DIGBY WELLS
ENVIRONMENTAL

# Environmental Regulatory Process in terms of the Thubelisha, Trichardtsfontein and Vaalkop Mining Right areas

## Groundwater Report

**Project Number:**

SAS3869

**Prepared for:**

Sasol Mining (Pty) Ltd

January 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: | Groundwater Report |
|---|---|
| Project Name: | Environmental Regulatory Process in terms of the Thubelisha, Trichardtsfontein and Vaalkop Mining Right areas |
| Project Code: | SAS3869 |

| Name | Responsibility | Signature | Date |
|---|---|---|---|
| Ayabonga Mpelwane | Report Writer | | 24 January 2018 |
| Robel Gebrekristos | Reviewer | | 24 January 2018 |

# EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) has been appointed by Sasol Mining (Pty) Ltd (hereafter Sasol) to undertake a Section 102 process in accordance with the Mineral and Petroleum Resources Development Act (MPRDA), in support of the required environmental authorisations required for four ventilation shafts, amendment of the Trichardtsfontein EMPR and the consolidation of the Twistdraai Colliery: Thubelisha Shaft EMPR, Vaalkop EMPR and the Trichardtsfontein EMPR. This groundwater report forms part of the environmental regulatory process to assess the potential impacts and mitigation plans pertaining to the groundwater environment during the construction (where this is found to be relevant), operation and closure phase of these mines.

High extraction mining using conventional bord-and-pillar mining followed by pillar extraction is currently being conducted at TCTS. Sasol proposes the same approach to be conducted at Trichardtsfontein and Vaalkop. Bord-and pillar extraction is associated with a risk of subsidence, however high extraction is susceptible to an even higher risk of subsidence. Subsidence poses a high risk to the groundwater environment due to fracturing of the overlying stratigraphy and increased geological permeability, increased groundwater recharge and increased contamination plume due to the disturbed area being larger.

Digby Wells conducted a hydrocensus (April 2017), and found that a total of 82 boreholes were located within the area of interest, with 19 being selected for local groundwater quality sampling and analysis. Groundwater was characterised as predominantly calcium-magnesium-bicarbonate type, consistent with previous investigations conducted at the project area. This indicates the occurrence of freshly recharged aquifers. The groundwater flow direction at the Olifants River Catchment, where the majority of the project area is located, is south-east to north-west. Minor portion of the project area are located in the Upper Vaal River Catchment and groundwater flows towards the south-west.

Digby Wells conducted slug tests at Trichardtsfontein (December 2013) to investigate the hydraulic conductivity of the shallow aquifers. The investigations concluded that hydraulic conductivity is approximately 0.05 m/d. On June 2017 slug tests were conducted by Digby Wells at Vaalkop the harmonic mean hydraulic conductivity of the aquifer was estimated at 0.06 m/d. The harmonic mean hydraulic conductivity of the aquifers at Thubelisha is estimated at 0.013 m/d (JMA, 2008).

The impact assessment, of the cone of depression and potential groundwater contamination plume as a result from the proposed mining activities, was conducted based on a numerical model which yielded the following findings:

- The cone of depression predominantly impacts the deep fractured aquifer. The weathered aquifer is impacted to lesser extent in isolated areas from dewatering due to the low vertical and horizontal hydraulic conductivity of the local aquifers.

- During dewatering the mine void receives groundwater inflows. The model predicts inflows ranging from 1 to 98 L/s over the duration of 39 years of mining throughout the entire project area.
- Post operation when dewatering is discontinued the hydraulic head recovers and groundwater flow reverts to its natural groundwater flow direction, however the contamination plume is confined within the project area at 100 years post closure because of the low hydraulic conductivity of the deep fractured aquifer.
- Post operation when dewatering is discontinued the hydraulic head is expected to recover. No decant is expected at the shafts however subsidence, sinkholes and unsealed deep boreholes give rise to potential decant locations throughout the project area.
- Impacts from the cone of depression and contamination plume are predominantly contained in the project area and immediate surrounding, this is attributed to the deeper fractured aquifer (where most of coal seam is located) having characteristics of very low hydraulic conductivity.

The recommended mitigation plans during the construction phase include:

- Site clearing should be restricted to areas absolute necessity and the activity should be conducted over a short duration;
- Site clearance and construction activities should take place above the water table (if possible), as then no impact on the groundwater will be expected;
- If trenches are going to be excavated below the water level, dewatering of the aquifer to lower the water table locally should be considered to ensure that the construction takes place above the groundwater level.

The recommended mitigation plans during the operation phase include:

- Dewatering should be conducted by abstracting groundwater ingress into mine voids during operation;
- Nitrate-based explosives can contaminate water thus no underground water should be discharged unless it meets standards to minimise ground and surface water contamination;
- If subsidence occurs during operation, it should be rehabilitated as soon as possible to minimise water and oxygen inflow from the atmosphere, as these components enable AMD reactions;
- Mine safety factors should be such that subsidence is limited or planned for and managed;
- Contaminated mine water should be stored in pollution control dams.

The following mitigation and management measures are recommended with regards to subsidence:

- In order to prevent subsidence during the bord-and-pillar mining phase, it is required that a safety factor that provides sufficient pillar stability is applied;
- The mine should be monitored on an annual basis for subsidence and areas of subsidence should be rehabilitated by backfilling with waste rock and topsoil thereafter revegetated;
- If possible, concurrent backfilling of the mine voids with fly ash should be conducted to minimise the risk of subsidence and neutralise any acid that might be generated; and
- Groundwater level and quality monitoring should be conducted on quarterly basis during operation, with special attention given to the subsidence areas. The monitoring frequency can be reduced post-closure depending on the trend of the monitoring results.

During the closure/post-closure phase management solutions should be sought in agreement with the farmers or communities with impacted groundwater.

Recommended mitigation activities proposed for the construction, operational and closure phase include:

- Groundwater monitoring should be conducted to assess the time series water level, water quality impacts and to observe trends to aid decision making;
- Annual monitoring for subsidence and sinkhole formation is highly recommended, followed by rehabilitation if required and decant monitoring at unsealed deep boreholes (greater than 30 mbgl in depth);
- The mine working should be designed to be stable in the long term or where high extraction is planned in areas that these can be well managed in a sustainable fashion;
- During operation, the numerical model should be updated every two years in the first four years and thereafter every five years based on groundwater monitoring results and updated every 5 years to calibrate with monitoring results post closure.

# TABLE OF CONTENTS

# LIST OF FIGURES



# LIST OF TABLES

# LIST OF APPENDICES

# 1 Introduction

Digby Wells Environmental (hereafter Digby Wells) has been appointed by Sasol Mining (Pty) Ltd (hereafter Sasol) to undertake a Section 102 process in accordance with the Minerals and Petroleum Resources Development Act (MPRDA), in support of the required environmental authorisations for the proposed Thubelisha Project.

The proposed project entails:

- The excavation of four ventilation shafts;
- Amendment of the Trichardtsfontein EMPR; and
- The consolidation of the Twistdraai Colliery: Thubelisha Shaft (hereafter TCTS) EMPR, Vaalkop EMPR and the Trichardtsfontein EMPR.

This groundwater report forms part of the environmental regulatory process to assess the potential impacts and mitigation plans pertaining to the groundwater environment during the construction (where this is found to be relevant), operation and closure phase of the mines.

## 1.1 Project Background

Sasol Mining (Pty) Ltd (Sasol Mining) holds mining rights for the Twistdraai Colliery: Thubelisha Shaft (TCTS) and the Vaalkop mining area, which were both incorporated into the regional Sasol Mining Right (Ref: MP30/5/1/2/2/138MR). It must be noted that no EMPr was compile for the Vaalkop mining right area even though a mining right was approved. Further to this, the mining right for the Trichardtsfontein Mine (Ref: MP30/5/1/2/2/10056MR) was ceded from Glencore Operations South Africa (Pty) Ltd in accordance with Section 11 of the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA) to Sasol Mining. Sasol Mining is proposing that the Trichardtsfontein mining right area be incorporated into the regional Sasol Mining Right (Ref: MP30/5/1/2/2/138MR). Therefore all mining right areas will operate under a single mining right (Sasol Mining Right).

It is therefore required that the Environmental Management Programme Reports (EMPrs) for the above mentioned mining right areas be compiled (Vaalkop), consolidated and updated to reflect changes in the mining plans and methodologies and consider additional infrastructure requirements.

The mining method which is currently being undertaken at TCTS includes bord and pillar mining method as well as high extraction mining in some areas. This mining method has also been proposed for Vaalkop. However, the mining method proposed for the extraction of coal at Trichardtsfontein only included the conventional bord-and-pillar method, with the use of continuous miners feeding shuttle cars.

Twistdraai Thubelisha is now proposing that in addition to the bord-and-pillar mining method, high extraction mining will be undertaken at the Trichardtsfontein Mine. Since this activity was excluded from the previous approved EMPr (2014), an amendment of the Trichardtsfontein EMPr is required to identify and assess the impacts associated with high extraction mining, particularly relating to surface subsidence. Sasol Mining therefore undertook the required specialist studies to determine the impact that may be experienced from high extraction mining methods.

Bord-and pillar extraction is associated with a risk of subsidence, however high extraction is susceptible to an even higher risk of subsidence. Areas of high extraction potentially encounter the following impacts as a result of disturbance caused by subsidence:

- Fracturing of the overlying stratigraphy and;
- Increased geological permeability.

The groundwater environment is then subjected to the following:

- Increased groundwater recharge;
- Potential increase of decant rates; and
- Expansion of the contamination plume into the weathered aquifer in areas where it would have not been expected if there was no subsidence.

Additionally it is proposed that Twistdraai Thubelisha will construct two ventilation shafts at TCTS (known as East ventilation shaft) and two ventilation shafts on Trichardtsfontein (known as South ventilation shaft). A Listed activity under listing notice 1 is considered to be triggered in accordance with the new Environmental Impact Assessment (EIA) Regulations, 2014 (As amended) promulgated in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) for the construction and operation of the ventilation shafts.

Digby Wells is therefore proposing a submission in terms of the provisions of Section 102 of the MPRDA and Regulation 31 of the EIA regulations, 2014 (as amended) promulgated in accordance with the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) to obtain the required authorisation for both the amendment and consolidation process of the EMPrs (referred to in general as the Environmental Authorisation (EA) Amendment process). A basic assessment process will also be undertaken to obtain environmental authorisation for the construction and operation of the ventilation shafts. This will be undertaken as a consolidated process in accordance with the one environmental system.

## 1.2 Scope of Work

The overall scope of work for the Thubelisha Project is to consolidate groundwater studies of the TCTS EMPR, Vaalkop EMPR and the Trichardtsfontein EMPR, presenting the following outcomes:

- A description of the project area baseline conditions;
- Delineation of the radius of influence on groundwater levels as a result of mine dewatering;

- Calculate the volume of groundwater that may seep into mine workings during mining;
- Predict the long-term impact of the mining activities on groundwater quality;
- Identify the impact of mine dewatering on private groundwater users as well as rivers and streams (receptors);
- Predict the timing and location of decant from the underground workings post closure;
- Use the model outputs to rate potential groundwater impacts due to mining based on significance scoring before and after mitigation methods are implemented; and
- Recommend management measures to minimise impacts of the mine on the groundwater environment.

# 2 Investigation Methodology

## 2.1 Desktop Study

During this task, all available data for the project area was collected and reviewed. This included all geological and hydrogeological reports. Information cited in this report is based on the following groundwater reports:

- Digby Wells, 2014, Trichartsdfontien EIA/EMP DMR Directive – Groundwater Study;
- JMA Consulting, 2008, Compilation of Geology and Groundwater Inputs for the Twistdraaai Colliery: Thubelisha Shaft; and
- Institute of Groundwater Studies, 2014, Acid-Base Accounting Report for Twistdraai Thubelisha Shaft;
- Institute of Groundwater Studies, 2016, Sasol Secunda Synfuels (SSO) Hub and Mining Pollution Plume Model.

## 2.2 Hydrocensus

A hydrocensus was conducted in April 2017, by Digby Wells. During the hydrocensus important data pertaining to the current groundwater conditions and use were collected. These include:

- Borehole locality;
- Owner and property details;
- Borehole depth;
- Rest water level;
- Borehole usage;
- Borehole status;

- Measurement of field parameters, including:
  - Electrical conductivity (EC);
  - Total Dissolved Solids (TDS); and
  - pH and temperature.

A total of 82 boreholes were identified (Appendix A), 19 of those boreholes considered to be representative of the area were selected for groundwater quality analysis and delivered to Aquatico Laboratories in Pretoria for analysis (results found in Appendix B).

## 2.3 Slug Testing

Digby Wells conducted slug tests in June 2017 on 5 boreholes at Vaalkop, to obtain hydraulic conductivity values for the local shallow aquifer. Slug test data analysis was conducted using the Flow Characteristic (FC) programme. The aquifer parameters calculated will assist in the characterisation of the aquifers and used as input parameters to the numerical model that will be part of the study.

# 3 Site Description

The project area is located in Mpumalanga Province, contained east of Secunda, west of Bethal and 17 km from Kriel along the south and south-east (Figure 3-1).

## 3.1 Site layout and Operation

The expected life of mine (LOM) for the mines (operations collectively) is 39 years, as shown in Figure 3-2, the proposed high extraction areas and schedule is shown in Figure 3-3. The infrastructure for the mines is presented in Figure 3-4.

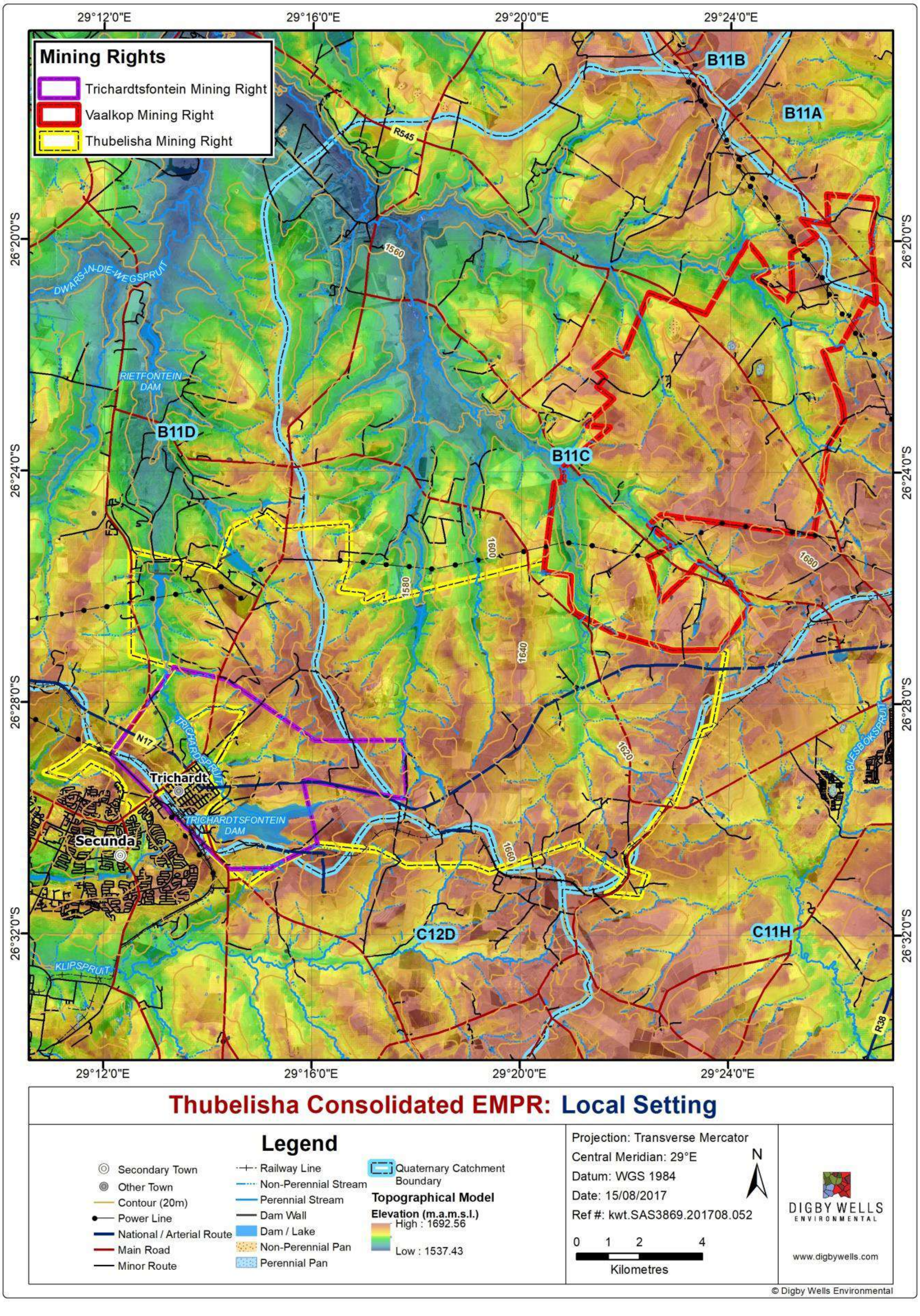


**Figure 3-1: Local Setting**

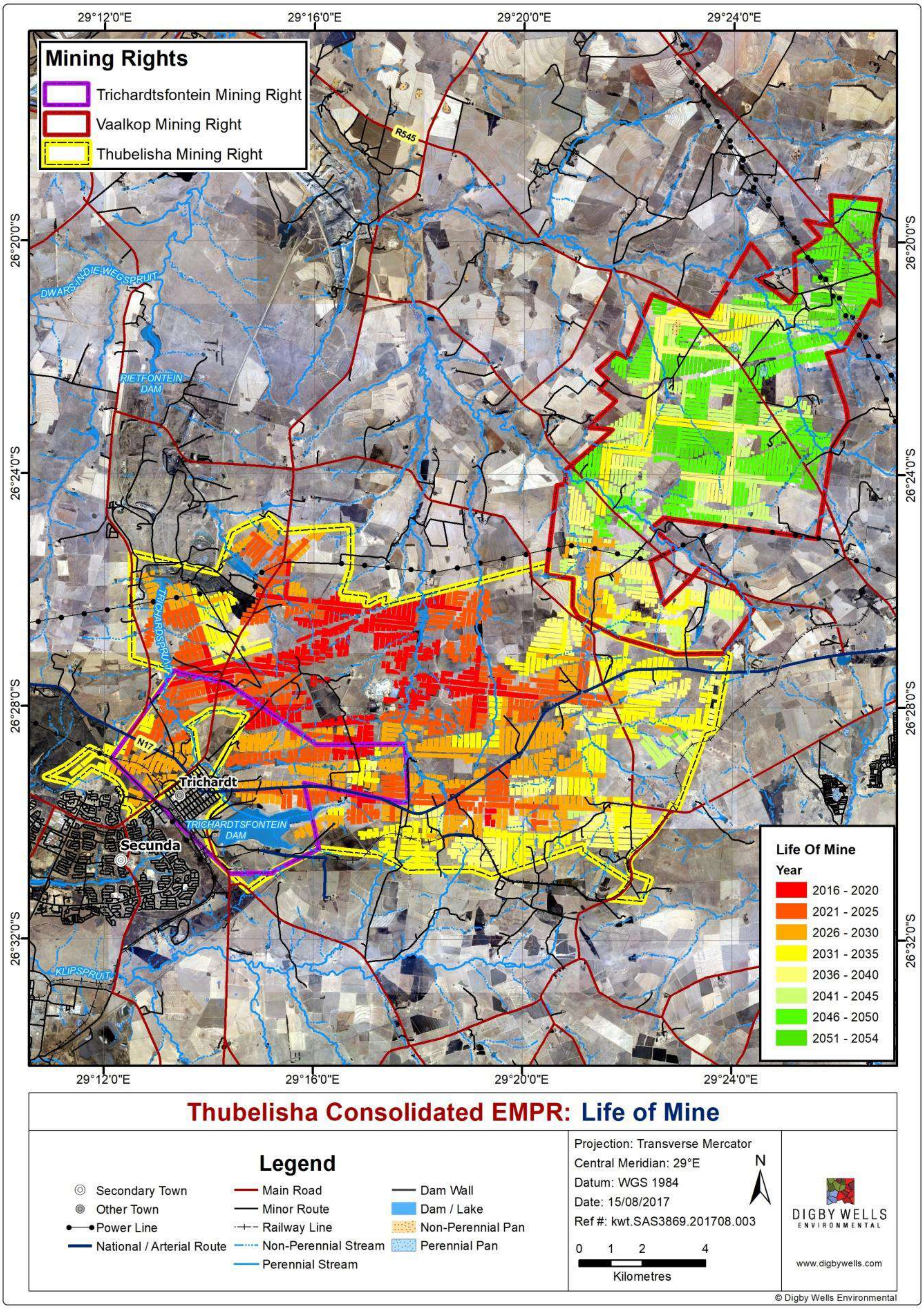


**Figure 3-2: Life of Mine**

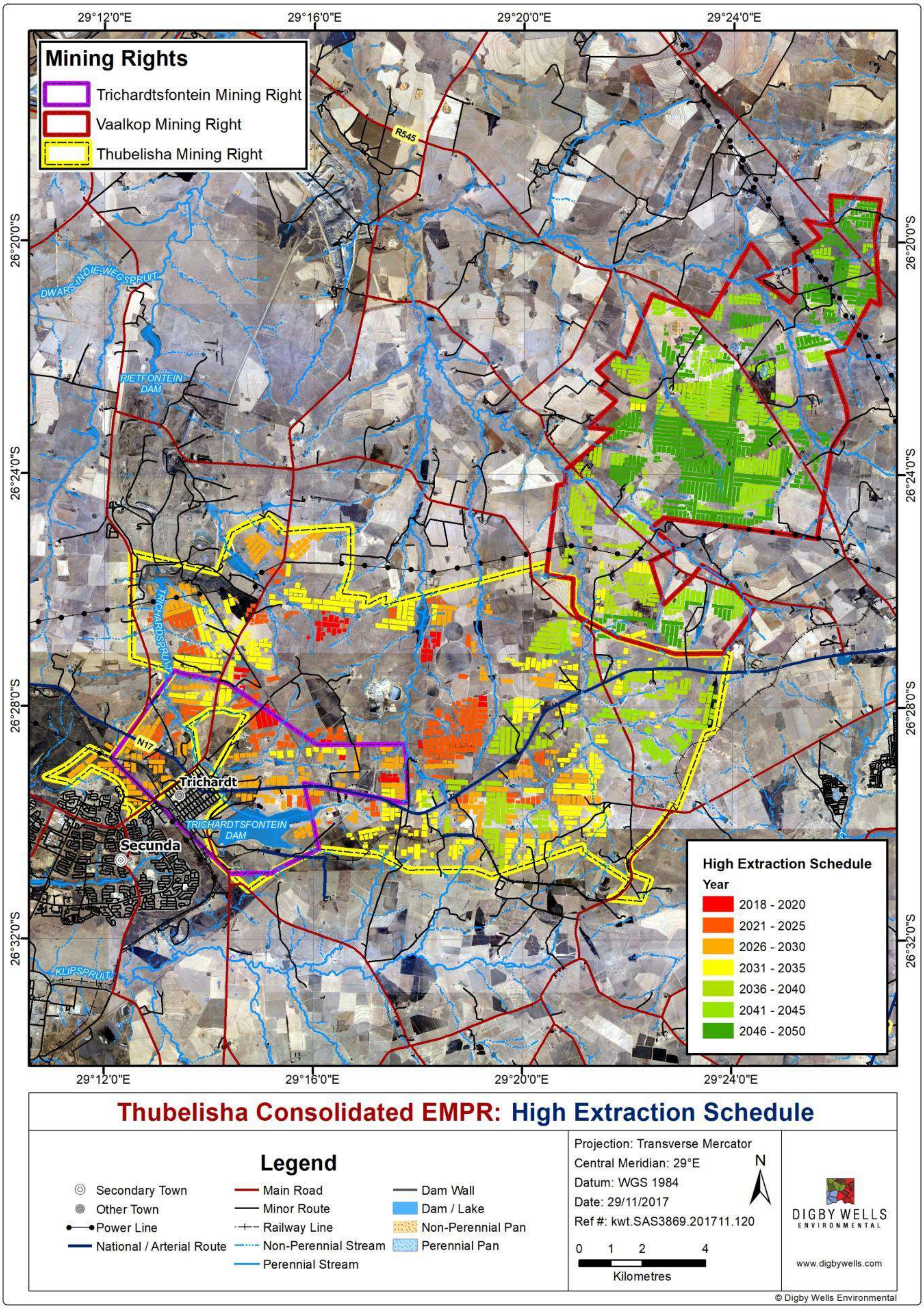


**Figure 3-3: High extraction schedule**

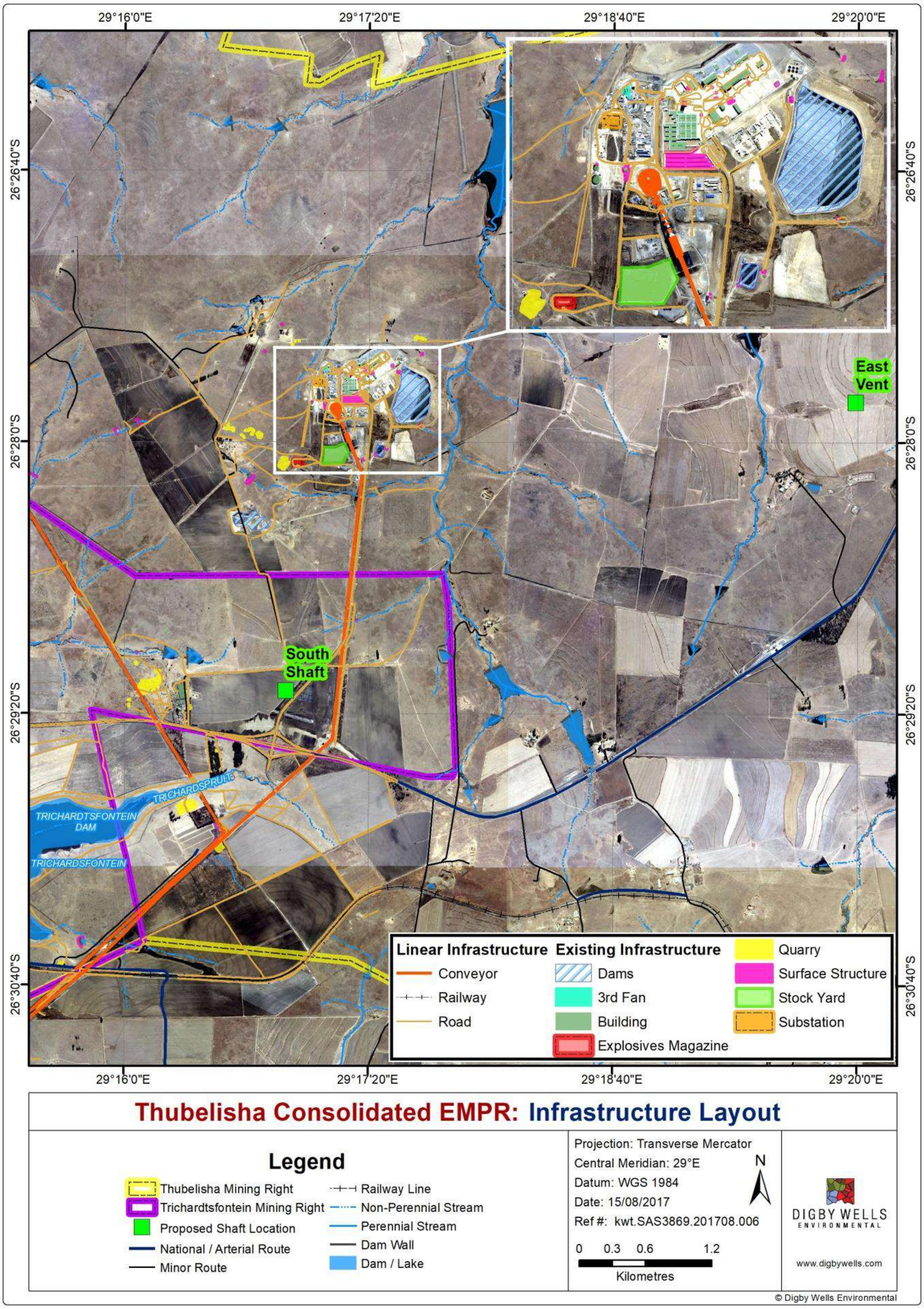


**Figure 3-4: Infrastructure**

## 3.2 Climate

Considering the extensive project area, climatic conditions are described according to the conditions found at Trichardtsfontein. The project area is situated in a summer rainfall region with an average annual rainfall ranging between 600 and 800 mm. Summer months are characterised by thunderstorms and majority of annual rainfall occurring between October and March, with maximum rainfall occurring in December. Winter months (June to August) are considerably dryer with minimal rainfall.

## 3.3 Topography and Drainage

The topography of these catchments consists of undulating hills and valleys, the elevation within the project area varies between 1685 mamsl to 1570 mamsl. Topographical highs occur along the north-east, south-east continuing along the south-west and topographical lows occur within the north-west. The nature of the topographic setting gives indication that the groundwater flow direction will predominantly be towards the north-west, with some localised flow in different directions due to surface water divides occurring in some parts of the project area.

The project area occurs largely within the Olifants River Catchment (in quaternary catchments B11A, B11C, B11D) with minor portions within the Upper Vaal River Catchment (in quaternary catchments C11H and C12D).

The main rivers draining the catchments are as follows:

- Olifants River Catchment: Elands, Wilge, Steelpoort and the Olifants River; and
- Upper Vaal River Catchment: Wilge, Liebenbergsvlei and Vaal River.

## 3.4 Geology

The geology at the project area is described according to an overview of the regional geology and more specific local geology found on site.

### 3.4.1 Regional Geology

The proposed project area's coal reserve falls within the north-eastern part of the Highveld Coalfield. The coalfield is underlain by pre-Karoo rocks, mainly Bushveld Complex and Pretoria Group volcanics. Glaciation events resulted in the deposition of tillite (Dwyka Formation) on the basement rocks over most of the area (Figure 3-5).

Within the Karoo Sedimentary Sequence, the Ecca Group superimposes the Dwyka Formation. The Dwyka Formation consists predominantly of tillite. The Ecca Group is the coal bearing geological formation; it consists predominantly of sandstone, siltstone, shale and coal.

The Ecca Group contains five bituminous coal seams, numbered 1-5 from bottom to top. Coal seam No. 4 and to a lesser degree No. 2 and No. 5 seams are the most economical coal seams in the Highveld Coalfield.

Overall, the coal seams follow the paleo-topography of the pre-Karoo rocks. This is especially applicable to the lower coal seams (No. 1 and No. 2), whereas the upper seams are less influenced by the pre-Karoo topography.

### 3.4.2 Local Geology

The local geology is defined according the geological investigation conducted at Trichardtsfontein by Digby Wells (2014). A typical stratigraphic column through the project area is shown in Figure 3-6. The stratigraphy is comprised of the No. 2, No. 3, No. 4L, No. 4H, No. 5L and the No. 5H coal seams, with sandstone and siltstone as inter-burden. Only No. 4 coal seam is economically viable to mine in the Trichardtsfontein area. The No. 5, No. 3 and No. 2 coal seams are currently considered uneconomical since they are too thin and erratic in distribution.

A presence of clay in the soil horizon is attributed to in-situ weathering of shallow dolerite sills over the area. The weathering depth is highly variable because of the presence of widespread dolerite sub-outcrops.

Shale is the predominant sedimentary rock in the project area which comprises of approximately 60% clay minerals, with smaller amounts of iron oxides, carbonates and in the case where coal formation is associated with the shale, sulphide minerals can also be present. The general mineral make-up of shale and expected mineralogy in the local geological formations is; chlorite, muscovite, kaolinite, k-feldspar, calcite, dolomite, pyrite and hematite.

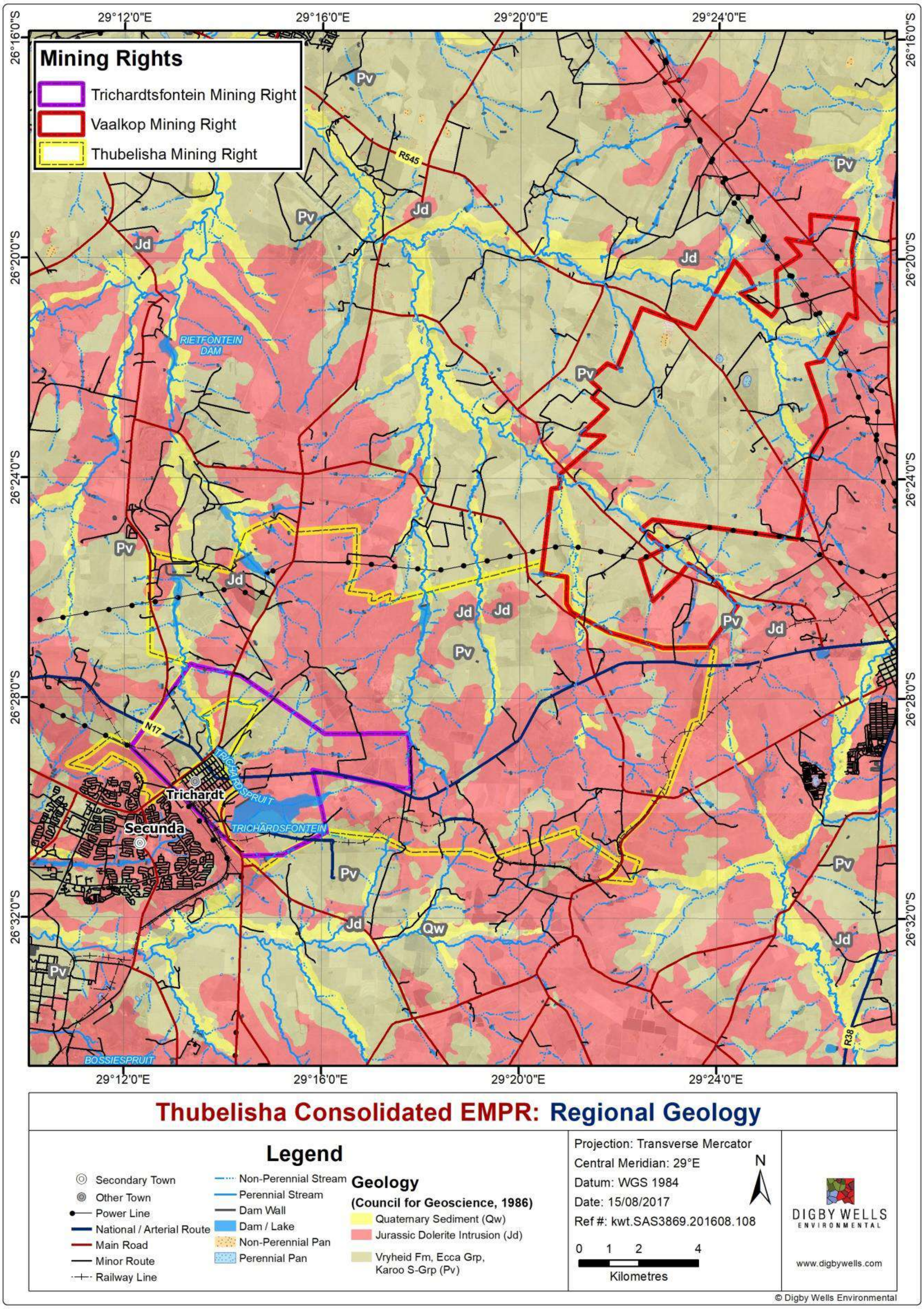


**Figure 3-5: Regional Geology**

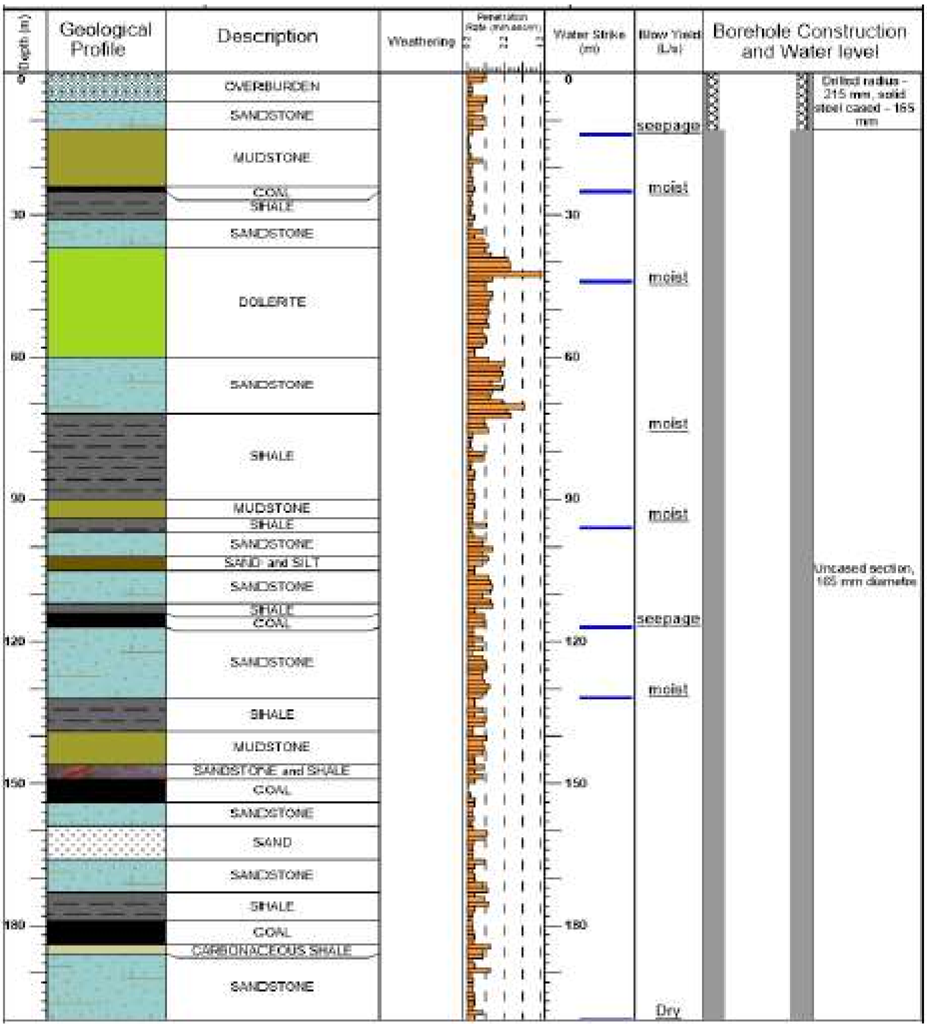


**Figure 3-6: Local Geology**

## 3.5 Boreholes

During groundwater sampling, samples were taken using double valve, decontaminated bailers, in the case of accessible boreholes and from pumps or taps in the case of boreholes which were in use; in which case a grab sample was taken.

In addition to the boreholes identified during the recently conducted hydrocensus, previously identified boreholes (176 in total) were included as part of the study and are shown in Figure 3-7.

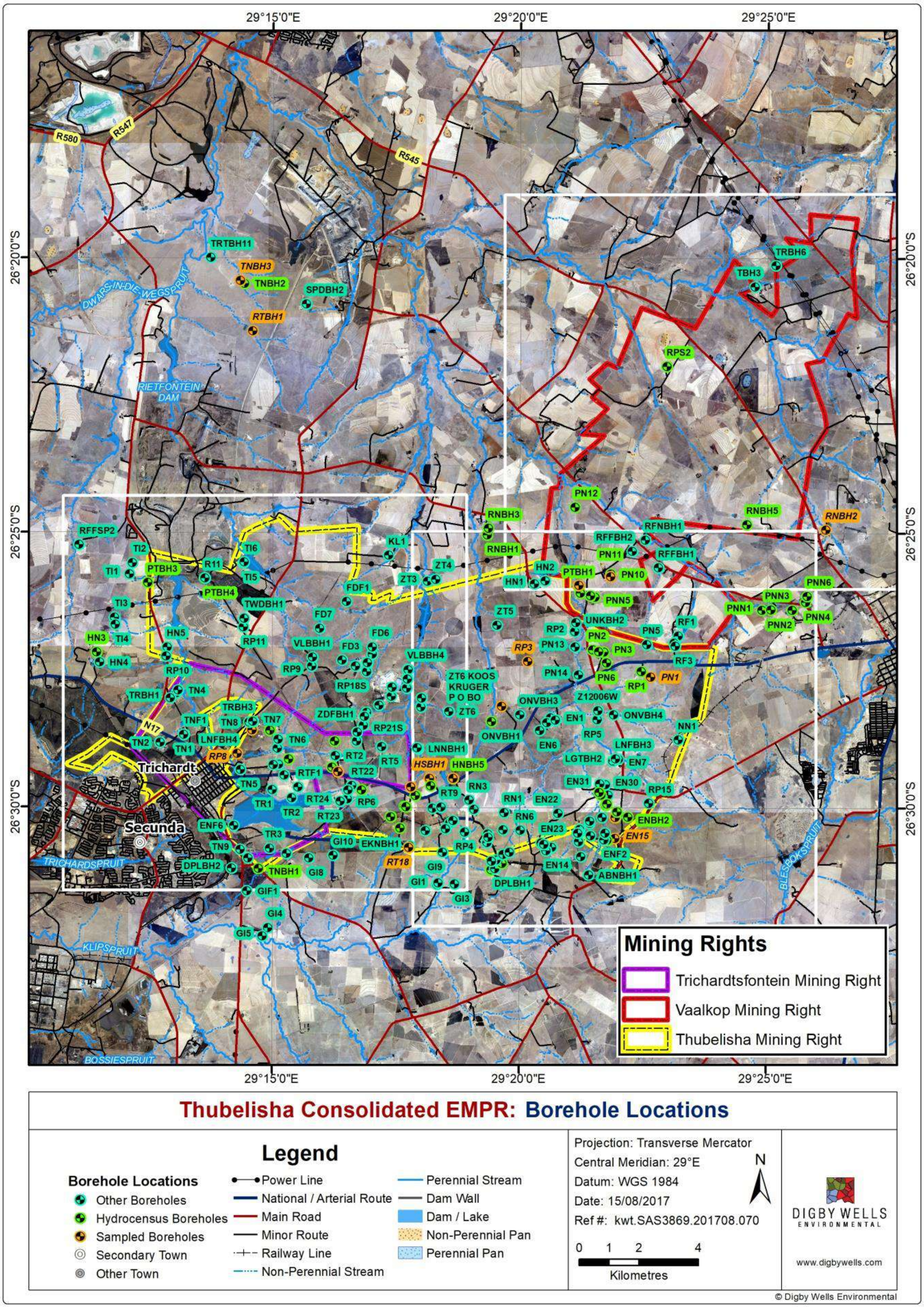


**Figure 3-7: Borehole Locations**

# 4 Baseline Hydrogeological Environment

## 4.1 Aquifer Description

JMA (2008) on a site specific level characterised the following four aquifer systems within the Ecca sedimentary succession:

- Shallow perched aquifer (clayey layer in soft overburden);
- Shallow weathered aquifer (weathered sandstone, siltstone and dolerite);
- Shallow fractured aquifer (mostly shallow fractured dolerite sill); and
- Deep fractured aquifer.

The average depth of the shallow perched aquifer is essentially limited to the soil (soft overburden) horizon.

The presence of a shallow dolerite sill over the area results in a discontinuous shallow weathered aquifer. Dolerite dykes and sills generally tend to form local weathered aquifer boundaries or act as groundwater flow pathways, depending on their degree of weathering.

The top of the shallow weathered aquifer is determined by the average depth to the water level. The bottom of the shallow weathered aquifer is determined by the weathering depth that is highly variable because of the presence of widespread dolerite sub-outcrops.

JMA (2008) conducted drilling and found that the weathered zone is not very deep where dolerite sub-outcrops are present and that the average depth of the shallow fractured aquifer is 22 m, but reaches depths of over 30 m. The dimensions of the shallow fractured aquifer are governed by the presence of the shallow dolerite sill over the area. A majority of the groundwater strikes in the study area are often associated with the shallow fractured dolerite.

The deeper fractured Karoo aquifer is less fractured than the shallow fractured aquifer as such water strikes in the deep fractured aquifer are limited. This translates into the deep fractured aquifer having low hydraulic conductivity.

## 4.2 Aquifer Classification

The aquifers of South Africa are defined according to their water supply potential, water quality and local importance for strategic purposes within an aquifer classification scheme and map. The aquifer classification map (Parsons, 1993) identifies the Karoo aquifers in the project area as predominantly minor systems with moderately-yielding aquifers of variable water quality and moderate vulnerability to some pollutants, but only when continuously discharged or leached.

## 4.3 Recharge

Hodgson and Krantz (1998) state that recharge within the Olifants River Catchment Water Management Area to the weathered Ecca aquifer is estimated at 1 to 3% of the annual precipitation.

The mean annual precipitation (MAP) throughout the project area ranges between 600 – 800 mm/a (Section 3.2) which results in an estimated recharge range of 6 to 24 mm/a.

## 4.4 Aquifer Hydraulic Parameters

Slug test data interpretation conducted on boreholes (HNBH4, HSBH3, PPN1, RNBH1 and RNBH4, shown in Figure 4-1) is summarized below;

- HBH4 reflected hydraulic conductivity of 0.019 m/d;
- HSBH3 reflected hydraulic conductivity of 1.16 m/d;
- PPN1 reflected hydraulic conductivity of 0.1 m/d;
- RNBH1 is almost dry with no significant conductivity; and
- RNBH4 reflected hydraulic conductivity of 0.16 m/d.

The harmonic mean hydraulic conductivity of the aquifer at Vaalkop is estimated at 0.06 m/d.

The hydraulic conductivity values of the shallow aquifer at Trichardtsfontein were obtained from slug tests conducted in December 2013 by Digby Wells (2014) which concluded hydraulic conductivity of approximately 0.05 m/d.

The harmonic mean hydraulic conductivity of the aquifers at Thubelisha is estimated at 0.013 m/d (JMA, 2008)

Digby Wells (2014) states that the deep fractured aquifer hydraulic conductivity is approximately 0.004 m/d.

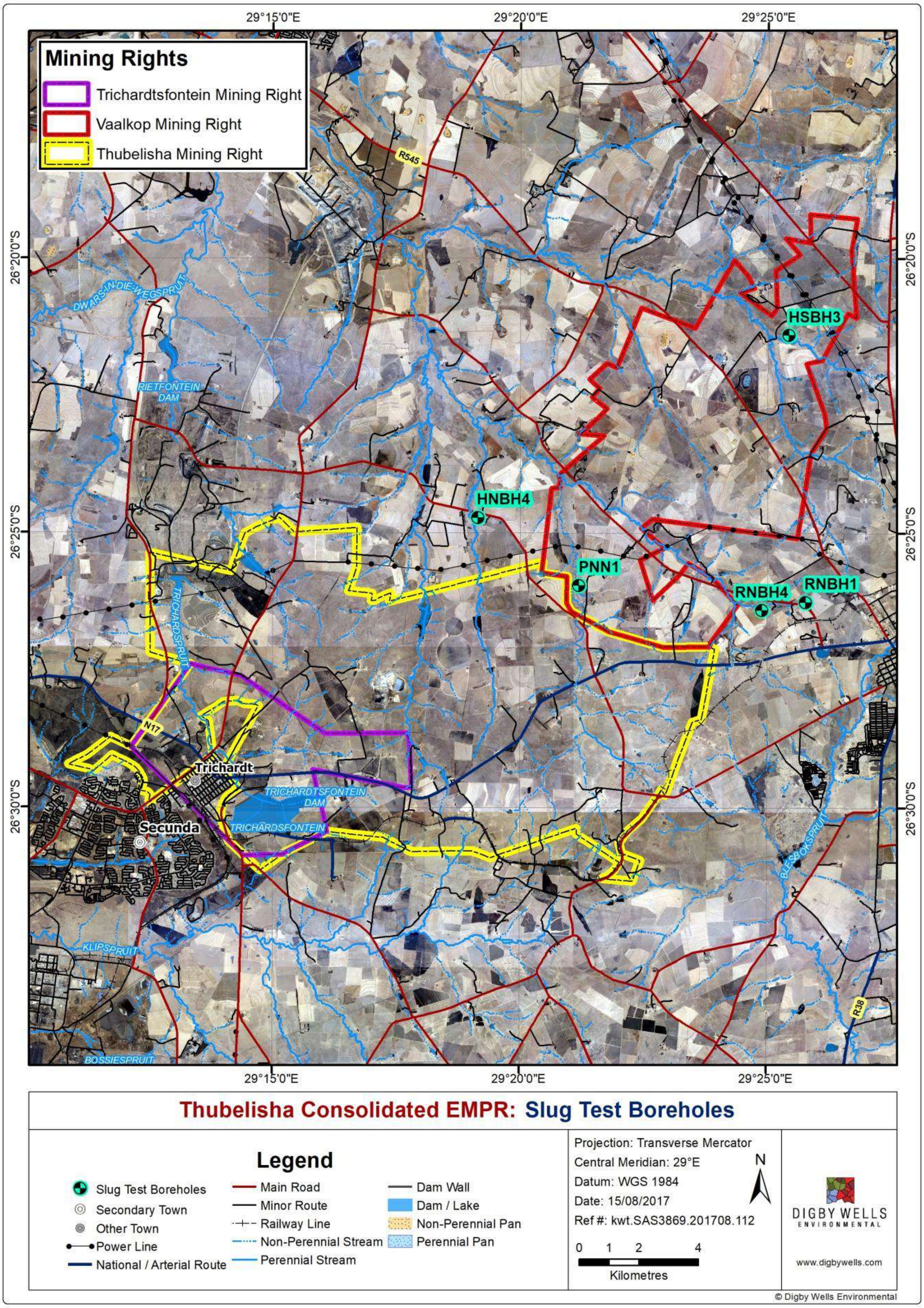


**Figure 4-1: Slug Tested Boreholes**

## 4.5 Groundwater Levels and Flow Directions

Groundwater levels acquired from the hydrocensus vary between 0 and 32 meters below ground level (mbgl), with an average of 5 mbgl. The localised groundwater level depth of 32 mbgl is a result of abstraction for domestic use. With the exclusion of deeper groundwater levels, undisturbed groundwater levels across the site show a strong correlation with topography. The groundwater flow direction at the Olifants River Catchment, where the majority of the project area is located, is from south-east to north-west (as predicted in Section 3.3), shown in Figure 4-2. In the Upper Vaal River Catchment where minor parts of the project area are located the groundwater flow direction is towards the south-west.

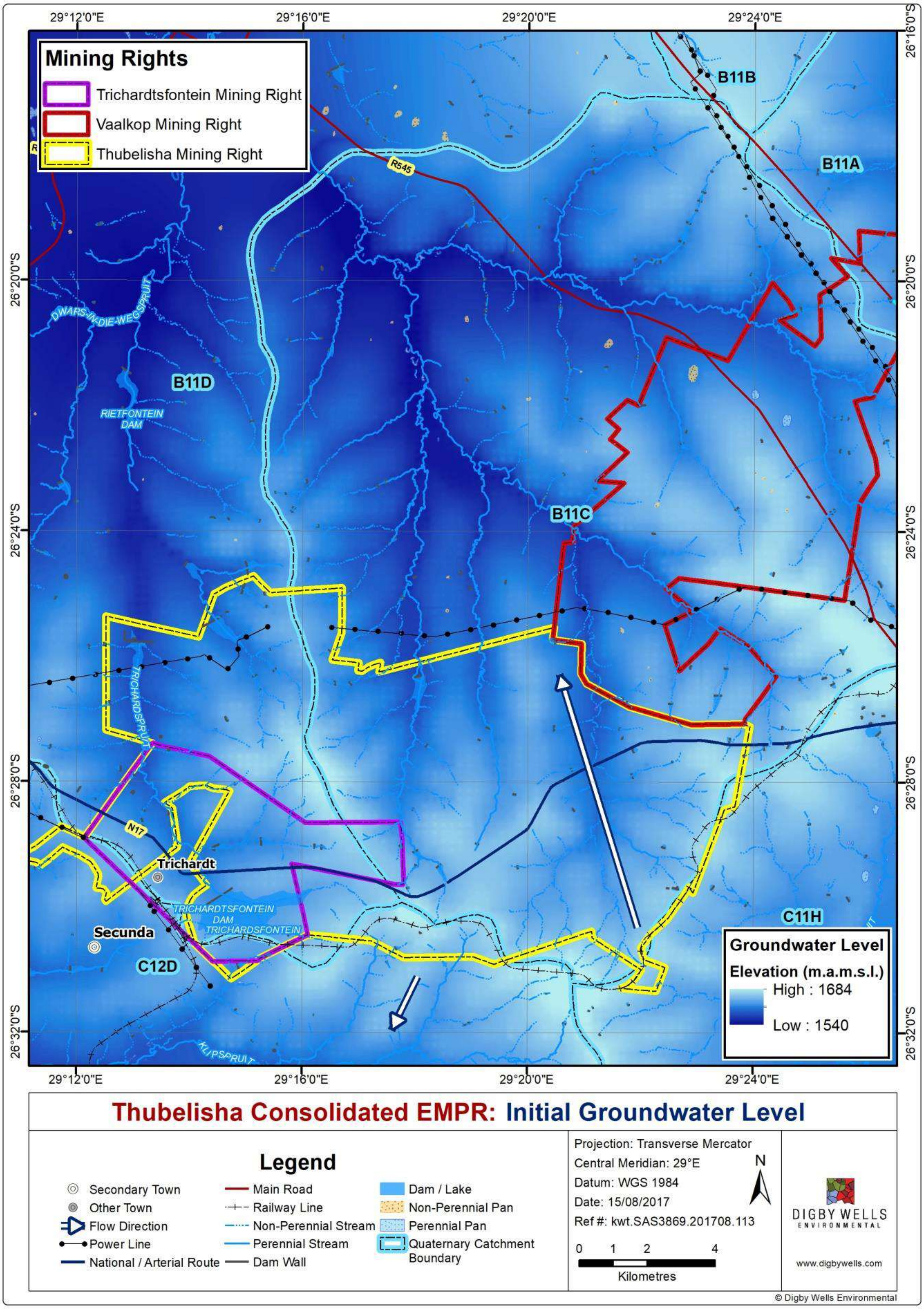


**Figure 4-2: Undisturbed Groundwater Levels**

## 4.6 Groundwater Quality

### 4.6.1 Groundwater Quality at Vaalkop

The groundwater quality results from the samples collected during the hydrocensus (Figure 3-7) have been compared to the South African National Standards (SANS) 241:2015 Standards for Drinking Water (Table 4-1).

SANS 241:2015 standards are divided into; aesthetic, operation, acute or chronic. Each of these categories has different effects on humans when consumed.

All boreholes are within the SANS standards for drinking water with the exception of PTBH2, ERN1 and RT3. Evaluations indicate the following:

- PTBH2 and RT3 have a nitrate concentration of 14 and 38.7 mg/L respectively, these concentrations exceed standards for aesthetic, acute and chronic effects (11 mg/L). The elevated concentrations of nitrate can be attributed to agricultural impacts; and
- ERN1 has a sulfate concentration of 388 mg/L. The concentration exceeds standards for aesthetic effects (250 mg/L) however it is below standards for acute chronic effects (500 mg/L). The elevated concentrations of sulfate can be attributed to mining related impacts.

Groundwater characterisation was conducted according to the Piper Diagram (Figure 4-3) and the groundwater quality is predominantly identified to be calcium-magnesium-bicarbonate type which is typically encountered in freshly recharged aquifers expected to contain water with relatively short residence time. RP8 and RT18 are characteristic of sodium-bicarbonate which is typical of mixing of high residence and freshly recharged water, with the sodium replacing the calcium and magnesium in solution.

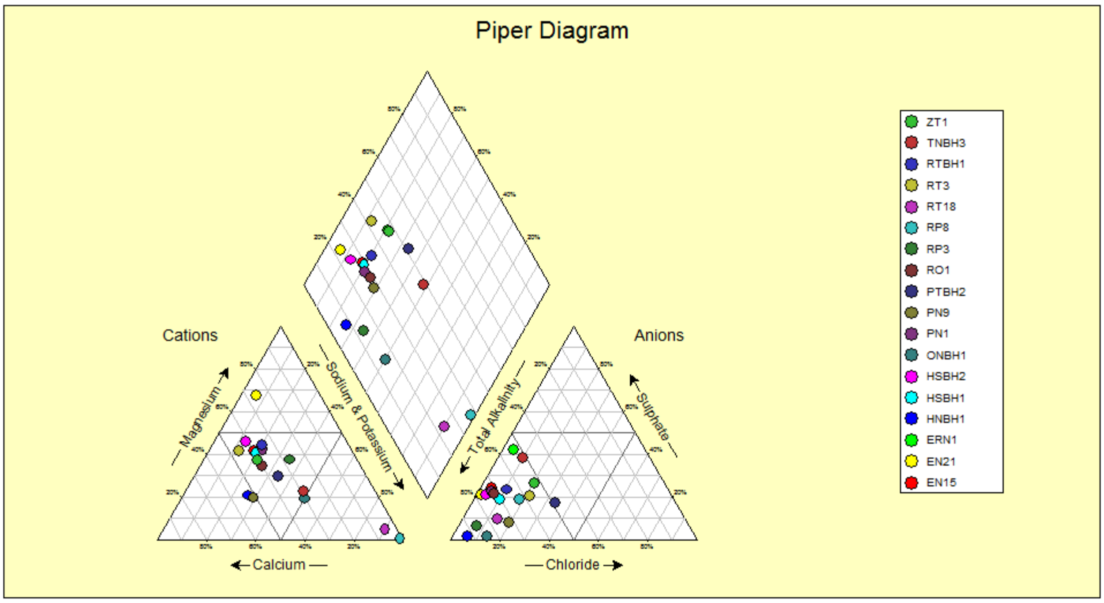


**Figure 4-3: Piper Diagram**

## Table 4-1: Baseline water quality classified based on the SANS 241: 2015

| Sample ID | | pH | EC (mS/m) | TDS (mg/l) | Cl (mg/l) | $SO_4$ (mg/l) | $NO_3$ (mg/l) | $NH_3$ (mg/l) | F (mg/l) | Na (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|
| **SANS 241:2015 Limits** | **Aesthetic** | - | **170** | **1200** | - | **250** | - | **1.5** | - | **200** |
| | **Operational** | **5 to 9.7** | - | - | - | - | - | - | - | - |
| | **Chronic health** | - | - | - | **300** | - | - | - | **1.5** | - |
| | **Acute health** | - | - | - | - | **500** | **11** | - | - | - |
| ONBH1 | 07/04/2017 | 8.74 | 67 | 402.00 | 39.30 | 6.38 | 0.61 | 0.02 | 0.52 | 97.70 |
| TNBH3 | 07/04/2017 | 8.71 | 88 | 596.00 | 33.50 | 170.00 | 7.42 | 0.02 | 0.32 | 98.60 |
| HSBH1 | 07/04/2017 | 8.57 | 78 | 508.00 | 31.60 | 75.80 | 1.64 | 0.02 | 0.34 | 40.70 |
| HSBH2 | 07/04/2017 | 8.61 | 70 | 438.00 | 12.80 | 86.10 | 0.93 | 0.01 | 0.27 | 27.90 |
| RNBH2 | 07/04/2017 | 8.76 | 101 | 738.00 | 162.00 | 56.00 | 5.91 | 0.02 | 0.29 | 90.90 |
| PTBH2 | 07/04/2017 | 7.62 | 25 | 236.00 | 18.90 | 12.80 | 14.00 | <0.005 | <0.26 | 14.20 |
| RTBH1 | 07/04/2017 | 8.56 | 79 | 582.00 | 38.60 | 111.00 | 1.35 | 0.02 | <0.26 | 48.10 |
| PN1 | 07/04/2017 | 8.82 | 67 | 482.00 | 16.00 | 89.70 | 5.31 | 0.03 | 0.31 | 43.80 |
| PN9 | 07/04/2017 | 8.63 | 40 | 254.00 | 31.90 | 17.40 | 1.20 | 0.01 | 0.32 | 26.50 |
| HNBH1 | 07/04/2017 | 8.58 | 47 | 326.00 | 13.50 | 3.98 | 1.48 | 0.01 | <0.26 | 27.70 |
| ERN1 | 07/04/2017 | 8.42 | 125 | 1024.00 | 32.90 | 388.00 | 0.24 | 0.01 | 0.40 | 96.50 |
| EN21 | 07/04/2017 | 8.86 | 72 | 462.00 | 5.92 | 91.70 | 1.55 | 0.02 | <0.26 | 13.60 |
| EN15 | 07/04/2017 | 8.54 | 72 | 502.00 | 14.30 | 107.00 | 2.38 | 0.01 | 0.31 | 38.80 |
| ZT1 | 07/04/2017 | 8.87 | 4 | 2.55 | 82.40 | 139.00 | 5.41 | 0.01 | 0.30 | 62.00 |
| RP3 | 07/04/2017 | 8.66 | 60 | 2.32 | 19.60 | 21.70 | 0.28 | 0.02 | 0.27 | 55.60 |
| RO1 | 07/04/2017 | 8.55 | 69 | 512.00 | 20.20 | 86.60 | 6.98 | 0.02 | 0.36 | 51.80 |
| RT18 | 07/04/2017 | 9.03 | 59 | 398.00 | 33.10 | 29.80 | 0.84 | 0.05 | 1.13 | 135.00 |
| RT3 | 07/04/2017 | 8.38 | 119 | 918.00 | 101.00 | 127.00 | 38.70 | 0.01 | 0.29 | 43.80 |
| RP8 | 07/04/2017 | 9.07 | 100 | 610.00 | 71.00 | 97.20 | 0.35 | 0.02 | 0.38 | 265.00 |

### 4.6.2 Groundwater Quality at Trichardtsfontein

Digby Wells (2014) collected eleven groundwater samples at Trichardtsfontein for groundwater evaluations, the results have been compared against South African National Standards (SANS241:2015).

Evaluations indicated the following:

- TRBH6 and TRTBH3 have a nitrate concentration of 21.5 and 11.3 mg/L respectively, these concentrations exceed standards acute effects (11 mg/L);
- TRBH1 and RP-8 have a sodium concentration of 205 and 279 mg/L respectively, exceeding standards for aesthetic effects (200 mg/L); and
- TRBH2, TRBH3, TRTBH11, RP-13, TRBH9, RPBH16D and TRTBH1 are within SANS 241:2015

Groundwater characterisation was conducted and majority of the boreholes were identified to be calcium-magnesium-bicarbonate type representative of freshly recharged aquifers.

### 4.6.3 Groundwater Quality at Thubelisha

Baseline groundwater quality status at Thubelisha was evaluated by JMA Consulting (2008) by comparing eighty boreholes against South African National Standards (SANS241:2005). The findings are summarized below (findings are discussed according to constituents found to be in excess any of the standards):

- No boreholes showed non-compliance with the water quality standards with regards to TDS concentration limits (Class III > 2400 mg/L), three boreholes coincide with Class II TDS limits (1000-2400 mg/L) and seventy-seven were within Class I limits (<1000 mg/L);
- Three boreholes showed non-compliance with the water quality standards regarding nitrate concentration limits (Class III > 20 mg/L), nine boreholes coincide with Class II TDS limits (10 - 20 mg/L) and sixty-eight were within Class I limits (<20 mg/L);
- Three boreholes showed non-compliance with the water quality standards regarding fluorine concentration limits (Class III > 1.5 mg/L), five boreholes coincide with Class II TDS limits (1 - 1.5 mg/L) and seventy-two were within Class I limits (<1 mg/L);
- No boreholes showed non-compliance with the water quality standards regarding calcium concentration limits (Class III > 300 mg/L), three boreholes coincide with Class II TDS limits (150 - 300 mg/L) and seventy-seven were within Class I limits (<150 mg/L);
- Five boreholes showed non-compliance with the water quality standards regarding magnesium concentration limits (Class III > 100 mg/L), nine boreholes coincide with Class II TDS limits (70 - 100 mg/L) and sixty-six were within Class I limits (<70 mg/L);

- No boreholes showed non-compliance with the water quality standards regarding sodium concentration limits (Class III > 400 mg/L), four boreholes coincide with Class II TDS limits (200 - 400 mg/L) and seventy-six were within Class I limits (<200 mg/L);
- No boreholes showed non-compliance with the water quality standards regarding chlorine concentration limits (Class III > 600 mg/L), two boreholes coincide with Class II TDS limits (200 - 600 mg/L) and seventy-eight were within Class I limits (<200 mg/L);
- Four boreholes showed non-compliance with the water quality standards regarding iron concentration limits (Class III > 2 mg/L), seven boreholes coincide with Class II TDS limits (0.2 - 2 mg/L) and sixty-nine were within Class I limits (<0.2 mg/L); and
- No boreholes showed non-compliance with the water quality standards regarding manganese concentration limits (Class III > 1 mg/L), seven boreholes coincide with Class II TDS limits (0.1 - 1 mg/L) and seventy-three were within Class I limits (<0.1 mg/L).

Groundwater was characterised as predominantly calcium-magnesium-bicarbonate type, indicating the presence of freshly recharged aquifers, with localized agricultural influences present at some locations.

## 4.7 Potential Contaminant Sources

Potential sources of contamination at TCTS were assessed for acid generation potential. A total of thirteen borehole cores were collected and sampled throughout the project area, with four located within the Vaalkop area, as shown in Figure 4-4. Assessments were conducted by the Institute of Groundwater Studies (2014), reference can be made to the report for more detail.

Based on geochemical assessments it is observed that the greatest potential for acid generation is apparent at the coal seams. Analysis on waste rock (overburden and interburden) also shows acid generating potential.

The potential contamination sources at Trichardtsfontein were identified as the coal material and waste rock. Seven samples (from three borehole core, as shown in Figure 4-4) were geochemically evaluated with the aim of defining the contamination expected to emanate from the local geology as a result of exposure to oxygen and air during mining activities. A more detailed discussion of the studies is found in Digby Wells (2014). The findings from the geochemical results show the following:

- Waste rock AMD (acid mine drainage) potential:
  - All the waste rock paste pH values were above 8, an indication of alkalinity with high buffering capacity;
  - All waste rock samples have total sulphur content that are well below the 0.3% guideline, therefore acid generation during oxidation is not expected;

    - The Nett Neutralising Potential (NNP) of the waste rock samples are below 20 therefore potentially acid generating; and
    - The waste rock is deemed potentially acid generating however with a high buffering capacity from the mineralogy results.

- Coal AMD potential:
    - The paste pH values of the coal material were alkaline;
    - The coal material for samples TRBH3-152 and TRBH3-114 had a S content above the 0.3% guideline, with 0.72 and 0.33% respectively, indicating a potential for acid generation;
    - Samples indicate low acid potential and the neutralising potential ratio is equal or below 1:3 indicating a potential for acid generation;
    - The NNP for two of the coal samples are below 0 indicating that if acid is generated the buffering capacity of the material can potentially not be enough to counter any acid generation; and
    - The coal material in whole is thus deemed as a rock type II and potentially acid generating.

From the static assessment, it can be concluded that the material that will be disturbed through mining can potentially cause AMD formation.

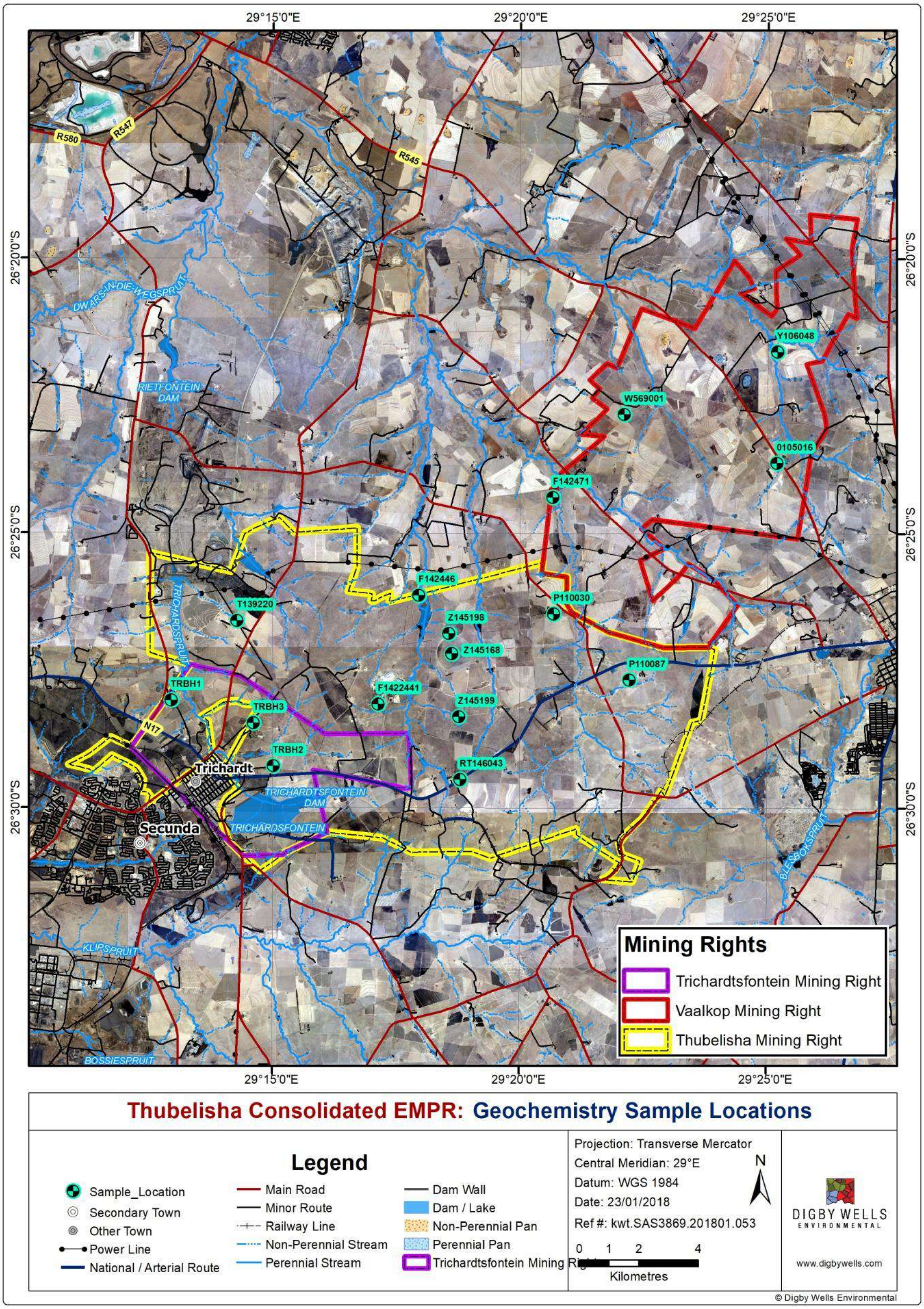


**Figure 4-4: Geochemical sample locations**

# 5 Numerical Model

The numerical model for the mine was constructed using Processing MODFLOW Pro, a pre- and post- processing package for MODFLOW and MT3DMS. MODFLOW is a modular three dimensional groundwater flow model and MT3DMS is a modular three dimensional solute transport model published by the United States Geological Survey. MODFLOW and MT3DMS use 3D finite differences discretization and flow codes to solve the governing equations. MODFLOW and MT3DMS are a widely used simulation codes, which are well documented.

## 5.1 Assumptions and Limitations

The following assumptions were made to develop this model:

- A numerical groundwater model is a representation of the real system; it is therefore an approximation of the groundwater system which in real life is complex and impossible to replicate accurately. This implies that there are always errors associated with groundwater models due to uncertainty in the data and the capability of numerical methods to accurately describe natural physical processes;
- High extraction is expected to increase permeability of the overlying stratigraphy. This has been assumed to occur throughout the areas of high extraction and incorporated into the model. However, the impacts of high extraction are likely to vary on site due to various factors such as the ductility of the overlying stratigraphy, its thickness, its stability and the mineral constituents;
- The spatial distribution and amount of recharge is uncertain. Due the extent of the area, recharge is simplified into the expected average recharge across the model;
- The dolerite intrusions and faults were not included into the numerical model as separate hydrogeological units as a result of limited understanding of their thickness, extent and hydraulic properties; and
- The hydraulic connection between the different aquifer systems and coal seams, expressed by vertical hydraulic conductivity is unknown and its value is estimated based on literature.

## 5.2 Model Setup

The model domain (Figure 5-1) is irregularly shaped with dimensions of 35.7 km by 32.9 km. The domain consists of 940 rows and 1019 columns that make up cells of 35 m by 35 m. Two layers have been modelled, simplifying the groundwater system into two aquifers. Properties assigned to the aquifers are based on the field investigations (at the shallow weathered aquifer) and literature review (this applies to the deeper aquifer).

The model boundaries were selected with the consideration of sub-catchments located far enough not to influence model results and the local rivers and tributaries were assigned as drains. The modelled area is shown in Figure 5-1.

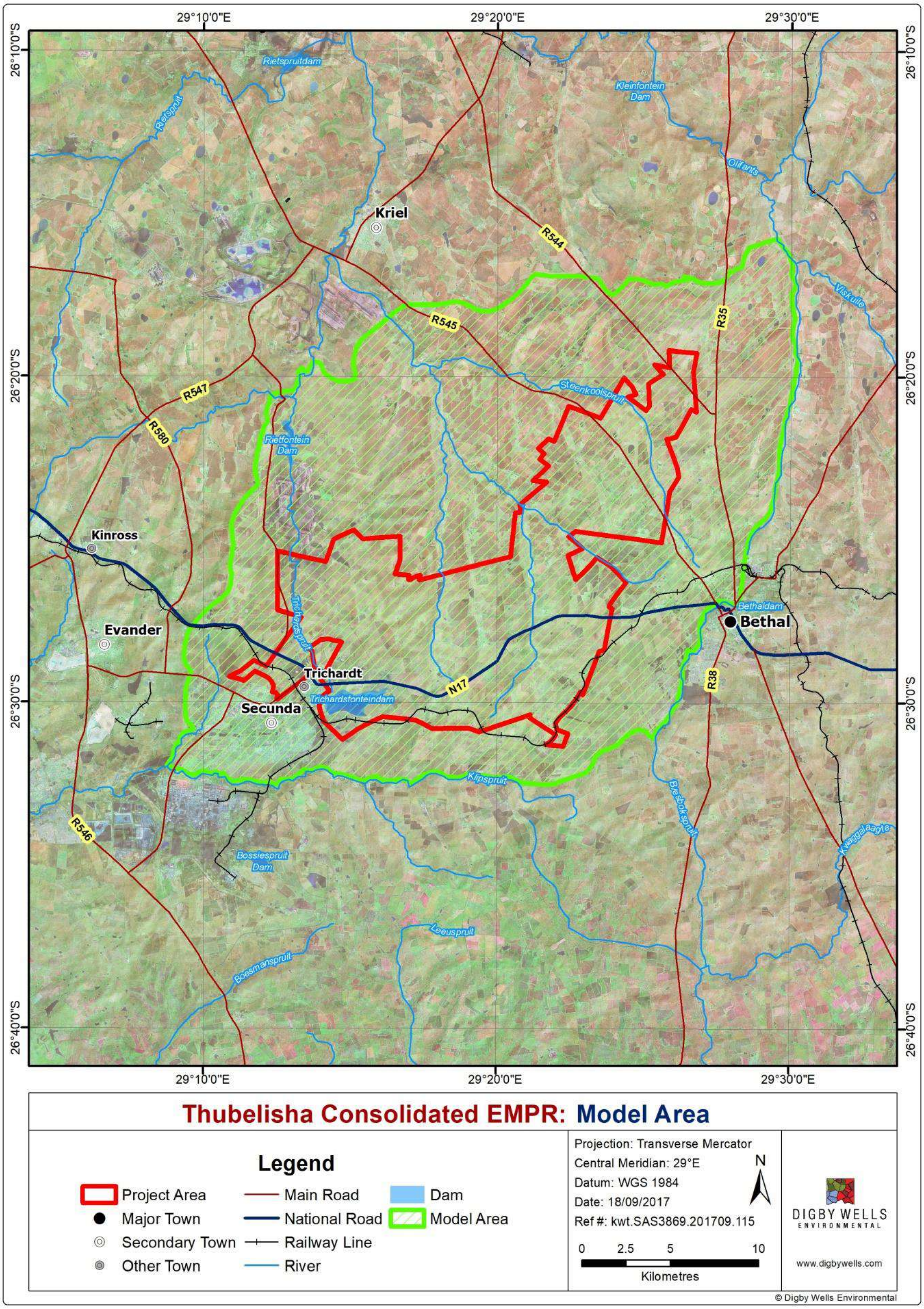


**Figure 5-1: Modelled Area**

## 5.3 Model Calibration

The model was calibrated by manually adjusting recharge, aquifer properties and drains (rivers); adjustments were kept within a range that speaks field investigations and available literature. Calibration was done to establish a good correlation between the groundwater levels calculated by the model and those observed on site.

The calibrated model yielded a 95% correlation between the observed groundwater levels and calculated groundwater levels (Figure 5-2).

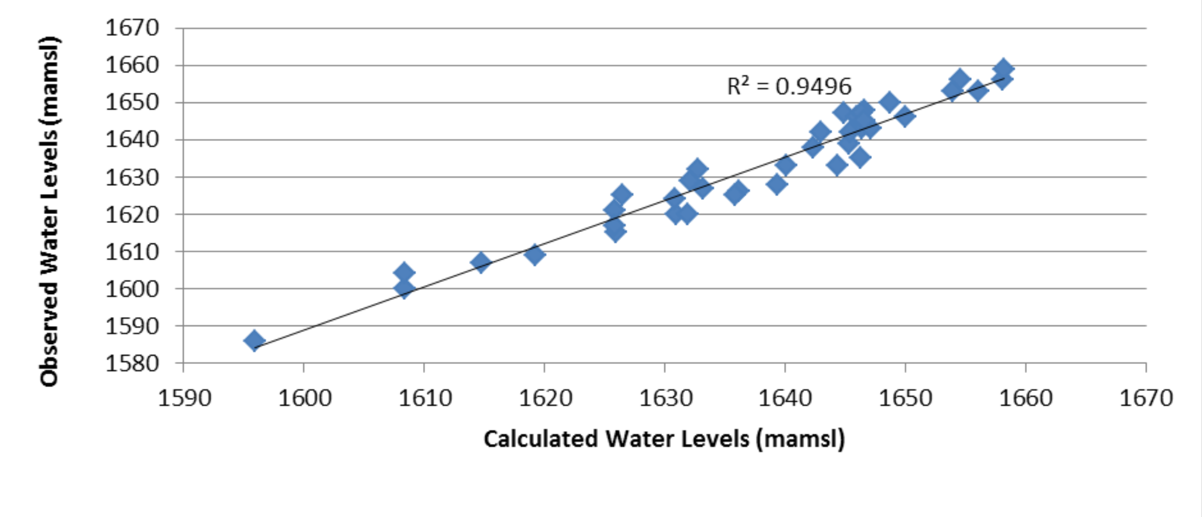


**Figure 5-2: Model Calibration Results**

# 6 Impact Assessment and Management Planning

## 6.1 Introduction

Details of the impact assessment methodology used to determine the significance of physical, bio-physical and socio-economic impacts are provided below.

The significance rating process follows the established impact/risk assessment formula:

| **Significance** = Consequence x Probability x Nature |
|---|

Where

| **Consequence** = Intensity + Extent + Duration |
|---|

And

| **Probability** = Likelihood of an impact occurring |
|---|

And

**Nature** = Positive (+1) or negative (-1) impact

Note: In the formula for calculating consequence, the type of impact is multiplied by +1 for positive impacts and -1 for negative impacts.

The matrix calculates the rating out of 147, whereby intensity, extent, duration and probability are each rated out of seven as indicated in Table 6-1. The weight assigned to the various parameters is then multiplied by +1 for positive and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of the mitigation has been applied; post-mitigation is referred to as the residual impact. The significance of an impact is determined and categorised into one of seven categories (The descriptions of the significance ratings are presented in Table 6-3).

It is important to note that the pre-mitigation rating takes into consideration the activity as proposed, (i.e., there may already be some mitigation included in the engineering design). If the specialist determines the potential impact is still too high, additional mitigation measures are proposed.

### Table 6-1: Impact assessment parameter ratings

| Rating | Intensity/Replaceability | | Extent | Duration/Reversibility | Probability |
|---|---|---|---|---|---|
| | Negative Impacts (Nature = -1) | Positive Impacts (Nature = +1) | | | |
| 7 | Irreplaceable loss or damage to biological or physical resources or highly sensitive environments. Irreplaceable damage to highly sensitive cultural/social resources. | Noticeable, on-going natural and / or social benefits which have improved the overall conditions of the baseline. | International The effect will occur across international borders. | Permanent: The impact is irreversible, even with management, and will remain after the life of the project. | Definite: There are sound scientific reasons to expect that the impact will definitely occur. >80% probability. |
| 6 | Irreplaceable loss or damage to biological or physical resources or moderate to highly sensitive environments. Irreplaceable damage to cultural/social resources of moderate to highly sensitivity. | Great improvement to the overall conditions of a large percentage of the baseline. | National Will affect the entire country. | Beyond project life: The impact will remain for some time after the life of the project and is potentially irreversible even with management. | Almost certain / Highly probable: It is most likely that the impact will occur. <80% probability. |

| Rating | Intensity/Replaceability | | Extent | Duration/Reversibility | Probability |
|---|---|---|---|---|---|
| | Negative Impacts (Nature = -1) | Positive Impacts (Nature = +1) | | | |
| 5 | Serious loss and/or damage to physical or biological resources or highly sensitive environments, limiting ecosystem function. Very serious widespread social impacts. Irreparable damage to highly valued items. | On-going and widespread benefits to local communities and natural features of the landscape. | Province/ Region Will affect the entire province or region. | Project Life (>15 years): The impact will cease after the operational life span of the project and can be reversed with sufficient management. | Likely: The impact may occur. <65% probability. |
| 4 | Serious loss and/or damage to physical or biological resources or moderately sensitive environments, limiting ecosystem function. On-going serious social issues. Significant damage to structures / items of cultural significance. | Average to intense natural and / or social benefits to some elements of the baseline. | Municipal Area Will affect the whole municipal area. | Long term: 6-15 years and impact can be reversed with management. | Probable: Has occurred here or elsewhere and could therefore occur. <50% probability. |

| Rating | Intensity/Replaceability | | Extent | Duration/Reversibility | Probability |
|---|---|---|---|---|---|
| | Negative Impacts (Nature = -1) | Positive Impacts (Nature = +1) | | | |
| 3 | Moderate loss and/or damage to biological or physical resources of low to moderately sensitive environments and, limiting ecosystem function.<br>On-going social issues. Damage to items of cultural significance. | Average, on-going positive benefits, not widespread but felt by some elements of the baseline. | Local<br>Local extending only as far as the development site area. | Medium term: 1-5 years and impact can be reversed with minimal management. | 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. <25% probability. |
| 2 | Minor loss and/or effects to biological or physical resources or low sensitive environments, not affecting ecosystem functioning.<br>Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected. | Low positive impacts experience by a small percentage of the baseline. | Limited<br>Limited to the site and its immediate surroundings. | Short term: Less than 1 year and is reversible. | Rare / improbable: Conceivable, but only in extreme circumstances. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures. <10% probability. |

| Rating | Intensity/Replaceability | | Extent | Duration/Reversibility | Probability |
|---|---|---|---|---|---|
| | Negative Impacts (Nature = -1) | Positive Impacts (Nature = +1) | | | |
| 1 | Minimal to no loss and/or effect to biological or physical resources, not affecting ecosystem functioning. Minimal social impacts, low-level repairable damage to commonplace structures. | Some low-level natural and / or social benefits felt by a very small percentage of the baseline. | Very limited/Isolated Limited to specific isolated parts of the site. | Immediate: Less than 1 month and is completely reversible without management. | Highly unlikely / None: Expected never to happen. <1% probability. |

**Table 6-2: Probability/consequence matrix**

Significance

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -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 |
| -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 |
| -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 |
| -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 |
| -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 |
| -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 |
| -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 6-3: Significance rating description

| Score | Description | Rating |
|---|---|---|
| 109 to 147 | A very beneficial impact that 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 | A positive impact. These impacts will usually result in positive medium to long-term effect on the natural and / or social environment | Minor (positive) (+) |
| 3 to 35 | A small positive impact. The impact will result in medium to short term effects on the natural and / or social environment | Negligible (positive) (+) |
| -3 to -35 | An acceptable negative impact for which mitigation is desirable. 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 natural and / or social environment | Negligible (negative) (-) |
| -36 to -72 | A minor negative impact 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 natural and / or social environment | Minor (negative) (-) |
| -73 to -108 | A moderate negative impact may prevent the implementation of the project. These impacts would be considered as constituting a major and usually a long-term change to the (natural and / or social) environment and result in severe changes. | Moderate (negative) (-) |
| -109 to -147 | A major negative impact 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. The impacts are likely to be irreversible and/or irreplaceable. | Major (negative) (-) |

## 6.2 Project Activities Assessed

The list of project activity that is relevant to the groundwater impact assessment is presented in Table 6-4.

**Table 6-4: Description of activities to be assessed**

| Project Phase | Project Activity | Project Structures |
|---|---|---|
| **Construction** | Excavation | Two Shafts per mining right area |
| | Water Abstraction and Use | Water Tanks and Pipes |
| **Operations** | Mining Operations | Heavy Machinery and Equipment |
| | Mine Dewatering | Underground Pumps and Pipes |
| **Mine Decommissioning and Closure** | Waste Generation | Mine void |

## 6.3 Impact Assessment

The proposed underground mine has the potential to have a negative impact on the groundwater environment; through the depletion of the local groundwater quantity and quality.

Mine dewatering is crucial to keep the mine workings dry for safe working conditions, dewatering will be conducted by abstracting groundwater ingress into mine voids during operation. The groundwater quality at most of the coal mines in the country is characterised by sulfate concentrations in the order of 2500 mg/L. Similar impacts could also occur at the project area and management plans should be put in place with this assumption.

The contamination plume presented in the figures is representative of 1% to 100% of the contamination at the source and the cone of depression presented is from a drawdown depth from 5 m and above.

Potential impacts are assessed in this section considering the construction, operational and closure phases. The list of project activities can be found in Table 6-4. Only project activities that are likely to result in a groundwater impact are assessed below.

### 6.3.1 Construction Phase

#### *6.3.1.1 Project Activities Assessed*

Site clearance (during the construction phase) conducted to accommodate the ventilation shafts presented in Section 3.1 could result in impacts to the groundwater. The activity brining about potential interaction with the groundwater environment and potential impact is presented in Table 6-5.

**Table 6-5: Interactions and impacts during the construction phase**

| Interaction | Impact |
|---|---|
| Site clearing | Lowering of the water table, if the site clearing will take place below the water table |

#### *6.3.1.1.1 Impact Description*

The water table at the project area ranges between 0 and 32 mbgl. Any site clearing or construction activities that would involve excavation below the water table depth may have a potential impact on the groundwater quantity and quality.

#### *6.3.1.1.2 Management Actions and Targets*

The following actions and targets are required:

- Site clearing to be restricted to areas that are absolute necessity and the activity should be conducted over a short duration;
- Site clearance and construction activities should take place above the water table (if possible), no impact on the groundwater level will then be expected;
- If trenches are going to be excavated below the water level, dewatering of the aquifer to lower the water table locally should be considered to ensure that the construction takes place above the groundwater level. Since the groundwater is not expected to be polluted at this stage, the utilisation of the water for activities such as dust suppression or irrigation (if applicable) will not cause negative environmental impacts; and
- Install long term monitoring boreholes. The positions of the monitoring boreholes are provided in Section 9.3.

#### *6.3.1.1.3 Construction Phase Impact Ratings*

The significance rating of the potential impacts before and after mitigation is provided in Table 6-6.

**Table 6-6: Potential Impacts during the Construction Phase**

| **Activity & Interaction: Site clearing for the development of surface infrastructure through the removal of the top soil and weathered rocks** | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| **Impact Description: Lowering of the water table** | | | |
| ***Prior to mitigation/ management*** | | | |
| **Duration** | Short term (2) | Construction activities are expected to be short-lived (limited to the duration of the construction phase) | Negligible (-18) |

<table>
<tr><th colspan="4">Activity & Interaction: Site clearing for the development of surface infrastructure through the removal of the top soil and weathered rocks</th></tr>
<tr><th>Dimension</th><th>Rating</th><th>Motivation</th><th>Significance</th></tr>
<tr><td>Extent</td><td>Limited (2)</td><td>Site clearing will only occur within project area</td><td rowspan="4"></td></tr>
<tr><td>Intensity x type of impact</td><td>Minor (-2)</td><td>Any dewatering will have minor environmental significance</td></tr>
<tr><td>Probability</td><td>Unlikely (3)</td><td>Dewatering during the construction phase (if any) is unlikely to cause environmental impact considering limited rock permeability, the duration and excavation depth.</td></tr>
<tr><td>Nature</td><td colspan="2">Negative</td></tr>
<tr><th colspan="4">Mitigation/ Management actions</th></tr>
<tr><td colspan="4"><ul><li>Site clearance and construction activities should take place above the water table (if possible), no impact on the groundwater level will then be expected.</li><li>Site clearance should be kept to a minimum area and short duration.</li><li>If trenches are going to be excavated below the water level, dewatering of the aquifer to lower the water table locally should be considered to ensure that the construction takes place above the groundwater level. Since the groundwater is not expected to be polluted at this stage, the utilisation of the water for activities such as dust suppression or irrigation will not cause negative environmental impacts.</li><li>Install monitoring boreholes.</li></ul></td></tr>
<tr><th colspan="4">Post- mitigation</th></tr>
<tr><td>Duration</td><td>Short term (2)</td><td>Any lowering of the water table during the construction phase is expected to be shallow and recover relatively quickly</td><td rowspan="5">Negligible<br>(-15)</td></tr>
<tr><td>Extent</td><td>Limited (2)</td><td>Only the area in the site clearing area will be affected</td></tr>
<tr><td>Intensity x type of impact</td><td>Minimal (-1)</td><td>Considering that any interaction with the water table will be avoided as much as possible and the activity will be limited to a short duration, the intensity will be minimal</td></tr>
<tr><td>Probability</td><td>Unlikely (3)</td><td>It is unlikely for groundwater impact to occur during the construction phase, especially with the implementation of the above proposed management plans</td></tr>
<tr><td>Nature</td><td colspan="2">Negative</td></tr>
</table>

### 6.3.2 Operational Phase

#### *6.3.2.1 Project Activity Assessed*

During the operational phase, mine dewatering could result in negative groundwater impacts and is assessed below. Interaction with the groundwater environment and potential impact are presented in Table 6-7.

**Table 6-7: Interactions and impacts during the operation phase**

| Interaction | Impact |
|---|---|
| Groundwater dewatering | Potential water level lowering |
| AMD generation at mine void | Potential groundwater contamination |
| Subsidence | Water level rising and groundwater contamination |

##### *6.3.2.1.1 Impact Description*

When mining below the water table, it is important to keep the mine workings dry for safe working conditions. Dewatering is recommended to start as excavations are initiated. This can potentially impact the groundwater environment negatively by lowering the water level and creating a cone of depression, affecting the local aquifers. As the cone of depression is created through dewatering, water flows into the mine voids.

Mining was simulated by applying drains, progressing according to the life of mine, located at the depth of the coal seam floor. The groundwater captured by the drains is reflective of the expected inflows. Inflow rates are not only a function of the aquifer properties but also the mine plans because the mined area, depth and excavation rate affect the inflow rates. Table 6-8, Figure 6-1 are presentations of expected inflows into the underground mine as the mine progresses.

**Table 6-8: Overview of estimated groundwater inflow rates**

| Year | Year of Operation | Inflows ($m^3$/d) | Inflows (L/s) | Mine area ($m^2$) | Cumulative area ($m^2$) |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |
| 2016 | 1 | 90 | 1 | 895900 | 895900 |
| 2017 | 2 | 352 | 4 | 2598200 | 3494100 |
| 2018 | 3 | 694 | 8 | 3521600 | 7015700 |
| 2019 | 4 | 1020 | 12 | 3511600 | 10527300 |
| 2020 | 5 | 1380 | 16 | 3763300 | 14290600 |
| 2025 | 10 | 3280 | 38 | 20236300 | 34526900 |
| 2030 | 15 | 4990 | 58 | 21015200 | 55542100 |
| 2035 | 20 | 6550 | 76 | 19000500 | 74542600 |
| 2040 | 25 | 7600 | 88 | 15604900 | 90147500 |
| 2045 | 30 | 7850 | 91 | 14498700 | 104646200 |
| 2050 | 35 | 8410 | 97 | 15324500 | 119970700 |
| 2054 | 39 | 8460 | 98 | 6430100 | 126400800 |

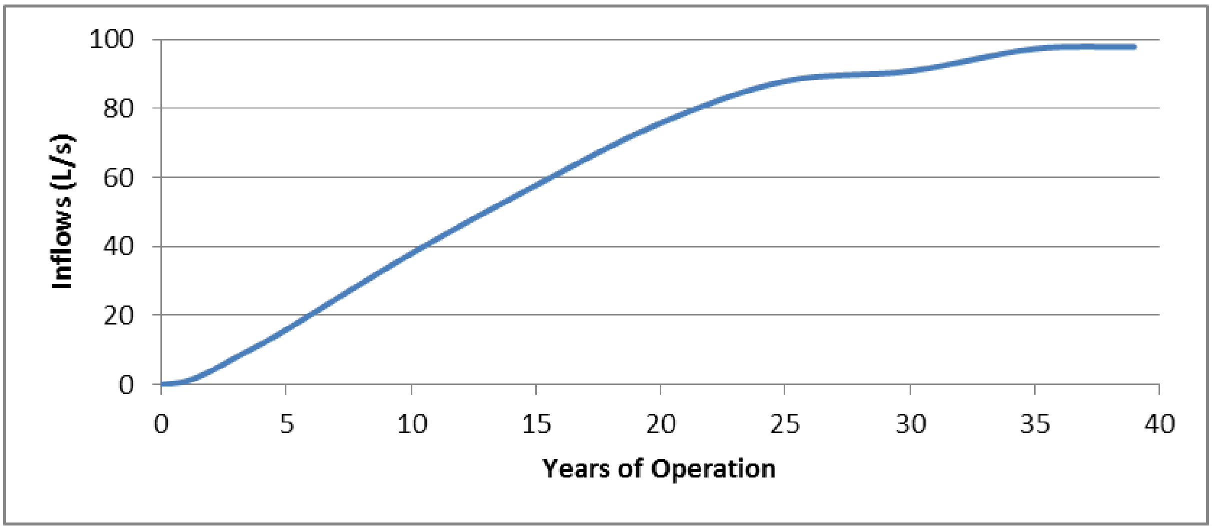


**Figure 6-1: Estimated groundwater inflow rates**

**Table 6-9: Site specific estimated groundwater inflow rates**

| Year | Year of Operation | Trichardtsfontein | Thubelisha | Vaalkop |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 2016 | 1 | 0 | 90 | 0 |
| 2017 | 2 | 0 | 352 | 0 |
| 2018 | 3 | 34 | 660 | 0 |
| 2019 | 4 | 112 | 909 | 0 |
| 2020 | 5 | 191 | 1189 | 0 |
| 2025 | 10 | 648 | 2635 | 0 |
| 2030 | 15 | 1101 | 3769 | 120 |
| 2035 | 20 | 1192 | 4942 | 413 |
| 2040 | 25 | 1171 | 5617 | 810 |
| 2045 | 30 | 1138 | 5460 | 1255 |
| 2050 | 35 | 1109 | 5285 | 2012 |
| 2054 | 39 | 1088 | 5155 | 2214 |

Areas where high extraction will be conducted are expected to experience subsidence during operation and or post-operation. The risk of subsidence is dependent on the characteristics of the local geology. The presence of dolerite sill or thick sandstone prevents fracturing of the overburden rock mass through to surface. The depth at which high extraction takes place is also a factor as the risk of subsidence increases with decreasing depth to coal seam from the ground surface. Figure 6-2 shows the high risk areas with regards to subsidence. The depth at which high extraction will be conducted is presented as well in the figure. The probability of subsidence can only be accurately quantified by conducting detailed geotechnical investigations which is outside the scope of this groundwater study.

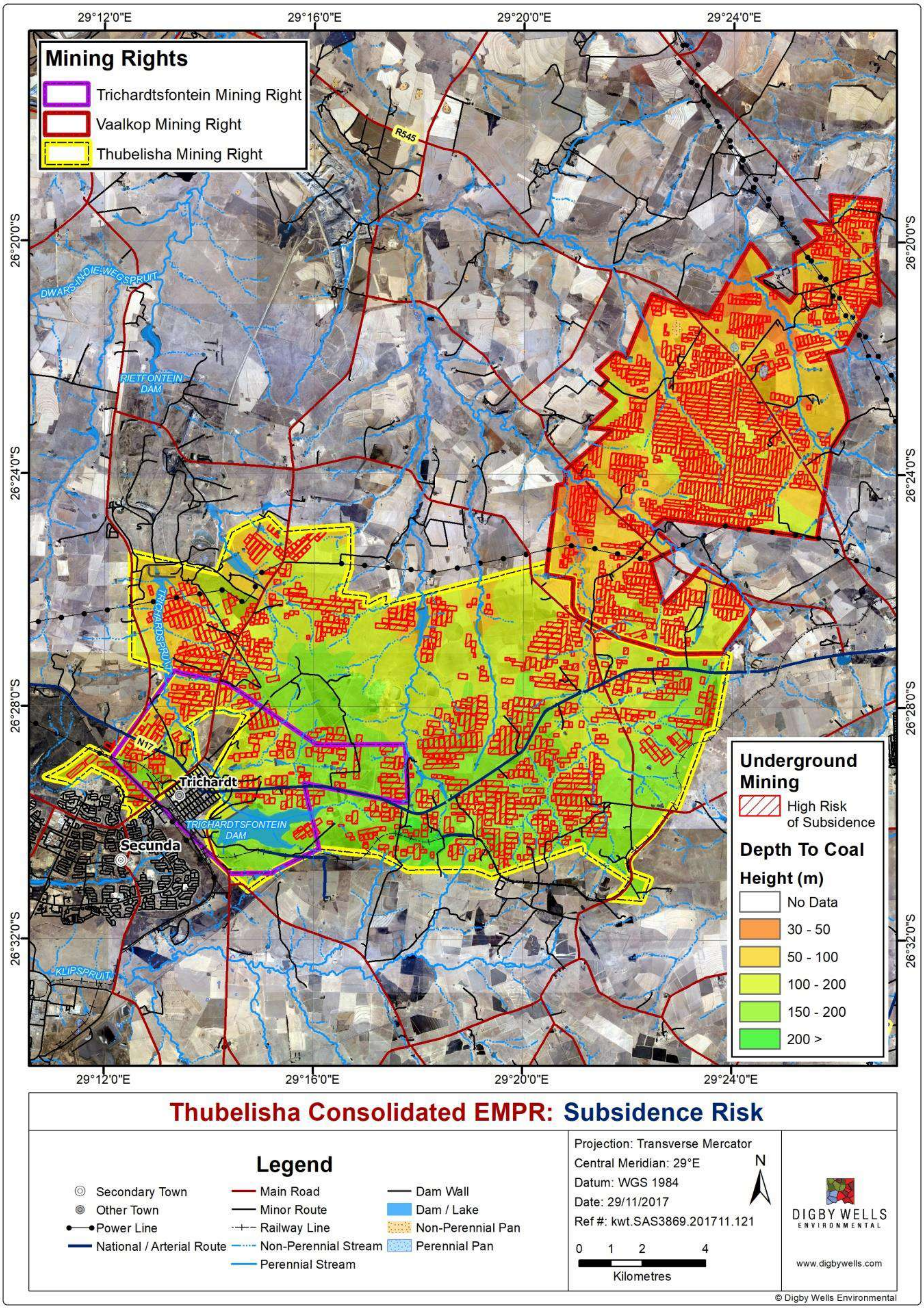


**Figure 6-2: High risk areas of subsidence**

Subsidence may result in fracturing of the overlying stratigraphy and increased geological permeability, resulting impacts to the groundwater and surface water environment. Additionally, damage to roads, power lines, buildings, and could even claimed the lives as e result of subsidence.

The groundwater environment may be subjected to the following impacts in areas of subsidence:

- Increased groundwater recharge, estimated to reach 9% of the MAP at the shallow weathered aquifer and 5% at deeper fractured aquifers (Vermeulen and Usher, 2006);
- Groundwater quality at the shallow weathered aquifer may be affected in the following ways:
  - Recharge will increase at areas of increased permeability and areas where fractures have developed as a result of subsidence; and
  - After hydraulic head recovery, recharge of contaminated water may occur through artificially created groundwater flow pathways (fractures).
- Increased chances of the occurrence of decant and increased decant rates; and
- Expansion of the contamination plume into the weathered aquifer in areas where it would have not been expected if there was no subsidence. This may occur because as the overlying stratigraphy becomes more permeable, migration of water through these rocks as well as the exposure to air can result in the generation of acid water if these rocks contain pyrite.

Groundwater quality deterioration is then expected to mainly occur at areas of subsidence. Figure 6-3 shows the expected contamination plume at the weathered aquifer, mainly associated with the impacts of subsidence and to a lesser degree diffusion, which is a result of concentration gradient. The contamination at the weathered aquifer is predominantly less than 20% of the source concentration and in isolated areas reaches a maximum of 35%.

During operation, any contaminants that will originate from the mine workings will be pumped out as part of the mine dewatering process. The contamination plume migrates primarily by advection therefore dewatering enables the management of the potential contamination plume (during the period that dewatering will be taking place at that location), preventing upward migration into the shallow weathered aquifer. With the progression of mining over the 53 years of operation, dewatering will cease in mined out areas and recovery will commence. This is when the contamination plume (to a relatively limited degree) starts being introduced into some parts of the weathered aquifer, mainly at areas of increased permeably as a result of subsidence (Figure 6-3). The abstracted water during the operational phase may be contaminated and therefore should be stored in pollution control dams and recycled for coal processing.

Majority of groundwater users utilize the shallow weathered aquifer and some are located within the area of high extraction, therefore monitoring is recommended and affected private borehole owners should be compensated if contamination is proven from monitoring. Deep boreholes intersecting the coal seam aquifer are likely to be impacted by the lowering of the water and generation of a contamination plume over time. The expected contamination plume at the deep fractured aquifer is shown in Figure 6-4.

As shown in geological map of Figure 3-5, dolerite sill covers a considerable portion of the mine area. The probability of subsidence is expected to be low in areas where the high extraction is to take place underneath these sills or thick sandstone layers.

Model results show that the cone of depression is mainly at the deep fractured aquifer; its extent is shown in Figure 6-5. The cone of dewatering impacts to the weathered aquifer are expected to be less significant compared to the fractured aquifer, occurring at isolated areas due to the low vertical hydraulic conductivity of the local aquifers. The drawdown in the weathered aquifer is expected to be less than 5 m and thus only drawdown in the coal seam aquifer has been illustrated.

###### *6.3.2.1.2 Management Actions and Targets*

The following actions and targets are required:

- Dewatering should be conducted by abstracting groundwater ingress into mine voids during operation;
- Contaminated mine water should be stored in pollution control dams.
- If subsidence occurs during operation, it should be rehabilitated as soon as possible to minimise water and oxygen inflow from the atmosphere, as these components enable AMD reactions;
- Nitrate-based explosives can contaminate water thus no underground water should be discharged unless it meets standards to minimise ground and surface water contamination;
- In order to prevent subsidence during the bord-and-pillar mining phase, it is required that a safety factor that provides sufficient pillar stability is applied;
- The mine should be monitored on an annual basis for subsidence and areas of subsidence should be rehabilitated by backfilling with waste rock and topsoil thereafter revegetated;
- If possible, concurrent backfilling of the mine voids with fly ash should be conducted to minimise the risk of subsidence and neutralise any acid that might be generated;
- Groundwater level and quality monitoring should be conducted on quarterly basis during operation, with special attention given to the subsidence areas. The monitoring frequency can be reduced post-closure depending on the trend of the monitoring results;

- Affected receptors (if proven through monitoring) should be compensated;
- Groundwater monitoring should be conducted to assess the time series water level and water quality trends; and
- Numerical model should be updated every two years in the first four years and thereafter every five years based on groundwater monitoring results.

Fly ash is recommended as backfilling material in areas of high subsidence risk or where the host rock is regarded to have non-acid generating potential. This recommendation is based on the nature of fly ash having a high base potential in alkaline solution environments, therefore may improve the chemistry of underground mine water in suitable environments. However, fly ash contains significant concentrations of heavy metals and is highly likely to release those metals in acidic environments (Hodgson and Krantz, 1995).

##### *6.3.2.1.3 Operational Phase Impact Ratings*

The significance rating of the potential impacts of subsidence before and after mitigation plans is provided in Table 6-10.

**Table 6-10: Potential impacts of subsidence**

| **Activity & Interaction: Subsidence as a result of high extraction** | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| **Impact Description: Groundwater quality deterioration** | | | |
| ***Prior to mitigation/ management*** | | | |
| **Duration** | Permanent (7) | If subsidence occurs damage will be permanent. | Moderate (-75) |
| **Extent** | Local (3) | Impacts of subsidence will only occur within the mining rights area | |
| **Intensity x type of impact** | Serious loss (-5) | There may be serious impacts associated with the subsidence with regards groundwater quality at the shallow aquifer (where private boreholes are mostly found) and an impact to the shallow aquifer may impact surface water bodies that receive baseflow. | |
| **Probability** | Likely (5) | Subsidence is likely to occur during high extraction however geotechnical evaluations are required to confirm the probability. | |
| **Nature** | Negative | | |
| ***Mitigation/ Management actions*** | | | |

| Activity & Interaction: Subsidence as a result of high extraction | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| ▪ In order to prevent subsidence during the bord-and-pillar mining phase, it is required that a safety factor that provides sufficient pillar stability is applied.<br>▪ The mine should be monitored on an annual basis for subsidence and areas of subsidence should be rehabilitated by backfilling with waste rock and topsoil thereafter revegetated.<br>▪ If possible, concurrent backfilling of the mine voids with fly ash should be conducted to minimise the risk of subsidence and neutralise any acid that might be generated.<br>▪ Groundwater level and quality monitoring should be conducted on a quarterly basis during operation, with special attention given to the subsidence areas. The monitoring frequency can be reduced post-closure depending on the trend of the monitoring results. | | | |
| ***Post- mitigation*** | | | |
| **Duration** | Project life (5) | If areas of subsidence are monitored and rehabilitated the impacts will occur over a short period. | Minor (-44) |
| **Extent** | Local (3) | Impacts of subsidence will only occur within the mining rights area | |
| **Intensity x type of impact** | Moderate (-3) | With the application of the mitigation measures, potential impact intensity reduces significantly | |
| **Probability** | Likely (4) | If rehabilitated as soon as impact is picked up on through monitoring impact will be short lived and reversible | |
| **Nature** | Negative | | |

The significance rating of the potential impacts of dewatering before and after mitigation plans is provided in Table 6-11.

**Table 6-11: Potential dewatering impacts during the operational phase**

| Activity & Interaction: Mine dewatering and creation of cone of dewatering | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| **Impact Description: Lowering of the water table** | | | |
| ***Prior to mitigation/ management*** | | | |
| **Duration** | Beyond Project Life (6) | The water level will remain below its natural level during the entire operation. | Minor |

| Activity & Interaction: Mine dewatering and creation of cone of dewatering | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| **Extent** | Limited (2) | The radius of influence will mainly be at the deep fractured aquifer within the site and limited to isolated parts of the weathered aquifer. | (-72) |
| **Intensity x type of impact** | Serious (-4) | Mine dewatering will result in lowering of the water table within the site at the deep fractured aquifer and isolated parts of the shallow weathered aquifer (potentially impacting private boreholes and surface water bodies). | |
| **Probability** | Almost certain (6) | It is likely that there will be a cone of drawdown formed due to the mine dewatering (potentially affecting the shallow weathered and deep fractured) with an impact to the groundwater system and its dependence. | |
| **Nature** | Negative | | |
| ***Mitigation/ Management actions*** | | | |
| ▪ Dewatering should be conducted by abstracting groundwater ingress into mine voids during operation;<br>▪ Contaminated mine water should be stored in pollution control dams and reused for mine processing;<br>▪ Groundwater monitoring should be conducted to assess the time series water level, water quality impacts and trends; and<br>▪ Numerical model should be updated every two years in the first four years and thereafter every five years based on groundwater monitoring results. | | | |
| ***Post- mitigation*** | | | |
| **Duration** | Beyond project life (6) | The water level will remain below its natural level for some time after the life of a project. | Negligible (-27) |
| **Extent** | Limited (2) | With the above stated mitigation methods, the extent is expected to be limited. | |
| **Intensity x type of impact** | Minimal (-1) | With compensation to the potentially impacted receptors (private boreholes and rivers) the environmental significance is rated as minimal. | |

| Activity & Interaction: Mine dewatering and creation of cone of dewatering | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| **Probability** | Unlikely (3) | With the application of the proposed mitigation plans, it is unlikely that the lowering of the water table will have an adverse negative impact. | |
| **Nature** | Negative | | |

The significance rating of the potential impacts of groundwater contamination before and after mitigation plans is provided in Table 6-12.

**Table 6-12: Potential impacts of contamination during the operational phase**

| Activity & Interaction: Groundwater contamination as a result of underground mining | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| **Impact Description: Groundwater contamination** | | | |
| ***Prior to mitigation/ management*** | | | |
| **Duration** | Beyond project life (6) | Groundwater contamination due to mine disturbance will occur during the operational phase and is expected to persist even after closure. | Minor (-56) |
| **Extent** | Local (3) | The contaminated groundwater may migrate into the shallow aquifer and feed into the rivers via baseflow; this is brought by the increased permeability of overlying stratigraphy due to high extraction. However during operation, the plume is not expected to extend beyond the project area. | |
| **Intensity x type of impact** | Serious (-5) | The weathered aquifer is expected to receive the contamination plume. This brings risk to the private borehole owners and local rivers that receive baseflow. However the shallow aquifer, which hosts most potential receptors, receives a relatively limited concentration of the source contaminant. Additionally mine dewatering plays a role of restricting the contamination plume available in the groundwater environment. | |

| Activity & Interaction: Groundwater contamination as a result of underground mining | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| **Probability** | Probable (4) | The impact is likely to occur, although the plume is unlikely to not migrate beyond the mine area during the operational phase. | |
| **Nature** | Negative | | |
| ***Mitigation/ Management actions*** | | | |
| <ul><li>If subsidence is formed during operation, it should be rehabilitated as soon as possible to minimise water and oxygen inflow from the atmosphere.</li><li>Nitrate-based explosives can contaminate water thus no underground water should be discharged unless it meets standards to minimise ground and surface water contamination.</li><li>Groundwater monitoring should be conducted to assess the time series water level, water quality impacts and trends; and</li><li>Numerical model should be updated every two years in the first four years and thereafter every five years based on groundwater monitoring results.</li></ul> | | | |
| ***Post- mitigation*** | | | |
| **Duration** | Beyond project life (6) | Groundwater contamination due to mine disturbance will occur during the operational phase and is expected to persist even after closure. | Negligible (-27) |
| **Extent** | Limited (2) | With the implementation of the above stated mitigation measures, the impact extent can be limited to the mine workings only. | |
| **Intensity x type of impact** | Minimal (1) | The dewatering of the underground mine will contain the pollution plume during the operational phase, with minor effects on the groundwater environment. | |
| **Probability** | Unlikely (3) | The impact is unlikely to be severe with the implementation of the above stated mitigation measures. | |
| **Nature** | Negative | | |

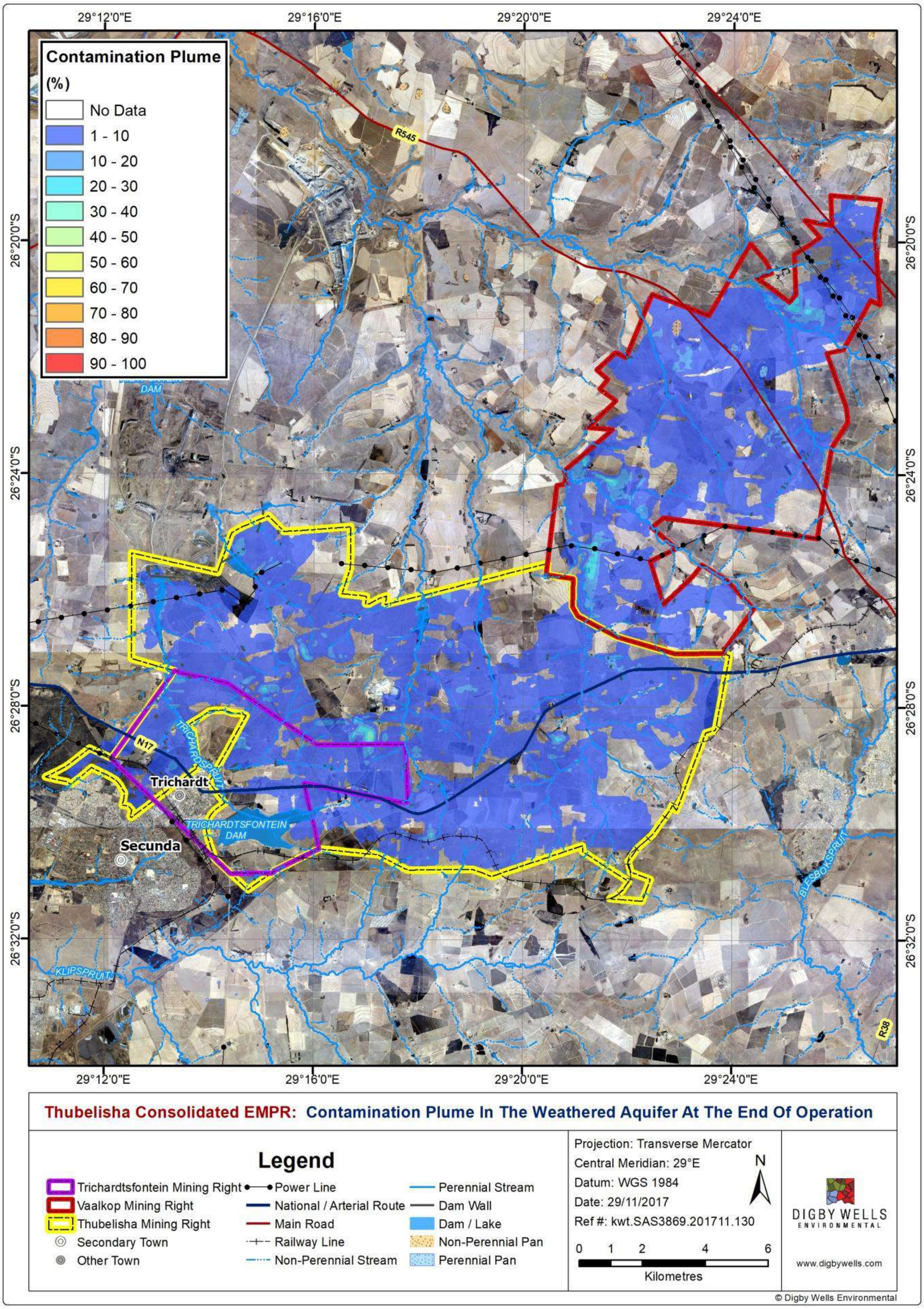


**Figure 6-3: Contamination plume in the weathered aquifer at the end of operation**

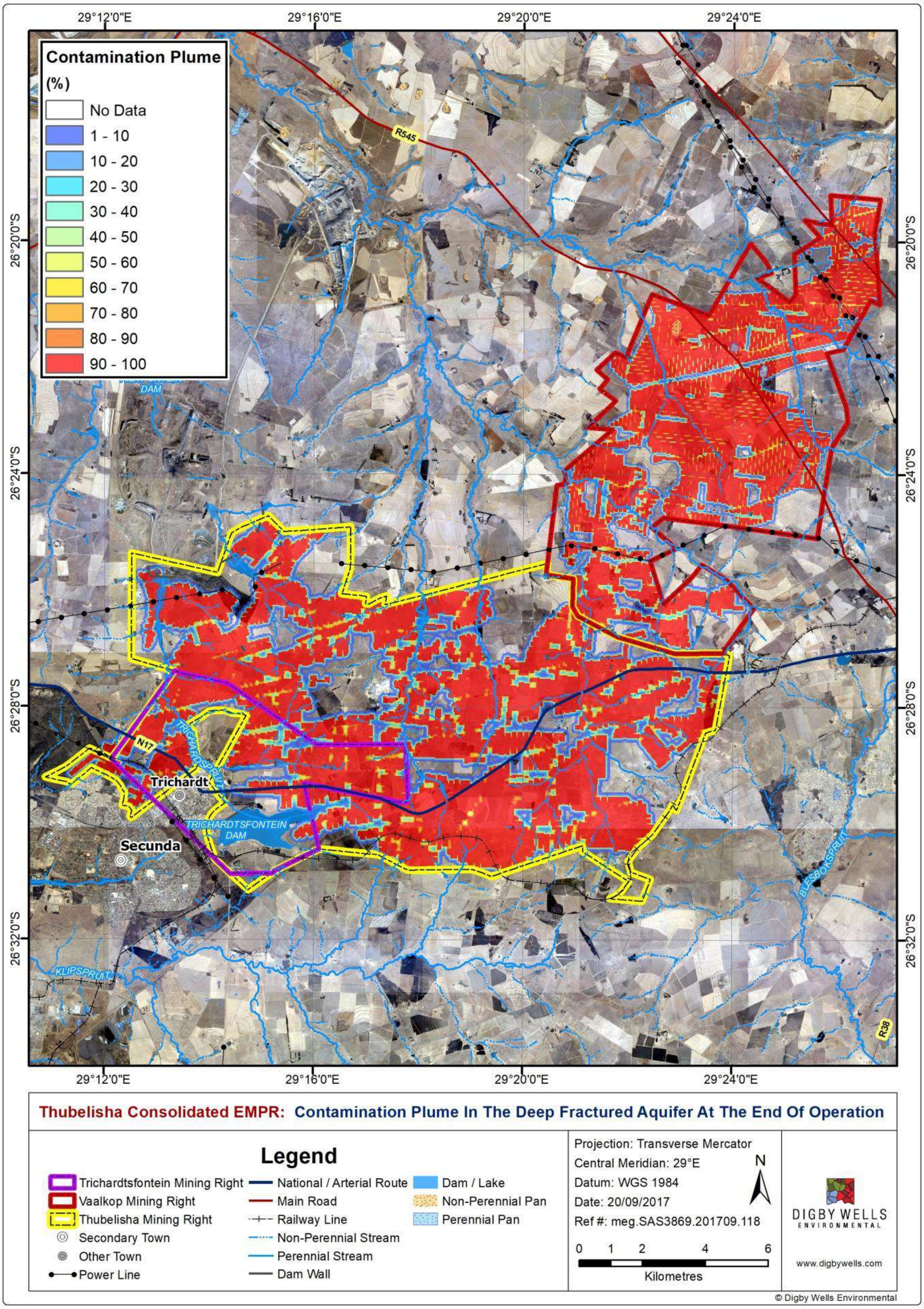


**Figure 6-4: Contamination plume in the deep fractured aquifer at the end of operation**

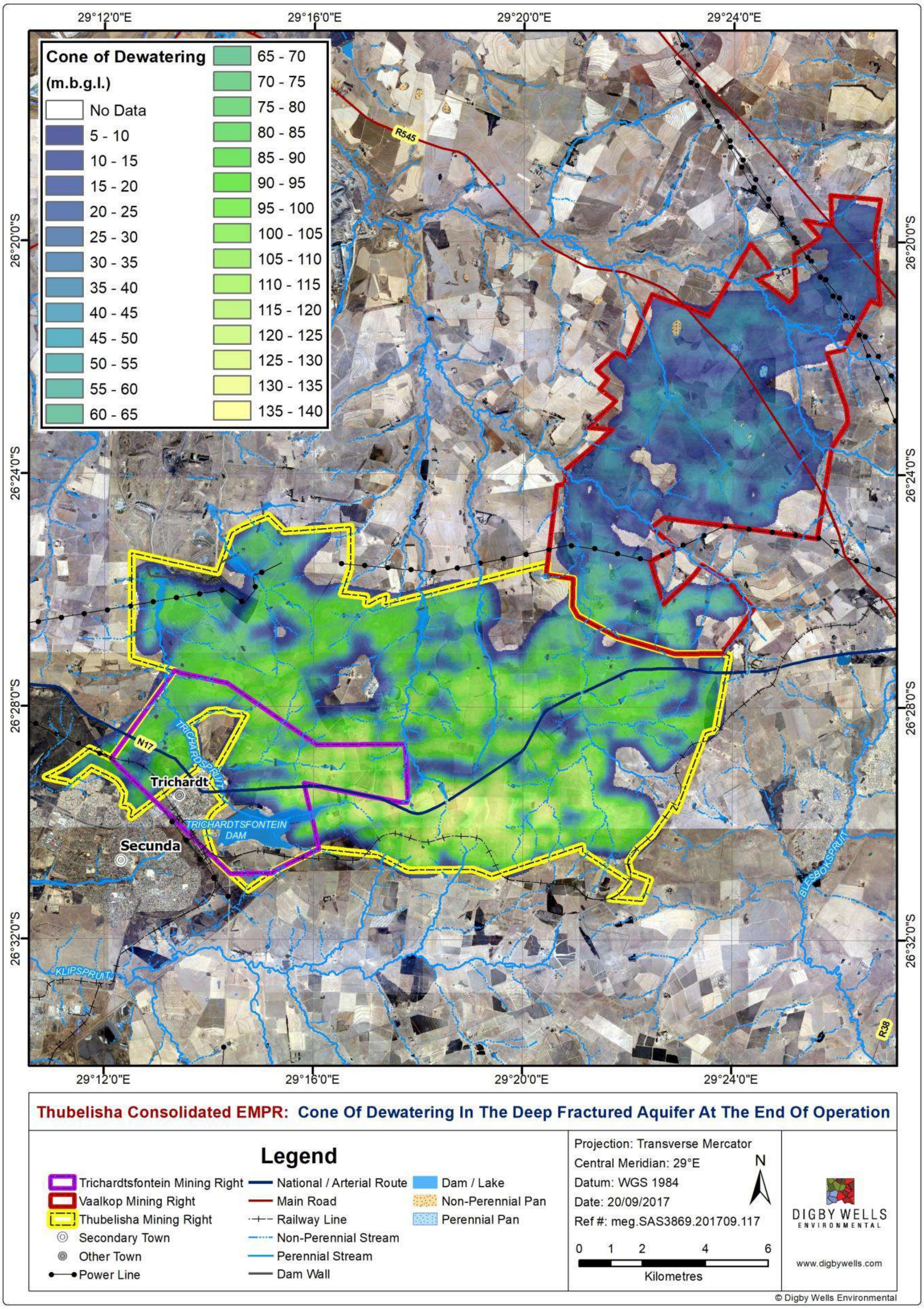


**Figure 6-5: Cone of depression in the deep fractured aquifer at the end of operation**

### 6.3.3 Decommissioning and Post-Closure Phases

#### *6.3.3.1 Project Activity Assessed*

During the decommissioning and post closure phases groundwater contamination is likely to occur. Table 6-13 provides the activity interaction and the resultant impact after mine closure.

**Table 6-13: Interactions and Impacts during the Decommissioning and Post-Closure Phase**

| Interaction | Impact |
|---|---|
| Mine contamination | Groundwater contamination |
| Mine decanting | Surface water contamination |

##### *6.3.3.1.1 Impact Description*

Once the mining and dewatering ceases, groundwater will start to recover towards reaching its pre-mining levels, due to the extensive area (126 km) full hydraulic head recovery varies in different parts of the impacted area. Contaminants may arise due to dissolution of heavy metals and the oxidation of sulphides, resulting in AMD or an excess of particular parameters when compared against various DWS water quality standards and project area's water use licence (WUL) water quality standards.

Following full recovery, the potential contaminants will start to migrate away from the mine site. The expected contamination plume 100 years post closure in the weathered aquifer is shown in Figure 6-6, a maximum of 40% of the source concentration from the mine voids will reach the weathered aquifer. Due to the low hydraulic conductivity in the deeper aquifers the contamination plume is expected to be retained within the project area at the deep fractured aquifer, Figure 6-7.

Model simulations show that decant is unlikely to occur even 100 years after closure at the shafts. Subsidence, sinkhole formation and unsealed deep boreholes have not been considered in the decant simulation. Should subsidence and sinkholes occur/form at elevations lower than the hydraulic head and or artificially extended geological structures that act as groundwater flow pathways, decanting is likely to occur at those areas. The potential decant areas are illustrated in Figure 6-8. It is impossible to inform at this moment if and when such structures will be formed. Additionally, exploration boreholes or abstraction boreholes (extending to the depth of the deep fractured aquifer where mining will be taking place) could also be decant zones, taking into consideration the extent of the mine and distribution of the boreholes, identifying the point of expected decant is not possible. Annual monitoring should be conducted for subsidence and sinkhole formation, followed by rehabilitation, as well as decant monitoring at unsealed deep boreholes (greater than 30 mbgl in depth). Investigations regarding subsidence and sinkhole formation probability, extent and location are limited. However are likely to occur as a result of high extraction mining, location and extent will depend on the depth of mining and character of the geological formations; the risk decreases with increasing depth of mining and the impacts on more ductile geological formations are less significant compared to brittle geological formations. In the event that decant is detected, it impacts are assessed below.

##### *6.3.3.1.2 Management Actions and Targets*

The following actions and targets are required:

- Affected receptors (if proven through monitoring) should be compensated;
- Decant should be collected and stored at a PCD as a short term solution;
- Long term management solutions for decant should be investigated;
- Monitoring groundwater levels and decant (rate and quality); and
- Numerical model should be updated every 5 years to calibrate with monitoring results.

##### *6.3.3.1.3 Post-Closure Phase Impact Ratings*

The significance rating of the potential impacts of subsidence before and after mitigation plans is provided in Table 6-14.

**Table 6-14: Potential impacts of subsidence**

| **Activity & Interaction: Subsidence as a result of high extraction** | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| **Impact Description: Lowering of the water table** | | | |
| ***Prior to mitigation/ management*** | | | |
| **Duration** | Permanent (7) | If subsidence occurs damage will be permanent. | Moderate (-80) |
| **Extent** | Local (3) | Impacts of subsidence will only occur within the mining rights area | |
| **Intensity x type of impact** | Serious loss (-6) | There may be serious impacts associated with the subsidence with regards groundwater quality at the shallow aquifer (where private boreholes are mostly found) and an impact to the shallow aquifer may impact surface water bodies that receive baseflow. Over time higher concentrations of the contamination source accumulate at the weathered aquifer (5% more than that what was observed at the end of operation and more extensive distribution of the higher | |

| Activity & Interaction: Subsidence as a result of high extraction | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| | | concentrations is observed. However the weathered aquifer is only expected to receive a maximum of 40% of the concentration of the source contamination. | |
| **Probability** | Likely (5) | Subsidence is likely to occur during high extraction however geotechnical evaluations are required to confirm the probability. | |
| **Nature** | Negative | | |
| ***Mitigation/ Management actions*** | | | |
| <ul><li>In order to prevent subsidence during the bord-and-pillar mining phase, it is required that a safety factor that provides sufficient pillar stability is applied.</li><li>The mine should be monitored on an annual basis for subsidence and areas of subsidence should be rehabilitated by backfilling with waste rock and topsoil thereafter revegetated.</li><li>If possible, concurrent backfilling of the mine voids with fly ash should be conducted to minimise the risk of subsidence and neutralise any acid that might be generated.</li><li>Groundwater level and quality monitoring should be conducted on a quarterly basis during operation, with special attention given to the subsidence areas. The monitoring frequency can be reduced post-closure depending on the trend of the monitoring results.</li></ul> | | | |
| ***Post- mitigation*** | | | |
| **Duration** | Project life (5) | If areas of subsidence are monitored and rehabilitated the impacts will occur over a short period. | Minor (-44) |
| **Extent** | Local (3) | Impacts of subsidence will only occur within the mining rights area | |
| **Intensity x type of impact** | Moderate (-3) | With the application of the mitigation measures, potential impact intensity reduces significantly | |
| **Probability** | Likely (4) | If rehabilitated as soon as impact is picked up on through monitoring impact will be short lived and reversible | |
| **Nature** | Negative | | |

The significance rating of the potential impacts of groundwater contamination during the decommissioning and post-closure is provided in Table 6-15.

### Table 6-15: Potential impacts of groundwater contamination during the post-closure phase

| Activity & Interaction: Groundwater contamination as a result of underground mining | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| **Impact Description: Groundwater contamination** | | | |
| ***Prior to mitigation/ management*** | | | |
| **Duration** | Beyond project life (6) | Groundwater contamination occurs due to dissolution of heavy metals forming potential acid mine drainage even after the mine closure. | Minor (-60) |
| **Extent** | Local (3) | The contamination plume predominantly stays within the project area. However the contaminated groundwater is likely to feed deep boreholes intersecting the coal seam aquifer and those at the shallow aquifer; posing a threat to the local potential receptors. | |
| **Intensity x type of impact** | Serious (-6) | At areas where the contamination plume extends into the shallow aquifer, receptors such as rivers and private boreholes may be impacted and receive groundwater of poor quality. Additionally, the contamination plume extends into the shallow aquifer zone at higher concentrations over time. | |
| **Probability** | Likely (4) | The impact is likely to occur since the groundwater will recover and the contamination plume is expected to migrate with the groundwater | |
| **Nature** | Negative | | |
| ***Mitigation/ Management actions*** | | | |
| ▪ Affected receptors (if proven through monitoring) should be compensated.<br>▪ Update numerical model every 5 years post closure to calibrate with monitoring results. | | | |
| ***Post management*** | | | |
| **Duration** | Beyond project life (6) | Groundwater contamination due to mine disturbance will continue even after mine closure | Negligible (-30) |
| **Extent** | Limited (2) | With the implementation of the above stated mitigation methods, the impact extent can be minimised to the site only | |

| Activity & Interaction: Groundwater contamination as a result of underground mining | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| **Intensity x type of impact** | Minor (-2) | If identified receptors are compensated the impacts of the contamination plume is regarded as minor, additionally the contamination plume is not expected to migrate beyond the project area | |
| **Probability** | Unlikely (3) | The impact is unlikely to occur if the above stated mitigation plans are implemented | |
| **Nature** | Negative | | |

The significance rating of the potential impacts of decant during the decommissioning and post-closure is provided in Table 6-16.

**Table 6-16: Potential impacts of decant**

| Activity & Interaction: Mine decanting and contamination of surface water bodies | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| **Impact Description: Decanting of the closed mine** | | | |
| ***Prior to mitigation/ management*** | | | |
| Duration | Permanent (7) | Once the mine starts to decant, it is not expected to stop naturally | Moderate (-96) |
| Extent | Municipal area (4) | Decant is likely to flow to the rivers within the project area, affecting the surface water quality and downstream water users unless it is prevented from doing so. | |
| Intensity x type of impact | Serous (5) | The decant is expected to have a significant impact and require effective management measures to prevent severe impacts | |
| Probability | Likely (6) | Based on analytical modelling, it is highly probable that there will be a decant after mine closure | |
| Nature | Negative | | |
| ***Mitigation/ Management actions*** | | | |
| ▪ Decant should be collected and stored at a PCD as a short term solution.<br>▪ Long term management solutions for decant should be investigated.<br>▪ Monitoring groundwater levels and decant (rate and quality). | | | |
| ***Post- mitigation*** | | | |
| Duration | Permanent (7) | Once the mine starts to decant, it is not expected to stop naturally | Negligible (-30) |

| Activity & Interaction: Mine decanting and contamination of surface water bodies | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| Extent | Limited (2) | With the decant stored in a PCD, the extent of impact will be limited | |
| Intensity x type of impact | Minimal (1) | Once the decanted water captured, the environmental significance is rated as minimal to no loss. | |
| Probability | Unlikely (3) | If the decant is captured, its impact is unlikely | |
| Nature | Negative | | |

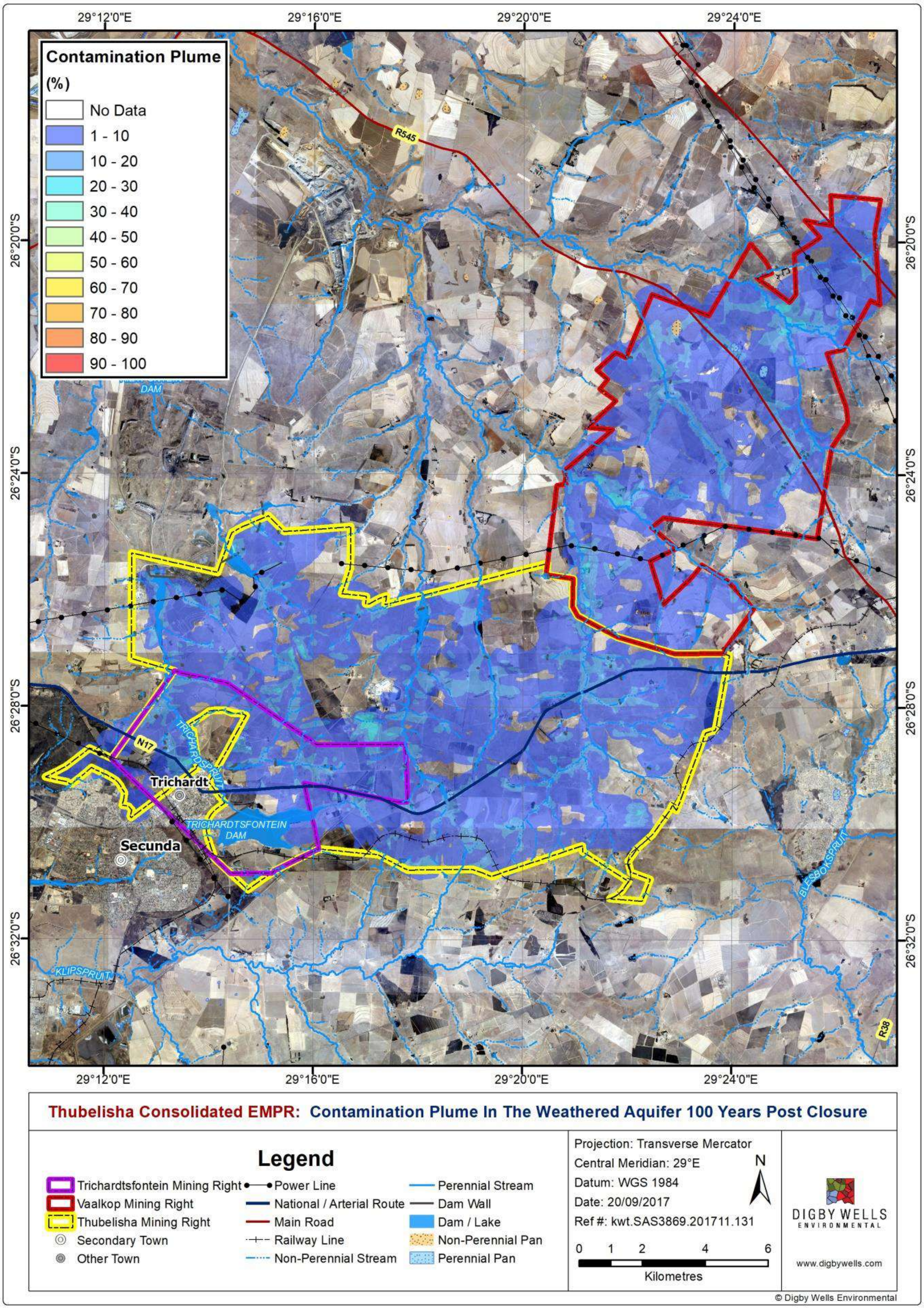


**Figure 6-6: Contamination plume in the weathered aquifer 100 years post-closure**

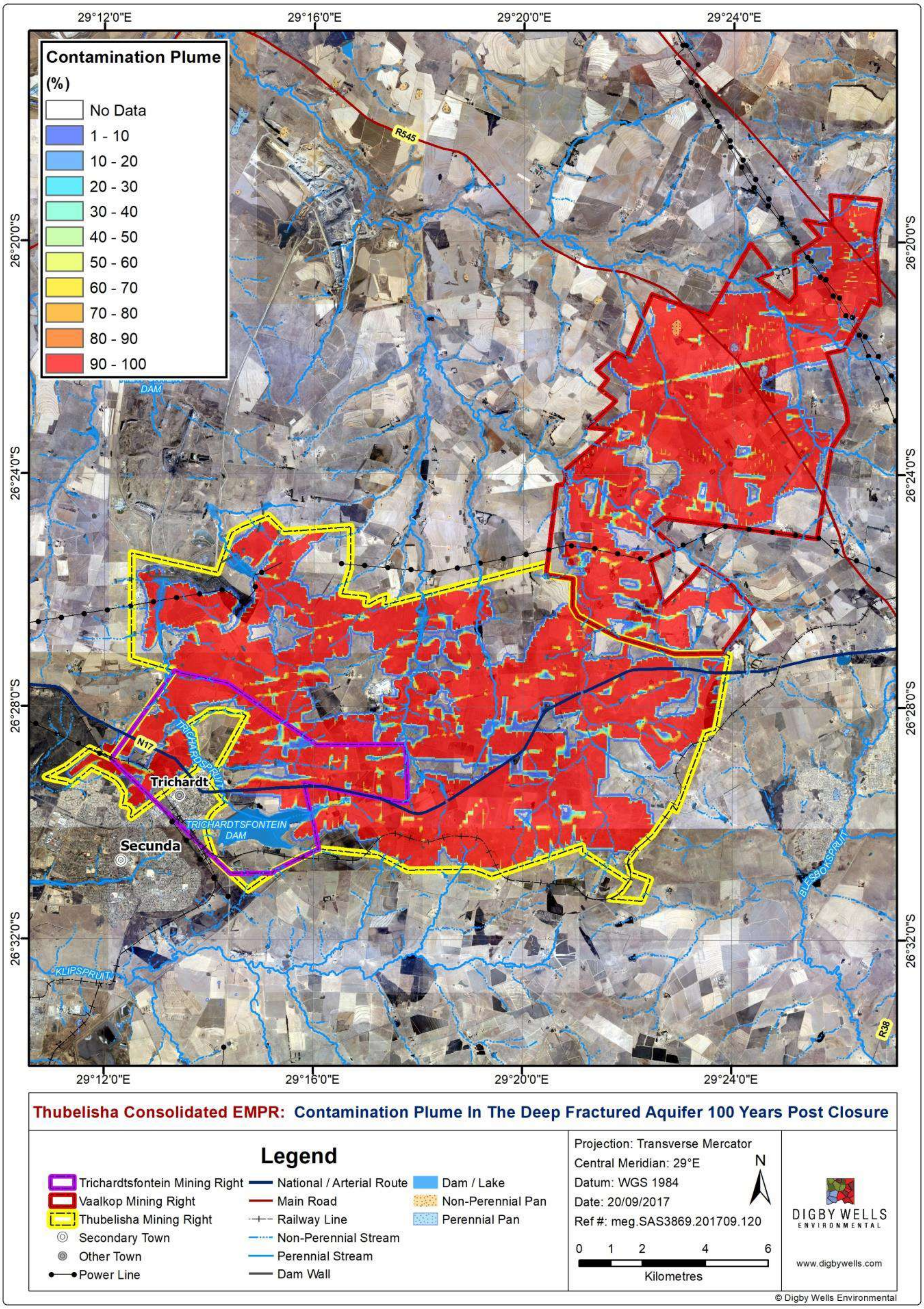


**Figure 6-7: Contamination plume in the deep fractured aquifer 100 years post-closure**

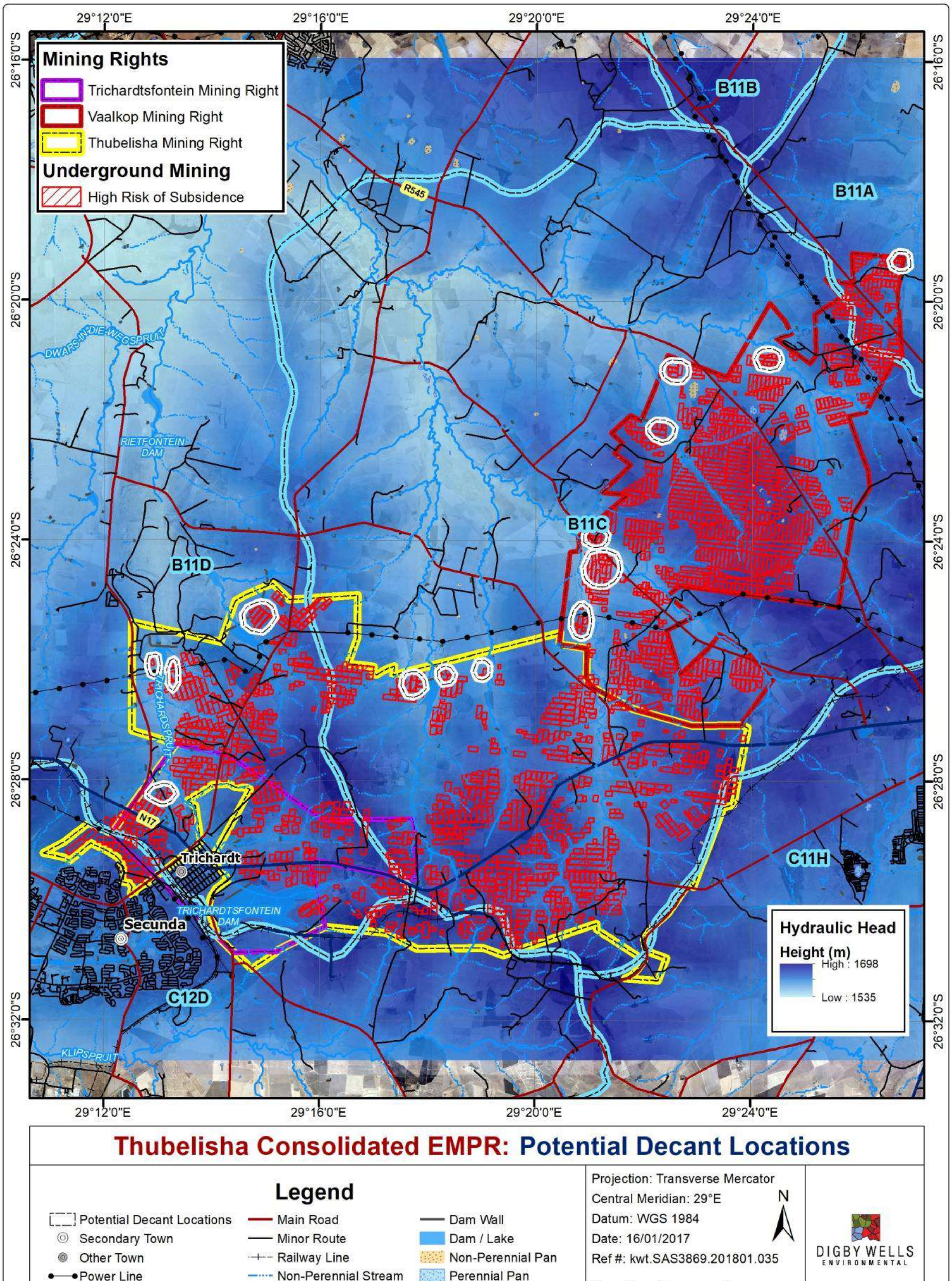


**Figure 6-8: Potential decant locations**

# 7 Cumulative Impacts

Observing the project area and its surroundings (10 km radius from the project area) it is evident that the area is dominated by mining related operations. Concentration of these facilities is observed especially downstream of the project area, as shown in Figure 7-1. All these operations are expected to have contributed or are currently contributing to the local groundwater quality deterioration. Impacts of dewatering activities and the contamination plume may extend beyond the project site considering cumulative impacts.

However, depending on the mine size, depth, life of mine and mining method, the cone of dewatering from the existing or future mines could possibility reach the project site. Considering the distance between the mines and the limited rock permeability, however, this is an unlikely scenario.

No decant is expected at the shafts however subsidence, sinkholes and unsealed deep boreholes were not taken into consideration when simulating the scenario of decant prediction.

The potential occurrence of the cone of dewatering in isolated parts of the shallow weathered aquifer may bring about cumulative impacts that could deteriorate water quantity at the local rivers that are part of the Olifants River Catchment. The potential groundwater contamination plume in the deep fractured aquifer from all the mines in the catchment is likely to have a negative impact on the groundwater quality, potentially impacting deep private boreholes.

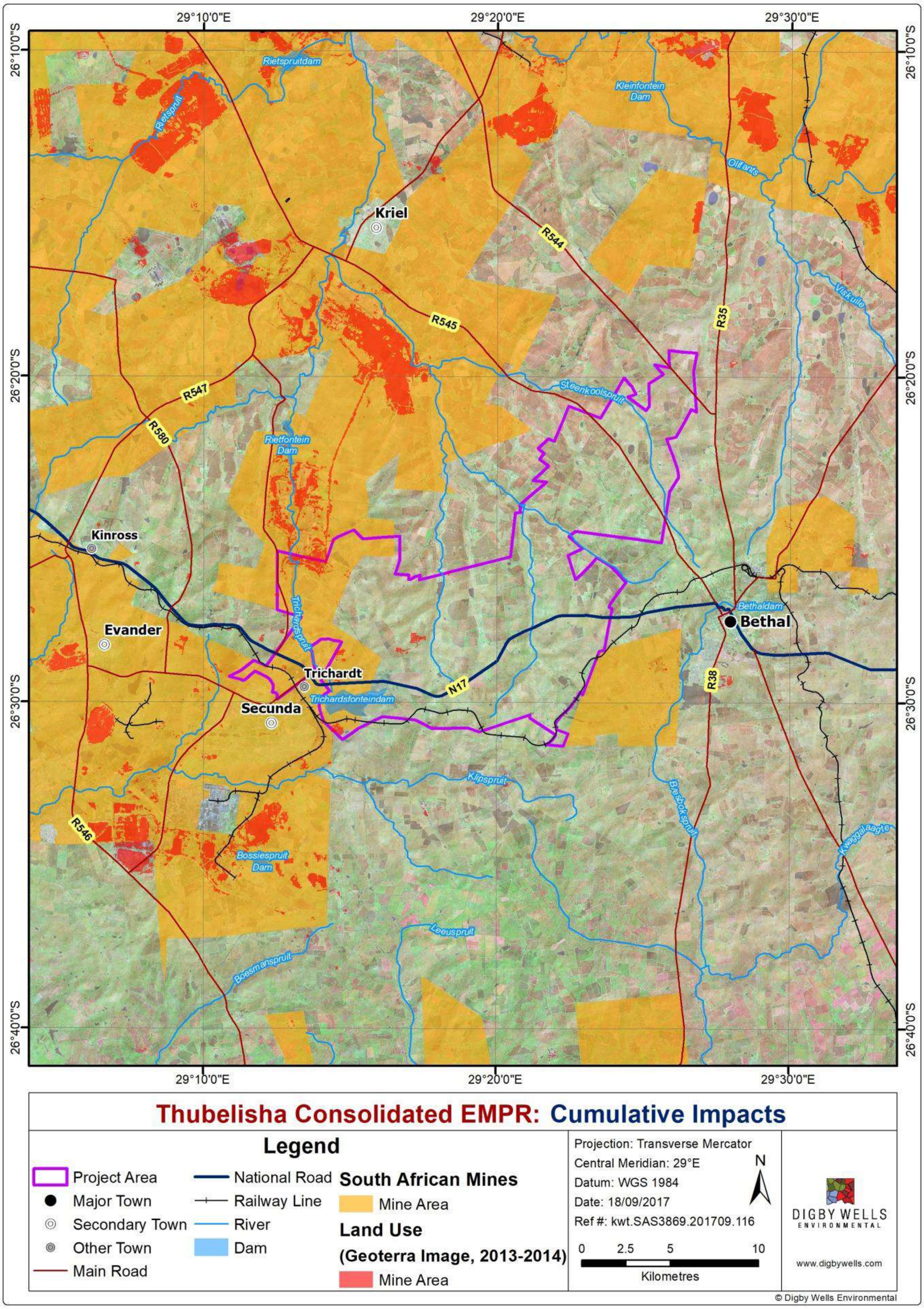


**Figure 7-1: Cumulative Impacts**

# 8 Unplanned Events and Low Risks

The unplanned events that may happen at the project site and the proposed mitigation plans are listed in Table 8-1.

**Table 8-1: Unplanned events, low risks and their management measures**

| Unplanned event | Potential impact | Mitigation / Management / Monitoring |
|---|---|---|
| Hydrocarbon spills from bulk storage tanks, vehicles and heavy machinery or hazardous materials or waste storage facilities at fuel bay. | ▪ Hydrocarbon contamination of the groundwater | ▪ Hydrocarbons and hazardous materials must be stored in bounded areas and refuelling should take place in contained areas;<br>▪ Ensure that oil and silt traps are well maintained;<br>▪ Vehicles and heavy machinery should be serviced and checked in a demarcated area on a regularly basis to prevent leakages and spills;<br>▪ Hydrocarbon spill kits must be available on site at all locations where hydrocarbon spills could take place;<br>▪ Monitoring boreholes, particularly those located within the construction area, have to be monitored for both water level and quality to detect any changes; and<br>▪ If a considerable amount of fluid is accidentally spilled, the contaminated soil should be scraped off and disposed of at an acceptable dumping facility. The excavation should be backfilled with soil of good quality. |
| Spills / leaks from the dewatering pipeline. | ▪ Contamination of groundwater | ▪ Regular inspections of the pipeline should be conducted for any leaks. Seeping pipeline should be sealed. |

# 9 Environmental Management Plan

The objective of an Environmental Management Plan (EMP) is to present mitigation measures that manage reasonably avoidable adverse impacts associated with the development and to enhance potential positives.

## 9.1 Project Activities with Potentially Significant Impacts

Potentially significant impacts that require mitigation or management are listed in Table 9-1.

**Table 9-1: Potentially significant impacts**

| Activity | Aspects | Potential Significant Impacts |
|---|---|---|
| Site clearing | Water table | ▪ Lowering of the water table if excavation during the site clearing process is going to take place below the water table. |
| Underground mine development | Dewatering | ▪ Depletion of the groundwater;<br>▪ Reduction of the flow rate of the streams; and<br>▪ Lowering of water tables in private boreholes. |
| | Groundwater contamination | ▪ Dissolution of heavy metals (AMD generation and deterioration of groundwater quality. |
| | Subsidence | ▪ Post operation the hydraulic head will recover and recharge will increase at areas of subsidence due to the increased permeability, introducing contaminated groundwater into the weathered aquifer;<br>▪ Reduction of the flow rate of the streams as water will pond or infiltrate at the area of subsidence, reducing or potentially eliminating flow downstream; and<br>▪ Dissolution of heavy metals (AMD generation and deterioration of groundwater quality as larger area will be disturbed. |
| Decant | Surface water | ▪ Deterioration of surface water quality. |

## 9.2 Summary of Mitigation and Management

Table 9-2 to Table 9-4 provide a summary of the proposed project activities, environmental aspects and impacts on the receiving environment. Information on the frequency of mitigation, relevant legal requirements, recommended management plans, timing of implementation, and roles / responsibilities of persons implementing the EMP.

**Table 9-2: Impacts**

| Activities | Phase | Size and scale of disturbance | Mitigation Measures | Compliance with standards | Time period for implementation |
|---|---|---|---|---|---|
| Site clearing | Construction | Approximately 5 $km^2$ | ▪ Site clearance and construction activities should take place above the water table, at the unsaturated zone, (if possible), no impact on the groundwater will then be expected;<br>▪ Site clearance should be kept to a minimum area and short duration;<br>▪ If trenches are going to be excavated below the water level, dewatering to lower the water table locally should be considered to ensure that the construction takes place above the groundwater level. Since the groundwater is not expected to be polluted at this stage, the utilisation of the water for activities such as dust suppression or irrigation (if applicable). | N/A | ▪ Groundwater monitoring must commence from the construction phase<br>▪ Where proven to be required, mitigation measures to reduce impact to the groundwater from the construction phase |
| Underground mine development - Dewatering | Operation and post closure | Approximately 126 $km^2$ | ▪ Affected private borehole users should be compensated, (impact is proven through monitoring records).<br>▪ Decant should be collected and stored at a PCD as a short term solution;<br>▪ Long term management solutions for decant should be investigated.<br>▪ Groundwater monitoring should be conducted to assess the time series water level, water quality impacts and trends.<br>▪ Updating of the numerical model as aquifer properties become available. | ▪ SANS.<br>▪ River quality objectives.<br>▪ South African water quality guidelines for drinking, irrigation and livestock watering. | ▪ Groundwater monitoring must commence from the start of the construction phase.<br>▪ Mine should supply private borehole owners with clean water when groundwater depletion is detected.<br>▪ During operation, conceptual and numerical models should be refined every two years in the first four years and thereafter every five years based on groundwater monitoring results. Post closure, numerical model should be updated every 5 years to calibrate with monitoring results. |
| Underground mine development - Groundwater contamination. | Operation and post closure | Approximately 126 $km^2$ | ▪ If subsidence is formed during operation, it should be rehabilitated as soon as possible to minimise water and oxygen inflow from the atmosphere.<br>▪ Nitrate-based explosives can contaminate water thus no underground water should be discharged unless it meets standards to minimise ground and surface water contamination.<br>▪ Affected private borehole users (if proven through monitoring records) should be compensated.<br>▪ Monitoring of groundwater quality and water levels.<br>▪ Updating of the numerical model as aquifer properties become available. | ▪ SANS.<br>▪ River quality objectives.<br>▪ South African water quality guidelines for drinking, irrigation and livestock watering. | ▪ Groundwater monitoring must commence from the start of the construction phase.<br>▪ Mine should supply private borehole owners with clean water when contamination is detected.<br>▪ During operation, conceptual and numerical models should be refined every two years in the first four years and thereafter every five years based on groundwater monitoring results. Post closure, numerical model should be updated every 5 years to calibrate with monitoring results. |

| Activities | Phase | Size and scale of disturbance | Mitigation Measures | Compliance with standards | Time period for implementation |
|---|---|---|---|---|---|
| Underground mine development- Subsidence | Operation and post closure | | ▪ In order to prevent subsidence during the bord-and-pillar mining phase, it is required that a safety factor of 2 is applied.<br>▪ The mine should be monitored on an annual basis for subsidence and areas of subsidence should be rehabilitated by backfilling with waste rock and topsoil thereafter revegetated.<br>▪ If possible, concurrent backfilling of the mine voids with fly ash should be conducted to minimise the risk of subsidence and neutralise any acid that might be generated.<br>▪ Groundwater level and quality monitoring should be conducted on a quarterly basis during operation, with special attention given to the subsidence areas. The monitoring frequency can be reduced post-closure depending on the trend of the monitoring results. | | ▪ Safety factors should be taken into consideration as mining commences;<br>▪ Groundwater level and quality monitoring at the shallow weathered aquifer (at high risk areas) should be conducted quarterly; and<br>▪ Annual subsidence monitoring (aerial surveys/ land surveys) throughout the project area. |
| Decant | Post closure | | ▪ Decant should be collected and stored at a PCD as a short term solution.<br>▪ Long term management solutions for decant should be investigated.<br>▪ Affected receptors (if proven through monitoring) should be compensated.<br>▪ Monitoring groundwater levels and decant (rate and quality). | ▪ SANS.<br>▪ River quality objectives. | ▪ Mitigation measures should be implemented as soon as decant is detected.<br>▪ Numerical model should be updated every 5 years to calibrate with monitoring results. |

**Table 9-3: Objectives and Outcomes of the EMP**

| Activities | Potential impacts | Aspects affected | Phase | Mitigation | Standard to be achieved/objective |
|---|---|---|---|---|---|
| Underground mine development - Dewatering | Groundwater and surface water depletion | Groundwater quantity | Operation | ▪ Mine should supply equal/better amount of water to affected private borehole owners.<br>▪ Contaminated mine water should be collect and stored at a PCD as a short term solution.<br>▪ Long term management solutions for decant should be investigated.<br>▪ Monitoring of water levels.<br>▪ Updating of the numerical model as aquifer properties become available. | ▪ SANS.<br>▪ River quality objectives.<br>▪ South African water quality guidelines for drinking, irrigation and livestock watering |
| Underground mine development - Groundwater contamination | Groundwater contamination | Groundwater quality | Operation and post-closure | ▪ If subsidence is formed during operation, it should be rehabilitated as soon as possible to minimise water and oxygen inflow from the atmosphere.<br>▪ Nitrate-based explosives can contaminate water thus no underground water should be discharged unless it meets standards to minimise ground and surface water contamination.<br>▪ Mine should supply equal/better amount of water to affected parties.<br>▪ Monitoring of groundwater quality.<br>▪ Updating of the numerical model as aquifer properties become available. | ▪ SANS.<br>▪ River quality objectives.<br>▪ South African water quality guidelines for drinking, irrigation and livestock watering. |

| Activities | Potential impacts | Aspects affected | Phase | Mitigation | Standard to be achieved/objective |
|---|---|---|---|---|---|
| Underground mine development- Subsidence | Groundwater and surface water depletion. Groundwater contamination. | Groundwater quality and groundwater quantity | Operation and post closure | ▪ In order to prevent subsidence during the bord-and-pillar mining phase, it is required that a safety factor of 2 is applied.<br>▪ The mine should be monitored on an annual basis for subsidence and areas of subsidence should be rehabilitated by backfilling with waste rock and topsoil thereafter revegetated.<br>▪ If possible, concurrent backfilling of the mine voids with fly ash should be conducted to minimise the risk of subsidence and neutralise any acid that might be generated.<br>▪ Groundwater level and quality monitoring should be conducted on a quarterly basis during operation, with special attention given to the subsidence areas. The monitoring frequency can be reduced post-closure depending on the trend of the monitoring results. | |
| Decant | Surface water contamination | Surface water quality | Post closure | ▪ Affected receptors (if proven through monitoring) should be compensated.<br>▪ Decant should be collected and stored at a PCD as a short term solution.<br>▪ Long term management solutions for decant should be investigated.<br>▪ Monitoring groundwater levels and decant (rate and quality). | ▪ SANS.<br>▪ River quality objectives. |

**Table 9-4: Mitigation**

| Activities | Potential impacts | Aspects affected | Mitigation type | Time period for implementation | Compliance with standards |
|---|---|---|---|---|---|
| Underground mine development - Dewatering | Groundwater and surface water depletion | Groundwater quantity | ▪ Potentially contaminated water should be collect and stored at a PCD as a short term solution.<br>▪ Long term management solutions for decant should be investigated.<br>▪ Affected private borehole users should be compensated, (impact is proven through monitoring records).<br>▪ Groundwater monitoring should be conducted to assess the time series water level, water quality impacts and trends.<br>▪ Updating of the numerical model as aquifer properties become available. | ▪ Mine should supply clean water when water depletion is detected in the private boreholes.<br>▪ Groundwater monitoring must commence from the start of the construction phase.<br>▪ During operation, conceptual and numerical models should be refined every two years in the first four years and thereafter every five years based on groundwater monitoring results. Post closure, numerical model should be updated every 5 years to calibrate with monitoring results. | ▪ SANS.<br>▪ River quality objectives.<br>▪ South African water quality guidelines for drinking, irrigation and livestock watering. |

| Activities | Potential impacts | Aspects affected | Mitigation type | Time period for implementation | Compliance with standards |
|---|---|---|---|---|---|
| Underground mine development - Groundwater contamination | Groundwater contamination | Groundwater quality | ▪ If subsidence is formed during operation, it should be rehabilitated as soon as possible to minimise water and oxygen inflow from the atmosphere.<br>▪ Nitrate-based explosives can contaminate water thus no underground water should be discharged unless it meets standards to minimise ground and surface water contamination.<br>▪ Affected private borehole users (if proven through monitoring records) should be compensated.<br>▪ Monitoring of groundwater quality and water levels.<br>▪ Updating of the numerical model as aquifer properties become available. | ▪ Mine should supply clean water when contamination is detected in the private boreholes.<br>▪ Groundwater monitoring must commence from the start of the construction phase.<br>▪ During operation, conceptual and numerical models should be refined every two years in the first four years and thereafter every five years based on groundwater monitoring results. Post closure, numerical model should be updated every 5 years to calibrate with monitoring results. | ▪ SANS.<br>▪ River quality objectives.<br>▪ South African water quality guidelines for drinking, irrigation and livestock watering. |
| Underground mine development-Subsidence | Groundwater and surface water depletion. Groundwater contamination. | Groundwater quality and groundwater quantity | ▪ In order to prevent subsidence during the bord-and-pillar mining phase, it is required that a safety factor of 2 is applied.<br>▪ The mine should be monitored on an annual basis for subsidence and areas of subsidence should be rehabilitated by backfilling with waste rock and topsoil thereafter revegetated.<br>▪ If possible, concurrent backfilling of the mine voids with fly ash should be conducted to minimise the risk of subsidence and neutralise any acid that might be generated.<br>▪ Groundwater level and quality monitoring should be conducted on a quarterly basis during operation, with special attention given to the subsidence areas. The monitoring frequency can be reduced post-closure depending on the trend of the monitoring results. | ▪ Safety factors should be taken into consideration as mining commences;<br>▪ Groundwater level and quality monitoring at the shallow weathered aquifer (at high risk areas) should be conducted quarterly; and<br>▪ Annual subsidence monitoring (aerial surveys/ land surveys) throughout the project area. | |
| Decant | Surface water contamination | Surface water quality | ▪ Decent should be collected and treated to river qual.y objectives before joining the streams,<br>▪ Affected receptors (if proven through monitoring) should be compensated.<br>▪ Alternatively, the potentially contaminated water can be stored at a PCD.<br>▪ Monitoring groundwater levels and decant (rate and quality). | ▪ Mitigation measures should be implemented as soon as decant is detected.<br>▪ Numerical model should be updated every 5 years to calibrate with monitoring results. | ▪ SANS.<br>▪ River quality objectives. |

**Table 9-5: Prescribed Environmental Management Standards, Practice, Guideline, Policy or Law**

| Specialist field | Applicable standard, practice, guideline, policy or law | | | |
|---|---|---|---|---|
| Groundwater | ▪ National Water Act, 1998 (Act No. 36 of 1998).<br>▪ National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended (NEMA), GNR 544 and GNR 545 (Section 24 (1)).<br>▪ Water Services Act 108 of 1997.<br>▪ National Environmental Management: Waste Act, 2008 (Act 59 of 2008) (NEMWA) and List of Waste Management Activities requiring a Waste Management Licence (WML) GN 718 of 2008. | ▪ Department of Water and Sanitation (DWS) (formerly DWAF). Government Gazette, No. 704 (GN 704). 1999. Regulations on the Use of Water for Mining and Related Activities Aimed at the Protection of Water Resources (Vol. 408, No. 20119). 4 June 1999.<br>▪ Hazardous Substances Act (Act 15 of 1973).<br>▪ Facilities Regulations (GNR 924 of 2004).<br>▪ Hazardous Chemical Substances Regulations (GN 1179 of 1995). | ▪ Department of Water and Sanitation (DWS) (formerly DWAF). 2006. Best Practice Guideline G3: Water Monitoring Systems.<br>▪ Department of Water and Sanitation (DWS) (formerly DWAF). 2006. Best Practice Guideline G1: Storm Water Management. | ▪ Department of Water and Sanitation (DWS) (formerly DWAF). 2006. Best Practice Guideline G2: Water and Salt Balances.<br>▪ Department of Water and Sanitation (DWS) (formerly DWAF). 2006. Best Practice Guideline A4: Pollution Control Dams. |

## 9.3 Monitoring Plan

Groundwater monitoring should be undertaken to establish the following:

- The impact of mine dewatering on the local aquifers, through monitoring of groundwater levels; and
- Groundwater quality trends, through sampling.

Deep and shallow aquifer monitoring is recommended:

- Shallow aquifer monitoring boreholes should be drilled to a maximum depth of 30 mbgl; and
- Deep aquifer monitoring boreholes should be drilled to depths ranging between 80 and 200 mbgl.

The monitoring boreholes are recommended to be equipped with piezometers to enable monitoring of both aquifers at the same borehole. The recommended groundwater monitoring locations are presented in Table 9-6. A total of 65 monitoring locations are proposed, 47 existing boreholes and 18 proposed boreholes to be drilled.

**Table 9-6: Recommended monitoring boreholes**

| Site ID | X m (Cape29) | Y m (Cape29) | Comment | Aquifer |
|---|---|---|---|---|
| **Trichardtsfontein** | | | | |
| TRBH2 | 24994 | -2930543 | Existing | Shallow |
| TRBH2D | 24994 | -2930543 | New | Deep |
| TRBH1 | 21521 | -2928293 | Existing | Shallow |
| TN2 | 21182.59 | -2929786.09 | Existing | Shallow |
| TN2D | 21182.59 | -2929786.09 | New | Deep |
| DPLBH2 | 23579.61 | -2934022.73 | Existing | Shallow |
| RP6 | 27472.00 | -2931694.01 | Existing | Shallow |
| HNBH1 | 29608.30 | -2931295.01 | Existing | Shallow |
| RP21 | 28009.00 | -2929216.01 | Existing | Shallow |
| TNBH1 | 24481.76 | -2934026.31 | Existing | Shallow |
| TRIBH1 | 25502 | -2928284 | New | Shallow |
| TRIBH2 | 18262 | -2930027 | New | Shallow |
| TRIBH3 | 22712 | -2932296 | New | Shallow |
| **Thubelisha** | | | | |

| Site ID | X m (Cape29) | Y m (Cape29) | Comment | Aquifer |
|---|---|---|---|---|
| RP10 | 21392.00 | -2926888 | Existing | Deep |
| RP11 | 23984.00 | -2925910 | Existing | Deep |
| RP12 | 29945.00 | -2928604 | Existing | Deep |
| RP13 | 25358 | -2930889 | Existing | Deep |
| RP14 | 25507 | -2930356 | Existing | Deep |
| RP16D | 27789 | -2929743 | Existing | Deep |
| RP16S | 27783 | -2929743 | Existing | Shallow |
| RP17D | 28955 | -2928244 | Existing | Deep |
| RP17S | 28953 | -2928244 | Existing | Shallow |
| RP18D | 28123 | -2927411 | Existing | Deep |
| RP18S | 28134 | -2927408 | Existing | Shallow |
| RP19D | 29469 | -2927946 | Existing | Deep |
| RP19S | 29469 | -2927964 | Existing | Shallow |
| RP2 | 35124.00 | -2926067 | Existing | Deep |
| RP20D | 29486.00 | -2927636 | Existing | Deep |
| RP20S | 29489.00 | -2927646 | Existing | Shallow |
| RP21D | 28018.00 | -2929223 | Existing | Deep |
| RP21S | 28009.00 | -2929216 | Existing | Shallow |
| RP3 | 33533.00 | -2927076 | Existing | Shallow |
| RP4 | 31419.00 | -2932807 | Existing | Shallow |
| RP5 | 35869.00 | -2929029 | Existing | Deep |
| RP7 | 24882 | -2929384 | Existing | Deep |
| RP8 | 23771 | -2930168 | Existing | Deep |
| RP9 | 26277.00 | -2927227 | Existing | Deep |
| RPS2 | 38216.94 | -2917156 | Existing | Shallow |
| RT18 | 29539.62 | -2933330 | Existing | Shallow |
| ZT3 | 30177.62 | -2924382 | Existing | Shallow |
| THUBH1 | 25894 | -2922395 | New | Shallow |
| THUBH2 | 23643.54 | -2922219 | New | Shallow |
| THUBH3 | 28732.11 | -2921753 | New | Shallow |

| Site ID | X m (Cape29) | Y m (Cape29) | Comment | Aquifer |
|---|---|---|---|---|
| THUBH4 | 37811.72 | -2934724 | New | Shallow |
| **Vaalkop** | | | | |
| HN2 | 34123.63 | -2924366 | Existing | Shallow |
| PN5 | 37547.64 | -2926506 | Existing | Shallow |
| PN9 | 36327.64 | -2924224 | Existing | Shallow |
| PTBH2 | 35263.71 | -2924516 | Existing | Shallow |
| RF1 | 38600.64 | -2926221 | Existing | Shallow |
| RFNBH1 | 37495.77 | -2922997 | Existing | Shallow |
| RNBH2 | 43552.15 | -2922652 | Existing | Shallow |
| RNBH2D | 43552.15 | -2922652 | New | Shallow |
| RNBH5 | 40906.93 | -2922474 | Existing | Shallow |
| RPS2 | 38216.94 | -2917156 | Existing | Shallow |
| TBH3 | 41188.27 | -2914485 | Existing | Shallow |
| VALBH1 | 35251 | -2917403 | New | Shallow |
| VALBH2 | 33929 | -2920905 | New | Shallow |
| VALBH3 | 39017 | -2915189 | New | Shallow |
| VALBH4 | 44898 | -2912117 | New | Shallow |
| VALBH5 | 43840 | -2911886 | New | Shallow |
| VALBH6 | 43873 | -2919154 | New | Shallow |
| VALBH7 | 43047 | -2915189 | New | Shallow |
| VALBH8 | 41164 | -2918460 | New | Shallow |
| VALBH9D | 38257 | -2920145 | New | Deep |
| VALBH9S | 38257 | -2920145 | New | Shallow |

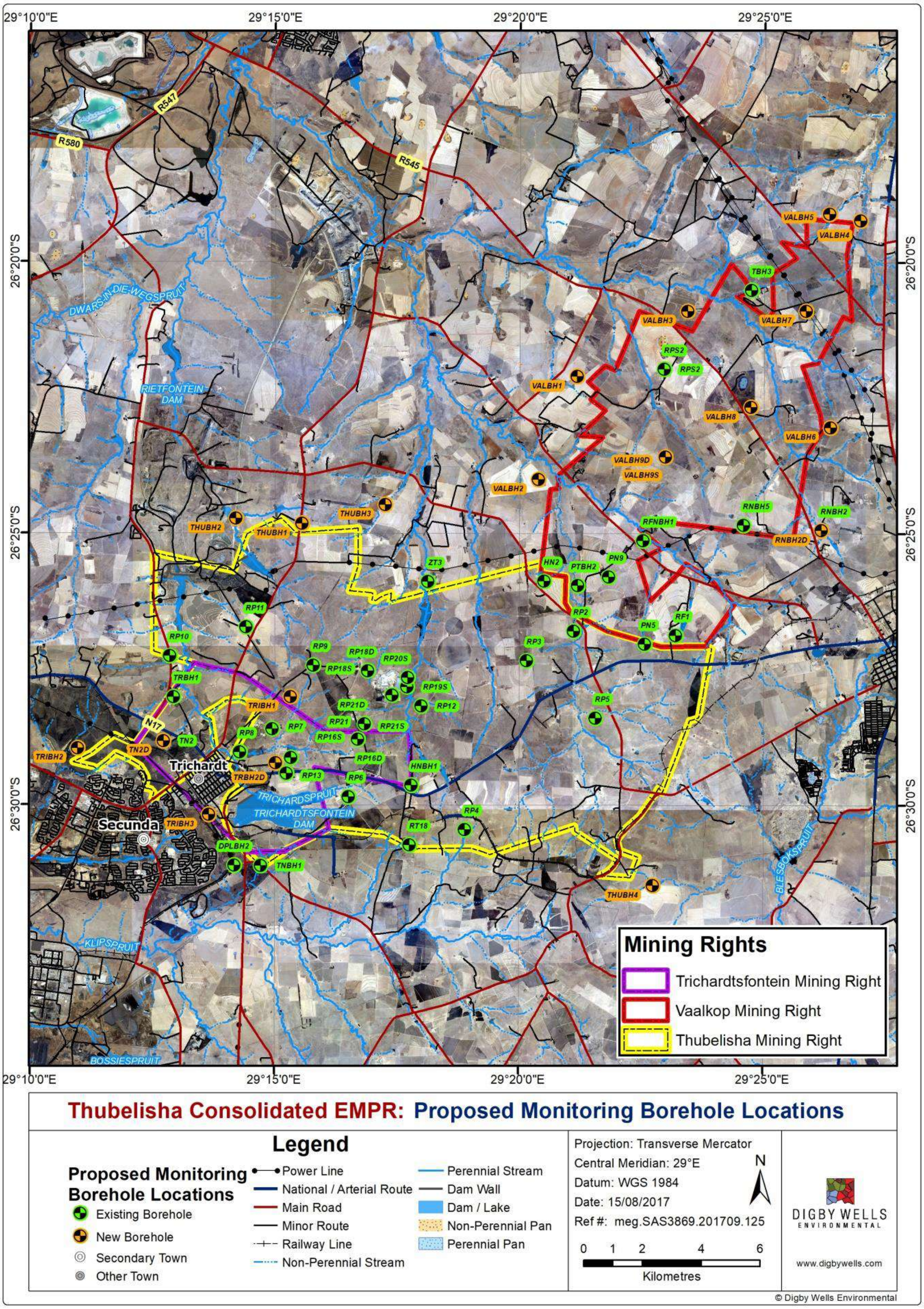


Figure 9-1: Proposed Groundwater Monitoring Boreholes

### 9.3.1 Water Level

Groundwater levels must be recorded on a quarterly basis to detect any changes or trends in groundwater elevation and flow direction.

### 9.3.2 Water Sampling and Preservation

When sampling the following procedures are proposed:

- One litre plastic bottles with a cap are required for the sampling exercises;
- Glass bottles are required if organic constituents are to be tested;
- Collected samples must be stored in cooler box or fridge while on site; and
- Sample bottles should be marked clearly with the borehole name, date of sampling, sampling depth and the sampler's name and submitted to a laboratory that analyses in accordance with the methods prescribed by the South African Bureau of Standards in terms of the Standards Act, Act 30 of 1982.

### 9.3.3 Sampling Frequency

Groundwater is a slow-moving medium and drastic changes in the groundwater composition are not normally encountered within days. Considering the proximity of private boreholes and streams to the proposed mine, monitoring should be conducted quarterly to reflect influences of wet and dry seasons. The sampling frequency could be adjusted following the trend analysis.

Samples should be collected by using Water Research Commission (WRC), 2007, Groundwater Sampling: A Comprehensive Guide for Sampling Methods and submitted to a laboratory that analyses in accordance with the methods prescribed by the South African Bureau of Standards in terms of the Standards Act, Act 30 of 1982.

It is suggested that quarterly samples be collected, extending up to two years post closure and based on the result trends it can be adjusted until a sustainable situation is reached and after it has been signed off by the authorities.

### 9.3.4 Parameters to be Monitored

- TDS, EC, pH, Alkalinity;
- Major ions i.e. Ca, Mg, Na, K, $SO_4$, $NO_3$, F, Cl; and
- Minor and trace metals, including As, Al, Co, Cr, Zn, Cd, Cu, Fe, Ni, V, Mn.

### 9.3.5 Data Storage

During any project, good hydrogeological decisions require good information developed from raw data. The production of good, relevant and timely information is the key to achieve qualified long-term and short-term plans. For the minimisation of groundwater contamination, it is necessary to utilize all relevant groundwater data.

The generation and collection of this data is very expensive as it requires intensive hydrogeological investigations and therefore the data has to be managed in a centralised database if funds are to be used in the most efficient way. Digby Wells has compiled a WISH-based database during the course of this investigation and it is highly recommended that the applicant utilise this database and continuously update and manage it as new data becomes available.

# 10 Consultation Undertaken

Farmers and relevant land owners were visited by Digby Wells (2017) during the hydrocensus programme to locate and access all known boreholes and surface water sites in the area.

# 11 Conclusions and Recommendations

## 11.1 Baseline Findings

From the hydrocensus conducted by Digby Wells (April 2017), a total of 82 boreholes were located within the area of interest, with 19 of those boreholes selected for local groundwater quality analysis. Groundwater was characterised as predominantly calcium-magnesium-bicarbonate type, consistent with previous investigations conducted at the project area, this indicates the occurrence of freshly recharged aquifers. From the groundwater characterisation it can be concluded that no mine-related impacts exist on the shallow aquifer at the project area currently.

Digby Wells conducted slug tests at Trichardtsfontein (December 2013) to investigate the hydraulic conductivity of the shallow aquifers, the investigations concluded hydraulic conductivity of approximately 0.05 m/d. In June 2017 slug tests were conducted by Digby Wells at Vaalkop and the harmonic mean hydraulic conductivity of the aquifer was estimated at 0.06 m/d.

The harmonic mean hydraulic conductivity of the aquifers at Thubelisha is estimated at 0.013 m/d (JMA, 2008)

Groundwater levels vary between 0 and 32 mbgl, with an average of 5 mbgl. The localised groundwater level depth of 32 mbgl is a result of abstraction for domestic use. The groundwater flow direction at the Olifants River Catchment, where the majority of the project area is located, is in a south to north-west. In the Upper Vaal River Catchment, where minor parts of the project area are located, the groundwater flow direction is towards the south-west.

Geochemistry assessments concluded that waste rock is deemed not to be acid generating with a sufficient buffering capacity from the mineralogy results but coal material is deemed as potentially acid generating.

## 11.2 Impact Assessment Findings

Dewatering and groundwater contamination impacts on the receiving environment are predicted to be the following with the use of the numerical model:

The cone of depression predominantly impacts the deep fractured aquifer. The weathered aquifer is impacted to lesser extent at isolated areas from dewatering due to the low vertical and horizontal hydraulic conductivity of the local aquifers.

During dewatering the mine void receives groundwater inflows. The model predicts inflows between 1 and 98 L/s over the duration of 39 years of mining throughout the entire project area.

Post operation when dewatering is discontinued the hydraulic head is expected to undergo recovery. No decant is expected at the shafts however subsidence, sinkholes and unsealed deep boreholes are potential decant locations and monitoring is required.

Post operation the hydraulic head recovers and groundwater flow reverts to its natural groundwater flow direction, however the contamination plume is retained within the project area even 100 years post closure because of the hydraulic conductivity at the deep fractured aquifer.

Impacts from the cone of depression and contamination plume will predominantly be contained at the project area and immediate surrounding. The restricted extent of the impacts is attributed to the deeper fractured aquifer (where coal seam is located) being characteristic of low hydraulic conductivity of approximately 0.004 m/d (Digby Wells, 2014). The cone of depression will mainly be restricted to the deep aquifer. Impacts of the contamination plume is expected to affect the deep aquifer and shallow aquifer water quality. Potential receptors such as private boreholes and surface water bodies may be impacted by the groundwater quality deterioration caused by mining activities.

## 11.3 Recommendations

Limitations to the numerical model (which was the basis of impact assessment) were discussed in Section 5.1. Further hydrogeological assessments are recommended to gain site specific rock permeability values through borehole drilling and aquifer testing the deep fractured aquifer and the local fractures. This will improve the conceptual model and numerical model accuracy.

The recommended mitigation plans during the construction phase include:

- Site clearing should be restricted to areas absolute necessity and the activity should be conducted over a short duration;
- Site clearance and construction activities should take place above the water table, at the unsaturated zone, (if possible), no impact on the groundwater will then be expected; and

- If trenches are going to be excavated below the water level, dewatering of the aquifer to lower the water table locally should be considered to ensure that the construction takes place above the groundwater level. Since the groundwater is not expected to be polluted at this stage, the utilisation of the water for activities such as dust suppression or irrigation (if applicable) will not cause negative environmental impacts.

The recommended mitigation plans during the operation phase include:

- Dewatering should be conducted by abstracting groundwater ingress into mine voids during operation;
- Nitrate-based explosives can contaminate water thus no underground water should be discharged unless it meets standards to minimise ground and surface water contamination;
- If subsidence occurs during operation, it should be rehabilitated as soon as possible to minimise water and oxygen inflow from the atmosphere, as these components enable AMD reactions; and
- Contaminated mine water should be stored in pollution control dams and investigations into long term management solutions should be conducted.

The following mitigation and management measures are recommended with regards to subsidence:

- In order to prevent subsidence during the bord-and-pillar mining phase, it is required that a safety factor that provides sufficient pillar stability is applied;
- The mine should be monitored on an annual basis for subsidence and areas of subsidence should be rehabilitated by backfilling with waste rock and topsoil thereafter revegetated;
- If possible, concurrent backfilling of the mine voids with fly ash should be conducted to minimise the risk of subsidence and neutralise any acid that might be generated; and
- Groundwater level and quality monitoring should be conducted on quarterly basis during operation, with special attention given to the subsidence areas. The monitoring frequency can be reduced post-closure depending on the trend of the monitoring results.

During the closure/post-closure phase management solutions should be sought for upon agreement with the farmers or communities with impacted groundwater.

Recommended mitigation activities proposed for the constructional, operational and closure phase include:

- Groundwater monitoring should be conducted to assess the time series water level, water quality impacts and to observe trends as to aid decision making;
- Annual monitoring for subsidence and sinkhole formation is highly recommended, followed by rehabilitation if required and decant monitoring at unsealed deep boreholes (greater than 30 mbgl in depth);
- During operation the numerical model should be updated every two years in the first four years and thereafter every five years based on groundwater monitoring results and updated every 5 years to calibrate with monitoring results post closure.

# 12 References

Digby Wells (2014). Trichartsdfontien EIA/EMP DMR Directive – Groundwater Study;

Hodgson F.D.I. and Krantz R.M. (1995). Investigation into Groundwater Quality Deterioration in the Olifants River Catchment above the Loskop Dam with Specialised Investigation in the Witbank Dam Sub-Catchment. WRC Report No. 291/1/95, ISBN 1 86845 182 8;

Institute of Groundwater Studies (2014). Acid-Base Accounting Report for Twistdraai Thubelisha Shaft;

Institute of Groundwater Studies (2016). Sasol Secunda Synfuels (SSO) Hub and Mining Pollution Plume Model;

JMA Consulting (2008). Compilation of Geology and Groundwater Inputs for the Twistdraaai Colliery: Thubelisha Shaft.

Vermeulen P.D. and Usher B.H. (2006). An Investigation into Recharge in South African Underground Collieries.

# Appendix A: Hydrocensus Results

| Name | Latitude | Longitude | Altitude | Water Level (mbgl) | Use | EC mS/m | ph | TDS | T ºC |
|---|---|---|---|---|---|---|---|---|---|
| ENBH2 | -26.4854 | 29.36668 | 1628.01 | 9.7 | Domestic Use | 2.17 | 8.8 | 3.11 | 19.1 |
| HNBH1 | -26.4173 | 29.32236 | 1610.78 | Equipped | Domestic Use | 2.69 | 8.21 | 1.81 | 19.9 |
| HNBH2 | -26.4154 | 29.32267 | 1575.7 | Equipped | Domestic Use | 2.71 | 8.3 | 1.93 | 19.3 |
| RT18 | -26.5119 | 29.29636 | 1654.93 | 32.24 | Domestic Use | 2.9 | 10.58 | 1.98 | 21.4 |
| ENBH1 | -26.4736 | 29.34536 | 1631.47 | 9.51 | Domestic Use | 3.1 | 8.9 | 2.7 | 16.4 |
| OGBH1 | -26.3903 | 29.43456 | 1630.76 | 3.51 | Domestic Use | 3.23 | 8.24 | 2.12 | 27.9 |
| PTBH2 | -26.3661 | 29.38263 | 1636.28 | Equipped | Not Used | 3.26 | 7.9 | 2.02 | 22.8 |
| RO1 | -26.4913 | 29.3109 | 1647.15 | 2.43 | Domestic Use | 3.27 | 8.74 | 2.41 | 22.1 |
| PN8 | -26.4362 | 29.35867 | 1617.48 | Equipped | Domestic Use | 3.32 | 8.78 | 2.2 | 21.3 |
| EN15 | -26.5093 | 29.36555 | 1659.62 | 3.48 | Domestic Use | 3.32 | 8.35 | 2.11 | 23.1 |
| EN21 | -26.5027 | 29.36548 | 1649.54 | Equipped | Domestic Use | 3.4 | 8.4 | 2.33 | 22 |
| PN9 | -26.43 | 29.36396 | 1631.58 | 3.84 | Domestic Use | 3.43 | 8.46 | 2.38 | 24.3 |
| RP8 | -26.4839 | 29.23814 | 1609.6 | 0.78 | Monitoring | 3.46 | 10.44 | 2.3 | 23 |
| RNBH2 | -26.4357 | 29.43006 | 1677.74 | 4.87 | Domestic Use | 3.5 | 8.2 | 2.4 | 24 |
| RT3 | -26.4894 | 29.27215 | 1653.84 | 6.79 | Domestic Use | 3.51 | 8.24 | 2.49 | 25 |
| RP7 | -26.4767 | 29.2493 | 1639.49 | 5.69 | Monitoring | 3.58 | 8.66 | 2.67 | 22 |
| RP3 | -26.4557 | 29.33596 | 1644.01 | 11.35 | Monitoring | 3.61 | 9.16 | 2.32 | 19.7 |
| SCHBH1 | -26.4719 | 29.33336 | 1651.21 | Equipped | Domestic Use | 3.61 | 9.23 | 2.55 | 19.5 |
| ZT1 | -26.4694 | 29.32728 | 1635.81 | 7.41 | Domestic Use | 3.66 | 8.87 | 2.55 | 19.3 |
| ERN1 | -26.4859 | 29.36478 | 1636.4 | 0.68 | Not Used | 3.76 | 7.8 | 2.61 | 22.6 |
| TNBH3 | -26.414 | 29.40975 | 1676.33 | 5.03 | Domestic Use | 3.8 | 7.4 | 2.6 | 21.2 |
| RTBH1 | -26.4823 | 29.29926 | 1613.24 | 3.83 | Domestic Use | 3.8 | 8.2 | 2.6 | |
| ONBH1 | -26.4156 | 29.43627 | 1596.54 | 10.49 | Domestic Use | 1026 | 8.89 | 733 | 19.1 |
| PN1 | -26.4604 | 29.37751 | 1656.26 | 4.96 | Domestic Use | 1289 | 8.9 | 87 | 24.1 |
| ONBH2 | -26.4052 | 29.445 | 1661.39 | - | Not Used | | | | |
| TNBH1 | -26.412 | 29.41436 | 1668.74 | 4.71 | Domestic Use | | | | |

| Name | Latitude | Longitude | Altitude | Water Level (mbgl) | Use | EC mS/m | ph | TDS | T ºC |
|---|---|---|---|---|---|---|---|---|---|
| OGBH2 | -26.3927 | 29.43741 | 1625.24 | 1.24 | Domestic Use | | | | |
| HSBH1 | -26.3419 | 29.41231 | 1618.68 | 5.78 | Domestic Use | | | | |
| HSBH2 | -26.3355 | 29.41923 | 1641.1 | Equipped | Unkown | | | | |
| HSBH3 | -26.3565 | 29.42374 | 1604.73 | 4.38 | Not Used | | | | |
| RNBH1 | -26.4376 | 29.42962 | 1674.75 | 16.56 | Not Used | | | | |
| RNBH3 | -26.4399 | 29.41796 | 1652.75 | Equipped | Domestic Use | | | | |
| RNBH4 | -26.4401 | 29.41492 | 1639.88 | 5.54 | Not Used | | | | |
| RNBH5 | -26.44 | 29.42505 | 1659.92 | Equipped | Domestic Use | | | | |
| PTBH1 | -26.376 | 29.38077 | 1624.35 | 5.18 | Domestic Use | | | | |
| PTBH3 | -26.3651 | 29.38966 | 1644.02 | Equipped | Not Used | | | | |
| PTBH4 | -26.3688 | 29.39643 | 1649.62 | Equipped | Not Used | | | | |
| RP1 | -26.4587 | 29.37431 | 1656.6 | 9.66 | Monitoring | | | | |
| PN6 | -26.4562 | 29.36254 | 1636.32 | 16.7 | Livestock | | | | |
| PN10 | -26.4291 | 29.36397 | 1631.58 | Equipped | Livestock | | | | |
| PN7 | -26.4327 | 29.35301 | 1590.3 | 1.94 | Livestock | | | | |
| PNN1 | -26.4326 | 29.35324 | 1594.87 | 4.97 | Not Used | | | | |
| PNN2 | -26.435 | 29.35366 | 1592.87 | 1.54 | Not Used | | | | |
| PN11 | -26.4223 | 29.37121 | 1616.84 | Equipped | Livestock | | | | |
| PNN3 | -26.4189 | 29.37557 | 1599.73 | Equipped | Livestock | | | | |
| PNN4 | -26.4272 | 29.37996 | 1612.02 | 8.48 | Livestock | | | | |
| PNN5 | -26.404 | 29.36392 | 1608.63 | - | Not Used | | | | |
| PNN6 | -26.3929 | 29.36379 | 1643.17 | Equipped | Livestock | | | | |
| PNN7 | -26.4022 | 29.35889 | 1590.97 | Equipped | Not Used | | | | |
| PN12 | -26.4088 | 29.35192 | 1592.91 | Equipped | Not Used | | | | |
| PN2 | -26.4521 | 29.35784 | 1560.89 | Equipped | Domestic Use | | | | |
| PN4 | -26.4528 | 29.35997 | 1579.31 | Equipped | Not Used | | | | |

| Name | Latitude | Longitude | Altitude | Water Level (mbgl) | Use | EC mS/m | ph | TDS | T ºC |
|---|---|---|---|---|---|---|---|---|---|
| PN3 | -26.4515 | 29.35987 | 1589.17 | Equipped | Not Used | | | | |
| HN3 | -26.4105 | 29.31689 | 1582.75 | 4.53 | Not Used | | | | |
| HNBH4 | -26.412 | 29.31912 | 1598.67 | 6.89 | Not Used | | | | |
| HNBH5 | -26.4113 | 29.31406 | 1594.77 | 6 | Domestic Use | | | | |
| ENR2 | -26.4852 | 29.36564 | 1630.92 | 4.83 | Domestic Use | | | | |
| BH1 | -26.4955 | 29.36015 | 1639.69 | 4.46 | Not Used | | | | |
| BH2 | -26.4963 | 29.36082 | 1639.43 | 1.51 | Domestic Use | | | | |
| ENF3 | -26.4989 | 29.36288 | 1640.9 | 1.47 | Not Used | | | | |
| EIBH1 | -26.5029 | 29.36991 | 1656.63 | 1.82 | Livestock | | | | |
| ELBH2 | -26.5005 | 29.36156 | 1636.52 | Equipped | Domestic Use | | | | |
| EN16 | -26.5099 | 29.363 | 1653.14 | Equipped | Not Used | | | | |
| ENL6 | -26.5095 | 29.3646 | 1657.72 | 1.86 | Not Used | | | | |
| FGBH1 | -26.519 | 29.32382 | 1660.52 | 1.25 | Domestic Use | | | | |
| FGBH2 | -26.5191 | 29.32372 | 1658.76 | 0.27 | Not Used | | | | |
| FGBH3 | -26.5187 | 29.32515 | 1666.38 | 6.66 | Domestic Use | | | | |
| FGBH4 | -26.5171 | 29.32752 | 1665.42 | Equipped | Not Used | | | | |
| FGBH5 | -26.5108 | 29.32245 | 1660.03 | 4.89 | Domestic Use | | | | |
| ZT2 | -26.474 | 29.32391 | 1632.76 | Equipped | Not Used | | | | |
| RT16 | -26.4936 | 29.3034 | 1654.1 | 3.79 | Domestic Use | | | | |
| TRN1 | -26.4912 | 29.30298 | 1651.04 | 7.29 | Domestic Use | | | | |
| RT11 | -26.503 | 29.29002 | 1667.58 | 2 | Domestic Use | | | | |
| RT17 | -26.5064 | 29.29304 | 1660.04 | 1.47 | Not Used | | | | |
| RT10 | -26.4999 | 29.29457 | 1671 | Equipped | Not Used | | | | |
| RPS1 | -26.4939 | 29.2967 | 1644.27 | spring | Domestic Use | | | | |
| RPS2 | -26.4965 | 29.29826 | 1652.17 | spring | Domestic Use | | | | |
| RT1 | -26.488 | 29.27019 | 1654.08 | 7.29 | Not Used | | | | |

| Name | Latitude | Longitude | Altitude | Water Level (mbgl) | Use | EC mS/m | ph | TDS | T ºC |
|---|---|---|---|---|---|---|---|---|---|
| RT4 | -26.48 | 29.27101 | 1653.06 | 6.89 | Not Used | | | | |
| RP14 | -26.4855 | 29.25555 | 1633.48 | 8.76 | Monitoring | | | | |
| JABH1 | -26.4871 | 29.25207 | 1636.22 | 11.64 | Not Used | | | | |
| JABH2 | -26.4822 | 29.25171 | 1620.07 | 1.8 | Domestic Use | | | | |

# Appendix B: Laboratory Results

# Test Report



| | | | |
|---|---|---|---|
| **Client:** | Digby Wells & Associates | **Date of certificate:** | 24 April 2017 |
| **Address:** | 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191 | **Date accepted:** | 07 April 2017 |
| **Report no:** | 39399 | **Date completed:** | 21 April 2017 |
| **Project:** | Digby Wells & Associates | **Revision:** | 0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Lab no:** | | | | 47980 | 47981 | 47982 | 47983 | 47984 | 47985 | 47986 |
| **Date sampled:** | | | | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 |
| **Sample type:** | | | | Water | Water | Water | Water | Water | Water | Water |
| **Locality description:** | | | | HSBH2 | HSBH1 | TNBH3 | ONBH1 | RP3 | ZT1 | EN15 |
| | **Analyses** | **Unit** | **Method** | | | | | | | |
| A | pH @ 25°C | pH | ALM 20 | 8.61 | 8.57 | 8.71 | 8.74 | 8.66 | 8.43 | 8.54 |
| A | Electrical conductivity (EC) @ 25°C | mS/m | ALM 20 | 70.3 | 77.8 | 88.1 | 67.0 | 59.5 | 99.0 | 72.0 |
| A | Total Dissolved solids @ 180°C | mg/l | ALM 24 | 438 | 504 | 596 | 402 | 338 | 660 | 502 |
| A | Total alkalinity | mg CaCO3/l | ALM 01 | 324 | 299 | 237 | 329 | 316 | 292 | 326 |
| A | Chloride (Cl) | mg/l | ALM 02 | 12.8 | 31.6 | 33.5 | 39.3 | 19.6 | 82.4 | 14.3 |
| A | Sulphate ($SO_4$) | mg/l | ALM 03 | 86.1 | 75.8 | 170 | 6.38 | 21.7 | 139 | 107 |
| A | Nitrate ($NO_3$) as N | mg/l | ALM 06 | 0.930 | 1.64 | 7.42 | 0.611 | 0.279 | 5.41 | 2.38 |
| A | Ammonium ($NH_4$) as N | mg/l | ALM 05 | 0.083 | 0.126 | 0.107 | 0.083 | 0.186 | 0.087 | 0.086 |
| N | Ammonia ($NH_3$) as N | mg/l | ALM 26 | 0.014 | 0.019 | 0.021 | 0.017 | 0.033 | 0.009 | 0.011 |
| A | Orthophosphate ($PO_4$) as P | mg/l | ALM 04 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| A | Fluoride (F) | mg/l | ALM 08 | 0.273 | 0.339 | 0.322 | 0.519 | 0.269 | 0.301 | 0.310 |
| A | Calcium (Ca) | mg/l | ALM 30 | 78.5 | 73.6 | 60.1 | 51.4 | 43.2 | 102 | 82.5 |
| A | Magnesium (Mg) | mg/l | ALM 30 | 53.2 | 45.6 | 28.4 | 19.7 | 35.8 | 57.4 | 51.5 |
| A | Sodium (Na) | mg/l | ALM 30 | 27.9 | 40.7 | 98.6 | 97.7 | 55.6 | 62.0 | 38.8 |
| A | Potassium (K) | mg/l | ALM 30 | 2.23 | 2.76 | 28.0 | 2.11 | 13.4 | 4.92 | 8.33 |
| A | Aluminium (Al) | mg/l | ALM 31 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Iron (Fe) | mg/l | ALM 31 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| A | Manganese (Mn) | mg/l | ALM 31 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A | Chromium (Cr) | mg/l | ALM 31 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 |
| A | Copper (Cu) | mg/l | ALM 31 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Nickel (Ni) | mg/l | ALM 31 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Zinc (Zn) | mg/l | ALM 31 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Cobalt (Co) | mg/l | ALM 31 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 |
| A | Cadmium (Cd) | mg/l | ALM 31 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Lead (Pb) | mg/l | ALM 31 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| A | Arsenic (As) | mg/l | ALM 34 | <0.006 | <0.006 | <0.006 | <0.006 | <0.006 | <0.006 | <0.006 |
| A | Selenium (Se) | mg/l | ALM 34 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Silicon (Si) | mg/l | ALM 33 | 18.9 | 22.4 | 26.4 | 16.4 | 2.66 | 10.1 | 22.2 |
| N | Silver (Ag) | mg/l | ALM 32 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

## Test Report



**Client:** Digby Wells & Associates
**Address:** 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
**Report no:** 39399
**Project:** Digby Wells & Associates

**Date of certificate:** 24 April 2017
**Date accepted:** 07 April 2017
**Date completed:** 21 April 2017
**Revision:** 0

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Lab no:** | | | | 47980 | 47981 | 47982 | 47983 | 47984 | 47985 | 47986 |
| **Date sampled:** | | | | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 |
| **Sample type:** | | | | Water | Water | Water | Water | Water | Water | Water |
| **Locality description:** | | | | HSBH2 | HSBH1 | TNBH3 | ONBH1 | RP3 | ZT1 | EN15 |
| | **Analyses** | **Unit** | **Method** | | | | | | | |
| A | Boron (B) | mg/l | ALM 33 | <0.013 | <0.013 | <0.013 | 0.111 | <0.013 | <0.013 | <0.013 |
| A | Barium (Ba) | mg/l | ALM 33 | <0.002 | <0.002 | <0.002 | 0.189 | <0.002 | <0.002 | <0.002 |
| A | Beryllium (Be) | mg/l | ALM 33 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| N | Bismuth (Bi) | mg/l | ALM 32 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| N | Lithium (Li) | mg/l | ALM 32 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A | Molybdenum (Mo) | mg/l | ALM 33 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| A | Strontium (Sr) | mg/l | ALM 33 | 0.373 | 0.360 | 0.275 | 0.523 | 0.222 | 1.18 | 0.307 |
| A | Vanadium (V) | mg/l | ALM 33 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| N | Antimony (Sb) | mg/l | ALM 36 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| N | Tin (Sn) | mg/l | ALM 36 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| N | Titanium (Ti) | mg/l | ALM 36 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A | Anions | meq | ALM 26 | 8.72 | 8.58 | 9.77 | 7.89 | 7.35 | 11.46 | 9.33 |
| A | Cations | meq | ALM 26 | 9.58 | 9.27 | 10.35 | 8.50 | 7.87 | 12.64 | 10.27 |
| A | Difference | % | ALM 26 | 4.70 | 3.90 | 2.91 | 3.72 | 3.40 | 4.87 | 4.76 |
| N | Acidity | mg CaCO3/l | ALM 60 | <0.001 | 18.4 | 15.7 | <0.001 | <0.001 | 15.6 | <0.001 |

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

**Authenticated signature on first page**

**Client:** Digby Wells & Associates
**Address:** 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
**Report no:** 39399
**Project:** Digby Wells & Associates

**Date of certificate:** 24 April 2017
**Date accepted:** 07 April 2017
**Date completed:** 21 April 2017
**Revision:** 0

| **Lab no:** | | | | 47987 | 47988 | 47989 | 47990 | 47991 | 47992 | 47993 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Date sampled:** | | | | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 |
| **Sample type:** | | | | Water | Water | Water | Water | Water | Water | Water |
| **Locality description:** | | | | EN21 | ENR1 | RT3 | RT18 | RO1 | RTBH1 | PTBH2 |
| | **Analyses** | **Unit** | **Method** | | | | | | | |
| A | pH @ 25°C | pH | ALM 20 | 8.86 | 8.42 | 8.38 | 9.03 | 8.55 | 8.56 | 7.62 |
| A | Electrical conductivity (EC) @ 25°C | mS/m | ALM 20 | 72.3 | 125 | 119 | 58.6 | 69.4 | 79.2 | 24.7 |
| A | Total Dissolved solids @ 180°C | mg/l | ALM 24 | 462 | 1024 | 918 | 398 | 512 | 582 | 236 |
| A | Total alkalinity | mg CaCO3/l | ALM 01 | 350 | 512 | 373 | 246 | 298 | 323 | 38.3 |
| A | Chloride (Cl) | mg/l | ALM 02 | 5.92 | 32.9 | 101 | 33.1 | 20.2 | 38.6 | 18.9 |
| A | Sulphate ($SO_4$) | mg/l | ALM 03 | 91.7 | 388 | 127 | 29.8 | 86.6 | 111 | 12.8 |
| A | Nitrate ($NO_3$) as N | mg/l | ALM 06 | 1.55 | 0.241 | 38.7 | 0.835 | 6.98 | 1.35 | 14.0 |
| A | Ammonium ($NH_4$) as N | mg/l | ALM 05 | 0.075 | 0.065 | 0.055 | 0.129 | 0.114 | 0.107 | 0.123 |
| N | Ammonia ($NH_3$) as N | mg/l | ALM 26 | 0.019 | 0.007 | 0.006 | 0.045 | 0.017 | 0.016 | <0.005 |
| A | Orthophosphate ($PO_4$) as P | mg/l | ALM 04 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | 0.101 |
| A | Fluoride (F) | mg/l | ALM 08 | <0.263 | 0.396 | 0.293 | 1.13 | 0.362 | <0.263 | <0.263 |
| A | Calcium (Ca) | mg/l | ALM 30 | 52.1 | 149 | 143 | 6.78 | 76.8 | 72.9 | 18.8 |
| A | Magnesium (Mg) | mg/l | ALM 30 | 83.4 | 107 | 78.5 | 3.79 | 39.8 | 55.7 | 9.33 |
| A | Sodium (Na) | mg/l | ALM 30 | 13.6 | 96.5 | 43.8 | 135 | 51.8 | 48.1 | 14.2 |
| A | Potassium (K) | mg/l | ALM 30 | 3.61 | 7.51 | 2.93 | 6.13 | 6.60 | 2.31 | 11.0 |
| A | Aluminium (Al) | mg/l | ALM 31 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Iron (Fe) | mg/l | ALM 31 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| A | Manganese (Mn) | mg/l | ALM 31 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A | Chromium (Cr) | mg/l | ALM 31 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 |
| A | Copper (Cu) | mg/l | ALM 31 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Nickel (Ni) | mg/l | ALM 31 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Zinc (Zn) | mg/l | ALM 31 | <0.002 | <0.002 | 0.455 | <0.002 | <0.002 | <0.002 | 1.19 |
| A | Cobalt (Co) | mg/l | ALM 31 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 |
| A | Cadmium (Cd) | mg/l | ALM 31 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Lead (Pb) | mg/l | ALM 31 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| A | Arsenic (As) | mg/l | ALM 34 | <0.006 | <0.006 | <0.006 | <0.006 | <0.006 | <0.006 | <0.006 |
| A | Selenium (Se) | mg/l | ALM 34 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Silicon (Si) | mg/l | ALM 33 | 21.1 | 15.2 | 32.0 | 19.5 | 20.8 | 17.5 | 25.0 |
| N | Silver (Ag) | mg/l | ALM 32 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

**Authenticated signature on first page**

| | | | |
|---|---|---|---|
| **Client:** | Digby Wells & Associates | **Date of certificate:** | 24 April 2017 |
| **Address:** | 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191 | **Date accepted:** | 07 April 2017 |
| **Report no:** | 39399 | **Date completed:** | 21 April 2017 |
| **Project:** | Digby Wells & Associates | **Revision:** | 0 |

| **Lab no:** | | | | 47987 | 47988 | 47989 | 47990 | 47991 | 47992 | 47993 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Date sampled:** | | | | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 |
| **Sample type:** | | | | Water | Water | Water | Water | Water | Water | Water |
| **Locality description:** | | | | EN21 | ENR1 | RT3 | RT18 | RO1 | RTBH1 | PTBH2 |
| | **Analyses** | **Unit** | **Method** | | | | | | | |
| A | Boron (B) | mg/l | ALM 33 | <0.013 | <0.013 | <0.013 | 0.653 | <0.013 | <0.013 | <0.013 |
| A | Barium (Ba) | mg/l | ALM 33 | <0.002 | <0.002 | 0.297 | <0.002 | <0.002 | <0.002 | 0.048 |
| A | Beryllium (Be) | mg/l | ALM 33 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| N | Bismuth (Bi) | mg/l | ALM 32 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| N | Lithium (Li) | mg/l | ALM 32 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A | Molybdenum (Mo) | mg/l | ALM 33 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| A | Strontium (Sr) | mg/l | ALM 33 | <0.001 | 0.346 | 0.590 | <0.001 | 0.277 | 0.500 | 0.045 |
| A | Vanadium (V) | mg/l | ALM 33 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| N | Antimony (Sb) | mg/l | ALM 36 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| N | Tin (Sn) | mg/l | ALM 36 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| N | Titanium (Ti) | mg/l | ALM 36 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A | Anions | meq | ALM 26 | 9.21 | 19.29 | 15.74 | 6.58 | 8.86 | 9.98 | 2.59 |
| A | Cations | meq | ALM 26 | 10.15 | 20.65 | 15.61 | 6.68 | 9.54 | 10.38 | 2.65 |
| A | Difference | % | ALM 26 | 4.87 | 3.40 | -0.40 | 0.71 | 3.70 | 1.94 | 1.18 |
| N | Acidity | mg CaCO3/l | ALM 60 | <0.001 | 19.2 | 17.7 | <0.001 | <0.001 | 7.20 | 10.2 |

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

**Authenticated signature on first page**

**Client:** Digby Wells & Associates
**Address:** 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191
**Report no:** 39399
**Project:** Digby Wells & Associates

**Date of certificate:** 24 April 2017
**Date accepted:** 07 April 2017
**Date completed:** 21 April 2017
**Revision:** 0

| Lab no: | | | | 47994 | 47995 | 47996 | 47997 | 47998 |
|---|---|---|---|---|---|---|---|---|
| Date sampled: | | | | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 |
| Sample type: | | | | Water | Water | Water | Water | Water |
| Locality description: | | | | RNBH2 | PN9 | PN1 | HNBH1 | RP8 |
| | Analyses | Unit | Method | | | | | |
| A | pH @ 25°C | pH | ALM 20 | 8.76 | 8.63 | 8.82 | 8.58 | 9.07 |
| A | Electrical conductivity (EC) @ 25°C | mS/m | ALM 20 | 101 | 40.1 | 66.9 | 47.3 | 100 |
| A | Total Dissolved solids @ 180°C | mg/l | ALM 24 | 738 | 254 | 482 | 326 | 610 |
| A | Total alkalinity | mg CaCO3/l | ALM 01 | 283 | 164 | 300 | 274 | 334 |
| A | Chloride (Cl) | mg/l | ALM 02 | 162 | 31.9 | 16.0 | 13.5 | 71.0 |
| A | Sulphate ($SO_4$) | mg/l | ALM 03 | 56.0 | 17.4 | 89.7 | 3.98 | 97.2 |
| A | Nitrate ($NO_3$) as N | mg/l | ALM 06 | 5.91 | 1.20 | 5.31 | 1.48 | 0.354 |
| A | Ammonium ($NH_4$) as N | mg/l | ALM 05 | 0.091 | 0.077 | 0.112 | 0.081 | 0.049 |
| N | Ammonia ($NH_3$) as N | mg/l | ALM 26 | 0.020 | 0.014 | 0.028 | 0.013 | 0.018 |
| A | Orthophosphate ($PO_4$) as P | mg/l | ALM 04 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| A | Fluoride (F) | mg/l | ALM 08 | 0.290 | 0.323 | 0.305 | <0.263 | 0.377 |
| A | Calcium (Ca) | mg/l | ALM 30 | 95.2 | 48.8 | 69.4 | 68.4 | 2.61 |
| A | Magnesium (Mg) | mg/l | ALM 30 | 39.7 | 11.4 | 49.1 | 16.4 | 0.619 |
| A | Sodium (Na) | mg/l | ALM 30 | 90.9 | 26.5 | 43.8 | 27.7 | 265 |
| A | Potassium (K) | mg/l | ALM 30 | 31.1 | 9.68 | 7.86 | 21.1 | 5.50 |
| A | Aluminium (Al) | mg/l | ALM 31 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Iron (Fe) | mg/l | ALM 31 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| A | Manganese (Mn) | mg/l | ALM 31 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A | Chromium (Cr) | mg/l | ALM 31 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 |
| A | Copper (Cu) | mg/l | ALM 31 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Nickel (Ni) | mg/l | ALM 31 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Zinc (Zn) | mg/l | ALM 31 | 0.370 | 0.357 | 0.023 | <0.002 | <0.002 |
| A | Cobalt (Co) | mg/l | ALM 31 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 |
| A | Cadmium (Cd) | mg/l | ALM 31 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Lead (Pb) | mg/l | ALM 31 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| A | Arsenic (As) | mg/l | ALM 34 | <0.006 | <0.006 | <0.006 | <0.006 | <0.006 |
| A | Selenium (Se) | mg/l | ALM 34 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A | Silicon (Si) | mg/l | ALM 33 | 18.7 | 17.5 | 21.5 | 18.3 | 1.47 |
| N | Silver (Ag) | mg/l | ALM 32 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

**Authenticated signature on first page**

| | | | |
|---|---|---|---|
| **Client:** | Digby Wells & Associates | **Date of certificate:** | 24 April 2017 |
| **Address:** | 48 Grosvenor Road, Turnberry Office Park, Bryanston, 2191 | **Date accepted:** | 07 April 2017 |
| **Report no:** | 39399 | **Date completed:** | 21 April 2017 |
| **Project:** | Digby Wells & Associates | **Revision:** | 0 |

| **Lab no:** | | | | 47994 | 47995 | 47996 | 47997 | 47998 |
|---|---|---|---|---|---|---|---|---|
| **Date sampled:** | | | | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 | 03-Apr-2017 |
| **Sample type:** | | | | Water | Water | Water | Water | Water |
| **Locality description:** | | | | RNBH2 | PN9 | PN1 | HNBH1 | RP8 |
| | **Analyses** | **Unit** | **Method** | | | | | |
| A | Boron (B) | mg/l | ALM 33 | <0.013 | <0.013 | <0.013 | <0.013 | 0.206 |
| A | Barium (Ba) | mg/l | ALM 33 | 0.130 | 0.108 | <0.002 | 0.056 | <0.002 |
| A | Beryllium (Be) | mg/l | ALM 33 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| N | Bismuth (Bi) | mg/l | ALM 32 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| N | Lithium (Li) | mg/l | ALM 32 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A | Molybdenum (Mo) | mg/l | ALM 33 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| A | Strontium (Sr) | mg/l | ALM 33 | 0.498 | 0.416 | 0.115 | 0.321 | <0.001 |
| A | Vanadium (V) | mg/l | ALM 33 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| N | Antimony (Sb) | mg/l | ALM 36 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| N | Tin (Sn) | mg/l | ALM 36 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| N | Titanium (Ti) | mg/l | ALM 36 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A | Anions | meq | ALM 26 | 11.82 | 4.65 | 8.72 | 6.07 | 10.76 |
| A | Cations | meq | ALM 26 | 12.78 | 4.79 | 9.62 | 6.52 | 11.87 |
| A | Difference | % | ALM 26 | 3.90 | 1.47 | 4.90 | 3.54 | 4.93 |
| N | Acidity | mg CaCO3/l | ALM 60 | 15.4 | 11.3 | <0.001 | 10.4 | <0.001 |

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

**Authenticated signature on first page**