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Hydrology Assessment for the Proposed Co-Disposal Facility & Water Treatment Plant at Kangra Maquasa East Operations

Report

Version - Final 1

17 November 2023

Kangra Coal

GCS Project Number: 22-0161

Client Reference: 111862



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DECLARATION OF INDEPENDENCE

GCS (Pty) Ltd was appointed to conduct this specialist surface water study and to act as the independent hydrological specialist. GCS objectively performed the work, even if this results in views and findings that are not favourable. GCS has the expertise in conducting the specialist investigation and does not have a conflict of interest in the undertaking of this study. This report presents the findings of the investigations which include the activities set out in the scope of work.

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

Table 1 - Requirements from Appendix 6 of GN 326 EIA Regulation 2017

Requirements from Appendix 6 of GN 326 EIA Regulation 2017	Chapter
(a) Details of: (i) The specialist who prepare the reports; and (ii) the expertise of that specialist to compile a specialist report including a curriculum vitae	Document pg ii. Appendix C.
(b) Declaration that the specialist is independent in a form as may be specialities by the competent authority	Document pg iii. 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 7.
(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 include of 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 6.
(g) Identification of any areas to be avoided, including buffers	Section 9.1.
(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	Section 9.
(k) Mitigation measures for inclusion in the EMPr	Section 9.2
(l) Conditions for inclusion in the environmental authorisation	Refer to Section 9.
(m) Monitoring requirements for inclusion in the EMPr or environmental authorisation	Refer to Section 9.
(n) Reasoned opinion – (i) as to whether the proposed activity, activities or portions thereof should be authorised. (iA) 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 9.3.
(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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LIST OF ACRONYMS

Acronym	Description
BA	Basic Assessment
BOD	Biological oxygen demand
COD	Chemical oxygen demand
CSWMP	The conceptual stormwater management plan
DEM	Digital Elevation Model
DWS	Department of Water and Sanitation
GCS	GCS Water and Environment (Pty) Ltd.
SW	Surface Water
GN704	General Notice 704
ha	Hectare
HRU	Hydrological Response Unit
IWULA	Integrated Water Use Licence Application
m^3	Cubic Metres
MAE	Mean annual evaporation
MAR	Mean Annual Runoff
MIPI	Midgley and Pitman
NEMA	National Environmental Management Agency
n-Value	Manning's Roughness Coefficients
NWA	National Water Act, 1998 (Act No. 36 of 1998)
PCD	Pollution Control Dam
PFD	Process flow diagram
SDF	Standard design flood
SPP	Sewage Package Plant
TDS	Total dissolved solids
TIN	Triangulated Irregular Network
WMA	Water Management Area
WR2012	Water Resources of South Africa 2012
MQE	Maquasa East

1 INTRODUCTION

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Kangra Coal (Pty) Ltd to undertake a hydrological assessment for the proposed development of a Co-Disposal Facility and Water Treatment Plant (WTP) in the Maquasa East, near Driefontein, Mpumalanga Province (refer to Figure 1-3). The project falls in quaternary catchment W51B of the Pongola to Mtamvuna Water Management Area (WMA) (DWS, 2016).

1.1 Project background

Kangra Coal is an existing coal mine located in Driefontein, near Piet Retief, in the Mkhondo Local Municipality within the Gert Sibande District Municipality. The Maquasa East (MQE) operations include the historical opencast and underground operations. Kangra is proposing to construct a water treatment plant as well as a co-disposal facility at their Maquasa East operations. The treatment plant will be used to treat water from the existing decant point as well as any surplus water within the mining operations.

1.1.1 Water Treatment Plant:

Decant is currently observed in the form of clear groundwater discharge emanating from the old underground workings at MQE close to the Heyshope Dam. This decant is observed at an elevation range of approx. 1303 to 1306 mamsl and is contained in an unlined contamination dam. This excess decant is currently pumped from the unlined dam back to the MQE PCDs. Based on available data from previous studies undertaken at the mine decant observed emanating from the old workings occurs at a rate ranging from 1 220 to 2 700 m^3/d (average 1 800 m^3/d), depending on the rainfall season.

Kangra intends to upgrade the current contamination dam with a correctly lined dam as approved by the Department of Water and Sanitation to prevent any seepages onto the Heyshope Dam. The decant will be pumped into the proposed wastewater treatment plant that will be situated close to the Maquasa East PCDs. Construction and operation of the discussed infrastructure will trigger listed activities that will require authorisation.

The master layout plan associated with the proposed water treatment plant and brine storage facilities proposed (and existing PCDs) is shown in Figure 1-1.

It should also be noted that Kangra is investigating the possibility of storing brine on the discard dump/co-disposal that will come from the water treatment plant. This is one of the two options, with the other being dedicated brine evaporation ponds. GCS has not yet received confirmation as to which option Kangra are opting for, thus impacts relating to both are considered in this assessment.

Treated water will be discharged into the Heyshope dam at the existing decant rate at pristine water quality (in line with GA limits for treated effluent discharge), and therefore will likely not have a negative impact on water quantity or quality. Compared to the active decant wate quality, the proposed activity is predicted to improve the Heyshope water quality. Proposed discharge will take place at an existing abstraction point west of Driefontein, that is no longer in use.

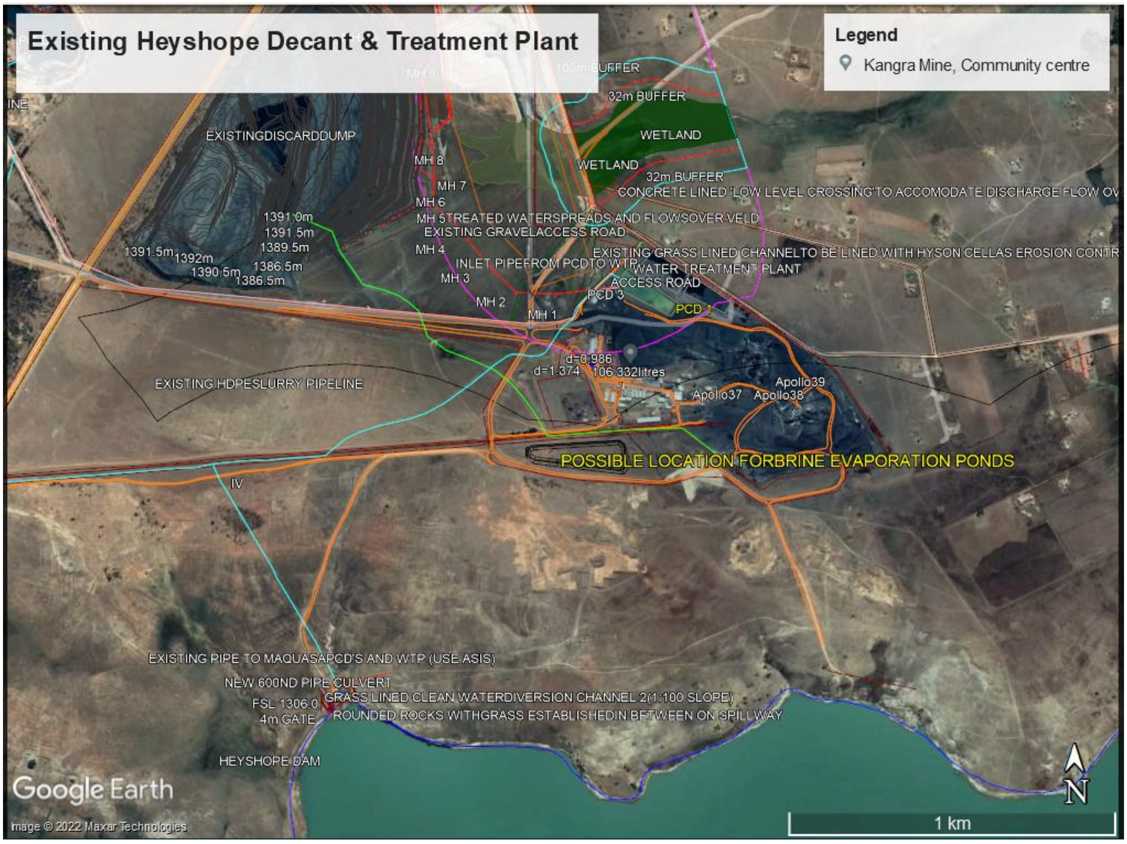

Figure 1-1: Proposed WTP and possible brine evaporation pond

1.1.2 Co-Disposal Facility

The discard dump at MQE has an approved environmental authorisation and a water use license. As a result of changing operational requirements, there is now a need for a co-disposal facility at MQE, this co-disposal facility is not authorised.

- The co-disposal facility will be located within the MQE operation on the remaining (RE) portion of the farm Rooikop 18 HT. The co-disposal facility will accommodate discarded produced from the benefaction plant located at Maquasa East, which currently washes and processes coal from the surrounding Kangra Coal operations and will receive coal from future expansion areas.
- This discard dump was originally designed as a three-compartment side hill-type dump with a footprint of approximately 65ha. The three-compartment layout allows for a modular implementation approach with the benefit of delaying capital expenditure. The implementation of this project will be done in two phases:

- Phase 1 will entail the use of the approved discard dump, and
- Phases 2 and 3 will entail the use of a co-disposal facility that requires authorisations.

In the phases, the plan is to build the full waste dump over 20 years. Phase 1 (7 years capacity), Phase 2 (7 years capacity), and Phase 3 (6 years capacity). GFK are undertaking detailed designs of the dump, as well as stormwater sizing. The facility will be lined with an impermeable barrier. The layout plan for the co-disposal facility is shown in Figure 1-2.

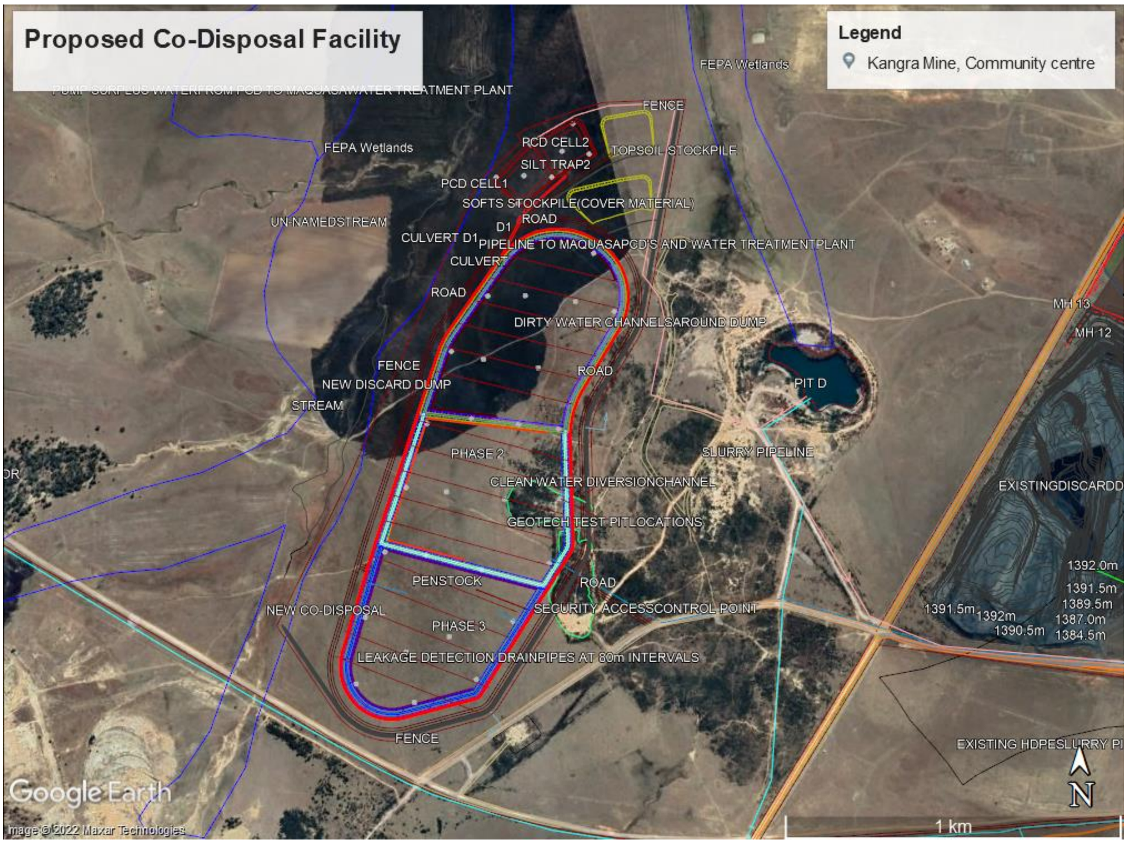

Figure 1-2: Proposed Co-Disposal Facility (Phase 1 already approved, Phase 2 & 3 will be co-disposal)

1.2 Objectives

The objectives of this study, were as follows:

- Undertake a site walkover assessment to identify natural and manmade drainage lines and establish baseline surface water quality.
- Evaluate the site's hydrological setting (i.e., climate, rainfall, drainage, etc.).
- Determine the 1:10, 1:20, 1:50, and 1:100-year peak flows for the non-perennial/ perennial streams associated with the site.

- Develop a conceptual stormwater management plan (CSWMP) to provide an overview of stormwater drainage, and formulate mitigative steps to circumvent erosion and control stormwater runoff (**detailed designs are being done by the project engineer, GFK**).
- Undertake a hydrological risk assessment and compile mitigation measures; and
- Compile a surface water monitoring plan to monitor the impact on the receiving environment.

1.3 Scope of Work

The scope of work completed, was as follows:

1. **Baseline Hydrology Review:**
    a. Hydro-meteorological data collection and analysis.
    b. Catchment delineation and drainage characteristics.
    c. Determination of catchment hydraulic and geometric parameters.
2. **Peak Flows & Flood Line Modelling:**
    a. Peak flood volume calculation for the 1:10, 1:20, 1:50, and 1:100-year recurring events.
    b. Flood line modelling using HEC-RAS hydraulic software – 1:50 and 1:100-year flood lines were presented; and
    c. Analysis of the modelling results.
3. **Conceptual Storm Water Management Plan and Stormwater Monitoring:**
    a. Identification of stormwater sub-catchments (i.e., clean and dirty areas)
    b. Determination of stormwater flows and volumes (1:10, 1:20, 1:50 and 1:100- yr return periods) were undertaken.
    c. Indications and explanations of the placement of stormwater attenuation infrastructure were offered.
    d. A stormwater monitoring system plan was drafted, to ensure that the stormwater discharge impact on the environment is managed and controlled.
4. **Risk assessment:**
    a. A hydrological risk assessment was undertaken, to contextualise the potential surface water risk of the project.
5. **Surface Water Monitoring Plan:**
    a. A surface water monitoring plan was developed.

6. **Reporting:**
    a. This report was compiled, composing the components above.

1.4 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.

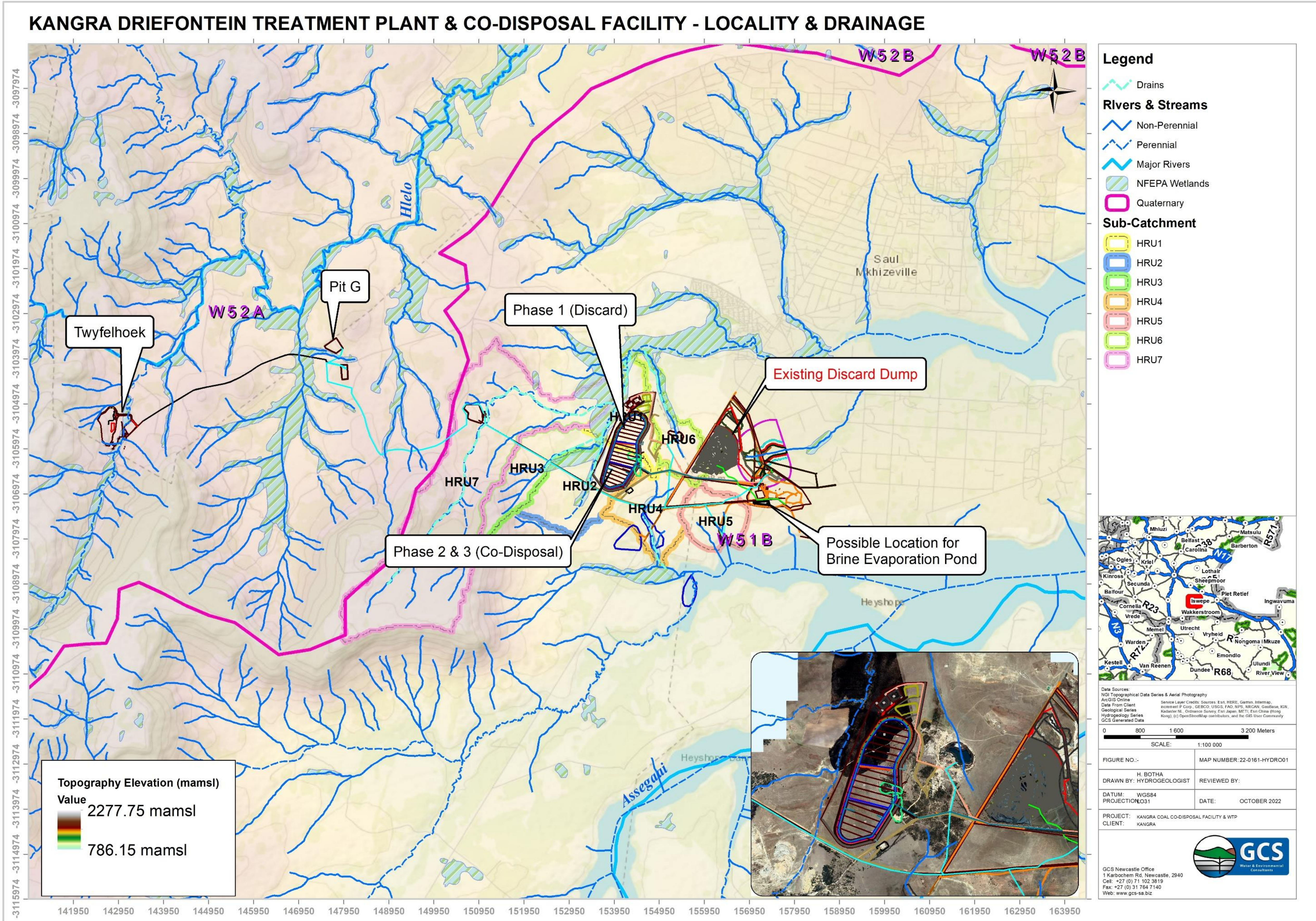

Figure 1-3: **Site locality and drainage**

2 METHODOLOGY

The methodological approach for the study is described in the sub-sections below.

2.1 Legal considerations

The National Water Act, (Act 36 of 1998) (NWA) governs the use of water and protection of water resources in South Africa. There are two sets of regulations on water use thus far:

- Government Notice No. 704, 4 June 1999, National Water Act, 1998 (No. 36 of 1998): Regulations on the use of water for mining and related activities aimed at the protection of water resources (GN704).
- Government Notice No. 1352, 12 November 1999, National Water Act, 1998 (No. 36 of 1998): Regulations requiring that water use be registered.

In terms of Section 144 of the National Water Act of 1998 (Act 36 of 1998), a flood line, representing the highest elevation that would probably be reached during a storm with a return interval of 100 years, must be indicated on all plans for the establishment of townships. The term, "establishment of townships" includes the subdivision of stands or farm portions in existing townships/development, if the 100-year flood lines are not already indicated on these plans, or when the land-use category of a particular portion of land is changed.

The National Environmental Management Act (Act 107 of 1998) (NEMA) stipulates that all relevant factors be considered for proposed developments to ensure that water pollution and environmental degradation are avoided. Section 2 of the Act establishes a set of principles that apply to the activities of all organs of the state that may significantly affect the environment. These include the following:

- Development must be sustainable
- Pollution must be avoided or minimized and remedied
- Waste must be avoided or minimized, reused or recycled
- Negative impacts must be minimized.

The requirements laid down by the National Building Regulations and Building Standards Act (Act 103 of 1977) in terms of development within the 1:50-year flood line area are based only on safety considerations without proper consideration and understanding of the underlying natural streamflow processes. The Town Planning and Townships Ordinance (Ordinance 15 of 1986) also makes provision in Regulation 44(3) for the extension of flood line areas up to 32 m from the centre of a stream in instances where the 1:50-year flood line is less than 62 m wide in total (CSIR, 2005).

Appendix 6 of GN 326 EIA Regulation 2017 regulations further govern hydrology assessments for EIAs. This hydrology report conforms to Appendix 6 of the EIA regulations, which include the following aspects (where applicable to this study) to be addressed:

(a) Details of:

(i) The specialist who prepare the reports; and

(ii) the expertise of that specialist to compile a specialist report including a curriculum vitae.

(b) Declaration that the specialist is independent in a form as may be specialities by the competent authority.

(c) Indication of the scope of, and purpose for which, the report was prepared:

(cA) Indication of the quality and age of base data used for the specialist report

(cB) A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change

(d) Duration, Date and season of the site investigation and the relevance of the season to the outcome of the assessment.

(e) Description of the methodology adopted in preparing the report or carrying out the specialised process including equipment and modelling used.

(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 alternatives.

(g) Identification of any areas to be avoided, including buffers.

(h) Map superimposing the activity and associated structures and infrastructure on environmental sensitivities of the site including areas to be avoided, including buffers.

(i) Description of any assumptions made and uncertainties or gaps in knowledge.

(j) A description of the findings and potential implications of such findings on the impact of the proposed activity including identified alternatives to the environment or activities.

(k) Mitigation measures for inclusion in the EMPr.

(l) Conditions for inclusion in the environmental authorisation.

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(i) as to whether the proposed activity, activities or portions thereof should be authorised.

(iA) 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

(o) Description of any consultation process that was undertaken during preparing the specialist report.

(p) A summary and copies of any comments received during any consultation process and where applicable all responses thereto.

(q) Any other information requested by the competent authority.

2.2 Hydrological assessment

Hydrometeorological data for the study area were obtained from various sources including the South African Water Resources Study WR2012 database (Bailey & Pitman, 2015), South African Atlas of Agrohydrology, and Climatology (Schulze, 1997), and the Daily Rainfall Data Extraction Utility (Lynch, 2004). Moreover, sources such as the Köppen Climate Classification (Kottek, et al., 2006), World Climate Data CMIP6 V2.1 (Eyring, 2016), and Meteoblue (Meteoblue, 2022) were used to refine hydrological data.

These sources provided methods of determining the Mean Annual Precipitation (MAP), Mean Annual Runoff (MAR), and Mean Annual Evaporation (MAE) of the study site as well as the design rainfall data. Data was applied to the site water balance calculations, runoff peak flow estimates for flood line modelling and stormwater runoff peak flow estimates for stormwater system sizing (where applicable to this study).

2.2.1 Catchment description and delineation

A 30 m Digital Terrain Model (DTM) data from the Advanced Land Observing Satellite (ALOS) (JAXA, 2022) were used to delineate the area draining to the streams relevant to this study, sub-catchment flow path as well as to derive river geometry characteristics. These characteristics (area, slopes, and hydraulic parameters) are used to parameterise the site hydraulic model for flood line modelling, water balance modelling or stormwater modelling.

2019 South African (SA) National Land Cover Data (DEA, 2019) was used to characterise the sub-catchment vegetation and derive Manning surface roughness (n-values) coefficients.

2.2.2 Design rainfall and peak flow

The Design Rainfall Estimation Software (Smithers & Schulze, 2002) data from the rainfall stations surrounding the study site were used to calculate the 24-hour design rainfall depths for various return periods. Critical storm durations for Rational Methods Alternative 3 were calculated using the Modified Hershfield Equation (Adamson, 1981).

The streams/drainage sections that were modelled applying the three widely used methods were used to calculate 1:10, 1:20, 1:50, and 1:100-year peak flows. These are the Rational Method, Midgley and Pitman (MIPI), and the Standard Design Flood (SDF) methods. A brief description of each of the peak flow methods can be seen in Table 2-1, below.

Methodologies for using the applied peak flow models are explained broadly in the South African Drainage Manual (SANRAL, 2013). Calibration of the runoff coefficients for the drainage areas was guided by the manual, the understanding of the runoff-generating processes as well as land cover attributes. The resulting peak flows calculated using the selected methods were evaluated and conservative values provided inputs into the 1D HEC-RAS flood line model.

Table 2-1: Summary of peak flow methods

Rational Method The rational method was developed in the mid-19th century and is one of the most widely used methods for the calculation of peak flows for small catchments (< 15 km^2). The formula indicates that Q = CIA, where I is the rainfall intensity, A is the upstream runoff area and C is the runoff coefficient. Q is the peak flow. There are 3 alternatives to the Rational Method which differ in the methodology used to calculate rainfall intensities. The first alternative (RM1) uses the depth-duration frequency relationships approach, the second uses the modified Hershfield equation and the third alternative uses the Design Rainfall software for South Africa (SANRAL, 2013).
Midgley and Pitman The Midgley and Pitman (MIPI) method is an empirical method that relates peak discharge to catchment size, slope, and distance from the drainage point to the centroid of the catchment (Campbell, 1986). The MIPI method uses 10-unit hydrographs for 10 zones in South Africa. The method does not consider overland flow as a component separate from streamflow but considers only the total longest flow path (Campbell, 1986).
Standard Design Flood Method The Standard Design Flood (SDF) method was developed specifically to address the uncertainty in flood prediction under South African conditions (Alexander, 2002). The runoff coefficient (C) is replaced by a calibrated value based on the subdivision of the country into 26 regions or Water Management Areas (WMAs). The design methodology is slightly different and looks at the probability of a peak flood event occurring at any one of a series of similarly sized catchments in a wider region, while other methods focus on point probabilities (SANRAL, 2013).

2.3 Flood line modelling

A 30 m ALOS digital terrain model (DTM) (JAXA, 2022) was used to derive the hydraulic and river geometry parameters. River/stream cross-sections and flow paths were prepared using RAS Mapper software and provided input into a 1D HEC-RAS (US Army Corps of Engineers, 2016) flood model. Visual assessment of riverbanks from the Google Earth Imagery and land cover types (DEA, 2019) was used to estimate Manning's 'n' coefficients along the river/streamlines. The 1:50 and 1:100-year flood lines were generated and mapped in Global Mapper and ArcGIS (ESRI, 2018).

2.4 Conceptual stormwater management plan (CSWMP)

The CSWMP was designed in conjunction with the provided infrastructure layout plans and available topographical data. The Rational Method was applied to determine stormwater peak flows (sub-catchments < 15 km^2) within each stormwater sub-catchment, and further considers SCS soil types and land impervious percentages.

The conceptual SWMP was designed to consider relevant South African legislation – the National Water Act (1998) (NWA, 1998) and the Council for Scientific and Industrial Research (CSIR) Human Settlement Planning and Design guidelines (CSIR, 2005).

2.5 Hydrological risk assessment

As per GNR 982 of the EIA Regulations (2014), the significance of potential hydrological impacts was assessed. 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 includes 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:

I. Cumulative impacts.
II. Nature of the impact.
III. The extent of the impact.
IV. Probability of the impact occurring.
V. The degree to which the impact can be reversed.
VI. The degree to which the impact may cause irreplaceable loss of resources; and
VII. The degree to which the impact can be mitigated.

Table 2-2 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 2-3.

Consequence = (Duration + Extent + Irreplaceability of resource) x Severity

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

Table 2-2: 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 effect of the impact extends beyond municipal boundaries.
	National (5)	The effect of the impact extends beyond more than 2 regional/ provincial boundaries.
	International (6)	The effect of the impact extends beyond country 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 - 5 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 but 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 (13 to 18)	
	Highly beneficial (19 to 24)	
	Extremely beneficial (25 to 33)	
Probability (the likelihood of the impact occurring)	Improbable (0)	It is highly unlikely or less than 50% likely that an impact will occur.
	Probable (1)	It is between 50 and 70% certain that the impact will occur.
	Definite (2)	It is more than 75% certain that the impact will occur, or the impact will occur.
Significance	Very high - negative (-49 to -66)	A function of Consequence and Probability.

Criteria	Rating Scales	Notes
	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)	

Table 2-3: 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 reseeding 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 that 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 to be 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) that there is 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 taken into account 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.

2.6 Surface water monitoring plan

The monitoring network is based on the principles of a monitoring network design as described by the DWAF Best Practice Guidelines: G3 Monitoring (DWAF, 2007). The methodological approach that the monitoring plan follows is represented in Figure 2-1, below.

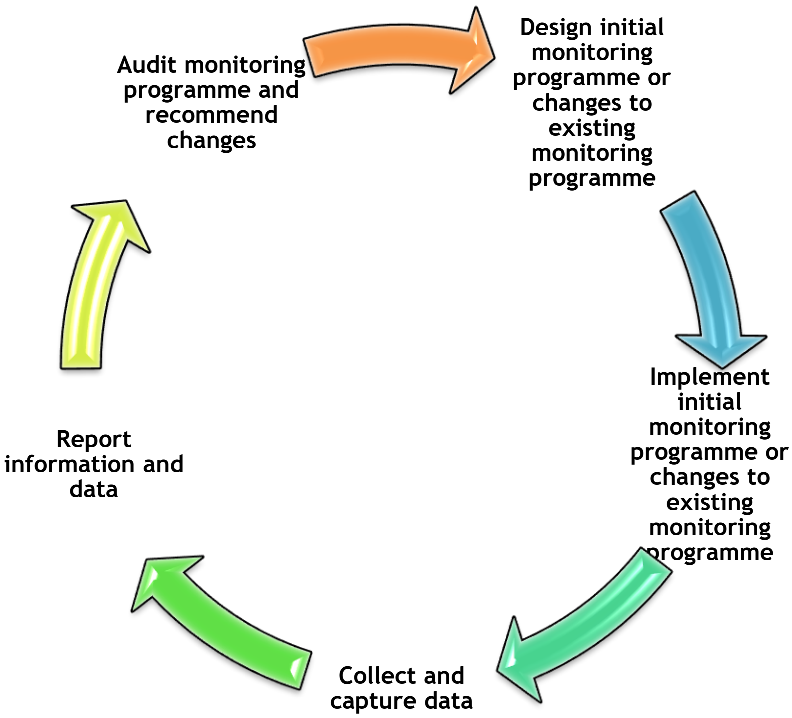


Figure 2-1: Monitoring Process

A surface water monitoring program that presents water quality constituencies to be analysed, the frequency of sampling, and the locality of sampling points were drafted. This plan included the construction and operational phase monitoring.

3 SITE OVERVIEW AND HYDROLOGY

As mentioned previously, the project falls in quaternary catchment W51B of the Pongola to Mtamvuna Water Management Area (WMA) (DWS, 2016). Elevations on the site typically range from 1 300 to 1 600 meters above mean sea level (mamsl).

3.1 Sub-catchments/hydrological response units (HRUs)

Seven (7) hydrological response unit (HRUs) describes the natural drainage for the study area (using a 1:1 000 stream count and 30 m DTM fill) – refer to Figure 1-3 and Figure 3-3-1. The sub-catchment relates well to desktop-delineated drainage lines for the project area, as well as verified streams associated with the project area.

Primary drainage from the position of the proposed co-disposal site, and much of the MQE area is towards the northeast, to the perennial Egude River, which makes up the bottom inflow of the Heyshope Dam. Drainage from the southern portions of the MQE area, and Maquassa West (MQW) is towards the south, via several perennial and non-perennial drainage lines, towards the southern inflow of the Heyshope Dam. The Heyshope Dam is therefore the end received of any surface water-related pollution that may take place at the MQE operations. The sub-catchments that are associated with the proposed co-disposal facility are HRU1 to 3, and HRU6. The sub-catchment associated with the proposed treatment area is HRU5.

3.2 Land cover & slope rise

The dominant land types associated with the sub-catchment are shown in Figure 3-3-1 (DEA, 2019), and is observed to be natural grasslands. The site is predominantly characterised by natural grassland. The land cover was simplified into 4 categories and is summarised in Table 3-1. Slope % rise for the general area is shown in Figure 3-2. Slope rise % was used to characterise the sub-catchment slope and runoff generation.

In the modelling process of the flood lines or stormwater runoff (whichever applies to this study), Manning's coefficient (n-values) was set to represent natural stream systems and was supplemented by Google Earth Imagery and field observations. These "n" values were further derived from the available vegetation and land cover data for the site.

Table 3-1: Summary of sub-catchment characteristics

Sub-Catchment		HRU1	HRU2	HRU3	HRU4	HRU5	HRU6	HRU7
Area (km²)		1.549	2.609	1.890	1.84	1.24	1.36	9.92
Longest Drainage Line (km)		1.99	1.08	1.148	1.18	0.57	1.33	7.26
Average Slope (%)		0.56%	1.23%	3.08%	2.01%	9.14%	1.70%	4.30%
Slope (%)	<3	35.66%	15.25%	8.46%	12.24%	4.19%	26.40%	20.00%
	3-10	63.80%	73.48%	42.12%	72.04%	66.11%	73.10%	10.00%
	10-30	0.53%	11.27%	39.28%	14.94%	29.70%	0.50%	20.00%
	>30	0.00%	0.00%	10.14%	0.78%	0.00%	0.00%	50.00%
Land Cover	Thick bush & plantation	18%	11%	8%	17%	2%	12%	5.91%
	Light bush & farm-lands	29%	11%	4%	4%	16%	2%	2.60%
	Grasslands	51.5%	61.3%	77.4%	75.6%	75.0%	63.1%	89.4%
	No Vegetation	1%	17%	10%	3%	7%	23%	2.08%

3.3 Local geology & soils

According to the 1:250 000 geological series (2730 Vryheid), the local surface geology is characterised by occurrences of dolerite, and sediments associated with the Vryheid Formation, of the Ecca Group, of the Karoo Sequence (DMEA, 1998g) – refer to Figure 3-3.

According to the Land types of South Africa databases (Land Type Survey Staff, 1972 – 2006c), the soils in the area typically conform to land types of the Bb36 group, which typically entail red and yellow, dystrophic/mesotrophic, apedal soils with plinthic subsoils (plinthic soils comprise > 10% of land type, red soils comprise < 33% of land type). According to WR2012 soil data for the area, the erodibility of the soils for the area can be considered medium (WRC, 2015).

In terms of Hydrological Soil Types, the soils in the project area are classified as Type C, with an erosion factor of 7 and runoff factor of about 0.39.

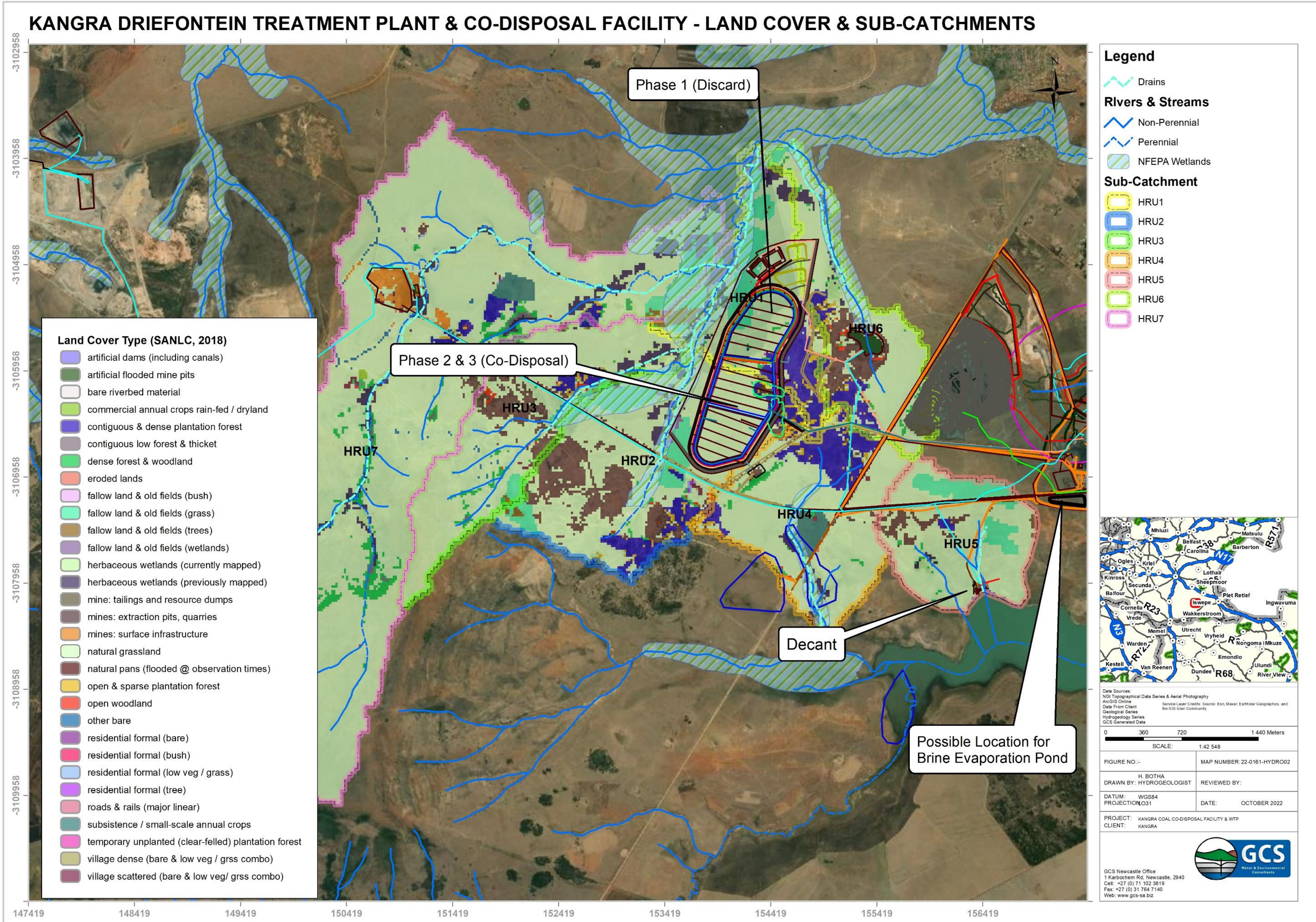


Figure 3-3-1: Sub-catchments and land cover types

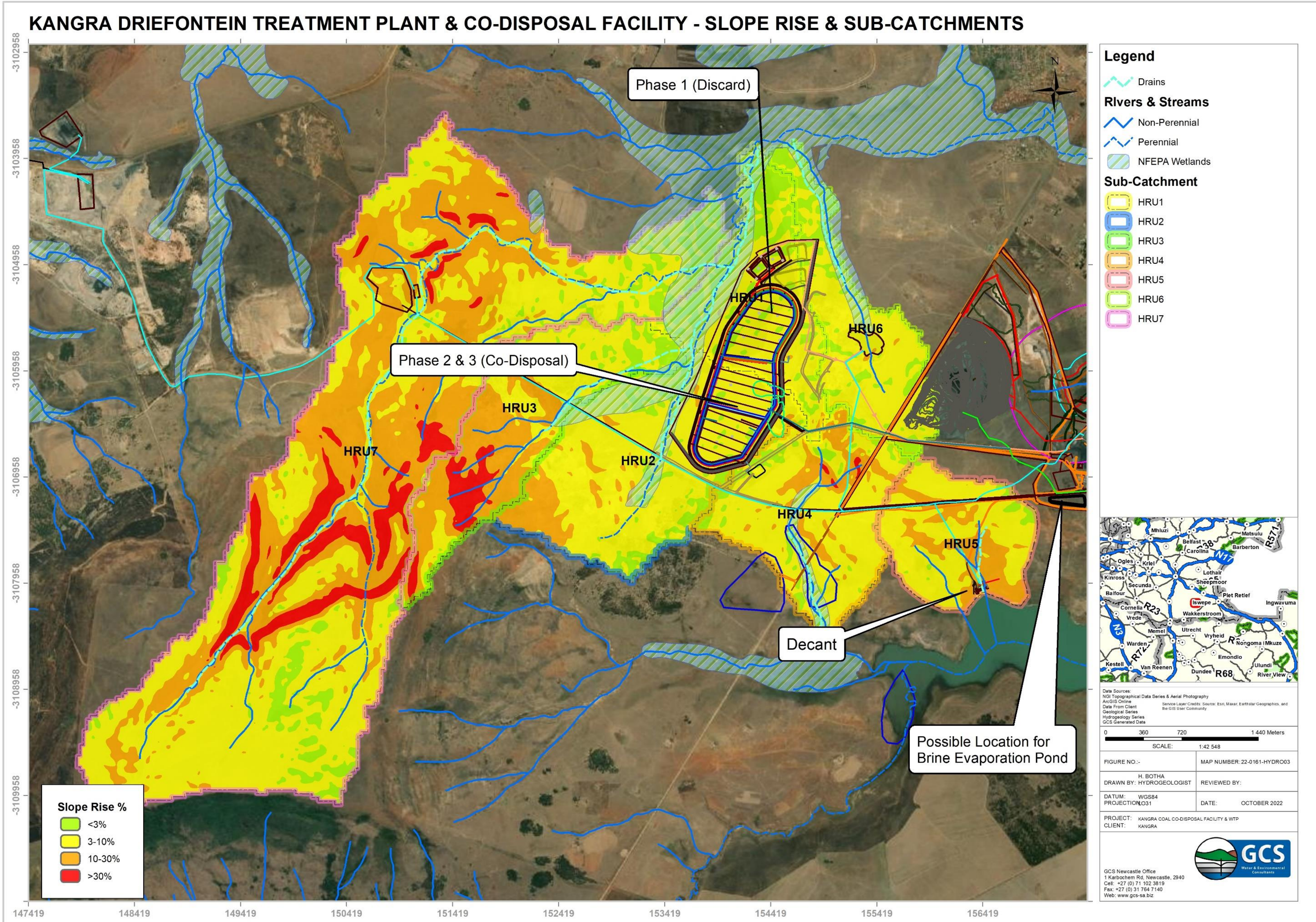


Figure 3-2: Sub-catchments and surface slope rise %

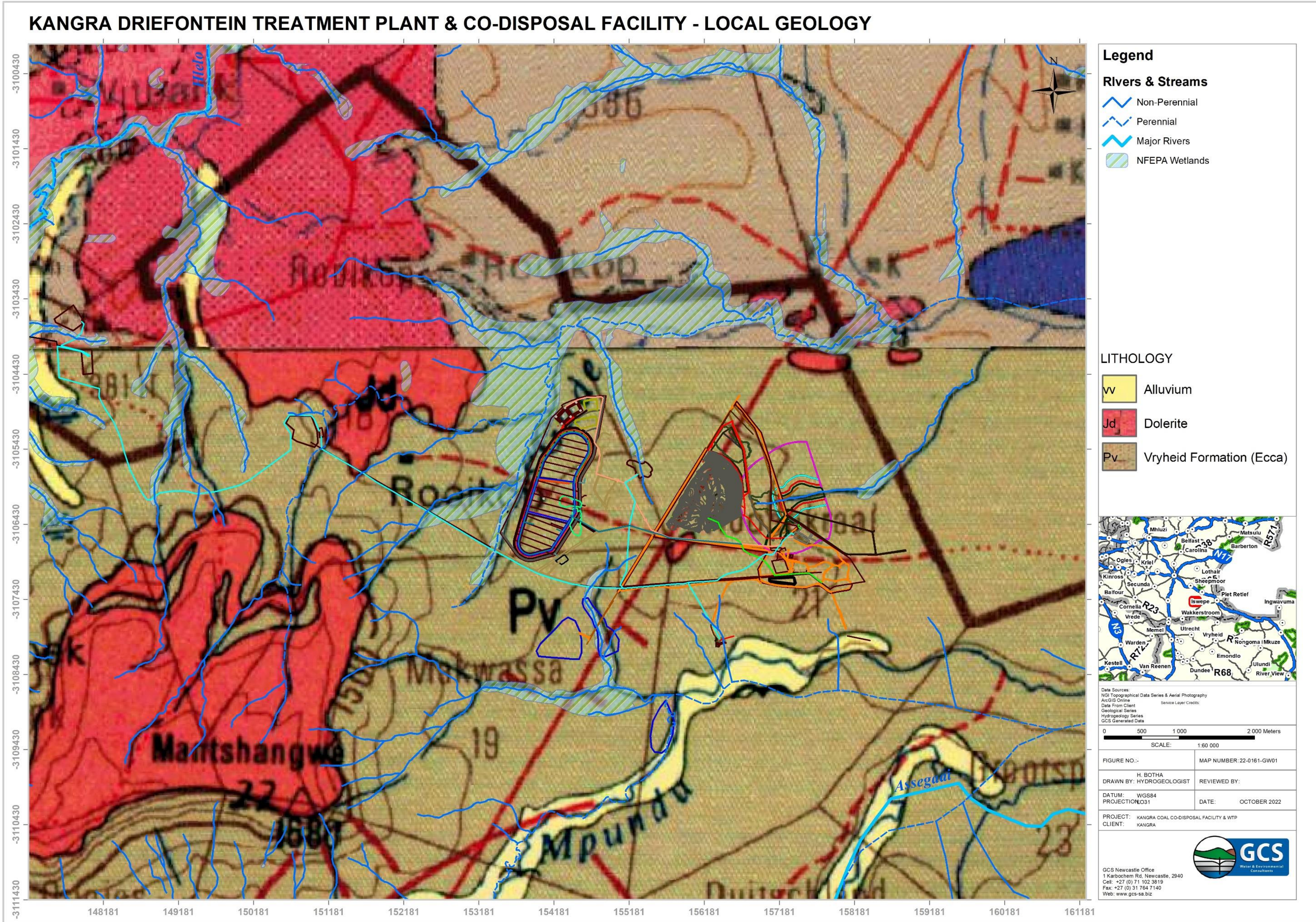


Figure 3-3: Local geology

3.4 Climate

Climate, amongst other factors, influences soil-water processes. 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.

3.4.1 Temperature

The average yearly temperature (refer to Figure 3-4) for the project area ranges from 25 to 33°C (high) and -4 to -2°C (Low). The study area is situated in a subtropical highland climate or temperate oceanic climate with dry winters (Cwb) area, as per the Köppen Climate Classification (Kottek, et al., 2006). The project area receives summer rainfall.

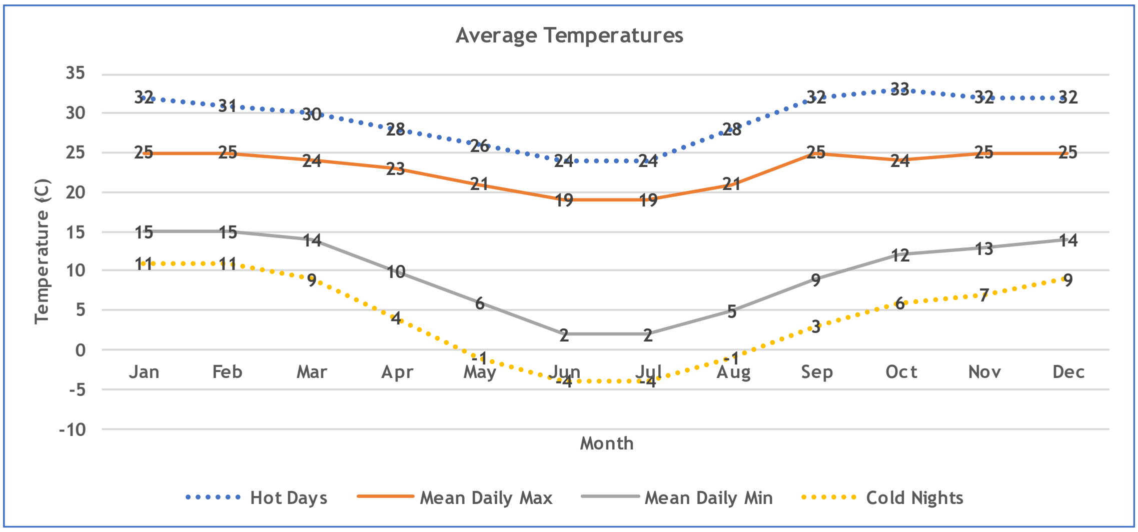


Figure 3-4: Average yearly temperatures (Meteoblue, 2022)

3.4.2 Wind speed and direction

Figure 3-5 shows the wind rose for the project area (Vryheid used as reference) and presents the number of hours per year the wind blows from the indicated direction. The wind blows from WW, ENE and E more often, at velocities ranging from 1 km/hr to 28 km/hr; and from other directions but less frequently and at lower velocities (< 19 km/hr).

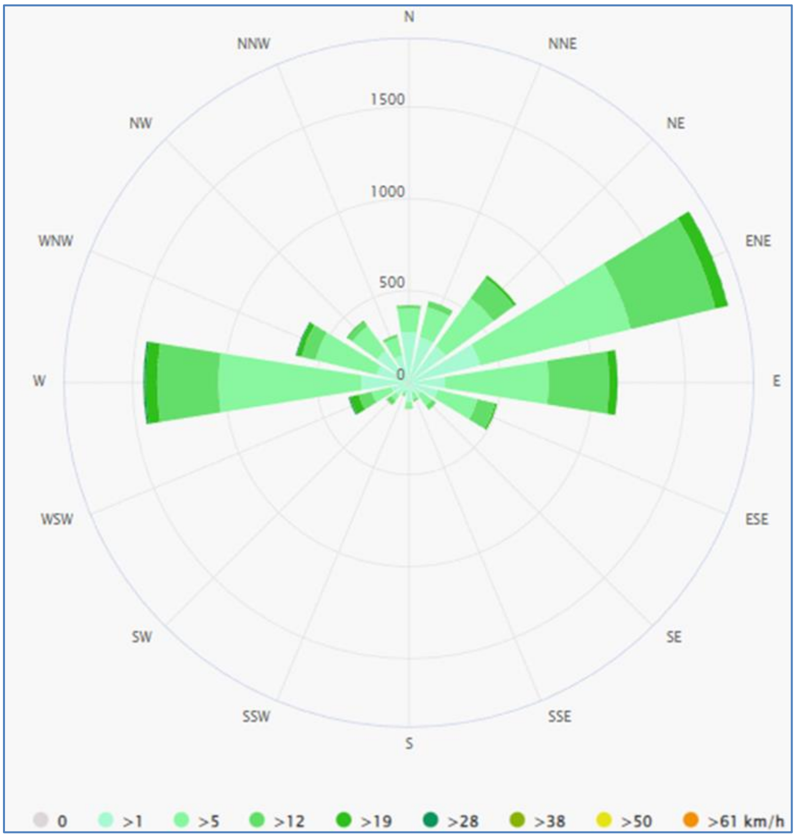


Figure 3-5: Wind rose (Meteoblue, 2022)

3.4.3 Rainfall and evaporation

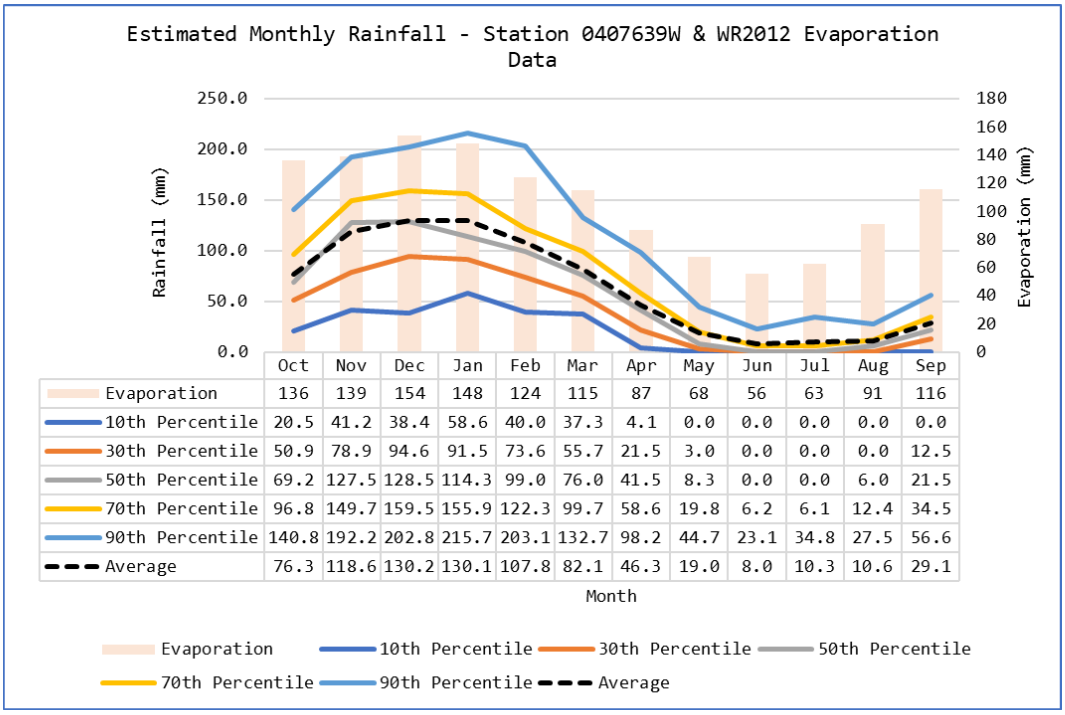
The project area is situated in rainfall zone W5A. The mean annual precipitation (MAP) measured at several rainfall stations that fall close to the site is summarised in Table 3-2, below.

Table 3-2: MAP of nearest rainfall stations

Station Name	ID	MAP (mm/yr)
GROOT RIETVLEI	0407639_W	770
DIRKIESDORP (POL)	0407730_W	681
SPITSKOP	0407397_W	800
BRERETON PARK	0443807_W	900
Average		**787.75**

The monthly rainfall data used to calculate MAP was obtained from rainfall station 0407639W (Grootvlei). The rainfall record is for the period 1929 to 2003 (74 years). Monthly rainfall for the site is likely to be distributed as shown in Figure 3-6, below.

Available rainfall data suggest a MAP ranging from 482 (30th percentile) to 1372 (90th percentile) mm/yr. The average rainfall is in the order of 768 mm/yr. The project area falls within evaporation zone 13A, 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 3-6, below.

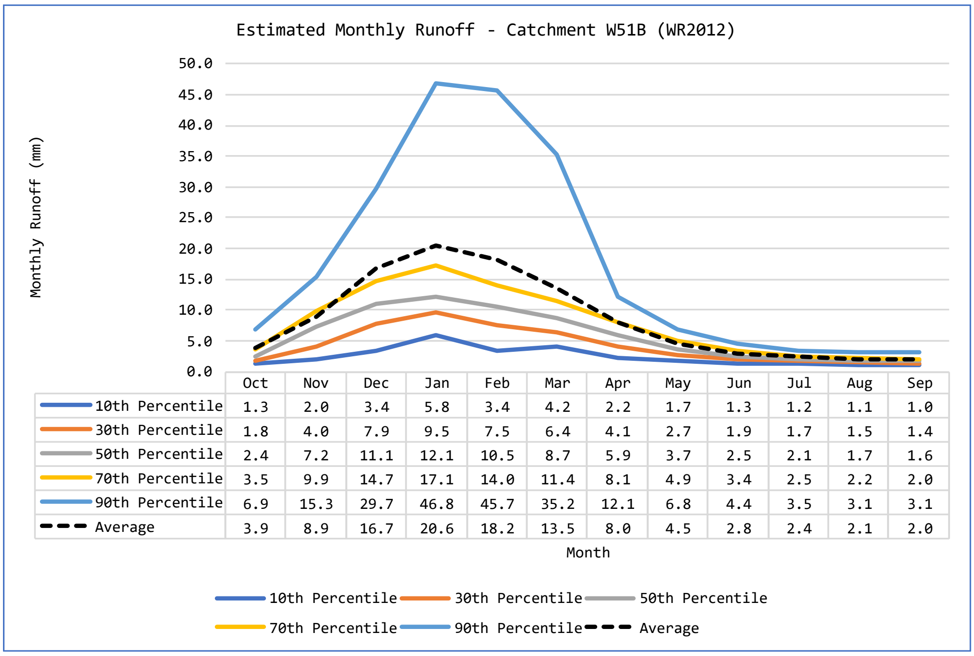


	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Evaporation	136	139	154	148	124	115	87	68	56	63	91	116
10th Percentile	20.5	41.2	38.4	58.6	40.0	37.3	4.1	0.0	0.0	0.0	0.0	0.0
30th Percentile	50.9	78.9	94.6	91.5	73.6	55.7	21.5	3.0	0.0	0.0	0.0	12.5
50th Percentile	69.2	127.5	128.5	114.3	99.0	76.0	41.5	8.3	0.0	0.0	6.0	21.5
70th Percentile	96.8	149.7	159.5	155.9	122.3	99.7	58.6	19.8	6.2	6.1	12.4	34.5
90th Percentile	140.8	192.2	202.8	215.7	203.1	132.7	98.2	44.7	23.1	34.8	27.5	56.6
Average	76.3	118.6	130.2	130.1	107.8	82.1	46.3	19.0	8.0	10.3	10.6	29.1

Figure 3-6: Average rainfall for Station 0407639W & WR2012 evaporation

3.4.4 Runoff

Runoff from natural (unmodified) catchments for quaternary catchment W51B is simulated in WR2012 (WRC, 2015) as being equivalent to 103.5 mm/yr (or 13% of the MAP). This is approximately 51.369 Mm^3/yr NMAR for the surface area of W51B.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
10th Percentile	1.3	2.0	3.4	5.8	3.4	4.2	2.2	1.7	1.3	1.2	1.1	1.0
30th Percentile	1.8	4.0	7.9	9.5	7.5	6.4	4.1	2.7	1.9	1.7	1.5	1.4
50th Percentile	2.4	7.2	11.1	12.1	10.5	8.7	5.9	3.7	2.5	2.1	1.7	1.6
70th Percentile	3.5	9.9	14.7	17.1	14.0	11.4	8.1	4.9	3.4	2.5	2.2	2.0
90th Percentile	6.9	15.3	29.7	46.8	45.7	35.2	12.1	6.8	4.4	3.5	3.1	3.1
Average	3.9	8.9	16.7	20.6	18.2	13.5	8.0	4.5	2.8	2.4	2.1	2.0

Figure 3-7: Simulated natural (unmodified) runoff for W51B

3.5 Surface water and groundwater users in the study area

According to Water Allocation Registration Management System (WARMS, 2019), there are no WARMS water users within a 5 km radius of the proposed activity. According to SADAC GIP and National Groundwater Activities (NGA) data, there are at least 3 registered boreholes within a 5 km radius of the proposed activities (refer to Figure 1-3 and Table 3-3).

Table 3-3: Groundwater users within a 2.5 km radius of the site

ID	Source	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Water Level (mbgl)
736675	SADAC GIP / NGA 2022	-27.06383	30.39031	1322	2.1
736687	SADAC GIP / NGA 2023	-27.02717	30.41504	1351	15
611988	SADAC GIP / NGA 2024	-26.974167	30.400833	1351	No Data

GCS (2022) identified two (2) groundwater boreholes within a 5km radius of the proposed co-disposal facility (namely FB7 and FB8) that are used for groundwater supply. The boreholes are used by Kangra to supply water to the Community Health Centre.

3.6 Depth to groundwater

According to (Vegter, 1995) and (DWAF, 2006), the groundwater levels within the region are expected to range from 15 to 30 mbgl (meters below ground level). Available monitoring boreholes data for Kangra suggest a water level range from 1.28 to 131 mbgl (nearing the MQW underground workings in the mountains), with an average water level in the order of 12.4 mbgl for the MQE area.

Available water level data for boreholes in the area suggest there is a good correlation between the surface topography and the groundwater table (refer to Figure 3-8, R ~ 90%). The groundwater table is expected to mimic the topography and be shallower closer to perennial streams (i.e. these are prominent groundwater contributions to base-flow areas or areas where groundwater seepage from the resource into the aquifer units may take place).

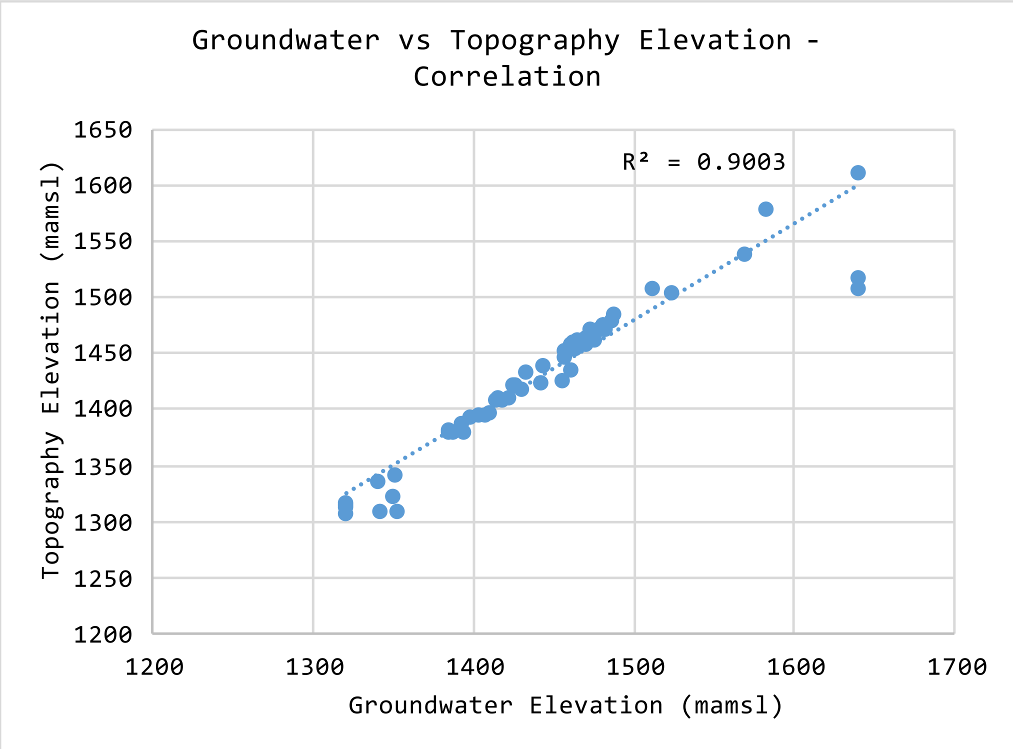


Figure 3-8: Groundwater elevation vs topography elevation - correlation (Kangra Monitoring Holes)

3.7 Wetland areas

Based on available National Wetland Freshwater Ecosystem Priority Areas (NFEPA) (Van Deventer, 2018) the non-perennial and perennial drainage areas situated downstream of the proposed co-disposal facility are classified as channelled valley bottom (CVB) wetland areas of the Mesic Highveld Grassland Bioregion (refer to Figure 1-3).

In terms of wetland geo-hydrology, base flow is considered the most important contributor to wetland health. Base flow (refer to Figure 3-9) is a non-process-related term to signify low amplitude high-frequency flow in a river during dry or fair-weather periods. Base flow is not a measure of the volume of groundwater discharged into a river or wetland, but it is recognised that groundwater contributes to the base-flow component of river or wetland flow.

Available literature (WRC, 2015; DWAF, 2006) suggests groundwater contribution to baseflow ranges from 9.8 mm/yr (PITMAN MODEL) to 43.45 mm/yr (HUGHES MODEL). This relates to approximately 2% to 6% of rainfall.

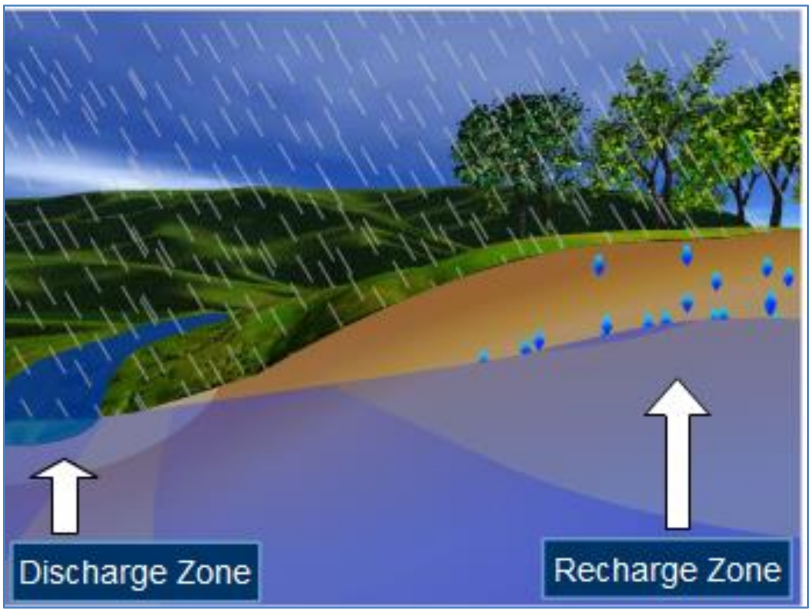


Figure 3-9: Groundwater base-flow concept (DWS, 2011)

3.8 Present ecological state (PES) and environmental sensitivity and ecological importance (EIS) – quaternary scale

Table 3-4 provides a summary of the PES and EIS for the quaternary catchment associated with the project area (WRC, 2015). It is recommended that the resource management objectives (RMO) for wetlands in the project area need to maintain the current PES and EIS post development

Table 3-4: Summary of PES and EIS for the Quaternary Catchment

Quat	PES	EIS
W51B	Class B: Largely Natural	High

3.9 Overview of site hydrological cycle

Based on the information attained for the study area (as presented in this section), existing groundwater and surface water users, climate, runoff and estimated base flow to wetland areas, a sub-catchment-specific hydrological cycle was developed (refer to Figure 3-10). *The impact of the proposed/existing activities at the site on the cycle was considered in the hydrological impact assessment*.

With regards to the hydrological cycle for the combined sub-catchment areas, the following is estimated:

- The average rainfall is in the order of 15.68 Mm³/yr (50% of the total water budget);
- Average runoff accounts for a volume in the order of 2.11 Mm³/yr (6.7% of the total water budget);
- The average groundwater contribution to base-flow to rivers/wetlands/streams is in the order of 0.89 Mm³/yr (2.8% of the total water budget);
- Evaporation accounts for a volume in the order of 11.9 Mm³/yr (37.9% of the total water budget); and
- Estimated groundwater use on a sub-catchment level accounts for 259.2 m³/yr (0.001%) and surface water use accounts for 0 Mm³/yr – very low volumes on a sub-catchment scale.

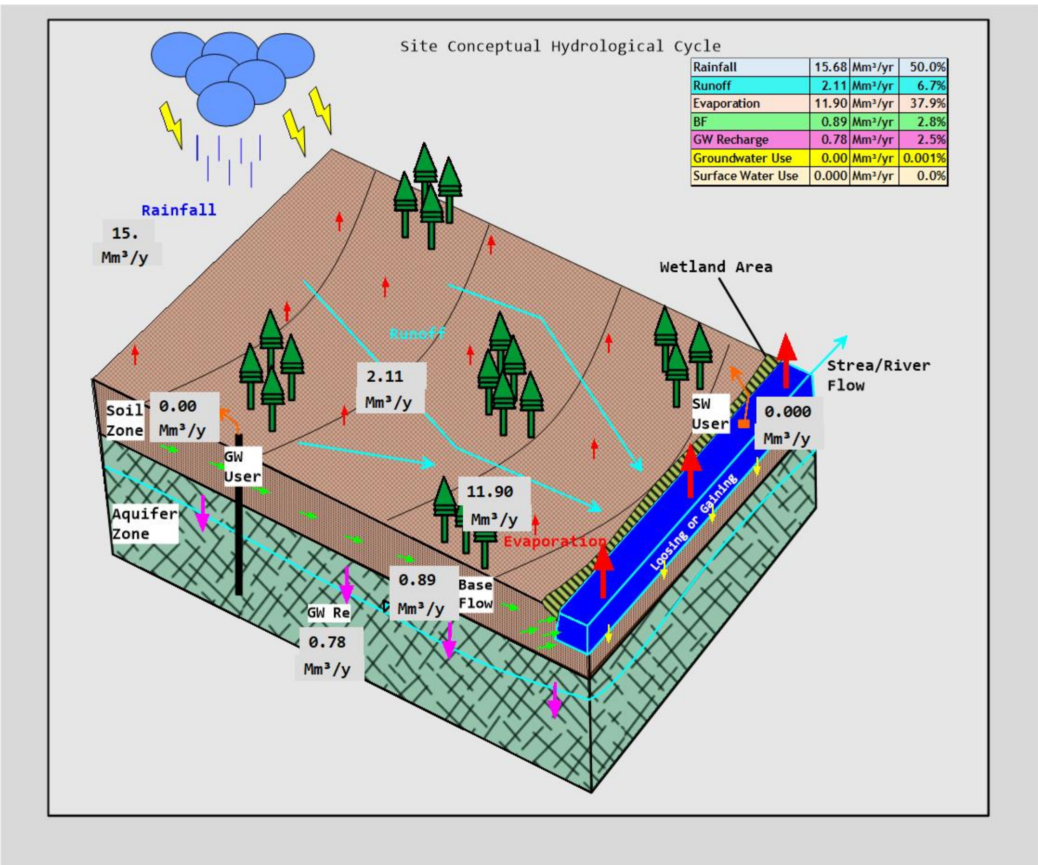


Figure 3-10: Simplified overview of the hydrological cycle at the site

4 WATER QUALITY

The MQE area consists of mine infrastructure, open cast areas, an overburden dump, a discard dump, pollution control dams, settling ponds and underground mine workings. A total of (19) nineteen groundwater sites and twenty-three (23) surface water sites exist in the MQE area and are monitored quarterly or monthly (depending on the sampling site type).

The sampling points at MQE are summarised in Table 4-1 and Table 4-2, and shown in Figure 8-1. This section captures the latest groundwater and quality results as presented in the GCS Monitoring Report for the MQE operations (GCS, August 2022).

Table 4-1: MQE surface water sampling sites

Site ID	Latitude (WGS84)	Longitude (WGS84)
Below Highwall Seepage	-27.0300	30.39053
Canal Along Main Road	-27.00575	30.4068
Discard Dump Dam 1	-27.01555	30.40247
Discard Dump Seepage 1	-27.01161	30.4032
Discard Plant	-27.02391	30.41937
Discharge into Heyshope Dam	-27.02665	30.40522
DS of Natural Seepage	-27.03175	30.42167
East Heyshope	-27.03188	30.40492
Enprotec Filter Discharge	-27.02567	30.41827
Export Plant	-27.02275	30.41793
Heyshope Dam Water / Abstraction	-27.0317	30.42058
Highwall Seepage	-27.02541	30.38938
Improtect Clarified	-27.02516	30.4177
Inland Plant	-27.02232	30.41798
Pit D East	-27.01373	30.39485
Plant Set Pond / Dam 2	-27.01917	30.41457
Plant Water Dam 3	-27.02003	30.41356
Water Treatment Maquasa Plant East	-27.02252	30.41292
West Heyshope	-27.03175	30.4054
924	-27.02259	30.43474
932	-27.00536	30.43202
933	-27.01793	30.41272
CSW04	-27.016445	30.412429

Monitoring Localities
Drinking Water Localities
Internal Process Water

Table 4-2: MQE groundwater sampling sites

Site ID	Latitude (WGS84)	Longitude (WGS84)
Well Yende	-27.02777	30.3892
Lab Filter	-27.02332	30.4155
Mbokazi Borehole	-27.00873	30.39835
Improtect Drinking Water Filtered	-27.02535	30.41737
Clinic Drinking Water	-27.02327	30.41408
Madonsela	-27.04415	30.37783
Shongwe Family	-26.99156	30.3553
923	-27.02103	30.42525
KGA 1	-27.0262	30.42043
GCS 11	-27.01114	30.40944
GCS 12	-27.01545	30.41217
GCS 13	-27.0333	30.42472
GCS 14	-27.03068	30.42221
GCS 15	-27.03058	30.41795
GCS 16	-27.03122	30.40452
GCS 17	-27.03267	30.40267
KGA 2	-27.01943	30.41199
BCBH01	-27.011241	30.410672
BCBH02	-27.012980	30.407350

Monitoring Localities
Drinking Water Localities
Internal Process Water

4.1 Groundwater Quality

The following observations were made during the 2022 second-quarter monitoring event:

- All groundwater monitoring points exhibited relatively neutral to slightly alkaline pH conditions, ranging between 6.5 and 7.6.
- BH 923, BCBH01, GCS11, GCS12, GCS13, GCS14 and GCS15 showed low to no significant impact from the site in July 2022.
  - Only nitrate concentrations slightly exceeded the WUL limit at GCS11, GCS12, GCS14 and GCS15, ranging between 0.3 and 3.2 mg/l, which is considered to be low to moderately low.
- The water quality at Well Yende, KGA1, KGA2, GCS16 and GCS17 was non-compliant when compared to the WUL limits.
  - Several parameter concentrations exceeded the WUL limits in July 2022:
    - Chloride and/or sodium were elevated at Well Yende and GCS17.
    - KGA2 indicated elevated EC and TDS concentrations during the July 2022 sampling event.
    - EC, TDS, total hardness, magnesium, sodium, potassium and chloride concentrations were elevated at KGA1.

  - EC, TDS, total alkalinity, total hardness, calcium, magnesium, sodium, potassium and chloride were significantly elevated at GCS16.
- Sulphate concentrations varied at the site; refer to Figure 4-1.
  - Sulphate at GCS16 has displayed a stable trend over time, consistently exceeding the WUL limit, recorded as 819 mg/l in July 2022. GCS16 is decanting directly from the underground workings at Maquasa East into a pollution control dam which is situated near the Heyshope Dam.
  - Sulphate at KGA1 has displayed an increasing trend over time and currently exceeds the WUL limit. A notable increase was observed in July 2022, recorded as 585 mg/l. KGA1 is situated downgradient of the Discard Plant.
  - Sulphates at KGA2 indicated an increasing trend over time, exceeding the WUL limits since October 2021. A decrease was observed in July 2022, recorded as 72 mg/l.
  - The remaining points displayed low sulphate concentrations (< 16 mg/l).
- Additionally, nitrate concentrations exceeded the WUL limit at KGA1 and GCS16 ranging between 1.1 and 3.2 mg/l.
- In terms of metal concentrations, manganese exceeded the WUL limits at GCS16 (0.48 mg/l) and KGA1 (0.48 mg/l).

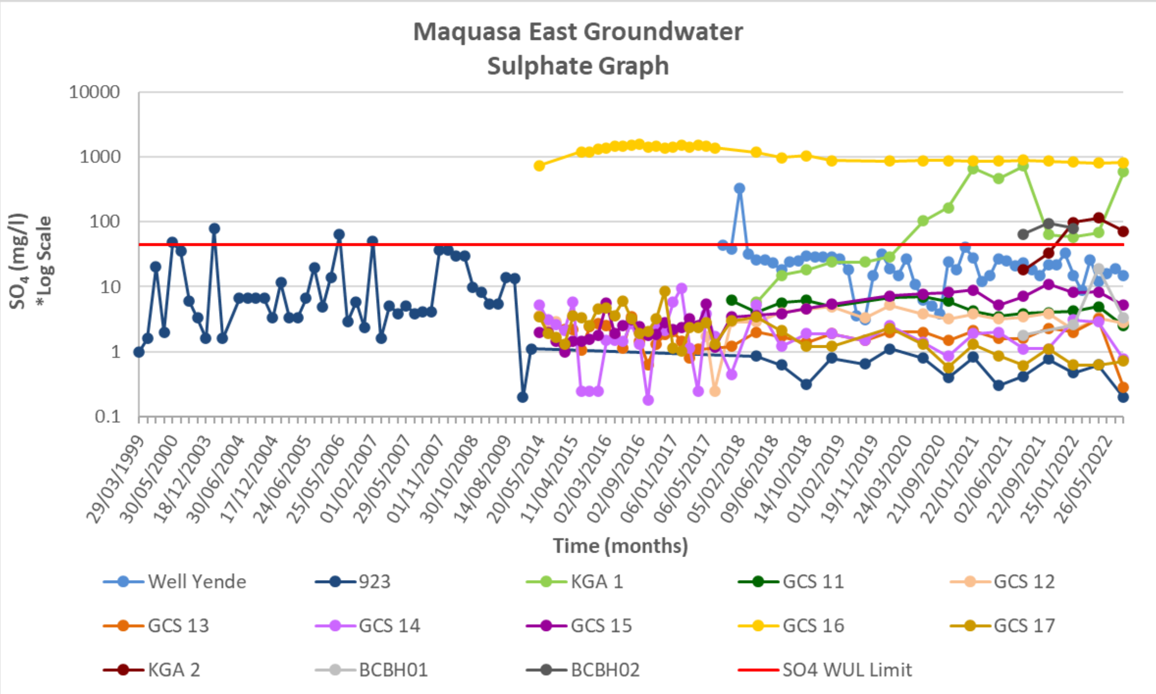


Figure 4-1: Maquasa East logarithmic groundwater sulphate graph

4.2 Surface Water Quality

One new surface water point (CSW04) was added to the surface water monitoring network in July 2021. Canal Along Main Road was dry throughout the second quarter whilst CSW04 was dry during the July 2022 sampling event.

The following observations were made during the 2022 second quarter:

- All surface water monitoring points exhibited neutral to slightly alkaline pH conditions throughout the second quarter, ranging between 6.8 and 8.3.
- Surface water points Below Highwall Seepage, Highwall Seepage, D/S of Natural Seepage, East Heyshope, Heyshope Dam Abstraction, West Heyshope and SW 932 displayed low to no significant impact from the site.
    - In terms of metal concentrations, manganese (< 0.65 mg/l) was elevated at Below Highwall Seepage, Highwall Seepage and SW 932 during the second quarter of 2022. Iron (< 0.15 mg/l) was elevated at East Heyshope, Heyshope Dam Abstraction and West Heyshope during the second quarter of 2022.
    - Aluminium concentrations were elevated at Heyshope Dam Abstraction and West Heyshope during the second quarter of 2022. The source is most likely the upstream discard dump. Aluminium is commonly associated with burnt clinker material generated by discard dumps.
    - Ammonia concentrations were elevated at Below Highwall Seepage, Highwall Seepage, D/S of Natural Seepage, East Heyshope, Heyshope Dam Abstraction, West Heyshope and SW 932 during the June 2022 sampling event, ranging between 7.3 and 7.9 mg/l.
- CSW04 and SW 933 indicated an impact from the site during the 2022 second quarter period. CSW04 was compliant with the Usuthu River Catchment TWQG during the May 2022 sampling event and could not be sampled during the July 2022 sampling event due to low water levels.
    - EC, TDS, calcium and sodium concentrations exceeded the Usuthu River Catchment TWQGs at SW 933 throughout the second quarter. TDS ranged between 2 00 mg/l and 3 300 mg/l; refer to Figure 4-2.
    - During the June 2022 sampling event, CSW04 indicated elevated EC, TDS, calcium and sodium concentrations exceeding the Usuthu River Catchment TWQGs. Elevated salt concentrations at CSW04 are likely due to evaporation at this locality causing the water to become more concentrated.

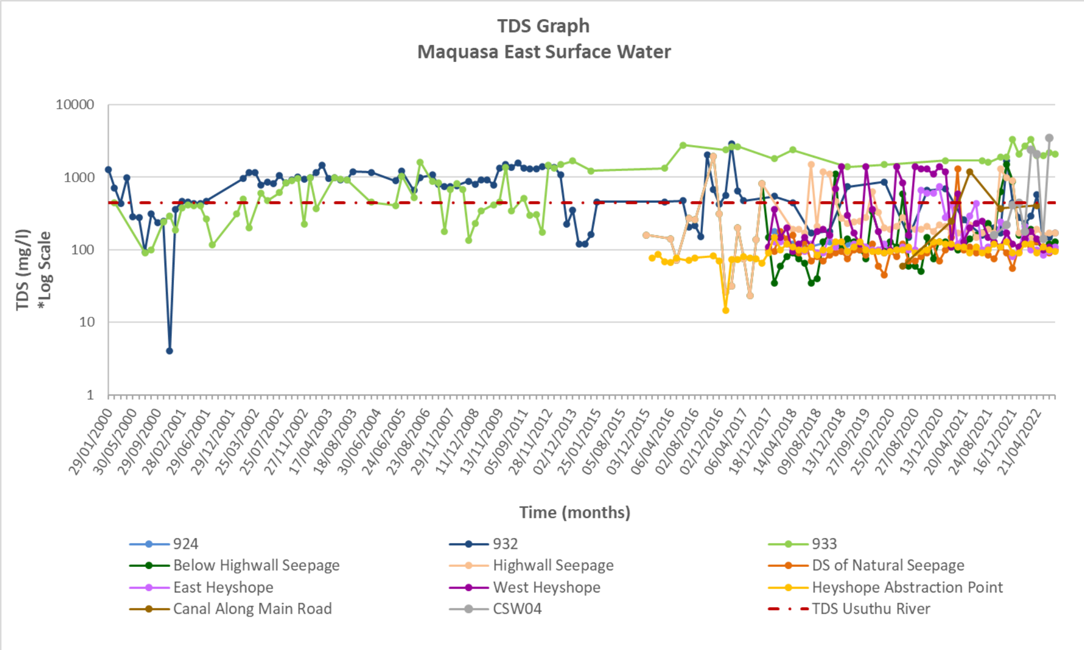


Figure 4-2: Maquasa East logarithmic surface water TDS graph

- Sulphate concentrations predominantly exceeded the Usuthu River Catchment TWQG at CSW04 and SW 933; refer to Figure 4-3.
  - Sulphate at SW 933, located downstream of the underground workings, has historically fluctuated however, a relatively stable trend has been observed since 2013. Sulphate ranged between 1 840 and 2 260 mg/l in the second quarter.
  - Sulphate at most localities indicated slight decreases in concentrations during the second quarter.
  - Sulphate exceeded the Usuthu River Catchment TWQG at CSW04 (3 230 mg/l) during the June 2022 sampling event.
- Additionally, ammonia (8 mg/l) and nitrate (30 mg/l) were elevated at CSW04 during the June 2022 sampling event. SW 933 indicated elevated ammonia (7.8 mg/l) concentrations during the June 2022 sampling event.
- In terms of metal concentrations, manganese was in exceedance at SW 933 and CSW04, ranging between 3 and 10.0 mg/l.

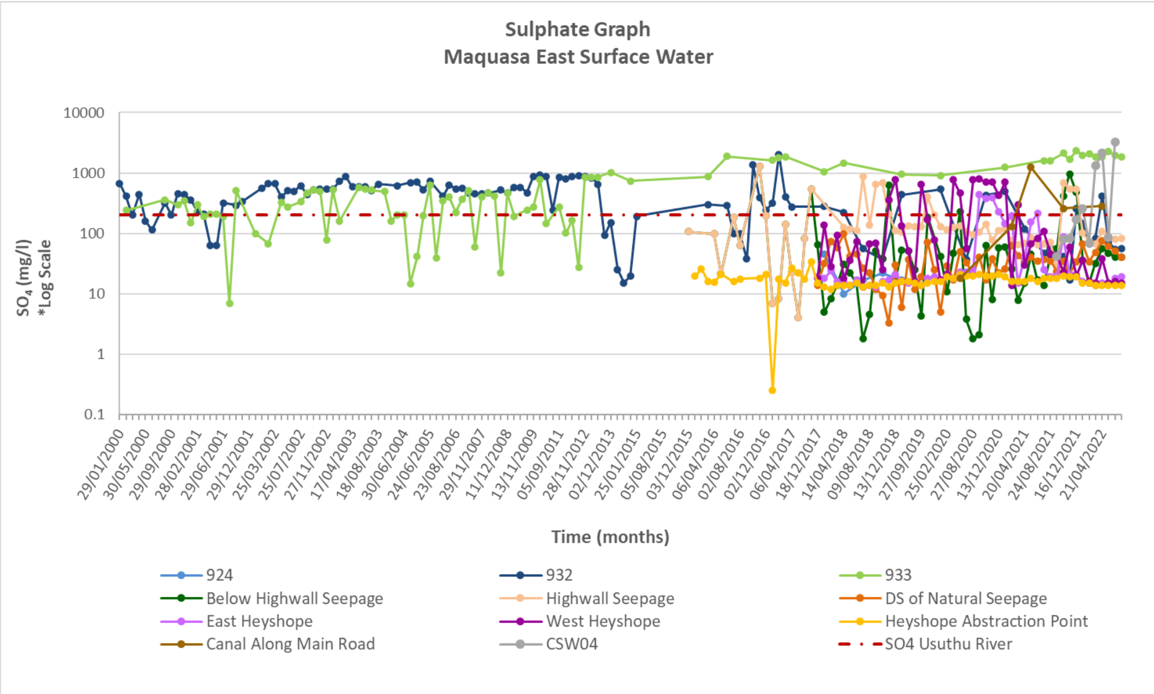


Figure 4-3: Maquasa East logarithmic surface water sulphate graph

4.3 Concluding remarks on water quality

The groundwater quality results for boreholes Well Yende, KGA1, KGA2, BCBH02, GCS16 and GCS17 indicate an impact from the site. KGA1 and GCS16 indicate the most significant impact, which is most likely a result of combined seepage from the discard facility and underground workings. These boreholes have displayed consistently non-compliant water quality, representative of high sulphate mine drainage as a result of decanting mine water from the underground workings.

Surface water points Canal Along Main Road, CSW04, SW 932 and SW 933 indicated an impact from the site; the remaining points displayed low to no significant impact.

The predominant trend at this site indicates intermittently impacted surface water quality. This may suggest periodic decant or dilution following rainfall events, at certain sample positions.

5 FLOOD LINE ASSESSMENT

Flood peak flow for the perennial stream portion associated with the sub-catchment was estimated with the Rational Method (3), Standard Design Flood (SDF) and Midgley & Pitman (MIPI) Method (refer to **Appendix A**). Design rainfall was retrieved from station 0407639W and used to calculate peak flow volumes. Table 5-1 provides a summary of the design rainfall data used to calculate peak flows, and time concentrations were calculated based on the sub-catchment sizes and parameters. The upper limit "U" was used to estimate worst-case peak flows.

Table 5-1: Summary of design rainfall data used for peak flow estimates

Duration	Return Period (years)						
	2U	5U	10U	20U	50U	100U	200U
5 min	17.3	23	27.1	31.3	37.2	42.1	47.3
10 min	22	29.2	34.4	39.7	47.1	53.3	60
15 min	25.3	33.5	39.5	45.6	54.2	61.3	68.9
30 min	31.6	41.9	49.5	57.1	67.8	76.7	86.3
45 min	36.1	47.8	56.4	65.1	77.3	87.5	98.4
1 hr	39.6	52.5	61.9	71.5	84.9	96.1	108
1.5 hr	45.1	59.9	70.6	81.5	96.8	109.6	123.2
2 hr	49.6	65.7	77.5	89.5	106.3	120.3	135.2
4 hr	58	77	90.8	104.8	124.5	140.9	158.4
6 hr	63.7	84.5	99.6	115	136.6	154.5	173.7
8 hr	68	90.2	106.4	122.8	145.8	165	185.5
10 hr	71.5	94.9	111.9	129.2	153.4	173.7	195.2
12 hr	74.6	98.9	116.7	134.7	159.9	181	203.5
16 hr	79.6	105.7	124.6	143.9	170.8	193.3	217.3
20 hr	83.8	111.2	131.1	151.4	179.7	203.4	228.6
24 hr	87.4	115.9	136.7	157.8	187.4	212.1	238.3
1 day	74.1	98.3	115.9	133.9	158.9	179.9	202.2
2 days	86.9	115.3	135.9	157	186.4	210.9	237.1
3 days	95.4	126.5	149.2	172.3	204.6	231.5	260.2
4 days	105.5	140	165	190.6	226.3	256.1	287.8
5 days	114.1	151.3	178.5	206.1	244.7	276.9	311.2
6 days	121.6	161.3	190.2	219.7	260.8	295.2	331.8
7 days	128.4	170.3	200.8	231.8	275.3	311.6	350.2

5.1 Estimated floods return periods

Calculated peak flows are summarised in Table 5-2. The RM(3) and MIPI methods produced lower peak flows when compared to the DSF method. The geometric average of the methods was applied to the HEC-RAS model. The flood line assessment is aimed at providing a worst-case inundation scenario to evaluate potential flooding risks. The peak flows presented are for the existing project setting.

Table 5-2: Summary of design peak flows for the delineated sub-catchments (m^3/s)

Catchment	Method											
	RM (3)			SDF			MIPI			Geometric Mean		
	1:20yr	1:50yr	1:100yr	1:20yr	1:50yr	1:100yr	1:20yr	1:50yr	1:100yr	1:20yr	1:50yr	1:100yr
	(m^3/s)											
HRU1	9	13	17	23	33	42	21	28	33	16	23	29
HRU2	35	52	71	61	89	113	41	54	63	44	63	80
HRU3	33	49	67	54	78	99	32	42	49	39	54	69
HRU4	24	35	48	47	69	87	31	41	48	33	46	59
HRU5	43	64	87	54	80	101	36	47	55	44	62	79
HRU6	16	23	32	32	47	59	22	29	34	22	32	40
HRU7	69	101	138	115	168	213	72	94	111	83	117	148

5.2 Flood line modelling

5.2.1 Software

HEC-RAS 6.1 (September 2021) was used to model the flood elevation profile for the 1:50 and 1:100-year flood events. HEC-RAS is a hydraulic programme designed to perform one-dimensional hydraulic calculations for a range of applications, from a single watercourse to a full network of natural or constructed channels. The software is used worldwide and has consequently been thoroughly tested through numerous case studies.

5.2.2 Topography profile data

A triangulated irregular network (TIN) from the 30 m DTM (JAXA, 2022) forms the foundation for the HEC-RAS model and was used to extract elevation data for the river profile together with the river cross-sections. Furthermore, the TIN was used to determine placement positions for the cross-sections along with the river profile, such that the watercourse can be accurately modelled to the resolution of the provided topographical data. The positions of the river sections were further refined, by evaluating Google Earth Imagery and its correlation to the DTM elevations (i.e., does the actual position of a river/stream correlate to the sub-catchment drainage line generated).

5.2.3 Manning's roughness coefficients

Manning's roughness factor (n) is used to describe the channel and adjacent floodplains' resistance to flow. A Manning factor of 0.03 to 0.035 best represents the frictional characteristics of the riverbanks and 0.03 for the channels (river).

5.2.4 Inflow and boundary conditions

Based on the HRUs and the confirmed drainage lines/streams in the project area, six (6) HEC-RAS rivers were defined, consisting of both normal depth (upstream) and critical depth slope boundary conditions. The normal depth slope was determined based on the ALOS DTM slope rise for the given sub-catchment drainage line.

5.2.5 Hydraulic structures

Hydraulic structures were not incorporated into the HEC-RAS model. Modelling of the hydraulic structures would have been hampered by the lack of good resolution topographical data (better than 30 m ALOS and 5 m contours).

5.2.6 Model assumptions

In line with the development of the flood lines, the following assumptions were made:

- The topographic data provided was of sufficient accuracy and coverage to enable hydraulic modelling at a suitable level of detail.
- The Manning's 'n' values used are considered suitable for use in the flooding events modelled, representing all the channels and floodplains.
- No abstractions or discharges into the stream sections were considered during the modelling.
- Hydraulic structures were not entered into the model due to the resolution of available topography data.
- Steady-state hydraulic modelling was undertaken, which assumes the flow is continuous at the peak rate; and
- A mixed flow regime that is tailored to both subcritical and supercritical flows was selected for running the steady-state model.

5.3 Model results

The 1:50-year and 1:100-year flood lines are shown in Figure 5-1. From the flood lines produced, it is noted that all the proposed infrastructure will be situated outside probable zones of inundation. There is no likely flooding risk.

5.4 Site-specific sensitivity & buffers (avoidance areas)

Based on the outputs of the flood line, no avoidance areas are recommended. However, the 1:100-year flood lines serve as future development buffer areas.

5.5 Limitations

Steady-state flood modelling was undertaken which is a conservative approach as it ignores the effect of storage within the system and therefore produces higher flood levels than would be expected to occur. A steady-state model will result in worst-case (conservative) estimates of flooding, and resultant flood levels and floodplain extents would decrease if unsteady state modelling were undertaken using an inflow hydrograph as opposed to continuous peak flow.

Despite the above-mentioned, Manning coefficients for the vegetation observed, and the low-resolution topographic data, the flood risk to the surface infrastructure has been adequately assessed for the project area. No further flood modelling work is considered necessary and would only be considered necessary when more detailed topographical data is available.

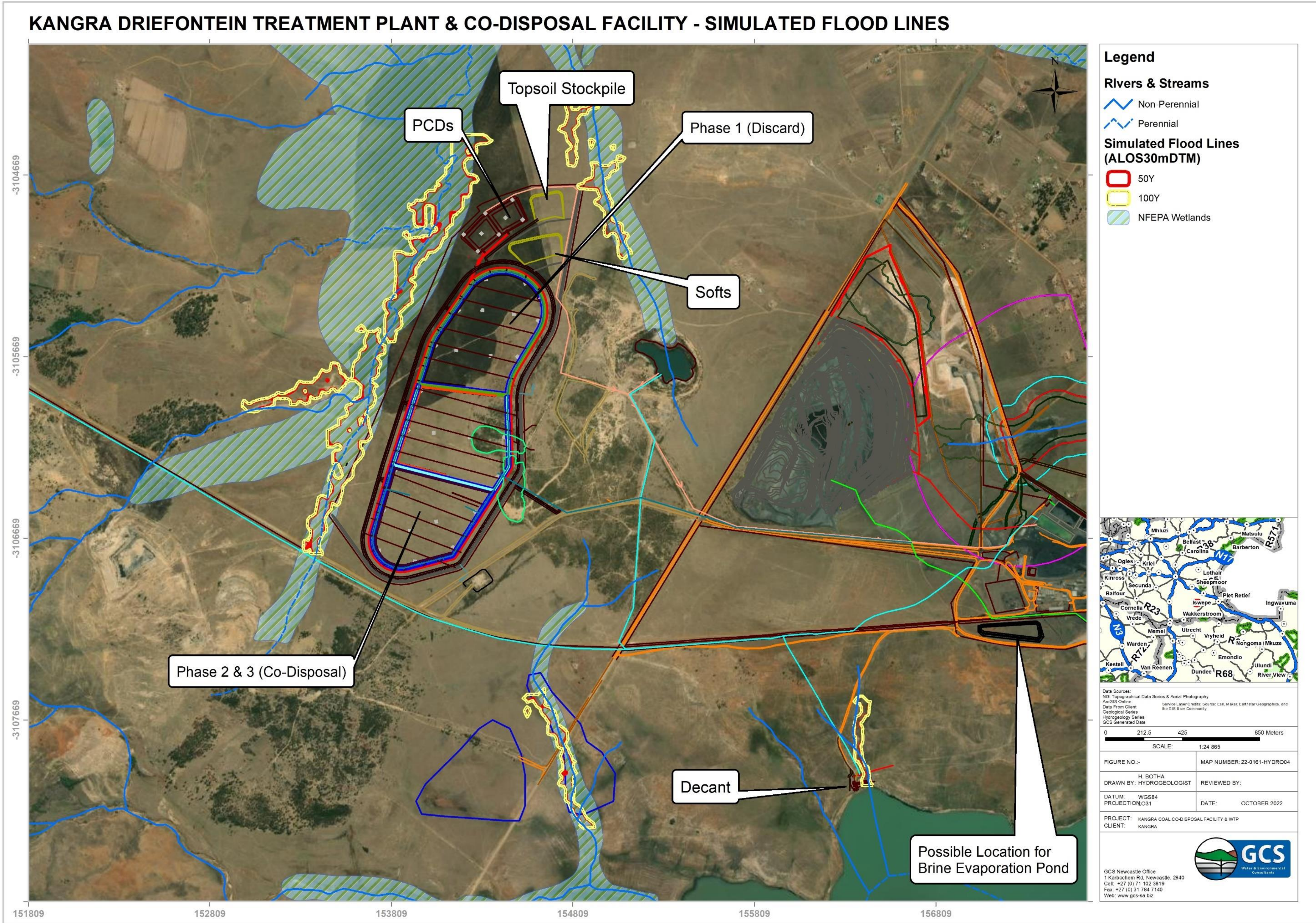


Figure 5-1: Simulated 1:50 and 1:100 year flood lines

6 CONCEPTUAL STORMWATER MANAGEMENT PLAN

The following section describes the CSWMP developed and is based on available hydrological data and site layout data.

6.1 Aim of the stormwater management plan

The CSWMP aims to:

- Illustrate likely stormwater sub-catchments (HRUs) and preferential overland runoff flow paths.
- Determine likely dirty and clean water HRUs (if any).
- Provide water containment and diversion systems to prevent the mixing of clean and dirty water, prevent soil erosion and flooding; and
- Attenuate stormwater back to the natural environment.

6.2 Existing stormwater infrastructure & proposed on-site stormwater management as per the design report

No existing stormwater systems were identified for the project area and the development site. However, it is understood that GFK (2022) are undertaking the detailed stormwater designs and PCD and dam sizing for the proposed WTP and co-disposal facility.

From draft schematics provided by GFK (2022), the following is noted (refer to Figure 6-1 and Figure 6-2):

- The co-disposal facility will be lined with an impermeable barrier;
- All the drainage and infiltration water will be captured by an under-drain system and diverted to the PCDs;
- A clean water interception and diversion trench is incorporated into the designs, to divert any runoff emanating from upper drainage areas; and
- A dirty water cutoff trench is incorporated into the design to capture any poor-quality runoff and prevent sedimentation from the co-disposal facility.

The PCDs and WRDs were sized by GFK to handle 1:2 to 1:100-year storm events and will be operated at a capacity that accommodates 1:2 to 1:100-year flooding events.

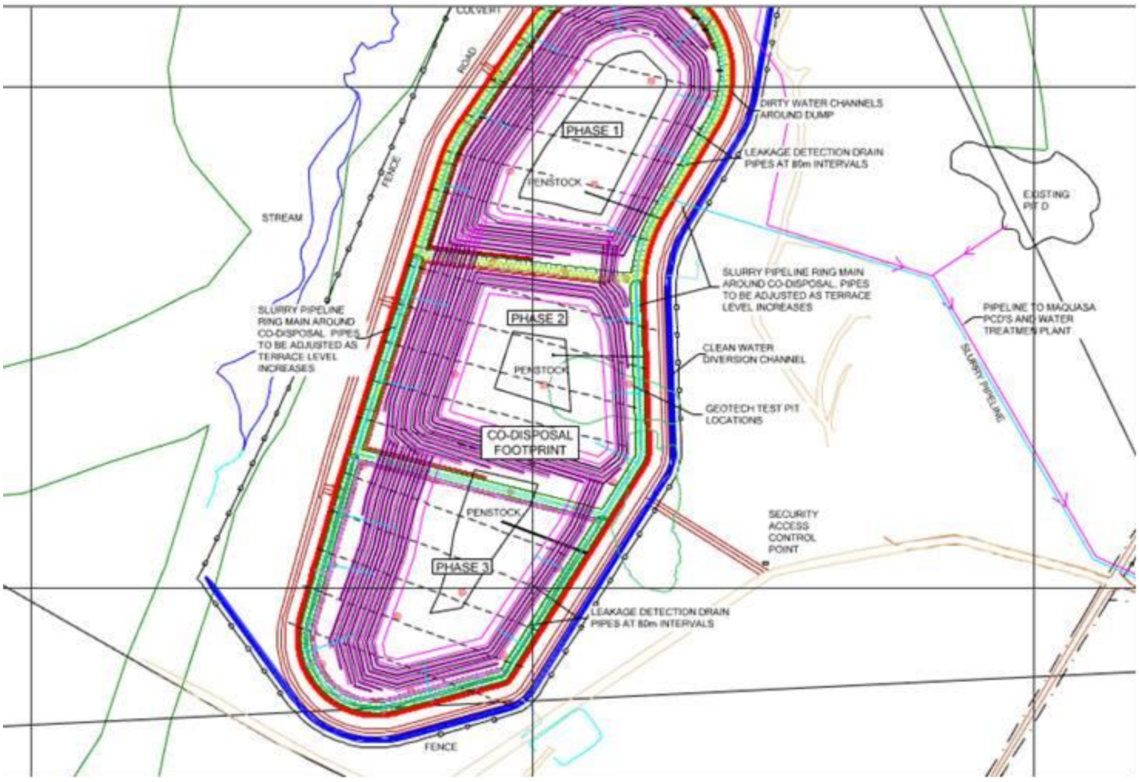


Figure 6-1: Draft layout of co-disposal (GFK, 2022)

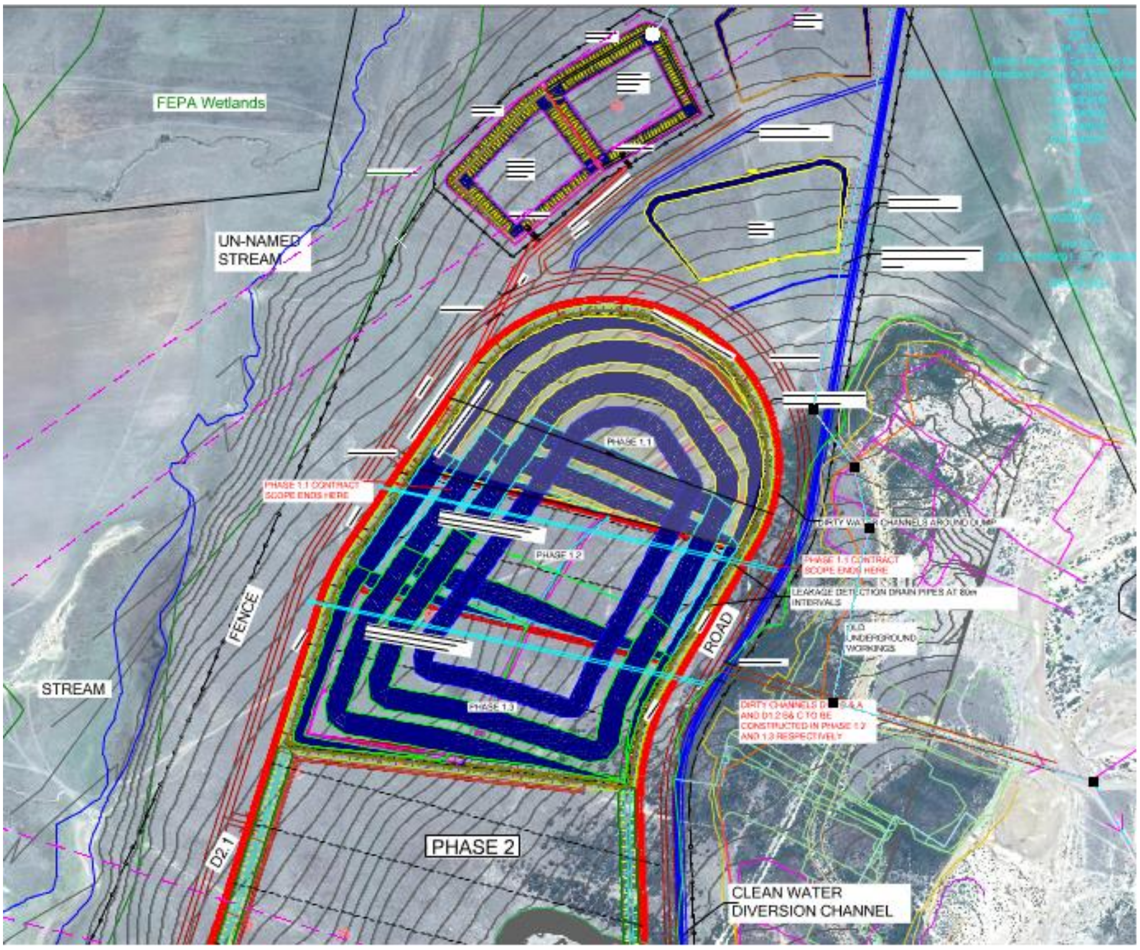


Figure 6-2: Discard dump Phase 1 (GFK, 2022)

6.3 Delineation of clean and dirty water areas

A total of five (5) small stormwater sub-catchments were delineated for the project area, three (3) of which are considered potentially dirty water areas (i.e. areas associated with the PCDs, and runoff from the co-disposal facility).

Efforts should be made in managing runoff from the upstream areas associated with the site back to the surrounding soils, and then managing the distribution of the accumulated water back to the environment. All runoff from the co-disposal facility as well as potential seepage and overflow from the PCDs should be captured and pumped to the PCDs. Stormwater monitoring will help determine the quality of the stormwater and the likely environmental impacts if released.

As the proposed WTP and brine pond are situated in areas with existing stormwater systems, as well as in dirty areas, these were not included in this investigation.

6.4 Assumptions & limitations

The following assumptions pertain to the CSWMP:

- Dynamic stormwater modelling and sizing of stormwater systems to an engineering degree is not part of the scope of this hydrology assessment.
- GFK will be sizing the PCDs and associated infrastructure. The stormwater peak flows in this report are purely conceptual, and can aid the sizing process undertaken by the engineers.
- No stormwater modelling was undertaken. The concepts presented should be modelled by a professional engineer.

6.5 Stormwater peak flows

Stormwater drainage directions expected from the site are shown in Figure 6-3. The rational method was used to calculate the stormwater peak flows for the sub-catchments delineated for the project area. The soils in the study area have an SCS rating of C soil types, with a high erodibility rating. Considering the vegetation cover observed on-site and the probable increase in land imperviousness, a run-off coefficient (C) in the order of 0.95 (95%) is estimated (Kindersley, 2012). 1:2, 1:10, 1:50 and 1:100 year return periods are presented and are tabulated in Table 6-2.

The 24hr design rainfall for station 0635862W was used to simulate the 1:2, 1:10, 1:50 and 1:100 year storm return periods (refer to Table 5-1). The potential stormwater from the sub-catchments and that of the development area are captured in Table 6-2. The stormwater infrastructure should be sized by a Registered Engineer to handle these minimum peak flow estimates, as per the proposed sizing and systems in the next section.

Table 6-1: Summary of design rainfall data used for peak flow estimates

Duration	Return Period (years)						
	2	5	10	20	50	100	200
24 hr	87.4	115.9	136.7	157.8	187.4	212.1	238.3

Table 6-2: Stormwater return period estimates for sub-catchments and the development areas

Storm HRU	Q2 -m^3/s	Q10 -m^3/s	Q50 -m^3/s	Q100 -m^3/s
D1	13.661	21.367	29.292	33.153
D2	14.685	22.969	31.487	35.638
D3	1.168	1.827	2.505	2.835
HRU1-C1	5.865	9.173	12.574	14.232
HRU2-C1	1.697	2.655	3.640	4.119

6.6 Proposed stormwater management measures

6.6.1 Construction phase

During the construction phase, it is recommended that sandbags and temporary berms (as per visual observations and ongoing weekly inspections during construction) be used, to manage stormwater runoff (if storms do occur). It is recommended that the construction phase take place during dry months, with a decreased probability of storm events. Temporary stormwater systems should be sufficient to manage the stormwater at the site during the construction phase.

6.6.2 Operational phase

Considering the proposed activities, the calculated peak flows and the ecological sensitivity of the project area, a mixture of free drainage from upstream catchments, interception of clean runoff water and capturing of poor quality runoff and seepage from the co-disposal facility and PCDs, as well as dedicated stormwater conveyance and capture systems, is proposed.

As the draft designs already have these systems in place, it is only recommended that the outlet drains of the clean water diversion trench be regulated by rock rip rap or vegetated covers, to decrease peak flows and capture sediment that makes it into the trench. The conceptual stormwater system is shown in Figure 6-4.

For detailed stormwater designs, we refer the reader of this report to the GFK (2022) engineering design report.

6.7 Other stormwater considerations

The following should be considered during the live cycle of the project:

- Minimise vegetation disturbance during construction.
- Re-vegetate as soon as possible to establish and maintain good ground cover across the site.
- Conduct regular inspections and maintenance of the site to ensure that vegetation cover is adequate, and no rivulets are generated.

6.8 Proposed stormwater monitoring requirements

It is advised that stormwater monitoring of the engineered stormwater system that will be put in place by the developer be undertaken, to ensure that the proposed stormwater system functions correctly. The following is proposed:

1. Routine hydraulic monitoring (i.e., observations of any blockages in the stormwater system) and cleaning out of the stormwater systems.
2. Routine re-vegetation and maintenance of the trenches, collection sumps, silt traps, and drains, to ensure optimum operation.
3. Water quality monitoring during storm events.

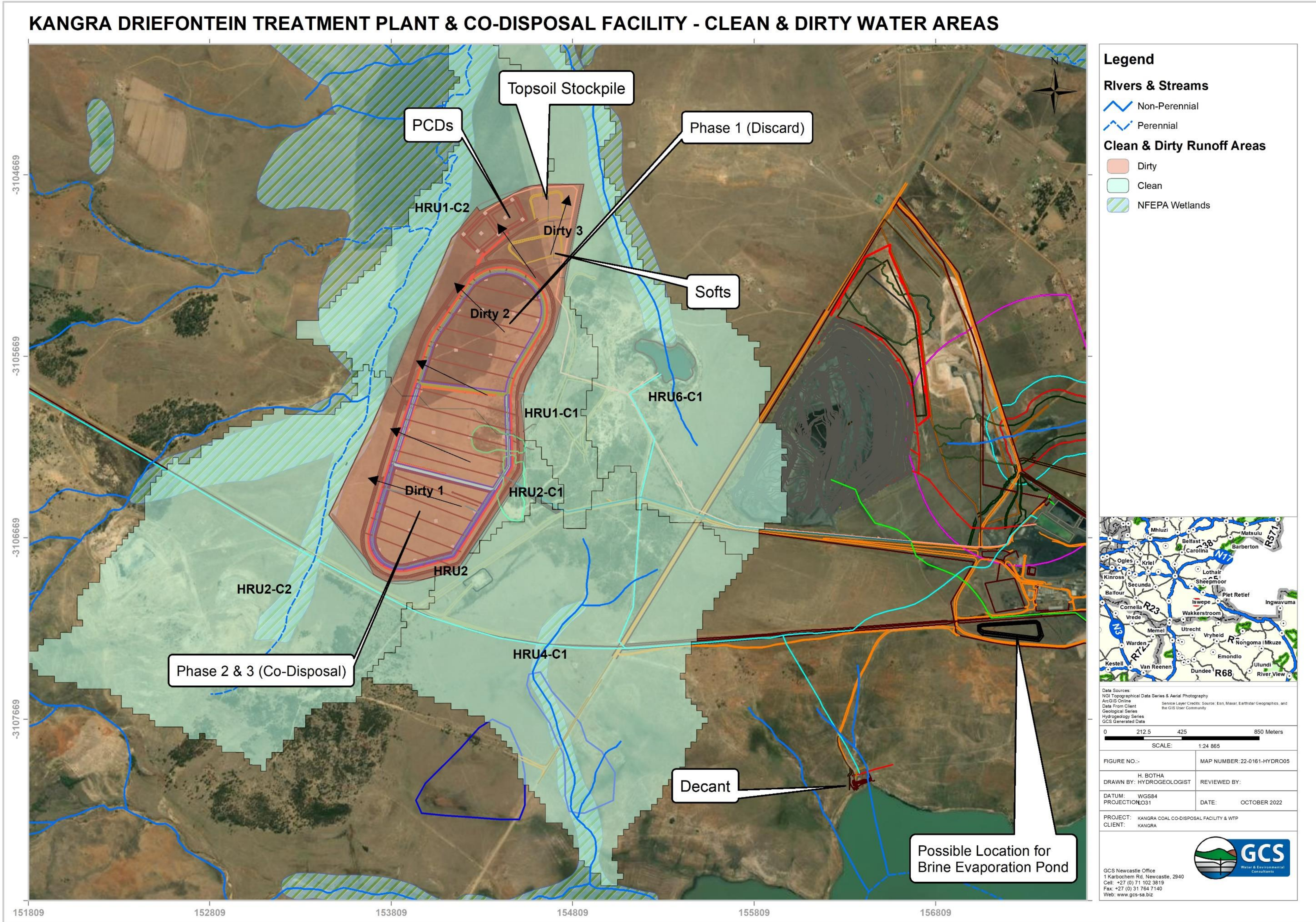


Figure 6-3: Dirty and clean stormwater catchments

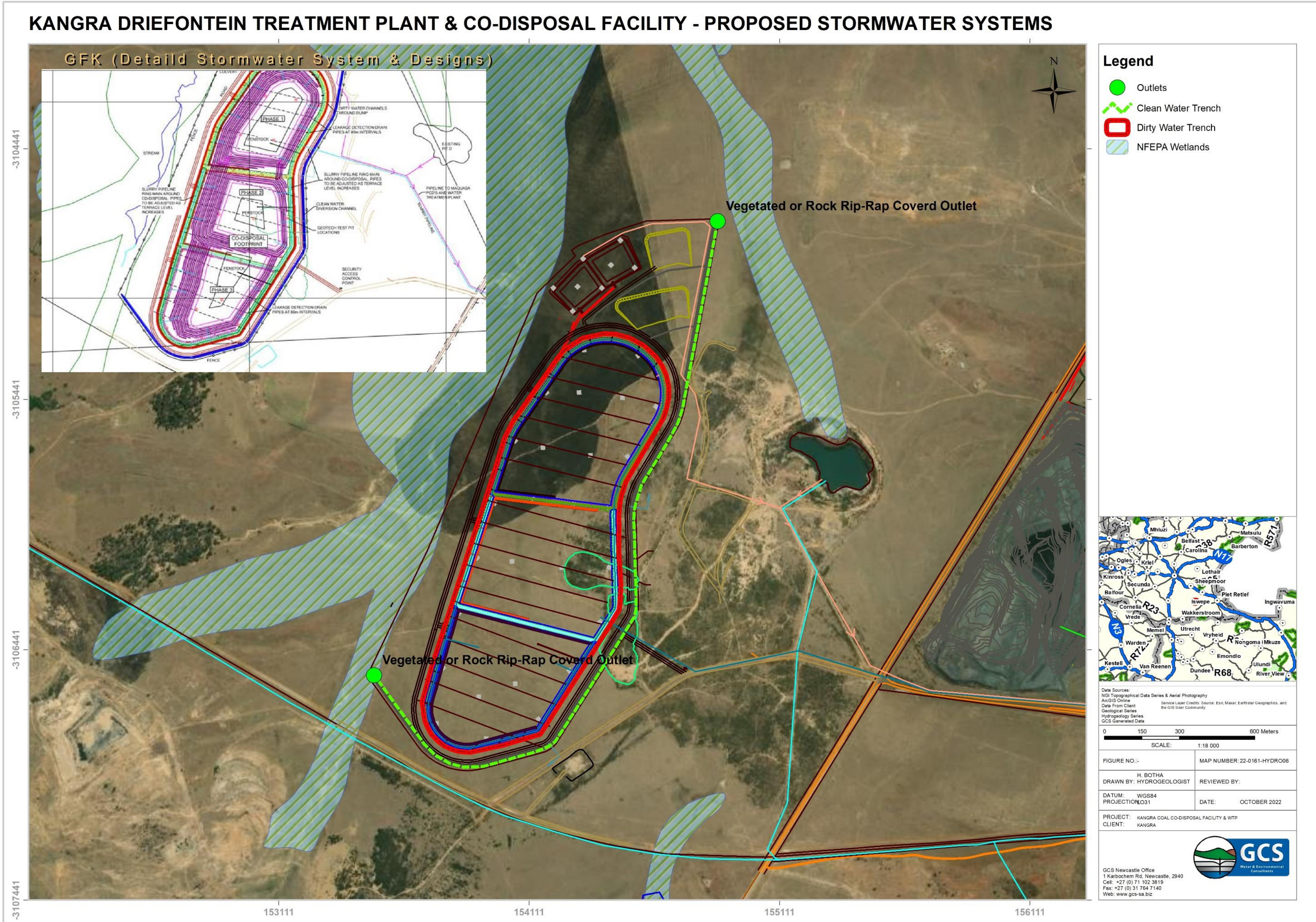


Figure 6-4: Conceptual stormwater management system

7 RISK ASSESSMENT & MITIGATION

The anticipated hydrological risk concerning the construction and operational phase of the WTP and co-disposal facility were assessed. The SPR model (DWAF, 2008) was used to evaluate potential pollution sources and primary receptors within the study area.

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:

Consequence = (Duration + Extent + Irreplaceability of resource) x Severity

And the environmental significance of an impact was determined by multiplying consequence by probability. The risk significance rating is summarised in Table 7-1.

Table 7-1: Risk rating scale

Criteria	Rating Scales
Significance	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)

In terms of the proposed developments, several hydrological risks were identified. The potential impacts identified and environmental significance for the construction, operational and closure phases are listed in Table 7-2 to Table 7-4.

7.1 Pre-mining/development phase

The activities during the pre-development phase will generally include the following:

- Typical earthworks are required to start construction of the disposal facility and WTP;
- Installation of liners/impermeable barriers;
- Excavation for the establishment of water management dams and systems;
- Establishment of access roads and other logistics infrastructure;
- Establishment of service platforms, material handling areas and other temporary infrastructure;
- Construction of the WTP facility, and stormwater system associated with the co-disposal facility; and

- The initial placing of discard/slurry mixtures, topsoil and soft rock on the designated dumps.

The identified risks for the construction/development phase include (refer to Table 7-2):

- The destruction of the localised geological units during excavations. This impact is permanent and is therefore not included in the impact table as no mitigation measures can be recommended.
- Clearing topsoil from footprint areas will influence the rate of infiltration of water to the shallow groundwater system and/or base-flow component to shallow streams.
- Handling of waste and transport of material can cause various types of spills (domestic waste, hydrocarbons) which can infiltrate and contaminate the groundwater system.
- Poor quality mine drainage from the coal waste.
- Oil and fuel spills and leakages at hard park areas may cause poor-quality seepage and soil contamination.
- Stripping of the topsoil may cause temporary sedimentation in the rivers and streams downstream of the site.

The continuation of the existing monitoring plan during construction is critical. This will ensure that water quality is continuously monitored. The collected information should be used as part of an active water management system and act as an early warning system for the application of mitigation measures. Except for the destruction of the geology, the other identified impacts during the construction phase are rated low after mitigation and management measures are applied. The identified impacts are therefore not likely to negatively affect the commencement of the proposed project.

7.2 Operational phase

The activities during the operational phase of the WTP and co-disposal facility include:

- Deposition of coal slurry and coal discard on one footprint. There is a possibility of the addition of brine to the discard dump.
- Seepage or spillages from Brine stored in the brine evaporation pond;
- Dirty runoff from surface water infrastructure, and potential spillages from stormwater systems (i.e. dirty water trenches) and containment systems (i.e. the PCDs).

The identified risks for the operational phase include (refer to Table 7-3).

- The destruction of the localised geological units as the opencast workings are developed. This impact is permanent and is therefore not included in the impact table as no mitigation measures can be recommended.

- Analyses showed that acid mine drainage (AMD) formation is expected and poor-quality leachate can occur based on the leaching potential of the material. This can influence runoff, soil, and groundwater quality. Containment systems are proposed and need to be regularly checked to ensure no seepage to the environment takes place.
- Poor quality runoff from the WTP and co-disposal facility.
- Poor quality seepage associated with the WTP brine effluent pond, co-disposal facility, soil stockpiles, and vehicles accessing the site (spillages of hydrocarbons) could impact the soils, and impact runoff water quality.
- Siltation of stormwater systems.

As the co-disposal facility is designed to contain potential seepage from the coal waste and to capture runoff from the site, low impacts are predicted. Impacts relating to the proposed PCDs and brine effluent ponds will likely only impact the environment if there are spillages or leakages from these facilities.

The treatment of decanting from the Heyshope decant containment dam is considered a very positive intervention in terms of limiting the impact on the Heyshope Dam.

7.3 Closure and decommissioning phases

The closure and decommissioning phases will be per an agreed and approved closure plan for the WTP (if decant ceases) and co-disposal facility. This will entail:

- Termination of landfill/ co-disposal activities onto the co-disposal footprint area and rehabilitation;
- Installation of long-term stormwater systems or upgrades to the operational stormwater system; and
- Termination of treatment activities and brine generation (only if no decant from the old MQE workings takes place).

The identified risks for these phases include (refer to Table 7-4):

- Poor quality seepage and runoff from the co-disposal facility;
- Poor quality seepage from vehicles accessing the site to do rehabilitation work; and
- Siltation of stormwater systems.

7.4 Cumulative impacts and impacts on the hydrological cycle

As all activities will take place on the same property, there will be cumulative impacts. The proposed WTP and brine storage pond are zoned in an area where existing mine impacts are noted.

The construction and operational phase risk table includes cumulative risk about the site, and activities thereon. Considering the sub-catchment conceptual hydrological cycle and the activities associated with the site and surroundings, no impacts are expected in terms of the hydrological cycle. This is due to the proposed site activities not significantly altering the hydrological functions of the given environment.

Table 7-2: Construction (preparation and development) phase hydrological risk

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation: Duration	Extent	Potential for impact on irreplaceable resources	Severity	Consequence	Probability	Significance	Recommended Mitigation Measures	Post Mitigation: Duration	Extent	Severity	Potential for impact on irreplaceable resources	Consequence	Probability	Significance	Confidence
Vadose zone soils	Disturbing vadose zone during soil excavations/activities.	Earthworks	Long-Term (4	Site (2)	Yes (1)	High (-3)	Highly detrimental (-19 to -24) (-21)	Definite (2)	High - negative (-37 to -48) (-42)	• Only excavate areas applicable to the project area. • Keep the site clean of all general and domestic waste. • All development footprint areas to remain as small as possible and vegetation clearing to be limited to what is essential. • Retain as much indigenous vegetation as possible. • Exposed soils to be protected using a suitable covering. • Existing roads should be used as far as practical to gain access to the site, and crossing the streams in areas where no existing crossing is apparent should be unnecessary, but if it is essential crossings should be made at right angles.	Long-Term (4	Site (2)	Yes (1)	Probable (-2)	Low - negative (-13 to -24) (-14)	Definite (2)	Moderate - negative (-25 to -36) (-28)	Medium
Primary Surface Water Receivers - > Non-perennial and non-perennial streams > Wetlands	Surface water contamination and sedimentation from the following activities: • Equipment and vehicles are washed in the water bodies (when there is water); • Erosion and sedimentation of watercourses due to unforeseen circumstances (i.e. bad weather); and • Alteration of natural drainage lines which may lead to ponding or increased runoff patterns (i.e. may cause stagnant water levels or increase erosion).	Earthworks	Long-Term (4	Site (2)	Yes (1)	Probable (-2)	Moderately detrimental (-13 to -18) (-14)	Definite (2)	Moderate - negative (-25 to -36) (-28)	• Install a temporary cut-off trench (if required) to contain poor-quality runoff. • Cover soil stockpiles with a temporary liner to prevent contamination (where required and visually determined). • Park vehicles in designated areas.	Long-Term (4	Site (2)	Yes (1)	Probable (-1)	Slightly detrimental (-7 to -12) (-7)	Probable (1)	Neutral - Very low (0 to -12) (-7)	Medium
Perched Water Table Dewatering	Temporary dewatering of perched groundwater (only expected during intense storm events and shortly thereafter).	Earthworks	Long-Term (4	Site (2)	Yes (1)	Low (-1)	Slightly detrimental (-7 to -12) (-7)	Definite (2)	Low (12 to -25) (-14)	• Water quality monitoring and routine visual assessment for contamination. • Discharge dewatered / rainwater collected into the nearby stream. May require authorisation. If water is contaminated, discharge to the closest greywater system (depending on the extent of contamination)	Long-Term (4	Site (2)	Yes (1)	Negligible (0)	Negligible (0 to -6) (-0)	Probable (1)	Neutral - Very low (0 to -12) (0)	Medium

Table 7-3: Operational phase hydrological risk

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation							Confidence
			Duration	Extent	Potential for impact on irreplaceable resources	Severity	Consequence	Probability	Significance		Duration	Extent	Severity	Potential for impact on irreplaceable resources	Consequence	Probability	Significance	
Vadose zone soils	*Seepage from the co-disposal facility (landfill), PCDs and brine effluent pond* • Poor quality seepage and runoff from vehicles parked at the site.	Site activities	Long-Term (4	Site (2)	Yes (1)	Low (-1)	Slightly detrimental (-7 to -12) (-7)	Probable (1)	Neutral - Very low (0 to -12) (-7)	• Keep the site clean of all general and domestic waste. • Water quality of the streams and sewer line monitoring. • soil covers in areas where erosion is noted, and dust suppression of the landfill to prevent dust migration onto soils.	Long-Term (4	Site (2)	Yes (1)	Probable (-1)	Slightly detrimental (-7 to -12) (-7)	Probable (1)	Neutral - Very low (0 to -12) (-7)	Medium
Primary Surface Water Receivers - > Non-perennial and non-perennial streams > Wetlands	*Stormwater runoff from WTP and co-disposal facility* • Potential surface water contamination as a result of poor stormwater drainage on-site. • Increased erosion due to vegetation loss. • Contaminated runoff water into nearby streams from parked vehicles at the site. • Sedimentation of watercourses due to altered runoff patterns.	Mine activities	Long-Term (4	Site (2)	Yes (1)	High (-3)	Highly detrimental (-19 to -24) (-21)	Definite (2)	High - negative (-37 to -48) (-42)	• Water quality monitoring and visual assessments. • Routine hydraulic monitoring of the stormwater system (monthly)	Long-Term (4	Site (2)	Yes (1)	Low (-1)	Slightly detrimental (-7 to -12) (-7)	Definite (2)	Low (12 to - 25) (-14)	Medium
	Seepage from the co-disposal facility • Poor quality seepage into the subsoils from landfill may impact soil quality, and eventually lead to poor quality seepage into the surroundings.	Mine activities	Long-Term (4	Site (2)	Yes (1)	High (-3)	Highly detrimental (-19 to -24) (-21)	Definite (2)	High - negative (-37 to -48) (-42)	• Water quality monitoring and visual assessments. • Routine inspections of all stormwater systems. • Ensure the facility is lined. • Ensure slopes are shaped to prevent erosion.	Long-Term (4	Site (2)	Yes (1)	Low (-1)	Slightly detrimental (-7 to -12) (-7)	Definite (2)	Low (12 to - 25) (-14)	Medium
	Treatment of decanting water into Heyshope Dam	Treatment activities	Long-Term (4	Site (2)	Yes (1)	High (3)	Highly beneficial (19 to 24) (21)	Definite (2)	High-positive (37 to 48) (42)	No mitigation is required.								High

Table 7-4: Closure Phase Hydrological Risks

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation: Duration	Extent	Potential for impact on irreplaceable resources	Severity	Consequence	Probability	Significance	Recommended Mitigation Measures	Post Mitigation: Duration	Extent	Severity	Potential for impact on irreplaceable resources	Consequence	Probability	Significance	Confidence
Vadose zone soils	Disturbing vadose zone during rehabilitation actions associated with the landfill (co-disposal facility). The reshaping and rehabilitation of the co-disposal facility will be beneficial to the environment. Capping and reducing infiltration into the dump will help mitigate any poor-quality seepage.	Earthworks	Long-Term (4	Site (2)	Yes (1)	Probable (-2)	Moderately detrimental (-13 to -18) (-14)	Definite (2)	Moderate - negative (-25 to -36) (-28)	• Only excavate areas applicable to the project area. • Keep the site clean of all general and domestic waste. • Revegate the co-disposal facility. • Cover the co-disposal facility with a suitable impermeable capping layer or compact t reduce recharge into the landfill.	Medium Term (4)	Site (2)	Yes (1)	High (3)	Highly beneficial (19 to 24) (21)	Definite (2)	High-positive (37 to 48) (42)	Medium
Primary Surface Water Receivers - > Non-perennial and non-perennial streams > Wetlands	*Seepage from the co-disposal facility* • Poor quality seepage into the subsoils from landfill may impact soil quality, and eventually lead to poor quality seepage into the surroundings.	The net result of facilities constructed and rehabilitation thereof	Long-Term (4)	Footprint (1)	Yes (1)	Probable (-1)	Negligible (-6 to 0) (-6)	Probable (1))	Neutral - Very low (0 to -12) (-6)	• After rehabilitation takes place, there should be limited seepage from the dump. • Routine inspections and water quality monitoring of the boreholes and surface water streams downstream of the site (quarterly) should be sufficient to determine closure objectives.								Medium
	Stormwater runoff from WTP and co-disposal facility • Potential surface water contamination as a result of poor stormwater drainage on-site. • Increased erosion due to vegetation loss. • Contaminated runoff water into nearby streams from parked vehicles at the site. • Sedimentation of watercourses due to altered runoff patterns.	The net result of facilities constructed and rehabilitation thereof	Long-Term (4)	Footprint (1)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral - Very low (0 to -12) (-6)	• After rehabilitation takes place, there should be limited seepage from the dump. • Routine inspections and water quality monitoring of the boreholes and surface water streams downstream of the site (quarterly) should be sufficient to determine closure objectives. • Routine hydraulic monitoring of the stormwater system (monthly)								Medium

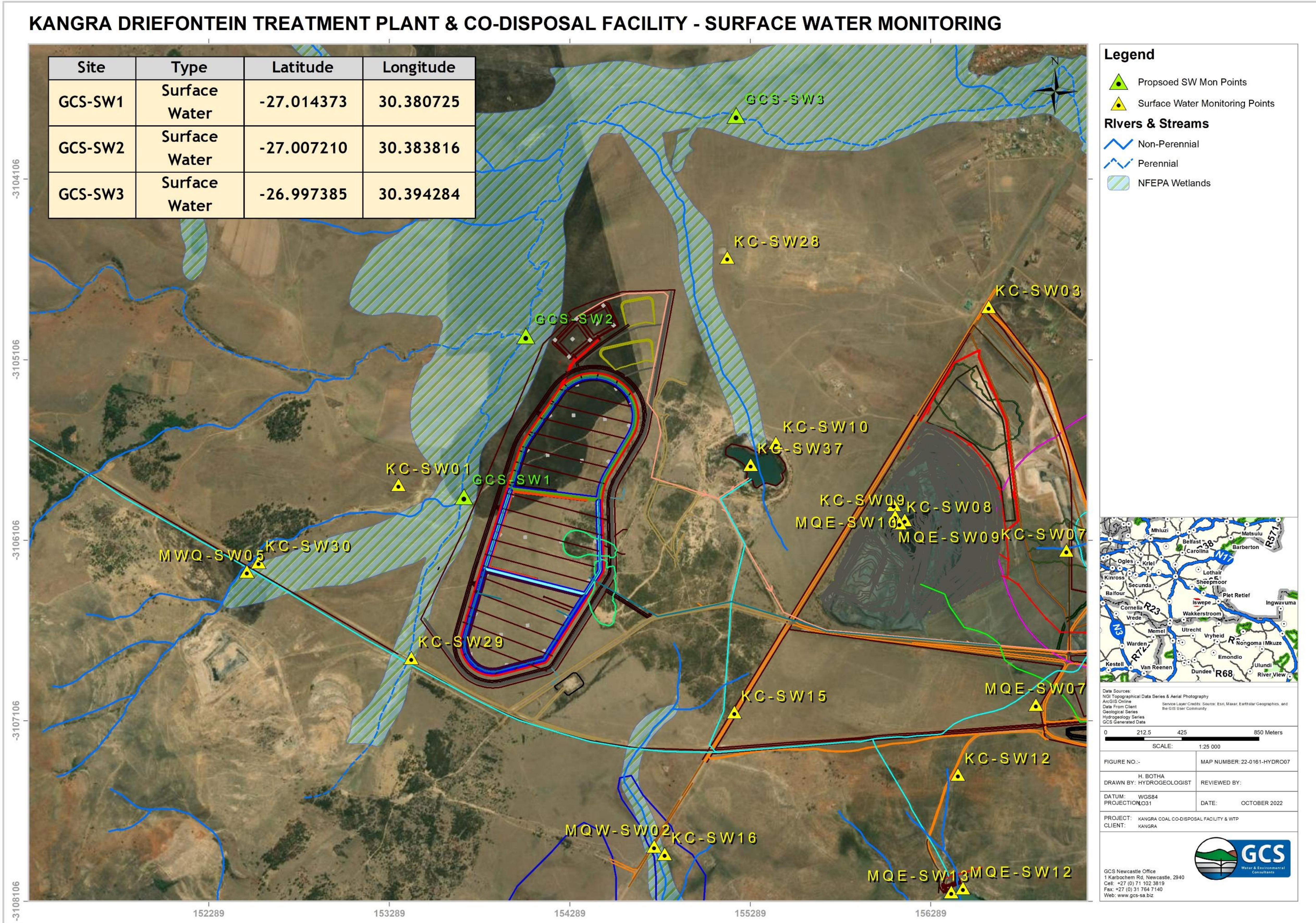
8 SURFACE WATER MONITORING

Kangra coal has an existing surface water monitoring system in place. The monitoring network is considered sufficient for the large scale, but may not be sensitive enough to verify local impacts associated with the proposed co-disposal facility. The WTP is considered a lower-risk infrastructure when compared to the co-disposal facility and hence will not require dedicated surface water monitoring.

It is proposed that at least 3 additional surface water monitoring points be added to the existing water monitoring network. The proposed additional surface monitoring points are listed in Table 8-1 and the positions are shown in Figure 8-1.

Table 8-1: Proposed monitoring points

Site	Type	Latitude	Longitude
GCS-SW1	Surface Water	-27.014373	30.380725
GCS-SW2	Surface Water	-27.007210	30.383816
GCS-SW3	Surface Water	-26.997385	30.394284



Site	Type	Latitude	Longitude
GCS-SW1	Surface Water	-27.014373	30.380725
GCS-SW2	Surface Water	-27.007210	30.383816
GCS-SW3	Surface Water	-26.997385	30.394284

Figure 8-1: Proposed additional surface water monitoring points

9 CONCLUSIONS

Based on the investigation undertaken, the following conclusions are made:

- The site is situated in Quaternary W51B of the Pongola to Mtamvuna Water Management Area.
    - The site means annual precipitation (MAP) is in the order of 769 mm/yr.
    - Natural runoff was recorded as approximately 103.5 mm/yr, which represents approximately 13% of the MAP.
    - Evaporation is reported as 1 200 to 1 300 mm/annum (S-Pan).
- The delineated drainage lines associated with the project area can be considered moderate flood hazard areas, based on the peak flows estimated and the flooding depth observed from the HEC-RAS model output. From the flood lines produced, it is noted that all the proposed infrastructure (co-disposal site, PCDs, WTP and brine effluent pond) will be situated outside probable zones of inundation. Hence, there is no likely flooding risk.
- The non-perennial and perennial streams downstream of the co-disposal facility, NFEPA wetland units and vadose zone soils are the main receptors of potential surface-related pollution at the site.
- The hydrological risk was evaluated (refer to Section 7) and the hydrological risk of the proposed activities range from high for the construction phase, to moderate and low for the operational and closure phases. Rehabilitation of the co-disposal facility and treatment of decanting water via the WTP are predicted to have positive or environmental impacts. Mitigation measures were proposed to circumvent potential impacts identified during the construction to closure phases (refer to Section 7).
- As all activities will take place on the same property, there will be cumulative impacts. The proposed WTP and brine storage pond are zoned in an area where existing mine impacts are noted. The construction and operational phase risk table includes cumulative risk about the site, and activities thereon. Considering the sub-catchment conceptual hydrological cycle and the activities associated with the site and surroundings, no impacts are expected in terms of the hydrological cycle. This is due to the proposed site activities not significantly altering the hydrological functions of the given environment.
- Several additional monitoring points are proposed, to be incorporated into the existing surface water monitoring program for the mine.

9.1 Avoidance areas

Limited sedimentation and erosion for the drainage lines and streams associated with the site are anticipated. The flood lines also suggest no flooding risk associated with the proposed development. *The 1:100-year flood line should be considered an avoidance area (buffer area) (CSIR, 2005).*

Care should be taken if development is to take place within the exclusion zone. If development does take place in the exclusion zone, proper flooding protocols and erosion prevention measures should be implemented. This could include gabion mattresses and cut-off walls, gutters and drains, roadside curbs, reed beds or stilling basins at discharged areas, integrated into the engineering designs for the development. Sub-surface infrastructure (i.e. sewer lines, water pipes etc.) will be less susceptible to surface flood damage, and can highly likely be constructed in the demarked flood line areas. It should, however, be noted that soils on steeply sloped areas (> 1:4) should be compacted to prevent slope failure which could cause mass wasting and sub-surface infrastructure damage. These systems would need to be sized by a civil engineer, considering runoff patterns and stormwater flow velocities from the final engineering designs for the development.

If linear infrastructure is zoned to occur in the demarcated flood line areas, the structures are to be designed to such a degree by a professional engineer to:

1. Prevent environmental damage if a flood does occur;
2. Prevent slope failure on the water course banks;
3. Prevent increased flooding potential;
4. Withstand the flood peak flow forces and buoyancy forces;
5. Effectively convey flood water/stormwater for safe discharge to the environment; and
6. Have erosion control measures in place at any point of discharge into the environment (stilling basins, reed beds, energy damping blocks or mats, gabion mattresses etc).

9.2 Mitigation measures for inclusion in the EMPr

The following mitigation measures can be implemented as part of the EMPr to further reduce the risk of flooding on site and contribution to stormwater generation potential:

- Stormwater management should focus on the following, for each site, before the work takes place:
  - **Assess the site constraints and any site-specific concerns, including:**
    - Specific vegetation that may need to be identified and/or isolated from the site disturbance.
    - Highly erodible soils may require additional erosion control measures.

    - The type of construction should consider landform. Avoid slab-on-ground construction on steep sites.
    - Up-slope drainage catchments that may need to be diverted around the work site.
    - Workspace limitations may require site-specific sediment control measures and/or the extensive use of skips or bins for material storage and waste management.
    - Expected rainfall intensity during the period of disturbance (wet season vs dry season).

- **<u>Stabilise the site entry/exiting points:</u>**
    - A stabilised site access must be established and if possible, limited to one point only. The access allows for the construction vehicles to enter the work area of goods while preventing the unnecessary tracking of sediment onto the nearby environment from multiple locations. A stabilised entry/exit point normally consists of a stabilised rock pad.

- **<u>Prevent erosion & manage stockpiles:</u>**
    - Suitable material storage areas must be located up-slope of the main sediment barrier (e.g. sediment fence).
    - Stockpiles kept on site for more than two weeks will require an impervious cover (e.g. builder's plastic or geofabric) to protect against raindrop impact. Stockpiles of sandy material located behind a sediment fence will only need a protective cover if the stockpiles are likely to be exposed to strong winds.
    - On steep sites and sites with limited available space, erodible materials may need to be stored in commercial-sized bins or mini-skips before use.

- **<u>Manage Site Waste</u>**
    - Adequate waste receptacles must be provided on-site and maintained in a way that potential and actual environmental harm resulting from such material waste is minimised.
    - Building activities must be carried out on a pervious surface, such as grass or open soil, or in such a manner that all sediment-laden runoff is prevented from discharging into a water body.

  - Based on the above mentioned, it is recommended that work take place in dry months, and don't leave excavations open or the area unrehabilitated before a rainfall month occurs. If work does commence in wet seasons, it is advised that the measures in this document be considered, as well as any means to prevent erosion and sediment runoff (i.e. temporary sandbags, reed beds, re-vegetation, temporary stilling basins, temporary berms etc.).

- Ensure a stormwater management plan is implemented, and that all stormwater systems are kept clean of any debris to reduce flooding risk.
- Ensure that eroded areas are re-vegetated, to ensure reduced sedimentation risk and reduced runoff volumes to the streams.
- Have fuel/oil spill kits on-site, for immediate clean-up of any hydrocarbons during the proposed activities. Park vehicles in dedicated areas, with drip trays to manage potential leakages.
- Conduct regular inspections and maintenance of the site to ensure that vegetation cover is adequate, and no rivulets are generated.

9.3 Reasoned opinion on whether the activity should be authorized

Based on the risks identified, and assuming the mitigation measures proposed will be implemented, it is proposed that the construction of the co-disposal facility and the WTP and the authorization of these activities be considered. This is grounded on the assumption that the proposed mitigation measures (Section 7), EMPr and EIA recommendations are implemented during the construction, operational and closure phases of the project.

APPENDIX A: PEAK FLOW ESTIMATES

HRU1

RATIONAL METHOD 3							
Description of catchment		HRU1					
River detail	Unnamed Tributary						
Calculated by	Hendrik Botha				Date	Friday, 14 October 2022	
Physical characteristics							
Size of catchment (A)	1.549	km^2		Rainfall region		W5A	
Longest watercourse (L)	1.99	km		Area distribution factors			
Average slope (S_{av})	0.0056	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	768	mm					
Rural				URBAN			
Surface slope	%	Factor	C_s	Description	%	Factor	C2
Vleis and pans (<3%)	35.66	0.03	1.07	**Lawns**			
Flat areas (3 - 10%)	63.80	0.08	5.10	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	0.53	0.16	0.08	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	0.00	0.26	0.00	Heavy s,flat<2%	0	0.15	0
Total	99.99	0.53	6.26	Heavy s,steep>7%	0	0.3	0
Permeability	%	Factor	C_p	**Residential Areas**			
Very permeable	80	0.04	3.20	Houses	0	0.5	0
Permeable	20	0.08	1.60	Flats	0	0.6	0
Semi-permeable	0	0.16	0.00	Industry			
Impermeable	0	0.26	0.00	Light industry	0	0.6	0
Total	100	0.54	4.80	Heavy industry	0	0.7	0
Vegetation	%	Factor	C_v	**Business**			
Thick bush & plantation	18	0.04	0.72	City centre	0	0.8	0
Light bush & farm-lands	29	0.11	3.19	Suburban	0	0.65	0
Grasslands	51.5	0.21	10.82	Streets	0	0.75	0
No vegatation	1	0.25	0.25	Max flood	0	1	0
Total	99.5	0.61	14.98	Total (C2)	0		0
Time of concentration (TC)							
Overland flow	Defined watercourse						
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$			Use Defined watercourse			
1.822 hours	0.829	hours					
Run-off coefficient							
Return Period (years)	2	5	10	20	50	100	PMF
Run-off coefficient, C_1	0.260	0.260	0.260	0.260	0.260	0.260	0.900
Adjusted for dolomitic areas, C_{1D}	0.260	0.260	0.260	0.260	0.260	0.260	0.900
Adj factor for initial saturation, F_t	0.5	0.55	0.6	0.67	0.83	1	1.00
Adjusted run - off coefficient, C_{1T}	0.130168	0.1431848	0.1562016	0.174	0.216	0.260	0.900
Combined run - off coefficient, C_T	0.130168	0.1431848	0.1562016	0.174	0.216	0.260	0.900
Rainfall							
Return Period (years)	2	5	10	20	50	100	PMF
Point rainfall (mm), P_T	48.00	63.64	75.04	86.65	102.92	116.49	130.93
Point Intensity (mm/h), P_{it}	57.87	76.72	90.48	104.47	124.08	140.45	157.85
Area reduction factor (%),ARF_T	1.086	1.086	1.086	1.086	1.086	1.086	1.086
Average intensity (mm/hour),I_T	62.826	83.294	98.227	113.421	134.712	152.478	171.375
Return Period (years)	2	5	10	20	50	100	PMF
Peak flow (m3/s)	3.519	5.132	6.602	8.512	12.525	17.08	66.36

STANDARD DESIGN FLOOD (SDF) METHOD							
Description of catchment		HRU1					
River detail	Unnamed Tributary						
Calculated by	Hendrik Botha				Date	14/10/2022	
Physical characteristics							
Size of catchment (A)	1.549	km^2		Days of thunder per year (R)		54	days
Longest watercourse (L)	1.99	km		Time of concentration, t_c		49.766	minutes
Average slope (S_{av})	0.006	m/m		$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}}\right]^{0.385}$			
SDF Basin	28			Time of			
2-year return period rainfall (M)	75	mm		concentration, T_c			0.8294
TR102 n-day rainfall data							
Weather Service Station				MAP		768	mm
Weather Service Station no.				Coordinates			
Duration	**Return Period (years)**						
	2	5	10	20	50	100	200
Rainfall							
Return Period (years), T	2	5	10	20	50	100	200
Point precipitation depth (mm) $P_{t,T}$	31.5	53.1	69.4	85.8	107.4	123.7	140.1
Area reduction factor (%),ARF_T	1.086	1.086	1.086	1.086	1.086	1.086	1.086
Average intensity (mm/hour),I_T	41.2	69.5	90.8	112.2	140.5	161.9	183.3
Run-off coefficient							
Calibration factors C_2 (%)	15		C_{100} (%)		60		
Return Period (years), T	2	5	10	20	50	100	200
Return period factors (Y_T)	0	0.84	1.28	1.64	2.05	2.33	2.58
Run-off coefficient, C_T	0.150	0.312	0.397	0.467	0.546	0.600	0.648
Peak flow (m3/s)	2.66	9.33	15.53	22.54	33.01	41.80	51.13

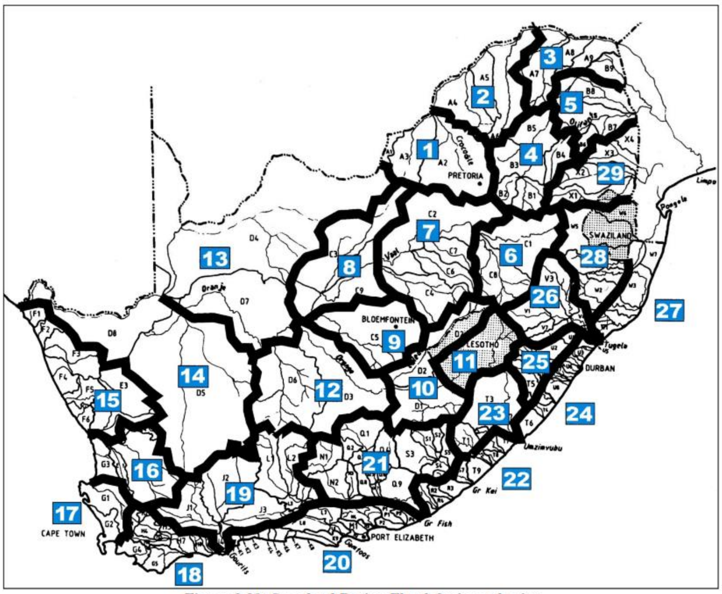
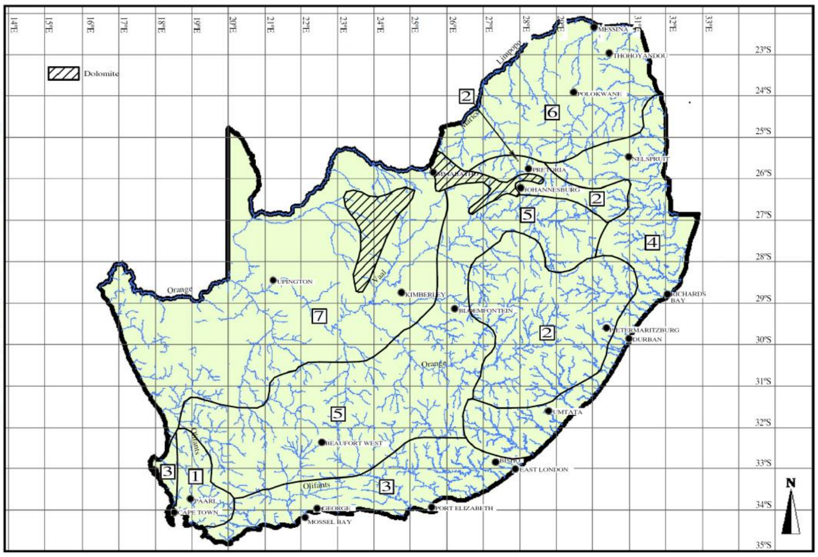


Figure 3.30: Standard Design Flood drainage basins

MIDGLEY & PITMAN (MIPI) METHOD															
River Detail	Catchment Area	MAP	S	L	Lc	Constant K_T				Catchment Parameter	Peak Flows				
	(km^2)	(mm)	m/m	km	km	1:10 year	1:20 Year	1: 50 year	1: 100 year	(Dimensionless)	1:10 year	1:20 Year	1: 50 year	1: 100 year
HRU1	1.549	768	0.0056	1.99	1.2	0.83	1.04	1.36	1.6	0.0485	17.06	21.38	27.96	32.89



HRU2

RATIONAL METHOD 3							
Description of catchment			HRU2				
River detail	Unnamed Tributary						
Calculated by	Hendrik Botha				Date	Friday, 14 October 2022	
Physical characteristics							
Size of catchment (A)	2.609	km^2		Rainfall region		W5A	
Longest watercourse (L)	1.08	km		Area distribution factors			
Average slope (S_{av})	0.0123	m/m		Rural (α)	Urban (Β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	768	mm					
Rural				URBAN			
Surface slope	%	Factor	C_s	Description	%	Factor	C2
Vleis and pans (<3%)	8.46	0.03	0.25	Lawns			
Flat areas (3 - 10%)	42.12	0.08	3.37	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	39.28	0.16	6.28	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	10.14	0.26	2.64	Heavy s,flat<2%	0	0.15	0
Total	100.00	0.53	12.54	Heavy s,steep>7%	0	0.3	0
Permeability	%	Factor	C_p	Residential Areas			
Very permeable	80	0.04	3.20	Houses	0	0.5	0
Permeable	20	0.08	1.60	Flats	0	0.6	0
Semi-permeable	0	0.16	0.00	Industry			
Impermeable	0	0.26	0.00	Light industry	0	0.6	0
Total	100	0.54	4.80	Heavy industry	0	0.7	0
Vegetation	%	Factor	C_v	Business			
Thick bush & plantation	11	0.04	0.44	City centre	0	0.8	0
Light bush & farm-lands	11	0.11	1.21	Suburban	0	0.65	0
Grasslands	61.3	0.21	12.87	Streets	0	0.75	0
No vegatation	17	0.25	4.25	Max flood	0	1	0
Total	100.3	0.61	18.77	Total (C2)	0		0

Time of concentration (TC)		
Overland flow	Defined watercourse	
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$	Use Defined watercourse
1.140 hours	0.383 hours	

Run-off coefficient							
Return Period (years)	2	5	10	20	50	100	PMF
Run-off coefficient, C_1	0.361	0.361	0.361	0.361	0.361	0.361	0.900
Adjusted for dolomitic areas, C_{1D}	0.361	0.361	0.361	0.361	0.361	0.361	0.900
Adj factor for initial saturation, F_t	0.5	0.55	0.6	0.67	0.83	1	1.00
Adjusted run - off coefficient, C_{1T}	0.180588	0.1986468	0.2167056	0.242	0.300	0.361	0.900
Combined run - off coefficient, C_T	0.180588	0.1986468	0.2167056	0.242	0.300	0.361	0.900

Rainfall							
Return Period (years)	2	5	10	20	50	100	PMF
Point rainfall (mm), P_T	41.14	54.57	64.33	74.30	88.23	99.87	112.25
Point Intensity (mm/h), P_{it}	107.50	142.60	168.11	194.14	230.55	260.98	293.32
Area reduction factor (%),ARF_T	1.033	1.033	1.033	1.033	1.033	1.033	1.033
Average intensity (mm/hour),I_T	111.076	147.341	173.704	200.606	238.222	269.671	303.085
Return Period (years)	2	5	10	20	50	100	PMF
Peak flow (m3/s)	14.537	21.212	27.280	35.181	51.755	70.59	197.69

STANDARD DESIGN FLOOD (SDF) METHOD							
Description of catchment	HRU2						
River detail	Unnamed Tributary						
Calculated by	Hendrik Botha			Date	14/10/2022		
Physical characteristics							
Size of catchment (A)	2.609	km^2		Days of thunder per year (R)		54	days
Longest watercourse (L)	1.08	km		Time of concentration, t		22.961	minutes
Average slope (S_{av})	0.012	m/m		$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}}\right]^{0.385}$			
SDF Basin	28			Time of concentration, T_c			
2-year return period rainfall (M)	75	mm					0.3827
TR102 n-day rainfall data							
Weather Service Station				MAP		768	mm
Weather Service Station no.				Coordinates			
Duration	Return Period (years)						
	2	5	10	20	50	100	200
Rainfall							
Return Period (years), T	2	5	10	20	50	100	200
Point precipitation depth (mm) $P_{t,T}$	24.5	41.3	54.1	66.8	83.6	96.4	109.1
Area reduction factor (%),ARF_T	1.033	1.033	1.033	1.033	1.033	1.033	1.033
Average intensity (mm/hour),I_T	66.2	111.6	146.0	180.4	225.8	260.2	294.6
Run-off coefficient							
Calibration factors C_2 (%)	15		C_{100} (%)	60			
Return Period (years), T	2	5	10	20	50	100	200
Return period factors (Y_T)	0	0.84	1.28	1.64	2.05	2.33	2.58
Run-off coefficient, C_T	0.150	0.312	0.397	0.467	0.546	0.600	0.648
Peak flow (m3/s)	7.19	25.25	42.02	61.01	89.34	113.14	138.40

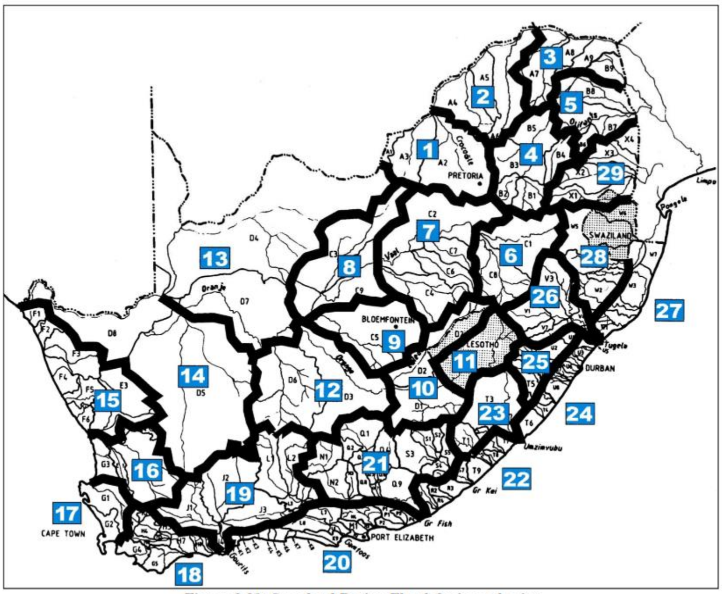


Figure 3.30: Standard Design Flood drainage basins

MIDGLEY & PITMAN (MIPI) METHOD															
River Detail	Catchment Area	MAP	S	L	Lc	Constant K_T				Catchment Parameter	Peak Flows			
	(km^2)	(mm)	m/m	km	km	1:10 year	1:20 Year	1: 50 year	1: 100 year	(Dimensionless)	1:10 year	1:20 Year	1: 50 year	1: 100 year
HRU2	2.609	768	0.0123	1.08	1.01	0.83	1.04	1.36	1.6	0.2653	32.76	41.05	53.69	63.16

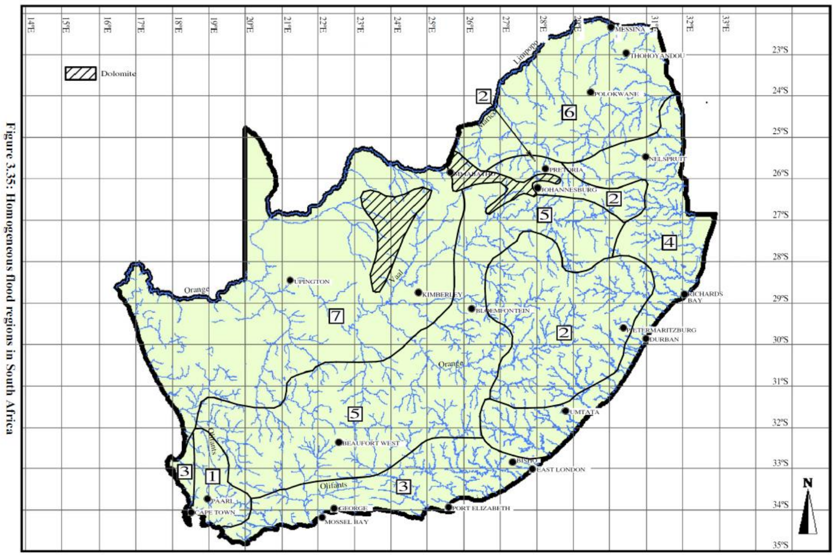


Figure 3.35: Homogeneous flood regions in South Africa

HRU3

RATIONAL METHOD 3							
Description of catchment		HRU3					
River detail	Unnamed Tributary						
Calculated by	Hendrik Botha			Date	Friday, 14 October 2022		
Physical characteristics							
Size of catchment (A)	1.89	km^2		Rainfall region		W5A	
Longest watercourse (L)	1.148	km		**Area distribution factors**			
Average slope (S_{av})	0.0308	m/m		Rural (α)	Urban (B)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	768	mm					
Rural				**URBAN**			
Surface slope	%	**Factor**	C_s	**Description**	%	**Factor**	C2
Vleis and pans (<3%)	8.46	0.03	0.25	**Lawns**			
Flat areas (3 - 10%)	42.12	0.08	3.37	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	39.28	0.16	6.28	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	10.14	0.26	2.64	Heavy s,flat<2%	0	0.15	0
Total	100.00	0.53	12.54	Heavy s,steep>7%	0	0.3	0
Permeability	%	**Factor**	C_p	**Residential Areas**			
Very permeable	80	0.04	3.20	Houses	0	0.5	0
Permeable	20	0.08	1.60	Flats	0	0.6	0
Semi-permeable	0	0.16	0.00	Industry			
Impermeable	0	0.26	0.00	Light industry	0	0.6	0
Total	100	0.54	4.80	Heavy industry	0	0.7	0
Vegetation	%	**Factor**	C_v	**Business**			
Thick bush & plantation	8	0.04	0.32	City centre	0	0.8	0
Light bush & farm-lands	4	0.11	0.44	Suburban	0	0.65	0
Grasslands	77.4	0.21	16.25	Streets	0	0.75	0
No vegatation	10	0.25	2.50	Max flood	0	1	0
Total	99.4	0.61	19.51	Total (C2)	0		0
Time of concentration (TC)							
Overland flow	Defined watercourse						
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$			Use Defined watercourse			
0.946 hours	0.282	hours					
Run-off coefficient							
Return Period (years)	2	5	10	20	50	100	PMF
Run-off coefficient, C_1	0.369	0.369	0.369	0.369	0.369	0.369	0.900
Adjusted for dolomitic areas, C_{1D}	0.369	0.369	0.369	0.369	0.369	0.369	0.900
Adj factor for initial saturation, F_t	0.5	0.55	0.6	0.67	0.83	1	1.00
Adjusted run - off coefficient, C_{1T}	0.184293	0.2027223	0.2211516	0.247	0.306	0.369	0.900
Combined run - off coefficient, C_T	0.184293	0.2027223	0.2211516	0.247	0.306	0.369	0.900
Rainfall							
Return Period (years)	2	5	10	20	50	100	PMF
Point rainfall (mm), P_T	38.85	51.49	60.72	70.13	83.27	94.26	105.95
Point Intensity (mm/h), P_{it}	137.92	182.80	215.56	248.96	295.62	334.62	376.10
Area reduction factor (%),ARF_T	1.038	1.038	1.038	1.038	1.038	1.038	1.038
Average intensity (mm/hour),I_T	143.093	189.659	223.650	258.299	306.707	347.169	390.210
Return Period (years)	2	5	10	20	50	100	PMF
Peak flow (m3/s)	13.845	20.185	25.967	33.488	49.261	67.18	184.37

STANDARD DESIGN FLOOD (SDF) METHOD							
Description of catchment	HRU3						
River detail	Unnamed Tributary						
Calculated by	Hendrik Botha			Date	14/10/2022		
Physical characteristics							
Size of catchment (A)	1.89	km^2		Days of thunder per year (R)	54	days	
Longest watercourse (L)	1.148	km		Time of concentration, t_c	16.902	minutes	
Average slope (S_{av})	0.031	m/m		$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}}\right]^{0.385}$			
SDF Basin	28			Time of concentration, T_c		0.2817	
2-year return period rainfall (M)	75	mm					
TR102 n-day rainfall data							
Weather Service Station				MAP	768	mm	
Weather Service Station no.				Coordinates			
Duration	Return Period (years)						
	2	5	10	20	50	100	200
Rainfall							
Return Period (years), T	2	5	10	20	50	100	200
Point precipitation depth (mm) $P_{t,T}$	21.7	36.7	48.0	59.3	74.2	85.5	96.8
Area reduction factor (%), ARF_T	1.038	1.038	1.038	1.038	1.038	1.038	1.038
Average intensity (mm/hour), I_T	80.1	135.1	176.8	218.4	273.4	315.0	356.7
Run-off coefficient							
Calibration factors C_2 (%)	15		C_{100} (%)	60			
Return Period (years), T	2	5	10	20	50	100	200
Return period factors (Y_T)	0	0.84	1.28	1.64	2.05	2.33	2.58
Run-off coefficient, C_T	0.150	0.312	0.397	0.467	0.546	0.600	0.648
Peak flow (m3/s)	6.31	22.15	36.86	53.51	78.36	99.24	121.39

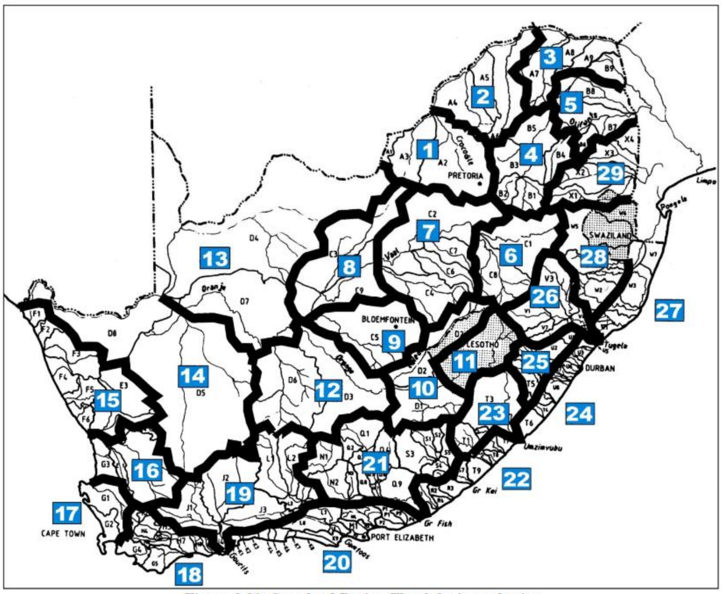
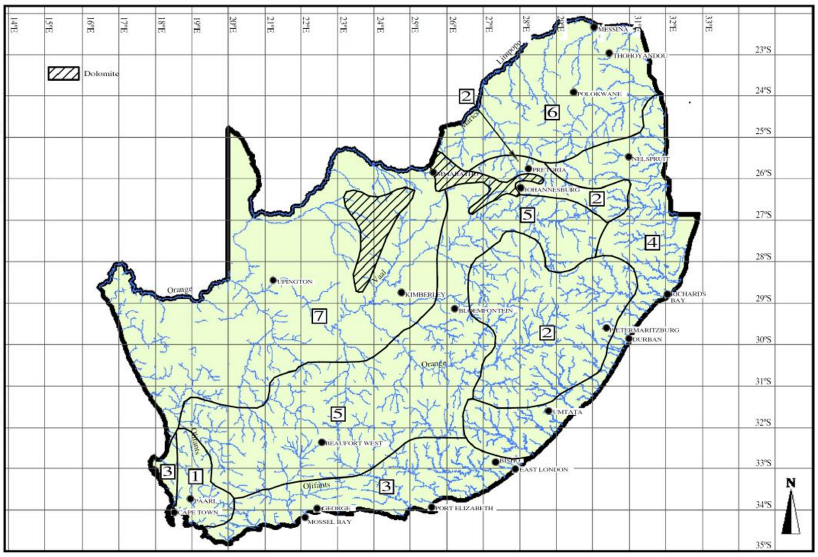


Figure 3.30: Standard Design Flood drainage basins

MIDGLEY & PITMAN (MIPI) METHOD														
River Detail	Catchment Area	MAP	S	L	Lc	Constant K_T				Catchment Parameter	Peak Flows			
	(km^2)	(mm)	m/m	km	km	1:10 year	1:20 Year	1: 50 year	1: 100 year	(Dimensionless)	1:10 year	1:20 Year	1: 50 year	1: 100 year
HRU3	1.89	768	0.0308	1.15	1.47	0.83	1.04	1.36	1.6	0.1966	25.43	31.86	41.67	49.02

Figure 3.35: Homogeneous flood regions in South Africa



HRU4

RATIONAL METHOD 3							
Description of catchment		HRU4					
River detail	Unnamed Tributary						
Calculated by	Hendrik Botha				Date	Friday, 14 October 2022	
Physical characteristics							
Size of catchment (A)	1.84	km^2		Rainfall region		W5A	
Longest watercourse (L)	1.18	km		Area distribution factors			
Average slope (S_{av})	0.0201	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	768	mm					
Rural				URBAN			
Surface slope	%	Factor	C_s	Description	%	Factor	C2
Vleis and pans (<3%)	12.24	0.03	0.37	Lawns			
Flat areas (3 - 10%)	72.04	0.08	5.76	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	14.94	0.16	2.39	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	0.78	0.26	0.20	Heavy s,flat<2%	0	0.15	0
Total	100.00	0.53	8.72	Heavy s,steep>7%	0	0.3	0
Permeability	%	Factor	C_p	Residential Areas			
Very permeable	80	0.04	3.20	Houses	0	0.5	0
Permeable	20	0.08	1.60	Flats	0	0.6	0
Semi-permeable	0	0.16	0.00	Industry			
Impermeable	0	0.26	0.00	Light industry	0	0.6	0
Total	100	0.54	4.80	Heavy industry	0	0.7	0
Vegetation	%	Factor	C_v	Business			
Thick bush & plantation	17	0.04	0.68	City centre	0	0.8	0
Light bush & farm-lands	4	0.11	0.44	Suburban	0	0.65	0
Grasslands	75.6	0.21	15.88	Streets	0	0.75	0
No vegatation	3	0.25	0.75	Max flood	0	1	0
Total	99.6	0.61	17.75	Total (C2)	0		0
Time of concentration (TC)							
Overland flow	Defined watercourse						
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}}\right]^{0.385}$			Use Defined watercourse			
1.059 hours	0.339	hours					
Run-off coefficient							
Return Period (years)	2	5	10	20	50	100	PMF
Run-off coefficient, C_1	0.313	0.313	0.313	0.313	0.313	0.313	0.900
Adjusted for dolomitic areas, C_{1D}	0.313	0.313	0.313	0.313	0.313	0.313	0.900
Adj factor for initial saturation, F_t	0.5	0.55	0.6	0.67	0.83	1	1.00
Adjusted run - off coefficient, C_{1T}	0.156348	0.1719828	0.1876176	0.210	0.260	0.313	0.900
Combined run - off coefficient, C_T	0.156348	0.1719828	0.1876176	0.210	0.260	0.313	0.900
Rainfall							
Return Period (years)	2	5	10	20	50	100	PMF
Point rainfall (mm), P_T	40.25	53.38	62.93	72.68	86.31	97.70	109.80
Point Intensity (mm/h), P_{it}	118.70	157.40	185.58	214.34	254.52	288.11	323.79
Area reduction factor (%),ARF_T	1.046	1.046	1.046	1.046	1.046	1.046	1.046
Average intensity (mm/hour),I_T	124.119	164.591	194.052	224.129	266.143	301.264	338.579
Return Period (years)	2	5	10	20	50	100	PMF
Peak flow (m3/s)	9.919	14.468	18.608	24.000	35.305	48.15	155.75

STANDARD DESIGN FLOOD (SDF) METHOD							
Description of catchment		HRU4					
River detail	Unnamed Tributary						
Calculated by	Hendrik Botha			Date		14/10/2022	
Physical characteristics							
Size of catchment (A)	1.84	km^2		Days of thunder per year (R)		54	days
Longest watercourse (L)	1.18	km		Time of concentration, t_c		20.346	minutes
Average slope (S_{av})	0.020	m/m		$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}} \right]^{0.385}$			
SDF Basin	28			Time of concentration, T_c			0.3391
2-year return period rainfall (M)	75	mm					
TR102 n-day rainfall data							
Weather Service Station				MAP		768	mm
Weather Service Station no.				Coordinates			
Duration	Return Period (years)						
	2	5	10	20	50	100	200
Rainfall							
Return Period (years), T	2	5	10	20	50	100	200
Point precipitation depth (mm) $P_{t,T}$	23.4	39.5	51.7	63.8	79.9	92.1	104.3
Area reduction factor (%),ARF_T	1.046	1.046	1.046	1.046	1.046	1.046	1.046
Average intensity (mm/hour),I_T	72.2	121.8	159.3	196.9	246.5	284.0	321.5
Run-off coefficient							
Calibration factors C_2 (%)	15		C_{100} (%)		60		
Return Period (years), T	2	5	10	20	50	100	200
Return period factors (Y_T)	0	0.84	1.28	1.64	2.05	2.33	2.58
Run-off coefficient, C_T	0.150	0.312	0.397	0.467	0.546	0.600	0.648
Peak flow (m3/s)	5.54	19.44	32.35	46.96	68.77	87.09	106.53

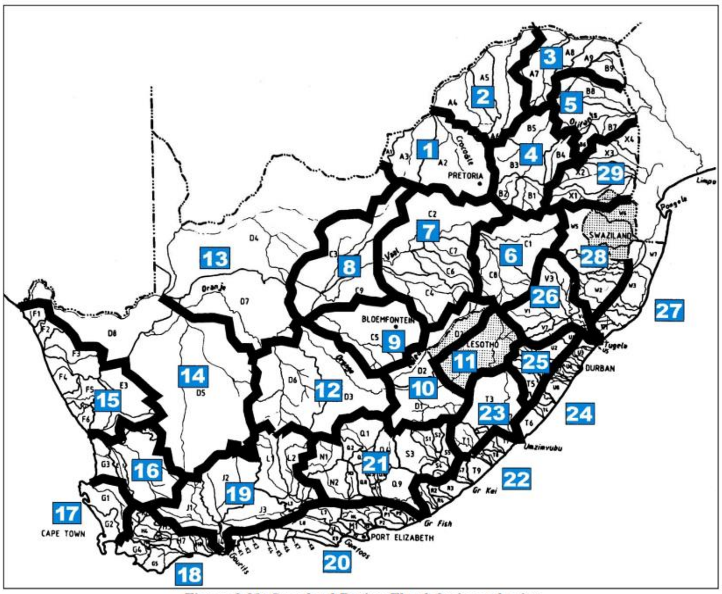
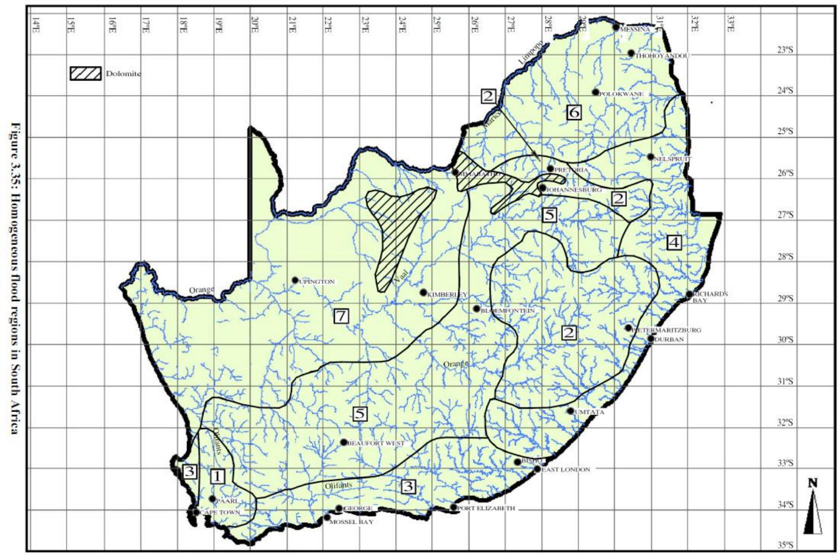


Figure 3.30: Standard Design Flood drainage basins

MIDGLEY & PITMAN (MIPI) METHOD															
River Detail	Catchment Area	MAP	S	L	Lc	Constant K_T				Catchment Parameter	Peak Flows			
	(km^2)	(mm)	m/m	km	km	1:10 year	1:20 Year	1: 50 year	1: 100 year	(Dimensionless)	1:10 year	1:20 Year	1: 50 year	1: 100 year
HRU4	1.84	768	0.0201	1.18	1.14	0.83	1.04	1.36	1.6	0.1939	24.96	31.27	40.89	48.11



HRU5

RATIONAL METHOD 3							
Description of catchment		HRU5					
River detail	Unnamed Tributary						
Calculated by	Hendrik Botha			Date	Friday, 14 October 2022		
Physical characteristics							
Size of catchment (A)	1.24	km^2		Rainfall region		W5A	
Longest watercourse (L)	0.57	km		**Area distribution factors**			
Average slope (S_{av})	0.0914	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	768	mm					
Rural				**URBAN**			
Surface slope	%	**Factor**	C_s	**Description**	%	**Factor**	**C2**
Vleis and pans (<3%)	4.19	0.03	0.13	**Lawns**			
Flat areas (3 - 10%)	66.11	0.08	5.29	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	29.70	0.16	4.75	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	0.00	0.26	0.00	Heavy s,flat<2%	0	0.15	0
Total	100.00	0.53	10.17	Heavy s,steep>7%	0	0.3	0
Permeability	%	**Factor**	C_p	**Residential Areas**			
Very permeable	80	0.04	3.20	Houses	0	0.5	0
Permeable	20	0.08	1.60	Flats	0	0.6	0
Semi-permeable	0	0.16	0.00	Industry			
Impermeable	0	0.26	0.00	Light industry	0	0.6	0
Total	100	0.54	4.80	Heavy industry	0	0.7	0
Vegetation	%	**Factor**	C_v	**Business**			
Thick bush & plantation	2	0.04	0.08	City centre	0	0.8	0
Light bush & farm-lands	16	0.11	1.76	Suburban	0	0.65	0
Grasslands	75	0.21	15.75	Streets	0	0.75	0
No vegatation	7	0.25	1.75	Max flood	0	1	0
Total	100	0.61	19.34	Total (C2)	0		0
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$			Use Defined watercourse			
0.529 hours	0.108	hours					
Run-off coefficient							
Return Period (years)	2	5	10	20	50	100	PMF
Run-off coefficient, C_1	0.343	0.343	0.343	0.343	0.343	0.343	0.900
Adjusted for dolomitic areas, C_{1D}	0.343	0.343	0.343	0.343	0.343	0.343	0.900
Adj factor for initial saturation, F_t	0.5	0.55	0.6	0.67	0.83	1	1.00
Adjusted run - off coefficient, C_{1T}	0.1715325	0.18868575	0.205839	0.230	0.285	0.343	0.900
Combined run - off coefficient, C_T	0.1715325	0.18868575	0.205839	0.230	0.285	0.343	0.900
Rainfall							
Return Period (years)	2	5	10	20	50	100	PMF
Point rainfall (mm), P_T	32.13	42.59	50.31	58.04	68.92	77.97	87.72
Point Intensity (mm/h), P_{it}	297.26	394.08	465.48	536.99	637.62	721.38	811.61
Area reduction factor (%),ARF_T	1.022	1.022	1.022	1.022	1.022	1.022	1.022
Average intensity (mm/hour),I_T	303.836	402.797	475.779	548.874	651.728	737.339	829.568
Return Period (years)	2	5	10	20	50	100	PMF
Peak flow (m3/s)	17.952	26.178	33.733	43.455	63.921	87.13	257.17

MIDGLEY & PITMAN (MIPI) METHOD														
River Detail	Catchment Area	MAP	S	L	Lc	Constant K_T				Catchment Parameter	Peak Flows			
	(km^2)	(mm)	m/m	km	km	1:10 year	1:20 Year	1: 50 year	1: 100 year	(Dimensionless)	1:10 year	1:20 Year	1: 50 year	1: 100 year
HRU5	1.24	768	0.0914	0.57	0.53	0.83	1.04	1.36	1.6	1.2409	28.55	35.77	46.78	55.03

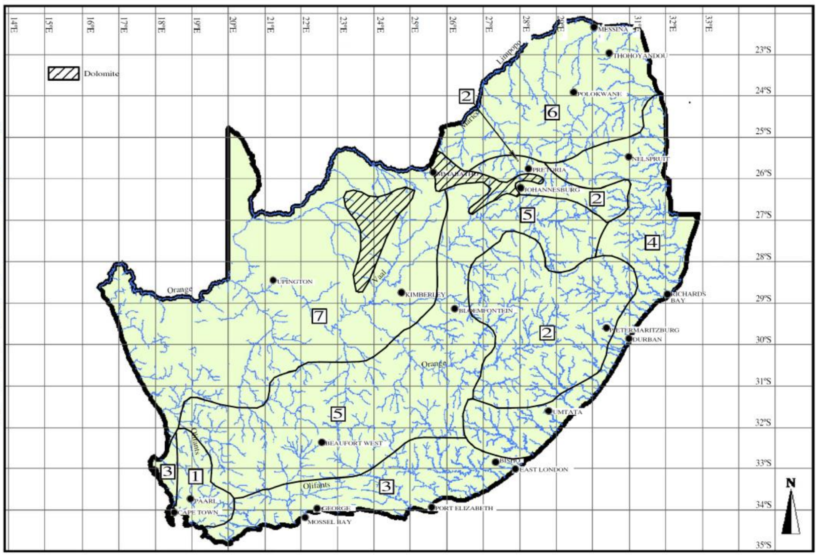


Figure 3.35: Homogeneous flood regions in South Africa

STANDARD DESIGN FLOOD (SDF) METHOD							
Description of catchment		HRU5					
River detail	Unnamed Tributary						
Calculated by	Hendrik Botha				Date	14/10/2022	
Physical characteristics							
Size of catchment (A)	1.24	km^2		Days of thunder per year (R)		54	days
Longest watercourse (L)	0.57	km		Time of concentration, t_c		6.485	minutes
Average slope (S_{av})	0.091	m/m		Time of concentration, T_c: $T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$			
SDF Basin	28						
2-year return period rainfall (M)	75	mm					0.1081
TR102 n-day rainfall data							
Weather Service Station				MAP		768	mm
Weather Service Station no.				Coordinates			
Duration	**Return Period (years)**						
	2	**5**	**10**	**20**	**50**	**100**	**200**
Rainfall							
Return Period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**200**
Point precipitation depth (mm) $P_{t,T}$	13.1	22.2	29.0	35.8	44.9	51.7	58.5
Area reduction factor (%),ARF_T	1.022	1.022	1.022	1.022	1.022	1.022	1.022
Average intensity (mm/hour),I_T	124.3	209.6	274.2	338.8	424.1	488.7	553.3
Run-off coefficient							
Calibration factors — C_2 (%)	15		C_{100} (%)	60			
Return Period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**200**
Return period factors (Y_T)	0	0.84	1.28	1.64	2.05	2.33	2.58
Run-off coefficient, C_T	0.150	0.312	0.397	0.467	0.546	0.600	0.648
Peak flow (m3/s)	6.42	22.54	37.51	54.46	79.75	101.00	123.55

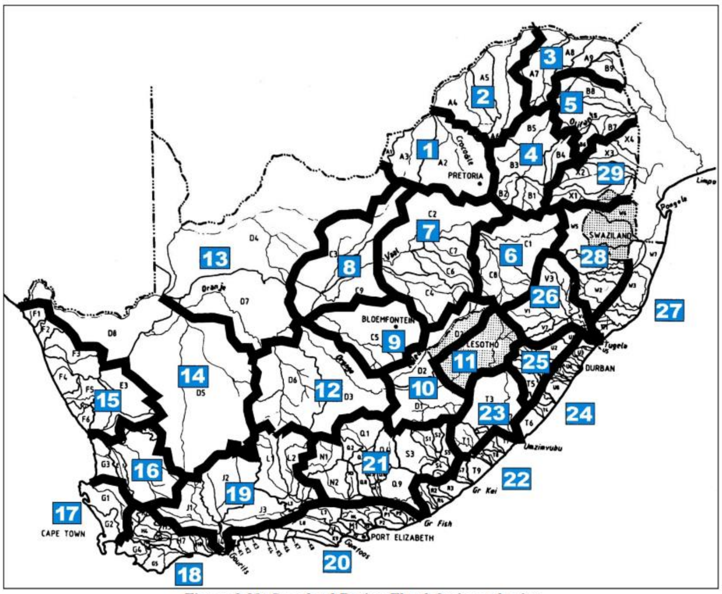


Figure 3.30: Standard Design Flood drainage basins

HRU6

RATIONAL METHOD 3							
Description of catchment		HRU6					
River detail	Unnamed Tributary						
Calculated by	Hendrik Botha			Date	Friday, 14 October 2022		
Physical characteristics							
Size of catchment (A)	1.36	km^2		Rainfall region		W5A	
Longest watercourse (L)	1.33	km		**Area distribution factors**			
Average slope (S_{av})	0.0170	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	768	mm					
Rural				**URBAN**			
Surface slope	%	Factor	C_s	Description	%	Factor	C2
Vleis and pans (<3%)	26.40	0.03	0.79	**Lawns**			
Flat areas (3 - 10%)	73.10	0.08	5.85	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	0.50	0.16	0.08	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	0.00	0.26	0.00	Heavy s,flat<2%	0	0.15	0
Total	100.00	0.53	6.72	Heavy s,steep>7%	0	0.3	0
Permeability	%	Factor	C_p	**Residential Areas**			
Very permeable	80	0.04	3.20	Houses	0	0.5	0
Permeable	20	0.08	1.60	Flats	0	0.6	0
Semi-permeable	0	0.16	0.00	Industry			
Impermeable	0	0.26	0.00	Light industry	0	0.6	0
Total	100	0.54	4.80	Heavy industry	0	0.7	0
Vegetation	%	Factor	C_v	**Business**			
Thick bush & plantation	12	0.04	0.48	City centre	0	0.8	0
Light bush & farm-lands	2	0.11	0.22	Suburban	0	0.65	0
Grasslands	63.1	0.21	13.25	Streets	0	0.75	0
No vegatation	23	0.25	5.75	Max flood	0	1	0
Total	100.1	0.61	19.70	Total (C2)	0		0

Time of concentration (TC)

Overland flow	Defined watercourse	
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$	Use Defined watercourse
1.165 hours	0.397 hours	

Run-off coefficient							
Return Period (years)	2	5	10	20	50	100	PMF
Run-off coefficient, C_1	0.312	0.312	0.312	0.312	0.312	0.312	0.900
Adjusted for dolomitic areas, C_{1D}	0.312	0.312	0.312	0.312	0.312	0.312	0.900
Adj factor for initial saturation, F_t	0.5	0.55	0.6	0.67	0.83	1	1.00
Adjusted run - off coefficient, C_{1T}	0.156105	0.1717155	0.187326	0.209	0.259	0.312	0.900
Combined run - off coefficient, C_T	0.156105	0.1717155	0.187326	0.209	0.259	0.312	0.900

Rainfall							
Return Period (years)	2	5	10	20	50	100	PMF
Point rainfall (mm), P_T	41.41	54.94	64.77	74.79	88.82	100.55	113.01
Point Intensity (mm/h), P_{it}	104.42	138.52	163.30	188.59	223.95	253.52	284.94
Area reduction factor (%),ARF_T	1.066	1.066	1.066	1.066	1.066	1.066	1.066
Average intensity (mm/hour),I_T	111.268	147.611	174.018	200.962	238.648	270.157	303.636
Return Period (years)	2	5	10	20	50	100	PMF
Peak flow (m3/s)	6.562	9.576	12.315	15.881	23.363	31.86	103.24

STANDARD DESIGN FLOOD (SDF) METHOD							
Description of catchment		HRU6					
River detail	Unnamed Tributary						
Calculated by	Hendrik Botha				Date	14/10/2022	
Physical characteristics							
Size of catchment (A)	1.36	km^2		Days of thunder per year (R)		54	days
Longest watercourse (L)	1.33	km		Time of concentration, t_c		23.796	minutes
Average slope (S_{av})	0.017	m/m		Time of concentration, T_c	$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}}\right]^{0.385}$		
SDF Basin	28						
2-year return period rainfall (M)	75	mm					0.3966
TR102 n-day rainfall data							
Weather Service Station				MAP		768	mm
Weather Service Station no.				Coordinates			
Duration	Return Period (years)						
	2	5	10	20	50	100	200
Rainfall							
Return Period (years), T	2	5	10	20	50	100	200
Point precipitation depth (mm) $P_{t,T}$	24.8	41.9	54.8	67.7	84.7	97.6	110.5
Area reduction factor (%),ARF_T	1.066	1.066	1.066	1.066	1.066	1.066	1.066
Average intensity (mm/hour),I_T	66.7	112.5	147.2	181.8	227.7	262.3	297.0
Run-off coefficient							
Calibration factors C_2 (%)	15		C_{100} (%)		60		
Return Period (years), T	2	5	10	20	50	100	200
Return period factors (Y_T)	0	0.84	1.28	1.64	2.05	2.33	2.58
Run-off coefficient, C_T	0.150	0.312	0.397	0.467	0.546	0.600	0.648
Peak flow (m3/s)	3.78	13.27	22.08	32.06	46.95	59.46	72.73

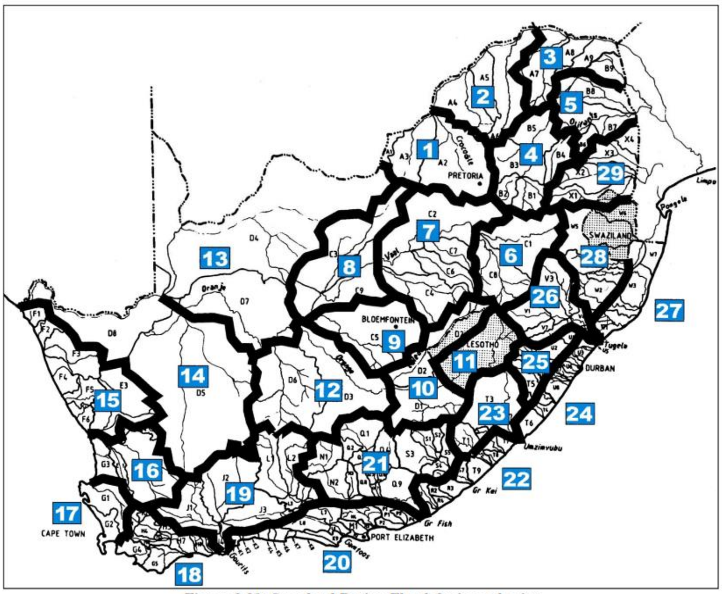


Figure 3.30: Standard Design Flood drainage basins

MIDGLEY & PITMAN (MIPI) METHOD														
River Detail	Catchment Area	MAP	S	L	Lc	Constant K_T				Catchment Parameter	Peak Flows			
	(km^2)	(mm)	m/m	km	km	1:10 year	1:20 Year	1: 50 year	1: 100 year	(Dimensionless)	1:10 year	1:20 Year	1: 50 year	1: 100 year
HRU6	1.36	768	0.0170	1.33	1.65	0.83	1.04	1.36	1.6	0.0808	17.47	21.89	28.63	33.68

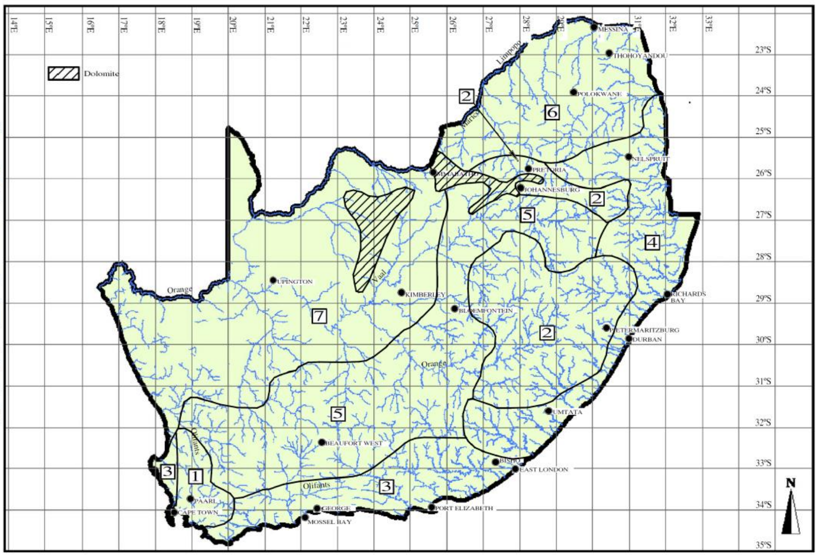


Figure 3.35: Homogeneous flood regions in South Africa

HRU7

RATIONAL METHOD 3							
Description of catchment		HRU7					
River detail	Unnamed Tributary						
Calculated by	Hendrik Botha			Date	Friday, 14 October 2022		
Physical characteristics							
Size of catchment (A)	9.92	km^2		Rainfall region		W5A	
Longest watercourse (L)	7.26	km		Area distribution factors			
Average slope (S_{av})	0.0430	m/m		Rural (α)	Urban (B)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	768	mm					
Rural				URBAN			
Surface slope	%	Factor	C_s	Description	%	Factor	C2
Vleis and pans (<3%)	20.00	0.03	0.60	Lawns			
Flat areas (3 - 10%)	10.00	0.08	0.80	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	20.00	0.16	3.20	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	50.00	0.26	13.00	Heavy s,flat<2%	0	0.15	0
Total	100.00	0.53	17.60	Heavy s,steep>7%	0	0.3	0
Permeability	%	Factor	C_p	Residential Areas			
Very permeable	80	0.04	3.20	Houses	0	0.5	0
Permeable	20	0.08	1.60	Flats	0	0.6	0
Semi-permeable	0	0.16	0.00	Industry			
Impermeable	0	0.26	0.00	Light industry	0	0.6	0
Total	100	0.54	4.80	Heavy industry	0	0.7	0
Vegetation	%	Factor	C_v	Business			
Thick bush & plantation	5.91	0.04	0.24	City centre	0	0.8	0
Light bush & farm-lands	2.6	0.11	0.29	Suburban	0	0.65	0
Grasslands	89.4	0.21	18.77	Streets	0	0.75	0
No vegatation	2.08	0.25	0.52	Max flood	0	1	0
Total	99.99	0.61	19.82	Total (C2)	0		0
Time of concentration (TC)							
Overland flow	Defined watercourse						
$T_C = 0.604 \left(\frac{rL}{\sqrt{S_{av}}} \right)^{0.467}$	$T_c = \left[\frac{0.87\, L^2}{1000\, S_{AV}} \right]^{0.385}$			Use Defined watercourse			
2.072 hours	1.025	hours					
Run-off coefficient							
Return Period (years)	2	5	10	20	50	100	PMF
Run-off coefficient, C_1	0.422	0.422	0.422	0.422	0.422	0.422	0.900
Adjusted for dolomitic areas, C_{1D}	0.422	0.422	0.422	0.422	0.422	0.422	0.900
Adj factor for initial saturation, F_t	0.5	0.55	0.6	0.67	0.83	1	1.00
Adjusted run - off coefficient, C_{1T}	0.211082	0.2321902	0.2532984	0.283	0.350	0.422	0.900
Combined run - off coefficient, C_T	0.211082	0.2321902	0.2532984	0.283	0.350	0.422	0.900
Rainfall							
Return Period (years)	2	5	10	20	50	100	PMF
Point rainfall (mm), P_T	49.90	66.11	77.98	90.05	106.95	121.04	136.03
Point Intensity (mm/h), P_{it}	48.68	64.49	76.07	87.85	104.34	118.08	132.71
Area reduction factor (%),ARF_T	1.004	1.004	1.004	1.004	1.004	1.004	1.004
Average intensity (mm/hour),I_T	48.899	64.777	76.410	88.240	104.804	118.607	133.299
Return Period (years)	2	5	10	20	50	100	PMF
Peak flow (m3/s)	28.442	41.445	53.333	68.775	101.192	137.98	330.58

STANDARD DESIGN FLOOD (SDF) METHOD

Description of catchment	HRU7				
River detail	Unnamed Tributary				
Calculated by	Hendrik Botha		Date	14/10/2022	
Physical characteristics					
Size of catchment (A)	9.92	km^2	Days of thunder per year (R)	54	days
Longest watercourse (L)	7.26	km	Time of concentration, t_c	61.504	minutes
Average slope (S_{av})	0.043	m/m	Time of concentration, T_c	$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}}\right]^{0.385}$	1.0251
SDF Basin	28				
2-year return period rainfall (M)	75	mm			

TR102 n-day rainfall data

Weather Service Station				MAP		768	mm
Weather Service Station no.				Coordinates			
Duration	Return Period (years)						
	2	5	10	20	50	100	200
Rainfall							
Return Period (years), T	2	5	10	20	50	100	200
Point precipitation depth (mm) $P_{t,T}$	33.4	56.3	73.6	90.9	113.9	131.2	148.5
Area reduction factor (%), ARF_T	1.004	1.004	1.004	1.004	1.004	1.004	1.004
Average intensity (mm/hour), I_T	32.7	55.1	72.1	89.1	111.6	128.6	145.5
Run-off coefficient							
Calibration factors — C_2 (%)	15		C_{100} (%)		60		
Return Period (years), T	2	5	10	20	50	100	200
Return period factors (Y_T)	0	0.84	1.28	1.64	2.05	2.33	2.58
Run-off coefficient, C_T	0.150	0.312	0.397	0.467	0.546	0.600	0.648
Peak flow (m3/s)	13.51	47.44	78.95	114.61	167.83	212.54	259.99

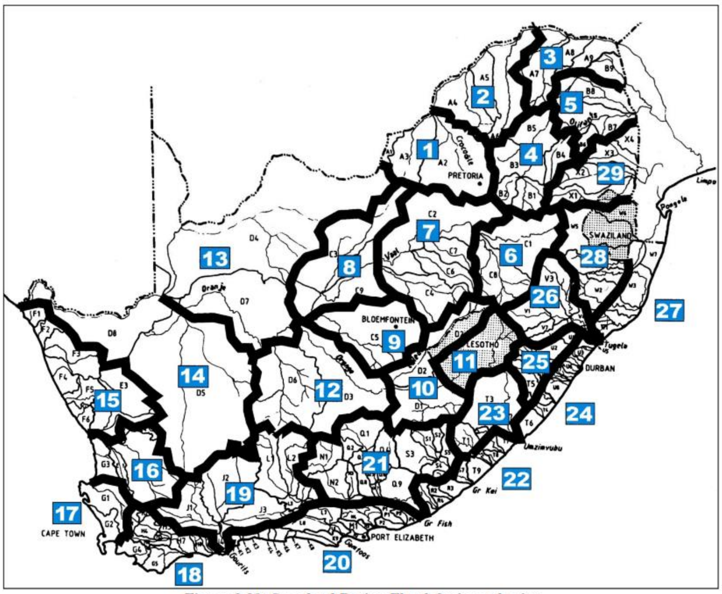


Figure 3.30: Standard Design Flood drainage basins

MIDGLEY & PITMAN (MIPI) METHOD														
River Detail	Catchment Area	MAP	S	L	Lc	Constant K_T				Catchment Parameter	Peak Flows			
	(km^2)	(mm)	m/m	km	km	1:10 year	1:20 Year	1: 50 year	1: 100 year	(Dimensionless)	1:10 year	1:20 Year	1: 50 year	1: 100 year
HRU7	9.92	768	0.0430	7.26	3.5	0.83	1.04	1.36	1.6	0.0810	57.59	72.16	94.36	111.01

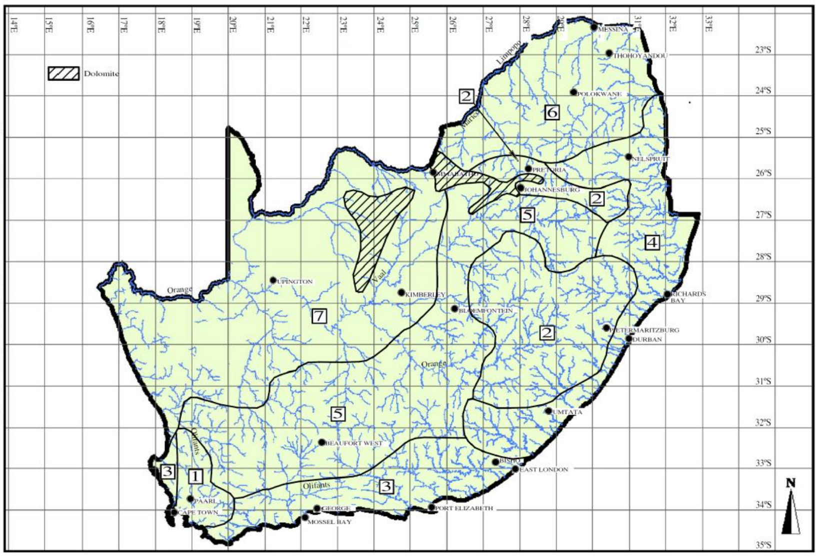


Figure 3.35: Homogeneous flood regions in South Africa

APPENDIX B: WATER QUALITY CERTIFICATES

APPENDIX C: DISCLAIMER AND DECELERATION OF INDEPENDENCE

The opinions expressed in this Report have been based on site /project information supplied to GCS (Pty) Ltd by Kangra Coal (Pty) and are based on public domain data, field data and data supplied to GCS by the client. GCS has acted and undertaken this assessment objectively and independently.

GCS has exercised all due care in reviewing the supplied information. Whilst GCS 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. GCS 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 GCS's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this report, about which GCS had no prior knowledge nor had the opportunity to evaluate.

DETAILS OF THE SPECIALIST, DECLARATION OF INTEREST AND UNDERTAKING UNDER OATH

Application for authorisation in terms of the National Environmental Management Act, Act No. 107 of 1998, as amended and the Environmental Impact Assessment (EIA) Regulations, 2014, as amended (the Regulations)

PROJECT TITLE

Hydrology Assessment for the Proposed Co-Disposal Facility & Water Treatment Plant at Kangra Maquasa East Operations

SPECIALIST INFORMATION

Specialist Company Name:	GCS Environmental SA			
B-BBEE	Contribution level (indicate 1 to 8 or non-compliant)	2	Percentage Procurement Recognition	
Specialist name:	Hendrik Botha			
Specialist Qualifications:	MSc Environmental Sciences (Geohydrology & Geochemistry) BSc Hons. Environmental Sciences (Hydrology) BSc. Geology and Chemistry			
Professional affiliation/registration:	PR SCI NAT 400139/17			
Physical address:	1 Karbochem Road, Newcastle, KZN			
Postal address:				
Postal code:	2940	Cell:		
Telephone:	071 102 3819	Fax:		
E-mail:	hendrikb@gcs-sa.biz			

DECLARATION BY THE SPECIALIST

I, _Hendrik Botha, declare that –

- I act as the independent specialist in this application.
- I will perform the work relating to the application objectively, even if this results in views and findings that are not favourable to the applicant.
- I declare that there are no circumstances that may compromise my objectivity in performing such work.
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity.
- I will comply with the Act, Regulations and all other applicable legislation.
- I have no, and will not engage in, conflicting interests in the undertaking of the activity.
- I undertake to disclose to the applicant 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 concerning the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority.
- all the particulars furnished by me in this form are true and correct; and
- 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.

17/10/2022
5:20:13
Pr.Sci.Nat (400139/17)

Signature of the Specialist

GCS

Name of Company:

17 November 2023

Date

CV OF SPECIALIST

Hendrik Botha

Technical Director

LinkedIn:

CORE SKILLS

- Project management
- Analytical and numerical groundwater modelling
- Geochemical assessments and geochemical modelling
- Hydropedology, hydrological assessments & yield assessments
- Hydrology, floodline 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

PROFILE

Hendrik (Henri) Botha is currently the manager of the GCS Newcastle Office and occupies the role of principal hydrogeologist. 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:

- Waste classification and Impact Assessments
- Aquifer vulnerability assessments
- Geochemical sampling, data interpretation and modelling
- Geophysical surveys and data interpretation
- GIS
- Water quality sampling and data interpretation
- 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)
- Stormwater Management Systems and Modelling
- Surface Water Yield Assessments
- Water and Salt Balances

SCAN ME
PROJECT RECORD

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