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Leeuwpan Coal Mine
2019 Integrated Water and Waste Management Plan Update

Report

Version – Final

12 June 2019

Exxaro Resources Ltd

GCS Project Number: 19-0504

Client Reference: PO: 4512331767



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EXECUTIVE SUMMARY

Exxaro Leeuwpan Coal Mine (Leeuwpan) began as an Iscor Mine in 1991, doing extensive exploration with the first box-cut commencing in 1992. Leeuwpan is currently an operational mine and became known as Exxaro Leeuwpan Coal Mine in 2007. Leeuwpan is located 10 kilometres (km) south east of Delmas, in the Victor Khanye Local Municipality. The mine falls within the Nkangala District Municipality in the Mpumalanga Province.

Leeuwpan is situated in the upper reaches of the Bronkhorstspruit catchment in quaternary catchment B20A. In compliance with the National Water Act, 1998 (Act No. 36 of 1998) (NWA), the Department of Water and Sanitation (DWS) issued an Integrated Water Use Licence (IWUL) to Leeuwpan (Licence No. 04/B21A/ABCGIJ/429) on the 25th March 2011. The IWUL was issued for various water uses being undertaken on site in terms of Section 21 of the NWA. The license was issued for the following water uses:

- Section 21(a) – Taking of water from a water resource;
- Section 21(b) – Storing of Water;
- Section 21(c) – Impeding or diverting the flow of water in a watercourse;
- Section 21(g) – Disposing of waste in a manner which may detrimentally impact on a water resource;
- Section 21(i) – Altering the bed, banks, course or characteristics of a watercourse; and
- Section 21(j) – Removing, discharging or disposing of water found underground.

An amendment to the IWUL for Leeuwpan was also issued in terms of Section 50 and Section 158 of the NWA on the 18th December 2015. This amendment was issued to amend / correct water uses licensed as part of the IWUL issued on the 25th March 2011. The following water uses in terms of Section 21 of the NWA were amended:

- Section 21(a) – Taking of water from a water resource;
- Section 21(c) – Impeding or diverting the flow of water in a watercourse;
- Section 21(g) – Disposing of waste in a manner which may detrimentally impact on a water resource;
- Section 21(i) – Altering the bed, banks, course or characteristics of a watercourse; and
- Section 21(j) – Removing, discharging or disposing of water found underground.

In addition, an Integrated Water Use Licence Application (IWULA) for the mining Block OI and OL Expansion was applied for as a separate application. The IWUL was awarded to Leeuwpan (Licence No. 04/B20A/CIJ/4032) on the 18th December 2015. The IWUL was issued for various

water uses required for the expansion project in terms of Section 21 of the NWA. The license was issued for the following water uses:

- Section 21(a) – Taking of water from a water resource;
- Section 21(c) – Impeding or diverting the flow of water in a watercourse;
- Section 21(g) – Disposing of waste in a manner which may detrimentally impact on a water resource;
- Section 21(i) – Altering the bed, banks, course or characteristics of a watercourse; and
- Section 21(j) – Removing, discharging or disposing of water found underground.

It is proposed that the mining Block OI will be expanded to include the area where planned infrastructure would have originally been located. This expansion area is referred to as OI West. Water uses for this expansion are triggered in terms of Section 21(c) and (i) of the NWA. The Integrated Water Use License Application (IWULA) to authorise the new water uses triggered for OI West is currently being applied for as a separate application to the DWS.

Opencast mining started on the farm Witklip in 1994. According to the mine's personnel, available coal reserves that are currently being mined include Blocks OI, OL, OMW and Weltevreden. Weltevreden, Moabsvelden (MBV), Block OJ and OL are earmarked for void closure rehabilitation. Block OJ is currently being backfilled and is expected to be finalised by end of 2019. The areas that are earmarked for shaping and grassing include Weltevreden, Moabsvelden, ODS, OG, OJ, Witklip and the Discard Workshop.

In terms of Condition 11.2 of Appendix IV of the IWULs issued for the existing (Licence No. 04/B21A/ABCGIJ/429) and new (Licence No. 04/B20A/CIJ/4032) operations at Leeuwpan Mine, the following is required to be undertaken:

- The Integrated Water and Waste Management Plan (IWWMP) and Rehabilitation Strategy and Implementation Plan (RSIP) shall thereafter be updated and annually submitted to the Regional Head for approval.

This report serves as the 2019 IWWMP update for the existing and new Leeuwpan operations required as per the licence conditions. This IWWMP update has been compiled as per the IWUL conditions of Licence No. 04/B21A/ABCGIJ/429 and its associated amendment as well as Licence No. 04/B20A/CIJ/4032. This report also provides the RSIP 2018 update compiled by Leeuwpan. The RSIP update serves to satisfy the respective licence conditions as stipulated above as well as the other environmental authorisations of the mine.

Current Mining:

Mining at Leeuwpan is carried out by opencast methods, involving blasting and truck and shovel operations. Leeuwpan is an existing coal mining operation with existing infrastructure associated with the following mining areas:

- Block OMW;
- Weltevreden;
- Block OL; and
- Block OI

Potential Environmental Impacts:

The impacts identified as a result of mining activities were found to be moderate in terms of significance as mitigation measures could be implemented to address these impacts.

A risk assessment was conducted based on the policies of the mine and the risks that the mining operation poses to the environment (with specific reference to surface- and groundwater). A management plan on how to deal with the risks was developed in order to mitigate these impacts. This plan relates to the management of water and waste and is reviewed on a continuous basis to achieve the best water and waste management practices necessary for the mining operation.

Public Participation Process:

The public participation process is not a legislative requirement for the IWWMP update. However, information is provided on the process undertaken during the previous Environmental Management Plan (EMP) Addendums and IWULAs. The purpose of its inclusion in the document is to indicate that Leeuwpan does recognise the importance of involving the public and stakeholders in all activities that may affect Interested and Affected Parties (I&APs).

Integrated Water and Waste Management Plan:

This IWWMP document includes the existing and new opencast mining activities being undertaken at Leeuwpan Mine. The main purpose of this IWWMP is to present all the various site-specific activities such as water balances, storm water management, water reuse, water conservation, waste minimisation and recycling into a simple implementable management plan.

The IWWMP takes into account the stresses in the Water Management Area (WMA) due to mining activities and other waste discharge and disposal activities.

The IWWMP is therefore a living document that will be revised and updated throughout the life of the operations to accommodate additional information and improved technologies. These will ensure that water and waste management is continually optimised and adapted to the changing needs of the mine and the WMA.

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1 INTRODUCTION

1.1 Activity Background

Exxaro Leeuwpan Coal Mine (Leeuwpan) began as an Iscor Mine in 1991, doing extensive exploration with the first box-cut commencing in 1992. Leeuwpan is currently an operational mine and became known as Exxaro Leeuwpan Coal Mine in 2007. Leeuwpan is located between 10 kilometres (km) south east of Delmas, in the Victor Khanye Local Municipality. The mine falls within the Nkangala District Municipality in the Mpumalanga Province.

Leeuwpan is an operational coal mine that has been operating in line with several approved Environmental Management Plans (EMP's). These EMP's were submitted to and approved by the Department of Mineral resources (DMR). As a result of the authorisations issued, Leeuwpan is a lawful mining operation in terms of the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA).

Leeuwpan is situated in the upper reaches of the Bronkhorstspruit catchment in quaternary catchment B20A. In compliance with the National Water Act, 1998 (Act No. 36 of 1998) (NWA), the Department of Water and Sanitation (DWS) issued an Integrated Water Use Licence (IWUL) to Leeuwpan (Licence No. 04/B21A/ABCGIJ/429) on the 25th March 2011.

An amendment to the IWUL for Leeuwpan was also issued in terms of Section 50 and Section 158 of the NWA on the 18th December 2015. This amendment was issued to amend / correct water uses licensed as part of the IWUL issued on the 25th March 2011.

Leeuwpan extended its mining operations to include Portions 1 and 2 on the Farm Rietkuil 249 IR and Portion 3 of the Farm Moabsvelden 248 IR, referred to as Block OI and OL. These farms are located within the approved mining right area of the mine and have been applied to be mined to the Mpumalanga Department of Agriculture, Rural Development, Land & Environmental Affairs (MDARDLEA), formerly Mpumalanga Department of Economic Development, Environment and Tourism (MDEDET) (reference number: 17/2/3N-180) and the Department of Mineral Resources (DMR) [reference number: MP 30/5/1/2/3/2/1 (171) EM]. Environmental Authorisation for these mining activities has been received by the MDARDLEA. Approval for the EMP from the DMR was granted on the 25th of April 2017.

The respective Integrated Water Use Licence Application (IWULA) for the Block OI and OL Expansion was applied for as a separate application. The IWUL was issued for various water uses proposed to be undertaken on site in terms of Section 21 of the NWA (Licence No. 04/B20A/CIJ/4032 dated 18th December 2015).

It is proposed that the mining Block OI will be expanded to include the area where planned infrastructure would have originally been located. This expansion area is referred to as OI West. Water uses for this expansion are triggered in terms of Section 21(c) and (i) of the NWA. The Integrated Water Use License Application (WIULA) to authorise the new water uses triggered for OI West is currently being applied for as a separate application to the DWS.

This report serves as the 2019 IWWMP update for the existing and new Leeuwpan operations required as per the licence conditions. This IWWMP update has been compiled as per the IWUL conditions of Licence No. 04/B21A/ABCGIJ/429 and its associated amendment as well as Licence No. 04/B20A/CIJ/4032. This report also provides the RSIP 2018 update compiled by Leeuwpan (Annexure A). The RSIP update serves to satisfy the respective licence conditions as stipulated above as well as the other environmental authorisations of the mine.

1.2 Contact Details

The contact details of the mine and the consultant compiling this IWWMP update can be seen in Table 1.1.

Table 1.1 Contact Details

Contact Details of the Applicant	
Name of the Company	Exxaro Resources Limited
Name of the Mine	Leeuwpan Coal Mine
Physical Address	R50 Delmas
Postal Address	PO Box 9229 Pretoria 0001
Telephone	(011) 441-6800
Fax Number	(011) 268 6734
Contact Person	Lucy Mogakane (Leeuwpan Mine Environmental Practitioner) Lucy.mogakane@exxaro.com
Contact Details of the Environmental Consultant	
Name of the Company	GCS Water and Environment (Pty) Ltd
Physical Address	63 Wessel Road, Rivonia, 2128
Postal Address	P.O. Box 2597, Rivonia, 2128
Telephone	(011) 803 5726
Fax Number	(011) 803 5745
Contact Person	Kate Cain (Water Use Authorisation Unit Manager) kate@gcs-sa.biz Shayna-Ann Cuthbertson (Water Use Authorisation Consultant) shaynac@gcs-sa.biz

1.3 Regional Setting and Location of Activity

The Leeuwpan Mining Right Area (MRA) is located approximately 10km south east of Delmas. The MRA is adjacent to Ferroglobe (formerly Thaba Chueu) Silica Mine and Stuart Coal. Refer to Figure 1.1 for the map indicating the location of the project area.

1.3.1 Magisterial District and Local Municipality

The project area is situated within the Nkangala District Municipality in the Victor Khanye Local Municipality. The municipal boundaries are indicated on Figure 1.2.

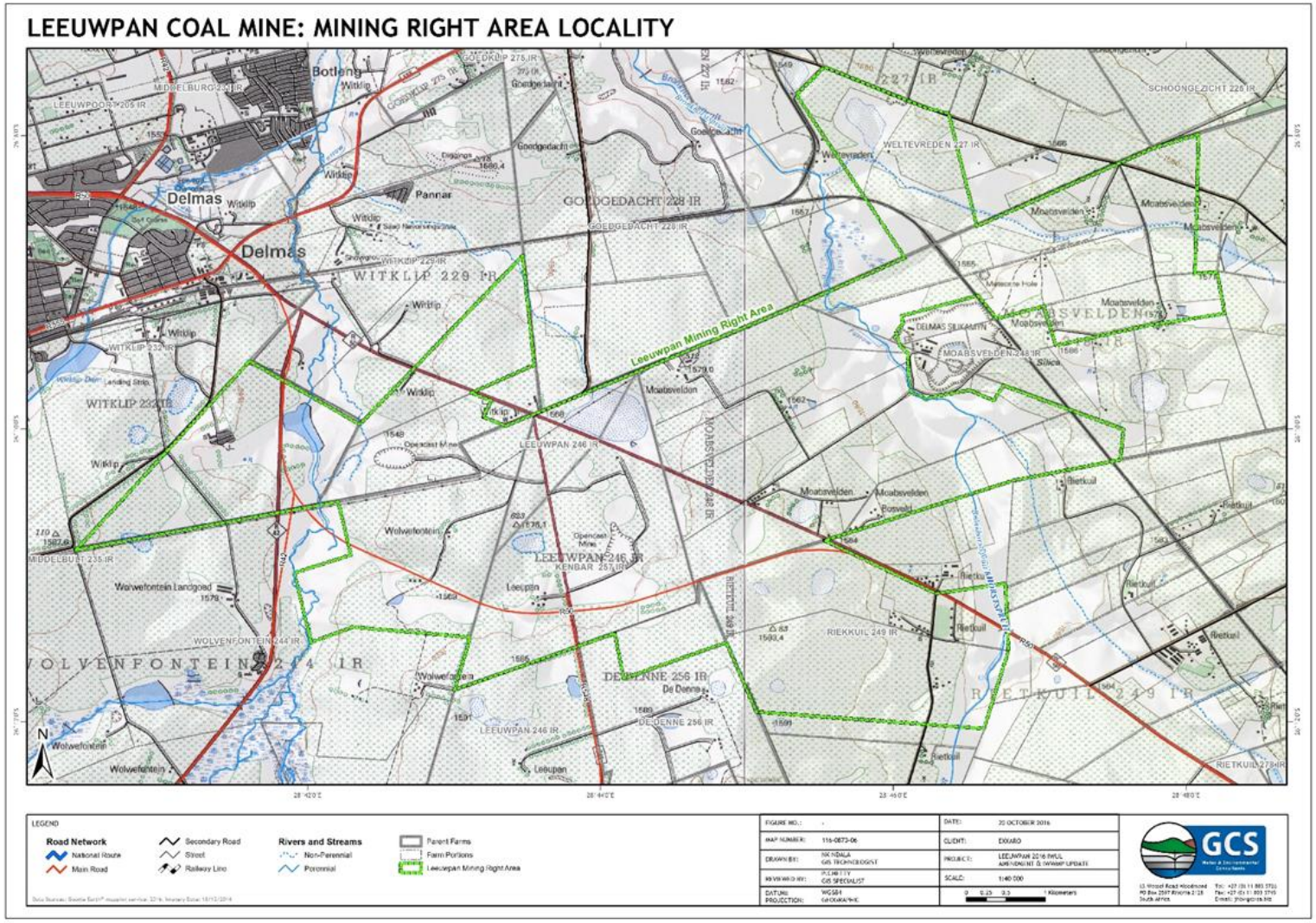


Figure 1.1 Locality Map

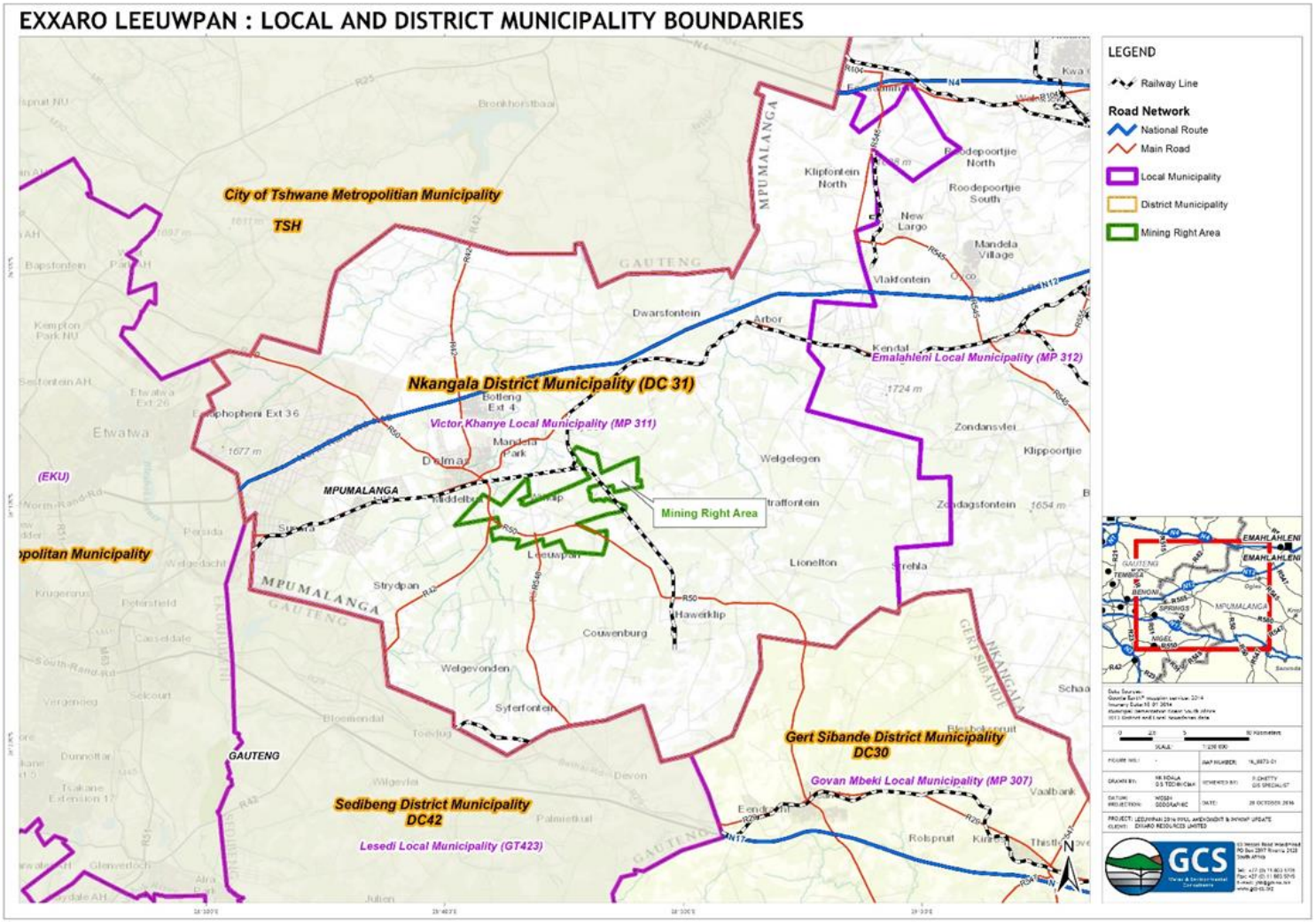


Figure 1.2 Locality within the Municipal Boundaries

1.4 Property Description

The MRA comprises eight (8) farms, namely Kenbar 257 IR, Leeuwpan 246 IR, Moabsvelden 248 IR, Weltevreden 227 IR, Witklip 229 IR, Witklip 232 IR, Wolvenfontein 244 IR and Rietkuil 249. Nine mineral resource blocks have been mined or are in the process of being mined.

Three Mineral resource blocks, located on Rietkuil 249 IR, Moabsvelden 248 IR and Wolvenfontein 244 IR are currently being mined. The property details for the MRA were obtained from the government deeds website (www.deeds.gov.za). The majority of the surface rights are privately owned.

Current infrastructure is located on the following farm portions (Table 1.2). The property boundaries in relation to the MRA are provided in Figure 1.3.

Table 1.2 Farm portions related to existing infrastructure

SG Number	Farm	Portion	Owner detail
T0IR00000000025700000	KENBAR 257	Portion 0	Exxaro Coal Pty Ltd
T0IR00000000024600003	LEEUWPAN 246	Portion 3	Exxaro Coal Pty Ltd
T0IR00000000024800001	MOABSVELDEN 248	Portion 01	Gouws Louis
T0IR00000000024800002	MOABSVELDEN 248	Portion 02	Exxaro Coal Pty Ltd
T0IR00000000024800003	MOABSVELDEN 248	Portion 03	Exxaro Coal Pty Ltd
T0IR00000000024800004	MOABSVELDEN 248	Portion 04	Phillem Beleggings Pty Ltd
T0IR00000000024800005	MOABSVELDEN 248	Portion 05	Exxaro Coal Pty Ltd
T0IR00000000024800006	MOABSVELDEN 248	Portion 06	Exxaro Coal Pty Ltd
T0IR00000000024800010	MOABSVELDEN 248	Portion 10	Exxaro Coal Pty Ltd
T0IR00000000024800012	MOABSVELDEN 248	Portion 12	Exxaro Coal Pty Ltd
T0IR00000000024800013	MOABSVELDEN 248	Portion 13	Exxaro Coal Pty Ltd
T0IR00000000024800016	MOABSVELDEN 248	Portion 16	Exxaro Coal Pty Ltd
T0IR00000000024800027	MOABSVELDEN 248	Portion 27	Transnet Ltd
T0IR00000000024800030	MOABSVELDEN 248	Portion 30	Transnet Ltd
T0IR00000000024800032	MOABSVELDEN 248	Portion 32	Transnet Ltd
T0IR00000000022700007	WELTEVREDEN 227	Portion 07	Exxaro Coal Pty Ltd
T0IR00000000022700037	WELTEVREDEN 227	Portion 37	Transnet Ltd
T0IR00000000022900004	WITKLIP 229	Portion 04	Exxaro Coal Pty Ltd
T0IR00000000022900006	WITKLIP 229	Portion 06	Hendrik Schoeman & Seuns Pty Ltd
T0IR00000000023200113	WITKLIP 232	Portion 113	Eskom Holdings Ltd
T0IR00000000023200016	WITKLIP 232	Portion 16	Hendrik Schoeman & Seuns Pty Ltd
T0IR00000000024400003	WOLVENFONTEIN 244	Portion 03	Endorsement: Exxaro Coal Pty Ltd

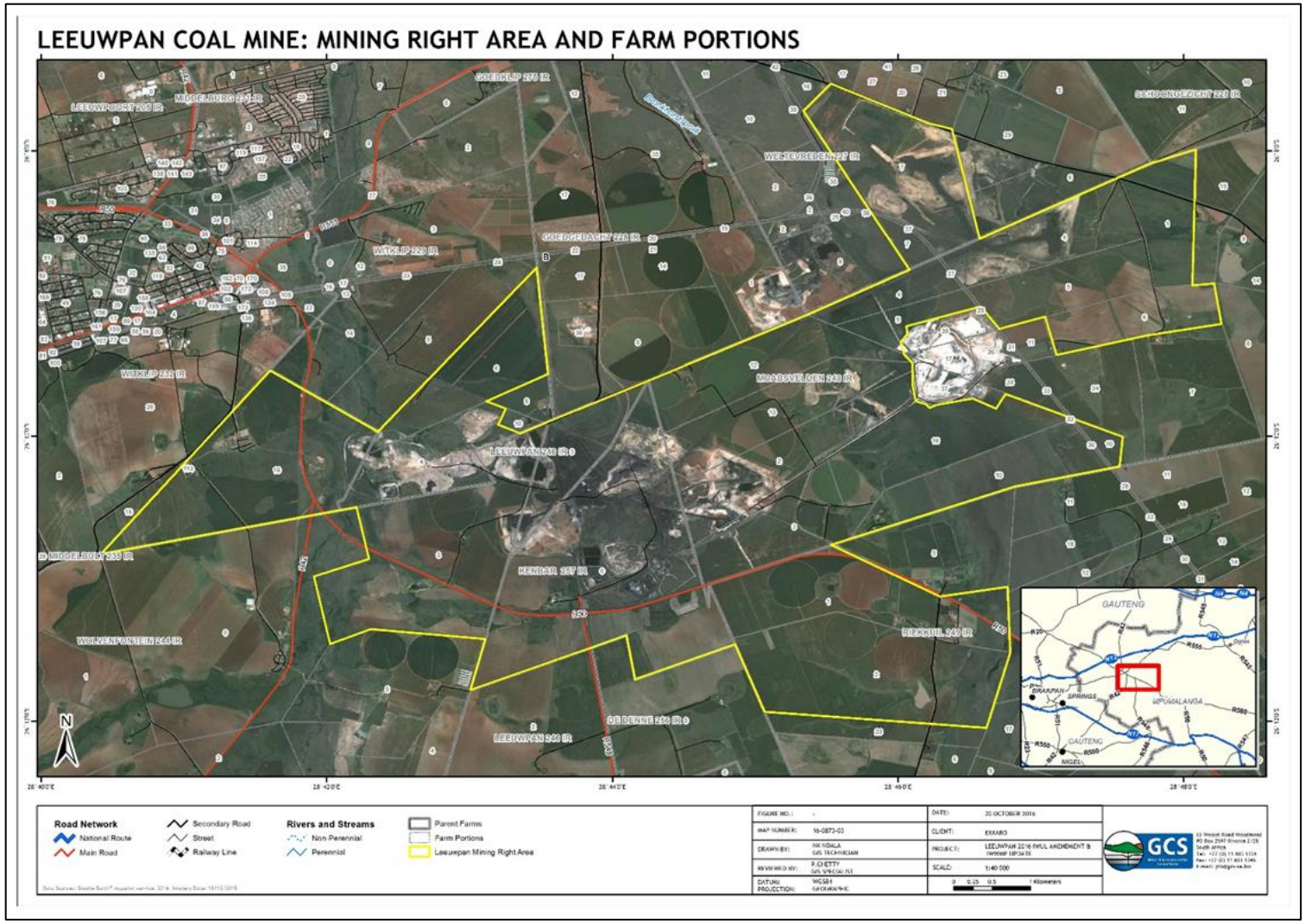


Figure 1.3 Leeuwpan MRA Property Boundaries

1.5 Purpose of the IWWMP

The purpose of the IWWMP includes:

- Compilation of a site specific, implementable, management plan addressing all the identified water use and waste management relates aspects of a specific activity, in order to meet set goals and objectives in accordance with Integrated Water Resource Management (IWRM) principles;
- Provision of a management plan to guide the water user regarding the water and waste related measures which must be implemented on site in a progressive, structures manner in the short, medium and long term;
- Documentation of all the relevant information, as specified in the IWWMP Guideline as compiled by the DWS, to enable DWS to make a decision regarding the authorisation of a water use;
- Clarification of the content of the IWWMP for DWS officials and the water users, as the various regional offices of DWS might have different interpretations regarding the contents of the IWWMP;
- Standardisation of the format of supporting documentation which DWS requires during the submission of a WULA;
- Provision of guidance on the content of information required in an IWWMP as part of the water use authorisation process and level of detail that DWS requires to enable them to evaluate the supporting documentation to make a decision on authorising a water use; and
- Ensuring that a consistent approach is adopted by DWS and the various Regional Offices and Catchment Management Agencies (CMA) with regards to IWWMPs.

The IWWMP also strives to show the DWS that the selected management measures included into the IWWMPs action plan adhere to the SMART concept which refers to:

- S – Sustainable;
- M – Measureable;
- A – Achievable;
- R – Resources Allocated; and
- T – Timeframe Specific.

2 CONCEPTUALISATION OF THE ACTIVITY

2.1 Description of the Activity

2.1.1 Existing Operations

Leeuwpan is an existing coal mining operation with existing infrastructure associated with the following mining areas:

- Block OMW;
- Weltevreden;
- Block OL; and
- Block OI

Opencast mining started on the farm Witklip in 1994. According to the mine's personnel, available coal reserves that are being mined include Blocks OI (Figure 2.1), OL, OMW and Weltevreden. Weltevreden, Moabsvelden (MBV), Block OJ and OL are earmarked for void closure rehabilitation. Block OJ is currently being backfilled and is expected to be finalised by end of 2019. The areas that are earmarked for shaping and grassing include Weltevreden, Moabsvelden, ODS, OG, OJ, Witklip and Discard Workshop. The approved, existing and proposed mining sections in relation to the MRA of Leeuwpan are presented in Figure 2.2.



Figure 2.1 Block OI box-cut

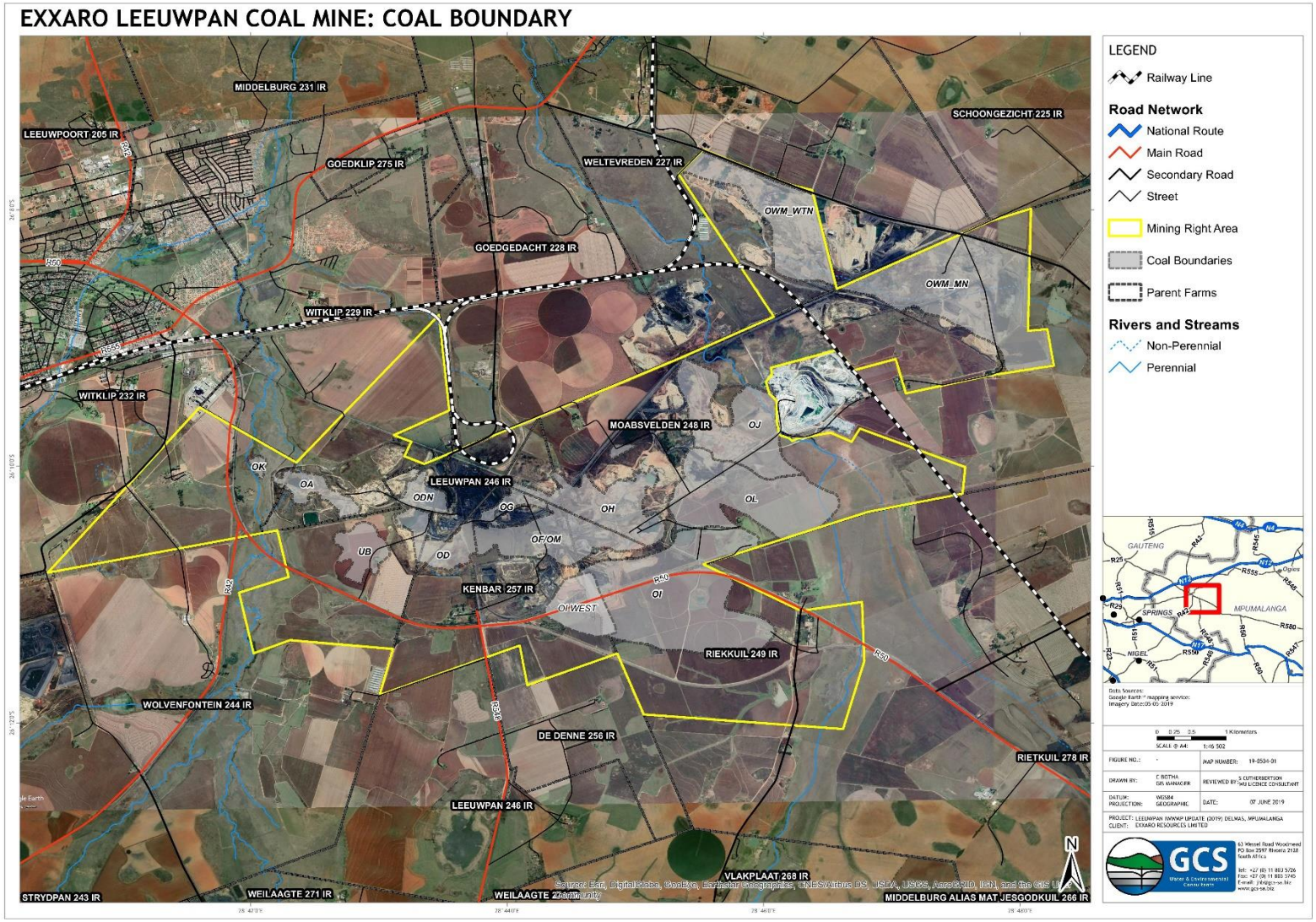


Figure 2.2 Mining Right Area and Mining Sections

2.2 Extent of the Activity

All activities relating to the mining activities take place within the approved MRA of Leeuwpan. The operations at Leeuwpan Coal spread over 4 256ha, of which the majority is comprised of mining areas (operational, rehabilitated and proposed mining areas), such as box-cuts, dams and stockpiled material. The remaining areas comprise of the Beneficiation Plant, as well as workshops and administration blocks which belong to both Exxaro Resources Limited as well as the appointed contractors.

2.3 Key Activity Related Processes and Product

2.3.1 Mining Method

Opencast coal mining techniques are used at Leeuwpan Mine to produce steam and metallurgical grade coal. Coal is selectively mined using a modified terrace method with a fleet of 100 ton class hydraulic excavators and 40 ton articulated dump trucks. The reserves are mined using the drilling, blasting, loading and hauling with truck and shovel, excavator and fleet methods. Once the coal has been mined it is transported to the plant area for processing.

2.3.2 Mineral Processing

Currently the coal distribution consists of a crusher plant and a washer to refine the coal by means of a wet process. A Final Phase Coal Processing Plant is used for washing and sorting. The Interim Phase processing plant has been dismantled and removed from the site. The final phase processing plant consists of two Dense Medium Separation (DMS) plants (operated by Frazer Alexander and one by Exxaro) and crush and stack plant (operated by B&E).

The Processing Plant area consists of various areas, such as the:

- Beneficiation plant;
- Run of Mine (ROM) Stockpiles;
- Crush and screening plant;
- Product stockpiles;
- Filter press;
- Pollution Control Dams (PCD);
- Laboratories; and
- Plant offices and control room.

2.3.2.1 Existing beneficiation plant:

The Beneficiation Plant consists of a Crushing and Washing Plant. Process water, consisting of groundwater ingress into the pits and make-up water from boreholes, is used at the Beneficiation Plant.

Process water is used on a continuous basis and is proportional to the amount of coal that is being washed per day. No significant daily fluctuations exist in the use of water on the mine. The Beneficiation Plant operates 24 hours a day for 313 days per year.

2.3.3 Product

The niche market for the mine is the production of low volatile coal. From the plant the processed coal is transported via conveyors to the load out area siding. The final coal product is transported by means of railroad to the different work centres or via road transport to other markets. Road transport is handled by means of a weighbridge.

2.4 Activity Life Description

Due to the mining of Block OI, the Life of Mine (LOM) will be extended by an extra 13 years from 2018. The life of mine has been determined by the availability of the coal resource that can be mined within the mining right area. Refer to Table 2.1 for the life of mine schedule.

Table 2.1 Mine Schedule

Mine Block / Pit	Mining Dates		Current Status	Scheduled Life of Mine
	Start Date	End Date		
OA Witklip	1996	Mar-2005	Decommissioned	-
ODN	May-2008	Sep-2010	Decommissioned	-
OE Midklip	1998	Jun-1999	Decommissioned	-
OF Kenbar	1992	Mar-2004	Decommissioned	-
ODS	Mar-2004	2014	Decommissioned	-
OM	Dec-1999	2014	Decommissioned	-
OH	Sep-2002	2016	Decommissioned	-
OG	Sep-2006	Jul-2011	Decommissioned	-
OJ	Oct-2008	2018	Decommissioned	-
OWM_WTN	Sep-2011	2017	Decommissioned	-
OWM_MN	Dec-2008	-	In Operation	2020
OL	2018	-	In Operation	2024
OI	2018	-	In Operation	2030
UB	-	-	Planned future mining	2024 - 2029

2.5 Activity Infrastructure Description

2.5.1 Existing and operational Infrastructure

As previously stated, Leeuwpan mine is an operational mine that has been operating in line with several approved EMPs. Infrastructure approved under the MPRDA at Leeuwpan is detailed in the sections that follow for each of the mining areas. Each table indicates what infrastructure still exists and what has been removed. Figure 2.3 shows the existing infrastructure of Leeuwpan Coal Mine.

2.5.1.1 Kenbar and Witklip

Table 2.2 indicates infrastructure and facilities approved under the MPRDA associated with the original EMP for Kenbar and Witklip.

Table 2.2 Kenbar/Witklip approved infrastructure from Original EMP

Activity / structure	Still existing
Discharge silo and conveyor band across the Delmas – Leandra road	No
Equipment workshop	Yes
Coal mixing bed and off-load facilities	Yes
Railroad of ± 3 km for the transport of coal from Leeuwpan	Yes
Weighbridge for the road transport	Yes
Ablution block and administration offices	Yes
A linking road with the R 50 route (between Delmas and Leandra) including security buildings	No
A linking road with the P 36-2 route between Delmas and Devon	No
Pit water dam and silt dams	No
Evaporation ponds	Yes
Additional storm water control measures (berms)	Yes
Electricity supply network	Yes
Closed water network for process water	Yes
Potable water supply via pipeline	Yes
Sewerage infrastructure	Yes
River diversion	Yes
Mining of Kenbar and Witklip sections	Yes – not operational

2.5.1.2 Block OE

A number of changes with regards to environmental management, particularly with respect to water management, came about at Leeuwpan Coal Mine during 1997. Approved activities and infrastructure under the MPRDA are indicated in Table 2.3.

Table 2.3 Block OE Activity/Infrastructure approved under MPRDA

Activity / structure	Still existing
Discharge of excess water into an unnamed tributary of the Bronkhorstspruit	No
Demolition of old plant (interim phase plant)	No
New plant (final phase plant)	Yes
Opencast block (Block OE)	Yes – not operational

Activity / structure	Still existing
River diversion	Yes

2.5.1.3 Blocks OD, OFPAD, OH and OM

The mining of Block OM, Block OH, Block OFPAD and Block OD involved the extension of the existing mining operation and Table 2.4 indicates the activities / infrastructure approved under the MPRDA that were added during the process.

Table 2.4 OM, OH, OFPAD and OD approved Infrastructure / Activities under the MPRDA

Activity / structure	Still existing
Extension of existing haul roads to Block OM, Block OH as well as Block OFPAD and Block OD	Yes
Relocation of the 11 kV powerlines and associated mini substations	Yes
Clean and dirty water systems around the mining area of Block OM, Block OH, Block OFPAD and Block OD	Yes
Road diversions and associated infrastructure	Yes
Mining activities	Yes

2.5.1.4 Block OJ and OL

The Addendum 4 EMP was compiled for the extension of Block OJ and OL on the Farm Moabsvelden 248 IR. Infrastructure and activities that was approved under the MPRDA in the proposed extension are shown in Table 2.5. As mentioned previously it was agreed in consultation with Mpumalanga Department of Land Administration (MDALA), since all activities are directly related to mining, that it was not be necessary to obtain authorisation in terms of the EIA Regulations. Block OJ is currently being backfilled and is expected to be finalised by end of 2019.

Table 2.5 OJ, OL Extension Infrastructure / Activity approved under the MPRDA

Activity / structure	Still existing
Infrastructure in the one in ten year flood line of a river or stream, or within 32 meters of the bank of a river or stream	Yes
The construction of a road that is wider than 4m	Yes
Development activity, including associated structure or infrastructure.	Yes
Mining of mining blocks	Yes

2.5.1.5 OD, OI and OWM

In 2006 an EIA/EMP was compiled for Kumba Coal for the mining of an extension of the existing Block OD on the farm Wolvenfontein 244 IR; and Block OI to be mined underground on the farm Rietkuil 249 IR.

Block OI however, has not been mined yet and only a box-cut has been established. Table 2.6 shows the infrastructure and activities approved under the MPRDA for the OD mining area.

As mentioned previously it was agreed in consultation with MDALA, since all activities are directly related to mining, that it was not be necessary to obtain authorisation in terms of the EIA Regulations.

Table 2.6 OD Infrastructure/Activities

Activity / structure	Still existing
Topsoil and overburden stockpiles	Yes
RoM stockpile	Yes
Storm water diversion channels	Yes
Expansion of existing haul roads	Yes
Pollution water management system	Yes
Water supply system	Yes
Ablution facilities	Yes
Diesel fuel tank	Yes
Workshop	Yes
Site offices	Yes
Explosives magazine	Yes
Mining of OD	Yes

In 2006 an EIA/EMP was also compiled for the mining of Block OWM on the farms Weltevreden 227 IR and Moabsvelden 248 IR. Table 2.7 below shows the approved infrastructure (under the MPRDA) associated with the proposed mining of Block OWM.

Table 2.7 OWM Infrastructure/Activities

Activity / structure	Still existing
Topsoil and overburden stockpiles	Yes
ROM stockpile	Yes
Water pollution management system	Yes
Storm water diversion measures, including the proposed stream alteration	Yes
Water supply system	Yes
Haul road and access roads	Yes
Portable ablution facilities	Yes
Diesel fuel tank	Yes
Temporary workshop	Yes
Portable site office	Yes
Explosives magazine	Yes
Mining of OWM	Yes

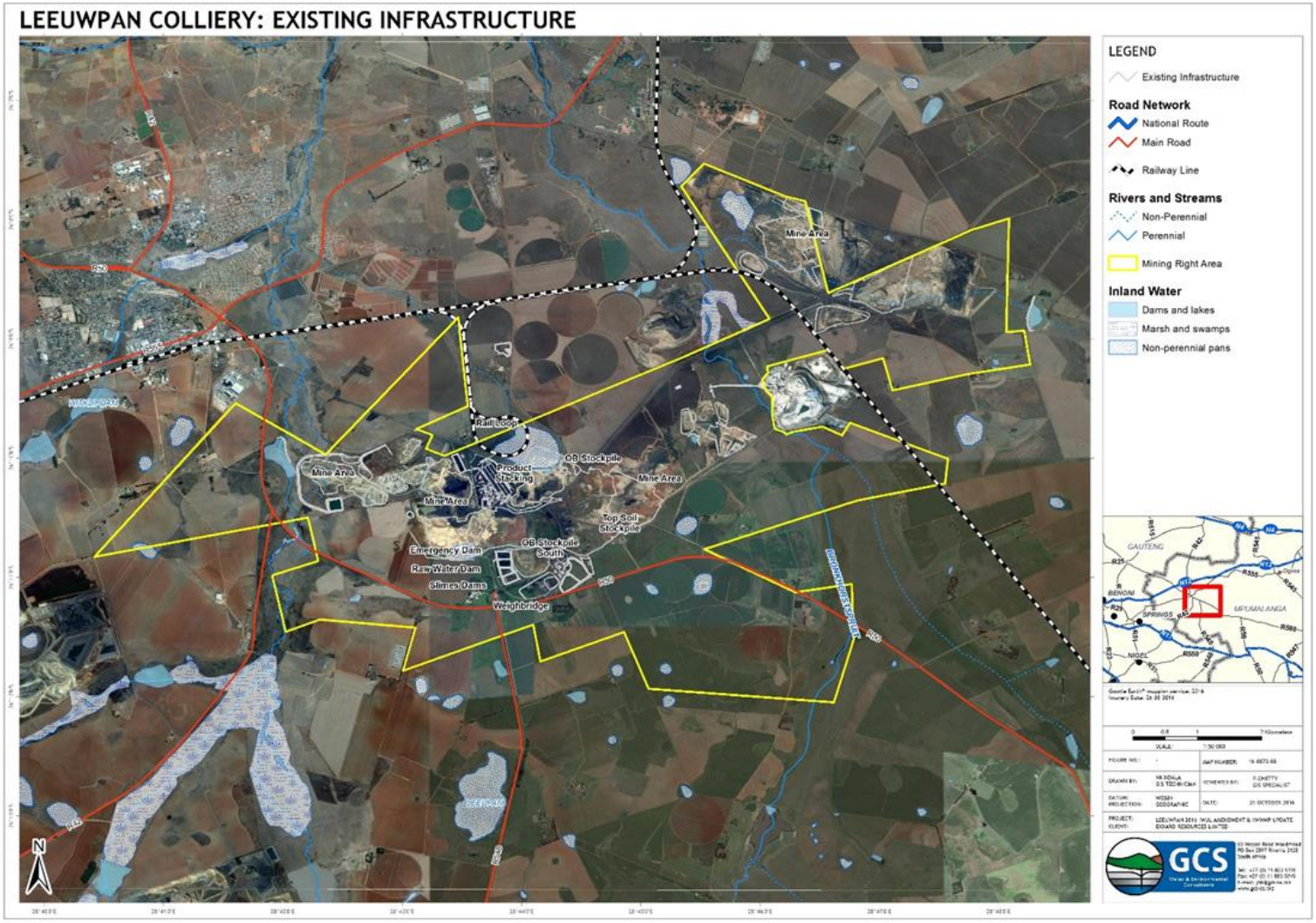


Figure 2.3 Existing Infrastructure at Leeuwpan Mine

2.6 Key Water Uses and Waste Streams

2.6.1 Key Water Uses

Leeuwpan was issued with an IWUL on the 25th March 2011 (Licence No. 04/B21A/ABCGIJ/429). The IWUL was issued for various water uses being undertaken on site in terms of Section 21 of the NWA. The license was issued for the following water uses:

- Section 21(a) – Taking of water from a water resource;
- Section 21(b) – Storing of Water;
- Section 21(c) – Impeding or diverting the flow of water in a watercourse;
- Section 21(g) – Disposing of waste in a manner which may detrimentally impact on a water resource;
- Section 21(i) – Altering the bed, banks, course or characteristics of a watercourse; and
- Section 21(j) – Removing, discharging or disposing of water found underground

An amendment to the IWUL for Leeuwpan was also issued in terms of Section 50 and Section 158 of the NWA on the 18th December 2015. This amendment was issued to amend / correct water uses licensed as part of the IWUL issued on the 25th March 2011. The following water uses in terms of Section 21 of the NWA were amended:

- Section 21(a) – Taking of water from a water resource;
- Section 21(c) – Impeding or diverting the flow of water in a watercourse;
- Section 21(g) – Disposing of waste in a manner which may detrimentally impact on a water resource;
- Section 21(i) – Altering the bed, banks, course or characteristics of a watercourse; and
- Section 21(j) – Removing, discharging or disposing of water found underground

In addition, an Integrated Water Use Licence Application (IWULA) for the Block OI and OL Expansion was applied for as a separate application. The IWUL was awarded to Leeuwpan (Licence No. 04/B20A/CIJ/4032) on the 18th December 2015. The IWUL was issued for various water uses being undertaken on site in terms of Section 21 of the NWA. The license was issued for the following water uses:

- Section 21(a) – Taking of water from a water resource;
- Section 21(c) – Impeding or diverting the flow of water in a watercourse;
- Section 21(g) – Disposing of waste in a manner which may detrimentally impact on a water resource;
- Section 21(i) – Altering the bed, banks, course or characteristics of a watercourse; and

- Section 21(j) – Removing, discharging or disposing of water found underground.

It is proposed that the mining Block OI will be expanded to include the area where planned infrastructure would have originally been located. This expansion area is referred to as OI West. Water uses for this expansion are triggered in terms of Section 21(c) and (i) of the NWA. The IWULA to authorise the new water uses triggered for OI West is currently being applied for as a separate application to the DWS.

Refer to Section 3 for detailed information regarding the water uses for Leeuwpan Mine.

2.6.2 Key Waste Streams

The waste streams associated with the Leeuwpan mining operation are limited to coal discard, polluted mine water, sewage, hydrocarbon wastes, and general waste. These include:

- Mine Residue Deposit (MRD), which includes:
    - Carbon-carrying shales;
    - Plant residue; and
    - Fine coal recovered from the slimes dams.
- Polluted mine water, which includes the various pollution control dams (PCDs);
- Hydrocarbon waste such as oil, diesel & grease; and
- General waste which is limited to domestic and commercial waste.

Refer to Section 5.2.4 of this report for more details pertaining to the waste generated on site and the management thereof.

2.7 Organisational Structure of the Activity

Please refer to Figure 2.4 for the Organisational Structure relating to Leeuwpan Mine.

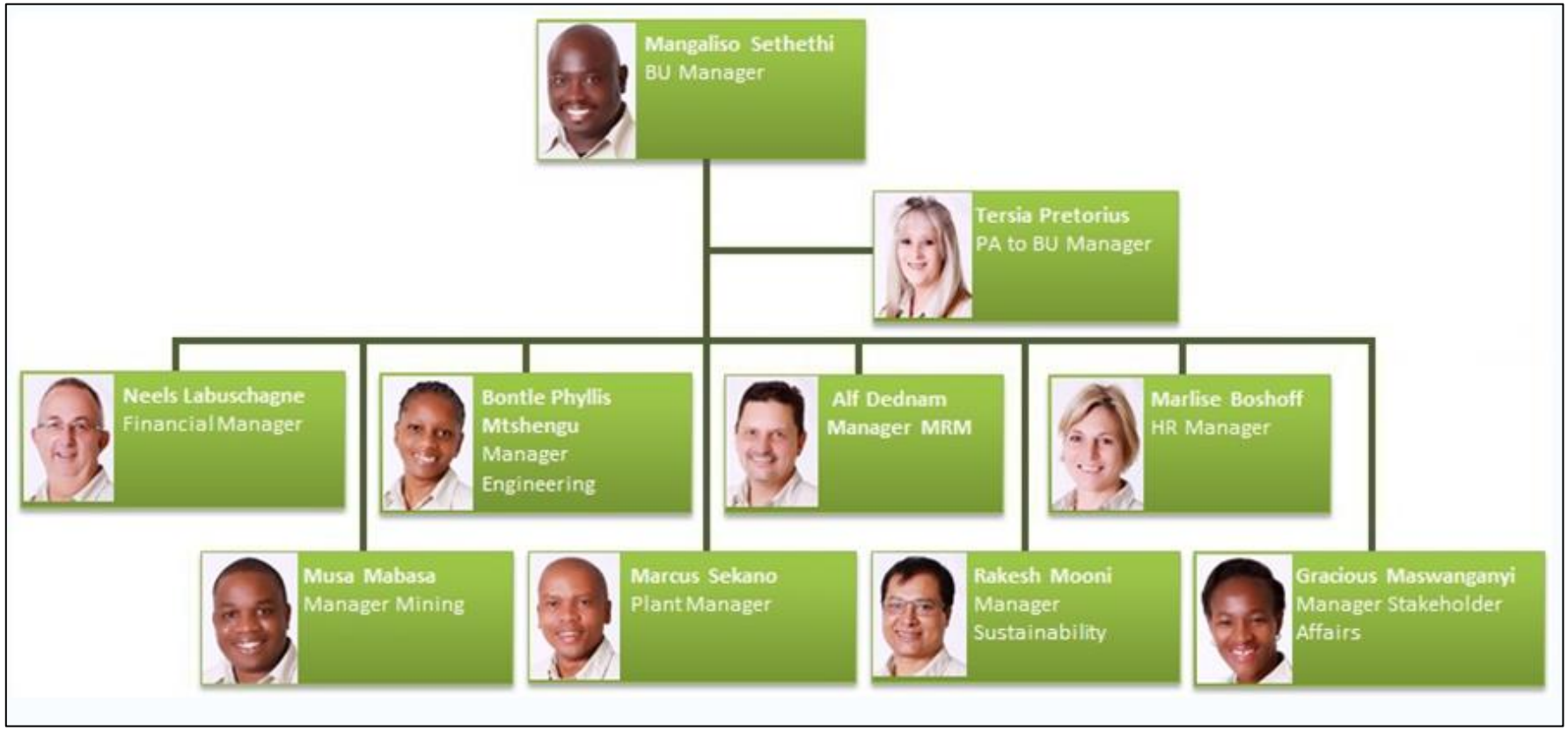


Figure 2.4 Organisational Structure of Leeuwpan

Table 2.8 provides details pertaining to the responsibilities in terms of environmental management appointments at Leeuwpan Mine.

Table 2.8 Environmental Management at Leeuwpan - Key Responsibilities

Responsible Person	Function and Responsibility
Mine Manager	Reports directly to the EXCO of Exxaro Resources and apart from his production responsibilities, is also responsible to ensure that the Safety, Health and Environmental (SHE) management system for Leeuwpan Coal is developed, implemented and maintained
Manager Mining	Reports directly to the Mine Manager of Leeuwpan Coal, and shall be responsible to co-ordinate coal extraction activities and to maintain the mining SHE system for Leeuwpan Coal, the training of personnel and the co-ordination of all administrative activities
Resident Engineer	Reports directly to the Mine Manager of Leeuwpan Coal and shall be responsible to co-ordinate the engineering activities and to maintain the engineering SHE system for Leeuwpan Coal, the training of personnel and the co-ordination of all administrative activities
Plant Manager	Reports directly to the Mine Manager of Leeuwpan Coal and shall be responsible to co-ordinate the beneficiation activities and to maintain the plant SHE system for Leeuwpan Coal, the training of personnel and the co-ordination of all administrative activities
SUSTAINABILITY Manager	Reports to the Mine Manager and is responsible to ensure that SUSTAINABILITY issues are promoted throughout the mine on a continuous basis. The SUSTAINABILITY Manager must report to management on accident and incidents to measure the SHE performance at Leeuwpan Coal.
Chief Safety Officer	Reports directly to the SHE Manager and is responsible to ensure that safety and health issues are promoted throughout the mine on a continuous basis including recommendations for improvements. Part of his duties is then also pertaining to environmental issues such as handling of water around the pits as this directly affects the safety of employees.
Environmental Specialist	Reports to the SUSTAINABILITY Manager and is responsible to ensure that environmental issues are promoted throughout the mine on a continuous basis including recommendations for improvement.
Human Resource Manager	Reports directly to the Mine Manager of Leeuwpan Coal and shall be responsible to co-ordinate the Human Resource Management activities for Leeuwpan Coal.
All other employees	All employees have the responsibility to act in such a manner that ensures SUSTAINABILITY incidents and pollution is prevented and when they occur that such incidents are immediately reported to management.

2.8 Business and Corporate Policies

2.8.1 Safety, Health and Environmental Policy

Leeuwpan implements the following health, safety and environmental policies:

- Environmental Policy Statement: Commits Leeuwpan to conducting its business in a manner that protects human health, natural resources and the environment. The company will cooperate with communities and regulatory agencies to implement sound management practices that ensure environmental protection whilst mining. Regarding legacy mining impacts, the company commits to identifying remediation

activities and implementing such plans in a manner that is credible and transparent; and

- Occupational Health and Safety Policy: Provides for the protection of all Leeuwpan employees and those who are not employees but who are directly affected by Leeuwpan's activities.

2.8.2 Objectives and Strategies

The **objectives of the Safety and Health** management system are to:

- Have an injury free working environment combined with zero tolerance for non-compliance or unsafe behaviour;
- Minimise major occupational risk in the work environment in order to eliminate occupational illness and disability; and
- Maintain high standards in respect to all of Leeuwpan's operations.

The **Environmental objectives** are to ensure sustainable exploitation of natural resources through dedicated programmes focusing on water resource management, air quality management and biodiversity management steered by the Environmental Management division.

The following strategically important water resource management objectives could be identified:

- Water Resource Protection;
- Water Use Management;
- Water Conservation (WC) and Water Demand Management (WDM); and
- Monitoring and Information Management.

It is necessary to consider that water impacts might increase over time. This entails that the cost for operational and closure water management will increase, as well as an increased risk to the environment (social, ecologic and economic) in the future.

An objective for this IWWMP is to provide the mine with a structured road map and procedure to achieve the following criteria:

- To internalise cost in order to design the best business scenario ensuring compliance with environmental legislation, policies and regulations with the associated reduction in long term environmental liabilities;

- To demonstrate to regulatory authorities that all reasonable measures and actions has been identified, initiated and applied during the operational stage of the mine to minimise impacts;
- That the IWWMP forms an integral part of the management process of the Licensee in order to assist in the planning of all activities during all phases of the operational life cycle to achieve the objectives set for operation, decommissioning and closure; and
- Providing an IWWMP that is understandable, easily implementable and practical.

The framework in which Leeuwpan proposes water management makes provision for the following requirements:

- Treatment technologies are expensive and will have associated long-term operating and maintenance costs;
- Industry needs to be profitable with a return on investment to shareholders;
- The operation has the responsibility to manage risks associated with water impacts. The applicant will be in a position to manage long-term liabilities and risks associated with post closure;
- Leeuwpan would have the liability for post closure environmental impacts (including water impacts); and
- It should be recognised that the cost to manage water is time dependent and intervention during the operational water management phase would reduce long-term liability.

3 REGULATORY WATER AND WASTE MANAGEMENT FRAMEWORK

3.1 Summary of all Water Uses

Refer to Table 3.1 for all of the licenced water uses as per the first issued IWUL (Licence No. 04/B21A/ABCGIJ/429) and its associated Amendment issued in 2015 as well as
Table 3.2 for all of the licenced water uses as per the expansion IWUL (Licence No. 04/B20A/CIJ/4032) issued.

Table 3.1 Existing Approved Water Uses

Water Uses - Leeuwpan Mine (04/B21A/ABCGIJ/429) Including 18th December 2015 Amendments				
Section 21(a)	**Site Name**	**Co-ordinates**	**Property**	**Volume Licenced**
Taking of water from a Borehole	Borehole	26°55'07.7"S 29°36'04.0"E	Kenbar 257 IR	68 400m^3

Abstraction of waste water from Block OD	Block OD	26°10'41.6"S 28°43'26.3"E	Kenbar 257 IR	226 992m³/a
Abstraction of waste water from Block OM	Block OM	S26°10'24.2" E28°44'58.4"	Kenbar 257 IR	20 000m³/a
Abstraction of waste water from Block OH	Block OH	S26°10'24.2" E28°44'58.4"	Kenbar 257 IR	26 400m³/a
Abstraction of waste water from Block OJ	Block OJ	S26°09'49.2" E28°45'45.2"	Moabsvelden 248 IR	292 000m³/a
Abstraction of waste water from Block OWM	Block OWM	S26°09'49.2" E28°45'45.2"	Moabsvelden 248 IR	31 880m³/a
Section 21(b)	**Site Name**	**Co-ordinates**	**Property**	**Capacity m³**
Low Lying Area 2: Storage capacity varying circular unlined	Low Lying Area 2	26°11'09.8"S 28°42'33.1"E	Wolvenfontein 244 IR	188 000
Section 21(c) and (i)	**Property**			
Block OWM River diversion – Weltevreden tributary of the Bronkhorstspruit	Moabsvelden 248 IR & Weltevreden 227 IR			
Section 21(g)	**Site Name**	**Co-ordinates**	**Property**	**Capacity / Size / Area/ Volume Licenced (m³/a)**
Dirty runoff and process water used for dust suppression	Dust Suppression	26°10'45.4"S 28°43'58.0"E	Kenbar 257 IR	6 552
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 1	26°10'53.1"S 28°44'20.4"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 2	26°10'54.8"S 28°44'17.5"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 3	26°10'55.4"S 28°44'18.5"E	Kenbar 257 IR	10m³

Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 4	26°10'56.2"S 28°44'16.9"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 5	26°10'57.7"S 28°44'20.2"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 6	26°11'09.2"S 28°43'46.4"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 7	26°11'06.4"S 28°43'36.5"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 8	26°11'08.4"S 28°43'36.5"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker	Septic Tank 9	26°11'08.4"S 28°43'37.3"E	Kenbar 257 IR	10m³

to the 7m³ STP located at the mining green area				
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 10	26°11'10.2"S 28°43'38.1"E	Kenbar 257 IR	10m³
Disused Slimes Dam 1 & 2 that are lined with composite lining	Slimes Dams 1 & 2	26°10'58.6"S 28°43'53.4"E	Kenbar 257 IR	Footprint Area = 2.1Ha Height = 2.5m Length = 40m Breadth = 15m Volume = 88800m³
Disused Slimes Dam 3 that are lined with composite lining	Slimes Dam 3	26°10'58.6"S 28°43'53.4"E	Kenbar 257 IR	Footprint Area = 1.4Ha Height = 2.5m Length = 40m Breadth = 15m Volume = 111 500m³
Plant reuse raw water dam compartment 1 - collects contaminated water from the Witklip evaporation Dam, mobile pit water tank, washbay low lying area and Block OD	Raw Water Dam Compartment 1	26°10'52.9"S 28°43'51.6"E	Kenbar 257 IR	Footprint Area = 2.1Ha Height = 2.7m Length = 10m Breadth = 10m Volume = 51 000m³
Plant reuse raw water dam compartment 2 - collects contaminated water from the Witklip evaporation Dam, mobile pit water tank, washbay low lying area and Block OD	Raw Water Dam Compartment 2	26°10'48.9"S 28°43'51.0"E	Kenbar 257 IR	Footprint Area = 2.2Ha Height = 2.6m Length = 10m Breadth = 10m Volume = 55 000m³
Wash bay low laying area - the low lying area collects clear water from the oil separator at the workshop & washbay as well as runoff from the washbay for reuse at the washbay or its pumped to the plant raw water dams - unlined	Wash bay low laying area	26°10'55.4"S 28°44'16.0"E	Kenbar 257 IR	Footprint Area = 0.6Ha Height = 0.5m Length = 250m Breadth = 100m Volume = 3007m³
Mobile pit water tank - this tank collects contaminated water pumped from the open pits and is pumped to the	Mobile pit water tank	26°10'24.9"S 28°44'30.0"E	Kenbar 257 IR	Footprint Area = 0.003Ha Height = 2m Length = 6m

plant raw water dams - steel tank				Breadth = 6m Volume = 60m^3
Process water storage tank 3 - process water from the plant is stored in this tank - steel tank	Process water storage tank 3	26°10'21.7"S 28°43'51.0"E	Kenbar 257 IR	Footprint Area = 0.035Ha Height = 3m Length = 0m Breadth = 0m Volume = 1050m^3
Process water storage tank 4 - process water from the plant is stored in this tank - steel tank	Process water storage tank 4	26°10'21.7"S 28°43'51.0"E	Kenbar 257 IR	Footprint Area = 0.023Ha Height = 4.7m Length = 0m Breadth = 0m Volume = 1081m^3
Plant raw water tank 1 - contaminated water from the plant raw water dams are stored in this dam for reuse - steel tank	Plant raw water tank 1	26°10'21.7"S 28°43'51.0"E	Kenbar 257 IR	Footprint Area = 0.007Ha Height = 2.5m Length = 0m Breadth = 0m Volume = 166m^3
Workshop Raw Water Tank - this tank stores contaminated water from the plant raw water dams for use at the wash bay - steel tank	Workshop raw water tank	26°10'54.3"S 28°44'18.8"E	Kenbar 257 IR	Footprint Area = 0.003Ha Height = 2m Length = 0m Breadth = 0m Volume = 60m^3
In-pit backfilling - disposal of plant discard from filter press and over burden into the open pits. Front pit area > total area of property on which waste is disposed	In-pit backfilling	26°10'19.7"S 28°42'45.6"E	Kenbar 257 IR	Footprint Area = 1548Ha Volume = 6 432 m^3/d
Low Lying Area 1 - this was an internal catchment area that exists as a result of the location of the infrastructure and the pits at Blocks OH, OM and OD. Only clean runoff was contained in this area. The water surface area at full supply level is 9.5 Hectares. But the area has in the meantime been cleaned up, and filled and compacted to be used as product stockpile area. This will be used to contain run-off water from product stockpile beds.	Low Lying Area 1 - Product Stockpile Area	26°10'21.7"S 28°43'51.0"E	Kenbar 257 IR	Footprint Area = 2.1Ha Height = 8m Length = 100m Breadth = 25m Volume = 30 000m^3/a
Conservancy Tank 1 - linked to STP of 4m^3 situated at plant offices	Conservancy Tank 1	26°10'19.6"S 28°43'47.4"E	Leeuwpan 246 IR	10m^3

Conservancy Tank 2 - linked to STP of 4m³ situated at plant offices	Conservancy Tank 2	26°10'17.3"S 28°43'49.3"E	Leeuwpan 246 IR	10m³
Conservancy Tank 3 - linked to STP of 4m³ situated at plant offices	Conservancy Tank 3	26°10'18.8"S 28°43'50.7"E	Leeuwpan 246 IR	10m³
Conservancy Tank 6 - linked to STP of 4m³ situated at plant offices	Conservancy Tank 6	26°10'15.7"S 28°43'41.1"E	Leeuwpan 246 IR	10m³
Conservancy Tank 7 - cleaned by Honey Sucker and disposed into STP of 4m³ situated at plant offices	Conservancy Tank 7	26°10'17.5"S 28°43'39.9"E	Leeuwpan 246 IR	10m³
Conservancy Tank 8 - cleaned by Honey Sucker and disposed into STP of 4m³ situated at plant offices	Conservancy Tank 8	26°10'24.5"S 28°43'40.7"E	Leeuwpan 246 IR	10m³
Conservancy Tank 16 - cleaned by Honey Sucker and disposed into STP of 4m³ situated at plant offices	Conservancy Tank 16	26°10'22.5"S 28°43'40.6"E	Leeuwpan 246 IR	10m³
Conservancy Tank 19 - cleaned by Honey Sucker and disposed into STP of 4m³ situated at plant offices	Conservancy Tank 19	26°09'57.8"S 28°43'47.8"E	Leeuwpan 246 IR	10m³
Package Sewage Treatment Plant	Package Sewage Treatment Plant	26°10'52.4"S 28°44'22.2"E	Kenbar 257 IR	7m³
Package Sewage Treatment Plant	Package Sewage Treatment Plant	26°92553"S 28°95365"E	Kenbar 257 IR	4m³
Plant Pollution Control Dam - the dam collects runoff from the plant and the coal product stockpiles that is used for dust suppression - Lined Dam, composite lining system	Plant Pollution Control Dam	26°10'02.8"S 28°43'28.5"E	Leeuwpan 246 IR & Wolvenfontein 244 IR	Ha Coverage = 2.1 Ha Height = 1.7m Length = 200m Breadth = 100m Volume = 90 000m³
Load Out Evaporation Dam - Direct rainfall at the load-out station is collected and left out to evaporate - not lined	Load Out Evaporation Dam	26°09'49.2"S 28°43'51.6"E	Leeuwpan 246 IR	Ha Coverage = 0.5Ha Height = 1.5m Length = 25m Breadth = 50m
Process Water Storage tank 1 - Process water tank 1 stores process water used at the plant - steel tank	Process Water Storage Tank 1	26°10'15.6"S 28°43'41.7"E	Leeuwpan 246 IR	Intake Water = 5328 and 20 000 m³ Ha Coverage = 0.038Ha Height = 3m Vol. Used = 1140 m³

Process Water Storage tank 2 - Process water tank 2 stores process water used in the plant - steel tank	Process Water Storage Tank 2	26°10'15.6"S 28°43'41.7"E	Leeuwpan 246 IR	Intake Water = 5328 and 20 000 m^3 Ha Coverage = 0.038Ha Height = 3m Vol. Used = 1140 m^3
Plant Raw Water Tank 2 - the tank stores contaminated water from the plant raw water dams for reuse at the plant - steel tank	Plant Raw Water Tank 2	26°10'15.6"S 28°43'41.7"E	Leeuwpan 246 IR	Intake Water = 5328 and 20 000 m^3 Ha Coverage = 0.0063Ha Height = 4.7m Vol. Used = 296 m^3
Jig Thickener Dam - contains water from the Jig Plant dirty water management system - Steel Dam	Jig Thickener Dam	26°10'14.5"S 28°43'41.6"E	Leeuwpan 246 IR	Ha Coverage = 0.00236Ha Height = 4.5m Vol. Used = 740 m^3
Jig Clarified Dam - contains water from the Jog plant water management system - Steel Dam	Jig Clarified Dam	26°10'14.5"S 28°43'41.6"E	Leeuwpan 246 IR	Intake Water = 3 000 m^3 Ha Coverage = 0.00035Ha Height = 4.5m Vol. Used = 160 m^3
Witklip Return Water Dam (Reg. 24059135) - process water from the plant is stored in this return dam. Sized to accept seepage from the under drainage system and decant system for up to 1:50 year rainfall event, over and above normal operating conditions	Witklip Return Water Dam	26°10'23.5"S 28°42'26.3"E	Witklip 229 IR	Intake Water = 5328 (a) and 20 000 m^3 (j) Ha Coverage = 50Ha Height = 4m Length = 100m Breadth = 200m
Witklip Evaporation Dam - the dirty storm water collected in this dam is left to evaporate - Lined with clay - application made with Dam Safety Office	Witklip Evaporation Dam	26°10'23.5"S 28°42'26.3"E	Witklip 229 IR Ptn 4	Intake Water = 5328 (a) and 20 000 m^3 (j) Ha Coverage = 3.3Ha Height = 5.9m Length = 50m Breadth = 50m
Section 21(j)	**Site Name**	**Co-ordinates**	**Property**	**Volume Licenced**
Abstraction of waste water from Block OD	Block OD	26°10'41.6"S 28°43'26.3"E	Kenbar 257 IR	226 992m^3/a
Abstraction of waste water from Block OM	Block OM	S26°10'24.2" E28°44'58.4"	Kenbar 257 IR	20 000m^3/a

Abstraction of waste water from Block OH	Block OH	S26°10'24.2" E28°44'58.4"	Kenbar 257 IR	26 400m³/a
Abstraction of waste water from Block OJ	Block OJ	S26°09'49.2" E28°45'45.2"	Moabsvelden 248 IR	292 000m³/a
Abstraction of waste water from Block OWM	Block OWM	S26°09'49.2" E28°45'45.2"	Moabsvelden 248 IR	31 880m³/a

Table 3.2 Existing Approved Water Uses (Block OI and OL)

Water Uses - Leeuwpan Mine (04/B20A/CIJ/4032) OI and OL Expansion				
Section 21(a)	**Site Name**	**Co-ordinates**	**Property**	**Volume Licenced**
Pit OI Dewatering	Block OI	S26°10'41.470" E28°45'10.920"	Moabsvelden 248 IR Ptn 2 and 16	72 000m³/annum
Section 21(c) and (i)	**Site Name**	**Co-ordinates**	**Property**	**Watercourse affected**
Open Pit OL	Block OL	S26°10'56.932" E28°45'32.971"	Moabsvelden 248 IR	Bronkhorstspruit
Open Pit OI	Block OI	S26°10'56.932" E28°45'7.258"	Riekkuil 249 IR	Bronkhorstspruit
New plant and infrastructure	New plant and infrastructure	S26°11'3.442" E28°44'22.714"	Kenbar 257 IR	Bronkhorstspruit
Section 21(g)	**Purpose**	**Co-ordinates**	**Property**	**Capacity / Size / Area/ Volume Licenced (m³/a)**
Raw Water Dam	Raw water from collection points will be stored in the raw water dam for use at the plant	S26°10'52.992" E28°43'52.048"	Kenbar 257 IR	28 931m³
Process Water Dam	A process water dam will be required and be located on the Plant terrace next to the storm water collection dam	S26°10'56.282" E28°44'26.069"	Kenbar 257 IR	10 116m³
Storm Water Dam	A storm water dam will be required to the control run-off from the natural environment	S26°10'57.732" E28°44'27.287"	Kenbar 257 IR	9 721m³
Stockpile	Water control measures at the stockpile areas	S26°11'2.249" E28°44'24.339"	Kenbar 257 IR	2 314m³
Dirty Water Dam	A dirty water dam to contain dirty water from the stockyard	S26°11'7.247" E28°44'17.246"	Kenbar 257 IR	11 337.5m³
Discard Backfilling for Pit OI	Pit OI will be backfilled once the mining is completed	S26°10'56.932" E28°45'32.971"	Moabsvelden 248 IR	250 000tons

Discard Backfilling for Pit OL	Pit OL will be backfilled once the mining is completed	S26°10'56.932" E28°45'7.258"	Riekkuil 249 IR	250 000t
Silt Trap	The stormwater dam will spill into the silt trap	S26°10'56.266" E28°44'17.246"	Kenbar 257 IR	9352m^3
Dust Suppression	Water for the dust suppression will be collected from the approved PCD's	S26°10'02.8" E28°43'28.5"	Leeuwpan 246	7650m^3
Pollution Control Dam	Collection of dirty water.	S26°17'42.6" E29°09'23.7"	Not provided in the WUL.	729 708m^3/a
Section 21(j)	**Purpose**	**Co-ordinates**	**Property**	**Volume Licenced**
Pit OI Dewatering	Abstraction of water from the proposed new Block OI to the Raw Water Dam	S26°10'41.470" E28°45'10.920"	Moabsvelden 248 IR Ptn 2 and 16	72 000m^3 month total for OI

*It is recommended that the water uses in the 2015 IWUL be checked for accuracy. Should it be determined that some aspects of the licenced uses are incorrect, an application should be made to the DWS to have them rectified.

3.2 Existing Lawful Water Uses

Existing Lawful Water Use (ELWU) is defined in Section 32 of the National Water Act 1998, (Act No. 36 of 1998) (NWA) as any water use which has taken place at any time during a period of two years immediately before the date of commencement of the NWA. It also includes any water use which has been declared an existing lawful water use under Section 33 and which was authorised by or under any law which was in force immediately before the date of commencement of the NWA.

As Leeuwpan Coal has been operational since 1992, several of the Water Use activities at the mine commenced before the promulgation of the NWA, 1998. The Existing Lawful Water Uses undertaken at the Existing Leeuwpan Coal in terms of section 21 are listed in Table 3.3.

Table 3.3 Existing Lawful Water Uses under Section 21

Property Name	Section 21	Description	Date Commenced
Witklip 229 IR, Portion 4	(a)	Witklip Borehole abstraction	1994
Witklip 229 IR, Portion 4	(c) & (i)	River diversion. Permit B187/1/220/6 in terms of Section 20 (1)(a) of the Water Act, (Act 54 of 1956).	1993
Witklip 229 IR, Portion 6	(c) & (i)	River diversion. Permit B187/1/220/6 in terms of Section 20 (1)(a) of the Water Act, (Act 54 of 1956).	1993
Witklip 229 IR, Portion 16	(c) & (i)	River diversion. Permit B187/1/220/6 in terms of Section 20 (1)(a) of the Water Act, (Act 54 of 1956).	1993

Property Name	Section 21	Description	Date Commenced
Kenbar 257 IR	(g)	Domestic wastewater disposal	1994
	(g)	In-pit backfilling.	1992
	(g)	Disused Slimes dams No. 1,2 and 3	1994
	(g)	Plant raw water dams.	1992
	(g)	Workshop raw water tank.	1992
Leeuwpan 246 IR	(g)	Domestic Waste Disposal	1994
	(g)	Load out Evaporation Dam	1992
Witklip 229 IR, Portion 4	(g)	Witklip evaporation dam.	1994
Witklip 229 IR, Portion 4	(j)	Pit Dewatering	1992
Kenbar 257 IR	(j)	Pit Dewatering	1992

The ELWUs listed in Table 3.3 were included in the licence that was issued in 2011 (Licence No. 04/B21A/ABCGIJ/429).

3.3 Relevant Exemptions

The Minister of the Department of Water and Sanitation is responsible for the protection, use, development, conservation, management and control of the water resources of South Africa on a sustainable basis. The requirements prescribed in terms of the regulations must be seen as minimum requirements to fulfil this goal.

In addition to the water uses that were originally applied for and approved, an application for exemption from certain Government Notice (GN704) activities was also included. These formed part of the IWULs that were issued to Leeuwpan.

3.4 Generally Authorised Water Uses

Leeuwpan's mining operation is a coal mining operation, making it a Category A mine. All water uses taking place at the mine have been authorised by the issuance of a Water use Licence.

3.5 New Water Uses to be Licenced

Water uses at Leeuwpan Mine are licensed in terms of the NWA. All water uses are authorised in terms of Section 21of the NWA.

In terms of the proposed mining to occur at Block OI West, Section 21(c) and (i) water uses have been triggered according to the NWA. The IWULA to authorise the new water uses

triggered for OI West is currently being applied for as a separate application to the DWS and do not form part of this IWWMP update.

3.6 Waste Management Activities and Waste Related Authorisations

3.6.1 Domestic Waste

The domestic waste that is generated on-site is disposed of into green allocated and marked waste bins/containers. Domestic waste is then collected and disposed of in steel skips located on site (i.e. at the workshop) within the Leeuwpan boundary area. The steel skips are collected by Interwaste and taken to the Klinkerstene for disposal. No domestic waste is dumped in any unauthorised landfill site/waste site or dumped in a pit.

Recyclable materials are collected and disposed of into dark blue allocated and marked waste bins / containers.

3.6.2 Mine Waste

Originally, the mine residue consisting of carbon-carrying shales, plant residue and fine coal recovered from the slimes dams, was compacted and disposed of into the mined-out pits below the groundwater table. It was then covered with a clay layer and topsoil so that it would be suitable for agricultural purposes at a later stage.

No mine residue disposal sites were constructed for Block OM, Block OH, Block OFPAD or Block OD. Discard material from these Blocks was placed back into the open pits.

For Blocks OJ and OL (Phase 1) the topsoil was stripped and used in rehabilitation operations. The initial box cut material was also used for the development of the stormwater management berms. Backfilling at Phase 1 Pit took place 45m from the working face. Due to the risk of pollution to the Bronkhorstspruit River, no discard was backfilled into the Phase 1 Pit.

For Block OWM and OD, carbonaceous residue material from the existing Process Plant(s), stockpiled top coal and slurry cakes from the existing filter press, as well as overburden are disposed of back into the pits as part of the mining rehabilitation process.

3.6.3 Hazardous Waste

All hazardous waste (excluding mine waste) is stored in accordance with the minimum requirements for the handling, classification and disposal of hazardous waste – including

appropriate roofing, fencing, locking (preventing unauthorised access), labelling, waterproof hard standing, protection from storm water ingress (bunding, etc.), drainage and collection system for spills and general protection from potential environmental pollution.

Any hazardous waste is disposed of in clearly marked black containers, which are then sent to the mine workshop hazardous waste storage area (which was observed to be in a bunded and roofed area). An additional bunded area for waste storage has been constructed and is in use. This storage area is located within the existing mine boundary area, and waste is removed by a waste contractor (Interwaste) to a licensed waste disposal site.

The hazardous waste storage facility permit that already exists at Leeuwpan has been renewed for the extension (for Blocks OI and OL) of the life of mine.

3.6.4 Other Authorisations and Regulations

Refer to Table 3.4 for a summary of the existing authorisations obtained for the Leeuwpan mining operation.

Table 3.4 Leeuwpan's Existing Authorisations

Description	Record of Decision (ROD) / Description
Existing Water Use Licences and Amendments	• River diversion. Permit B187/1/220/6 in terms of Section 20 (1)(a) of the Water Act, (Act 54 of 1956). • IWUL for Leeuwpan Mining activities (Licence No. 04/B21A/ABCGIJ/429); • IWUL Amendment (Licence No. 04/B21A/ABCGIJ/429) issued 18th December 2015; and • IWUL issued for Block OI and OL Expansion (Licence No. 04/B20A/CIJ/4032);
EMPs	• Various EMPs authorised and approved by DMR (5 addendums as referred to above in Section 2.1); • Consolidated EMP, including the proposed expansion activities, approved 25 April 2017 [Reference number: MP 30/5/1/2/3/2/1 (171) EM].
Environmental Authorisation	• Previous NEMA authorisation not required; • Environmental Authorisation received for expansion activities from MDARDLEA (MDEDET reference number: 17/2/3N-180)
Waste Permit	• Leeuwpan has an approved hazardous waste storage facility permit

3.7 Legal Assessment

One of the main and ever-continuing concerns in South Africa is the sustainability of water provision, and the costs associated with the prevention and remediation of pollution in a country with an average rainfall below international standards. The NWA is one of the Government’s answers to some of these challenges and is based on the constitutional right to access to sufficient water (Section 27 of the Constitution), and furthermore functions as sectoral legislation within the framework of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA).

The main purpose of the IWWMP is to consolidate all the various site specific programmes (e.g. water and salt balances, storm water management plans, water reuse and reclamation plans, water conservation and demand management plans, waste minimization and recycling) of a specific water user into a simple implementable management plan, clearly reflecting the implementation of all strategic objectives.

The IWWMP's key objective is the summation of all relevant water resource management information into an action plan in order to prevent duplication of information and the submission of unnecessary information. Further objectives of an IWWMP include:

- To support and underpin the objectives and requirements of Integrated Water Resource Management by managing water and waste;
- To identify appropriate and effective action plans in the control and regulation of water (containing waste) and waste as sources of pollution;
- To assist water resource managers at regional level to focus on high risk pollution sources and to ensure that site specific management plans are in place, implemented and to ultimately achieve the set Resource Quality Objectives in a catchment; and
- To utilise the IWWMP to its full extent to prevent pollution at source.

Water management at mines is primarily controlled by the following legislation:

- The NWA;
- The MPRDA and
- The NEMA.

3.7.1 The Constitution of South Africa, 1996 (Act No.108 of 1996)

The Constitution reigns supreme and the advancement of human rights is one of the foundations of South Africa's democracy. Furthermore, the Bill of Rights plays a central role in the democratic regime because it embodies a set of fundamental values which should be promoted at all times. One of the fundamental values is contained in Section 24 and is, arguably, the cornerstone for environmental governance in South Africa which includes the mining industry. Section 24 of the constitution provides:

Everyone has the right:

a) to an environment that is not harmful to their health or well-being;
b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that
    i. prevent pollution and ecological degradation;

ii. promote conservation; and
iii. secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

Mining companies are thus duty-bound to constitutional, legislative, and other measures to prevent pollution and ecological degradation, promote conservation and to develop in a sustainable manner.

The constitutional environmental right elevates the importance of environmental protection and conservation and emphasises the significance that South Africans attach to a sound and healthy environment. In addition, the environmental right applies horizontally and this implies that the mining industry has to exercise a duty of care if liability, on the basis of the constitutional environmental right, is to be avoided. The constitutional environmental right is given effect to by means of detailed statutory provisions ranging from framework to sectoral legislation which relate to mining.

3.7.2 The National Environmental Management Act, 1998 (Act No.107 of 1998)

NEMA is South Africa's overarching framework for environmental legislation. The NEMA sets out the principles of Integrated Environmental Management (IEM). NEMA aims to promote sustainable development, with wide-ranging implications for national, provincial, and local government. Included amongst the key principles is that all development must be environmentally, economically and socially sustainable and that environmental management must place people and their needs at the forefront, and equitably serve their physical, developmental, psychological, cultural and social interest.

NEMA is the environmental framework legislation promulgated to replace the Environmental Conservation Act, 1989 (Act No. 73 of 1989), and ensure that the environmental rights contemplated in Section 24 of the Constitution are realised. NEMA sets out:

- the fundamental principles that need to be incorporated in the environmental decision making process;
- the principles that are necessary to achieve sustainable development;
- provides for duty of care to prevent, control and rehabilitate the effect of significant pollution and environmental degradation; and
- it allows for the prosecution of environmental crimes.

The Duty of Care Principle is discussed in Section 28 of NEMA and it states that:

I. Every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or, in so far as such to harm the environment is authorized by law or cannot reasonably be avoided or stopped, to minimize and rectify such pollution or degradation of the environment;

II. Without limiting the generality of the duty in subsection (1), the persons on whom subsection (1) imposes an obligation to take reasonable measures, include an owner of land or premise, a person in control of land or premises or a person who has a right to use the land or premises on which:

(a) any activity or process is or was performed or undertaken; or

(b) any other situation exists.

Which causes, has caused or is likely to cause significant pollution or degradation of the environment.

The NEMA provides for the identification of activities which will impact the environment. The impacts of the listed activities must be investigated, assessed and reported to the competent authority before authorisation to commence with such listed activities can be granted.

Listed activities under the NEMA didn't come into effect before 2006 and therefore Leeuwpan's existing infrastructure didn't need approval under the NEMA. For the EMPP Addendums 4 and 5 conducted in 2006 – 2007, mining applications were excluded until further notice from the EIA process legislated under the NEMA. Several activities associated with the mining operations that were proposed in Addendums 4 and 5 have however been listed under the NEMA EIA Regulations (No. GNR 385, 386 and 387 of 2006). As was agreed then in consultation with Mpumalanga Department of Land Administration (MDALA), since all activities are directly related to mining, it was not be necessary to obtain authorisation in terms of the EIA Regulations for those addendums.

3.7.3 The Mineral and Petroleum Resources Development Act, 2002 (Act No.48 of 2002)

This Act makes provision for the equitable access to and sustainable development of South Africa's mineral and petroleum resources. Regulations under the Act ensure that activities relating to the mining of minerals are undertaken in a manner that is sustainable and that is equitable to all.

In terms of Section 38 of the MPRDA, mining companies are required to familiarize themselves of potential environmental impacts; manage any environmental impacts; and rehabilitate the

environment in so far as is reasonably possible. Furthermore, Section 38(1)(e) states that such holders, whose mining causes or results in ecological degradation, pollution, or environmental damage that may be harmful to the health or well-being of anyone:

"…is responsible for any environmental damage, pollution or ecological degradation as a result of his or her operations and which may occur inside and outside the boundaries of the area to which such right, permit or permission relates."

These holders will ***"…remain responsible for any environmental liability, pollution or ecological degradation and the management thereof until a closure certificate has been issued"***.

Section 39 provides that a mine must indicate how it will contain or remedy the cause of pollution or degradation and migration of pollutants and comply with any prescribed waste standards or management practice.

Granting of permission to mine or prospect, among others, is conditional on an environmental management programme and plan being submitted and accepted by the relevant government authority. Section 43 is one of the most important provisions as it deals with the responsibility for any environmental liability, pollution or ecological degradation until the issue of the closure certificate. It is important to note that environmental liability will not necessarily cease or fall away by the issuing of a closure certificate. In addition to the broader liability provisions above, Section 45 provides that the relevant authority may direct a mine to undertake remedial measures where:

"...any prospecting, mining, reconnaissance or production operations cause or results in ecological degradation, pollution or environmental damage which may be harmful to the health or well-being of anyone and requires urgent remedial measures."

Where the mine fails to take these measures, the relevant authority will act on its behalf and then recover costs incurred from the mine. If the mine fails to compensate the authority, the latter is empowered to seize and sell the mine's property to recover the costs. The mine will thus remain financially liable for the rehabilitation, even if it chooses to ignore the government directive.

3.7.4 The National Water Act, 1998 (Act No.36 of 1998)

Section 19 of the NWA mirrors the provision of Section 28 of NEMA and addresses the prevention and remediation of the effects of pollution. The NWA provides a wide duty of care in that:

"(1) an owner of land, a person in control of land or a person who occupies or uses the land on which-

(a) any activity or process is or was performed or undertaken; or

(b) any other situation exists, which causes, has caused or is likely to cause pollution of a water resource must take all reasonable measures to prevent any such pollution from occurring, continuing or recurring."

The words "likely to cause pollution" broadens the scope of the duty, which enables an activity, or situation that is land-based, to trigger the application of the duty. The "reasonable measures" are not prescribed, but may include measures intended to:

"cease, modify or control any act or process causing the pollution; comply with any prescribed waste standard or management practice; contain or prevent the movement of pollutants; eliminate any source of pollution; remedy the effects of pollution; and remedy the effects of any disturbance to the bed and banks of a watercourse."

The NWA, furthermore, provides for water use authorisations which a mine will have to apply for, before commencing with its primary activity of mining. Various conditions may be attached to these licenses and a breach thereof will result in criminal and civil liability. The conditions attached to water use authorisations will function alongside the additional protective measures, duty of care and statutory liability provisions provided by the NWA and other legislation to regulate a whole array of water issues.

The detrimental impact of mining on water resources is further regulated by the NWA in a comprehensive set of regulations titled: *"Regulations on the Use of Water for Mining and Related Activities Aimed at the Protection of Water Resources"* (GN R704 of 4 June 1999) (hereinafter referred to as the "*NWA: Mining Water Regulations*"). In terms of these regulations:

"No person in control of a mine or [mining] activity may place or dispose of any residue or substance which causes or is likely to cause pollution of a water resource, in the workings of any underground or opencast mine excavation, prospecting diggings, pit or any other excavation."

Regulation 7 provides for a whole array of provisions which specifically aim to protect water resources from mining. These provisions state that every person in control of a mine or mining activity must take all reasonable measures to, inter alia: prevent water containing waste or any substance which causes or is likely to cause pollution from entering any water resource; design, modify, locate, construct and maintain all water systems including residue deposits, to prevent the pollution of any water resource through the operation or use thereof; cause effective measures to be taken to minimise the flow of any surface water or floodwater into mine workings, opencast workings, other workings or subterranean caverns; prevent the erosion or leaching of materials from any residue deposit or stockpile from any area; and ensure that water used in any process at a mine or activity is recycled as far as practicable. These provisions specifically relate to the protection of water resources and they clearly set out further additional liabilities for mines as far as their water resource protection activities are concerned.

Activities which have the potential to impact on a water resource require a water use licence (WUL) issued by the DWS, under the NWA. Section 21 of the NWA identifies certain water uses which have to be authorised.

Furthermore, Section 27 of the NWA specifies that the following factors, regarding water use authorization, must be taken into consideration:

- The efficient and beneficial use of water in the public interest;
- The socio-economic impact of the decision whether or not to issue a license;
- Alignment with the catchment management strategy;
- The impact of the water use and possible resource directed measures; and
- Investments made by the applicant in respect of the water use in question.

Section 27 considerations is included in the IWWMP. This will assist the mine in ensuring that the water uses applied for, are undertaken in a manner that does not negatively impact on the public, water resources, or downstream water users or compromise any of the country's international obligations with regards to shared water resources.

4 PRESENT ENVIRONMENTAL SITUATION

4.1 Climate

4.1.1 Regional Climate

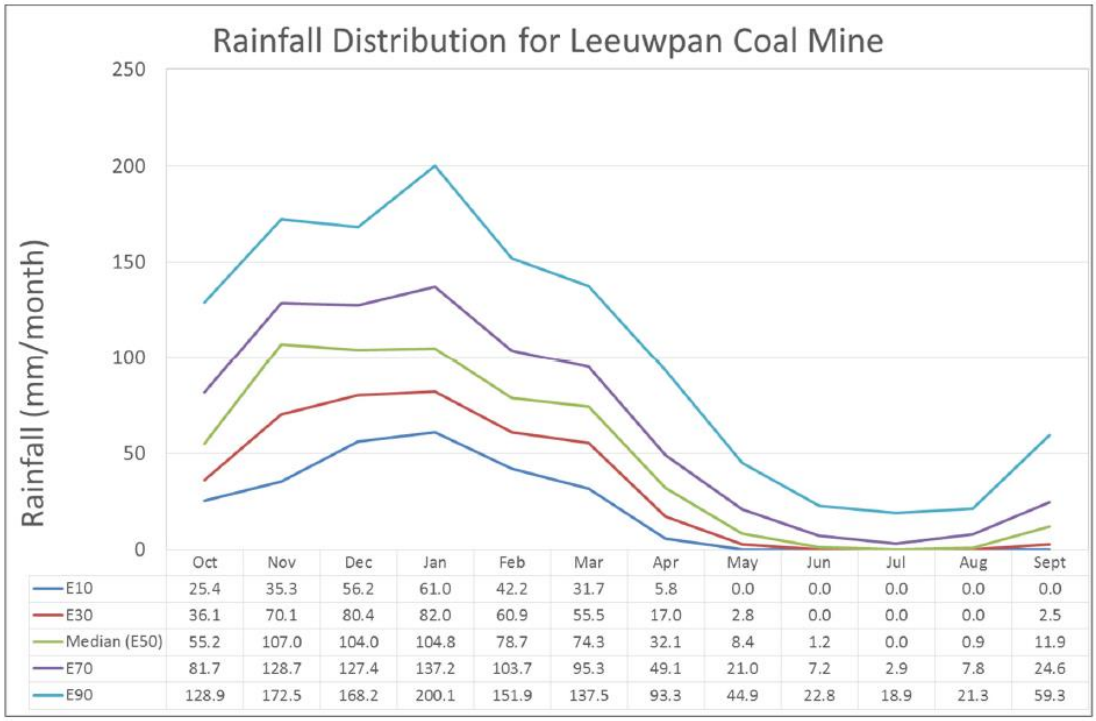
The mine site is located in a temperate climatic zone of South Africa, which is characterised by warm summers and dry cold winters. Table 4.1 shows that the area experiences – on average - lowest temperatures in July and is warmest during January (Cleanstream, 2003). The monthly average minimum and maximum temperatures recorded in the town of Delmas are 7.7°C and 23.6°C, respectively.

Table 4.1 Average minimum and maximum temperatures at Delmas

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum (°C)	14.0	13.4	11.7	8.0	3.0	-0.6	-1.6	1.2	6.2	10.1	12.4	14.0
Maximum (°C)	27.0	26.3	25.6	23.8	21.8	18.1	18.9	20.7	24.1	25.1	25.2	26.4

4.1.2 Rainfall

The Mean Annual Precipitation (MAP) for the Leeuwpan site is 668 mm. The distribution of this rainfall is indicated in Figure 4.1. The rainfall characteristics typify wet summers and dry winters.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
E10	25.4	35.3	56.2	61.0	42.2	31.7	5.8	0.0	0.0	0.0	0.0	0.0
E30	36.1	70.1	80.4	82.0	60.9	55.5	17.0	2.8	0.0	0.0	0.0	2.5
Median (E50)	55.2	107.0	104.0	104.8	78.7	74.3	32.1	8.4	1.2	0.0	0.9	11.9
E70	81.7	128.7	127.4	137.2	103.7	95.3	49.1	21.0	7.2	2.9	7.8	24.6
E90	128.9	172.5	168.2	200.1	151.9	137.5	93.3	44.9	22.8	18.9	21.3	59.3

Figure 4.1 Rainfall Distribution of the Leeuwpan Area

4.1.3 Evaporation

According to WR2012, a mean annual evaporation of 1 677 mm is typical of the Leeuwpan area and its distribution can be seen in Figure 4.2. The summer months have higher rates of evaporation than the winter months.

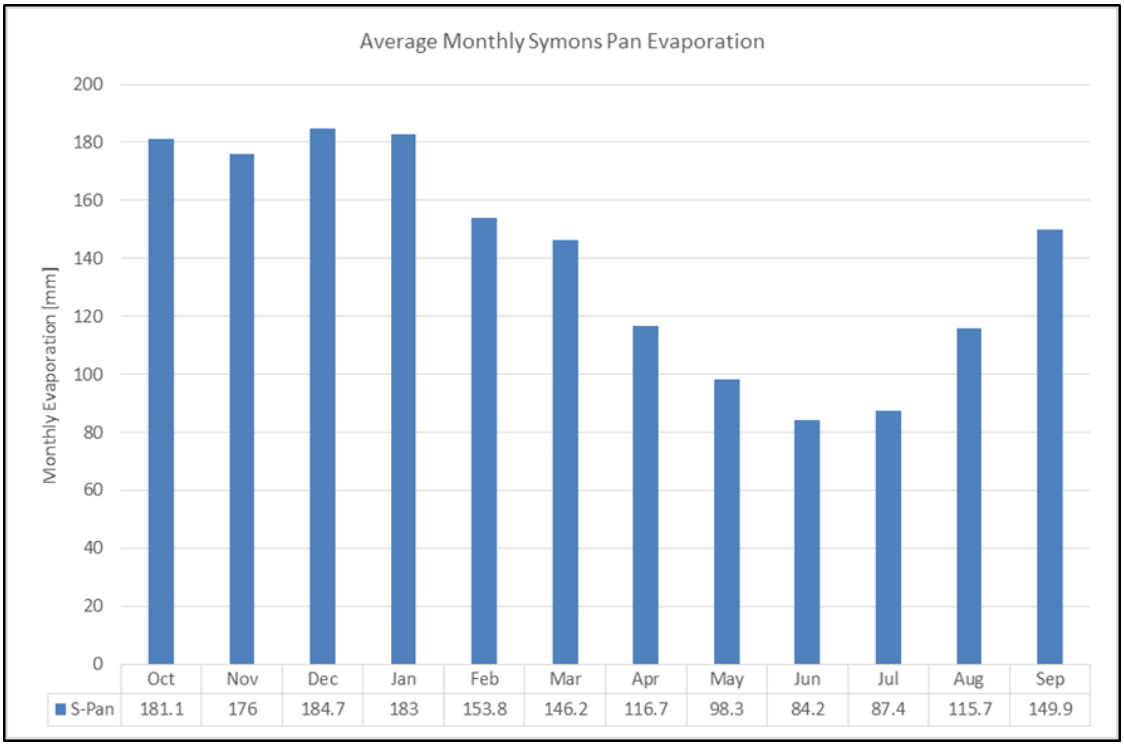


Figure 4.2 S-Pan Evaporation at Leeuwpan

4.2 Surface Water

4.2.1 Water Management Area

The project area is located in the Olifants Water Management Area and falls within the B20A quaternary catchment (Figure 4.3).

With reference to 'The PES EIS 2014 models,' DWS has identified that the Drainage Region B2 is classified as:

- Moderate in its Ecological Importance and Sensitivity (EIS); and
- Largely Modified, Class D in its Present Ecological State (PES).

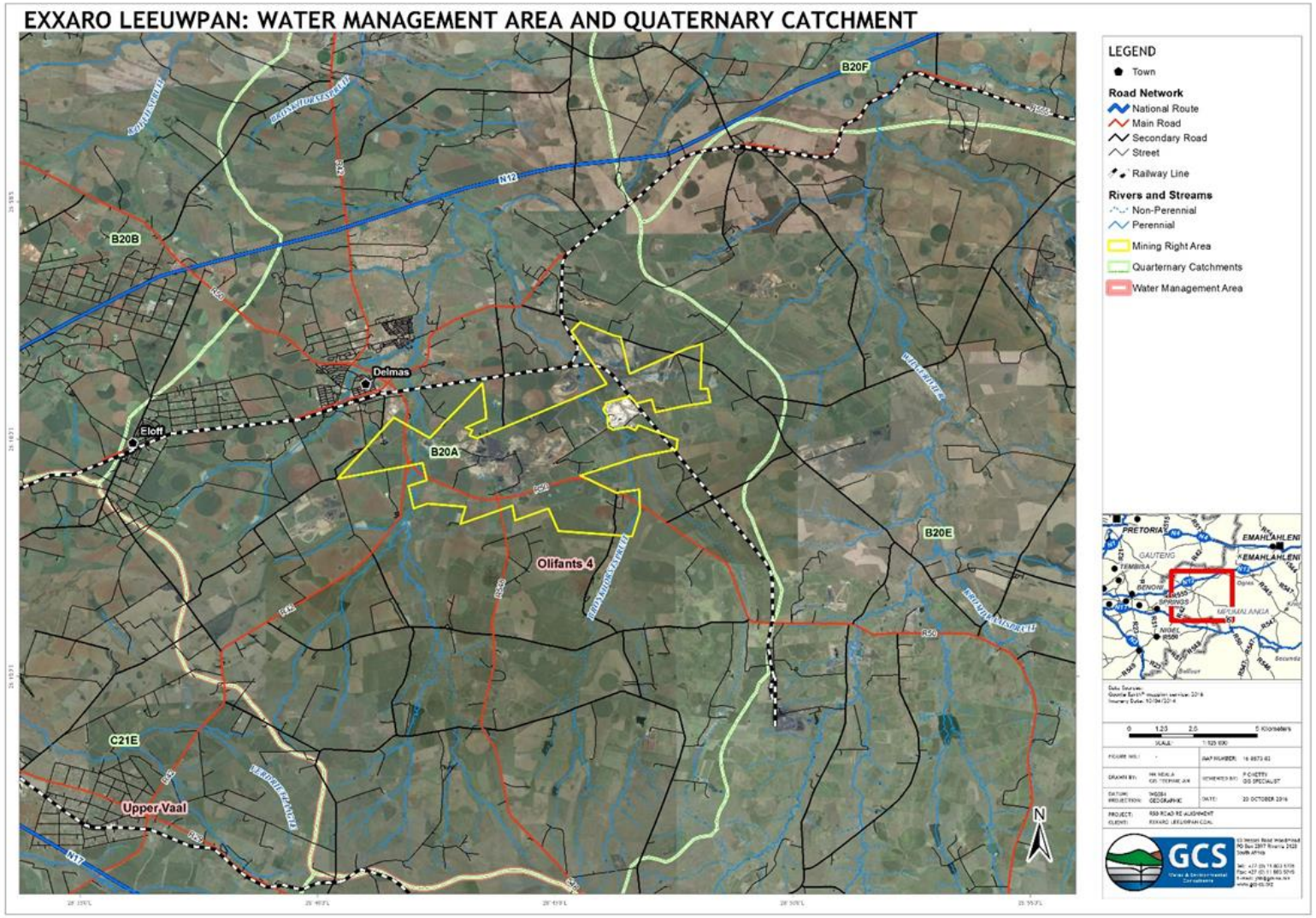


Figure 4.3 Water Management Area of Leeuwpan

4.2.2 Surface Water Hydrology

The Bronkhorstspruit River flows in a south-north direction through the site to eventually end in the Bronkhorstspruit Dam downstream of the site area. Natural water features on site include tributaries of the Bronkhorstspruit River and pans. Artificial water features on site include farm dams, old void areas, Pollution Control Dams (PCD's), rain water in open cast pits and river diversion channels.

4.2.3 Surface Water Quality

The surface water quality results were obtained from the Monthly Water Monitoring Report conducted by Golder Associates Africa (Pty) Ltd (Golder) in April 2019 (Annexure B).

The following sites are monitored for surface water monitoring (refer to Section 5.4 for the geographical information relating to each Sampling point):

- Potable Water:
    - Drinking water supply tank;
    - Load-out bay offices drinking water;
    - Drinking water at Laboratory; and
    - Drinking water on Piet Schutte's farm.
- River/Stream Samples (Resource Protection):
    - Bronkhorstspruit tributary, upstream;
    - Bronkhorstspruit tributary, downstream;
    - Bronkhorstspruit at Delmas Silica – Downstream;
    - Bronkhorstspruit downstream;
    - Weltevreden Spruit – Upstream;
    - Bronkhorstspruit – upstream;
    - Bronkhorstspruit - upstream of Block OI;
    - Downstream of River Diversion 2, Between RD2 and LSW05;
    - Water from Stuart Coal; and
    - Bronkhorstspruit at haul road.
- Process Water (Waste Water):
    - Kenbar Return Water Dam;
    - Downstream of workshop oil separator sump;
    - Marsh area next to workshop road;
    - Pollution Control Dam;
    - OD Pit Water (closed pit);
    - OG Pit Water (backfilled pit);
    - OH Pit Water (backfilled pit);
    - OJ Pit Water;

  - OM Pit Water;
  - OWM (Moabsvelden) Pit Water;
  - Weltevreden Pit; and
  - New Witklip Return Water Dam.
- Final Effluent (Waste Water):
  - Final Effluent from septic tanks at plant; and
  - Final effluent at sewage plant behind workshop.
- Additional Sampling Points (not IWUL related):
  - Backfilled former Kenbar Pit; and
  - Field barrels for experimental work.

The surface water sample locations are sampled on a monthly basis. The water analyses results are measured against various standards and limits to ascertain the water quality. The standards against which the water samples are compare include:

- SANS 241-1: 2015;
- IWUL 2011 limits (Licence no. 04/B21A/ABCGIJ/429);
- IWUL 2015 limits (Licence no. 04/B21A/ABCGIJ/429 amendment); and
- IWUL 2015 limits (Licence No. 04/B20A/CIJ/4032).

The surface water sites sampled in April 2019 included 9 of the targeted 12 process water sites, 8 of the targeted 10 receiving environment sites and all targeted final sewage effluent sites. The surface water sites that were not sampled in April 2019 for various reasons including dry sites, backfilled pits and no leachates being present in the field barrels.

4.2.3.1 Field Measurements

All targeted drinking water sites, 9 of the targeted 12 process water sites, 8 of the targeted 10 receiving environment sites and all targeted final sewage effluent sites were sampled in April 2019. All mine process water, sewage effluent and drinking water sites were compliant to the respective limits and standards.

Non-compliance of the IWUL receiving environment limits were as follows:

- WP01: Electrical conductivity and dissolved oxygen;
- WP02: Electrical conductivity and dissolved oxygen;
- LSW05: Electrical conductivity and dissolved oxygen;
- LSW07: Dissolved oxygen;
- LSW08: Dissolved oxygen;
- LSW13: Electrical conductivity; and
- RD1: Electrical conductivity and dissolved oxygen.

4.2.3.2 Drinking Water Samples

All targeted drinking water sites were sampled in April 2019 and were screened against the SANS 241-1: 2015 drinking water standards. Marginal exceedance of arsenic was observed in drinking waters sampled from the laboratory (LWDL) and the drinking water supply tank (LDWST); furthermore, all other analysed parameters from all portable water sites were compliant to the drinking water standards.

4.2.3.3 Surface Water Samples

The April 2019 laboratory results from waters sampled from receiving environment sites were compared against the IWUL resource protection limits. The results of the water samples are presented in Annexure B.

The following parameters (mine water parameters in **bold**) were not compliant to water quality limits specified in the IWUL in April 2019 (Golder, 2019):

- WP01 (Bronkhorstspruit tributary upstream of the mine): **electrical conductivity,** ammonia, calcium, potassium, **manganese**, total alkalinity, Chlorophyll a, *E. coli* and dissolved oxygen;
- WP02 (Bronkhorstspruit tributary downstream of the mine): total dissolved solids, electrical conductivity, ammonia, calcium, magnesium, manganese, total alkalinity, E. coli, and dissolved oxygen;
- LSW08 (Bronkhorstspruit, upstream of Block OI): ammonia, calcium, manganese, total alkalinity, Chlorophyll a, E. coli and dissolved oxygen;
- LSW07 (Bronkhorstspruit, upstream): fluoride, ammonia, calcium, total alkalinity, E. coli, Chlorophyll a, dissolved oxygen and organic carbon;
- LSW03 (Bronkhorstspruit adjacent to Delmas Silica): electrical conductivity, ammonia, calcium, total alkalinity, E. coli, Chlorophyll a, dissolved oxygen and dissolved organic carbon;
- RD1 (Bronkhorstspruit at haul road): electrical conductivity, ammonia, calcium, magnesium, manganese, total alkalinity, dissolved oxygen and chlorophyll a;
- LSW13 (Stuart Coal): electrical conductivity, sulphate, ammonia, calcium and manganese, total alkalinity, E. coli and Chlorophyll a; and
- LSW05 (Bronkhorstspruit downstream): electrical conductivity, ammonia, calcium, magnesium, total alkalinity, dissolved oxygen, chlorophyll a and E. coli.

The following constituents (mine water parameters in **bold**) increased at downstream sites compared to upstream in April 2019:

- WP02: The levels of turbidity, ammonia, potassium, total hardness, alkalinity, chlorophyll a and dissolved organic carbon; total dissolved iron, E. coli and dissolved oxygen (negative increase decreased) downstream compared to upstream; and
- LSW05: Total dissolved solids, electrical conductivity, magnesium, dissolved oxygen, E. coli and total hardness.

Below is a summary (Figure 4.4) of the surface water sample results that are exceeding the IWUL limit in April 2019.

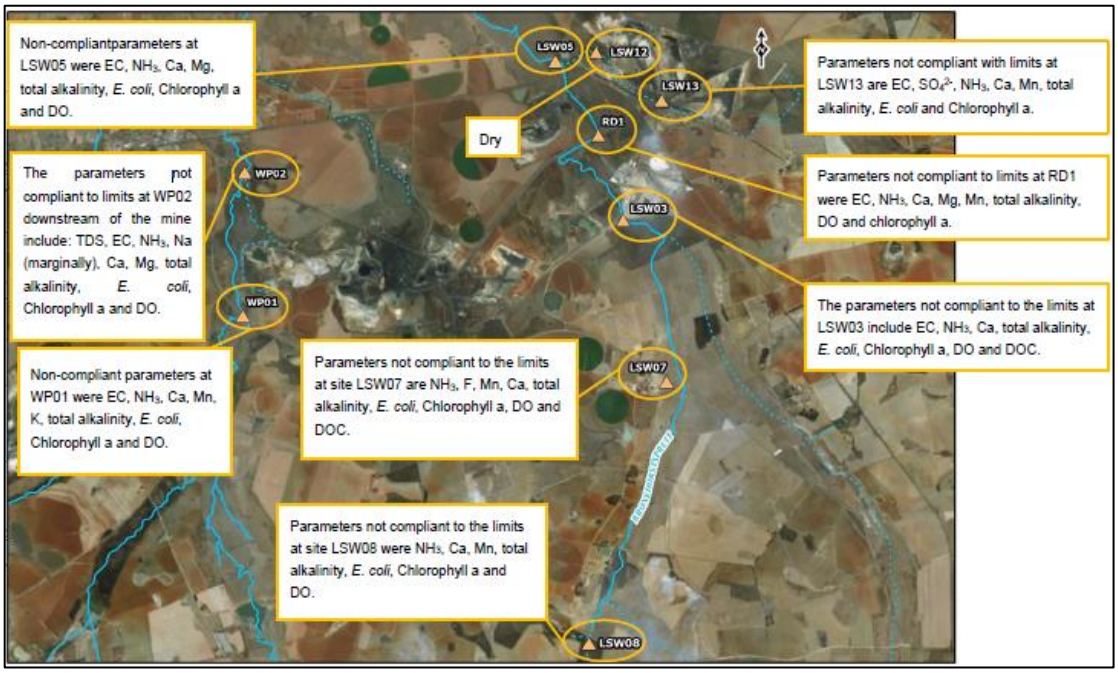


Figure 4.4 Summary of surface water results exceeding IWUL limits in April 2019 (Golder, 2019)

4.2.3.4 Process Water Samples

The mine process water was classified as follows based on pH and sulphate content, in April 2019:

- Saline Drainage: LSW09, OM pit, KR01A, ODN pit, OWM pit and WP04; and
- Neutral mine drainage: KR03, KR04 and WLV pit.

Screening indicates levels of fats, oils and greases measured in waters sampled from the Downstream of workshop oil separator sump (KR03) not adhering the limits; furthermore, all other parameters from all sampled sites were compliant to the waste water limits.

4.2.3.5 Final effluent from sewage works

Final effluent from the sewage plant behind workshop (LWP-SP-W): increases were observed in total suspended solids (increased from 15 mg/L to 43 mg/L), chemical oxygen demand

(COD, settled) (increased from 63 mg/L to 365 mg/L), E. coli counts (from 0 colonies/100ml to 540 colonies/100ml); nitrate (increased from 2.97 mg/L to 9.09 mg/L. Increased in E. coli counts and led to non-compliance of the IWUL limit in April as opposed to the exceedance observed in March 2019). A decreasing trend was observed from March to April 2019 in ammonia (from 82 mg/L to 40 mg/L); non-compliant against the amended IWUL limits.
The sewage treatment plant requires attention to ensure that it operates efficiently to avoid release of contaminated effluent into the environment.

Final effluent from the septic tanks at the plant (LWP-SP-P): Ammonia and *E. coli* remained noncompliant against the IWUL limits in April 2019 as for the previous month. Decreases were observed in total suspended solids (from 53 mg/L to 10 mg/L) and chemical oxygen demand (COD, settled) (from 276 mg/L to 44 mg/L), however an increase in *E. coli* (from below detection limit to 1 180 000 colonies/100ml) from March to April 2019.

The effluent from the septic tank should not be allowed to enter the environment but should continue to be emptied by an accredited waste removal company and disposed of to an authorised waste water treatment works.

4.2.4 Mean Annual Runoff

The climate data used in this study were obtained from the Water Resources of South Africa, 2012 Study (WRC, 2012) which contains the climatic and catchment information of each quaternary catchment in South Africa. The project site is located in Quaternary Catchment B20A of the Olifants WMA. The Mean Annual Precipitation (MAP) calculated for this area is 668mm while the Mean Annual Evaporation (MAE) is 1 677mm and the Mean Annual Runoff (MAR) is 25.6 minimum control measure (mcm). Table 4.2 provides the average climatic data.

Table 4.2 B20A - Mean Monthly & Annual Precipitation, Evaporation and Runoff

Month	Precipitation (mm)	Evaporation (mm)	Runoff (mcm)
Oct	66	181	1.3
Nov	105	176	2.1
Dec	109	185	2.5
Jan	118	183	3.9
Feb	90	154	4.2
Mar	84	146	3.5
Apr	40	117	2.2
May	17	98	1.7
Jun	8	84	1.3
Jul	5	87	1.1
Aug	6	116	1.0
Sep	19	150	0.8
Annual	**668**	**1677**	**25.6**

4.2.5 Resource Class and River Health

In South Africa, a river health classification scheme is used to standardise the output of different river systems. The document titled "Resource Directed Measures for Protection of Water Resources: River Ecosystems Version 1.0.24", dated September 1999, compiled by the DWS, provides the indexes of Attainable Ecological Management Classes (AEMC) as shown in Table 4.3. Each index is calibrated so that its results can be expressed in terms of ecological and management perspectives.

Table 4.3 Resource Classes at set out by the DWS

River Health Class	Ecological perspective	Management perspective
Natural / Excellent (Class A)	No or negligible modification of in-stream and riparian habitats and biota	Protected rivers; relatively untouched by human hands; no discharge or impoundments allowed
Good (Class B)	Ecosystems essentially in good state; biodiversity largely intact	Some human-related disturbance but mostly of low impact potential
Fair (Class C)	A few sensitive species may be lost; lower abundance of biological populations are likely to occur, or sometimes, higher abundances of tolerant or opportunistic species occur.	Multiple disturbances associated with need for socio-economic development, e.g. impoundment habitat modification and water quality degradation
Poor Class D)	Habitat diversity and availability have declined; mostly only tolerant species present; species present are often diseased; population dynamics have been disrupted (e.g. biota can no longer reproduce or alien species have invaded the ecosystem)	Often characterised by high human densities or extensive resource exploitation. Management intervention is needed to improve river health – e.g. to restore flow patterns, river habitats or water quality.

According to the "Classes and Resource Quality Objectives of Water Resources for The Olifants Catchment" published on the 22nd of April 2016 in the Government Gazette No.39943, Regulation 466, the Bronkhorstspruit river catchment falls into the Ecological Management Class C as defined in Table 4.4.

Table 4.4 Resource Classes for the Bronkhorstspruit

River Name	Integrated Unit of Analysis (IUA)	Water Resource Class for IUA	Biophysical Node Name	Quaternary Catchment	Ecological Category to be maintained
Bronkhorstspruit (outlet of quaternary)	2 Wilge River catchment area	II	HN21/RU21	B20A	C

4.2.5.1 Receiving Water Quality Objectives

Constant increases in water demands, particularly from the Olifants River, motivated the DWS to investigate the water requirements of users in terms of both water quantity and quality, as well as the current management of the water resource. According to the "Classes and Resource Quality Objectives of Water Resources for The Olifants Catchment" published

on the 22nd of April 2016 in the Government Gazette No.39943, Regulation 466, no Resource Water Quality Objectives (RWQOs) have been set for the Bronkhorstspruit.

RWQOs have however been set for the Wilge River, of which the Bronkhorstspruit merges downstream. The RWQOs for the Wilge River at the outlet of the identified IUA (in quaternary catchment B20J) are presented in Table 4.5.

Table 4.5 Wilge River RWQOs

Sulphates	<200mg/L
F	≤ 2.50 mg/L
Al	≤ 0.105mg/L
Pb hard	≤ 9.5 µg/L
As	≤ 0.095mg/L
Se	≤ 0.022mg/L
Cd hard	≤ 3.0 µg/L
Cr(VI)	≤ 121 µg/L
Cu hard	≤ 6.0 µg/L
Hg	≤ 0.97 µg/L
Mn	≤ 0.990mg/L
Zn	≤ 25.2 µg/L
Chlorine	≤3 dissolve.1 µg/L free Cl
Endosulfan	≤ 0.13 µg/L
Atrazine	≤ 78.5 µg/

4.2.6 Surface Water User Survey

There are four (4) main uses of water that have been identified for the sub catchment of the Bronkhorstspruit up to the receiving water body, namely the Bronkhorstspruit Dam. The surface water uses include the following:

- Domestic use by formal and informal communities along the affected watercourse;
- Irrigation of crops, especially maize;
- Livestock watering including cattle, sheep and poultry; and
- Aquatic ecosystems including fish, macro and micro-invertebrates.

Very few water bodies in the Delmas area are used for recreational purposes due to their seasonal nature. In most cases, dams are used for fishing.

No direct abstraction of water from the Bronkhorstspruit occurs for commercial irrigation or extensive domestic use. Dams are usually filled with water from the boreholes and this clean water is mainly used for irrigation. Numerous pans occur in the Delmas area but are not utilised as a source of water for the above mentioned purposes.

4.2.7 Sensitive Areas (Wetlands)

The National Wetland Inventory (SANBI, 2011) and the Atlas of Freshwater Ecosystem Priority Areas in South Africa (Nel et al., 2011) indicates a number of valley bottom, hillslope seepage and pan wetlands as occurring on site. None of the wetlands are classed as FEPA's (Freshwater Ecosystem Priority Areas), and no FEPA wetlands occur within 3km of the study area boundary.

4.2.7.1 Wetland Delineation

In total, the area classified as wetland covers 1 382ha of the total mining right area, which makes up roughly 32.5% of the study area. Approximately 820ha of the site has however already been disturbed by surface mining activities, suggesting that the wetland extent on site was likely significantly more prior to the onset of mining activities. Table 4.6 summarises the wetlands located within the mining right area.

Table 4.6 Extent of wetland types identified on site

Wetland Type	Wetland Area (ha)	% of wetland area	% of study area
Channelled Valley Bottom	77.77	5.63	1.83
Hillslope Seepage	906.55	65.58	21.28
Pan	37.02	2.68	0.87
Unchannelled Valley Bottom	321.78	23.28	7.55
Dam	35.98	2.6	0.84
River Diversion	3.15	0.23	0.07
Total	1382.25	100	32.45

The wetland extent on site is dominated by extensive hillslope seepage wetlands. These wetlands make up more than 65% of the wetland area on site and cover more than 20% of the entire site. The majority of the seepage wetlands are considered seasonal to temporary wetlands (i.e. implying temporary to seasonal saturation of the soil profile) that are maintained by a shallow perched water table within the soil profile. The perched water table is derived and maintained from rainfall that infiltrates the soil profile and is prevented from deeper infiltration by an aquitard within the soil profile, usually a hard of soft plinthic layer. It is suspected that little interaction between deeper groundwater and this perched water table occurs, though no testing or modelling to support this statement was undertaken on site.

In many areas, the temporary edges of the hillslope seepage wetlands have been cultivated and are either still currently under maize cultivation or have been converted to planted pastures. Especially on the Farm Rietkuil, the intrusion of cultivation into the hillslope seepage wetlands has been extensive. Nonetheless, the remaining areas of hillslope seepage wetland characterised by natural vegetation represent, together with the two large valley bottom wetlands, the largest expanse of natural grassland within the study area.

Three (3) valley bottom wetlands were delineated within the study area (refer to Figure 4.5), consisting of the Bronkhorstspruit and two of its tributaries. Some confusion exists with regards to the naming of the Bronkhorstspruit, as the 1:50 000 topographical maps name the large valley bottom wetland in the east of the site as the Bronkhorstspruit, while road signs along the R50 tar road name the western valley bottom as the Bronkhorstspruit. For the purpose of this study, the naming as per the 1:50 000 topographical maps will be followed.

The Bronkhorstspruit valley bottom wetland consists of a broad, mostly unchannelled system characterised by vertic clay soils. The upper catchment as well as the upper reach of the wetland on site is utilised agriculturally, with livestock grazing the main activity within the wetland. On site, mining takes place on either side of the wetland and includes the Silica Mine that extends significantly into the wetland. A dam as well as several berms have been constructed within this reach of the wetland to control flows through the mining area. Downstream of the study area the character of the wetland changes significantly as flows become confined and a clearly incised channel forms where the alluvial deposits associated with the upper wetland end and the river flows over dolomite.

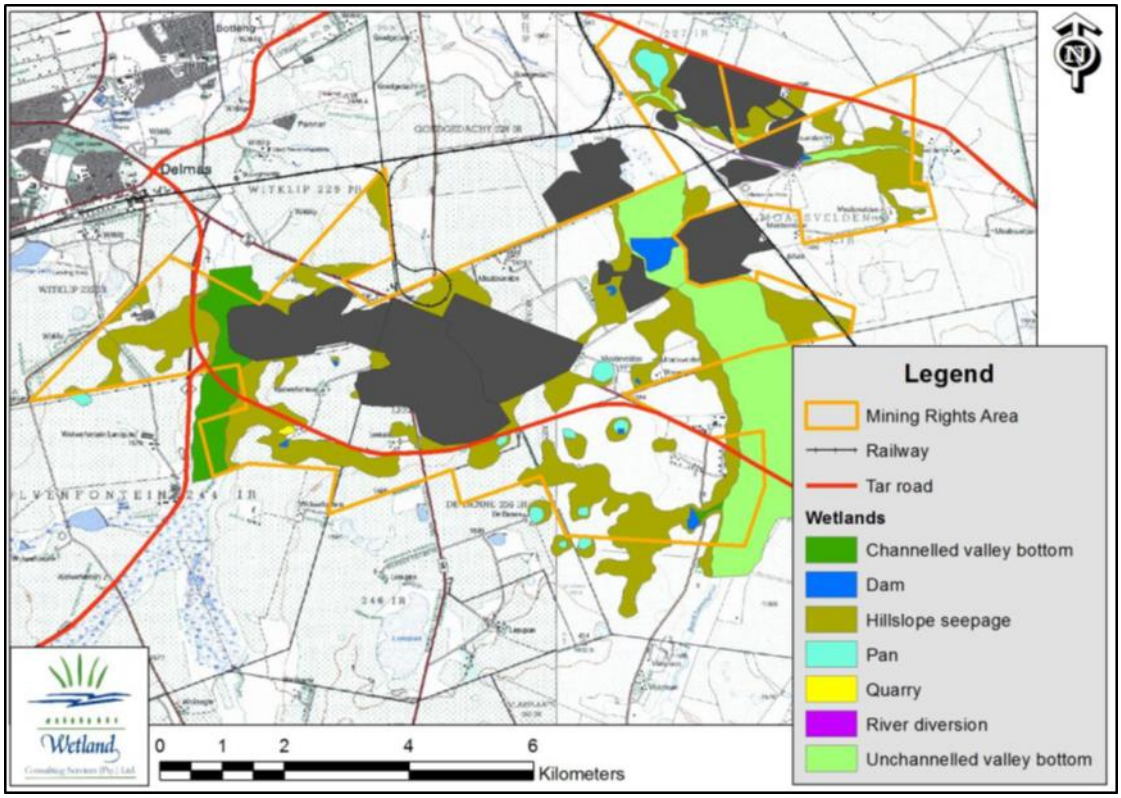


Figure 4.5 Identified Wetland Areas

A small unnamed tributary enters the Bronkhorstspruit from the east. This valley bottom wetland passes between the Leeuwpan mining activities and the Stuart East Colliery mining area and has necessitated a river diversion. A dam has been constructed on the upstream side of the mining activities and channels flows via a narrow, approximately 3m wide trench, around the mining activities.

In the east of the study area a further unnamed tributary of the Bronkhorstspruit flows from south to north across the study area. This is again a broad valley bottom wetland characterised by mostly vertic soils, though in contrast to the Bronkhorstspruit system on site, this system is clearly incised. Existing mining activities also extend into this wetland system and have required the construction of a large berm to divert flows around the mine activities. This activity has been authorized under the WULA that was submitted and approved for the mining of the OWM Reserves (Koos Smit, pers. comm., 2013)

Eight (8) pans occur within the study area, ranging in size from 0.4 to over 18ha. Most of these pans are shallow, seasonal depressions that are characterised by *Leersia hexandra* across their full width, though the pan at sampling point LP2 (see Figure 4.6 below) appears to be a permanent pan as it is lined by *Phragmites australis*. This pan is thought to be used as water storage for irrigation and is thus a highly modified system. A number of further pans have been significantly impacted by the construction of roads and irrigation dams within the pan basins.

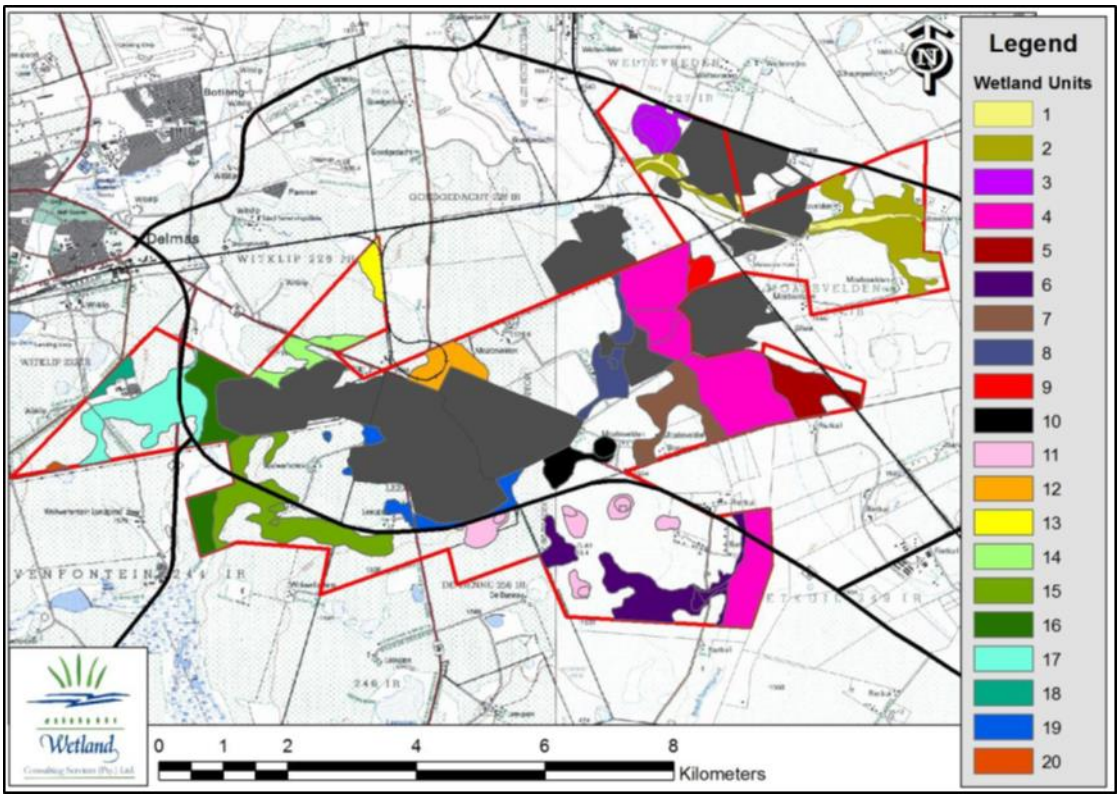


Figure 4.6 Map showing wetland units

4.2.7.2 Functional Assessment

Wetlands have been shown to perform a wide range of functions related to water quality improvement, flood attenuation, resource provision and erosion control, among others. However, each wetland is unique in the extent to which it is able to perform these functions, and the opportunity it is provided to perform these functions.

Many of the functions and services attributed to a wetland are inferred from the HGM classification of the wetland, as well as the levels of disturbance, cultural importance, and potential for the wetland to perform various functions. The nature of the functions that the wetlands perform and the services they provide were assessed using the WET-Eco Services tool, whereby both existing information and a field assessment were required.

At a site specific scale, as well as at the local and regional scale, the wetlands (especially the large valley bottom wetlands) represent the dominant remaining extent of natural vegetation and thus play a highly significant role in biodiversity support at this level. Virtually all terrestrial habitat on site has been significantly transformed due to agricultural and mining activities and most terrestrial areas are under cultivation, forcing species that under natural conditions might not be directly dependent on wetland habitats to frequent wetland habitats on site.

Loss of the wetland habitat on site would thus result not only in the loss of wetland dependent fauna, but also impact significantly on terrestrial faunal species that remain on site. At the National and International level, the importance of many of the smaller hillslope seepage wetlands and pans in biodiversity support is limited due to the disturbances that have already taken place within these systems, the generally low species richness of wetlands compared to other ecosystems (e.g. terrestrial grassland), and the limited number of Red Data species likely to occur on site.

Hillslope Seepage Wetlands:
As alluded to earlier, hillslope seepage wetlands are maintained by shallow sub-surface interflow, derived from rainwater.

Rainfall infiltrates the soil profile, percolates through the soil until it reaches an impermeable layer (e.g. a plinthic horizon or the underlying sandstone), and then percolates laterally through the soil profile along the aquitard (resulting in the formation of a perched water table). Such a perched water table occurs across large areas of the Mpumalanga Highveld, not only within hillslope seepage wetlands, but also within terrestrial areas, only at greater depth.

The hillslope seepage wetlands are merely the surface expression of this perched water table in those areas where a shallow soil profile results in the perched water table leading to saturation of the profile within 50cm of the soil surface. The importance of individual seepage wetlands in temporarily storing and then discharging flows to downslope wetlands (flow regulation) varies and depends on a number of factors. Generally, seepage wetlands associated with springs and located adjacent to terrestrial areas characterised by deep, well-drained soils are more likely to play an important role in flow regulation than seepage wetlands where the wetland and catchment are characterised by shallower soils. Such seepage wetlands are likely often maintained mostly by direct rainfall and lose most of their water to evapotranspiration, and surface run-off during large storm events.

Hillslope seeps can support conditions that facilitate both sulphate and nitrate reduction as interflow emerges through the organically rich wetland soil profile, and are thus thought to contribute to water quality improvement and/or the provision of high quality water. The greatest importance of the hillslope seepage wetlands on site is thus taken to be the movement of clean water through the hillslope seepage wetlands and into the adjacent valley bottom wetlands, though the flow contribution from hillslope seepage wetlands to downslope wetlands was not quantified.

As hillslope seepage wetlands, for the most part, are dependent on the presence of an aquiclude, either a hard or soft plinthic horizon, they are not generally regarded as significant sites for groundwater recharge (Parsons, 2004). However, by retaining water in the landscape and then slowly releasing this water into adjacent valley bottom or floodplain wetlands, some hillslope seepage wetlands can contribute to stream flow augmentation, especially during the rainy season and early dry season.

From an overall water yield perspective there is evidence that seepage wetlands contribute to water loss. The longer the water is retained on or near the surface the more likely it is to be lost through evapo-transpiration (McCartney, 2000).

Hillslope seepage wetlands are not generally considered to play an important role in flood attenuation, though early in the season, when still dry, the seeps have some capacity to retain water and thus reduce surface run-off. Later in the rainy season when the wetland soils are typically saturated, infiltration will decrease and surface run-off increase. Further flood attenuation can be provided by the surface roughness of the wetland vegetation; the greater the surface roughness of a wetland, the greater is the frictional resistance offered to the flow of water and the more effective the wetland will be in attenuating floods (Reppert et al., 1979).

In terms of the hillslope seepage wetlands on site, the surface roughness is taken to be moderately low, given that most of the seepage wetlands are either cultivated of characterised by typical grassland vegetation, thus offering only slight resistance to flow.

Valley Bottom Wetlands:

The linear nature of valley bottom wetlands within the landscape and their connectivity to the larger drainage system provides the opportunity for these wetlands to play an important role as an ecological corridor allowing the movement and migration of fauna and flora between remaining natural areas within the landscape.

Although modified in certain respects due to changes in landuse having brought about hydrological changes to these wetlands as well as vegetation transformation, the wetlands still provide a natural refuge for biodiversity, and within the study area and surroundings, the large valley bottom wetlands with associated footslope seepage wetlands represent the most significant extent of remaining natural vegetation, further enhancing their importance from a biodiversity support function.

Channelled valley bottom wetlands, through the erosion of a channel through the wetland, indicate that sediment trapping is not always an important function of these wetlands, except where regular overtopping of the channel occurs and flows spread across the full width of the wetland. Under low and medium flows, transport of sediment through, and out, of the system are more likely to be the dominant processes. Erosion may be both vertical and/or lateral and reflect the attempts of the stream to reach equilibrium with the imposed hydrology. From a functional perspective channelled valley bottom wetlands can play a role in flood attenuation when flows over top the channel bank and spread out over a greater width, with the surface roughness provided by the vegetation further slowing down the flood flows. These wetlands are considered to play only a minor role in the improvement of water quality given the short contact period between the water and the soil and vegetation within the wetland.

Un-channelled valley bottom wetlands reflect conditions where surface flow velocities are such that they do not, under existing flow conditions, have sufficient energy to transport sediment to the extent that a channel is formed. In addition to the biodiversity associated with these systems it is expected that they play an important role in retaining water in the landscape as well as in contributing to influencing water quality through for example mineralisation of rain water. These wetlands could be seen to play an important role in nutrient removal, including ammonia, through adsorption onto clay particles. The large size of the unchannelled valley bottom wetland associated with the Bronkhorstspruit suggests that this wetland plays an important role in flood attenuation – the temporary storage of flood waters within the wetland.

Pans/Depressions:

Given the position of many pans within the landscape, which is usually isolated from any stream channels, the opportunity for pans to attenuate floods is fairly limited, though some run-off is stored in pans. In the cases where pans are linked to the drainage network via seep zones, the function of flood attenuation is somewhat elevated. Pans are also not considered important for sediment trapping, as many pans are formed through the removal of sediment by wind when the pan basins are dry. Some precipitation of minerals and de-nitrification is expected to take place within pans, which contributes to improving water quality. Some of the accumulated salts and nutrients can however be exported out of the system and deposited on the surrounding slopes by wind during dry periods.

An important function usually performed by pans is the support of faunal and floral biodiversity, which is enhanced by the diversity in habitat types offered by different pans. Within the study area however, the small size of most of the pans, together with their

seasonal nature and the disturbed vegetation, the biodiversity support of these pans individually is expected to be limited. All of the pans are seasonal or even ephemeral systems, though the differences in pan basin size and depth, as well as catchment size and catchment soil characteristics results in pans that fill up and drain at different rates and times. As a consequence a great diversity of habitat is provided by the pans on site and in the surrounding area, and though they are all seasonal systems, the differing hydro periods result in the fact that at least some of the pans are likely to have water at any one time. The pans when seen as a complex of pan wetlands are thus of high importance in terms of biodiversity support, whereas if each pan is assessed in isolation, its importance in terms of biodiversity is limited.

4.3 Groundwater

4.3.1 Aquifer Characterisation

According to the IWWMP compiled by Clean Stream in 2009, the general conceptual aquifer model for the existing operations of the Leeuwpan Mine were defined and is presented below.

Underlying the mining area is sandstone shale and coal beds of the Vryheid Formation. The coal layers in this area are exceptionally thick, with an average thickness of 20 m. A near-surface weathered zone (soft material) is present and extends down to about 15 m. This unit includes transported colluvium and *in situ* weathered sediments and is underlain by consolidated sedimentary rocks of the Vryheid Formation.

The coal seams are situated at a depth between 20 and 40 m, forming layered sequences within the hard rock sedimentary units. The weathered upper zone and the coal seams are normally associated with higher hydraulic conductivities. In most cases, a multi-layered aquifer system is developed with a perched water table on or near the soft rock / hard rock contact and a deeper water table associated with secondary fractures within the hard rock sedimentary units.

Dolerite intrusions in the form of dykes and sills are widespread in both the Karoo Supergroup as well as the Malmani Subgroup, and are often found in this area. A dolerite sill or dyke is known to sub-outcrop immediately to the south of the mining area. These intrusions can serve as both aquifers and aquicludes. Thick unbroken dykes will inhibit the flow of water, while the baked and cracked contact zones can be highly conductive. The conductive zones effectively interconnect the layered strata of the Ecca sediments both vertically and horizontally into a single, but highly heterogeneous and an-isotropic unit. These structures thus tend to dominate the flow of groundwater.

4.3.2 Groundwater Quality

The groundwater quality information was obtained from the March 2019 Quarterly Monitoring Report (Annexure C). Nineteen groundwater sites were sampled in December 2018.The parameters measured in the field were compliant to SANS drinking water standards at all sites apart from TDS and EC in water from boreholes KENMB2_D, WELMB13_S and WOLMB15_S.

The following sites are monitored for groundwater monitoring (Refer to Section 5.4 for the geographical information relating to each Sampling point):

- West of ODN pit;
- Fuel Dispensary;
- Silver Dams 1and 2;
- Plant Stockpiles 1 and 2;
- Plant conveyor 2;
- North of Witklip;
- South West, South and South East of Kenbar;
- South of Delmas Silica (borehole does not exist);
- Moabsvelden Groundwater;
- Block OI New Mine Area 1 and 2;
- Block OH;
- Block OJ / Stuart Coal Upstream;
- De Denne Monitoring Borehole upstream of Block UI;
- Rietkuil Monitoring Boreholes;
- Moabsvelden 1 and 2;
- Block OA;
- ODN/PCD1 and 2;
- Weltevreden Monitoring Boreholes;
- Block UB; and
- Wolwenfontein Monitoring Boreholes.

The groundwater sample locations are sampled on a quarterly basis. The water analyses results are measured against various standards and limits to ascertain the water quality. The standards against which the water samples are compare include:

- SANS 241-1: 2015;
- IWUL 2011 limits (Licence no. 04/B21A/ABCGIJ/429); and
- IWUL 2015 limits (Licence no. 04/B21A/ABCGIJ/429 amendment).

4.3.2.1 Field Measurements

Groundwater sampling was conducted on monitoring boreholes in and around the mine as well as boreholes that are used for drinking water in surrounding farms. Groundwater was collected from 18 sampling sites and the sites that were not sampled were due to non-operational pumps, collapsed/blocked boreholes, presence of bees, and destroyed boreholes.

4.3.2.2 Groundwater Quality Results

The static groundwater level varied from 1.22 mbgl in borehole WELMB-S to 53.44 mbgl in borehole MOAMB9 in December 2018. The following trends were observed between September and December 2018:

- Stable water levels: KENMM3_D (0.02 m) and LEEMB18_D (0.05 m);
- Increases in water level: MOAMB7 (0.27 m), LW07 (0.28 m, compared to December 2017) and WELMB13_S (0.68 m); and
- Decreases in water levels: WWN02_D (-5.31 m), MOAMB9 (-3.99 m), KENMB2_D (-2.15 m), WOLMB15_S (-1.84 m), WOLMB15_D (-1.65 m), WWNMB16 (-1.24 m), RIE10B (-0.82 m), MOAMB10 (-0.61 m), RKL01 (- 0.6 m), KENMM3_S (-0.54 m), WITMB14 (-0.51 m), WELMB13_D (-0.33 m), RKL02 (-0.23 m) and MOAMB4 (-0.13 m).

Changes in water levels could be attributed to recharge by rainfall; and changes in rates of abstraction for agricultural activities (e.g. WWNMB16 and RKL02) and mine dewatering activities.

The water level data indicates a water divide around MOAMB4 and RKL01, with water generally flowing to the northeast and northwest in alignment with topography, and towards the Bronkhorstspruit to the east as well as the Bronkhorstspruit tributary to the west.
The following observations are made from the boreholes data:

- WWNMB16: The borehole water was characterised by a calcium/magnesium bicarbonate signature, typical of groundwater that is not affected by mining activities. The water was compliant to SANS 241:2015 drinking water quality standards (Table 11), and the levels of measured constituents were relatively stable in December compared to September 2018 apart from sulphate, which decrease;
- RIE10B: The borehole water was characterised by a calcium/magnesium bicarbonate signature. There were no major changes to levels of measured constituents apart from nitrate, which increased in December relative to September 2018. The levels of all constituents were below the drinking water standards in December; and
- MOAMB10: The borehole water was characterised by a calcium/magnesium bicarbonate signature. The levels of measured constituents were relatively stable and below the SANS 241: 2015 drinking water standards in December 2018.

4.3.3 Hydrocensus

The hydrogeological assessment that was compiled and undertaken as part of the Block OI Expansion is attached as Annexure D to this report.

As part of the study conducted for the Expansion IWULA, a total of 41 groundwater samples were assessed, taken from the hydrocensus and mine monitoring boreholes (existing and then newly drilled). The analytical results were compared to the DWS South African Water Quality Guidelines for Domestic Use Target Values (DWS SAWQTV) and South Africa National Standard (SANS 241-1:2011) Drinking Water Standard in order to evaluate the groundwater quality. The average background groundwater quality was also included in the analytical result tables for comparative purposes. The sampled boreholes are presented in Figure 4.7.

From the laboratory analysis (included in Annexure D), the following was determined:

- Hydrocensus Boreholes (2012):
    - Most of the water samples that were analysed indicated water with a calcium-magnesium-bicarbonate nature, which is indicative of an aquifer of dolomitic nature; and
    - A number of monitoring points plot within the sulphate dominant field (Ca, Mg – SO_4), which suggests mining related impacts.
- Monitoring Boreholes (existing):
    - The dominant water type was assessed to be calcium/magnesium-sulphate rich which is indicative of mining related impacts;
    - The fluoride concentration in monitoring borehole WTN02s exceeded SANS 241 Drinking water standard of 1.5 mg/l;
    - Three monitoring boreholes (WTN02s and WTN01s), exceeded the concentration compliance objectives for manganese;
    - Monitoring boreholes E2, WWN02s and WWN02s exceeded the SANS 241 Drinking water standard for iron;
    - The sulphate concentrations that were detected in monitoring borehole WWN01 exceeded the SANS 241 Drinking water standard 500 mg/l; and
    - Although the sulphate concentrations in borehole WWN02d, WWN02s were compliant with the SANS 241 Drinking water standard, they were elevated and exceeded the SAWG Domestic Use Target Value. Boreholes WWN02s and WWN02d are located up gradient of the dam west of the OD block opencast. Borehole WNN01 is located up gradient of this dam.
- Newly Drilled Monitoring Boreholes:

- The SANS 241 Drinking water standard was exceeded for sulphate in boreholes: KENMB3_D, MOAMB10, LEEMB18_D and KENMB2_D;
- The TDS concentrations exceeded SANS 241 Drinking water standard in boreholes: KENMB3_D, MOAMB10 and KENMB2_D;
- Manganese concentrations exceeded the SANS 241 Drinking water standard in MOAMB10 and WELMB13_D;
- In KENMB2_D and WELMB13_D the concentrations for electrical conductivity (EC) and iron exceeded the SANS 241 drinking water standard; and
- The dominant water type was assessed to be calcium/magnesium-sulphate rich which is indicative of mining related impacts. Only boreholes: WITMB14, KENMB3_S, WWNMB16 and MOAMB9 were determine to be calcium/magnesium-bicarbonate when assessed in the piper diagrams.

Overall, the dominant water type remains the calcium/magnesium-bicarbonate water which is indicative of water that is un-impacted by coal mining activities. A secondary type of calcium/magnesium-sulphate-chloride water is also found which indicates groundwater impacts related to mining activities. Sodium-bicarbonate type water is also present in the area.

4.3.3.1 Groundwater Users

Groundwater uses other than the Leeuwpan Coal, have been identified to include the following:

- Domestic use,
- Surrounding Mines in the area;
- Livestock watering,
- Garden,
- Maize milling, and
- Crop irrigation.

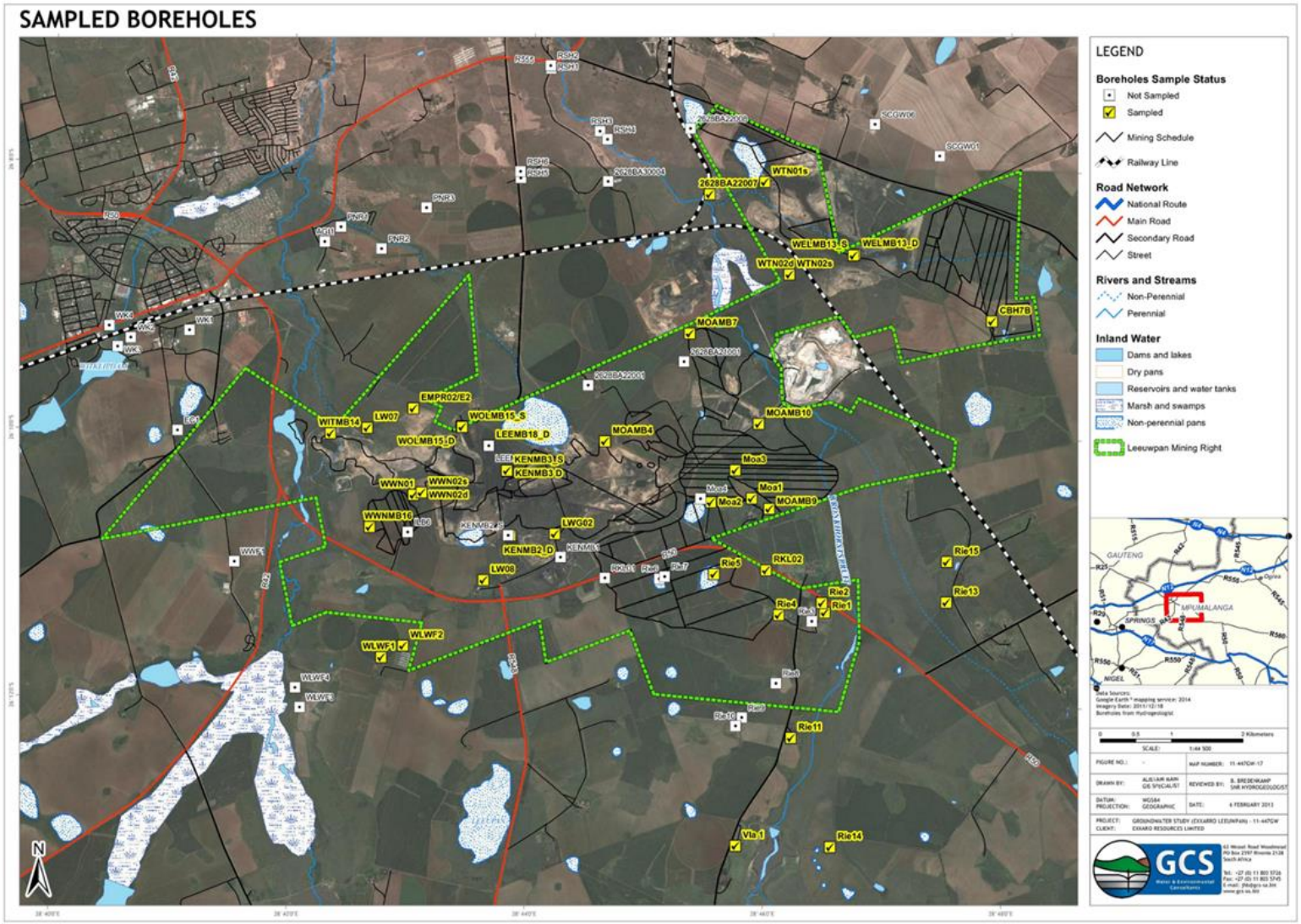


Figure 4.7 Sampled Boreholes

4.3.4 Potential Pollution Source Identification

Potential sources of groundwater pollution are present at Leeuwpan, as at any coal mining operation, due to the nature of the activity. The pollution of groundwater is very likely in the event should water storage facilities not be adequately lined to prevent any ingress of dirty water into the groundwater regime. However, negative impacts on the groundwater regime can be minimised if the commitments stipulated in the various authorisations and licenses are adhered to.

Potential sources of groundwater pollution at Leeuwpan Coal include:

- All open pits;
- All stockpiles;
- All slimes dams, whether in use or not;
- Wash bays;
- All process water storage facilities;
- All domestic waste water systems / installations;
- Water holding facilities associated with the Plant; and
- Evaporation dams.

4.3.5 Groundwater Model

Numerical groundwater modelling can be considered to be one of the most reliable methods of anticipating and quantifying the likely impacts on the groundwater regime. The model construction is described in detail below, followed by predicted impacts in terms of groundwater quality and quantity for all the relevant phases. Fetter (2001) described modelling as a method “to understand why a system is behaving in a particular observed manner or to predict how it will behave in the future”.

The model was constructed using GMS9.1, a pre- and post-processing package for MODFLOW and MT3DMS. GMS is the Graphical User Interface (GUI) for the well-established MODFLOW-2005 (Harbaugh et al, 2005) and MT3DMS (Zheng & Wang, 1999) numerical codes.

MODFLOW is a 3D, cell-centred, finite difference, saturated flow model developed by the United States Geological Survey. MODFLOW can perform both steady state and transient analyses and supports a wide variety of boundary conditions and input options. It was developed by McDonald and Harbaugh of the US Geological Survey in 1984 and updated several times since.

MT3DMS is a 3D model for the simulation of advection, dispersion, and chemical reactions of dissolved constituents in groundwater systems. MT3DMS uses a modular structure similar to

the structure utilised by MODFLOW, and is used in conjunction with MODFLOW in a two-step flow and transport simulation. Heads are computed by MODFLOW during the flow simulation and utilized by MT3DMS as the flow field for the transport portion of the simulation.

The usual required steps in numerical modelling are:

- *Data collecting and interpreting field data*: Collecting of field data is required to identify the processes and status of the specific area of interest. It is important to follow a thorough quality control/quality assurance program to ensure that collected data can be used with a high level of confidence;
- *Formulation of a site conceptual model:* The site is conceptualised in a manner which simplifies the natural conditions and processes;
- *Computer code and algorithm:* An acceptable computer code should be selected to ensure optimal modelling results and flow model construction;
- *Model calibration:* Model calibration and validation are essential for specific models before any predictions are made. The main aim of calibration is to obtain a degree of correspondence between the model simulation and the groundwater system. Calibration can be performed manually or automatically (by means of inverse modelling); and
- *Predictive simulations:* Once a model has been calibrated and validated it can be used as a predictive tool to simulate certain scenarios.

4.3.5.1 Model Construction

The model was constructed by GCS in 2014, using the latest groundwater and mine data in order to:

- Simulate current and future groundwater levels;
- Calculate the groundwater inflow volume into the active mining areas;
- Simulate the migration of potential contaminant plumes from mining related activities; and
- Simulate recovery of water levels.

Boundaries

The flow of groundwater in nature is impacted by boundary conditions. Where practical, natural topographical and groundwater water divides were used as flow boundaries in the top layer, assuming that the groundwater elevation follows the topography. A topographical divide flow boundary (groundwater divide) was used in the western, southern and eastern sections of the modelled area.

These boundaries were used on the north of the area, where flow is likely to occur parallel to streams (i.e. groundwater unlikely to move across a streamline during unstressed conditions). Constant head boundaries were used as part of the northern boundary to ensure numerical stability. A constant head boundary was used over a length of three kilometres of the Bronkhorstspruit. All the model boundaries were constructed a sufficient distance from the mining areas so as not to influence the model solution. The model boundaries in layer 2 to 3 have the same lateral extent as the top layer.

Model Discretisation

The modelling area was discretised by a 300 x 250 grid in the x and y direction, (see Figure 4.8). A refined cell size of 50 m x 50 was used in the mining area with gradual increase to about 400m on a regional scale. All modelled features, like opencasts and other sources were sizably larger than these dimensions, and the grid was thus adequate for the purpose.

The subsurface was modelled in three dimensions (three-layer model), as depicted in Figure 4.9 to Figure 4.11 below. The upper layer 40m thick layer represents the weathered and fractured Karoo aquifer system within which the coal resides, as well as the much older dolomite and Timball Hill formation ferruginous quartzite/shale inliers. Where the coal seams are at a deeper level, the bottom of this layer was lowered to reflect the actual coal floor. In the two deeper layers, the Dwyka tillite underlies the Karoo sediments as a thin 10m layer, while the dolomite underlies this all as a third layer of 50m. The quartzite was continued from the first to the third layer. All materials were digitized form the applicable geological map, but adjusted somewhat close to the mining area to include all pits in the Karoo. In particular, the model was designed to represent the Dwyka tillite in the second layer and the underlying dolomite in the third layer. Although the dip of the bedrock (especially the quartzite) is not included in the model layout, it is also insignificant to the depth of the model. It is also far enough removed from the area of interest to have any substantial influence on the groundwater flow.

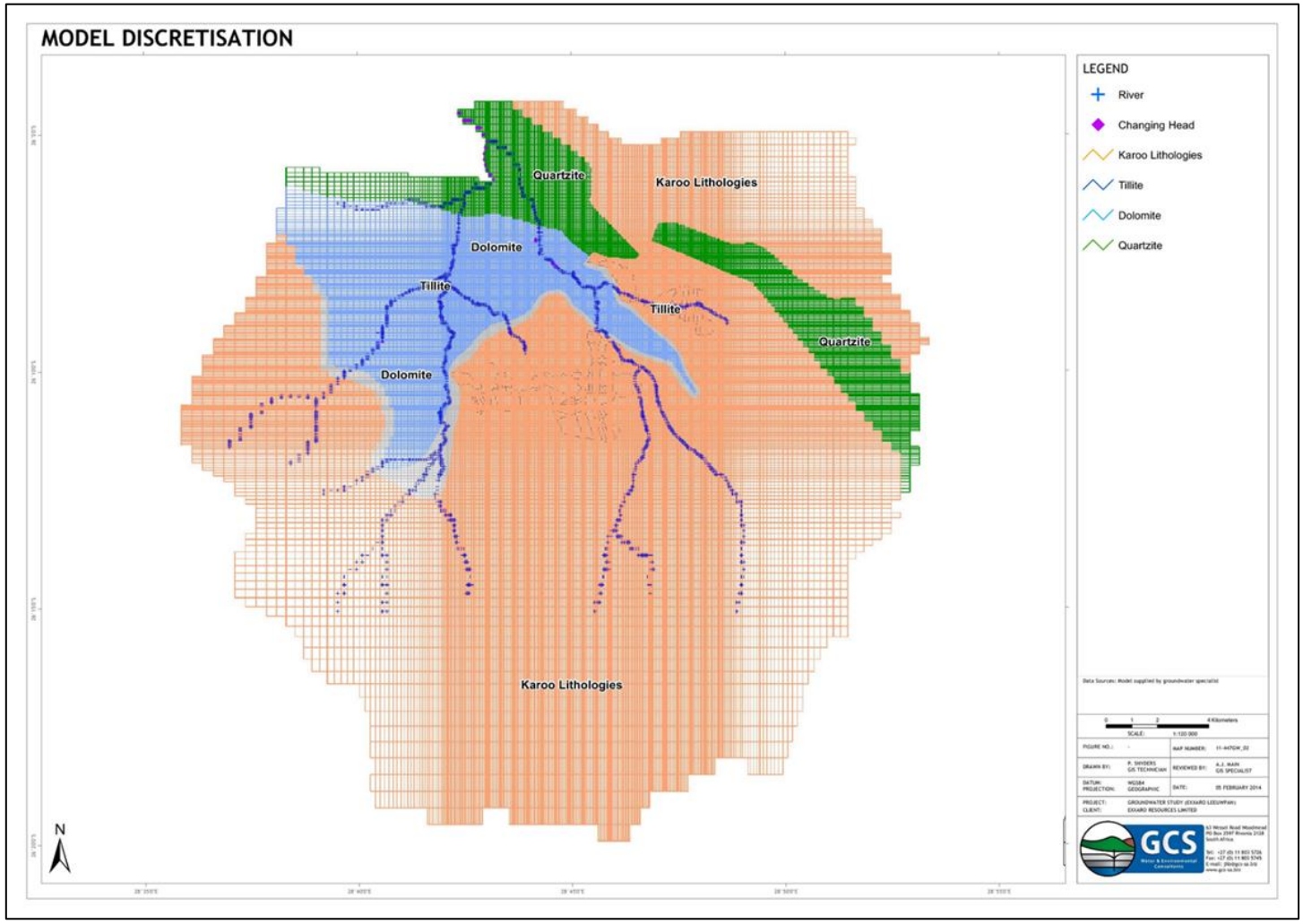


Figure 4.8 Model Discretisation and Boundaries

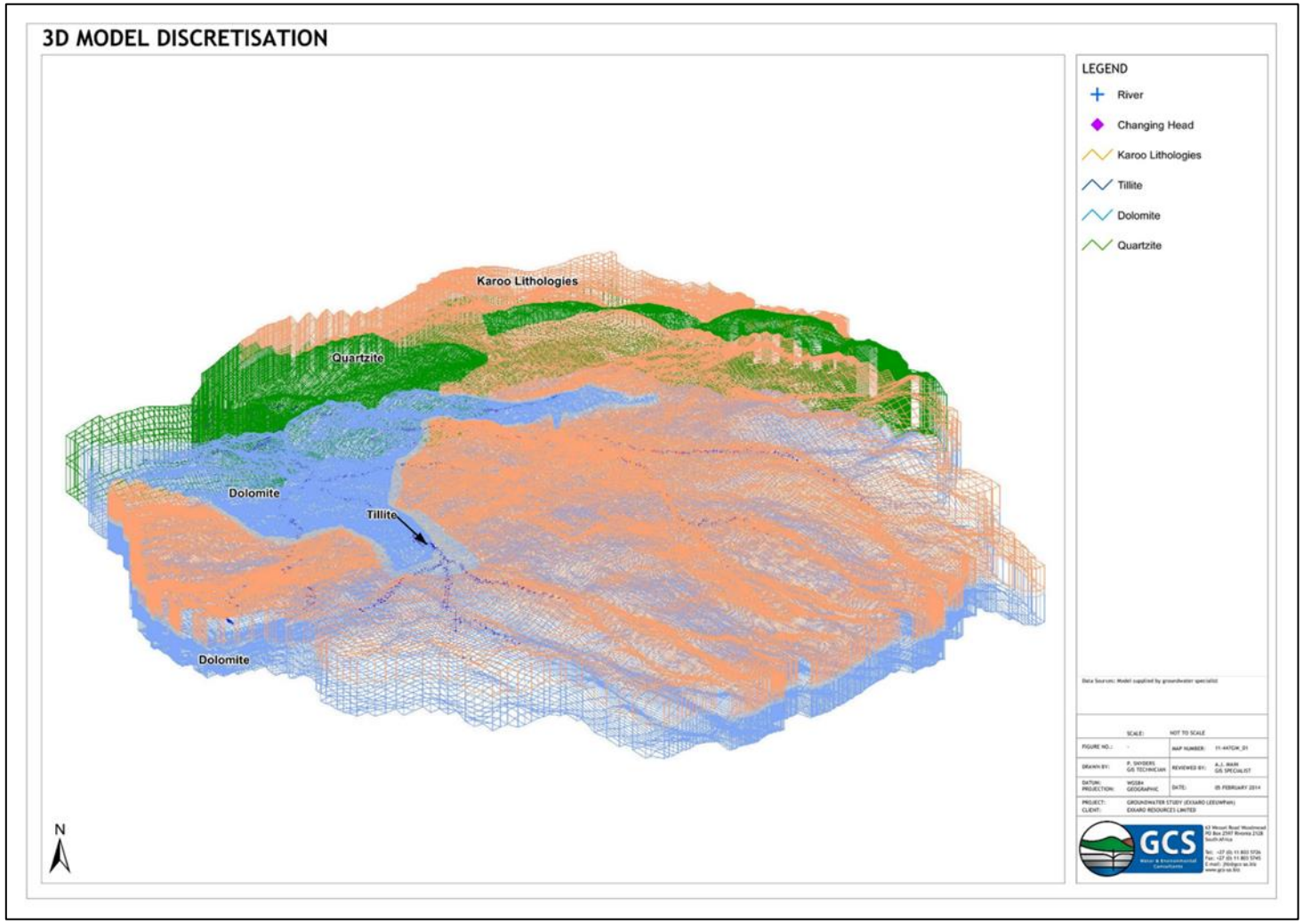


Figure 4.9 3D Model Discretisation

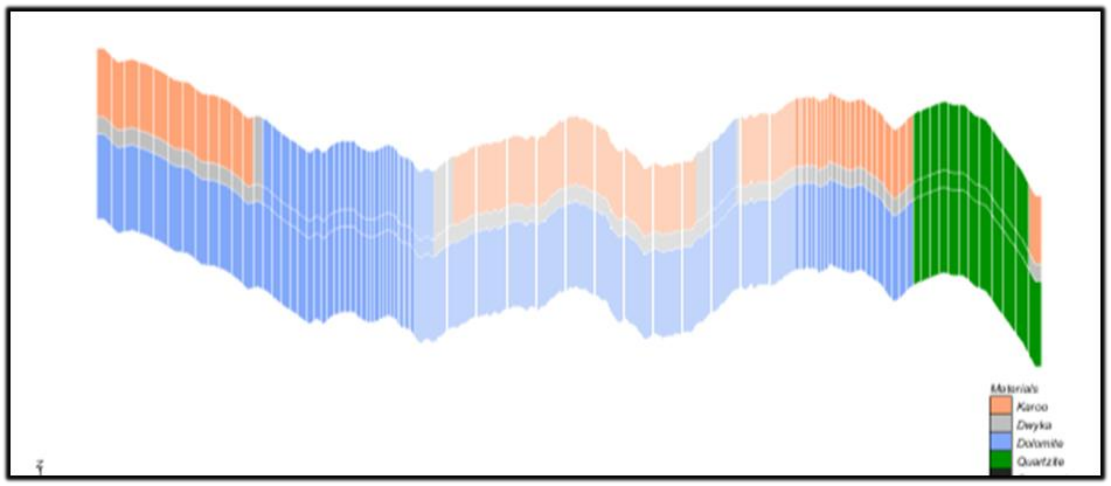


Figure 4.10 Section of Materials - East to West

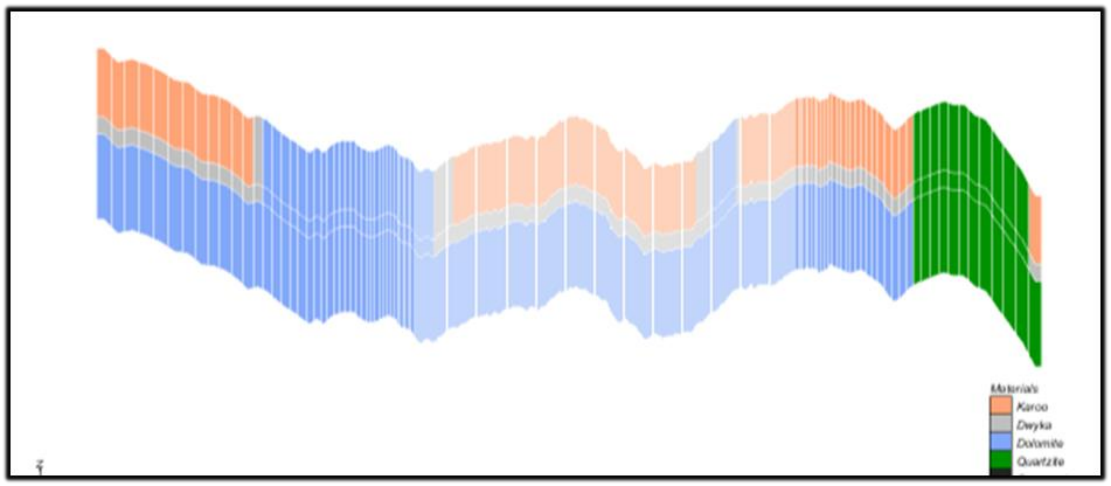


Figure 4.11 Section of Materials - South to North

Aquifer Parameters

Although the most relevant aquifer parameters are optimised by the calibration of the model (Section 0), many parameters are calculated or assumed due to experiences in similar environments. The following fixed assumptions and input parameters were used for the numerical model of this area:

- Recharge = 20 mm/a ≈ 0.00005 m/d. This value relates to a recharge percentage of about 2.7%, about the same value proposed by the previous groundwater studies;
- Evapotranspiration was used, a value of 0.0001 m/d was used which is average for grasslands, an extinction of 1m was simulated;
- Vertical Hydraulic Anisotropy (KH/KV) of the bedrock = 10. This is an estimate based on the sub-horizontal layering of the Karoo sediments;

- The specific yield (effective porosity) value was taken as 0.05, declining gradually to 0.01 at a depth of 100. This value could not be determined directly and were taken as typical of the fractured bedrock;
- Longitudinal dispersion was taken as 50 metres, which is about 10% of expected plume dimensions, as recommended in various modelling guidelines;
- Transverse and vertical dispersion was taken as 5m and 0.5m respectively, being about 10% and 1% of the longitudinal dispersion respectively, as recommended in various textbooks;
- The hydraulic conductivity of the rehabilitated opencasts was taken as 10 m/d. This is a typical value derived from pump tests in rehabilitated opencasts;
- The hydraulic conductivity of the weathered and fractured Karoo rock was taken as 0.02 m/d, the Dwyka tillite was assigned 0.005 m/d. These hydraulic conductivities correlate with the hydraulic conductivity estimated from the aquifer tests and previous studies at the mine.
- The dolomite was assigned a hydraulic conductivity of 10 m/d and the quartzite 0.01 m/d;
- A specific storage (S) value of $1x10^{-6}$ was used for all layers. This value relates to the compressibility of the aquifer and water and is approximately constant with depth. The specific storage of the dolomite was however estimated as $1x10^{-4}$ and used in the model;
- The effective porosity of the Karoo aquifers usually ranges between 1 and 5%. An effective porosity of 5% was assumed for the first layer, while a value of 25% was used for the opencasts;
- A 15% recharge was used for the backfilled opencast areas (Hodgson et. al, 2007); and
- Rivers were used to simulate groundwater loss from smaller ephemeral streams. The river conductance value used is 1 m^2/day.

Model Calibration

Aquifer parameters used in the model were obtained from previous field measurements and model calibration, using measured groundwater levels. The model was calibrated using "natural" steady state conditions in order to simulate pre mining water levels.

The calibration was done manually in various stages. Since it is apparent that the groundwater level in the dolomitic aquifer dominates groundwater levels in the upstream Karoo aquifer, the hydraulic conductivity in the dolomitic aquifer was firstly adjusted until modelled groundwater levels matched with measured values. Following that, the hydraulic conductivity in the Karoo aquifers were similarly adjusted and fitted to measured values. Lastly, boreholes

that obviously do not coincide with the regional groundwater levels were deactivated and minor final adjustments made to improve the overall fit over the modelled area.

The measured values not used in the calibration were mostly the boreholes reported as being pumped during the hydrocensus. One borehole in the dolomite (PNR3) was deactivated as a very shallow groundwater level was measured compared to all other boreholes in the dolomite. It was thus deduced that it was drilled in an isolated area, most likely a shallow perched aquifer on the regional dolomitic aquifer.

The calibration error statistics are presented in Table 4.7, the mean absolute residual and root mean square error was low (about 6m) and the mean error in the order of 1m. This is acceptable considering the size of the modelled area and the heterogeneity of the aquifers. Figure 4.12 shows the comparison between modelled heads obtained after calibration and observed heads. The current mining calibrated flow contours are presented in Figure 4.13. Using the observed water levels, a good fit of computed and measured groundwater levels was obtained, as can be visualised through the residual heads seen in Figure 4.14. The residual heads (green bars in the figure) are less than 10m, which is less than 10% of groundwater level differences over the modelled area as prescribed in various modelling guidelines such as Mandle (2002).

Table 4.7 Error Statistics

Summary Statistics for Calibration Targets	Value
Number of Targets	24
Mean Residual (Head)	-2.01
Mean Absolute Residual (Head)	4.78
Root Mean Squared Residual (Head)	6.02

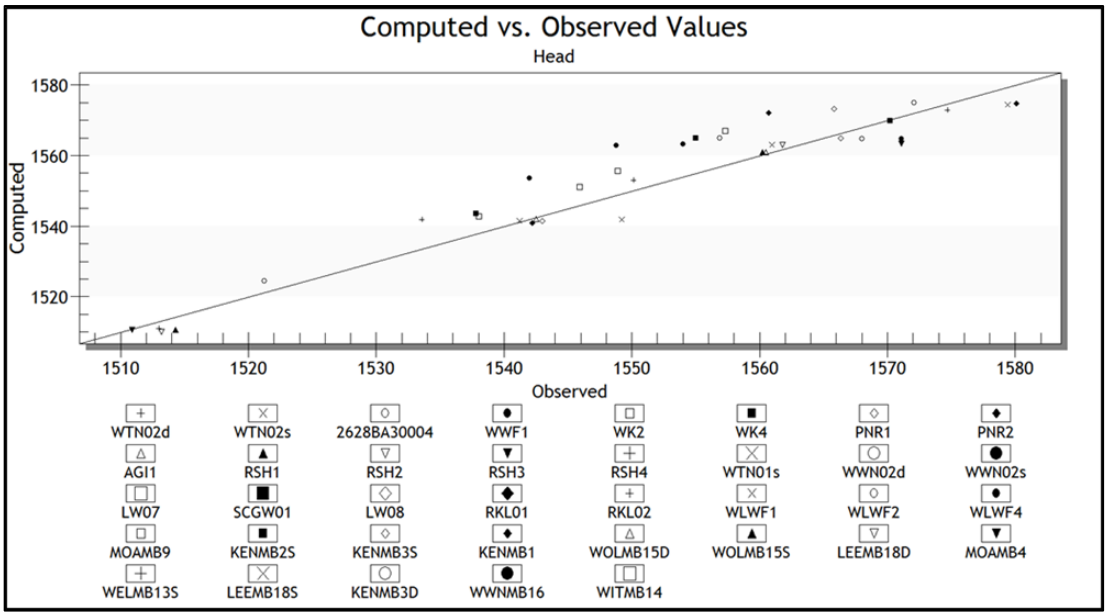


Figure 4.12 Observed versus Computed Water Levels

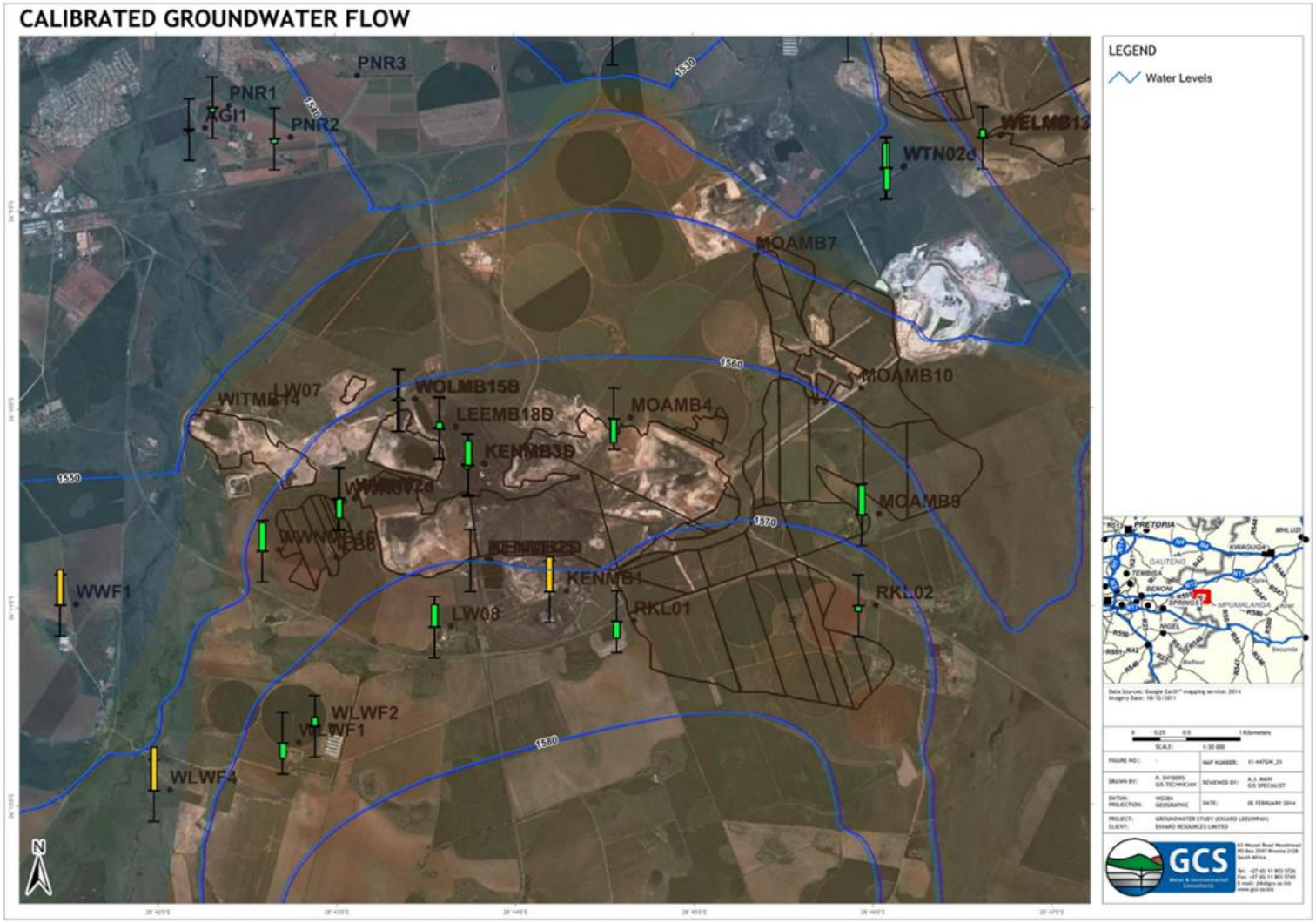


Figure 4.13 Current Mining Calibrated Flow

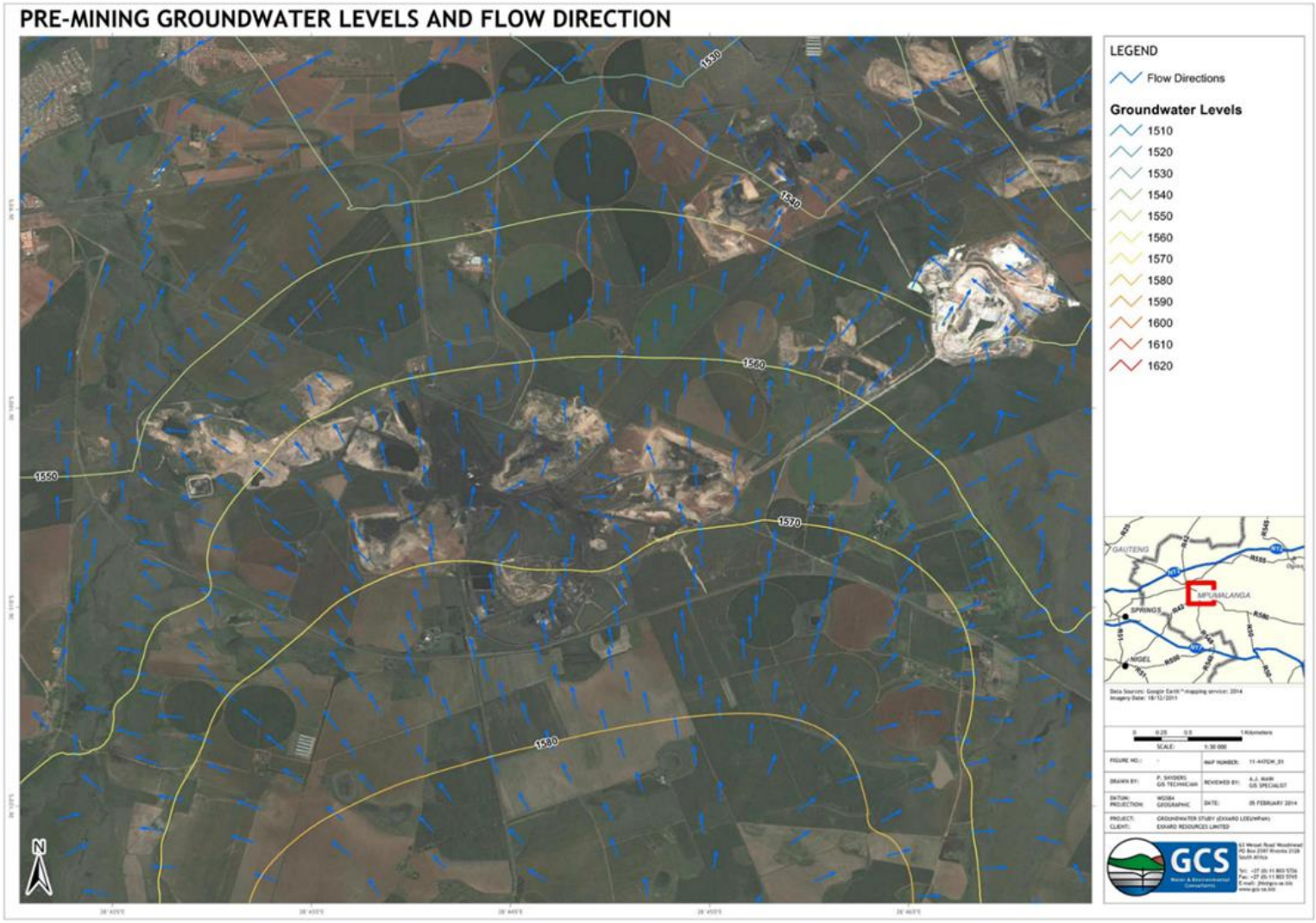


Figure 4.14 Pre-mining groundwater levels and flow direction

4.3.5.2 Simulating Dewatering of Mining Area

Groundwater flow into the existing and proposed mining area at Leeuwpan was modelled with drain cells. The elevation of the drain cells was specified according to the mine floor elevations.

Cumulative Impacts of Surrounding Mines

As previously mentioned a number of operating and defunct mines border the Leeuwpan Colliery. A few mines located adjacent to it may contribute to the impacts posed by Leeuwpan. Stuart Coal is located to the east of the OWN_WTN Block (Weltevreden) opencast, as well as another section to the north of the OJ Block open cast Leeuwpan. Furthermore Ferroglobe (Silica Mine) is located east of the OJ Block opencast. Ferroglobe are however exploiting quartzite underlying the coal rich Karoo Ecca Group. The impact of the surrounding mines and visa versa were not assessed during the scenarios.

Contaminated Transport Model

The calibrated groundwater flow model was used as a basis for developing a contaminant transport model. Sulphate concentration was used to determine the impact of mining on the aquifer. Sulphate is considered to be a water soluble oxidation product of ARD and is considered to be a representative indicator of the impact of coal mining on groundwater quality. The model is based on the following assumptions:

- Contaminant movement will mostly take place as a result of advection. This assumption is based on the calculation of the Peclet number (Pe) for the aquifer which indicates that advection is the main flow mechanism; and
- Chemical reaction between rock and dissolved species were not taken into consideration during simulations. Therefore a worst case scenario is assumed.

Movement of contaminant particles takes advection, dispersion and also flux sources into account. Longitudinal dispersion was taken as 50m, which is about a tenth of the maximum transport distance. Concentrations at different transport distances in the plume also take dilution from natural rainwater recharge and mixing into account (sources).

Due to the assumptions made and limited calibration data available, the results from the contaminant transport model are considered to represent a first approximation of the impact on groundwater quality. Due to the nature of the simulations, the estimated concentrations will reflect expected conditions within an order of magnitude.

It is advisable to recalibrate the flow model and transport model once more information regarding water qualities and new mining areas become available.

The sulphate source concentrations in the various opencasts were taken as 2500 mg/l SO4, as determined during the geochemical assessment.

4.3.5.3 Model Limitations

A numerical model does not provide a unique solution. Therefore, numerical modelling will always have inaccuracies due to the uncertainty in data, the capabilities/limitations of numerical modelling code to describe the natural processes and the factors selected by the modeller to resolve the non-unique solution. The modelling was performed within the limitations of the scope of work of this study and the amount of water level data available. All efforts have been made to base the model on sound assumptions and was calibrated to observed data, however the results obtained from this exercise should be considered in accordance with the assumptions made.

Field data is essential in calibrating model conditions. Specific assumptions related to the available field data include:

- The top of the aquifer is represented by the surface topography and available surface elevations (STRM data in this case) are used to construct a representative spatial extent;
- The current geological information is sufficient to describe the extent of the different aquifers;
- The aquifer parameters calculated is representative of the aquifers beyond the area, where data is not available (no aquifer parameters were available beyond the local mining areas); and
- The assumption that a fractured aquifer will behave as a homogeneous porous medium can lead to error. However, on a large enough scale (bigger than the REF, Representative Elemental Volume) this assumption should be acceptable.

Limitations of models are the result of generalisations, interpretations and assumptions made in attempting to simulate the natural environment. The following limitations are true for all numerical groundwater models:

- The complexities of fractured rock aquifers imply that the model can only be used as a guide to determine the order of magnitude of dewatering and contaminant transport; and
- The interpretation of modelled results should be based on the assumptions the model was built on and actual results will vary as unknown aquifer conditions and parameters vary in the natural system.

4.3.6 Acid Mine Drainage Plan

Acid mine drainage (AMD) also known as acid rock drainage (ARD) is a well-defined process where sulphide minerals (mainly pyrite) are oxidized to produce acidic leachate. This reaction is a two-step process where the first reaction result in sulphuric acid and ferrous sulphate, then with further oxidation ferric hydroxide and more sulphuric acid is formed. Pyrite is a common minor constituent in many mineral deposits, such as coal.

In the natural environment this reaction takes place at a very slow rate and as a result naturalization almost always removes the acidity. Mining activities disturb the in-situ rocks and expose pyrite, which accelerates the oxidation reaction.

4.3.6.1 Site Characterisation and Field Work

An AMD management strategy should consist of the following actions:

- **Development of a site specific conceptual model**. This model will describe the following:
    - Conceptualize the source – Identify all geological units that are disturbed during mining? Determine which of these units are potential acid forming?;
    - Conceptualize the pathway – What is the most likely pathway for contaminants to migrate off site and reach potential receptors (surface or groundwater); and
    - Identify the receptors – identify all potential current and future receptors.
- **Sample selection**. Based on the conceptual model a sample plan should be developed to get information of the disturbed geological units (geochemical analyses) as well as the surface and groundwater quality. The sample plan will determine which materials and locations needs to be sampled.
- **Test work** (as described below).

Test Work

Geochemical test work to predict AMD consists of the following:

- Static testing, such as Acid Base Accounting (ABA). Static test gives an indication of the overall potential that a rock sample will generate acidic leachate. It determines the balance of acid generating and acid neutralizing capacity of a sample. This is a relatively low-cost procedure which can be done in a matter of hours to a few days.
- Kinetic testing, such as humidity cell tests attempt to predict the quality of the leachate over time. Rocks / samples with a net acid generating potential will be subjected to kinetic test. Kinetic test is defined as a group of test work procedure wherein acid generation and metal mobilization from a sample is measured over time. These procedures could take up to 26 weeks to complete.

Field trails are set up as large-scale column leach tests on the sites – under actual field conditions. Laboratory tests need to be converted to field conditions and the best way of "calibrating" the lab results are with field trails.

4.3.6.2 Acid Mine Drainage Management Plan for Leeuwpan Mine

The following Acid Mine Drainage management plan have been developed for Leeuwpan Mine:

- A review of geological units that are disturbed during mining has been done. The geological database was used to develop conceptual geochemical units of all the disturbed lithologies.
- Geochemical units have been sampled and submitted for static test work.
- Samples from geological units that are potentially acid forming have been submitted for kinetic test work.
- Field trails have been set up on the mine with potentially acid forming samples.
- Review all surface and groundwater chemical data with reference to acidic leachate is done on a continuous basis.
- Once the results of the field trials are available a geochemical report will be produced which will make proposals for the handling and disposal of potentially acidic materials. This report will also inform closure scenario selections for the various mining voids.

4.4 Socio-Economic Environment

The social baseline of the Socio-Economic environment has been assessed and determined for the various applications made.

4.4.1 Regional Context

Mpumalanga literally means "the place where the sun rises". Mpumalanga lies in eastern South Africa, north of KwaZulu-Natal and borders Swaziland and Mozambique. In the north it borders on the Limpopo Province, while to the west it borders on the Gauteng Province, to the southwest it borders on the Free State Province and to the south the KwaZulu-Natal Province. The capital is of the Province is Mbombela (previously known as Nelspruit).

Mpumalanga Province is divided into three District Municipalities (DM), which are further subdivided into 17 Local Municipalities (LM). The DMS for the Mpumalanga Province are provided below:

- District Municipalities
    - Gert Sibande DM;
    - **Nkangala DM;** and
    - Ehlanzeni DM.

The Nkangala DM is divided into the following LM:

- Emalahleni LM;
- Thembisile Hani LM;
- Dr JS Moroka LM;
- Steve Tshwete LM;
- **Victor Khanye LM; and**
- Emakhazeni LM

4.4.2 Local Context

Victor Khanye LM (formerly Delmas Local Municipality) is located in the Western Highveld of the Nkangala DM. The Victor Khanye LM's boasts a growing economy, with the trade sector, agriculture and mining sector forming the cornerstones of the economy. Mining activities within the LM are currently concentrated on coal and silica. Agriculture is, however, the main source of employment in the area and is growing constantly.

The Victor Khanye LM consist the following main places:

- Delmas;
- Botleng;
- Eloff; and
- Sundra

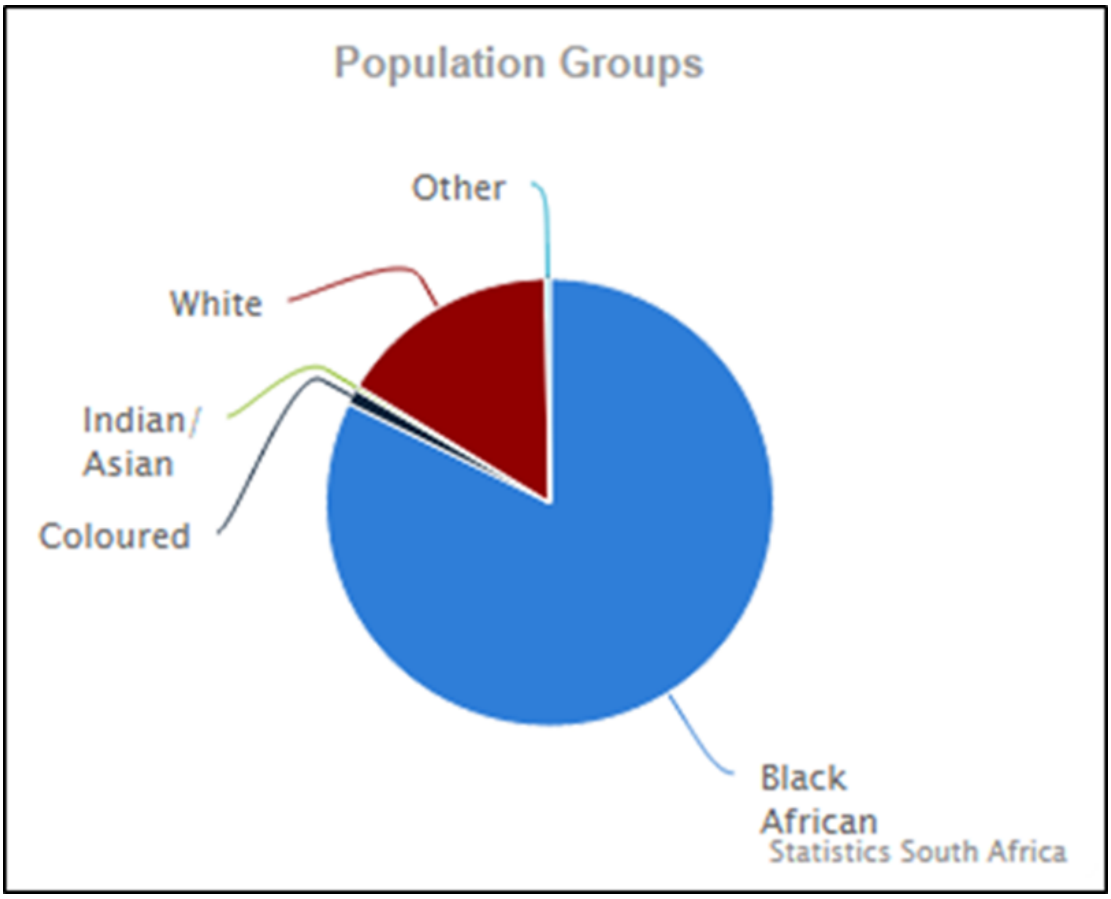
4.4.2.1 Demographic profile

Population and household profile:

The total population of Victor Khanye LM is approximately 75 452 persons, which amounts to 5.8% of the total Nkangala DM population of 1 308 129 and 1.8% of the Mpumalanga province population of 4 039 939. The average household size in Nkangala DM and Victor Khanye LM is 3.5 and 3.6 respectively.

Population group:

Figure 4.15 indicates that the Victor Khanye LM population in 2011 were composed of mostly Black African persons (82.3%) followed by 16% White persons. Both the percentage of Black African's, as well as White people has increased, whilst the percentage of Coloured people residing in the LM has decreased since 2010.



Source: Stats SA

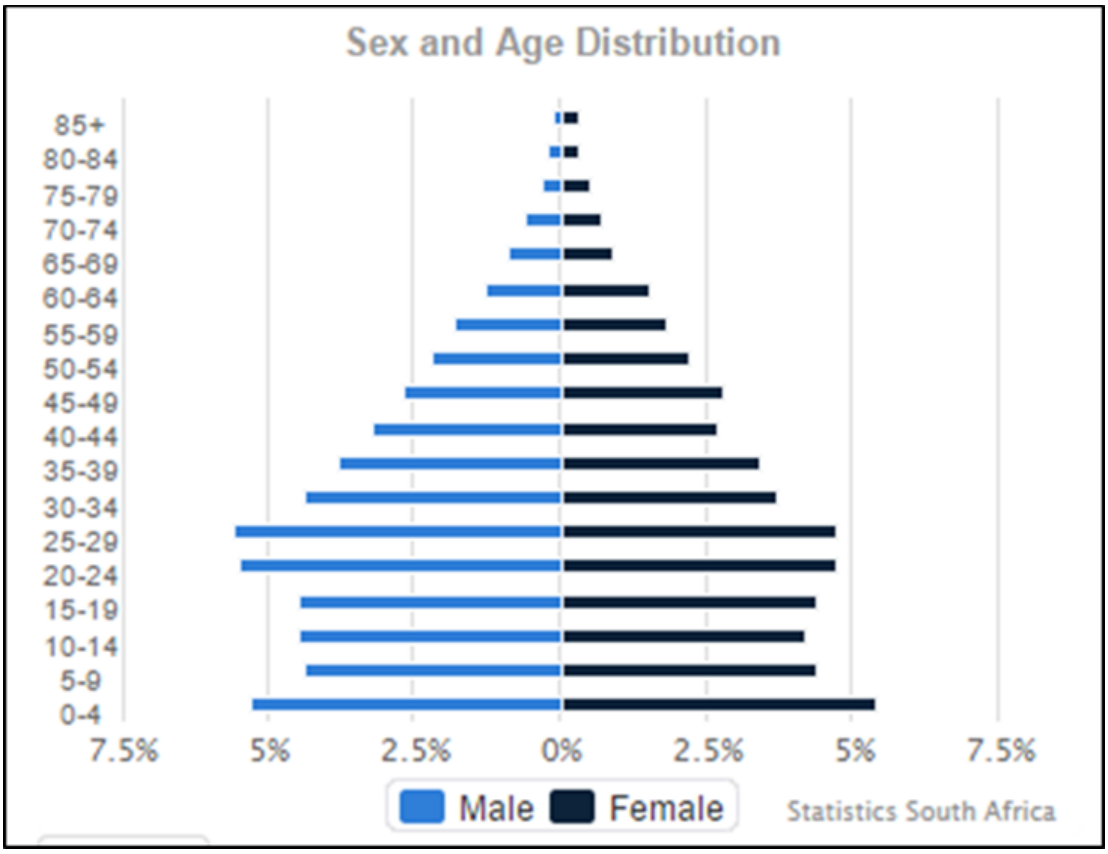
Figure 4.15 Population group (2011)

Age:

It is important to assess the age distribution of persons in order to determine both the current and future needs of an area. Age is an important indicator as it relates to education, skills and dependency. A young population may require an improved educational system, whereas an older society may need an accented focus on healthcare.

The Victor Khanye LM population has a large adolescent population with 28.2% of the population being younger than 15 years of age (Figure 4.16), indicating that they do not form part of the Economically Active Population (EAP) of the area. A bit more than two thirds (67.1%) of the Victor Khanye LM population falls within the EAP (16 to 64 year) age band. These persons normally have more work experience and usually fall within the higher skilled and higher salary bracket. One can clearly note that the population starts decreasing from the age of 29 years, leaving fewer economically active individuals. The elderly population (65 years and older) is very small (4.7%), which means that less burden is placed on the EAP to support persons that are no longer economically active.

The Nkangala DM has a similar age group division of people residing in the DM with 28.5% of the population being younger than 15 years of age, 66.5% fall within the 16-64 years of age band and 5% being 65 years or older.



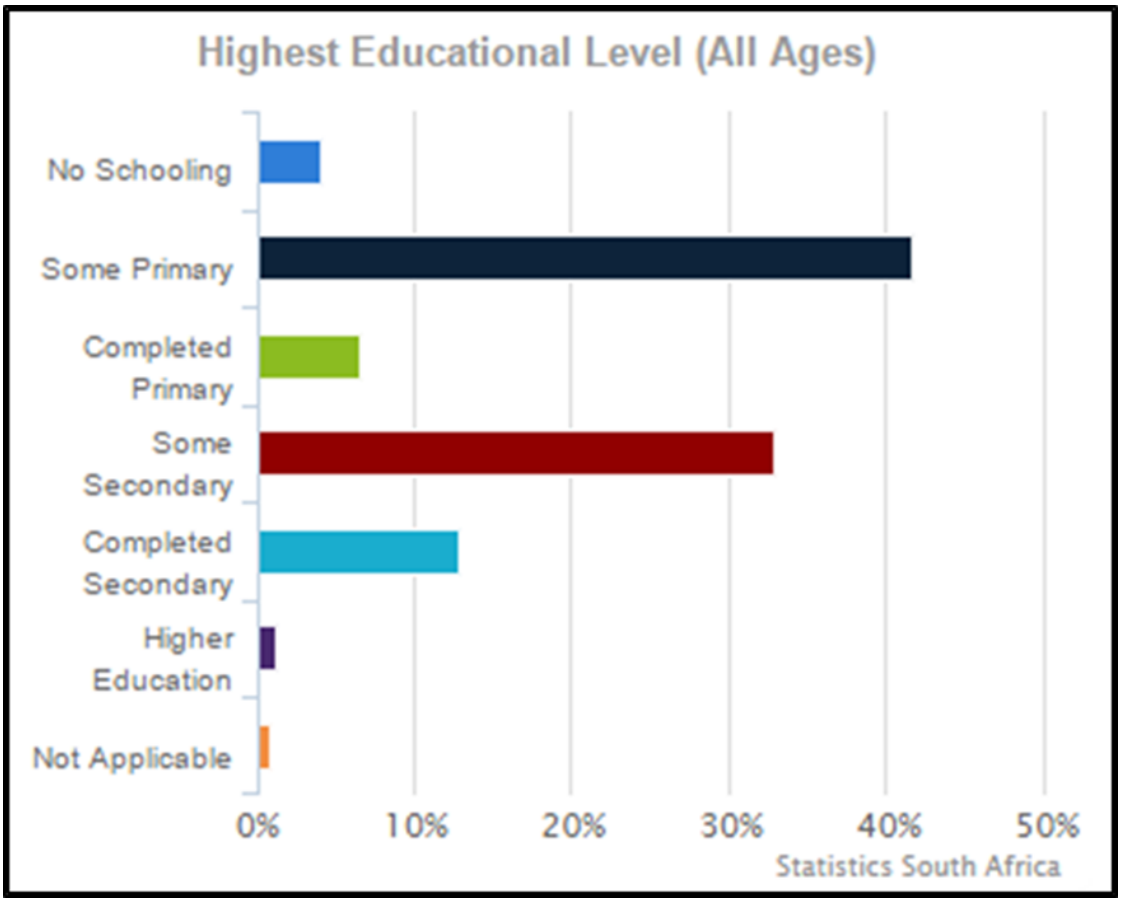
Source: Stats SA

Figure 4.16 Age Distribution (2011)

Education

The largest percentage of people in the Nkangala DM has finalised matric (29.4%), 11.5% of the residents in the DM have no schooling at all and 10.2% have higher education.

The largest percentage of people in the Victor Khanye LM have some primary education (41.6%), 6.5% have completed their primary education. 32.8% of the people in the LM have some secondary education, 12.9% have completed their secondary education. 4.1% of the residents of the LM have no schooling and 1.3% have higher education levels (Figure 4.17).



Source: Stats SA

Figure 4.17 Education Level (2011)

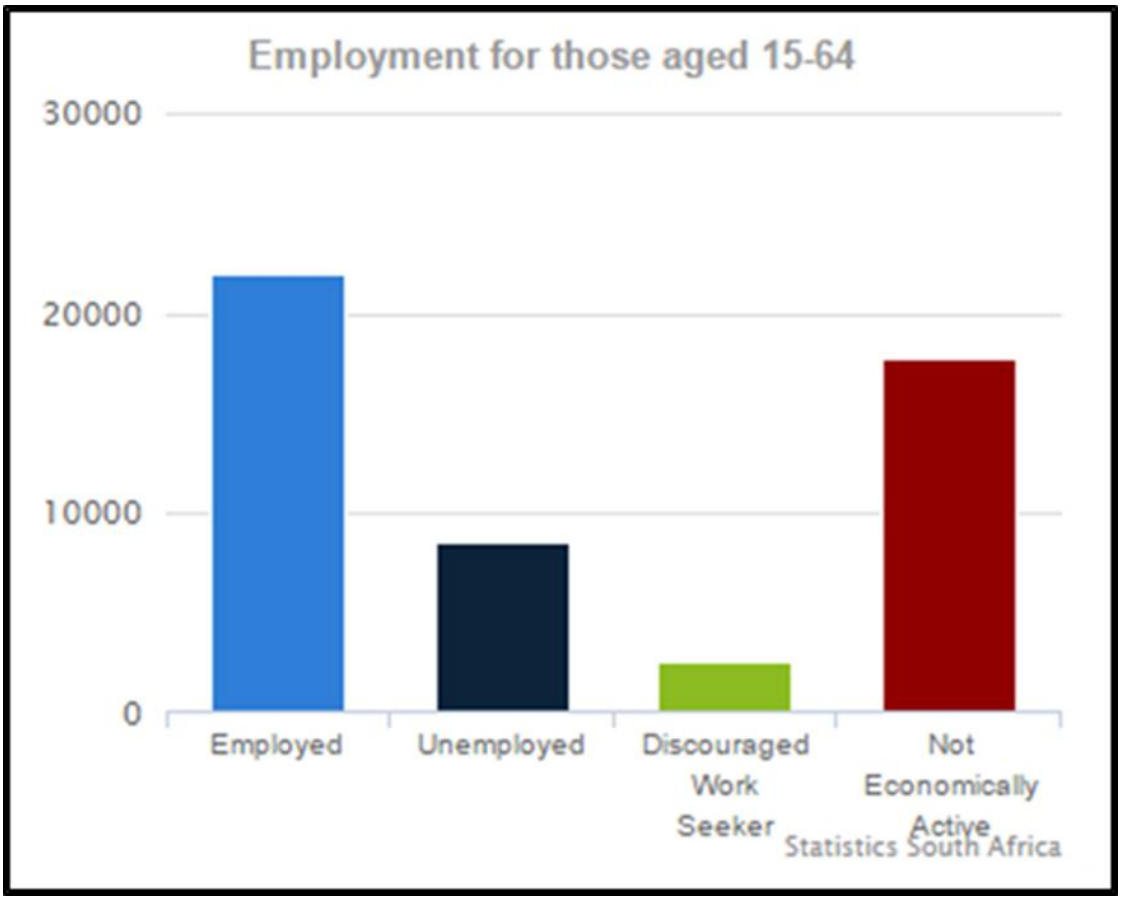
4.4.2.2 Economic Profile

This section provides a delineation of the study area and a brief economic status quo pertaining to employment and labour profile.

Employment and labour profile

The employment status of the population has a variety of important implications. Economically active and employed persons can contribute to the overall welfare of a specific community by paying their taxes, looking after the youth and aged and by stimulating the economy. However, should a community have a large number of economically inactive and / or unemployed persons, the burden on the EAP of that community are amplified.

The unemployment rate in both the Nkangala DM, as well as the Victor Khanye LM are high, 30% and 28.2% respectively. Youth unemployment levels are even higher for the DM and LM, 39.6% and 35.8% respectively (Figure 4.18).



Source: Stats SA

Figure 4.18 Economic Status

The main economic sectors in the Nkangala DM are: mining, manufacturing, energy and agriculture.

Regarding the Victor Khanye LM, farming is the most dominant economic activity occupying approximately 60% of the total physical area. However, in terms of output and proportional contribution to the local economy, the largest sector is trade, followed by agriculture and mining sectors.

4.4.2.3 Services and Infrastructure Profile

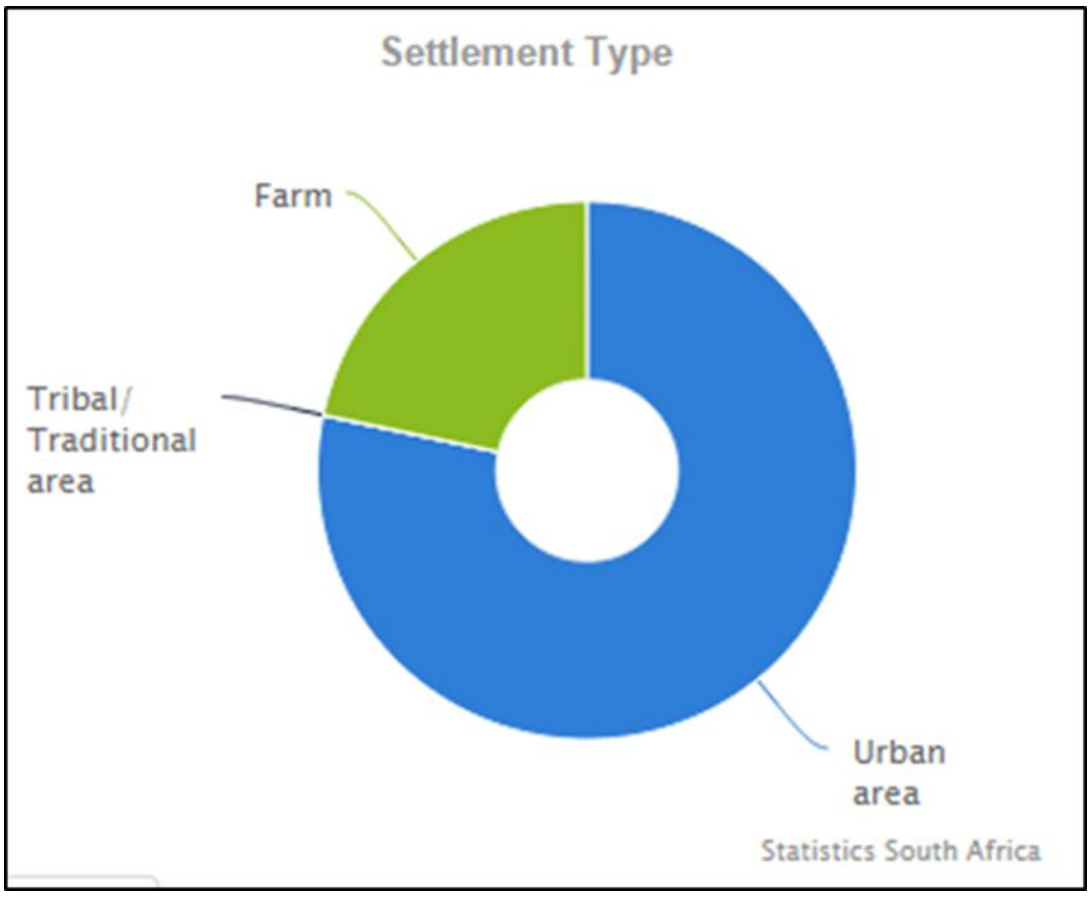
Social service delivery centres on the provision of health, education and community development facilities and services. The concept of service delivery also comprises various elements such as affordability, quality, efficiency and access.

This indicator therefore examines the level of service provision in the study area. Services assessed include sanitation, water, housing and electrification. There are three priority

services (water, sanitation and electricity) for the promotion of health, convenience and quality of life.

Housing

The majority of households within the Nkangala DM reside in formal dwellings (82.8%) and 58.9% of the people are house owners. The figures for the Victor Khanye LM are similar, with 79.2% of the households residing in formal dwellings and 53.7% of the households own their homes. 21.7% of the residents in the LM stay on farms (Figure 4.19).



Source: Stats SA

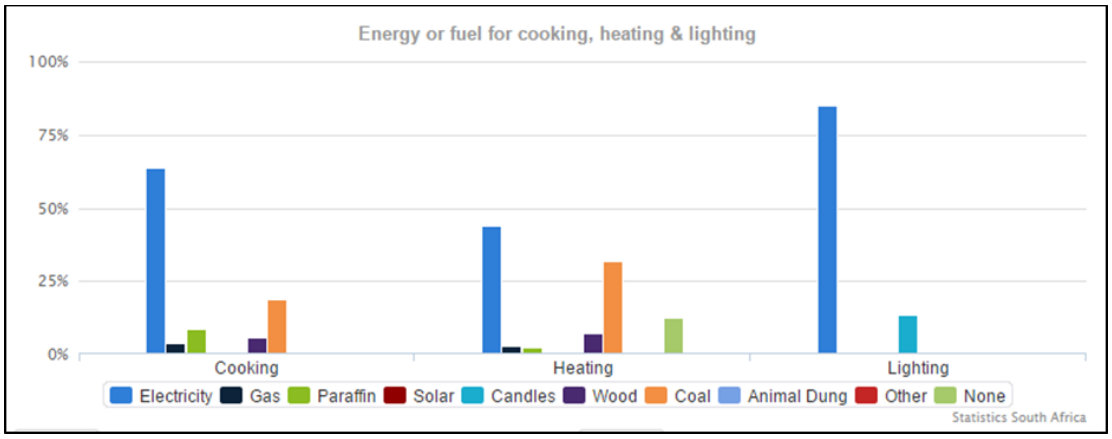
Figure 4.19 Type of Dwelling (2011)

Energy use

In the Nkangala DM 85.7% of the households make use of electricity for lighting. In the Victor Khanye LM this figure is similar with 84.9% of the households using electricity for lighting. 13.1% of the households use candles for lighting.

For cooking the majority of the households make use of electricity (63.5%), followed by the use of coal (18.7%), paraffin (8.2%), wood (5.6%) and gas (3.4%). For heating the trend is

similar with the majority of the households using electricity for heating (43.9%), followed by the use of coal (31.6%), wood (6.9%), gas (2.7%) and paraffin (2.3%). 12.2% of the households don't heat their dwellings (Figure 4.20).

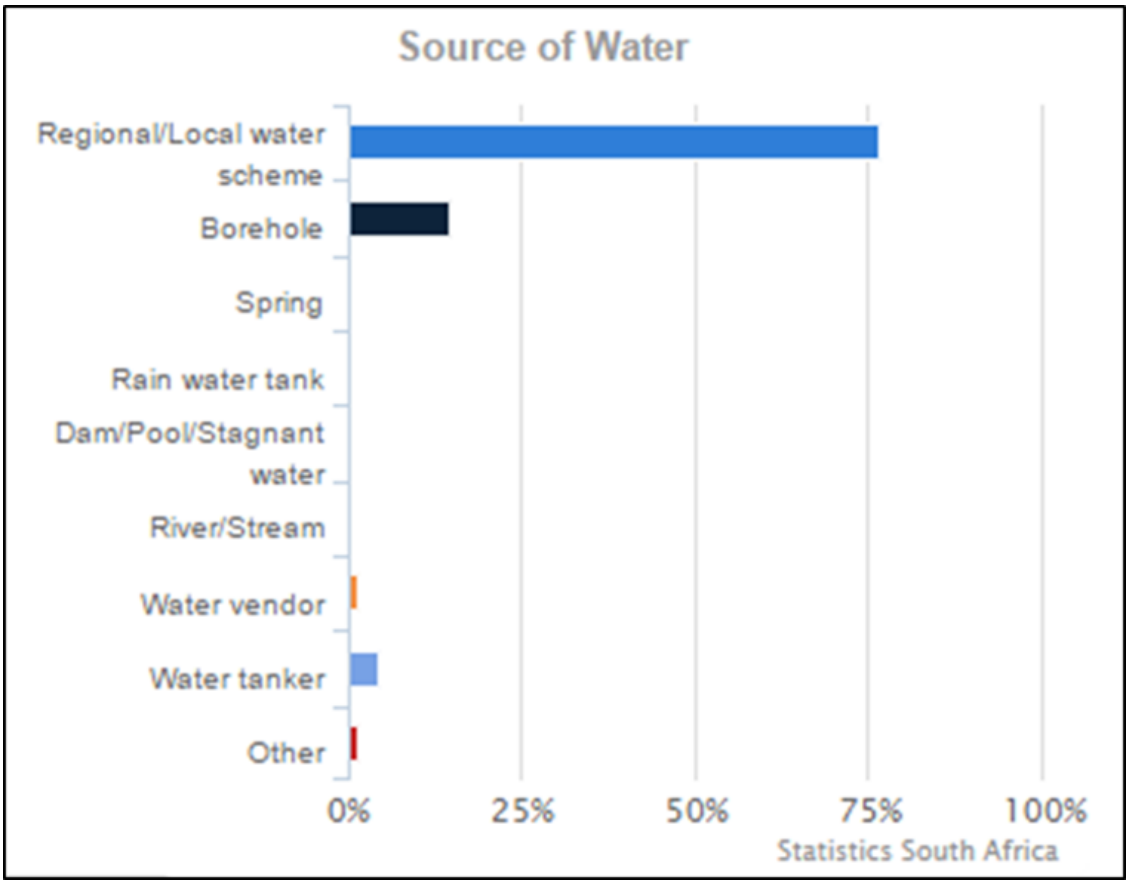


Source: Stats SA

Figure 4.20 Sources and Use of Energy (2011)

Water

40.6% of the households in the Nkangala DM have access to piped water in their dwelling. Most households in the Victor Khanye LM (48.4%) have access to piped water in their dwelling, with 34.8% of the households having access to piped water in their yard. Only 4.3% of the households do not have access to piped water (Figure 4.21).



Source: Stats SA

Figure 4.21 Type of water source (2011)

Healthcare

HIV/AIDS in South Africa has increased rapidly over the past decade. The social and economic consequences of the disease are far reaching and affect every facet of life in South Africa. Despite South Africa creating a progressive and far-sighted policy and legislative environment for dealing with HIV/AIDS, the prevalence of HIV/AIDS continues to increase. This indicates that policies and laws have not been adequately implemented and have not impacted significantly on the ground.

Mpumalanga is one of the three (3) Provinces with the highest infection rates of HIV/AIDS. The latest statistics from Census 2011 for the Province reveal that Victor Khanye LM has an increased infection rate; as measured in pregnant women tested, of 55%, the 3rd highest in the province. With respect to HIV prevalence, excluding pregnant women the trend reflected a decrease to 23.0% (Victor Khanye IDP, 2014/2015).

5 ANALYSES AND CHARACTERISATION OF ACTIVITY

5.1 Site Delineation for Characterisation

Refer to Figure 1.3 for the property boundaries of the study area. No mining or mining related activities will take place outside of this area.

5.2 Water and Waste Management

The water balance for the Leeuwpan Mining Operations was updated in November 2018 by the GCS and the process flow diagram is illustrated in Figure 5.1. The Water balance update (Table 5.1) compiled for the Mine is attached as Annexure E to this report.

Three water balances were calculated for the Leeuwpan Coal mine and are used to provide a general insight into the overall total water demands and uses. These include an annual average water balance, an average monthly balance and an average daily water balance.

All water balance calculations were based on the optimised volumes obtained from the mine personnel as well as the estimated calculations using hydrological principles. The inclusion of the OI block into the water balance calculations resulted in 372 796 m3/a of excess water. This necessitates the requirement to provide an additional storage of dirty water within the plant site. The following recommendations are made in this regard:

- Pumping dirty water from the Silver PCD's to the Witklip PCD and allow it to evaporate
- Due to the limitation of storage capacity of the Witklip PCD, complete the rehabilitation of the OWM Moabsvelden Pit, OWM Weltervreden Pit, Pit OJ and Pit OH & OM to reduce the quantities of water that have to be abstracted into the Silver PCDs; and
- Pit OD (South and North) can be used as an additional storage facility because of large volume. This increase dirty water losses through evaporation.

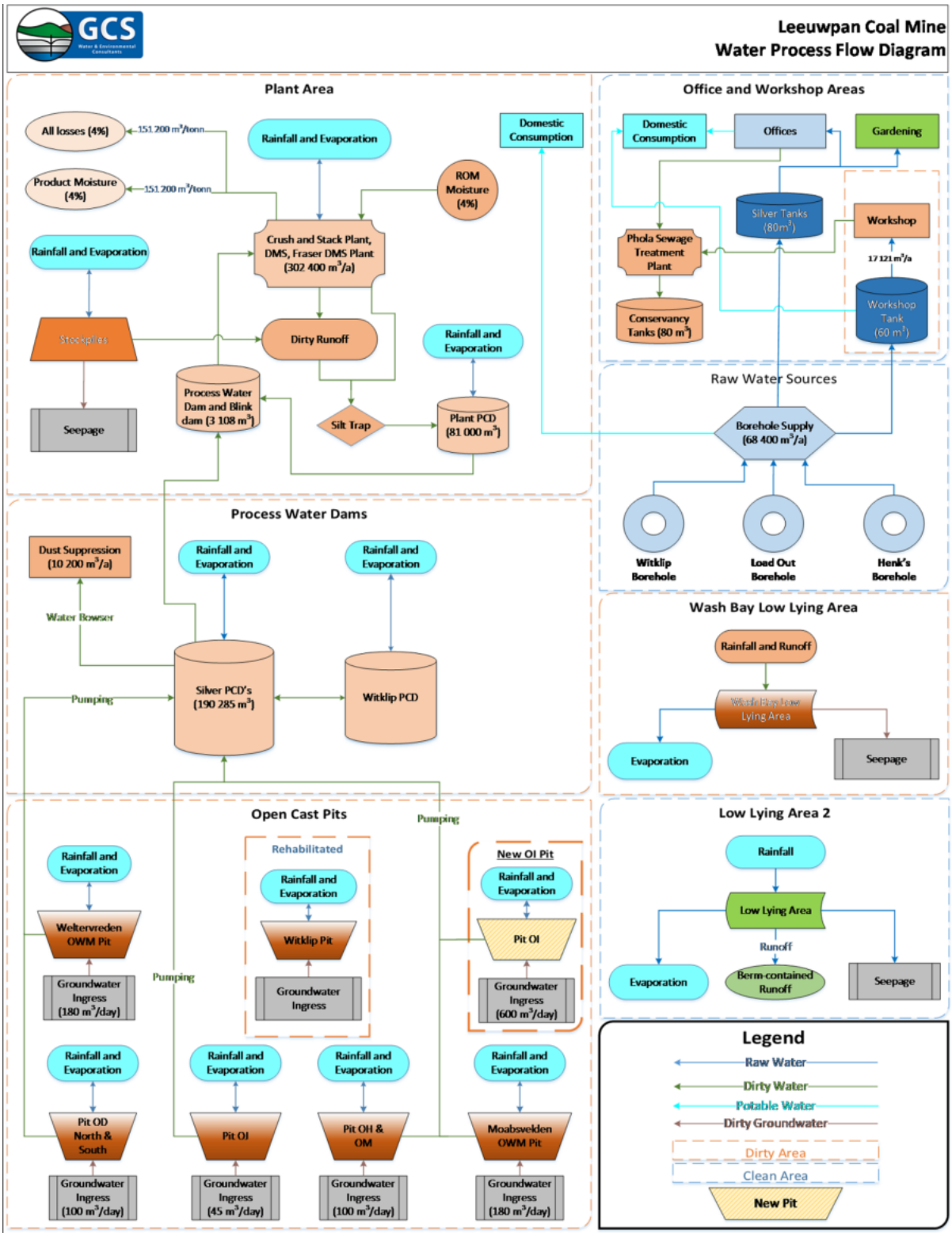
In order to improve the accuracy of the mine water balances, it is recommended that additional flow meter and records of water flow volumes be conducted at:

- Flow meter at the outlet of the Silver PCDs to the plant beneficiation;
- Flow meter at the outlet of the Plant PCD to the plant beneficiation to account for water re-use volumes;
- Water abstractions from all dewatering pits should also be measured at the inlet of the Silver PCDs; and

- Keep records of daily water volumes used for dust suppression and raw water usage from the boreholes.

Table 5.1 Annual Average Water Balance

Annual Average Water Balance for Leeuwpan Coal Mine					
Facility Name	**Water In**		**Water Out**		**Balance**
Leeuwpan Coal Mine	**Water Circuit/stream**	**Quantity (m^3/year)**	**Water Circuit/stream**	**Quantity (m^3/year)**	
Raw Water	From: Witklip Borehole	30 864	To: Workshop	20 600	
	From: Henk's Borehole	36 336	To: Offices	20 400	
	From: Load Out Borehole	1 200	To: Plant offices	21 600	
			To: Gardening	5 800	
	Total	**68 400**		**68 400**	-
Domestic Consumption	From: Workshop	20 600	To: Phola STP	37 576	
	From: Offices	20 400	To: Domestic Consumption	3 424	
	Total	**41 000**		**41 000**	-
Phola Sewage Treatment Plant	From: Phola STP	37 576	To: Honey Sucker	37 576	
	Total	**37 576**		**37 576**	-
Plant Beneficiation (Crush and Stack, DMS, Frazer DMS)	From: Silver PCD's	139 209	To: Losses (other)	151 200	
	From: Plant PCD	11 991	To: Product Moisture	151 200	
	From: ROM Mositure	151 200			
	Total	**302 400**		**302 400**	-
Silver PCD's	From: Pit OD	39 665	To: Evaporation	64 900	
	From: Pit OH & OM	42 024	To: Plant Beneficiation	139 209	
	From: Pit OI	334 452	To: Dust Supression	10 200	
	From: Pit OJ	59 414	To: Witklip PCD	17 208	
	From: Weltevrededn OWM Pit	100 035	To: Excess	372 796	
	From: Rainfall	28 724			
	Total	**604 313**		**604 313**	-
Witklip PCD	From: Rainfall	17 368	To: Evaporation	26 161	
	From: Silver PCD's	17 208	To: Silver PCD's	8 415	
	Total	**34 576**		**34 576**	-
Plant PCD	From: Dirty Runoff Water	37 230	To: Evaporation	45 279	
	From: Rainfall	20 040	To: Plant Beneficiation	11 991	
	Total	**57 270**		**57 270**	-
Pit OJ	From: Groundwater Seepage	16 500	To: Evaporation	14 230	
	From: Rainfall	70 140	To: Storage/Losses	59 414	
			To: Silver PCD's	12 996	
	Total	**86 640**		**86 640**	-
Weltervreden OWM Pit	From: Groundwater Seepage	65 700	To: Evaporation	114 557	
	From: Rainfall	601 200	To: Storage/Losses	452 308	
			To: Silver PCD's	100 035	
	Total	**666 900**		**666 900**	-
Pit OD North and South	From: Groundwater Seepage	65 700	To: Evaporation	195 722	
			To: Silver PCD's	39 665	
	From: Rainfall	198 730	To: Storage/Losses	29 044	
	Total	**264 430**		**264 430**	-
Moabsvelden OWM Pit	From: Groundwater Seepage	65 700	To: Evaporation	13 416	
			To: Storage/Losses	102 025	
	From: Rainfall	78 602	To: Silver PCD's	28 860	
	Total	**144 302**		**144 302**	-
Pit OH & OM	From: Groundwater Seepage	29 200	To: Evaporation	63 855	
	From: Rainfall	76 678	To: Silver PCD's	42 024	
	Total	**105 878**		**105 878**	-
Pit OI	From: Groundwater Seepage	219 000	To: Evaporation	201 911	
			To: Storage/Losses	1 693 317	
	From: Rainfall	2 010 680	To: Silver PCD's	334 452	
	Total	**2 229 680**		**2 229 680**	-
Total Water Balance		**4 499 063**		**4 499 063**	-



*The Silver PCDs labelled in this flow diagram are licenced as Slimes dams 1, 2 & 3.

Figure 5.1 Water process flow diagram - Leeuwpan Mine

5.2.1 Process Water

The only process where water is used for industrial purposes is at the existing coal beneficiation plant. Process water is supplied from a closed system, which includes the plant, PCDs, mobile tanks and process dams. Water replenishment comes from the pits, but if this is insufficient, make-up water from six boreholes is also used.

Water is used on a constant basis and is proportional to the amount of coal that is being washed per day. No significant daily fluctuations exist in the use of water on the mine. The beneficiation plant operates 24 hours a day for 313 days per year.

5.2.1.1 Pollution Control Dams, Settling Dams, Slurry Dams, Evaporation Dams

The prevention of water pollution at Leeuwpan Coal Mine is managed by way of a closed water circuit. Mine water is pumped from the open pits to evaporation dams. Plant water is first pumped to slurry dams where settling of coal fines occur and is then re-used in the coal washing process. Water is then pumped back to the plant from the evaporation dams for re-use.

The polluted water from the existing coal refinement plant is separated in a condenser and pumped back to the plant. The slimes from the condenser are pumped to the settling dams, from where the run-off is pumped back to the plant.

The settling dams consisted of three separate dams. The settling dams were used on a rotational basis and the dried silt was reclaimed with the aid of mechanical equipment, and sold or returned to the pit. The mine stopped using these pits in 2003. The decommissioned settling dams / slimes disposal dams will be recommissioned for the OI project. The dams are being cleared of all additional material and lined.

The Witklip Pit Water Settling/Evaporation Dam (PCD) (140 000m^3) operated as an industrial water storage dam. Water from this dam is pumped to the raw water settling dam. When necessary, water from the emergency overflow dam can be pumped to this dam for storage. The dam had been upgraded to include an HDPE liner.

The Raw Water Settling Dam also acts as an industrial water storage dam. Surplus water from the Raw Water Settling Dam overflows to the Emergency Overflow Dam. These dams are unlined.

The Stockpile Settling Dams capture runoff from the stockpile area and the main processing plant areas.

The Slurry Dams, which contain coal fines were discontinued and were allowed to dry.

A filter press was commissioned in 2003 to dewater the slimes at the main plant area. This advanced technology allows the mine to re-use process water very efficiently. The filter press allows for approximately 60-80% of the water in the product to be regained.

5.2.2 Storm Water

Government Notice No. 704, published in terms of the National Water Act (Act No. 36 of 1998) requires the following, which will be adhered to:

- All clean water systems must be designed and operated in such a manner that they are at all times capable of handling the 1:50 year flood event on top of their mean operation level without spilling;
- Any water arising from an area, which causes, has caused or is likely to cause pollution of a water resource, including polluted storm water, must be contained within a dirty water system. In order to reduce the volume of polluted water, contaminated areas should be minimised. While clean water should be diverted to natural water courses, polluted water should be re-used wherever possible, thereby reducing the use of clean water; and
- Design, construct, maintain and operate any dam or tailings facility that forms part of a dirty water system to have a minimum freeboard of 0.8m above full supply level.

5.2.2.1 Current Storm Water Management Infrastructure

Some of the existing storm water measures and infrastructure at the mine include:

- Storm water canals were built around the evaporation dams in order to prevent clean storm water from entering the dirty water area;
- For Blocks OJ and OL, the initial box cut material was used for the development of the stormwater management berms;
- Storm water cut-off trenches have been constructed around all areas where affected mine water occurs or where water might become affected. This was done to prevent clean water from mixing with affected water;
- All storm water that falls within this area has been channelled to the evaporation dams from where it will be either evaporated or re-used;
- Pollution control dams are designed to have an 800 mm freeboard. The pollution control dams can therefore accommodate run-off events bigger than the 1:50 year flows;
- Storm water management facilities includes, all clean and dirty water separation structures such as berms, cut-off trenches (Figure 5.2), and silt traps;

- All water falling within a dirty water area is collected within dirty water dams for re-use;
- A series of berms and storm water diversion channels collect all the storm waters towards the Pits and respective Pollution Control Dams; and
- The pollution control dams, with the exceptions of the Raw Water Settling Dam and Emergency Overflow Dam which are unlined, are HDPE lined to prevent leakages and ingress into ground water and possibly contaminating the surface and ground water.



Figure 5.2 Cut-off trenches in plant area

5.2.2.2 Storm Water Management along Road

Currently the storm water management that is in place along the haul road that Leeuwpan shares with Stuart Coal is in need of repair and maintenance (Figure 5.3). These observations presented below were obtained during the external IWUL Audits undertaken by GCS in 2016 and 2017.



Figure 5.3 Gaps in berm along main road

A plan has been compiled in order for these identified problems to be resolved. This plan involves the construction of silt traps along the side of the road. These silt traps will further aid in directing the flow of the storm water to the pits where the water is either pumped to the respective dams or re-used in the mining process. However, due to the nature of ownership of the road, a decision needs to be made together with Stuart Coal on the matter. Currently, Leeuwpan Mine are still attempting to communicate with Stuart Coal with regards to the management measures and infrastructure that has been proposed for the road. Communication on the matter has also taken place with the Department on the matter but an outcome on the matter is yet to be determined. As such, no new infrastructure in terms of storm water management has been implemented.

5.2.2.3 GN 704 Audit

An Audit on site, in line with GN 704, was undertaken in May 2019 by Greene Consulting Engineers (Pty) Ltd (Annexure J). The area of focus for this audit report was the Processing Plant area. Further to this, a verification report was also submitted to Exxaro by Greene Consulting Engineers.

After the audit, recommendations were made and prioritised. Priorities were determined as follows:

- Priority 1 = Minor maintenance work to be completed no later than 3 months after submission of this report;
- Priority 2 = Major maintenance work to be completed no later than 2 year after submission of this report; and
- Priority 3 = New design and construction work to be completed no later than 5 years after submission of this report. Work dependent on Engineering Designs.

Various recommendations with regards to the observations and findings from the audit conducted were made. Progress with regards to the 'open actions' is provided in section 5.2.3.

The areas within the Processing Plant where grading was identified as a problem is:

- Blending Area;
- DMS Area; and
- JIG Area.

On the day of the site inspection there was no rain. Water observed was from operations.

The plant area

The plant area predominantly drains from east to west via concrete lined canals through a recently constructed silt trap into the existing PCD, from where the water is re-used in the beneficiation plant. The western part of the site will drain to a concrete lined cut-off drain along the western boundary of the site. This will contain all dirty water within the dirty footprint of the plant area.

Clean water is prevented from entering the site by means of earth berms. These berms must be maintained on a regular basis to ensure a 1:50 year; 2-hour storm can be directed away from the dirty areas. Areas within the plant are to be shaped to drain to the drainage canals in order to minimise ponding of water.

Blending Area Grading Findings

The following was observed and assessed on site during the 2019 audit for the processing plant storm water management (refer to Table 5.222 for photographic evidence):

- Ponding and erosion were observed at the Blending area;
- Product is stockpiled in this area and moved again at a later stage, which means that levels will not be maintained in the long run; and

- Most of the ponding is next to the conveyors. This water needs to be conveyed to a point where it can drain into the containment canals; if it cannot drain towards the subsoil drains.

Blending Area - Actions

The following overall recommendations were made for the Blending Area:

- Ponding must be prevented by grading to ensure flow to the existing canals; and
- After initial grading this must be maintained to prevent ponding in the future.

DMS Area grading findings

The following was observed and assessed on site during the 2019 audit for the DMS area storm water management (refer to Table 5.322 for photographic evidence):

- Ponding at the DMS area were observed;
- Water does flow away overland in most areas but at a very low speed; and
- There are water ponds under the conveyors due to the low points created.

DMS Area grading - Actions

The following overall recommendations were made for the DMS Area:

- Levelling and shaping of the area will ensure all areas are sufficiently drained with minimal ponding occurring during and after rainstorms; and
- Conveyance will be through gravity drains with pumping of storm water being kept to a minimum.

JIG Area grading findings

The JIG area has been graded recently. Overall the ground slopes towards the canals (refer to Table 5.2 for photographic evidence).

- The only points of concern are under the conveyor structures where low points hinder the flow of water towards canals.

JIG Area grading - Actions

It is recommended that the conveyor structures be examined in more detail in order to minimise ponding be either constructing sumps with drainage pipes or levelling.

Refer to Table 5.2 for photographic log of the non-conformance photographs taken during the May 2019 GN704 site inspection by Greene Consulting Engineers.

Table 5.2 Non-conformance for GN704 Audit (2019)

NONCONFORMANCE	PHOTOGRAPHIC EVIDENCE
Blending Area	
Ponding where material has been moved at Blending area.	
Ponding observed next to conveyor at Blending area.	
DMS Area	
Ponding observed at DMS area	
Slow overland flow of water observed at DMS area.	

NONCONFORMANCE	PHOTOGRAPHIC EVIDENCE
JIG area	
Ponding observed at Conveyor structures at JIG area.	

5.2.3 Progress on GN 704 Audit Recommendations

As presented above, the GN704 audit conducted assessed various areas of non-compliances and provided various recommendations in this regard. Progress with regards to the various non-compliances are presented in Table 5.3. Completed actions have also been detailed in the Table.

Table 5.3 Progress on GN704 Audit Recommendations

Non -conformance	Recommended Action	Comment	Status
Storm water drainage canals within plant area not maintained.	Weekly maintenance job cards to be created and implemented to ensure that storm water drainage canals are clear of any construction at all times.	At the time of the inspection the canals were clean and contained little silt.	Completed
Storm water drainage canals within plant area are damaged.	Damage to existing canals need to be rectified.	At the time of the inspection the canals were repaired and in good state as per GN 704 requirements.	Completed
Vegetation evident in the canal and this causes obstruction to the storm water drainage canals	All vegetation in existing canals north of site must be cleaned and maintained.	Vegetation still visible in canals north of site.	Open
The 800mm freeboard in the PCD not maintained as required by the GN704 regulations freeboard.	Steel plate at emergency overflow to be removed to reinstate 800mm	The steel plate at an emergency overflow has been removed.	Completed
The PCD is highly silted and no capacity to contain dirty water from the plant area.	Silt in PCD to be removed to obtain the design capacity	Desilting of the plant PDC has commenced and is in progress.	In progress
The existing cut-off berms east of the site	Earth canal to be constructed to facilitate	The earth canal has not been constructed. There	Open

must reinstated to allow the separation of clean and dirty water	emergency overflow from PCD to OD North.	are still openings in the cut-off berm to let storm water through. An earth channel is proposed next to the berm to transport Storm water to the existing northern canal.	
Ponding is visible in most areas of the plant i.e blending, DMS, and JIG areas	Site to be levelled to facilitate drainage and prevent ponding.	Some levelling has been done, however there are still some areas where ponding occurs.	In progress
The ground slopes towards the conveyors and not towards the centre where the subsoil drainage is located	The Subsoil drains beneath the blending area must be inspected to ensure it is in good working order.	Subsoil drains could not be inspected as itis buried underground.	Open

5.2.4 Groundwater

Groundwater is abstracted from the existing pits. The water is abstracted for the safe continuation of mining activities and used as process water in the processing of the ore mined.

The IWUL issued to Leeuwpan also licensed the abstraction of groundwater from boreholes located at the mine. The borehole water is used for process water at the mine when there is insufficient water from the pits.

5.2.5 Waste

There are several waste sources that have been identified as part of the mining activities at Leeuwpan. These waste sources include:

- Mine Residue Deposit (MRD), which includes:
    - carbon-carrying shales;
    - plant residue; and
    - fine coal recovered from the slimes dams;
- Polluted mine water, which includes the various pollution control dams;
- Hazardous and Hydrocarbon waste such as oil, diesel & grease; and
- General waste which is limited to domestic and commercial waste.

Refer to Section 3.6 for details pertaining to the management and disposal of the various waste streams generated at Leeuwpan.

5.3 Operational Management

5.3.1 Organisational Structure

Refer to Figure 2.4 above in Section 2.7 for the organisation structure of Leeuwpan Mine.

5.3.2 Resources and Competence

Leeuwpan Coal comprises of mining-, process-, technical-, administration- and the surface infrastructure related operations that are undertaken during all phases of the operation. The mine's Environmental Management System (EMS) is ISO 14001:2004 and OHSAS 18001:2007 based and describes the principles of implementing policies and environmental programmes.

The management, operational and monitoring procedures and codes of practices have been compiled to manage the significant aspects and impacts of the activities and products of Leeuwpan Coal. The system also involves local Authorities, contractors working on-site, government agencies and Interested and Affected Parties (I&APs).

Leeuwpan Coal is committed to the implementation of the Exxaro Resources Safety, Health and Environmental (SHE) Management Policy. Exxaro Resources actively care for the health and safety of people, the environment and resources by ensuring sustainable Safety, Health and Environmental (SHE) conditions at all of Exxaro's activities.

Exxaro Resources is committed to:

- Consulting with employees and representatives and other stakeholders in appropriate forums to develop, communicate and review responsible and innovative policies, programmes and guidelines that proved safeguards for the community, employees, contractors and the environment, while providing flexibility to meet the needs of the Exxaro businesses;
- Achieving high standards of environmental care and providing a safe and healthy workplace for employees, contractors and other relevant persons;
- Ensuring a proper organisational structure and resources to manage safety, health and environmental matters including sustainable development and legal compliance;
- Implementing internationally accepted standards for safety, occupational health and Environmental Management Systems (EMS);
- Complying with all applicable SHE legislation and relevant international obligations as a minimum requirement and implementing company standards, programmes and processes to achieve greater protection against risks;
- Maintaining continuous hazard and aspect identification and risk assessment regarding safety, health and environmental impact;
- Establishing competence and awareness regarding relevant safety, health and environmental matters of employees and contractors through effective training, mentoring and communication;

- Conserving natural resources and reducing the environmental burden of waste generation, disposal and emissions to the air, water and land through strategies focusing on reducing, re-using, recycling and safe deposit / disposal of waste;
- Establish objectives / targets and continuously improve operations regarding safety, health and environmental performance and management systems;
- Ensuring that all employees report potential safety, health and environmental hazards and impacts, and be included in the planning and implementing of solutions;
- Ensuring that all incidents leading to an environmental impact, injury, occupational disease, damage to property or process losses are reported and analysed thoroughly in order to determine all contributing factors to promptly implement corrective and preventive action;
- Establishing and maintaining appropriate controls, including periodic audits and reviews, to ensure that this policy is being implemented and updated; and
- Maintaining a high level of emergency preparedness and response to manage any potential emergency.

5.3.3 Education and Training

The awareness and training information is contained in the Training Awareness and Competence Procedure (No. SP LP-SHE 006, dated September 2015). This procedure provides a framework to ensure all staff, contractors and consultants at Leeuwpan Coal, whose work may create a significant risk on the Integrated Management Systems (IMS), receives appropriate training. It provides guidelines for increasing over-all employee awareness on SHE issues in general, the significant environmental aspects, SHE hazards at Leeuwpan Coal and the SHE policy.

5.3.4 Internal and External Communication

Leeuwpan Coal has implemented the Communication and Consultation Procedure, dated December 2004, to outline the procedure followed by the mine to ensure effective internal and external communication. Internal or external complaints are handled according to SPI LP-SHE.001. The information from this procedure is summarised below.

Communication at Leeuwpan Coal is conducted according to the following (Figure 5.4):

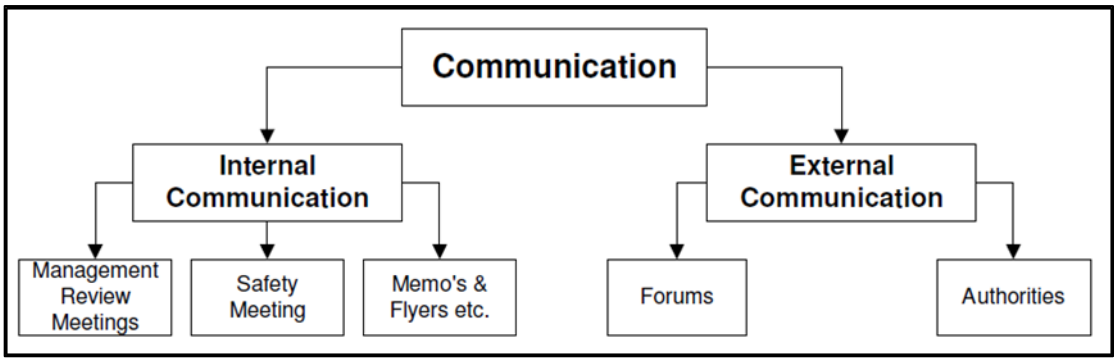


Figure 5.4 Internal Communication

The Mine Manager of Leeuwpan Coal must ensure that all relevant SHE information is passed on to the line managers for dissemination to employees at all levels regarding the effectiveness of the SHE system. The SHE Manager ensures that consultation & communication on SHE matters is conducted during the scheduled SHE Forum meetings. Communication is also conducted at the scheduled SHE management review meetings.

Employees are informed and involved with relevant risk assessments and where changes to work places occur. SHE Representatives have been appointed and employees are informed as to whom it is. The signature on the risk assessment documentation is proof of the consultation process regarding that specific risk.

Communication on internal SHE issues takes place when necessary through personnel information sessions, newsletters, production meetings, SHE Forum meetings, etc.

Key stakeholders have been identified for Leeuwpan Coal. These include surrounding industries, other mines in the area, the Delmas Municipality, Eskom as well as the surrounding landowners. The key stakeholder list is updated for every new project taking place at Leeuwpan Coal to ensure that public involvement in the decision making process.

Relevant Authorities for Leeuwpan Coal have also been identified. These include the following Departments, which are consulted at all stages of project planning to ensure that correct processes are followed at all times:

- Department of Water and Sanitation (DWS);
- Department of Minerals and Energy (DME); and
- Department of Economic Development, Environment and Tourism (DEDET).

5.3.5 Awareness Raising

The Training, Awareness and Competence Procedure (No. SP LP-SHE 006, dated September 2005) will ensure that all staff is made aware of their individual roles and responsibilities in achieving conformance with the SHE policy, procedures and the requirements of the IMS, including emergency preparedness and response. This procedure describes:

- The assessment of the competence of all personnel in terms of the IMS;
- The provision of training and other actions to satisfy the identified needs;
- The evaluation of the effectiveness of the actions taken;
- The assurance that those personnel are aware of the relevance and importance of their activities and how they contribute to the achievement of the SHE objectives; and
- The maintenance of education, training, skills and experience records.

5.4 Monitoring and Control

The key to the success of environmental management lies in the effective implementation of the proposed mitigation and management measures. Monitoring provides qualitative and quantitative information pertaining to the possible impacts of the development on the environment and enables the measurement of the effectiveness of environmental management measures.

This monitoring programme will allow the mine to monitor its compliance in terms of the NWA for its entire mining operations. Refer to Table 5.4 for a summary of all monitoring components for Leeuwpan Coal.

Table 5.4 Summary of Components monitoring for Leeuwpan

Aspect	Component	Frequency of data collection
Surface water	Surface water quality	Monthly
	Water consumption levels	Daily
Groundwater	Groundwater quality	Quarterly
Wetland Monitoring	Assess current status of affected wetlands	Biannually
Biomonitoring	Biological integrity of aquatic habitats	Biannually

The objective of the water monitoring programme currently in place at Leeuwpan Coal is to assess and quantify the impacts of the existing Leeuwpan on the aquatic ecosystems and receiving waters.

Sampling is performed according to recognised legal procedures (minimum requirements for water monitoring at waste management facilities, Department of Water Affairs and Forestry (DWAF), 1998) and follows approved laboratory analysis techniques.

The NWA sets out a framework for the management of water resources in South Africa. This framework provides for the establishment of water management institutions, made up of role-players in each catchment. It is therefore of utmost importance that the requirements of down-stream users be determined pro-actively.

5.4.1 Surface Water Monitoring

Monthly monitoring of the various surface water monitoring points is conducted, as well as from the Bronkhorstspruit localities, which are up- and downstream from potential impact points that may originate from Leeuwpan. Results generated at these localities are used to characterise and identify potential pollution sources on the mine, and for early detection of acid mine water formation. Samples are also taken on a monthly basis from each of the monitoring localities for drinking water. A sample is taken in a sterile container and this water is analysed for bacterial species richness and diversity

The main objectives of the surface water monitoring:

- To assess, on a monthly basis, the quality of the surface water resources in and around the Leeuwpan study area in accordance with the mine's approved IWUL (number 04/B21A/ABCGIJ/429) and its amendments;
- To make use of the data for both human and environmental health and impact assessments;
- To compare results to previous survey results with the aim of detecting environmental trends in the surface water quality; and
- To identify potential impacts of the mining operations on the receiving water resources and provide suitable mitigation measures for adaptive management.

The surface water monitoring points and their respective geographical information is provided in Table 5.5. The geographical positions are illustrated in Figure 5.5.

Table 5.5 Leeuwpan Surface Water Sampling Points

Locality	Description	Coordinates	
		Latitude	Longitude
Drinking water and final sewerage effluent			
LDWST	Drinking Water Supply Tank	S-26.18005	E28.73602
LLBDW	Loadout Bay Offices Drinking Water	S-26.16590	E28.72990
LWDL	Drinking water at Laboratory	S-26.17128	E28.72797

Locality	Description	Coordinates	
		Latitude	Longitude
Piet Schutte	Drinking Water on Piet Schuttes Farm	S-26.14150	E28.80170
Final effluent samples (Waste water)			
LWP SP P	Final Effluent From Septic Tanks at Plant	S-26.1716	E28.7302
LWP SP W	Final Effluent at Sewage Plant behind workshop	S-26.1812	E28.7396
Surface water and receiving environment			
LSW07	Bronkhorstspruit, upstream	S-26.18860	E28.77635
LSW05	Bronkhorstspruit, downstream	S-26.13750	E28.75700
LSW03	Bronkhorstspruit at Delmas Silica	S-26.16279	E28.76881
LSW08	Bronkhorstspruit upstream of Block OI	S-26.23022	E28.76264
LSW06	Weltevreden Spruit at Farm - Upstream	S-26.1439	E28.7955
LSW12	Wetland In River Diversion 2, Between RD2 And LSW05	S-26.13610	E28.76410
LSW13	Stormwater flowing into River diversion 2	S-26.14380	E28.77560
RD1	River Diversion 1	S-26.14930	E28.76450
WP01	Bronkhorstspruit, upstream	S-26.17799	E28.70221
WP02	Bronkhorstspruit, downstream	S-26.15510	E28.70260
Mine water-Process water			
LSW09	Pollution Control Dam	S-26.16601	E28.72541
KRO1A	Kenbar Return Water Dam	S-26.18087	E28.72995
KRO3	Workshop oil separator sump	S-26.18197	E28.73827
KRO4	Marsh area next to workshop road	S-26.18672	E28.73381
WP04	New Witklip Return Water Dam	S-26.17234	E28.70640
0G Pit	0G Pit Water (backfilled pit)	S-26.17119	E28.73397
OH_PIT	OH Pit Water	S26.16698	E28.75338
OJ Pit	OJ Pit Water	5-26.16854	E28.74505
OWM Pit	OWM Pit Water	S-26.14440	E28.74875
ODN Pit	OD Pit North	S-26.17122	E28.72381
OM Pit	OM Pit Water	S-26.17278	E28.74875
WLV Pit	Weltevreden Pit	S-26.12888	E28.76050
Additional sampling points (not specified in the WUL)			
Kenbar Rehab	Backfilled former Kenbar Pit	S26.1735	E28.7333
OJ-O	Field Barrels for experimental work		
OJ-S4-DISC			
OH-WEATH			
OL-OVB(2A+2B)			

5.4.1.1 Parameters Tested for

The parameters that are tested for are as provided below:

- pH
- Electrical Conductivity (EC)
- Total Dissolved Solids (TDS);
- Dissolved Oxygen Saturation
- Total Hardness as $CaCO_3$
- Turbidity
- Calcium (Ca)
- Magnesium (Mg)
- Sodium (Na)
- Potassium (K)
- Total Alkalinity as $CaCO_3$
- Chloride (Cl^-)
- Sulphate (SO_4^{2-})
- Fluoride (F^-)
- Nitrate (NO_3^-) as N
- Nitrite (NO_2^-) as N

- Ammonia (NH_3) as N
- Orthophosphate as PO_4^{3-}
- Sodium Adsorption Ratio
- Oil and grease (SOG)
- Dissolved organic carbon
- Chemical oxygen demand (COD)
- Hexavalent Chromium (Cr^{6+})
- Total phosphorus
- Total inorganic nitrogen (TIN)
- Escherichia coli
- Total coliforms
- Chlorophyll-a
- Zinc as Zn
- Antimony as Sb
- Arsenic as As
- Barium as Ba
- Boron as B
- Cadmium as Cd
- Total Chromium as Cr
- Copper as Cu
- Cyanide (recoverable as CN^-)
- Iron as Fe
- Manganese as Mn
- Mercury as Hg
- Nickel as Ni
- Selenium as Se
- Uranium as U
- Aluminium as Al

5.4.2 Groundwater Monitoring

Groundwater monitoring is conducted at Leeuwpan Mine by Golder. The quarterly water monitoring results are found in the Monthly water monitoring report for March 2019 attached as Annexure B to this report.

The main objectives of the groundwater monitoring:

- To assess, on a quarterly basis, the quality of the groundwater resources in and around the Leeuwpan study area in accordance with the mine's approved IWUL (number 04/B21A/ABCGIJ/429) and its amendments;
- To make use of the data for both human and environmental health and impact assessments;
- To compare results to previous survey results with the aim of detecting environmental trends in the groundwater quality; and
- To identify potential impacts of the mining operations on the receiving water resources and provide suitable mitigation measures for adaptive management.

The parameters that are tested for are provided in section 5.4.1.1. The groundwater monitoring points and their respective geographical information is provided in Table 5.6 and Figure 5.5.

Table 5.6 Leeuwpan Groundwater Sampling Points

Locality	Description	Co-ordinates	
		Latitude	Longitude
Drinking water supply samples (Potable water)			
LDWST	Drinking Water Supply Tank	S26.18005	E28.73602
LLBDW	Load-out Bay Offices Drinking Water	S26.16590	E28.72990
LWDL	Drinking Water at Laboratory	S26.17128	E28.72797
PIET-SCHUTTE	Drinking Water on Piet Schutte's Farm	S26.14150	E28.80170
River/ stream samples (Resource protection)			
WP01	Bronkhorstspruit tributary, upstream	S26.17799	E28.70221
WP02	Bronkhorstspruit tributary, downstream	S26.15510	E28.70260
LSW03	Bronkhorstspruit at Delmas Silica, downstream	S26.16279	E28.76881
LSW05	Bronkhorstspruit, downstream	S26.13750	E28.75700
LSW06	Weltevredenspruit, upstream	S26.14390	E28.79550
LSW07	Bronkhorstspruit, upstream	S26.18860	E28.77635
LSW08	Bronkhorstspruit, upstream of Block OI	S26.23022	E28.76264
LSW12	Downstream of River Diversion 2, Between RD2 and LSW05	S26.13610	E28.76410
LSW13	Water from Stuart Coal	S26.14380	E28.77560
RD1	Bronkhorstspruit at haul road	S26.14930	E28.76450
Process water samples (Waste water)			
KR01A	Kenbar Return Water Dam	S26.18087	E28.72995
KR03	Downstream of workshop oil separator sump	S26.18197	E28.73827
KR04	Marsh area next to workshop road	S26.18672	E28.73381
LSW09	Pollution Control Dam	S26.16601	E28.72541
ODN_PIT	OD Pit Water (closed pit)	S26.17122	E28.72381
OG_PIT	OG Pit Water (backfilled pit)	S26.17119	E28.73397
OH_PIT	OH Pit Water (backfilled pit)	S26.16698	E28.75338
OJ_PIT	OJ Pit Water	S26.16854	E28.74505
OM_PIT	OM Pit Water	S26.17278	E28.74875
OWM_PIT	OWM (Moabsvelden) Pit Water	S26.14440	E28.79241
WLV-PIT	Weltevreden Pit	S26.12888	E28.76050
WP04	New Witklip Return Water Dam	S26.17234	E28.70640
Final effluent samples (Waste water)			
LWP_SP_P	Final effluent from septic tanks at plant	S26.1716	E28.7302
LWP_SP_W	Final effluent at sewage plant behind workshop	S26.1812	E28.7396
Additional sampling points (not specified in the WUL)			
Kenbar rehab	Backfilled former Kenbar Pit	S26.1735	E28.7333
OJ-O	Field Barrels for experimental work		
OJ-S4-DISC			
OH-WEATH			
OL-OVB(2A+2B)			

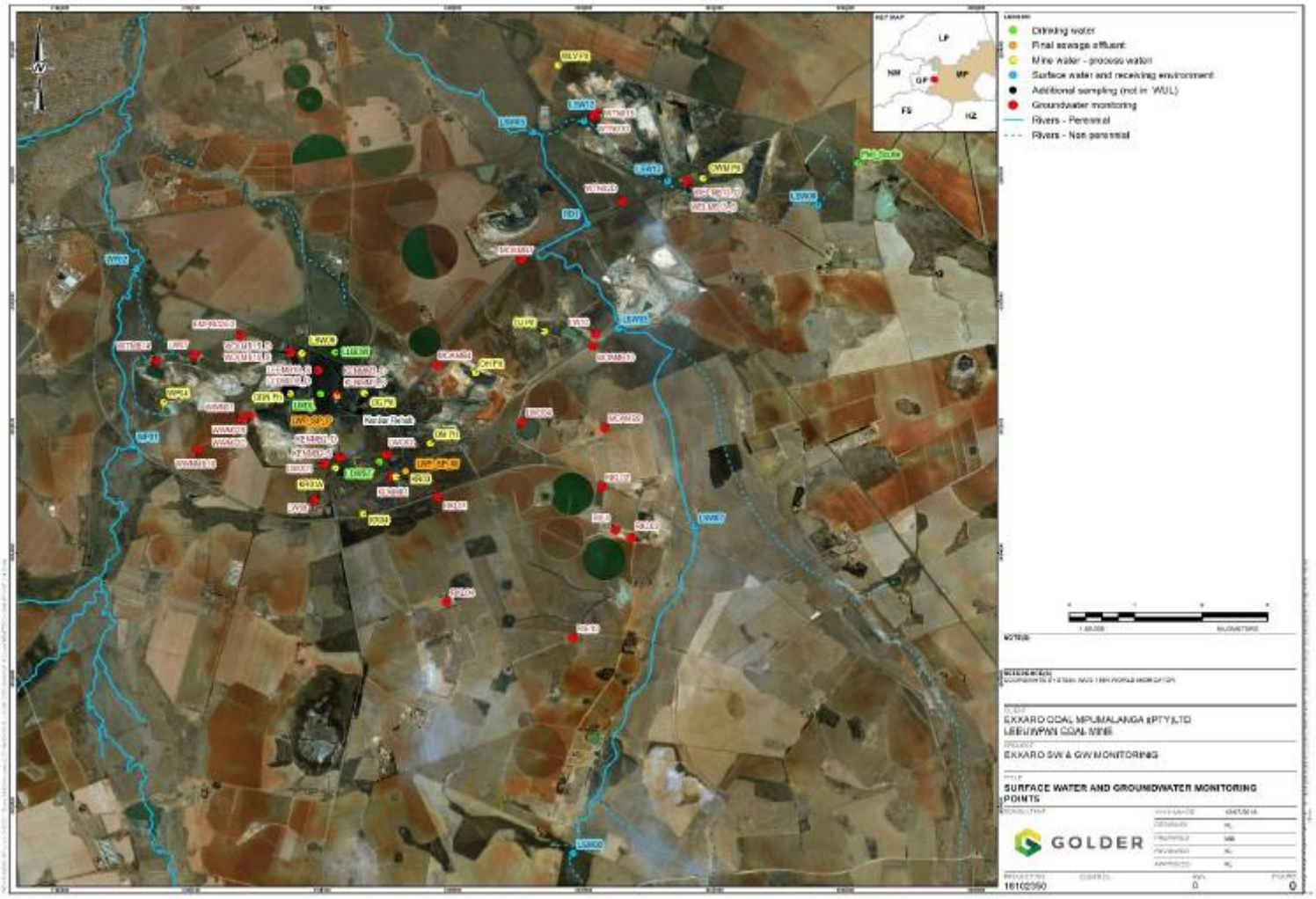


Figure 5.5 Leeuwpan - Surface Water and Groundwater Monitoring Points

5.4.3 Biomonitoring

Biomonitoring at the Leeuwpan Mine is currently conducted by Clean Stream, Biological Services (Pty) Ltd (Clean Stream). The latest biomonitoring report (June 2018) for the Mine is attached as Annexure F to this report.

Biomonitoring for the Leeuwpan mine is conducted on a biannual basis, during the wet season and the dry season. The latest biomonitoring report was compiled in June 2018. The primary objectives of the biomonitoring programme for Leeuwpan are as follows:

- Determine the **biotic integrity** (in terms of aquatic macro-invertebrates and fish) of the Bronkhorstspruit, Rietkuil Tributary and Weltevreden Tributary within the vicinity of Leeuwpan Coal Mine;
- Monitor the water quality within natural watercourses and interpret the findings according to guideline limits for aquatic ecosystems;
- Determine whether biotic integrity is improved or degraded downstream of potential Leeuwpan Coal Mine impacts, i.e. **spatial variation** of biotic integrity;
- Establish and populate a dataset in order to observe **temporal variation** of biotic integrity, i.e. improvement/deterioration over the long term; and
- Determine the potential **acute/chronic toxicity risk** associated with all Leeuwpan Coal Mine (and another mine) effluents (to the receiving environment) in order to quantify and classify the acute risk associated with such potential sources of pollution.

Biomonitoring sites were selected to be easily accessible and representative of as many habitats as possible. Four biomonitoring sites were selected within the Bronkhorstspruit and its tributaries (receiving watercourses).

The study area includes two sampling localities in the Bronkhorstspruit Tributary in the vicinity of Leeuwpan Coal Mine. One site (LP-BS-US) was selected to be upstream of current activities and another (LP-BS-DS) to be downstream of mining activities. Two more biomonitoring localities (LP-RK-US and LP-WEL-DS) were selected in the Bronkhorstspruit catchment on the Weltevreden and Rietkuil Tributaries respectively, upstream and downstream of potential Leeuwpan Coal Mine impacts. The downstream site (LP-WEL-DS) receives inputs from Leeuwpan Coal Mine and other non-Leeuwpan activities and therefore measures the cumulative impact of all users in this sub-catchment.

Toxicity testing was performed at all of the above-mentioned biomonitoring localities. Three additional toxicity testing sites (samples) were selected for analyses from the final Leeuwpan

Coal Mine Pollution Control Dam (LSW09), the Rietkuilspruit upstream of the study area (LSW08) and another colliery's PCD (RD2).

Table 5.7 provides the geographical and sampling information for each of the biomonitoring sites. The localities of the biomonitoring sites are illustrated in Figure 5.6.

Table 5.7 Biomonitoring Sites - geographical and sampling information

Monitoring site	Description	Recommended biomonitoring protocols		GPS coordinates	
		Protocol	Frequency per annum	Latitude (South)	Longitude (East)
LP-BS-US	Bronkhorstspruit, upstream of all potential Leeuwpan impacts.	Water Quality, *SASS5	Twice	26.1779	28.7018
		Toxicity Testing (screening)	Twice		
		Diatoms	Twice		
		**FAII	Once		
		Wetland Integrity and Wetland Fauna	Once		
LP-BS-DS	Bronkhorstspruit, downstream of potential Leeuwpan impacts draining towards this receiving waterbody.	Water Quality, *SASS5	Twice	26.1553	28.7026
		Toxicity Testing (screening)	Twice		
		Diatoms	Twice		
		**FAII	Once		
		Wetland Integrity and Wetland Fauna	Once		
LSW-08	Rietkuil unchannelled valley bottom wetland upstream of the study area	Wetland Integrity and Wetland Fauna	Once	26.2291	28.7626
LP-RK-US	Rietkuil tributary, upstream of potential Leeuwpan impacts.	Water Quality, *SASS5	Twice	26.1878	28.7763
		Toxicity Testing (screening)	Twice		
		Wetland Integrity and Wetland Fauna	Once		
LP-RK-Wet1	Rietkuil wetland upstream of all Leeuwpan mining activities.	Wetland Integrity and Wetland Fauna	Once	26.1960	28.7716
LP-RK-Wet2	Rietkuil wetland upstream of Leeuwpan activities but downstream of the R50.	Water Quality, *SASS5	Twice	26.1635	28.7679
		Toxicity Testing (screening)	Twice		
		Wetland Integrity and Wetland Fauna	Once		
LP-RK-DS	Diversion within the Rietkuil wetland downstream of the Leeuwpan haul road connecting the eastern and western blocks.	Water Quality, *SASS5	Twice	26.1488	28.7646
		Toxicity Testing (screening)	Twice		
		Wetland Integrity and Wetland Fauna	Once		
LP-WEL-US	Weltevreden tributary upstream of Leeuwpan activities.	Wetland Integrity and Wetland Fauna	Once	26.1435	28.7955
LP-WEL-DS	Weltevreden tributary, downstream of Leeuwpan impacts but inclusive of non-Leeuwpan impacts.	Water Quality, *SASS5	Twice	26.1373	28.7569
		Toxicity Testing (screening)	Twice		
		Diatoms	Twice		
		Wetland Integrity and Wetland Fauna	Once		
D-US	Diversion, sampled at the upstream end (relative to Leeuwpan activities).	Water Quality	Twice	26.1469	28.7951
		Toxicity Testing (screening)	Twice		
		Soil particle size analysis	Once		
		Wetland Integrity	Once		

Monitoring site	Description	Recommended biomonitoring protocols		GPS coordinates	
		Protocol	Frequency per annum	Latitude (South)	Longitude (East)
D-DS	Diversion, sampled at the downstream end (relative to Leeuwpan activities).	Water Quality	Twice	26.1438	28.7744
		Toxicity Testing (screening)	Twice		
		Soil particle size analysis	Once		
		Wetland Integrity	Once		
D-DS	Diversion, sampled at the downstream end (relative to Leeuwpan activities).	***Acute/chronic **screening** toxicity	Quarterly	26.1442	28.7756
LP-RK-DS	Toxicity sample, upstream of LP-RK-US in the Rietkuil tributary	***Acute/chronic **screening** toxicity	Quarterly	26.2291	28.7626
LSW09	Leeuwpan PCD, that may potentially impact on the Bronkhorstspruit.	***Acute/chronic **screening** toxicity	Quarterly	26.1664	28.7247

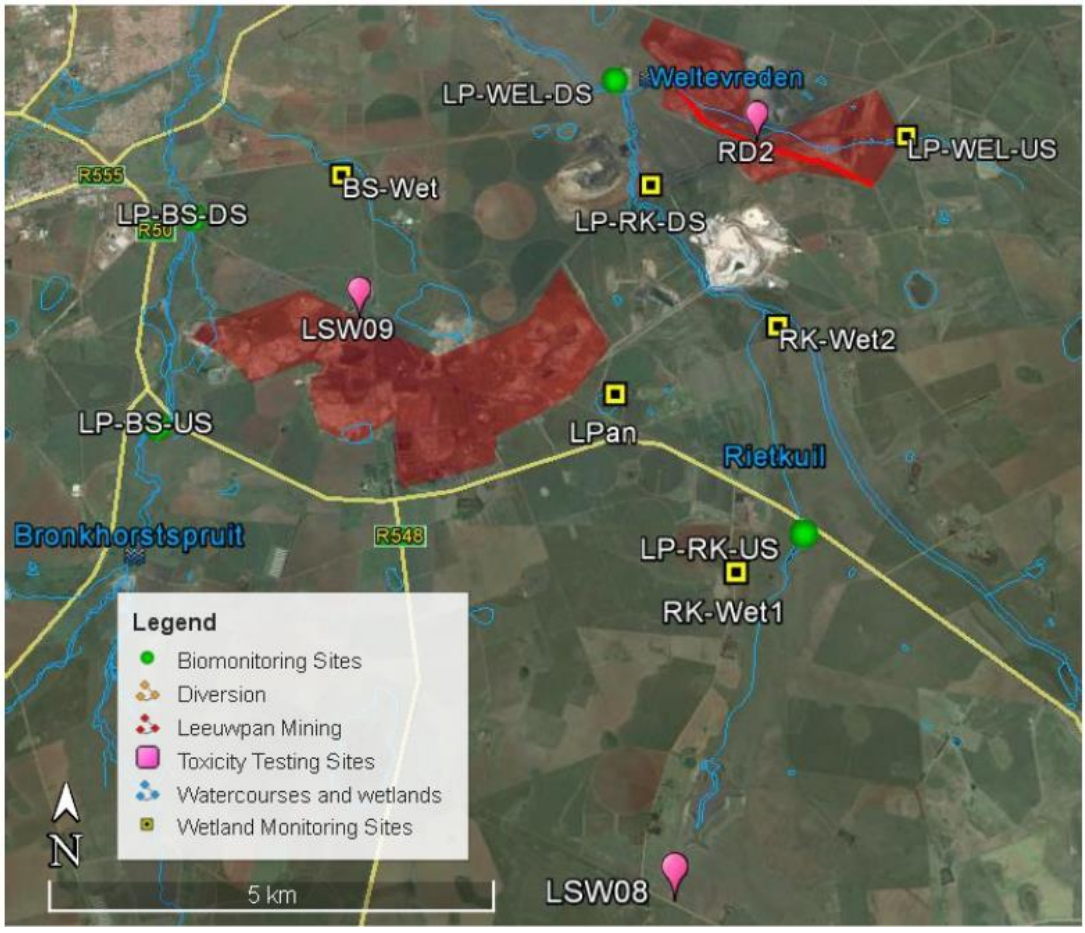


Figure 5.6 Biomonitoring Sites - Localities

5.4.3.1 Overall Assessment

The findings of the June 2018 biomonitoring survey are summarised below:

Over the past year, the top part of the diversion has been mined through. As such, there was no upstream site available for sampling. While a trench has been constructed to the south of the original diversion, it does not drain any wetland areas and, as such, is not considered a wetland diversion, merely a trench. It is strongly recommended that a wetland specialist be consulted prior to constructing any new developments. These activities have essentially caused the loss of the wetland diversion and its associated biota. Not only does this amount to a loss of biodiversity, but it is likely to contribute to a decline in water quality downstream of the diversion, as well a reduction in flow within receiving wetlands (resulting in a gradual drying of wetland areas). A new wetland diversion should be constructed, in consultation with a wetland specialist.

An informal road has been constructed through the wetland at site LP-RK-Wet2, adjacent to new mining areas in the west. While it is unclear who is responsible for this road, it should be noted that a Water Use Licence is required for any construction activities taking place in a wetland. No provision has been made for stormwater drainage beneath this road (which has essentially been constructed from gravel deposited directly into the wetland) and it is likely that the road will cause erosion and water quality deterioration. This road should either be formalised in accordance with Water Use Licence requirements or should be removed from the wetland in its entirety.

Water sampled from all sites posed a **Class II (Slight) acute toxicity hazard**. Therefore, there was a slight risk of contamination to aquatic biota.

Salinity was extremely high in the Bronkhorstspruit and Rietkuil wetland. The salinity remained elevated in the receiving Weltevredenspruit, which also receives water from the diversion. The salinity at the downstream site was far greater than at the upstream site (281 mg/l at site LP-WEL-DS compared with 183mg/l at site LP-RK-US). High salt concentrations promote the proliferation of algae which, in turn, smother benthic and marginal habitats and affect water chemistry.

Sulphates were elevated in both the diversion and Rietkuilspruit, indicating contamination from mining activities.

Manganese was elevated at the downstream end of the diversion and exceeded the guideline limit for aquaculture, indicating a limitation to aquatic biota.

Turbidity was elevated within the Rietkuil wetland at site LP-RK-Wet2, largely due to the construction of the road within this wetland (i.e. the placement of gravel within the wetland for a temporary road).

Within the Bronkhorstspruit sub-catchment, the SASS5 score and ASPT decreased between the upstream site (LP-BS-US) and the downstream site (LP-BS-DS), this trend being confirmed by the most comparable biotope (vegetation). This suggests a decline in water quality between the two sites and echoes the results of the diatom assessment which found that species associated with industrial activities were more abundant at the downstream site, suggesting possible mining-related impacts. Both sulphates and ammonia increased in a downstream direction. It should be noted that ammonia can be toxic to aquatic biota.

The SASS5 results for the Rietkuil wetland were inconclusive due to low diversity. Reference should be made to the surface water quality monitoring data.

Further downstream, however, the SASS score and ASPT were higher than usual within the Weltevredenspruit. Flows were higher than usual (possibly due to recent rainfall or other inflows such as from a leaking pipeline) at site LP-WEL-DS and the biota had responded to the greater availability of habitats. The SASS score and ASPT were the highest recorded at this site since 2012.

The following recommendations are made:

- The diversion should be re-engineered to ensure that water from the upstream wetland reaches the receiving Weltevredenspruit, rather than being intercepted by mining areas. This should be done in consultation with a wetland specialist or hydrologist.
- The road that is being constructed through the wetland at site LP-RK-Wet2 should be formalised according to Water Use Licence conditions. Alternatively, it should be responsibly removed from the wetland.
- Water within the diversion, which discharges into the receiving Weltevredenspruit wetland, should be managed so that metal and salt concentrations fall within guideline limits for aquatic ecosystems and aquaculture (fish). The Class II toxicity hazard should be reduced by managing water quality.
- Reference should be made to surface water monitoring data to establish the source of salts reaching the receiving watercourses.
- Toxicity testing should include all PCDs and return water dams that could potentially discharge (in a controlled or uncontrolled manner) into receiving wetlands. Leeuwpan Colliery should identify the need for inclusion of additional PCDs in the toxicity testing programme.

5.4.4 Waste Monitoring

In terms of the waste monitoring that is performed on site, a risk management approach is adopted. Continuous assessment are also performed i.e. audits, in order to assess the performance of the waste management on site. After the evaluation and the necessary controls have been set up to eliminate wastages, the environmental management have to ensure continuity and follow up:

- Issue based assessments regarding Waste Management, when required;
- Continuous assessments regarding Waste Management;
- Training and education with regards to the Waste Management;
- PPE (application, availability, types, usage, and costs);
- Purchasing standards with regards to waste producing equipment and machinery;
- Periodic review of the Base Line Risk Assessment regarding Waste; and
- Periodic review of this procedure.

All necessary tests are carried out by the contracted waste removal company.

5.4.5 Wetland Monitoring

Wetland Consulting Services (Pty.) Ltd. was appointed by Clean Stream Biological Services (CSBS) to undertake the wetland component (Summer 2017/2018) of the Biomonitoring Programme developed for Leeuwpan Coal Mine and being undertaken by CSBS. The report can be found in Annexure G. In addition to the wetland monitoring, Exxaro has contracted Digby Wells Environmental to update the Leeuwpan Coal Mine Wetland Offset Strategy. According to Leeuwpan personnel, this report is a draft and can be found in Annexure I.

Seven (7) monitoring sites were selected for the wetland monitoring component. These monitoring sites overlap with those selected for other components of the greater biomonitoring programme and are based on monitoring recommendations from the various environmental authorisation applications.

Two of the recommended monitoring sites (Figure 5.7), LP-RK-US and WCS 2, were however located on the same system and within 200m of each other along the same R50 road crossing over the wetland. For the purpose of the wetland component, these two sites were therefore consolidated into a single monitoring site.

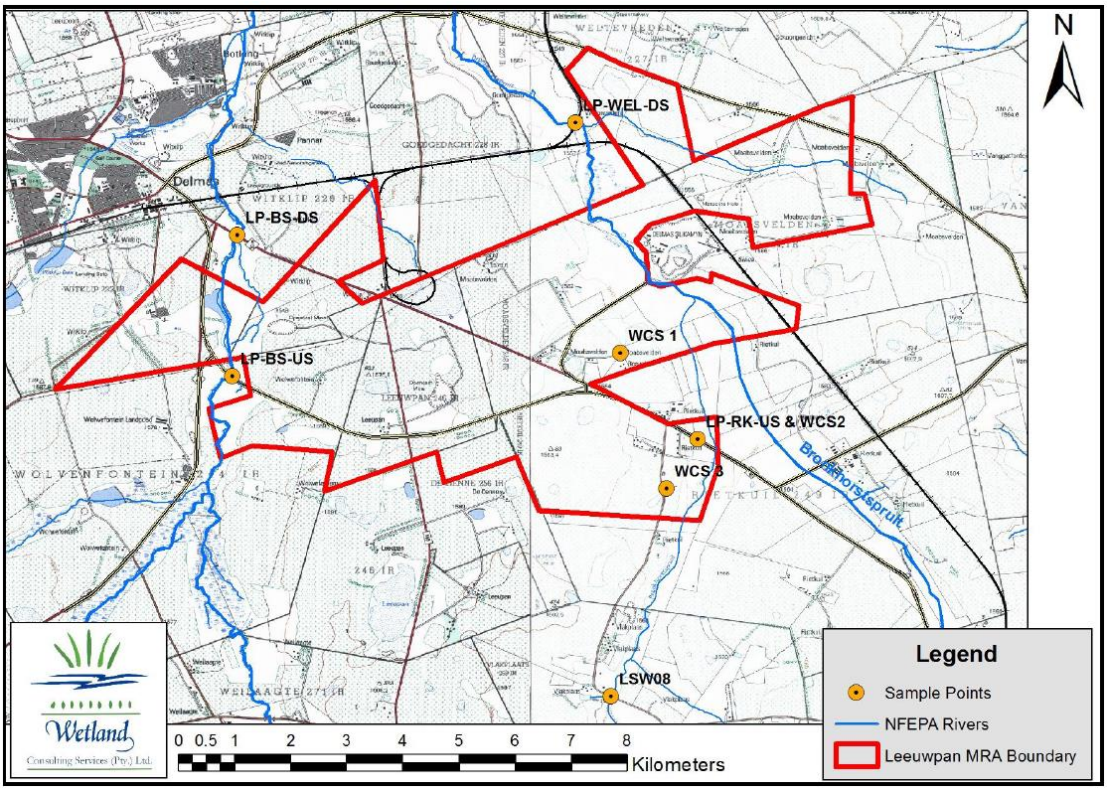


Figure 5.7 Sample sites for the wetland monitoring

The following Table 5.8 summarises the monitoring sites for the wetland monitoring.

Table 5.8 Summary of monitoring sites included for the wetland component

Sample Site	Wetland Type	X co-ordinate	Y co-ordinate
LP-BS-DS	Channelled valley bottom	-26.155300	28.702600
LP-BS-US	Channelled valley bottom	-26.177907	28.701807
LP-WEL-DS	Channelled valley bottom	-26.137301	28.756897
WCS 1	Hillslope seepage	-26.174193	28.764151
LP-RK-US & WCS2	Unchannelled valley bottom	-26.187985	28.776571
WCS 3	Channelled valley bottom	-26.195952	28.771537
LSW08	Unchannelled valley bottom	-26.229100	28.762594

5.4.5.1 River Diversion

The findings of the walkdown survey and ecological assessment of the river diversion largely echo the findings from previous year's wetland monitoring reports (WCS, 2016 and 2017), with the significant exception that the upper end of the diversion has been mined through and no connection exists between the diversion and the upstream wetland. As such the diversion is currently not functional and urgent intervention is required to ensure clean water flows from upstream enter the diversion and flow further into downstream water resources.

In addition, large sections of the river diversion still have the appearance of a temporary diversion canal rather than a permanent stream diversion. The entire diversion is highly disturbed and generally poorly vegetated, being dominated by weedy and pioneer species. It appears as though little if any longitudinal flow occurs along the diversion under normal conditions. Lateral flows are also largely obstructed from entering the diversion.

From an ecological point of view the confined nature of the diversion, vertical channel walls for long sections and adjacent berms and stockpiles, severely limit the opportunity for the formation of a lateral ecotonal link between the aquatic habitat and the remaining adjacent terrestrial habitat. The only possible hydrological variation in the system under current conditions is vertical.

5.4.5.2 PES Assessment

Five (5) of the 7 wetland units assessed were found to be in a moderately modified condition (PES category C), with only wetland LP-WEL-DS considered largely modified (PES category D) and wetland WCS 03 considered seriously modified (PES category E). These results largely mirror the results of the previous two summer season assessments, with no change in PES categories for 6 of the wetlands. The only significant change occurred in the unchannelled valley bottom wetland at sample site LP-RK-US. This wetland has deteriorated from a PES C (score of 2.7) to a borderline PES C/D (score of 3.9). This is as a direct consequence of the construction of the re-aligned R50 tar road. At the time of this survey the raised road berm had been constructed across the full length of the wetland, though culverts had not yet been installed, i.e. there was no flow connectivity across the road under construction. Road culverts have however subsequently been installed.

5.4.5.3 Alien Vegetation Survey

A number of alien species were identified within the wetland units assessed. All alien invasive species and populations observed during the previous two summer season surveys were still present on site and have increased, indicating that no clearance of alien vegetation had been done within these wetlands and the diversion. It is of great importance that the management

of alien vegetation receives attention within the Leeuwpan Mining Rights Area and that clearing and control measures are implemented.

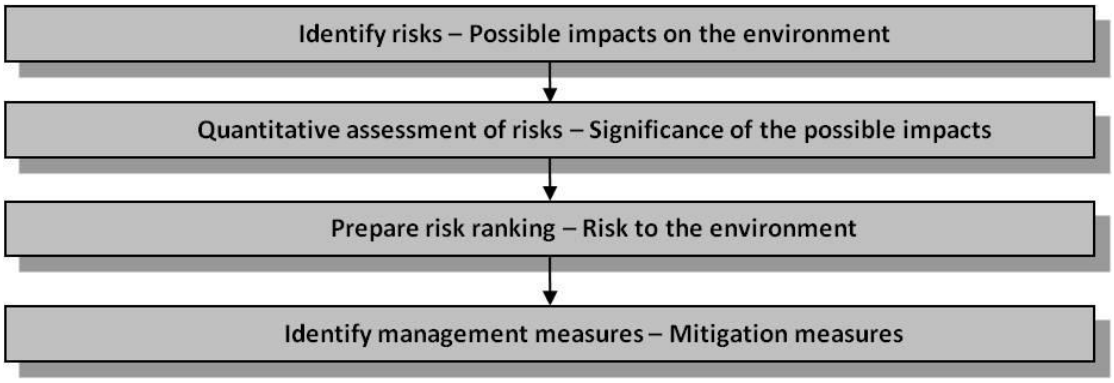
Of concern was the increased presence of the Pompom weed (Campuloclinium macrocephalum) in a number of wetland units. First observed during the 2015/16 summer season as isolated stands or individuals, this species has now spread into larger colonies, with additional infestation areas also noted. It is recommended that these infestations be addressed and controlled through the alien vegetation management plan of the mine before they become more established and spread further.

5.5 Risk Assessment/Best Practice Assessment

To ensure uniformity, the assessment of potential impacts will be addressed in a standard manner so that a wide range of impacts is comparable. For this reason a clearly defined rating scale will be provided to the specialist to assess the impacts associated with their investigation.

Each impact identified will be assessed in terms of probability (likelihood of occurring), scale (spatial scale), magnitude (severity) and duration (temporal scale). To enable a scientific approach to the determination of the environmental significance (importance), a numerical value will be linked to each rating scale.

The following process will be followed:



The following criteria will be applied to the impact assessment for the EIA/EMP:

Occurrence

- Probability of occurrence (how likely is it that the impact may occur?); and
- Duration of occurrence (how long may impact last?).

Severity

- Magnitude (severity) of impact (will the impact be of high, moderate or low severity?); and
- Scale/extent of impact (will the impact affect the national, regional or local environment, or only that of the site?).

Status of Impact

- +: Positive impact
- -: Negative impact
- N: Neutral (no impact)

In order to assess each of these factors for each impact, the following ranking scales were used:

Probability:=P 5 – Definite/don't know 4 – Highly probable 3 – Medium probability 2 – Low probability 1 – Improbable 0 – None	*Duration:=D* 5 – Permanent 4 - Long-term (ceases with the operational life) 3 - Medium-term (5-15 years) 2 - Short-term (0-5 years) 1 – Immediate
Scale:=S 5 – International 4 – National 3 – Regional 2 – Local 1 – Site only 0 – None	*Magnitude:=M* 10 - Very high/don't know 8 – High 6 – Moderate 4 – Low 2 – Minor
Status of Impact +: Positive -: Negative N: Neutral	

Once the above factors have been ranked for each impact, the environmental significance of each was assessed using the following formula:

SP = (magnitude + duration + scale) x probability

The maximum value that can be achieved is 100 Significance Points (SP). Environmental effects were rated as follows:

SIGNIFICANCE	*ENVIRONMENTAL SIGNIFICANCE POINTS*	*COLOUR CODE*
High (positive)	>60	H
Medium (positive)	30 to 60	M
Low (positive)	<30	L
Neutral	0	N
Low (negative)	>-30	L
Medium (negative)	-30 to -60	M
High (negative)	<-60	H

No specialist findings have been modified by the Consultant. The information provided within this report reflects the opinion of the specialists, in agreement with the Consultant. The applicant has reviewed all the conditions.

The potential impacts associated with all of Leeuwpan's existing water uses and associated mining activities have been detailed in this section. All of the impacts relating to groundwater, surface water and wetland areas have been assessed and presented in Table 5.9 – Table 5.11.

Table 5.9 Impacts and Management Measures - Section 21(a) & (j)

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	MINING AREA	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP
Issues related to GROUNDWATER																	
Dewatering of the surrounding aquifers.	Pumping out of water entering the mining void to allow for safe mining	All open cast sections	6	5	2	4	52	-	M	• The water levels in the monitoring boreholes should be measured on a quarterly basis; • These results should be recorded on a data sheet • Determine the extent and origin of impact, implement management measures, commission consultation with impacted parties to determine short and long term solutions.	4	5	2	4	44	-	M
Groundwater quality impacts	Backfilling of carbonaceous material in the pit areas as part of concurrent rehabilitation	All open cast sections	6	5	2	4	52	-	M	• Opencast areas will be rehabilitated as soon as possible to reduce the availability of oxygen and volume of infiltration, the carbonaceous material is deposited in the bottom of the pit below the coal horizon to ensure permanent inundation under water after Closure; • This will be according to sequential layering of carbonaceous material with highest pollution potential at the bottom of the pit. • Determine the extent and origin of impact, implement management measures, commission consultation with impacted parties to determine short and long term solutions.	4	5	2	4	44	-	M
Impacts on groundwater levels and thereby the potential abstraction rates in surrounding boreholes	Open cast mining	All opencast areas	6	5	2	4	52	-	M	• Monitor static groundwater levels in all boreholes within the affected zone surrounding the mine (i.e. within at least 2 km radius from the mine) as identified during the hydrocensus; • Water levels should be monitored on a quarterly basis;	2	5	2	4	36	-	M

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	MINING AREA	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP
										• This will ensure that any change in the quantity of groundwater for the utilisation of legitimate groundwater users can be detected and can be reacted to appropriately; • These results should be recorded on a data sheet; • This may be done through the installation of additional boreholes for water supply purposes or an alternative water supply for farmers abstracting water from the Karoo sediments.							
The mining of Block OH will result in the destruction of boreholes ILB 12 and ILB13.	Open cast mining operation	OH	8	5	1	5	70	-	H	• Water should be supplied from an alternative source or the future use of these boreholes should be agreed and settled with the owner/users; • The mine should compensate the affected parties. This may be done through the installation of additional boreholes for water supply purposes or an alternative water supply for farmers abstracting water from the Karoo sediments.	6	5	1	5	60	-	M
The yield of boreholes ILB11, ILB24 and ILB25 might be affected.	Open cast mining	OD, OH, OM	2	4	1	3	21	-	L	• Monitor static groundwater levels in all boreholes within the affected zone surrounding the mine (i.e. within at least 2 km radius from the mine) as identified during the hydrocensus; • Water levels should be monitored on a quarterly basis. This will ensure that any change in the quantity of groundwater for the utilisation of legitimate groundwater users can be detected and can be reacted to appropriately; • These results should be recorded on a data sheet. • If it can be proven that the quantity of groundwater available to certain users are being affected by the proposed mine, the mine should compensate the affected parties. This may be done through the	2	4	1	3	21	-	L

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	MINING AREA	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP
										installation of additional boreholes for water supply purposes or an alternative water supply for farmers abstracting water from the Karoo sediments.							
The yield of boreholes ILB6 and ILB10 might be affected.	Open cast mining	OD, OH, OM	2	4	1	3	21	-	L	• Monitor static groundwater levels in all boreholes within the affected zone surrounding the mine (i.e. within at least 2 km radius from the mine) as identified during the hydrocensus; • Water levels should be monitored on a quarterly basis. This will ensure that any change in the quantity of groundwater for the utilisation of legitimate groundwater users can be detected and can be reacted to appropriately; • These results should be recorded on a data sheet; • If it can be proven that the quantity of groundwater available to certain users are being affected by the proposed mine, the mine should compensate the affected parties. This may be done through the installation of additional boreholes for water supply purposes or an alternative water supply for farmers abstracting water from the Karoo sediments.	2	4	1	3	21	-	L

Table 5.10 Impacts and Management Measures - Section 21 (c) & (i)

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	MINING AREA	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP
Issues related to WETLANDS																	
Loss of vegetation and habitat due destruction of wetlands	Open cast mining	All mining areas	6	5	1	5	60	-	M	• Maintain storm water management infrastructure; • Fence off and maintain existing fencing around wetland areas/or mining areas to prevent access to wetlands.	4	5	1	5	50	-	M
Change in Hydrology and water quality of the wetlands	Open cast mining	All mining areas	6	5	1	5	60	-	M	• Maintain storm water management infrastructure; • Fence off and maintain existing fencing around wetland areas/or mining areas to prevent access to wetlands.	4	5	1	5	50	-	M
Altered flow to wetland areas	Maintenance of river diversions	River Diversions	0	0	0	0	0	-	L	This impact cannot be mitigated until the end of LoM. Management by means of inspections and maintenance of the river diversion should be undertake on a regular basis. Ensure that no sedimentation into the river diversion in taking place. Maintain aquatic monitoring programme	0	0	0	0	0	-	L
Deteriorating water quality due to coal spillages	Operation of conveyor and roads	All mining areas	6	4	1	4	44	-	M	• Gantries should be used for all conveyor wetland crossings to minimise spills and dust; • Should larger spillages occur due to malfunctioning of the conveyor or for any other reason, clean-up of the spillages should be undertaken as soon as possible following the event; • In this regard regular inspection of the entire conveyor route should be undertaken; • No belt transfers are to be located within the wetland areas on site;	4	4	1	3	27	-	L

										• Where belt transfers are located in close proximity to wetland areas a small, shallow berm should be constructed between the belt transfer site and the wetland area to prevent direct run-off of storm water from the belt transfer site into the valley bottom wetland							
Storm water discharge into wetlands	Roads	All mining areas	6	4	1	5	55	-	M	• Storm water should not be allowed to accumulate on the road surface; • Regular discharge points into adjacent grassland should be provided; • Discharge points should be protected against erosion; • No storm water should be discharged directly into the wetland	4	4	1	3	27	-	L
Altered flows in wetlands	conveyor and roads	All mining areas	6	4	1	4	44	-	M	• Any proposed bridge structures should aim to be clear span across the active channels of wetlands, and aim to maintain wetting of the full wetland front downslope of the crossing through the incorporation of as many culvert structures as required to achieve this; • Use of a single pipe culvert for crossings over hill slope seepage wetlands should be avoided; • Capacity of crossing structures should be such that no impounding of flows upslope of the crossing occurs under normal flow events.	4	4	1	3	27	-	L
Water quality deterioration due to leaks or pipe failure	Pipeline	All mining areas	8	4	2	3	42	-	M	• Leak detection measures should be installed along the pipeline so that pipe failure, should it occur, will be noticed immediately and water flow through the pipe can be stopped; • Twice monthly checks along the route should be undertaken to scan for signs of leaks.	6	4	1	2	22	-	L
Disturbance to wetland habitat due to maintenance activities	Power line	All mining areas	4	4	1	4	36	-	M	• No burning of vegetation within the wetlands should take place unless it forms part of the burning regime established in a fire management plan for the colliery compiled by a suitably qualified expert; • Maintenance access to the servitudes should be via a single access track, with no vehicular movement through the wetlands along the servitudes other than along the maintenance track.	2	4	1	3	21	-	L

Storm water discharge into wetlands	Roads	All mining areas	6	4	1	5	55	-	M	• Storm water should not be allowed to accumulate on the road surface; • Regular discharge points into adjacent grassland should be provided. Discharge points should be protected against erosion; • No storm water should be discharged directly into any wetland.	4	4	1	3	27	-	L
Water quality deterioration - seepage out of dams	Operation of dirty water containment dams	All mining areas	8	4	1	4	52	-	M	All dirty water dams should be lined. Regular inspections and maintenance of the liner should be undertaken to ensure no seepage of polluted water out of the dams. If damaged, the liner should be repaired or replaced as soon as possible. The existing water quality monitoring plan should be expanded to include all water management infrastructures on the colliery (existing and proposed).	4	4	1	3	27	-	L
Water quality deterioration - dam overflow	Operation of dirty water containment dams	All mining areas	6	4	1	3	33	-	M	It should be ensured that the storage capacity of all dams is sufficient and compliant with legislation and best practice guidelines. Water levels in the dams should at all times be carefully managed so as to ensure sufficient storage capacity. Daily inspections of water levels should be undertaken during the summer months (October to April) and a log book kept. Every overflow of dirty water dams should be recorded in a detailed log book, including reasons for overflow (e.g. amount of rainfall preceding overflow event).	4	4	1	3	27	-	L
Erosion due to overflow of dams	Operation of dirty water containment dams	All mining areas	4	4	1	4	36	-	M	See mitigation measures recommended above to minimise overflow events. In addition, any overflow spillways as well as their discharge points should be protected from erosion by ensuring establishment of dense vegetation cover within the spillway and at its discharge point. Should erosion pose a significant problem, protection of the spillway with harder measures (e.g. gabions, rock aprons etc.) should be considered, as well as the use of energy dissipaters	4	4	1	3	27	-	L

Table 5.11 Impacts and Management Measures - Section 21(g)

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	MINING AREA	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP
Issues related to WETLAND																	
Water quality deterioration - seepage out of dams	Operation of dirty water containment dams	All mining areas	8	4	1	4	52	-	M	All dirty water dams should be lined. Regular inspections and maintenance of the liner should be undertaken to ensure no seepage of polluted water out of the dams. If damaged, the liner should be repaired or replaced as soon as possible. The existing water quality monitoring plan should be expanded to include all water management infrastructures on the colliery (existing and proposed).	4	4	1	3	27	-	L
Water quality deterioration - dam overflow	Operation of dirty water containment dams	All mining areas	6	4	1	3	33	-	M	It should be ensured that the storage capacity of all dams is sufficient and compliant with legislation and best practice guidelines. Water levels in the dams should at all times be carefully managed so as to ensure sufficient storage capacity. Daily inspections of water levels should be undertaken during the summer months (October to April) and a log book kept. Every overflow of dirty water dams should be recorded in a detailed log book, including reasons for overflow (e.g. amount of rainfall preceding overflow event).	4	4	1	3	27	-	L
Erosion due to overflow of dams	Operation of dirty water containment dams	All mining areas	4	4	1	4	36	-	M	See mitigation measures recommended above to minimise overflow events. In addition, any overflow spillways as well as their discharge points should be protected from erosion by ensuring establishment of dense vegetation cover within the spillway and at its discharge point. Should erosion pose a significant problem, protection of the spillway with harder measures (e.g. gabions, rock aprons etc.) should be considered, as well as the use of energy dissipaters	4	4	1	3	27	-	L

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	MINING AREA	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP
Deterioration in water quality	Stockpiles	All mining areas	6	4	1	5	55	-	M	A detailed surface water management plan should be drawn up for the main shaft area that complies fully with GN704 in terms of the separation of clean and dirty storm water. Dirty storm water should be captured in a pollution control dam on site and no discharge of dirty storm water should be allowed into the wetlands on site. The dirty water management system should have a minimum capacity to cope with a 1:50 year storm event without overflow.	4	4	1	4	36	-	M
Issues related to SURFACE WATER																	
Change to drainage patterns and reduction of the effective catchment area.	Open cast mining operation	OD, OH, OM, OWM, OD ext.	6	5	1	5	60	-	M	• Storm water diversion trenches will be constructed in order to divert clean runoff around the open cast area; • A clean water cut-off trench (storm water diversion trench) will be installed around Block OM, Block OH, Block OFPAD and Block OD; • This storm water diversion trench will be designed to cater for the runoff water from a 1:50 year 24-hour storm event with a 0.8m freeboard.	4	5	1	3	30	-	M
Creation of dirty water and the subsequent requirement to pump water out pits and contain it	Storm water runoff and direct rainfall into opencast pits	All open cast sections	10	4	1	5	75	-	H	• An upstream clean and dirty water separation system to be installed close to the edge of the open pit area; • This separation system should be designed in terms of the GN704 requirements as to divert a 1:50 year flood event and take the clean water around the site without allowing the water to spill into the pit area; • Therefore this diversion structure should take into account the size of the upstream catchment area and should be sized accordingly;	4	2	2	2	16	-	L

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	MINING AREA	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP
										• The diversion channel to be protected against erosion through the installation of energy dissipaters as to break the velocity of the water; • Concurrent rehabilitation of pits will ensure that voids which are not in use will not retain runoff.							
Water input from the catchment is reduced due to the presence of the infrastructure	Plant operations	All plants	6	4	2	3	36	-	M	• Maintain a closed water circuit throughout the LoM; • Trenches will be put in place in such a way to allow clean run-off to be directed towards the Bronkhorstspruit; • The river diversion berm at the Witklip section will be maintained throughout the life of mining operations in order to ensure that no run-off enters the open pit.	4	4	2	3	30	-	M
Clean surface run-off water entering the crushing and screening area from the upstream and becoming contaminated.	Clean run-off becoming contaminated	All plants	8	4	2	4	56	-	M	• Clean and dirty water separation system to be constructed upstream from the beneficiation area and divert clean water around the area as to prevent it from entering the area.	4	4	2	3	30	-	M
Reduction in catchment yield. Stream flow reduction will be caused by separating the clean and dirty water through berms and trenches.	Clean and dirty water separation infrastructure	All dams	6	3	2	4	44	-	M	Ensure the dirty water catchment area is as small as possible to avoid unnecessary losses to the stream flow.	4	3	2	3	27	-	L

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	MINING AREA	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP
Runoff from clean water areas if allowed to flow into the dirty water footprint area could mix with polluted water and overflow into river systems or reduce flow into local river systems.	Clean and dirty water separation infrastructure	PCD	4	4	3	3	33	-	M	A designed system of berms and drains separating clean and dirty water and allowing clean water to pass into local streams must be established.	4	4	2	1	10	-	L
Contamination of the soil stockpiled during the Construction Phase due to coming into contact with carbonaceous material or contaminated surface runoff.	Open cast mining operation	OWM, OD ext.	8	5	1	5	70	-	H	A soil monitoring schedule should be put in place. The extent of areas of surface disturbance will be minimised, by strictly controlling the movement of vehicles to, from, and within the proposed land use areas. All soils contaminated with hydrocarbons (as a result of the proposed mining and related activities) will be rehabilitated immediately after spillage, as far as practical,	6	5	1	5	60	-	M
Issues related to GROUNDWATER																	
Groundwater quality impacts	Backfilling of carbonaceous material in the pit areas as part of concurrent rehabilitation	All open cast sections	6	5	2	4	52	-	M	• Opencast areas will be rehabilitated as soon as possible to reduce the availability of oxygen and volume of infiltration, the carbonaceous material is deposited in the bottom of the pit below the coal horizon to ensure permanent inundation under water after Closure; • This will be according to sequential layering of carbonaceous material with highest pollution potential at the bottom of the pit.	4	5	2	4	44	-	M

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	MINING AREA	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP
										• Determine the extent and origin of impact, implement management measures, commission consultation with impacted parties to determine short and long term solutions.							
Poor quality seepage may occur into the underlying strata if the dams are situated on permeable soil formation or on a groundwater flow path like dykes and/or faults systems. Overflow of dams can also result in down-stream contamination of surface water bodies and seepage into groundwater.	Pollution control dams	All mining areas	6	4	2	3	36	-	M	Lining of all pollution control dams will be undertaken by the mine. Dam levels will be kept at the required levels (refer to GN 704). Groundwater quality monitoring networks must be set up prior to the construction phase so that any groundwater quality and quantity issues can be addressed accordingly.	4 6	3 4	1 2	2 3	16 36	- -	L M
Negative impact on groundwater quality from the infiltration of dirty water into the groundwater environment and contamination of the groundwater environment. Seepage of dirty water into underlying aquifer.	Contamination of groundwater Groundwater contamination	All mining areas	8	5	3	4	64	-	H	Storm water management and implementation Lining of dirty water retention facilities	8	4	2	2	28	-	L

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	MINING AREA	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION						
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP
Deterioration of groundwater quality	infiltration of contaminated water from the ROM	Mining operations	6	5	2	4	52	-	M	Dirty water should be contained. Any accidental hydrocarbon spills will be avoided. Emergency spills will be swiftly dealt with so as to minimise the consequent impacts of such a spill on the groundwater. All significant spills will be reported to the DWAF and other relevant authorities. All spillages will be contained and cleaned up and all contaminated material will be disposed of in accordance with legislative requirements,	6	4	1	3	33	-	M

5.6 Issues and Responses from Public Consultation Process

Public consultation was undertaken as part of the previous EMP Addendums and was outlined in the previous applications and associated reports. During the Public Participation process comment and issues from interested and affected parties for the proposed expansion project were recorded and presented in order to be addressed. Some of the comment raised have relevance to the current operations. Refer to Table 5.12 for comments and responses raised pertaining to the existing operations.

Table 5.12 Issues and Responses Register

Comment Raised	By Whom	Designation	Where and Date	Environmental Parameter Impacted	Response by EAP
Wetlands will be destroyed	Mopale Nyakale; George Mtshweni	Resident at Delmas Settlement	Open Day - 27 November 2012	Wetlands	Impacts identified as part of Wetland Assessment, management measures identified. Exxaro intends to continue with mining but will investigate in conjunction with DWS wetland offsets.
Are you mining Weltevredenpan?	Elise Tempelhoff	Journalist - Beeld	Open Day - 27 November 2012	Ecology	Mining has stopped at Weltevredenpan pending court case (2012) Not applicable end 2013.
How far are you from the river? You know that you are not allowed to be within 100m from the river?	Elise Tempelhoff	Journalist - Beeld	Open Day - 27 November 2012	Wetlands; Surface water	No mining will take place within any rivers. The proximity to wetlands will be applied for with the DWS under Section 21(c) and (i).
Where is the Water Use Licence for Weltevredenpan?	Elise Tempelhoff	Journalist - Beeld	Open Day - 27 November 2012		That matter is not open for discussion and not part of the current project (Exxaro comment)
I'm worried about the quality of the groundwater at my farm.	Willie Joubert	Farmer	Open Day - 27 November 2012	Groundwater	Refer to Section 4.3.2 of this report regarding Groundwater quality and the results found
Water quality has decreased over the past couple of years.	Willie Joubert	Farmer	Open Day - 27 November 2012	Groundwater	Refer to Section 4.3.2 of this report regarding Groundwater quality and the results found
Water quality is poor and I need to pump water a great distance to my farm. Someone took water quality samples and I would like to have a look at the results.	Jaco Oosterhuis	Neighbouring farmer	4 March 2013 - in reply to mail notification of the DSR.	Hydrology	Monitoring report are available from Exxaro. Water Quality result presented in application documents.
The tar road caused changes to the wetland and flow of water. We complained constantly to the Mine, phoned and even tried to make appointments, with no reaction.	JHP Snyman	Farmer	18 April 2013 - Fax received	Surface water and Wetland Assessments	This is addressed in the surface water and wetland Assessment done by GCS and Wetland Consulting Services respectively.

Comment Raised	By Whom	Designation	Where and Date	Environmental Parameter Impacted	Response by EAP
The water mass on both sides of the road gets thrown into one stream. The water mass is too much and floods the road at two places, increasing the risk of accidents.	JHP Snyman	Farmer	18 April 2013 - Fax received	Surface water and Wetland Assessments	This is addressed in the surface water and wetland Assessment done by GCS and Wetland Consulting Services respectively.
Cement tunnels weren't placed at the entrance of the farm road, thus the water washes away all the topsoil causing erosion. This has become so bad that no farming implements can move through it.	JHP Snyman	Farmer	18 April 2013 - Fax received	Soils assessment	This is addressed in the Soils Assessment done for the EIA
A video was recorded and submitted to the mine. Mr Harmse was involved with the construction of the road, and we constantly phoned him, Mr Schutte was also approached to come and look at the flow direction of the water in order to come up with a solution. No response was received.	JHP Snyman	Farmer	18 April 2013 - Fax received	Social	This impact is not part of this project, and can thus not be addressed directly. Exxaro has been notified of this concern.
The water table lowered.	JHP Snyman	Farmer	18 April 2013 - Fax received	Groundwater assessment	Refer to Section 4.3 of the report regarding Groundwater results found. Also refer to Section 5.5 regarding the impacts and mitigation measures pertaining to groundwater
The water has a strong Sulphur smell, and we had to buy two filter systems in order to be able to drink the water.	JHP Snyman	Farmer	18 April 2013 - Fax received	Groundwater assessment	This has been brought to Exxaro's attention. Refer to Section 4.3 of the report regarding Groundwater results found. Also refer to the Section regarding the impacts and mitigation measures pertaining to groundwater
A submersible pump of roughly R30 000 is stuck in the borehole due to the shaft that moved. We had to give up the pump and the water.	JHP Snyman	Farmer	18 April 2013 - Fax received	Groundwater and Social assessment	This has been brought to Exxaro's attention.

5.7 Matters Requiring Attention/Problem Statement

Not applicable to this application.

5.8 Assessment of Level and Confidence of Information

All information contained in this IWWMP was sourced from the following:

- Specialist studies conducted for the project area which include:
  - Clean Stream Biological Services – Biomonitoring and Toxicity Monitoring;
  - Golder – Water Monitoring Report; and
  - GCS 2018 Water Balance Update.
- The EIA / EMP consolidation compiled and submitted to the DMR and the MDEDET for the expansion project; and
- Previous environmental reports conducted for the Leeuwpan Mine

The specialists appointed to undertake the various investigations are considered to be competent in their particular fields. In light of the above, the level of confidence with regards to the information and reports used to compile this document is high.

6 WATER AND WASTE MANAGEMENT

6.1 Water and Waste Management Philosophy

The project policy of Leeuwpan Coal is to provide a benchmark for its employees, customers and contractors to meet the highest standards and make every effort to conform to all legal requirements including all set key performance objectives.

Leeuwpan Coals project management philosophy is to continually improve the project execution performances of their project activities and to set objectives so as to reduce risks associated with those actions.

The Directors and the project team are wholly committed to a safe, accident free working environment and must endeavour to show continual improvement in employee safety and health.

The company should make effort to ensure that safety, health and environmental legislation and regulations are complied with, in execution of project activities.

The project team should continually improve the quality of actions to ensure that key performance objectives are met.

6.1.1 Process Water

The philosophy with respect to process water management is to:

- Minimise the amount of process water produced (continually investigate emerging technologies for processing);
- Contain all process water to ensure zero discharge to the environment; and
- Re-use process water for dust suppression and in the process.

6.1.2 Storm Water

The philosophy for stormwater management on site is in keeping with the GN704 principles:

- To keep clean and dirty water separated;
- To contain any dirty water within a system;
- To prevent contamination of clean water; and
- To return clean water to the catchment.

6.1.3 Groundwater

The philosophy for waste management of groundwater is:

- Ensure that all potential groundwater impacts are identified; and
- Ensure that groundwater monitoring is conducted quarterly and that records are kept and a database compiled to identify trends over time.

6.1.4 Waste

The philosophy for the management of the various waste streams on site is:

- Minimisation of waste through reducing, re-using and recycling of waste;
- Monitoring of waste management practises;
- Best practise storage and disposal of waste; and
- Consideration of alternative, cost effective technologies with regards to waste Management.

6.2 Strategies

The following strategies have been outlined and implemented for Leeuwpan

6.2.1 Process Water

Process water management will consist of:

- Investigating new alternatives for process water treatment and re-use; and

- Continued, regular monitoring of dirty water dams which contain process water to ensure that the water quality is appropriate for re-use.

6.2.2 Storm Water

A storm water management plan should be developed and updated for Leeuwpan operations. Storm water management will comprise of:

- Regular monitoring of surface water quality; and
- Regular monitoring and maintenance of stormwater control structures.

6.2.3 Groundwater

Groundwater management strategies will comprise of:

- Continued, regular monitoring of groundwater levels and quality; and
- Annual compliance audits.

6.2.4 Waste

Waste management strategies will consist of:

- Implementation of good housekeeping and best practises;
- Investigating new, cleaner and more cost effective technologies to reduce and manage waste;
- Monitor compliance with best practises; and
- Creating environmental awareness and sensitivity through improvements to the induction programme for employees.

6.3 Performance Objectives/Goals

The following objectives and strategies are followed in order to achieve the Safety, Health, Environment and Community Policy:

- Compliance:
    - Identify all applicable legislation and other applicable requirements to the identified environmental aspects and ensure that the operations remain in compliance with such legislation and requirements.
- Pollution Prevention:
    - Identify the impacts that all operations, processes and products have on the environment and will ensure that pollution on the environment is prevented or minimised.
- Improvement:

- Set objectives and targets to improve environmental performance and the Environmental Management System and will continually strive to find even better sustainable solutions to problems.

- Competence:
  - Ensure that all people who perform work for or on behalf of Leeuwpan Coal are competent and understand the impact of their activities on the environment, and their role in the prevention of pollution and the maintenance of the Environmental Management System.
- Communication:
  - Actively communicate this policy to persons working for and on behalf of Leeuwpan Coal to ensure that they understand the content intent and will make it available to the public.
- Review:
  - Review the continued sustainability and adequacy of this policy at least annually to ensure it remains valid at all times.

6.4 Measures to Achieve and Sustain Performance Objectives

The IWWMP must clearly demonstrate that they have incorporated all of the above objectives/principles or, alternatively, must clearly motivate why any of the above principles are not relevant.

The water resource can be protected in the following ways by applying water conservation, pollution prevention and minimisation of impacts principles:

- Reduction in the level of contamination of water through implementation of pollution prevention strategies thereby increasing the economic reuse of the water without treatment; and
- Minimisation of impacts through capture, containment, reuse & reclamation of contaminated water thereby preventing discharges/releases.

6.5 Option Analysis and Motivation for Implementation of Preferred Options

Alternative mining methods and schedules as well as the no-go option were investigated as presented as part of the previous applications. No alternatives have been assessed for the amendment application as these are existing activities or new required amendments. The mine is an existing coal mine that has been operational for years. No new infrastructure or mining activity outside of the MRA or current infrastructure footprint has been proposed as part of this amendment application. As such, it was deemed acceptable that no alternatives be investigated or identified for this IWWMP update and IWUL Amendment Application.

6.6 IWWMP Action Plan

An Action Plan provided herein shall provide water and waste management options for issues requiring immediate attention at the Leeuwpan mine. The broad objective of the Action Plan is to provide robust and sustainable water and waste management practice for the mining operation. The following aspects will be addressed as part of the Action Plan:

- Key performance areas
- Objectives
- Roles and responsibilities
- Timeframes

The compilation of an IWWMP is a long-term commitment in terms of resources requirements including technical investigations that are conducted. These also require disbursing financial resources to implement management measures which can in most cases take months. With this in mind, this IWWMP has been developed for medium term (i.e. first 5 years of operation of the mine), with the Action Plan herein reviewed and updated every year. It is thus the intention of the mine to have yearly interaction with DWS and update the Action Plan accordingly. Refer to Table 6.1 for the Leeuwpan IWWMP Action Plan.

Table 6.1 Leeuwpan IWWMP Action Plan

	Action	Implementation Date	Person Responsible
1	Appoint a qualified groundwater specialist & undertake quarterly groundwater monitoring	Operational Phase (Ongoing)	Environmental Specialist
2	Maintain/update centralised monitoring database (for surface water and groundwater)	Operational Phase (Ongoing)	Environmental Specialist
3	Undertake concurrent and final rehabilitation in accordance with the approved Rehabilitation Plan (as per the EMP)	Operational Phase (Ongoing)	Engineering Manager/Environmental Specialist
4	Maintain a relationship with surrounding groundwater users to determine if there are any potential issues	Operational Phase (Ongoing)	Environmental Specialist/Human Resources Manager
6	Compile and implement a maintenance schedule for the stormwater management infrastructure	Operational Phase (Ongoing)	Environmental Specialist
7	Include the regular inspection and maintenance of fences in the maintenance schedule	Operational Phase (Ongoing)	Environmental Specialist
10	Conduct weekly inspection along conveyor route and maintain conveyor on a regular basis	Operational Phase (Ongoing)	Engineering manager
11	Clean up spillages when they occur	Operational Phase (Ongoing)	Engineering manager

	Action	Implementation Date	Person Responsible
12	Construct and maintain leakage detection structures	Ongoing - Monthly	Engineering Manager
13	Fence off wetlands and conduct induction to inform workers of no-go areas	Operational Phase	Mine Manager/Environmental Officer
14	Sampling sites should be located so that any contamination of water resources from the water management infrastructure can be rapidly identified and located. Emergency response procedures for failure of any water infrastructure on the mine should be established and regularly tested. All staff should be aware of the procedures and how to alert management of any failures	Ongoing	Environmental control Specialist/Project Manager
15	Silt traps should be installed upstream of all pollution control dams and dirty water storage dams to limit silt deposition in the dams. Dams should be inspected for siltation and cleaned (if necessary) before the start of every summer rainfall season	Ongoing	Environmental Specialist/Project Manager
16	The spillways and discharge points should be inspected for erosion damage at the end of every rainfall season and all erosion damage repaired.	Ongoing	Environmental Specialist/Project Manager
17	Dirty water should be re-used as far as possible within the mining operations	Ongoing	Environmental Specialist/Project Manager
18	Ensure the approved SWMP infrastructure have all been correctly constructed as per the updated SWMP.	Operational Phase	Contractor/Environmental Specialist
19	Implement inspection and maintenance schedule for river diversions	Monthly	Environmental Specialist
20	Maintenance and operation of clean and dirty water system and erosion control measures will be ensured at all times	Ongoing	Environmental Specialist/Project Manager
21	A dynamic water and salt balance will be drawn up and updated by the mine to reflect the operational activities.	Monthly	Environmental Specialist/Project Manager
22	Surface water quality sampling will be undertaken on a monthly basis and analysed according to the prescribed monitoring programme contained in the EIA/EMP.	Quarterly	Environmental control officer/Water Quality Specialist
23	Quarterly surface water monitoring reports will be generated by the mine or through a qualified water quality specialist.	Quarterly	Environmental control officer/Water Quality Specialist
24	In the event that water quality issues are identified based on the monitoring programme, an independent specialist should be consulted to determine the best course of action to ameliorate the situation.	In the event of occurrence.	Environmental control officer/Water Quality Specialist
25	Ensure that adequate storm water management measures and clean and dirty separation mechanisms are implemented on site.	Ongoing	Environmental control officer
26	Soil stored in stockpiles and used for the construction of surface water infrastructure and for rehabilitation will be monitored on a	Ongoing	Environmental control officer/Project Manager

	Action	Implementation Date	Person Responsible
	quarterly basis, increasing in frequency during the rainy season, so as to ensure that the soil conservation measures which have been implemented have been effective, and to highlight areas where soil management can be improved.		
27	PCDs will be inspected regularly to monitor and mitigate the possibility of seepage.	Weekly	Environmental Control Officer/Project Manager
28	Dirty water will be contained in specially designated water holding facilities to minimise the volume of contaminated water seepage to the groundwater.	Ongoing	Environmental control officer/Project Manager
29	Implement recommendations as per GN 704 Audit 2016.	Ongoing	Environmental control officer/Project Manager

6.6.1 2019 IWUL Audit Non-compliances

GCS was contracted to conduct the 2019 annual external audit at Leeuwpan to determine their compliance with relation to the conditions detailed in the IWULs.

6.6.1.1 Main IWUL (License No. 04/B21A/ABCGIJ/429):

From the audit findings, it is the opinion of the auditor that Leeuwpan give attention to the following identified non-compliances:

Flow Metre Calibration:

- Flow metres are utilised by the mine. Flow metres are inspected regularly, and maintenance is conducted when required. Flow metre calibration certificates were provided for all of the flow metres. Two of the calibration certificates (dated November 2015) for flow metres (Pit OH and Pit OWM dewatering) are however outdated. Telemetric flow meters were sourced and installed for Leeuwpan in December 2012. The specific technology does not allow for off-site calibration. This was communicated to DWS during a site visit presentation during 2015. Proof of submission of updated calibration certificates to the department was provided to GCS.
    - It is recommended that calibration certificates for flow metres for Pit OH and Pit OWM be updated. In the instances where calibration cannot be undertaken (due to the flow metre type), DWS should be notified in writing and motivation should be presented in this regard. A response on this from DWS should be attained before the next external IWUL Audit.
- A total of ten Calibration certificates were submitted to the Regional Head on the 7th July 2017. Eight out of the 10 certificates are due for updates in July 2019.Two of the 10 certificates were due in November 2017.

- It is recommended that proof of submission to DWS for the outdated calibration certificates be submitted in the next external audit. If this is not possible, DWS should be notified in writing and motivation should be presented in this regard. A response on this from DWS should be attained before the next external IWUL Audit.

Quantity of water

- The volumes of water authorised to be abstracted in terms of Section 21(a) are within the authorised limits, as per the amendment issued in December 2015, except for the Devon Load Out Borehole. The authorised volume for this borehole is 120m^3/a, however, a total of 285m^3/a was abstracted for the period of January 2018 - December 2018. Proof of volume readings was provided to GCS.
    - It is recommended that abstraction be done within the authorised limits. If this is not achievable, it is recommended that an amendment application be submitted to the DWS to increase the abstraction volume authorised for this borehole.
- The dam has no level meter readings. Based on abstraction volumes measured, the storage volumes of the dams are calculated and maintained. The freeboard is managed. However, floating level metres have been identified as a potential future option. A Safety Dam Assessment was conducted in September 2018. A copy of the assessment report was provided to GCS.
    - It is recommended that the potential for floating level metres should be further investigated for the Section 21(b) dams on site. Proof of investigation should be provided by the next external IWUL Audit.

Quality of water

- The quality of process water disposed of at the mine for all measured constituents were within the IWUL amended wastewater limits at all sampled sites except for nitrate which exceeded the IWUL limits in OWM pit and OJ Pit in December 2018. The sewage treatment plant was not operating optimally throughout the fourth quarter with ammonia, orthophosphate and E. coli consistently exceeding the IWUL limits and chemical oxygen demand being elevated. The operation requires constant attention to prevent discharge of non-compliant effluent to the environment.
    - Contaminated water from site should not be allowed to enter the environment. Monitoring on site should continue to be conducted as per the IWUL conditions. The sewage treatment plant should be investigated in order to reduce the high concentration's parameters experienced. The quality of dirty water disposed of shall be within the IWUL limits.
- Exceedances, when compared to the IWUL limits, were assessed for both the tributary and the Bronkhorstspruit for the third quarter of 2018 sampling period.

Generally, a higher number of IWUL exceedances were recorded at the downstream point compared to upstream sites along both streams. The following parameters exceeded the IWUL limits: total dissolved solids, electrical conductivity, sulphate, magnesium, manganese A copy of the report for the monthly water monitoring done by Golder was provided to GCS.

- It is recommended that parameters exceeding the IWUL limits recorded at the downstream point should be minimised or mitigation measures investigated in order to adhere to the IWUL limits.

Monitoring and reporting:

- Minor deviations from the applied for river diversion route were undertaken. Details of the activities and monitoring taking place on site with regards to the river diversion were included in 2016 IWWMP update, however, a detailed description of the deviation was not included.
    - It is recommended that the licensee informs the DWS about the minor deviations.

Erosion:

- Minor erosion was observed on site (refer to condition 1.7 above). The road was observed to be structurally stable. However, due to the road not being level, ponding during rainfall events is experienced. This ponding is deemed a safety hazard and was noted in the previous IWUL Audit. As a result of this, gaps in the berm were strategically placed in order to alleviate this. An audit in terms of GN 704 was undertaken in 2016. This audit report contained recommendations and actions to be undertaken in order to improve the storm water management on site.
    - The haul road should be levelled during the dry winter months to minimise the risk of ponding on the road. Erosion control measures should be put in place where necessary.
- As was noted in condition 1.7 above, erosion is evident on site, particularly on the soil stockpiles Runoff from the stockpiles where no vegetation cover exists, is anticipated. It must be noted that the GCS auditors saw the river diversion from afar, and increased vegetation cover was observed.
    - It is recommended erosion control measures be implemented where vegetation growth has not taken place. These erosion control measures should be implemented as per the rehabilitation plan.
- Minor erosion is evident on site, particularly on the soil stockpiles. It must be noted that the GCS auditors saw the river diversion from afar, and vegetation was noted. Refer to Section 4 of the report for site photos.

    - Erosion prevention measures are recommended to be constructed/implemented as soon as practicably possible in areas were erosion is occurring.
- No major storm/flooding events have occurred since the previous external IWUL Audit. It is however, predicted that should a storm event (magnitude of once in every 100 years) occur, that damage would be done as no erosion measures have been put in place. It should be noted that flow is already restricted due to upstream activities.
    - Erosion prevention measures specifically near the diversion are recommended to be constructed/implemented as soon as practicably possible. Erosion control measures should be done as per the wetland rehabilitation report.

Structures and Maintenance:

- As built drawings were not submitted for the river diversion. Designs of the crossing were not changed from the conceptual designs. Conceptual designs were submitted with the original IWULA. To date, as built drawings have not been submitted.
    - It is recommended that the licensee informs the DWS about the minor deviations.
- The engineering department, with certified engineers, have been appointed at the mine to ensure that the structures are maintained in line with the design specifications. However, this has not been approved in writing by the Regional Head. Stompi Nel was on site during construction.
    - It is recommended that a letter be compiled indicating that the engineering department, with certified engineers, is responsible for maintaining the structures in line with the design specifications. Follow up with DWS should be conducted on the mater once the letter has been submitted.
- A leaking dirty water pipe was observed at the slimes dam during the audit. The slimes dams are currently clay lined. Furthermore, vegetation was still observed in the PCD. Refer to Section 4 of the report for site photos.
    - The leaking pipe should be fixed as soon as possible. The PCD should also be cleaned as often as possible.

Waste Management:

- The mine has designated waste storage areas. Notifications and signs of the waste types to be disposed of are provided on the skips. A waste classification assessment was undertaken and compiled in 2016. During the site visit however, it was observed that some general waste materials were being placed on the floor next to the bins. It was also observed that the hydrocarbon waste skips at the Plant area were not roofed. Furthermore, there were waste skips placed directly on the soil. Refer to Section 4 of this report for site photos.

- It is recommended that waste be disposed of as per the waste regulations. The waste storage areas should be covered (with a roof) as per the new waste regulations.

Storm Water Management on Site:

- Alterations to the berms along the road have been made. A GN 704 audit was undertaken during 2016. The recommendations from this audit have formed the base for a new storm water management plan for the mine. The recommendations of GN 704 audit have been put in an action plan and progress reports on these actions are compiled. Refer to Section 2 of Appendix IV for details of the storm water management near the river diversion.
    - The recommendations relating to the GN 704 audit should be implemented as soon as practicably possible. The storm water management along the haul road needs to be corrected in line with GN 704 principles as soon as practicably possible.
- A rehabilitation plan has been developed for the wetland and the river diversion. Consideration in the rehabilitation plan has been given to various control measures. Earthern berms are present at the river diversion, however due to the gaps in the berms, storm water runoff from the haul road flows straight into the river. Erosion is also evident at the topsoil stockpiles Refer to section 4 of this report for site photos.
    - It is recommended that the GN 704 audit recommendations and management measures be implemented as soon as practicably possible. The storm water management along the haul road needs to be corrected. Erosion prevention measures should be put in place.
- Due to the road not being level, ponding during rainfall events is experienced. This ponding is deemed a safety hazard. As a result of this, gaps in the berms along the haul road have been strategically placed in order to alleviate this. Dirty storm water run-off from the haul road flows directly into the river diversion/wetland through the gaps as described above. In addition, the berm that runs parallel to the plant appeared to have been destroyed and no longer adequate to keep stormwater in the dirty footprint area. Refer to section 4 of this report for site photos.
    - The GN 704 audit recommendations should be implemented as soon as practicably possible. Storm water runoff must be allowed to enter the wetland area. The haul road should be levelled during the dry winter months to minimise the risk of ponding on the road. In addition, it is highly recommended that the berm along the plant be repaired immediately.
- Berms have been erected along the haul road. Gaps in the berms along the haul road have been constructed. In some areas, storm water flows through these gaps where it is collected by a trench. In other locations the storm water flows into the

environment, as was noted by the December 2016 biomonitoring report and observed on site. The storm water management along the road was observed to be inadequate. An audit in terms of GN 704 was undertaken in 2016. Refer to Section 4 of this report for site photos. Recommendations on Priority 1 (critical) incidents have been implemented, whereas actions on Priority 3 (high) incidents are still in progress.

  - The GN 704 audit recommendations are currently being implemented as practicably possible. Storm water runoff must be allowed to enter the wetland area.

- Storm water trenches near and in the plant, have improved, however, they were observed to contain silt, and dust-aside It was also observed during the site visit that stockpiles were falling into the trenches. Stormwater channels by the workshop area were observed to be well maintained however did contain some silt and dust-aside. Refer to Section 4 of this report for site photos.
  - It is recommended that the management measures and actions from the GN 704 audit for the Plant Area and Workshop Area be undertaken and completed as soon as practicably possible.
- The plant was observed to have storm water channels while the workshop had channels and sumps. The plant area is concreted and hard covered. The workshop area is partly concreted and hard covered. Ponding of storm water was observed in the plant area during the audit, however this was minimal.
  - It is recommended that the management measures and actions from the GN 704 audit for the Plant Area and Workshop Area be undertaken and completed as soon as practicably possible.
- Storm water dams were observed to be below the freeboard of 0.8 metres. As part of the ongoing progress with regards to the GN 704 audit recommendations, new canals will be constructed to transport dirty water to the silver dams. The need for new berms has also been identified for the clean and dirty water separation. An earth channel is also proposed next to the berm to transport Stormwater to the existing northern canal.
  - It is recommended that the management measures and actions from the GN 704 audit for the Plant Area and Workshop Area be undertaken and completed as soon as practicably possible.

6.6.1.2 OI and OL IWUL (License No. 04/B20A/CIJ/4032):

From the audit findings, it is the opinion of the auditor that Leeuwpan give attention to the following identified non-compliances:

Quantity of water S21(a) and (j):

- No flow meters have been installed at Pit OI and therefore, no volumes for dewatering could be established. A record of water taken can therefore also not be compiled. Leeuwpan mine personnel indicated that they are in the process of establishing a pipeline strategy which will be implemented this year in which flow meters will be installed.
    - It is recommended that flow meters be implemented as soon as possible to record the amount of water being dewatered at the OI Pit.
- The groundwater form pit OI is not being disposed of into the PCD on farm Moabsvelden 248IR Portion 2 and 16. Instead, the water is being transferred to a PCD on Kenbar 257IR.
    - It is recommended that Leeuwpan apply for the location of this PCD to be amended as well as inform the Department that they will be transferring the water to the PCD located on the Kenbar property.
- Wastewater for dust suppression is being taken from the main PCD as the PCD licenced in this licenced is not being built. The licence has authorised 7650m^3 for dust suppression, however, 9316m^3 for the year 2018 was used.
    - It is recommended that Leeuwpan apply for this condition to be amended as the PCD is not being constructed. It is also recommended that Leeuwpan do not exceeded the authorised limit for dust suppression.

Quality of water:

- According to Golder's quarterly water monitoring report (December 2018), the following constituents increased at downstream sites compared to upstream at least once during the reporting period: total dissolved solids, electrical conductivity, sulphate (exceeded IWUL limit), sodium, calcium, magnesium (exceeded IWUL limits), total hardness, total phosphorus E. coli (exceeded IWUL), sodium absorption ratio and dissolved oxygen (a positive sign) increased downstream.
    - It is recommended that Leeuwpan investigate the cause of the decrease in water quality to downstream users as well as the implementation of appropriate mitigation measures as soon as possible.
- Golder conducts the surface water monitoring monthly and the groundwater quarterly. January's 2018 report includes the test for all trace metal elements, however, July's 2018 report did not test for such.
    - It is recommended that Leeuwpan test all surface and groundwater monitoring points for a full spectrum of heavy metals twice a year.

Biota (Bronkhorstspruit):

- According to the report by Clean Stream (June 2018), the Average Score Per Taxon (ASPT) has declined, indicating a decline in water quality and the loss of taxa with a requirement for good water quality.

- It is recommended that Leeuwpan investigate the cause of the decrease in diversity and implement mitigation plans as soon as possible. GCS and Clean Stream are aware that Leeuwpan is not the only mine along the Bronkhorstspruit.

Monitoring and reporting:

- Non-compliances were highlighted in the internal audit, however, corrective actions for the non-compliances were not listed.
  - It is recommended that Leeuwpan include all mitigation measures and a record of corrective actions.
- Annual public participation meetings are undertaken by Exxaro. The last meeting was a farmer's engagement which was held on the 15 March 2019. Proof was provided to the auditors. However, the proof was not submitted to the Provincial Head before the 31st March 2019.
  - It is recommended that the proof is submitted to the Provincial Head as soon as possible.

6.6.2 Leeuwpan IWUL Action Plans

Below, Table 6.2 and Table 6.3 indicate Leeuwpan's action plan to the non-compliances for both licenses.

Table 6.2 Main IWUL Action Plan

INTEGRATED WATER USE LICENCE 04/B21A/ABCGIJ/429 External AUDIT March 2019 SAP Number:152941						
Number	**Date of audit**	**Findings**	**Actions**	**Responsible person**	**Accountable Person**	**Due date**
1	13-Mar-19	Flow Meter Calibration	It is recommended that calibration certificates for flow metres for Pit OH and Pit OWM be updated.	M. Mbatha	B. Mtshengu	TBC
2	13-Mar-19	Quantity of water: Devon Load Out Borehole exceeded the annual limits authorised.	It is recommended that abstraction be done within the authorised limits.	S. Hinani	R. Mooni	TBC
3	13-Mar-19	The dam has no level meter readings	It is recommended that the potential for floating level metres should be further investigated for the Section 21(b) dams on site	M. Mbatha	B. Mtshengu	TBC

4	13-Mar-19	Exceedances, when compared to the IWUL limits, were assessed for both the tributary and the Bronkhorstspruit for the third quarter of 2018 sampling period.	parameters exceeding the IWUL limits recorded at the downstream point should be minimised or mitigation measures investigated in order to adhere to the IWUL limits.	S. Hinani	R. Mooni	TBC
5	13-Mar-19	Dirty water infrastructure needs to be better maintained.	Continuous maintenance of trenches at the plant and around the mine.	R. Pillay	J. Struwig	TBC
6	13-Mar-19	The Plant PCD (LSW09) in terms of Nitrates.	check the source and do continuous monitoring to see the trend.	S. Hinani	R. Mooni	TBC
7	13-Mar-19	Silver dams (KR01) in terms of TDS and Magnesium.	check the source and do continuous monitoring to see the trend.	S. Hinani	R. Mooni	TBC
8	13-Mar-19	Erosion and ponding of water at the haul road	The haul road must be levelled during the dry winter months to minimise the risk of ponding on the road. Erosion control measures should be put in place where necessary	N. Stenyberg	M. Mabasa	TBC
9	13-Mar-19	A leaking dirty water pipe was observed at the slimes dam during the audit.	The leaking pipe should be fixed as soon as possible.	M.Mbatha	B. Mtshengu	TBC
10	13-Mar-19	Dirty storm water run-off from the haul road flows directly into the river diversion/wetland through the gaps as described above	The haul road should be levelled during the dry winter months to minimise the risk of ponding on the road.	N. Stenyberg	M. Mabasa	TBC

Table 6.3 OI&OL IWUL Action Plan

04/B20A/CIJ/4032 (OI & OL) SAP Number :152941						
Number	**Date of audit**	**Findings**	**Actions**	**Responsible person**	**Accountable Person**	**Due date**

1	13-Mar-19	According to Golder's quarterly water monitoring report (December 2018), the following constituents increased at downstream sites compared to upstream at least once during the reporting period: total dissolved solids, electrical conductivity, sulphate (exceeded IWUL limit), sodium, calcium, magnesium (exceeded IWUL limits), total hardness, total phosphorus E. coli (exceeded IWUL), sodium absorption ratio and dissolved oxygen (a positive sign) increased downstream	investigate the cause of the decrease in water quality to downstream users as well as the implementation of appropriate mitigation measures	S.Hinani	R.Mooni	TBC
2	13-Mar-19	No flow meters have been installed at Pit OI and therefore	Install flow meter and record accurate the dewatering volume	N.Stenyberg	M.Mabasa	TBC

6.7 Control and Monitoring

6.7.1 Monitoring of Change in Baseline information

6.7.1.1 Surface Water Monitoring

Refer to Section 5.4.1 for the monitoring undertaken for surface water resources at Leeuwpan Mine.

6.7.1.2 Groundwater Monitoring

Refer to Section 5.4.2 for the monitoring undertaken for groundwater resources at Leeuwpan Mine.

6.7.1.3 Biomonitoring

Refer to Section 5.4.3 for the biomonitoring undertaken at Leeuwpan Mine.

6.7.1.4 Wetland Monitoring

Refer to Section 5.4.4 for the wetland monitoring undertaken at Leeuwpan Mine.

6.7.2 Audit and Report on Performance Measures

Each component within the IWWMP has an associated audit and performance review component. Regular review and auditing is important to ensure systems are up-to-date and still relevant for current situations. Evaluation is required to verify its appropriateness and suitability by comparing performance to objectives set. Changes or adjustments to systems

are required where review/auditing highlights shortcomings or gaps. Performance should be measured against:

- Internal audit (conducted annually);
- External audit (conducted annually); and
- DWS reporting (conducted bi-annually).

6.7.3 Audit and Report on Relevance of IWWMP Action Plan

All existing and new systems need to be reviewed and modified to ensure continual improvement. It is considered good practice to review or audit all systems at least annually and to update the IWWMP as required in the IWUL.

6.7.3.1 Other Environmental Legal Audits

Other environmental audits conducted / should be conducted include:

- Annual waste audits;
- Annual Performance Assessment; and
- Annual Integrated Water Use License Audits once the expansion IWULA has been approved.

7 CONCLUSION

7.1 Regulatory Status of Activity

There are currently two Water Use Licences for the Leeuwpan mining operation. The IWULs that pertains to this report were issued in 2011 (Licence No. 04/B21A/ABCGIJ/429) and its associated amendment, as well as the IWUL for the OI and OL expansion (Licence No. 04/B20A/CIJ/4032) that was issued in 2015 for the current, existing and future mining operations. Furthermore, mining Block OI will be expanded to include the area where planned infrastructure would have been located. This area (OI West) is currently being applied for as a separate application.

This document serves as the 2019 updated IWWMP that serves to satisfy the respective IWUL condition (Licence No. 04/B21A/ABCGIJ/429) and (Licence No. 04/B20A/CIJ/4032) in this regard and will be submitted to DWS accordingly.

7.2 Statement of Water Uses Requiring Authorisation

No new water uses are being applied as part of this IWWMP update for 2019. All water uses pertaining to this IWWMP have been licenced in terms of Section 21 of the NWA by DWS.

7.3 Statement on IWWMP Update

The IWWMP Update is required on an annual basis in order to ensure compliance with the conditions of the IWUL issued to Leeuwpan Coal Mine. The IWWMP is a living document that is required to be updated on an annual basis in order to ensure its relevance to the mining activities which are continuously changing as the operational life of the mine progresses. Since the last IWWMP submitted to the DWS, no major changes in terms of infrastructure have taken place at Leeuwpan Coal Mine. The areas that require attention in terms of water use and waste generation have been discussed in this document.

7.4 Section 27 Motivation

Refer to Annexure H for the Section 27 Motivation compiled for the 2019 IWWMP update.

7.5 Proposed License Conditions

All the water uses that have been authorised under Licence No. 04/B21A/ABCGIJ/429 have been done so for the period of 10 years from the date of issuance with a review period of 3 years. All water uses that have been authorised under Licence No. 04/B20A/CIJ/4032 have been done so for a period of 20 years from the date of issuance with a review period of 5 years. This report serves as the 2019 updated IWWMP only and does not make provision for the application of any water uses not included in the IWULs and associated amendment.

8 REFERENCES

Environmental Authorisation and Environmental Management Plan reports compiled for the Block OI Expansion project.

Clean Stream Environmental Consultants, 2009. Exxaro Coal, Leeuwpan Coal, Integrated Water and Waste Management Plan, December 2009.

Stats SA; (2015). Victor Khanye. www.statssa.gov.za/?page_id=993&id=victor-khanye-municipality. Accessed 01 November 2018.

Specialist Studies conducted for the Leeuwpan monitoring programme.

Specialist Studies conducted for the Block OI Expansion project.

Victor Khanye Local Municipality. (2015). Victor Khanye Local Municipality Integrated Development Plan Final 2014/15 Review.

Annexure A
2018 RSIP Update



Rehabilitation Strategy and Implementation Programme (RSIP) for Exxaro Leeuwpan Coal- Annual Update

COMPILED BY:

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DOCUMENT CONTROL

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1	29 June 2017	Update for 2017 review
2	31 May 2018	Update for 2018 submission

ABBREVIATIONS AND ACRONYMS

The following acronyms are applicable to this document: For more details, please consult the Glossary.

ACRONYM	DESCRIPTION
AMD	Acid Mine Drainage
BU	Business Unit
DWS	Department of Water and Sanitation
EMP	Environmental management Plan
EMPR	Environmentl Management Plan Report
FLFD	Final Land Form Design
FLUP	Final Land Use Plan
IAP'S	Interested And Affected Parties
LOM	Life of Mine
OGL	Original Ground Level
RSIP	Rehabilitation Strategy Implementation Plan

ACRONYM	DESCRIPTION
SIA	Social Impact Assesment
WUL	Water Use Licence

REFERENCES

The following documents are either **Applicable Documents** - applicable to the extent specified herein and thus forming part of this document. The applicability will generally relate to the Project in terms of policy, procedures, standards, qualification, etc.; or **Reference Documents** - where the information concerned has been fully extracted from the reference document and added to this document, or where the reference document contains information relevant to this document, or for information only.

DOCUMENT NAME	RELEVANCE
Exxaro Leeuwpan Coal Rehabilition Plan under MPRDA ref number 11/447 under MR 151 & 172	Completed based on updated specialist studies and consolidation process under section 102 of the MPRDA for submission to DMR as well as MDEDET for approval
Integrated Water Use License	Complianced to Water Use License condition for Exxaro Leeuwpan Coal Mine ref: 16/2/7/B100/C27

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1 INTRODUCTION

Exxaro Leeuwpan Coal is located approximately 10 km south east of the town of Delmas in Mpumalanga Province. The district forms part of the Highveld maize production area of Mpumalanga, and is mainly used as cultivated farm land except for those areas not suitable, which are utilized for grazing. Open pit mining methods are used for the extraction of coal and the production rate for the mine is approximately 3.7 Million tonnes per annum of coal. Conventional opencast mining methods are used in a modified terrace configuration.

Leeuwpan Coal Mine has recently got Consolidated EMP which includes OI expansion project approval. Block OI is an opencast pit mining and is located on farm portion as indicated in Table 2. Leeuwpan open cast pit locality plan is shown in Figure 1.

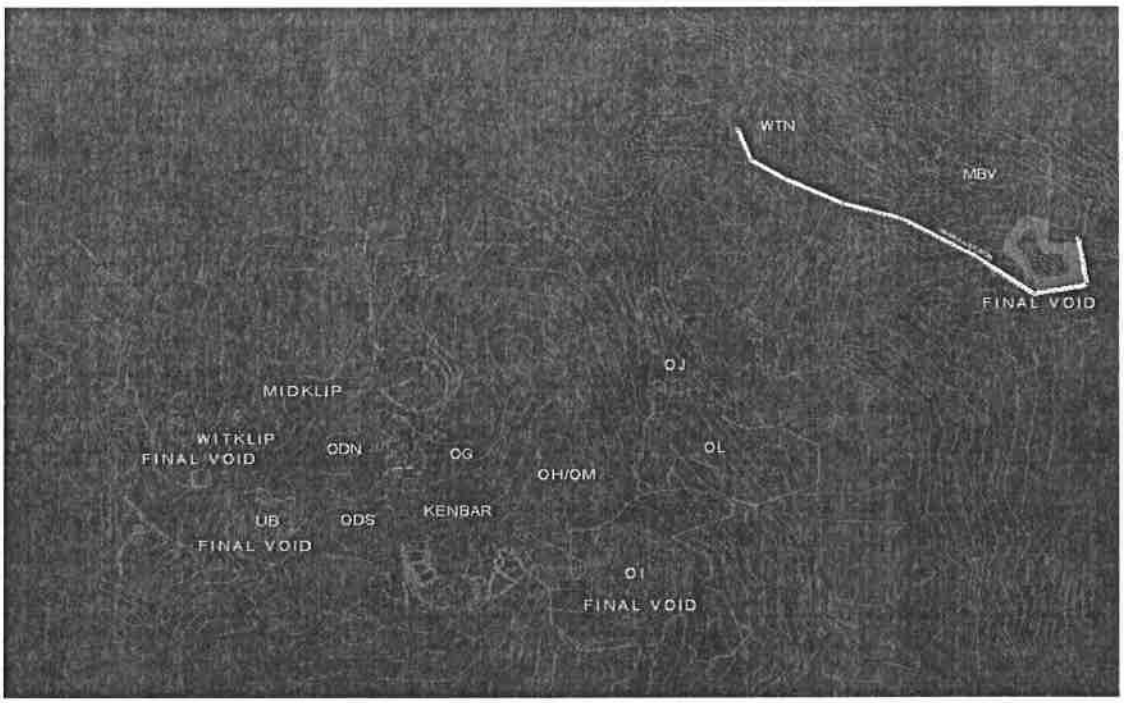


Figure 1: Leeuwpan Opencast Pit Locality Map

2 PURPOSE

The purpose of land rehabilitation involves recreating the landform and regenerating flora and fauna disturbed by mining, to a condition compatible with the pre-mining land use. Rehabilitation is a continuous process and the Exxaro Leeuwpan Coal mine has rehabilitation standards and procedures in place to ensure rehabilitation and mine plans implementation minimises the amount of land disturbed.

Exxaro Leeuwpan Coal Mine has a requirement in the Mines Integrated Water Use License (IWUL) that states that a Rehabilitation Strategy Implementation Plan (RSIP) needs to be updated within 1 year from the date of issuance of the license and submitted to the Department of Water and Sanitation (DWS). The purpose of the RSIP is to guide the Mine's Rehabilitation Programme towards the achievement of a sustainable agreed Final Land Use and in compliance with the IWUL RSIP requirements.

3 OBJECTIVES

The overall objectives for Rehabilitation of Exxaro Leeuwpan Coal Mine is contingent upon the following:

- The final outcome of the mine site rehabilitation would be a land capability suitable for selective, low-intensity grazing and agricultural production/crops purposes;
- Final landforms of the back-filled pits and other profiled areas must:
    - Enhance flow of routed clean surface water to downstream local catchments;
    - Be resilient to natural and human/animal-induced perturbation; and
    - Be self-sustaining to obviate/limit further/ongoing intervention and maintenance by Exxaro;
- Environmental and human quality of life requirements, in general, would not be compromised.
- Closure related rehabilitation of mining infrastructure and land disturbed by mining must be conducted to allow for pre-determined post-mining end land uses as agreed with stakeholders. In this regard the rehabilitated areas must be safe, stable and non-polluting for integration into the current economic, social and cultural ventures/initiates of the area;
- Priority must be given to the use of locally available natural materials and/or vegetation as opposed to imported/synthetic material and/or exotic vegetation to improve/add to the 'natural' feel of the rehabilitated areas and sites. Moreover, the measures provided must be appropriate for the site specific conditions;
- Risk-based approaches must be applied, as necessary, with Closure Planning and these approaches must form the basis of the development of the rehabilitation, decommissioning and Closure Plan;

4 LEGAL REQUIREMENTS

The MPRDA, 2002 section 43 (1) states:

The holder of a prospecting right, mining right, retention permit , mining permit, or previous holder of an old order right or previous owner of works that has ceased to exist, remains responsible for any environmental liability, pollution, ecological degradation, the pumping and treatment of extraneous water, compliance to the conditions of the environmental authorisation and the management and sustainable closure thereof, until the Minister has issued a closure certificate in terms of this Act to the holder or owner concerned.

Exxaro Leeuwpan Coal currently holds consolidated EMPR which was approved in 2017 with addendum 1-5 as described in Table 1.

Table 1: Leeuwpan list of EMPR's

EMPR	*DESCRIPTION*	*FARM PORTIONS*	*MINING BLOCKS*	*APPROVAL STATUS*
Original EMPR	*Leeuwpan Steenkoolmyn (Yskor Mynbou) June 1995*	*Farms: Kenbar 257- IR; Leeuwpan 24 IR portion 3; Witklip 229 IR R/E of Portion 4; Portion 6 and*	*Kenbar Block OA - Witklip East and West*	*Approved*

		R/E of portion 16			
Addendum 1	*Steenkoolmyn Omgewings bestuursplan, May 1996*	*Farms: Kenbar 257- IR; Leeuwpan 24 IR portion 3; Witklip 229 IR R/E of Portion 4; Portion 6 and R/E of portion 16*		*Mining of a clay reserve on Witklip to make bricks*	*Approved 03 May 1996*
Addendum 2	*Clean Stream Environmental Services, February 2000, "Leeuwpan Colliery, Environmental Management Programme Report, Addendum 2"*	*Section 4 of Witklip 229 IR*		*Block OE - Midklip*	*Approved 13 December 2000*
Addendum 3	*Clean Stream Environmental Services Report*	Witklip: Block OD; Block OFPAD	Leeuwpan 246 IR (Portion 3 (a portion of portion 1)	*Blocks OH, OM, OFPAD and OD*	*Approved with Addendum 5*
		Kenbar (Block OFPAD)	Kenbar 257 IR		
		Kenbar: Block OH	Moabsvelden 248 IR (remaining extent of Portion 2)		
		Kenbar: Block OM	Moabsvelden 248 IR (Portion 3 (a portion of portion 2)		
Addendum 4	*Synergistics Environmental Services- June 2007*	*Portions 2 and 13 of the Farm Moabsvelden 248 IR*		*Block OJ & OL*	*Approved 19 June 2008*
Addendum5	*Clean Stream Environmental Services - 2007*	*Block OD (Wolwenfontein) UI (Rietkuil) and OWM (Weltevreden and Moabsvelden)*		*Block OD, UI and OWM*	*Approved 24 March 2010*
Approved Consolidated EMPR including OL and OI	*GCS (Pty) Ltd.*	*All above portions*		*All blocks mentioned previously including OL and OI*	*Approved 2017*

All the Leeuwpan EMPRs relates to certain areas or mining pits with certain commitments relating to rehabilitation and closure.

5 REHABILITATION IMPLEMENTATION STRATEGY - 2018

5.1 REHABILITATION OF THE VOIDS

The areas earmarked for void closure rehabilitation in 2018 are Weltervreden (WTN), Moadsvelden (MBV), Block OJ and OL. The estimate amount of the material moved for concurent rehabilitation is indicated in the table below:

Pit Name	Concurrent Rehabilitation (tons)
Moadsvelden	16 948 767
Weltevreden	986 372
OJ	5 167 734
OL	1 453 091
Total	**24 555 964t**

The backlog rehabilitation for Moadsvelden Pit is estimated at 927 442 tonnes. There are no changes on the Final Land Form Designs (FLFDs) for these areas. The schedule for void closure is indicated in Figure 2.

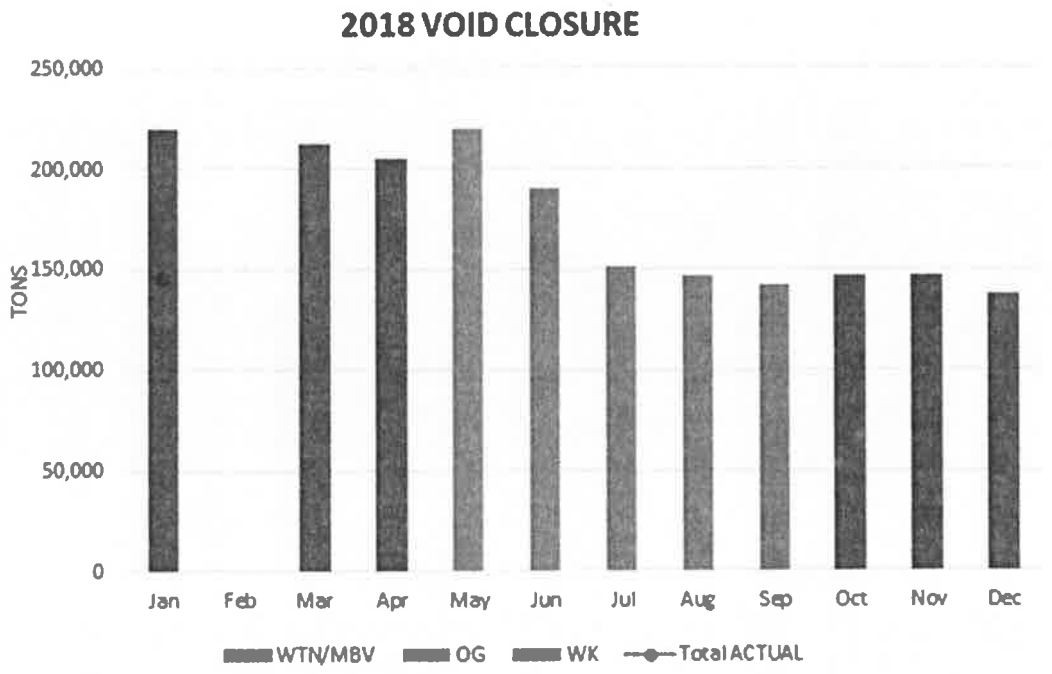


Figure 2 : Schedule for Voids Rehabilitation

5.2 SHAPING AND GRASSING

The areas earmarked for shaping and grassing as aprt of rehabilitation in 2018 are Weltervreden (WTN), Moabsvelden, ODS, OG, OJ, Witklip and Discard Workshop. The shaping at Moabsvelden/Weltervreden occurred in March and an area of 15 hactares was covered. The shaping of ODS occurred in May and an area of 25 hactares was covered. The shaping at OG pit will occurred in July and an area of 45 hactares was covered. Witklip shaping started in

August and will continue till September.The shaping of Discard Workshop will take place in November and December. The schedule for shaping and grassing is indicated in Figure 3.

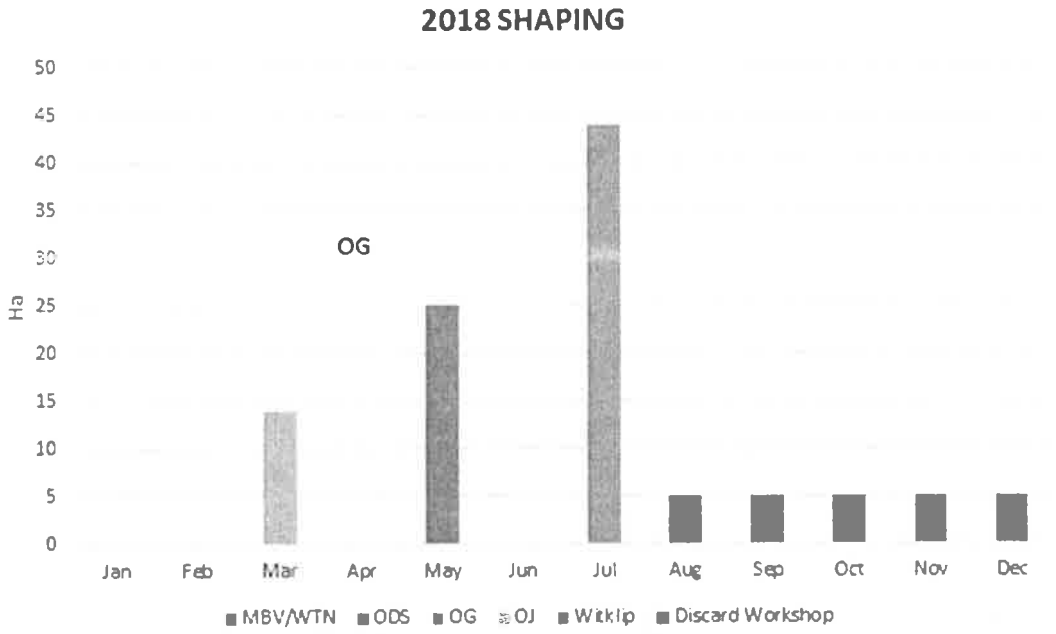


Figure 3: Schedule for Shaping and Grassing

6 BLOCK OI INFRASTRUCTURE

New infrastructure and activities that are associated with the approved Block OI expansion project includes the following:

- Boxcut for access to opencast pit;
- Explosive magazine;
- New and extension of haul road from the mine entrance ramp to the tip terrace;
- Tip terrace, crushers, conveyors;
- Screen house;
- Crushing and screening plant (DMS);
- Weirs;
- Plant buildings;
- Stockyard, including stockyard conveyors;
- ROM and product stockpiles;
- Diesel storage of 1000 cubic metres - Fuel Depot;
- Water pipelines (from OI) and pipelines between PCDs;
- Existing return water dams will be put back in use – combined capacity of 80000 Cubic metres;
- Stormwater drains, trenches and cut-off trenches;
- Clean and dirty water systems;
- Evaporation dam, pollution control dam;
- Services including potable water, process water, fire water, electricity reticulation; and
- 11kV bulk electrical supply from Eskom substation.

The expected design life of mine is projected to be 17 years. The proposed block OI will be situated on the following farm portions:

Table 2: Farm Portions

SG Number	Farm	Portion	Owner detail
T0IR00000000024800002	MOABSVELDEN 248	Portion 02	Exxaro Coal Pty Ltd
T0IR00000000024800003	MOABSVELDEN 248	Portion 03	Exxaro Coal Pty Ltd
T0IR00000000024800010	MOABSVELDEN 248	Portion 10	Exxaro Coal Pty Ltd
T0IR00000000024800016	MOABSVELDEN 248	Portion 16	Exxaro Coal Pty Ltd
T0IR00000000024900001	RIETKUIL 249	Portion 01	Hannes Potgieter Trustfonds
T0IR00000000024900002	RIETKUIL 249	Portion 02	Hannes Potgieter Trustfonds

Figure 4 and 5 shows the location of the infrastructure associated with the Block OI project.

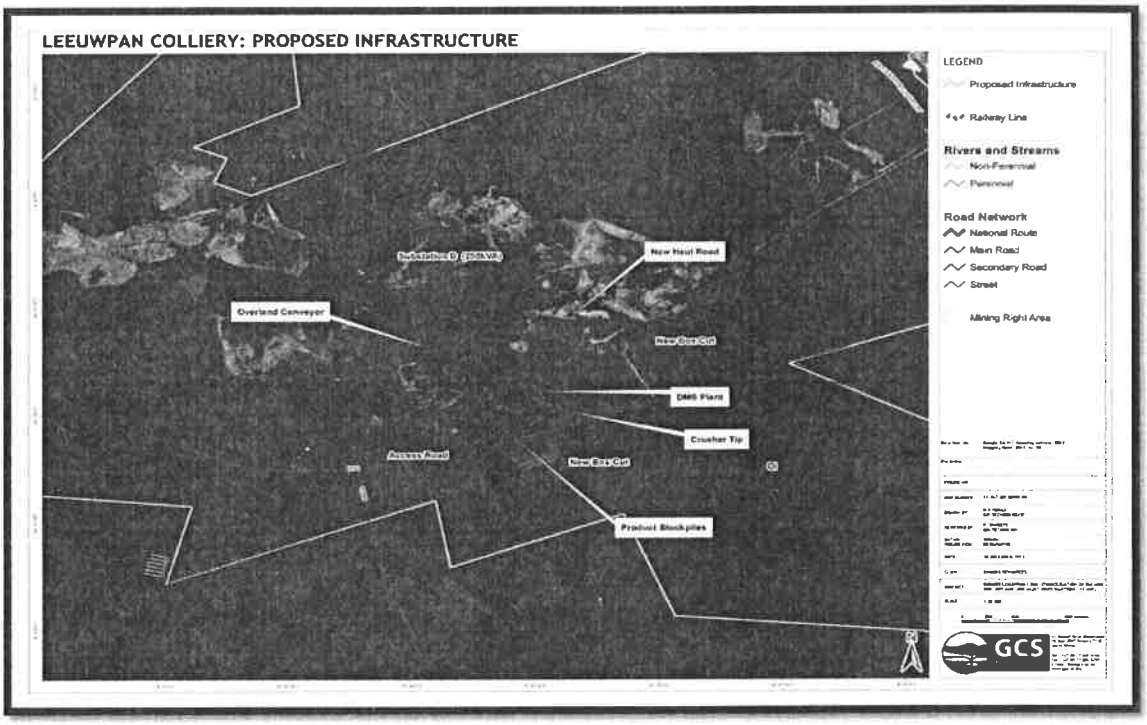


Figure 4: Proposed Infrastructure associated with Block OI

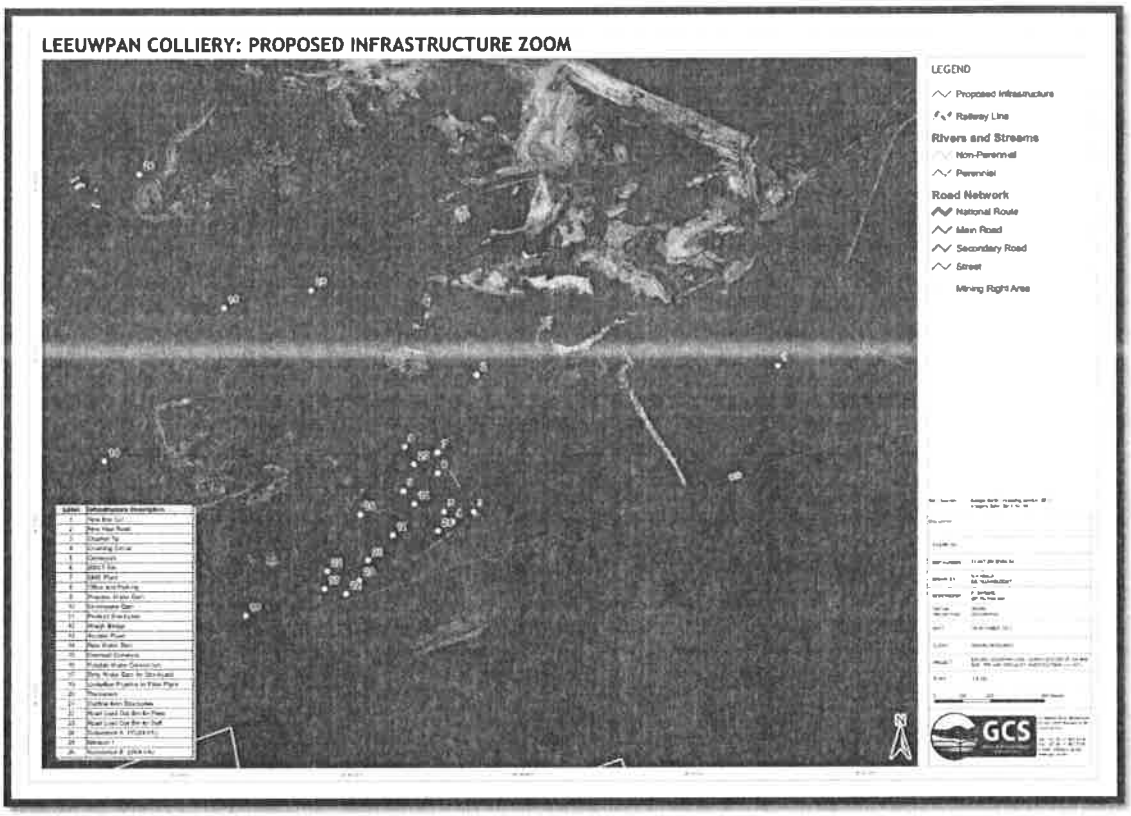


Figure 5: Proposed infrastructure

6.1 Main activities for each phase

The main activities which are expected during the different phases of the mine life cycle are summarized in Figure 6 below:

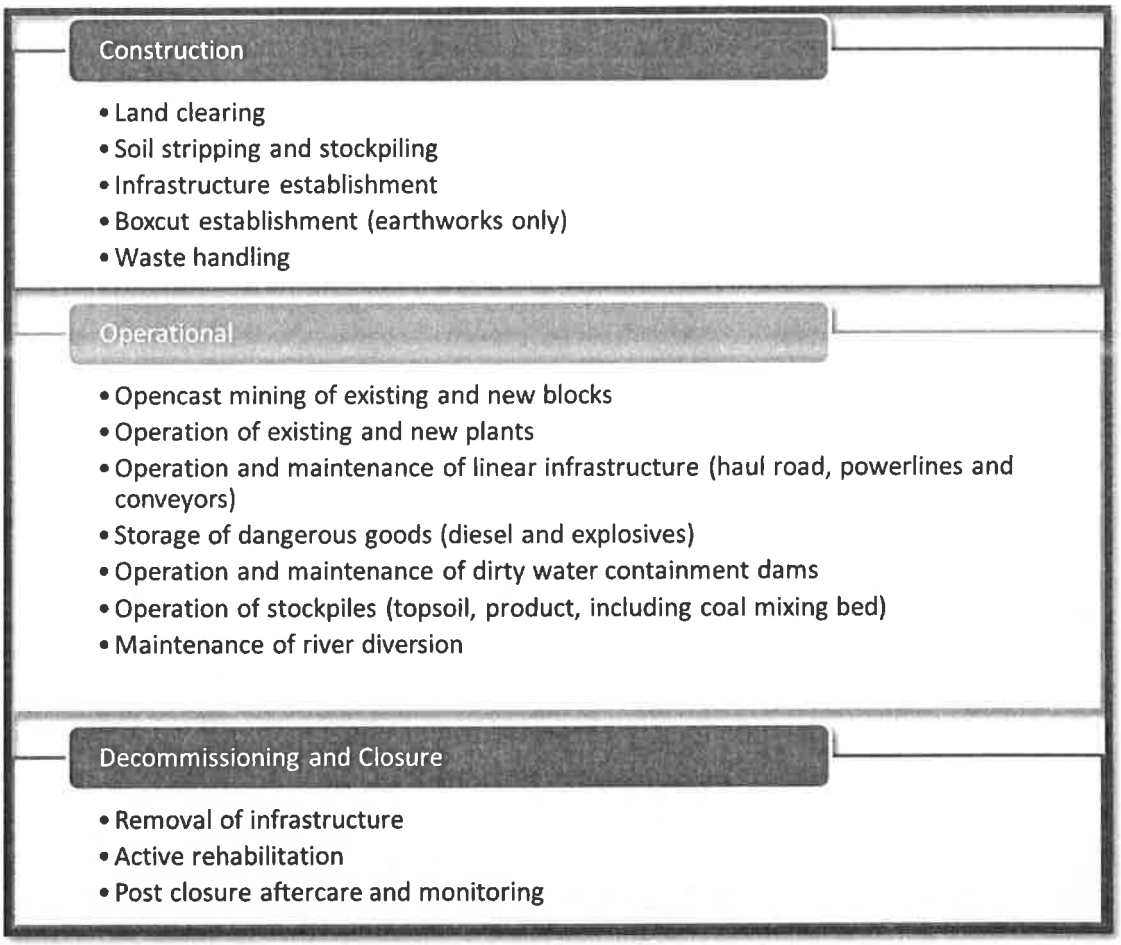


Figure 6: Activities associated with different phases of the project

6.1.1 Construction Phase

During the construction phase, the following activities may have impact on the bio-physical environment and the cultural/social setting:

- Stripping of vegetation;
- Stripping of topsoil and subsoil as the construction activities start on site;
- Oil and fuel spills;
- Soil compaction;
- Dust dispersion from construction vehicles, infrastructure construction and boxcut construction activities;
- Noise generated by construction activities;
- Blasting;
- Establishment of new infrastructure;
- Temporary workers disrupting communities; and
- Increased traffic.

6.1.2 Operational Phase

During the operational phase, the following activities could impact on the bio-physical environment and the cultural/social setting:

- Removal of coal resources;
- Topographic alteration;
- Oil and fuel spills;
- Possible compaction of soils;
- Opencast Mining Activities;
- Plant Operation;
- Change of land use;
- Establishment of waste facilities;
- Dust dispersion from vehicles and workings;
- Noise generated by earthmoving equipment and workings;
- Blasting;
- Temporary workers disrupting communities;
- Increased traffic;
- Stockpiling of RoM and overburden;
- Transport of coal product via road and conveyor systems;
- Erosion of soil stockpiles and berms by wind and water; and
- Ancillary activities (workshops, offices, etc).

6.1.3 Decommissioning and Closure Phase

When the decision is taken to decommission the mine, the following objectives and proposed actions for the decommissioning and closure phase of the mine would be considered:

- Prevention of Acid Mine Drainage;
- Demolition of structures not to be used in the future;
- Ripping of all compacted areas, which will be followed with amelioration and vegetation;
- Ensure that all remaining dumps, piles and slopes are sufficiently shaped to blend in with the surrounding infrastructure;
- Amelioration and vegetation of all disturbed areas;
- Maintenance of all re-vegetated areas up until such areas initiate succession and create a sustainable cover;
- Monitoring of key environmental variables (i.e. soils, vegetation, groundwater and surface water) in order to demonstrate stability of rehabilitated areas;
- Weed management after closure, limited to areas disturbed by mining or included in the mining area; and

Monitoring will be undertaken for a specific period after closure or up until such time that all areas create a sustainable cover and ecosystem and a closure certificate is obtained.

6.2 Waste Manegment

6.2.1 Mine Waste

Backfilling will take place for the Block OI project as with all other sections on the mine and there will be no discard dumps. Topsoil and overburden will be stockpiled for rehabilitation purposes. Once steady state of production is achieved, discard material and the overburden for OI will be backfilled into the OI pit concurrently throughout the operations of OI.

6.2.2 Hazardous Waste

Any hazardous waste is disposed of in clearly marked containers, which are then sent to the mine workshop hazardous waste storage area, located within the existing mine boundary area, and removed by a contractor to a licensed waste disposal site. The already existing hazardous waste storage facility permit that of Leeuwpan Coal Mine will be renewed for the extension of the life of mine and to incorporate the OI Expansion.

7 FINAL LAND FORM DESIGNS (FLFDS)

7.1 Witklip and Midklip

The Witklip and Midklip areas are situated on portion 4 of the farm Witklip 229 IR and the planned rehabilitation areas is ±72ha

The key activities that apply to the Witklip Pit are:

- Backfill final void (160 000m^3)
- Doze Slopes (240 000m^3)
- Seal with clay (41 000m^3)
- Shape 47.8 ha
- Topsoil
- Re-vegetation

The key activities that apply to the Midklip Pit are:

- Shape (100 000m^3)
- Topsoil
- Re-vegetation

The FLFD indicates that there will be a void left after rehabilitation. The surface runoff water will be chanelled by 1:100 berms to the void. Figure 7 shows the FLFD for Witklip pit.

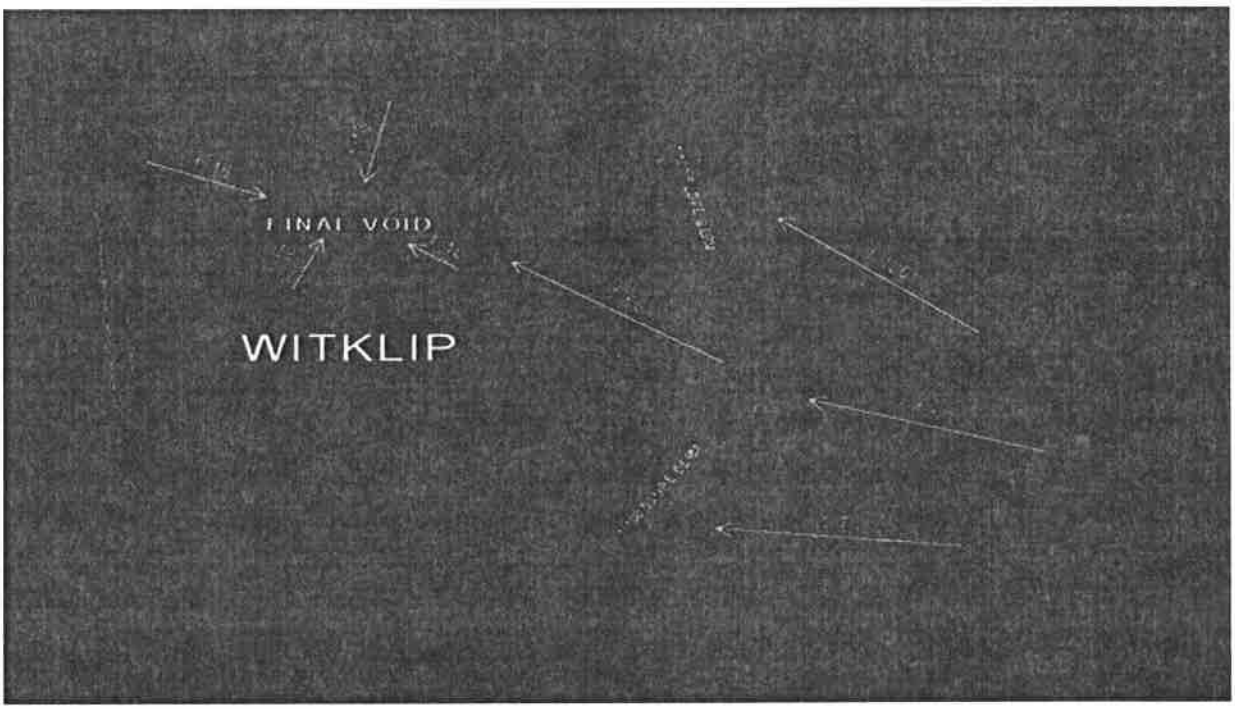


Figure 7: Witklip FLFD

7.2 Pit OG

Pit OG is situated on portion 1 of the farm Kenbar 257 IR and the planned rehabilitation area is 53.2ha.

The key activities that applies to Pit OG are:

- Backfill final void (160 000m3)
- Shape 53.2 ha
- Topsoil
- Re-vegetation

The FLFD for OG pit is shown in Figure 8 and it dictates that there will be no void left after the pit has been backfilled and rehabilitated. The pit will be rehabilitated to approximate original ground level. The block OH cut material will be used for filling of the void.

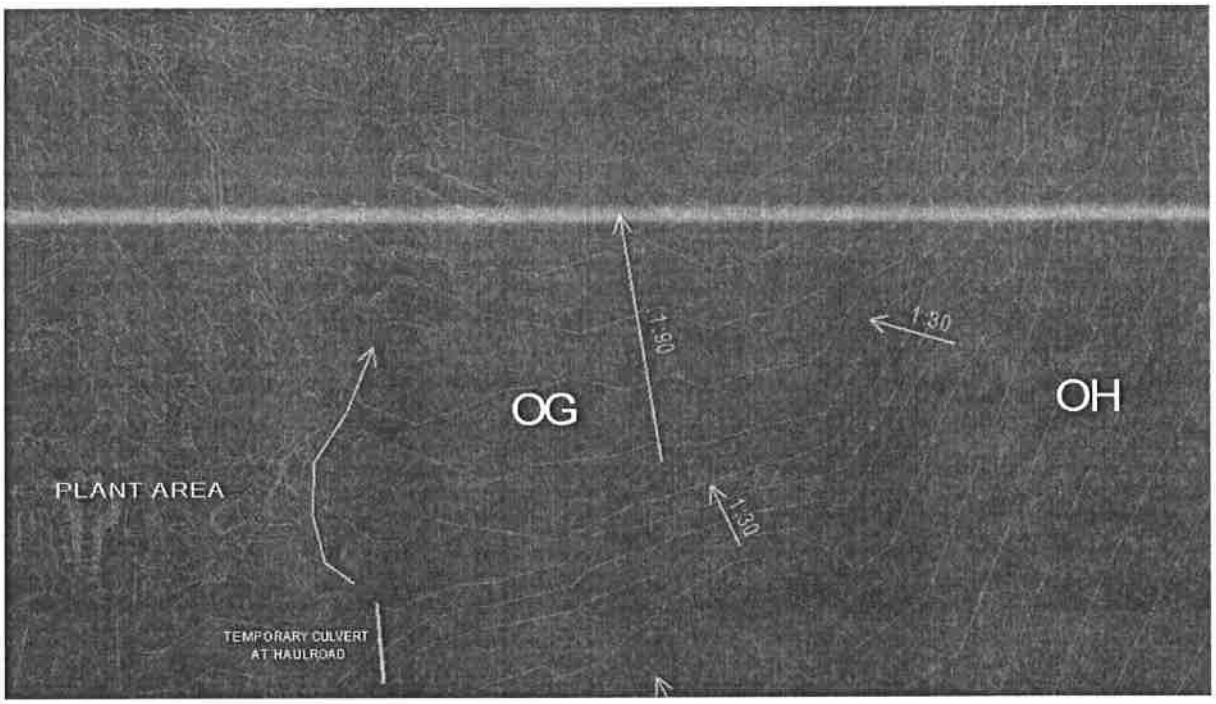


Figure 8: OG FLFD

7.3 Moabsvelden

The FLFD depicts that there will be a void that will be left due to the shortage of material. Northern area surface water runoff will be directed to the original catchment area. Southern area surface water will be directed to the river diversion. The FLFD is shown in Figure 9.

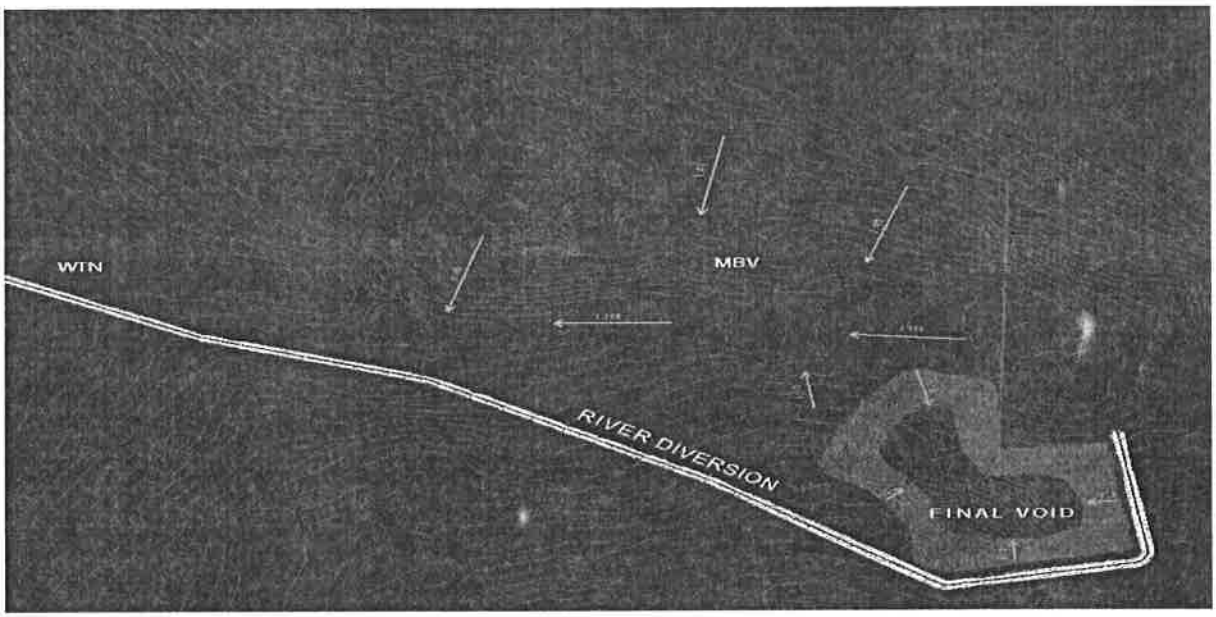


Figure 9: Moabsvelden FLFD

7.4 Weltervreden

The Weltevreden pit is situated on Portion 7 of the farm Weltevreden 227 IR and the planned rehabilitation area is 80.9ha.

The Final Land Form Design for Weltervreden Pit is indicated in the Figure 10. There will be no void left after the pit has been backfilled and fully rehabilitated. The water runoff from Moabsvelden from the West will be channelled to the river diversion to pass the Weltevreden pit on the Southern side.

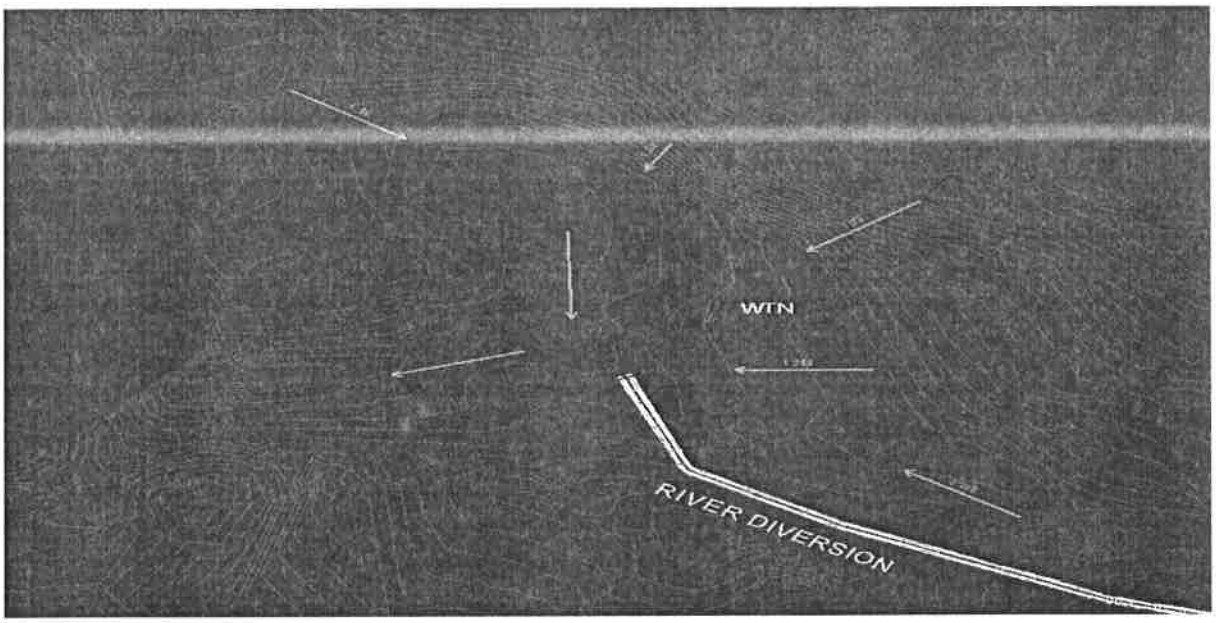


Figure 10: Weltervreden FLFD

7.5 Block OI

The FLFD for block OI pit indicates that there will be no void left after the pit has been backfilled and rehabilitated. The pit will be rehabilitated to approximate Original Ground Level. The block OL cut material will be used for filling of the void.

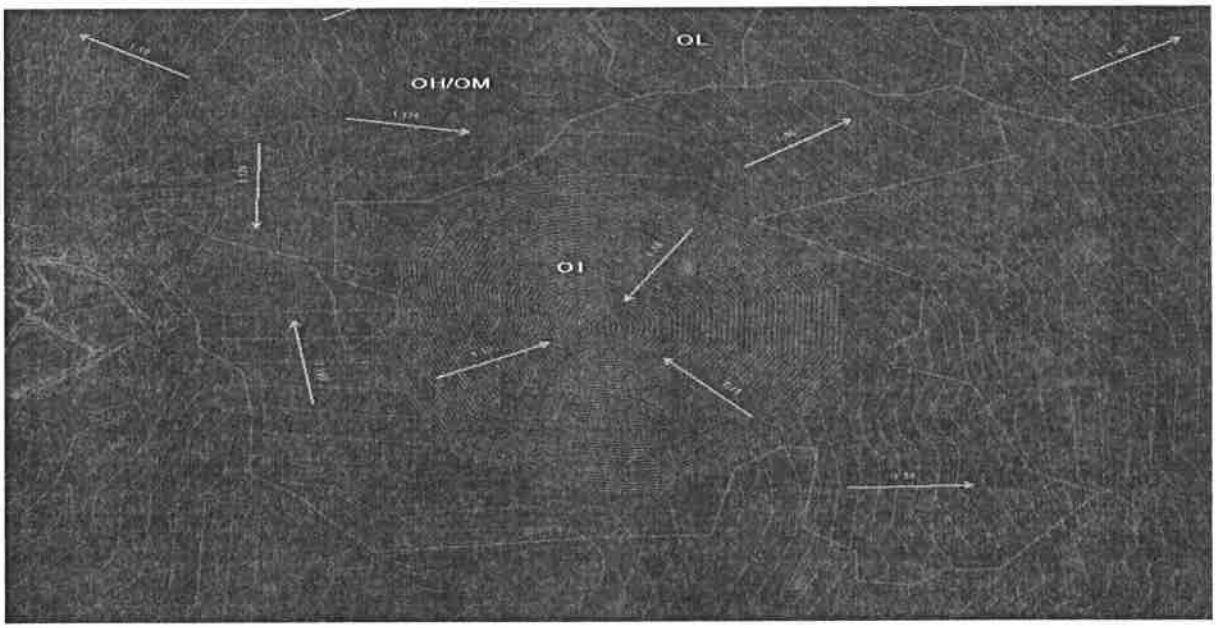


Figure 11: Block OI FLFD

8 LAND USE

The current land use of the proposed Leeuwpan Coal Mine Block OI area consists of mainly of crop production and cattle farming. Due to large resources of underground water available for irrigation and the high crop production potential of soils in the area, land with arable crop production are used mostly for irrigated crop production under centre pivot irrigation and some fields for dryland crop production.

8.1 End Land Use for Each Area Rehabilitated

The planning contained in this report has taken into consideration the end land use of Block OI expansion project:

Table 3: End Land Use for Each Area

End Land use per area			
Pit	EMPR	Void	EMPR End Land Use
Witklip	Original EMPR	Yes	Grazing
Kenbar	Original EMPR	Yes	Grazing
Midklip	Addendum 2	Yes	Grazing
ODN	Addendum 3	No	Agriculture production / crops
ODS	Addendum 3	No	Agriculture production / crops
OG	Addendum 3	No	Agriculture production / crops
OH	Addendum 3	No	Agriculture production / crops
OM	Addendum 3	No	Agriculture production / crops
OFPAD	Addendum 3	No	Agriculture production / crops
OJ	Addendum 4	No	Agriculture production / crops
Weltevreden	Addendum 5	No	Grazing
Moabsvelden	Addendum 5	No	Grazing
OL	Consolidated EMPR	Yes	Grazing
OI	Consolidated EMPR	No	Grazing
O/UB	Consolidated EMPR	No	Not yet planned

9 COMMITMENTS

The following commitments are proposed from the EMPR's:

- Geology - Rehabilitation of the open cast workings will be concurrent with the mining operation. Compaction of the overburden and sub- soils will be undertaken before the placement of topsoil. The utilization of the stormwater diversion trenches/berms and haul road will not impact on the geology.
- Topography - Concurrent rehabilitation of the mining area will take place, which will involve the filling of the pits (i.e. removal of stockpiles) and the sloping, levelling and shaping of the area to be free draining. The shaped area will then be seeded with a mixture of grasses in order to obtain a vegetative cover in order to reduce erosion
- Soils - During the operational phase, the overburden will be selectively removed and stockpiled namely, the topsoil first (up to 400 mm), followed by the sub soils and then the remaining overburden. Each will be stockpiled separately. During rehabilitation, the sub soils will be placed over the overburden material. After levelling, a topsoil layer (a minimum of 400 mm) will be spread over the area as a final topping. The topsoil will be analysed to determine the imbalances prior to the replacement of the soil. Inorganic fertilizers will be used to supplement the soils before the seeding of the area takes place. Appropriate soil conservation measures will also be provided in order to prevent soil erosion and the loss of topsoil.
- Land capability - Concurrent rehabilitation of the mining area will take place, which will involve, the filling of the pits, the sloping and the seeding of the area with a mixture of grasses in order to obtain a vegetative cover. It will be attempted to eventually return the sites to their arable land capability.
- Land use - Concurrent rehabilitation of the mining area will take place, which will involve the filling of the pits and the sloping/seeding of the area with a mixture of grasses in order to obtain a vegetative cover. It will be attempted to eventually return the sites to their arable land capability.
- Natural vegetation - The disturbed areas will be topsoiled and sloped. A variety of pioneer and climax grasses will be used in order to establish a vegetative cover: *Cynodon dactylon* (10 kg/ha) *Digitaria eriantha* (12 kg/ha) *Eragrostis curvula* (3 kg/ha) *Eragrostis tef* (2 kg/ha) *Chloris gayana* (5 kg/ha) These species could also be used for vegetating the berms associated with the storm water diversion trenches in order to reduce potential erosion and loss of soil.
- The rehabilitated area will not be grazed before the climax species are well established. Through the process of succession, it is anticipated that indigenous species will re-establish.
- Regular site inspections will be conducted to identify any declared weeds or invader plants. If identified, the plants will be eradicated using the appropriate method. The stipulations, in terms of the Mpumalanga Nature Conservation Act, 1998 (Act 10 of 1998), and the Conservation of Agricultural Resources Act, 1983, with regards to declared weeds and plants must be noted.
- The concentration of sulphates in the pit can become quite high. Therefore, the correct management of coal and carbonaceous discards during the operational period is of extreme importance to prevent excessive acid mine drainage after closure. It will especially be of prime importance to isolate these sulphite-bearing materials as far as possible from both atmospheric and water dissolved oxygen to prevent oxidation to sulphate.
- Groundwater flowing into the active mining area, should be pumped out as soon as feasible to prevent this relative uncontaminated water to deteriorate in the pit and creating a future surface water problem. Sulphide containing wastes should be dumped in mined low-lying area of the open pit where is can be completely covered by water, thereby reducing the availability of oxygen.
- If this cannot be achieved and wastes are exposed to the atmosphere, it should be covered with soil with as low permeability as possible, preferably clay if available. This will not only help to isolate the waste from atmospheric oxygen, but also create a local groundwater mound that will at least cover more of the material with water.
- Air quality - The haul roads will be wet twice daily by use of water carts. In the event of excessive wind conditions, this wetting frequency will be increased if necessary to suppress the dust. Water for dust suppression will be obtained from the pollution control dam. The mine manager or his appointed representative will ensure that dust is kept to a minimum.

- Maintenance - Maintenance of the rehabilitated land and water pollution structures (storm water diversion structures) will be continued until such time as it can be proven that a steady state has been achieved. Care will be taken to ensure that traffic will not be allowed to traverse the newly rehabilitated surfaces. This will assist in reducing potential erosion. Periodic visits will be made to the rehabilitated areas after decommissioning in order to determine the status thereof. If deemed necessary, correctional measures will be implemented

The following specific measures are recommended to attain this certain closure and rehabilitation objectives:

- As much open water as feasible must be left in the final void to enhance evaporation. This will also increase the catchments area for rainfall. However, the mine is situated in an area with a negative water balance, and evaporation is about double the rainfall on an annual basis.
- If inflow in the pit can be minimised by applying a clay layer to the sides, this will be ideal, and must be applied where feasible.
- Limited supply of clayish material should rather be utilised as a final top cover, reducing oxygen migration into the waste and thereby inhibiting the oxidation of sulphide minerals.
- Monitoring of the groundwater quantity (water levels) and quality after mine closure is imperative. If the impact of the mine on the receiving groundwater regime exceeds acceptance levels containment/rehabilitative measures must be employed. These decisions should, however, be based on time related monitoring results.

Maintenance - Control measures, e.g. regular visual inspections, will be done until a closure certificate is obtained. Other necessary monitoring actions will take place and remedial actions will be implemented as and when necessary.

10 EARTHWORKS

Earthworks will be done by the Leeuwpan Mining department by means of allocating equipment for rehabilitation. Earthworks will include:

- Loading of stockpiles and filling of voids by excavators and dump trucks;
- Spreading and sloping of soil by dozers.

The planned gradients and levels must be pegged by the Leeuwpan Survey department and sloped accordingly by the Leeuwpan Mining department.

11 TOPSOIL TESTING BEFORE RE-VEGETATION

As per the commitments of the EMPR, topsoil samples will be taken and analysed to determine imbalances and if it is required to undertake amelioration of the topsoil material. Organic material must then be used to increase the total organic levels

12 RE-VEGETATION

- Ripping (Optional)

  Should there be heavy compaction of the in-situ material on site, it would be necessary to rip the entire area to a depth of 300mm.

- Harrowing

  The areas to be vegetated are to be scarified manually or mechanically, forming large drills running parallel to the contours. The drills are to be at least 30-50mm deep and 75-100mm apart.

- Hydroseeding

  An all-in-one mixture of specific and selected grass seeds, fertilisers, combined with soil binder or tackifier, fiber mulch, soil ameliorates, growth stimulants and water must be applied to surfaces at a predetermined application rate.

The seed mixture to be used as per the prescribed by the Exxaro senior Ecological specialist is presented below:

Species	Weight /ha
Eragrostis tef	1.5 kg
Cynodon dactylon	6.5 kg
Digitaria eriantha	8 kg
Cenchrus ciliaris	7 kg
Chloris gayana	7 kg
TOTAL	**30 kg**

13 AFTER MONITORING AND MAINTENANCE

All rehabilitated areas will be maintained for a period of five (5) years after formal rehabilitation ceases. During maintenance, the following will be done:

- Clearing of alien and invasive plants to allow indigenous plants to out-compete invasive and take a strong hold in the area;
- Watering of larger trees that were planted during rehabilitation to allow for these tree to establish adequately;
- Patching/fixing of any areas that have eroded since rehabilitation;
- If hydro-seeding was not effective during the first application, a second application of hydro-seed mixture may have to be applied in certain areas. The application of hydro-seed will be at the discretion of the hydro-seeding specialist;
- Maintain water runoff areas so as to not increase chances of further potential erosion or water ingress into the rehabilitated voids;
- Encourage growth of plants and grasses by cordoning off, fertilizing and watering areas that have struggled to take root or re-vegetate;
- Areas of high importance (i.e. slopes and riparian areas) will be more vigorously maintained, fertilized and watered during maintenance;
- Along the crest of steep gradients' a 1 m high hessian screen will be placed around the facility to assist with the trapping of seeds and to protect the crest from wind erosion;
- Regular application of fertilizer will take place in order to ensure efficient establishment of vegetation cover until such time as sufficient organic matter is being produced by the established grasses to allow for self-sustaining growth;
- The process of unification can be utilized to ensure a constant supply of organic compost (fertilizer). This entails the establishment of a compost heap, where cleared indigenous organic matter is stored and allowed to break down naturally to the point of resembling garden compost;
- Care will be taken to ensure that ONLY indigenous plant matter is utilized for this process, as the presence of alien invaders may cause the establishment of invader plant communities in the rehabilitated areas: and
- With the re-establishment on natural ecological processes, fauna and flora will slowly return to normal on the mining areas.

14 CONCLUSION

Exxaro Leeuwpan Coal mine will ensure that all activities associated with rehabilitation are conducted in an environmentally friendly and safely manner. The mine commits to update the RSIP on an annual basis in order to fulfil the IWUL conditions requirements.

Annexure B
April 2019 Water Monitoring Report



REPORT

EXXARO COAL MPUMALANGA (PTY) LTD

Leeuwpan Coal Mine Monthly Water Monitoring Report - April 2019

Submitted to:

Exxaro Coal Mpumalanga (Pty) Ltd
Leeuwpan Coal Mine

Submitted by:

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Exxaro Coal Mpumalanga (Pty) Ltd	Sthembiso Hinani	Final	07 May 2019	Email

Executive Summary

Golder Associates Africa (Pty) Ltd (Golder) was appointed by Exxaro Coal Mpumalanga (Pty) Ltd (Exxaro) to conduct surface and groundwater monitoring and analysis for their Leeuwpan Coal Mine for a three-year period to ensure compliance to one of the conditions of their approved Integrated Water Use License (IWUL) number 04/B21A/ABCGIJ/429 and its amendments.

The following are findings of the April 2019 surface water monitoring event:

1) The water from all drinking water sources was characterised by a calcium/magnesium bicarbonate signature, typical of shallow, freshly recharged groundwater or water from a dolomitic aquifer.

2) Load-out Bay Offices Drinking Water and Drinking Water on Piet Schutte's Farm were ere compliant to SANS 241:2015 drinking water quality standard in April 2019, but Drinking Water Supply Tank and Drinking Water at Laboratory were non-compliant due to an exceedance in *E. coli* (these two sources are not used for drinking).

3) The following constituents (mine water parameters in **bold**) increased at downstream sites compared to upstream in April 2019, noting that an increase in dissolved oxygen is a positive:

    a. WP02: The levels of turbidity, ammonia, potassium, total hardness, alkalinity, chlorophyll a and dissolved organic carbon; total dissolved iron, *E. coli* and dissolved oxygen (negative increase decreased) downstream compared to upstream; and

    b. LSW05: **Total dissolved solids**, **electrical conductivity**, **magnesium**, dissolved oxygen, *E. coli* and total hardness.

4) The following parameters (mine water parameters in **bold**) were not compliant to water quality limits specified in the IWUL in April 2019:

    a. WP01 (Bronkhorstspruit tributary upstream of the mine): **electrical conductivity,** ammonia, calcium, potassium, **manganese**, total alkalinity, Chlorophyll a, *E. coli* and dissolved oxygen;

    b. WP02 (Bronkhorstspruit tributary downstream of the mine): **total dissolved solids**, **electrical conductivity**, ammonia, calcium, **magnesium**, **manganese**, total alkalinity, *E. coli*, and dissolved oxygen;

    c. LSW08 (Bronkhorstspruit, upstream of Block OI): ammonia, calcium, **manganese**, total alkalinity, *Chlorophyll a, E. coli* and dissolved oxygen;

    d. LSW07 (Bronkhorstspruit, upstream): fluoride, ammonia, calcium, total alkalinity, *E. coli, Chlorophyll a,* dissolved oxygen and organic carbon;

    e. LSW03 (Bronkhorstspruit adjacent to Delmas Silica): **electrical conductivity**, ammonia, calcium, total alkalinity, *E. coli, Chlorophyll a,* dissolved oxygen and dissolved organic carbon;

    f. RD1 (Bronkhorstspruit at haul road): **electrical conductivity,** ammonia, calcium, **magnesium, manganese***,* total alkalinity, dissolved oxygen and chlorophyll *a*;

    g. LSW13 (Stuart Coal): **electrical conductivity, sulphate**, ammonia, calcium and **manganese,** total alkalinity, *E. coli* and *Chlorophyll a*; and

h. LSW05 (Bronkhorstspruit downstream): **electrical conductivity**, ammonia, calcium, **magnesium**, total alkalinity, dissolved oxygen, chlorophyll a and *E. coli.*

5) The mine process water was classified based on pH and sulphate content, in April 2019 as:

   a. Saline Drainage: LSW09, OM pit, KR01A, ODN pit, OWM pit and WP04;

   b. Neutral mine drainage: KR03, KR04 and WLV pit; and

6) Levels of most constituents in waters sampled from the process water sites fluctuated from March 2019 to April 2019. Hexavalent chromium and orthophosphate were present in amounts that were below the detectable levels for all sites. KR03 remained non-compliant to the fats, oils and greases IWUL limit from March 2019 to April 2019.

7) The sewage works behind the workshop (LWP_SP_W) performed unacceptably as levels of ammonia and *E. coli* exceeded the waste water limits.

   The water from the septic tanks at the plant (LWP-SP-P) should continue to not be allowed to enter the environment but should continue to be emptied by an accredited waste removal company and disposed of to an authorised waste water treatment works.

8) Relative percentage difference values between field and laboratory measured parameters were acceptable for all pH and electrical conductivity values; and for most total dissolved solids and dissolved oxygen values. The relative percentage difference for intra-lab samples (analysed at Jones laboratory) and inter- lab samples (analysed at UIS and Jones laboratories) were acceptable for most parameters in surface water samples. The ionic charge balance error was within acceptable ranges for all surface water samples. The ratios of most calculated TDS vs laboratory measured TDS and the ratios of calculated TDS vs field measured TDS were not within the 1 to 1.2 range for most surface water samples. The ratios of laboratory measured TDS to laboratory measured EC were acceptable for most surface water samples and was within the acceptable range for all field measurements.

9) It is difficult to obtain samples from the closed pits such as Kenbar Rehab, OG Pit and OH Pit. Surface water does not readily accumulate, as it infiltrates through the rehabilitated ground. Access is also not possible to pits which have not been backfilled. The water quality of rehabilitated pits should be monitored through boreholes drilled into the backfilled spoils – becoming part of the groundwater monitoring programme instead of the surface water monitoring programme and sampling points should be removed from the surface water programme. Closed pits which cannot be accessed will need boreholes drilled once they have been backfilled.

10) The four kinetic barrels (OJ-O, OJ-S4-DISC, OH-WEATH, OL-OVB (2A+2B)) were dry as the taps are damaged, meaning that any leachate was lost. Consideration should be given to changing the design of the drainage system.

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APPENDICES

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Surface Water Quality Trend

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Document Limitations

1.0 INTRODUCTION

Golder Associates Africa (Pty) Ltd (Golder) was appointed by Exxaro Coal Mpumalanga (Pty) Ltd (Exxaro) to conduct surface and groundwater monitoring and analyses for their Leeuwpan Coal Mine for a three-year period to ensure compliance to their approved Integrated Water Use License (IWUL) number 04/B21A/ABCGIJ/429, which was amended in December 2015.

The Leeuwpan Coal Mine is an active mine located to the east of the town of Delmas in the Victor Khanye Local Municipality in Mpumalanga. The mine is situated within the Upper Olifants River Catchment, quaternary catchment B20A of the Olifants Water Management Area.

The main river in the sub-catchment is the Bronkhorstspruit River flowing on the eastern side of the mine and the Bronkhorstspruit tributary flowing on the western side of the mine. The confluence of the two is approximately 8 kilometers north of the mine before it enters the Bronkhorstspruit Dam.

The scope of work for the project includes monthly surface water monitoring and data interpretation in accordance with the conditions stipulated in the mines IWUL and amendments. This report presents results of the April 2019 surface water monitoring event.

1.1 Project Objectives

The primary objectives for the surface monitoring programme are:

- To assess, monthly, the quality of the surface water resources respectively in and around the Leeuwpan study area in accordance with the mine's approved IWUL (number 04/B21A/ABCGIJ/429) and its amendments;
- To make use of the data for both human and environmental health impact assessments;
- To compare results to previous survey results with the aim of detecting environmental trends in the surface water quality; and
- To identify potential impacts of the mining operations on the receiving water resources so that the mine can identify and implement suitable mitigation for adaptive management.

1.2 Monitoring sites

The monthly surface water monitoring sites are set out in Table 1 and illustrated in Figure 1.

Table 1: Surface water monitoring sites

Sample ID	Description	Y Co-ordinates	X Co-ordinates
Drinking water supply samples (Potable water)			
LDWST	Drinking Water Supply Tank	S26.18005	E28.73602
LLBDW	Load-out Bay Offices Drinking Water	S26.16590	E28.72990
LWDL	Drinking Water at Laboratory	S26.17128	E28.72797
PIET-SCHUTTE	Drinking Water on Piet Schutte's Farm	S26.14150	E28.80170

Sample ID	Description	Y Co-ordinates	X Co-ordinates
River/ stream samples (Resource protection)			
WP01	Bronkhorstspruit tributary, upstream	S26.17799	E28.70221
WP02	Bronkhorstspruit tributary, downstream	S26.15510	E28.70260
LSW03	Bronkhorstspruit at Delmas Silica, downstream	S26.16279	E28.76881
LSW05	Bronkhorstspruit, downstream	S26.13750	E28.75700
LSW06	Weltevredenspruit, upstream	S26.14390	E28.79550
LSW07	Bronkhorstspruit, upstream	S26.18860	E28.77635
LSW08	Bronkhorstspruit, upstream of Block OI	S26.23022	E28.76264
LSW12	Downstream of River Diversion 2, Between RD2 and LSW05	S26.13610	E28.76410
LSW13	Water from Stuart Coal	S26.14380	E28.77560
RD1	Bronkhorstspruit at haul road	S26.14930	E28.76450
Process water samples (Waste water)			
KR01A	Kenbar Return Water Dam	S26.18087	E28.72995
KR03	Downstream of workshop oil separator sump	S26.18197	E28.73827
KR04	Marsh area next to workshop road	S26.18672	E28.73381
LSW09	Pollution Control Dam	S26.16601	E28.72541
ODN_PIT	OD Pit Water (closed pit)	S26.17122	E28.72381
OG_PIT	OG Pit Water (backfilled pit)	S26.17119	E28.73397
OH_PIT	OH Pit Water (backfilled pit)	S26.16698	E28.75338
OJ_PIT	OJ Pit Water	S26.16854	E28.74505
OM_PIT	OM Pit Water	S26.17278	E28.74875
OWM_PIT	OWM (Moabsvelden) Pit Water	S26.14440	E28.79241
WLV-PIT	Weltevreden Pit	S26.12888	E28.76050
WP04	New Witklip Return Water Dam	S26.17234	E28.70640

Sample ID	Description	Y Co-ordinates	X Co-ordinates
Final effluent samples (Waste water)			
LWP_SP_P	Final effluent from septic tanks at plant	S26.1716	E28.7302
LWP_SP_W	Final effluent at sewage plant behind workshop	S26.1812	E28.7396
Additional sampling points (not specified in the WUL)			
Kenbar rehab	Backfilled former Kenbar Pit	S26.1735	E28.7333
OJ-O	Field Barrels for experimental work		
OJ-S4-DISC			
OH-WEATH			
OL-OVB(2A+2B)			

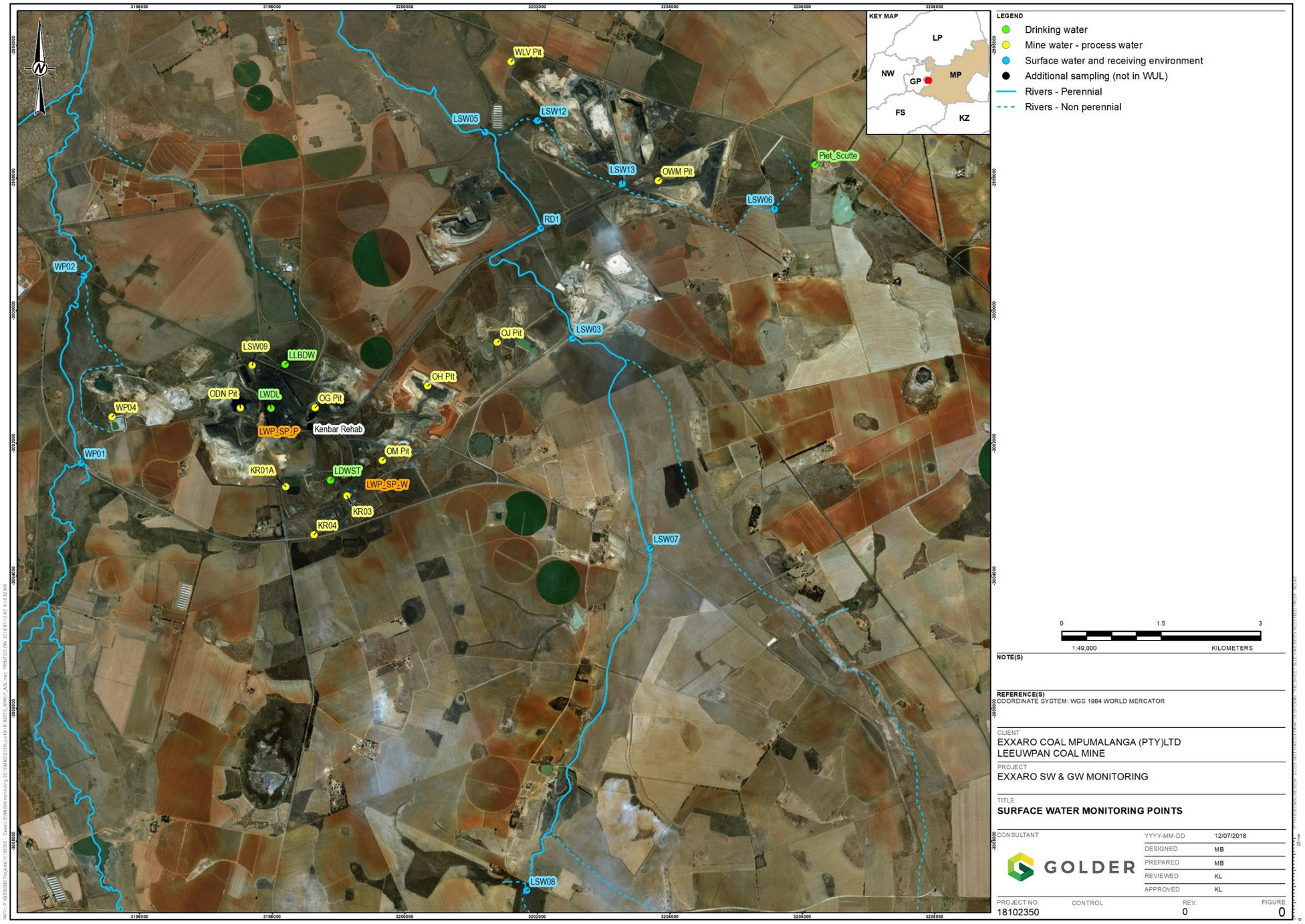


Figure 1: Surface water monitoring points at Leeuwpan

1.3 Water quality parameters and compliance values

The parameters and standards against which the water samples are compared to are set out in Table 2.

Table 2: Parameters and standards

Parameter	Units	Potable Water and Groundwater	Resource Protection	Waste water
		SANS 241-1: 2015	IWUL 04/B21A/ABCGIJ/429-2011	IWUL 04/B21A/ABCGIJ/429-2015 Amendment
pH	pH units	≥ 5 to ≤ 9.7[#]	≥ 6.5 to ≤ 8.4	≥ 5 to ≤ 10
Electrical Conductivity (EC)	mS/m	≤ 170*	≤ 35	≤ 750
Total Dissolved Solids (TDS)	mg/L	≤ 1 200*	≤ 280	≤ 3 800
Total Suspended Solids (TSS)	mg/L	-	-	-
Dissolved Oxygen Saturation (DO)	%	-	≥ 70	-
Total hardness as $CaCO_3$	mg/L	-	-	-
Turbidity	NTU	≤ 1[#] / ≤ 5*	-	-
Calcium (Ca)	mg/L	-	≤ 25	-
Magnesium (Mg)	mg/L	-	≤ 20	≤ 300
Sodium (Na)	mg/L	≤ 200*	≤ 20	≤ 500
Potassium (K)	mg/L	-	≤ 10	≤ 40
Total alkalinity as $CaCO_3$	mg/L	-	≤ 120	-
Chloride (Cl^-)	mg/L	≤ 300*	≤ 20	≤ 500
Sulphate (SO_4^{2-})	mg/L	≤ 500[ac] / ≤ 250*	≤ 30	≤ 3 200
Fluoride (F^-)	mg/L	≤ 1.5[ch]	≤ 0.5	≤ 5
Nitrate (NO_3^-) as N	mg/L	≤ 11[ac]	≤ 6	≤ 20**
Nitrite (NO_2^-) as N	mg/L	≤ 0.9[ac]	-	-
Ammonia (NH_3) as N	mg/L	≤ 1.5*	≤ 0.007	≤ 10
Orthophosphate as PO_4^{3-}	mg/L	-	≤ 0.05	≤ 10
Sodium Adsorption Ratio (SAR)	---	-	≤ 1	-
Oil and grease (SOG)	mg/L	-	≤ 5	≤ 1 000

Parameter	Units	Potable Water and Groundwater	Resource Protection	Waste water
		SANS 241-1: 2015	IWUL 04/B21A/ABCGIJ/429-2011	IWUL 04/B21A/ABCGIJ/429-2015 Amendment
Dissolved organic carbon (DOC)	mg/L	-	≤ 10	≤ 100
Chemical oxygen demand (COD)	mg/L	-	-	-
Hexavalent chromium (Cr^{6+})	mg/L	-	≤ 0.05	-
Total phosphorus (TP)	mg/L	-	≤ 0.25	≤ 20
Total inorganic nitrogen (TIN)	mg/L	-	≤ 2.5	≤ 15
Escherichia coli	CFU/100ml	0	≤ 50	≤ 10
Total coliforms	CFU/100ml	≤ 100	-	-
Chlorophyll-*a*	mg/L	-	≤ 0.02	≤ 0.15
Zinc as Zn	mg/L	≤ 5*	-	-
Antimony as Sb	mg/L	≤ 0.02[ch]	-	-
Arsenic as As	mg/L	≤ 0.01[ch]	-	-
Barium as Ba	mg/L	≤ 0.7[ch]	-	-
Boron as B	mg/L	≤ 2.4[ch]	≤ 0.5	-
Cadmium as Cd	mg/L	≤ 0.003[ch]	-	-
Total Chromium as Cr	mg/L	≤ 0.05[ch]	-	≤ 5
Copper as Cu	mg/L	≤ 2[ch]	-	-
Iron as Fe	mg/L	≤ 2[ch]/ ≤ 0.3*	≤ 0.5	≤ 20
Manganese as Mn	mg/L	≤ 0.4[ch]/ ≤ 0.1*	≤ 0.18	≤ 10
Mercury as Hg	mg/L	≤ 0.006[ch]	-	-
Nickel as Ni	mg/L	≤ 0.07[ch]	-	-
Selenium as Se	mg/L	≤ 0.04[ch]	-	-
Uranium as U	mg/L	≤ 0.03[ch]	-	-
Aluminium as Al	mg/L	≤ 0.3[#]	≤ 0.02	≤ 10

#operational; *aesthetic; [ac]acute health; [ch]chronic health standard; **Nitrate as NO_3^-

1.4 Sampling Methodology

Latex gloves were worn when collecting samples at each site. Field measurements were done for temperature, pH, EC and TDS. Three bottles were filled at each surface water sampling site:

i) A 50 ml bottle with 2 ml of 1% nitric acid for analysis of dissolved metals;

ii) A 50 ml bottle with 2 ml of 1% sulphuric acid for analysis of nitrogen species; and

iii) A 250 ml bottle for analysis of pH, TDS, EC, alkalinity and anions.

An additional sample was collected in a sterile glass bottle from potable water sources and surface water receiving environment for bacteriological analysis. A 2-litre plastic container was also filled at receiving environment monitoring sites for chlorophyll analysis. All the samples were kept in a cooler box with ice packs.

2.0 WATER QUALITY RESULTS

2.1 Field Observations

All targeted drinking water sites, nine of the targeted twelve process water sites, eight of the targeted ten receiving environment sites and all targeted final sewage effluent sites were sampled in April 2019. The physiochemical on-site measured parameters compared against the IWUL wastewater limits, surface and receiving environment IWUL limits and the SANS 241-1:2015 drinking water standards, for the respective water sources are presented in Table 3. All mine process water, sewage effluent and drinking water sites were compliant to the respective limits and standards.

Non-compliance of the IWUL receiving environment limits were as follows (Table 3):

- WP01: Electrical conductivity and dissolved oxygen,
- WP02: Electrical conductivity and dissolved oxygen,
- LSW05: Electrical conductivity and dissolved oxygen,
- LSW07: Dissolved oxygen,
- LSW08: Dissolved oxygen,
- LSW13: Electrical conductivity; and
- RD1: Electrical conductivity and dissolved oxygen.

The twenty-three sampled surface water sites had pH values ranging from circum-neutral to alkaline ($6.78 \leq pH \geq 8.41$, Table 3. Samples were analysed at Jones laboratory except for those indicated otherwise, which were analysed at UIS laboratory. Chlorophyll *a*, bacteriological samples and triplicate pairs were analysed at UIS laboratory. All bacteriological and chlorophyll *a* samples were taken on the last day of the sampling round (03/04/2019) due to the required sample holding period.

Table 4 presents the surface water sites that were not sampled in April 2019 for various reasons including dry sites, backfilled pits and no leachates being present in the field barrels.

Table 3: April 2019 Surface water field measurements

Site name	Laboratory ID	Date sampled	Temp (ºC)	pH	EC (mS/m)	TDS (mg/l)	DO (%)	Comments
				≥ 5 to ≤ 10*	≤ 750*	≤ 3 800*	-	
				≥ 6.5 to ≤ 8.4**	≤ 35**	≤ 280**	≥ 70**	
				≥ 5 to ≤ 9.7***	≤ 170***	≤ 1 200***	-	
Mine Dam/ pit water samples								
KR01A	LNP19_M04_023 LNP19_M04_024 LNP19_M04_025 (UIS)	3/4/2019	18.9	7.73	276	1980	60.3	Circum-neutral. Triplicate samples
KR03	LNP19_M04_020	3/4/2019	20.5	7.68	120	860	14.6	Circum-neutral
KR04	LNP19_M04_019	3/4/2019	19.6	8.2	72	520	77.3	Alkaline
WP04	LNP19_M04_029	3/4/2019	23.2	8.31	297	2 140	58.5	Alkaline
OWM_Pit	LNP19_M04_009	2/4/2019	21.4	7.61	202	1 470	68.4	Circum-neutral
OM_Pit	LNP19_M04_027	3/4/2019	23.1	8.07	196	1 410	53.4	Alkaline
ODN_Pit	LNP19_M04_028	3/4/2019	23.8	7.91	266	1 910	69.3	Alkaline
WLV_Pit	LNP19_M04_008	2/4/2019	21.2	7.79	72	520	74.6	Circum-neutral
LSW09	LNP19_M04_030	3/4/2019	24.1	8.41	222	1 550	72.6	Alkaline
OJ_Pit	LNP19_M04_026	3/4/2019	21.6	8.27	118	850	53	Alkaline

Site name	Laboratory ID	Date sampled	Temp (°C)	pH	EC (mS/m)	TDS (mg/l)	DO (%)	Comments
				≥ 5 to ≤ 10*	≤ 750*	≤ 3 800*	-	
				≥ 6.5 to ≤ 8.4**	≤ 35**	≤ 280**	≥ 70**	
				≥ 5 to ≤ 9.7***	≤ 170***	≤ 1 200***	-	
Final sewage effluent								
LWP-SP-P	LNP19_M04_033 LNP19_M04_034 (UIS)	3/4/2019	24	7.76	111	800	6	Circum-neutral
LWP-SP-W	LNP19_M04_021 LNP19_M04_022 (UIS)	3/4/2019	20.9	8.14	129	930	35.4	Alkaline
Surface water and receiving environment								
WP01	LNP19_M04_017 LNP19_M04_018 (UIS)	3/4/2019	16.6	8.03	39	280	44.4	Alkaline
WP02	LNP19_M04_015 LNP19_M04_016 (UIS)	3/4/2019	17.2	7.91	46	330	52.3	Alkaline
LSW03	LNP19_M04_010 LNP19_M04_011 LNP19_M04_012 (UIS)	2/4/2019	20	7.81	32	240	76.9	Circum-neutral
LSW05	LNP19_M04_041 LNP19_M04_042 (UIS)	3/4/2019	19.9	7.67	44	320	39.7	Circum-neutral
LSW07	LNP19_M04_035 LNP19_M04_036 (UIS)	3/4/2019	24.2	8.39	29	210	61.7	Alkaline

Site name	Laboratory ID	Date sampled	Temp (°C)	pH	EC (mS/m)	TDS (mg/l)	DO (%)	Comments
				≥ 5 to ≤ 10*	≤ 750*	≤ 3 800*	-	
				≥ 6.5 to ≤ 8.4**	≤ 35**	≤ 280**	≥ 70**	
				≥ 5 to ≤ 9.7***	≤ 170***	≤ 1 200***	-	
LSW08	LNP19_M04_037 LNP19_M04_038 (UIS)	3/4/2019	20.2	8.12	28	200	64.4	Alkaline
LSW13	LNP19_M04_006 LNP19_M04_007 (UIS)	2/4/2019	20.7	7.53	36	260	89.3	Circum-neutral
RD1	LNP19_M04_004 LNP19_M04_005 (UIS)	2/4/2019	22.8	7.01	47	330	69.7	Circum-neutral
Drinking water								
LDWST	LNP19_M04_001 LNP19_M04_002 LNP19_M04_003 (UIS)	2/1/2019	19.2	6.78	56	410	81.4	Circum-neutral
LLBDW	LNP19_M04_013 LNP19_M04_014 (UIS)	3/4/2019	17.1	7.61	53	380	26.3	Circum-neutral
Piet Schutte	LNP19_M04_039 LNP19_M04_040 (UIS)	3/4/2019	21.7	7.82	12	90	43.4	Circum-neutral
LWDL	LNP19_M04_031 LNP19_M04_032 (UIS)	3/4/2019	28.7	8.27	56	410	57.7	Alkaline

Notes

Highlighted cells exceed water quality standard or IWUL limit

*Wastewater IWUL limit **Surface and receiving environment IWUL limit ***Drinking water quality standard

Table 4: List of surface water sites not sampled in April 2019

Site Name	Date of site visit	Comments
Surface water and receiving environment		
LSW06	03/04/2019	Dry due to mining activities progressing to the site, monitoring point should be removed from monitoring programme as there is no longer a stream upstream of the current pit.
LSW12	03/04/2019	Dry.
Mine Dam/ pit water		
OG Pit	03/04/2019	Backfilled pit, no water accumulation.
OH Pit	03/04/2019	Partially backfilled and final void not accessible – surface water monitoring point should be removed from the monitoring programme and a borehole drilled into the pit when completely rehabilitated to monitor pit water levels and quality.
Additional sampling points		
Kenbar Rehab	02/04/2019	No water accumulation. A borehole should be drilled in the pit when completely backfilled to monitor pit water levels and quality
OJ-O	03/04/2019	No leachate; taps on field barrels are broken.
OJ-S4-DISC	03/04/2019	
OH-WEATH	03/04/2019	
OL-OVB(2A+2B)	03/04/2019	

2.2 Potable water samples

Table 5 presents laboratory results of potable water sites that were sampled in April 2019, screened against the SANS 241-1:2015 drinking water standards. The levels of measured constituents from all drinking water sites were within the drinking water standards; and all sites had alkaline pH values ranging from 7.6 to pH 8.2.

A plot of major cations and anions classified the waters as calcium magnesium bicarbonate (Figure 2), typical of shallow, freshly recharged groundwater or water from a dolomitic aquifer.

Levels of most constituents were stable from March to April 2019 apart from:

- Load-out Bay Offices Drinking Water (LLBDW): a decline in manganese concentration from 0.291 mg/L in March 2019 to 0.014 mg/L in April 2019; and an increase in zinc concentration (from 0.053 mg/L in March 2019 to 0.127 mg/L in April 2019) and ammoniacal nitrogen concentration (0.05 mg/L in March 2019 to 0.14 mg/L in April 2019);
- Drinking Water Supply Tank (LDWST): increasing trends were observed in levels of ammoniacal nitrogen (from 0.017 mg/L in March 2019 to 0.16 mg/L in April 2019) and electrical conductivity (from 40 mS/m in March 2019 to 58 mS/m in April 2019);

- Drinking Water on Piet Schutte's Farm (Piet Schutte): increases were recorded in levels nitrate (from 0.6 mg/L to 1.3 mg/L in April 2019), copper (from 0.007 mg/L to 0.015 mg/L in April 2019 and manganese (from 0.004 mg/L to 0.019 mg/L in April 2019) and declines in potassium (from 0.5 mg/L to 0.3 mg/L in April 2019), total dissolved solids (from 79 mg/L to 71 mg/L in April 2019), and *E.coli* (from 2 colonies/100ml to 0 colonies/100ml, which lead from non-compliance in April 2019 to a compliance in April 2019 (Figure 3).
- (LWDL): increasing trends were observed in levels of ammoniacal nitrogen (from 0.04 mg/L in March 2019 to 0.49 mg/L in April 2019), manganese (from 0.002 mg/L to 0.056 mg/L in April 2019), and declines in zinc (from 0.394 mg/L to 0.006 mg/L in April 2019);

  Water from LWDL and Drinking Water Supply Tank (LDWST) should not be used for drinking; as an exceedance in *E. coli* was observed in April 2019 (Figure 3).

Table 5: April 2019 potable water samples results

Parameter	Units	SANS 241: 2015 Drinking water Standard	LWDL	LLBDW	LDWST*	Piet Schutte
			LNP19_M04_031	LNP19_M04_013	LNP19_M04_039	LNP19_M04_001 LNP19_M04_002 LNP19_M04_003
pH	pH units	≥ 5 to ≤ 9.7	7.9	8.1	8	7.2
Total Dissolved Solids (TDS)	mg/L	≤ 1 200	359	291	380	71
Electrical Conductivity (EC)	mS/m	≤ 170	60	56	58	12
Nitrate (NO_3^-) as N	mg/L	≤ 11	1.7	0.1	1.8	1.3
Nitrite (NO_2^-) as N	mg/L	≤ 0.9	<0.05	<0.05	<0.05	<0.05
Sulphate (SO_4^{2-})	mg/L	≤ 500	81	46	77	1
Fluoride (F^-)	mg/L	≤ 1.5	<0.3	<0.3	0.3	<0.3
Ammonia (NH_3) as N	mg/L	≤ 1.5	0.49	0.14	0.14	0.04
Chloride (Cl^-)	mg/L	≤ 300	35	34	34	2
Dissolved Sodium (Na)	mg/L	≤ 200	33	32	32	4
Dissolved Aluminium (Al)	mg/L	≤ 0.3	<0.02	<0.02	0.005	<0.02
Dissolved Antimony (Sb)	mg/L	≤ 0.02	<0.002	<0.002	<0.002	<0.002
Dissolved Arsenic (As)	mg/L	≤ 0.01	<0.0025	<0.0025	0.0094	<0.0025
Dissolved Barium (Ba)	mg/L	≤ 0.7	0.06	0.16	0.08	0.04
Dissolved Boron (B)	mg/L	≤ 2.4	0.14	0.07	0.07	0.02

Parameter	Units	SANS 241: 2015 Drinking water Standard	LWDL	LLBDW	LDWST*	Piet Schutte
			LNP19_M04_031	LNP19_M04_013	LNP19_M04_039	LNP19_M04_001 LNP19_M04_002 LNP19_M04_003
Dissolved Cadmium (Cd)	mg/L	≤ 0.003	<0.0005	<0.0005	<0.0005	<0.0005
Dissolved Calcium (Ca)	mg/L	-	48	40	47	9
Dissolved Copper (Cu)	mg/L	≤ 2	<0.007	<0.007	0.0075	0.015
Dissolved Lead (Pb)	mg/L	≤ 0.01	<0.005	<0.005	<0.005	<0.005
Dissolved Magnesium (Mg)	mg/L	-	25	27	25	6
Dissolved Manganese (Mn)	mg/L	≤ 0.4	0.06	0.01	0.02	0.02
Dissolved Mercury (Hg)	mg/L	≤ 0.006	<0.001	<0.001	<0.001	<0.001
Dissolved Nickel (Ni)	mg/L	≤ 0.07	0.003	<0.002	0.007	<0.002
Dissolved Potassium (K)	mg/L	-	2.8	1.6	3.2	0.3
Dissolved Selenium (Se)	mg/L	≤ 0.04	0.005	<0.003	0.001	<0.003
Dissolved Uranium (U)	mg/L	≤ 0.03	<0.005	<0.005	0.003	<0.005
Dissolved Zinc (Zn)	mg/L	≤ 5	0.01	0.13	0.06	0.02
Orthophosphate as PO_4^{3-}	mg/L	-	<0.03	<0.03	0.014	0.07
Total Alkalinity as $CaCO_3$	mg/L	-	152	181	152	45
Total Dissolved Chromium (Cr)	mg/L	≤ 0.05	<0.0015	<0.0015	<0.0015	<0.0015
Total Dissolved Iron (Fe)	mg/L	≤ 2	<0.02	0.031	0.05	<0.02
Total Hardness (as $CaCO_3$)	mg/L	-	224	215	222	48
Escherichia coli	Colonies/100 ml	0	5	0	2	0

Notes*Average of triplicate samples LNP19_M04_001, LNP19_M04_002 and LNP19_M04_003 collected for QAQC assessment.

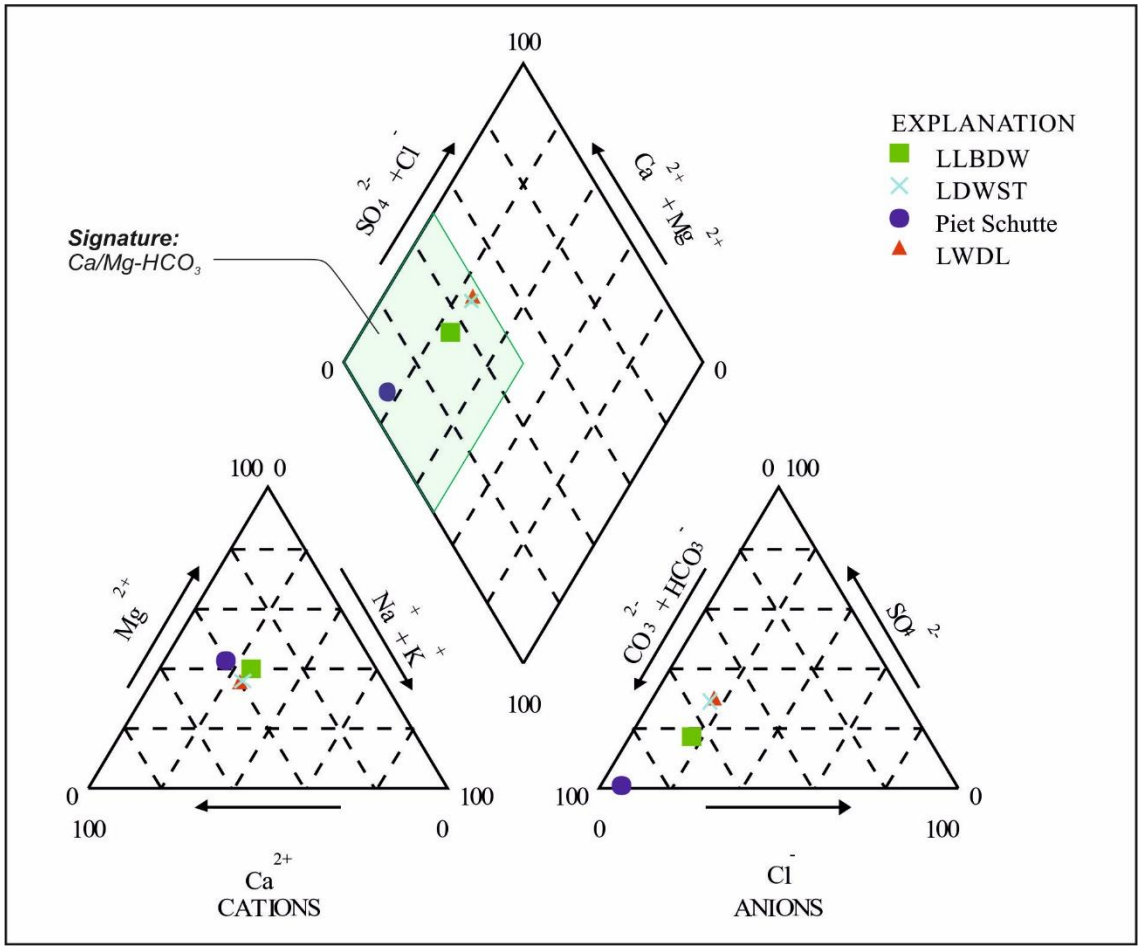


Figure 2: April 2019 drinking water piper diagram

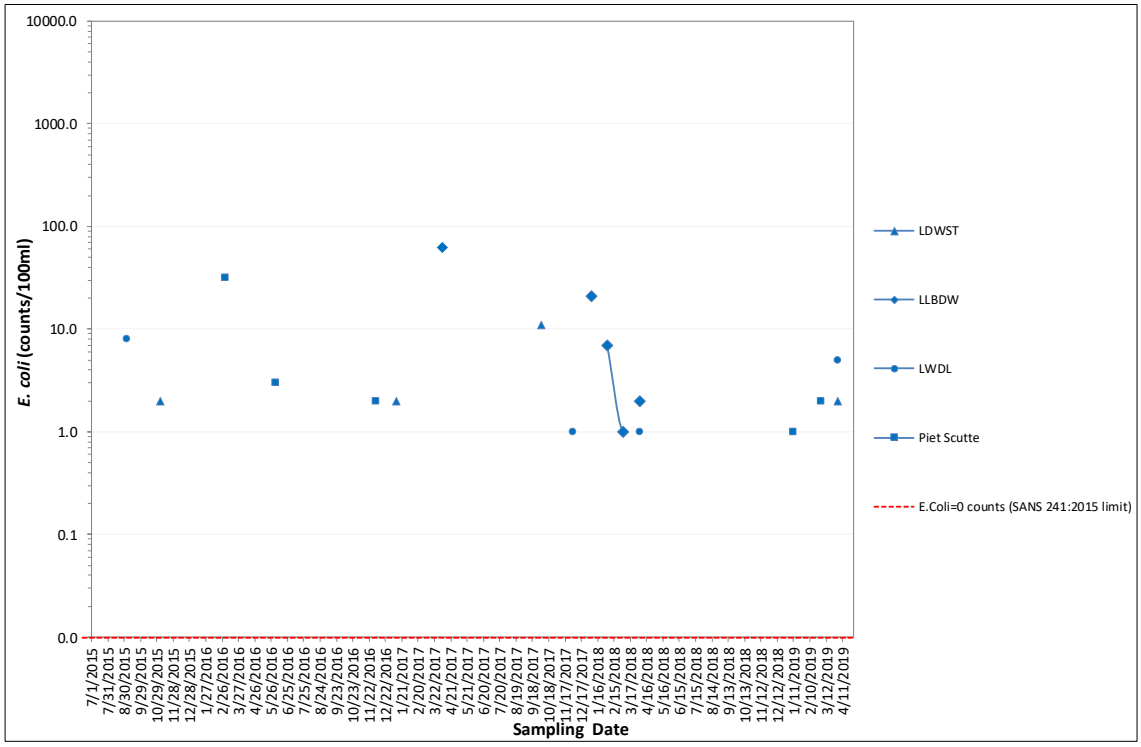


Figure 3: April 2019 *E. coli* counts/ 100ml in drinking water

2.3 Surface water samples

Laboratory results of receiving environment sites sampled in April 2019 are presented in Table 6. The results were compared to the IWUL resource protection (Table 6) and it was observed that four or more constituents across all sampled sites were present in levels exceeding the IWUL limits; exceedances are summarised in Figure 4.

The following changes were observed downstream compared to the upstream sites in April 2019:

- WP02: levels of turbidity, ammonia, potassium, total hardness, alkalinity, chlorophyll a and dissolved organic carbon increased downstream of the Bronkhorstspruit tributary (WP02) compared to upstream at WP01. total dissolved iron, *E. coli* and dissolved oxygen (negative increase decreased) downstream compared to upstream.
- LSW05: Total dissolved solids, electrical conductivity, magnesium, dissolved oxygen, *E. coli* and total hardness increased downstream (LSW05) in the Bronkhorstspruit compared to upstream (LSW08). Huge decreases were recorded in total dissolved iron downstream of the Bronkhorstspruit.

  The increased levels of electrical conductivity and magnesium at the downstream sites could be attributed to mining activities.

Trend graphs are presented in APPENDIX A. Fluctuations were observed in the levels of most constituents; with the following observations made in the trends of receiving environment water samples in March 2019 relative to April 2019:

- Bronkhorstspruit tributary, upstream (WP01): Declining trends were observed in levels of ortho phosphate, total dissolved iron, total phosphorus, *E. coli* and chlorophyll *a*, and increases in nitrate, magnesium, manganese and boron.
- Bronkhorstspruit tributary, downstream (WP02): Increments from March 2019 to April 2019 were noted in levels of turbidity, ammonia, dissolved organic carbon and chlorophyll a; and decreases in *E. coli*, dissolved oxygen and total dissolved iron.
- Bronkhorstspruit at Delmas Silica, downstream (LSW03): turbidity, aluminium, total phosphorous, ammonia, dissolved organic carbon, boron, aluminium, manganese and potassium decreased; whilst total dissolved solids, electrical conductivity, sulphate, chloride, calcium, magnesium, alkalinity, total hardness dissolved, chlorophyll *a and E. coli* increased from March to April 2019.
- Bronkhorstspruit upstream (LSW07): Levels of most constituents were dominated by increasing trends; whereas total dissolved iron, total phosphorus and chlorophyll *a* decreased.
- Water from Stuart Coal (LSW13): Fluctuations were observed in most constituents, with decreasing trends dominating the changes. Turbidity, chloride and potassium increased from March to April 2019.

Table 6: April 2019 surface water samples results

Parameters	Units	IWUL Limit	WP01	WP02	LSW03*	LSW05	LSW06	LSW07	LSW08	LSW12	LSW13	RD1
			LNP19_M04_017	LNP19_M04_015	LNP19_M04_010 /LNP19_M04_011 LNP19_M04_012	LNP19_M04_041	No Sample	LNP19_M04_035	LNP19_M04_037	No Sample	LNP19_M04_006	LNP19_M04_004
pH	pH units	≥ 6.5 to ≤ 8.4	7.6	7.9	7.5	7.9	Dry due to mining activities progressing to the site.	7.8	7.8	Dry	7.6	7.8
Total Dissolved Solids (TDS)	mg/L	≤ 280	258	290	230	278		200	174		199	270
Turbidity	NTU	-	299	24	15	97		311	126		27	92
Electrical Conductivity at (EC)	mS/m	≤ 35	41	49	41	47		30	28		38	52
Nitrate (NO_3^-) as N	mg/L	≤ 6	1.67	<0.05	<0.05	<0.05		<0.05	<0.05		0.05	0.13
Sulphate (SO_4^{2-})	mg/L	≤ 30	23	7	28	24		11	3		41	29
Fluoride (F^-)	mg/L	≤ 0.5	0.4	<0.3	<0.3	<0.3		0.7	0.5		<0.3	<0.3
Ammonia (NH_3) as N	mg/L	≤ 0.007	1.2	0.09	0.43	0.09		0.54	0.6		0.1	0.15
Chloride (Cl^-)	mg/L	≤ 20	13	8	9	19		7	1		16	18
Dissolved Sodium (Na)	mg/L	≤ 20	14	17	12	14		19	6		9	14
Dissolved Aluminium (Al)	mg/L	≤ 0.02	<0.02	<0.02	0.015	<0.02		<0.02	<0.02		<0.02	<0.02
Dissolved Boron (B)	mg/L	≤ 0.5	0.03	0.02	0.02	0.02		0.03	0.02		0.02	0.03
Dissolved Calcium (Ca)	mg/L	≤ 25	35	44	32	40		21	29		33	42
Dissolved Magnesium (Mg)	mg/L	≤ 20	18	26	14	26		12	12		20	27
Dissolved Manganese (Mn)	mg/L	≤ 0.18	0.63	0.23	0.12	0.09		0.16	2.52		0.59	0.72
Dissolved Potassium (K)	mg/L	≤ 10	12	5	8	3		10	7		2	3
Orthophosphate as PO_4^{3-}	mg/L	-	0.05	<0.03	0.06	<0.03		<0.03	<0.03		<0.03	<0.03
Total Alkalinity as $CaCO_3$	mg/L	≤ 120	156	234	121	185		127	131		115	194
Total Dissolved Iron (Fe)	mg/L	≤ 0.5	<0.02	<0.02	0.22	<0.02		0.03	0.07		0.03	0.07
Total Hardness (as $CaCO_3$)	mg/L	-	161	221	138	211		100	121		165	217
Escherichia coli	CFU/100ml	≤ 50	6200	180	170	260		440	43		270	8
Total Phosphorus (TP)	mg/L	≤ 0.25	0.15	0.07	0.14	0.05		0.19	0.2		0.03	0.08

Parameters	Units	IWUL Limit	WP01	WP02	LSW03*	LSW05	LSW06	LSW07	LSW08	LSW12	LSW13	RD1
			LNP19_M04_017	LNP19_M04_015	LNP19_M04_010 /LNP19_M04_011 LNP19_M04_012	LNP19_M04_041	No Sample	LNP19_M04_035	LNP19_M04_037	No Sample	LNP19_M04_006	LNP19_M04_004
Sodium Adsorption Ratio (SAR)	meq/L$^{0.5}$	≤ 1	0.5	0.5	0.4	0.4		0.8	0.2		0.3	0.4
Hexavalent Chromium (CrVI)	mg/L	≤ 0.05	<0.006	<0.006	<0.006	<0.006		<0.006	<0.006		<0.006	<0.006
Dissolved Oxygen (DO)	% Saturation	≥ 70	42	25	11	72		42	41		76	51
Dissolved Organic Carbon (DOC)	mg/L	≤ 10	10	5	15	6		20	7		2	5
Chlorophyll a	mg/L	≤ 0.02	1	11	65	4		5	73		4	7
Oil and grease	mg/L	5	0.01	0.01	<0.01	0.01		0.01	0.01		0.01	0.01

Notes

Highlight - exceeds IWUL limits for resource protection (receiving water environment); *Average of three samples LNP19_M04_010, LNP19_M04_011 and LNP19_M04_012 collected for QAQC (duplicates and triplicates).

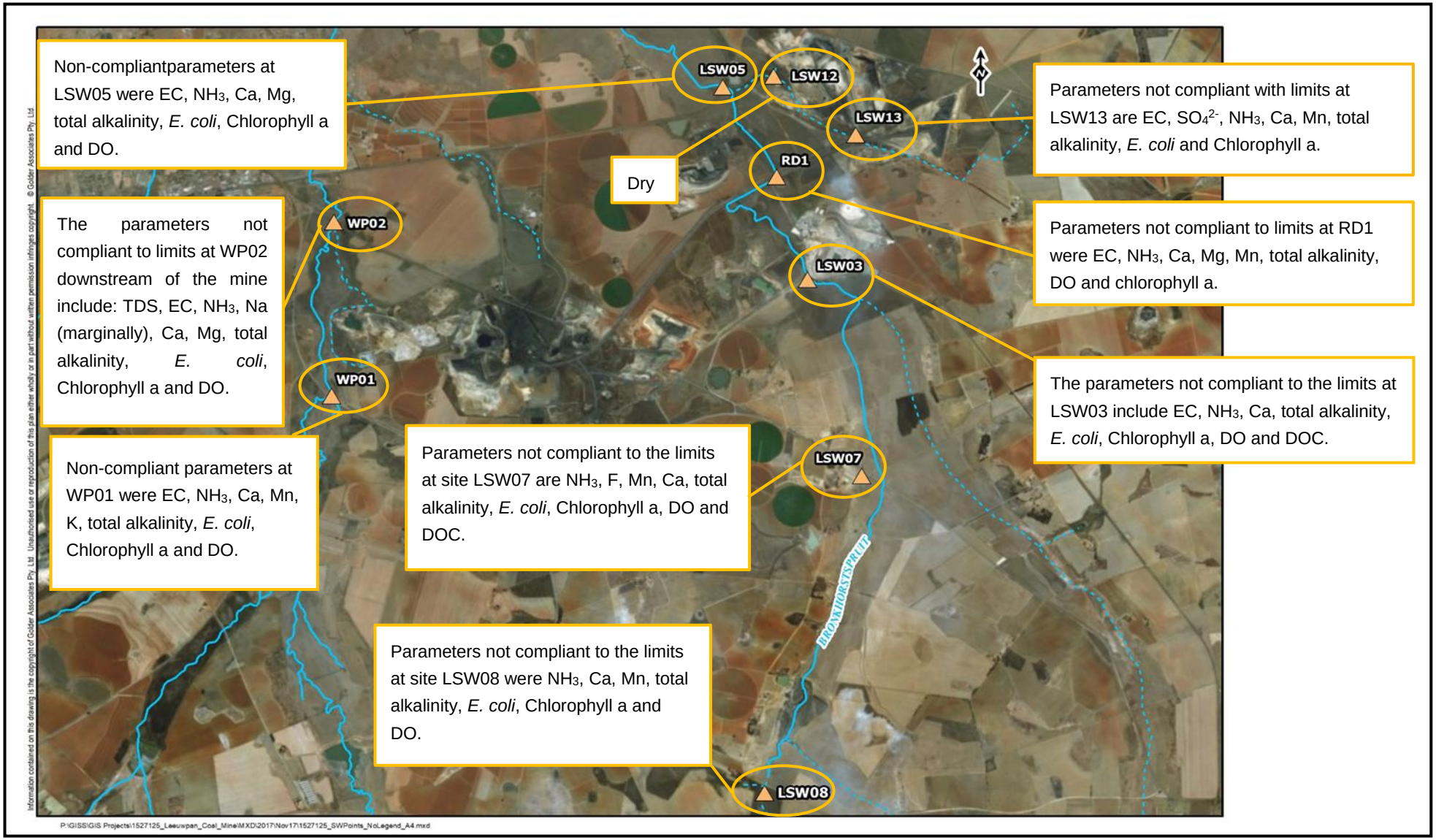


Figure 4: Summary of surface water sample results exceeding IWUL limit in April 2019

- Bronkhorstspruit, upstream of Block OI (LSW08): levels of turbidity, manganese, ammonia, chlorophyll a and total phosphorus increased; and total dissolved solids, electrical conductivity, chloride, sodium, boron, total alkalinity, magnesium, *E. coli* and Dissolved Organic Carbon decreased from March to April 2019;
- Bronkhorstspruit downstream (LSW05): Majority of the constituents increased from March to April 2019. Total dissolved iron and boron decreased in April 2019.
- Bronkhorstspruit at haul road (RD1): most of the measured constituents increased except for total dissolved iron, *E. coli* and Dissolved Organic Carbon, which decreased in April 2019.

2.4 Process water samples

April 2019 laboratory results of the sampled mine process water were screened against the IWUL wastewater limits and are presented in Table 7. Screening indicates levels of fats, oils and greases measured in waters sampled from the Downstream of workshop oil separator sump (KR03) not adhering the limits; furthermore, all other parameters from all sampled sites were compliant to the waste water limits.

Laboratory measured sulphate and pH values were used to classify process water samples. The samples had pH values that ranged from acidic to alkaline (7.3≤ pH ≥ 7.9). The classification of waters sampled from WLV pit, and KR04 remained unchanged from March 2019 to April 2019 and were classified as neutral mine drainage. LSW09, OM pit, KR01A, ODN pit and WP04 remained in the saline mine drainage field from March 2019 to April 2019. However, OWM pit changed from neutral mine drainage in March to saline mine drainage April 2019 (Figure 5).

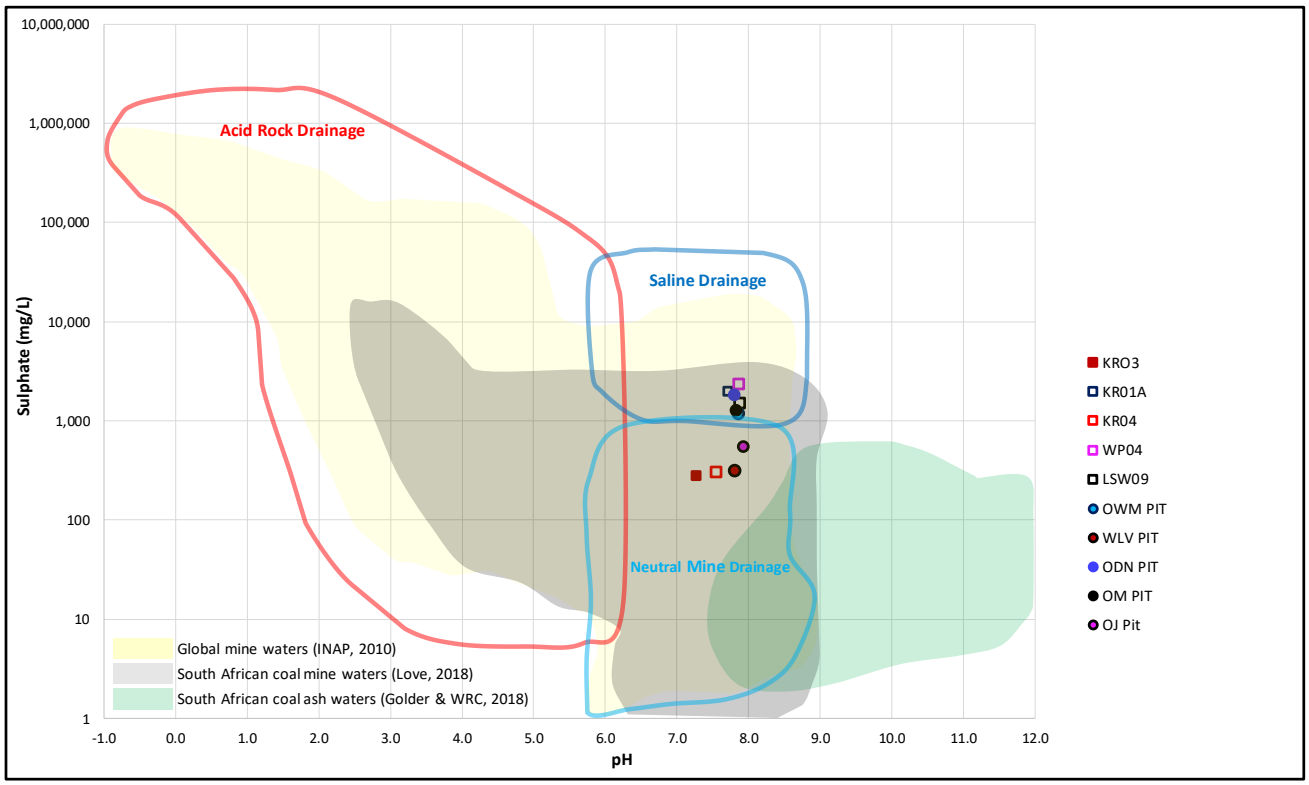


Figure 5: April 2019 classification of process water at Leeuwpan based on sulphate concentration and pH (modified after INAP, 2010)

Table 7: April 2019 Process water samples results

Parameters	Units	Standard IWUL 04/B21A/ABCGIJ/429- 2015 Amendment	KR03	KR01A*	KR04	OWM pit	WLV Pit	WP04	LSW09	ODN Pit	OH Pit	OG Pit Rehab Area	OM Pit	OJ Pit	Kenbar Rehabbed Area
			LNP19_M04_020	LNP19_M04_023/LNP19_M04_024/LNP19_M04_025	LNP19_M04_019	LNP19_M04_009	LNP19_M04_008	LNP19_M04_029	LNP19_M04_030	LNP19_M04_028	No sample	No sample	LNP19_M04_027	LNP19_M04_026	No sample
pH	pH units	≥ 5 to ≤ 10	7.3	7.7	7.6	7.9	7.8	7.9	7.9	7.8	Partially backfilled and final void not accessible	Backfilled pit, no water accumulation	7.8	7.9	No water accumulation.
Total Dissolved Solids (TDS)	mg/L	≤ 3800	1 035	3 397	546	2 165	579	3 798	2 582	3 193			2 112	1 076	
Turbidity	NTU	-	624	32	346	141	122	10	4	233			21	14	
Electrical Conductivity (EC)	mS/m	≤ 750	140	361	79	232	80	354	258	313			227	133	
Nitrate (NO_3^-)	mg/L	≤ 20	<0.05	0.06	<0.05	0.14	0.6	<0.05	10.11	0.12			5.75	0.77	
Sulphate (SO_4^{2-})	mg/L	≤ 3200	277	1 953	300	1 162	306	2 325	1 507	1 819			1 261	538	
Fluoride (F^-)	mg/L	≤ 5	<0.3	<0.3	0.4	<0.3	<0.3	0.5	0.4	<0.3			<0.3	<0.3	
Ammonia (NH_3)	mg/L	≤ 10	0.53	0.07	<0.03	1.04	0.08	0.05	0.5	0.19			0.1	<0.03	
Chloride (Cl^-)	mg/L	≤ 500	80	12	11	3	7	25	12	11			7	9	
Dissolved Sodium (Na)	mg/L	≤ 500	107	49	33	37	9	88	47	43			33	25	
Sodium Absorption Ratio (SAR)	$meq/L^{0.5}$	-	2.1	0.4	0.8	0.4	0.2	0.8	0.5	0.4			0.4	0.4	
Dissolved Aluminium (Al)	mg/L	≤ 10	0.026	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02			<0.02	<0.02	
Dissolved Boron (B)	mg/L	-	0.28	0.08	0.05	0.16	0.05	0.1	0.13	0.07			0.1	0.07	
Dissolved Calcium (Ca)	mg/L	-	120	553	68	333	111	564	398	551			342	179	
Dissolved Magnesium (Mg)	mg/L	≤ 300	42	223	39	154	32	234	151	200			135	66	
Dissolved Manganese (Mn)	mg/L	≤ 10	0.67	0.32	0.16	0.35	0.02	0.15	0.06	0.95			0.26	0.19	
Dissolved Potassium (K)	mg/L	≤ 40	27.7	3.7	1.7	1	0.4	0.6	1.2	<0.1			1.9	1.5	
Orthophosphate as PO_4^{3-}	mg/L	≤ 10	3.94	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03			<0.03	<0.03	
Total Alkalinity as $CaCO_3$	mg/L	-	302	170	56	255	63	58	73	196			94	141	

Parameters	Units	Standard IWUL 04/B21A/ABCGIJ/429- 2015 Amendment	KR03	KR01A*	KR04	OWM pit	WLV Pit	WP04	LSW09	ODN Pit	OH Pit	OG Pit Rehab Area	OM Pit	OJ Pit	Kenbar Rehabbed Area
			LNP19_M04_020	LNP19_M04_023/LNP19_M04_024/LNP19_M04_025	LNP19_M04_019	LNP19_M04_009	LNP19_M04_008	LNP19_M04_029	LNP19_M04_030	LNP19_M04_028	No sample	No sample	LNP19_M04_027	LNP19_M04_026	No sample
Total Dissolved Iron (Fe)	mg/L	≤ 20	0.48	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02			<0.02	<0.02	
Total Hardness (as $CaCO_3$)	mg/L	-	477	2313	333	1480	414	2393	1630	2215			1422	722	
Total Phosphorus (TP)	mg/L	≤ 20	4.69	0.04	0.04	0.03	0.03	0.03	0.03	0.04			0.03	0.04	
Fats, Oils and Greases	mg/L	≤ 1000	145 449	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	<0.01	
Hexavalent Chromium	mg/L	-	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006			<0.006	<0.006	
Dissolved Oxygen (DO)	%	-	12	46	75	85	93	93	97	84			91	92	
Dissolved Organic Carbon (DOC)	mg/L	≤ 100	78	<2	5	<2	<2	15	<2	<2			<2	<2	

Notes: Highlight - exceeds IWUL limits for waste water; *Average of two samples LNP19_M04_023, LNP19_M04_024 and LNP19_M04_025 collected for QAQC (duplicates and triplicates).

Trend graphs of major constituents are provided in APPENDIX A. The following trends in chemistry of process water were observed in April 2019:

- Downstream of workshop oil separator sump (KR03): Most of the measured constituents remained below the exceeds IWUL limits except for fats, oils and grease which exceeded the limit by an order of 145 for April 2019); this is an indication that the oil separator is not working and needs to be fixed;
- Kenbar Return Water Dam (KR01A): Most measured constituents were relatively stable. Huge decreases were recorded in nitrate (from 0.715 mg/L to 0.05 mg/L in April 2019), dissolved oxygen (from 59.7 % to 46.4 % in April 2019); and ammonia (0.04 mg/L to 0.53 mg/L), Manganese (0.16 mg/L to 0.67 mg/L) and total alkalinity (109 mg/L to 169.7 mg/L) increased from March to April 2019;
- Marsh area next to workshop road (KR04): increasing trends were observed in the levels of most constituents; whilst small decreases were observed in Potassium (from 1.8 mg/L to 1.7mg/L in April 2019), Calcium (from 73.7 mg/L to 67.5 mg/L in April 2019) and total phosphorus (from 0.039 mg/L in March 2019 to 0.036 mg/L in April 2019);
- OWM (Moabsvelden) Pit Water: levels of most constituents increased, while remaining within the IWUL limits. Declining trends were observed in levels of chloride (from 4.4mg/L to 2.9mg/L in April 2019)
- Weltevreden Pit (WLV): Most constituents were stable. Increases were observed in turbidity (from 9.6 NTU to 122 NTU in April 2019), ammonia (from 0.05 mg/L to 0.08 mg/L in April 2019), and manganese (from 0.011mg/L to 0.019 mg/L in April 2019). A decrease from 0.9 mg/L in March 2019 to 0.6 mg/L in April 2019 was observed in nitrate;
- New Witklip Return Water Dam (WP04): Stability was observed in the levels of most from March 2019 to April 2019, apart from increases recorded in levels of turbidity (from 6.1 NTU to 9.8 NTU in April 2019) and potassium (from 0.1 mg/L to 0.6 mg/L in April 2019); A decrease from 0.09 mg/L in March 2019 to 0.05 mg/L in April 2019 was observed in ammonia;
- Pollution Control Dam (LSW09): A decrease was observed in ammonia (from 0.74 mg/L to 0.50 mg/L in April 2019). Increases were recorded in manganese (from 0.009m /L to 0.056 mg/L in April 2019) turbidity (from 2.9 NTU to 3.5 NTU in April 2019), nitrate (from 8.23 mg/L to 10.11 mg/L in April 2019, chloride (from 9.8mg/L to 12 mg/L in April 2019), potassium (from 0.7mg/L 1.2 mg/L in April 2019) and dissolved oxygen (from 58.8% to 96.6% in April 2019);
- ODN Pit Water (ODN Pit): Stability was observed in the levels of most from March 2019 to April 2019, apart from increases recorded in levels of turbidity (from 4.8 NTU to 233 NTU in April 2019), ammonia (from 0.15 mg/L to 0.19 mg/L in April 2019) and total phosphorus (from 0.028 mg/L to 0.041 mg/L in April 2019); A decrease from 0.17 mg/L in March 2019 to 0.12 mg/L in April 2019 was observed in nitrate;
- OM Pit Water (OM Pit): Most constituents were stable. Increases were observed in total dissolved solids (from 1533 mg/L to 2112 mg/L in April 2019), turbidity (from 11.9 NTU to 20.8 NTU in April 2019) and manganese (from 0.062 mg/L to 0.26 mg/L in April 2019). A decrease from 0.59 mg/L in March 2019 to 0.1 mg/L in April 2019 was observed in ammonia; and
- OJ Pit Water (OJ Pit): Stability was observed in levels of most constituents apart from decreases recorded in nitrate (from 9.86 mg/L to 0.77 mg/L in April 2019), boron (from 0.084 mg/L to 0.066 mg/L in April 2019) and magnesium (from 88.8 mg/L to 66 mg/L in April 2019); and increases in chloride (from 5.8 mg/L to 8.8 mg/L in April 2019), manganese (from 0.07 mg/L to 0.191mg/L) and total phosphorous (from 0.026 mg/L 2019 to 0.035 mg/L in April 2019).

2.5 Final effluent from sewage works

Laboratory results of the sampled final effluent sites are presented in Table 8 and compared against the amended IWUL waste water limits. Levels of ammonia and *E. coli* measured at both sewage effluent sites were not compliant to the IWUL waste water limits in April 2019.

The following observations were made in April 2019 relative to March 2019:

- Final effluent from the sewage plant behind workshop (LWP-SP-W): increases were observed in total suspended solids (increased from 15 mg/L to 43 mg/L), chemical oxygen demand (COD, settled) (increased from 63 mg/L to 365 mg/L), *E. coli counts* (from 0 colonies/100ml to 540 colonies/100ml); nitrate (increased from 2.97 mg/L to 9.09 mg/L. Increased in *E. coli counts* and led to non-compliance of the IWUL limit in April as opposed to the exceedance observed in March 2019). A decreasing trend was observed from March to April 2019 in ammonia (from 82 mg/L to 40 mg/L); non-compliant against the amended IWUL limit (Figure 6).

  The sewage treatment plant requires attention to ensure that it operates efficiently to avoid release of contaminated effluent into the environment.

- Final effluent from the septic tanks at the plant (LWP-SP-P): Ammonia and *E. coli* remained non-compliant against the IWUL limits in April 2019 as for the previous month. Decreases were observed in total suspended solids (from 53 mg/L to 10 mg/L) and chemical oxygen demand (COD, settled) (from 276 mg/L to 44 mg/L), however an increase in *E. coli* (from below detection limit to 1 180 000 colonies/100ml) from March to April 2019.

  The effluent from the septic tank should not be allowed to enter the environment but should continue to be emptied by an accredited waste removal company and disposed of to an authorised waste water treatment works.

Table 8: April 2019 Final sewage effluent laboratory results

Parameters	**Units**	**IWUL 04/B21A/ABCGIJ /429 (Amendment)**	LWP-SP-W	LWP-SP-P
			LNP19_M04_021	LNP19_M04_033
Total Suspended Solids (TSS)	mg/L	-	43	10
Nitrate (NO_3^-)	mg/L	≤ 20	9.1	0.1
Ammonia (NH_3) *	mg/L	≤ 10	40	67
Orthophosphate as PO_4^{3-}	mg/L	≤ 10	9	5
Chemical oxygen demand (COD)	mg/L	-	365	44
Escherichia coli	CFU/100ml	≤ 10	540	1 180 000

Notes: Highlighted value - exceeds IWUL limits for waste water; *Calculated from Ammoniacal nitrogen as N

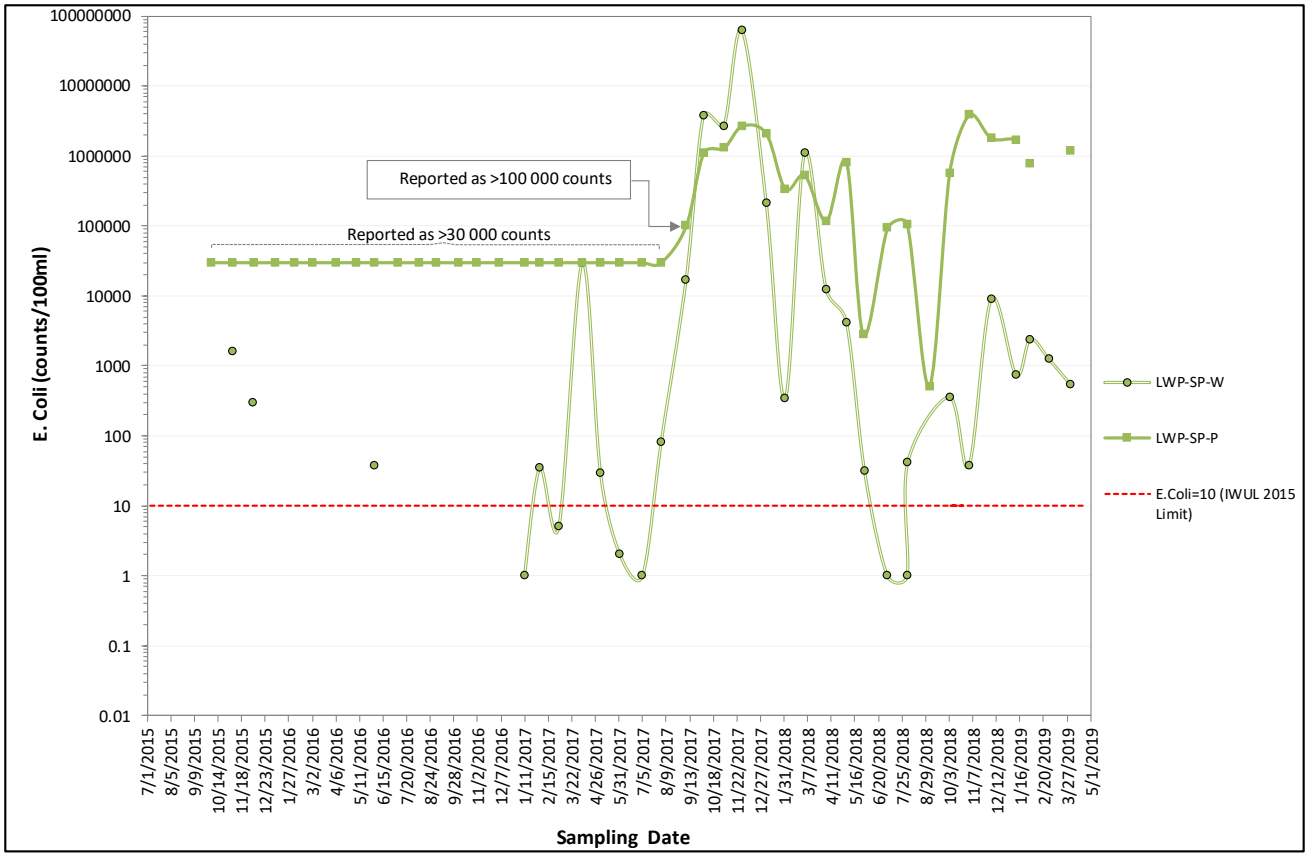


Figure 6: Variation of E. coli counts in sewage effluent with time

2.6 Quality Assurance/Quality control

The following QA/QC measures agreed with Exxaro, have been implemented:

- Measurement of EC and pH in the field and in the laboratory;
- Use of unique numbering system for each site for each sampling occasion; and
- Collection of duplicate and triplicate samples of both groundwater and surface water (Table 9).

Table 9: April 2019 triplicate samples sites

Site Identity	Sample Identity	Comments
LDWST	LNP19_M04_001 (Jones), LNP19_M04_002(Jones) and LNP19_M04_003 (UIS).	Potable water - sampled
LSW03	LNP19_M04_010 (Jones), LNP19_M04_011 (Jones) and LNP19_M04_012 (UIS).	Surface water - sampled

Site Identity	Sample Identity	Comments
KR01A	LNP19_M04_023 (Jones), LNP19_M04_024 (Jones) and LNP19_M04_025 (UIS).	Process water - sampled

An assessment of analytical data accuracy, precision and comparability was carried out. The assessment included ionic charge balance checks, comparison of field and laboratory measurements, comparison of measured and calculated TDS and computation of relative percent difference for duplicate pairs and triplicate samples analysed at Jones and UIS laboratories, respectively.

2.6.1 Relative percentage difference

Laboratory duplicate and triplicate samples were used to assess precision, which is an estimate of the reproducibility of the sampling and analytical system. The statistical relationship between duplicate pair and inter-laboratory duplicate pair (triplicates) results was compared to the average of the results by computing the relative percentage difference (RPD) for analytes reported at or above the detection limits in at least one sample of the pair.

The relative percentage difference was calculated for field and laboratory measurement, duplicate and triplicate samples according to the following equation:

$$RPD\% = \frac{X1-X2}{X_{ave}} \times 100$$

Where:
$X1$ = concentration observed in the first sample
$X2$ = concentration observed in duplicate sample
X_{ave} = average concentration = $\frac{X1+X2}{2}$.

Relative percent differences of between ± 30 % for water samples are considered acceptable (USEPA, 1996). The RPDs for field and laboratory measurements, laboratory duplicate and triplicate samples of surface water, were compared to acceptable limits and exceedances are presented in Figure 7.

The relative percentage difference for field and laboratory measurements was within acceptable ranges for all pH values, all electrical conductivity, most total dissolved solids values and most dissolved oxygen values (Figure 7).

The relative percentage differences for samples analysed at Jones versus those analysed at UIS (Inter-lab samples) were within acceptable ranges for most constituents; except for nitrate, manganese, dissolved oxygen, ammonia and turbidity in the pair 29 (KR01A), dissolved oxygen, ammonia, manganese, turbidity in pair 30 (LSW03); and potassium in pair 31 (LDWST).

Intra-lab samples (analysed at Jones laboratory) were within acceptable ranges for most parameters apart from discrepancies recorded in nitrate in pair 32 (KR01A); and ammonia, dissolved oxygen in pair 33 (LSW03) was outside the acceptable ranges for intra laboratory (analysed at Jones) sample pairs.

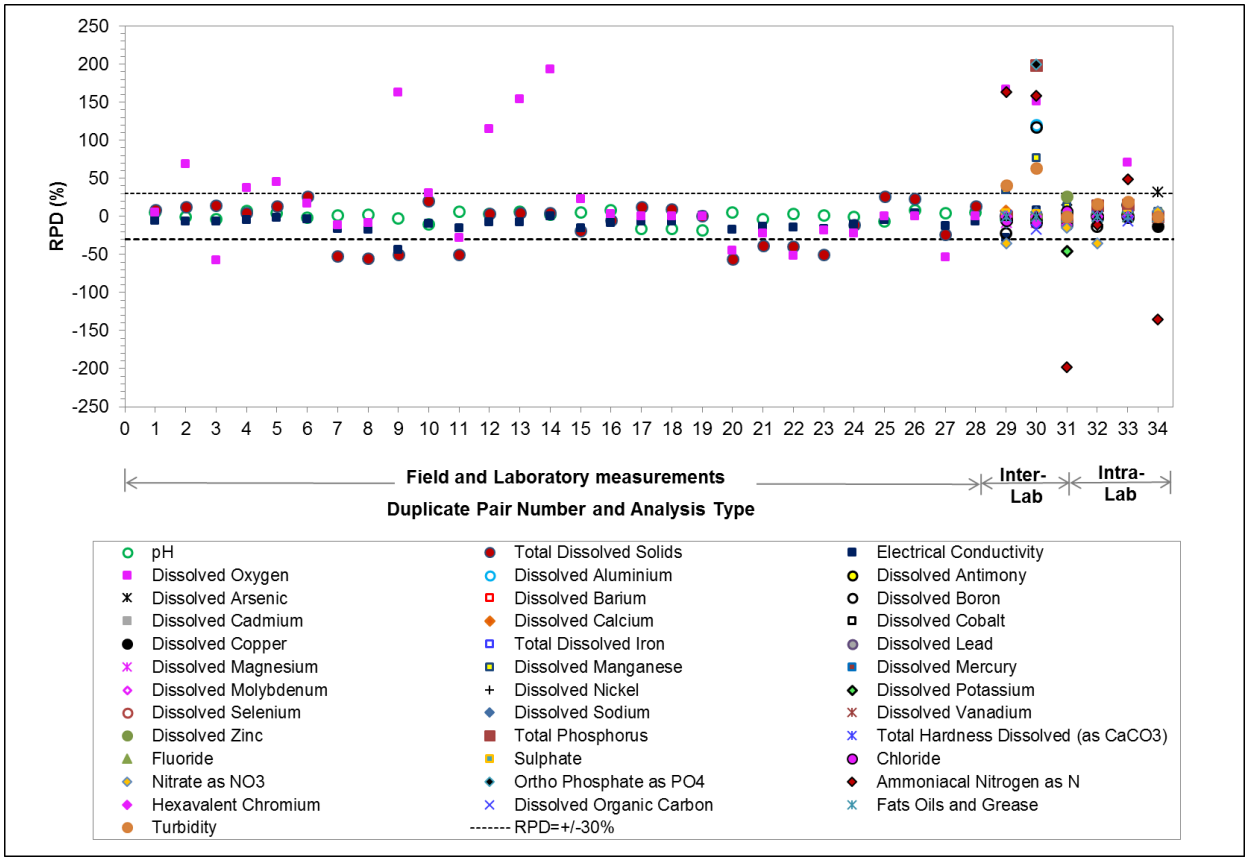


Figure 7: April 2019 relative percent difference for analyses on surface water samples

2.6.2 Ionic Charge Balance

Calculations of ion charge balances for all water samples were evaluated to assess the accuracy of the analyses. In electrically neutral solutions, the equivalents of cations analysed in the solution should balance that of the analysed anions. The charge imbalance (CI) calculation was obtained as a percentage by taking the difference of the equivalent concentration of major cations and anions and dividing by the sum times 100 as shown in the equation:

$$CI(\%) = \frac{\sum Cations - \sum Anions}{\sum Cations + \sum Anions} \times 100$$

Percentage ionic charge balance errors of between 5 – 10 % are regarded as acceptable (Zhao et.al. 2010), and charge imbalances greater than 20 % are unreliable for further interpretation (Nordstrom et al. 2009).

The ionic charge imbalance was within acceptable ranges for all April 2019 surface water samples; with the largest imbalance being +7.2 % (Figure 8).

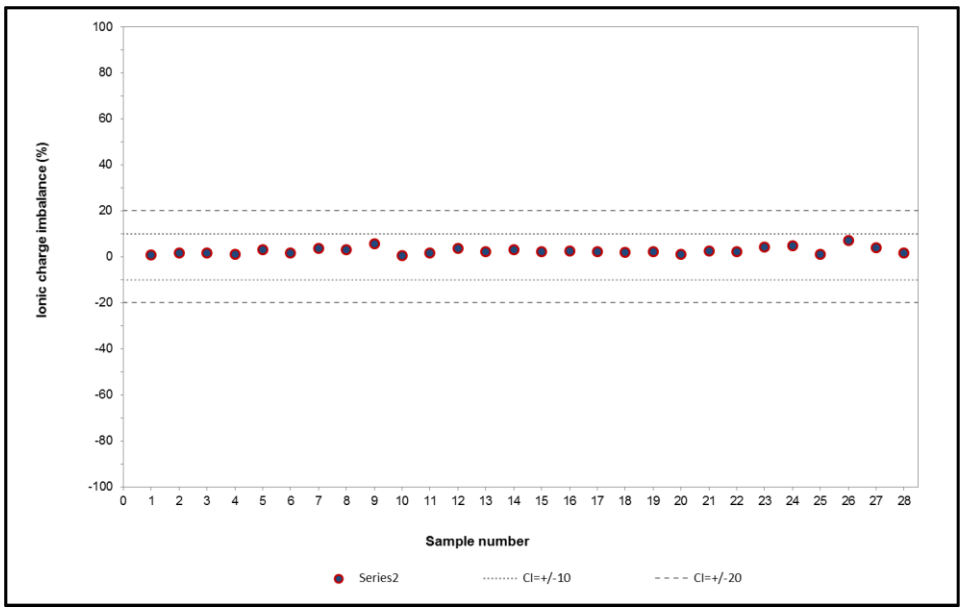


Figure 8: April 2019 ionic charge balance error of surface water samples

2.6.3 TDS evaluation

The ratio of TDS measured at the laboratories and TDS measured in the field to TDS by summation of measured cations and anions were both computed. Values between 1 and 1.2 are considered acceptable. The ratio of TDS to EC was also computed for field and laboratory measurements and values between 0.55 and 1.00 were considered acceptable based on the pH range of the samples and electrical conductivity values, which were less than 5 000 µS/cm (Hubert and Wolkersdorfer, 2015).

The ratios of calculated TDS vs field measured TDS and the ratios of calculated TDS vs laboratory measured TDS were unacceptable (89 %) for most samples (Figure 9).

The ratios of TDS to EC were acceptable (71 %) for most laboratory measurements and all field measured ratios (Figure 10).

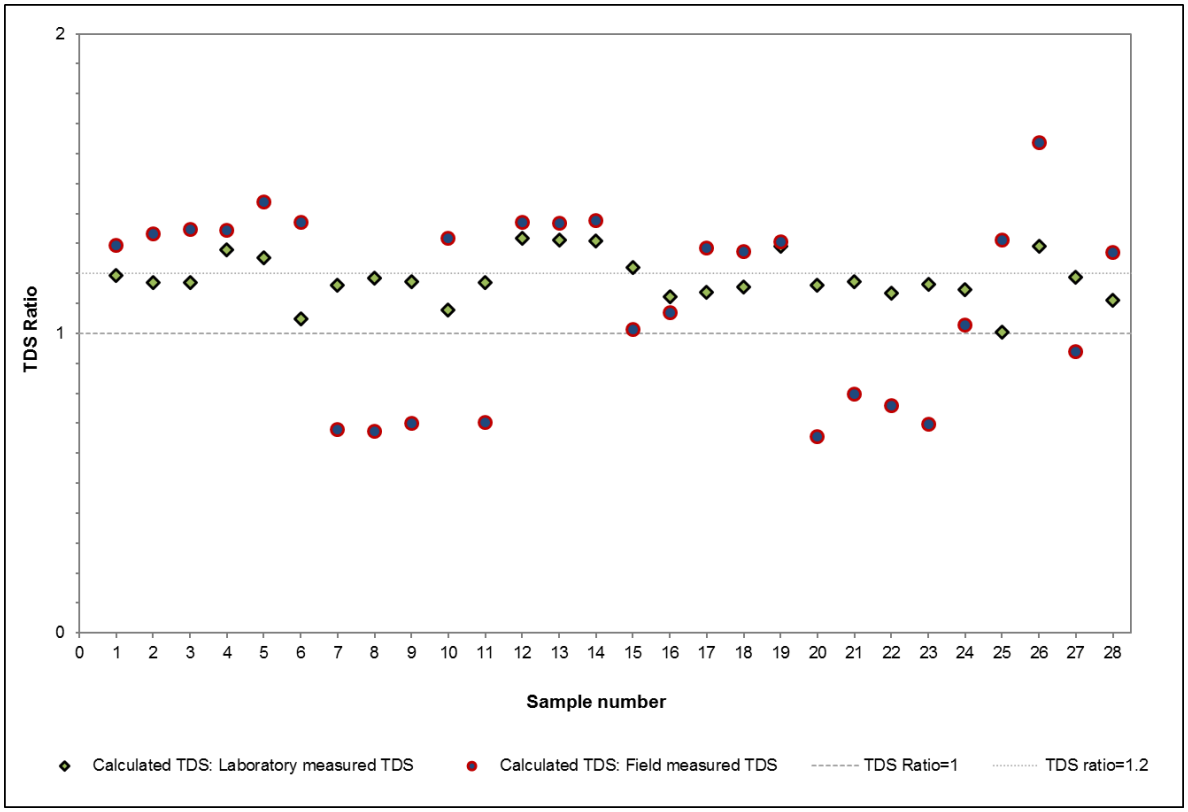


Figure 9: April 2019 TDS ratios of surface water samples

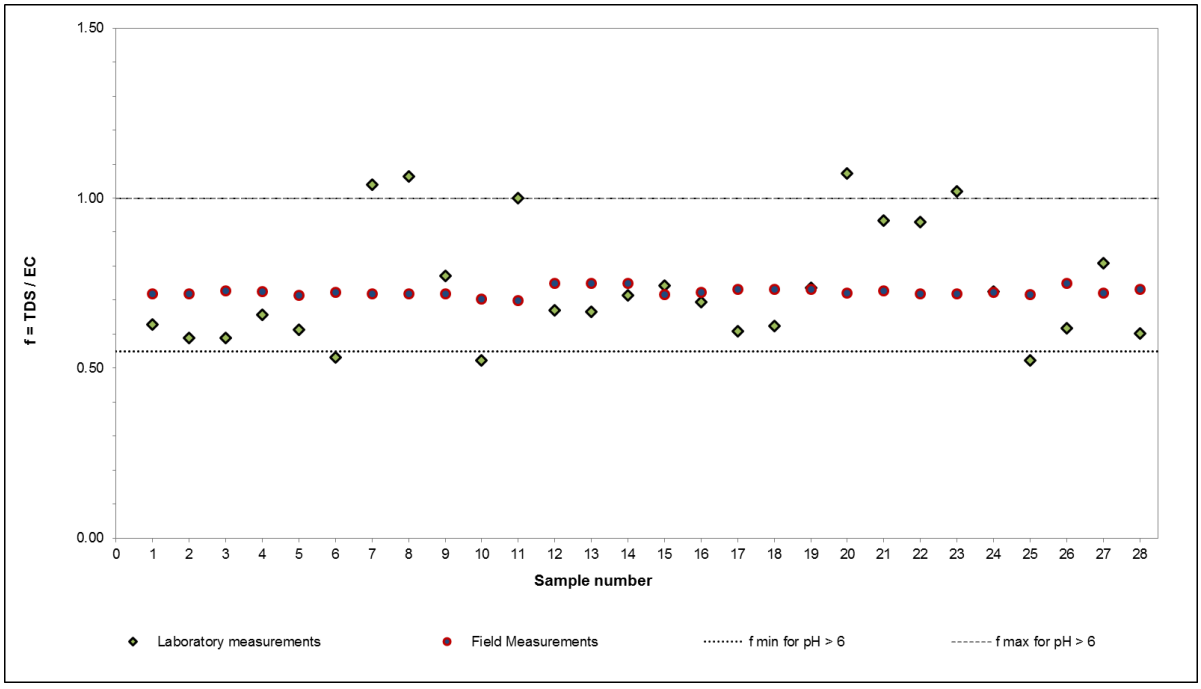


Figure 10: April 2019 TDS/EC for surface water samples

3.0 CONCLUSIONS

1) The water from all drinking water sources was characterised by a calcium/magnesium bicarbonate signature, typical of shallow, freshly recharged groundwater or water from a dolomitic aquifer.

2) Load-out Bay Offices Drinking Water and Drinking Water on Piet Schutte's Farm were ere compliant to SANS 241:2015 drinking water quality standard in April 2019, but Drinking Water Supply Tank and Drinking Water at Laboratory were non-compliant due to an exceedance in *E. coli* (these two sources are not used for drinking).

3) The following constituents (mine water parameters in **bold**) increased at downstream sites compared to upstream in April 2019, noting that an increase in dissolved oxygen is a positive:

   c. WP02: The levels of turbidity, ammonia, potassium, total hardness, alkalinity, chlorophyll a and dissolved organic carbon; total dissolved iron, *E. coli* and dissolved oxygen (negative increase decreased) downstream compared to upstream; and

   d. LSW05: **Total dissolved solids**, **electrical conductivity**, **magnesium**, dissolved oxygen, *E. coli* and total hardness.

4) The following parameters (mine water parameters in **bold**) were not compliant to water quality limits specified in the IWUL in April 2019:

   i. WP01 (Bronkhorstspruit tributary upstream of the mine): **electrical conductivity,** ammonia, calcium, potassium, **manganese**, total alkalinity, Chlorophyll a, *E. coli* and dissolved oxygen;

   j. WP02 (Bronkhorstspruit tributary downstream of the mine): **total dissolved solids**, **electrical conductivity**, ammonia, calcium, **magnesium**, **manganese**, total alkalinity, *E. coli*, and dissolved oxygen;

   k. LSW08 (Bronkhorstspruit, upstream of Block OI): ammonia, calcium, **manganese**, total alkalinity, *Chlorophyll a, E. coli* and dissolved oxygen;

   l. LSW07 (Bronkhorstspruit, upstream): fluoride, ammonia, calcium, total alkalinity, *E. coli, Chlorophyll a,* dissolved oxygen and organic carbon;

   m. LSW03 (Bronkhorstspruit adjacent to Delmas Silica): **electrical conductivity**, ammonia, calcium, total alkalinity, *E. coli, Chlorophyll a,* dissolved oxygen and dissolved organic carbon;

   n. RD1 (Bronkhorstspruit at haul road): **electrical conductivity,** ammonia, calcium, **magnesium, manganese***,* total alkalinity, dissolved oxygen and chlorophyll *a*;

   o. LSW13 (Stuart Coal): **electrical conductivity, sulphate**, ammonia, calcium and **manganese,** total alkalinity, *E. coli* and *Chlorophyll a*; and

   p. LSW05 (Bronkhorstspruit downstream): **electrical conductivity**, ammonia, calcium, **magnesium**, total alkalinity, dissolved oxygen, chlorophyll a and *E. coli.*

5) The mine process water was classified based on pH and sulphate content, in April 2019 as:

   c. Saline Drainage: LSW09, OM pit, KR01A, ODN pit, OWM pit and WP04;

   d. Neutral mine drainage: KR03, KR04 and WLV pit; and

6) Levels of most constituents in waters sampled from the process water sites fluctuated from March 2019 to April 2019. Hexavalent chromium and orthophosphate were present in amounts that were below the detectable levels for all sites. KR03 remained non-compliant to the fats, oils and greases IWUL limit from March 2019 to April 2019.

7) The sewage works behind the workshop (LWP_SP_W) performed unacceptably as levels of ammonia and *E. coli* exceeded the waste water limits.

   The water from the septic tanks at the plant (LWP-SP-P) should continue to not be allowed to enter the environment but should continue to be emptied by an accredited waste removal company and disposed of to an authorised waste water treatment works.

8) Relative percentage difference values between field and laboratory measured parameters were acceptable for all pH and electrical conductivity values; and for most total dissolved solids and dissolved oxygen values. The relative percentage difference for intra-lab samples (analysed at Jones laboratory) and inter- lab samples (analysed at UIS and Jones laboratories) were acceptable for most parameters in surface water samples. The ionic charge balance error was within acceptable ranges for all surface water samples. The ratios of most calculated TDS vs laboratory measured TDS and the ratios of calculated TDS vs field measured TDS were not within the 1 to 1.2 range for most surface water samples. The ratios of laboratory measured TDS to laboratory measured EC were acceptable for most surface water samples and was within the acceptable range for all field measurements.

9) It is difficult to obtain samples from the closed pits such as Kenbar Rehab, OG Pit and OH Pit. Surface water does not readily accumulate, as it infiltrates through the rehabilitated ground. Access is also not possible to pits which have not been backfilled. The water quality of rehabilitated pits should be monitored through boreholes drilled into the backfilled spoils – becoming part of the groundwater monitoring programme instead of the surface water monitoring programme and sampling points should be removed from the surface water programme. Closed pits which cannot be accessed will need boreholes drilled once they have been backfilled.

10) The four kinetic barrels (OJ-O, OJ-S4-DISC, OH-WEATH, OL-OVB (2A+2B)) were dry as the taps are damaged, meaning that any leachate was lost. Consideration should be given to changing the design of the drainage system.

4.0 CONCLUDING REMARKS

This report has been reviewed by Lee Boyd (Senior Water Resources Specialist) and David Love (Technical Director). Please contact Keretia Lupankwa for any queries or discussion

Signature Page

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APPENDIX A

Surface Water Quality Trend

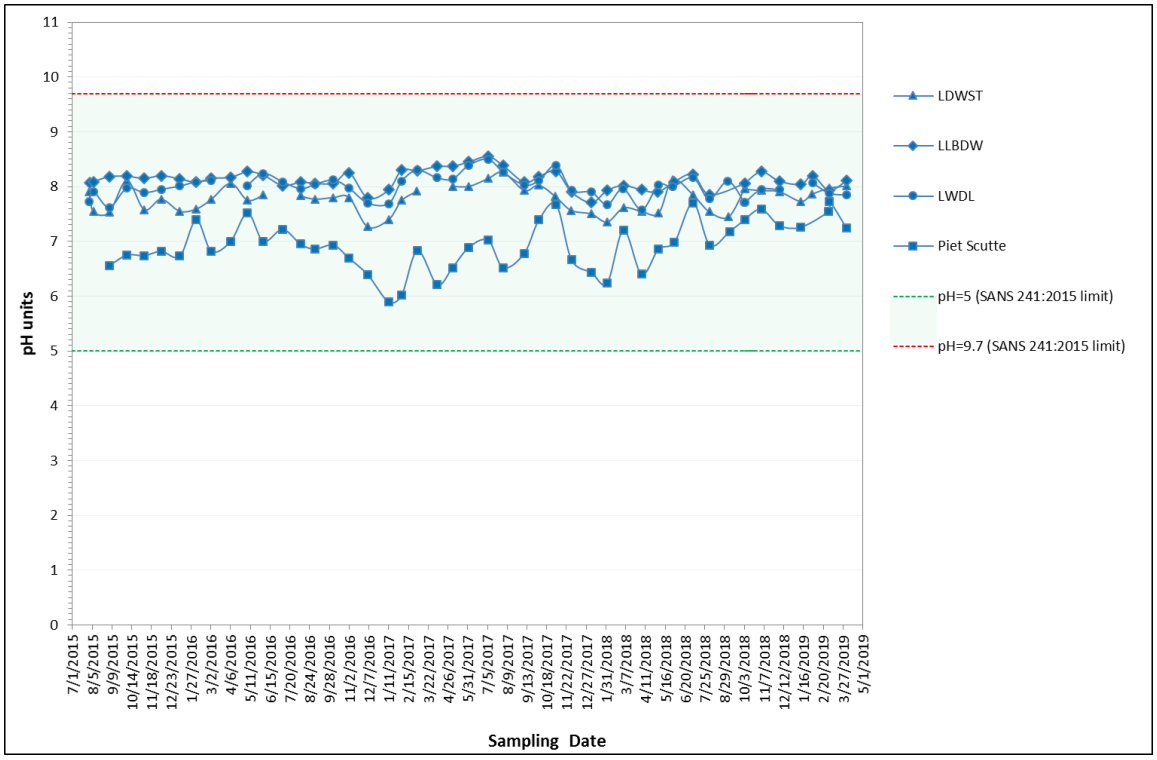


Figure A1: Variation of potable water pH

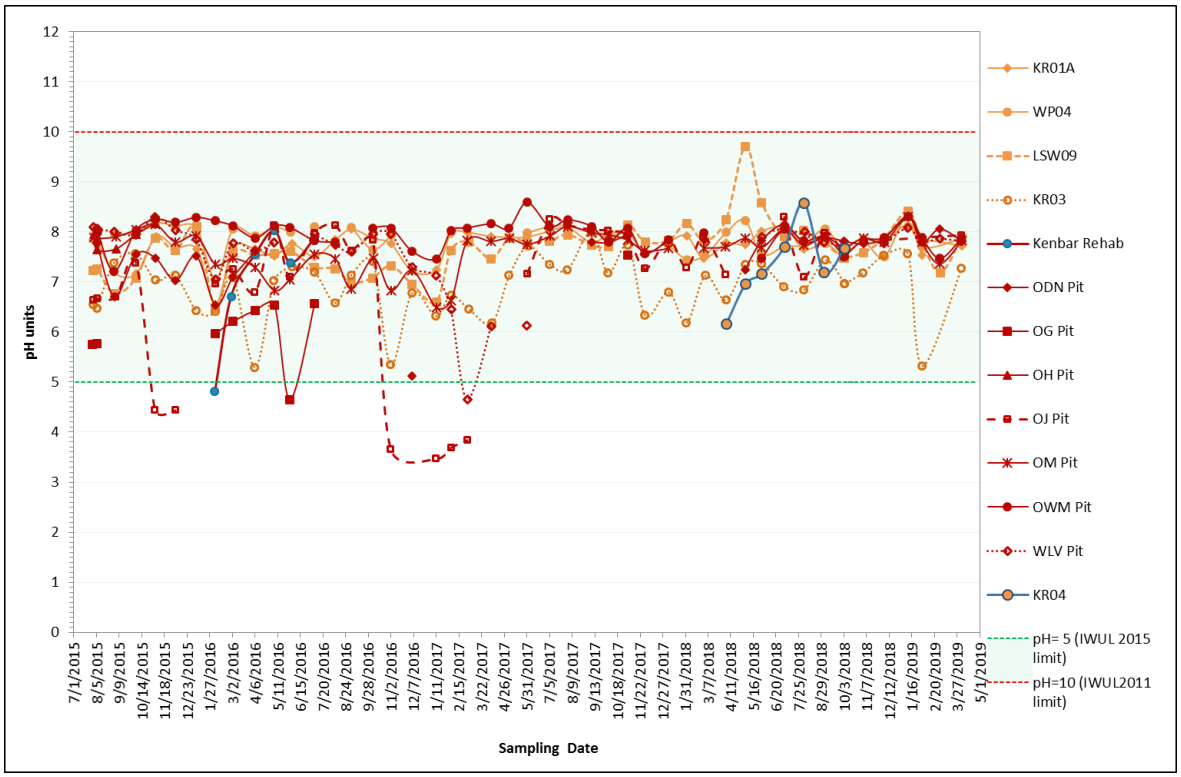


Figure A2: Variation of process water pH

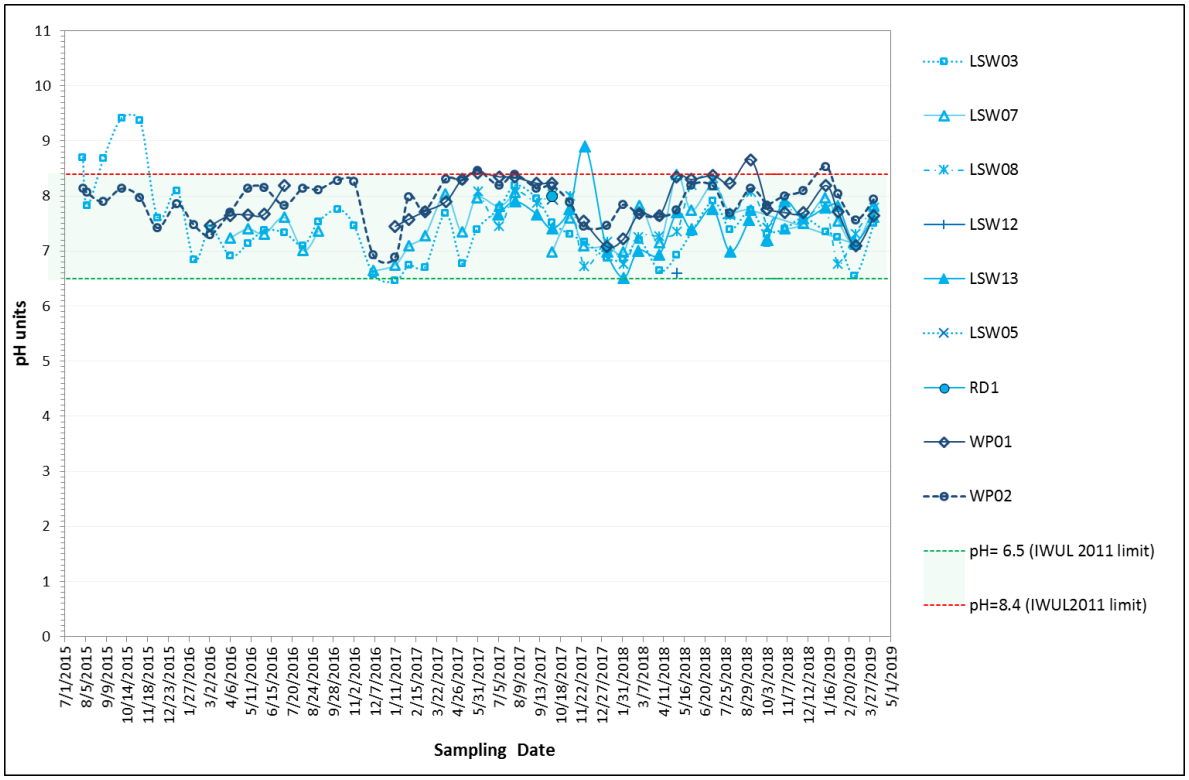


Figure A3: Variation of surface water pH

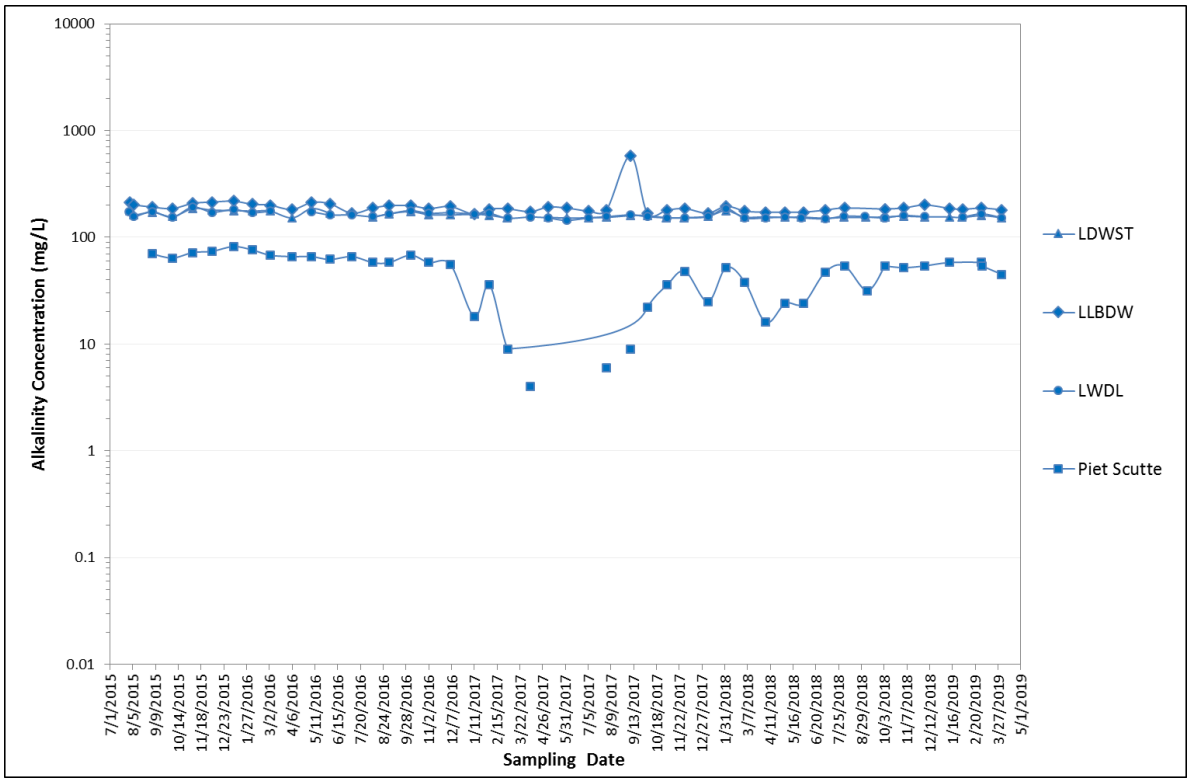


Figure A4: Variation of potable water alkalinity

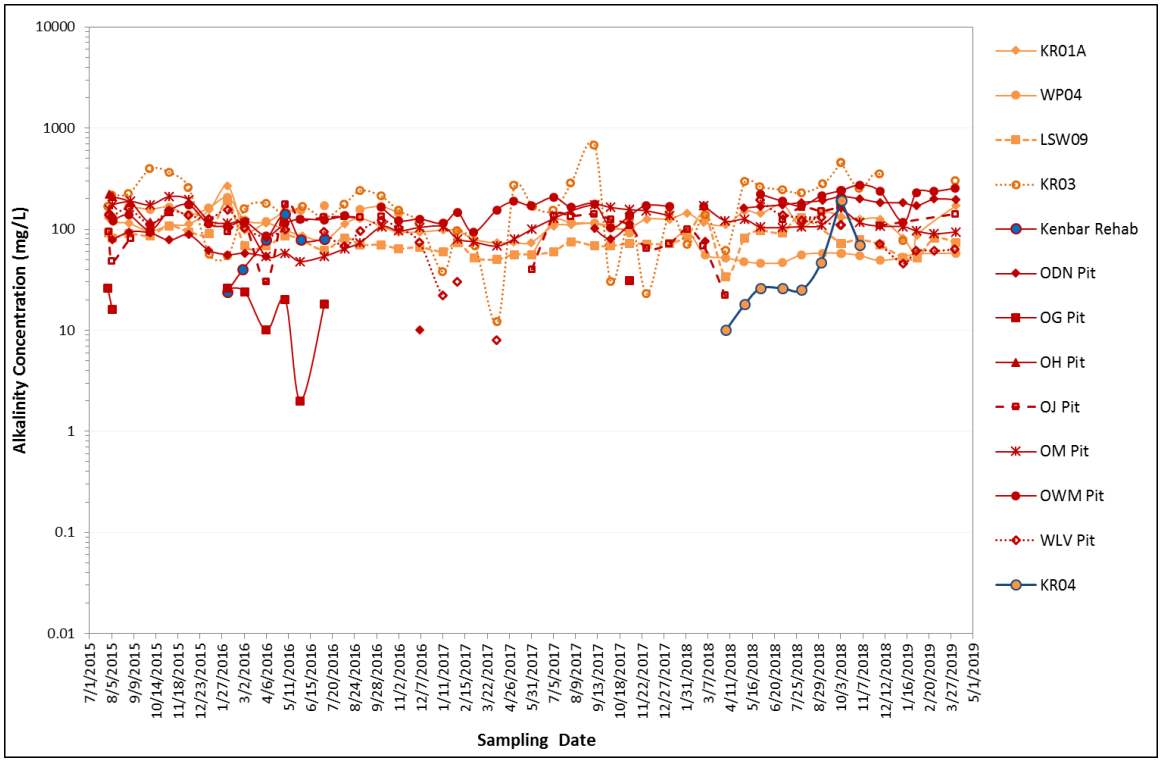


Figure A5: Variation of process water alkalinity

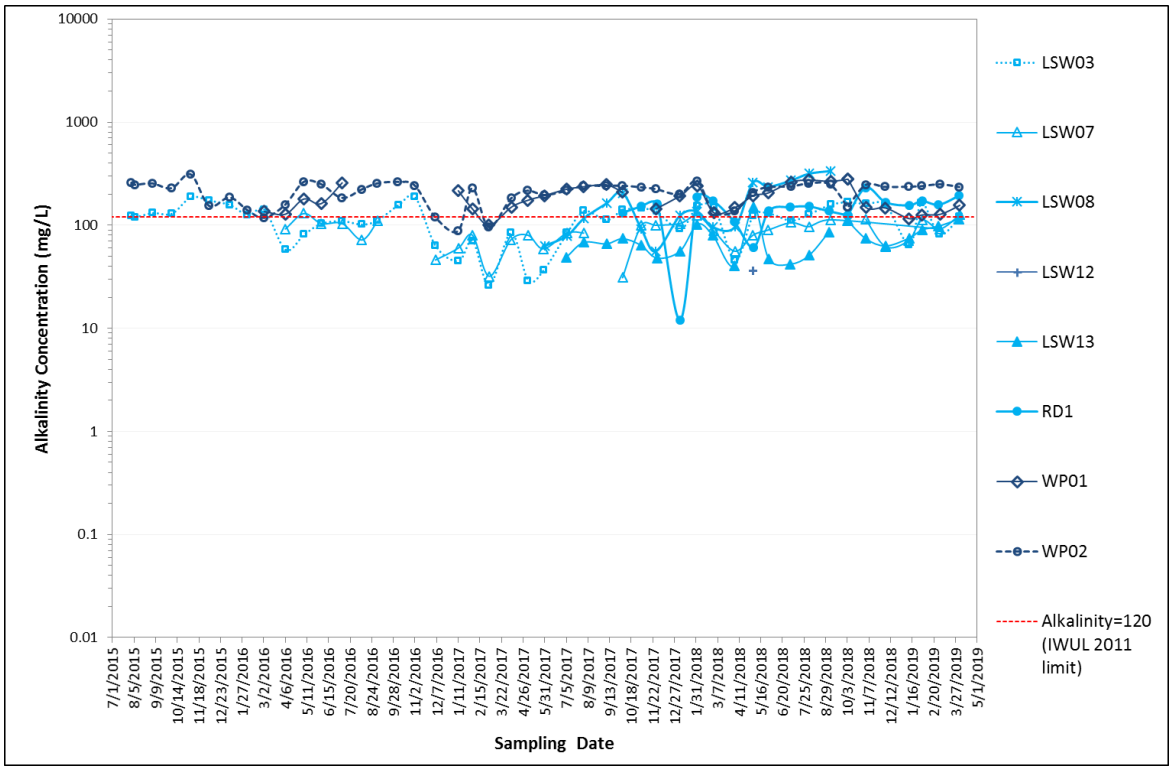


Figure A6: Variation of surface water alkalinity

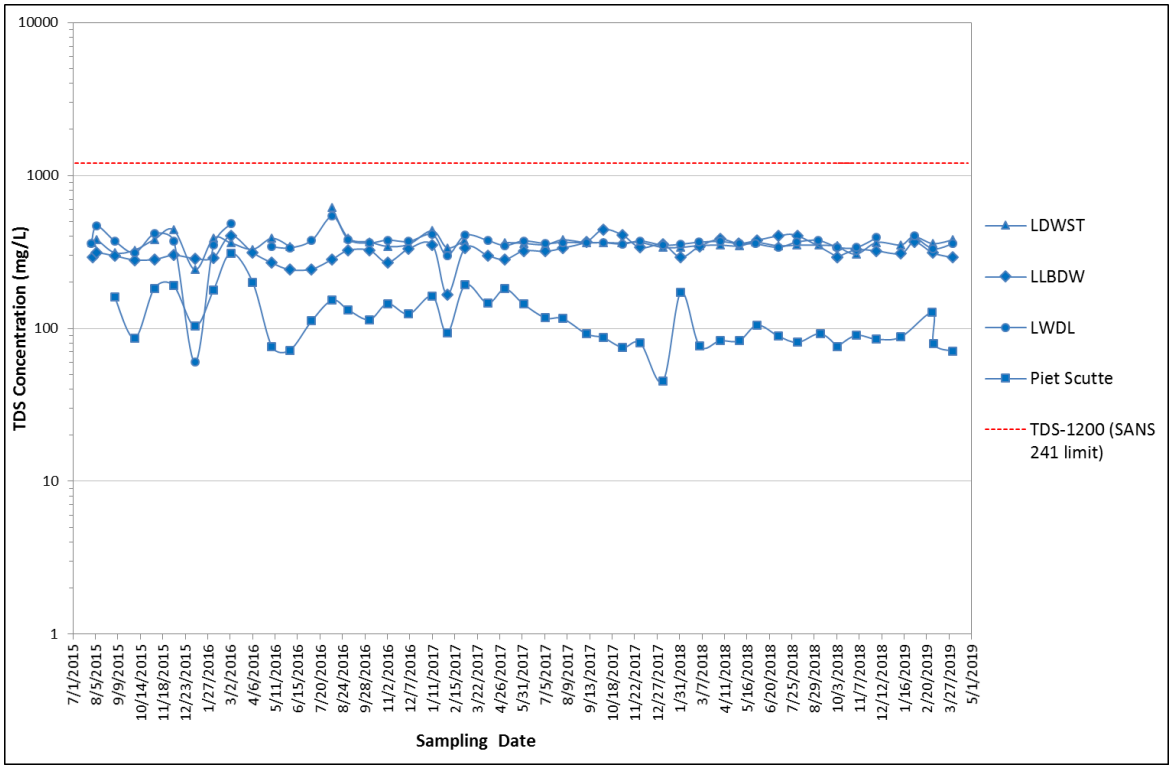


Figure A7: Variation of potable water TDS

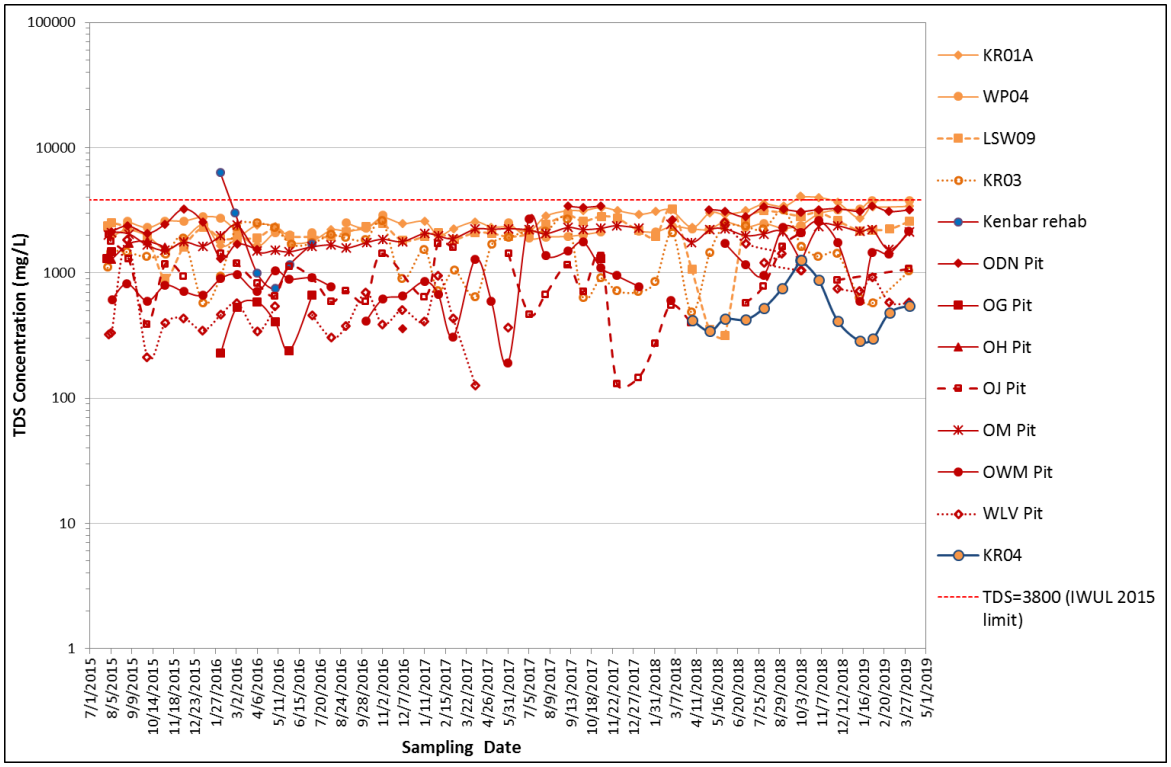


Figure A8: Variation of process water TDS

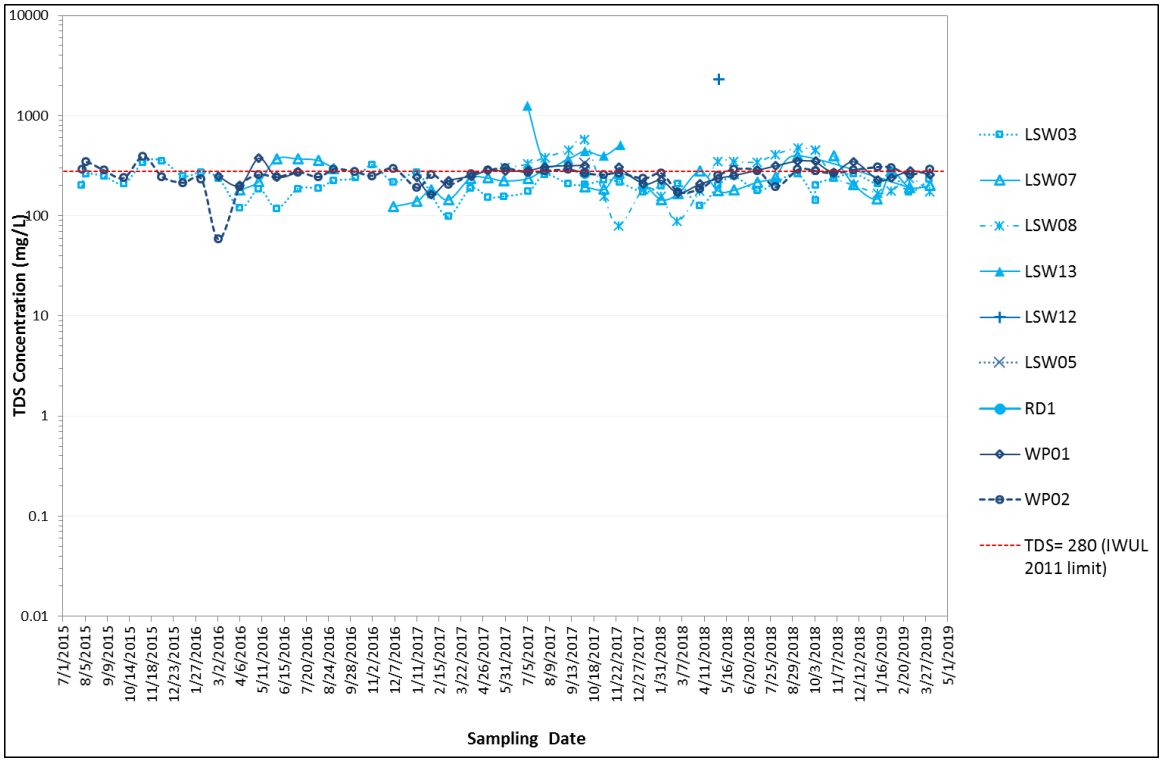


Figure A9: Variation in surface water TDS

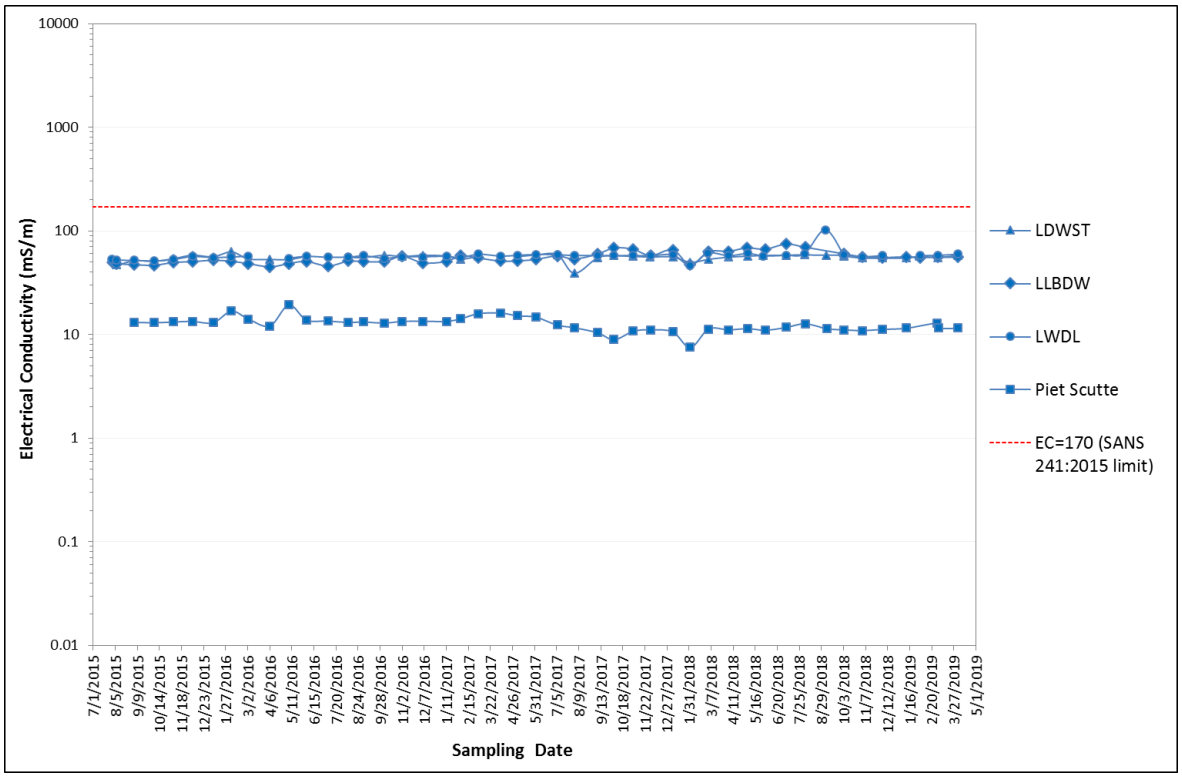


Figure A10: Variation of potable water electrical conductivity

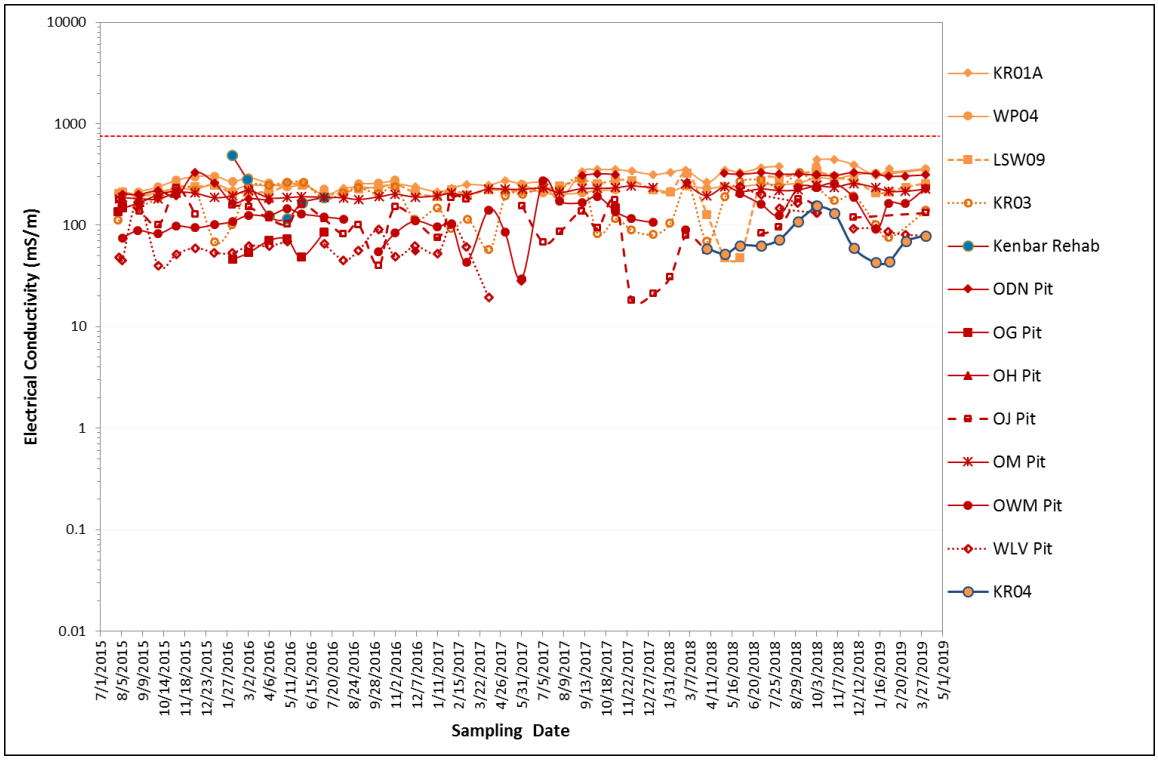


Figure A11: Variation of process water electrical conductivity

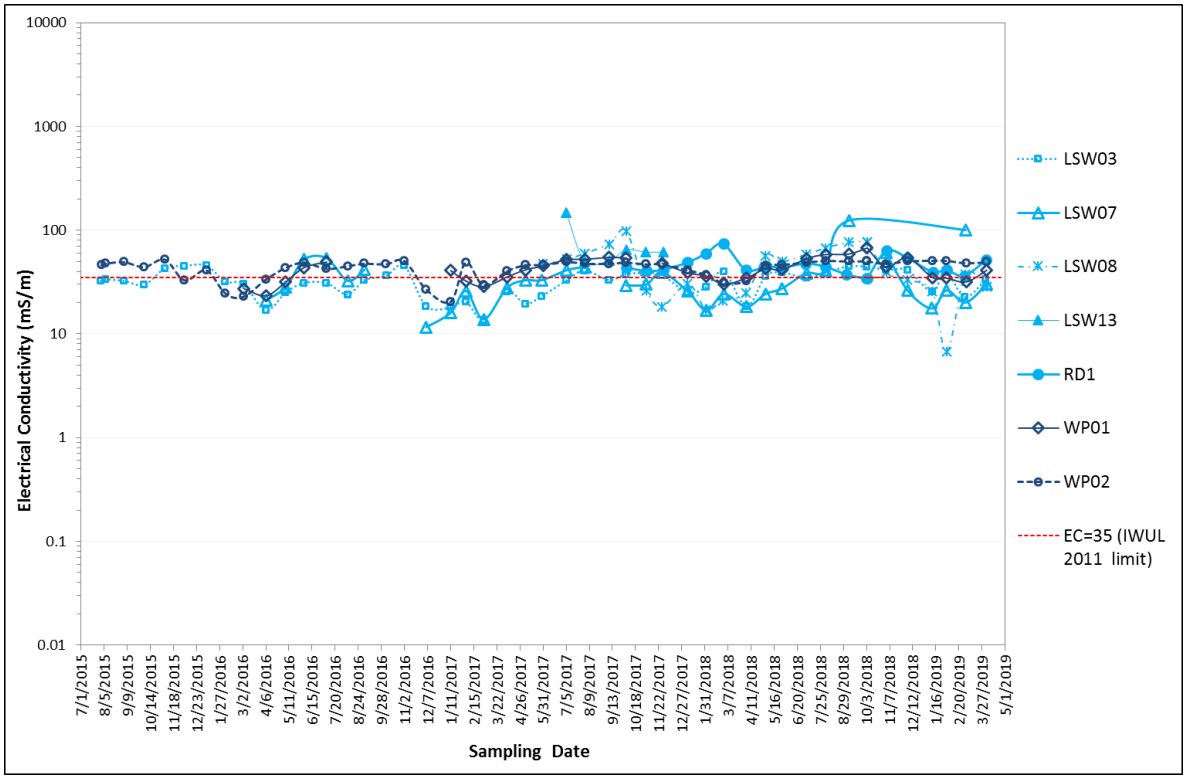


Figure A12: Variation of surface water electrical conductivity

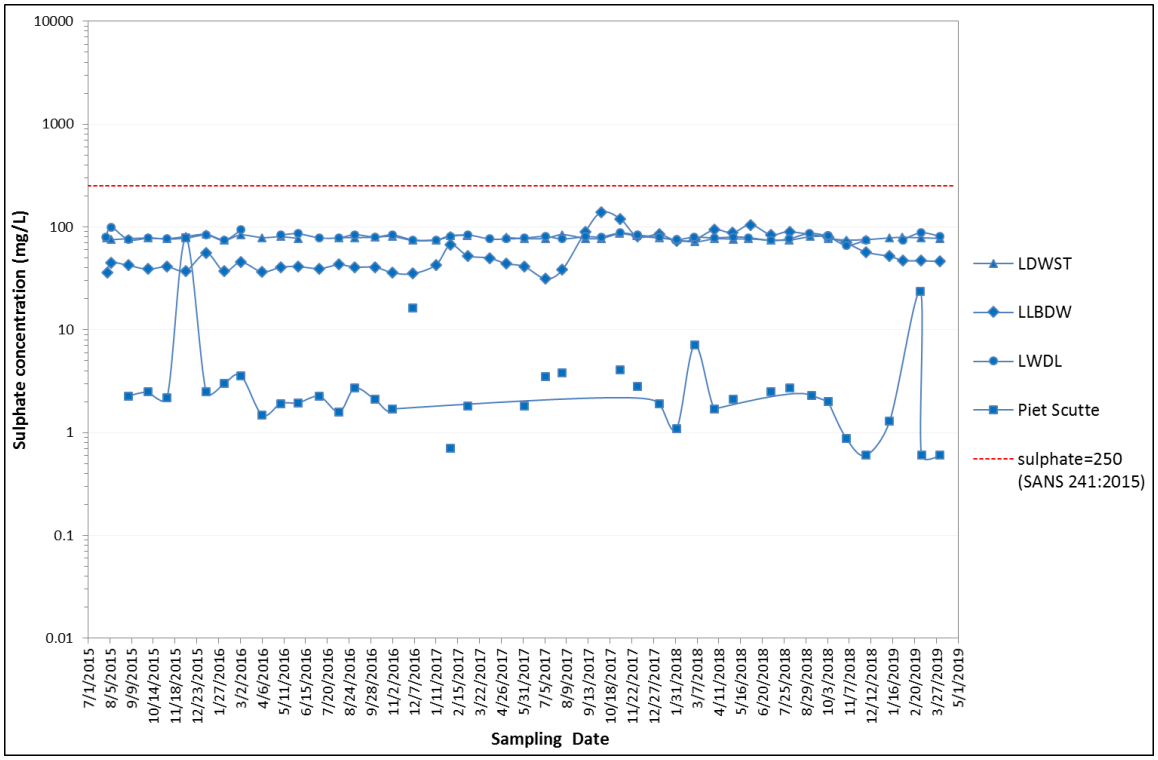


Figure A13: Variation of potable water sulphate

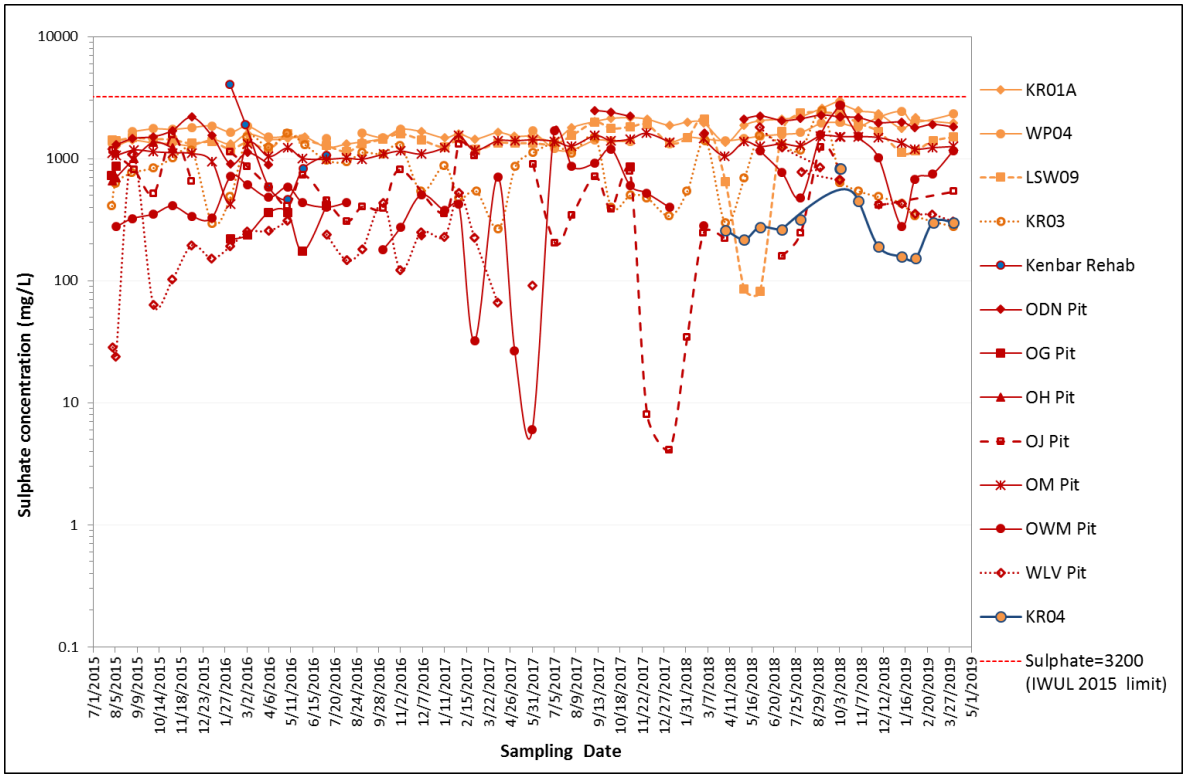


Figure A14: Variation of process water sulphate

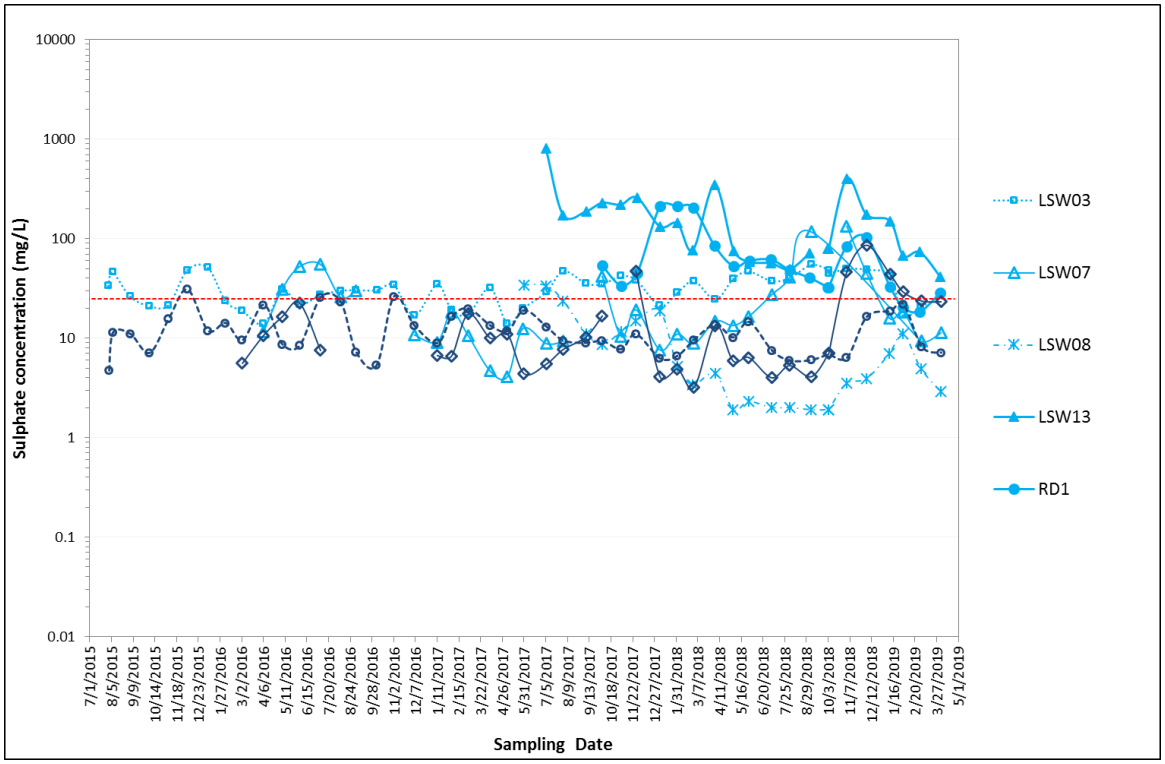


Figure A15: Variation of surface water sulphate

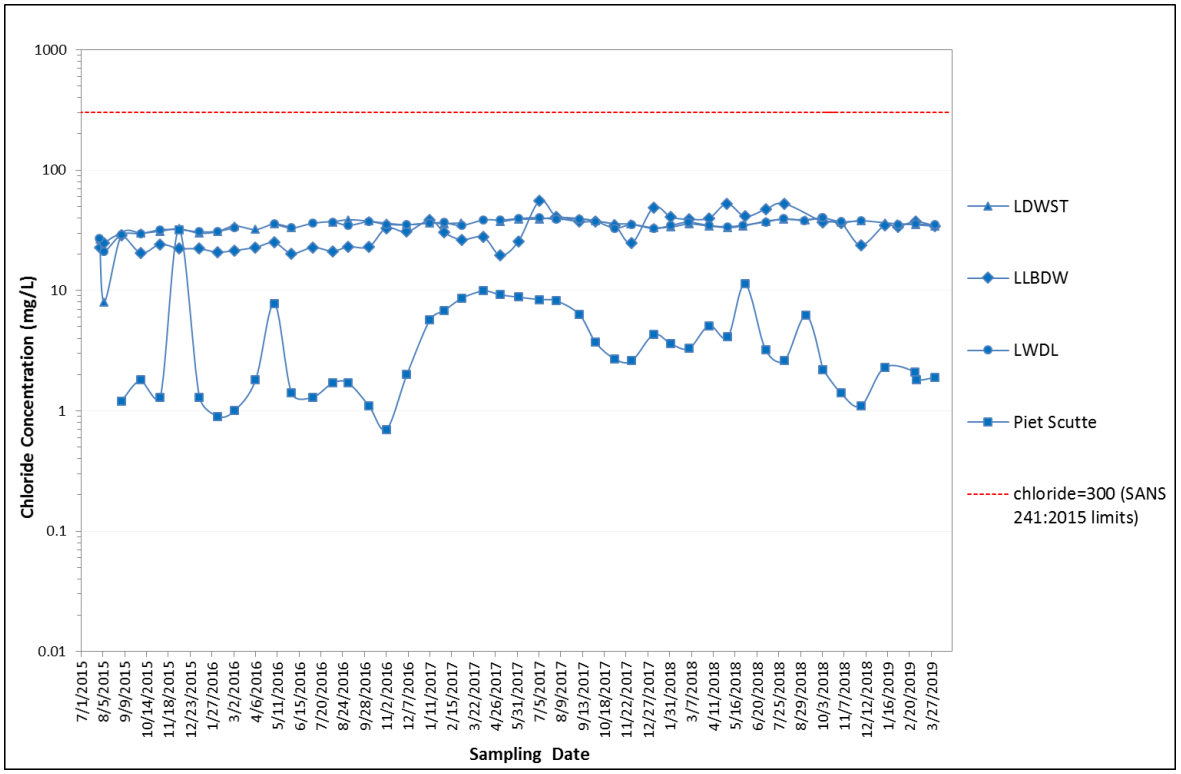


Figure A16: Variation of drinking water chloride

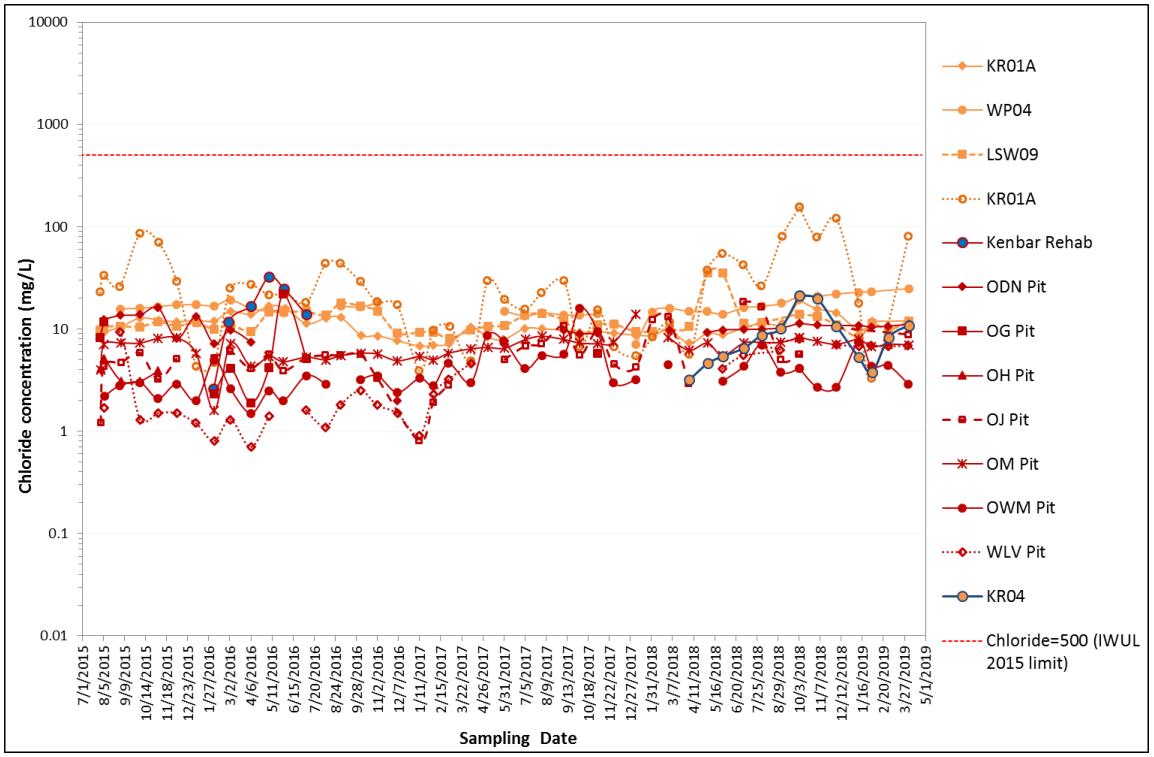


Figure A17: Variation of process water chloride

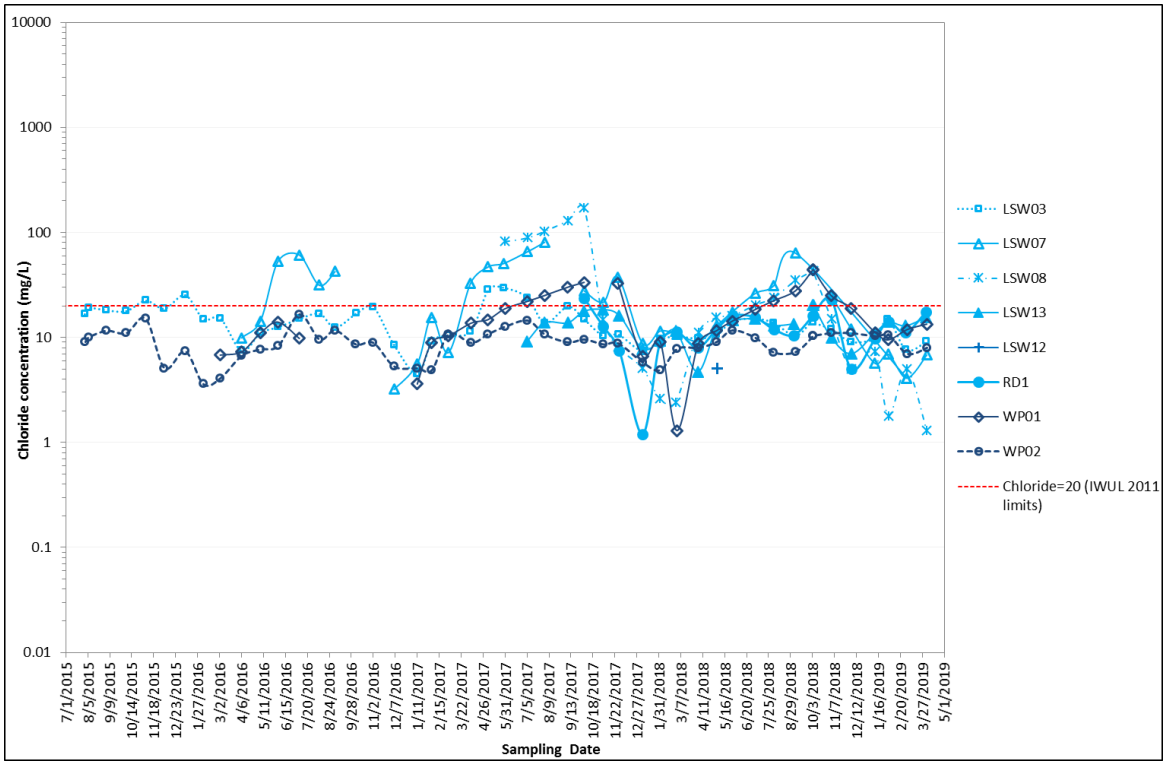


Figure A18: Variation of surface water chloride

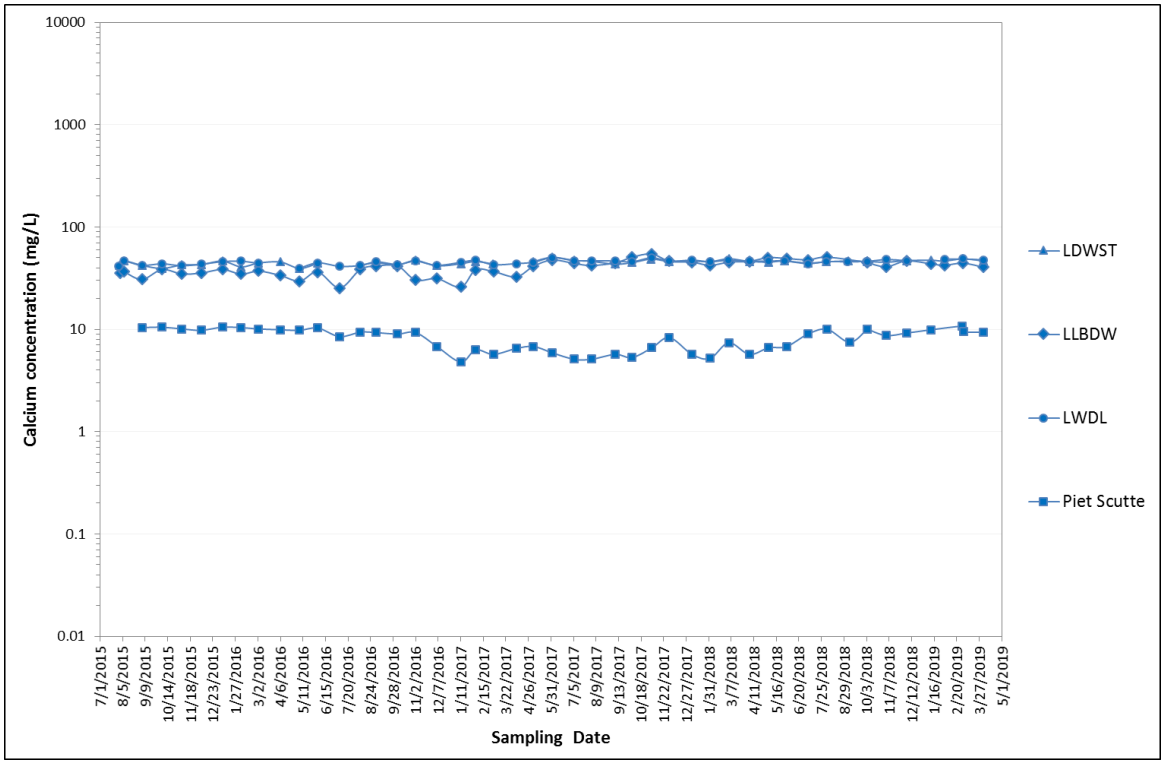


Figure A19: Variation of potable water calcium

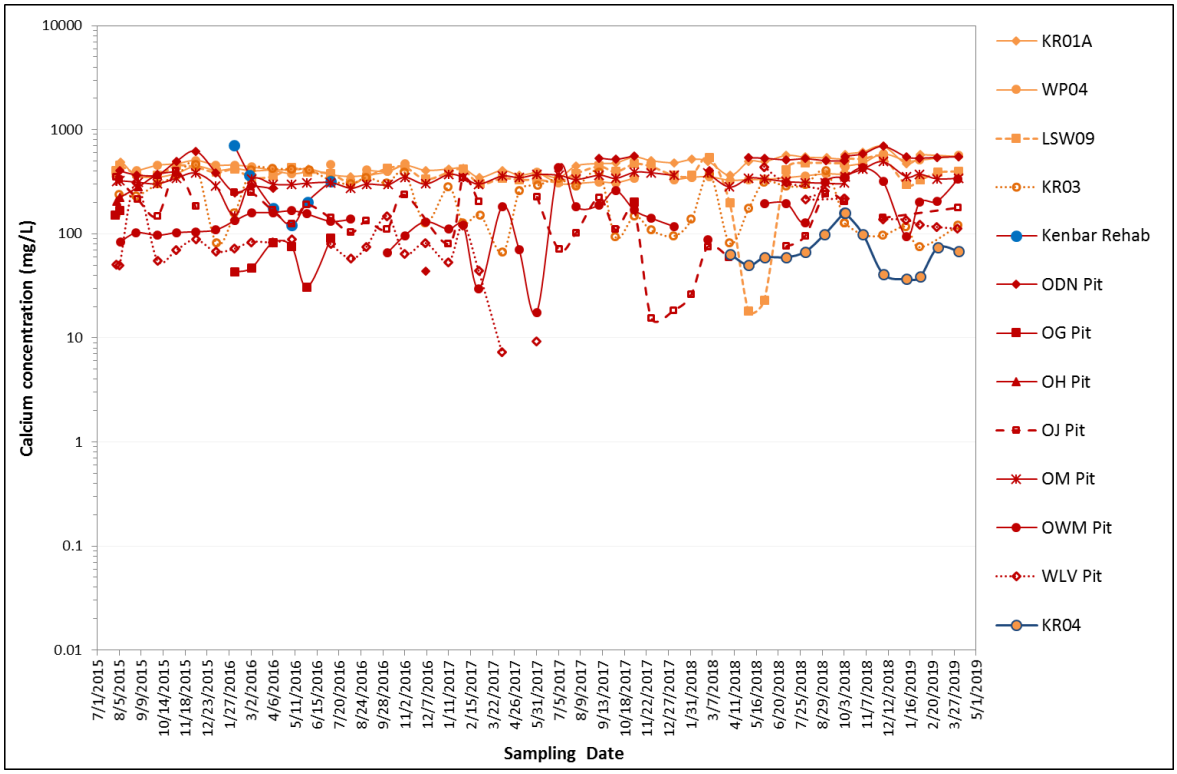


Figure A20: Variation of process water calcium

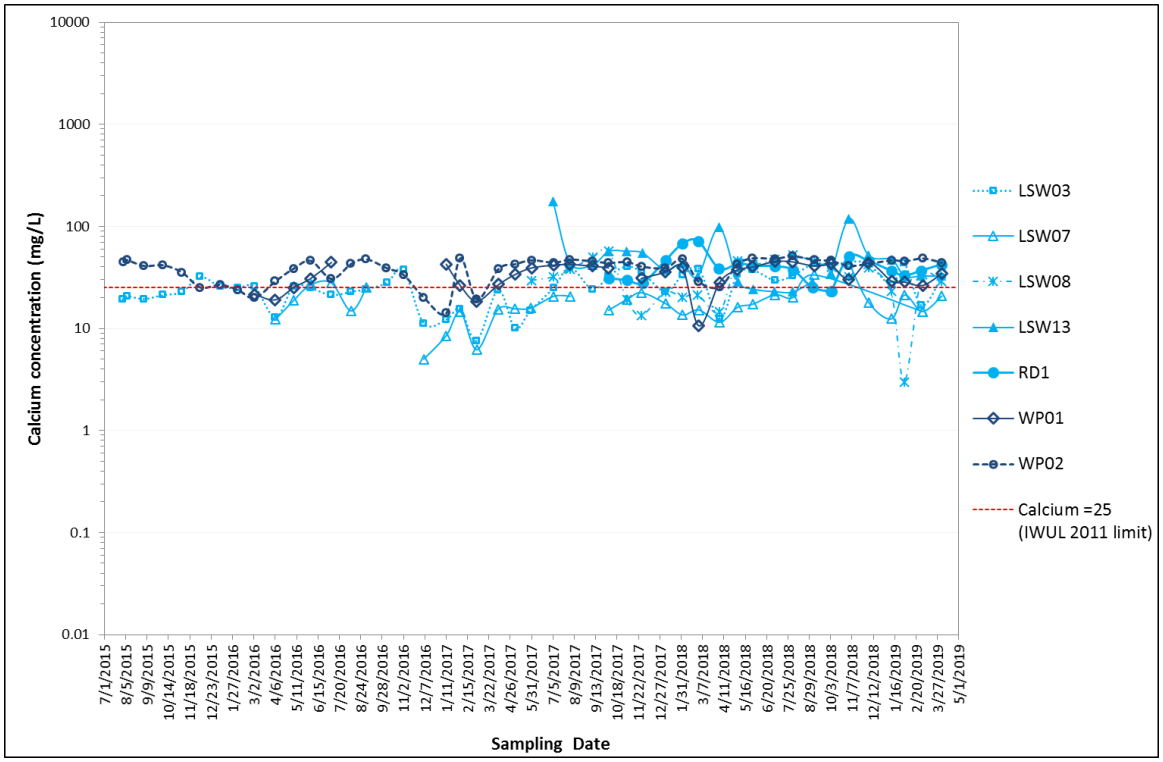


Figure A21: Variation of surface water calcium

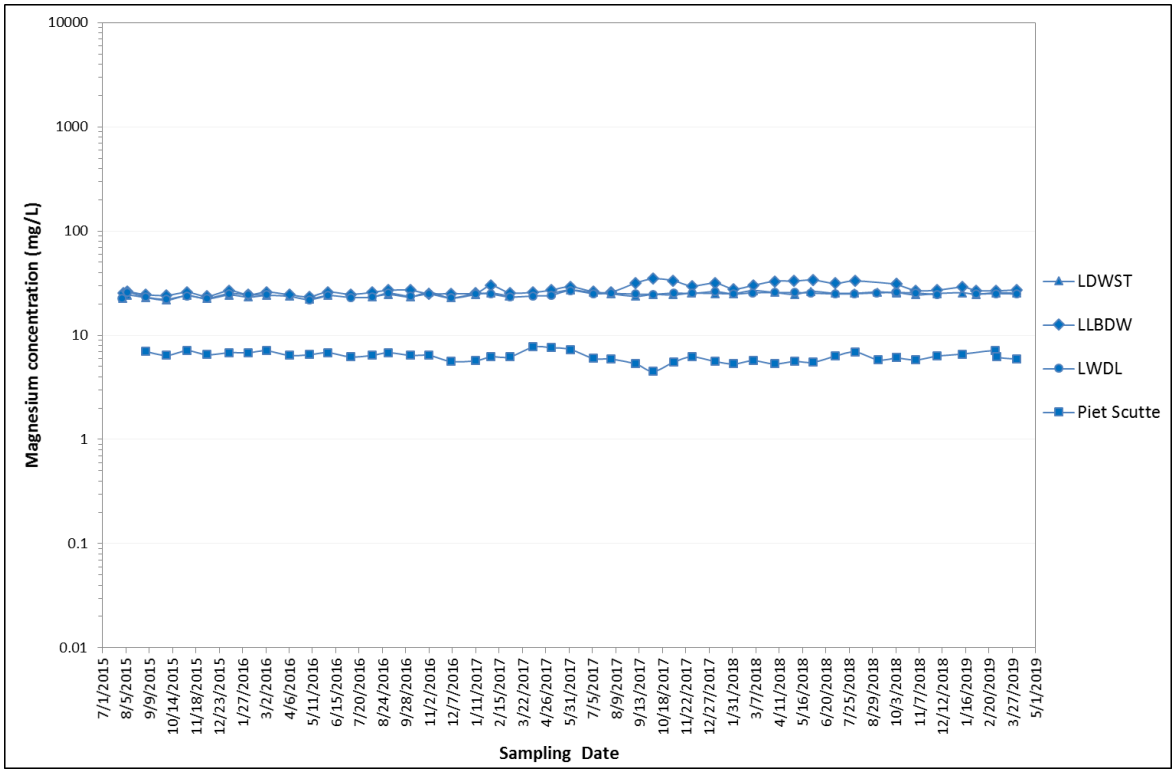


Figure: A22: Variation of potable water magnesium

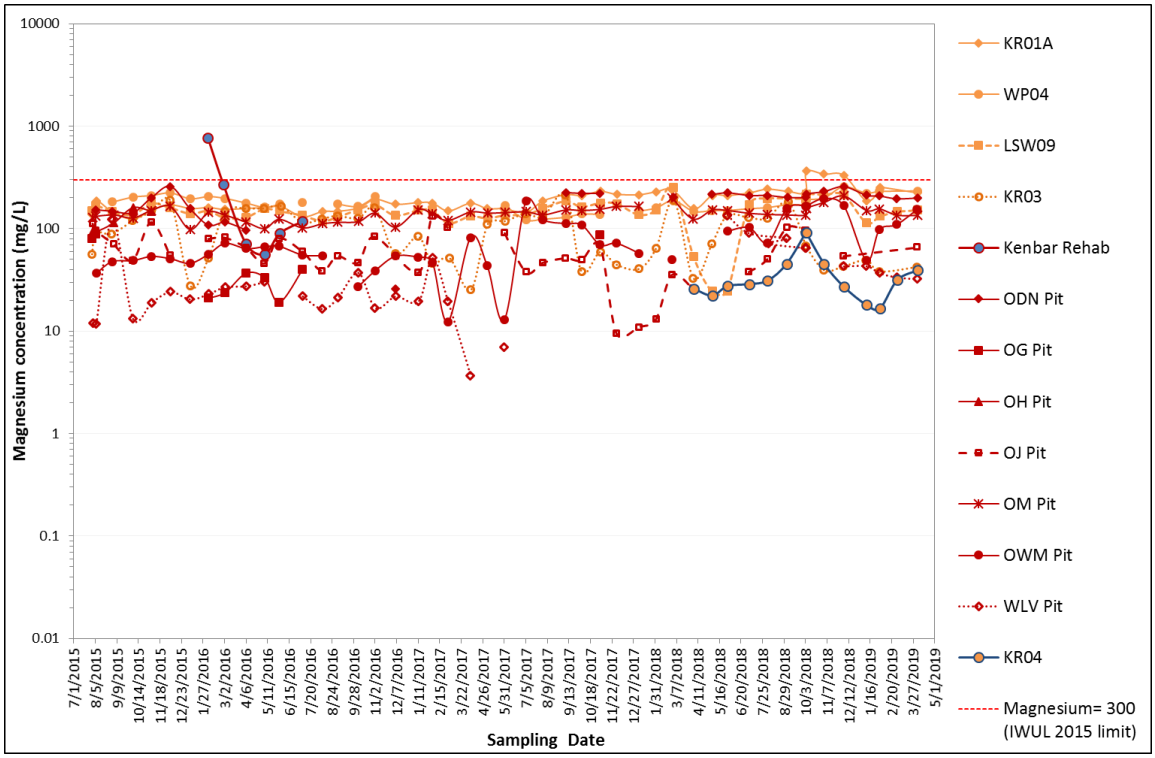


Figure A23: Variation of process water magnesium

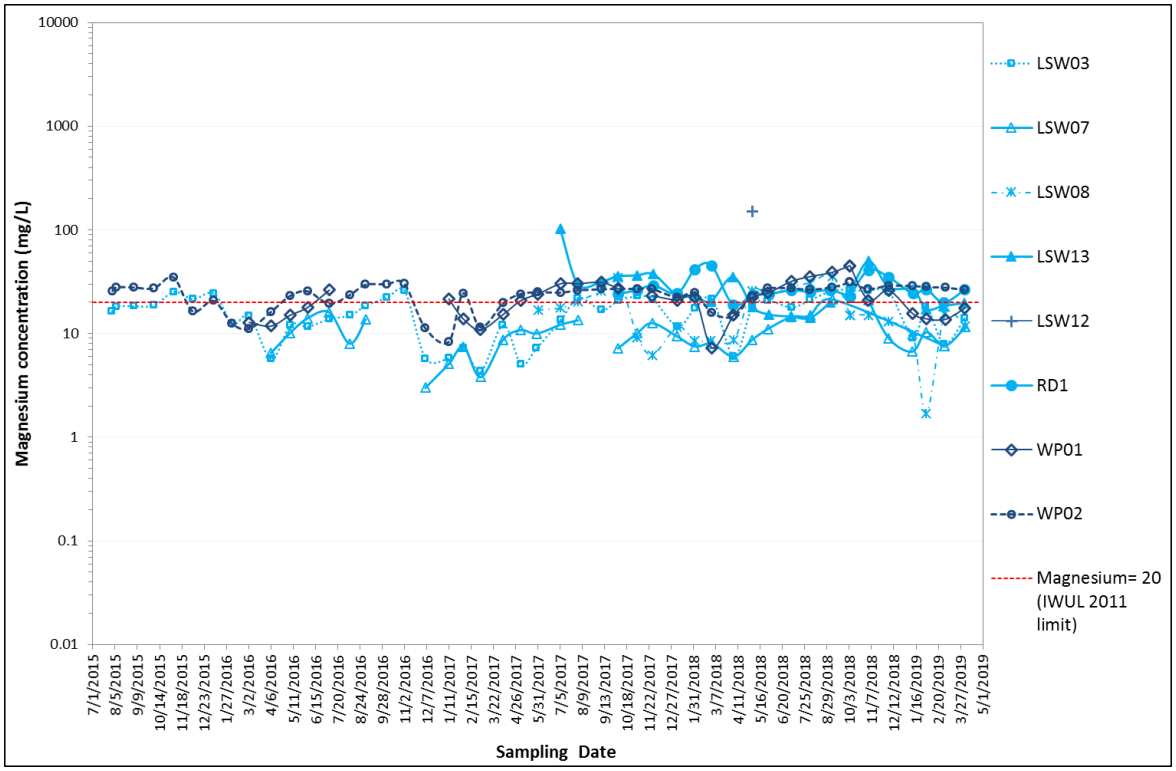


Figure A24: Variation of surface water magnesium

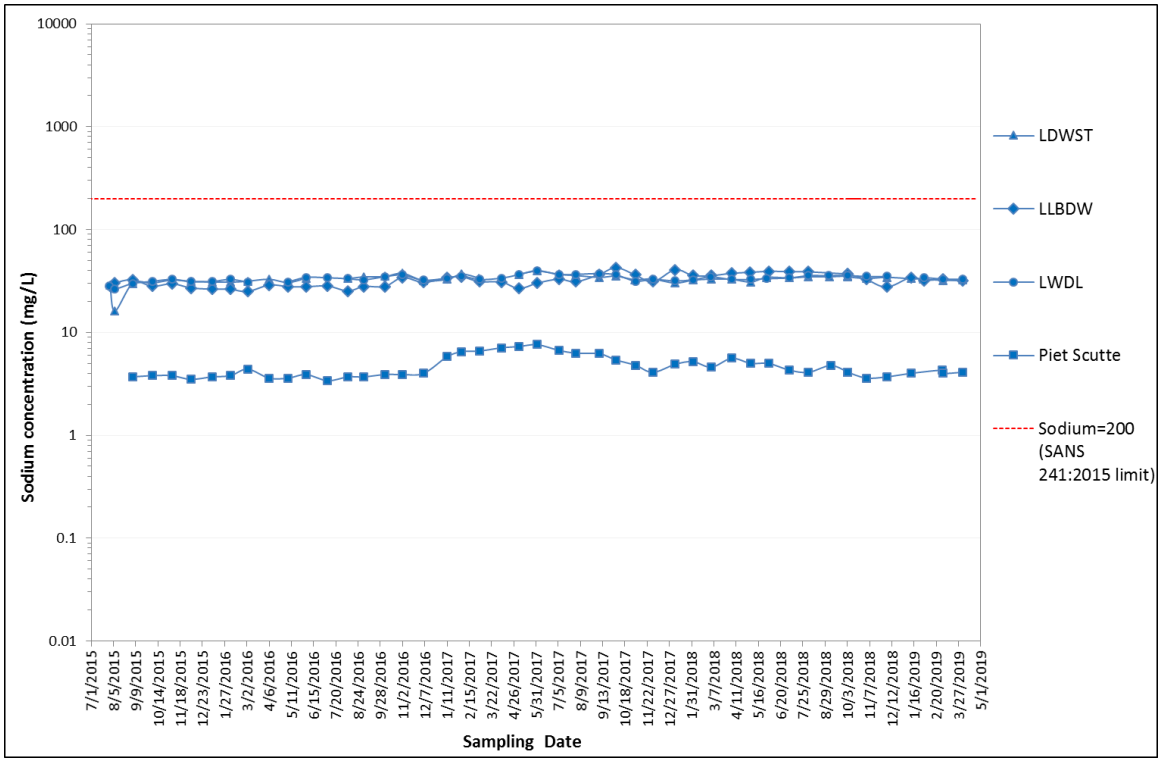


Figure A25: Variation of potable water sodium

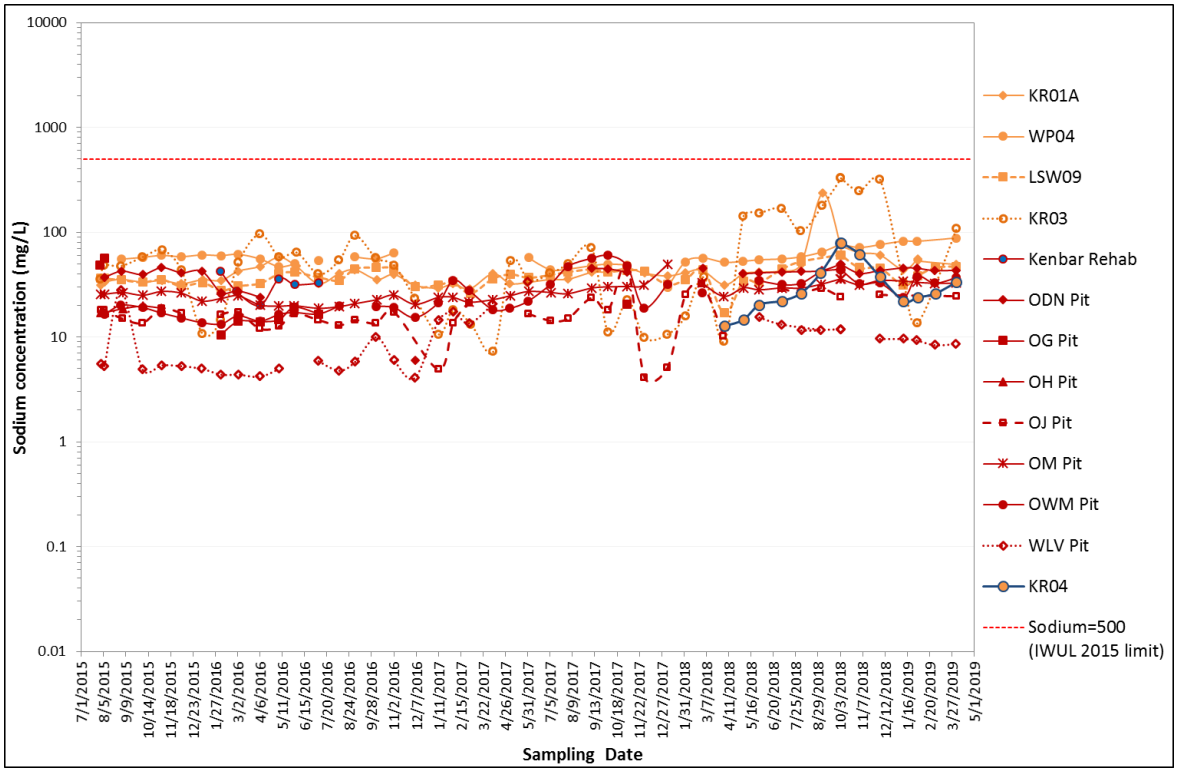


Figure A26: Variation of process water sodium

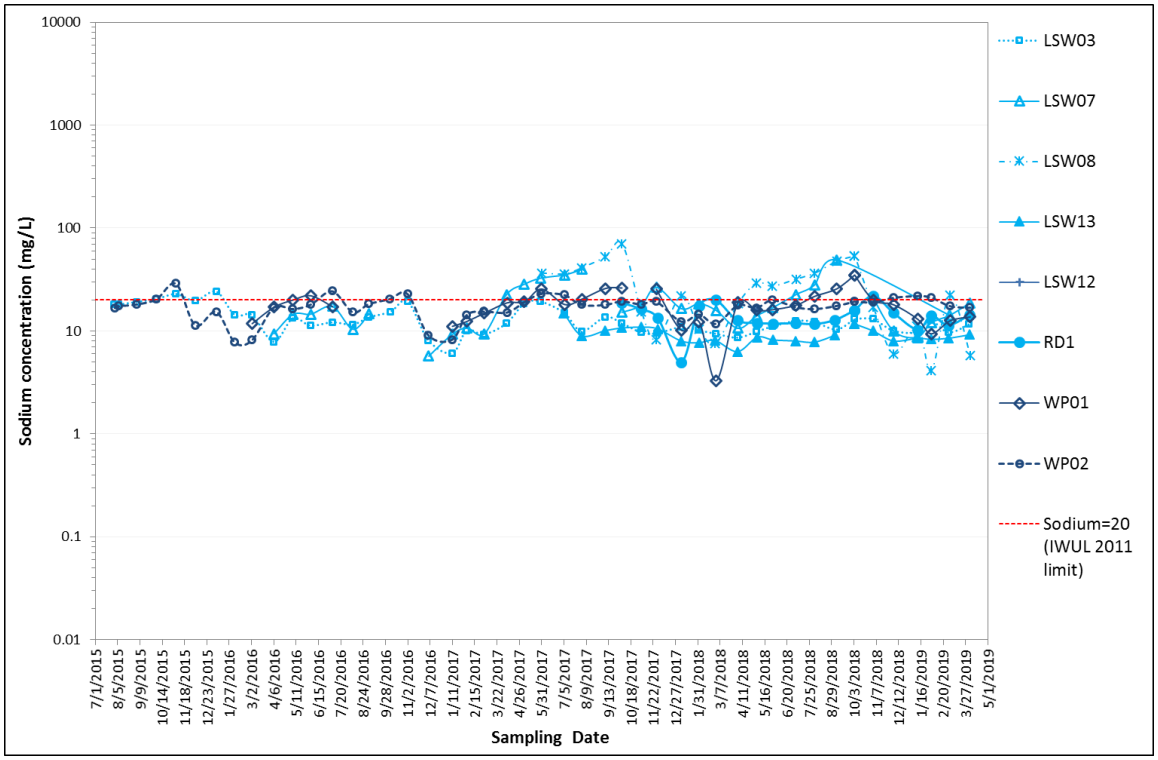


Figure A27: Variation of surface water sodium

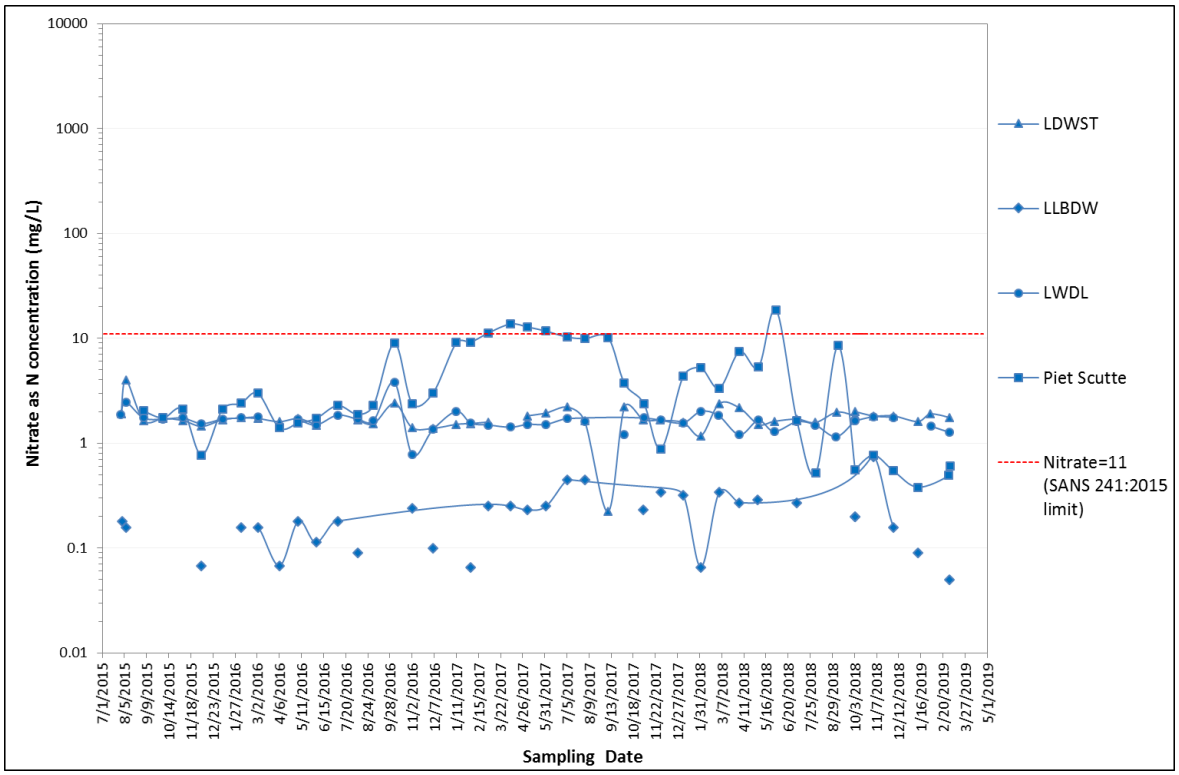


Figure A28: Variation of potable water nitrate

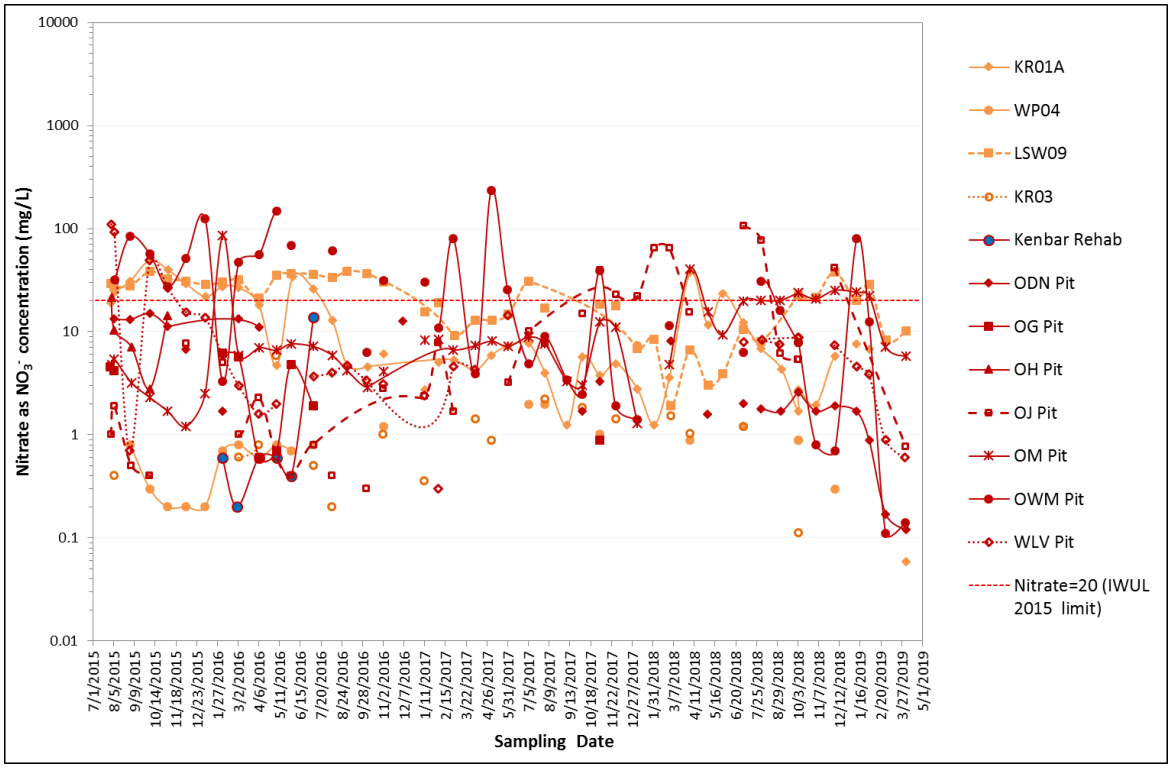


Figure A29: Variation of process water nitrate

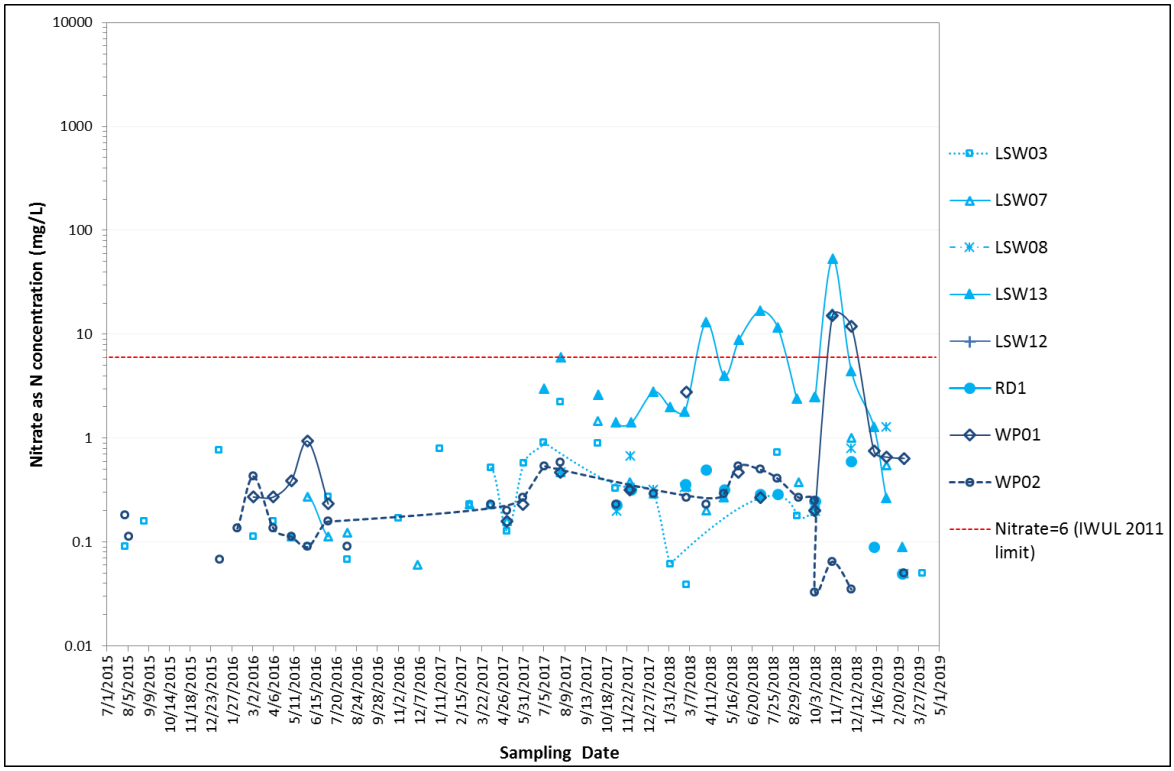


Figure A30: Variation of surface water nitrate

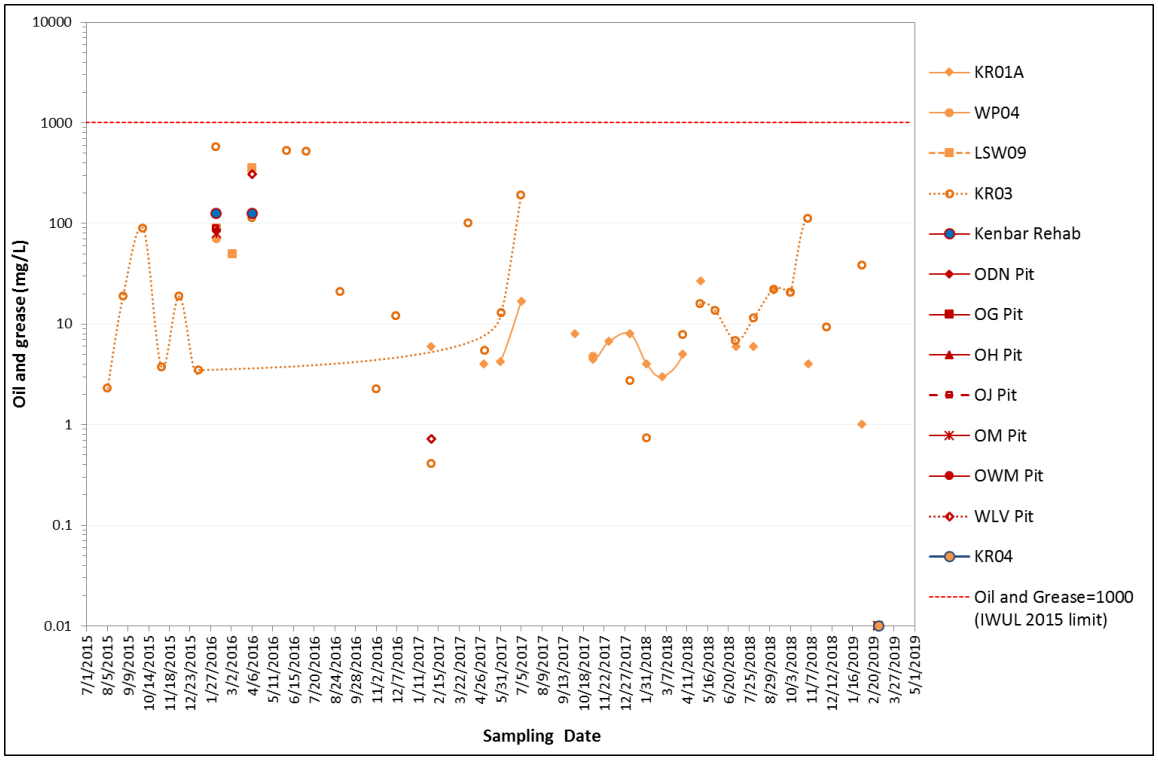


Figure A31: Variation of process water oil and grease

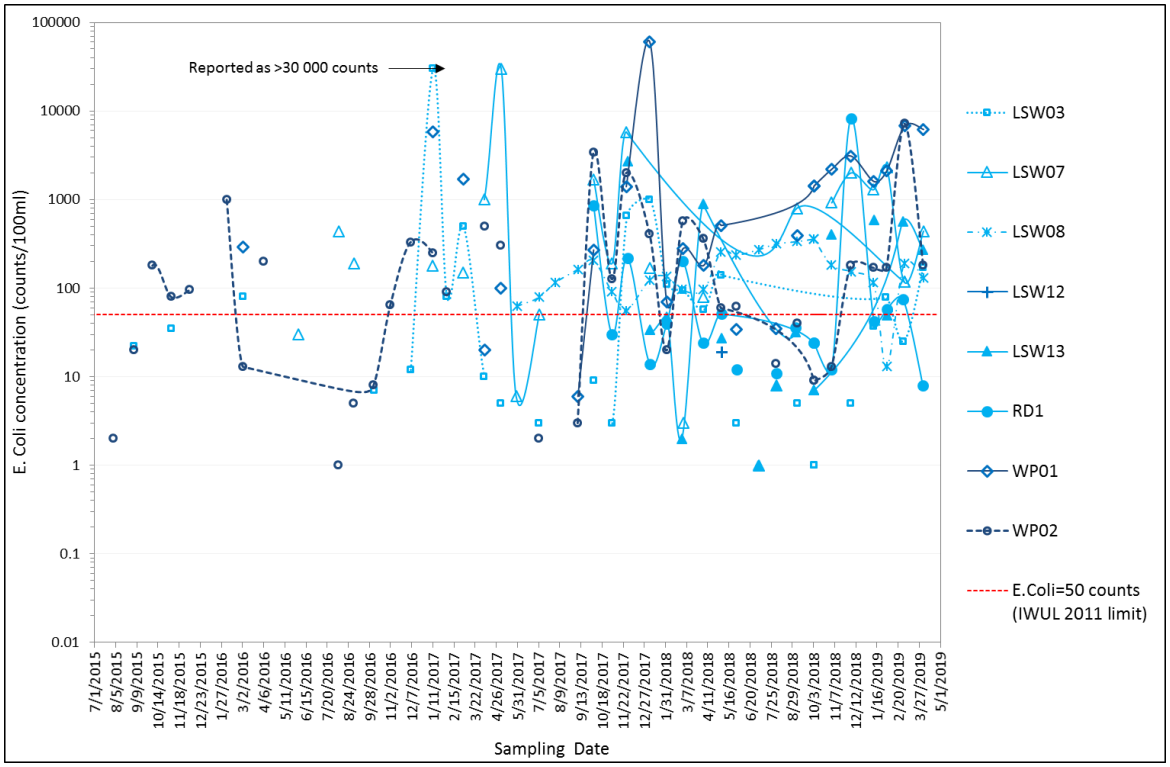


Figure A32: Variation of surface water E. coli

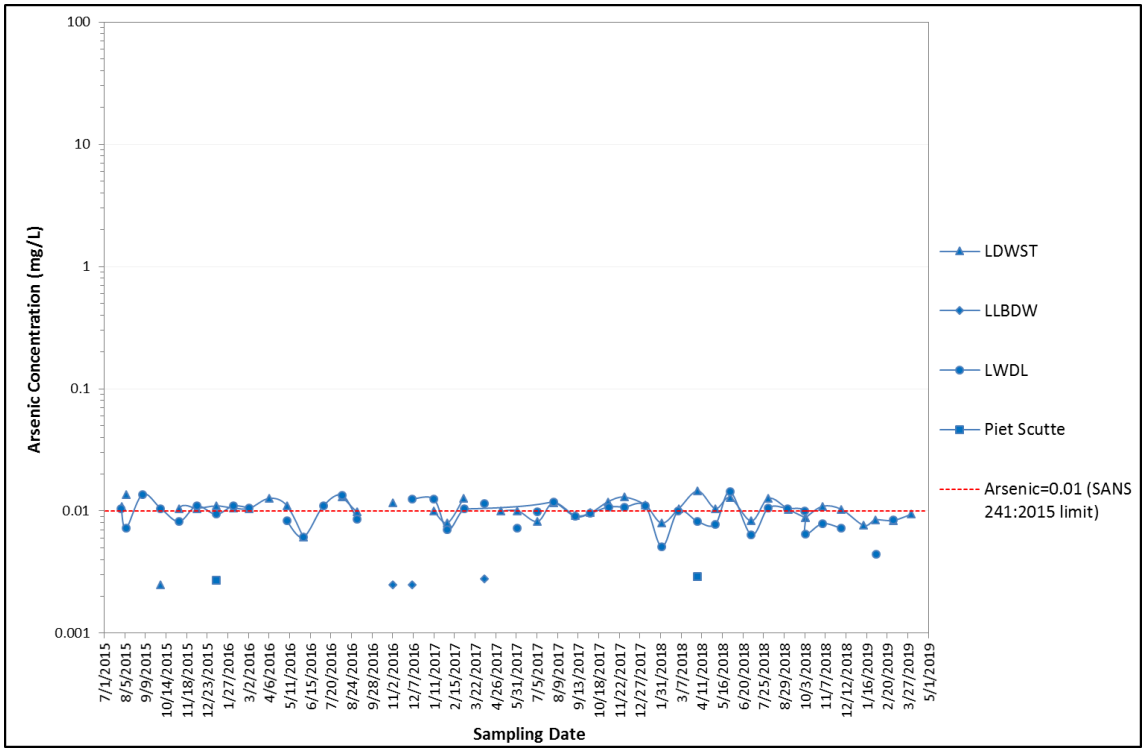


Figure A33: Variation of portable water arsenic

APPENDIX B

Laboratory Certificates

Exova Jones Environmental South Africa

Unit D2/5
9 Quantum Road
Firgrove Business Park
Somerset West
7130
South Africa

Golder Associates (Pty) Ltd
Halfway House, 2nd Floor Podium at Menlyn
43 Ingersol Road
Menlyn
Pretoria
Gauteng
South Africa
0081

Attention :	Keretia Lupankwa
Date :	17th April, 2019
Your reference :	18102350
Our reference :	Test Report 19/281 Batch 1
Location :	Leeuwpan
Date samples received :	8th April, 2019
Status :	Interim report
Issue :	1

Twenty seven samples were received for analysis on 8th April, 2019 of which twenty seven were scheduled for analysis. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

Analysis was undertaken at either Exova Jones Environmental (UK), which is ISO 17025 accredited under UKAS (4225) or Exova Jones Environmental (SA) which is ISO 17025 accredited under SANAS (T0729) or a subcontract laboratory where specified.

NOTE: Under International Laboratory Accreditation Cooperation (ILAC), ISO 17025 (UKAS) accreditation is recognised as equivalent to SANAS (South Africa) accreditation.

Compiled By:

Simon Gomery BSc
Project Manager

Organics Laboratory:

Paloma Booi
Technical Signatory (Organics)

Inorganics Laboratory:

Musa Tiki
Technical Signatory (Inorganics)

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/281

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

J E Sample No.	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	LOD/LOR	Units	Method No.
Sample ID	LNP19_M04_004	LNP19_M04_006	LNP19_M04_008	LNP19_M04_009	LNP19_M04_010	LNP19_M04_011	LNP19_M04_015	LNP19_M04_017	LNP19_M04_019	LNP19_M04_020			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G			
Sample Date	02/04/2019	02/04/2019	02/04/2019	02/04/2019	02/04/2019	02/04/2019	03/04/2019	03/04/2019	03/04/2019	03/04/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019			
Dissolved Aluminium*	<20	<20	<20	<20	<20	<20	<20	<20	<20	26	<20	ug/l	UK_TM30/UK_PM14
Dissolved Antimony*	-	-	-	-	-	-	-	-	-	-	<2	ug/l	UK_TM30/UK_PM14
Dissolved Arsenic*	-	-	-	-	-	-	-	-	-	-	<2.5	ug/l	UK_TM30/UK_PM14
Dissolved Barium*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Dissolved Boron*	28	18	50	155	22	19	19	34	48	275	<12	ug/l	UK_TM30/UK_PM14
Dissolved Cadmium*	-	-	-	-	-	-	-	-	-	-	<0.5	ug/l	UK_TM30/UK_PM14
Dissolved Calcium [SA]	42.4	32.7	111.4	333.4	32.2	31.7	44.0	34.7	67.5	120.0	<0.3	mg/l	SA_TM27/SA_PM0
Total Dissolved Chromium*	-	-	-	-	-	-	-	-	-	-	<1.5	ug/l	UK_TM30/UK_PM14
Dissolved Copper*	-	-	-	-	-	-	-	-	-	-	<7	ug/l	UK_TM30/UK_PM14
Total Dissolved Iron*	72	28	<20	<20	218	224	<20	<20	<20	478	<20	ug/l	UK_TM30/UK_PM14
Dissolved Magnesium [SA]	26.5	19.7	32.3	153.8	13.9	13.7	26.4	17.7	39.1	42.1	<0.2	mg/l	SA_TM27/SA_PM0
Dissolved Potassium [SA]	3.3	1.8	0.4	1.0	8.1	7.9	4.9	11.5	1.7	27.7	<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Sodium [SA]	14.4	9.2	8.6	36.7	11.8	11.8	16.8	13.7	33.4	107.3	<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Lead*	-	-	-	-	-	-	-	-	-	-	<5	ug/l	UK_TM30/UK_PM14
Dissolved Manganese*	719	591	19	353	175	180	232	631	162	672	<2	ug/l	UK_TM30/UK_PM14
Dissolved Mercury*	-	-	-	-	-	-	-	-	-	-	<1	ug/l	UK_TM30/UK_PM14
Dissolved Nickel*	-	-	-	-	-	-	-	-	-	-	<2	ug/l	UK_TM30/UK_PM14
Dissolved Selenium*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Dissolved Uranium*	-	-	-	-	-	-	-	-	-	-	<5	ug/l	UK_TM30/UK_PM14
Dissolved Zinc*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Total Hardness Dissolved (as CaCO3)	217.3	164.5	414.2	1479.5	138.9	136.8	220.9	161.1	333.0	476.8	<1.6	mg/l	SA_TM27/SA_PM0
Total Phosphorus*	81	30	27	31	232	198	65	148	36	4685	<5	ug/l	UK_TM30/UK_PM14
Fats Oils and Grease	<10	<10	<10	<10	<10	<10	<10	<10	<10	145448634 [AC]	<10	ug/l	SA_TM5/SA_PM30
Chloride*	17.6	15.6	6.9	2.9	8.9	9.0	8.0	13.4	10.8	79.8	<0.3	mg/l	UK_TM38/UK_PM0
Ammoniacal Nitrogen as N*	0.15	0.10	0.08	1.04	1.02	0.62	0.09	1.20	0.03	0.53	<0.03	mg/l	UK_TM38/UK_PM0
Hexavalent Chromium*	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO3 [SA]	194	115	63	255	120	122	234	156	56	302	<3	mg/l	SA_TM32/SA_PM0
COD (Settled) [SA]	-	-	-	-	-	-	-	-	-	-	<9	mg/l	SA_TM57/SA_PM0
Dissolved Oxygen (% Saturation)	51.2	75.5	92.9	85.1	20.9	10.0	25.4	42.1	74.6	11.6	<0.1	%	SA_TM59/SA_PM0
Temperature	24.4	24.2	24.3	24.3	24.4	24.0	24.2	24.4	24.4	24.0	<0.1	Degrees C	SA_TM59/SA_PM0
Electrical Conductivity @25C [SA]	517	375	799	2320	345	346	493	411	787	1395	<2	uS/cm	SA_TM28/SA_PM0
Dissolved Organic Carbon*	5	2	<2	<2	17	18	5	10	5	78	<2	mg/l	UK_TM60/UK_PM0
Fluoride*	0.3	0.3	<0.3	<0.3	<0.3	<0.3	<0.3	0.4	0.4	0.3	<0.3	mg/l	UK_TM173/UK_PM0
Nitrite as N*	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	mg/l	UK_TM38/UK_PM0
Nitrate as N*	0.13	<0.05	0.60	0.14	<0.05	<0.05	<0.05	1.67	<0.05	<0.05	<0.05	mg/l	UK_TM38/UK_PM0
Ortho Phosphate as P*	<0.03	<0.03	<0.03	<0.03	<0.03	0.09	<0.03	0.05	<0.03	3.94	<0.03	mg/l	UK_TM38/UK_PM0
pH [SA]	7.76	7.62	7.82	7.87	7.55	7.33	7.94	7.64	7.56	7.27	<2.00	pH units	SA_TM19/SA_PM0
Sulphate as SO4*	28.8	41.0	305.5	1162.4	28.2	27.7	7.1	23.2	299.6	277.0	<0.5	mg/l	UK_TM38/UK_PM0
Total Dissolved Solids [SA]	270	199	579	2165	231	230	290	258	546	1035	<35	mg/l	SA_TM20/SA_PM31

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/281

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

J E Sample No.	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	LOD/LOR	Units	Method No.
Sample ID	LNP19_M04_004	LNP19_M04_006	LNP19_M04_008	LNP19_M04_009	LNP19_M04_010	LNP19_M04_011	LNP19_M04_015	LNP19_M04_017	LNP19_M04_019	LNP19_M04_020			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G			
Sample Date	02/04/2019	02/04/2019	02/04/2019	02/04/2019	02/04/2019	02/04/2019	03/04/2019	03/04/2019	03/04/2019	03/04/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019			
Total Suspended Solids [SA]	-	-	-	-	-	-	-	-	-	-	<10	mg/l	SA_TM37/SA_PM0
Turbidity	91.8	26.6	122.0	141.0	19.6	16.2	24.2	299.0	346.0	624.0	<0.1	NTU	SA_TM34/SA_PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/281

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

J E Sample No.	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100	LOD/LOR	Units	Method No.
Sample ID	LNP19_M04_023	LNP19_M04_024	LNP19_M04_026	LNP19_M04_027	LNP19_M04_028	LNP19_M04_029	LNP19_M04_030	LNP19_M04_035	LNP19_M04_037	LNP19_M04_041			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G			
Sample Date	03/04/2019	03/04/2019	03/04/2019	03/04/2019	03/04/2019	03/04/2019	03/04/2019	03/04/2019	03/04/2019	03/04/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019			
Dissolved Aluminium*	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	ug/l	UK_TM30/UK_PM14
Dissolved Antimony*	-	-	-	-	-	-	-	-	-	-	<2	ug/l	UK_TM30/UK_PM14
Dissolved Arsenic*	-	-	-	-	-	-	-	-	-	-	<2.5	ug/l	UK_TM30/UK_PM14
Dissolved Barium*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Dissolved Boron*	72	82	66	100	69	95	129	30	16	18	<12	ug/l	UK_TM30/UK_PM14
Dissolved Cadmium*	-	-	-	-	-	-	-	-	-	-	<0.5	ug/l	UK_TM30/UK_PM14
Dissolved Calcium SA	564.4 AB	567.7 AB	178.9	342.3	550.9 AB	564.4 AB	398.1	20.8	28.9	40.3	<0.3	mg/l	SA_TM27/SA_PM0
Total Dissolved Chromium*	-	-	-	-	-	-	-	-	-	-	<1.5	ug/l	UK_TM30/UK_PM14
Dissolved Copper*	-	-	-	-	-	-	-	-	-	-	<7	ug/l	UK_TM30/UK_PM14
Total Dissolved Iron*	<20	<20	<20	<20	<20	<20	<20	28	68	20	<20	ug/l	UK_TM30/UK_PM14
Dissolved Magnesium SA	218.5 AB	214.7 AB	65.5	134.7	199.5 AB	233.8 AB	151.2	11.5	11.7	26.3	<0.2	mg/l	SA_TM27/SA_PM0
Dissolved Potassium SA	<0.1	0.5	1.5	1.9	<0.1	0.6	1.2	10.1	6.8	3.0	<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Sodium SA	47.8	47.9	24.5	32.7	43.4	88.1	47.2	18.8	5.8	14.3	<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Lead*	-	-	-	-	-	-	-	-	-	-	<5	ug/l	UK_TM30/UK_PM14
Dissolved Manganese*	353	351	191	260	948	150	56	156	2522	88	<2	ug/l	UK_TM30/UK_PM14
Dissolved Mercury*	-	-	-	-	-	-	-	-	-	-	<1	ug/l	UK_TM30/UK_PM14
Dissolved Nickel*	-	-	-	-	-	-	-	-	-	-	<2	ug/l	UK_TM30/UK_PM14
Dissolved Selenium*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Dissolved Uranium*	-	-	-	-	-	-	-	-	-	-	<5	ug/l	UK_TM30/UK_PM14
Dissolved Zinc*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Total Hardness Dissolved (as CaCO3)	2328.7 AB	2321.0 AB	722.4	1421.5	2215.2 AB	2393.0 AB	1630.3	100.3	121.4	211.2	<1.6	mg/l	SA_TM27/SA_PM0
Total Phosphorus*	44	38	35	32	41	31	32	191	196	50	<5	ug/l	UK_TM30/UK_PM14
Fats Oils and Grease	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	SA_TM5/SA_PM30
Chloride*	11.8	11.8	8.8	7.0	11.1	24.9	12.0	6.8	1.3	19.0	<0.3	mg/l	UK_TM38/UK_PM0
Ammoniacal Nitrogen as N*	0.09	0.10	0.30	0.10	0.19	0.05	0.50	0.54	0.60	0.09	<0.03	mg/l	UK_TM38/UK_PM0
Hexavalent Chromium*	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO3 SA	170	169	141	94	196	58	73	127	131	185	<3	mg/l	SA_TM32/SA_PM0
COD (Settled) SA	-	-	-	-	-	-	-	-	-	-	<9	mg/l	SA_TM57/SA_PM0
Dissolved Oxygen (% Saturation)	67.8	65.4	91.8	90.7	83.6	92.6	96.6	42.0	40.5	71.6	<0.1	%	SA_TM59/SA_PM0
Temperature	24.6	24.4	24.1	23.7	23.5	23.9	23.9	23.4	23.5	23.9	<0.1	Degrees C	SA_TM59/SA_PM0
Electrical Conductivity @25C SA	3260	3270	1331	2270	3130	3540	2580	304	284	472	<2	uS/cm	SA_TM28/SA_PM0
Dissolved Organic Carbon*	<2	<2	<2	<2	<2	15	<2	20	7	6	<2	mg/l	UK_TM60/UK_PM0
Fluoride*	<0.3	<0.3	<0.3	0.3	<0.3	0.5	0.4	0.7	0.5	<0.3	<0.3	mg/l	UK_TM173/UK_PM0
Nitrite as N*	<0.05	<0.05	0.19	0.20	<0.05	<0.05	0.65	<0.05	<0.05	<0.05	<0.05	mg/l	UK_TM38/UK_PM0
Nitrate as N*	0.07	0.10	0.77	5.75	0.12	<0.05	10.11	<0.05	<0.05	<0.05	<0.05	mg/l	UK_TM38/UK_PM0
Ortho Phosphate as P*	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	mg/l	UK_TM38/UK_PM0
pH SA	7.66	7.54	7.93	7.83	7.81	7.87	7.88	7.82	7.79	7.93	<2.00	pH units	SA_TM19/SA_PM0
Sulphate as SO4*	1973.4	1994.8	538.0	1260.9	1818.7	2324.7	1507.4	11.3	2.9	23.7	<0.5	mg/l	UK_TM38/UK_PM0
Total Dissolved Solids SA	3390	3481	1076	2112	3193	3798	2582	200	174	278	<35	mg/l	SA_TM20/SA_PM31

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/281

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

J E Sample No.	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100	LOD/LOR	Units	Method No.
Sample ID	LNP19_M04_023	LNP19_M04_024	LNP19_M04_026	LNP19_M04_027	LNP19_M04_028	LNP19_M04_029	LNP19_M04_030	LNP19_M04_035	LNP19_M04_037	LNP19_M04_041			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G			
Sample Date	03/04/2019	03/04/2019	03/04/2019	03/04/2019	03/04/2019	03/04/2019	03/04/2019	03/04/2019	03/04/2019	03/04/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019			
Total Suspended Solids [SA]	-	-	-	-	-	-	-	-	-	-	<10	mg/l	SA_TM37/SA_PM0
Turbidity	38.3	32.6	14.0	20.8	233.0	9.8	3.5	311.0	126.0	96.9	<0.1	NTU	SA_TM34/SA_PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/281

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

J E Sample No.	101-104	105-108	109-112	113-116	117-120	121-124	125-128				LOD/LOR	Units	Method No.
Sample ID	LNP19_M04_001	LNP19_M04_002	LNP19_M04_013	LNP19_M04_031	LNP19_M04_039	LNP19_M04_033	LNP19_M04_021						
Depth													
COC No / misc													
Containers	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P						
Sample Date	02/04/2019	02/04/2019	02/04/2019	02/04/2019	02/04/2019	02/04/2019	02/04/2019						
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water						
Batch Number	1	1	1	1	1	1	1						
Date of Receipt	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019						
Dissolved Aluminium*	<20	<20	<20	<20	<20	-	-				<20	ug/l	UK_TM30/UK_PM14
Dissolved Antimony*	<2	<2	<2	<2	<2	-	-				<2	ug/l	UK_TM30/UK_PM14
Dissolved Arsenic*	11.2	8.1	<2.5	<2.5	<2.5	-	-				<2.5	ug/l	UK_TM30/UK_PM14
Dissolved Barium*	78	78	164	60	35	-	-				<3	ug/l	UK_TM30/UK_PM14
Dissolved Boron*	66	64	65	135	17	-	-				<12	ug/l	UK_TM30/UK_PM14
Dissolved Cadmium*	<0.5	<0.5	<0.5	<0.5	<0.5	-	-				<0.5	ug/l	UK_TM30/UK_PM14
Dissolved Calcium SA	47.6	47.9	40.4	47.8	9.4	-	-				<0.3	mg/l	SA_TM27/SA_PM0
Total Dissolved Chromium*	<1.5	<1.5	<1.5	<1.5	<1.5	-	-				<1.5	ug/l	UK_TM30/UK_PM14
Dissolved Copper*	<7	8	<7	<7	15	-	-				<7	ug/l	UK_TM30/UK_PM14
Total Dissolved Iron*	<20	<20	31	<20	<20	-	-				<20	ug/l	UK_TM30/UK_PM14
Dissolved Magnesium SA	24.8	24.9	27.2	24.9	5.9	-	-				<0.2	mg/l	SA_TM27/SA_PM0
Dissolved Potassium SA	2.7	2.7	1.6	2.8	0.3	-	-				<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Sodium SA	32.9	32.9	31.6	32.9	4.1	-	-				<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Lead*	<5	<5	<5	<5	<5	-	-				<5	ug/l	UK_TM30/UK_PM14
Dissolved Manganese*	16	15	14	56	19	-	-				<2	ug/l	UK_TM30/UK_PM14
Dissolved Mercury*	<1	<1	<1	<1	<1	-	-				<1	ug/l	UK_TM30/UK_PM14
Dissolved Nickel*	2	2	<2	3	2	-	-				<2	ug/l	UK_TM30/UK_PM14
Dissolved Selenium*	<3	<3	<3	5	<3	-	-				<3	ug/l	UK_TM30/UK_PM14
Dissolved Uranium*	<5	<5	<5	<5	<5	-	-				<5	ug/l	UK_TM30/UK_PM14
Dissolved Zinc*	65	62	127	6	19	-	-				<3	ug/l	UK_TM30/UK_PM14
Total Hardness Dissolved (as CaCO3)	223.2	224.3	215.2	224.1	48.3	-	-				<1.6	mg/l	SA_TM27/SA_PM0
Total Phosphorus*	-	-	-	-	-	-	-				<5	ug/l	UK_TM30/UK_PM14
Fats Oils and Grease	-	-	-	-	-	-	-				<10	ug/l	SA_TM5/SA_PM30
Chloride*	34.9	35.0	34.1	35.3	1.9	-	-				<0.3	mg/l	UK_TM38/UK_PM0
Ammoniacal Nitrogen as N*	0.05	0.26	0.14	0.49	0.04	55.51	32.57				<0.03	mg/l	UK_TM38/UK_PM0
Hexavalent Chromium*	-	-	-	-	-	-	-				<0.006	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO3 SA	152	153	181	152	45	-	-				<3	mg/l	SA_TM32/SA_PM0
COD (Settled) SA	-	-	-	-	-	365_{AA}	44				<9	mg/l	SA_TM57/SA_PM0
Dissolved Oxygen (% Saturation)	-	-	-	-	-	-	-				<0.1	%	SA_TM59/SA_PM0
Temperature	-	-	-	-	-	-	-				<0.1	Degrees C	SA_TM59/SA_PM0
Electrical Conductivity @25C SA	596	596	556	597	115	-	-				<2	uS/cm	SA_TM28/SA_PM0
Dissolved Organic Carbon*	-	-	-	-	-	-	-				<2	mg/l	UK_TM60/UK_PM0
Fluoride*	<0.3	<0.3	<0.3	<0.3	<0.3	-	-				<0.3	mg/l	UK_TM173/UK_PM0
Nitrite as N*	<0.05	<0.05	<0.05	<0.05	<0.05	-	-				<0.05	mg/l	UK_TM38/UK_PM0
Nitrate as N*	1.75	1.64	<0.05	1.65	1.26	<0.05	9.09				<0.05	mg/l	UK_TM38/UK_PM0
Ortho Phosphate as P*	<0.03	<0.03	<0.03	<0.03	0.07	5.27	8.94				<0.03	mg/l	UK_TM38/UK_PM0
pH SA	7.95	7.96	8.11	7.85	7.24	-	-				<2.00	pH units	SA_TM19/SA_PM0
Sulphate as SO4*	77.2	79.3	46.3	80.8	0.6	-	-				<0.5	mg/l	UK_TM38/UK_PM0
Total Dissolved Solids SA	363	372	291	359	71	-	-				<35	mg/l	SA_TM20/SA_PM31

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/281

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

J E Sample No.	101-104	105-108	109-112	113-116	117-120	121-124	125-128				LOD/LOR	Units	Method No.
Sample ID	LNP19_M04_001	LNP19_M04_002	LNP19_M04_013	LNP19_M04_031	LNP19_M04_039	LNP19_M04_033	LNP19_M04_021						
Depth													
COC No / misc													
Containers	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P						
Sample Date	02/04/2019	02/04/2019	02/04/2019	02/04/2019	02/04/2019	02/04/2019	02/04/2019						
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water						
Batch Number	1	1	1	1	1	1	1						
Date of Receipt	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019	08/04/2019						
Total Suspended Solids [SA]	-	-	-	-	-	43	<10				<10	mg/l	SA_TM37/SA_PM0
Turbidity	-	-	-	-	-	-	-				<0.1	NTU	SA_TM34/SA_PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa

J E Job No.	Batch	Sample ID	Depth	J E Sample No.	Analysis	Reason
No deviating sample report results for job 19/281						

Please note that only samples that are deviating are mentioned in this report. If no samples are listed it is because none were deviating.
Only analyses which are accredited are recorded as deviating if set criteria are not met.

NOTES TO ACCOMPANY ALL SCHEDULES AND REPORTS

JE Job No.: 19/281

SOILS

Please note we are only MCERTS accredited (UK soils only) for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

% Asbestos in Asbestos Containing Materials (ACMs) is determined by reference to HSG 264 The Survey Guide - Appendix 2 : ACMs in buildings listed in order of ease of fibre release.

Negative Neutralization Potential (NP) values are obtained when the volume of NaOH (0.1N) titrated (pH 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 - 2.5. Any negative NP values are corrected to 0.

The calculation of Pyrite content assumes that all oxidisable sulphides present in the sample are pyrite. This may not be the case. The calculation may be an overesitimate when other sulphides such as Barite (Barium Sulphate) are present.

WATERS

Please note we are not a UK Drinking Water Inspectorate (DWI) Approved Laboratory .

ISO17025 accreditation applies to surface water and groundwater and usually one other matrix which is analysis specific, any other liquids are outside our scope of accreditation.

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

DEVIATING SAMPLES

Samples must be received in a condition appropriate to the requested analyses. All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. If this is not the case you will be informed and any test results that may be compromised highlighted on your deviating samples report.

SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

DILUTIONS

A dilution suffix indicates a dilution has been performed and the reported result takes this into account. No further calculation is required.

BLANKS

Where analytes have been found in the blank, the sample will be treated in accordance with our laboratory procedure for dealing with contaminated blanks.

NOTE

Data is only reported if the laboratory is confident that the data is a true reflection of the samples analysed. Data is only reported as accredited when all the requirements of our Quality System have been met. In certain circumstances where all the requirements of the Quality System have not been met, for instance if the associated AQC has failed, the reason is fully investigated and documented. The sample data is then evaluated alongside the other quality control checks performed during analysis to determine its suitability. Following this evaluation, provided the sample results have not been effected, the data is reported but accreditation is removed. It is a UKAS requirement for data not reported as accredited to be considered indicative only, but this does not mean the data is not valid.
Where possible, and if requested, samples will be re-extracted and a revised report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.

REPORTS FROM THE SOUTH AFRICA LABORATORY

Any method number not prefixed with SA has been undertaken in our UK laboratory unless reported as subcontracted.

ABBREVIATIONS and ACRONYMS USED

#	ISO17025 (UKAS Ref No. 4225) accredited - UK.
SA	ISO17025 (SANAS Ref No.T0729) accredited - South Africa.
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance
SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
++	Result outside calibration range, results should be considered as indicative only and are not accredited.
*	Analysis subcontracted to an Exova Jones Environmental approved laboratory.
AD	Samples are dried at 35°C ±5°C
CO	Suspected carry over
LOD/LOR	Limit of Detection (Limit of Reporting) in line with ISO 17025 and MCERTS
ME	Matrix Effect
NFD	No Fibres Detected
BS	AQC Sample
LB	Blank Sample
N	Client Sample
TB	Trip Blank Sample
OC	Outside Calibration Range
AA	x5 Dilution
AB	x10 Dilution
AC	x100 Dilution

JE Job No: 19/281

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
SA_TM19	Determination of pH by bench pH meter	SA_PM0	No preparation is required.	Yes			
SA_TM20	Modified BS 1377-3: 1990 Gravimetric determination of Total Dissolved Solids	SA_PM31	Sample is filtered	Yes			
SA_TM27	Major ions by Ion Chromatography	SA_PM0	No preparation is required.				
SA_TM27	Major ions by Ion Chromatography	SA_PM0	No preparation is required.	Yes			
SA_TM28	Determination of Electrical Conductivity with hand held manual conductivity probe.	SA_PM0	No preparation is required.	Yes			
SA_TM32	Determination of Alkalinity by titration of the sample with a standard solution of acid by visual detection of end points.	SA_PM0	No preparation is required.	Yes			
SA_TM34	Turbidity by TL2300 Turbidity Meter	SA_PM0	No preparation is required.				
SA_TM37	Modified BS EM 872:2005 .Gravimetric determination of Total Suspended Solids. Sample is filtered and the resulting residue is dried and weighed.	SA_PM0	No preparation is required.	Yes			
SA_TM5	Modified USEPA 8015B method for the determination of solvent Extractable Petroleum Hydrocarbons (EPH) with carbon banding within the range C8-C40 GC-FID.	SA_PM30	Water samples are extracted with solvent using a magnetic stirrer to create a vortex.				
SA_TM57	Modified US EPA Method 410.4. Chemical Oxygen Demand is determined by hot digestion with Potassium Dichromate and measured spectrophotometerically.	SA_PM0	No preparation is required.	Yes			

JE Job No: 19/281

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
SA_TM59	Determination of Dissolved Oxygen using the Hach HQ30D Oxygen Meter	SA_PM0	No preparation is required.				
UK_TM173	Analysis of fluoride by ISE (Ion Selective Electrode) using modified ISE method 340.2	UK_PM0	No preparation is required.				
UK_TM30	Determination of Trace Metal elements by ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometry). Modified US EPA Method 200.7, 6010B and BS EN ISO 11885 2009	UK_PM14	Analysis of waters and leachates for metals by ICP OES/ICP MS. Samples are filtered for dissolved metals and acidified if required.				
UK_TM38	Soluble Ion analysis using the Thermo Aquakem Photometric Automatic Analyser. Modified US EPA methods 325.2, 375.4, 365.2, 353.1, 354.1	UK_PM0	No preparation is required.				
UK_TM60	Modified USEPA 9060. Determination of TOC by calculation from Total Carbon and Inorganic Carbon using a TOC analyser, the carbon in the sample is converted to CO2 and then passed through a non-dispersive infrared gas analyser (NDIR).	UK_PM0	No preparation is required.				

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FINAL CERTIFICATE OF ANALYSIS	
Report Date	2019-04-16
Date Required	2019-04-14
Contract No	
Order/Ref No	18102350 Leeuwpan

sanas Testing Laboratory T0184

18102350 Leeuwpan

Notes
The results relate specifically to the items tested.
The report shall not be reproduced except in full, without the written approval of the laboratory.
[1] SANAS accredited analysis included in the SANAS Schedule of Accredition for this laboratory.
[2] Not SANAS accredited analysis and not included in the SANAS schedule of accreditation for this laboratory.
[3] Outsourced not performed by this laboratory.

Request ID: 26553 **Sample ID:** 623725 **Received:** 2019-04-04 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M04_005 **Revision Number:** 0

Method: [2]UIS-OS-T034(Chlorophyll A) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Chlorophyll -a	7	ug/l

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Escherichia coli	8	Colonies/100ml

Request ID: 26553 **Sample ID:** 623726 **Received:** 2019-04-04 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M04_007 **Revision Number:** 0

Method: [2]UIS-OS-T034(Chlorophyll A) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Chlorophyll -a	4	ug/l

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Escherichia coli	270	Colonies/100ml

Request ID: 26553 **Sample ID:** 623727 **Received:** 2019-04-04 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M04_014 **Revision Number:** 0

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Escherichia coli	0	Colonies/100ml

Request ID: 26553 **Sample ID:** 623728 **Received:** 2019-04-04 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M04_016 **Revision Number:** 0

Method: [2]UIS-OS-T034(Chlorophyll A) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Chlorophyll -a	11	ug/l

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Escherichia coli	180	Colonies/100ml

Request ID: 26553 **Sample ID:** 623729 **Received:** 2019-04-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M04_018 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-04-16

Parameter	Value	Unit
²Chlorophyll -a	1	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-04-16

Parameter	Value	Unit
²Escherichia coli	6200	Colonies/100ml

Request ID: 26553 **Sample ID:** 623730 **Received:** 2019-04-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M04_022 **Revision Number:** 0

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-04-16

Parameter	Value	Unit
²Escherichia coli	540	Colonies/100ml

Request ID: 26553 **Sample ID:** 623731 **Received:** 2019-04-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M04_032 **Revision Number:** 0

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-04-16

Parameter	Value	Unit
²Escherichia coli	5	Colonies/100ml

Request ID: 26553 **Sample ID:** 623732 **Received:** 2019-04-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M04_034 **Revision Number:** 0

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-04-16

Parameter	Value	Unit
²Escherichia coli	1180000	Colonies/100ml

Request ID: 26553 **Sample ID:** 623733 **Received:** 2019-04-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M04_036 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-04-16

Parameter	Value	Unit
²Chlorophyll -a	5	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-04-16

Parameter	Value	Unit
²Escherichia coli	440	Colonies/100ml

Request ID: 26553 **Sample ID:** 623734 **Received:** 2019-04-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M04_038 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-04-16

Parameter	Value	Unit
²Chlorophyll -a	73	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-04-16

Parameter	Value	Unit
²Escherichia coli	43	Colonies/100ml

Request ID: 26553 **Sample ID:** 623735 **Received:** 2019-04-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M04_040 **Revision Number:** 0

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-04-16

Parameter	Value	Unit
²Escherichia coli	0	Colonies/100ml

Request ID: 26553 **Sample ID:** 623736 **Received:** 2019-04-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M04_042 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-04-16

Parameter	Value	Unit
²Chlorophyll -a	4	ug/l

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Escherichia coli	260	Colonies/100ml

Method: [2]UIS-OS-T034(Chlorophyll A) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Chlorophyll -a	65	ug/l

Method: [2]UIS-CP-T009(Total Inorganic Nitrogen (Dissolved)) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Total Inorganic Nitrogen	0.094	mg/l

Method: [1]UIS-EA-T001(pH) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	7.61		[2]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	31.9	mSm	[1]Total Conductivity	31.9	mS/m	[2]TC Temperature	22.1	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	207	mg/l	[2]TDS by EC*7	223	mg/l

Method: [1]UIS-EA-T005(Total Dissolved Solids) **Completed:** 2019-04-16

Parameter	Value	Unit
[1]Total Dissolved Solids at 180C	228	mg/l

Method: [2]UIS-CP-T004(Calculated Hardness) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca Hardness	77.8	mg/l CaCO3	[2]Mg Hardness	61	mg/l CaCO3	[2]Total Hardness	139	mg/l CaCO3

Method: [2]UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]TDS by Summation	137	mg/l

Method: [2]UIS-CP-T006(Calculated Sodium Adsorption Ratio) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Sodium Adsorption Ratio	0.409	

Method: [2]UIS-EA-T029(Turbidity) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Turbidity	8.42	NTU

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	120	mg/l CaCO3

Method: [1]UIS-AC-T007(Dissolved Elements in Water by ICP-OES) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	<0.05	mg/l	[2]B	<0.05	mg/l	[1]Ca	31.1	mg/l
[2]Fe	0.09	mg/l	[1]K	8.27	mg/l	[1]Mg	14.8	mg/l
[2]Mn	0.08	mg/l	[1]Na	11.1	mg/l			

Method: [1]UIS-EA-T034(Anions by Photometry) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Fluoride F	0.352	mg/l	[1]Chloride Cl	9.75	mg/l	[2]Nitrate NO3	<0.13	mg/l
[1]Nitrate NO3 as N	<0.13	mg/l	[2]Nitrite NO2	0.021	mg/l	[1]Phosphate PO4 as P	0.005	mg/l
[2]Nitrite NO2 as N	0.006	mg/l	[1]Phosphate PO4	0.014	mg/l	[1]Sulphate SO4	26.9	mg/l

Method: [2]UIS-CP-T005(Ion Balance Error Gallery) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	3.48	me/l	[2]Sum of Anions	2.86	me/l	[2]Ion Error Balance	9.76	%

Method: [2]UIS-EA-T111(Hexavalent Chromium in Liquid (Photometry)) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Hexavalent Chromium in Liquid (Photometry)	<0.001	mg/l

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Escherichia coli	170	Colonies/100ml

Method: [2]UIS-EA-T035(Dissolved Oxygen) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Dissolved Oxygen	1.4	mg/l O2

Method: [2]UIS-EA-T007(Determination of Oil and Grease) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Total Oil and Grease	<1	ppm

Method: [1]UIS-EA-T034a(Ammonia by Photometry) **Completed:** 2019-04-16

Parameter	Value	Unit
[1]Ammonia as N	0.071	mg/l

Method: [2]UIS-TEA-T002(Total Cations in Water by ICP-OES) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Total P as P	0.58	mg/l

Method: [3]UIS-OS-T015(Dissolved Organic Carbon) **Completed:** 2019-04-16

Parameter	Value	Unit
[3]Dissolved Organic Carbon (OL)	21.3	mg/l

Request ID: 26553 **Sample ID:** 623738 **Received:** 2019-04-04 **Matrix:** Water **Page:** 4 / 6
Sample Number: LNP19_M04_003 **Revision Number:** 0

Method: [2]UIS-EA-T043(Total trace elements in liquid by ICP-MS) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Tot. Cr	0.002	mg/l

Method: [1]UIS-EA-T001(pH) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	8.12		[2]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	55.1	mSm	[1]Total Conductivity	55.1	mS/m	[2]TC Temperature	22	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	358	mg/l	[2]TDS by EC*7	386	mg/l

Method: [1]UIS-EA-T005(Total Dissolved Solids) **Completed:** 2019-04-16

Parameter	Value	Unit
[1]Total Dissolved Solids at 180C	406	mg/l

Method: [2]UIS-CP-T004(Calculated Hardness) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca Hardness	111	mg/l CaCO3	[2]Mg Hardness	108	mg/l CaCO3	[2]Total Hardness	219	mg/l CaCO3

Method: [2]UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]TDS by Summation	197	mg/l

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	152	mg/l CaCO3

Method: [1]UIS-AC-T007(Dissolved Elements in Water by ICP-OES) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	<0.05	mg/l	[2]B	0.07	mg/l	[1]Ca	44.5	mg/l
[2]Fe	<0.05	mg/l	[1]K	4.31	mg/l	[1]Mg	26.2	mg/l
[2]Mn	<0.05	mg/l	[1]Na	30.7	mg/l			

Method: [1]UIS-EA-T034(Anions by Photometry) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Fluoride F	0.232	mg/l	[1]Chloride Cl	32.5	mg/l	[2]Nitrate NO3	8.97	mg/l
[1]Nitrate NO3 as N	2.03	mg/l	[2]Nitrite NO2	0.014	mg/l	[1]Phosphate PO4 as P	0.005	mg/l
[2]Nitrite NO2 as N	0.004	mg/l	[1]Phosphate PO4	0.014	mg/l	[1]Sulphate SO4	75.6	mg/l

Method: [2]UIS-CP-T005(Ion Balance Error Gallery) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	5.83	me/l	[2]Sum of Anions	5.18	me/l	[2]Ion Error Balance	5.92	%

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Escherichia coli	2	Colonies/100ml

Method: [2]UIS-AC-T100(Trace elements in liquids by ICP-MS) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]As	0.009	mg/l	[2]Ba	0.055	mg/l	[2]Cd	<0.0001	mg/l
[2]Co	<0.001	mg/l	[2]Cr	<0.001	mg/l	[2]Cu	0.001	mg/l
[2]Hg	<0.0001	mg/l	[2]Mn	0.014	mg/l	[2]Mo	0.002	mg/l
[2]Ni	0.007	mg/l	[2]Pb	<0.001	mg/l	[2]Sb	<0.001	mg/l
[2]Se	0.001	mg/l	[2]U	<0.0001	mg/l	[2]V	0.004	mg/l
[2]Zn	0.05	mg/l						

Method: [1]UIS-EA-T034a(Ammonia by Photometry) **Completed:** 2019-04-16

Parameter	Value	Unit
[1]Ammonia as N	<0.009	mg/l

Request ID: 26553 **Sample ID:** 623739 **Received:** 2019-04-04 **Matrix:** Water **Page:** 5 / 6
Sample Number: LNP19_M04_025 **Revision Number:** 0

Method: [2]UIS-CP-T009(Total Inorganic Nitrogen (Dissolved)) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Total Inorganic Nitrogen	0.008	mg/l

Method: [1]UIS-EA-T001(pH) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	7.96		[2]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	431	mSm	[1]Total Conductivity	431	mS/m	[2]TC Temperature	22.4	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	2800	mg/l	[2]TDS by EC*7	3020	mg/l

Method: [1]UIS-EA-T005(Total Dissolved Solids) **Completed:** 2019-04-16

Parameter	Value	Unit
[1]Total Dissolved Solids at 180C	3320	mg/l

Method: [2]UIS-CP-T004(Calculated Hardness) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca Hardness	1320	mg/l CaCO3	[2]Mg Hardness	975	mg/l CaCO3	[2]Total Hardness	2290	mg/l CaCO3

Method: [2]UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]TDS by Summation	928	mg/l

Method: [2]UIS-CP-T006(Calculated Sodium Adsorption Ratio) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Sodium Adsorption Ratio	0.469	

Method: [2]UIS-EA-T029(Turbidity) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Turbidity	25.2	NTU

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	170	mg/l CaCO3

Method: [1]UIS-AC-T007(Dissolved Elements in Water by ICP-OES) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	<0.05	mg/l	[2]B	0.09	mg/l	[1]Ca	527	mg/l
[2]Fe	<0.05	mg/l	[1]K	10.6	mg/l	[1]Mg	237	mg/l
[2]Mn	0.25	mg/l	[1]Na	51.7	mg/l			

Method: [1]UIS-EA-T034(Anions by Photometry) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Fluoride F	<0.042	mg/l	[1]Chloride Cl	12.4	mg/l	[1]Nitrate NO3 as N	<0.13	mg/l
[2]Nitrite NO2	0.028	mg/l	[1]Phosphate PO4 as P	<0.002	mg/l	[2]Nitrite NO2 as N	0.008	mg/l
[1]Phosphate PO4	0.004	mg/l	[1]Sulphate SO4	1890	mg/l			

Method: [2]UIS-CP-T005(Ion Balance Error Gallery) **Completed:** 2019-04-16

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	48.3	me/l	[2]Sum of Anions	42.6	me/l	[2]Ion Error Balance	6.3	%

Method: [2]UIS-EA-T111(Hexavalent Chromium in Liquid (Photometry)) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Hexavalent Chromium in Liquid (Photometry)	0.003	mg/l

Method: [2]UIS-EA-T035(Dissolved Oxygen) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Dissolved Oxygen	6.14	mg/l O2

Method: [2]UIS-EA-T007(Determination of Oil and Grease) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Total Oil and Grease	<1	ppm

Method: [1]UIS-EA-T034a(Ammonia by Photometry) **Completed:** 2019-04-16

Parameter	Value	Unit
[1]Ammonia as N	<0.009	mg/l

Method: [2]UIS-TEA-T002(Total Cations in Water by ICP-OES) **Completed:** 2019-04-16

Parameter	Value	Unit
[2]Total P as P	<0.05	mg/l

Method: [3]UIS-OS-T015(Dissolved Organic Carbon) **Completed:** 2019-04-16

Parameter	Value	Unit
[3]Dissolved Organic Carbon (OL)	<10	mg/l

Petunia Moleta
AUTHORISED SIGNATORY

APPENDIX C

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GOLDER ASSOCIATES AFRICA (PTY) LTD



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Annexure C
March 2019 Quarterly Monitoring Report



REPORT

EXXARO COAL MPUMALANGA (PTY) LTD

Leeuwpan Coal Mine Quarterly Water Monitoring Report, March 2019

Submitted to:

Exxaro Coal Mpumalanga (Pty) Ltd
Leeuwpan Coal Mine

Submitted by:

Golder Associates Africa (Pty) Ltd.
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18102350-325741-14

April 2019



Distribution List

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Record of Issue

Company	Client Contact	Version	Date Issued	Method of Delivery
Exxaro Coal Mpumalanga (Pty) Ltd	Sthembiso Hinani	Final	9 April 2019	Email

Executive Summary

Golder Associates Africa (Pty) Ltd Mine Water Africa Group (GAA), was appointed by Exxaro Coal Mpumalanga (Pty) Ltd (Exxaro) to conduct surface and groundwater monitoring and analysis for their Leeuwpan Coal Mine for a three-year period to ensure compliance to their approved Integrated Water Use License (IWUL) number 04/B21A/ABCGIJ/429 and its amendments.

The main observations from the data of the first quarter of 2019 were:

1) The drinking water from all potable water sources was characterized by a calcium/magnesium-bicarbonate signature throughout the first quarter of 2019, which is typical of shallow, freshly recharged groundwater or water from dolomitic aquifer not affected by mining activities.

2) The levels of constituents in drinking water was compliant to SANS 241: 2015 drinking water quality standards from January to March 2019 apart from marginal exceedance of *Escherichia coli* in water from the drinking water in January 2019 (Piet Schutte).

3) The levels of measured constituents in drinking water were relatively stable throughout the first quarter in drinking water from all sources apart from slight decreases in sulphate levels in drinking water from Piet Schutte borehole in March 2019.

4) The following parameters (mine water parameters in bold) were not compliant to water quality limits specified in the IWUL at least once during the first quarter of 2019:

    a. LSW08 (Bronkhorstspruit, upstream of Block OI): **electrical conductivity**, **ammonia,** sodium, calcium, **aluminium, manganese**, total alkalinity, iron, **dissolved oxygen**, chlorophyll *a, E. coli* and dissolved organic carbon;

    b. LSW07 (Bronkhorstspruit upstream of Leeuwpan mine): ammonia, potassium, *E. coli,* total phosphorous, dissolved oxygen, chlorophyll *a* and dissolved organic carbon;

    c. LSW03 (Bronkhorstspruit adjacent to Delmas Silica): **electrical conductivity, sulphate, fluoride**, ammonia, aluminum, calcium, **manganese**, potassium, total phosphorous, *E. coli,* dissolved oxygen and dissolved organic carbon;

    d. RD1 (Bronkhorstspruit at haul road): **electrical conductivity**, **sulphate**, ammonia, calcium, **manganese, magnesium,** total alkalinity, Chlorophyll a, dissolved oxygen and *E. coli*;

    e. LSW13 (Stuart Coal): **total dissolved solids**, **electrical conductivity**, **sulphate**; ammonia, calcium, **magnesium, manganese,** *E. coli*, chlorophyll a and dissolved oxygen;

    f. LSW05 (Bronkhorstspruit downstream): **electrical conductivity**, **sulphate**, ammonia, calcium, **magnesium**, **manganese**, total alkalinity, dissolved oxygen and *E. coli;*

    g. WP01 (Bronkhorstspruit tributary upstream of the mine): sulphate, ammonia, calcium, **manganese**, potassium, total alkalinity, total phosphorous, dissolved oxygen and *E. coli*; and

h. WP02 (Bronkhorstspruit tributary downstream of the mine): **total dissolved solids**, **electrical conductivity**, ammonia, calcium, **magnesium, manganese,** sodium, total alkalinity, *E. coli*, dissolved oxygen and dissolved organic carbon.

5) The levels of most constituents were elevated at the upstream compared to the downstream sites during the first quarter of 2018. The following constituents (mine water parameters in bold) increased at downstream sites compared to upstream at least once during the reporting period:

   a. WP02: The level of calcium, total alkalinity, total hardness, dissolved oxygen (a positive sign) and chlorophyll *a*; and

   b. LSW05: The levels **conductivity, sulphate** (exceeded IWUL limit), calcium, magnesium (exceeded IWUL limits), dissolved oxygen (a negative sign) increased downstream.

6) The increases in levels and non-compliance of sulphate suggests impacts of mining activities on the streams- however, sources are broader than just the Leeuwpan Coal Mine and could include Delmas Silica and Stuart Coal. In addition to mining activities, nitrate could be from agricultural activities.

7) The elevated levels of sulphate and near-neutral to alkaline pH in mine process water can be attributed to oxidation of sulphides in coal, wall rock and in-pit spoils and their subsequent neutralization by carbonate minerals. The mine process water was classified based on pH and sulphate levels as:

   a. Saline Drainage: KR01A, WP04, LSW09, ODN pit and OM pit; and

   b. Neutral mine drainage: OWM pit, KR03, KR04, WLV pit and OJ pit.

8) The levels of all constituents measured at the process water sites were within the IWUL limits, except for nitrate at the OWM pit in January 2019;

9) The sewage plant performance has improved by March 2019, but the effluent remains non-compliant in terms of ammonia concentrations

10) The concentrations of ammonia, orthophosphate and *E. Coli* were above the IWUL limit in January and February 2019 of the first quarter. Chemical oxygen demand was elevated and increased throughout the reporting period for the LWP-SP-P sewage treatment plant. The septic tank should continue to be emptied by an accredited waste removal company and disposed of to an authorized wastewater treatment works.

11) Decreases in water depth levels were recorded in most boreholes during March 2019. The highest decrease in water level of 5.29 m was recorded in borehole WOLMB15_S.

12) The water level data indicates a water divide around MOAMB4 and RKL01, with water generally flowing to the northeast and northwest in alignment with topography, and towards the Bronkhorstspruit to the east as well as the Bronkhorstspruit tributary to the west.

13) The levels of most measured constituents were relatively stable in most sampled boreholes.

14) Most measured constituents were compliant to SANS 241: 2015 drinking water in most sampled boreholes in March 2019. Exceptions were:

   a. RKL02: chronic health exceedance of iron and aesthetic standard exceedance of manganese;

b. RKL01: chronic health standard exceedance of manganese;

c. KENMB2-D: aesthetic standards exceedances of total dissolved solids and electrical conductivity, and acute health standards exceedance of sulphate;

d. WELMB13-S: aesthetic standards exceedances of total dissolved solids, acute health standard exceedance of sulphate; and chronic health standard exceedances of iron and manganese;

e. WELMB13-D: aesthetic standard exceedance of manganese;

f. LEEMB18-D: aesthetic standards of sulphate;

g. LW07: aesthetic standards of iron;

h. MOAMB9: aesthetic standard exceedance of iron and manganese;

i. WOLMB15-S: aesthetic standard exceedances of total dissolved solids and electrical conductivity; and acute health standard exceedance of sulphate; and

j. WOLMB15-D: aesthetic standards of sulphate; and

k. RIE4: chronic health standard exceedances of iron and manganese, , aesthetic standard for alkalinity.

15) Groundwater in boreholes WOLMB15S, WOLMB15D, WELMB13S, KENMB2D, LEEMB18D and WELMB13D was characterized by a calcium/magnesium-sulphate signature whilst water in boreholes and RIE4 was characterized by a magnesium/calcium-chloride signature. This suggest that the groundwater in these boreholes is impacted by mining activities.

16) Quality assurance showed discrepancies were recorded between laboratory measured and field measured dissolved oxygen. The inter-lab sample pairs, intra-lab sample pairs and ion charge balance were generally acceptable for most samples. The TDS ratios were generally acceptable for laboratory measurements and unacceptable for most field measurements on both surface and groundwater.

17) It is difficult to obtain samples from the closed pits such as Kenbar Rehab, OG Pit and OH Pit. Surface water does not readily accumulate, as it infiltrates through the rehabilitated ground. The water quality of rehabilitated pits should be monitored through boreholes drilled into the backfilled spoils – becoming part of the groundwater monitoring programme instead of the surface water monitoring programme.

18) The following boreholes need to be drilled out or replaced: EMPR02/E2, KENMB1, KENMB2-S, LGW04, WTN01-D, WWN01, LW10 and RKL03.

19) Stuart Coal must be approached again to agree to access to WTN02-D and to provide a letter for monitoring staff to show.

20) The four kinetic barrels remain non-functional. Consideration should be given to fixing the taps and to placing the barrels on an elevated platform so that drainage can be collected during the rainy season.

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1.0 INTRODUCTION

Golder Associates Africa (Pty) Ltd Mine Water Africa Group (GAA), was appointed by Exxaro Coal Mpumalanga (Pty) Ltd (Exxaro) to conduct surface and groundwater monitoring and analysis for their Leeuwpan Coal Mine for a three-year period to ensure compliance to their approved Integrated Water Use License (IWUL) number 04/B21A/ABCGIJ/429, which was amended in December 2015.

The Leeuwpan Coal Mine is an active mine located to the east of the town of Delmas in the Victor Khanye Local Municipality in Mpumalanga.

The mine is situated within the Upper Olifants River Catchment, quaternary catchment B20A. The main river in the sub-catchment is the Bronkhorstspruit River flowing on the eastern side of the mine and the Bronkhorstspruit tributary flowing on the western side of the mine. The confluence of the two is approximately 8 kilometres north of the mine before it enters the Bronkhorstspruit Dam.

The underlying geology comprises sedimentary rocks of the Karoo Supergroup (including sandstone, shale, coal, and tillite) which overlies the chert and dolomites of the Transvaal Supergroup. Dolerite intrusions (dykes and sills) of late Karoo age are widespread in the project area.

According to GCS (2014), groundwater occurs in three aquifer systems at Leeuwpan that are reported to be interconnected by faults and fractures:

- a shallow weathered zone aquifer (5-12 metres below ground level (mbgl)), locally perched and low yielding (0,01-0.14 l/s);
- a deeper aquifer associated with fractures in Karoo rocks and associated intrusive rocks as well as fractured contact zones. This aquifer is reported to be approximately 40 m thick, has variable yields (0.1-5.0 l/s) and water quality, and is classified as a minor aquifer; and
- a fractured and karst aquifer hosted in the Transvaal dolomites, which is a major aquifer in the area with high yields (>5 l/s) and good quality water. This aquifer is abstracted mainly for large scale irrigation in the area.

The scope of work for the project includes monthly and quarterly surface water and groundwater monitoring and interpretation respectively, in accordance with the conditions stipulated in the mine's IWUL and amendments. The water quality results and trends for the period January to March 2019 are presented and discussed in this report.

1.1 Project Objectives

The primary objectives for the surface monitoring programme are:

- To assess, monthly, the quality of the surface water resources respectively in and around the Leeuwpan study area in accordance with the mine's approved IWUL (number 04/B21A/ABCGIJ/429) and its amendments;
- To make use of the data for both human and environmental health impact assessments;
- To compare results to previous survey results with the aim of detecting environmental trends in the surface water quality; and
- To identify potential impacts of the mining operations on the receiving water resources so that the mine can identify and implement suitable mitigation measures for adaptive management.

1.2 Monitoring sites

The groundwater monitoring sites are set out in Table 1 and the monthly surface water monitoring sites are set out in Table 2. Locations of all the sampling points are given in Figure 1.

Table 1: Leeuwpan Coal mine groundwater sampling points

Site name	Description	Y Co-ordinate	X-Co-ordinates	Altitude
EMPR02/E2	West of ODN pit	S 26° 9.7314'	E 28°43.0668'	1569
KENMB1	Fuel Dispensary	S 26° 10.9176'	E 28°44.2698'	1581
KENMB2-D	Silver Dam 2	S 26°10.7604'	E 28°43.8452'	1598
KENMB2-S	Silver Dam 1	S 26° 10.761'	E 28°43.827'	1585
KENMB3-D	PLANT/Stockpile 1	S 26°10.1738'	E 28°44.2325'	1581
KENMB3-S	PLANT/Stockpile 2	S 26°10.2819'	E 28°43.8080'	1574
LEEMB18-D	Plant Conveyor 2	S 26°10.0902'	E 28°43.6521'	1579
LW07	North of Witklip	S 26°09.9706'	E 28°42.6314'	1563
LW08	South West of Kenbar	S 26°11.0940'	E 28°43.6227'	1587
LW10	South of Delmas Silica (borehole does not exist)	S 26°9.8760'	E 28°45.90'	1562
LWG01	South of Kenbar	S 26°10.7796'	E 28°43.7256'	1578
LWG02	South East of Kenbar	S 26°10.7461'	E 28°44.2200'	1601
LWG04	Moabsvelden Groundwater	S 26°10.4568'	E 28° 45.3546'	1580
MOAMB10	Block OI New Mine Area 1	S 26°09.9010'	E 28°45.9177'	1564
MOAMB4	Block OH	S 26°10.0472'	E 28°44.6280'	1597
MOAMB7	Block OJ / Stuart Coal Upstream	S 26°09.2321'	E 28°45.3272'	1567
MOAMB9	Block OI New Mine Area2	S 26°10.5353'	E 28°46.0158'	1582
RIE10	Rietkuil Monitoring Borehole	S 26°12.0996'	E 28°45.8058'	1581
RIE10B	Rietkuil Monitoring Borehole	S 26°12.0783'	E 28°45.8202'	1591
RIE4	Rietkuil Monitoring Borehole	S 26°11.3292'	E 28°46.104'	1579
RKL01	Rietkuil Monitoring Borehole	S 26°11.0684'	E 28°44.6443'	1597

Site name	Description	Y Co-ordinate	X-Co-ordinates	Altitude
RKL03	Rietkuil Monitoring Borehole	S 26°11.355'	E 28°46.248'	1578
RKL04	De Denne Monitoring Borehole upstream of Block UI	S 26°11.8884'	E 28°44.5146'	1601
RKL02	Rietkuil Monitoring Borehole	S 26°10.9936'	E 28°45.9942'	1584
WELMB13-D	Moabsvelden 1	S 26°08.6306'	E 28°46.7083'	1564
WELMB13-S	Moabsvelden 2	S 26°08.6364'	E 28°46.6961'	1560
WITMB14	Block OA	S 26°10.0137'	E 28°42.3247'	1556
WOLMB15-D	ODN/PCD1	S 26°09.9538'	E 28°43.4233'	1581
WOLMB15-S	ODN/PCD 2	S 26°09.9548'	E 28°43.4306'	1575
WTN02-D	Weltevreden Monitoring Borehole – Deep	S 26°8.7840'	E 28°46.1604'	1560
WTN02S	Weltevreden Monitoring Borehole – Shallow	S 26°8.7840'	E 28°46.1598'	1555
WTN01-D	Weltevreden Monitoring Borehole	S 26°8.0976'	E 28°45.942'	1547
WTN01-S	Weltevreden Monitoring Borehole – Shallow	S 26° 8.0976'	E 28° 45.942'	1547
WWNMB16	Block UB	S 26°10.7110'	E 28°42.6609'	1574
WWN01	Wolwenfontein Monitoring Borehole	S 26° 10.4628'	E 28° 43.0332'	1570
WWN02D	Wolwenfontein Monitoring Borehole – deep	S 26°10.4475'	E 28°43.0969'	1577

Table 2: Surface water monitoring sites

Sample ID	Description	Y Co-ordinates	X Co-ordinates
Drinking water supply samples (Potable water)			
LDWST	Drinking Water Supply Tank	S 26° 10.803'	E 28° 44.1612'
LLBDW	Load-out Bay Offices Drinking Water	S 26° 09.954'	E 28° 43.7940'
LWDL	Drinking water at Laboratory	S 26° 10.277'	E 28°43.6782'
PIET-SCHUTTE	Drinking Water on Piet Schutte's Farm	S 26° 08.490'	E 28°48.1020'

Sample ID	Description	Y Co-ordinates	X Co-ordinates
River/ stream samples (Resource protection)			
WP01	Bronkhorstspruit tributary, upstream	S 26° 10.679'	E 28° 42.1326'
WP02	Bronkhorstspruit tributary, downstream	S 26° 09.306'	E 28° 42.1560'
LSW03	Bronkhorstspruit at Delmas Silica - Downstream	S 26° 09.767'	E 28° 46.1286'
LSW05	Bronkhorstspruit downstream	S 26° 08.250'	E 28° 45.4200'
LSW06	Weltevreden Spruit - Upstream	S 26° 08.634'	E 28° 47.7300'
LSW07	Bronkhorstspruit – upstream	S 26° 11.316'	E 28° 46.5810'
LSW08	Bronkhorstspruit - upstream of Block OI	S 26° 13.813'	E 28° 45.7584'
LSW12	Downstream of River Diversion 2, Between RD2 and LSW05	S 26° 08.166'	E 28° 45.8460'
LSW13	Water from Stuart Coal	S 26° 08.628'	E 28° 46.5360'
RD1	Bronkhorstspruit at haul road	S 26° 08.958'	E 28° 45.8700'
Process water samples (Waste water)			
KR01A	Kenbar Return Water Dam	S 26° 10.8522'	E 28° 43.7970'
KR03	Downstream of workshop oil separator sump	S 26° 10.9182'	E 28° 44.2962'
KR04	Marsh area next to workshop road	S 26° 11.2032'	E 28° 44.0286'
LSW09	Pollution Control Dam	S 26° 09.9606'	E 28° 43.5246'
ODN_PIT	OD Pit Water (closed pit)	S 26° 10.2732'	E 28° 43.4286'
OG_PIT	OG Pit Water (backfilled pit)	S 26° 10.2714'	E 28° 44.0382'
OH_PIT	OH Pit Water (backfilled pit)	S 26° 10.0188'	E 28° 45.2028'
OJ_PIT	OJ Pit Water	S 26° 10.1124'	E 28° 44.7030'
OM_PIT	OM Pit Water	S 26° 10.3668'	E 28° 44.9250'
OWM_PIT	OWM (Moabsvelden) Pit Water	S 26° 08.6640'	E 28° 47.5446'

Sample ID	Description	Y Co-ordinates	X Co-ordinates
WLV-PIT	Weltevreden Pit	S26° 07.7328'	E 28° 45.6300'
WP04	New Witklip Return Water Dam	S 26° 10.3404'	E 28° 42.3840'
Final effluent samples (Waste water)			
LWP_SP_P	Final effluent from septic tanks at plant	S 26° 10.2960'	E 28° 43 8120'
LWP_SP_W	Final effluent at sewage plant behind workshop	S 26° 10.8720'	E 28° 44 3760'
Additional sampling points (not specified in the WUL)			
Kenbar rehab	Backfilled former Kenbar Pit	S 26° 10.4100'	E 28° 43. 9980
OJ-O	Field Barrels for experimental work		
OJ-S4-DISC			
OH-WEATH			
OL-OVB(2A+2B)			

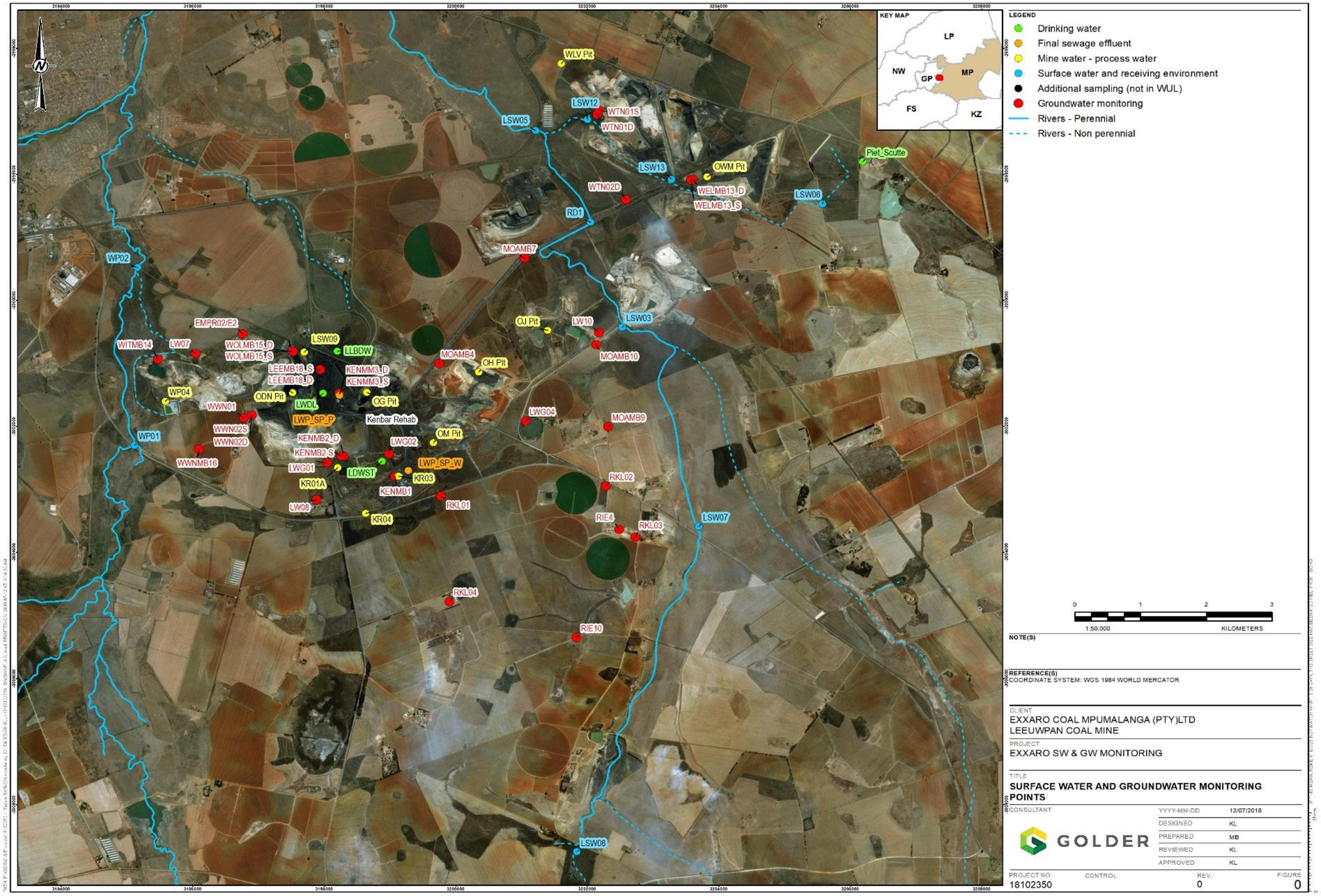


Figure 1: Location of different monitoring point types

1.3 Water quality parameters and compliance values

The parameters and standards against which the water samples are compared are set out in Table 3.

Table 3: Parameters and standards

Parameter	Units	Potable Water and Groundwater	Resource Protection	Waste water
		SANS 241-1: 2015	IWUL 04/B21A/ABCGIJ/ 429 - 2011	IWUL 04/B21A/ABCGIJ/429-2015 Amendment
pH	pH units	≥ 5 to ≤ 9.7[#]	≥ 6.5 to ≤ 8.4	≥ 5 to ≤ 10
Electrical Conductivity (EC)	mS/m	≤ 170*	≤ 35	≤ 750
Total Dissolved Solids (TDS)	mg/L	≤ 1 200*	≤ 280	≤ 3 800
Total Suspended Solids (TSS)	mg/L	-	-	-
Dissolved Oxygen Saturation	%	-	≥70	-
Total hardness as $CaCO_3$	mg/L	-	-	-
Turbidity	NTU	≤ 1[#] / ≤ 5*	-	-
Calcium (Ca)	mg/L	-	≤ 25	-
Magnesium (Mg)	mg/L	-	≤ 20	≤ 300
Sodium (Na)	mg/L	≤ 200*	≤ 20	≤ 500
Potassium (K)	mg/L	-	≤ 10	≤ 40
Total alkalinity as $CaCO_3$	mg/L	-	≤ 120	-
Chloride (Cl^-)	mg/L	≤ 300*	≤ 20	≤ 500
Sulphate (SO_4^{2-})	mg/L	≤ 500[ac] ≤ 250*	≤ 30	≤ 3 200
Fluoride (F^-)	mg/L	≤ 1.5[ch]	≤ 0.5	≤ 5
Nitrate (NO_3^-) as N	mg/L	≤ 11[ac]	≤ 6	≤ 20**
Nitrite (NO_2^-) as N	mg/L	≤ 0.9[ac]	-	-
Ammonia (NH_3) as N	mg/L	≤ 1.5*	≤ 0.007	≤ 10
Orthophosphate as PO_4^{3-}	mg/L	-	≤ 0.05	≤ 10
Sodium Adsorption Ratio	---	-	≤ 1	-
Oil and grease (SOG)	mg/L	-	≤ 5	≤ 1 000
Dissolved organic carbon	mg/L	-	≤ 10	≤ 100
Chemical oxygen demand (COD)	mg/L	-	-	-

Parameter	Units	Potable Water and Groundwater	Resource Protection	Waste water
		SANS 241-1: 2015	IWUL 04/B21A/ABCGIJ/ 429 - 2011	IWUL 04/B21A/ABCGIJ/429-2015 Amendment
Hexavalent Chromium (Cr^{6+})	mg/L	-	≤ 0.05	-
Total phosphorus	mg/L	-	≤ 0.25	≤ 20
Total inorganic nitrogen (TIN)	mg/L	-	≤ 2.5	≤ 15
Escherichia coli	CFU/100ml	0	≤ 50	≤ 10
Total coliforms	CFU/100ml	≤ 100	-	-
Chlorophyll-a	mg/L	-	≤ 0.02	≤ 0.15
Zinc as Zn	mg/L	≤ 5*	-	-
Antimony as Sb	mg/L	≤ 0.02[ch]	-	-
Arsenic as As	mg/L	≤ 0.01[ch]	-	-
Barium as Ba	mg/L	≤ 0.7[ch]	-	-
Boron as B	mg/L	≤ 2.4[ch]	≤ 0.5	-
Cadmium as Cd	mg/L	≤ 0.003[ch]	-	-
Total Chromium as Cr	mg/L	≤ 0.05[ch]	-	≤ 5
Copper as Cu	mg/L	≤ 2[ch]	-	-
Cyanide (recoverable as CN^-)	mg/L	≤ 0.2[ac]	-	-
Iron as Fe	mg/L	≤ 2[ch]/ ≤ 0.3*	≤ 0.5	≤ 20
Manganese as Mn	mg/L	≤ 0.4[ch]/ ≤ 0.1*	≤ 0.18	≤ 10
Mercury as Hg	mg/L	≤ 0.006[ch]	-	-
Nickel as Ni	mg/L	≤ 0.07[ch]	-	-
Selenium as Se	mg/L	≤ 0.04[ch]	-	-
Uranium as U	mg/L	≤ 0.03[ch]	-	-
Aluminium as Al	mg/L	≤ 0.3[#]	≤ 0.02	≤ 10

#operational; *aesthetic; [ac]acute health; [ch]chronic health; **Nitrate as NO_3^-

1.4 Sampling Methodology

1.4.1 Surface water sampling

Latex gloves were worn when collecting samples at each site. Field measurements were done for temperature, pH, EC and TDS. Three bottles were filled at each surface water sampling site:

i) A 50 ml bottle with 2 ml of 1% nitric acid for analysis of dissolved metals;

ii) A 50 ml bottle with 2 ml of 1% sulphuric acid for analysis of nitrogen species; and

iii) Two 250 ml bottles for analysis of pH, TDS, EC, alkalinity and anions.

An additional sample was collected in a sterile glass bottle from potable water sources, final sewage effluent and surface water receiving environment for bacteriological analysis. A 2-litre plastic container was also filled at receiving environment monitoring sites for chlorophyll analysis. A 250 ml glass bottle was filled at receiving environment and process water site for the analysis of oil and grease. All the samples were kept in a cooler box with ice packs.

1.4.2 Groundwater sampling

A low flow pump was used for purging and collecting groundwater from boreholes. However, pumping was not feasible in boreholes that were deeper than 25 meters. As a result, a bailer was used for sampling these boreholes. Measurements of temperature, pH, EC and TDS were taken onsite, and three bottles were filled at each site for:

i) A 50 ml bottle with 2 ml of 1% nitric acid for analysis of dissolved metals;

ii) A 50 ml bottle with 2 ml of 1% sulphuric acid for analysis of nitrogen species; and

iii) Two 250 ml bottles for analysis of pH, TDS, EC, alkalinity and anions.

All the samples were kept in a cooler box with ice packs.

2.0 WATER QUALITY RESULTS

2.1 Field Observations

2.1.1 Surface Water

The number of sites sampled each month varied, with 22 in January; 23 in February; and 23 in March 2019 (Table 4).

Table 4: Sampling record for quarter one of 2019.

Sample ID	Jan-19	Feb-19	Mar-19
Drinking Water			
LDWST	√	√	√
LLBDW	√	√	√
LWDL	No water in taps since December. Visited site on 10th and 11th of January	√	√
PIET-SCHUTTE	√	√	√
River/ stream samples (Resource protection)			
WP01	√	√	√
WP02	√	√	√

Sample ID	Jan-19	Feb-19	Mar-19
LSW03	√	√	√
LSW05	√	√	√
LSW06	Dry, original position mined out and mining activities progressing along the watercourse		
LSW07	√	√	√
LSW08	√	√	√
LSW12	Dry	Dry	Dry
LSW13	√	√	√
RD1	√	√	√
Process Water (Waste Water)			
KR01A	√	√	√
KR03	√	√	Dry and muddy. Oiled separator not operational
KR04	√	√	√
LSW09	√	√	√
ODN_PIT	√	√	√
OG_PIT	Rehabilitated, no water accumulation		
OH_PIT	Backfilled pit, no water accumulation		
OJ_PIT	No access, heaps of dumped waste blocked access		√
OM_PIT	√	√	√
OWM_PIT	√	√	√
WLV-PIT	√	√	√
WP04	√	√	√
Sewage effluent			
LWP_SP_P	√	√	√
LWP_SP_W	√	√	√
Additional sites (not specified in IWUL)			
Kenbar rehab	Rehabilitated, no water accumulation		
OJ-O	Taps on field barrels for experimental work are broken, hence accumulation of leachate		
OJ-S4-DISC			
OH-WEATH			
OL-OVB(2A+2B)			

Notes: √- means the site was sampled

The field data for the period January to March 2019 is presented in APPENDIX A. The following observations are made on the field measurements:

- All drinking water sites were compliant to SANS drinking water quality standards for pH, TDS and EC from January to March 2019;
- All process water and sewage effluent sites were compliant to IWUL limits for pH, TDS and EC throughout the first quarter of 2019; and
- The following sampled receiving environment sites show at least one non-compliance:
  - pH: All sites throughout the quarter
  - Electrical conductivity: All sites throughout the quarter apart from LSW03, LSW07, LSW08 and WP01, which were compliant in January; LSW07, LSW08 and LSW13, were compliant in February; and LSW03, LSW07, LSW08 and WP01, were below the limit in March 2019;
  - Total dissolved solids: WP02 in January to December; LSW03 in February and March; LSW05 in February; LSW13 in March; and RD1 in February 2019; and
  - Dissolved oxygen: All sites throughout the quarter except for LSW07, LSW08, WP01 and WP02 in March; and LSW13 in February and March 2019.

2.1.2 Groundwater

Sixteen groundwater sites were sampled in March 2019 (Table 5). The parameters measured in the field were compliant to SANS drinking water standards at all sites apart from TDS and EC in water from borehole WOLMB15_S (Table 5).

The boreholes that were not sampled due various reasons are presented in Table 6.

Table 5: Groundwater field measurements for March 2019

Site Name	Sample ID	Date	Time	Static water level mbgl	BH depth (m)	Temp (°C)	pH	EC (mS/m)	TDS (mg/l)	DO (% Sat)	Comment
SANS 241-1: 2015 drinking water quality standards							≥ 5 to ≤ 9.7	≤ 170	≤ 1 200	No standard	
KENMB2_D	LNP19_Q1_011	2/3/2019	9:01	24.52	40	19.2	7.73	143	1030	49.5	Deep Borehole
LEEMB18_D	LNP19_Q1_006	1/3/2019	13:58	7.4	29	22.4	7.04	131	940	26.7	Deep Borehole
	LNP19_Q1_007										
	LNP19_Q1_008										
LW07	LNP19_Q1_018	3/3/2019	8:34	7.73	-	18.6	8.14	43	310	48.1	
MOAMB10	LNP19_Q1_003	1/3/2019	10:28	14.75	26	20	7.3	24	170	49.9	Deep Borehole
RIE4	LNP19_Q1_014	2/3/2019	12:24	3.29	40	21.4	6.63	30	210	61.8	Deep Borehole
MOAMB9	LNP19_Q1_016	2/3/2019	14:14	49.14	55	21.1	7.04	36	260	59.2	Deep Borehole
RIE10B	LNP19_Q1_013	2/3/2019	11:18	21.84	38*	19.5	7.89	34	250	80.8	Deep Borehole
RKL01	LNP19_Q1_012	2/3/2019	10:15	10.12	29.8*	19.7	7.52	32	230	62.8	Deep Borehole
RKL02	LNP19_Q1_015	2/3/2019	13:41	2.87	26.55*	19.7	7.17	27	190		Deep Borehole
WELMB13_D	LNP19_Q1_002	28/02/2019	16:05	18.2	24	19.6	6.54	18	130	31.6	Deep Borehole
WELMB13_S	LNP19_Q1_001	28/02/2019	15:43	1	10	22.2	7.36	119	860	34.3	Shallow Borehole
WITMB14	LNP19_Q1_005	1/3/2019	12:44	3.38	25	19.9	7.67	72	510	22.31	Deep borehole
WOLMB15_D	LNP19_Q1_010	1/3/2019	16:03	2.29	10	20.9	7.04	87	630	45.3	Shallow Borehole
WOLMB15_S	LNP19_Q1_009	1/3/2019	15:45	1.32	50	22	7.24	214	1530	48.3	Shallow Borehole
WWN02_D	LNP19_Q1_004	1/3/2019	11:48	14.85	16	18.4	7.5	43	460	60.9	Deep Borehole
WWNMB16	LNP19_Q1_017	2/3/2019	15:44	13.45	31.15*	19.2	7.68	24	170	113.8	Deep Borehole

Notes

*Approximate borehole depths measured with a dip meter. The other depths are assumed to be equal to end of borehole depths provided on the borehole drilling logs (GCS, 2014).

Highlighted cells show values that exceed drinking water quality standard

Table 6: List of groundwater points not sampled

Site Name	Date	Comments	Recommendations
EMPR02/ E2	1/3/2019	Borehole collapsed at 17.77 m above the water level.	Borehole needs to be drilled out or replaced.
KENMB1	28/2/2019	Blocked at 22.18 m above the water level.	Borehole needs to be drilled out or replaced.
KENMB2-S	1/3/2019	Borehole blocked at 10 m above the water level.	Borehole needs to be drilled out or replaced.
LWG01	1/3/2019	An electrical pump exists but the power is cut off. Trench in the vicinity of borehole filled with water.	The electrical power should be reconnected.
LWG02	1/3/2019	Borehole not sampled, covered by rubbles.	Remove rubble.
LWG04	28/0/2019	Borehole collapsed at 18.43 m above the water level.	Borehole needs to be drilled out or replaced.
LW08	2/3/2019	Bees were found in the borehole during the time of sampling.	Bee removal services should be considered to relocate the bee hive.
LW10		Borehole does not exist this was confirmed by the Exxaro survey team.	New shallow borehole needs to be drilled.
RIE10	2/3/2019	Pump installed, but not working. No access to take water level or sample.	Get pump fixed.
RKL03	1/3/2019	Borehole destroyed. Blocked, no cap for casing and filled with rocks.	A new borehole should be drilled, unless it is decided to remove the borehole from the monitoring programme – note that RIE4 is nearby but might not intersect same aquifer.
RKL04	1/3/2019	Pump already installed, and the water is kept in a tank. There is no access to insert a water sampling pump into the borehole to measure water levels and collect a water sample.	No space for monitoring water level in borehole due to pump installation. Installation of a “conduit pipe” is recommended. This is an extra, small diameter tubing which allows free access into the equipped borehole.
WTN01-D	28/2/2019	Borehole collapsed at 34.94 m above the water level depth.	Borehole needs to be drilled out or replaced.
WTN01-S	28/2/2019	Not enough water to purge the borehole.	No action.

Site Name	Date	Comments	Recommendations
WTN02-D	1/3/2019	Access was organised by the environmental practitioner, but access was not granted by Stuart Coal.	Stuart Coal must be approached again to agree to access and to provide a letter for monitoring staff to show.
WTN02S	1/3/2019	Bees were found in the borehole during the time of sampling.	Bee removal services should be considered to relocate the bee hive. .
WWN01	1/3/2019	The borehole is destroyed.	A new borehole should be drilled, although WWN02D is nearby, the latter is a deep borehole.
MOAMB4	1/3/2019	Boulder at access point	Remove the boulder at the access point
MOAMB7	1/3/2019	New fence installed on side used to access the borehole	Grant access to the barricaded area
KENMM3_D	1/3/2019	Borehole destroyed due to construction at the offices	
KENMM3_S	1/3/2019	Borehole destroyed due to construction at the offices	

2.2 Potable water samples

Laboratory results of potable water samples collected from January to March 2019 were compared to the SANS 241-1: 2015 drinking water standards and are presented in Table 7. The drinking water was near-neutral to alkaline at all sites throughout the third quarter (7.3≤pH≤8.3). All measured parameters in drinking water from all sources were compliant to the drinking water standards throughout the reporting period apart from *E. coli* at Piet Schutte in January 2019. In many previous months there have been very marginal exceedances of arsenic in drinking water from the drinking water supply tank (LDWST) and LWDL, but not in Q1 of 2019. It is advised that the mine continue not to use the water from the sampled sources for drinking and mark all sources with a sign similar to the ones at LLBDW and LWDL taps (Figure 3).

All drinking water samples had a calcium/magnesium carbonate signature throughout the first quarter of 2019 as indicated on the Piper diagram (Figure 2). The signature is typical of shallow, freshly recharged groundwater or water from a dolomitic aquifer.

The levels of measured parameters were generally stable in drinking water from all sources throughout the first quarter of 2019 apart from sulphate, which decreased in drinking water from Piet Schutte borehole in March 2019 (Table 7).

Table 7: Potable water samples results for quarter one 2019

Parameter	Units	SANS 241: 2015 Drinking water Standard	LWDL			LLBDW			LDWST*			Piet Schutte		
			No Sample	LNP_M02_040 LNP_M02_041 (UIS)	LNP19_M03_068 NP19_M03_069 (UIS)	LNP19_M01_016 LNP19_M01_017 (UIS)	LNP_M02_016 LNP_M02_017 (UIS)	LNP19_M03_081 LNP19_M03_082 (UIS)	LNP19_M01_022 LNP19_M01_023 LNP19_M01_024 (UIS)	LNP_M02_022 LNP_M02_023 LNP_M02_024 (UIS)	LNP19_M03_071 LNP19_M03_072 LNP19_M03_073 (UIS)	LNP19_M01_036 LNP19_M01_037(UIS)	LNP_M02_036/ LNP_M02_037 (UIS)	LNP19_M03_087 LNP19_M03_088 (UIS)
				1-Feb	1-Mar	11-Jan	1-Feb	2-Mar	11-Jan	31-Jan	2-Mar	11-Jan	1-Feb	3-Mar
pH	pH units	≥ 5 to ≤ 9.7	No water from tap	8.07	7.88	8.04	8.2	7.93	7.73	7.86	7.97	7.26	7.55	7.73
Total Dissolved Solids (TDS)	mg/L	≤ 1 200		403	332	308	367	311	352	398	358	88	127	79
Electrical Conductivity (EC)	mS/m	≤ 170		58	58	56	55	56	55	57	40	12	13	12
Nitrate (NO_3^-) as N	mg/L	≤ 11		1.45	1.27	0.09	<0.05	0.05	1.61	1.90	1.76	0.38	0.49	0.6
Nitrite (NO_2^-) as N	mg/L	≤ 0.9		<0.16	0.05	<0.020	<0.16	0.05	<0.02	<0.16	<0.16	<0.020	<0.16	0.05
Sulphate (SO_4^{2-})	mg/L	≤ 500		74.9	87.8	51.8	47.4	46.8	78.4	79.3	78.5	1.3	23.6	0.6
Fluoride (F^-)	mg/L	≤ 1.5		<0.3	0.15	<0.3	<0.3	0.15	<0.3	<0.3	<0.3	<0.3	<0.3	0.15
Ammonia (NH_3) as N	mg/L	≤ 1.5		<0.03	0.04	<0.03	<0.03	0.05	<0.03	0.07	0.02	<0.03	0.18	0.03
Chloride (Cl^-)	mg/L	≤ 300		35.4	35.6	34.9	33.8	37.5	36.5	35.9	35.2	2.3	2.1	1.8
Dissolved Sodium (Na)	mg/L	≤ 200		34.3	33.1	34.3	32.1	32.8	33.3	33.0	32.1	4	4.3	4
Dissolved Aluminium (Al)	mg/L	≤ 0.3		<0.02	0.01	<0.02	<0.02	0.01	<0.02	<0.02	<0.02	<0.02	<0.02	0.01
Dissolved Antimony (Sb)	mg/L	≤ 0.02		<0.002	0.001	0.003	<0.002	0.001	<0.002	<0.002	<0.002	<0.002	<0.002	0.001
Dissolved Arsenic (As)	mg/L	≤ 0.01		0.0044	0.0084	<0.0025	<0.0025	0.0025	0.0076	0.0085	0.0084	<0.0025	<0.0025	0.0025
Dissolved Barium (Ba)	mg/L	≤ 0.7		0.077	0.08	0.207	0.207	0.231	0.0767	0.0687	0.0690	0.028	0.038	0.025
Dissolved Boron (B)	mg/L	≤ 2.4		0.076	0.082	0.073	0.076	0.08	0.0640	0.0667	0.0697	0.021	0.024	0.025
Dissolved Cadmium (Cd)	mg/L	≤ 0.003		<0.0005	0.0005	<0.0005	<0.0005	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0005
Dissolved Calcium (Ca)	mg/L	nl		48.5	48.7	43.7	42.3	44.4	47.4	46.5	48.8	9.9	10.7	9.5
Dissolved Copper (Cu)	mg/L	≤ 2		<0.007	0.036	<0.007	<0.007	0.007	<0.007	<0.007	<0.007	0.013	0.009	0.007
Dissolved Lead (Pb)	mg/L	≤ 0.01		<0.005	0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Dissolved Magnesium (Mg)	mg/L	nl		24.8	25.1	28.9	26.9	26.7	25.57	24.73	25.60	6.6	7.1	6.2
Dissolved Manganese (Mn)	mg/L	≤ 0.4		0.006	0.002	0.079	0.006	0.291	0.07	0.03	0.02	0.005	0.01	0.004
Dissolved Mercury (Hg)	mg/L	≤ 0.006		<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Dissolved Nickel (Ni)	mg/L	≤ 0.07		0.003	0.002	<0.002	<0.002	0.002	0.0047	<0.002	<0.002	<0.002	<0.002	0.002

Parameter	Units	SANS 241: 2015 Drinking water Standard	LWDL		LLBDW			LDWST*			Piet Schutte		
		No Sample	LNP_M02_040 LNP_M02_041 (UIS)	LNP19_M03_068 NP19_M03_069 (UIS)	LNP19_M01_016 LNP19_M01_017 (UIS)	LNP_M02_016 LNP_M02_017 (UIS)	LNP19_M03_081 LNP19_M03_082 (UIS)	LNP19_M01_022 LNP19_M01_023 LNP19_M01_024 (UIS)	LNP_M02_022 LNP_M02_023 LNP_M02_024 (UIS)	LNP19_M03_071 LNP19_M03_072 LNP19_M03_073 (UIS)	LNP19_M01_036 LNP19_M01_037(UIS)	LNP_M02_036/ LNP_M02_037 (UIS)	LNP19_M03_087 LNP19_M03_088 (UIS)
			1-Feb	1-Mar	11-Jan	1-Feb	2-Mar	11-Jan	31-Jan	2-Mar	11-Jan	1-Feb	3-Mar
Dissolved Potassium (K)	mg/L	nl	4.8	3.1	3	3.5	1.9	4.1	4.9	3.5	1.4	1.6	0.5
Dissolved Selenium (Se)	mg/L	≤ 0.04	<0.003	0	<0.003	<0.003	0	<0.003	<0.003	<0.003	<0.003	<0.003	0
Dissolved Uranium (U)	mg/L	≤ 0.03	<0.005	0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
Dissolved Zinc (Zn)	mg/L	≤ 5	0.246	0.394	0.029	0.175	0.053	0.057	0.065	0.049	0.023	0.049	0.015
Orthophosphate as PO_4^{3-}	mg/L	nl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.17	0.12	0.1
Total Alkalinity as $CaCO_3$	mg/L	nl	154	166	187	183	188	155	153	160	58	58	54
Total Dissolved Chromium (Cr)	mg/L	≤ 0.05	<0.0015	0.0015	<0.0015	<0.0015	0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	0.0015
Total Dissolved Iron (Fe)	mg/L	≤ 2	<0.02	0.02	<0.02	0.028	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.038
Total Hardness (as $CaCO_3$)	mg/L	nl	225	227.2	230.6	219	223.1	225.1	219.7	228.5	52.5	57	49.8
Escherichia coli	Colonies/100 ml	0	0	0	0	0	0	0	0	0	1	0	0

Notes

Highlighted values exceeds drinking water standards *Average of triplicate samples collected for QAQC assessment.

nl – no set limit

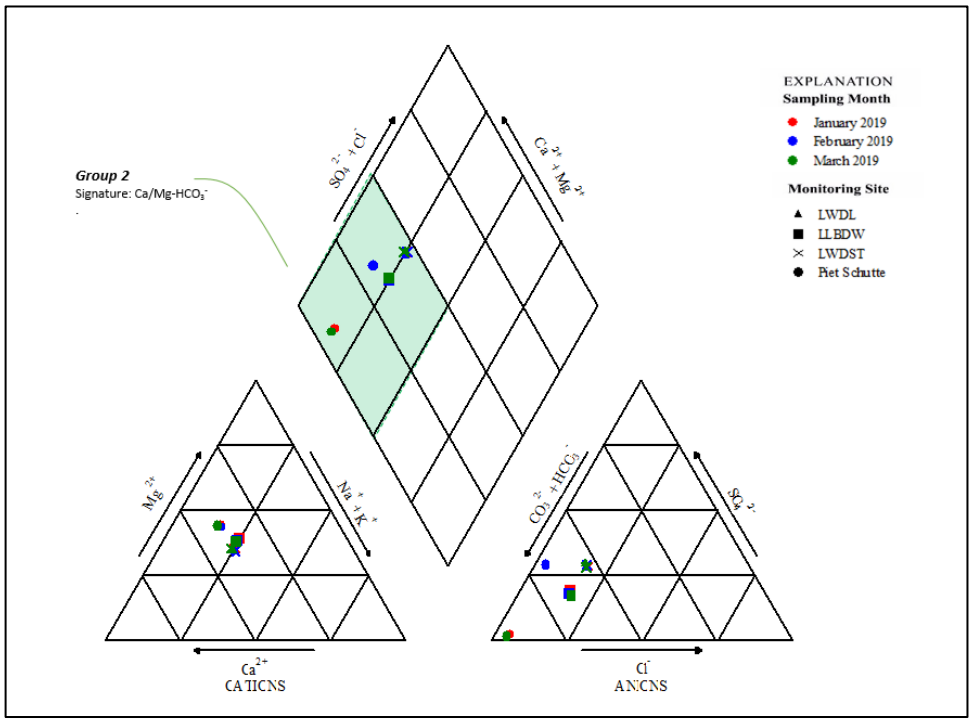


Figure 2: Drinking water Piper Diagram for samples collected during quarter one of 2019



Figure 3: LLBDW sampling tap

2.3 Surface water

Laboratory results of the surface water samples collected during the first quarter of 2019 and screened against IWUL resource protection limits are presented in Table 8. Exceedances are highlighted and summarized in Figure 4. The following trends in water quality were recorded downstream compared to the upstream sites during the first quarter of 2019:

- WP02: Levels of most measured constituents decreased downstream (WP02) compared to upstream (WP01) on the Bronkhorstspruit tributary throughout the first quarter of 2019. Exceptions were manganese and total alkalinity (increase in alkalinity is a positive sign), which increased at WP02 throughout the quarter; calcium, total hardness and iron, and chlorophyll and *E. coli* was higher at WP02 in March. The levels of electrical conductivity, ammonia, calcium, magnesium, manganese and total alkalinity exceeded IWUL limits at both sites throughout the reporting period (Table 8). The levels of nitrate, sulphate, chloride, sodium, aluminum, potassium, total phosphorus and dissolved organic carbon were generally elevated and exceeded the limits at least once at the upstream site compared to the downstream site during the first quarter (Table 8).
- LSW05: Levels of sulphate, magnesium, and dissolved oxygen (increase in dissolved oxygen is a positive sign) increased downstream at LSW05 compared to upstream at LSW08 throughout the first quarter. Total hardness decreased at LSW05 in March; and *E. coli* was elevated downstream in January and February 2019. The levels of total phosphorus increased LSW05 in February 2019 and total dissolved solids, electrical conductivity, chloride, sodium, manganese, potassium, total alkalinity, total dissolved iron and absorption ratio decreased at LSW05 in March 2019. The levels of ammonia, calcium and alkalinity were non-compliant to the IWUL limits at both sites from January to March 2019 (Table 8). The levels of magnesium were non-compliant to IWUL limits at LSW05 but were compliant at LSW08 throughout the first quarter.

  Increased concentrations of sulphate and magnesium at the downstream site could be attributed at least in part to mining activities at Leeuwpan and Stuart coal.

Graphs showing levels of pH, alkalinity, total dissolved solids, electrical conductivity, sulphate, chloride, calcium, magnesium, sodium, nitrate and *E. coli* over time, are presented in APPENDIX B. The following trends were observed during the first quarter of 2019:

- Bronkhorstspruit tributary, upstream (WP01): Increases were recorded in levels of boron, total dissolved solids, total alkalinity and *E. coli* throughout the first quarter; dissolved oxygen, sodium adsorption ratio, total phosphorus, orthophosphate, boron, sodium, turbidity and total dissolved in March 2019. Decreasing trends were observed for total hardness and nitrate throughout the first quarter, sodium absorption ratio, dissolved oxygen and dissolved organic carbon in February; electrical conductivity, chloride, and calcium and in March 2019.
- Bronkhorstspruit tributary, downstream (WP02): increases were recorded in levels of total alkalinity and chlorophyll *a* in January to March; sulphate, chloride, boron, manganese, potassium and total alkalinity in February, turbidity, calcium, total dissolved iron, total hardness, dissolved oxygen and *E. Coli* in March 2019. Decreases were recorded in levels of dissolved oxygen, total hardness, sodium and turbidity during February; electrical conductivity, ammonia, chloride, boron and potassium in March. The levels of the other constituents were generally stable throughout the first quarter.

Table 8: Surface Water Samples Results for quarter one of 2019

Parameters	Units	IWUL Limit	WP01			WP02			LSW03*			LSW05		
			LNP19_M01_020 LNP19_M01_021	LNP19_M02_020 LNP19_M02_021	LNP19_M03_085 LNP19_M03_086	LNP19_M01_018 LNP19_M01_019	LNP19_M02_018 LNP19_M02_019	LNP19_M03_083 LNP19_M03_084	LNP19_M01_031 LNP19_M01_032 LNP19_M01_033	LNP19_M02_031 LNP19_M02_032 LNP19_M02_033	LNP19_M03_061 LNP19_M03_062 LNP19_M03_063	LNP19_M01_038 LNP19_M01_039	LNP19_M02_038 LNP19_M02_039	LNP19_M03_089 LNP19_M03_090
			11-Jan	1-Feb	3-Mar	11-Jan	1-Feb	3-Mar	11-Jan	1-Feb	1-Mar	11-Jan	31-Jan	3-Mar
pH	pH units	≥ 6.5 to ≤ 8.4	8.19	7.71	7.09	8.53	8.03	7.56	7.35	7.24	6.55	8.28	7.82	7.29
Total Dissolved Solids (TDS)	mg/L	≤ 280	228	240	280	306	302	258	207	272	173	229	280	223
Turbidity	NTU	-	236	205	206	27	5	14	28	26	22	3	3	4
Electrical Conductivity at (EC)	mS/m	≤ 35	35	35	32	51	51	48	25	41	23	40	43	37
Nitrate (NO_3^-) as N	mg/L	≤ 6	0.75	0.66	0.64	0.09	0.025	0.05	0.025	0.025	0.055	0.09	0.025	0.05
Sulphate (SO_4^{2-})	mg/L	≤ 30	44	29	24	19	22	8	43	17	21	34	16	19
Fluoride (F^-)	mg/L	≤ 0.5	0.400	0.300	0.150	0.400	0.150	0.150	0.299	0.150	0.212	0.300	0.150	0.150
Ammonia (NH_3) as N	mg/L	≤ 0.007	0.630	2.960	1.160	0.100	0.050	0.040	0.140	0.746	1.143	0.040	0.090	0.030
Chloride (Cl^-)	mg/L	≤ 20	11	10	12	10	11	7	10	15	8	10	18	12
Dissolved Sodium (Na)	mg/L	≤ 20	13	9	13	22	21	17	10	13	10	10	15	12
Dissolved Aluminium (Al)	mg/L	≤ 0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.099	0.031	0.044	0.01	0.01	0.01
Dissolved Boron (B)	mg/L	≤ 0.5	0.012	0.032	0.042	0.017	0.029	0.022	0.019	0.021	0.028	0.024	0.018	0.024
Dissolved Calcium (Ca)	mg/L	≤ 25	29	29	26	46	46	49	27	44	17	37	36	37
Dissolved Magnesium (Mg)	mg/L	≤ 20	16	14	14	29	28	28	9	18	8	25	26	21
Dissolved Manganese (Mn)	mg/L	≤ 0.18	0.35	1.48	0.47	0.10	0.18	0.24	1.04	0.93	0.43	0.07	1.05	0.04
Dissolved Potassium (K)	mg/L	≤ 10	10	13	10	6	7	4	9	7	15	3	5	3
Orthophosphate as PO_4^{3-}	mg/L	-	0.03	0.03	0.15	0.03	0.03	0.03	0.028	0.03	0.029	0.25	0.03	0.03
Total Alkalinity as $CaCO_3$	mg/L	≤ 120	116	126	128	236	239	249	65	165	81	160	182	166
Total Dissolved Iron (Fe)	mg/L	≤ 0.5	0.01	0.01	0.04	0.01	0.01	0.028	0.29	0.33	0.27	0.03	0.13	0.05
Total Hardness (as $CaCO_3$)	mg/L	-	138	130	124	237	232	238	105	185	75	198	200	179
Escherichia coli	CFU/100 ml	≤ 50	1 600	2 100	6 800	170	170	7200	37	79	25	53	370	38
Total Phosphorus (TP)	mg/L	≤ 0.25	0.26	0.25	0.37	0.06	0.05	0.08	0.33	0.26	0.29	0.03	0.05	0.05
Sodium Adsorption Ratio (SAR)	$meq/L^{0.5}$	≤ 1	0.48	0.36	0.50	0.62	0.61	0.49	0.41	0.40	0.49	0.32	0.45	0.38

Parameters	Units	IWUL Limit	WP01			WP02			LSW03*			LSW05		
			LNP19_M01_020 LNP19_M01_021	LNP19_M02_020 LNP19_M02_021	LNP19_M03_085 LNP19_M03_086	LNP19_M01_018 LNP19_M01_019	LNP19_M02_018 LNP19_M02_019	LNP19_M03_083 LNP19_M03_084	LNP19_M01_031 LNP19_M01_032 LNP19_M01_033	LNP19_M02_031 LNP19_M02_032 LNP19_M02_033	LNP19_M03_061 LNP19_M03_062 LNP19_M03_063	LNP19_M01_038 LNP19_M01_039	LNP19_M02_038 LNP19_M02_039	LNP19_M03_089 LNP19_M03_090
			11-Jan	1-Feb	3-Mar	11-Jan	1-Feb	3-Mar	11-Jan	1-Feb	1-Mar	11-Jan	31-Jan	3-Mar
Hexavalent Chromium	mg/L	≤ 0.05	0.003	0.003	0.006	0.003	0.003	0.006	0.003	0.003	0.012333	0.003	0.003	0.006
Dissolved Oxygen (DO)	% Saturation	≥ 70	66	31	46	85	53	54	13	7	10	70	49	39
Dissolved Organic Carbon (DOC)	mg/L	≤ 10	9	7	8	12	4	2	30	13	21	6	8	7
Chlorophyll a	mg/L	≤ 0.02	0.004	0.004	7	0.009	0.012	1	0.139	0.02	15	0.0005	0.004	n/a
Oil and grease	mg/L	5	<0.01	0.005	0.01	<0.01	0.005	0.01	<0.01	0.005	0.173333	<0.01	0.005	0.01

Notes

Highlight - exceeds IWUL limits for resource protection (receiving water environment); *Average of triplicates

Table 8 Continued

Parameters	Units	IWUL Limit	LSW07			LSW08			LSW13			RD1		
			LNP19_M01_001/ LNP19_M01_002	LNP_M02_001/ LNP_M02_002	LNP19_M03_079	LNP19_M01_003/ LNP19_M01_004	LNP_M02_003/ LNP_M02_004	LNP19_M03_077	LNP19_M01_029/ LNP19_M01_030	LNP_M02_029/ LNP_M02_030	LNP19_M03_052	LNP19_M01_027/ LNP19_M01_028	LNP_M02_027/ LNP_M02_028	LNP19_M03_050
			10-Jan	1-Feb	2-Mar	10-Jan	1-Feb	2-Mar	11-Jan	1-Feb	28-Feb	11-Jan	1-Feb	28-Feb
pH	pH units	≥ 6.5 to ≤ 8.4	7.97	7.54	7.13	7.77	6.76	7.32	7.79	7.82	7.17	8.12	7.86	7.37
Total Dissolved Solids (TDS)	mg/L	≤ 280	147	275	192	169	176	237	334	254	157	235	250	205
Turbidity	NTU	-	44	269	54	96	621	13	9	12	23	5	5	3
Electrical Conductivity at (EC)	mS/m	≤ 35	18	26	20	26	7	37	48	35	34	40	41	36
Nitrate (NO_3^-) as N	mg/L	≤ 6	0.03	0.55	0.05	0.03	1.28	0.05	0.29	0.06	0.09	0.09	0.025	0.05
Sulphate (SO_4^{2-})	mg/L	≤ 30	16	18	9	7	11	5	150	68	73	33	20	19
Fluoride (F^-)	mg/L	≤ 0.5	0.40	0.40	0.15	0.4	0.15	0.15	0.5	0.3	0.15	0.15	0.15	0.15
Ammonia (NH_3) as N	mg/L	≤ 0.007	0.05	0.24	0.4	0.16	0.41	0.03	0.07	0.06	0.05	0.04	0.11	0.09
Chloride (Cl^-)	mg/L	≤ 20	6	7	4	7	2	5	11	14	13	10	14	11

Parameters	Units	IWUL Limit	LSW07			LSW08			LSW13			RD1		
			LNP19_M01_001/ LNP19_M01_002	LNP_M02_001/ LNP_M02_002	LNP19_M03_079	LNP19_M01_003/ LNP19_M01_004	LNP_M02_003/ LNP_M02_004	LNP19_M03_077	LNP19_M01_029/ LNP19_M01_030	LNP_M02_029/ LNP_M02_030	LNP19_M03_052	LNP19_M01_027/ LNP19_M01_028	LNP_M02_027/ LNP_M02_028	LNP19_M03_050
			10-Jan	1-Feb	2-Mar	10-Jan	1-Feb	2-Mar	11-Jan	1-Feb	28-Feb	11-Jan	1-Feb	28-Feb
Dissolved Sodium (Na)	mg/L	≤ 20	9	12	14	11	4	22	9	8	9	10	14	11
Dissolved Aluminium (Al)	mg/L	≤ 0.02	0.01	0.01	0.01	0.01	0.185	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Dissolved Boron (B)	mg/L	≤ 0.5	0.022	0.032	0.034	0.006	0.018	0.03	0.02	0.024	0.017	0.016	0.019	0.024
Dissolved Calcium (Ca)	mg/L	≤ 25	12.4	21.3	14.7	23.3	3.0	33.7	47.2	32.4	32.7	36.6	33.0	37.0
Dissolved Magnesium (Mg)	mg/L	≤ 20	7	10	8	10	2	15	27	17	19	24	27	20
Dissolved Manganese (Mn)	mg/L	≤ 0.18	0.04	0.33	0.06	3.01	0.04	1.65	1.51	0.87	0.82	1.26	1.35	0.66
Dissolved Potassium (K)	mg/L	≤ 10	9	12	6	8	4	8	3	5	1	3	5	3
Orthophosphate as PO_4^{3-}	mg/L	-	0.15	0.03	0.03	0.03	0.26	0.03	0.03	0.03	0.03	0.03	0.03	0.05
Total Alkalinity as $CaCO_3$	mg/L	≤ 120	71	112	92	115	13	191	75	90	98	156	172	158
Total Dissolved Iron (Fe)	mg/L	≤ 0.5	0.06	0.01	0.09	1.46	0.13	0.07	0.01	0.01	0.03	0.29	0.20	0.21
Total Hardness (as $CaCO_3$)	mg/L	-	59	97	69	99	15	149	230	153	160	194	195	176
Escherichia coli	CFU/100ml	≤ 50	1 290	2 300	118	460	25 000	160	590	49	570	42	58	75
Total Phosphorous (TP)	mg/L	≤ 0.25	0.15	0.19	0.42	0.09	0.22	0.10	0.04	0.04	0.03	0.09	0.10	0.08
Sodium Adsorption Ratio (SAR)	$meq/L^{0.5}$	≤ 1	0.49	0.53	0.75	0.49	0.47	0.80	0.25	0.29	0.29	0.32	0.44	0.38
Hexavalent Chromium	mg/L	≤ 0.05	<0.006	0.003	0.006	<0.006	0.003	0.006	<0.006	0.003	0.006	<0.006	0.003	0.006
Dissolved Oxygen (DO)	% Saturation	≥ 70	76	19	9	7	45	44	98	70	59	67	41	49
Dissolved Organic Carbon (DOC)	mg/L	≤ 10	13	13	18	16	4	10	3	1	2	10	9	8
Chlorophyll a	mg/L	≤ 0.02	0.001	0.012	11	0.007	0.001	8	0.021	0.007	13	0.004	0.335	4
Oil and grease	mg/L	5	<0.01	0.005	0.01	<0.01	0.005	0.01	<0.01	0.005	0.01	<0.01	0.005	0.01

Notes

Highlight - exceeds IWUL limits for resource protection (receiving water environment);

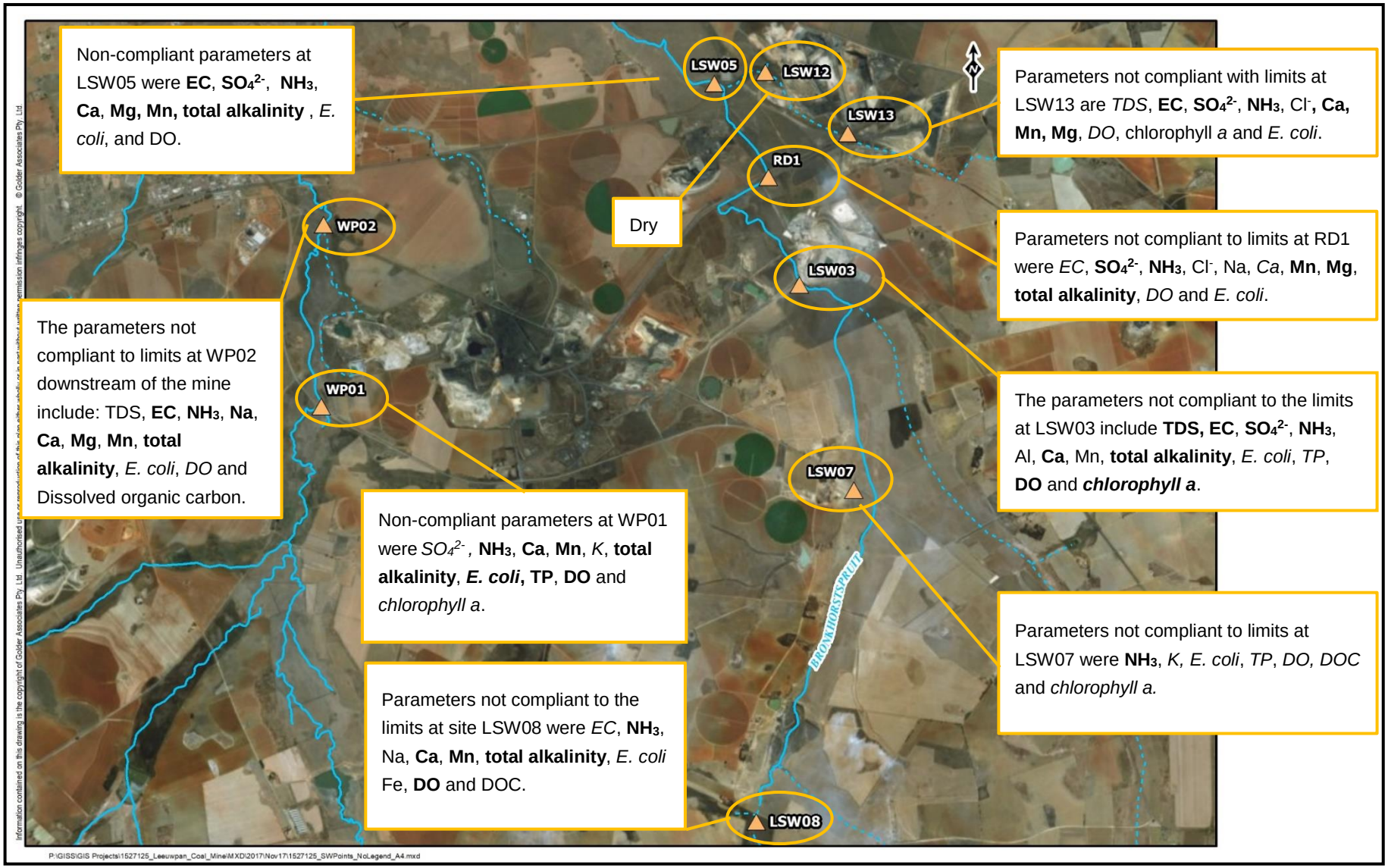


Figure 4: Summary of surface water sample results exceeding IWUL limit during first quarter of 2019. Constituents in italics (except E. coli) exceeded the limit twice, the ones in bold exceeded the limit every month during the quarter

- Bronkhorstspruit, upstream of Block OI (LSW08): Increases were recorded in levels of ammonia, chloride, turbidity and sulphate in February; and manganese, sodium adsorption ratio, total hardness and total alkalinity in March 2019. Increasing trends were noted for total dissolved solids and total dissolved iron (positive sign) throughout the first quarter. Electrical conductivity, fluoride, chloride, sodium, calcium, magnesium, manganese, potassium, total alkalinity, total hardness and dissolved organic carbon decreased in February; dissolved oxygen, total phosphorus, *E. coli*, orthophosphate, ammonia, nitrate and turbidity in March 2019. The levels of the other constituents were stable throughout the first quarter.
- Bronkhorstspruit, upstream (LSW07): Increases were recorded in levels of sodium boron, total phosphorus chlorophyll a and sodium adsorption ration throughout the first quarter whilst dissolved oxygen decreased during the same period. The levels of total dissolved solids, turbidity, electrical conductivity, sulphate, ammonia, chloride, calcium, magnesium, manganese, potassium, total alkalinity, total hardness and *E. coli* increased whilst total dissolved iron, orthophosphate, (negative sign) decreased in February compared to January 2019. The levels of total dissolved solids, turbidity, electrical conductivity, sulphate, ammonia, chloride, calcium, magnesium, manganese, potassium, total alkalinity, total hardness and *E. coli* decreased whilst total dissolved iron, orthophosphate (positive sign) increased in March compared to February 2019.
- Bronkhorstspruit at Delmas Silica, downstream (LSW03): Decreases were recorded in levels of turbidity, chloride, sodium, manganese, throughout the first quarter whilst ammonia, boron, increased during the same period. The levels of total dissolved solids, electrical conductivity, aluminum, calcium, magnesium, potassium, orthophosphate, total alkalinity, total dissolved iron, total hardness, total phosphorus, sodium adsorption ratio, dissolved oxygen, dissolved organic carbon, chlorophyll a and *E. coli* increased whilst total dissolved iron, orthophosphate, (negative sign) decreased in February compared to January 2019. The levels of total dissolved solids, electrical conductivity, aluminum, calcium, magnesium, potassium, orthophosphate, total alkalinity, total dissolved iron, total hardness, total phosphorus, sodium adsorption ratio, dissolved oxygen, dissolved organic carbon, chlorophyll a and *E. coli* decreased whilst total dissolved solids, electrical conductivity, sulphate, fluoride, calcium, magnesium, potassium, total alkalinity, total dissolved iron, orthophosphate, total hardness, *E. coli*, total phosphorus and dissolved oxygen (negative sign) decreased in March compared to January2019.
- Bronkhorstspruit at haul road (RD1): The levels of total dissolved solids, electrical conductivity, chloride, sodium, boron, manganese, potassium, total alkalinity, total hardness, total phosphorus and sodium adsorption ratio increased in February and January 2019. Decreases were recorded in levels of total dissolved solids, electrical conductivity, chloride, sodium, boron, manganese, potassium, total alkalinity, total hardness, total phosphorus and sodium adsorption ratio in March and February 2019. Decreases were recorded in levels of sulphate and dissolved organic carbon throughout the first quarter whilst chlorophyll a and *E. coli* increased during the same period. The rest of the constituents were relatively stable.
- Water from Stuart Coal (LSW13): Increases were recorded in levels of turbidity, throughout the first quarter whilst electrical conductivity, ammonia, manganese, decreased during the same period. Increasing trends were recorded for levels of chloride, boron, potassium, total alkalinity and sodium adsorption ratio in January and February 2019 whilst sulphate, sodium, calcium, magnesium, total hardness, dissolved oxygen, dissolved organic carbon, chlorophyll a and *E. coli* decreased during the same period.
- Bronkhorstspruit downstream (LSW05): Increases were recorded in levels of dissolved oxygen and nitrate throughout the first quarter. Increases were also recorded in levels of total dissolved solids, electrical conductivity, ammonia, chloride, sodium, magnesium, manganese, potassium, total alkalinity, total hardness,

E. coli, sodium adsorption ratio in February 2019, whilst orthophosphate and boron decreased during the same period. Decreasing trends were recorded for total dissolved solids, orthophosphate, dissolved organic carbon, turbidity, electrical conductivity, total alkalinity, total hardness, *E. coli* and sodium adsorption ratio (negative sign) in March 2019.

2.4 Process water samples

The results of process water samples collected during the period January to March 2019 are presented and screened against the IWUL limits in Table 9. Trend graphs of major constituents are provided in APPENDIX B. The following observations are made from the results:

- Downstream of workshop oil separator sump (KR03): The levels of manganese and fats, oils and grease increased by a huge margin (from 0.75 mg/L to 3.83 mg/L), (from 0.005 mg/l to 38.37 mg/l), respectively, in February 2019 compared to January 2019. The reason for this spike is not known, but it was noted in March 2019 that the oil separator was not operational. The water collected downstream of the workshop oil sump was classified as neutral drainage from January to February 2019 on the basis of sulphate and pH levels (Figure 5).
- OWM Pit: The levels of major constituents were generally stable in January and February 2019 apart from sulphate, total dissolved solids, electrical Conductivity, total Hardness and calcium which increased, and nitrate, which decreased in January and February; and total dissolved solids, nitrate and ammonia decreased whilst total hardness, turbidity increased in March 2019. The levels of most of the measured constituents were below the IWUL limits throughout the first quarter apart from nitrate in January 2019 (Table 9), and the water was classified as neutral drainage on the basis of pH and sulphate levels (Figure 5).
- WLV pit: There were generally no major changes in levels of measured constituents in February compared to January 2019 apart from total dissolved, which increased. The levels of total dissolved solids and nitrate decreased in March compared to February 2019 whilst turbidity increased. The levels of all measured constituents were below the IWUL limits throughout the quarter (Table 9). The sampled water was classified as neutral mine drainage on the basis of pH and sulphate levels (Figure 5).
- ODN pit: The levels of measured constituents were generally stable and within IWUL limits throughout the first quarter apart from turbidity, which decreased in January and March, and increased in February as well as potassium, which decreased in March 2019. The water from the pit was classified as saline drainage on the basis of pH and sulphate levels (Figure 5).

Table 9: Process water samples results for quarter 1 of 2019

Parameters	Units	Standard IWUL 04/B21A/ABCGIJ/429-2015 Amendment	KR03			KR01A*						KR04			OWM pit			WLV Pit		
			LNP19_M01_015	LNP19_M02_015	No Sample	LNP19_M01_011 LNP19_M01_012 LNP19_M01_013			LNP19_M02_011 LNP19_M02_012 LNP19_M02_013			LNP19_M03_074 LNP19_M03_075 LNP19_M03_076			LNP19_M01_014	LNP19_M02_014	LNP19_M03_059	LNP19_M01_007	LNP19_M02_007	LNP19_M03_055	LNP19_M01_006	LNP19_M02_006	LNP19_M03_054
			10-Jan	1-Feb	2-Mar	10-Jan			1-Feb			2-Mar			10-Jan	1-Feb	2-Mar	10-Jan	31-Jan	28-Feb	10-Jan	31-Jan	28-Feb
pH	pH units	≥ 5 to ≤ 10	7.56	5.32		8.13			7.53			7.41			8.18	7.92	6.96	8.31	7.89	7.47	8.08	7.80	7.86
Total Dissolved Solids (TDS)	mg/L	≤ 3800	632	577		2 735			3 731			3 180			286	300	482	597	1 459	1 423	721	922	583
Turbidity	NTU	-	12.7	4.6		18.8			53.6			30.0			39.8	31.5	5.0	8.8	3.0	5.2	2.2	3.5	9.6
Electrical Conductivity (EC)	mS/m	≤ 750	101	75		309			360			335			43	44	69	91	164	164	93	86	80
Nitrate (NO_3^-)	mg/L	≤ 20	0.1	0.11		7.6			0.1			0.7			0.6	0.1	0.1	79.4	12.6	0.1	4.6	3.9	0.9
Sulphate (SO_4^{2-})	mg/L	≤ 3200	431	339		1 779			2 177			2 029			158	152	302	281	674	746	425	354	350
Fluoride (F^-)	mg/L	≤ 5	0.4	0.8		0.15			0.15			0.15			0.7	0.7	0.15	0.5	0.15	0.15	0.15	0.15	0.15
Ammonia (NH_3)	mg/L	≤ 10	0.02	0.67		0.16			0.08			0.04			0.06	0.10	0.05	2.59	1.60	0.48	0.11	0.11	0.05
Chloride (Cl^-)	mg/L	≤ 500	18	3		10			12			11			5	4	8	8	4	4	7	7	7
Dissolved Sodium (Na)	mg/L	≤ 500	33	14		44			55			50			22	24	26	24	38	33	10	9	8
Sodium Absorption Ratio (SAR)	$meq/L^{0.5}$	-	0.6	0.3		0.4			0.5			0.5			0.7	0.8	0.6	0.5	0.5	0.5	0.2	0.2	0.2
Dissolved Aluminium (Al)	mg/L	≤ 10	0.01	1.09		0.01			0.01			0.01			0.01	0.01	0.01	0.01	0.01	0.01	0.022	0.03	0.02
Dissolved Boron (B)	mg/L	-	0.07	0.06		0.09			0.105			0.09			0.03	0.03	0.04	0.16	0.19	0.16	0.06	0.05	0.06
Dissolved Calcium (Ca)	mg/L	-	117	75		472			564			550			37	39	74	94	200	206	136	122	116
Dissolved Magnesium (Mg)	mg/L	≤ 300	49	38		187			244			216			18	17	32	49	98	110	43	37	34
Dissolved Manganese (Mn)	mg/L	≤ 10	0.75	3.83		0.03			0.03			0.16			0.01	0.01	0.02	0.05	0.20	0.25	0.18	0.01	0.01
Dissolved Potassium (K)	mg/L	≤ 40	6	5		6			13			4			2	2	2	5	5	1	2	3	1
Orthophosphate as PO_4^{3-}	mg/L	≤ 10	0.16	0.03		0.03			0.03			0.023			0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Total Alkalinity as $CaCO_3$	mg/L	-	76	1.5		82			52			109			46	30	30	117	230	236	46	61	61
Total Dissolved Iron (Fe)	mg/L	≤ 20	0.036	0.263		0.01			0.01			0.037			0.01	0.01	0.02	0.01	0.01	0.021	0.01	0.01	0.02
Total Hardness (as $CaCO_3$)	mg/L	-	499	346		1 962			2 429			2 274			168	167	317	440	912	975	521	460	431
Total Phosphorous (TP)	mg/L	≤ 20	0.20	0.08		0.03			0.02			0.03			0.05	0.04	0.04	0.02	0.02	0.03	0.03	0.04	0.04
Fats, Oils and Greases	mg/L	≤ 1000	0.005	38.37		0.01			0.01			1.00			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Hexavalent Chromium	mg/L	-	0.003	0.003		0.00			0.003			0.003			0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003

Parameters	Units	Standard IWUL 04/B21A/ABCGIJ/429-2015 Amendment	KR03			KR01A*						KR04			OWM pit			WLV Pit		
			LNP19_M01_015	LNP19_M02_015	No Sample	LNP19_M01_011 LNP19_M01_012 LNP19_M01_013			LNP19_M02_011 LNP19_M02_012 LNP19_M02_013			LNP19_M03_074 LNP19_M03_075 LNP19_M03_076			LNP19_M01_014	LNP19_M02_014	LNP19_M03_059	LNP19_M01_007	LNP19_M02_007	LNP19_M03_055	LNP19_M01_006	LNP19_M02_006	LNP19_M03_054
			10-Jan	1-Feb	2-Mar	10-Jan			1-Feb			2-Mar			10-Jan	1-Feb	2-Mar	10-Jan	31-Jan	28-Feb	10-Jan	31-Jan	28-Feb
Dissolved Oxygen (DO)	%	-	33	10		88			75			69			77	77	60	96	74	76	97	86	90
Dissolved Organic Carbon (DOC)	mg/L	≤ 100	5	7		1			1			5			6	4	5	2	1	1	1	1	1

Notes

Red highlight - exceeds amended IWUL limits for waste water; *Average of triplicate samples

Table 9 continued

Parameters	Units	Standard IWUL 04/B21A/ABCGIJ/429- 2015 Amendment	WP04			LSW09			ODN Pit			OM Pit			OJ Pit		
			LNP19_M01_005	LNP_M02_005	LNP19_M03_065	LNP19_M01_010	LNP_M02_010	LNP19_M03_070	LNP19_M01_009	LNP_M02_009	LNP19_M03_058	LNP19_M01_008	LNP_M02_008	LNP19_M03_057	No Sample	No Sample	LNP19_M03_056
			10-Jan	31-Jan	1-Mar	10-Jan	1-Feb	1-Mar	10-Jan	31-Jan	28-Feb	10-Jan	31-Jan	28-Feb	10-Jan	31-Jan	28-Feb
pH	pH units	≥ 5 to ≤ 10	8.37	7.7	7.47	8.41	7.77	7.18	8.32	7.79	8.06	8.3	7.79	7.36	No access, heaps of dumped waste blocked access	No access, heaps of dumped waste blocked access	7.54
Total Dissolved Solids (TDS)	mg/L	≤ 3800	3241	3752	3346	2161	2197	2234	3100	3423	3088	2139	2219	1533			1190
Turbidity	NTU	-	5	5	6	5	34	3	7	19	5	4	81	12			15
Electrical Conductivity	mS/m	≤ 750	325	322	324	208	213	237	318	303	306	234	217	216			147
Nitrate (NO_3^-)	mg/L	≤ 20	<0.2	0.11	0.05	20.02	28.79	8.23	1.68	0.89	0.17	24.09	22.36	7.09			9.86
Sulphate (SO_4^{2-})	mg/L	≤ 3200	2443	2001	2118	1120	1166	1404	2002	1802	1915	1344	1201	1232			650
Fluoride (F^-)	mg/L	≤ 5	0.5	0.4	0.4	0.3	0.3	0.4	0.4	0.15	0.15	0.4	0.15	0.15			0.15
Ammonia (NH_3)	mg/L	≤ 10	0.11	0.28	0.09	0.08	0.45	0.74	0.08	0.15	0.15	0.42	0.33	0.59			2.62
Chloride (Cl^-)	mg/L	≤ 500	23	23	23	8	11	10	11	11	11	8	7	7			6
Dissolved Sodium (Na)	mg/L	≤ 500	82	82	84	31	39	46	46	45	43	34	33	33			26
Sodium Absorption Ratio (SAR)	meq/L 0.5	-	0.769	0.756	0.777	0.387	0.454	0.502	0.419	0.421	0.403	0.383	0.365	0.378			0.388

Parameters	Units	Standard IWUL 04/B21A/ABCGIJ/429- 2015 Amendment	WP04			LSW09			ODN Pit			OM Pit			OJ Pit		
			LNP19_M01_005	LNP_M02_005	LNP19_M03_065	LNP19_M01_010	LNP_M02_010	LNP19_M03_070	LNP19_M01_009	LNP_M02_009	LNP19_M03_058	LNP19_M01_008	LNP_M02_008	LNP19_M03_057	No Sample	No Sample	LNP19_M03_056
			10-Jan	31-Jan	1-Mar	10-Jan	1-Feb	1-Mar	10-Jan	31-Jan	28-Feb	10-Jan	31-Jan	28-Feb	10-Jan	31-Jan	28-Feb
Dissolved Aluminium (Al)	mg/L	≤ 10	<0.02	0.01	0.01	<0.02	0.024	0.01	<0.02	0.03	0.02	0.03	0.021	0.07			0.01
Dissolved Boron (B)	mg/L	-	0.085	0.094	0.092	0.091	0.117	0.152	0.065	0.073	0.066	0.097	0.099	0.096			0.084
Dissolved Calcium (Ca)	mg/L	-	502	510	529	298	329	390	549	535	543	354	374	338			196
Dissolved Magnesium (Mg)	mg/L	≤ 300	222	231	222	115	132	147	212	209	196	151	156	136			89
Dissolved Manganese (Mn)	mg/L	≤ 10	0.34	0.273	0.197	0.03	0.042	0.009	0.61	0.605	0.872	0.171	0.119	0.062			0.07
Dissolved Potassium (K)	mg/L	≤ 40	5	14	0	4	10	1	3	10	1	5	11	2			2
Orthophosphate as PO_4^{3-}	mg/L	≤ 10	<0.06	0.03	0.03	<0.06	0.03	0.03	<0.06	0.03	0.03	<0.06	0.03	0.03			0.04
Total Alkalinity as $CaCO_3$	mg/L	-	53	57	58	52	52	81	182	170	198	106	96	90			140
Total Dissolved Iron (Fe)	mg/L	≤ 20	<0.02	0.01	0.02	<0.02	0.021	0.02	<0.02	0.01	0.026	<0.02	0.01	0.031			0.02
Total Hardness (as $CaCO_3$)	mg/L	-	2 188	2 245	2 254	1 225	1 377	1 590	2 261	2 213	2 179	1 516	1 592	1 414			864
Total Phosphorous (TP)	mg/L	≤ 20	0.03	0.039	0.031	0.035	0.038	0.036	0.03	0.031	0.028	0.026	0.042	0.027			0.026
Fats, Oils and Greases	mg/L	≤ 1000	<0.01	0.005	0.005	<0.01	0.005	0.005	<0.01	0.005	0.005	<0.01	0.005	0.005			0.005
Hexavalent Chromium	mg/L	-	<0.006	0.003	0.003	<0.006	0.003	0.003	<0.006	0.003	0.003	<0.006	0.003	0.003			0.003
Dissolved Oxygen (DO)	%	-	94	81	76	100	62	59	98	84	84	103	82	77			80
Dissolved Organic Carbon (DOC)	mg/L	≤ 100	13	13	13	<2	1	1	<2	1	1	<2	1	1			1

Notes

Red highlight – exceeds amended IWUL limits for waste water

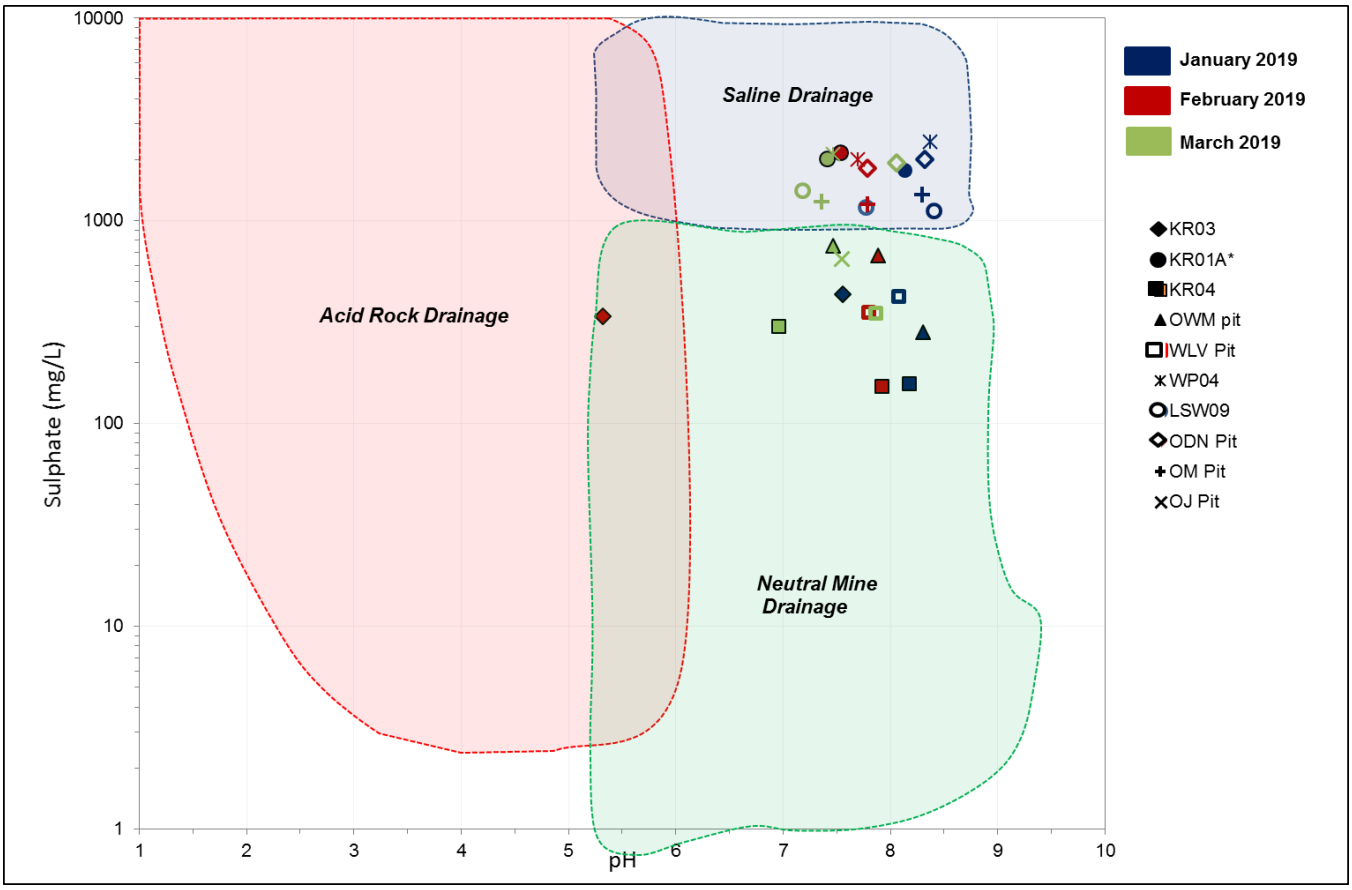


Figure 5: Classification of process water sampled during the first quarter of 2019 at Leeuwpan based on sulphate concentration and pH (modified after INAP, 2010)

- OM Pit: The levels of measured constituents were generally stable during the first quarter apart from total dissolved solids, total hardness and turbidity, which increased in February and decreased in March; sulphate which decreased in February and increased in March. The levels of nitrate exceeded the IWUL limit in January and February 2019 and all the constituents were compliant to the limits throughout the quarter. The pit water was classified and saline drainage from January to March 2019 on the basis of pH and sulphate concentration (Figure 5).
- OJ Pit. The pit was not sampled in January and February 2019 as a heap of waste rock materials blocked the access point. All the of the constituents were compliant to the IWUL limits in March (Table 9). The pit water was classified on the basis of pH and sulphate levels as neutral mine drainage in March 2019 (Figure 5).
- Kenbar return water dam (KR01A): The levels of most major constituents were relatively stable during the first quarter of 2019 apart from total dissolved solids, turbidity, electrical conductivity, sulphate and total hardness in February; and decreases in nitrate, in February; total dissolved solids, turbidity, magnesium and potassium in March 2019. All of the measured constituents were within the IWUL limits throughout the first quarter of 2019 (Table 9). The water samples were classified as saline drainage throughout the reporting period on the basis of pH and sulphate levels (Figure 5).

- Marsh area next to workshop road (KR04): Increasing trends in total dissolved solids, sodium, calcium and electrical conductivity whilst turbidity throughout the first quarter. All the measured constituents were compliant to IWUL limits throughout the first quarter of 2019. The water samples were classified as neutral mine drainage on the basis of pH and sulphate levels from January to March 2019 (Figure 5).
- New Witklip Return Water Dam (WP04): The levels of measured constituents were relatively stable and within IWUL limits throughout the first quarter of 2019 apart from increases in levels of total dissolved solids in February; and sulphate and calcium in March 2019 (Table 9). The water samples were classified as saline drainage during the reporting period on the basis of pH and sulphate levels (Figure 5).
- Pollution Control Dam (LSW09): Increasing trends in levels of total dissolved solids, electrical conductivity, sulphate, ammonia, sodium, sodium adsorption ratio, boron and total hardness throughout the first quarter, Decrease in nitrate, potassium and turbidity in March. The levels of nitrate exceeded the IWUL limit in January and February 2019. All the other constituents were compliant to the IWUL limits (Table 9). The water samples were classified as saline drainage from January to March 2019 on the basis of pH and sulphate (Figure 5).

2.5 Final effluent from sewage works

Laboratory results of final effluent sampled from the sewage plant behind the workshop (LWP_SP_W) and the septic tanks at the plant (LWP_SP_P) are presented and compared against the amended IWUL limits in Table 10. The following observations are made from the data:

- LWP-SP-W: The levels of total suspended solids (TSS), orthophosphate, chemical oxygen demand (COD) and ammonia decreased throughout the first quarter of 2019. The levels of nitrate and *E. coli* increased in February; and chemical oxygen demand (COD) remained relatively stable between February and March 2019.The levels of ammonia exceeded IWUL limits throughout the first quarter whilst orthophosphate and *E. coli* levels were non-compliant to IWUL limits in January and February 2019; and nitrate, was non-compliant in January 2019 (Table 10).

  The sewage plant performance has improved by March 2019, but the effluent remains non-compliant in terms of ammonia concentrations

Table 10: Final Sewage effluent Results for first quarter of 2019

Parameters	Units	IWUL 04/B21A/ABCGIJ/429 (Amendment)	LWP-SP-W			LWP-SP-P		
			LNP19_M01_025 LNP19_M01_026	LNP19_M02_025 LNP19_M02_026	LNP19_M03_060 LNP19_M03_061	LNP19_M01_034 LNP19_M01_035	LNP19_M02_034 LNP19_M02_035	LNP19_M03_066 LNP19_M03_067
			11-Jan	1-Feb	1-Mar	11-Jan	1-Feb	1-Mar
Total Suspended Solids (TSS)	mg/L	-	182	25	15	301	42	53
Nitrate (NO_3^-)	mg/L	≤ 20	33.2	2.5	3.0	0.4	0.1	0.1
Ammonia (NH_3) *	mg/L	≤ 10	74.6	70.0	66.6	47.3	48.4	43.1
Orthophosphate as PO_4^{3-}	mg/L	≤ 10	25.3	15.5	8.0	11.2	11.1	4.3
Chemical oxygen demand (COD)	mg/L	-	102	63	63	54	240	276
Escherichia coli	CFU/100ml	≤ 10	740	2 400	0	1 700 000	780 000	0

Notes

Highlight - exceeds IWUL limits for waste water

*Calculated from Ammoniacal nitrogen as N

- LWP-SP-P: The levels of chemical oxygen demand increase throughout the first quarter, whilst orthophosphate decreased during the same period; ammonia increased in January and February, and it decreased in March; and *E. coli* decreased in January and February and decreased to below detection limit in March 2019. The levels of ammonia, orthophosphate and *E. Coli* were consistently above the IWUL limit.

The sewage effluent from the septic tank should not be allowed to enter the environment but should continue to be emptied by an accredited waste removal company and disposed of to an authorized wastewater treatment works

2.6 Groundwater

The static groundwater level varied from 1.00 mbgl in borehole WELMB-S to 49.14 mbgl in borehole MOAMB9 in March 2019. The following trends were observed between December 2018 and March 2019:

- Stable water levels: RIE10B (0.02 m) and WWNMB16 (0.06 m);
- Increases in water level: KENMB2_D (0.52 m), LW07 (0.18m), RKL01 (0.62 m) and WITMB14 (0.18 m); and
- Decreases in water levels: LEEMB_18 (-0.16 m), MOAMB10 (0.24 m), MOAMB9 (-4.3 m), RKL02 (-0.41 m), WELMB13_D (-0.29 m), WELMB13_S (-0.22 m), WOLMB15_D (-4.28 m), WOLMB15_S (-5.29 m) and WWNMB16 (-1.95 m).

Changes in water levels could be attributed to recharge by rainfall; and changes in rates of abstraction for agricultural activities (e.g. WOLMB15_S, WOLMB15_D and MOAMB9) and mine dewatering activities.

The water level data indicates a water divide around MOAMB4 and RKL01, with water generally flowing to the northeast and northwest in alignment with topography, and towards the Bronkhorstspruit to the east as well as the Bronkhorstspruit tributary to the west (Figure 7).

The laboratory results for groundwater samples collected in March 2019 at Leeuwpan and screened against the SANS 241 drinking water standards are presented in Table 11. The major cations and anions data are also presented on a Piper Diagram in Figure 8 and time series trend graphs in APPENDIX C.

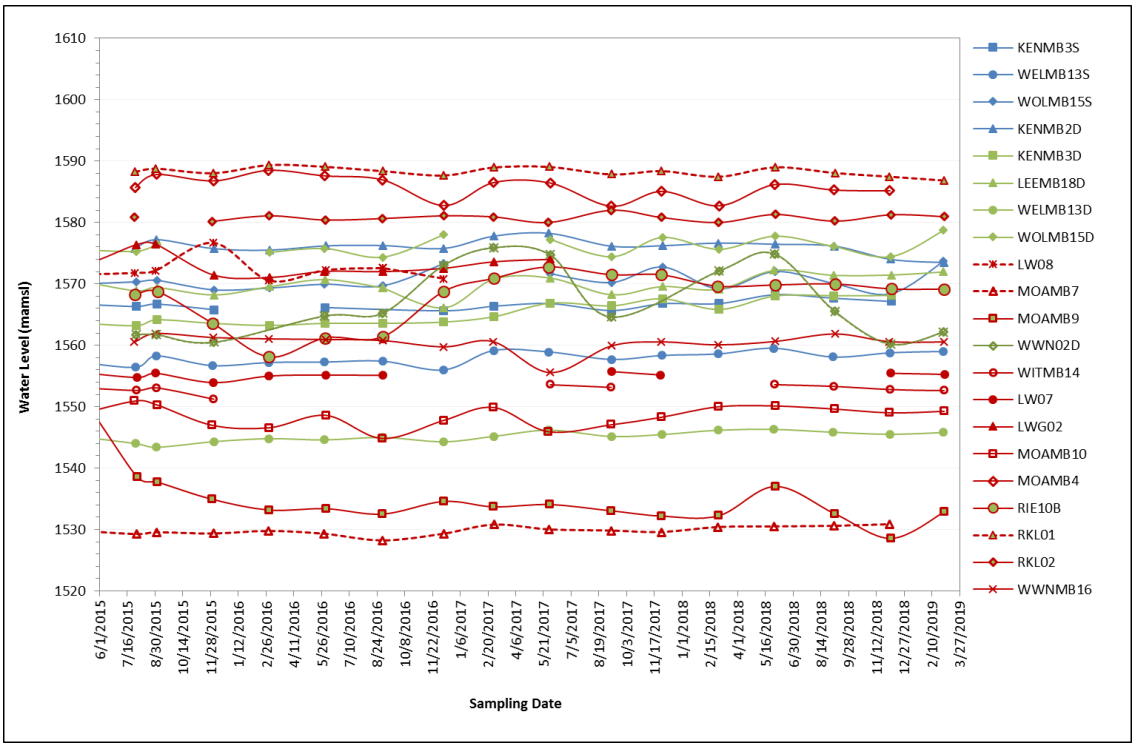


Figure 6: Variation of water levels with time.

The following observations are made from the boreholes data:

- WWNMB16: The borehole water was characterized by a calcium/magnesium bicarbonate signature (Figure 8), typical of groundwater that is not affected by mining activities. The water was compliant to SANS 241:2015 drinking water quality standards (Table 11), and the levels of measured constituents were relatively stable in March 2019 compared to December 2018 apart from total dissolved solids, which increased.
- RIE10B: The borehole water was characterized by a calcium/magnesium bicarbonate signature (Figure 8). There were no major changes to levels of measured constituents apart from potassium, which increased whilst sodium decreased in March 2019 relative to December 2018. The levels of all constituents were below the drinking water standards in March 2019.
- MOAMB10: The borehole water was characterized by a calcium/magnesium sulphate signature (Figure 8). The levels of measured constituents were relatively stable and within the SANS 241: 2015 drinking water standards in March 2019.

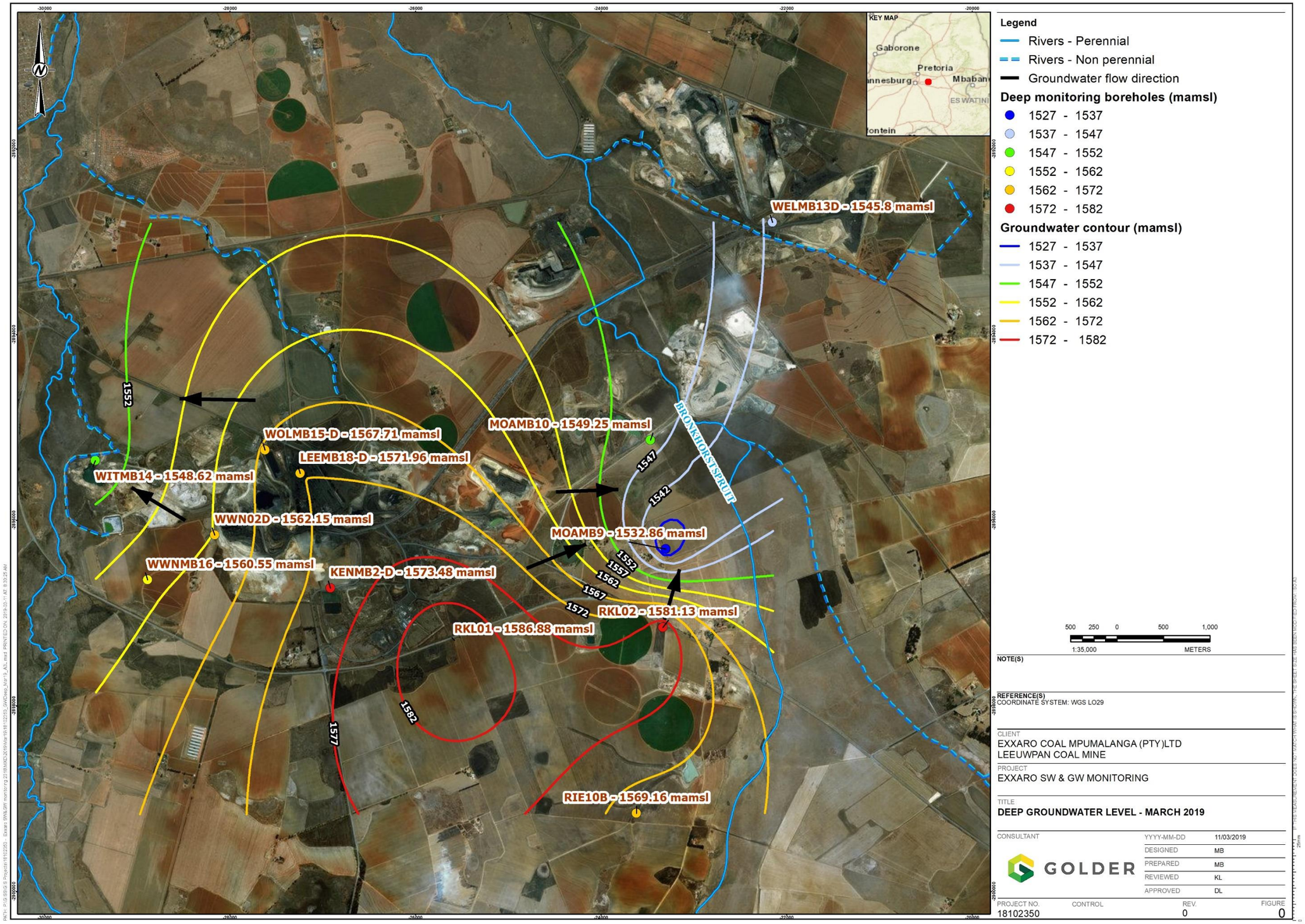


Figure 7: Groundwater level contours and flow directions

Table 11: Groundwater chemistry compared against drinking water standards

Constituent	Units	SANS 241-1:2015 Drinking Water Quality Standards	WWNMB16	LW08	RIE10B	MOAMB10	RKL02	RKL01	KENMB2-D	WELMB13-D	WELMB13-S	MOAMB7	RIE4
			LNP19_Q1_017	No Sample	LNP19_Q1_013	LNP19_Q1_003	LNP19_Q1_015	LNP19_Q1_012	LNP19_Q1_011	LNP19_Q1_002	LNP19_Q1_001	No Sample	LNP19_Q1_014
			2-Mar	2-Mar	2-Mar	1-Mar	2-Mar	2-Mar	2-Mar	28-Feb	28-Feb	1-Mar	2-Mar
pH	pH units	≥ 5 to ≤ 9.7[#]	7.77	Bees were found in the borehole during the time of sampling.	7.68	7.08	7.65	7.26	7.5	6.47	7.31	New fence installed on side used to access the borehole	6.59
Total Dissolved Solids	mg/l	≤ 1 200”	184		272	170	172	248	2 167	155	1 207		165
Electrical Conductivity	mS/m	≤ 170”	27		42	23	28	39	222	17	135		27
Fluoride	mg/l	≤ 1.5[ch]	0.2		0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.1
Sulphate	mg/l	≤ 500[ac]/≤250”	1		18	12	1	51	1 276	50	796		35
Chloride	mg/l	≤ 300”	5		14	13	5	3	9	6	4		25
Nitrate as NO_3^-	mg/l	-	6.77		7.5	4.85	0.025	0.07	0.025	0.025	0.025		0.35
Ortho Phosphate as PO_4^{3-}	mg/l	-	0.015		0.015	0.015	0.015	0.015	0.015	0.015	0.015		0.015
Dissolved Aluminium	mg/l	≤ 0.3”	0.02		0.02	0.02	0.02	0.02	0.02	0.02	0.02		0.02
Dissolved Calcium	mg/l	-	23.3		41.2	18.3	18.2	36.8	330.4	13.3	118.3		13
Total Dissolved Iron	mg/l	≤ 2[ch]/ ≤ 0.3”	0.0		0.1	0.0	3.5	0.0	0.1	0.1	4.4		10
Dissolved Magnesium	mg/l	-	14.5		15.8	11.3	9.1	24.2	159.8	8.9	121.4		9
Dissolved Manganese	mg/l	≤ 0.4[ch]/ ≤ 0.1”	0.004		0.023	0.009	0.36	0.997	0.024	0.105	0.907		0.678
Dissolved Potassium	mg/l	-	11		23	11	32	9	45	5	24		21
Dissolved Sodium	mg/l	≤ 200”	2.4		4.2	0.6	1.8	4	0.5	0.2	0.1		10.3
Total Alkalinity as $CaCO_3$	mg/l	-	104		154	15	140	150	175	4	60		63

Notes

“aesthetic; [#]operational; [ac]acute health; [ch]chronic health

Orange highlight exceeds aesthetic and operational standards

Red highlight exceeds chronic or acute health standard

Table 11 continued

Constituent	Units	SANS 241-1:2015 Drinking water Quality Standard	KENMB3-D	KENMB3-S	LEEMB18-D	LW07	MOAMB4	MOAMB9	WITMB14	WOLMB15-S	WOLMB15-D	WWN02-D
			No Sample	No sample	LNP19_Q1_006 LNP19_Q1_007 LNP19_Q1_008	LNP19_Q1_018	No Sample	LNP19_Q1_016	LNP19_Q1_005	LNP19_Q1_009	LNP19_Q1_010	LNP19_Q1_004
					1-Mar	3-Mar	1-Mar	2-Mar	1-Mar	1-Mar	1-Mar	1-Mar
pH	pH units	≥ 5 to ≤ 9.7[#]	Borehole destroyed due to construction at the offices	Borehole destroyed due to construction at the offices	7.29	8.08	Boulder at access point	7.21	7.62	6.62	7.37	7.55
Total Dissolved Solids	mg/l	≤ 1 200”			1 170	229		225	479	2 258	708	466
Electrical Conductivity	mS/m	≤ 170”			131	44		37	73	227	90	65
Fluoride	mg/l	≤ 1.5[ch]			0.075	0.075		0.075	0.075	0.075	0.075	0.075
Sulphate	mg/l	≤ 500[ac]/≤250”			433	6		5	98	1 403	401	240
Chloride	mg/l	≤ 300”			5	13		25	16	11	12	5
Nitrate as NO_3^-	mg/l	-			5.967	0.025		0.025	2	5.34	2.07	0.09
Ortho Phosphate as PO_4^{3-}	mg/l	-			<0.06	0.015		0.015	0.015	0.015	0.015	0.015
Dissolved Aluminium	mg/l	≤ 0.3”			0.02	0.02		0.02	0.02	0.02	0.02	0.02
Dissolved Calcium	mg/l	-			194	33		27	48	350	110	46
Total Dissolved Iron	mg/l	≤ 2[ch]/ ≤ 0.3”			0.0215	0.845		0.719	0.066	0.01	0.01	0.01
Dissolved Magnesium	mg/l	-			76	22		11	38	158.6	45.2	32.2
Dissolved Manganese	mg/l	≤ 0.4[ch]/ ≤ 0.1”			0.002	0.061		0.144	0.01	0.006	0.002	0.01
Dissolved Potassium	mg/l	-			22	32		39	40	40	23	46
Dissolved Sodium	mg/l	≤ 200”			9	2		2.2	0.7	0.8	1.6	0.1
Total Alkalinity as $CaCO_3$	mg/l	-			134	206		150	262	29	40	84

Notes

“aesthetic; [#]operational; [ac]acute health; [ch]chronic health

Orange highlight exceeds aesthetic and operational standards

Red highlight exceeds chronic or acute health standard

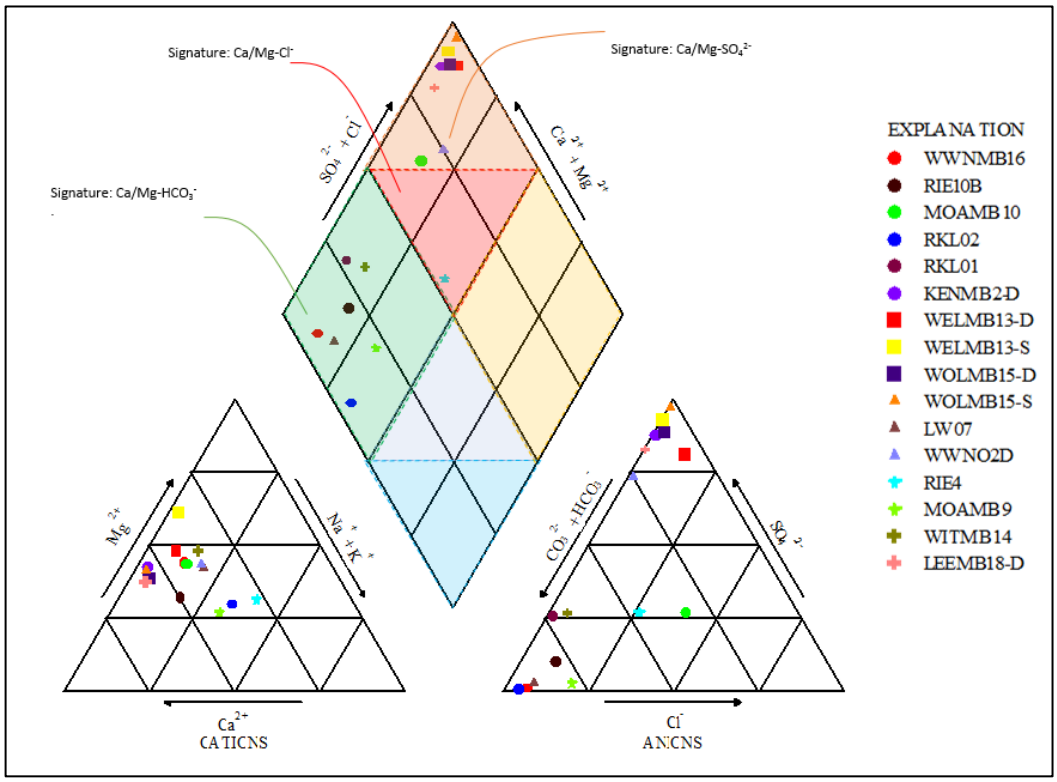


Figure 8: Piper Diagram for groundwater quality

- RKL02: The borehole water was characterized by a calcium/magnesium-bicarbonate signature (Figure 8). The level of calcium, magnesium, sodium and iron increased whilst total dissolved solids decreased in March 2019 compared to December 2018 apart from sodium, which increased. The levels of iron and sodium exceeded the chronic and aesthetic drinking water standards, respectively. The other constituents were compliant to the drinking water standards (Table 11).
- RKL01: The borehole water was characterized by a calcium/magnesium-bicarbonate signature (Figure 8). The levels of total dissolved solids, electrical conductivity, sulphate, nitrate, calcium, magnesium, and alkalinity increased whilst iron decreased in March 2019 compared to December 2018. The levels of the measured constituents were below the drinking water standards apart from manganese, which exceeded the chronic health drinking water standards (Table 11).
- KENMB2-D: The borehole water was characterized by elevated levels of electrical conductivity, total dissolved solids, calcium, magnesium and sulphate possibly due to seepage from the Kenbar return water dam (KR01). The water had a calcium/magnesium sulphate signature (Figure 8), typical of water affected by mining activities. The levels of pH, sodium, iron, chloride, calcium and magnesium decrease whilst all the other constituents were generally stable in March 2019 compared to December 2018. The levels of total dissolved solids and electrical conductivity exceeded aesthetic drinking water quality standards whilst sulphate levels exceeded the acute health standards. The levels of all the other constituents were compliant to the standards (Table 11).
- WELMB13-D: The water was slightly acidic (pH=6.5) and characterized by a calcium/magnesium sulphate signature in March 2019 (Figure 8), typical of water affected by mining activities. The levels of measured

constituents were relatively stable in March 2019 and within the SANS 241:2015 drinking water quality standards (Table 11) apart from increases in levels of total dissolved solids, sulphate and manganese. The levels of manganese exceeded aesthetic drinking water quality standards

- WELMB13-S: The water was characterized by elevated levels of total dissolved solids and a calcium/magnesium-sulphate signature (Table 11and Figure 8). The mining activities in OWM pit are likely to be affecting the groundwater at this site. The levels of total dissolved solids (by a huge margin), magnesium, calcium, electrical conductivity, sulphate and manganese decreased in March 2019 compared to December 2018, whilst potassium increased during the same period. The other constituents were relatively stable. The levels of total dissolved solids exceeded the aesthetic drinking water standards; sulphate exceeded acute health standards; and iron and manganese exceeded the chronic health drinking water quality standards. All the other constituents were below the drinking water standards in March 2019 (Table 11).
- RIE4: The water was of a calcium/magnesium-chloride signature (Figure 8).The levels of the measured constituents were below the drinking water standards apart from iron and manganese, which exceeded the chronic health drinking water standards (Table 11).
- LEEMB18-D: The water was of a calcium/magnesium-sulphate signature (Figure 8). The levels of sulphate, nitrate, total alkalinity, potassium, magnesium, calcium, total dissolved solids and electrical conductivity increased whilst chloride and sodium decreased in March 2019 compared to December 2018. The concentration of sulphate exceeded the aesthetic drinking water standard. The levels of all the other constituents were below the drinking water quality standards (Table 11).
- LW07: The water was characterized by a calcium/magnesium-bicarbonate signature (Figure 8). The levels of all constituents were below the SANS 241:2015 drinking water quality standards apart from iron, which exceeded the aesthetic standard (Table 11).
- MOAMB9: The water was of a calcium/magnesium-bicarbonate signature (Figure 8) and it exceeded the aesthetic drinking water quality standards for iron and manganese (Table 11). The levels of the other constituents were compliant to SANS 241:2015 drinking water quality standards. The levels of total dissolved solids and potassium increased whilst chloride and sodium decreased in March 2019 compared to December 2018.
- WITMB14: The water was characterized by a calcium/magnesium-bicarbonate signature in March 2019 (Figure 8). The levels of all measured constituents were stable and below drinking water quality standards apart from calcium, which decreased whilst total dissolved solids and potassium increased in March 2019 compared to December 2018.
- WOLMB15-S: The water was characterized by elevated levels of total dissolved solids and electrical conductivity and was of a calcium/magnesium-sulphate signature (Table 11 and Figure 8). The levels of measured constituents were generally stable apart from calcium, and magnesium, which decreased; and potassium, which increased. The levels of total dissolved solids and electrical conductivity exceeded the aesthetic drinking water quality standards whilst sulphate exceeded the acute health standard. None of the other constituents exceeded the drinking water quality standards (Table 11).
- WOLMB15-D: The water was of a calcium/magnesium-sulphate signature (Figure 8). The levels of total dissolved solids, magnesium, potassium, sulphate, and nitrate increased apart from sodium and chloride, decreased in March 2019 compared to December 2018. The levels of measured constituents were below the

SANS 241:2015 drinking water quality standards apart from sulphate, which exceeded the aesthetic health water quality standard in December (Table 11).

- WWN02-D: The water was characterized by a calcium/magnesium-sulphate signature (Figure 8) and levels of most measured constituents increased apart from sodium and chloride, which decreased in March 2019 compared to December 2018. The levels of the measured constituents were below the drinking water standards apart from sulphate, which exceeded the aesthetic health drinking water standards (Table 11).

2.7 QA/QC

The following QA/QC measures, which were agreed with Exxaro, were implemented:

- Measurement of EC and pH in the field and in the laboratory;
- Use of unique numbering system for each site for each sampling occasion; and
- Collection of duplicate and triplicate samples of both groundwater and surface water (Table 12).

Table 12: Triplicate Samples Sites.

Site Identity	Comments
KR01A	Process water – sampled from January to March 2019
LDWST	Potable water – sampled from January to March 2019
LSW03	Surface water – sampled from January to March 2019
LEEMB18D	Groundwater – January to March 2019
LW08	Groundwater –not sampled due to presence of bees in borehole. Should be replaced

An assessment of analytical data accuracy, precision and comparability was carried out. The assessment included ionic charge balance checks, comparison of field and laboratory measurements, comparison of measured and calculated TDS and computation of relative percent difference for duplicate pairs and triplicate samples analysed at Jones and UIS laboratories, respectively.

2.7.1 Relative percentage difference

Laboratory duplicate and triplicate samples were used to assess precision, which is an estimate of the reproducibility of the sampling and analytical system. The statistical relationship between duplicate pair and inter-laboratory duplicate pair (triplicates) results was compared to the average of the results by computing the relative percentage difference (RPD) for analytes reported at or above the detection limits in at least one sample of the pair.

The relative percentage difference was calculated for field and laboratory measurement, duplicate and triplicate samples according to the following equation:

$$RPD\% = \frac{X1-X2}{X_{ave}} \times 100$$

Where:
$X1$ = concentration observed in the first sample

$X2$ = concentration observed in duplicate sample
X_{ave} = average concentration = $\frac{X1+X2}{2}$.

Relative percent differences of between ± 30 % for water samples are considered acceptable (USEPA, 1996). The RPDs for surface water field and laboratory measurements were compared to acceptable limits and exceedances are presented in Figure 9; laboratory duplicate and triplicate samples of surface water are presented in Figure 10; and those for groundwater are presented in Figure 11.

The relative percentage differences for field and laboratory measurements were acceptable for all pH values from January to March 2019; was acceptable for most electrical conductivity and total dissolved solids values during the reporting period; and was acceptable for most dissolved oxygen values throughout the first quarter of 2019 (Figure 9).

The relative percentage differences for samples analyzed at Jones versus those analyzed at UIS (Inter-lab samples were within acceptable ranges for most constituents during the first quarter. Exceptions were turbidity, chloride, orthophosphate, ammoniacal nitrogen, total phosphorous, fluoride, dissolved oxygen, total dissolved solids and sulphate in at least one pair during the reporting period (Figure 10).

Intra-lab samples (analyzed at Jones laboratory) were within acceptable ranges for most parameters from January to March 2019. Discrepancies were recorded for turbidity, dissolved oxygen, ammoniacal nitrogen, orthophosphate and sulphate in at least one pair (Figure 10).

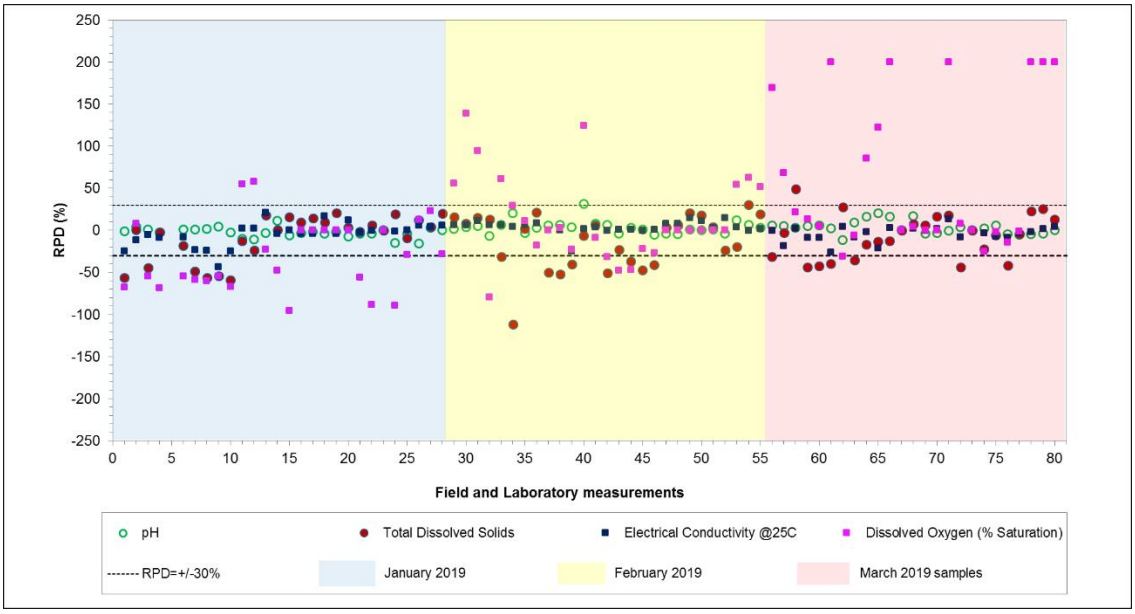


Figure 9: Relative percent difference for Q1 field and laboratory measurements on surface water samples

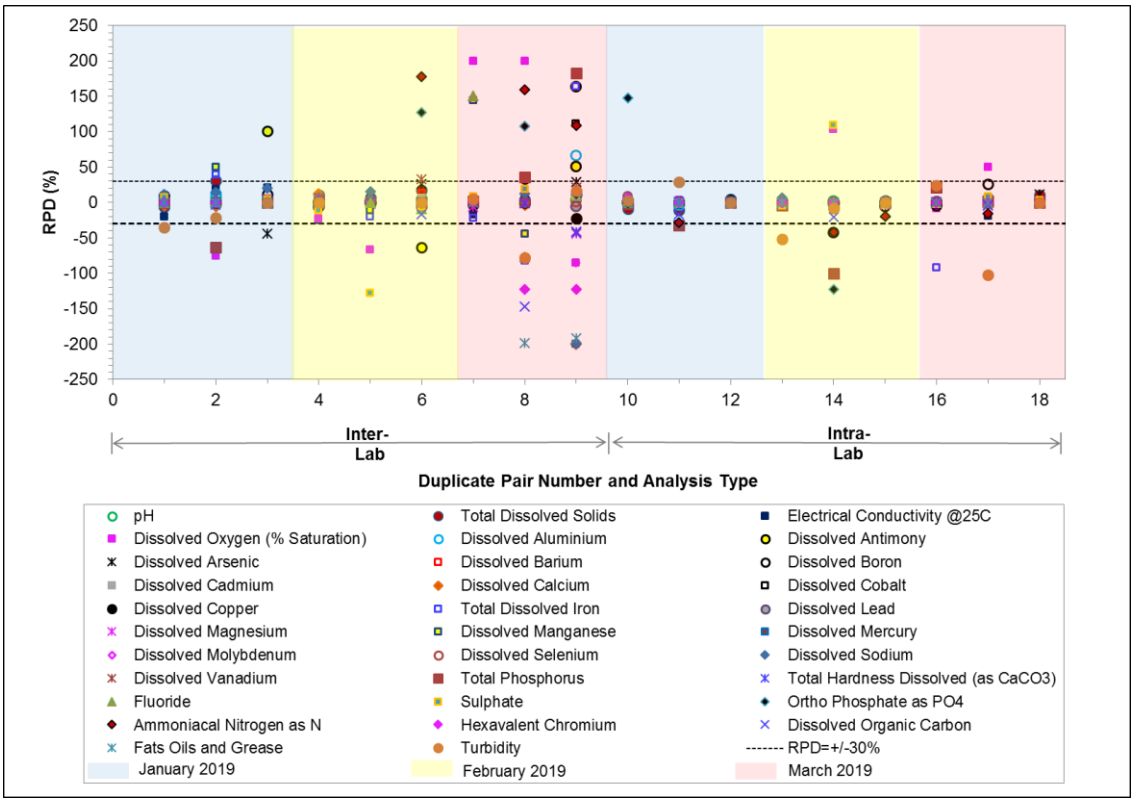


Figure 10: Relative percent difference for Q1 surface water duplicate and triplicate samples

The relative percentage differences for groundwater field and laboratory measurements were acceptable for all pH and electrical conductivity measurements; and most total dissolved measurements in March 2019 (Figure 11). The relative percentage differences for Inter-lab and Intra-lab samples were within acceptable ranges for most parameters apart from aluminum, fluoride, orthophosphate and electrical conductivity in the inter-lab samples; and iron in the intra-lab samples Figure 11

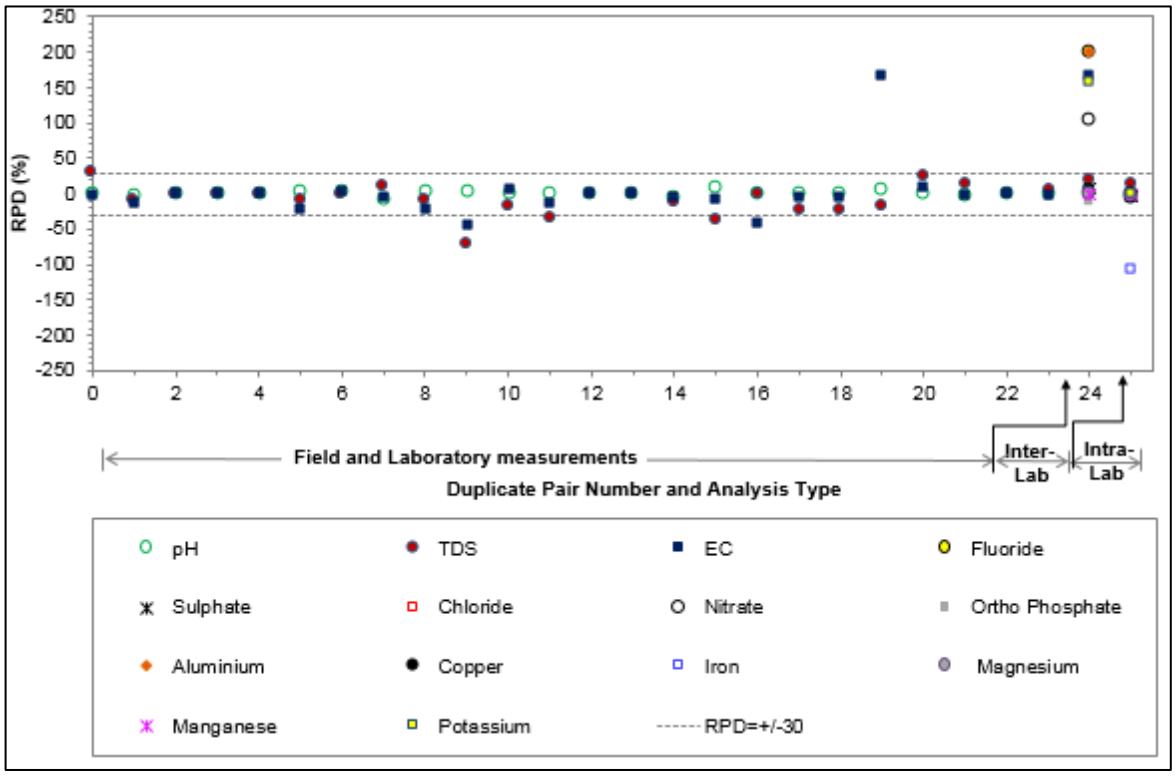


Figure 11: Relative percent difference for March 2019 groundwater samples

2.7.2 Ionic Charge Balance

Calculations of ion charge balances for all water samples were evaluated to assess the accuracy of the analyses. In electrically neutral solutions, the equivalents of cations analysed in the solution should balance that of the analysed anions. The charge imbalance (CI) calculation was obtained as a percentage by taking the difference of the equivalent concentration of major cations and anions and dividing by the sum times 100 as shown in the equation:

$$CI(\%) = \frac{\sum Cations - \sum Anions}{\sum Cations + \sum Anions} \times 100$$

Percentage ionic charge balance errors of between 5 – 10 % are regarded as acceptable (Zhao et.al. 2010), and charge imbalances greater than 20 % are unreliable for further interpretation (Nordstrom et al. 2009).

The ionic charge balance errors were acceptable for all surface water samples in January and March 2019 whilst in February 2019 only one sample fell outside the acceptable range (Figure 12).The ionic charge balance errors were within acceptable limits for all apart from one groundwater samples (Figure 13).

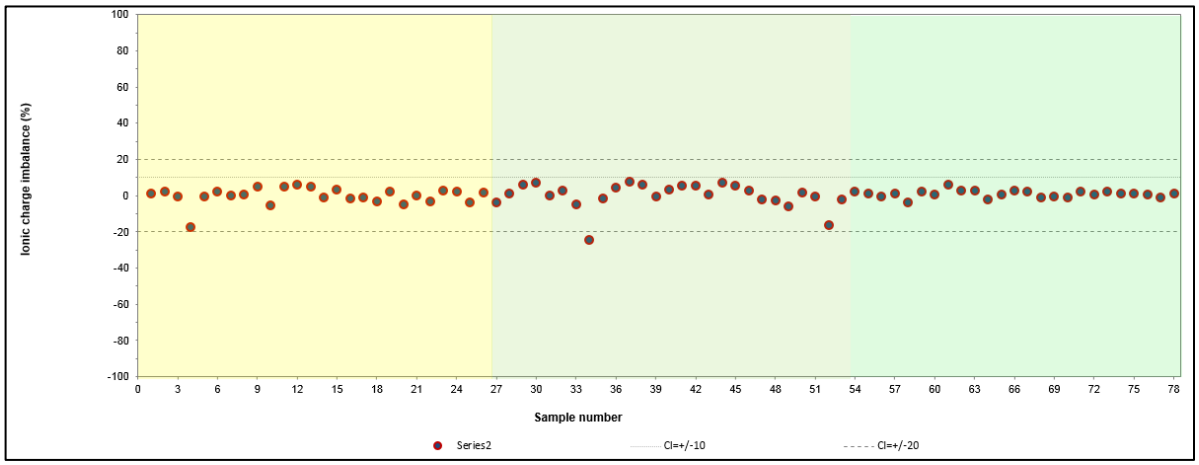


Figure 12: Ionic charge balance error of surface water samples collected during Q1 of 2019

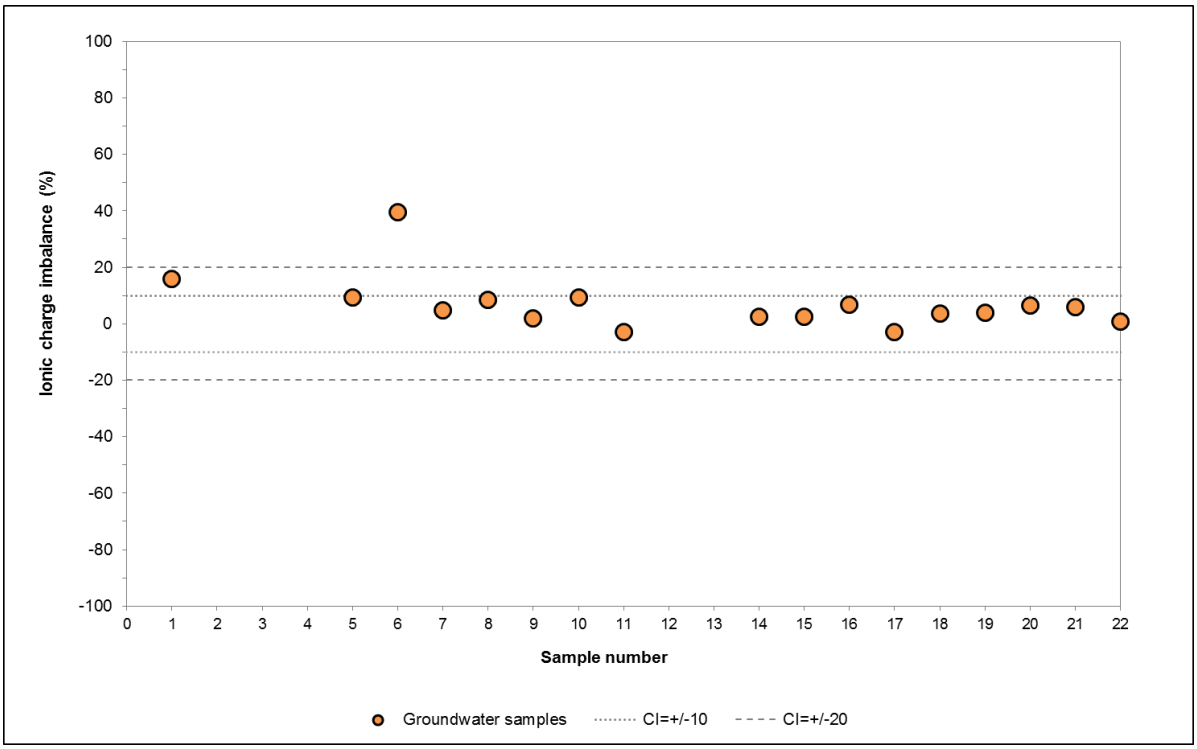


Figure 13: Ionic charge balance error of groundwater samples collected in March 2019

2.7.3 TDS evaluation

The ratio of TDS measured at the laboratories and in the field respectively, to TDS by summation of measured cations and anions was computed. Values between 1 and 1.2 are considered acceptable. The ratio of TDS to EC was also computed for field and laboratory measurements and values between 0.55 and 1.00 were considered acceptable based on the pH range of the samples and electrical conductivity values, which were less than 5 000 µS/cm (Hubert and Wolkersdorfer, 2015).

The ratios of calculated TDS vs field measured TDS were unacceptable for most surface water throughout the first quarter as was the calculated TDS vs laboratory measured TDS for most surface water samples in February 2019.

The calculated TDS vs laboratory measured TDS for most surface water samples was acceptable in January and March 2019. The ratios of calculated TDS vs field measured TDS were unacceptable for most groundwater samples in March 2019; whereas the calculated TDS vs laboratory measured TDS was acceptable for 82 % of the groundwater samples (Figure 14 and Figure 15). The ratios of TDS to EC were acceptable for most field measurements on surface water and groundwater. The ratios were acceptable for most field measured TDS to EC for surface water in throughout the first quarter of 2019 (Figure 16 and Figure 17) after the ratio set on the field probe was corrected.

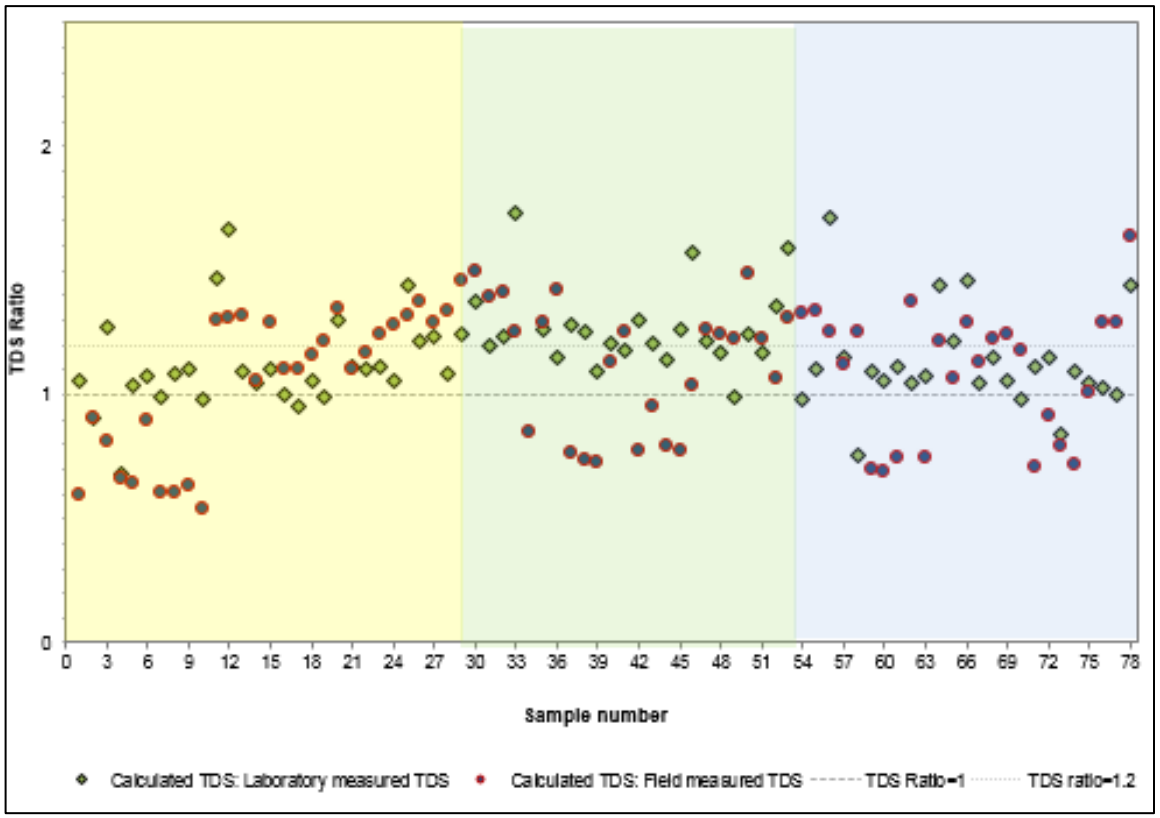


Figure 14: TDS ratios of surface water samples collected during Q1 of 2019

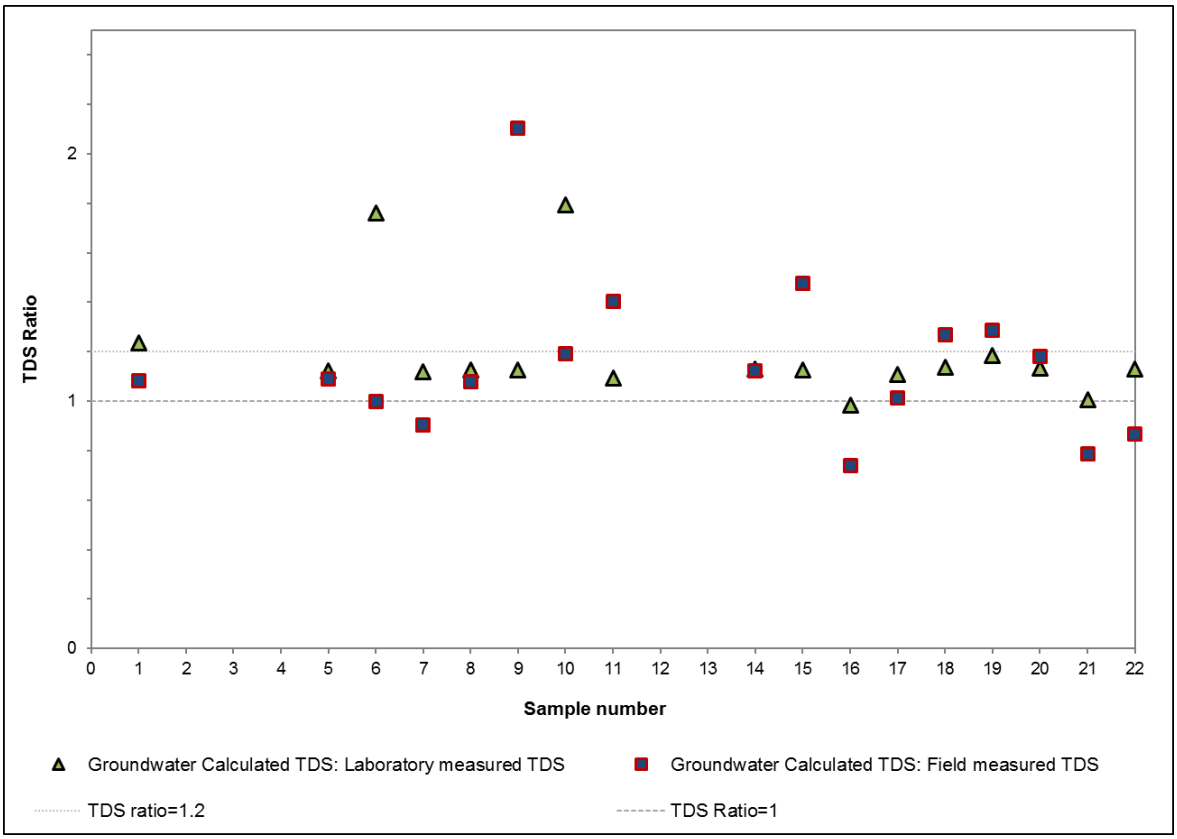


Figure 15: TDS ratios of groundwater samples collected in March 2019

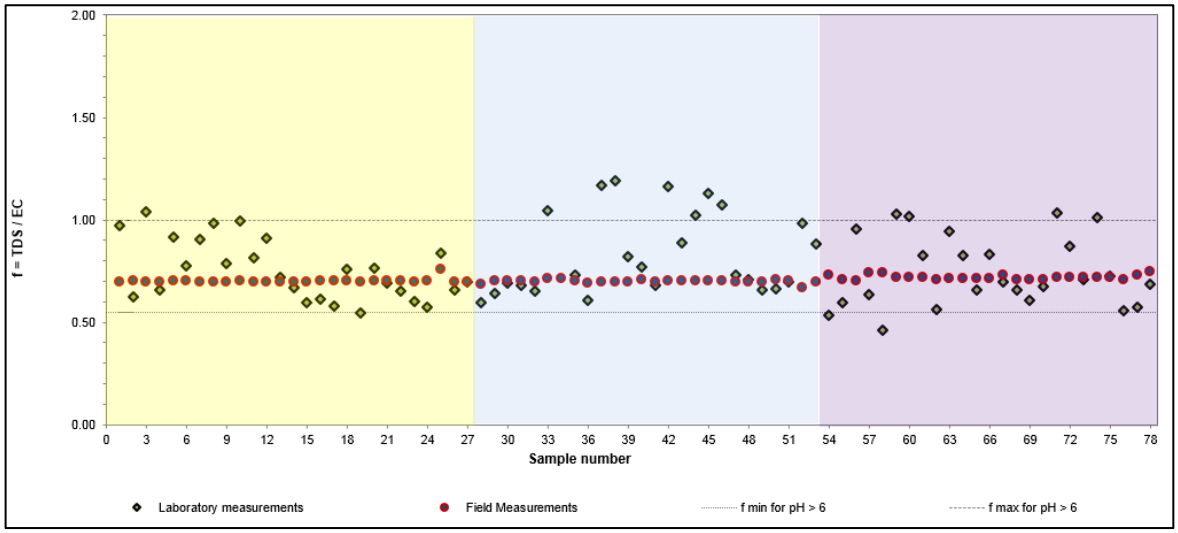


Figure 16: TDS/EC for surface water samples collected during Q1 of 2019

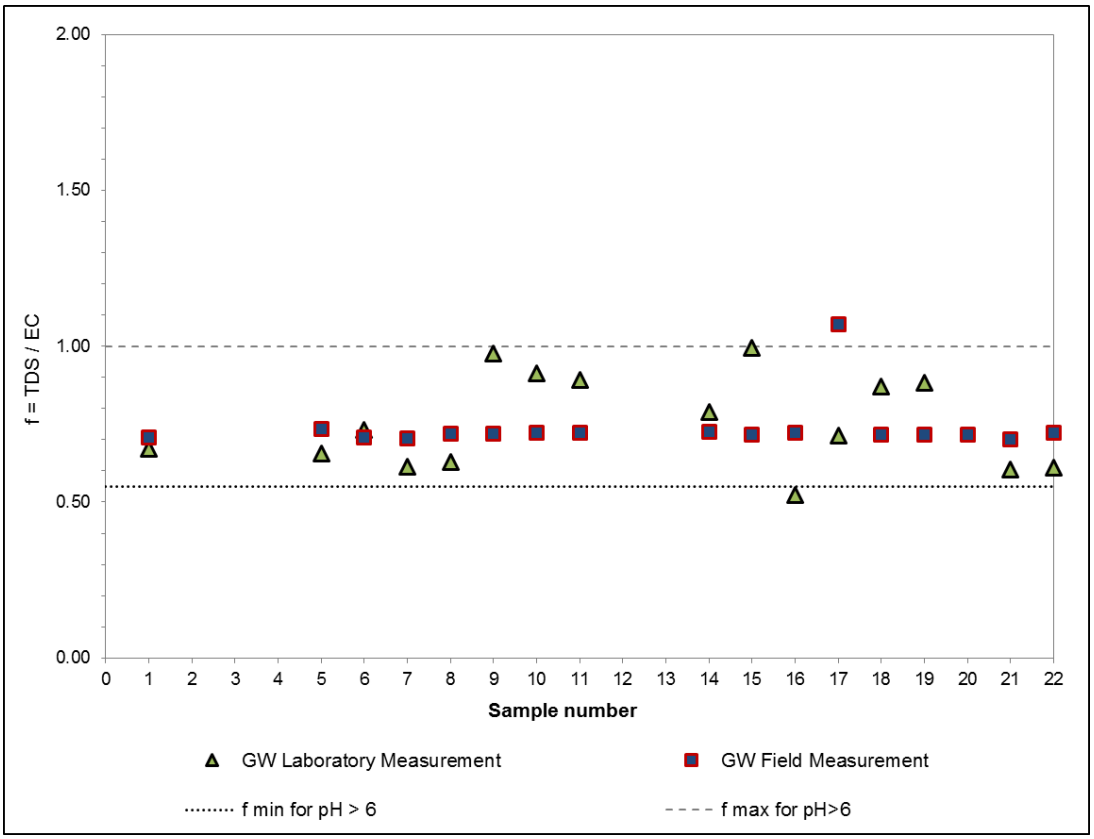


Figure 17: TDS/EC for groundwater samples collected in March 2019

3.0 CONCLUSIONS

1) The drinking water from all potable water sources was characterized by a calcium/magnesium-bicarbonate signature throughout the first quarter of 2019, which is typical of shallow, freshly recharged groundwater or water from dolomitic aquifer not affected by mining activities.

2) The levels of constituents in drinking water was compliant to SANS 241: 2015 drinking water quality standards from January to March 2019 apart from exceedance of *Escherichia coli* in water from the drinking water in January 2019 (Piet Schutte).

3) The levels of measured constituents in drinking water were relatively stable throughout the first quarter in drinking water from all sources apart from slight decreases in sulphate levels in drinking water from Piet Schutte borehole in March 2019.

4) The following parameters (mine water parameters in bold) were not compliant to water quality limits specified in the IWUL at least once during the first quarter of 2019:

    a. LSW08 (Bronkhorstspruit, upstream of Block OI): **electrical conductivity**, **ammonia,** sodium, calcium, **aluminium, manganese**, total alkalinity, iron, **dissolved oxygen**, chlorophyll *a, E. coli* and dissolved organic carbon;

    b. LSW07 (Bronkhorstspruit upstream of Leeuwpan mine): ammonia, potassium, *E. coli,* total phosphorous, dissolved oxygen, chlorophyll *a* and dissolved organic carbon;

c. LSW03 (Bronkhorstspruit adjacent to Delmas Silica): **electrical conductivity, sulphate, fluoride**, ammonia, aluminum, calcium, **manganese**, potassium, total phosphorous, *E. coli,* dissolved oxygen and dissolved organic carbon;

d. RD1 (Bronkhorstspruit at haul road): **electrical conductivity**, **sulphate**, ammonia, calcium, **manganese, magnesium,** total alkalinity, Chlorophyll a, dissolved oxygen and *E. coli*;

e. LSW13 (Stuart Coal): **total dissolved solids**, **electrical conductivity**, **sulphate**; ammonia, calcium, **magnesium, manganese,** *E. coli*, chlorophyll a and dissolved oxygen;

f. LSW05 (Bronkhorstspruit downstream): **electrical conductivity**, **sulphate**, ammonia, calcium, **magnesium**, **manganese**, total alkalinity, dissolved oxygen and *E. coli;*

g. WP01 (Bronkhorstspruit tributary upstream of the mine): sulphate, ammonia, calcium, **manganese**, potassium, total alkalinity, total phosphorous, dissolved oxygen and *E. coli*; and

h. WP02 (Bronkhorstspruit tributary downstream of the mine): **total dissolved solids**, **electrical conductivity**, ammonia, calcium, **magnesium, manganese,** sodium, total alkalinity, *E. coli*, dissolved oxygen and dissolved organic carbon.

5) The levels of most constituents were elevated at the upstream compared to the downstream sites during the first quarter of 2018. The following constituents (mine water parameters in bold) increased at downstream sites compared to upstream at least once during the reporting period:

a. WP02: The level of calcium, total alkalinity, total hardness, dissolved oxygen (a positive sign) and chlorophyll *a*; and

b. LSW05: The levels **conductivity, sulphate** (exceeded IWUL limit), calcium, magnesium (exceeded IWUL limits), dissolved oxygen (a negative sign) increased downstream.

6) The increases in levels and non-compliance of sulphate suggests impacts of mining activities on the streams- however, sources are broader than just the Leeuwpan Coal Mine and could include Delmas Silica and Stuart Coal. In addition to mining activities, nitrate could be from agricultural activities.

7) The elevated levels of sulphate and near-neutral to alkaline pH in mine process water can be attributed to oxidation of sulphides in coal, wall rock and in-pit spoils and their subsequent neutralization by carbonate minerals. The mine process water was classified based on pH and sulphate levels as:

a. Saline Drainage: KR01A, WP04, LSW09, ODN pit and OM pit; and

b. Neutral mine drainage: OWM pit, KR03, KR04, WLV pit and OJ pit.

8) The levels of all constituents measured at the process water sites were within the IWUL limits, except for nitrate at the OWM pit in January 2019;

9) The sewage plant performance has improved by March 2019, but the effluent remains non-compliant in terms of ammonia concentrations

10) The concentrations of ammonia, orthophosphate and *E. Coli* were above the IWUL limit in January and February 2019 of the first quarter. Chemical oxygen demand was elevated and increased throughout the

reporting period for the LWP-SP-P sewage treatment plant. The septic tank should continue to be emptied by an accredited waste removal company and disposed of to an authorized wastewater treatment works.

11) Decreases in water depth levels were recorded in most boreholes during March 2019. The highest decrease in water level of 5.29 m was recorded in borehole WOLMB15_S.

12) The water level data indicates a water divide around MOAMB4 and RKL01, with water generally flowing to the northeast and northwest in alignment with topography, and towards the Bronkhorstspruit to the east as well as the Bronkhorstspruit tributary to the west.

13) The levels of most measured constituents were relatively stable in most sampled boreholes.

14) Most measured constituents were compliant to SANS 241: 2015 drinking water in most sampled boreholes in March 2019. Exceptions were:

    a. RKL02: chronic health exceedance of iron and aesthetic standard exceedance of manganese;
    b. RKL01: chronic health standard exceedance of manganese;
    c. KENMB2-D: aesthetic standards exceedances of total dissolved solids and electrical conductivity, and acute health standards exceedance of sulphate;
    d. WELMB13-S: aesthetic standards exceedances of total dissolved solids, acute health standard exceedance of sulphate; and chronic health standard exceedances of iron and manganese;
    e. WELMB13-D: aesthetic standard exceedance of manganese;
    f. LEEMB18-D: aesthetic standards of sulphate;
    g. LW07: aesthetic standards of iron;
    h. MOAMB9: aesthetic standard exceedance of iron and manganese;
    i. WOLMB15-S: aesthetic standard exceedances of total dissolved solids and electrical conductivity; and acute health standard exceedance of sulphate;
    j. WOLMB15-D: aesthetic standards of sulphate; and
    k. RIE4: chronic health standard exceedances of iron and manganese, aesthetic standard for alkalinity.

15) Groundwater in boreholes WOLMB15S, WOLMB15D, WELMB13S, KENMB2D, LEEMB18D and WELMB13D was characterized by a calcium/magnesium-sulphate signature whilst water in boreholes and RIE4 was characterized by a magnesium/calcium-chloride signature. This suggest that the groundwater in these boreholes is impacted by mining activities.

16) Quality assurance showed discrepancies were recorded between laboratory measured and field measured dissolved oxygen. The inter-lab sample pairs, intra-lab sample pairs and ion charge balance were generally acceptable for most samples. The TDS ratios were generally acceptable for laboratory measurements and unacceptable for most field measurements on both surface and groundwater.

17) It is difficult to obtain samples from the closed pits such as Kenbar Rehab, OG Pit and OH Pit. Surface water does not readily accumulate, as it infiltrates through the rehabilitated ground. The water quality of rehabilitated

pits should be monitored through boreholes drilled into the backfilled spoils – becoming part of the groundwater monitoring programme instead of the surface water monitoring programme.

18) The following boreholes need to be drilled out or replaced: EMPR02/E2, KENMB1, KENMB2-S, LGW04, WTN01-D, WWN01, LW10 and RKL03.

19) Stuart Coal must be approached again to agree to access to WTN02-D and to provide a letter for monitoring staff to show.

20) The four kinetic barrels remain non-functional. Consideration should be given to fixing the taps and to placing the barrels on an elevated platform so that drainage can be collected during the rainy season

4.0 CONCLUDING REMARKS

This report has been reviewed by Lee Boyd (Senior Water Resources Specialist) and David Love (Technical Director). Please contact Keretia Lupankwa for any queries or discussion.

Golder Associates Africa (Pty) Ltd.



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MB/DL/nbh

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Directors: RGM Heath, MQ Mokulubete, SC Naidoo, GYW Ngoma

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APPENDIX A

Field Data

Table A1: Field data for surface water samples (January-March 2019)

Site name	Laboratory ID	Date sampled	Time	Temp (ºC)	pH	EC (mS/m)	TDS (mg/l)	DO (%)
	IWUL 04/B21A/ABCGIJ/429 limits and drinking water quality standards				**≥ 5 to ≤ 10***	**≤ 750***	**≤ 3 800***	**-**
					≥ 6.5 to ≤ 8.4**	**≤ 35****	**≤ 280****	**≥ 70**
					≥ 5 to ≤ 9.7***	**≤ 170*****	**≤ 1 200*****	**-**
Mine Process/dam/ pit water samples								
KR01A	LNP19_M01_011	10/1/2019	18:06	24.3	8.3	227	1589	49
	LNP19_M01_012							
	LNP19_M01_013 (UIS)							
	LNP19_M02_011	31/01/2019	14:36	30.2	8.0	329	2300	69
	LNP19_M02_012							
	LNP19_M02_013 (UIS)							
	LNP19_M03_074	2/3/2019	8:41	20.4	7.7	288	2080	77
	LNP19_M03_075							
	LNP19_M03_076 (UIS)							
KR03	LNP19_M01_015	10/1/2019	18:36	23.7	7.9	91	637	35
	LNP19_M02_015	1/2/2019	11:08	22.4	7.3	76	540	43
	-	1/3/2019	9:15	Dry and muddy. Oild separator not operational				
KR04	LNP19_M01_014	10/1/2019	18:27	24	9	41	288	47
	NP19_M02_014	1/2/2019	10:25	22	9	46	320	71
	NP19_M03_059	1/3/2019	8:54	20	8	71	520	63
LSW09	LNP19_M01_010	10/1/2019	17:51	26	8	197	1377	57
	LNP19_M02_010	1/2/2019	15:20	23	8	210	1480	76
	LNP19_M03_070	1/3/2019	15:20	28	8	219	1560	56
ODN_Pit	LNP19_M01_009	10/1/2019	17:37	25	8	249	1740	48
	LNP19_M02_009	31/01/2019	18:55	24	8	301	2110	68
	LNP19_M03_058	28/02/2019	17:29	25	8	280	2020	73
OJ_Pit		10/1/2019	No acess, tipping in progress. See pictures					
			No acess, tipping in progress. See pictures					
	LNP19_M03_056	28/02/2019	11:16	26.4	7.38	142	1020	69
OM_Pit	LNP19_M01_008	10/1/2019	17:26	25	8.18	190	1328	59
	LNP19_M02_008	31/01/2019	18:06	25.1	8.06	218	1530	51

Site name	Laboratory ID	Date sampled	Time	Temp (°C)	pH	EC (mS/m)	TDS (mg/l)	DO (%)
	IWUL 04/B21A/ABCGIJ/429 limits and drinking water quality standards				≥ 5 to ≤ 10*	≤ 750*	≤ 3 800*	-
					≥ 6.5 to ≤ 8.4**	≤ 35**	≤ 280**	≥ 70
					≥ 5 to ≤ 9.7***	≤ 170***	≤ 1 200***	-
	LNP19_M03_057	28/02/2019	17:07	27	7.79	201	1450	76
OWM_Pit	LNP19_M01_007	10/1/2019	16:45	26.4	8.1	84	585	47
	LNP19_M02_007	31/01/2019	17:29	24.3	7.61	165	1160	46
	LNP19_M03_055	28/02/2019	15:11	24.7	7.65	158	1140	59
WLV_Pit	LNP19_M01_006	10/1/2019	16:23	26.3	8.16	86	601	55
	LNP19_M02_006	31/01/2019	16:30	25.9	7.4	87	610	66
	LNP19_M03_054	28/02/2019	14:51	24.7	7.46	78	560	89
WP04	LNP19_M01_005	10/1/2019	15:27	26.1	8.19	253	1771	47
	LNP19_M02_005	31/01/2019	19:02	24.9	8.24	320	2240	59
	LNP19_M03_065	1/3/2019	12:15	26	7.78	298	2140	82
Final sewage effluent samples								
LWP_SP_P	LNP19_M01_034	11/1/2019	10:36	25	7.26	95	662	4
	LNP19_M01_035 (UIS)							
	LNP19_M02_034	1/2/2019	12:44	22.3	7.55	103	720	9
	LNP19_M02_035 (UIS)							
	LNP19_M03_066	1/3/2019	13:35	30.8	7.64	105	760	0
	LNP19_M03_067 (UIS)							
LWP_SP_W	LNP19_M01_025	11/1/2019	8:54	23	8.07	130	904	20
	LNP19_M01_026 (UIS)							
	LNP19_M02_025	1/2/2019	11:20	23.5	8.11	132	990	51
	LNP19_M02_026 (UIS)							
	LNP19_M03_060	1/3/2019	9:29	27	8.13	133	960	0
	LNP19_M03_064 (UIS)							
Surface water and receiving environment samples								
LSW03	LNP19_M01_031	11/1/2019	9:59	23.7	6.79	28	192	17
	LNP19_M01_032							
	LNP19_M01_033 (UIS)							
	LNP19_M02_031	31/01/2019	15:50	27.2	7.51	44	310	20

Site name	Laboratory ID	Date sampled	Time	Temp (°C)	pH	EC (mS/m)	TDS (mg/l)	DO (%)
	IWUL 04/B21A/ABCGIJ/429 limits and drinking water quality standards				≥ 5 to ≤ 10*	≤ 750*	≤ 3 800*	-
					≥ 6.5 to ≤ 8.4**	≤ 35**	≤ 280**	≥ 70
					≥ 5 to ≤ 9.7***	≤ 170***	≤ 1 200***	-
	LNP19_M02_032							
	LNP19_M02_033 (UIS)							
	LNP19_M03_061	1/3/2019	9:56	22.1	7.82	21	150	30
	LNP19_M03_062							
	LNP19_M03_063 (UIS)							
LSW05	LNP19_M01_038	11/1/2019	11:53	25.9	7.12	40	278	27
	LNP19_M01_039 (UIS)							
	LNP19_M02_038	1/2/2019	15:20	22.1	7.32	46	320	21
	LNP19_M02_039 (UIS)							
	LNP19_M03_089	3/3/2019	10:43	24.3	7.51	38	270	66
	LNP19_M03_090 (UIS)							
LSW07	LNP19_M01_001	10/1/2019	13:17	27.4	7.68	18	134	57
	LNP19_M01_002 (UIS)							
	LNP19_M02_001	1/2/2019	1/0/1900	22.4	8.03	28	200	36
	LNP19_M02_002 (UIS)							
	LNP19_M03_079	2/3/2019	1/0/1900	26.9	7.56	20	140	103
	LNP19_M03_080 (UIS)							
LSW08	LNP19_M01_003	10/1/2019	13:39	23.2	6.64	27	191	8
	LNP19_M01_004 (UIS)							
	LNP19_M02_003	1/2/2019	14:10	19.5	8.3	7	50	60
	LNP19_M02_004 (UIS)							
	LNP19_M03_077	2/3/2019	11:57	23.1	7.69	31	230	90
	LNP19_M03_078 (UIS)							
LSW13	LNP19_M01_029	11/1/2019	9:31	23.5	7.48	47	330	55
	LNP19_M01_030 (UIS)							
	LNP19_M02_029	31/01/2019	17:08	29.6	7.6	37	260	79
	LNP19_M02_030 (UIS)							
	LNP19_M03_052	28/02/2019	14:26	25.2	7.4	35	260	74

Site name	Laboratory ID	Date sampled	Time	Temp (°C)	pH	EC (mS/m)	TDS (mg/l)	DO (%)
	IWUL 04/B21A/ABCGIJ/429 limits and drinking water quality standards				≥ 5 to ≤ 10*	≤ 750*	≤ 3 800*	-
					≥ 6.5 to ≤ 8.4**	≤ 35**	≤ 280**	≥ 70
					≥ 5 to ≤ 9.7***	≤ 170***	≤ 1 200***	-
	LNP19_M03_053 (UIS)							
RD1	LNP19_M01_027	11/1/2019	9:16	22.3	7.65	40	276	24
	LNP19_M01_028 (UIS)							
	LNP19_M02_027	1/2/2019	12:05	20.7	8.13	45	310	34
	LNP19_M02_028 (UIS)							
	LNP19_M03_050	28/02/2019	14:09	24.4	6.59	38	270	36
	LNP19_M03_051 (UIS)							
WP01	LNP19_M01_020	11/1/2019	7:55	19.9	7.89	35	243	26
	LNP19_M01_021 (UIS)							
	LNP19_M02_020	1/2/2019	10:08	19.9	7.97	36	250	39
	LNP19_M02_021 (UIS)							
	LNP19_M03_085	3/3/2019	9:50	22.6	7.98	33	230	80
	LNP19_M03_086 (UIS)							
WP02	LNP19_M01_018	11/1/2019	7:33	21	7.78	49	342	36
	LNP19_M01_019 (UIS)							
	LNP19_M02_018	1/2/2019	9:45	21.7	8.03	54	370	40
	LNP19_M02_019 (UIS)							
	LNP19_M03_083	3/3/2019	9:14	22.2	8.05	48	350	103
	LNP19_M03_084 (UIS)							
Drinking water samples								
LDWST	LNP19_M01_022	11/1/2019	8:31	21.8	7.52	56	393	23
	LNP19_M01_023							
	LNP19_M01_024 (UIS)							
	LNP19_M02_022	31/01/2019	15:15	26.4	7.67	63	440	47
	LNP19_M02_023							
	LNP19_M02_024 (UIS)							
	LNP19_M03_071	2/3/2019	8:14	19.9	7.78	58	410	86
	LNP19_M03_072							

Site name	Laboratory ID	Date sampled	Time	Temp (°C)	pH	EC (mS/m)	TDS (mg/l)	DO (%)
	IWUL 04/B21A/ABCGIJ/429 limits and drinking water quality standards				≥ 5 to ≤ 10*	≤ 750*	≤ 3 800*	-
					≥ 6.5 to ≤ 8.4**	≤ 35**	≤ 280**	≥ 70
					≥ 5 to ≤ 9.7***	≤ 170***	≤ 1 200***	-
	LNP19_M03_073 (UIS)							
LLBDW	LNP19_M01_016	11/1/2019	7:20	20.6	7.91	54	379	33
	LNP19_M01_017 (UIS)							
	LNP19_M02_016	1/2/2019	9:03	24.6	8.2	62	440	39
	LNP19_M02_017 (UIS)							
LLBDW	LNP19_M03_081	3/3/2019	8:11	20.7	7.58	55	390	70
	LNP19_M03_082 (UIS)							
LWDL	No sample	No water in taps since December. Visited site on 10th and 11th of January						
	LNP19_M02_040	1/2/2019	13:18	22.4	8.17	60	420	50
	LNP19_M02_041 (UIS)							
	LNP19_M03_068	1/3/2019	14:42	39.9	7.56	59	430	0
	LNP19_M03_069 (UIS)							
Piet Schutte	LNP19_M01_036	11/1/2019	11:40	29.8	6.74	13	91	45
	LNP19_M01_037 (UIS)							
	LNP19_M02_036	1/2/2019	14:51	22.5	7.24	15	100	47
	LNP19_M02_037 (UIS)							
	LNP19_M03_087	3/3/2019	10:22	22.9	7.77	12	90	0
	LNP19_M03_088 (UIS)							

Notes

Highlighted cells exceed water quality standard or IWUL limit

*Wastewater IWUL limit

**Surface and receiving environment IWUL limit

***Drinking water quality standard

APPENDIX B

Surface Water Chemistry Trend Graphs

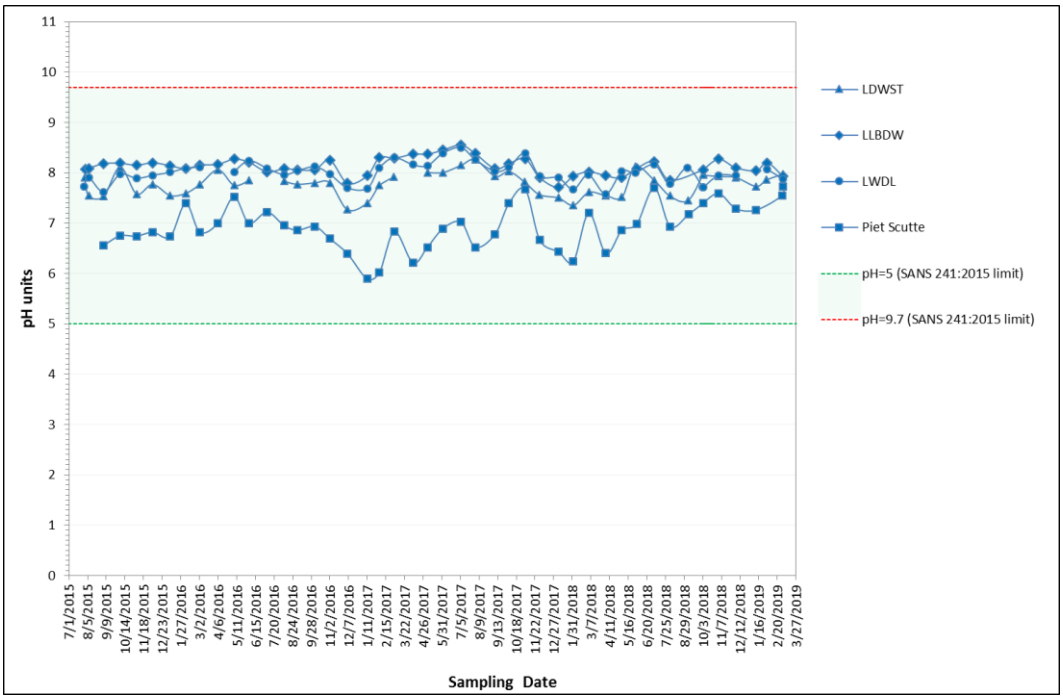


Figure B1: Variation of potable water pH

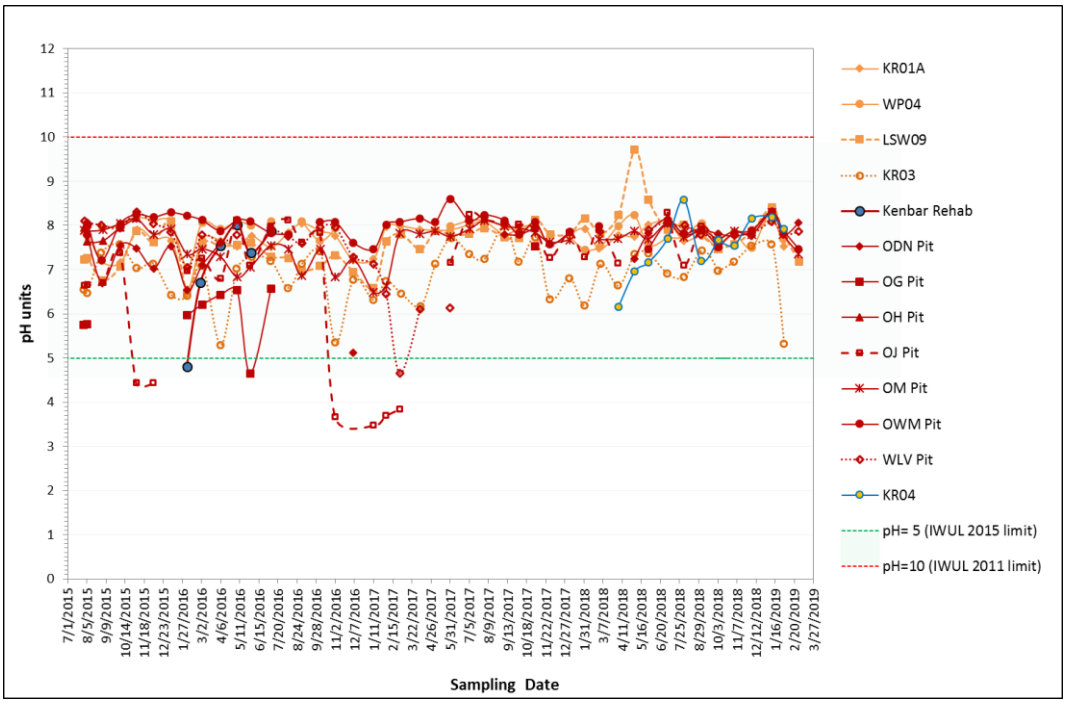


Figure B2: Variation of process water pH

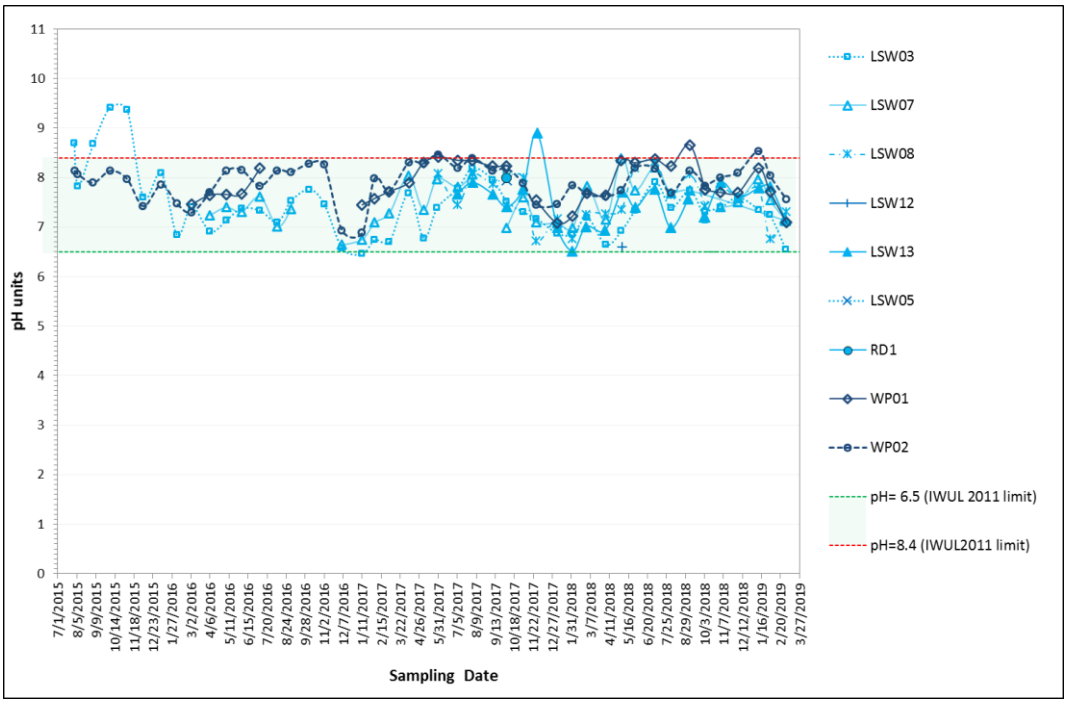


Figure B3: Variation of surface water pH

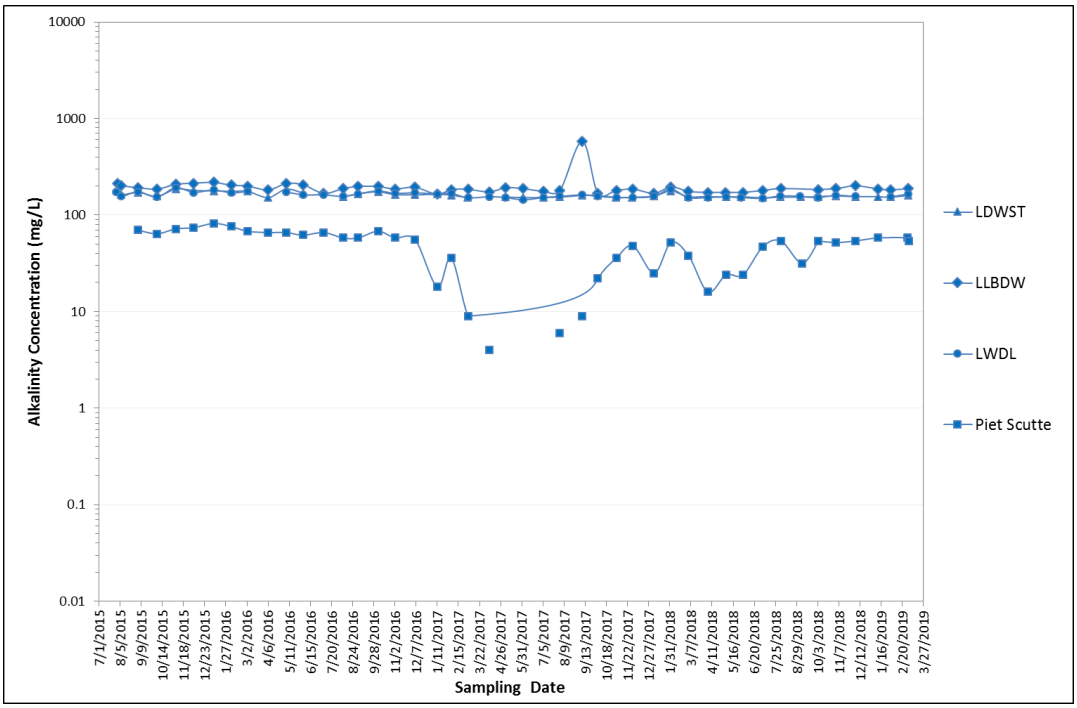


Figure B4: Variation of potable water alkalinity

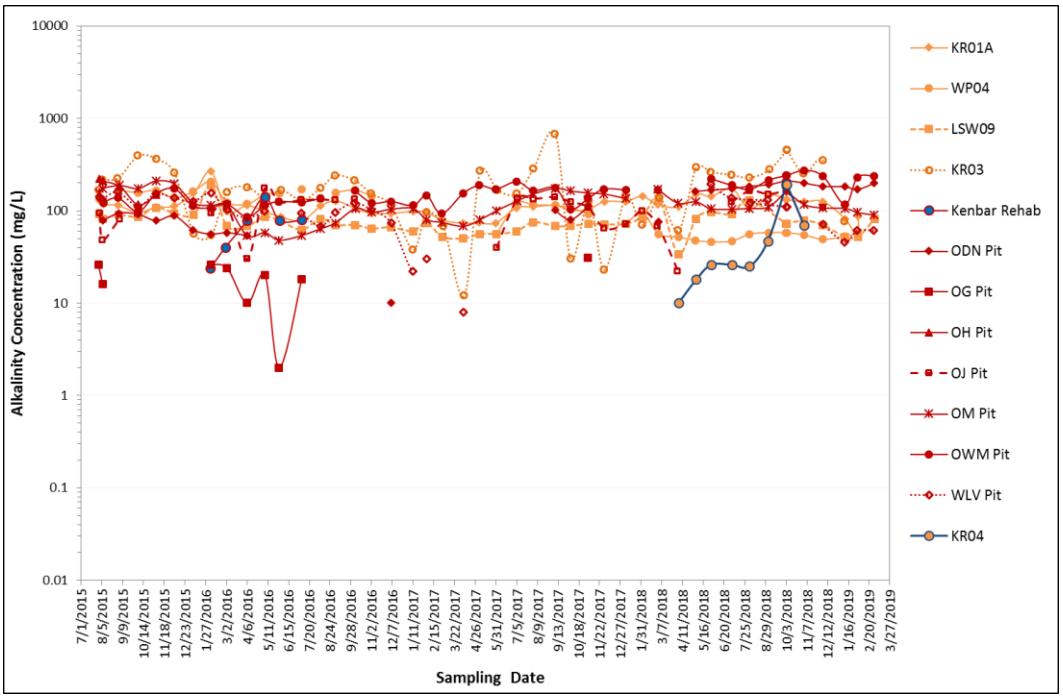


Figure B5: Variation of process water alkalinity

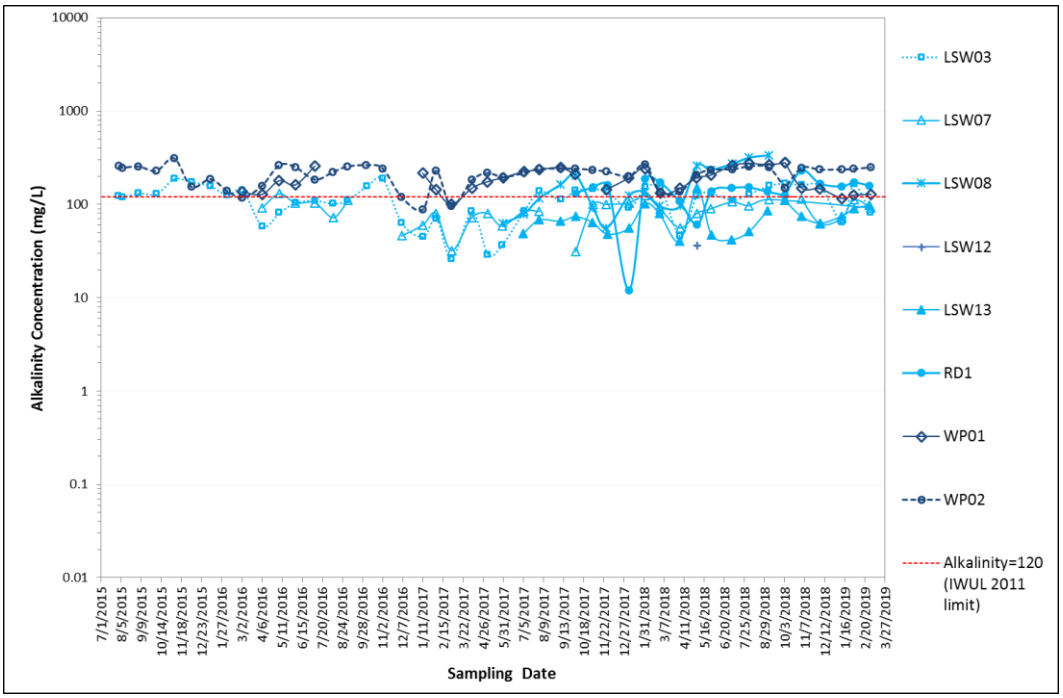


Figure B6: Variation of surface water alkalinity

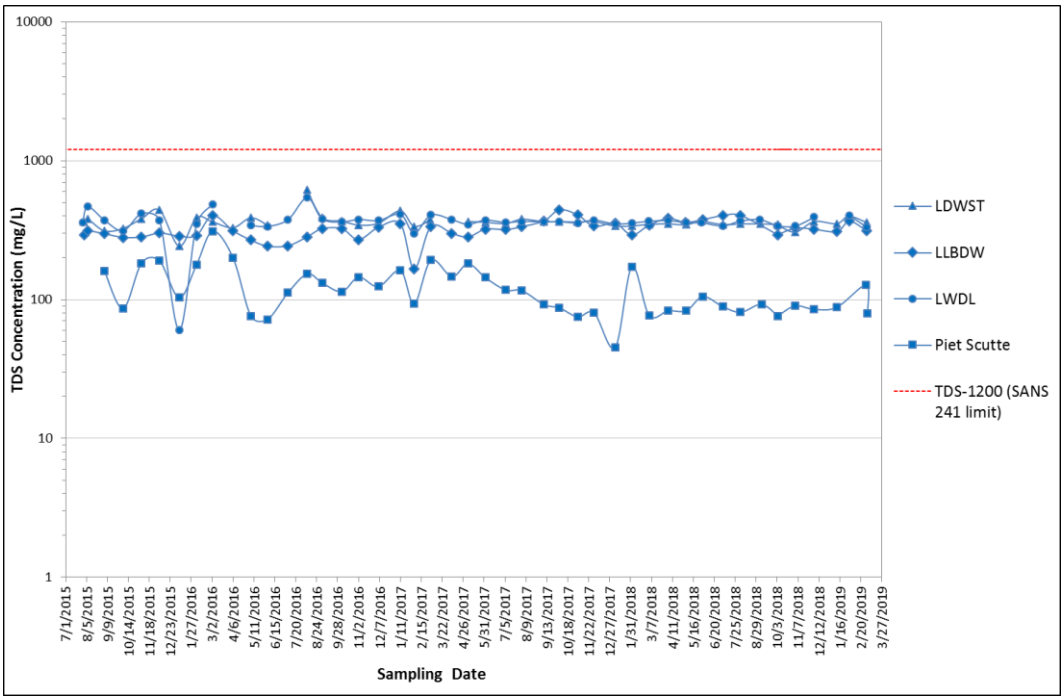


Figure B7: Variation of potable water TDS

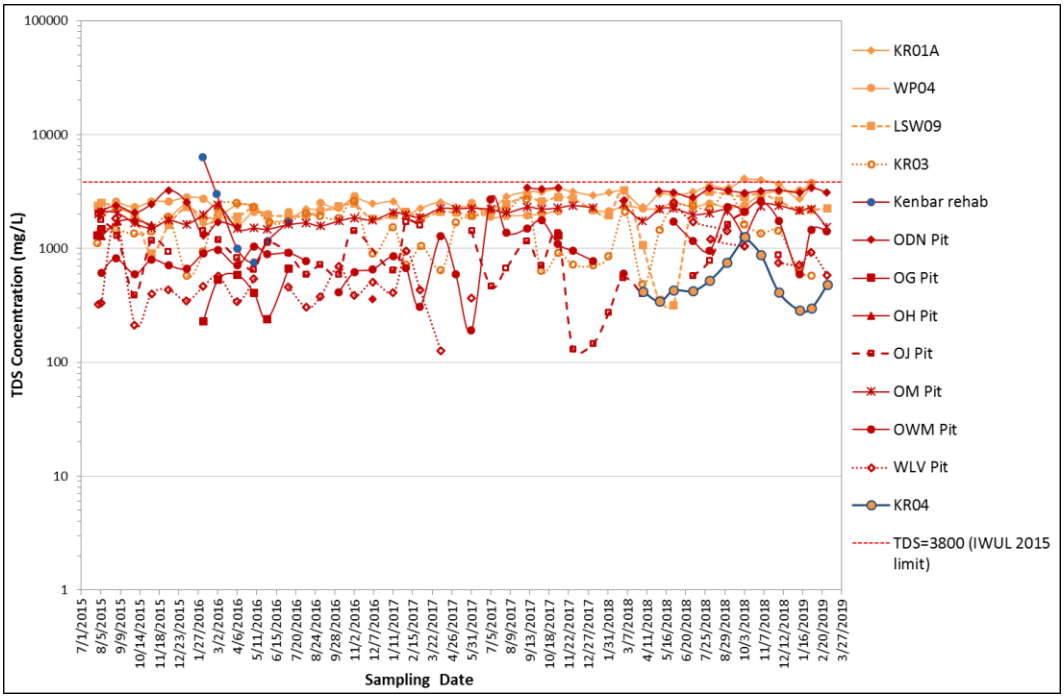


Figure B8: Variation of process water TDS

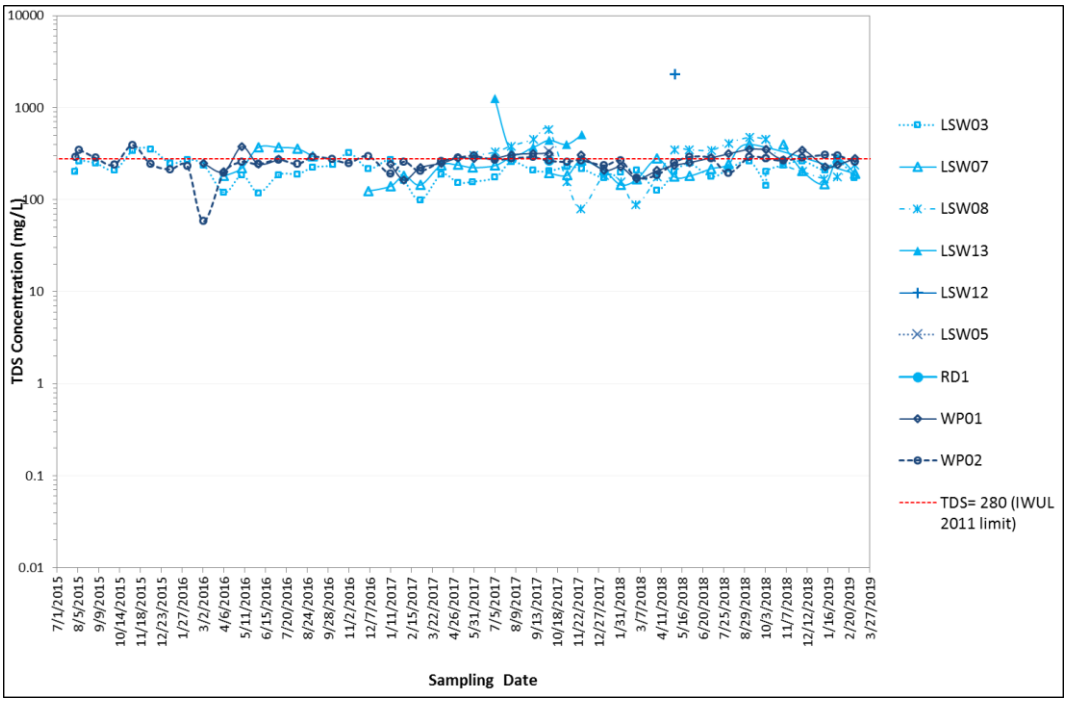


Figure B9: Variation in surface water TDS

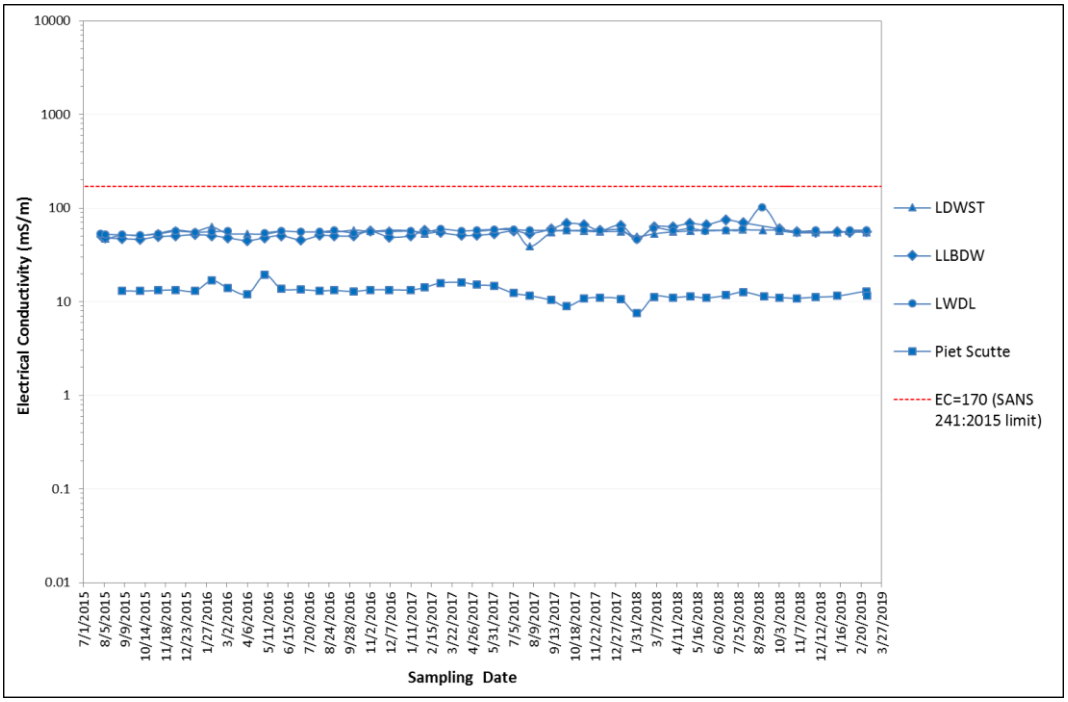


Figure B10: Variation of potable water electrical conductivity

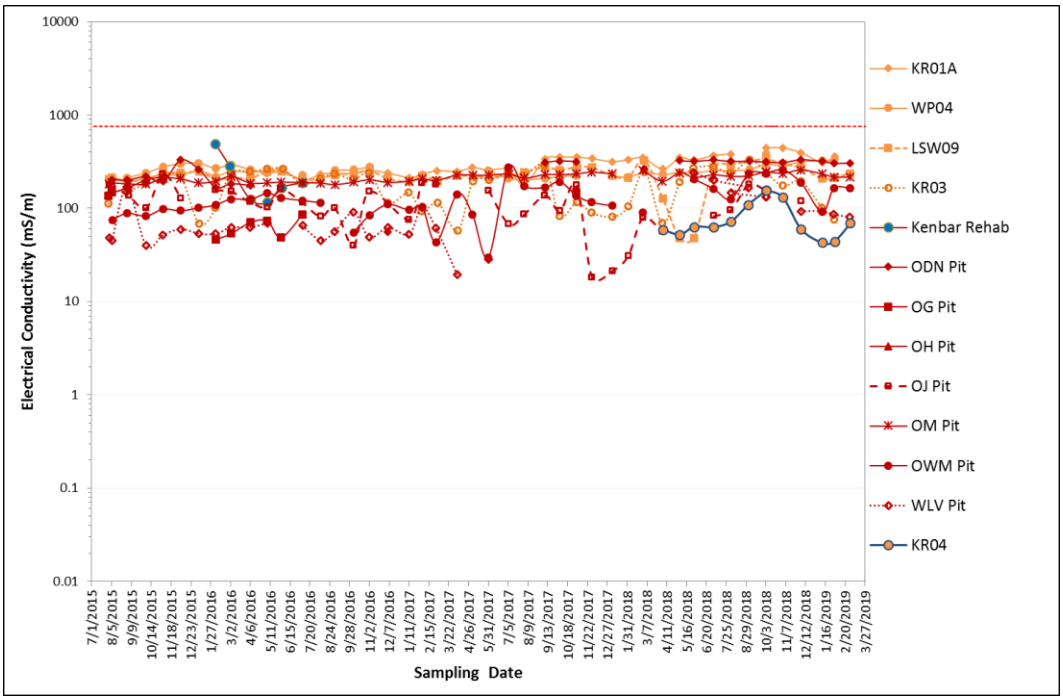


Figure B11: Variation of process water electrical conductivity

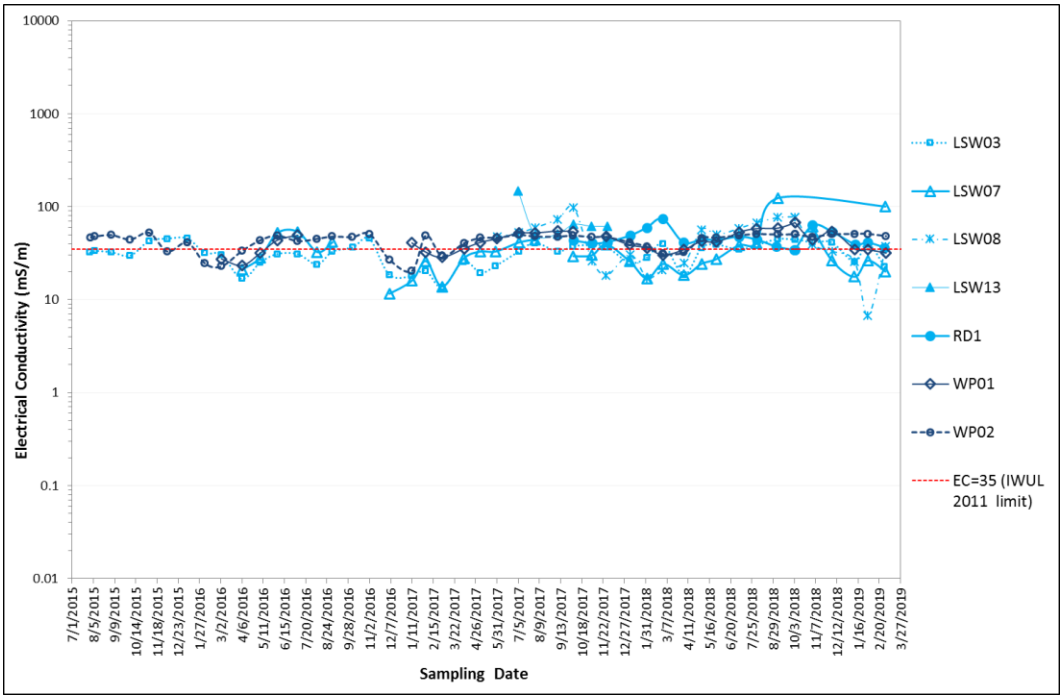


Figure B12: Variation of surface water electrical conductivity

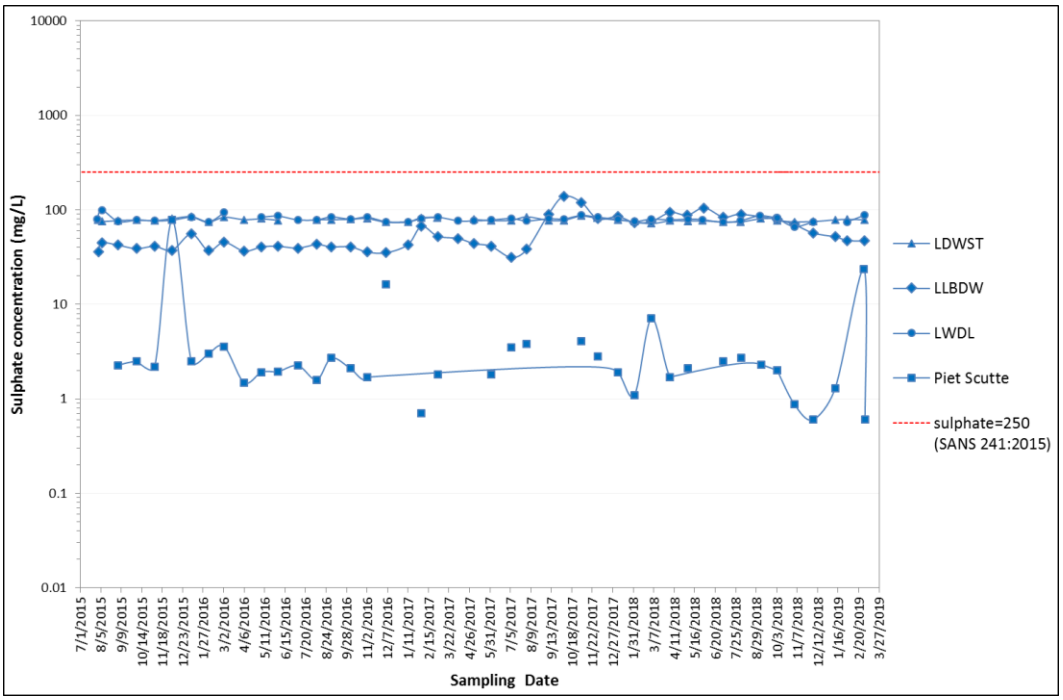


Figure B13: Variation of potable water sulphate

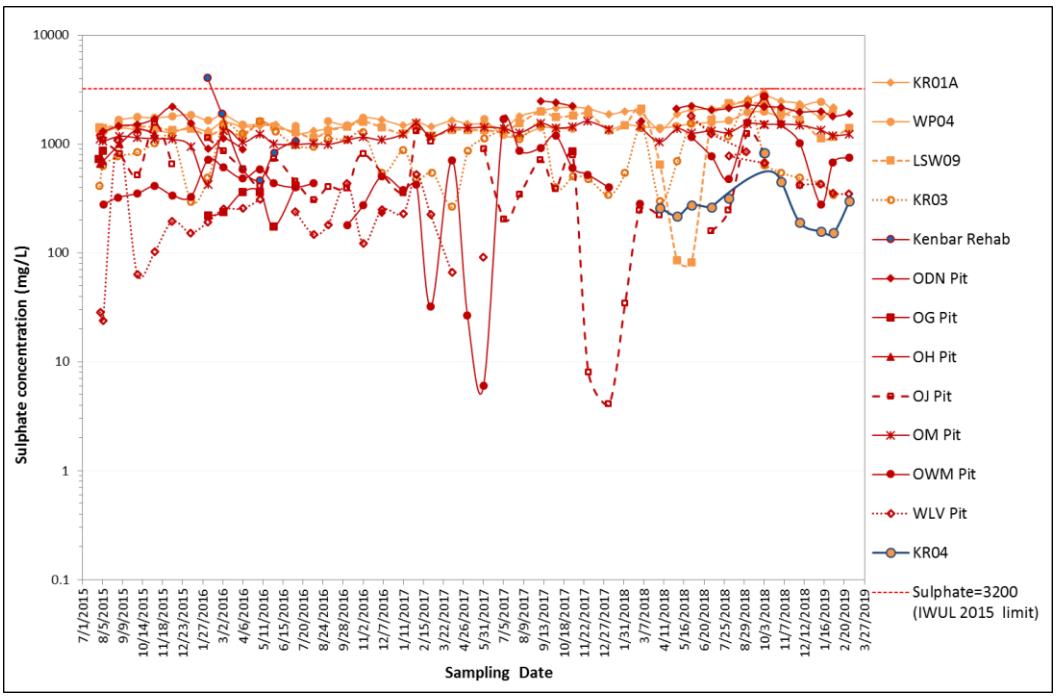


Figure B14: Variation of process water sulphate

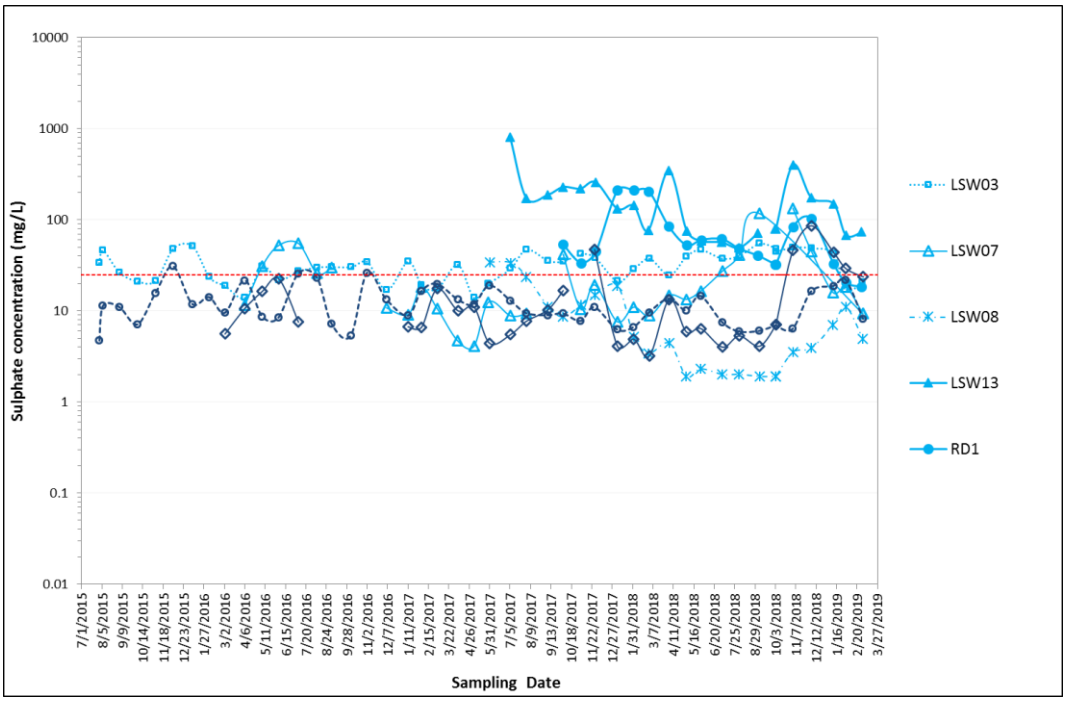


Figure B15: Variation of surface water sulphate

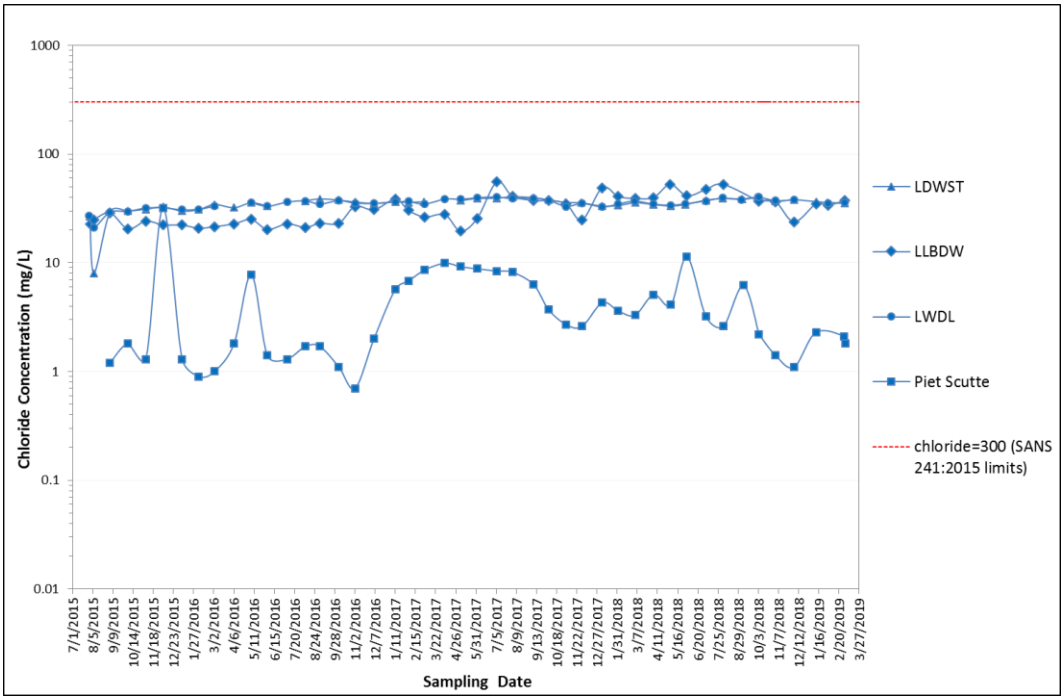


Figure B16: Variation of drinking water chloride

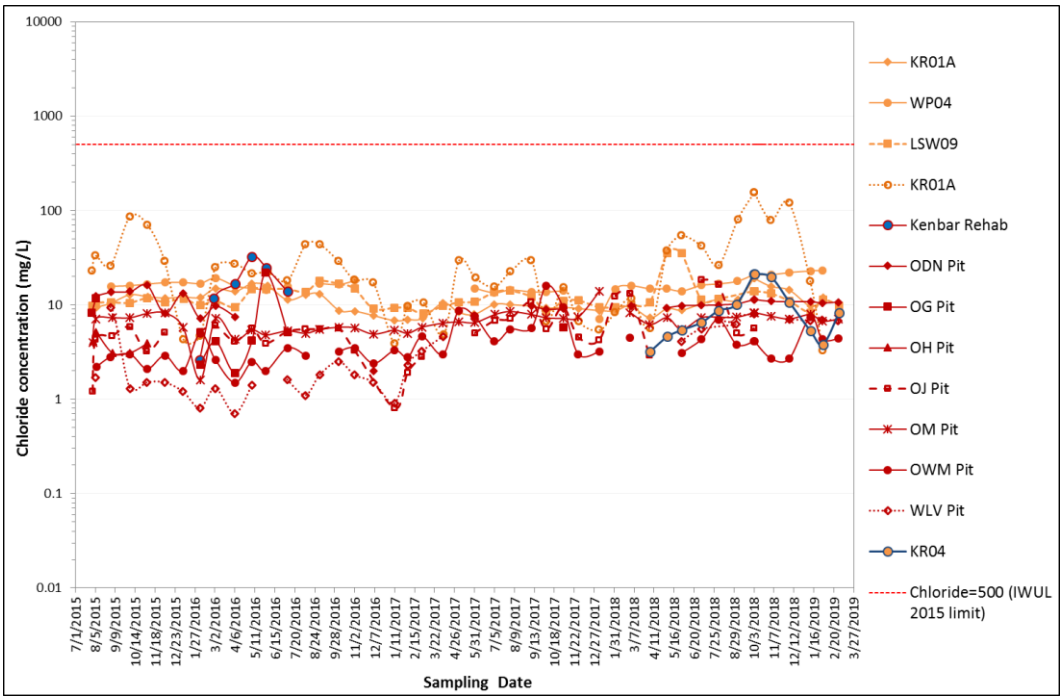


Figure B17: Variation of process water chloride

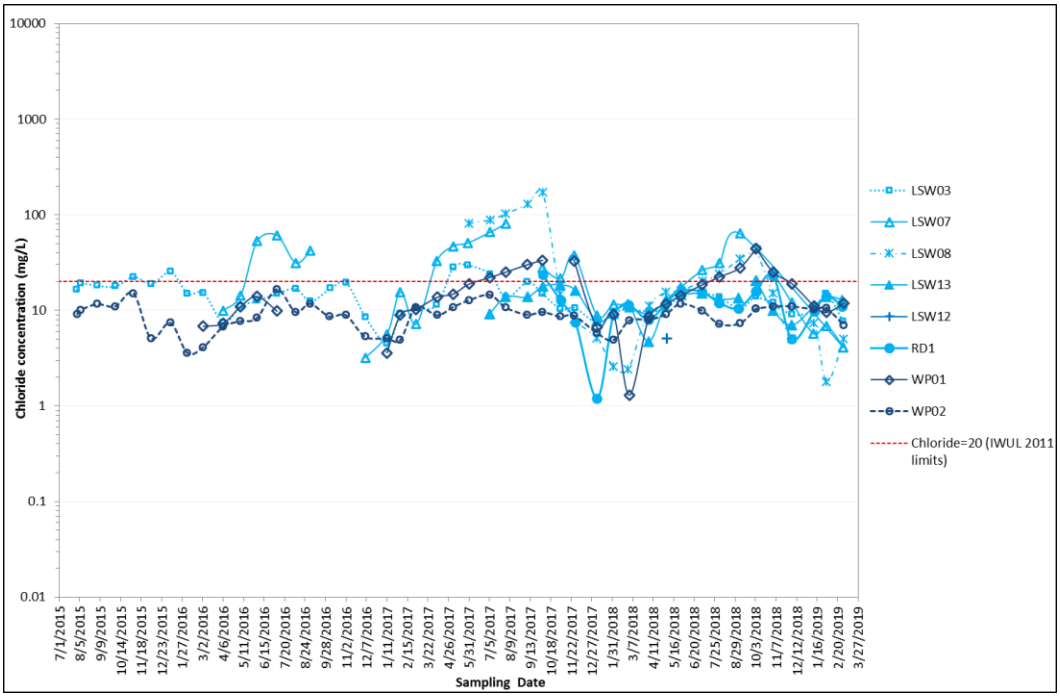


Figure B18: Variation of surface water chloride

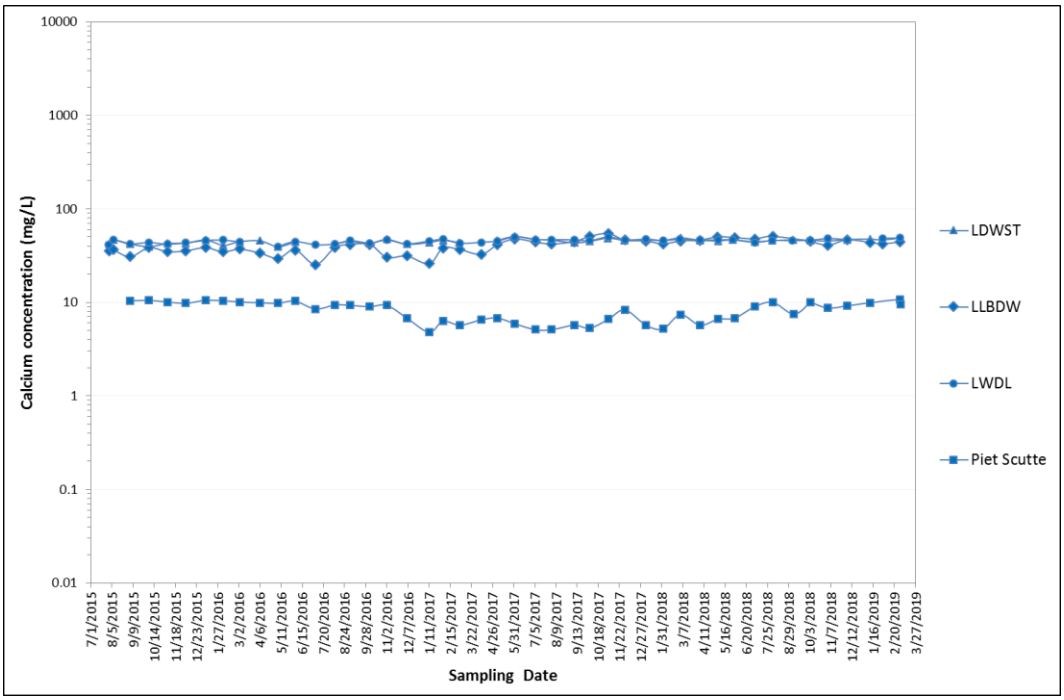


Figure B19: Variation of potable water calcium

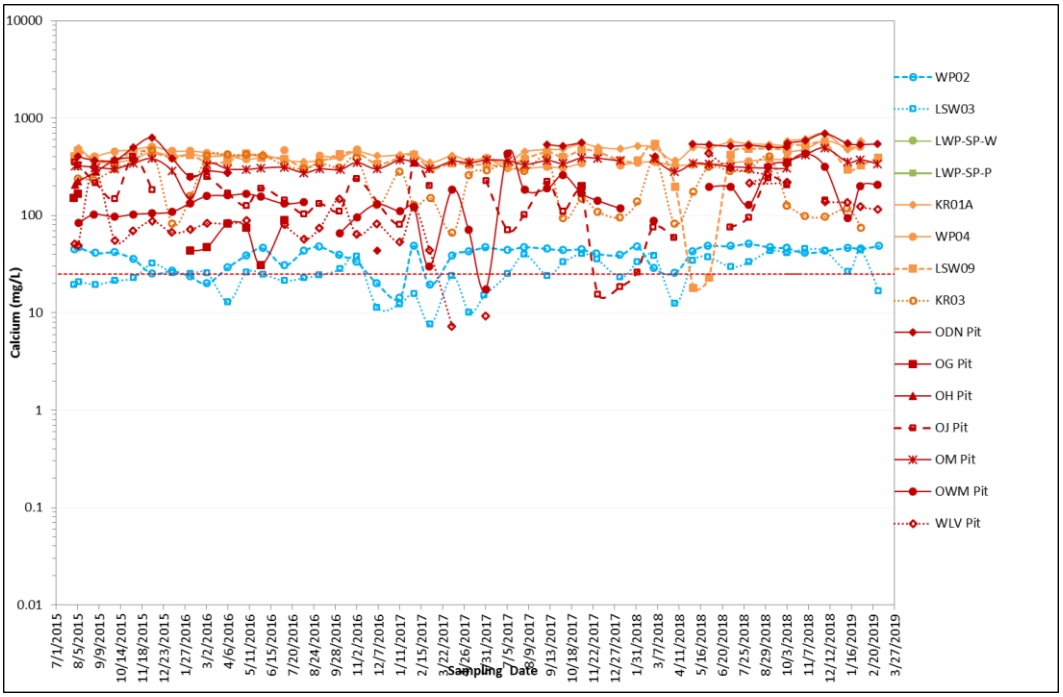


Figure B20: Variation of process water calcium

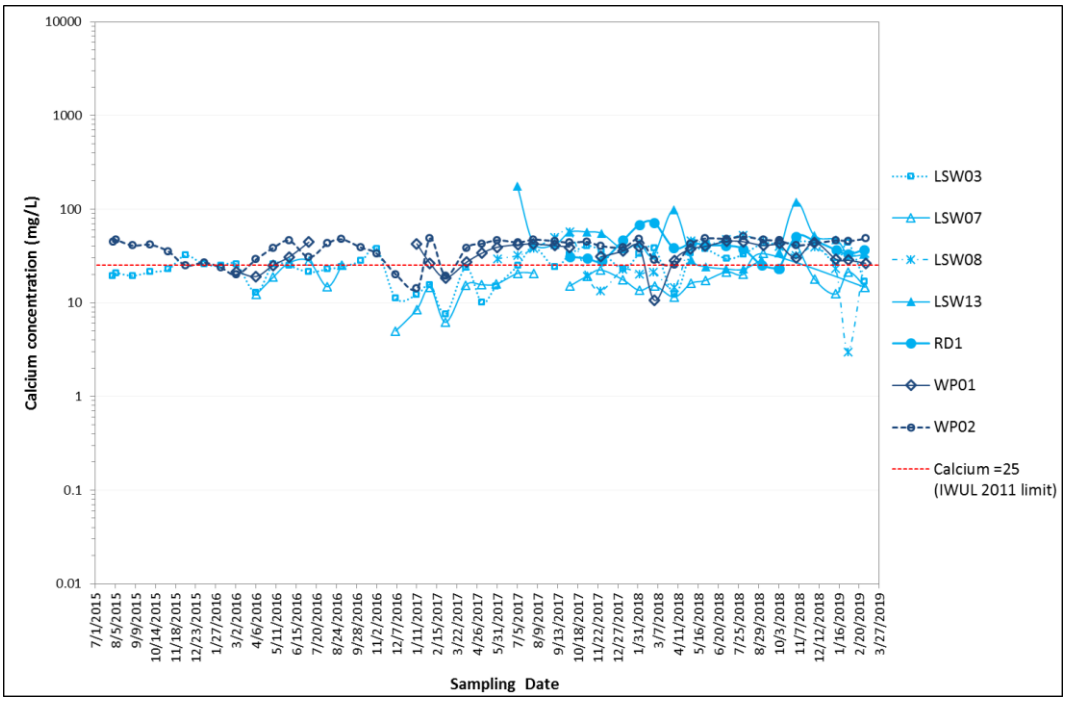


Figure B21: Variation of surface water calcium

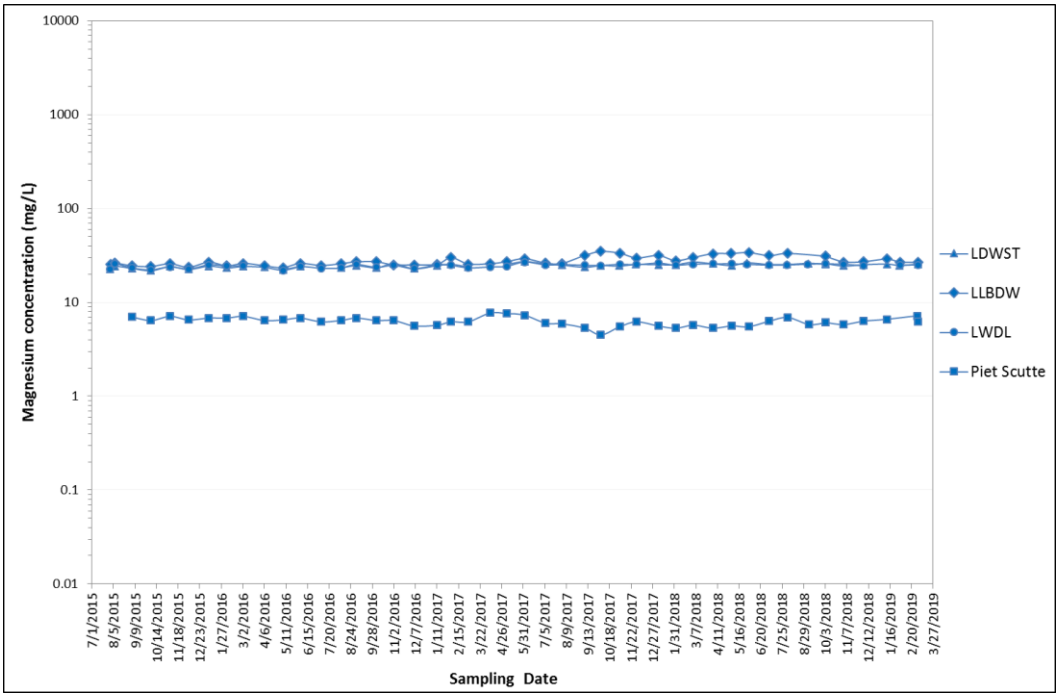


Figure: B22: Variation of potable water magnesium

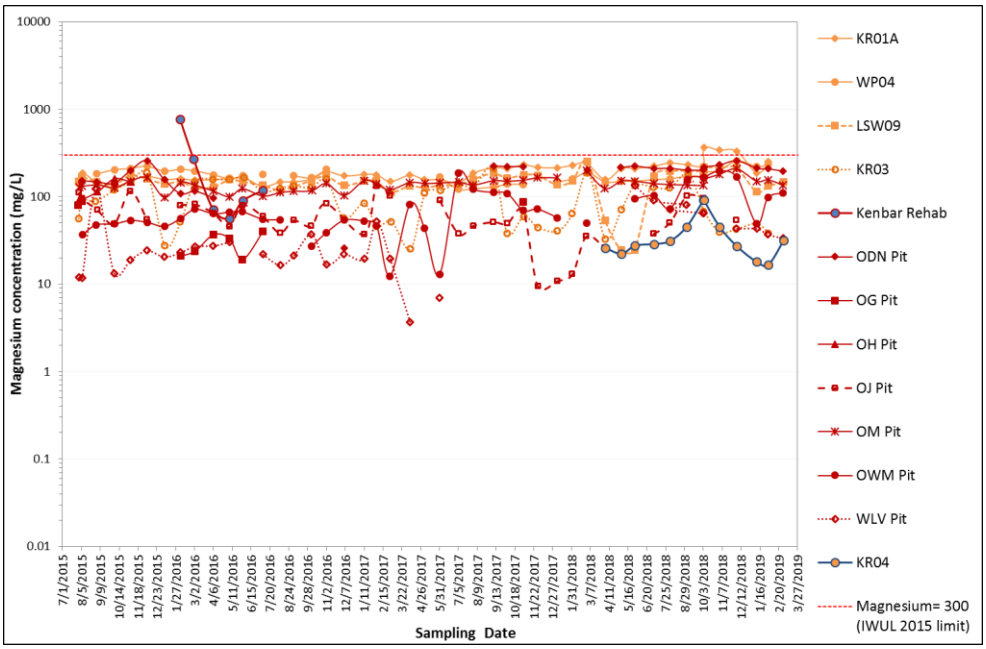


Figure B23: Variation of process water magnesium

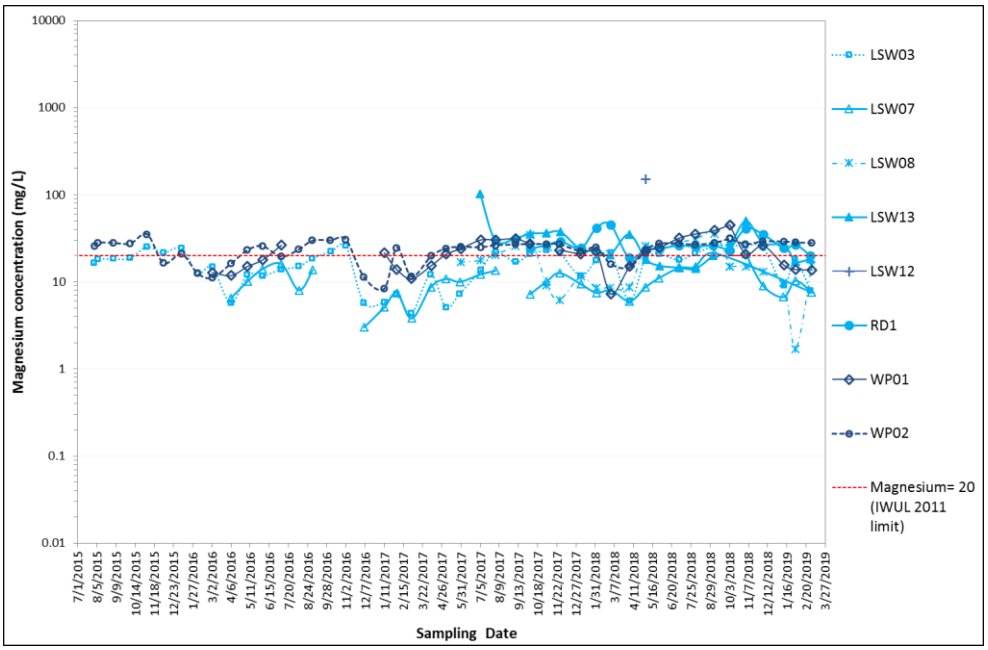


Figure B24: Variation of surface water magnesium

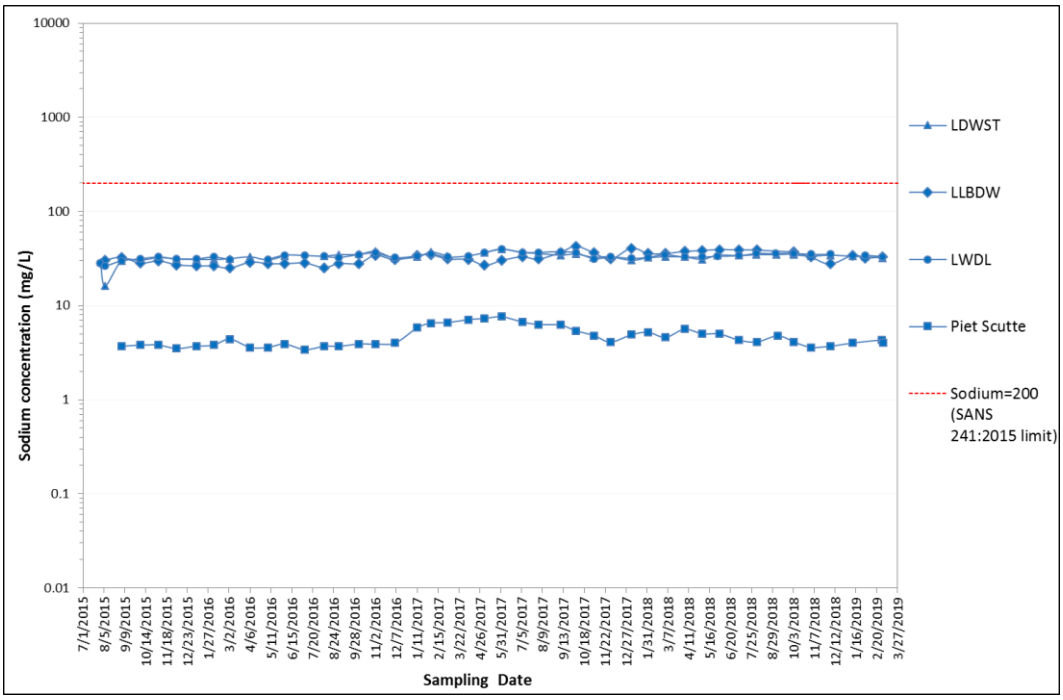


Figure B25: Variation of potable water sodium

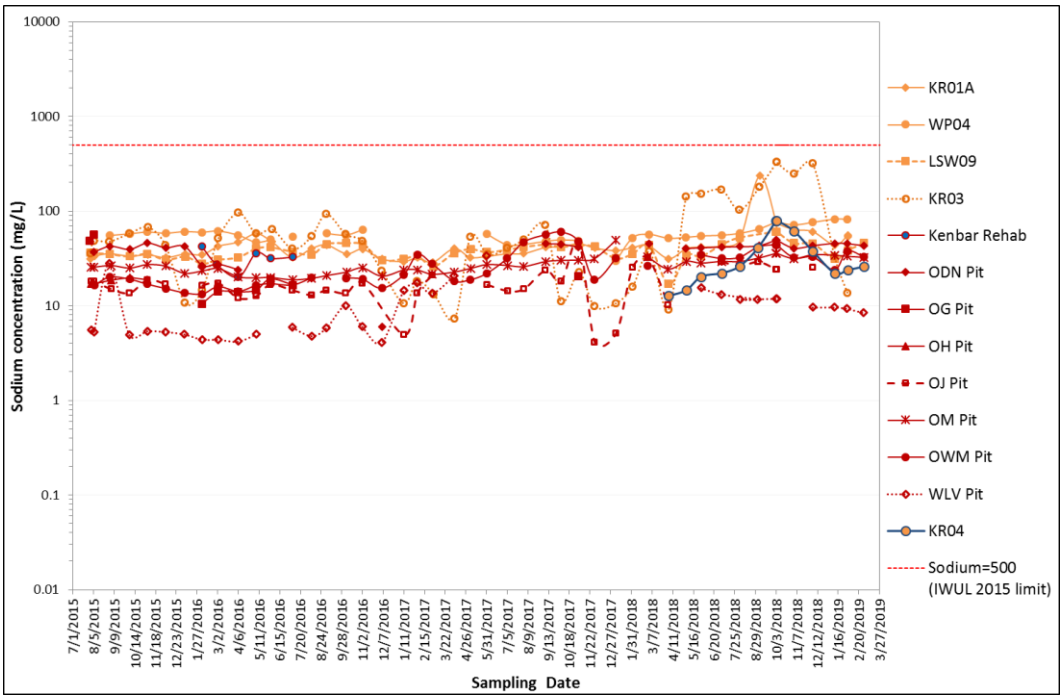


Figure B26: Variation of process water sodium

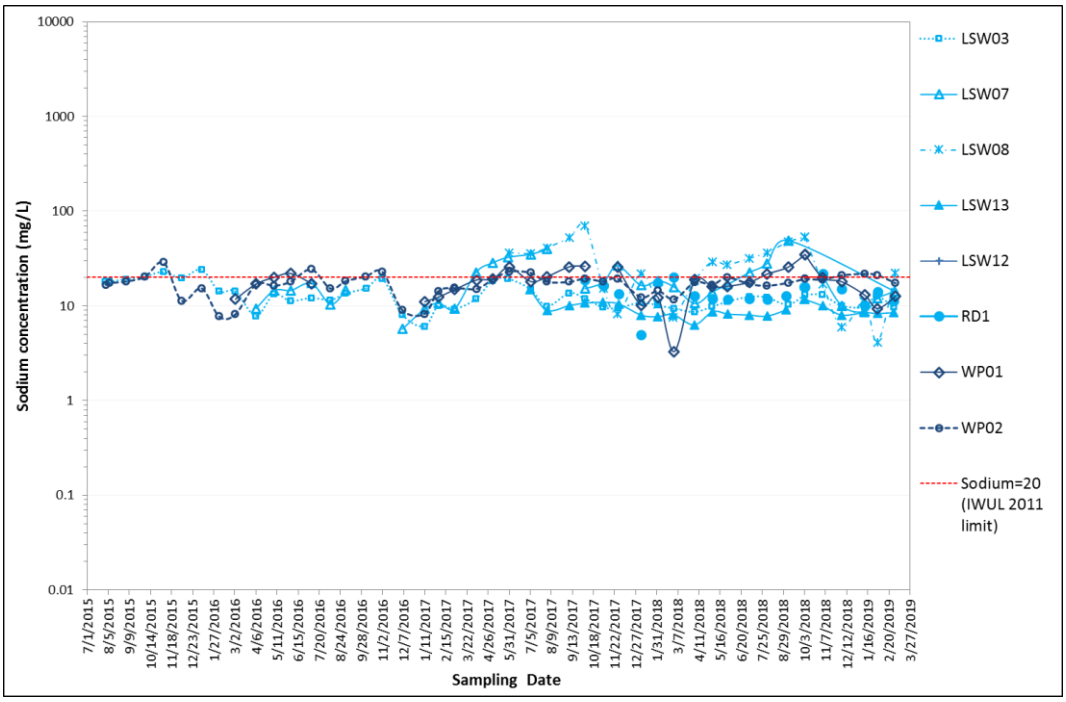


Figure B27: Variation of surface water sodium

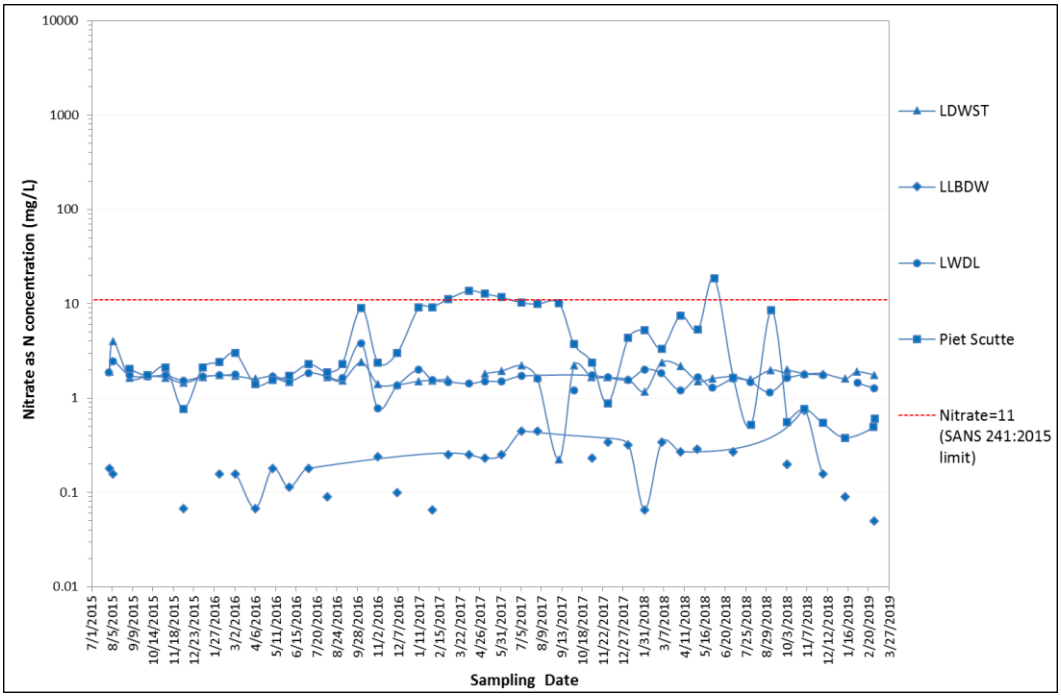


Figure B28: Variation of potable water nitrate

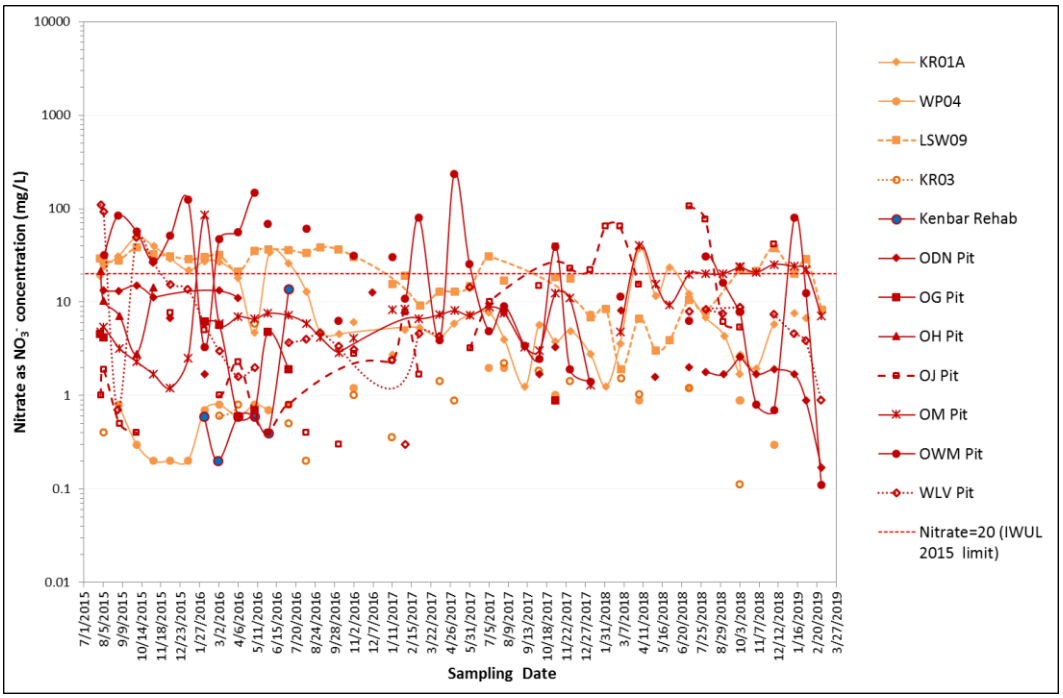


Figure B29: Variation of process water nitrate

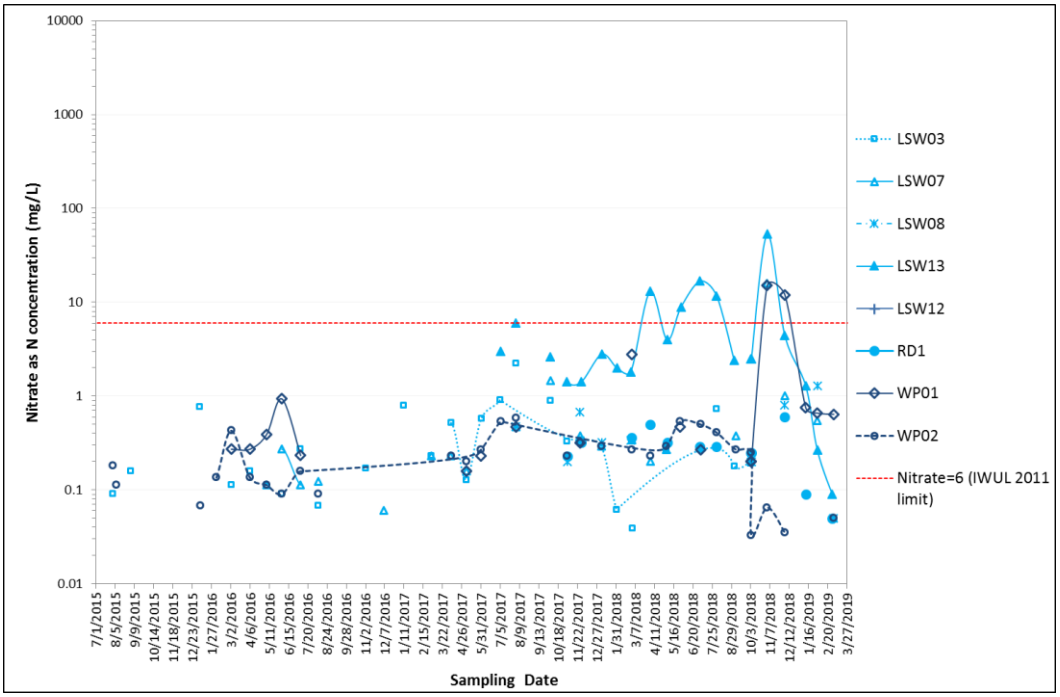


Figure B30: Variation of surface water nitrate

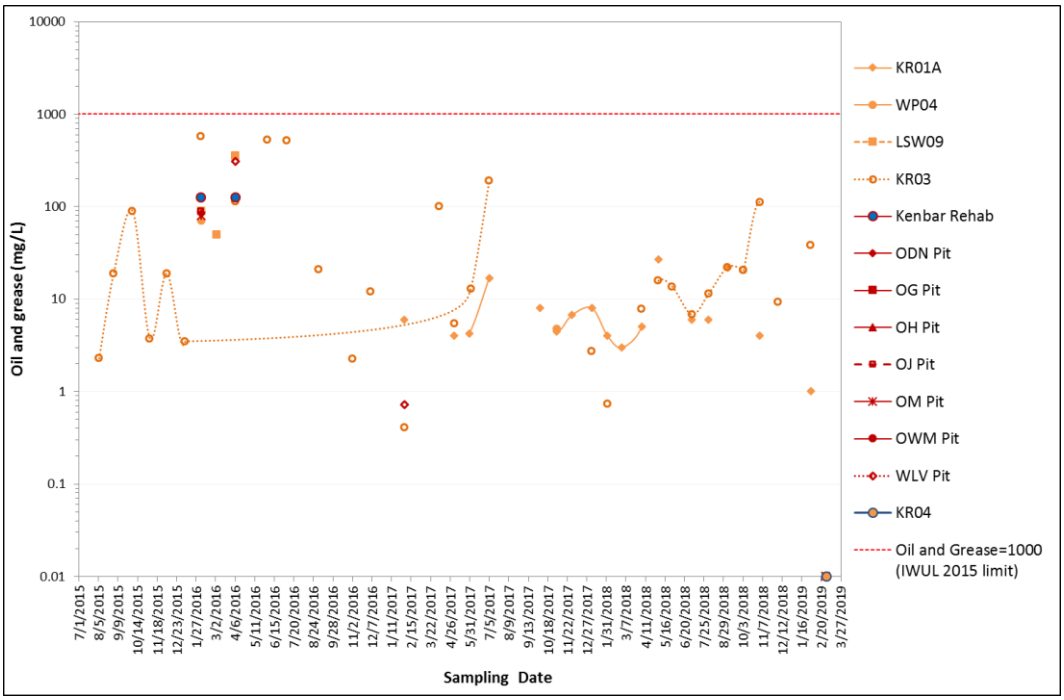


Figure B31: Variation of process water oil and grease

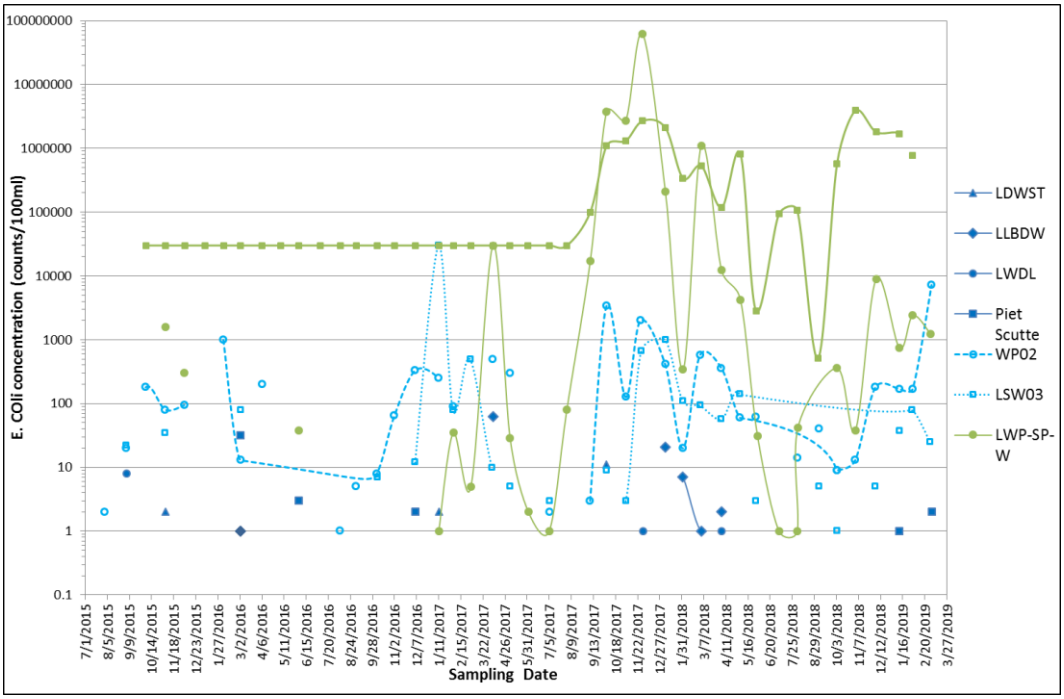


Figure B32: Variation of sewage effluent *E. coli*

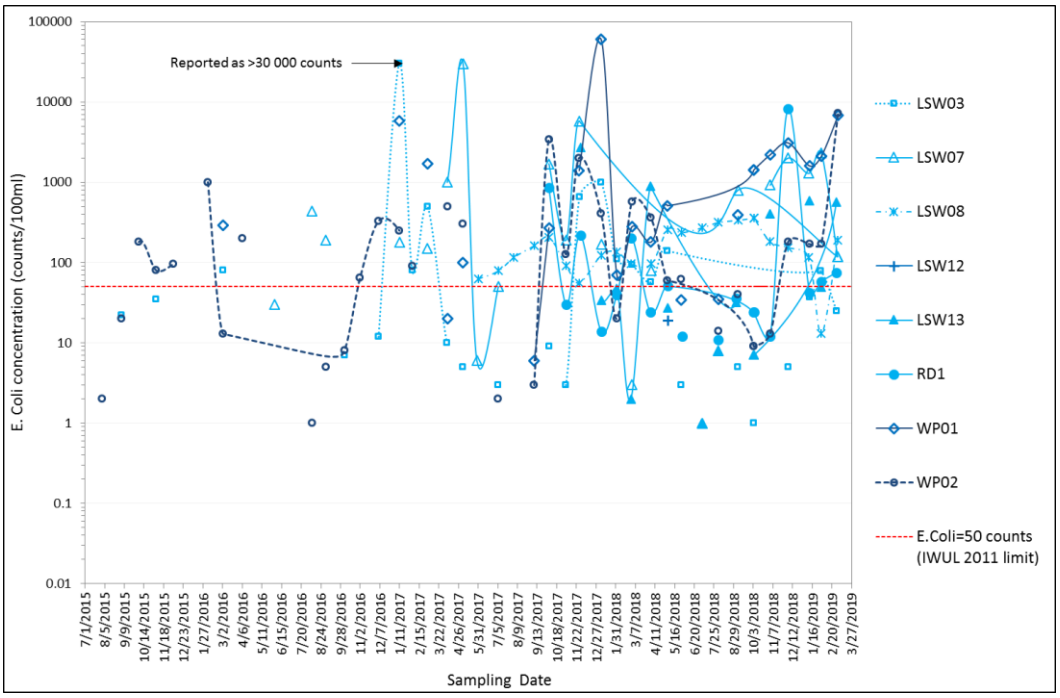


Figure B33: Variation of surface water *E. coli*

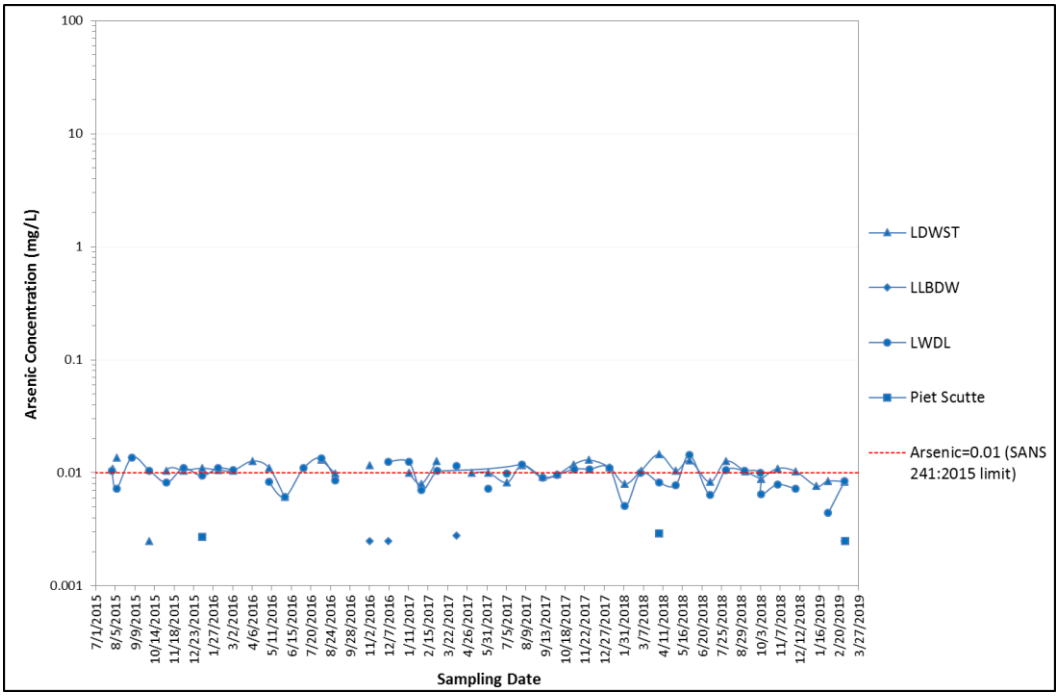


Figure B34: Variation of potable water arsenic

APPENDIX C

Groundwater Chemistry Trend Graphs

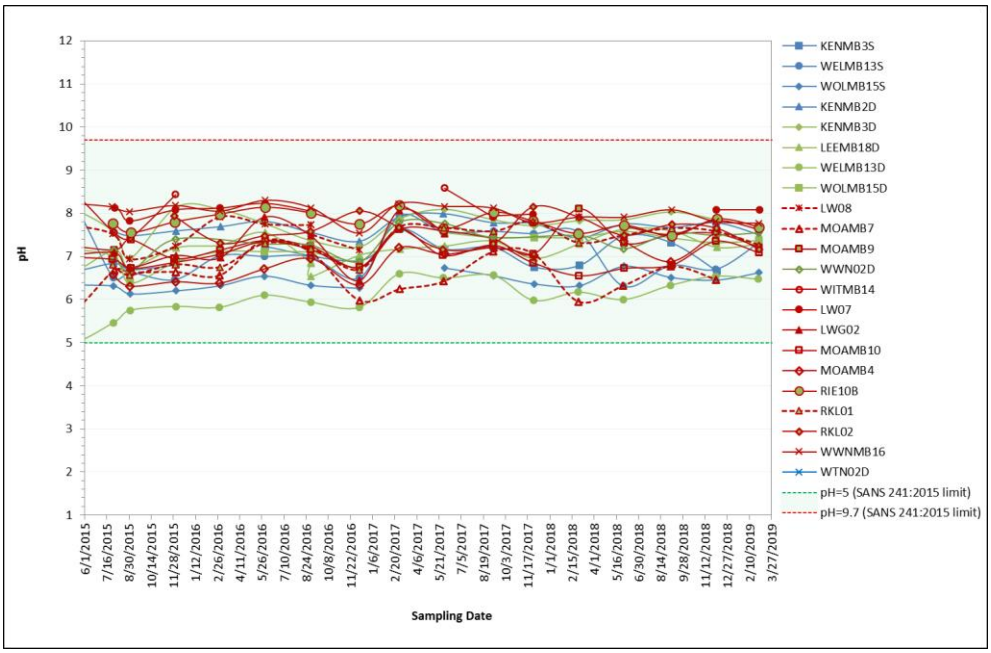


Figure C1: Variation of groundwater pH

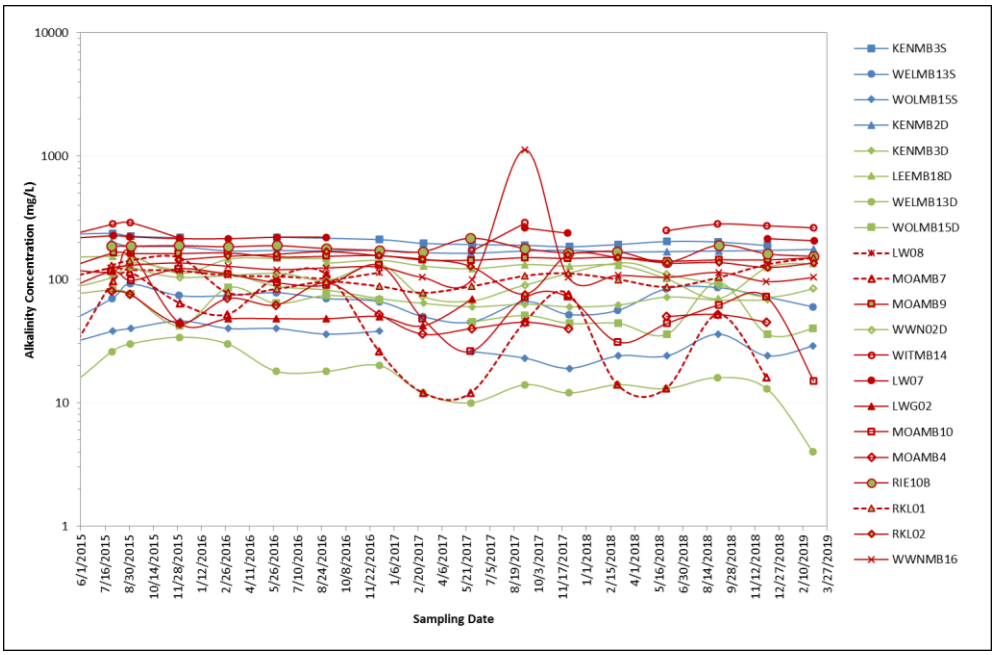


Figure C2: Variation of groundwater alkalinity

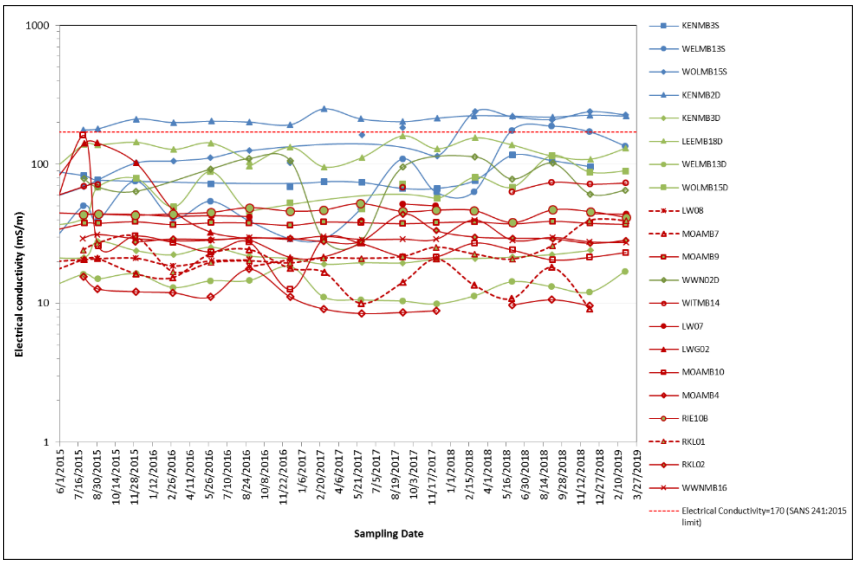


Figure C3: Variation of groundwater electrical conductivity

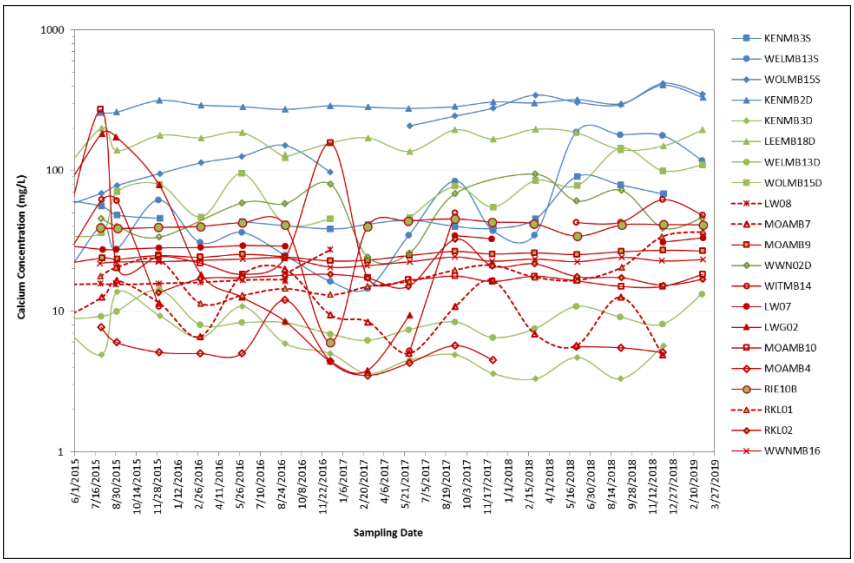


Figure C4: Variation of groundwater calcium

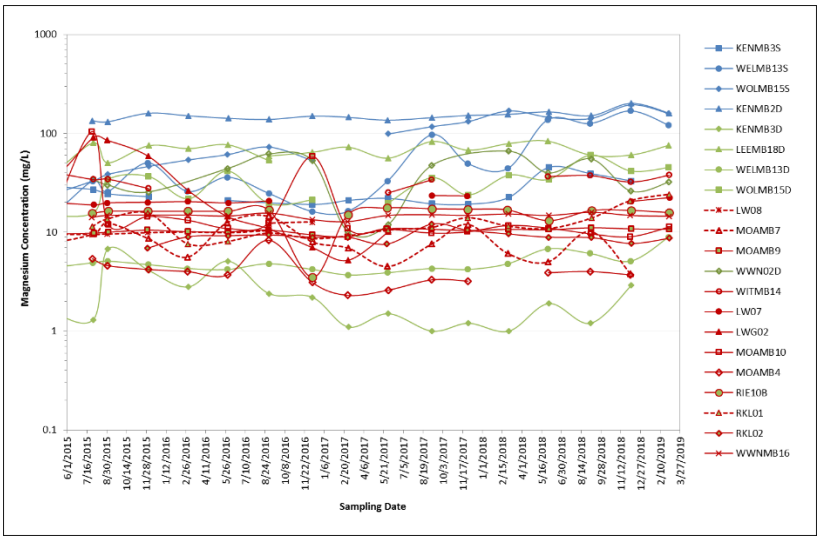


Figure C5: Variation of groundwater magnesium

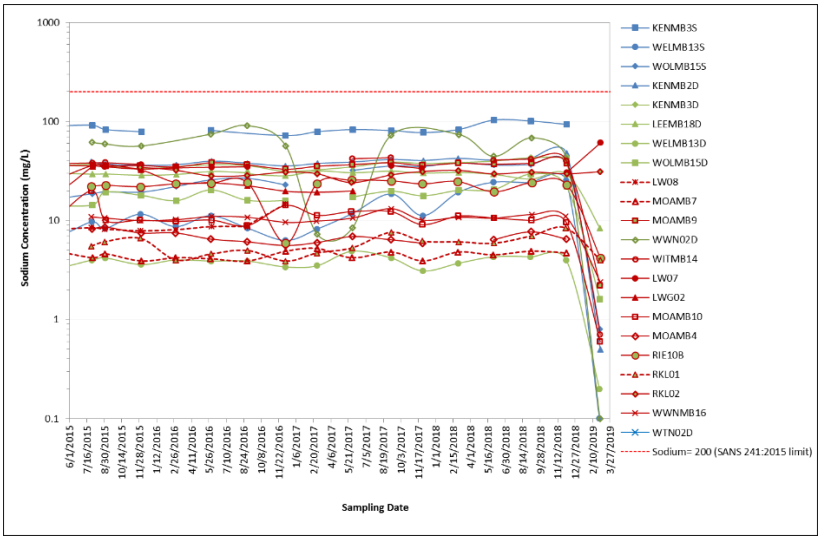


Figure C6: Variation of groundwater sodium

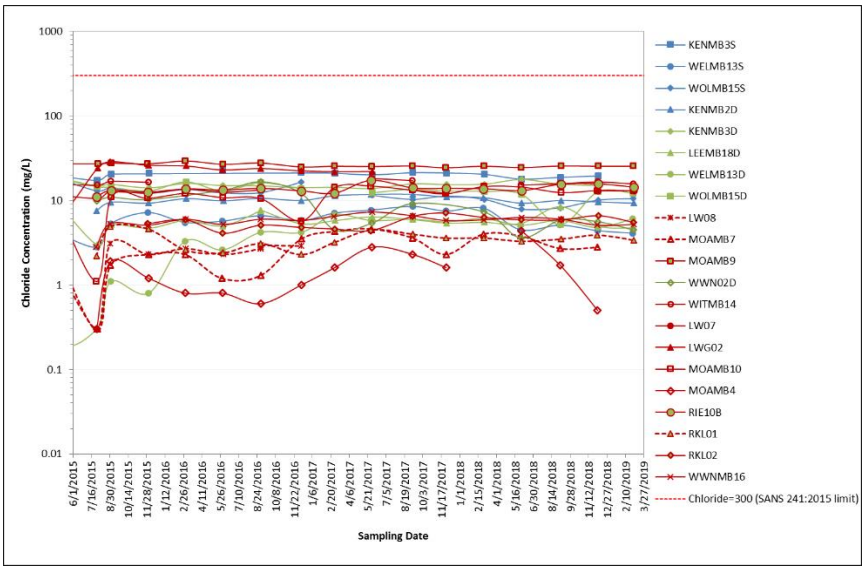


Figure C7: Variation of groundwater chloride

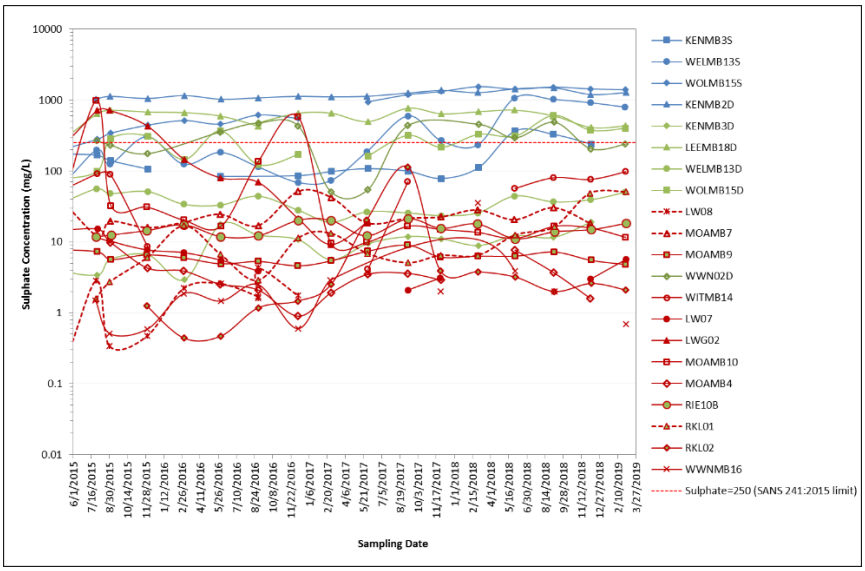


Figure C8: Variation of groundwater sulphate

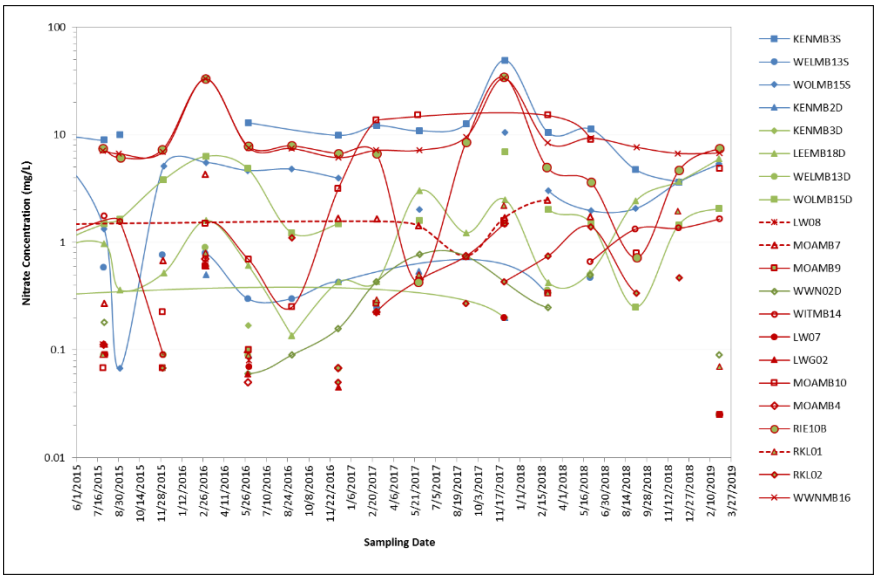


Figure C9: Variation of groundwater nitrate

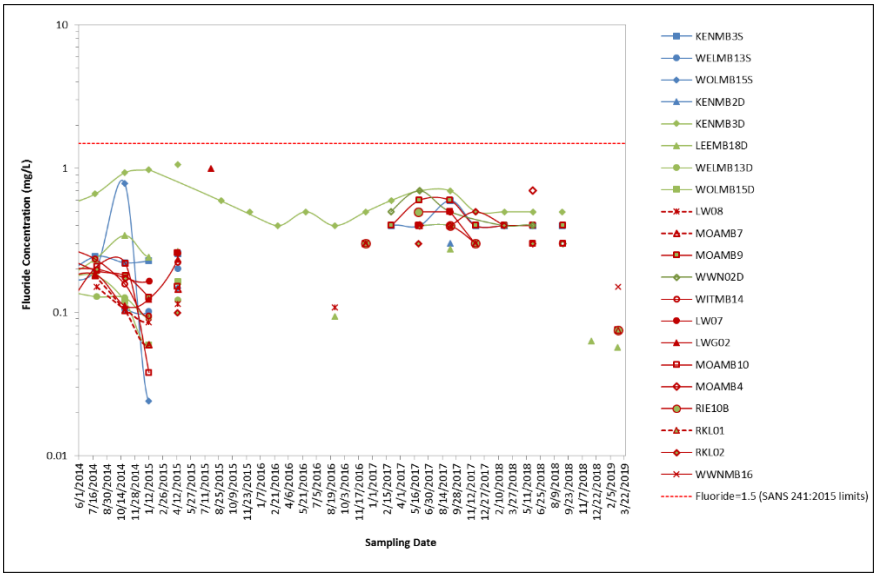


Figure C10: Variation of groundwater fluoride

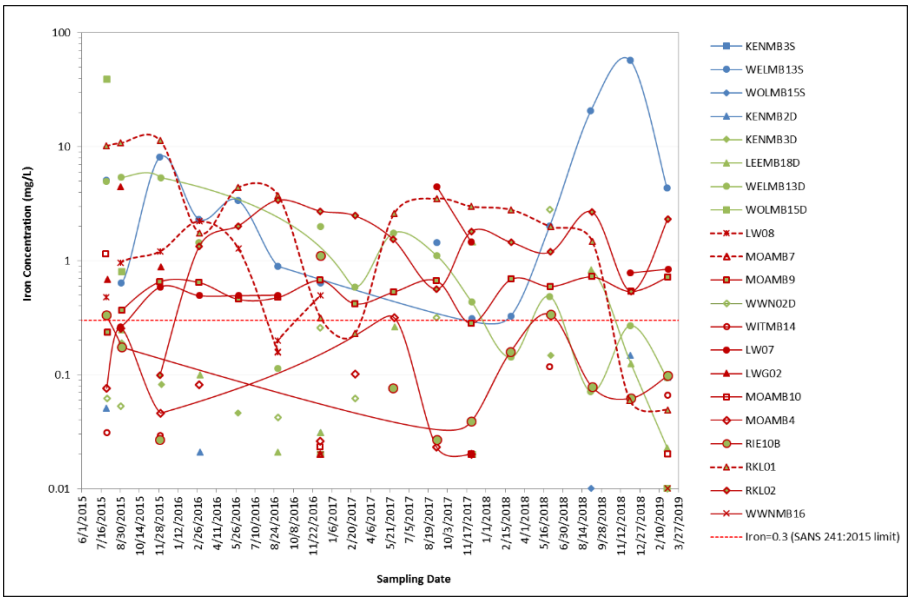


Figure C11: Variation of groundwater iron

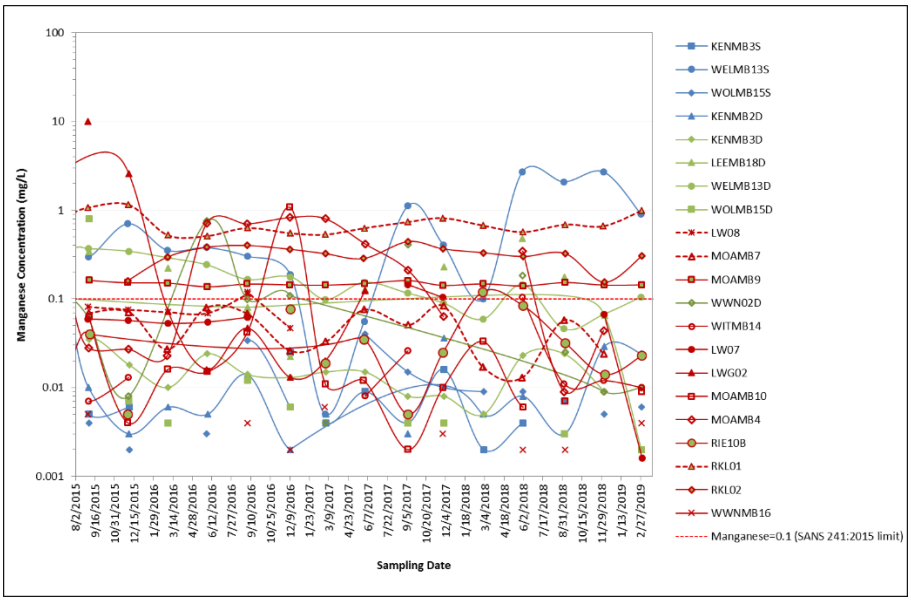


Figure C12: Variation of groundwater manganese

APPENDIX D

Laboratory Certificates

Exova Jones Environmental South Africa

Unit D2/5
9 Quantum Road
Firgrove Business Park
Somerset West
7130
South Africa

Golder Associates (Pty) Ltd
Building no.1
Magwa Crescent West
Waterfall City, Midrand
Johannesburg
Gauteng
South Africa
1685

Attention :	Vhulenda Mandiwana
Date :	29th January, 2019
Your reference :	1527125
Our reference :	Test Report 19/18 Batch 1
Location :	Leeuwpan
Date samples received :	15th January, 2019
Status :	Final report
Issue :	1

Twenty five samples were received for analysis on 15th January, 2019 of which twenty five were scheduled for analysis. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

Analysis was undertaken at either Exova Jones Environmental (UK), which is ISO 17025 accredited under UKAS (4225) or Exova Jones Environmental (SA) which is ISO 17025 accredited under SANAS (T0729) or a subcontract laboratory where specified.

NOTE: Under International Laboratory Accreditation Cooperation (ILAC), ISO 17025 (UKAS) accreditation is recognised as equivalent to SANAS (South Africa) accreditation.

Compiled By:

Paul Boden BSc
Project Manager

Organics Laboratory:

Paloma Booi
Technical Signatory (Organics)

Inorganics Laboratory:

Musa Tiki
Technical Signatory (Inorganics)

Client Name: Golder Associates (Pty) Ltd
Reference: 1527125
Location: Leeuwpan
Contact: Vhulenda Mandiwana
JE Job No.: 19/18

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

J E Sample No.	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	LOD/LOR	Units	Method No.
Sample ID	LNP19_M01_20	LNP19_M01_18	LNP19_M01_31	LNP19_M01_32	LNP19_M01_38	LNP19_M01_001	LNP19_M01_003	LNP19_M01_029	LNP19_M01_027	LNP19_M01_010			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G			
Sample Date	11/01/2019	11/01/2019	11/01/2019	11/01/2019	11/01/2019	10/01/2019	10/01/2019	11/01/2019	11/01/2019	10/01/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019			
Dissolved Aluminium*	<20	<20	101	105	<20	<20	<20	<20	<20	<20	<20	ug/l	UK_TM30/UK_PM14
Dissolved Antimony*	-	-	-	-	-	-	-	-	-	-	<2	ug/l	UK_TM30/UK_PM14
Dissolved Arsenic*	-	-	-	-	-	-	-	-	-	-	<2.5	ug/l	UK_TM30/UK_PM14
Dissolved Barium*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Dissolved Boron*	34	17	19	19	24	22	<12	20	16	91	<12	ug/l	UK_TM30/UK_PM14
Dissolved Cadmium*	-	-	-	-	-	-	-	-	-	-	<0.5	ug/l	UK_TM30/UK_PM14
Dissolved Calcium [SA]	29.0	46.4	26.2	26.1	37.2	12.4	23.3	47.2	36.6	297.6$_{AA}$	<0.3	mg/l	SA_TM27/SA_PM0
Total Dissolved Chromium*	-	-	-	-	-	-	-	-	-	-	<1.5	ug/l	UK_TM30/UK_PM14
Dissolved Copper*	-	-	-	-	-	-	-	-	-	-	<7	ug/l	UK_TM30/UK_PM14
Total Dissolved Iron*	<20	<20	327	336	26	57	1460	<20	294	<20	<20	ug/l	UK_TM30/UK_PM14
Dissolved Magnesium [SA]	15.5	28.8	9.1	9.0	25.0	6.7	9.8	26.6	24.4	114.6$_{AA}$	<0.2	mg/l	SA_TM27/SA_PM0
Dissolved Potassium [SA]	10.0	5.8	9.0	8.9	3.1	9.4	8.2	3.4	3.1	3.7	<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Sodium [SA]	13.0	21.8	10.1	10.2	10.4	8.7	11.1	8.5	10.3	31.0	<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Lead*	-	-	-	-	-	-	-	-	-	-	<5	ug/l	UK_TM30/UK_PM14
Dissolved Manganese*	345	96	1193	1206	68	43	3008	1507	1261	30	<2	ug/l	UK_TM30/UK_PM14
Dissolved Mercury*	-	-	-	-	-	-	-	-	-	-	<1	ug/l	UK_TM30/UK_PM14
Dissolved Nickel*	-	-	-	-	-	-	-	-	-	-	<2	ug/l	UK_TM30/UK_PM14
Dissolved Selenium*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Dissolved Uranium*	-	-	-	-	-	-	-	-	-	-	<5	ug/l	UK_TM30/UK_PM14
Dissolved Zinc*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Total Hardness Dissolved (as CaCO3)	137.6	237.0	103.7	103.1	198.0	59.1	99.4	229.7	194.0	1225.3$_{AA}$	<1.6	mg/l	SA_TM27/SA_PM0
Total Phosphorus*	257	57	229	316	28	151	89	42	86	35	<5	ug/l	UK_TM30/UK_PM14
Fats Oils and Grease	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	SA_TM5/SA_PM30
Fluoride [SA]	0.4	0.4	0.3	<0.3	0.3	0.4	0.4	0.5	<0.3	0.3	<0.3	mg/l	SA_TM27/SA_PM0
Chloride [SA]	11.1	10.3	10.1	10.0	10.0	5.7	7.4	11.1	9.8	8.3	<0.3	mg/l	SA_TM27/SA_PM0
Sulphate [SA]	43.7	18.7	42.6	42.8	33.6	15.9	7.0	150.2	32.8	1120.2$_{AA}$	<0.5	mg/l	SA_TM27/SA_PM0
Nitrite as N [SA]	0.040	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.018	<0.006	0.073	<0.006	mg/l	SA_TM27/SA_PM0
Nitrate as N [SA]	0.75	0.09	<0.05	<0.05	0.09	<0.05	<0.05	0.29	0.09	4.52	<0.05	mg/l	SA_TM27/SA_PM0
Ammoniacal Nitrogen as N*	0.63	0.10	0.12	0.16	0.04	0.05	0.16	0.07	0.04	0.07	<0.03	mg/l	UK_TM38/UK_PM0
Hexavalent Chromium*	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO3 [SA]	116	236	66	64	160	71	115	75	156	52	<3	mg/l	SA_TM32/SA_PM0
COD (Settled) [SA]	-	-	-	-	-	-	-	-	-	-	<9	mg/l	SA_TM57/SA_PM0
Dissolved Oxygen (% Saturation)	66.0	84.5	9.5	9.2	69.6	75.8	7.2	97.9	67.2	100.4	<0.1	%	SA_TM59/SA_PM0
Temperature	24.6	23.7	23.2	24.1	24.6	23.5	22.4	22.5	22.1	22.2	<0.1	Degrees C	SA_TM59/SA_PM0
Electrical Conductivity @25C [SA]	349	509	268	268	400	176	257	483	395	2081	<2	uS/cm	SA_TM28/SA_PM0
Dissolved Organic Carbon*	9	12	27	32	6	13	16	3	10	<2	<2	mg/l	UK_TM60/UK_PM0
Ortho Phosphate as PO4*	<0.06	<0.06	<0.06	<0.06	0.25	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	mg/l	UK_TM38/UK_PM0
pH [SA]	8.19	8.53	7.49	7.56	8.28	7.97	7.77	7.79	8.12	8.41	<2.00	pH units	SA_TM19/SA_PM0
Total Dissolved Solids [SA]	228	306	218	244	229	147	169	334	235	2161	<35	mg/l	SA_TM20/SA_PM31

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 1527125
Location: Leeuwpan
Contact: Vhulenda Mandiwana
JE Job No.: 19/18

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

J E Sample No.	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	LOD/LOR	Units	Method No.
Sample ID	LNP19_M01_20	LNP19_M01_18	LNP19_M01_31	LNP19_M01_32	LNP19_M01_38	LNP19_M01_001	LNP19_M01_003	LNP19_M01_029	LNP19_M01_027	LNP19_M01_010			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G			
Sample Date	11/01/2019	11/01/2019	11/01/2019	11/01/2019	11/01/2019	10/01/2019	10/01/2019	11/01/2019	11/01/2019	10/01/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019			
Total Suspended Solids [SA]	-	-	-	-	-	-	-	-	-	-	<10	mg/l	SA_TM37/SA_PM0
Turbidity	236.0	26.7	28.5	21.2	2.8	44.3	95.6	8.6	4.7	4.9	<0.1	NTU	SA_TM34/SA_PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 1527125
Location: Leeuwpan
Contact: Vhulenda Mandiwana
JE Job No.: 19/18

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

J E Sample No.	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-99	LOD/LOR	Units	Method No.
Sample ID	LNP19_M01_011	LNP19_M01_012	LNP19_M01_015	LNP19_M01_014	LNP19_M01_005	LNP19_M01_007	LNP19_M01_008	LNP19_M01_009	LNP19_M01_006	LNP19_M01_022			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P			
Sample Date	10/01/2019	10/01/2019	10/01/2019	10/01/2019	10/01/2019	10/01/2019	10/01/2019	10/01/2019	10/01/2019	11/01/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019			
Dissolved Aluminium*	<20	<20	<20	<20	<20	<20	30	<20	22	<20	<20	ug/l	UK_TM30/UK_PM14
Dissolved Antimony*	-	-	-	-	-	-	-	-	-	3	<2	ug/l	UK_TM30/UK_PM14
Dissolved Arsenic*	-	-	-	-	-	-	-	-	-	6.4	<2.5	ug/l	UK_TM30/UK_PM14
Dissolved Barium*	-	-	-	-	-	-	-	-	-	79	<3	ug/l	UK_TM30/UK_PM14
Dissolved Boron*	88	88	70	31	85	157	97	65	55	67	<12	ug/l	UK_TM30/UK_PM14
Dissolved Cadmium*	-	-	-	-	-	-	-	-	-	<0.5	<0.5	ug/l	UK_TM30/UK_PM14
Dissolved Calcium SA	464.6AA	464.9AA	117.0	36.8	502.2AA	93.8	353.7AA	548.7AA	135.9	47.4	<0.3	mg/l	SA_TM27/SA_PM0
Total Dissolved Chromium*	-	-	-	-	-	-	-	-	-	<1.5	<1.5	ug/l	UK_TM30/UK_PM14
Dissolved Copper*	-	-	-	-	-	-	-	-	-	<7	<7	ug/l	UK_TM30/UK_PM14
Total Dissolved Iron*	<20	<20	36	<20	<20	<20	<20	<20	<20	<20	<20	ug/l	UK_TM30/UK_PM14
Dissolved Magnesium SA	188.3AA	188.4AA	49.1	18.0	222.1AA	48.9	150.5AA	211.7AA	43.2	25.9	<0.2	mg/l	SA_TM27/SA_PM0
Dissolved Potassium SA	4.1	4.0	6.0	2.1	5.0	4.8	5.2	3.4	1.9	4.1	<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Sodium SA	45.4	45.2	33.0	22.1	82.3	24.0	34.1	45.6	9.6	35.5	<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Lead*	-	-	-	-	-	-	-	-	-	<5	<5	ug/l	UK_TM30/UK_PM14
Dissolved Manganese*	33	34	753	9	340	47	171	610	180	73	<2	ug/l	UK_TM30/UK_PM14
Dissolved Mercury*	-	-	-	-	-	-	-	-	-	<1	<1	ug/l	UK_TM30/UK_PM14
Dissolved Nickel*	-	-	-	-	-	-	-	-	-	4	<2	ug/l	UK_TM30/UK_PM14
Dissolved Selenium*	-	-	-	-	-	-	-	-	-	<3	<3	ug/l	UK_TM30/UK_PM14
Dissolved Uranium*	-	-	-	-	-	-	-	-	-	<5	<5	ug/l	UK_TM30/UK_PM14
Dissolved Zinc*	-	-	-	-	-	-	-	-	-	61	<3	ug/l	UK_TM30/UK_PM14
Total Hardness Dissolved (as CaCO3)	1952.4AA	1953.5AA	498.7	167.6	2188.3AA	439.9	1516.4AA	2260.9AA	521.2	227.3	<1.6	mg/l	SA_TM27/SA_PM0
Total Phosphorus*	32	34	201	53	30	21	26	30	27	-	<5	ug/l	UK_TM30/UK_PM14
Fats Oils and Grease	<10	<10	<10	<10	<10	<10	<10	<10	<10	-	<10	ug/l	SA_TM5/SA_PM30
Fluoride SA	<0.3	<0.3	0.4	0.7	0.5	0.5	0.4	0.4	<0.3	<0.3	<0.3	mg/l	SA_TM27/SA_PM0
Chloride SA	9.9	9.9	17.8	5.3	22.9	7.5	7.9	10.8	6.8	36.8	<0.3	mg/l	SA_TM27/SA_PM0
Sulphate SA	1819.4AA	1818.0AA	430.9AA	157.8	2442.8AA	280.5	1343.9AA	2001.5AA	425.4AA	79.5	<0.5	mg/l	SA_TM27/SA_PM0
Nitrite as N SA	<0.006	<0.006	<0.006	0.021	<0.006	0.481	0.037	0.186	0.027	<0.006	<0.006	mg/l	SA_TM27/SA_PM0
Nitrate as N SA	1.81	1.81	<0.05	0.14	<0.05	17.94	5.44	0.38	1.04	1.69	<0.05	mg/l	SA_TM27/SA_PM0
Ammoniacal Nitrogen as N*	0.04	0.23	<0.03	0.05	0.09	2.14	0.35	0.07	0.09	<0.03	<0.03	mg/l	UK_TM38/UK_PM0
Hexavalent Chromium*	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	-	<0.006	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO3 SA	88	80	76	46	53	117	106	182	46	156	<3	mg/l	SA_TM32/SA_PM0
COD (Settled) SA	-	-	-	-	-	-	-	-	-	-	<9	mg/l	SA_TM57/SA_PM0
Dissolved Oxygen (% Saturation)	88.8	90.5	32.7	76.9	94.2	95.8	102.8	97.5	96.5	-	<0.1	%	SA_TM59/SA_PM0
Temperature	23.7	23.0	23.1	22.9	24.1	25.1	24.7	24.4	25.0	-	<0.1	Degrees C	SA_TM59/SA_PM0
Electrical Conductivity @25C SA	2870	2880	1014	428	3250	911	2340	3180	930	583	<2	uS/cm	SA_TM28/SA_PM0
Dissolved Organic Carbon*	<2	<2	5	6	13	2	<2	<2	<2	-	<2	mg/l	UK_TM60/UK_PM0
Ortho Phosphate as PO4*	<0.06	<0.06	0.16	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	mg/l	UK_TM38/UK_PM0
pH SA	8.25	8.19	7.56	8.18	8.37	8.31	8.30	8.32	8.08	7.76	<2.00	pH units	SA_TM19/SA_PM0
Total Dissolved Solids SA	2601	2833	632	286	3241	597	2139	3100	721	357	<35	mg/l	SA_TM20/SA_PM31

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 1527125
Location: Leeuwpan
Contact: Vhulenda Mandiwana
JE Job No.: 19/18

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

J E Sample No.	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-99	LOD/LOR	Units	Method No.
Sample ID	LNP19_M01_011	LNP19_M01_012	LNP19_M01_015	LNP19_M01_014	LNP19_M01_005	LNP19_M01_007	LNP19_M01_008	LNP19_M01_009	LNP19_M01_006	LNP19_M01_022			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P			
Sample Date	10/01/2019	10/01/2019	10/01/2019	10/01/2019	10/01/2019	10/01/2019	10/01/2019	10/01/2019	10/01/2019	11/01/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019			
Total Suspended Solids [SA]	-	-	-	-	-	-	-	-	-	-	<10	mg/l	SA_TM37/SA_PM0
Turbidity	15.3	19.4	12.7	39.8	4.5	8.8	3.5	6.7	2.2	-	<0.1	NTU	SA_TM34/SA_PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 1527125
Location: Leeuwpan
Contact: Vhulenda Mandiwana
JE Job No.: 19/18

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

J E Sample No.	100-103	104-107	108-111	112-115	116-119						LOD/LOR	Units	Method No.
Sample ID	LNP19_M01_023	LNP19_M01_016	LNP19_M01_036	LNP19_M01_034	LNP19_M01_025								
Depth													
COC No / misc													
Containers	H HN P	H HN P	H HN P	H HN P	H HN P								
Sample Date	11/01/2019	11/01/2019	11/01/2019	11/01/2019	11/01/2019								
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water								
Batch Number	1	1	1	1	1								
Date of Receipt	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019								
Dissolved Aluminium*	<20	<20	<20	-	-						<20	ug/l	UK_TM30/UK_PM14
Dissolved Antimony*	<2	3	<2	-	-						<2	ug/l	UK_TM30/UK_PM14
Dissolved Arsenic*	6.5	<2.5	<2.5	-	-						<2.5	ug/l	UK_TM30/UK_PM14
Dissolved Barium*	76	207	28	-	-						<3	ug/l	UK_TM30/UK_PM14
Dissolved Boron*	65	73	21	-	-						<12	ug/l	UK_TM30/UK_PM14
Dissolved Cadmium*	<0.5	<0.5	<0.5	-	-						<0.5	ug/l	UK_TM30/UK_PM14
Dissolved Calcium SA	47.9	43.7	9.9	-	-						<0.3	mg/l	SA_TM27/SA_PM0
Total Dissolved Chromium*	<1.5	<1.5	<1.5	-	-						<1.5	ug/l	UK_TM30/UK_PM14
Dissolved Copper*	<7	<7	13	-	-						<7	ug/l	UK_TM30/UK_PM14
Total Dissolved Iron*	<20	<20	<20	-	-						<20	ug/l	UK_TM30/UK_PM14
Dissolved Magnesium SA	26.0	28.9	6.6	-	-						<0.2	mg/l	SA_TM27/SA_PM0
Dissolved Potassium SA	4.1	3.0	1.4	-	-						<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Sodium SA	35.6	34.3	4.0	-	-						<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Lead*	<5	<5	<5	-	-						<5	ug/l	UK_TM30/UK_PM14
Dissolved Manganese*	71	79	5	-	-						<2	ug/l	UK_TM30/UK_PM14
Dissolved Mercury*	<1	<1	<1	-	-						<1	ug/l	UK_TM30/UK_PM14
Dissolved Nickel*	4	<2	<2	-	-						<2	ug/l	UK_TM30/UK_PM14
Dissolved Selenium*	<3	<3	<3	-	-						<3	ug/l	UK_TM30/UK_PM14
Dissolved Uranium*	<5	<5	<5	-	-						<5	ug/l	UK_TM30/UK_PM14
Dissolved Zinc*	62	29	23	-	-						<3	ug/l	UK_TM30/UK_PM14
Total Hardness Dissolved (as CaCO3)	229.0	230.6	52.5	-	-						<1.6	mg/l	SA_TM27/SA_PM0
Total Phosphorus*	-	-	-	-	-						<5	ug/l	UK_TM30/UK_PM14
Fats Oils and Grease	-	-	-	-	-						<10	ug/l	SA_TM5/SA_PM30
Fluoride SA	<0.3	<0.3	<0.3	-	-						<0.3	mg/l	SA_TM27/SA_PM0
Chloride SA	36.9	34.9	2.3	-	-						<0.3	mg/l	SA_TM27/SA_PM0
Sulphate SA	79.7	51.8	1.3	-	-						<0.5	mg/l	SA_TM27/SA_PM0
Nitrite as N SA	<0.006	<0.006	<0.006	-	-						<0.006	mg/l	SA_TM27/SA_PM0
Nitrate as N SA	1.69	0.09	0.38	0.09	7.50						<0.05	mg/l	SA_TM27/SA_PM0
Ammoniacal Nitrogen as N*	0.17	<0.03	<0.03	39.05	61.63						<0.03	mg/l	UK_TM38/UK_PM0
Hexavalent Chromium*	-	-	-	-	-						<0.006	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO3 SA	155	187	58	-	-						<3	mg/l	SA_TM32/SA_PM0
COD (Settled) SA	-	-	-	54	102						<9	mg/l	SA_TM57/SA_PM0
Dissolved Oxygen (% Saturation)	-	-	-	-	-						<0.1	%	SA_TM59/SA_PM0
Temperature	-	-	-	-	-						<0.1	Degrees C	SA_TM59/SA_PM0
Electrical Conductivity @25C SA	585	563	115	-	-						<2	uS/cm	SA_TM28/SA_PM0
Dissolved Organic Carbon*	-	-	-	-	-						<2	mg/l	UK_TM60/UK_PM0
Ortho Phosphate as PO4*	0.22	<0.06	0.17	11.21	25.26						<0.06	mg/l	UK_TM38/UK_PM0
pH SA	7.64	8.04	7.26	-	-						<2.00	pH units	SA_TM19/SA_PM0
Total Dissolved Solids SA	340	308	88	-	-						<35	mg/l	SA_TM20/SA_PM31

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 1527125
Location: Leeuwpan
Contact: Vhulenda Mandiwana
JE Job No.: 19/18

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

J E Sample No.	100-103	104-107	108-111	112-115	116-119							
Sample ID	LNP19_M01_023	LNP19_M01_016	LNP19_M01_036	LNP19_M01_034	LNP19_M01_025							
Depth												
COC No / misc												
Containers	H HN P	H HN P	H HN P	H HN P	H HN P							
Sample Date	11/01/2019	11/01/2019	11/01/2019	11/01/2019	11/01/2019							
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water							
Batch Number	1	1	1	1	1							
Date of Receipt	15/01/2019	15/01/2019	15/01/2019	15/01/2019	15/01/2019							
Total Suspended Solids [SA]	-	-	-	301	182						<10	mg/l
Turbidity	-	-	-	-	-						<0.1	NTU

Please see attached notes for all abbreviations and acronyms

LOD/LOR	Units	Method No.
<10	mg/l	SA_TM37/SA_PM0
<0.1	NTU	SA_TM34/SA_PM0

Client Name: Golder Associates (Pty) Ltd
Reference: 1527125
Location: Leeuwpan
Contact: Vhulenda Mandiwana

J E Job No.	Batch	Sample ID	Depth	J E Sample No.	Analysis	Reason
No deviating sample report results for job 19/18						

Please note that only samples that are deviating are mentioned in this report. If no samples are listed it is because none were deviating.
Only analyses which are accredited are recorded as deviating if set criteria are not met.

NOTES TO ACCOMPANY ALL SCHEDULES AND REPORTS

JE Job No.: 19/18

SOILS

Please note we are only MCERTS accredited (UK soils only) for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

% Asbestos in Asbestos Containing Materials (ACMs) is determined by reference to HSG 264 The Survey Guide - Appendix 2 : ACMs in buildings listed in order of ease of fibre release.

Negative Neutralization Potential (NP) values are obtained when the volume of NaOH (0.1N) titrated (pH 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 - 2.5. Any negative NP values are corrected to 0.

The calculation of Pyrite content assumes that all oxidisable sulphides present in the sample are pyrite. This may not be the case. The calculation may be an overesitimate when other sulphides such as Barite (Barium Sulphate) are present.

WATERS

Please note we are not a UK Drinking Water Inspectorate (DWI) Approved Laboratory .

ISO17025 accreditation applies to surface water and groundwater and usually one other matrix which is analysis specific, any other liquids are outside our scope of accreditation.

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

DEVIATING SAMPLES

Samples must be received in a condition appropriate to the requested analyses. All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. If this is not the case you will be informed and any test results that may be compromised highlighted on your deviating samples report.

SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

DILUTIONS

A dilution suffix indicates a dilution has been performed and the reported result takes this into account. No further calculation is required.

BLANKS

Where analytes have been found in the blank, the sample will be treated in accordance with our laboratory procedure for dealing with contaminated blanks.

NOTE

Data is only reported if the laboratory is confident that the data is a true reflection of the samples analysed. Data is only reported as accredited when all the requirements of our Quality System have been met. In certain circumstances where all the requirements of the Quality System have not been met, for instance if the associated AQC has failed, the reason is fully investigated and documented. The sample data is then evaluated alongside the other quality control checks performed during analysis to determine its suitability. Following this evaluation, provided the sample results have not been effected, the data is reported but accreditation is removed. It is a UKAS requirement for data not reported as accredited to be considered indicative only, but this does not mean the data is not valid.
Where possible, and if requested, samples will be re-extracted and a revised report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.

REPORTS FROM THE SOUTH AFRICA LABORATORY

Any method number not prefixed with SA has been undertaken in our UK laboratory unless reported as subcontracted.

ABBREVIATIONS and ACRONYMS USED

#	ISO17025 (UKAS Ref No. 4225) accredited - UK.
SA	ISO17025 (SANAS Ref No.T0729) accredited - South Africa.
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance
SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
++	Result outside calibration range, results should be considered as indicative only and are not accredited.
*	Analysis subcontracted to an Exova Jones Environmental approved laboratory.
AD	Samples are dried at 35°C ±5°C
CO	Suspected carry over
LOD/LOR	Limit of Detection (Limit of Reporting) in line with ISO 17025 and MCERTS
ME	Matrix Effect
NFD	No Fibres Detected
BS	AQC Sample
LB	Blank Sample
N	Client Sample
TB	Trip Blank Sample
OC	Outside Calibration Range
AA	x10 Dilution

JE Job No: 19/18

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
SA_TM19	Determination of pH by bench pH meter	SA_PM0	No preparation is required.	Yes			
SA_TM20	Modified BS 1377-3: 1990 Gravimetric determination of Total Dissolved Solids	SA_PM31	Sample is filtered	Yes			
SA_TM27	Major ions by Ion Chromatography	SA_PM0	No preparation is required.				
SA_TM27	Major ions by Ion Chromatography	SA_PM0	No preparation is required.	Yes			
SA_TM28	Determination of Electrical Conductivity with hand held manual conductivity probe.	SA_PM0	No preparation is required.	Yes			
SA_TM32	Determination of Alkalinity by titration of the sample with a standard solution of acid by visual detection of end points.	SA_PM0	No preparation is required.	Yes			
SA_TM34	Turbidity by TL2300 Turbidity Meter	SA_PM0	No preparation is required.				
SA_TM37	Modified BS EM 872:2005 .Gravimetric determination of Total Suspended Solids. Sample is filtered and the resulting residue is dried and weighed.	SA_PM0	No preparation is required.	Yes			
SA_TM5	Modified USEPA 8015B method for the determination of solvent Extractable Petroleum Hydrocarbons (EPH) with carbon banding within the range C8-C40 GC-FID.	SA_PM30	Water samples are extracted with solvent using a magnetic stirrer to create a vortex.				
SA_TM57	Modified US EPA Method 410.4. Chemical Oxygen Demand is determined by hot digestion with Potassium Dichromate and measured spectrophotometerically.	SA_PM0	No preparation is required.	Yes			

JE Job No: 19/18

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
SA_TM59	Determination of Dissolved Oxygen using the Hach HQ30D Oxygen Meter	SA_PM0	No preparation is required.				
UK_TM30	Determination of Trace Metal elements by ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometry). Modified US EPA Method 200.7, 6010B and BS EN ISO 11885 2009	UK_PM14	Analysis of waters and leachates for metals by ICP OES/ICP MS. Samples are filtered for dissolved metals and acidified if required.				
UK_TM38	Soluble Ion analysis using the Thermo Aquakem Photometric Automatic Analyser. Modified US EPA methods 325.2, 375.4, 365.2, 353.1, 354.1	UK_PM0	No preparation is required.				
UK_TM60	Modified USEPA 9060. Determination of TOC by calculation from Total Carbon and Inorganic Carbon using a TOC analyser, the carbon in the sample is converted to CO2 and then passed through a non-dispersive infrared gas analyser (NDIR).	UK_PM0	No preparation is required.				

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FINAL CERTIFICATE OF ANALYSIS	
Report Date	2019-01-23
Date Required	2019-01-21
Contract No	
Order/Ref No	18102350 Leeuwpan

T0184

18102350 Leeuwpan

Notes
The results relate specifically to the items tested.
The report shall not be reproduced except in full, without the written approval of the laboratory.
[1] SANAS accredited analysis included in the SANAS Schedule of Accredition for this laboratory.
[2] Not SANAS accredited analysis and not included in the SANAS schedule of accreditation for this laboratory.
[3] Outsourced not performed by this laboratory.

Request ID: 25229 **Sample ID:** 602892 **Received:** 2019-01-11 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M01_017 **Revision Number:** 0

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Escherichia coli	0	Colonies/100ml

Request ID: 25229 **Sample ID:** 602893 **Received:** 2019-01-11 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M01_037 **Revision Number:** 0

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Escherichia coli	1	Colonies/100ml

Request ID: 25229 **Sample ID:** 602894 **Received:** 2019-01-11 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M01_021 **Revision Number:** 0

Method: [2]UIS-OS-T034(Chlorophyll A) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Chlorophyll -a	4	ug/l

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Escherichia coli	1600	Colonies/100ml

Request ID: 25229 **Sample ID:** 602895 **Received:** 2019-01-11 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M01_019 **Revision Number:** 0

Method: [2]UIS-OS-T034(Chlorophyll A) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Chlorophyll -a	9	ug/l

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Escherichia coli	170	Colonies/100ml

Request ID: 25229 **Sample ID:** 602896 **Received:** 2019-01-11 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M01_039 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-01-21

Parameter	Value	Unit
²Chlorophyll -a	<1	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-01-21

Parameter	Value	Unit
²Escherichia coli	53	Colonies/100ml

Request ID: 25229 **Sample ID:** 602897 **Received:** 2019-01-11 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M01_002 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-01-21

Parameter	Value	Unit
²Chlorophyll -a	1	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-01-21

Parameter	Value	Unit
²Escherichia coli	1290	Colonies/100ml

Request ID: 25229 **Sample ID:** 602898 **Received:** 2019-01-11 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M01_004 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-01-21

Parameter	Value	Unit
²Chlorophyll -a	7	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-01-21

Parameter	Value	Unit
²Escherichia coli	460	Colonies/100ml

Request ID: 25229 **Sample ID:** 602899 **Received:** 2019-01-11 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M01_030 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-01-21

Parameter	Value	Unit
²Chlorophyll -a	21	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-01-21

Parameter	Value	Unit
²Escherichia coli	590	Colonies/100ml

Request ID: 25229 **Sample ID:** 602900 **Received:** 2019-01-11 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M01_028 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-01-21

Parameter	Value	Unit
²Chlorophyll -a	4	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-01-21

Parameter	Value	Unit
²Escherichia coli	42	Colonies/100ml

Request ID: 25229 **Sample ID:** 602901 **Received:** 2019-01-11 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M01_035 **Revision Number:** 0

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-01-21

Parameter	Value	Unit
²Escherichia coli	1700000	Colonies/100ml

Request ID: 25229 **Sample ID:** 602902 **Received:** 2019-01-11 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M01_026 **Revision Number:** 0

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-01-21

Parameter	Value	Unit
²Escherichia coli	740	Colonies/100ml

Request ID: 25229 **Sample ID:** 602903 **Received:** 2019-01-11 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M01_033 **Revision Number:** 0

Method: [2]UIS-OS-T034(Chlorophyll A) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Chlorophyll -a	139	ug/l

Method: [2]UIS-CP-T009(Total Inorganic Nitrogen (Dissolved)) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Total Inorganic Nitrogen	<0.001	mg/l

Method: [1]UIS-EA-T001(pH) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	7.01		[2]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	22.2	mSm	[1]Total Conductivity	22.2	mS/m	[2]TC Temperature	28.9	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	144	mg/l	[2]TDS by EC*7	155	mg/l

Method: [1]UIS-EA-T005(Total Dissolved Solids) **Completed:** 2019-01-23

Parameter	Value	Unit
[1]Total Dissolved Solids at 180C	160	mg/l

Method: [2]UIS-CP-T004(Calculated Hardness) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca Hardness	68.9	mg/l CaCO3	[2]Mg Hardness	38	mg/l CaCO3	[2]Total Hardness	107	mg/l CaCO3

Method: [2]UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]TDS by Summation	92.3	mg/l

Method: [2]UIS-CP-T006(Calculated Sodium Adsorption Ratio) **Completed:** 2019-01-23

Parameter	Value	Unit
[2]Sodium Adsorption Ratio	0.369	

Method: [2]UIS-EA-T029(Turbidity) **Completed:** 2019-01-23

Parameter	Value	Unit
[2]Turbidity	35.5	NTU

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	64.9	mg/l CaCO3

Method: [1]UIS-AC-T007(Dissolved Elements in Water by ICP-OES) **Completed:** 2019-01-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	0.09	mg/l	[2]B	<0.05	mg/l	[1]Ca	27.6	mg/l
[2]Fe	0.22	mg/l	[1]K	7.72	mg/l	[1]Mg	9.23	mg/l
[2]Mn	0.72	mg/l	[1]Na	8.78	mg/l			

Method: [1]UIS-EA-T034(Anions by Photometry) **Completed:** 2019-01-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Fluoride F	0.298	mg/l	[1]Chloride Cl	9.81	mg/l	[1]Nitrate NO3 as N	<0.13	mg/l
[1]Phosphate PO4 as P	0.009	mg/l	[2]Nitrite NO2 as N	<0.001	mg/l	[1]Phosphate PO4	0.028	mg/l
[1]Sulphate SO4	42.8	mg/l						

Method: [2]UIS-CP-T005(Ion Balance Error Gallery) **Completed:** 2019-01-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	2.76	me/l	[2]Sum of Anions	2.27	me/l	[2]Ion Error Balance	9.85	%

Method: [2]UIS-EA-T111(Hexavalent Chromium in Liquid (Photometry)) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Hexavalent Chromium in Liquid (Photometry)	<0.001	mg/l

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Escherichia coli	37	Colonies/100ml

Method: [2]UIS-EA-T035(Dissolved Oxygen) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Dissolved Oxygen	1.84	mg/l O2

Method: [2]UIS-EA-T007(Determination of Oil and Grease) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Total Oil and Grease	2	ppm

Method: [1]UIS-EA-T034a(Ammonia by Photometry) **Completed:** 2019-01-21

Parameter	Value	Unit
[1]Ammonia as N	<0.009	mg/l

Method: [2]UIS-TEA-T002(Total Cations in Water by ICP-OES) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Total P as P	0.44	mg/l

Method: [3]UIS-OS-T015(Dissolved Organic Carbon) **Completed:** 2019-01-21

Parameter	Value	Unit
[3]Dissolved Organic Carbon (OL)	<10	mg/l

Method: [2]UIS-EA-T043(Total trace elements in liquid by ICP-MS) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Tot. Cr	0.016	mg/l

Method: [1]UIS-EA-T001(pH) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	7.79		[2]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	47.2	mSm	[1]Total Conductivity	47.2	mS/m	[2]TC Temperature	29.1	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	307	mg/l	[2]TDS by EC*7	330	mg/l

Method: [1]UIS-EA-T005(Total Dissolved Solids) **Completed:** 2019-01-21

Parameter	Value	Unit
[1]Total Dissolved Solids at 180C	358	mg/l

Method: [2]UIS-CP-T004(Calculated Hardness) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca Hardness	117	mg/l CaCO3	[2]Mg Hardness	102	mg/l CaCO3	[2]Total Hardness	219	mg/l CaCO3

Method: [2]UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]TDS by Summation	197	mg/l

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	154	mg/l CaCO3

Method: [1]UIS-AC-T007(Dissolved Elements in Water by ICP-OES) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	<0.05	mg/l	[2]B	0.06	mg/l	[1]Ca	47	mg/l
[2]Fe	<0.05	mg/l	[1]K	4.12	mg/l	[1]Mg	24.8	mg/l
[2]Mn	0.07	mg/l	[1]Na	28.9	mg/l			

Method: [1]UIS-EA-T034(Anions by Photometry) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Fluoride F	0.254	mg/l	[1]Chloride Cl	35.9	mg/l	[2]Nitrate NO3	6.39	mg/l
[1]Nitrate NO3 as N	1.44	mg/l	[1]Phosphate PO4 as P	0.008	mg/l	[2]Nitrite NO2 as N	<0.001	mg/l
[1]Phosphate PO4	0.025	mg/l	[1]Sulphate SO4	75.9	mg/l			

Method: [2]UIS-CP-T005(Ion Balance Error Gallery) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	5.76	me/l	[2]Sum of Anions	5.27	me/l	[2]Ion Error Balance	4.45	%

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Escherichia coli	0	Colonies/100ml

Method: [2]UIS-AC-T100(Trace elements in liquids by ICP-MS) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]As	0.01	mg/l	[2]Au	<0.001	mg/l	[2]Ba	0.075	mg/l

[2]Cd	<0.0001	mg/l	[2]Co	0.001	mg/l	[2]Cr	<0.001	mg/l
[2]Cu	0.002	mg/l	[2]Ga	<0.001	mg/l	[2]Hg	<0.0001	mg/l
[2]Mo	0.004	mg/l	[2]Ni	0.006	mg/l	[2]Pb	<0.001	mg/l
[2]Sb	0.001	mg/l	[2]Se	0.001	mg/l	[2]U	<0.0001	mg/l
[2]V	0.003	mg/l	[2]Zn	0.047	mg/l			

Method: [1]UIS-EA-T034a(Ammonia by Photometry) **Completed:** 2019-01-21

Parameter	Value	Unit
[1]Ammonia as N	<0.009	mg/l

Method: [2]UIS-CP-T009(Total Inorganic Nitrogen (Dissolved)) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Total Inorganic Nitrogen	1.563	mg/l

Method: [1]UIS-EA-T001(pH) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	7.96		[2]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	352	mSm	[1]Total Conductivity	352	mS/m	[2]TC Temperature	25.5	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	2290	mg/l	[2]TDS by EC*7	2460	mg/l

Method: [2]UIS-CP-T004(Calculated Hardness) **Completed:** 2019-01-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca Hardness	1220	mg/l CaCO3	[2]Mg Hardness	761	mg/l CaCO3	[2]Total Hardness	1980	mg/l CaCO3

Method: [1]UIS-EA-T005(Total Dissolved Solids) **Completed:** 2019-01-21

Parameter	Value	Unit
[1]Total Dissolved Solids at 180C	2770	mg/l

Method: [2]UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2019-01-23

Parameter	Value	Unit
[2]TDS by Summation	769	mg/l

Method: [2]UIS-CP-T006(Calculated Sodium Adsorption Ratio) **Completed:** 2019-01-23

Parameter	Value	Unit
[2]Sodium Adsorption Ratio	0.395	

Method: [2]UIS-EA-T029(Turbidity) **Completed:** 2019-01-23

Parameter	Value	Unit
[2]Turbidity	21.8	NTU

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	78.1	mg/l CaCO3

Method: [1]UIS-AC-T007(Dissolved Elements in Water by ICP-OES) **Completed:** 2019-01-21

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	<0.05	mg/l	[2]B	0.08	mg/l	[1]Ca	487	mg/l
[2]Fe	<0.05	mg/l	[1]K	9.96	mg/l	[1]Mg	185	mg/l
[2]Mn	<0.05	mg/l	[1]Na	40.4	mg/l			

Method: [1]UIS-EA-T034(Anions by Photometry) **Completed:** 2019-01-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Fluoride F	<0.042	mg/l	[1]Chloride Cl	9.34	mg/l	[2]Nitrate NO3	6.85	mg/l
[1]Nitrate NO3 as N	1.55	mg/l	[2]Nitrite NO2	0.009	mg/l	[2]Nitrite NO2 as N	0.003	mg/l
[1]Sulphate SO4	1700	mg/l						

Method: [2]UIS-CP-T005(Ion Balance Error Gallery) **Completed:** 2019-01-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	41.6	me/l	[2]Sum of Anions	37.1	me/l	[2]Ion Error Balance	5.73	%

Method: [2]UIS-EA-T111(Hexavalent Chromium in Liquid (Photometry)) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Hexavalent Chromium in Liquid (Photometry)	<0.001	mg/l

Method: [2]UIS-EA-T035(Dissolved Oxygen) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Dissolved Oxygen	7.26	mg/l O2

Method: [2]UIS-EA-T007(Determination of Oil and Grease) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Total Oil and Grease	7	ppm

Method: [1]UIS-EA-T034a(Ammonia by Photometry) **Completed:** 2019-01-21

Parameter	Value	Unit
[1]Ammonia as N	<0.009	mg/l

Method: [2]UIS-TEA-T002(Total Cations in Water by ICP-OES) **Completed:** 2019-01-21

Parameter	Value	Unit
[2]Total P as P	<0.05	mg/l

Method: [3]UIS-OS-T015(Dissolved Organic Carbon) **Completed:** 2019-01-21

Parameter	Value	Unit
[3]Dissolved Organic Carbon (OL)	<10	mg/l

Petunia Moleta
AUTHORISED SIGNATORY

Exova Jones Environmental South Africa

Unit D2/5
9 Quantum Road
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South Africa
1685

Attention :	Keretia Lupankwa
Date :	4th March, 2019
Your reference :	1527125
Our reference :	Test Report 19/69 Batch 1
Location :	Leeuwpan
Date samples received :	5th February, 2019
Status :	Final report
Issue :	1

Twenty six samples were received for analysis on 5th February, 2019 of which twenty six were scheduled for analysis. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

Analysis was undertaken at either Exova Jones Environmental (UK), which is ISO 17025 accredited under UKAS (4225) or Exova Jones Environmental (SA) which is ISO 17025 accredited under SANAS (T0729) or a subcontract laboratory where specified.

NOTE: Under International Laboratory Accreditation Cooperation (ILAC), ISO 17025 (UKAS) accreditation is recognised as equivalent to SANAS (South Africa) accreditation.

Compiled By:

Aatifah Latief

Organics Laboratory:

David Adams
Technical Signatory (Organics)

Inorganics Laboratory:

Musa Tiki
Technical Signatory (Inorganics)

Client Name: Golder Associates (Pty) Ltd
Reference: 1527125
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/69

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

J E Sample No.	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	LOD/LOR	Units	Method No.
Sample ID	LNP19_M02_020	LNP19_M02_018	LNP19_M02_031	LNP19_M02_032	LNP19_M02_038	LNP19_M02_001	LNP19_M02_003	LNP19_M02_029	LNP19_M02_027	LNP19_M02_010			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G			
Sample Date	01/02/2019	01/02/2019	31/01/2019	31/01/2019	31/01/2019	01/02/2019	01/02/2019	01/02/2019	01/02/2019	01/02/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019			
Dissolved Aluminium*	<20	<20	33	34	<20	<20	185	<20	<20	24	<20	ug/l	UK_TM30/UK_PM14
Dissolved Antimony*	-	-	-	-	-	-	-	-	-	-	<2	ug/l	UK_TM30/UK_PM14
Dissolved Arsenic*	-	-	-	-	-	-	-	-	-	-	<2.5	ug/l	UK_TM30/UK_PM14
Dissolved Barium*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Dissolved Boron*	32	29	15	23	18	32	18	24	19	117	<12	ug/l	UK_TM30/UK_PM14
Dissolved Cadmium*	-	-	-	-	-	-	-	-	-	-	<0.5	ug/l	UK_TM30/UK_PM14
Dissolved Calcium*	28.5	45.5	44.3	44.5	35.8	21.3	3.0	32.4	33.0	328.9	<0.2	mg/l	UK_TM30/UK_PM14
Total Dissolved Chromium*	-	-	-	-	-	-	-	-	-	-	<1.5	ug/l	UK_TM30/UK_PM14
Dissolved Copper*	-	-	-	-	-	-	-	-	-	-	<7	ug/l	UK_TM30/UK_PM14
Total Dissolved Iron*	<20	<20	295	319	133	<20	130	<20	201	21	<20	ug/l	UK_TM30/UK_PM14
Dissolved Lead*	-	-	-	-	-	-	-	-	-	-	<5	ug/l	UK_TM30/UK_PM14
Dissolved Magnesium*	13.9	28.2	17.9	18.0	26.4	10.3	1.7	17.2	26.8	132.0	<0.1	mg/l	UK_TM30/UK_PM14
Dissolved Manganese*	1482	175	1154	1191	1053	331	44	870	1347	42	<2	ug/l	UK_TM30/UK_PM14
Dissolved Mercury*	-	-	-	-	-	-	-	-	-	-	<1	ug/l	UK_TM30/UK_PM14
Dissolved Nickel*	-	-	-	-	-	-	-	-	-	-	<2	ug/l	UK_TM30/UK_PM14
Dissolved Potassium*	13.2	6.8	7.1	7.5	5.2	11.5	4.2	4.8	5.2	9.5	<0.1	mg/l	UK_TM30/UK_PM14
Dissolved Selenium*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Dissolved Sodium*	9.4	21.1	13.2	13.2	14.5	12.0	4.1	8.3	14.1	38.5	<0.1	mg/l	UK_TM30/UK_PM14
Dissolved Uranium*	-	-	-	-	-	-	-	-	-	-	<5	ug/l	UK_TM30/UK_PM14
Dissolved Zinc*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Total Phosphorus*	250	49	189	570	54	187	224	40	100	38	<5	ug/l	UK_TM30/UK_PM14
Total Hardness Dissolved (as CaCO3)*	130	232	186	187	200	97	15	153	195	1377	<1	mg/l	UK_TM30/UK_PM14
Fats Oils and Grease	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	SA_TM5/SA_PM30
Chloride*	9.5	10.5	13.2	20.2	17.8	6.9	1.8	14.0	14.1	11.3	<0.3	mg/l	UK_TM38/UK_PM0
Ammoniacal Nitrogen as N*	2.96	0.05	1.14	1.74	0.09	0.24	0.41	0.06	0.11	0.37	<0.03	mg/l	UK_TM38/UK_PM0
Hexavalent Chromium*	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO3 [SA]	126	239	160	161	182	112	13	90	172	52	<3	mg/l	SA_TM32/SA_PM0
COD (Settled) [SA]	-	-	-	-	-	-	-	-	-	-	<9	mg/l	SA_TM57/SA_PM0
Dissolved Oxygen (% Saturation)	31.2	52.6	11.0	3.5	48.5	18.9	44.6	70.4	40.6	62.2	<0.1	%	SA_TM59/SA_PM0
Temperature	22.9	23.3	22.8	22.9	23.8	23.7	23.6	23.7	24.5	23.7	<0.1	Degrees C	SA_TM59/SA_PM0
Electrical Conductivity @25C [SA]	345	509	412	413	430	263	67	347	412	2131	<2	uS/cm	SA_TM28/SA_PM0
Dissolved Organic Carbon*	7	4	13	16	8	13	4	<2	9	<2	<2	mg/l	UK_TM60/UK_PM0
Fluoride*	0.3	<0.3	<0.3	<0.3	<0.3	0.4	<0.3	0.3	<0.3	0.3	<0.3	mg/l	UK_TM173/UK_PM0
Nitrite as N*	0.24	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.81	<0.05	mg/l	UK_TM38/UK_PM0
Nitrate as N*	0.66	<0.05	<0.05	<0.05	<0.05	0.55	1.28	0.06	<0.05	6.50	<0.05	mg/l	UK_TM38/UK_PM0
Ortho Phosphate as PO4*	<0.06	<0.06	0.06	0.25	<0.06	<0.06	0.26	<0.06	<0.06	<0.06	<0.06	mg/l	UK_TM38/UK_PM0
pH [SA]	7.71	8.03	7.36	7.22	7.82	7.54	6.76	7.82	7.86	7.77	<2.00	pH units	SA_TM19/SA_PM0
Sulphate as SO4*	29.1	21.9	19.4	5.7	16.4	18.4	11.1	67.7	20.4	1166.0	<0.5	mg/l	UK_TM38/UK_PM0
Total Dissolved Solids [SA]	240	302	264	285	280	275	176	254	250	2197	<35	mg/l	SA_TM20/SA_PM31

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 1527125
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/69

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

J E Sample No.	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	LOD/LOR	Units	Method No.
Sample ID	LNP19_M02_020	LNP19_M02_018	LNP19_M02_031	LNP19_M02_032	LNP19_M02_038	LNP19_M02_001	LNP19_M02_003	LNP19_M02_029	LNP19_M02_027	LNP19_M02_010			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G			
Sample Date	01/02/2019	01/02/2019	31/01/2019	31/01/2019	31/01/2019	01/02/2019	01/02/2019	01/02/2019	01/02/2019	01/02/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019			
Total Suspended Solids [SA]	-	-	-	-	-	-	-	-	-	-	<10	mg/l	SA_TM37/SA_PM0
Turbidity	205.0	4.5	24.6	26.6	2.5	269.0	621.0	11.5	5.1	34.3	<0.1	NTU	SA_TM34/SA_PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 1527125
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/69

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

J E Sample No.	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-99	LOD/LOR	Units	Method No.
Sample ID	LNP19_M02_011	LNP19_M02_012	LNP19_M02_015	LNP19_M02_014	LNP19_M02_005	LNP19_M02_007	LNP19_M02_008	LNP19_M02_009	LNP19_M02_006	LNP19_M02_022			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P			
Sample Date	01/02/2019	01/02/2019	01/02/2019	01/02/2019	31/01/2019	31/01/2019	31/01/2019	31/01/2019	31/01/2019	31/01/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019			
Dissolved Aluminium*	<20	<20	1091	<20	<20	<20	21	30	31	<20	<20	ug/l	UK_TM30/UK_PM14
Dissolved Antimony*	-	-	-	-	-	-	-	-	-	2	<2	ug/l	UK_TM30/UK_PM14
Dissolved Arsenic*	-	-	-	-	-	-	-	-	-	6.2	<2.5	ug/l	UK_TM30/UK_PM14
Dissolved Barium*	-	-	-	-	-	-	-	-	-	74	<3	ug/l	UK_TM30/UK_PM14
Dissolved Boron*	103	102	59	29	94	190	99	73	52	68	<12	ug/l	UK_TM30/UK_PM14
Dissolved Cadmium*	-	-	-	-	-	-	-	-	-	<0.5	<0.5	ug/l	UK_TM30/UK_PM14
Dissolved Calcium*	580.5	594.1	74.6	38.6	510.1	200.3	374.4	534.5	122.2	47.6	<0.2	mg/l	UK_TM30/UK_PM14
Total Dissolved Chromium*	-	-	-	-	-	-	-	-	-	<1.5	<1.5	ug/l	UK_TM30/UK_PM14
Dissolved Copper*	-	-	-	-	-	-	-	-	-	<7	<7	ug/l	UK_TM30/UK_PM14
Total Dissolved Iron*	<20	<20	263	<20	<20	<20	<20	<20	<20	<20	<20	ug/l	UK_TM30/UK_PM14
Dissolved Lead*	-	-	-	-	-	-	-	-	-	<5	<5	ug/l	UK_TM30/UK_PM14
Dissolved Magnesium*	240.9	244.6	38.0	16.8	230.8	97.8	156.1	208.7	36.9	24.0	<0.1	mg/l	UK_TM30/UK_PM14
Dissolved Manganese*	32	33	3834	13	273	204	119	605	10	36	<2	ug/l	UK_TM30/UK_PM14
Dissolved Mercury*	-	-	-	-	-	-	-	-	-	<1	<1	ug/l	UK_TM30/UK_PM14
Dissolved Nickel*	-	-	-	-	-	-	-	-	-	<2	<2	ug/l	UK_TM30/UK_PM14
Dissolved Potassium*	13.1	12.3	4.8	1.6	13.7	5.4	10.8	10.2	3.4	4.9	<0.1	mg/l	UK_TM30/UK_PM14
Dissolved Selenium*	-	-	-	-	-	-	-	-	-	<3	<3	ug/l	UK_TM30/UK_PM14
Dissolved Sodium*	55.7	52.2	13.6	23.8	81.9	37.9	33.3	45.3	9.3	33.9	<0.1	mg/l	UK_TM30/UK_PM14
Dissolved Uranium*	-	-	-	-	-	-	-	-	-	<5	<5	ug/l	UK_TM30/UK_PM14
Dissolved Zinc*	-	-	-	-	-	-	-	-	-	70	<3	ug/l	UK_TM30/UK_PM14
Total Phosphorus*	23	24	76	36	39	22	42	31	36	-	<5	ug/l	UK_TM30/UK_PM14
Total Hardness Dissolved (as CaCO3)*	2463	2513	346	167	2245	912	1592	2213	460	220	<1	mg/l	UK_TM30/UK_PM14
Fats Oils and Grease	<10	<10	38366	<10	<10	<10	<10	<10	<10	-	<10	ug/l	SA_TM5/SA_PM30
Chloride*	12.0	11.5	3.3	3.8	23.2	4.3	6.7	10.5	6.9	35.2	<0.3	mg/l	UK_TM38/UK_PM0
Ammoniacal Nitrogen as N*	0.07	0.07	0.55	0.08	0.23	1.32	0.27	0.12	0.09	0.09	<0.03	mg/l	UK_TM38/UK_PM0
Hexavalent Chromium*	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	-	<0.006	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO3 SA	53	54	<3	30	57	230	96	170	61	153	<3	mg/l	SA_TM32/SA_PM0
COD (Settled) SA	-	-	-	-	-	-	-	-	-	-	<9	mg/l	SA_TM57/SA_PM0
Dissolved Oxygen (% Saturation)	69.1	67.5	9.9	77.3	80.7	74.1	82.4	83.9	86.2	-	<0.1	%	SA_TM59/SA_PM0
Temperature	24.5	24.5	24.8	24.5	24.4	23.9	24.9	24.7	24.6	-	<0.1	Degrees C	SA_TM59/SA_PM0
Electrical Conductivity @25C SA	3280	3280	748	442	3220	1639	2165	3030	860	580	<2	uS/cm	SA_TM28/SA_PM0
Dissolved Organic Carbon*	<2	<2	7	4	13	<2	<2	<2	<2	-	<2	mg/l	UK_TM60/UK_PM0
Fluoride*	<0.3	<0.3	0.8	0.7	0.4	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	mg/l	UK_TM173/UK_PM0
Nitrite as N*	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	mg/l	UK_TM38/UK_PM0
Nitrate as N*	<0.05	<0.05	<0.05	<0.05	<0.05	2.84	5.05	0.20	0.87	1.78	<0.05	mg/l	UK_TM38/UK_PM0
Ortho Phosphate as PO4*	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	mg/l	UK_TM38/UK_PM0
pH SA	7.50	7.43	5.32	7.92	7.70	7.89	7.79	7.79	7.80	7.96	<2.00	pH units	SA_TM19/SA_PM0
Sulphate as SO4*	2062.0	2168.0	339.0	152.3	2001.3	674.0	1200.8	1801.8	353.9	76.0	<0.5	mg/l	UK_TM38/UK_PM0
Total Dissolved Solids SA	3826	3906	577	300	3752	1459	2219	3423	922	424	<35	mg/l	SA_TM20/SA_PM31

Please see attached notes for all abbreviations and acronyms

Exova Jones Environmental

Client Name: Golder Associates (Pty) Ltd
Reference: 1527125
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/69

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

J E Sample No.	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-99	LOD/LOR	Units	Method No.
Sample ID	LNP19_M02_011	LNP19_M02_012	LNP19_M02_015	LNP19_M02_014	LNP19_M02_005	LNP19_M02_007	LNP19_M02_008	LNP19_M02_009	LNP19_M02_006	LNP19_M02_022			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P			
Sample Date	01/02/2019	01/02/2019	01/02/2019	01/02/2019	31/01/2019	31/01/2019	31/01/2019	31/01/2019	31/01/2019	31/01/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019			
Total Suspended Solids [SA]	-	-	-	-	-	-	-	-	-	-	<10	mg/l	SA_TM37/SA_PM0
Turbidity	39.7	67.5	4.6	31.5	4.7	3.0	81.3	18.8	3.5	-	<0.1	NTU	SA_TM34/SA_PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 1527125
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/69

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

J E Sample No.	100-103	104-107	108-111	112-115	116-119	120-123					LOD/LOR	Units	Method No.
Sample ID	LNP19_M02_023	LNP19_M02_016	LNP19_M02_040	LNP19_M02_036	LNP19_M02_034	LNP19_M02_025							
Depth													
COC No / misc													
Containers	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P							
Sample Date	31/01/2019	01/02/2019	01/02/2019	01/02/2019	01/02/2019	01/02/2019							
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water							
Batch Number	1	1	1	1	1	1							
Date of Receipt	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019							
Dissolved Aluminium*	<20	<20	<20	<20	-	-					<20	ug/l	UK_TM30/UK_PM14
Dissolved Antimony*	2	<2	<2	<2	-	-					<2	ug/l	UK_TM30/UK_PM14
Dissolved Arsenic*	7.2	<2.5	4.4	<2.5	-	-					<2.5	ug/l	UK_TM30/UK_PM14
Dissolved Barium*	75	207	77	38	-	-					<3	ug/l	UK_TM30/UK_PM14
Dissolved Boron*	72	76	76	24	-	-					<12	ug/l	UK_TM30/UK_PM14
Dissolved Cadmium*	<0.5	<0.5	<0.5	<0.5	-	-					<0.5	ug/l	UK_TM30/UK_PM14
Dissolved Calcium*	47.5	42.3	48.5	10.7	-	-					<0.2	mg/l	UK_TM30/UK_PM14
Total Dissolved Chromium*	<1.5	<1.5	<1.5	<1.5	-	-					<1.5	ug/l	UK_TM30/UK_PM14
Dissolved Copper*	<7	<7	<7	9	-	-					<7	ug/l	UK_TM30/UK_PM14
Total Dissolved Iron*	<20	28	<20	<20	-	-					<20	ug/l	UK_TM30/UK_PM14
Dissolved Lead*	<5	<5	<5	<5	-	-					<5	ug/l	UK_TM30/UK_PM14
Dissolved Magnesium*	24.8	26.9	24.8	7.1	-	-					<0.1	mg/l	UK_TM30/UK_PM14
Dissolved Manganese*	36	6	6	10	-	-					<2	ug/l	UK_TM30/UK_PM14
Dissolved Mercury*	<1	<1	<1	<1	-	-					<1	ug/l	UK_TM30/UK_PM14
Dissolved Nickel*	<2	<2	3	<2	-	-					<2	ug/l	UK_TM30/UK_PM14
Dissolved Potassium*	5.0	3.5	4.8	1.6	-	-					<0.1	mg/l	UK_TM30/UK_PM14
Dissolved Selenium*	<3	<3	<3	<3	-	-					<3	ug/l	UK_TM30/UK_PM14
Dissolved Sodium*	33.4	32.1	34.3	4.3	-	-					<0.1	mg/l	UK_TM30/UK_PM14
Dissolved Uranium*	<5	<5	<5	<5	-	-					<5	ug/l	UK_TM30/UK_PM14
Dissolved Zinc*	74	175	246	49	-	-					<3	ug/l	UK_TM30/UK_PM14
Total Phosphorus*	-	-	-	-	-	-					<5	ug/l	UK_TM30/UK_PM14
Total Hardness Dissolved (as CaCO3)*	223	219	225	57	-	-					<1	mg/l	UK_TM30/UK_PM14
Fats Oils and Grease	-	-	-	-	-	-					<10	ug/l	SA_TM5/SA_PM30
Chloride*	35.2	33.8	35.4	2.1	-	-					<0.3	mg/l	UK_TM38/UK_PM0
Ammoniacal Nitrogen as N*	0.11	<0.03	<0.03	0.18	39.98	57.82					<0.03	mg/l	UK_TM38/UK_PM0
Hexavalent Chromium*	-	-	-	-	-	-					<0.006	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO3 SA	154	183	154	58	-	-					<3	mg/l	SA_TM32/SA_PM0
COD (Settled) SA	-	-	-	-	240_{AA}	63					<9	mg/l	SA_TM57/SA_PM0
Dissolved Oxygen (% Saturation)	-	-	-	-	-	-					<0.1	%	SA_TM59/SA_PM0
Temperature	-	-	-	-	-	-					<0.1	Degrees C	SA_TM59/SA_PM0
Electrical Conductivity @25C SA	583	553	580	129	-	-					<2	uS/cm	SA_TM28/SA_PM0
Dissolved Organic Carbon*	-	-	-	-	-	-					<2	mg/l	UK_TM60/UK_PM0
Fluoride*	<0.3	<0.3	<0.3	<0.3	-	-					<0.3	mg/l	UK_TM173/UK_PM0
Nitrite as N*	<0.05	<0.05	<0.05	<0.05	-	-					<0.05	mg/l	UK_TM38/UK_PM0
Nitrate as N*	1.83	<0.05	1.45	0.49	<0.05	0.57					<0.05	mg/l	UK_TM38/UK_PM0
Ortho Phosphate as PO4*	<0.06	<0.06	<0.06	0.12	11.14	15.48					<0.06	mg/l	UK_TM38/UK_PM0
pH SA	8.03	8.20	8.07	7.55	-	-					<2.00	pH units	SA_TM19/SA_PM0
Sulphate as SO4*	78.5	47.4	74.9	23.6	-	-					<0.5	mg/l	UK_TM38/UK_PM0
Total Dissolved Solids SA	413	367	403	127	-	-					<35	mg/l	SA_TM20/SA_PM31

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 1527125
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/69

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

J E Sample No.	100-103	104-107	108-111	112-115	116-119	120-123					LOD/LOR	Units	Method No.
Sample ID	LNP19_M02_023	LNP19_M02_016	LNP19_M02_040	LNP19_M02_036	LNP19_M02_034	LNP19_M02_025							
Depth													
COC No / misc													
Containers	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P							
Sample Date	31/01/2019	01/02/2019	01/02/2019	01/02/2019	01/02/2019	01/02/2019							
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water							
Batch Number	1	1	1	1	1	1							
Date of Receipt	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019	05/02/2019							
Total Suspended Solids [SA]	-	-	-	-	42	25					<10	mg/l	SA_TM37/SA_PM0
Turbidity	-	-	-	-	-	-					<0.1	NTU	SA_TM34/SA_PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 1527125
Location: Leeuwpan
Contact: Keretia Lupankwa

J E Job No.	Batch	Sample ID	Depth	J E Sample No.	Analysis	Reason
No deviating sample report results for job 19/69						

Please note that only samples that are deviating are mentioned in this report. If no samples are listed it is because none were deviating.
Only analyses which are accredited are recorded as deviating if set criteria are not met.

NOTES TO ACCOMPANY ALL SCHEDULES AND REPORTS

JE Job No.: 19/69

SOILS

Please note we are only MCERTS accredited (UK soils only) for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

% Asbestos in Asbestos Containing Materials (ACMs) is determined by reference to HSG 264 The Survey Guide - Appendix 2 : ACMs in buildings listed in order of ease of fibre release.

Negative Neutralization Potential (NP) values are obtained when the volume of NaOH (0.1N) titrated (pH 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 - 2.5. Any negative NP values are corrected to 0.

The calculation of Pyrite content assumes that all oxidisable sulphides present in the sample are pyrite. This may not be the case. The calculation may be an overesitimate when other sulphides such as Barite (Barium Sulphate) are present.

WATERS

Please note we are not a UK Drinking Water Inspectorate (DWI) Approved Laboratory .

ISO17025 accreditation applies to surface water and groundwater and usually one other matrix which is analysis specific, any other liquids are outside our scope of accreditation.

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

DEVIATING SAMPLES

Samples must be received in a condition appropriate to the requested analyses. All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. If this is not the case you will be informed and any test results that may be compromised highlighted on your deviating samples report.

SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

DILUTIONS

A dilution suffix indicates a dilution has been performed and the reported result takes this into account. No further calculation is required.

BLANKS

Where analytes have been found in the blank, the sample will be treated in accordance with our laboratory procedure for dealing with contaminated blanks.

NOTE

Data is only reported if the laboratory is confident that the data is a true reflection of the samples analysed. Data is only reported as accredited when all the requirements of our Quality System have been met. In certain circumstances where all the requirements of the Quality System have not been met, for instance if the associated AQC has failed, the reason is fully investigated and documented. The sample data is then evaluated alongside the other quality control checks performed during analysis to determine its suitability. Following this evaluation, provided the sample results have not been effected, the data is reported but accreditation is removed. It is a UKAS requirement for data not reported as accredited to be considered indicative only, but this does not mean the data is not valid.
Where possible, and if requested, samples will be re-extracted and a revised report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.

REPORTS FROM THE SOUTH AFRICA LABORATORY

Any method number not prefixed with SA has been undertaken in our UK laboratory unless reported as subcontracted.

ABBREVIATIONS and ACRONYMS USED

#	ISO17025 (UKAS Ref No. 4225) accredited - UK.
SA	ISO17025 (SANAS Ref No.T0729) accredited - South Africa.
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance
SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
++	Result outside calibration range, results should be considered as indicative only and are not accredited.
*	Analysis subcontracted to an Exova Jones Environmental approved laboratory.
AD	Samples are dried at 35°C ±5°C
CO	Suspected carry over
LOD/LOR	Limit of Detection (Limit of Reporting) in line with ISO 17025 and MCERTS
ME	Matrix Effect
NFD	No Fibres Detected
BS	AQC Sample
LB	Blank Sample
N	Client Sample
TB	Trip Blank Sample
OC	Outside Calibration Range
AA	x2 Dilution

JE Job No: 19/69

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
SA_TM19	Determination of pH by bench pH meter	SA_PM0	No preparation is required.	Yes			
SA_TM20	Modified BS 1377-3: 1990 Gravimetric determination of Total Dissolved Solids	SA_PM31	Sample is filtered	Yes			
SA_TM28	Determination of Electrical Conductivity with hand held manual conductivity probe.	SA_PM0	No preparation is required.	Yes			
SA_TM32	Determination of Alkalinity by titration of the sample with a standard solution of acid by visual detection of end points.	SA_PM0	No preparation is required.	Yes			
SA_TM34	Turbidity by TL2300 Turbidity Meter	SA_PM0	No preparation is required.				
SA_TM37	Modified BS EM 872:2005 .Gravimetric determination of Total Suspended Solids. Sample is filtered and the resulting residue is dried and weighed.	SA_PM0	No preparation is required.	Yes			
SA_TM5	Modified USEPA 8015B method for the determination of solvent Extractable Petroleum Hydrocarbons (EPH) with carbon banding within the range C8-C40 GC-FID.	SA_PM30	Water samples are extracted with solvent using a magnetic stirrer to create a vortex.				
SA_TM57	Modified US EPA Method 410.4. Chemical Oxygen Demand is determined by hot digestion with Potassium Dichromate and measured spectrophotometerically.	SA_PM0	No preparation is required.	Yes			
SA_TM59	Determination of Dissolved Oxygen using the Hach HQ30D Oxygen Meter	SA_PM0	No preparation is required.				
UK_TM173	Analysis of fluoride by ISE (Ion Selective Electrode) using modified ISE method 340.2	UK_PM0	No preparation is required.				

JE Job No: 19/69

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
UK_TM30	Determination of Trace Metal elements by ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometry). Modified US EPA Method 200.7, 6010B and BS EN ISO 11885 2009	UK_PM14	Analysis of waters and leachates for metals by ICP OES/ICP MS. Samples are filtered for dissolved metals and acidified if required.				
UK_TM38	Soluble Ion analysis using the Thermo Aquakem Photometric Automatic Analyser. Modified US EPA methods 325.2, 375.4, 365.2, 353.1, 354.1	UK_PM0	No preparation is required.				
UK_TM60	Modified USEPA 9060. Determination of TOC by calculation from Total Carbon and Inorganic Carbon using a TOC analyser, the carbon in the sample is converted to CO2 and then passed through a non-dispersive infrared gas analyser (NDIR).	UK_PM0	No preparation is required.				

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FINAL CERTIFICATE OF ANALYSIS	
Report Date	2019-02-20
Date Required	2019-02-14
Contract No	
Order/Ref No	18102350 Leeuwpan

T0184

18102350 Leeuwpan

Notes
The results relate specifically to the items tested.
The report shall not be reproduced except in full, without the written approval of the laboratory.
[1] SANAS accredited analysis included in the SANAS Schedule of Accredition for this laboratory.
[2] Not SANAS accredited analysis and not included in the SANAS schedule of accreditation for this laboratory.
[3] Outsourced not performed by this laboratory.

Request ID: 25581 **Sample ID:** 608497 **Received:** 2019-02-04 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M02_017 **Revision Number:** 0

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Escherichia coli	0	Colonies/100ml

Request ID: 25581 **Sample ID:** 608498 **Received:** 2019-02-04 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M02_037 **Revision Number:** 0

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Escherichia coli	0	Colonies/100ml

Request ID: 25581 **Sample ID:** 608499 **Received:** 2019-02-04 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M02_021 **Revision Number:** 0

Method: [2]UIS-OS-T034(Chlorophyll A) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Chlorophyll -a	4	ug/l

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Escherichia coli	2100	Colonies/100ml

Request ID: 25581 **Sample ID:** 608500 **Received:** 2019-02-04 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M02_019 **Revision Number:** 0

Method: [2]UIS-OS-T034(Chlorophyll A) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Chlorophyll -a	12	ug/l

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Escherichia coli	170	Colonies/100ml

Request ID: 25581 **Sample ID:** 608501 **Received:** 2019-02-04 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M02_039 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-02-20

Parameter	Value	Unit
²Chlorophyll -a	4	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-02-20

Parameter	Value	Unit
²Escherichia coli	370	Colonies/100ml

Request ID: 25581 **Sample ID:** 608502 **Received:** 2019-02-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M02_002 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-02-20

Parameter	Value	Unit
²Chlorophyll -a	12	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-02-20

Parameter	Value	Unit
²Escherichia coli	2300	Colonies/100ml

Request ID: 25581 **Sample ID:** 608503 **Received:** 2019-02-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M02_004 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-02-20

Parameter	Value	Unit
²Chlorophyll -a	1	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-02-20

Parameter	Value	Unit
²Escherichia coli	25000	Colonies/100ml

Request ID: 25581 **Sample ID:** 608504 **Received:** 2019-02-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M02_030 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-02-20

Parameter	Value	Unit
²Chlorophyll -a	7	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-02-20

Parameter	Value	Unit
²Escherichia coli	49	Colonies/100ml

Request ID: 25581 **Sample ID:** 608505 **Received:** 2019-02-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M02_028 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-02-20

Parameter	Value	Unit
²Chlorophyll -a	335	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-02-20

Parameter	Value	Unit
²Escherichia coli	58	Colonies/100ml

Request ID: 25581 **Sample ID:** 608506 **Received:** 2019-02-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M02_035 **Revision Number:** 0

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-02-20

Parameter	Value	Unit
²Escherichia coli	780000	Colonies/100ml

Request ID: 25581 **Sample ID:** 608507 **Received:** 2019-02-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M02_026 **Revision Number:** 0

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-02-20

Parameter	Value	Unit
²Escherichia coli	2400	Colonies/100ml

Request ID: 25581 **Sample ID:** 608508 **Received:** 2019-02-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M02_033 **Revision Number:** 0

Method: [2]UIS-OS-T034(Chlorophyll A) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Chlorophyll -a	20	ug/l

Method: [2]UIS-CP-T009(Total Inorganic Nitrogen (Dissolved)) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Total Inorganic Nitrogen	0.109	mg/l

Method: [1]UIS-EA-T001(pH) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	7.15		[2]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	39.2	mSm	[1]Total Conductivity	39.2	mS/m	[2]TC Temperature	23.3	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	255	mg/l	[2]TDS by EC*7	274	mg/l

Method: [2]UIS-CP-T004(Calculated Hardness) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca Hardness	106	mg/l CaCO3	[2]Mg Hardness	75.4	mg/l CaCO3	[2]Total Hardness	182	mg/l CaCO3

Method: [1]UIS-EA-T005(Total Dissolved Solids) **Completed:** 2019-02-20

Parameter	Value	Unit
[1]Total Dissolved Solids at 180C	266	mg/l

Method: [2]UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]TDS by Summation	183	mg/l

Method: [2]UIS-CP-T006(Calculated Sodium Adsorption Ratio) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Sodium Adsorption Ratio	0.365	

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	173	mg/l CaCO3

Method: [1]UIS-AC-T007(Dissolved Elements in Water by ICP-OES) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	<0.05	mg/l	[2]B	<0.05	mg/l	[1]Ca	42.6	mg/l
[2]Fe	0.39	mg/l	[1]K	7.06	mg/l	[1]Mg	18.3	mg/l
[2]Mn	1.33	mg/l	[1]Na	11.3	mg/l			

Method: [1]UIS-EA-T034(Anions by Photometry) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Fluoride F	0.293	mg/l	[1]Chloride Cl	11.8	mg/l	[1]Nitrate NO3 as N	<0.13	mg/l
[2]Nitrite NO2	0.025	mg/l	[1]Phosphate PO4 as P	0.018	mg/l	[2]Nitrite NO2 as N	0.008	mg/l
[1]Phosphate PO4	0.056	mg/l	[1]Sulphate SO4	26	mg/l			

Method: [2]UIS-CP-T005(Ion Balance Error Gallery) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	4.37	me/l	[2]Sum of Anions	3.78	me/l	[2]Ion Error Balance	7.26	%

Method: [2]UIS-EA-T111(Hexavalent Chromium in Liquid (Photometry)) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Hexavalent Chromium in Liquid (Photometry)	<0.001	mg/l

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Escherichia coli	79	Colonies/100ml

Method: [2]UIS-EA-T035(Dissolved Oxygen) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Dissolved Oxygen	0.77	mg/l O2

Method: [2]UIS-EA-T007(Determination of Oil and Grease) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Total Oil and Grease	<1	ppm

Method: [2]UIS-CP-T012(Ammonium calculated photometry) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]NH4+ calculated	0.129	mg/l

Method: [1]UIS-EA-T034a(Ammonia by Photometry) **Completed:** 2019-02-20

Parameter	Value	Unit
[1]Ammonia as N	0.101	mg/l

Method: [2]UIS-TEA-T002(Total Cations in Water by ICP-OES) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Total P as P	<0.05	mg/l

Method: [3]UIS-OS-T015(Dissolved Organic Carbon) **Completed:** 2019-02-20

Parameter	Value	Unit
[3]Dissolved Organic Carbon (OL)	19	mg/l

Method: [2]UIS-EA-T043(Total trace elements in liquid by ICP-MS) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Tot. Cr	0.02	mg/l

Method: [1]UIS-EA-T001(pH) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	7.59		[2]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	54.3	mSm	[1]Total Conductivity	54.3	mS/m	[2]TC Temperature	23.3	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	353	mg/l	[2]TDS by EC*7	380	mg/l

Method: [1]UIS-EA-T005(Total Dissolved Solids) **Completed:** 2019-02-20

Parameter	Value	Unit
[1]Total Dissolved Solids at 180C	358	mg/l

Method: [2]UIS-CP-T004(Calculated Hardness) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca Hardness	111	mg/l CaCO3	[2]Mg Hardness	105	mg/l CaCO3	[2]Total Hardness	216	mg/l CaCO3

Method: [2]UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]TDS by Summation	198	mg/l

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	153	mg/l CaCO3

Method: [1]UIS-AC-T007(Dissolved Elements in Water by ICP-OES) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	<0.05	mg/l	[2]B	0.06	mg/l	[1]Ca	44.5	mg/l
[2]Fe	<0.05	mg/l	[1]K	4.66	mg/l	[1]Mg	25.4	mg/l
[2]Mn	<0.05	mg/l	[1]Na	31.8	mg/l			

Method: [1]UIS-EA-T034(Anions by Photometry) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Fluoride F	0.252	mg/l	[1]Chloride Cl	37.2	mg/l	[2]Nitrate NO3	9.23	mg/l
[1]Nitrate NO3 as N	2.08	mg/l	[2]Nitrite NO2	0.059	mg/l	[1]Phosphate PO4 as P	0.014	mg/l
[2]Nitrite NO2 as N	0.018	mg/l	[1]Phosphate PO4	0.042	mg/l	[1]Sulphate SO4	83.4	mg/l

Method: [2]UIS-CP-T005(Ion Balance Error Gallery) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	5.82	me/l	[2]Sum of Anions	5.5	me/l	[2]Ion Error Balance	2.89	%

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Escherichia coli	0	Colonies/100ml

Method: [2]UIS-AC-T100(Trace elements in liquids by ICP-MS) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]As	0.012	mg/l	[2]Ba	0.057	mg/l	[2]Cd	<0.0001	mg/l

[2]Co	0.007	mg/l	[2]Cr	<0.001	mg/l	[2]Cu	<0.001	mg/l
[2]Hg	<0.0001	mg/l	[2]Mn	0.021	mg/l	[2]Mo	0.003	mg/l
[2]Ni	0.004	mg/l	[2]Pb	<0.001	mg/l	[2]Sb	<0.001	mg/l
[2]Se	0.002	mg/l	[2]U	<0.0001	mg/l	[2]V	0.002	mg/l
[2]Zn	0.05	mg/l						

Method: [2]UIS-CP-T012(Ammonium calculated photometry) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]NH4+ calculated	<0.001	mg/l

Method: [1]UIS-EA-T034a(Ammonia by Photometry) **Completed:** 2019-02-20

Parameter	Value	Unit
[1]Ammonia as N	<0.009	mg/l

Request ID: 25581 **Sample ID:** 608510 **Received:** 2019-02-04 **Matrix:** Water **Page:** 5 / 6
Sample Number: LNP19_M02_041 **Revision Number:** 0

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Escherichia coli	0	Colonies/100ml

Request ID: 25581 **Sample ID:** 608511 **Received:** 2019-02-04 **Matrix:** Water **Page:** 5 / 6
Sample Number: LNP19_M02_013 **Revision Number:** 0

Method: [2]UIS-CP-T009(Total Inorganic Nitrogen (Dissolved)) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Total Inorganic Nitrogen	0.014	mg/l

Method: [1]UIS-EA-T001(pH) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	7.67		[2]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	423	mSm	[1]Total Conductivity	423	mS/m	[2]TC Temperature	26.6	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	2750	mg/l	[2]TDS by EC*7	2960	mg/l

Method: [1]UIS-EA-T005(Total Dissolved Solids) **Completed:** 2019-02-20

Parameter	Value	Unit
[1]Total Dissolved Solids at 180C	3460	mg/l

Method: [2]UIS-CP-T004(Calculated Hardness) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca Hardness	1290	mg/l CaCO3	[2]Mg Hardness	1020	mg/l CaCO3	[2]Total Hardness	2310	mg/l CaCO3

Method: [2]UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]TDS by Summation	865	mg/l

Method: [2]UIS-CP-T006(Calculated Sodium Adsorption Ratio) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Sodium Adsorption Ratio	0.527	

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	49.6	mg/l CaCO3

Method: [1]UIS-AC-T007(Dissolved Elements in Water by ICP-OES) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	<0.05	mg/l	[2]B	0.11	mg/l	[1]Ca	516	mg/l
[2]Fe	<0.05	mg/l	[1]K	13.5	mg/l	[1]Mg	247	mg/l
[2]Mn	<0.05	mg/l	[1]Na	58.3	mg/l			

Method: [1]UIS-EA-T034(Anions by Photometry) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Fluoride F	<0.042	mg/l	[1]Chloride Cl	11.1	mg/l	[1]Nitrate NO3 as N	<0.13	mg/l
[2]Nitrite NO2	0.045	mg/l	[1]Phosphate PO4 as P	0.004	mg/l	[2]Nitrite NO2 as N	0.014	mg/l
[1]Phosphate PO4	0.012	mg/l	[1]Sulphate SO4	2300	mg/l			

Method: [2]UIS-CP-T005(Ion Balance Error Gallery) **Completed:** 2019-02-20

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit

[2]Sum of Cations	49	me/l	[2]Sum of Anions	49.1	me/l	[2]Ion Error Balance	-0.12	%

Method: [2]UIS-EA-T111(Hexavalent Chromium in Liquid (Photometry)) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Hexavalent Chromium in Liquid (Photometry)	0.005	mg/l

Method: [2]UIS-EA-T035(Dissolved Oxygen) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Dissolved Oxygen	7.15	mg/l O2

Method: [2]UIS-EA-T007(Determination of Oil and Grease) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]Total Oil and Grease	2	ppm

Method: [2]UIS-CP-T012(Ammonium calculated photometry) **Completed:** 2019-02-20

Parameter	Value	Unit
[2]NH4+ calculated	<0.001	mg/l

Method: [1]UIS-EA-T034a(Ammonia by Photometry) **Completed:** 2019-02-20

Parameter	Value	Unit
[1]Ammonia as N	<0.009	mg/l

Method: [3]UIS-OS-T015(Dissolved Organic Carbon) **Completed:** 2019-02-20

Parameter	Value	Unit
[3]Dissolved Organic Carbon (OL)	<10	mg/l

Petunia Moleta
AUTHORISED SIGNATORY

Exova Jones Environmental South Africa

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Attention :	Keretia Lupankwa
Date :	12th March, 2019
Your reference :	18102350
Our reference :	Test Report 19/162 Batch 1
Location :	Leeuwpan
Date samples received :	6th March, 2019
Status :	Final report
Issue :	1

Twenty six samples were received for analysis on 6th March, 2019 of which twenty six were scheduled for analysis. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

Analysis was undertaken at either Exova Jones Environmental (UK), which is ISO 17025 accredited under UKAS (4225) or Exova Jones Environmental (SA) which is ISO 17025 accredited under SANAS (T0729) or a subcontract laboratory where specified.

NOTE: Under International Laboratory Accreditation Cooperation (ILAC), ISO 17025 (UKAS) accreditation is recognised as equivalent to SANAS (South Africa) accreditation.

Compiled By:

Aatifah Latief

Organics Laboratory:

David Adams
Technical Signatory (Organics)

Inorganics Laboratory:

Musa Tiki
Technical Signatory (Inorganics)

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/162

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

J E Sample No.	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	LOD/LOR	Units	Method No.
Sample ID	LNP19_M03_085	LNP19_M03_083	LNP19_M03_061	LNP19_M03_062	LNP19_M03_089	LNP19_M03_079	LNP19_M03_077	LNP19_M03_052	LNP19_M03_050	LNP19_M03_070			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G			
Sample Date	03/03/2019	03/03/2019	01/03/2019	01/03/2019	03/03/2019	02/03/2019	02/03/2019	28/02/2019	28/02/2019	01/03/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019			
Dissolved Aluminium*	<20	<20	51	48	<20	<20	<20	<20	<20	<20	<20	ug/l	UK_TM30/UK_PM14
Dissolved Antimony*	-	-	-	-	-	-	-	-	-	-	<2	ug/l	UK_TM30/UK_PM14
Dissolved Arsenic*	-	-	-	-	-	-	-	-	-	-	<2.5	ug/l	UK_TM30/UK_PM14
Dissolved Barium*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Dissolved Boron*	42	22	35	27	24	34	30	17	24	152	<12	ug/l	UK_TM30/UK_PM14
Dissolved Cadmium*	-	-	-	-	-	-	-	-	-	-	<0.5	ug/l	UK_TM30/UK_PM14
Dissolved Calcium [SA]	26.4	48.5	16.6	16.5	36.8	14.7	33.7	32.7	37.0	389.9 [AA]	<0.3	mg/l	SA_TM27/SA_PM0
Total Dissolved Chromium*	-	-	-	-	-	-	-	-	-	-	<1.5	ug/l	UK_TM30/UK_PM14
Dissolved Copper*	-	-	-	-	-	-	-	-	-	-	<7	ug/l	UK_TM30/UK_PM14
Total Dissolved Iron*	40	28	183	180	46	90	66	26	206	<20	<20	ug/l	UK_TM30/UK_PM14
Dissolved Magnesium [SA]	13.7	27.8	7.8	8.1	20.7	7.6	15.4	18.5	19.9	146.5 [AA]	<0.2	mg/l	SA_TM27/SA_PM0
Dissolved Potassium [SA]	9.9	4.0	10.3	22.1	2.9	6.4	7.7	1.0	2.8	0.7	<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Sodium [SA]	12.6	17.4	10.0	10.1	11.7	14.2	22.2	8.5	11.4	45.8	<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Lead*	-	-	-	-	-	-	-	-	-	-	<5	ug/l	UK_TM30/UK_PM14
Dissolved Manganese*	465	238	475	472	36	58	1646	820	655	9	<2	ug/l	UK_TM30/UK_PM14
Dissolved Mercury*	-	-	-	-	-	-	-	-	-	-	<1	ug/l	UK_TM30/UK_PM14
Dissolved Nickel*	-	-	-	-	-	-	-	-	-	-	<2	ug/l	UK_TM30/UK_PM14
Dissolved Selenium*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Dissolved Uranium*	-	-	-	-	-	-	-	-	-	-	<5	ug/l	UK_TM30/UK_PM14
Dissolved Zinc*	-	-	-	-	-	-	-	-	-	-	<3	ug/l	UK_TM30/UK_PM14
Total Hardness Dissolved (as CaCO3)	123.5	238.0	74.3	75.3	178.9	68.7	148.9	159.5	176.1	1590.1 [AA]	<1.6	mg/l	SA_TM27/SA_PM0
Total Phosphorus*	374	81	565	555	47	416	97	33	82	36	<5	ug/l	UK_TM30/UK_PM14
Fats Oils and Grease	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	SA_TM5/SA_PM30
Chloride*	11.9	7.0	7.3	7.0	11.5	4.1	5.0	12.9	11.1	9.8	<0.3	mg/l	UK_TM38/UK_PM0
Ammoniacal Nitrogen as N*	1.16	0.04	1.85	2.17	<0.03	0.40	<0.03	0.05	0.09	0.74	<0.03	mg/l	UK_TM38/UK_PM0
Hexavalent Chromium*	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO3 [SA]	128	249	80	93	166	92	191	98	158	81	<3	mg/l	SA_TM32/SA_PM0
COD (Settled) [SA]	-	-	-	-	-	-	-	-	-	-	<9	mg/l	SA_TM57/SA_PM0
Dissolved Oxygen (% Saturation)	45.5	53.7	12.1	7.3	38.7	8.5	44.2	59.2	48.8	58.8	<0.1	%	SA_TM59/SA_PM0
Temperature	18.5	18.2	19.0	18.7	20.4	19.4	18.5	18.4	19.8	20.5	<0.1	Degrees C	SA_TM59/SA_PM0
Electrical Conductivity @25C [SA]	317	482	214	260	373	201	372	342	364	2370	<2	uS/cm	SA_TM28/SA_PM0
Dissolved Organic Carbon*	8	2	22	23	7	18	10	<2	8	<2	<2	mg/l	UK_TM60/UK_PM0
Fluoride*	0.3	<0.3	<0.3	<0.3	<0.3	0.3	0.3	<0.3	<0.3	0.4	<0.3	mg/l	UK_TM173/UK_PM0
Nitrite as N*	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.73	<0.05	mg/l	UK_TM38/UK_PM0
Nitrate as N*	0.64	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.09	<0.05	8.23	<0.05	mg/l	UK_TM38/UK_PM0
Ortho Phosphate as P*	0.15	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.05	<0.03	<0.03	mg/l	UK_TM38/UK_PM0
pH [SA]	7.09	7.56	6.65	6.38	7.29	7.13	7.32	7.17	7.37	7.18	<2.00	pH units	SA_TM19/SA_PM0
Sulphate as SO4*	23.6	8.1	22.5	20.8	18.8	9.3	4.9	73.3	18.5	1404.4	<0.5	mg/l	UK_TM38/UK_PM0
Total Dissolved Solids [SA]	280	258	177	171	223	192	237	157	205	2234	<35	mg/l	SA_TM20/SA_PM31

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/162

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

J E Sample No.	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	LOD/LOR	Units	Method No.
Sample ID	LNP19_M03_085	LNP19_M03_083	LNP19_M03_061	LNP19_M03_062	LNP19_M03_089	LNP19_M03_079	LNP19_M03_077	LNP19_M03_052	LNP19_M03_050	LNP19_M03_070			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G			
Sample Date	03/03/2019	03/03/2019	01/03/2019	01/03/2019	03/03/2019	02/03/2019	02/03/2019	28/02/2019	28/02/2019	01/03/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019			
Total Suspended Solids [SA]	-	-	-	-	-	-	-	-	-	-	<10	mg/l	SA_TM37/SA_PM0
Turbidity	206.0	14.1	13.2	40.9	3.5	53.8	13.1	23.3	2.6	2.9	<0.1	NTU	SA_TM34/SA_PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/162

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

J E Sample No.	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-99	LOD/LOR	Units	Method No.
Sample ID	LNP19_M03_074	LNP19_M03_075	LNP19_M03_059	LNP19_M03_065	LNP19_M03_056	LNP19_M03_055	LNP19_M03_057	LNP19_M03_058	LNP19_M03_054	LNP19_M03_071			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P			
Sample Date	02/03/2019	02/03/2019	01/03/2019	01/03/2019	28/02/2019	28/02/2019	28/02/2019	28/02/2019	28/02/2019	02/03/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019			
Dissolved Aluminium*	<20	<20	<20	<20	<20	<20	70	<20	23	<20	<20	ug/l	UK_TM30/UK_PM14
Dissolved Antimony*	-	-	-	-	-	-	-	-	-	<2	<2	ug/l	UK_TM30/UK_PM14
Dissolved Arsenic*	-	-	-	-	-	-	-	-	-	10.1	<2.5	ug/l	UK_TM30/UK_PM14
Dissolved Barium*	-	-	-	-	-	-	-	-	-	76	<3	ug/l	UK_TM30/UK_PM14
Dissolved Boron*	87	91	42	92	84	156	96	66	55	70	<12	ug/l	UK_TM30/UK_PM14
Dissolved Cadmium*	-	-	-	-	-	-	-	-	-	<0.5	<0.5	ug/l	UK_TM30/UK_PM14
Dissolved Calcium [SA]	560.6[AA]	557.6[AA]	73.7	529.4[AA]	196.3	205.7	337.6	542.6[AA]	115.9	48.6	<0.3	mg/l	SA_TM27/SA_PM0
Total Dissolved Chromium*	-	-	-	-	-	-	-	-	-	<1.5	<1.5	ug/l	UK_TM30/UK_PM14
Dissolved Copper*	-	-	-	-	-	-	-	-	-	<7	<7	ug/l	UK_TM30/UK_PM14
Total Dissolved Iron*	<20	54	<20	<20	<20	21	31	26	<20	<20	<20	ug/l	UK_TM30/UK_PM14
Dissolved Magnesium [SA]	211.9[AA]	210.8[AA]	31.6	221.5[AA]	88.8	109.6	135.8	195.8[AA]	33.6	25.1	<0.2	mg/l	SA_TM27/SA_PM0
Dissolved Potassium [SA]	<0.1	<0.1	1.8	<0.1	1.8	0.7	1.6	0.6	0.5	3.0	<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Sodium [SA]	50.1	50.2	26.0	84.4	26.1	32.6	32.5	43.0	8.4	33.0	<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Lead*	-	-	-	-	-	-	-	-	-	<5	<5	ug/l	UK_TM30/UK_PM14
Dissolved Manganese*	155	158	17	197	70	248	62	872	11	16	<2	ug/l	UK_TM30/UK_PM14
Dissolved Mercury*	-	-	-	-	-	-	-	-	-	<1	<1	ug/l	UK_TM30/UK_PM14
Dissolved Nickel*	-	-	-	-	-	-	-	-	-	2	<2	ug/l	UK_TM30/UK_PM14
Dissolved Selenium*	-	-	-	-	-	-	-	-	-	<3	<3	ug/l	UK_TM30/UK_PM14
Dissolved Uranium*	-	-	-	-	-	-	-	-	-	<5	<5	ug/l	UK_TM30/UK_PM14
Dissolved Zinc*	-	-	-	-	-	-	-	-	-	53	<3	ug/l	UK_TM30/UK_PM14
Total Hardness Dissolved (as CaCO3)	2291.5[AA]	2279.4[AA]	317.0	2253.8[AA]	863.7	974.6	1414.4	2178.9[AA]	430.9	226.9	<1.6	mg/l	SA_TM27/SA_PM0
Total Phosphorus*	36	29	39	31	26	27	27	28	36	-	<5	ug/l	UK_TM30/UK_PM14
Fats Oils and Grease	<10	<10	<10	<10	<10	<10	<10	<10	<10	-	<10	ug/l	SA_TM5/SA_PM30
Chloride*	11.1	11.0	8.3	23.3	5.8	4.4	7.1	10.7	6.8	36.3	<0.3	mg/l	UK_TM38/UK_PM0
Ammoniacal Nitrogen as N*	0.04	0.04	0.05	0.09	2.62	0.48	0.59	0.15	0.05	<0.03	<0.03	mg/l	UK_TM38/UK_PM0
Hexavalent Chromium*	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	-	<0.006	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO3 [SA]	111	112	30	58	140	236	90	198	61	164	<3	mg/l	SA_TM32/SA_PM0
COD (Settled) [SA]	-	-	-	-	-	-	-	-	-	-	<9	mg/l	SA_TM57/SA_PM0
Dissolved Oxygen (% Saturation)	66.9	72.8	59.7	76.0	80.1	75.7	77.0	84.1	90.0	-	<0.1	%	SA_TM59/SA_PM0
Temperature	20.8	19.4	19.6	19.6	20.4	20.5	19.9	20.1	20.3	-	<0.1	Degrees C	SA_TM59/SA_PM0
Electrical Conductivity @25C [SA]	3150	3150	691	3240	1467	1636	2163	3060	803	584	<2	uS/cm	SA_TM28/SA_PM0
Dissolved Organic Carbon*	<2	<2	5	13	<2	<2	<2	<2	<2	-	<2	mg/l	UK_TM60/UK_PM0
Fluoride*	<0.3	<0.3	<0.3	0.4	<0.3	<0.3	0.3	<0.3	<0.3	<0.3	<0.3	mg/l	UK_TM173/UK_PM0
Nitrite as N*	<0.05	<0.05	<0.05	<0.05	0.36	<0.05	0.13	<0.05	<0.05	<0.05	<0.05	mg/l	UK_TM38/UK_PM0
Nitrate as N*	0.78	0.65	<0.05	<0.05	9.86	0.11	7.09	0.17	0.90	1.76	<0.05	mg/l	UK_TM38/UK_PM0
Ortho Phosphate as P*	<0.03	<0.03	<0.03	<0.03	0.04	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	mg/l	UK_TM38/UK_PM0
pH [SA]	7.33	7.32	6.96	7.47	7.54	7.47	7.36	8.06	7.86	8.06	<2.00	pH units	SA_TM19/SA_PM0
Sulphate as SO4*	2069.9	2117.5	301.6	2118.0	650.3	746.3	1232.3	1914.6	350.0	81.7	<0.5	mg/l	UK_TM38/UK_PM0
Total Dissolved Solids [SA]	3244	3197	482	3346	1190	1423	1533	3088	583	385	<35	mg/l	SA_TM20/SA_PM31

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/162

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

J E Sample No.	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-99	LOD/LOR	Units	Method No.
Sample ID	LNP19_M03_074	LNP19_M03_075	LNP19_M03_059	LNP19_M03_065	LNP19_M03_056	LNP19_M03_055	LNP19_M03_057	LNP19_M03_058	LNP19_M03_054	LNP19_M03_071			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P			
Sample Date	02/03/2019	02/03/2019	01/03/2019	01/03/2019	28/02/2019	28/02/2019	28/02/2019	28/02/2019	28/02/2019	02/03/2019			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019			
Total Suspended Solids [SA]	-	-	-	-	-	-	-	-	-	-	<10	mg/l	SA_TM37/SA_PM0
Turbidity	22.1	17.4	5.0	6.1	14.8	5.2	11.9	4.8	9.6	-	<0.1	NTU	SA_TM34/SA_PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/162

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

Please see attached notes for all abbreviations and acronyms

J E Sample No.	100-103	104-107	108-111	112-115	116-119	120-123					LOD/LOR	Units	Method No.
Sample ID	LNP19_M03_072	LNP19_M03_081	LNP19_M03_068	LNP19_M03_087	LNP19_M03_066	LNP19_M03_060							
Depth													
COC No / misc													
Containers	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P							
Sample Date	02/03/2019	02/03/2019	01/03/2019	03/03/2019	01/03/2019	01/03/2019							
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water							
Batch Number	1	1	1	1	1	1							
Date of Receipt	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019							
Dissolved Aluminium*	<20	<20	<20	<20	-	-					<20	ug/l	UK_TM30/UK_PM14
Dissolved Antimony*	<2	<2	<2	<2	-	-					<2	ug/l	UK_TM30/UK_PM14
Dissolved Arsenic*	9.0	<2.5	8.4	<2.5	-	-					<2.5	ug/l	UK_TM30/UK_PM14
Dissolved Barium*	74	231	80	25	-	-					<3	ug/l	UK_TM30/UK_PM14
Dissolved Boron*	69	80	82	25	-	-					<12	ug/l	UK_TM30/UK_PM14
Dissolved Cadmium*	<0.5	<0.5	<0.5	<0.5	-	-					<0.5	ug/l	UK_TM30/UK_PM14
Dissolved Calcium [SA]	48.5	44.4	48.7	9.5	-	-					<0.3	mg/l	SA_TM27/SA_PM0
Total Dissolved Chromium*	1.8	<1.5	<1.5	<1.5	-	-					<1.5	ug/l	UK_TM30/UK_PM14
Dissolved Copper*	<7	<7	36	<7	-	-					<7	ug/l	UK_TM30/UK_PM14
Total Dissolved Iron*	<20	<20	<20	38	-	-					<20	ug/l	UK_TM30/UK_PM14
Dissolved Magnesium [SA]	25.1	26.7	25.1	6.2	-	-					<0.2	mg/l	SA_TM27/SA_PM0
Dissolved Potassium [SA]	3.0	1.9	3.1	0.5	-	-					<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Sodium [SA]	33.1	32.8	33.1	4.0	-	-					<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Lead*	<5	<5	<5	<5	-	-					<5	ug/l	UK_TM30/UK_PM14
Dissolved Manganese*	16	291	<2	4	-	-					<2	ug/l	UK_TM30/UK_PM14
Dissolved Mercury*	<1	<1	<1	<1	-	-					<1	ug/l	UK_TM30/UK_PM14
Dissolved Nickel*	3	<2	2	<2	-	-					<2	ug/l	UK_TM30/UK_PM14
Dissolved Selenium*	<3	<3	<3	<3	-	-					<3	ug/l	UK_TM30/UK_PM14
Dissolved Uranium*	<5	<5	<5	<5	-	-					<5	ug/l	UK_TM30/UK_PM14
Dissolved Zinc*	52	53	394	15	-	-					<3	ug/l	UK_TM30/UK_PM14
Total Hardness Dissolved (as CaCO3)	226.7	223.1	227.2	49.8	-	-					<1.6	mg/l	SA_TM27/SA_PM0
Total Phosphorus*	-	-	-	-	-	-					<5	ug/l	UK_TM30/UK_PM14
Fats Oils and Grease	-	-	-	-	-	-					<10	ug/l	SA_TM5/SA_PM30
Chloride*	36.2	37.5	35.6	1.8	-	-					<0.3	mg/l	UK_TM38/UK_PM0
Ammoniacal Nitrogen as N*	<0.03	0.05	0.04	<0.03	43.06	66.55					<0.03	mg/l	UK_TM38/UK_PM0
Hexavalent Chromium*	-	-	-	-	-	-					<0.006	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO3 [SA]	161	188	166	54	-	-					<3	mg/l	SA_TM32/SA_PM0
COD (Settled) [SA]	-	-	-	-	276	63					<9	mg/l	SA_TM57/SA_PM0
Dissolved Oxygen (% Saturation)	-	-	-	-	-	-					<0.1	%	SA_TM59/SA_PM0
Temperature	-	-	-	-	-	-					<0.1	Degrees C	SA_TM59/SA_PM0
Electrical Conductivity @25C [SA]	571	558	581	115	-	-					<2	uS/cm	SA_TM28/SA_PM0
Dissolved Organic Carbon*	-	-	-	-	-	-					<2	mg/l	UK_TM60/UK_PM0
Fluoride*	<0.3	<0.3	<0.3	<0.3	-	-					<0.3	mg/l	UK_TM173/UK_PM0
Nitrite as N*	<0.05	<0.05	<0.05	<0.05	-	-					<0.05	mg/l	UK_TM38/UK_PM0
Nitrate as N*	1.76	<0.05	1.27	0.60	<0.05	2.97					<0.05	mg/l	UK_TM38/UK_PM0
Ortho Phosphate as P*	<0.03	<0.03	<0.03	0.10	4.30	7.97					<0.03	mg/l	UK_TM38/UK_PM0
pH [SA]	8.03	7.93	7.88	7.73	-	-					<2.00	pH units	SA_TM19/SA_PM0
Sulphate as SO4*	79.3	46.8	87.8	0.6	-	-					<0.5	mg/l	UK_TM38/UK_PM0
Total Dissolved Solids [SA]	347	311	332	79	-	-					<35	mg/l	SA_TM20/SA_PM31

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/162

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

J E Sample No.	100-103	104-107	108-111	112-115	116-119	120-123					LOD/LOR	Units	Method No.
Sample ID	LNP19_M03_072	LNP19_M03_081	LNP19_M03_068	LNP19_M03_087	LNP19_M03_066	LNP19_M03_060							
Depth													
COC No / misc													
Containers	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P							
Sample Date	02/03/2019	02/03/2019	01/03/2019	03/03/2019	01/03/2019	01/03/2019							
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water							
Batch Number	1	1	1	1	1	1							
Date of Receipt	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019							
Total Suspended Solids [SA]	-	-	-	-	53	15					<10	mg/l	SA_TM37/SA_PM0
Turbidity	-	-	-	-	-	-					<0.1	NTU	SA_TM34/SA_PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa

J E Job No.	Batch	Sample ID	Depth	J E Sample No.	Analysis	Reason
No deviating sample report results for job 19/162						

Please note that only samples that are deviating are mentioned in this report. If no samples are listed it is because none were deviating.
Only analyses which are accredited are recorded as deviating if set criteria are not met.

NOTES TO ACCOMPANY ALL SCHEDULES AND REPORTS

JE Job No.: 19/162

SOILS

Please note we are only MCERTS accredited (UK soils only) for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

% Asbestos in Asbestos Containing Materials (ACMs) is determined by reference to HSG 264 The Survey Guide - Appendix 2 : ACMs in buildings listed in order of ease of fibre release.

Negative Neutralization Potential (NP) values are obtained when the volume of NaOH (0.1N) titrated (pH 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 - 2.5. Any negative NP values are corrected to 0.

The calculation of Pyrite content assumes that all oxidisable sulphides present in the sample are pyrite. This may not be the case. The calculation may be an overesitimate when other sulphides such as Barite (Barium Sulphate) are present.

WATERS

Please note we are not a UK Drinking Water Inspectorate (DWI) Approved Laboratory .

ISO17025 accreditation applies to surface water and groundwater and usually one other matrix which is analysis specific, any other liquids are outside our scope of accreditation.

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

DEVIATING SAMPLES

Samples must be received in a condition appropriate to the requested analyses. All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. If this is not the case you will be informed and any test results that may be compromised highlighted on your deviating samples report.

SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

DILUTIONS

A dilution suffix indicates a dilution has been performed and the reported result takes this into account. No further calculation is required.

BLANKS

Where analytes have been found in the blank, the sample will be treated in accordance with our laboratory procedure for dealing with contaminated blanks.

NOTE

Data is only reported if the laboratory is confident that the data is a true reflection of the samples analysed. Data is only reported as accredited when all the requirements of our Quality System have been met. In certain circumstances where all the requirements of the Quality System have not been met, for instance if the associated AQC has failed, the reason is fully investigated and documented. The sample data is then evaluated alongside the other quality control checks performed during analysis to determine its suitability. Following this evaluation, provided the sample results have not been effected, the data is reported but accreditation is removed. It is a UKAS requirement for data not reported as accredited to be considered indicative only, but this does not mean the data is not valid.
Where possible, and if requested, samples will be re-extracted and a revised report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.

REPORTS FROM THE SOUTH AFRICA LABORATORY

Any method number not prefixed with SA has been undertaken in our UK laboratory unless reported as subcontracted.

ABBREVIATIONS and ACRONYMS USED

#	ISO17025 (UKAS Ref No. 4225) accredited - UK.
SA	ISO17025 (SANAS Ref No.T0729) accredited - South Africa.
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance
SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
++	Result outside calibration range, results should be considered as indicative only and are not accredited.
*	Analysis subcontracted to an Exova Jones Environmental approved laboratory.
AD	Samples are dried at 35°C ±5°C
CO	Suspected carry over
LOD/LOR	Limit of Detection (Limit of Reporting) in line with ISO 17025 and MCERTS
ME	Matrix Effect
NFD	No Fibres Detected
BS	AQC Sample
LB	Blank Sample
N	Client Sample
TB	Trip Blank Sample
OC	Outside Calibration Range
AA	x10 Dilution

JE Job No: 19/162

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
SA_TM19	Determination of pH by bench pH meter	SA_PM0	No preparation is required.	Yes			
SA_TM20	Modified BS 1377-3: 1990 Gravimetric determination of Total Dissolved Solids	SA_PM31	Sample is filtered	Yes			
SA_TM27	Major ions by Ion Chromatography	SA_PM0	No preparation is required.				
SA_TM27	Major ions by Ion Chromatography	SA_PM0	No preparation is required.	Yes			
SA_TM28	Determination of Electrical Conductivity with hand held manual conductivity probe.	SA_PM0	No preparation is required.	Yes			
SA_TM32	Determination of Alkalinity by titration of the sample with a standard solution of acid by visual detection of end points.	SA_PM0	No preparation is required.	Yes			
SA_TM34	Turbidity by TL2300 Turbidity Meter	SA_PM0	No preparation is required.				
SA_TM37	Modified BS EM 872:2005 .Gravimetric determination of Total Suspended Solids. Sample is filtered and the resulting residue is dried and weighed.	SA_PM0	No preparation is required.	Yes			
SA_TM5	Modified USEPA 8015B method for the determination of solvent Extractable Petroleum Hydrocarbons (EPH) with carbon banding within the range C8-C40 GC-FID.	SA_PM30	Water samples are extracted with solvent using a magnetic stirrer to create a vortex.				
SA_TM57	Modified US EPA Method 410.4. Chemical Oxygen Demand is determined by hot digestion with Potassium Dichromate and measured spectrophotometerically.	SA_PM0	No preparation is required.	Yes			

JE Job No: 19/162

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
SA_TM59	Determination of Dissolved Oxygen using the Hach HQ30D Oxygen Meter	SA_PM0	No preparation is required.				
UK_TM173	Analysis of fluoride by ISE (Ion Selective Electrode) using modified ISE method 340.2	UK_PM0	No preparation is required.				
UK_TM30	Determination of Trace Metal elements by ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometry). Modified US EPA Method 200.7, 6010B and BS EN ISO 11885 2009	UK_PM14	Analysis of waters and leachates for metals by ICP OES/ICP MS. Samples are filtered for dissolved metals and acidified if required.				
UK_TM38	Soluble Ion analysis using the Thermo Aquakem Photometric Automatic Analyser. Modified US EPA methods 325.2, 375.4, 365.2, 353.1, 354.1	UK_PM0	No preparation is required.				
UK_TM60	Modified USEPA 9060. Determination of TOC by calculation from Total Carbon and Inorganic Carbon using a TOC analyser, the carbon in the sample is converted to CO2 and then passed through a non-dispersive infrared gas analyser (NDIR).	UK_PM0	No preparation is required.				

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FINAL CERTIFICATE OF ANALYSIS	
Report Date	2019-03-14
Date Required	2019-03-14
Contract No	
Order/Ref No	18102350 Leeuwpan SW

sanas Testing Laboratory T0184

18102350 Leeuwpan SW

Notes
The results relate specifically to the items tested.
The report shall not be reproduced except in full, without the written approval of the laboratory.
[1] SANAS accredited analysis included in the SANAS Schedule of Accredition for this laboratory.
[2] Not SANAS accredited analysis and not included in the SANAS schedule of accreditation for this laboratory.
[3] Outsourced not performed by this laboratory.

Request ID: 26052 **Sample ID:** 616563 **Received:** 2019-03-04 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M03_082 **Revision Number:** 0

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Escherichia coli	0	Colonies/100ml

Request ID: 26052 **Sample ID:** 616564 **Received:** 2019-03-04 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M03_069 **Revision Number:** 0

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Escherichia coli	0	Colonies/100ml

Request ID: 26052 **Sample ID:** 616565 **Received:** 2019-03-04 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M03_086 **Revision Number:** 0

Method: [2]UIS-OS-T034(Chlorophyll A) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Chlorophyll -a	1	ug/l

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Escherichia coli	7200	Colonies/100ml

Request ID: 26052 **Sample ID:** 616566 **Received:** 2019-03-04 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M03_084 **Revision Number:** 0

Method: [2]UIS-OS-T034(Chlorophyll A) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Chlorophyll -a	7	ug/l

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Escherichia coli	6800	Colonies/100ml

Request ID: 26052 **Sample ID:** 616567 **Received:** 2019-03-04 **Matrix:** Water **Page:** 1 / 6
Sample Number: LNP19_M03_090 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-03-14

Parameter	Value	Unit
²Chlorophyll -a	<1	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-03-14

Parameter	Value	Unit
²Escherichia coli	38	Colonies/100ml

Request ID: 26052 **Sample ID:** 616568 **Received:** 2019-03-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M03_080 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-03-14

Parameter	Value	Unit
²Chlorophyll -a	11	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-03-14

Parameter	Value	Unit
²Escherichia coli	118	Colonies/100ml

Request ID: 26052 **Sample ID:** 616569 **Received:** 2019-03-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M03_078 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-03-14

Parameter	Value	Unit
²Chlorophyll -a	8	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-03-14

Parameter	Value	Unit
²Escherichia coli	160	Colonies/100ml

Request ID: 26052 **Sample ID:** 616570 **Received:** 2019-03-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M03_053 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-03-14

Parameter	Value	Unit
²Chlorophyll -a	13	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-03-14

Parameter	Value	Unit
²Escherichia coli	570	Colonies/100ml

Request ID: 26052 **Sample ID:** 616571 **Received:** 2019-03-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M03_051 **Revision Number:** 0

Method: ²UIS-OS-T034(Chlorophyll A) **Completed:** 2019-03-14

Parameter	Value	Unit
²Chlorophyll -a	4	ug/l

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-03-14

Parameter	Value	Unit
²Escherichia coli	75	Colonies/100ml

Request ID: 26052 **Sample ID:** 616572 **Received:** 2019-03-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M03_088 **Revision Number:** 0

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-03-14

Parameter	Value	Unit
²Escherichia coli	2	Colonies/100ml

Request ID: 26052 **Sample ID:** 616573 **Received:** 2019-03-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M03_067 **Revision Number:** 0

Method: ²UIS-MB-T004(Escherichia coli) **Completed:** 2019-03-14

Parameter	Value	Unit
²Escherichia coli	0	Colonies/100ml

Request ID: 26052 **Sample ID:** 616574 **Received:** 2019-03-04 **Matrix:** Water **Page:** 2 / 6
Sample Number: LNP19_M03_064 **Revision Number:** 0

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Escherichia coli	1240	Colonies/100ml

Request ID: 26052 **Sample ID:** 616575 **Received:** 2019-03-04 **Matrix:** Water **Page:** 3 / 6
Sample Number: LNP19_M03_063 **Revision Number:** 0

Method: [2]UIS-OS-T034(Chlorophyll A) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Chlorophyll -a	15	ug/l

Method: [2]UIS-CP-T009(Total Inorganic Nitrogen (Dissolved)) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Total Inorganic Nitrogen	0.552	mg/l

Method: [1]UIS-EA-T001(pH) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	6.63		[2]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	20.4	mSm	[1]Total Conductivity	20.4	mS/m	[2]TC Temperature	25.7	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	133	mg/l	[2]TDS by EC*7	143	mg/l

Method: [2]UIS-CP-T004(Calculated Hardness) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca Hardness	42.9	mg/l CaCO3	[2]Mg Hardness	32.6	mg/l CaCO3	[2]Total Hardness	75.4	mg/l CaCO3

Method: [1]UIS-EA-T005(Total Dissolved Solids) **Completed:** 2019-03-14

Parameter	Value	Unit
[1]Total Dissolved Solids at 180C	170	mg/l

Method: [2]UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]TDS by Summation	88.8	mg/l

Method: [2]UIS-EA-T029(Turbidity) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Turbidity	11.2	NTU

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	71.4	mg/l CaCO3

Method: [1]UIS-AC-T007(Dissolved Elements in Water by ICP-OES) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	0.05	mg/l	[2]B	<0.05	mg/l	[1]Ca	17.2	mg/l
[2]Fe	0.44	mg/l	[1]K	12.1	mg/l	[1]Mg	7.91	mg/l
[2]Mn	0.75	mg/l	[1]Na	8.82	mg/l			

Method: [1]UIS-EA-T034(Anions by Photometry) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Fluoride F	0.336	mg/l	[1]Chloride Cl	8.64	mg/l	[2]Nitrate NO3	<0.13	mg/l
[1]Nitrate NO3 as N	<0.13	mg/l	[2]Nitrite NO2	0.001	mg/l	[1]Phosphate PO4 as P	0.009	mg/l
[2]Nitrite NO2 as N	<0.001	mg/l	[1]Phosphate PO4	0.027	mg/l	[1]Sulphate SO4	18.7	mg/l

Method: [2]UIS-CP-T005(Ion Balance Error Gallery) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	2.25	me/l	[2]Sum of Anions	1.84	me/l	[2]Ion Error Balance	9.98	%

Method: [2]UIS-EA-T032(Hexavalent Chromium in water) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Cr6+	<0.05	mg/l

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Escherichia coli	25	Colonies/100ml

Method: [2]UIS-EA-T035(Dissolved Oxygen) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Dissolved Oxygen	0.64	mg/l O2

Method: [2]UIS-EA-T007(Determination of Oil and Grease) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Total Oil and Grease	<1	ppm

Method: [1]UIS-EA-T034a(Ammonia by Photometry) **Completed:** 2019-03-14

Parameter	Value	Unit
[1]Ammonia as N	0.547	mg/l

Method: [2]UIS-TEA-T002(Total Cations in Water by ICP-OES) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Total P as P	<0.05	mg/l

Method: [3]UIS-OS-T015(Dissolved Organic Carbon) **Completed:** 2019-03-14

Parameter	Value	Unit
[3]Dissolved Organic Carbon (OL)	33.5	mg/l

Method: [2]UIS-EA-T043(Total trace elements in liquid by ICP-MS) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Tot. Cr	0.002	mg/l

Method: [1]UIS-EA-T001(pH) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	7.82		[2]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	50.7	mSm	[1]Total Conductivity	50.7	mS/m	[2]TC Temperature	25.8	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	330	mg/l	[2]TDS by EC*7	355	mg/l

Method: [2]UIS-CP-T004(Calculated Hardness) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca Hardness	123	mg/l CaCO3	[2]Mg Hardness	110	mg/l CaCO3	[2]Total Hardness	232	mg/l CaCO3

Method: [1]UIS-EA-T005(Total Dissolved Solids) **Completed:** 2019-03-14

Parameter	Value	Unit
[1]Total Dissolved Solids at 180C	342	mg/l

Method: [2]UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]TDS by Summation	203	mg/l

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	154	mg/l CaCO3

Method: [1]UIS-AC-T007(Dissolved Elements in Water by ICP-OES) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	<0.05	mg/l	[2]B	0.07	mg/l	[1]Ca	49.2	mg/l
[2]Fe	<0.05	mg/l	[1]K	4.51	mg/l	[1]Mg	26.6	mg/l
[2]Mn	<0.05	mg/l	[1]Na	30.2	mg/l			

Method: [1]UIS-EA-T034(Anions by Photometry) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Fluoride F	0.23	mg/l	[1]Chloride Cl	33.1	mg/l	[2]Nitrate NO3	8.55	mg/l
[1]Nitrate NO3 as N	1.93	mg/l	[2]Nitrite NO2	0.017	mg/l	[1]Phosphate PO4 as P	0.003	mg/l
[2]Nitrite NO2 as N	0.005	mg/l	[1]Phosphate PO4	0.011	mg/l	[1]Sulphate SO4	74.6	mg/l

Method: [2]UIS-CP-T005(Ion Balance Error Gallery) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	6.08	me/l	[2]Sum of Anions	5.21	me/l	[2]Ion Error Balance	7.78	%

Method: [2]UIS-MB-T004(Escherichia coli) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Escherichia coli	0	Colonies/100ml

Method: [2]UIS-AC-T100(Trace elements in liquids by ICP-MS) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]As	0.006	mg/l	[2]Ba	0.057	mg/l	[2]Cd	<0.0001	mg/l
[2]Co	<0.001	mg/l	[2]Cr	<0.001	mg/l	[2]Cu	0.002	mg/l
[2]Fe	<0.01	mg/l	[2]Hg	<0.0001	mg/l	[2]Mo	<0.001	mg/l
[2]Ni	0.005	mg/l	[2]Pb	<0.001	mg/l	[2]Sb	<0.001	mg/l
[2]Se	<0.001	mg/l	[2]U	<0.0001	mg/l	[2]V	0.002	mg/l
[2]Zn	0.043	mg/l						

Method: [1]UIS-EA-T034a(Ammonia by Photometry) **Completed:** 2019-03-14

Parameter	Value	Unit
[1]Ammonia as N	<0.009	mg/l

Request ID: 26052 **Sample ID:** 616577 **Received:** 2019-03-04 **Matrix:** Water **Page:** 5 / 6
Sample Number: LNP19_M03_076 **Revision Number:** 0

Method: [2]UIS-CP-T009(Total Inorganic Nitrogen (Dissolved)) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Total Inorganic Nitrogen	<0.001	mg/l

Method: [1]UIS-EA-T001(pH) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	7.58		[2]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	374	mSm	[1]Total Conductivity	374	mS/m	[2]TC Temperature	24.9	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	2430	mg/l	[2]TDS by EC*7	2620	mg/l

Method: [2]UIS-CP-T004(Calculated Hardness) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca Hardness	1330	mg/l CaCO3	[2]Mg Hardness	925	mg/l CaCO3	[2]Total Hardness	2250	mg/l CaCO3

Method: [1]UIS-EA-T005(Total Dissolved Solids) **Completed:** 2019-03-14

Parameter	Value	Unit
[1]Total Dissolved Solids at 180C	3100	mg/l

Method: [2]UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]TDS by Summation	878	mg/l

Method: [2]UIS-EA-T029(Turbidity) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Turbidity	50.6	NTU

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	104	mg/l CaCO3

Method: [1]UIS-AC-T007(Dissolved Elements in Water by ICP-OES) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	<0.05	mg/l	[2]B	0.09	mg/l	[1]Ca	531	mg/l
[2]Fe	<0.05	mg/l	[1]K	10.6	mg/l	[1]Mg	225	mg/l
[2]Mn	<0.05	mg/l	[1]Na	48.3	mg/l			

Method: [1]UIS-EA-T034(Anions by Photometry) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Fluoride F	<0.042	mg/l	[1]Chloride Cl	9.67	mg/l	[1]Nitrate NO3 as N	<0.13	mg/l
[2]Nitrite NO2	0.002	mg/l	[1]Phosphate PO4 as P	0.003	mg/l	[2]Nitrite NO2 as N	<0.001	mg/l
[1]Phosphate PO4	0.009	mg/l	[1]Sulphate SO4	1900	mg/l			

Method: [2]UIS-CP-T005(Ion Balance Error Gallery) **Completed:** 2019-03-14

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	47.4	me/l	[2]Sum of Anions	41.6	me/l	[2]Ion Error Balance	6.47	%

Method: [2]UIS-EA-T032(Hexavalent Chromium in water) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Cr6+	<0.05	mg/l

Method: [2]UIS-EA-T035(Dissolved Oxygen) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Dissolved Oxygen	5.86	mg/l O2

Method: [2]UIS-EA-T007(Determination of Oil and Grease) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Total Oil and Grease	3	ppm

Method: [1]UIS-EA-T034a(Ammonia by Photometry) **Completed:** 2019-03-14

Parameter	Value	Unit
[1]Ammonia as N	<0.009	mg/l

Method: [2]UIS-TEA-T002(Total Cations in Water by ICP-OES) **Completed:** 2019-03-14

Parameter	Value	Unit
[2]Total P as P	<0.05	mg/l

Method: [3]UIS-OS-T015(Dissolved Organic Carbon) **Completed:** 2019-03-14

Parameter	Value	Unit
[3]Dissolved Organic Carbon (OL)	13.2	mg/l

Petunia Moleta
AUTHORISED SIGNATORY

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Waterfall City, Midrand
Johannesburg
Gauteng
South Africa
1685

Attention :	Keretia Lupankwa
Date :	15th March, 2019
Your reference :	18102350
Our reference :	Test Report 19/161 Batch 1
Location :	Leeuwpan
Date samples received :	6th March, 2019
Status :	Final report
Issue :	1

Seventeen samples were received for analysis on 6th March, 2019 of which seventeen were scheduled for analysis. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

Analysis was undertaken at either Exova Jones Environmental (UK), which is ISO 17025 accredited under UKAS (4225) or Exova Jones Environmental (SA) which is ISO 17025 accredited under SANAS (T0729) or a subcontract laboratory where specified.

NOTE: Under International Laboratory Accreditation Cooperation (ILAC), ISO 17025 (UKAS) accreditation is recognised as equivalent to SANAS (South Africa) accreditation.

Compiled By:

Aatifah Latief

Inorganics Laboratory:

Musa Tiki
Technical Signatory (Inorganics)

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/161

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

J E Sample No.	1-4	5-8	9-12	13-16	17-20	21-24	25-28	29-32	33-36	37-40	LOD/LOR	Units	Method No.
Sample ID	LNP19_Q1_001	LNP19_Q1_002	LNP19_Q1_003	LNP19_Q1_004	LNP19_Q1_005	LNP19_Q1_006	LNP19_Q1_007	LNP19_Q1_009	LNP19_Q1_010	LNP19_Q1_011			
Depth													
COC No / misc													
Containers	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P			
Sample Date	28/02/2019	28/02/2019	01/03/2019	01/03/2019	01/03/2019	01/03/2019	01/03/2019	01/03/2019	01/03/2019	02/03/2019			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019			
Dissolved Aluminium*	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	ug/l	UK_TM30/UK_PM14
Dissolved Calcium [SA]	118.3	13.3	18.3	46.2	48.1	201.0	194.9	350.0	109.7	330.4	<0.3	mg/l	SA_TM27/SA_PM0
Total Dissolved Iron*	4357	94	20	<20	66	33	<20	<20	<20	95	<20	ug/l	UK_TM30/UK_PM14
Dissolved Magnesium [SA]	121.4	8.9	11.3	32.2	37.8	76.1	75.4	158.6	45.2	159.8	<0.2	mg/l	SA_TM27/SA_PM0
Dissolved Potassium [SA]	<0.1	0.2	0.6	0.1	0.7	<0.1	0.1	0.8	1.6	0.5	<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Sodium [SA]	24.1	5.1	11.1	46.0	40.4	31.8	31.7	39.9	22.8	45.3	<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Manganese*	907	105	9	10	10	2	<2	6	<2	24	<2	ug/l	UK_TM30/UK_PM14
Chloride*	4.1	6.1	13.0	4.5	15.7	4.8	4.7	10.5	12.1	9.3	<0.3	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO3 [SA]	60	4	15	84	262	138	133	29	40	175	<3	mg/l	SA_TM32/SA_PM0
Electrical Conductivity @25C [SA]	1354	170	232	653	733	1368	1370	2270	898	2220	<2	uS/cm	SA_TM28/SA_PM0
Fluoride*	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	mg/l	UK_TM173/UK_PM0
Nitrate as N*	<0.05	<0.05	4.85	0.09	1.65	0.51	0.49	5.34	2.07	<0.05	<0.05	mg/l	UK_TM38/UK_PM0
Ortho Phosphate as P*	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	mg/l	UK_TM38/UK_PM0
pH [SA]	7.31	6.47	7.08	7.55	7.62	7.34	7.43	6.62	7.37	7.50	<2.00	pH units	SA_TM19/SA_PM0
Sulphate as SO4*	796.0	50.1	11.6	240.3	97.9	650.1	634.0	1402.7	401.1	1276.3	<0.5	mg/l	UK_TM38/UK_PM0
Total Dissolved Solids [SA]	1207	155	170	466	479	1191	1210	2258	708	2167	<35	mg/l	SA_TM20/SA_PM31

Please see attached notes for all abbreviations and acronyms

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa
JE Job No.: 19/161

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

J E Sample No.	41-44	45-48	49-52	53-56	57-60	61-64	65-68				LOD/LOR	Units	Method No.
Sample ID	LNP19_Q1_012	LNP19_Q1_013	LNP19_Q1_014	LNP19_Q1_015	LNP19_Q1_016	LNP19_Q1_017	LNP19_Q1_018						
Depth													
COC No / misc													
Containers	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P						
Sample Date	02/03/2019	02/03/2019	02/03/2019	02/03/2019	02/03/2019	02/03/2019	03/03/2019						
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water						
Batch Number	1	1	1	1	1	1	1						
Date of Receipt	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019	06/03/2019						
Dissolved Aluminium*	<20	<20	<20	<20	<20	<20	<20				<20	ug/l	UK_TM30/UK_PM14
Dissolved Calcium SA	36.8	41.2	13.3	18.2	26.8	23.3	33.3				<0.3	mg/l	SA_TM27/SA_PM0
Total Dissolved Iron*	49	98	10140	3484	719	<20	845				<20	ug/l	UK_TM30/UK_PM14
Dissolved Magnesium SA	24.2	15.8	9.1	9.1	10.7	14.5	22.4				<0.2	mg/l	SA_TM27/SA_PM0
Dissolved Potassium SA	4.0	4.2	10.3	1.8	2.2	2.4	1.6				<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Sodium SA	9.3	22.9	21.2	31.5	38.5	10.5	31.9				<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Manganese*	997	23	678	360	144	4	61				<2	ug/l	UK_TM30/UK_PM14
Chloride*	3.4	14.4	25.3	4.6	25.4	5.2	12.9				<0.3	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO3 SA	150	154	63	140	150	104	206				<3	mg/l	SA_TM32/SA_PM0
Electrical Conductivity @25C SA	394	415	273	280	369	274	437				<2	uS/cm	SA_TM28/SA_PM0
Fluoride*	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3				<0.3	mg/l	UK_TM173/UK_PM0
Nitrate as N*	0.07	7.50	0.35	<0.05	0.05	6.77	<0.05				<0.05	mg/l	UK_TM38/UK_PM0
Ortho Phosphate as P*	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03				<0.03	mg/l	UK_TM38/UK_PM0
pH SA	7.26	7.68	6.59	7.65	7.21	7.77	8.08				<2.00	pH units	SA_TM19/SA_PM0
Sulphate as SO4*	50.8	18.3	34.6	<0.5	4.8	0.7	5.7				<0.5	mg/l	UK_TM38/UK_PM0
Total Dissolved Solids SA	248	272	165	172	225	184	229				<35	mg/l	SA_TM20/SA_PM31

Please see attached notes for all abbreviations and acronyms

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Client Name: Golder Associates (Pty) Ltd
Reference: 18102350
Location: Leeuwpan
Contact: Keretia Lupankwa

J E Job No.	Batch	Sample ID	Depth	J E Sample No.	Analysis	Reason
No deviating sample report results for job 19/161						

Please note that only samples that are deviating are mentioned in this report. If no samples are listed it is because none were deviating.
Only analyses which are accredited are recorded as deviating if set criteria are not met.

NOTES TO ACCOMPANY ALL SCHEDULES AND REPORTS

JE Job No.: 19/161

SOILS

Please note we are only MCERTS accredited (UK soils only) for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

% Asbestos in Asbestos Containing Materials (ACMs) is determined by reference to HSG 264 The Survey Guide - Appendix 2 : ACMs in buildings listed in order of ease of fibre release.

Negative Neutralization Potential (NP) values are obtained when the volume of NaOH (0.1N) titrated (pH 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 - 2.5. Any negative NP values are corrected to 0.

The calculation of Pyrite content assumes that all oxidisable sulphides present in the sample are pyrite. This may not be the case. The calculation may be an overesitimate when other sulphides such as Barite (Barium Sulphate) are present.

WATERS

Please note we are not a UK Drinking Water Inspectorate (DWI) Approved Laboratory .

ISO17025 accreditation applies to surface water and groundwater and usually one other matrix which is analysis specific, any other liquids are outside our scope of accreditation.

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

DEVIATING SAMPLES

Samples must be received in a condition appropriate to the requested analyses. All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. If this is not the case you will be informed and any test results that may be compromised highlighted on your deviating samples report.

SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

DILUTIONS

A dilution suffix indicates a dilution has been performed and the reported result takes this into account. No further calculation is required.

BLANKS

Where analytes have been found in the blank, the sample will be treated in accordance with our laboratory procedure for dealing with contaminated blanks.

NOTE

Data is only reported if the laboratory is confident that the data is a true reflection of the samples analysed. Data is only reported as accredited when all the requirements of our Quality System have been met. In certain circumstances where all the requirements of the Quality System have not been met, for instance if the associated AQC has failed, the reason is fully investigated and documented. The sample data is then evaluated alongside the other quality control checks performed during analysis to determine its suitability. Following this evaluation, provided the sample results have not been effected, the data is reported but accreditation is removed. It is a UKAS requirement for data not reported as accredited to be considered indicative only, but this does not mean the data is not valid.
Where possible, and if requested, samples will be re-extracted and a revised report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.

REPORTS FROM THE SOUTH AFRICA LABORATORY

Any method number not prefixed with SA has been undertaken in our UK laboratory unless reported as subcontracted.

ABBREVIATIONS and ACRONYMS USED

#	ISO17025 (UKAS Ref No. 4225) accredited - UK.
SA	ISO17025 (SANAS Ref No.T0729) accredited - South Africa.
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance
SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
++	Result outside calibration range, results should be considered as indicative only and are not accredited.
*	Analysis subcontracted to an Exova Jones Environmental approved laboratory.
AD	Samples are dried at 35°C ±5°C
CO	Suspected carry over
LOD/LOR	Limit of Detection (Limit of Reporting) in line with ISO 17025 and MCERTS
ME	Matrix Effect
NFD	No Fibres Detected
BS	AQC Sample
LB	Blank Sample
N	Client Sample
TB	Trip Blank Sample
OC	Outside Calibration Range

JE Job No: 19/161

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
SA_TM19	Determination of pH by bench pH meter	SA_PM0	No preparation is required.	Yes			
SA_TM20	Modified BS 1377-3: 1990 Gravimetric determination of Total Dissolved Solids	SA_PM31	Sample is filtered	Yes			
SA_TM27	Major ions by Ion Chromatography	SA_PM0	No preparation is required.	Yes			
SA_TM28	Determination of Electrical Conductivity with hand held manual conductivity probe.	SA_PM0	No preparation is required.	Yes			
SA_TM32	Determination of Alkalinity by titration of the sample with a standard solution of acid by visual detection of end points.	SA_PM0	No preparation is required.	Yes			
UK_TM173	Analysis of fluoride by ISE (Ion Selective Electrode) using modified ISE method 340.2	UK_PM0	No preparation is required.				
UK_TM30	Determination of Trace Metal elements by ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometry). Modified US EPA Method 200.7, 6010B and BS EN ISO 11885 2009	UK_PM14	Analysis of waters and leachates for metals by ICP OES/ICP MS. Samples are filtered for dissolved metals and acidified if required.				
UK_TM38	Soluble Ion analysis using the Thermo Aquakem Photometric Automatic Analyser. Modified US EPA methods 325.2, 375.4, 365.2, 353.1, 354.1	UK_PM0	No preparation is required.				

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FINAL CERTIFICATE OF ANALYSIS	
Report Date	2019-03-14
Date Required	2019-03-14
Contract No	
Order/Ref No	1527125 Leeuwpan GW

T0184

1527125 Leeuwpan GW

Notes
The results relate specifically to the items tested.
The report shall not be reproduced except in full, without the written approval of the laboratory.
[1] SANAS accredited analysis included in the SANAS Schedule of Accredition for this laboratory.
[2] Not SANAS accredited analysis and not included in the SANAS schedule of accreditation for this laboratory.
[3] Outsourced not performed by this laboratory.

Request ID: 26051 **Sample ID:** 616562 **Received:** 2019-03-04 **Matrix:** Water **Page:** 1 / 2
Sample Number: LNP19_Q1_008 **Revision Number:** 0

Method: [1]UIS-EA-T001(pH) **Completed:** 2019-03-13

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	7.1		[2]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2019-03-13

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	118	mSm	[1]Total Conductivity	118	mS/m	[2]TC Temperature	25.8	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2019-03-13

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	767	mg/l	[2]TDS by EC*7	826	mg/l

Method: [1]UIS-EA-T005(Total Dissolved Solids) **Completed:** 2019-03-13

Parameter	Value	Unit
[1]Total Dissolved Solids at 180C	1110	mg/l

Method: [2]UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2019-03-13

Parameter	Value	Unit
[2]TDS by Summation	374	mg/l

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2019-03-13

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	132	mg/l CaCO3

Method: [1]UIS-AC-T007(Dissolved Elements in Water by ICP-OES) **Completed:** 2019-03-13

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	<0.05	mg/l	[1]Ca	187	mg/l	[2]Fe	<0.05	mg/l
[1]K	3.65	mg/l	[1]Mg	75.7	mg/l	[2]Mn	<0.05	mg/l
[1]Na	27.7	mg/l						

Method: [1]UIS-EA-T034(Anions by Photometry) **Completed:** 2019-03-13

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Fluoride F	<0.042	mg/l	[1]Chloride Cl	4.73	mg/l	[2]Nitrate NO3	0.162	mg/l
[1]Nitrate NO3 as N	<0.13	mg/l	[1]Phosphate PO4 as P	0.017	mg/l	[1]Phosphate PO4	0.054	mg/l
[1]Sulphate SO4	599	mg/l						

Method: [2]UIS-CP-T005(Ion Balance Error Gallery) **Completed:** 2019-03-13

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	16.9	me/l	[2]Sum of Anions	14.8	me/l	[2]Ion Error Balance	6.49	%

Method: [2]UIS-TEA-T002(Total Cations in Water by ICP-OES) **Completed:** 2019-03-13

Parameter	Value	Unit
[2]Total Fe as Fe	0.05	mg/l

Petunia Moleta
AUTHORISED SIGNATORY

APPENDIX E

Document Limitations

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GOLDER ASSOCIATES AFRICA (PTY) LTD



golder.com

Annexure D
Hydrogeological Assessment



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Leeuwpan Colliery Hydrogeological Investigation

Report

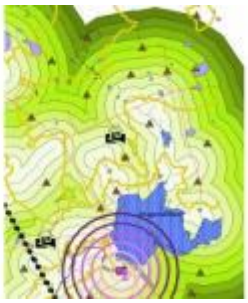
Final

17 February 2014

Exxaro Resources Limited

GCS Project Number: 11-447GW




Report
Final



February 2014

Exxaro Resources Limited

11-447GW

DOCUMENT ISSUE STATUS

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Author	Jorette van Rooyen		January 2014
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Director	Alkie Marais		February 2014

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GLOSSARY

Aquifer – A body of rock, consolidated or unconsolidated, that is sufficiently permeable to conduct groundwater and to yield significant quantities of water to wells and springs.

Bedrock – A general term for the rock that underlies soil or other unconsolidated superficial material.

Cone of depression – A depression in the potentiometric surface of a body of groundwater that has the shape of an inverted cone and develops around a well/mine shaft/open pit mine from which water is being withdrawn.

A confined aquifer - a formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations; confined groundwater is generally subject to pressure greater than atmospheric pressure.

Drawdown – The decline of the water table or potentiometric surface as a result of withdrawals from wells or excavations.

Effective porosity - is the percentage of the bulk volume of a rock or soil that is occupied by interstices that are connected.

Fault – A fracture or fracture zone along which there has been displacement of the sides relative to one another parallel to the fracture.

Fracture – A crack, joint, fault or other break in rocks caused by mechanical failure.

Groundwater table - is the surface between the zone of saturation and the zone of aeration; the surface of an unconfined aquifer.

Heterogeneous -indicates non-uniformity in a structure.

Hydraulic conductivity (K) - 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.

Hydraulic gradient - is the rate of change in the total head per unit distance of flow in a given direction.

Hydraulic head – Generally the altitude of the free surface of a body of water above a given datum.

Interflow **–** The lateral movement of water in the unsaturated zone during and immediately after precipitation. Interflow occurs when the zone above a low permeability horizon becomes saturated and lateral flow is initiated parallel to the barrier.

Joint **–** A fracture in rock along which there has been no visible movement.

Mechanical dispersion – is the process whereby the initially close group of pollutants are spread in a longitudinal as well as a transverse direction because of velocity distributions.

Observation borehole - is a borehole drilled in a selected location for the purpose of observing parameters such as water levels.

Perched Water Table – The upper surface of a body of unconfined groundwater separated from the main body of groundwater by unsaturated material.

Permeability - the ease with which a fluid can pass through a porous medium and is defined as the volume of fluid discharged from a unit area of an aquifer under unit hydraulic gradient in unit time. Permeability is not to be confused with hydraulic conductivity. While similar, permeability considers the properties of the fluid being transmitted.

pH - is a measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity.

Piezometric head - is the sum of the elevation and pressure head. An unconfined aquifer has a water table and a confined aquifer has a piezometric surface, which represents a pressure head. The piezometric head is also referred to as the hydraulic head.

Porosity **–** The ratio of the aggregate volume of interstices in a rock or soil to its total volume. It is usually stated as a percentage.

Pumping tests - are conducted to determine aquifer or borehole characteristics.

Recharge - is the addition of water to the zone of saturation; also, the amount of water added.

Static water level - is the level of water in a borehole that is not being affected by withdrawal of groundwater.

Specific yield - the ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium. Specific yield is a ratio between 0 and 1 indicating the amount of water released due to drainage, from lowering the water table in an unconfined aquifer.

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. It is a volume of water per volume of aquifer released as a result of a change in head. For a confined aquifer, the storage coefficient is equal to the product of the specific storage and aquifer thickness.

Total dissolved solids (TDS) - is a term that expresses the quantity of dissolved material in a sample of water.

Transmissivity (T) - is a measure of the ease with which groundwater flows in the subsurface. It is the two-dimensional form of hydraulic conductivity and is defined as the hydraulic conductivity multiplied by the saturated aquifer thickness.

An unconfined, water table or phreatic aquifer - are different terms used for the same aquifer type which is bounded from below by an impermeable layer. The upper boundary is the water table, which is in contact with the atmosphere so that the system is open.

Vadose zone - is the zone containing water under pressure less than that of the atmosphere, including soil water, intermediate vadose water, and capillary water. This zone is limited above by the land surface and below by the surface of the zone of saturation, that is, the water table.

Water table - is the surface between the vadose zone and the groundwater, that surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere.

ABA - Acid Base Accounting

ANC - Acid Neutralising Capacity

ARD - Acid Rock Drainage

DWA - Department of Water Affairs (Used to be DWAF)

EC - Electrical Conductivity (mS/m)

Fe - Iron (mg/l)

K - Hydraulic Conductivity

LOM - Life of Mine

mamsl - Metres above mean sea level

mbgl - Metres below ground level

NAG - Net Acid Generation

NGDB - National Groundwater Database

S - Storativity

SO_4 - Sulphate (mg/l)

TDS - Total Dissolved Solids (mg/l)

EXECUTIVE SUMMARY

Exxaro Resources Ltd ("Exxaro") appointed GCS (Pty) Ltd (GCS) to undertake a hydrogeological investigation at Leeuwpan Colliery (also referred to as LPN). The investigation is required for the update and consolidation of the current Environmental Management Plans (EMPs) and EMP Addendums into one consolidated EIA and EMP document according to the Minerals and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA).

In addition, this investigation also assessed the new block OI on the farm Rietkuil 249 IR (Portions 1 and 2) and Block OL on farm Moabsvelden 248 (Portion 2, 10 and 16). This will also involve the authorisation of various listed activities under the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) and the inclusion of the activities under the National Water Act, 1998 (Act No. 37 of 1998).

There are three aquifer types present in the Leeuwpan area. These aquifers vary with regard to aquifer characteristics and are generally interconnected by fractures:

- The shallow aquifer formed in the weathered zone, often perched on the fresh bedrock;
- The deeper aquifer formed by fracturing of the Karoo sediments and dolerite intrusions; and
- The dolomite & chert rich karst aquifer of the Malmani Subgroup which underlies the Karoo type aquifer.

The coal reserves which are exploited at Leeuwpan are associated with the fractured Karoo aquifer can be classified as a minor (low yielding) aquifer system. A prominent dolerite sill intrusion (±15m thick) is present at Leeuwpan. The unsaturated zone (~5 - 26 mbgl) in the study area consists of colluvial material and clay (residual dolerite and shale) that is underlain by weathered sandstone / siltstone / mudstone / shale and coal of the Ecca Group that becomes less weathered with depth. The Dwyka tillite underlies the Ecca Group sediments and is found to be highly weathered at shallow depths and unweathered and depth.

Groundwater is mainly used for domestic supply, small scale irrigation (gardens), livestock watering as well as large scale pivot irrigation of crops. The boreholes used for large scale irrigation exploit the dolomitic aquifer as the yields from the Karoo Supergroup are too low to sustain the high abstraction rates. The groundwater quality in the area is generally good.

The water levels of the monitoring boreholes representing the shallow weathered Karoo aquifer ranged from 1.9 to 9.8 mbgl with an average groundwater level of 7 mbgl. The static water levels for the boreholes representative of the deeper fractured Karoo aquifer ranged between 2.4 and 30 mbgl with the average calculated as 15 mbgl. In the dolomitic aquifer the groundwater levels range from 5.5 to 34 mbgl and averaged at ~17 mbgl. The groundwater levels in the Karoo aquifers generally follow topography in the absence of anthropogenic activities in the identified aquifers.

The hydraulic conductivity ranges from 0.01-0.6 m/d with a harmonic mean of ~0.05 m/d. The transmissivity ranges from 0.2 to 20 m^2/d with a harmonic mean of ~0.7 m^2/d. These values are typical of the Karoo type aquifers.

Drainage from the opencast backfill will become acidic over the long-term as the ABA results show that the material has the potential to generate acid-mine drainage. The sandstone and soft overburden have limited potential for acidic generation. The shale samples show a great variance in net acidic generation, but may have a potential for acidic generation. Elevation of TDS and SO_4 will occur as a result of pyrite oxidation. In the opencast the SO_4 will increase roughly to about 2 500 mg/l over the long term;

It is not foreseen that significant elevation in metals will occur at near-neutral conditions. After acidification non-compliance for Al, Fe and Mn may occur. Cr, Ni and to a lesser degree As and V are some of the other trace elements that may be slightly elevated and may reach occasional marginal to non-compliance.

Leeuwpan Colliery is an existing operation and as a result there are numerous contaminant sources already present such as the plant area, pollution and return water dams, rehabilitated opencasts and operational opencast.

The sulphate concentrations are elevated in boreholes LEEMB18_D, KENMB3_D, KENMB2_D and WWN01 located within the plant area as well as in boreholes WITMB14, WOLMB15_S, KENMB3_S, WWN02d and WWN02s located in the immediate areas surrounding the plant. From the plant area the groundwater flow direction is predominantly in a north westerly direction. Boreholes WOLMB15_S and WOLMB15_D located down gradient of the plant PCD also indicate impact of mining related activities. High sulphate concentrations were also encountered in the north easterly part of the mine toward the Moabsvelden and Weltevreden pits in boreholes MOAMB10, Moa1, WTN02d, WTN02s, WELMB13_S and WELMB13_D. The borehole KENMB2_D located down gradient of the No. 5. Emergency overflow dam is also impact by mining related contaminants. Boreholes WWN02s, WWN02d and WNN01 are located adjacent to a dam west of the OD block opencast which are also impacted by mining related contaminants. Borehole WITMB14 located down gradient of the Witklip pit (Block OA) showed an impact by mining related contaminants although still compliant with the SANS 241 Drinking water standard. The borehole MOAMB10 located adjacent to OJ Block opencast has been negatively impacted by mining in term of elevated sulphate, TDS and EC. The shallow borehole WTN02s contained sulphate concentrations above the background levels (although still compliant). It is likely that this borehole has been impacted by a shallow contaminant source associated with the haul road (coal spillage).

Shallow and deep boreholes (WELMB13_D and WELMB13_S) located down gradient of the OWN_MN Block (Moabsvelden) opencast are also slightly impact by mining related contaminants.

The majority of privately owned boreholes are associated with the underlying dolomitic aquifer which in unlikely to be impact by any dewatering activities.

It is likely that preferential flow paths along faults and dolerite intrusion related to fracturing is not significant in the area based on the available data. While it is still anticipated that localised preferential flow zones will exist in relation to dolerite dykes, these zones have not been recorded and it is thought that they are not well developed. As mentioned above the drainage occurs towards the low lying areas such as rivers and streams (Bronkhorstspruit and its tributaries). Some of these streams may be impacted by contaminated seepage and decant.

During construction of the new activities (Block OI and OL) minimal additional impacts in the groundwater system is expected. The impacts are expected to have a low significance rating.

Groundwater levels could be lowered over relative large area around the opencasts during the operational phase. Groundwater inflows into Block OI can range from ~500 m^3/d in 2016 to 360 m^3/d in 2027. The inflows into the proposed Block OL may approach ~60 m^3/d at the beginning of 2020 may approach which then increases to ~340 m^3/d in 2029. Groundwater flow directions will be directed towards the mining areas due to the mine dewatering. Therefore contamination will be contained within the mining area, and little contamination will be able to migrate away from the mining area. Some monitoring boreholes were however affected by contaminants emanating from surface related contaminant sources. The impact significance can be assumed to be low during the operational phase

Once the mining has ceased, ARD is still likely to form given the unsaturated conditions in the facility and contact of water and oxygen through natural process including rainfall. Therefore a groundwater contaminant plumes are likely to migrate from the mining areas once the water level in the rehabilitated pits have reached long term steady state conditions (i.e. each pit water level has reached the decant level). No privately owned boreholes located in the fractured Karoo aquifer is likely to be impacted based on the impact simulations post closure. However shallow contaminated seepage may impact on the Bronkhorstspruit post closure and increase the salt load of the system. Given the significance of the underlying dolomite aquifer, the interaction between the dolomite and the Karoo aquifers should be further investigated. If these aquifers are in hydraulic connection and a flow gradient form the Karoo aquifer exists towards the dolomite aquifer exists the dolomitic aquifer may be impacted on post closure by contaminants.

Surface decanting of mine water is likely to occur in most opencasts, the estimated decant volumes for all the opencasts at Leeuwpan can range from ~1960 m^3/d ot ~3675 m^3/d. This should however re-assessed, once more information regarding rehabilitation and backfilling are obtained. Boreholes should be drilled into the opencasts to monitoring the rate of water level recovery.

A groundwater management plan and monitoring network has been developed for Leeuwpan. The following recommendations are made:

- The groundwater monitoring network should be reviewed and expanded for the existing and future mining activities at Leeuwpan. An updated and optimised monitoring program should be developed and submitted to DWA.
- Boreholes should be drilled into the rehabilitated opencast so that the rate of flooding and water level recovery, and water quality can be established.
- Stage curves should be developed which would aid in the management of closure phase.
- The numerical model should be updated bi-annually by using the measured water ingress and water levels to re-calibrate and refine the impact predictive scenario.

- Field parameter profiling (EC, pH etc.) should be conducted on the monitoring boreholes to determine the optimal sampling depth.
- The interaction between the Karoo and dolomitic aquifer should be further investigated. This should be used to determine the risk associated with contamination of the dolomitic aquifer.

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1 INTRODUCTION

Exxaro Resources Ltd ("Exxaro") appointed GCS (Pty) Ltd (GCS) to undertake a hydrogeological investigation at Leeuwpan Colliery (also referred to as LPN). The investigation is required for the update and consolidation of the current Environmental Management Plans (EMPs) and EMP Addendums into one consolidated EIA and EMP document according to the Minerals and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA).

In addition, this investigation also assessed the new block OI on the farm Rietkuil 249 IR (Portions 1 and 2) and Block OL on farm Moabsvelden 248 (Portion 2, 10 and 16). This will also involve the authorisation of various listed activities under the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) and the inclusion of the activities under the National Water Act, 1998 (Act No. 37 of 1998).

2 SCOPE OF WORK

The following tasks were completed during the groundwater study:

- Data and information review;
- Hydrocensus investigation;
- Geophysical survey, borehole drilling, aquifer testing;
- Geochemical characterisation
- Conceptual model development;
- Numerical flow and contaminant transport modelling
- Reporting

3 METHODOLOGY

3.1 Data and Information Review

All relevant public domain information was reviewed including, but not limited to geological, hydrogeological and climatic information. All previous reports from other groundwater studies conducted in the area by GCS and other consultancies were also reviewed. The following reports formed part of the review process:

- Cleanstream Environmental Services, 2007. Leeuwpan Colliery: Report on Geohydrological Investigation as part of the EMPR for the proposed Wolwenfontein, Weltevreden and Rietkuil projects.
- Exxaro, 2004. Block OJ & OL – Phase 1 Groundwater Report.

- Exxaro, 2011, Pre-Feasibility Study Report for Leeuwpan O/I Project.
- GCS, 2013. DRAFT Environmental Impact Assessment and Environmental Management Programme (EIA/EMP).
- Geo Pollution Technologies Consulting Environmental Scientists, 2002. Environmental Management Programme Report (EMPR) for the proposed new Open Pit Collieries at Leeuwpan.
- Geo Pollution Technologies Consulting Environmental Scientists, 2004. Environmental management program report for the proposed new open pit collieries at Weltevreden.
- Hodgson, 1993 Geohydrological investigation at Leeuwpan and Witklip Collieries with the purpose of submitting and application to mine.

3.2 Hydrocensus

A hydrocensus was conducted within a 2 km radius of the proposed and existing opencast mining activities at Leeuwpan in April and July 2012. A total of 48 privately owned boreholes and 11 mine monitoring boreholes were visited.

The purpose of the hydrocensus was to update regional groundwater users and hydrogeological information. The scope of this task included the following:

- Identify/update all water users within this surrounding area;
- Obtain GPS locations all production boreholes, monitoring boreholes, and springs;
- Verify the general status of boreholes;
- Update the groundwater user information, including purpose of abstraction, abstraction rates etc.; and
- Take hydrogeological field measurements (static water levels and borehole depths).

All of the data collected during both of the hydrocensus investigations were captured and analyzed. The results of the hydrocensus are presented in Section 6.2 and borehole localities are shown in Figure 6.1.

3.3 Geophysical Survey

A surface geophysical survey was conducted in October 2013 to identify underlying geological structures, such as dykes and faults, which could potentially act as preferential flow-paths to groundwater. Both the magnetic and electromagnetic methods were used in the identification of structures. The data was used to site the monitoring boreholes.

Electromagnetic method:

The electromagnetic data was collected with an EM 34-3 unit at 10 metre intervals using a 20 meter cable (suitable for small areas). The EM unit operates in the following way: Variations in the subsurface conductivity depend on the nature of the underlying geological strata. The alternating current in the transmitter coil of the apparatus generates a pulsing primary magnetic field that induces an electrical current at depth. This induced current off the different geological strata produce a secondary magnetic field. The secondary magnetic field generated is picked up by the receiver coil and read as an apparent conductivity (measured as mS/m).

The EM data interpretation was based on the identification of patterns within a data set. Background values were gained from traversing over areas of uniform geology and hydrogeology. Anomalies were interpreted as geological structures in the underlying geology.

Magnetic method:

The magnetic data was collected with a G4 Proton Magnetometer. Readings were taken at 5 metre intervals. The magnetometer records the magnetic signature of the underlying rocks that is due to the earth's magnetic field. This is recorded as the total magnetic field (nTesla) at that point. Changes or fluctuations in the data are observed as anomalies. These anomalies can indicate the presence of intrusions (for example dykes, sills) and geological contacts.

The geophysical field data is presented in Appendix A and the results are discussed in Section 6.3.

3.4 Drilling Programme

A total of seventeen (17) new monitoring boreholes were drilled at positions determined based on the geophysical interpretations as well as drilling rig accessibility. The borehole localities are shown in Figure 6.3. Drilling of the new monitoring boreholes was completed using an air percussion drill rig coupled to a compressor unit. Drilling was completed at a diameter of 165 mm, or similar, and constructed using 125 mm ID[1], uPVC casing. Both slotted and solid casings were used, the distribution of which was determined by the site hydrogeologist once drilling was completed. The required head works (i.e. 2 m sanitary seal, concrete plinth, steel standpipe, marker board and lockable cap) were installed to ensure validity as monitoring boreholes.

All boreholes were logged in terms of lithology and aquifer intersections by the hydrogeologist on site. The borehole logs are presented in Appendix B.

3.5 Aquifer Testing

Constant discharge pump and recovery tests were conducted on selected newly drilled monitoring boreholes at Leeuwpan. Slug tests (falling head test) were however conducted on the lower yielding boreholes. The results of these tests were interpreted to obtain aquifer parameters (such as transmissivity). These parameters are required as inputs for the conceptual and numerical models. The aquifer testing is discussed in Section 6.5

3.6 Sampling

3.6.1 Groundwater

Groundwater samples were collected from the newly drilled boreholes and selected hydrocensus boreholes. The samples were submitted to a SANAS (South African National Accreditation System) accredited laboratory for analyses and the analysis was carried out in accordance with methods prescribed by and obtained from the South African Bureau of Standards (SABS), in terms of the Standards Act, Act 30 of 1982. The results were compared to the SANS (South African National Standards) 241:2011 Class 1 water quality standards for drinking water.

The laboratory analyses included:

- Major anion and cations;
- ICP metal scan; and
- pH, Total Dissolved Solids (TDS), Bicarbonates, Electrical Conductivity (EC), and Total Hardness.

[1] ID – Inside diameter

The methodology in the collection and preservation of groundwater samples is important for the reliability of the analysis. Samples were taken and preserved to ensure a correct version of the on-site conditions at the site area. This work was undertaken in accordance to the following publications:

- SABS ISO 5667-11:1993 Guidance on sampling of groundwater;
- SABS ISO 5667-2:1991 Guidance on sampling techniques; and
- SABS ISO 5667-3:1994 Guidance on the preservation and handling of samples.

3.6.2 Geochemical Sampling and Testing

A geochemical assessment was conducted on waste (overburden and discard) and coal samples collected at Leeuwpan. Samples were also collected of discard and slurry cake backfilled into the Witklip (OA) Pit. The samples were collected for geochemical testing :

- To describe the geochemical nature of the mine material;
- To determine the long-term net acid generation potential of the material; and
- To identify metals that may be present in drainage from the disturbed areas.

The geochemical analyses were conducted by Waterlab Pty Ltd. A total of seventeen (17) samples were collected and the findings are discussed in Section 8.

3.7 Modelling

3.7.1 Conceptual Modelling

A groundwater conceptual model was constructed using all available site information. The conceptual model quantifies and describes the interactions between the hydrogeological, geological and hydrological environments which assist in the construction of a numerical model. The conceptual model further includes all potential sources of contamination as well as preferential pathways that were identified during the analysis of the field work results.

3.7.2 Numerical Modelling

The model was constructed using GMS9.1, a pre- and post-processing package for MODFLOW and MT3DMS. GMS is the Graphical User Interface (GUI) for the well-established MODFLOW-2005 (Harbaugh et al, 2005) and MT3DMS (Zheng & Wang, 1999) numerical codes.

MODFLOW is a 3D, cell-centred, finite difference, saturated flow model developed by the United States Geological Survey. MODFLOW can perform both steady state and transient analyses and supports a wide variety of boundary conditions and input options. It was developed by McDonald and Harbaugh of the US Geological Survey in 1984 and updated several times since.

MT3DMS is a 3D model for the simulation of advection, dispersion, and chemical reactions of dissolved constituents in groundwater systems. MT3DMS uses a modular structure similar to the structure utilized by MODFLOW, and is used in conjunction with MODFLOW in a two-step flow and transport simulation. Heads are computed by MODFLOW during the flow simulation and utilized by MT3DMS as the flow field for the transport portion of the simulation.The numerical modelling was undertaken in a number of steps, as detailed below.

3.7.2.1 Model Construction & Calibration

Model set-up and calibration involved the following:

- Model construction during which the model boundaries was identified and quantified, the project sub-catchment was discretized into a model grid, time steps were allocated and error criteria for heads and the water balance was set; and
- Calibration of a flow model refers to a demonstration that the model is capable of reproducing field-measured heads and flows which are the calibration values.

Calibration was achieved when a set of parameters, boundary conditions and stresses are found that produce simulated heads that match field measured data. This is a crucial step in the modelling project, which will aid in ensuring that model results are reliable.

Following calibration the model was used to simulate various scenarios for future mining and infrastructure development at the site.

3.7.2.2 Scenario modelling

Scenario modelling is typically used to run future scenarios on varying changes in the natural environment or anthropogenic inputs. Aquifer dewatering, rebound of water levels after mining cessation and contaminant transport (potential pollution plumes) are potential simulations that can be run using the model.

TOPOGRAPHICAL ENVIRONMENT

3.8 Location

Leeuwpan is situated approximately 8 km east of the town of Delmas. The area falls within the Victor Khanye Local Municipality area, Nkangala District Municipality in the Mpumalanga Province.

3.9 Climate and Surface Water Drainage

The climate is generally moderate and dry with harsh winters, coupled with heavy frost. Rainfall is typical of Highveld conditions and occurs mainly during summer.

The rainfall station used to describe rainfall conditions on site was the South African Weather Service (SAWS) Delmas rain station (477309). The station has a Mean Annual Precipitation (MAP) of 681mm. The station has rain data from 1907 to 1999.

The study area is located in the Olifants Water Management Area 4 and quaternary catchment area B20A. The Bronkhorstspruit River flows through the eastern, central and western sections of the mining area. Locally, drainage occurs towards the river.

Natural water features on site include tributaries of the Bronkhorstspruit River and pans. Artificial water features on site include small pans, farm dams, old void areas, Pollution Control Dams (PCD's), rain water in open cast pits and river diversion channels.

On a larger scale, due to the topographical high on which the southern part of the mining right are situated, the drainage occurs in a general northerly direction toward the lower lying areas. A locality map can be seen in Figure 4.1.

4 MINING ACTIVITIES

Table 4.1 shows a summary of the current and future status of the mining blocks or pits. Opencast mining activities at Leeuwpan Colliery of the OF (Kenbar) pit commenced in 1992 and is located to the south of the current plant area. Thereafter mining of the OA (Witklip) pit located on the western extent of the mine commenced in 1996 and was decommissioned in March 2005. The mining blocks OG, OH, OD and OM were commissioned progressively from 2002 to 2008. These mining blocks as well as the OF (Kenbar) pit are located immediately adjacent to each other and form one mining block and they are all currently operational with the exception of the OF and OG pit which was decommissioned in 2004 and 2011 respectively.

The Wolvenfontein (UB) reserve is a westward extension of the current OD, OF (Kenbar) opencast pits and is yet to be mined. Opencast mining of the Weltevreden (OWM_WTN) and Moabsvelden (OWM_MN) reserves is situated approximately 4.5 km the north-east of the current active OJ opencast pit. The Samquarz Silica mine is also currently in operation and located north east of the OJ opencast pit.

The expansion of the mining activities to blocks OL and OI are scheduled for commencement in 2019 and 2016 respectively as indicated in Table 4.1.

The proposed Block OI opencast is situated directly south-east of the current OH and OM opencast mining blocks. The proposed Block OL is located east of Block OH and south of Block OJ.

Stuart Coal is mining immediately north of the OWM_MN pit and north east of the OWM_WTN pit. Stuart Coal is also mining to the north of the OJ reserve. Stuart Coal and Leeuwpan share a haul road toward the OWM_MN and OWM_WTN pits. Immediately south of the OWM_MN the Samquarz Silica mine is in operation.

4.1 Mine residue

The mine residue consists of overburden and plant residue (fine and coarse). The slurry fraction recovered from the slimes dams (located west of the OB stockpile) is compacted and backfilled into to the mined-out pits. The coarser discard material is also backfilled in selective opencast area. It is then covered with a clay layer and topsoil. Thus no permanent mine residue disposal sites were constructed for the mining operations.

Backfilling at Blocks OJ opencast took place 45 m from the working face. Due to the risk of pollution to the Bronkhorstspruit River, no discard was backfilled into the pit.

Furthermore, backfilling at Block OI and OL will be conducted in the same manner as the other mined out pits, thus discard and slurry cake will be disposed of as part of the backfilling process. Figure 4.2 shows a layout of the mining areas at Leeuwpan Mine.

Table 4.1: Current and Future Status of the Mining Blocks/Pits

Mine Block / Pit	Mining Dates		Current Status	Scheduled LOM*
	Start Date	End Date		
Witklip OA	1996	Mar-2005	Decommissioned	-
ODN	May-2008	Sep-2010	Decommissioned	-
OE Midklip	1998	Jun-1999	Decommissioned	-
OF Kenbar	1992	Mar-2004	Decommissioned	-
OD	Mar-2004	-	In Operation	2014
OM	Dec-1999	-	In Operation	2014-2016
OH	Sep-2002	-	In Operation	2014-2015
OG	Sep-2006	Jul-2011	Decommissioned	-
OJ	Oct-2008	-	In Operation	2016-2018
OWM_WTN	Sep-2011	-	In Operation	2014-2015
OWM_MN	Dec-2008	-	In Operation	2014-2022
OL	-	-	Not currently mined – Part of future planning	2019-2029
OI	-	-	Not currently mined – Part of future planning	2016-2027
UB	-	-	Not currently mined – Part of future planning	2021-2026

*LOM – Life of Mine

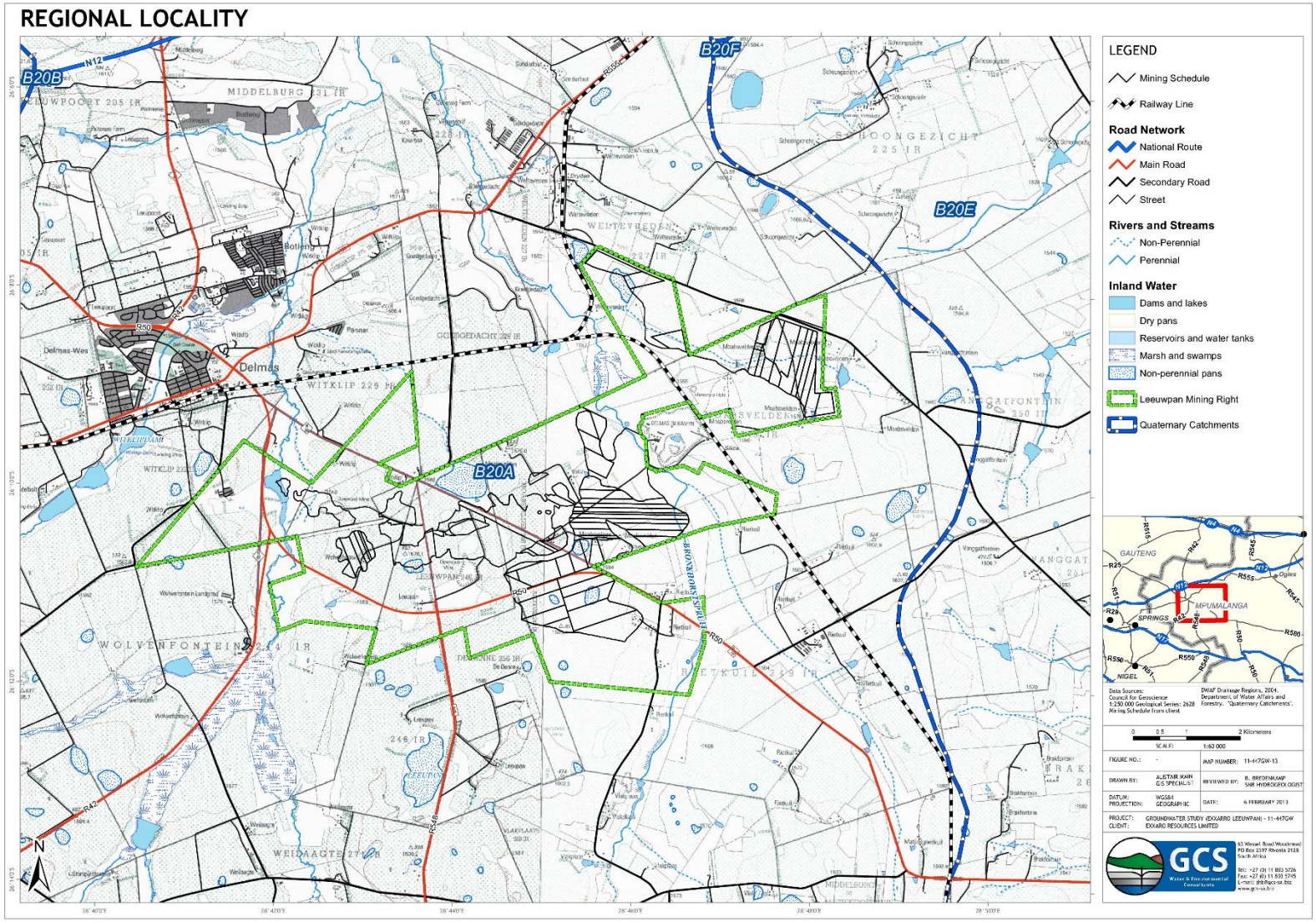


Figure 4.1: Leeuwpan Locality Map

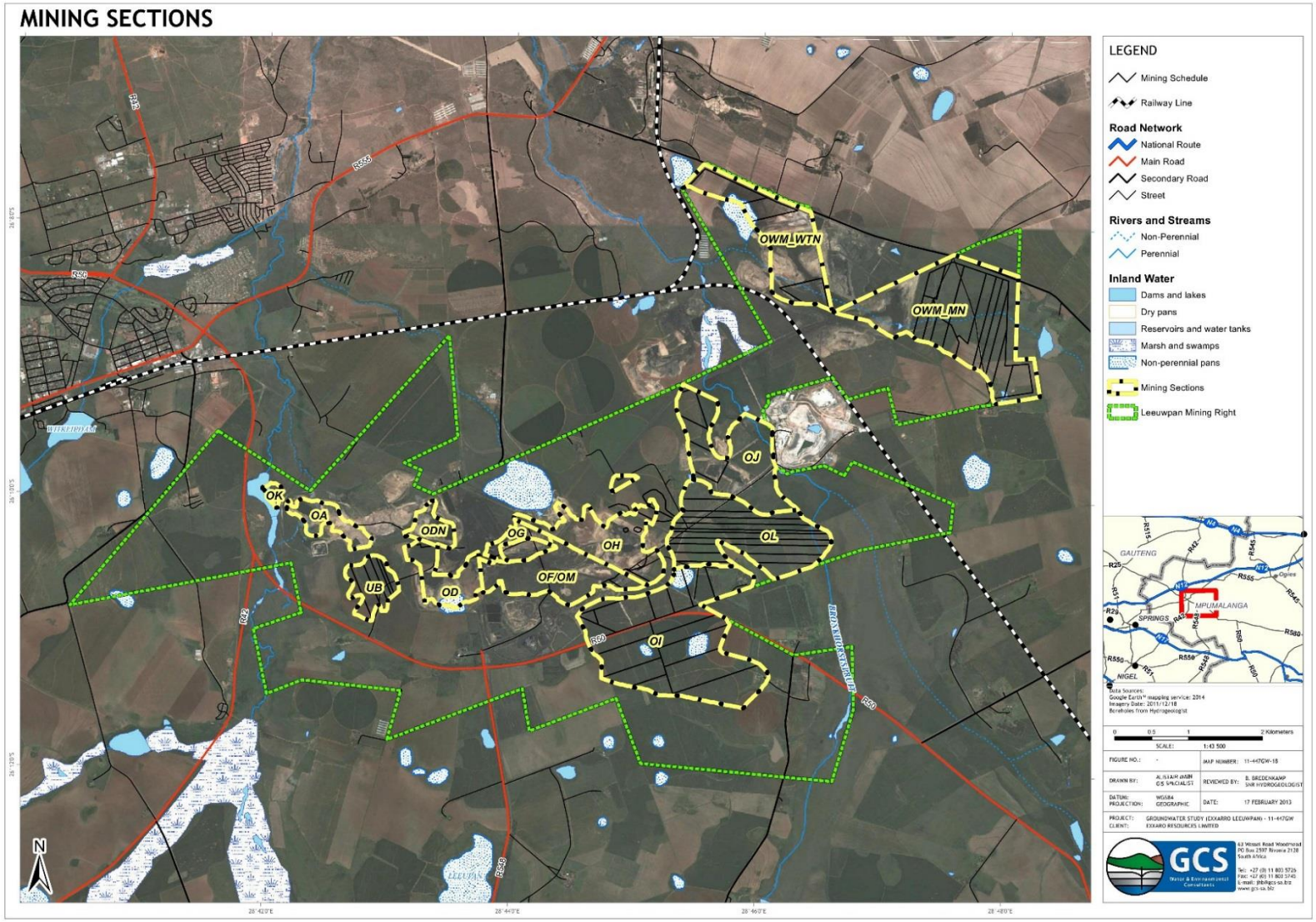


Figure 4.2: Leeuwpan mining areas and coal resources

5 GEOLOGICAL SETTING

5.1.1 Regional Geology

The coal reserves located at Leeuwpan Colliery forms part of the Witbank Coalfield (Figure 5.1). The coal in the Witbank Coalfield occurs in the Vryheid Formation of the Ecca Group forming part of the Karoo Supergroup. In the area of Leeuwpan Colliery the coal measures overly tillite of the Dwyka Group, where the latter forms the lower-most stratigraphic unit of the Karoo Supergroup. The tillite overlies the chert and dolomite of the Malmani Subgroup of the Transvaal Supergroup. Ferruginous shale and quartzite of the Timeball Hill Formation, Pretoria Group (Transvaal Supergroup) are located to the north and northeast of the site. Abnormal thickening of the coal measures in the mining area is the result of the paleo-karst landscape that was present during peat formation.

The Vryheid Formation is unconformable overlain in places by sandstone of the Volksrust Formation of the Ecca Group.

The Karoo Supergroup has been intruded by younger Jurassic age dolerite dykes and sills.

5.1.2 Local Geology

The factors which control geological and grade continuity are mainly surface weathering, significant variation in seam thickness due an undulating tillite floor and devolatilisation and weathering due to dolerite intrusions (sills and dykes). The overburden thickness varies from 35m to 90m and the coal seam dips are controlled by the highly irregular undulating floor (Exxaro, 2011).

The coal measures are up to 16m thick and are divided on site into a Bottom Coal Seam (±5m thick) and a Top Coal Zone (±5m thick). The Bottom Coal Seam is correlated with Number 2 Seam of the Witbank Coalfield. The Top Coal Zone can be correlated with the Number 4 Lower Seam, Number 4 Upper Seam and Number 5 Seam of the Witbank Coalfield (Exxaro, 2011).

These two seams are separated by a sandstone interburden layer (±2m thick) named the O-sandstone.

The bottom seam consists of massive dull coal with scattered bands of lustrous coal. The average thickness of the lower seam is 8m, of which the lowest 2 m consists mainly of vitriol-rich lustrous coal. The division between the lower and middle seam is generally shale (0.4 m to 1.4 m thick). In the central part of the Witklip Section, a coal succession in a trough-like structure (graben) is evident. This reaches a maximum thickness of 18 m. The bottom seam overlies tillite that consists mainly of chert fragments, with a shale-rich matrix. The base of the coal is very uneven, possibly as a result of sinkholes in the dolomite, before and after coal deposition. At the Witklip Section of the existing Leeuwpan Coal, the capping is on average 10m thick and consists, for the most part, of clay. At the Kenbar Section, the coal is overlain by clayey and sandy weathered sediments approximately 27m thick.

The upper seam is on average 5 m thick and consists mainly of dull and lustrous coal with alternating shale bands of which the uppermost 0.5m to 0.8m consists of vitrinite-rich lustrous coal. (Exxaro, 2011).

Dolerite intrusions in the form of dykes and sills are widespread in both the Karoo Supergroup as well as the Malmani Subgroup, and are often found in the Leeuwpan Coal area. A prominent dolerite sill intrusion (±15m thick) is present at Leeuwpan and plays a significant role in the quality distribution within the coal seams due to the thermal effect, this effect is directly proportional to the position and proximity of the sill in respect to the coal seams.

This dolerite sill transgresses through the coal measures on the northern border with resource block OM and overlies the majority of the OI-resource, causing devolatilization to the top coal due to its close proximity. The sill is a competent and hard rock layer with cooling joints on the top and bottom contacts as well as within country rock. Sub vertical chlorite and calcite filled cleats are also found in the coal.

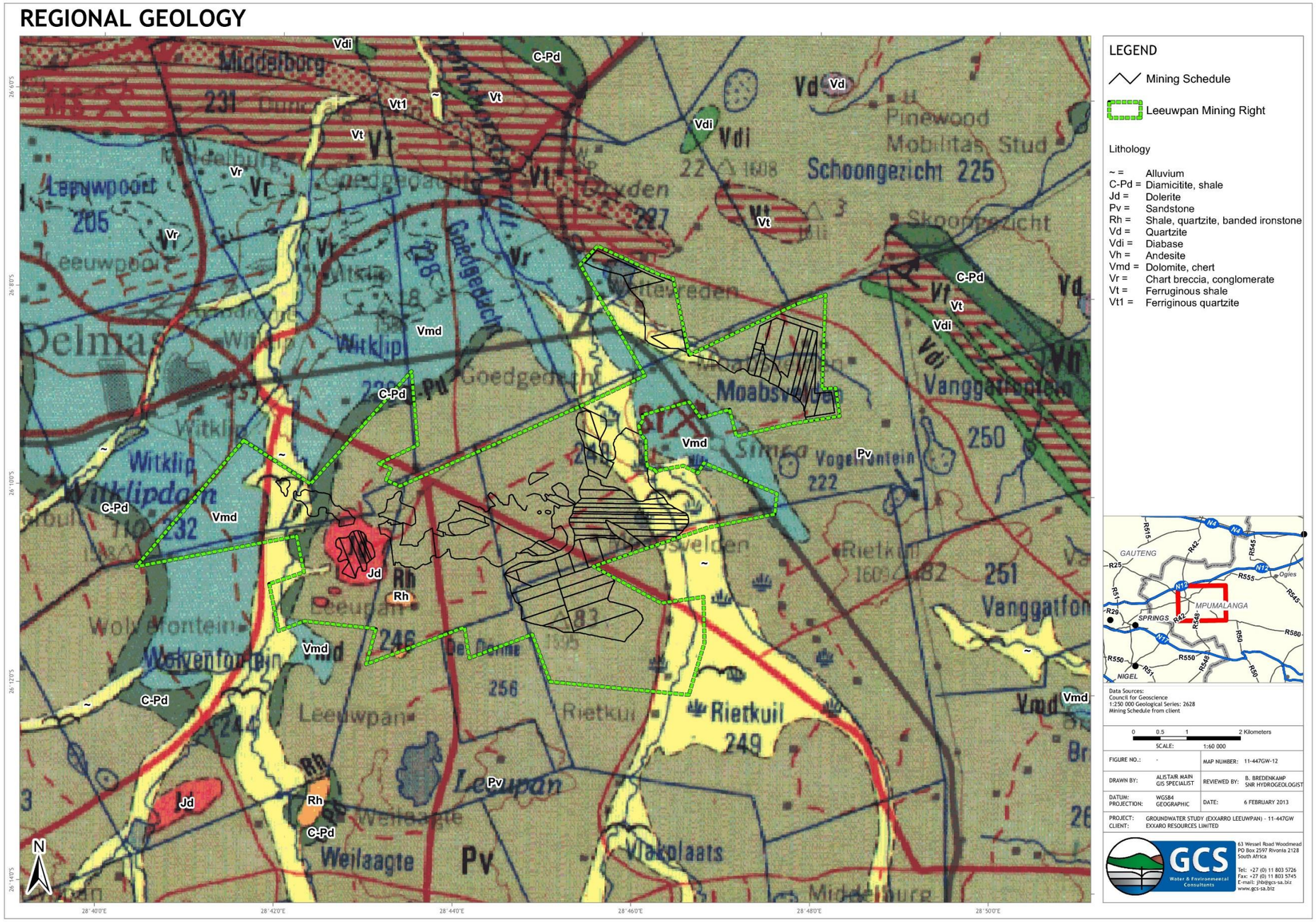


Figure 5.1: Regional Geology Map

6 HYDROGEOLOGICAL BASELINE INFORMATION

6.1 General aquifer description

There are three aquifer types or hydrogeological units present in the Leeuwpan area. These aquifers or hydrogeological units vary with regard to aquifer characteristics and are generally interconnected by fractures and faults:

- A shallow aquifer formed in the weathered zone of the Karoo sediments and which is locally perched on the fresh bedrock;
- A deeper aquifer formed by fracturing of the Karoo sediments and dolerite intrusions; and
- A fractured and karst aquifer hosted in the dolomite and chert rich Malmani Subgroup.

6.1.1 Shallow weathered Aquifer

Unconsolidated colluvium and weathered sediments overlie the consolidated formations and dolerite intrusions. The underlying mudstone and siltstone bedrock often result in perched aquifer conditions. The depth of the weathering range between 5 to 12 mbgl in the study area and experiences relatively high recharge from rainfall (3%) (Hodgson et al, 2007). The water level of this perched aquifer is shallow and may daylight as springs occasionally when intersected by barriers such as topography, dykes and basement highs in valleys and topographic lows/depressions (Hodgson et al, 2007). This aquifer is low yielding (0.01 – 0.14 l/s) due to the thickness. As a result, groundwater is rarely abstracted from this aquifer. This aquifer is important as it often acts as a pathway for contaminants migrating from surface activities to surface water bodies such as rivers.

6.1.2 Fractured Karoo rock aquifers

Most of the groundwater flow associated with mining will be along the fractures, cracks and joints that occur in Karoo Sediments and contact with dolerite intrusions. These conductive zones effectively interconnect the strata of the Karoo sediments, both vertically and horizontally into a highly heterogeneous and anisotropic unit.

The dolerite sill and dyke intrusions prevalent in the Karoo Supergroup and the study area generally act as aquitards and compartmentalize the groundwater regime. However fractured contact zones between the host rock and the intrusions often represent highly conductive groundwater flow paths. The horizontal and vertical extensive nature of the dolerite intrusions means that these conductive zones are interconnected and govern groundwater flows. The aquifer characteristics of these contact zones are heterogeneous. The newly drilled boreholes where dolerite was intersected at shallow depths did not encounter any water strikes.

The fractured Karoo aquifer can be classified as a minor (low yielding) aquifer system (Parsons, 1995) which displays variable yields and water quality. The Ecca Group is not known for the development of major aquifers, but occasional moderate - yielding boreholes may be present. This aquifer is reported to be approximately 40m thick and shows characteristics of the intergranular and fractured regime (Barnard, 1999) which indicate groundwater storage and flow occurs mainly within the fractures of the rock. Dominant yield classes vary from the 0.1 - 5.0 l/s ranges.

6.1.3 Malmani Dolomitic Aquifer

The formation consists mainly of alternating layers of chert free dolomite and chert rich dolomite (Visser, 1989). Overlying this is the Vryheid Formation of thick sandstone and gritstone alternated by sandy shale and coal beds. The Dwyka Group of the Karoo Supergroup separates the dolomitic aquifer from the Vryheid Formation. The Dwyka tillite consists of gravely diamictite with minor shale and mudstone that is less permeable than both the Vryheid Formation and the Malmani dolomite. The Dwyka is normally considered as an aquiclude. It should however be verified if this is the case in the Leeuwpan mining area, especially as a number if dykes, sinkholes and boreholes may have connected to the aquifers.

An effective depth of 300m has been accepted as the maximum depth to which significant dissolution of the dolomite has been taking place. A hydraulic conductivity that varies between 10 to 100 m/day is considered representative of the Malmani dolomite.

The Malmani Subgroup is a major aquifer system which is normally high yielding and produces good quality water. This aquifer can be classified as a karstic aquifer (Barnard, 1999), denoting cavities associated with fracturing and jointing and the groundwater yield is normally more than 5 l/s.

6.2 Hydrocensus

GCS conducted a hydrocensus in the project area during April and July 2012 within a 2 km radius of the proposed mining activities. A total of fifty nine (59) boreholes were visited of which eleven (11) boreholes formed part of the existing Leeuwpan monitoring network. Table 6.1 presents all of the boreholes visited during GCS 2012 hydrocensus investigations and Figure 6.1 shows the locations of the boreholes visited.

6.2.1 Privately Owned Boreholes

A total of 48 privately owned boreholes were identified of which 11 boreholes were not in use (see Table 6.1). Information pertaining to water use of the 48 boreholes is shown below:

- 84% of the boreholes were used for domestic, stock watering purposes and limited irrigation;
- 13 boreholes (68%) were used for large scale (central pivots) irrigational purposes. Some of these boreholes were also used for domestic and stock watering purposes.

It was evident that the boreholes are used for mainly domestic supply, small scale irrigation (gardens), livestock watering as well as large scale pivot irrigation of crops. The boreholes used for large scale irrigation exploit the dolomitic aquifer as the yields from the Karoo Supergroup are too low to sustain the high abstraction rates.

6.2.2 Leeuwpan Monitoring Boreholes

Leeuwpan Colliery has an active groundwater monitoring programme, with a number of monitoring boreholes involved including the following boreholes described in Table 6.2. A total of 18 boreholes are included in the monitoring programme of which only 12 boreholes are accessible and still usable. The monitoring at Leeuwpan is conducted by Aquatico (Pty) Ltd.

Table 6.1: Summary of Hydrocensus Boreholes

BH ID	Coordinates (WGS84 LO29)		Elev. (DEM)	SWL	Field Measurements			Uses				Farm Name	Contact	Comments
	X	Y	(mamsl)	(mbgl)	pH	EC (mS/m)	Temp. (°C)	Domestic	Livestock water	Irrigation	None			
Moa1	-23548	-2896171	1573	-	8.3	105	21	X				Moabsvelden, 248	Felix Matsenge	Borehole equipped with submersible pump.
Moa2	-24119	-2896232	1583	-	8.6	56	19.2	X				Moabsvelden, 248	Marius v. Heerden	30 m deep borehole equipped with submersible pump
Moa3	-23783	-2895786	1569	-	8.4	57	21.3			X		Moabsvelden, 248	Marius v. Heerden	Borehole yield is approximately 15 000 l/hr
Moa4	-24265	-2896188	1584	-	-	-	-				X	Moabsvelden, 248	Marius v. Heerden	
Vla 1	-23705	-2900964	1593	-	16	44	16.4	X				Vlakplaats, 268	Ferreira	Borehole yield is between 8 000 -10 000 l/hr
Rie1	-22504	-2897727	1564	-	-	-	-			X		Rietkuil, 249	Hannes Potgieter	53 m deep borehole. Borehole yield is approximately 5 000l/hr
Rie2	-22546	-2897595	1565	-	-	-	-			X		Rietkuil, 249	Hannes Potgieter	72 m deep borehole. Borehole yield is approximately 5 000l/hr
Rie3	-22683	-2897855	1571	-	7.7	84	18.6	X	X			Rietkuil, 249	Hannes Potgieter	Supply borehole is equipped with an old pump
Rie4	-23148	-2897771	1578	-	8.1	0.01	19.7	X				Rietkuil, 249	Hannes Potgieter	Supply borehole is equipped with a mono-pump. Borehole yield is approximately 5 000l/hr
Rie5	-24062	-2897221	1589	6.7	-	-	-				X	Rietkuil, 249	Hannes Potgieter	Borehole equipped with a submersible pump and has an estimated yield of approximately 20 000l/hr.
Rie6	-24822	-2897299	1593	48	-	-	-			X		Rietkuil, 249	Hannes Potgieter	Borehole is equipped with a submersible pump and 138 meters deep.
Rie7	-24748	-2897268	1593	19.6	-	-	-			X		Rietkuil, 249	Hannes Potgieter	Borehole is 94 meters deep. Cumulative yield with Rie6 is 110 000 l/hr.
Rie8	-23169	-2898716	1573	9.7	-	-	-			X		Rietkuil, 249	Hannes Potgieter	Borehole yield is approximately 15 000 litres/hr
Rie9	-23642	-2899197	1579	-	-	-	-			X		Rietkuil, 249	Hannes Vermaak	Borehole depth is 146 meters and yield is approximately 20 000 litres/hr
Rie10	-23726	-2899313	1583	-	-	-	-			X		Rietkuil, 249	Hannes Vermaak	Borehole depth is 143 meters and yield is approximately 45 000 litres/hr.
Rie11	-22953	-2899464	1578	-	7	45	17.2	X				Rietkuil, 249	Hannes Vermaak	Borehole yield is between 8 000 -10 000 l/hr
Rie13	-20806	-2897563	1566	14.9	8.3	62	19.7	X				Rietkuil, 249	Sckalekamp	
Rie14	-22383	-2900962	1571	-	8.7	55	21.8	X				Rietkuil, 249	Snyman	Borehole is equipped with a submersible pump
Rie15	-20807	-2897004	1569	-	8.8	47	20.4			X		Rietkuil, 249	Snyman	
2628BA21001	-24524	-2894301	1566	Sealed	-	-	-				X	Moabsvelden 248 PTN12	Leeuwpan Mine	Pipe cut off
ILB6	-28351	-2896710	1575	28	6.81	40	17.7	X	X			Wolvenfontein 244 PTN3	Leeuwpan Mine	
2628BA30004	-25625	-2891833	1555	34.75	-	-	-	X		X		Goedgedacht 225 PTN35	Leeuwpan Mine	
2628BA22008	-24482	-2891083	1549	-	-	-	-				X	Weltevreden 227 PTN35	Leeuwpan Mine	No water @ 60m
2628BA22001	-25859	-2894646	1577	Sealed	-	-	-					Moabsvelden 248 PTN12	Leeuwpan Mine	
2628BA22007	-24200	-2891982	1544	Sealed	7.33	54	17.5		X			Weltevreden 227 PTN35	Leeuwpan Mine	
SCGW06	-21905	-2890988	1575	Blocked	-	-	-				X	Weltevreden 227 PTN29	Leeuwpan Mine	Monitoring Borehole
SCGW01	-20992	-2891411	1580	29	8.24	12	17.9				X	Weltevreden 227 PTN6	Leeuwpan Mine	Monitoring Borehole
CBH7B	-20225	-2893676	1570	30.8	7.22	29	20.7				X	Moabsvelden, 248 PTN6	Leeuwpan Mine	Monitoring Borehole
EC1	-31595	-2895350	1560	Sealed	7.83	18	18.1	X				Eskom Camp	Leeuwpan Mine	Water supply borehole
WWF1	-30771	-2897150	1569	15	6.95	27	18.9	X	X	X		Wolwefontein	Tommie Olkers	
WK1	-31444	-2893968	1555	Sealed	-	-	-			X		Witklip	Tommie Olkers	Used in Planting Season - Everyday all day pumping
WK2	-32264	-2894081	1554	21	-	-	-		X	X		Witklip	Tommie Olkers	
WK3	-32447	-2894207	1554	-	7.15	79	16.1	X	X	X		Witklip	Tommie Olkers	Busy Pumping
WK4	-32569	-2893921	1553	19.2	-	-	-		X	X		Witklip	Tommie Olkers	
WLWF1	-28699	-2898436	1581	6.6	7.56	31	14.2	X	X	X		Wolwefontein	Jaco Oosthuyse	
WLWF2	-28397	-2898276	1581	12.9	7.17	25	17.4		X			Wolwefontein	Jaco Oosthuyse	
WLWF3	-29830	-2899147	1561	-	7.31	57	17.1			X		Wolwefontein	Jaco Oosthuyse	WLWF3 & 4 pumps into same pipe - Busy Pumping
WLWF4	-29898	-2898877	1560	14.2	-	-	-					Wolwefontein	Jaco Oosthuyse	Busy Pumping - Just switched the power off
PNR1	-29351	-2892513	1544	6	7.66	38	18.4	X		X		Pannar Seeds	Le Roux	PNR1 & 2 influence each other; PNR2 was just switched off
PNR2	-28777	-2892806	1549	10.8	7.52	34	19.8			X		Pannar Seeds	Le Roux	
PNR3	-28157	-2892233	1566	8.7	-	-	-				X	Pannar Seeds	Le Roux	
AGI1	-29572	-2892720	1545	5.5	7.99	36	16.4	X		X		Afgri	Brent Parrot	Takes 1h to fill the tanks
RSH1	-26443	-2890285	1536	25.7	-	-	-	X	X	X		Roosenhof	Francois Hoffman	All of the boreholes are connected with a pipeline that feeds >100000l dam
RSH2	-26450	-2890245	1536	24.8	-	-	-	X	X	X		Roosenhof	Francois Hoffman	RSH1, 2, 3, 4 are linked with pipeline
RSH3	-25749	-2891139	1535	27.1	5.44	15	17.5				X	Roosenhof	Francois Hoffman	
RSH4	-25639	-2891252	1535	26	-	-	-	X	X	X		Roosenhof	Francois Hoffman	
RSH5	-26846	-2891802	1564	-	-	-	-			X		Roosenhof	Francois Hoffman	Busy Pumping
RSH6	-26849	-2891712	1565	-	-	-	-				X	Roosenhof	Francois Hoffman	No Water @ 60m

*SWL – Static Water Level

Table 6.2: Existing Leeuwpan Monitoring Boreholes

Sample ID	Description	Coordinates (WGS84, LO29)		Groundwater levels
		X	Y	(mbgl)
LW07	North of Witklip	-28940	-2895277	7.6
LW08	South West of Kenbar	-27282	-2897355	15.05
LW10	*South of Delmas Silica*	*-23432*	*-2894971*	*To be mined out*
LWG01	*South of Kenbar*	*-27143*	*-2896828*	*Destroyed*
LWG04	*Moabsvelden Groundwater*	*-24432*	*-2896230*	*Blocked*
LWG02	South East of Kenbar	-26296	-2896700	29.76
EMPR02/E2	Borehole (E2)	-28299	-2894999	10.71
WTN01d	*Weltevreden Monitoring borehole-deep*	*-23459*	*-2891862*	*Dry at 35m*
WTN01s	Weltevreden Monitoring borehole-shallow	-23430	-2891800	3.61
WTN02d	Weltevreden Monitoring borehole-deep	-23069	-2893073	29.23
WTN02s	Weltevreden Monitoring borehole-shallow	-278730	-3187041	4.02
WWN01	Wolwenfontein Monitoring borehole	-28279	-2896193	2.53
WWN02d	Wolwenfontein Monitoring borehole-deep	-28169	-2896156	2.79
WWN02s	Wolwenfontein Monitoring borehole-shallow	-28169	-2896156	1.47
RKL01	Rietkuil Monitoring borehole 01	-25585	-2897302	7.9
RKL02	Rietkuil Monitoring borehole 02	-23333	-2897155	2.89
RKL03	*Rietkuil Monitoring borehole 03*	*-22930*	*-2897879*	*Blocked*
RKL04	*Rietkuil Monitoring borehole 04*	*25462*	*-2898804*	*Equipped*

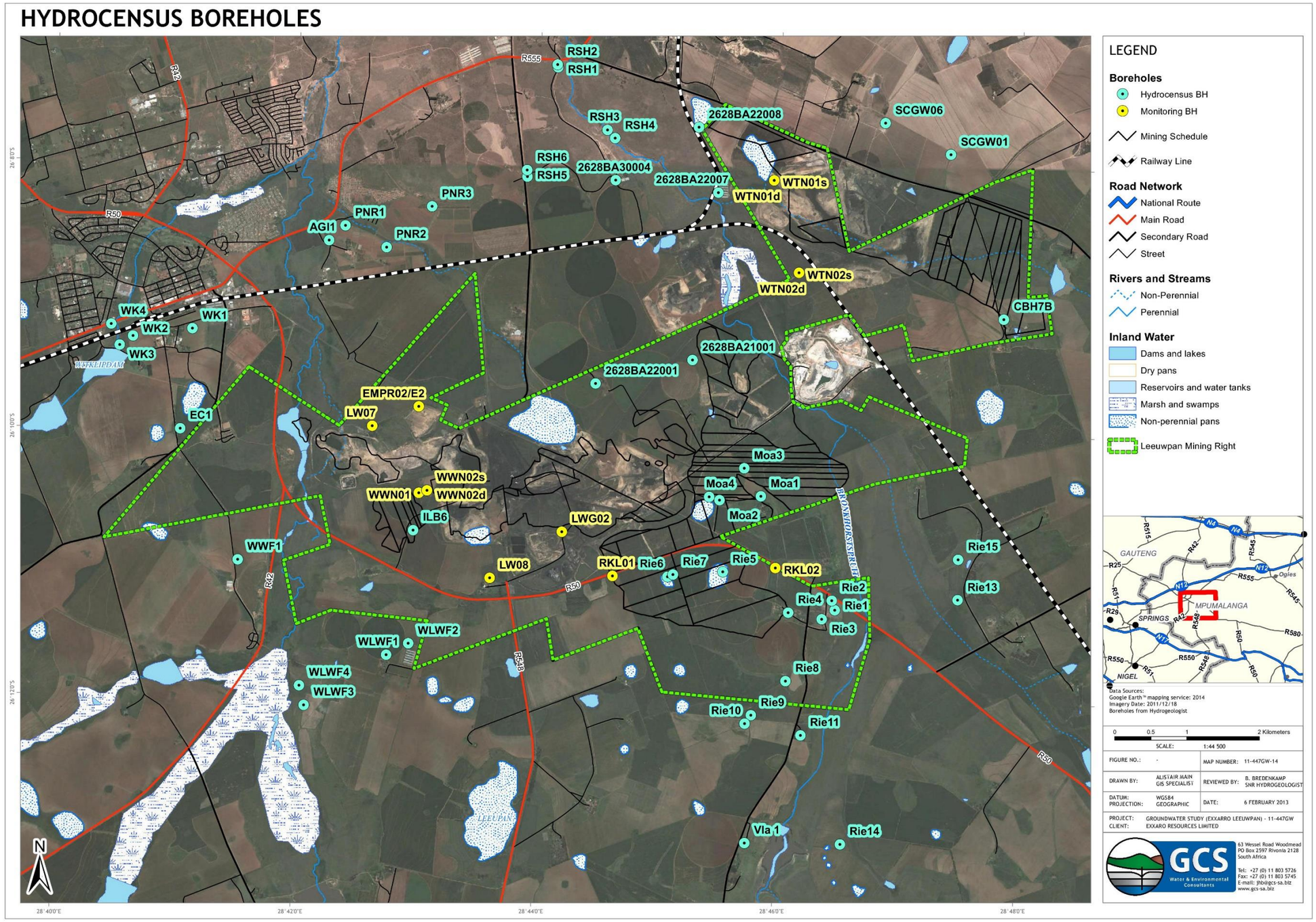


Figure 6.1: Hydrocensus Boreholes

6.3 Surface Geophysical Survey

GCS conducted a geophysical investigation between 23 October 2013 and 31 October 2013 with the intent of siting monitoring boreholes. There were some limitations during the investigation such as the presence of fences as well as power lines which caused interference with the magnetic as well as electromagnetic equipment. Drilling positions were furthermore moved based on accessibility of the drilling rigs as well as placements to comply with a monitoring system. No major anomalies were identified during the investigation.

Table 6.3 provides the details of the geophysical traverses conducted in 2013. The electrical interferences were also taken into consideration during the interpretation of the data gathered.

The results of the 2013 geophysical investigation are presented in Appendix A and Figure 6.2 shows the localities of geophysical lines conducted.

Table 6.3: Summary of Geophysical Investigation

Traverse ID	Date of Survey	Total Length (m)	Traverse Direction	Equipment Used
T1	30/10/2013	390	East-west to North-south	EM[2] & MAG[3]
T2	30/10/2013	460	North to South	EM & MAG
T6	25/10/2013	810	South east to North west	EM
T7	23/10/2013	270	East to West	EM
T9	29/10/2013	750	North east to South west	EM & MAG
T10	23/10/2013	390	South west to North east	EM
T11	31/10/2013	520	East to South west	EM & MAG
T12	31/10/2013	200	North north west to South south east	EM & MAG
T13	30/10/2013	720	South to North	EM & MAG

[2] EM – EM34-3 measuring apparent conductivity
[3] MAG -Magnetometer

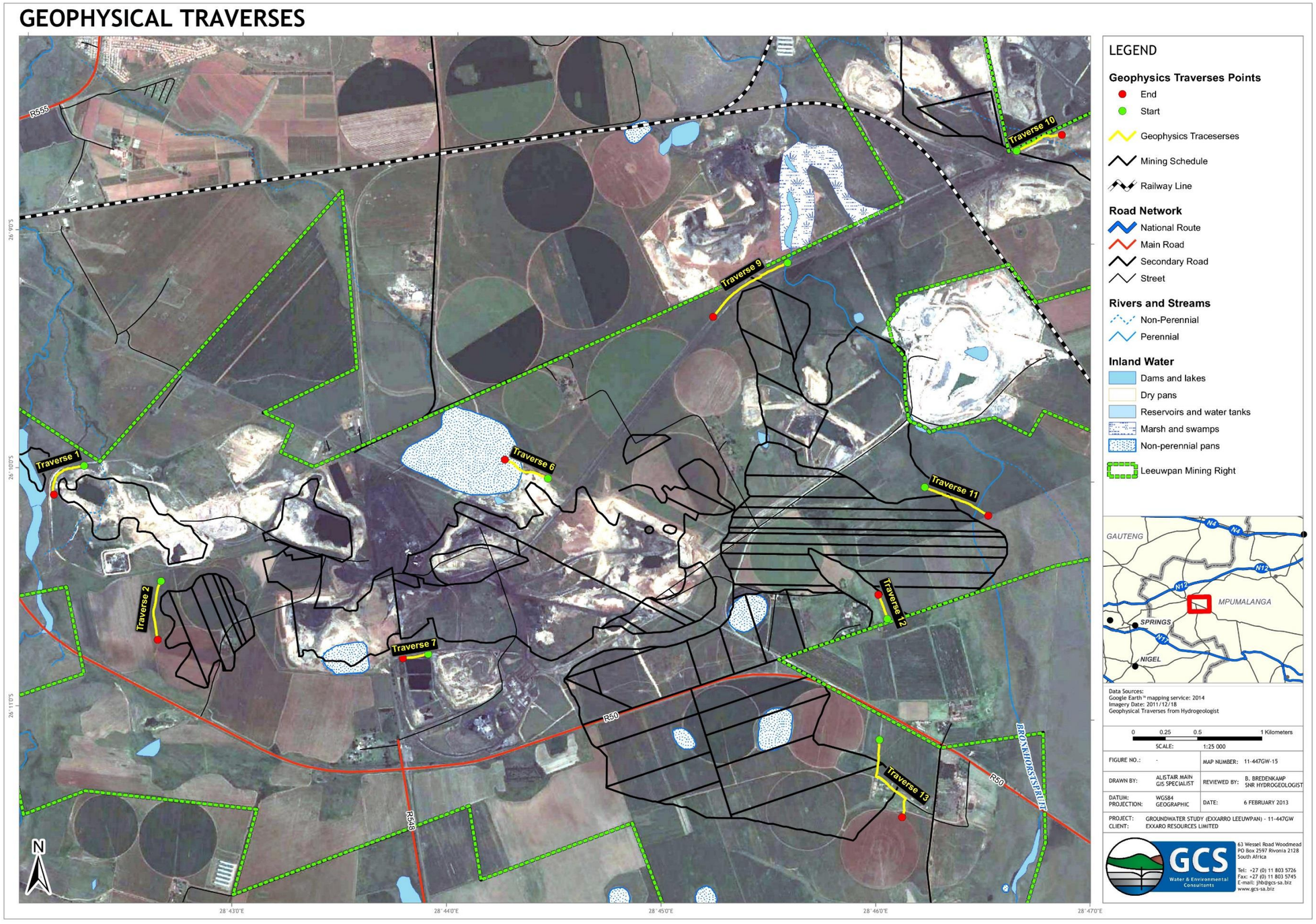


Figure 6.2: Locations of Geophysical Traverses

6.4 Installation of monitoring boreholes

Percussion drilling of seventeen (17) additional monitoring boreholes commenced on 21 November 2013 and were completed on 30 November 2013. Drilling depths ranged between 10 and 55 m. There were five (5) pairs of shallow and deep borehole combinations included in the drilling programme. The boreholes were drilled at a diameter of 203 mm to a depth with more competent rock and thereafter drilled at a diameter of 165 mm to completion. Figure 6.3 shows the localities of the newly drilled boreholes on the site.

The upper 5m up a maximum to maximum 26m consisted of clay-rich regolith of weathered Karoo mudstone and dolerite. Boreholes located on the outskirts of the site generally intersected less clay and more colluvial and tillite materials. The presence of dolerite in boreholes KENMB1, KENMB2_D, LEEMB18_D and WOLMB15_D was encountered at depths varying from 8 mbgl to 10 mbgl. A dolerite sill is likely to cover the areas near Block ODN, OD, OI, OL, and eastern portions of OWN_MN as identified by aeromagnetic data (Mahanyele, 2010). The weathered dolerite sill has weathered to clay in these areas at shallow depths. The Dwyka tillite depths across the site varied from 13 mbgl to as deep as 54 mbgl.

The water strikes intersected during the drilling program was encountered on contact zones between highly weathered rock or materials and more competent rock. No water strikes were encountered within the dolerite sill. Only 2 of the 17 boreholes had water strikes in excess of 1.5 l/s. MOAMB10 intersected water within the tillite at 26 mbgl. WITMB14 intersected 5 l/s on the contact of tillite and sandstone at 13 m. The aquifer can generally be considered a minor aquifer based on the drilling.

Table 6.4 shows a summary of the drilling programme and results and Table 6.5 shows a summary of the construction for each borehole during the drilling programme. Documented borehole logs during drilling was consolidated and presented in Appendix B.

Table 6.4: Drilling Summary

BH ID	Coordinates WGS84, LO29		Elev. (SRTM)	Date Finished	BH Depth	Water Strike	Yield	SWL
	X	Y	(mamsl)		(mbgl)	(m)	(l/s)	(mbgl)
KENMB3_D	-26967.21	-2895847.87	1577	21/11/2013	29	-	-	16.79
KENMB3_S	-26977.03	-2895839.03	1577	21/11/2013	10	-	-	7.21
MOAMB7	-24450.44	-2893907.47	1563	22/11/2013	43	-	-	35.02
KENMB2_D	-26915.09	-2896734.43	1582	22/11/2013	40	-	-	23.83
KENMB1	-26210.54	-2897024.26	1583	23/11/2013	20	-	-	19.51
KENMB2_S	-26946.18	-2896732.50	1581	25/11/2013	10	2	Seepage	9.56
LEEMB18_D	-27239.58	-2895496.90	1575	25/11/2013	29	-	-	9.71
LEEMB18_S	-27236.34	-2895504.31	1575	25/11/2013	10	-	-	9.15
WOLMB15_D	-27626.03	-2895239.12	1571	26/11/2013	25	-	-	7.73
WOLMB15_S	-27611.42	-2895244.74	1571	26/11/2013	10	-	-	7.88
WWNMB16	-28888.23	-2896643.72	1568	26/11/2013	50	17	<0.1	10.97
MOAMB9	-23301.68	-2896308.21	1571	27/11/2013	55	-	-	11.59
MOAMB10	-23468.44	-2895139.21	1557	27/11/2013	26	26	1.6	14.74
WELMB13_D	-22155.85	-2892777.94	1554	28/11/2013	24	-	-	20.12
WELMB13_S	-22175.52	-2892795.48	1554	28/11/2013	10	-	-	2.36
MOAMB4	-25613.14	-2895412.71	1583	29/11/2013	40	-	-	9.27
WITMB14	-29453.45	-2895360.47	1552	30/11/2013	16	13	5	2.44

Table 6.5: Borehole Construction Summary

BH ID	PVC (125mm)				Steel (177mm)			
	Solid		Slotted		Solid		Slotted	
	From (m)	To (m)	From (m)	To (m)	From (m)	To (m)	From (m)	To (m)
KENMB3_D	0	25.2	25.2	29	0	24		
KENMB3_S	0	2.8	2.8	10				
MOAMB7	0	28	28	43	0	18		
KENMB2_D	0	22.4	22.4	40	0	18		
KENMB1	0	8.4	8.4	20	0	18		
KENMB2_S	0	2.8	2.8	10	0	4	4	10
LEEMB18_D	0	16.8	16.8	29	0	12		
LEEMB18_S	0	2.8	2.8	10				
WOLMB15_D	0	14	14	25	0	12		
WOLMB15_S	0	2.8	2.8	10				
WWNMB16	0	28	28	50	0	14		
MOAMB9	0	25.2	25.2	55	0	12		
MOAMB10	0	14	14	26	0	12		
WELMB13_D	0	14	14	24	0	12		
WELMB13_S	0	2.8	2.8	10	0	4	4	10
MOAMB4	0	22.4	22.4	40	0	12		
WITMB14	0	7.6	7.6	16	0	12		

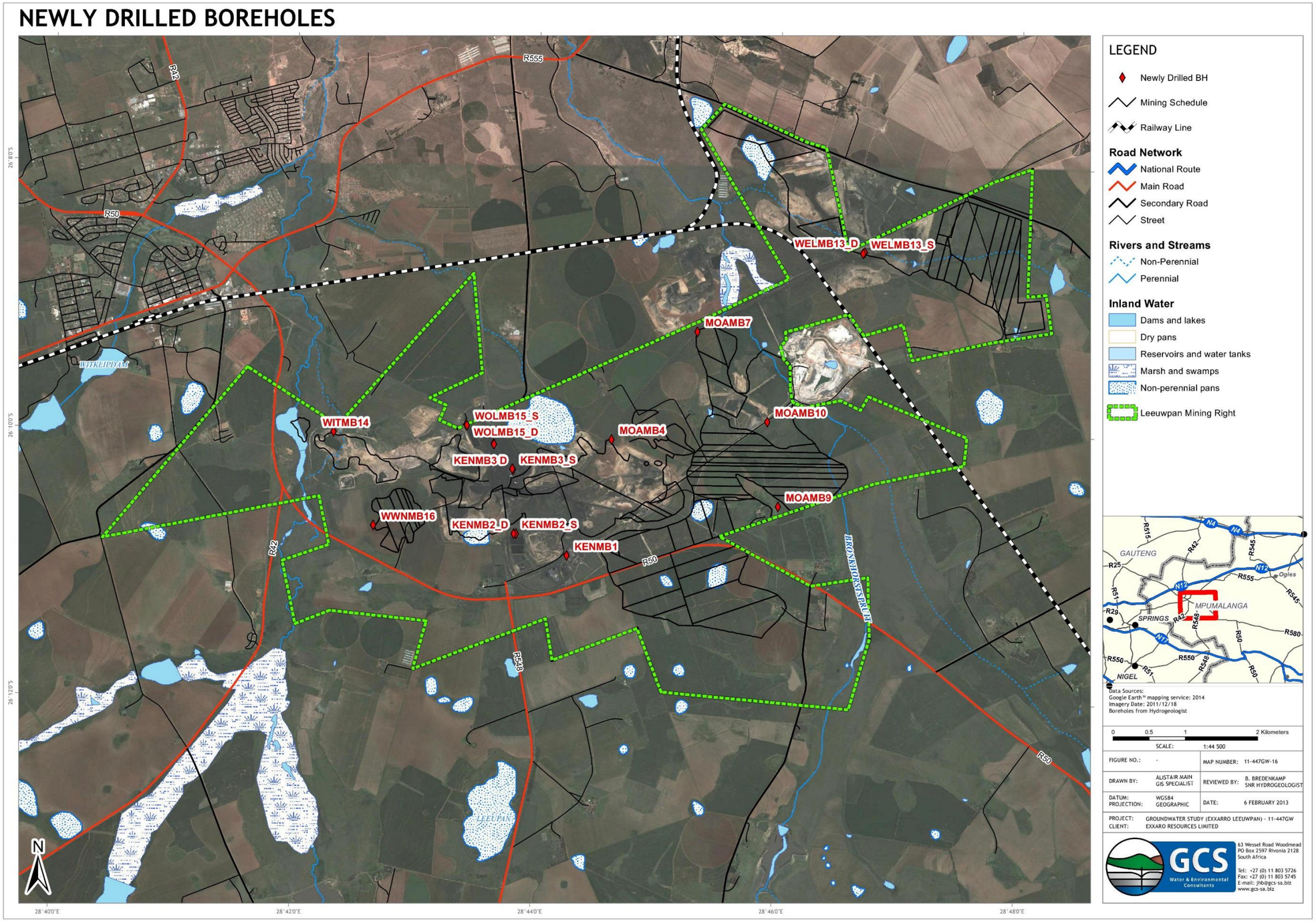


Figure 6.3: Localities of the Newly Drilled Monitoring Boreholes

6.5 Aquifer Testing

Pumping tests, consisting of constant discharge and recovery tests, were conducted on selected newly drilled monitoring boreholes at Leeuwpan. Slug tests (falling head test) were however conducted on the lower yielding boreholes. During drilling of the monitoring boreholes there were no major water strikes intersected except for WITMB1 and MOAMB9. Table 6.6 shows which tests was conducted on each borehole. Aquifer testing commenced on 4 December 2013 and completed on 13 December 2013. The water levels were measured before pump insertion and allowed to stabilize before testing commenced. The logger/diver was installed immediately above the pump to log the water levels during the tests.

Table 6.7 provides a summary of the aquifer test results. The Hvorslev, Bower & Rice and Cooper curve fitting methods were used to estimate the hydraulic conductivity, while the Cooper Jacob method was used to estimate the transmissivity of the aquifer tests. The hydraulic conductivity ranges from 0.01-0.6 m/d with a harmonic mean of ~0.05 m/d. The transmissivity ranges from 0.2 to 20 m^2/d with a harmonic mean of ~0.7 m^2/d. These values are typical of the Karoo type aquifers and correspond with the values identified in previous studies (Cleanstream Environmental Services, 2007). The data and interpretations are provided in Appendix C.

Table 6.6: Testing Methods per Borehole

Borehole	Date Tested	Test Method
MOAMB10	2013/12/04	Pump Test
MOAMB9	2013/12/06	Pump Test
KENMB2_S	2013/12/07	Falling Head Test
KENMB2_D	2013/12/07	Pump Test
KENMB3_S	2013/12/08	Falling Head Test
KENMB1	2013/12/08	Falling Head Test
WOLMB15_D	2013/12/08	Falling Head Test
WOLMB15_S	2013/12/09	Falling Head Test
LEEMB18_D	2013/12/09	Falling Head Test
MOAMB4	2013/12/12	Pump Test
WELMB13_S	2013/12/11	Falling Head Test
LEEMB18_S	2013/12/11	Falling Head Test
MOAMB7	2013/12/13	Falling Head Test
KENMB3_D	2013/12/13	Pump Test
WELMB13_D	2013/12/13	Slug Test
WWNMB16	2013/12/13	Slug Test
WITMB14	2013/12/09	Slug Test (borehole not accessible with pump test rig)

Table 6.7: Summary of Aquifer Test Results

BH ID	Hvorslev (K)	Bower & Rice (K)	Cooper (T)	Cooper Jacob (T)
	Hydraulic conductivity (m/d)		Transmissivity (m^2/d)	
MOAMB10				>20
MOAMB9				2.30
KENMB2_S	No displacement			
KENMB2_D				2.60
KENMB3_S	No displacement			
KENMB1	0.33	0.23		
WOLMB15_D	0.26	0.20		
WOLMB15_S	0.01	0.01	0.22	
LEEMB18_D	0.05	0.04	1.40	
MOAMB4				0.26
WELMB13_S	0.29	0.21		
LEEMB18_S	No displacement			
MOAMB7	No displacement			
KENMB3_D				2.20
WELMB13_D	0.15	0.10		
WWNMB16	0.60	0.60		
WITMB14	No displacement			
Harmonic mean	0.048 (m/d)		0.67 (m^2/d)	

6.6 Groundwater Levels

The water levels of mine monitoring boreholes (Table 6.2) drilled into the shallow weathered Karoo aquifer are relative shallow and ranged from 1.9 to 9.8 mbgl with an average groundwater level of 7 mbgl.

The static water levels for the boreholes representative of the deeper fractured Karoo aquifer ranged between 2.4 and 30 mbgl with the average calculated as 15 mbgl.

In the dolomitic aquifer the groundwater levels range from 5.5 to 34 mbgl and averaged at ~17 mbgl. The relatively deep water level in borehole Rie6 (48 mbgl) can be ascribed to recent abstraction that took place from this irrigation borehole.

At the time of the investigation the deep fractured Karoo aquifer boreholes LWG02, MOAMB7, WELMB13D, KENMB1 and KENMB2D were slightly affected by the drawdown cone of the existing mining activities. These boreholes are located adjacent to existing opencasts. These water levels range from 20 to 35 mbgl with an average of 25 mbgl. Borehole MOAMB7 has most likely been impacted by an adjacent mine cone of depression (water level of ~35 mbgl). Monitoring borehole (WTN01d) adjacent to the OWM_WTN Block opencast is also impacted by mining (borehole is dry at ~35 mbgl). The location of these boreholes can be seen in Figure 6.1 and Figure 6.3.

A linear correlation was observed between groundwater levels and surface topography elevations. As evident in Figure 6.4, a good correlation of groundwater levels in the shallow weathered Karoo aquifer was found (R^2 = 95%). The correlation of groundwater levels versus surface topography in the deeper fractured Karoo aquifer was poor to fair (61%) as can be expected due to heterogeneities and minor impact by mining activities. The correlation of all the boreholes grouped together is also fairly good at 84%. This evidence suggests that the groundwater levels for the area generally follow topography in the absence of anthropogenic activities in the identified aquifers.

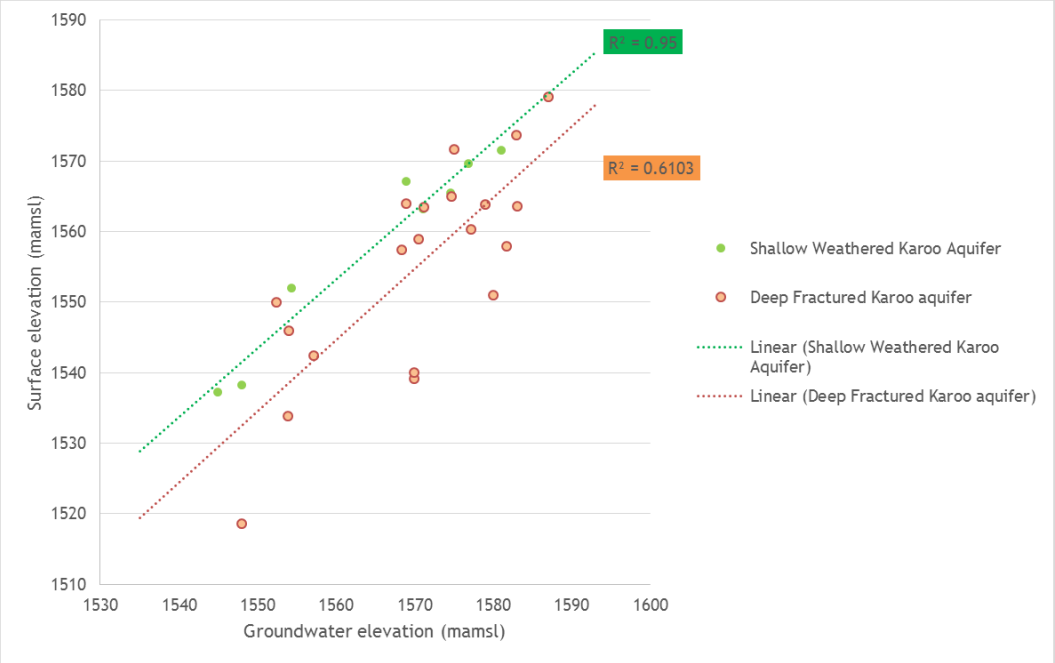


Figure 6.4: Correlation between surface elevation and groundwater level

8 GEOCHEMICAL ASSESSMENT

A total of seventeen (17) samples were collected for geochemical testing. A description of the samples is given in Table 8.1 below. The following samples were collected:

- 1 soft overburden sample;
- 1 sandstone sample;
- 3 shale samples;
- 8 coal samples;
- 2 discard samples from plant; and
- 2 mixed backfill samples (comprising discard and slurry).

With regard to the representativeness and quality control the following comments could be made:

- All accessible lithologies were sampled down to the mined coal at three locations in the mining pit. The complete litho-stratigraphical profile was sampled between the three locations; and
- For quality control purposes 3 (18%) of the 17 samples were analysed in duplicate in the acid-base accounting (ABA) test.

Table 8.1: Sample description

Sample ID	Rock Type	*	Description
Moabs Sandstone	Sandstone		Weathered sandstone
Moabs Shale	Shale		Highly carbonaceous
Moabs Nr 4U	Coal	4U	
Moabs Shale Interburden	Shale		Carbonaceous
Moabs Nr 4L	Coal	4L	
Moabs Nr. 2 Coal Sample 2	Coal	2	
Moabs Nr. 2 Coal Sample 1	Coal	2	
OH Shale	Shale		Highly weathered
OH Coal Sample 2	Coal	2	Burned coal with weathering to clay
OH Coal Sample 1	Coal	2	Burned coal
Weltevreden Soft Ovbn	Overburden		Soft overburden with remnants of rock
Weltevreden Weathered Coal	Coal	4	Weathered
LEEUWPAN ROM 1	ROM Coal		Run of mine coal
LEEUWPAN DIS W2	Discard/slurry cake /backfill		Discard and slurry backfilled into Witklip Pit
LEEUWPAN DIS W3	Discard/slurry cake /backfill		Discard and slurry backfilled into Witklip Pit
LEEUWPAN DIS P4	Discard		Discard
LEEUWPAN DIS P5	Discard		Discard

8.1 Mineralogical Composition

The mineralogical and total element compositions for 3 of the samples (Moabs Sandstone, Moabs Shale Interburden and LEEUWPAN Discard P4 samples) were determined by means of X-ray Diffraction (XRD) and X-ray fluorescence (XRF) respectively. The results are reported below as follows:

- A simplified classification of the identified minerals are listed in Table 8.2; and
- The XRD and XRF results are presented in Table 8.3 to Table 8.5 below.

The following pertains to the XRD method used:

- The samples were prepared for XRD analysis using a back loading preparation method. They were analysed with a PANalytical X'Pert Pro powder diffractometer with X'Celerator detector and variable divergence- and fixed receiving slits with Fe filtered Co-K radiation. The phases were identified using X'Pert Highscore plus software;
- Amorphous phases were not taken into account in the quantification;
- Trace minerals at concentrations below ±1% are often not detected by means of XRD testing on whole rock samples as the error might become larger than the analyses reported; and

- The weight percentages of the minerals were determined using the Rietveld method (Autoquan Program).

With regard to the mineralogy and total element composition of the samples the following comments could be made:

- Kaolinite is present as a dominant mineral in the shale and discard samples (88.71 wt% and 69.31 wt% respectively) and as a major mineral in the sandstone sample. Generally a good correlation between the ash and the kaolinite content in the coal is present in the Vryheid Formation coal. Kaolinite is generally precipitated by authigenic processes during coal formation;
- Quartz is present as a dominant mineral in the sandstone sample and as a minor mineral in the shale and discard samples. The quartz grains generally have a detrital origin and originate from the felsic mother rock;
- Microcline (K-feldspar) was detected as a minor mineral in the sandstone and discard samples but is absent from the shale sample. Generally K-feldspar occurs frequently in both coal and clastic rocks of the Vryheid Formation, although they are slightly more frequent in clastic rocks. K-feldspar forms an incomplete solution series with albite, and K-feldspar will often contain small amounts of Na;
- Plagioclase was detected in the sandstone as a minor mineral but is absent from both the shale and discard samples. In these sedimentary rocks, the plagioclase will typically be higher in its Na content than Ca. The plagioclase has a detrital origin and originate from the felsic mother rock;
- Muscovite is present as a minor mineral in the sandstone sample but is absent from both the shale and discard samples. If the muscovite is glauconitic, it is evident of marine transgressions. Glauconite characteristically forms small rounded pellets in clastic sediments deposited under marine conditions where the presence of the glauconite also colour the sediments green;
- Calcite was detected as a trace to accessory mineral in the sandstone and discard samples but is absent from the shale sample. Dolomite is present as minor mineral in the discard samples but is absent from both the sandstone and shale samples. Calcite and dolomite are important minerals in the neutralization of acidity produced by pyrite oxidation in acid-mine drainage (AMD);
- Gypsum was detected as a trace mineral (0.25 wt %) in the sandstone sample but is absent from the shale and discard samples. Gypsum is a secondary mineral that form from the precipitation of SO_4 and Ca which are typical products of pyrite oxidation and carbonate mineral dissolution respectively;
- Pyrite is a trace mineral generally the highest in the coal as it is formed under reducing conditions. Pyrite was detected as a minor mineral in the discard sample

and trace mineral in the shale samples. No pyrite was detected in the sandstone sample. Generally, pyrite can form during or very shortly after peat accumulation (authigenic) or as veins later in the coal's burial history (epigenetic);

- SiO_2 and K_2O are slightly elevated above the Average Upper Crust (AUC) of Rudnick and Gao (2003) in the sandstone samples. SiO2 elevation can be ascribed to the fact that sandstones are typically dominated by quartz minerals, while the presence of muscovite and microcline contribute to the slight elevation in K_2O;
- Kaolinite is present as the dominant mineral in the shale samples, contributing to the elevation in Al_2O_3;
- The presence of rutile, anatase or Al-silicates like kaolinite may contribute to the elevation in TiO_2. In the kaolinite Ti, as a trace element, may often replace the Al;
- Overall, few trace elements are significantly elevated above the AUC. Trace elements that are 3 - 5 times elevated include: As, Ce, Yb in discard; Mo, Nd, Sn, Th, Y, Yb in shale; and Mo and Yb in the sandstone samples;
- Trace elements that are 5 times or more elevated above the average upper crust include Cd, La, Mo and Se in the discard; and Hg, La and Se in the shale sampels; and
- Elevation above the AUC is however not an indication of the leachability of the trace elements and metals with meteoric water under field conditions. The leachability was assessed through leaching tests in Section 8.2.4 below.

Table 8.2: Description of Identified Minerals

Mineral	*	Formula	Mineral type/group	Sub-group
Calcite		$CaCO_3$	Anhydrous Carbonate	Calcite group
Dolomite		$CaMg(CO_3)_2$	Anhydrous Carbonate	Dolomite group
Gypsum		$Ca(SO_4)\cdot 2(H_2O)$	Hydrated Sulfate (Mono-hydrates)	Kieserite Group
Kaolinite		$Al_2Si_2O_5(OH)_4$	Phyllosilicate 1:1 layer	Kaolinite Group
Microcline		$KAlSi_3O_8$	Tectosilicate	K(Na,Ba) feldspar subgroup
Muscovite		$KAl_2(Si_3Al)O_{10}(OH,F)_2$	Phyllosilicate 2:1 layer	Mica Group (Muscovite subgroup)
Plagioclase		$(Na,Ca)(Si,Al)_4O_8$	Tectosilicate	Plagioclase series
Pyrite		FeS_2	Sulfides	Pyrite group
Quartz		SiO_2	Tectosilicate	Tectosilicate

* Mineral Type: Blue = Carbonates, Yellow = Sulphides and Sulphates, Red = Phyllosilicates and Green = Tectosilicates

Table 8.3: X-ray Diffraction (XRD) Results Weight %

Sample ID	Moabs Sandstone	Moabs Shale Interburden	LEEUWPAN DIS P4
Description/Rock Type	Sandstone	Shale	Discard
Calcite	0.33	-	3.60
(Error)	0.19	-	0.48
Dolomite	-	-	4.33
(Error)	-	-	0.84
Gypsum	0.25	-	-
(Error)	0.18	-	-
Kaolinite	28.55	88.71	69.31
(Error)	0.84	1.20	1.23
Microcline	14.56	-	6.76
(Error)	0.75	-	0.84
Muscovite	6.47	-	-
(Error)	0.51	-	-
Plagioclase	7.86	-	-
(Error)	0.66	-	-
Pyrite	-	0.16	5.95
(Error)	-	0.23	0.36
Quartz	41.98	11.13	10.05
(Error)	0.84	1.17	0.93

* Rock Type: Brown = Soft overburden, Orange = Sandstone, Grey = Shale, Red Brown = Discard

Table 8.4: XRF Major Oxide Results (weight %)

Oxide (%)	Moabs Sandstone	Moabs Shale Interburden	LEEUWPAN DIS P4	Average Upper Crust*
	Sandstone	Shale	Discard	
SiO_2	71.04	30.01	20.79	66.60
TiO_2	0.62	0.97	0.62	0.64
Al_2O_3	14.19	21.11	14.13	15.40
Fe_2O_3	5.21	0.66	3.69	11.20
MnO	<0.09	<0.09	<0.09	0.10
MgO	0.26	0.29	0.48	2.48
CaO	0.24	0.56	1.92	3.59
Na_2O	0.43	0.11	0.13	3.27
K_2O	3.25	0.31	0.28	2.80
P_2O_5	0.12	<0.02	0.16	0.15
Cr_2O_3	<0.04	<0.04	<0.04	See trace
SO_3	<0.35	<0.35	1.47	See trace
LOI	4.38	45.53	56.79	-
Total	100.01	99.78	100.46	-
H_2O-	0.15	2.20	2.28	-

* Rock Type: Brown = Soft overburden, Orange = Sandstone, Grey = Shale, Red Brown = Discard

* Rudnick and Gao, 2003

Table 8.5: XRF Trace Elements Results (ppm)

Trace Elements (ppm)	Moabs Sandstone	Moabs Shale Interburden	LEEUWPAN DIS P4	Average Upper Crust *
	Sandstone	Shale	Discard	
As	<5.60	<5.60	14.20	4.80
Ba	980	300	242	628
Bi	<0.80	<0.80	<0.80	0.16
Br	1.45	1.79	1.89	1.60
Cd	<1	<1	1.96	0.09
Ce	79.1	258	202	63
Cl	89.70	57.60	102	370
Co	42	<1	25.90	17.30
Cr	20.20	42.90	38.40	92
Cs	2.90	2.64	2.22	4.90
Cu	<21	26.20	33	28
Ga	24.60	29.60	22.80	17.50
Ge	<2.10	<2.10	<2.10	1.4
Hf	4.58	7.22	4.30	5.30
Hg	<0.10	0.25	<0.10	0.05
La	<18	21.10	31.50	31
Lu	1.10	1.43	1.24	0.31
Mo	1.53	1.39	5.09	1.1
Nb	8.76	29.40	16.20	12
Nd	31.20	92.40	69.50	27
Ni	44.60	8.35	30	47
Pb	32	39.20	38.70	17
Rb	138	26.70	15.80	84
Sb	<1	<1	<1	0.40
Sc	16.60	13.70	12.40	14
Se	<1	1.63	2.09	0.09
Sm	5.03	10.10	6.54	4.70
Sn	3.80	8.29	<0.80	2.10
Sr	109	91.80	262	320
Ta	<1.60	2.18	2.52	0.90
Te	<3.90	13.70	40.80	-
Th	13.40	32.70	18.90	10.50
Tl	<6.60	<6.60	<6.60	0.90
U	<4.30	5.03	5.12	2.70
V	106	214	144	97
W	4.06	3.51	2.90	1.90
Y	18	64.30	37.10	21
Yb	6.03	5.89	7.83	2
Zn	76.30	<6	13.10	67
Zr	166	361	151	193

* Rock Type: Brown = Soft overburden, Orange = Sandstone, Grey = Shale, Red Brown = Discard

* Rudnick and Gao, 2003

8.2 ABA and NAG Tests

8.2.1 ABA Terminology and Screening Methods

Acid-base Accounting (ABA) is a static test where the net potential of the rock in order to produce acidic drainage is determined. This test is an important first order assessment of the potential leachate that could be expected from the rock material. A description of the different ABA components is given below:

- If pyrite is the only sulphide in the rock the AP (Acid Potential) is determined by multiplying the %S with a factor of 31.25. The unit of AP is kg $CaCO_3$/t rock and indicates the theoretical amount of calcite neutralized by the acid produced;
- The NP (Neutralization Potential) is determined by treating a sample with a known excess of standardized hydrochloric or sulphuric acid (the sample and acid are heated to insure reaction completion). The paste is then back-titrated with standardized sodium hydroxide in order to determine the amount of unconsumed acid. NP is also expressed as kg $CaCO_3$/t rock as to represent the amount of calcite theoretically available to neutralize the acidic drainage; and
- NNP is determined by subtracting AP from NP.

In order for the material to be classified in terms of their acid-mine drainage (AMD) potential, the ABA results could be screened in terms of its NNP, %S and NP:AP ratio as follows:

- A rock with NNP < 0 kg $CaCO_3$/t will theoretically have a net potential for acidic drainage. A rock with NNP > 0 kg $CaCO_3$/t rock will have a net potential for the neutralization of acidic drainage. Because of the uncertainty related to the exposure of the carbonate minerals or the pyrite for reaction, the interpretation of whether a rock will actually be net acid generating or neutralizing is more complex. Research has shown that a range from -20 kg $CaCO_3$/t to 20 kg $CaCO_3$/t exists that is defined as a "grey" area in determining the net acid generation or neutralization potential of a rock. Material with a NNP above this range is classified as *Rock Type IV - No Potential for Acid Generation*, and material with a NNP below this range as *Rock Type I - Likely Acid Generating*;
- Further screening criteria could be used that attempts to classify the rock in terms of its net potential for acid production or neutralization. The following screening methods given in Table 8.6 below, as proposed by Price (1997), use the NP:AP ratio to classify the rock in terms of its potential for acid generation; and

- Soregaroli and Lawrence (1998) further states that samples with less than 0.3% sulphide sulphur are regarded as having insufficient oxidisable sulphides to sustain long term acid generation. Material with a %S below 0.3% is therefore classified as *Rock Type IV - No Potential for Acid Generation*, and material with a %S of above 0.3%, as *Rock Type I - Likely Acid Generating*.

Table 8.6: Screening Methods Using the NP:AP Ratio (Price, 1997)

Potential for Acid Generation	NP:AP screening criteria	Comments
Rock Type I. Likely Acid Generating.	< 1:1	Likely AMD generating.
Rock Type II. Possibly Acid Generating.	1:1 – 2:1	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides.
Rock Type III. Low Potential for Acid Generation.	2:1 – 4:1	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficient reactive NP.
Rock Type IV. No Potential for Acid Generation.	>4:1	No further AMD testing required unless materials are to be used as a source of alkalinity.

8.2.2 NAG Test Terminology and Screening Methods

In the Net-acid Generating (NAG) test hydrogen peroxide (H_2O_2) is used to oxidize sulphide minerals in order to predict the acid generation potential of the sample. The NAG test provides a direct assessment of the potential for a material to produce acid after a period of exposure (to a strong oxidant) and weathering. The test can be used to refine the results of the ABA predictions.

In general, the static NAG test involves the addition of 250 ml of 15% H_2O_2 to 2.5 g of sample in a 500 ml wide mouth conical flask, or equivalent. The sample is covered with a watch glass, and placed in a fumehood or well-ventilated area. Once "boiling" or effervescing ceases, the solution is allowed to cool to room temperature and the final pH (NAG pH) is determined. A quantitative estimation of the amount of net acidity remaining (the NAG capacity) in the sample is determined by titrating it with NaOH to pH 4.5 (and/or pH 7.0) to obtain the NAG Value.

In order to determine the acid generation potential of a sample, the screening method given in Table 8.7 of Miller et al. (1997) is used.

Table 8.7: NAG Test Screening Method (edited from Miller et al., 1997)

Rock Type	NAG pH	NAG Value (H_2SO_4 kg/t)	NNP ($CaCO_3$ kg/t)
Rock Type Ia. High Capacity Acid Forming.	< 4	> 10	Negative
Rock Type Ib. Lower Capacity Acid Forming.	< 4	≤ 10	-
Uncertain, possibly Ib.	< 4	> 10	Positive
Uncertain.	≥ 4	0	Negative (Reassess mineralogy)*
Rock Type IV. Non-acid Forming.	≥ 4	0	Positive

8.2.3 ABA and NAG Test Results

Acid-base Accounting (ABA) and Net-Acid Generating (NAG) tests were performed by *Waterlab (Pty) Ltd*. The ABA test was performed on all 17 samples and 12 samples were selected for the NAG test. The test results are presented as follows:

- The ABA results are presented in Table 8.8 below. The results above were screened as discussed in Section 8.2.1 above as *Rock Type I to IV*;
- A summary of the ABA results for the various lithologies is presented in Table 8.9;
- The potential risk of the sample to generate AMD is presented in Table 8.10 below;
- The NAG test results are presented in Table 8.11. The results above were screened as discussed in Section 8.2.2 above as *Rock Type I to IV*; and
- The classification of the sample in terms of %S and NP/AP is depicted in Figure 8.1.

From the ABA and NAG test results the following observations could be made:

- The NP/AP indicates the potential for the rock to generate acid drainage, whereas the %S indicates whether this drainage will be over the long term. In Figure 8.1 the red lines assess acid production potential, while the yellow line assesses the long term acid generation potential;
- The total S% (determined in a LECO furnace) was used to determine the Acid Potential (AP) of the rock. This is an overestimation as it assumes that all the sulphur in the rock will be acid-producing;
- The coal and discard samples have a much higher acidification potential than neutralisation potential and a high %S (average of 0.57% and 2.04% respectively)

Based on the %S and NP/AP ratio these samples have a very high potential to generate acidic drainage;

- The sandstone and soft overburden samples have a low %S and low AP with no neutralization potential. These samples have no potential for acid mine generation based on their %S and NP/AP ratio but also no significant potential to neutralise acidity generated in the mine;
- Based on the NP:AP ratio, all the samples have a possible net potential to generate acidic drainage;
- The NAG test results in Table 8.11 confirmed that the discard samples have a high potential for acid generation, while the rest of the Moabs samples are classified as uncertain or Rock Type IV;
- The sandstone and soft overburden samples have no potential for acid generation; and
- Overall, the samples have a high acidification potential with the worst case assumptions that 1) all sulphur are from sulphides and 2) pyrite is the only sulphide present.

Table 8.8: Acid-Base Accounting (ABA) Results

Sample ID	*	Paste pH	Total %S	AP CaCO3 kg/t	NP CaCO3 kg/t	NNP CaCO3 kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
Moabs Sandstone		6.9	0.01	0.31	0.00	-0.31	0.00	Uncertain	IV	I
Moabs Shale		4.3	0.51	15.94	0.00	-15.94	0.00	Uncertain	I	I
Moabs Nr 4U	4U	7.1	0.18	5.63	16.33	10.71	2.90	Uncertain	II	III
Moabs Shale Interburden		7.4	0.11	3.44	2.05	-1.39	0.60	Uncertain	II	I
Moabs Nr 4L	4L	6.8	0.20	6.25	7.66	1.41	1.23	Uncertain	II	II
Moabs Nr. 2 Coal Sample 2	2	6.7	2.98	93.13	14.04	-79.09	0.15	I	I	I
Moabs Nr. 2 Coal Sample 1	2	7.4	0.19	5.94	7.15	1.21	1.20	Uncertain	II	II
OH Shale		6.9	0.01	0.31	0	-0.31	0.00	Uncertain	IV	I
OH Shale (D)		7.0	0.01	0.31	0	-0.31	0.00	Uncertain	IV	I
OH Coal Sample 2	2	7.0	0.03	0.94	0	-0.94	0.00	Uncertain	IV	I
OH Coal Sample 1	2	6.8	0.32	10.00	0	-10.00	0.00	Uncertain	I	I
Weltevreden Soft Ovbn		5.7	0.01	0.31	0	-0.31	0.00	Uncertain	IV	I
Weltevreden Weathered Coal		5.4	0.17	5.31	0	-5.31	0.00	Uncertain	II	I
Weltevreden Weathered Coal (D)		5.8	0.17	5.31	0	-5.31	0.00	Uncertain	II	I
LEEUWPAN ROM 1		7.0	0.49	15.31	16.01	0.70	1.05	Uncertain	I	II
LEEUWPAN DIS W2		7.1	0.97	30.31	10.08	-20.23	0.33	IV	I	I
LEEUWPAN DIS W3		7.3	0.87	27.19	19.39	-7.74	0.71	IV	I	I
LEEUWPAN DIS P4		7.6	2.72	84.87	21.50	-63.38	0.25	IV	I	I
LEEUWPAN DIS P5		7.4	3.58	111.9	13.36	-98.56	0.12	IV	I	I
LEEUWPAN DIS P5 (D)		7.3	3.58	111.8	12.88	-99.00	0.12	IV	I	I

* Rock Type: Brown = Soft overburden, Orange = Sandstone, Grey = Shale, Red Brown = Discard

Table 8.9: Acid-Base Accounting (ABA) Results Average for Different Lithologies

Lithology	Total	Total %S	AP $CaCO_3$ kg/t	NP $CaCO_3$ kg/t	NNP $CaCO_3$ kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
Coal	8	0.57	17.81	7.65	-10.16	0.82	Uncertain	I	I
Shale	3	0.21	6.56	1.03	-5.54	0.16	Uncertain	IV	I
Sandstone	1	0.01	0.31	0.00	-0.31	0.00	Uncertain	IV	I
Overburden	1	0.01	0.31	0	-0.31	0.00	Uncertain	IV	I
Discard	4	2.04	63.60	16.08	-47.51	0.35	I	I	I

Table 8.10: Potential Risk of Samples to Generate Acidic Drainage

Criteria	Number of samples	Rock Type (%S) I Rock Type (NP/AP) I or II	Rock Type (%S) I Rock Type (NP/AP) III or IV	%S 0.1 - 0.3 Rock Type (NP/AP) I or II	%S 0.1 - 0.3 Rock Type (NP/AP) III or IV	%S <0.1 Rock Type (NP/AP) I or II	%S <0.1 Rock Type (NP/AP) III or IV
Coal	8	38	0	38	13	13	0
Sandstone	1	0	0	0	0	100	0
Shale	3	33	0	33	0	33	0
Overburden	1	0	0	0	0	100	0
Discard	4	100	0	0	0	0	0
Potential for acid mine drainage		High potential for acid generation. High salt load.	Low to high potential for acid generation. Low to high salt load.	Low to medium potential for acid generation. Low to medium salt load.	Low potential for acid generation. Low salt load.	No potential for acidic drainage Very low/no salt load.	No potential for acidic drainage. Very low/no salt load.

Table 8.11: Net Acid Generation (NAG) Test Result

Sample ID	Description/ Rock Type	*	NAG pH: (H_2O_2)	Titration with NaOH	Final pH: (H_2O_2)	NAG (kgH_2SO_4 /t)	NNP ($CaCO_3$ kg/t)	Rock Type
Moabs Sandstone	Sandstone		5.5	<0.01	5.5	<0.01	-79.09	Uncertain
Moabs Shale	Shale		4.2	2.30	4.6	4.51	-15.94	Uncertain
Moabs Nr 4U	Coal		3.6	12.60	4.5	24.70	10.71	Uncertain, possibly Ib.
Moabs Shale Interburden	Shale		6.8	<0.01	6.8	<0.01	-0.31	Uncertain
Moabs Shale Interburden (D)	Shale		6.7	<0.01	6.7	<0.01	-1.39	Uncertain
Moabs Nr 4L	Coal		4.2	3.80	4.5	7.45	1.41	IV
LEEUWPAN ROM 1	Run of mine		7.1	<0.01	7.1	<0.01	0.70	IV
LEEUWPAN DIS W2	Discard/slurry cake /backfill		4.5	<0.01	4.5	<0.01	-20.23	Uncertain
LEEUWPAN DIS W3	Discard/slurry cake /backfill		6.1	<0.01	6.1	<0.01	-7.80	Uncertain
LEEUWPAN DIS P4	Discard		2.6	7.40	4.6	14.50	-63.50	Ia
LEEUWPAN DIS P5	Discard		2.1	27.10	4.5	53.12	-98.52	Ia
LEEUWPAN DIS P5 (D)	Discard		2.1	23.20	4.5	45.47	-99.00	Ia

* Rock Type: Brown = Soft overburden, Orange = Sandstone, Grey = Shale, Red Brown = Discard

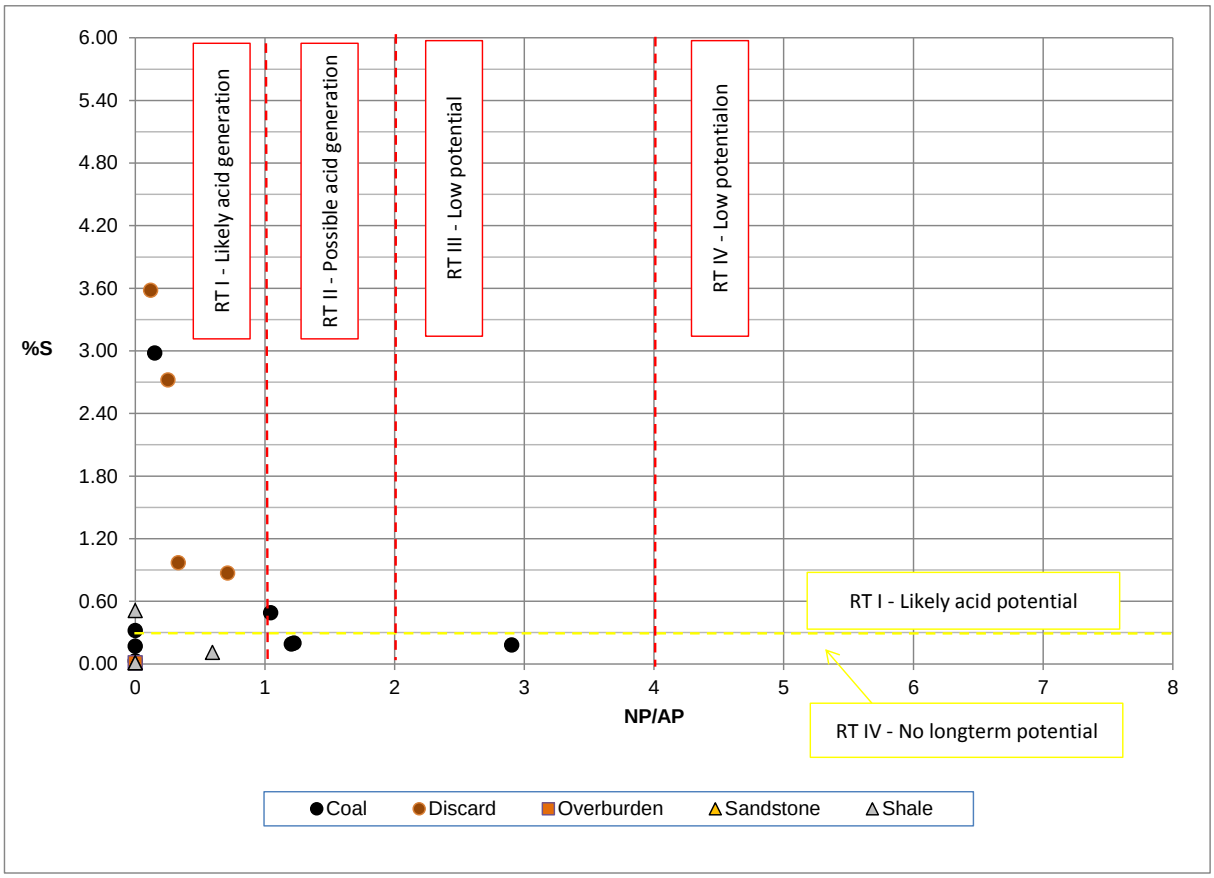


Figure 8.1: Classification of samples in terms of %S and NP/AP

8.2.4 Static Leaching Test

Selected material was submitted for leach testing. System parameters and anions measured in the leachate are listed in Table 8.12, with the ICP-OES analytical results listed in Table 8.13. The following pertain to the leaching test method used:

- Leaching tests were performed by *Waterlab (Pty) Ltd, Pretoria*;
- The material was leached by means of peroxide extraction; and
- For the peroxide extraction a rock/water ratio of 1:100 was used where 4 g of the sample was reacted with 400 ml of 15% hydrogen peroxide.

From the leaching test results the following comments could be made:

- Leaching tests identify the elements that will leach out of waste but do not reflect the site-specific concentration of these elements in actual seepage since a different 1) water/rock ratio and 2) contact time will be present in the field. Kinetic leach testing will give a better quantification than static leach test of the chemicals that may potentially leach out of the rock;

- It is also important to note that the peroxide extraction simulates extreme conditions where all the sulphides is oxidised at once, which will never happen under field conditions. Under field conditions 1) not all sulphides will be oxidised as some minerals are physically shielded by the rock matrix, and 2) oxidation will occur over a longer period of time;
- SO_4 is the only anion that was elevated in the leachate. The elevation of SO_4 is a direct result of the sulphide oxidation. High %S and AP, especially in the discard samples contribute to the elevated SO_4 and acidity. Figure 8.2 shows a positive correlation between the SO_4 leached from the samples and %S;
- The sandstone sample has a near-neutral pH value (6.7) which shows that the sandstone does not have a ready available net acidity. The shale samples have a pH of 7.1 and 5.2. The Moabs shale sample has a high acid potential and no neutralization potential contributing a lower pH of 5.2. Both the discard samples have higher acidification potential than neutralization potential producing lower pH values (5 and 2.9 respectively). The LEEUWPAN Discard P4 sample has an AP almost 4 times higher than the NP resulting in a very low pH of 2.9; and
- Samples with a lower pH (the samples with the highest Net Acid Potential, i.e. shale and discard) leached more metal/ trace elements. These elements include Al, As, Cr, Fe, Mn, Ni, and V.

Table 8.12: System Parameters, Major Anions in Peroxide Leach Extraction Test

Sample ID	Description/ Rock Type	*	pH (value)	EC (mS/m)	TDS (mg/l)	Total Alkalinity (mg/l)	SO_4 (mg/l)	NO_3 (mg/l)	Cl (mg/l)	F (mg/l)
Moabs Sandstone	Sandstone		6.7	3	20	<5	<5	0.40	6	<0.20
Moabs Shale	Shale		5.2	37.40	251	<5	150	<0.20	<5	<0.20
Moabs Shale Interburden	Shale		7.1	35.80	240	52	40	0.90	5	<0.20
LEEUWPAN DIS W2	Discard/slurry cake /backfill		5	106	710	36	258	2.20	6	<0.20
LEEUWPAN DIS P4	Discard		2.9	168	1 126	<5	721	<0.20	<5	<0.20
SANS 241:2011	0-50% of limit		6 - 8.4	<85	<600	-	<250	<5.5	<150	<0.75
	50-100% of limit		5-6; 8.4-9.7	85-170	600-1200	-	250-500	5.5-11	150-300	0.75-1.5
	Above limit		<5 ; >9.7	>170	>1200	-	>500	>11	>300	>1.5

* Rock Type: Brown = Soft overburden, Orange = Sandstone, Grey = Shale, Red Brown = Discard

Table 8.13: ICP-OES Results of the Peroxide Extraction Test

Sample ID	Moabs Sandstone		Moabs Shale		Moabs Shale Interburden		LEEUWPAN DIS W2		LEEUWPAN DIS P4		SANS 241:2011		
	Sandstone		Shale		Shale		Discard		Discard		0-50% of limit	50%-100% of limit	Above limit
	(mg/l)	(mg/kg)	(mg/l)	(mg/kg)	(mg/l)	(mg/kg)	(mg/l)	(mg/kg)	(mg/l)	(mg/kg)			
Ag	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	-	-	-
Al	0.403	40	3.590	359	0.199	20	6.220	622	4.870	487	<0.15	0.15-0.3	>0.3
As	<0.010	<1.000	<0.010	<1.000	<0.010	<1.000	<0.010	<1.000	0.032	3.200	<0.005	0.005-0.01	>0.01
B	<0.025	<2.500	0.130	13	0.124	12	0.270	27	0.105	11	-	-	-
Ba	<0.025	<2.500	<0.025	<2.500	0.927	93	0.578	58	0.146	15	-	-	-
Be	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	-	-	-
Bi	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	-	-	-
Ca	<2	<200	10	1000	22	2200	31	3100	104	10400	-	-	-
Cd	<0.005	<0.500	<0.005	<0.500	<0.005	<0.500	<0.005	<0.500	<0.005	<0.500	<0.0015	0.0015-0.003	>0.003
Co	<0.025	<2.500	0.184	18	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.25	0.25-0.5	>0.5
Cr	<0.025	<2.500	0.034	3.400	0.257	25.700	0.219	22	<0.025	<2.500	<0.025	0.025-0.05	>0.05
Cu	<0.025	<2.500	0.169	17	<0.025	<2.500	0.121	12	0.052	5.200	<1	1-2	>2
Fe	0.305	31	23	2300	<0.025	<2.500	12	1200	144	14400	<1	1-2	>2
K	<1.0	<100	1.300	130	1.600	160	1.700	170	1.300	130	-	-	-
Li	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	-	-	-
Mg	<2	<200	6	600	9	900	17	1700	25	2500	-	-	-
Mn	0.026	2.600	8.050	805	<0.025	<2.500	1.190	119	0.804	80	<0.25	0.25-0.5	>0.5
Mo	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	0.043	4.300	-	-	-

Sample ID	Moabs Sandstone		Moabs Shale		Moabs Shale Interburden		LEEUWPAN DIS W2		LEEUWPAN DIS P4		SANS 241:2011		
	Sandstone		Shale		Shale		Discard		Discard		0-50% of limit	50%-100% of limit	Above limit
	(mg/l)	(mg/kg)	(mg/l)	(mg/kg)	(mg/l)	(mg/kg)	(mg/l)	(mg/kg)	(mg/l)	(mg/kg)			
Na	<2	<200	<2	<200	<2	<200	4	400	<2	<200	<100	100-200	>200
Ni	<0.025	<2.500	0.260	26	<0.025	<2.500	0.204	20	<0.025	<2.500	<0.035	0.035-0.07	>0.07
P	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	-	-	-
Pb	<0.020	<2.000	<0.020	<2.000	<0.020	<2.000	<0.020	<2.000	<0.020	<2.000	<0.005	0.005-0.01	>0.01
S	<0.100	<10	105	10500	22	2200	109	10900	280	28000	<0.01	-	-
Sb	<0.010	<1.000	<0.010	<1.000	<0.010	<1.000	<0.010	<1.000	<0.010	<1.000	<0.005	0.01-0.02	>0.02
Se	<0.020	<2.000	<0.020	<2.000	<0.020	<2.000	<0.020	<2.000	<0.020	<2.000	-	0.005-0.01	>0.01
Si	3.800	380	3.800	380	2.500	250	3.800	380	2.300	230	-	-	-
Sn	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	0.041	4.100	<0.025	<2.500	-	-	-
Sr	<0.025	<2.500	0.062	6.200	0.429	43	0.512	51	0.463	46	-	-	-
Ti	0.068	6.800	<0.025	<2.500	<0.025	<2.500	0.206	21	<0.025	<2.500	-	-	-
V	<0.025	<2.500	<0.025	<2.500	0.391	39	<0.025	<2.500	<0.025	<2.500	<0.1	0.1-0.2	>0.2
W	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	-	-	-
Zn	<0.025	<2.500	0.591	59	<0.025	<2.500	0.699	70	0.405	41	<2.5	2.5-5.0	>5
Zr	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	<0.025	<2.500	-	-	-

* Rock Type: Brown = Soft overburden, Orange = Sandstone, Grey = Shale, Red Brown = Discard

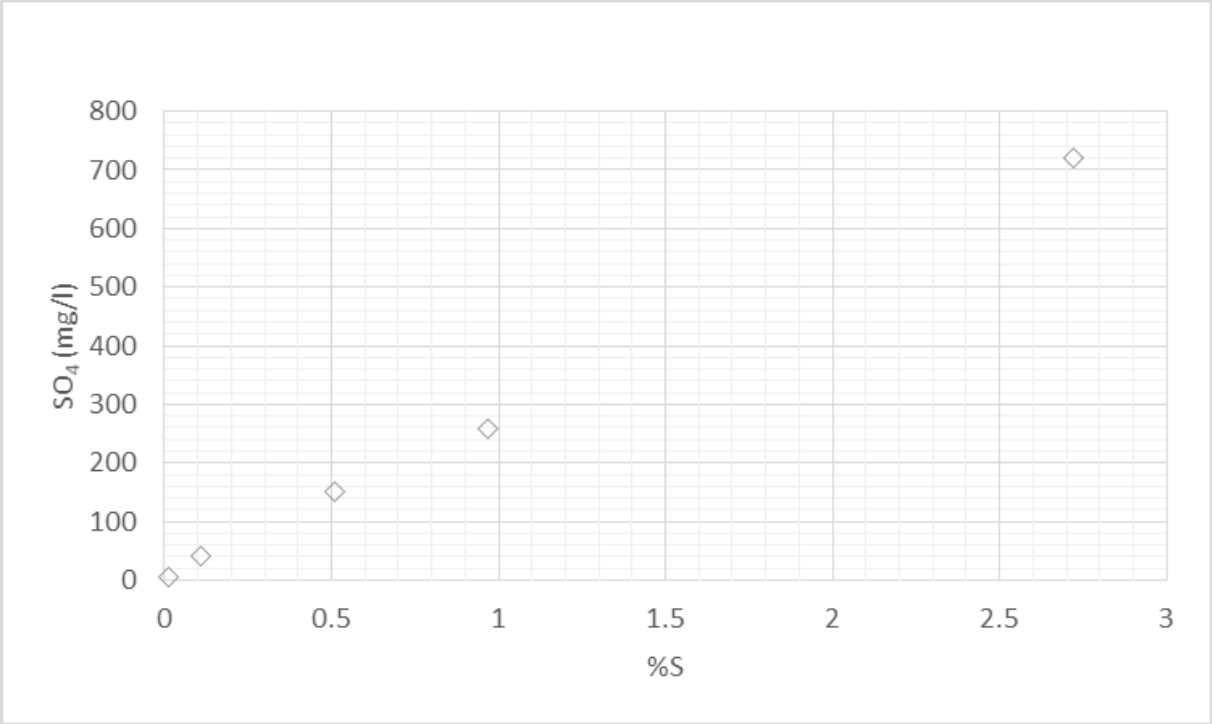


Figure 8.2: Correlation between SO_4 Leached from the Samples and %S

8.3 Discussion

From the results of the study a first order impact assessment was performed. An environmental impact assessment is inherently a prediction of eventualities which could possibly/probably occur in future, based on an interpretation/assessment of data/information available at the time of compilation of such an assessment.

8.3.1 Conditions Required for Acid Mine Drainage

The following comments relate to acid mine drainage in general:

- The impact on drainage from a mine or mining waste depends on the interaction between the 1) solid, 2) water, and 3) air phase;
- The degree of acid-mine drainage will depend on the minerals present in order to generate or neutralize acidic drainage, as well as the interaction of the minerals with the oxygen and water;
- Without any of these three phases no acid mine drainage will be possible. For instance, if a mine is sealed off from the atmosphere then no oxygen ingress is possible with no resultant oxidation of sulphides; and

- If oxygen is present, but no sulphides, then mine drainage will most likely not become acidic. However, some metals may still leach at near-neutral conditions from material but at a much lower concentration than in acidic drainage.

The following comments relate to the water and oxygen ingress into the opencasts:

- During the operational phase, water is pumped from the opencasts in order to keep the pit dry. The pumped-out water has a low residence time in the pit (short contact period with rock) and no significant increase in the salt load will occur in the pit water;
- After closure the pit water level will rise until it reaches the surface decant elevation;
- The pit backfill above the decant elevation will be unsaturated after closure;
- Sulphide oxidation will occur in the unsaturated zone as a result of oxygen infiltration. According to the ABA test results the waste rocks have a variable potential to generate net acidity. The sandstone and shale samples have low potential for acid generation and discard samples have a higher potential to generate acidity;
- A conceptual model of the physico-chemical processes that occur in mining waste in contact with atmosphere is depicted in Figure 8.3 below;
- Consumption of oxygen will lead to a gradient in oxygen fugacity in the material that initiates oxygen diffusion (flow from high concentration to low concentration). The oxygen concentration will be at its highest in material directly in contact with the atmosphere, and due to its consumption, the oxygen concentration will gradually become depleted within only a few meters; and
- Initially only the upper part of the material will be situated in the oxidation zone. The oxidation zone will shift deeper into the material as sulphide minerals are depleted. The temperature in the material will eventually rise due to the oxidation of sulphides. Temperature differences will result in differences in gas pressure that initiate the process of oxygen advection.

From the above discussion the following conclusion could be made:

- Acid-mine drainage will occur in the opencast mines as the material contain inadequate neutralisation potential and some contain sufficient sulphides for net acid generation (i.e. the shale and discard); and
- It is not foreseen that metals will significantly be present in neutral drainage. Al, Fe, Mn will be present at elevated concentrations in acidic mine drainage. Other metals that may leach in acidic drainage include Cr, Ni and to a lesser degree As and V.

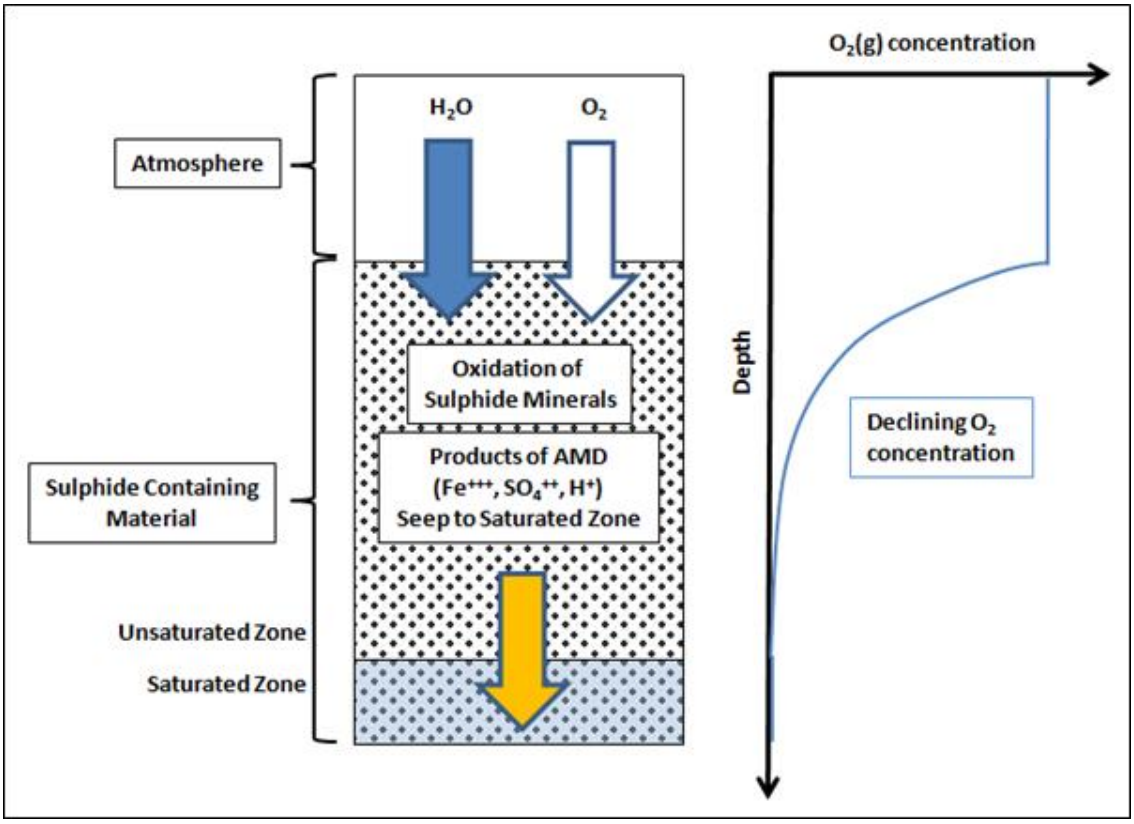


Figure 8.3: Conceptual Model of the Physico-chemical Processes in Mining Waste in Contact with the Atmosphere

8.3.2 Geochemical Reactions

The following observations relate to the geochemical reactions in the mine material:

- Fe is inherently associated with pyrite. The reaction of Fe^{2+} in solution under the presence of oxygen at neutral to alkaline conditions is presented in Equation 1 below. Fe^{2+} produced from the sulphide oxidation will hydrolize to form $Fe(OH)_3$ and 2 mol adicity (Equation 1);

$$Fe^{2+} + 2.5H_2O + 0.25O_{2(aq)} \rightarrow Fe(OH)_{3(ppd)} + 2H^+ \qquad \text{Equation 1}$$

- Pyrite (FeS_2) is present in all the rock material tested. The net dissolution reaction of pyrite under neutral to alkaline oxidising conditions will form 4 mol of acidity (Equation 3). The intermediate reaction where Fe^{2+} is first formed is also shown below (Equation 2);

$$\text{pyrite} + 3.5O_2(aq) + H_2O \rightarrow Fe^{++} + 2SO_4^{2-} + 2H^+ \qquad \text{Equation 2}$$

$$\text{pyrite} + 3.75O_2(aq) + 3.5H_2O \rightarrow Fe(OH)_3(ppd) + 2SO_4^{2-} + 4H^+ \qquad \text{Equation 3}$$

- Water serves as the transport medium for the product of acid-mine drainage (AMD) as it percolates through the mine/waste material. The water phase also serves as the medium in which dissolution of neutralizing minerals can take place. The acid produced by the oxidation of the sulphide minerals will be consumed by calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) present in the rock. The neutralization reactions under neutral to alkaline conditions are given in Equation 4 and 5 below:

  calcite + $H^+ \rightarrow HCO_3^- + Ca^{++}$ Equation 4

  dolomite + $2H^+ \rightarrow 2HCO_3^- + Ca^{2+} + Mg^{2+}$ Equation 5

- Under increasing acid production (pH < 6.3) calcite and dolomite will consume additional acidity according to Equation 6 and 7 below:

  calcite + $2H^+ \rightarrow CO_2(g) + Ca^{2+} + H_2O$ Equation 6

  dolomite + $4H^+ \rightarrow 2CO_2(g) + Ca^{2+} + Mg^{2+} + 2H_2O$ Equation 7

- Together wil SO_4 the Ca^{2+} produced will form gypsum ($CaSO_4 \cdot 2H_2O$) as follows:

  $Ca^{2+} + 2H_2O + SO_4^{2-} \rightarrow$ gypsum Equation 8

- The formation of gypsum will help to keep SO_4 values below 2 500mg/l in drainage water. However, if Ca is produced too slowly, the SO_4 concentration may reach even higher values;
- If all the carbonate minerals are depleted then the drainage from the mine material becomes acidic. Silicate minerals can also consume some of the acidity. However, silicate minerals react too slowly to prevent acidication in material with a significant potential to generate acidic drainage; and
- In acidic seepage, metals will also be leached out at elevated concentrations and the final stage of AMD would have been reached.

8.3.3 Expected Non-compliance in Drainage Water

The following methodology was followed in order to determine the expected non-compliance in drainage from the mine:

- The results from the ABA and leaching tests were used in order to determine expected non-compliance that may occur in seepage and pit water; and
- Generally, good correlation could be found between leaching test results and drainage from mine waste material. However, care must always be taken to interpret leaching test results for the following reasons:
  - The same water/rock ratio is not present in leaching tests than under field conditions;
  - The same water/rock contact time is not present in leaching tests than under field conditions;

- It is assumed that the sample tested is representative of the waste material.

The following comments relate to the expected non-compliance of drainage/seepage from the mine material and discard:

- The drainage from the opencast backfill will become acidic over the long-term as the ABA results show that the material has the potential to generate acid-mine drainage. The sandstone and soft overburden have no potential for acidic generation. The shale samples show a great variance in net acidic generation, but may have a potential for acidic generation;
- Elevation of TDS and SO_4 will occur as a result of pyrite oxidation. In the open cast the SO_4 will increase roughly to about 2 500 – 3 500 mg/l over the long term;
- It is not foreseen that significant elevation in metals will occur at near-neutral conditions. After acidification non-compliance for Al, Fe and Mn may occur; and
- Cr, Ni and to a lesser degree As and V are some of the other trace elements that may be slightly elevated and may reach occasional marginal to non-compliance.

9 GROUNDWATER QUALITY

A total of 41 groundwater samples were assessed, taken from the hydrocensus and mine monitoring boreholes (existing and newly drilled). The analytical results were compared to the Department of Water Affairs' South African Water Quality Guidelines for Domestic Use Target Values (DWA SAWQTV) and South Africa National Standard (SANS 241-1:2011) Drinking Water Standard in order to evaluate the groundwater quality. The average background groundwater quality was also included in the analytical result tables for comparative purposes. The analytical results can be seen in Table 9.1 to Table 9.3. The baseline groundwater characteristics were presented with a Piper- and Stiff diagrams (Figure 9.2 and Figure 9.7) for the analytical results of groundwater collected from hydrocensus and monitoring boreholes.

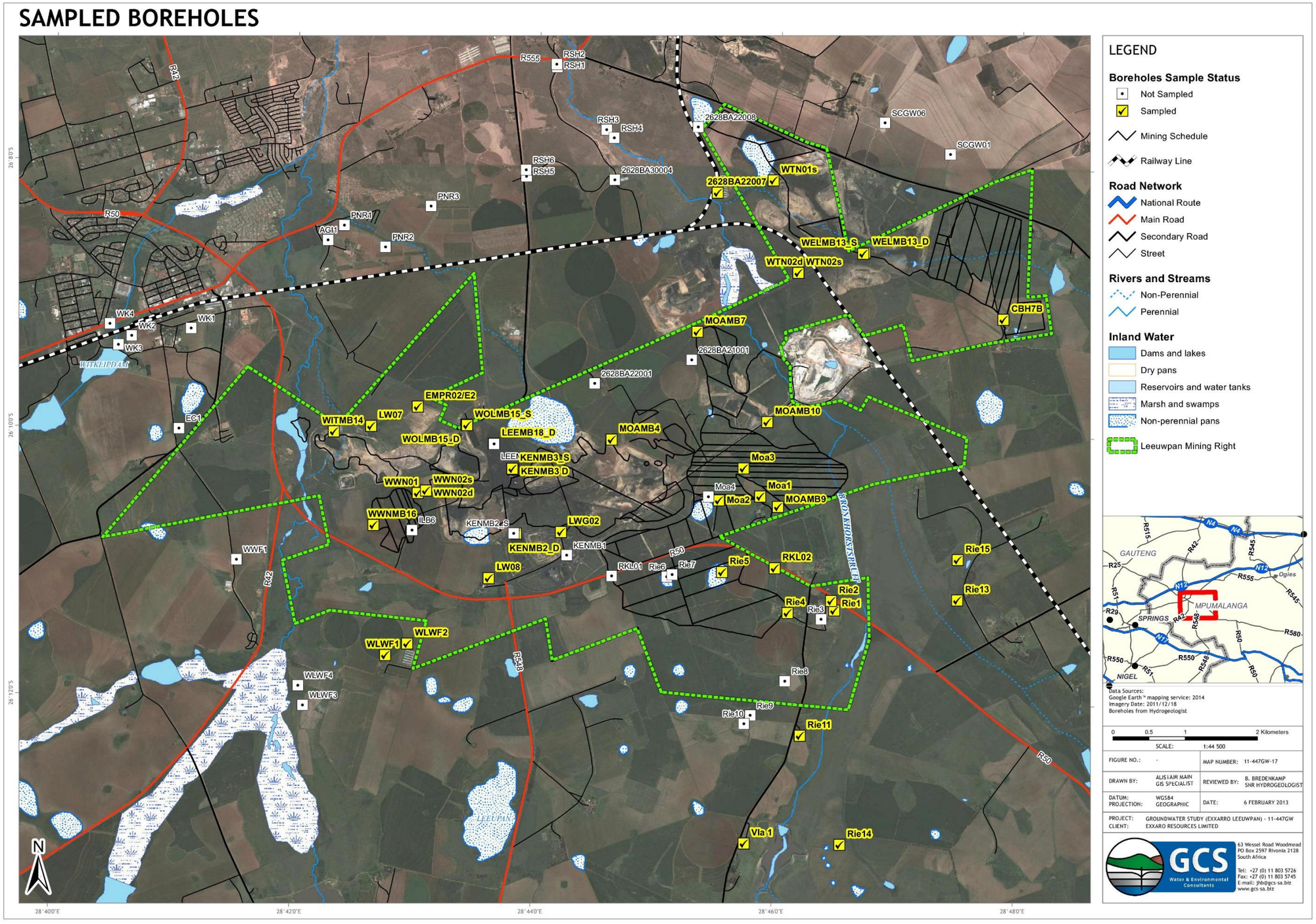


Figure 9.1: Sampled Boreholes

9.1.1 Hydrocensus Water Quality Results (2012)

A total of 16 water samples were collected during the GCS hydrocensus investigation in 2012. The water samples obtained mainly represented samples from production boreholes which are mainly used for domestic water supply or livestock watering. The hydrocensus groundwater quality results are outlined in Table 9.1. The following observations were made from the results:

- Rie1 and Rie2 only exceeded the SANS 241 Drinking water limits for nitrates (NO_3);
- Rie5 has exceeded the SANS 241 Drinking water limits for manganese (Mn) and iron (Fe);
- The remainder of the boreholes and their constituents remained compliant with the relevant standard limits for drinking water.

Table 9.1: Hydrochemistry Results - 2012

Parameter (mg/l)	SAWQG Domestic Use Target Values	SANS 241-1: 2011 Drinking Water Standard	Background groundwater quality	Moa1	Moa2	Moa3	Vla1	Rie1	Rie2	Rie4	Rie5	Rie11	Rie13	Rie14	Rie15	2628BA22007	CBH7B	WLWF2	WLWF1
pH at 25ºC	6-9	5-9.7	7.6	7.7	7.9	7.9	7.5	7.3	7.7	7.4	6.8	8	7.6	8.2	8	7.67	7.33	7.43	7.5
Conductivity mS/m @ 25°C	<70	<170	39	83.9	47.7	47.6	37	77.9	63	28	56.4	39.8	51.7	52.4	44.1	47.9	22.35	23.91	27.68
Total Dissolved Solids	<450	<1200	239	580	310	288	256	606	396	216	358	250	310	314	274	257	107	112	143
Calcium, Ca	<32	NS	28	79	39	37	42	63	51	21	53	27	23	16	13	46.26	16.77	19.25	26.68
Magnesium, Mg	<30	NS	15	44	17	20	10	36	23	10	26	9	12	9	9	26.66	7.35	12.78	16.09
Sodium, Na	<100	<200	23	29	26	26	10	13	31	13	26	38	59	74	66	9.92	13.25	9.22	9.7
Potassium, K	<50	NS	5	4.8	9.7	6.5	9.9	8.3	5.2	8.7	6.8	6.5	3.9	3.9	2.3	3.32	2.39	2.4	2.67
Total Hardness as CaCO3	NS	NS	130	328	167	175	146	305	222	94	239	104	107	77	69	225	72	101	133
Bicarbonate, HCO_3	NS	NS	160	293	244	219	200	122	210	122	341	215	205	224	219	132.9	67.3	97.4	119.3
Carbonate, CO_3	NS	NS	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Chloride, Cl	<100	<300	25	35	30	40	13	95	57	15	18	23	59	57	32	15.76	17.97	5.82	8.37
Sulphate, SO_4	<200	<500	18	187	15	35	<5	9	19	<5	<5	9	25	13	19	73.82	8.09	<0.13	3.68
Nitrate, NO_3	<26.6	<48.7	4	3.1	11	1	19	146	66	26	0.8	8.4	2.7	1.1	0.9	0.947	0.06	3.55	4
Fluoride, F	1	1.5	0.3	0.2	0.2	0.3	<0.2	<0.2	0.2	0.2	0.2	0.3	0.6	1.1	0.7	<0.183	0.292	<0.183	0.217
Aluminium, Al	<0.15	NS	0.1	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.12	<0.100	<0.100	<0.100	<0.100	<0.100	<0.006	<0.006	<0.006	<0.006
Manganese, Mn	<0.05	0.5	0.2	<0.025	<0.025	0.052	<0.025	<0.025	<0.025	<0.025	14	0.076	<0.025	<0.025	0.032	<0.001	<0.001	<0.001	<0.001
Iron, Fe	<0.1	2	0.2	0.092	0.03	0.052	0.046	<0.025	<0.025	0.414	14	0.095	0.095	<0.025	0.113	<0.006	<0.006	<0.006	<0.006
Zinc, Zn	<3	5	0.1	0.755	0.043	<0.025	0.33	0.028	<0.025	0.034	0.025	0.055	0.286	<0.025	<0.025	<0.004	<0.004	<0.004	<0.004
Lead, Pb	<0.01	0.01	BDL	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.006	0.001	<0.001	<0.001
Copper, Cu	<1.0	2	BDL	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.001	<0.001	<0.001	<0.001
Cobalt, Co	NS	<0.5	BDL	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.002	<0.002	<0.002	<0.002

Exceeding least stringent limit

Exceeding most stringent limit

As indicated in the Piper plot (Figure 9.2), most of the water samples that were analysed plot within the middle section of diamond field, which indicate water with a calcium-magnesium-bicarbonate nature, which is indicative of an aquifer of dolomitic nature.

Figure 9.3 presents a compilation of stiff diagrams for the hydrocensus boreholes and correlates with the results from the piper diagram in Figure 9.2.



Figure 9.2: Hydrocensus Piper Plot

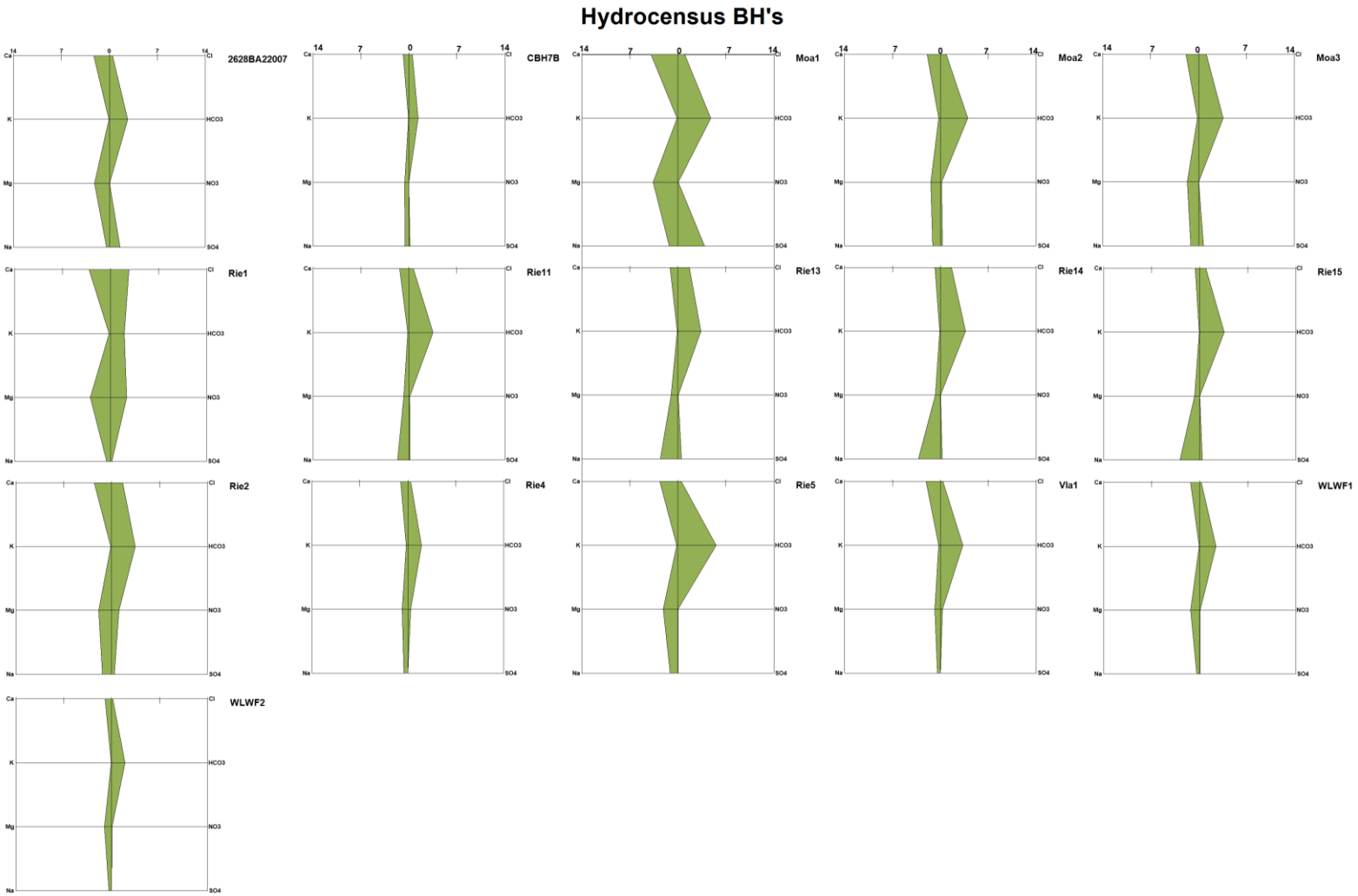


Figure 9.3: Stiff Diagrams for the Hydrocensus Boreholes

9.1.2 Existing Monitoring Boreholes' Water Quality Results (2012)

The existing groundwater monitoring boreholes exceeded the following compliance objectives (Table 9.2):

- The fluoride concentration in monitoring borehole WTN02s exceeded SANS 241 Drinking water standard of 1.5 mg/l;
- Three monitoring boreholes (WTN02s and WTN01s), exceeded the concentration compliance objectives for manganese;
- Monitoring boreholes E2, WWN02s and WWN02s exceeded the SANS 241 Drinking water standard for iron; and
- The sulphate concentrations that were detected in monitoring borehole WWN01 exceeded the SANS 241 Drinking water standard 500 mg/l.
- Although the sulphate concentrations in borehole WWN02d, WWN02s were compliant with the SANS 241 Drinking water standard, they were elevated and exceeded the SAWG Domestic Use Target Value. Boreholes WWN02s and WWN02d are located up gradient of the dam west of the OD block opencast. Borehole WNN01 is located up gradient of this dam.

Table 9.2: Existing Monitoring Borehole Chemistry Results (2012)

Parameter (mg/l)	SAWQG Domestic Use Target Values	SANS 241-1: 2011 Drinking Water Standards	Background groundwater quality	WTN01s	WTN02d	WTN02s	E2	LW07	LW08	RKL02	WWN01	WWN02d	WWN02s	LWG02
pH at 22ºC	6-9	5-9.7	7.6	7.97	7.67	6.87	7.35	8.34	7.97	8.84	6.97	7.88	7.86	8.79
Conductivity mS/m @ 25°C	<70	<170	39	20.3	12.7	12.5	61.0	43.4	18.3	22.0	102.6	84.4	98.4	42.8
Total Dissolved Solids	<450	<1200	239	153.0	104.0	277.0	264.0	219.0	97.0	122.0	776.0	588.0	707.0	222.0
Calcium, Ca	<32	NS	28	16.5	11.7	24.0	30.3	25.1	15.7	9.1	119.0	61.4	73.3	7.5
Magnesium, Mg (mg/l)	<30	NS	15	12.0	7.2	23.3	20.7	16.4	8.7	4.0	55.6	39.7	65.9	30.2
Sodium, Na	<100	<200	23	19.5	14.3	15.8	17.9	39.0	8.2	33.9	27.6	61.5	36.7	26.8
Potassium, K	<50	NS	5	1.3	1.3	2.1	11.8	3.1	2.0	2.4	6.7	1.9	3.2	5.8
Total Hardness as CaCO3	NS	NS	130	90.0	59.0	156.0	161.0	130.0	75.0	39.0	526.0	317.0	454.0	143.0
Bicarbonate, HCO_3	NS	NS	160	78.3	60.6	8.8	257.6	196.2	88.7	89.9	80.6	124.7	103.7	148.8
Chloride, Cl	<100	<300	25	25.9	10.9	16.0	19.0	12.7	4.8	13.7	17.9	14.6	16.1	18.0
Sulphate, SO_4	<200	<500	18	30.6	21.0	189.9	9.1	4.9	4.0	4.4	501.1	334.5	449.0	43.9
Nitrate as NO_3	<6	<11	4	0.21	0.93	0.30	0.26	0.09	0.21	0.31	0.12	0.13	0.13	0.17
Fluoride, F	1	1.5	0.3	<0.183	<0.183	1.87	0.337	0.244	<0.183	<0.183	<0.183	0.409	0.191	<0.183
Aluminium, Al	<0.15	NS	0.1	<0.006	0.02	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Manganese, Mn	<0.05	0.5	0.2	1.002	<0.001	5.3	0.14	<0.001	<0.001	<0.001	<0.001	<0.001	0.018	<0.001
Iron, Fe	<0.1	2	0.2	<0.006	<0.006	10.6	2.24	<0.006	<0.006	0.024	0.163	<0.006	2.03	<0.006
Zinc, Zn	<3	5	0.1	<0.004	<0.004	<0.004	0.017	<0.004	<0.004	<0.004	0.023	<0.004	<0.004	<0.004
Cobalt, Co	NS	<0.5	BDL	0.011	<0.002	0.021	<0.002	-0.002	<0.002	-0.002	<0.002	<0.002	<0.002	<0.002
Copper, Cu	<1.0	2	BDL	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Exceeding least stringent limit

Exceeding most stringent limit

According to the Piper plot below (Figure 9.4), a number of monitoring points plot within the sulphate dominant field (Ca, Mg – SO_4), which suggests mining related impacts (WWN02d, WWN02s; WTN02s; and WWN01).

The remainder of the existing monitoring boreholes plot towards the middle section of the plot, which is indicative of calcium-magnesium-bicarbonate nature.

Figure 9.5 presents a compilation of the stiff diagrams for the various existing monitoring boreholes and results correlated well with the results of the piper plot in Figure 9.4.

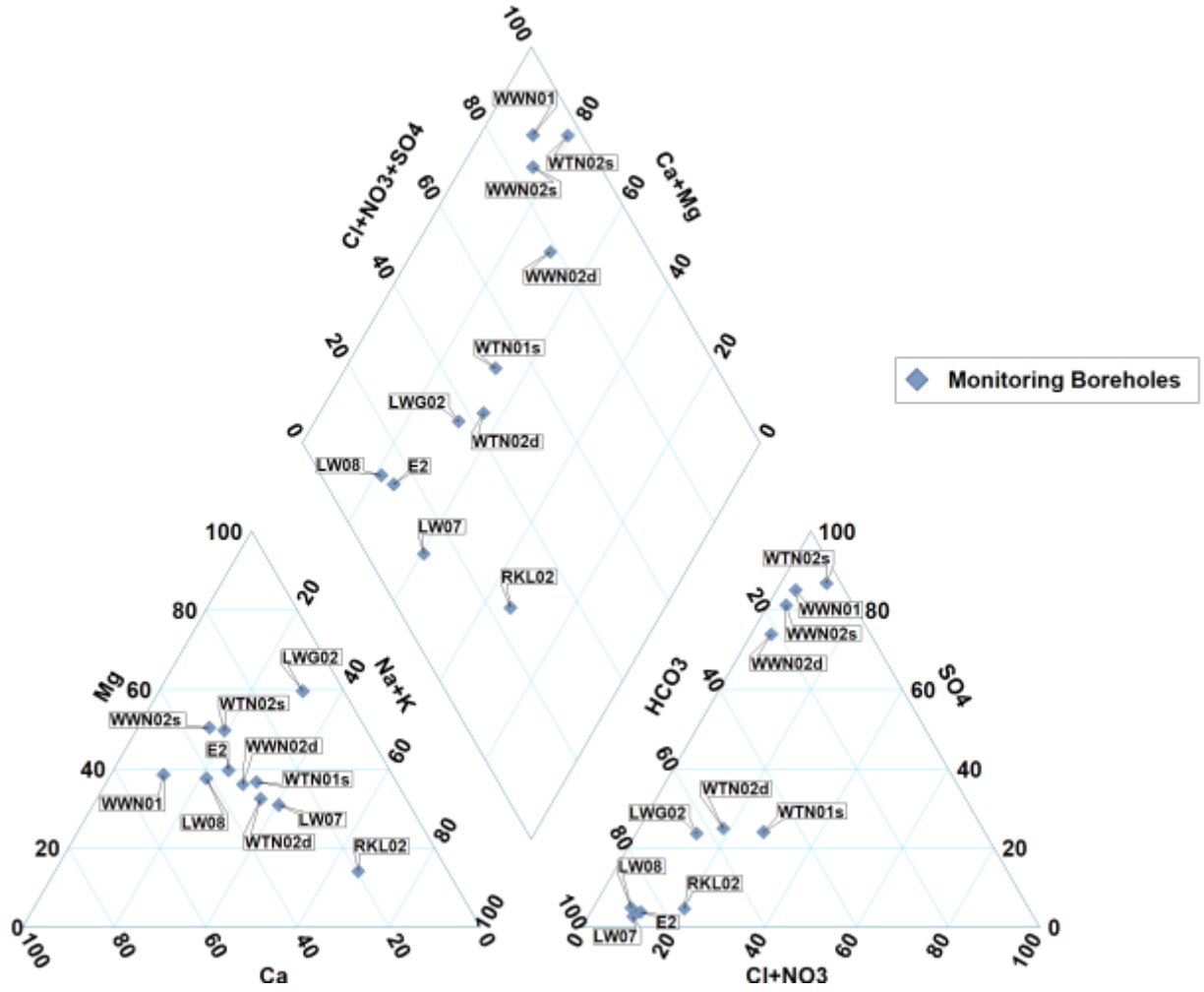


Figure 9.4: Existing Monitoring Boreholes Piper Plot

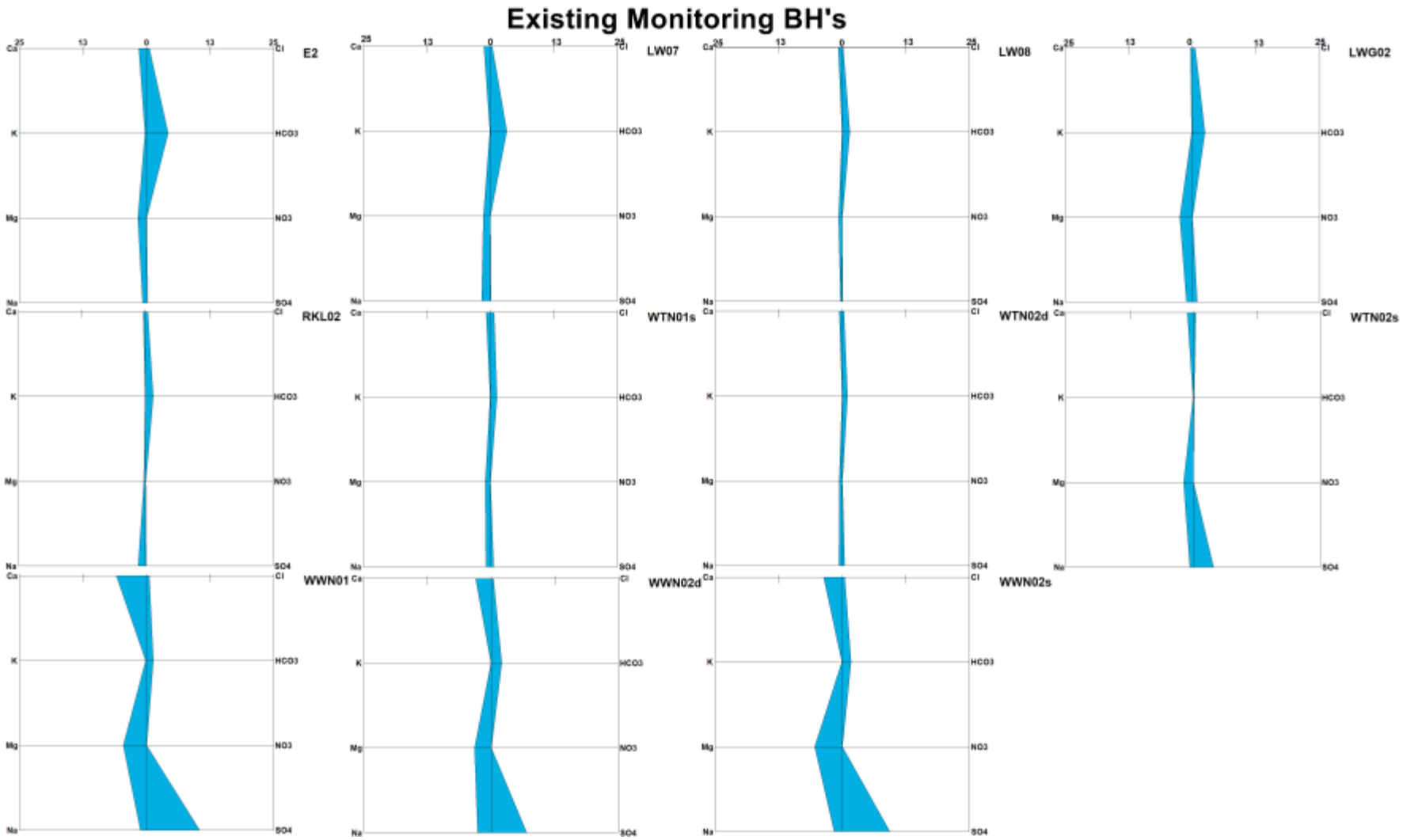


Figure 9.5: Stiff Diagrams for the Existing Monitoring Boreholes

9.1.3 New Monitoring Boreholes Water Quality Results (2013-2014)

A total of fourteen (14) groundwater samples were collected from the water bearing boreholes. Six (6) groundwater samples were collected during the aquifer testing from 4 December to 14 December 2013. An additional eight (8) groundwater samples were collected on 10 January 2014 using disposable bailers. Borehole KENMB1, KENMB2_S and LEEMB18_S could not be sampled due an insufficient water column in the boreholes at the time of sampling.

The water quality results are presented in Table 9.3 and Figure 9.6 graphically presents the dominant water quality domain of the groundwater at Leeuwpan in the form of a piper plot.

The following observations were made from the results:

- The SANS 241 Drinking water standard was exceeded for sulphate in boreholes: KENMB3_D, MOAMB10, LEEMB18_D and KENMB2_D;
- The TDS concentrations exceeded SANS 241 Drinking water standard in boreholes: KENMB3_D, MOAMB10 and KENMB2_D;
- Manganese concentrations exceeded the SANS 241 Drinking water standard in MOAMB10 and WELMB13_D; and
- In KENMB2_D and WELMB13_D the concentrations for electrical conductivity (EC) and iron exceeded the SANS 241 Drinking water standard.

Table 9.3: Water Quality Results for the New Monitoring Boreholes (2013-2014)

Parameter (mg/l)	SAWQG Domestic Use Target Values	SANS 241-1: 2011 Drinking Water Standard	Background groundwater quality	WOLMB15_D	WOLMB15_S	KENMB3_D	KENMB3_S	MOAMB10	LEEMB18_D	MOAMB4	MOAMB9	WITMB14	WELMB13_D	WELMB13_S	KENMB2_D	WWNMB16	MOAMB7
pH at 22ºC	6-9	5-9.7	7.6	7.55	6.74	7.7	6.63	7.19	7.63	6.54	7.37	7.72	5.83	8.37	7.63	8.11	5.88
Conductivity mS/m @ 25°C	<70	<170	39	54.1	69.3	170	86.2	166	112	10.6	30.5	75.2	31	36.7	179	26.7	11.2
Total Dissolved Solids	<450	<1200	239	384	499	1327	648	1268	903	81	193	466	191	203	1498	162	82
Calcium, Ca	<32	NS	28	52.5	69.5	210	61.9	216	148	4	23.7	63.8	23.2	27.3	223	22.2	4.79
Magnesium, Mg	<30	NS	15	24.3	38.2	122	28.4	115	61.4	3.13	11.1	38.8	15.5	13.3	126	12.5	4.63
Sodium, Na	<100	<200	23	18.9	11.5	34.8	84	16.8	29.8	4.85	18.7	36.3	0.804	11.2	32.3	4.81	3.56
Potassium, K	<50	NS	5	3.93	4.73	8.31	2.59	4.94	4.52	4.43	3.6	2.68	1.45	3.44	7.17	3.94	3.24
Free and Saline Ammonia as NH_4	<1	NS	0.5	0.315	0.083	0.03	0.104	0.36	0.036	0.048	0.089	0.069	0.233	1.69	0.042	0.637	0.081
Total Hardness as CaCO3	NS	NS	130	231	331	1028	271	1014	624	23	105	319	122	123	1073	107	31
Total Alkalinity as $CaCO_3$	NS	NS	57	118	46.3	218	219	121	140	-2.48	109	275	16.5	55.1	227	105	17.5
Bicarbonate, HCO_3	NS	NS	160	117	46.3	217	219	121	139	-0.01	109	274	16.5	53.8	226	104	17.5
Chloride, Cl	<100	<300	25	19.3	15	15.1	19.6	9.77	11.6	14.4	24.5	15.6	3.45	13.1	11.8	6.02	6.17
Sulfate, SO_4	<200	<500	18	135	274	749	211	809	520	15.1	11.9	105	112	93.3	901	8.08	15.9
Nitrate, NO_3	<26.6	<48.7	4	3.17	2.49	0.457	8.99	0.442	1.77	0.968	0.568	1.6	0.262	0.357	0.263	4.06	1.24
Fluoride,F	1	1.5	0.3	0.232	0.135	0.091	0.235	0.132	0.226	0.332	0.314	0.299	1.16	0.336	0.094	0.187	0.135
Aluminium, Al	<0.15	NS	0.1	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	0.748	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003
Manganese, Mn	<0.05	0.50	0.2	-0.001	-0.001	-0.001	0.173	0.797	0.093	-0.001	0.058	0.033	0.612	0.077	-0.001	0.212	-0.001
Iron, Fe	<0.1	2	0.2	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	0.124	-0.003	-0.003	3.25	-0.003	-0.003	-0.003	-0.003
Zinc, Zn	<3	5	0.1	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	0.009	-0.002
Lead, Pb	<0.01	0.01	BDL	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004
Copper, Cu	<1.0	2.0	BDL	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Total Chromium, Cr	NS	0.05	BDL	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Boron, B	NS	NS	0.03	0.014	0.008	-0.003	0.018	0.05	0.014	0.017	0.018	0.023	0.023	0.095	0.006	0.019	-0.003
Phosphate as PO_4	NS	NS	BDL	-0.008	-0.008	-0.008	-0.008	-0.008	-0.008	-0.008	-0.008	-0.008	-0.008	-0.008	-0.008	-0.008	-0.008
Barium, Ba	NS	NS	0.1	0.08	0.091	0.042	0.192	0.054	0.072	0.249	0.104	0.231	0.103	0.065	0.019	0.04	0.138
Beryllium, Be	NS	NS	BDL	-0.001	0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.001	0.001	-0.001	0.001	-0.001	-0.001
Bismuth, Bi	NS	NS	0.01	0.041	0.017	0.036	-0.004	0.017	0.034	0.019	0.033	0.034	0.015	-0.004	0.023	-0.004	-0.004
Cadmium, Cd	<0.005	<0.005	BDL	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Cobalt, Co	NS	<0.5	0.00	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Lithium, Li	NS	NS	0.01	0.014	0.001	0.012	0.005	0.028	0.016	0.01	0.03	0.008	0.05	0.004	0.012	0.002	0.004
Molybdenum, Mo	NS	NS	0.01	0.018	0.012	0.014	0.019	0.02	0.019	0.009	0.013	0.016	0.008	0.015	0.016	0.018	0.013
Nickel, Ni	NS	<0.15	BDL	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Silver, Ag	NS	NS	BDL	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Strontium, Sr	NS	NS	0.1	0.308	0.256	1.2	0.344	1.38	0.626	0.068	0.207	0.199	0.15	0.18	1.02	0.094	0.044
Thallium, Tl	NS	NS	BDL	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037	-0.037
Vanadium, V	<0.1	<0.2	BDL	-0.001	-0.001	0.002	0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.006	-0.001	-0.001

Exceeding least stringent limit

Exceeding most stringent limit

The dominant water type according to Figure 9.6 is calcium/magnesium-sulphate rich which is indicative of mining related impacts. Only boreholes: WITMB14, KENMB3_S, WWNMB16 and MOAMB9 are calcium/magnesium-bicarbonate of the plot.

A compilation of stiff diagrams for the various new monitoring boreholes were compiled and presented in Figure 9.7.

The results in the stiff diagrams correlate with the results obtained in the piper plot.

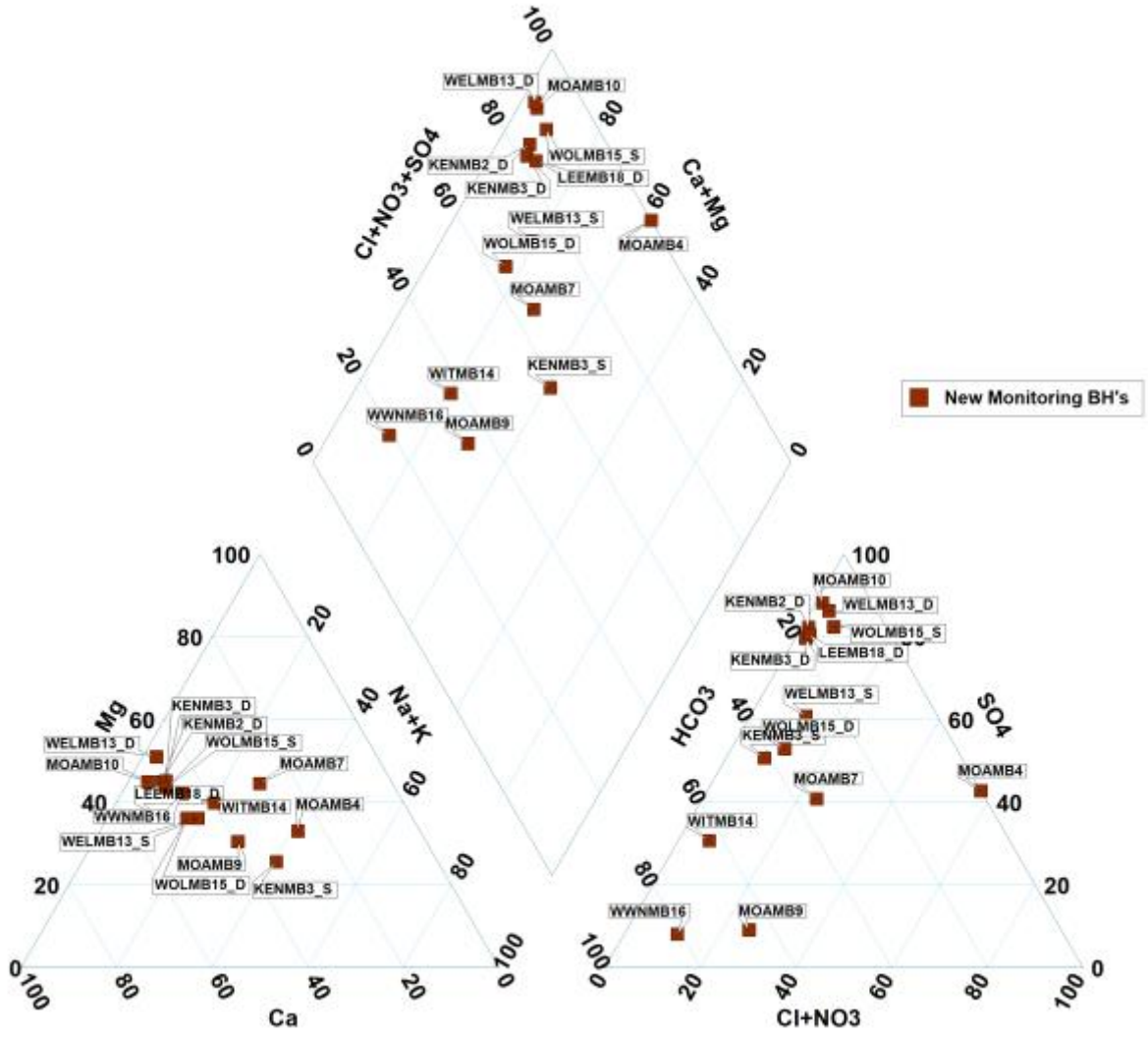


Figure 9.6: New Monitoring Borehole Piper Plot

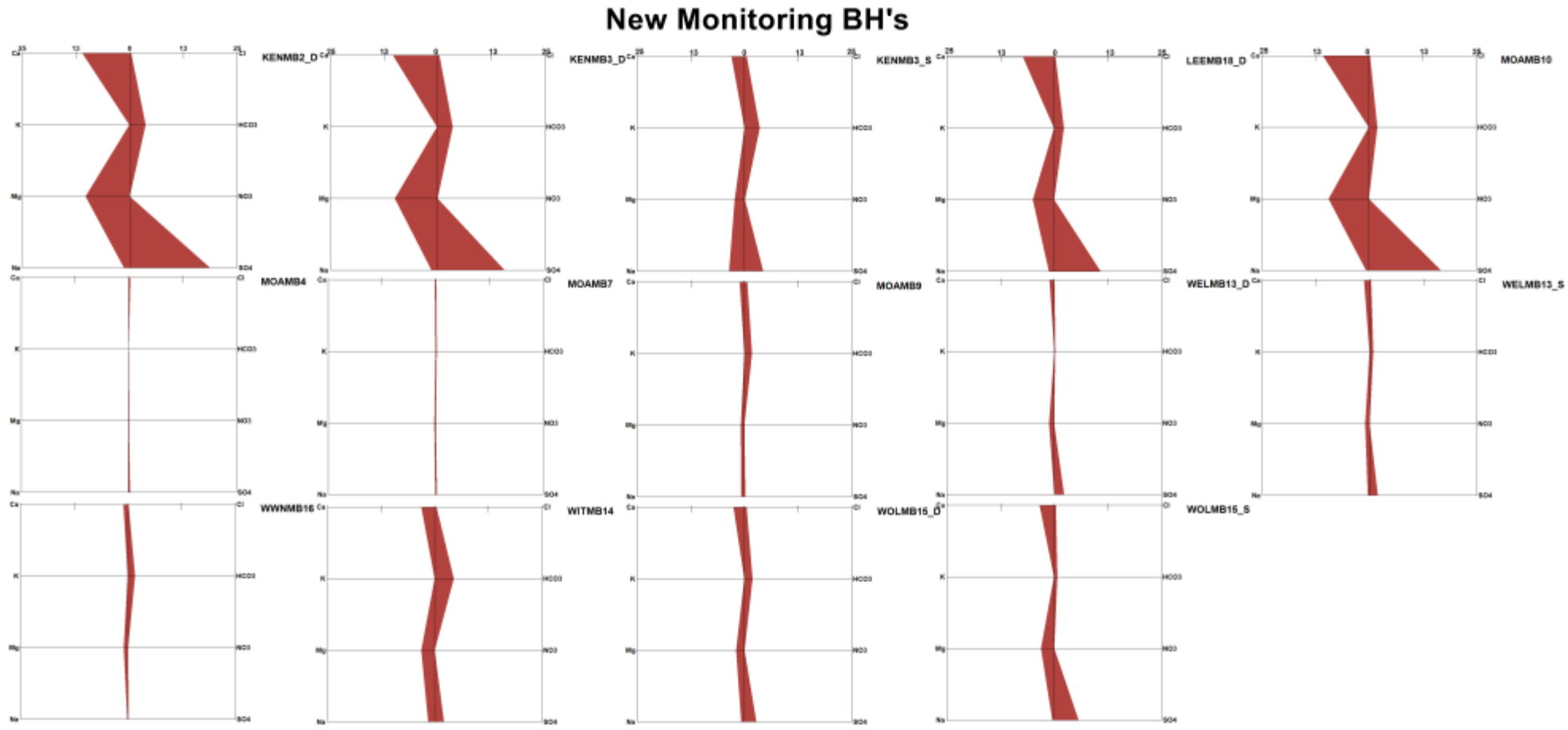


Figure 9.7: Stiff Diagrams of the New Monitoring Boreholes

9.1.4 Spatial Analysis

The hydrochemical results for all of the boreholes were compiled and spatially analysed in order to determine the collective influence of contamination across the entire Leeuwpan Mine area. Figure 9.8 presents a collective piper plot for all of the boreholes discussed.

The dominant water type remains the calcium/magnesium-bicarbonate water which is indicative of water that is un-impacted by coal mining activities. A secondary type of calcium/magnesium-sulphate-chloride water is also found which indicates groundwater impacts related to mining activities. Sodium-bicarbonate type water is also present in the area.

Figure 9.9 presents the distribution of the SO_4 concentrations for the entire mining area. Figure 9.10 shows a spatial pie chart plot with all the major anions and cations. The SO_4 concentrations correlate with the concentrations shown in Figure 9.10. The boreholes that did not show high sulphate concentrations were bicarbonate dominant which correlates with the piper plot in Figure 9.8. **Figure 9.11** shows the spatially consolidated stiff diagrams which re-affirm the findings of Figure 9.9 to Figure 9.10. Each mining section is discussed in the headings below:

Plant, PCD, OF Block Opencast

The figure shows that the sulphate concentrations are high in boreholes LEEMB18_D, KENMB3_S, KENMB3_D, and KENMB2_D located within the plant area. Boreholes WOLMB15s and WOLMB15d located down gradient of the plant PCD also indicate impact of mining related activities.

OWM_WTN ans OWM_MN Block Opencast

High sulphate concentrations were also encountered in the north easterly part of the mine toward the Moabsvelden and Weltevreden pits in boreholes, WTN02d, WTN02s, WELMB13S and WELMB13D. Shallow and deep boreholes (WELMB13_D and WELMB13_S) located down gradient of the OWM_MN Block (Moabsvelden) opencast are also slightly impact by mining related contaminants. Boreholes WTN02s and WTN02d are located adjacent to a haul road and is most likely impacted by a secondary source. The shallow borehole WTN02s contained sulphate concentrations above the background levels (although still compliant). It is likely that this borehole has been impacted by a shallow contaminant source associated with the haul road (coal spillage).

OJ Block Opencast

The borehole MOAMB10 located adjacent to OJ Block opencast has been negatively impacted by mining in term of elevated sulphate, TDS and EC. The private borehole Moa1 contains elevated SO_4 concentrations (although still complaint), it is however unlikely to be directly impacted by mining related activities.

Emergency overflow dam

The borehole KENMB2D located down gradient of the No. 5. Emergency overflow dam is also impacted by mining related contaminants.

Earth dam west of Block OD opencast

Boreholes WWN02s, WWN02d and WNN01 are located adjacent to a dam west of the OD block opencast which are also impacted by mining related contaminants.

OA Block (Witklip) Opencast

Borehole WITMB14 located down gradient of the Witklip pit (Block OA) showed an impact by mining related contaminants although still compliant with the SANS 241 Drinking water standard.

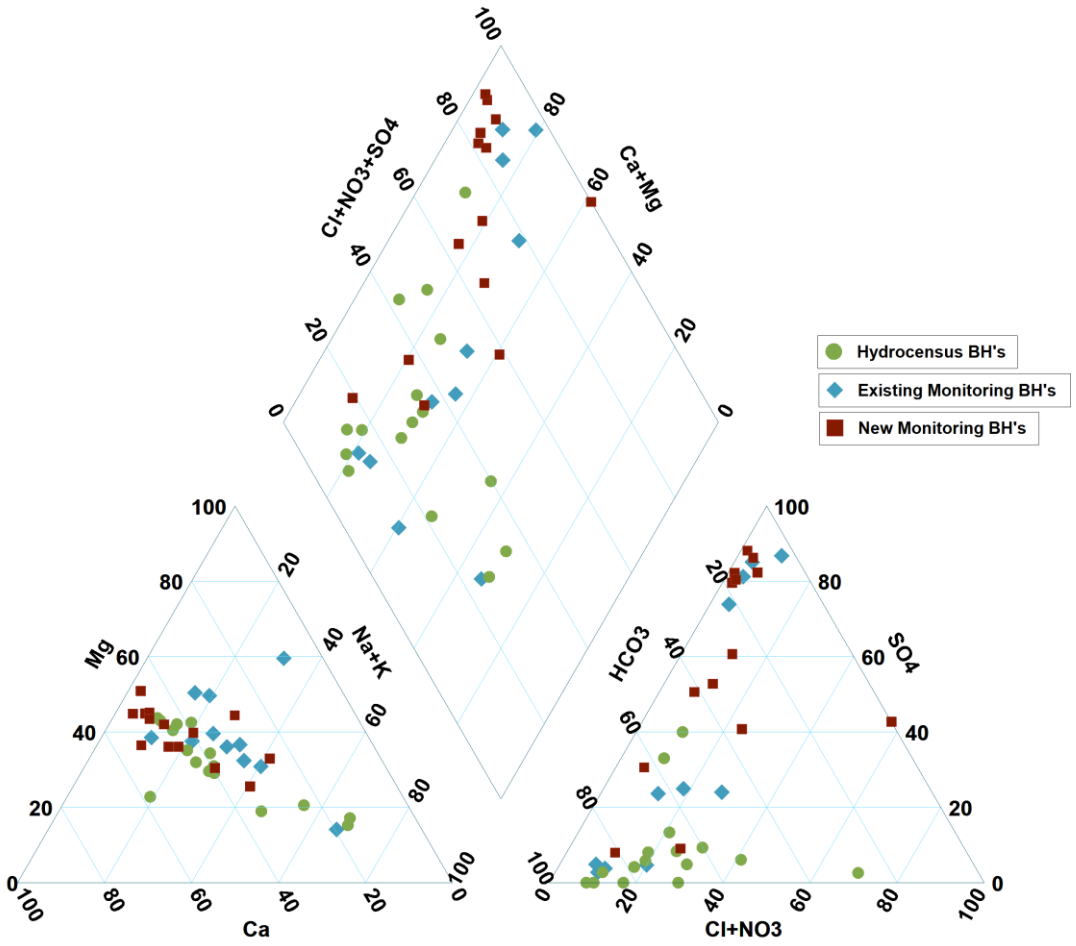


Figure 9.8: Collective Piper Plot

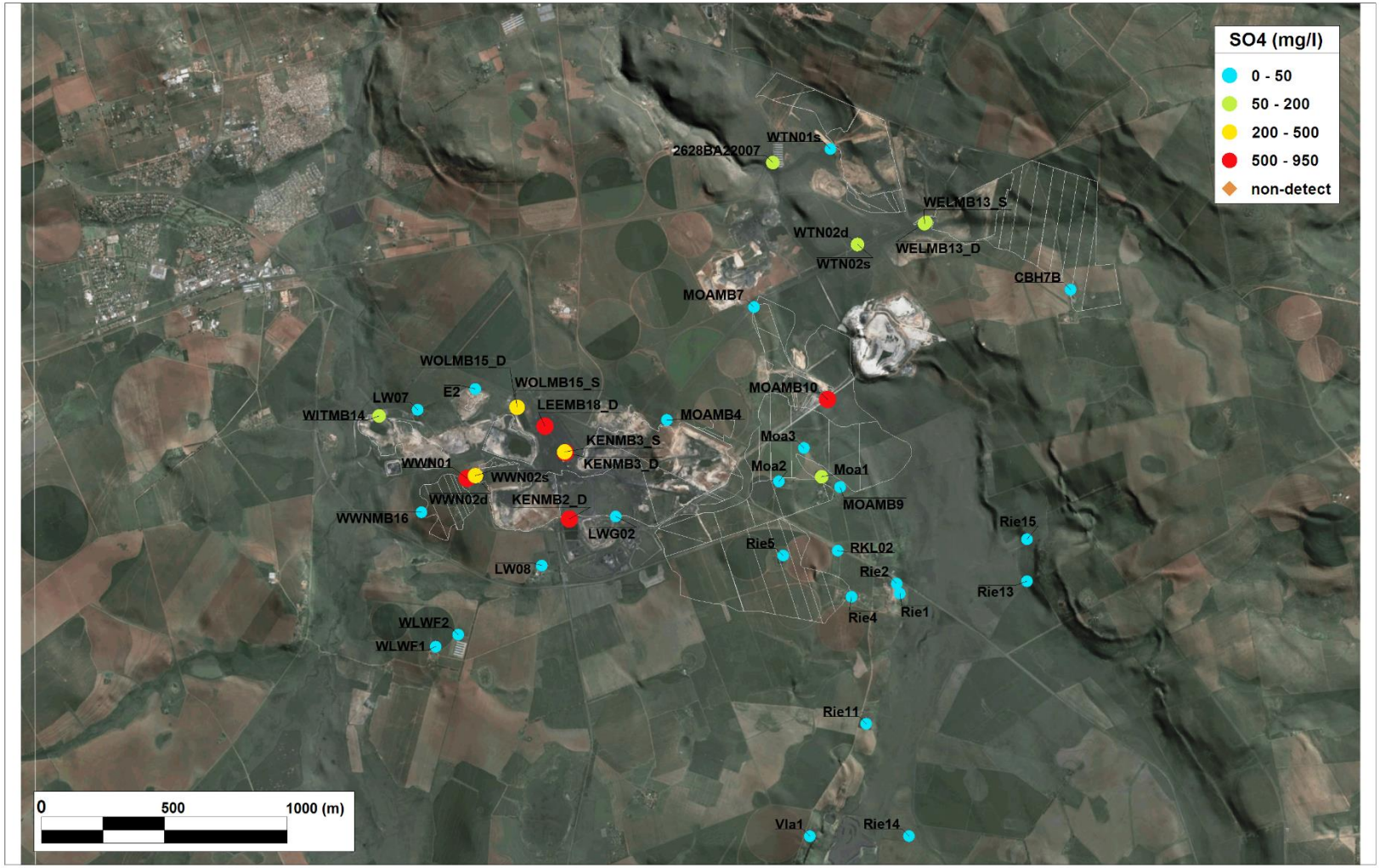


Figure 9.9: Spatial SO4 Concentrations (mg/l)

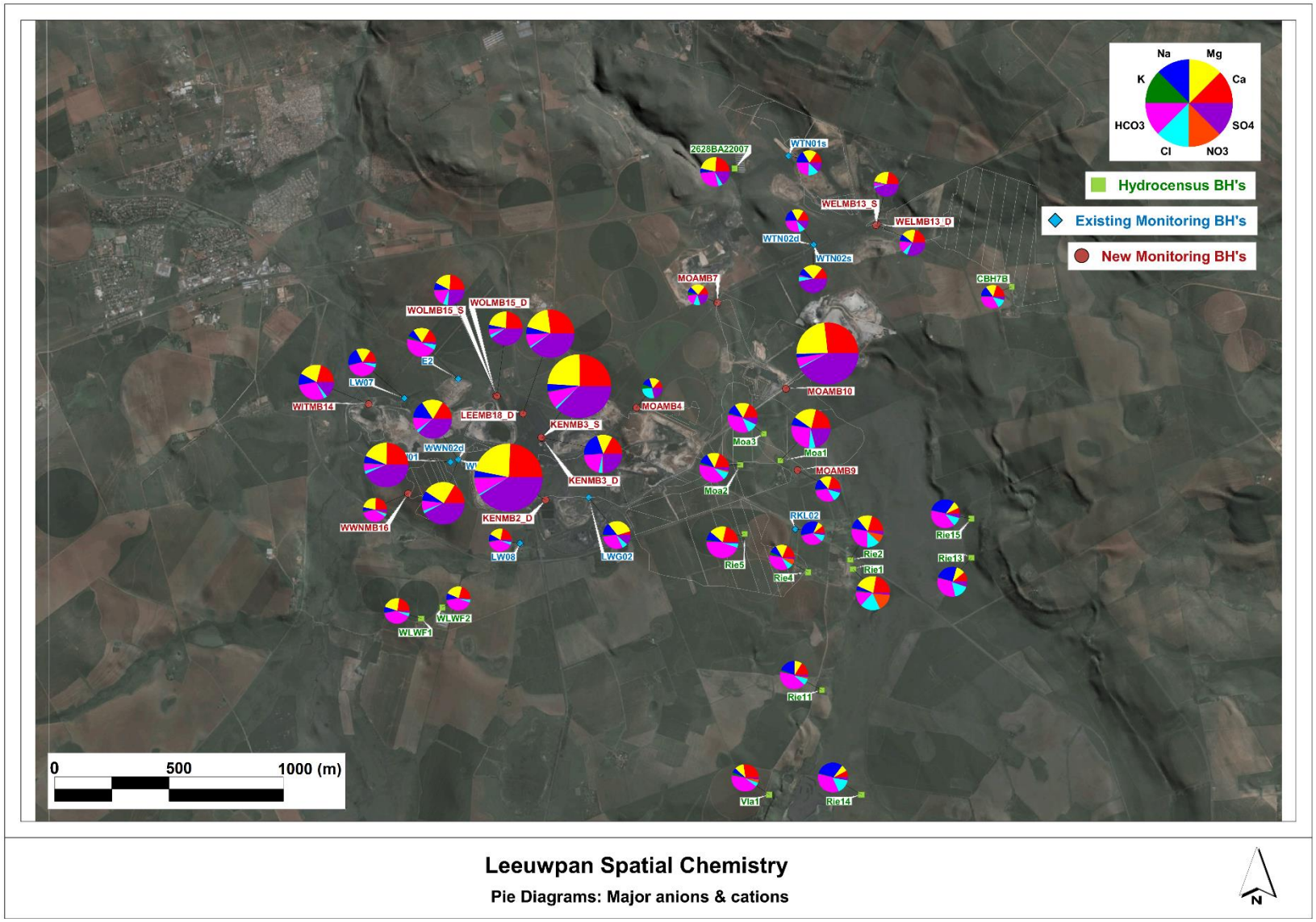
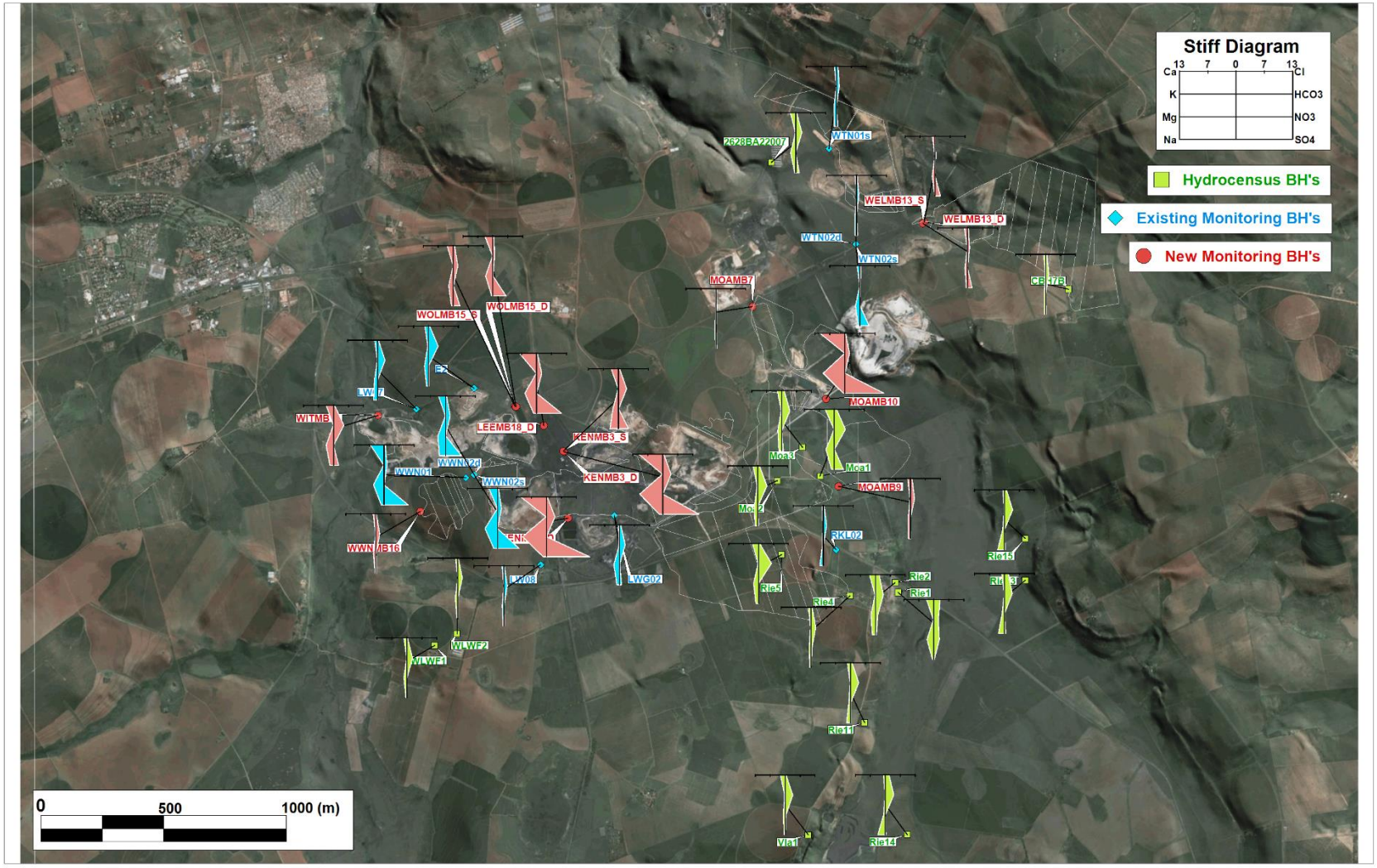


Figure 9.10: Pie Charts (in meq/l)



Leeuwpan Spatial Chemistry
Stiff Diagrams

Figure 9.11: Consolidated Stiff Diagrams (in meq/l)

10 CONCEPTUAL MODELLING

The conceptual model describes the hydrogeological environment and is used to design and construct the numerical model to represent simplified, but relevant conditions of the groundwater system. The conditions should be chosen in view of the specific objective of the modelling and might not be relevant for other modelling objectives. The conceptual model is based on the source-pathway-receptor principle. The conceptual model, based on the regional and site-specific geology can be generalised as depicted in Figure 10.1 below.

10.1 Source

Leeuwpan Colliery is an existing operation and as a result there are numerous contaminant sources already present such as the plant area, pollution and return water dams, rehabilitated opencast and operational opencast areas. The workshops and petroleum handling facilities are also likely to be petroleum hydrocarbon contaminant sources.

During the operational phase of the opencast mining, the mined out areas were backfilled with waste rock material as well as coal discard and slurry cake. Block OA (Witklip), Block OE (Midklip) and Block OF (Kenbar) were backfilled at the time of the investigation. Coal discard and slurry is further also discarded in the opencasts. Block ODN opencast has been mined out and still to be backfilled. The OD, OH, OM, OJ, OWM_WTN and OWM_MN Block opencasts were being mined at various stages during the investigation. The proposed OI and OL mining Blocks will thus also act a potential contaminant sources.

After closure the water level in the pits will rise as a result of groundwater inflow and natural ingress of rain water. The water levels in the rehabilitated area will recover to a new equilibrium level up to the decant elevation. Above the decant elevation the backfilled material will be unsaturated and oxidation of sulphur minerals are likely to impact on the overall mine water quality.

10.2 Pathway

Leeuwpan Colliery is situated with the Karoo Supergroup weathered and fractured rock aquifer, a typical unconfined to semi-confined aquifer. Groundwater flow occurs mainly within fault zones, fractures and bedding plane fractures. The three aquifer units present in the Leeuwpan area are:

- The shallow aquifer formed in the weathered zone, often perched on the fresh bedrock;
- The deeper aquifer formed by fracturing of the Karoo sediments and dolerite intrusions; and

- The dolomite & chert rich karst aquifer of the Malmani Subgroup which underlies the Karoo type aquifer.

The karst dolomitic aquifer is thought to be separated from the overlying Karoo aquifer by Dwyka tillite aquitard. It must further be noted that the Karoo rock aquifers overlying the dolomitic aquifer is likely to remain the aquifer of concern. The interaction between Karoo and dolomitic aquifer should however be assessed and will become important to investigate for the post closure phase, as these aquifers may be interconnected.

The general groundwater flow is in a northern direction. The recharge in the area covered by Karoo rocks is estimated between 1 and 3% of mean annual precipitation (MAP). Where dolomite outcrop occurs, the effective recharge percentage is likely to be higher and is estimated to be between 2 and 6%.

The hydraulic conductivity of the shallow and deep Karoo aquifers range between 0.01-0.6 m/d. These values are typical of the Karoo type aquifers and correspond with the values identified in previous studies.

The unsaturated zone (~5 - 26 mbgl) in the study area consists of colluvial material and clay (residual dolerite and shale) that is underlain by weathered sandstone / siltstone / mudstone / shale and coal of the Ecca Group that becomes less weathered with depth. The Dwyka tillite is highly weathered at shallow depths and is found to be more competent at depth. A dolerite sill is likely to cover the areas near Block ODN, OD, OI, OL, and eastern portions of OWN_MN.

No water strikes were associated with the sill. Water strikes were encountered on contact zones between highly weathered rock or materials and more competent rock. The aquifer can generally be considered a minor aquifer as substantiated by the drilling results (only 3 of the 17 boreholes have water strikes in excess of 0.1 l/s). Two boreholes drilled into the fractured Karoo aquifer had yields of 1.6 and 5 l/s.

The surrounding river systems also act as potential pathway for contamination, especially when decant or contaminated seepage is found. The surrounding river system is the Bronkhorstspruit River system. When decanting occurs from the operations the contaminated water may enter the streams, were the contaminants are transported to downstream receptors. Seepage emanating from certain areas may impact on the perched aquifer and migrate towards surface drainage features.

10.3 Receptor

Domestic supply boreholes are considered sensitive receptors. However none of these privately owned boreholes identified during the hydrocensus were likely to be affected by mining related contaminants. In contrast a number of the on site monitoring boreholes had been impacted by mining related contaminants.

The majority of privately owned boreholes are associated with the underlying dolomitic aquifer which in unlikely to be impact by any mining related dewatering activities. The impact of abstraction for irrigation and industrial users should however be assessed.

It is likely that preferential flow paths along faults and dolerite intrusion related to fracturing is not significant in the area based on the available data. While it is still anticipated that localised preferential flow zones will exist in relation to dolerite dykes, these zones have not been recorded and it is thought that they are not well developed.

As mentioned above the drainage occurs towards the low lying areas such as rivers and streams (Bronkhorstspruit and its tributaries). Some of these streams may be impacted by contaminated seepage and decant.

It must be noted that a number of mines are located in the area which may also impact on these rivers.

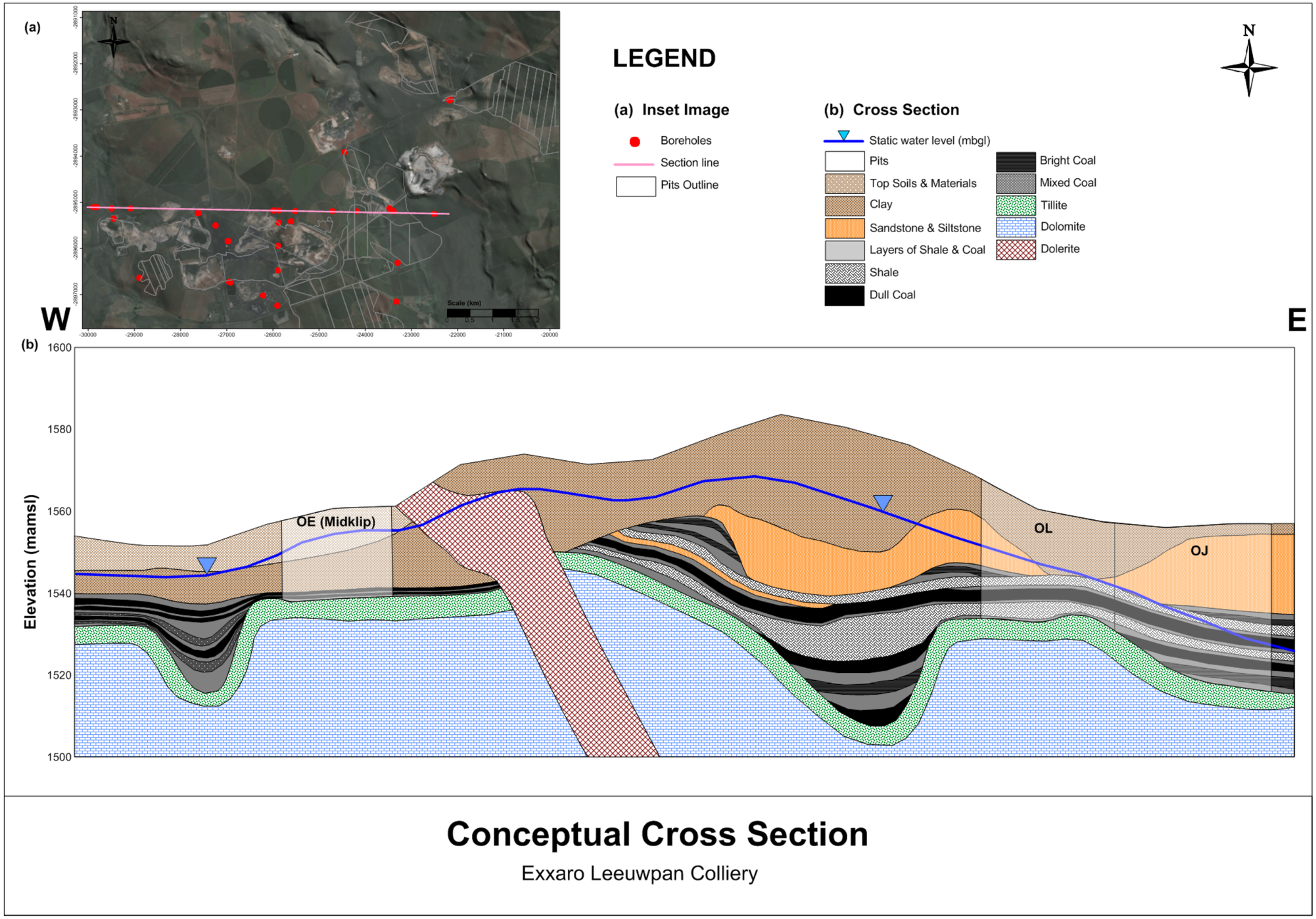


Figure 10.1: Leeuwpan Conceptual Cross Section

11 NUMERICAL MODELLING

Numerical groundwater modelling can be considered to be one of the most reliable methods of anticipating and quantifying the likely impacts on the groundwater regime. The model construction is described in detail below, followed by predicted impacts in terms of groundwater quality and quantity for all the relevant phases. Fetter (2001) described modelling as a method "to understand why a system is behaving in a particular observed manner or to predict how it will behave in the future".

The model was constructed using GMS9.1, a pre- and post-processing package for MODFLOW and MT3DMS. GMS is the Graphical User Interface (GUI) for the well-established MODFLOW-2005 (Harbaugh et al, 2005) and MT3DMS (Zheng & Wang, 1999) numerical codes.

MODFLOW is a 3D, cell-centred, finite difference, saturated flow model developed by the United States Geological Survey. MODFLOW can perform both steady state and transient analyses and supports a wide variety of boundary conditions and input options. It was developed by McDonald and Harbaugh of the US Geological Survey in 1984 and updated several times since.

MT3DMS is a 3D model for the simulation of advection, dispersion, and chemical reactions of dissolved constituents in groundwater systems. MT3DMS uses a modular structure similar to the structure utilized by MODFLOW, and is used in conjunction with MODFLOW in a two-step flow and transport simulation. Heads are computed by MODFLOW during the flow simulation and utilized by MT3DMS as the flow field for the transport portion of the simulation.

The usual required steps in numerical modelling are:

- *Data collecting and interpreting field data*: Collecting of field data is required to identify the processes and status of the specific area of interest. It is important to follow a thorough quality control/quality assurance program to ensure that collected data can be used with a high level of confidence;
- *Formulation of a site conceptual model:* The site is conceptualised in a manner which simplifies the natural conditions and processes;
- *Computer code and algorithm:* An acceptable computer code should be selected to ensure optimal modelling results and flow model construction;
- *Model calibration:* Model calibration and validation are essential for specific models before any predictions are made. The main aim of calibration is to obtain a degree of correspondence between the model simulation and the groundwater system. Calibration can be performed manually or automatically (by means of inverse modelling); and

- *Predictive simulations:* Once a model has been calibrated and validated it can be used as a predictive tool to simulate certain scenarios.

11.1 Model Construction

The model was constructed using the latest groundwater and mine data in order to:

- Simulate current and future groundwater levels;
- Calculate the groundwater inflow volume into the active mining areas;
- Simulate the migration of potential contaminant plumes from mining related activities;
- Simulate recovery of water levels; and

11.1.1 Boundaries

The flow of groundwater in nature is impacted by boundary conditions. Where practical, natural topographical and groundwater water divides were used as flow boundaries in the top layer, assuming that the groundwater elevation follows the topography (see Section 6.6). A topographical divide flow boundary (groundwater divide) was used in the western, southern and eastern sections of the modelled area.

These boundaries were used on the north of the area, where flow is likely to occur parallel to streams (i.e. groundwater unlikely to move across a streamline during unstressed conditions). Constant head boundaries were used as part of the northern boundary to ensure numerical stability. A constant head boundary was used over a length of three kilometres of the Bronkhorstspruit. All the model boundaries were constructed a sufficient distance from the mining areas so as not to influence the model solution. The model boundaries in layer 2 to 3 have the same lateral extent as the top layer.

11.1.2 Model Discretisation

The modelling area was discretised by a 300 x 250 grid in the x and y direction, (see Figure 11.1). A refined cell size of 50 m x 50 was used in the mining area with gradual increase to about 400m on a regional scale. All modelled features, like opencasts and other sources were sizably larger than these dimensions, and the grid was thus adequate for the purpose.

The subsurface was modelled in three dimensions (three-layer model), as depicted in Figure 11.2 to Figure 11.4 below. The upper layer 40m thick layer represents the weathered and fractured Karoo aquifer system within which the coal resides, as well as the much older dolomite and Timball Hill formation ferruginous quartzite/shale inliers. Where the coal seams are at a deeper level, the bottom of this layer was lowered to reflect the actual coal floor. In the two deeper layers, the Dwyka tillite underlies the Karoo sediments as a thin 10m layer, while the dolomite underlies this all as a third layer of 50m. The quartzite was continued from the first to the third layer. All materials were digitized form the applicable geological map, but adjusted somewhat close to the mining area to include all pits in the Karoo. In particular, the model was designed to represent the Dwyka tillite in the second layer and the underlying dolomite in the third layer. Although the dip of the bedrock (especially the quartzite) is not included in the model layout, it is also insignificant to the depth of the model. It is also far enough removed from the area of interest to have any substantial influence on the groundwater flow.

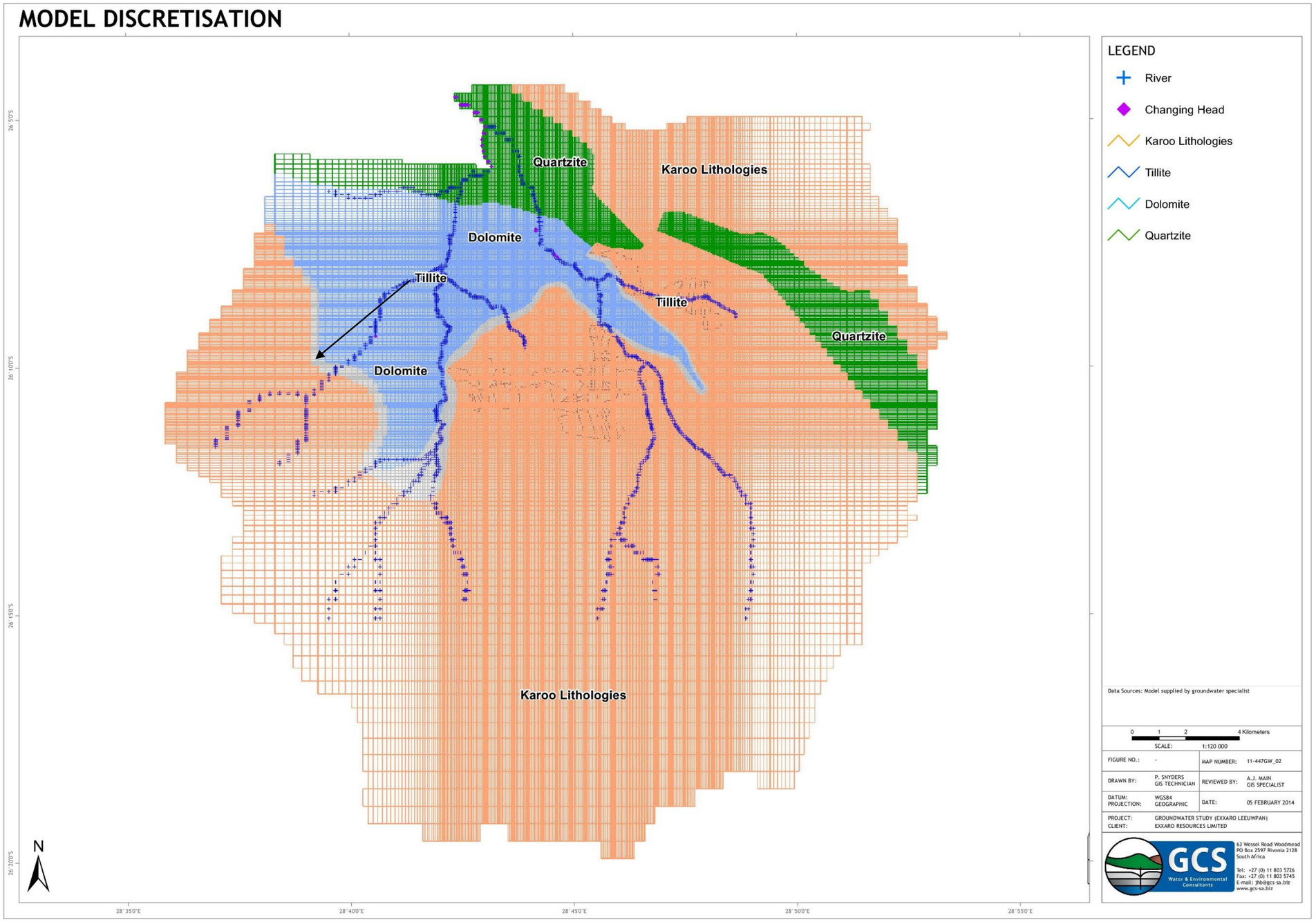


Figure 11.1: Model Discretisation and Boundaries

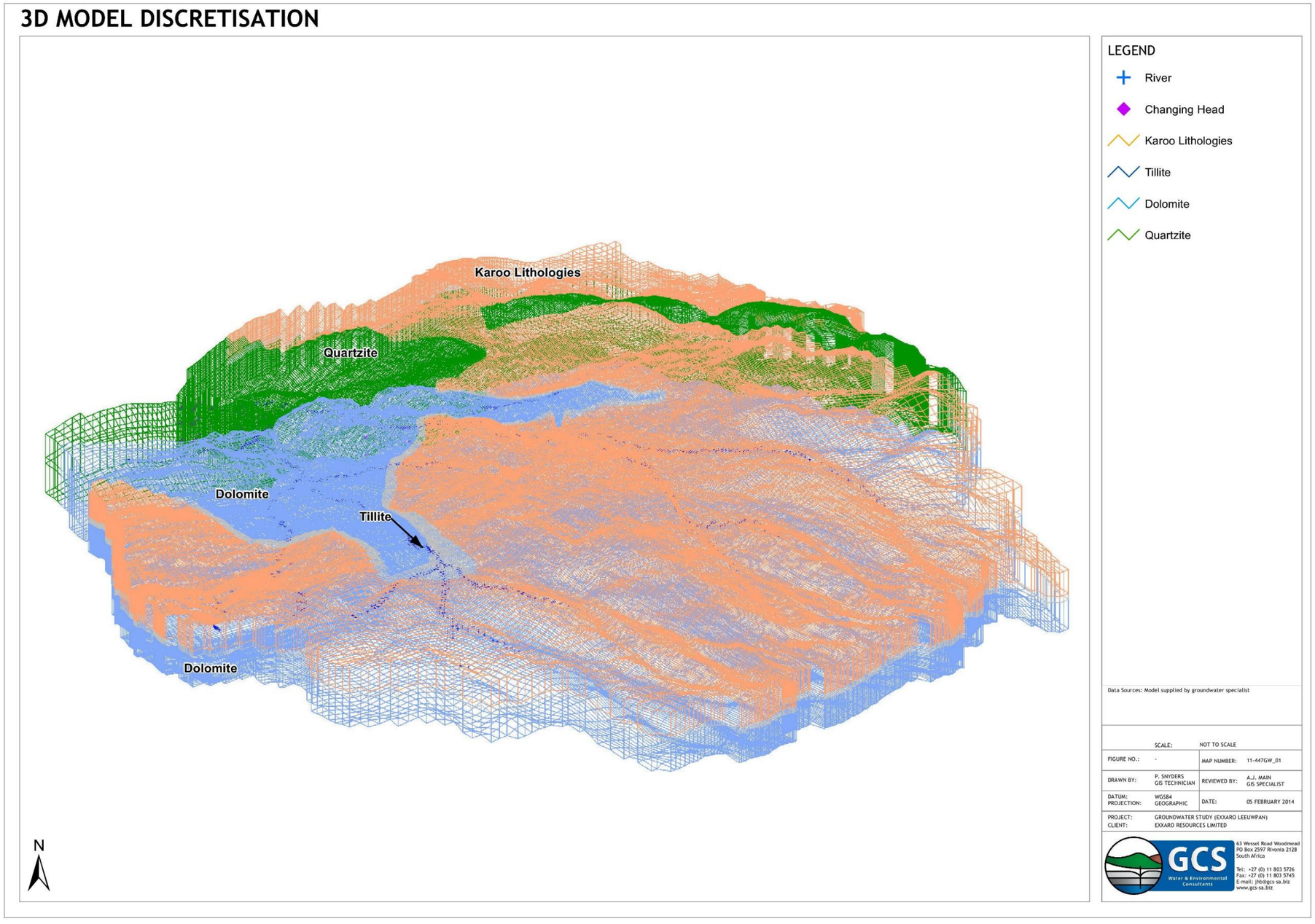


Figure 11.2: 3D Model Discretisation

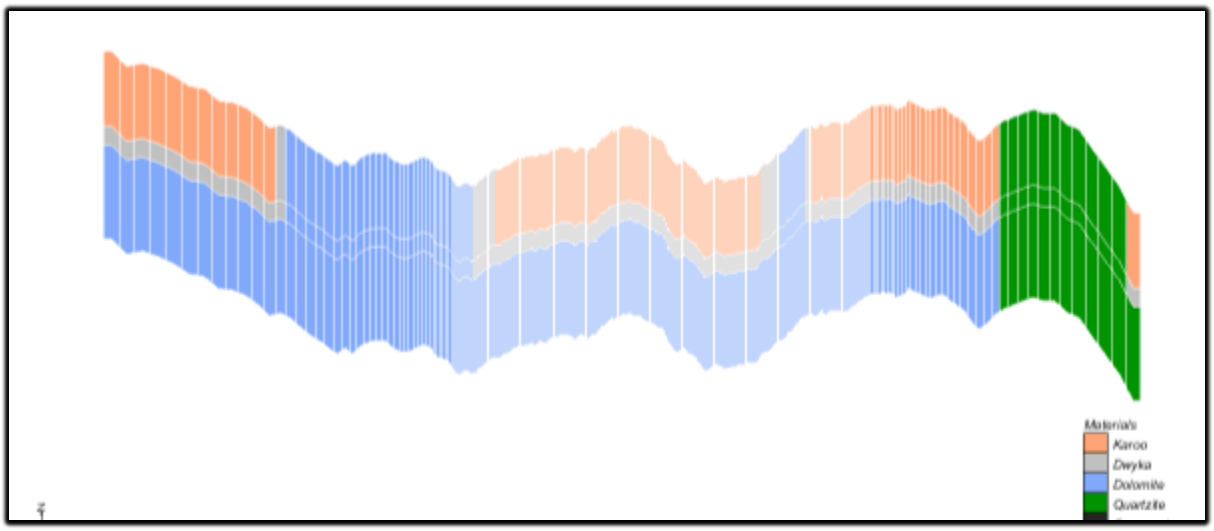


Figure 11.3: Section of Materials – East to West

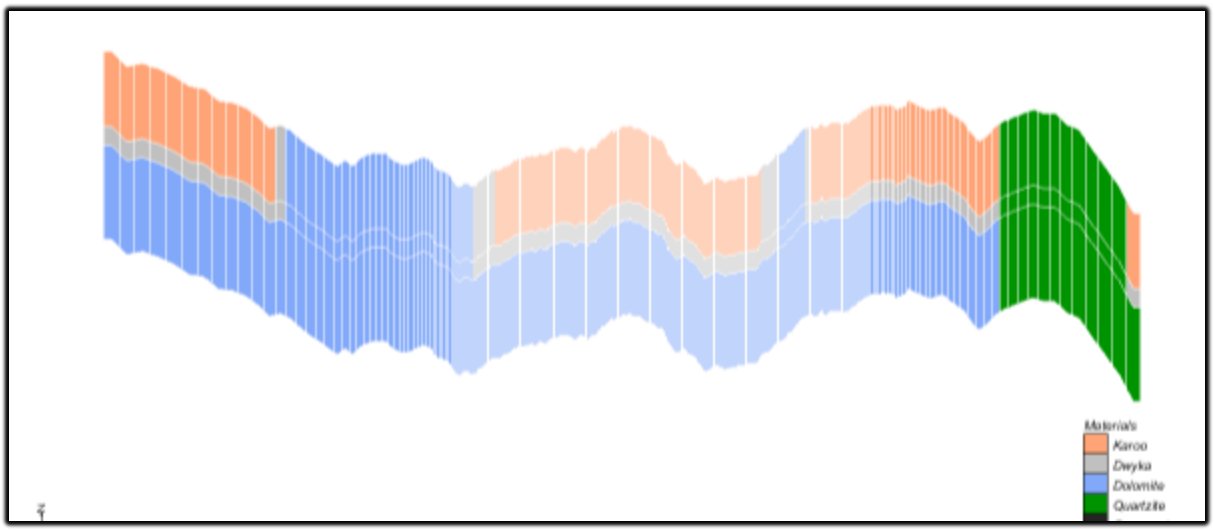


Figure 11.4: Section of Materials – South to North

11.1.3 Aquifer Parameters

Although the most relevant aquifer parameters are optimised by the calibration of the model (Section 11.1.4), many parameters are calculated or assumed due to experiences in similar environments. The following fixed assumptions and input parameters were used for the numerical model of this area:

- Recharge = 20 mm/a ≈ 0.00005 m/d. This value relates to a recharge percentage of about 2.7%, about the same value proposed by the previous groundwater studies;

- Evapotranspiration was used, a value of 0.0001 m/d was used which is average for grasslands, an extinction of 1m was simulated;
- Vertical Hydraulic Anisotropy (KH/KV) of the bedrock = 10. This is an estimate based on the sub-horizontal layering of the Karoo sediments;
- The specific yield (effective porosity) value was taken as 0.05, declining gradually to 0.01 at a depth of 100. This value could not be determined directly and were taken as typical of the fractured bedrock;
- Longitudinal dispersion was taken as 50 metres, which is about 10% of expected plume dimensions, as recommended in various modelling guidelines;
- Transverse and vertical dispersion was taken as 5m and 0.5m respectively, being about 10% and 1% of the longitudinal dispersion respectively, as recommended in various textbooks;
- The hydraulic conductivity of the rehabilitated opencasts was taken as 10 m/d. This is a typical value derived from pump tests in rehabilitated opencasts;
- The hydraulic conductivity of the weathered and fractured Karoo rock was taken as 0.02 m/d, the Dwyka tillite was assigned 0.005 m/d. These hydraulic conductivities correlate with the hydraulic conductivity estimated from the aquifer tests and previous studies at the mine.
- The dolomite was assigned a hydraulic conductivity of 10 m/d and the quartzite 0.01 m/d.
- A specific storage (S) value of $1x10^{-6}$ was used for all layers. This value relates to the compressibility of the aquifer and water and is approximately constant with depth. The specific storage of the dolomite was however estimated as $1x10^{-4}$ and used in the model;
- The effective porosity of the Karoo aquifers usually ranges between 1 and 5%. An effective porosity of 5% was assumed for the first layer, while a value of 25% was used for the opencasts;
- A 15% recharge was used for the backfilled opencast areas (Hodgson et. al, 2007); and
- Rivers were used to simulate groundwater loss from smaller ephemeral streams. The river conductance value used is 1 m^2/day.

11.1.4 Model Calibration

Aquifer parameters used in the model were obtained from previous field measurements and model calibration, using measured groundwater levels. The model was calibrated using "natural" steady state conditions in order to simulate pre mining water levels.

The calibration was done manually in various stages. Since it is apparent that the groundwater level in the dolomitic aquifer dominates groundwater levels in the upstream Karoo aquifer, the hydraulic conductivity in the dolomitic aquifer was firstly adjusted until modelled groundwater levels matched with measured values. Following that, the hydraulic conductivity in the Karoo aquifers were similarly adjusted and fitted to measured values. Lastly, boreholes that obviously do not coincide with the regional groundwater levels were deactivated and minor final adjustments made to improve the overall fit over the modelled area.

The measured values not used in the calibration were mostly the boreholes reported as being pumped during the hydrocensus. One borehole in the dolomite (PNR3) was deactivated as a very shallow groundwater level was measured compared to all other boreholes in the dolomite. It was thus deduced that it was drilled in an isolated area, most likely a shallow perched aquifer on the regional dolomitic aquifer.

The calibration error statistics are presented in Table 11.1, the mean absolute residual and root mean square error was low (about 6m) and the mean error in the order of 1m. This is acceptable considering the size of the modelled area and the heterogeneity of the aquifers. Figure 11.5 shows the comparison between modelled heads obtained after calibration and observed heads. The current mining calibrated flow contours are presented in Figure 11.6. Using the observed water levels, a good fit of computed and measured groundwater levels was obtained, as can be visualised through the residual heads seen in Figure 11.6. The residual heads (green bars in the figure) are less than 10m, which is less than 10% of groundwater level differences over the modelled area as prescribed in various modelling guidelines such as Mandle (2002).

Table 11.1: Error Statistics

Summary Statistics for Calibration Targets	Value
Number of Targets	24
Mean Residual (Head)	-2.01
Mean Absolute Residual (Head)	4.78
Root Mean Squared Residual (Head)	6.02

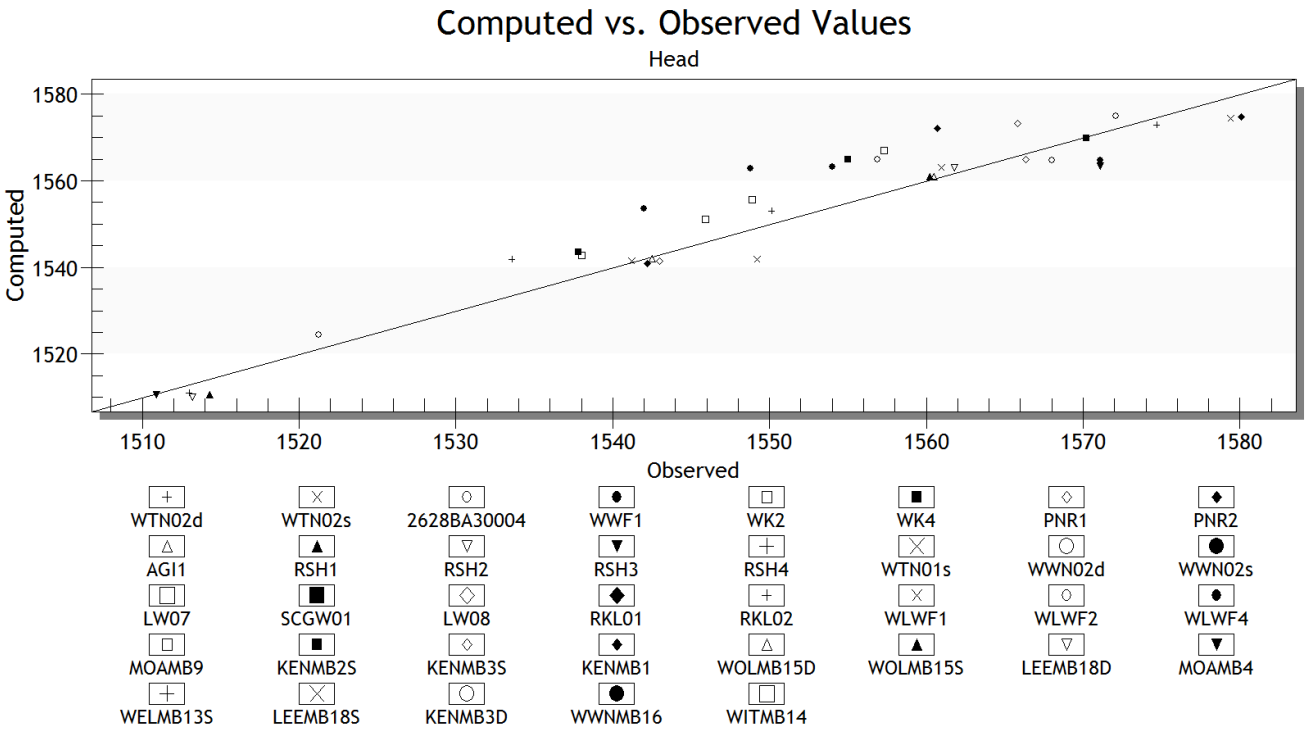


Figure 11.5: Observed versus Computed Water Levels

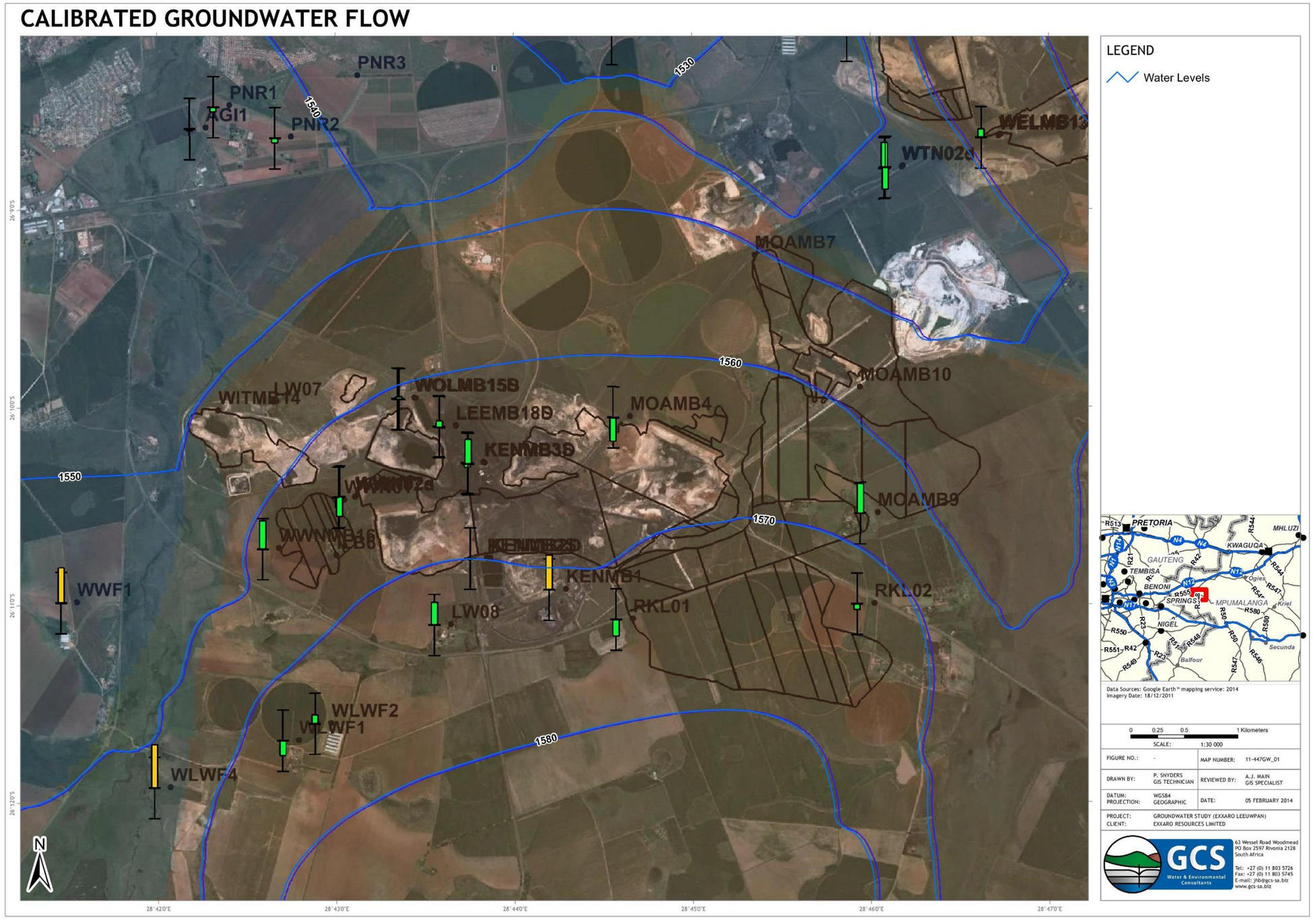


Figure 11.6: Current Mining Calibrated Flow

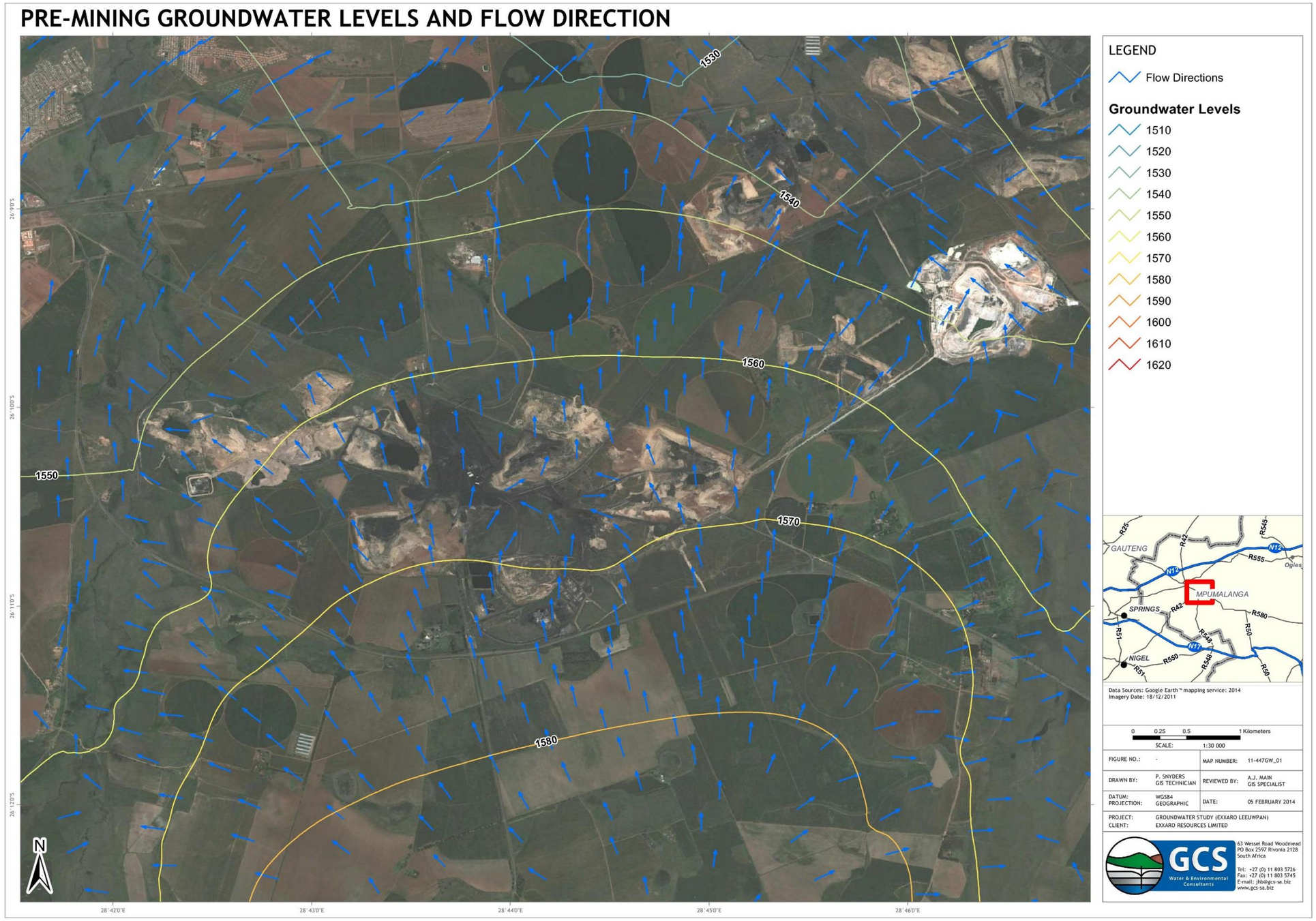


Figure 11.7: Pre-mining groundwater levels and flow direction

11.2 Simulating Dewatering of Mining Area

Groundwater flow into the existing and proposed mining area at Leeuwpan was modelled with drain cells. The elevation of the drain cells was specified according to the mine floor elevations.

11.2.1 Cumulative Impacts of Surrounding Mines

As previously mentioned a number of operating and defunct mines border the Leeuwpan Colliery. A few mines located adjacent to it may contribute to the impacts posed by Leeuwpan. Stuart Coal is located to the east of the OWN_WTN Block (Weltevreden) opencast, as well as another section to the north of the OJ Block open cast Leeuwpan. Furthermore Samquartz (Silica Mine) is located east of the OJ Block opencast. Samquartz is however exploiting quartzite underlying the coal rich Karoo Ecca Group. The impact of the surrounding mines and vica versa were not assessed during the scenarios.

11.2.2 Contaminated Transport Model

The calibrated groundwater flow model was used as a basis for developing a contaminant transport model. Sulphate concentration was used to determine the impact of mining on the aquifer. Sulphate is considered to be a water soluble oxidation product of ARD and is considered to be a representative indicator of the impact of coal mining on groundwater quality. The model is based on the following assumptions:

- Contaminant movement will mostly take place as a result of advection. This assumption is based on the calculation of the Peclet number (Pe) for the aquifer which indicates that advection is the main flow mechanism; and
- Chemical reaction between rock and dissolved species were not taken into consideration during simulations. Therefore a worst case scenario is assumed.

Movement of contaminant particles takes advection, dispersion and also flux sources into account. Longitudinal dispersion was taken as 50m, which is about a tenth of the maximum transport distance. Concentrations at different transport distances in the plume also take dilution from natural rainwater recharge and mixing into account (sources).

Due to the assumptions made and limited calibration data available, the results from the contaminant transport model are considered to represent a first approximation of the impact on groundwater quality. Due to the nature of the simulations, the estimated concentrations will reflect expected conditions within an order of magnitude.

It is advisable to recalibrate the flow model and transport model once more information regarding water qualities and new mining areas become available.

The sulphate source concentrations in the various opencasts were taken as 2500 mg/l SO_4, as determined during the geochemical assessment.

11.3 Modelling Limitations

A numerical model does not provide a unique solution. Therefore, numerical modelling will always have inaccuracies due to the uncertainty in data, the capabilities/limitations of numerical modelling code to describe the natural processes and the factors selected by the modeller to resolve the non-unique solution. The modelling was performed within the limitations of the scope of work of this study and the amount of water level data available. All efforts have been made to base the model on sound assumptions and was calibrated to observed data, however the results obtained from this exercise should be considered in accordance with the assumptions made.

Field data is essential in calibrating model conditions. Specific assumptions related to the available field data include:

- The top of the aquifer is represented by the surface topography and available surface elevations (STRM data in this case) are used to construct a representative spatial extent;
- The current geological information is sufficient to describe the extent of the different aquifers;
- The aquifer parameters calculated is representative of the aquifers beyond the area, where data is not available (no aquifer parameters were available beyond the local mining areas); and
- The assumption that a fractured aquifer will behave as a homogeneous porous medium can lead to error. However, on a large enough scale (bigger than the REF, Representative Elemental Volume) this assumption should be acceptable.

Limitations of models are the result of generalisations, interpretations and assumptions made in attempting to simulate the natural environment. The following limitations are true for all numerical groundwater models:

- The complexities of fractured rock aquifers imply that the model can only be used as a guide to determine the order of magnitude of dewatering and contaminant transport; and
- The interpretation of modelled results should be based on the assumptions the model was built on and actual results will vary as unknown aquifer conditions and parameters vary in the natural system.

12 GROUNDWATER IMPACTS

The impacts on groundwater levels and as contaminant transport away from the contaminant sources due to the exsiting and proposed mining activities were quantified using the 3D numerical groundwater flow and contaminant transport model.The significance of the potential impacts were asseses using a standard methodology and discussed below.

12.1 Environmental Impact Significance Rating Methodology

To ensure uniformity, the assessment of potential impacts has been addressed in a standard manner so that a wide range of impacts are comparable. The methodology utilised is from the South African Department of Environmental Affairs and Tourism guideline document on EIA Regulations (April 1998). The following descriptive-value added evaluation method will be used to determine the significance of the impacts.

Extent (spatial scale)
Extent is an indication of the physical and spatial scale of the impact.

Low (1)	Low/Medium (2)	Medium (3)	Medium/High (4)	High (5)
Impact is localised within the site boundary: Site only	Impact is beyond the site boundary: Local	Impacts felt within adjacent biophysical and social environments: Regional	Impact widespread far beyond site boundary: Regional	Impact extend National or over international boundaries

Consideration to be given to:

- Access to resources;
- Amenity;
- Threats to lifestyles, traditions and values; and
- Cumulative impacts, including possible changes to land uses around the site.

Duration
Duration refers to the time frame over which the impact is expected to occur, measured in relation to the lifetime of the proposed project.

Low (1)	Low/Medium (2)	Medium (3)	Medium/High (4)	High (5)
Immediate mitigating measures, immediate progress	Impact is quickly reversible, short term impacts (0-5 years)	Reversible over time; medium term (5-15 years)	Impact is long-term	Long term; beyond closure; permanent; irreplaceable or irretrievable commitment of resources

Consideration to be given to:

- Cost-benefit economical and socially (e.g. long or short term costs / benefits)

Intensity of magnitude / severity

Intensity refers to the degree or magnitude to which the impact alters the functioning of an element of the environment. The magnitude of alteration can either be positive or negative, as were also taken into consideration during the assessment of severity.

Type of criteria	Negative				
	H-(10)	M/H-(8)	M-(6)	M/L-(4)	L-(2)
Qualitative	Very high deterioration, high quantity of deaths, injury of illness / total loss of habitat, total alteration of ecological processes, extinction of rare species	Substantial deterioration, death, illness or injury, loss of habitat / diversity or resource, severe alteration or disturbance of important processes	Moderate deterioration, discomfort, partial loss of habitat / biodiversity or resource, moderate alteration	Low deterioration, slight noticeable alteration in habitat and biodiversity. Little loss in species numbers	Minor deterioration, nuisance or irritation, minor change in species / habitat / diversity or resource, no or very little quality deterioration.
Quantitative	Level of deterioration is so high that the level thereof is not always measureable	Measurable deterioration. Recommended level will occasionally be violated.	Measurable deterioration. Recommended level will occasionally be violated	Rare violation of recommended level. Very slight measurable deterioration.	No measurable change. Recommended level will never be violated.

Consideration to be given to:

- Cost-benefit economically and socially (e.g. high net cost = substantial deterioration); and
- Impacts on future management (e.g. easy / practical to manage with change or recommendation).

Probability of occurrence

Probability describes the likelihood of the impacts actually occurring. This determination is based on previous experience with similar projects and/or based on professional judgment.

Low (1)	Medium/Low (2)	Medium (3)	Medium/High (4)	High (5)
Improbable; low likelihood; seldom. No known risk or vulnerability to natural or induced hazards.	Likely to occur from time to time. Low risk or vulnerability to natural or induced hazards	Possible, distinct possibility, frequent. Low to medium risk or vulnerability to natural or induced hazards.	Probable if mitigating measures are not implemented. Medium risk of vulnerability to natural or induced hazards.	Definite (regardless of preventative measures), highly likely, continuous. High risk or vulnerability to natural or induced hazards.

Significance

Significance is determined through a synthesis of the above impact characteristics, and is an indication of the overall importance of the impact. The significance of the impact "without mitigation:" is the prime determinant of the nature and degree of mitigation required. For this assessment, the significance of the risk without prescribed mitigation actions was measured.

The significance of the identified impacts on components of the affected environment were determined as significance points (SP) = (magnitude + duration + spatial scale) x probability.

The maximum value per aspect is 100 SP. Environmental effects were rated as high, moderate or low significance, based on the following:

- more than 60 significance points indicated high (H) environmental significance;
- between 30 and 60 significance points indicted moderate (M) environmental significance; and
- less than 30 significance points indicated low (L) environmental significance.

12.2 Construction Phase – New Activities

During construction of the new activities (Block OI and OL) minimal additional impacts in the groundwater system is expected. The main activities that could impact on groundwater in this phase include constructing and clearing of footprint areas for construction Table 12.1 below lists the groundwater impacts expected during this phase, the impacts are expected to have a low significance rating.

Table 12.1: Impacts on groundwater during Construction Phase

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION		RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION	
		TOTAL	SP		TOTAL	SP
Water quality						
Clearing topsoil for footprint areas can increase infiltration rates of water to the groundwater system.	Footprint Clearance / Construction	4	L	Mitigation is not possible.	4	L
Handling of waste and transport of building material can cause various types of spills (hydrocarbons) which can infiltrate and contaminate the groundwater system.	Waste / hydrocarbon Handling	15	L	Waste should to be discarded in the allocated waste area. The waste area should be bunded. Spills should be cleaned up immediately according to the WULA conditions. The DWA should be notified in the event of a significant spill. Solid waste must similarly either be stored at site on an approved waste disposal area, or removed by credible contractors.	12	L

12.3 Operational Phase

There are number of opencast in operation at the time of the investigation. The environmental impact significance is expected to be low can be seen in Table 12.2.

12.3.1 Groundwater Quantity (Groundwater level drawdown)

The mine floor elevation is below the general groundwater level thus causing groundwater inflows into the opencast mining areas from the surrounding aquifers during operations. The mining areas will have to be actively dewatered to ensure a safe working environment. Pumping water that seeps into the mine areas to surface will cause dewatering of the surrounding aquifers and an associated decrease in groundwater level within the zone of influence of the dewatering cone.

The zone of influence of the dewatering cone depends on several factors including the depth of mining below the regional groundwater level, recharge from rainfall to the aquifers, the size of the mining area, and the aquifer transmissivity amongst others. The 3-D numerical groundwater flow model was used to simulate the development of the drawdown cone over time in the study area. The latest mining schedules (at the time of investigation) also taken in consideration when calculating the drawdown.

During the operational phase, it is expected that the main impact on the groundwater environment will be dewatering of the surrounding aquifer. At the time of the investigation boreholes MOAMB10, MOAMB7, WELMB13D, KENMB1, KENMB2D and WTN01d were slightly affected by the drawdown cone of the existing mining activities.

In order to interpret the changing cone of groundwater depression as mining progress at the different opencasts, various scenarios has been modelled as illustrated in Figure 12.1 to Figure 12.3.

Mining until 2015

The OD, OH, OM, OJ, OWM_WTN and OWM_MN Block opencasts were being mined at various stages during the investigation. The proposed OI and OL mining Blocks are only likely to mined during and after 2016. The potential extent of the groundwater cone of depression in 2015 before OI and OL are mined can be seen in Figure 12.1. It can be seen that a dewatering cone has developed around the OWM_WTN and OWM_MN Block opencasts (Moabsvelden and Weltevreden) as well around the OJ, OH and OD blocks which will still be mined in 2015. The extent of groundwater cone of depression around the OWM_WTN and OWM_MN Block opencasts (Moabsvelden and Weltevreden) is generally confined to mining area. The extent of drawdown around the OJ, OH and OD mined blocks as well as the previously mined Block OA (Witklip), Block OE (Midklip) and Block OF (Kenbar) range from 200m to 1000m around the mining complex.

The previously mined Block OA (Witklip), Block OE (Midklip) and Block OF (Kenbar) were backfilled and mined out. As a result the water levels in pit were busy rebounding especially in the OA (Witklip) and OE (Midklip) mined areas. Block OF (Kenbar) is however still likely to connected the OH Block which will be mined until 2016.

No privately owned boreholes (located in the dolomitic aquifer) are likely to be impact by lowering of groundwater levels. A number of monitoring boreholes may however be slightly impacted.

Mining until 2020

The OI and OL mining areas are scheduled to start mining in 2015. By the year 2020, these opencast areas were also likely to results in a lower of the groundwater level surrounding the opencasts as is evident in Figure 12.2. It also be seen that the extent of groundwater cone of depression around the OD, OH, OM, OJ, OA (Witklip), OE (Midklip) and Block OF (Kenbar) has decreased as the groundwater level rising in the aquifer surrounding these mined out opencasts. The OWM_MN Block opencast (Moabsvelden) was scheduled to be mined up to 2020 and therefore still has a negative impact on the groundwater levels. The simulated extent of drawdown extends 200-300m from the active mining area, with a larger extent of 1000m to the north and 1600m to the south of the mining complex as seen in Figure 12.2.

Mining until 2029

Only the OL, OI UB and a small portion of the OWM_MN Block opencast (Moabsvelden) are scheduled to be mined between 2020 and 2029. The extent of drawdown around these opencast areas range from 100 to 1000m as seen in Figure 12.3. As the mined out opencasts start filling with water the groundwater levels around the opencast will also rebound.

The following deductions can be made:

- The water levels could be lowered over relative large area around the opencasts, especially in the upstream direction to the south;
- There are several monitoring boreholes in the potential affected area that might experience a decline in water levels of 5m or more. No privately owned borehole is likely to be impacted by the lowering of water levels as a result of the Leeuwpan mining activities based on the simulations. However boreholes Rie6, Moa1, Moa2 and Moa6 are likely to be mined out in the OI and OL blocks. It is however important that these boreholes are comprehensively sealed and grouted before mining commenced to prevent contamination from the underlying dolomitic aquifer.

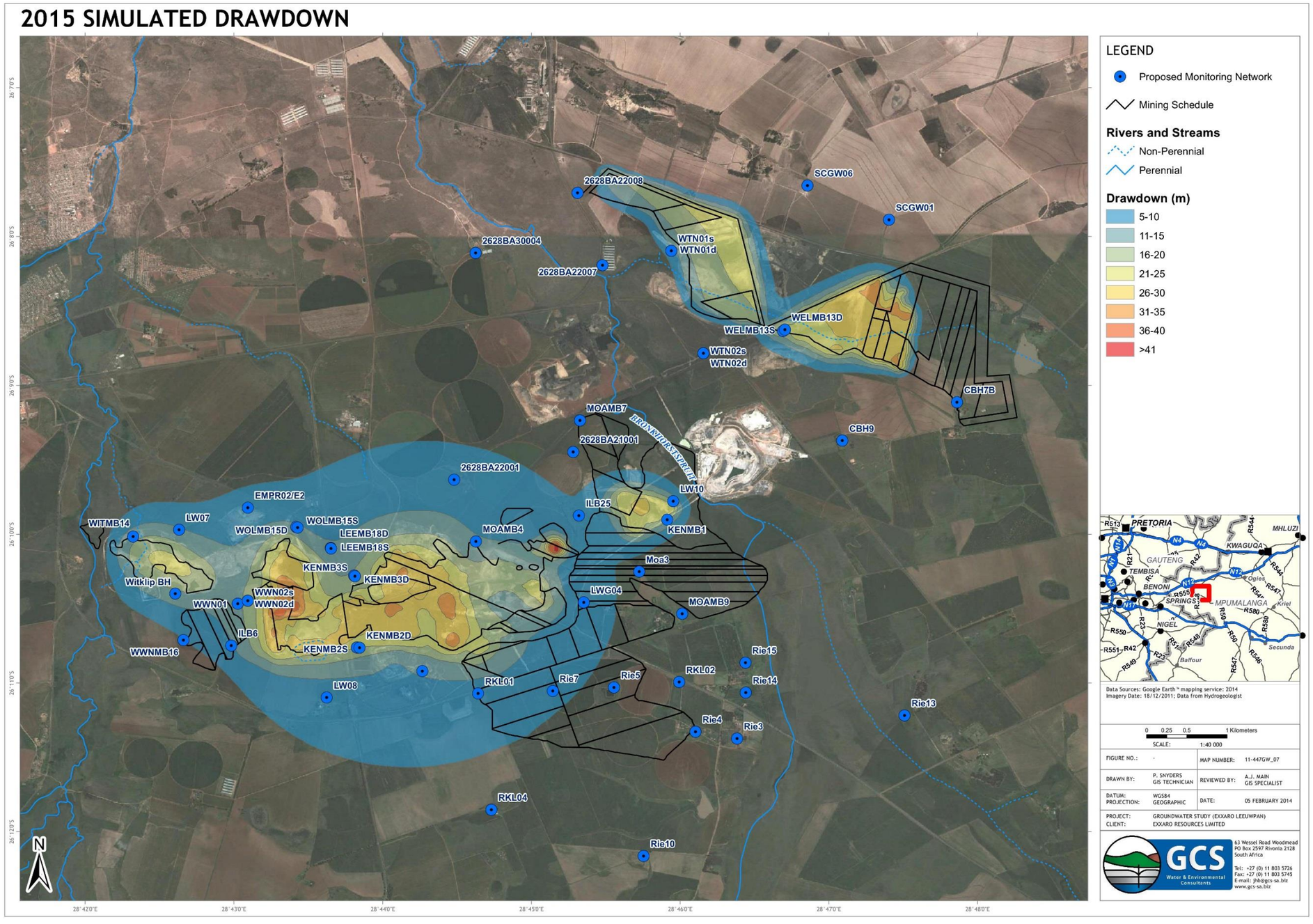


Figure 12.1: Groundwater drawdown in 2015

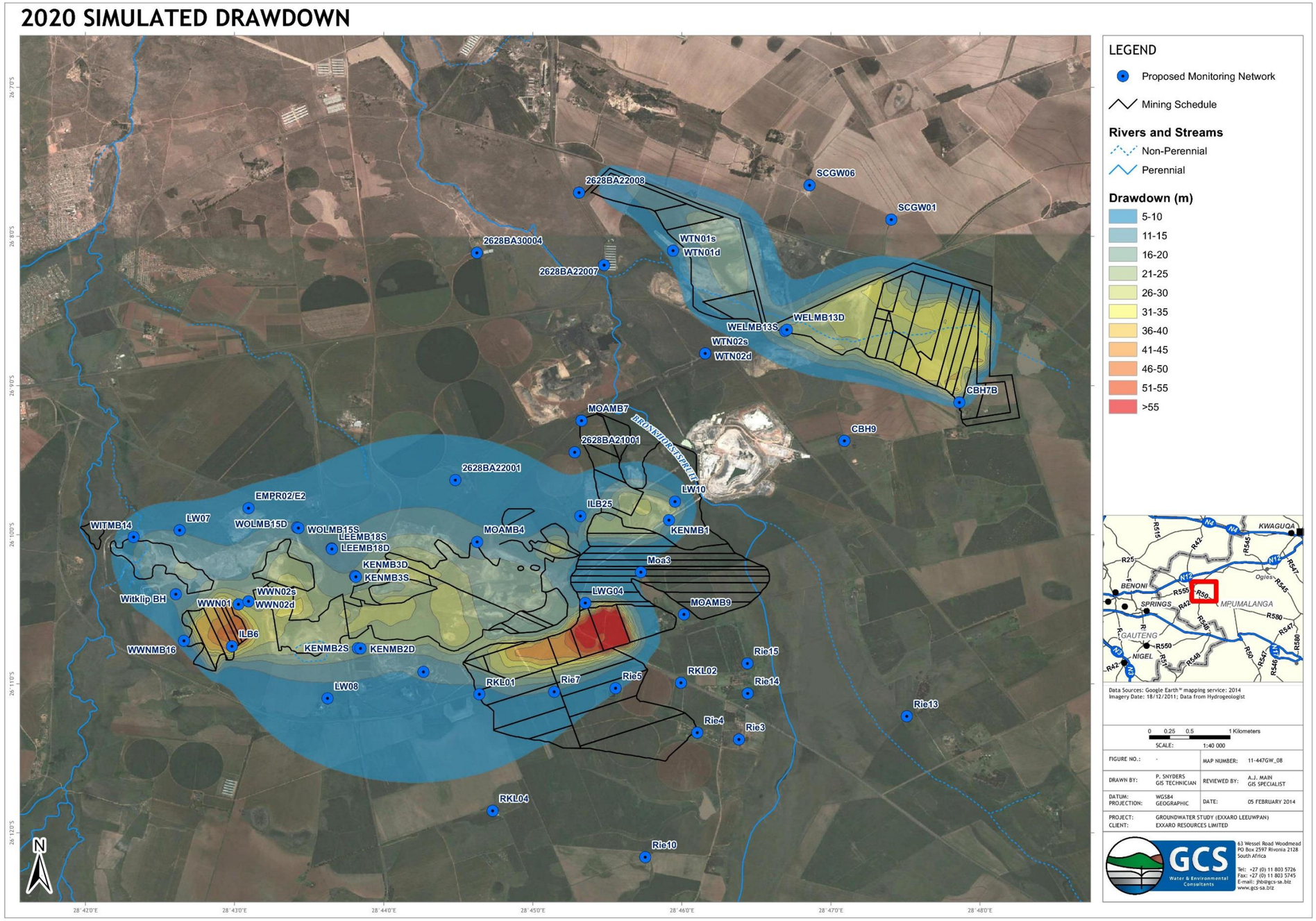


Figure 12.2: Groundwater drawdown in 2020

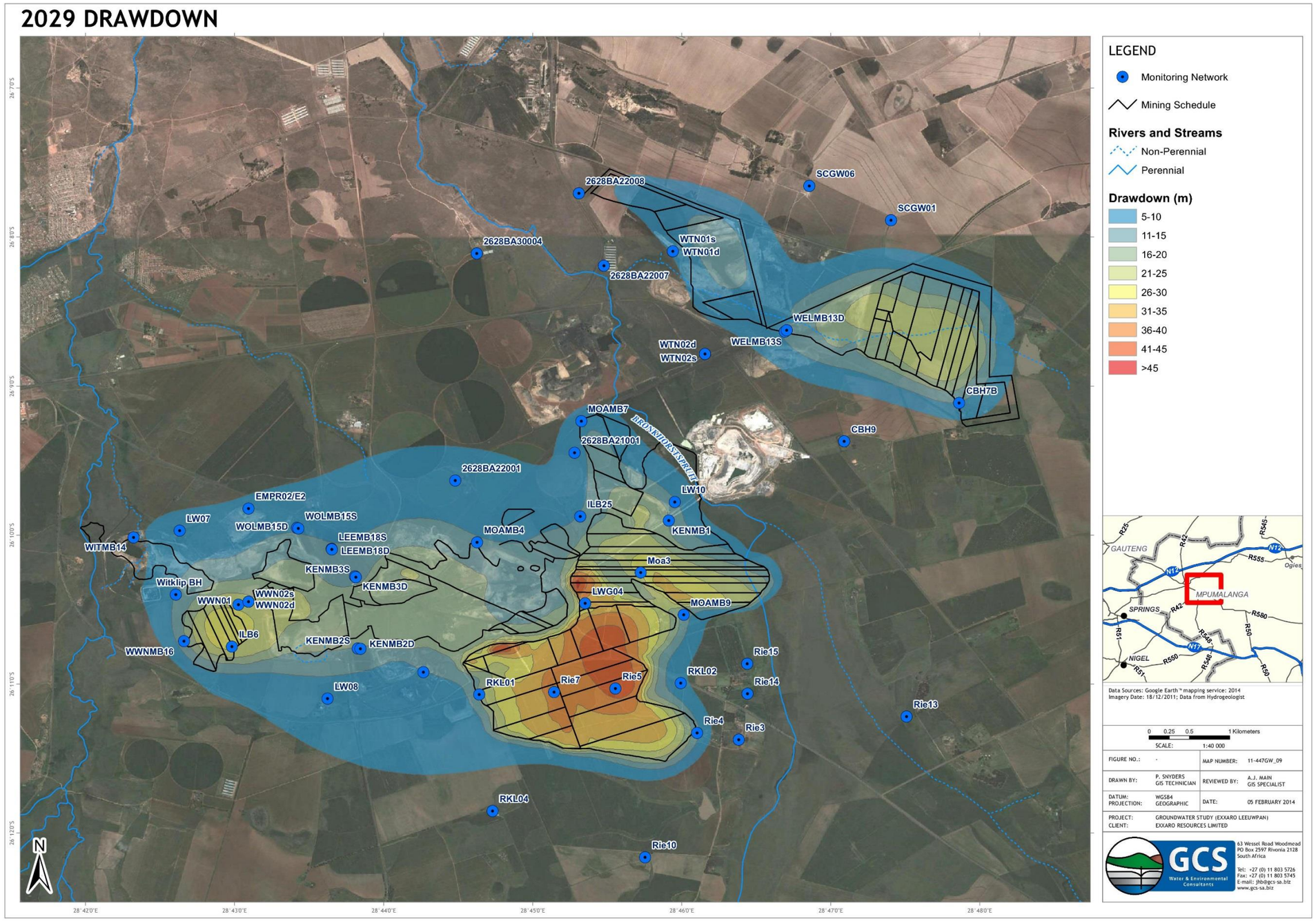


Figure 12.3: Groundwater drawdown in 2029

12.3.2 Mine inflow volumes

It was possible to calculate the inflow into the opencasts for each mining cut from the numerical model. The computed inflow into each opencast was calculated as shown below in Figure 12.4 to Figure 12.5 below based on the mine schedules. Due to several assumptions that had to be made for this model, these numbers must be considered as order of magnitude only, and actual values could deviate considerably from these.

The mine inflows into the proposed Block OI opencast can be seen below in Figure 12.4. The inflows during the first cut is (~500 m^3/d), mainly due to the mining depth ranging from 60 to 67 mbgl in 2016. The inflow increases at the end of 2019 (~600 m^3/d) as the mining depth increases to 65-78 mbgl. Inflows reduce from 2021 to 2029 mainly due the active mining cut moving adjacent to an already mined out area, as such most of the aquifer storage has been dewatered. These inflows reduce from 430 m^3/d to 360 m^3/d in 2027.

The proposed Block opencast OL mining depth is shallower than OI and the mine floor depths are envisaged to increase from ~17 mbgl in the north east to ~44 mbgl in the south west. As a result the expected groundwater inflows (Figure 12.5) are likely to be less than Block OI. The inflows at the beginning of 2020 may approach ~60 m^3/d which then increases to ~340 m^3/d in 2029 (as the mining depth increases).

It is also important to view these volumes for the water make of the mine in relation to natural evaporation. Evaporation will take place over the whole area of the opencasts, and will remove large amounts of water, especially in the dry season.

It must be cautioned that these calculations have been done using simplified assumptions of homogeneous aquifer conditions. The reality could deviate substantially from this and the model should thus be updated as more information becomes available.

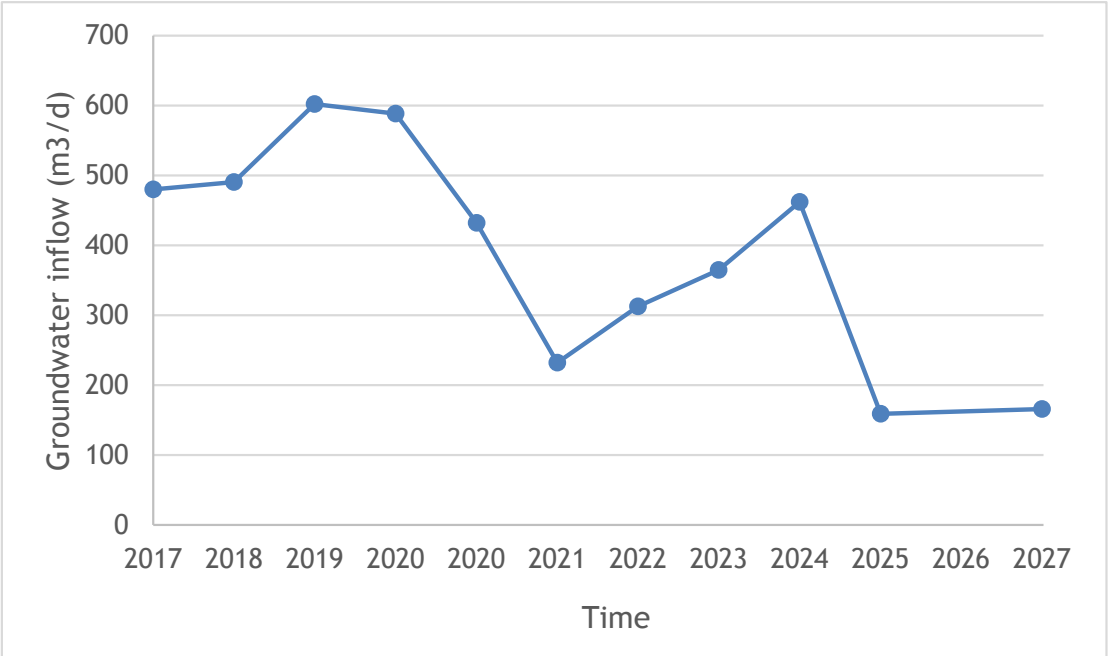


Figure 12.4: Simulated groundwater Inflows into the proposed Block OI opencast

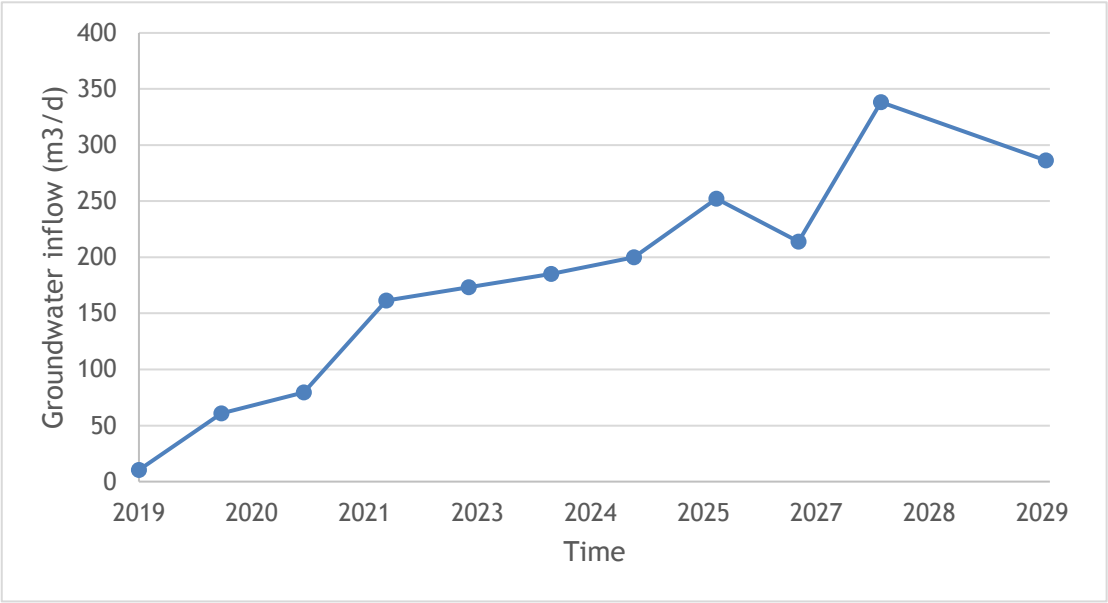


Figure 12.5: Simulated groundwater Inflows into the proposed Block OL opencast

12.3.3 Groundwater Quality (Contamination of the surrounding aquifers)

The life of mine for the existing and proposed mining at Leeuwpan is planned until 2029. This allows sufficient time for chemical reactions to take place in the mined out areas, overburden dumps and other potential pollution sources to produce ARD conditions. Groundwater flow directions will be directed towards the mining areas due to the mine dewatering. Therefore contamination will be contained within the mining area, and little contamination will be able to migrate away from the mining area. The water balancing dam and pollution control dams should be lined, thereby preventing contamination of the underlying aquifers.

The mine residue consisting of overburden, plant residue and fine coal recovered from the slimes dams, was compacted and introduced to the mined-out pits. Thus no mine residue disposal sites were constructed for the mining operations. Discard material was also placed back into the open pits.

Backfilling at Blocks OJ opencast took place 45 m from the working face. Due to the risk of pollution to the Bronkhorst River, no discard was backfilled into the pit.

Furthermore, backfilling at Block OI and OL will be conducted in the same manner as the other mined out pits, thus discard and slurry cake will be disposed of as part of the backfilling process.

Contamination from the mining areas is generally contained within the mining areas. It is furthermore evident that selected boreholes have been impacted by contaminants at the plant area. The borehole KENMB2D located down gradient of the No. 5. Emergency overflow dam is also impact by mining related contaminants. Boreholes WWN02s, WWN02d and WNN01 are located adjacent to a dam west of the OD block opencast which is also impacted by mining related contaminants (seepage from this dam). Borehole WITMB14 located down gradient of the Witklip pit (Block OA) showed an impact by mining related contaminants although still compliant with the SANS 241 Drinking water standard. The borehole MOAMB10 located adjacent to OJ Block opencast has been negatively impacted by mining in term of elevated sulphate, TDS and EC. The shallow borehole WTN02s contained sulphate concentrations above the background levels (although still compliant). It is likely that this borehole has been impacted by a shallow contaminant source associated with the haul road (coal spillage). Shallow and deep boreholes (WELMB12d and WELMB13s) located down gradient of the OWN_MN Block (Moabsvelden) opencast are also slightly impact by mining related contaminants.

These impact monitoring boreholes are mostly affected by contaminants emanating from surface related contaminant sources.

Table 12.2: Impacts on groundwater during Operational Phase

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION		RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION	
		TOTAL	SP		TOTAL	SP
Water quantity						
Opencast mining will result in groundwater inflows into the workings which need to be pumped out for mine safety and the resultant dewatering (water level decrease) of the groundwater system in the immediate vicinity of the workings.	Opencast Mining	24	L	Keeping the workings dry is necessary for mining and mitigation is not possible. No users are currently likely to be affected.	24	L
Water quality						
Stockpiling of coal will expose coal to water and oxygen, resulting in ARD from roads and stockpiles. Contamination of the groundwater system will occur from these sites, although at a lower significance than the opencast pits.	Coal stockpiling (Plant)	28	L	Clean water needs to be kept away from the stockpiling area to minimise water infiltrating from the site. Keep stockpiles as small as possible, to minimise their footprint.	21	L
Handling of waste and transport of building material can cause various types of spills (domestic waste, sewage water, hydrocarbons) which can infiltrate and cause contamination of the groundwater system.	Waste Handling	20	L	Waste needs to be discarded and spills cleaned up immediately according to the WULA conditions. The DWA should be notified in the event of a spill.	16	L

12.4 Decommissioning Phase

During this phase it is assumed that active mining has stopped and the opencasts will be rehabilitated. All the surface contaminant sources (plant areas, dams, and stockpiles) has been decommissioned and no longer acts as a source. No additional impacts on the groundwater of the study area other than the impacts discussed above are expected during the decommissioning phase of the project.

12.5 Post Closure Phase

In the post closure phase all the opencasts are deemed to be backfilled and vegetated. Table 12.5 also lists the groundwater impacts expected during this phase. Water and oxygen will react with the backfilled material and as a result ARD will peak during this phase. The environmental impact significance is expected to be moderate to high.

12.5.1 Groundwater Quality

Once the mining has ceased, ARD is still likely to form given the unsaturated conditions in the facility and contact of water and oxygen through natural process including rainfall. Therefore a groundwater contaminant plumes are likely to migrate from the mining areas once the water level in the rehabilitated pits have reached long term steady state conditions (i.e. each pit water level has reached the decant level). The contaminant plume emanating from the rehabilitated opencasts will have a cumulative impact on the groundwater quality as seen in the post mining simulations (Figure 12.6 and Figure 12.7). The migration of contaminated water from the opencasts has been simulated for 50 and 100 years after colliery closure (i.e. it is assumed that all opencast have been rehabilitated and backfilled). Experience has shown that the plume stagnates after about 80-100 years, and no further movement after such time is expected.

The contaminant plume emanating from the Blocks OA, UB, OWM_MN and OWM_WTN opencasts will move in a north westerly direction towards the dolomitic area and the Bronkhorstspruit. The contaminant plume migrating from Blocks ODN, OD, OF, OM, OH, OG and OJ will move in a northerly direction, while the plume from OI and OL will moved in an easterly direction towards the Bronkhorstspruit. The contaminant concentration is likely to increase over time as the plume develops.

No privately owned boreholes located in the fractured Karoo aquifer is likely to be impacted based on the impact simulations. However shallow contaminated seepage may impact on the Bronkhorstspruit. The SO_4 salt load contribution from contaminated groundwater seepage in the stream can be seen in Table 12.3. The Block OA (Witklip), OJ, OI and OWM_WTN opencast are likely to be the main contaminant sources which may impact on the salt load of the Bronkhorstspruit and its tributaries. It must be noted that this does not include any contribution from decant. These impact is however likely to be moderate as seen in Table 12.5.

Table 12.3: Estimated groundwater seepage salt loads on Bronkhorstspruit and its tributaries

Contaminant source	Average baseflow volumes (m^3/s)*	SO_4 salt load (kg/d)	max SO_4 concentration in seepage (mg/l)	SO_4 concentration in stream (mg/l)
Block OA	0.03	7	1700	2
Block OL and OJ	0.013	24	1000	21
Block OWM_WTN	0.01	0.5	100	0.5

* - baseflow was average per annum and obtain from the Bronkhorstspruit catchment calculation

Given the significance of the underlying dolomite aquifer, the interaction between the dolomite and the Karoo aquifers should be further investigated. If these aquifers are in hydraulic connection and a flow gradient form the Karoo aquifer exists towards the dolomite aquifer exists the dolomitic aquifer may be impacted on post closure by contaminants.

The results must be viewed with caution as a layered homogeneous aquifer has been assumed. Heterogeneities in the aquifer are unknown and the effect of this cannot be predicted. Furthermore, no chemical interaction of the sulphate with the minerals in the surrounding bedrock has been assumed. As there may be some interaction and retardation of the plume, it is likely that this prediction will represent a worst-case scenario.

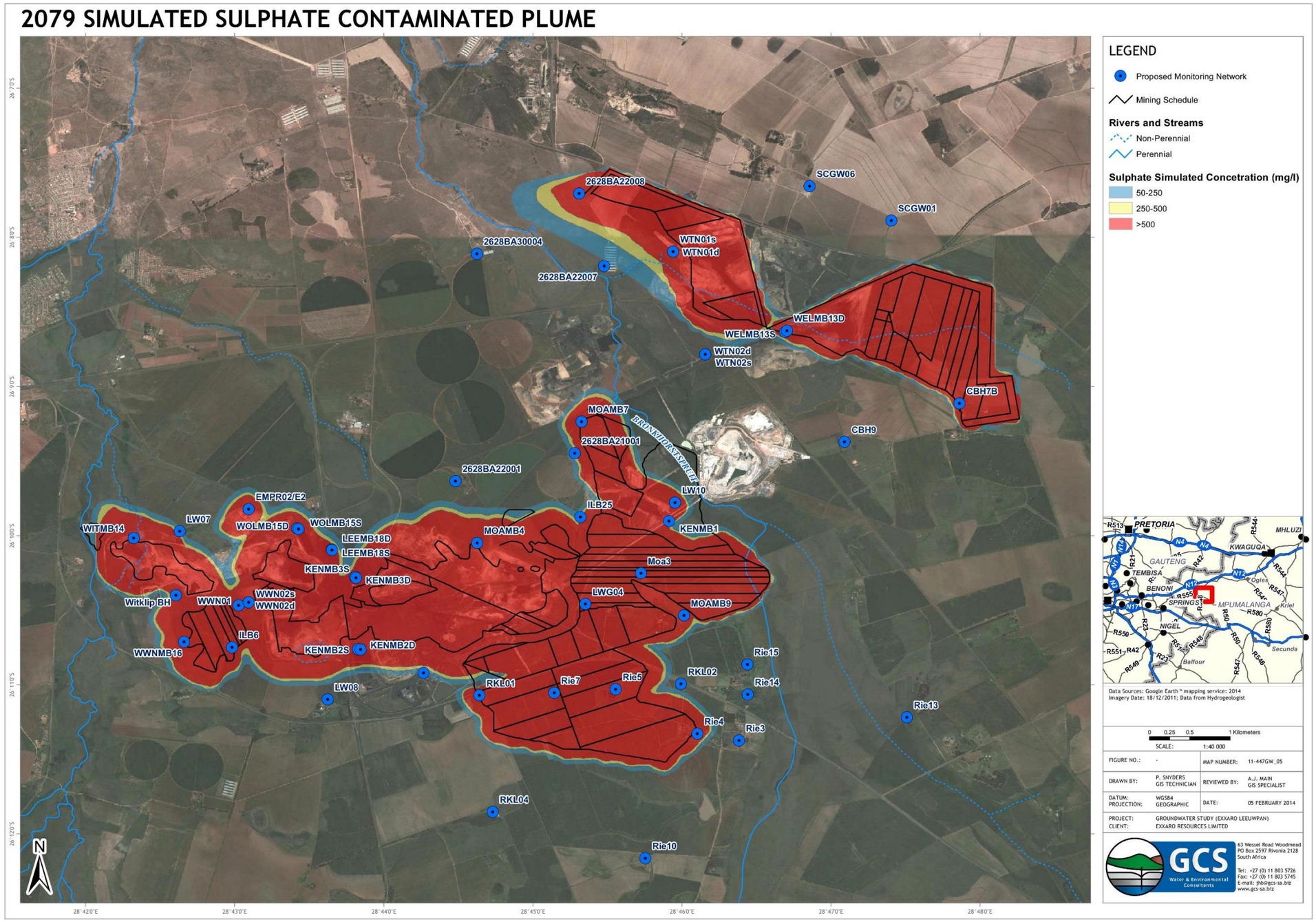


Figure 12.6: Simulated SO_4 Contaminant Plume – 2079 (50 years post closure)

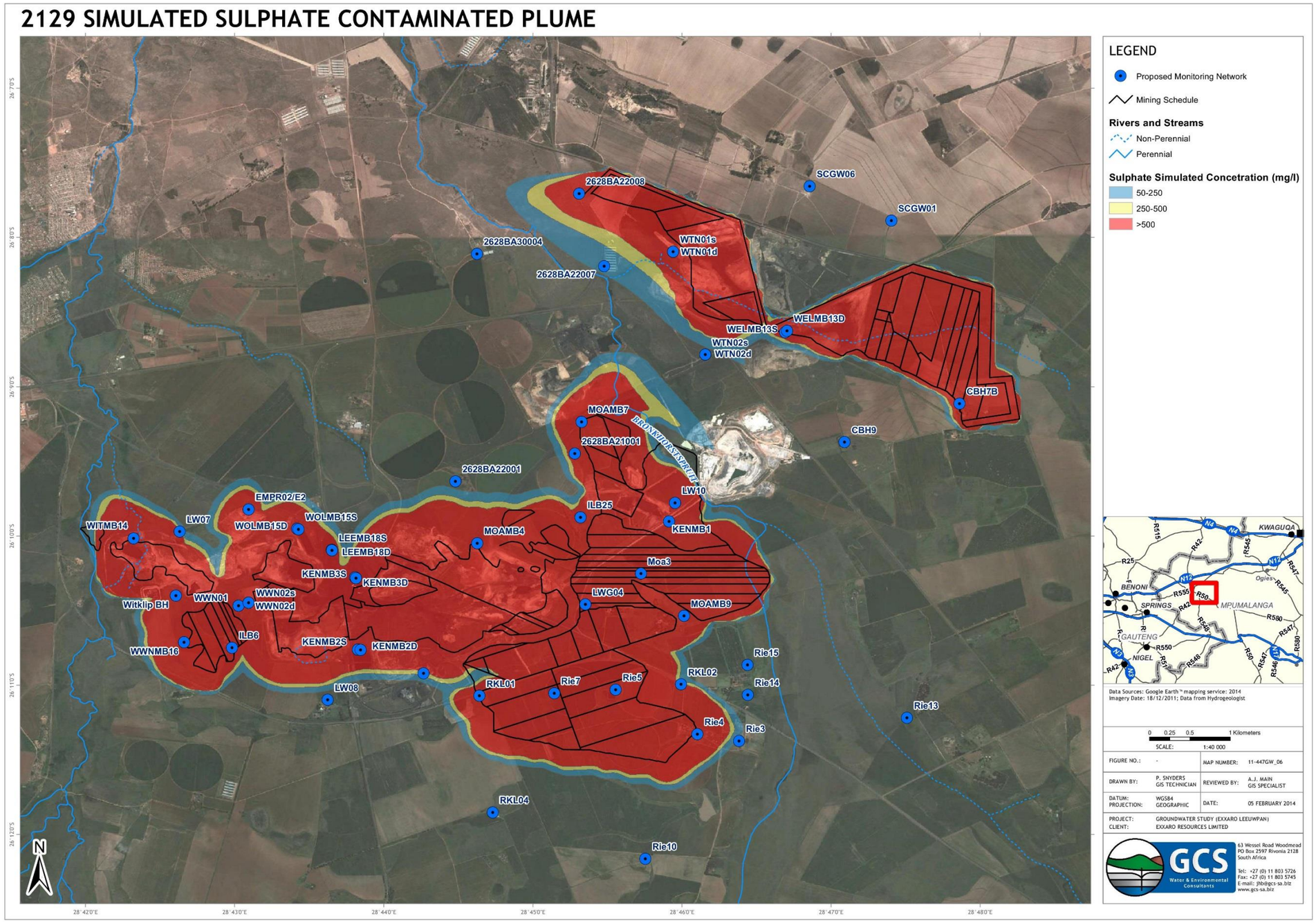


Figure 12.7: Simulated SO_4 Contaminant Plume – 2129 (100 years post closure)

12.5.2 Mine Water Decant

Decanting occurs when the mine water level in the rehabilitated and backfilled workings rebounds to a level above the topographic elevation, resulting in mine water discharging onto surface. Surface decanting refers to direct discharge of mine water to surface through backfilled material, voids, shafts, adits and other direct paths. Decant take place at the lowest topographic level that intersects the flow path and/or opencast. The location of the decant positions can be seen in Figure 12.8. A summary of the decant levels and volume for the opencasts can be seen in Table 12.4. The expected significance of the impact is high as seen in Table 12.5.

The decant volume and period to decant is based on a backfilled opencast with no final void, and does not take evapotranspiration into account. Based on the available opencast floor elevations all the opencast floors will be fully flooded.

It is recommended that boreholes are drilled into the backfilled opencast to determine the inflow rates as the mines flood. Therefore the active monitoring of the water levels in the mining areas should take place so that more precise decant predictions can be made.

Table 12.4: Summary of the estimated decant status of opencast

Mine Block / Pit	Decant level (mamsl)	Decant volume (m^3/d) (8% rech)	Decant volume (m^3/d) (10% rech)	Decant volume (m^3/d) (15% rech)	Description
Witklip OA	1549	48	60	90	Assuming total backfilling
ODN	1563	42	52	78	Assuming total backfilling
OE Midklip	1561	5	6	8	Assuming total backfilling
OD	1569	106	132	198	Assuming total backfilling
OF (Kenbar)/OG	1569	364	456	683	All pits to decant through OG
OG/OH	1569				
OM	1569				
OJ	1549	59	73	110	Assuming total backfilling
OWM_WTN	1545	199	248	372	Assuming total backfilling
OWM_MN	1550	380	475	713	Assuming total backfilling
OL	1553	254	317	476	Assuming total backfilling
OI	1570	446	557	836	Assuming total backfilling
UB	1561	58	73	110	Assuming total backfilling
Sum		**1960**	**2450**	**3675**	

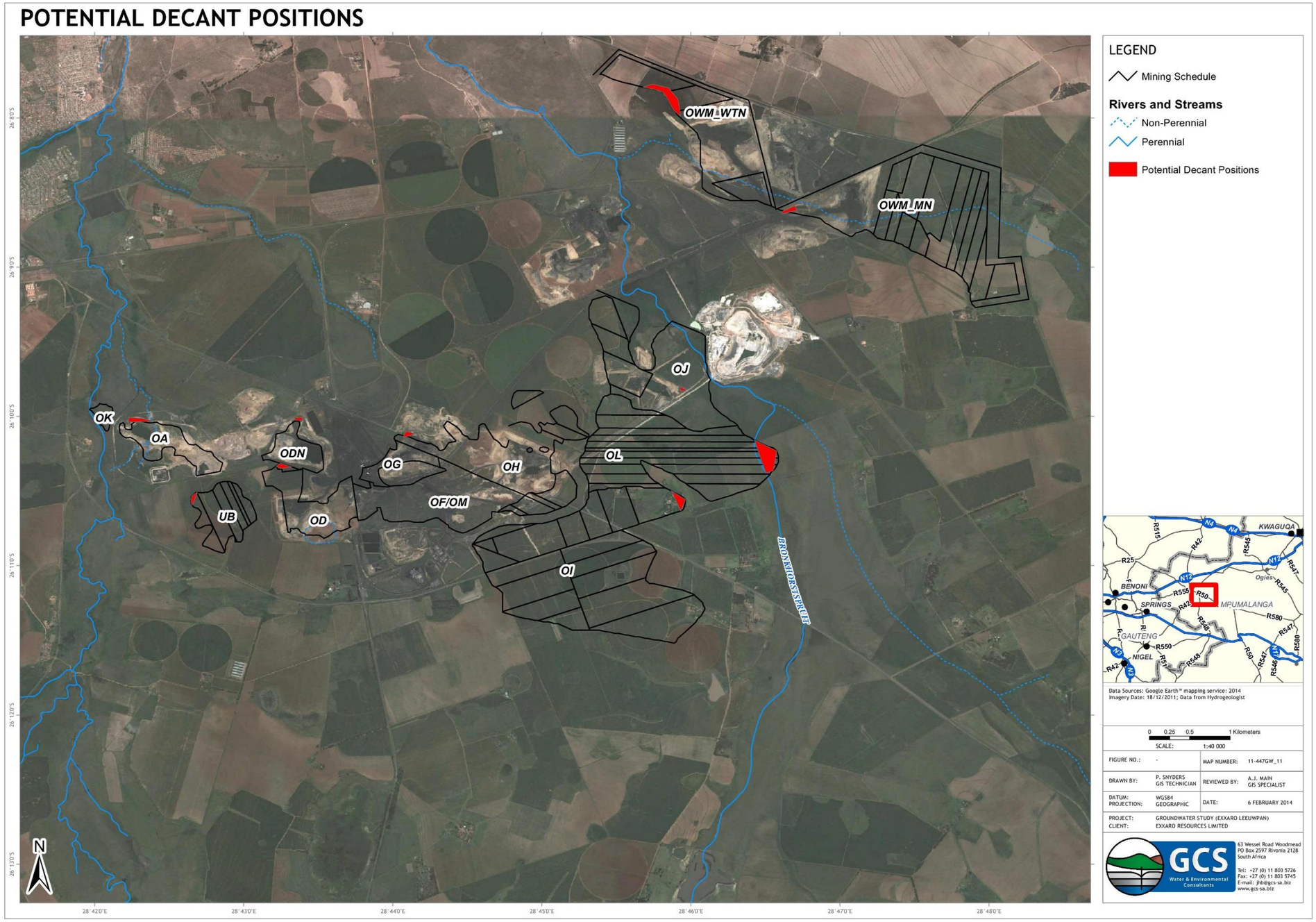


Figure 12.8: Location of potential decant positions

Table 12.5: Impacts on groundwater Post Closure Phase

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION		RECOMMENDED MITIGATION MEASURES/ REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION	
		TOTAL	SP		TOTAL	SP
Water Quality						
Contaminated groundwater seepage to streams (salt load)	Rehabilitated mining areas	52	M	Groundwater levels in the backfilled pits will recover. Pollution plumes may migrate to surface water bodies. All mined areas should be flooded as soon as possible to bar oxygen from reacting with remaining pyrite. The final backfilled opencast topography should be engineered such that runoff is directed away from the opencast areas. The final layer (just below the topsoil cover) should be as clayey as possible and compacted if feasible, to reduce recharge to the opencasts. Intercepting decant by a downstream trench is also an option to investigate. Surface water monitoring of the streams will be essential. Quarterly groundwater sampling should be done to establish a database of plume movement trends, to aid eventual mine closure. The drilling of boreholes into mining areas is recommended so that recovery of water in mining areas can be monitored.	39	M
Groundwater contaminant plume	Rehabilitated mining areas	55	M	Groundwater levels in the backfilled pits will recover. Pollution plumes may migrate to surface water bodies. All mined areas should be flooded as soon as possible to bar oxygen from reacting with remaining pyrite. The final backfilled opencast topography should be engineered such that runoff is directed away from the opencast areas. The final layer (just below the topsoil cover) should be as clayey as possible and compacted if feasible, to reduce recharge to the opencasts. Intercepting decant by a downstream trench is also an option to investigate. Surface water monitoring of the streams will be essential. Quarterly groundwater sampling should be done to establish a database of plume movement trends, to aid eventual mine closure. The drilling of boreholes into mining areas is recommended so that recovery of water in mining areas can be monitored. The absence of groundwater users should be assessed bi-annually	44	M
Decant from opencast operations	Residual Impacts Post Closure (All Opencast)	60	H	Surface water should be diverted away from the rehabilitated area. Proper compacting and rehabilitation may lower recharge to the backfilled area and minimise infiltration, thereby minimising geochemical reactions that will occur. Reduction of the recharge would entail capping the backfill of the opencast with a semi-permeable layer. Leaving a final void in the opencast areas, would be able evaporate potential decanting volume on average through the year, a dirty water / pollution control dam could be used to intercept polluted seepage water from enter water courses (streams). Decant can also be treatment to an acceptable water quality for discharge or re-use	60	H

13 GROUNDWATER MANAGEMENT PLAN

13.1 Construction Phase (New Activities)

13.1.1 Actions

- Separate clean and dirty runoff and contain dirty water in adequately sized pollution control dams. Ensure that pollution control dams are adequately sized according to the specifications in DWAF's GN704 or other applicable regulations;
- Prevent dirty water runoff from leaving the general mining area;
- Minimise dirty foot prints;
- Compact the base of dirty areas, like the ROM coal stockpile, workshops and oil and diesel storage areas to minimise infiltration of poor quality water to the underlying aquifers;
- A credible company should remove used oil from the workshops;
- A sufficient supply of absorbent fibre should be kept at the site to contain accidental spills;
- Groundwater monitoring boreholes should be installed to comply with the design requirements of a groundwater monitoring system; and
- Contain dirty water in return water dams and re-use dirty water for dust suppression and make up water in the plant. Pollution control dams should be lined; and
- The pollution control dams should preferably not be constructed on the Phase 9 opencast footprint. This is done to minimise the risk of increased infiltration through the opencast should the dam leak.

13.2 Operational Phase

Restrict the impact of polluted groundwater to the mining area and mitigate the impact on groundwater levels in the catchment.

13.2.1 Actions

- All boreholes to mined out should be grouted and sealed to prevent cross contamination of aquifers;
- During the operational phase the mine water must be used or pumped to dirty water dams or pollution control facilities in order to avoid deterioration of the mine water. The longer the mine water resides in the pit the higher it's TDS will be. It is not foreseen that mine water in contact with the pit material will acidify during the operational phase of future mining;

- As much as possible coal must be removed from the opencast mine during the operational phase;
- Carbonaceous rocks (especially shale) and discard should be placed in the deepest part of the pit (as far as practical possible) and below the long-term pit water level in order to ensure that it is flooded and that pyrite oxidation is minimized;
- Soft overburden and weathered rock must be placed at the top of the backfill in order to minimize oxygen diffusion into the pit;
- The mined out sections of the pit must be backfilled, compacted and rehabilitated as soon as possible. Rehabilitation must include covering with a topsoil layer as well as vegetation thereof. Installation of a soil cover will significantly decrease water infiltration and contamination. If less water is infiltrating it will not have a negative effect on mine water quality (increasing in TDS) as the salt content is controlled by mineral saturation rather than straightforward dilution;
- Adequately sized pollution control facilities should be constructed;
- Minimise the footprint of dirty water areas like the pollution control dam and coal stockpiles, workshops and oil and diesel storage areas;
- Proper storm water management should be implemented. Berms should also be constructed to ensure separation of clean water and dirty water areas;
- Contain poor quality runoff from dirty areas and divert this water to pollution control dam for re-use;
- Static groundwater levels should be monitored as mentioned in 13.4 to ensure that any deviation of the groundwater flow from the idealised predictions is detected in time;
- The numerical model should be updated annually by using the measured water ingress and water levels to re-calibrate and refine the impact predictive scenario;
- If it can be proven that the mining operation is indeed affecting the quantity of groundwater available to certain users, the affected parties should be compensated. This may be done through the installation of additional boreholes for water supply purposes, or an alternative water supply;
- The monitoring results must be interpreted annually by a qualified hydrogeologist and network audited annually as well to ensure compliance with regulations;
- The rehabilitated opencasts should be free draining away from the pit to reduce drainage into the pit;
- All old exploration boreholes must be sealed off after closure;
- Sewage effluent emanating from latrines or ablution blocks should be treated to acceptable levels before discharge into the environment;

- Boreholes should be drilled into the mine workings so that the rate of flooding and water level recovery and quality could be established. Stage curves should made which would aid in the management of closure phase;
- A detailed mine closure plan should be prepared during the operational phase, including a risk assessment, water resource impact prediction etc. as stipulated in the DWA Best Practice Guidelines. The implementation of the mine closure plan, and the application for the closure certificate can be conducted during the decommissioned phase; and
- It is recommended that the geochemical assessment is updated during the life of the mine in order to calibrate and validate its results and to construct an effective closure plan. A geochemical model should be performed to assess the effectiveness of potential mitigation measures.

13.3 Groundwater Closure

The following objectives are envisaged for the closure phase:

- Negotiate and obtain groundwater closure objectives approved by Government during the Decommissioning Phase of the project, based on the results of the monitoring information obtained during the construction and operational phases of the project, and through verification of the numerical model constructed for the project;
- Continue with the groundwater quality and groundwater level monitoring for a period of two to four years after mining ceases in order to establish post-closure groundwater level and quality trends. The monitoring information must be used to update, verify and recalibrate the predictive tools used during the study to increase the confidence in the closure objectives and management plans;
- Present the results of the monitoring programme to Government on an annual basis. The post-closure monitoring programme will be re-evaluated on an annual basis in consultation with Government; and
- Negotiate mine closure with Government based on the results of the groundwater monitoring undertaken, after the two-four year post-closure monitoring periods.

13.3.1 Actions

- Multiple-level monitoring boreholes must be constructed to monitor base-flow quality within the identified sensitive zones and to monitor groundwater level behaviour in the backfilled pits. Use the results of the monitoring programme to confirm/validate the predicted impacts on groundwater availability and quality after closure;

- Update existing predictive tools to verify long-term impacts on groundwater, if required;
- Present the results to Government on an annual basis to determine compliance with the closure objectives set during the Decommissioning Phase;
- Reduce recharge, this would entail capping the backfill of the opencast with an impermeable layer, and is encouraged if practical;
- Pollution control dam could be used to intercept polluted seepage water. This should be considered if it is found that the stream is indeed negatively affected by pollution. Regular sampling of the stream is essential;
- Implement as many closure measures during the operational phase, while conducting appropriate monitoring programmes to demonstrate actual performance of the various management actions during the life of mine;
- All mined areas should be flooded as soon as possible to bar oxygen from reacting with remaining pyrite;
- The final backfilled opencast topography should be engineered such that runoff is directed away from the opencast areas;
- An evapotranspiration cover should be constructed on top of the opencasts. A capillary break should also be constructed between the overburden/clay and top soil. Root depth of grass is usually 0.4 to 0.6m, therefore the thickness of the top soil should be sufficient to promote root development.
- The final layer (just below the topsoil cover) should be as clayey as possible and compacted if feasible, to reduce recharge to the opencasts; and
- Audit the monitoring network annually.

13.4 Groundwater Monitoring Network

The groundwater monitoring network design should comply with the risk based source-pathway -receptor principle. A groundwater-monitoring network should contain monitoring positions which can assess the groundwater status at certain areas. Both the impact on water quality and water quantity should be catered for in the monitoring system. The boreholes in the network should cover the following: contaminant sources, receptors and potential contaminant plumes. Furthermore monitoring of the background water quality and levels is also required.

Groundwater monitoring should be conducted to assess the following:

- The impact of mine dewatering on the surrounding aquifers. This will be achieved through monitoring of groundwater levels in the monitoring boreholes. If private

boreholes are identified within the zone of impact on groundwater levels, these will be included in the monitoring programme;

- Groundwater inflow into the mine workings. This will be achieved through monitoring of groundwater levels in the monitoring boreholes as well as measuring water volumes pumped from mining areas;
- Groundwater quality trends. This will be achieved through sampling of the groundwater in the boreholes at the prescribed frequency; and
- The rate of groundwater recovery and the potential for decant after mining ceases. This can be achieved through drilling of additional boreholes into the opencast workings for monitoring purposes. These boreholes should be drilled in the deepest sections of the mine. Stage curves will be drawn to assess the inflow into defunct workings.

Groundwater Monitoring should be undertaken to SANS and DWA requirement according to the schedule presented in Table 13.1 below. The existing Leeuwpan monitoring network and the proposed additional borehole can be seen in Figure 13.1 and tabulated in Table 13.2. It is envisaged that the frequency of monitoring remains on a quarterly basis.

The groundwater monitoring network should however be reviewed and expanded for the existing and future mining activities at Leeuwpan. An updated and optimised monitoring program should be developed and submitted to DWA.

Table 13.1: Groundwater Monitoring Programme

Monitoring position	Sampling interval	Analysis	Water Quality Standards
Construction, Operational, Decommissioning and Post Closure Phases			
All monitoring boreholes	Quarterly: measuring the depth of groundwater levels	N/a	N/a
All monitoring boreholes	Quarterly: sampling for water quality analysis	• Full analysis in April and October • Groundwater level	South African Water Quality Guidelines: Domestic Use
Rainfall	Daily at the mine	N/a	N/a

13.4.1 Monitoring Parameters

The identification of the monitoring parameters is crucial and depends on the chemistry of possible pollution sources. They comprise a set of physical and/or chemical parameters (e.g. groundwater levels and predetermined organic and inorganic chemical constituents). The parameters should be revised after each sampling event, some metals may be added to the analyses during the operational phase, especially if the pH decreases.

13.4.2 Full Analysis

Physical Parameters:

- Groundwater levels

Chemical Parameters:

- Field measurements: pH, EC
- Laboratory analyses: Anions and cations (Ca, Mg, Na, K, NO_3, Cl, SO_4, F, Fe, Mn, Al, & Alkalinity); Other parameters (pH, EC, TDS)
- Petroleum hydrocarbon contaminants (where applicable, near workshops and petroleum handling facilities)

Sewage related contaminants (E.Coli, faecal coliforms) in borehole in proximity to septic tanks or sewage plants.

Laboratory analysis techniques will comply with SABS guidelines. The groundwater monitoring database will be updated on a monthly basis as information becomes available. The database should be used to analyse the information and evaluate trends noted.

An annual compliance report should be compiled and submitted to the authorities for evaluation and comment. This report should be submitted annually for the construction, operational and decommissioning phases as well as for two years after mining ceases. The mine must develop a monitoring response protocol. This protocol will describe procedures in the event that groundwater monitoring information indicates that action is required.

Table 13.2: Existing Leeuwpan and proposed OI/OL Monitoring Network

Sample ID	Coordinates (WGS84, LO29)		Description	Groundwater levels
	X	Y		(mbgl)
Existing Leeuwpan monitoring network				
LW07	-28940	-2895277	North of Witklip	7.6
LW08	-27282	-2897355	South West of Kenbar	15.05
LW10	*-23432*	*-2894971*	*South of Delmas Silica*	*To be mined out*
LWG01	*-27143*	*-2896828*	*South of Kenbar*	*Destroyed*
LWG04	*-24432*	*-2896230*	*Moabsvelden Groundwater*	*Blocked*
LWG02	-26296	-2896700	South East of Kenbar	29.76
EMPR02/E2	-28299	-2894999	Borehole (E2)	10.71
WTN01d	*-23459*	*-2891862*	*Weltevreden Monitoring borehole-deep*	*Dry at 35m*
WTN01s	-23430	-2891800	Weltevreden Monitoring borehole-shallow	3.61
WTN02d	-23069	-2893073	Weltevreden Monitoring borehole-deep	29.23
WTN02s	-278730	-3187041	Weltevreden Monitoring borehole-shallow	4.02
WWN01	-28279	-2896193	Wolwenfontein Monitoring borehole	2.53
WWN02d	-28169	-2896156	Wolwenfontein Monitoring borehole-deep	2.79
WWN02s	-28169	-2896156	Wolwenfontein Monitoring borehole-shallow	1.47
RKL01	-25585	-2897302	Rietkuil Monitoring borehole 01	7.9
RKL02	-23333	-2897155	Rietkuil Monitoring borehole 02	2.89
RKL03	*-22930*	*-2897879*	*Rietkuil Monitoring borehole 03*	*Blocked*
RKL04	*-25462*	*-2898804*	*Rietkuil Monitoring borehole 04*	*Equipped*
Proposed additional monitoring boreholes for OI and OL				
Rie10	-23726	-2899313	Third party borehole	Equipped
Rie4	-23148	-2897771	Third party borehole	Equipped
MOAMB9	-23302	-2896308	East of proposed OI opencast	11.59
MOAMB10	-23468	-2895139	North east of proposed OL opencast	14.74

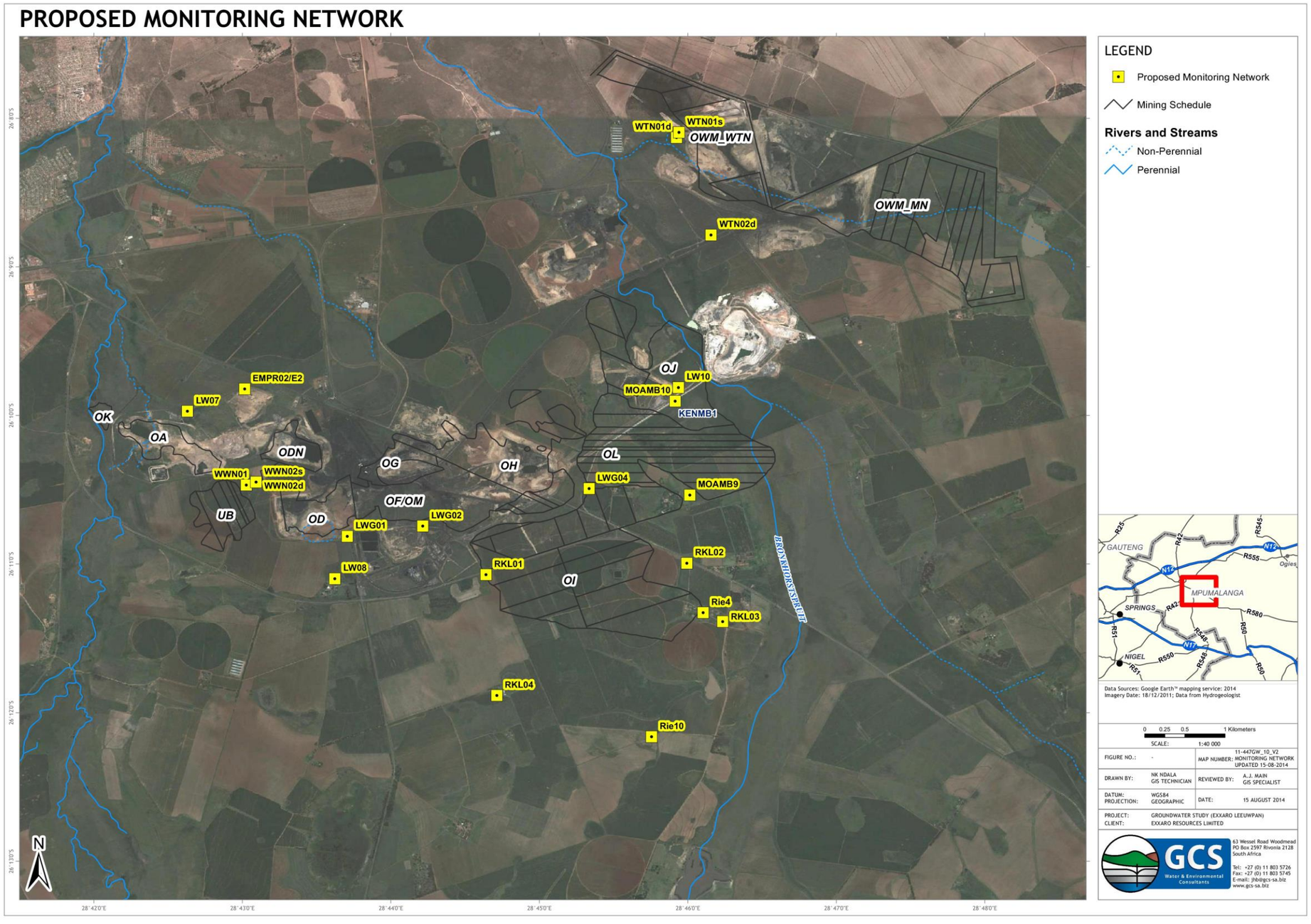


Figure 13.1: Proposed Monitoring Network

14 CONCLUSIONS AND RECOMMENDATIONS

There are three aquifer types present in the Leeuwpan area. These aquifers vary with regard to aquifer characteristics and are generally interconnected by fractures:

- The shallow aquifer formed in the weathered zone, often perched on the fresh bedrock;
- The deeper aquifer formed by fracturing of the Karoo sediments and dolerite intrusions; and
- The dolomite & chert rich karst aquifer of the Malmani Subgroup which underlies the Karoo type aquifer.

The coal reserves which are exploited at Leeuwpan are associated with the fractured Karoo aquifer can be classified as a minor (low yielding) aquifer system. A prominent dolerite sill intrusion (±15m thick) is present at Leeuwpan. The unsaturated zone (~5 - 26 mbgl) in the study area consists of colluvial material and clay (residual dolerite and shale) that is underlain by weathered sandstone / siltstone / mudstone / shale and coal of the Ecca Group that becomes less weathered with depth. The Dwyka tillite underlies the Ecca Group sediments and is found to be highly weathered at shallow depths and unweathered and depth.

Groundwater is mainly used for domestic supply, small scale irrigation (gardens), livestock watering as well as large scale pivot irrigation of crops. The boreholes used for large scale irrigation exploit the dolomitic aquifer as the yields from the Karoo Supergroup are too low to sustain the high abstraction rates. The groundwater quality in the area is generally good.

The water levels of the monitoring boreholes representing the shallow weathered Karoo aquifer ranged from 1.9 to 9.8 mbgl with an average groundwater level of 7 mbgl. The static water levels for the boreholes representative of the deeper fractured Karoo aquifer ranged between 2.4 and 30 mbgl with the average calculated as 15 mbgl. In the dolomitic aquifer the groundwater levels range from 5.5 to 34 mbgl and averaged at ~17 mbgl. The groundwater levels in the Karoo aquifers generally follow topography in the absence of anthropogenic activities in the identified aquifers.

The hydraulic conductivity ranges from 0.01-0.6 m/d with a harmonic mean of ~0.05 m/d. The transmissivity ranges from 0.2 to 20 m^2/d with a harmonic mean of ~0.7 m^2/d. These values are typical of the Karoo type aquifers.

Seepage through the opencast backfill will become acidic over the long-term as the ABA results show that the material has the potential to generate acid-mine drainage. The sandstone and soft overburden have limited potential for acidic generation. The shale samples show a great variance in net acidic generation, but may have a potential for acidic generation. Elevation of TDS and SO_4 will occur as a result of pyrite oxidation. In the opencast the SO_4 will increase roughly to about 2 500 mg/l over the long term;

It is not foreseen that significant elevation in metals will occur at near-neutral conditions. After acidification non-compliance for Al, Fe and Mn may occur. Cr, Ni and to a lesser degree As and V are some of the other trace elements that may be slightly elevated and may reach occasional marginal to non-compliance.

Leeuwpan Colliery is an existing operation and as a result there are numerous contaminant sources already present such as the plant area, pollution and return water dams, rehabilitated opencasts and operational opencast.

The sulphate concentrations are elevated in boreholes LEEMB18_D, KENMB3_D, KENMB2_D and WWN01 located within the plant area as well as in boreholes WITMB14, WOLMB15_S, KENMB3_S, WWN02d and WWN02s located in the immediate areas surrounding the plant. From the plant area the groundwater flow direction is predominantly in a north westerly direction. Boreholes WOLMB15_S and WOLMB15_D located down gradient of the plant PCD also indicate impact of mining related activities. High sulphate concentrations were also encountered in the north easterly part of the mine toward the Moabsvelden and Weltevreden pits in boreholes MOAMB10, Moa1, WTN02d, WTN02s, WELMB13_S and WELMB13_D. The borehole KENMB2_D located down gradient of the No. 5. Emergency overflow dam is also impact by mining related contaminants. Boreholes WWN02s, WWN02d and WNN01 are located adjacent to a dam west of the OD block opencast which are also impacted by mining related contaminants. Borehole WITMB14 located down gradient of the Witklip pit (Block OA) showed an impact by mining related contaminants although still compliant with the SANS 241 Drinking water standard. The borehole MOAMB10 located adjacent to OJ Block opencast has been negatively impacted by mining in term of elevated sulphate, TDS and EC. The shallow borehole WTN02s contained sulphate concentrations above the background levels (although still compliant). It is likely that this borehole has been impacted by a shallow contaminant source associated with the haul road (coal spillage).

Shallow and deep boreholes (WELMB13_D and WELMB13_S) located down gradient of the OWN_MN Block (Moabsvelden) opencast are also slightly impact by mining related contaminants.

The majority of privately owned boreholes are associated with the underlying dolomitic aquifer which in unlikely to be impact by any dewatering activities.

It is likely that preferential flow paths along faults and dolerite intrusion related to fracturing is not significant in the area based on the available data. While it is still anticipated that localised preferential flow zones will exist in relation to dolerite dykes, these zones have not been recorded and it is thought that they are not well developed. As mentioned above the drainage occurs towards the low lying areas such as rivers and streams (Bronkhorstspruit and its tributaries). Some of these streams may be impacted by contaminated seepage and decant.

During construction of the new activities (Block OI and OL) minimal additional impacts in the groundwater system is expected. The impacts are expected to have a low significance rating.

Groundwater levels could be lowered over relative large area around the opencasts during the operational phase. Groundwater inflows into Block OI can range from ~500 m^3/d in 2016 to 360 m^3/d in 2027. The inflows into the proposed Block OL may approach ~60 m^3/d at the beginning of 2020 may approach which then increases to ~340 m^3/d in 2029. Groundwater flow directions will be directed towards the mining areas due to the mine dewatering. Therefore contamination will be contained within the mining area, and little contamination will be able to migrate away from the mining area. Some monitoring boreholes were however affected by contaminants emanating from surface related contaminant sources. The impact significance can be assumed to be low during the operational phase

Once the mining has ceased, ARD is still likely to form given the unsaturated conditions in the facility and contact of water and oxygen through natural process including rainfall. Therefore a groundwater contaminant plumes are likely to migrate from the mining areas once the water level in the rehabilitated pits have reached long term steady state conditions (i.e. each pit water level has reached the decant level). No privately owned boreholes located in the fractured Karoo aquifer is likely to be impacted based on the impact simulations post closure. However shallow contaminated seepage may impact on the Bronkhorstspruit post closure and increase the salt load of the system. Given the significance of the underlying dolomite aquifer, the interaction between the dolomite and the Karoo aquifers should be further investigated. If these aquifers are in hydraulic connection and a flow gradient form the Karoo aquifer exists towards the dolomite aquifer exists the dolomitic aquifer may be impacted on post closure by contaminants.

Surface decanting of mine water is likely to occur in most opencasts, the estimated decant volumes for all the opencasts at Leeuwpan can range from ~1960 m^3/d ot ~3675 m^3/d. This should however re-assessed, once more information regarding rehabilitation and backfilling are obtained. Boreholes should be drilled into the opencasts to monitoring the rate of water level recovery.

A groundwater management plan and monitoring network has been developed for Leeuwpan. The following recommendations are made:

- The groundwater monitoring network should be reviewed and expanded for the existing and future mining activities at Leeuwpan. An updated and optimised monitoring program should be developed and submitted to DWA.
- Boreholes should be drilled into the rehabilitated opencast so that the rate of flooding and water level recovery, and water quality can be established.
- Stage curves should be developed which would aid in the management of closure phase.
- The numerical model should be updated bi-annually by using the measured water ingress and water levels to re-calibrate and refine the impact predictive scenario.
- Field parameter profiling (EC, pH etc.) should be conducted on the monitoring boreholes to determine the optimal sampling depth.
- The interaction between the Karoo and dolomitic aquifer should be further investigated. This should be used to determine the risk associated with contamination of the dolomitic aquifer.
- The impact of abstraction for irrigation and industrial users on the aquifers should be assessed.

15 REFERENCES

Barnard, H. (1999). The Johannesburg Hydrogeological Map (JHM).

Cleanstream Environmental Services (2007). Leeuwpan Coal: Extension of Block OD and UI, Draft EIA. Ref No: ERL/LC/03/2007.

Cleanstream Environmental Services (2007). Leeuwpan Colliery: Report on Geohydrological Investigation as part of the EMPR for the proposed Wolwenfontein, Weltevreden and Rietkuil projects.

Exxaro, (2011), Pre-Feasibility Study Report for Leeuwpan O/I Project.

Geo Pollution Technology Consulting Environmental Scientists (July 2002). Environmental Management Programme Report (EMPR) for the proposed new Open Pit Collieries at Leeuwpan (Report Number: LEEUWPAN/01/222).

Hodgson, FDI and Krantz, RM, (1998). Groundwater Quality Deterioration in the Olifants River Catchment above the Loskop Dam with Specialised Investigations in the Witbank Dam Sub-catchment. WRC.Report No.29/1/98

Hodgson, F.D.I., Krantz, R.M., (1995). Investigation into groundwater quality deterioration in the Olifants River catchment above the Loskop Dam with specialized investigation in the Witbank Dam sub-catchment. Institute for Groundwater Studies, University of the Orange Free State. WRC Report No. 291/1/95

Institute of Groundwater Studies for the Water Research Commission (1998) Groundwater Quality Deterioration in the Olifants River Catchment above the Loskop Dam with Specialised Investigations in the Witbank Dam sub-catchment. WRC Report No 291/1/98.

Mahanyele, P.J. (2010), Interpretation of airborne magnetic data over selected areas of the Witbank Coalfield, South Africa: An aid to mine planning, M.Sc. Dissertation

Parsons, R. (1995). A South African Aquifer System Management Classification. Water Research Commission Report No. KV 77/95.

South African National Standard for Drinking Water (SANS 241-1: 2011). Part 1: Microbiological, physical, aesthetic and chemical determinants.

South African Water Quality Guidelines for Domestic Use, (1996). Volume 1, Second Edition, Department of Water Affairs & Forestry.

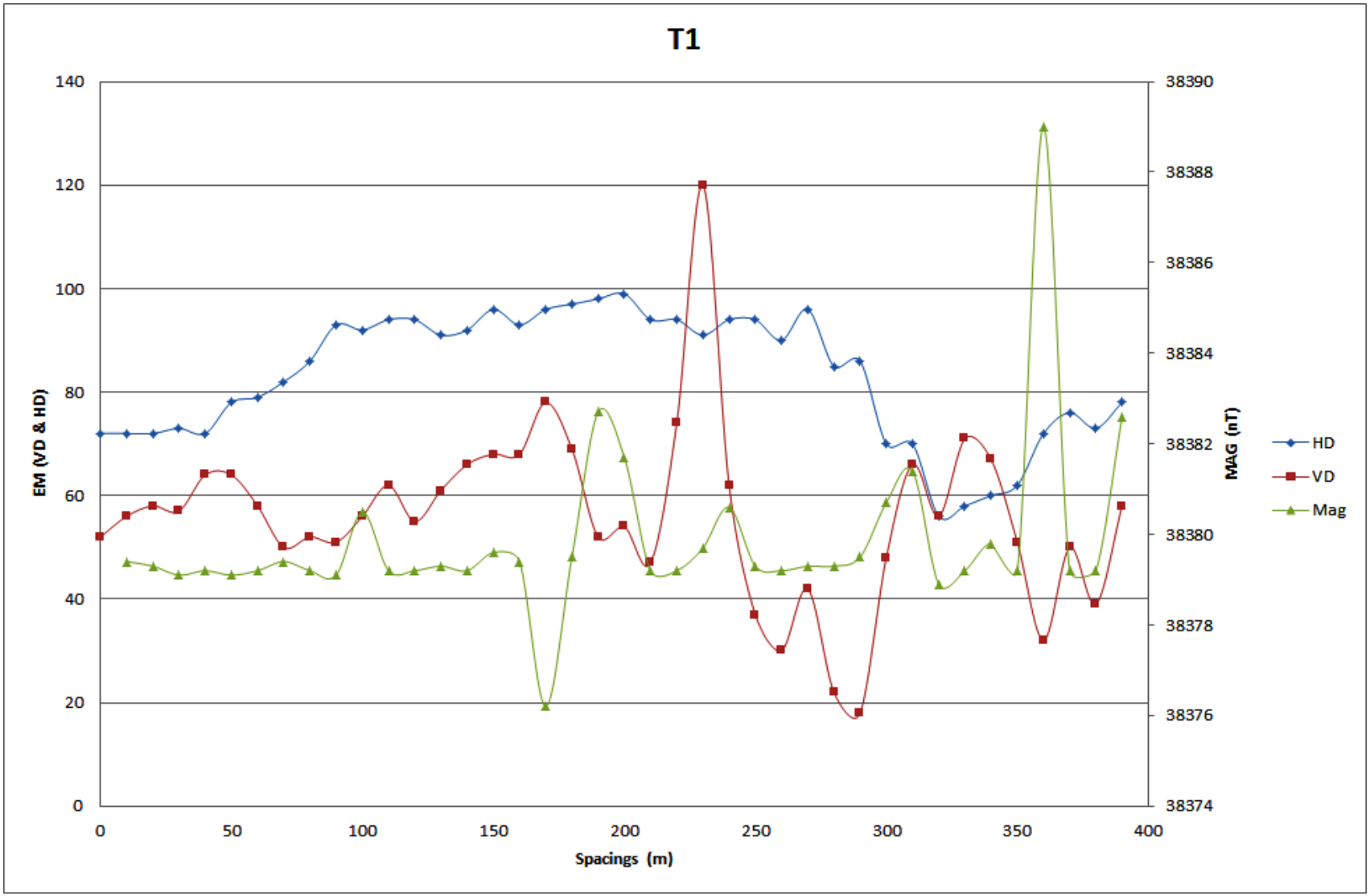
South African Water Quality Guidelines for Agricultural Water Use, (1996). Volume 4, Second Edition, Department of Water Affairs & Forestry.

Minimum Requirements for water monitoring at waste management facilities (1998). Department of Water Affairs & Forestry, Waste Management Series, 1998).

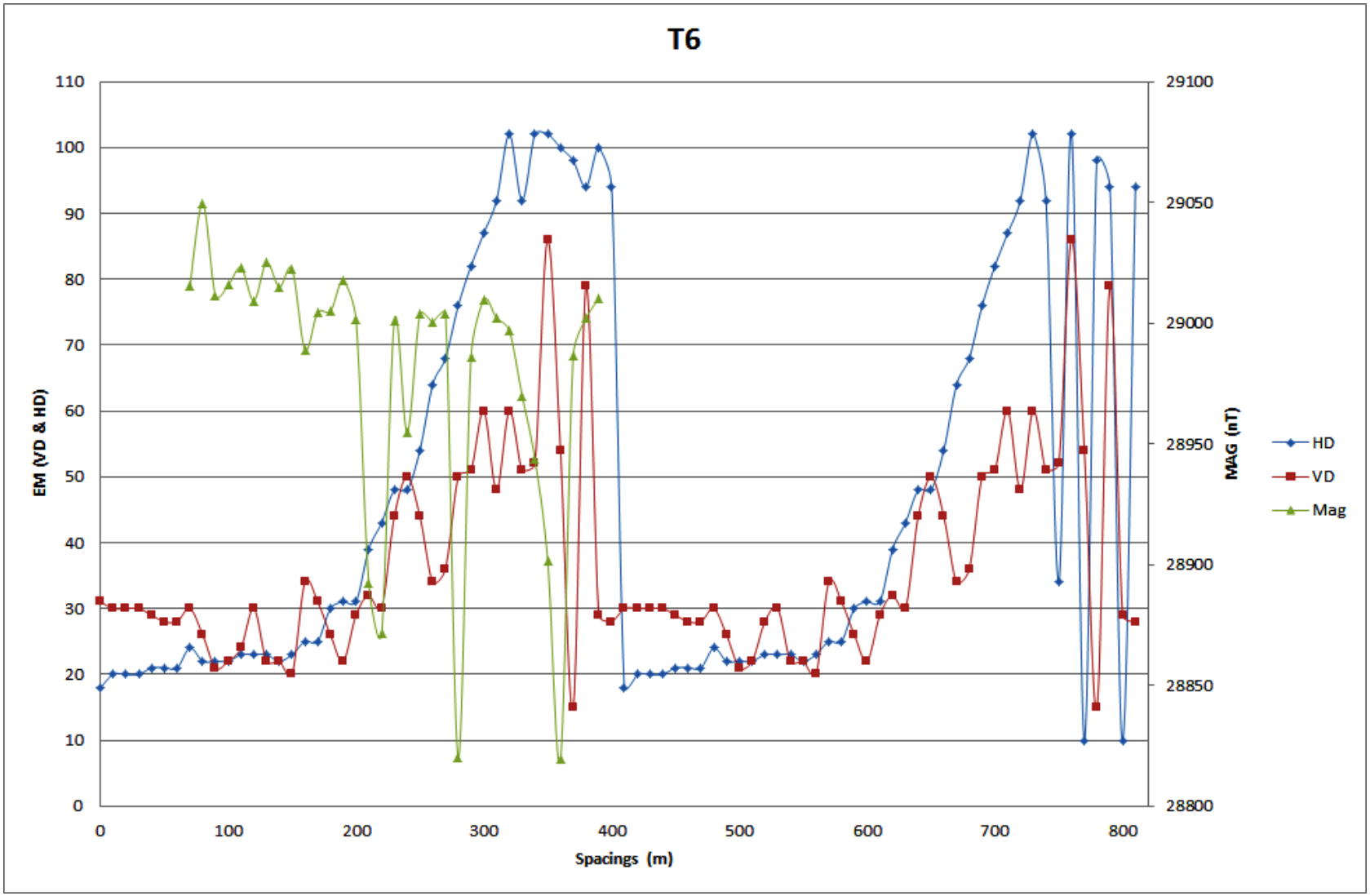
The groundwater harvest potential of the Republic of South Africa. (1996). Department of Water Affairs and Forestry, South Africa.

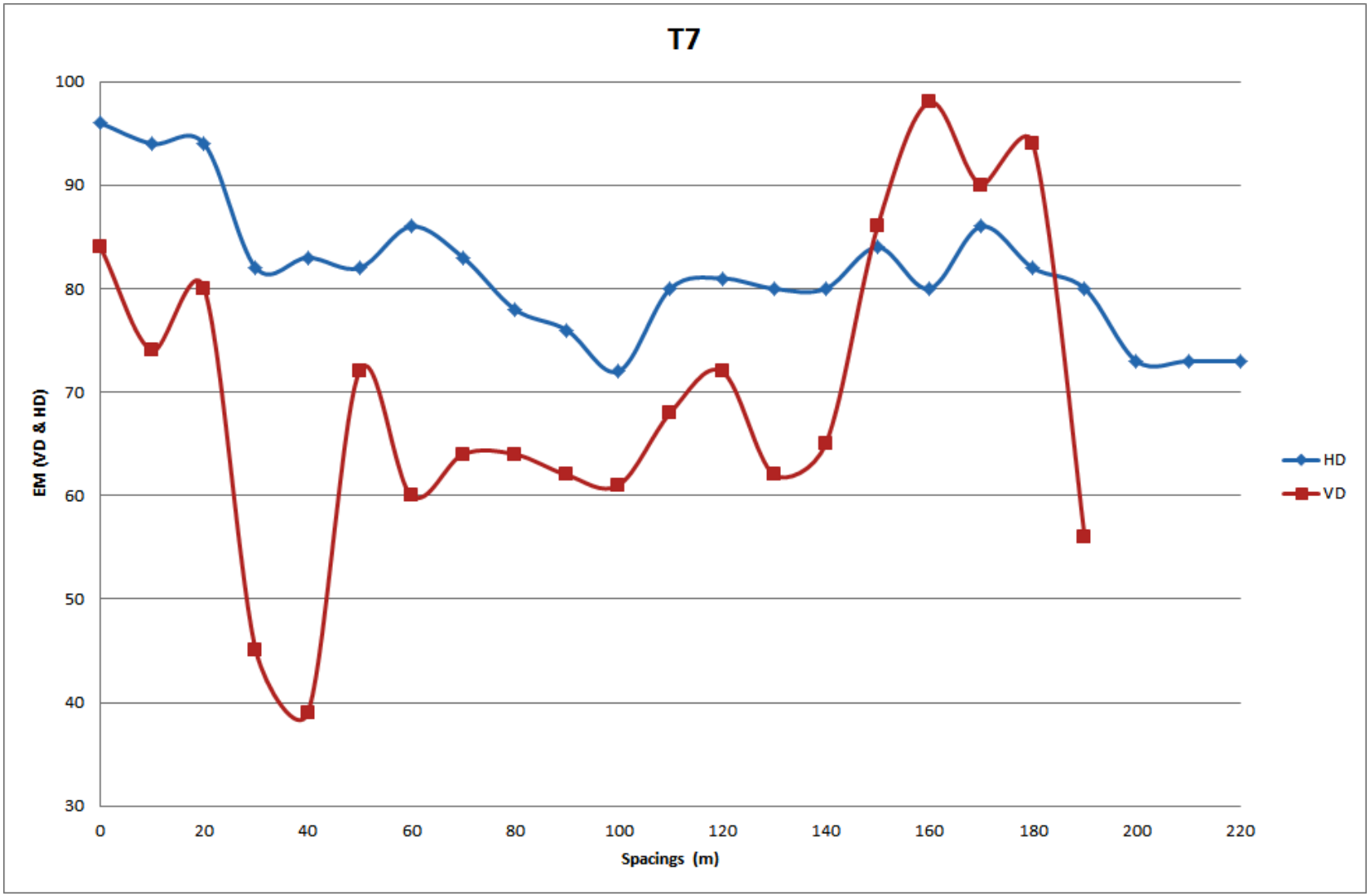
The groundwater resources of the Republic of South Africa, sheets 1 and 2. (1996). Water Research Commission and Department of Water Affairs & Forestry.

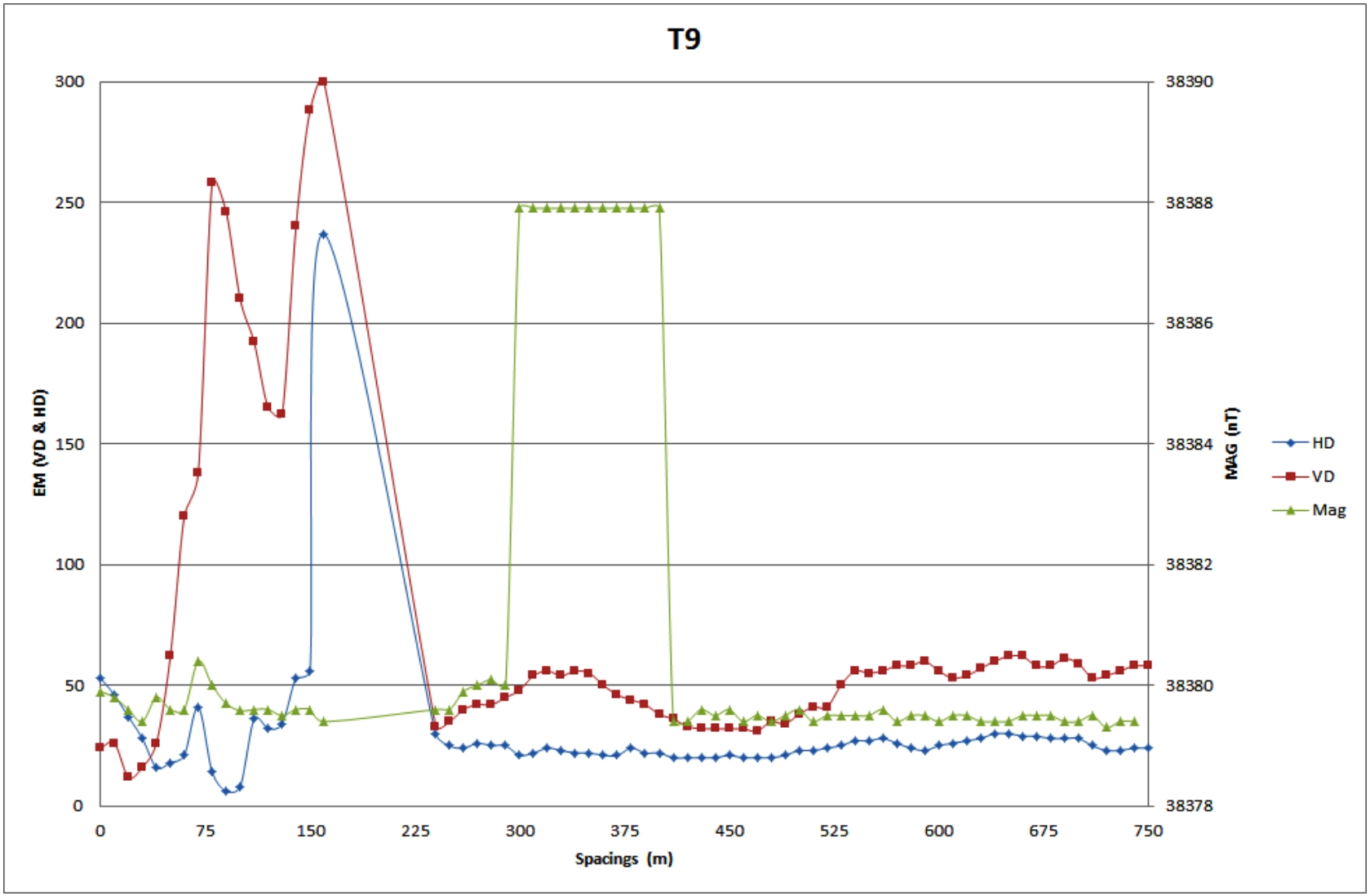
APPENDIX A : RESULTS OF GEOPHYSICAL SURVEY

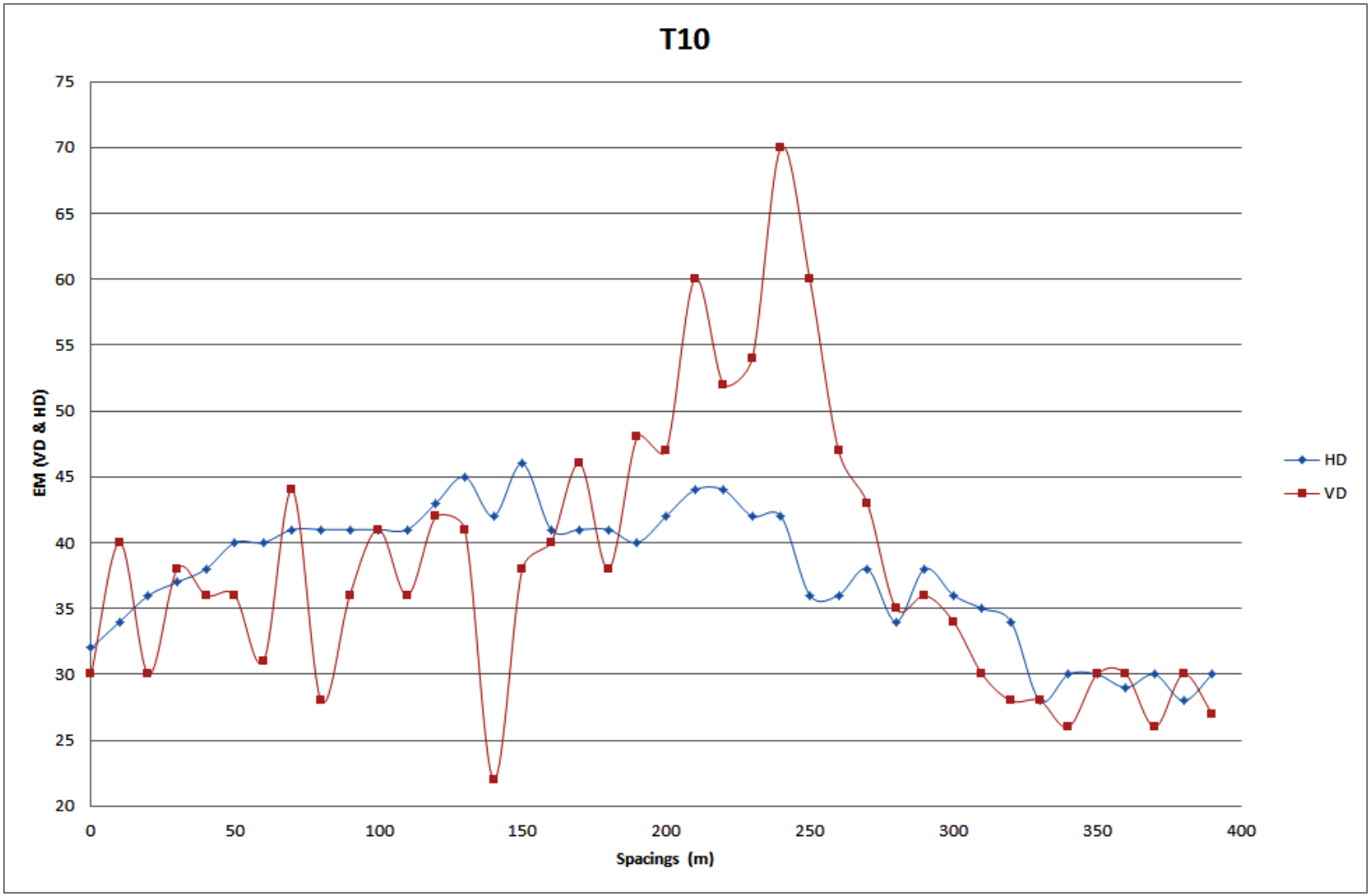

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Mag
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60
80
100
120
140
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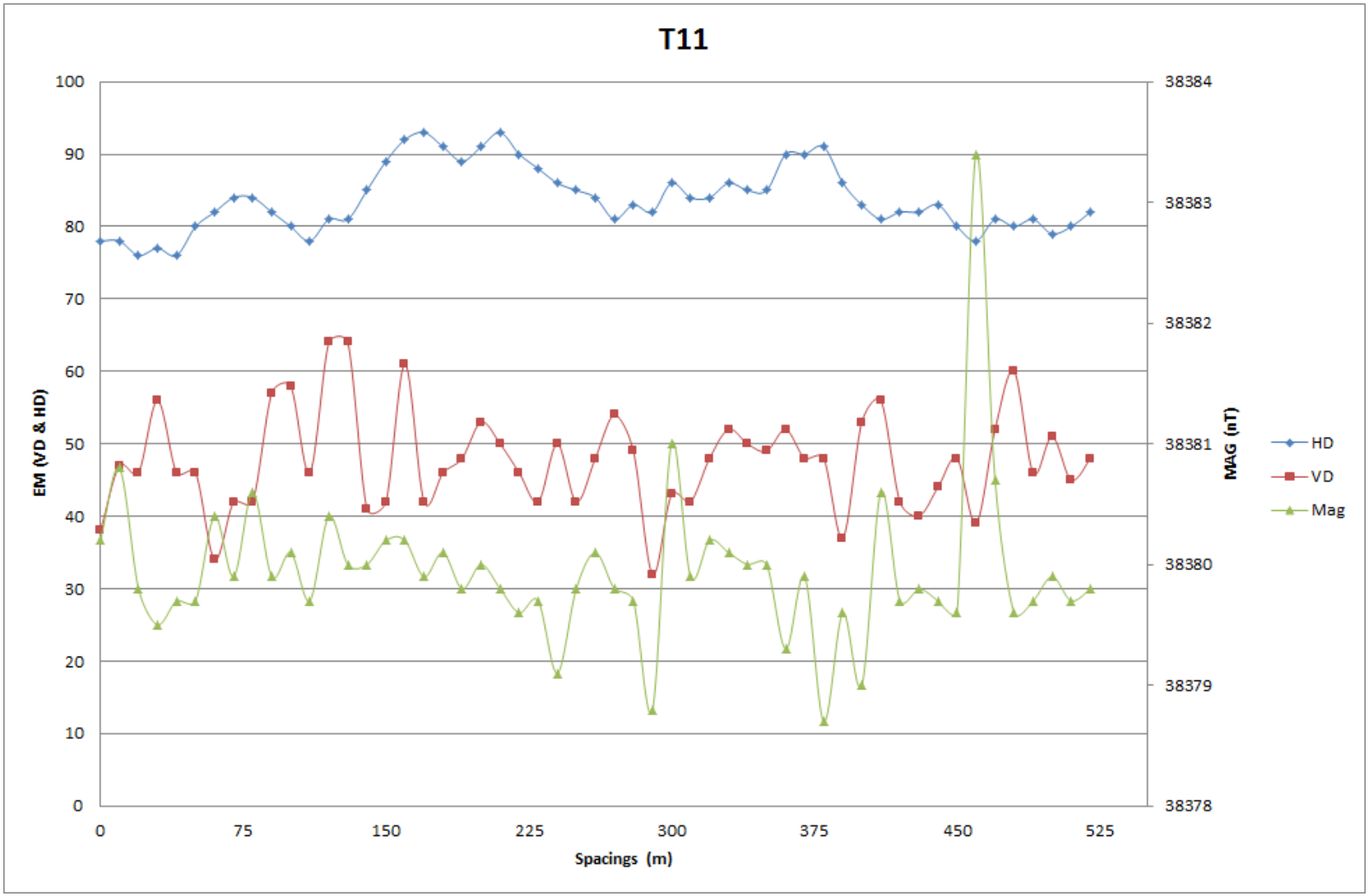

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Mag
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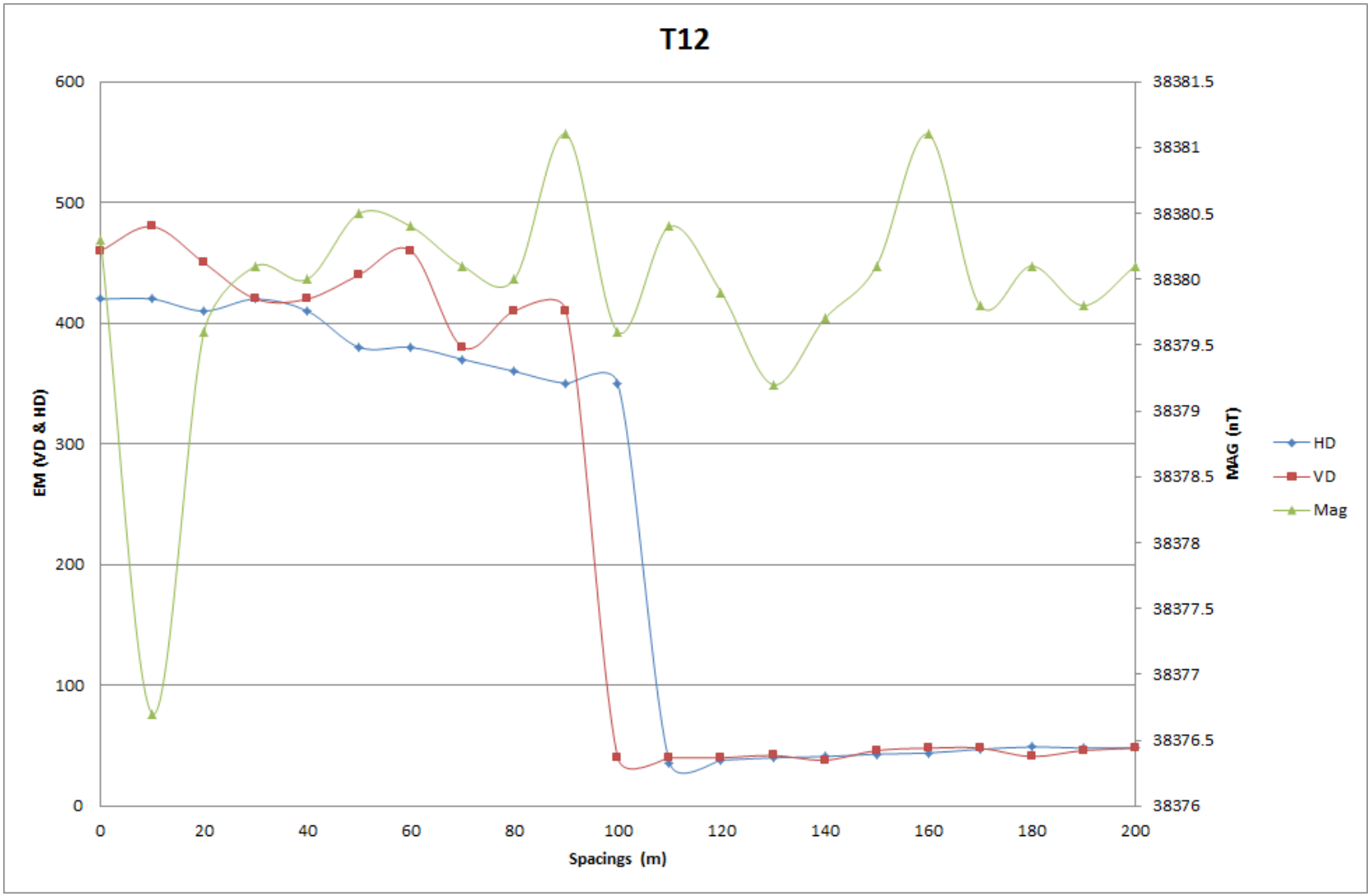

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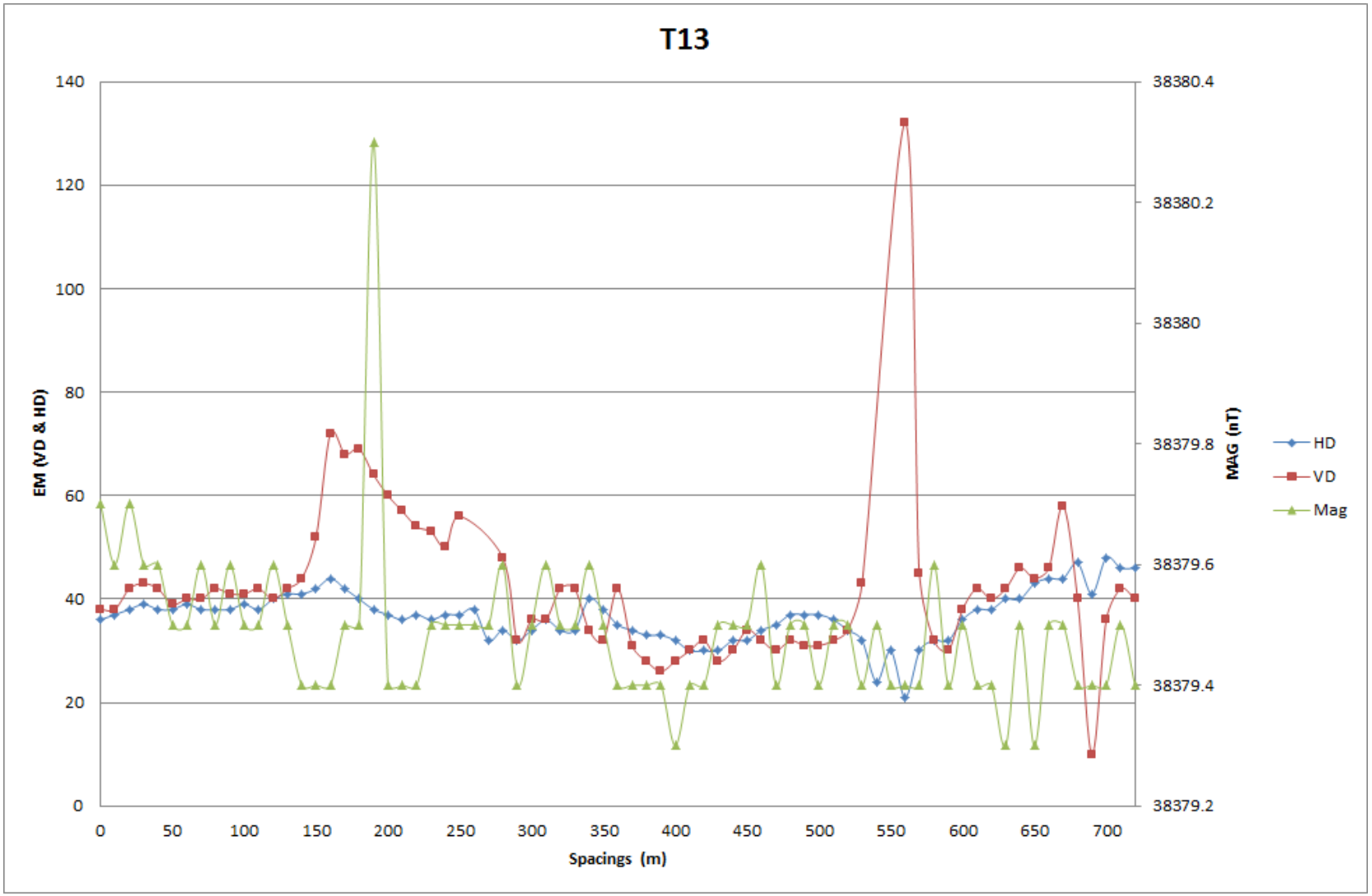

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80
100
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180
200
220
Spacings (m)
HD
VD


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EM (VD & HD)
MAG (nT)
Spacings (m)
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VD
Mag
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375
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525
600
675
750


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65
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30
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100
150
200
250
300
350
400
Spacings (m)
HD
VD


T11
EM (VD & HD)
MAG (nT)
Spacings (m)
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VD
Mag
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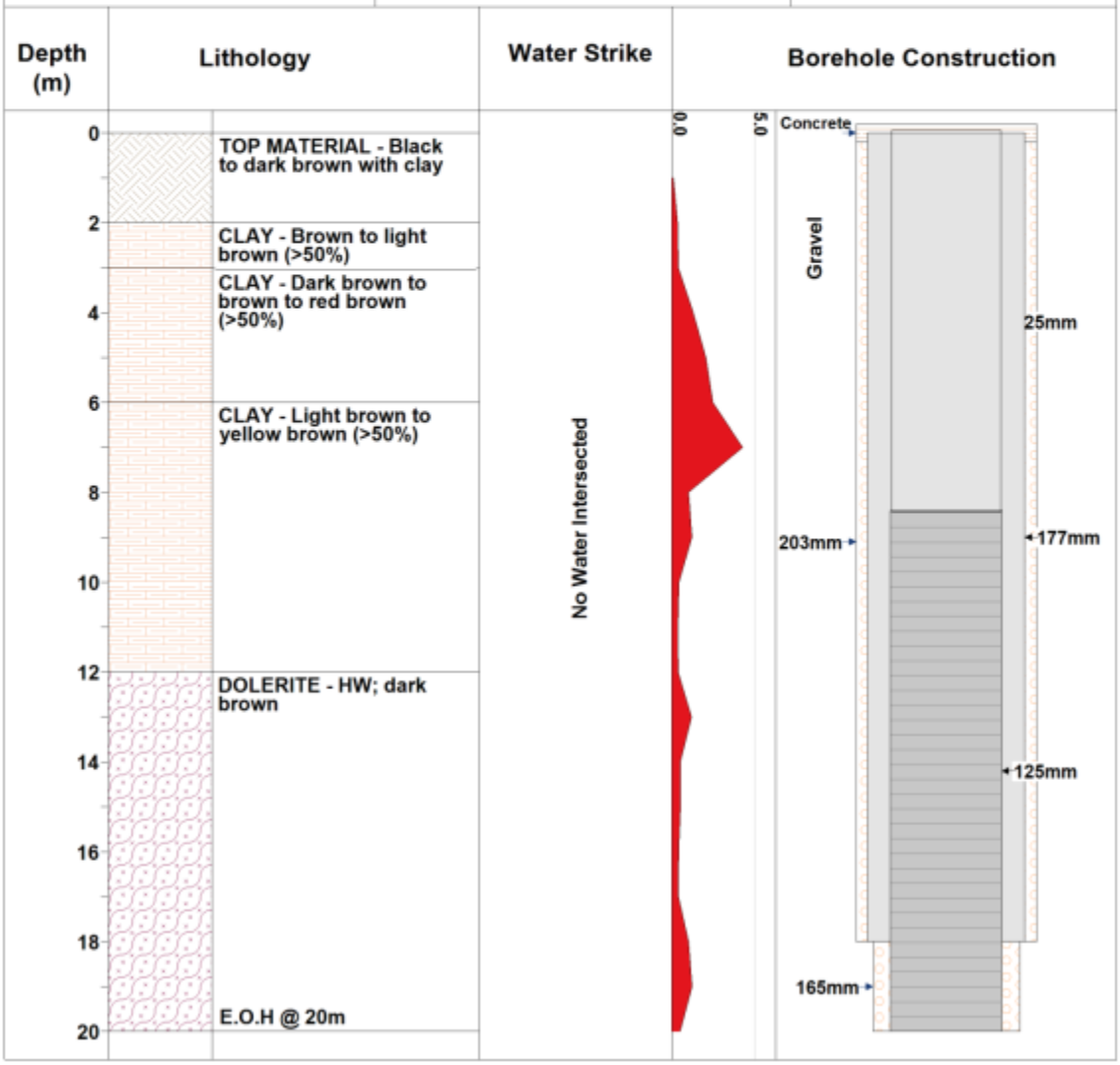

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Spacings (m)
HD
VD
Mag


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APPENDIX B: BH LOGS

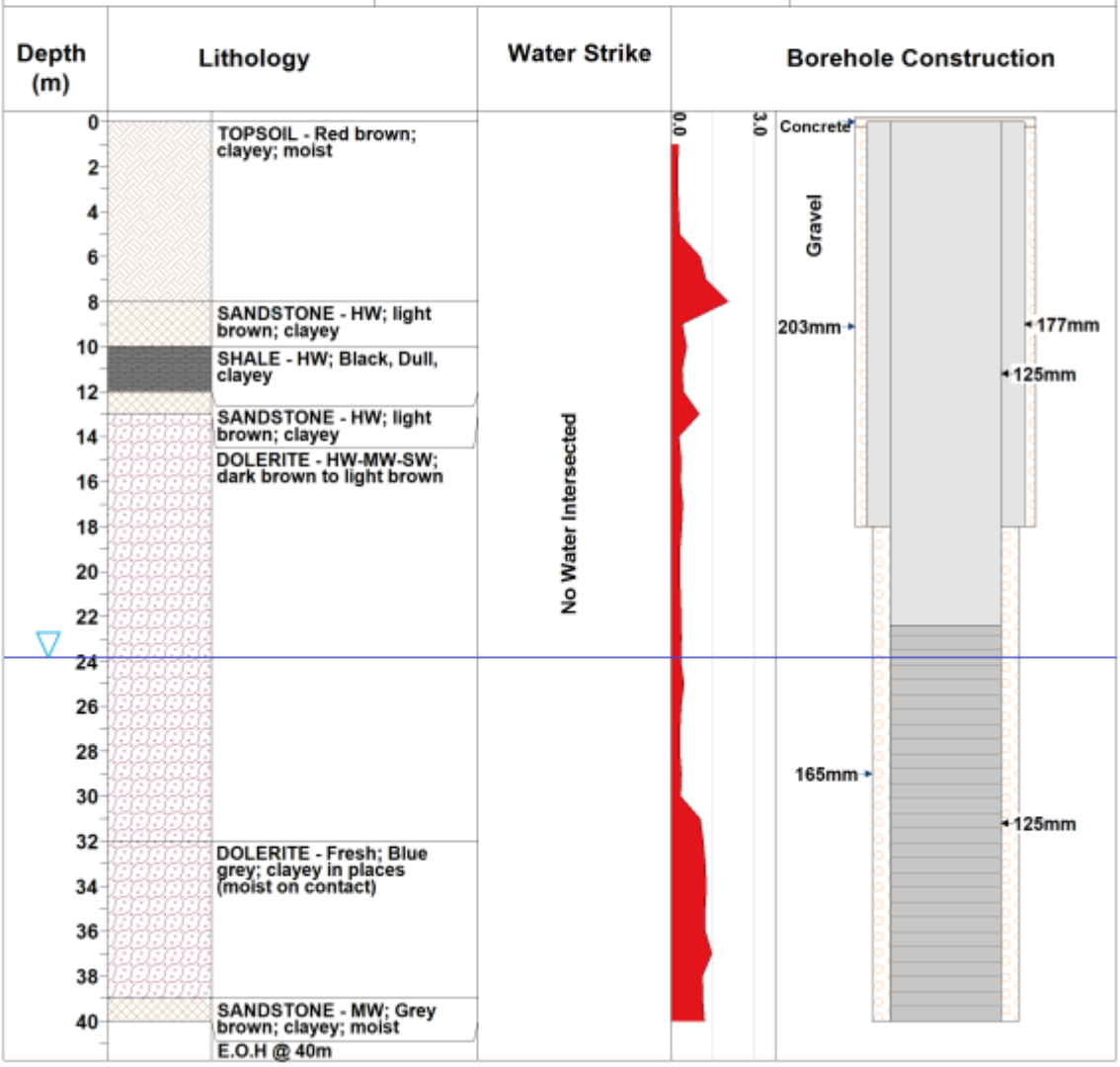
Well KENMB1 Location Leeuwpan

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Y Coordinate:	-2897024.3	Casing:	Steel & PVC		
Elev. (mamsl)	1583.1	BH Diameter (mm)	203 - 165		
Depth (mbgl):	20.0	SWL (mbgl):	-	Logged By:	JvR
				Date:	23/11/2013



Well *KENMB2_D* **Location** *Leeuwpan*

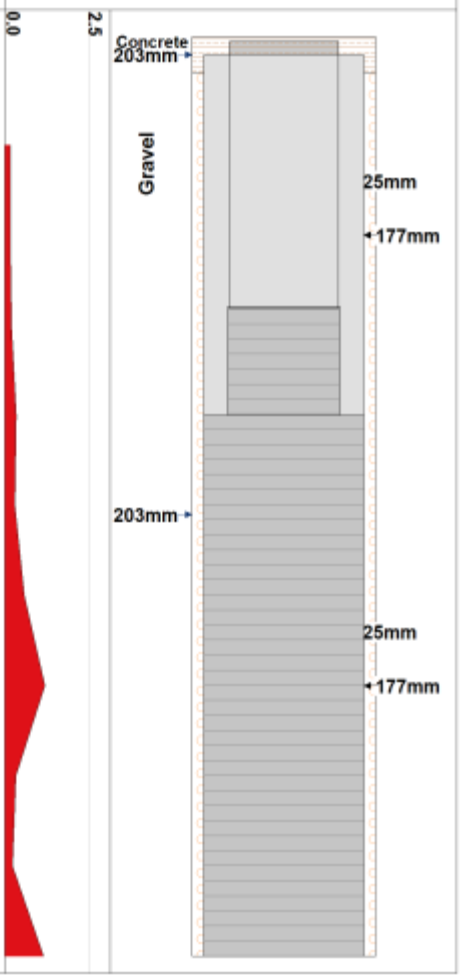
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Y Coordinate:	*-2896734.4*	**Casing:**	*Steel & PVC*		
Elev. (mamsl)	*1581.8*	**BH Diameter (mm)**	*203 - 165*		
Depth (mbgl):	*40.0*	**SWL (mbgl):**	*23.89*	**Logged By:**	*JvR*
				Date:	*22/11/2013*



Well *KENMB2_S* Location *Leeuwpan*

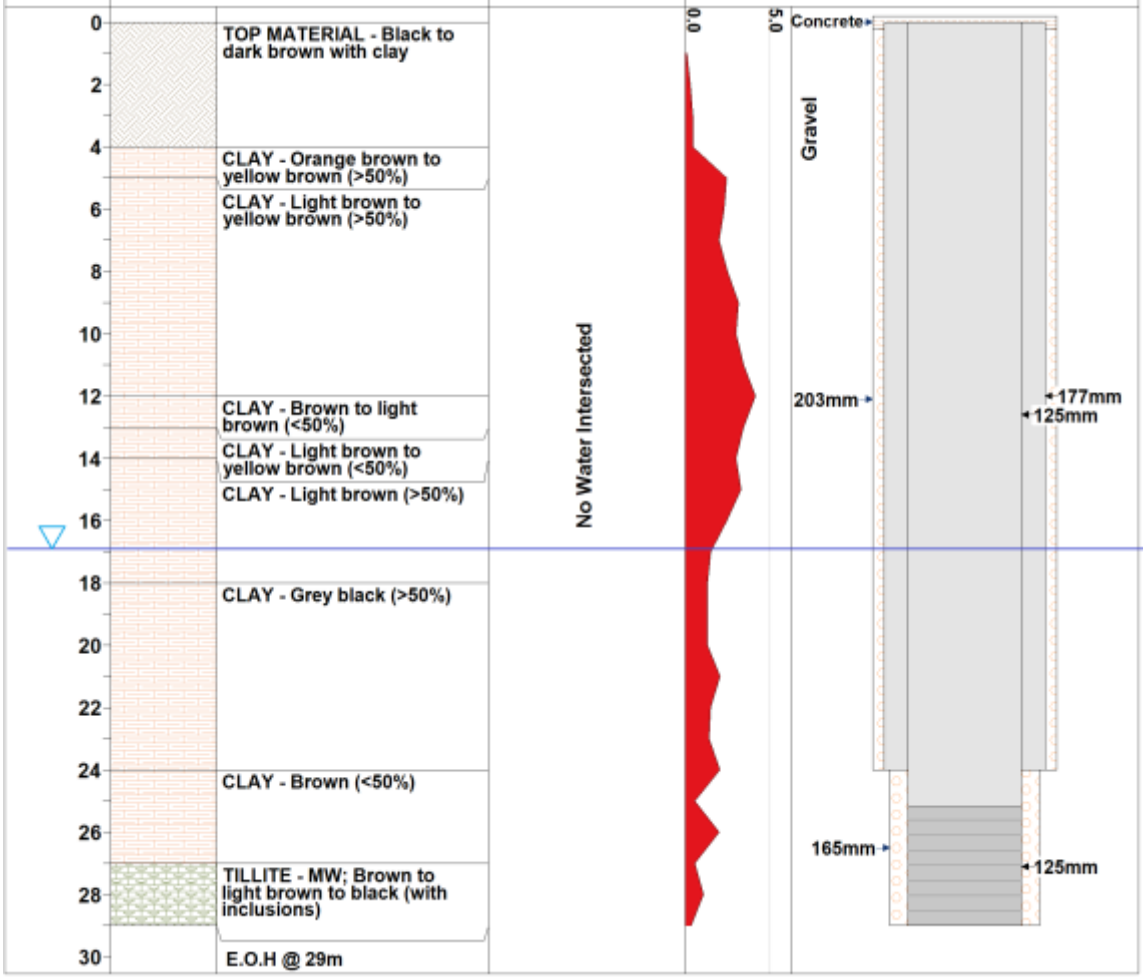
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Elev. (mamsl)	1581.0	BH Diameter (mm)	203		
Depth (mbgl):	10.0	SWL (mbgl):	-		

Depth (m)	Lithology	Water Strike	Borehole Construction
0	TOP MATERIAL - Black to dark brown with clay		
2	CLAY - Dark brown to black (>50%)	Seepage @ 2m	
10	E.O.H @ 10m		



Well KENMB3_D Location Leeuwpan

Project No.:	11-447GW	Drilling Contractor:	Bentex Drilling	Logged By:	JvR
X Coordinate:	-26967.2	Drilling Method:	Percussion	Date:	21/11/2013
Y Coordinate:	-2895847.9	Casing:	Steel & PVC		
Elev. (mamsl)	1577.2	BH Diameter (mm)	203 - 165		
Depth (mbgl):	29.0	SWL (mbgl):	16.98		



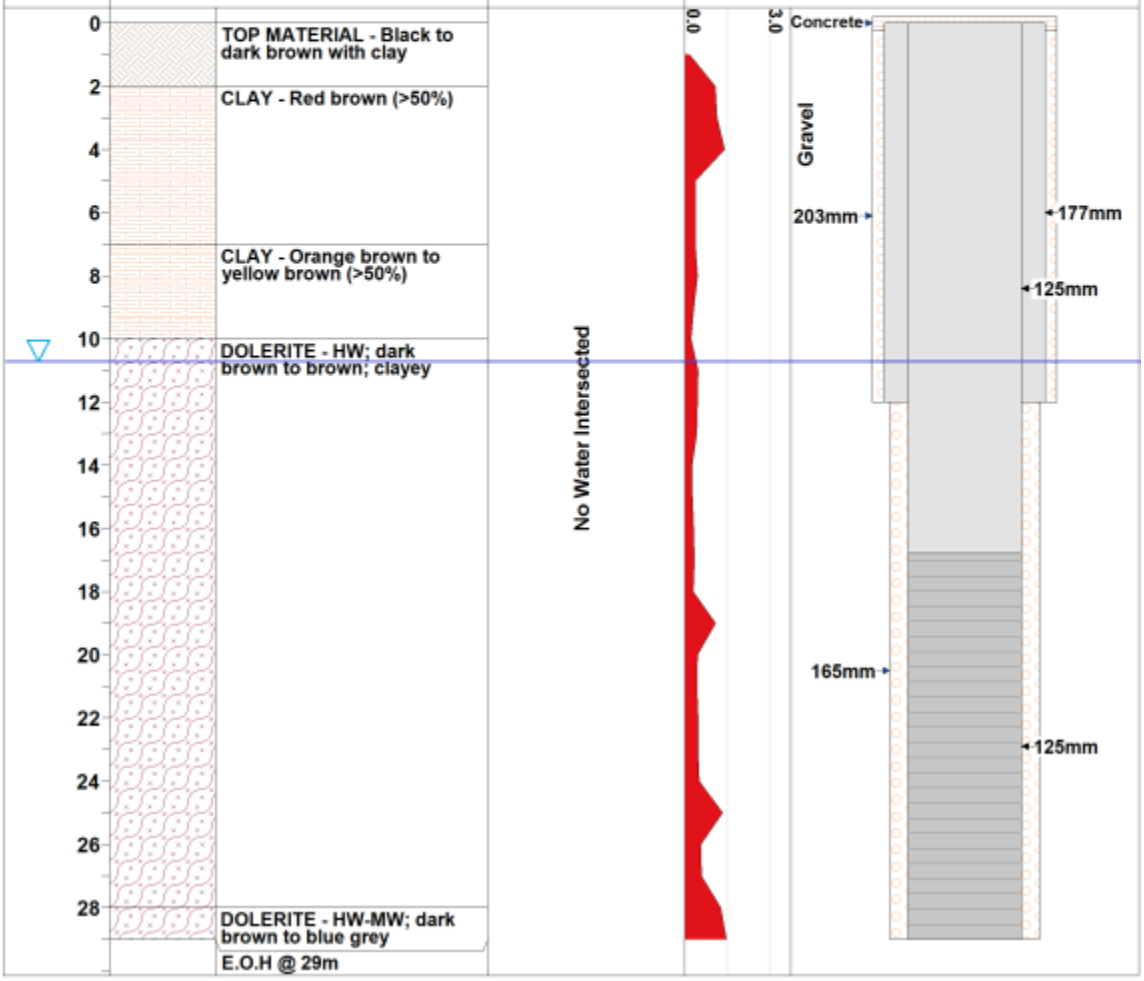
Well *KENMB3_S* Location *Leeuwpan*

Project No.:	11-447GW	Drilling Contractor:	Bentex Drilling		
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Y Coordinate:	-2895839.0	Casing:	PVC		
Elev. (mamsl)	1576.9	BH Diameter (mm)	203		
Depth (mbgl):	10.0	SWL (mbgl):	-	Logged By:	JvR
				Date:	21/11/2013

Depth (m)	Lithology	Water Strike	Borehole Construction
0	TOP MATERIAL - Black to dark brown with clay	No Water Intersected	Concrete 203mm; Gravel; 125mm; 203mm; 125mm
1			
2	CLAY - Light brown to brown (>50%)		
3			
4			
5	CLAY - Orange brown to yellow brown (>50%)		
6			
7	CLAY - Yellow brown to light brown (<30%)		
8			
9			
10	E.O.H @ 10m		

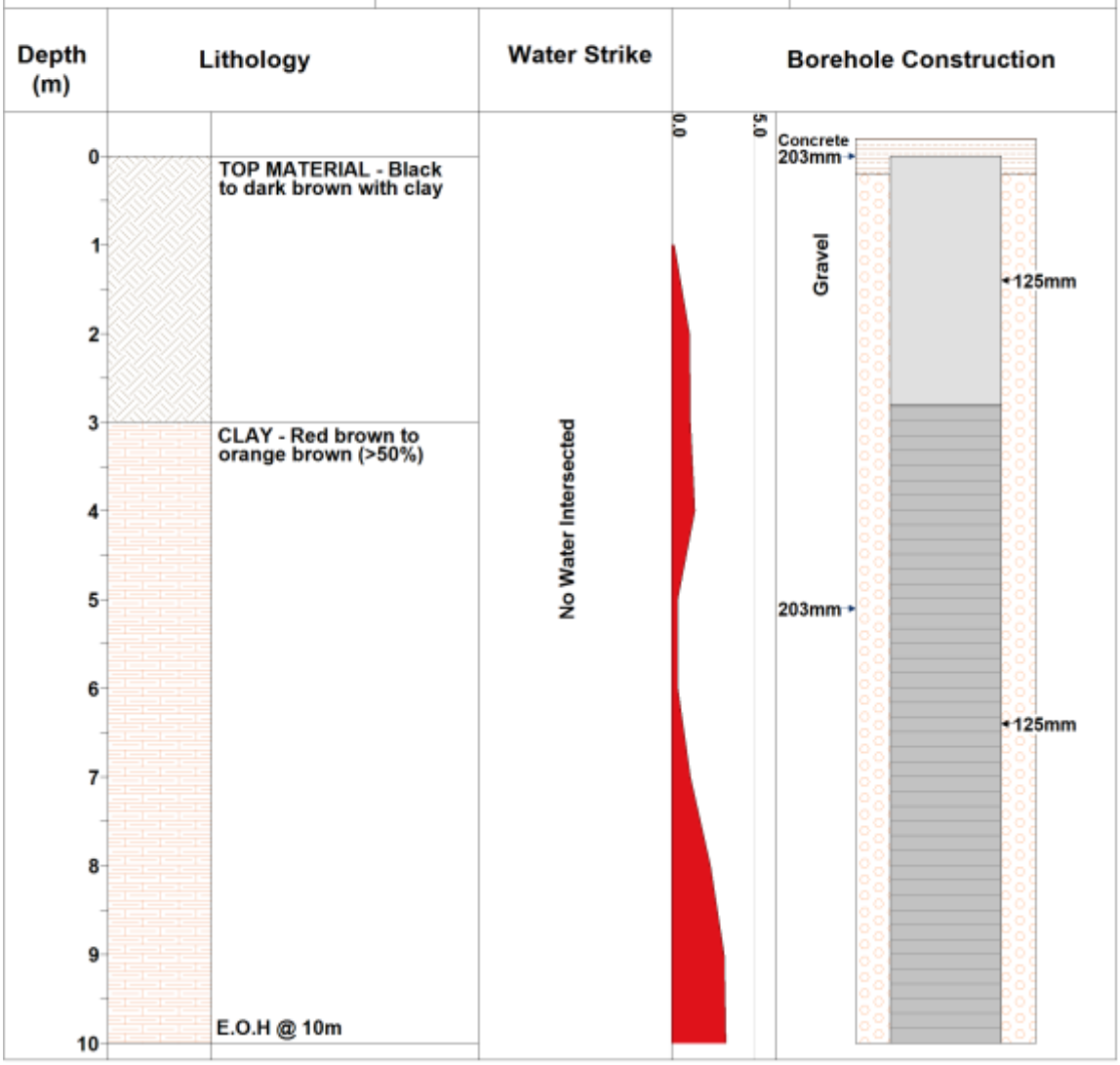
Well LEEMB18_D Location Leeuwpan

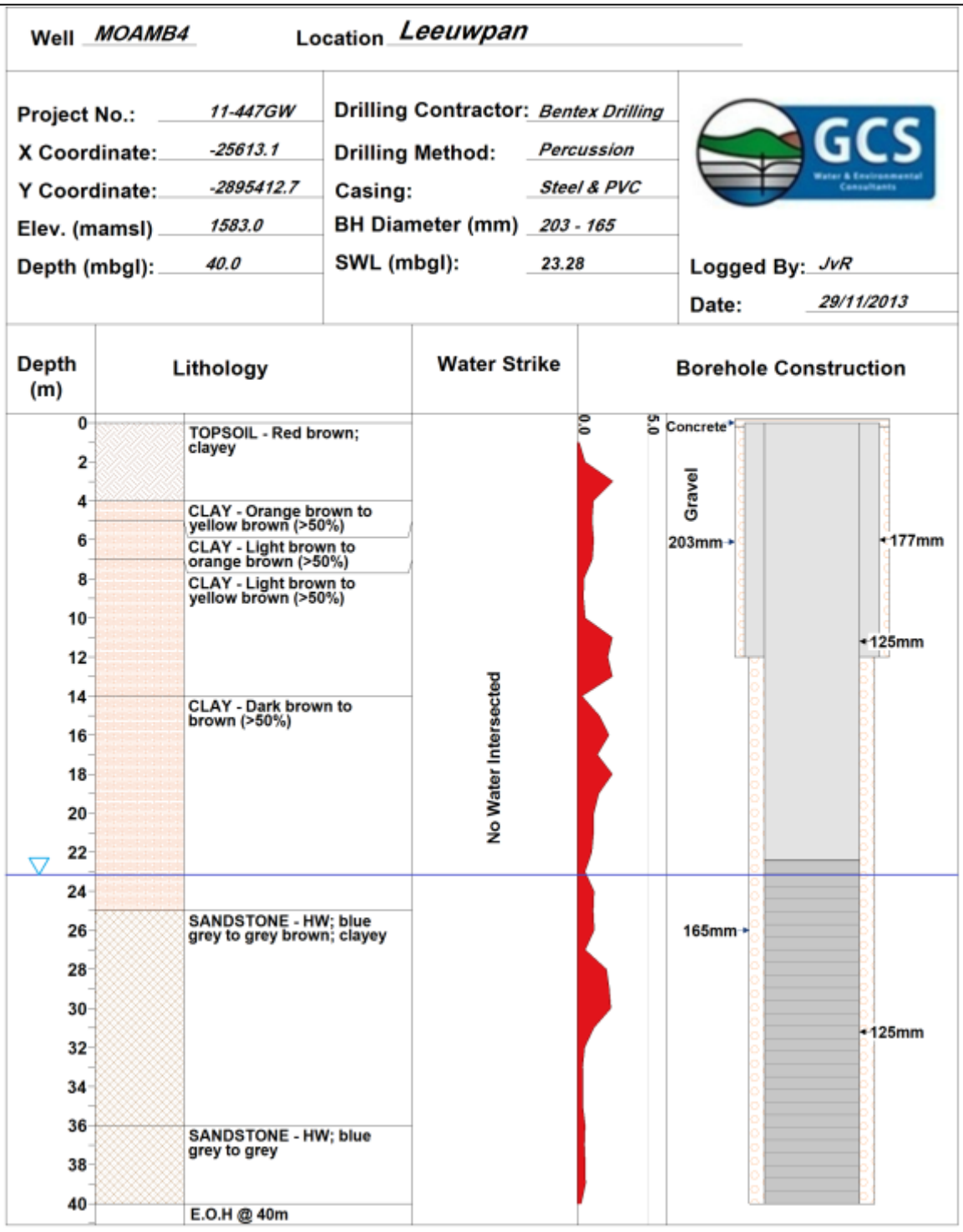
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Y Coordinate:	-2895496.9	Casing:	Steel & PVC		
Elev. (mamsl)	1574.7	BH Diameter (mm)	203 - 165		
Depth (mbgl):	29.0	SWL (mbgl):	10.68		



Well LEEMB18_S Location Leeuwpan

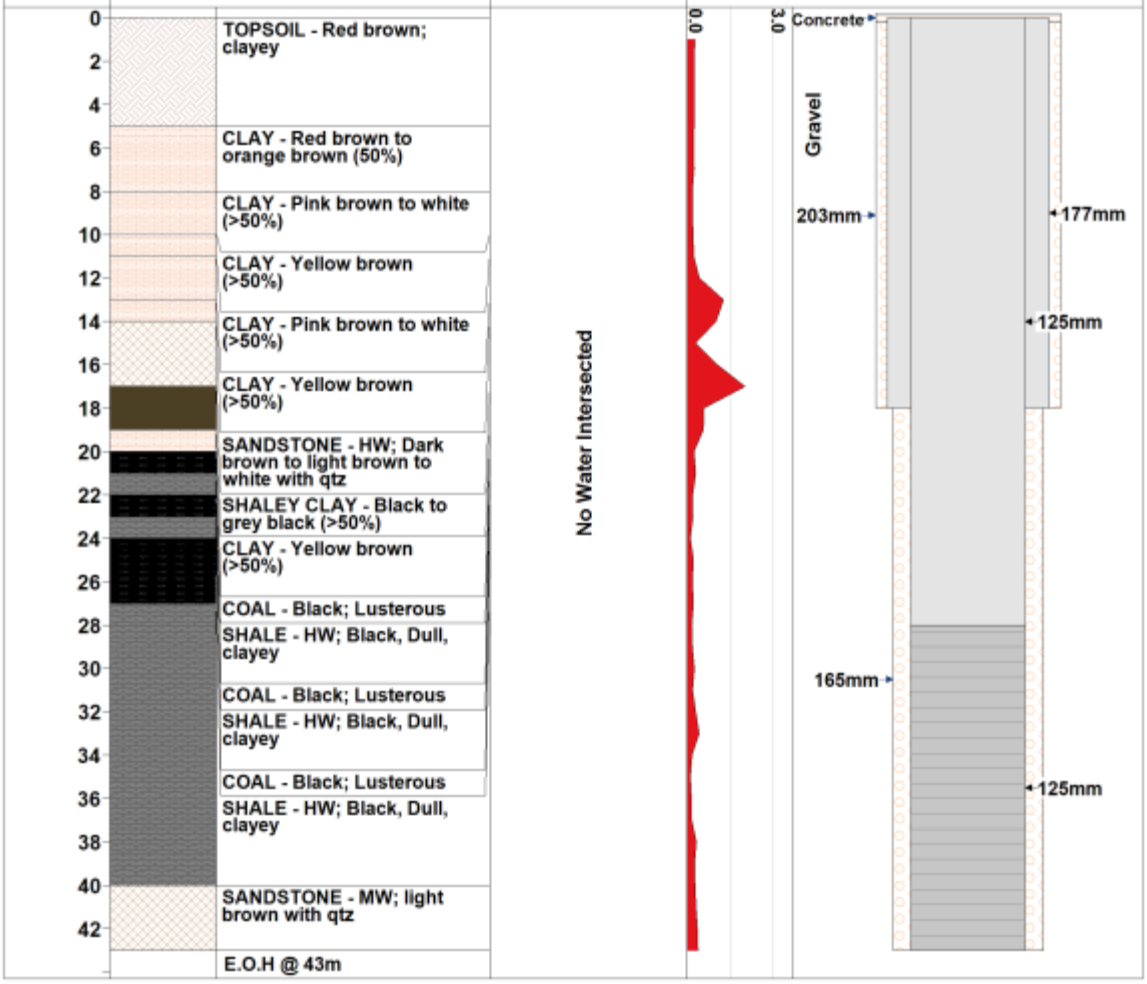
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Depth (mbgl):	10.0	SWL (mbgl):	-		




Well MOAMB4
Location Leeuwpan
Project No.: 11-447GW
X Coordinate: -25613.1
Y Coordinate: -2895412.7
Elev. (mamsl) 1583.0
Depth (mbgl): 40.0
Drilling Contractor: Bentex Drilling
Drilling Method: Percussion
Casing: Steel & PVC
BH Diameter (mm) 203 - 165
SWL (mbgl): 23.28
Logged By: JvR
Date: 29/11/2013
Depth (m)
Lithology
Water Strike
Borehole Construction
TOPSOIL - Red brown; clayey
CLAY - Orange brown to yellow brown (>50%)
CLAY - Light brown to orange brown (>50%)
CLAY - Light brown to yellow brown (>50%)
CLAY - Dark brown to brown (>50%)
SANDSTONE - HW; blue grey to grey brown; clayey
SANDSTONE - HW; blue grey to grey
E.O.H @ 40m
No Water Intersected
0.0
5.0
Concrete
Gravel
203mm
177mm
125mm
165mm
125mm

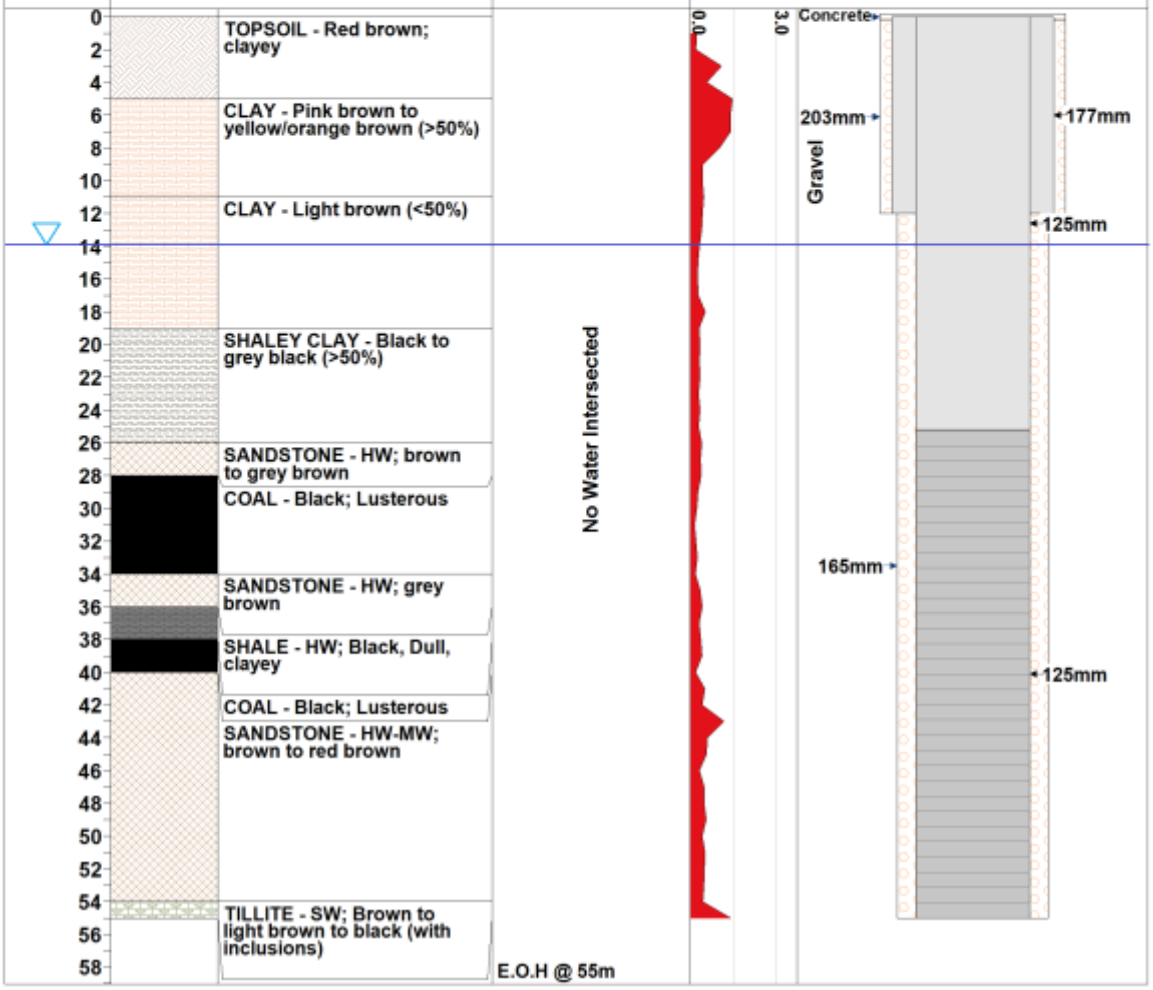
Well MOAMB7 **Location** Leeuwpan

Project No.:	11-447GW	Drilling Contractor:	Bentex Drilling	Logged By:	JvR
X Coordinate:	-24450.4	Drilling Method:	Percussion	Date:	22/11/2013
Y Coordinate:	-2893907.5	Casing:	Steel & PVC		
Elev. (mamsl)	1562.6	BH Diameter (mm)	203 - 165		
Depth (mbgl):	43.0	SWL (mbgl):	-		



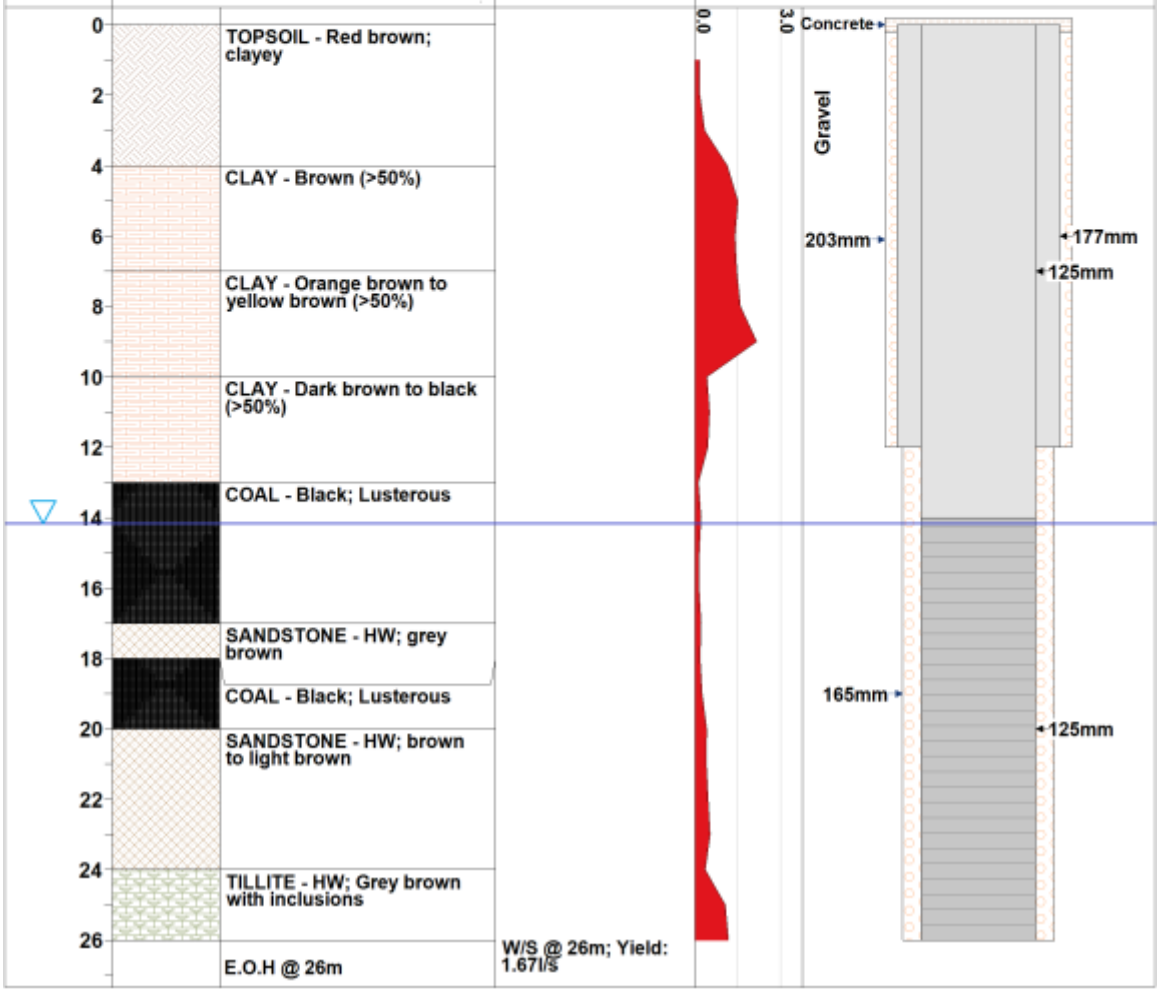
Well MOAMB9 Location Leeuwpan

Project No.:	11-447GW	Drilling Contractor:	Bentex Drilling	Logged By:	JvR
X Coordinate:	-23301.7	Drilling Method:	Percussion	Date:	27/11/2013
Y Coordinate:	-2896308.2	Casing:	Steel & PVC		
Elev. (mamsl)	1570.5	BH Diameter (mm)	203 - 165		
Depth (mbgl):	55.0	SWL (mbgl):	13.95		



Well MOAMB10 Location Leeuwpan

Project No.:	11-447GW	Drilling Contractor:	Bentex Drilling	Logged By:	JvR
X Coordinate:	-23468.4	Drilling Method:	Percussion	Date:	27/11/2013
Y Coordinate:	-2895139.2	Casing:	Steel & PVC		
Elev. (mamsl)	1557.2	BH Diameter (mm)	203 - 165		
Depth (mbgl):	26.0	SWL (mbgl):	14.21		

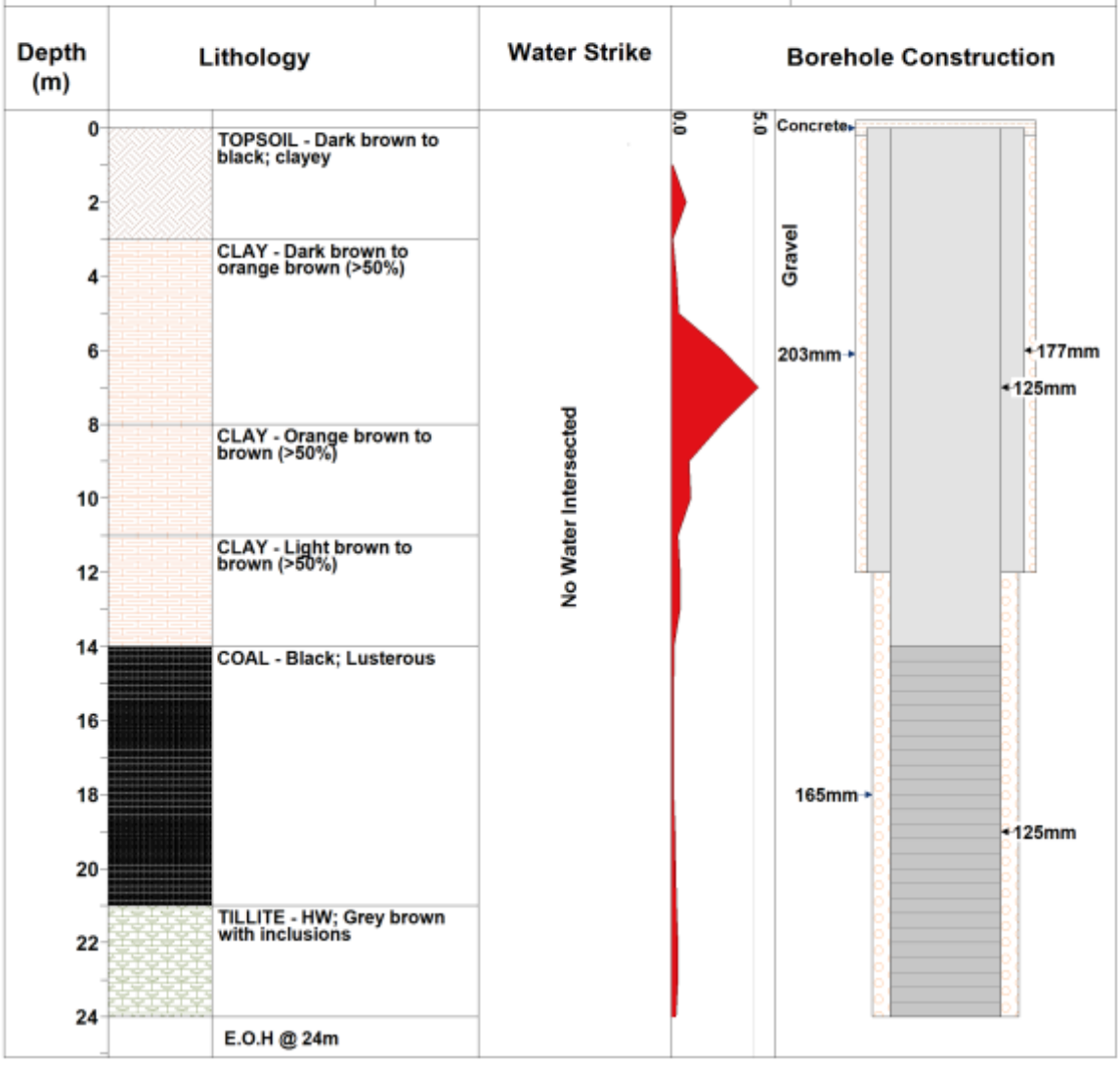


Well WELMB13_D **Location** Leeuwpan

Project No.:	11-447GW	Drilling Contractor:	Bentex Drilling
X Coordinate:	-22155.9	Drilling Method:	Percussion
Y Coordinate:	-2892777.9	Casing:	Steel & PVC
Elev. (mamsl)	1553.9	BH Diameter (mm)	203 - 165
Depth (mbgl):	24.0	SWL (mbgl):	-

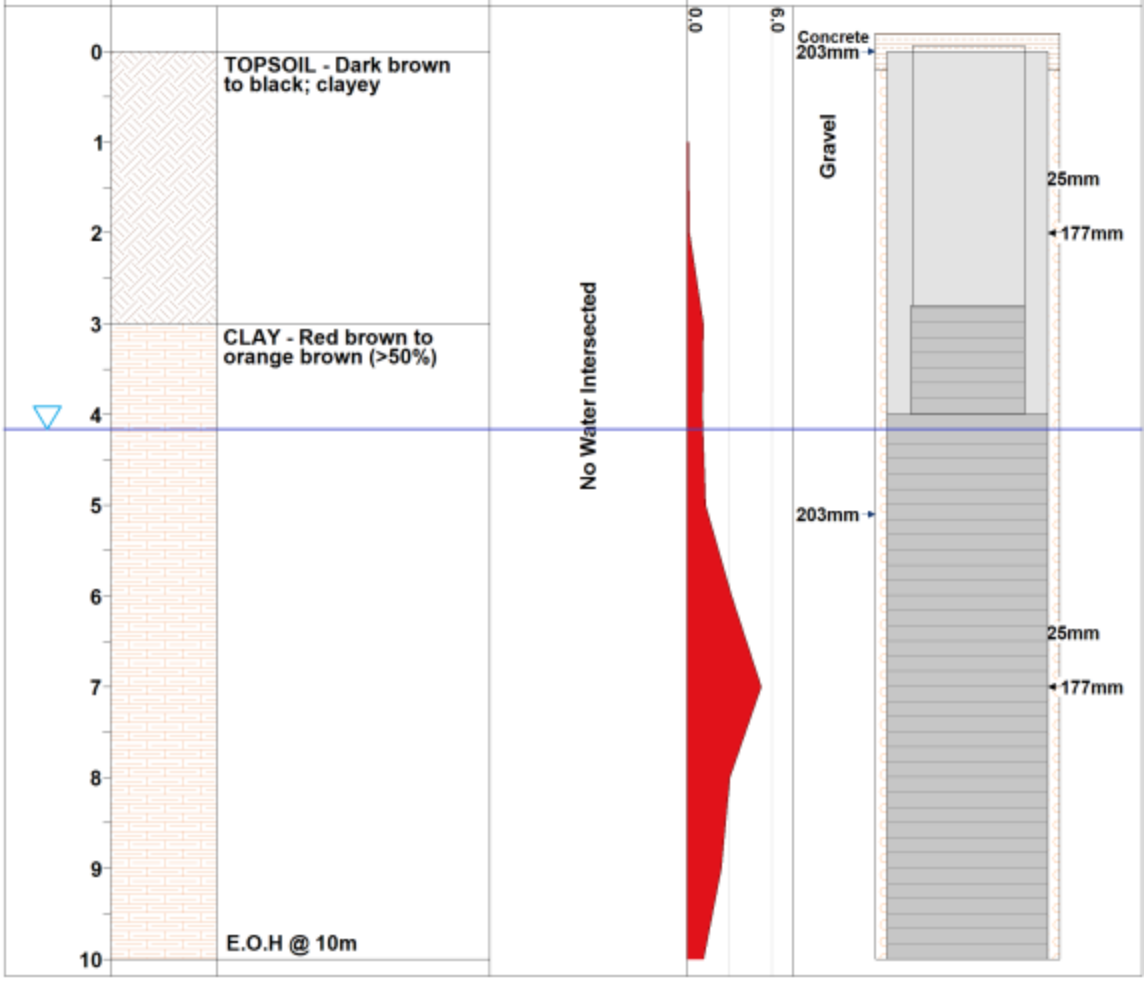
Logged By: JvR

Date: 28/11/2013



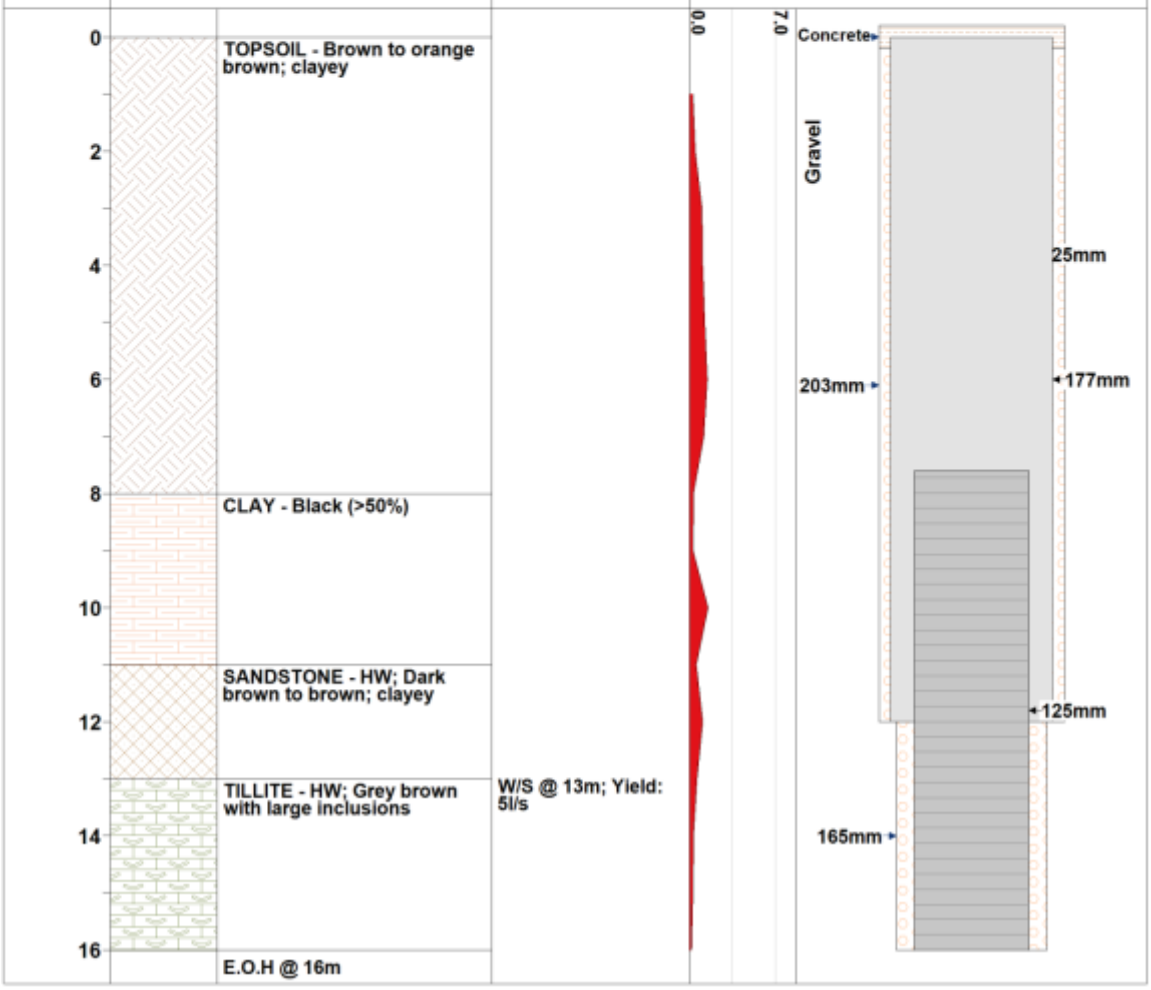
Well WELMB13_S Location Leeuwpan

Project No.:	11-447GW	Drilling Contractor:	Bentex Drilling	Logged By:	JvR
X Coordinate:	-22175.5	Drilling Method:	Percussion	Date:	28/11/2013
Y Coordinate:	-2892795.5	Casing:	Steel & PVC		
Elev. (mamsl)	1554.4	BH Diameter (mm)	203		
Depth (mbgl):	10.0	SWL (mbgl):	4.36		



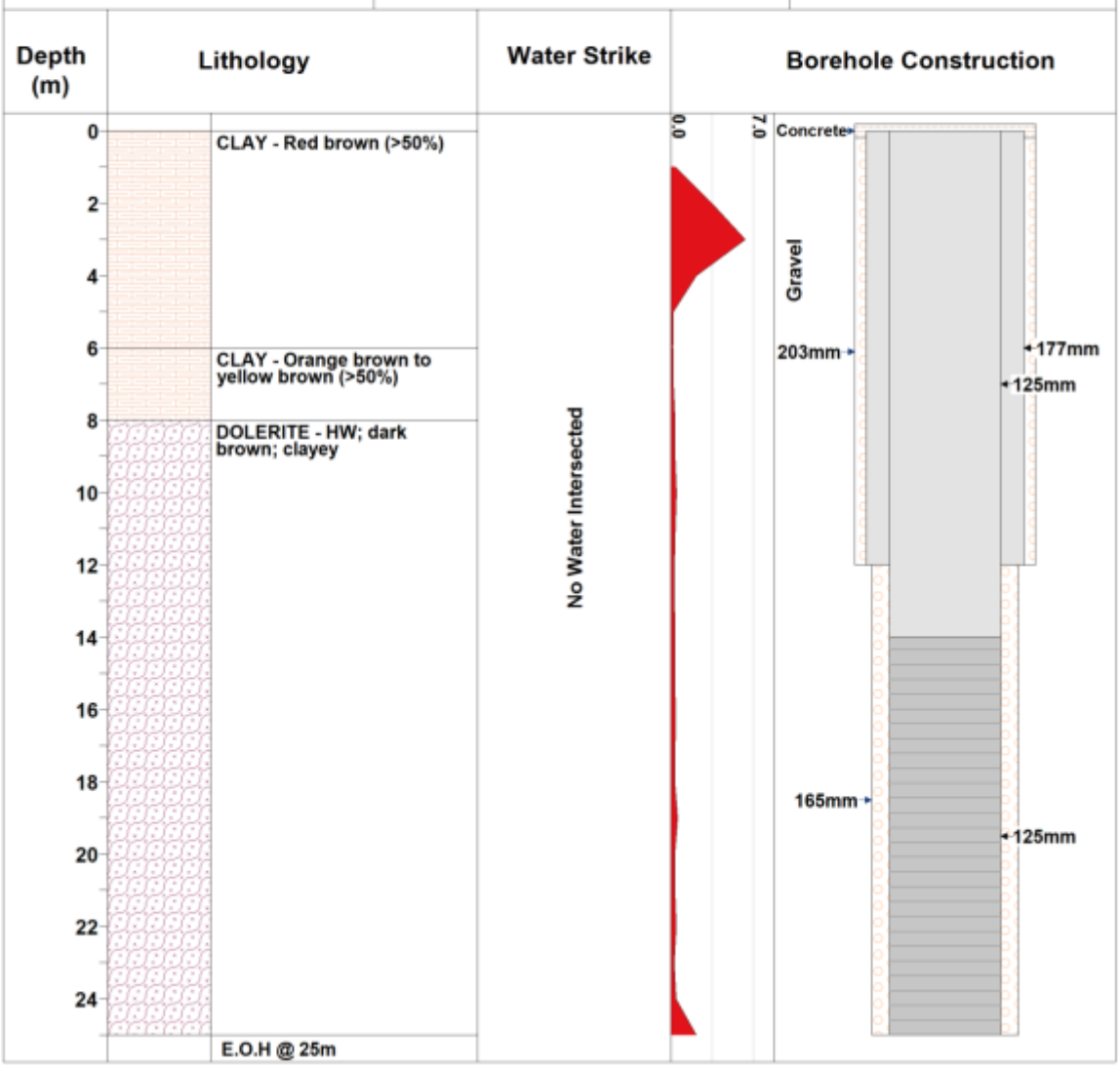
Well WITMB14 **Location** Leeuwpan

Project No.:	11-447GW	Drilling Contractor:	Bentex Drilling	Logged By:	JvR
X Coordinate:	-29453.5	Drilling Method:	Percussion	Date:	30/11/2013
Y Coordinate:	-2895360.5	Casing:	Steel & PVC		
Elev. (mamsl)	1552.4	BH Diameter (mm)	203 - 165		
Depth (mbgl):	16.0	SWL (mbgl):	-		



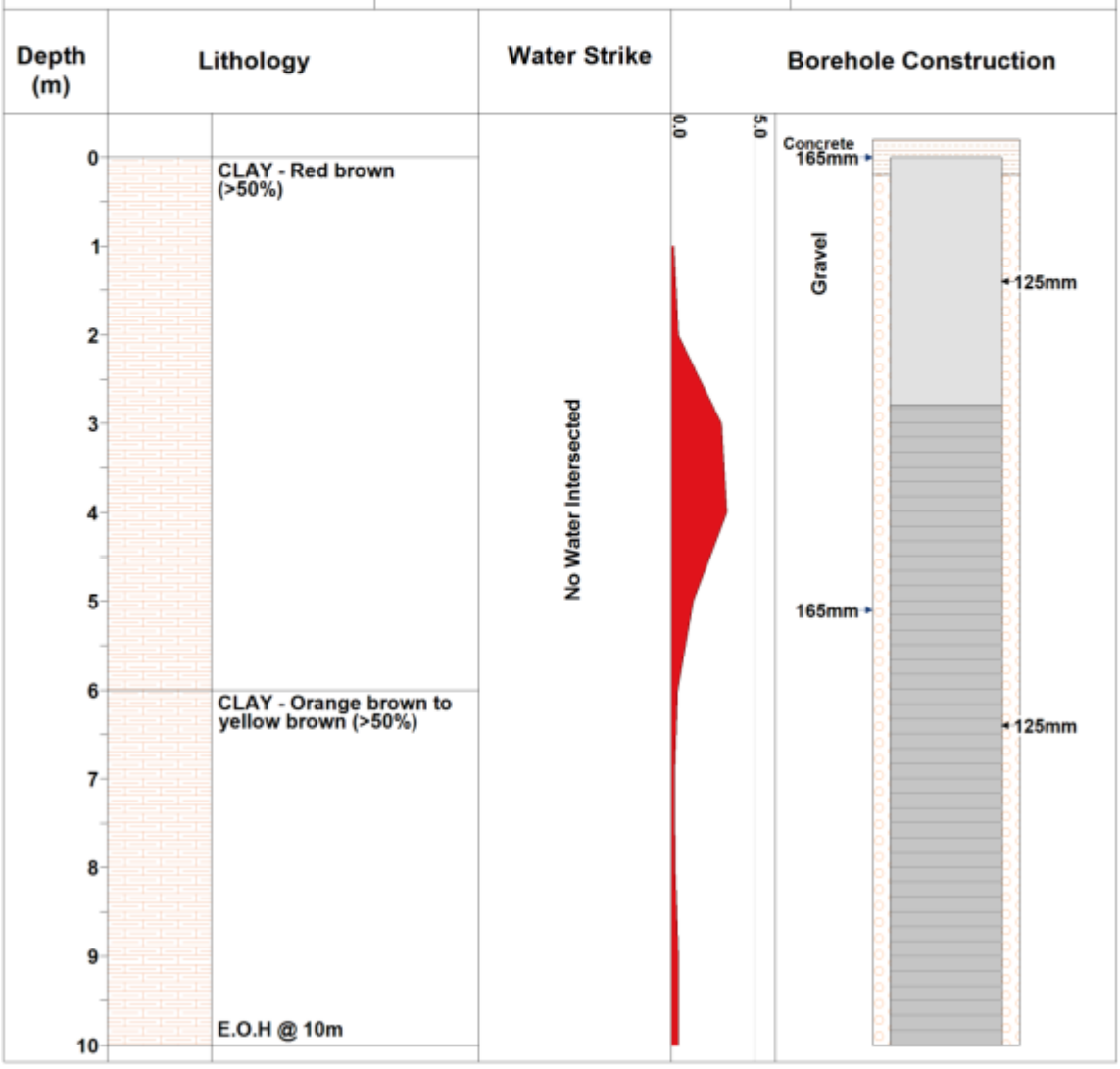
Well *WOLMB15_D* **Location** *Leeuwpan*

Project No.:	*11-447GW*	**Drilling Contractor:**	*Bentex Drilling*		
X Coordinate:	*-27626.0*	**Drilling Method:**	*Percussion*		
Y Coordinate:	*-2895239.1*	**Casing:**	*Steel & PVC*		
Elev. (mamsl)	*1571.2*	**BH Diameter (mm)**	*203 - 165*		
Depth (mbgl):	*25.0*	**SWL (mbgl):**	-	**Logged By:**	*JvR*
				Date:	*26/11/2013*



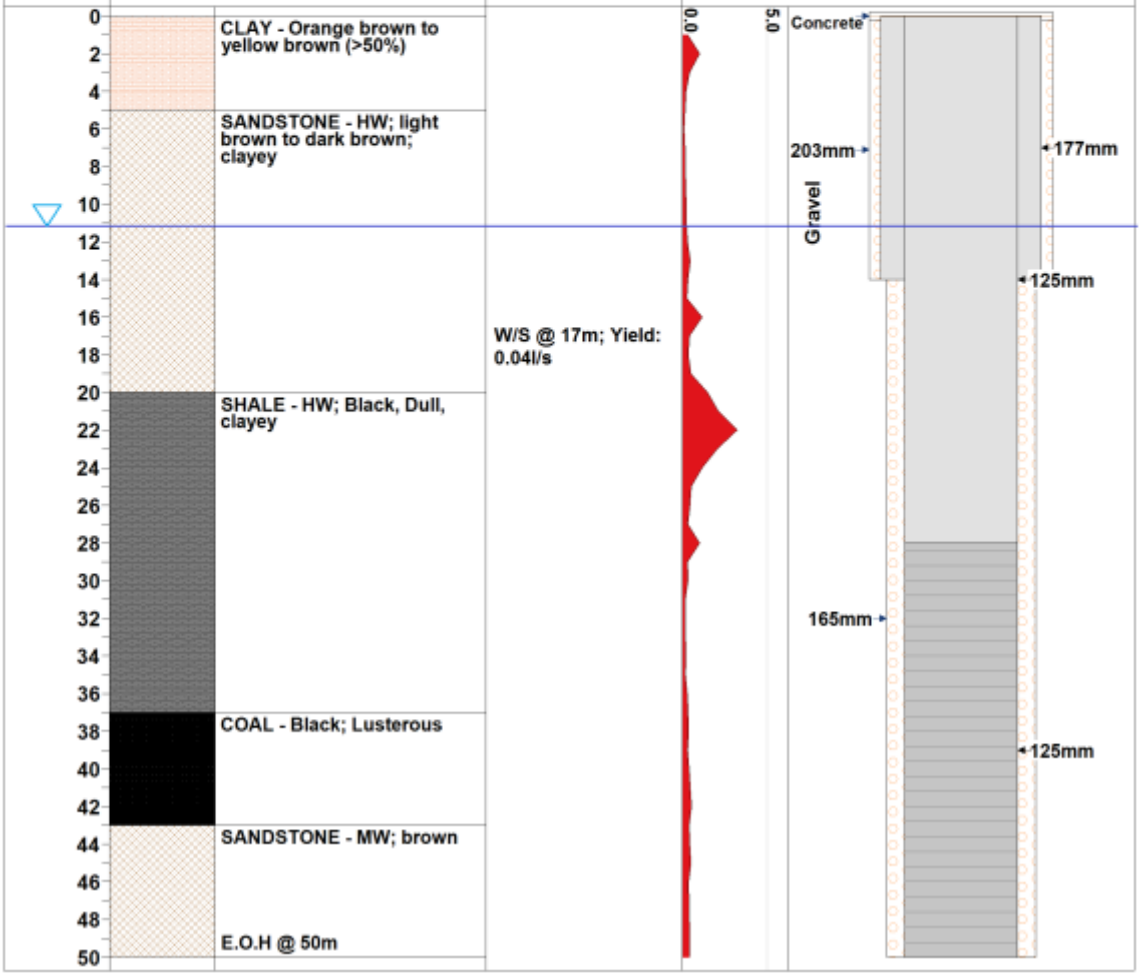
Well WOLMB15_S Location Leeuwpan

Project No.:	11-447GW	Drilling Contractor:	Bentex Drilling		
X Coordinate:	-27611.4	Drilling Method:	Percussion		
Y Coordinate:	-2895244.7	Casing:	PVC		
Elev. (mamsl)	1571.1	BH Diameter (mm)	203		
Depth (mbgl):	10.0	SWL (mbgl):	-	Logged By:	JvR
				Date:	26/11/2013

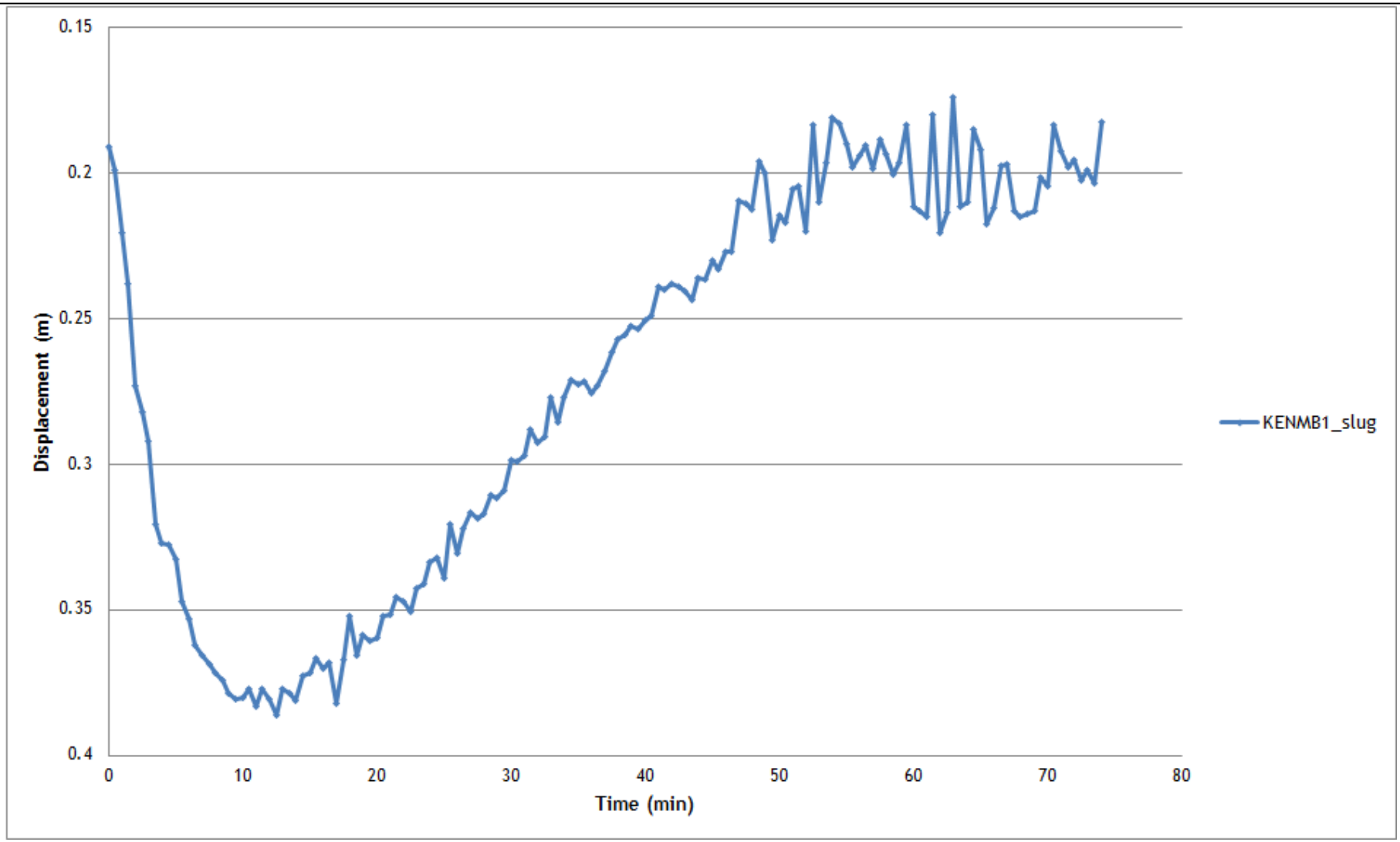


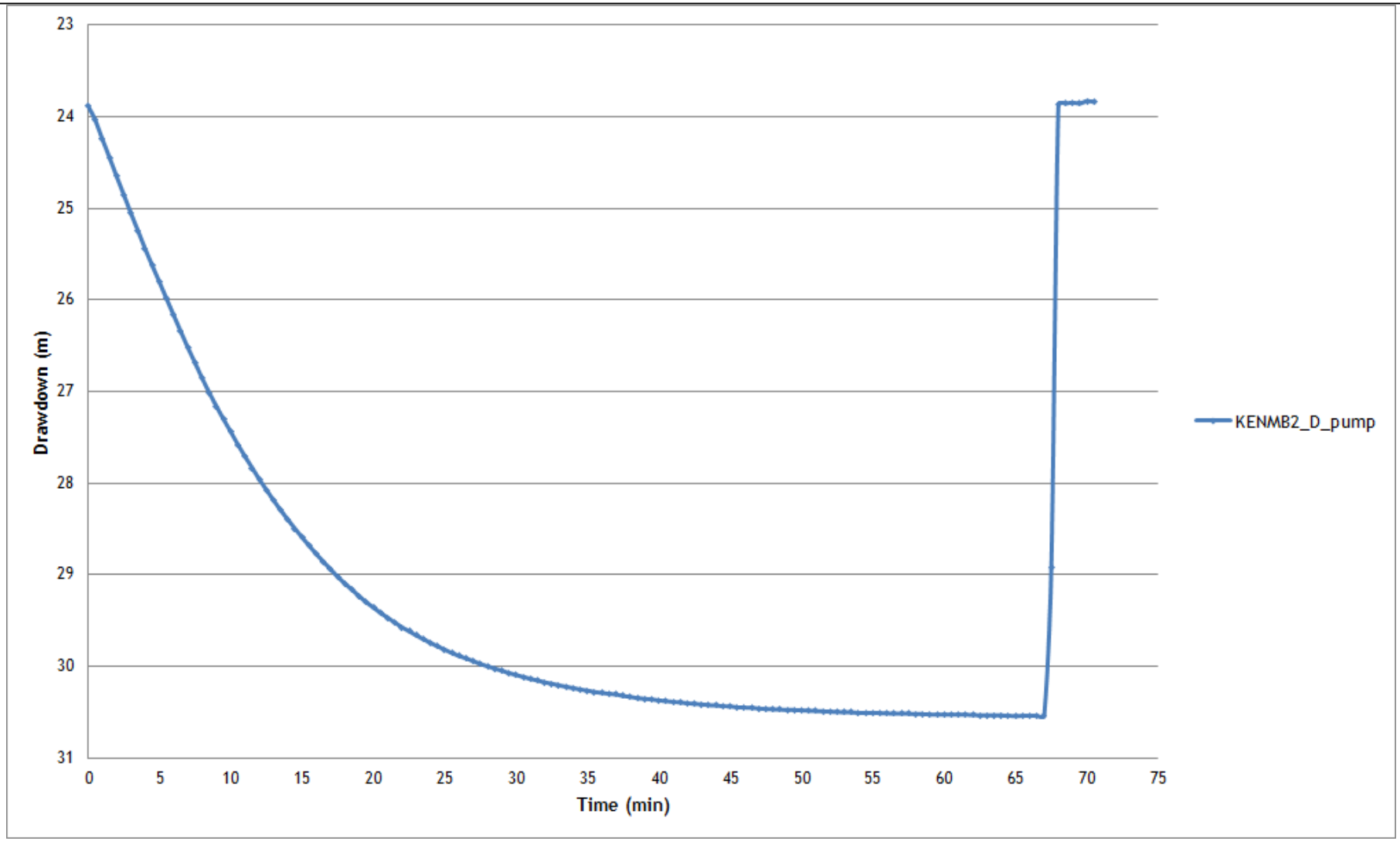
Well WWNMB16 Location Leeuwpan

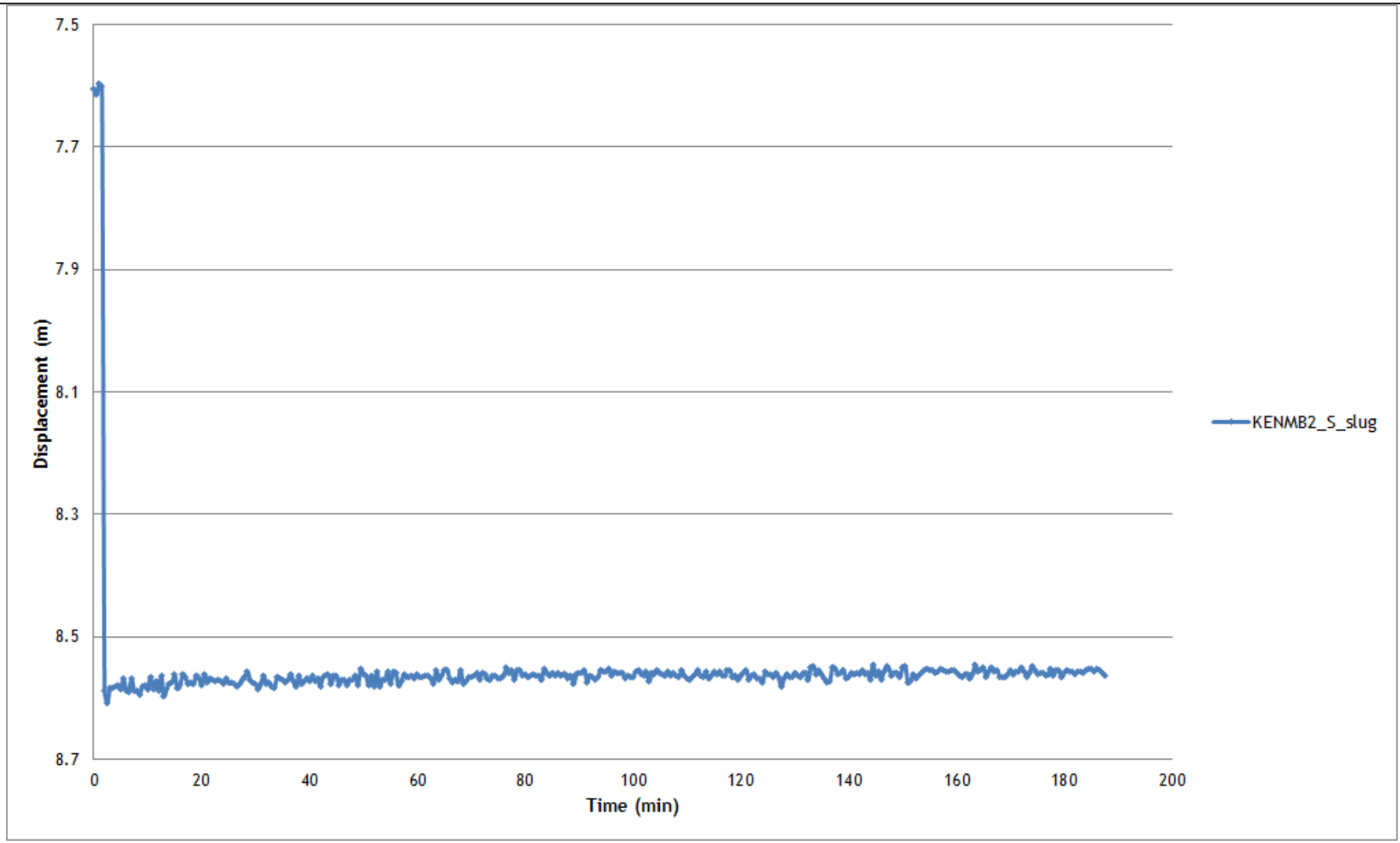
Project No.:	11-447GW	Drilling Contractor:	Bentex Drilling	Logged By:	SD
X Coordinate:	-28888.2	Drilling Method:	Percussion	Date:	26/11/2013
Y Coordinate:	-2896643.7	Casing:	Steel & PVC		
Elev. (mamsl)	1568.4	BH Diameter (mm)	203 - 165		
Depth (mbgl):	50.0	SWL (mbgl):	11.03		

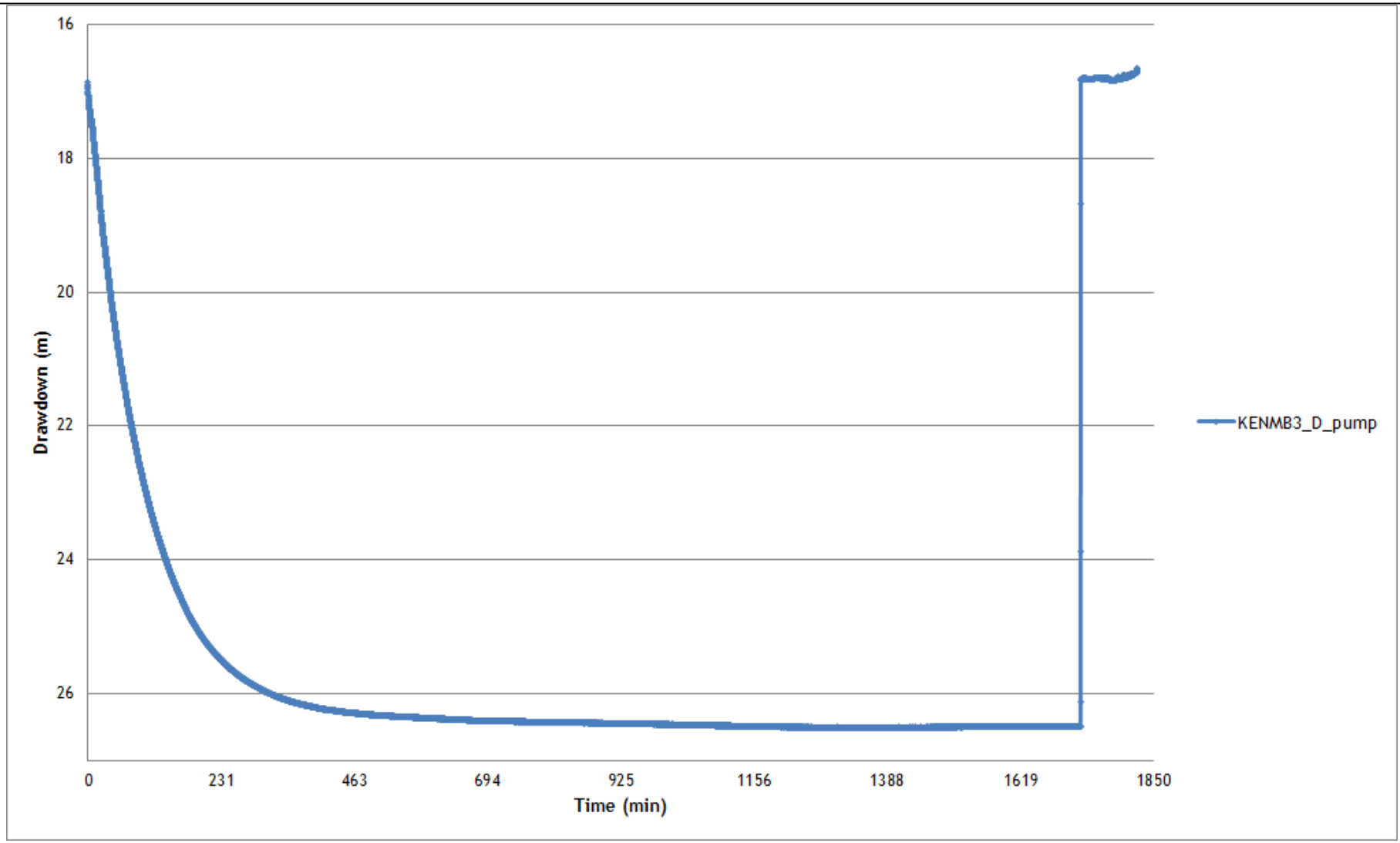


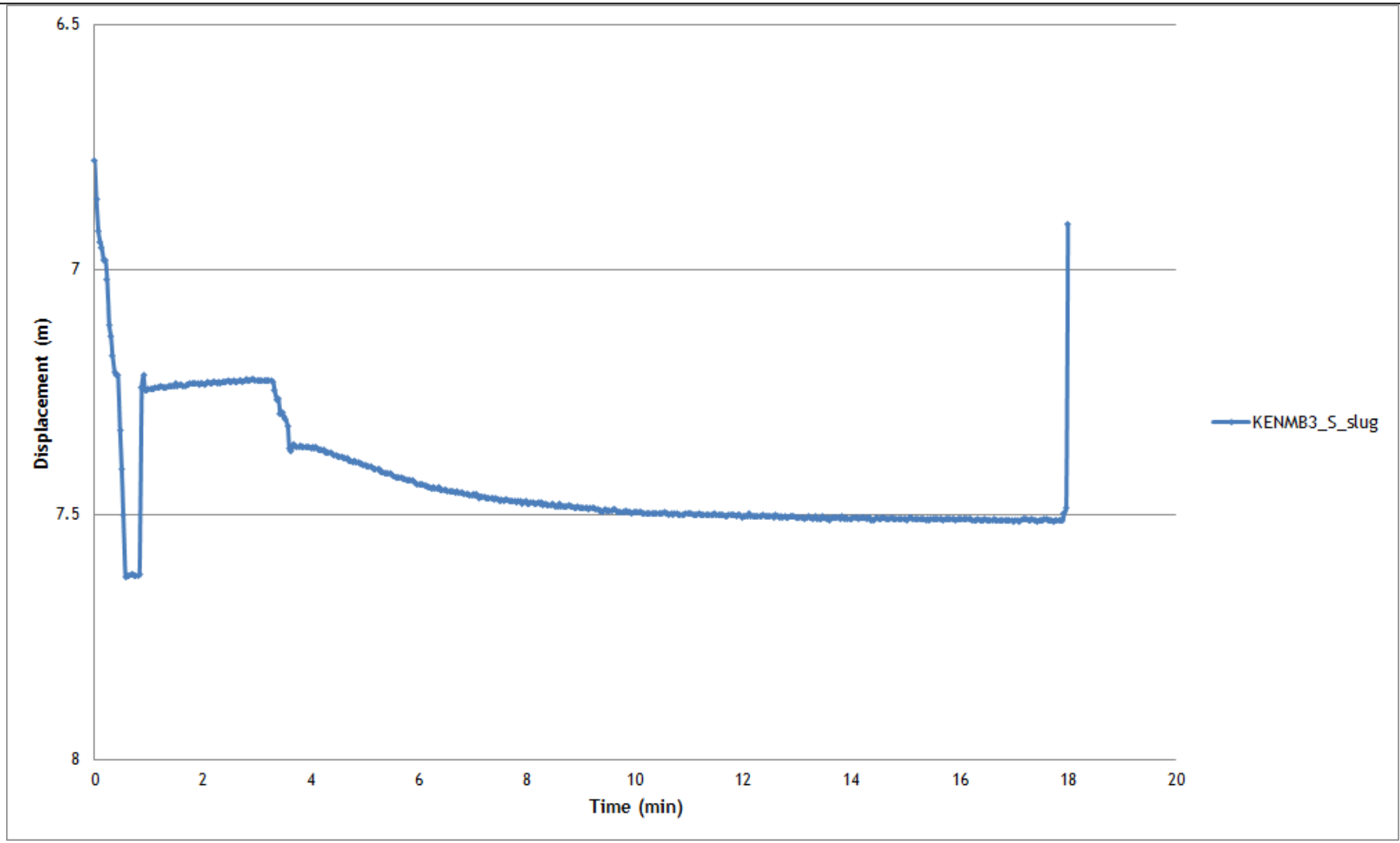
APPENDIX C: AQUIFER TEST RESULTS

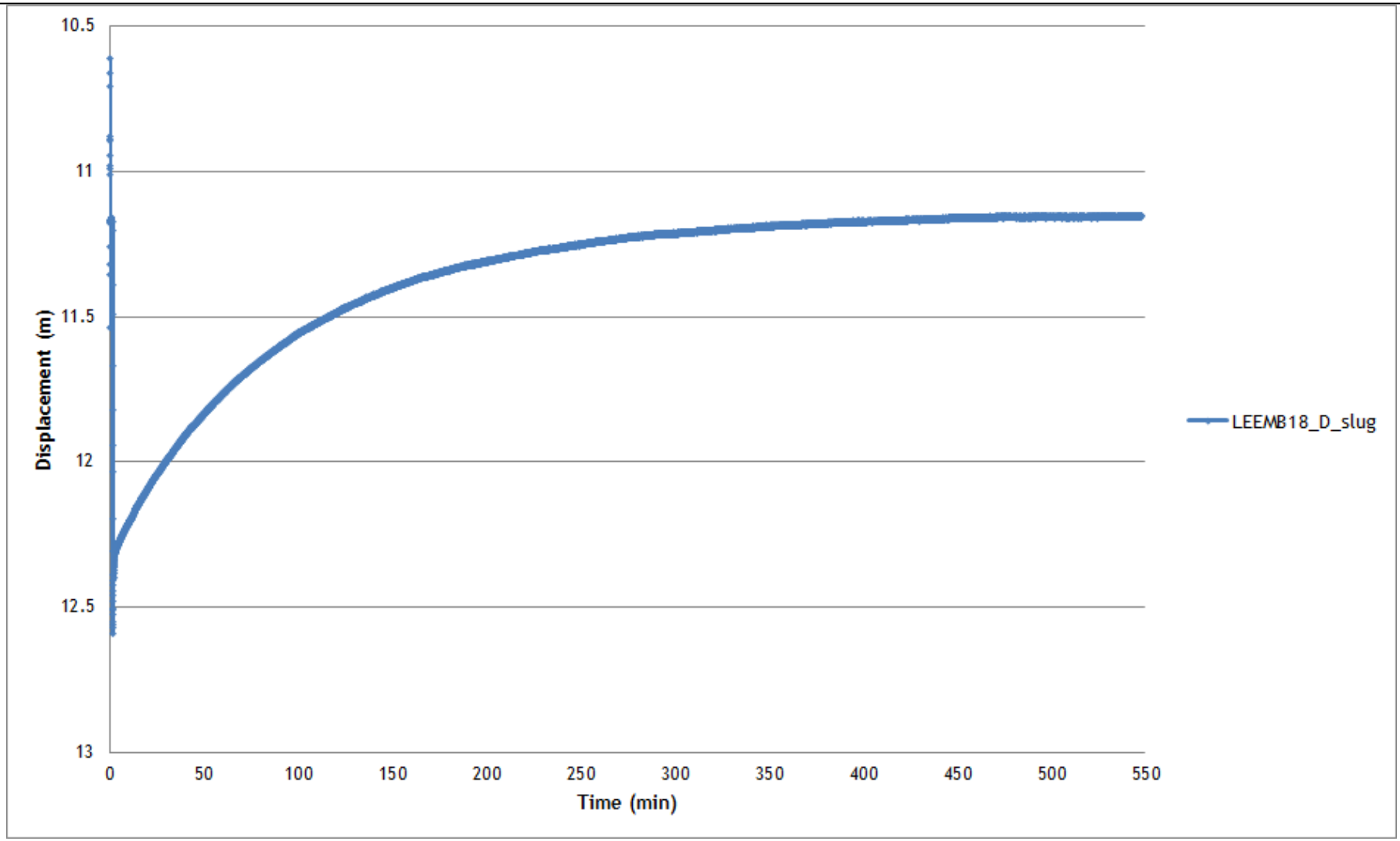

0.15
0.2
0.25
0.3
0.35
0.4
Displacement (m)
0
10
20
30
40
50
60
70
80
Time (min)
KENMB1_slug

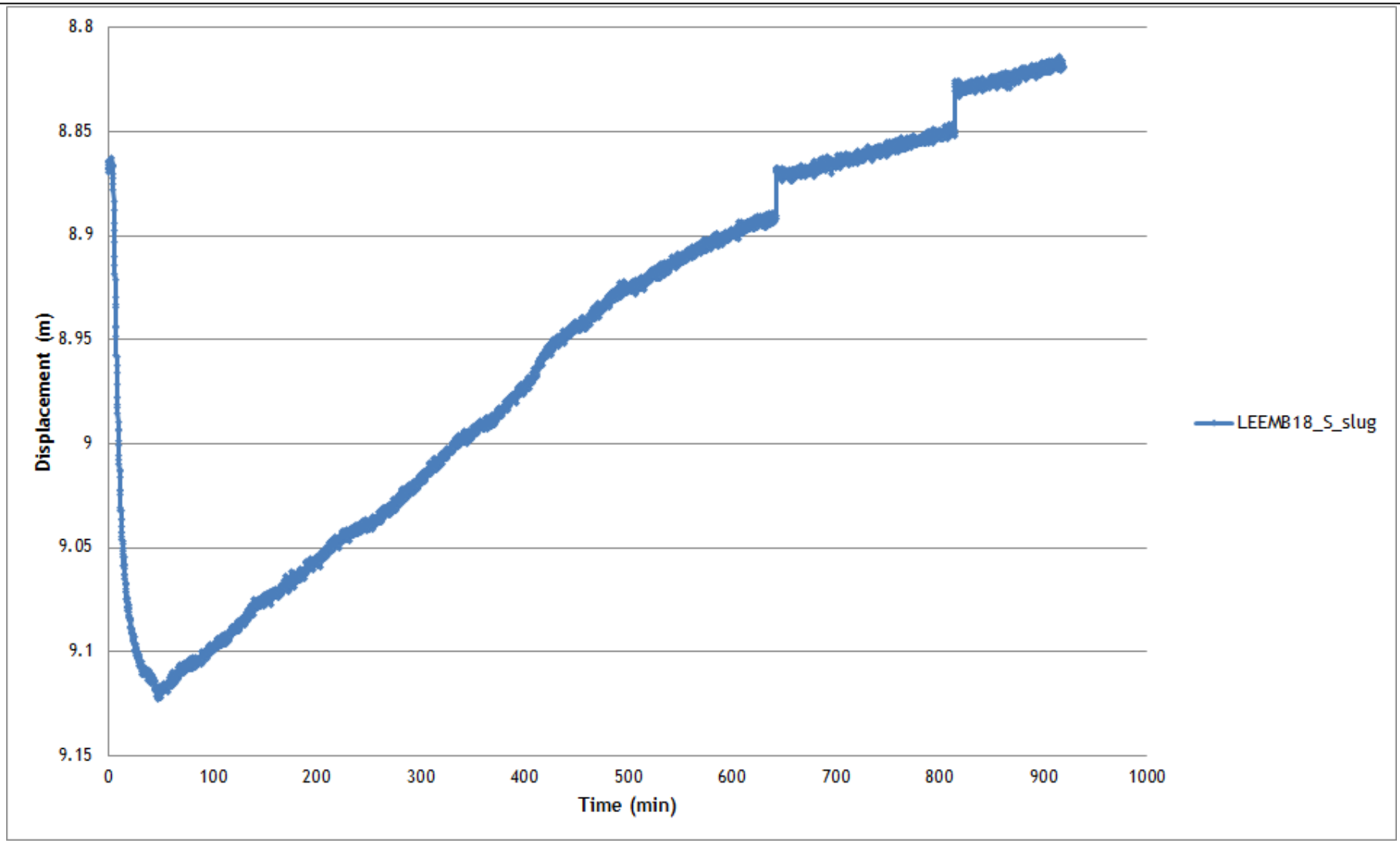

23
24
25
26
27
28
29
30
31
Drawdown (m)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Time (min)
KENMB2_D_pump

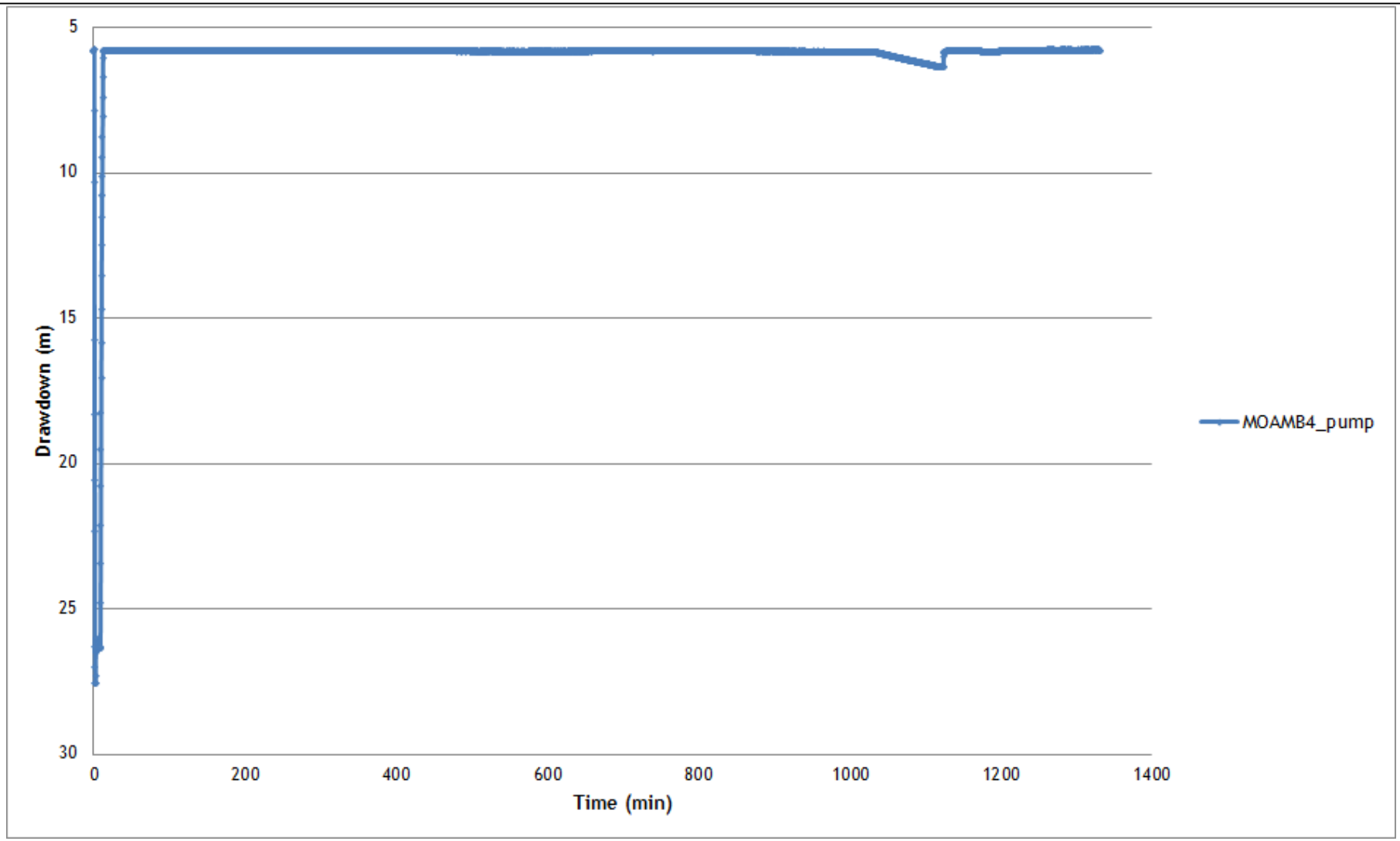

7.5
7.7
7.9
8.1
8.3
8.5
8.7
Displacement (m)
0
20
40
60
80
100
120
140
160
180
200
Time (min)
KENMB2_S_slug

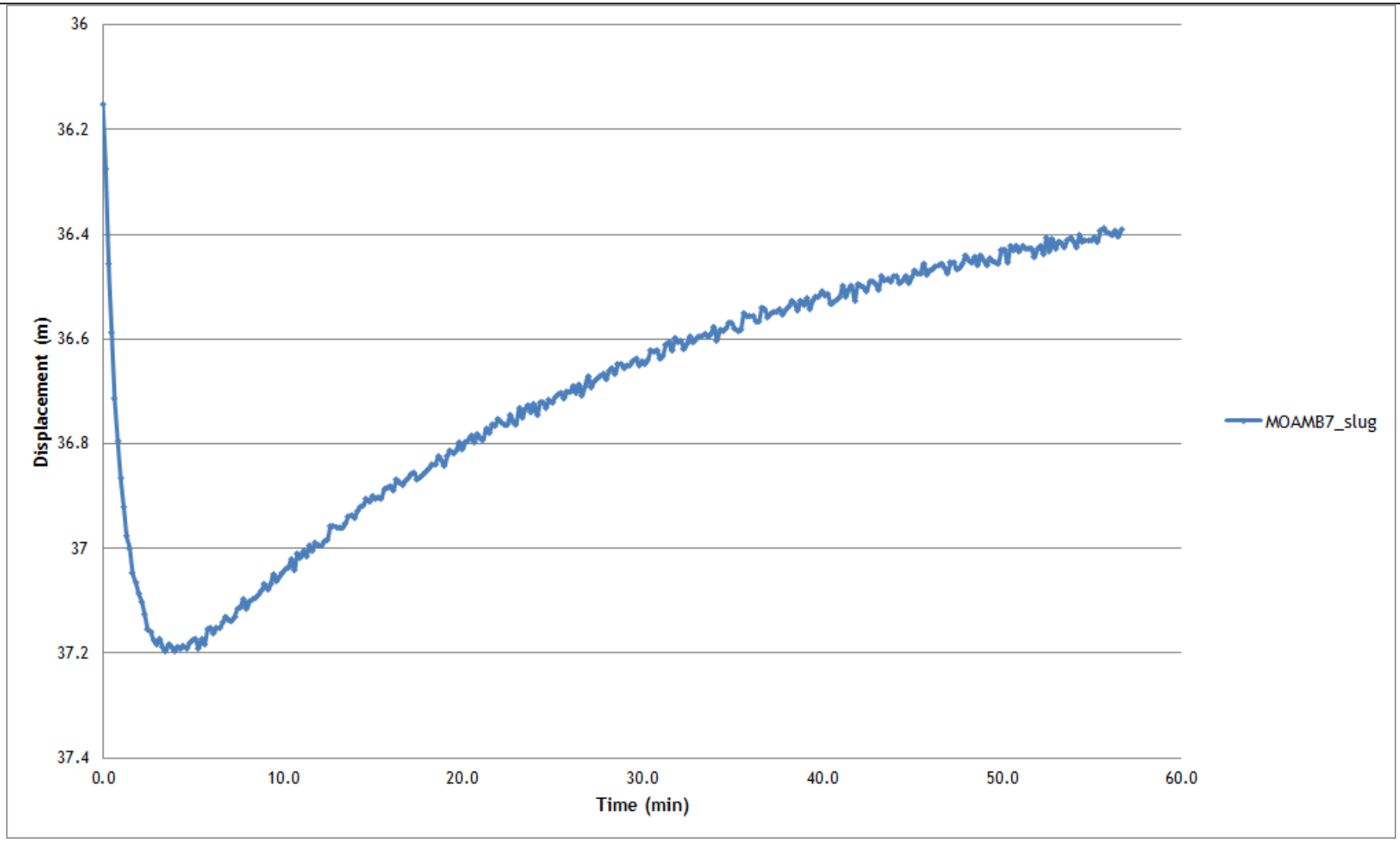

16
18
20
22
24
26
Drawdown (m)
0
231
463
694
925
1156
1388
1619
1850
Time (min)
KENMB3_D_pump

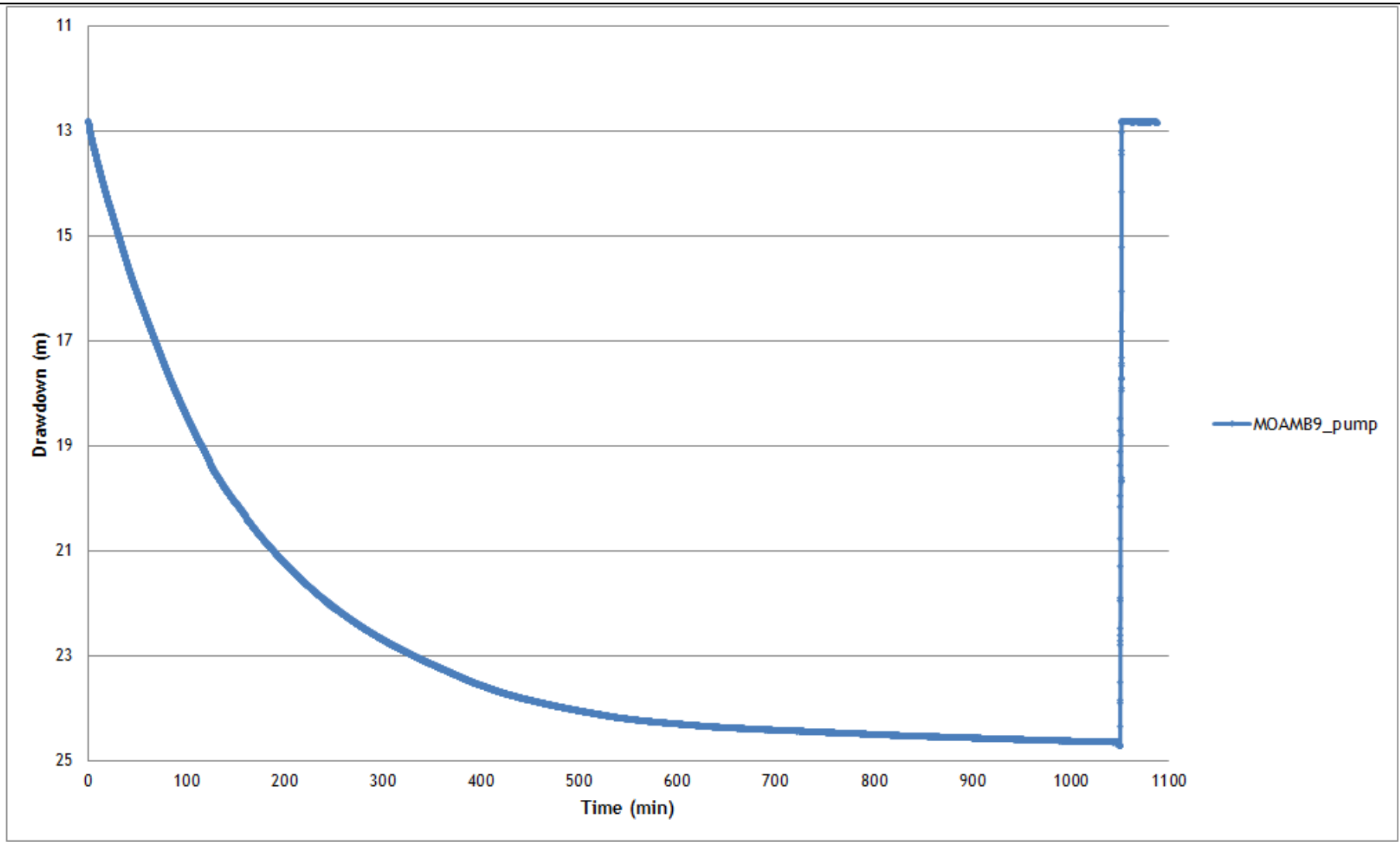

6.5
7
7.5
8
Displacement (m)
0
2
4
6
8
10
12
14
16
18
20
Time (min)
KENMB3_S_slug

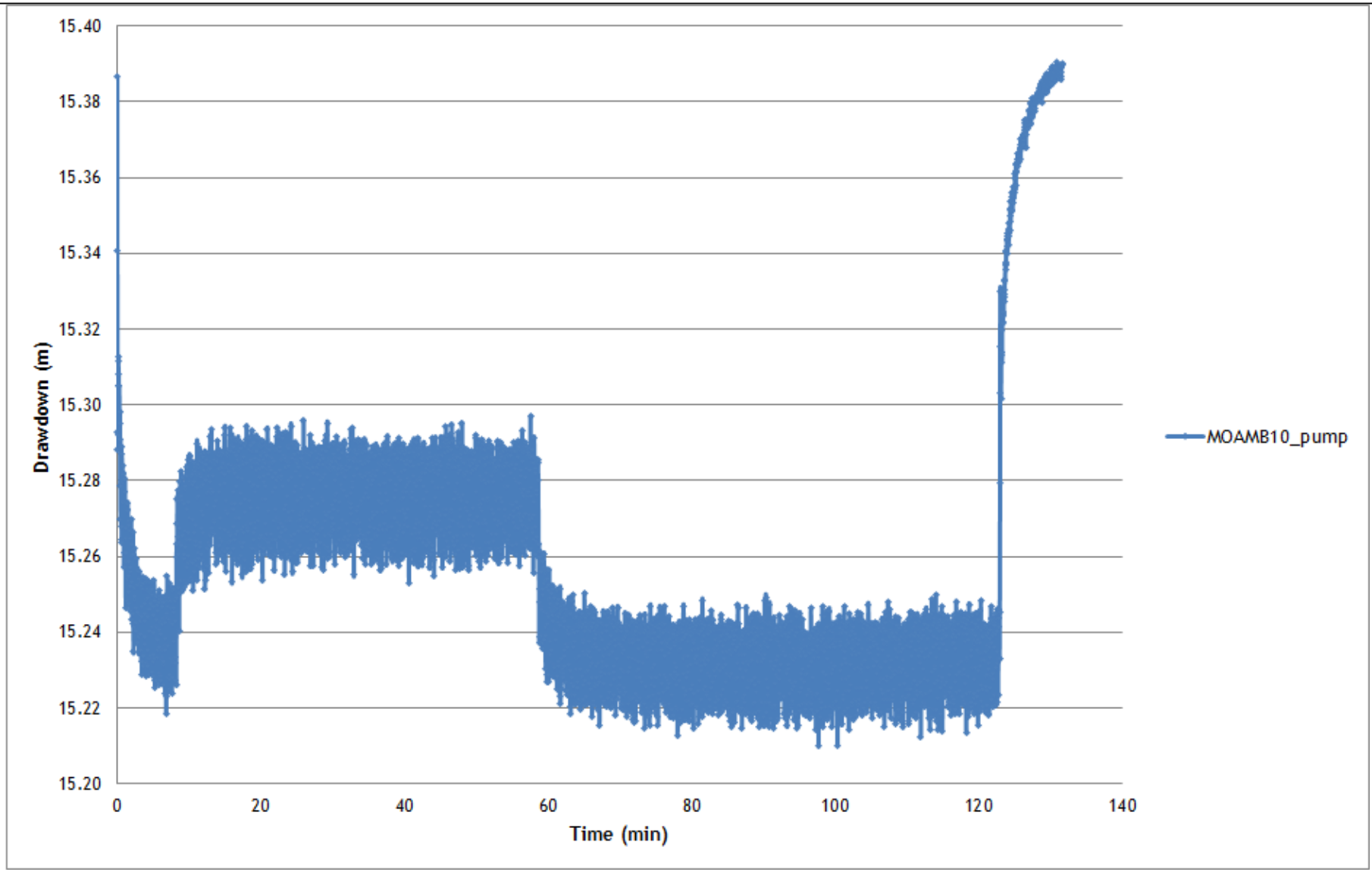

10.5
11
11.5
12
12.5
13
Displacement (m)
0
50
100
150
200
250
300
350
400
450
500
550
Time (min)
LEEMB18_D_slug

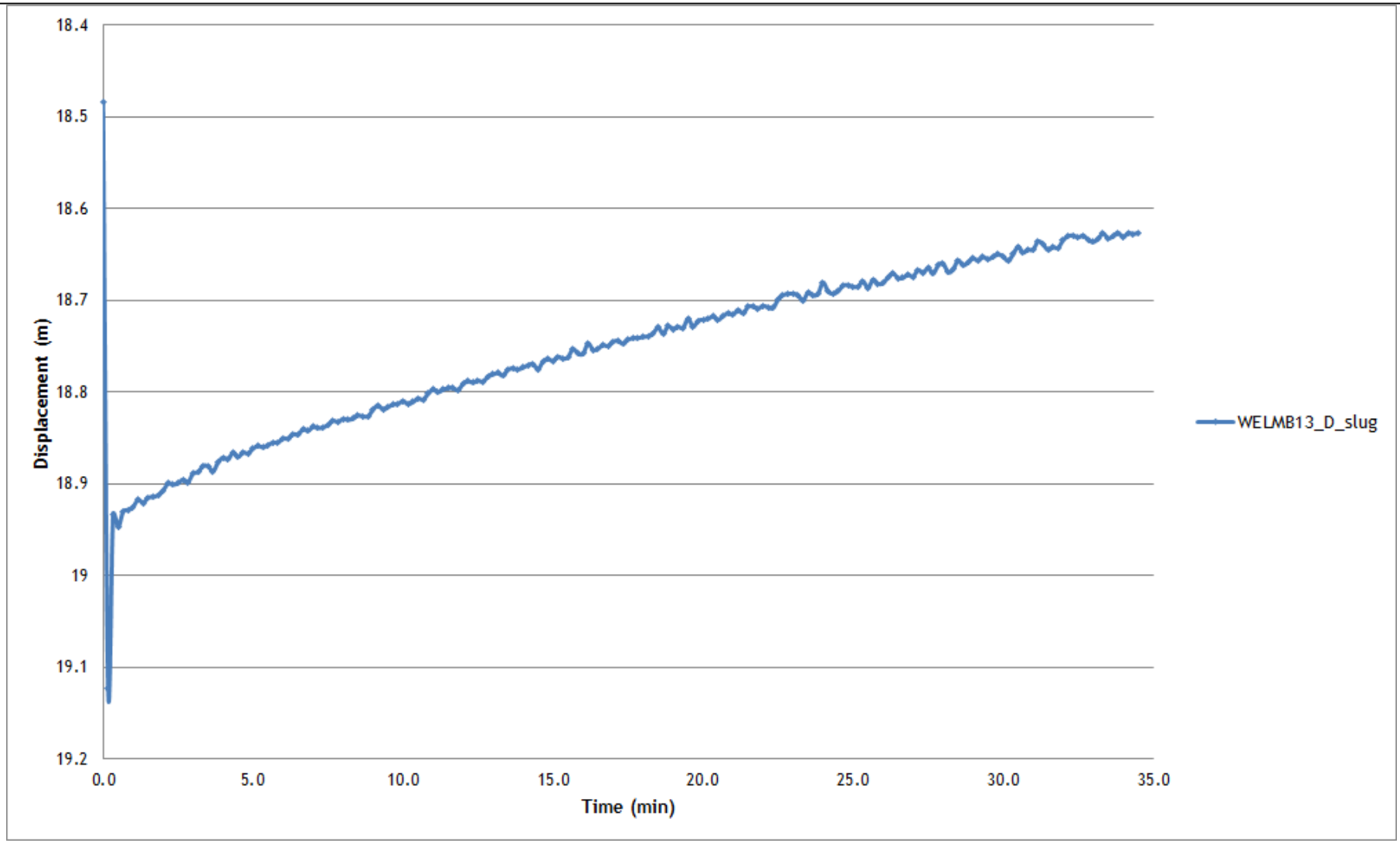

8.8
8.85
8.9
8.95
9
9.05
9.1
9.15
Displacement (m)
0
100
200
300
400
500
600
700
800
900
1000
Time (min)
LEEMB18_S_slug

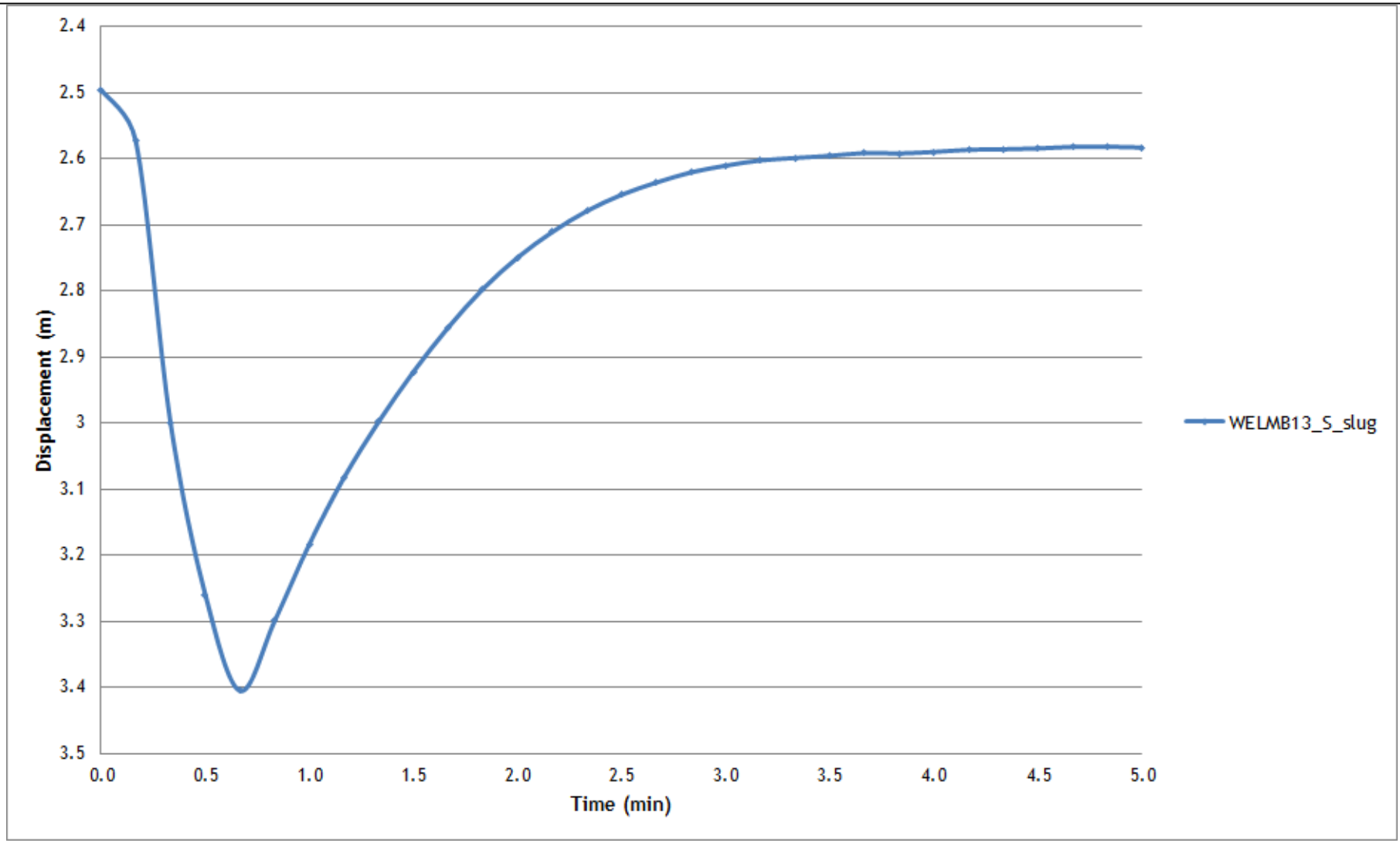

5
10
15
20
25
30
Drawdown (m)
0
200
400
600
800
1000
1200
1400
Time (min)
MOAMB4_pump

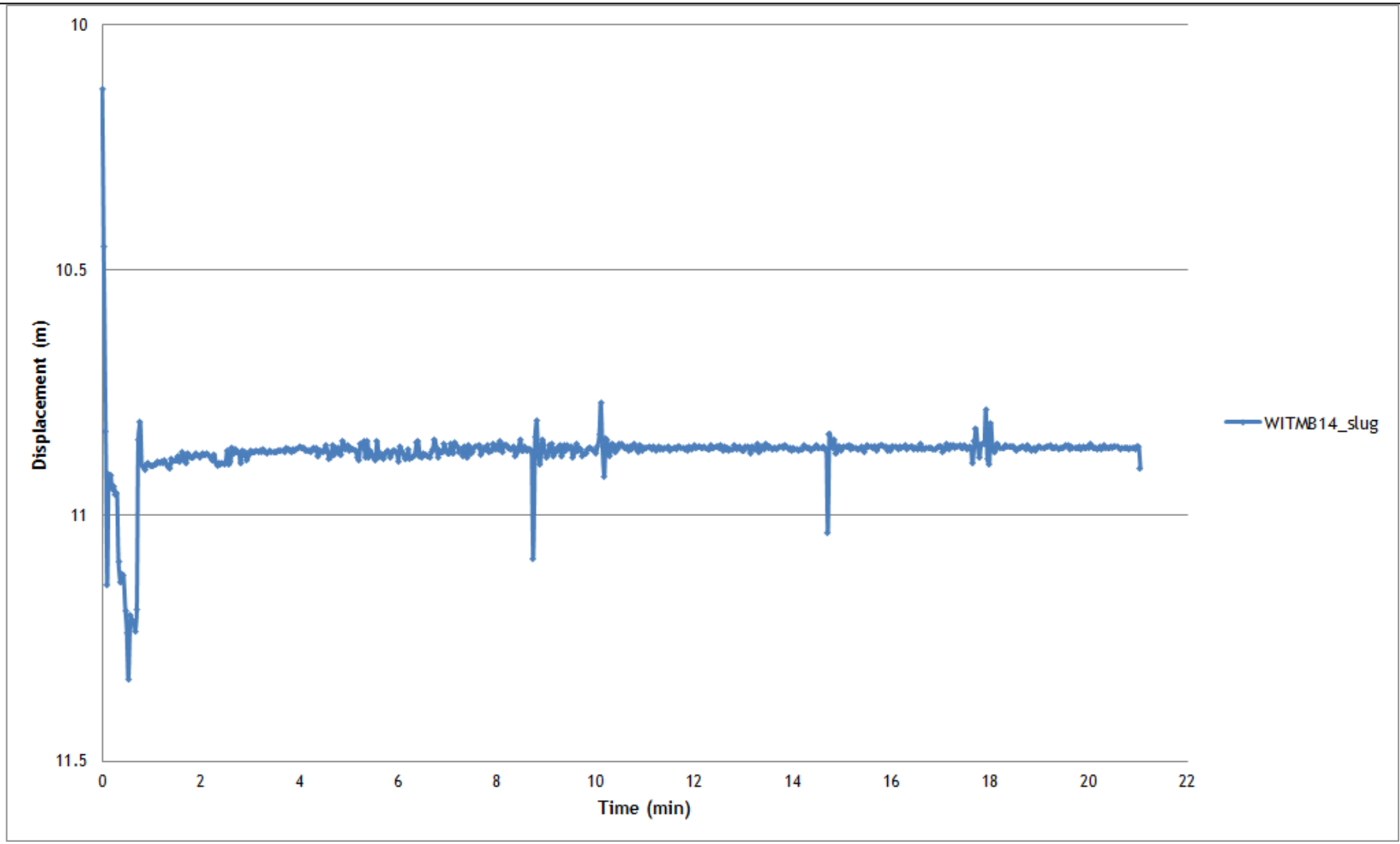

36
36.2
36.4
36.6
36.8
37
37.2
37.4
Displacement (m)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Time (min)
MOAMB7_slug

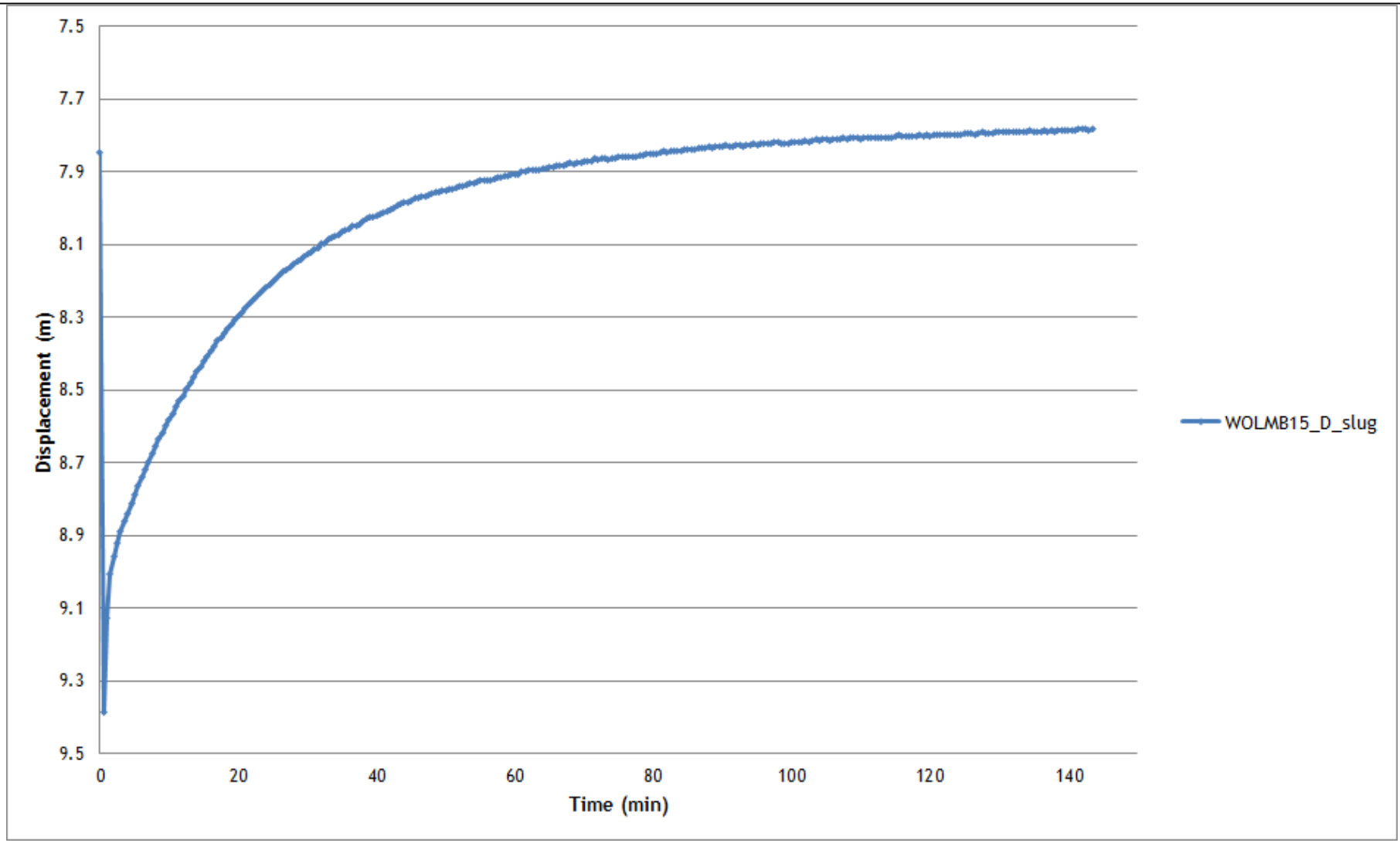

11
13
15
17
19
21
23
25
Drawdown (m)
0
100
200
300
400
500
600
700
800
900
1000
1100
Time (min)
MOAMB9_pump

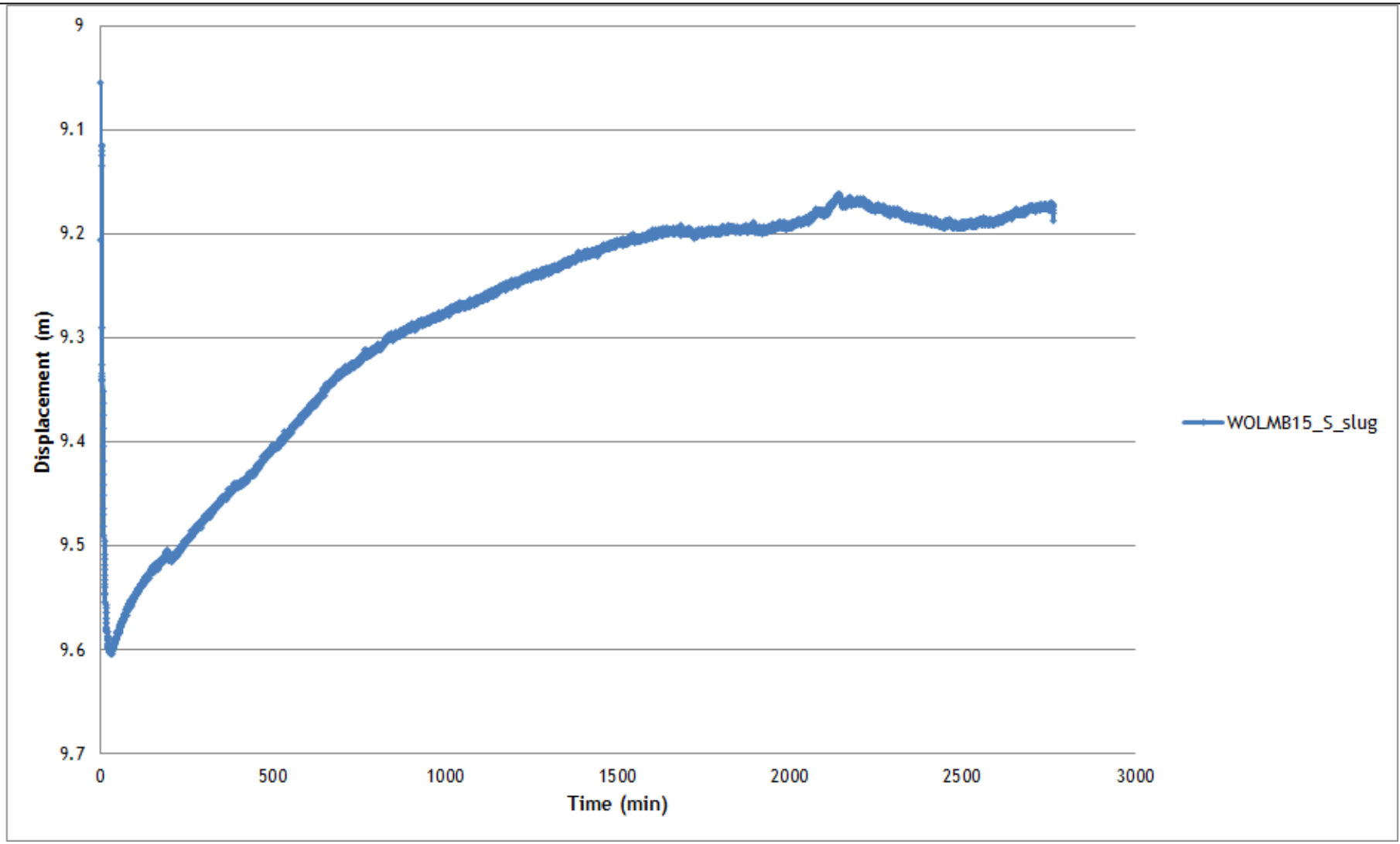

15.40
15.38
15.36
15.34
15.32
15.30
15.28
15.26
15.24
15.22
15.20
Drawdown (m)
0
20
40
60
80
100
120
140
Time (min)
MOAMB10_pump

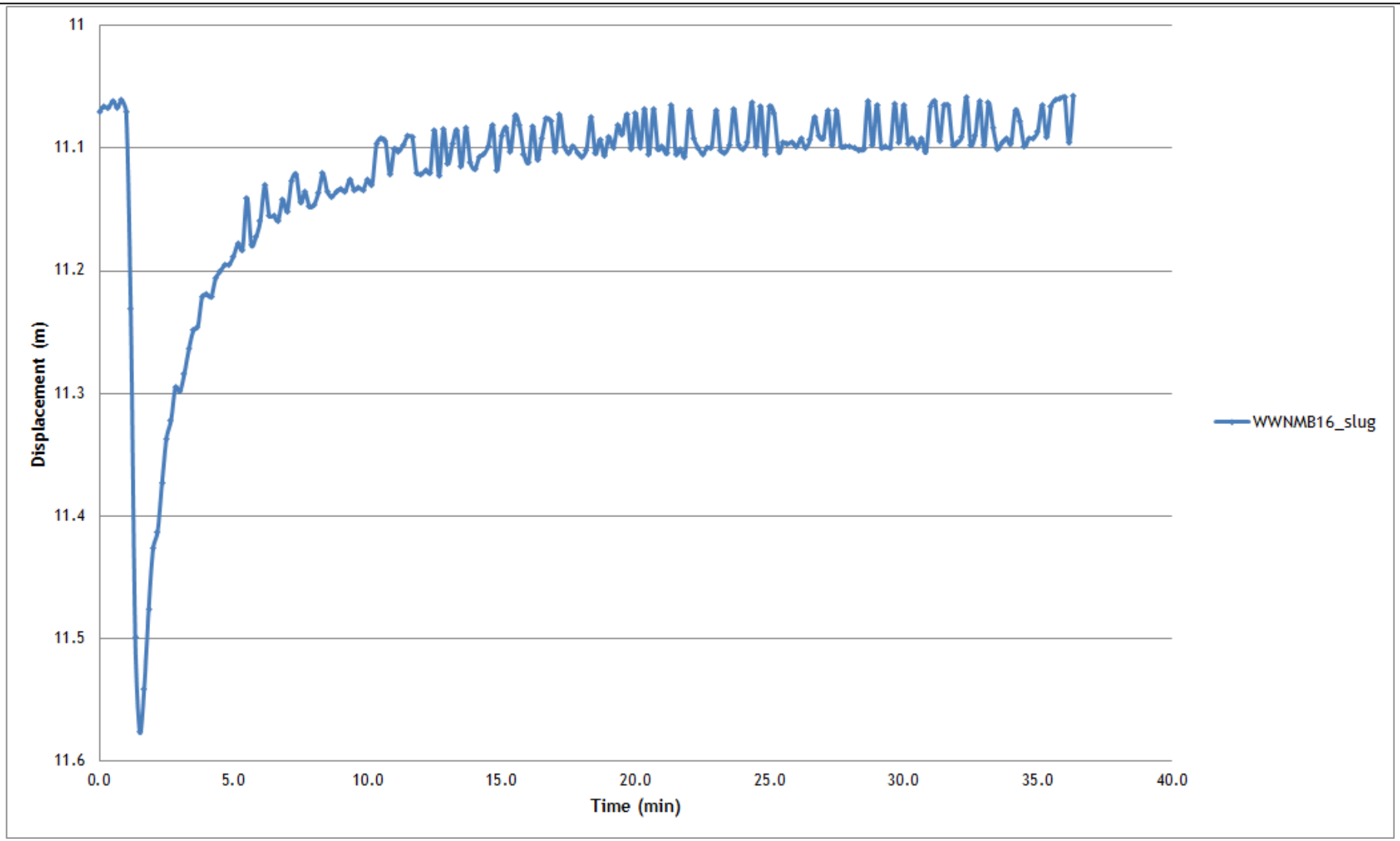

18.4
18.5
18.6
18.7
18.8
18.9
19
19.1
19.2
Displacement (m)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
Time (min)
WELMB13_D_slug


2.4
2.5
2.6
2.7
2.8
2.9
3
3.1
3.2
3.3
3.4
3.5
Displacement (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Time (min)
WELMB13_S_slug

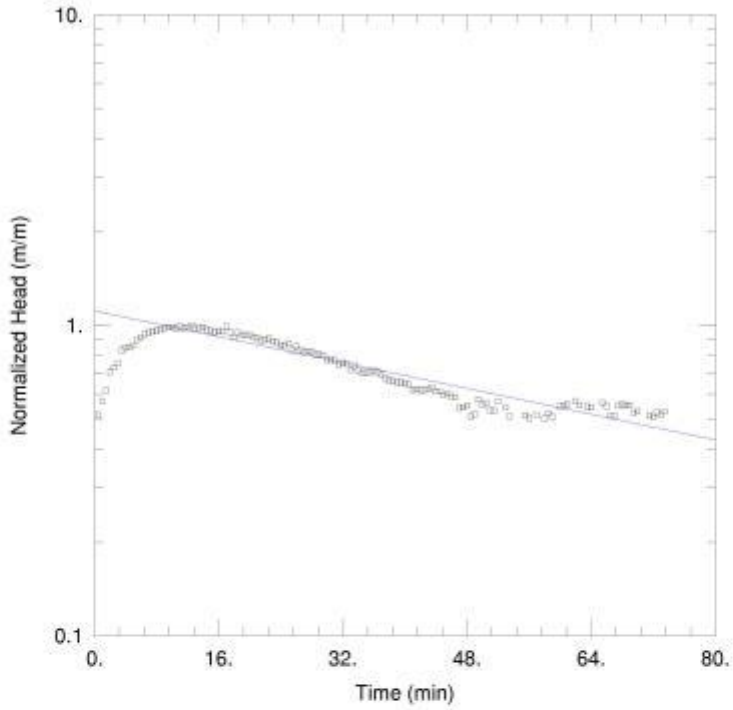

10
10.5
11
11.5
Displacement (m)
0
2
4
6
8
10
12
14
16
18
20
22
Time (min)
WITMB14_slug


7.5
7.7
7.9
8.1
8.3
8.5
8.7
8.9
9.1
9.3
9.5
Displacement (m)
0
20
40
60
80
100
120
140
Time (min)
WOLMB15_D_slug


9
9.1
9.2
9.3
9.4
9.5
9.6
9.7
Displacement (m)
0
500
1000
1500
2000
2500
3000
Time (min)
WOLMB15_S_slug


11
11.1
11.2
11.3
11.4
11.5
11.6
Displacement (m)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
Time (min)
WWNMB16_slug

Bouwer-Rice



WELL TEST ANALYSIS

Data Set: C:\...\KENMB1_slug.aqt
Date: 12/19/13 Time: 11:44:36

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: KENMB1_slug
Test Date: 2013/12/08

AQUIFER DATA

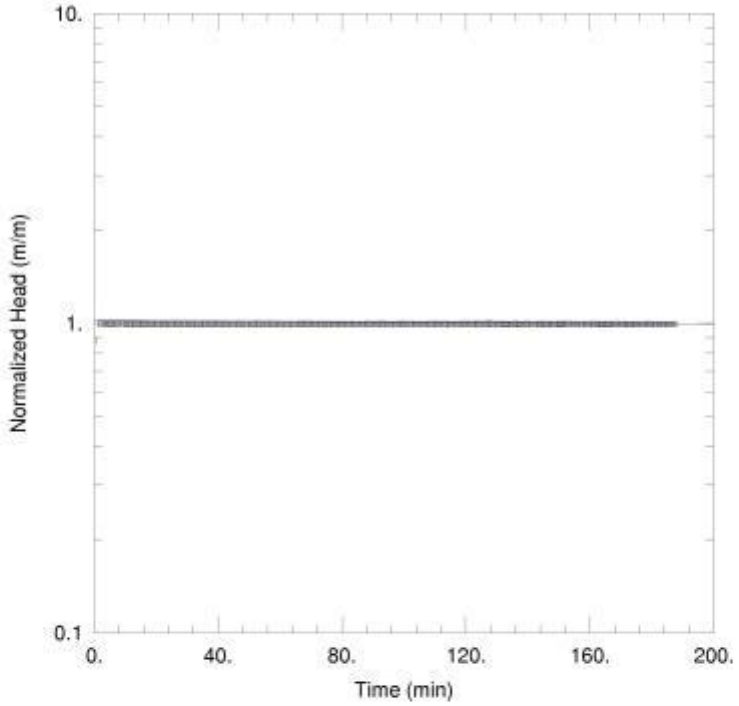
Saturated Thickness: 1. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (KENMB1_slug)

Initial Displacement: -0.386 m
Total Well Penetration Depth: 20. m
Casing Radius: 0.125 m
Static Water Column Height: -0.191 m
Screen Length: 11.6 m
Well Radius: 0.125 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice
K = 0.3726 m/day y0 = -0.4295 m



WELL TEST ANALYSIS

Data Set: C:\...\KENMB2_slug.aqt
Date: 01/07/14 Time: 13:28:18

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: KENMB2_S_slug
Test Date: 2013/12/07

AQUIFER DATA

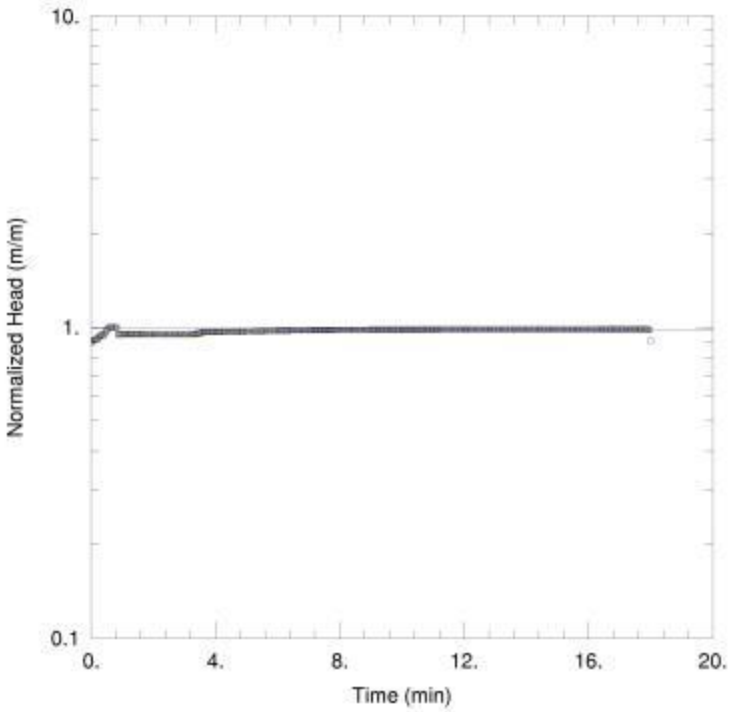
Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (KENMB2_S_slug)

Initial Displacement: -8.609 m
Total Well Penetration Depth: 10. m
Casing Radius: 0.125 m
Static Water Column Height: -7.62 m
Screen Length: 7.2 m
Well Radius: 0.125 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice
K = 0.0007555 m/day
y0 = -8.795 m



WELL TEST ANALYSIS

Data Set: C:\...\KENMB3_S_slug.aqt
Date: 01/07/14 Time: 13:55:54

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: KENMB3_S_slug
Test Date: 2013/12/08

AQUIFER DATA

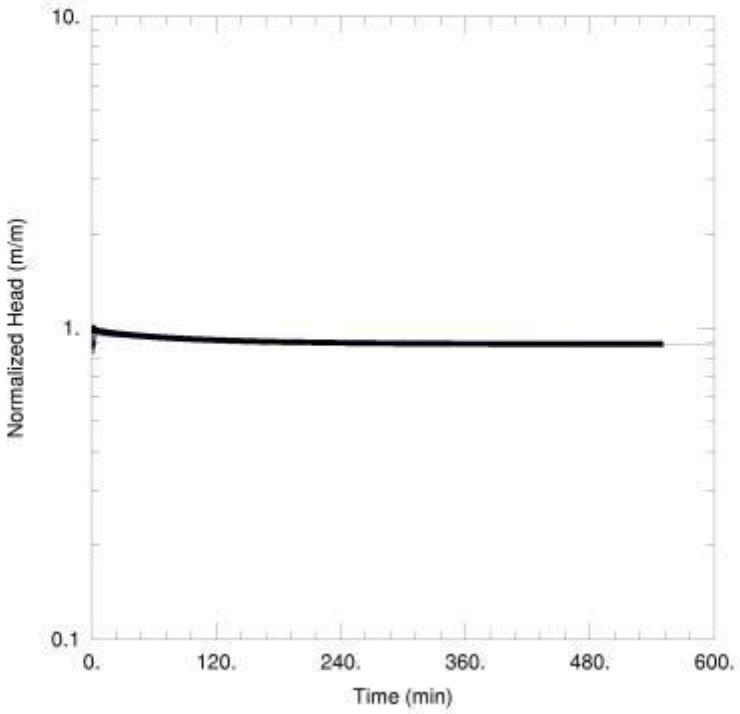
Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (KENMB3_S_slug)

Initial Displacement: -7.627 m
Total Well Penetration Depth: 10. m
Casing Radius: 0.125 m
Static Water Column Height: -6.77 m
Screen Length: 7.2 m
Well Radius: 0.125 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice
K = 0.003966 m/day y0 = -7.574 m



WELL TEST ANALYSIS

Data Set: C:\...\LEEMB18_D_slug.aqt
Date: 12/19/13 Time: 13:17:38

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: LEEMB13_D_slug
Test Date: 2013/12/09

AQUIFER DATA

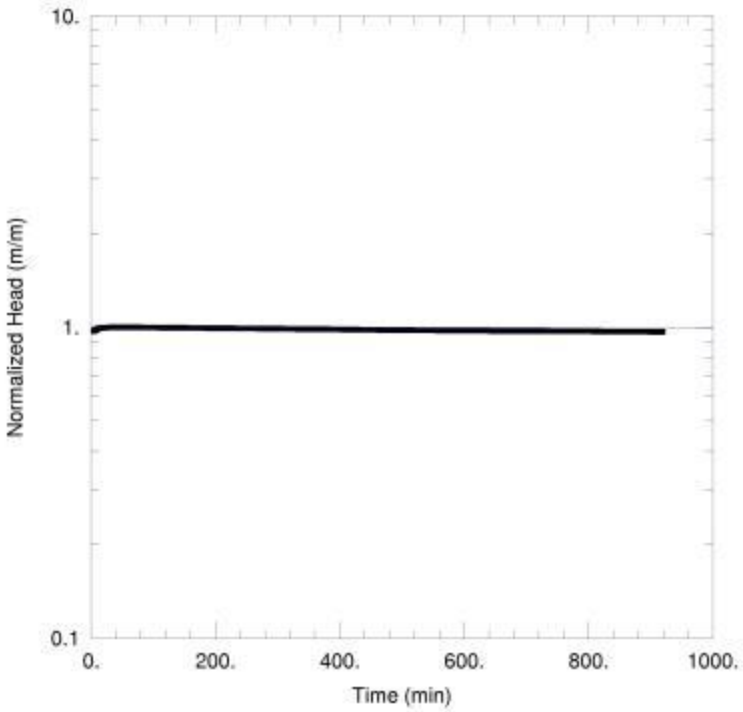
Saturated Thickness: 29. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (LEEMB18_D_slug)

Initial Displacement: -12.59 m
Total Well Penetration Depth: 29. m
Casing Radius: 0.125 m
Static Water Column Height: -10.66 m
Screen Length: 12.2 m
Well Radius: 0.125 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice
K = 0.0004039 m/day y0 = -11.78 m



WELL TEST ANALYSIS

Data Set:
Date: 12/19/13 Time: 11:28:20

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: LEEMB18_S_slug
Test Date: 2013/12/11

AQUIFER DATA

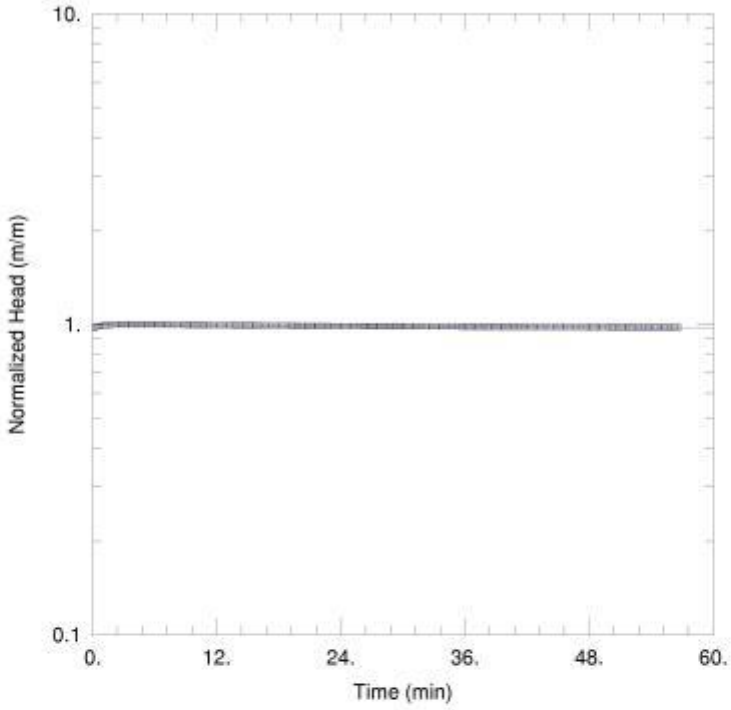
Saturated Thickness: 1. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (LEEMB18_S_slug)

Initial Displacement: -9.123 m
Total Well Penetration Depth: 10. m
Casing Radius: 0.125 m
Static Water Column Height: -10.08 m
Screen Length: 7.2 m
Well Radius: 0.125 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice
K = 2.326E-5 m/day y0 = -9.111 m



WELL TEST ANALYSIS

Data Set: C:\...\MOAMB7_slug.aqt
Date: 01/07/14 Time: 10:56:16

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: MOAMB7_slug
Test Date: 2013/12/13

AQUIFER DATA

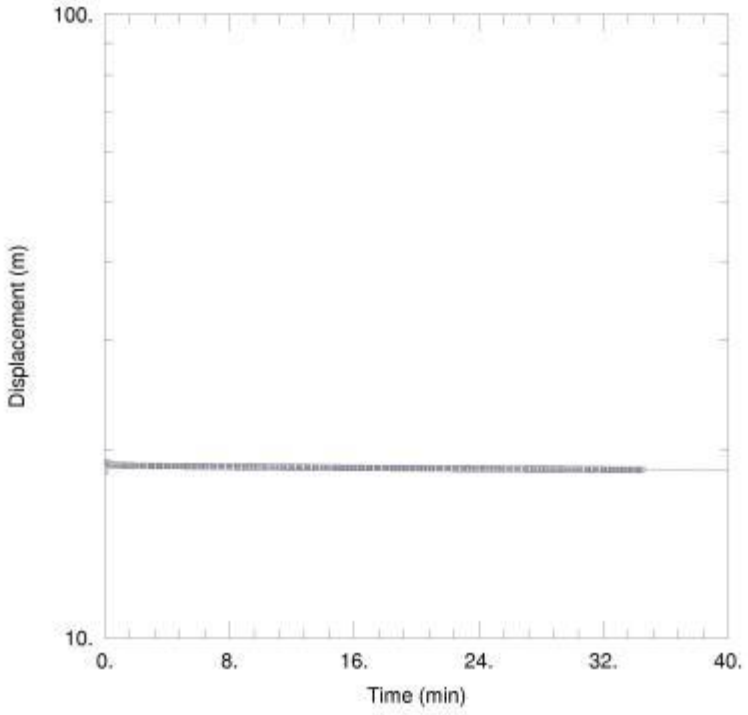
Saturated Thickness: 43. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MOAMB7_slug)

Initial Displacement: -37.2 m
Total Well Penetration Depth: 40. m
Casing Radius: 0.125 m
Static Water Column Height: -36.29 m
Screen Length: 15. m
Well Radius: 0.125 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice
K = 0.001104 m/day y0 = -37.1 m



WELL TEST ANALYSIS

Data Set: C:\...\WELMB13_D_slug.aqt
Date: 01/07/14 Time: 14:07:03

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: WELMB13_D_slug
Test Date: 2013/12/13

AQUIFER DATA

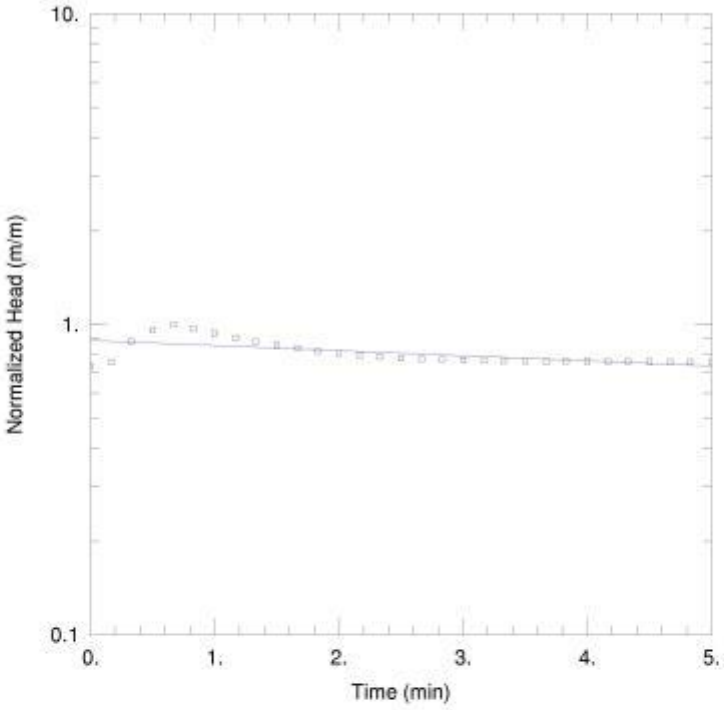
Saturated Thickness: 24. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (WELMB13_D_slug)

Initial Displacement: 19.12 m
Total Well Penetration Depth: 24. m
Casing Radius: 0.125 m
Static Water Column Height: 18.48 m
Screen Length: 10. m
Well Radius: 0.125 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice
K = 0.002003 m/day y0 = 18.9 m



WELL TEST ANALYSIS

Data Set: C:\...\WELMB13_S_slug.aqt
Date: 12/19/13 Time: 13:33:25

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: WELMB13_S
Test Date: 2013/12/11

AQUIFER DATA

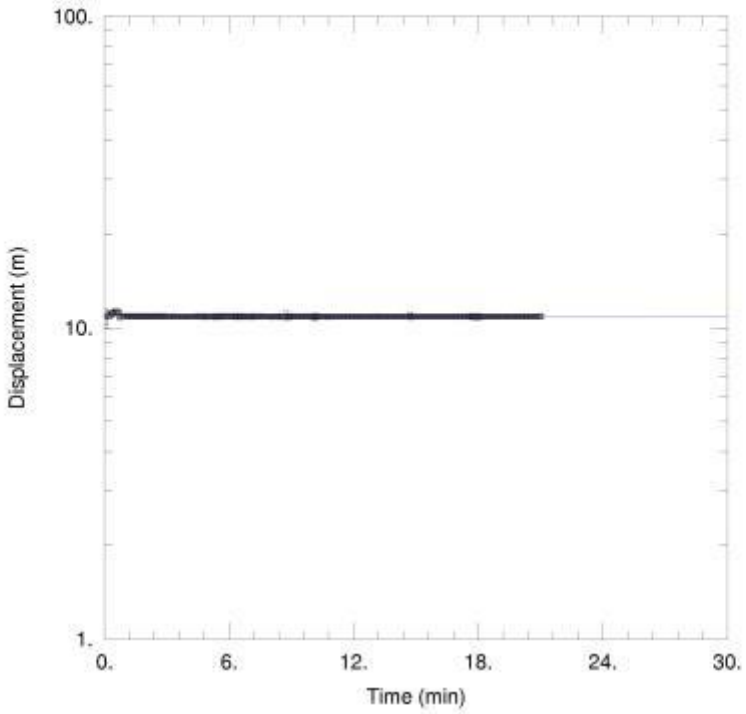
Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (WELMB13_S)

Initial Displacement: -3.405 m
Total Well Penetration Depth: 10. m
Casing Radius: 0.125 m
Static Water Column Height: -2.49 m
Screen Length: 7.2 m
Well Radius: 0.125 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice
K = 0.1959 m/day y0 = -3.024 m



WELL TEST ANALYSIS

Data Set: C:\...\WITMB14_slug.aqt
Date: 01/07/14 Time: 14:42:36

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: WITMB14_slug
Test Date: 2013/12/09

AQUIFER DATA

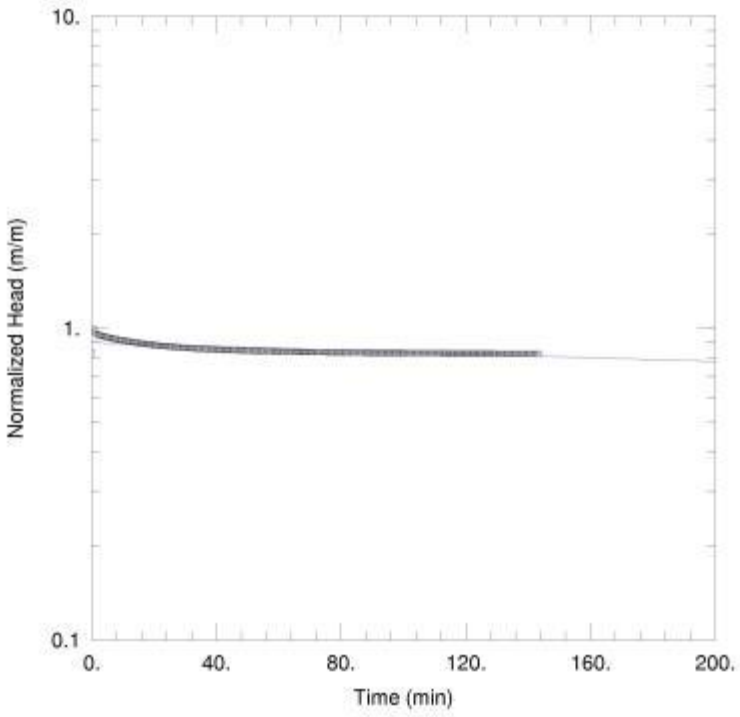
Saturated Thickness: 16. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (WITMB14_slug)

Initial Displacement: 11.33 m
Total Well Penetration Depth: 16. m
Casing Radius: 0.125 m
Static Water Column Height: 10.12 m
Screen Length: 8.4 m
Well Radius: 0.125 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice
K = 0.001003 m/day y0 = 10.9 m



WELL TEST ANALYSIS

Data Set: C:\...\WOLMB15_D_slug.aqt
Date: 12/19/13 Time: 12:13:44

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: WOLMB15_D_slug
Test Date: 2013/12/08

AQUIFER DATA

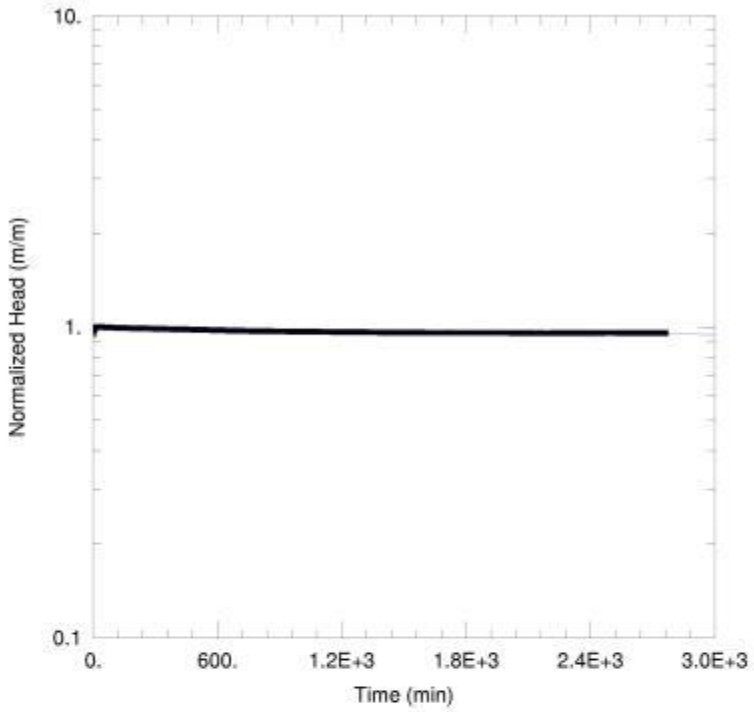
Saturated Thickness: 1. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (WOLMB15_D_slug)

Initial Displacement: -9.384 m
Total Well Penetration Depth: 25. m
Casing Radius: 0.125 m
Static Water Column Height: -8.42 m
Screen Length: 11. m
Well Radius: 0.125 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice
K = 0.02213 m/day y0 = -8.441 m



WELL TEST ANALYSIS

Data Set: C:\...\WOLMB15_S_slug.aqt
Date: 12/19/13 Time: 12:57:14

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: WOLMB15_S_slug
Test Date: 2013/12/09

AQUIFER DATA

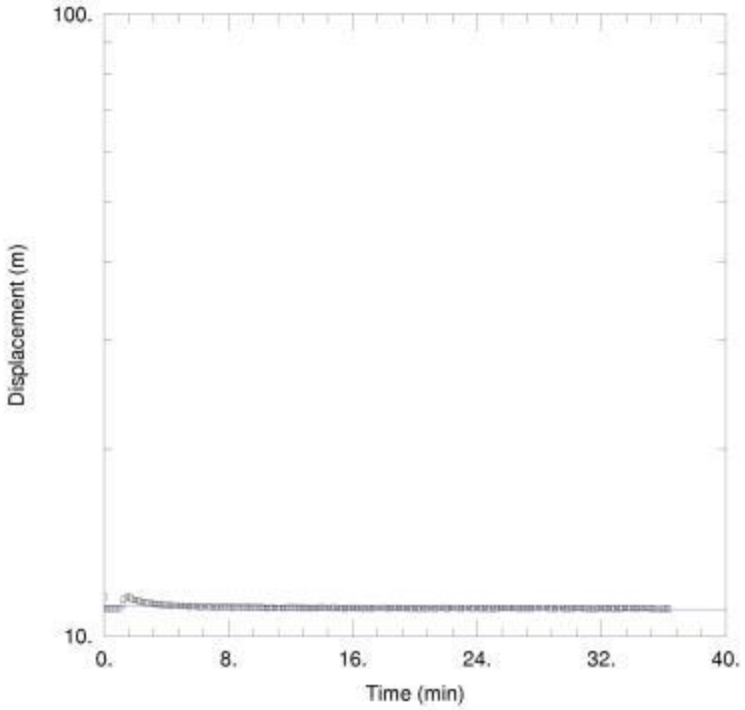
Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (WOLMB15_S_slug)

Initial Displacement: -9.604 m
Total Well Penetration Depth: 10. m
Casing Radius: 0.125 m
Static Water Column Height: -9.05 m
Screen Length: 7.2 m
Well Radius: 0.125 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice
K = 7.254E-5 m/day y0 = -9.458 m



WELL TEST ANALYSIS

Data Set: C:\...\WWNMB16_slug.aqt
Date: 01/07/14 Time: 14:17:29

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: WWNMB16_slug
Test Date: 2013/12/13

AQUIFER DATA

Saturated Thickness: 50. m Anisotropy Ratio (Kz/Kr): 1.

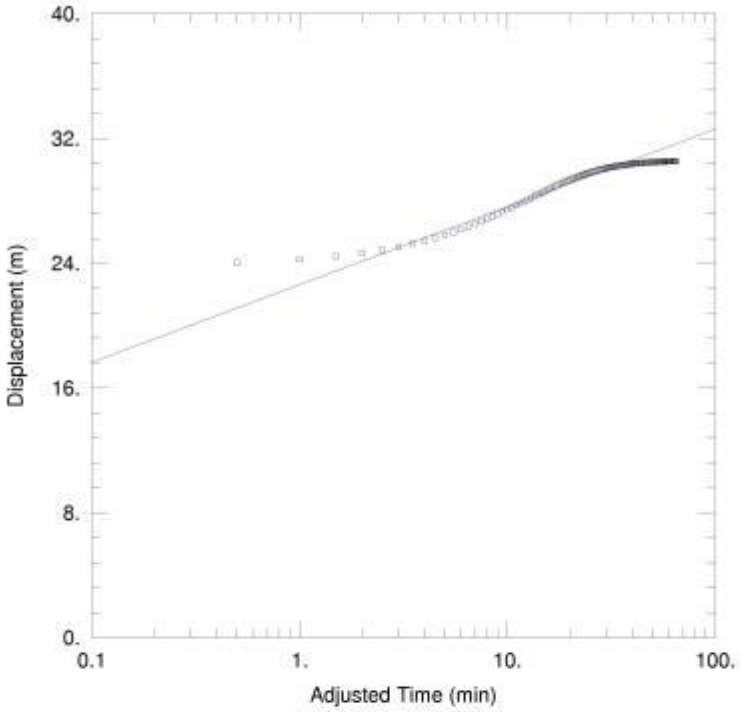
WELL DATA (WWNMB16_slug)

Initial Displacement: 11.58 m
Total Well Penetration Depth: 50. m
Casing Radius: 0.125 m
Static Water Column Height: 11.07 m
Screen Length: 22. m
Well Radius: 0.125 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice
K = 0.0008962 m/day y0 = 11.2 m

Cooper-Jacob



WELL TEST ANALYSIS

Data Set:
Date: 12/19/13 Time: 10:25:57

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: KENMB2_D
Test Date: 2013/12/07

AQUIFER DATA

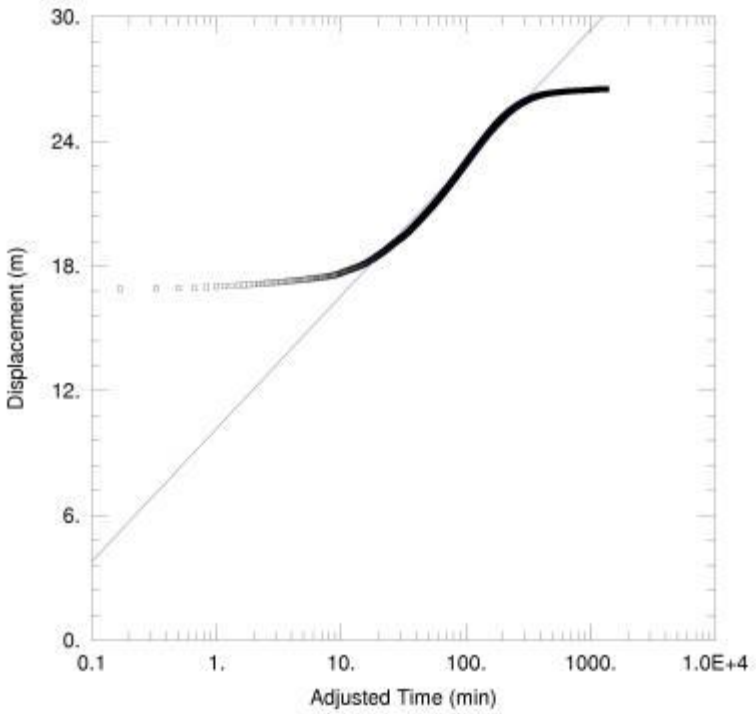
Saturated Thickness: 31. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (m)	Y (m)	Well Name	X (m)	Y (m)
KENMB2_D	0	0	KENMB2_D	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob
T = 3.177 m^2/day S = 9.129E-6



WELL TEST ANALYSIS

Data Set: C:\...\KENMB3_D_pump.aqt
Date: 01/07/14 Time: 13:06:50

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: KENMB3_D_pump
Test Date: 2013/12/13

AQUIFER DATA

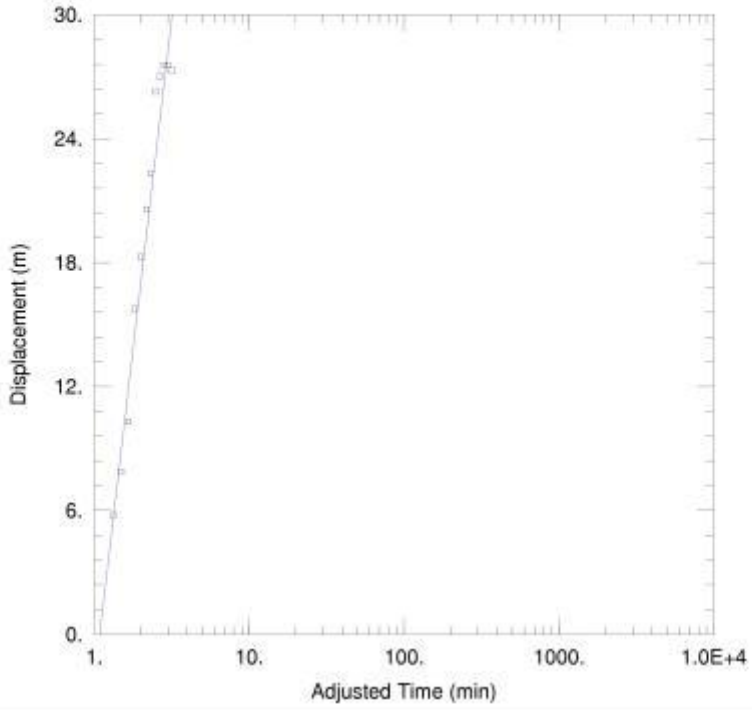
Saturated Thickness: 29. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (m)	Y (m)	Well Name	X (m)	Y (m)
KENMB3_D_pump	0	0	KENMB3_D_pump	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob
T = 2.97 m^2/day S = 0.007626



WELL TEST ANALYSIS

Data Set: C:\...\MOAMB4_pump.aqt
Date: 12/19/13 Time: 13:59:34

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: MOAMB4_pump
Test Date: 2013/12/12

AQUIFER DATA

Saturated Thickness: 40. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

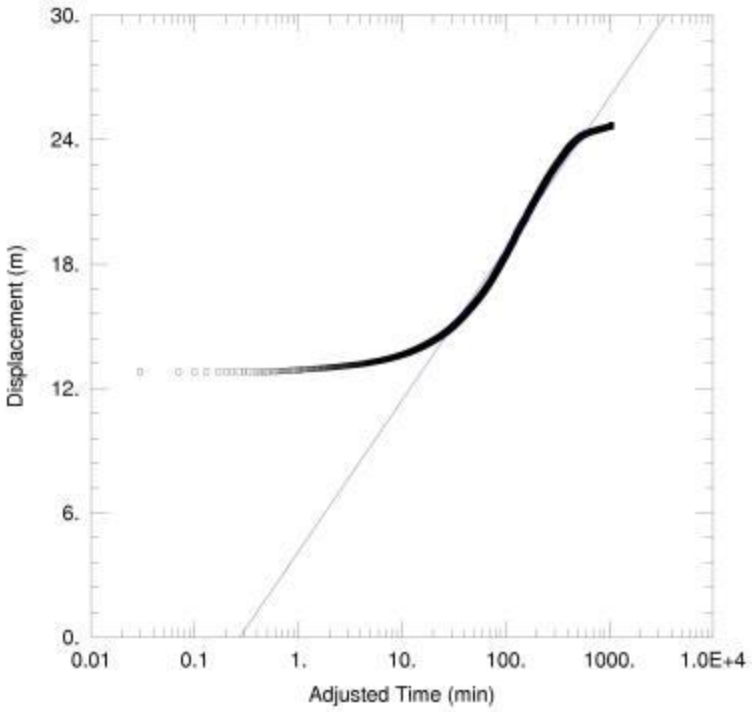
Well Name	X (m)	Y (m)
MOAMB4_pump	0	0

Observation Wells

Well Name	X (m)	Y (m)
MOAMB4_pump	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob
T = 0.2716 m^2/day S = 0.02947



WELL TEST ANALYSIS

Data Set: C:\...\MOAMB9_pump.aqt
Date: 01/07/14 Time: 12:52:22

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: MOAMB9_pump
Test Date: 2013/12/06

AQUIFER DATA

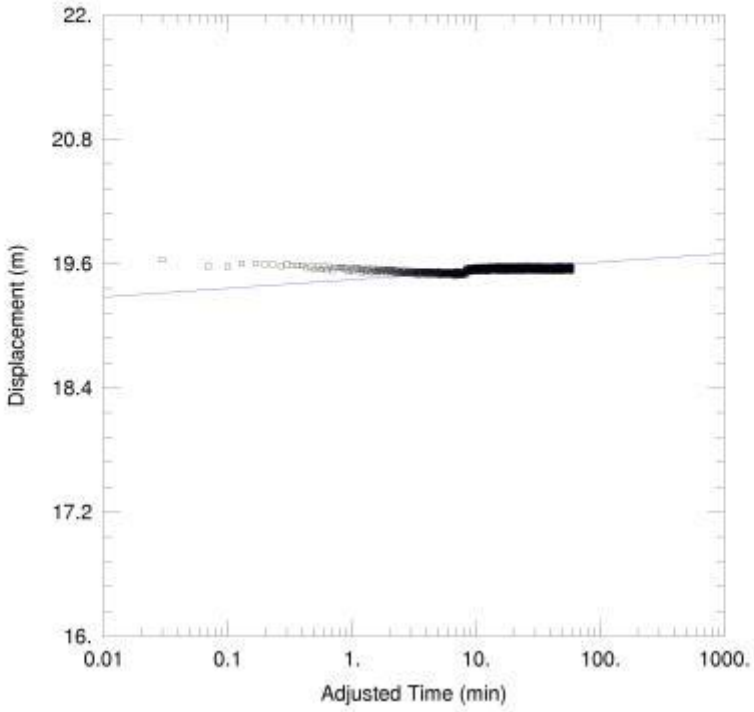
Saturated Thickness: 55. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (m)	Y (m)	Well Name	X (m)	Y (m)
MOAMB9_pump	0	0	MOAMB9_pump	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob
T = 2.775 m^2/day S = 0.07557



WELL TEST ANALYSIS

Data Set: C:\...\MOAMB10_pump.aqt
Date: 01/07/14 Time: 12:35:10

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: MOAMB10_pump
Test Date: 2013/12/04

AQUIFER DATA

Saturated Thickness: 15.4 m Anisotropy Ratio (Kz/Kr): 1.

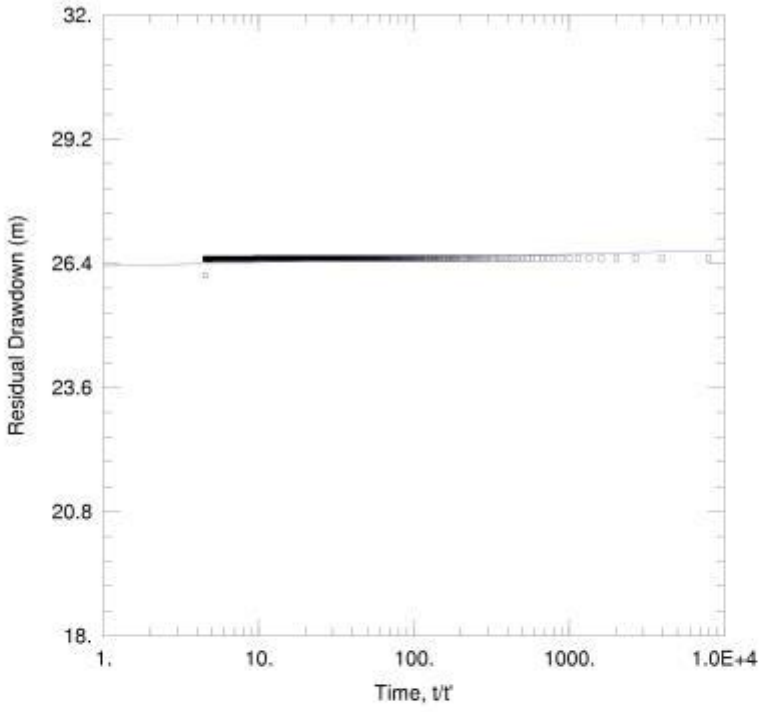
WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (m)	Y (m)	Well Name	X (m)	Y (m)
MOAMB10_pump	0	0	MOAMB10_pump	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob
T = 241.8 m^2/day S = 2.125E-231

THEIS



WELL TEST ANALYSIS

Data Set: C:\...\KENMB3_D_pump.aqt
Date: 01/07/14 Time: 13:05:09

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: KENMB3_D_pump
Test Date: 2013/12/13

AQUIFER DATA

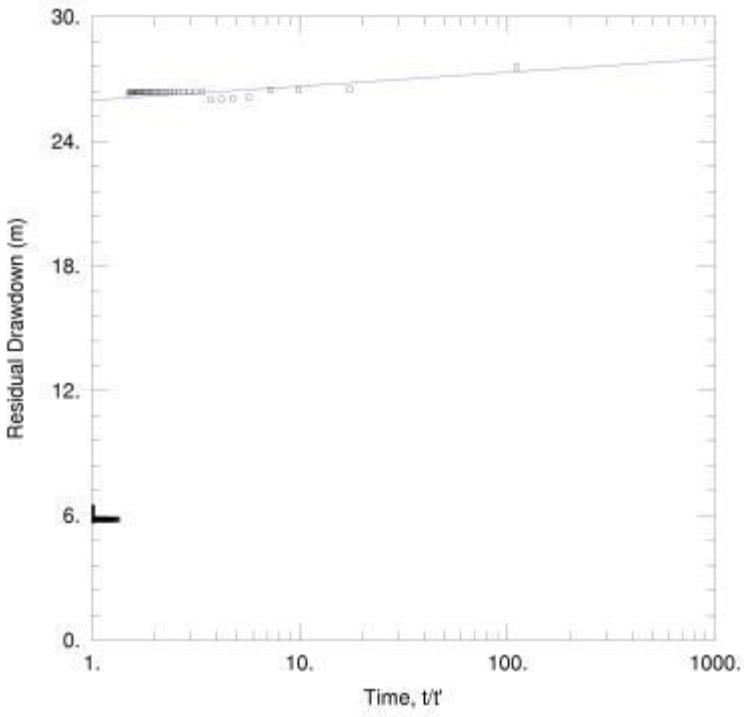
Saturated Thickness: 29. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (m)	Y (m)	Well Name	X (m)	Y (m)
KENMB3_D_pump	0	0	KENMB3_D_pump	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)
T = 210.9 m^2/day S/S' = 5.297E-293



WELL TEST ANALYSIS

Data Set: C:\...\MOAMB4_pump.aqt
Date: 12/19/13 Time: 14:03:47

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: MOAMB4_pump
Test Date: 2013/12/12

AQUIFER DATA

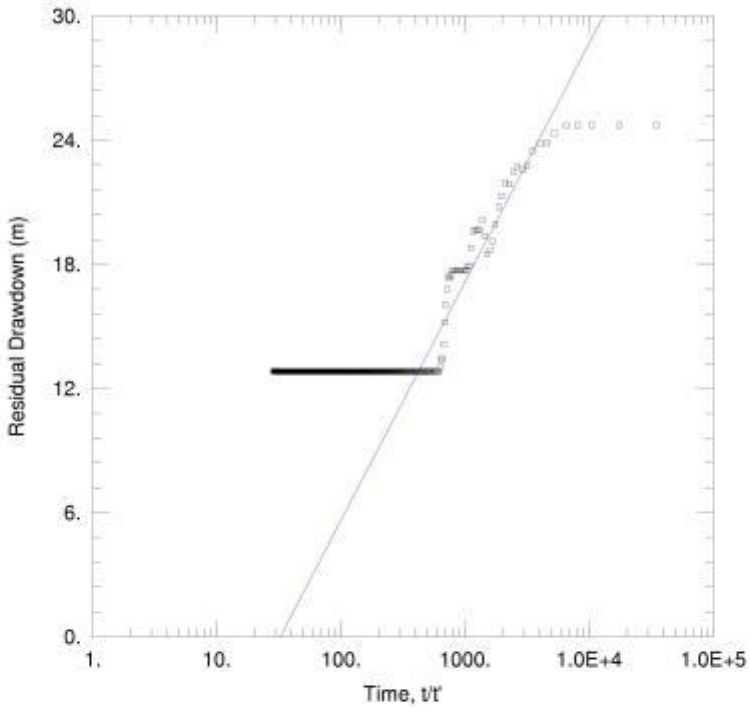
Saturated Thickness: 40. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (m)	Y (m)	Well Name	X (m)	Y (m)
MOAMB4_pump	0	0	MOAMB4_pump	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)
T = 26.01 m^2/day S/S' = 1.606E-39



WELL TEST ANALYSIS

Data Set: C:\...\MOAMB9_pump.aqt
Date: 01/07/14 Time: 12:53:48

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: MOAMB9_pump
Test Date: 2013/12/06

AQUIFER DATA

Saturated Thickness: 55. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

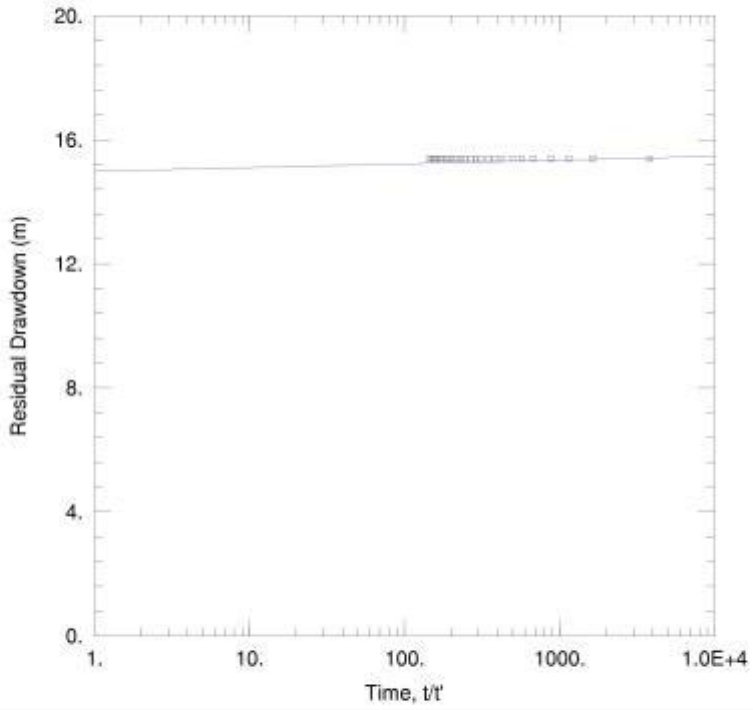
Well Name	X (m)	Y (m)
MOAMB9_pump	0	0

Observation Wells

Well Name	X (m)	Y (m)
MOAMB9_pump	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)
T = 1.758 m^2/day S/S' = 32.58



WELL TEST ANALYSIS

Data Set: C:\...\MOAMB10_pump.aqt
Date: 01/07/14 Time: 12:36:57

PROJECT INFORMATION

Company: GCS
Client: Exxaro
Project: 11-447GW
Location: Leeuwpan Colliery
Test Well: MOAMB10_pump
Test Date: 2013/12/04

AQUIFER DATA

Saturated Thickness: 15.4 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MOAMB10_pump	0	0

Observation Wells

Well Name	X (m)	Y (m)
MOAMB10_pump	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)
T = 168.5 m^2/day S/S' = 2.716E-125

Annexure E
Water Balance 2018



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Water Balance Update Study for the Leeuwpan Coal Mine

Report

Version – 1

28 November 2018

Exxaro Leeuwpan Coal

GCS Project Number: 18-0538

Client Reference: GCS Water Balance Update – Leeuwpan Coal



Report
Version - 1

28 November 2018

Exxaro Leeuwpan Coal

18-0538

DOCUMENT ISSUE STATUS

Report Issue	1		
GCS Reference Number	GCS Ref - 18-0538		
Client Reference	Leeuwpan Water Balance Update		
Title	Water Balance Update for the Leeuwpan Coal Mine		
	Name	**Signature**	**Date**
Author	Sbongiseni Mazibuko		28th of November 2018
Document Reviewer	Kevin Scott		28th of November 2018
Unit Manager	Alkie Marais		28th of November 2018

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LIST OF ACRONYMS

DEM	Digital Elevation Model
DMS	Dense Medium Separation
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
GCS	GCS Water and Environment (Pty) Ltd
GN704	General Notice 704
HDPE	High-Density Polyethylene
MAE	Mean Annual Evaporation
mamsl	meters above mean sea level
MAP	Mean Annual Precipitation
PCD	Pollution Control Dam
PFD	Process Flow Diagram
RM2	Rational Method Alternative 2
RM3	Rational Method Alternative 3
ROM	Run of Mine
SDF	Standard Design Flood
SoW	Scope of Work
STP	Sewage Treatment Plant
WMA	Water Management Area
WR2012	South African Water Resources 2012 Study
WUL	Water Use Licence

EXECUTIVE SUMMARY

GCS (Pty) Ltd (GCS) was appointed by Exxaro Leeuwpan Coal (Exxaro) to undertake a water balance update study for the existing Leeuwpan Coal Mine (Leeuwpan), near the town of Delmas in the Mpumalanga Province of South Africa. Leeuwpan is located in quaternary catchment B20A of the Olifants Water Management Area (WMA-2). This study is required to update the water balance for the Leeuwpan mine that is required in terms of the existing Water Use Licence. The revised water balance needs to include the new Block OI pit and the three operational mine process plants.

Leeuwpan mine is situated in the Mpumalanga Highveld, which is characterised by warm wet summers and dry cold winters. Although monthly average temperatures range between 7.7ºC, and 23.6ºC, peak temperatures of about 37°C can be expected in mid-summer. Minimum daily temperatures will seldom fall below 3°C, and frost is rare for this area. Most rain falls between the summer months of November to January. Average monthly evaporation exceeds average rainfall throughout the year. Mean Annual Evaporation (MAE) (Symons Pan) of 1 677 mm, and Mean Annual Precipitation (MAP) of 667 mm are reported for the site. The surrounding topography is relatively flat high-veld grasslands with large areas of cultivated farmland. The mine is situated in the upper catchment of the Bronkhortspruit.

A site visit on the 13th of September 2018 allowed the inspection of water infrastructure on the mine and collection of information that was used to compile a Process Flow Diagram (PDF) that provides a basis for the calculation of the overall mine water balance.

The mine relies on the three (3) boreholes (Witklip, Henk's and Load Out) for raw water supply to offices and workshop areas for domestic consumption. Water from six (6) open cast pits (OD north & south, OJ, OH & OM, Weltervreden OWM, and Moabsvelden OWM) is used for mine process plant operations. Pits receive water from groundwater ingress, runoff and rainfall, and lose water to seepage and evaporation. Water used in the process plant is pumped to, and supplied from three (3) reservoirs, which are referred to as the Silver PCDs. The Witklip PCD provides added back-up storage. The Plant PCD should, in theory trap runoff from the plant and stockpile area for re-use in the plant. During the September site visit, it was noted that the silt-trap upstream of this PCD was under-sized and the PCD was largely filled with sediments.

The beneficiation process at the Leeuwpan Coal Mine is conducted with three (3) plants: Crush and Stack, Dense Medium Separator (DMS) and Frazer DMS on a 24hrs basis for 313 days per year. These plants process - on a monthly basis – 7 174 ton (Crush and Stack Plant), 5 776 ton (Fraser DMS Plant), and 7 381 ton (DMS Plant) of Run of Mine (ROM). Frazer DMS and DMS plants produce 2 298 and 2 899 ton of coal per month, respectively.

The calculated annual, monthly and daily average water balances were based on the information received from the client, mine site visit, and previous relevant studies conducted for the Leeuwpan Mine. The total volume of water used on the mine was calculated at 302 400 m^3/a, where an annual volume of 139 209 m^3 is abstracted from the Silver PCDs and 11 991 m^3/a is re-used water from the Plant PCD. Dust suppression water is supplied from the Silver PCD and accounts for 10 200 m^3/a. The inclusion of the OI Pit into the mine water balance will provide an excess of 372 796 m^3 of water per year. Current dirty water storage facilities (Silver and Witklip PCDs) cannot contain this volume of excess water.

Recommendations made as a result of this study include:

- Water flow meters should be installed to monitor inflows into and outflows from; the Plant Beneficiation, Silver PCDs, dust suppression bowser, and Phola Sewage Treatment Plant (STP). Flow volume data will provide a better understanding of water flow patterns at the mine and facilitate the calibration of more accurate water balance calculations.
- Upgrading of, and improved maintenance of, the silt trap at the Plant PCD. This will improve efficiency of the system and mitigate sedimentation in the Plant PCD.
- Raw water abstractions from boreholes should be monitored to ensure that the mine adheres to conditions of the water use licence issued for the mine. Flow volume data for the period January 2018 to August 2018 suggests that raw water on the mine has increased, which implies that the mine should apply for a new water use license that reflects current and future demands.
- Additional storage for excess water expected from the dewatering of the new OI pit needs to be planned. Water storage issues can be addressed as follows:
    - Back-filled pits that are far from the plant area should be rehabilitated in order to reduce the quantities of water flowing into the Silver PCD.
    - Use Pit OD (South and North) as a storage facility. This will allow storage of some excess water, and allow for increased evaporative water losses.
    - Pump water from the Silver PCDs into the Witklip PCD where water will evaporate or could be treated and discharged back into the environment.

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1 INTRODUCTION

GCS (Pty) Ltd (GCS) was appointed by Exxaro Leeuwpan Coal to update the water balance study for the Leeuwpan Coal Mine (Leeuwpan). The mine is located situated 8 km east of the town of Delmas, within the Victor Khanye Local Municipality in the Mpumalanga Province of South Africa. The mine site lies in headwaters of quaternary B20A of the Olifants Water Management Area (WMA-2) (Figure 1.1).

Leeuwpan Coal Mine aims to apply principles of sustainable water management and contribute towards integrated water management in the region. This involves the development of a water balance model and monitoring systems that will facilitate accurate water accounting for the mine. Leeuwpan is in the process of updating its mine water balance and incorporating open cast Block OI into the existing Water Use Licence. A recent water balance study conducted in 2017 by (Linstrom, 2017) was not in line with the Best Practice Guidelines (BPG) for Water Resource Protection in the mining sector: Guideline G2 (Salt and Water Balances) (DWAF, 2006c) and did not explicitly include all mine components. This study intends to provide a detailed water balance that adheres to this guideline.

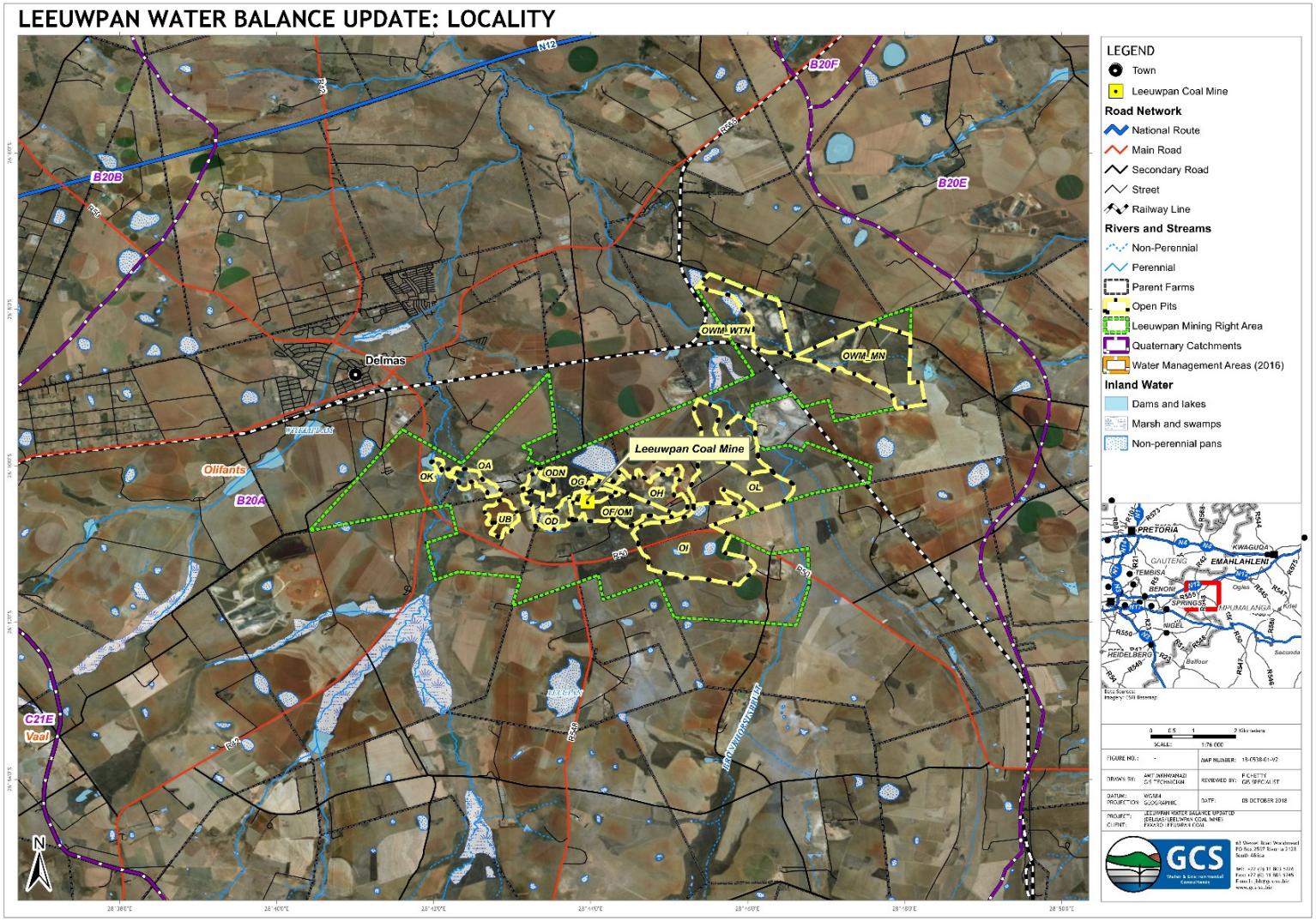


Figure 1.1: Study site locality

2 SCOPE OF WORK

The Scope of Work (SoW) was defined as follows:

1. Information Sourcing and Literature Review:
    - Acquisition and assessment of the relevant existing literature regarding Leeuwpan mine water balance;
    - Review of the legislative and policy framework relating to mine water use and water use licence (s) (WUL).
2. Site Visit:
    - A mine site visit to ground-truth the existing mine infrastructure relative to water reticulation and use;
    - Collection of relevant information that can be used to complete a mine Process Flow Diagram (PFD) and for the calculation of an overall mine water balance;
3. Baseline Climate and Hydrology:
    - Provide relevant information on climate and hydrology for the mine site area;
    - Calculation of rainfall, runoff and evaporation volumes to and from all mine pits and other water infrastructure;
4. Mine Water Balance Update:
    - Update a water Process Flow Diagram;
    - Update the average annual mine water balance; and
    - Develop annual, monthly and daily water balances.
5. Reporting:
    - Compile a report that describes findings and conclusions drawn from the study and recommends interventions to improve the water balance and mine-water management on site.

3 METHODOLOGY

3.1 Site Visit

A site visit on the 13th of September 2018 allowed the inspection of water infrastructure on the mine and collection of information that was used to compile a Process Flow Diagram (PDF) that provides a basis for the calculation of the overall mine water balance.

3.2 Information Sourcing and Literature Review

The following documents and reports were reviewed during the study:

- Previous Leeuwpan water balance studies conducted by GCS in 2016 (GCS, 2016) and Exxaro in 2017 (Linstrom, 2017);
- Hydrogeological study report conducted by (GCS, 2014);
- Previous Integrated Water and Waste Management Plan report (GCS, 2014a) and the Integrated Water Use Licence Application (GCS, 2014b);
- Raw water consumption figures from the measuring points on various mine site units;
- General Notice 704 (South Africa, 1998) of the South African National Water Act (Act No. 36 of 1998) (NWA); and
- The South African Department of Water and Sanitation (DWS) (formerly the Department of Water Affairs and Forestry – DWAF) Best Practice Guideline (BPG) G2: Water and Salt Balances (DWAF, 2006c).

3.3 General Climate and Local Hydrology

Baseline climate and hydrological information for the site was updated using data obtained from the South African Water Resources Study (WR2012) database (Bailey & Pitman, 2015) and the South African Atlas of Agrohydrology and Climatology (Schulze, 1997). This information was used to derive seasonal distribution patterns of variables that are used as inputs into the mine water balance computations.

3.4 Average Water Balance

The water balance update was conducted in accordance with the DWS Best Practice Guideline G2: Salt and Water Balances (DWAF, 2006c). An updated schematic process flow diagram, which shows all relevant water flow linkages, was generated using the existing PDF and water balance information (Linstrom, 2017) and information obtained during a site visit. The client signed off the updated PFD before water balance models were generated.

4 LEGISLATIVE REQUIREMENTS AND BEST PRACTICE GUIDELINES

4.1 The National Water Act and Water Use for Mining and Related Activities

4.1.1 The National Water Act

Water resources management in South Africa is governed by the National Water Act (NWA). The Department of Water and Sanitation (DWS) must, as custodians of water, ensure that resources are used, conserved, protected, developed, managed and controlled in a sustainable manner for the benefit of all persons and the environment.

4.1.2 Regulations on the use of Water for Mining and Related Activities

General Notice 704 (South Africa, 1998) of the National Water Act (Act 36 of 1998) regulates the used of water for mining activities. Clean and dirty water must be separated. Dirty water must be captured and contained on the mine for either use, re-use, evaporation or purification prior to disposal. GN704 also stipulates that water used in any mine process should be recycled and re-used as far as possible.

4.2 Best Practice Guidelines

4.2.1 Water Balances

Water Use licences for most mines include conditions that include detailed and accurate water balances that meet DWS Best Practice Guidelines for Water and Salt Balances (DWAF, 2006c). Mine water balances should be dynamic to consider seasonal changes incorporate changes in, inter alia, water storage levels. Principles used in this study include:

- Dynamic water balances based on variable climate inputs and should including all inflows and outflows from any mining activity. Water balances must also reflect surface and groundwater interconnections with the water resource;
- The water balance should incorporate accurate measured volumes of water abstracted, used, or discharged at any point in the mine. Water uses include, process water intake, outflows to and return water from waste management facilities and water abstracted from mine workings;
- Water balances should incorporate accurate values determined from suitable measurement of flows or modelling of rainfall, runoff, groundwater seepage and evaporation. Where flow is not monitored, a calculated water balance should be determined through mass balance calculations;
- Measures taken to manage the flow of water should have clear objectives and should account for both current and future mining situations;

5 GENERAL CLIMATE AND LOCAL HYDROLOGY

5.1 Climate

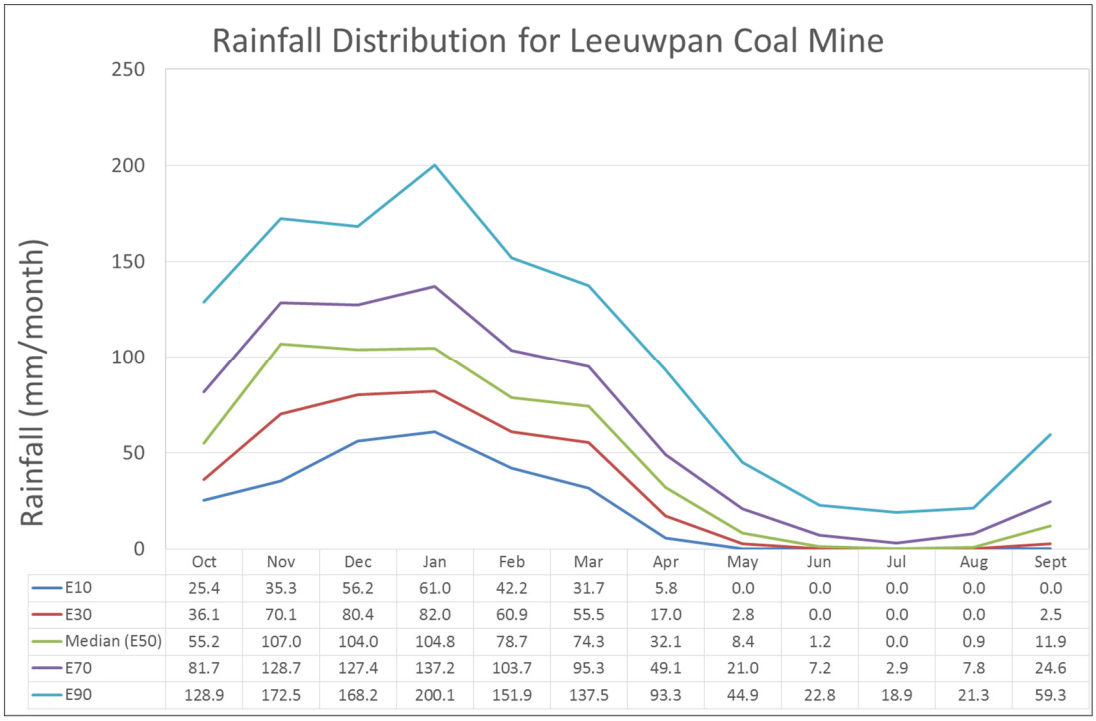
The mine site is located in a temperate climatic zone of South Africa, which is characterised by warm summers and dry cold winters. Table 5.1 shows that the area experiences - on average - lowest temperatures in July and is warmest during January (Cleanstream, 2003). The monthly average minimum and maximum temperatures recorded in the town of Delmas are 7.7°C and 23.6°C, respectively.

Table 5.1: Average minimum and maximum temperatures at Delmas (source: (Cleanstream, 2003)

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum (°C)	14.0	13.4	11.7	8.0	3.0	-0.6	-1.6	1.2	6.2	10.1	12.4	14.0
Maximum (°C)	27.0	26.3	25.6	23.8	21.8	18.1	18.9	20.7	24.1	25.1	25.2	26.4

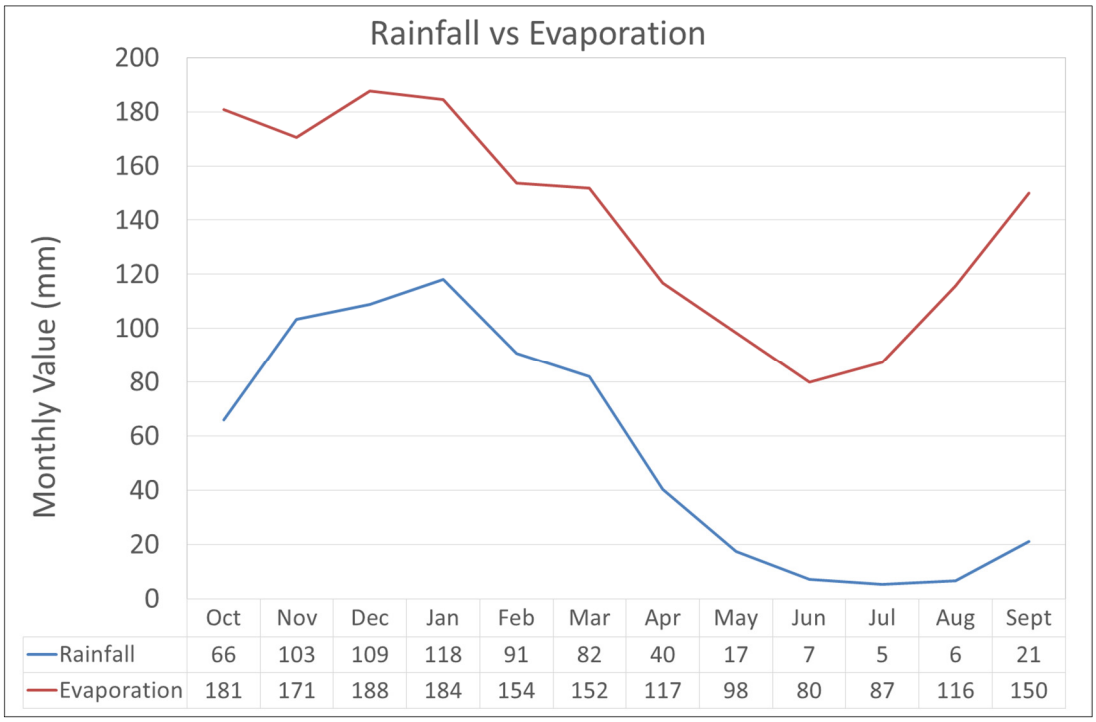
5.2 Rainfall and Evaporation

Most rain falls between the summer months of November to January. Average monthly evaporation exceeds average rainfall throughout the year. Mean Annual Evaporation (MAE)(Symons Pan) of 1677 mm, and Mean Annual Precipitation (MAP) of 667 mm are reported for the site (Bailey & Pitman, 2015).



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
E10	25.4	35.3	56.2	61.0	42.2	31.7	5.8	0.0	0.0	0.0	0.0	0.0
E30	36.1	70.1	80.4	82.0	60.9	55.5	17.0	2.8	0.0	0.0	0.0	2.5
Median (E50)	55.2	107.0	104.0	104.8	78.7	74.3	32.1	8.4	1.2	0.0	0.9	11.9
E70	81.7	128.7	127.4	137.2	103.7	95.3	49.1	21.0	7.2	2.9	7.8	24.6
E90	128.9	172.5	168.2	200.1	151.9	137.5	93.3	44.9	22.8	18.9	21.3	59.3

Figure 5.1: Monthly rainfall distribution for the Leeuwpan Coal mine (source: Bailey & Pitman, 2015)



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Rainfall	66	103	109	118	91	82	40	17	7	5	6	21
Evaporation	181	171	188	184	154	152	117	98	80	87	116	150

Figure 5.2: Mean monthly rainfall and evaporation for the Leeuwpan Coal mine (source: Bailey & Pitman, 2015)

5.3 Local Runoff

Leeuwpan Coal Mine is located in the upper catchment of the Bronkhorstspruit (Quaternary Catchment B20A) which flows in a north-easterly direction. The area has flat to gentle topography with wide valley bottoms near the mine. While some seepage from back-filled mine pits is expected, most mine runoff is contained in residual pit lakes and PCD's. Ponded water is lost through evaporation.

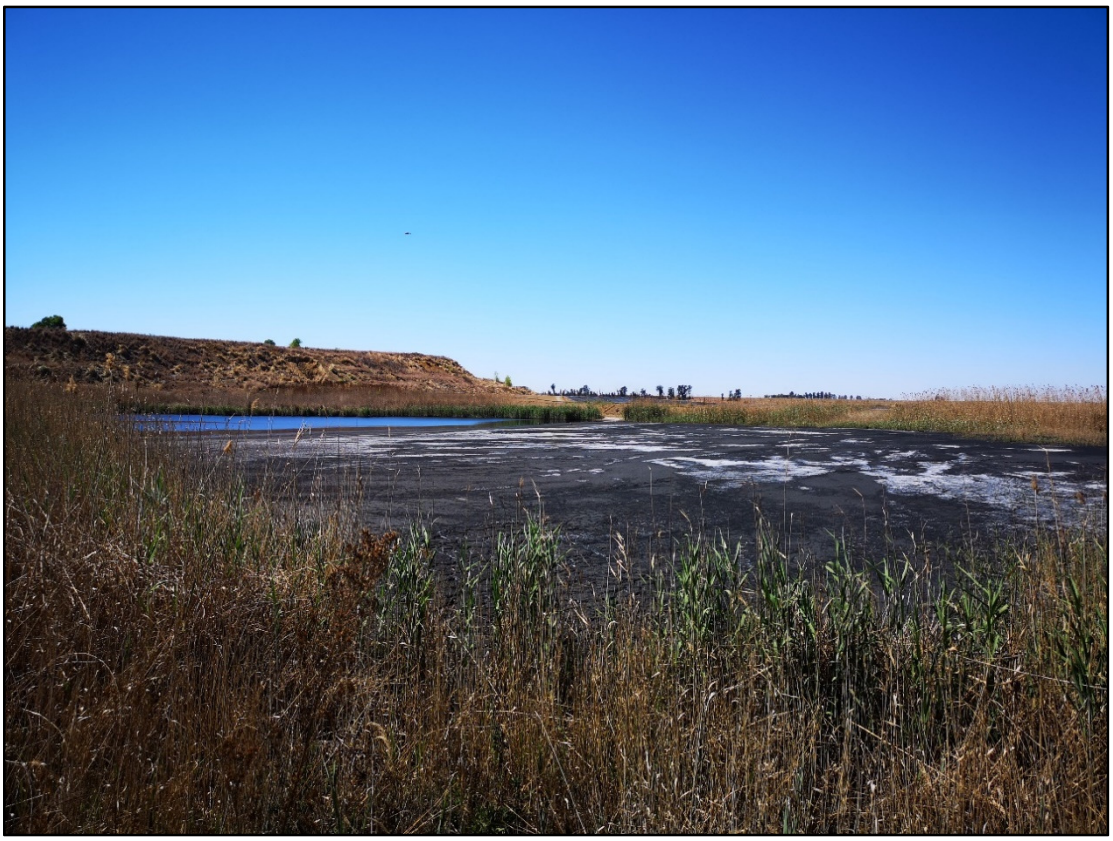
6 SITE VISIT

A site visit was conducted on the 13th of September 2018 to inspect mine infrastructure and facilities, develop an understanding of water balance processes and collect information. Information collected during this visit informed the development of a water Process Flow Diagram (PFD), on which detailed water balance calculations were based.

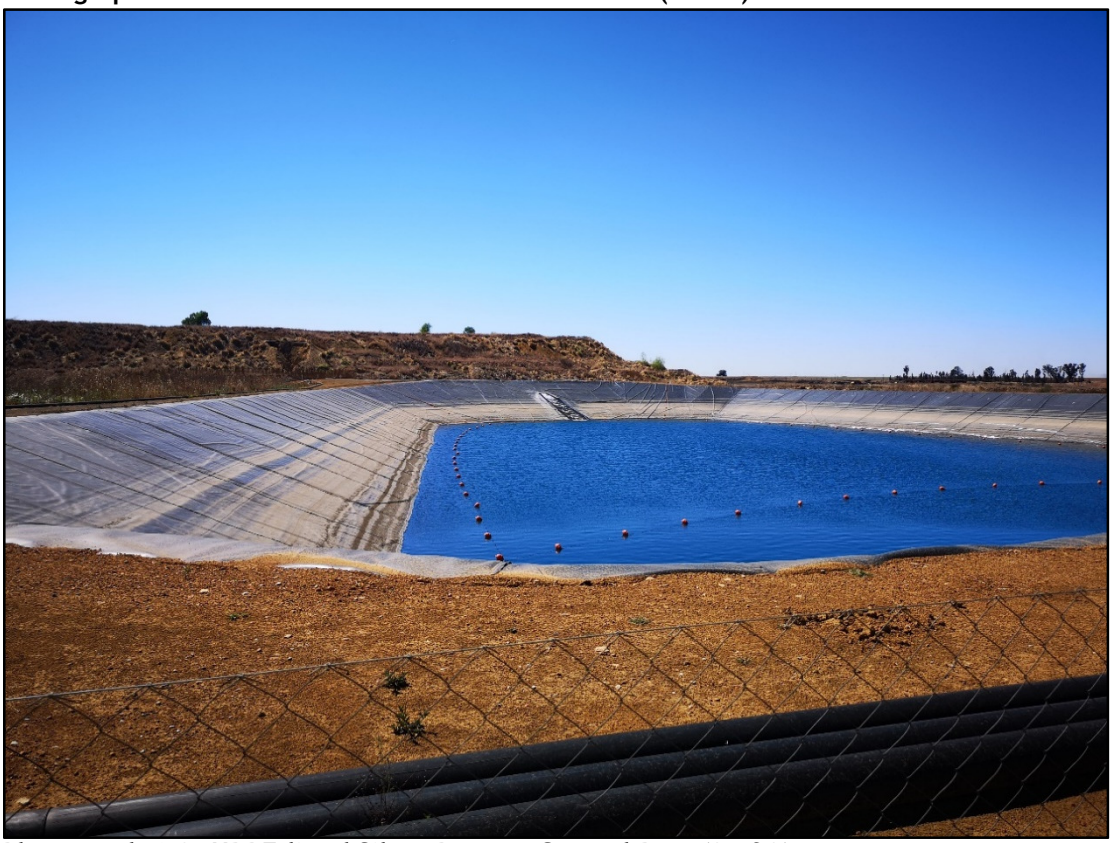
Photograph 6.1 to 6.3 show the three dams which comprise Silver Process Control Dams (Silver PCDs) that store dirty water for mine operation. Currently dam 1 and 2 (Photograph 6.1 and Photograph 6.2) are filled with silt and only dam 3 has been upgraded with High-Density Polyethylene (HDPE) lining. The intention is that the reservoirs and 'Dam 3' will be used to control the flow of 'dirty water' and that the unlined dams will be rehabilitated.



Photograph 6.1: Unlined Silver Process Control Dam (1 of 3)



Photograph 6.2: Unlined Silver Process Control Dam (2 of 3)



Photograph 6.3: HDPE-lined Silver Process Control Dam (3 of 3)

The Witklip PCD (Photograph 6.4) is used a storage facility to supplement plant process water when the supply is exceeded by the demand. With the decommissioning of the Witklip pit, this PCD currently only receives water from rainfall and the Witklip borehole, but provides back-up storage for the Silver PCDs (Leeuwpan personnel, 2018).



Photograph 6.4: Witklip Dam

Photograph 6.5 shows Pit OD (South) which forms part of a number of open pits used to supply process water for the Leeuwpan mine. All the pits receive water from rainfall and groundwater ingress and losses are through evaporation. Pit OD has relatively large storage capacity could allow for storage and evaporation of surplus dirty water.

Pit OI (see Photograph 6.6) is a new pit that is being developed. Dewatering of this pit is likely to lead to significant excesses of dirty water if current water management practices are followed. After the completion of the cut, the open surface area for the OI pit will 3 010 000 m^2 and is assumed that any pit lake will be limited to only 5% of this surface area.



Photograph 6.5: Pit OD South



Photograph 6.6: New Pit OI

Large quantities of silt are contained in dirty water discharged from the plant area to a silt trap (Photograph 6.8). Although maintenance of a silt trap does take place, the volume of sediments in the Plant PCD (Photograph 6.8) suggests that the efficiency of the silt trap is low. This negates the effective storage capacity of the PCD and affects mine water balances.



Photograph 6.7: Silt trap



Photograph 6.8: Plant PCD

7 MINE WATER BALANCE

7.1 Process Flow Diagram and Linkages

The insights into how all water flow processes within the Leeuwpan mine are linked are presented with a Process Flow Diagram (PFD) which was confirmed by the client. The mine operational philosophy (obtained from the previous reports), site visit and the information obtained from the mine personnel were used to draft a PFD and to formulate the assumptions used in the calculation of the mine water balances. All this information is summarised as follows:

- All infrastructure footprint and catchment areas used in the water balance calculations are based on the provided infrastructure layout plan.
- One hundred (100) litres per person per day of potable water will be used by 1 094 permanent employees at the mine site (Leeuwpan personnel, 2018). It was assumed that of the 100 L supplied, 10% will be consumed and the remaining 90% is retuned into the system through the Phola sewer treatment facility.
- Raw water is abstracted from the Witklip, Henk's and Load Out boreholes and pumped into the Silver and Workshop Tanks with a capacity of 80 m^3.and 60 m^3, respectively as well as to the plant area. The three boreholes are licenced to abstract 68 200 m^3/a (Leeuwpan personnel, 2018).
- Silver Tanks supply raw water for domestic consumption and for gardening service in the office area whereas the workshop areas domestic is supplied by Workshop Tanks. An annual total of 40 000 m^3 of water is allocated for domestic water use in the workshop and office areas (Linstrom, 2017). Based on the number of permanent employees of the mine, the annual total volume of 34 242 m^3 is required for domestic use. An estimated volume of 3 424 m^3/a of water is consumed and 30 818 m^3/a returns to the system through Phola Sewage Treatment Plant (STP).
- Sewage effluent from the mine site is stored in ten (10) Conservancy Tanks (80 m^3) at the Phola STP near the workshop area where it is collected and transported out of mine site by a honey sucker.
- Rain falling onto the Wash bay low Lying dirty area (79 187 m^2) infiltrates and some runoff into the low-topography zones where it percolated into the ground. The clean Low Lying Area 2 (295 779 m^2) also experiences a similar hydrological phenomenon. Water losses in these areas are through evaporation from the ponded surfaces.

- There are currently five (5) dewatering open pit areas (OD north & south, OJ, OH & OM, Weltervreden OWM and Moabsvelden OWM) which are used as a source of water for mine processes through the Silver PCDs. These pits receive water from rainfall, groundwater ingress and surface runoff from the pits wall sloping into the pit. Groundwater ingress quantities to all pits were obtained from groundwater simulation results given in a hydrogeological report (GCS, 2014). Water losses are through evaporation from the open surface water and pit slopes.
- No measurements of rainfall and evaporation data are available for the qualification of inflow and outflows into the system. Therefore, it was assumed that between 15% and 25% of rain falling in the backfilled pits contributes to the pit sumps as runoff and is available for pumping. The backfilled voids and high porosity of the soils allows for large storage capacity of water which is assumed to percolate to the base of the local point of the pit.
- Rainfall, surface runoff, evaporation, and groundwater ingress estimated data for the open pits and other dirty water areas used in the calculation of the water balances are summarised in Table 7.1.
- Water from all pits is pumped into the Silver PCD's with the exception of the Witklip pit which is pumped into the Witklip PCD. However, the Witklip PCD is also connected to the Silver PCD's where it is used to supply when there is an increased demand and is also used to store water when there is surplus from the Silver PCD's (Leeuwpan personnel, 2018). The calculation of the water balances assumed that the two unlined dams (section 6) will be lined and there will be no groundwater seepage.
- The three (3) Silver PCD's are at the centre of mine process water. These PCDs store and supply water to the plant area for processing and for dust suppression which accounts for 10 200 m^3/year (Linstrom, 2017).
- The Leeuwpan mine has three plants: Crush and Stack, Dense Medium Separator (DMS), and Fraser DMS which were all assumed to be operation 24 hours per day for 313 days/year (GCS, 2014a). The average monthly and annual quantities of Run of Mine and Product processed by the three plants are summarised in Table 7.2. Estimation and the calculation of volumes of water balance components for the mine were based on the information obtained from the client. Based on the information provided, the following assumptions were made:
    - The Crush and Stack Plant use dry operation and does not use water.
    - Only the DMS and Fraser DMS plants use water.
    - ROM moisture was estimated at 4% whereas product moisture and other losses were at 8% and 4%, respectively (Linstrom, 2017).

- The average annual ROM and product sold from the mine are 151 200 m^3/tonn and 3 780 000 m^3/tonn. Total losses (product and plant loses) are estimated to be 4% (151 200 m^3/tonn) of the product sold (Linstrom, 2017).

Table 7.1: Rainfall, runoff, evaporation and groundwater ingress for the Leeuwpan Mine

Component	Area (m^2)	Rainfall (m^3/a)	Runoff (m^3/a)	Evaporation (m^3/a)	Groundwater Ingress (m^3/a)
Silver PCD's	43 000	28 724	-	26 161	HDPE lined
Witklip PCD	26 000	17 368	-	64 900	HDPE lined
Plant PCD	30 000	20 040	37 230	45 279	HDPE lined
Pit OD (North & South)	297 500	198 730	79 492	14 230	65 700
Pit OH & OM	114 788	76 678	26 837	114 557	29 200
Pit OI	3 010 000	2 010 680	603 204	13 416	219 000
Pit OJ	105 000	70 140	17 535	152 667	16 500
Weltervreden OWM Pit	900 000	601 200	240 480	311 551	65 700
Moabsvelden OWM Pit	117 667	78 602	31 441	132 797	65 700

Table 7.2: Leeuwpan Coal Mine average monthly and annual coal production (source: (Leeuwpan personnel, 2018)

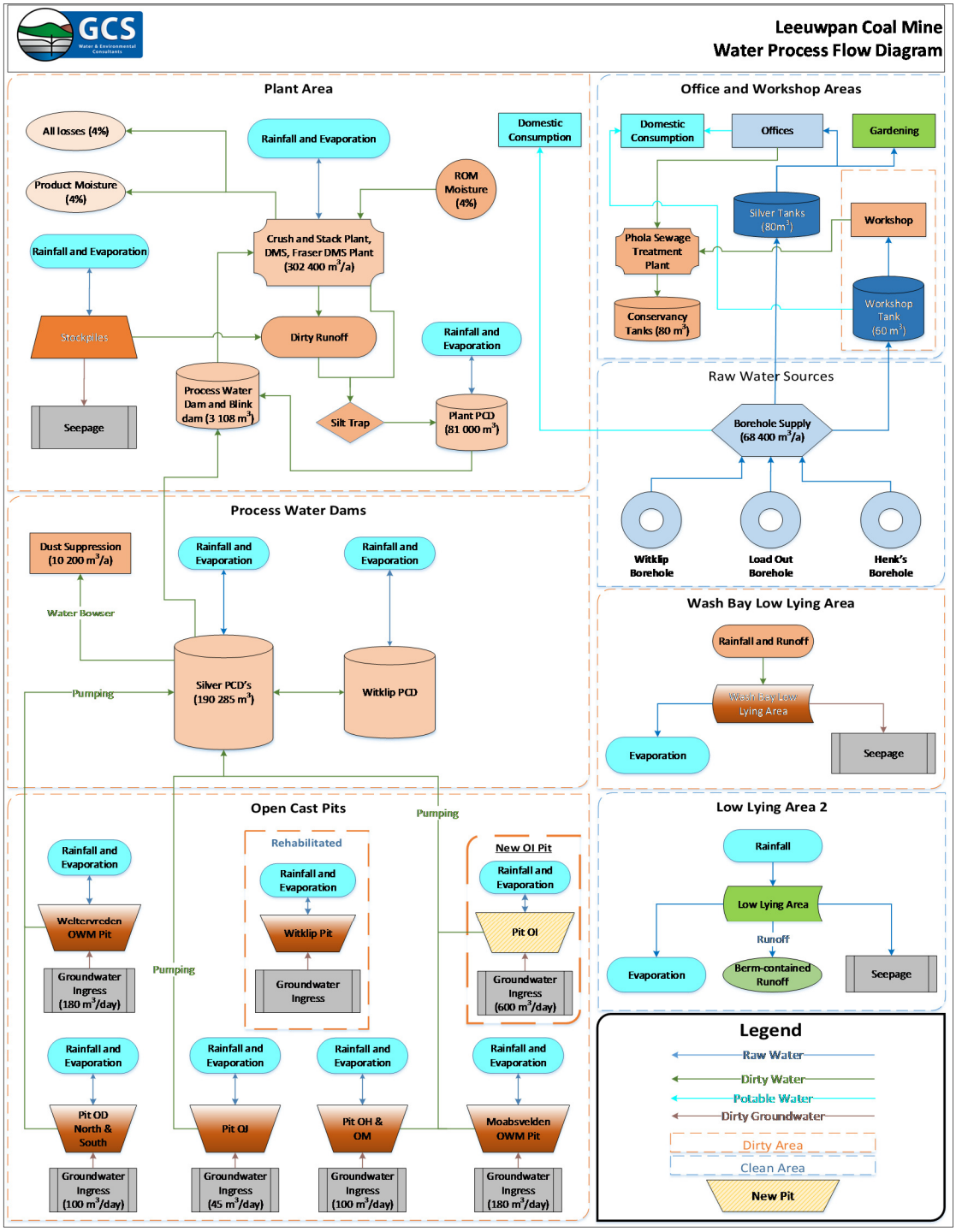
Plant	ROM		Product	
	(tonn/month)	(tonn/annum)	(tonn/month)	(tonn/annum)
DMS	7 381	2 310 253	2 899	907 387
Frazer DMS	5 776	1 807 888	2 298	719 274
Crush and Stack Plant	7 174	2 245 462	7 174	2 245 462

The client (Leeuwpan personnel, 2018) provided the measured volumes of raw water abstracted from the boreholes for the period January 2018 to August 2018 (Table 7.3). It is evident from the table that the mine is complying with their water use licence in terms of water abstraction. During the compilation of this report, the total volume of water abstracted from the boreholes for year 2018 accounts for 128 062 m^3, which is in excess of 63 862 m^3 of the licensed volume. The provision of these data was aimed at optimising the calculation of the mine components that use raw water. These data were, therefore, not used in the overall water balance calculations.

Table 7.3: Measured water volumes abstracted from Leeuwpan Coal Mine (all in m^3)

Boreholes	**Jan-18**	**Feb-18**	**Mar-18**	**Apr-18**	**May-18**	**Jun-18**	**Jul-18**	**Aug-18**	Total
Witklip	13 035	17 553	16 308	17 898	9 693	16 877	17 525	18 777	127 666
Henks	28	34	34	26	33	16	23	24	218
Load Out	20	23	20	17	18	18	62	0	178
Total	**13 083**	**17 610**	**16 362**	**17 941**	**9 744**	**16 911**	**17 610**	**18 801**	**128 062**

Figure 7.1: Water Process Flow Diagram



7.2 Water Balances

Three water balances were calculated for the Leeuwpan Coal mine and are used to provide a general insight into the overall total water demands and uses. These include an annual average water balance (Table 7.4), an average monthly balance (Table 7.5) and an average daily water balance (Table 7.6).

All water balance calculations were based on the optimised volumes obtained from the mine personnel as well as the estimated calculations using hydrological principles. The inclusion of the OI block into the water balance calculations resulted in 372 796 m^3/a of excess water. This necessitates the requirement to provide an additional storage of dirty water within the plant site. The following recommendations are made in this regard:

- Pumping dirty water from the Silver PCD's to the Witklip PCD and allow it to evaporate.
- Due to the limitation of storage capacity of the Witklip PCD, complete the rehabilitation of the OWM Moabsvelden Pit, OWM Weltervreden Pit, Pit OJ and Pit OH & OM to reduce the quantities of water that have to be abstracted into the Silver PCDs.
- Pit OD (South and North) can be used as an additional storage facility because of large volume. This increase dirty water losses through evaporation.

In order to improve the accuracy of the mine water balances, it is recommended that additional flow meter and records of water flow volumes be conducted at:

- Flow meter at the outlet of the Silver PCDs to the plant beneficiation;
- Flow meter at the outlet of the Plant PCD to the plant beneficiation to account for water re-use volumes;
- Water abstractions from all dewatering pits should also be measured at the inlet of the Silver PCDs;
- Keep records of daily water volumes used for dust suppression and raw water usage from the boreholes.

Table 7.4: Average annual water balance

Annual Average Water Balance for Leeuwpan Coal Mine					
Facility Name	**Water In**		**Water Out**		**Balance**
Leeuwpan Coal Mine	**Water Circuit/stream**	**Quantity (m^3/year)**	**Water Circuit/stream**	**Quantity (m^3/year)**	
Raw Water	From: Witklip Borehole	30 864	To: Workshop	20 600	
	From: Henk's Borehole	36 336	To: Offices	20 400	
	From: Load Out Borehole	1 200	To: Plant offices	21 600	
			To: Gardening	5 800	
	Total	**68 400**		**68 400**	-
Domestic Consumption	From: Workshop	20 600	To: Phola STP	37 576	
	From: Offices	20 400	To: Domestic Consumption	3 424	
	Total	**41 000**		**41 000**	-
Phola Sewage Treatment Plant	From: Phola STP	37 576	To: Honey Sucker	37 576	
	Total	**37 576**		**37 576**	-
Plant Beneficiation (Crush and Stack, DMS, Frazer DMS)	From: Silver PCD's	139 209	To: Losses (other)	151 200	
	From: Plant PCD	11 991	To: Product Moisture	151 200	
	From: ROM Mositure	151 200			
	Total	**302 400**		**302 400**	-
Silver PCD's	From: Pit OD	39 665	To: Evaporation	64 900	
	From: Pit OH & OM	42 024	To: Plant Beneficiation	139 209	
	From: Pit OI	334 452	To: Dust Supression	10 200	
	From: Pit OJ	59 414	To: Witklip PCD	17 208	
	From: Weltevrededn OWM Pit	100 035	To: Excess	372 796	
	From: Rainfall	28 724			
	Total	**604 313**		**604 313**	-
Witklip PCD	From: Rainfall	17 368	To: Evaporation	26 161	
	From: Silver PCD's	17 208	To: Silver PCD's	8 415	
	Total	**34 576**		**34 576**	-
Plant PCD	From: Dirty Runoff Water	37 230	To: Evaporation	45 279	
	From: Rainfall	20 040	To: Plant Beneficiation	11 991	
	Total	**57 270**		**57 270**	-
Pit OJ	From: Groundwater Seepage	16 500	To: Evaporation	14 230	
	From: Rainfall	70 140	To: Storage/Losses	59 414	
			To: Silver PCD's	12 996	
	Total	**86 640**		**86 640**	-
Weltervreden OWM Pit	From: Groundwater Seepage	65 700	To: Evaporation	114 557	
	From: Rainfall	601 200	To: Storage/Losses	452 308	
			To: Silver PCD's	100 035	
	Total	**666 900**		**666 900**	-
Pit OD North and South	From: Groundwater Seepage	65 700	To: Evaporation	195 722	
			To: Silver PCD's	39 665	
	From: Rainfall	198 730	To: Storage/Losses	29 044	
	Total	**264 430**		**264 430**	-
Moabsvelden OWM Pit	From: Groundwater Seepage	65 700	To: Evaporation	13 416	
			To: Storage/Losses	102 025	
	From: Rainfall	78 602	To: Silver PCD's	28 860	
	Total	**144 302**		**144 302**	-
Pit OH & OM	From: Groundwater Seepage	29 200	To: Evaporation	63 855	
	From: Rainfall	76 678	To: Silver PCD's	42 024	
	Total	**105 878**		**105 878**	-
Pit OI	From: Groundwater Seepage	219 000	To: Evaporation	201 911	
			To: Storage/Losses	1 693 317	
	From: Rainfall	2 010 680	To: Silver PCD's	334 452	
	Total	**2 229 680**		**2 229 680**	-
Total Water Balance		**4 499 063**		**4 499 063**	-

Table 7.5: Average monthly balance

Monthly Average Water Balance for Leeuwpan Coal Mine					
Facility Name	**Water In**		**Water Out**		**Balance**
Leeuwpan Coal Mine	**Water Circuit/stream**	**Quantity (m^3/month)**	**Water Circuit/stream**	**Quantity (m^3/month)**	
Raw Water	From: Witklip Borehole	2 572	To: Workshop	1 717	
	From: Henk's Borehole	3 028	To: Offices	1 700	
	From: Load Out Borehole	100	To: Plant offices	1 800	
			To: Gardening	483	
	Total	**5 700**		**5 700**	-
Domestic Consumption	From: Workshop	1 717	To: Phola STP	3 131	
	From: Offices	1 700	To: Domestic Consumption	285	
	Total	**3 417**		**3 417**	-
Phola Sewage Treatment Plant	From: Phola STP	3 131	To: Honey Sucker	3 131	
	Total	**3 131**		**3 131**	-
Plant Beneficiation (Crush and Stack, DMS, Frazer DMS)	From: Silver PCD's	11 601	To: Losses (other)	12 600	
	From: Plant PCD	999	To: Product Moisture	12 600	
	From: ROM Mositure	12 600			
	Total	**25 200**		**25 200**	-
Silver PCD's	From: Pit OD	3 305	To: Evaporation	5 408	
	From: Pit OH & OM	3 502	To: Plant Beneficiation	11 601	
	From: Pit OI	27 871	To: Dust Supression	850	
	From: Pit OJ	4 951	To: Witklip PCD	1 434	
	From: Weltevrededn OWM Pit	8 336	To: Excess	31 066	
	From: Rainfall	2 394			
	Total	**50 359**		**50 359**	-
Witklip PCD	From: Rainfall	1 447	To: Evaporation	2 180	
	From: Silver PCD's	1 434	To: Silver PCD's	701	
	Total	**2 881**		**2 881**	-
Plant PCD	From: Dirty Runoff Water	3 103	To: Evaporation	3 773	
	From: Rainfall	1 670	To: Plant Beneficiation	999	
	Total	**4 773**		**4 773**	-
Pit OJ	From: Groundwater Seepage	1 375	To: Evaporation	1 186	
	From: Rainfall	5 845	To: Storage/Losses	4 951	
			To: Silver PCD's	1 083	
	Total	**7 220**		**7 220**	-
Weltervreden OWM Pit	From: Groundwater Seepage	5 475	To: Evaporation	9 546	
	From: Rainfall	50 100	To: Storage/Losses	37 692	
			To: Silver PCD's	8 336	
	Total	**55 575**		**55 575**	-
Pit OD North and South	From: Groundwater Seepage	5 475	To: Evaporation	16 310	
			To: Silver PCD's	3 305	
	From: Rainfall	16 561	To: Storage/Losses	2 420	
	Total	**22 036**		**22 036**	-
Moabsvelden OWM Pit	From: Groundwater Seepage	5 475	To: Evaporation	1 118	
			To: Storage/Losses	8 502	
	From: Rainfall	6 550	To: Silver PCD's	2 405	
	Total	**12 025**		**12 025**	-
Pit OH & OM	From: Groundwater Seepage	2 433	To: Evaporation	5 321	
	From: Rainfall	6 390	To: Silver PCD's	3 502	
	Total	**8 823**		**8 823**	-
Pit OI	From: Groundwater Seepage	18 250	To: Evaporation	16 826	
			To: Storage/Losses	141 110	
	From: Rainfall	167 557	To: Silver PCD's	27 871	
	Total	**185 807**		**185 807**	-
Total Water Balance		**374 922**		**374 922**	-

Table 7.6: Average daily water balance

Daily Average Water Balance for Leeuwpan Coal Mine					
Facility Name	**Water In**		**Water Out**		**Balance**
Leeuwpan Coal Mine	**Water Circuit/stream**	**Quantity (m^3/day)**	**Water Circuit/stream**	**Quantity (m^3/day)**	
Raw Water	From: Witklip Borehole	85	To: Workshop	56	
	From: Henk's Borehole	100	To: Offices	56	
	From: Load Out Borehole	3	To: Plant offices	59	
			To: Gardening	16	
	Total	**187**		**187**	-
Domestic Consumption	From: Workshop	56	To: Phola STP	103	
	From: Offices	56	To: Domestic Consumption	9	
	Total	**112**		**112**	-
Phola Sewage Treatment Plant	From: Phola STP	103	To: Honey Sucker	103	
	Total	**103**		**103**	-
Plant Beneficiation (Crush and Stack, DMS, Frazer DMS)	From: Silver PCD's	381	To: Losses (other)	414	
	From: Plant PCD	33	To: Product Moisture	414	
	From: ROM Mositure	414			
	Total	**828**		**828**	-
Silver PCD's	From: Pit OD	109	To: Evaporation	178	
	From: Pit OH & OM	115	To: Plant Beneficiation	381	
	From: Pit OI	916	To: Dust Supression	28	
	From: Pit OJ	163	To: Witklip PCD	47	
	From: Weltevrededn OWM Pit	274	To: Excess	1 021	
	From: Rainfall	79			
	Total	**1 656**		**1 656**	-
Witklip PCD	From: Rainfall	48	To: Evaporation	72	
	From: Silver PCD's	47	To: Silver PCD's	23	
	Total	**95**		**95**	-
Plant PCD	From: Dirty Runoff Water	102	To: Evaporation	124	
	From: Rainfall	55	To: Plant Beneficiation	33	
	Total	**157**		**157**	-
Pit OJ	From: Groundwater Seepage	45	To: Evaporation	39	
	From: Rainfall	192	To: Storage/Losses	163	
			To: Silver PCD's	36	
	Total	**237**		**237**	-
Weltervreden OWM Pit	From: Groundwater Seepage	180	To: Evaporation	314	
	From: Rainfall	1 647	To: Storage/Losses	1 239	
			To: Silver PCD's	274	
	Total	**1 827**		**1 827**	-
Pit OD North and South	From: Groundwater Seepage	180	To: Evaporation	536	
			To: Silver PCD's	109	
	From: Rainfall	544	To: Storage/Losses	80	
	Total	**724**		**724**	-
Moabsvelden OWM Pit	From: Groundwater Seepage	180	To: Evaporation	37	
			To: Storage/Losses	280	
	From: Rainfall	215	To: Silver PCD's	79	
	Total	**395**		**395**	-
Pit OH & OM	From: Groundwater Seepage	80	To: Evaporation	175	
	From: Rainfall	210	To: Silver PCD's	115	
	Total	**290**		**290**	-
Pit OI	From: Groundwater Seepage	600	To: Evaporation	553	
			To: Storage/Losses	4 639	
	From: Rainfall	5 509	To: Silver PCD's	916	
	Total	**6 109**		**6 109**	-
Total Water Balance		**12 326**		**12 326**	-

8 CONCLUSIONS

The main conclusions derived from this study based on the water balances computation are presented below:

- The greater Leeuwpan Coal mine is located in a temperate climatic zone of South Africa which is characterised by wet hot summers and dry cold winters. A Mean Annual Precipitation (MAP) and Mean Annual Evaporation (MAE) of 667 mm and 1 677 mm, respectively, is experienced by the area.
- Raw water for domestic consumption is abstracted from three (3) boreholes which have a licenced annual allocation of 68 000 m^3 and is stored in the Silver tanks (Mine offices) and Workshop tanks. The recorded abstraction volumes for the period January 2018 to August 2018 show that the mine does not comply with raw water use licences as the volumes exceeded the licenced volume. Due to the lack of flow records at the end users, not conclusive explanations were provided as to where could these quantities of water are used.
- Sewage effluent is stored and collected by a honey sump from Phola Sewage treatment Plant, however, there are no measurements of the actual quantities of water taken out of the site for treatment.
- Due to the lack of water flow volume data in most components of the mine, water balance calculations were based on assumptions drawn from the information received and using the principles of hydrological system.
- A total of six (6) dewatering open pits (including OI Pit) are the source of mine plant process water. Water from these pits is pumped into the Silver PCD's where it is used for plant beneficiation (302 400 m^3/a) and dust suppression (10 200 m^3/a).
- The total volume of water required for the Plant Beneficiation process was calculated at 139 209 m^3/a from the Silver PCDs and 11 991 m^3/a re-used water from the Plant PCD.
- It was calculated that when the OI pit is dewatering, the mine site will have an excess of 372 796 m^3/a of mine water, based on the assumption that the process plant demand will remain similar to the current status. Additional mine water storage that can allow water to evaporate or be treated and discharged into the surrounding environment is required.

9 RECOMMENDATIONS

Recommendations made as a result of this study include:

- Water flow meters should be installed to monitor inflows into and outflows from; the Plant Beneficiation, Silver PCDs, dust suppression bowser, and Phola Sewage Treatment Plant (STP). Flow volume data will provide a better understanding of water flow patterns at the mine and facilitate the calibration of more accurate water balance calculations.
- Upgrading of, and improved maintenance of, the silt trap at the Plant PCD. This will improve efficiency of the system and mitigate sedimentation in the Plant PCD.
- Raw water abstractions from boreholes should be monitored to ensure that the mine adheres to conditions of the water use licence issued for the mine. Flow volume data for the period January 2018 to August 2018 suggests that raw water on the mine has increased, which implies that the mine should apply for a new water use license that reflects current and future demands.
- Additional storage for excess water expected from the dewatering of the new OI pit needs to be planned. Water storage issues can be addressed as follows:
    - Back-filled pits that are far from the plant area should be rehabilitated in order to reduce the quantities of water flowing into the Silver PCD.
    - Use Pit OD (South and North) as a storage facility. This will allow storage of some excess water, and allow for increased evaporative water losses.
    - Pump water from the Silver PCDs into the Witklip PCD where water will evaporate or could be treated and discharged back into the environment.

10 REFERENCES

Bailey, A., & Pitman, W. (2015). *Water Resources of South Africa 2012 Study (WR2012): Executive Summary Version 1. WRC Report No. K5/2143/1*. Gezina, South Africa: Water Research Commision Report.

Cleanstream. (2003). *Environmental Programme Report: Addendum 3*. Emalahleni: Clean Stream Environmental Services.

DWAF. (2006c). *Best Practice Guideline G2: Water and Salt Balances*. Pretoria, South Africa: Department of Water Affairs and Forestry.

GCS. (2014). *Leeuwpan Colleiry Hydrogeological Investigation*. Johannesburg: GCS (Pty) ltd.

GCS. (2014a). *Integrated Water and Waste Management Plan (IWWMP) for Leeuwpan Coal*. Johannesburg: GCS (Pty) Ltd.

GCS. (2014b). *Integrated Water Use Licence Application for Expansion Activities at Leeuwpan Coal Mine*. Johannesburg: GCS (Pty) Ltd.

GCS. (2016). *Water Balance Update Study for Leeuwpan Mine*. Johannesburg: GCS (Pty) Ltd.

Leeuwpan personnel. (2018, October 31). e-mail communication. Delmas.

Linstrom, C. (2017). *Integrated Water Balance Report for Leeuwpan Mine*. Pretoria: Exxaro Resources Ltd.

Schulze, R. (1997). *South African Atlas of Agrohydrology and Climatology. WRC Report No. TT85/96*. Pretoria: Water Research Commision.

South Africa. (1998). *General Notice 704 of the National Water Act (36 of 1998)*. Pretoria: Department of Water and Forestry.

Annexure F
Biomonitoring Report



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Exxaro Leeuwpan Coal Mine

BIOMONITORING AND ENVIRONMENTAL TOXICITY PROGRAMME

WET SEASON SURVEY
June 2018

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1. INTRODUCTION

Leeuwpan Coal Mine is owned by Exxaro Resources and is situated 80 km south-east of Pretoria close to the town of Delmas. Leeuwpan comprises two conventional open pit mining operations, processing through a jig plant and separate coal washing facility.

This report is based on the dry season biomonitoring survey during June 2018. Biomonitoring for Leeuwpan is performed biannually during the wet season and the dry season. Previous surveys were conducted by Clean Stream Biological Services (Pty) Ltd as follows:

Year	Month	Report numbers
2000	May	CS-C-2000
2012	December	LP-A-12
2013	July and November	LP-A-13 and LP-B-13
2014	December	LP-A-14
2016	January, June and December	LP-A-16, LP-B-16 and LP-A-17
2017	June and December	LP-B-17 and LP-A-18
2018	June	LP-B-18

In a water stressed country such as South Africa, water is a precious natural resource that supports a range of economic activities and land uses (e.g. mining, agriculture, residential activities and industries). The degradation of river systems due to these activities can impact negatively on the sustainable utilisation of water. Therefore, careful management of water resources, based on sound ecological research, is required.

Biological communities reflect the overall ecological integrity of a river system by integrating different stressors over time and thus providing a broad measure of their aggregate impact. The monitoring of biological communities therefore provides an ecological measure of fluctuating environmental conditions. The biomonitoring protocols applied in this project should give a good reflection of the human impacts on the ecological systems under investigation. During this survey the general habitat condition and availability and biotic integrity, based on aquatic macro-invertebrates and fish, were assessed to determine the impact of Leeuwpan Coal Mine activities, together with other human impacts, on the ecological integrity of the receiving streams and rivers within its vicinity. Toxicity testing was performed to provide further information on water quality, both within natural watercourses and within the mine's pollution control facilities.

The primary objectives of the biomonitoring programme are as follows:

- Determine the **biotic integrity** (in terms of aquatic macro-invertebrates and fish) of the Bronkhorstspruit, Rietkuil Tributary and Weltevreden Tributary within the vicinity of Leeuwpan Coal Mine.
- Monitor the water quality within natural watercourses and interpret the findings according to guideline limits for aquatic ecosystems.
- Determine whether biotic integrity is improved or degraded downstream of potential Leeuwpan Coal Mine impacts, i.e. **spatial variation** in biotic integrity.
- Establish and populate a dataset to observe **temporal variation** of biotic integrity, i.e. improvement/deterioration over the long term.
- Determine the potential **acute/chronic toxicity risk** associated with all Leeuwpan Coal Mine (and another mine) effluents (to the receiving environment) to quantify and classify the acute risk associated with such potential sources of pollution.

From January 2016 onwards, the following additional aspects were included:

- Wet season monitoring of wetland integrity within wetlands affected by Leeuwpan Mine, as well as the stream diversion constructed around the Eastern Block. This includes monitoring of sediment deposition within the diversion.
- Wet season monitoring of wetland fauna.
- Diatom assessments.

These additional aspects are submitted as stand-alone reports once results become available.

2. MATERIALS & METHODS

Refer to appendix 1 for a description of methodology applied during this assessment.

3. RESULTS & DISCUSSION

3.1 Study area and sampling sites

Biomonitoring sites were selected to be easily accessible and representative of as many habitats as possible. Four biomonitoring sites were selected within the Bronkhorstspruit and its tributaries (receiving watercourses).

The criteria for site selection were as follows:

- The locations should ideally be selected to be both upstream and downstream of potential pollution sources, and as far as possible, exclude other potential impacts not related to the biomonitoring programme (non-Leeuwpan Coal Mine impacts).
- The habitat diversity should be representative of the river/stream being monitored and, as far as possible, be comparable between sites on a spatial scale.
- The habitats should, as far as possible, be suitable for the application of the selected biomonitoring protocols.
- The sampling sites should at least be accessible by off-road vehicle to enable the transport of the required sampling equipment.

The study area includes two sampling localities in the Bronkhorstspruit Tributary in the vicinity of Leeuwpan Coal Mine. One site (LP-BS-US) was selected to be upstream of current activities and another (LP-BS-DS) to be downstream of mining activities (Table 1 & Figure 1).

Two more biomonitoring localities (LP-RK-US and LP-WEL-DS) were selected in the Bronkhorstspruit catchment on the Weltevreden and Rietkuil Tributaries respectively, upstream and downstream of potential Leeuwpan Coal Mine impacts. The downstream site (LP-WEL-DS) receives inputs from Leeuwpan Coal Mine and other non-Leeuwpan activities and therefore measures the cumulative impact of all users in this subcatchment.

Toxicity testing was performed at all of the above-mentioned biomonitoring localities. Three additional toxicity testing sites (samples) were selected for analyses from the final Leeuwpan Coal Mine Pollution Control Dam (LSW09), the Rietkuilspruit upstream of the study area (LSW08) and another colliery's PCD (RD2) (Table 1 & Figure 1).

During January 2016, wetland monitoring was included in the biomonitoring programme. For the sake of completeness, these sites are described in Table 1 and Figure 1, although the findings will be presented in a stand-alone report.

Table 1: Coordinates and protocols applied and frequency of sampling at sites for routine biomonitoring.

Monitoring site	Description	Recommended biomonitoring protocols		GPS coordinates	
		Protocol	Frequency per annum	Latitude (South)	Longitude (East)
LP-BS-US	Bronkhorstspruit, upstream of all potential Leeuwpan impacts.	Water Quality, *SASS5	Twice	26.1779	28.7018
		Toxicity Testing (screening)	Twice		
		Diatoms	Twice		
		**FAII	Once		
		Wetland Integrity and Wetland Fauna	Once		
LP-BS-DS	Bronkhorstspruit, downstream of potential Leeuwpan impacts draining towards this receiving waterbody.	Water Quality, *SASS5	Twice	26.1553	28.7026
		Toxicity Testing (screening)	Twice		
		Diatoms	Twice		
		**FAII	Once		
		Wetland Integrity and Wetland Fauna	Once		
LSW-08	Rietkuil unchannelled valley bottom wetland upstream of the study area	Wetland Integrity and Wetland Fauna	Once	26.2291	28.7626
LP-RK-US	Rietkuil tributary, upstream of potential Leeuwpan impacts.	Water Quality, *SASS5	Twice	26.1878	28.7763
		Toxicity Testing (screening)	Twice		
		Wetland Integrity and Wetland Fauna	Once		
LP-RK-Wet1	Rietkuil wetland upstream of all Leeuwpan mining activities.	Wetland Integrity and Wetland Fauna	Once	26.1960	28.7716
LP-RK-Wet2	Rietkuil wetland upstream of Leeuwpan activities but downstream of the R50.	Water Quality, *SASS5	Twice	26.1635	28.7679
		Toxicity Testing (screening)	Twice		
		Wetland Integrity and Wetland Fauna	Once		
LP-RK-DS	Diversion within the Rietkuil wetland downstream of the Leeuwpan haul road connecting the eastern and western blocks.	Water Quality, *SASS5	Twice	26.1488	28.7646
		Toxicity Testing (screening)	Twice		
		Wetland Integrity and Wetland Fauna	Once		
LP-WEL-US	Weltevreden tributary upstream of Leeuwpan activities.	Wetland Integrity and Wetland Fauna	Once	26.1435	28.7955
LP-WEL-DS	Weltevreden tributary, downstream of Leeuwpan impacts but inclusive of non-Leeuwpan impacts.	Water Quality, *SASS5	Twice	26.1373	28.7569
		Toxicity Testing (screening)	Twice		
		Diatoms	Twice		
		Wetland Integrity and Wetland Fauna	Once		
D-US	Diversion, sampled at the upstream end (relative to Leeuwpan activities).	Water Quality	Twice	26.1469	28.7951
		Toxicity Testing (screening)	Twice		
		Soil particle size analysis	Once		
		Wetland Integrity	Once		

Monitoring site	Description	Recommended biomonitoring protocols		GPS coordinates	
		Protocol	Frequency per annum	Latitude (South)	Longitude (East)
D-DS	Diversion, sampled at the downstream end (relative to Leeuwpan activities).	Water Quality	Twice	26.1438	28.7744
		Toxicity Testing (screening)	Twice		
		Soil particle size analysis	Once		
		Wetland Integrity	Once		
D-DS	Diversion, sampled at the downstream end (relative to Leeuwpan activities).	***Acute/chronic **screening** toxicity	Quarterly	26.1442	28.7756
LP-RK-DS	Toxicity sample, upstream of LP-RK-US in the Rietkuil tributary	***Acute/chronic **screening** toxicity	Quarterly	26.2291	28.7626
LSW09	Leeuwpan PCD, that may potentially impact on the Bronkhorstspruit.	***Acute/chronic **screening** toxicity	Quarterly	26.1664	28.7247

Note: The system referred to as the Bronkhorstspruit is, strictly speaking, a tributary of the Bronkhorstspruit. Similarly, site LP-WEL-DS is situated within an eastern tributary of the Bronkhorstspruit and is, in fact, situated downstream of the confluence between the Weltevreden Tributary and the Rietkuil Tributary. The naming convention for these sites has been continued for the sake of consistency with previous reports.

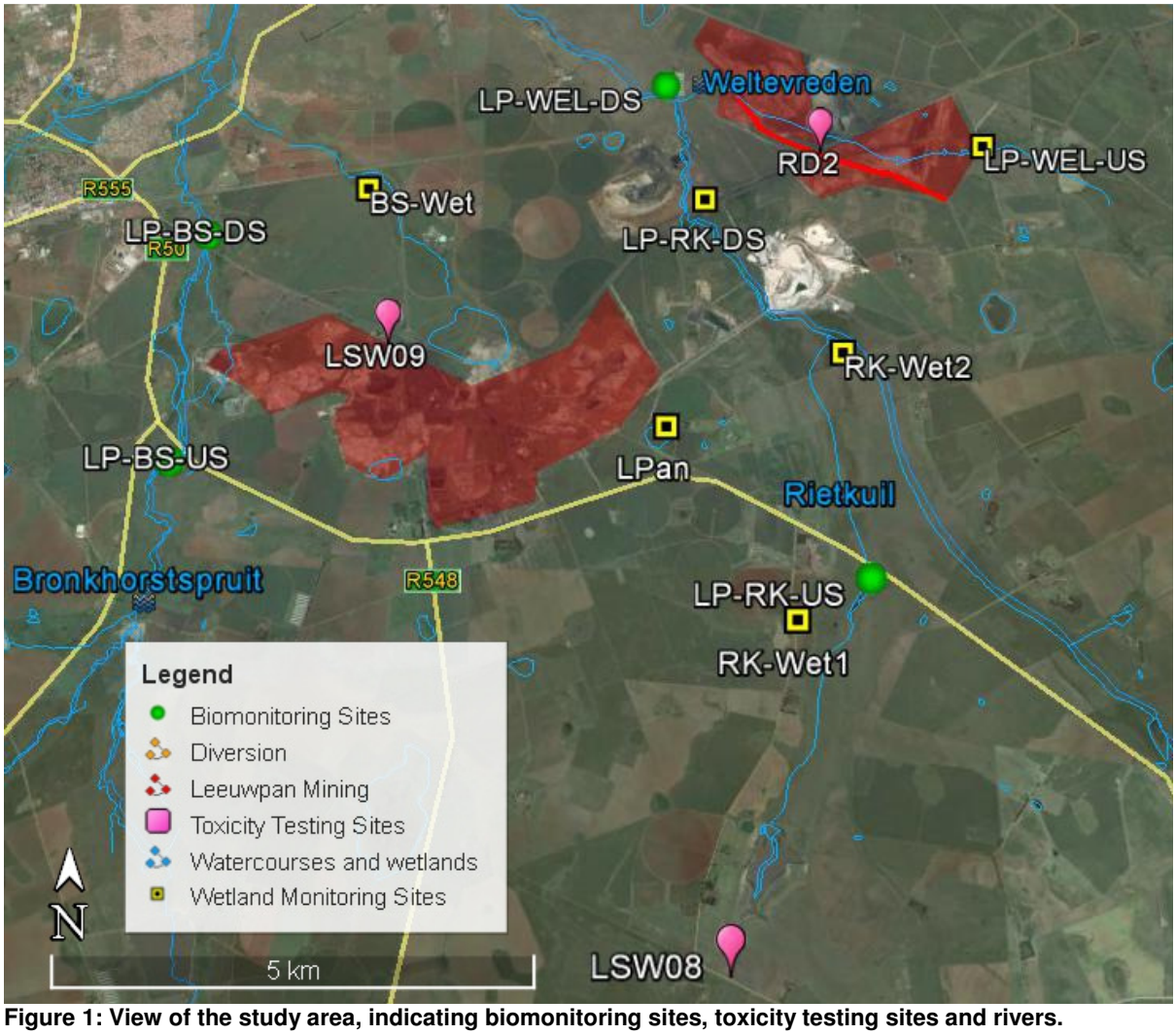


Figure 1: View of the study area, indicating biomonitoring sites, toxicity testing sites and rivers.

3.2 Water Quality

Selected water quality variables were measured on-site at the time of biological sampling. The on-site water quality results for June 2018 are shown in Table 2. These were followed up with laboratory analyses of major anions and cations and ICP-scans for selected metals (Table 3). Results were compared against DWAF (1996) guideline limits for ecosystems, agriculture, irrigation and livestock watering. These limited water quality assessments are merely to inform the interpretation of the ecological data and do not constitute a detailed surface water quality assessment.

The pH fell within the target water quality ranges for fish health (Table 2). The target for fish health is between 6.5 and 9.0 and it is expected that most aquatic species will tolerate and reproduce successfully within this pH range (DWAF, 1996).

The dissolved oxygen concentrations fell within the guideline limit (> 5 mg/l) set by Kempster *et.al.* (1980) at all sites except for wetland sites with standing water (sites LP-RK-US and LP-RK-Wet2) where low oxygen concentrations are expected and are not considered problematic.

Within the Bronkhorstspruit, there was a slight decrease in salinity (as reflected by the electrical conductivity) between upstream and downstream sites. Salt concentrations were, however, elevated at both sites and may have been limiting to sensitive species. Salinity levels exceeding 250mg/ℓ can cause the proliferation of algae (Chutter and Walmsley 1994) which, in turn, compromises habitat availability and suitability. The guideline for aquatic ecosystems is a maximum fluctuation in salinity of 15% (DWAF 1996).

There was a pronounced increase in salinity within the Rietkuil/Weltevreden wetland system upstream and downstream of the haul road (i.e. between sites LP-RK-Wet2 and LP-RK-DS). This indicates inputs of salts (mostly sulphates, based on Table 3) in runoff from the haul road crossing. These salinity levels are likely to have been limiting to sensitive aquatic biota and exacerbated the proliferation of algae, which, in turn, would compromise habitat suitability.

The salinity remained elevated further downstream in the receiving Weltevredenspruit, which also receives water from the diversion. The salinity at the downstream site was far greater than at the upstream site (281 mg/l at site LP-WEL-DS compared with 183mg/l at site LP-RK-US). Salinity is likely to have been problematic at the downstream site, particularly in terms of the proliferation of algae.

Sulphates were elevated in both the diversion and Rietkuilspruit, indicating contamination from mining activities.

Manganese was elevated at the downstream end of the diversion and exceeded the guideline limit for aquaculture (Table 3), indicating a limitation to aquatic biota. This may have contributed to the slight (Class II) toxicity hazard at this site (Section 3.3).

Turbidity and suspended solids (settleable solids) were high within the Rietkuil wetland, upstream of Leeuwpan mining. However, this site has been affected by construction of a road through the wetland (discussed in section 3.5). This has caused sediments to have been washed into the wetland, compromising the substrate through sedimentation and increasing the turbidity of the water.

Table 2: On-site water quality variables measured at the time of sampling during June 2018. Orange shading indicates variables of concern.

Monitoring site	EC (mS/m)	pH	Oxygen saturation (%)	Dissolved oxygen (mg/l)	Water temp (ºC)	Turbidity (visual)	Flow (visual)
LP-BS-US	49.0	8.3	85.9	6.9	9.6	Clear	Trickle
LP-BS-DS	45.8	7.9	83.6	6.6	10.7	Slightly turbid	Trickle
LP-RK-US	30.1	7.4	42.8	3.8	6.6	Turbid	No flow
LP-RK-Wet	32.6	7.4	42.4	3.7	6.8	Slightly turbid	No flow
LP-RK-DS	43.4	7.6	75.0	5.9	10.5	Slightly turbid	Moderate
LP-WEL-DS	43.5	7.7	87.5	7.0	12.3	Clear	Moderate

Table 3: Results of laboratory analyses of water quality (June 2018) (Red shading indicates exceedances, while orange shading indicates elevated levels).

	Div-US	DIV-DS	LP-RK-US	LP-RK-WET2	LP-RK-DS	LP-WEL-DS	LP-BS-US	LP-BS-DS	Ecosystems	Aquaculture	Irrigation	Livestock watering
pH	Dry	6.9	8.4	8.4	8.1	8.5	8.7	8.6	5% or 0,5 unit variation	6,5-9	6,5-8,4	
EC (mS/m)		23.6	27.2	25.6	42.8	43.3	46.7	43.9			<40	500
TDS (mg/l)		148	183	201	285	281	301	272	<15% variation	<2000 mg/l	<260	<1000
Cl (mg/l)		14.8	21	13.8	19.4	19.7	17.7	14.3	<400	<600	100	1500
SO4 (mg/l)		52.9	19.2	36	71.5	71.1	-0.141	7.98			200	1000
NO3 (mg/l)		2.63	-0.194	-0.194	0.202	-0.194	-0.194	-0.194		300		100
NH4 (mg/l)		0.056	0.096	0.038	0.077	0.023	0.022	0.061				
NH3 (Calc.)(mg/l)		-0.005	0.008	-0.005	-0.005	-0.005	-0.005	0.007				
PO4 (mg/l)		-0.005	-0.005	-0.005	-0.005	-0.005	0.008	-0.005	<5% variation	0.1		
Ca (mg/l)		20.6	20.8	31	44.2	43.6	45.8	43.2				1000
Mg (mg/l)		13.7	13.3	17.4	26.8	26.6	31.3	27			300	500
Na (mg/l)		7.74	19.1	11.8	12.9	12.9	17	18			70	2000
K (mg/l)		1.75	12.6	6.11	5.2	5.21	9.46	7.9				
Al (mg/l)		-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	0.01	0.03	5	5
Fe (mg/l)		-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	10% variation	0,02-175	50	10
Mn (mg/l)		0.251	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.8	0.1	0.02	10
Turbidity (NTU)		3.63	22.2	17.8	3.87	3.81	1.83	3.48				
SS (mg/l)		-4.5	20	60	5	-4.5	5	7	<10% variation OR <100		<50	

3.3 Toxicity testing

As per SANAS requirements, the toxicity testing report was compiled independently by Biotox Laboratory Services (Pty) Ltd. All results contained in this section are sourced from the stand-alone Biotox report, included as Addendum A.

Toxicity testing (conducted as part of this biomonitoring programme) is applied by exposing biota under laboratory conditions to various water types (pollution control dams and/or streams) to determine the potential risk of such waters to the biota of the receiving water bodies. Toxicity results indicate the potential risk posed to the Bronkhorstspruit (and Rietkuil/Weltevreden tributaries) in the event of release, seepage or overflow from potential sources of pollution. Four trophic levels of biota i.e., vertebrates (*Poecilia reticulata*), invertebrates (*Daphnia magna*), bacteria (*Vibrio fischeri*) and primary producers (*Selenastrum capricornutum*) are exposed to the samples according to standard procedures under laboratory conditions and thereafter a risk/hazard category is determined by application of the latest **DEEEP**[1] DWA recommended protocols and hazard classification. This risk category equates to the level of acute risk posed by the selected potential pollution source/stream towards the biota of the receiving water

[1] DEEEP = Direct Estimation of Ecological Effect Potential. This is a battery of tests that can measure toxicity of complex mixtures based on a set of parameters stemming from the results of effects, even if all constituents are not known. A hazard class is determined based on the resulting parameters of the battery of tests.

bodies. Although the final risk classification is expressed in terms of **acute**[2] toxicity risk, the *Selenastrum capricornutum* and individual test results allow for **chronic**[3] toxicity hazard interpretation. This is because this test exposure is performed over a relatively long period of time in relation to the life cycle of the micro-algae and furthermore provides the growth inhibition rate, thereby also qualifying as a chronic test.

Water samples were tested at a **screening**[4] acute level (not on a **definitive**[5] level). The level of toxicity determines the frequency and level of testing. If toxicity levels increase, it may become relevant and useful to increase the frequency and/or level of testing. For this reason, the toxicity testing protocols are reviewed annually.

3.3.1 Hazard classification for screening tests (undiluted sample)

After the determination of the percentage effect[6] (EP), obtained with each of the ***battery of toxicity screening*** tests performed, the sample is ranked into one of the following five classes:

Class I	**No acute/chronic environmental toxicity hazard -** none of the tests shows a toxic effect
Class II	**Slight acute/chronic environmental toxicity hazard -** a statistically significant percentage effect is reached in at least one test, but the effect level is below 50%
Class III	**Acute/chronic environmental toxicity hazard -** the percentage effect level is reached or exceeded in at least one test, but the effect level is below 100%
Class IV	**High acute/chronic environmental toxicity hazard -** the 100% percentage effect is reached in at least one test
Class V	**Very high acute/chronic environmental toxictiy hazard -** the 100% percentage effect is reached in all the tests

Weighting: Each sample is furthermore weighted according to its relative toxicity levels (out of 100%). Higher values indicate that more of the individual tests indicated toxicity within a specific class.

A **Class II (Slight) toxicity hazard** was recorded for water sampled from all sites within the Rietkuil wetland system. This included the site upstream of the study area, suggesting regional impacts to water quality, rather than impacts due to Leeuwpan mining.

Water sampled from the diversion, also posed a **Class II (Slight) toxicity hazard**. This indicates that there was a slight risk that the water would be toxic to aquatic biota within the receiving Weltevredenspruit.

Within the receiving Weltevredenspruit, downstream of both the diversion and the Rietkuil Tributary, water also posed a **Class II (Slight) acute toxicity hazard**. This essentially means that there was a slight risk that water leaving the study area was toxic to aquatic biota within downstream reaches.

[2] Acute = Acute refers to an exposure over a relatively short period of the lifespan of biota. Acute toxicity testing is always a relevant starting point (within a toxicity monitoring programme) to determine the level of toxicity. If no acute toxicity prevails for a period of time, it becomes relevant to also perform chronic toxicity testing in an attempt to determine if long-term exposure to the pollution source may have a negative impact on the biota of the receiving water bodies.

[3] Chronic = Chronic refers to prolonged exposures over an extended period of the lifespan of test organisms. Chronic toxicity testing becomes relevant in the event that no acute toxicity is observed over a period of time within a toxicity monitoring programme. It requires different testing protocols, test biota and duration of exposure (as compared to acute protocols).

[4] Screening = A screening toxicity test refers to an undiluted (100% concentration) sample. This is usually performed on a sample from the biomonitoring sites in the receiving water bodies (river/streams) to determine if any toxicity is present. This is performed both up- and downstream of the potential impacts to enable the determination of downstream increases or decreases in toxicity.

[5] Definitive = A definitive toxicity test refers to the exposure of test organisms to both the 100% concentration as well as a range of dilutions, generally used to determine the risk of a pollution source that may have a toxicity effect on the receiving water body (such as effluents and PCD's). The range of dilutions are therefore useful if the 100% sample concentration presents acute toxicity, and allows for the determination of a safe dilution factor, to negate toxicity effects on the receiving water bodies.

[6] EP (Percentage effect) = an effect measured either as a mortality rate or inhibition rate (depending on the type of test). A 10% effect is regarded as a slight acute toxicity for daphnia and guppies, while a 20% effect is regarded as a slight acute toxicity for algae and bacteria (vibrio). A 50% effect is regarded as an acute toxicity for all tests (daphnia, guppies, algae and bacteria.

Table 4: Toxicity results and hazard classification for selected samples (June 2018).

	Results	LP BS US	LP BS DS	LP RK US	LP RK WET (LP-RK-1)	LP RK DS (LP-RK-2)	DIV-DS (D-DS)	LSW09	LP WEL DS
WQ Water quality	pH @ 25°C (A)	8.5	8.4	8.2	8.1	8.1	6.8	7.9	8.2
	EC (Electrical conductivity) (mS/m) @ 25°C (A)	51.3	47.9	32.4	34.1	47.3	28.2	260.0	47.3
	Dissolved oxygen (mg/l) (N)	8.0	8.2	8.0	8.0	8.1	8.2	8.2	8.1
V. fischeri (bacteria) (A)	Test started on yy/mm/dd	18-06-21	18-06-21	18-06-21	18-06-21	18-06-21	18-06-21	18-06-21	18-06-21
	%30min inhibition (-) / stimulation (+) (%)	-14	-18	-18	-21	-20	-25	-20	-29
	EC/LC20 (30 mins)	*	*	*	*	*	*	*	*
	EC/LC50 (30 mins)	*	*	*	*	*	*	*	*
	Toxicity unit (TU) / Description	no short-chronic hazard	no short-chronic hazard	no short-chronic hazard	S.D.O.T.H.	no short-chronic hazard	S.D.O.T.H.	no short-chronic hazard	S.D.O.T.H.
S. capricornutum (micro-algae) (A)	Test started on yy/mm/dd	18-06-19	18-06-19	18-06-19	18-06-19	18-06-19	18-06-19	18-06-19	18-06-19
	%72hour inhibition (-) / stimulation (+) (%)	5	1	4	2	8	-1	9	5
	EC/LC20 (72hours)	*	*	*	*	*	*	*	*
	EC/LC50 (72hours)	*	*	*	*	*	*	*	*
	Toxicity unit (TU) / Description	no short-chronic hazard	no short-chronic hazard	no short-chronic hazard	no short-chronic hazard	no short-chronic hazard	no short-chronic hazard	no short-chronic hazard	no short-chronic hazard
D. magna (waterflea) (A)	Test started on yy/mm/dd	18-06-18	18-06-18	18-06-18	18-06-18	18-06-18	18-06-18	18-06-18	18-06-18
	%48hour mortality rate (-%)	0	0	0	0	-5	0	0	0
	EC/LC10 (48hours)	*	*	*	*	*	*	*	*
	EC/LC50 (48hours)	*	*	*	*	*	*	*	*
	Toxicity unit (TU) / Description	no acute hazard	no acute hazard	no acute hazard	no acute hazard	no acute hazard	no acute hazard	no acute hazard	no acute hazard
P. reticulata (guppy) (A)	Test started on yy/mm/dd	18-06-18	18-06-18	18-06-18	18-06-18	18-06-18	18-06-18	18-06-18	18-06-18
	%96hour mortality rate (-%)	-17	-17	-33	-17	-25	-8	-25	-17
	EC/LC10 (96hours)	*	*	*	*	*	*	*	*
	EC/LC50 (96hours)	*	*	*	*	*	*	*	*
	Toxicity unit (TU) / Description	S.D.O.T.H.	S.D.O.T.H.	S.D.O.T.H.	S.D.O.T.H.	S.D.O.T.H.	no acute hazard	S.D.O.T.H.	S.D.O.T.H.
	Overall classification - Hazard class* **	Class II - Slight acute hazard	Class II - Slight acute hazard	Class II - Slight acute hazard	Class II - Slight acute/chronic hazard	Class II - Slight acute hazard	Class II - Slight acute/chronic hazard	Class II - Slight acute hazard	Class II - Slight acute/chronic hazard
	Weight (%)	25	25	25	50	25	25	25	50

Key:

WQ = Water quality at the time of starting the *Daphnia magna* testing.

% = for definitive testing, only the 100% concentration (undiluted) sample mortality/inhibition/stimulation is reflected by this summary table. The dilution series results are considered for EC/LC values and Toxicity unit determinations

***** = EC/LC values not determined, definitive testing required if a hazard was observed and persists over subsequent sampling runs

S.D.O.T.H = Some degree of acute/chronic toxic hazard based on this single test organism, refer to overall hazard classification, which takes into account the full battery of test organisms.

(F) = Inhibition/Mortality rate with "(F)" indicates that the sample was filtered, this is often essential with turbid or coloured samples to perform the algae and bacteria tests. Filtration could potentially lower the toxicity for the specific test, but daphnia and guppy test samples are never filtered and hence toxicity will still be detected if affected by filtration

******* = The overall hazard classification takes into account the full battery of tests and is not based on a single test result. Note that the overall hazard classification is expressed as acute/chronic level of toxicity, due to the fact that the *S. capricornutum* (micro-

Weight (%) = relative toxicity levels (out of 100%), higher values indicate that more of the individual tests indicated toxicity within a specific class

A = Accredited; N = Non accredited; O = Outsourced; S = Sub-contracted; NR = Not requested; RTF = Results to follow

site/sample name shaded in purple = screening test

site/sample name shaded in orange = definitive test

3.3.2 June 2018 survey results

The June 2018 results are given in Table 4.

Water sampled from the Leeuwpan PCD (SW09) was classified as posing a **Class II (Slight) acute toxicity hazard**. Any releases from this PCD at the time of sampling may have been toxic to aquatic biota.

Within the Bronkhorstspruit, a **Class II (Slight) acute toxicity hazard** was recorded for water sampled at both the upstream and downstream sites (site LP-BS-US and LP-BS-DS). There was therefore slight risk of toxicity to aquatic biota. However, as both upstream and downstream sites were affected, it is likely that water quality was affected at a regional level, rather than impacted specifically by mining activities.

3.4 Diatom Assessment

The results of the diatom assessments are summarised in Table 5 and discussed below. The full report is available upon request.

Table 5. Result of diatom analyses.

Site	No species	SPI score	Class	Category	PTV (%)	Valve deformities (%)
Dec 2017						
LP-BS-US	36	13.4	Moderate quality	C	7	0
LP-BS-DS	54	11.4	Moderate quality	C/D	21.8	0
LP-WEL-DS	42	10.4	Moderate quality	C/D	11	0
Jun 2018						
LP-BS-US	32	12.7	Moderate quality	C	31.0	1
LP-BS-DS	42	10.2	Moderate quality	C/D	38.5	0
LP-WEL-DS	27	14.0	Moderate quality	C	23.3	0.75

3.4.1 Bronkhorstspruit

Based on diatoms, biological water quality has improved within the Bronkhorstspruit over the past two years.

Water quality within the Bronkhorstspruit was mainly impacted by organic contamination. Agricultural activities seem to be the main reason for this, with low flows in the winter months exacerbating impacts. Valve deformities (suggesting heavy metal contamination) were noted for the first time at the upstream site in June 2018, although below general threshold limits.

Species associated with industrial activities were more abundant downstream of Leeuwpan in June 2018, suggesting possible mining-related impacts; a trend also observed in 2016 and 2017. However, no valve deformities were noted at the downstream site in June 2018.

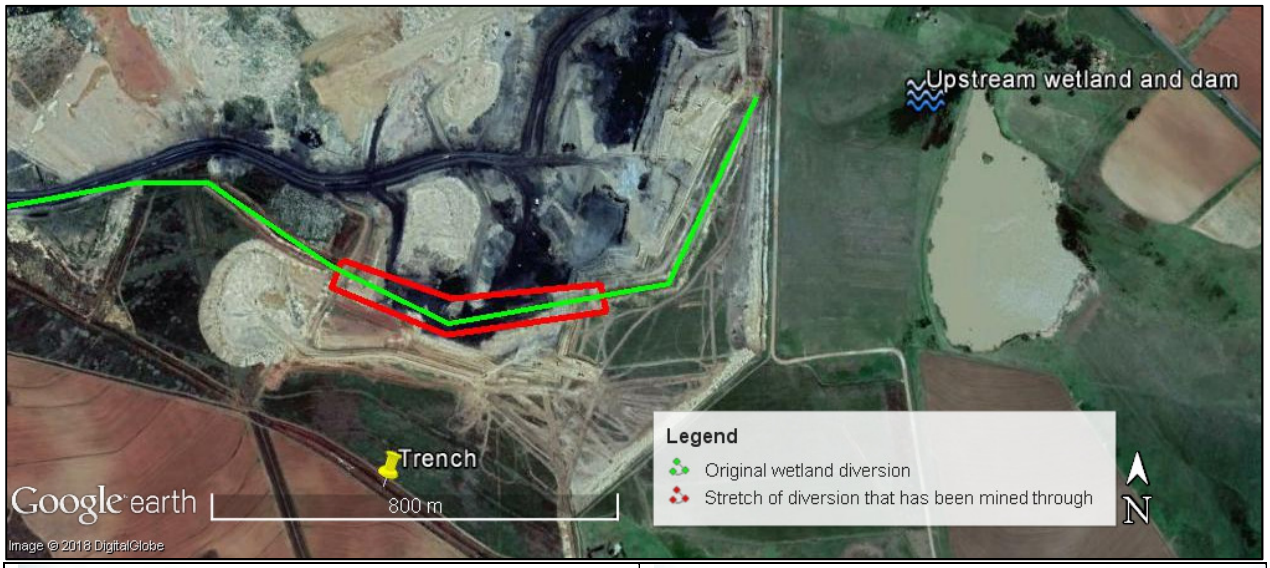
The biological water quality of the Bronkhorstspruit was characterised by Moderate water quality. Overall the diatom community preferred moderate to poor water quality with high organic pollution and nutrient loads.

3.4.2 Weltevredenspruit (site LP-Wel-DS)

The biological water quality in the Weltevredenspruit at site LP-WEL-DS is characterised by Moderate water quality. During wet seasons, water quality conditions deteriorate due to increased salinity and organic pollution. In the dry season, these levels improve. This trend reflects increased stormwater runoff entering the channel during the wet season. Valve deformities were noted at an abundance of 0.75%, a slight increase from December 2017, but remained below threshold limits.

3.5 Habitat Assessment

Over the past year, the top part of the diversion has been mined through (Figure 2). As such, there is no upstream site available for sampling. While a trench has been constructed to the south of the original diversion, it does not drain any wetland areas and, as such, is not considered a wetland diversion, merely a trench. It is strongly recommended that a wetland specialist be consulted prior to constructing any new developments. These activities have essentially caused the loss of the wetland diversion and its associated biota. Not only does this amount to a loss of biodiversity, but it is likely to be followed by increased contamination of both groundwater and surface water. Reference should be made to the requirements stipulated in the Mine's Water Use Licence regarding this diversion. A new wetland diversion should be constructed, in consultation with a wetland specialist.





The original diversion which has been closed off and mined through.



New trench constructed in a non-wetland area (therefore not serving as a wetland diversion).

Figure 2. Photo and Google Earth map showing the destruction of the wetland diversion.

An informal road has been constructed through the wetland at site LP-RK-Wet2, adjacent to new mining areas in the west (Figure 3). Again, a Water Use Licence is required for any construction activities taking place in a wetland. No provision has been made for stormwater drainage beneath this road (which has essentially been constructed from gravel deposited directly into the wetland) and it is likely that the road will cause erosion and water quality deterioration. This road should either be formalised in accordance with Water Use Licence requirements or should be removed from the wetland in its entirety.



Figure 3. Road construction through a wetland above site LP-RK-Wet2. Sediments have been washed into the wetland, causing sedimentation of habitats and increased turbidity.

Table 6 gives the particle size analysis conducted during June 2018. The mean particle size (modulus) is greater at the downstream site. The deposition of coarse soil particles in the lower end of the diversion points to erosion of topsoil along the diversion. This essentially will result in a gradual terrestrialisation of the wetland (i.e. a gradual drying of soils as soil depth increases), followed by colonisation by alien vegetation.

Table 6. Result of the Soil Gradation Analysis

	DIV-US	DIV-DS
Coarse Sand 2.000-0.425mm	11	13
Coarse Fine Sand 0.425-0.250mm	8	12
Medium Fine Sand 0.250-0.150mm	9	13
Fine Fine Sand 0.150-0.075mm	8	10
Silt and clay <0.075mm	64	52
MODULUS	0.85	1.08

3.6 Aquatic invertebrate assessment: South African Scoring System 5

The South African Scoring System (Version 5) is a site-specific index, which, together with an associated habitat index (biotope suitability index), gives a general perspective of the biotic integrity (based on macro-invertebrates) and the impact of water quality on the biotic integrity of the specific sites (Thirion *et.al*., 1995; Dickens and Graham, 2001). The biotope suitability index takes into account the suitability of the different sampled biotopes in terms of quality and availability. It thereby firstly assesses whether the total SASS5 scores of two sites are directly comparable by comparing the total biotope suitability scores. If the total biotope suitability scores are very different this would imply that the total SASS5 scores should not be compared, but instead the most comparable SASS biotope scores. The most comparable SASS biotope scores are identified by comparing the various individual biotope suitability scores. In addition to the biotope suitability index, the Integrated Habitat Assessment System, version 2 (IHAS) was also applied and included for the purpose of macro-invertebrate specific habitat descriptions (Appendix 2).

The Average Score per Taxon (ASPT) was also calculated for each site. According to field trials assessed by Dickens and Graham (2001) the ASPT score was less variable than total SASS5 scores when conducted within a given river reach by different operators, considering all biotopes.

3.6.1 Spatial trends (June 2018)

Within the Bronkhorstspruit sub-catchment, the SASS5 score and ASPT decreased between the upstream site (LP-BS-US) and the downstream site (LP-BS-DS), this trend being confirmed by the most comparable biotope (vegetation) (Table 7). This suggests a decline in water quality between the two sites and echoes the results of the diatom assessment which found that species associated with industrial activities were more abundant at the downstream site, suggesting possible mining-related impacts. Both sulphates and ammonia increased in a downstream direction. It should be noted that ammonia can be toxic to aquatic biota.

There was also an increase in SASS score between the Rietkuil wetland sites upstream and downstream of the haul road bridge (LP-RK-Wet2 and LP-RK-DS) (Table 7). However, the ASPT declined, indicating a decline in water quality and the loss of taxa with a requirement for good water quality. It should be noted, however, that the diversity was quite low at both sites and only one family with a moderate requirement for good water quality (Hydracarina) was recorded from both sites. All other taxa were widespread, tolerant taxa. As such, this result was likely to have reflected habitat differences rather than water quality. Reference should be made to the toxicity testing and surface water quality data for a more meaningful assessment.

Table 7: SASS5, ASPT and habitat suitability/availability index scores for biomonitoring sites within the Bronkhorstspruit (June 2018).

Monitoring site	SASS5 score	ASPT	SASS5-score per biotope			Biotope availability and suitability (Scores)			
			$SASS_{Stones}$	$SASS_{Vegetation}$	$SASS_{GSM}$	Stones	Vegetation	GSM	Combined
LP-BS-US	54	4.50	32	47	11	4	5	4	13
LP-BS-DS	46	3.83	0	39	22	0	5	3	8
LP-RK-US	60	4.00	0	46	21	0	6	2	8
LP-RK-Wet	37	4.11	0	34	20	0	6	2	8
LP-RK-DS	47	3.92	0	46	18	0	6	3	9
LP-WEL-DS	100	5.00	15	95	14	2	7	4	13

There was a pronounced improvement in biotic integrity (based on both SASS score and ASPT) between site LP-RK-DS (in the Rietkuil wetland) and site LP-WEL-DS (the receiving Weltevredenspruit). This was confirmed by the most comparable biotopes (vegetation and gravel-sand-mud). Four taxa with a moderate requirement were recorded from this site (Hydracarina, Dixidae, Leptophlebiidae and Aeshnidae) compared to only one taxon (Hydracarina) at LP-RK-DS. Therefore, there were no apparent impacts to the ecological integrity within the Weltevredenspruit wetland system, based on the SASS5 protocol. Flows were

higher than usual (possibly due to recent rainfall or other inflows such as from a leaking pipeline) at site LP-WEL-DS and the biota had responded to the greater availability of habitats. The SASS score and ASPT were the highest recorded at this site since 2012.

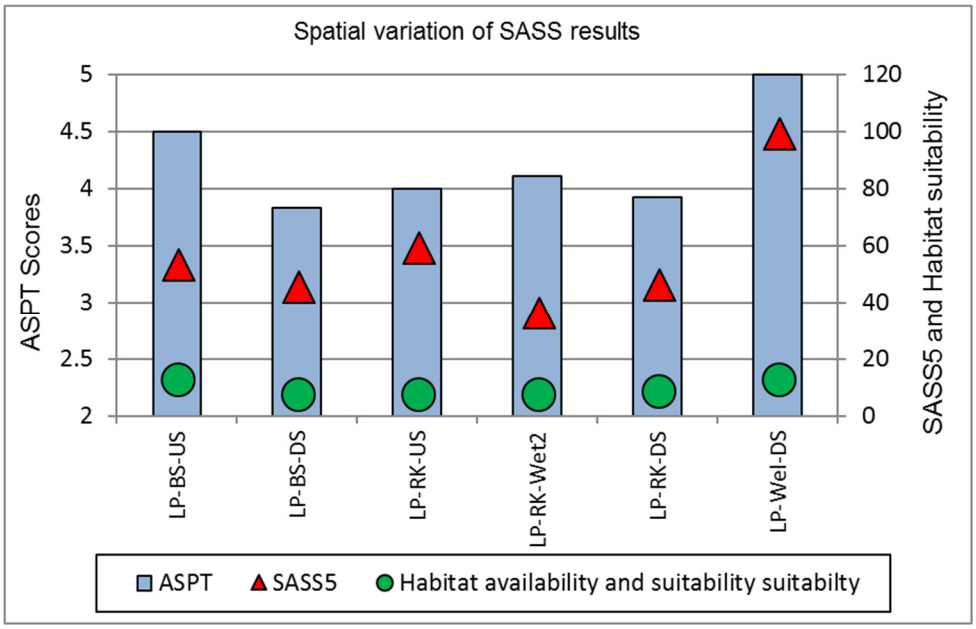


Figure 4: Summary of SASS5 results for Leeuwpan biomonitoring sites during June 2018.

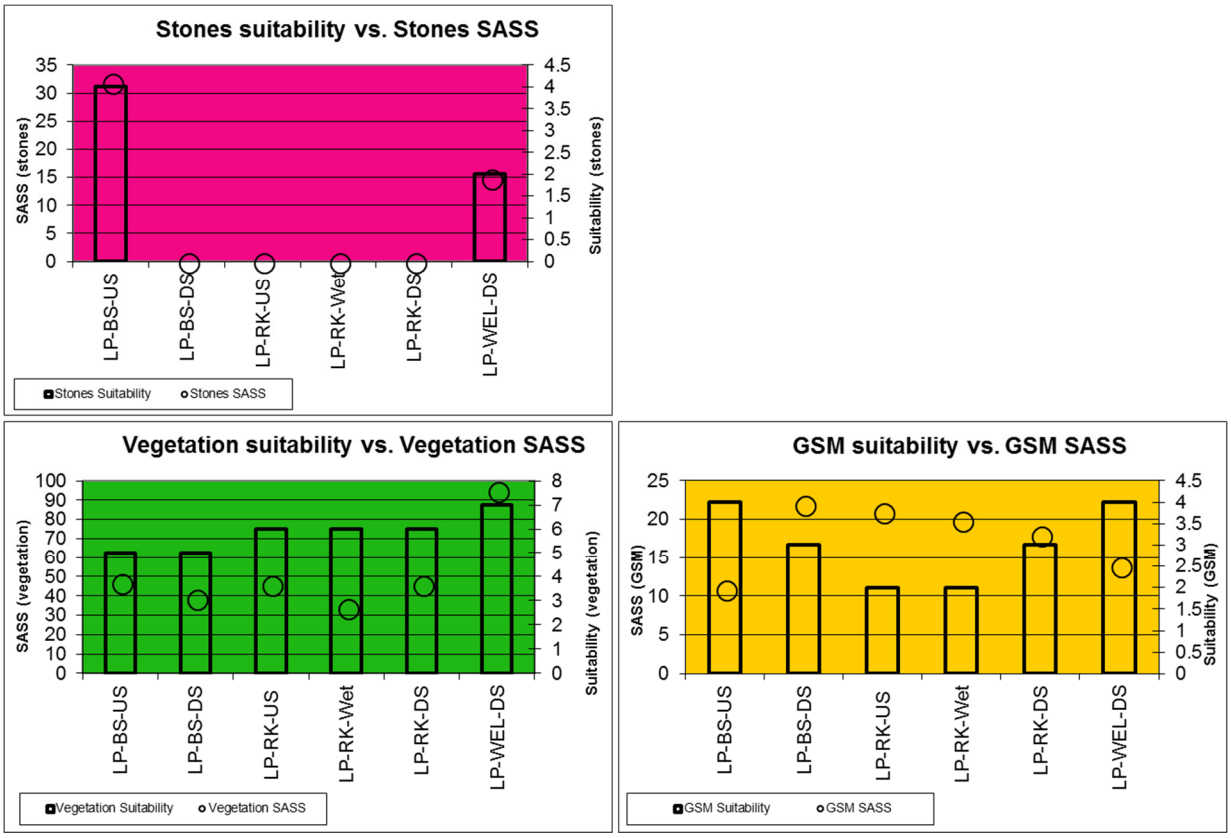


Figure 5: SASS biotope and biotope suitability & availability scores for Leeuwpan biomonitoring sites during June 2018.

3.6.2 Temporal trends

Many of the Leeuwpan biomonitoring sites are dry during winter months, making it difficult to analyse temporal trends. The only site that has consistently had sufficient water for SASS5 sampling has been the downstream Bronkhorstspruit site (LP-BS-DS). This site has shown substantial variation in SASS5 score in response to seasonal changes in water levels and associated habitat availability and suitability. The SASS score has, however, shown a declining linear trend (Figure 6), suggesting a loss of sensitive taxa in response to deteriorating water quality and/or declining habitats (e.g. lower water levels due to groundwater abstraction or algal proliferation due to increased nutrient or salt content). This trend should be closely monitored going forward to confirm (or negate) this negative trend.

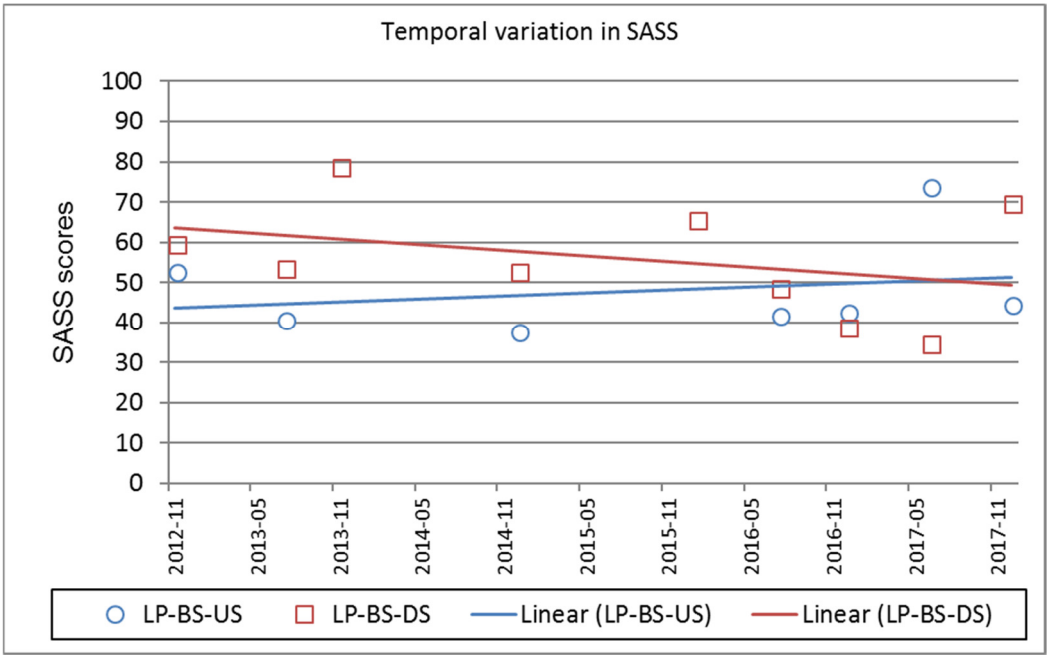


Figure 6.Temporal variation in SASS scores within the Bronkhostspruit since 2012.

3.7 Fish Assemblage Integrity Index (FAII)

Fish are sampled annually during the wet season survey (December). The results of the December 2017 survey are shown below.

Based on morphological characteristics and the limited number of sites, each sampling site was classified as a separate fish habitat segment. Therefore, the "frequency of occurrence of fish within segments" was omitted from FAII for separate monitoring sites. Comparison of relative FAII scores for different sites would firstly give a perspective of the relative condition of the fish community at different sites and secondly indicate on the potential impact of various anthropogenic activities up- and downstream of the different sites. Scores should however be treated with circumspection because the *frequency of occurrence* criterion was not considered, and the FAII scores are therefore less accurate. The list of fish species expected to occur at the sites under investigation is based on available information (Skelton, 1993, Le Roux & Steyn, 1968, Kleynhans et al., 2007) as well as experience from previous surveys (various Clean Stream biomonitoring programmes within similar catchments over the past two decades). The species intolerance ratings used in the calculation of the FAII was taken from Kleynhans (2002) and was based on specialisation of preferences towards habitat, food, flowing water and water quality.

3.7.1 Spatial trends (based on 2016-2017 fish data)

Five of the expected six indigenous fish species were sampled within the Bronkhorstspruit during the 2016/2017 surveys (Table 8).

The FAII (the Fish Assemblage Integrity Index) (Table 9), which is based on the last two sampling occasions to provide more accurate data (as species may be missed in a single sampling effort), indicates an improvement in biotic integrity, based on fish, at both upstream and downstream Bronkhorstspruit sites, with improving conditions in a downstream direction. No impacts due to Leeuwpan activities were therefore detected by the FAII.

Table 8: Naturally occurring indigenous fish species expected and observed during the last two surveys.

Species	Common name	Native/Exotic	LP-BS-US		LP-BS-DS	
			Exp	Obs	Exp	Obs
Enteromius anoplus	Chubbyhead barb	Native		2013 2014 2016 2017		2013 2014 2016 2017
Enteromius paludinosus	Straightfin barb	Native		2013 2014 2016		 2014 2016
Enteromius trimaculatus	Threespot barb	Native				
Clarias gariepinus	Sharptooth catfish	Native		2017		
Pseudocrenilabrus philander	Southern mouthbrooder	Native		2013		2013 2016 2017
Tilapia sparrmanii	Banded tilapia	Native		2013		2016
No. of naturally occuring species expected/present			6	3	6	4
% expected / observed (2016/2017)			50		67	

Key: Not sampled during the past two surveys, sampled the previous survey, sampled this survey

* Exotic species are by definition not expected to occur under natural conditions and therefore not taken into account for FAII calculations

Table 9: Relative FAII scores calculated at different sampling sites.

LOCALITY	RELATIVE FAII (%)
LP-BS-US Dec 2012	67.3
LP-BS-US Dec 2012/Dec 2013	67.3
LP-BS-US Dec 2013/Dec 2014	67.3
LP-BS-US Dec 2014/Jan 2016	67.3
LP-BS-US Jan 2016/Dec 2016	42.3
LP-BS-US Dec 2016/Dec 2017	53.8
LP-BS-DS Dec 2012	37.5
LP-BS-DS Dec 2012/Dec 2013	37.5
LP-BS-DS Dec 2013/Dec 2014	54.8
LP-BS-DS Dec 2014/Jan 2016	67.3
LP-BS-DS Jan 2016/Dec 2016	67.3
LP-BS-DS Dec 2016/Dec 2017	67.3

Most of the fish species expected within the study area (four of the six) are considered “tolerant” of changes in environmental conditions (such as water quality and flow), while two species were considered “moderately tolerant” (Table 10). No moderately to largely intolerant species are expected within the study area. It should be noted that these are seasonally flowing wetland systems and a high diversity is not

expected. Only slow-deep and slow-shallow biotopes are typically available for sampling at these sites (Figure 7), reflecting the wetland conditions within this watercourse.

The FAII index could not be applied at Weltevreden and Rietkuil sites. The limited habitat availability and suitability at these sites renders FAII results unreliable.

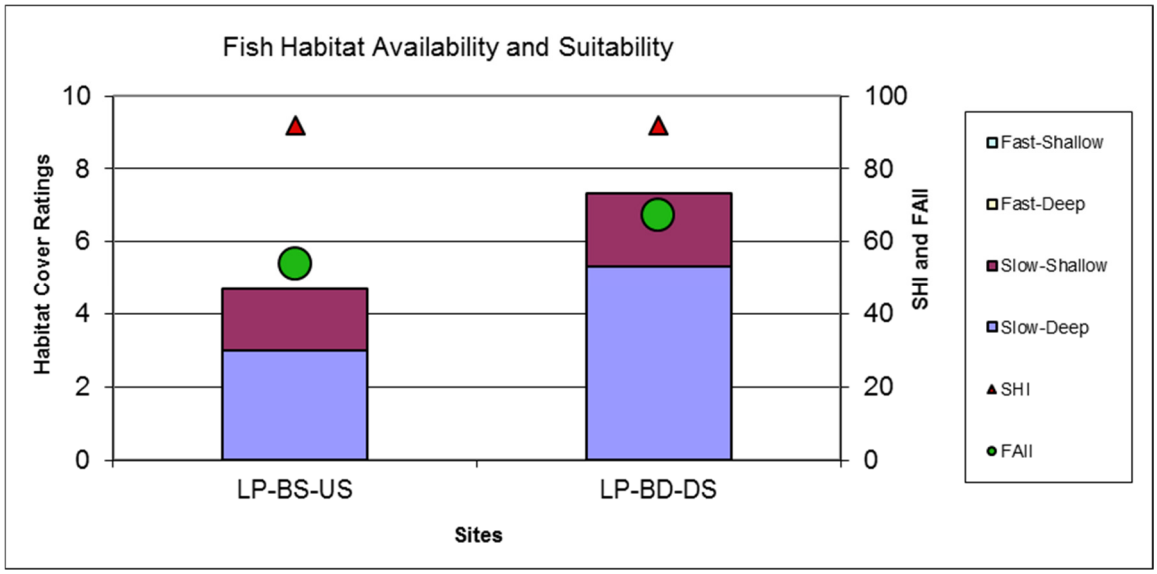


Figure 7: Relative FAII and HCR scores at the Bronkhorstspruit biomonitoring sites during December 2017.

Table 10: The relative tolerance of each expected species towards changes in the environment.

SPECIES NAME	Common name	Trophic specialisation	Habitat specialisation	Flow dependance	Requirement for high water quality	Total intolerance ratings
Barbus anoplus	Chubbyhead barb	2,8	2,8	2,3	2,6	2,6
Barbus trimaculatus	Threespot barb	3,1	1,4	2,7	1,8	2,2
Barbus paludinosus	Straightfin barb	1,6	1,4	2,3	1,8	1,8
Pseudocrenilabrus philander	Southern mouthbrooder	1,3	1,4	1,0	1,4	1,3
Tilapia sparrmanii	Banded tilapia	1,6	1,4	0,9	1,4	1,3
Clarias gariepinus	Sharptooth catfish	1,0	1,2	1,7	1,0	1,2

Key:
Intolerance ratings are colour shaded on a scale from green to red, with green being least inteolerant and red being most intolerant
Species are sorted in decending order from most intolerant (total intolerance rating) to least intolerant
1-2 = Tolerant 2-3 = Moderate tolerant 3-4 = Moderately intolerant 4-5 = Intolerant

4. CONCLUSIONS AND RECOMMENDATIONS

The findings of the June 2018 biomonitoring survey are summarised below:

Over the past year, the top part of the diversion has been mined through. As such, there was no upstream site available for sampling. While a trench has been constructed to the south of the original diversion, it does not drain any wetland areas and, as such, is not considered a wetland diversion, merely a trench. It is strongly recommended that a wetland specialist be consulted prior to constructing any new developments. These activities have essentially caused the loss of the wetland diversion and its associated biota. Not only does this amount to a loss of biodiversity, but it is likely to contribute to a decline in water quality downstream of the diversion, as well a reduction in flow within receiving wetlands (resulting in a gradual drying of wetland areas). A new wetland diversion should be constructed, in consultation with a wetland specialist.

An informal road has been constructed through the wetland at site LP-RK-Wet2, adjacent to new mining areas in the west. While it is unclear who is responsible for this road, it should be noted that a Water Use Licence is required for any construction activities taking place in a wetland. No provision has been made for stormwater drainage beneath this road (which has essentially been constructed from gravel deposited directly into the wetland) and it is likely that the road will cause erosion and water quality deterioration. This road should either be formalised in accordance with Water Use Licence requirements or should be removed from the wetland in its entirety.

Water sampled from all sites posed a **Class II (Slight) acute toxicity hazard**. Therefore, there was a slight risk of contamination to aquatic biota.

Salinity was extremely high in the Bronkhorstspruit and Rietkuil wetland. The salinity remained elevated in the receiving Weltevredenspruit, which also receives water from the diversion. The salinity at the downstream site was far greater than at the upstream site (281 mg/l at site LP-WEL-DS compared with 183mg/l at site LP-RK-US). High salt concentrations promote the proliferation of algae which, in turn, smother benthic and marginal habitats and affect water chemistry.

Sulphates were elevated in both the diversion and Rietkuilspruit, indicating contamination from mining activities.

Manganese was elevated at the downstream end of the diversion and exceeded the guideline limit for aquaculture, indicating a limitation to aquatic biota.

Turbidity was elevated within the Rietkuil wetland at site LP-RK-Wet2, largely due to the construction of the road within this wetland (i.e. the placement of gravel within the wetland for a temporary road).

Within the Bronkhorstspruit sub-catchment, the SASS5 score and ASPT decreased between the upstream site (LP-BS-US) and the downstream site (LP-BS-DS), this trend being confirmed by the most comparable biotope (vegetation). This suggests a decline in water quality between the two sites and echoes the results of the diatom assessment which found that species associated with industrial activities were more abundant at the downstream site, suggesting possible mining-related impacts. Both sulphates and ammonia increased in a downstream direction. It should be noted that ammonia can be toxic to aquatic biota.

The SASS5 results for the Rietkuil wetland were inconclusive due to low diversity. Reference should be made to the surface water quality monitoring data.

Further downstream, however, the SASS score and ASPT were higher than usual within the Weltevredenspruit. Flows were higher than usual (possibly due to recent rainfall or other inflows such as from a leaking pipeline) at site LP-WEL-DS and the biota had responded to the greater availability of habitats. The SASS score and ASPT were the highest recorded at this site since 2012.

Recommendations

The following recommendations are made:

- The diversion should be re-engineered to ensure that water from the upstream wetland reaches the receiving Weltevredenspruit, rather than being intercepted by mining areas. This should be done in consultation with a wetland specialist or hydrologist.
- The road that is being constructed through the wetland at site LP-RK-Wet2 should be formalised according to Water Use Licence conditions. Alternatively, it should be responsibly removed from the wetland.
- Water within the diversion, which discharges into the receiving Weltevredenspruit wetland, should be managed so that metal and salt concentrations fall within guideline limits for aquatic ecosystems and aquaculture (fish). The Class II toxicity hazard should be reduced by managing water quality.
- Reference should be made to surface water monitoring data to establish the source of salts reaching the receiving watercourses.
- Toxicity testing should include all PCDs and return water dams that could potentially discharge (in a controlled or uncontrolled manner) into receiving wetlands. Leeuwpan Colliery should identify the need for inclusion of additional PCDs in the toxicity testing programme.

5. REFERENCES

ABOATOX Oy. 2012. BO1243-500 BioToxTM Kit. Instructions for use. Savikuja 2. FIN-21250, Masku Finland. www.aboatox.com

BARBOUR MT and STRIBLING JB (1994) A technique for assessing stream habitat structure. Pp. 156-178, In: Proceedings of the conference "Riparian Ecosystems of the Humid U.S. Management, functions, and Values". National Association of Conservation Districts. Washington, DC

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1996. South African Water Quality Guidelines (second edition). Volume 4: Agricultural water use: Irrigation.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1996. South African Water Quality Guidelines (second edition). Volume 5: Agricultural water use: Livestock watering.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1996. South African Water Quality Guidelines (second edition). Volume 6: Agricultural water use: Aquaculture.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1996. South African Water Quality Guidelines (second edition). Volume 7: Aquatic Ecosystems.

DICKENS C and GRAHAM M (2001) South African Scoring System (SASS) Version 5 Rapid Bioassessment Method for Rivers. River Health Programme Web Page.

KEMPSTER, P. L. HATTINGH, W. H. J. & VAN VLIET, H. R. 1982. Summarised water quality criteria. Technical report NR. Tr 108. Department of Environmental Affairs.

KILIAN V. 1996. Fish Pathology (FHAI): A biomonitoring procedure for rapid evaluation of fish health and condition. Institute of Water Quality Studies, DWAF.

KLEYNHANS, C. J. 1997. *An exploratory investigation of the Instream Biological Integrity of the Crocodile River, Mpumalanga, as based on the Assessment of Fish Communities*. Draft Report, Department of Water Affairs and Forestry, Institute for Water Quality Studies. 61 pp.

KLEYNHANS, C. J. 1997. *An exploratory investigation of the Instream Biological Integrity of the Crocodile River, Mpumalanga, as based on the Assessment of Fish Communities*. Draft Report, Department of Water Affairs and Forestry, Institute for Water Quality Studies. 61 pp.

KLEYNHANS, C.J. 2002. Fish Intolerance ratings. Personal electronic communication of proceedings resulting from the national fish workshop held at the WRC during 2001.

KLEYHANS CJ, LOUW MD, MOOLMAN J. 2007. Reference frequency of occurrence of fish species in South Africa. Report produced for the Department of Water Affairs and Forestry (Resource Quality Services) and the Water Research Commission. Report TT 331-08.

LE ROUX, P & STEYN, S. 1968. Visse van Transvaal. Kaap & Transvaal Drukkers Beperk, Kaapstad. 108pp.

McMILLAN, P. H. 1998. *An Integrated Habitat Assessment System (IHAS v2), for the Rapid Biological Assessment of Rivers and Streams.* A CSIR research project. Number ENV-P-I 98132 for the Water Resources Management Programme. CSIR. ii + 44 pp.

MICROBIOTEST INC. 2012. DAPHTOXKIT F^{TM} MAGNA. Crustacean Toxicity Screening Test for freshwater. Standard Operational Procedure. Kleimoer 15, 9030 Mariakerke (Gent), Belgium. www.microbiotest.be.

SKELTON P. H., 1993. A complete guide to freshwater fishes of Southern Africa. Southern Book Publishers (Pty) Ltd., Halfway House. 388pp.

THIRION, C. A.; MOCKE, A & WOEST, R. 1995. Biological Monitoring of Streams and Rivers using SASS4: A User Manual. Final Report, No. N 000/00/REQ/1195. Institute of Water Quality Studies, Department of Water Affairs and Forestry.

Appendix 1: Methodology applied during this biomonitoring assessment.

1. *In-situ* water quality

The following surface water quality variables were measured on site: pH and Conductivity (Hatch HQ40d multimeter), water temperature, dissolved oxygen and oxygen saturation (Hatch HQ40d multimeter).

Water samples were submitted to Aquatico Scientific (Pty) Ltd for limited laboratory analysis (major anions and cations and selected metals only). Results were interpreted according to DWAF (1996) guidelines for aquatic ecosystems, aquaculture, irrigation and livestock watering.

2. Habitat assessment

An evaluation of habitat quality and availability to biota is critical to any assessment of ecological integrity and should be conducted at each site at the time of biological sampling. On site habitat assessments were conducted by using existing habitat evaluation indices.

3. Fish Habitat Assessment

This assessment is aimed at the determination of the potential of a site to provide habitat for fish (Fish habitat cover ratings) and to identify the potential human impact on the fish habitat (Site fish habitat integrity) (Kleynhans, 1997).

Fish Habitat Cover Rating (HCR)

This approach was developed to assess habitats according to different attributes that are surmised to satisfy the habitat requirements of various fish species (Kleynhans, 1997). At each site, the following depth-flow (df) classes are identified, namely:
Slow (<0.3m/s), shallow (<0.5m) - Shallow pools and backwaters.
Slow, deep (>0.5m) - Deep pools and backwaters.
Fast (>0.3m/s), shallow - Riffles, rapids and runs.
Fast, deep - Usually rapids and runs.

The relative contribution of each of the above mentioned classes at a site was estimated and indicated as:
0 = Absent
1 = Rare (<5%)
2 = Sparse (5-25%)
3 = Moderate (25-75%)
4 = Extensive (>75%)

For each depth-flow class, the following cover features (cf), considered to provide fish with the necessary cover to utilise a particular flow and depth class, were investigated:
- Overhanging vegetation
- Undercut banks and root wads
- Stream substrate
- Aquatic macrophytes

The amount of cover present at each of these cover features (cf) was noted as:
0 = absent
1 = Rare/very poor (<5%)
2 = Sparse/poor (5-25%)
3 = Moderate/good (25-75%)
4 = Extensive/excellent (>75%)

The fish habitat cover rating (HCR) was calculated as follows:
- The contribution of each depth-flow class at the site was calculated ($df/\Sigma df$).
- For each depth-flow class, the fish cover features (cf) were summed (Σcf).

$HCR = df/\Sigma df \times \Sigma cf$.

Site fish habitat integrity (SHI)

This approach is based on the assessment of physical habitat disturbance and is directed towards the indirect qualitative evaluation of fish habitat integrity, compared to the expected natural condition (Kleynhans, 1997). The following impacts (cause for fish habitat integrity degradation) is investigated, namely: Water abstraction, flow modification, bed modification, channel modification, inundation, exotic macrophytes, solid waste disposal, indigenous vegetation removal, exotic vegetation encroachment and bank erosion. Estimation of the impact of each of these modifications on the fish habitat integrity at a site is scored as follows:
No Impact = 0
Small impact = 1
Moderate Impact = 3
Large impact = 5

4. Aquatic invertebrate assessment: South African Scoring System, Version 5.

Benthic macro-invertebrate communities of the selected sites were investigated according to the South African Scoring System, version 5 (SASS5) approach (Dickens & Graham, 2001). This method is based on the British Biological Monitoring Working Party (BMWP) method and has been adapted for South African conditions by Dr. F. M. Chutter (Thirion *et al*., 1995). The SASS method is a rapid, simple and cost effective method, which has progressed through four different upgrades/versions. The current upgrade is Version 5, which is specifically designed to comply with international accreditation protocols.

Sample Collection

An invertebrate net (30 x 30cm square with 1mm mesh netting) was used for the collection of the organisms. The available biotopes at each site were identified on arrival. Each of the biotopes was sampled by different methods explained later (samples should not be collected when the river is in flood).

The biotopes were combined into three different groups, which were sampled and assessed separately:

a) Stone (S) Biotopes:
Stones in current (SIC) or any solid object: *Movable stones of at least cobble size (3 cm diameter) to approximately 20 cm in diameter, within the fast and slow flowing sections of the river.* Kicksampling is used to collect organisms in this biotope. This is done by putting the net on the bottom of the river, just downstream of the stones to be kicked, in a position where the current will carry the dislodged organisms into the net. The stones are then kicked over and against each other to dislodge the invertebrates (kicksampling) for ± 2 minutes.
Stones out of current (SOOC): *Where the river is still, such as behind a sandbank or ridge of stones or in backwaters.* Collection is again done by the method of kicksampling, but in this case the net is swept across the area sampled to catch the dislodged biota. Approximately 1 m^2 is sampled in this way.
Bedrock or other solid substrate: Bedrock includes stones greater than 30cm, which are generally immovable, including large sheets of rock, waterfalls and chutes. The surfaces are scraped with a boot or hand and the dislodged organisms collected. Sampling effort is included under SIC and SOOC above.

b) Vegetation (VG) Biotopes:
Marginal vegetation (MV): *This is the overhanging grasses, bushes, twigs and reeds growing on the edge of the stream, often emergent, both in current (MvegIC) and out of current (MvegOOC).* Sampling is done by holding the net perpendicular to the vegetation (half in and half out of the water) and sweeping back and forth in the vegetation (± 2m of vegetation).
Submerged vegetation (AQV): *This vegetation is totally submerged and includes Filamentous algae and the roots of floating aquatics such as water hyacinth.* Sampled by pushing the net (under the water) against and amongst the vegetation in an area of approximately one square meter.

c) Gravel, Sand and Mud (GSM) biotopes:
Sand: *This includes sandbanks within the river, small patches of sand in hollows at the side of the river or sand between the stones at the side of the river.* This biotope is sampled by stirring the substrate by shuffling or scraping of the feet, which is done for half a minute, whilst the net is continuously swept over the disturbed area.
Gravel: *Gravel typically consists of smaller stones (2-3 mm up to 3 cm).* Sampling similar to that of sand.
Mud: *It consists of very fine particles, usually as dark-collared sediment.* Mud usually settles to the bottom in still or slow flowing areas of the river. Sampling similar to that of sand.

d) Hand picking and visual observation:
Before and after disturbing the site, approximately 1 minute of "hand-picking" for specimens that may have been missed by the sampling procedures was carried out.

Sample preparation
The organisms sampled in each biotope group were identified and their relative abundance also noted on the SASS5 datasheet.

SASS-Habitat Assessment
A SASS-habitat assessment index, according to the habitats sampled, was performed due to the fact that changes in habitat can be responsible for changes in SASS5 scores. This was done by the application of the habitat suitability and availability index.

5. Fish Assemblage Integrity Index (FAII) (Kleynhans, 1997)
Due to the difficulty of applying the generally used Index of Biotic Integrity (IBI) in rivers of South Africa, Kleynhans (1997) developed an alternative approach. The following procedures were used in the application of the FAII:

Species tolerance ratings
The species intolerance ratings used in the calculation of the FAII were taken from Kleynhans (2002). Four components are taken into account in estimating the intolerance of the relevant fish species, namely habitat preferences and specialisation (HS), food preference and specialisation (TS), requirements for flowing water during different life-stages (FW) and water quality requirements (WQ). Each of these aspects are scored for a species according to low requirement/specialisation (rating=1), moderate requirement/ specialisation (rating=3) and high requirement/specialisation (rating=5). The total intolerance (IT) of a fish species is estimated as follows:
IT = (HS+TS+FW+WQ)/4

Health
The percentage of fish with externally evident disease or other anomalies are used to score this metric. The following procedure is used to score the health of individual species:
Frequency of affected fish >5%, score = 1
Frequency of affected fish 2 - 5%, score = 3
Frequency of affected fish <2%, score = 5
The expected health for a species living under unperturbed conditions is assumed to be unimpaired and would score 5.

The FAII is calculated as follows:
The *expected index score* [FAII (exp.)] per segment:
FAII (exp.) = Σ(TxH)
where: T = Tolerance rating for individual species
H = Expected health rating for individual species.

The *observed index score* [FAII (obs)] is calculated on a similar basis but is based on the information collected during the survey:
FAII (obs) = Σ(TxH).
The observed fish assemblage index score for a segment is expressed as a percentage of the expected total FAII score to arrive at a relative FAII rating:
FAII (obs) / FAII (exp.) x 100

Appendix 2: Detailed Results (SASS5, IHAS and FAII)

Table A1: IHAS results for Leeuwpan biomonitoring sites (June 2018).

Sampling Habitat	LP-BS-US		LP-BS-DS		LP-RK-US		LP-RK-Wet		LP-RK-DS		LP-WEL-DS	
	Desc	Score	Desc	Score	Desc	Score	Desc	Score	Desc	Score	Desc	Score
Stones In Current (SIC)												
Total length of white water rapids (ie: bubbling water) (in meters)	none	0	none	0	none	0	none	0	none	0	none	0
Total length of submerged stones in current (run) (in meters)	none	0	none	0	none	0	none	0	none	0	0-2	1
Number of separate SIC area's kicked	0	0	0	0	0	0	0	0	0	0	2-3	2
Average stone sizes kicked (in cm's)	none	0	none	0	none	0	none	0	none	0	>2-10	2
Amount of stone surface clear (in %)	n/a	0	n/a	0	n/a	0	n/a	0	n/a	0	0-25	1
Protocol: time spent actually kicking SIC's (in mins)	none	0	none	0	none	0	none	0	none	0	>1-2	2
SIC score (max 20)		0		0		0		0		0		8
Vegetation (VEG)												
Length of fringing vegetation sampled (banks) (in meters)	2	4	2	4	>1-2	3	>1-2	3	2	4	2	4
Amount of aquatic vegetation/algae sampled (in square meters)	0-0.5	1	0-0.5	1	>1	3	>1	3	>0.5-1	2	>1	3
Fringing vegetation sampled in	mix	5	pool	3	pool	3	pool	3	mix	5	mix	5
Type of veg. (percent leafy as apposed to stems/shoots)	26-50	3	26-50	3	26-50	3	26-50	3	26-50	3	26-50	3
Veg score (max 15)		13		11		12		12		14		15
Other Habitat / General (O.H.)												
Stones Out Of Current (SOOC) sampled (in square meters)	1	3	none	0	none	0	none	0	none	0	0-0.5	1
Sand sampled (in minutes)	none	0	none	0	none	0	none	0	under	1	under	1
Mud sampled (in minutes)	0.5	3	0.5	3	0.5	3	0.5	3	0.5	3	0.5	3
Gravel sampled (in minutes)	none	0	none	0	none	0	none	0	none	0	0-0.5	1
Bedrock sampled (all = no SIC, sand, gravel)	some	1	none	0	none	0	none	0	none	0	none	0
Algal presence (m^2)	>1-2sqm	2	>2sqm	0	isolated	4	isolated	4	>1-2sqm	2	>2sqm	0
Tray identification	correct	3	correct	3	correct	3	correct	3	correct	3	correct	3
O.H. score (max 20)		12		6		10		10		9		9
Sampling habitat totals (max 55)		25		17		22		22		23		32
Stream Condition												
Physical												
River make up	2 mix	4	pool	0	pool	0	pool	0	2 mix	4	2 mix	4
Average width of stream (in meters)	1-2	4	>2-5	5	>2-5	5	>2-5	5	1-2	4	1-2	4
Average depth of stream (in meters)	0.5	4	>0.5-1	3	0.5	4	>0.5-1	3	>0.5	5	>0.5	5
Approximate velocity of stream	mix	5	mix	5	still	0	still	0	mix	5	medium	3
Water colour	discoloured	3	discoloured	3	discoloured	3	discoloured	3	clear	5	clear	5
Recent disturbances	none	5	none	5	none	5	none	5	none	5	other	3
Bank/Riparian vegetation	grass	2	grass	2	grass	2	grass	2	grass	2	grass	2
Surrounding impacts	farming	1	farming	1	farming	1	farming	1	other	3	other	3
Left bank cover (rocks and vegetation) (in %)	51-80	1	51-80	1	51-80	1	51-80	1	51-80	1	>95	3
Right bank cover (rocks and vegetation) (in %	51-80	1	51-80	1	51-80	1	51-80	1	51-80	1	>95	3
Stream condition total (max 45)		30		26		22		21		35		35
Total IHAS score (%)		55		43		44		43		58		67

Table A2: SASS5 results for Leeuwpan biomonitoring sites (June 2018).

Taxon	Common name	LP-BS-US				LP-BS-DS				LP-RK-US				LP-RK-Wet				LP-RK-DS				LP-WEL-DS			
		Stones	Veg	GSM	Total	Stones	Veg	GSM	Total	Stones	Veg	GSM	Total	Stones	Veg	GSM	Total	Stones	Veg	GSM	Total	Stones	Veg	GSM	Total
Oligochaeta	Aquatic earthworms	A	-	B	B	-	-	A	A	-	A	A	A	-	-	-	-	-	-	A	A	-	-	1	1
Leeches	Leaches	-	-	-	-	-	-	-	-	-	A	-	A	-	-	-	-	-	-	-	-	-	-	-	-
HYDRACARINA	Water mites	A	B	-	B	-	B	A	B	-	A	-	A	-	B	A	B	-	1	1	A	-	1	-	1
Baetidae 1 sp.	Small minnow flies	A	B	-	B	-	A	-	A	-	A	-	A	-	A	-	A	-	-	-	-	A	-	-	A
Baetidae 2 spp.	Small minnow flies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	B	-	B	-	B	B	B
Caenidae	Cainflies	A	-	-	A	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	A
Leptophlebiidae	Prongills	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Coenagrionidae	Damselflies	-	A	-	A	-	1	-	1	-	A	1	A	-	-	-	-	-	A	-	A	-	A	-	A
Aeshnidae	Dragonflies	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	1	-	1
Libelludae	Dragonflies	-	-	-	-	-	-	-	-	-	A	-	A	-	-	-	-	-	-	-	-	1	-	-	1
Belostomatidae*	Giant water bug	-	-	-	-	-	-	-	-	-	A	-	A	-	1	-	1	-	1	-	1	-	1	-	1
Corixidae*	Water boatmen	B	B	B	C	-	-	A	A	-	-	A	A	-	-	A	A	-	1	A	A	-	-	-	-
Gerridae*	Pond skater	-	-	-	-	-	-	-	-	-	A	-	A	-	-	-	-	-	-	-	-	-	A	-	A
Notonectidae*	Back swimmers	A	A	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	1
Pleidae*	Pigmy backswimmers	-	-	-	-	-	A	-	A	-	A	-	A	-	A	A	B	-	B	B	B	-	B	-	B
Veliidae*	Broad-shouldered water strid	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Dytiscidae (adults*)	Predacious diving beetles	A	B	A	B	-	A	-	A	-	1	-	1	-	A	1	A	-	A	-	A	-	A	-	A
Hydrophilidae (adults*)	Water scavenger beetles	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-
Ceratopogonidae	Biting midges	-	A	-	A	-	A	A	B	-	-	-	-	-	A	-	A	-	-	-	-	A	A	1	A
Chironomidae	Midges	A	B	B	B	-	B	B	B	-	B	B	B	-	A	-	A	-	A	A	B	A	A	A	B
Culicidae*	Mosquitoes	-	-	-	-	-	A	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dixidae*	Meniscus midges	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	A
Ancylidae	Limpets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	A
Physidae*	Pouch snails	-	A	-	A	-	-	-	-	-	-	A	A	-	-	-	-	-	A	-	A	-	A	-	A
Planorbinae*	Orb snails	-	-	-	-	-	-	-	-	-	A	-	A	-	A	-	A	-	-	-	-	-	A	-	A
Sphaeridae	Pill clams	-	-	-	-	-	-	B	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total SASS5 score		32	47	11	54	0	39	22	46	0	46	21	60	0	34	20	37	0	46	18	47	15	95	14	100
No. of families		8	10	4	12	0	9	6	12	0	12	6	15	0	8	4	9	0	11	5	12	4	18	4	20
ASPT		4.00	4.70	2.75	4.50	0.00	4.33	3.67	3.83	0.00	3.83	3.50	4.00	0.00	4.25	5.00	4.11	0.00	4.18	3.60	3.92	3.75	5.28	3.50	5.00
Total IHAS					55				43				44				43				58				67
IHAS - Habs sampled					25				17				22				22				23				32
IHAS - Stream condition					30				26				22				21				35				35
Suitability score		4	5	4	13	0	5	3	8	0	6	2	8	0	6	2	8	0	6	3	9	2	7	4	13

Key: High requirement for unmodified water quality
Moderate requirement for unmodified water quality
Low requirement for unmodified water quality
Very low requirement for unmodified water quality
Veg=Vegetation

A = 1-10 individuals; B = 11-100 individuals; C = 101-1000 individuals; ASPT = Average score per taxon.

Table A3: Fish Assemblage Integrity Index (FAII) scores calculated for the different sampling sites (2016/2017).

SPECIES	Tolerance rating		Health rating		SCORE	
	LP-BS-US	LP-BS-DS	LP-BS-US	LP-BS-DS	LP-BS-US	LP-BS-DS
ENTEROMIUS ANOPLUS	2.6	2.6	5	5	13.0	13.0
ENTEROMIUS PALUDINOSUS	1.8	1.8	5	5	9.0	9.0
ENTEROMIUS TRIMACULATUS	2.2	2.2	5	5	11.0	11.0
CLARIAS GARIEPINUS	1.2	1.2	5	5	6.0	6.0
PSEUDOCRENILABRUS PHILANDER	1.3	1.3	5	5	6.5	6.5
TILAPIA SPARRMANII	1.3	1.3	5	5	6.5	6.5
				Expected	52.0	52.0
ENTEROMIUS ANOPLUS	2.6	2.6	5	5	13.0	13.0
ENTEROMIUS PALUDINOSUS	1.8	1.8	5	5	9.0	9.0
ENTEROMIUS TRIMACULATUS					0.0	0.0
CLARIAS GARIEPINUS	1.2		5		6.0	0.0
PSEUDOCRENILABRUS PHILANDER		1.3		5	0.0	6.5
TILAPIA SPARRMANII		1.3		5	0.0	6.5
				Observed	28.0	35.0
				Relative (%)	**53.8**	**67.3**

Appendix 3: Site photos of Leeuwpan biomonitoring sites




Plate A1: View of site LP-BS-US June 2017




Plate A2: View of site LP-BS-US December 2017




Plate A3: View of site LP-BS-US June 2018




Plate B1: View of site LP-BS-DS June 2017




Plate B2: View of site LP-BS-DS December 2017




Plate B3: View of site LP-BS-DS June 2018



Plate C1: View of site LP-RK-US June 2017



Plate C2: View of site LP-RK-US December 2017



Plate C3: View of site LP-RK-US June 2018




Plate E1: View of site LP-RK-Wet2 June 2018




Plate F1: View of site LP-RK-DS June 2017




Plate F2: View of site LP-RK-DS December 2017




Plate F3: View of site LP-RK-DS June 2018




Plate G1: View of site LP-WEL-DS – June 2017




Plate G2: View of site LP-WEL-DS – December 2017




Plate G3: View of site LP-WEL-DS – June 2018

Addendum A: Toxicity Testing Report

Annexure G
May 2018 Wetland Monitoring Report



Leeuwpan Coal Mine
Wetland Monitoring Summer Season 2017/18



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DOCUMENT SUMMARY DATA

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INDEMNITY AND CONDITIONS RELATING TO THIS REPORT

The findings, results, observations, conclusions and recommendations given in this report are based on the author's best scientific and professional knowledge as well as available information. The report is based on survey and assessment techniques which are limited by time and budgetary constraints relevant to the type and level of investigation undertaken and Wetland Consulting Services (Pty.) Ltd. and its staff reserve the right to modify aspects of the report including the recommendations if and when new information may become available from ongoing research or further work in this field, or pertaining to this investigation.

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1. BACKGROUND INFORMATION

Wetland Consulting Services (Pty.) Ltd. was appointed by Clean Stream Biological Services (CSBS) to undertake the wetland component of the Biomonitoring Programme developed for Leeuwpan Coal Mine and being undertaken by CSBS.

The specific objectives of this report, the wetland component, are as follows:

- Assess the current status of selected sample wetlands in terms of habitat integrity.
- Determine spatial and temporal changes in wetland status in relation to mining activities.
- Conduct monitoring on potential receiving wetlands associated with Leeuwpan mining activities.
- Establish and broaden baseline wetland data against which future changes in the health of these systems can be evaluated.
- Recommend refinements for an efficient and appropriate wetland component to the biomonitoring programme to be followed for routine biomonitoring.

This is the third annual wetland monitoring report being compiled for Leeuwpan Coal Mine. Previous monitoring reports were compiled for the 2015/16 summer season (WCS, 2016) and the 2016/17 summer season (WCS, 2017).

2. SCOPE OF WORK

The following task formed part of the agreed upon scope of work:

- To conduct wetland monitoring as part of a broader biomonitoring and habitat monitoring programme using the wetland-IHI or other suitable monitoring protocols.
- Wetland monitoring to be conducted annually (in summer, January - March).
- The ecological integrity of the diversion to be assessed annually in terms of erosion and sedimentation and rehabilitation success.
- Invasion by alien vegetation to be assessed annually at monitoring sites.
- Monitoring sites as specified in the ‘Scope of Work’ document and shown in Figure 1 below.
- Assess the ecological status of wetlands and watercourses upstream and downstream of mining areas using appropriate tools.
- Assess the integrity of habitats and impacts (or improvements) to aquatic ecosystems as a result of mining activities.
- Establish and populate a dataset in order to observe temporal variation in biotic integrity, i.e. improvement/deterioration over time.
- Compile a report detailing the findings and giving practical recommendations for mitigation or management.

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3. LIMITATIONS & ASSUMPTIONS

No delineation or verification of wetland boundaries was undertaken as part of this wetland monitoring component. Use was made of existing wetland information as detailed in the specialist wetland report accompanying the EIA and Water Use License submissions for Leeuwpan Coal Mine: *Wetland Delineation and Assessment for the Exxaro Leeuwpan Coal Mine near Delmas, Mpumalanga*. October 2012. Report reference 842/2012. Wetland Consulting Services.

The site visits were undertaken over two days in summer 2017/18 in the month of February 2018:

- 7 & 8 February 2018

4. MONITORING SITES

The Leeuwpan Coal Mine is located to the south east of Delmas in the Mpumalanga Province. The R50 road to Leandra crosses the Leeuwpan Mining Rights Area (MRA).

The Bronkhorstspruit and an unnamed tributary cross the MRA roughly from south to north.

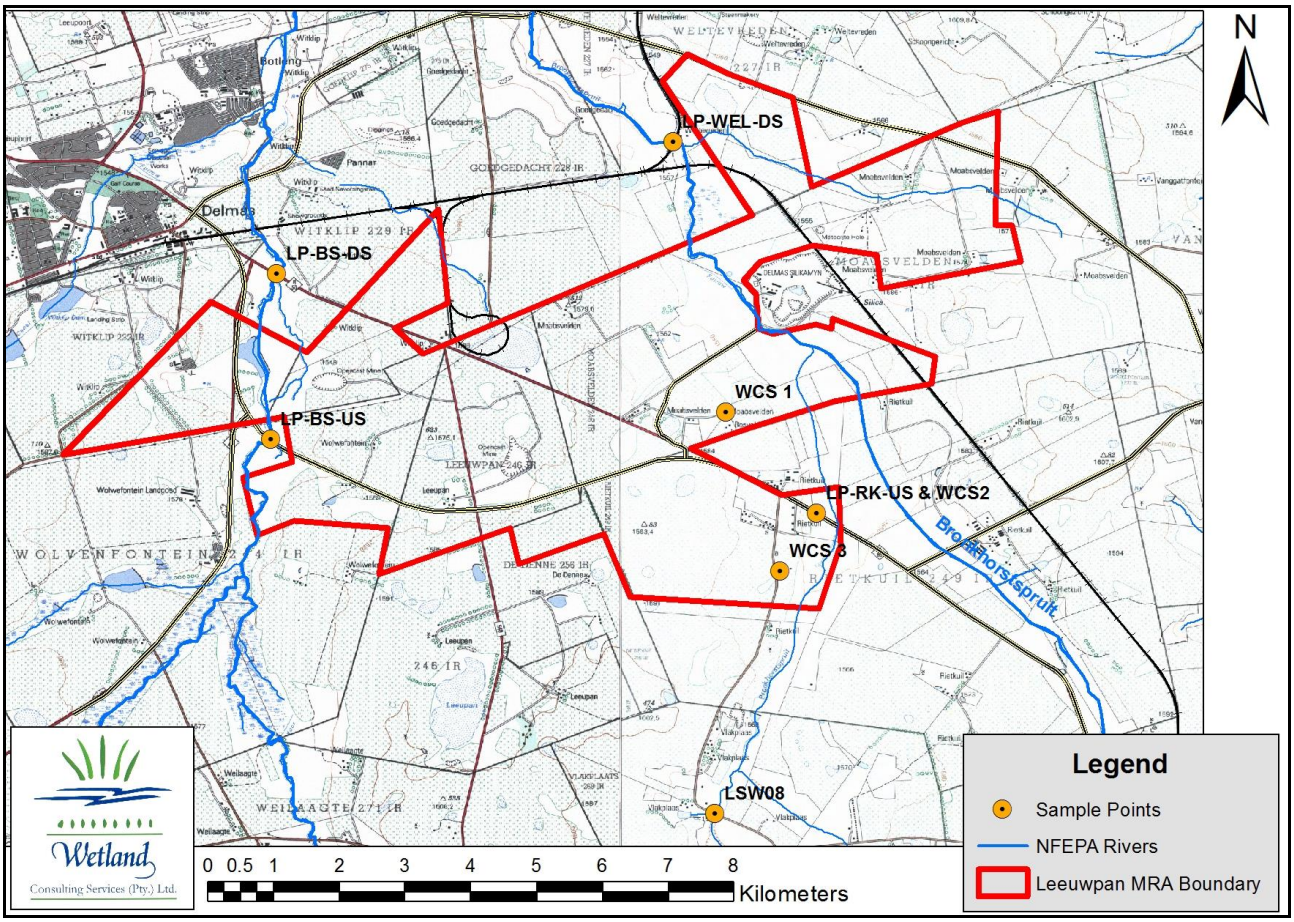


Figure 1. Map showing the location of the sample sites included in the wetland component.

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7 monitoring sites were selected for the wetland monitoring component. These monitoring sites overlap with those selected for other components of the greater biomonitoring programme and are based on monitoring recommendations from the various environmental authorisation applications.

Two of the recommended monitoring sites, LP-RK-US and WCS 2, were however located on the same system and within 200m of each other along the same R50 road crossing over the wetland. For the purpose of the wetland component, these two sites were therefore consolidated into a single monitoring site.

Table 1. Summary of monitoring sites included for the wetland component.

Sample Site	Wetland Type	X co-ordinate	Y co-ordinate
LP-BS-DS	Channelled valley bottom	-26.155300	28.702600
LP-BS-US	Channelled valley bottom	-26.177907	28.701807
LP-WEL-DS	Channelled valley bottom	-26.137301	28.756897
WCS 1	Hillslope seepage	-26.174193	28.764151
LP-RK-US & WCS2	Unchannelled valley bottom	-26.187985	28.776571
WCS 3	Channelled valley bottom	-26.195952	28.771537
LSW08	Unchannelled valley bottom	-26.229100	28.762594

5. APPROACH

5.1 Ecological Integrity of Diversion

A walk down survey was undertaken of the entire river diversion, from the discharge near the western boundary of the Leeuwpan MRA to the upstream end of the diversion trench. The purpose of the walkdown was to collect observations on the ecological integrity of the diversion. Specifically the following aspects were considered:

- Structural stability of the diversion (e.g. slumping of side slopes etc.).
- Signs of erosion within the diversion and along side slopes.
- Signs of sedimentation.
- Establishment of vegetation.
- Presence of alien plant species.
- Connectivity of diversion habitat with adjacent habitats and wetland systems.
- Impact of adjacent activities on the river diversion.

5.2 Wetland Monitoring

Initially it had been indicated that the Wetland Index of Habitat Integrity (Wetland-IHI) (DWAF, 2007) should be utilized as the monitoring tool for the wetlands on site. However, the Wetland-IHI is only applicable to channelled floodplain and valley bottom wetland systems and as such would

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only be useful at three of the seven wetland monitoring sites, with a different tool required for the remaining 4 wetland sites. Rather than undertake monitoring via different protocols at various sites, ***it was therefore decided that the WET-Health Level 1 methodology be applied at all of the wetland monitoring sites.***

A present ecological state (PES) assessment was conducted for every wetland monitoring unit selected. For the purpose of this study the Level 1 assessment as described by the WET-Health manual (Macfarlane *et al*., 2009), was applied for the determination of the PES.

5.2.1 Selection of wetland monitoring units

The specific wetland monitoring points have been specified within previous biomonitoring studies and environmental authorizations. In order to tie in with these documents, the same monitoring points were used for the wetland monitoring component.

However, the WET-Health assessment tool was designed to be applied at the level of a wetland hydro-geomorphic unit (HGM unit), and not on a point locality. For each wetland monitoring point, a wetland assessment unit was therefore identified. In most cases a wetland section approximately 1 km in length was selected as the assessment unit, though in the case of monitoring sites WCS 1 and WCS 3, the assessment units are somewhat smaller given the location and types of wetland systems in question.

5.3 Alien Vegetation Survey

At each of the wetland monitoring points a rapid alien vegetation survey was undertaken. The purpose of the survey was to identify invasive alien species occurring within the wetlands and to provide an indication of the size and extent of the infestation. The survey did not aim to provide a complete list of all alien species occurring within the wetlands, but focused on invasive alien species. Naturalised alien species such as for example *Paspalum urvillei* or *Oenothera rosea* were not included in the alien vegetation survey.

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6. FINDINGS

6.1 Ecological Integrity of River Diversion

At the time of the field survey in February 2018, there was found to be no link between the upstream wetland and the Leeuwpan river diversion. The diversion was therefore considered to be wholly dysfunctional at the time.

A map of the Leeuwpan river diversion is provided in Figure 2. The diversion was constructed in phases as mining progressed in a westerly direction, and had been extended between the first monitoring event in the 2015/16 summer and the previous monitoring event during the 2016/17 summer season (refer to Figure 2), and altered again prior to the current monitoring survey in the 2017/18 summer, with the upstream end of the diversion mined through. This phased construction of the diversion is also clearly evident on site in terms of vegetation succession along the diversion, with the upstream end being the most recently constructed and largely devoid of vegetation, and the downstream end being the oldest and thus furthest along in terms of succession.

Based on our observations, it appears as though no attempt had been made to establish vegetation within the diversion, but that re-vegetation had been left to occur naturally.

The diversion was divided into three approximate zones based on the stage of succession and vegetation characteristics of the diversion, as discussed below and illustrated in Figure 2:

Zone A – B: Most upstream zone of the diversion surveyed during summer 2015/16 and 2016/17, but which has been mined through and no longer exists.
Zone B – C: Intermediate zone.
Zone C – D: More established zone

Zone A - B represents the most upstream zone of the diversion surveyed during summer 2015/16 and 2016/17, but which has been mined through and no longer exists. ***There is currently no link between the upstream wetland and the stream diversion, and as such no link from the upstream wetland to the watercourses downstream of the mine***.

Zone B - C of the diversion stretches for approximately 0.55 km is characterized by a narrower base to the diversion, but gentler sloped side slopes and a partially vegetated diversion base. Plant species however were typical pioneer and weed species, including agricultural weeds such as *Bidens bipinnata, B. pilosa, Conyza albida, Cyperus esculentus, Datura ferox, Panicum sp.* and *Tagetes minuta*. Very few if any obligate wetland species were observed. Although the diversion base within this reach was mostly dry, occasional pools of turbid water were observed, though no signs of significant longitudinal flow along the diversion could be observed in terms of flow debris. Immediately adjacent to the diversion a number of berms and overburden/soil stockpiles occur that create barriers between the diversion and surrounding terrestrial and wetland habitats, isolating the diversion habitat.

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- Point 1 (see Figure 2 above) - an infestation of the invasive alien tree *Acacia mearnsii* (black wattle) was observed, with more than 10 individuals of varying sizes, indicating active recruitment. These trees were also noted during the previous surveys.
- Point 2 – flow impoundment was observed adjacent to the diversion on the upslope side. The presence of berms along the diversion prevent lateral flow from the sideslope entering the diversion. Also observed was stormwater from the haul road entering the diversion, resulting in sedimentation.

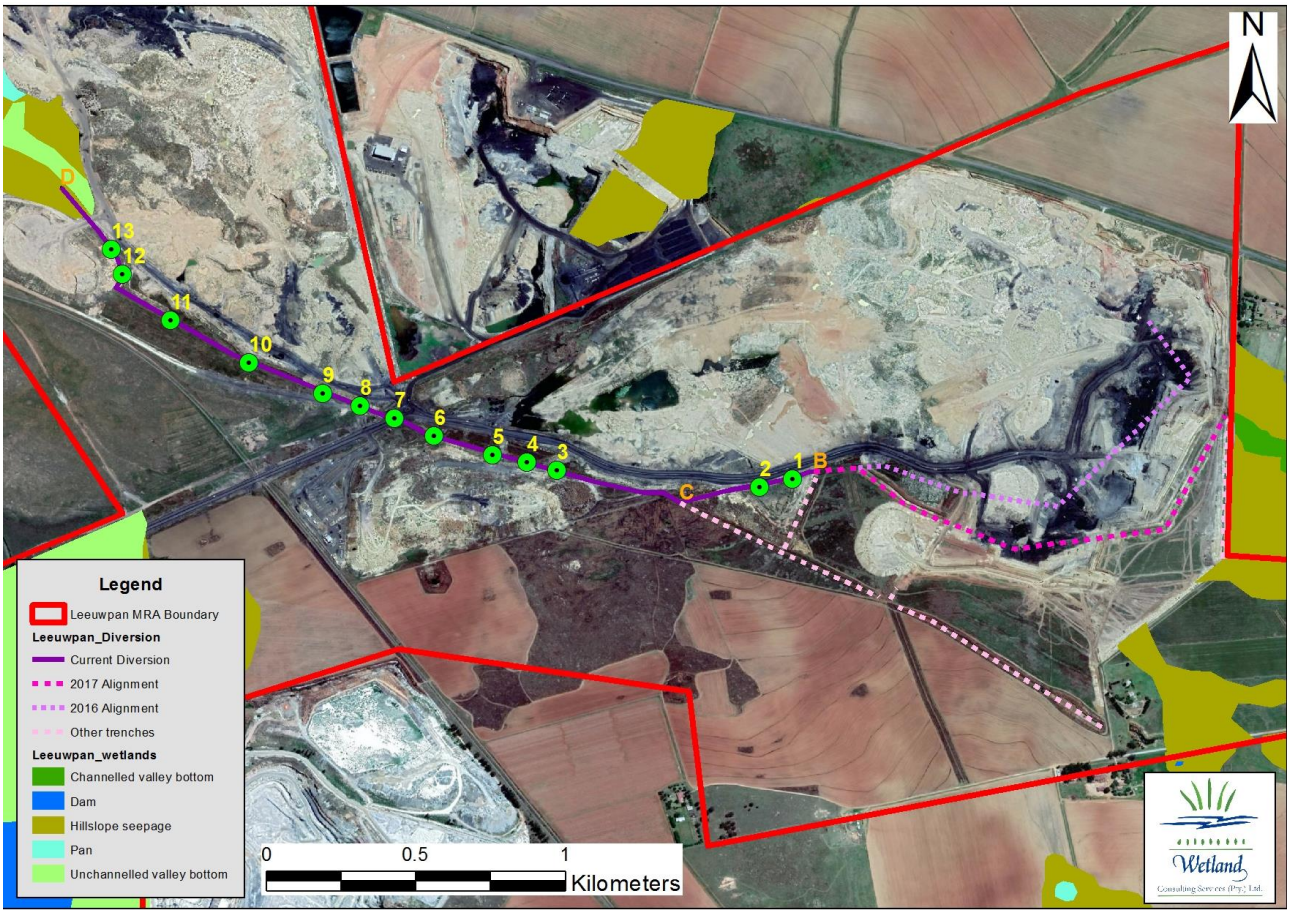


Figure 2. Map of the river diversion in relation to mining activities and remaining wetlands. Note the changes to the upstream end of the diversion over the years. Points marked along the diversion (A-D and 1-9) are discussed in the text below.

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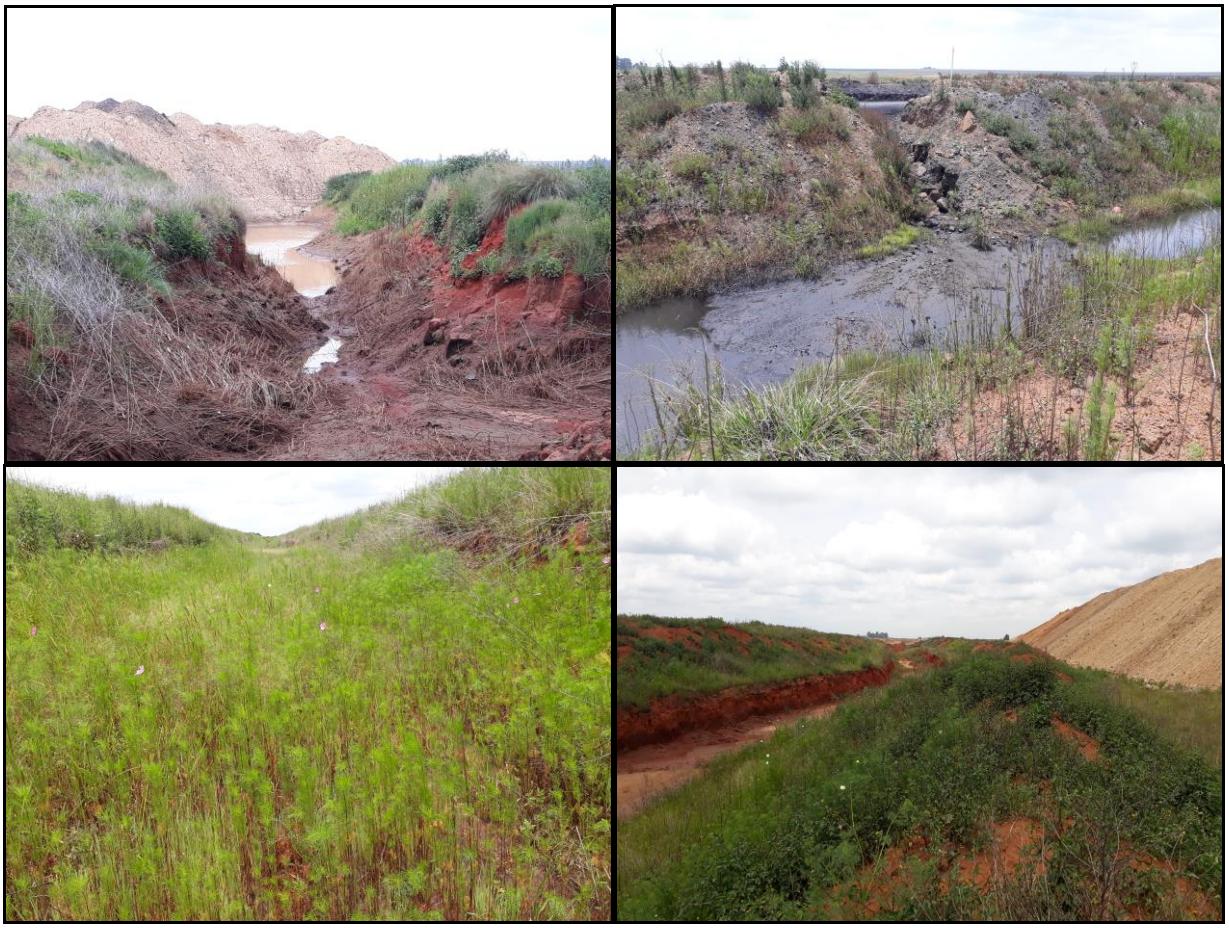


Figure 3. Photographs of the river diversion in zone B-C. Upstream end of diversion cut off by mining activity (top left), stormwater from haul road entering diversion and leading to sedimentation (top right), vegetation dominated by the alien weed *Bidens formosa* (bottom left) and vertical banks and poor vegetation cover characterise large section of the upstream end of the diversion (bottom right).

Zone C - D, which stretches for roughly 2.3 km, represents the most established section of the diversion. The diversion is characterized by a base roughly 5-8 meters wide and fairly gentle side slopes for most of the reach, while the diversion is also mostly vegetated. Weeds and pioneers predominate in terms of vegetation species, though obligate wetland species typically observed in surrounding natural wetland systems also occur in areas of increased wetness. In the vicinity of the haul road crossing (Point 6) reed beds have become established in areas where water accumulates in the diversion; *Typha capensis* upstream of the haul road and *Phragmites australis* downstream of the haul road. Other typical wetland species observed include *Agrostis lachnantha, Leersia hexandra* and *Persicaria* sp. Once again however the vegetation is dominated for large parts by weeds and pioneers typical of agricultural fields. No longitudinal flow of water, or signs thereof, could be observed within the diversion. African Clawed Toad (*Xenopus laevis*) tadpoles were observed within the diversion, indicating the presence of permanent or near permanent water. Of further interest were the tracks of water mongoose (*Atilax paludinosus*) and cape clawless otter (*Aonyx capensis*) observed within the diversion.

Points of interest along this section include:

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- Point 3 – flow impoundment occurs at this point due to excessive sediment inputs, presumably entering the diversion via stormwater runoff from the adjacent overburden dump. Low flows are impounded and do not pass this point, though high flows are likely to pass. This was already observed during the previous survey.
- Point 4 – erosion of the adjacent stockpile is causing excessive sedimentation within the diversion.
- Point 5 – two individuals each of the alien species *Acacia mearnsii* and *Tamarix ramosissima* were observed at this location. These were already observed during the previous survey.
- Point 6 – several individuals of *Salix babylonica* and *Acacia mearnsii* observed within the diversion.
- Point 7 – haul road crossing.
- Point 8 – several Poplar saplings (probably *Populus deltoides*) observed.
- Point 9 – the alien pom-pom weed, *Campuloclinium macrocephalum*, was observed at this point. This stand is rapidly spreading; during the previous summer season in the region of 50 – 100 flowering heads were noted. This year it was estimated that more than 1000 flowering heads occurred.
- Point 10 – a single *Salix babylonica* specimen observed, roughly 3.5 m in size.
- Point 11 – a single Poplar specimen (probably *Populus deltoides*) observed, roughly 2 m in size.
- Point 12 - the large alien grass, *Cortaderia*, occurs along this section of the diversion.
- Point 13 – adjacent overburden stockpile eroding into diversion, resulting in excessive sediment deposition.



Figure 4. Photographs of the river diversion in zone C-D. Recent excavation within the diversion (left) and infestation of Pompom Weed (*Campuloclinum macrocephalum*) along the diversion (right).

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Figure 5. Photographs of the river diversion in zone C-D. Numerous saplings of *Populus deltoides* were observed along the diversion (left) and overburden stockpiles located immediately adjacent to the diversion and eroding into the diversion (right).

The findings of the walkdown survey and ecological assessment of the river diversion largely echo the findings from previous year's wetland monitoring reports (WCS, 2016 and 2017), with the significant exception that the upper end of the diversion has been mined through and **NO CONNECTION EXISTS BETWEEN THE DIVERSION AND THE UPSTREAM WETLAND**. As such the diversion is currently not functional and urgent intervention is required to ensure clean water flows from upstream enter the diversion and flow further into downstream water resources.

In addition, large sections of the river diversion have the appearance of a temporary diversion canal rather than a permanent stream diversion. The entire diversion is highly disturbed and generally poorly vegetated, being dominated by weedy and pioneer species. It appears as though little if any longitudinal flow occurs along the diversion under normal conditions. Lateral flows are also largely obstructed from entering the diversion.

From an ecological point of view the confined nature of the diversion, vertical channel walls for long sections and adjacent berms and stockpiles, severely limit the opportunity for the formation of a lateral ecotonal link between the aquatic habitat and the remaining adjacent terrestrial habitat. The only possible hydrological variation in the system under current conditions is vertical.

It is our recommendation that the design of the river diversion be re-evaluated in terms of hydrological functionality as well as ecological sustainability in the long-term (post-mining) and that interventions are implemented to improve the diversion. The following ecological objectives should be considered:

- To improve habitat heterogeneity across the entire footprint of the diversion;
- To improve longitudinal flow connectivity along the diversion;
- To improve the availability of suitable habitat for aquatic fauna;
- To improve the quality or suitability of existing habitats for aquatic fauna;
- To increase lateral connectivity between the diversion and the adjacent terrestrial habitat;
- To manage water quality;

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- To increase in-stream habitat diversity and velocity variation to improve longitudinal connectivity and biodiversity; and
- To try to improve the aesthetics of the feature, imparting a more “natural” appearance.

It was indicated by mine personnel that the intention is to recreate a watercourse across the rehabilitated opencast area. If this is the case, the design of the re-created watercourse should be guided by the same objectives as listed above, but should also consider the risks of increased ingress of water into the opencast pits, which could lead to an increase in the generation of dirty/decant water requiring treatment. The recreated watercourse will therefore need to be appropriately designed to ensure ingress is limited. ***It is also considered of critical importance that specialist inputs from a wetland scientist and/or ecologist are obtained to ensure appropriate design of the recreated watercourse***.

The re-design of the river diversion is however likely to be a lengthier process. In the short term, the following should be addressed:

- All alien invasive species should be removed from the diversion, with regular follow-up surveys to ensure all invasive species are eradicated.
- All flow impediments in the diversion need to be removed to ensure flow through the diversion is possible.
- Lateral flows from clean catchment should be allowed to enter the diversion. Flow impoundment along soil berms adjacent to the diversion must be avoided.

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Table 2. List of plant species recorded at 4 sites within the stream diversion for monitoring purposes. Note the high occurrence of ruderal and weedy species.

Wetland System	Diversion			
Point 1	-26.14062; 28.767602			
Point 2	-26.141451; 28.769131			
Point 3	-26.145017; 28.777045			
Point 4	-26.148773; 28.788453			
Point	**1**	**2**	**3**	**4**
Species				
*Acacia mearnsii**			●	
Agrostis lachnantha	●			
Agrostis montevidensis	●			
*Bidens bipinnata**			●	
*Bidens formosa**	●		●	●
*Bidens pilosa**				●
*Campuloclinum macrocephalum**	●			
Nidorella podocephala			●	
*Cortaderia sp.**	●		●	
Cynodon dactylon				●
Cyperus denudatus	●			
*Cyperus esculentus**	●			
*Datura ferox**			●	
Eleocharis acutangula		●		
Eleocharis dregeana		●		
Eragrostis curvula				●
Gomphocarpus fruticosus			●	
Imperata cylindrica			●	●
Juncus effusus		●		
Kylinga erecta	●			
Leersia hexandra	●		●	
Melinis repens			●	
Panicum sp.		●		
Paspalum dilatatum	●			
Paspalum urvillei	●			
Persicaria sp.			●	
Pogonathria squarrosa	●			
*Populus sp.**		●		
*Salix babylonica**			●	
Schoenoplectus sp.		●		
*Tagetes minuta**				●
Typha capensis			●	
*Verbena bonariensis**			●	
TOTAL	**12**	**6**	**14**	**6**

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6.2 Wetland Monitoring – Wet-Health Assessment Results

A map of the wetland assessment units at each of the 7 sampling sites is provided in Figure 6. Results from last year's summer wetland monitoring survey (WCS, 2016) are shown. These scores are used as the baseline conditions against which change can be monitored.

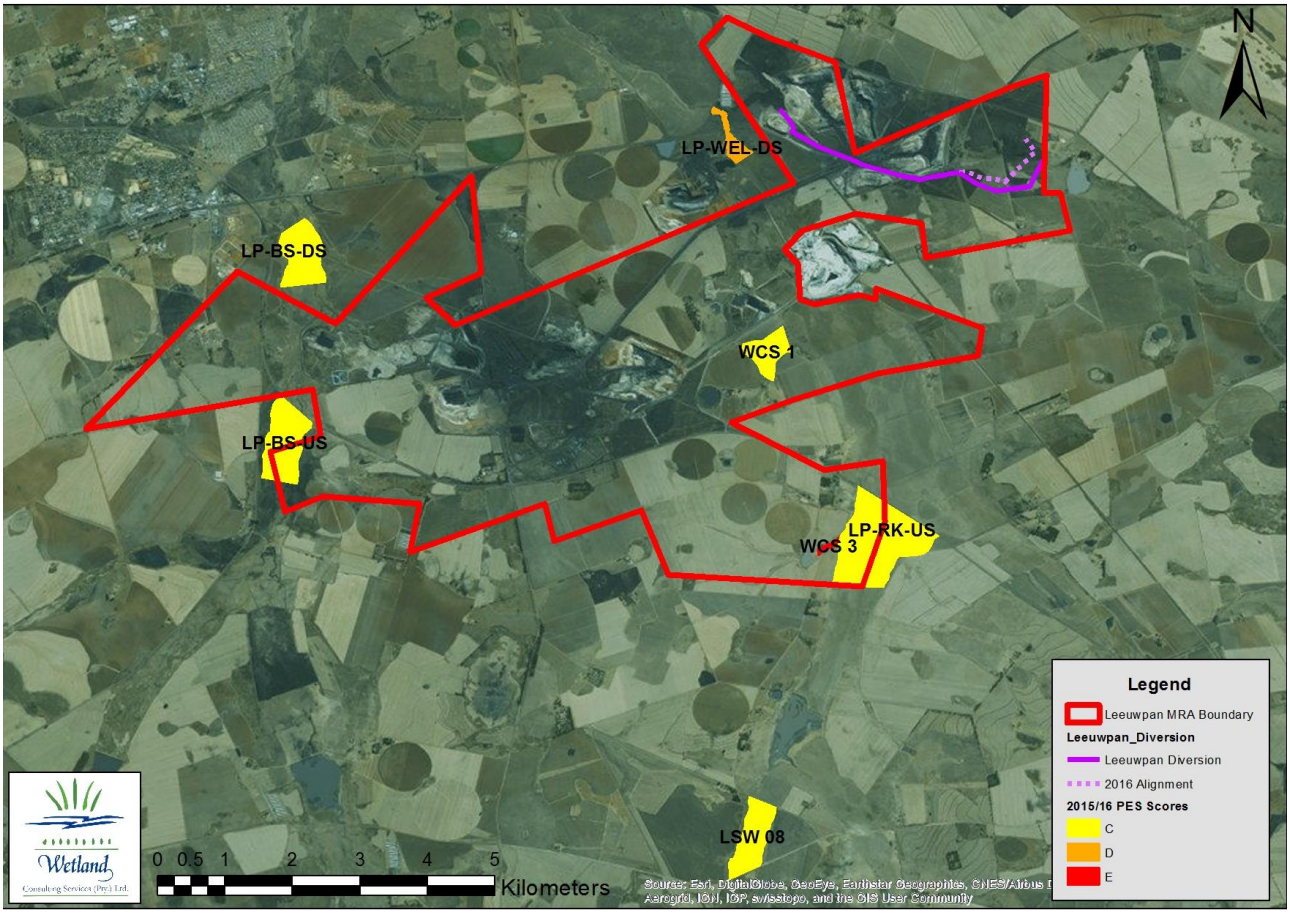


Figure 6. Map of the wetland assessment units showing PES scores from the 2015/16 summer monitoring survey (WCS, 2016).

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6.2.1 LP-BS-US – Channelled valley bottom wetland

WETLAND MONITORING DATA SHEET			
Wetland ID:	**LP-BS-US**		
Location:	-26.177930; 28.701794		
HGM Type:	Channelled valley bottom wetland		
Date of Assessment:	8 February 2018		
Wetland Area (ha):	52.9 ha		
Wetland Vegetation Monitoring Points:	-26.178488 ; 28.701755 -26.178975; 28.701794		
Catchment Impacts			
Catchment extensively cultivated; mostly dryland but some irrigation. Numerous farm dams present on all tributaries, expected to lead to a minor reduction in flow and flood peaks. Many linear infrastructure crossings over wetlands.			
Within Wetland Impacts			
R50 tar road crossing over wetland along downstream edge of assessment unit. Slightly incised channel. Small secondary channel west of main channel. Both channels visible on aerial imagery from 1944/45 (Image 55_009_00384A), but main channel appears to now be more incised. Heavy grazing.			
Present Ecological State (PES) - WET-Health Level 1			
Component	***Score***	***Category***	***Description***
Hydrology	4.0	D	Decreased flow and flood peaks. Channel incision
Geomorphology	3.2	C	Flow confinement due to road crossing
Vegetation	1.6	B	Largely intact primary vegetation, some overutilization.
Combined PES Score	**3.1**	**C**	**MODERATELY MODIFIED**
Alien Vegetation			
Several individuals of *Acacia mearnsii* observed in road reserve.			

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Table 3. List of plant species recorded along the vegetation transect in wetland LP-BS-US.

Wetland System	LP-BS-US							
HGM Type	Channelled valley bottom wetland							
Transect Start	-26.178395; 28.698446							
Transect End	-26.180124; 28.703063							
Transect Length (m)	493							
Section	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Length (m)	**82**	**65**	**28**	**23**	**77**	**38**	**157**	**23**
Species								
Berkheya radula	●				●			●
Berkheya sp.	●			●				
Cirsium vulgare			●					
Conyza albida			●			●		
Nidorella podocephala								●
Lotononis listii		●						
Cymbopogon pospischilii	●			●				
Cynodon dactylon	●							
Cyperus fastigiatus			●					●
Eleocharis dregeana								●
Eragrostis capensis							●	
Eragrostis chloromelas	●				●		●	
Eragrostis plana	●				●	●	●	
Eragrostis racemosa							●	
Euphorbia clavarioides					●		●	
Gomphocarpus fruticosus						●		
Haplocarpha scaposa					●			
Hemathria altissima			●					
Kylinga erecta								●
Leersia hexandra			●					●
Nidorella anomala	●	●		●		●	●	
Oenothera rosea	●							
Persicaria sp.			●					
Plantago lanceolata			●					
Poaceae						●		
Rumex crispus		●	●					
Scabiosa columbaria	●					●		
Schkuhria pinnata	●							
Senecio inornatus	●	●						●
Senecio polyodon	●							
Setaria incrassata		●						
Solanum panduriforme		●						
Themeda triandra	●		●	●			●	●
Typha capensis			●					
Verbena bonariensis			●					
TOTAL	**13**	**6**	**11**	**4**	**5**	**6**	**7**	**8**

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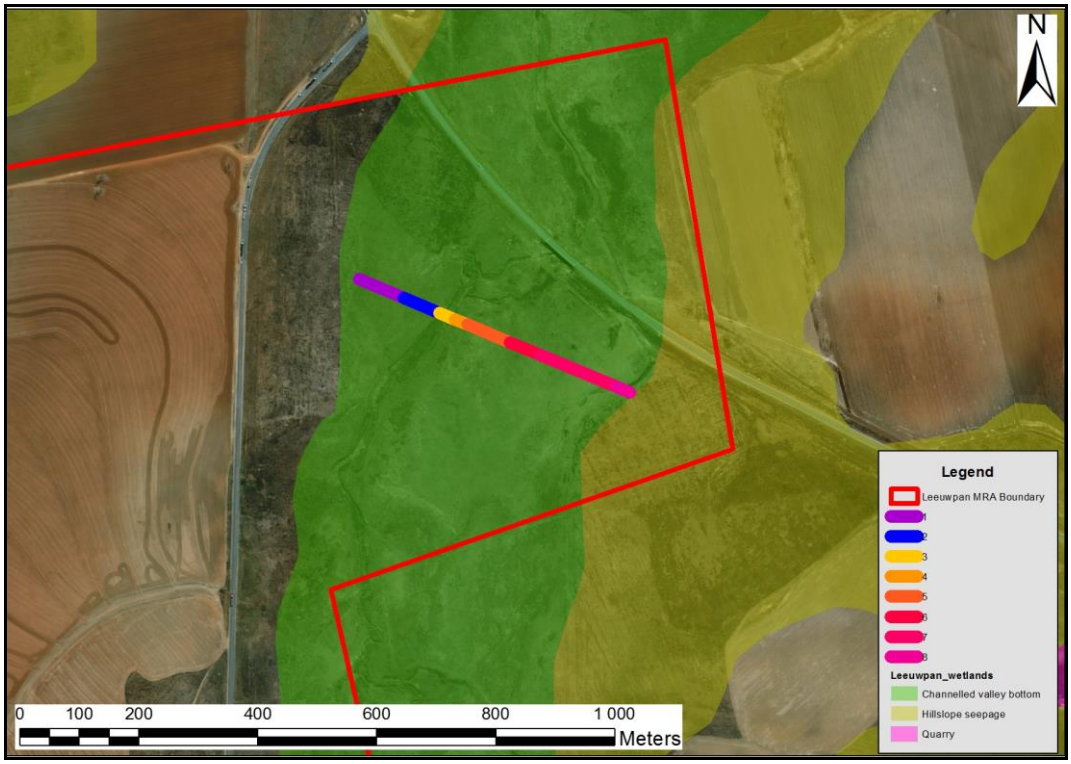


Figure 7. Map of the vegetation transect surveyed in wetland LP-BS-US.

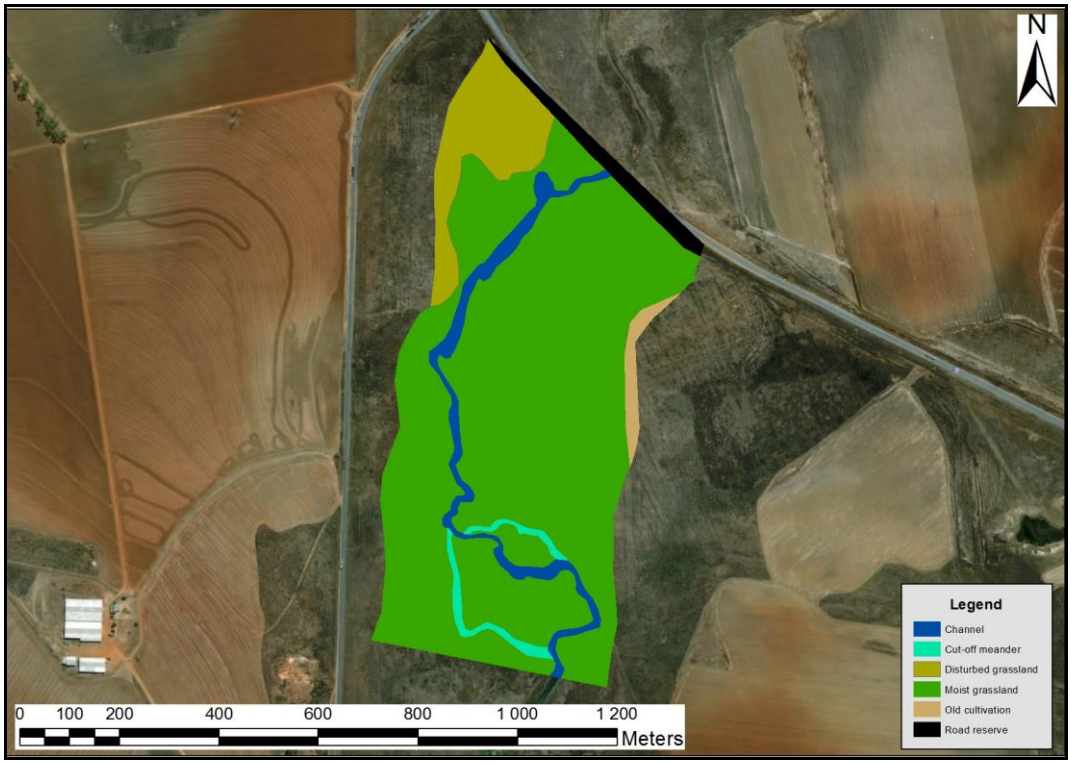


Figure 8. Map of the disturbance units mapped in wetland LP-BS-US to inform the PES assessment.

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6.2.2 LP-BS-DS – Channelled valley bottom wetland

WETLAND MONITORING DATA SHEET			
Wetland ID:	**LP-BS-DS**		
Location:	-26.155300; 28.702600		
HGM Type:	Channelled valley bottom		
Year of Assessment:	7 February 2018		
Wetland Area (ha):	43.6 ha		
Wetland Vegetation Monitoring Points:	-26.156621 ; 28.703136 -26.156772; 28.704161		
Catchment Impacts			
Catchment extensively cultivated; mostly dryland but some irrigation. Numerous farm dams present on all tributaries, expected to lead to a minor reduction in flow and flood peaks. Many linear infrastructure crossings over wetlands. Leeuwpan Mine located immediately upstream.			
Within Wetland Impacts			
Tar road crossing over wetland. Leeuwpan Mine extends into valley bottom wetland just upstream of assessment unit with berm and diversion channel controlling flow. Dense stand of alien *Populus* trees along wetland edge. Incised channel due to flow concentration; channel competency expected to have significantly increased as a result. Past disturbance of vegetation evidence by secondary vegetation along edges of wetland.			
Present Ecological State (PES) - WET-Health Level 1			
Component	***Score***	***Category***	***Description***
Hydrology	4.0	D	Decreased flow and flood peaks. Channel incision. Impoundment upslope of road crossing.
Geomorphology	4.0	D	Flow confinement due to road crossing and upstream diversion channel.
Vegetation	2.0	C	Mostly intact. Some aliens, some secondary vegetation.
Combined PES Score	**3.4**	**C**	**MODERATELY MODIFIED**
Alien Vegetation			
Populus x canescens			Small, sparse stand just upstream of bridge in an area maybe 5 x 3 meters
Populus x canescens			Large stand of small trees and isolated large trees along edge of valley bottom wetland
Acacia mearnsii			Several individuals in road reserve

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Table 4. List of plant species recorded along the vegetation transect in wetland LP-BS-DS.

Wetland System	LP-BS-DS							
HGM Type	Channelled valley bottom							
Transect Start	-26.156915; 28.699851							
Transect End	-26.156693; 28.704564							
Transect Length (m)	469							
Section	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Length (m)	**22**	**94**	**99**	**14**	**96**	**26**	**41**	**77**
Agrostis lachnantha								●
Aristida junciformis	●							
Berkheya radula	●	●		●	●		●	
Berkheya zeyheri					●			
Bidens formosa		●	●	●				
Carex sp.								●
Nidorella podocephala		●	●				●	
Crinum bulbispernum			●	●				
Cymbopogon pospischilii					●			
Cynodon dactylon			●					
Cyperus fastigiatus				●		●		
Cyperus longus						●		
Eragrostis chloromelas							●	
Eragrostis plana			●					
Eragrostis sp.					●			
Erythrina zeyheri							●	
Euphorbia striata							●	
Fimbrostylus complanata	●							
Fingerhuthia sesleriiformis					●			
Fuirena pubescens	●							
Gladiolus elliotii		●	●					
Hemathria altissima								●
Hibiscus trionum			●					
Imperata cylindrica						●		
Ledebouria sp.			●		●		●	
Leersia hexandra				●		●		●
Persicaria sp.						●		
Phragmites australis				●		●		●
Pycreus sp.	●							
Scabiosa columbaria			●		●			
Schkuhria pinnata				●				
Schoenoplectus decipiens				●				
Senecio inornatus		●						
Senecio polyodon							●	
Setaria incrassata		●	●					
Solanum panduriforme			●					
Themeda triandra	●	●		●	●		●	
Verbena bonariensis								●
Veronica anagallis-aquatica						●		
Lotononis listii		●						
TOTAL	**6**	**8**	**11**	**9**	**8**	**7**	**8**	**6**

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Figure 9. Map of the vegetation transect surveyed in wetland LP-BS-DS.

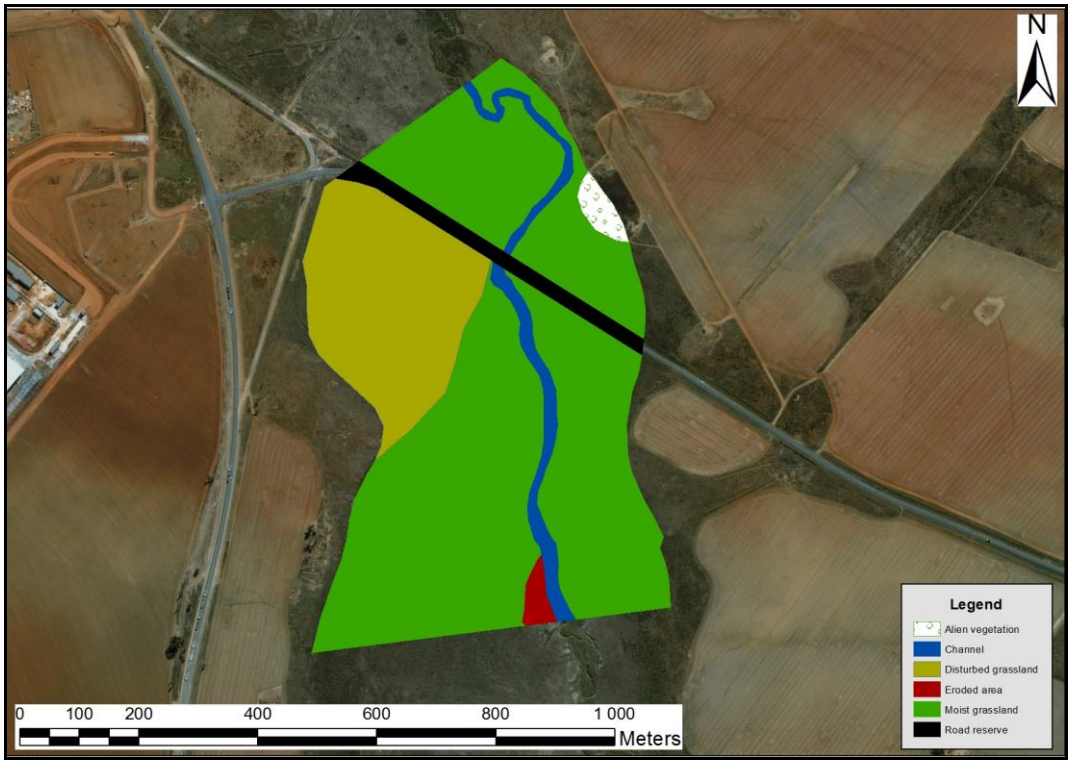


Figure 10. Map of the disturbance units mapped in wetland LP-BS-DS to inform the PES assessment.

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6.2.3 LSW 08 – Unchannelled valley bottom wetland

WETLAND MONITORING DATA SHEET			
Wetland ID:	**LSW 08**		
Location:	-26.229100; 28.762594		
HGM Type:	Unchannelled valley bottom		
Year of Assessment:	8 February 2018		
Wetland Area (ha):	38 ha		
Wetland Vegetation Monitoring Point:	-26.229596 ; 28.762569		
Catchment Impacts			
Catchment utilised agriculturally – extensive cultivation, mostly dryland but some irrigation. Livestock grazing in wetlands mostly. Numerous farm dams present on all tributaries, expected to lead to a reduction in flow and flood peaks. Many linear infrastructure crossings over wetlands.			
Within Wetland Impacts			
Gravel road crossing at upstream and downstream edge of assessment unit. Slightly incised, vegetated channel formed across most of the wetland reach, but appears stable (same channel extent visible on historical imagery from 1944/45). Extreme upper reach still unchannelled.			
Present Ecological State (PES) - WET-Health Level 1			
Component	***Score***	***Category***	***Description***
Hydrology	4.0	D	Decreased flow and flood peaks. Erosion gully. Road crossings.
Geomorphology	1.3	B	Mostly intact. Flow concentration from road crossings.
Vegetation	1.9	B	Generally intact.
Combined PES Score	**2.6**	**C**	**MODERATELY MODIFIED**
Alien Vegetation			
No invasive alien species of concern.			

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Table 5. List of plant species recorded along the vegetation transect in wetland LSW08.

Wetland System	LSW 08							
HGM Type	Unchannelled valley bottom							
Transect Start	-26.229954; 28.761191							
Transect End	-26.229902; 28.764030							
Transect Length (m)	283							
Section	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Length (m)	**19**	**49**	**56**	**11**	**10**	**12**	**120**	**6**
Species								
Agrostis lachnantha	●	●						
Berkheya radula			●					
Berkheya zeyheri			●				●	
Bidens formosa		●	●	●	●		●	●
Chamaecrista mimosoides	●							
Conyza albida				●				
Nidorella podocephala							●	
Crinum bulbispernum			●	●	●		●	
Cynodon dactylon		●		●				●
Cyperus denudatus				●				
Denekia capensis		●						
Eragrostis chloromelas							●	
Eragrostis curvula							●	●
Eragrostis plana				●				
Eragrostis rotifer	●	●		●				
Gladiolus sp.							●	
Hyparrhenia hirta								●
Hyparrhenia tamba								●
Kylinga erecta		●						
Ledebouria sp.							●	●
Leersia hexandra		●			●			
Oenothera rosea				●			●	
Paspalum dilatatum		●			●			
Paspalum urvillei		●						
Plantago lanceolata	●			●				
Pseudognaphalium luteo-album				●				
Ranunculus multifidus							●	
Scabiosa columbaria			●					
Schkuhria pinnata				●				●
Schoenoplectus decipiens		●			●			
Senecio inornatus			●					
Senecio polyodon			●					
Setaria incrassata			●				●	
Themeda triandra			●	●	●		●	
Typha capensis	●				●			
Verbena bonariensis	●	●					●	
TOTAL	**6**	**11**	**9**	**12**	**7**		**13**	**7**

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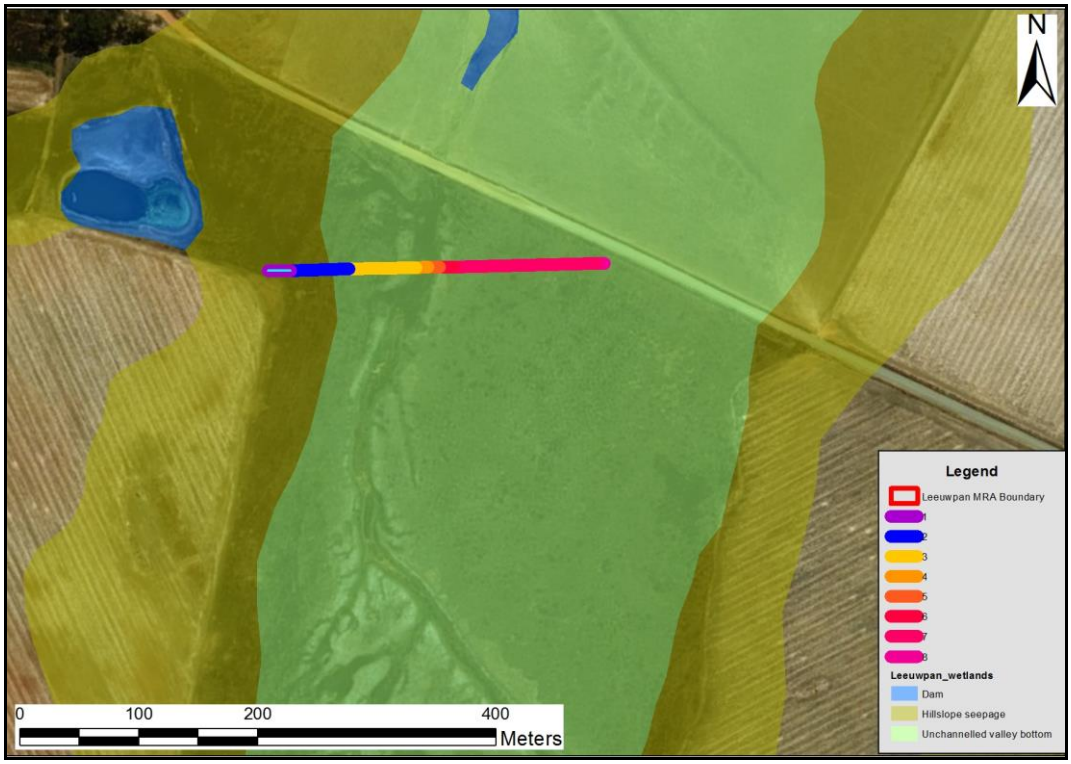


Figure 11. Map of the vegetation transect surveyed in wetland LSW08.

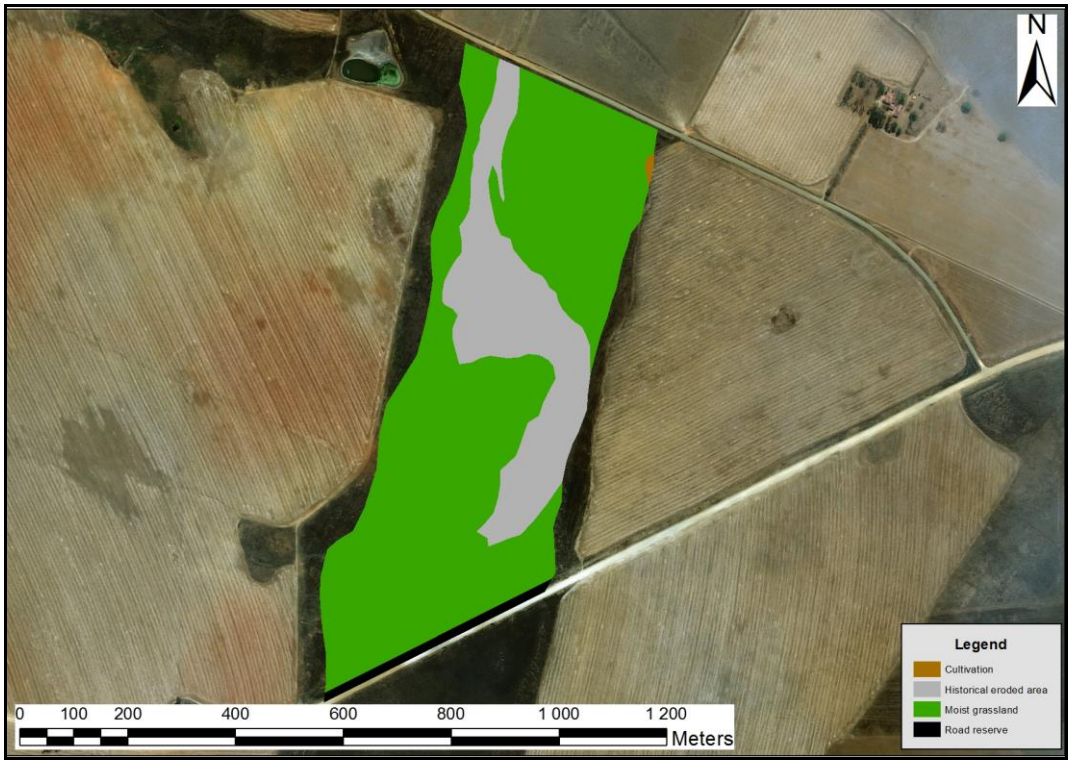


Figure 12. Map of the disturbance units mapped in wetland LSW08 to inform the PES assessment.

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6.2.4 LP-RK-US – Unchannelled valley bottom wetland

WETLAND MONITORING DATA SHEET			
Wetland ID:	**LP-RK-US**		
Location:	-26.188001; 28.776560		
HGM Type:	Unchannelled valley bottom		
Year of Assessment:	8 February 2018		
Wetland Area (ha):	113 ha		
Wetland Vegetation Monitoring Points:	-26.188412 28.776582		
Catchment Impacts			
Catchment extensively cultivated; mostly dryland but some irrigation. Large farm dam 1.5km upstream and numerous farm dams present on all tributaries, expected to lead to a minor reduction in flow and flood peaks. Many linear infrastructure crossings over wetlands. Morgan Beef feed lot in catchment.			
Within Wetland Impacts			
R50 tar road crossing. Re-alignment of road currently under construction. Very heavy livestock grazing in wetland (cattle and sheep); overgrazing evident. Some channel incision from road crossing upstream, but appears stable.			
Present Ecological State (PES) - WET-Health Level 1			
Component	***Score***	***Category***	***Description***
Hydrology	6.5	E	Decreased flow and flood peaks. Channel eroded in system from culvert. Road crossings. New road has added further culverts.
Geomorphology	1.4	B	Mostly intact. Flow concentration from road crossings. New road has added further culverts.
Vegetation	2.4	C	Generally intact. Heavy grazing pressure. Construction of re-aligned road has lead to some loss of natural vegetation.
Combined PES Score	**3.9**	**C**	**MODERATELY MODIFIED**
Alien Vegetation			
No invasive alien species of concern.			

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Table 6. List of plant species recorded along the vegetation transect in wetland LP-RK-US.

Wetland System	LP-RK-US						
HGM Type	Unchannelled valley bottom						
Transect Start	-26.190683; 28.781001						
Transect End	-26.190151; 28.776735						
Transect Length (m)	424						
Section	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Length (m)	**23**	**56**	**36**	**20**	**58**	**142**	**89**
Species							
Berkheya zeyheri			●			●	●
Cirsium vulgare							●
Nidorella podocephala						●	
Crinum bulbispernum						●	●
Cymbopogon pospischilii							
Cynodon dactylon			●	●		●	●
Cyperus denudatus						●	
Cyperus sp.					●		
Denekia capensis		●			●		
Eleocharis dregeana		●	●		●		
Eleocharis sp.					●		
Eragrostis heteromera						●	
Eragrostis plana			●	●	●	●	●
Gomphocarpus fruticosus						●	●
Kylinga erecta			●				
Leersia hexandra	●	●			●		
Marsilea macrocarpa					●		
Panicum sp.		●					
Paspalum dilatatum						●	●
Paspalum distichum		●					
Poaceae					●		
Pseudognaphalium luteo-album			●			●	●
Pycreus sp.				●	●	●	
Ranunculus multifidus						●	●
Rumex crispus						●	
Setaria pallide-fusca							●
Sporobolus africana						●	
TOTAL	**1**	**5**	**6**	**3**	**9**	**14**	**10**

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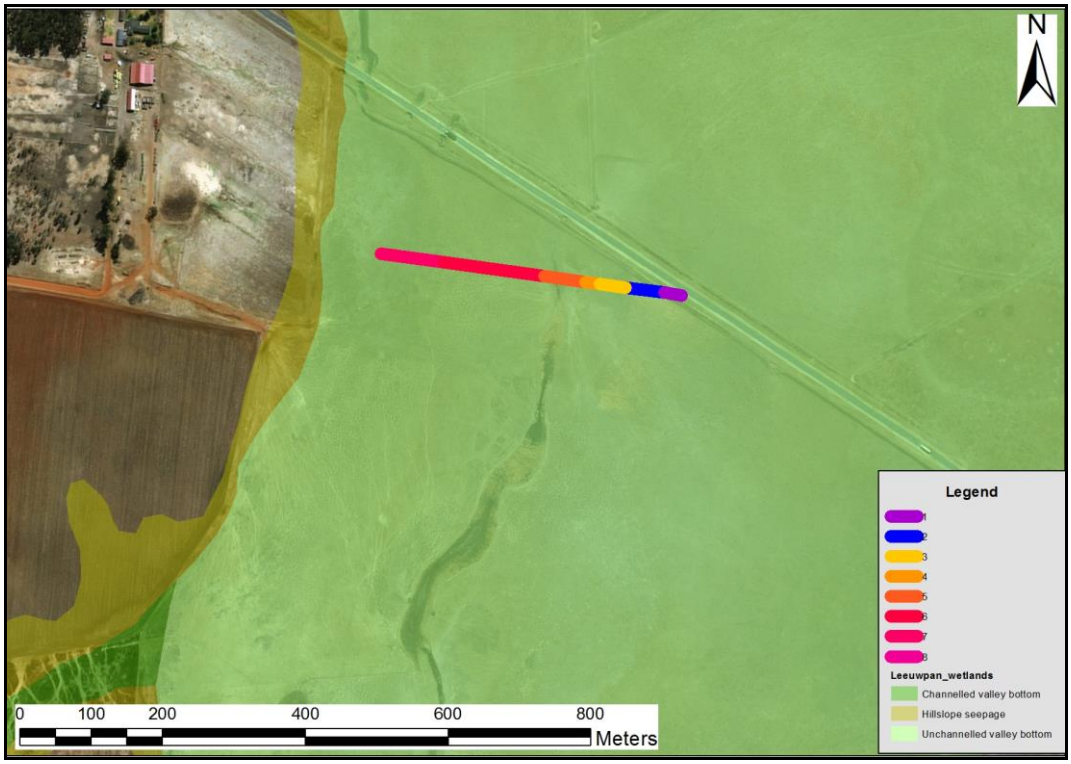


Figure 13. Map of the vegetation transect surveyed in wetland LP-RK-US.

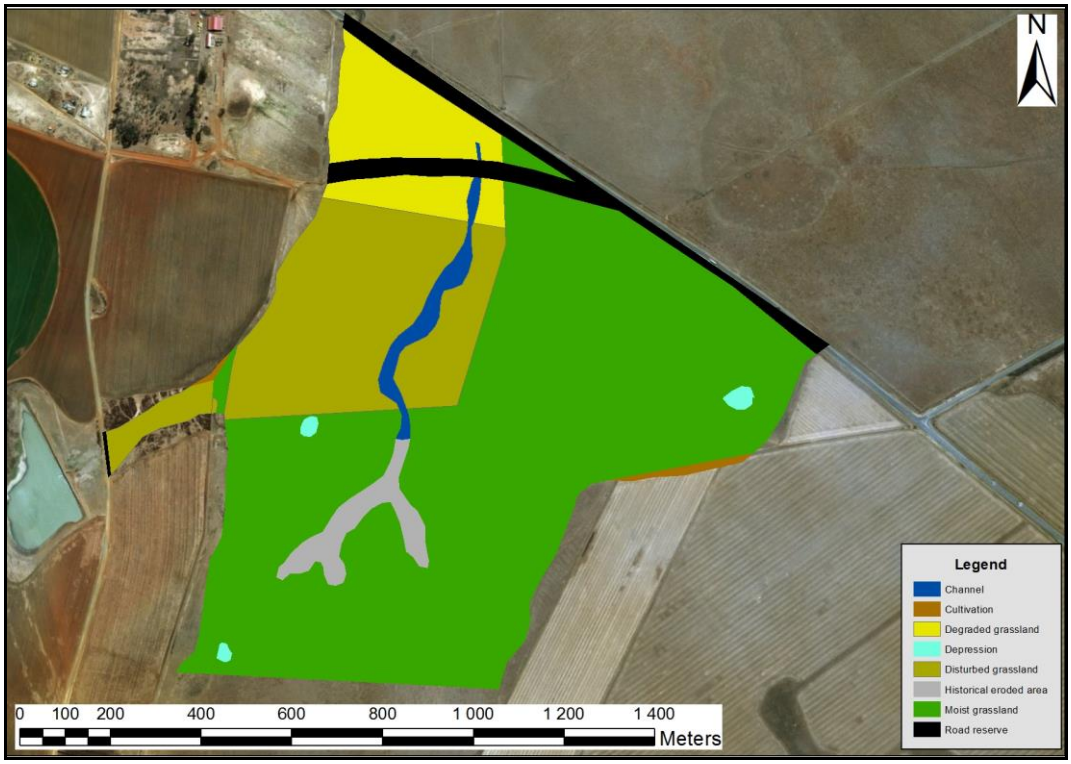


Figure 14. Map of the disturbance units mapped in wetland LP-RK-US to inform the PES assessment.

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6.2.5 LP-WEL-DS – Channelled valley bottom wetland

WETLAND MONITORING DATA SHEET			
Wetland ID:	**LP-WEL-DS**		
Location:	-26.137406; 28.756924		
HGM Type:	Channelled valley bottom		
Year of Assessment:	7 February 2018		
Wetland Area (ha):	11 ha		
Wetland Vegetation Monitoring Points:	-26.138148 ; 28.758524		
Catchment Impacts			
Various mines in catchment, Leeuwpan and Stuart Coal immediately upstream. Extensive cultivation. Numerous farm dams in upper catchment. River diversions in upstream water courses. Numerous linear infrastructure crossings.			
Within Wetland Impacts			
Wetland becomes naturally channel in this reach due to geological flow confinement. Channel straightening from diversion channel in upper reach. Two railway crossings. Small dam in wetland.			
Present Ecological State (PES) - WET-Health Level 1			
Component	***Score***	***Category***	***Description***
Hydrology	6.5	E	Decreased flow and flood peaks. Channel eroded in system from culvert. Road crossings.
Geomorphology	4.0	D	Mostly intact. Flow concentration from road crossings.
Vegetation	1.8	B	Generally intact. Small dam leads to increased wetness and inundation. Edge effect around railway crossings.
Combined PES Score	**4.7**	**D**	**LARGELY MODIFIED**
Alien Vegetation			
Campuloclinium macrocephalum			Increasing. 50-odd plants observed.

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Table 7. List of plant species recorded along the vegetation transect in wetland LP-WEL-DS.

Wetland System	LP-WEL-DS						
HGM Type	Channelled valley bottom						
Transect Start	-26.138967; 28.758164						
Transect End	-26.138789; 28.758942						
Transect Length (m)	78						
Section	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Length (m)	**14**	**11**	**20**	**11**	**6**	**9**	**7**
Species							
Aristida junciformis					●	●	
Berkheya radula	●			●			●
Crinum bulbispernum		●			●		
Cyperus denudatus				●			
Digitaria eriantha						●	
Eragrostis chloromelas	●			●			●
Eragrostis inamoena					●	●	
Eragrostis plana					●	●	
Fimbrostylus complanata					●		
Hemathria altissima		●		●			
Hypoxis sp.					●		
Juncus oxycarpus				●			
Kylinga erecta					●		
Leersia hexandra		●	●	●			
Nidorella anomala						●	
Oenothera rosea				●			
Persicaria sp.		●	●	●			
Pseudognaphalium luteo-album					●		
Pycreus sp.		●		●			
Ranunculus multifidus				●			
Schkuhria pinnata					●		
Schoenoplectus decipiens				●			
Senecio inornatus				●			
Seteria sphacelata					●	●	
Themeda triandra	●			●			●
Wahlenbergia calendonica						●	
Typha capensis			●				
Cyperus fastigiatus			●				
Hyparrhenia hirta	●						
TOTAL	**4**	**5**	**4**	**13**	**10**	**7**	**3**

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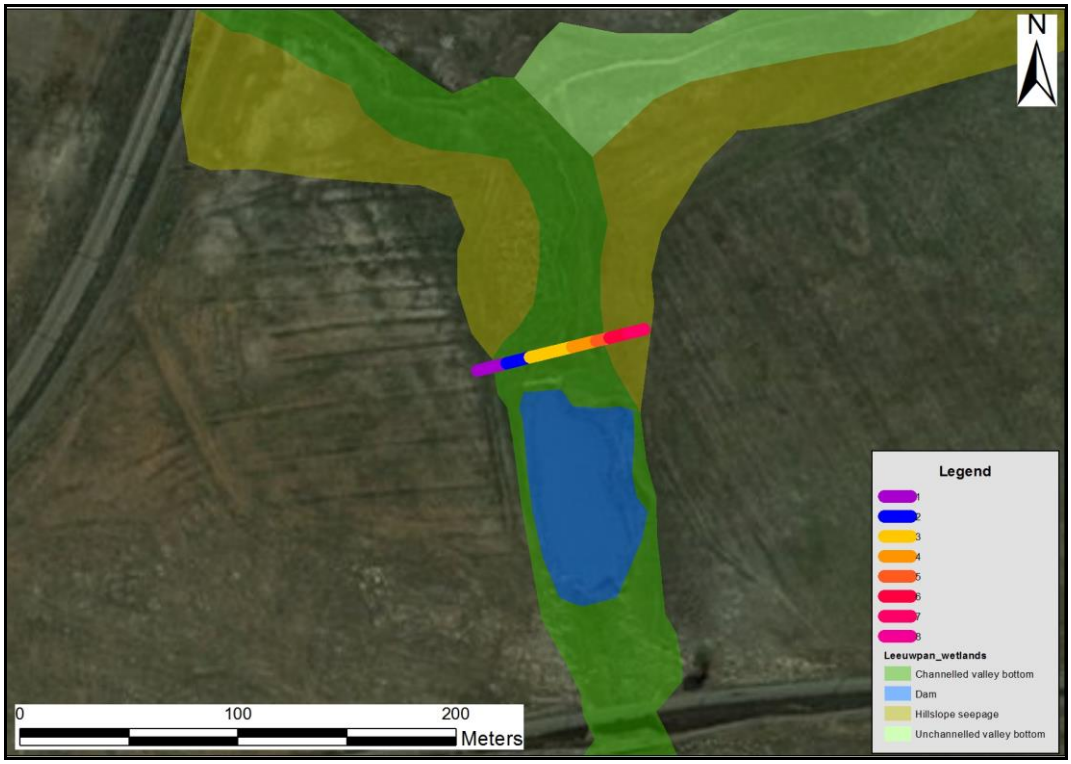


Figure 15. Map of the vegetation transect surveyed in wetland LP-WEL-DS.

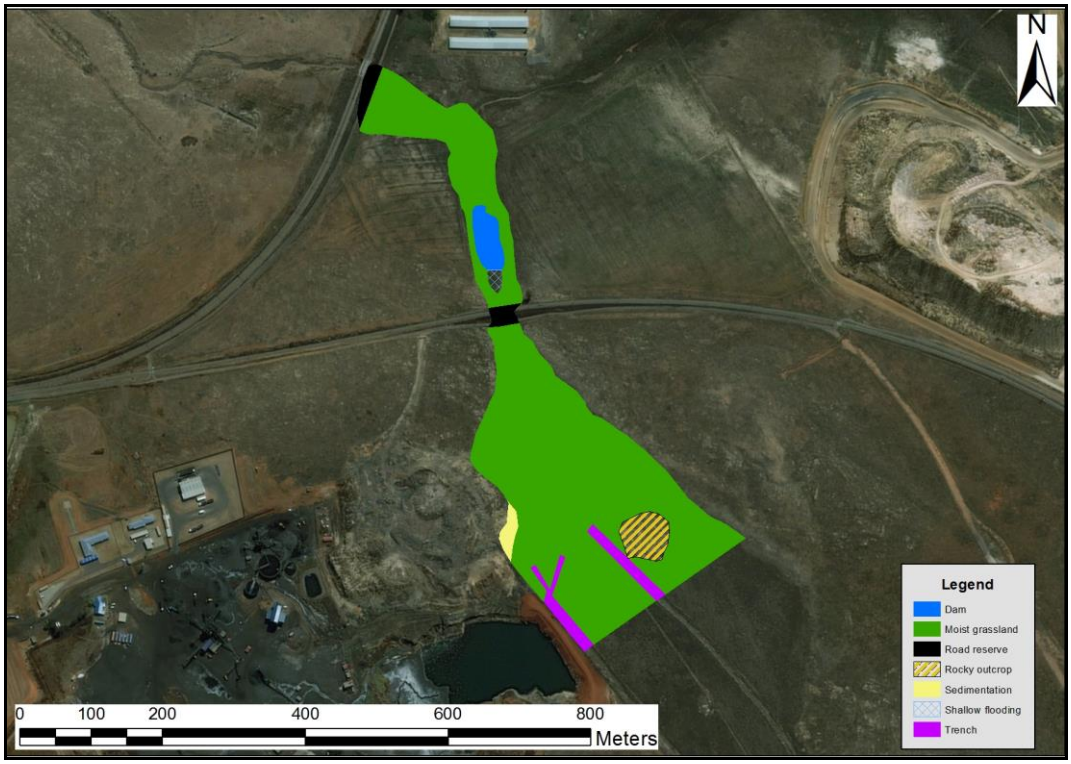


Figure 16. Map of the disturbance units mapped in wetland LP-WEL-DS to inform the PES assessment.

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6.2.6 WCS 1 – Hillslope seepage wetland

WETLAND MONITORING DATA SHEET			
Wetland ID:	**WCS 1**		
Location:	-26.174203; 28.764132		
HGM Type:	Hillslope seepage wetland		
Year of Assessment:	8 February 2018		
Wetland Area (ha):	23.8		
Wetland Vegetation Monitoring Points:	-26.172281 ; 28.764498		
Catchment Impacts			
The wetland is located immediately downslope of a centre-pivot irrigation field. Catchment is mostly cultivated though some planted pasture and two farm yards also occur. A pan utilised for irrigation water storage occurs at the top of the catchment. The wetland is expected to receive increased flows from its catchment.			
Within Wetland Impacts			
Cultivation extends into the temporary edges of the seepage wetland. Secondary vegetation characterises areas previously cultivated. Farm tracks and some small erosion gullies form preferential flow paths.			
Present Ecological State (PES) - WET-Health Level 1			
Component	***Score***	***Category***	***Description***
Hydrology	2.0	C	Increased flow and flood peaks due to irrigation. Some flow concentration by erosion gullies & tracks
Geomorphology	3.0	C	Increased runoff
Vegetation	4.8	D	Fairly disturbed. Current and past cultivation.
Combined PES Score	**3.1**	**C**	**MODERATELY MODIFIED**
Alien Vegetation			
Campuloclinium macrocephalum			Several small clumps just upslope of monitoring point
Bidens formosa			Fairly sparse but widespread, especially upslope
Pennisetum clandestinum			Limited to areas close to roads

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Table 8. List of plant species recorded along the vegetation transect in wetland WCS 1.

Wetland System	WCS 1						
HGM Type	Hillslope seepage						
Transect Start	-26.171549; 28.762804						
Transect End	-26.171582; 28.764481						
Transect Length (m)	166						
Section	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Length (m)	**20**	**15**	**13**	**40**	**56**	**18**	**4**
Species							
Agrostis lachnantha		●					
Agrostis montevidensis			●				
Berkheya radula		●	●	●	●	●	
Bidens formosa	●	●		●	●		●
Campuloclinum macrocephalum	●					●	
Nidorella podocephala						●	
Cynodon dactylon	●	●	●		●	●	●
Cyperus congestus					●		
Cyperus denudatus					●		
Cyperus esculentus	●						
Eragrostis curvula	●						
Eragrostis plana	●	●			●		●
Eragrostis sp.		●	●				
Fimbrostylus complanata					●		
Helictotrichon turgidulum	●		●		●		
Hyparrhenia hirta							●
Hypoxis sp.				●			
Kylinga erecta						●	
Nidorella anomala				●		●	
Oenothera rosea			●	●	●		
Paspalum dilatatum		●			●		●
Pennisetum clandestinum	●						
Plantago lanceolata				●	●		
Poaceae		●	●				
Pycreus sp.					●		
Schkuhria pinnata				●			
Schoenoplectus decipiens					●		
Senecio inornatus				●			
Seteria sphacelata			●	●	●		
Sorghum bicolor							●
Themeda triandra			●	●			
Verbena bonariensis		●	●	●	●	●	
Wahlenbergia calendonica						●	
TOTAL	**8**	**9**	**10**	**11**	**15**	**8**	**6**

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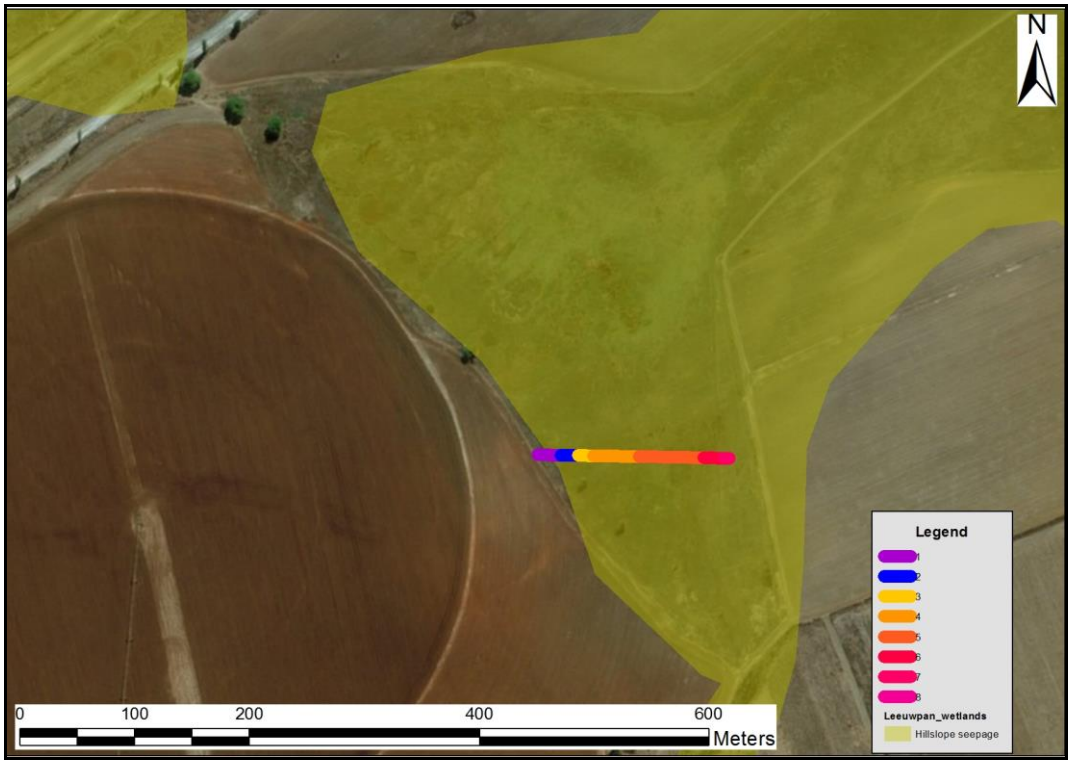


Figure 17. Map of the vegetation transect surveyed in wetland WCS 1.

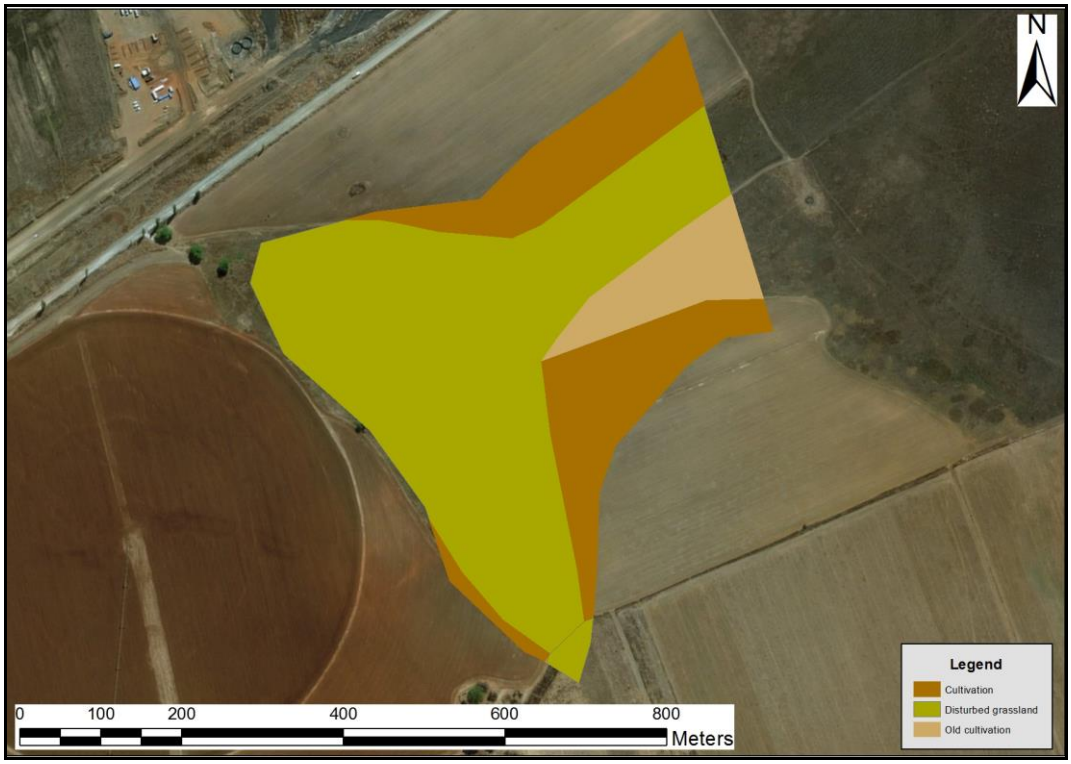


Figure 18. Map of the disturbance units mapped in wetland WCS 1 to inform the PES assessment.

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6.2.7 WCS 3 - Channelled valley bottom

WETLAND MONITORING DATA SHEET			
Wetland ID:	**WCS 3**		
Location:	-26.195952; 28.771537		
HGM Type:	Channelled valley bottom wetland		
Year of Assessment:	8 February 2018		
Wetland Area (ha):	2.1 ha		
Wetland Vegetation Monitoring Points:	-26.195831; 28.771459 -26.196089 ; 28.771792		
Catchment Impacts			
Entire catchment cultivated, both dryland and irrigated. Irrigation dam located just upstream of assessment unit.			
Within Wetland Impacts			
Wetland system completely dominated by *Bidens formosa* (Cosmos). Weakly channel valley bottom wetland, channel more pronounced in lower reach. Sediment inputs from road			
Present Ecological State (PES) - WET-Health Level 1			
Component	***Score***	***Category***	***Description***
Hydrology	6.5	E	Large dam immediately upslope, no releases. Channel straightening
Geomorphology	6.0	E	Channel straightening. Road crossing with no culvert.
Vegetation	5.6	D	Totally dominated by *Bidens formosa*. Historically cultivated.
Combined PES Score	**6.1**	**E**	**SERIOUSLY MODIFIED**
Alien Vegetation			
Campuloclinium macrocephalum			Small population, approximately 50 flowering heads observed
Bidens formosa			Completely dominates wetland and smothers all other vegetation
Canna indica			Small stand of around 20 plants just outside wetland area.

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Table 9. List of plant species recorded along the vegetation transect in wetland WCS 3.

Wetland System	WCS 3		
HGM Type			
Transect Start			
Transect End			
Transect Length (m)	93		
Section	**1**	**2**	**3**
Length (m)	**50**	**26**	**17**
Species			
Bidens formosa		●	●
Nidorella podocephala			●
Cynodon dactylon		●	
Cyperus esculentus		●	
Leersia hexandra		●	
Paspalum dilatatum		●	
Pycreus sp.		●	
Themeda triandra			●
Verbena bonariensis			●
Setaria pallide-fusca		●	
Zea mays	●		
Tagetes minuta		●	
Oxalis depressa			●
TOTAL	**1**	**8**	**5**



Figure 19. Map of the vegetation transect surveyed in wetland WCS 3.

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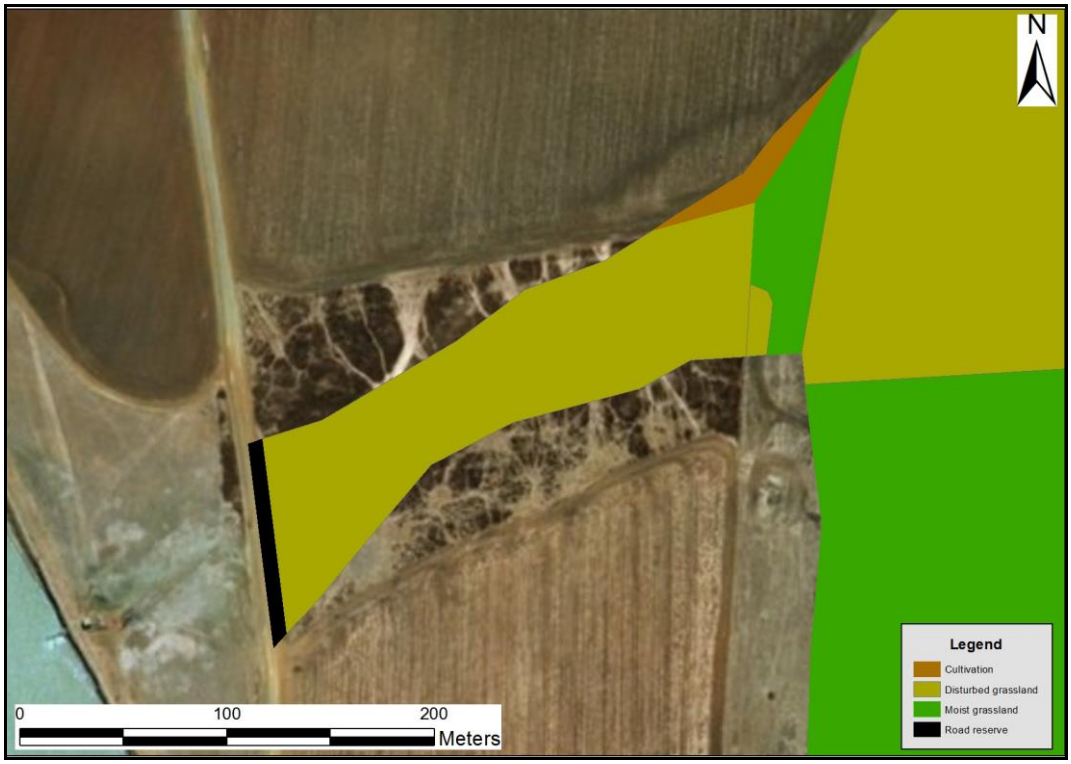


Figure 20. Map of the disturbance units mapped in wetland WCS 3 to inform the PES assessment.

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6.3 Summary of PES Assessment

5 of the 7 wetland units assessed were found to be in a moderately modified condition (PES category C), with only wetland LP-WEL-DS considered largely modified (PES category D) and wetland WCS 03 considered seriously modified (PES category E). ***These results largely mirror the results of the previous two summer season assessments, with no change in PES categories for 6 the wetlands***. The only significant change occurred in the unchannelled valley bottom wetland at sample site LP-RK-US. This wetland has deteriorated from a PES C (score of 2.7) to a borderline PES C/D (score of 3.9). This is as a direct consequence of the construction of the re-aligned R50 tar road. At the time of this survey the raised road berm had been constructed across the full length of the wetland, though culverts had not yet been installed, i.e. there was no flow connectivity across the road under construction. Road culverts have however subsequently been installed.

The above results correspond largely with the PES results obtained during the 2013 wetland specialist study. Both wetlands LP-BS-US and LP-BS-DS (PES category C) were rated one category better than in the 2013 assessment; this is attributed to the assessment units differing between these assessments and not to a change in wetland condition, which was found to be much the same as during the 2013 survey.

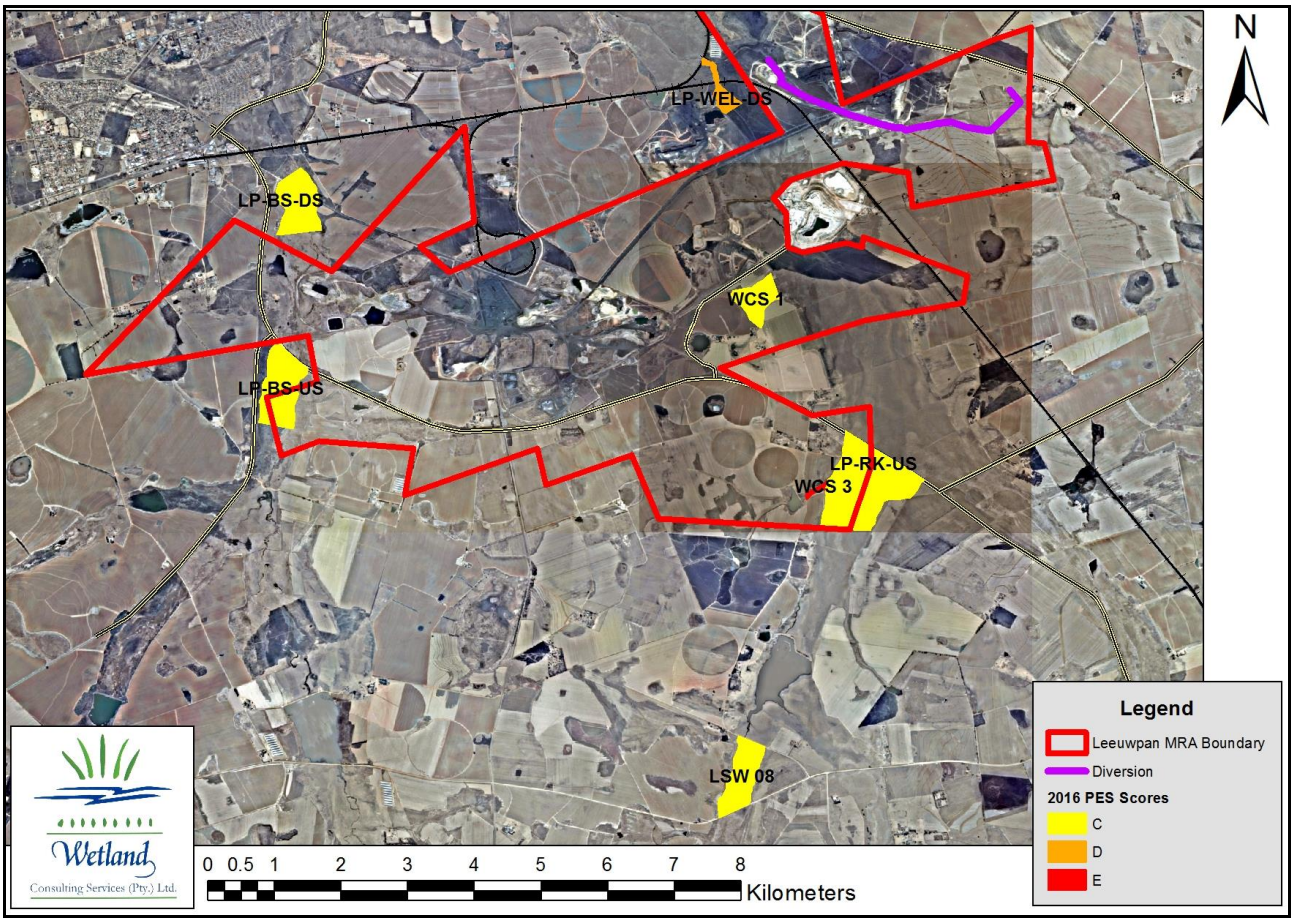


Figure 21. Map summarising the PES assessment results for the wetland monitoring units assessed in 2016.

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In general, little if any observable change was noted between the 2016/17 summer season survey and the current (2017/178) survey, other than on the stream diversion and in wetland LP-RK-US. The alien invasive pompom weed, *Campuloclinium macrocephalum,* has however increased in occurrence at a number of locations and it is clear that few, if any, recommendations from the previous monitoring reports have been implemented..

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6.4 Fixed Point Photography

A map of fixed point photograph locations is provided in Figure 6. Photographs per site follow below. Upstream and downstream photographs were taken at each point. Table 2 provides point co-ordinates of fixed photography sites. Due to mining through of the upper portion of the river diversion, the "River Diversion US" point could not be visited.

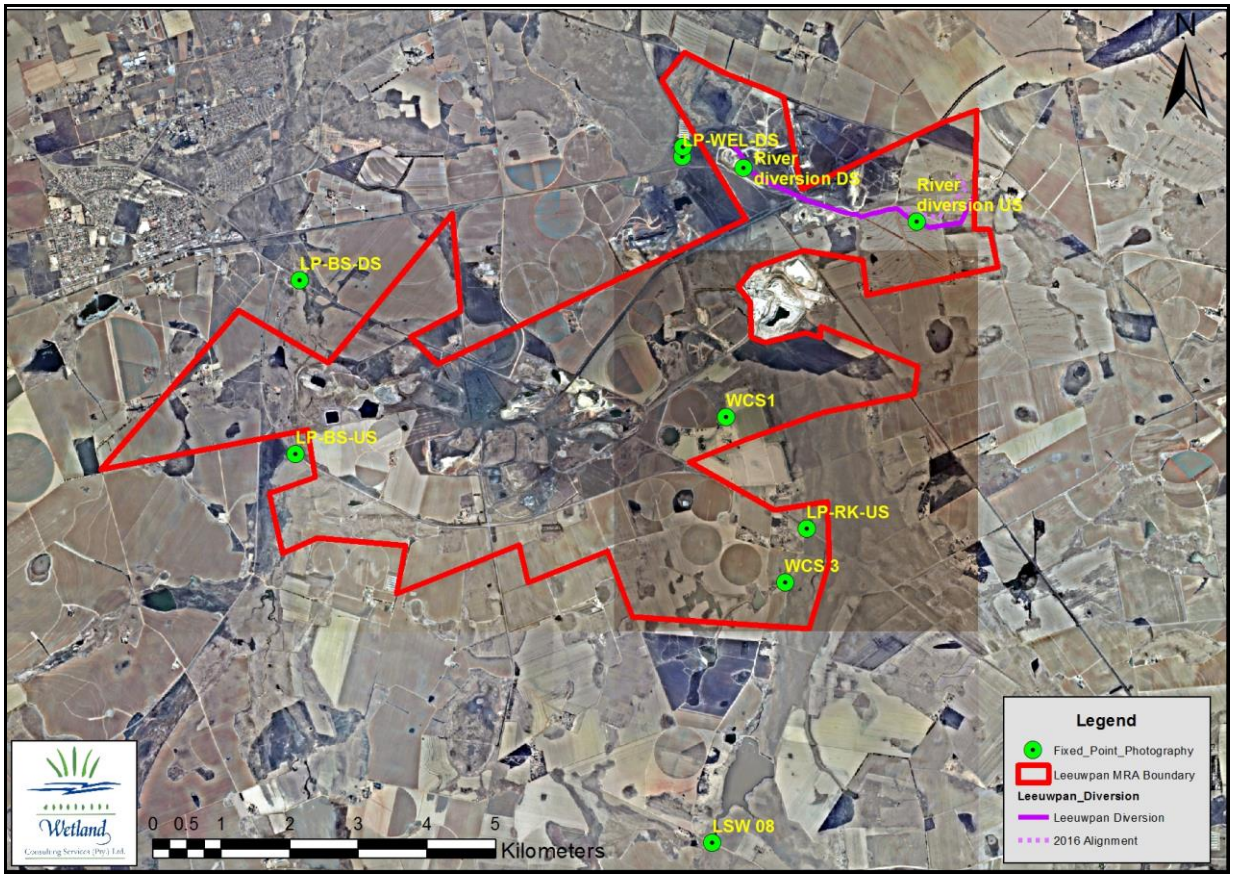


Figure 22. Map of fixed point photographs for the various wetland monitoring points and river diversion.

Table 10. Co-ordinates of fixed point photographic record points

	Monitoring Point	X co-ordinate	Y co-ordinate	Comments
1	River diversion US	-26.147608	28.792689	
2	River diversion DS	-26.14057213	28.76740289	From 90° bend in diversion
3	LSW 08	-26.22919340	28.76260166	From gravel road bridge
4	WCS 3	-26.19500100	28.77336300	From corner fence post
5	LP-RK-US	-26.18796811	28.77652690	From tar road bridge
6	LP-WEL-DS	-26.13905500	28.75848800	From small dam wall downstream
		-26.13780400	28.75857600	From fence upstream
7	LP-BS-US	-26.17797078	28.70186390	From tar road bridge
8	LP-BS-DS	-26.15516037	28.70258448	From tar road bridge
9	WCS1	-26.17327700	28.76481200	Along fence line

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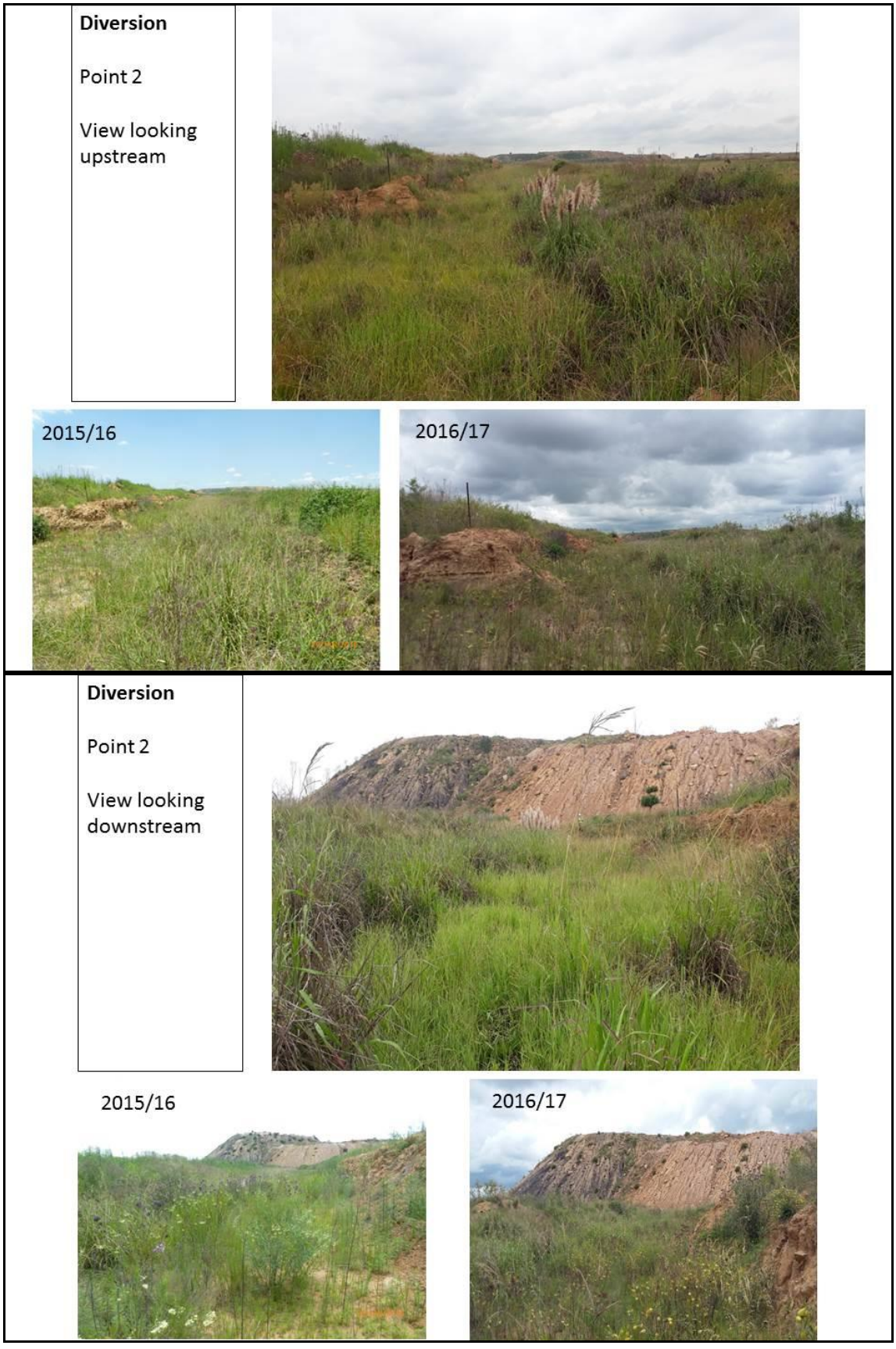


Figure 23. Fixed point photographs for downstream river diversion site (Point 2 in Table 2). Note increased vegetation cover and increase in alien *Cortaderia* sp.

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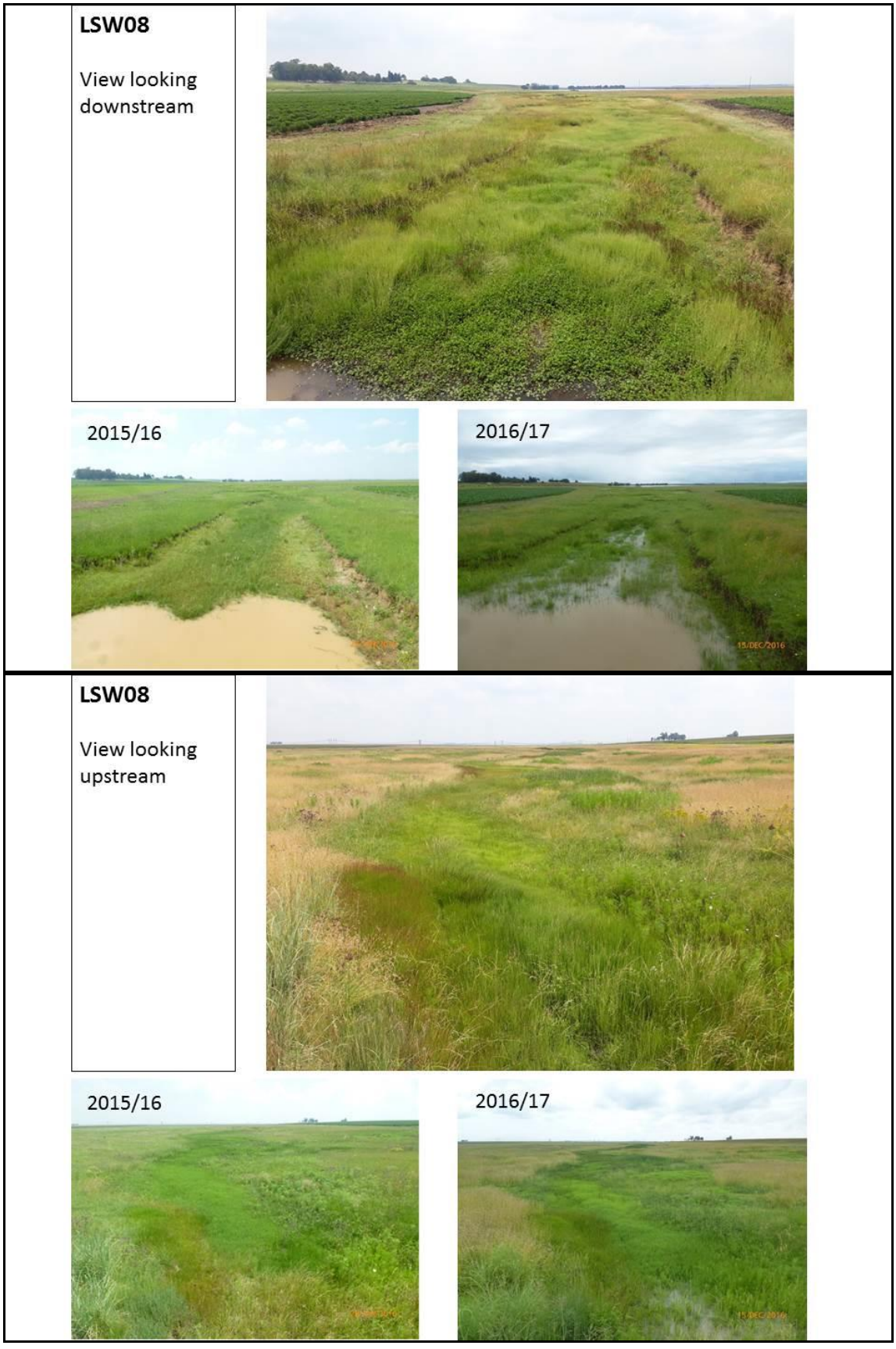


Figure 24. Fixed point photographs for monitoring site LSW 08. No significant change observed.

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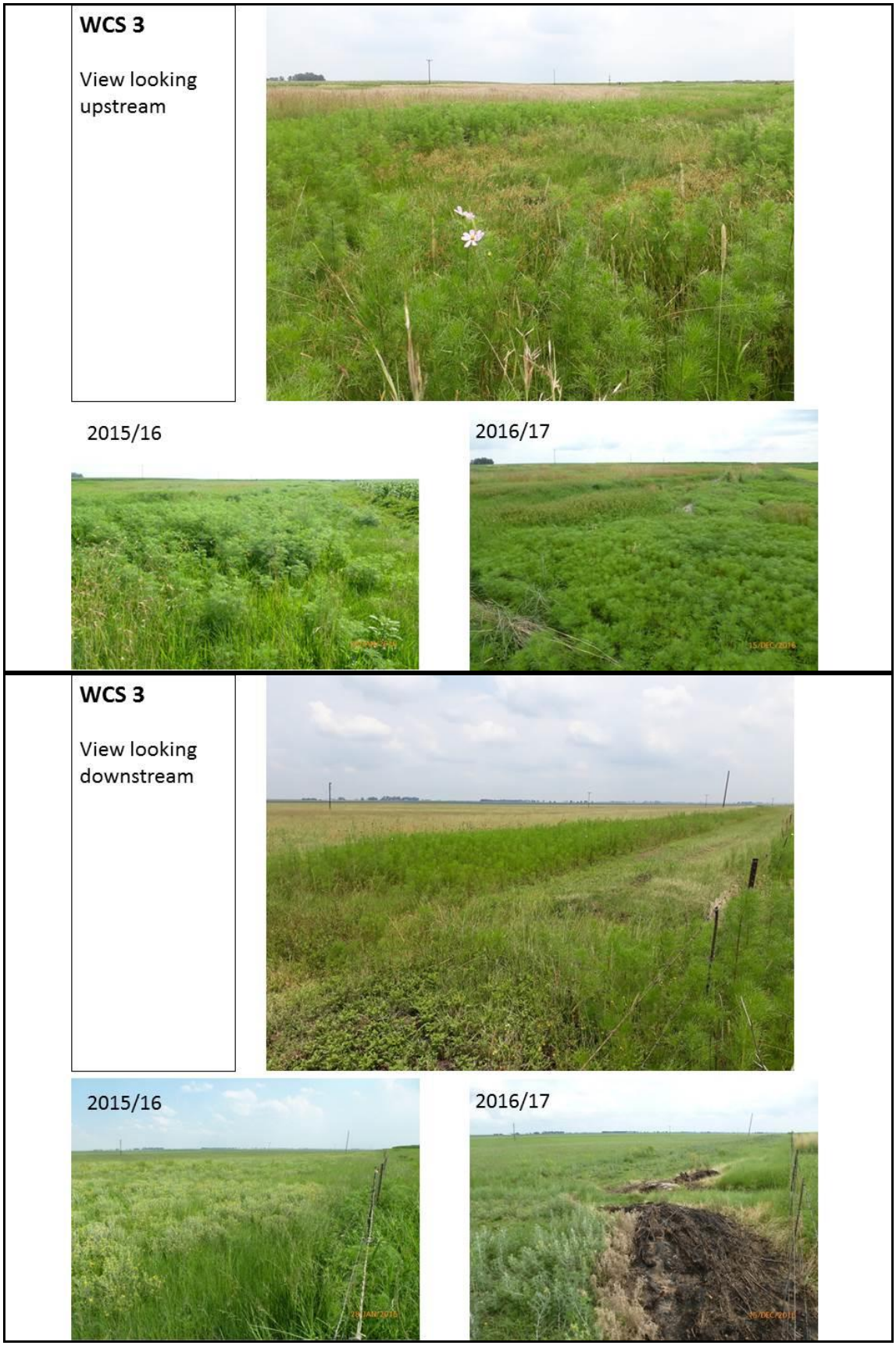


Figure 25. Fixed point photographs for monitoring site WCS 3. Note extensive *Bidens formosa* (Cosmos) cover, as well as increase in *Bidens formosa* along firebreak (downstream view)

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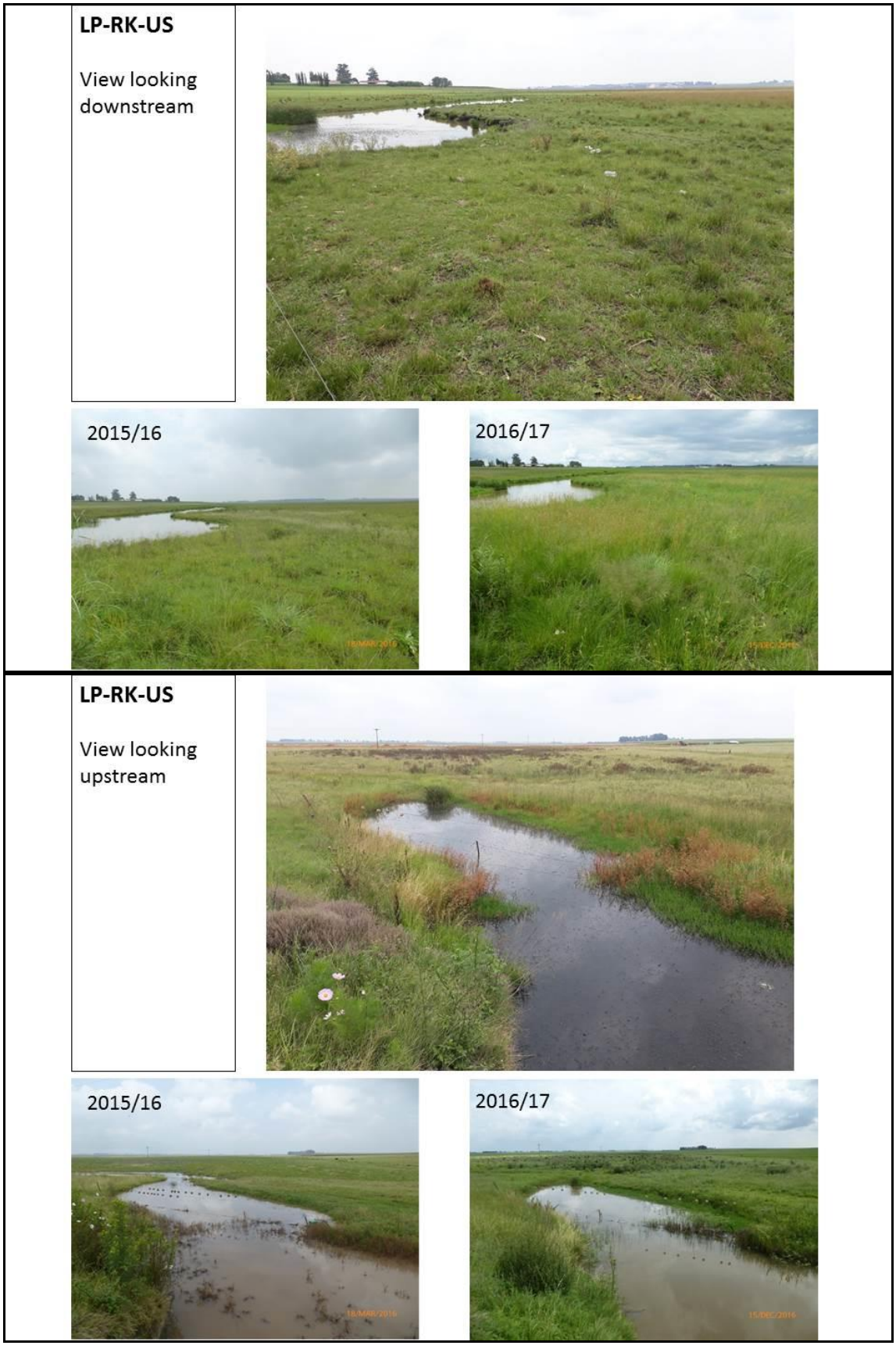


Figure 26. Fixed point photographs for monitoring site LP-RK-US. No significant change observed.

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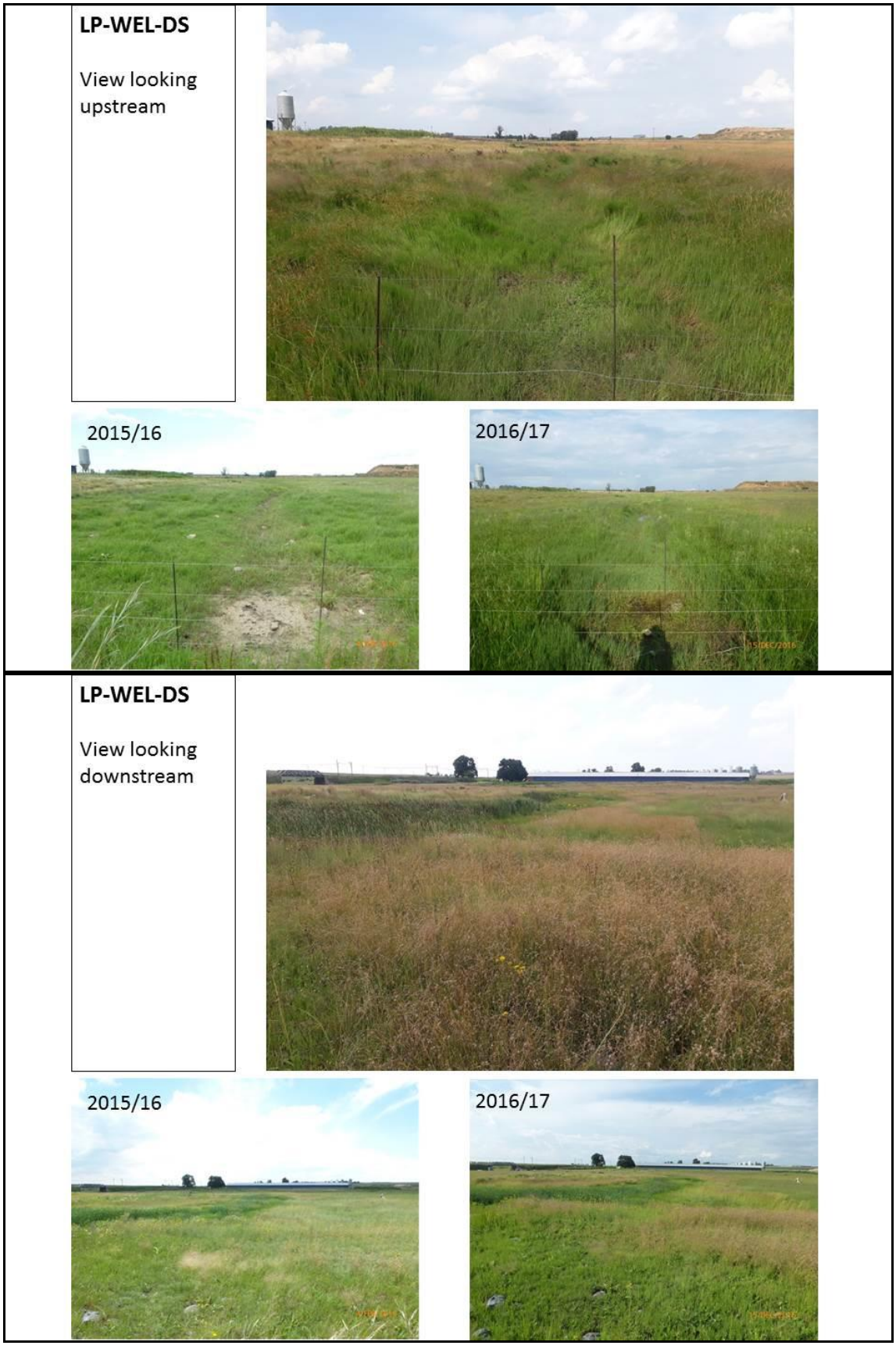


Figure 27. Fixed point photographs for monitoring site LP-WEL-DS. No significant change observed.

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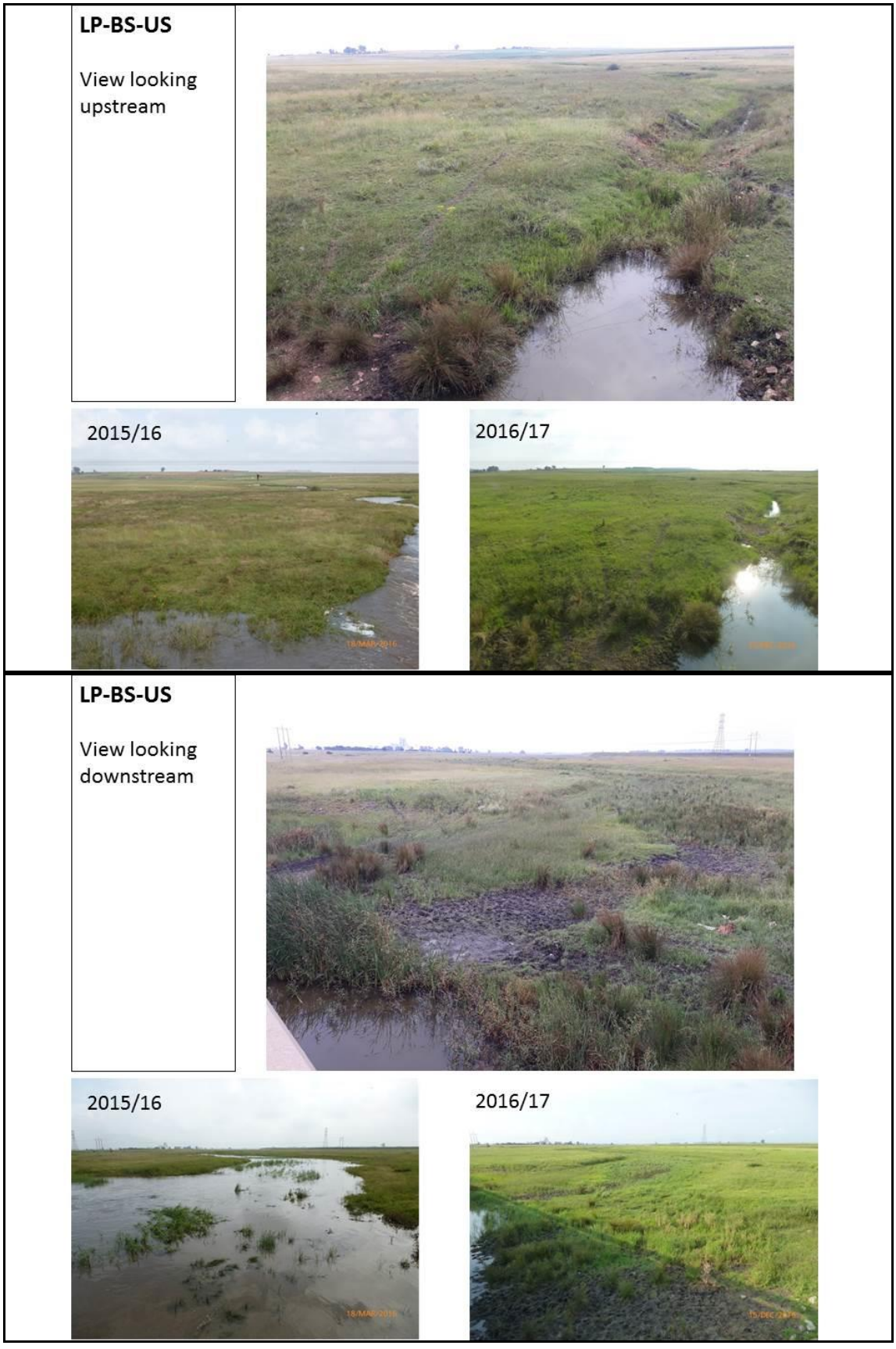


Figure 28. Fixed point photographs for monitoring site LP-BS-US. Note livestock trampling (downstream view). No significant change observed.

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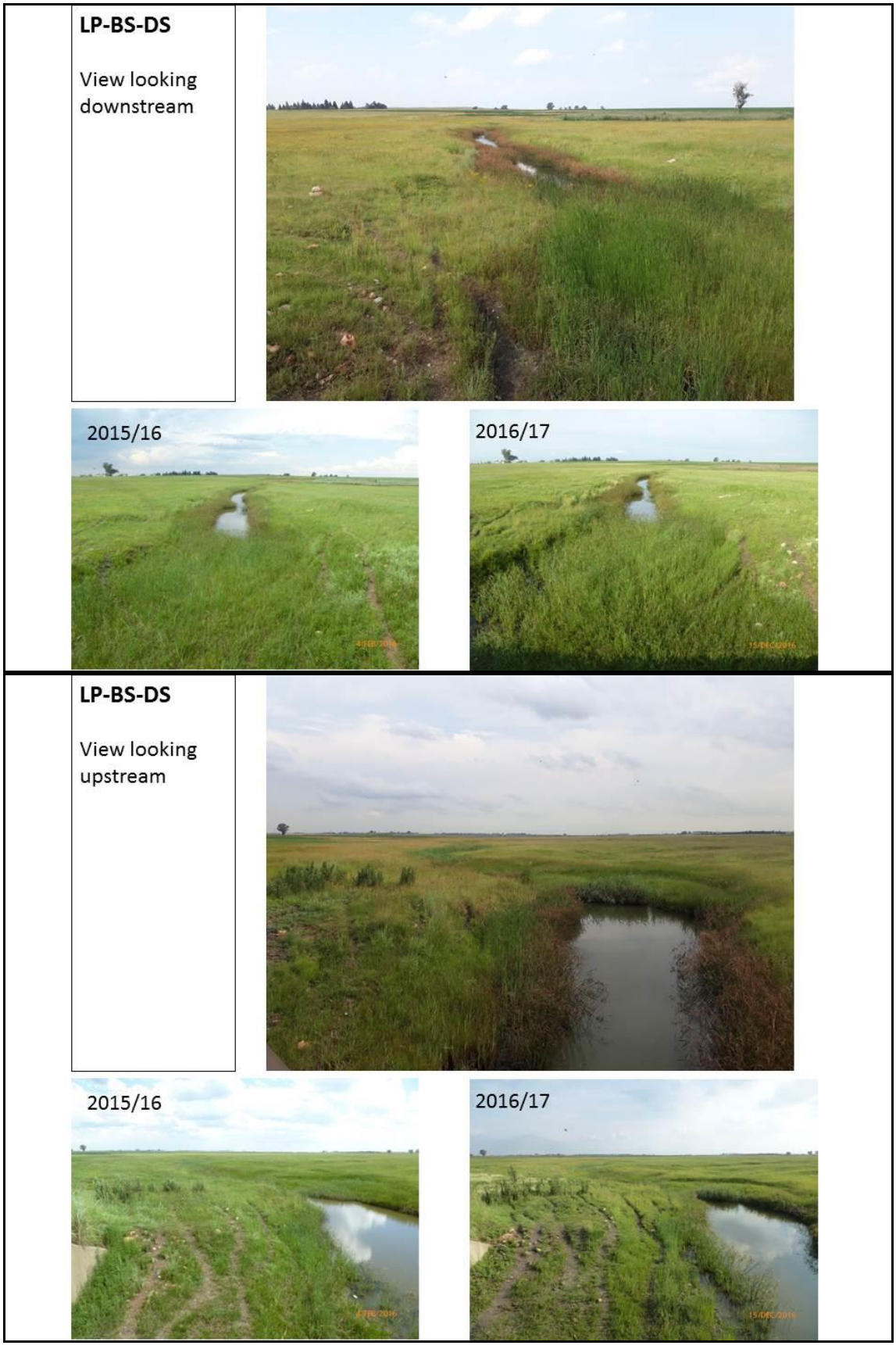


Figure 29. Fixed point photographs for monitoring site LP-BS-DS. No significant change observed.

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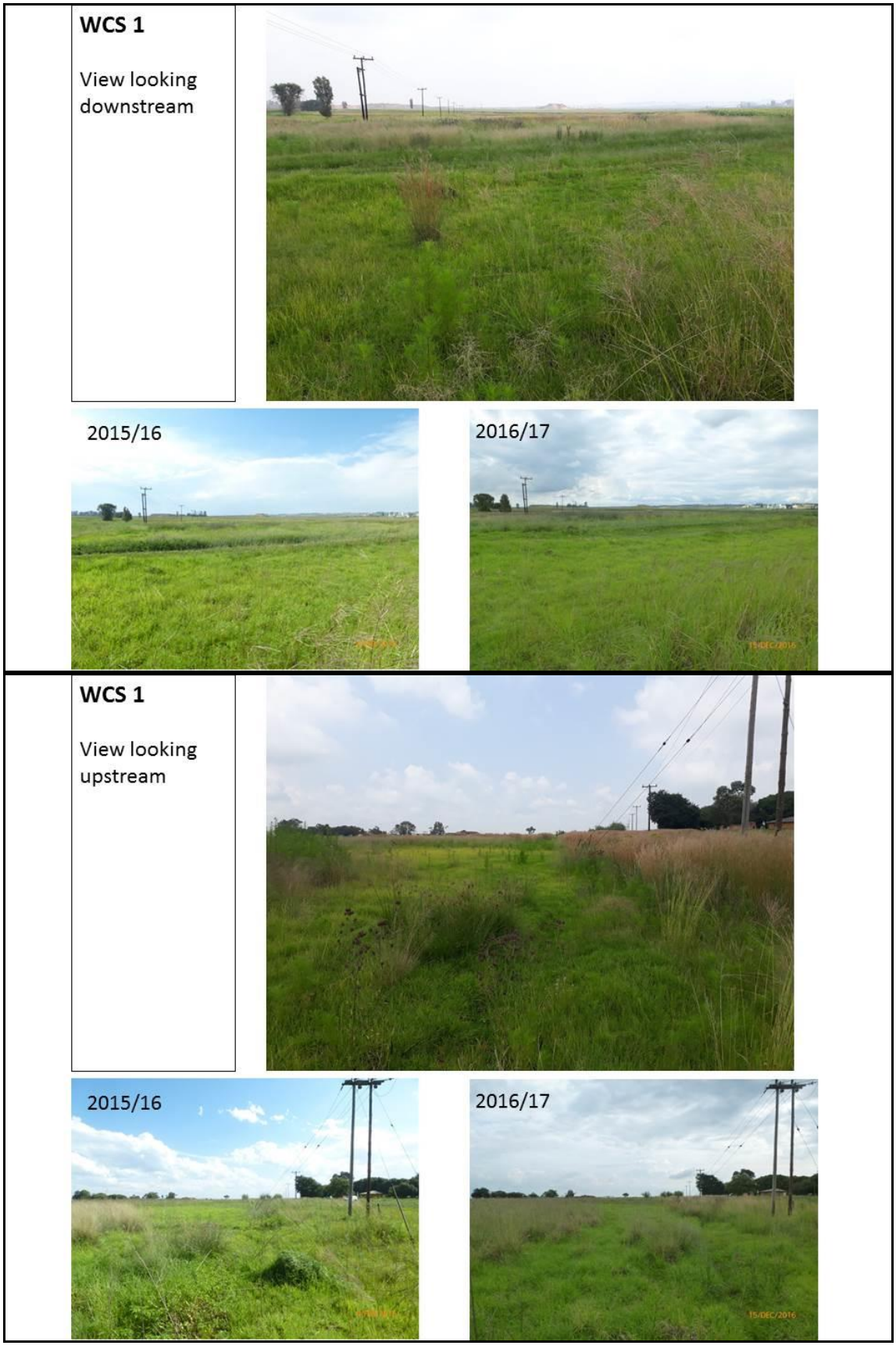


Figure 30. Fixed point photographs for monitoring site WCS 1. No significant change observed.

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7. CONCLUSION & RECOMMENDATIONS

River Diversion

The findings of the walkdown survey and ecological assessment of the river diversion largely echo the findings from previous year's wetland monitoring reports (WCS, 2016 and 2017), with the significant exception that the upper end of the diversion has been mined through and **NO CONNECTION EXISTS BETWEEN THE DIVERSION AND THE UPSTREAM WETLAND**. As such the diversion is currently not functional and urgent intervention is required to ensure clean water flows from upstream enter the diversion and flow further into downstream water resources.

In addition, large sections of the river diversion still have the appearance of a temporary diversion canal rather than a permanent stream diversion. The entire diversion is highly disturbed and generally poorly vegetated, being dominated by weedy and pioneer species. It appears as though little if any longitudinal flow occurs along the diversion under normal conditions. Lateral flows are also largely obstructed from entering the diversion.

From an ecological point of view the confined nature of the diversion, vertical channel walls for long sections and adjacent berms and stockpiles, severely limit the opportunity for the formation of a lateral ecotonal link between the aquatic habitat and the remaining adjacent terrestrial habitat. The only possible hydrological variation in the system under current conditions is vertical.

It is our recommendation that the design of the river diversion be re-evaluated in terms of hydrological functionality as well as ecological sustainability in the long-term (post-mining) and that interventions are implemented to improve the diversion. The following ecological objectives should be considered:

- To improve habitat heterogeneity across the entire footprint of the diversion;
- To improve longitudinal flow connectivity along the diversion;
- To improve the availability of suitable habitat for aquatic fauna;
- To improve the quality or suitability of existing habitats for aquatic fauna;
- To increase lateral connectivity between the diversion and the adjacent terrestrial habitat;
- To manage water quality;
- To increase in-stream habitat diversity and velocity variation to improve longitudinal connectivity and biodiversity; and
- To try to improve the aesthetics of the feature, imparting a more "natural" appearance.

It was indicated by mine personnel that the intention is to recreate a watercourse across the rehabilitated opencast area. If this is the case, the design of the re-created watercourse should be guided by the same objectives as listed above, but should also consider the risks of increased ingress of water into the opencast pits, which could lead to an increase in the generation of dirty/decant water requiring treatment. The recreated watercourse will therefore need to be appropriately designed to ensure ingress is limited. ***It is also considered of critical importance that specialist inputs from a wetland scientist and/or ecologist are obtained to ensure appropriate design of the recreated watercourse***.

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The re-design of the river diversion is however likely to be a lengthier process. In the short term, the following should be addressed:

- All alien invasive species should be removed from the diversion, with regular follow-up surveys to ensure all invasive species are eradicated.
- All flow impediments in the diversion need to be removed to ensure flow through the diversion is possible.
- Lateral flows from clean catchment should be allowed to enter the diversion. Flow impoundment along soil berms adjacent to the diversion must be avoided.

PES Assessment

5 of the 7 wetland units assessed were found to be in a moderately modified condition (PES category C), with only wetland LP-WEL-DS considered largely modified (PES category D) and wetland WCS 03 considered seriously modified (PES category E). ***These results largely mirror the results of the previous two summer season assessments, with no change in PES categories for 6 of the wetlands***. The only significant change occurred in the unchannelled valley bottom wetland at sample site LP-RK-US. This wetland has deteriorated from a PES C (score of 2.7) to a borderline PES C/D (score of 3.9). This is as a direct consequence of the construction of the re-aligned R50 tar road. At the time of this survey the raised road berm had been constructed across the full length of the wetland, though culverts had not yet been installed, i.e. there was no flow connectivity across the road under construction. Road culverts have however subsequently been installed.

Alien Vegetation Survey

A number of alien species were identified within the wetland units assessed. All alien invasive species and populations observed during the previous two summer season surveys were still present on site and have increased, indicating that no clearance of alien vegetation had been done within these wetlands and the diversion. ***It is of great importance that the management of alien vegetation receives attention within the Leeuwpan Mining rights Area and that clearing and control measures are implemented***.

Of concern was the increased presence of the Pompom weed (*Campuloclinium macrocephalum*) in a number of wetland units. First observed during the 2015/16 summer season as isolated stands or individuals, this species has now spread into larger colonies, with additional infestation areas also noted. It is recommended that these infestations be addressed and controlled through the alien vegetation management plan of the mine before they become more established and spread further.

Recommendations for future monitoring

It is recommended that the annual monitoring of the river diversion and wetlands continues as per the current protocol, with the following additional monitoring activity:

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8. REFERENCES

Department of Water Affairs and Forestry, 2005. A practical field procedure for identification and delineation of wetland and riparian areas. DWAF, Pretoria.

Ferrar, A.A. and Lötter, M.C. 2006. Mpumalanga Biodiversity Conservation Plan Map. Mpumalanga Tourism and Parks Agency, Nelspruit.

Macfarlane, D.M., Kotze, D.C., Ellery, W. N., Walters, D., Koopman, V., Goodman, P. and Goge, C. 2009. WET-Health: A technique for rapidly assessing wetland health. Water Research Commsision. Report No. TT340/09

Midgley, D.C., Pitman, W.V. and Middelton, B.J. 1994. Surface Water Resources of South Africa 1990 Book of Maps: Volume 1. Water Research Commission. WRC 298/1.2/94

Wetland Consulting Services. 2013. Wetland Delineation and Assessment for the Exxaro Leeuwpan Coal Mine near Delmas, Mpumalanga. Reference: 842/2012

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APPENDIX 1

Species Name	LP-WEL-DS	LP-BS-DS	WCS1	LP-RK-US	WCS3	LSW08	LP-BS-US	Diversion
Acacia mearnsii								●
Agrostis lachnantha		●	●			●		●
Agrostis montevidensis			●					●
Aristida junciformis	●	●						
Berkheya radula	●	●	●			●	●	
Berkheya zeyheri		●		●		●	●	
Bidens bipinnata								●
Bidens formosa		●	●		●	●		●
Bidens pilosa								●
Campuloclinum macrocephalum			●					●
Carex sp.		●						
Chamaecrista mimosoides						●		
Cirsium vulgare				●			●	
Conyza albida						●	●	
Nidorella podocephala		●	●	●	●	●		●
Cortaderia sp.								●
Crinum bulbispernum	●	●		●		●		
Cymbopogon pospischilii		●		●			●	
Cynodon dactylon		●	●	●	●	●	●	●
Cyperus congestus			●					
Cyperus denudatus	●		●	●		●		●
Cyperus esculentus			●		●			●
Cyperus fastigiatus	●	●					●	
Cyperus longus		●						
Cyperus sp.				●				
Datura ferox								●
Denekia capensis				●		●		
Digitaria eriantha	●							
Eleocharis acutangula								●
Eleocharis dregeana				●			●	●
Eleocharis sp.				●				
Eragrostis capensis							●	
Eragrostis chloromelas	●	●				●	●	
Eragrostis curvula			●			●		●
Eragrostis heteromera				●				
Eragrostis inamoena	●							
Eragrostis plana	●	●	●	●		●	●	
Eragrostis racemosa							●	
Eragrostis rotifer						●		
Eragrostis sp.		●	●					
Erythrina zeyheri		●						
Euphorbia clavarioides							●	
Euphorbia striata		●						
Fimbrostylus complanata	●	●	●					
Fingerhuthia sesleriiformis		●						
Fuirena pubescens		●						

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Species Name	LP-WEL-DS	LP-BS-DS	WCS1	LP-RK-US	WCS3	LSW08	LP-BS-US	Diversion
Gladiolus elliotii		●						
Gladiolus sp.						●		
Gomphocarpus fruticosus				●			●	●
Haplocarpha scaposa							●	
Helictotrichon turgidulum			●					
Hemathria altissima	●	●					●	
Hibiscus trionum		●						
Hyparrhenia hirta	●		●			●		
Hyparrhenia tamba						●		
Hypoxis sp.	●		●					
Imperata cylindrica		●						●
Juncus effusus								●
Juncus oxycarpus	●							
Kylinga erecta	●		●	●		●	●	●
Ledebouria sp.		●				●		
Leersia hexandra	●	●		●	●	●	●	●
Marsilea macrocarpa				●				
Melinis repens								●
Nidorella anomala	●		●				●	
Oenothera rosea	●		●			●	●	
Oxalis depressa					●			
Panicum sp.				●				●
Paspalum dilatatum			●	●	●	●		●
Paspalum distichum				●				
Paspalum urvillei						●		●
Pennisetum clandestinum			●					
Persicaria sp.	●	●					●	●
Phragmites australis		●						
Plantago lanceolata			●			●	●	
Poaceae			●	●			●	
Pogonathria squarrosa								
Populus sp.								●
Pseudognaphalium luteo-album	●			●		●		
Pycreus sp.	●	●	●	●	●			
Ranunculus multifidus	●			●		●		
Rumex crispus				●			●	
Salix babylonica								●
Scabiosa columbaria		●				●	●	
Schkuhria pinnata	●	●	●			●	●	
Schoenoplectus decipiens	●	●	●			●		
Schoenoplectus sp.								●
Senecio inornatus	●	●	●			●	●	
Senecio polyodon		●				●	●	
Setaria incrassata		●				●	●	
Setaria pallide-fusca				●	●			
Seteria sphacelata	●		●					
Solanum panduriforme		●					●	
Sorghum bicolor			●					
Sporobolus africana				●				
Tagetes minuta					●			●

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Species Name	LP-WEL-DS	LP-BS-DS	WCS1	LP-RK-US	WCS3	LSW08	LP-BS-US	Diversion
Tamarix sp.								●
Themeda triandra	●	●	●		●	●	●	
Typha capensis	●					●	●	●
Verbena bonariensis		●	●		●	●	●	●
Veronica anagallis-aquatica		●						
Wahlenbergia calendonica	●		●					
Lotononis listii		●					●	
Zea mays					●			

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Annexure H
Section 27 Motivation



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Section 27 Motivation

National Water Act, 1998 (Act No. 36 of 1998)

Report

Version – Final

07 June 2019

Exxaro Leeuwpan

GCS Project Number: 19-0504

Client Reference: PO: 4512331767



Section 27 Motivation

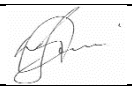
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1 EXISTING LAWFUL WATER USE

Existing Lawful Water Use (ELWU) is defined in section 32 of the National Water Act 1998, (Act No. 36 of 1998) (NWA) as any water use which has taken place at any time during a period of two years immediately before the date of commencement of the NWA or which has been declared an existing lawful water use under section 33 and which was authorised by or under any law which was in force immediately before the date of commencement of the NWA.

As Leeuwpan Coal has been operational since 1992, several of the Water Use activities at the mine commenced before the promulgation of the NWA, 1998. The ELWUs undertaken at the Existing Leeuwpan Coal Mine in terms of section 21 of the NWA are listed in Table 1.1 below.

Table 1.1 Existing Lawful Water Uses under Section 21

Property Name	Section 21	Description	Date Commenced
Witklip 229 IR, Portion 4	(a)	Witklip Borehole abstraction	1994
Witklip 229 IR, Portion 4	(c) & (i)	River diversion. Permit B187/1/220/6 in terms of Section 20 (1)(a) of the Water Act, (Act 54 of 1956).	1993
Witklip 229 IR, Portion 6	(c) & (i)	River diversion. Permit B187/1/220/6 in terms of Section 20 (1)(a) of the Water Act, (Act 54 of 1956).	1993
Witklip 229 IR, Portion 16	(c) & (i)	River diversion. Permit B187/1/220/6 in terms of Section 20 (1)(a) of the Water Act, (Act 54 of 1956).	1993
Kenbar 257 IR	(g)	Domestic wastewater disposal	1994
	(g)	In-pit backfilling.	1992
	(g)	Disused Slimes dams No. 1,2 and 3	1994
	(g)	Plant raw water dams.	1992
	(g)	Workshop raw water tank.	1992
Leeuwpan 246 IR	(g)	Domestic Waste Disposal	1994
	(g)	Load out Evaporation Dam	1992
Witklip 229 IR, Portion 4	(g)	Witklip evaporation dam.	1994
Witklip 229 IR, Portion 4	(j)	Pit Dewatering	1992
Kenbar 257 IR	(j)	Pit Dewatering	1992

Leeuwpan mine have also been issued with two licences from the Department of Water and Sanitation (DWS). The licences issued are as follows:

- Licence No. 04/B21A/ABCGIJ/429 issued on the 25th March 2011. An amendment to the IWUL was also issued in terms of section 50 and section 158 of the NWA on the 18 December 2015; and
- Licence No. 04/B20A/CIJ/4032 issued on the 18th December 2015. The licence was issued for the proposed expansion mining activities in Block OI and OL.

The ELWUs listed in Table 1.1 were included in the licence that was issued in 2011 (Licence No. 04/B21A/ABCGIJ/429).

Refer to Table 1.2 for all of the licenced water uses as per the issued IWUL (Licence No. 04/B21A/ABCGIJ/429) and its associated Amendment issued in 2015.

Table 1.2 Existing Approved Water Uses

Water Uses - Leeuwpan Mine (04/B21A/ABCGIJ/429) Including 18th December 2015 Amendments				
Section 21(a)	**Site Name**	**Co-ordinates**	**Property**	**Volume Licenced**
Taking of water from a Borehole	Borehole	26°55'07.7"S 29°36'04.0"E	Kenbar 257 IR	68400m³
Abstraction of waste water from Block OD	Block OD	26°10'41.6"S 28°43'26.3"E	Kenbar 257 IR	226 992m³/a
Abstraction of waste water from Block OM	Block OM	S26°10'24.2" E28°44'58.4"	Kenbar 257 IR	20000m³/a
Abstraction of waste water from Block OH	Block OH	S26°10'24.2" E28°44'58.4"	Kenbar 257 IR	26400m³/a
Abstraction of waste water from Block OJ	Blovk OJ	S26°09'49.2" E28°45'45.2"	Moabsvelden 248 IR	292000m³/a
Abstraction of waste water from Block OWM	Block OWM	S26°09'49.2" E28°45'45.2"	Moabsvelden 248 IR	31880m³/a
Section 21(b)	**Site Name**	**Co-ordinates**	**Property**	**Capacity m³**
Low Lying Area 2: Storage capacity varying circular unlined	Low Lying Area 2	26°11'09.8"S 28°42'33.1"E	Wolvenfontein 244 IR	188 000
Section 21(c) and (i)	**Property**			
Block OWM River diversion – Weltevreden tributary of the Bronkhorstspruit	Moabsvelden 248 IR & Weltevreden 227 IR			
Section 21(g)	**Site Name**	**Co-ordinates**	**Property**	**Capacity / Size / Area/ Volume Licenced (m³/a)**
Dirty runoff and process water used for dust suppression	Dust Suppression	26°10'45.4"S 28°43'58.0"E	Kenbar 257 IR	6 552
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 1	26°10'53.1"S 28°44'20.4"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 2	26°10'54.8"S 28°44'17.5"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 3	26°10'55.4"S 28°44'18.5"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 4	26°10'56.2"S 28°44'16.9"E	Kenbar 257 IR	10m³

Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 5	26°10'57.7"S 28°44'20.2"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 6	26°11'09.2"S 28°43'46.4"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 7	26°11'06.4"S 28°43'36.5"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 8	26°11'08.4"S 28°43'36.5"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 9	26°11'08.4"S 28°43'37.3"E	Kenbar 257 IR	10m³
Disposing of waste into the pollution control dam in a manner which may detrimentally impact on a water resource - Septic tank (all these tanks are transported via honey sucker to the 7m³ STP located at the mining green area	Septic Tank 10	26°11'10.2"S 28°43'38.1"E	Kenbar 257 IR	10m³
Disused Slimes Dam 1 & 2 that are lined with composite lining	Slimes Dams 1 & 2	26°10'58.6"S 28°43'53.4"E	Kenbar 257 IR	Footprint Area = 2.1Ha Height = 2.5m Length = 40m Breadth = 15m Volume = 88800m³
Disused Slimes Dam 3 that are lined with composite lining	Slimes Dam 3	26°10'58.6"S 28°43'53.4"E	Kenbar 257 IR	Footprint Area = 1.4Ha Height = 2.5m Length = 40m Breadth = 15m Volume = 111 500m³
Plant reuse raw water dam compartment 1 - collects contaminated water from the Witklip evaporation Dam, mobile pit water tank, washbay low lying area and Block OD	Raw Water Dam Compartment 1	26°10'52.9"S 28°43'51.6"E	Kenbar 257 IR	Footprint Area = 2.1Ha Height = 2.7m Length = 10m Breadth = 10m Volume = 51 000m³
Plant reuse raw water dam compartment 2 - collects contaminated water from the Witklip evaporation Dam, mobile pit water tank, washbay low lying area and Block OD	Raw Water Dam Compartment 2	26°10'48.9"S 28°43'51.0"E	Kenbar 257 IR	Footprint Area = 2.2Ha Height = 2.6m Length = 10m Breadth = 10m Volume = 55 000m³
Wash bay low laying area - the low lying area collects clear water from the oil separator at the workshop & washbay as	Wash bay low laying area	26°10'55.4"S 28°44'16.0"E	Kenbar 257 IR	Footprint Area = 0.6Ha Height = 0.5m

well as runoff from the washbay for reuse at the washbay or its pumped to the plant raw water dams – unlined				Length = 250m Breadth = 100m Volume = 3007m³
Mobile pit water tank - this tank collects contaminated water pumped from the open pits and is pumped to the plant raw water dams - steel tank	Mobile pit water tank	26°10'24.9"S 28°44'30.0"E	Kenbar 257 IR	Footprint Area = 0.003Ha Height = 2m Length = 6m Breadth = 6m Volume = 60m³
Process water storage tank 3 - process water from the plant is stored in this tank - steel tank	Process water storage tank 3	26°10'21.7"S 28°43'51.0"E	Kenbar 257 IR	Footprint Area = 0.035Ha Height = 3m Length = 0m Breadth = 0m Volume = 1050m³
Process water storage tank 4 - process water from the plant is stored in this tank - steel tank	Process water storage tank 4	26°10'21.7"S 28°43'51.0"E	Kenbar 257 IR	Footprint Area = 0.023Ha Height = 4.7m Length = 0m Breadth = 0m Volume = 1081m³
Plant raw water tank 1 - contaminated water from the plant raw water dams are stored in this dam for reuse - steel tank	Plant raw water tank 1	26°10'21.7"S 28°43'51.0"E	Kenbar 257 IR	Footprint Area = 0.007Ha Height = 2.5m Length = 0m Breadth = 0m Volume = 166m³
Workshop Raw Water Tank - this tank stores contaminated water from the plant raw water dams for use at the wash bay - steel tank	Workshop raw water tank	26°10'54.3"S 28°44'18.8"E	Kenbar 257 IR	Footprint Area = 0.003Ha Height = 2m Length = 0m Breadth = 0m Volume = 60m³
In-pit backfilling - disposal of plant discard from filter press and over burden into the open pits. Front pit area > total area of property on which waste is disposed	In-pit backfilling	26°10'19.7"S 28°42'45.6"E	Kenbar 257 IR	Footprint Area = 1548Ha Volume = 6 432 m³/d
Low Lying Area 1 - this was an internal catchment area that exists as a result of the location of the infrastructure and the pits at Blocks OH, OM and OD. Only clean runoff was contained in this area. The water surface area at full supply level is 9.5 Hectares. But the area has in the meantime been cleaned up, and filled and compacted to be used as product stockpile area. This will be used to contain run-off water from product stockpile beds.	Low Lying Area 1 - Product Stockpile Area	26°10'21.7"S 28°43'51.0"E	Kenbar 257 IR	Footprint Area = 2.1Ha Height = 8m Length = 100m Breadth = 25m Volume = 30 000m³/a
Conservancy Tank 1 - linked to STP of 4m³ situated at plant offices	Conservancy Tank 1	26°10'19.6"S 28°43'47.4"E	Leeuwpan 246 IR	10m³
Conservancy Tank 2 - linked to STP of 4m³ situated at plant offices	Conservancy Tank 2	26°10'17.3"S 28°43'49.3"E	Leeuwpan 246 IR	10m³
Conservancy Tank 3 - linked to STP of 4m³ situated at plant offices	Conservancy Tank 3	26°10'18.8"S 28°43'50.7"E	Leeuwpan 246 IR	10m³
Conservancy Tank 6 - linked to STP of 4m³ situated at plant offices	Conservancy Tank 6	26°10'15.7"S 28°43'41.1"E	Leeuwpan 246 IR	10m³
Conservancy Tank 7 - cleaned by Honey Sucker and disposed into STP of 4m³ situated at plant offices	Conservancy Tank 7	26°10'17.5"S 28°43'39.9"E	Leeuwpan 246 IR	10m³

Conservancy Tank 8 - cleaned by Honey Sucker and disposed into STP of 4m³ situated at plant offices	Conservancy Tank 8	26°10'24.5"S 28°43'40.7"E	Leeuwpan 246 IR	10m³
Conservancy Tank 16 - cleaned by Honey Sucker and disposed into STP of 4m³ situated at plant offices	Conservancy Tank 16	26°10'22.5"S 28°43'40.6"E	Leeuwpan 246 IR	10m³
Conservancy Tank 19 - cleaned by Honey Sucker and disposed into STP of 4m³ situated at plant offices	Conservancy Tank 19	26°09'57.8"S 28°43'47.8"E	Leeuwpan 246 IR	10m³
Package Sewage Treatment Plant	Package Sewage Treatment Plant	26°10'52.4"S 28°44'22.2"E	Kenbar 257 IR	7m³
Package Sewage Treatment Plant	Package Sewage Treatment Plant	26°92553"S 28°95365"E	Kenbar 257 IR	4m³
Plant Pollution Control Dam - the dam collects runoff from the plant and the coal product stockpiles that is used for dust suppression - Lined Dam, composite lining system	Plant Pollution Control Dam	26°10'02.8"S 28°43'28.5"E	Leeuwpan 246 IR & Wolvenfontein 244 IR	Ha Coverage = 2.1 Ha Height = 1.7m Length = 200m Breadth = 100m Volume = 90 000m³
Load Out Evaporation Dam - Direct rainfall at the load-out station is collected and left out to evaporate - not lined	Load Out Evaporation Dam	26°09'49.2"S 28°43'51.6"E	Leeuwpan 246 IR	Ha Coverage = 0.5Ha Height = 1.5m Length = 25m Breadth = 50m
Process Water Storage tank 1 - Process water tank 1 stores process water used at the plant - steel tank	Process Water Storage Tank 1	26°10'15.6"S 28°43'41.7"E	Leeuwpan 246 IR	Intake Water = 5328 and 20 000 m³ Ha Coverage = 0.038Ha Height = 3m Vol. Used = 1140 m³
Process Water Storage tank 2 - Process water tank 2 stores process water used in the plant - steel tank	Process Water Storage Tank 2	26°10'15.6"S 28°43'41.7"E	Leeuwpan 246 IR	Intake Water = 5328 and 20 000 m³ Ha Coverage = 0.038Ha Height = 3m Vol. Used = 1140 m³
Plant Raw Water Tank 2 - the tank stores contaminated water from the plant raw water dams for reuse at the plant - steel tank	Plant Raw Water Tank 2	26°10'15.6"S 28°43'41.7"E	Leeuwpan 246 IR	Intake Water = 5328 and 20 000 m³ Ha Coverage = 0.0063Ha Height = 4.7m Vol. Used = 296 m³
Jig Thickener Dam - contains water from the Jig Plant dirty water management system -Steel Dam	Jig Thickener Dam	26°10'14.5"S 28°43'41.6"E	Leeuwpan 246 IR	Ha Coverage = 0.00236Ha Height = 4.5m Vol. Used = 740 m³
Jig Clarified Dam - contains water from the Jog plant water management system - Steel Dam	Jig Clarified Dam	26°10'14.5"S 28°43'41.6"E	Leeuwpan 246 IR	Intake Water = 3 000 m³ Ha Coverage = 0.00035Ha Height = 4.5m Vol. Used = 160 m³
Witklip Return Water Dam (Reg. 24059135) - process water from the plant is stored in this return dam. Sized to accept seepage from the under drainage system and decant system for up to 1:50 year rainfall event, over and above normal operating conditions	Witklip Return Water Dam	26°10'23.5"S 28°42'26.3"E	Witklip 229 IR	Intake Water = 5328 (a) and 20 000 m³ (j) Ha Coverage = 50Ha Height = 4m Length = 100m Breadth = 200m

Witklip Evaporation Dam - the dirty storm water collected in this dam is left to evaporate - Lined with clay - application made with Dam Safety Office	Witklip Evaporation Dam	26°10'23.5"S 28°42'26.3"E	Witklip 229 IR Ptn 4	Intake Water = 5328 (a) and 20 000 m^3 (j) Ha Coverage = 3.3Ha Height = 5.9m Length = 50m Breadth = 50m
Section 21(j)	**Site Name**	**Co-ordinates**	**Property**	**Volume Licenced**
Abstraction of waste water from Block OD	Block OD	26°10'41.6"S 28°43'26.3"E	Kenbar 257 IR	226 992m^3/a
Abstraction of waste water from Block OM	Block OM	S26°10'24.2" E28°44'58.4"	Kenbar 257 IR	20000m^3/a
Abstraction of waste water from Block OH	Block OH	S26°10'24.2" E28°44'58.4"	Kenbar 257 IR	26400m^3/a
Abstraction of waste water from Block OJ	Blovk OJ	S26°09'49.2" E28°45'45.2"	Moabsvelden 248 IR	292000m^3/a
Abstraction of waste water from Block OWM	Block OWM	S26°09'49.2" E28°45'45.2"	Moabsvelden 248 IR	31880m^3/a

2 THE NEED TO REDRESS THE RESULTS OF PAST RACIAL AND GENDER DISCRIMINATION

The paragraphs which follow hereunder will indicate how Leeuwpan addresses and facilitates the results of past racial and gender discrimination in the context of public policies.

Policy/Plan	Provision
South Africa's National Policy Framework for Women's Empowerment and Gender Equality	To promote a society in which women and men are able to realise their full potential and to participate as equal partners in creating a just and prosperous society for all.
The Broad Based Socio Economic Empowerment Charter for the South African Mining and Minerals Industry	The objectives of the Mining Charters is to: ➢ promote equitable access to the nation's mineral resources to all the people of South Africa; ➢ substantially and meaningfully expand opportunities for Historically Disadvantaged South Africans (HDSA) to enter the mining and minerals industry and to benefit from the exploration of the nation's mineral resources; ➢ utilise and expand the existing skills base for the empowerment of HDSA; ➢ promote employment and advance the social and economic welfare of mine communities; ➢ promote beneficiation of South Africa's mineral communities; and ➢ promote sustainable development and growth of the mining industry.
A Beneficiation Strategy for the Minerals Industry of South Africa	The strategy outlines a framework that will enable an orderly development of the country's mineral value chains, thus ensuring South Africa's mineral wealth is developed to its full potential and to the benefit of the entire population.
Minerals and Mining Policy for South Africa	Equitable access to all natural resources is required, based on economic efficiency and sustainability. The creation of wealth and employment is required for the economic empowerment of communities, both directly and through the multiplier effect. This is especially relevant in the underdeveloped regions of the country.

Fundamentals of Leeuwpan's compliance with the abovementioned policies/strategies:

2.1 Procurement

Effective partnership is a requisite instrument to effect meaningful integration of HDSA into the mainstream economy. Leeuwpan aims to achieve a substantial change in racial and gender disparities prevailing in the sharing of mining assets and to pave the way for meaningful participation of HDSA for attainment of sustainable growth of the mining industry.

Leeuwpan is committed to the following preferential purchasing and procurement objectives:

- Creating an enabling environment for HDSA companies to do business with Leeuwpan;
- Ensuring that an increasing proportion of contracts are awarded to HDSA companies;

- Providing opportunities to businesses that implement their own proven economic empowerment programmes; and
- Creating awareness, understanding and support of economic empowerment objectives among key stakeholders.

Leeuwpan is dedicated to developing entrepreneurs in the informal business sector, which is the largest employer of people. To achieve the aforementioned, Exxaro has adopted the Business Incubator model to develop entrepreneurs and to overcome barriers to employment. The Business Incubator aims to develop the youth, the unemployed and to start up enterprises. The Incubator will provide support to entrepreneurs by means of operational business support and funding. The ultimate objective is to establish sustainable, financially and operationally independent businesses as a means to create jobs and grow the economy of the area.

To ensure the objective of increasing the number of HDSA SMME suppliers is met, capacity building initiatives as well as training and development are undertaken which enables small operators in the local area to become more efficient.

2.2 Employment Equity

Workplace diversity and equitable representation at all levels are catalysts for social cohesion, transformation and competitiveness of the mining industry.

In line with Exxaro's Employment Equity policy, Leeuwpan's broad objectives are to accelerate the training and promotion of designated groups and to create an environment of sustainable diversity through the implementation of Employment Equity programmes. In addition to the aforementioned, Leeuwpan strives to achieve the following:

- Preventing the existence of unfair discriminatory practices;
- Preventing sexual and racial harassment;
- Preventing the existence of barriers in the workplace which unfairly restrict employment and promotion opportunities of any person;
- Achieving an enhanced representation of underrepresented categories of people with the emphasis on individuals from designated groups, at all levels in the organisation, focused on the long-term objective of reflecting the demographics of the South African population; and
- Creating an organisational culture in which diversity is encouraged and valued while focusing on shared values in order to develop team spirit, promote mutual understanding, optimise potential and achieve organisational goals in serving the community.

2.3 Women in Mining

Leeuwpan aims to attract women to, and retain women in the mining industry and to encourage the active participation of women in the mines. Table 2.1 hereunder represents Leeuwpan's five year project projection to achieve successful participation of women in mining from 2015 - 2019.

Table 2.1 Women in mining – Five year project projection

Women in mining (Paterson bands)		Projection - 2019					
		African	Coloured	Indian	White	Total	%
F & E	Top & senior management	0	0	0	0	0	0
D	Middle management	6	0	0	2	8	40%
C	Junior management, non-managerial	24	1	1	3	29	19%
B	Semi-skilled	49	3	0	2	54	15%
A	Unskilled	8	0	0	0	8	50%
Total number of women		**87**	**4**	**1**	**7**	**99**	**15%**
Total number of employees = 640 in core operations (% based on core)							

2.4 Skills Development Plan

Leeuwpan's Skills Development Plan (hereinafter referred to as the "SDP") focuses on equipping employees with skills to promote their progression in the minerals industry and to develop into other fields and sectors according to their aspirations.

The objectives of the SDP are to ensure the availability of mining and or production operations specific skills and competencies of the workforce, as well as skilling of employees for portable skills that can be utilised by employees outside the life of mine in the mining or production industries.

2.4.1.1 Adult Basic Education and Training

Adult Basic Education and Training (ABET) training at Leeuwpan Coal will be delivered in line with Exxaro's ABET policy. The mine uses accredited training providers to do yearly assessments on ABET needs and this is incorporated into the annual workplace skills plan. The Learning Coordinator manages the ABET students and tracks and monitors progress against the WSP and shortcomings thereof.

The ABET Plan includes:

- Block release (sixteen weeks full-time) for ABET 1;
- Delivery by an accredited provider;
- Monthly meetings with all ABET students to determine needs and progress;
- Six monthly meetings with potential and lapsed ABET students, and with the unions, to motivate enrolment;
- Annual screening for new applicants;
- Identification of relevant foremen and production heads as mentors for the different ABET levels;
- Career progression planning for learners entering ABET 4;
- Monitoring of implementation by mine management; and
- Union support to continuously motivate and engage employees needing ABET training.

2.4.1.2 Learnerships

Leeuwpan supports the development of employees and the youth towards full or part qualifications. Learnerships are a full qualification. Employees can be developed as part of their career development through a learnership. Learnerships in the core and critical disciplines of mining necessitates the maintenance of a talent pipeline in identified and approved learnerships. For the talent pipeline, the unemployed youth are recruited and selected for development via learnerships.

For both employees and the youth, the Mining Qualifications Authority (MQA) seven step process is used to develop people through learnerships. When the unemployed youth have been developed they are not automatically guaranteed a position, but the benefit is that with completion of the programme they are in possession of a nationally accepted qualification that will make them marketable when applying for a job.

The budget for learners (unemployed youth) is guided by the minimum remuneration and conditions of the sectoral determination for learnerships which forms part of the Basic Conditions of Employment Act. Added to this is the cost for recruitment and selection, the institutional phase at a training provider (e.g. Colliery Training College (CTC), accommodation and travel where relevant and other personal requirements like a toolbox and Personal Protective Equipment (PPE) requirements. The average period in training for these learners is 24-30 months.

Employees selected and approved towards learnerships (18.1) receive the normal remuneration of the position for which they have been appointed while they are being trained. They are assessed through the MQA seven step process. Other costs involved are selection costs, assessment costs, and costs to the training provider for required institutional training.

Leeuwpan develops employees and the youth towards the core and critical disciplines of engineering, mining and plant learnerships. Opportunities are also offered to contractors based them meeting the entry requirements of the programme. Only accredited MQA providers are used.

2.5 Mentorship Plan

Leeuwpan has developed and is currently implementing a mentorship plan aimed at facilitating the developmental needs of its employees. Particular focus is placed on transfer of skills, knowledge and competencies to HDSA.

Mentorship will be used as one of the interventions to address a suitable socialisation programme for the induction of protégés into the new/anticipated managerial/leadership environment. Psychological preparation, acquisition of career management skills, and addressing the values, fears and aspirations of protégés are essential for the success of the programme.

Leeuwpan will facilitate the allocation of a mentor to all candidates in training as well as development schemes in order to guide employees through the career development processes.

Students and employees on formal training programs and in the talent pool will benefit from the mentoring process. The mentoring will be based on group mentoring, peer mentoring, external mentoring and also senior manager mentoring.
The benefits of the Mentorship Plan are that a trainee becomes:

- An appropriately trained and developed competent professional who can take responsibility for a wide range of engineering activities;
- A well-integrated professional who can contribute meaningfully to the profession;
- A professional who can ensure economic benefit;
- A professional who can contribute to the continuing mentorship of others; and
- A professional who renders a service to the community with integrity and who adheres to the professions code of conduct.

Mentorship will be managed formally through a deliberate, structured, and focused process at Leeuwpan. Mentorship will be used as one of the interventions to address a suitable socialization programme for the induction of trainees into the new/anticipated managerial/leadership environment. Psychological preparation, acquisition of career management skills, and addressing the values, fears and aspirations of trainees are essential for the success of the programme.

2.6 Internship and Bursary Plan

Internships are organized programmes whereby students gain practical work experience relevant to their field of study. Leeuwpan Coal will provide learning opportunities to youth in the community who are in possession of a diploma and who require the experiential learning for the completion of the diploma.

Bursary plans consist of providing financial assistance to students to pay for study related cost and offering them the opportunity to gain work experience in their field of study during vacation periods. Bursaries are allocated in the following engineering fields namely, mining, metallurgy, geology, engineering (electrical and mechanical), and industrial and in the following support services, namely human resources and environmental studies. Candidates are chosen according to set selection criteria to ensure that they are given the best opportunity to fulfil the university requirements.

Leeuwpan has developed an Internship and Bursary Plan which conforms to the Skills Development Plan, and which focuses on building capacity in various skills and careers for HDSAs. Through offering the opportunity of internships to unemployed graduates, Leeuwpan will increase participants' chances of finding employment in the future.

Workplace diversity and equitable representation at all levels are catalysts for social cohesion, transformation and competitiveness of the mining industry.

3 EFFICIENT AND BENEFICIAL USE OF WATER IN THE PUBLIC INTEREST

In 2012, Ms Susan Shabangu, the then Minister of Mineral Resources of South Africa, in an address at the 2012 South African Coal Export Conference, exclaimed the vital and strategic role played by coal in South Africa's economy. The role played by this industry is supported by the vast resources illustrated in the country's world rankings. According to the Chamber of Mines of South Africa (CMSA), the country is home to 3.5% of the world's coal resources.

The approved IWULs enables the Leeuwpan mining operations to produce coal from the activities which contributes to the abovementioned strategic role that the coal industry plays in South Africa's economy. Furthermore, the public indirectly benefits from coal through fuel and electricity usage. Coal provides 81% of the power generated by state-owned power utility Eskom. In addition, the coal industry benefits the public through being a large employer of workers. According to the CMSA, excluding Sasol, the coal sector employs in the region of 87,500 people, the third largest group in the mining sector after gold and platinum group metals. Their annual earnings are in the region of R20 billion.

This highlights the economic contribution, and therefore summarises the economic context within which the industry operates.

The concept of "public interest" is a very complex one. Under the Water Act of 1956, permits were issued to users provided that they use the water beneficially. The use was considered beneficial if the applicant was going to make a profit. Public interest however, goes much wider.

The fact that the applicant has to undertake a public participation process for proposed mining activities, and the public's opinion is to be elicited, means that, at least, the public opinion can be gauged by the response and the comments and concerns received.

As public trustee of the water resources, the Department of Water and Sanitation (DWS) must ensure that the water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner for the benefit of all users. The Minister, through the department has to ensure that the water is allocated equitably and used beneficially in the public interest, while promoting environmental values.

A detailed public participation process for the project was undertaken and all the identified impacts were able to be mitigated taking the other water users into consideration.

Leeuwpan recognises that water is a scarce resource which belongs to all people and will strive (through adherence to the conditions and provisions of the IWULs and the IWWMP) to meet the following principles (as stipulated in Section 2 of the NWA) which form the foundation of the NWA:

- Redressing the results of past racial and gender discrimination;
- Promoting the efficient, sustainable and beneficial use of water in the public interest;
- Facilitating social and economic development;
- Protecting aquatic and associated ecosystems and their biological diversity; and
- Reducing and preventing pollution and degradation of water resources.

In addition to the abovementioned, Leeuwpan will adhere to Section 19 of the NWA which stipulates that a water user must take all reasonable measures to prevent any pollution of a water resource from occurring, continuing or recurring. By adhering to the provision, Leeuwpan will ensure that the surrounding water resources are protected and utilised in a beneficial manner.

Water use activities may not commence without an approved water use authorisation. Thus, approval of the water use will indirectly contribute to the beneficial use of water by illustrating that Leeuwpan is committed to adhere to the regulatory regime governing water use in South Africa. Furthermore, Leeuwpan is committed to responsible management of its approved water uses and strives to adhere to the principles of water conservation and demand management which will benefit the community in terms of employment. Monitoring of water resources has been implemented to detect any impacts during the early stages and to mitigate these as soon as practically possible.

As a world-class minerals producer, Exxaro has a moral and legal obligation to ensure responsible and sound environmental management performances. Leeuwpan has an environmental management programme as required under the MPRDA, as well as ISO 14001 accreditation, reflecting global industry standards to minimise environmental impacts.

Exxaro has a Water Management Programme which guides the implementation of best practice water management through-out the organisation. The Water Management Programme focusses on the availability and security of water supply, the efficient and responsible use of scarce resources as well as regulatory compliance. The programme is aligned to best-practice guidelines from the DWS covering integrated water and waste management planning, storm water management planning, water and salt balances and water monitoring systems amongst other issues.

The current water uses are undertaken, managed and controlled in such a way as to ensure that pollution of the water resources is minimised and avoided.

Social and economic development will be facilitated through the employment of local residence and the technical training which these employees receive. Goods and services will be sourced from local businesses as far as possible, to enhance the economic benefits of the project.

During the Water Conservation and Demand Management (WCDM) process at the mining operation, they will deal with Pollution Prevention and also reiterate the key issues relating to impact minimisation, i.e. Water Re-use and Reclamation. It is worthwhile emphasising that consideration and application of water conservation strategies will also often have a direct and significant effect on pollution prevention.

Accordingly, Leeuwpan contributes to the efficient and beneficial use of water by adhering to the regulatory provisions as contained in the IWUL, the provisions of the NWA, best practice standards as well as new best practice technologies.

4 THE SOCIO ECONOMIC IMPACT

4.1 Of the water use or uses if authorised

4.1.1 The Social Impact:

Not applicable to this IWWMP Update. The water uses applied for have been authorised in the IWULs issued to Leeuwpan by the DWS. However, the approved IWULs and associated amendment enables Leeuwpan Mine to operate which has a definite socio-economic impact.

The authorisation of the water uses enables Leeuwpan to continue and expand their initiatives which include, but are not limited to:

- Skills transfer;
- Training initiatives;
- Scholarship opportunities; and
- Other financial contributions made by Leeuwpan.

In addition to the abovementioned, Leeuwpan employs 510 permanent employees and 499 long-term contractors with employees coming primarily from the local municipality, Delmas area in Mpumalanga and others from other parts of South Africa. By the year 2018 the labour force will comprise +/- 540 permanent employees and +/- 550 contractors due to the OI expansion activities.

4.1.2 Economic Impact

Leeuwpan's mining operations have a positive impact on the economy, which has lead to increased business sales and increased standards of living in the greater community. Increased employment is associated with increased income and consequently with increased buying power in the area, thus leading to new business sales. The economic benefits mostly include an increase in trade such as local shops, accommodation and transport services.

With the increased employment and a subsequent increase in monthly income, increased business opportunities are experienced within the local environment. The economic benefits that could be generated include an increase in trade, and the development of new trade such as local spaza shops, stalls, etc.

To enhance the positive economic impact of Leeuwpan's operations on the surrounding community, Leeuwpan has an objective of increasing the number of HDSA SMME suppliers through capacity building initiatives which will allow small operators in the local area to become more efficient. At Leeuwpan there are locally owned HDSA companies from which the mine currently procure and if required they will be targeted for a mentorship programme to

ensure the sustainability of their business. In addition Leeuwpan plans to procure additional goods/services that are core to the operations of the mine from other locally owned HDSA companies.

4.2 Of the failure to authorise the water use or uses:

No new water uses are being applied for as part of the IWWMP update.

5 ANY CATCHMENT MANAGEMENT STRATEGY APPLICABLE TO THE RELEVANT WATER RESOURCE

The DWS, in the spirit of the NWA, recognises the past imbalances relating to water allocation and seeks to regulate water use by enforcing better sharing of water and water related benefits between the whites who have historically been the “high volume water users” and the historically disadvantaged and mostly poor black population.

Catchment Management Agencies (CMAs) are recognised in the NWA as operational institutions to actively support the implementation of integrated catchment (watershed) management policies and strategies at a local level. The agencies are tasked with ensuring that the nation's water resources are protected, used, developed, conserved, managed and controlled in an equitable manner. The CMA is responsible inter alia for: (a) developing and implementing a catchment management strategy that reflects the needs and concerns of all role-players, and (b) coordinating the activities of water users and water. The Olifants River Basin is one of 19 catchment-based water management areas in the country to be managed by a Catchment Management Agency (CMA).

The Olifants River Basin Catchment Management Agency (CMA) is in the process of being established. It will take over direct water resource management responsibilities in the basin currently being performed by DWS. The CMA co-ordinates water-related activities in the basin and provides an effective mechanism for stakeholder participation in water management.

6 THE LIKELY EFFECT OF THE WATER USE TO BE AUTHORISED ON THE WATER RESOURCE AND ON OTHER WATER USERS

6.1 Surface Water

There are four (4) main uses of water that have been identified for the sub catchment of the Bronkhorstspruit up to the receiving water body, namely the Bronkhorstspruit Dam. The surface water uses include the following;

- Domestic use by formal and informal communities along the affected watercourse,

- Irrigation of crops, especially maize,
- Livestock watering including cattle, sheep and poultry and
- Aquatic ecosystems including fish, macro and micro-invertebrates.

Very few water bodies in the Delmas area are used for recreational purposes due to their seasonal nature. In most cases, dams are used for fishing.

No direct abstraction of water from the Bronkhorstspruit occurs for commercial irrigation or extensive domestic use. Dams are usually filled with water from the boreholes and this clean water is mainly used for irrigation. Numerous pans occur in the Delmas area, but are not utilized as a source of water for the above mentioned purposes.

6.2 Groundwater

Groundwater is mainly used for domestic supply, small scale irrigation (gardens), livestock watering as well as large scale pivot irrigation of crops. The boreholes used for large scale irrigation exploit the dolomitic aquifer as the yields from the Karoo Supergroup are too low to sustain the high abstraction rates. The groundwater quality in the area is generally good.

Drainage from the opencast backfill will become acidic over the long-term as the ABA results show that the material has the potential to generate acid-mine drainage. The sandstone and soft overburden have limited potential for acidic generation. The shale samples show a great variance in net acidic generation, but may have a potential for acidic generation. Elevation of TDS and SO_4 will occur as a result of pyrite oxidation. In the opencast the SO_4 will increase roughly to about 2 500 mg/l over the long term.

It is not foreseen that significant elevation in metals will occur at near-neutral conditions. After acidification non-compliance for Al, Fe and Mn may occur. Cr, Ni and to a lesser degree As and V are some of the other trace elements that may be slightly elevated and may reach occasional marginal to non-compliance.

The majority of privately owned boreholes are associated with the underlying dolomitic aquifer which in unlikely to be impact by any dewatering activities.

It is likely that preferential flow paths along faults and dolerite intrusion related to fracturing is not significant in the area based on the available data. While it is still anticipated that localised preferential flow zones will exist in relation to dolerite dykes, these zones have not been recorded and it is thought that they are not well developed. As mentioned above the drainage occurs towards the low lying areas such as rivers and streams (Bronkhorstspruit and its tributaries). Some of these streams may be impacted by contaminated seepage and decant.

7 THE CLASS AND THE RESOURCE QUALITY OBJECTIVES OF THE WATER RESOURCE

In South Africa, a river health classification scheme is used to standardise the output of different river systems. The document titled "Resource Directed Measures for Protection of Water Resources: River Ecosystems Version 1.0.24", dated September 1999, compiled by the DWAF, provides the indexes of Attainable Ecological Management Classes (AEMC) as shown in Table 7.1 below. Each index is calibrated so that its results can be expressed in terms of ecological and management perspectives.

Table 7.1 Resource classes as set out by the DWS

River Health Class	Ecological Perspective	Management Perspective
Natural / Excellent (Class A)	No or negligible modification of in-stream and riparian habitats and biota	Protected rovers; relatively untouched by human hands; no discharges or impoundments allowed
Good (Class B)	Ecosystems essentially in good state; biodiversity largely intact	Some human-related disturbance but mostly of low impact potential
Fair (Class C)	A few sensitive species may be lost; lower abundances of biological populations are likely to occur, or sometimes, higher abundances of tolerant or opportunistic species occur	Multiple disturbances associated with need for socio-economic development, e.g. impoundment, habitat modification and water quality degradation
Poor (Class D)	Habitat diversity and availability have declined; mostly only tolerant species present; species present are often diseased; population dynamics have been disrupted (e.g. biota can no longer reproduce or alien species have invaded the ecosystem)	Often characterised by high human densities or extensive resource exploitation. Management intervention is needed to improve river health – e.g. to restore flow patterns, river habitats or water quality

According to the "Classes and Resource Quality Objectives of Water Resources for The Olifants Catchment" published on the 22nd of April 2016 in the Government Gazette No.39943, Regulation 466, the Bronkhorstspruit river catchment falls into the Ecological Management Class C as defined in Table 7.2.

Table 7.2 Resource classes for the Bronkhorstspruit

River Name	Integrated Unit of Analysis (IUA)	Water Resource Class for IUA	Biophysical Node Name	Quaternary Catchment	Ecological Category to be maintained
Bronkhorstspruit (outlet of quaternary)	2 Wilge River catchment area	II	HN21/RU21	B20A	C

7.1 Receiving water quality objectives and the reserve

Constant increases in water demands, particularly from the Olifants River, motivated the DWS to investigate the water requirements of users in terms of both water quantity and quality, as well as the current management of the water resource. According to the "Classes and Resource

Quality Objectives of Water Resources for The Olifants Catchment" published on the 22nd of April 2016 in the Government Gazette No.39943, Regulation 466, no Resource Water Quality Objectives (RWQOs) have been set for the Bronkhorstspruit.

RWQOs have however been set for the Wilge River, of which the Bronkhorstspruit merges downstream. The RWQOs for the Wilgre River at the outlet of the identified IUA (in quaternary catchment B20J) are presented in Table 7.3.

Table 7.3 System variables (DWA 2001)

Sulphates	<200mg/L
F	≤ 2.50 mg/L
Al	≤ 0.105mg/L
Pb hard	≤ 9.5 µg/L
As	≤ 0.095mg/L
Se	≤ 0.022mg/L
Cd hard	≤ 3.0 µg/L
Cr(VI)	≤ 121 µg/L
Cu hard	≤ 6.0 µg/L
Hg	≤ 0.97 µg/L
Mn	≤ 0.990mg/L
Zn	≤ 25.2 µg/L
Chlorine	≤3 dissolve.1 µg/L free Cl
Endosulfan	≤ 0.13 µg/L
Atrazine	≤ 78.5 µg/

8 INVESTMENTS ALREADY MADE AND TO BE MADE BY THE WATER USER IN RESPECT TO THE WATER USE IN QUESTION

Substantial investments, time and various authorisation have been undertaken for the various authorisations of Leeuwpan's coal mining activities. The Leeuwpan Mining Operations is a coal mining operation seeking to optimise its operations, increase productivity while achieving environmental and social goals and objectives.

Leeuwpan's current investments and future investments relates to the continuous maintenance and upkeep of the current closed water systems which includes the operation of all water pipelines on the mine, and the maintenance of all trenches and channels, and Dams that is part of the clean and dirty water systems. Leeuwpan will not intentionally discharge water into the environment as the mine works on a closed water system.

9 THE STRATEGIC IMPORTANCE OF THE WATER USES TO BE AUTHORISED

In strict economic terms, the overall mining industry is paramount to South Africa's current and future prosperity. The primary value chain alone accounts for approximately 500 000 jobs directly and indirectly creates further employment opportunities and jobs that contribute to the economy. As per the CMSA's Integrated Annual Review for 2015, real mining GDP increased by 3% as the sector's production recovered from the strike-related disruption in the platinum sector in 2014. Overall, mining directly accounted for 7.7% of South Africa's GDP. Mining further pays a similar percentage of corporate tax. It accounts for half of all traffic moved by Transnet and the majority of the power generated in this country.

Numerous Mining Companies are further listed on the Johannesburg Stock Exchange (JSE), which therefore helps create wealth for millions of South African pension fund holders and investors, while at the same time attracting significant foreign capital flows that help unlock our mineral potential. And, perhaps most critically, more than half of our export earnings are derived from mining and mineral products.

With specific reference to coal mining, in 2014, South Africa produced 260Mt of coal. Of this, 182.7Mt was sold internally (with a value of R54.7 billion) while 69.6Mt (worth R46.7 billion) was exported. Coal-to-liquid-fuel plants, operated by Sasol, account for a further 40Mt consumption. Coal therefore plays a vital role in South Africa's energy-economy (CMSA, 2015).

The mining industry is of strategic importance to South Africa and thus awarding the water use licence will enable Leeuwpan to actively participate as an essential element of South Africa's economy. As previously stated, Leeuwpan directly contributes to the South African economy by means of the following:

- Promoting BEE;
- Creating jobs;
- Developing its people, and in so doing contributing to the transformation of the industry's leadership and skills base; and
- By having a positive impact on the local communities through economic development and sustainable social initiatives.

10 THE QUALITY OF WATER IN THE WATER RESOURCE WHICH MAY BE REQUIRED FOR THE RESERVE AND FOR MEETING INTERNATIONAL AGREEMENTS

10.1 International Agreements

International negotiations and institutional arrangements are handled at National Level. From a WMA management perspective, it will be required to communicate all issues relating to the international agreements through the appropriate channels at National Level.

The Olifants WMA falls within the Limpopo River Basin, which is shared by South Africa, Botswana, Zimbabwe and Mozambique. As the Olifants River flows directly from South Africa into Mozambique, where it joins the Limpopo River, developments in South Africa directly impact upon Mozambique.

Discussions have been held between Mozambique and South Africa as far back as 1971 with the development of the Massingir Agreement of 1971. This agreement dealt specifically with the building of the Massingir Dam. The principles of the Helsinki Rules were used prior to 2000 to guide the relations between South Africa and neighbouring states. In 1995, the SADC countries established the 1995 Protocol dealing with Shared Watercourse Systems. The 1995 Protocol was repealed in September 2003 and replaced with the 2000 Protocol which is now used to guide management and development on Shared Watercourse Systems.

Joint utilization of the water resources of the Olifants River is facilitated through the bilateral Joint Water Commission between South Africa and Mozambique. International co-operation with respect to the use and management of the watercourses in the Limpopo River Basin, was overseen by the Limpopo Basin Permanent Technical Committee (LBPTC) with membership by South Africa, Botswana, Zimbabwe and Mozambique. The LBPTC was replaced by the Limpopo Water Course Commission, established in November 2003 (*Olifant ISP*).

10.2 Surface Water Quality

The surface water sample locations are sampled on a monthly basis. The water analyses results are measured against various standards and limits to ascertain the water quality. The standards against which the water samples are compare include:

- SANS 241-1: 2015;
- IWUL 2011 limits (Licence no. 04/B21A/ABCGIJ/429)
- IWUL 2015 limits (Licence no. 04/B21A/ABCGIJ/429 amendment)

The surface water sites sampled in April 2019 included 9 of the targeted 12 process water sites, 8 of the targeted 10 receiving environment sites and all targeted final sewage effluent sites. The surface water sites that were not sampled in April 2019 for various reasons including dry sites, backfilled pits and no leachates being present in the field barrels.

10.2.1.1 Field Measurements

All targeted drinking water sites, 9 of the targeted 12 process water sites, 8 of the targeted 10 receiving environment sites and all targeted final sewage effluent sites were sampled in April 2019. All mine process water, sewage effluent and drinking water sites were compliant to the respective limits and standards.

10.2.1.2 Drinking Water Samples

All targeted drinking water sites were sampled in August 2018 and were screened against the SANS 241-1: 2015 drinking water standards. Marginal exceedance of arsenic was observed in drinking waters sampled from the laboratory (LWDL) and the drinking water supply tank (LDWST); furthermore, all other analysed parameters from all portable water sites were compliant to the drinking water standards.

10.2.1.3 Surface Water Samples

The April 2019 laboratory results from waters sampled from receiving environment sites were compared against the IWUL resource protection limits. The results of the water samples are presented in Annexure B.

The following parameters (mine water parameters in **bold**) were not compliant to water quality limits specified in the IWUL in April 2019 (Golder, 2019):

- WP01 (Bronkhorstspruit tributary upstream of the mine): **electrical conductivity,** ammonia, calcium, potassium, **manganese**, total alkalinity, Chlorophyll a, *E. coli* and dissolved oxygen;
- WP02 (Bronkhorstspruit tributary downstream of the mine): total dissolved solids, electrical conductivity, ammonia, calcium, magnesium, manganese, total alkalinity, E. coli, and dissolved oxygen;
- LSW08 (Bronkhorstspruit, upstream of Block OI): ammonia, calcium, manganese, total alkalinity, Chlorophyll a, E. coli and dissolved oxygen;
- LSW07 (Bronkhorstspruit, upstream): fluoride, ammonia, calcium, total alkalinity, E. coli, Chlorophyll a, dissolved oxygen and organic carbon;
- LSW03 (Bronkhorstspruit adjacent to Delmas Silica): electrical conductivity, ammonia, calcium, total alkalinity, E. coli, Chlorophyll a, dissolved oxygen and dissolved organic carbon;
- RD1 (Bronkhorstspruit at haul road): electrical conductivity, ammonia, calcium, magnesium, manganese, total alkalinity, dissolved oxygen and chlorophyll a;

- LSW13 (Stuart Coal): electrical conductivity, sulphate, ammonia, calcium and manganese, total alkalinity, E. coli and Chlorophyll a; and
- LSW05 (Bronkhorstspruit downstream): electrical conductivity, ammonia, calcium, magnesium, total alkalinity, dissolved oxygen, chlorophyll a and E. coli.

The following constituents (mine water parameters in **bold**) increased at downstream sites compared to upstream in April 2019:

- WP02: The levels of turbidity, ammonia, potassium, total hardness, alkalinity, chlorophyll a and dissolved organic carbon; total dissolved iron, E. coli and dissolved oxygen (negative increase decreased) downstream compared to upstream; and
- LSW05: Total dissolved solids, electrical conductivity, magnesium, dissolved oxygen, E. coli and total hardness.

10.2.1.4 Process Water Samples

The mine process water was classified as follows based on pH and sulphate content, in April 2019:

- Saline Drainage: LSW09, OM pit, KR01A, ODN pit, OWM pit and WP04; and
- Neutral mine drainage: KR03, KR04 and WLV pit.

Screening indicates levels of fats, oils and greases measured in waters sampled from the Downstream of workshop oil separator sump (KR03) not adhering the limits; furthermore, all other parameters from all sampled sites were compliant to the waste water limits.

10.2.1.5 Final effluent from sewage works

Final effluent from the sewage plant behind workshop (LWP-SP-W): increases were observed in total suspended solids (increased from 15 mg/L to 43 mg/L), chemical oxygen demand (COD, settled) (increased from 63 mg/L to 365 mg/L), E. coli counts (from 0 colonies/100ml to 540 colonies/100ml); nitrate (increased from 2.97 mg/L to 9.09 mg/L. Increased in E. coli counts and led to non-compliance of the IWUL limit in April as opposed to the exceedance observed in March 2019). A decreasing trend was observed from March to April 2019 in ammonia (from 82 mg/L to 40 mg/L); non-compliant against the amended IWUL limits.
The sewage treatment plant requires attention to ensure that it operates efficiently to avoid release of contaminated effluent into the environment.

Final effluent from the septic tanks at the plant (LWP-SP-P): Ammonia and E. coli remained noncompliant against the IWUL limits in April 2019 as for the previous month. Decreases were observed in total suspended solids (from 53 mg/L to 10 mg/L) and chemical oxygen demand (COD, settled) (from 276 mg/L to 44 mg/L), however an increase in E. coli (from below detection limit to 1 180 000 colonies/100ml) from March to April 2019.

The effluent from the septic tank should not be allowed to enter the environment but should continue to be emptied by an accredited waste removal company and disposed of to an authorised waste water treatment works.

10.3 Groundwater Quality

The groundwater sample locations are sampled on a quarterly basis. The water analyses results are measured against various standards and limits to ascertain the water quality. The standards against which the water samples are compare include:

- SANS 241-1: 2015;
- IWUL 2011 limits (Licence no. 04/B21A/ABCGIJ/429); and
- IWUL 2015 limits (Licence no. 04/B21A/ABCGIJ/429 amendment)

Groundwater sampling was conducted on monitoring boreholes in and around the mine as well as boreholes that are used for drinking water in surrounding farms. Groundwater was collected from 18 sampling sites and the sites that were not sampled were due to non-operational pumps, collapsed/blocked boreholes, presence of bees, and destroyed boreholes.

10.3.1.1 Field Measurements

Groundwater sampling was conducted on monitoring boreholes in and around the mine as well as boreholes that are used for drinking water in surrounding farms. Groundwater was collected from 18 sampling sites and the sites that were not sampled were due to non-operational pumps, collapsed/blocked boreholes, presence of bees, and destroyed boreholes.

10.3.1.2 Groundwater Quality Results

Ground water samples had pH values ranging from circum-neutral to alkaline (6.0≤ pH ≤ 7.9); with all pH values being compliant to the IWUL limits. Laboratory measured parameters were screened against the SANS 241 drinking water standards.

Exceedances were observed in boreholes RIE10B (aesthetic exceedance of iron, marginally), RKL02 (aesthetic exceedance of iron and manganese), RKL01 (chronic exceedance of iron and manganese), KENMB2-D (aesthetic exceedance of electrical conductivity and acute exceedance in sulphate), WELMB13-S (acute exceedance in concentrations of sulphate and manganese; and chronic exceedance in iron), WELMB13-D (aesthetic exceedance in concentrations of iron and manganese), KENMB3-S (aesthetic exceedance in levels of sulphate), LEEMB18-D (aesthetic exceedance in levels of TDS and iron, acute exceedance in sulphate and chronic exceedance in the concentration of manganese), MOAMB4 (aesthetic exceedance of manganese), MOAMB9 (aesthetic exceedance in iron and manganese concentrations), WOLMB15-D (aesthetic exceedance of sulphate), WOLMB15-S (TDS and

electrical conductivity were not adherent to the aesthetic limits and sulphate was not adherent to acute health standards) and WWN02-D (aesthetic standard for sulphate and manganese and chronic health for iron).

The following trends in water chemistry were observed in June 2018 relative to March 2018:

- WWNMB16: levels of constituents were relatively stable apart from decreases in electrical conductivity and sulphate; and an increase in total dissolved solids from March to June 2018.
- WWN02-D: Levels of constituents were variable, with decreases observed in electrical conductivity, total dissolved solids, calcium, magnesium, sodium, alkalinity, chloride and sulphate; and increases observed in potassium, nitrate, fluoride and manganese.
- WOLMB15-S: declining trends were observed in electrical conductivity, total dissolved, calcium, magnesium, sulphate and nitrate.
- WOLMB15-D: Major elements generally decreased with the exception of an increase observed in the concentration of potassium.
- WELMB13-S: Electrical conductivity, total dissolved solids, calcium, magnesium, sodium, alkalinity, sulphate, iron and manganese increased; and levels of potassium and chloride decreased from the first to the second quarter 2018.
- WELMB13-D: a decrease in potassium and increases in levels of electrical conductivity, total dissolved solids, calcium, magnesium, sodium, sulphate, nitrate, iron and manganese were observed in June 2018.
- RIE10B: All major constituents decreased, and the concentration of iron increased in June 2018.
- MOAMB9: pH changed from alkaline (8.1) to circum-neutral (7.3) in June 2018. Decreases were recorded in all major constituents except for an increase in total dissolved solids.
- MOAMB7: Levels of all major constituents decreased from March to June 2018.
- MOAMB10: declining trends were observed in all major constituents; with exception of increases observed in total dissolved solids and alkalinity.
- RKL02: Major constituents were relatively stable, with slight decreases observed in all major constituents except increases recorded in chloride, sulphate and nitrate.
- RKL01: fluoride remained below detectable amounts in June. Levels of total dissolved solids and sulphate increased from March to June; all other constituents decreased in June 2018.
- LEEMB18-D: Increasing trends were observed in concentrations of magnesium, sulphate and nitrate and levels of all other constituents decreased in the second quarter.

- KENMB3-S: large increases were recorded in levels of electrical conductivity, total dissolved solids, calcium, magnesium, sodium, alkalinity, sulphate, nitrate and manganese; and a decrease was observed in potassium and chloride.
- KENMB3-D: constituents were relatively stable apart from increases observed in calcium, chloride, sulphate and iron; and decreases in total dissolved solids and nitrate from March to June 2018.
- KENMB2-D: A decline was observed in the level of total dissolved solids and increases were observed in calcium, magnesium and sulphate in quarter two.

Fluctuations in water levels could be attributed to changes in rates of abstraction for agricultural activities (e.g. WWNMB16 and RKL02), mining activities, and rainfall recharge.

11 THE PROBABLE DURATION OF ANY UNDERTAKING OR WHICH A WATER USE IS TO BE AUTHORISED

All the water uses taking place at the mine have been licenced in terms of the IWULs issued. This Section 27 forms part of the 2018 IWWMP update for the Leeuwpan Mine. As such, no licence recommendations have been included.

12 REFERENCES

Chamber of Mines of South Africa. 2016; Coal. http://www.chamberofmines.org.za/sa-mining/coal. Accessed 06 June 2016

Chamber of Mines of South Africa. 2016; Integrated Annual Review 2015 www.chamberofmines.org.za. Accessed 06 June 2016

Department of Water Affairs and Forestry (DWAF), South Africa.2001; Olifants River Ecological Water Requirements Assessment. Prepared by A Singh and M van Veelen on behalf of the Directorate: National Water Resource Planning. DWAF Report No. PB-000-00-5299.

Department of Water Affairs and Forestry, South Africa. 2004. *Olifants Water Management Area: Internal Strategic Perspective*. Prepared by GMKS, Tlou and Matji and WMB on behalf of the Directorate: National Water Resource Planning. DWAF Report No P WMA 04/000/00/0304.

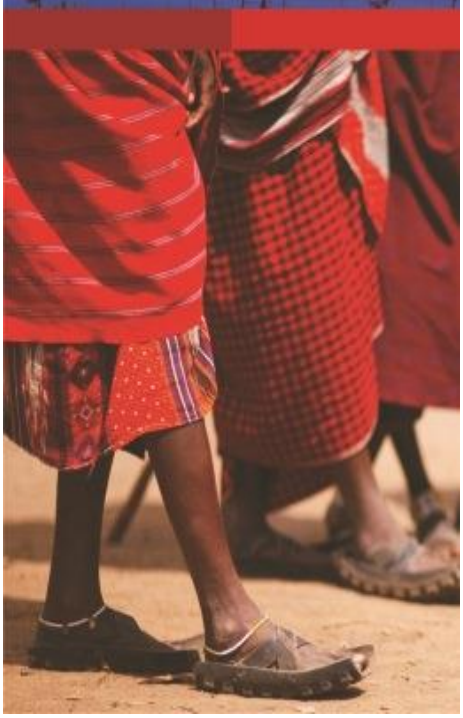
Exxaro Leeuwpan Coal. 2015; Social and Labour Plan 25 March 2015 until 24 March 2020. Doc No. MCX-000321-PMG-PLN.

Annexure I
Leeuwpan Coal Mine Wetland Offset Strategy Update (Draft)









DIGBY WELLS
ENVIRONMENTAL

Wetland Offset and Design

Leeuwpan Coal Mine Wetland Offset Strategy Update

Project Number:

EXX5501

Prepared for:

Exxaro Mpumalanga Coal (Pty) Ltd

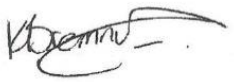
January 2019

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Report Type:	**Leeuwpan Coal Mine Wetland Offset Strategy Update**
Project Name:	**Wetland Offset and Design**
Project Code:	**EXX5501**

Name	Responsibility	Signature	Date
Kieren Bremner Pr. Sci. Nat.	Report Writer		31-01-2019
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This report is provided solely for the purposes set out in it and may not, in whole or in part, be used for any other purpose without Digby Wells Environmental prior written consent.

EXECUTIVE SUMMARY

Digby Wells Environmental (hereinafter Digby Wells), was appointed by Exxaro Mpumalanga Coal (Pty) Ltd In November 2018 to review and update the Wetland Offset Report compiled by Land Resources International (hereinafter LRI) for the Leeuwpan Coal Mine in Mpumalanga, South Africa. Following this report, LRI submitted an onsite wetland rehabilitation plan for the Leeuwpan Coal Mine's proposed block OI and OL mining development in 2016. Since the submission of the LRI 2016 report, mining of block OI has commenced. Mining of block OL is due to commence on approval of this updated Wetland Offset Report. The Integrated Water Use License (IWUL; no.: 04/B20A/CIJ/4032) for the Exxaro Coal (Pty) Ltd: Leeuwpan Coal Mine OI and OL Expansion was granted provided that wetland offset areas were identified to compensate for the loss of wetlands.

Further to this, an additional pit, Block OI West, has been proposed, the required offsets of which have been included in this report for consideration of inclusion into the Integrated Water Use License. The additional proposed Block OI West, would result in the destruction of 18.36 ha of hillslope seepage wetlands as well as a pan, 2.21 ha in extent.

According to the LRI (2013) report, the wetlands within Block OI were delineated in 2012, with mining activities within Block OI expected to impact on at least 134.62 ha of wetlands (68.4 ha fall within the direct footprint of proposed opencast areas and mining activities within Block OL expected to impact on at least 120.30 ha of wetlands.

On calculation of the hectare equivalents required for the calculation of the required functional and conservation offset targets for both Blocks OI and OL, a total of 87.23 hectare equivalents are expected to be lost. The additional proposed Block OI West will result in an additional loss of 10.51 hectare equivalents. The required functional offset target is thus calculated at 97.7 hectare equivalents and the conservation offset target is 561.4 hectare equivalents.

According to the LRI (2013) report, if it is assumed that the remaining wetlands on site can be rehabilitated so as to increase their present ecological state category by one level, this would imply an approximate 20% gain in functional area. As such, this would result in a gain of about 206.59 hectare equivalents. However, on consideration of the additional loss of wetlands as a result of the proposed Block OI West, the gain would be reduced to 202.48 hectare equivalents.

During the field assessment carried out in December 2018, three portions of wetland that are regarded as destroyed as a result of mining activities were identified as potential sites for rehabilitation. The rationale behind this approach is such that should rehabilitation of these sites be considered, this would provide the potential to restore stream connectivity between upstream and downstream areas that have become fragmented as well as improve the ecological importance and sensitivities of the systems present as a whole. Assuming each of these wetland portions can be rehabilitated to a category D, the direct wetland gain in terms of hectare equivalents may be regarded as 166.47 ha. However, in order to realise both these gains, as well as the 202.48 ha of gains discussed above, it is estimated that a

minimum of 204.10 ha of the surrounding catchment areas will require rehabilitation and a further 87.12 ha of buffers located in selected areas around the mining rights area are recommended to protect the wetlands present and prevent further losses to the wetland systems present. Thus, a total of 660.17 ha have been identified towards achieving the wetland conservation target of 561.4 ha. In terms of functional offset targets, the direct gains in hectare equivalents total 368.95 ha, which may be regarded as more than sufficient to achieve the above-mentioned functional offset target requirement of 97.7 ha.

It must be noted that in terms of the “like-for-like” offset requirement, the conservation offset target falls short of the required hectare equivalents for hillslope seep wetlands, however, consideration as to the potential improvements and rehabilitation of selected wetland systems within the Mining Rights Area were regarded as valuable inclusions within the proposed offset strategy, not only from the perspective of improvements to the present ecological state of the systems as a whole, but also in terms of improvements to ecological importance and service provision within the greater catchment. The value of including the proposed rehabilitation measures within the offset strategy thus serve as grounds for the consideration of an “out-of-kind” offset (to some extent).

In summary the total costs for the rehabilitation measures and interventions considered equals to **R88,524,584.57 (VAT Excl)**. In saying this, the majority of the costs can be assigned to the existing financial provision that would be in place for closure. Based on this only an additional **R 1 503 904.00** would be required for the interventions recommended.

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1 Introduction

Wetlands are sensitive ecosystems that perform many complex functions including the maintenance of water quality, assimilation of nutrients, carbon storage, stream-flow regulation, flood attenuation, assimilation of nutrients, various social benefits as well as the maintenance of biodiversity (Kotze *et al*., 2007). The Ramsar Convention on Wetlands refers to wetlands as one of the most important life support systems on earth owing to the services provided. Wetlands are defined according to the National Water Act, 1998 (Act 36 of 1998) (NWA) as: *"land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil."*

Wetlands in South Africa are poorly conserved owing primarily to a general underestimation of the ecological and economic importance of these systems (Swanepoel and Barnard, 2007). It is approximated that between 35-50% of all the wetland areas within South Africa have been destroyed as a result of anthropogenic stressors (Swanepoel and Barnard, 2007) and a cumulative loss of these important systems is on-going. Some of the major contributing factors to the decline of wetlands in South Africa include mining, industrial and agricultural activities as well as poor treatment of waste water from industry and mining (Oberholster *et al.*, 2011).

Wetlands are highly susceptible to the degradation of quality and a reduction in quantity as a result of anthropogenic resource use activities, land surface development and landscape-management (Kotze and Breen, 1994; Whitlow, 1992), all practices that alter the hydrological regime impacting these wetland systems (Winter and Llamas, 1993). Historically, wetlands have been perceived to be wastelands (Maltby, 1986). This has resulted in the exploitation, alteration and in many cases the complete destruction of these valuable ecosystems, with an accompanying loss of associated ecosystem goods and services (Begg, 1986). It is now acknowledged that these ecosystems perform functions making them invaluable to the management of both water quantity and quality, and as a result wetlands are regarded as integral components of catchment systems (Jewitt and Kotze, 2000; Dickens *et al*., 2003).

The dilemma facing South Africa is that there is a growing demand for energy (currently in the form of coal) and there is also a need to protect wetland ecosystems. Wetlands are inextricably linked to coal mining in the highveld as coal deposits are often overlain by wetlands. It is imperative that wetlands in South Africa are managed in a sustainable way and that they are not damaged during the process of meeting the needs of the growing South African economy. The purpose of an environmental offset is to maintain existing levels of environmental quality whilst still allowing for further development (Duncan and Morrison 2008). The central idea is to conserve and/or rehabilitate a site nearby to the existing site that is to be developed. The result is that the overall stock of natural assets is not lost. The purpose of this report is to identify the extent of wetland habitat affected by historical, current

and future mining activities, to determine the extent of the offsets required and to identify candidate wetland offset areas to be rehabilitated and regarded as a 'no-go' zone for future development to compensate for the loss of wetlands on site. The South African National Biodiversity Institute (SANBI) and Department of Water and Sanitation (DWS) have recently released the Wetland Offset Calculator (2014) which was used for this assessment.

2 Background of the study

Digby Wells Environmental (hereinafter Digby Wells), was appointed by Exxaro Mpumalanga Coal (Pty) Ltd) In November 2018 to review and update the Wetland Offset Report compiled by Land Resources International (hereinafter LRI) for the Leeuwpan Coal Mine in Mpumalanga, South Africa. The Leeuwpan Phase 1 Wetland Rehabilitation and Planning Report was compiled and submitted in November 2013. Following this report, LRI submitted an onsite wetland rehabilitation plan for the Leeuwpan Coal Mine's proposed block OI and OL mining development in 2016. Since the submission of the LRI 2016 report, mining of block OI has commenced. Mining of block OL is due to commence on approval of this updated Wetland Offset Report.

This report will take into account all wetlands affected to date as well as wetlands to be affected within the blocks OI and OL mining footprint. Management and mitigation for protection of the wetland areas not directly affected by the current and proposed mining activities will be provided.

Due to opencast mining at the Leeuwpan Coal Mine, wetland habitat has been lost and further losses are anticipated. The Integrated Water Use License (IWUL; no.: 04/B20A/CIJ/4032) for the Exxaro Coal (Pty) Ltd: Leeuwpan Coal Mine OI and OL Expansion was granted provided that wetland offset areas were identified to compensate for the loss of wetlands. Thus, this wetlands assessment and Wetland Offset Strategy update will provide a detailed updated description of the baseline environment, the wetlands present in the study area and their ecological conditions, updated offset calculations and the updated rehabilitation interventions that will be required for the wetland offset areas so that the Leeuwpan Coal Mine remains compliant to the terms of the existing IWUL.

3 Terms of Reference

This report aims to provide the following:

- A review and update of the Wetland Offset Report compiled by LRI for Leeuwpan including the following:
  - Review of the previous Rehabilitation Plan Phase 1 Report for Leeuwpan Mine Wetlands;
  - Review of Onsite Wetland Rehabilitation Plan for Leeuwpan Proposed Block OI and OL Mining Development;

- The calculation of offset requirements based on wetlands impacted from the mining footprint and activities to date, as well as the approved mining activities to impact wetlands during the course of the Life of Mine (LOM); and
- Consideration of the existing recommended offsets and compensation locations (LRI, 2016) and the provision of an updated wetland rehabilitation and wetland offset strategy.

4 Locality

The Leeuwpan Coal Mine is located in the Mpumalanga Province, South Africa. The Leeuwpan Mining Rights Area (MRA) is situated along the R50 road south-east of the town of Delmas (Figure 4-1). The MRA covers an estimated 4260 hectares and includes portions of the following farms:

- Witklip 232-IR;
- Witklip 229-IR;
- Wolvenfontein 244-IR;
- Goedgedacht 228-IR;
- Leeuwpan 246-IR;
- De Denne 256-IR;
- Rietkuil 249-IR;
- Moabsvelden 248-IR; and
- Weltevreden 227-IR.

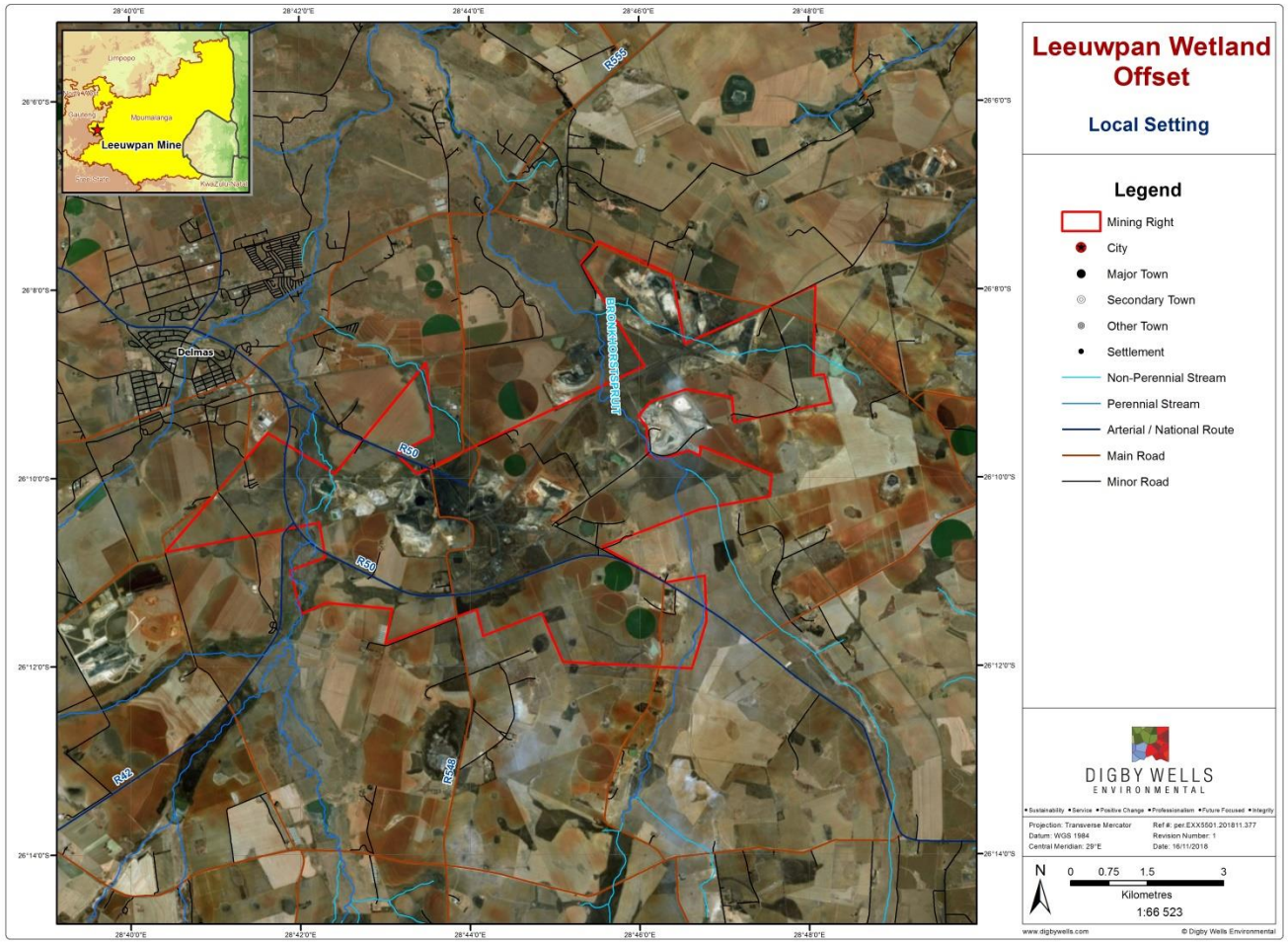


Figure 4-1: Locality of the project area

5 Policy and Legal Framework

The wetlands assessment aims to support the following regulations, regulatory procedures and guidelines:

- Section 24 of the Constitution of the Republic of South Africa ,1996 (Act No. 108 of 1996);
- The National Water Act, 1998 (Act No. 36 of 1998) (NWA);
- National Environmental Management Biodiversity Act, 2004 (Act No. 10 of 2004) (NEM:BA);
- Section 5 of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA);

6 Methodology

6.1 Wetland Assessment

6.1.1 Historical Report Reviews and Desktop Assessment

For the purposes of this project, historical delineations and data results (LRI, 2013) were used as a baseline for the wetland extents, present ecological states and ecological importance and sensitivities prior to any further disturbance as a result of the ongoing mining activities that have taken place within the Leeuwpan Coal Minining rights area since the 2013 wetland assessment. In addition, baseline and background information was researched and used to understand the area on a desktop level prior to fieldwork; this included but was not limited to:

- L04768 Leeuwpan Phase 1 Report (LRI, 2013);
- Onsite Wetland Rehabilitation Plan for the Leeuwpan Coal Mine's proposed block OI and OL mining development;
- National Freshwater Ecosystem Priority Areas (NFEPA; Nel *et al*., 2011);
- Mining and Biodiversity Guidelines;
- Water Management Areas (WMA) and Quaternary Catchments; and
- Mpumalanga Biodiversity Sector Plan (2014).

6.1.1.1 National Freshwater Ecosystem Priority Areas

The NFEPA project provides a collated, nationally consistent information source of wetland and river ecosystems for incorporating freshwater ecosystem and biodiversity goals into planning and decision-making processes (Nel *et al.* 2011). The spatial layers include the nationally delineated wetland areas that are classified into hydrogeomorphic (HGM) NFEPA

project types and ranked in terms of their biodiversity importance. These layers were assessed to evaluate the importance of the wetland areas located within the project area.

Whilst being an invaluable tool, it is important to note that the NFEPA's were delineated and studied at a desktop and low resolution level. Thus, the wetlands delineated via the ground-truthing work done through this study may differ from the NFEPA data layers. The NFEPA assessment does, however, hold significance from a national perspective. As mentioned above, the NFEPA wetlands have been ranked in terms of importance in the conservation of biodiversity and Table 6-1 below indicates the criteria considered.

Table 6-1: NFEPA Wetland Classification Ranking Criteria

Criteria	Rank
Wetlands that intersect with a RAMSAR site.	1
▪ Wetlands within 500 m of an IUCN threatened frog point locality; ▪ Wetlands within 500 m of a threatened water-bird point locality; ▪ Wetlands (excluding dams) with the majority of their area within a sub-quaternary catchment that has sightings or breeding areas for threatened Wattled Cranes, Grey Crowned Cranes and Blue Cranes; ▪ Wetlands (excluding dams) within a sub-quaternary catchment identified by experts at the regional review workshops as containing wetlands of exceptional Biodiversity importance, with valid reasons documented; and ▪ Wetlands (excluding dams) within a sub-quaternary catchment identified by experts at the regional review workshops as containing wetlands that are good, intact examples from which to choose.	2
Wetlands (excluding dams) within a sub-quaternary catchment identified by experts at the regional review workshops as containing wetlands of biodiversity importance, but with no valid reasons documented.	3
Wetlands (excluding dams) in A or B condition AND associated with more than three other wetlands (both riverine and non-riverine wetlands were assessed for this criterion); and Wetlands in C condition AND associated with more than three other wetlands (both riverine and non-riverine wetlands were assessed for this criterion).	4
Wetlands (excluding dams) within a sub-quaternary catchment identified by experts at the regional review workshops as containing Impacted Working for Wetland sites.	5
Any other wetland (excluding dams).	6

6.1.1.2 Mining and Biodiversity Guideline

The Mining and Biodiversity Guideline was developed collaboratively by the South African Biodiversity Institute (SANBI), the Department of Environmental Affairs (DEA), the

Department of Mineral Resources (DMR), the Chamber of Mines and the South African Mining and Biodiversity Forum in 2013. The purpose of the guideline was to provide the mining sector with a manual to integrate biodiversity into the planning process thereby encouraging informed decision-making around mining development and environmental authorisations. The aim of the guideline is to explain the value for mining companies to consider biodiversity management throughout the planning process. The guideline highlights the importance of biodiversity in managing the social, economic and environmental risk of the proposed mining project. The country has been mapped into biodiversity priority areas including the four categories listed in

Table 6-2 below, each with associated risks and implications.

Table 6-2: Mining and Biodiversity Guideline Categories (SANBI, 2013)

Category	Risk and Implications for Mining
Legally protected	Mining prohibited; unless authorised by ministers of both the DEA and DMR.
Highest Biodiversity Importance	Highest Risk for Mining: the EIA process must confirm significance of the biodiversity features that may be seen as a fatal flaw to the proposed project. Specialists must provide site-specific recommendations for the application of the mitigation hierarchy that informs the decision making processes of mining licences, water use licences and environmental authorisations. If granted, authorisations should set limits on allowed activities and specify biodiversity related management outcomes.
High Biodiversity Importance	High Risk for Mining: the EIA process must confirm the significance of the biodiversity features for the conservation of biodiversity priority areas. Significance of impacts must be discussed as mining options are possible but must be limited. Authorisations may set limits and specify biodiversity related management outcomes.
Moderate Biodiversity Importance	Moderate Risk for Mining: the EIA process must confirm the significance of the biodiversity features and the potential impacts as mining options must be limited but are possible. Authorisations may set limits and specify biodiversity related management outcomes.

6.1.1.3 Mpumalanga Biodiversity Sector Plan

The Mpumalanga Biodiversity Sector Plan (MBSP) is a spatial tool that forms part of the national biodiversity planning tools and initiatives that are provided for in national legislation and policy. The MBSP was published in 2014 by the Mpumalanga Tourism and Parks Agency (MTPA) and comprises a set of maps of biodiversity priority areas accompanied by contextual information and land-use guidelines for use in land-use and development

planning, environmental assessment and regulation, and natural resource management. Strategically the MBSP enables the province to:

- Implement the NEM:BA, 2004 provincially, and comply with requirements of the National Biodiversity Framework, 2009 (NBF) and certain international conventions;
- Identify those areas of highest biodiversity that need to be considered in provincial planning initiatives, and
- Address threat of climate change (ecosystem-based adaptation).

The publication includes terrestrial and freshwater biodiversity areas that are mapped and classified in Protected Areas (PAs), Critical Biodiversity Areas (CBAs), Ecological Support Areas (ESAs) or Other Natural Areas (ONAs). Wetlands in Mpumalanga Province have been extensively degraded and, in many cases, irreversibly modified and lost through a combination of inappropriate land-use practices, development and mining. Wetlands represent ecosystems of high value for delivering, managing and storing good quality water for human use, and they are vulnerable to harmful impacts. It is therefore in the interest of national water security that all wetlands are protected by law. The management objectives of these areas are summarised below.

Table 6-3: Mpumalanga Biodiversity Sector Plan Categories

Map category	Definition	Desired management objectives
PA	Those areas that are proclaimed as protected areas under national or provincial legislation, including gazetted protected environments.	Areas that are meeting biodiversity targets and therefore must be kept in a natural state, with a management plan focused on maintaining or improving the state of biodiversity.
CBAs	Areas that are required to meet biodiversity targets, for species, ecosystems or ecological processes. CBA Wetlands are those that have been identified as FEPA wetlands that are important for meeting biodiversity targets for freshwater ecosystems.	Must be kept in a natural state, with no further loss of habitat. Only low-impact, biodiversity-sensitive land-uses are appropriate.

Map category	Definition	Desired management objectives
ESAs	Areas that are not essential for meeting biodiversity targets, but that play an important role in supporting the functioning of protected areas or CBAs and for delivering ecosystem services. ESAs Wetlands are those that are non-FEPA and ESA Wetland Clusters are clusters of wetlands embedded within a largely natural landscape that function as a unit, and allow for the migration of species such as frogs and insects between individual wetlands.	Maintain in a functional, near-natural state, but some habitat loss is acceptable. A greater range of land-uses over wider areas is appropriate, subject to an authorisation process that ensures the underlying biodiversity objectives are not compromised.
ONAs	Areas that have not been identified as a priority in the current systematic biodiversity plan but retain most of their natural character and perform a range of biodiversity and ecological infrastructural functions. Although they have not been prioritised for biodiversity, they are still an important part of the natural ecosystem.	An overall management objective should be to minimise habitat and species loss and ensure ecosystem functionality through strategic landscape planning. These areas offer the greatest flexibility in terms of management objectives and permissible land-uses, but some authorisation may still be required for high-impact land-uses.
Heavily or Moderately Modified Areas	Areas that have been modified by human activity to the extent that they are no longer natural, and do not contribute to biodiversity targets. These areas may still provide limited biodiversity and ecological infrastructural functions, even if they are never prioritised for conservation action.	Such areas offer the most flexibility regarding potential land-uses, but these should be managed in a biodiversity-sensitive manner, aiming to maximise ecological functionality and authorisation is still required for high-impact land-uses. Moderately modified areas (old lands) should be stabilised and restored where possible, especially for soil carbon and water-related functionality.

6.1.2 Wetland Ecological Health Assessment (WET-Health)

According to Macfarlane *et al*. (2009) the health of a wetland can be defined as a measure of the deviation of wetland structure and function from the wetland's natural reference condition. A level 1 WET-Health assessment was done on selected wetlands earmarked for rehabilitation in accordance with the method described by Kotze *et al.* (2007) to determine the current integrity (health) of the relevant HGM units. Level 1 was selected due to the large size of the proposed wetland rehabilitation areas, as well as due to the restricted site access in some areas due to safety constraints and current mining activities throughout the Project

area. A Present Ecological State (PES) analysis was conducted for each site both prior to the proposed rehabilitation (current condition) as well as post proposed rehabilitation (the estimated condition target). The health assessment attempts to evaluate the hydrological, geomorphological and vegetation health in three separate modules to attempt to estimate similarity to or deviation from natural conditions.

Central to WET-Health is the characterisation of HGM Units, which have been defined based on geomorphic setting (e.g. hillslope or valley-bottom; whether drainage is open or closed), water source (surface water dominated or sub-surface water dominated) and pattern of water flow through the wetland unit (diffusely or channelled) as described above.

The overall approach is to quantify the impacts of human activity or clearly visible impacts on wetland health, and then to convert the impact scores to a Present State score. This takes the form of assessing the spatial *extent* of the impact of individual activities and then separately assessing the *intensity* of the impact of each activity in the affected area. The extent and intensity are then combined to determine an overall *magnitude* of impact. The rationale behind the application of the WET-Health tool to the proposed rehabilitation areas is to determine the potential gains in hectare equivalents within each wetland, should the integrity of each HGM unit be improved though the proposed rehabilitation efforts at each site. The impact scores and Present State categories are provided in Table 6-4.

Table 6-4: Impact Scores and Present Ecological State Categories used by WET-Health

Impact Category	Description	Combined Impact Score	PES Category
None	Unmodified, natural.	0-0.9	A
Small	Largely natural with few modifications. A slight change in ecosystem processes is discernible and a small loss of natural habitats and biota has taken place.	1-1.9	B
Moderate	Moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place but the natural habitat remains predominantly intact.	2-3.9	C
Large	Largely modified. A large change in ecosystem processes and loss of natural habitat and biota has occurred.	4-5.9	D
Serious	The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognisable.	6-7.9	E

Impact Category	Description	Combined Impact Score	PES Category
Critical	Modifications have reached a critical level and ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota.	8-10	F

As is the case with the Present State, future threats to the state of the wetland may arise from activities in the catchment upstream of the unit or within the wetland itself or from processes downstream of the wetland. In each of the individual sections for hydrology, geomorphology and vegetation, five potential situations exist depending upon the direction and likely extent of change (Table 6-5).

Table 6-5: Trajectory of Change classes and scores used to evaluate likely future changes to the present state of the wetland.

Change Class	Description	HGM change score	Symbol
Substantial improvement	State is likely to improve substantially over the next 5 years	2	↑↑
Slight improvement	State is likely to improve slightly over the next 5 years	1	↑
Remain stable	State is likely to remain stable over the next 5 years	0	→
Slight deterioration	State is likely to deteriorate slightly over the next 5 years	-1	↓
Substantial deterioration	State is expected to deteriorate substantially over the next 5 years	-2	↓↓

Once all HGM Units have been assessed, a summary of health for the wetland as a whole needs to be calculated. This is achieved by calculating a combined score for each component by area-weighting the scores calculated for each HGM Unit. Recording the health assessments for the hydrology, geomorphology and vegetation components provide a summary of impacts, Present State, Trajectory of Change and Health for individual HGM Units and for the entire wetland. In this instance, scores for both pre and post rehabilitation have been calculated.

As mentioned above, the WET-Health results of the wetland assessment conducted in 2013 have been utilised in this report for the historically delineated wetlands found throughout the mining rights area, with the exception of the rehabilitation areas considered and further discussed in Section 10.

6.1.3 Ecological Importance and Sensitivity

Further to the application of the WET-Health tool, the historical wetland assessment made use of the Ecological Importance and Sensitivity (EIS) tool to assess the various wetland systems' abilities to resist disturbance and the capability of each to recover from disturbance once it has occurred. The purpose of assessing importance and sensitivity of water resources is to be able to identify those systems that provide higher than average ecosystem services, biodiversity support functions or are especially sensitive to impacts. Water resources with higher ecological importance may require managing such water resources in a better condition than the present to ensure the continued provision of ecosystem benefits in the long term.

The methodology outlined by DWAF (1999) and updated in Rountree and Kotze, (2012), in Rountree *et al.* (2012) was used to assess the current and target EIS values for the proposed wetlands to be rehabilitated.

In this method there are three suites of importance criteria; namely:

- **Ecological Importance and Sensitivity:** incorporating the traditionally examined criteria used in EIS assessments of other water resources by DWS and thus enabling consistent assessment approaches across water resource types;
- **Hydro-functional Importance:** which considers water quality, flood attenuation and sediment trapping ecosystem services that the wetland may provide; and
- **Importance in terms of Basic Human Benefits:** this suite of criteria considers the subsistence uses and cultural benefits of the wetland system.

These determinants are assessed for the wetlands on a scale of 0 to 4, where 0 indicates no importance and 4 indicates very high importance. It is recommended that the highest of these three suites of scores be used to determine the overall Importance and Sensitivity category of the wetland system, as defined in Table 6-6.

Table 6-6: Interpretation of Overall EIS Scores for Biotic and Habitat Determinants

Ecological Importance and Sensitivity Category (EIS)	Range of Median
Very high Systems that are considered ecologically important and sensitive on a national or even international level. The biodiversity of these systems is usually very sensitive to flow and habitat modifications. They play a major role in moderating the quantity and quality of water of major rivers.	>3 and <=4
High Systems that are considered to be ecologically important and sensitive. The biodiversity of these systems may be sensitive to flow and habitat modifications. They play a role in moderating the quantity and quality of water of major rivers.	>2 and <=3

Ecological Importance and Sensitivity Category (EIS)	Range of Median
Moderate Systems that are considered to be ecologically important and sensitive on a provincial or local scale. The biodiversity of these systems 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.	>1 and <=2
Low/marginal Systems that are not ecologically important and sensitive at any scale. The biodiversity of these systems is ubiquitous and not sensitive to flow and habitat modifications. They play an insignificant role in moderating the quantity and quality of water of major rivers.	>0 and <=1

6.2 Offset Strategy

Offset areas are considered in order to preserve and protect lost and/or threatened biodiversity. The offset areas are defined by the International Council on Mining and Metals (ICMM) as "Sustainable conservation actions intended to compensate for the residual, unavoidable harm to biodiversity caused by development projects, so as to aspire to no net loss in biodiversity. Before developers contemplate offsets, they should have first sought to avoid and minimise harm to biodiversity." Most important for offsets are paragraphs 7 and 10 of the International Finance Corporation (IFC) Performance Standard 6, reproduced below:

"7. As a matter of priority, the client should seek to avoid impacts on biodiversity and ecosystem services. When avoidance of impacts is not possible, measures to minimize impacts and restore biodiversity and ecosystem services should be implemented. Given the complexity in predicting projects impacts on biodiversity and ecosystem services over the long term, the client should adopt a practice of adaptive management in which the implementation of mitigation and management measures are responsive to changing conditions and the results of monitoring throughout the project's lifecycle.

10. For the protection and conservation of biodiversity, the mitigation hierarchy includes biodiversity offsets, which may be considered only after appropriate avoidance, minimization, and restoration measures have been applied, A biodiversity offset should be designed and implemented to achieve measureable conservation outcomes that can reasonably be expected to result in no net loss and preferably a net gain of biodiversity; however, a net gain is required in critical habitats. The design of a biodiversity offset must adhere to the "like-for-like or better" principle and must be carried out in alignment with best available information and current practices. When a client is considering the development of an offset as part of the mitigation strategy, external experts with knowledge in offset design and implementation must be involved."

Important associated definitions and details provided by the IFC include the following:

- "Biodiversity offsets are measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development and persisting after appropriate avoidance, minimization and restoration measures have been taken;
- Measurable conservation outcomes for biodiversity must be demonstrated in situ (on-the-ground) and on an appropriate geographic scale (e.g., local, landscape level, national, regional);
- The principle of "like-for-like or better" indicates that biodiversity offsets must be designed to conserve the same biodiversity values that are being impacted by the project (an "in-kind" offset). In certain situations, however, areas of biodiversity to be impacted by the project may be neither a national or local priority, and there may be other areas of biodiversity with like values that are a higher priority for conservation and sustainable use and under imminent threat or need of protection or effective management. In these situations, it may be appropriate to consider an "out-of-kind"

offset that involves “trading up” (i.e., where the offset targets biodiversity of higher priority than that affected by the project) that will, for critical habitats, meet the requirements of paragraph 17 of this Performance Standard; and

- No net loss is defined as the point at which project-related impacts on biodiversity are balanced by measures taken to avoid and minimize the project’s impacts, to undertake on-site restoration and finally to offset significant residual impacts, if any, on an appropriate geographic scale (e.g., local, landscape-level, national, regional). ICMM indicates that there is not only a biodiversity advantage to biodiversity offsets, but also a good business case for offsets. The ICMM states that “Offsets could offer a means of ensuring continued access to resources, securing licence to operate and given increasing interest from investors in offsets for risk management purposes) continued access to finance.

6.2.1 Offset calculations

The wetland offset requirements calculated and described in the “LRI (2013) Phase 1: Determination of Offset Requirements” report, were reviewed and the results deemed suitable for the provision of an indication of the functional value and habitat intactness of the wetlands present both prior to- and post-development.

In this report, both the functional and ecosystem conservation ratios were determined, the greater of which was used in this report to ensure compliance of the Wetland Offset Strategy and to update the Wetland Rehabilitation Plan.

6.2.2 Wetland Offset Strategy and Impacts

The potential wetland offset locations identified by Wetland Consulting Services in 2013 consisted of wetland units similar in type and functioning to the wetland units to be either impacted on or destroyed due to the proposed mining activities. An additional consideration for the potential offset locations was the level of risk posed by the areas being mined in the future.

In this report, the state of the wetland systems impacted within, as well as in the immediate vicinity of the Leeuwpan Coal Mine, was considered. Consideration as to the potential improvements and rehabilitation of selected wetland systems within the Mining Rights Area were regarded as valuable inclusions within the proposed offset strategy, not only from the perspective of improvements to the present ecological state of the systems as a whole, but also in terms of improvements to ecological importance and service provision within the greater catchment.

Thus, while the principle of “like-for-like” discussed above, was considered as far as possible, the value of including the proposed rehabilitation measures within the offset strategy serve as grounds for the consideration of an “out-of-kind” offset (to some extent) that involves “trading up” and improving the biodiversity, restoring stream connectivity and improving the functioning of each of the systems as a whole. In addition to this, is the added benefit that the Leeuwpan Coal Mine, is already in possession of the surface rights to these

proposed rehabilitation areas and thus, may be more likely to follow through on these commitments in the long term.

This report provides information pertaining to the planning and framework of the strategy and the required measures to achieve the set objectives. The WET-RehabPlan was considered in order to support the formulation of the strategy in order to assist in undertaking a well-planned and well-informed Wetland Offset and Compensation Strategy that is integrated into the broader management of the wetland and catchment, and which produces sustainable outcomes (WRC, 2008). Methodologies described by the Water Research Commission (2008) pertaining to mitigation banking have been considered for this study. Two methods which were considered for compensatory credits (WRC, 2008) include:

- Restoration - This is defined as the re-establishment or rehabilitation of a wetland with the goal of returning natural or historic functions and characteristics to a former or degraded wetland. This process improves wetland function, and in some cases increases wetland area; and
- Enhancement - This process attempts to heighten, intensify or improve wetland ecological functions. This process will not yield an increase in wetland area, but does improve wetland function.

6.2.3 Hectare equivalents

In order to allow for the quantification of wetland losses due to development and the gains due to wetland offsets and rehabilitation, as well as the comparison between the two, a unit of measure is required to use as a common currency for evaluating impacts and assessing the adequacy of offset proposals. This is achieved through use of the '**hectare equivalent'**.

A hectare equivalent is a quantitative expression of the ecological integrity of a wetland hydrogeomorphic (HGM) unit under a given landuse. It represents the common currency that enables the wetland functional area restored to the landscape by restoration, rehabilitation and artificial creation to be compared to that removed from the landscape by a development. Most environmental authorities advocate a no-net-loss of resources approach, be it to biodiversity or wetland functioning, and the hectare equivalent provides the conceptual means of judging whether these rehabilitation objectives have been satisfied.

'Hectare equivalent' is a measure of wetland functional area obtained through a conversion of the wetland health (PES) rating and the wetland aerial extent (hectares). This is done by converting the overall health (PES) score to an intactness score and then multiplying by the wetland area (in hectares) to obtain a measure of functional area:

((10-PES score)/10) X wetland area = hectare equivalent

As an example, a 10 ha wetland with a PES score of 3 (category C – moderately modified) would be equal to:

((10-3)/10) X 10 = 7 hectare equivalents

In essence, this reflects that a wetland which is moderately modified (PES category C) is only expected to be performing 70 % of the function that the wetland could have performed under pristine conditions.

7 Baseline Environment

7.1 Drainage and Quaternary Catchment

The water resources of South Africa are divided into quaternary catchments, which are regarded as the principal water management units in the country (DWAF 2011). A quaternary catchment is a fourth order catchment in a hierarchical classification system in which the primary catchments are the major units. The primary drainages are further grouped into or fall under Water Management Areas (WMA) and Catchment Management Agencies (CMA). The Department of Water and Sanitation (DWS) has established nine WMAs and nine CMAs as contained in the National Water Resource Strategy 2 (2013) in terms of Section 5 subsection 5(1) of the National Water Act, 1998 (Act No. 36 of 1998). The establishment of these WMAs and CMAs is to improve water governance in different regions of the country, to ensure a fair and equal distribution of the Nations water resources, while making sure that the resource quality is sustained.

Figure 7-1 and Figure 7-2 indicate the water resource management classification associated with the project area. The project area falls within the Olifants Water Management Area (WMA 4) and it is associated with primary drainage B. The affected quaternary catchment is B20A. According to the WRC (2012), the freshwater resources within this catchment area have been classified with a PES rating of D (largely modified), moderate Ecological Importance (EI) and high Ecological Sensitivity (ES). The Brokhorstspruit and its associated tributaries were identified as the main river reaches draining this site.

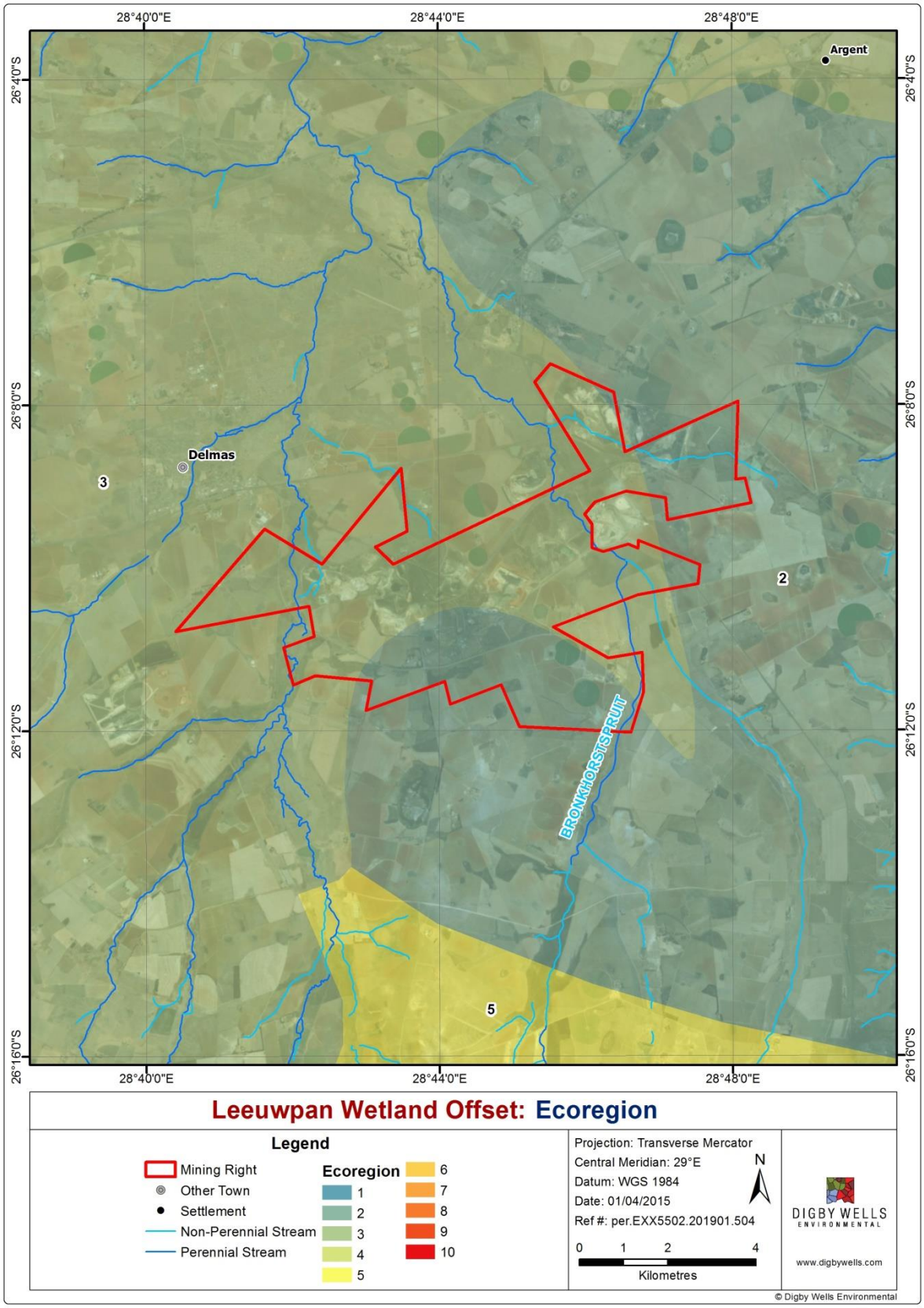


Figure 7-1: Ecoregion

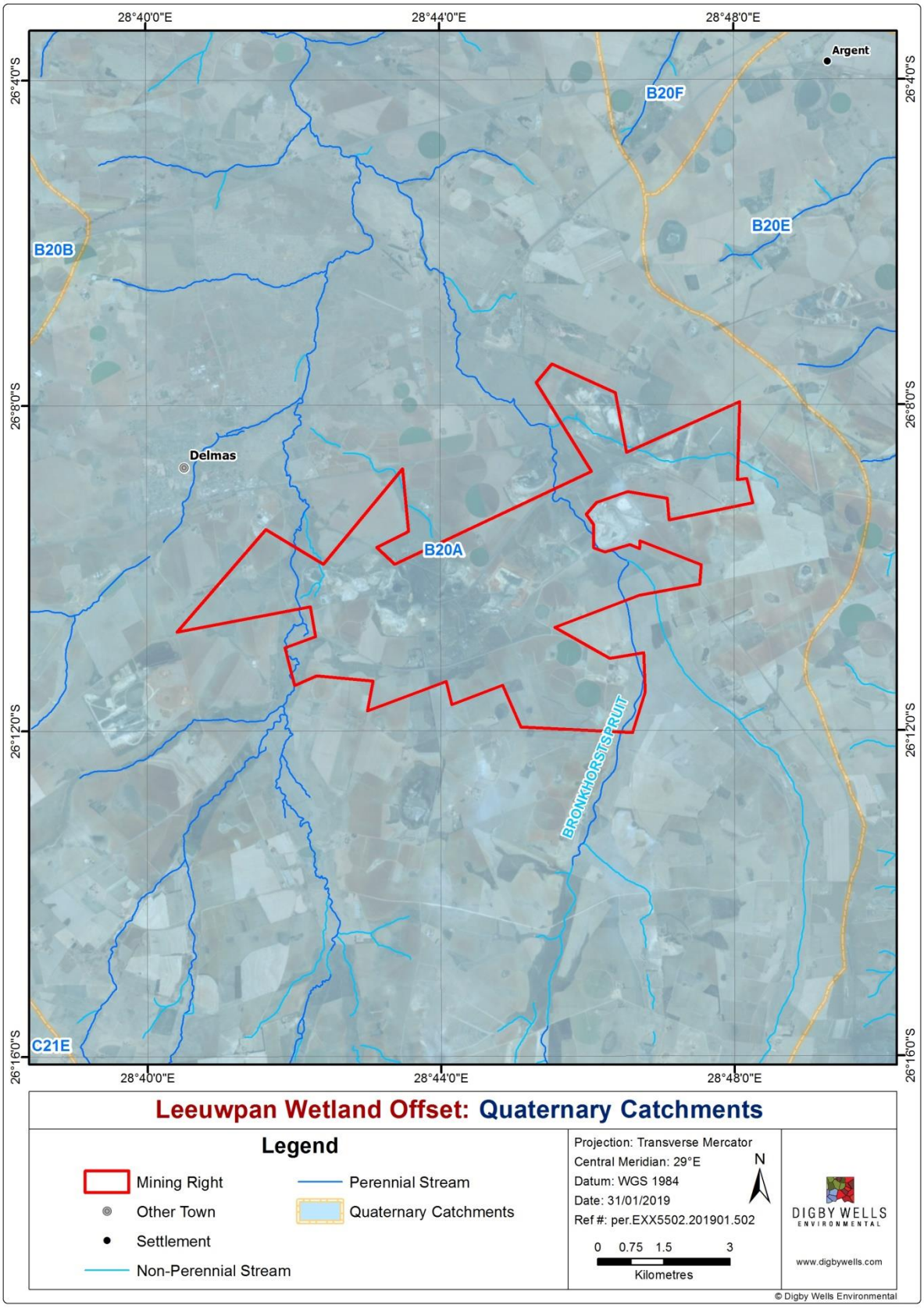


Figure 7-2: Quaternary catchments

7.2 Regional Vegetation

The project area falls within the Grassland Biome (Mucina and Rutherford, 2012), one of the nine South African plant Biomes and the second most bio-diverse biome in South Africa. The Grassland Biome is situated primarily on the central plateau of South Africa, and the inland areas of Kwa-Zulu-Natal and the Eastern Cape provinces. This biome is rich in flora and fauna diversity but is under threat due to rapid urbanisation and expansion of mining and industrial activities.

The project area occurs in the Eastern Highveld Grassland, with small portions occurring within the Eastern Temperate Freshwater Wetlands and the Soweto Highveld Grassland regional vegetation types (Mucina and Rutherford, 2012). Table 7-1 lists the species characteristic of the Eastern Highveld Grassland, Table 7-2 lists species characteristic of Eastern Temperate Freshwater Wetlands and Table 7-3 lists species characteristic of the Soweto Highveld Grassland.

Table 7-1: Plant Species Characteristic of the Eastern Highveld Grasslands

Plant Form	Species
Graminoids	*Aristida aequiglumis, A. congesta, A. junciformis subsp. galpinii, Brachiaria serrata, Cynodon dactylon, Digitaria monodactyla, D. tricholaenoides, Elionurus muticus, Eragrostis chloromelas, E. capensis, E. curvula, E. gummiflua, E. patentissima, E. plana, E. racemosa, E. sclerantha, Heteropogon contortus, Loudetia simplex, Microchloa caffra, Monocymbium ceresiiforme, Setaria sphacelata, Sporobolus africanus, S. pectinatus, Themeda triandra, Trachypogon spicatus, Tristachya leucothrix, T. rehmannii, Alloteropsis semialata subsp. eckloniana, Andropogon appendiculatus, A. schirensis, Bewsia biflora, Ctenium concinnum, Diheteropogon amplectens, Harpochloa falx, Panicum natalense, Rendlia altera, Schizachyrium sanguineum, Setaria nigrirostris, Urelytrum agropyroides*
Herbs	*Berkheya setifera, Haplocarpha scaposa, Justicia anagalloides, Pelargonium luridum, Acalypha angustata, Chamaecrista mimosoides, Dicoma anomala, Euryops gilfillanii, E. transvaalensis subsp. setilobus, Helichrysum aureonitens, H. caespititium, H. callicomum, H. oreophilum, H. rugulosum, Ipomoea crassipes, Pentanisia prunelloides subsp. latifolia, Selago densiflora, Senecio coronatus, Vernonia oligocephala, Wahlenbergia undulata.*
Geophytic herbs	*Gladiolus crassifolius, Haemanthus humilis subsp. hirsutus, Hypoxis rigidula var. pilosissima, Ledebouria ovatifolia*
Succulent Herbs	*Aloe ecklonis*

Table 7-2: Plant species characteristic of the Eastern Temperate Freshwater Wetlands

Type	Plant form	Species
Marshes	Megagraminoid	*Cyperus congestus* (d)
	Graminoids	*Agrostis lachnantha* (d), *Carex acutiformis* (d), *Eleocharis palustris* (d), *Eragrostis plana* (d), *E. planiculmis* (d), *Fuirena pubescens* (d), *Helictotrichon turgidulum* (d), *Hemarthria altissima* (d), *Imperata cylindrica* (d), *Leersia hexandra* (d), *Paspalum dilatatum* (d), *P. urvillei* (d), *Pennisetum thunbergii* (d), *Schoenoplectus decipiens* (d), *Scleria dieterlenii* (d), *Setaria sphacelata* (d), *Andropogon appendiculatus*, *A. eucomus*, *Aristida aequiglumis*, *Ascolepis capensis, Carex austro-africana*, *C. schlechteri*, *Cyperus cyperoides*, *C. distans*, *C. longus*, *C. marginatus*, *Echinochloa holubii*, *Eragrostis micrantha*, *Ficinia acuminata*, *Fimbristylis complanata*, *F. ferruginea*, *Hyparrhenia dregeana*, *H. quarrei, Ischaemum fasciculatum*, *Kyllinga erecta*, *Panicum schinzii*, *Pennisetum sphacelatum*, *Pycreus macranthus*, *P. nitidus*, *Setaria pallide-fusca*, *Xyris gerrardii*.
	Herbs	*Centella asiatica* (d), *Ranunculus multifidus* (d), *Berkheya radula*, *B. speciosa*, *Berula erecta* subsp. *thunbergii*, *Centella coriacea*, *Chironia palustris*, *Equisetum ramosissimum*, *Falckia oblonga, Haplocarpha lyrata, Helichrysum difficile*, *H. dregeanum*, *H. mundtii*, *Hydrocotyle sibthorpioides, H. verticillata*, *Lindernia conferta*, *Lobelia angolensis, L. flaccida*, *Mentha aquatica*, *Monopsis decipiens*, *Pulicaria scabra*, *Pycnostachys reticulata*, *Rorippa fluviatilis* var. *fluviatilis*, *Rumex lanceolatus*, *Senecio inornatus*, *S. microglossus*, *Sium repandum*, *Thelypteris confluens*, *Wahlenbergia banksiana*.
	Geophytic herbs	*Cordylogyne globosa*, *Crinum bulbispermum*, *Gladiolus papilio*, *Kniphofia ensifolia*, *K. fluviatilis*, *K. linearifolia*, *Neobolusia tysonii, Satyrium hallackii* subsp. *hallackii*.
Reed & sedge beds	Megagraminoids	*Phragmites australis* (d), *Schoenoplectus corymbosus* (d), *Typha capensis* (d), *Cyperus immensus*.
	Graminoid	*Carex cernua*.
Water bodies	Aquatic herbs	*Aponogeton junceus*, *Ceratophyllum demersum*, *Lagarosiphon major*, *L. muscoides*, *Marsilea capensis*, *Myriophyllum spicatum, Nymphaea lotus*, *N. nouchali* var. *caerulea*, *Nymphoides thunbergiana*, *Potamogeton thunbergii*.

Type	Plant form	Species
	Carnivorous herb	*Utricularia inflexa*.
	Herb	*Marsilea farinosa subsp. farinosa.*

Table 7-3: Plant species characteristic of the Soweto Highveld Grassland

Plant Form	Species
Graminoids	*Andropogon appendiculatus, Brachiaria serrata, Cymbopogon pospischilii, Cynodon dactylon, Elionurus muticus, Eragrostis capensis, E. chloromelas, E. curvula, E. plana, E. plana, E. paniculmis, E, racemose, Heteropogon contortus, Hyparrhenia hirta, Setaria nigrirostris, S. sphacelata, Themeda triandra, Tristachya leucothrix, Andropogon schirensis, Aristida adscensionis, A. bipartite, A. congesta, A. junciformis* subsp. *galpinii, Cymbopogon caesius, Digitaria diagonalis, Diheteropogon amplectens, Eragrostis micrantha, E. superba, Harpochloa falx, Microchloa caffra, Paspalum dilatatum*
Herbs	*Hermannia depressa, Acalypha angustata, Berkheya setifera, Dicoma anomala, Euryops gilfillanii, Geigeria aspera* var. *aspera, Graderia subintegra, Haplocarpha scaposa, Helichrysum miconiifolium, H. nudifolium* var. *nudifolium, H. rugulosum, Hibiscus pusillus, Justicia anagalloides, Lippia scaberrima, Rhynchosia effuse, Schistostephium crataegifolium, Selago densiflora, Senecio coronatus, Vernonia oligocephala, Wahlenbergia undulata*
Geophytic herbs	*Haemanthus humilis* subsp. *hirsutus, H. montanus*
Herbaceous climber	*Rhynchosia totta*
Low shrubs	*Anthospermum hispidulum, A. rigidum* subsp. *Pumilum, Berkheya annectens, Felicia muricata, Ziziphus zeyheriana*

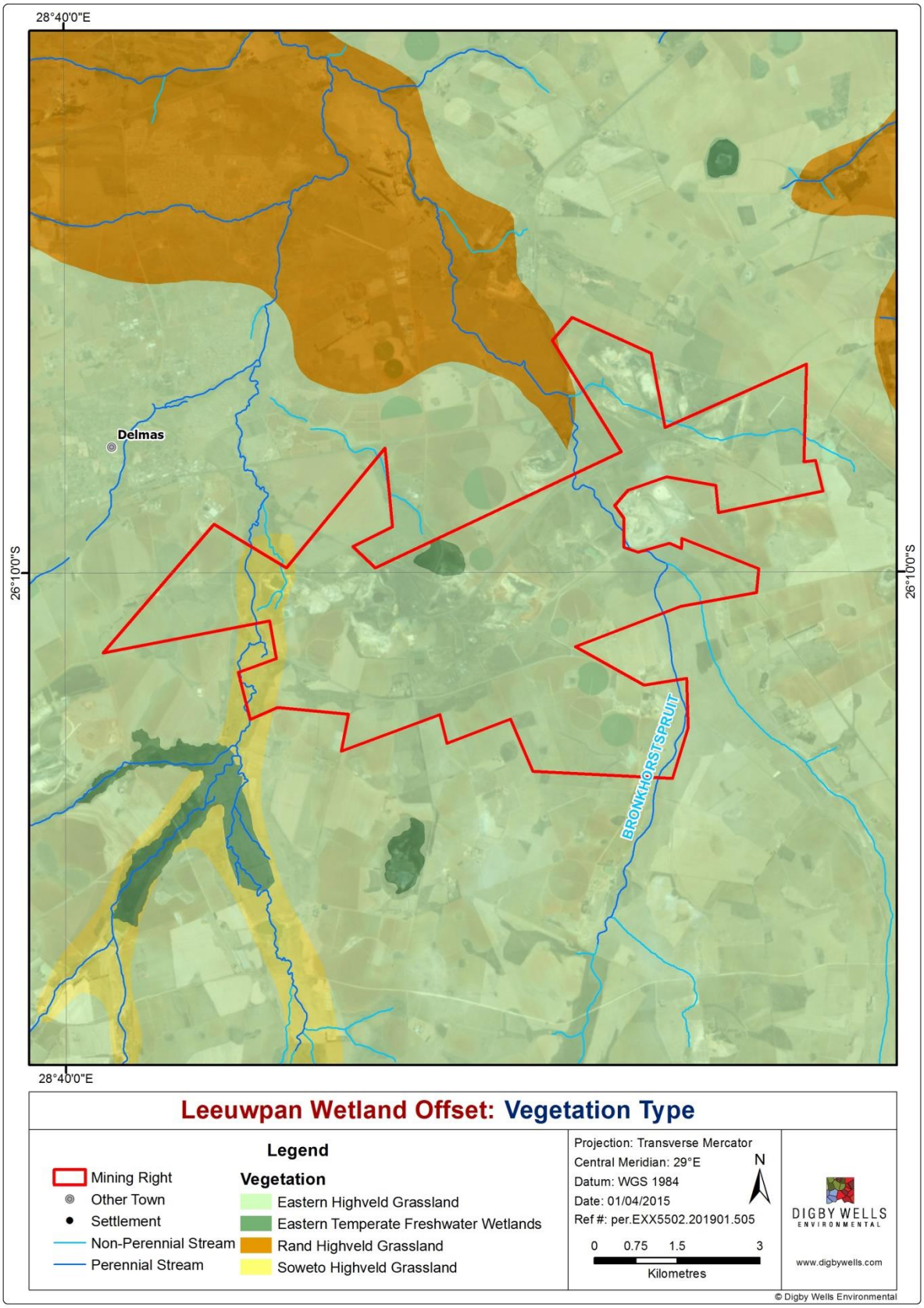


Figure 7-3: Regional vegetation

7.3 National Freshwater Ecosystem Priority Areas (NFEPAs)

The NFEPA project provides information of wetland and river ecosystems for integrating into freshwater ecosystem and biodiversity planning and decision-making processes. The assessor considered the strategic spatial priorities for conserving the country's freshwater ecosystems and supporting sustainable use of water resources contained therein to evaluate the importance of the wetland areas located within the project area (Nel *et al.* 2011).

Figure 7-4 demonstrates the distribution of NFEPA wetlands within the project area.

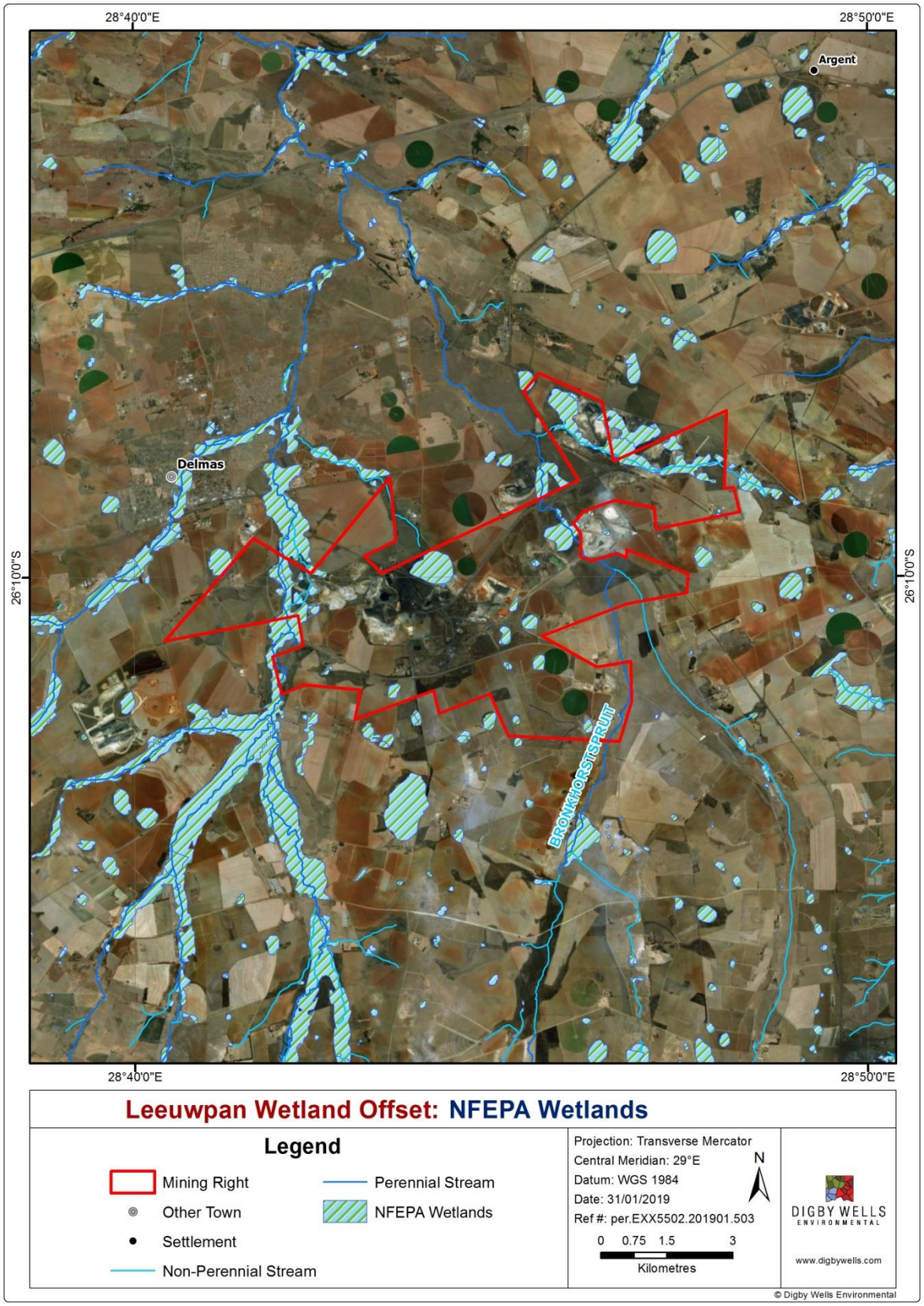


Figure 7-4: NFEPA Wetlands

7.4 Mining and Biodiversity Guidelines

The Mining and Biodiversity Guideline (2013) can be seen as a cumulative finding of all available biodiversity and ecological related information with a final mapped area. The assessment looks at NFEPA and regional biodiversity plans such as the MBSP. This is shown in Figure 7-5 below.

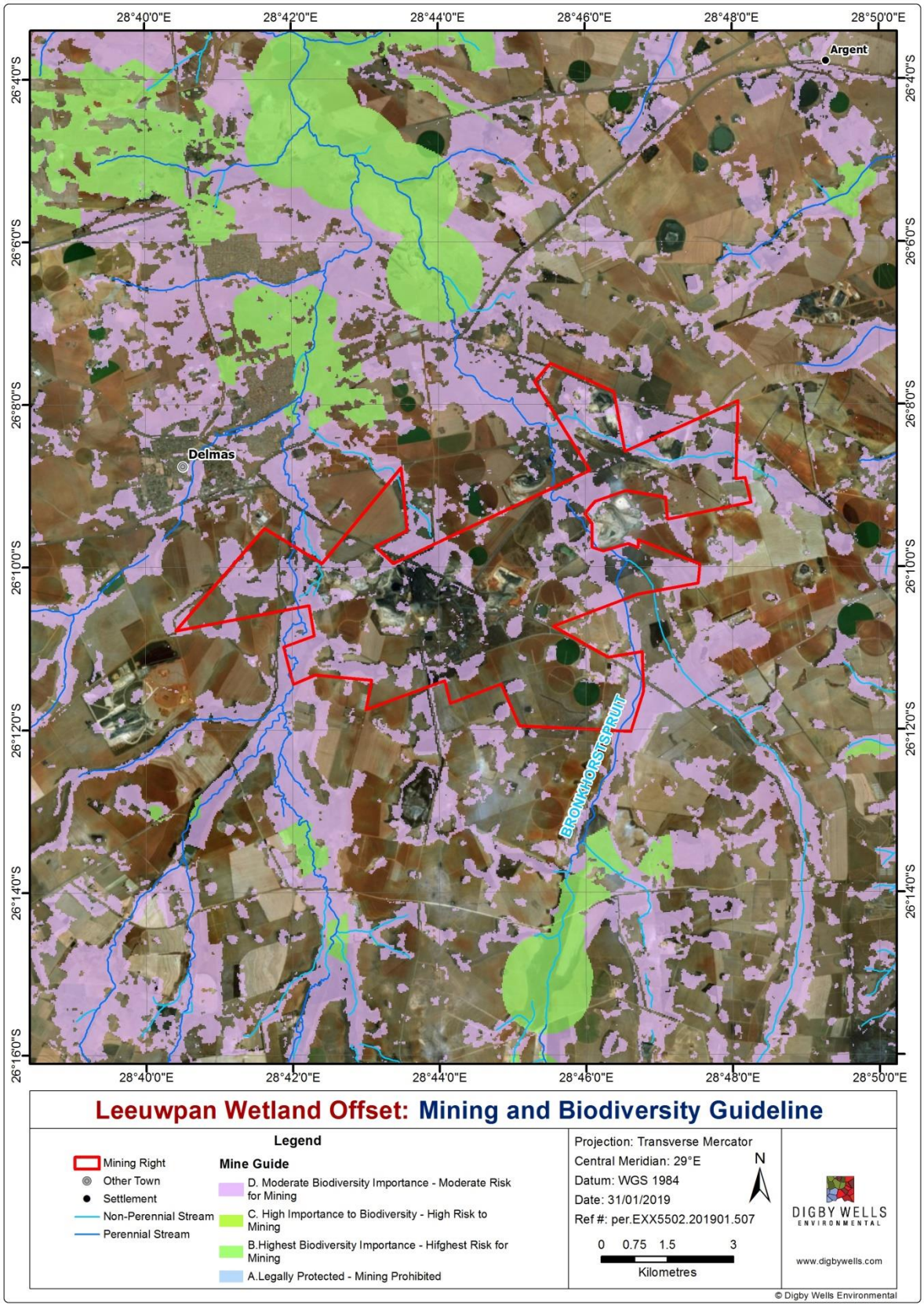


Figure 7-5: Mining and Biodiversity Guideline

7.5 Mpumalanga Biodiversity Sector Plan

The MBSP (2013) is a spatial tool that forms part of the national biodiversity planning. The terrestrial MBSP has delineated two small portions of the project area as ‘CBA Optimal’ and a further two portions as ‘CBA Irreplaceable’. According to the guidelines from the MSBP, CBAs must be kept in a natural state with no further loss of habitat; where only low-impact, biodiversity-sensitive land-uses are appropriate.

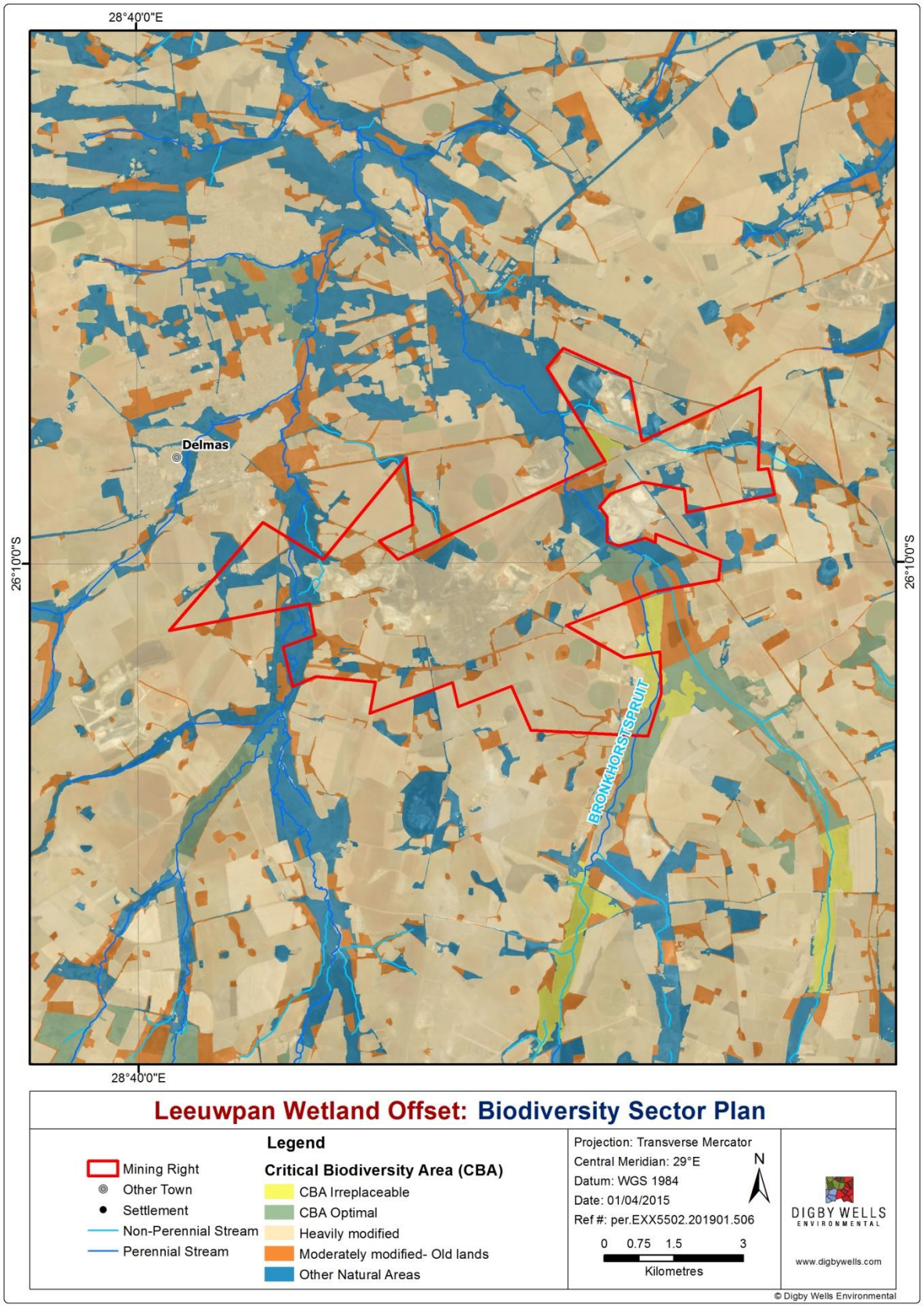


Figure 7-6: Mpumalanga Biodiversity Sector Plan

8 Wetland Assessment Review

8.1 Wetland delineation, classification, PES and EIS

8.1.1 Block OI

According to the LRI (2013) report, the wetlands within Block OI were delineated in 2012, with mining activities within Block OI expected to impact on at least 134.62 ha of wetlands (68.4 ha fall within the direct footprint of proposed opencast areas.

Wetlands are dominated by extensive hillslope seepage wetlands, though three pans also occur. The pans have also been significantly altered by agricultural activities, with two of the pans being utilised as irrigation dams. It is noted that the Red Data listed Greater Flamingo was recorded on several occasions from these pans, and they may thus be regarded as of increased importance in terms of the maintenance of biodiversity.

The wetlands were considered to be largely to seriously modified (PES category D and E). The north eastern seepage wetland was considered moderately modified (PES category C). EIS of these wetland systems were found to be of Low/Marginal to Moderate in terms of importance and sensitivity.

8.1.2 Block OL

According to the LRI (2013) report, the wetlands within Block OI were delineated in 2012, with mining activities within Block OL expected to impact on at least 120.30 ha of wetlands.

The wetlands systems present were found to be dominated by extensive hillslope seepage wetlands. One portion of a valley bottom wetland was also identified within Block OL. All of the hillslope seepage wetlands were found to have been significantly impacted by cultivation, as well as existing mining activities.

Wetlands were found to be moderately to largely modified (PES category C and D), with relatively Low/Marginal to Moderate ecological importance and sensitivity.

8.1.3 Block OI West

The wetlands which occur within the Block OI West form part of the historical wetland delineation carried out by Wetland Consulting Services (Pty) Ltd in 2012. The proposed Block OI West is expected to impact on at least 20.57 ha of wetlands.

These systems are comprised of portions of two hillslope seep wetlands and a pan wetland. The wetlands were observed to be impacted by severe alien vegetation encroachment, cultivation as well as infrastructure developments related to the existing mine activities.

Both the hillslope wetlands were found to be seriously modified (PES category E), with relatively Low/Marginal ecological importance and sensitivity, while the pan wetland was found to be largely modified (PES category D), with a Moderate to Low ecological importance and sensitivity.

8.2 Hectare Equivalents

The hectare equivalents determined for each of the individual hydro-geomorphoc wetland units within Block OI, Block OL and the proposed Block OI West are presented in the tables below.

Table 8-1: Hectare equivalents to be lost within Block OI (LRI, 2013).

HGM Unit	Current/Pre-mining				
	Type	Area (ha)	PES	EIS	Hectare equivalents
H1	Hillslope seepage	41.98	C	C	14.69
H2	Hillslope seepage	6.83	E	D	2.05
H3	Hillslope seepage	9.28	E	D	2.78
H4	Hillslope seepage	6.29	E	D	1.89
H6	Hillslope seepage	9.57	D	D	4.79
H7	Hillslope seepage	24.56	D	D	9.82
H9	Hillslope seepage	21.28	E	D	3.19
PAN1	Pan	8.29	D/E	D	3.32
PAN2	Pan	4.16	D	C	2.08
PAN3	Pan	2.38	E	D	0.71
TOTAL		134.62			45.32

Table 8-2: Hectare equivalents to be lost within Block OL (LRI, 2013).

HGM Unit	Current/Pre-mining				
	Type	Area (ha)	PES	EIS	Hectare equivalents
H1	Hillslope seepage	41.98	C	C	14.69
H5	Hillslope seepage	33.09	D	D	14.89
H8	Hillslope seepage	13.00	C	C	9.10
UVB1	Hillslope seepage	32.23	D	D	3.22
TOTAL		120.30			41.91

Table 8-3: Hectare equivalents to be lost within Block OI West.

HGM Unit	Current/Pre-mining (Wetland assessment: WCS, 2012)			
	Area (ha)	PES	EIS	Hectare equivalents
Hillslope seeps	18.36	E	D	9.18
Pan	2.21	D	D	1.33
Total	**20.57**			**10.51**

In total, for both Blocks OI and OL, as well as the proposed Block OI West, 97.7 hectare equivalents are expected to be lost.

8.3 Offset calculations and offset targets for Blocks OI and OL

According to the LRI (2013) "Phase 1: Determination of Wetland Offset Requirements – Appendix A", the required functional offset target for Blocks OI and OL would be 87.23 hectare equivalents and the required conservation offset target is 549 hectare equivalents. The additional proposed Block OI West will result in an additional loss of 10.51 hectare equivalents. The required functional offset target, taking the proposed Block OI West into consideration is thus calculated at 97.7 hectare equivalents and the conservation offset target is 561.4 hectare equivalents.

The results of the wetland offset calculations are presented in the tables below.

Table 8-4: Results of the wetland offset calculation for Block OI (LRI, 2013).

HGM Unit	Current/Pre-mining					Functional Offset Target	Ecosystem Conservation Target		
	Type	Area (ha)	PES	EIS	Hectare equivalents	Functional Hectare Equivalents	Habitat Hectare Equivalent	Offset multiplier (SANBI)	Ecosystem Conservation Target
H1	Hillslope seepage	41.98	C	C	14.69	14.69	10.50	9.98	104.69
H2	Hillslope seepage	6.83	E	D	2.05	2.05	1.37	6.48	8.85
H3	Hillslope seepage	9.28	E	D	2.78	2.78	0.93	6.51	6.04
H4	Hillslope seepage	6.29	E	D	1.89	1.89	1.26	6.48	8.15
H6	Hillslope seepage	9.57	D	D	4.79	4.79	1.91	6.45	12.35
H7	Hillslope seepage	24.56	D	D	9.82	9.82	9.58	6.27	60.06
H9	Hillslope seepage	21.28	E	D	3.19	3.19	0.64	6.72	4.29
PAN1	Pan	8.29	D/E	D	3.32	3.32	1.66	6.36	10.54
PAN2	Pan	4.16	D	C	2.08	2.08	1.66	9.11	15.15
PAN3	Pan	2.38	E	D	0.71	0.71	0.71	9.77	6.97
TOTAL		134.62			45.32	**45.32**	30.21	7.41	**237.09**

Table 8-5: Results of the wetland offset calculation for Block OL (LRI, 2013).

HGM Unit	Current/Pre-mining					Functional Offset Target	Ecosystem Conservation Target		
	Type	Area (ha)	PES	EIS	Hectare equivalents	Functional Hectare Equivalents	Habitat Hectare Equivalent	Offset multiplier (SANBI)	Ecosystem Conservation Target
H1	Hillslope seepage	41.98	C	C	14.69	14.69	10.50	9.98	104.69
H5	Hillslope seepage	33.09	D	D	14.89	14.89	14.89	6.27	93.36
H8	Hillslope seepage	13.00	C	C	9.10	9.10	7.80	9.65	75.23
UVB1	Hillslope seepage	32.23	D	D	3.22	3.22	3.22	11.99	38.63
TOTAL		120.30			41.91	**41.91**	36.41	9.47	**311.91**

Table 8-6: Results of the wetland offset calculation for the proposed Block OI West

HGM Unit	Current/Pre-mining				Functional Offset Target	Ecosystem Conservation Target		
	Area (ha)	PES	EIS	Hectare equivalents	Functional Hectare Equivalents	Habitat Hectare Equivalent	Ecosystem Conservation Ratio	Ecosystem Conservation Target
Hillslope seeps	18.36	E	D	9.18	9.18	7.3	1.4	9.9
Pan	2.21	D	D	1.33	1.33	1.8	1.4	2.5
Total	20.57			10.51	10.51	9.1	2.8	12.4

9 Opportunities for onsite rehabilitation

The project area is characterised by multiple wetland systems, including pans, hillslope seepage wetlands and valley bottom wetland systems. Should mining activities proceed as planned, and the proposed Block OI west is approved, roughly 1012.4 hectares are expected to remain (LRI, 2013).

The required functional offset target is 97.7 hectare equivalents and the conservation offset target is 561.4 hectare equivalents should offsets be approved for Blocks OI, OL and OI West. According to the LRI (2013) report, if it is assumed that the remaining wetlands on site can be rehabilitated so as to increase their present ecological state category by one level, this would imply an approximate 20% gain in functional area. As such, this would result in a gain of about 202.48 hectare equivalents.

From the field assessment carried out in December 2018, three portions of wetland that are regarded as destroyed as a result of mining activities were identified as potential sites for rehabilitation. The rationale behind this approach is such that should rehabilitation of these sites be considered, this would provide the potential to restore stream connectivity between upstream and downstream areas that have become fragmented as well as improve the ecological importance and sensitivities of the systems present as a whole. The present ecological state of each of these areas to be rehabilitated was calculated by applying the WET-Health tool to the entire portion of each of the selected wetlands within the mining rights area prior to rehabilitation of the destroyed wetland portions. The WET-Health tool was then applied taking into consideration the proposed rehabilitation efforts and the hectare gains were calculated according to the associated hectare equivalents expected to be

gained from each rehabilitated portion. Assuming each of these wetland portions can be rehabilitated to a category D, the direct wetland gain in terms of hectare equivalents may be regarded as 166.47 ha. However, in order to realise both these gains, as well as the 202.48 ha described above, it is estimated that a minimum of 204.10 ha of the surrounding catchment areas will require rehabilitation and a further 87.12 ha of buffers located in selected areas around the mining rights area are recommended to protect the wetlands present and prevent further losses to the wetland systems present. Thus, a total of 660.16 ha have been identified towards achieving the wetland conservation target of 561.4 ha. In terms of functional offset targets, the direct gains in hectare equivalents total 368.95 ha, which may be regarded as more than sufficient to achieve the abovementioned functional offset target requirement of 97.7 ha.

It must be noted that in terms of the "like-for-like" offset requirement, the conservation offset target falls short of the required hectare equivalents for hillslope seep wetlands, however, as discussed above in Section 6.2.2, consideration as to the potential improvements and rehabilitation of selected wetland systems within the Mining Rights Area were regarded as valuable inclusions within the proposed offset strategy, not only from the perspective of improvements to the present ecological state of the systems as a whole, but also in terms of improvements to ecological importance and service provision within the greater catchment. The value of including the proposed rehabilitation measures within the offset strategy thus serve as grounds for the consideration of an "out-of-kind" offset (to some extent).

The results of both the LRI (2013) assessment and the December 2018 assessment have been merged and are presented below.

Table 9-1: Remaining extent of wetland habitat within the mining rights area in the post-mining scenario, the 20% gains and the required functional offset targets (LRI, 2013), as well as the expected gains as a result of the proposed rehabilitation activities described and the conservation offset targets.

Wetland Type	Extent remaining	20% gain	Proposed rehabilitation gain	Required functional offset	Required conservation offset
Channelled valley bottom	77.77	15.55	35.61	-	-
Hillslope seepage	598.67	119.73	Potential hillslope seep gains assuming a potential category D PES can be attained 97.92	87.07	487.61
Pan	56.36	11.27	32.94	7.44	35.16
Unchannelled valley bottom	279.60	55.92	-	3.22	38.63
Recommended buffers			87.12		
Required catchment rehabilitation			204.10		

Wetland Type	Extent remaining	20% gain	Proposed rehabilitation gain	Required functional offset	Required conservation offset
Total	**1012.4**	**202.48**	**166.47** (direct wetland gain) **291.22** (indirect wetland conservation gain)	**97.74**	**561.4**

9.1 Impact Assessment

Various impacts were identified within each of the wetland areas observed within the mining rights area, with a particular emphasis on wetland offset and rehabilitation opportunities. In order to formulate an effective offset strategy, taking into consideration the current land uses, an assessment of impacts to the wetland units will consider the threat to the future capacity of the wetland units to provide goods and services.

Identified impacts, primarily as a result of the current land-uses, considered for the offset strategy includes:

- Cultivation;
- Lack of culverts;
- Dams and berms;
- Livestock grazing and trampling;
- Alien and invasive plants; and
- Current mining activities

10 Rehabilitation Interventions towards Offsets

The Section below provides details with respect to the Offsets that can be gained, interventions that can be adopted and associated costs of adopting such interventions. It must be noted that a large portion of the costs presented below can be offset against the existing rehabilitation provision that is currently in place. A summary is provided for in Section 10.3 for which costs should be catered for under the existing financial provision.

10.1 Rehabilitation Offset Areas Affected by Mining

The entire mining right was evaluated to determine where offsets could be achieved on site first prior to looking at off site offsets. The sections below look at rehabilitation interventions that can be implemented to aid in the improvement of wetland functionality within the catchment and system connectivity, which could contribute to the overall offset that is potentially required.

10.1.1 Option 1 – Pan Offsets Requirements

Within this area there is a pan that is approximately 96.67 ha in extent of which 54.89 ha has been impacted upon as a result of mining activities. The overall functionality of this pan

system is an E. The main impacts contributing to this categorisation are impacts to the hydrological health of the wetland as a result of excavation, reduced roughness and the formation of gullies and artificial drainage channels.

The proposed rehabilitation measures are as follows:

- Contaminated soils be assessed and removed. These soils should either be rehabilitated in situ or disposed of at a registered land fill site;
- Prior to re-profiling of the pan system, all alien invasive trees need to be removed;
- Removal of all debris within the pan;
- Re-profiling of the pan catchment (South portion) needs to be re-profiled towards the centre of the pan;
- The northern section of the pan currently has trenches that need to be filled to prevent drainage of the pan system to the surrounding areas. This would also improve connectivity within the pan system;
- Grazing/Agricultural activities are also undertaken within the North Eastern portion of the pan. It is recommended that these grazing activities are stopped to aid in increasing surface roughness within the pan and thus providing greater flood attenuation and water storage surface
- Wetland sub and topsoil to be open casted mined at Block OI can be stripped and utilised as the wetland soil material within the south pan catchment. It is important that this wetland soil utilised should be stripped from the OI development and is utilised immediately to ensure that maintenance of the soil integrity and associated seed bank;
- The wetland topsoil and subsoil needs to be stripped separately and transported separately to avoid mixing of these soil to avoid the overall potential reduction in the capability of these wetland soils;
- Seeding then can be undertaken utilising appropriate hydrophilic plant species (Refer to Section 11.4, for species list);
- Once the rehabilitation has commenced this area must be designated as a no-go zone;
- On-going monitoring of Alien Invasive Plant species and removal of such species according to the Alien Invasive Management Plan; and
- An appropriate buffer (of at least 50 m) around the pan should be investigated and implemented. The above mentioned rehabilitation interventions should apply to the buffer accordingly;;

Should all of these intervention measures be implemented it is expected that overtime with implementing the correct monitoring measures the overall condition of the wetland can be improved from a Class F to a Class D.

Refer to Table 10-1, for the costs associated with Option 1 and the pan system.

Table 10-1: Summary of Costs for Option 1

Measures	Quantity	Unit	Rate	Amount
Clean up footprint	306000	m²	R13.04	R3,991,012.61
Removal of Alien Invasive Tree Species	3	ha	R8,284.55	R27,339.00
Reprofiling of Surface (assuming 50% requires profiling)	27	ha	R2,512.00	R68,941.78
Backfilling of trench	1500	m³	R18.80	R28,204.95
Placement of soil	548900	m²	R23.80	R13,066,436.93
Seeding	55	Ha	R26,539.92	R1,456,776.25
Total				**R 18,638,711.52**

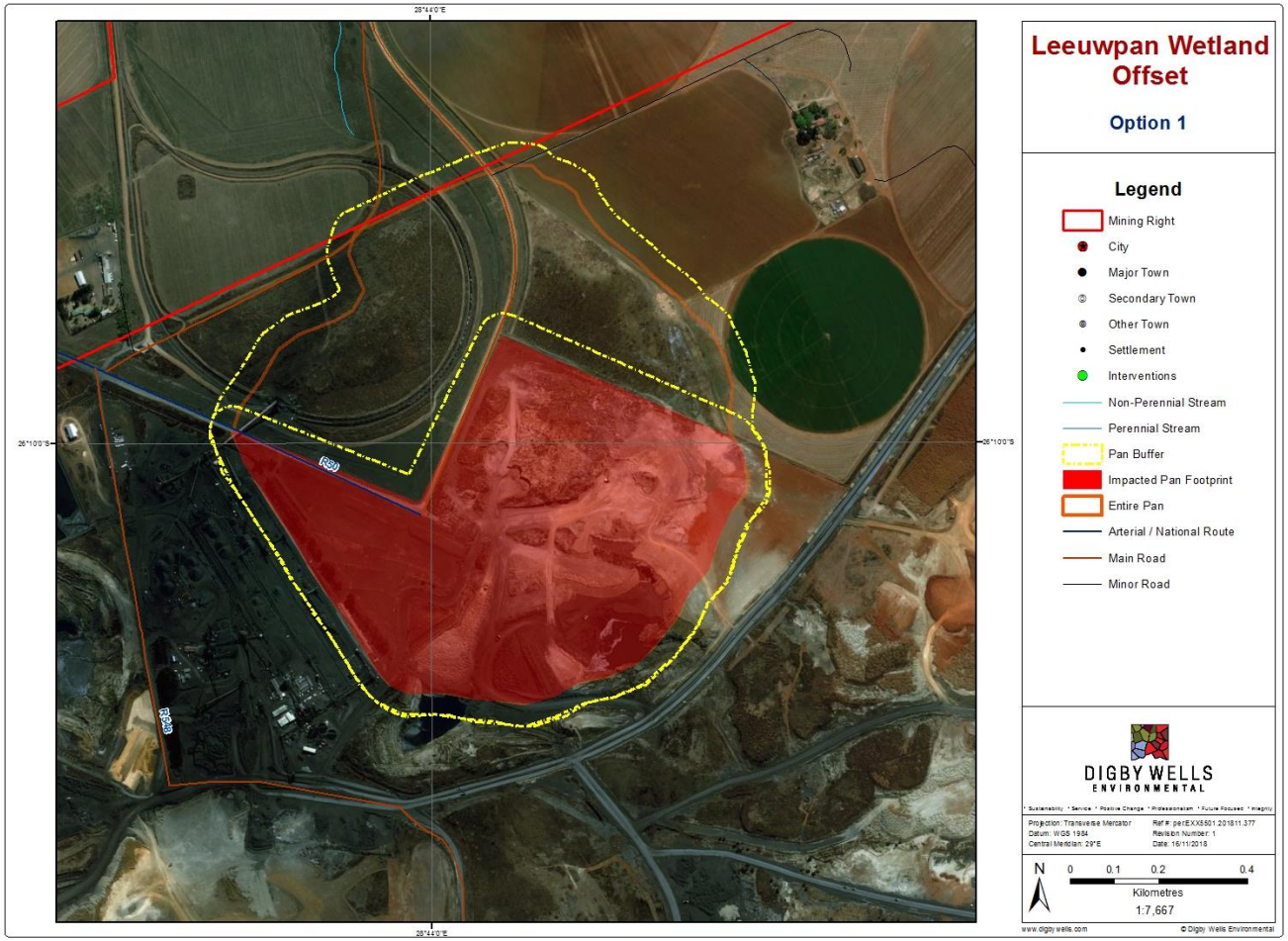


Figure 10-1: Option 1 – Pan Rehabilitation

10.1.2 Option 2 - Weltevreden Unchannelled Valley Bottom System Area

This area has significantly been impacted upon as a result of mining activities through open cast mining methods and stockpiling activities. The unchannelled valley bottom system occurring in the Weltevreden area comprises of a total of 64.3 ha. Of this 59.4 ha (Western and Eastern areas inclusive) has been impacted upon. Inclusive of the impacts within this system, are extensive stockpiling and dumping activities, Excavation activities, access roads a stream diversion, which may be regarded as disconnected from the upstream portion as well as the downstream portion of the system. These activities have resulted in fragmentation of the upstream and downstream portions of this system, resultinng in a loss of connectivity, stream integrity and overall contribution of water services to the downstream catchment.

A collapsed culvert on the lower end of the river diversion as well as stockpiling directly adjacent to the river diversion has is resulting in sedimentation of the downstream portions of the system.

The resulted impacts have caused moderate to severe deviations in the hydrological and geomorphological functioning of the system as well as substantial loss in the natural vegetation structures present. This system may be regarded as a category F.

It must be noted that Exxaro is not required by virtue of the Water Use Licence that is held for this area to be considered as a loss of wetlands, thus resulting in offsets for the impacts that have occurred here not being required. However in the interest of maintaining stream connectivity and enhance the overall connectivity of the system as a whole it is deemed appropriate to consider the rehabilitation of this area as an offset for the Leeuwpan Coal Mine.

The ultimate aim for the rehabilitation of this area is to take into consideration the rehabilitation of the surrounding catchment areas, which historically comprised largely of hillslope seepage wetland on either side of the channel.

While the reinstatement of the hillslope seepage wetlands cannot be granted, the contribution of surface flow to the unchannelled valley bottom system is regarded as an important contribute to the formation and functioning of this system. Any rehabilitation efforts will thus rely heavily on rehabilitation of the surrounding area.

The following rehabilitation interventions have been considered:

- Contaminated soils be assessed and removed. These soils should either be rehabilitated in situ or disposed of at a registered land fill site;
- Prior to re-profiling of the unchannelled valley bottom wetland and surrounding catchment all Alien Invasive Plants including Pampas Grasses observed should be removed;
- Removal of all debris within the system and fuelling systems noted in the vicinity of the system should be removed;

- The access road needs to be ripped and profiled according;
- It is recommended that when the road is removed, that this is area is connected to the historically unchannelled valley bottom system (river diversion connection). This should be considered as wetland species have already started to establish within this area as a result of water being present;
- Eastern Section of System;
  - Re-profiling of the eastern section of the catchment towards the unchannelled valley bottom wetland needs to be undertaken (This is depicted in Figure 10-2);
  - Backfilling of the open pits;
  - The diversion is a critical component of the entire system, that should remain in place as this forms the connectivity between the eastern and western portions of the unchannelled valley bottom system;
  - Should additional wetland soils be required, these soils can be acquired from the hillslope seepage and unchannelled valley bottom wetlands portions to be mined out in block OL;
- Western Section of the System:
  - Rehabilitation of a portion of the North section of the unchannelled valley bottom wetland inclusive of the unchannelled valley bottom wetland and diversion to be rehabilitated;
  - Re-profiling of the western section of the catchment towards the unchannelled valley bottom wetland needs to be undertaken (This is depicted in Figure 10-2);
  - Removal of the soil stockpiles directly adjacent to the river diversion;
  - Removal of the access road and collapsed culvert, as well as the sediment deposits directly downstream of said culvert;
- The wetland topsoil and subsoil needs to be stripped separately and transported separately to avoid mixing of these soil to avoid the overall potential reduction in the capability of these wetland soils;
- Seeding then can be undertaken utilising appropriate hydrophilic plant species (Refer to Section 11.4, for species list);
- Once the rehabilitation has commenced this area must be designated as a no-go zone;
- On-going monitoring of Alien Invasive Plant species and removal of such species according to the Alien Invasive Management Plan; and
- An appropriate buffer (of at least 50 m) running parallel to the river diversion should be implemented

Should all of these intervention measures be implemented, the overall hectare equivalent gain is estimated to be 35.62 ha of unchannelled valley bottom habitat, exclusive of this is a 259.3 ha requirement for rehabilitation of the surrounding catchment, portions of which may have the potential of developing hillslope seepage characteristics over the long term.

Should these interventions be implemented this system has the potential to improve from a category F to a category D.

It must be noted that a separate Wetland Rehabilitation Plan is in the process of being compiled and will provide further detail with respect to rehabilitation that will be undertaken within portions of this area. The above interventions are a summary of what measures are required.

Table 10-2, provides details with respect to the estimated costs for the associated intervention that could be adopted as noted above.

Table 10-2: Summary of Costs for Option 2

Measures	Quantity	Unit	Rate	Amount
Option 2 Weltevreden				
Clean up footprint (Assuming 20% of footprint needs to be cleared)	518600	m²	R13.04	R6,763,853.39
Re-profiling of Surface (assuming 50% requires profiling)	130	ha	R2,512.00	R325,680.52
Placement of soil (assuming 50% will require soil)	648250	m²	R23.80	R15,431,440.59
Seeding	259	Ha	R26,539.92	R6,881,801.46
Option 2 Weltevreden - Surrounding Catchment				
Clean up footprint (Assuming 30% of footprint needs to be cleared)	178200	m²	R13.04	R2,324,177.93
Removal of Alien Invasive Species	5	ha	R8,284.55	R41,422.73
Re-profiling of Surface (assuming 50% requires profiling)	59	ha	R2,512.00	R149,212.67
Removal of Road	47000	m²	R7.89	R370,701.73
Placement of soil (assuming 50% will require soil)	297000	m²	R23.80	R7,070,015.97

Measures	Quantity	Unit	Rate	Amount
Seeding	59	Ha	R26,539.92	R1,576,471.29
Total				**R 40,934,778.29**

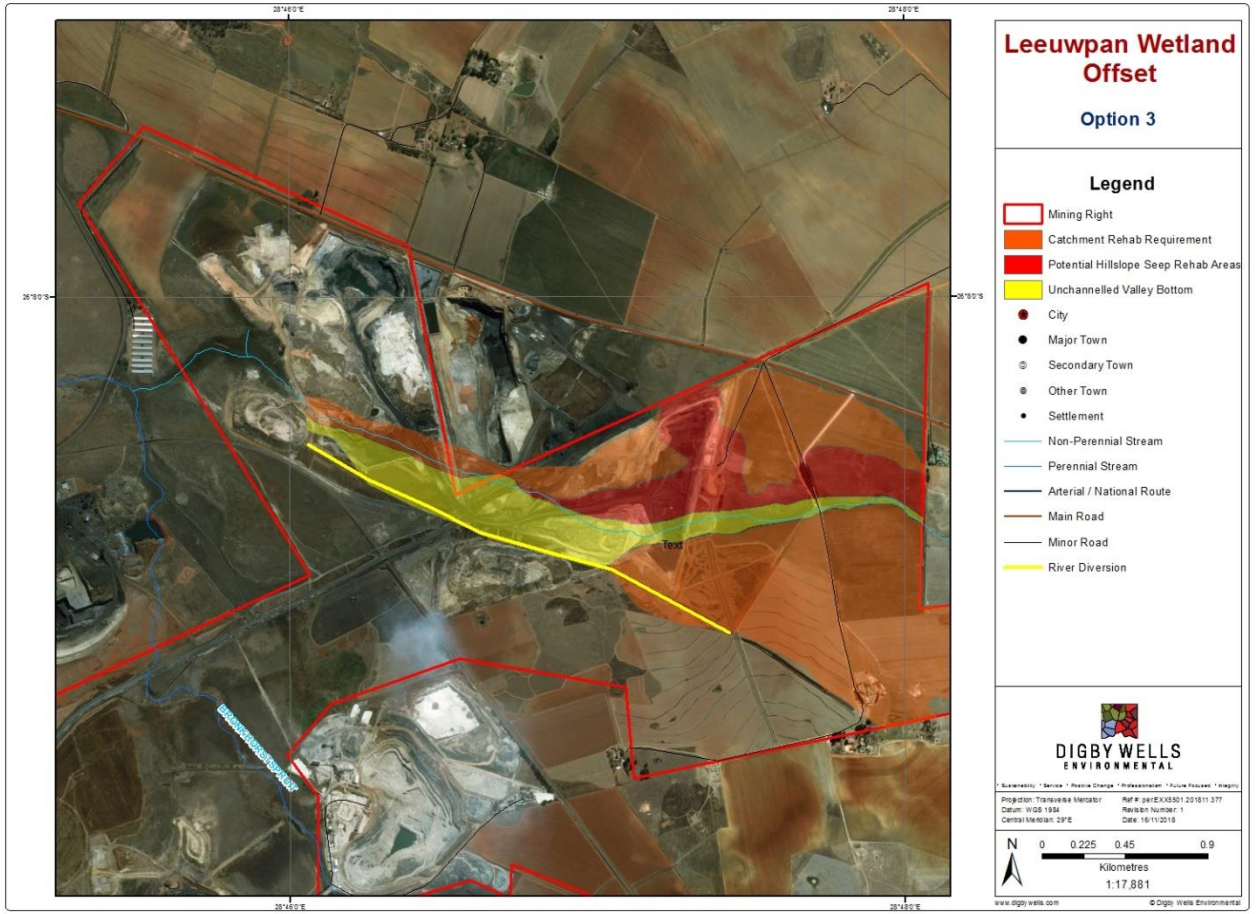


Figure 10-2: Option 2 Rehabilitation Interventions

10.1.3 Option 3 - Western Historical Mining Area and Water Storage Facility

This section is located in the western portion of the mining right. Historical mining activities have taken place within this area and partial rehabilitation has been undertaken. There is a water storage facility that is also located within this area and it is assumed that this structure will remain post closure for water management purposes.

It was difficult to determine the historical extent of the wetlands that would have occurred in this area, however it is anticipated that should this area be appropriately rehabilitated, the resultant land use may contribute to the integrity and functionality of the surrounding remaining wetland system.

There is a river diversion that runs adjacent to this area to the west, which connects the upstream portion to the downstream portion of the wetland that would have existed within this area prior to mining. It is recommended that the diversion remains in place and profiling be undertaken within this historical mining area. It is recommended that re-profiling on either side of the diversion is undertaken and stabilisation of the banks is achieved through vegetation of hydrophilic species as recommended in the species plan.

It should be noted that during the site assessments, not water was evident and thus the integrity of the diversion should be questions from a functional point of view. Surface water was observed in the original channel directly upstream and downstream of the confluence of the diversion channel, thus supporting the suspicion that the surrounding areas may have provided some hillslope seepage function. Based on the above site observations the following rehabilitation interventions are recommended:

- Diversion to remain, however corrective action is required to ensure flow of water from upstream to downstream ensuring connectivity of the system;
- Removal of perimeter berm that runs in a northerly direction (adjacent to the river diversion) which then turns in a easterly direction around the remaining open pit;
- Stockpiles remaining in this area should be utilised to backfill and profile this and the surrounding areas. The soil that was utilised to create the berm can be used as the growth medium to rehabilitated the profiled footprint;
- Profiling of the area should be done in a north North-West direction with a gentle profile to avoid erosion issues forming (refer to Figure 10-3 for profiling direction).
- Concurrent rehabilitation of this area and surrounds to the east should be undertaken to prevent sedimentation and erosion and contamination and the ingress of contaminants into this rehabilitated area;
- Seeding then can be undertaken utilising appropriate hydrophilic plant species (Refer to Section 11.4, for species list);
- Once the rehabilitation has commenced this area must be designated as a no-go zone; and

- On-going monitoring of Alien Invasive Plant species and removal of such species according to the Alien Invasive Management Plan.

Based on the above the gain is 108 ha of potential hillslope seepage areas, however, as the potential integrity of this area cannot be guaranteed at this stage, any overall gain will need to be evaluated during monitoring assessments that should occur on an annual basis during rehabilitation and into the mine closure phase.

Refer to Table 10-3, for the cost for Option 3 Interventions.

Table 10-3: Summary of Costs for Option 3

Measures	Quantity	Unit	Rate	Amount
Clean up footprint (Assuming 20% of footprint needs to be cleared	216000	m^2	R13.04	R2,817,185.37
Removal of Perimeter Berm	49600	m^3	R18.80	R932,643.75
Re-profiling of Surface (assuming 50% requires profiling)	54	ha	R2,512.00	R135,647.88
Placement of soil (assuming 40% will require soil)	432000	m^2	R23.80	R10,283,659.60
Seeding	108	Ha	R26,539.92	R2,866,311.44
Total				**R 17,035,448.04**



Figure 10-3: Option 3, Hillslope Seep Catchment

10.2 Surrounding Interventions On-site

This section below provides information with respect to specific on-site interventions that could be implemented in order to ensure that the necessary offsets can be achieved. Refer to Figure 10-4 for the location of the on-site interventions that can be implemented.

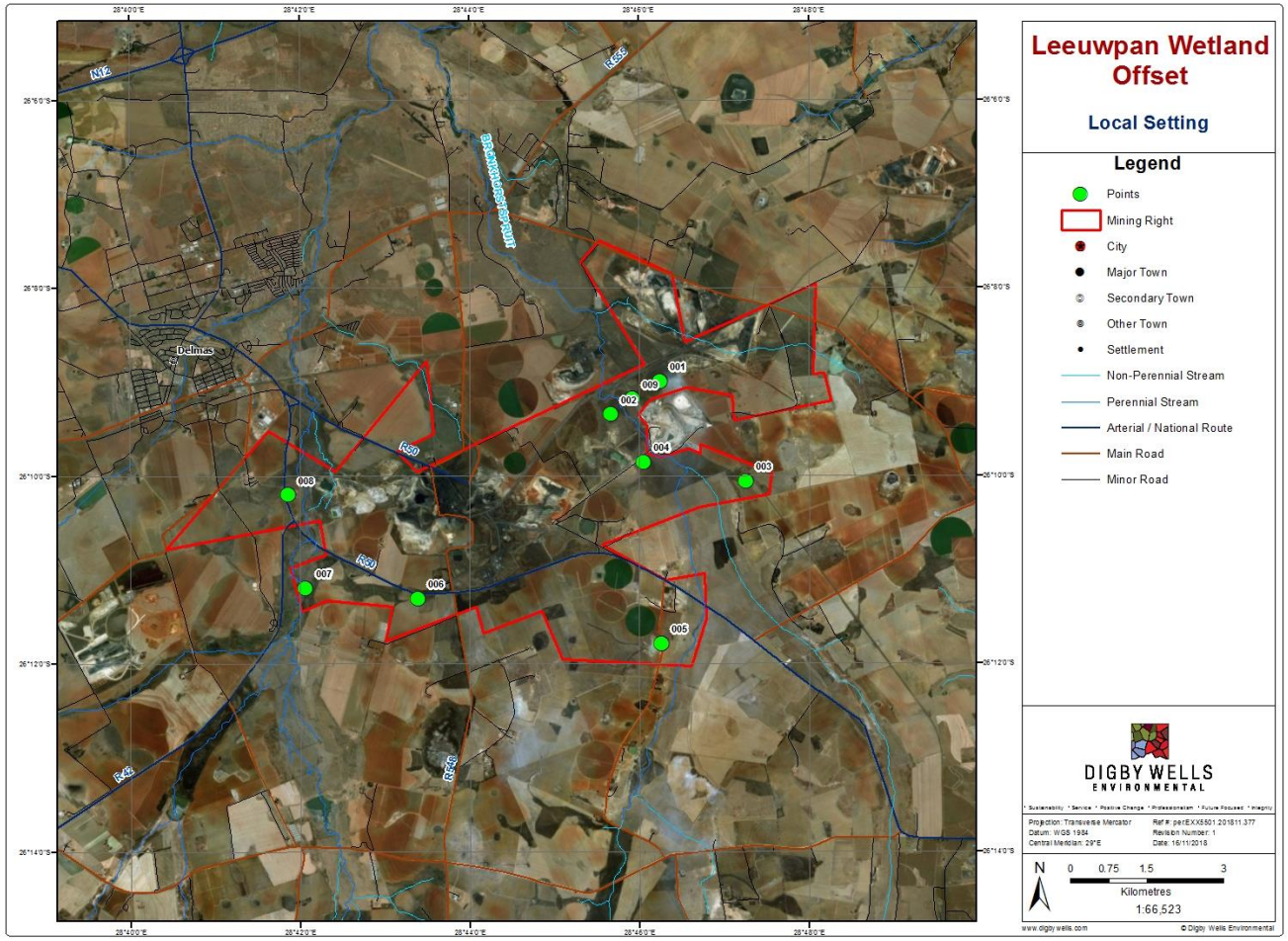


Figure 10-4: On-site Interventions

10.2.1 Intervention 1

There is a berm, borrow bit and road located within a hillslope seep. These impacts have resulted in fragmentation of habitat. It is recommended that the road be removed within thus wetland. It should be ripped and re-profiled in accordance with the surrounding landscape and seeding undertaken as recommended.

The borrow pit should be backfilled making use of the adjacent berm and reseeded accordingly. In addition there are remains of a fence that bisects the wetland and should be removed.

Table 10-4, provides details with respect to the associated costs for Intervention 1.

Table 10-4: Summary of Costs for Intervention 1

Measures	Quantity	Unit	Rate	Amount
Removal of Berm and Fill Borrow Pit	696	m^3	R18.80	R13,087.10
Removal of Road	1200	m^2	R7.89	R9,464.73
General Clean Up	1200	m^2	R13.04	R15,651.03
Ripping of Area	1200	m^2	R23.80	R28,565.72
Removal of Fence	399	m	R14.57	R5,814.94
Seeding	0.17	Ha	R26,539.92	R4,450.74
Total				**R 77,034.26**

10.2.2 Intervention 2

Intervention 2 is for an unchannelled valley bottom system and the PES is a C. There are several berms that are located within this wetland. There is a large berm that runs in an east-west direction through this wetland. From the site assessment it was noted that there is already wetland vegetation that has established with several sensitive species, inclusive of this Crinum. All species of Crinum are considered to be Protected Plants in Section 69 (1)(a) of the Mpumalanga Conservation Act No. 10 of 1998. It is suggested that this berm remain in place based on the surrounding sensitivities, however if water flow needs to be improved to the downstream areas, additional channels through the berm can be constructed, but must be done so utilised minimal machinery (by hand). The other small remaining berms can be removed also by hand.

A number of edge effects have already impacted this wetland, including sedimentation, vehicular disturbance, dumping of debris and soil compaction. It is recommended that the portion of mining and access road to the west of this wetland be rehabilitated and

implemented as a buffer zone to protect this wetland. The wetland and this buffer zone must be designated as a no-go zone. The hectare gain (Offset Protection Area) with taking the above into account potentially will be 121.6 ha, which includes an additional buffer zone of 55.1ha. There is a small portion of agricultural fields that should be removed and is 3.1 ha is size.

Table 10-5, provides details with respect to the associated costs for Intervention 2.

Table 10-5: Summary of Costs for Intervention 2

Measures	Quantity	Unit	Rate	Amount
Removal of Berms and infilling of box cuts	32871	m^3	R18.80	R618,083.32
Cuts through Larger Berm	5772	m^3	R18.80	R108,532.66
Removal of Road	5100	m^2	R7.89	R40,225.08
General Seeding	3	Ha	R26,539.92	R77,984.90
Rehabilitation of Buffer Area (Profiling)	55	ha	R2,512.00	R138,411.08
Rehabilitation of Buffer Area (Soil Placement assuming 60% of Area)	330600	m^2	R23.80	R7,869,856.16
Rehabilitation of Buffer Area (Seeding)	55	Ha	R26,539.92	R1,462,349.64
Removal of Agricultural Lands	3	ha	R8,671.83	R26,969.38
Vegetation of Agricultural Lands	3	Ha	R26,539.92	R82,539.15
Total				**R 10,424,951.37**

10.2.3 Intervention 3

This intervention is located within a hillslope seep wetland within the mining rights area located to the South East of the Silica Mine. There are agricultural fields within this wetland, in addition there is a fences that intersect this wetland should be removed in addition to the removal of the agricultural fields. During the site assessment there was not active planting of crops, however the area seem to have been ploughed. The purpose of this intervention is to improve the overall biodiversity and species richness. The potential gain could be 16.48 ha of hillslope seepage wetlands.

Table 10-6, provides details with respect to the associated costs for Intervention 3.

Table 10-6: Summary of Costs for Intervention 3

Measures	Quantity	Unit	Rate	Amount
Removal of Agricultural Fields	10	ha	R8,671.83	R87,585.46
Removal of Fence	1330	m	R14.57	R19,383.15
Seeding	10	Ha	R26,539.92	R268,053.20
Total				**R 375,021.80**

10.2.4 Intervention 4

There are two roads that run towards the Silica Mine which provides access to this mine and Waste Rock Dump. It was noted that during the site assessment that these roads have fragmented the wetland located within this area. It is recommended that appropriately designed culverts be installed at roughly 30 m intervals (4 culverts) to allow flow of surface water for the road that runs to the Waste Rock Dump. For the access road to the offices at least two double portal culverts should be installed. At closure it is recommended that the roads are removed, but this is dependent on closure of the Silica Mine and may be the responsibility of that mine to do.

The buffer mentioned in intervention 002 is envisage to play a two-fold role in protecting the remaining portion of the hillslope seepage wetland adjacent to the unchannelled valley bottom wetland. Edge effects from emanating the OL Pit should be mitigated as far as possible with the implementation of an erosion berm. This erosion berm should not enter the wetland located within the vicinity of intervention 4. The erosion berm should be along the edge of the OL Pit. The erosion berm should be seeded with stoloniferous grasses, such as *Cynodon Dactylon*. It is recommended that this berm be put into place to avoid the wetland from further degradation, desiccation and edge effects.

Any gains will be counteracted by the development of the OL pit, as such any interventions in the vicinity of intervention 4 are regarded as valuable with respect to maintaining connectivity.

Table 10-7, provides details with respect to the associated costs for Intervention 4.

Table 10-7: Summary of Costs for Intervention 4

Measures	Quantity	Unit	Rate	Amount
Instillation of Culverts (6 Culverts)	125	m	R1,764.00	R220,500.00
Instillation of Berm	12900	m^3	R14.76	R190,398.29
Total				**R 410,898.29**

10.2.5 Intervention 5

There is a culvert that should be cleared out to improve surface water flow and increase the wetness signature through the wetland area. In addition to this in the vicinity of the road crossing and culvert, a notable portion of soil dumping and disturbance was observed and opportunistic alien invasive species have established. These alien species should be removed and the areas re-profiled and seeded with stoloniferous wetland species.

Table 10-8, provides details with respect to the associated costs for Intervention 5.

Table 10-8: Summary of Costs for Intervention 5

Measures	Quantity	Unit	Rate	Amount
Clearing out Culvert				R11,025.00
Removal of Alien Invasive Tree Species				R6,959.02
Re-profiling of Area				R2,260.80
Seeding				R23,885.93
Total				**R 44,130.75**

10.2.6 Intervention 6

There is a combination of building rubble and general waste that has been disposed of within a hillslope seep wetland. It is recommend that the rubble is removed and the trenches backfilled, this should be followed by reseeding with suitable wetland grass species. This will promote water distribution, wetness signature and promote vegetation establishment and recolonization. In addition, this will increase the diffuse flow of water across the wetland and decrease the rate of passage of water through the wetland.

Lastly Alien Invasive Plant species should be removed within this wetland and in the general vicinity of the hillslope seep.

Table 10-9, provides details with respect to the associated costs for Intervention 6.

Table 10-9: Summary of Costs for Intervention 6

Measures	Quantity	Unit	Rate	Amount
Removal of Alien Invasive Tree Species	c	ha	R8,284.55	R12,178.28
Clean Up of Rubble	5200	m²	R13.04	R67,821.13
Profiling of Area	3	ha	R2,512.00	R6,279.99
Seeding	3	Ha	R26,539.92	R66,349.80

Total				**R 154,629.21**

10.2.7 Intervention 7

In this area, the wetland that has been impacted upon by a trench, a channel that had been dug and rocks placed within the wetland. This wetland is a channelled valley bottom wetland and has a current PES of D. Removal of the rock; trench and channel would potentially improve the class to a C, but can only be achieved if grazing is restricted within the channel to prevent further development of erosion. It is recommended that the work undertaken within this area is done by hand.

Table 10-10, provides details with respect to the associated costs for Intervention 7.

Table 10-10: Summary of Costs for Intervention 7

Measures	Quantity	Unit	Rate	Amount
General Clean Up	380	m^2	R13.04	R4,956.16
Infilling of Trench and Channel	2568	m^3	R18.80	R48,286.88
Total				**R 53,243.04**

10.2.8 Intervention 8

This wetland is a category C, hillslope seepage wetlands. If interventions are adopted is not anticipated that the category would increase to a B, but the ecological service provision can be improved. It is recommend that areas of disturbance and dumping be re-profiled and rehabilitated and that alien invasive species, such as blue gums and wattle observed within this wetland are removed. Cosmos was also noted in certain areas, which can also be removed.

Table 10-11, provides details with respect to the associated costs for Intervention 8.

Table 10-11: Summary of Costs for Intervention 8

Measures	Quantity	Unit	Rate	Amount
Removal of Alien Invasive Tree Species	8	ha	R8,284.55	R67,021.98
Profiling of Borrow Pit	4	ha	R2,512.00	R8,942.71
Seeding	4	Ha	R26,539.92	R94,482.12
Total				**R 170,446.81**

10.2.9 Intervention 9

There is a powerline servitude that runs towards the Silica mine. It is recommended that those culverts are inserted along the servitude to allow water flow through the system and provide connectivity between and lateral flow.

Table 10-12, provides details with respect to the associated costs for Intervention 9.

Table 10-12: Summary of Costs for Intervention 9

Measures	Quantity	Unit	Rate	Amount
Installation of Culverts (6 Culverts)	125	m	R1,764.00	R220,500.00
Total				**R 220,500.00**

10.3 Summary of Costs

Table 10-13 below, provides a summary of the costs and which costs are can be partitioned towards the rehabilitation provision that should be currently in place. The assumptions for the costs are based on the following:

- Large earthmoving costs have been excluded, such cost as backfilling of voids and removal or associated stockpiles;
- Costs have been provided in certain sections for general clean up and profiling where required; and
- The costs provided are provisional costs and need to be aligned with the updated financial provision that is currently underway.

In summary the total costs for the rehabilitation measures and interventions considered equals to **R88,317,293.38 (VAT Excl)**. In saying this, the majority of the costs can be assigned to the existing financial provision that would be in place. Based on this an additional **R 1 503 904.00** would be required for the interventions recommended.

Table 10-13: Summary of Costs

Area/Intervention	Estimated Costs	Offset Against Financial Provision
Rehabilitation Offset Areas (Option 1, 2 and 3)	R76,608,937.85	Yes
Intervention 1	R77,034.26	No – Additional Cost
Intervention 2	R10,424,951.37	Yes
Intervention 3	R375,021.80	No – Additional Cost
Intervention 4	R410,898.29	No – Additional Cost
Intervention 5	R44,130.75	No – Additional Cost
Intervention 7	R152,629.21	No – Additional Cost
Intervention 8	R53,243.04	No – Additional Cost
Intervention 9	R170,446.81	No – Additional Cost
Intervention 10	R 220,500.00	No – Additional Cost
Sub-total	**R88,317,293.38**	

11 General Rehabilitation Guidelines

11.1 Erosion Control

When vegetation cover is insufficient to hold the sediment during high rainfall events, erosion gullies form in wetlands. The aim of implementing erosion control measures on site is to eliminate all gulley and headcut erosion and to ensure that all wetland area is vegetated with no exposed substrate.

Gabion baskets or Reno mattresses are used for embankment stability and scour lining for erosion control. A Gabion basket is a flexible wire basket that is filled with rock to form a permeable structure allowing drainage yet preventing erosion. Reno mattresses are used to line the channel/wetland floor where it is susceptible to erosion. It is advisable that Gabion structures are considered in any areas where road or bridge crossings are resulting in erosion as a result of sheet runoff during high rainfall periods. Examples of gabions are represented in Figure 11-1.

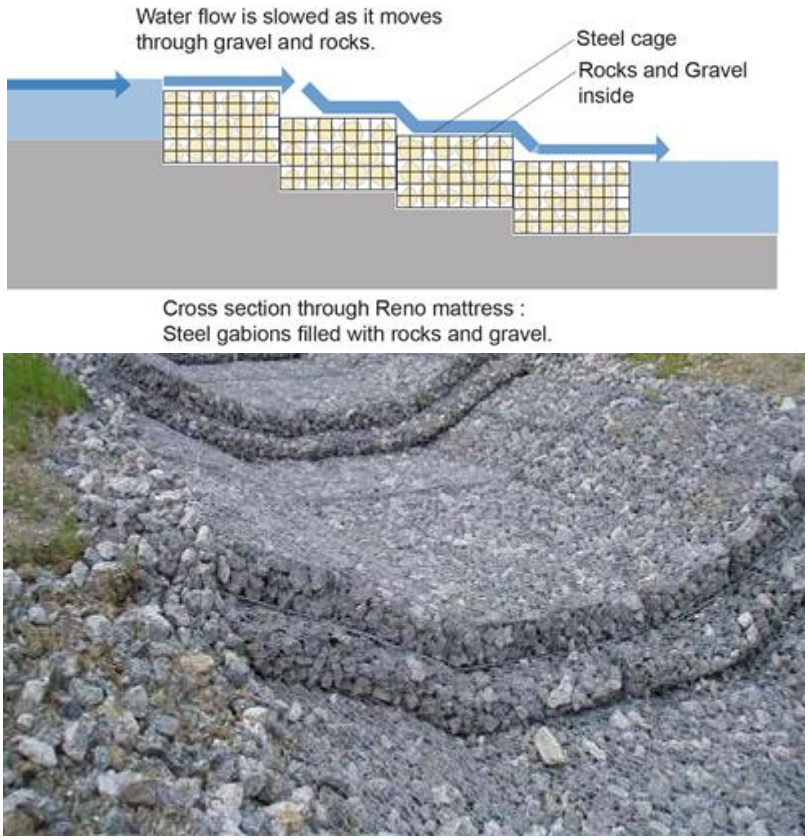


Figure 11-1: Example of Gabion and Reno structures

11.2 Alien Plant Control

Alien species in South Africa are categorised according to the Alien and Invasive Species Lists, 2016 (GN R 864 in *GG* 40166 of 29 July 2016) of the NEMBA (Act 10 of 2004).

The national list of invasive plant species listed in NEMBA represents the following categories:

- Category 1a: Species requiring compulsory control;
- Category 1b: Invasive species controlled by an invasive species management programme;
- Category 2: Invasive species controlled by area, and
- Category 3: Invasive species controlled by activity.

Not only are landowners under legal obligation to remove alien invasive plant species, but these plants are also detrimental to the ecological functioning of landscapes and this is particularly true for wetlands.

Grey Poplars (*Populus x canescens*) invade rivers, streams and wetlands, colonising area that would naturally be colonised by native hydrophilic vegetation (Bromilow 2010). This is typical of pioneer invaders. *P. canescens* spreads through coppicing in response to damage to the tree (when young vigorous shoots are produced from the base of the adult tree). This coppicing ability hampers effective removal through mechanical control unless adult trees are ring-barked and the entire root system is removed.

Stands of *Acacia mearnsii* and *Eucalyptus camaldulensis* were found in stands throughout the mining rights and also on the edges of wetlands.

In addition to alien tree species, dense stands of alien forbs, mostly: *C. bipinnatus* and smaller areas of *B. pilosa* were identified in the wetland areas during the December 2018 assessment. *C. bipinnatus* is highly invasive and colonises areas that would otherwise be left for native wetland-dependant plants to be established. *C. bipinnatus* produces a large amount of seed and is difficult to control. Table 11-1 lists alien plant species that should be controlled on site.

Table 11-1: List of alien plant species to be removed

Species	NEMBA Category	Control mechanism
Acacia mearnsii	2	Chemical control for juveniles: Glyphosate (ammonium)-680g/kg WG of Roundup Max 680 WG (L6790). Strip bark and cut to stumps for adult trees. Monitor regularly and remove seedlings before individuals

Species	NEMBA Category	Control mechanism
		reach seed-bearing height.
Cosmos bipinnatus		It is recommended that plants are mechanically removed (pulling) or burned. The substrate is likely to have a substantial seedbank and as a result, regular hand-hoeing during the growing season (autumn) is necessary. Individuals should be removed before they reach flowering or seed-bearing size.
Eucalyptus camaldulensis	1b	Mechanical control for juveniles in the form of hand-pulling. Adults can be cut to stumps and treated with a herbicide: Fluroxypyr 80 + Picloram 80 g/L ME (Plenum)
Pinus patula	2	Mechanical control in the form of felling.
Populus X canescens	2	Picloram (as potassium salt) 240g/L SL (Access) is registered for *P. canescens.* It is recommended that control of trees takes place after the rainy season between April and November and herbicide usage should be restricted within the water course.

In order to effectively eradicate and control the alien trees identified, the program cycle takes three years consisting of an initial clearing and then two follow-up interventions, after which an evaluation takes place as to the requirement for further treatments.

The importance of this cycle is:

- To ensure that the trees have been effectively treated in the initial clearing;
- That the follow-up treatments are conducted effectively;
- That any existing or new emergent seedlings are dealt with timeously and
- That there is employment continuity for the team that removes the species, as well as skills and knowledge retention.
- Where possible, biocontrol agents and mechanical removal should be utilised instead of herbicides. Herbicide usage should be restricted within the water course.

11.3 Buffers

Buffer zones are a requirement of the NWA to facilitate the protection of the delineated wetland areas within the project area. The purpose of the establishment of buffer zones is to

minimise the anthropogenic impacts associated with the proposed development on the receiving water resources. A buffer zone is defined as:

"*the strips of undeveloped, typically vegetated land (composed in many cases of riparian habitat or terrestrial plant communities) which separate development or adjacent land uses from aquatic ecosystems (rivers and wetlands).*"

The following justifications have been provided for the establishment of buffer zones, some of which are listed below:

- Reducing the impacts of adjacent land uses on water resource quality and the associated biodiversity; and
- Sustaining or improving the ability of the water resources to provide goods and services to the current and future water end users within the catchment area.

The NWA stipulates that suitable buffers should be placed around wetlands. In order to improve both functionality as well as the various conservation efforts of the candidate offset wetlands, it is imperative that the buffer strips around them are reinstated. Where possible, farming should be excluded from these zones to promote the natural assimilative capacity of wetland vegetation.

An estimated 87.12 ha of buffer area has been identified and is expected to be sufficient for the offset requirements for the wetland systems present. However, alien plant invasion is expected, due to disturbance of the soil and this should be monitored. Any alien seedlings that establish should be removed before they grow to seed-bearing size.

11.4 Re-vegetation

The project area is situated in the grassland biome. Wetland-dependant plant species that occur naturally in wetlands in the region are listed in Table 11-2 and examples of some of these species is represented in Figure 11-2. It is recommended that a specific seed-mix is applied to the areas where alien plants have been removed, over areas where rehabilitation efforts take place and areas where erosion control measures have been implemented. It is advisable that all plants used for revegetation are native highveld grassland species. Seed may be harvested from species that have been recorded on site during the winter months to save on costs.

In addition to the application of a mixed-seed spray, individual "plugs" of *I. cylindrica* and *C. dactylon* should be planted over approximately 10% of wetland area. Since these species are stoloniferous, they have a high soil stabilising capacity.

Table 11-2: Grass and sedge species recommended for re-seeding

Species	Common Name	Degree of wetland tolerance
Agrostis lachnantha	African Bent Grass	Permanent hydrophyte

Andropogon appendiculatus	Blue Grass / Blougras	Facultative hydrophyte
Andropogon eucomis	Snowflake Grass	Permanent hydrophyte
Cynodon dactylon	Couch Grass	Facultative hydrophyte
Eragrostis gummiflua	Gum Grass	Facultative hydrophyte
Imperata cylindrica	Cottonwool Grass	Permanent hydrophyte
Juncus effusus	Common Rush	Permanent hydrophyte
Setaria sphacelata	Golden Bristle Grass	Permanent hydrophyte
Sporobolus africanus	Spear Grass	Facultative hydrophyte



Figure 11-2: Examples of species to be used for revegetation

11.5 Signage

An important companion to the declaration of an offset area is a means of notifying the public in the form of signage. It is recommended that a sign is placed in a suitable area on the boundary of the wetland to identify the offset wetland and also to educate the public about the importance of wetlands. An example of signage that can be used is represented in Figure 11-3. This sign can be translated to Zulu and Xhosa so that it can be understandable to the local community.



Figure 11-3: Example of signage

12 Monitoring

After rehabilitation interventions have been implemented, monitoring of wetlands is necessary, to ensure that the objectives for rehabilitation are met and that ecological functionality is restored. This should be undertaken by a suitably qualified wetlands specialist. Monitoring will benefit the managers of the wetlands, as practical objectives can be set, which can provide tangible feedback into the wetland offset strategy. The objectives are to monitor the following:

- Wetland extent – impacts such as damming and infilling can result in a loss of wetland area, whereas seepage may cause an increase in wetland extent;
- Wetland Integrity – A basic level 1 health assessment is necessary to detect changes to the health of vegetation (including alien invasion), hydrology and geomorphology of the wetlands associated with the site. This allows for the determination of the Present Ecological State (PES); and
- Wetland functionality – The EIS of the wetlands should be regularly determined in order to detect any alteration to functionality.

Monitoring should take place bi-annually for the duration of the rehabilitation phase and into the closure phase, or for a minimum of 5-7 years, depending on the effectiveness of rehabilitation interventions.

Vegetation monitoring is necessary to detect a transition from hydrophytic to dryland species, which will be indicative of wetland desiccation. Further to this, the site should be monitored for alien plant species establishment. These plants are easier to control when

they are removed as seedlings, before they become seed-bearing and are allowed to spread across the landscape.

It is recommended that the stratified random sampling technique is employed across transects through the wetland areas and that species are recorded as they are encountered. The GPS location of the edge of hydrophytic plants should be recorded and the area of alien bushclump cover should be determined. Alien species should be monitored for up to five years unless no recruitment is recorded for one year.

Fixed-point photography should be undertaken at specific points on either side of each transect, facing the wetland area at 1.5 m from the ground. Monitoring of vegetation should take place annually between November and February, according to the Minimum Requirements for Biodiversity Assessments (Mpumalanga Parks and Tourism Agency (MPTA) which states that floristic surveys must be conducted during the growing season of all species that may potentially occur.

13 Conclusion

Digby Wells Environmental (hereinafter Digby Wells), was appointed by Exxaro Mpumalanga Coal (Pty) Ltd) In November 2018 to review and update the Wetland Offset Report compiled by Land Resources International (hereinafter LRI) for the Leeuwpan Coal Mine in Mpumalanga, South Africa. Following this report, LRI submitted an onsite wetland rehabilitation plan for the Leeuwpan Coal Mine's proposed block OI and OL mining development in 2016. Since the submission of the LRI 2016 report, mining of block OI has commenced. Mining of block OL is due to commence on approval of this updated Wetland Offset Report. The Integrated Water Use License (IWUL; no.: 04/B20A/CIJ/4032) for the Exxaro Coal (Pty) Ltd: Leeuwpan Coal Mine OI and OL Expansion was granted provided that wetland offset areas were identified to compensate for the loss of wetlands.

Further to this, an additional pit, Block OI West, has been proposed, the required offsets of which have been included in this report for consideration of inclusion into the Integrated Water Use License. The additional proposed Block OI West, would result in the destruction of 18.36 ha of hillslope seepage wetlands as well as a pan, 2.21 ha in extent.

According to the LRI (2013) report, the wetlands within Block OI were delineated in 2012, with mining activities within Block OI expected to impact on at least 134.62 ha of wetlands (68.4 ha fall within the direct footprint of proposed opencast areas and mining activities within Block OL expected to impact on at least 120.30 ha of wetlands.

On calculation of the hectare equivalents required for the calculation of the required functional and conservation offset targets for both Blocks OI and OL, a total of 87.23 hectare equivalents are expected to be lost. The additional proposed Block OI West will result in an additional loss of 10.51 hectare equivalents. The required functional offset target is thus

calculated at 97.7 hectare equivalents and the conservation offset target is 561.4 hectare equivalents.

According to the LRI (2013) report, if it is assumed that the remaining wetlands on site can be rehabilitated so as to increase their present ecological state category by one level, this would imply an approximate 20% gain in functional area. As such, this would result in a gain of about 206.59 hectare equivalents. However, on consideration of the additional loss of wetlands as a result of the proposed Block OI West, the gain would be reduced to 202.48 hectare equivalents.

During the field assessment carried out in December 2018, three portions of wetland that are regarded as destroyed as a result of mining activities were identified as potential sites for rehabilitation. The rationale behind this approach is such that should rehabilitation of these sites be considered, this would provide the potential to restore stream connectivity between upstream and downstream areas that have become fragmented as well as improve the ecological importance and sensitivities of the systems present as a whole. Assuming each of these wetland portions can be rehabilitated to a category D, the direct wetland gain in terms of hectare equivalents may be regarded as 166.47 ha. However, in order to realise both these gains, as well as the 202.48 ha of gains discussed above, it is estimated that a minimum of 204.10 ha of the surrounding catchment areas will require rehabilitation and a further 87.12 ha of buffers located in selected areas around the mining rights area are recommended to protect the wetlands present and prevent further losses to the wetland systems present. Thus, a total of 660.17 ha have been identified towards achieving the wetland conservation target of 561.4 ha. In terms of functional offset targets, the direct gains in hectare equivalents total 368.95 ha, which may be regarded as more than sufficient to achieve the above-mentioned functional offset target requirement of 97.7 ha.

It must be noted that in terms of the “like-for-like” offset requirement, the conservation offset target falls short of the required hectare equivalents for hillslope seep wetlands, however, consideration as to the potential improvements and rehabilitation of selected wetland systems within the Mining Rights Area were regarded as valuable inclusions within the proposed offset strategy, not only from the perspective of improvements to the present ecological state of the systems as a whole, but also in terms of improvements to ecological importance and service provision within the greater catchment. The value of including the proposed rehabilitation measures within the offset strategy thus serve as grounds for the consideration of an “out-of-kind” offset (to some extent).

In summary the total costs for the rehabilitation measures and interventions considered equals to **R88,524,584.57 (VAT Excl)**. In saying this, the majority of the costs can be assigned to the existing financial provision that would be in place for closure. Based on this only an additional **R 1 503 904.00** would be required for the interventions recommended.

14 References

Begg G. 1986. The Wetlands of Natal (Part 1). An Overview of their Extent, Role, and Present Status. Natal Town and Regional Planning Commission, Pietermaritzburg, Report 68, 114 pp.

Bromilow, Clive. 2010: Problem Plants and Alien Weeds of South Africa. Briza. Pretoria.

Duthie A, MacKay H, De Lange M (editors). 1999. Present Ecological Status (PES) Method. Department of Water Affairs and Forestry, South Africa

DWAF, 1999. Determining the Ecological Importance and Sensitivity (EIS) and Ecological Management Class (EMC). Version 1.0. 24 September 1999.

DWAF. 2005. A practical field procedure for identification and delineation of wetlands and riparian areas. Pretoria: Department of Water Affairs and Forestry.

Jewitt G.P.W. and Kotze D.C. 2000. Wetland conservation and rehabilitation as Components of Integrated Catchment Management in the Mgeni Catchment, KwaZulu-Natal, South Africa. In: Bergkamp G, Pirot JY and Hostettler S (eds.) Integrated Wetlands and Water Resources Management.

Kotze, D.C., Marneweck, G.C., Batchelor, A.L., Lindley, D.C., and Collins, N.B. 2007. A Technique for rapidly assessing ecosystem services supplied by wetlands. Mondi Wetland Project.

Kotze, D.C. and Breen, C.M., 1994. Agricultural land-use impacts on wetland functional values. Water Research Commission.

Kotze, D.C. and Marneweck, G.C. 1999. Guidelines for delineating the boundaries of a wetland and the zones within a wetland in terms of South African Water Act. As part of the development of a protocol for determining the ecological reserve for wetlands in terms of the Water Act resource protection and assessment policy implementation process. Department of Water Affairs and Forestry, South Africa.

Kotze, D.C., Marneweck, G.C., Batchelor, A.L., Lindley, D.C., and Collins, N.B. 2007. A Technique for rapidly assessing ecosystem services supplied by wetlands. Mondi Wetland Project.

LRI, 2013. Rehabilitation Plan Phase 1 Report. Report No: L04768/251113/01.

Maltby E. 1986. Waterlogged Wealth: Why Waste the Worlds Wet Places? Earthscan, London. 200 pp.

Macfarlane, D., Kotze, D., Ellery, W., Walters, D., Koopman, V., Goodman, P., et al. 2009. A technique for rapidly assessing wetland health: Wet-Health. Water Research Commission.

Nel J.L., Murray K.M., Maherry A.M., Petersen C.P., Roux D.J., Driver A., Hill L., van Deventer H., Funke N., Swartz E.R., Smith-Adao L.B., Mbona N., Downsborough L.,

Nienaber S. 2011. Technical report for the National Freshwater Ecosystem Priority Areas project. Water Research Commission. WRC report No. 1801/2/11, ISBN 978-1-4312-0149-5. Set no. 978-1-4312-0148-7.

Oberholzer P.J., Myburgh J.G., Ashton P.J., Coetzee J.J., Botha A.M. 2011. Bioaccumulation of aluminium and iron in the food chain of Lake Loskop, South Africa. Ecotoxicology and Environmental Safety 75:134-141 p.

Rountree, M.W., H. Malan and B. Weston (editors). 2012. Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0). Joint Department of Water Affairs/Water Research Commission Study.

Swanepoel C.M, and Barnard R.O. 2007. Discussion paper: Wetlands in Agriculture. ARC Report Number GW/A/2007/43.

Annexure J
Grading Verification – Processing Plant Area (GN704)



EXXARO LEEUWPAN

GRADING VERIFICATION – PROCESSING PLANT AREA

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1. INTRODUCTION

Greene Consulting have been appointed by Exxaro Resources Limited to do a Grading Verification Audit at the Processing Plant area after grading was done following the findings of the GN704 Audit done in 2016. Exxaro Resources Limited owns and operates Leeuwpan Coal Mine located approximately 6 km southeast of Delmas in the Mpumalanga Province. The integrated Water Use Licence was approved March 2011 by the Department of Water and Environmental Affairs. (Licence no. 04/B21A/ADCGIJ/429, File no. 16/2/7/B100/C27).

The main aim of this audit is to verify that the grading was done to facilitate overland flow into the existing canals. During the visual inspection on site all the findings from the GN704 Report 0082C-A22-GN704-01.00 of 2016 have been successfully implemented.

The area of focus for this report is the Processing Plant area (See figure 1.1).



Figure 1.1 Leeuwpan Coal Processing Plant
Source: Google Earth

2. GN 704 FINDINGS

The original GN704 site inspection was done on 26 May 2016 by Greene Consulting Engineers.
Recommendations were made and had to be done according to priority. Priorities were determined as follows:

- **Priority 1** = Minor maintenance work to be completed no later than 3 months after submission of this report.
- **Priority 2** = Major maintenance work to be completed no later than 2 year after submission of this report.
- **Priority 3** = New design and construction work to be completed no later than 5 years after submission of this report. Work dependent on Engineering Designs.

The follow up site inspection was done on 13 May 2019.
A summary of the GN704 findings and indication of completion for Priority 1 work is given in table 2.1.

2016 GN704 Findings	2019 Audit Findings
All vegetation and rubble in existing canals north of site must be cleaned and maintained.	Vegetation still visible in canals north of site 
Steel plate at emergency overflow to be removed to reinstate 800mm freeboard.	Plate has been removed
Silt in PCD to be removed to obtained design capacity.	Silt was removed 2016. On the date of inspection contractors was again in the process of de-silting the dam.
The existing cut-off drains east of the site must be cleaned and reinstated where required.	There are still openings in the cut-off berms

2016 GN704 Findings	2019 Audit Findings
	

Table 2.1 Priority 1 Findings

A summary of the GN704 findings and indication of completion for Priority 2 work is given in table 2.2.

2016 GN704 Findings	2019 Audit Findings
Damage to existing concrete canals in plant area need to be rectified.	Damaged canals in the plant area have been rectified
The new containment canal west of the site that is in the construction phase needs to be completed.	Canal is completed
An earth canal is proposed next to the berm to transport Storm water to the existing northern canal.	The earth canal has not been constructed. There are still openings in the cut-off berm to let storm water through 
The Subsoil drains beneath the blending area must be inspected to ensure it is in good working order.	Subsoil drains could not be inspected as it is buried underground
Site to be levelled to facilitate drainage and prevent ponding.	Some levelling has been done, however there are still some areas where ponding occurs. This will be discussed in more

2016 GN704 Findings	2019 Audit Findings
	detail under point 3 in this report
Earth canal to be constructed to facilitate emergency overflow from PCD to OD North.	No canal has been constructed at the time of this audit

Table 2.2 Priority 2 Findings

No Priority 3 work was identified for the Processing Plant Area.

3. GRADING VERIFICATION

The areas within the Processing Plant where grading was identified as a problem is:

- Blending Area
- DMS Area
- JIG Area

On the day of the site inspection there was no rain. Water observed was from operations.

3.1. BLENDING AREA GRADING FINDINGS

Ponding and erosion were observed at the Blending area. The ground slopes towards the conveyors and not towards the center where the subsoil drainage is located which was shown on drawing LPN-GCE-CL-0022. Product is stockpiled in this area and moved again at a later stage, which means that levels won't be maintained in the long run. Most of the ponding is next to the conveyors. This water needs to be conveyed to a point where it can drain into the containment canals if it can't drain towards the subsoil drains.



Figure 3.1.1 Erosion next to conveyor at Blending area



Figure 3.1.2 Ponding where material has been moved at Blending area



Figure 3.1.3 Ponding next to conveyor at Blending area



Figure 3.1.4 Ponding next to conveyor at Blending area



Figure 3.1.5 Ponding next to conveyor at Blending area

3.2. DMS AREA GRADING FINDINGS

Ponding at the DMS area were observed. Water does flow away overland in most areas but at a very low speed. Under the conveyors water ponds due to the low points created.



Figure 3.2.1 Ponding at DMS area



Figure 3.2.2 Slow overland flow of water at DMS area



Figure 3.2.3 Ponding next to building at back of DMS area



Figure 3.2.4 Ponding under conveyor at DMS area

3.3. JIG AREA GRADING FINDINGS

The JIG area has been graded recently. Overall the ground slopes towards the canals. The only points of concern are under the conveyor structures where low points hinder the flow of water towards canals.



Figure 3.3.1 Grading done at JIG area



Figure 3.3.2 Ponding at Conveyor structures at JIG area

4. CONCLUSION

In conclusion there are still a lot of ponding in the plant area and grading to facilitate water flow to the canals have not been completed in all areas. Some areas, especially next to and underneath the conveyor structures will have to be looked at in more detail in order to minimise ponding be either constructing sumps with drainage pipes or levelling. At the Blending area a conveyance system for water must be designed and constructed to facilitate water flow to canals. Item number 6c of the GN704 conditions state: “Every person in control of a mine or activity must collect the water arising within any dirty area, including water seeping from mining operations, outcrops or any other activity, into a dirty water system”.