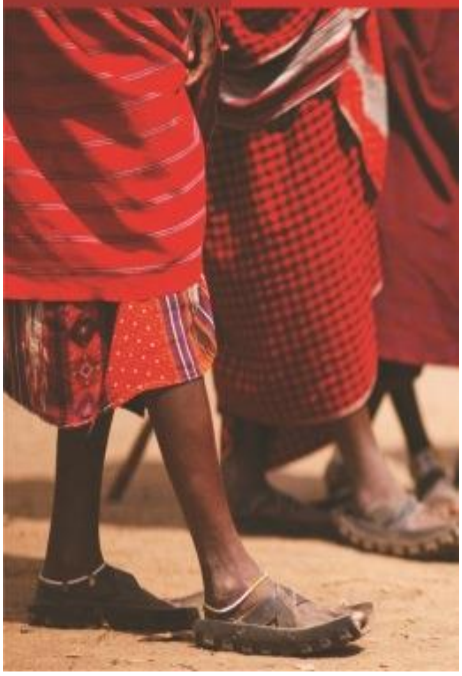

DIGBY WELLS
ENVIRONMENTAL

Sasol Sigma Defunct Colliery Surface Mitigation Project: Proposed River Diversion and Flood Protection Berms

Surface Water Specialist Study

Project Number:

SAS5250

Prepared for:

Sasol Mining (Pty) Ltd

September 2018

Digby Wells and Associates (South Africa) (Pty) Ltd
Co. Reg. No. 2010/008577/07. Turnberry Office Park, 48 Grosvenor Road, Bryanston, 2191. Private Bag X10046, Randburg, 2125, South Africa
Tel: +27 11 789 9495, Fax: +27 11 069 6801, info@digbywells.com, www.digbywells.com

This document has been prepared by Digby Wells Environmental.

Report Type:	**Surface Water Specialist Study**
Project Name:	**Sasol Sigma Defunct Colliery Surface Mitigation Project: Proposed River Diversion and Flood Protection Berms**
Project Code:	**SAS5250**

Name	**Responsibility**	**Signature**	**Date**
André van Coller	Specialist input and impact assessment		September 2018

EXECUTIVE SUMMARY

This report details the findings of the Surface Water Specialist Study that forms part of the environmental impact assessment of the proposed surface mitigation project at the defunct Sigma Defunct Colliery owned and operated by Sasol Mining (Pty) Ltd.

The surface mitigation measures that were considered include full stream diversions, partial stream diversion and ash backfilling of mined panels or various combinations thereof. A description of the various diversions types is provided below:

- Full stream diversion:
  - Typically consists of a diversion canal which follows along a completely new alignment from the original stream alignment. The stream flow is diverted along the new route and discharges back into the existing stream downstream of the affected area. A diversion canal mitigates the risk by moving the stream away from the significant risk area.
- Partial stream diversion:
  - A partial stream diversion entails confining the stream flow by means of either channelling the stream or flood protection berms or both in order for it not to cross areas where a high chance of pillar failure which will result in subsidence could occur. The purpose of flood protection berms is to prevent the existing stream flow from entering significant risk areas. Where possible, flood protection berms are used in isolation, however if the position of a berm obstructs the natural stream flow (i.e. crossing existing watercourse centreline), flood protection berms are used in combination with channelling the stream. This prevents unnecessary secondary issues, for example backwater or ponding upstream of the berm, and allows unimpeded flow of the stream past the problem areas.
- Backfilling:
  - Ash backfilling is predominantly used where a full stream diversion or partial stream diversion alone does not mitigate the risk or where a diversion canal cannot avoid crossing over a significant risk area. In the case where a full diversion or partial diversion is not possible, only backfilling is proposed.
  - It must be noted that although mentioned, ash backfilling is being dealt with as a separate project and is not considered to be incorporated as part of this environmental authorisation process.

Baseline Environment

To identify potential impacts a desktop assessment and review was conducted to discuss the baseline surface water environment.

The Sigma Defunct Colliery falls under the jurisdiction of the Metsimaholo Local Municipality (MLM) situated in the Fezile Dabi District Municipality (FDDM) close to the town of Sasolburg. The site is mainly used for agricultural purposes including cattle and crop farming. Other land uses within the mining licence area include a tannery, a commercial feedlot, a sand mining operation, a property let to privately owned businesses and farmhouses. Specifically, to the northern section of the Leeuspruit, a large portion of the site is owned by Sasol Mining and is used as a game farm.

The proposed project area is located within the Water Management Area (WMA) of the Upper Vaal River system. The proposed area is located within the secondary drainage C2 in quaternary catchment C22K. Mean annual runoff (MAR) after evaporation and recharge is 3%. The mean annual precipitation (MAP) is 644 mm with a mean annual evaporation (MAE) of 1 625 mm. The natural water balance is thus a negative one with evaporation being much higher than rainfall. The area is characterised by warm summers and cold winters, rainfall occurs mainly during the summer months (December to February).

Monitoring points SIG/1 (downstream) and SIG/2 (upstream) represents the water quality of the Leeuspruit. In addition, SIG/5 and SIG/6 monitors a tributary of the Leeuspruit that flows from the east and joins the Leeuspruit between the SIG/1 and SIG/2 monitoring points. This last-mentioned tributary as well as the Leeuspruit is directed past an ash dam and old coal stockpiles before joining each other at the confluence point directly downstream of the ash dam which can potentially influence the water quality of the Leeuspruit and change the chemistry slightly between SIG/2 and SIG/1.

The water type of both SIG/1 and SIG/2 can be described as sodium-bicarbonate water with SIG/1 (downstream) more enriched with sulphate (SO_4) than that of the upstream point SIG/2. The upstream point of the tributary (SIG/5) also has lower SO_4 concentration then the downstream point (SIG/6). Changes in pH and occasional peaks in SO_4 for the downstream points above the guideline values confirms the conclusion that the ash dam does have some influence on the water quality during high rainfall and runoff periods.

In general, from the trend graphs it can be concluded that in the last 12 month there is a general trend of deteriorating water qualities in a downstream direction of both the Leeuspruit and its tributary that can be due to the contribution of the ash dam and coal stockpiles located at 3 Shaft Complex operated by Mooikraal Colliery. From the other parameters analysed and compared against the water quality guidelines in January 2018 all are within a tolerable range excluding sodium (Na), manganese (Mn), nitrate (NO_3), phosphate (PO_4) and total suspended solids (TSS) that are at unacceptable levels for the Leeuspruit and its tributary. Faecal coliform is also above guideline values in both drainages.

Potential current impacts in the upstream areas of the Leeuspruit as well as its tributaries that can have an influence on the above water quality are:

- Potential discharge from the underground working during high rainfall and recharge periods;

- Discharge from sewage plants in the upstream areas of the Leeuspruit; and
- Uncontrolled storm water from built up areas and informal communities.

The upstream monitoring point of the Rietspruit is represented by SIG/4 with the downstream point being SIG/3. Mainly farming activity occurs between these two points with only underground mining that was part of the Sigma Defunct Colliery being the other activities. Both sampling points show a calcium-bicarbonate water type with only a change in alkalinity from upstream to downstream. This can be due to various factors but none that will impact on the quality of the water. Generally, the water quality trends for Rietspruit do however remain stable and the water quality show no significant changes over time;

In the Rietspruit Fluoride (F), aluminium (Al), iron (Fe), Mn, PO_4, ammonium (NH_4) and TSS exceed the recommended guideline limits. F, Al, Fe and Mn will be due to ion exchange reactions with the stream sediments. PO_4 and NH_4 will be from animal activity. Faecal coliforms exceed the guideline values but this is normal for natural streams flowing through areas with human, farming and animal activities.

Both the Vaal Upstream and Downstream points are characterised as sodium-sulphate water. The downstream monitoring point does show occasional spikes in Cl and pH that can potentially be due to the influence of the Leeuspruit. This is however not frequent and thus not proven. All other constituents for the Vaal River points are well within the recommended guideline ranges except for TSS. TSS can increase during periods when river flow rates and levels increase and decrease with the velocity of the river being at a rate at which suspended solids are transported downstream.

The general trend observed is that the upstream sampling point water quality is generally worse than that of the downstream point in the Vaal River. This is unusual if you consider the contribution of the Leeuspruit and its tributary with the contaminated water from the ash dams and coal stockpiles. This does however show that the Vaal River is already impacted by upstream activities that include mining, sewage discharge and general human impacts from settlements.

From current data it can be concluded that water from the project area flowing down the Leeuspruit and Rietspruit does not have a significant impact on the Vaal River quality.

Stream Flows

Jones & Wagner calculated various flow peaks (from 1:2 year event up to 1:100 year event) for the design of the flood protection berms and diversion canals. The design criteria and flows used will ensure that:

- Downstream yield increase or reduction will have a variance of less than 1%; and
- Change in peak flow rate will be less than 5%.

With the above design criteria, the proposed infrastructure will have almost no effect on the water volumes reporting downstream to the remaining Leeuspruit/Rietspruit sections as well as the Vaal River. However, flow velocities will increase and the floodlines will change from the current natural floodlines.

Impact Assessment:

Based on the proposed surface mitigation activities the main impact on the surface water environment will be during the construction phase of the project. After the completion of the construction (12-month construction period) it is of the specialist's opinion that the stream flow volumes and catchment yield will not be influenced with only minor impacts expected due to increased velocity due to the channelling of water. The following impacts have been identified as part of the construction phase of the project:

Activity	Impact
Berm construction	Siltation of the Leeuspruit because of increased soil exposure and disturbance during the construction of the flood protection berm can lead to impacts on the water quality of the Leeuspruit. This will further be impacted due to increased concentrated flow.
Alteration in the seasonality and flow of the river reaches (floodlines)	Changes in the floodplain due to a change in the flow path will result in impacts on the wetlands, erosion of new areas that can lead to siltation and water quality changes.
Canal Construction	The largest potential impact is the excavation of the system to construct the canals. This activity is likely to result in a floodline changes (impact on wetlands) as well as large impacts in the downstream reaches of the Leeuspruit such as erosion, sedimentation and altered water quality.

Activities associated with the construction of these Leeuspruit river diversion measures includes site clearing, soil disturbance, topsoil stockpiling, storage and dumping of building materials, compaction of soils and crossing of the wetland and river systems. Associated potential impacts include erosion and sedimentation, the potential further loss of biodiversity and habitat fragmentation of the systems present a potential loss of catchment yields, loss of migration routes and surface water recharge to the systems further downstream. Among the impacts associated with the proposed construction phase are minor potential impacts to soil and water quality because of the ingress of hydrocarbons. Larger impacts include compaction of soils, potential loss of vegetation and the increased potential for erosion and sedimentation near any cleared areas and resulting in impacts further downstream.

The following is recommended to manage the potential impacts of the proposed surface mitigation activities:

- Dust suppression measures must be implemented on the cleared areas during construction;
- Reprofile the slopes to mimic the natural topography;
- Berms and cleared areas should be reseeded with indigenous grasses to prevent erosion;
- In high erosion areas, mulch or hessian should be used to protect the soil and growth of new seedlings;
- All erosion noted within the construction footprint should be remedied immediately and included as part of an ongoing rehabilitation plan;
- Sufficient drains need to be installed to facilitate seepage underneath berms;
- Berms should be monitored after large rainfall events to ensure that they are draining sufficiently;
- It should be ensured that energy dissipation measures be installed to slow and spread the flow of water at discharge points to reduce the potential for erosion and to assist with infiltration;
- Furthermore, it is deemed critical that regular care and maintenance of the canal be undertaken to ensure no build-up of litter and debris, which would affect the flow of the system and negate any efforts at maintaining migrations routes and flow connectivity.
- Ensure soil management programme is implemented and maintained to minimise erosion and sedimentation;
- During the construction phase, erosion berms should be installed on roadways and downstream of stockpiles to prevent gully formation and siltation of the freshwater resources. The following points should serve to guide the placement of erosion berms:
  - Where the track has a slope of less than 2%, berms every 50m should be installed;
  - Where the track slopes between 2% and 10%, berms every 25m should be installed;
  - Where the track slopes between 10%-15%, berms every 20m should be installed; and
  - Where the track has slope greater than 15%, berms every 10m should be installed.
- Limit the footprint area of the construction activities to what is essential to minimise impacts because of vegetation clearing and compaction of soils (all areas but critically so in wetland areas);

- Active rehabilitation, re-sloping, and re-vegetation of disturbed areas immediately after construction;
- Permit only essential personnel within the 100m zone of regulation for all freshwater features identified;
- No unnecessary crossing of the wetland features and their associated buffers should take place and the substrate conditions of the wetlands and downstream stream connectivity must be maintained;
- No material may be dumped or stockpiled within any rivers, tributaries or drainage lines;
- No vehicles or heavy machinery may be allowed to drive indiscriminately within any wetland or instream areas and their associated zones of regulation (notwithstanding those areas to be directly impacted upon because of the proposed activities). All vehicles must remain on demarcated roads and within the construction footprint;
- All vehicles must be regularly inspected for leaks;
- Re-fueling must take place at a diesel facility, on a sealed surface area away from wetlands to prevent ingress of hydrocarbons into topsoil;
- All spills should be immediately cleaned up and treated accordingly;
- Appropriate sanitary facilities must be provided for the duration of the construction activities and all waste must be removed to an appropriate waste facility; and
- The proposed monitoring plan outlined in this report as well as the wetland, aquatic and soil specialist reports should be implemented.

No Go Alternative

Areas that have a significant potential for pillar failure can result in subsidence in those areas that will lead to seepage/flow from the Leeuspruit and Rietspruit into the underground workings. The last-mentioned impact will influence the catchment yield downstream because of flow losses to the underground.

The impact of not going ahead with the project is thus much higher than the impacts during construction of the proposed surface activities. If the project goes ahead some impacts on the floodplains, water quality and erosion will occur but this can be mitigated and managed. The impact on the volumes of flow and the catchment yield is negligible compared to the loss of water if subsidence occurs and the stream flow is lost to the underground working. This last-mentioned event will almost certainly reduce catchment yield and flow from the Leeuspruit and Rietspruit to the Vaal River.

Thus, although negative impacts do exist they are short term and can be mitigated. The no-go alternatives impacts cannot be mitigated.

TABLE OF CONTENTS

1 Introduction ... 1
1.1 Background and Project Description ... 1
1.2 Surface Mitigation Measures ... 6
1.3 Deliverables ... 7
1.4 Project Team ... 7
2 Methodology ... 7
2.1 Desktop Assessment and Baseline Description ... 7
2.2 Surface Water Impact Assessment ... 8
3 Baseline Environment ... 8
3.1 Hydrological Setting ... 8
3.1.1 Catchment Description ... 8
3.1.2 Climate ... 11
3.1.3 Geology ... 12
3.1.4 Land Use and Vegetation ... 15
3.2 Surface Water Quality ... 15
3.2.1 Leeuspruit ... 19
3.2.2 Rietspruit ... 23
3.2.3 Vaal River Up- and Downstream ... 25
4 Stream Flow Description ... 28
4.1.1 Calculated Peak Flows for Diversion and Berm Designs ... 28
4.1.2 Dry Weather Flow ... 29
5 Surface Water Impact Assessment ... 30
5.1 Impact Rating Methodology ... 30
5.2 Project Activities ... 36
5.3 Construction Phase ... 39
5.3.1 Impact Description ... 39
5.3.2 Construction Phase Mitigation and Management Measures ... 60
5.4 Operational Phase ... 62

5.4.1 Impact Description ... 62
5.4.2 Operational Phase Mitigation and Management Measures ... 62
5.5 No Go Alternative ... 64
6 Surface Water Monitoring Plan ... 65
7 Conclusions ... 66
7.1 Baseline Conclusions ... 66
7.1.1 Project Hydrological Setting ... 66
7.1.2 Water Quality ... 67
7.1.3 Stream Flows ... 69
7.2 Impact Assessment Conclusions ... 70
8 Recommendations ... 70
9 References ... 72

LIST OF FIGURES

Figure 1-1: Project Regional Setting ... 4
Figure 1-2: Project Local Setting ... 5
Figure 3-1: Photographs of the Leeuspruit (Left) and the Rietspruit (Right) River Channels .. 9
Figure 3-2: Quaternary Catchments ... 10
Figure 3-3: Summary of the Average Monthly Climatic Data for C22K Quaternary Catchment ... 12
Figure 3-4: Location of Sub-catchments around the Sigma Defunct Mine ... 14
Figure 3-5: Simplified geological profile found within Sigma Mine ... 15
Figure 3-6: Surface Water Quality Monitoring points ... 18
Figure 3-7: Stiff diagrams illustrating the water quality of Leeuspruit (SIG/1 & SIG/2) and its tributary (SIG/5 & SIG/6) (IGS, 2018) ... 20
Figure 3-8: Electrical conductivity, pH, chloride and sulphate time graphs for Leeuspruit (SIG/1 & SIG/2) and its tributary (SIG/5 & SIG/6) (IGS, 2018) ... 21
Figure 3-9: Stiff diagrams of the Rietspruit upstream (SIG/4) and downstream (SIG/3) (IGS, 2018) ... 24

Figure 3-10: Electrical conductivity, pH, chloride and sulphate time graphs for the Rietspruit (IGS, 2018) 24

Figure 3-11: Stiff diagrams of the Vaal River upstream and downstream (IGS, 2018) 26

Figure 3-12: Major cation, anion and electrical conductivity time graphs of the Vaal River upstream and downstream (IGS, 2018) 27

Figure 5-2: Leeuspruit Section 2 and proposed activity 42

Figure 5-3: Leeuspruit Section 3 and proposed activity 47

Figure 5-4: Leeuspruit Section 4 and potential activities 52

Figure 5-5: Leeuspruit Section 5 and proposed activities 54

Figure 5-6: Rietspruit Section 1 and proposed activities 58

LIST OF TABLES

Table 3-1: Summary of the C22K catchment attributes 9

Table 3-2: Summary of Rainfall Data extracted from the WR2012 11

Table 3-3: Summary of the Parameters/Variables Analysed 16

Table 3-4: Surface Water Monitoring Points 16

Table 3-6: Leeuspruit water quality vs. the prescribed Leeu/Taaiboschspruit Catchment water quality guidelines (IGS, 2018) 22

Table 3-7: Leeuspruit bacteriological analysis results (IGS, 2018) 22

Table 3-8: Rietspruit water quality vs. the prescribed Leeu/Taaiboschspruit Catchment water quality guidelines (IGS, 2018) 25

Table 3-9: Rietspruit bacteriological analysis results (IGS, 2018) 25

Table 3-10: Vaal River Barrage water quality vs. the prescribed Leeu/Taaiboschspruit Catchment water quality guidelines (IGS, 2018) 27

Table 3-11: The Vaal River Barrage bacteriological analysis results (IGS, 2018 28

Table 4-2: Peak flow and average velocities of design (J&W, 2018) 28

Table 5-1: Surface Water Impact Assessment Parameter Ratings 31

Table 5-2: Probability Consequence Matrix for Impacts 34

Table 5-3: Significance Threshold Limits 35

Table 5-4: Project Activities 37

Table 5-7: Identified Impacts – Leeuspruit Section 2 39

Table 5-8: Impact assessment parameter ratings for the construction phase for Leeuspruit Section 2 39

Table 5-9: Identified Impacts – Leeuspruit Section 3 43

Table 5-10: Impact assessment parameter ratings for the construction phase for Leeuspruit Section 3 44

Table 5-11: Identified Impacts – Leeuspruit Section 4 48

Table 5-12: Impact assessment parameter ratings for the construction phase for Leeuspruit Section 4 49

Table 5-13: Identified Impacts – Rietspruit Section 1 55

Table 5-14: Impact assessment parameter ratings for the construction phase for Rietspruit Section 1 55

Table 5-15: Impact assessment parameter ratings for the construction phase for all sections 59

Table 5-16: Impact rating table for the No Go Alternative 64

Table 6-1: Surface Water Monitoring Pan 66

1 Introduction

This report details the findings of the Surface Water Specialist Study that forms part of the environmental impact assessment of the proposed surface mitigation project at the Sigma Defunct Colliery owned and operated by Sasol Mining (Pty) Ltd. The regional and local project location is shown in Figure 1-1 and Figure 1-2.

1.1 Background and Project Description

Sasol Mining's Sigma Defunct Colliery now referred to as the Sigma Defunct Colliery occupies a mining area of approximately 11 643 ha. Mining activities at the Sigma Defunct Colliery was conducted under Mining Licences No. 1/2001 and 3/2001, granted by the Department of Mineral Resources (DMR).

Sigma Defunct Colliery commenced operations in 1952 with underground mining, holding mineral rights to several coal deposits in the Sasolburg district. Underground mining methods was the primary method of extracting these reserves and included mechanised board-and-pillar and rib pillar extraction and bottom coaling methods. Access to the underground operations was via several shafts, and the coal was then conveyed to a 'dry' coal handling plant at 3 Shaft where the coal was screened and fed to silos.

In 1992 the Wonderwater opencast mine was developed to extract coal from the north-eastern side of the reserves which occupied a mining area of approximately 385 ha. The Wonderwater opencast mine was mined utilising truck and shovel methods. The mining ceased in 2005 after which the opencast mine was backfilled and rehabilitated. The final voids were left as part of the water management of the underground workings.

The Mohlolo Operations, situated adjacent to the Wonderwater opencast mine commenced with its activities in 1999 and occupied a mining area or approximately 264 ha. The underground operations were accessed from the Wonderwater opencast mines highwalls in the north and the south and divided the operations into Moholo North and Mohlolo South. The underground mining was scaled down and ceased by 2005, the underground mine workings were left to be flooded.

Sigma Defunct Colliery applied for mine closure where a closure application and closure report was submitted to the DMR in 2009. Sigma Defunct Colliery began to implement the proposed mitigation measures as per the requirements of the closure plan and Environmental Management Programme (EMP) to address all the significant risks and rehabilitation measures which were required to obtain the needed closure certificate. Jones and Wagener (J&W) were appointed to assist Sasol Mining in the compilation of a Risk Assessment Report for mine closure process to identify all the significant latent risks which Sigma Defunct Colliery have and rate them in accordance with the Sasol Risk Assessment Methodology. This report further proposed mitigation measures to be implemented to reduce the significant rated risks to an acceptable residue risk level. The report was compiled in 2015 and has now been updated in 2018.

As part of the Risk Assessment Report, mitigation measures have been proposed and grouped together as underground mitigation measures (ash backfilling) and surface mitigation measures (river diversions and berm constructions). Sasol Mining have allocated funds in accordance with the mines financial provision to provide for the implementation of the project.

The Underground Mitigation Measures which includes ash backfilling of certain areas with ash slurry is being dealt with as a separate project and under a separate environmental authorisation process.

The Surface Mitigation Measures proposed in the Risk Assessment Report requires environmental authorisation. Two rivers flow through the Sigma mining area namely the Rietspruit and the Leeuspruit. Beneath these water courses or floodplains a hazard of pillar failure exists which can result in subsidence. Subsidence is expected to have a significant impact on surface aspects should it occur and no mitigation measures are implemented. The risk of this occurring is considered to be significant. Therefore various mitigation measures have been proposed to reduce the significant risk areas to an acceptable residual risk (insignificant risk).

According to the J&W Design Report, 2018 a total of 37 potentially significant risks (associated with underground mined panels where a high potential of pillar failure has been identified) were identified of which 36 are located within the Leeuspruit and only one within the Rietspruit. J&W's Design Report, 2018 sub-divided the Leeuspruit into four sections numbered in the direction of stream flow (from south to north).

It should be noted that J&W have indicated that no upgrades to any existing culverts or bridge crossings are proposed as part of this project.

The surface mitigation measures that were considered include full stream diversions, partial stream diversion and ash backfilling of mined panels or various combinations thereof. A description of the various diversions types is provided below:

- Full stream diversion:
  - Typically consists of a diversion canal which follows along a completely new alignment from the original stream alignment. The stream flow is diverted along the new route and discharges back into the existing stream downstream of the affected area. A diversion canal mitigates the risk by moving the stream away from the significant risk area.
- Partial stream diversion:
  - A partial stream diversion entails confining the stream flow by means of either channelling the stream or flood protection berms or both in order for it not to cross areas where a high chance of pillar failure which will result in subsidence could occur. The purpose of flood protection berms is to prevent the existing stream flow from entering significant risk areas. Where possible, flood protection berms are used in isolation, however if the position of a berm obstructs the natural

stream flow (i.e. crossing existing watercourse centreline), flood protection berms are used in combination with channelling the stream. This prevents unnecessary secondary issues, for example backwater or ponding upstream of the berm, and allows unimpeded flow of the stream past the problem areas.

- Backfilling:
  - Ash backfilling is predominantly used where a full stream diversion or partial stream diversion alone does not mitigate the risk or where a diversion canal cannot avoid crossing over a significant risk area. In the case where a full diversion or partial diversion is not possible, only backfilling is proposed.
  - It must be noted that although mentioned, ash backfilling is being dealt with as a separate project and is not considered to be incorporated as part of this environmental authorisation process.

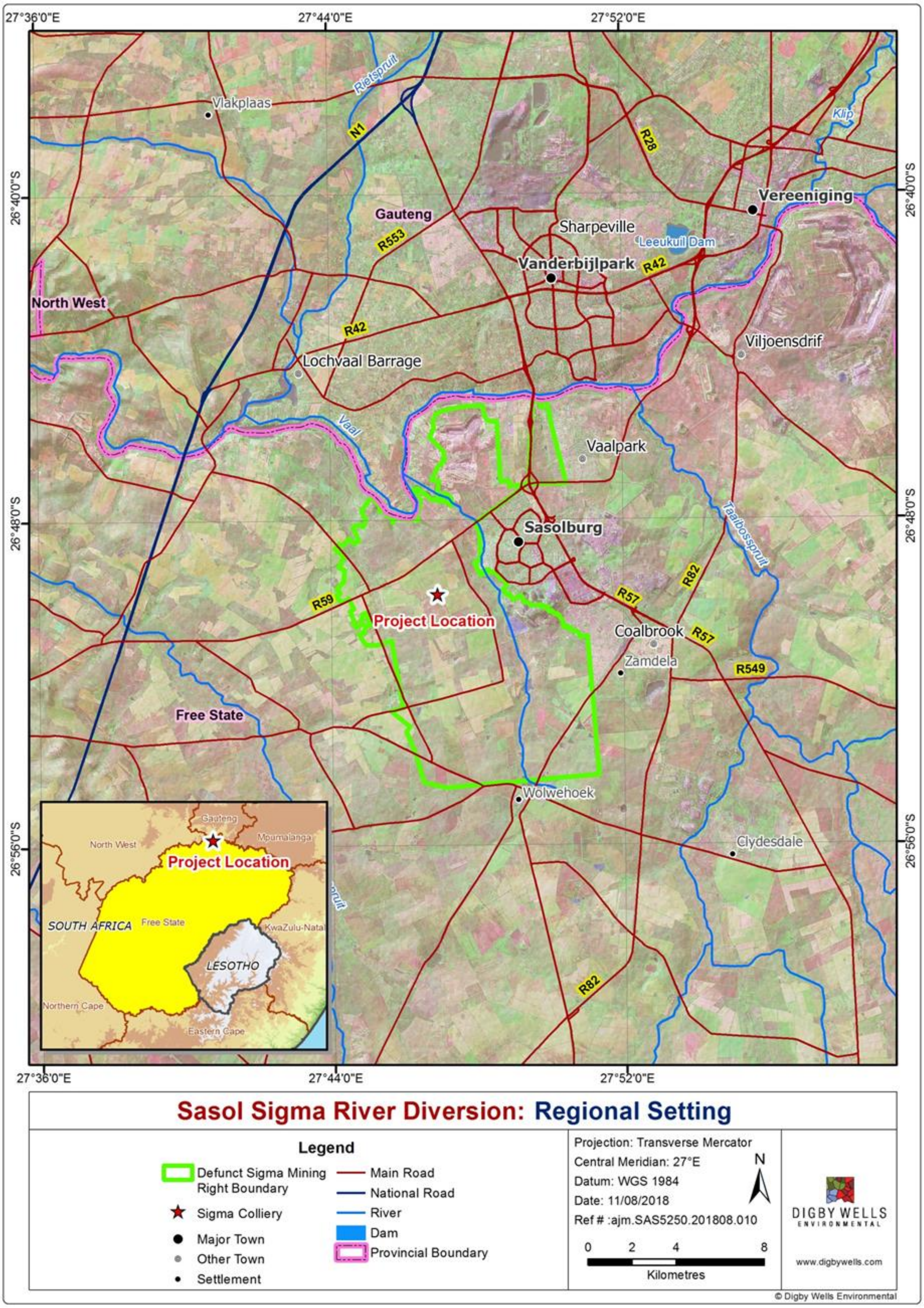

Figure 1-1: Project Regional Setting

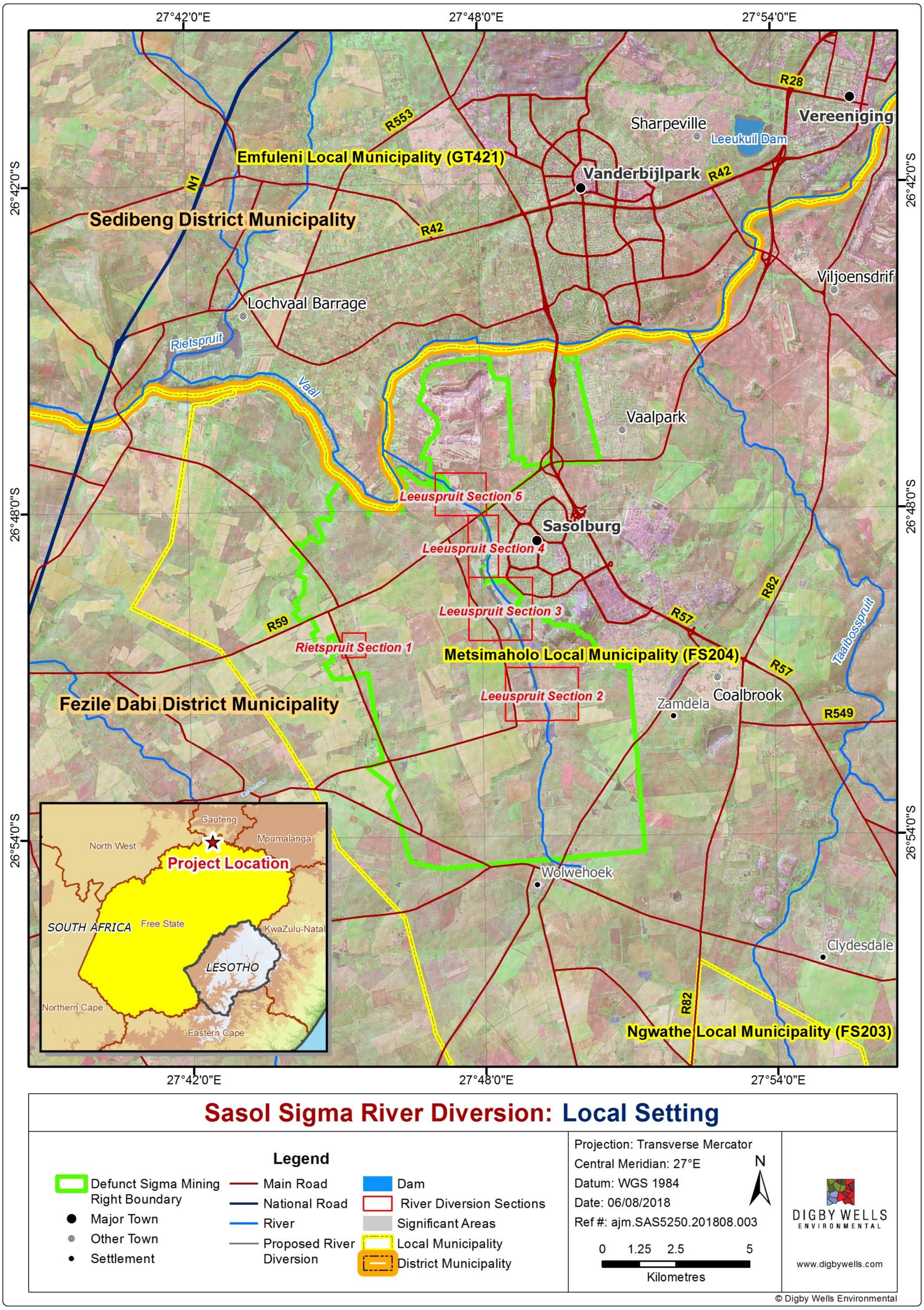

Figure 1-2: Project Local Setting

1.2 Surface Mitigation Measures

As mentioned above the surface mitigation measures have been divided into 5 sections along the Leeuspruit with only one section in the Rietspruit. A description of each section is provided below with the location of each section shown in Figure 1-2.

Significant Risk Area	Mitigation Measure Implemented	Description
Leeuspruit: Section 2	■ Flood protection berm to be constructed to avoid one area of significant risk.	■ The flood protection berm will comprise of suitable material, typically clayey sand or sandy clay material obtained from other necessary excavations.
Leeuspruit: Section 3	■ Combination of diversion canals, flood protection berms and ash backfilling.	■ The proposed design comprises of two flood protection berms to direct the flow of water away from significant areas; ■ A formalised canal to divert the stream flow away from the natural stream flow path (Armorflex or a similar approved lining); and ■ Ash backfilling will be utilised were diversions are not possible. Ash Backfilling is considered to be a separate project and under a separate environmental authorisation process.
Leeuspruit: Section 4	■ Two Full stream diversion canals are proposed, namely the Southern diversion canal and Northern diversion canal; ■ Flood protection berms will also be utilised; and ■ Ash Backfilling will also be utilised.	■ This section is located immediately west of the Sasolburg residential area and comprises approximately 2.3km of the Leeuspruit, from the Afrikaans High Sasolburg up to the R59 provincial road; and ■ Ash backfilling will be utilised were diversions are not possible. Ash Backfilling is considered to be a separate project and under a separate environmental authorisation process.

Significant Risk Area	Mitigation Measure Implemented	Description
Leeuspruit: Section 5	■ This section's design comprises mainly of backfilling polygons due to surface restrictions on either side of the stream.	■ Located on the south-western side of the area is private infrastructure and northeast is an operational sand mine; and ■ Some of these areas have already been backfilled. Ash Backfilling is considered to be a separate project and under a separate environmental authorisation process.
Rietspruit: Section 1	■ Only one significant risk area has been identified; and ■ A flood protection berm is proposed.	■ Small diameter pipes will also be installed at low points along the berm to allow the slow release of water accumulated behind the berms.

1.3 Deliverables

The following deliverables formed part of this specialist study:

- Baseline description and background water quality; and
- Surface water impact assessment and report with findings and recommendations.

1.4 Project Team

The following team members were involved in the surface water specialist study:

Name	Position	Project Responsibility
Nancy Ntseze	Intern Water Specialist	Field work, data processing and baseline reporting
Mashudu Rafundisani	Manager: Surface Water (Hydrologist)	Specialist input and reporting
André van Coller	Divisional Manager: Water Services (Principal Water Consultant)	Review and impact assessment

2 Methodology

2.1 Desktop Assessment and Baseline Description

The desktop assessment and reporting included the following:

- Desktop review of existing literature on the area, as well as an assessment of aerial imagery;
- Description of hydrological baseline conditions prior to the commencement of the project. This includes description of the affected topography, catchment characteristics, rainfall and evaporation (climate); and
- The baseline hydrology characterisation includes an analysis and interpretation of surface water quality carried out by the Institute for Groundwater Studies (IGS). Water quality results were compared to the existing baseline quality of the Leeu/Taaiboschspruit catchment Water Quality Guidelines;

2.2 Surface Water Impact Assessment

The impact assessment phase comprises of the following:

- Potential surface water (quality and quantity) impacts that may result from the proposed project activities, based on the established baseline conditions, have been identified;
- A numerical environmental significance rating process that utilises the probability of an event occurring and the severity of the impact as factors to determine the significance of a particular environmental risk have been undertaken; and
- Mitigation measures have been proposed based on the impact assessment for each section of the stream based on the areas where pillar failure has been identified.

3 Baseline Environment

3.1 Hydrological Setting

3.1.1 Catchment Description

The proposed project area is located within the Water Management Area (WMA) of the Upper Vaal River system. The proposed area is located within the secondary drainage C2 in quaternary catchment C22K (Figure 3-2). The catchment characteristics for the C22K are presented in Table 3-1 and is summarised from the Water Research Commission (WRC), 2012.

The resultant mean annual runoff (MAR) after evaporation and recharge is 3%. The mean annual precipitation (MAP) is 644 mm with a mean annual evaporation (MAE) of 1 625 mm. The natural water balance is thus a negative one with evaporation being much higher than rainfall. However, recharge does contribute to the groundwater system which is important in the area.

Table 3-1: Summary of the C22K catchment attributes

Quaternary Catchment	Area (km_2)	Rainfall Zone	MAP (mm)	MAR (mm)	Evaporation Zone	MAE (mm)
C22K	434	C2C	644	20.9	11A	1625

The two main tributaries are the Leeuspruit (perennial) which drains the upper sections of the project site and the Rietspruit (non-perennial) draining the lower project boundary into the Vaal Barrage. The Leeuspruit and Rietspruit rivers flow parallel to each other towards Vaal Barrage. The Rietspruit presents well-defined dry river channels whilst the Leeuspruit is slow flowing with varying channel shapes. Pictures from a recent site visits are presented in Figure 3-1. The Taaibosspruit drains the area to the east of Sasolburg and the Kromelmboogspuit flows outside the project area to the west. Both these drainages are not influenced by the proposed activities.

Figure 3-1: Photographs of the Leeuspruit (Left) and the Rietspruit (Right) River Channels

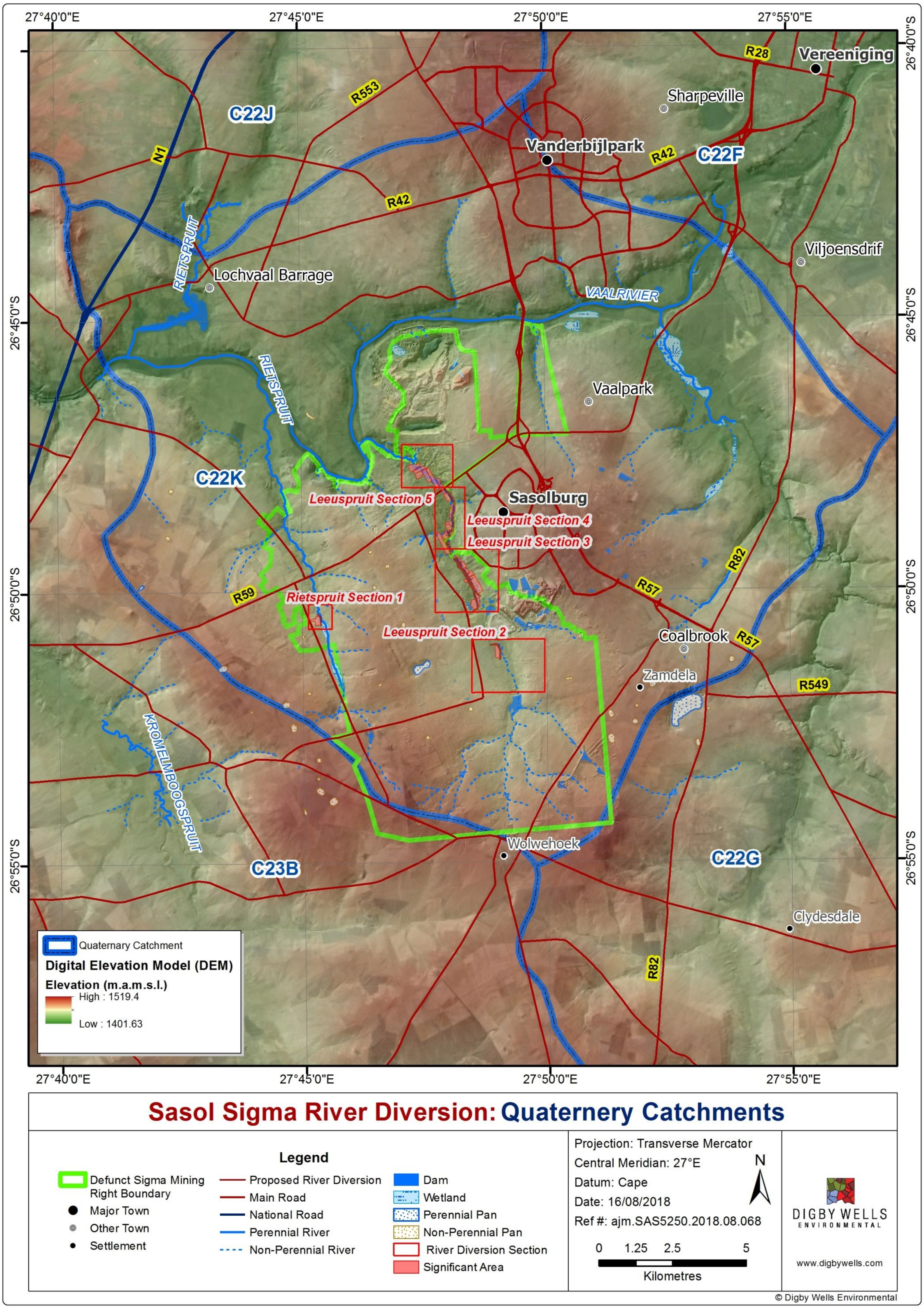

Figure 3-2: Quaternary Catchments

3.1.2 Climate

The area is characterised by warm summers and cold winters and has an average annual rainfall of 644 mm which occurs mainly during the summer months (December to February). Average daily temperatures vary between 8.9°C in June to 21.7°C in January. The average monthly rainfall for the quaternary catchments C22K and rainfall zone C2C is illustrated in Table 3-2. This is based on the averages of monthly rainfall data from a period of 1920 to 2009. The summary for the rainfall and evaporation data for C22K quaternary catchment can be viewed in

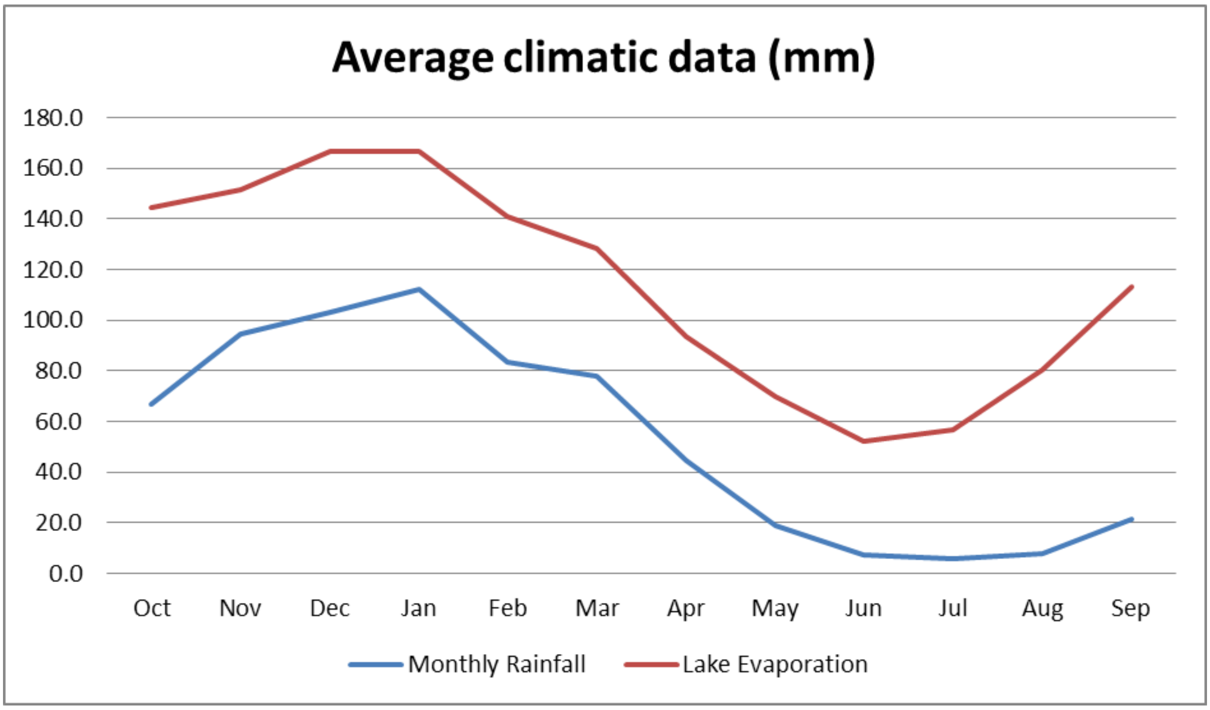

Figure 3-3 with the sub-catchments shown in Figure 3-4.

Table 3-2: Summary of Rainfall Data extracted from the WR2012

Months	Rainfall (mm)
January	112.4
February	83.3
March	77.7
April	44.6
May	18.7
June	7.3
July	6.0
August	8.0
September	21.4

Months	Rainfall (mm)
October	66.6
November	94.5
December	103.3
MAP	**644**

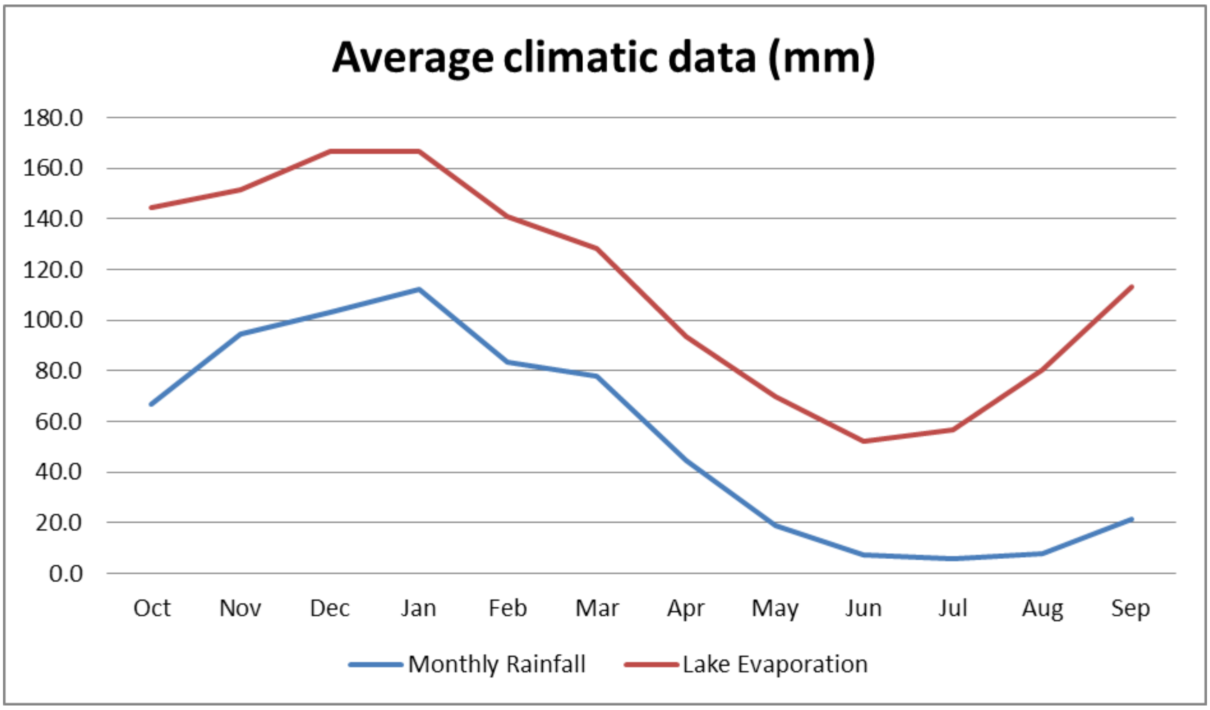

Figure 3-3: Summary of the Average Monthly Climatic Data for C22K Quaternary Catchment

3.1.3 Geology

The Sigma Defunct Colliery is found within the Sasolburg–Vereeniging Coalfield, which is part of the Karoo Supergroup. The lava and dolomite of the Ventersdorp and Transvaal Systems underlie the Sigma Basin. The Sigma Basin is approximately 9.5 km wide and trends approximately 129 km north – south from the Vaal River to beyond Dover Station.

Four mineable coal seams are found in the Sigma basin (DWE, 2018). They are number 1, 2A, 2B and 3 coal seams, as identified from the base upwards (Figure 3-5). The coal seams are situated at between 20 m and 250 m below surface and extend over an area of approximately 300 km^2. The general southward dip of the strata, together with a northward sloping land surface which drains towards the Vaal River, can be seen to have caused the wide variation in depth below surface.

Throughout the basin, number 2A, 2B and 3 coal seams can be found. The distance between the coal seams are variable and increases towards the south for number 2B and 3 coal seams. Between number 2A and 2B seams there is rarely more than a 100 cm of mudstone and in some areas, there is no parting between these two seams. This results in a combined seam thickness of approximately 6 m. Generally, the overburden consists of medium to coarse grained sandstone, dolerite, siltstone, mudstone and shale and in the far northern regions a thick, unconsolidated sand unit can be found (DWE, 2018). Between 65 and 85 meters below surface, two dolerite sills have displaced the strata at Sigma Defunct Colliery and relatively small faults with a maximum displacement of about 5 m have been encountered underground (DWE, 2018).

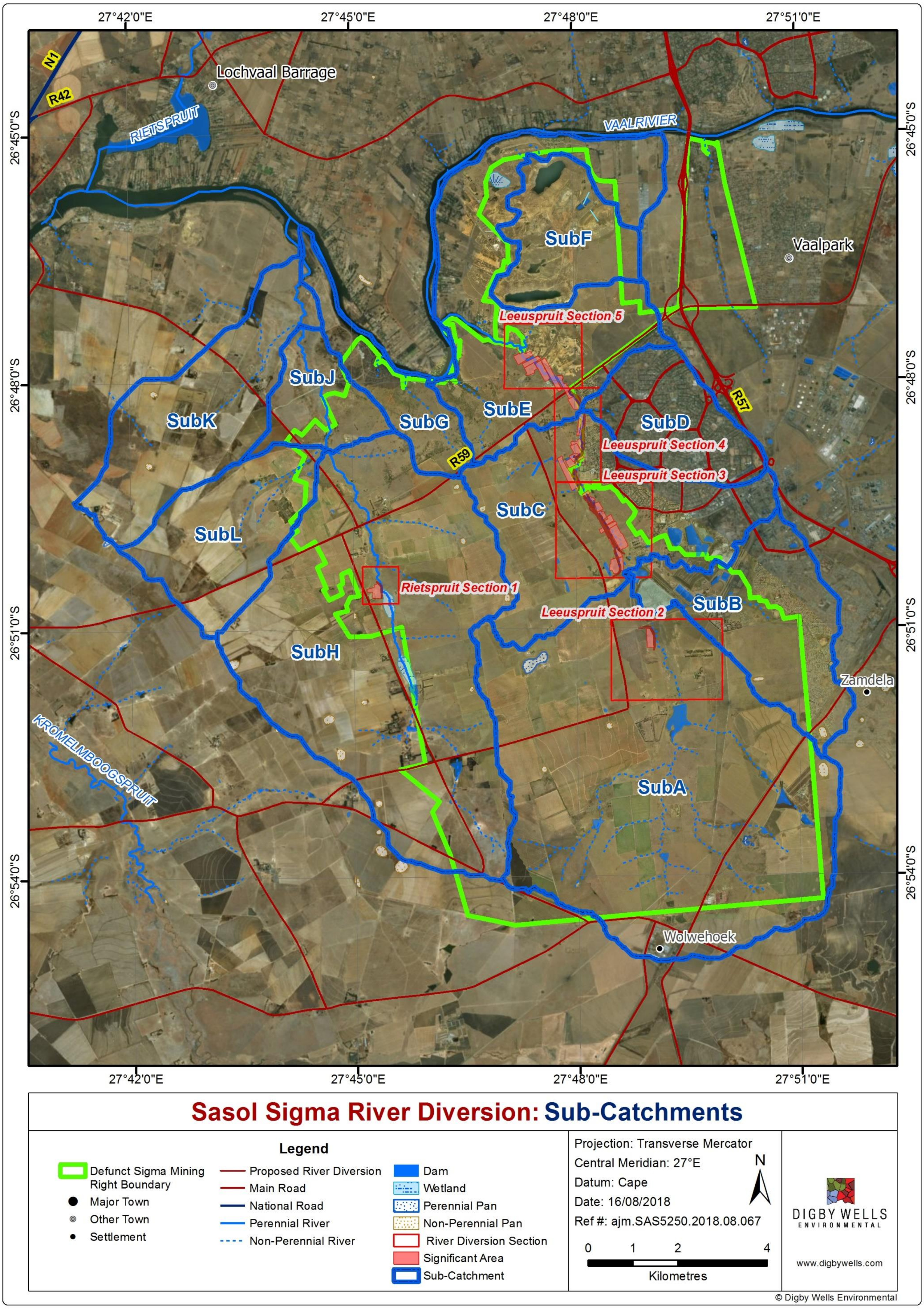

Figure 3-4: Location of Sub-catchments around the Sigma Defunct Mine

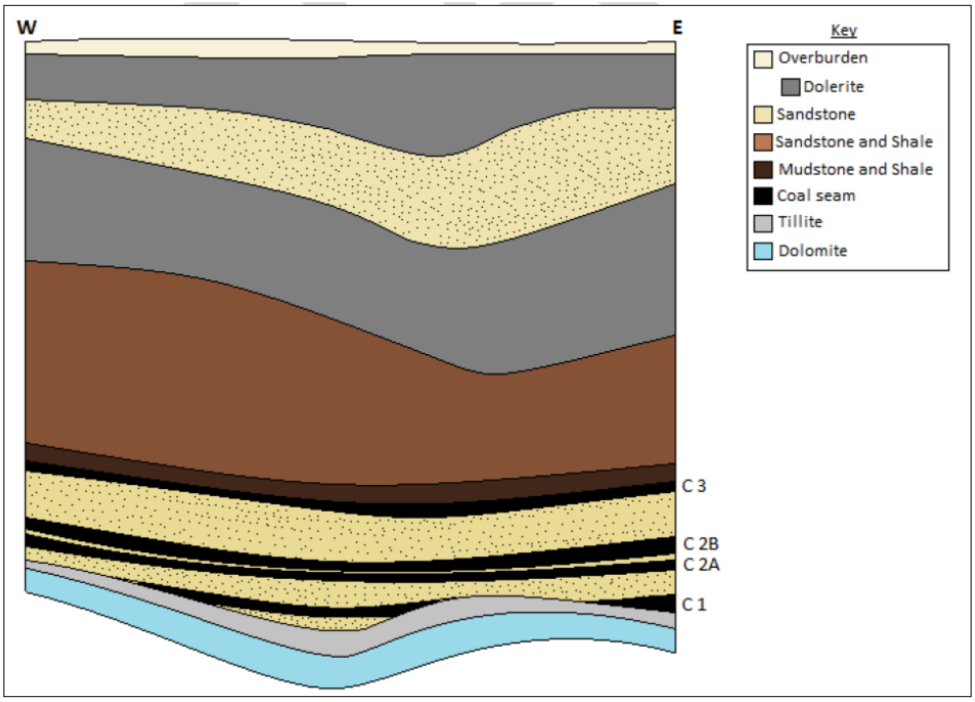

Figure 3-5: Simplified geological profile found within Sigma Mine

3.1.4 Land Use and Vegetation

The Sigma Defunct Colliery falls under the jurisdiction of the Metsimaholo Local Municipality (MLM) situated in the Fezile Dabi District Municipality (FDDM) close to the town of Sasolburg.

The site is mainly used for agricultural purposes including cattle and crop farming. Other land uses within the mining licence area include a tannery, a commercial feedlot, a sand mining operation, a property let to privately owned businesses and farmhouses. Specifically, to the northern section of the Leeuspruit, a large portion of the site is owned by Sasol Mining and is used as a game farm.

3.2 Surface Water Quality

IGS was appointed by Sasol Mining (Pty) Ltd to conduct the water monitoring of the Sigma Defunct Colliery. This section constitutes a summary of the water quality descriptions based on the latest water quality analysis by IGS (January 2018) which outlines the results of the on-going bi-annual monitoring programme conducted for Sigma Defunct Colliery. The monitoring programme focuses on an integrated approach where all water resources are holistically monitored for potential impacts of mining. The water quality data obtained from the Sigma Defunct Colliery was analysed in an accredited laboratory, South African National Accreditation Systems (SANAS) and was verified by IGS. The components analysed are displayed in Table 3-3.

Table 3-3: Summary of the Parameters/Variables Analysed

Analysed Parameters[1]						
pH	EC	TDS	Ca	Mg	Na	K
P-Alk	M-Alk	Cl	SO_4	NO_2/NO_3 as N		Cd
Al	Fe	Mn	NH_4/NH_3	as	N	B
Cr	Co	Cu	Pb	PO_4	COD	DOC
phenols	TOC	Turbidity	Suspended Solids	Faecal Coliform	Si	F

In total, 64 surface water monitoring sites forms part of the monitoring program at Sigma Defunct Colliery. However, the 3 main surface water features discussed as part of this project are the Rietspruit and Leeuspruit as these two watercourses will be directly impacted by the proposed surface mitigation project. In addition, for baseline purposes, the Vaal River monitoring results are also discussed. Monitoring locations that are discussed are listed in Table 3-4 and shown in Figure 3-6.

Data quality control was carried out by comparing the new data set with historic records to check for errors. Additionally, an ion balance error of ± 5% was used as an acceptable range after which the data was stored in the Sigma Defunct Colliery WISH database. The results reported in this section dates from June 2017 to January 2018 (given that a bi-annual monitoring program is being carried out at the defunct mine) and was sourced from the IGS reports.

Table 3-4: Surface Water Monitoring Points

AREA	SITE ID	STATUS	COMMENTS
Vaal River Barrage	Vaal Downstream	Monitored	Vaal river downstream
Vaal River Barrage	Vaal Upstream	Monitored	Vaal river upstream
Sigma	SIG/1	Monitored	Leeuspruit Downstream
Sigma	SIG/2	Monitored	Leeuspruit Upstream
Sigma	SIG/3	Monitored	Rietspruit Downstream
Sigma	SIG/4	Monitored	Rietspruit Upstream
Sigma	SIG/5	Monitored	Leeuspruit Tributary Upstream

[1] The units are mg/l except pH and EC measured in pH units and mS/m respectively.

AREA	SITE ID	STATUS	COMMENTS
Sigma	SIG/6	Monitored	Leeuspruit Tributary Downstream

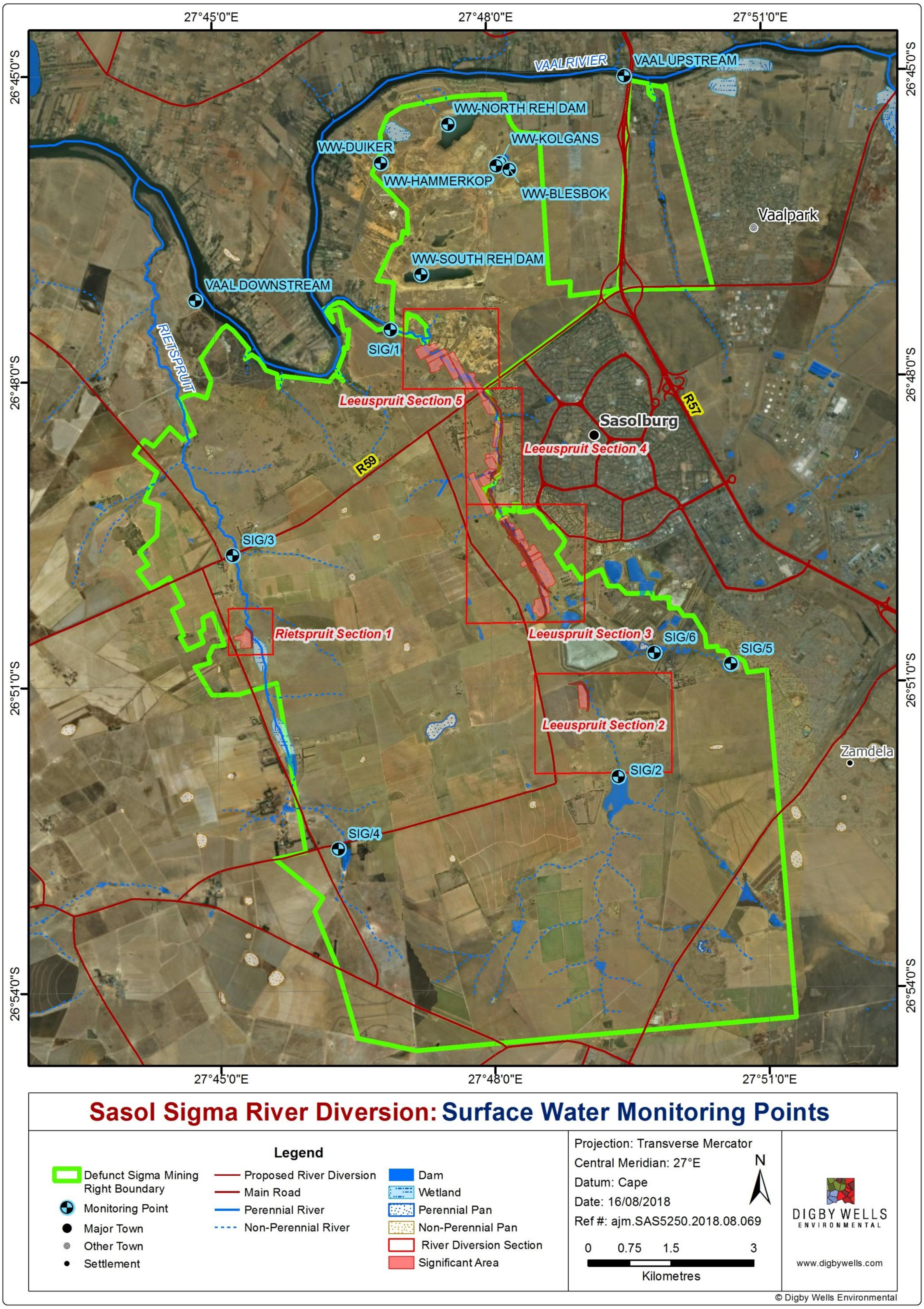

Figure 3-6: Surface Water Quality Monitoring points

3.2.1 Leeuspruit

Monitoring points SIG/1 (downstream) and SIG/2 (upstream) represents the water quality of the Leeuspruit. In addition, SIG/5 and SIG/6 monitors a tributary of the Leeuspruit that flows from the east and joins the Leeuspruit between the SIG/1 and SIG/2 monitoring points. This last-mentioned tributary as well as the Leeuspruit is directed past an ash dam and old coal stockpiles before joining each other at the confluence point directly downstream of the ash dam which can potentially influence the water quality of the Leeuspruit and change the chemistry slightly between SIG/2 and SIG/1.

From the Stiff diagrams shown in Figure 3-7 the water type of both SIG/1 and SIG/2 can be described as sodium-bicarbonate water with SIG/1 (downstream) more enriched with sulphate (SO_4) than that of the upstream point SIG/2. The upstream point of the tributary (SIG/5) also has lower SO_4 concentration that the downstream point (SIG/6). The change in sulphate concentrations of the tributary is illustrated in it characters that change from a calcium-bicarbonate water at the upstream point to a sodium-bicarbonate water at the downstream point. The effect of the ash dams and the associated activities are clear in the change of water quality with SO_4 concentration being a clear indicator element of seepage and runoff from an ash facility.

Trend graphs (chemistry vs time) for electrical conductivity (EC), pH, SO_4 and chloride (Cl) sourced from the bi-annual IGS report (IGS, 2018) is shown in Figure 3-8. In addition, the water quality was compared against the Leeu/Taaiboschspruit Catchment water quality guidelines and is shown in Table 3-5 and Table 3-6.

From the above graph and table, the following can be concluded on the water quality of the Leeuspruit and its tributary:

- Changes in pH and occasional peaks in SO_4 for the downstream points above the guideline values confirms the conclusion that the ash dam does have some influence on the water quality during high rainfall and runoff periods;
- Cl and EC generally stay within the guideline concentration ranges for all monitoring points. However, in the last two monitoring runs a clear increase in these parameters are observed with EC increasing to above guideline values in SIG/1, SIG/2 and SIG/6. This correlates with the rainfall seasons at the end of the year and confirms the potential contribution of the ash dams and old coal stockpiles to the water quality;
- In general, from the trend graphs it can be concluded that in the last 12 month there is a general trend of deteriorating water qualities in a downstream direction of both the Leeuspruit and its tributary that can be due to the contribution of the ash dam and coal stockpiles located at 3 Shaft Complex operated by Mooikraal Colliery;
- From the other parameters analysed and compared against the water quality guidelines in January 2018 all are within a tolerable range excluding sodium (Na), manganese (Mn), nitrate (NO_3), phosphate (PO_4) and total suspended solids (TSS)

that are at unacceptable levels for the Leeuspruit and its tributary. Faecal coliform is also above guideline values in both drainages;

- Mn and Na are naturally occurring elements that are enriched in the soils and geology of the area which is the source of these contaminants. Faecal coliform, NO_3 and PO_4 are most likely from animal and farming activities (bird life and cattle around the drainage lines and pesticides); and
- Although the Leeuspruit is perennial, flow volumes and rates are generally low with high flows generally associated with high rainfall events. High runoff can cause the increase in TSS observed in the January results that represent a wet season survey

Potential current impacts in the upstream areas in the Leeuspruit as well as its tributaries that can have an influence on the above water quality are:

- Discharge from sewage plants in the upstream areas of the Leeuspruit; and
- Uncontrolled storm water from built up areas and informal communities.

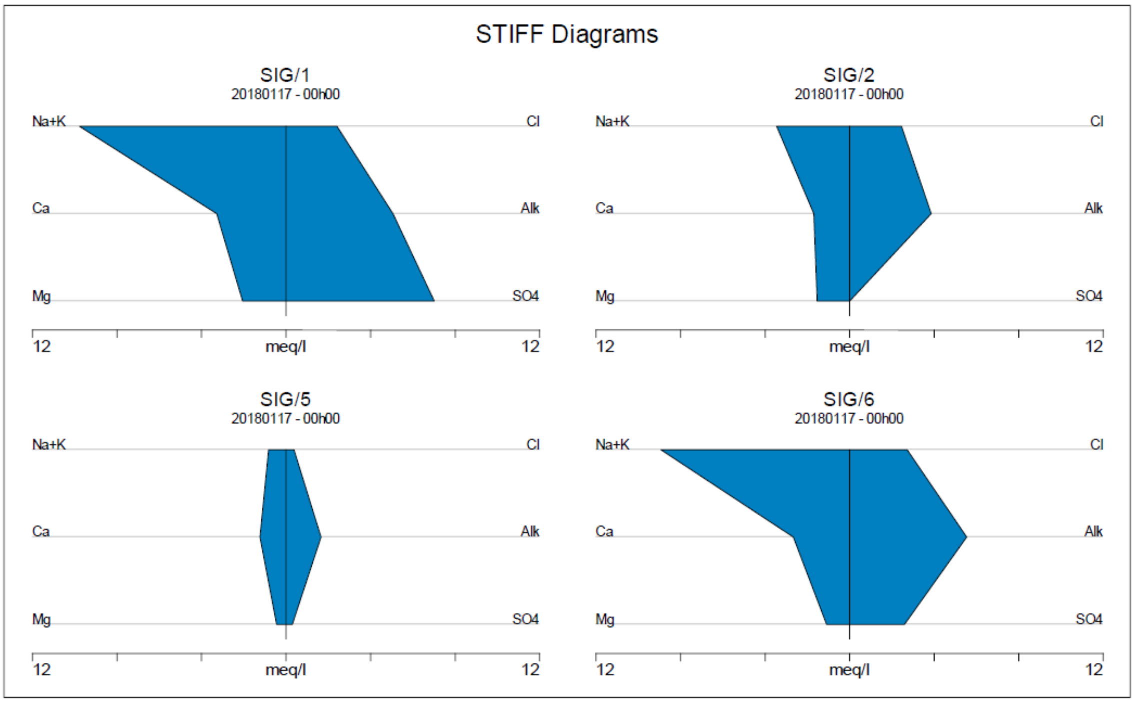

Figure 3-7: Stiff diagrams illustrating the water quality of Leeuspruit (SIG/1 & SIG/2) and its tributary (SIG/5 & SIG/6) (IGS, 2018)

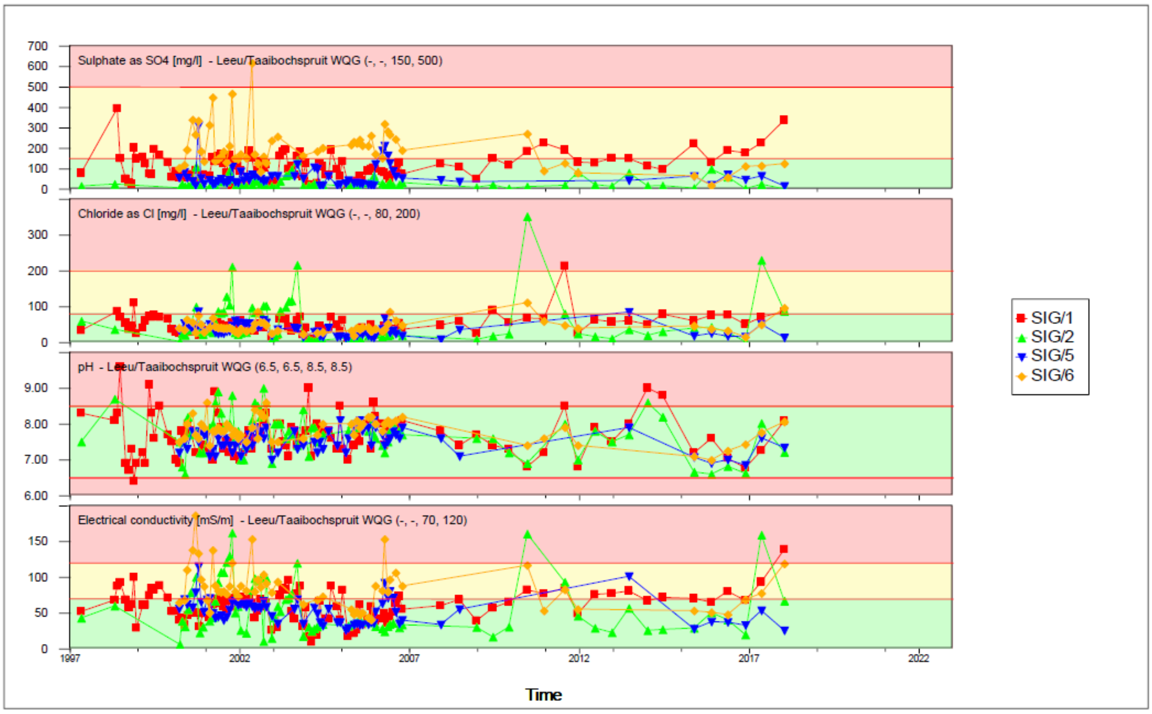

Figure 3-8: Electrical conductivity, pH, chloride and sulphate time graphs for Leeuspruit (SIG/1 & SIG/2) and its tributary (SIG/5 & SIG/6) (IGS, 2018)

Table 3-5: Leeuspruit water quality vs. the prescribed Leeu/Taaiboschspruit Catchment water quality guidelines (IGS, 2018)

SiteName	EC	pH	Ca	Mg	Na	K	PAlk	MAlk	F	Cl	NO2(N)
SWQG	mS/m		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Acceptable	<70	6.5-8.5	N/S	<30	<100	N/S	N/S	N/S	<0.7	<150	<3.0
Tolerable	70-120	N/S	N/S	30-70	100-150	N/S	N/S	N/S	0.7-1.0	150-200	3.0-6.0
Unacceptable	>120	<6.5; >8.5	N/S	>70	>150	N/S	N/S	N/S	>1.0	>200	>6.0
SIG1	139	8.1	66	25	218	11.8	0	253	0.37	86	<0.1
SIG2	67	7.2	34	19	54	42.5	0	193	0.72	87	<0.01
SIG5	26	7.3	25	5	15	7.2	0	83	0.51	13	0.56
SIG6	119	8.1	53	13	190	26.7	0	277	0.51	97	<0.1

SiteName	NO3(N)	PO4	SO4	Al	Fe	Mn	NH4(N)	TDS	B	Si	Cd
SWQG	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Acceptable	<3.0	<0.4	<300	<0.3	<0.5	<0.5	<1.5	N/S	N/S	N/S	N/S
Tolerable	3.0-6.0	0.4-0.6	300-500	0.3-0.5	0.5-1.0	0.5-1.0	1.5-5.0	N/S	N/S	N/S	N/S
Unacceptable	>6.0	>0.6	>500	>0.5	>1.0	>1.0	>5.0	N/S	N/S	N/S	N/S
SIG1	<0.5	<1	337	0.034	0.032	0.029	0.12	992	1.178	1.083	<0.003
SIG2	0.17	<0.1	0	0.041	2.425	3.455	1.05	432	<0.040	16.333	<0.003
SIG5	0.73	1.08	14	0.333	0.578	0.122	0.09	170	<0.040	4.523	<0.003
SIG6	17.34	<1	125	0.244	0.161	0.023	0.06	857	0.459	4.774	<0.003

SiteName	Co	Cr	Cu	Pb	Turb	COD	Susp. Solids	Phenol	DOC	TOC	
SWQG	mg/L	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	mg/lO2	mg/L	
Acceptable	N/S	N/S	N/S	N/S	N/S	N/S	<30	N/S	N/S	N/S	
Tolerable	N/S	N/S	N/S	N/S	N/S	N/S	30-55	N/S	N/S	N/S	
Unacceptable	N/S	N/S	N/S	N/S	N/S	N/S	>55	N/S	N/S	N/S	
SIG1	<0.020	<0.020	0.020	0.001	12	65	27	<0.010	10	10	
SIG2	<0.020	<0.020	0.019	0.002	164	343	1160	<0.010	47	54	
SIG5	<0.020	<0.020	0.022	0.000	335	134	730	<0.010	10	14	
SIG6	<0.020	<0.020	0.026	0.001	>800	1280	1552	<0.010	10	12	

SWQG - Leeuspruit/Taaiboschspruit prescribed surface water quality guidelines
N/S - Not specified

Table 3-6: Leeuspruit bacteriological analysis results (IGS, 2018)

SiteName	Faecal Coliforms	E.Coli
SWQG	cfu/100ml	cfu/100ml
Acceptable	<126	N/S
Tolerable	126-1000	N/S
Unacceptable	>1000	N/S
SIG1	>2420	866
SIG2	1300	1300
SIG5	65	45
SIG6	1825	1380

SWQG - Leeuspruit/Taaiboschspruit prescribed surface water quality guidelines
N/S - Not specified

3.2.2 Rietspruit

The upstream monitoring point of the Rietspruit is represented by SIG/4 with the downstream point being SIG/3. Mainly farming activity occurs between these two points with only underground mining that was part of the Sigma Defunct Colliery being the other activities.

The Stiff diagrams are illustrated in Figure 3-9 with the trend graphs and water quality tables shown in Figure 3-10, Table 3-7 and Table 3-8. From the above data sets and illustrations, the following can be concluded on the baseline water quality for the Rietspruit:

- Both sampling points show a calcium-bicarbonate water type with only a change in alkalinity from upstream to downstream. This can be due to various factors but none that will impact on the quality of the water;
- Analysis of the chemistry vs time trends show that the downstream point (SIG/3) generally remains stable with a decrease in pH over the last 3 monitoring runs. This can be due to high rainfall;
- The upstream point (SIG/4) is however more variable with spikes in parameters during certain periods. Periods of prominent increases in Cl and SO_4 are observed at SIG/4 and this can be due to evaporation during the dry winter months which increases salt concentrations;
- Generally, the water quality trends do however remain stable and the water quality shows no significant changes over time;
- Fluoride (F), aluminium (Al), iron (Fe), Mn, PO_4, ammonium (NH_4) and TSS exceed the recommended guideline limits. F, Al, Fe and Mn will be due to ion exchange reactions with the stream sediments. PO_4 and NH_4 will be from animal activity;
- Faecal coliforms exceed the guideline values but this is normal for natural streams flowing through areas with human, farming and animal activities; and
- The Rietspruit water quality has generally remained stable and within the ranges of background data.

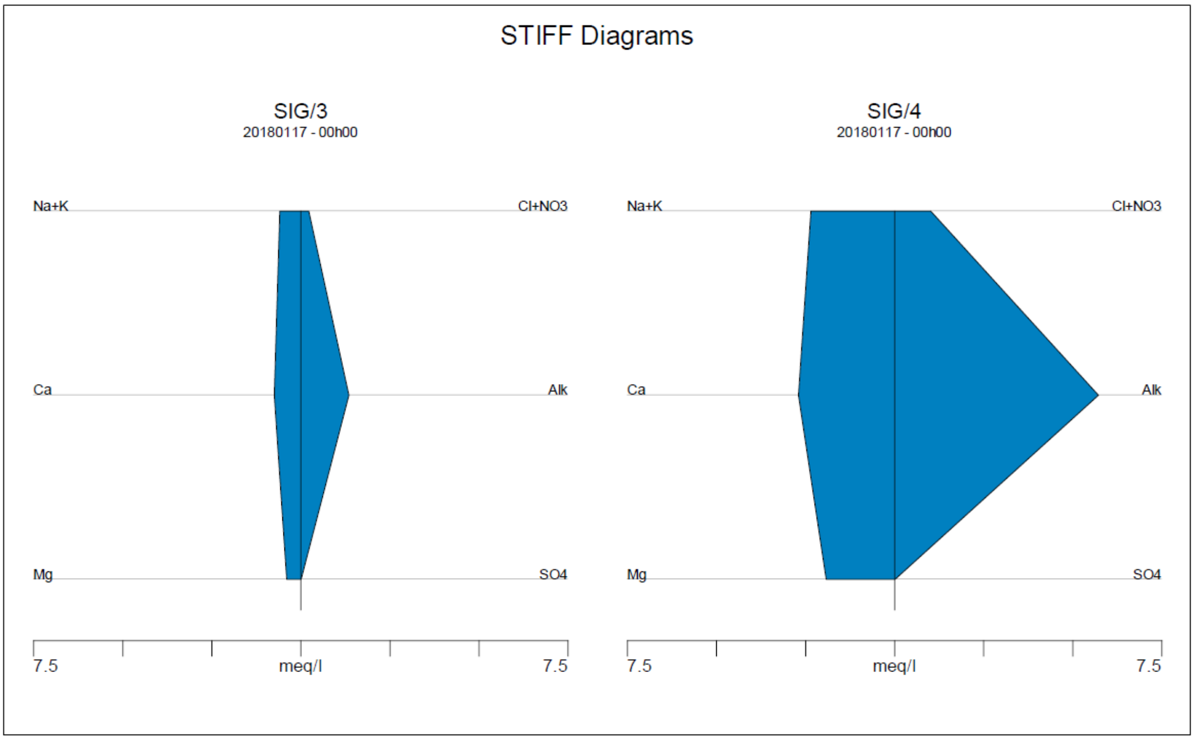

Figure 3-9: Stiff diagrams of the Rietspruit upstream (SIG/4) and downstream (SIG/3) (IGS, 2018)

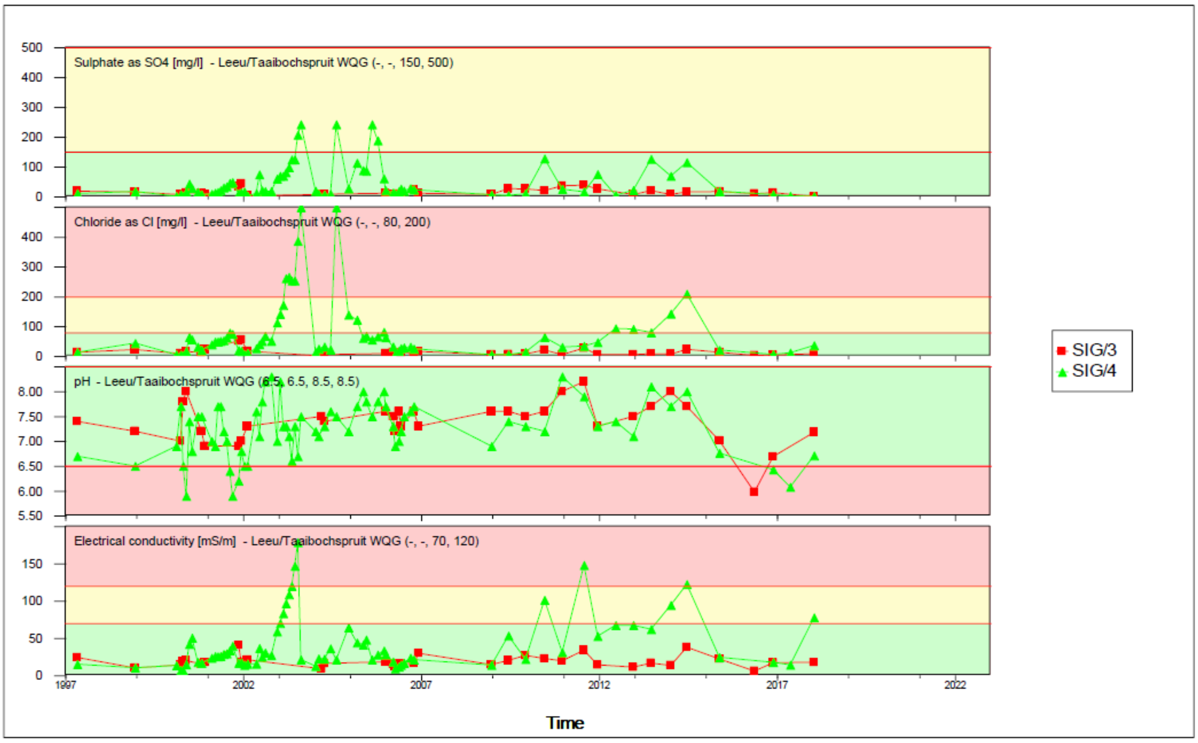

Figure 3-10: Electrical conductivity, pH, chloride and sulphate time graphs for the Rietspruit (IGS, 2018)

Table 3-7: Rietspruit water quality vs. the prescribed Leeu/Taaiboschspruit Catchment water quality guidelines (IGS, 2018)

SiteName	EC	pH	Ca	Mg	Na	K	PAlk	MAlk	F	Cl	NO2(N)
SWQG	mS/m		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Acceptable	<70	6.5-8.5	N/S	<30	<100	N/S	N/S	N/S	<0.7	<150	<3.0
Tolerable	70-120	N/S	N/S	30-70	100-150	N/S	N/S	N/S	0.7-1.0	150-200	3.0-6.0
Unacceptable	>120	<6.5; >8.5	N/S	>70	>150	N/S	N/S	N/S	>1.0	>200	>6.0
SIG3	18	7.2	15	5	9	8.1	0	67	0.49	8	<0.01
SIG4	78	6.7	54	23	29	43.1	0	286	11.79	36	<0.01

SiteName	NO3(N)	PO4	SO4	Al	Fe	Mn	NH4(N)	TDS	B	Si	Cd
SWQG	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Acceptable	<3.0	<0.4	<300	<0.3	<0.5	<0.5	<1.5	N/S	N/S	N/S	N/S
Tolerable	3.0-6.0	0.4-0.6	300-500	0.3-0.5	0.5-1.0	0.5-1.0	1.5-5.0	N/S	N/S	N/S	N/S
Unacceptable	>6.0	>0.6	>500	>0.5	>1.0	>1.0	>5.0	N/S	N/S	N/S	N/S
SIG3	<0.05	<0.1	0	0.679	1.194	0.052	0.07	113	<0.040	6.391	<0.003
SIG4	0.22	10.29	1	0.046	1.635	2.824	17.75	495	<0.040	7.977	<0.003

SiteName	Co	Cr	Cu	Pb	Turb	COD	Susp. Solids	Phenol	DOC	TOC	
SWQG	mg/L	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	mg/lO2	mg/L	
Acceptable	N/S	N/S	N/S	N/S	N/S	N/S	<30	N/S	N/S	N/S	
Tolerable	N/S	N/S	N/S	N/S	N/S	N/S	30-55	N/S	N/S	N/S	
Unacceptable	N/S	N/S	N/S	N/S	N/S	N/S	>55	N/S	N/S	N/S	
SIG3	<0.020	<0.020	0.025	0.002	121	100	251	<0.010	21	23	
SIG4	<0.020	<0.020	0.039	<0.0006	>800	6810	8617	<0.010	77	94	

SWQG - Leeuspruit/Taaiboschspruit prescribed surface w ater quality guidelines
N/S - Not specified

Table 3-8: Rietspruit bacteriological analysis results (IGS, 2018)

SiteName	Faecal Coliforms	E.Coli
SWQG	cfu/100ml	cfu/100ml
Acceptable	<126	N/S
Tolerable	126-1000	N/S
Unacceptable	>1000	N/S
SIG3	>2420	52
SIG4	>2420	866

SWQG - Leeuspruit/Taaiboschspruit prescribed surface w ater quality guidelines
N/S - Not specified

3.2.3 Vaal River Up- and Downstream

Both the Vaal Upstream and Downstream points are characterised as sodium-sulphate water as illustrated in the Stiff diagrams (Figure 3-11). The water character of both points is almost identical.

From the data in Figure 3-12, Table 3-9 and Table 3-10 the following can be concluded:

- The SO_4 and EC trends of the upstream and downstream point follows the same trend;
- The downstream monitoring point does show occasional spikes in Cl and pH that can potentially be due to the influence of the Leeuspruit. This is however not frequent and this not proven;
- All other constituents are well within the recommended guideline ranges except for TSS. TSS can increase during periods when river flow rates and levels increase and decrease with the velocity of the river being at a rate at which suspended solids are transported downstream. This usually occurs at the start or end of the wet season;
- Faecal coliform results are above the guideline values in the upstream sample. This can be due to sewage discharge as well as farming (livestock) activities upstream.

The general trend observed is that the upstream sampling point water quality is generally worse than that of the downstream point. This is unusual if you consider the contribution of the Leeuspruit and its tributary with the contaminated water from the ash dams and coal stockpiles. This does however show that the Vaal River is already impacted by upstream activities that include mining, sewage discharge and general human impacts from settlements.

From current data it can be concluded that water from the project area flowing down the Leeuspruit and Rietspruit does not have a significant impact on the Vaal River quality.

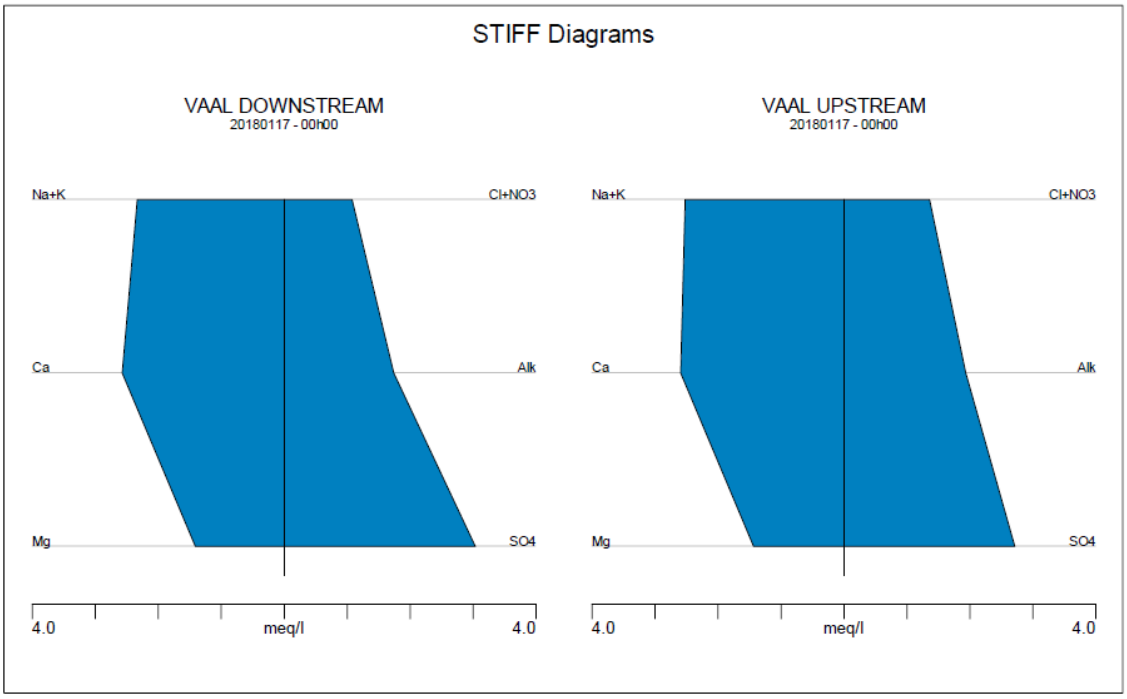

Figure 3-11: Stiff diagrams of the Vaal River upstream and downstream (IGS, 2018)

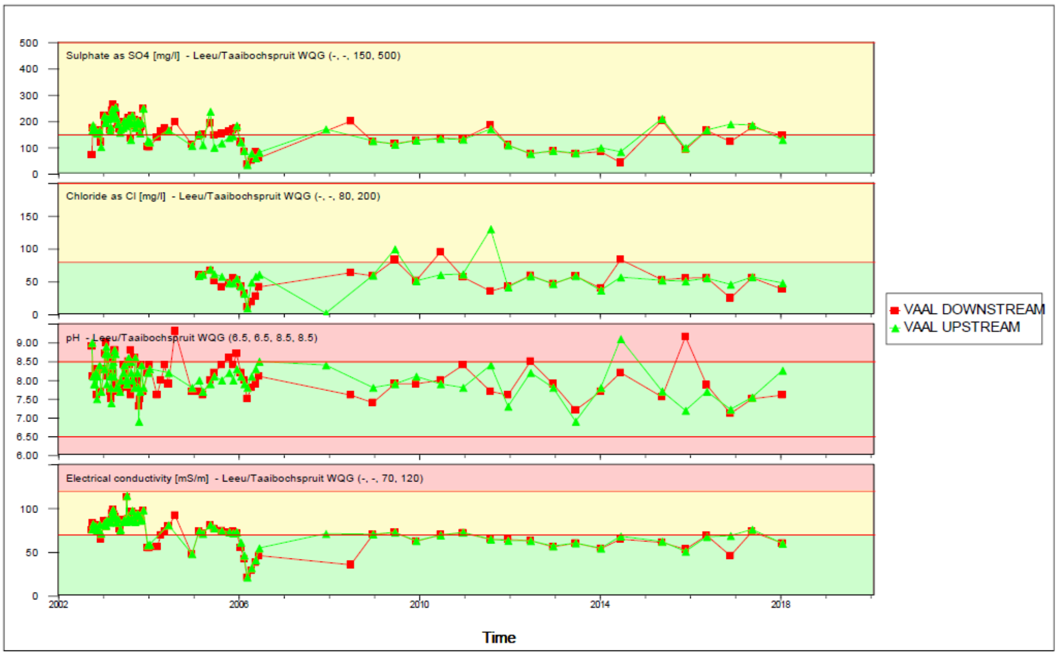

Figure 3-12: Major cation, anion and electrical conductivity time graphs of the Vaal River upstream and downstream (IGS, 2018)

Table 3-9: Vaal River Barrage water quality vs. the prescribed Leeu/Taaiboschspruit Catchment water quality guidelines (IGS, 2018)

SiteName	EC	pH	Ca	Mg	Na	K	PAlk	MAlk	F	Cl	NO2(N)
SWQG	mS/m		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Acceptable	<70	6.5-8.5	N/S	<30	<100	N/S	N/S	N/S	<0.7	<150	<3.0
Tolerable	70-120	N/S	N/S	30-70	100-150	N/S	N/S	N/S	0.7-1.0	150-200	3.0-6.0
Unacceptable	>120	<6.5; >8.5	N/S	>70	>150	N/S	N/S	N/S	>1.0	>200	>6.0
VAAL UPSTREAM	60	8.3	52	17	53	9.1	0	97	0.33	48	0.05
VAAL DOWNSTREAM	60	7.6	52	17	49	8.6	0	87	0.21	38	<0.1
SiteName	NO3(N)	PO4	SO4	Al	Fe	Mn	NH4(N)	TDS	B	Si	Cd
SWQG	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Acceptable	<3.0	<0.4	<300	<0.3	<0.5	<0.5	<1.5	N/S	N/S	N/S	N/S
Tolerable	3.0-6.0	0.4-0.6	300-500	0.3-0.5	0.5-1.0	0.5-1.0	1.5-5.0	N/S	N/S	N/S	N/S
Unacceptable	>6.0	>0.6	>500	>0.5	>1.0	>1.0	>5.0	N/S	N/S	N/S	N/S
VAAL UPSTREAM	2.71	0.21	130	0.109	0.082	<0.020	0.55	419	0.075	0.84	<0.003
VAAL DOWNSTREAM	1.58	<1	146	0.045	0.041	<0.020	0.57	402	0.085	0.46	<0.003
SiteName	Co	Cr	Cu	Pb	Turb	COD	Susp. Solids	Phenol	DOC	TOC	
SWQG	mg/L	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	mg/lO2	mg/L	
Acceptable	N/S	N/S	N/S	N/S	N/S	N/S	<30	N/S	N/S	N/S	
Tolerable	N/S	N/S	N/S	N/S	N/S	N/S	30-55	N/S	N/S	N/S	
Unacceptable	N/S	N/S	N/S	N/S	N/S	N/S	>55	N/S	N/S	N/S	
VAAL UPSTREAM	<0.020	<0.038	0.016	<0.0001	25	55	141	<0.010	7	7	
VAAL DOWNSTREAM	<0.020	<0.037	0.017	0.000	5	42	13	<0.010	8	8	

SWQG - Leeuspruit/Taaiboschspruit prescribed surface w ater quality guidelines

N/S - Not specified

Table 3-10: The Vaal River Barrage bacteriological analysis results (IGS, 2018

SiteName	Faecal Coliforms	E.Coli
SWQG	cfu/100ml	cfu/100ml
Acceptable	<126	N/S
Tolerable	126-1000	N/S
Unacceptable	>1000	N/S
VAAL UPSTREAM	326	135
VAAL DOWNSTREAM	82	2
SWQG - Leeuspruit/Taaiboschspruit prescribed surface w ater quality guidelines		
N/S - Not specified		

4 Stream Flow Description

4.1.1 Calculated Peak Flows for Diversion and Berm Designs

Jones & Wagner calculated various flow peaks (from 1:2 year event up to 1:100 year event) for the design of the flood protection berms and diversion canals. The design criteria and flows used will ensure that (J&W, 2018):

- Downstream yield increase or reduction will have a variance of less than 1%; and
- Change in peak flow rate will be less than 5%.

With the above design criteria, the proposed infrastructure will have almost no effect on the water volumes reporting downstream to the remaining Leeuspruit/Rietspruit sections as well as the Vaal River. However, flow velocities will increase and the floodlines will change from the current natural floodlines.

The following peak flows and expected velocity changes apply to the various sections (Table 4-1).

Table 4-1: Peak flow and average velocities of design (J&W, 2018)

Section	Peak runoff (1:100) (m^3/s)	Average velocity (m/s)		
		Pre-construction	Post-construction	% increase
Leeuspruit Section 2	129	0.61	0.81	33%
Leeuspruit Section 3	239	0.89	3.52	296%
Leeuspruit Section 4	345	0.92	4.05	340%
Rietspruit Section 1	37	0.61	0.87	43%

From Table 4-1 the biggest impact on the downstream surface water environment will not be the volumes reporting to the downstream catchments but the velocity at which they will occur. Due to the change in velocity and diversion of the water from its natural pathways this will also affect the floodlines.

4.1.2 Dry Weather Flow

4.1.2.1 Rietspruit

The Rietspruit has low flows of zero. It is non-perennial with stream flows during the wet season only. Flows during the dry season will only occur under abnormal winter rains and or discharge from dams or facilities upstream. It was dry during the fieldwork which was undertaken in the dry season.

4.1.2.2 Leeuspruit

The Leeuspruit is a perennial stream with water flow in the dry season as was observed during the site visit, which was undertaken in the dry season. This is mainly due to the various settlements, mining activities and dams upstream that contribute to flow in the dry season.

As per the groundwater study done for the Sigma Defunct Colliery, areas with a significant potential for pillar failure which can result in subsidence are potential decant points. Decant has been predicted in groundwater models in subsidence areas with elevation of 1424 mamsl near the Leeuspruit. Should subsidence not occur, the decant elevation at the Leeuspruit is 1426 mamsl. Decant can also be a potential contributor to flow in the Leeuspruit.

5 Surface Water Impact Assessment

5.1 Impact Rating Methodology

The methodology utilised to assess the significance of impacts is discussed in detail below.

The significance rating formula is as follows:

Significance = Consequence x Probability

Where

Consequence = Type of Impact x (Intensity + Spatial Scale + Duration)

And

Probability = Likelihood of an Impact Occurring

In addition, the formula for calculating consequence:

Type of Impact = ***+1*** *(Positive Impact) or* ***-1*** *(Negative Impact)*

The weight assigned to the various parameters for positive and negative impacts is provided for in the formula and is presented in Table 5-1. The probability consequence matrix for impacts is displayed in Table 5-2, with the impact significance rating described in Table 5-3.

Table 5-1: Surface Water Impact Assessment Parameter Ratings

Rating	Intensity		Spatial scale	Duration	Probability
	Negative Impacts ***(Type of Impact = -1)***	***Positive Impacts*** ***(Type of Impact = +1)***			
7	High significant impact on the environment. Irreparable damage to highly valued species, habitat or ecosystem. Persistent severe damage. Irreparable damage to highly valued items of great cultural significance or complete breakdown of social order.	Noticeable, on-going social and environmental benefits which have improved the livelihoods and living standards of the local community in general and the environmental features.	International The effect will occur across international borders.	Permanent: No Mitigation The impact will remain long after the life of the Project.	Certain/ Definite. There are sound scientific reasons to expect that the impact will occur.
6	Significant impact on highly valued species, habitat or ecosystem. Irreparable damage to highly valued items of cultural significance or breakdown of social order.	Great improvement to livelihoods and living standards of a large percentage of population, as well as significant increase in the quality of the receiving environment.	National Will affect the entire country.	Beyond Project Life The impact will remain for some time after the life of a Project.	Almost certain/Highly probable It is most likely that the impact will occur.

Rating	Intensity		Spatial scale	Duration	Probability
	Negative Impacts ***(Type of Impact = -1)***	***Positive Impacts*** ***(Type of Impact = +1)***			
5	Very serious, long-term environmental impairment of ecosystem function that may take several years to rehabilitate. Very serious widespread social impacts. Irreparable damage to highly valued items.	On-going and widespread positive benefits to local communities which improves livelihoods, as well as a positive improvement to the receiving environment.	Province/ Region Will affect the entire province or region.	Project Life The impact will cease after the operational life span of the Project.	Likely The impact may occur.
4	Serious medium term environmental effects. Environmental damage can be reversed in less than a year. On-going serious social issues. Significant damage to structures / items of cultural significance.	Average to intense social benefits to some people. Average to intense environmental enhancements.	Municipal Area Will affect the whole municipal area.	Long term 6-15 years.	Probable Has occurred here or elsewhere and could therefore occur.

Rating	Intensity		Spatial scale	Duration	Probability
	Negative Impacts (Type of Impact = -1)	***Positive Impacts (Type of Impact = +1)***			
3	Moderate, short-term effects but not affecting ecosystem function. Rehabilitation requires intervention of external specialists and can be done in less than a month. On-going social issues. Damage to items of cultural significance.	Average, on-going positive benefits, not widespread but felt by some.	Local Extending across the site and to nearby settlements.	Medium term 1-5 years.	Unlikely Has not happened yet but could happen once in the lifetime of the Project, therefore there is a possibility that the impact will occur.
2	Minor effects on biological or physical environment. Environmental damage can be rehabilitated internally with/ without help of external consultants. Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Low positive impacts experience by very few of population.	Limited Limited to the site and its immediate surroundings.	Short term Less than 1 year.	Rare/ improbable Conceivable, but only in extreme circumstances and/ or has not happened during lifetime of the Project but has happened elsewhere. The possibility of the impact materialising is very low because of design, historic experience or implementation of adequate mitigation measures.

Rating	Intensity		Spatial scale	Duration	Probability
	Negative Impacts ***(Type of Impact = -1)***	***Positive Impacts*** ***(Type of Impact = +1)***			
1	Limited damage to minimal area of low significance that will have no impact on the environment. Minimal social impacts, low-level repairable damage to commonplace structures.	Some low-level social and environmental benefits felt by very few of the population.	<u>Very limited</u> Limited to specific isolated parts of the site.	<u>Immediate</u> Less than 1 month.	<u>Highly unlikely/None</u> Expected never to happen.

Table 5-2: Probability Consequence Matrix for Impacts

Probability		Significance																																			
	7	-147	-140	-133	-126	-119	-112	-105	-98	-91	-84	-77	-70	-63	-56	-49	-42	-35	-28	-21	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147
	6	-126	-120	-114	-108	-102	-96	-90	-84	-78	-72	-66	-60	-54	-48	-42	-36	-30	-24	-18	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126
	5	-105	-100	-95	-90	-85	-80	-75	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
	4	-84	-80	-76	-72	-68	-64	-60	-56	-52	-48	-44	-40	-36	-32	-28	-24	-20	-16	-12	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84
	3	-63	-60	-57	-54	-51	-48	-45	-42	-39	-36	-33	-30	-27	-24	-21	-18	-15	-12	-9	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63
	2	-42	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
	1	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
		-21	**-20**	**-19**	**-18**	**-17**	**-16**	**-15**	**-14**	**-13**	**-12**	**-11**	**-10**	**-9**	**-8**	**-7**	**-6**	**-5**	**-4**	**-3**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
Consequence																																							

Table 5-3: Significance Threshold Limits

Score	Description	Rating
109 to 147	A very beneficial impact which may be sufficient by itself to justify implementation of the Project. The impact may result in permanent positive change.	**Major (positive)**
73 to 108	A beneficial impact which may help to justify the implementation of the Project. These impacts would be considered by society as constituting a major and usually a long-term positive change to the (natural and/or social) environment.	Moderate (positive)
36 to 72	An important positive impact. The impact is insufficient by itself to justify the implementation of the Project. These impacts will usually result in positive medium to long-term effect on the social and/or natural environment.	Minor (positive)
3 to 35	A small positive impact. The impact will result in medium to short term effects on the social and/or natural environment.	Negligible (positive)
-3 to -35	An acceptable negative impact for which mitigation is desirable but not essential. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in negative medium to short term effects on the social and/or natural environment.	Negligible (negative)
-36 to -72	An important negative impact which requires mitigation. The impact is insufficient by itself to prevent the implementation of the Project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in negative medium to long-term effect on the social and/or natural environment.	Minor (negative)
-73 to -108	A serious negative impact which may prevent the implementation of the Project. These impacts would be considered by society as constituting a major and usually a long-term change to the (natural and/or social) environment and result in severe effects.	Moderate (negative)
-109 to -147	A very serious negative impact which may be sufficient by itself to prevent implementation of the Project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects.	Major (negative)

5.2 Project Activities

The potential impacts/ risks identified in this section are a result of both the environment in which the project activities take place, as well as the actual activities. The potential impacts/ risks are discussed per aspect, per River Section and per each phase of the project i.e. the Construction Phase. It is also noted that although the impacts for the construction phase of the various sections may be different the operational phase is predicted to be relatively similar for each section therefore only one operational phase for each aspect has been assessed. No decommissioning phase will be undertaken for this project as once the surface mitigation measures have been implemented these changes are proposed to be permanent.

The activities for the proposed river diversion project that will be assessed are listed below in Table 5-4.

Table 5-4: Project Activities

Significant Risk Area	Phase	Project Activity
Leeuspruit Section 2- 5 and Rietspruit Section 1	General Construction Activities	▪ Contractor Camp / Laydown Area Establishment; ▪ Site clearing, including the removal of topsoil and vegetation; ▪ Excavation of soils from water course ▪ Stockpiling of soil once excavated ▪ Water Management (Ensure flow of river is not significantly impacted) ▪ Construction activities within a water courses and wetlands (Heavy vehicles and excavators); ▪ Temporary storage of hazardous products, including fuel; and ▪ Storage of waste. ▪ Utilise existing roads to access the various river sections
Leeuspruit Section 2	Construction Phase	▪ Construction of flood protection berm ▪ Vegetation of flood protection berm
Leeuspruit Section 3	Construction Phase	▪ Construction of flood protection berm ▪ Vegetation of flood protection berm ▪ Construction of formalised canal
Leeuspruit Section 4	Construction Phase	▪ Construction of flood protection berm ▪ Vegetation of flood protection berm ▪ Construction of formalised canal
Leeuspruit Section 5	Construction Phase	▪ Ash backfilling has been assessed as a separate environmental authorisation project. Mitigation measures proposed from this project will be implemented in this

Significant Risk Area	Phase	Project Activity
		section
Rietspruit: Section 1	Construction Phase	▪ Construction of flood protection berm ▪ Vegetation of flood protection berm
Leeuspruit Section 2- 5 and Rietspruit Section 1	Operational Phase	▪ Revegetate area to ensure erosion does not occur ▪ Maintenance and monitoring activities ▪ Removal of all machinery and equipment utilised during construction phase ▪ Rehabilitate areas affected by laydown area and machinery ▪ Removal of waste

5.3 Construction Phase

5.3.1 Impact Description

5.3.1.1 Leeuspruit Section 2

The construction of flood protection berms at Leeuspruit Section 2 is likely to result in an alteration in the seasonality and flow of the river reaches (floodlines). The floodplain will potentially be pushed over to the east (Figure 5-1) and encroach onto the area closer to the ash dump to the north east of the section. This can potentially increase capturing of contaminants from runoff from the ash dam. The concentrated flow of water may also result in increased erosion and potential for gulley formation, loss of vegetation and increased potential for sedimentation of the freshwater resources downstream. In addition, the bare soil could potentially result in sedimentation and thereby alter water quality within the Leeuspruit.

Figure 5-1 indicates the surface mitigation measures planned for Leeuspruit Section 2 and Table 5-6 summarises potential impacts to the freshwater courses identified during the construction phase. The impact ratings are presented in Table 5-6.

Table 5-5: Identified Impacts – Leeuspruit Section 2

Activity	Impact
Berm construction	Siltation of the Leeuspruit because of increased soil exposure and disturbance during the construction of the flood protection berm can lead to impacts on the water quality of the Leeuspruit. This will further be impacted due to increased concentrated flow.
Alteration in the seasonality and flow of the river reaches (floodlines)	The floodplain will potentially be pushed over to the east (Figure 5-1) and encroach onto the area closer to the ash dump to the north east of the section. This can potentially increase capturing of contaminants from runoff from the ash dam.

Table 5-6: Impact assessment parameter ratings for the construction phase for Leeuspruit Section 2

Dimension	Rating	Motivation	Significance
Activity and Interactions: Berm Construction			
Prior to Mitigation/Management			
Duration	Project Life of 1 year (3)	Construction is planned for 12 months	Minor (negative) –

Dimension	Rating	Motivation	Significance
Extent	Local (3)	Will only affect the immediate downstream section of the Leeuspruit	63
Intensity x type of impact	Moderate, short-term effects (3)	Serious medium term environmental effects due to increased erosion and siltation. Environmental damage can be reversed in less than a year.	
Probability	Certain (7)	Should no precautionary measures be implemented, further impacts are considered certain	
Nature	Negative		
Post-Mitigation			
Duration	Less than 1 year (2)	The impact will cease between 1 and 5 years.	Negligible (negative) - 30
Extent	Limited (2)	Limited to specific isolated parts of the site.	
Intensity x type of impact	Minor effects on the biological or physical environment (2)	Due to the impacted nature of the systems present, should the appropriate precautions and management or mitigation measures be employed, the project could result in only a minor impact to the freshwater systems present	
Probability	Likely (5)	Although mitigation will reduce the intensity and duration the impact is still likely to occur.	
Nature	Negative		

Dimension	Rating	Motivation	Significance
Activity and Interactions: Alteration in the seasonality and flow of the river reaches (floodlines)			
Prior to Mitigation/Management			
Duration	Beyond Project Life (6)	The impact will cease after the life of the project has been completed.	Moderate (negative) – 91
Extent	Local (3)	Erosion and general scouring from sedimentation, as well as degraded habitat due to water quality deterioration will affect entire watercourse and river reaches.	

Dimension	Rating	Motivation	Significance
Intensity x type of impact	Serious medium term environmental effects (4)	Due to the already degraded nature of the systems present, should no management or mitigation measures be employed, activities could result in serious medium-term impacts.	
Probability	Certain (7)	Should no precautionary measures be implemented, further impacts to the water courses present are considered certain	
Nature	Negative		
Post-Mitigation			
Duration	Medium term (3)	The impact will cease between 1 and 5.	
Extent	Limited (2)	Impacts will be limited only to the local area and will be rehabilitated accordingly on completion of the construction phase.	
Intensity x type of impact	Minor effects on the biological or physical environment (2)	Due to the impacted nature of the systems present, should the appropriate precautions and management or mitigation measures be employed, the project could result in only a minor impact to the freshwater systems present	Minor (negative) - 28
Probability	Probable (4)	Should the proposed project proceed, impacts on the systems present are still considered probable.	
Nature	Negative		

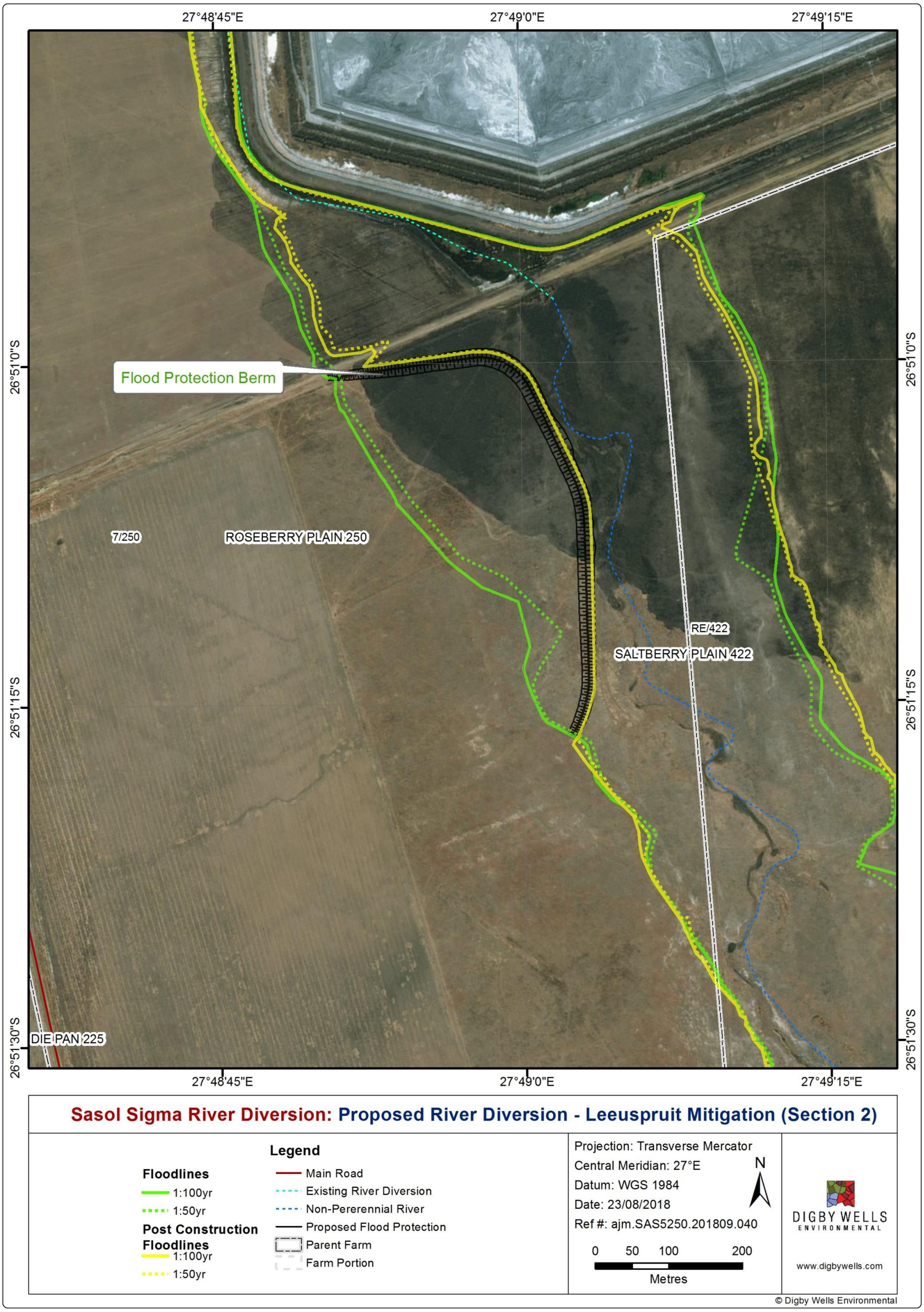

Figure 5-1: Leeuspruit Section 2 and proposed activity

5.3.1.2 Leeuspruit Section 3

The construction of flood protection berms at Leeuspruit Section 3 may result in an alteration in the seasonality and flow of the Leeuspruit. A slight narrowing of the floodplain may potentially take place as the natural seasonal flooding over the berm area is considered unlikely, thus resulting in the containment of water within a smaller area and an indirect loss of flooded area (wetland within the floodplains). The concentrated flow of water may also result in increased erosion and potential for gulley formation, loss of vegetation and increased potential for sedimentation downstream.

The largest potential impact is the excavation of the system to construct the canals. This activity is likely to result in a floodline changes (impact on wetlands) as well as large impacts in the downstream reaches of the Leeuspruit such as erosion, sedimentation and altered water quality. Natural flow will remain but the canalisation of water will increase the velocity that will start to take place during construction and this will increase erosion. Fragmentation of the system is also a risk.

Approximately 15.2 ha of floodplains (including a small portion of hillslope seep) are expected to be lost through construction of the berm and the canal.

Figure 5-2 illustrates the surface mitigation measures planned for Leeuspruit Section 3 whilst Table 5-7 summarises potential impacts to the surface water identified during the construction phase. Table 5-8 shows the impact ratings.

Table 5-7: Identified Impacts – Leeuspruit Section 3

Activity	Impact
Berm construction	Siltation of the Leeuspruit because of increased soil exposure and disturbance during the construction of the flood protection berm can lead to impacts on the water quality of the Leeuspruit. This will further be impacted due to increased concentrated flow.
Alteration in the seasonality and flow of the river reaches (floodlines)	The floodplain will potentially be pushed over to the east (Figure 5-1) and encroach onto the area closer to the ash dump to the north east of the section. This can potentially increase capturing of contaminants from runoff from the ash dam.
Canal Construction	The largest potential impact is the excavation of the system to construct the canals. This activity is likely to result in a floodline changes (impact on wetlands) as well as large impacts in the downstream reaches of the Leeuspruit such as erosion, sedimentation and altered water quality.

Table 5-8: Impact assessment parameter ratings for the construction phase for Leeuspruit Section 3

Dimension	Rating	Motivation	Significance
Activity and Interactions: Berm Construction			
Prior to Mitigation/Management			
Duration	Project Life of 1 year (3)	Construction is planned for 12 months	Minor (negative) – 63
Extent	Local (3)	Will only affect the immediate downstream section of the Leeuspruit	
Intensity x type of impact	Moderate, short-term effects (3)	Moderate impacts due to soil erosion and siltation of the downstream sections are expected.	
Probability	Certain (7)	Should no precautionary measures be implemented, further impacts are considered certain	
Nature	Negative		
Post-Mitigation			
Duration	Less than 1 year (2)	The impact will cease between 1 and 5 years.	Negligible (negative) - 30
Extent	Limited (2)	Limited to specific isolated parts of the site.	
Intensity x type of impact	Minor effects on the biological or physical environment (2)	If mitigations are implemented the intensity of the event will be reduced	
Probability	Likely (5)	Although mitigation will reduce the intensity and duration the impact is still likely to occur.	
Nature	Negative		

Dimension	Rating	Motivation	Significance
Activity and Interactions: Alteration in the seasonality and flow of the river reaches (floodlines)			
Prior to Mitigation/Management			
Duration	Beyond Project Life (6)	Floodplains will change permanently	Moderate (negative) – 91
Extent	Municipal (3)	Erosion and general scouring from sedimentation, as well as degraded habitat due to water quality deterioration will affect entire watercourse and river reaches.	
Intensity x type of impact	Serious medium term environmental effects (4)	Change of flood events and reaches of the floods will have serious medium-term impacts until the system has adapted to the changes.	
Probability	Certain (7)	Should no precautionary measures be implemented, further impacts to the water courses present are considered certain	
Nature	Negative		
Post-Mitigation			
Duration	Medium term (3)	The impact will cease between 1 and 5 years.	Negligible (negative) - 28
Extent	Limited (2)	Impacts will be limited only to the local area and will be rehabilitated accordingly on completion of the construction phase.	
Intensity x type of impact	Minor effects on the biological or physical environment (2)	Due to the impacted nature of the systems present, should the appropriate precautions and management or mitigation measures be employed, the project could result in only a minor impact to the freshwater systems present	
Probability	Probable (4)	Should the proposed project proceed, impacts on the systems present are still considered probable.	
Nature	Negative		

Dimension	Rating	Motivation	Significance
Activity and Interactions: Canal Construction			
Prior to Mitigation/Management			
Duration	Beyond Project Life (6)	Impacts will remain after life of project if no mitigations are implemented	Major (negative) – 105
Extent	Municipal (3)	Erosion and general scouring from sedimentation, as well as degraded habitat due to water quality deterioration will affect entire watercourse and river reaches.	
Intensity x type of impact	Significant impact on highly valued species, habitat or ecosystem. (6)	Increased erosion due to higher velocities will increase the intensity of the impact over time.	
Probability	Certain (7)	Should no precautionary measures be implemented, further impacts to the water courses present are considered certain	
Nature	Negative		
Post-Mitigation			
Duration	Medium term (3)	The impact will cease between 1 and 5 years.	Minor (negative) - 50
Extent	Municipal (3)	Erosion and general scouring from sedimentation, as well as degraded habitat due to water quality deterioration will affect entire watercourse and river reaches.	
Intensity x type of impact	Serious medium term environmental effects. Environmental damage can be reversed in less than a year. (4)	The impact will continue after completion of construction. Mitigation measures will however reduce the intensity of erosion and siltation as a result of increased velocity	
Probability	Likely (5)	Should the proposed project proceed, impacts on the systems present are still considered likely.	
Nature	Negative		

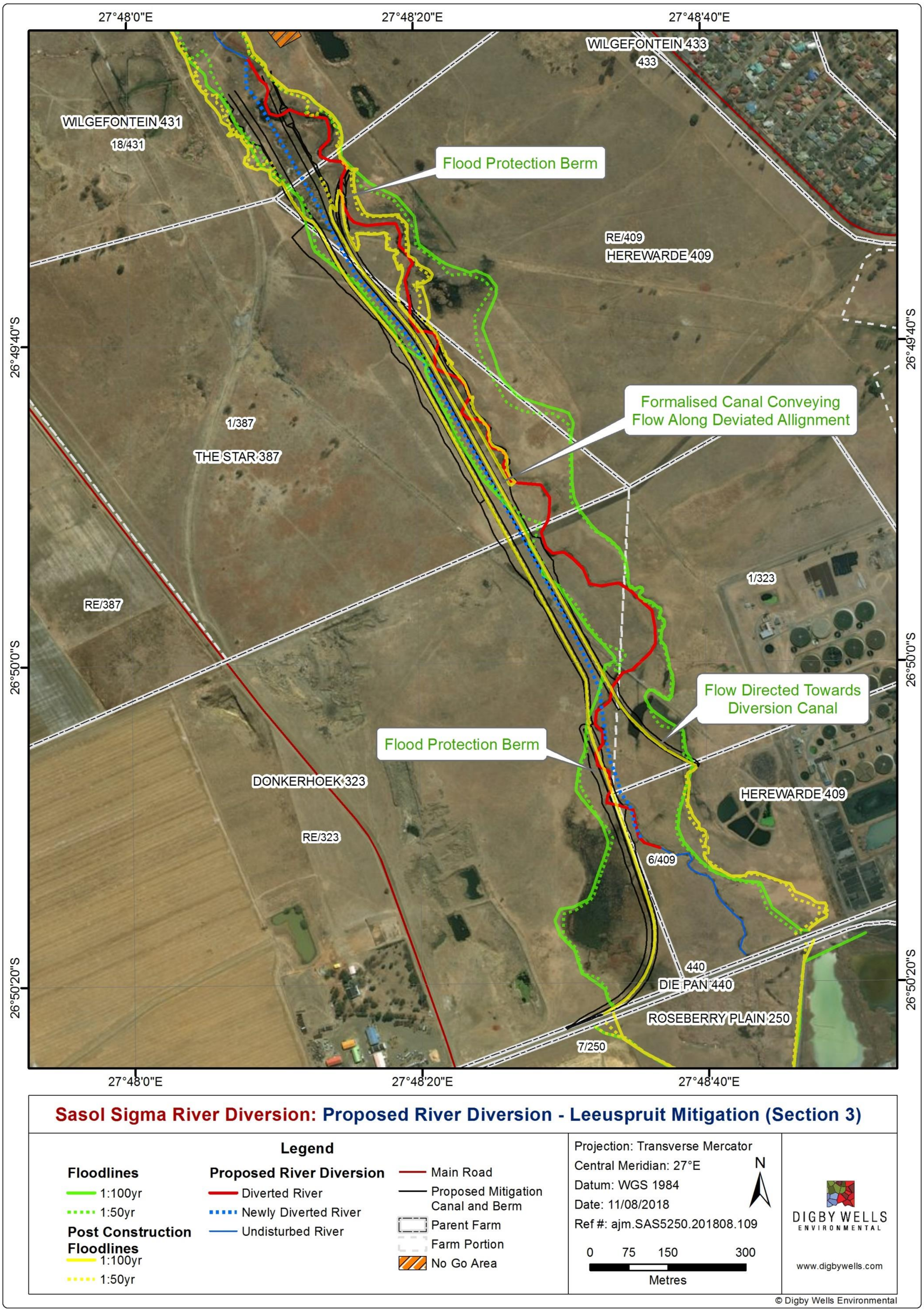

Figure 5-2: Leeuspruit Section 3 and proposed activity

5.3.1.3 Leeuspruit Section 4

The construction of flood protection berms at Leeuspruit Section 4 may result in an alteration in the seasonality and flow of the Leeuspruit. A slight narrowing of the floodplain may potentially take place as the natural seasonal flooding over the berm area is considered unlikely, thus resulting in the containment of water within a smaller area and an indirect loss of flooded area (wetland within the floodplains). The concentrated flow of water may also result in increased erosion and potential for gulley formation, loss of vegetation and increased potential for sedimentation downstream.

The largest potential impact is the excavation of the system to construct the canals. This activity is likely to result in a floodline changes (impact on wetlands) as well as large impacts in the downstream reaches of the Leeuspruit such as erosion, sedimentation and altered water quality. Natural flow will remain but the canalisation of water will increase the velocity that will start to take place during construction and this will increase erosion. Fragmentation of the system is also a risk.

Figure 5-2 illustrates the surface mitigation measures planned for Leeuspruit Section 4 whilst Table 5-9 summarises potential impacts to the surface water identified during the construction phase. Table 5-8 shows the impact ratings.

Table 5-9: Identified Impacts – Leeuspruit Section 4

Activity	Impact
Berm construction	Siltation of the Leeuspruit because of increased soil exposure and disturbance during the construction of the flood protection berm can lead to impacts on the water quality of the Leeuspruit. This will further be impacted due to increased concentrated flow.
Alteration in the seasonality and flow of the river reaches (floodlines)	The floodplain will potentially be pushed over to the east (Figure 5-1) and encroach onto the area closer to the ash dump to the north east of the section. This can potentially increase capturing of contaminants from runoff from the ash dam.
Canal Construction	The largest potential impact is the excavation of the system to construct the canals. This activity is likely to result in a floodline changes (impact on wetlands) as well as large impacts in the downstream reaches of the Leeuspruit such as erosion, sedimentation and altered water quality.

Table 5-10: Impact assessment parameter ratings for the construction phase for Leeuspruit Section 4

Dimension	Rating	Motivation	Significance
Activity and Interactions: Berm Construction			
Prior to Mitigation/Management			
Duration	Project Life of 1 year (3)	Construction is planned for 12 months	Minor (negative) – 63
Extent	Local (3)	Will only affect the immediate downstream section of the Leeuspruit	
Intensity x type of impact	Moderate, short-term effects (3)	Moderate impacts due to soil erosion and siltation of the downstream sections are expected.	
Probability	Certain (7)	Should no precautionary measures be implemented, further impacts are considered certain	
Nature	Negative		
Post-Mitigation			
Duration	Less than 1 year (2)	The impact will cease between 1 and 5 years.	Negligible (negative) - 30
Extent	Limited (2)	Limited to specific isolated parts of the site.	
Intensity x type of impact	Minor effects on the biological or physical environment (2)	If mitigations are implemented the intensity of the event will be reduced	
Probability	Likely (5)	Although mitigation will reduce the intensity and duration the impact is still likely to occur.	
Nature	Negative		

Dimension	Rating	Motivation	Significance
Activity and Interactions: Alteration in the seasonality and flow of the river reaches (floodlines)			
Prior to Mitigation/Management			
Duration	Beyond Project Life (6)	Floodplains will change permanently	Moderate (negative) – 91
Extent	Municipal (3)	Erosion and general scouring from sedimentation, as well as degraded habitat due to water quality deterioration will affect entire watercourse and river reaches.	
Intensity x type of impact	Serious medium term environmental effects (4)	Change of flood events and reaches of the floods will have serious medium-term impacts until the system has adapted to the changes.	
Probability	Certain (7)	Should no precautionary measures be implemented, further impacts to the water courses present are considered certain	
Nature	Negative		
Post-Mitigation			
Duration	Medium term (3)	The impact will cease between 1 and 5 years.	Negligible (negative) - - 28
Extent	Limited (2)	Impacts will be limited only to the local area and will be rehabilitated accordingly on completion of the construction phase.	
Intensity x type of impact	Minor effects on the biological or physical environment (2)	Due to the impacted nature of the systems present, should the appropriate precautions and management or mitigation measures be employed, the project could result in only a minor impact to the freshwater systems present	
Probability	Probable (4)	Should the proposed project proceed, impacts on the systems present are still considered probable.	
Nature	Negative		

Dimension	Rating	Motivation	Significance
Activity and Interactions: Canal Construction			
Prior to Mitigation/Management			
Duration	Beyond Project Life (6)	Impacts will remain after life of project if no mitigations are implemented	Major (negative) – 112
Extent	Municipal (3)	Erosion and general scouring from sedimentation, as well as degraded habitat due to water quality deterioration will affect entire watercourse and river reaches.	
Intensity x type of impact	Significant impact on highly valued species, habitat or ecosystem. (6)	Increased erosion due to higher velocities will increase the intensity of the impact over time.	
Probability	Certain (7)	Should no precautionary measures be implemented, further impacts to the water courses present are considered certain	
Nature	Negative		
Post-Mitigation			
Duration	Medium term (3)	The impact will cease between 1 and 5 years of.	Minor (negative) - 50
Extent	Municipal (3)	Erosion and general scouring from sedimentation, as well as degraded habitat due to water quality deterioration will affect entire watercourse and river reaches.	
Intensity x type of impact	Serious medium term environmental effects. Environmental damage can be reversed in less than a year. (4)	The impact will continue after completion of construction. Mitigation measures will however reduce the intensity of erosion and siltation as a result of increased velocity	
Probability	Likely (5)	Should the proposed project proceed, impacts on the systems present are still considered likely.	
Nature	Negative		

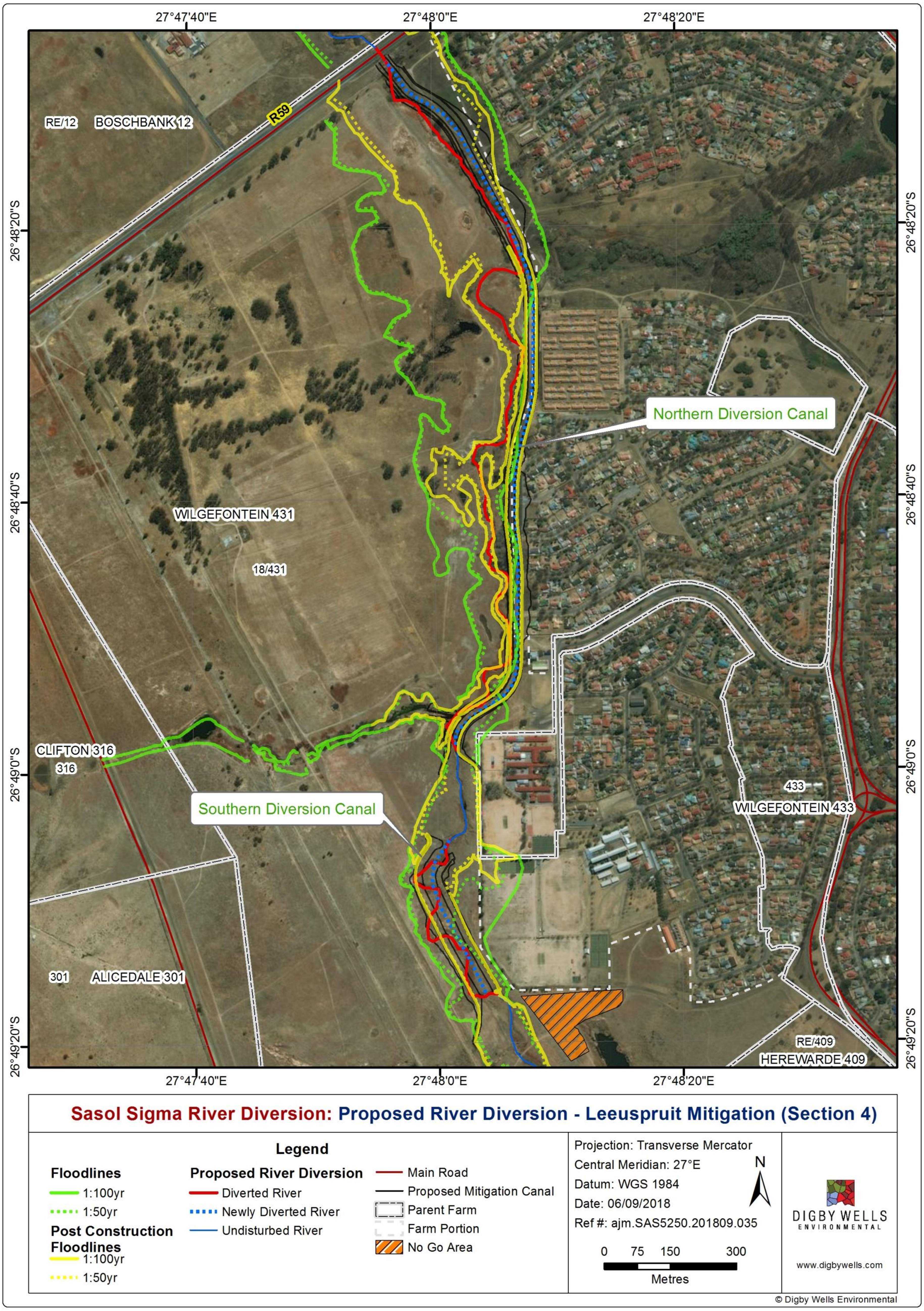

Figure 5-3: Leeuspruit Section 4 and potential activities

5.3.1.4 Leeuspruit Section 5

The backfilling of various polygons is planned for the Leeuspruit Section 5; no surface mitigation measures are planned. The backfilling has been addressed in a separate report. Figure 5-4 illustrates the surface mitigation measures planned for Leeuspruit Section 5.

It must be noted, however, that should the R59 culvert not be sufficient for a 1:10 year flood (as is the current situation), it could cause damage to the bridge and road and this may impact on the flows and velocities in turn impacting on the floodplains, wetlands and the instream habitat in Leeuspruit Section 5.

Figure 5-4: Leeuspruit Section 5 and proposed activities

5.3.1.5 Rietspruit Section 1

The construction of flood protection berms at Rietspruit Section 1 may result in an alteration in the seasonality and flow of the Rietspruit. A slight narrowing of the floodplain may potentially take place as the natural seasonal flooding over the berm area is considered unlikely, thus resulting in the containment of water within a smaller area and an indirect loss of flooded area (wetland within the floodplains). The concentrated flow of water may also result in increased erosion and potential for gulley formation, loss of vegetation and increased potential for sedimentation downstream.

Figure 5-1 indicates the surface mitigation measures planned for Rietspruit Section 1 and Table 5-6 summarises potential impacts to the freshwater courses identified during the construction phase. The impact ratings are presented in Table 5-6.

Table 5-11: Identified Impacts – Rietspruit Section 1

Activity	Impact
Berm construction	Siltation of the Rietspruit because of increased soil exposure and disturbance during the construction of the flood protection berm can lead to impacts on the water quality of the Rietspruit. This will further be impacted due to increased concentrated flow.
Alteration in the seasonality and flow of the river reaches (floodlines)	The floodplain will potentially be pushed over to the east (Figure 5-1) and encroach onto the area closer to the ash dump to the north east of the section. This can potentially increase capturing of contaminants from runoff from the ash dam.

Table 5-12: Impact assessment parameter ratings for the construction phase for Rietspruit Section 1

Dimension	Rating	Motivation	Significance
Activity and Interactions: Berm Construction			
Prior to Mitigation/Management			
Duration	Project Life of 1 year (3)	Construction is planned for 12 months	Minor (negative) – 60
Extent	Local (3)	Will only affect the immediate downstream section of the Rietspruit	
Intensity x type of impact	Moderate, short-term effects (3)	Serious medium term environmental effects due to increased erosion and siltation. Environmental damage can be reversed in less than a year.	

Dimension	Rating	Motivation	Significance
Probability	Certain (7)	Should no precautionary measures be implemented, further impacts are considered certain	
Nature	Negative		
Post-Mitigation			
Duration	Less than 1 year (2)	The impact will cease between 1 and 5 years.	Negligible (negative) - 30
Extent	Limited (2)	Limited to specific isolated parts of the site.	
Intensity x type of impact	Minor effects on the biological or physical environment (2)	Due to the impacted nature of the systems present, should the appropriate precautions and management or mitigation measures be employed, the project could result in only a minor impact to the freshwater systems present	
Probability	Likely (5)	Although mitigation will reduce the intensity and duration the impact is still likely to occur.	
Nature	Negative		

Dimension	Rating	Motivation	Significance
Activity and Interactions: Alteration in the seasonality and flow of the river reaches (floodlines)			
Prior to Mitigation/Management			
Duration	Beyond Project Life (6)	The impact will cease after the life of the project has been completed.	Moderate (negative) – 91
Extent	Local (3)	Erosion and general scouring from sedimentation, as well as degraded habitat due to water quality deterioration will affect entire watercourse and river reaches.	
Intensity x type of impact	Serious medium term environmental effects (4)	Due to the already degraded nature of the systems present, should no management or mitigation measures be employed, activities could result in serious medium-term impacts.	
Probability	Certain (7)	Should no precautionary measures be implemented, further impacts to the water courses present are considered certain	
Nature	Negative		

Dimension	Rating	Motivation	Significance
Post-Mitigation			
Duration	Medium term (3)	The impact will cease between 1 and 5.	Negligible (negative) - 28
Extent	Limited (2)	Impacts will be limited only to the local area and will be rehabilitated accordingly on completion of the construction phase.	
Intensity x type of impact	Minor effects on the biological or physical environment (2)	Due to the impacted nature of the systems present, should the appropriate precautions and management or mitigation measures be employed, the project could result in only a minor impact to the freshwater systems present	
Probability	Probable (4)	Should the proposed project proceed, impacts on the systems present are still considered probable.	
Nature	Negative		

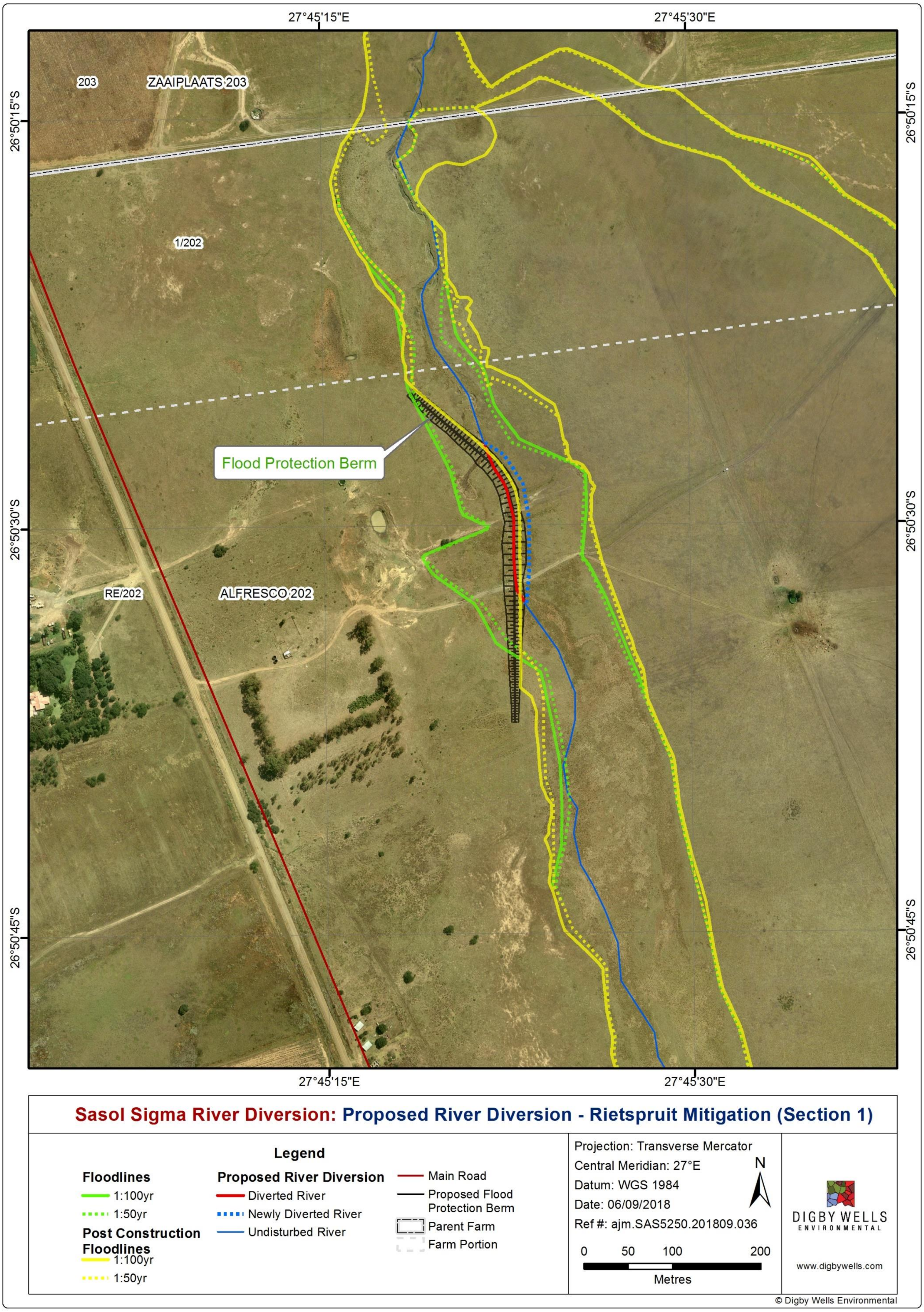

Figure 5-5: Rietspruit Section 1 and proposed activities

5.3.1.6 All sections

Activities associated with the construction of these surface mitigation measures includes site clearing, soil disturbance, topsoil stockpiling, storage and dumping of building materials, compaction of soils and crossing of the wetland and river systems. Associated potential impacts include erosion and sedimentation, the potential further loss of biodiversity and habitat, fragmentation of the systems present a potential loss of catchment yields, loss of migration routes and surface water recharge to the systems further downstream. Among the impacts associated with the proposed construction phase are minor potential impacts to soil and water quality because of the ingress of hydrocarbons. Larger impacts include compaction of soils, potential loss of vegetation and the increased potential for erosion and sedimentation near any cleared areas and resulting in impacts further downstream.

Table 5-13 summarises potential impacts to the freshwater ecology identified during the construction phase.

Table 5-13: Impact assessment parameter ratings for the construction phase for all sections

Dimension	Rating	Motivation	Significance
Activity and Interactions: Site access and disturbance			
Prior to Mitigation/Management			
Duration	Project Life of 1 year (3)	Construction is planned for 12 months	Minor (negative) – 66
Extent	Greater municipal area (4)	General scouring from sedimentation, as well as degraded habitat due to water quality deterioration will affect entire watercourse and river reaches.	
Intensity x type of impact	Serious medium term environmental effects (4)	Due to the already degraded nature of the systems present, should no management or mitigation measures be employed, activities could result in serious medium-term impacts.	
Probability	Almost certain (6)	Should no precautionary measures be implemented, further impacts to the wetlands present are considered highly probable.	
Nature	Negative		
Post-Mitigation			
Duration	Project Life of 1 year (3)	Construction is planned for 12 months	Negligible (negative) - 32

Dimension	Rating	Motivation	Significance
Extent	Limited (3)	Impacts will be limited only to the local area and will be rehabilitated accordingly on completion of the construction phase.	
Intensity x type of impact	Minor effects on the biological or physical environment (2)	Due to the impacted nature of the systems present, should the appropriate precautions and management or mitigation measures be employed, the project could result in only a minor ecological impact to the wetland systems present	
Probability	Probable (4)	Should the proposed project proceed, impacts to the ecological integrity of the systems present are still considered probable.	
Nature	Negative		

5.3.2 Construction Phase Mitigation and Management Measures

The following mitigation and management measures have been prescribed for the construction phase:

5.3.2.1 Berms

- Sufficient drains need to be installed to facilitate seepage underneath berms;
- Clearing of vegetation must be limited to the development footprint;
- Dust suppression measures must be implemented on the cleared areas during construction
- Berms should be monitored after large rainfall events to ensure that they are draining sufficiently;
- Berms should be reseeded with indigenous grasses to prevent erosion;
- In high erosion areas, mulch or hessian should be used to protect the soil and growth of new seedlings; and
- All erosion noted along berms should be remedied immediately and included as part of a rehabilitation plan.

5.3.2.2 Canal

- It should be ensured that energy dissipation measures be installed to slow and spread the flow of water at discharge points to reduce the potential for erosion and to assist with infiltration;

- Furthermore, it is deemed critical that regular care and maintenance of the canal be undertaken to ensure no build-up of litter and debris, which would affect the flow of the system and negate any efforts at maintaining migrations routes and flow connectivity.

5.3.2.3 General

- Ensure soil management programme is implemented and maintained to minimise erosion and sedimentation;
- During the construction phase, erosion berms should be installed on roadways and downstream of stockpiles to prevent gully formation and siltation of the freshwater resources. The following points should serve to guide the placement of erosion berms:
  - Where the track has a slope of less than 2%, berms every 50m should be installed;
  - Where the track slopes between 2% and 10%, berms every 25m should be installed;
  - Where the track slopes between 10%-15%, berms every 20m should be installed; and
  - Where the track has slope greater than 15%, berms every 10m should be installed.
- Limit the footprint area of the construction activities to what is essential to minimise impacts because of vegetation clearing and compaction of soils (all areas but critically so in wetland areas);
- All erosion noted within the construction footprint should be remedied immediately and included as part of an ongoing rehabilitation plan;
- Active rehabilitation, re-sloping, and re-vegetation of disturbed areas immediately after construction;
- All soils compacted because of construction activities should be ripped/scarified (<300mm) and profiled (see the Soil Specialist Report for more information);
- Permit only essential personnel within the 100m zone of regulation for all freshwater features identified;
- No unnecessary crossing of the wetland features and their associated buffers should take place and the substrate conditions of the wetlands and downstream stream connectivity must be maintained;
- No material may be dumped or stockpiled within any rivers, tributaries or drainage lines;

- No vehicles or heavy machinery may be allowed to drive indiscriminately within any wetland or instream areas and their associated zones of regulation (notwithstanding those areas to be directly impacted upon because of the proposed activities). All vehicles must remain on demarcated roads and within the construction footprint;
- All vehicles must be regularly inspected for leaks;
- Re-fueling must take place at a diesel facility, on a sealed surface area away from wetlands to prevent ingress of hydrocarbons into topsoil;
- All spills should be immediately cleaned up and treated accordingly; and
- Appropriate sanitary facilities must be provided for the duration of the construction activities and all waste must be removed to an appropriate waste facility.

5.4 Operational Phase

5.4.1 Impact Description

The only activities to take place during the operational phase are monitoring and maintenance. Once the construction phase is completed a loss of catchment yield during operation is not seen as probable due to the same volumes of water being transferred downstream with only changes to the route. The only change will be the velocity of the flow that will lead to potential increased erosion that will be mitigated through the implementation of the measures put in place during the construction phase.

The main activities during the operational phase that could result in impacts to the surface water of the area are associated with the monitoring and maintenance activities. This include the site access and roads to be used for monitoring and maintenance as well as any minor earth works to rectify/maintain any changes to the berms/canals that was constructed due to high flow or extensive erosion. This will however be of short duration.

If large maintenance on berms or canals are required (extensive damage from floods) the impacts identified for the construction phase will again be applicable (refer to section 5.3). If the maintenance does occur the mitigation measured proposed during the construction phase should again be implemented.

5.4.2 Operational Phase Mitigation and Management Measures

The following mitigation and management measures have been prescribed for the operational phase:

5.4.2.1 Berms

- Flood protection berms should be monitored after large rainfall events / monthly to ensure that they are not being eroded by the stream channels (Leeuspruit Section 2, Section 3 and Rietspruit Section 1) thereby reducing the functionality and health of the surface water environment;

- Slow release outlet pipes installed within the berm should be monitored to ensure that any blockages are discovered and removed; and
- Berms should be monitored for erosion. Erosion must be remedied. If recurring erosion is taking place, alternatives should be explored.

5.4.2.2 Canal

- Monitoring the effectiveness of the canals by a suitably qualified engineer.

5.4.2.3 General

- Limit the footprint area of the operational activities to what is essential to minimise impacts because of any potential vegetation clearing and compaction of soils (all areas but critically so in freshwater areas);
- If it is unavoidable that any of the freshwater areas present will be affected, disturbance must be minimised and suitably rehabilitated;
- Ensure that no incision and canalisation of the freshwater features present takes place because of the proposed operational activities;
- All erosion noted within the operational footprint because of any potential surface activities should be remedied immediately and included as part of the ongoing rehabilitation plan (see Rehabilitation Report);
- No unnecessary crossing of the wetland features, instream areas and their associated buffers, as well as the constructed berms or canals should take place and the substrate conditions of the wetlands, instream areas and downstream stream connectivity must be maintained;
- No vehicles or heavy machinery may be allowed to drive indiscriminately within any freshwater areas and their associated zones of regulation. All vehicles must remain on demarcated roads;
- Monitor all systems for erosion and incision;
- All erosion noted within the footprint should be remedied immediately and included as part of an ongoing rehabilitation plan;
- Ensure soil management programme is implemented and maintained to minimise erosion and sedimentation;
- All soils compacted because of construction activities should be ripped/scarified (<300mm) and profiled (see the Soil Specialist Report for more information); and
- Permit only essential personnel within the 100m zones of regulation for all freshwater features identified.

5.5 No Go Alternative

Areas that have a significant potential for pillar failure can result in subsidence in those areas that will lead to seepage/flow from the Leeuspruit and Rietspruit into the underground workings. The last-mentioned impact will influence the catchment yield downstream because of flow losses to the underground.

The impact of not going ahead with the project is thus much higher than the impacts during construction of the proposed surface activities. If the project goes ahead some impacts on the floodplains, water quality and erosion will occur but this can be mitigated and managed. The impact on the volumes of flow and the catchment yield is negligible compared to the loss of water if subsidence occurs and the stream flow is lost to the underground working. This last-mentioned event will almost certainly reduce catchment yield and flow from the Leeuspruit and Rietspruit to 0.

Thus, although negative impacts do exist they are short term and can be mitigated. The no-go alternatives impacts cannot be mitigated.

The impact rating for the no go alternative is provided in Table 5-14. If the project does not go ahead the impact will be major. If the project does go ahead impacts will still exist but be of shorter duration with less intensity and thus have less of an impact (moderate impact).

Table 5-14: Impact rating table for the No Go Alternative

Dimension	Rating	Motivation	Significance
Activity and Interactions: No-go alternative – potential pillar failure which could result in subsidence			
Prior to Mitigation/Management			
Duration	Permanent (7)	The impact may be irreversible and has the potential to remain after the life of the project. Freshwater resource habitat and function may be destroyed.	Major (negative) - 126
Extent	Region (5)	The no-go option may have a regional impact due to decreased catchment yield to the Vaal River.	
Intensity x type of impact	Irreplaceable loss or damage to biological resources, limiting ecosystem function (6)	Loss of water, decline in water quality and loss of natural habitat may be irreplaceably lost, thereby limiting ecosystem form and function throughout the system and reducing the habitat for instream ecology	

Dimension	Rating	Motivation	Significance
Probability	Definite (7)	Severe impacts to the system may occur should no mitigation measures be implemented to prevent subsidence.	
Nature	Negative		
Post-Mitigation			
Duration	Permanent (7)	The impact is irreversible and will remain after the life of the project. Freshwater resource habitat and function will be destroyed.	Moderate (negative) -98
Extent	Local (3)	Habitat loss within the canals will affect the local watercourse and river reaches directly downstream.	
Intensity x type of impact	Serious loss and of biological resources or moderately sensitive environments, limiting ecosystem function. (4)	Impact on water quality and siltation of the rivers will still cause some serious impacts to the ecology and wetlands.	
Probability	Definite (7)	Severe impacts to the system may occur	
Nature	Negative		

6 Surface Water Monitoring Plan

Implementing a monitoring programme as a management tool is of great importance as it facilitates the detection of negative impacts as they arise and ensure that the necessary mitigation measures are implemented. This programme serves as an early detection tool for surface water quality as well as when the mitigation must be carried out. Sigma Defunct Colliery has an existing monitoring programme in place. It is proposed that monitoring should be implemented throughout the project (12 months) as well as during operation (at least 3 years or until impacts are not identified through monitoring). The impacts on water quality will be determined by benchmarking the monitoring data against the Leeu/Taaiboschspruit Water Quality Guidelines RWQO to determine any impact on the quality of water (positive/negative). The surface water monitoring plan is summarised in

Table 6-1.

Table 6-1: Surface Water Monitoring Pan

Monitoring Element	Comment	Frequency	Responsibility
Water quality	Ensure water quality monitoring as per existing monitoring program and all the locations indicated in Table 3-4. Parameters should include but not limited to the components displayed in Table 3-3	-Monthly during construction -Monitoring needs to carry on three years after the project has ceased, as is standard practice to detect residual impacts.	Environmental Officer
Physical structures (diversion channels and proposed berms)	Overflows and system malfunctions should be monitored by personnel and mitigated appropriately.	Continuous monthly process for at least 3 years after construction	Environmental Officer
	Protection berms and diversion canals are inspected for silting and blockages of inflow pipelines for hydraulic integrity;		

7 Conclusions

The following conclusions can be reached from the baseline and impact assessment studies discussed and summarised in this report.

7.1 Baseline Conclusions

7.1.1 Project Hydrological Setting

- The Sigma Defunct Colliery falls under the jurisdiction of the Metsimaholo Local Municipality (MLM) situated in the Fezile Dabi District Municipality (FDDM) close to the town of Sasolburg.

- The site is mainly used for agricultural purposes including cattle and crop farming. Other land uses within the mining licence area include a tannery, a commercial feedlot, a sand mining operation, a property let to privately owned businesses and farmhouses.
- Specifically, to the northern section of the Leeuspruit, a large portion of the site is owned by Sasol Mining and is used as a game farm.
- The proposed project area is located within the Water Management Area (WMA) of the Upper Vaal River system. The proposed area is located within the secondary drainage C2 in quaternary catchment C22K.
- Mean annual runoff (MAR) after evaporation and recharge is 3%. The mean annual precipitation (MAP) is 644 mm with a mean annual evaporation (MAE) of 1 625 mm. The natural water balance is thus a negative one with evaporation being much higher than rainfall.
- The area is characterised by warm summers and cold winters and has an average annual rainfall of 644 mm which occurs mainly during the summer months (December to February).

7.1.2 Water Quality

- Leeuspruit:
  - Monitoring points SIG/1 (downstream) and SIG/2 (upstream) represents the water quality of the Leeuspruit. In addition, SIG/5 and SIG/6 monitors a tributary of the Leeuspruit that flows from the east and joins the Leeuspruit between the SIG/1 and SIG/2 monitoring points.
  - This last-mentioned tributary as well as the Leeuspruit is directed past an ash dam and old coal stockpiles before joining each other at the confluence point directly downstream of the ash dam which can potentially influence the water quality of the Leeuspruit and change the chemistry slightly between SIG/2 and SIG/1.
  - The water type of both SIG/1 and SIG/2 can be described as sodium-bicarbonate water with SIG/1 (downstream) more enriched with sulphate (SO4) than that of the upstream point SIG/2. The upstream point of the tributary (SIG/5) also has lower SO_4 concentration that the downstream point (SIG/6).
  - Changes in pH and occasional peaks in SO_4 for the downstream points above the guideline values confirms the conclusion that the ash dam does have some influence on the water quality during high rainfall and runoff periods;
  - In general, from the trend graphs it can be concluded that in the last 12 month there is a general trend of deteriorating water qualities in a downstream direction of both the Leeuspruit and its tributary that can be due to the contribution of the

ash dam and coal stockpiles located at 3 Shaft Complex operated by Mooikraal Colliery;

- From the other parameters analysed and compared against the water quality guidelines in January 2018 all are within a tolerable range excluding sodium (Na), manganese (Mn), nitrate (NO_3), phosphate (PO_4) and total suspended solids (TSS) that are at unacceptable levels for the Leeuspruit and its tributary. Faecal coliform is also above guideline values in both drainages.

- Rietspruit:
  - The upstream monitoring point of the Rietspruit is represented by SIG/4 with the downstream point being SIG/3. Mainly farming activity occurs between these two points with only underground mining that was part of the Sigma Defunct Colliery being the other activities.
  - Both sampling points show a calcium-bicarbonate water type with only a change in alkalinity from upstream to downstream. This can be due to various factors but none that will impact on the quality of the water;
  - Generally, the water quality trends do however remain stable and the water quality shows no significant changes over time;
  - Fluoride (F), aluminium (Al), iron (Fe), Mn, PO_4, ammonium (NH_4) and TSS exceed the recommended guideline limits. F, Al, Fe and Mn will be due to ion exchange reactions with the stream sediments. PO_4 and NH_4 will be from animal activity;
  - Faecal coliforms exceed the guideline values but this is normal for natural streams flowing through areas with human, farming and animal activities; and
  - The Rietspruit water quality has generally remained stable and within the ranges of background data.

- Vaal River:
  - Both the Vaal Upstream and Downstream points are characterised as sodium-sulphate water.
  - The downstream monitoring point does show occasional spikes in Cl and pH that can potentially be due to the influence of the Leeuspruit. This is however not frequent and thus not proven.
  - All other constituents are well within the recommended guideline ranges except for TSS. TSS can increase during periods when river flow rates and levels increase and decrease with the velocity of the river being at a rate at which suspended solids are transported downstream.
  - The general trend observed is that the upstream sampling point water quality is generally worse than that of the downstream point. This is unusual if you

consider the contribution of the Leeuspruit and its tributary with the contaminated water from the ash dams and coal stockpiles. This does however show that the Vaal River is already impacted by upstream activities that include mining, sewage discharge and general human impacts from settlements.

- From current data it can be concluded that water from the project area flowing down the Leeuspruit and Rietspruit does not have a significant impact on the Vaal River quality.

7.1.3 Stream Flows

- Jones & Wagner calculated various flow peaks (from 1:2 year event up to 1:100 year event) for the design of the flood protection berms and diversion canals. The design criteria and flows used will ensure that:
  - Downstream yield increase or reduction will have a variance of less than 1%; and
  - Change in peak flow rate will be less than 5%.
- With the above design criteria, the proposed infrastructure will have almost no effect on the water volumes reporting downstream to the remaining Leeuspruit/Rietspruit sections as well as the Vaal River. However, flow velocities will increase and the floodlines will change from the current natural floodlines.

7.2 Impact Assessment Conclusions

Based on the proposed surface mitigation activities the main impact on the surface water environment will be during the construction phase of the project. After the completion of the construction (12-month construction period) it is of the specialist's opinion that the stream flow volumes and catchment yield will not be influenced with only minor impacts expected due to increased velocity due the channelling of water. The following impacts have been identified as part of the construction phase of the project:

Activity	Impact
Berm construction	Siltation of the Leeuspruit because of increased soil exposure and disturbance during the construction of the flood protection berm can lead to impacts on the water quality of the Leeuspruit. This will further be impacted due to increased concentrated flow.
Alteration in the seasonality and flow of the river reaches (floodlines)	Changes in the floodplain due to a change in the flow path will result in impacts on the wetlands, erosion of new areas that can lead to siltation and water quality changes.
Canal Construction	The largest potential impact is the excavation of the system to construct the canals. This activity is likely to result in a floodline changes (impact on wetlands) as well as large impacts in the downstream reaches of the Leeuspruit such as erosion, sedimentation and altered water quality.

The mitigation measures of the above impacts as well as any additional general impacts are proposed under the specialist recommendations.

8 Recommendations

The following is recommended to manage the potential impacts of the proposed surface mitigation activities:

- Clearing of vegetation must be limited to the development footprint;
- Dust suppression measures must be implemented on the cleared areas during construction;
- Reprofile the slopes to mimic the natural topography;
- Berms and cleared areas should be reseeded with indigenous grasses to prevent erosion;

- In high erosion areas, mulch or hessian should be used to protect the soil and growth of new seedlings; and
- All erosion noted within the construction footprint should be remedied immediately and included as part of an ongoing rehabilitation plan.
- Sufficient drains need to be installed to facilitate seepage underneath berms;
- Berms should be monitored after large rainfall events to ensure that they are draining sufficiently;
- It should be ensured that energy dissipation measures be installed to slow and spread the flow of water at discharge points to reduce the potential for erosion and to assist with infiltration;
- Furthermore, it is deemed critical that regular care and maintenance of the canal be undertaken to ensure no build-up of litter and debris, which would affect the flow of the system and negate any efforts at maintaining migrations routes and flow connectivity.
- Ensure soil management programme is implemented and maintained to minimise erosion and sedimentation;
- During the construction phase, erosion berms should be installed on roadways and downstream of stockpiles to prevent gully formation and siltation of the freshwater resources. The following points should serve to guide the placement of erosion berms:
  - Where the track has a slope of less than 2%, berms every 50m should be installed;
  - Where the track slopes between 2% and 10%, berms every 25m should be installed;
  - Where the track slopes between 10%-15%, berms every 20m should be installed; and
  - Where the track has slope greater than 15%, berms every 10m should be installed.
- Limit the footprint area of the construction activities to what is essential to minimise impacts because of vegetation clearing and compaction of soils (all areas but critically so in wetland areas);
- Active rehabilitation, re-sloping, and re-vegetation of disturbed areas immediately after construction;
- Permit only essential personnel within the 100m zone of regulation for all freshwater features identified;

- No unnecessary crossing of the wetland features and their associated buffers should take place and the substrate conditions of the wetlands and downstream stream connectivity must be maintained;
- No material may be dumped or stockpiled within any rivers, tributaries or drainage lines;
- No vehicles or heavy machinery may be allowed to drive indiscriminately within any wetland or instream areas and their associated zones of regulation (notwithstanding those areas to be directly impacted upon because of the proposed activities). All vehicles must remain on demarcated roads and within the construction footprint;
- All vehicles must be regularly inspected for leaks;
- Re-fueling must take place at a diesel facility, on a sealed surface area away from wetlands to prevent ingress of hydrocarbons into topsoil;
- All spills should be immediately cleaned up and treated accordingly; and
- Appropriate sanitary facilities must be provided for the duration of the construction activities and all waste must be removed to an appropriate waste facility.
- The proposed monitoring plan outlined in this report as well as the wetland, aquatic and soil specialist reports should be implemented.

9 References

Digby Wells Environmental (DWE), 2018. Sasol Mining Sigma Defunct Colliery Ash Backfilling Project, Sasolburg, Free State Province. Surface Water Assessment Report. Project Number SAS5184

IGS, 2018. Sigma Colliery: Water Monitoring Report for Sigma Colliery Operations January 2018. Report No. 41

J&W, 2018. Sigma Defunct Mine Closure Leeuspruit and Rietspruit Ingress Mitigations Feasibility Design Report. Report No.: JW030/18/F903 - Rev 0