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Wetland flow driver assessment Proposed 60-year Ash Dump Facility (ADF) at Kusile Power Station

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Geo Pollution Technologies (Pty) Ltd

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M. Burger; M. Sc.; Pr. Sci. Nat (400296/12)

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NEMA Regs (2014) - Appendix 6	Relevant section in report
Details of the specialist who prepared the report	Page i
The expertise of that person to compile a specialist report including a curriculum vitae	Page i
A declaration that the person is independent in a form as may be specified by the competent authority	Page i
An indication of the scope of, and the purpose for which, the report was prepared	Detailed in report
The date and season of the site investigation and the relevance of the season to the outcome of the assessment	Detailed in report
A description of the methodology adopted in preparing the report or carrying out the specialised process	Detailed in report
The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	Detailed in report
An identification of any areas to be avoided, including buffers	Detailed in report
A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Detailed in report
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Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Detailed in report
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised and	Detailed in report
If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	
A description of any consultation process that was undertaken during the course of carrying out the study	N/A
A summary and copies if any comments that were received during any consultation process	N/A
Any other information requested by the competent authority	N/A

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LIST OF ABBREVIATIONS

Abbreviation	**Explanation**
ARD	Acid Rock Drainage
BPG	Best Practice Guidelines
CMS	Catchment Management Strategy
CSM	Conceptual Site Model
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
IWRMP	Integrated Water Resources Management Plan
IWRM	Integrated Water Resources Management
km^2	Square kilometre
L/s	Litres per second
mamsl	Metres above mean sea level
Ml/d	Megalitres per day
m	metre
mm	Millimetre
mm/a	Millimetres per annum
mS/m	Millisiemens per metre
m^3	Cubic metre
MAP	Mean Annual Precipitation
MPRDA	Mining and Petroleum Resources Development Act (Act No. 73 of 2002) 1989)
NEMA	National Environmental Management Act (Act No. 107 of 1998)
NWA	National Water Act (Act No. 36 of 1998)
ppm	Parts per million
RDM	Resource Directed Measures
RQO	Resource Quality Objective
RWQO	Resource Water Quality Objective
TDS	Total Dissolved Solids
WMA	Water Management Area
WMP	Water Management Plan

DEFINITIONS

Definition	Explanation
Aquiclude	A geologic formation, group of formations, or part of formation through which virtually no water moves
Aquifer	A geological formation which has structures or textures that hold water or permit appreciable water movement through them. Source: National Water Act (Act No. 36 of 1998).
Borehole	Includes a well, excavation, or any other artificially constructed or improved underground cavity which can be used for the purpose of intercepting, collecting or storing water in or removing water from an aquifer; observing and collecting data and information on water in an aquifer; or recharging an aquifer. Source: National Water Act (Act No. 36 of 1998).
Boundary	An aquifer-system boundary represented by a rock mass (e.g. an intruding dolerite dyke) that is not a source of water, and resulting in the formation of compartments in aquifers.
Cone of Depression	The depression of hydraulic head around a pumping borehole caused by the withdrawal of water.
Confining Layer	A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers; it may lie above or below the aquifer.
Dolomite Aquifer	See “Karst” Aquifer
Drawdown	The distance between the static water level and the surface of the cone of depression.
Fractured Aquifer	An aquifer that owes its water-bearing properties to fracturing.
Groundwater	Water found in the subsurface in the saturated zone below the water table.
Groundwater Divide or Groundwater Watershed	The boundary between two groundwater basins which is represented by a high point in the water table or piezometric surface.
Groundwater Flow	The movement of water through openings in sediment and rock; occurs in the zone of saturation in the direction of the hydraulic gradient.
Hydraulic Conductivity	Measure of the ease with which water will pass through the earth's material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (m/d).
Hydraulic Gradient	The rate of change in the total hydraulic head per unit distance of flow in a given direction.
Infiltration	The downward movement of water from the atmosphere into the ground.
Intergranular Aquifer	A term used in the South African map series referring to aquifers in which groundwater flows in openings and void spaces between grains and weathered rock.
Karst (Karstic)	The type of geomorphological terrain underlain by carbonate rocks where significant solution of the rock has occurred due to flowing groundwater.

Definition	**Explanation**
Karst (Karstic) Aquifer	A body of soluble rock that conducts water principally via enhanced (conduit or tertiary) porosity formed by the dissolution of the rock. The aquifers are commonly structured as a branching network of tributary conduits, which connect together to drain a groundwater basin and discharge to a perennial spring.
Monitoring	The regular or routine collection of groundwater data (e.g. water levels, water quality and water use) to provide a record of the aquifer response over time.
Observation Borehole	A borehole used to measure the response of the groundwater system to an aquifer test.
Phreatic Surface	The surface at which the water level is in contact with the atmosphere: the water table.
Piezometric Surface	An imaginary or hypothetical surface of the piezometric pressure or hydraulic head throughout all or part of a confined or semi-confined aquifer; analogous to the water table of an unconfined aquifer.
Porosity	Porosity is the ratio of the volume of void space to the total volume of the rock or earth material.
Production Borehole	A borehole specifically designed to be pumped as a source of water supply.
Recharge	The addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.
Recharge Borehole	A borehole specifically designed so that water can be pumped into an aquifer in order to recharge the ground-water reservoir.
Saturated Zone	The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.
Specific Capacity	The rate of discharge from a borehole per unit of drawdown, usually expressed as m3/d•m.
Specific Yield	The ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.
Transmissivity	Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.
Unsaturated Zone (Also Termed Vadose Zone)	That part of the geological stratum above the water table where interstices and voids contain a combination of air and water.
Watershed (Also Termed Catchment)	Catchment in relation to watercourse or watercourses or part of a watercourse means the area from which any rainfall will drain into the watercourses or part of a watercourse through surface flow to a common point or points. Source: National Water Act (Act No. 36 of 1998).
Water Table	The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is equal to that of the atmosphere.

1 INTRODUCTION

Geo Pollution Technologies (Pty) Ltd (GPT) was appointed to conduct a wetland flow driver (hydro pedological) assessment for the proposed 60-year Ash Disposal Facility (ADF) at Kusile Power Station near Bronkhorstspruit in Mpumalanga. The purpose of the study is to quantify the potential wetland flow losses on the downgradient wetland system directly related to the construction of the 60 Year ADF.

The flow river assessment was based on the guideline for hydro pedological assessments and minimum requirements - Van Tol, J.J., Bouwer, D. & Le Roux, P.A.L., 2021.

Hydro pedological surveys aim to characterise dominant surface and sub-surface flow paths of water through the landscape to wetlands and streams or groundwater. The objective of these guidelines is to standardise hydro pedological survey methodology to identify dominant hydrological drivers and responses of landscapes in order to quantify the impact of new development on water resources. This will assist decision makers to understand the hydrological system and thereby make sensible decisions with regards to sustainable water management. These guidelines were developed from numerous scientific and consultancy projects (van Tol, 2020) and are divided into four steps:

1) Identification of dominant hillslopes.

2) Conceptualising hillslope hydro pedological responses.

3) Quantification of hydraulic properties and flowrates.

4) Quantification of hydro pedological fluxes.

1.1 Normative references

The following normative references are indispensable to this report as it contains information used in terms of wetland flow drivers:

- Prime Africa Consultants (March 2018), Environmental Management Plan for the rehabilitation of wetlands identified in the Kusile wetland offset plan.
- Prime Africa Consultants (July 2017), Kusile Wetland Offset Strategy - Deliverable 2: Phase 1 Planning Report
- Prime Africa Consultants (December 2017), Kusile Wetland offset rehabilitation design report - Deliverable 5: Finalisation of Rehab Reports
- Prime Africa Consultants (October 2015), Kusile 60-year ash dump facility wetland offset strategy;
- Wetland Consulting Services (Pty) Ltd (June 2013), Wetland Delineation and Impact Assessment Kusile 60-year Ash Disposal Facility

1.2 Main report findings

Prime Africa Consultants (March 2018) - EMPR

The wetlands in the area are generally moderately modified, denoted as a PES category of C (WCS 2012) with a few HGMs that are largely modified (PES category of D). The predominant cause of this deviation from the reference state is historical and current agricultural activities, both within and adjacent to wetland delineated areas. The hillslope seepage wetlands especially have been impacted by historical cultivation activities. Furthermore, significant channel erosion and incision has occurred within some of the valley bottom wetlands associated with the Holspruit and Klipfonteinspruit. Storm water runoff from the Kusile Power Station has increased erosion and turbidity in many of these wetlands and is encroaching many of the delineation boundaries. Poor grazing management such as livestock over-grazing or under-grazing also occurs within many of the wetlands and buffer zones. This has drastically altered floral species composition along many of the wetlands and alien plant species, particularly annual weeds, are plentiful. The Wilge River itself has been assessed as a category C river (DWS, 2014; applicable to the entire SQ of 44km length) with agricultural encroachment, abstraction, damming and alien vegetation cited as the main determinants.

Measures of ecological importance and sensitivity for wetlands in the area were taken from the 2012/2013 study by WCS (2013) for all wetlands and tributaries associated with the Wilge River and from the nation-wide PES-EI-ES study conducted by DWS including the Wilge River itself (2014; SQ B20F-01150). With the exception of a few channelled valley bottom wetlands that have an integrated ecological importance and sensitivity (EIS) of High, the majority of the wetlands, not including the Wilge River itself, have an EIS of Moderate. This was defined as "Wetlands that are considered to be ecologically important and sensitive on a provincial or local scale. The biodiversity of these wetlands is not usually sensitive to flow and habitat modifications. They play a small role in moderating the quantity and quality of water of major rivers" (WCS, 2014). The Wilge River itself has been assigned a High ecological importance and a Very High ecological sensitivity (DWS, 2014; applicable to the entire SQ of 44km length), with an integrated EIS of High.

The main problems identified in these systems relate to altered hydrology, geomorphology and vegetation….

Prime Africa Consultants (July 2017) – Phase 1 planning report

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The main problems identified in these systems relate to altered hydrology, geomorphology and vegetation….

Wetland Consulting Services (Pty) Ltd (June 2013)

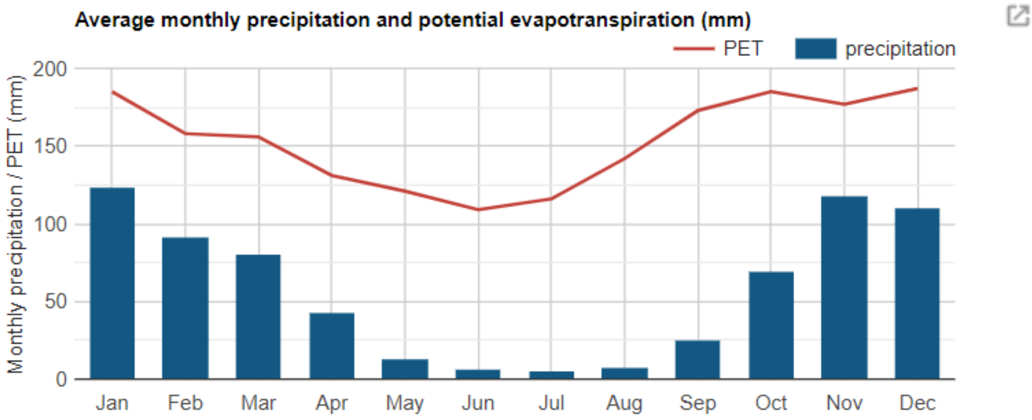
Within the western section of solution GA the main wetland on site consists of a hillslope seepage wetland and associated valley bottom wetland that drains west into the Wilge River. Past cultivation has also impacted significantly on the vegetation composition of the wetland, with the 1:50 000 topographical maps indicating that cultivation used to extend right across the wetland. The extreme upper reach of the wetland also shows signs of very heavy grazing.

2 SITE INFORMATION

2.1 Climate

Climatic data was obtained from the SamSam Water Climate Tool[1] for the Ogies area (Figure 1). The proposed ADF is located in the summer rainfall region of Southern Africa with precipitation usually occurring in the form of convectional thunderstorms. The average annual rainfall (measured over a period of 30 years) is approximately ±700 mm, with the high rainfall months falling between October and April.

[1] SamSam Water Climate Tool: https://www.samsamwater.com/climate/



description	PET	precipitation
01 - January	185	124
02 - February	158	92
03 - March	156	81
04 - April	131	43
05 - May	121	13
06 - June	109	7
07 - July	116	5
08 - August	142	8
09 - September	173	25
10 - October	185	70
11 - November	177	118
12 - December	187	111
Total	1,846	697

Figure 1:Rainfall data representation

2.2 Site visit and observations

A site visit was done on 26 and 27 May 2022 with land use surrounding the wetlands mostly cultivated land (maize). Significant channel erosion has occurred within some of the valley bottom wetlands. The wetlands on site make up the headwaters of the perennial Wilge River, through channelled flow in the non-perennial Holfontein and Klipfontein spruits, which are fed by the various wetland systems.

The upgradient area to the east of the proposed ADF of the Wilge River is characterised by rocky ridges and outcrops. The Wilge river is associated with a channelled valley bottom wetland with narrow riparian zones. At the confluence of the Holfontein and Klipfontein spruit a floodplain wetland system is present with numerous large cut-off meanders and a narrow riparian fringe along the channel. At its widest (at the confluence), the floodplain is more than 600m across.

In addition to the Holfontein and Klipfontein spruit and its tributaries, a number of further unnamed streams drain towards the Wilge River from the east. It should also be noted that there is unknown mining activities upgradient of the proposed ADF development.

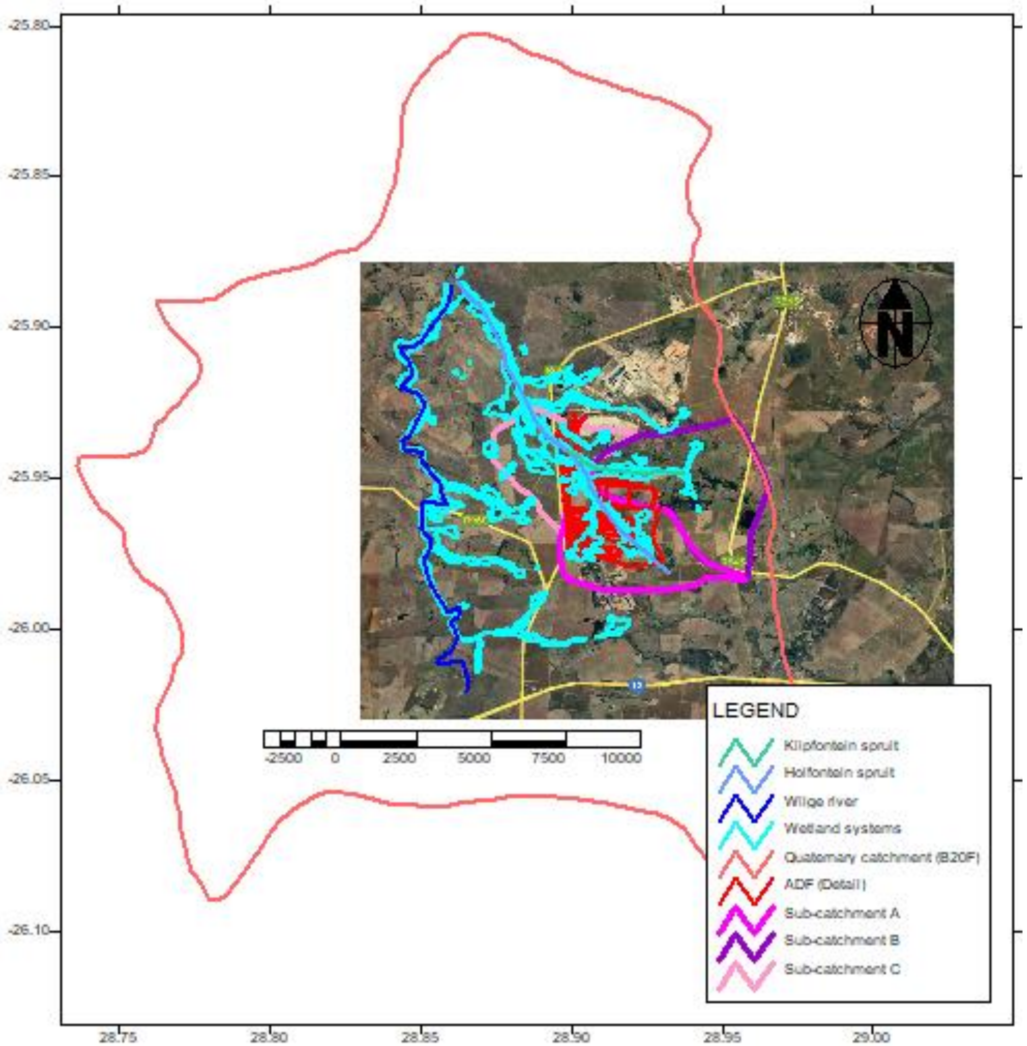


Figure 2: Site Layout within quaternary catchment (B20F).

3 IDENTIFICATION OF DOMINANT HILLSLOPES

The wetlands are dominated by extensive hillslope seepage wetlands that feed into channelled valley bottom wetlands (Klipfontein and Holfontein spruits). Precipitation first strikes vegetative surfaces before hitting the soil. Depending on the humidity within the canopy, a certain amount of the water temporarily sorbed onto vegetative surfaces evaporates before moving to the soil.

The amount of water is the ratio of vegetative surface area to the underlying ground surface area. Leaf area indices range from as little as 1.0 for short grasses and desert scrub, around 3.0– 4.0 for grasslands and savannahs.

Infiltration is the movement of water into the soil, and the hydrology and water quality of a watershed is controlled to a large degree by the infiltration characteristics of the surface soils. Although infiltration rates in wetlands themselves are typically low, infiltration rates across the landscapes surrounding wetlands can have a strong effect on the routing of water to the wetlands. Water infiltrates into the soil and enters the vegetative root system to be used in evapotranspiration, travels by subsurface pathways to surface waters (streams, wetlands) found at the base of slopes, or percolates to groundwater. Human land-use activities that compact or denude soils reduce infiltration rates, often reducing them so much they are exceeded by commonly experienced rainfall. When rainfall rates exceed infiltration rates, the excess water runs off the soil surface, rapidly carrying sediment and contaminants to surface waters and increasing storm flows. Maintenance of good hydrologic and water-quality conditions in surface waters is largely a matter of maintaining high infiltration rates. The physics of infiltration are very complicated. Infiltration rates in soils are affected by soil physical properties (porosity, structure, and texture, discussed above), antecedent moisture content, the amount of `vegetative detritus on the soil surface, vegetation, layering of soils, vertebrate and invertebrate activity in the topsoil, landscape position, groundwater dynamics, and even air temperature. For given soil conditions, the potential infiltration rate decreases asymptotically over time during a wetting event thus only indicative modelling can be done.

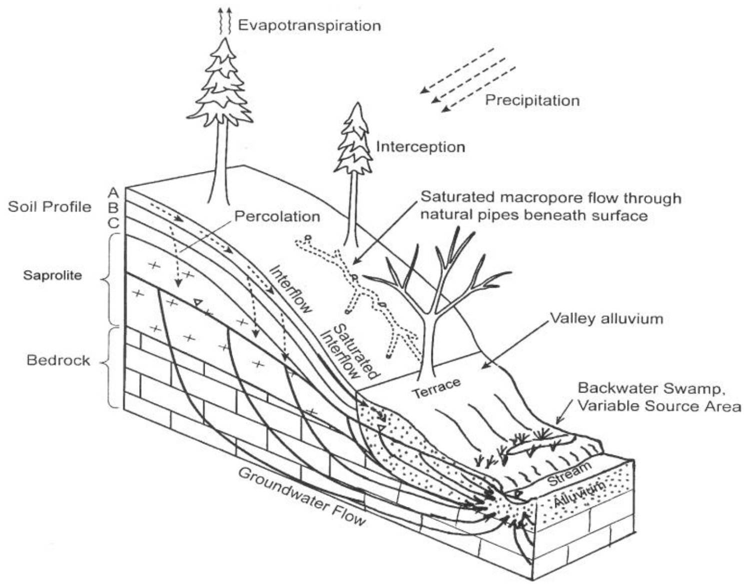


Figure 3: Conceptual understanding[2]

2 Wetland Soils, Hydrology, and Geomorphology C. RHETT JACKSON, JAMES A. THOMPSON, and RANDALL K. KOLKA

3.1 Surface runoff

The proposed ADF is located in the Olifants River Catchment (Quaternary Catchment B20F). The site ranges in altitude from 1510 mamsl (Holfontein spruit enters the quaternary catchment) and 1440 mamsl at the north-western corner of the proposed ADF.

The following parameters were obtained for the catchment:

- Runoff from natural (unmodified) catchments in this area is simulated in WR2012 as being equivalent to 16.7 millimetres per year over the surface area and is equal to approximately 2.5 % of the Mean Annual Rainfall.
- Groundwater recharge was calculated as 60 mm per year or 9%.
- Baseflow was calculated as 21 mm per year or 3%.
- Once off flow measured in the Holfontein spruit was measured at 280 m^3/day and the Klipfontein spruit to the north of the proposed ADF at 230 m^3/day.
- There are three sub-catchments within the AFD footprint area:
    - Sub-catchment A (Holfontein spruit)
    - Sub-catchment B (Klipfonteinspruit north of the proposed ADF)
    - Sub-catchment C (west of the proposed ADF and confluence of the Holfontein spruit and the Klipfontein spruit)

Table 1 (Based on GRDM data - 2003)

Name	Area (km2)	Mean Annual Precipitation (mm)	Mean Annual Recharge (Mm3/a)	Baseflow (Mm3/a)	Allocatable Groundwater (Mm3/a)	Present Ecological Status	Use (Mm3/a)
B20F	504.200	667	33	11	75.00	C	0.21

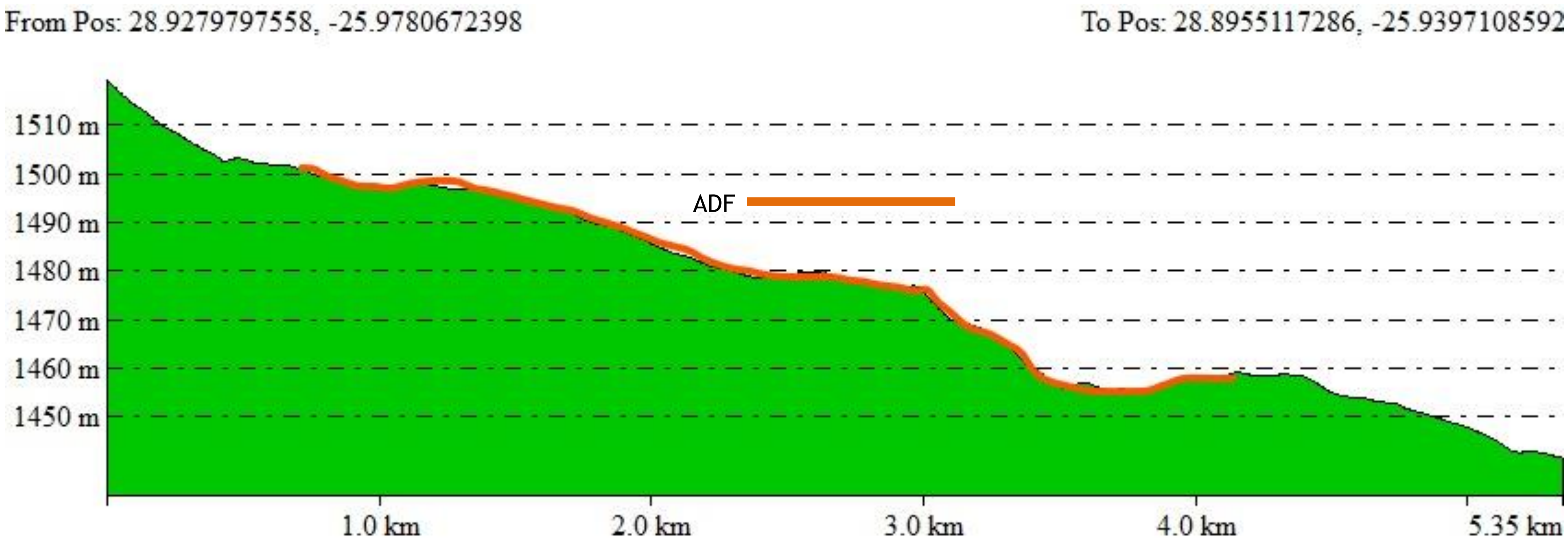


Figure 4: Site drainage and topography – Cross section.

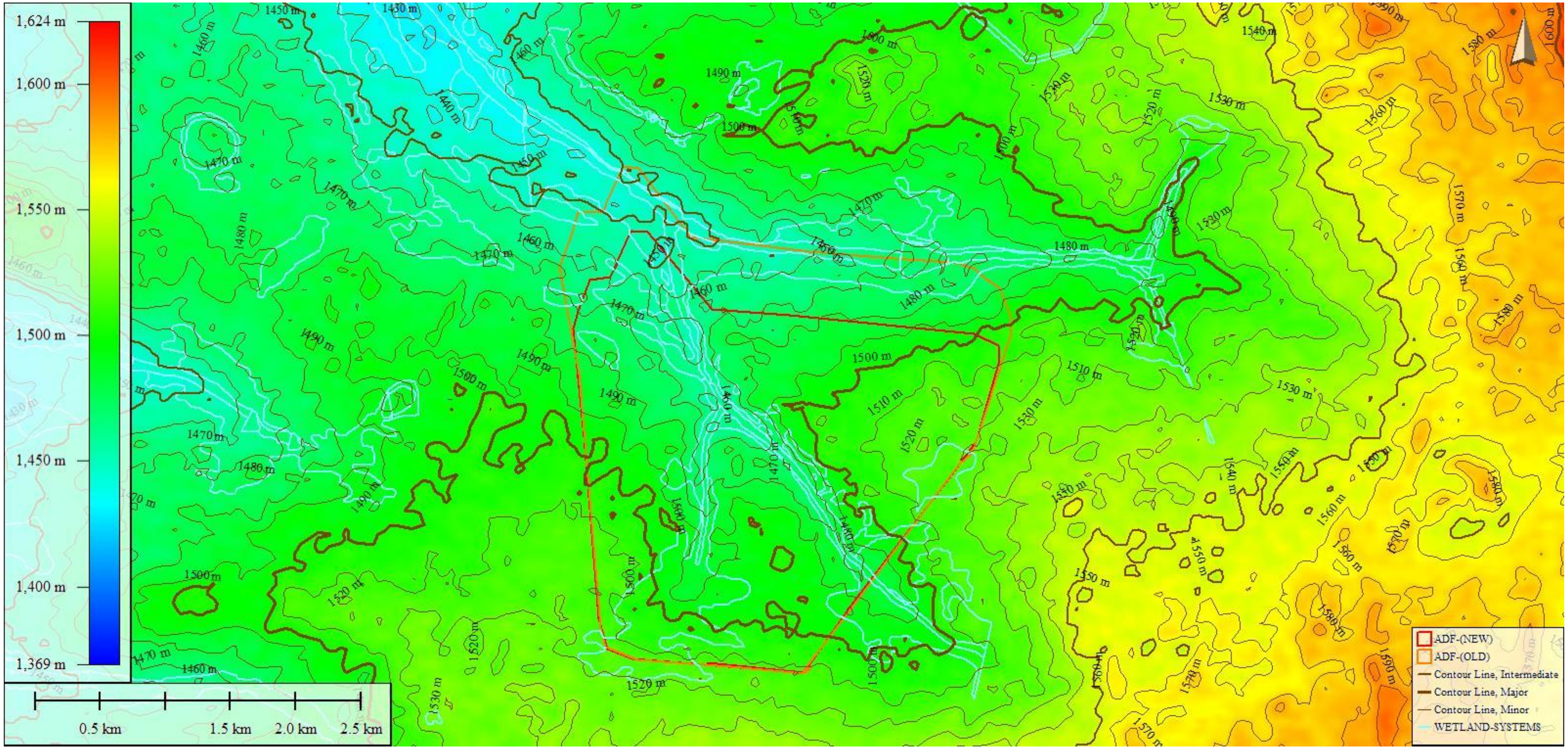


Figure 5: Site drainage and topography – Digital elevation model

3.2 Conceptualize hillslope hydro-pedological responses

Auger holes and test pits were done to delineate the soils and are described in the table below. Bucket augers were done at selected points within the site boundary. A summary of the soil types is discussed below. In Figure 5 an attempt to delineate the soils hydro-pedologically was made using available desktop information, site visits and transect information. Note that the responsive and interflow soils were grouped together as it was difficult to accurately delineate this transition zone

3.2.1 Recharge soils

The rocky soils are generally shallow and overlie an impeding layer such as hard rock or weathering saprolite. The main soil forms found in rocky soils were Mispah and Glenrosa.

The agricultural soils found on site support an industry of commercial maize production. These soils include Clovelly and Avalon. These soils have deep yellow-brown B-horizons with minimal structure.

3.2.2 Interflow or transitional soils

The transitional soil unit comprises the soils found between clay soils and the agricultural soils. These soils often have signs of clay accumulation or water movement in the lower horizons. These soils are usually indicative of seasonal or temporary wetland conditions. The main soil forms found in transitional soils were Kroonstad, Wasbank, Longlands and Westleigh.

3.2.3 Responsive soil

The Katspruit soil form is most commonly found in areas of semi-permanent wetness. The soil is made up of an Orthic A-horizon over a diagnostic G-horizon.

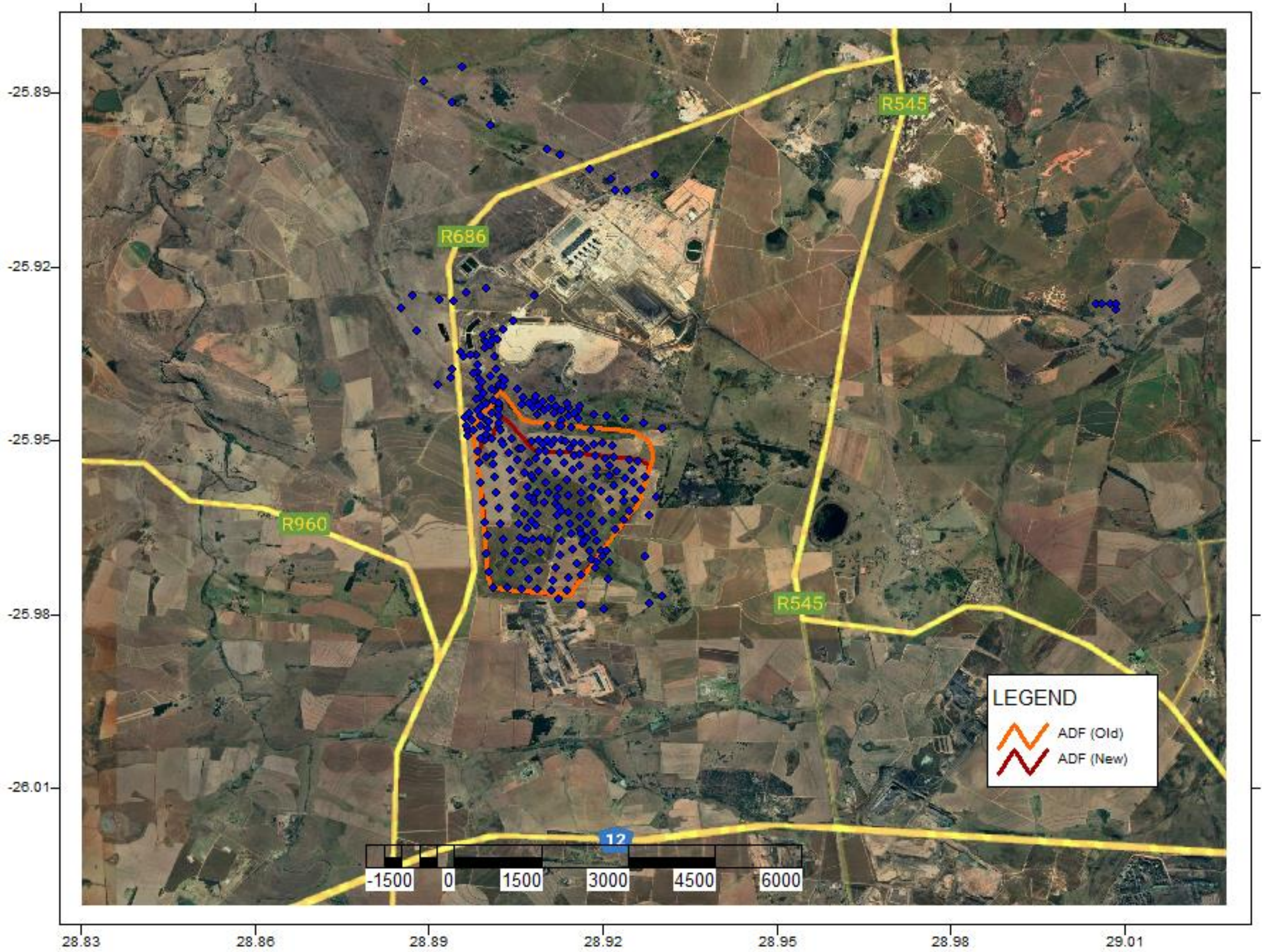

-25.89
-25.92
-25.95
-25.98
-26.01
28.83
28.86
28.89
28.92
28.95
28.98
29.01
R545
R686
R960
R545
12
-1500
0
1500
3000
4500
6000
LEGEND
ADF (Old)
ADF (New)

Figure 6: Test pit and auger hole positions

Figure 7: Klipfontein spruit

Figure 8: Responsive soils.

Figure 9: Klipfontein spruit wetland system.

Figure 10: Agricultural/Responsive soils

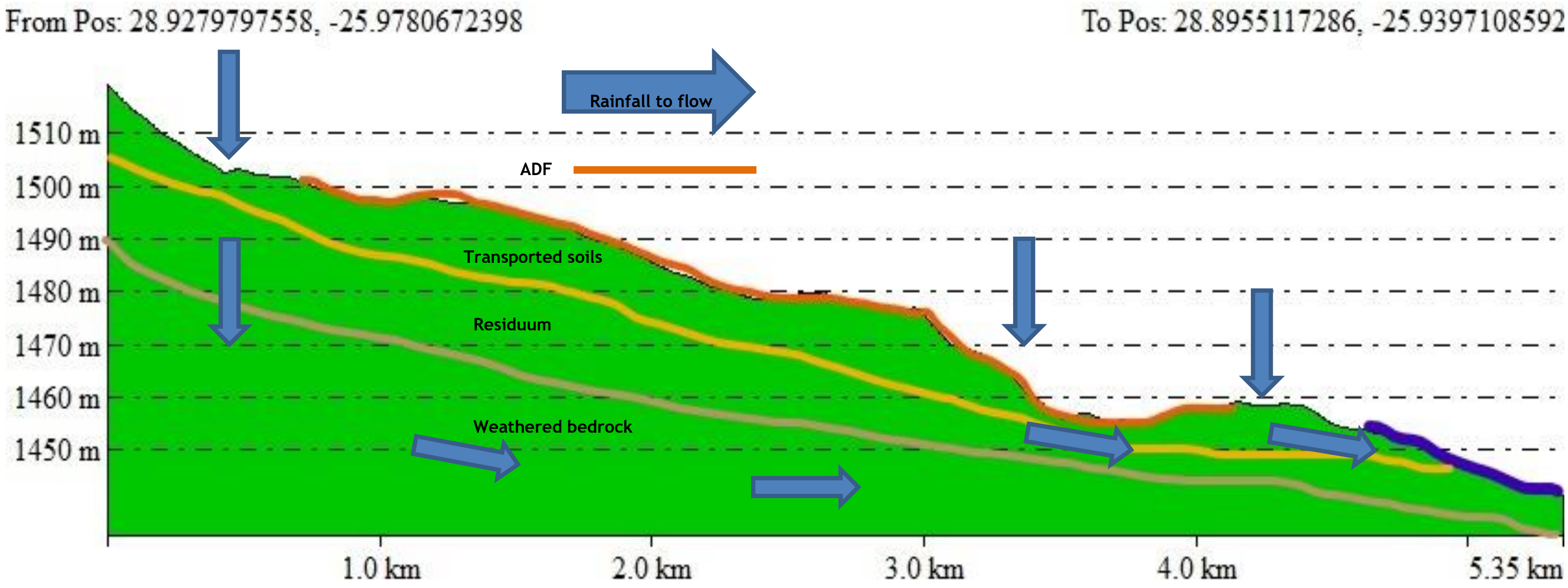


Figure 11: Conceptual site model.

3.3 Quantification of hydraulic properties and flowrates.

Quantification of hydraulic properties was done through the following:

1. In situ field infiltration tests;
2. Falling head permeability tests;
3. Wetland delineation; and,
4. Site observations.

An interpolated map of the hydro pedological soil types based on the above is detailed Figure 12 below.

3.3.1 In situ infiltration tests

In situ infiltration tests (falling head permeability test) to estimate the rate at which runoff will infiltrate, or pass through the soil profile were done as follows:

Step 1: Test hole with the following dimensions Depth 50 cm, Diameter 10 cm

Step 2: Determine soil texture through a ribbon test

Step 3: Fill the hole with water and measure time to drain the hole completely

Step 4: Calculate the infiltration rate using the following formula

$$k = \frac{2.3A}{F(t_2 - t_1)} \log \frac{h_1}{h_2}$$

A summary of the falling permeabilities is shown Table 2 . The following observations can be made regarding the permeabilities:

- The auger holes permeabilities are typical of clay and can be regarded as responsive soils. These soils 'respond' quickly to rain events and typically generate overland flow. These soils can be shallow and overlie relatively impermeable bedrock, with limited storage capacity that is quickly exceeded following a rain event. Alternatively, they are soils with morphological indications of long periods of saturation. Given that the latter soils are close to saturation during the rainy season, additional precipitation will typically flow overland due to saturation excess.

A summary of the soil results from the test pits are shown in Table 3 below. The following observations can be made regarding the permeabilities:

- The majority of the samples are typical recharge soils without any morphological indication of saturation. Vertical flow through and out of the profile into the underlying bedrock is the dominant flow direction.
- Test pits highlighted in Table 4 exhibited interflow soils where interflow is dominant at the A/B horizon interface and those where interflow is dominant at the soil/bedrock interface.

Table 2: Auger hole positions and infiltration rates

Point Name	Coordinate		Soil texture	Infiltration rate	Area of test
	X	Y	Description	cm/s	
In Situ infiltration test					
AH1	29.818296	-25.789005	Clay loam	7.11E-09	Within delineated seep wetland
AH2	29.819391	-25.787417	Clay loam	3.91E-08	Within delineated seep wetland
AH3	29.819735	-25.786657	Clay loam	6.40E-09	Within delineated seep wetland
AH4	29.819894	-25.785414	Clay loam	5.49E-08	Within delineated seep wetland
AH5	29.819778	-25.78468	Clay loam	2.40E-08	Within delineated seep wetland

Table 3: Test pits soil results summary

Point name	m/s	% Clay	% Silt	% Sand	% Gravel	Material Description
AD-TP04	1.18115E-08	3	7	17	72	SANDY GRAVEL
AD-TP04	3.77732E-08	7	22	40	30	GRAVELLY SAND
AD-TP05	6.75348E-08	8	25	38	30	GRAVELLY SAND
AD-TP09	2.37714E-09	16	23	36	25	GRAVELLY SAND
AD-TP09	4.22543E-07	22	37	26	14	SANDY SILT
AD-TP11	1.21438E-08	2	9	22	67	SANDY GRAVEL
AD-TP13	5.29906E-08	8	21	37	34	GRAVELLY SAND
AD-TP13	7.21713E-10	8	19	21	53	SANDY GRAVEL
AD-TP15	4.36311E-09	11	18	66	5	SILTY SAND
AD-TP17	1.78577E-09	7	17	42	35	GRAVELLY SAND
AD-TP17	1.1381E-09	6	17	47	29	GRAVELLY SAND
AD-TP20	2.63553E-08	5	24	70	1	SILTY SAND
AD-TP21	5.48467E-09	15	61	12	12	CLAYEY SILT
AD-TP23	5.01137E-09	9	46	25	20	SANDY SILT
AD-TP23	8.24717E-09	10	66	15	9	SANDY SILT
AD-TP24	2.56193E-09	20	33	47	0	SILTY SAND
AD-TP25	1.8129E-09	5	18	77	0	SILTY SAND
AD-TP28	4.97497E-09	7	15	76	1	SILTY SAND
AD-TP29	2.39533E-09	26	61	12	1	CLAYEY SILT
AD-TP30	1.15907E-08	10	21	69	0	SILTY SAND
AD-TP31	1.273E-08	6	49	39	6	SANDY SILT
AD-TP34	3.4054E-09	4	8	31	57	SANDY GRAVEL
AD-TP35	1.162E-09	17	26	50	7	SILTY SAND
AD-TP36	1.0229E-08	13	38	48	0	SILTY SAND
AD-TP37	9.0125E-10	5	19	68	8	SILTY SAND
AD-TP38	1.8496E-09	4	7	34	55	SANDY GRAVEL
AD-TP47	1.1897E-09	6	13	35	46	SANDY GRAVEL
AD-TP48	2.15792E-09	8	33	37	22	SILTY SAND
AD-TP50	4.69985E-09	15	16	33	37	SANDY GRAVEL
AD-TP53	2.75972E-09	16	18	30	36	SANDY GRAVEL
AD-TP54	3.67426E-09	10	27	35	28	GRAVELLY SAND
AD-TP55	8.28006E-09	1	21	63	15	SILTY SAND
AD-TP57	2.83023E-09	5	13	57	26	GRAVELLY SAND
AD-TP73	1.96152E-09	11	28	33	28	SILTY SAND
AD-TP83	1.19508E-09	6	22	40	33	GRAVELLY SAND

Responsive or transistion soil based on clay content < 15% which was considered relevant for the build-up of water in the soil - Bouwer D, Le Roux PAL, van Tol JJ, van Huyssteen CW. 2015. Using ancient and recent soil properties to design a conceptual

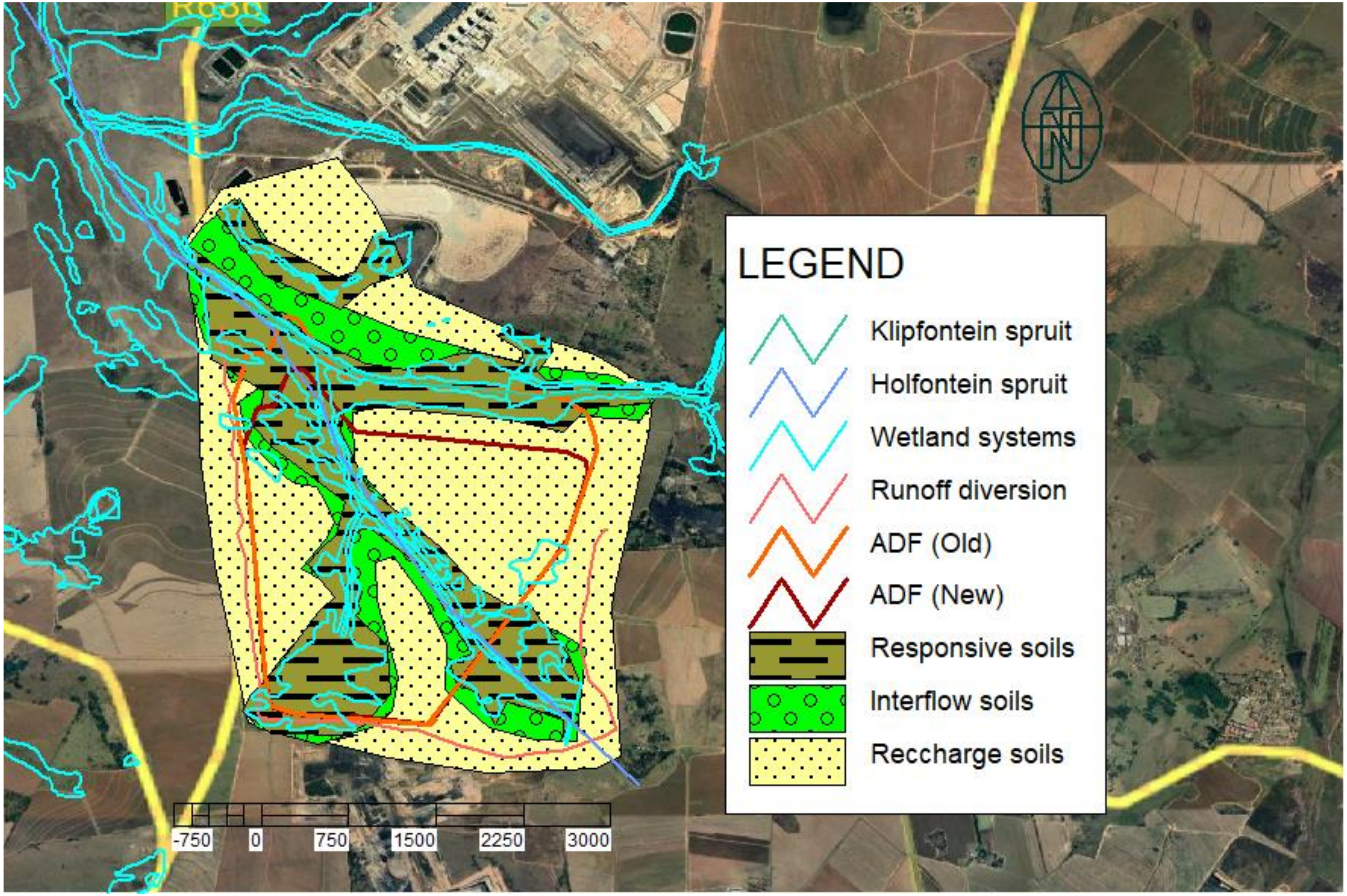


Figure 12: Hydro pedological interpolation from auger holes and test pits.

4 QUANTIFICATION OF HYDROPEDOLOGICAL FLUXES

The ADF and associated infrastructure could impact on the flow drivers of the wetland systems through interception systems such as drainage systems, berms, increased/decreased recharge and water quality changes.

4.1 Wetland catchment flow reduction

The SANBI Biodiversity Series 22, (2013) Classification System for Wetlands and other Aquatic Ecosystems in South Africa. User Manual: Inland Systems was consulted in determining the estimated flow losses to the specific wetland catchment systems due to the proposed ADF.

Many wetlands are hydrologically and ecologically linked to adjacent groundwater bodies, but the degree of interaction can vary greatly. Some wetlands may be completely dependent on groundwater discharge under all climatic conditions, whilst others may have very limited dependence such as only under very dry conditions – and some may have no connection with groundwater at all. The wetlands can characterise as follows:

- Channelled valley bottom (Holfontein and Klipfontein spruit channels)
- Hillslopes feeding the Holfontein and Klipfontein spruit channels
- Floodplain confluence of Holfontein and Klipfontein spruits

4.2 Assumptions

Wetlands are dependent on rainfall infiltrating the upslope soil, being partitioned by the subsoil and fractured rock, before flowing down slope to return to the soil surface and wetland, sometimes via a river system (see Figure 11). A wetland may thus be considered a signature of the hydrological dynamics of its surrounding catchment.

The wetland's catchment determines the relative extent of different hydrological response types in the catchment and within specific hillslopes contained within the catchment. The impact on flow drivers of the wetland catchment is detailed below and is based on the following assumptions (*status quo*). A water balance[3] on the wetland catchment is represented by:

- Rainfall 100% of flow input – ±700 mm
- Evapotranspiration is 50 – 70% of rainfall (outflow) - ±400 mm
- Runoff is 2.5% (outflow)[4] – ±17 mm
- Groundwater recharge is 9%[5] (outflow) - ± 60 mm
- 20 -30 % of the water being left in or stored the unsaturated zone or interflow zone feeding the wetland

The impact assessment is only valid for Kusile Power Station. Based on the site visit, historic mining activity and agricultural activities has impacted on the wetland systems. Current flow driver impacts from existing and neighbouring mines/agricultural activities was not part of the impact assessment;

[3] Dynamics of MODIS evapotranspiration in South Africa, Nebo Jovanovic1*, Qiaozhen Mu2, Richard DH Bugan1 and Maosheng Zhao3, 1CSIR, Natural Resources and Environment. ISSN 0378-4738 = Water SA Vol. 41 No. 1 January 2015

[4] Midgley, D.C., Pitman, W.V. & Middleton, B.J. (1994) Surface Water Resources of South Africa 1990. Water Research Commission Report No 298/5.1/94, Pretoria, South Africa.

[5] An investigation into recharge in South African underground collieries by P.D. Vermeulen* and B.H. Usher. The Journal of The Southern African Institute of Mining and Metallurgy- Volume 106 -

however, it was deemed necessary to indicate the impact on the existing seepage wetland. Furthermore, the model should not be seen as exact as there are numerous variables which are impossible to simulate, the model should therefore only be seen as a tool for planning purposes.

4.3 Current flow drivers -seepage wetland

The flow driver's pre ADF deposition is expected to be in the order of the following as shown in Figure 13 below. As expected, the water stored in the wetland soils is the dominant wetland flow driver in terms of volume.

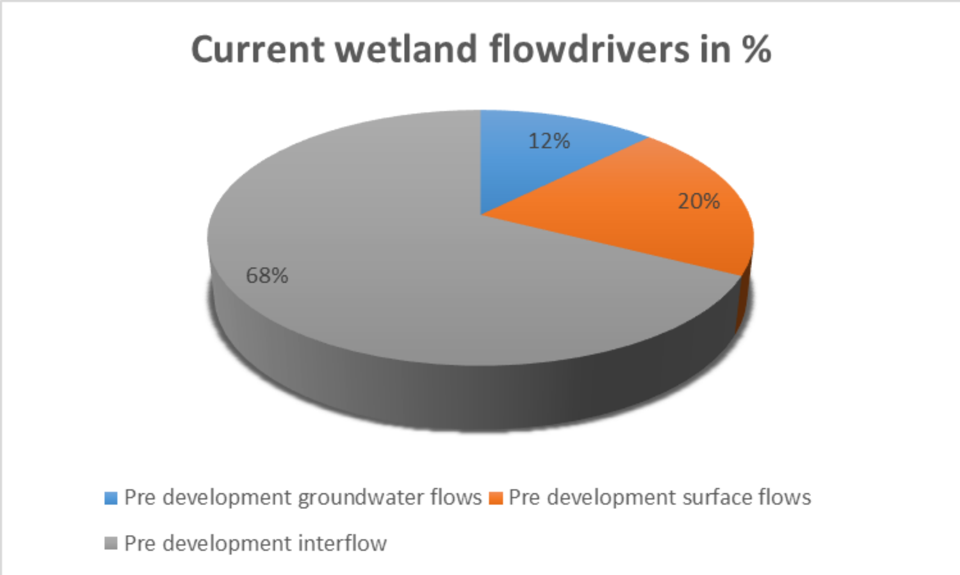


Figure 13: Wetland flow drivers pre development

4.4 Expected impacts by proposed ADF

The impact by proposed ADF (new design, old design and new design with mitigations) is shown in Table 4 and Figure 14 below:

- <u>Old ADF as designed</u> - As expected, the old ADF design has the largest impact due to its footprint covering the largest area especially on sub-catchment B and cutting of flow from the Klipfontein spruit.
- <u>New ADF design with Holfontein spruit diversion</u> -There is an improved total flow driver reduction of 4% based on the new ADF design compared to the old ADF design which is mostly due to the reduction in size and undisturbed flow of the Klipfontein spruit to the north of the proposed ADF. It is important to highlight that there is an 60% less impact on sub-catchment B (Klipfontein spruit) with the unmitigated new ADF design.
- <u>New ADF design without Holfontein spruit diversion -</u> There is an improved total flow driver reduction on the new ADF design with proposed mitigation (the removal of the Holfontein stream diversion (i.e., clean water cut-off drains) compared to the old ADF design which is mostly due to the reduction in size and the removal of the diversion of the Holfontein spruit.

Based on the flow driver quantification it is clear that impacts on the wetland system are inevitable; however, the new ADF design with the proposed removal of the stream diversion of the Holfontein spruit can reduce this impact by 50% (total impact reduction from 22% to 11% wetland flow loss) when compared to the Old ADF design.

Table 4: Flow driver impacts relative to each other - Kusile wetland system

Wetland system	Pre development total flows	Flow losses					
		Old ADF (no mitigations)		New ADF (no mitigations)		New ADF (With mitigations)	
	m3/a	m3/a	% Wetland Flow Loss	m3/a	% Wetland Flow Loss	m3/a	% Wetland Flow Loss
Sub-catchment A	4088000	2142917	52%	2142917	52%	1034775	25%
Sub-catchment B	5236000	657950	13%	269080	5%	181629	3%
Sub-catchment C	13691300	2354918	17%	1811322	13%	1233168	9%
Total	23015300	5155784	22%	4223319	18%	2449572	11%

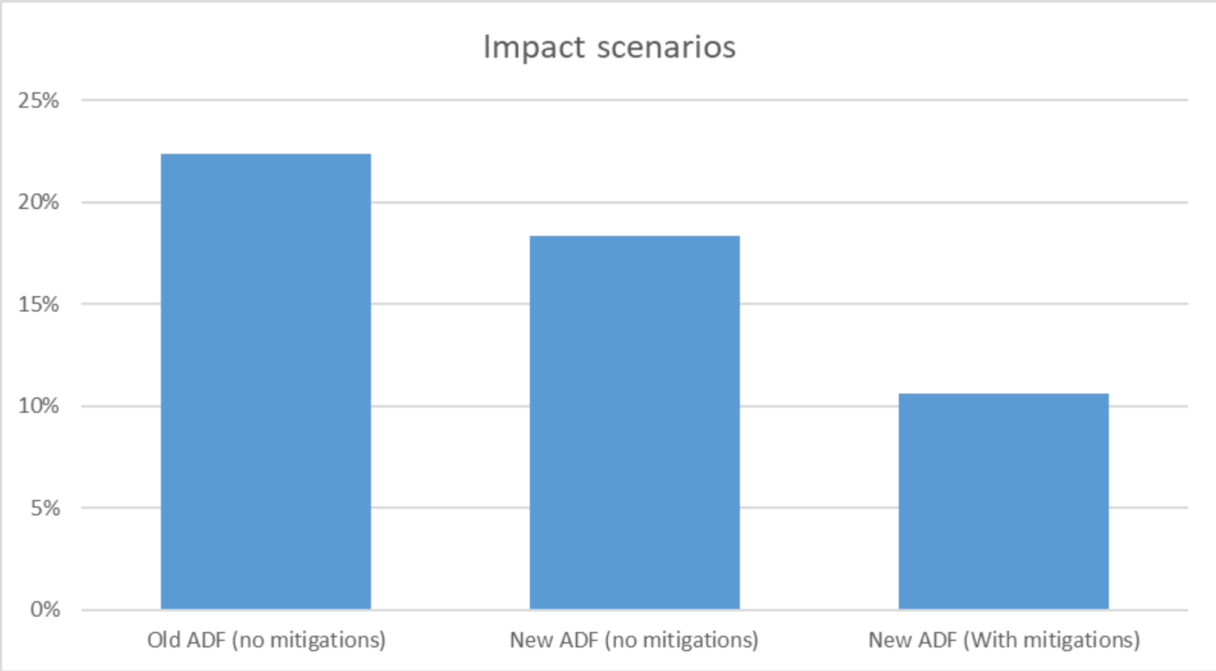


Figure 14: Impact % relative to each other

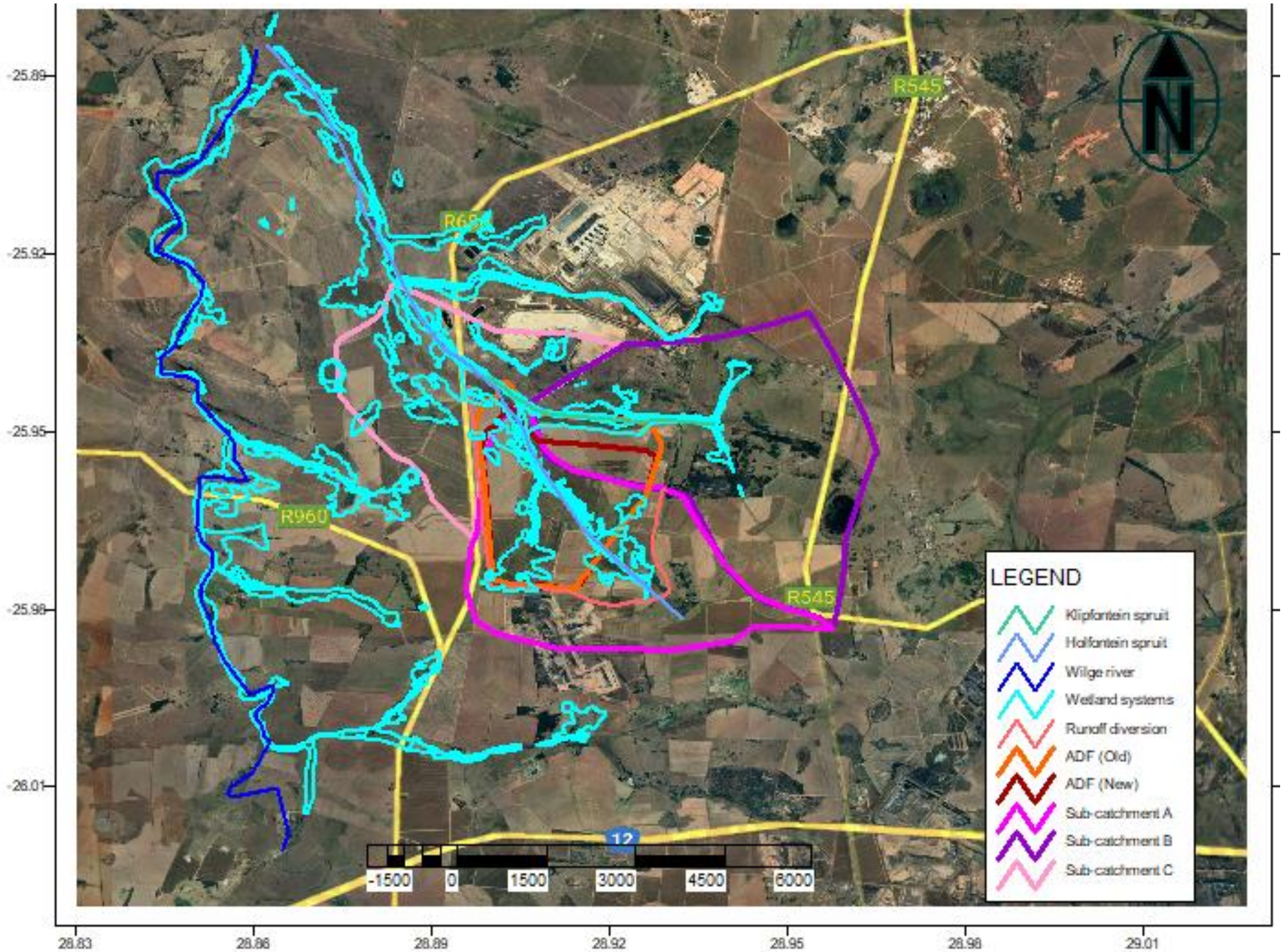


Figure 15: Wetland catchments

5 IMPACT ASSESSMENT

The wetlands on site reflect the behaviour of water, predominantly rainfall, and its behaviour following interception and infiltration into the soils. Thus, activities that affect the movement of water as well as its quality in the catchment areas supporting wetlands, translate into changes in the wetlands to which they are invariably linked. Expected impacts include:

- Loss and destruction of vegetation and wetland habitat within the proposed footprint during construction/operation;
- Soil compaction and increased risk of soil erosion due to machinery and vehicles used during construction and during routine maintenance in the operational phase;
- Change in water quality due to change in flow; and,
- Loss of wetlands and the biodiversity supported by these wetlands.

Impacts that lead to a change in hydrology include all impacts that influence the quantity (e.g., increased or decreased run-off) and velocity (e.g., concentration of flows) of flows leaving the site.

Impacts that lead to deteriorating water quality, together with the impacts that change the hydrology, are expected to be the most significant impacts on site. From a wetland perspective, mitigation measures and management plans should focus on these impacts and it will need to be clearly shown in the EIA and EMPr how these impacts will be ameliorated to prevent significant deterioration of the quality and quantity of water discharged to downstream areas. The impact assessment is discussed below.

The impact quantification was done using the procedures for the assessment and minimum criteria for reporting aquatic biodiversity in terms of sections 24(5)(a) and (h) and 44 of the National Environmental Management Act, 1998. In terms of groundwater the proposed development impact on the functioning of the aquatic feature is in terms of:

- Baseflow.
- Quantity of water including change in the hydrological regime or hydroperiod of the aquatic ecosystem.
- Quality of water.
- The location of areas not suitable for development, which are to be avoided during construction and operation, where relevant.
- Additional environmental impacts expected from the proposed development
- The degree to which impacts, and risks can be mitigated.
- The degree to which the impacts and risks can be reversed.
- The degree to which the impacts and risks can cause loss of irreplaceable resources.
- A suitable construction and operational buffer for the aquatic ecosystem, using the accepted methodologies.

5.1 Environmental Impact Assessment (EIA) Regulations, 2017

The Environmental Impact Assessment (EIA) 2014 Regulations [as amended] promulgated in terms of Sections 24 (5), 24M and 44 of the National Environmental Management Act, 1998 (Act No. 107 of

1998) [as amended] (NEMA), requires that all identified potential impacts associated with the proposed project be assessed. It is clear that impacts on the total wetland area assessed are unavoidable; however, the new ADF design significantly lowers the impact on sub-catchment B from medium to low in terms of hydropedology.

Table 5: Significance Rating of Impact(s)

Activity	Impact	Aspect	Phases	Risk Rating	Type Watercourse	Risk Rating
				No Mitigation		With Mitigation
				RR	Type Watercourse	RR
Old ADF Design						
Sub-catchment A	Flow driver impact	Flow cut-off/direct impact on wetland	Construction/Operation	H	Non-Perennial	H
Sub-catchment B	Flow driver impact	Flow cut-off/direct impact on wetland	Construction/Operation	M	Non-Perennial	M
Sub-catchment C	Flow driver impact	Flow cut-off/direct impact on wetland	Construction/Operation	M	Non-Perennial	L
All catchments	Flow driver impact	Flow cut-off/direct impact on wetland	Construction/Operation	M	Non-Perennial	M
New ADF Design						
Sub-catchment A	Flow driver impact	Flow cut-off/direct impact on wetland	Construction/Operation	H	Non-Perennial	H
Sub-catchment B	Flow driver impact	Flow cut-off/direct impact on wetland	Construction/Operation	L	Non-Perennial	L
Sub-catchment C	Flow driver impact	Flow cut-off/direct impact on wetland	Construction/Operation	M	Non-Perennial	L
All catchments	Flow driver impact	Flow cut-off/direct impact on wetland	Construction/Operation	M	Non-Perennial	M

6 MITIGATION MEASURES

To address these issues the following rehabilitation objectives have been identified:

- To address channel incision of main active channels as much as is practically possible;
- To re-route channel diversions back to the original alignment/s;
- To promote dispersal and retention of flow in areas where this is beneficial to wetlands;
- To remove perennial alien invasive plants species;
- To restore water retention and seepage functionality to hillslope seep wetlands; and,

The following mitigation are proposed:

- Offsetting of the wetland system due to unavoidable flow losses especially on sub-catchment A.
- If offsetting is allowed preferably implement the new ADF design as it prevents direct impact on sub-catchment B (Klipfontein spruit).
- Isolate the ash dam from the surrounding catchment through installation of a suitable liner system as per the Waste Classification Guidelines.
- Install seepage collection infrastructure to collect and contain seepage out of the ash dam.
- Develop and implement a construction stormwater management plan prior to the start of construction activities. See recommendations in wetland report.
- Install and regularly maintain and repair sediment barriers along the downslope edge of cleared areas.
- No vegetation clearing should take place in any wetland outside the direct development footprint.
- Phase vegetation clearing to limit exposed area at any one time. As far as possible, limit the major clearing activities and earthworks to the dry season.
- Install sediment barriers and/or low-level berms along the downslope edge of cleared areas.
- Rehabilitate all cleared areas outside the direct development footprint as soon as possible following the disturbance.
- Water quality monitoring and biomonitoring to be undertaken based on recommendations by an ecologist/wetland specialist.
- Inspect and maintain all stormwater discharge points. These points should be dispersive as far possible.
- Ensure separation of clean and dirty water. No dirty water to be discharged.
- Install clean water diversion of surface and sub-surface flow from upgradient to downgradient:
    - Groundwater and sub-surface flow - 2449573 m^3/annum

7 CONCLUSIONS

The following conclusions could be drawn from the assessment:

- The proposed ADF is located in the Olifants River Catchment (Quaternary Catchment B20F). The site ranges in altitude from 1510 mamsl (Holfontein spruit enters the quaternary catchment) and 1440 mamsl at the north-western corner of the proposed ADF.
- A site visit was done on 26 and 27 May 2022 with land use surrounding the wetlands mostly cultivated land (maize). Significant channel erosion has occurred within some of the valley bottom wetlands. The wetlands on site make up the headwaters of the perennial Wilge River, through channelled flow in the non-perennial Holfontein and Klipfontein spruits, which are fed by the various wetland systems. The upgradient area to the east of the proposed ADF of the Wilge River is characterised by rocky ridges and outcrops. The Wilge river is associated with a channelled valley bottom wetland with narrow riparian zones. At the confluence of the Holfontein and Klipfontein spruit a floodplain wetland system is present with numerous large cut-off meanders and a narrow riparian fringe along the channel. At its widest (at the confluence), the floodplain is more than 600m across. In addition to the Holfontein and Klipfontein spruit and its tributaries, a number of further unnamed streams drain towards the Wilge River from the east.
- Once off flow measured in the Holfontein spruit was measured at 280 m^3/day and the Klipfontein spruit to the north of the proposed ADF at 230 m^3/day. There are three sub-catchments within the AFD footprint area:
    - Sub-catchment A (Holfontein spruit)
    - Sub-catchment B (Klipfonteinspruit north of the proposed ADF)
    - Sub-catchment C (west of the proposed ADF and confluence of the Holfontein spruit and the Klipfontein spruit)
- The agricultural soils found on site support an industry of commercial maize production. These soils include Clovelly and Avalon. These soils have deep yellow-brown B-horizons with minimal structure.
- The transitional soil unit comprises the soils found between clay soils and the agricultural soils. These soils often have signs of clay accumulation or water movement in the lower horizons. These soils are usually indicative of seasonal or temporary wetland conditions. The main soil forms found in transitional soils were Kroonstad, Wasbank, Longlands and Westleigh.
- The Katspruit soil form is most commonly found in areas of semi-permanent wetness. The soil is made up of an Orthic A-horizon over a diagnostic G-horizon.
- **Old ADF as designed** - As expected, the old ADF design has the largest impact due to its footprint covering the largest area especially on sub-catchment B and cutting of flow from the Klipfontein spruit.
- **New ADF design with Holfontein spruit diversion** -There is an improved total flow driver reduction of 4% based on the new ADF design compared to the old ADF design which is mostly due to the reduction in size and undisturbed flow of the Klipfontein spruit to the north of the proposed ADF. It is important to highlight that there is an 60% less impact on sub-catchment B (Klipfontein spruit) with the unmitigated new ADF design.
- **New ADF design without Holfontein spruit diversion -** There is an improved total flow driver reduction on the new ADF design with proposed mitigation (the removal of the Holfontein stream diversion (i.e., clean water cut-off drains) compared to the old ADF design which is mostly due to the reduction in size and the removal of the diversion of the Holfontein spruit.

- Based on the flow driver quantification it is clear that impact on the wetland system is inevitable, however the new ADF design with proposed removal of stream diversion of the Holfontein spruit and clean water management underneath the ADF can reduce this impact by 50% (Total impact 22% to 11%) if compared to the Old ADF design.

8 RECOMMENDATIONS/MITIGATION MEASURES

The following mitigation are proposed:

- Offsetting of the wetland system due to unavoidable flow losses especially on sub-catchment A.
- If offsetting is allowed preferably implement the new ADF design as it prevents direct impact on sub-catchment B (Klipfontein spruit).
- Isolate the ash dam from the surrounding catchment through installation of a suitable liner system as per the Waste Classification Guidelines.
- Install seepage collection infrastructure to collect and contain seepage out of the ash dam.
- Develop and implement a construction stormwater management plan prior to the start of construction activities. See recommendations in wetland report.
- Install and regularly maintain and repair sediment barriers along the downslope edge of cleared areas.
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- Phase vegetation clearing to limit exposed area at any one time. As far as possible, limit the major clearing activities and earthworks to the dry season.
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- Inspect and maintain all stormwater discharge points. These points should be dispersive as far possible.
- Ensure separation of clean and dirty water. No dirty water to be discharged.
- Install clean water diversion of surface and sub-surface flow from upgradient to downgradient:
    - Groundwater and sub-surface flow - 2449573 m^3/annum

APPENDIX I: TEST PIT/AUGER HOLE POSITIONS

Site Name	Xcoord	Ycoord	Zcoord	Site Type
KusAH1	28.92102155	-25.9738811	-1.00	Auger hole
KusAH2	28.91888985	-25.9718734	-1.00	Auger hole
KusAH3	28.91682028	-25.9674137	-1.00	Auger hole
KusAH4	28.91245026	-25.9615203	-1.00	Auger hole
KusAH5	28.90787152	-25.9561711	-1.00	Auger hole
KusAH6	28.91241954	-25.9474265	-1.00	Auger hole
KusAH7	28.90533652	-25.9691275	-1.00	Auger hole
KusAH8	28.90399159	-25.9727742	-1.00	Auger hole
KusAH9	28.89391689	-25.9390874	-1.00	Auger hole
KusAH10	28.89168637	-25.9405084	-1.00	Auger hole
AD 104	28.91798136	-25.9483142	1457.78	Test pit
RVD 03	28.93034293	-25.9479998	1478.55	Test pit
RVD 04	28.92710435	-25.9470543	1475.40	Test pit
RVD 05	28.92390019	-25.9463603	1474.29	Test pit
RVD 06	28.92074026	-25.9459177	1469.23	Test pit
RVD 15	28.91845044	-25.9454453	1468.31	Test pit
AD 103	28.91462879	-25.9478176	1453.64	Test pit
RVD 02	28.91299169	-25.9475362	1452.00	Test pit
AD 102	28.91036308	-25.9474905	1449.50	Test pit
CWD 02	28.91576295	-25.9462473	1459.37	Test pit
PCD RQ 12	28.91299394	-25.9464826	1454.15	Test pit
CWD 05	28.9141336	-25.9457657	1459.09	Test pit
CWD 03	28.91509518	-25.9452305	1464.41	Test pit
CWD 01	28.91583771	-25.9447523	1463.00	Test pit
RVD 07	28.91619635	-25.9441263	1472.98	Test pit

Site Name	Xcoord	Ycoord	Zcoord	Site Type
PCD RQ 10	28.90880669	-25.9456582	1450.98	Test pit
PCD 19	28.91167321	-25.9453225	1460.17	Test pit
PCD 20	28.91301596	-25.9448361	1464.34	Test pit
CWD 04	28.91423978	-25.9443603	1464.04	Test pit
RVD 08	28.91377554	-25.9436015	1474.08	Test pit
PCD 18	28.91191148	-25.9440323	1459.75	Test pit
PCD 17	28.91074696	-25.9444083	1465.17	Test pit
PCD 16	28.90997371	-25.9448418	1460.65	Test pit
PCD 13	28.90805456	-25.9443912	1444.00	Test pit
PCD 14	28.90892818	-25.9439742	1463.21	Test pit
PCD 15	28.9096694	-25.9434241	1459.06	Test pit
RVD 09	28.91112087	-25.942855	1478.66	Test pit
PCD 10	28.90597569	-25.9439608	1444.23	Test pit
PCD 11	28.90731934	-25.9435283	1447.19	Test pit
PCD 12	28.90829413	-25.9431729	1466.00	Test pit
RVD 10	28.90851273	-25.9424949	1458.98	Test pit
PCD 09	28.9062738	-25.9426607	1455.65	Test pit
RVD 11	28.90525924	-25.9412617	1455.17	Test pit
AD-TP48	28.9045101	-25.9295043	1458.24	Test pit
AD-TP47	28.90297034	-25.9308739	1458.24	Test pit
AD-TP49	28.90093337	-25.9314648	1458.24	Test pit
AD-TP50	28.89947381	-25.9318828	1458.24	Test pit
AD-TP51	28.89960212	-25.9328775	1458.24	Test pit
AD-TP52	28.89960153	-25.9339493	1458.24	Test pit
ED 01	28.90003753	-25.9331523	1473.05	Test pit
ED 10	28.90070541	-25.9335841	1476.02	Test pit
ED 14	28.90094407	-25.932906	1476.45	Test pit
ED 04	28.90113351	-25.9322733	1475.96	Test pit
ED 06	28.90181018	-25.932633	1478.74	Test pit

Site Name	Xcoord	Ycoord	Zcoord	Site Type
AD-TP56	28.89544739	-25.9348718	1458.24	Test pit
AD-TP55	28.89605688	-25.9356069	1458.24	Test pit
AD-TP54	28.89734001	-25.9353042	1458.24	Test pit
AD-TP53	28.89822217	-25.9352178	1458.24	Test pit
AD-TP46	28.90151146	-25.9354899	1458.24	Test pit
AD-TP57	28.89839903	-25.9369923	1458.24	Test pit
AD-TP45	28.90173583	-25.9377731	1458.24	Test pit
RVD 14	28.89776785	-25.9385747	1439.55	Test pit
RVD 13	28.9006677	-25.9390206	1450.09	Test pit
KBH05	28.90268321	-25.9393062	1460.72	Test pit
RVD 12	28.90317276	-25.9397964	1457.03	Test pit
PCD 02	28.89929228	-25.9399397	1441.37	Test pit
PCD 01	28.90280886	-25.9407554	1454.44	Test pit
PCD 03	28.90089511	-25.9412136	1442.77	Test pit
KBH04	28.9015434	-25.9415114	1443.85	Test pit
PCD 05	28.89940405	-25.9418101	1446.04	Test pit
PCD RQ 03	28.89813186	-25.9429159	1446.12	Test pit
PCD 04	28.90118631	-25.9430366	1445.01	Test pit
PCD 07	28.90001499	-25.9436017	1441.00	Test pit
AD-TP58	28.89854338	-25.9382897	1458.24	Test pit
AD-TP59	28.89862452	-25.9393236	1458.24	Test pit
AD-TP44	28.90207266	-25.9403248	1458.24	Test pit
AD-TP60	28.89875518	-25.9410219	1458.24	Test pit
AD-TP61	28.89903679	-25.9427416	1458.24	Test pit
AD-TP43	28.90223305	-25.9436257	1458.24	Test pit
PCD RQ 05	28.89702017	-25.9452262	1453.15	Test pit
PCD 06	28.89854415	-25.9448009	1448.95	Test pit
PCD 08	28.90103581	-25.9453696	1450.34	Test pit

Site Name	Xcoord	Ycoord	Zcoord	Site Type
PCD RQ 01	28.90055917	-25.9467705	1454.76	Test pit
AD-BH01	28.90224675	-25.9440201	-1.00	Test pit
AD-TP62	28.89910714	-25.9441237	1458.24	Test pit
AD-TP42	28.90223305	-25.9446582	1458.24	Test pit
AD-TP40	28.89633445	-25.9460891	1458.24	Test pit
AD-TP39	28.8974279	-25.9466398	1458.24	Test pit
AD-TP63	28.89901686	-25.9457803	1458.24	Test pit
AD-TP34	28.89989638	-25.9465274	1458.24	Test pit
AD-TP38	28.896588	-25.9474848	1458.24	Test pit
AD-TP64	28.89908722	-25.9475237	1458.24	Test pit
AD-TP36	28.89677336	-25.9482856	1458.24	Test pit
AD-TP37	28.89787281	-25.9482087	1458.24	Test pit
AD-TP33	28.90013409	-25.9480181	1458.24	Test pit
AD-TP30	28.90241864	-25.9481306	1458.24	Test pit
AD-TP35	28.89688429	-25.9492161	1458.24	Test pit
AD-TP29	28.89901552	-25.9496659	1458.24	Test pit
AD-TP32	28.90003868	-25.9490828	1458.24	Test pit
AD-TP28	28.90100628	-25.9497007	2916.48	Test pit
AD-TP26	28.90279415	-25.9506808	1458.24	Test pit
AD-TP27	28.90439594	-25.9497356	4374.71	Test pit
AD-TP31	28.90227067	-25.9470788	1458.24	Test pit
AD-TP41	28.90220754	-25.945781	1458.24	Test pit
AD-BH02	28.90212613	-25.9477025	-1.00	Test pit
AD-BH03	28.89967132	-25.9499326	-1.00	Test pit
AD-BH04	28.90261232	-25.9501176	-1.00	Test pit
AD-TP65	28.89997885	-25.9529414	1458.24	Test pit
AD-TP25	28.90392404	-25.9521557	1458.24	Test pit
AD-TP24	28.90617436	-25.9514566	1458.24	Test pit
AD-TP23	28.90855546	-25.953176	1458.24	Test pit

Site Name	Xcoord	Ycoord	Zcoord	Site Type
AD-TP22	28.9102794	-25.9519153	1458.24	Test pit
AD-TP21	28.91274285	-25.95205	1458.24	Test pit
AD-TP20	28.91599801	-25.9523037	1458.24	Test pit
AD-TP19	28.91884963	-25.9525455	1458.24	Test pit
AD-TP18	28.92188103	-25.9529222	1458.24	Test pit
AD-TP66	28.92131701	-25.9543065	1458.24	Test pit
AD-TP17	28.92470575	-25.9533093	1458.24	Test pit
AD-TP16	28.92615846	-25.9537443	1458.24	Test pit
AD-TP15	28.92169484	-25.95092	1458.24	Test pit
AD-TP14	28.9199475	-25.9505031	1458.24	Test pit
AD-TP13	28.91853782	-25.9506386	1458.24	Test pit
AD-TP12	28.91733031	-25.9513921	1458.24	Test pit
AD-TP11	28.91625539	-25.9505451	1458.24	Test pit
AD-TP10	28.9151568	-25.9504726	1458.24	Test pit
AD-TP09	28.91438137	-25.9514156	1458.24	Test pit
AD-TP08	28.9137362	-25.9502087	1458.24	Test pit
AD-TP07	28.91298961	-25.949957	1458.24	Test pit
AD-TP06	28.91177263	-25.9500293	1458.24	Test pit
AD-TP05	28.91109074	-25.950723	1458.24	Test pit
AD-TP03	28.90982641	-25.9506805	1458.24	Test pit
AD-TP04	28.91054618	-25.9500251	1458.24	Test pit
AD-TP02	28.90912084	-25.9500251	1458.24	Test pit
AD-TP01	28.90775135	-25.9501613	1458.24	Test pit
AD-BH05	28.90567273	-25.9513245	-1.00	Test pit
AD-BH06	28.90905128	-25.951811	-1.00	Test pit
AD-BH07	28.91520038	-25.9527003	-1.00	Test pit
AD-BH08	28.92055804	-25.9532336	-1.00	Test pit
AD-BH09	28.90730977	-25.9538702	-1.00	Test pit
AD-BH10	28.90801559	-25.9599203	-1.00	Test pit
AD-BH11	28.90785703	-25.9640056	-1.00	Test pit

Site Name	Xcoord	Ycoord	Zcoord	Site Type
AD-BH12	28.90685282	-25.9674258	-1.00	Test pit
AD-BH13	28.91642216	-25.9661448	-1.00	Test pit
AD-TP77	28.90483456	-25.9708744	1458.24	Test pit
AD-TP76	28.91560937	-25.9711974	1458.24	Test pit
AD-TP75	28.91770376	-25.9691536	1458.24	Test pit
AD-TP74	28.91723883	-25.9667859	1458.24	Test pit
AD-TP73	28.90803889	-25.9670122	1458.24	Test pit
AD-TP71	28.90710903	-25.965225	1458.24	Test pit
AD-TP72	28.91450091	-25.9643485	1458.24	Test pit
AD-TP70	28.90666993	-25.9625784	1458.24	Test pit
AD-TP69	28.91186252	-25.9609733	1458.24	Test pit
AD-TP67	28.90721235	-25.9597927	1458.24	Test pit
AD-TP68	28.91064993	-25.9590958	1458.24	Test pit
AD 03	28.89840935	-25.9520206	1469.78	Test pit
AD 56	28.89881313	-25.953995	1478.15	Test pit
AD 05	28.89896104	-25.957395	1484.12	Test pit
AD 84	28.89938754	-25.960701	1493.19	Test pit
AD 07	28.89966633	-25.9641532	1498.00	Test pit
AD 47	28.90015238	-25.9662526	1505.15	Test pit
AD 80	28.90002819	-25.9695391	1510.36	Test pit
AD 88	28.90042437	-25.9728277	1510.47	Test pit
AD 10	28.90109905	-25.9754284	1514.00	Test pit
AD 21	28.90355208	-25.9754939	1512.39	Test pit
AD 20	28.90609677	-25.9756567	1511.96	Test pit
AD 31	28.90887894	-25.9756544	1511.23	Test pit
AD 87	28.9112342	-25.975856	1510.75	Test pit
AD 30	28.91395642	-25.9758636	1508.22	Test pit
AD 89	28.90110645	-25.9523165	1466.69	Test pit
AD 02	28.90120742	-25.9541331	1469.65	Test pit
AD 01	28.90137444	-25.9563088	1478.55	Test pit

Site Name	Xcoord	Ycoord	Zcoord	Site Type
AD 22	28.90163202	-25.9590954	1485.35	Test pit
AD 12	28.90206703	-25.9617264	1490.46	Test pit
AD 48	28.90240427	-25.9644935	1495.24	Test pit
AD 85	28.90285729	-25.9670073	1498.36	Test pit
AD 46	28.90304212	-25.9696327	1499.69	Test pit
AD 86	28.90409386	-25.9726333	1500.86	Test pit
AD 79	28.90733685	-25.9738396	1504.83	Test pit
AD 91	28.91148597	-25.9741875	1502.45	Test pit
AD 28	28.91405789	-25.9735942	1499.00	Test pit
AD 73	28.91622292	-25.9732044	1496.16	Test pit
AD 04	28.90536936	-25.9534729	1456.24	Test pit
AD 54	28.9105257	-25.953609	1473.93	Test pit
AD 98	28.9133712	-25.9538039	1480.20	Test pit
AD 23	28.91607231	-25.9543338	1486.88	Test pit
AD 64	28.91895224	-25.9547892	1493.54	Test pit
AD 32	28.9225738	-25.9553064	1502.04	Test pit
AD 94	28.92507346	-25.955173	1504.66	Test pit
AD 41	28.92724459	-25.9563223	1511.30	Test pit
AD 13	28.90408405	-25.9549846	1465.89	Test pit
AD 82	28.9045712	-25.9571469	1470.94	Test pit
AD 66	28.90481257	-25.9595735	1477.10	Test pit
AD 08	28.90505003	-25.9617662	1479.43	Test pit
AD 81	28.90546673	-25.9644965	1485.03	Test pit
AD 17	28.90572791	-25.9669141	1487.99	Test pit
AD 09	28.90582588	-25.9691444	1486.48	Test pit
AD 92	28.90660843	-25.9710237	1489.96	Test pit
AD 77	28.90898421	-25.9724311	1495.90	Test pit
AD 19	28.91201835	-25.9719482	1496.18	Test pit
AD 11	28.90663585	-25.9555616	1458.13	Test pit

Site Name	Xcoord	Ycoord	Zcoord	Site Type
AD 65	28.90708627	-25.9579222	1464.24	Test pit
AD 83	28.90819635	-25.960823	1467.65	Test pit
AD 06	28.90880839	-25.9626775	1475.96	Test pit
AD 78	28.90862115	-25.9646151	1481.31	Test pit
AD 74	28.90946935	-25.9668265	1488.11	Test pit
AD 75	28.909261	-25.9692862	1488.92	Test pit
PD RQ07	28.92120134	-25.9710381	1489.10	Test pit
PD RQ03	28.91905502	-25.9709367	1483.00	Test pit
AD 36	28.91801698	-25.9704167	1483.70	Test pit
PD RQ02	28.91995075	-25.9700418	1486.37	Test pit
PD RQ01	28.92081867	-25.9691301	1495.10	Test pit
AD 95	28.9197431	-25.9689351	1491.05	Test pit
AD 18	28.91274036	-25.9696793	1493.96	Test pit
AD 27	28.91497904	-25.9689108	1488.99	Test pit
AD 62	28.91651993	-25.9677194	1477.64	Test pit
AD 37	28.91909705	-25.9674319	1491.59	Test pit
AD 55	28.92230601	-25.9654619	1507.04	Test pit
AD 63	28.91853895	-25.9658017	1493.29	Test pit
AD 53	28.92365616	-25.9636433	1510.97	Test pit
AD 45	28.92477155	-25.962143	1513.27	Test pit
AD 39	28.92576095	-25.9602935	1516.54	Test pit
AD 42	28.92652108	-25.9585013	1517.54	Test pit
AD 50	28.92368298	-25.9605111	1514.01	Test pit
AD 38	28.92184448	-25.9624443	1510.41	Test pit
AD 70	28.91997857	-25.9639459	1503.73	Test pit
KBH03	28.91070146	-25.9674249	1491.70	Test pit
AD 26	28.91282022	-25.9673113	1491.31	Test pit
AD 16	28.91460217	-25.9661708	1481.69	Test pit
AD 29	28.91602938	-25.9653502	1475.09	Test pit

Site Name	Xcoord	Ycoord	Zcoord	Site Type
AD 93	28.91734461	-25.9644231	1490.52	Test pit
AD 76	28.91254122	-25.9650291	1484.52	Test pit
AD 61	28.91603388	-25.9632621	1487.00	Test pit
AD 35	28.91796495	-25.9626506	1498.69	Test pit
AD 59	28.9212982	-25.9603368	1512.68	Test pit
AD 43	28.92369799	-25.9590349	1515.54	Test pit
AD 40	28.92533114	-25.9573835	1513.31	Test pit
AD 72	28.9122256	-25.9629457	1475.83	Test pit
KBH02	28.91292453	-25.9621569	1468.87	Test pit
AD 25	28.91414015	-25.9625412	1470.47	Test pit
AD 90	28.91632019	-25.9606753	1494.60	Test pit
AD 34	28.91812976	-25.9599844	1503.29	Test pit
AD 60	28.91987189	-25.9588535	1509.29	Test pit
AD 44	28.92195696	-25.95788	1511.00	Test pit
AD 51	28.92388452	-25.9564674	1508.99	Test pit
AD 68	28.90994719	-25.9607899	1469.13	Test pit
AD 67	28.91224191	-25.9597863	1471.42	Test pit
AD 100	28.91402767	-25.9594558	1487.07	Test pit
AD 24	28.91623072	-25.9589487	1497.15	Test pit
AD 33	28.91822513	-25.9579401	1503.41	Test pit
AD 52	28.92126497	-25.9560264	1503.38	Test pit
AD 15	28.90875535	-25.9589703	1460.70	Test pit
AD 14	28.91018956	-25.9573848	1472.25	Test pit
AD 97	28.91233567	-25.9582371	1482.89	Test pit
AD 69	28.913933	-25.9568292	1488.03	Test pit
AD 58	28.91664371	-25.9567469	1497.31	Test pit
AD 96	28.91913557	-25.9561547	1500.49	Test pit
KBH01	28.90808262	-25.9564771	1456.91	Test pit
AD 99	28.90903234	-25.9552495	1469.17	Test pit

Site Name	Xcoord	Ycoord	Zcoord	Site Type
AD 57	28.91202115	-25.9556314	1481.73	Test pit
AD 49	28.9149254	-25.9551595	1488.33	Test pit
AD-TP78	28.91239185	-25.977326	-1.00	Test pit
AD-TP79	28.91645477	-25.978316	-1.00	Test pit
AD-TP80	28.92020874	-25.9791589	-1.00	Test pit
AD-TP81	28.92797976	-25.9780672	-1.00	Test pit
AD-TP82	28.93029087	-25.9768208	-1.00	Test pit
AD-TP83	28.92735396	-25.9701272	-1.00	Test pit
AD-TP84	28.92813998	-25.9629227	-1.00	Test pit
AD-TP85	28.92935506	-25.9597148	-1.00	Test pit