

DESKTOP HYDROPEDOLOGY ASSESSMENT FOR THE PROPOSED ACID MINE DRAINAGE TREATMENT AT THE BALLENGEICH COLLIERY IN KWAZULU-NATAL

23 April 2025

COMPILED FOR

M² Environmental Connections (Pty) Ltd

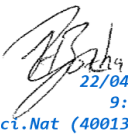


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REPORT DETAILS

Report Title	Desktop Hydropedology Assessment for the Proposed Acid Mine Drainage Treatment at the Ballengeich Colliery, in KwaZulu-Natal	
Client	M ² Environmental Connections (Pty) Ltd	
Report Number	EWS24-12_GW	
Report Revision	Final 1	
Date of Report	21 Apr. 25	
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REPORT VERSION HISTORY

Final	23 April 2025
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EXECUTIVE SUMMARY

Elemental Water Services Proprietary Limited (EWS) was appointed by M2 Environmental Connections (Pty) Ltd (MENCO) to undertake this hydrogeology assessment for the proposed Acid Mine Drainage (AMD) Treatment at the Ballengeich Colliery In KwaZulu-Natal.

The Ballengeich operation is located approximately 15 km south of Newcastle and consists of a historic open cast pit, discard dump, underground mine workings, adits and shafts, pollution control dams and infrastructure. The adits and shafts have been sealed, and sections of the open-cast mine have been backfilled and rehabilitated. The Ballengeich operation is currently not operational. The historic mining rights area falls within the farm Ballengeich Ptn. 19 - Sub 1 of Ballengeich 3299. The colliery falls within the upper catchment of the Horn River, which subsequently drains into the Ngagane River.

Ballengeich Siding needs water treatment technology following a DWS Directive. Kangra has inherited a settling pond system (7 ponds) that is seeping into the Horn River. Passive and self-sustainable treatment options are preferred. The settling ponds are subject to liner systems, but the feasibility is arguable. Kangra is looking for the Best Environmental Options to deal with the pollution problem.

The source control principle was used to determine the layout of the AMD treatment, and this is to ensure that the effluent is treated before it gets into the Rivers. The main pollution sources are (Bhekhani Pty Ltd, 2023):

1. Old underground workings decanting effluent water into the Horn River
2. Effluent discharge into the West decant sump and seepage from the old Horn River into the Ngagane and Horn River.

For Ballengeich, the passive treatment of AMD is proposed, consisting of anoxic limestone drains (ALD), successive alkalinity-producing systems (SAPS), oxidation ponds and aerobic wetlands.

This hydropedology assessment was compiled to evaluate the existing and predicted future hydropedological environments and risks associated with the proposed Project. This report is intended to supplement the Water Use License Application (WULA) for the water uses triggered by the proposed Project.

This hydropedology study found that The Ballengeich surface operations are situated within quaternary catchment W31G, with the old underground workings extending into V31F and V31K of the Mtamvuna-Pongola Water Management Area. The MAP of the site is in the order of 739 mm/yr, MAE is in the order of 1200 mm/yr, and MAR is in the order of 104 mm/yr.

One (1) hydropedological response units (PED-HRU) describe the natural drainage and expected unsaturated zone drainage directions (i.e. upslope to downslope, with both vertical and horizontal soil water flux) of the Project Area. The PED-HRU mimics that of the groundwater resource unit due to expected interflow characteristics.

The moisture regime in these soils is often dominated by the presence of restricting rock and soil layers at depths that lead to the perching of water in localised water tables and lateral seepage zones. The soils are, therefore, characterised by distinct zones of water fluctuation, zones of prolonged saturation with clearly expressed redox morphology features and zones where water manifests close or at the surface through return flow.

The predicted impact on the flow drivers associated with the proposed activities is calculated as “no-impact”. Therefore, the proposed activities are predicted to have a marginal impact on the hydropedological flow functions. The current PES and EIS will likely be maintained. However, considering that the treatment system will remove salts and metals and stabilise pH, a slight improvement in PES and EIS is expected over time.

There is an existing groundwater impact and surface water impact associated with the Ballengeich Mine. The status is predicted to improve after rolling out of the treatment system. Thus far, and based on surface water quality and quantity data for the existing setting, the impact on the hydropedological flow functions appears to be marginal.

Limited operational phases exist, and the impact on the hydropedological flow cycle will be marginal due to the Project Type. The tables below consider the mentioned cumulative impacts in the impact rating.

No alternatives are available, and the proposed treatment system must be placed in the pre-defined areas in order to ensure optimum efficiency of the treatment of AMD. No hydropedological buffers or offsets were identified.

Based on the findings of this assessment, EWS believes that the proposed activities will benefit the receiving groundwater, hydropedological, and surface water environments. The approval of the activity should be considered to enable Kangra to mitigate the impacts associated with the Legacy Ballengeich Mine.

APPENDIX 6 OF THE EIA REGULATION – CHECKLIST AND REFERENCE FOR THIS REPORT

Requirements from Appendix 6 of GN 326 EIA Regulation 2017	Chapter
(a) Details of: (i) The specialist who prepares the reports; and (ii) the expertise of that specialist to compile a specialist report, including a curriculum vitae	Appendix C.
(b) Declaration that the specialist is independent in a form as may be specialities by the competent authority	Appendix C.
(c) Indication of the scope of, and purpose for which, the report was prepared	Section 1.
(cA) Indication of the quality and age of base data used for the specialist report	Sections 1, 2 and 3.
(cB) A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 6.
(d) Duration, Date and seasons of the site investigation and the relevance of the season to the outcome of the assessment	Section 1.4.
(e) Description of the methodology adopted in preparing the report or carrying out the specialised process, including equipment and modelling used	Section 2.
(f) Details of an assessment of the specifically identified sensitivity of the site related to the proposed activity or activities and its associate's structures and infrastructure, inclusive of a site plan identifying alternative	Sections 1, 4 and 5.
(g) Identification of any areas to be avoided, including buffers	Section 5.
(h) Map superimposing the activity and associated structures and infrastructure on environmental sensitivities of the site, including areas to be avoided, including buffers	Section 1, 3.
(i) Description of any assumptions made and uncertainties or gaps in knowledge	Sections 2, 4, and 5.
(j) A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives on the environment or activities	Sections 4 and 5
(k) Mitigation measures for inclusion in the EMPr	Section 6.2.
(l) Conditions for inclusion in the environmental authorisation	Refer to Section 6.
(m) Monitoring requirements for inclusion in the EMPr or environmental authorisation	Refer to Section 6.
(n) Reasoned opinion – (i) as to whether the proposed activity, activities or portions thereof should be authorised. (a) regarding the acceptability of the proposed activity or activities and (ii) if the opinion is that the proposed activity, activities, or portions thereof should be authorised, and avoidance, management, and mitigation measures should be included in the EMPr, and where applicable, the closure plan	Section 6.3.
(o) Description of any consultation process that was undertaken during preparing the specialist report	None required.
(p) A summary and copies of any comments received during any consultation process and, where applicable, all responses thereto	None required.
(q) Any other information requested by the competent authority	None required.

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DETAILS OF AUTHOR

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Hendrik (Henri) Botha is a Principal Hydrogeologist with over twelve (12) years of experience. He holds a BSc Hons. Degree in Hydrology and an MSc in Environmental Science in Geohydrology and Geochemistry. A registered SACNASP Professional Natural Scientist (400139/17) in the Earth Science Field, Henri is also a member of the Groundwater Division of GSSA, GAKZN and IMWA. Henri's expertise includes groundwater, geochemistry and surface hydrology, as well as knowledge of water chemistry together with GIS and analytical and numerical modelling skills. General and applied logical knowledge are his key elements in problem-solving. Henri has a long-standing relationship with multiple clients in the mining and private sector and has completed various specialist hydrogeology and hydrology studies in South Africa, Nigeria, Namibia, Liberia, Malawi and Botswana.

CONFIDENTIALITY

The contents of this Report are of a confidential nature and intended for M² Environmental Connections (Pty) Ltd (hereinafter referred to as the Client or "MENCO"), permitting authorities, if applicable, and South African law. Any unauthorised use, alteration, or dissemination of the contents of this Report is strictly prohibited. The protection of the information in this Report is awarded in terms of the *Promotion of Access to Information Act, 2002 (Act No. 2 of 2002)* and without limiting this claim, especially the protection afforded by Chapter 4 of the Act.

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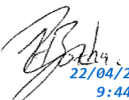
DECLARATION OF INDEPENDENCE

Elemental Water Services Proprietary Limited (EWS) was appointed to conduct this specialist surface water study and to act as the independent specialist. EWS objectively performed the work, even if this resulted in views and findings that were not favourable. EWS has the expertise to conduct the specialist investigation and does not have a conflict of interest in undertaking this study. This Report presents the findings of the investigations, which include the activities set out in the scope of work.

This specialist report, based on the independent assessment, as per the requirements set out by the *National Environmental Management Act 107 of 1998 (NEMA)* and the Department of Water and Sanitation (DWS), is independent and free of any external prejudice or influence. The contents of this specialist report are based solely on observations made during the physical site inspection and review of documents, as presented by the mine. The specialist further declares that, as a representative of Elemental Water Services Proprietary Limited:

- I act as the independent specialist for the Specialist Report.
- All work undertaken in relation to the assessment was conducted in an objective, independent and uninfluenced manner, even if this results in views and findings that are not favourable to the Licensee.
- There is no compromise on the objectivity exercised in undertaking the assessment.

- The relevant knowledge, expertise, and experience required to undertake this assessment are held by the specialist, including but not limited to NEMA and NWA, as well as relevant regulations and guidelines relevant to the activity.
- All information furnished in this Report is true and correct at the time of the assessment being finalised.
- I have expertise in conducting/compiling independent specialist assessments, including knowledge of NWA and any relevant legislation and guidelines that are relevant to the activity.
- I have no and have not engaged in conflicting interests while undertaking the assessment.
- I have undertaken to disclose to the Licensee and the Competent Authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the project by the Competent Authority and the objectivity of any report, plan or document prepared by myself for submission to the Competent Authority.
- All the particulars I furnished in this Report are true and correct.
- I realise that a false declaration is an offence in terms of Regulation 48 and is punishable in terms of section 24F of the Act.
- I do not have and will not have any vested interest (either business, financial, personal or other) in the project other than remuneration for work performed.



22/04/2025
9:44:26
Pr.Sci.Nat (400139/17)

Hendrik Botha
23 April 2025

GENERAL LIST OF ACRONYMS

A	Diagnostic A horizon
A/B	Interflow soil type A/B
A/Bedrock	Interflow soil type A/Bedrock
B (B1, B2, B3 etc.)	Diagnostic B horizon
BA	Basic Assessment
BOD	Biological oxygen demand
COD	Chemical oxygen demand
CSWMP	A conceptual stormwater management plan
CVB	Channelled valley bottom wetland
DEM	Digital Elevation Model
DWS	Department of Water and Sanitation
E	Diagnostic E horizon
EIS	Ecological Importance and Sensitivity
EWS	Elemental Water Services (Pty) Ltd
G	G Horizon/soil
GN704	General Notice 704
ha	Hectare
HOSASH	Hydrology of South African Soils and Hillslopes
HRU	Hydrological Response Unit
HST	Hydrological Soil Type
IWULA	Integrated Water Use Licence Application
m³	Cubic Metres
MAE	Mean annual evaporation
MAR	Mean Annual Run-off
MIPI	Midgley and Pitman (run-off calculation method)
MI	megalitre
NEMA	National Environmental Management Agency
NFEPA	National Freshwater Environmental Protected Areas
n-Value	Manning's Roughness Coefficients
NWA	National Water Act, 1998 (Act No. 36 of 1998)
O	Orthic Horizon/soil
PCD	Pollution Control Dam
PES	Present Ecological State
PFD	Process flow diagram
RP	Riparian zone/wetland
S	Seepage wetland
SDF	Standard design flood
SW	Surface Water
TDS	Total dissolved solids
TIN	Triangulated Irregular Network
UCVB	Unchanneled valley bottom wetland
UVB	un-channelled valley bottom
V	Vertic Horizon/soil
WMA	Water Management Area
WR2012	Water Resources of South Africa 2012
WTW	Water Treatment Works

LIST OF KEY DEFINITIONS

Acronym	Description
HRU	A Hydrologic Response Unit (HRU) is a spatial unit that combines land use, soil, and slope characteristics to represent areas that will respond similarly to weather and precipitation events.
MAE	Mean annual evaporation is the average amount of water that evaporates over a specific period of time, calculated by adding up the total evaporation over that period and dividing by the number of years.
MAR	Mean annual runoff (MAR) is the average amount of water that flows down a river per year
n-Value	Roughness coefficients represent the resistance to flow in channels and floodplains. Roughness is usually presented in the form of a Manning's n value in HEC-RAS.
IFR	Instream flow requirements (IFR) are the minimum amount of water needed to maintain the health of aquatic ecosystems.
EWR	Ecological water requirements (EWRs) are the amount, quality, and timing of water needed to maintain the health of ecosystems like rivers, lakes, wetlands, and estuaries
EIS	Ecological sensitivity refers to the adaptability of an ecosystem to changes in the natural environment and disturbances from human activities on the premise that the quality of the ecological environment is not damaged
NMAR	Naturalised MAR removes the effects of human activities to estimate what the water flow would be in natural conditions
nMAR	Normalised MAR adjusts runoff for basin size, so different basins can be compared regardless of their area.
RU	A group of areas with similar physical characteristics that are expected to respond to weather and precipitation in a similar way.
PES	Ecological status described in terms of Ecological Categories: A – near natural, B – largely natural C – moderately modified D – essentially modified E – seriously modified F - critically modified.
REC	a resource is a component of an ecosystem that maintains it, while ecological condition is the state of that ecosystem
TEC	A Target Ecological Category (TEC) is the goal to achieve a sustainable system that is both ecologically and economically sound
SQ	A sub-quaternary catchment reach (SQR) is a unit of information used to assess the aquatic ecology of a region
NDWF	Dry weather flow (DWF) is the average daily flow of sewage into a sewer or wastewater treatment plant during a period without rain

1 INTRODUCTION

Elemental Water Services Proprietary Limited (EWS) was appointed by M2 Environmental Connections (Pty) Ltd (MENCO) to undertake this desktop hydropedology assessment for the proposed Acid Mine Drainage (AMD) Treatment at the Ballengeich Colliery in KwaZulu-Natal (refer to Figure 1-5).

1.1 Project Background

The Ballengeich operation is located approximately 15 km south of Newcastle and consists of a historic open cast pit, discard dump, underground mine workings, adits and shafts, pollution control dams and infrastructure. The adits and shafts have been sealed, and sections of the open-cast mine have been backfilled and rehabilitated. The Ballengeich operation is currently not operational. The historic mining rights area falls within the farm Ballengeich Ptn. 19 - Sub 1 of Ballengeich 3299. The colliery falls within the upper catchment of the Horn River, which subsequently drains into the Ngagane River.

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1. Old underground workings decanting effluent water into the Horn River
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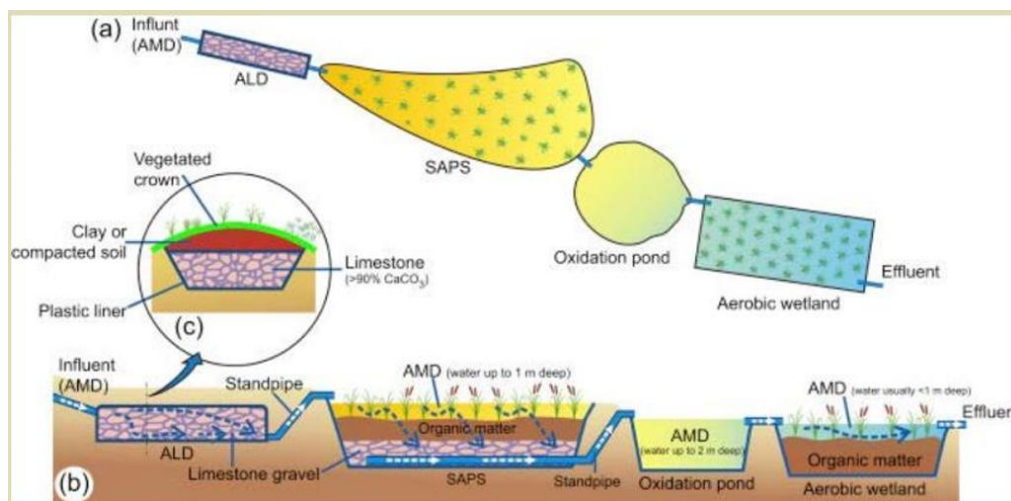


Figure 1-1: Passive treatment system proposed (Bhekhani Pty Ltd, 2023)

1.1.1 Treatment of Old UG Workings

The proposed AMD treatment will be constructed in two areas. The whole treatment train (ALD to SAPS to Oxidation Pond and Aerobic wetland) will be built to treat effluent from the decanting of old underground workings. 6 hectares of land is available in this area for treatment of effluent from underground workings. The conceptual layout of the AMD treatment from the old underground workings is shown in Figure 1-2.

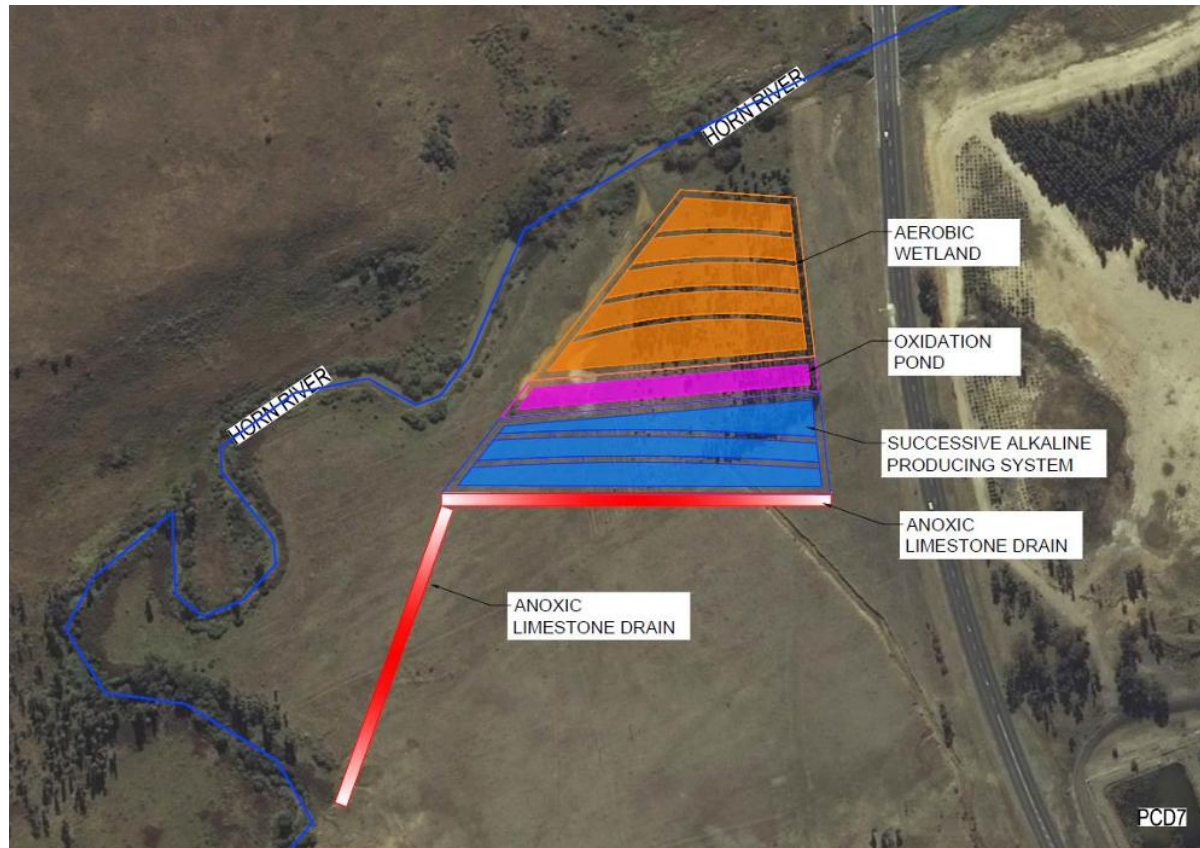


Figure 1-2: Area with underground workings to receive full treatment train (Bhekhani Pty Ltd, 2023)

1.1.2 Treatment of Effluent from West Decant Sump

An average of 1 198 155 kg/annum of sulphate salt ends up in the West Decant Sump on the Ballengeich Mine, and this salt load may discharge/seep into the Horn River or transpire through the surrounding tree area. Due to the space available between the West Decant Sump and the Horn River, two treatment methods will be constructed to treat effluent from Old open-cast workings and Unger ground workings to prevent further degradation of the Horn River. An anoxic limestone drain will be built after the west decant, along with an Aerobic wetland, which will treat all seepage water from the Old Horn River and the existing pollution control dams. A stormwater berm will be constructed along the Ngagane River to ensure that there is no spillage of the 1:100-year storm into the Ngagane River. The proposed west discard sump is shown in Figure 1-3.



Figure 1-3: *West Decant Sump area to be treated with ALD and cut off Aerobic Wetland along Horn River boundary*

1.1.3 Anoxic Limestone drain (ALD)

An Anoxic Limestone Drain (ALD) is a passive treatment system that is typically used to treat net acidic, anoxic mine drainage of low to moderate flow with low to mild acidity (range) and dissolved metals. The ALD is constructed to intercept subsurface mine water flows and prevent/ minimise exposure to atmospheric oxygen. Keeping oxygen out of the water prevents the oxidation of metals and armouring of the limestone. The sole purpose of an ALD is to provide alkalinity through the limestone dissolution process. The increase in alkalinity helps reduce the acidity of the AMD. Retaining carbon dioxide in the drain can improve limestone dissolution and, thus, alkalinity generation.

An ALD is essentially a buried trench or basin filled with limestone overlain by a soil cover. The trench can be rectangular in shape with vertical side walls or can be constructed as an inverted trapezoidal prism (basin). The limestone is wrapped like a “burrito” in a synthetic liner to prevent water leaking, minimize the introduction of air and prevent the surrounding soil from migrating into the limestone layer. An influent pipe transports water into one end or side of the ALD, and an effluent pipe discharges water from the opposite downstream end or side. The effluent pipe carries water to the surface and is positioned at an elevation to ensure the limestone layer remains fully submerged and anoxic (minimal or no headspace within the ALD).

The ALD will meet the following design requirements.

- ✚ Shallow in depth (1-2m)
- ✚ Limestone layer 1-2m thick
- ✚ 0.6m compacted impermeable soil cover

ALD maintenance proposed (Bhekhani Pty Ltd, 2023):

Limestone: The limestone can require maintenance and periodic partial replacement, primarily due to clogging from metal precipitate. Therefore, the default recommendation in AMD Treatment is to replace 50% of the limestone every 10 years.

Liner: Often, liners are destroyed, especially synthetic ones, while maintenance is being done on passive treatment systems. Thus, AMD Treatment recommends planning to replace a portion of the liner while the limestone is being replaced. The default assumption is to replace 50% of the Limestone every 10 years, so the same assumptions are recommended for Liner recapitalization.

Pipe: Piping is often exposed at the surface and can become damaged by vandalism, falling trees, and other factors. AMD Treatment assumes 50% of the piping will require replacement after 25 years of service.

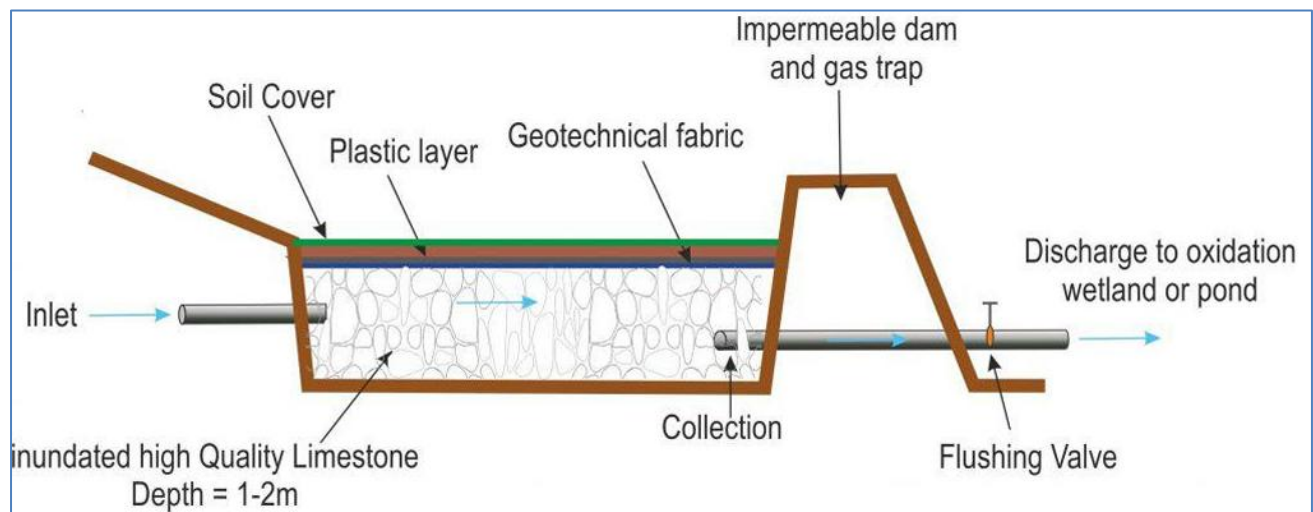


Figure 1-4: Typical section of Anoxic Limestone drainage system

1.1.4 Successive Alkaline Producing System (SAPS)

The SAPS systems combine ALD and compost wetland systems with a vertical flow of water. First, the acidic water flows through the low hydraulic conductivity compost part of the SAPS, where dissolved oxygen is consumed, and ferric iron (Fe^{3+}) is reduced to ferrous iron (Fe^{2+}). As a result, the water becomes anoxic and will flow through the anoxic layer of limestone, resulting in alkaline water without any iron precipitating on the limestone. The removal capacity of the SAPS system is approximately 10 g acidity /m²/d and has an estimated lifetime of 20-30 years. The area-adjusted contaminant removal rate was derived by Hedin et al. (1994a). For systems that must meet regulatory standards, a value of 10 g/m²/d for iron and 0.5 g/m²/d for manganese is recommended. The effluent discharged from Ballengeich has a design loading of 1000 m³/d 189 mg/L iron and 4.0 mg/L manganese. The minimum required area is 18 900 m².

1.1.5 Sedimentation/Oxidation Pond

Oxidation ponds, also called lagoons or stabilization ponds, are large, shallow ponds designed to treat wastewater through the interaction of sunlight, bacteria, and algae. Algae grow using energy from the sun and carbon dioxide and inorganic compounds released by bacteria in water. During the process of photosynthesis, the algae release oxygen needed by aerobic bacteria. Mechanical aerators are sometimes installed to supply yet more oxygen, thereby reducing the required size of the pond.

The sedimentation/oxidation pond is designed based on a 24-hour retention time at the design flow of 1000 m³/day, a water depth of 1500 mm and a 600 mm freeboard. The pond shall feature the following:

- ✚ total surface area: 670 m²;
- ✚ flow distributing inlets; • maximum length to breadth ratio of 3:1;
- ✚ side slopes of 1:2;
- ✚ scour valves for desludging;
- ✚ No. of ponds: at least two ponds are proposed;
- ✚ HDPE lining is constructed to the same detail as the aerobic wetland.

1.1.6 Aerobic wetland

Aerobic wetlands are relatively shallow, either constructed or natural ponds that are filled with flooded gravel, soil and organic substrate for plant growth. The cells are usually 30 cm deep or less, lined with impermeable sediments, and water flows above the substrate. Constructed aerobic wetlands are based on the aeration of the water to be treated, resulting in the transformation of dissolved Fe to the solid phase via oxidation. Thus, aerobic wetland treatment is very effective in treating Iron-rich mine waters, yet they have commonly limited capability to neutralize acidity. In addition, commonly accompanying manganese requires specific conditions for removal: circum-neutral to basic pH, and Fe²⁺ will be oxidized to prevent manganese from reducing.

The proposed wetlands will have the following properties (Bhekani Pty Ltd, 2023):

- ✚ Soil depth to be 400 mm. Important aspects of soil quality are as follows:
 - It does not contain huge stones or other sharp objects, which may puncture pond liners and impede plant growth;
 - The soil is not contaminated. The best way to ensure this is to ensure a reliable analysis is made of it;
 - It contains sufficient nutrients, in appropriate proportions, to support reed growth;
- ✚ The depth of water above the soil surface will be 1 m plus 600 mm freeboard;
- ✚ Aquatic plants, typically reeds, are to be planted at a density of 3-4/m²;
- ✚ Flow distributing inlets;
- ✚ maximum length-to-breadth ratio of 3:1;
- ✚ side slopes of 1:2;
- ✚ The subgrade shall be prepared with a 150 mm G7 sand layer with a maximum particle size of 3 mm. A 2 mm thick, smooth HDPE lining, complying with SANS 10409, overlaying A4 geotextile with the anchor trench detailed below, is proposed.

1.1.7 Predicted impact on water quality of the treatment system proposed

The current situation at Ballengeich Colliery is that acidic decant (AMD) is allowed to enter the Horn River uncontrolled, from where it is further diluted at the confluence with the Ngagane River. AMD Characterisation:

- ✚ Net acidic: pH <4.5
- ✚ DO : >5mg/l
- ✚ Fe²⁺ / Fe³⁺ ratio : >25% (35%)

✚ Al: <25mg/l

✚ Flow (ℓ/min) : < 200 l/min.

The predicted water quality changes after treatment and assimilation by the passive wetland system are captured in Table 1-1 and Table 1-2. An improvement in the raw and water quality is simulated. However, If the modelled results are compared to an RQO Class III category as per GN 1873 of March 2022, it is found that the heavy metals (Fe, Al and Mn) exceed the set RQOs. Total Dissolved Solids (TDS) and sulphate (SO₄) have the potential to exceed the more stringent RQO as contained in GN 1873 (MENCO, 2022)

Table 1-1: Assimilated capacity for Ngagane River (MENCO, 2022)

Variable	Unit (mg/l)	Predicted USEPA Model	Predicted RWQ Model	RQO	RQO Class III
Total Dissolved Solids	mg/l	337.56	353.08	≤350	≤1200
Total Alkalinity	mg/l	41.04	57.57		
Chloride	mg/l	8.52	9.71	≤120	≤300
Sulphate	mg/l	147.30	137.08	≤165	≤500
Sodium	mg/l	20.20	17.09		≤200
Potassium	mg/l	2.33	2.71		
Calcium	mg/l	33.78	38.19		≤150
Magnesium	mg/l	21.34	23.44		≤70
Aluminium	mg/l	0.36	0.48	≤0.105	
Iron	mg/l	5.36	3.54	≤0.1	
Manganese	mg/l	0.92	0.79	≤0.15	

Table 1-2: Assimilated capacity for Horn River inclusive of decant (MENCO, 2022)

Variable	Unit (mg/l)	Predicted USEPA Model	Predicted RWQO Model	RQO	RQO Class III
Total Dissolved Solids	mg/l	449.99	546.40	≤350	≤1200
Total Alkalinity	mg/l	43.90	74.57		
Chloride	mg/l	9.81	13.75	≤120	≤300
Sulphate	mg/l	204.56	239.02	≤165	≤500
Sodium	mg/l	35.11	28.50		≤200
Potassium	mg/l	2.27	3.14		
Calcium	mg/l	35.43	52.07		≤150
Magnesium	mg/l	27.84	39.32		≤70
Aluminium	mg/l	0.13	0.24	≤0.105	
Iron	mg/l	7.47	5.23	≤0.1	
Manganese	mg/l	0.22	0.75	≤0.15	

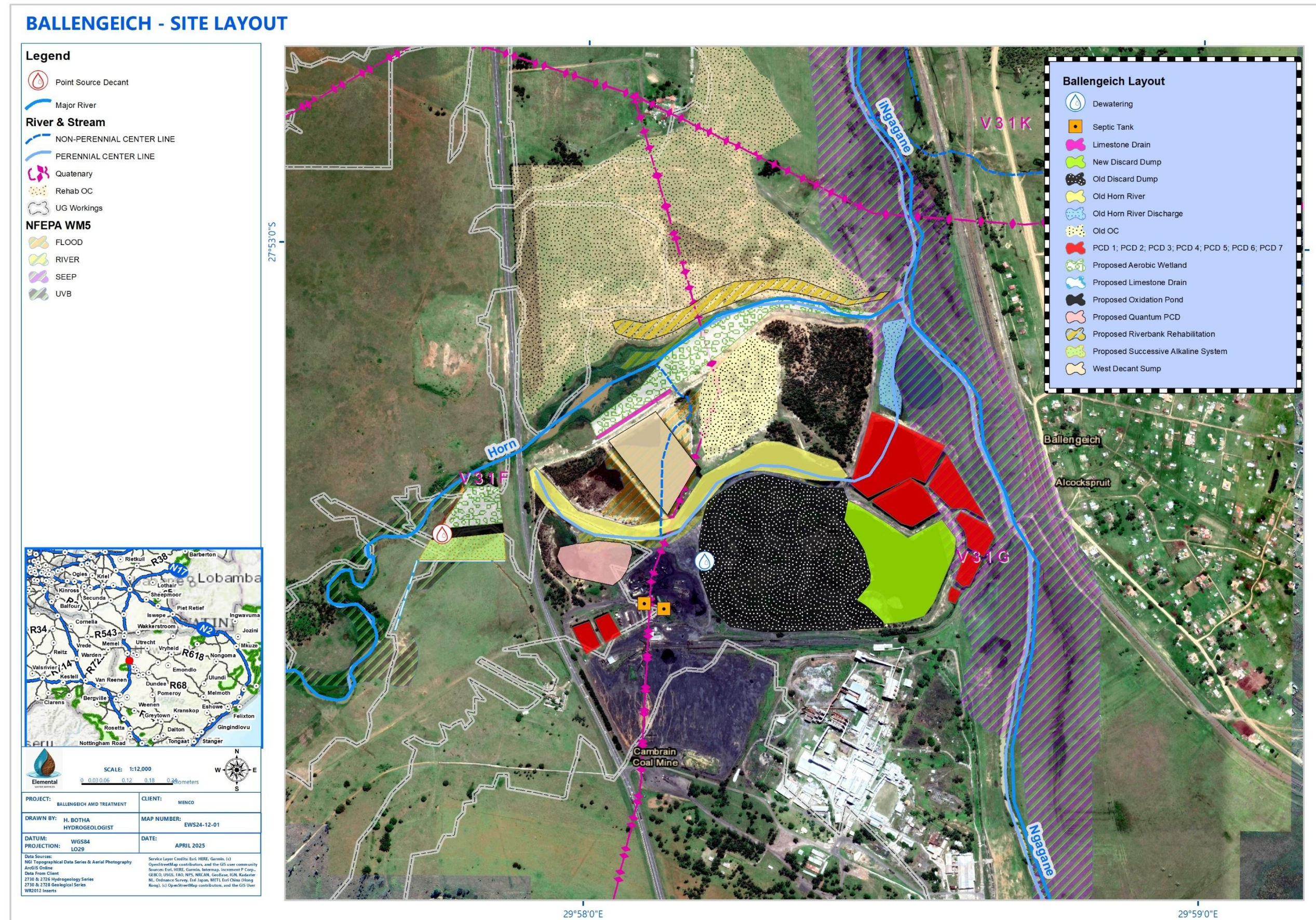


Figure 1-5: Site layout

1.2 Study objectives and methodology

Soils develop over time under the influence of chemical, physical, and biological processes (refer to Figure 1-6). Soils are predominantly the result of in-situ weathering of the host rock (i.e., has characteristics associated with the parent geological occurrence/rock). Soil has an interactive correlation with hydrology (i.e., climate, rainfall duration, run-off patterns, groundwater contribution to baseflow, evaporation, etc.). It is a product of water-related processes (physical and chemical) and a first-order control of the destination of rainwater. Though hydrological processes change seasonally, soil characteristics and water transfer capabilities remain similar throughout the year. A once-off study was undertaken.

The objectives of this hydropedological assessment were to:

1. Evaluate the soils in the study area on a desktop level.
 - Soils were classified per the taxonomic system for South Africa (Department of Agricultural Development, 1991); (SCWG, 2018)
 - Soil permeability was estimated based on available data (i.e. field, characterised textures and public soil data) and according to best practice guidelines (FAO, 1980); and (DWS, 2011).
 - Determine Hydrological Soil Types (HST) on a preliminary and desktop level (Van Tol, et al., 2013).
2. Conceptualise the water flow dynamics and derive hydropedological flow buffer areas (if required) for wetlands identified in the area.
 - Hydrological processes were perceived from traceable signatures in the soil matrix resulting from the soil's ability to transmit, store and react with water (Le Roux, et al., 2011).
3. Identify potential hydropedological impacts per standard DWS & EIA impact criteria and risk rating.
4. Define potential hydropedological buffer areas based on the flow driver assessment.

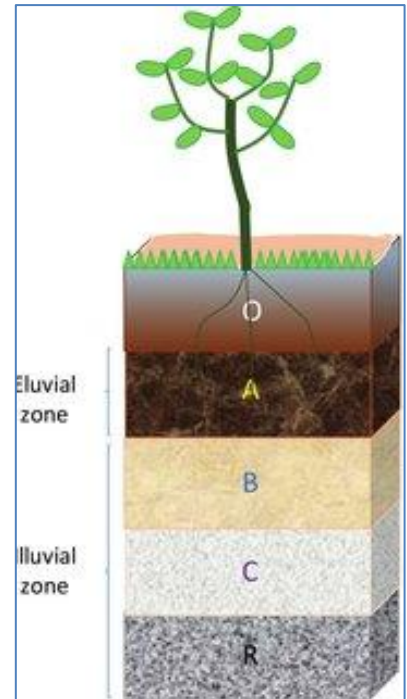


Figure 1-6: Typical soil genesis (Anon, 2020)

1.3 Study relevance to the season in which it was undertaken

This study was undertaken as a once-off study and relies on historical hydrological and climate data for the site, as well as recognised hydrological and water resource databases for South Africa. Data generated during the time of this study is not seasonally bound as average yearly data was applied where required and as scientifically acceptable. A follow-up (wet or dry) assessment is not deemed a requirement due to the Project Type (i.e. treatment system with little further operational activities).

1.4 Scope of works

The scope of work completed was as follows:

1. Desktop study:

- a. All available reports (which were provided by the client) relating to the site were assessed. This included wetland and previous soil investigation reports.
- b. Evaluation of soil occurrences in the study area, based on available South African databases. The soils identified in the study area were screened per the Soil Classification guidelines for South Africa (Department of Agricultural Development, 1991) and (SCWG, 2018) to derive hydropedological flow regimes.

2. Hydropedological assessment:

- a. Meteorological evaluation.
- b. Catchment delineation.
- c. Estimation of soil permeability and soil flow processes based on field observation and desktop data.
- d. HOSASH (Hydrology of South African Soils and Hillslopes) index.

3. Risk assessment and mitigation measures:

- a. The risk and impact criteria (refer to **Appendix B**) were applied to the study area to evaluate hydropedological risks.
- b. Natural flow losses were estimated using a spreadsheet water balance developed for the site.
- c. Mitigation measures and potential hydropedology buffers were estimated.

4. Mapping and Report:

- a. Several hydrological hillslope profiles, soil distribution and hydrological soil type maps were produced. This Report was compiled.

1.5 Gaps and limitations

The following study limitations are recognised:

- ✚ The concepts presented are simplifications of the temporal variability of water transfer functions. Realistically, water transfer functions, such as throughflow and groundwater sources, may take a few months up to several years to recharge streams (Le Roux, et al., 2011). However, hydropedology hillslopes have been effectively applied to simulate run-off response mechanisms (Van Tol, et al., 2013).

- Per minimum requirements for hydropedology studies published by DWS (Van Tol, J.J., Bouwer, D. & Le Roux, P.A.L., 2021), this "Level 2" study was undertaken (field investigation, conceptualisation of hillslopes and soil flow suppression). No numerical unsaturated flow modelling (Level 3 and Level 4) was undertaken and was pre-determined by the project activity (i.e., a small development with limited activities that could potentially impact the soil flow regime).

2 AREA OF INVESTIGATION

The Ballengeich Colliery is situated on the southern side of the Horn River and the western side of the Ingagane River, at the confluence of the two (2) rivers, about 12km South of the Town of Newcastle in the KwaZulu-Natal Province. The Ballengeich surface operations are situated within quaternary catchment W31G, with the old underground workings extending into V31F and V31K of the Mtamvuna-Pongola Water Management Area (DWS, 2016). Based on the topography, the drainage is towards the northeast. Elevations on the site typically range from 1184 to 1325 metres above mean sea level (mamsl). A typical topography cross-section is shown in Figure 2-1.

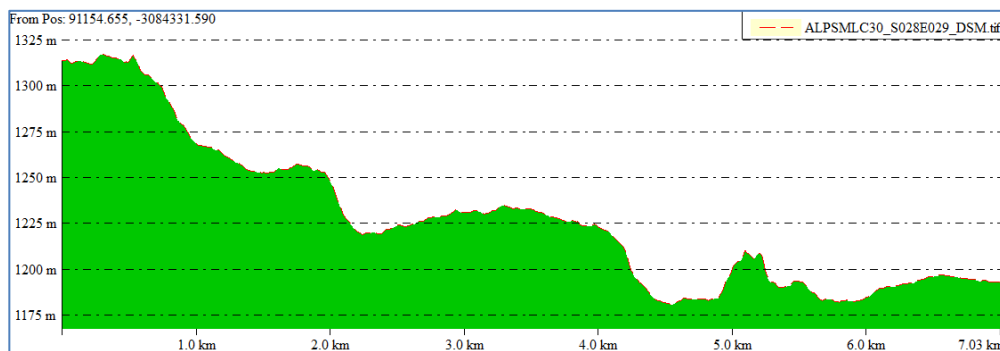


Figure 2-1: Typical cross section of surface topography (30m DTM based)

2.1 Sub-catchments / groundwater resource units (PED HRU)

One (1) hydropedological response units (PED-HRU) describe the natural drainage and expected unsaturated zone drainage directions (i.e. upslope to downslope, with both vertical and horizontal soil water flux) of the Project Area. The PED-HRU mimics that of the groundwater resource unit due to expected interflow characteristics – refer to Figure 2-2. The land cover types associated with the HRU are shown in Figure 2-3, and the topography slope rise % is shown in Figure 2-4. Table 2-1 provides a summary of the physical attributes associated with the PED HRU / GW HRU.

Table 2-1: Summary of PED HRU / GW HRU attributes

Sub-Catchment		PED HRU / GW HRU
Area (km ²)		27.995
Longest Drainage Line (km)		NA
Average Slope (%)		2.40%
Slope (%)	<3	17.26%
	3-10	58.29%
	10-30	22.35%
	>30	2.10%
Land Cover	Thick bush & plantation	3.66%
	Light bush & farm-lands	27.46%
	Grasslands	60.81%
	No Vegetation	8.07%

2.2 Local surface geology

The regional geology of the area is dominated by a succession of near-horizontal sedimentary rocks of the Vryheid Formation (Pv) of the Ecca Group of the Karoo Supergroup (DMEA, 1998g). These sediments comprise a cyclic succession of sandstones, shales, mudstones, carbonaceous shales, and coal seams, underlain by older basement granitic and granitoid rocks. Intrusive dolerite (Jd) sills and dykes are known to occur in the project area.

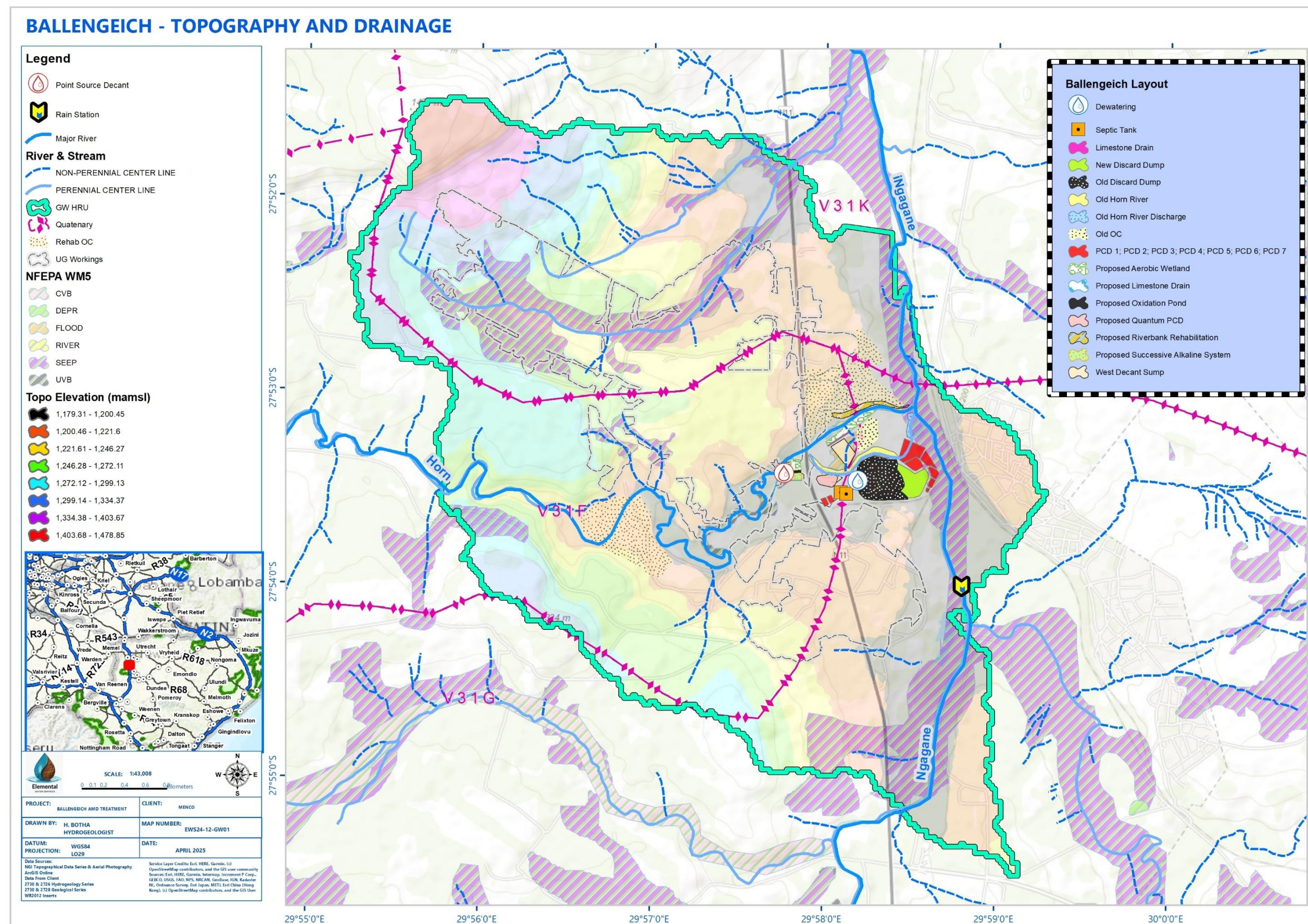


Figure 2-2: Topography and drainage

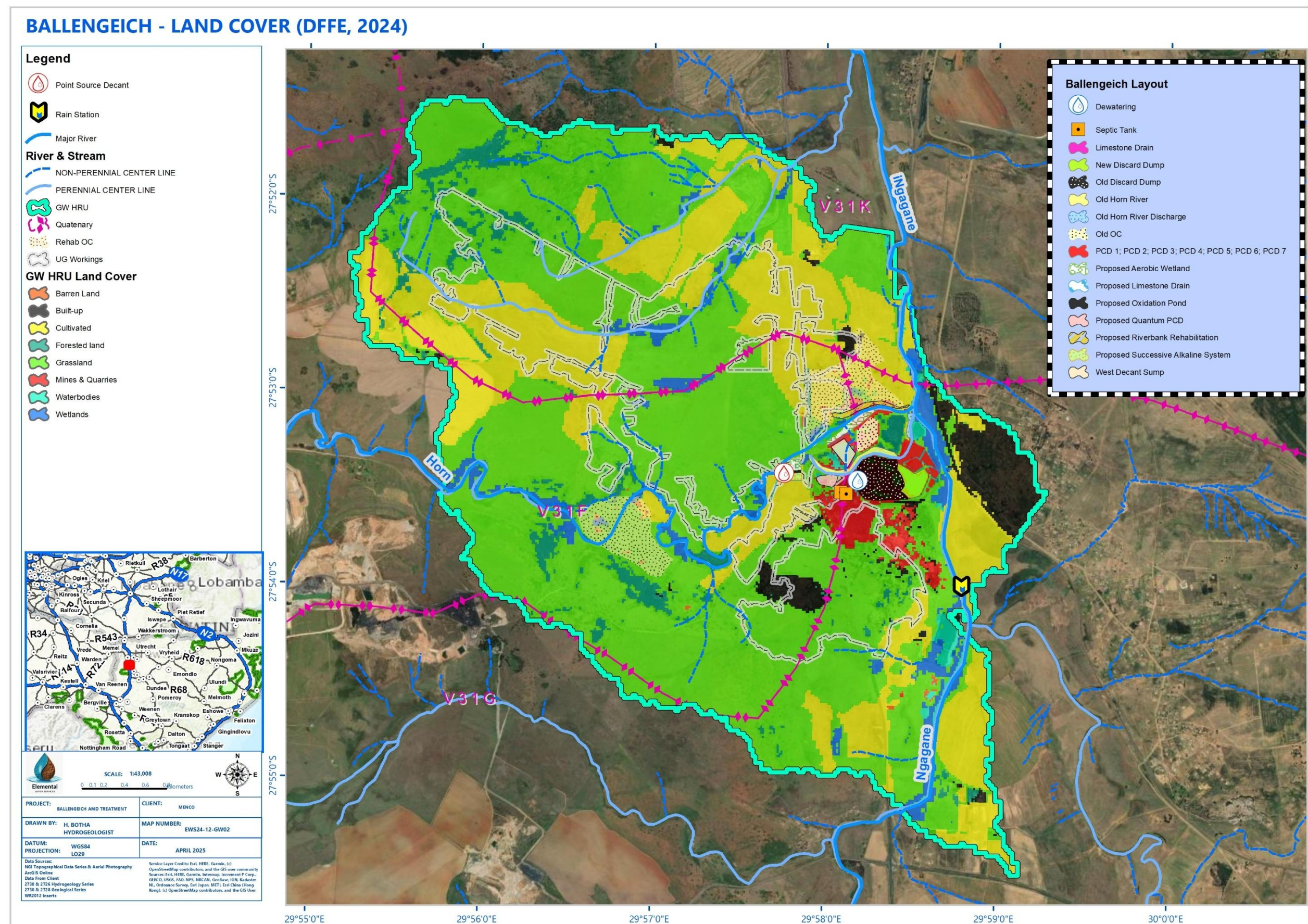


Figure 2-3: Sub-catchments & land cover types

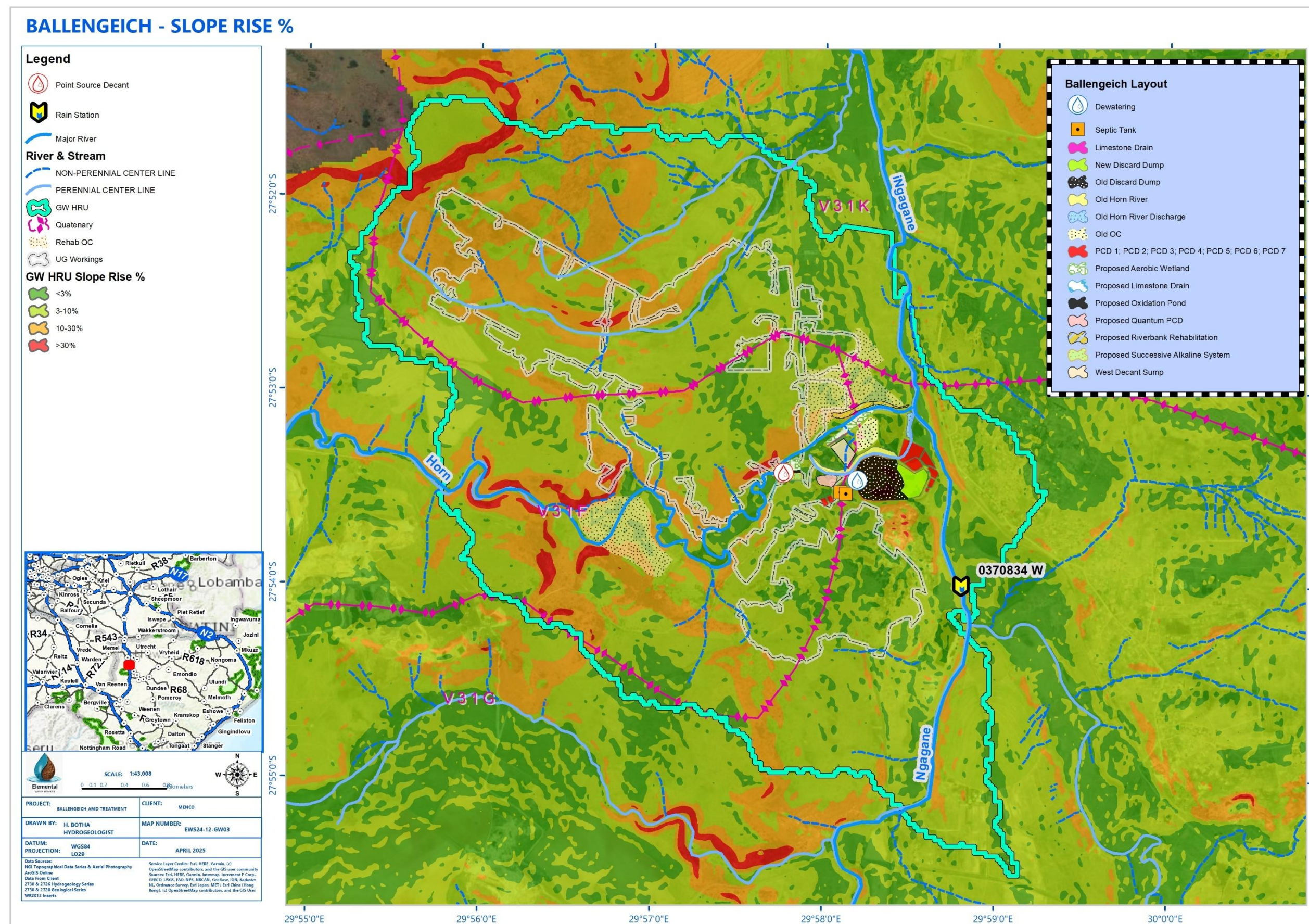


Figure 2-4: Sub-catchments & slope rise %

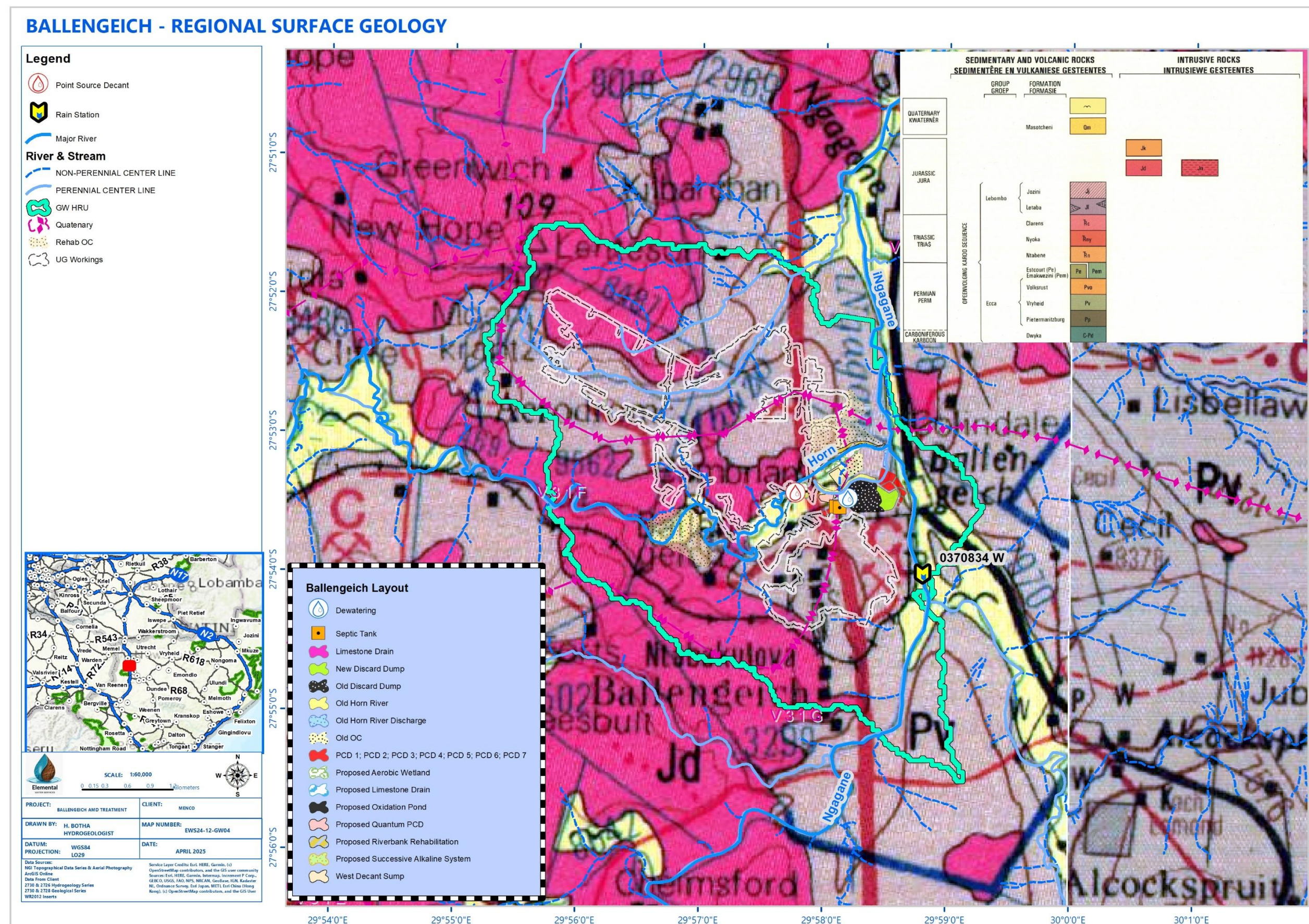


Figure 2-5: Regional surface geology

2.3 Climate

Climate, amongst other factors, influences soil-water processes, runoff, and peak flows. The most influential climatic parameter is rainfall. Rainfall intensity, duration, evaporative demand, and runoff were considered in this study to indicate rainfall partitioning within the project area.

2.3.1 Temperature

The average yearly temperature (refer to Figure 2-6) for the project area ranges from 27 to 35°C (high) and 1 to 4°C (Low). As per the Köppen Climate Classification (Kottek, et al., 2006), the study area is situated in a humid subtropical climate (Köppen: Cfa).

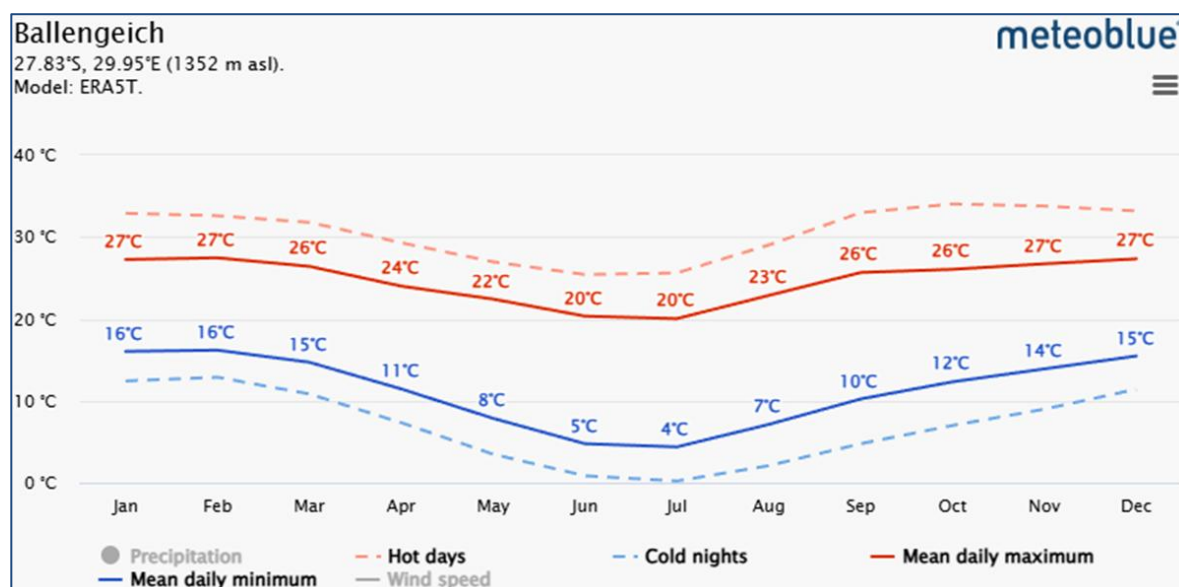


Figure 2-6: Average yearly temperatures (Meteoblue, 2025)

2.3.2 Rainfall and evaporation

The project area is situated in rainfall zone V3B. The Mean Annual Precipitation (MAP) recorded at the nearest rainfall stations is summarised in Table 2-2 (WRC, 2015). The MAP for several sites is within the same order of magnitude.

Table 2-2: Summary of MAP recorded at nearest rainfall stations

Site	ID	Record (Yrs)	MAP (mm/yr)
BALLENGEICH	0370834_W	52	858
CHELMSFORD DAM	0370807_W	39	794
CECILIA, NEWCASTLE	0370655_A	31	931
BOARDLANDS, DANNHAUSER	0371029_A	25	753
Average			834

The monthly rainfall that represents the site was obtained from WR2012 rainfall station 0370834W. The rainfall record is for the period 1920 to 1972 (52 years). Monthly rainfall for the site is likely to be distributed, as shown in Figure 2-7. Available rainfall data suggest a MAP ranging from 503 (30th percentile) to 1517 (90th percentile) mm/yr.

To further refine the rainfall of the site, satellite rainfall data from the Climate Hazards group IR Precipitation with Stations (CHIRPS) was applied ((SERVIR, 2025) & (ClimateSERV 2.0, 2025)). This dataset, known as CHIRPS, offers a spatially and temporally consistent view of global rainfall patterns, enabling accurate monitoring and assessment of large-scale trends. The annual rainfall record for the Site [Ballengeich] from 2010 to 2024 is shown in Figure 2-8, and the daily average rainfall is shown in Figure 2-9. The average annual rainfall for the Project Site is in the order of 739 mm/yr.

The project area falls within evaporation zone 21A, of which Mean Annual Evaporation (MAE) ranges from 1 200 to 1 300 mm/yr. The MAE far exceeds the MAP for the site, which implies greater evaporative losses when compared to incident rainfall. Monthly evapotranspiration for the site is likely to be distributed, as shown in Figure 2-7.

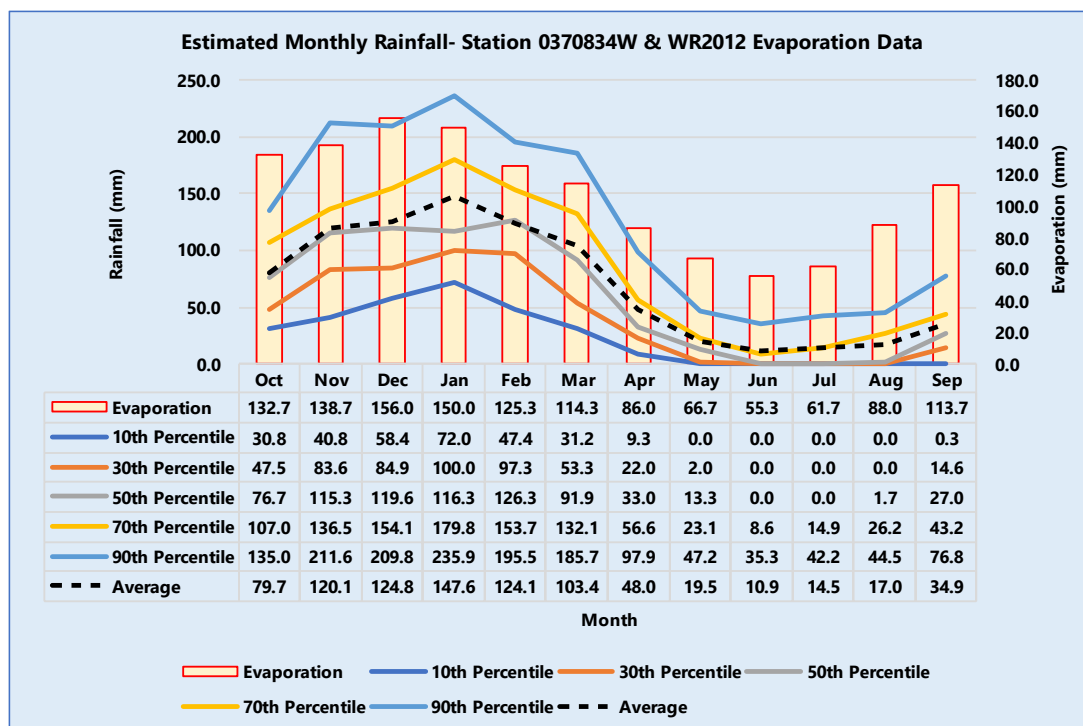


Figure 2-7: Average rainfall for Station 0370834W & WR2012 evaporation

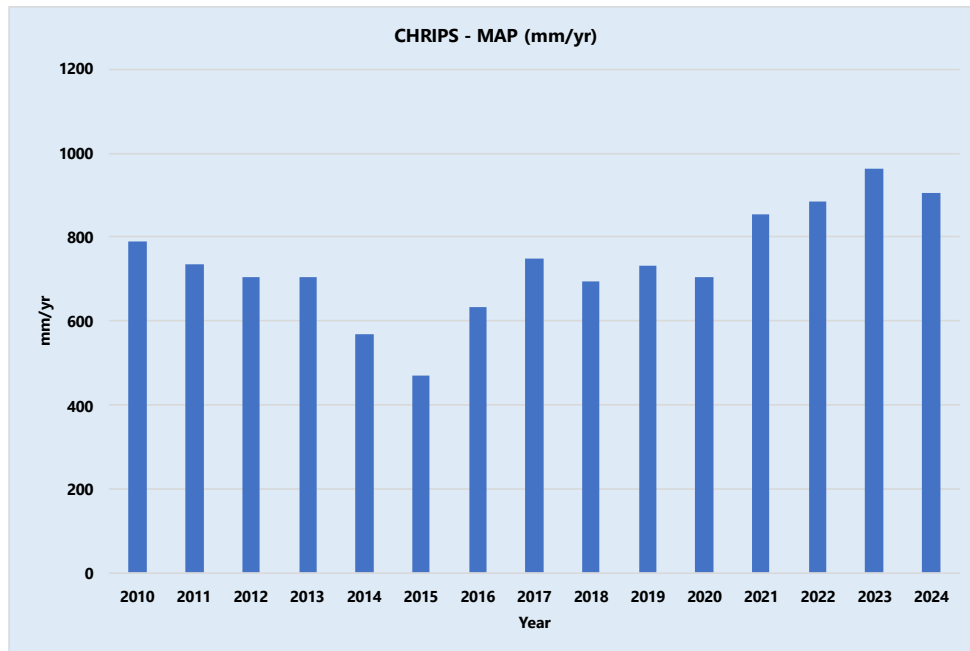


Figure 2-8: CHIRPS rainfall data for the site (2010 to 2024)

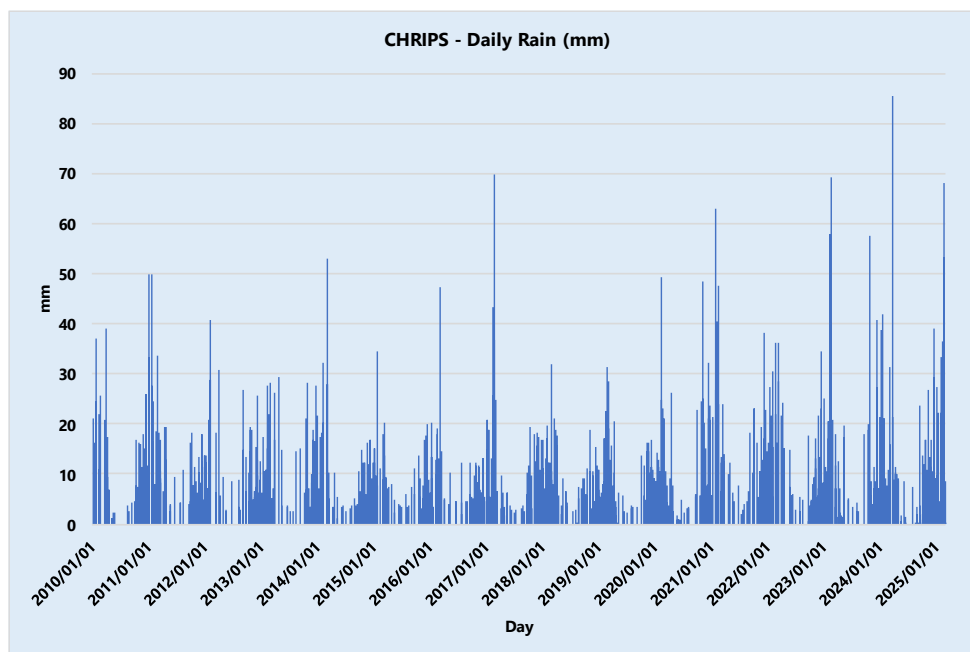


Figure 2-9: CHIRPS daily data for the site (2010 to 2024)

2.3.3 Run-off

Run-off from natural (unmodified) catchments for the quaternary, as simulated in WR2000/WR2012 models (WRC, 2015), is (refer to Figure 2-10 to Figure 2-12):

- ✚ 57.8 mm/yr for V31K.
- ✚ 114.5 mm/yr for V31F.
- ✚ 89.7 mm/yr for V31G.

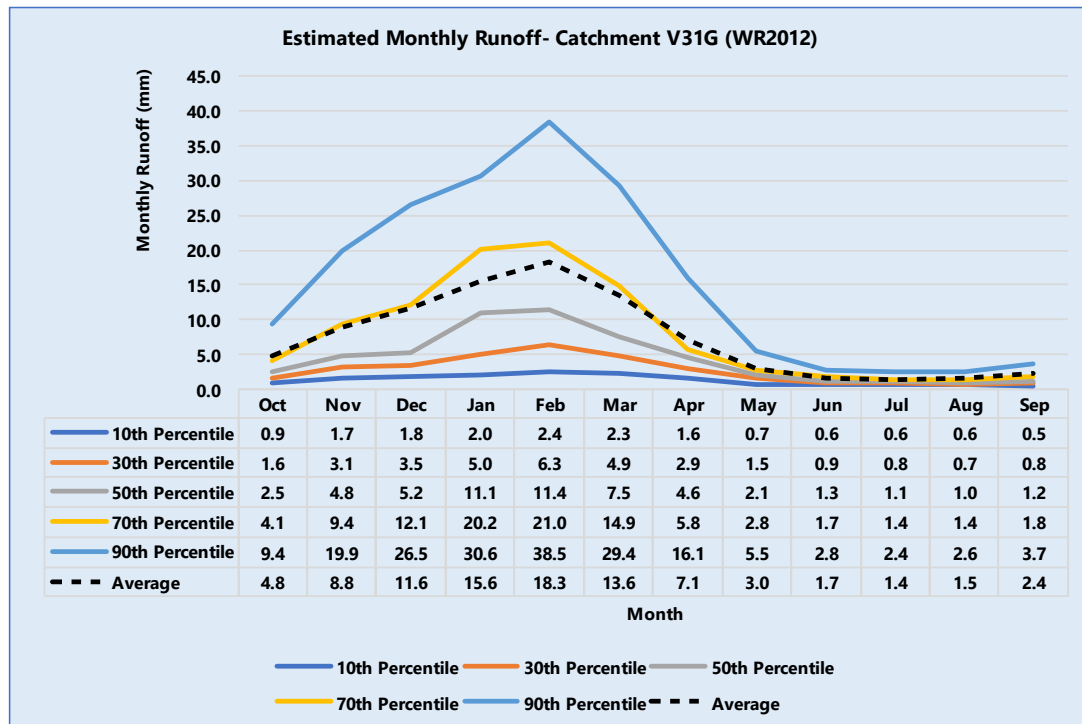


Figure 2-10: Simulated run-off distribution for V31G

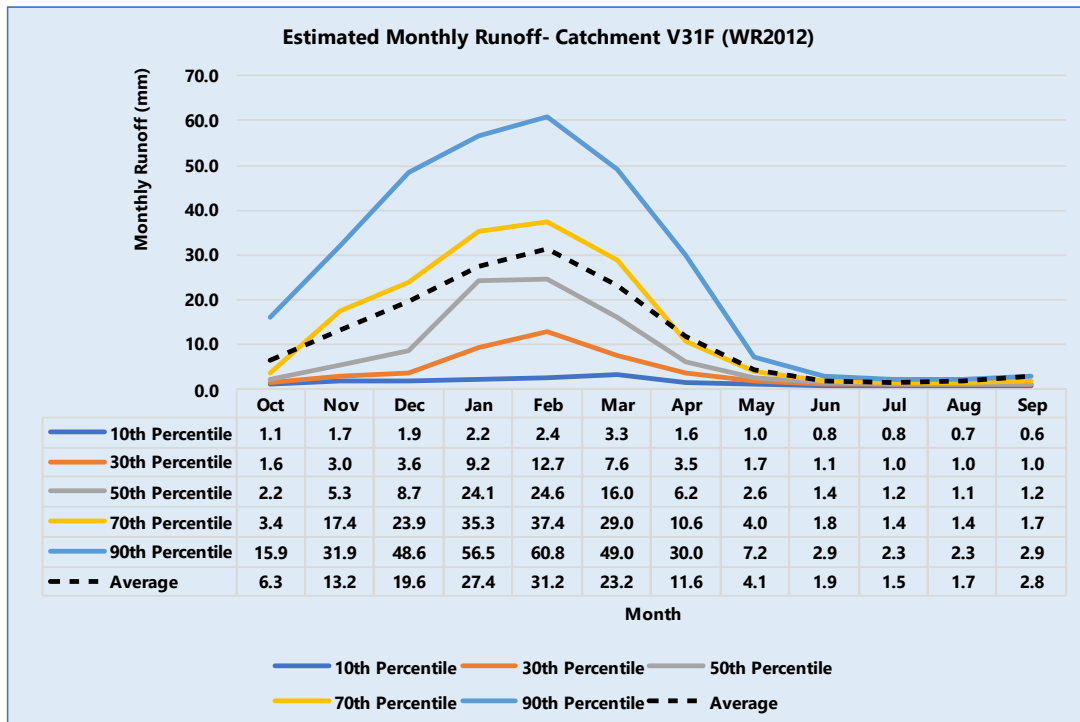


Figure 2-11: Simulated run-off distribution for V31F

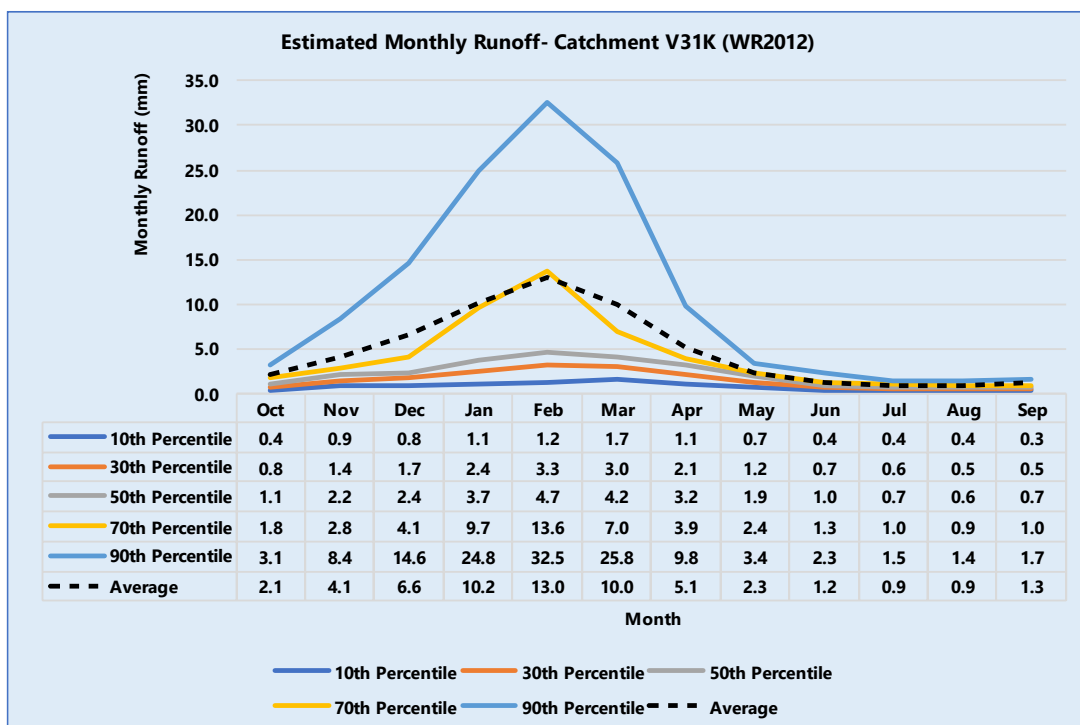


Figure 2-12: Simulated run-off distribution for V31K

2.3.4 Climate change considerations

The Paris Agreement of 2015 sets out a global framework to limit global warming to well below 2°C, preferably to 1.5°C (degrees Celsius), compared to pre-industrial levels. To achieve this global temperature goal, countries aim to reduce the growth of greenhouse gas emissions as soon as possible and rapidly reduce them, thereafter, based on the best available science.

The effects of climate change are already well visible by increasing air temperatures, melting glaciers, decreasing polar ice caps, rising sea levels, and increasing desertification, as well as by more frequent extreme weather events such as heat waves, droughts, floods, and storms. Climate change is not globally uniform and affects some regions more than others. In the following diagrams, you can see how climate change has already affected the area of Ballengeich during the past 40 years. The data source used is ERA5, the fifth-generation ECMWF atmospheric reanalysis of the global climate, covering the time range from 1979 to 2021, with a spatial resolution of 30 km.

Figure 2-6 shows the estimate of the mean annual temperature for the larger region of Ballengeich. The dashed blue line shows the linear climate change trend. If the trend line goes up from left to right, the temperature trend is positive, and Ballengeich is getting warmer due to climate change. If it is horizontal, no clear trend is seen, and if it is going down, conditions in Ballengeich are becoming colder over time. In the lower part, the graph shows the so-called warming stripes. Each coloured stripe represents the average temperature for a year - blue for colder and red for warmer years.

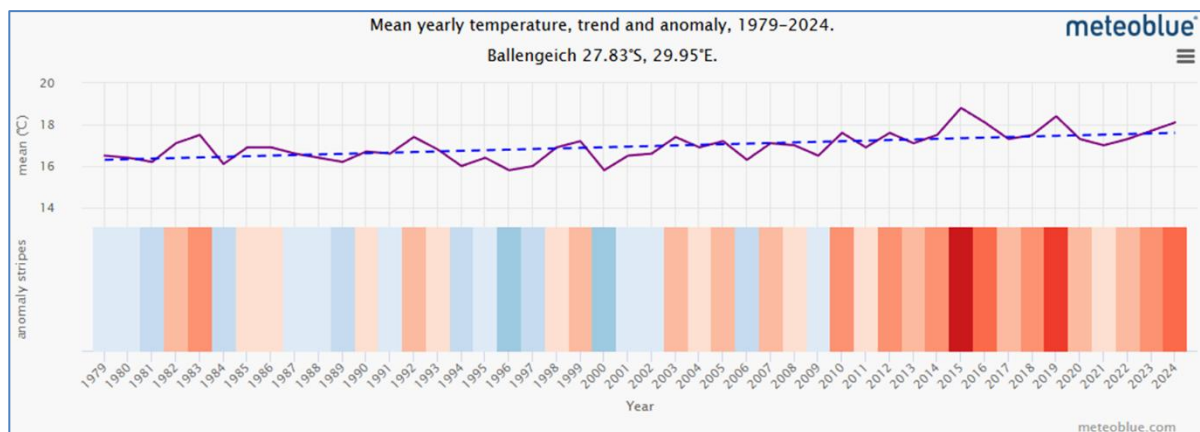


Figure 2-13: Yearly Temperature Change (Meteoblue, 2025)

Figure 2-14 shows an estimate of the mean total precipitation for the larger region of Ballengeich. The dashed blue line shows the linear climate change trend. If the trend line goes up from left to right, the precipitation trend is positive, and Ballengeich gets wetter due to climate change. If it is horizontal, no clear trend is seen, and if it is going down, conditions are becoming drier in Ballengeich over time. In the lower part, the graph shows the so-called precipitation stripes. Each coloured stripe represents the total precipitation of a year - green for wetter and brown for drier years.

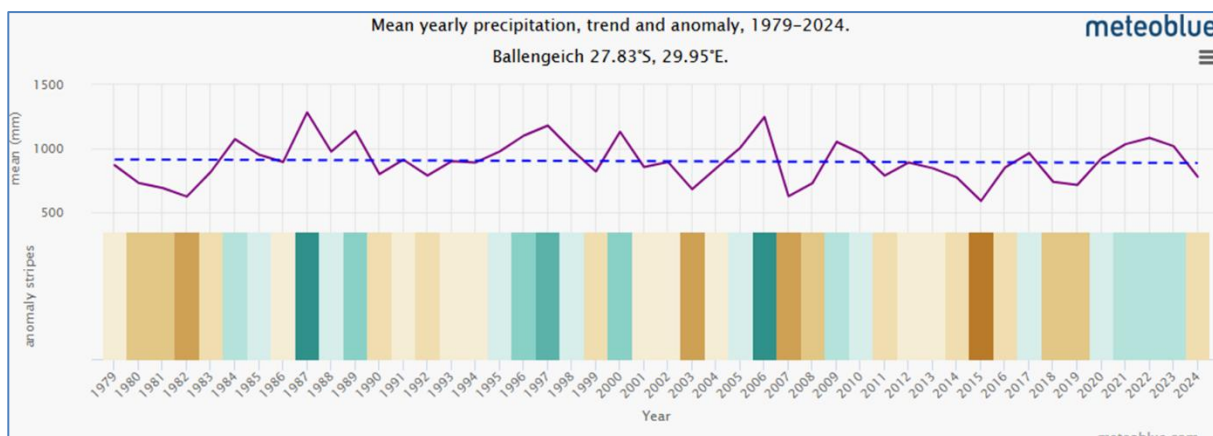


Figure 2-14: Yearly Precipitation Change (Meteoblue, 2025)

Figure 2-15 shows the temperature anomaly for every month since 1979 up to now. The anomaly tells you by how much it was warmer or colder than the 30-year climate mean of 1980-2010. Thus, red months were warmer and blue months were more frigid than usual. In most locations, you will find an increase in warmer months over the years, which reflects the global warming associated with climate change. The precipitation anomaly for every month since 1979 up to now is also shown in Figure 2-15. The anomaly tells you if a month had more or less precipitation than the 30-year climate mean of 1980-2010. Thus, green months were wetter and brown months were drier than usual.

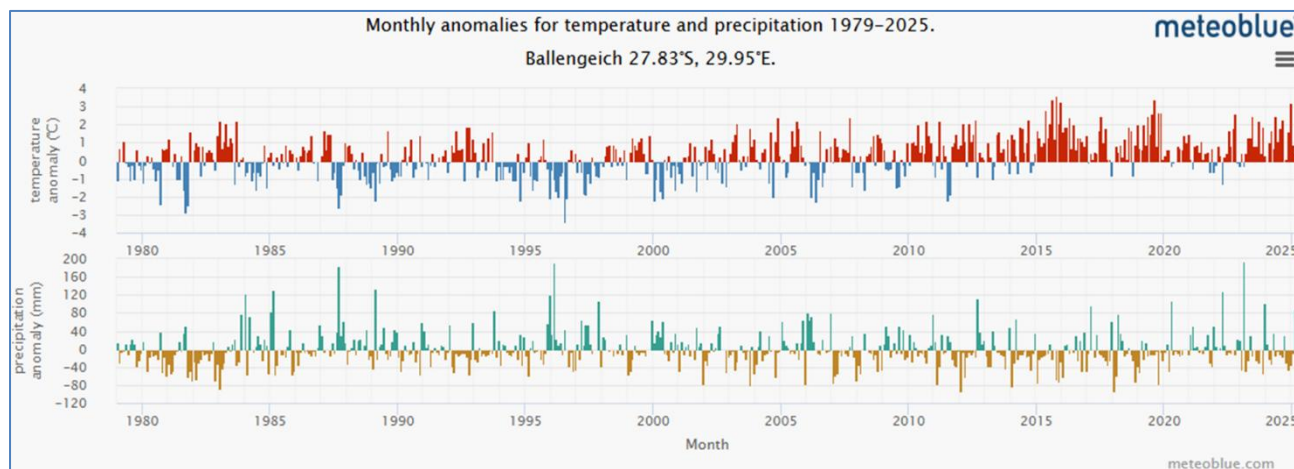


Figure 2-15: Monthly Anomalies of Temperature and Precipitation (Meteoblue, 2025)

Based on the above, it is predicted that there will be future temperature increases with more frequent extreme temperatures, which will result in fewer days of rainfall. Based on the rainfall decrease projections, it is concluded that there will be less frequent storm events (though not extreme) to facilitate the projected decreases in annual rainfall.

2.4 Hydrogeology and depth to groundwater

Available hydrogeology data suggests that three (3) aquifers exist in the area (refer to EWS Hydrogeology Assessment, 2025):

- ✚ An unconfined aquifer associated with the unconsolidated sands along the Horn River & Ingagane River, particularly in floodplain areas.
- ✚ A shallower aquifer system is associated with weathered to partly consolidated sedimentary rock as well as moderately to partially weathered sandstone and shale of the Ecca Group.
- ✚ A deeper confined fractured aquifer network associated with the Dwyka Group Tillite of the Karoo Sequence.

Historical underground workings have likely led to the formation of a hydrogeological unit in the mines that have undergone coal extraction. Significantly higher hydraulic conductivity and storage values are expected for the aquifer due to the presence of mine voids or backfilled material with higher permeability than surrounding sediment/rock. The flooded underground workings are believed to be in a pseudo-steady state and decanting near the Horn River.

The weathered zone for the area is estimated to be 5 - 28 m thick, followed by a subsequent thicker intergranular & fractured aquifer zone. The groundwater levels for the Ballengeich colliery range from artesian (decant area) to an average of 5.7 metres below ground level (mbgl). Groundwater is found within mined-out voids (underground workings beneath the regional water table), the weathered zone (perched), as well as fractures and bedrock contacts, contacts between lithologies or at unconformities and dolerite/diabase dyke contacts. The groundwater table mimics the topography, and groundwater flows from high-lying areas (water divides) to low-lying areas. Recharge to the underlying weathered aquifer is estimated to range from 4 to 6 % of the MAP, and that of deeper aquifer zones is estimated to be <3% (DWAF, 2006).

The groundwater at the Ballengeich Mine can be classified as Na-Cl (GW16), Ca-HCO₃ (UGBH5) and Ca-SO₄ (GW12, GW6, GW1). These are typical attributes of fresh shallow groundwater, deep ancient groundwaters, and groundwater impacted by mine drainage.

2.5 Wetland areas

Based on available National Wetland Freshwater Ecosystem Priority Areas (NFEPA) (Van Deventer, 2018), sections of the Horn River and the old Horn River have been classified as unchanneled valley bottom (UVB) wetlands, and the flood plain of the Ingagane River has been classified as seepage slope (Seep) wetland areas – refer to Figure 1-5. The presence of the wetland units mentioned was confirmed by (MENCO, 2022) – refer to Figure 2-16.

MENCO (2022) determined that the present ecological state and environmental importance and significance of the wetland is Class C (moderately modified and essential).

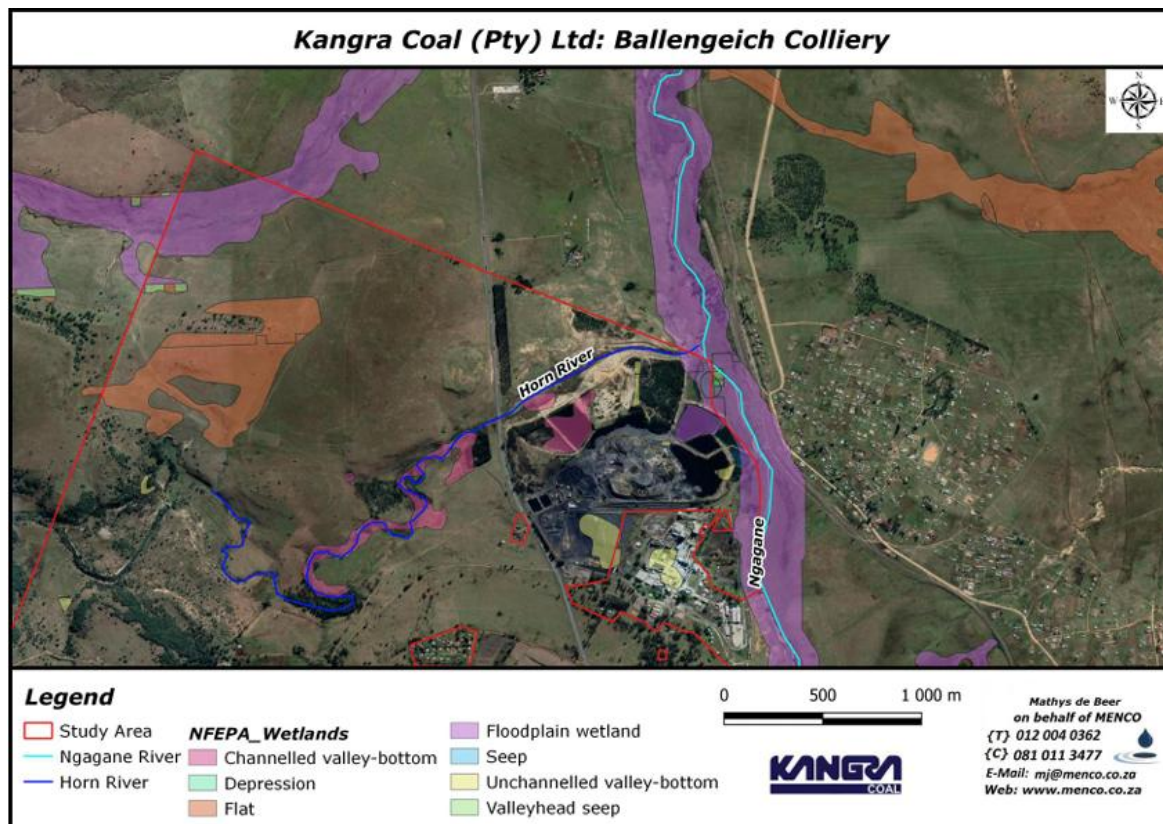


Figure 2-16: Wetland areas identified by Menco (2022)

In terms of wetland hydrogeology, baseflow is considered the most important contributor to wetland health. Baseflow (refer to Figure 2-17) is a non-process-related term that signifies low amplitude high-frequency flow in a river during dry or fair-weather periods. Baseflow is not a measure of the volume of groundwater discharged into a river or wetland, but it is recognised that groundwater contributes to the baseflow component of a river or wetland flow.

Available literature (WRC, 2015; DWAF, 2006) suggests that groundwater contribution to baseflow ranges from 7 mm/yr (PITMAN MODEL) to 37 mm/yr (HUGHES MODEL). This relates to approximately 0.9% to 4.4% of rainfall. Indications from the water monitoring of the Ngagane River suggest little impact relating to the Ballengeich operations, and therefore, it is believed that the Ngagane River is a losing river system (i.e. limited groundwater baseflow into the river takes place).

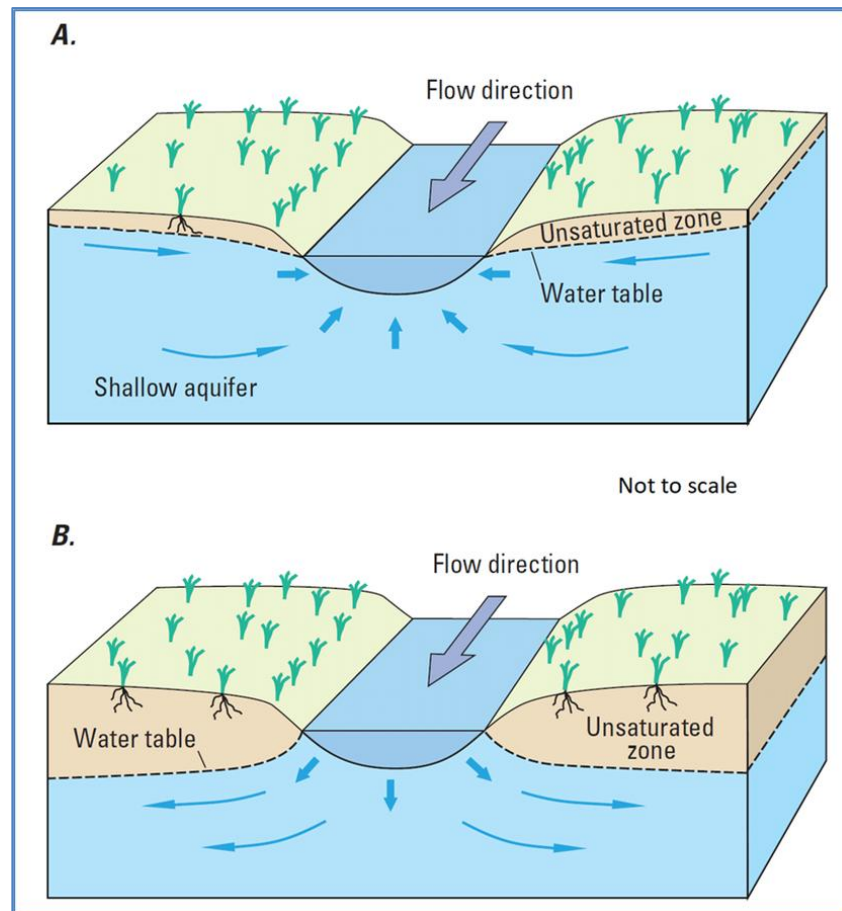


Figure 2-17: Groundwater baseflow concept

2.6 Present ecological state (PES), ecological importance and sensitivity (EIS), Ecological Water Reserve (EWR) and recommended ecological category (REC)

Table 2-3 provides a summary of the PES, EIS, REC and EWR (as a percentage of the MAR / Instream Rating Curves (IRF)) for the quaternary catchments associated with the project area. The same conditions are inferred to apply to delineated sub-catchments. It was decided that EWR could be simplified and represented as a percentage of Normal Dry Weather Flow (NDWF). The total releases for EWR were accounted for in the yield estimate.

Table 2-3: Summary of PES, EIS and EWR

Quat	PES	EIS	REC	Total Flow EWR (% nMAR)	Source
V31K – V31G	C	Moderately High	C/D	19.44 %	DWS Proposed Reserve Determination for Water Resources of the Thukela Catchments in the Pongola-Mtamvuna Water Management Area (DWS, 2024)

2.7 Land morphology and soils

Different soil types are typically encountered within the shoulder, mid-slope and valley positions of the project area (referred to as soil hillslope) and are mainly due to sub-surface geology, products of weathering, degree of saturation, soil texture and slope position (refer to Figure 2-18). The terrain in the project area ranges from flat to steep rolling hills, with soil depths ranging from 100 millimetres (mm) to < 1200 mm and clay content ranging from 10 - 30%.

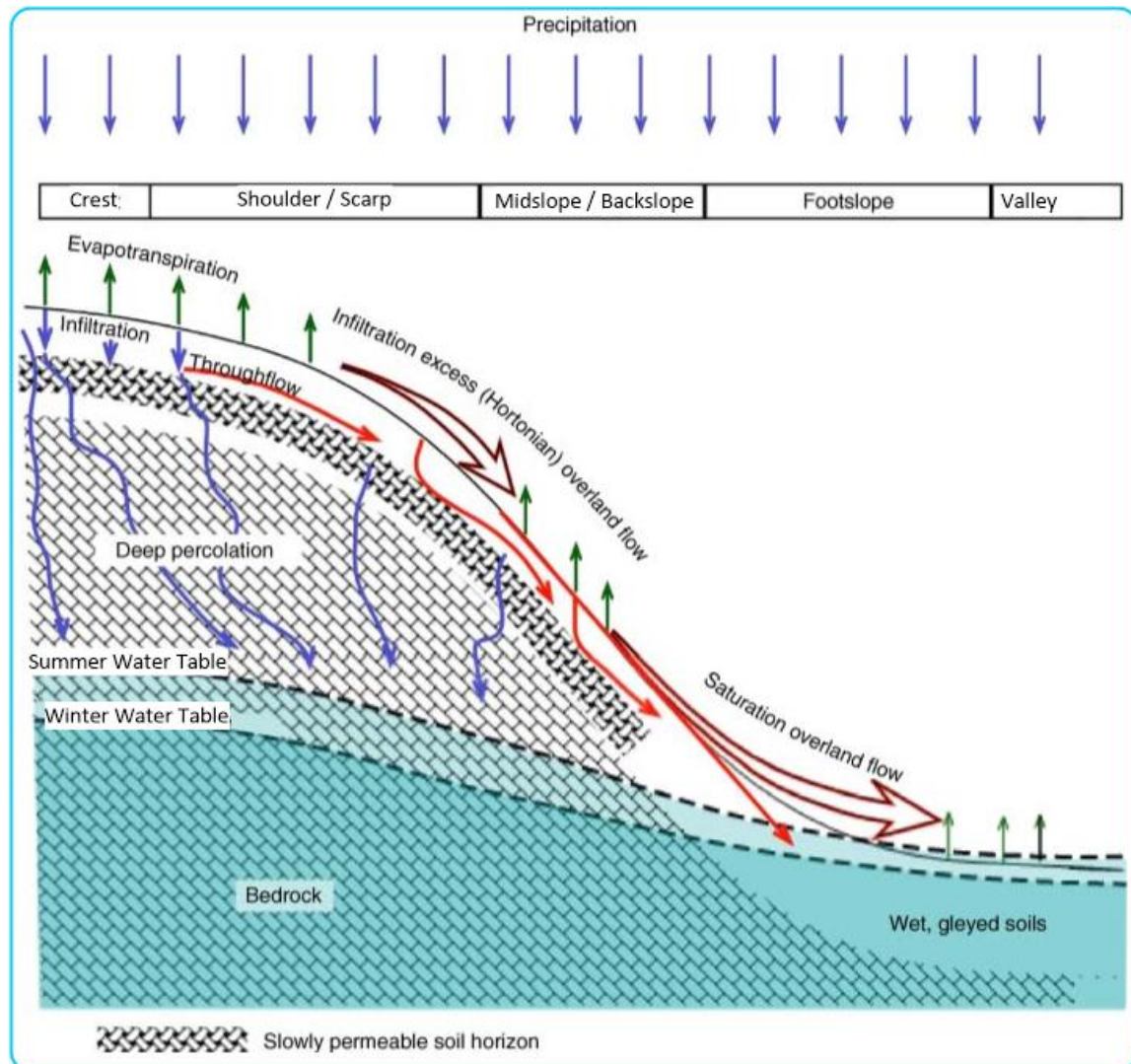


Figure 2-18:

Land morphology concept (Almond, 2016)

According to the Land Types of South Africa databases (ARC, 2006), the soils in the area fall within the Bb land types. Soils associated with these groups typically entail:

- ✚ Bb - Red and yellow, dystrophic/mesotrophic, apedal soils with plinthic subsoils (plinthic soils comprise >10% of land type, red soils comprise <33% of land type) – refer to Figure 2-19 and Figure 2-20.

The moisture regime in these soils is often dominated by the presence of restricting rock and soil layers at depths that lead to the perching of water in localised water tables and lateral seepage zones. The soils are, therefore, characterised by distinct zones of water fluctuation, zones of prolonged saturation with clearly expressed redox morphology features and zones where water manifests close or at the surface through return flow. The redox morphology indicative of the presence of the water is often used in the textbook description of mottling and grey colour as indicative of wetland conditions. It, therefore, follows that landscapes with plinthic soils have a large proportion of the soil-covered surface that qualifies as wetlands with distinct permanent, extensive seasonal/seepage and temporary wetland zones. Due to the generally accepted notion that the degree and duration of saturation are expressed increasingly through grey and bleached soil colours, it follows that the red soil-dominated plinthic landscapes (viz. Ba and Bc land types) tend to exhibit smaller wetland soil distributions than yellow and bleached soil dominated plinthic landscapes (viz. Bb and Bd land types). The Ba land type soil distribution can be considered the “modal” example of colour juxtaposition that is used for the identification of terrestrial and wetland zones in a landscape (Der Waals, 2019).

The land capability of plinthic landscapes is very strongly linked to 1) the depth of the soil profiles and 2) the extent and degree of lateral seepage and water-feeding mechanisms at depth. Euphemistically, these soils are often referred to as being characterised by “subsoil irrigation” processes. These processes lead to good crop yields in most years, average and dry years, with high rainfall years proving problematic due to the inundation of fields and drowning of plants. The extensive temporary and seasonal seepage areas provide a degree of insurance to land users against crop failures in the variable rainfall environment of South Africa’s grain crop production areas (Der Waals, 2019).

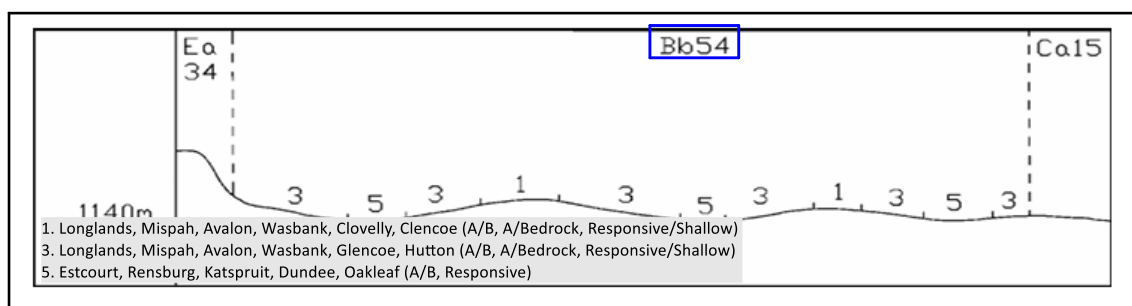


Figure 2-19: Bb54 land type

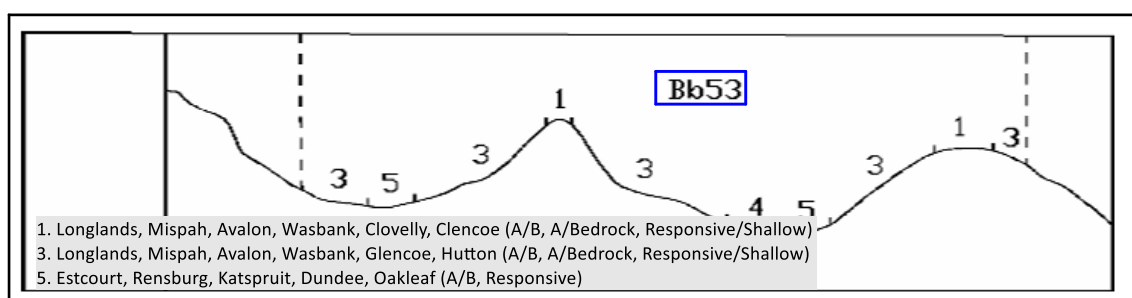


Figure 2-20: Bb53 land type

According to Soil Conservation Service (SCS) data for the project area, the soils are divided into "Type A/B" soils. SCS curve number is a function of the ability of soils to allow infiltration of water, land use and the antecedent soil moisture condition. Table 2-4 provides a summary of the hydrological characteristics of the different SCS soil types. The soils have a moderate erosion potential.

Table 2-4: Summary of SCS soil type hydrological characteristics (Muthu, 2015)

Hydrological Soil	Type of Soil	Runoff Potential	Final Infiltration Rate (mm/hr)	Remarks
Group A	Deep, well-drained sands and gravel	Low	>7.5	High rate of water transmission
Group B	Moderately deep, well-drained with moderately fine to coarse textures	Moderate	3.8 – 7.5	Moderate rate of water transmission
Group C	Clay loams, shallow sandy loam, soils with moderately fine to fine textures	Moderately high	1.3 – 3.8	Moderate rate of water transmission
Group D	Clay soils that swell significantly when wet, heavy plastic and soils with a permanent high-water table	High	<1.3	Low rate of water transmission

2.8 Soil permeability

Based on available soil data for the project area, it is observed that the soils are characterised by silty-clay soils. The estimated permeabilities, as indicated in Table 2-5 and Table 2-6, apply to the project Site.

Table 2-5: Soil permeability classes for agriculture and conservation (Food and Agriculture Organization (FAO, 1980))

Soil Texture	Permeability (cm/hour)
Sand	5
Sandy Loam	2.5
Loam	1.3
Clay Loam	0.8
Silty Clay	0.25
Clay	0.05

Table 2-6: DWS range of hydraulic conductivities in different soil types (DWS, 2011)

Type	Saturated Hydraulic Conductivity, Ks (cm/s)
Gravel	$3 \times 10^{-2} - 3$
Coarse Sand	$9 \times 10^{-5} - 6 \times 10^{-1}$
Medium Sand	$9 \times 10^{-5} - 5 \times 10^{-2}$
Fine Sand	$2 \times 10^{-5} - 2 \times 10^{-2}$
Loamy Sand	4.1×10^{-3}
Sandy Loam	1.2×10^{-3}

Type	Saturated Hydraulic Conductivity, Ks (cm/s)
Loam	2.9×10^{-4}
Silt, Loess	$1 \times 10^{-7} - 2 \times 10^{-3}$
Silt Loam	1.2×10^{-4}
Till	$1 \times 10^{-10} - 2 \times 10^{-4}$
Clay	$1 \times 10^{-9} - 4.7 \times 10^{-7}$
Sandy Clay Loam	3.6×10^{-4}
Silty Clay Loam	1.9×10^{-5}
Clay Loam	7.2×10^{-5}
Sandy Clay	3.3×10^{-5}
Silty Clay	5.6×10^{-6}
Un-weathered marine clay	$8 \times 10^{-11} - 2 \times 10^{-7}$

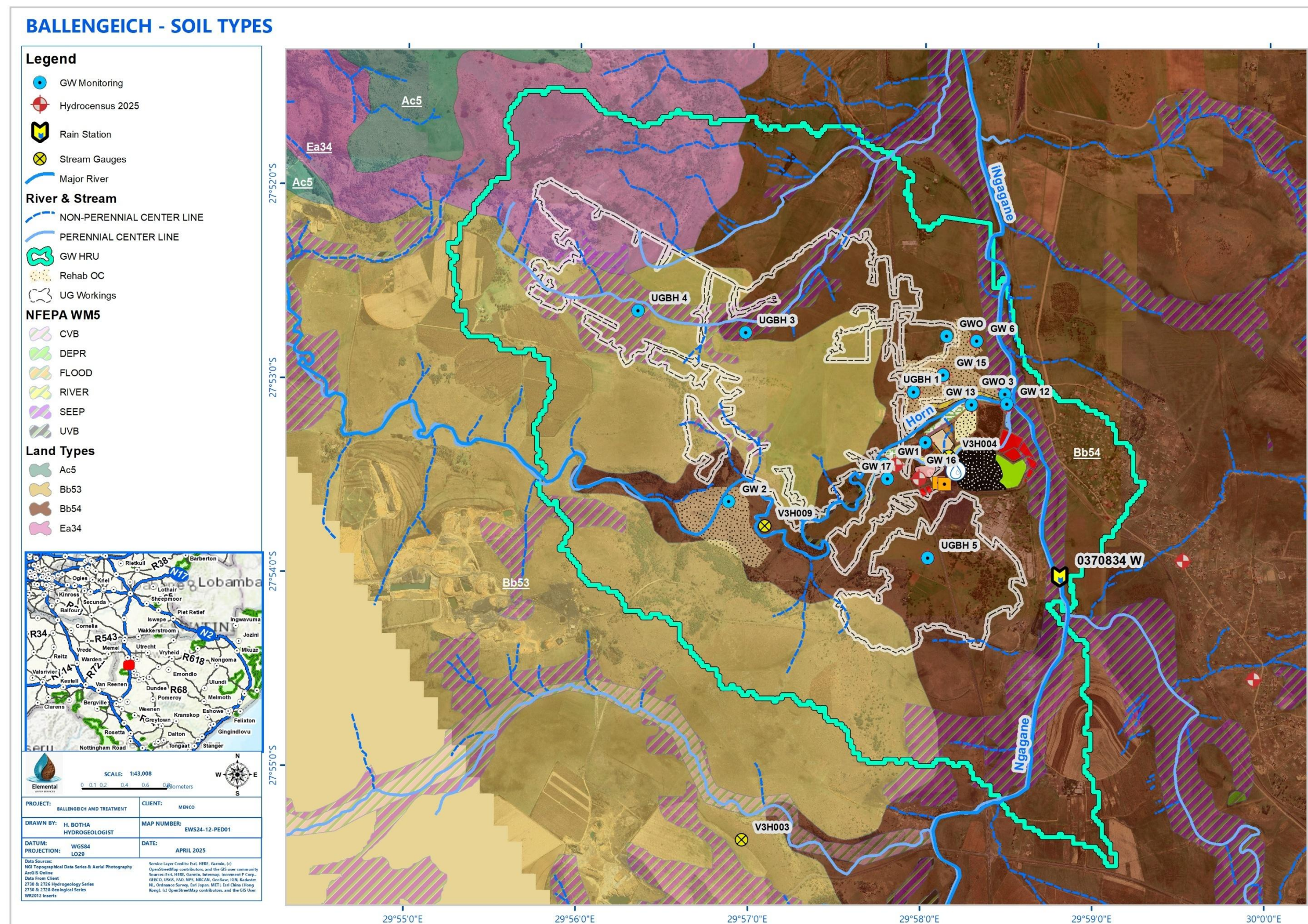


Figure 2-21: SA land cover types (ARC-LRN)

3 HYDROPEDOLOGY ASSESSMENT

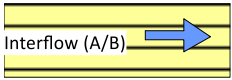
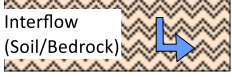
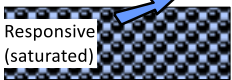
Soil genesis is influenced by physical and chemical water-related processes, and soils are, therefore, the first-order control of hydrological processes. The water transfer function of soils varies depending on several factors, including soil properties, topography, and climate.

Characteristic soil properties make it possible to conceptualise hillslope hydrological responses within catchments. As per Section 2.7, the soil in the study and that associated with the Bb land types are generally dominated by the presence of restricting rock and soil layers at depths that lead to the perching of water in localised water tables and lateral seepage zones.

3.1 Hydrological Soil Types (HST)

In the determination of Hydrological Soil Types (HST), soils were divided into classes based on their expected hydrological responses (Van Tol, et al., 2013). Hydrological processes were perceived from traceable signatures in the soil matrix resulting from the soil's ability to transmit, store and react with water (Le Roux, et al., 2011). The HST descriptions and representative symbols are presented in Table 3-1.

Table 3-1: Hydrological soil types

Hydrological soil type	Description	Symbol
Recharge	The soils do not have any morphological indication of saturation. Vertical flow through and out of the profile into the underlying bedrock is the dominant flow path. These soils are deep and freely drained and are experiencing the leaching of nutrients to underlying soil horizons.	
Stagnating	Stagnating soils tend to act like interflow (soil/bedrock) soil types. However, due to the presence of abundant clays, lateral discharge is slow. A build-up of water content in the soil profile leads to temporary perched groundwater after high rainfall events.	
Interflow (A/B)	The soils have a textural discontinuity, which facilitates the build-up of water in the topsoil. The water that sits on the upper layer then flows laterally into the stream on the A/B horizon interface. The flow path is predominantly downslope in a lateral direction.	
Interflow (Soil/Bedrock) Or Interflow (A/ Bedrock)	Soils overlying relatively impermeable bedrock. Hydromorphic properties signify the temporal build of water on the soil/bedrock interface and slow discharge in a predominantly lateral direction.	
Responsive (Shallow)	The soils are shallow, and they are over a relatively less permeable, weathered rock or bedrock. They have limited storage capacity, which results in the generation of overland flow after rainfall events.	
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.	

*Adapted from (Van Tol, et al., 2013)

3.2 Conceptual hydropedological flow process

The expected dominant hydropedological flow processes associated with the Ballengeich area are shown in Figure 3-1. In general, the project site is dominated by interflow (soil/bedrock), responsive (shallow) and shallow recharge soils. It is believed that shallow groundwater baseflow from perched groundwater tables and shallow bedrock contributes to the wetland systems. The wetlands can, therefore, be considered gaining in wet months and may become losing systems to the regional water table during the dry months.

1. a. These are shallow soil profiles underlain by weathered bedrock, which are prone to causing a buildup of water on the soil/bedrock interface with a slow discharge predominantly in a lateral direction (downslope). Secondary percolation deeper into the profile can take place, however, depending on the degree of weathering and clay content of the deepest soil profile.

2.a. Shallow soils with limited storage capacity are prone to cause overland runoff during and shortly after rainfall events. Perched groundwater tables may also occur and are expected to be seasonal. These soils are classified as responsive (shallow) hydrological soils.

3.a. Vertical flow through and out of the profile into the underlying bedrock is the dominant flow path. These soils are deep and freely drained and are experiencing the leaching of nutrients to underlying soil horizons. Recharge to the regional groundwater table is expected to occur via the saturated soils and will follow the hydraulic head associated with the regional water table.

4. Depending on the degree of weathering, joints and fractures associated with the Karoo rock, there may be deep vertical percolation into the groundwater table.

It is important to note that the proposed development of artificial wetlands could induce new hydropedological flow processes relating to stagnant or responsive (saturated) HSTs. The impact, however, will be small, as the footprint of the proposed wetland and pre-treatment limestone drains is <0.5% of the total sub-catchment area.

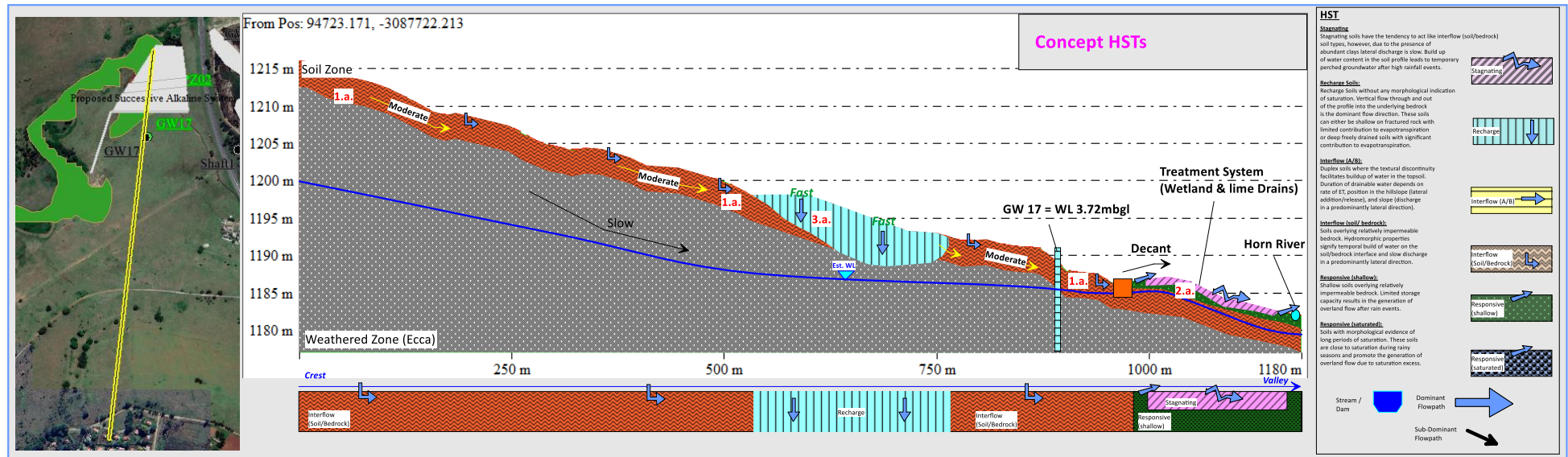


Figure 3-1: Conceptual hillslope of the expected HSTs for the Ballengeich Mine

4 HYDROPEDOLOGY IMPACT ASSESSMENT

For the Ballengeich Mine, there are existing impacts due to decant and poor-quality seepage into the groundwater table and directly into the Horn River. The activities proposed aim to improve the environmental status and reduce the impacts relating to the decant and poor-quality seepage.

There may be some construction phase risk for the development of the artificial wetland, limestone drains, ALD and SAPS. The operational phase of the treatment proposed will have positive environmental impacts.

The potential impact on hydropedological flow drivers and risk associated with the activities mentioned above were further investigated in the sub-sections below.

4.1 Flow driver impact categories

Table 4-1 summarises the criteria used for the hydropedological flow driver impact assessment. The flow driver impact assessment aims to characterise the likely impacts on the hydropedological flow drivers (i.e., what are the likely impacts of the development on the hydropedological flow drives sustaining a wetland or stream after the development has taken place).

Table 4-1: Impact categories for describing the impact on the wetlands and associated hydropedological drivers

Severity	Flow Driver Reduction	Change Class	Description
No Impact	0 – 2.5%	No change	The hydropedological process is predicted to be unmodified, and the functionality of the wetland/river will remain unchanged.
Low	2.5 – 5%	No Significant change	A small effect on the hydropedological process is predicted. However, the functionality of the wetland/river remains unchanged, and no change in resource class is expected.
Low to Moderate	5 – 10%	Limited change with a change in the PES category is possible	A slight change in hydropedological processes is predicted, and a small change in the wetland/river may have taken place but is changed to the (present ecological state) PES, EIS (ecological importance and sensitivity) or wetland/river functionality and eco service provision is limited with no more than one PES class predicted.
Moderate	10 – 15%	A significant change with a change in PES Category definite and possibly a change of more than one category	A moderate change in the hydropedological processes is predicted to occur; the change in PES may exceed one category, but no change in EIS will take place. No loss of important eco-services is predicted to occur.
High	15 – 22.5%	A very significant change with a change in PES of more than two categories	Modifications have reached a very significant level, and the hydropedological processes are predicted to be largely modified with a large change in the PES and EIS of the wetland/river feature as well as a significant loss in eco service provision.
Very High	22.5 - 60%	Serious to Critical change with a change in PES of more than three categories or a permanent complete loss of wetland/river resource	Modifications have reached a serious level, and the hydropedological processes have been seriously modified, resulting in an almost complete loss of wetland/river integrity, functionality, and service provision.

4.2 Flow driver loss calculation/impact estimation

A water balance approach was adopted to estimate the potential impacts on the flow drivers. The equation used was as follows:

$$\text{Flow Loss \%} = \frac{FN (m^3/yr.)}{WT (m^3/yr.)} \times 100 \text{ (convert to \%)} \quad \text{Equation 1}$$

Where:

✚ FN = Sum of Total Negative flow driver impacts in a given sub-catchment.

✚ WT = Total water in the system.

And:

$$FN = RRI + GBR + AII + NRF \quad \text{Equation 2}$$

✚ RRI = Est. direct rainfall run-off intercepted by the development (m³/yr.).

✚ GBR = Est. reduced groundwater contribution to flow drivers/GW dewatering (m³/yr.).

✚ AII = Est. aquifer and soil interflow intercepted by the development/activity (m³/yr.); and

✚ NRF = Est. surface run-off intercepted, which would naturally flow from upper catchments to the downstream environment (m³/yr.) – estimated at 30% of the MAP.

Adding positive water releases to the flow driver system (i.e., diverting rainwater to the environment via stormwater systems) may offset the negative. The equation used was as follows:

$$\text{Net Flow loss impact (\%)} = \frac{[\Sigma \text{Total Negative flow driver impacts (m}^3/\text{yr.)} - \text{Positive Adjustments (m}^3/\text{yr.)}]}{\text{Total water in the system (m}^3/\text{yr.)}} \times 100 \text{ (convert to \%)} \quad \text{Equation 3}$$

Where:

The Sum of Positive Adjustments (m³/yr.) are:

✚ Est. positive flow releases previously impacted (m³/yr.); and

✚ Est. new positive flow releases not impacted on (m³/yr.).

4.2.1 Assumptions

The following assumptions were made:

- ✚ In the calculation, it is assumed that all soil water is fed by rainwater, and a semi-closed back model is considered. A "closed model water balance" assumes that all water within a system stays within that system, meaning no water enters or exits from external sources, while a "semi-closed model water balance" allows for some limited exchange of water with the surrounding environment, typically with controlled inflows and outflows.
- ✚ Constant evaporation of 30% is assumed for the sub-catchments.
- ✚ No groundwater dewatering is included in the calculation. Abstraction volumes are not known.
- ✚ MAP is in the order of 739 mm/yr.
- ✚ Groundwater recharge is in the order of 5.1% (DWAF, 2006).
- ✚ Vegetation soil water uptake is not considered in the calculation.
- ✚ Groundwater contribution to baseflow is assumed to be in the order of 7.86 mm/yr (DWAF, 2006).
- ✚ Existing land developments have been included as impermeable surfaces contributing to the cumulative impact of hydropedology flow on the sub-catchments.
- ✚ No interception of upstream catchment overland flow paths is considered (i.e., no deep mining that cuts into the bedrock or trench systems where water is intercepted upstream of the site and removed from the flux system.
- ✚ No artificial recharge, other than in the case of a mitigation measure (i.e., attenuated stormwater releases to rivers/streams/drainage lines or artificial irrigation), is accounted for. Recharge seepage from waterbodies (i.e., losing wetlands, dams, rivers, and lakes) is not accounted for due to the lack of data available for these systems. Uniform recharge in the order of available literature data is assumed.
- ✚ The existing setting and activities are evaluated. Built-up areas are assessed as being impermeable or having no flow boundaries. Areas where artificial release of water will take place are seen as sources of water entering the vadose zone. This was done to evaluate the likely impacts of PES/EIS.
- ✚ The above-mentioned assumptions were made to give a worst-case overview of the likely impacts on the hydropedological flow water balance as a result of the activities at the site.

4.2.2 Calculations

The calculations for impact on the hydropedological flow drivers, pre- and post-mitigation, are shown in Table 4-2.

Table 4-2: Calculated hydropedological flow balance and impacts thereon

		Rainfall	PED HRU / GW HRU
		mm/yr	739.193
		GW Recharge - DEEP	PED HRU / GW HRU
		%	5.10
		mm/yr	37.7
		BF - SHALLOW	PED HRU / GW HRU
		mm/yr	7.86
		Runoff	PED HRU / GW HRU
		Stormwater factor (%)	20%
		Runoff Factor (%)	69%
Where negative = Surplus of soil flow induced due to proposed mitigation measure			
Drivers	Status	km ²	
Natural Water Processes	+	Total Rain Volume (m ³ /yr)	20,693,700.57
	-	Runoff (m ³ /yr)	14,278,653.39
	+	Re AQ - Deep / Shallow Percolation (m ³ /yr)	1,055,378.73
	+	BF - Shallow Soil Interflow (m ³ /yr)	219,947.38
	+	Interflow / Transfer from Upstream Sub-Catchments	-
	-	Evap (m ³ /yr)	5,139,721.06
		Balance	-
		Interflow / Percolation Component	1,275,326.11
Description		Development	PED HRU / GW HRU
The area that becomes impermeable or altered. Activities that may impact interflow and deep percolation.		Est. Disturbance Area (km ²) - Above Ground / Impermeable	0.032
		Est. Disturbance Area (km ²) - Soil Removal	0.010
		Est. Disturbance Area (km ²) - Under Ground	-
		Est. Intercepted Flow Area (m ²)	-
		Est. Groundwater Dewatering (l/sec)	-
		Est. Dewater/Decant Rate	HRU1
		m ³ /day	
Drivers	Status	Impact	PED HRU / GW HRU
Impacted Processes	-	Rainfall Intercepted (m ³ /yr)	23,572.86
	-	Soil Zone Water Loss (m ³ /yr)	75.16
	-	Deeper Zone Water Loss (under soils) (m ³ /yr)	-
	-	Deeper Vadose Zone & Water Table - DEWATER (m ³ /yr)	-
	-	Horizontal Interflow Removed (m ³ /yr)	-
	+	Attenuation Pond (m ³ /yr)	-
		Negative Impacts	23,648.02
		% Impact on Natural Flow System	1.85%

4.3 Estimated flow losses and risk rating

The overall impacts on the natural soil flow systems/flux were estimated and combined in context with the PED HRU / GW HRU. Table 4-3 summarises the estimated % loss ratings for the sub-catchments – pre- and post-mitigation.

The predicted impact on the flow drivers associated with the proposed activities is calculated as “no-impact”. Therefore, the proposed activities are predicted to have a marginal impact on the hydropedological flow functions.

The current PES and EIS will likely be maintained. However, considering that the treatment system will remove salt metals and stabilise pH, a slight improvement in PES and EIS is expected over time.

Table 4-3: Estimated % Loss rating for micro-catchments (hillslopes)

Sub-Catchment	Est. Flow Driver Impact (No Mitigation)	Severity
HRU1	1.85%	No Impact

4.4 Hydropedological buffers and avoidance areas

No hydropedological buffers are required as the predicted impact is marginal.

5 RISK ASSESSMENT

Risk assessment entails understanding the generation of a hazard, the probability that the hazard will occur, and the consequences if it should occur. The net consequence is established by the following equation:

$$\text{Consequence} = \text{Duration} + \text{Extent} + (\text{Irreplaceability of resource}) \times \text{Severity}$$

And

$$\text{Environmental Significance (SP)} = \text{Consequence} \times \text{Probability}$$

The risk significance rating is summarised in Table 5-1

Table 5-1: Risk rating scale

Criteria	Rating Scales
Environmental Significance (SP)	Very high – negative (-49 to -66)
	High – negative (-37 to -48)
	Moderate – negative (-25 to -36)
	Low – negative (-13 to -24)
	Neutral - Very low (0 to -12)
	Low-positive (0 to 12)
	Moderate-positive (13 to 24)
	High-positive (37 to 48)
	Very high – positive (49 to 66)

The anticipated hydropedological impacts for the preparation, operational and closure phases impacts are summarised in Table 5-2 to Table 5-3. The risks were evaluated in the context of the hydropedological setting, as well as existing impacts and predicted impacts.

5.1 Preparation phase

The following activities are anticipated during the preparation phase of the project:

- ✚ Typical earthworks are required to clear the areas.
- ✚ Construction of access roads.
- ✚ Establish service platforms, material handling areas, and other temporary infrastructure.
- ✚ Dust suppression of access roads.
- ✚ Construction of the wetlands, ponds, dams and associated drains.
- ✚ Placing of topsoil in designated areas; and
- ✚ Constructing laydown areas and temporary stormwater systems and berms.

The identified possible hydrology impacts for the preparation phase include (refer to Table 5-2):

- ✚ The destruction of the vadose zone sediments by clearing activities. This impact is permanent and is therefore not included in the impact table, as no mitigation measures can be recommended. This could lead to sediment runoff and surface water contamination.
- ✚ Secondary seepage from the decant area as a result of diversion and temporary management of the decant is needed to construct the required semi-passive treatment system.
- ✚ Clearing topsoil from footprint areas will influence the rate of infiltration of water to the shallow groundwater system and/or baseflow component to shallow streams.
- ✚ Transporting material can cause various types of spills (i.e. hydrocarbons or dosing chemicals), which can infiltrate and contaminate the soils and groundwater system.
- ✚ Oil and fuel spills and leakages at vehicle park areas and in the project areas may cause poor-quality seepage and soil contamination.

Overall, the predicted impact is low and may decrease to marginal if mitigation measures are implemented – refer to the tables below. Ongoing quarterly groundwater and surface water monitoring will help to establish new impacts, and weekly site inspections will be keen to determine issues that could lead to environmental incidents.

5.2 Operational Phase

The operational phase will be indefinite, as decant and AMD will be treated indefinitely. The predicted impacts are as follows (refer to Table 5-3):

- ✚ Ongoing passive treatment of AMD.
- ✚ Improvement of the environmental status of the Horn River and Ingagane River, as well as reduced salt loads into the watercourses.
- ✚ The groundwater impact will remain mostly unchanged until the Ballengeich discard dump is rehabilitated, as well as pollution control dams.

5.3 Offsets and alternatives

No alternatives are available, and the proposed treatment system must be placed in the pre-defined areas in order to ensure optimum efficiency of the treatment of AMD. No hydropedological buffers or offsets were identified.

5.4 Cumulative impacts and impacts on soil water flow and quality

There is an existing groundwater impact and surface water impact associated with the Ballengeich Mine. The status is predicted to improve after rolling out of the treatment system. Thus far, and based on surface water quality and quantity data for the existing setting, the impact on the hydropedological flow functions appears to be marginal.

Limited operational phases exist, and the impact on the hydropedological flow cycle will be marginal due to the Project Type. The tables below consider the mentioned cumulative impacts in the impact rating.

Table 5-2: Impacts during the preparation phase

Component being impacted	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation						
			Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance		Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance
Soil interflow processes: ✚ Infilling of watercourses inducing alternative flow paths (if infilling occurs). ✚ Alteration to natural hydropedological flow paths. ✚ Impacts on the macro-soil structure. ✚ Impacts on the hydropedological processes supporting the watercourses. Soil structure & land capability: ✚ Exposure to soil leads to increased runoff from cleared areas and erosion of the watercourses, thus increasing the potential for sedimentation. ✚ Vegetation loss. ✚ Soil compaction and ✚ Soil erosion. Soil quality: ✚ Natural nutrient content decreases due to soil exposure. ✚ Loss of natural bio-organisms essential to soil processes.	✚ Site preparation, including placement of contractor laydown areas and storage (i.e., temporary stockpiles, bunded areas, etc.) facilities.	Earthworks	Medium Term (4)	Site (2)	Yes (1)	Low (-1)	Slightly detrimental (-7 to -12) (-7)	Definite (2)	Low (12 to -25) (-14)	✚ Only excavate areas applicable to the project area. ✚ Backfill the material in the same order it was excavated to reduce contamination of deeper soils with shallow, oxidised soils. ✚ Cover excavated soils with a temporary liner to prevent contamination.	Medium Term (4)	Site (2)	Yes (1)	Negligible (0)	Negligible (0 to -6) (-0)	Probable (1)	Negligible (0 to -12) (0)
	✚ Disturbing vadose zone during soil excavations/infilling activities.	Earthworks	Medium Term (4)	Site (2)	Yes (1)	Moderate (-2)	Moderately detrimental (-14 to -24) (-14)	Definite (2)	Moderate – negative (-24 to -36) (-28)	✚ Keep the site clean of all general and domestic wastes. ✚ All development footprint areas are to remain as small as possible, and vegetation clearing is to be limited to what is essential. ✚ Retain as much indigenous vegetation as possible. ✚ Exposed soils are to be protected using a suitable covering or revegetating.	Medium Term (4)	Site (2)	Yes (1)	Negligible (0)	Negligible (0 to -6) (-0)	Probable (1)	Negligible (0 to -12) (0)
	✚ Vegetation clearing & soil stockpiling.	Earthworks	Medium Term (4)	Site (2)	Yes (1)	Moderate (-2)	Moderately detrimental (-14 to -24) (-14)	Definite (2)	Moderate – negative (-24 to -36) (-28)	✚ Existing roads should be used as far as practical to gain access to the site, and crossing watercourses in areas where no existing crossing is apparent should be unnecessary, but if it is essential, crossings should be made at right angles. ✚ Have emergency fuel & oil spill kits on site. ✚ Soil quality monitoring & visual assessments – monthly basis. If obvious pollution is noted (visually), then soil screening should be undertaken.	Medium Term (4)	Site (2)	Yes (1)	Negligible (0)	Negligible (0 to -6) (-0)	Probable (1)	Negligible (0 to -12) (0)

Component being impacted	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation						
			Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance		Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance
Soil quality	⚠️ AMD spillages occurred during excavations and installation of the treatment system. Moreover, oil & fuel spills from vehicles parked at the site may compromise soil quality. Prolonged pollution may migrate to the nearby watercourse and/or percolate into the groundwater table.	Earthworks	Medium Term (4)	Site (2)	Yes (1)	Low (-1)	Slightly detrimental (-7 to -12) (-7)	Definite (2)	Low (12 to -25) (-14)	⚠️ Have emergency fuel & oil spill kits on site. ⚠️ Ensure proper AMD management berms and water-managed strategies are incorporated into the development phase of the treatment system.	Medium Term (4)	Site (2)	Yes (1)	Negligible (0)	Negligible (0 to -6) (-0)	Probable (1)	Negligible (0 to -12) (0)
Primary Surface Water Receivers ⚠️ Horn River ⚠️ Wetland units	Erosion and sedimentation runoff may enter the stream (worst case). To date, no sedimentation has taken place (i.e. no evidence observed during the site walkover assessment).	The net result of the installation of the treatment system	Medium Term (3)	Site (2)	Yes (1)	High (-3)	Highly detrimental (-19 to -24) (-18)	Probable - definite(1.5)	Moderate - negative (-25 to -36) (-27)	⚠️ Use temporary or permanent stormwater systems (as per this report) to prevent erosion and manage sediment runoff. ⚠️ Visual inspections of all vehicles entering and operating at the site. ⚠️ Use silt traps or fences where required to manage runoff and areas prone to cause erosion. This will decrease sedimentation risk.	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low - negative (-13 to -24) (-24)
	Decant from the underground workings into the Horn River and flow into the Ingagane River.	Decant	Long Term (4)	Site (2)	Yes (1)	High (-3)	Extremely detrimental (-25 to -33) (-28)	Definite(2)	Very high - negative (-49 to -66) (-56)	⚠️ Temporary diversion methods are used to manage the runoff of AMD into the Horn River during the construction of the lime drains and treatment ponds. ⚠️ Ensure that AMD water is kept within already impacted drainage servitudes.	Long Term (4)	Site (2)	Yes (1)	High (-3)	Extremely detrimental (-25 to -33) (-28)	Probable - definite(1.5)	High - negative (-37 to -48) (-42)

Table 5-3: Impacts during the closure operational & decommissioning phase

Component being impacted	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation						
			Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance		Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance
Soil interflow processes: ✚ Alteration to natural hydropedological flow paths. ✚ Impacts on the macro-soil structure. ✚ Impacts on the hydropedological processes supporting the watercourses.	✚ Disturbing the inner-soil architecture of the original soil profile will disturb natural flow processes (i.e., a result of infilling or cut-and-fill activities). ✚ Excavated soil will be placed in other areas (i.e., on top of other soils) and will have an impact on the flow dynamics of the soil it is dumped on top of. This may reduce rainfall infiltration and induce runoff. ✚ Impermeable areas (urbanisation) may decrease rainfall infiltration into recharge soils and hence reduce recharge and interflow (A/B and A/bedrock) or lateral flow to downstream river areas.	The net result of the development	Long-term (4)	Site (2)	Yes (1)	Low (-1)	Slightly detrimental (-7 to -12) (-7)	Definite (2)	Low (12 to -25) (-14)	✚ Revegetate areas (with vegetation growing at the site) where heavy machinery movement takes place to prevent erosion. ✚ Establish where excavated soils will be placed during the construction phase and determine if the area is suitable for receiving the excavated soils. ✚ Cover excavated soils to be protected using a suitable covering.	Long-term (4)	Site (2)	Yes (1)	Negligible (0)	Negligible (0 to -6) (0)	Probable (1)	Negligible (0 to -12) (0)
	✚ The development of dedicated wetland attenuation could enhance hydropedological flow into the wetland area.	Artificial interflow generation	Long-term (4)	Site (2)	Yes (1)	High (+3)	Highly beneficial (19 to 24) (21)	Definite (2)	High-positive (24 to 48) (42)	✚ No mitigation is required. Positive effects.							
Soil structure & land capability: ✚ Exposure to soil leads to increased runoff from cleared areas and erosion of the watercourses, thus increasing the potential for sedimentation. ✚ Vegetation loss. ✚ Soil compaction and ✚ Soil erosion.	✚ In areas that are backfilled with collapsible soils, there may be a probability of subsidence/erosion. Likely associated with soil structure compaction.	Collapsible soils/erosion	Long-term (4)	Site (2)	Yes (1)	Low (-1)	Slightly detrimental (-7 to -12) (-7)	Definite (2)	Low (12 to -25) (-14)	✚ Retain as much indigenous vegetation as possible. ✚ Have emergency fuel & oil spill kits on site.	Long-term (4)	Site (2)	Yes (1)	Negligible (0)	Negligible (0 to -6) (0)	Probable (1)	Negligible (0 to -12) (0)

Component being impacted	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation						
			Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance		Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance
Primary Surface Water Receivers 📍Horn River 📍Wetland units	Decant from the underground workings into the Horn River and flow into the Ingagane River. The AMD will be treated via the proposed semi-passive treatment system.	Decant	Long Term (4)	Site (2)	Yes (1)	High Positive (+3)	Extremely beneficial (25 to 33) (28)	Definite (2)	Very high – positive (49 to 66) (56)	📍 Continue with groundwater monitoring and surface water monitoring up to 5 years after the system is installed. Re-evaluate the requirement for monitoring based on quality trends thereafter.							
Regional water table	Poor quality seepage percolation into the groundwater table	Seepage from existing infrastructure at Ballengeich Mine	Long Term (4)	Site (2)	Yes (1)	High (-3)	Extremely detrimental (-25 to -33) (-28)	Definite(2)	Very high – negative (-49 to -66) (-56)	📍 Rehabilitate the discard dump at the site's closure. 📍 Ensure that PCDs are rehabilitated or re-purposed at closure. 📍 Ensure that the plants and stockpiles are rehabilitated. 📍 Continue with groundwater and surface water monitoring up to 5 years after the closure of the mine to confirm closure trends and mitigation measures that will be required.	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)

6 CONCLUSIONS

The moisture regime in these soils is often dominated by the presence of restricting rock and soil layers at depths that lead to the perching of water in localised water tables and lateral seepage zones. The soils are, therefore, characterised by distinct zones of water fluctuation, zones of prolonged saturation with clearly expressed redox morphology features and zones where water manifests close or at the surface through return flow.

The predicted impact on the flow drivers associated with the proposed activities is calculated as “no-impact”. Therefore, the proposed activities are predicted to have a marginal impact on the hydropedological flow functions. The current PES and EIS will likely be maintained. However, considering that the treatment system will remove salt metals and stabilise pH, a slight improvement in PES and EIS is expected over time.

There is an existing groundwater impact and surface water impact associated with the Ballengeich Mine. The status is predicted to improve after rolling out of the treatment system. Thus far, and based on surface water quality and quantity data for the existing setting, the impact on the hydropedological flow functions appears to be marginal.

Limited operational phases exist, and the impact on the hydropedological flow cycle will be marginal due to the Project Type. The tables below consider the mentioned cumulative impacts in the impact rating.

6.1 Hydropedological buffers and mitigation measures

No alternatives are available, and the proposed treatment system must be placed in the pre-defined areas in order to ensure optimum efficiency of the treatment of AMD. No hydropedological buffers or offsets were identified.

6.2 Mitigation measures for inclusion in the EMPr

The following mitigation measures can be considered as part of the EMPr:

- ✚ Ensure fuel spill cleaning kits are on site.
- ✚ It is recommended that mitigation measures, as described in Section 4, be implemented during the construction and operational phase of this Project.

6.3 Reasoned opinion on whether the activity should be authorised

Based on the findings of this assessment, EWS believes that the proposed activities will benefit the receiving groundwater, hydropedological, and surface water environments. The approval of the activity should be considered to enable Kangra to mitigate the impacts associated with the Legacy Ballengeich Mine.

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APPENDIX A: RISK ASSESSMENT

Due to the assessment forming part of a larger risk assessment for the study area, the potential impacts and the determination of impact significance were assessed. The process of assessing the potential impacts of the Project encompasses the following four activities:

1. Identification and assessment of potential impacts.
2. Prediction of the nature, magnitude, extent, and duration of potentially significant impacts.
3. Identification of mitigation measures that could be implemented to reduce the severity or significance of the impacts of the activity and
4. Evaluation of the significance of the impact after the mitigation measures have been implemented, i.e., the significance of the residual impact.

Per GNR 982 of the EIA Regulations (2014), the significance of potential impacts was assessed in terms of the following criteria:

1. Cumulative impacts.
2. Nature of the impact.
3. The extent of the impact.
4. Probability of the impact occurring.
5. The degree to which the impact can be reversed.
6. The degree to which the impact may cause irreplaceable loss of resources and
7. The degree to which the impact can be mitigated.

Table 7-1 provides a summary of the criteria used to assess the significance of the potential impacts identified. An explanation of these impact criteria is provided in Table 7-2.

[Consequence = (Duration + Extent + Irreplaceability of resource) x Severity] Equation 4

The environmental significance of an impact was determined by multiplying the consequence by probability.

[Environmental Significance = (Consequence x (Probability + Reversibility))] Equation 5

Table 7-1: Proposed Criteria and Rating Scales to be used in the Assessment of the Potential Impacts

Criteria	Rating Scales	Notes
Nature	Positive (+)	An evaluation of the effect of the impact related to the proposed development.
	Negative (-)	
Extent	Footprint (1)	The impact only affects the area in which the proposed activity will occur.
	Site (2)	The impact will affect only the development area.
	Local (3)	The impact affects the development area and adjacent properties.
	Regional (4)	The impact extends beyond municipal boundaries.
	National (5)	The impact extends beyond more than 2 regional/provincial boundaries.
	International (6)	The impact extends beyond the country's borders.
Duration	Temporary (1)	The duration of the activity associated with the impact will last 0-6 months.
	Short-term (2)	The duration of the activity associated with the impact will last 6-18 months.
	Medium-term (3)	The duration of the activity associated with the impact will last 18 months years.
	Long-term (4)	The duration of the activity associated with the impact will last more than 5 years.
Severity	Low (1)	Where the impact affects the environment in such a way that natural, cultural, and social functions and processes are minimally affected.
	Moderate (2)	Where the affected environment is altered, natural, cultural, and social functions and processes continue, albeit in a modified way, and valued, important, sensitive, or vulnerable systems or communities are negatively affected.
	High (3)	Where natural, cultural, or social functions and processes are altered to the extent that the natural process will temporarily or permanently cease, and valued, important, sensitive, or vulnerable systems or communities are substantially affected.
Potential for impact on irreplaceable resources	No (0)	No irreplaceable resources will be impacted.
	Yes (1)	Irreplaceable resources will be impacted.
Consequence	Extremely detrimental (-25 to -33)	A combination of extent, duration, intensity, and the potential for impact on irreplaceable resources.
	Highly detrimental (-19 to -24)	
	Moderately detrimental (-13 to -18)	
	Slightly detrimental (-7 to -12)	
	Negligible (-6 to 0)	
	Slightly beneficial (0 to 6)	
	Moderately beneficial (7 to 18)	
	Highly beneficial (19 to 24)	
Probability (the likelihood of the impact occurring)	Extremely beneficial (25 to 33)	It is highly unlikely or less than 50% likely that an impact will occur.
	Improbable (0)	
	Probable (1)	
	Definite (2)	
Significance	Very high – negative (-49 to -66)	A function of Consequence and Probability.
	High – negative (-37 to -48)	
	Moderate – negative (-25 to -36)	
	Low – negative (-13 to -24)	
	Neutral - Very low (0 to -12)	
	Low-positive (0 to 12)	
	Moderate-positive (13 to 24)	
	High-positive (24 to 48)	
	Very high – positive (49 to 66)	

Table 7-2: Explanation of Assessment Criteria

Criteria	Explanation
Nature	This is an evaluation of the type of effect the construction, operation, and management of the proposed development would have on the affected environment. Will the impact of change on the environment be positive, negative, or neutral?
Extent or Scale	This refers to the spatial scale at which the impact will occur. The extent of the impact is described as footprint (affecting only the footprint of the development), site (limited to the site), and regional (limited to the immediate surroundings and closest towns to the site). The extent of scale refers to the actual physical footprint of the impact, not to the spatial significance. It is acknowledged that some impacts, even though they may be of a small extent, are of very high importance, e.g., impacts on species of very restricted range. To avoid "double counting, specialists have been requested to indicate spatial significance under "intensity" or "impact on irreplaceable resources" but not under "extent" as well.
Duration	The lifespan of the impact is indicated as temporary, short, medium, and long-term.
Severity	This is a relative evaluation within the context of all the activities and the other impacts within the framework of the Project. Does the activity destroy the impacted environment, alter its functioning, or render it slightly altered?
Impact on irreplaceable resources	This refers to the potential for an environmental resource to be replaced should it be impacted. A resource could be replaced by natural processes (e.g., by natural colonisation from surrounding areas), through artificial means (e.g., by reseeded disturbed areas or replanting rescued species) or by providing a substitute resource, in certain cases. In natural systems, providing substitute resources is usually not possible, but in social systems, substitutes are often possible (e.g., by constructing new social facilities for those who are lost). Should it not be possible to replace a resource, the resource is essentially irreplaceable, e.g., red data species that are restricted to a particular site or habitat to a very limited extent.
Consequence	The consequence of the potential impacts is a summation of the above criteria, namely the extent, duration, intensity, and impact on irreplaceable resources.
Probability of occurrence	The probability of the impact occurring is based on the professional experience of the specialist with environments of a similar nature to the site and/or with similar projects. It is important to distinguish between the probability of the impact occurring and the probability that the activity causing a potential impact will occur. Probability is defined as the probability of the impact occurring, not as the probability of the activities that may result in the impact.
Significance	Impact significance is defined as a combination of the consequence (as described below) and the probability of the impact occurring. The relationship between consequence and probability highlights that the risk (or impact significance) must be evaluated in terms of the seriousness (consequence) of the impact, weighted by the probability of the impact occurring. In simple terms, if the consequence and probability of an impact are high, then the impact will have a high significance. The significance defines the level to which the impact will influence the proposed development and/or environment. It determines whether mitigation measures need to be identified and implemented and whether the impact is important for decision-making.
Degree of confidence in predictions	Specialists and the EIR team were required to indicate the degree of confidence (low, medium, or high) in the predictions made for each impact based on the available information and their level of knowledge and expertise. The degree of confidence is not considered in the determination of consequence or probability.
Mitigation measures	Mitigation measures are designed to reduce the consequence or probability of an impact or to reduce both consequence and probability. The significance of impacts has been assessed both with mitigation and without mitigation.

APPENDIX B: DISCLAIMER

The opinions expressed in this Report have been based on site /project information supplied to Elemental Water Services Proprietary Limited (EWS) and are based on public domain data and data supplied to EWS by the client. EWS has acted and undertaken this assessment objectively and independently.

EWS has exercised all due care in reviewing the supplied information. Whilst EWS has compared key supplied data with expected values, the accuracy of the results and conclusions are entirely reliant on the accuracy and completeness of the supplied data. EWS does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them.

Opinions presented in this Report apply to the site conditions and features as they existed at the time of EWS investigations, as well as those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which EWS had no prior knowledge nor had the opportunity to evaluate.

APPENDIX C: CV OF SPECIALIST



Elemental
WATER SERVICES

Hendrik Botha

Principal Hydrogeologist & Director

LinkedIn:



CORE SKILLS

- ✦ Project management
- ✦ Analytical and numerical groundwater modelling
- ✦ Geochemical assessments and geochemical modelling
- ✦ Hydropedology and soil pollution assessments
- ✦ Hydrology, floodline modelling, yield modelling, storm water management
- ✦ Groundwater vulnerability, impact, and risk assessments
- ✦ Technical report writing
- ✦ GIS and mapping

DETAILS

Qualifications

- ✦ BSc Chemistry and Geology (Environmental Sciences) (2012)
- ✦ BSc Hons Hydrology (Environmental Sciences) (2013)
- ✦ MSc Geohydrology and Hydrology (Environmental Sciences) (2014-2016)

Membership

- ✦ Groundwater Division of GSSA
- ✦ Groundwater Association of KwaZulu Natal Member
- ✦ International Mine Water Association (IMWA)

Languages

- ✦ Afrikaans – Speak, read, write.
- ✦ English – Speak, read, write.

Projects undertaken in

- ✦ South Africa
- ✦ Nigeria
- ✦ Namibia
- ✦ Liberia
- ✦ Malawi
- ✦ Botswana

PROFILE

Hendrik (Henri) Botha is a Principal Hydrogeologist. He holds an MSc in Environmental Science in Geohydrology & Geochemistry and a BSc Hons. Degree in Hydrology. He is registered as a SACNASP Professional Natural Scientist in the Earth Science Field. Groundwater, geochemistry and surface hydrology, as well as knowledge of water chemistry together with GIS and analytical and numerical modelling skills, are some of his sought-after expertise. General and applied logical knowledge are his key elements in problem-solving.

Professional Affiliations:

SACNASP Professional Natural Scientist (400139/17)

Areas of Expertise:

- ✦ Project Management of water and environmental projects for mining, industrial and agriculture sectors.
- ✦ Integrated Water Investigations
- ✦ Waste Classification and Impact Assessments
- ✦ Aquifer vulnerability assessments
- ✦ Geochemical sampling, data interpretation and modelling
- ✦ Groundwater impact and risk assessments
- ✦ Numerical and Conceptual Visual Modelling (Visual Modflow, ModflowFLEX, Voxler, RockWorks, Surfer and Excel)
- ✦ Hydropedology (Hydrological Soil Types) & Soils Assessments
- ✦ Floodline Modelling (HEC-RAS)
- ✦ Conceptual Stormwater Management Assessments and EPA SWMM modelling
- ✦ Surface Water Yield Assessments
- ✦ Water and Salt Balance



SCAN ME
PROJECT RECORD

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