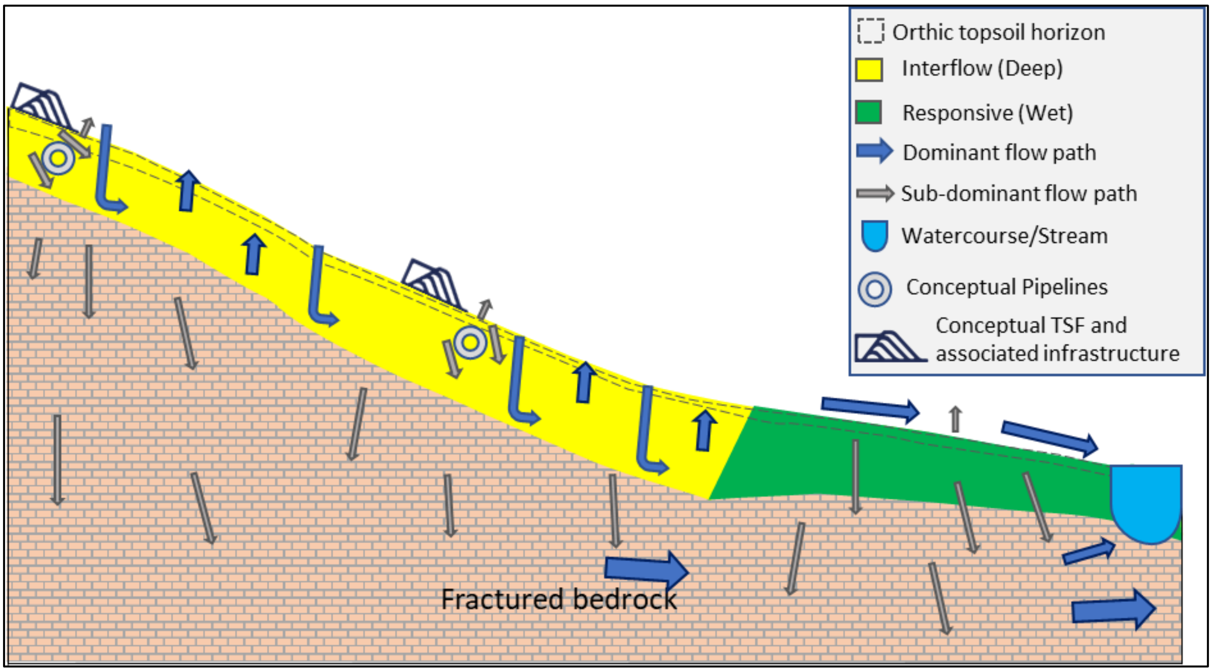

Figure 4-18 Hillslope hydrology three of six of the distinct hydropedological patterns after the construction of the Harmony Valley Tailings Storage Facility Project and associated infrastructure

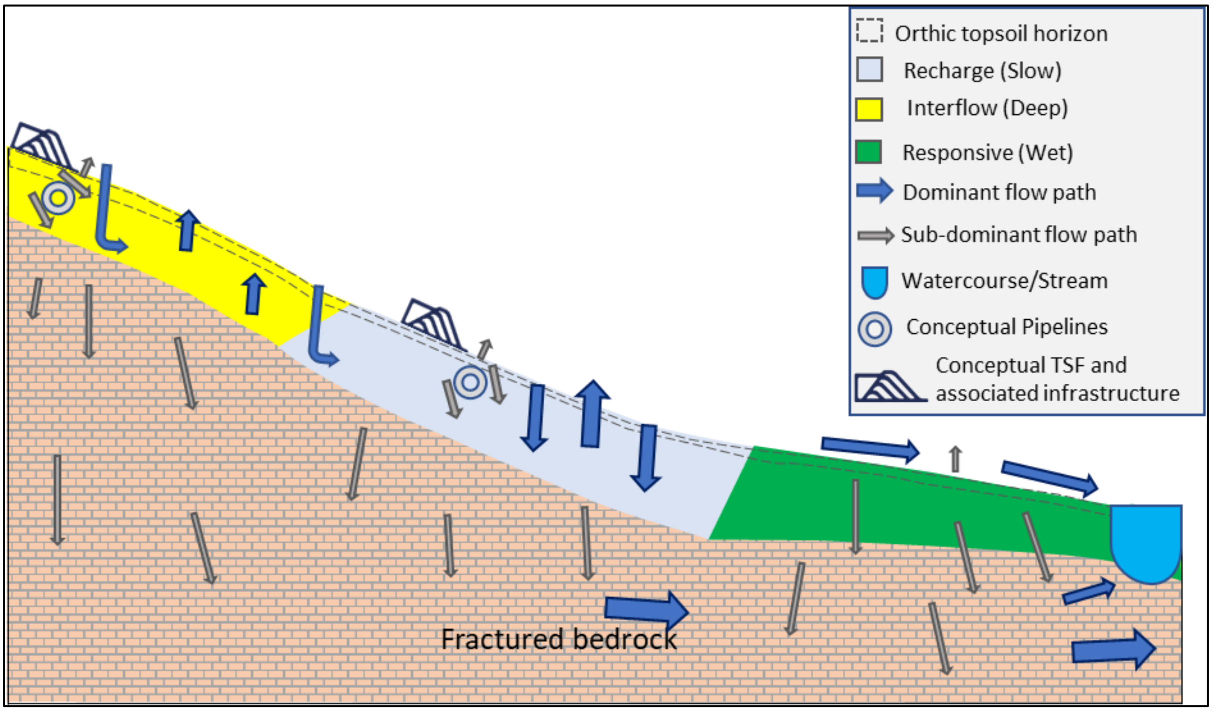

Figure 4-19 Hillslope hydrology four of six of the distinct hydropedological patterns after the construction of the Harmony Valley Tailings Storage Facility Project and associated infrastructure

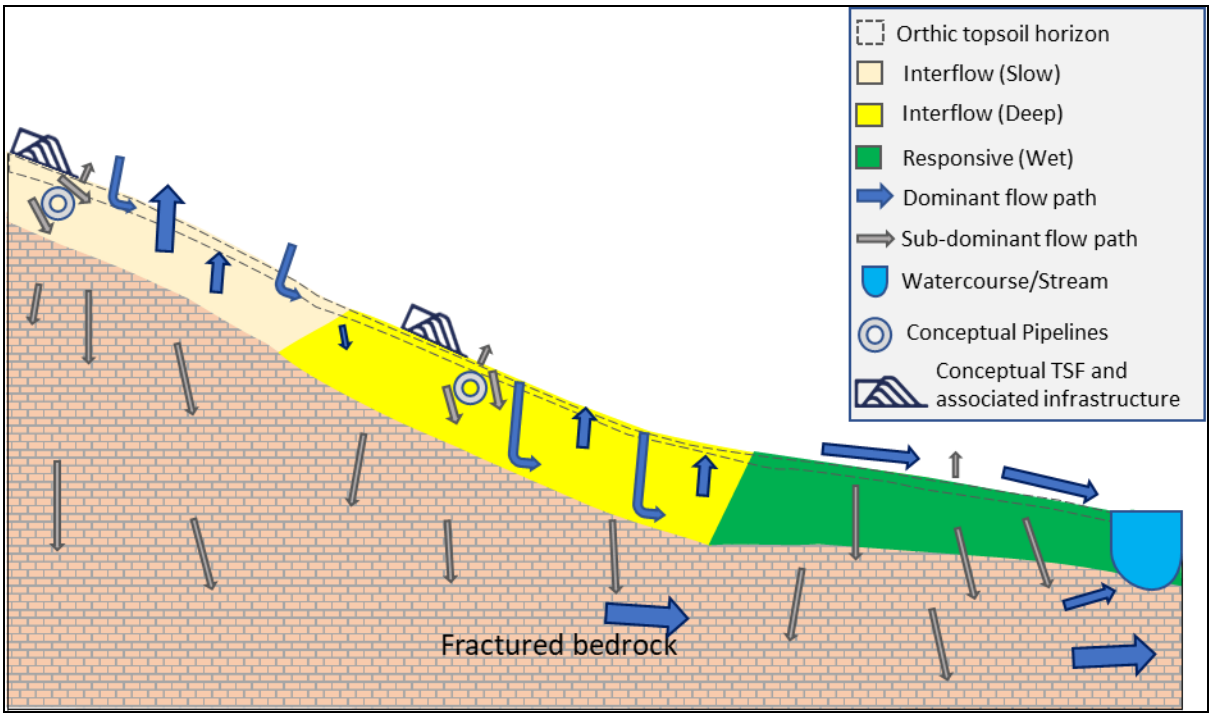

Figure 4-20 Hillslope hydrology five of six of the distinct hydropedological patterns after the construction of the Harmony Valley Tailings Storage Facility Project and associated infrastructure

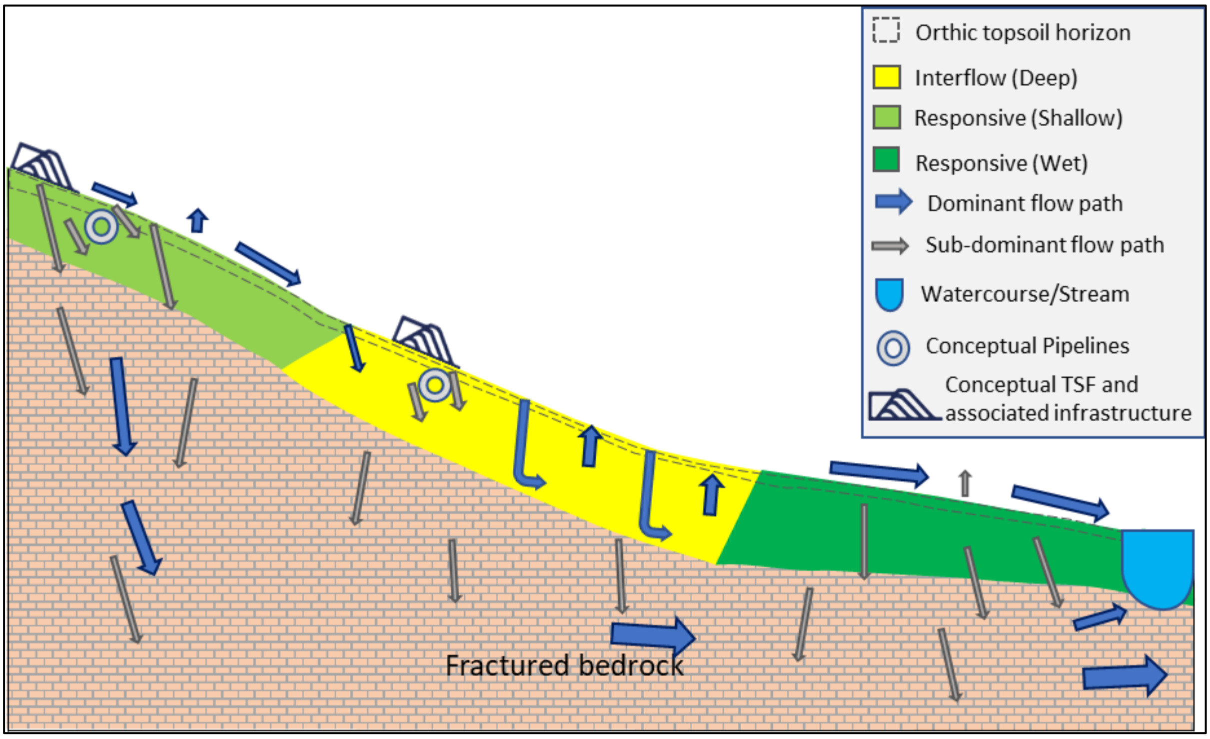

Figure 4-21 Hillslope hydrology six of six of the distinct hydropedological patterns after the construction of the Harmony Valley Tailings Storage Facility Project and associated infrastructure

4.6 Impact Assessment

4.6.1 Construction and Operation phase

The expected impacts on the catchment water regimes were assessed following the EIMS (2025) impact matrix methodology. The following existing infrastructure includes expansion of the existing RWD and stockpile areas, construction of the TSF, upgrading of the RWD, water channels and installation of a clean water channel or pipelines. Soil erosion, sedimentation or overland flows can occur due to increased traffic on the surface during the construction phase of the new infrastructure and operation of the existing infrastructure or activities within the proposed mining right area which can also result in compaction and surface sealing. Overland flow and potential erosion of terrestrial and watercourse or channels soils can occur which can lead to loss of fertile topsoil. Soil erosion can also contribute to water pollution and siltation of rivers. Surface sealing will also promote head cutting instreams and loss of fertile topsoil. Paved areas will intercept lateral flow paths (i.e. areas like parking or roads) and remove connectivity between recharge zones and lateral flow zones. Alteration of this flow path will likely change the water regimes negatively, even though the impact should be acceptable. The existing infrastructure and activities are expected to have low impacts post mitigation and the proposed infrastructure from construction to operation will have a low moderate to moderate minimal impact post mitigation. These effects are manageable as the post mitigation has been scored low to moderate for overland flows and potential soil erosion.

4.6.2 Decommissioning and Closure Phase

Soil erosion, sedimentation or overland flows can occur due to increased traffic on the surface during the construction phase which can also result in compaction and surface sealing. Overland flow and potential erosion of terrestrial and wetlands soils can occur which can lead to loss of fertile topsoil. Soil erosion can also contribute to water pollution and siltation of rivers. Surface sealing will also promote head cutting instreams and loss of fertile topsoil. Existing sealed areas or compacted areas can intercept lateral flow paths and remove connectivity between recharge zones and lateral flow zones. Alteration of this flow path will likely change the water regimes negatively, even though the impact should be acceptable. The draw-down effect on the water flows can also occur impacting the water regimes as well. These effects are manageable as the post mitigation for the existing infrastructure has been scored low and low to medium post mitigation for the proposed infrastructure.

4.6.3 Decommissioning and Closure Phase

The phase will include closure and ceasing of the processing plant, stockpiles and associated infrastructure processing activities. Some of the infrastructure will be removed from the site for decommissioning, this will be done with specialist on the site. Increased traffic will occur on-site, though the effects are expected to be minimal and manageable and mitigation measures will already be implemented. These effects are manageable as the post mitigation has been scored low.

Table 4-5 Impact assessment of erosion due to increased overland flow and potential decrease in subsurface lateral flow and return flow on the environment for the proposed infrastructure.

Impact	Phase	Pre-Mitigation Impact	Post-mitigation Impact	Final Significance
Soil erosion due to increased overland flow	Construction	Medium to low -	Low -	Low -
Potential decrease in subsurface lateral flow and return flow	Construction	Medium to high -	Low -	Medium to Low -
Mitigation Measures				
• Proposed mitigations on the flow behaviours changes are interconnected on flow response; mitigations are provided in section 4.6.4 below to avoid repetition • Specific mitigations are recommended below; • Minimise soil compaction in surrounding areas and keep the soil covered with residue and vegetative cover; • Enforce and restore a minimum 32-metre buffer zone around all wetlands (recommended by wetland specialist), using indigenous vegetation. • Infiltration basin or trench only where necessary can minimise surface overflows or runoffs and allow water that runs off to settle and re-infiltrate				
Soil erosion due to increased overland flow	Operation	Medium to low -	Low -	Low -
Potential decrease in subsurface lateral flow and return flow	Operation	Medium to low -	Low -	Medium to Low -
Mitigation Measures				
• Proposed mitigations on the flow behaviours changes are interconnected on flow response; mitigations are provided in section 4.6.4 below to avoid repetition; • Conduct quarterly inspections of lined dams and storage areas to ensure integrity. • Keep updated emergency response plans for dam overflow or containment breaches. • Routinely inspect and maintain stormwater infrastructure to prevent overflow and sediment discharge. • Use adaptive management, adjusting mitigation based on monitoring data, and conduct annual environmental audits.				
Soil erosion due to increased overland flow	Decommissioning and Closure	Low -	Low -	Low -
Potential decrease in subsurface lateral flow and return flow	Decommissioning and Closure	Low -	Low -	Low -
Mitigation Measures				
• Proposed mitigations on the flow behaviours changes are interconnected on flow response; mitigations are provided in section 4.6.4 below to avoid repetition • Prioritize progressive rehabilitation during decommissioning, using silt curtains, sediment ponds, erosion mats, and contour bunds to control runoff and sediment.				

Table 4-6 Impact assessment of erosion due to increased overland flow and potential decrease in subsurface lateral flow and return flow on the environment for the existing infrastructure.

Impact	Phase	Pre-Mitigation Impact	Post-mitigation Impact	Final Significance
Soil erosion due to increased overland flow	Construction	Medium to low -	Low -	Low -
Potential decrease in subsurface lateral flow and return flow	Construction	Medium to low -	Low -	Medium to Low -
Mitigation Measures				
• Proposed mitigations on the flow behaviours changes are interconnected on flow response; mitigations are provided in section 4.6.4 below to avoid repetition • Specific mitigations are recommended below; • Minimise soil compaction in surrounding areas and keep the soil covered with residue and vegetative cover; • Enforce and restore a minimum 32-metre buffer zone around all wetlands (recommended by wetland specialist), using indigenous vegetation. • Infiltration basin or trench only where necessary can minimise surface overflows or runoffs and allow water that runs off to settle and re-infiltrate				
Soil erosion due to increased overland flow	Operation	Medium to low -	Low -	Low -
Potential decrease in subsurface lateral flow and return flow	Operation	Medium to low -	Low -	Low -
Mitigation Measures				
• Proposed mitigations on the flow behaviours changes are interconnected on flow response; mitigations are provided in section 4.6.4 below to avoid repetition • Conduct quarterly inspections of lined dams and storage areas to ensure integrity. • Keep updated emergency response plans for dam overflow or containment breaches. • Routinely inspect and maintain stormwater infrastructure to prevent overflow and sediment discharge. • Use adaptive management, adjusting mitigation based on monitoring data, and conduct annual environmental audits.				
Soil erosion due to increased overland flow	Decommissioning and Closure	Low -	Low -	Low -
Potential decrease in subsurface lateral flow and return flow	Decommissioning and Closure	Low -	Low -	Low -
Mitigation Measures				
• Proposed mitigations on the flow behaviours changes are interconnected on flow response; mitigations are provided in section 4.6.4 below to avoid repetition • Prioritize progressive rehabilitation during decommissioning, using silt curtains, sediment ponds, erosion mats, and contour bunds to control runoff and sediment.				

4.6.4 Mitigation Measures

Mitigations are recommended for both the existing and new proposed activities and associated infrastructure. Subsurface drainage on associated infrastructure should be included in the water management plan for stormwater which can minimise overland flow from paved surfaces. This can also allow the water from the associated infrastructure like the concrete areas, parking lots, or offices to percolate and re-infiltrate. Slurry, water, or effluent pipes leakages need to be fixed and ensure measures are in place to prevent future leakages. Measures like contacting the responsible authorities immediately for sewage or faecal sludge associated with sanitation systems and having response guidelines. Good quality water should be applied downstream with acceptable organic or inorganic elements following recommended practices or groundwater specialist studies for clean water discharge of the project area to ensure recharges within the catchment.

The following measures can promote infiltration, and percolation flows during the project construction and operation:

The following measures can promote infiltration and percolation flows:

- Minimise soil compaction in the surrounding areas to the TSF and keep the soil covered with residue and vegetative cover,
- Prevent flood damage or concentration of run-off;
- Divert stormwater and surface run-off from buildings, roads, and parking areas into an attenuation pond;
- Preserve the natural and beneficial functions of the natural drainage system downstream;
- Preserve and enhance the quality of clean stormwater runoff into the receiving environment; and
- Adhering to the project footprint and minimum watercourse or wetland buffers as recommended with the wetland specialist will be sufficient to reduce the deductible water losses in the catchment. Also prevent any discharge of untreated potential slurry or effluent and wastewater into the catchment as responsive saturated soils (mostly associated with water channels) have a high tendency to promote contaminant (i.e., Bacteria and inorganic elements) migrations towards water resources.

5 Conclusion

Six (6) hillslope pattern types which were identified, includes the presence of recharge (deep and slow), interflow (slow and deep) and responsive (shallow and wet) hydropedological types. The transects align with the Ae 4, Bd 20 and Dc 9 land types, commonly characterized with deep or shallow soils with some rocky areas from the crest to the lower midslope areas with duplex and saturated soils. The observed upper hillslope crest areas are predominated with vertical flows due to the presence of recharge slow, shallow, and deep hydropedological types and overland flows from the subdominant interflow (slow and deep) hydropedological types. The midslope sections are also characterized by recharge and interflow (deep) hydropedological types with vertical and lateral flows. Surface runoffs or water stagnation can also promote the occurrence of evaporation effects as water will be lost from the topsoil horizons or surface runoffs. During the rainy season surface overland flow behaviour will occur towards the lower landscape areas. The lower midslope towards the valley bottom areas have recharge (slow and deep), responsive (wet) and interflow (deep) hydropedological types in some areas, with most areas with wetlands characterized by responsive (wet) types dominated with surface overland flows recharging wetlands and watercourses in the catchment.

Most of the hillslopes with recharge soils dominating throughout as well as the size of the greater catchment have acceptable impacts. Lateral flow from interflow (slow and deep) changes can occur in the hillslopes which may increase surface run-offs, surface return flows, and overland flows. However, their effects will have acceptable impacts on the total streamflow or total deductible water regime losses of watercourses in the larger catchment as both lateral and vertical flow paths will occur in response to the flow impediment.

The Harmony Valley Tailings Storage Facility Project and associated infrastructure (existing and proposed) will require mitigation measures being implemented due to impacts expected on some of the identified hillslopes in the assessment area. Changes in water regime stores will occur, which can require mitigations. Measures which can promote infiltration will result in the addition of the water regimes back in the catchment. Measures can also be set on soils which will experience some changes in flow paths following the development and associated infrastructure. Flow impediment can be managed well to minimise saturation conditions and surface return flows to promote subsurface groundwater recharge and storage. Valley bottom soils are responsive hydromorphic soils due to long periods of saturation. Usually, development should avoid areas with responsive (wet) hydropedological soil types mostly associated to and found in areas like wetlands which act as water regime receptors for the water balance in the hillslopes` catchment. These soils also have a high tendency to promote migration of inorganic (chemical elements) and organic (faecal bacteria) from a pollution source towards water resources in the catchment.

5.1 Impact Statement

The project has an overall medium-low residual impact, and this is acceptable. The following aspects must be considered for the development to reduce overland flows and surface return flows:

- Prevent flood damage or concentration of run-off;
- Divert stormwater and surface run-off from buildings, roads, and parking areas into an attenuation pond;
- Preserve the natural and beneficial functions of the natural drainage system downstream;
- Preserve and enhance the quality of clean stormwater runoff into the receiving environment;
- Attenuate the difference between pre- and post-development flows; and

- Prevent disposal of untreated wastewater or effluent into the catchment system or surrounding areas.

Such measures for these systems will ensure that adequate water deducted from the catchment as run-off will be re-applied into the system which can minimise losses from the total deductible regimes as most of the hillslopes have recharge soils. Application of good quality water will promote lateral flows associated with these hydropedological groups. Improved water quality in the area is important to minimise pollutes migrations. Effluent leakages and slurry migrations should be immediately fixed or minimised, and the affected areas mitigated to protect human health and the environment. From a hydropedological perspective, the proposed monitoring will be sufficient for water flows and groundwater recharge receptors.

5.2 Specialist Opinion

From a hydropedological perspective while minor changes in water regimes will occur, the impact of the development on hydropedological flow paths, post mitigation would be acceptable, and the impacts can be managed sustainably.

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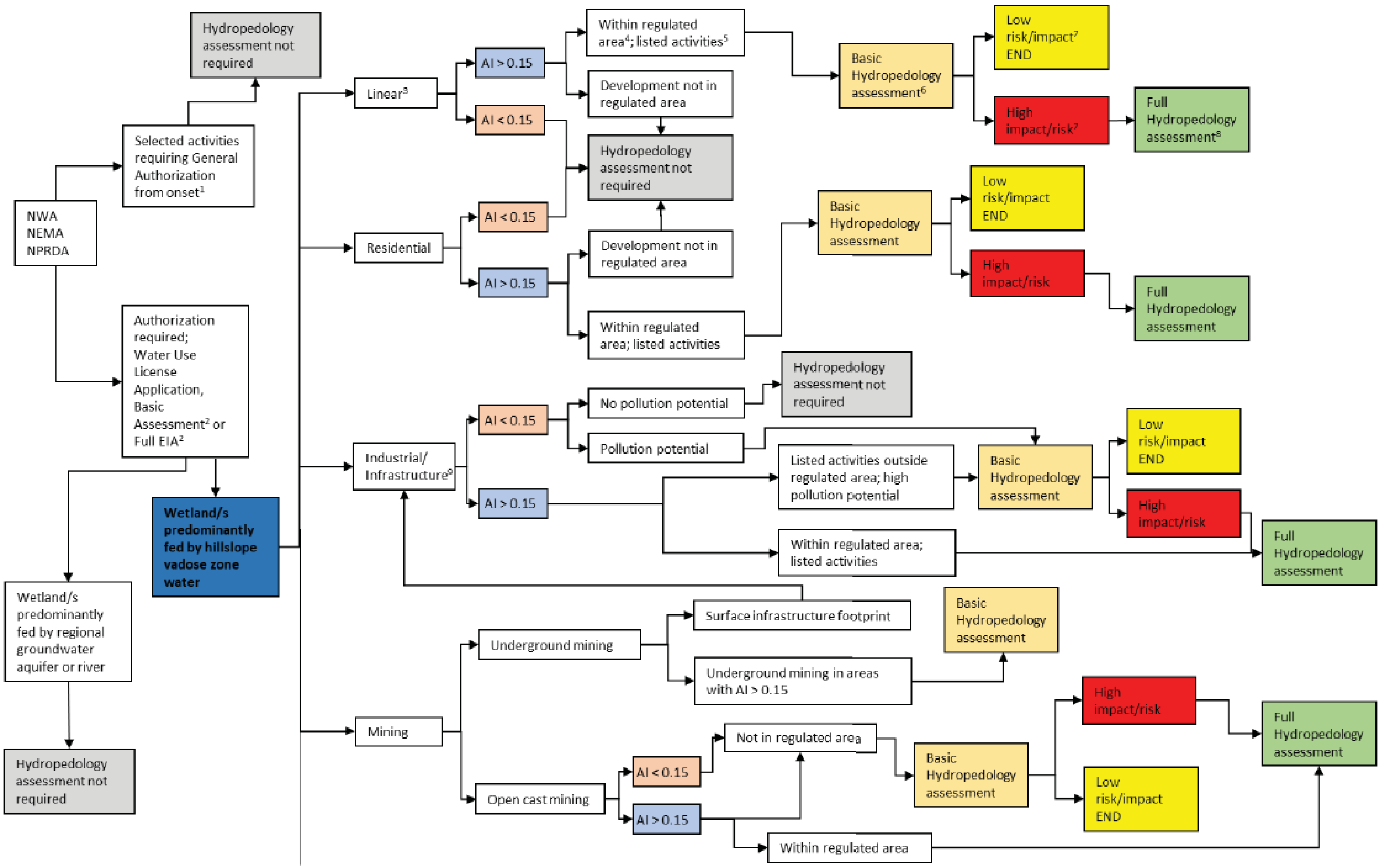
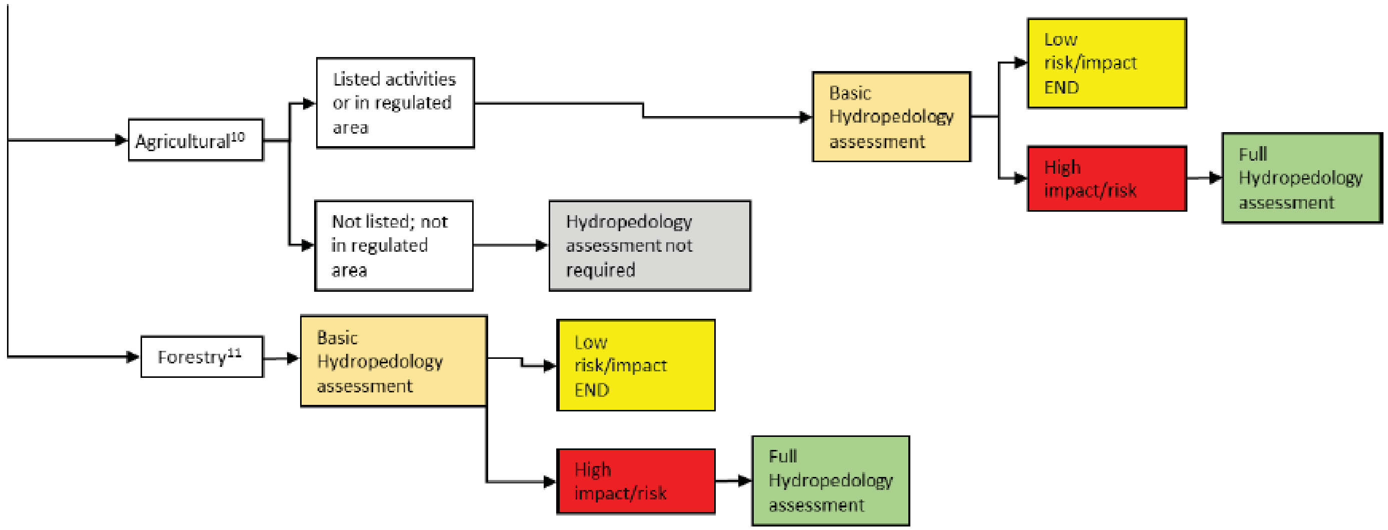
7 Appendix: Decision tree for when and the type of hydropedological assessment required




Agricultural[10]
Listed activities or in regulated area
Basic Hydropedology assessment
Low risk/impact END
High impact/risk
Full Hydropedology assessment
Not listed; not in regulated area
Hydropedology assessment not required
Forestry[11]
Basic Hydropedology assessment
Low risk/impact END
High impact/risk
Full Hydropedology assessment

7.1 EIMS Impact Assessment for the proposed activities

Pre-Mitigation											Post-Mitigation														
Impact	Phase	Pre-Nature	Pre-Extent	Pre-Duration	Pre-Magnitude	Pre-Reversibility	Consequence	Pre-Probability	Pre-Mitigation Significance Score	Pre-Mitigation Significance	Post-Nature	Post-Extent	Post-Duration	Post-Magnitude	Post-Reversibility	Consequence2	Post-Probability	Post-mitigation Significance Score	Post-Mitigation Significance	Confidence	Cumulative Impact	Irreplaceable loss	Priority Factor	Final score	Final Significance
Erosion due to overland flow	Construction	-1	2	3	3	3	-2,75	3	-8,25	Medium to low -	-1	1	2	2	2		2	-3,5	Low -	Medium	2	1	1,13	-3,94	Low -
Decrease in subsurface flows and return flows	Construction	-1	3	3	3	3	-3	3	-9	Medium to high -	-1	2	2	2	2		2	-4	Low -	Medium	2	1	1,13	-4,50	Medium to low -
Erosion due to overland flow	Operation	-1	2	2	3	2	-2,25	3	-6,75	Medium to low -	-1	1	2	2	2	-1,75	2	-3,5	Low -	High	2	1	1,13	-3,94	Low -
Decrease in subsurface flows and return flows	Operation	-1	2	3	3	3	-2,75	3	-8,25	Medium to low -	-1	2	2	2	2	-2	2	-4	Low -	High	2	1	1,13	-4,50	Medium to low -
Erosion due to overland flow	Rehab and Closure	-1	2	2	1	2	-1,75	2	-3,5	Low -	-1	1	1	1	1	-1	2	-2	Low -	Medium	2	1	1,13	-2,25	Low -
Decrease in subsurface flows	Rehab and Closure	-1	2	2	2	2	-2	2	-4	Low -	-1	1	1	1	1	-1	2	-2	Low -	Medium	2	1	1,13	-2,25	Low -

and return flows																									

7.2 EIMS Impact Assessment for the existing activities

Pre-Mitigation											Post-Mitigation														
Impact	Phase	Pre-Nature	Pre-Extent	Pre-Duration	Pre-Magnitude	Pre-Reversibility	Consequence	Pre-Probability	Pre-Mitigation Significance Score	Pre-Mitigation Significance	Post-Nature	Post-Extent	Post-Duration	Post-Magnitude	Post-Reversibility	Consequence2	Post-Probability	Post-mitigation Significance Score	Post-Mitigation Significance	Confidence	Cumulative Impact	Irreplaceable loss	Priority Factor	Final score	Final Significance
Erosion due to overland flow	Construction	-1	2	2	3	3	-2,5	3	-7,5	Medium to low -	-1	1	2	2	2	-1,75	2	-3,5	Low -	Medium	2	1	1,13	-3,94	Low -
Decrease in subsurface flows and return flows	Construction	-1	2	3	3	3	-2,75	3	-8,25	Medium to low -	-1	2	2	2	2	-2	2	-4	Low -	Medium	2	1	1,13	-4,50	Medium to low -
Erosion due to overland flow	Operation	-1	2	2	2	2	-2	3	-6	Medium to low -	-1	1	1	1	1	-1	2	-2	Low -	High	2	1	1,13	-2,25	Low -
Decrease in subsurface flows and return flows	Operation	-1	2	3	2	2	-2,25	2	-4,5	Medium to low -	-1	1	2	1	1	-1,25	2	-2,5	Low -	High	2	1	1,13	-2,81	Low -

Erosion due to overland flow	Rehab and Closure	-1	2	2	1	2	-1,75	2	-3,5	Low -	-1	1	1	1	1	-1	2	-2	Low -	Medium	2	1	1,13	-2,25	Low -
Decrease in subsurface flows and return flows	Rehab and Closure	-1	2	2	2	2	-2	2	-4	Low -	-1	1	1	1	1	-1	2	-2	Low -	Medium	2	1	1,13	-2,25	Low -