February 2011

BELFAST PROJECT

Surface Water Assessment

Submitted to:
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REPORT

Report Number: 12433-9312-2

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Golder Associates

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1.0 INTRODUCTION

Exxaro Resources Limited (Exxaro) commissioned Golder Associates Africa (Pty) Ltd (Golder) to undertake a surface water assessment for the Belfast Colliery Project.

Exxaro is evaluating a potential coal resource in the province of Mpumalanga, approximately 10 km southwest of Belfast. This proposed new open cast operation targets mainly the 2 Seam and has been the subject of several external and internal studies. The proposed mining development will be developed in two phases. For the first three years of the project (Phase 1) only crushing and screening will be undertaken. A coal wash plant will be installed after three years during phase 2 of the project which lasts until the end of the life of mine in 30 years time. This has a significant influence on the water requirements for the project.

An assessment of the surface water environment, including baseline characterisation, mine water management plan, and potential impacts associated with the proposed mining was compiled and is presented in this report.

2.0 PROJECT OBJECTIVES

The objectives of the study were to:

- Collect hydrology data to describe baseline hydrology.
- Develop an integrated site wide water management plan covering all areas of the proposed mine. The water management plan includes stormwater and pit water management and will cover the construction, operational, decommissioning and post closure phases of the project.
- Achieve compliance with Regulation 704 of the National Water Act of 1998 and meet the Best Practise Guidelines for the integrated site wide water management plan.
- Provide the hydrology baseline, impact and mitigation input needed for an EIA/EMP.
- Determine the sizes of the water management infrastructure including diversion berms and pump capacities.
- Develop a water quality monitoring program for surface.
- Conceptual level design of sewage and potable water treatment plants.
- Provide hydraulic inputs to the design of the haul road and conveyor river crossings.

3.0 LEGISLATION OVERVIEW

In order to limit impacts on the environment, the mine is to comply with the National Water Act, and more particularly to Regulation 704 of the National Water Act related to the mining industry. The various issues to be addressed are presented in Table 1.

Besides regulations, the Department of Water Affairs (DWA) has developed documents (DWAF, 2003) describing the best practice guideline for management of water in the mining industry. This is not presented in this chapter but is discussed in the chapters where they are relevant.

Table 1: Summary of National Water Act legislation relevant to the Belfast project

ACT	IMPORTANT SECTION
NATIONAL WATER ACT NO. 36 OF 1998 **Enforcing agency** Department of Water Affairs and Forestry **Aspects covered** The Act recognises the State as the public trustee of the country's water resources. All the power to regulate use, flow and control of water is enacted upon government. The National Water Act was enacted on 26 August 1998, but certain sections only came into effect on 1 October 1998, with Proclamation R6298. The Act requires that "the reserve" is determined and the water allocations are restricted in favour of the reserve. The reserve is the quality and quantity of water required for basic human needs, aquatic ecosystems and other water users' requirements in the area. Many of the criteria will be applied in licensing that will come from the Catchment Management Strategies, although some will come directly from consideration of the National Water Act. Catchment Management Strategies are informed by the National Water Resource Strategy, as well as by the development and environmental strategies for the regions within which the catchments fall.	**Section 19:** Pollution prevention and remedying Measures should be taken to prevent pollution of water resources caused by the activities on the land.
	Section 21: Water Use A license is required for all water users. Water use is defined as the following: ■ taking water from a water resource; ■ storing water; ■ impeding or diverting the flow of water in a watercourse; ■ engaging in a stream flow reduction activity (Section 36); ■ engaging in a controlled activity (Section 37(1) or 38(1); ■ discharging waste or water containing waste into a water resource through pipe canal sewer or other conduit; ■ disposing of waste to have a detrimental impact on the water resource and disposing water which contains waste; ■ removing, discharging or disposing of water found underground and using water for recreational purposes.
	Section 22: Permissible Water Use Water use without a license is prohibited unless the use is a continuation of an existing use that was authorised by any law in force before the National Water Act came into effect.
	Section 26: Regulations on Use of Water The Minister (DWAF) may make various regulations regarding the use of water.
	Chapter 12: Sections 117-123: Safety of dams The mine must abide by the control measures stated in these sections to reduce the potential harm to the public, damage to property or resource quality.
REGULATION NO 704 OF THE NATIONAL WATER ACT **Enforcing Agency**	**Section 3: Exemption from requirements of regulations** The Minister may grant exemption from specific requirements of the Regulations.

Department of Water Affairs and Forestry **Aspects Covered** Regulation 704 regulates the use of water for mining and related activities aimed at the protection of water resources.	**Section 4: Restrictions on locality** ■ No residue deposit, dam, reservoir, or associated infrastructure may be located in the 1:100 year floodline within 100m of any watercourse, estuary, borehole or well (except pollution monitoring boreholes/wells), nor on water-logged ground or ground likely to become water-logged, undermined, unstable or cracked. ■ No underground or open cast mining, prospecting or any other activity within the 1:50 year floodline or within 100m from any watercourse/estuary, whichever is the greatest. ■ No person in control of a mine or activity may dispose of any residue or substance which causes / or is likely to cause pollution of a water resources, in working or any excavation. ■ No area within the 1:50 year floodline of any watercourse may be used for any substance or facility that causes/ is likely to cause pollution (i.e. sanitary convenience, fuel depots).
	Section 5: Restrictions on use of material No residue or substance which causes / is likely to cause pollution of a water resource may be used for construction of any dam, embankment, road or railway.
	Section 6: Capacity requirements of clean and dirty water ■ Unpolluted water must be confined to a clean water system, away from any dirty area; ■ The clean water system may not spill into any dirty water system more than once in 50 years; and visa versa the dirty water system may not spill into any clean water more than once in 50 years; ■ All dirty water, including seepage from mining operations, outcrops, etc, should be collected into a dirty water system; ■ Any dam or tailings dam that forms part of a dirty water system must be designed, constructed, maintained and operated in such a way that it has a minimum freeboard of 0.8m above fully supply level; ■ All water systems must be designed, constructed and maintained in such a manner as to guarantee the serviceability of such conveyances for the flow up to and including those arising from a maximum flood of 1:50 years.

	Section 7: Protection of water resources ■ Prevent polluted, dirty or waste containing water from entering a water resource; ■ Design, modify, locate, construct and maintain water systems to prevent disturbance of vegetation and habitat through pollution, erosion or sedimentation. ■ Prevent surface water from flowing into any mine workings or openings; ■ Design, modify, construct, maintain and use all disposal or storage structures or sites so that the water/waste therein or falling in, will not cause failure or impair stability; ■ Prevent erosion/leaching of materials from residue deposits or stockpiles and contain such leached/eroded substances; ■ Ensure the recycling of mining process water; ■ Keep water systems at all times free from any matter or obstruction that might influence their efficiency; ■ Cause all domestic waste, including wash-water, which cannot be disposed of in a municipal sewage system, to be disposed of in terms of authorisation under the Act.
	Section 8: Security and additional measures Any impoundment or dams containing poisonous, toxic or injurious substances must be fenced off and have warning notices; Ensure access control into areas used for stockpiling or disposal of water resource pollution causing substances; Protect existing pollution control measures or replace measures where affected by mining operations.
	Section 12: Technical investigation and monitoring The Minister (DWAF) may, after consultation with DME and DEAT, require the mine to conduct a technical investigation of water management infrastructure and pollution prevention measures. The Minister may then require the mine to implement pollution prevention measures or rectify pollution.

4.0 SITE DESCRIPTION

4.1 Location

The project is situated in the province of Mpumalanga, 10 km south east of Belfast on the farms Leeuwbank, Zoekop and Blyvooruitzicht. The location of the mine is presented in Figure 1. The proposed development area is located in the headwaters of the Komati River catchment.

4.2 Topography

The topography within the project area is sloping gently towards the south. The area is divided in three catchments with three streams running southward, namely the Leeubankspruit, Klein Komati and Driehoek Spruit.

Elevations vary between 1,870 mamsl, in the north of the catchments and 1,740 mamsl in the south of the catchments. The majority of the catchment supports cattle grazing, and crop cultivation activities. The natural vegetation and lands that are being rested are covered by grasslands. There are a few stands of trees in the catchment.

4.3 Rainfall

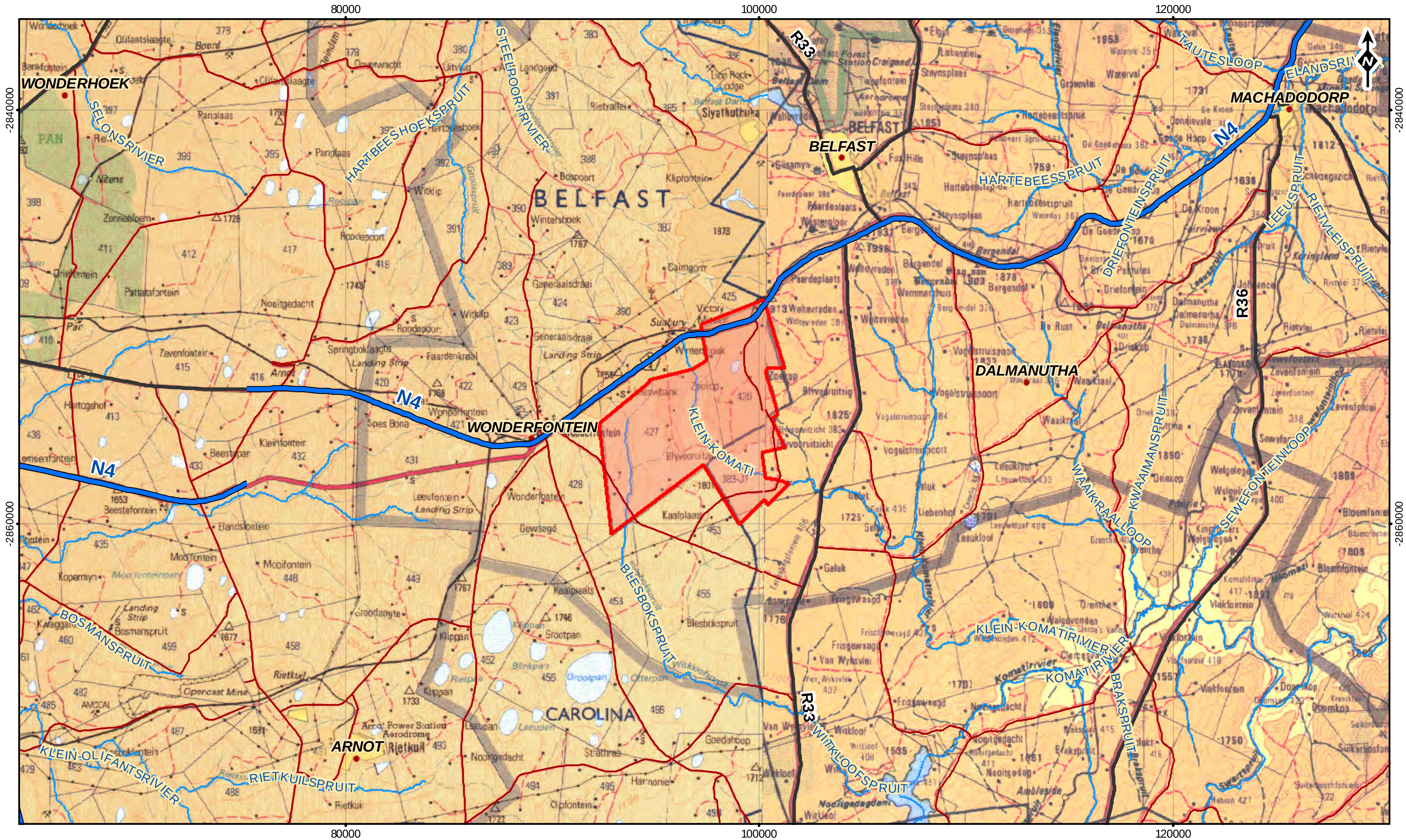
Record from Roodepoort rain gage (No. 0516554), located 18 km away from the mine site, as given in the Computer Centre for Water Resources daily rainfall record database was used. This station was chosen because of its long record and the quality of the record. The daily rainfall record covered the period January 1903 to September 2000. A cumulative plot of the daily record shown in Figure 2 was used to check the record for any anomalies. The plot does not highlight any inconsistencies in the record.

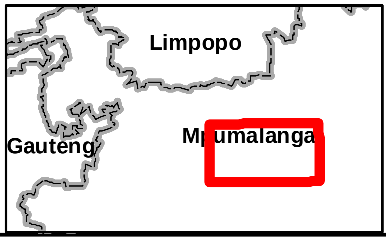
The Mean Annual Precipitation (MAP) in the vicinity of the mine is about 690mm. About 85% of the yearly rainfall falls in summer (October – March), in the form of showers and thunderstorms, with the maximum precipitation falling in January. The average number of rain days is 55 per year.

The 24 hour rainfall depths for the different recurrence interval storms are listed in Table 2.

Table 2 : 24 hour rainfall depths for the different Recurrence Intervals

Recurrence Interval (Years)	**2**	5	10	20	50	100	2**00**
24 hour Rainfall Depth (mm)	58	77	90	104	123	137	153





LEGEND

- Towns
- National Route
- Main road
- Secondary road
- Rivers - Perennial
- Mineral rights

NOTES

REFERENCE

Projection: LO 29 Cape

PROJECT

SURFACE WATER ASSESSMENT - BELFAST PROJECT

TITLE

LOCALITY OF THE PROPOSED MINING AREA

Golder Associates
Johannesburg, South Africa

PROJECT No. 12433		SCALE 1:250,000	A4	REV. 0
PHASE: 1	TASK: 0			
GIS	KG	30/11/2009		
CHECK	SC	30/11/2009		
REVIEW	TJC	30/11/2009		

FIGURE 1

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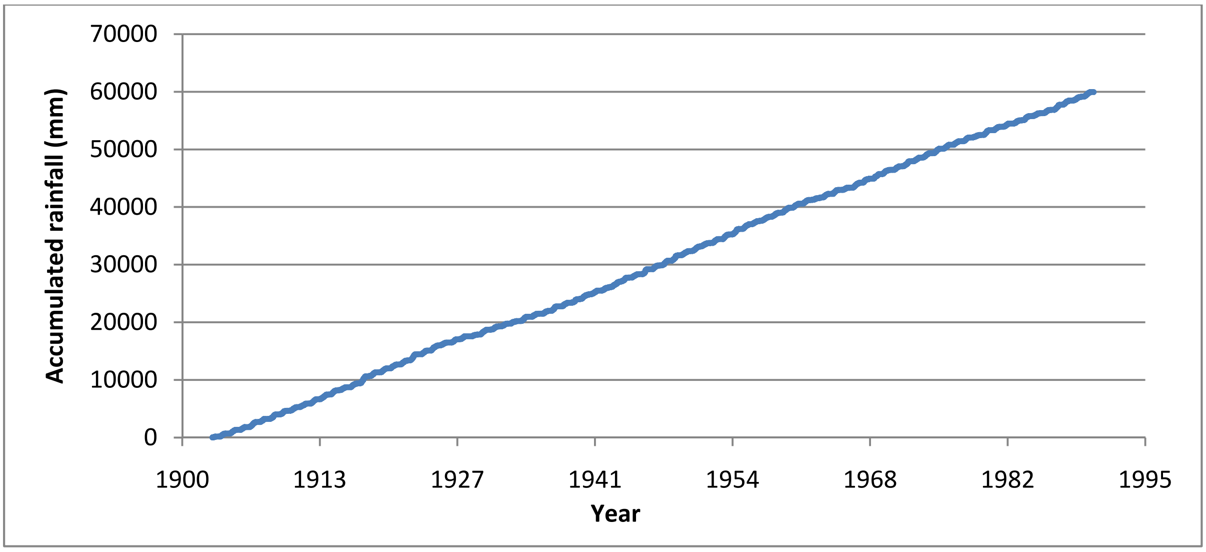


Figure 2: Plot of cumulative rainfall depth measured at the Roodepoort rain gauge

4.4 Evaporation

The mean annual Symons-pan evaporation in the vicinity of the mine is 1,450mm (WR90). Mean monthly evaporation values are presented in Table 3.

Table 3: Mean Monthly S-Pan Evaporation values for Belfast area.

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Average evaporation (mm)	138	138	156	164	140	138	104	91	75	81	102	124	1451

4.5 Regional hydrology

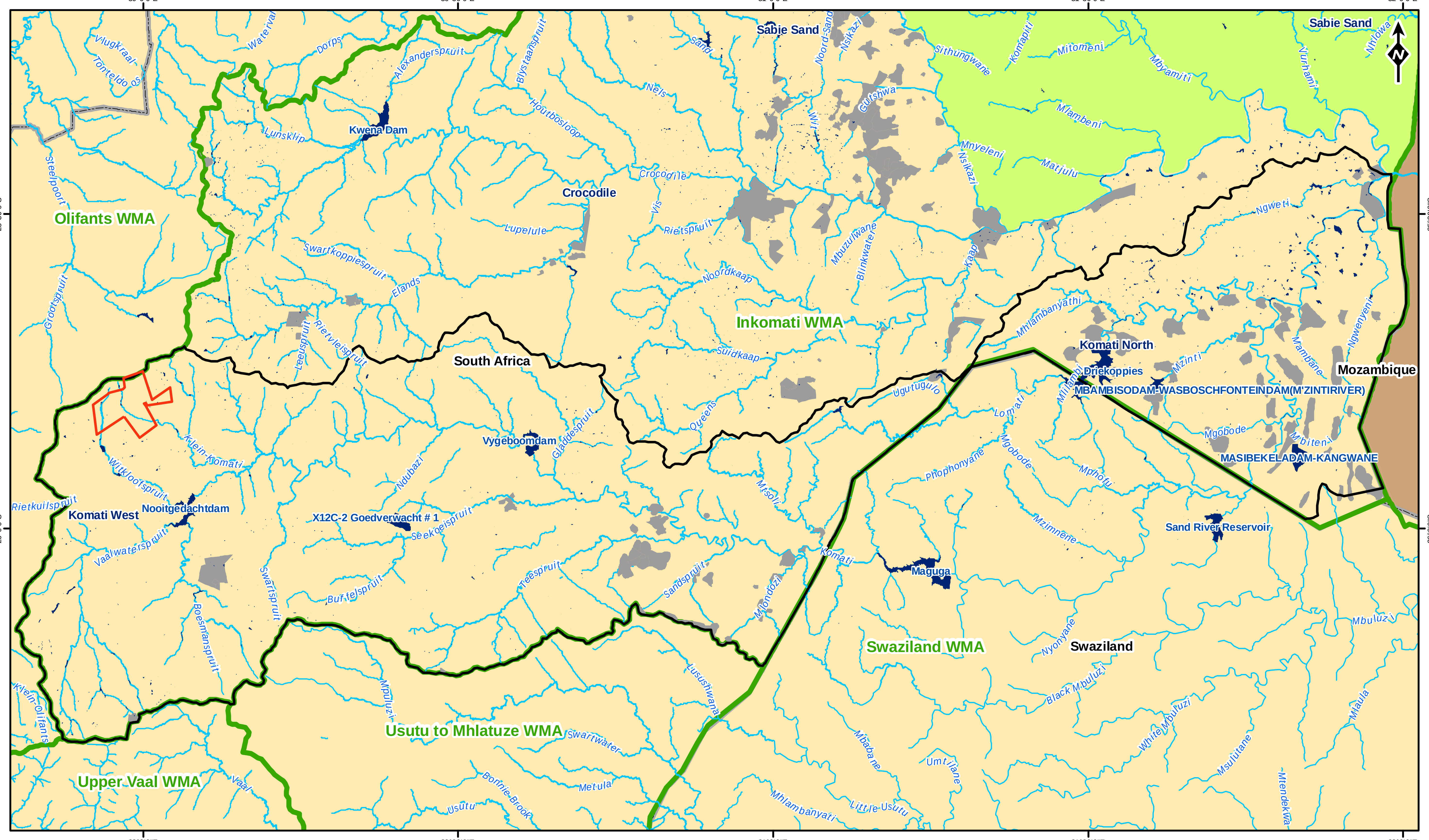
The proposed development is located in the headwaters of the Komati River. Three streams cross the proposed development area, namely the Leeubankspruit, Klein Komati stream and Driehoek Spruit. The Leeubankspruit discharges its water in the Nooitgedacht dam whereas the Klein Komati stream and Driehoek Spruit discharge their water into the Klein Komati River between the Nooitgedacht and Vygeboom dams.

The Komati River falls within the X1 drainage region (see Figure 3) of South Africa and has a catchment area of about 11,200 km^2. The river is bordered by towns such as Carolina, Eerstehoek, Machadodorp, Waterval Boven, Ekulindeni, Mbojane, Barberton, Emangweni, Sibayeni and Komatipoort. The river is a shared watercourse, and crosses the South African border into Swaziland, and back into South Africa, to the north of Swaziland, and eventually flows into Mozambique. The major water requirements in the catchment are power generation demands in the Olifants Water Management Area (WMA) met by water transferred from the Komati, irrigation, afforestation, industrial activities and an increasing domestic water demand (AfriDev, 2006).

Currently the major stresses facing the Inkomati WMA are the high water demands for Eskom, irrigation, afforestation and industry and rapidly increasing domestic water demands. The water shortages experienced in the area have led to competition for the available water resources among user sectors. A substantial portion of the population in the catchment does not have access to a basic level of services and a number of planned expansions to water uses have been put on hold. Furthermore the major dams in the study area change the flow regime and impact on the water quality.

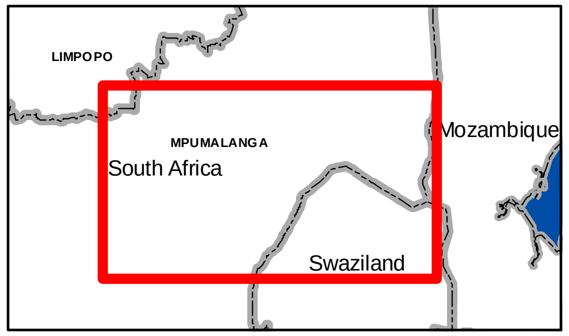
The Komati River Catchment study detailed in a report by AfriDev Consultants (AfriDev, 2006) revealed that the water in the headwaters of the Komati River was generally of good quality with no major water quality problems being experienced. Some water quality impact is experienced in terms of dry land farming and forestry in the Upper Komati River between Nooitgedacht and Vygeboom Dams, however the catchment is in good ecological condition (AfriDev, 2006). The two main dams in the Upper Komati catchment are operated to ensure the maximum yield. The volumes of water abstracted are based on the water available through the inter-basin transfers from the Vaal-Eastern Sub-system. The water is abstracted by Eskom for power generation. Eskom power stations receiving water from the Komati catchment were designed for use of this high quality (low sulphate) water. The continued supply of good quality water to Eskom is of strategic national importance and a key factor for the management of the catchment water resources. Due to the abstraction and rigid operating rules, the low flows of the Komati River between the dams have been impacted upon. This has resulted in an increase of nutrients in this reach of the river due to trout dams and tourism activities (AfriDev, 2006). The low flow reduction coupled with trout dams, agricultural and tourism activities has resulted in increased nutrient concentrations in the river.

Water management in the Upper Komati region is therefore very sensitive and attention has to be given to changes in flow and water quality.



LEGEND

- Mineral rights boundary
- Secondary catchment
- Dam
- Communities
- River
- Water Management area
- Krugar National Park
- Provincial boundary



NOTES

10 5 0 10 20 30 40
Kilometers

REFERENCE

Projection: GCS WGS 1984

PROJECT
BELFAST
SURFACE WATER ASSESSMENT

TITLE
KOMATI RIVER CATCHMENT

Golder Associates
Johannesburg, South Africa

PROJECT No. 12433			SCALE 1:648,000	A3	REV. 1
PHASE: 1		TASK:			
GIS	MM	30/11/2009	FIGURE 3		
CHECK	SC	30/11/2009			
REVIEW	TJC	30/11/2009			

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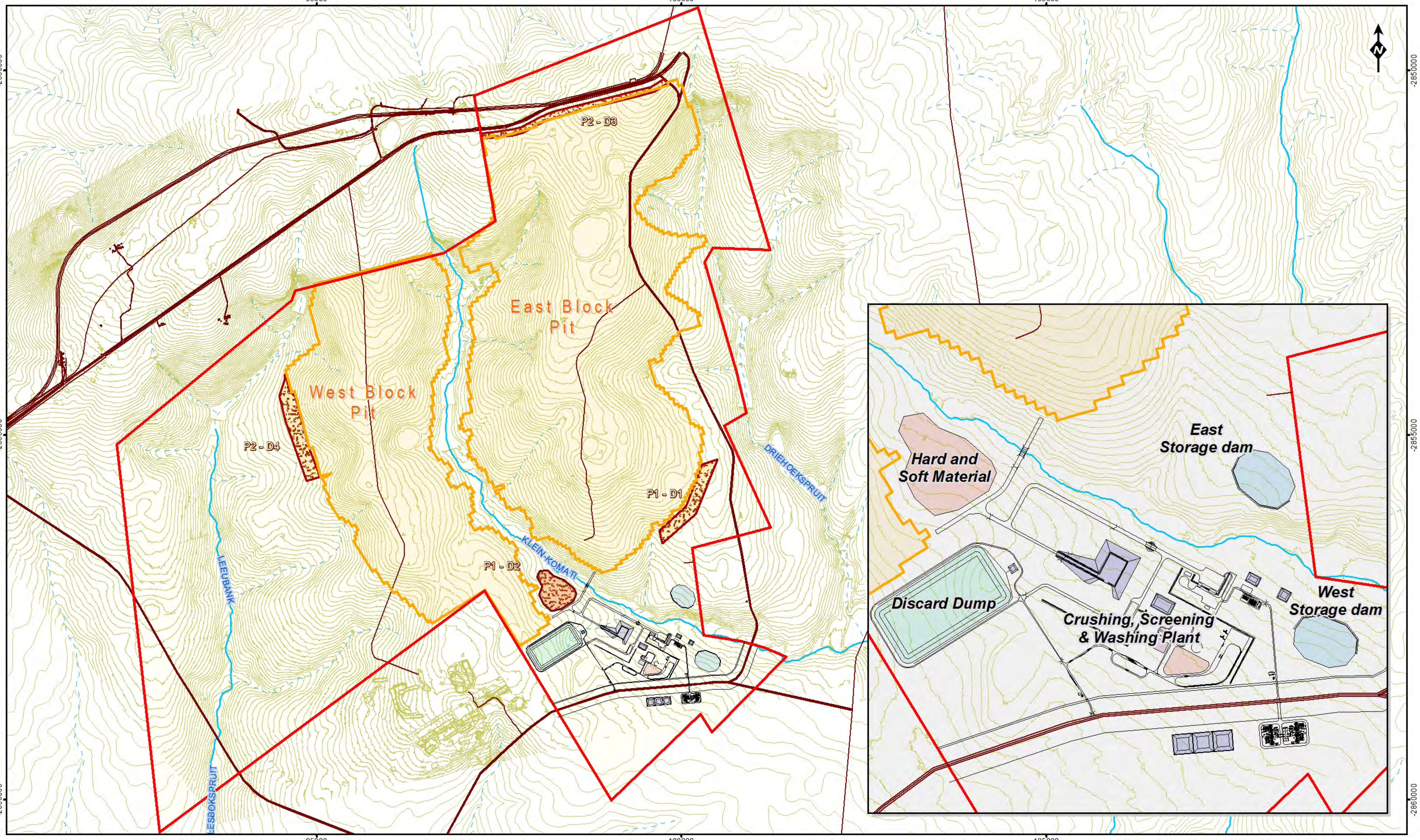
4.6 Description of Infrastructure

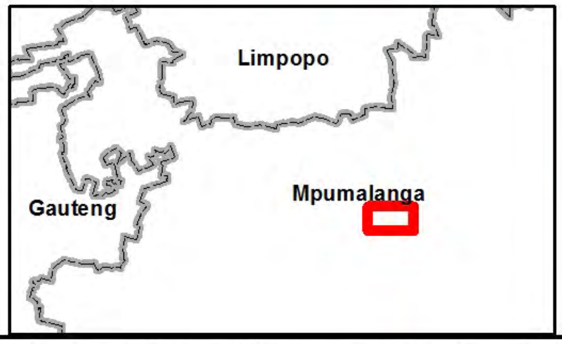
The proposed mining area will consist of a coal washing plant, tailings dam and two open cast pits. Mining is planned to start in 2011 with the East Block pit while the West Block pit will start being mined in 2016. During the first 2 years, a crushing and screening plant will operate. A washing plant will then be installed in 2013 for Phase 2 of the project and will run until 2040. For both pits mining will occur uphill towards the north as shown in the mining plan provided by Exxaro in Figure 4.

The West Block proposed mining area is flanked by the Leeubankspruit on the west running to the south and the Klein Komati running on the west. The proposed East Block mining area is flanked by the Klein Komati on the west and the Driehoek Spruit running on the east. The proposed development is therefore drained by three streams. The plant and discard dump location are located south of both mining areas next to the Klein Komati.

The main mine infrastructures and the proposed storm water control facilities are listed below and are shown on Figure 4.

- Two pits with associated stockpiles and water containment facilities;
- Discard dump;
- Crushing screening and washing plant;
- Borehole water supply and reservoirs;
- Haul roads;
- Storm water control measures;
- Various mining offices;
- Sewage and treatment waste plants.





LEGEND

- Plant layout
- Roads
- Rivers
- Rivers - Non-perennial
- 2m & 5m Contours
- Mineral rights
- Coal reserve
- Dumps

NOTES

REFERENCE

Projection: LO 29 Cape

PROJECT

SURFACE WATER ASSESSMENT - BELFAST PROJECT

TITLE

PROPOSED MINE INFRASTRUCTURE

Golder Associates, Johannesburg, South Africa

PROJECT No. 12433			SCALE 1:50,097	A3 REV. 1
PHASE: 2		TASK: 0		
GIS	MM	24/02/2011	FIGURE 4	
CHECK	SC	24/02/2011		
REVIEW	TJC	24/02/2011		

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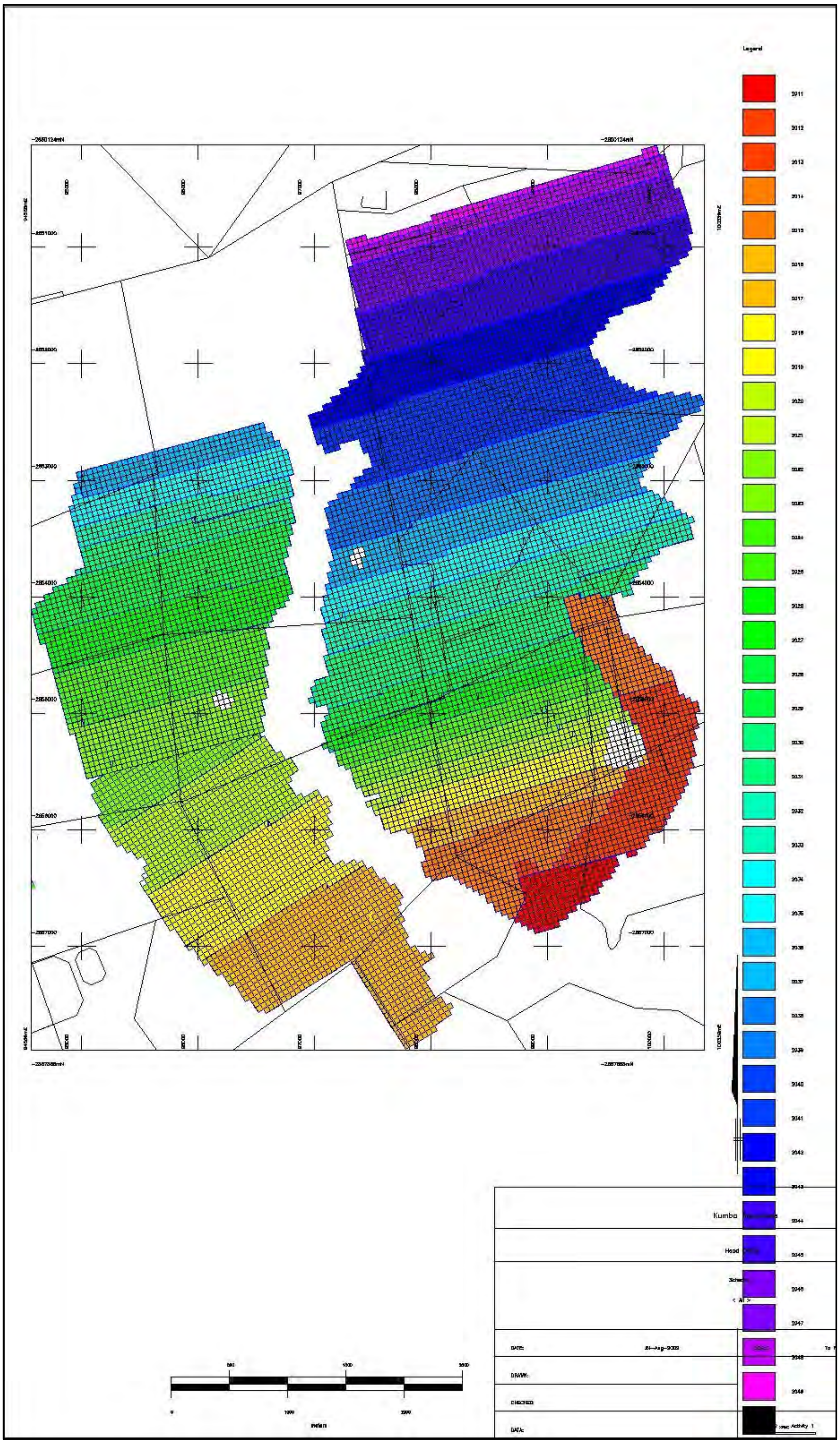


Figure 5: Mining plan

5.0 SITE HYDROLOGY

5.1 Catchment characteristics

The three catchments are characterised by moderately undulating plains and pans, with grasslands vegetation and no industrial/urban areas. A photo of the Leeubankspruit and its floodplain is shown in Figure 6. There are a number of farm dams located in the water courses draining the area. The location of the mining facilities and catchment can be seen on Figure 7.

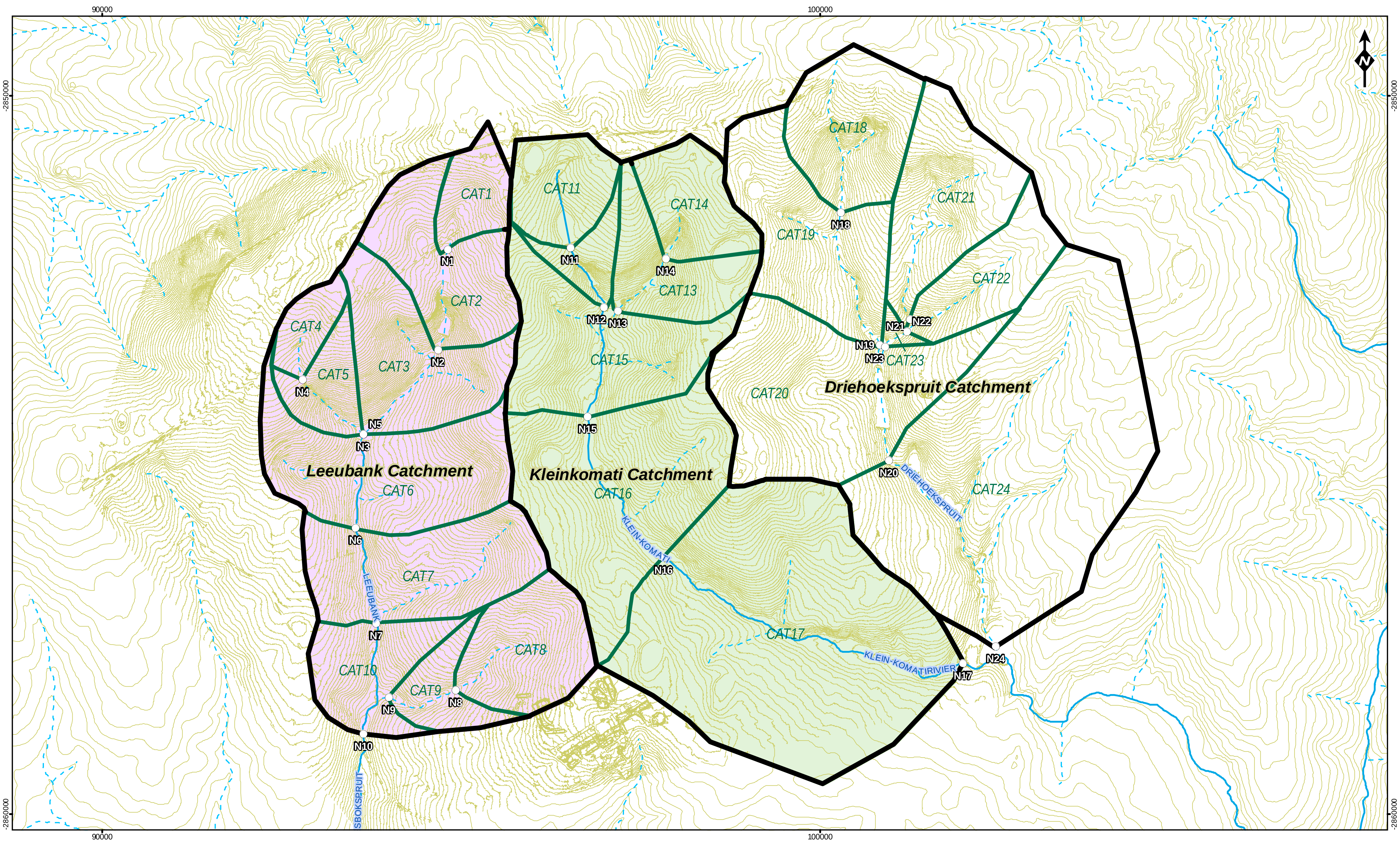
Figure 6: Photo of the Leeubankspruit - Looking upstream

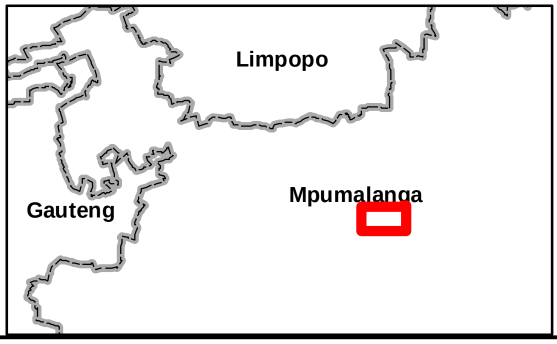
5.2 Floodline determination

5.2.1 Study approach and methods

The approach adopted in the study can be summarised as follows:

- The site was visited to assess the site specific hydrological conditions of the three streams, which will influence the flood line determination;
- The catchment areas were determined;
- A flood peak analysis was undertaken to determine the different recurrence interval flood peaks for the Leeubankspruit, Klein Komati and Driehoek Spruit;
- The flood peaks and the survey data of the study area were used as inputs to the HEC-RAS backwater program to determine the surface water elevations for the 1: 50 and 1:100 year floods peaks;
- The floodlines were plotted on the available mapping.





LEGEND

- Catchment Nodes
- Rivers
- Rivers - Non-perennial
- 2m & 5m contours
- Subcatchments

NOTES

REFERENCE

Projection: LO 29 Cape

PROJECT	SURFACE WATER ASSESSMENT - BELFAST PROJECT
TITLE	NATURAL CATCHMENTS

Golder Associates
Johannesburg, South Africa

PROJECT No. 12433			SCALE 1:50,000	A3	REV. 0
PHASE: 1	TASK: 0		FIGURE 7		
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CHECK	SC	30/11/2009			
REVIEW	TJC	30/11/2009			

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5.2.2 Limitations and assumptions

The following limitations and assumptions have been made in this specialist study:

- No flow data against which the runoff calculations might be calibrated were available. The runoff volumes were therefore calculated theoretically;
- Since no flow data was available for estimation of the roughness coefficients, the Manning's coefficients were estimated by comparing the vegetation and nature of the channel surfaces to published data (Barnes, 1967; Chow, 1959; Hicks and Mason, 1991);
- The 0.5m Lidar survey data was supplied by Exxaro.
- 5m contours from the Chief Directorate of Survey and Mapping were made available for catchment areas not covered by the Lidar survey

5.2.3 Flood peaks

The following methods were used in determining the adopted peak discharges:

- The EPA Storm Water Management Model using PCSWMM software
- The Regional Maximum Flood (RMF) or TR137 method (DWAF,1998)

PCSWMM is a dynamic rainfall-runoff simulation model used for single event or long-term simulation of runoff quantity. The model allows the input of site specific storms and can be used to generate flood peaks for different storm durations for the design recurrence interval. Flood peaks estimated for the catchment node point which are shown in Figure 7 and are tabulated in Table 4 are shown in Table 5.

Table 5

Table 4: Catchment characteristics

Name	Area (ha)	% Slope (%)
CAT1	122.2	4.1
CAT2	313.3	3.7
CAT3	347.8	4.5
CAT4	85.3	3.3
CAT5	121.4	4.7
CAT6	472.1	4.2
CAT7	415.1	3.9
CAT8	272.1	3.2
CAT9	117.1	2.6
CAT10	221.7	2.9
CAT11	186.3	3.5
CAT12	88.0	3.8
CAT13	215.7	4.3
CAT14	199.6	4.2
CAT15	438.6	3.5
CAT16	693.2	3.2
CAT17	1324.3	2.2
CAT18	319.7	5.8
CAT19	419.9	3.8
CAT20	636.6	2.7
CAT21	355.1	3.8
CAT22	215.9	3.8

CAT23	17.5	3.5
CAT24	1383.6	3.1

Table 5: Flood peaks estimates

Name	1in50 year flood peaks (m3/s)	1in100 year flood peaks (m3/s)	RMF (m3/s)
N1	10.5	12.9	108
N2	23.5	29.5	154
N3	28.7	36.1	161
N4	7.4	9.1	94
N5	59.9	74.0	108
N6	89.5	113.4	180
N7	110.9	135.8	172
N8	17.5	17.5	146
N9	17.5	21.6	106
N10	132.7	163.6	135
N11	16.6	20.4	127
N12	23.5	28.9	95
N13	13.9	17.2	134
N14	16.9	20.7	130
N15	67.7	84.1	175
N16	95.5	120.8	209
N17	130.2	167.3	267
N18	24.6	30.4	156
N19	43.5	53.6	173
N20	71.5	90.5	202
N21	19.0	23.5	162
N22	13.9	17.2	134
N23	32.9	40.6	52
N24	100.0	129.3	271

5.2.4 Floodline modelling

Cross-sectional data was obtained from topographical map provided by Exxaro. Locations and numbering of the cross-sections are shown in Figure 8. The site was visited and photographs of the study area were taken. The Manning's n resistance coefficients for the stream channel and the stream banks were estimated by comparing the vegetation and nature of the channel surface with published data (Barnes, 1967; Chow, 1959; Hicks and Mason, 1991). Since no flow data was available for estimation of the roughness coefficients, slightly conservative estimations were adopted. The Manning's n coefficient of 0.04 and 0.035 has been estimated for the river bed and river banks respectively

The floodlines were calculated using US Army Corp of Engineers HEC-RAS model. A sensitivity analysis was performed to assess the effect of the Manning's n resistance coefficient. A low sensitivity was found.

The flood levels for the 1:50-year and 1:100-year flood peaks were determined and plotted in Figure 8. The HEC-RAS output results are listed in Appendix A.

5.2.5 River crossing

A haulage road is planned to be constructed on the southern part of the pits. After discussion with Exxaro's engineers, it was decided that the culvert should be designed to cater for a 1 in 10 year storm peak. The storm peak at the location of the crossing was estimated to be 49 m^3/s.

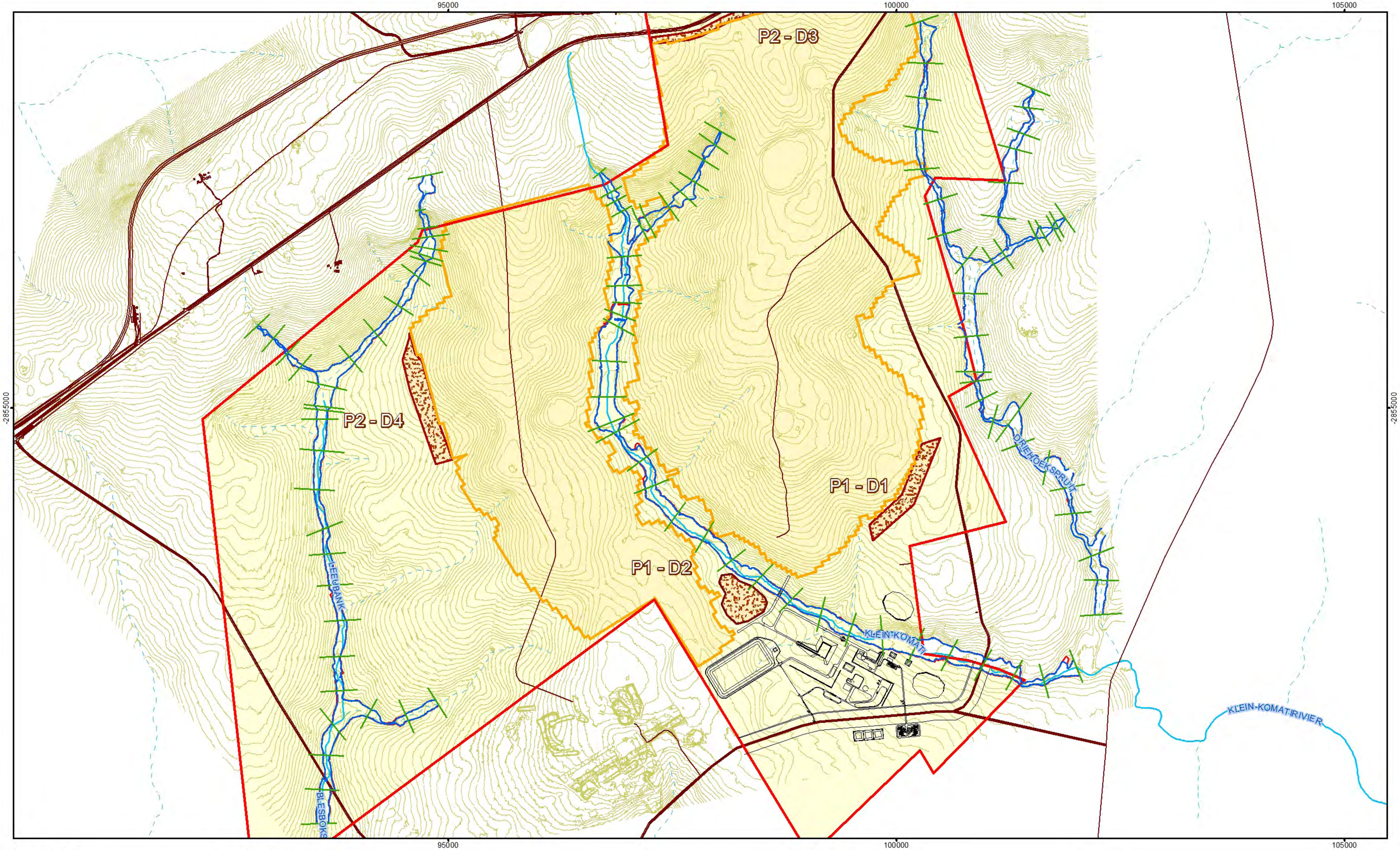
The size of the culvert was estimated using PROCULV software. The size of culvert is given in Table 6. The adjusted floodline with addition of the haulage road crossing is given in Figure 9.

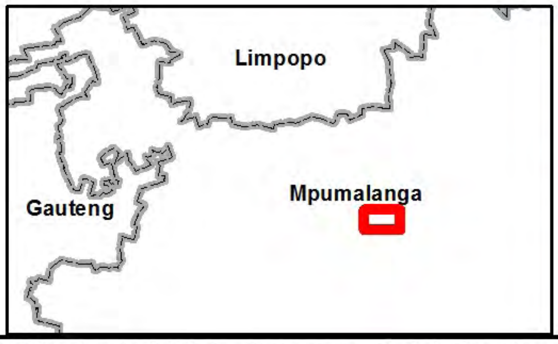
Table 6: Culvert size characteristics

No of boxes	Height	Span
5x	1.8	2

5.2.6 Interpretation of results

All the mine infrastructures are located outside the 1:50 and 1:100 year floodlines except two small sections of the East Block pit. These sections are located in the upper reach of the Driehoekspruit and Klein Komati. The mine plan will have to be modified to prevent the pit from encroaching into the 1:100 year floodline.





LEGEND

- Cross sections
- 1 in 50 year floodline
- 1 in 100 year floodline
- Plant layout
- Roads
- Rivers
- Rivers - Non-perennial
- Mineral rights
- Coal reserve
- Dumps

NOTES

REFERENCE

Projection: LO 29 Cape

PROJECT

SURFACE WATER ASSESSMENT - BELFAST PROJECT

TITLE

PRE-MINING RIVER FLOODLINES

Golder Associates
Johannesburg, South Africa

PROJECT No. 12433			SCALE 1:40,000	A3	REV. 1
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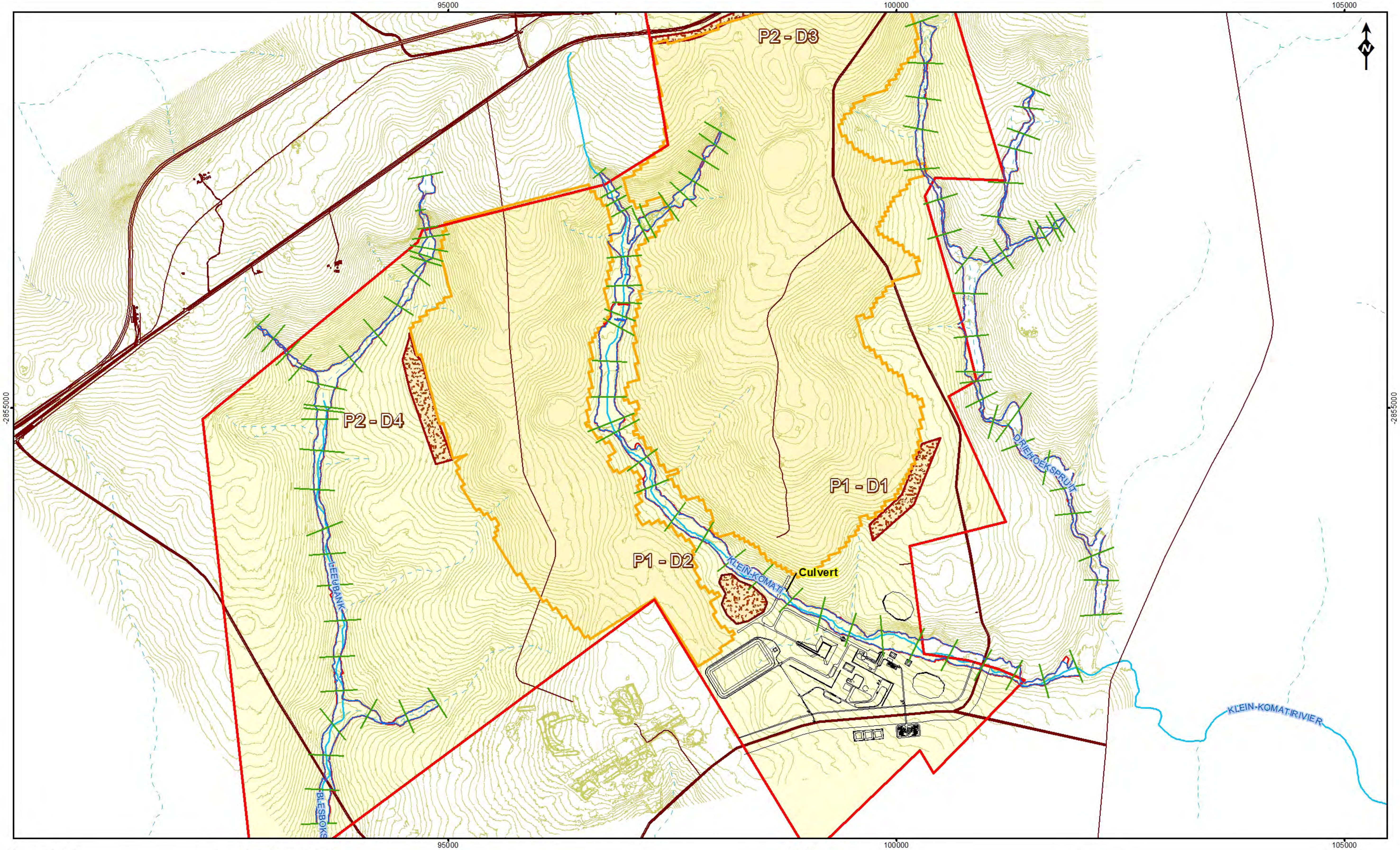

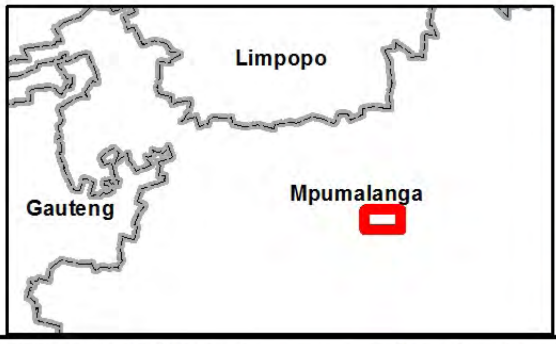

LEGEND

- Cross sections
- 1 in 50 year floodline
- 1 in 100 year floodline
- Plant layout
- Roads
- Rivers
- Rivers - Non-perennial
- Mineral rights
- Coal reserve
- Dumps

NOTES

REFERENCE

Projection: LO 29 Cape

PROJECT

SURFACE WATER ASSESSMENT - BELFAST PROJECT

TITLE

RIVER FLOODLINES WITH CULVERT INCLUDED

Golder Associates
Johannesburg, South Africa

PROJECT No. 12433			SCALE 1:40,000	A3 REV. 1
PHASE: 2		TASK: 0	FIGURE 9	
GIS	MM	24/02/2011		
CHECK	SC	24/02/2011		
REVIEW	TJC	24/02/2011		

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5.3 Baseline water quality

5.3.1 Study approach and methods

In order to assess the future impact on the Leeubankspruit, Klein Komati and Driehoek Spruit, in-stream Water Quality Objectives (RWQO) are required for the river against which to compare the measure instream water qualities. No RWQO are available for these rivers. In the absence of Water Quality Objectives, the South African Water Quality Guidelines (DWAF,1996) for the recognised water users were used to determine the most sensitive water user requirements. The derivation of water quality guidelines was based on the following protocol:

- Identify the recognised water users present.
- List the water quality requirements for each user in terms of the water quality variables of concern to the particular user.
- Analyse the different requirements with respect to each water quality variable and identify the most sensitive user.

The most sensitive user requirement then determines the water quality guideline value for a specific variable of concern.

5.3.2 Identification of water users

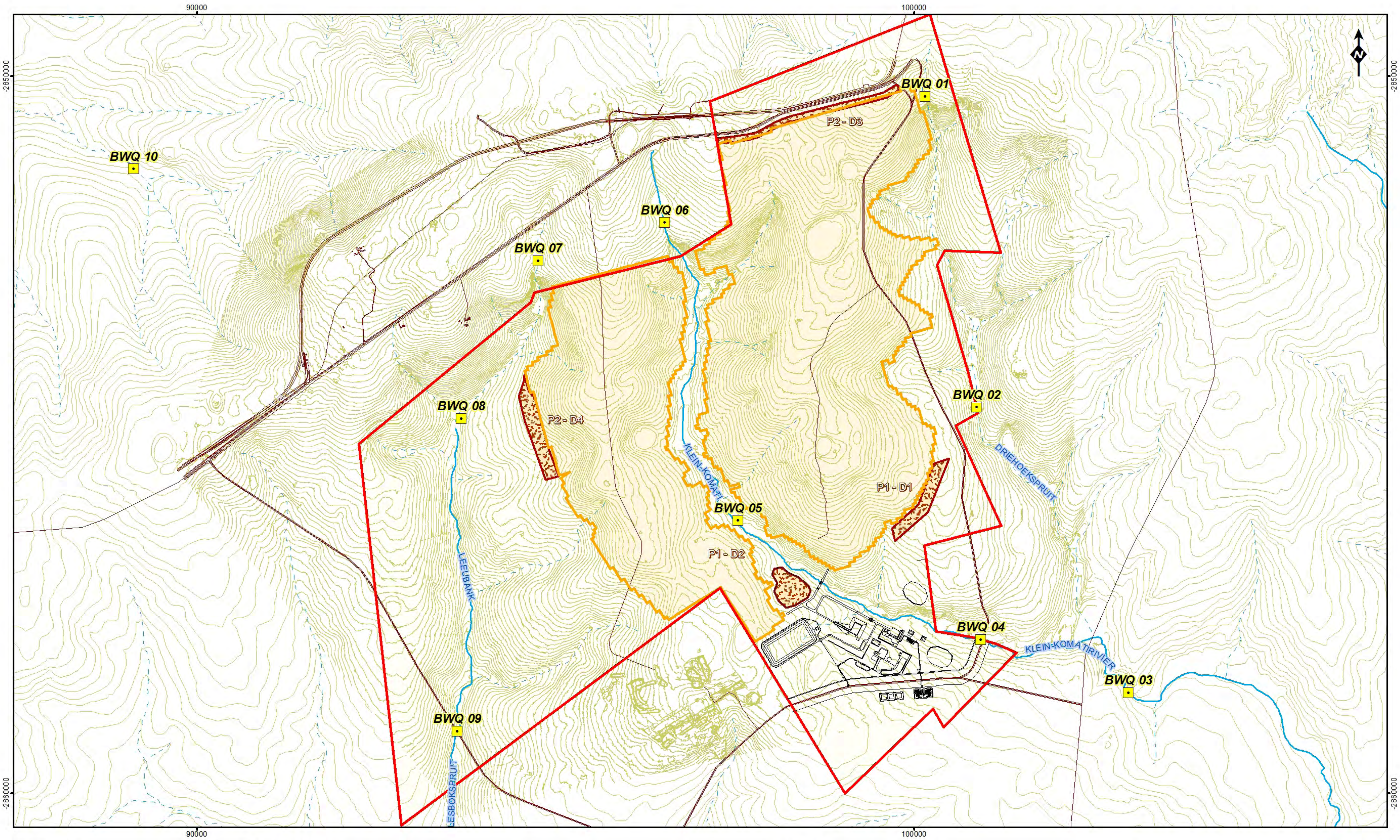
At a regional scale, significant catchment development, including industrial growth, widespread mining activities, afforestation, agricultural activity and formal and informal urbanisation has impacted on the surface water resources of the Komati catchment areas. The Leeubankspruit, Klein Komati and Driehoek Spruit are tributaries of the Komati River. Downstream water users include:

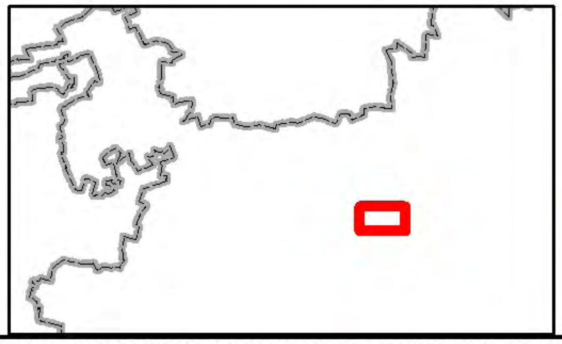
- Domestic use (Class 1)
- Industrial use (Class 1)
- Power generation
- Irrigation
- Livestock watering

5.3.3 Water quality data analysis

The water quality status assessment has been based on the routine monitoring conducted by Clean Stream. Surface water quality samples were taken for the three streams over the period September 2008 to September 2009. The locations of the sampling points are shown in Figure 11 and described in Table 7.

It is to be noted that 4 locations were measuring stream water quality while the other 6 measured dam water quality, therefore they cannot be directly correlated.





LEGEND

- Sample Locations
- Plant layout
- Roads
- Rivers
- Rivers - Non-perennial
- 2m & 5m contours
- Mineral rights
- Coal reserve
- Dumps

NOTES

REFERENCE

Projection: LO 29 Cape

PROJECT

SURFACE WATER ASSESSMENT - BELFAST PROJECT

TITLE

LOCATION OF EXISTING SURFACE WATER SAMPLING POINTS

Golder Associates
Johannesburg, South Africa

PROJECT No. 12433			SCALE 1:50,000	A3 REV. 1
PHASE: 2	TASK: 0			
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CHECK	SC	24/02/2011		
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FIGURE 10

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Table 7: Sample location description

Sample No	Description	River	Latitude	Longitude
Bwq 01	Dam In North-Eastern Corner	Driehoek Spruit	25º 45' 35" S	29º 59' 53" E
Bwq 02	Dam In Eastern Corner	Driehoek Spruit	25º 47' 56" S	30º 00' 20" E
Bwq 03	Stream Draining Towards The South-East	Klein Komati	25º 50' 04" S	30º 01' 37" E
Bwq 04	Stream Draining Towards South	Klein Komati	25º 49' 41" S	30º 00' 23" E
Bwq 05	Central Stream Draining Towards Bwq 04	Klein Komati	25º 48' 48" S	29º 58' 21" E
Bwq 06	Dam In Northern Corner	Klein Komati	25º 46' 33" S	29º 57' 43" E
Bwq 07	Dam In North-Western Corner	Leeubankspruit	25º 46' 51" S	29º 56' 40" E
Bwq 08	Dam In Western Corner	Leeubankspruit	25º 48' 02" S	29º 56' 02" E
Bwq 09	Stream Draining Towards The South-West	Leeubankspruit	25º 50' 24" S	29º 56' 01" E
Bwq 10	Dam To The Northwest Of Belfast Nbc		25º 46' 10" S	29º 56' 01" E

The water quality status is presented in this section in graphical form. Software used for data manipulation included Microsoft Office Excel for basic statistical analyses and graphical presentation.

The data sets obtained have been represented in the form of box and whisker diagrams, which depict the data distribution as:

- 5^{th}, 25^{th}, 50^{th}, 75^{th} and 95^{th} percentile values.

The water quality status along the river was then compared to the most stringent user Target Water Quality Ranges (TWQR) as specified in the South African Water Quality Guidelines (DWAF, 1996) for the identified water quality variables.

5.3.4 Identification of Key Variables

The original data obtained from Clean Stream included a comprehensive list of variables that are monitored. This study focussed on the following water quality variables which were selected based on the major land use activities (agriculture, urban development, settlements, industrial activity), current water quality issues in the Komati river catchment (eutrophication, salinisation) and water user requirements (power generation, industry, domestic, agriculture).

- Chloride (Cl)
- Electrical Conductivity (EC)
- Ammonia (NH_4)
- Nitrate and nitrite (NO_3 and NO_2)
- Sodium (Na)
- Phosphorus (PO_4) (Inorganic)
- Sulphate (SO_4)
- pH
- Magnesium (Mg)

- Total Alkalinity

5.3.5 Water Quality Guidelines

The South African Water Quality Guidelines (SAWQG) (DWAF, 1996) were used as the target guideline criteria. These serve as the primary source of information for determining the water quality requirements of different users and for the protection and maintenance of the health of aquatic ecosystems.

The most stringent applicable target water quality range (TWQR) amongst the user groups (most stringent user requirement) per identified variable was selected as the target concentration against which the current water quality status was compared. The most stringent TWQR was used in order to obtain an indication of how good or bad the water quality is for intended uses. The results would therefore provide a perspective on what level of protection RWQOs should be set at. The water quality guidelines used for the assessment are listed in Table 8 (DWAF, 1996).

Table 8: Quality guidelines used to assess water quality status

Water Quality Variable	Most Stringent user	Water Quality Guideline Concentration (TWQR)
Chloride	Industrial: Category 1	20 mg/l
Ammonia as N	Aquatic ecosystem	≤0.007 mg/l N
Electrical conductivity	Industrial: Category 1	15 mS/m
Nitrate as N	Domestic: Class 0	6 mg/l N
pH	Domestic: Class 0	6 – 9 pH units
Phosphorus as P (inorganic)	Aquatic ecosystem	<0.005 mg/l
Sodium	Irrigation	≤70 mg/l
Sulphate	Industrial: Category 1	30 mg/l
Magnesium	Domestic: Class 0	30 mg/l
Alkalinity	Industrial: Category 1	50 mg $CaCO_3$/l

5.3.6 Results of the Water Quality Analysis

The 5^{th}, 25^{th}, 50^{th}, 75^{th} and 95^{th} percentiles of each of the identified water quality variables were calculated using the data sets obtained from Clean Water.

The observed concentrations for each variable were compared to the most stringent TWQR guideline selected as per the SAWQGs in Table 8.

Chloride

Concentrations in the Driehoek spruit are within the TWQR guideline limit of 20 mg/l. Concentrations in the lower part of the Klein Komati catchment and Leeubankspruit catchment are reasonably good. However high concentrations of chloride are observed in the upper part of these two catchments (BWQ6, BWQ7) as shown in Figure 11. Chloride concentrations decrease downstream on the Klein Komati and Leeubankspruitdue to the addition of low chloride concentration water.

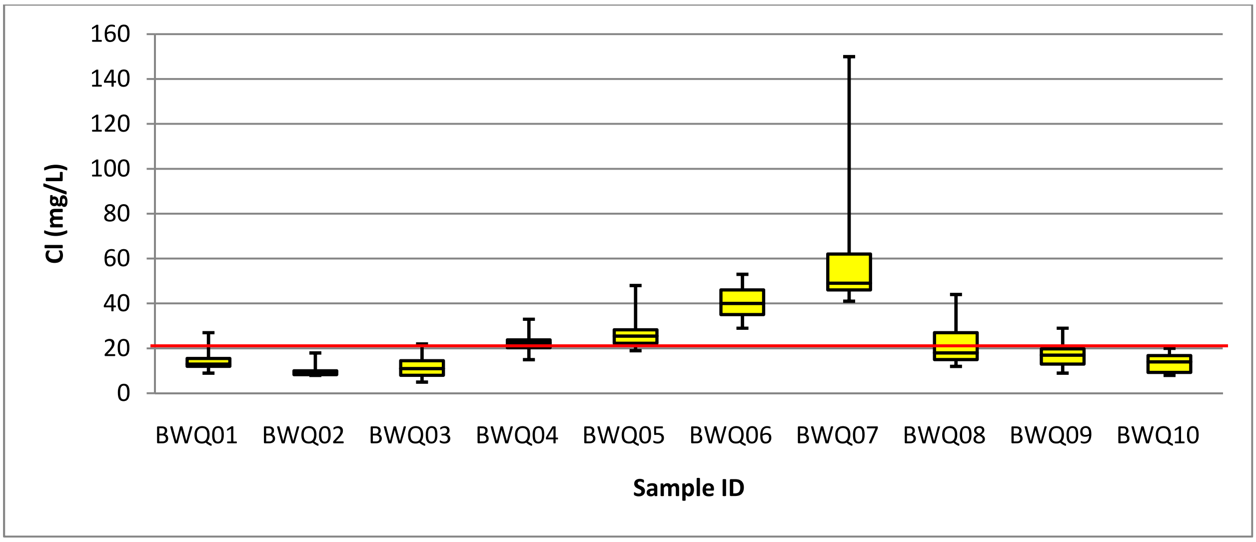


Figure 11: Spatial variation in chloride concentrations in the proposed mining area

Electrical conductivity (Ec)

The Ec in the Driehoekspruit are within the TWQR guideline limit of 15 mS/m. Mean Ec values in the Klein Komati River downstream of the mine drops to below 10 mS/m as shown in Figure 12. Ec values exceeds the TWQR were measured in the upper part of the catchments at BWQ 07 and BWQ 06. The Ec concentrations decreases further downstream with the addition of low Ec water as the water moves downstream.

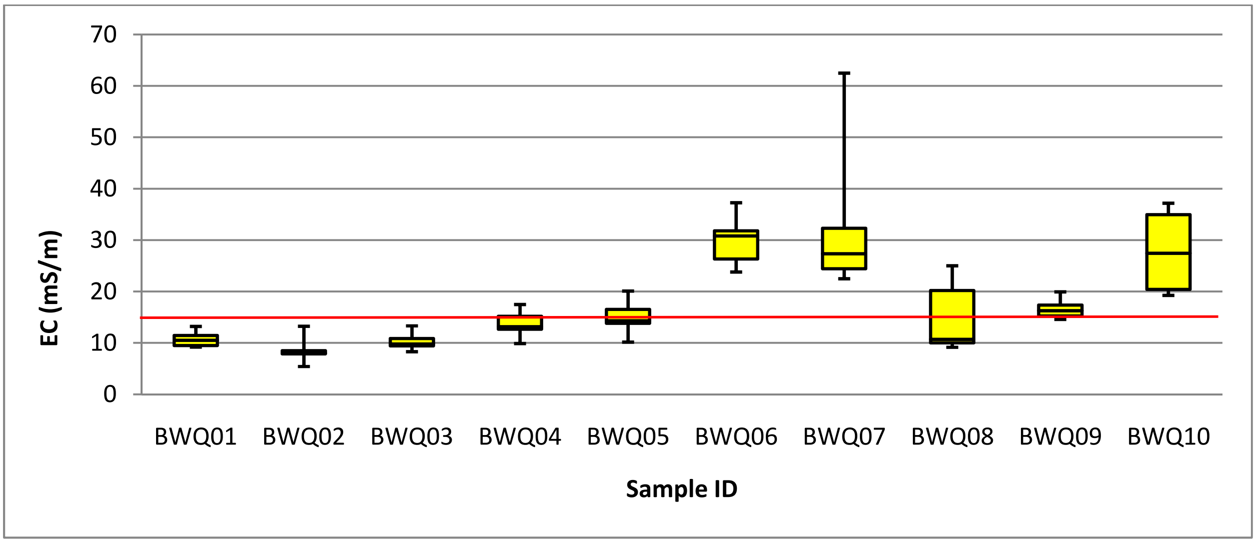


Figure 12: Spatial variation in EC concentrations in the proposed mining area

Ammonia

Mean concentration of ammonia are fairly higher than the TWQR guideline limit of 0.007mg/l in all part of the catchment ranging from 0.05mg/l to 0.1 mg/l.

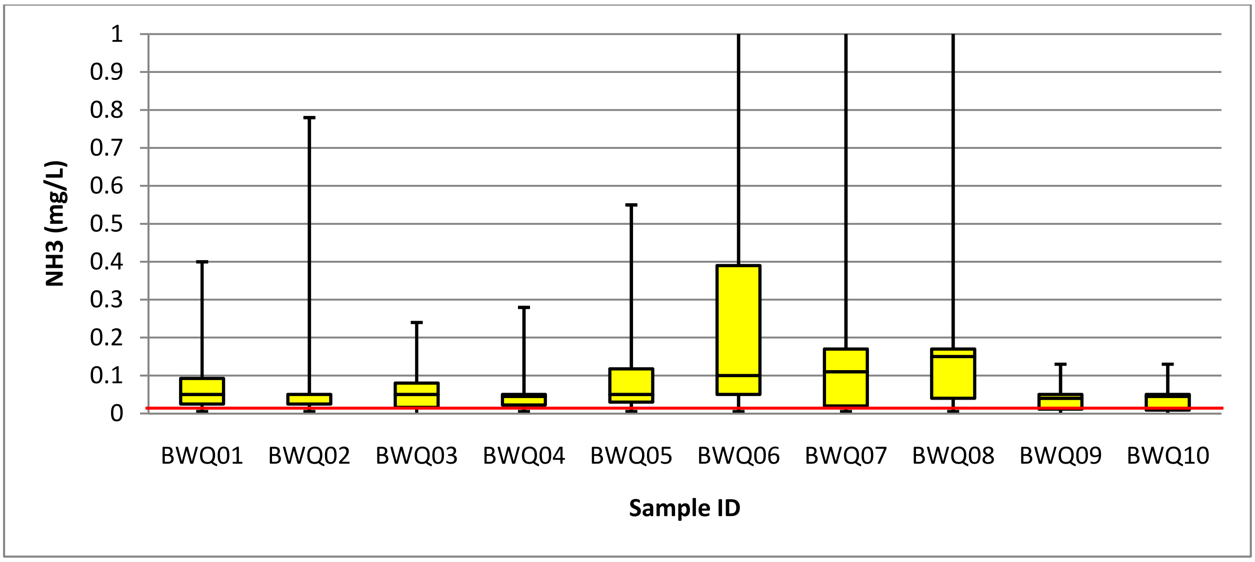


Figure 13: Spatial variation in Ammonia concentrations in the proposed mining area

Nitrate

The concentration of nitrate in all the streams is low and below the TWQR limit of 6mg/l. The highest readings were observed in the dams at the upstream section of the Klein Komati and Leeubankspruit catchments.

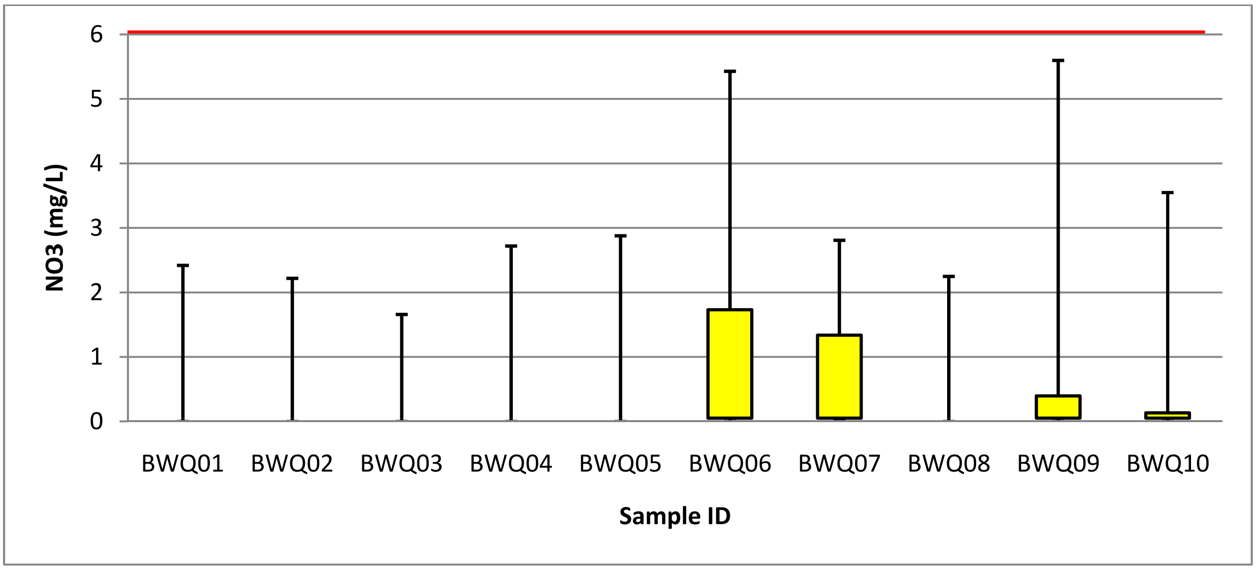


Figure 14: Spatial variation in nitrates concentrations in the proposed mining area

Sodium

The recorded sodium concentrations are below the domestic and irrigation TWQR guideline limit of 70mg/l. Median concentrations ranges between 8mg/l and 12mg/l for the three rivers.

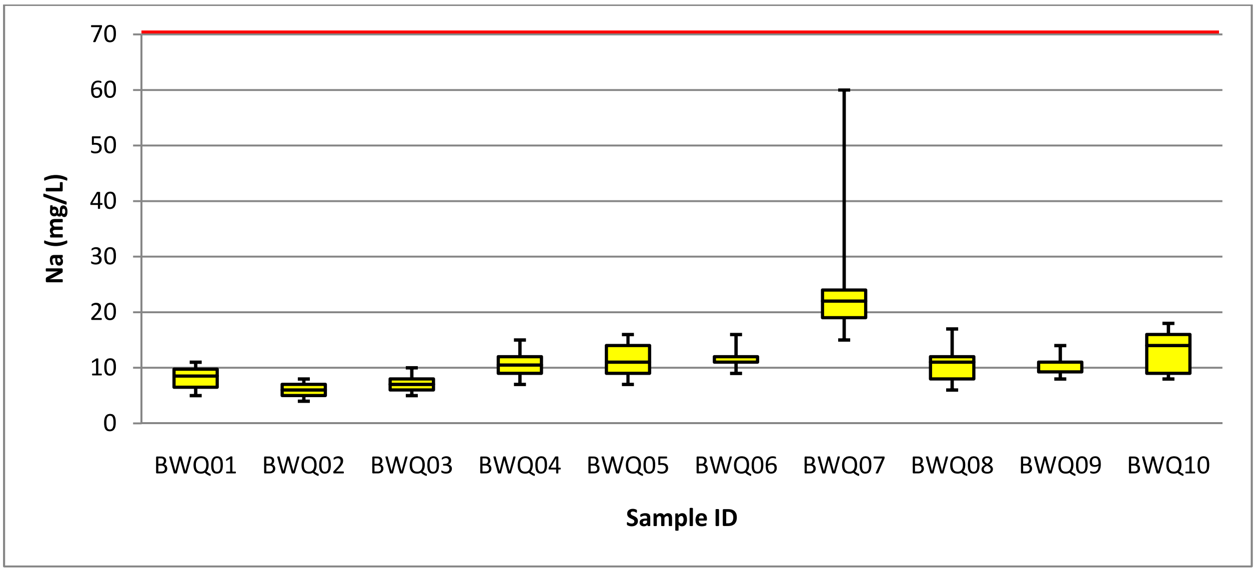


Figure 15: Spatial variation in sodium concentrations in the proposed mining area

Phosphates

The TWQR is based on the upper bound of the phosphorus concentration needed to ensure oligotrohic conditions in the river system. The typical range of measured concentrations is 0.02mg/l to 0.05mg/l. This range of concentration indicates that the trophic status could be between mesotrophic and eutrophic.

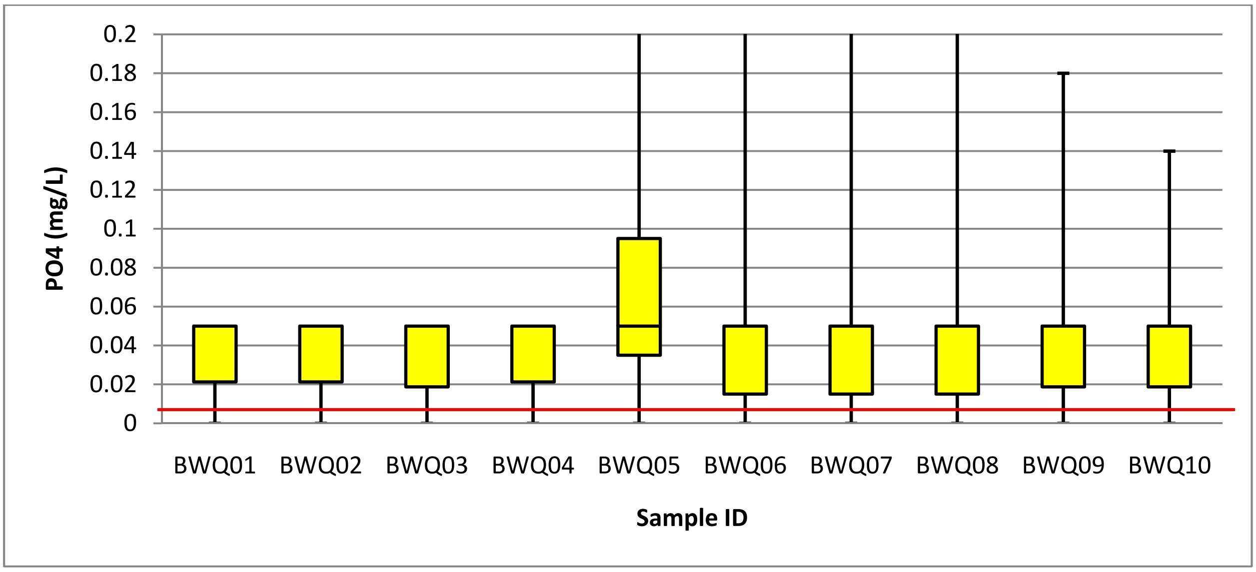


Figure 16: Spatial variation in phosphates concentrations in the proposed mining area

Sulphates

Concentrations in the Driehoekspruit are within the TWQR guideline limit of 30 mg/l. Concentrations in the lower part of the Klein Komati catchment and Leeubankspruit catchment are reasonably good. However significant concentrations of sulphates are observed in the upper part of these two catchments (BWQ6, BWQ7) as shown in Figure 17. Sulphates concentrations decrease as the Klein Komati and Leeubankspruit flows downstream.

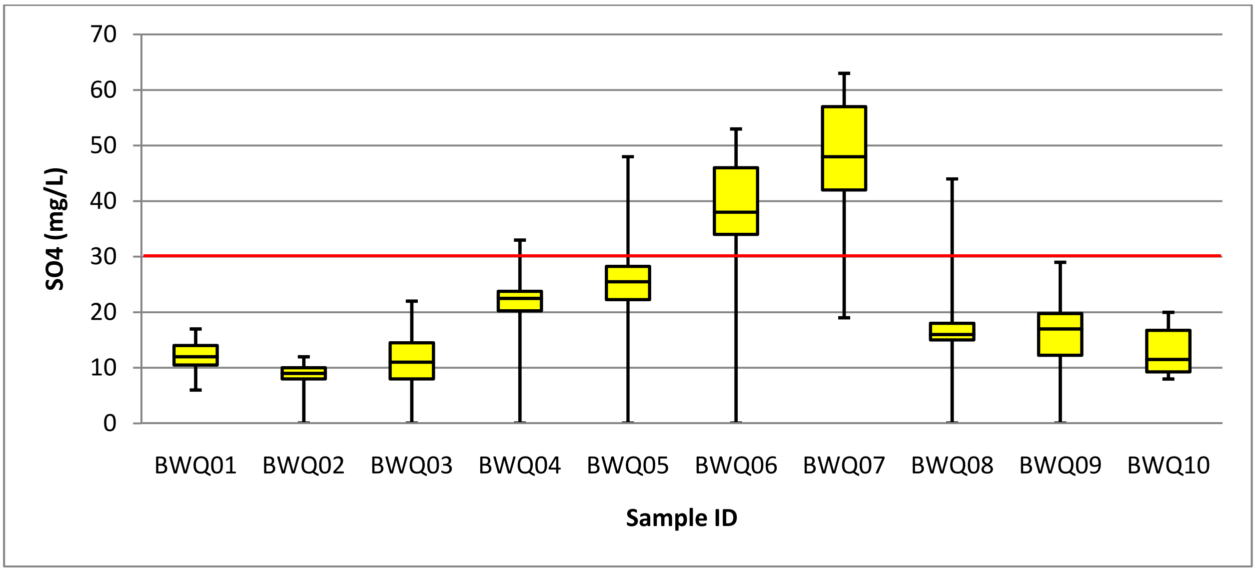


Figure 17: Spatial variation in sulphates concentrations in the proposed mining area

pH

In general the observed values are compliant with the TWQR guideline limits.

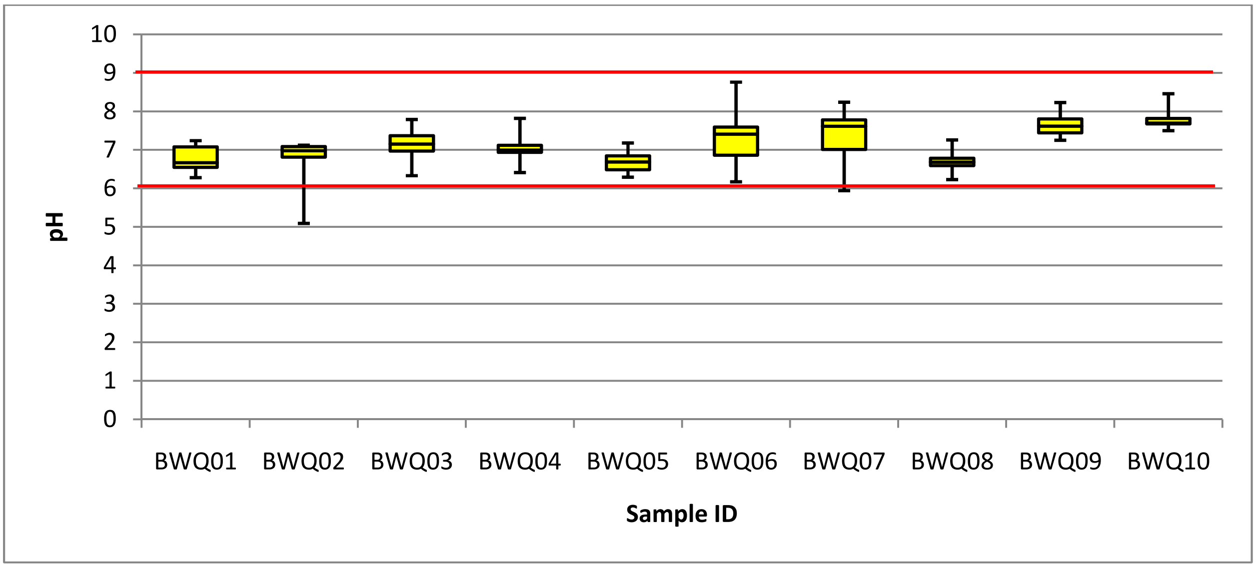


Figure 18: Spatial variation in pH in the proposed mining area

Magnesium

No specific trend is observed in magnesium concentrations. The observed values are compliant with the TWQR guideline limits.

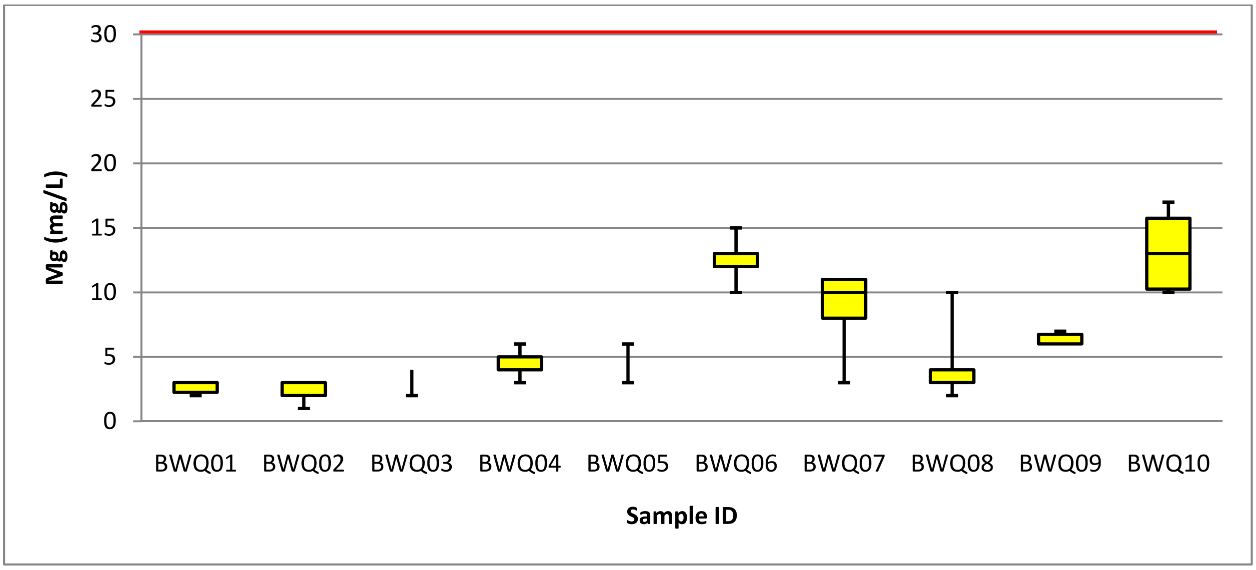


Figure 19: Spatial variation in magnesium concentrations in the proposed mining area

Total Alkalinity

The median total alkalinity in the rivers ranges from 15 to 40 mg $CaCO_3$/l. The concentrations are below the TWQR guidelines except for the upper catchment of the Klein Komati where mean values of 72mg/l were observed.

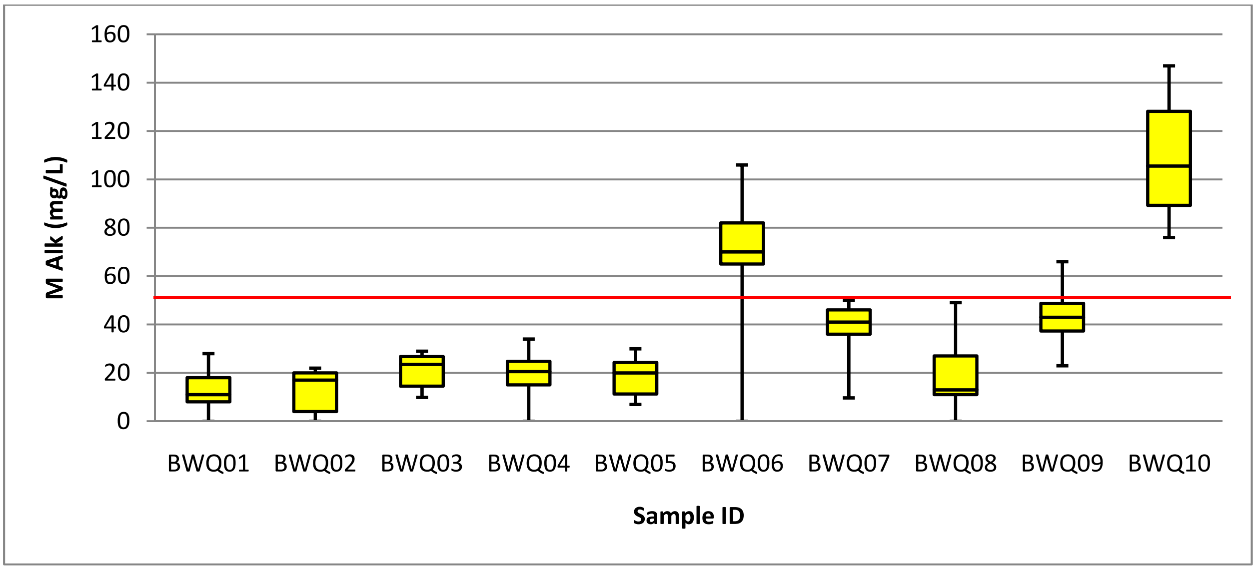


Figure 20: Spatial variation in alkalinity in the proposed mining area

5.3.7 General Discussion of Results

Overall, the water quality in the Driehoek spruit can be described as being in a good condition. The monitoring stations near the two dams at the upstream section of the Klein Komati (BWQ6) and Leeubank spruit (BWQ7) catchments revealed that the quality of water in these tributaries is in a relatively poor state water quality when compared to the most sensitive users. The quality improves in the downstream section of these catchments where the water quality can be described as good. This would suggest that there could be a diffuse source of pollution at the upstream of these catchments. The Google Earth image of the upper catchments of the Klein Komati and Leeubankspruit (Figure 21) shows that agricultural areas contributes to around 80% to 90% of the dam catchments where the samples were taken (BWQ6, BWQ7). This contribution decreases as more clean water contributes to the flow further downstream.

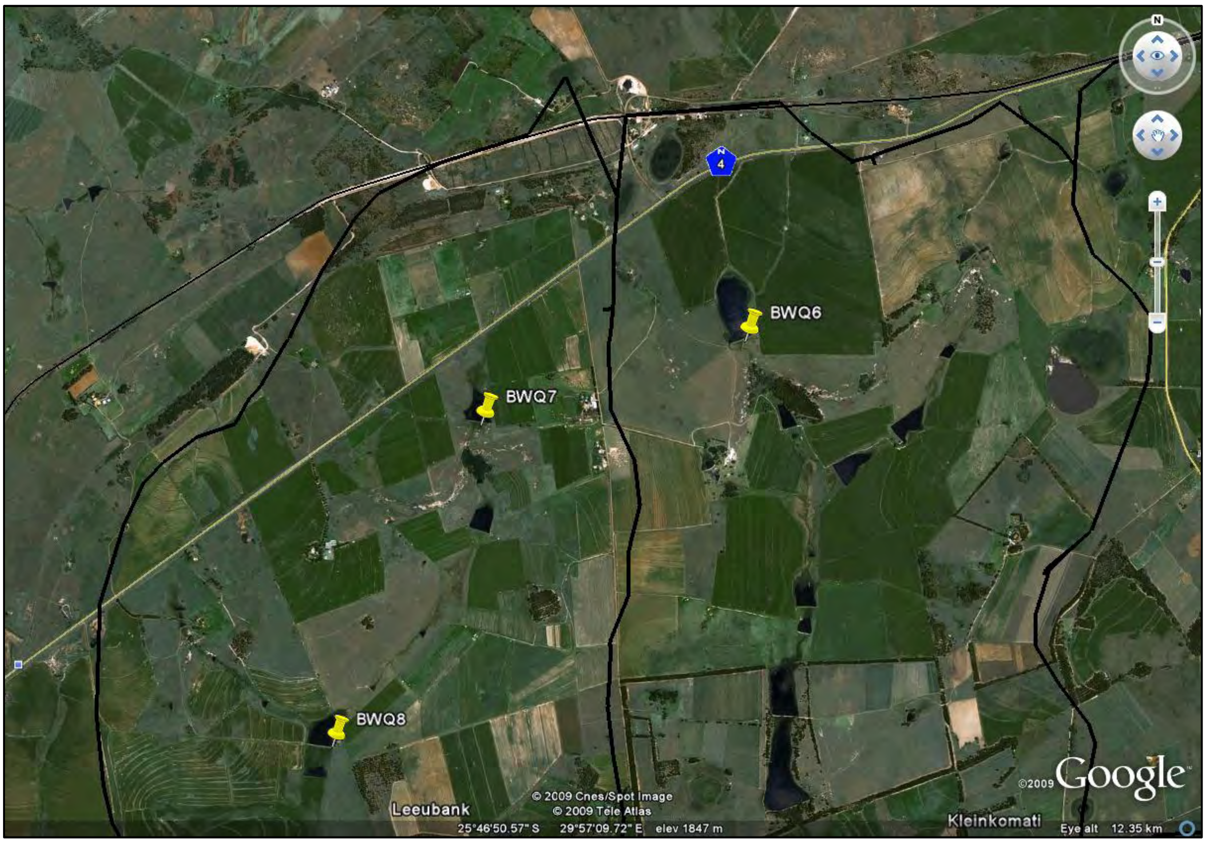


Figure 21: Google image of the upper catchments of the Klein Komati and Leeubankspruit

5.4 Impact on water availability

DWA has recently completed the Inkomati Water Availability Assessment Study during which the hydrology of the Inkomati Basin was updated. The hydrology was produced at quinary level. At quaternary level, the Leeubankspruit falls within the X11C catchment whereas the Klein Komati and Driehoekspruit fall within the X11D catchment as shown in Figure 22. The study produced a naturalised flow record for the 226 km^2 X11C and 572 km^2 X11D catchments. The maximum catchment area that is isolated by the mine was calculated to be 0.7km^2 and 2.5km^2 for the X11C and X11D catchments. The impact of the mine on the flows can be assessed by removing the area isolated by the mine water management system from the quaternary catchments and looking at the impact on the naturalized hydrology. The minimum, average and maximum monthly flow volumes are given in Table 9 and Table 10 for the catchments with and without the mining area isolated. The reduction in the naturalized MAR for the X11C catchment is from 11.35 million m^3/a to 11.32 million m^3/a which is a reduction of 0.30% which is in line with the fraction of the area that is isolated by the mining. The reduction in the naturalized MAR for the X11D catchment is from 47.49 million m^3/a to 47.29 million m^3/a which is a reduction of 0.42%.The reduction is therefore small for this single mine. However if other mines are established in the catchment, an integrated approach should be followed by DWA.

The Komati river catchment is particularly sensitive due to abstraction of water from the Nooitgedacht Dam and Vygeboom Dam for power supply, therefore the impact on water availability at these dams was investigated. Results are shown in Table 11 and Table 12. The impact is relatively low as a reduction of the MAR of 0.06% and 0.12% is expected at the Nooitgedacht Dam and Vygeboom Dam respectively.

Table 9: Average, minimum and maximum naturalized monthly runoff volumes for Quaternary X11C (million m^3/month) without and with the mining area

Month	Area	Oc	Nov	Dec	Jan	Feb	Mar	Ap	Ma	Ju	Jul	Au	Se	Tot
Average (without	230	0.3	1.26	1.86	2.24	2.31	1.4	0.7	0.3	0.2	0.2	0.1	0.1	11.3
Average (with mine)	229	0.3	1.26	1.85	2.23	2.3	1.4	0.7	0.3	0.2	0.2	0.1	0.1	11.3
Minimum (without	230	0.0	0.09	0.12	0.23	0.21	0.18	0.1	0.0	0.1	0.0	0.0	0.0	1.44
Minimum (with	229	0.0	0.09	0.12	0.23	0.21	0.18	0.1	0.0	0.1	0.0	0.0	0.0	1.44
Maximum (without	230	4.4	12.1	13.4	16.3	22.1	16.4	6.1	4.4	0.5	0.5	0.5	1.8	99.0
Maximum (with	229	4.4	12.1	13.4	16.2	22.0	16.3	6.1	4.3	0.5	0.5	0.5	1.8	98.7

Table 10: Average, minimum and maximum naturalized monthly runoff volumes for Quaternary X11D (million m^3/month) without and with the mining area

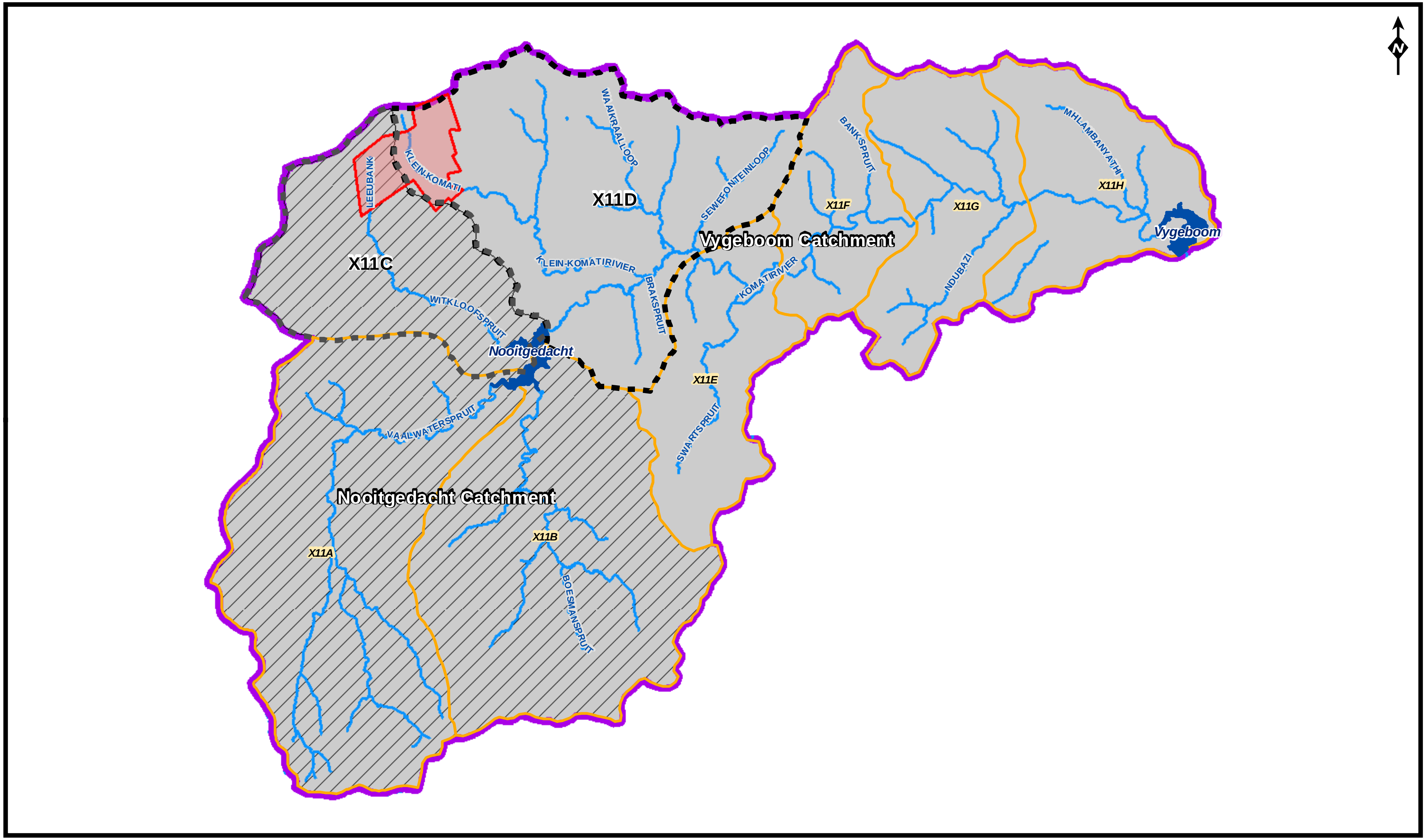
Month	Area	Oc	Nov	Dec	Jan	Feb	Mar	Apr	May	Ju	Jul	Au	Se	Total
Average (without	593	1.4	3.63	5.85	7.8	8.91	7.34	4.96	2.98	1.6	1.1	0.9	0.8	47.4
Average (with	591	1.4	3.61	5.83	7.77	8.87	7.31	4.94	2.97	1.6	1.1	0.9	0.8	47.2
Minimum (without	593	0.4	0.4	0.76	1.18	1.14	1.51	1.18	0.65	0.5	0.5	0.4	0.4	9.24
Minimum (with	591	0.4	0.4	0.76	1.17	1.14	1.5	1.17	0.65	0.5	0.5	0.4	0.4	9.2
Maximum (without	593	4.8	16.8	26.1	28.0	48.8	39.3	24.3	21.1	8.9	4.0	3.3	3.0	229.
Maximum (with	591	4.8	16.7	26.0	27.9	48.6	39.1	24.2	21.0	8.8	4.0	3.3	3.0	228.

Table 11: Average, minimum and maximum naturalized monthly runoff volumes for Nooitgedacht Dam (million m^3/month) without and with the mining area

Month	Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Ma	Ju	Jul	Au	Sep	Tota
Average (without	1174	2.4	7.8	10.	12.	13.2	8.3	4.4	2.2	1.5	1.3	1.1	1.1	67.3
Average (with	1173	2.4	7.8	10.	12.	13.2	8.3	4.4	2.2	1.5	1.3	1.1	1.1	67.3
Minimum (without	1174	0.4	0.5	0.7	1.3	1.24	1.1	0.7	0.5	0.6	0.5	0.5	0.3	8.84
Minimum (with	1173	0.4	0.5	0.7	1.3	1.24	1.1	0.7	0.5	0.6	0.5	0.5	0.3	8.84
Maximum (without	1174	28.	75.	81.	99.	133.	100.	36.	27.	3.7	3.4	3.8	11.	606.
Maximum (with	1173	28.	75.	81.	99.	133.	100.	36.	27.	3.7	3.4	3.8	11.	605.

Table 12: Average, minimum and maximum naturalized monthly runoff volumes for Vygeboom Dam (million m^3/month) without and with the mining area

Month	Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Ma	Ju	Jul	Au	Se	Total
Average (without	2723	8.5	23.6	35.9	43.8	48.6	38.2	24.3	13.	7.7	5.3	4.2	4.2	258.3
Average (with	2720	8.5	23.6	35.9	43.8	48.6	38.2	24.3	13.	7.6	5.3	4.2	4.2	258.1
Minimum	2723	2.1	2.6	3.5	5.96	6.86	6.67	4.93	3.1	2.5	2.3	2.1	1.8	44.74
Minimum (with	2720	2.1	2.6	3.5	5.95	6.85	6.66	4.92	3.1	2.5	2.3	2.1	1.8	44.7
Maximum	2723	57.	133.	171.	202.	310.	248.	125.	79.	26.	15.	14.	23.	1411.
Maximum (with	2720	57.	133.	170.	202.	310.	248.	125.	79.	26.	15.	14.	23.	1409.



LEGEND

Regional Catchments
- X11D
- X11C
- Nooitgedacht Catchment
- Vygeboom Catchment
- Rivers - Perennial
- Quarternary Catchments
- Mineral rights
- Dams

NOTES

REFERENCE

Projection: GCS WGS 1984

PROJECT	SURFACE WATER ASSESSMENT - BELFAST PROJECT
TITLE	CATCHMENT STUDIED FOR WATER AVAILABILITY ASSESSMENT

Golder Associates, Johannesburg, South Africa

PROJECT No. 12433			SCALE 1:500,000	A4 REV. 0
PHASE: 1		TASK: 0		
GIS	KG	04/12/2009		
CHECK	SC	04/12/2009		
REVIEW	TJC	04/12/2009		

FIGURE 22

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6.0 MINE WATER MANAGEMENT

6.1 Introduction

Critical to the development of the water management plan is the use of appropriate models. A development like Belfast requires:

- A flood analysis model; and
- a daily time step model of the whole complex that can be applied to all the phases of the project.

The flood model is used to size hydraulic conveyance structures such as diversion berms to carry the 50 year recurrence interval flood peak as per Regulation 704. The daily time step model is used to size pollution control dams, pumps and pipelines. The daily time step model must also produce the wet, dry and average water balances to meet the regulatory requirements as well as assess the 10 wettest years as required for the 21g licence application.

6.2 Water system

6.2.1 Operational phase

The mine-wide water balance on Belfast is a relatively simple operation consisting of the pits, coal plants, water dams and discard dump. Figure 23 shows a schematic of the water circuits on the mine which are modelled in the water balance.

Water collected in the pits sumps will be used for dust suppression and excess water will be pumped into one of the two storage dams (East storage dam and West storage dam) that will be used as a buffer. Dewatering of the backfilled spoils will occur for three scenarios:

- to prevent water from decanting into the Klein Komati,
- to prevent water from overflowing into the pit,
- to supply water to the plant,

The following two approaches will be followed to manage excess mine water on site:

- The excess water will be stored in the backfill of the pits if storage capacity is available
- Once the available pit storage is used, the excess water will need to be treated for discharge to the river

The stormwater runoff from the waste dumps located around the pits will be collected in sumps prior to being pumped back to the storage dam.

Seepage and runoff from the discard dump will be collected into a collection sump and pumped to the storage dam. The plant area runoff will be collected in a stormwater dam to contain the dirty water runoff.

The plant water demand will then be supplied in order of priority by the water recovered at the filter press, the storage dams and finally by the raw water dam if shortage of water on the mine. Raw water will be supplied either from boreholes or river water. Water drawn from the three sources will be pumped into a process water dam. The process water dam is to contain on any time a volume equivalent to 5 days of plant water demand to ensure continuous operation of the plant.

Water for potable use will be drawn from the raw water dam and treated on site for users on the mine. A sewage treatment plant will be installed on site with the treated water discharged back to the river.

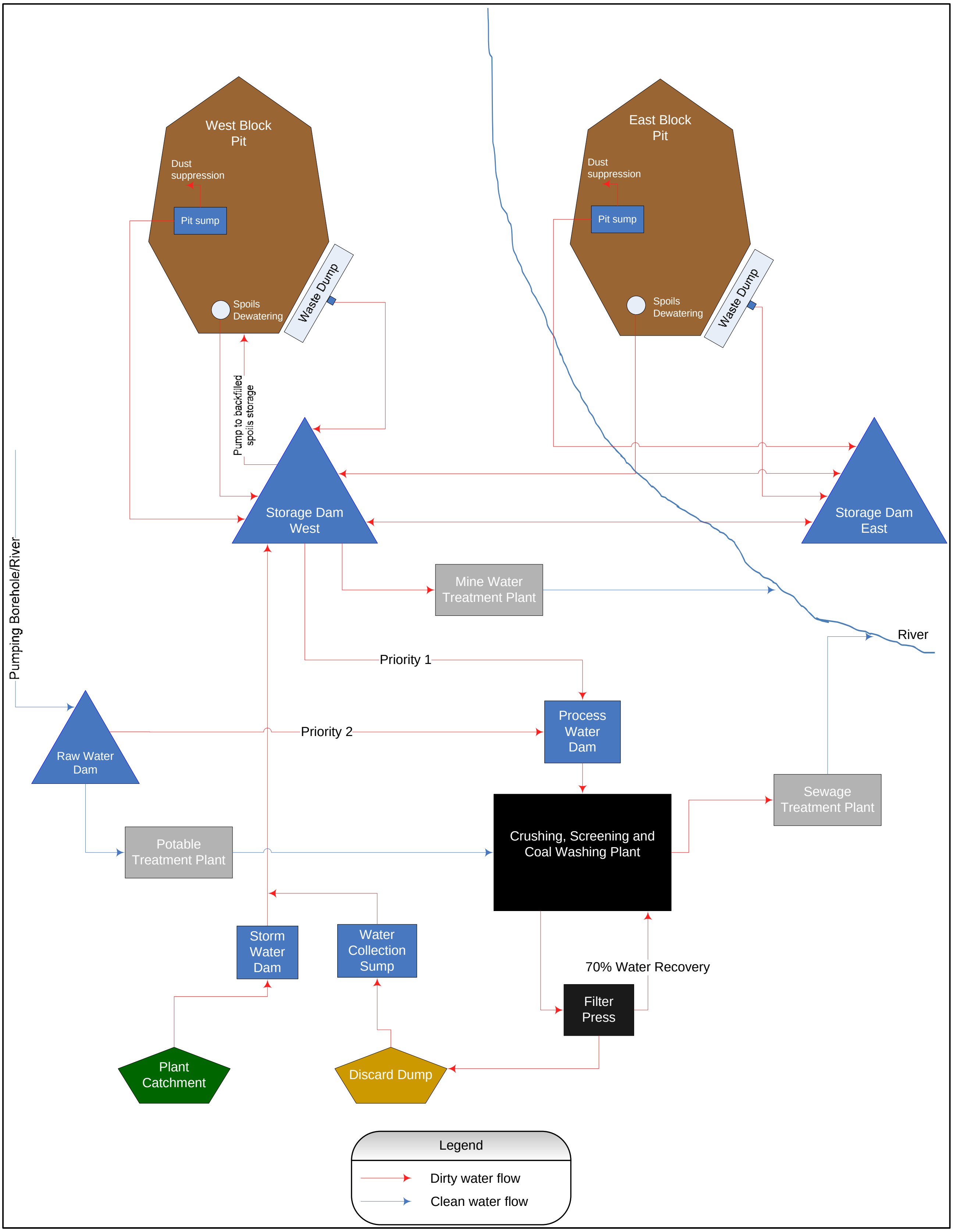


Figure 23: Mine water circuit schematics – Operational phase

6.2.2 Post-Closure phase

Figure 24 shows the water circuit for the post-closure phase. The management of the water in the backfilled spoils will be pumping water back to one of the storage dams before being treated in a desalination plant and discharged. The excess mine water volume that will have to be managed post-closure was based on the following assumptions:

- The plant areas will be removed and the area rehabilitated
- The discard dump will be rehabilitated
- One of the storage dams will be removed and rehabilitated
- The pits will be rehabilitated to be free draining with a standard 600mm thick cover
- The waste dumps located adjacent to the pits will be removed and returned to the pits
- A desalination plant will be constructed to treat the excess water. The appropriate waste and lime management facilities associated with the treatment plant will be provided

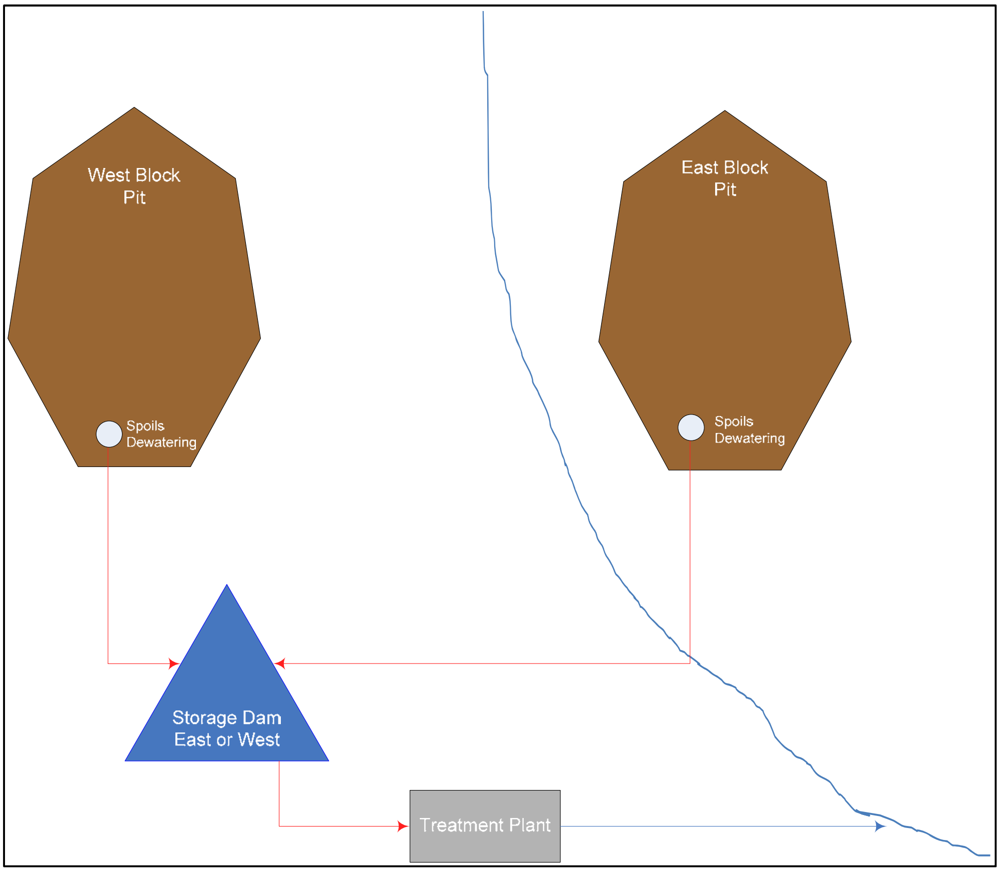


Figure 24: Mine water circuit schematics - Closure phase

6.3 Stormwater Management

6.3.1 Description of the proposed infrastructure

A stormwater management plan was designed in order to prevent polluted water from entering a water resource and separate the clean water system from any dirty area. The regulation 704 of the DWA was applied in sizing the stormwater management facilities.

A layout of the proposed stormwater management system is shown in Figure 25. The following structures are proposed:

- The crushing, screening and washing plant area will be platformed to slope in a south east direction. Storm water will be collected by drains on the north and west side of the area and will drain into the plant stormwater dam.
- Runoff from the hard and soft material dump will be diverted into the plant dirty water system to prevent from running into the Nkomati
- Clean storm water coming from the catchments upstream of the plant (CAT2, CAT3, CAT9, CAT12, CAT14) will be diverted away from the dirty areas
- Storm water runoff from the waste dumps will be collected in local sumps
- Mining being upslope, berms will need to be constructed ahead of mining to prevent clean runoff from entering the workings. Berms will need to be sized and designed for the 1 in 50 year recurrence interval flood peak as mining progresses.

6.3.2 Modelling and sizing of the proposed infrastructure

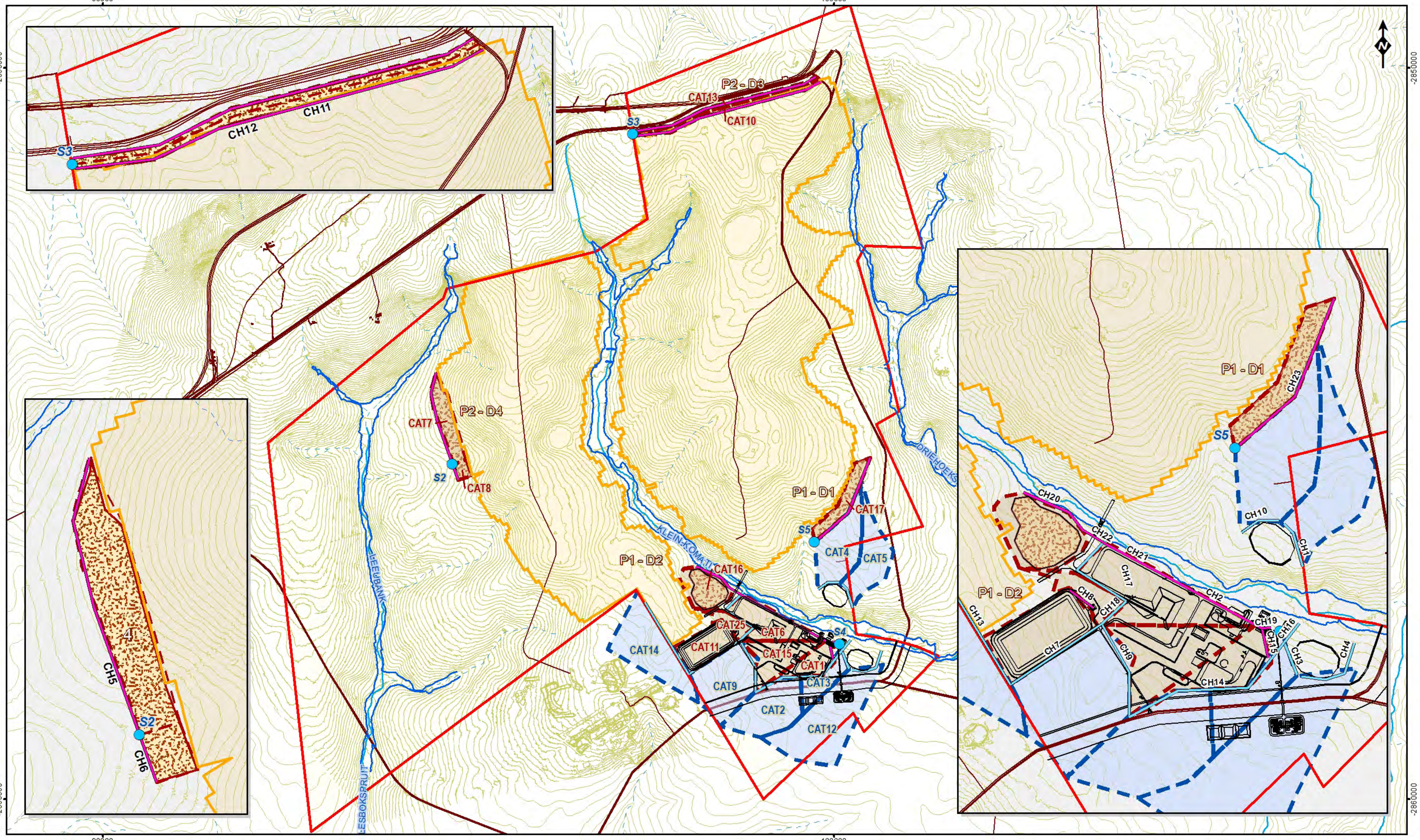
The PCSWMM model was used as the flood analysis model. PCSWMM is a dynamic rainfall-runoff simulation model used for single event or long-term simulation of runoff quantity. This model was set up for the site and used to size the conveyance structures for separation of clean and dirty stormwater runoff.

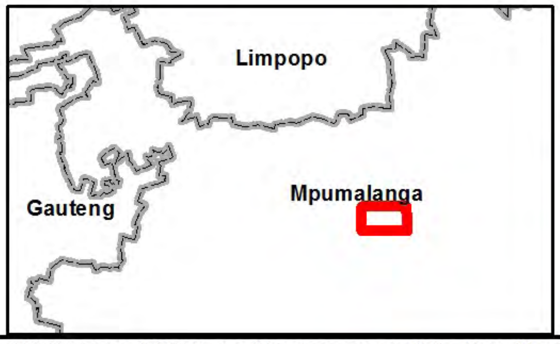
Simulated runoff volumes and flood peaks are summarised in Table 13 for the 50 year recurrence interval storm event.

All diversion channels have been sized to divert runoff up to the 50 year return period flood peak as per regulation 704 of the National Water Act. A freeboard of 0.3 m was included. Size of the structures are given in Table 14.

Table 13: Simulated clean and dirty 50 year recurrence interval flood peaks and volumes

Name	Area (ha)	Total Runoff Volume (m^3)	50 year flood Peak (m^3/s)
CAT1	21.3	11280	1.55
CAT2	56.9	14570	4.02
CAT3	22.4	5530	1.49
CAT4	51.6	12440	3.28
CAT5	44.8	6940	1.46
CAT6	39.5	18630	2.33
CAT7	24.2	1650	1.00
CAT8	4.4	760	0.66
CAT9	64.3	14820	3.81
CAT10	13.3	1450	1.01
CAT11	31.1	7510	1.99
CAT12	97.3	5490	0.93
CAT13	12.9	1260	0.85
CAT14	71.3	12340	2.72
CAT15	35.0	16530	2.07
CAT16	28.6	6130	1.51
CAT17	20.0	1950	0.76
CAT18	7.0	750	0.53
CAT25	10.5	1080	0.20





LEGEND

- Dirty water storage
- Plant layout
- Clean water channels
- Dirty water channels
- Roads
- 1 in 100 year floodline
- Rivers
- Rivers - Non-perennial
- 2m & 5m contours
- Clean stormwater catchment
- Dirty stormwater catchment
- Mineral rights
- Coal reserve
- Dumps

REFERENCE

Projection: LO 29 Cape

PROJECT

SURFACE WATER ASSESSMENT - BELFAST PROJECT

TITLE

LAYOUT OF PROPOSED STORMWATER MANAGEMENT STRUCTURES

Golder Associates
Johannesburg, South Africa

PROJECT No. 12433		SCALE 1:50,000	A3 REV. 1
PHASE: 2	TASK: 0		
GIS	MM	24/02/2011	
CHECK	SC	24/02/2011	
REVIEW	TJC	24/02/2011	

FIGURE 25

Path: G:\GIS\Gis Projects\12433 Surface Water Assessment for Belfast Project\Maps\Feb 2011\12433_SWManagement.mxd

Table 14: Stormwater drains characteristics

Name	Length (m)	Roughness	Cross-Section	Height (m)	Width (m)	Left slope (1:H)	Right slope (1:H)	Slope of conduit (m/m)	Maximum Flow (m^3/s)	Maximum Velocity (m/s)
CH1	365	0.035	TRAPEZOIDAL	0.8	0.5	3	3	0.0110	1.461	1.31
CH2	877	0.035	TRAPEZOIDAL	1.2	1.5	3	3	0.0040	4.369	1.18
CH3	270	0.035	TRAPEZOIDAL	0.6	0.2	3	3	0.0130	1.487	1.41
CH4	580	0.035	TRAPEZOIDAL	0.7	0.5	3	3	0.0172	0.932	1.39
CH5	1308	0.035	TRAPEZOIDAL	1	0.5	3	3	0.0031	0.741	1.86
CH6	227	0.035	TRAPEZOIDAL	0.6	0.2	3	3	0.0176	0.642	1.60
CH7	839	0.035	TRAPEZOIDAL	1	1.5	3	3	0.0179	5.436	2.17
CH8	226	0.035	TRAPEZOIDAL	0.6	0.2	3	3	0.0243	1.987	1.91
CH9	762	0.035	TRAPEZOIDAL	0.8	0.5	3	3	0.0112	3.746	1.69
CH10	318	0.035	TRAPEZOIDAL	1	1	3	3	0.0126	3.283	1.68
CH11	2699	0.035	TRAPEZOIDAL	0.8	0.5	3	3	0.0019	0.647	1.75
CH12	2660	0.035	TRAPEZOIDAL	0.8	0.5	3	3	0.0019	0.549	1.69
CH13	1152	0.035	TRAPEZOIDAL	1.3	2.5	3	3	0.0022	5.446	1.00
CH14	1408	0.035	TRAPEZOIDAL	1.1	1.5	3	3	0.0153	3.818	1.92
CH15	230	0.035	TRAPEZOIDAL	1.1	1.5	3	3	0.0152	1.519	1.45
CH16	185	0.035	TRAPEZOIDAL	1.1	1.5	3	3	0.0324	5.23	2.66
CH17	805	0.035	TRAPEZOIDAL	1.5	2	3	3	0.0050	8.665	1.52
CH18	257	0.035	TRAPEZOIDAL	1.2	1.5	3	3	0.0234	8.54	2.68
CH19	74	0.035	TRAPEZOIDAL	1.2	1.5	3	3	0.0204	5.662	2.29
CH20	543	0.035	TRAPEZOIDAL	0.75	1	3	3	0.0018	1.436	0.70
CH21	469	0.035	TRAPEZOIDAL	0.8	0.5	3	3	0.0043	1.041	0.87
CH22	157	0.035	CIRCULAR	1	0	0	0	0.0127	1.083	1.51
CH23	1379	0.035	TRAPEZOIDAL	0.7	0.5	3	3	0.0116	0.65	1.89
CH24	428	0.01	TRAPEZOIDAL	1	1	3	3	0.0047	0.506	1.81

6.4 Integrated site wide model

6.4.1 General Description of Model

A water balance was developed of the integrated water system using Goldsim simulation software. The mine water balance is dynamic and depends on many factors including rainfall, the mine plan, floor contours, rehabilitation scheduling and standards as well as mine water requirements. Water will have to be managed either for use to meet the mine water requirements or treatment and discharge.

To represent the mine water management system, the following elements have been included in the model:

- Climate element
- A mine pit element
- Discard dump
- Dam
- Coal plant
- Catchment

The above elements can be used to build up a mine water system. The operating rule and connectivity govern how the water streams produced from the different elements are linked together. The connectivity and operating rule are programmed into the Goldsim model.

The time step of the model is dependent on the objective of the model. An annual time step can be used to give an indication of the average water volumes that may need to be managed and an overall indication of the mine water balance. Such a long time step does not address the seasonal or daily variations and therefore cannot be used to size storage facilities. In the case of large storage capacities such as those generally associated with mine workings, an annual water balance accounting for the annual variation of rainfall can be used to determine mine filling times and average recharge rates to the workings. A monthly time step accounts for the seasonal variations and can be used to provide indicative sizing of storage facilities such as pollution control dams. The monthly time step can also be used to provide an indication of the capacities of the pumping infrastructure needed to convey the water between storage elements. A daily time step model allows for a more accurate determination of the pollution control dam sizes and pump/pipeline capacities. A daily time step was used for this model.

The approach and algorithms used to model the different elements are described in the following sections.

6.4.2 Climate

6.4.2.1 Stochastic daily rainfall generation

Water management on an open cast mine is further complicated by the unpredictable and seasonal character of rainfall. A stochastic daily rainfall generator is a model capable of reproducing key statistical characteristics of historic records at not only a daily level but also monthly levels. The stochastically generated daily rainfall record can be used to assess the performance of the management system for future scenarios. This allows different sequences of daily rainfall to be generated within the model to determine the probability of spill and failure of supply for a particular water management strategy.

A daily time step stochastic rainfall generator has been developed in the model. The parameters of the stochastic model are determined by fitting the model to a measured daily rainfall record considered to be representative of the area. Record from Roodepoort rain gage (section 4.3) was used to calibrate the stochastic daily rainfall model.

The following statistics were compared to test the fit of the stochastic model to the measured daily rainfall depths:

- The monthly averages shown in Figure 26

- The probability distribution of the measured and stochastic daily rainfall depths as shown in Figure 27
- The average number of rainfall days in each month shown in Figure 28
- Distribution of the number of days of consecutive rain shown in Figure 29
- Comparison of the number of days between rainfall events shown in Figure 30

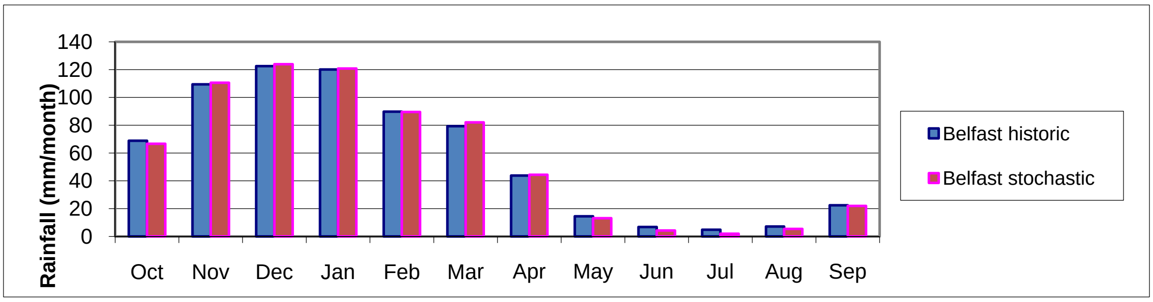


Figure 26 : Comparison of stochastic and measured average monthly rainfall depths

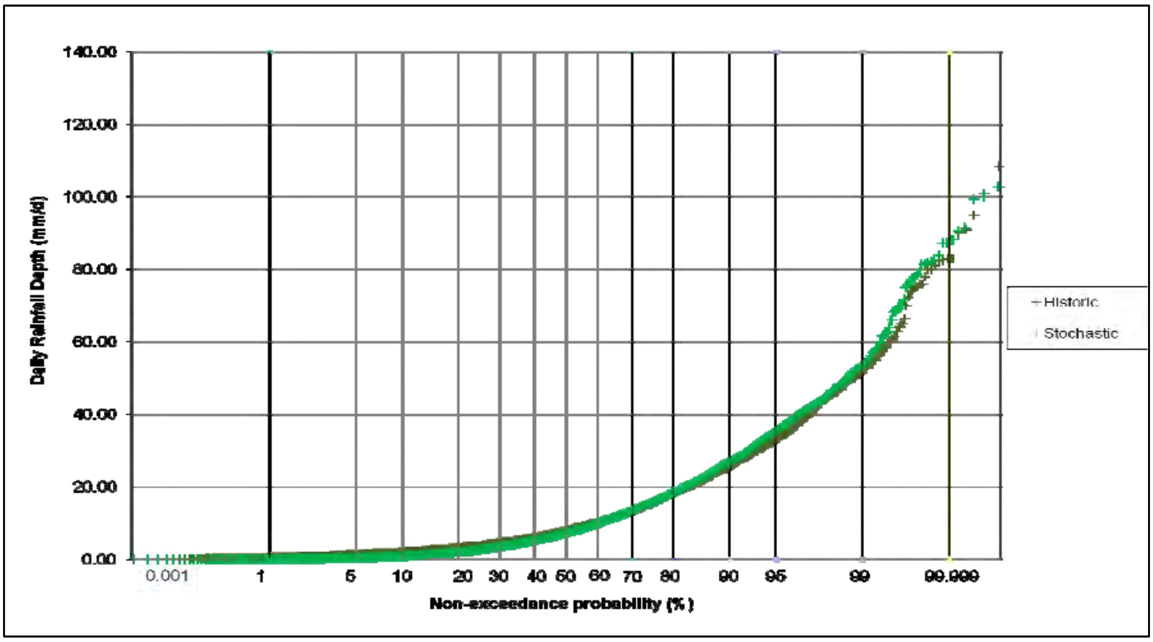


Figure 27 : Comparison of stochastic and measured daily rainfall depths

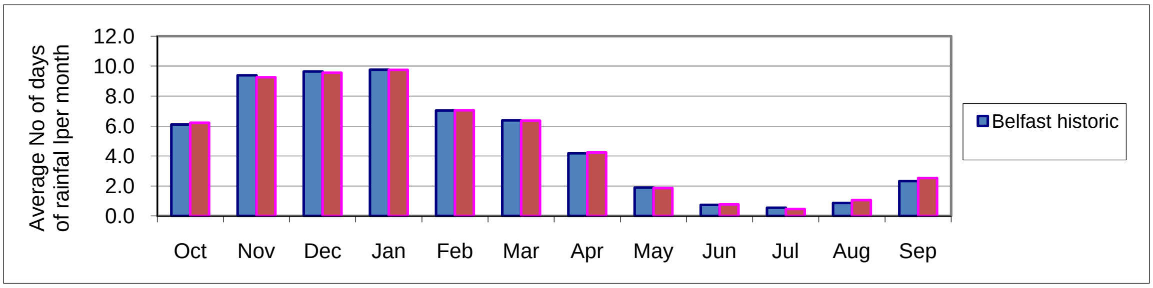


Figure 28 : Comparison of the average number of days of rainfall in each month

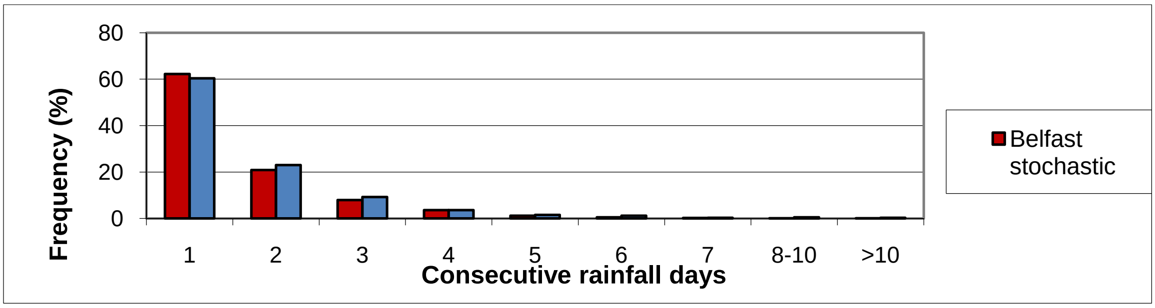


Figure 29 : Comparison of distribution of the number of days of consecutive rain

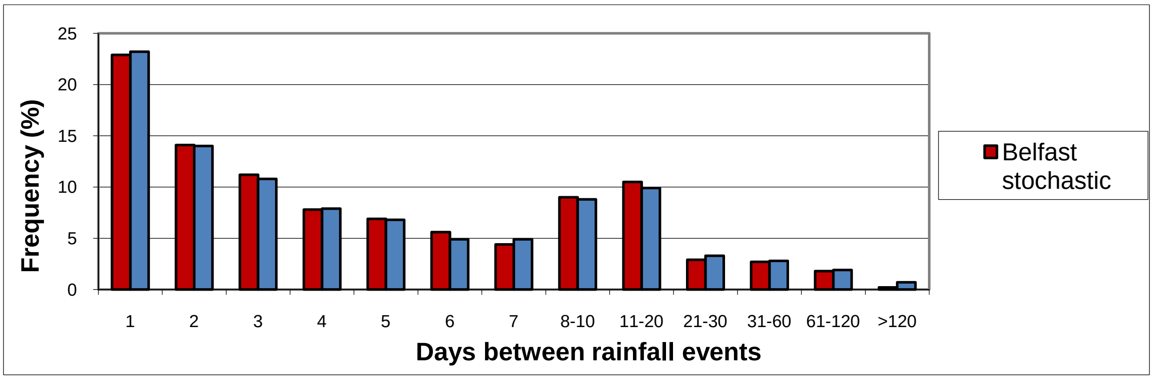


Figure 30 : Comparison of days between rainfall events

The stochastic model was run to generate 1 000 sequences of 365 days each. The distribution of the daily rainfall depths for each day is shown in Figure 31. The plots show that the stochastic model is generating a range of daily depths and the seasonality is well captured. The annual rainfall totals simulated ranged from 460 mm in a dry year to 930 mm in the wet year.

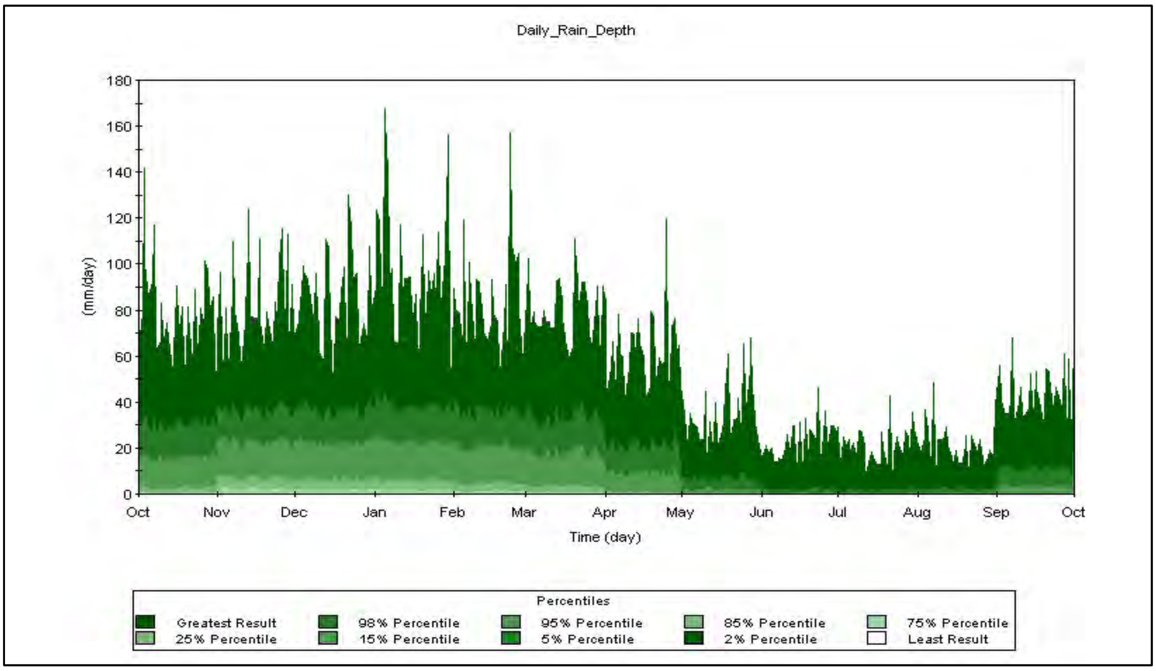


Figure 31 : Plot of percentiles of stochastic daily rainfall depths for the 1000 sequences

6.4.2.2 Evaporation data

Average monthly potential Symons Pan evaporation as given in Midgeley et al (1990) is input into the model. The potential Symons Pan evaporation is used together with a pan factor to calculate the evaporation from the water surfaces of the pollution control dams. The average monthly Symons Pan potential evaporation used in the model and the pan factors are listed in Table 15.

Table 15 : Average monthly Symons Pan potential evaporation and pan factors

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Average evaporation (mm)	138	138	156	164	140	138	104	91	75	81	102	124	1451
Pan factor (lake/dam evaporation)	0.81	0.82	0.83	0.84	0.88	0.88	0.88	0.87	0.85	0.83	0.81	0,81	NA

6.4.3 Mine Pits

6.4.3.1 Background

The element used to model the mine pits accounts for the changes in the different mining areas over time as given in the mine plan. The operating opencast mine sections represent a complex dynamic system as far as the pathways for the flow of water is concerned. The model used for this study is based on the approach given in van Niekerk (1997), where the detailed mine plan is used to set up a grid system describing the mine sequencing, depth to floor, volume of material in each element and the status of the element. The status of the element refers to the element being in a pre-stripped, workings, spoils or rehabilitated spoils state.

The components and the links between the components used to model the mine pits are shown in Figure 32. The individual elements and routes are described in the sections below.

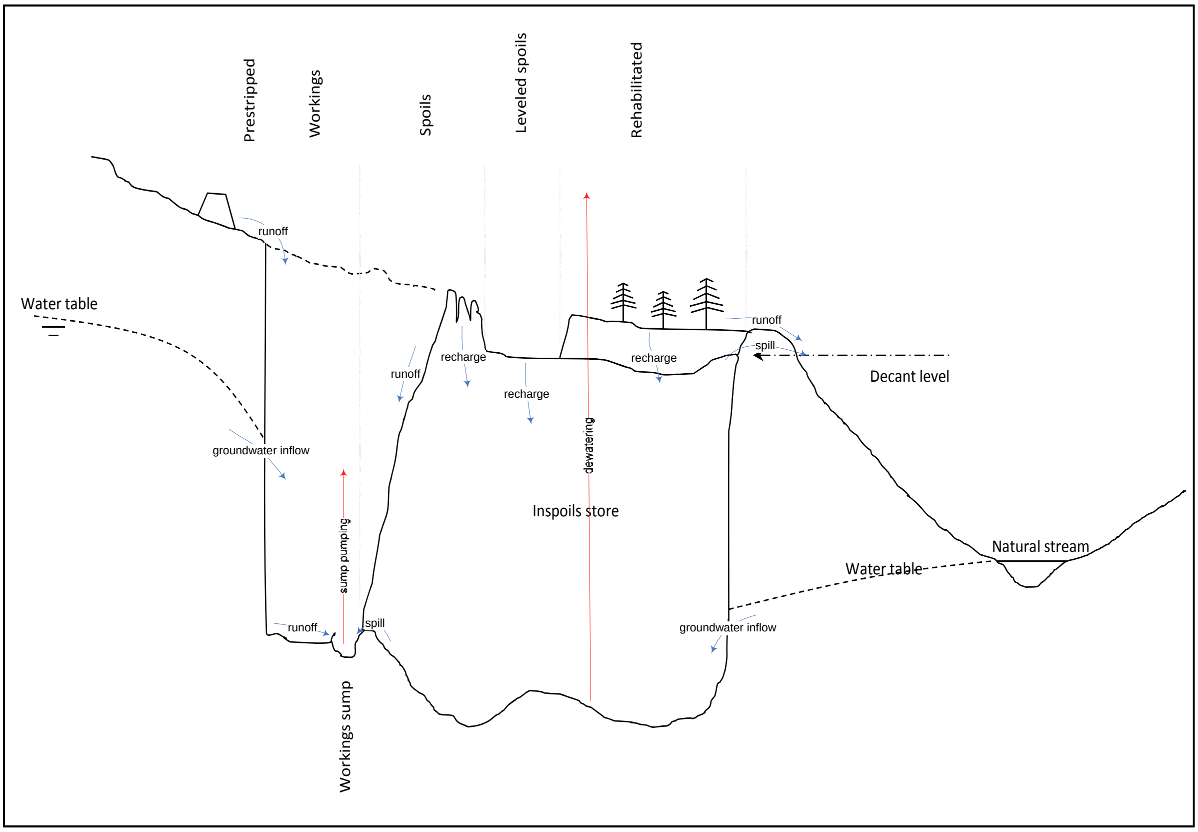


Figure 32 : Schematic showing the components making up the mine pit element

6.4.3.2 Description of elements in pit element

1) **Prestrip area** is the area that has been stripped of top soil and overburden ahead of mining. The stripped soil is stored for later use in the rehabilitation program. Mining is upslope, therefore berms will need to be constructed ahead of mining to prevent runoff from entering the workings. The surface runoff from the prestrip area reports to the mine workings area and has to be managed with the runoff from the mine workings.

2) **Workings area** which has been stripped of overburden and spoil material. This is the area where the coal is being removed and includes the areas of the ramps used to access the mine workings. The runoff from this area reports to the pit sump.

3) **Workings sump** is the storage area provided in the workings area where the water entering the workings area is stored and pumped out of the pit.

4) **Spoils heaps** are the spoils material from the current mining strip which has been placed in the previous mining strip. The runoff and recharge from this area is assumed to report to the mine workings area.

5) **Levelled spoils areas**, where the un-rehabilitated spoil areas have been levelled but as yet not top soiled. The runoff from these areas is assumed to be diverted away from the workings and allowed to leave the mine water system. The recharge from the levelled spoils area reports to the floor of the workings and is added to the volume stored in the inspoils store.

6) **Inspoils store** is the volume of water that can be stored in the spoils. The volume that can be stored in the inspoils store depends on the floor contours and the porosity of the spoils material. The capacity of the inspoils store varies with the stage of mining. Mining is taking place upslope, water can be stored in the inspoils store behind mining. If the workings bottom level is below the decant level, water will spill to the workings sump once the capacity of the inspoils store is exceeded. Otherwise water will spill into the river. It is hypothised in this study that decant will occur when water reaches the weathered rock zone 5m below the decant level. The capacity of the inspoils store changes over the life of mine.

7) **Rehabilitated spoils free draining,** where the spoil heaps have been levelled, top soiled and re-vegetated. The soil cover is generally a combination of overburden and top soil. The typical depths used are 300 mm of top soil and 300 mm of overburden. In the model this area is assumed to be levelled to be free draining so that the surface runoff from the area will flow off the rehabilitated areas. For this area the surface runoff is assumed to leave the mine water system. The recharge through the spoils reports to the floor of the mine workings, where it becomes part of the volume stored in the inspoils store.

6.4.3.3 Description of routes in pit element

Surface Runoff

Surface runoff is the runoff from pervious catchment areas. A double soil layer model together with the Green-Ampt equation is used to model the soil moisture budget. A double layer model is adequate for typical mine catchment areas. These areas are generally small and do not contain a defined water course or channel which intercepts the groundwater table. The catchments will produce runoff with the recharge or percolation from the catchment reporting to the groundwater system which reports to a water course.

A schematic showing the soil moisture budget is given in Figure 33. The elements are the daily rainfall generated in the climate module, an interception storage, the Green-Ampt equation which is used to determine the infiltration capacity, and the Corey-Brooke equation to determine percolation between layers. The interception storage layer represents the interception of rainfall by the catchment vegetation. The water held in the interception store is evaporated, with the excess spilling from the interception store to the ground. The Green and Ampt equation is used to determine the infiltration depth from the excess water that spills from the interception storage. The difference between the excess water and the runoff infiltrates into the soil layer. The moisture in the soil layer is budgeted for by adding in the infiltration and subtracting the evaporation and the percolation from the moisture in the soil store. The equations governing the fluxes between the stores are given below.

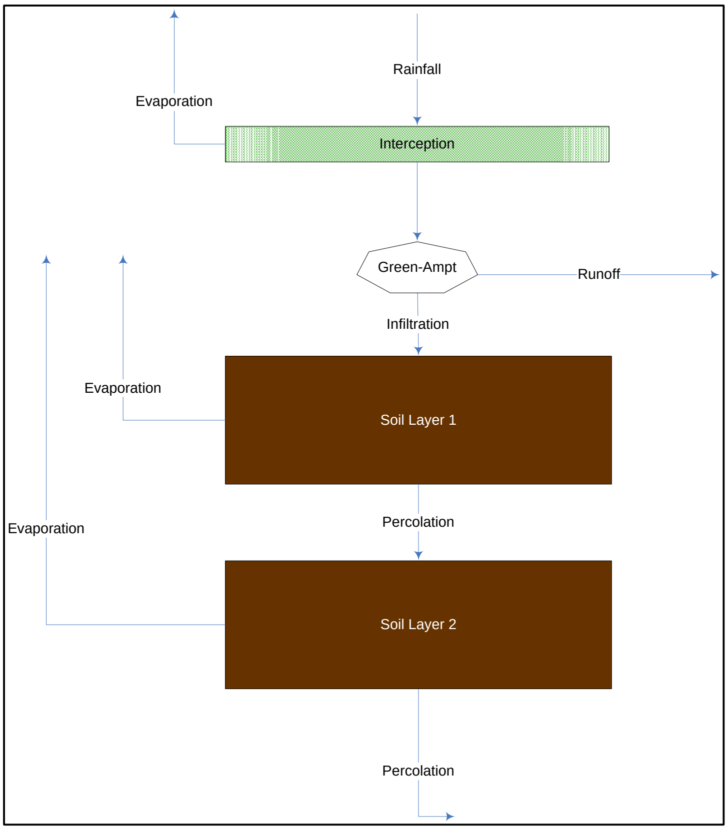


Figure 33 : Schematic showing schematic of double layer soil moisture budget

The depth of water stored in the interception storage is given by

$$I_{ste} = I_{st0} + R\Delta t - E\Delta t$$

where I_{ste} is the depth (mm) in the store at the end of the time step (day), I_{st0} is the depth (mm) in the store at the start of the time step, R (mm/d) is the daily rainfall depth, E (mm/d) is the potential evaporation and Δt is the time step which is a day. If I_{ste} exceeds the capacity of the store then the excess water that spills from the interception store is given as

$$I_{sp} = \frac{(I_{ste} - I_{cap})}{\Delta t}$$

where I_{sp} (mm/d) is the spill depth and I_{cap} (mm) is the capacity of the interception storage.

The infiltration capacity into the top layer is calculated using the Green-Ampt equation as follows:

$$f = K_s\left(1 + (\theta_s - \theta_i)\frac{S}{F}\right)$$

where f is the infiltration capacity (mm), K_s (mm/hr) is the saturated conductivity of the soil, S (mm) is the capillary suction, F (mm) is the cumulative depth, θ_s and θ_i are the saturated and initial soil moisture content

The infiltration is then calculated as

$$Inf = \min((\theta_s - \theta), f, I_{sp})$$

where Inf is the infiltration (mm).

The surface runoff can then be calculated as:

$$R_{off} = I_{sp} - Inf$$

where R_{off} is the runoff depth (mm)

The soil moisture budgeting for the top layer is described by the following equations

$$\theta_e = \theta_0 + \left(I_{sp}\Delta t - R_{off}\Delta t - E_p\Delta t - Perc\Delta t\right)d_1$$

where θ_0 is the moisture content of the soil at the start of the time step, θ_e is moisture content at the end of the time step, E_p (mm/d) is the soil evaporation and transpiration after the interception storage evaporation is satisfied, $Perc$ (mm/d) is the water depth that percolates from the upper soil layer to the lower layers and d_1 (mm) is the depth of the top soil layer.

$Perc$ is calculated using the Corey-Brooke equation as follows

$$Perc = K_s\left(\frac{\theta - \theta_r}{\theta_s - \theta_r}\right)^m$$

where θ_r is the residual moisture content

The soil evaporation and the transpiration from the soil profile are included in the model. The evaporation model is based on the model presented in Holden (1993). The soil evaporation and the transpiration is reduced as the moisture content in the soil reduced. The leafy area index (LAI) is used to split the potential evaporation between the soil and transpiration. The LAI is the degree of shading of the soil ie the ratio of shaded to unshaded areas.

The equation used to determine the potential evaporation from the soil E_{sp} (mm/d) is given by:

$$E_{sp} = E_p e^{-LAI}$$

with the balance of the evaporation potential being available for transpiration T_p.

The actual soil evaporation rate E_{sa} (mm/d) varies with soil moisture content. If the moisture content of the soil is greater than the field capacity of the soil then E_{sa} equals E_{sp}. If the moisture content of the soil is less than the field capacity then E_{sa} reduces linearly from E_{sp} at field capacity to 0 at θ_r where θ_r is the residual moisture content of the soil.

The relationship of Doorenbos and Kassam as given in Holden (1993) was used to describe the reduction in soil moisture content on the transpiration rate T_a (mm/d). The relationship relates the plant available moisture (PAM) to T_a and the potential evaporation rate at which plant stress sets in. The relationship is given by:

$$T_a = PAM * 14.98 * 2.781^{0.543T_p}$$

$$PAM = \frac{\theta - \theta_r}{\theta_s - \theta_r}$$

The soil moisture budgeting for the bottom layer is described by the following equations

$$\theta_e = \theta_0 + (Perc\Delta t - Perc_2\Delta t)d_2$$

where $Perc_2$ is the percolation below the second and d_2 (mm) is the depth of the bottom soil layer.

Recharge

Recharge, in the light of the mine pit, is the volume of water that escapes from the evaporation zone and percolates through the soil/spoil body to the floor of the pit. The recharge is calculated in the model using the percolation depth from the surface runoff calculations. The following equation is used to calculate the percolation volume:

$$Recharge = Perc_2 * Area$$

The Belfast Project is at an early stage and due to the lack of local data. Typical recharge values from other work undertaken in the Witbank Coal Fields were used to calibrate the model. The values are given in Table 16 for different sources of water in opencast pits.

Table 16 : Typical water recharge characteristics for opencast mining (Hodgson et al, 2006)

Sources which Contribute Water	Water Sources into Opencast Pits	Suggested Average Values
Rain onto ramps and voids	20 – 100% of rainfall	70% of rainfall
Rain onto spoils heaps (runoff and seepage)	30-80% of rainfall	60% of rainfall
Rain onto levelled spoils (runoff)	3-7% of rainfall	5% of rainfall
Rain onto levelled spoils (seepage)	15-30% of rainfall	20% of rainfall
Rain onto rehab spoils (runoff)	5-15% of rainfall	10% of rainfall
Rain onto rehab spoils (seepage)	5-10% of rainfall	8% of rainfall

Groundwater inflow to workings and spoils

During the mining process the local groundwater drains into the mine section as the cone of depression forms. The groundwater inflow was modelled by Groundwater Complete. Groundwater inflow time series from the groundwater models were included as input into Goldsim. Two groundwater streams have been allowed for in the model viz the groundwater flow directly into the workings and into the inspoils storage.

Spill from inspoils store to mine workings

The recharge water accumulates in the inspoils store. The model keeps track of the volume in the inspoils store accounting for the recharge and dewatering from the store. If the volume stored reaches the capacity of the inspoils store at a particular time (the capacity of the inspoils store is variable) then the excess water spills either to:

- the workings where it reports to the workings sump if the sump elevation is below the decant level
- the river if the decant level is below the sump elevation

Dewatering

The backfilled spoils are used in the model to store water when possible. Dewatering occurs when the plant demand is not met or if water is about to overflow into the pit sump, or over the decant level. If there is insufficient volume in the stores, then only the available volume will be abstracted.

Sump pump

The model assumes that the water is pumped from the workings sump for dust suppression first and the rest into the storage dam. The pumping rate from the sump to the dam is limited by the sump pump capacity which is input to the model. The operating rule for the sump pump is that the pumping to the storage dam takes place regardless of the storage in the storage dam. If there is no storage capacity available in the storage dam, then the dam spills.

Decant management post closure

Once the mining of a pit is completed, the model allows the pit to fill with water up to 5m below the decant level. Once the pit has reached this elevation then water is abstracted at the capacity of the pumping system. The water being discharge into the storage dam associated with the pit.

6.4.4 Dam Element

The inflows to a typical dam element are:

- Runoff from a catchment area, which would be calculated using the catchment element.
- Pumping inputs which could be one of the routes from the mine workings or pumping from other dams in the system.
- Rain is the rainfall falling directly on the surface of the dam. This is calculated as the daily rainfall depth times the water surface area of the dam.

The outputs from a typical dam are:

- Evaporation from the surface of the dam which is calculated as the product of the evaporation depth for water body times the water surface area.
- Seepage from the dam floor which is calculated as the product of a seepage rate and the water surface area in the dam. The seepage is assumed to leave the mine water system.
- Pumping from the dam which is governed by the operating rule. The pumping outputs could be to meet local water demands or to support the supply drawn from other dams in the system.
- Spillage from the dam occurs when the dam is full and overflows.

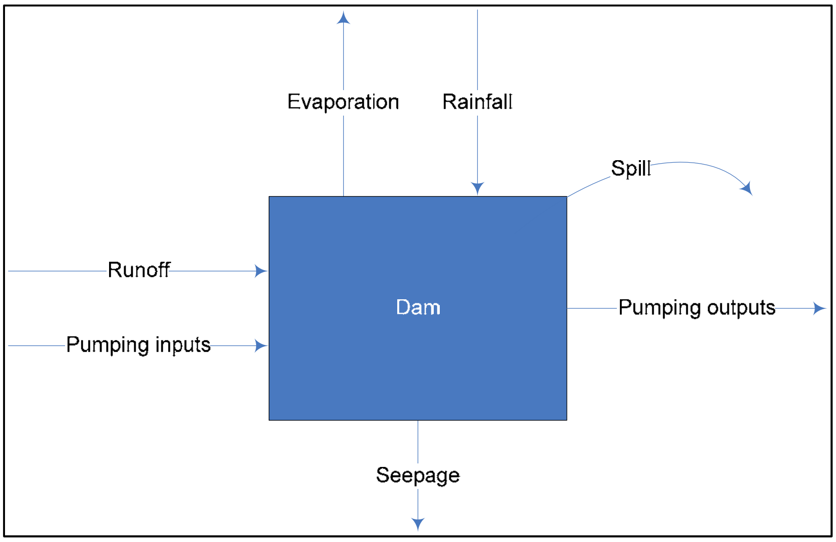


Figure 34 : Schematic showing inputs and output routes for dam element

The balance equation for the dam is

$$V_e = V_0 + \left(R_{off} + Q_{pump\ in} + R * A_{ws} - E * A_{ws} - K_{sat} * A_{ws} - Q_{pump\ out}\right) * \Delta t$$

Where V_e is the volume (m^3) in storage at the end of the day, V_0 is the volume (m^3) at the beginning of the day, R_{off} is the runoff volume (m^3/d), $Q_{pump\ in}$ the volume (m^3/d) pumped into the dam, A_{ws} is the area (m^2) of the water surface of the water stored in the dam, K_{sat} (m/d) is the saturated hydraulic conductivity of the base of the dam and $Q_{pump\ out}$ is the volume of water (m^3/d) pumped from the dam.

If V_e exceeds the dam capacity, then the spill volume is calculated as the difference between V_e and the dam capacity. The area in the dam is represented in the model as a lookup table relating storage volume to water surface area. When the dam runs out of water then the order of meeting the outputs is evaporation, seepage and finally the pumped outputs.

6.4.5 Coal Plant

The water circuits within the coal plant are not included in the water balance model. The coal plant is treated as a box (See Figure 35) with the main streams of water into and out of the box being included in the model. The water requirements of the plant are dependent on the Run of Mine (ROM) processed in the plant.

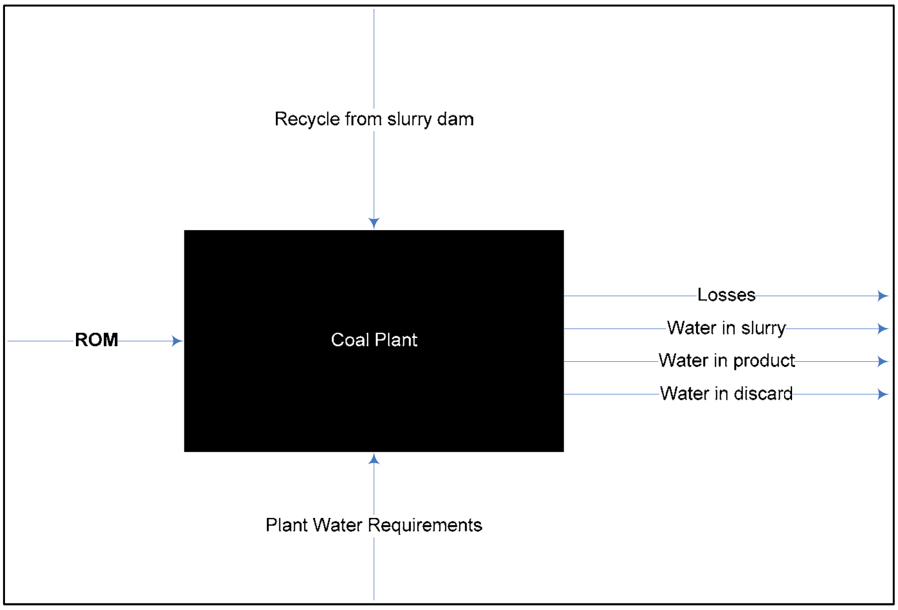


Figure 35: Streams included in the model for the coal beneficiation plant water balance

The inputs to the coal plant are:

- Moisture in the ROM. The volume of water in the ROM is estimated as the product of the moisture content of the ROM and the dry mass of the ROM.
- The make up water into the plant required to run the plant. The make up water volume is calculated by undertaking a water balance across the plant.
- The recycle from the tailings dam. This is estimated as a fraction of the water that goes out with the slurry.

The outputs from the coal plant:

- The water in the discard and the coal product. The moisture in the coal product and discard is calculated as the product of the dry mass of the discard and coal product and the moisture contents for the two streams. The dry mass of discard is calculated as a fraction of the ROM.
- The water in the slurry pumped to the filter press. The water in the slurry is calculated using the slurry density, the mass of solids in the slurry and the specific gravity of the coal. The dry mass of the slurry is calculated as the mass of the ROM remaining after the product and the discard has been subtracted. The equation used in determining the volume of water in the slurry is:

$$V_{slurry} = M_s \frac{1 - RD_{slurry}/SG}{(RD_{slurry} - 1)\rho_w}$$

  Where V_{slurry} is the volume of water (m^3/d) in the slurry, M_s (tonne/d) is the dry mass of solids in the slurry, RD_{slurry} is the density of the slurry, SG is the specific gravity of the solids and ρ_w (tonne/m^3) is the density of water.

- Losses are the losses incurred within the plant

6.4.6 Catchment Element

The calculation of the surface runoff from the catchment element is calculated using the algorithm described in section 6.4.3.3 dealing with the runoff from the different areas associated with the pit. The catchment areas have to be input into the model for each of the catchments as well as the input parameters associated with that soil layer.

6.4.7 Dust Suppression Demands

The dust suppression demands of the mine pits are calculated as follows:

- A daily dust suppression demand is entered into the model. After discussion with Exxaro, the value was set to be a fixed value of 500m^3/d for the whole mine during the life of the mine.
- The dust suppression is only supplied when the pit is active. If the mining of the pit has not started or the mining of the pit is complete the dust suppression demand is set to zero.
- If the pit is active and the daily rainfall depth is less than 8 mm/d, then the dust suppression demand is applied
- If the daily rainfall depth is greater than 8 mm/d then the dust suppression demand is not applied.

6.5 Results of modelling

6.5.1 Operational phase

Pumping sizes and storage capacities were adjusted to optimise the pumping sizes and storage capacity so that it meets Regulation 704. The calibrated model was run to simulate 50 realisation of the period 2011-2040 corresponding to the operational phase of the mine. Results of this simulation are presented in this chapter.

6.5.1.1 Plant water demand

The discard time series provided by Exxaro lumped the coarse discard, spiral discard and slimes disposal and therefore could not be used directly in the model. The plant water demand was calibrated using the macro water balance provided by Exxaro as shown in Figure 36. The modelled tonnages are shown in Figure 37.

The plant water demand distribution as modelled is presented in Figure 38. During the first phase of the project, there is no washing plant installed and therefore very little water is required. During the second phase of the project an average of 1,600 m^3/d is required.

The plant water demand varies over the years due to changes in tonnages. The yearly average water demand fluctuates and peaks in 2039 at 1,850 m^3/d when it operates at 455 ROM tonnes/hr. The lowest plant demand during phase 2 is reached in 2013 at about 1,500 m^3/d. Fluctuations within a year are due to change of moisture in the ROM, discard and product.

It is to be noted that the values are in accordance with the macro balance value of 1,878 m^3/d when the plant operates at a ROM feed of 480 tonnes/hr.

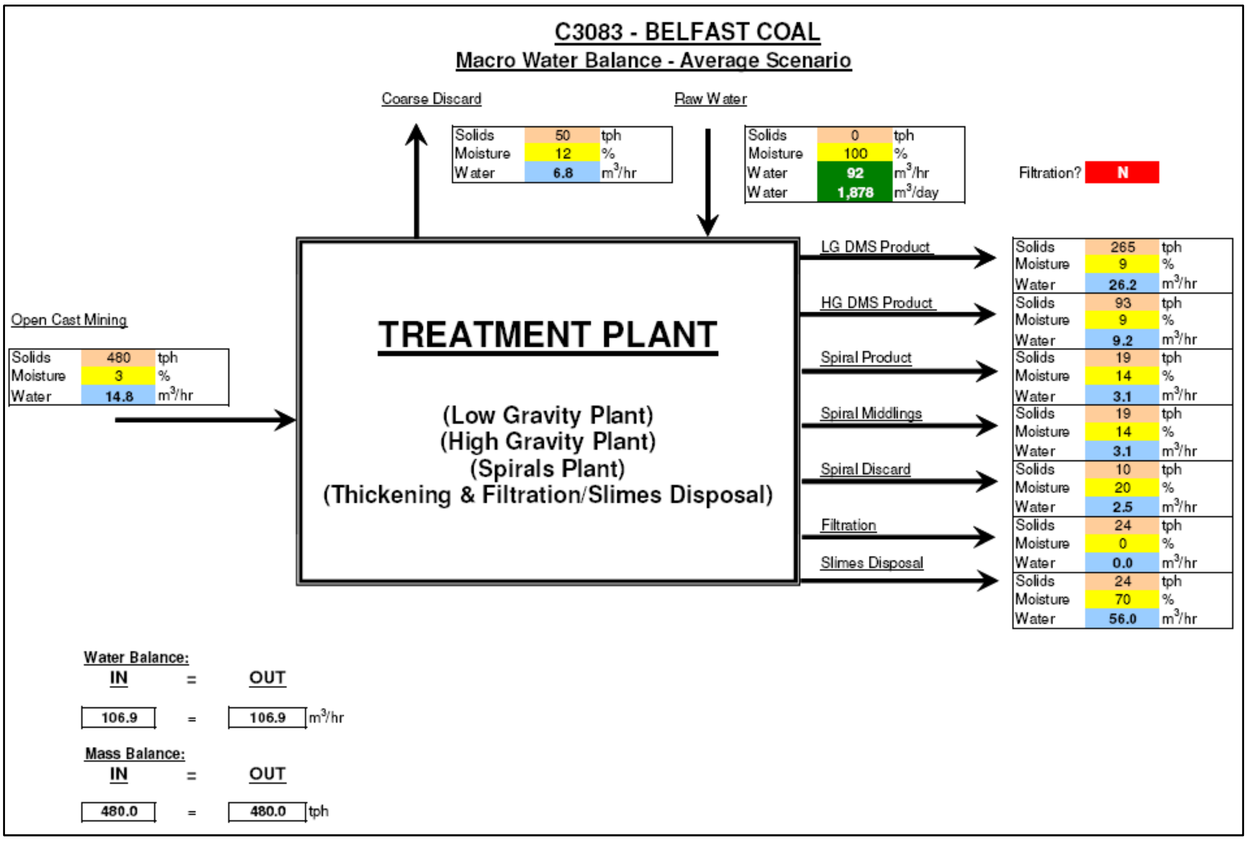


Figure 36: Macro water balance provided by Exxaro

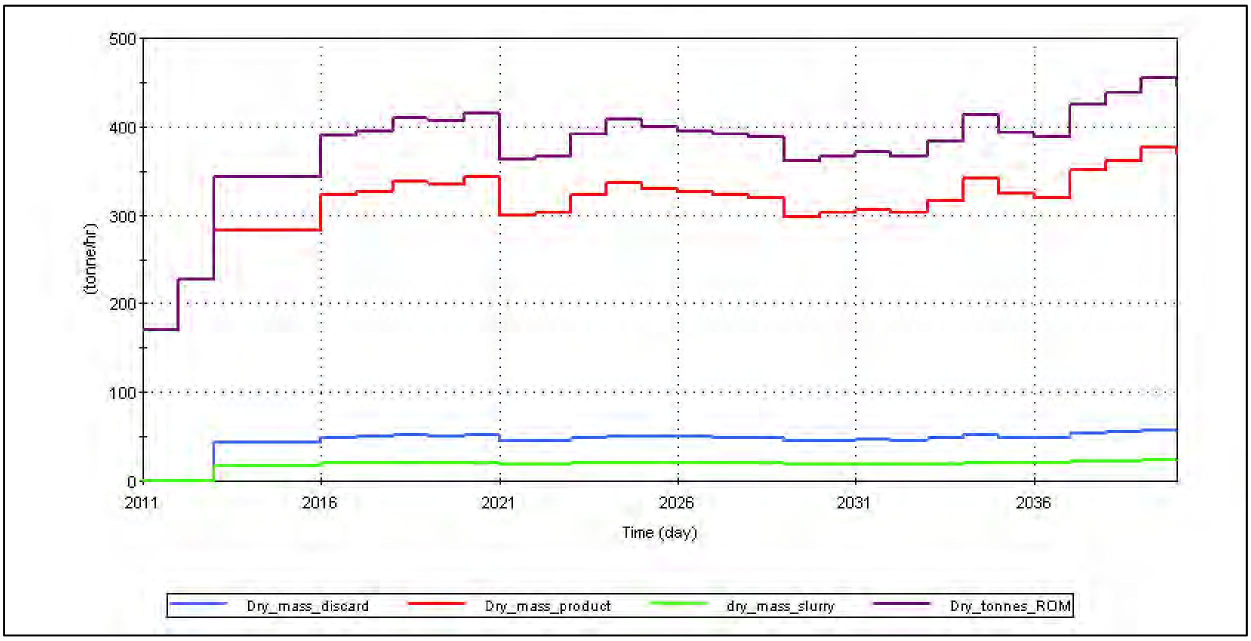


Figure 37: Modelled plant hourly tonnages

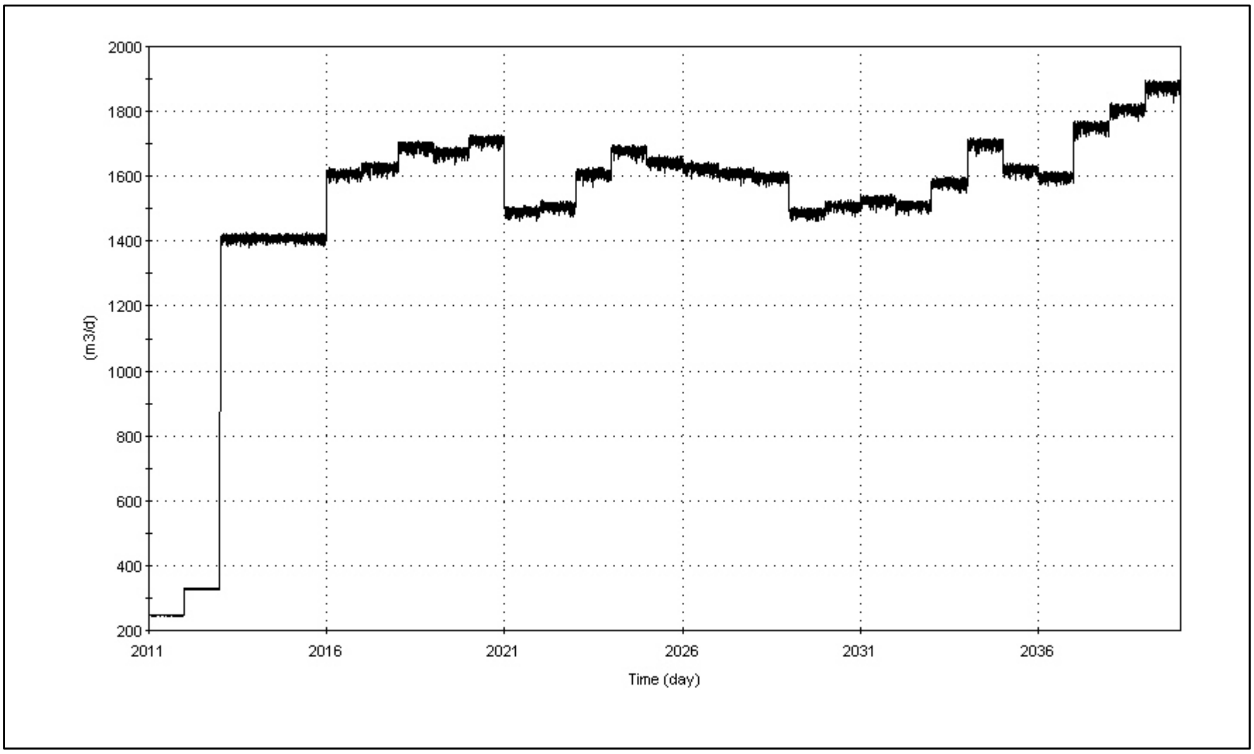
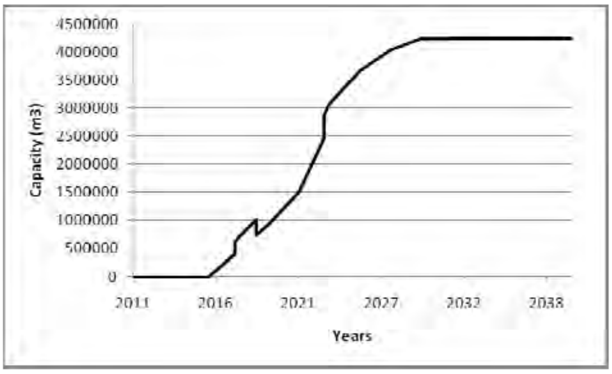


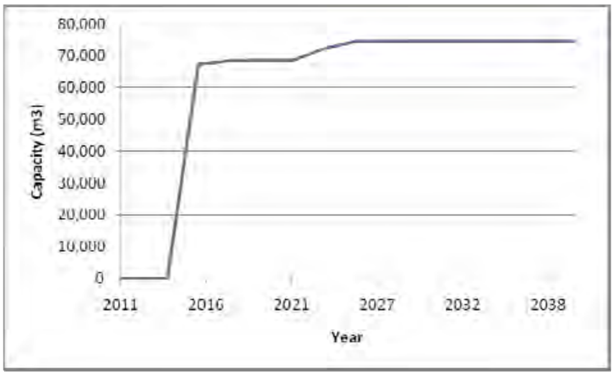
Figure 38: Plant daily water demand

6.5.1.2 Backfilled spoils

The storage capacity within the backfilled spoils increases as mining continues. The rehabilitated area grows from 0m^2 in 2010 to 8.9 km^2 and 10.9 km^2 for the West block and East Block respectively. Volumes were estimated using the floor contours and mining plan. A typical value of 0.28 was used for the porosity of the backfilled spoils. The variation of storage over the course of operation is shown in Figure 39. It can be seen that there is very significant storage in the West block with a capacity reaching its peak in 2029 at 4,200,000 m^3. There is almost no storage in East block and therefore East block will present no buffer storage.



West Block

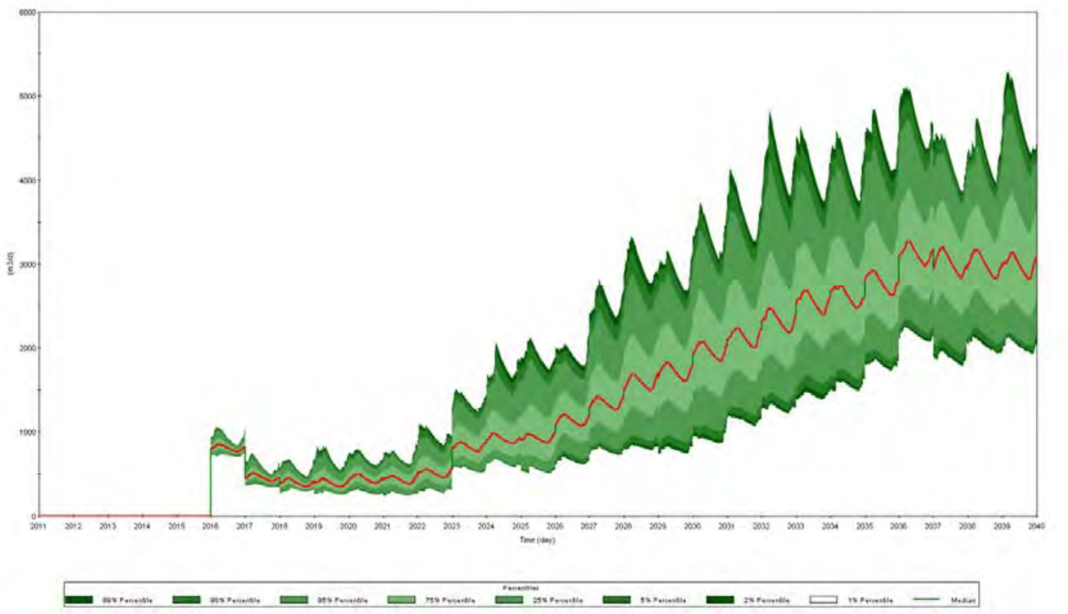


East Block

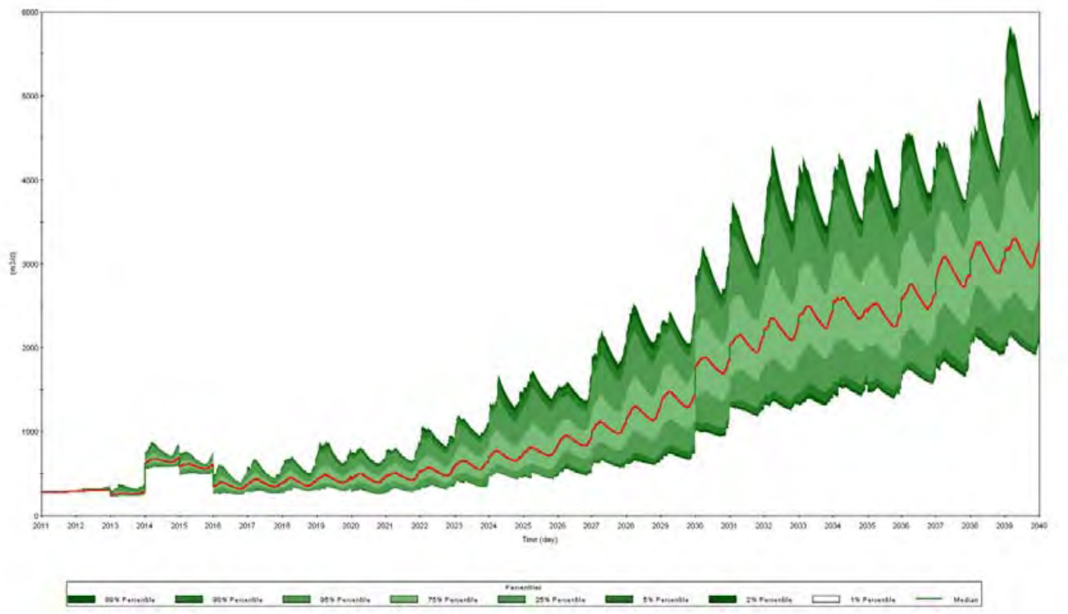
Figure 39: Storage capacities of the backfilled spoils

Modelled inflow into the backfilled spoils is shown in Figure 40. Average inflow into the West Block backfilled spoils gradually increases to plateau at around 3,000m^3/d in 2036 when mining stops. The inflow reaches 3,800 m^3/d for the 75th percentile and 4,800 m^3/d for the 95th percentile. Average inflow into the East Block backfilled spoils gradually increases to peak at 3,200m^3/d in 2040 when mining stops. The inflow reaches 4 000 m^3/d for the 75th percentile and 5,250 m^3/d for the 95th percentile.

Due to the low capacity of storage in the East block backfilled spoils, dewatering should be continuous and water should be kept at a low level for the life of the mine. A pump of capacity of 230 l/s was selected and used in the model. A pump capacity of 115 l/s was selected for the West block dewatering. The simulated volume of water stored in the backfilled spoils is shown in Figure 41.



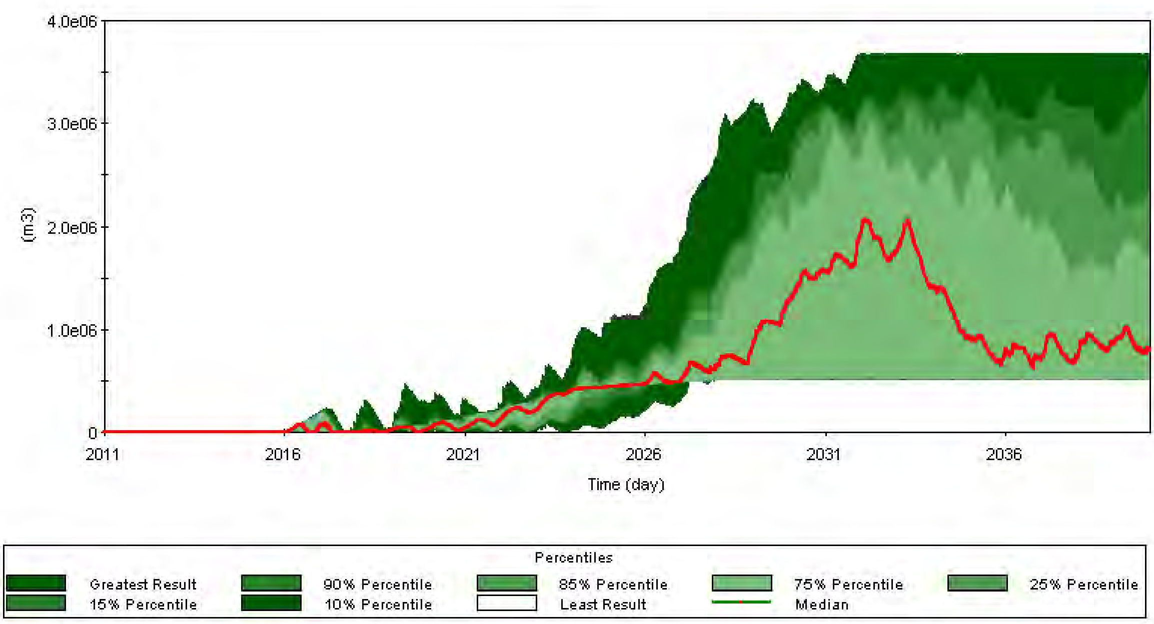
West Block



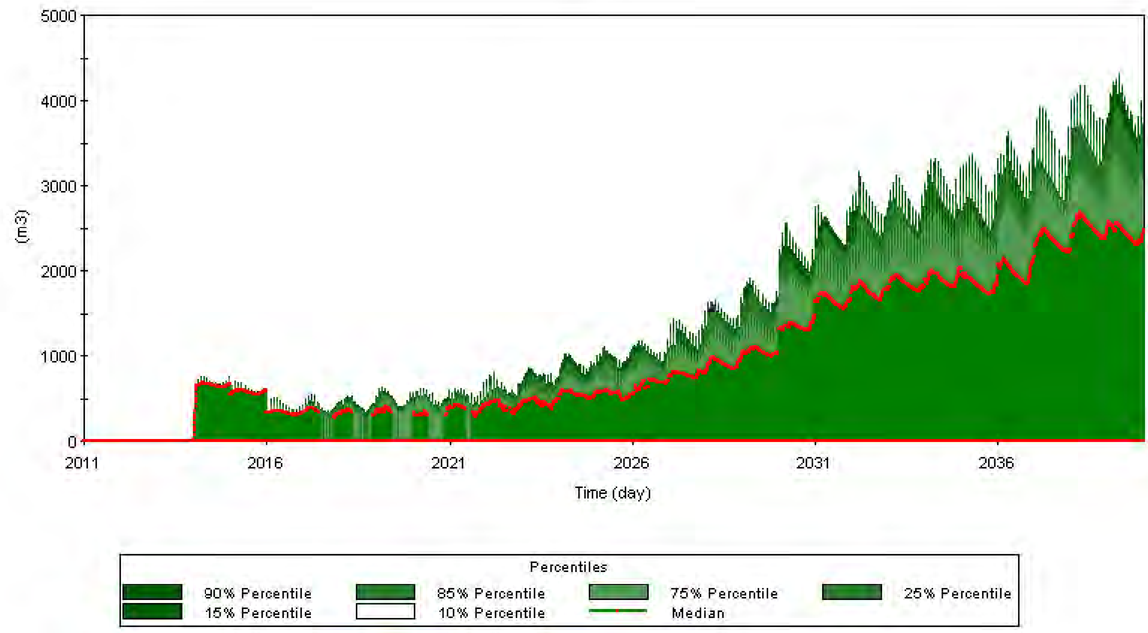
East Block

Figure 40: Backfilled spoils water recharge (m^3/d)

Golder Associates



West Block



East Block

Figure 41: Volume of water in backfilled spoils (m^3)

6.5.1.3 Pit sump pump sizing

The pit sumps should be kept dry at all times to limit pit flooding interfering with the mining operation. The modelled pump capacities required are given in Table 17.

Table 17: Pit sump characteristics

Pit Sump	Pump Capacity
East Block	175 l/s
West Block	175 l/s

6.5.1.4 Polluted water storage dam sizing

Surface water runoff from the waste dumps and plant area stage 1 will be collected into sumps and pumped to the storage dam (see chapter 6.3.1). These sumps should be kept dry at all time so that it can cater for a 1:50 year storm event. The sizes of the structures are presented in Table 18.

Table 18: Dirty water storage size characteristics

Sumps	Description	Capacity (m^3)	Pump Capacity (l/s)
S2	Collect P2-D4 dump runoff	2,700	32
S3	Collect P2-D3 dump runoff	5,200	60
S4	Plant Stormwater Dam	52,000	600
S5	Collect P1-D1 dump runoff	2,100	24

6.5.1.5 Storage dams and desalination plant sizing

Due to topographic constraints, 2 storage dams are proposed to be built. The total storage dam capacity should be sized with the desalination plant. Attention was given to minimizing the size of the desalination plant and to maximizing its year of activation to reduce operating costs. Storage capacity can be provided by the west block backfilled spoils during the life of the mine. Nevertheless, the west block pit is only being mined in 2016. Very little water is being used by the mine during phase 1. The total capacity of the dams is therefore constrained by the amount of excess water during the period 2011-2016.

A total capacity of 350,000 m^3 was selected. A treatment plant capacity of 5,000 m^3/d was chosen. Due to the high volumes of water to be treated, passive treatment is not possible in this project as the area required for passive treatment would be too large. In order to satisfy Regulation 704 the dam will need to have a 0.8m freeboard. Given the locations of the proposed storage dams, a total capacity of 460,000m^3 will be required to satisfy Regulation 704.

In the model, the West and East storage dams were given an operating capacity of 175,000 m^3 each. The West storage dam was considered to be in place from the beginning of the simulation in 2011. The second storage dam (East storage dam) would get activated once the volume in the West storage dam was above 90% of its total capacity. The probability distribution for the date of activation of the second dam is shown in Figure 42. It shows that the second storage dam would need to be activated within the period 2011-2018 with the highest probability for the dam activation of 2014.

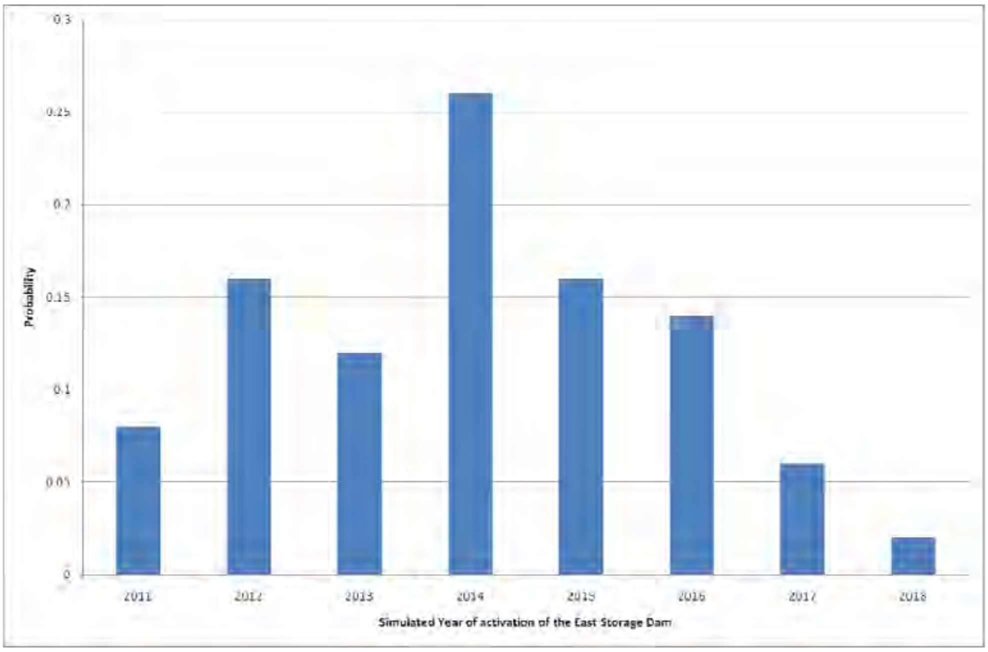


Figure 42: Probability distribution of the activation date for the East storage dam

The time series of the volume of water in the West storage dam and East storage dam are shown in Figure 43 and Figure 44 respectively. The plot shows that the two 175,000m^3 dam (at operating capacity) with the 5,000m^3/d treatment plant will be able to cope with high rainfall sequences.

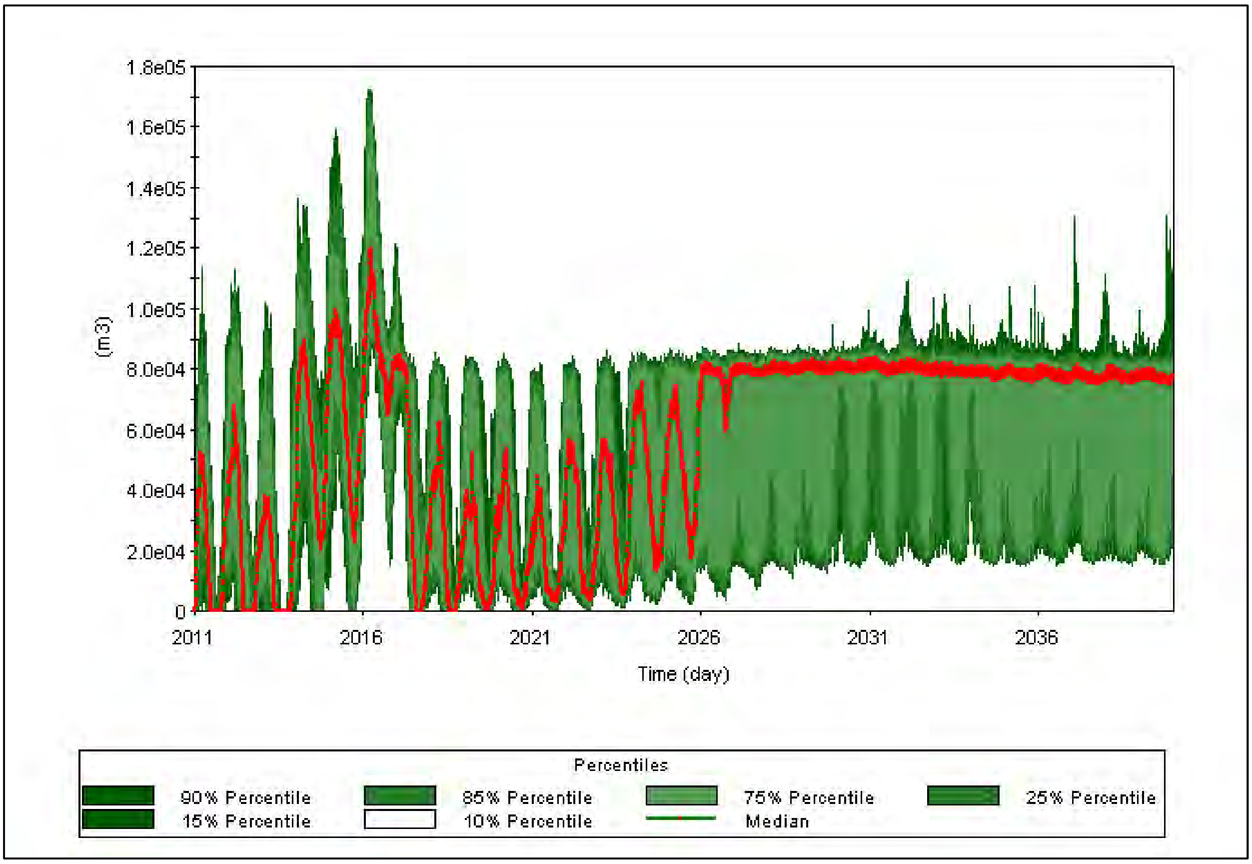


Figure 43: Simulated volume of water in the West storage dam

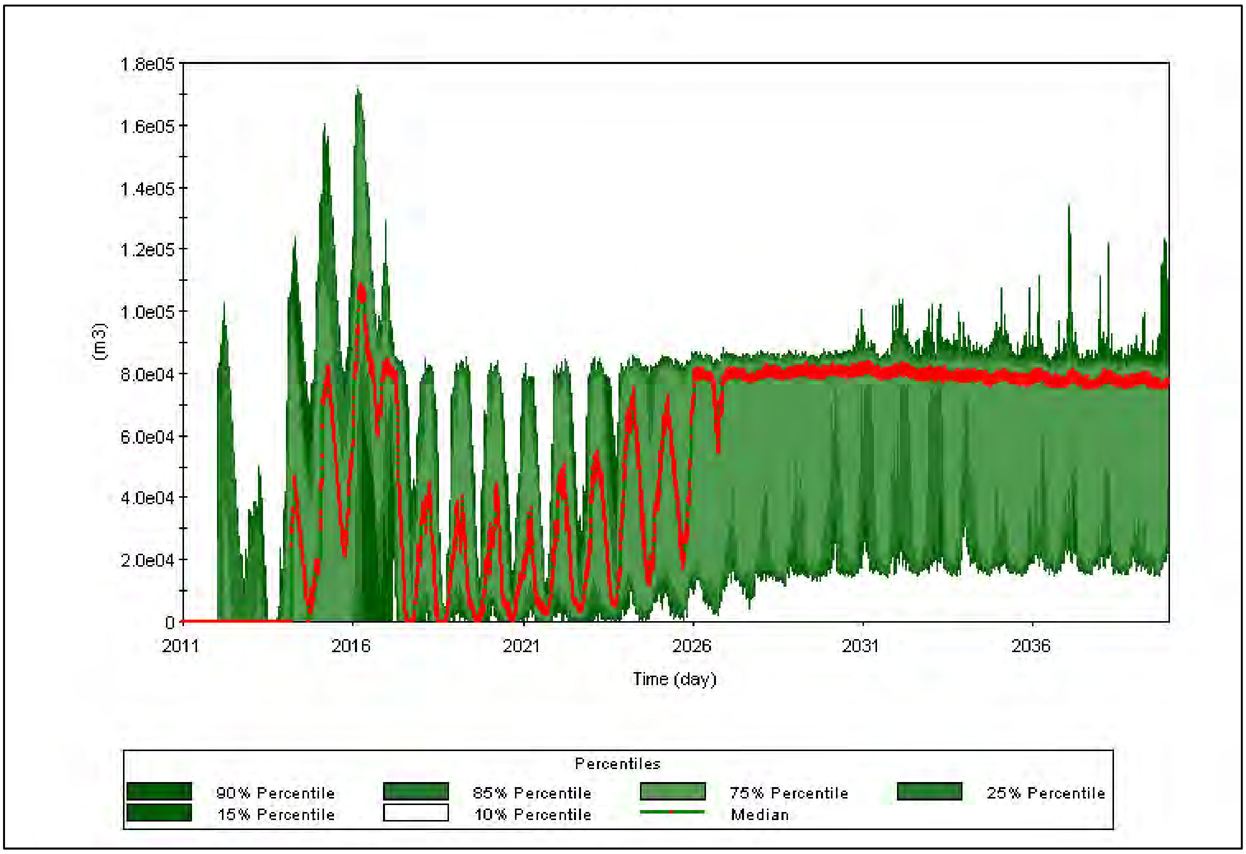


Figure 44: Simulated volume of water in the East storage dam

6.5.1.6 Water requirements

Water will be abstracted from boreholes and the river if there is a water deficit in the system. A twelve month moving average of the water requirements is presented in Figure 45. It compares the amount of water required at the coal plant to the net inflow of water available for the coal washing plant, namely the net inflow to the storage dams. 70% of the water in the slurry stream is extracted and reports back to the plant. The plant demand minus the return water from the filter press is also shown in Figure 45 as it represents the actual plant water demand.

It can be seen that there is almost no excess water during phase 1.

The volume of mine water will grow as the mine grows until the volume generated on the mine exceeds the coal plant requirements. The system will first cope with the excess by pumping water back to the West block backfilled spoils as shown in Figure 46. This is likely to start between 2018 to 2024. The model showed that a pump capacity of 230l/s would be sufficient to prevent the east pit from decanting.

The water will start to exceed the water requirement and there will be insufficient storage in the west block backfilled spoils. The desalination plant will then have to be constructed to prevent water in the backfilled spoils from decanting to the river.

The plant will be required to be constructed between 2026 and 2033 with a mean implementation date of 2029.

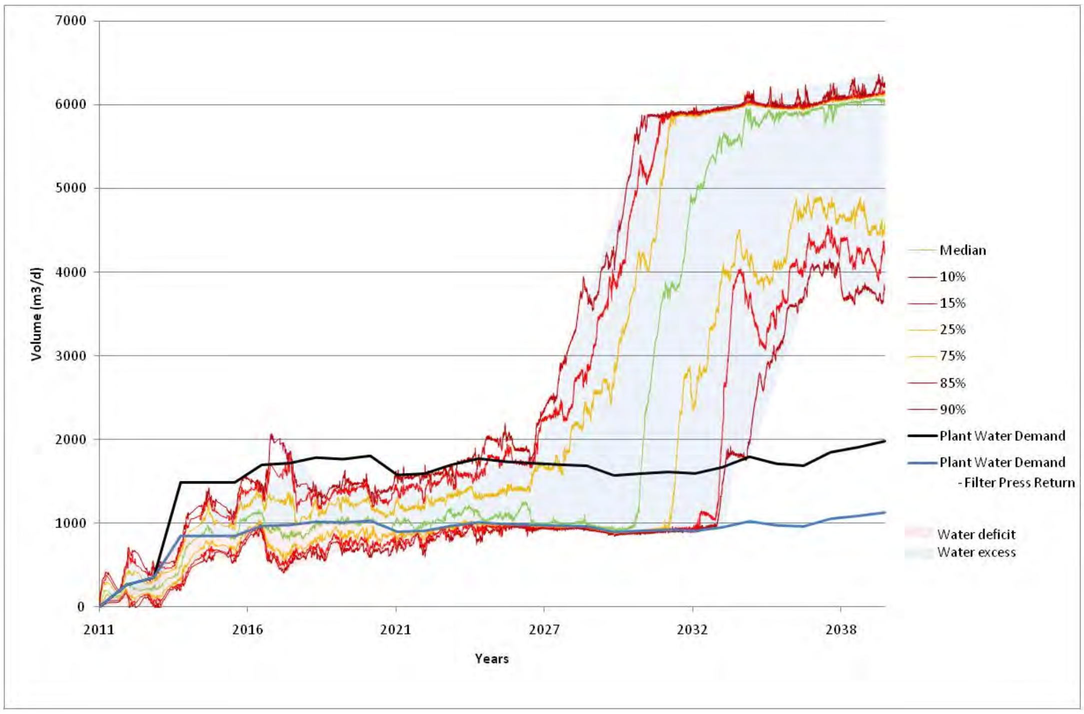


Figure 45: 12 month moving average of mine water demand versus water available

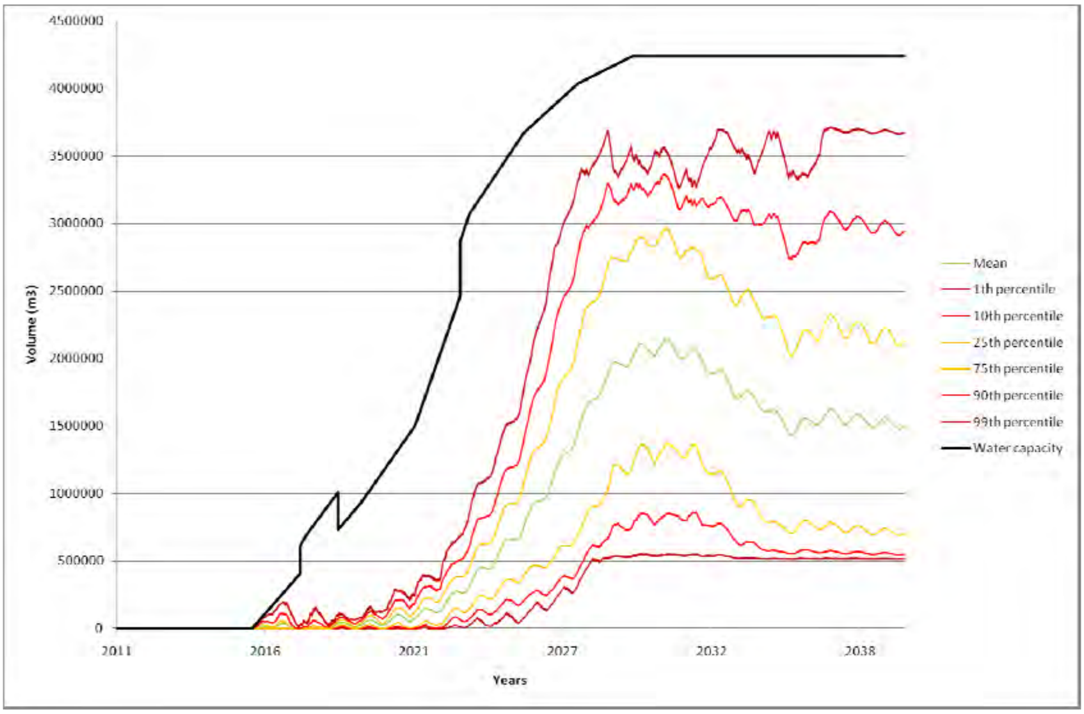


Figure 46: Volume of water in the West block backfill spoils versus storage capacity

The time series of the modelled plant make up water from the boreholes or river is shown in Figure 47. Water will need to be extracted at a maximum rate of 1,000 m^3/d between 2011 and 2021 mostly during the dry season. The make-up water will then slowly decrease as more water is available in the backfilled spoils. There will be almost no make up water required by the year 2023.

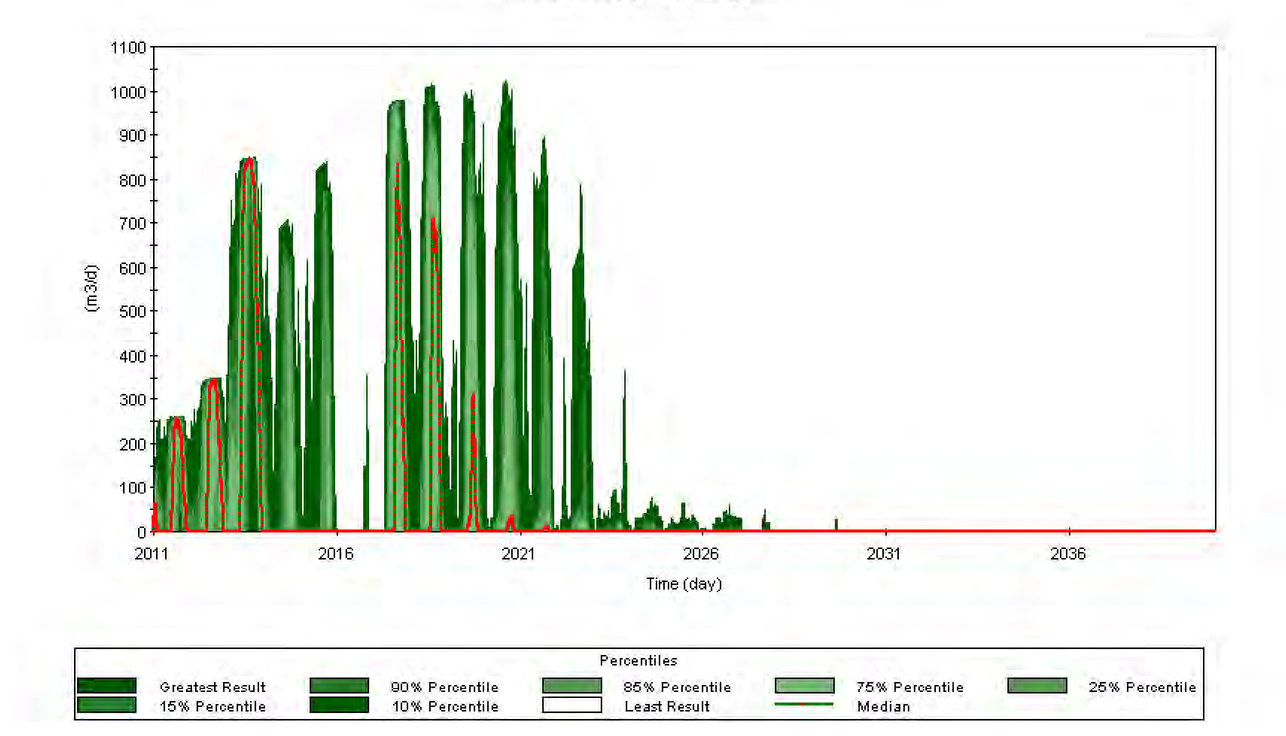


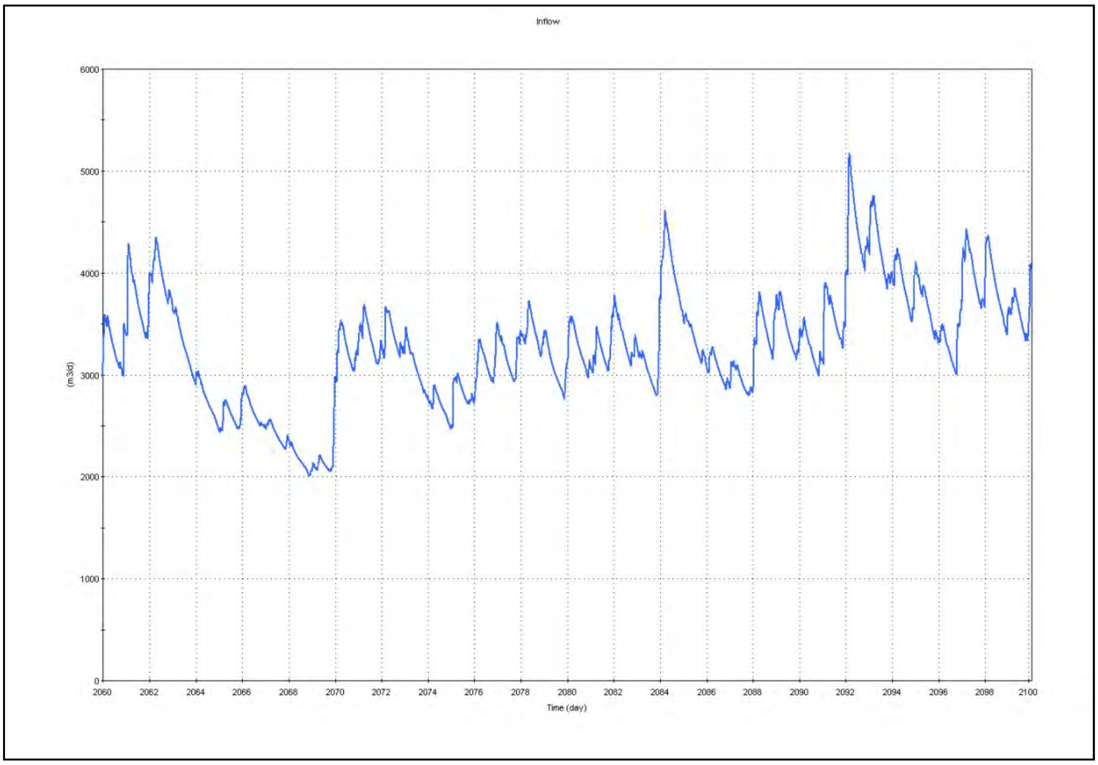
Figure 47: Plant make-up water from external sources

6.5.2 Post-closure phase

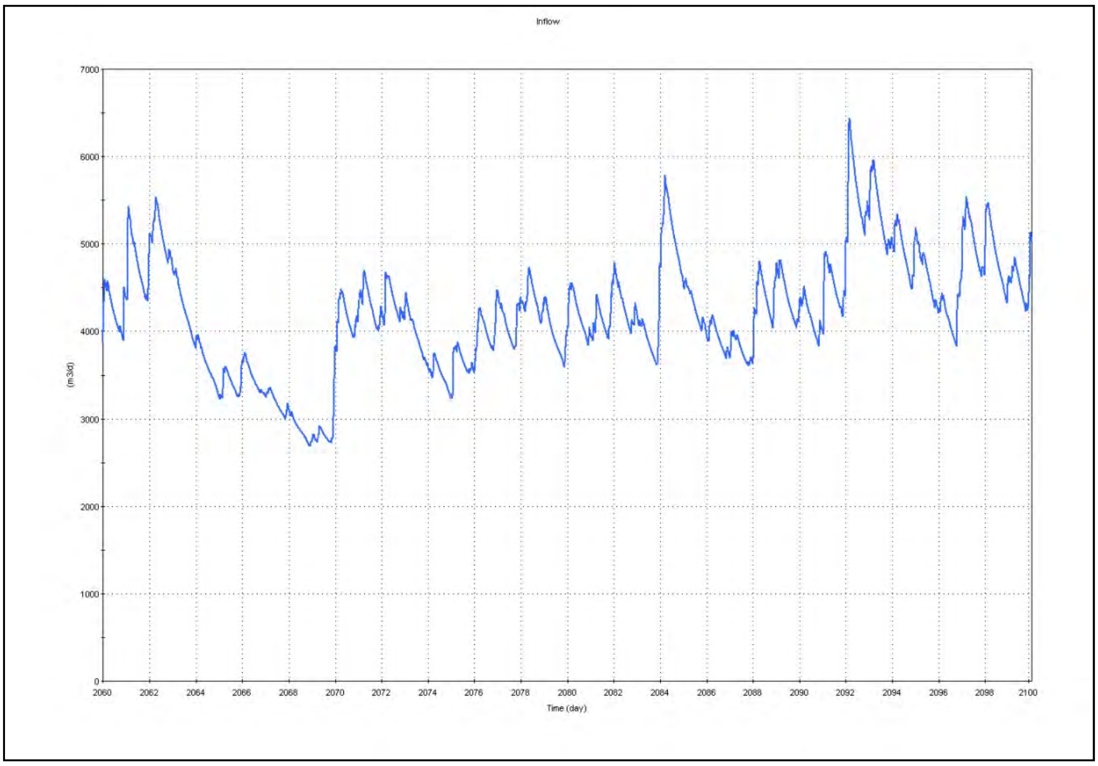
The model was adjusted to minimize the size of the treatment plant.

According to the groundwater study undertaken by Groundwater Complete, there is a groundwater inflow of 550m^3/d and 700m^3/d for the West block and East Block respectively. This value was considered to be constant over the course of the simulation. The model showed that there is an average recharge inflow into the backfilled spoils of 3,600m^3/d and 4,300m^3/d for the West block and East Block respectively.

The treatment plant during closure will therefore require a capacity of 7,900m^3/d.



West block



East block

Figure 48: Modelled inflow into the backfilled spoils during closure

6.6 Potable water

Potable water is required for domestic use – food preparation (canteen), drinking, showers and toilets. It is assumed that no process water supply (cooling, fire water, etc) will require potable water.

6.6.1 Basis of Design

6.6.1.1 Flow Rate

The volume of potable water required is based on the following assumptions:

- Staff complement : maximum 250 persons per day;
- Water requirement: 100-140 litres/capita/day;
- Design safety factor of 1.2;
- 10% loss through plant either as sludge/waste or backwash water.

The design daily water requirement is therefore approximately 35-40 m^3/d.

A package potable water treatment plant can be procured for this application.

6.6.1.2 Water Source

Water for potable use can be sourced from either surface water sources or groundwater sources (boreholes).

Surface Water

Possible surface water sources can be from locations as per monitoring points:

- 0BWQ02 – Dam eastern corner,
- BWQ03 – stream draining towards the south-east,
- BWQ04 – stream draining towards the south, or
- BWQ05 - central stream draining towards BWQ04.

Groundwater

There are a number of boreholes reported, but the locations of the boreholes are unknown. The yield from the boreholes needs to be determined to select an appropriate borehole. This needs to be compared to the water quality from the borehole to determine the suitability of the underground water for potable use. The required yield is very low: 0.5 l/s sustained over a 24hr/d period. The choice in borehole will likely be based on the water quality and proximity to the plant area.

6.6.1.3 Water Quality

Surface Water

The surface water quality is generally within chemical potable water quality limits, but treatment process provision is required to address the following:

- High turbidity during rainfall events;
- High iron concentrations in the water – staining of fixtures, sediment and taste/smell occurring;
- Low alkalinity – that may cause corrosive conditions should mild steel pipes be used.

Groundwater

0Many of the reported borehole qualities are suitable for potable use. Some are contaminated and their use is not recommended.

6.6.2 Potable Water Treatment

6.6.2.1 *Surface Water*

Treatment required for potable water from surface water sources are as follows:

- Lime dosing to precipitate dissolved iron;
- Polymer dosing (cationic polymer) suitable for low alkalinity water at high turbidity;
- Mixing, coagulation and flocculation;
- Settlement in a clarifier; or
- Direct gravity sand filtration to eliminate suspended solids/turbidity;
- Disinfection;
- Storage and distribution;
- Sludge drying or ploughing in on areas to be rehabilitated.

6.6.2.2 *Groundwater*

Treatment required for potable water from groundwater sources are as follows:

- Direct gravity sand filtration;
- Disinfection;
- Storage and distribution.

6.7 Sewage water

6.7.1 Basis of Design

6.7.1.1 *Flow Rate*

Sewage will be the only contributor to the effluent treatment plant. It is assumed that 90-95% of the potable supply will be discharged to the sewerage system.

The sewage flow rate is based on 35-38 m^3/d, including a 1.2 design safety factor. It is assumed that there will not be storm water infiltration into this system.

A package sewage treatment plant will be suitable for this application.

6.7.1.2 *Effluent Quality*

A standard domestic effluent quality is assumed.

6.7.2 Effluent Treatment

The recommended effluent treatment process should be based on an activated sludge process to ensure removal of both organics (expressed as COD) and nutrients (as nitrogen and phosphorus).

A typical biofilter plant will remove COD only (Biopack and similar), but can be combined with a small anaerobic/anoxic tank and recycle system. A biodisk type package plant can be similarly adapted. Extended aeration activated sludge plants remove COD and nitrogen (as nitrate and ammonia).

Depending on the final discharge or re-use of the treated effluent, limited nutrient removal may be required. It can be used for gardening/lawn irrigation on site or dust suppression.

Sludge from the plant will consist mainly of the excess and dead organisms (activated sludge) and can be dried by solar heating/evaporation on drying beds. The sludge can then be buried or ploughed in on an area that is being rehabilitated.

Screenings (rags) and grit can be buried to minimise odours, rodents and flies in the area.

Treatment required will consist typically of the following unit processes:

- Screening and grit removal;
- Balancing tank to equalise the flows over a 24hr period;
- Activated sludge treatment;
- Settlement/clarification;
- Disinfection;
- Storage and re-use on site;
- Sludge treatment on sludge drying beds or ploughed in.

6.8 Water monitoring plan

6.8.1 Objectives

As per DWAF (2006), the most common environmental management actions require data and thus the objectives of water monitoring include:

- Development of environmental and water management plans based on incident and impact monitoring which facilitates decision making and serves as an early warning system to allow remedial measures and subsequent actions to be taken for the mine and region.
- Generation of baseline / background data before the project implementation phase.
- Identifying the sources of pollution and the extent thereof, which constitutes legal implications or liabilities associated with risks of contamination, moving off site from the current mining operations or activities.
- Monitoring of water usage (including downstream and upstream) by various users. This also implies costs in usage of water and water re-use activities and potentials.
- Verification and calibration of various prediction and assessment models. This includes planning for decommissioning and closure pertaining to financial provisions and required actions.
- Assessment of compliance with set standards and legislation such as Integrated Water Use licenses, Environmental Management Plans, etc.
- Assessment of the impacts of the mining operation and activities on the receiving water environment.
- Quantification of waste discharge changes.

The water quality monitoring system should therefore be designed so as to allow for remedial action and for sustainable water management.

6.8.2 Potential point or diffuse source of pollution

6.8.2.1 Point sources

The following sources have been identified as potential point sources of pollution:

- Pit decant
- Pollution control dam spillage
- Sewage treatment plant discharge

- Desalination plant

6.8.2.2 Diffuse sources

The following sources have been identified as potential diffuse sources of pollution:

- Pollution control dam seepage
- Discard dump seepage
- Dumps seepage
- Dust
- Dirty water area runoff

6.8.3 Description of surface water monitoring points

The location of the proposed monitoring points is presented in Figure 33. The water quality for monitoring as listed in Table 19 and the monitoring programme detail in Table 20.

Two sets of monitoring points have been proposed. The points SW1 to SW6 are located on the streams. SW1, SW2 and SW6 are located upstream while SW3, SW4 and SW5 are located downstream of the mine area. These points will be used to assess diffuse impacts due to mining. The potential point source discharges due to spills from the pollution control dams will be monitored using points DW1 to DW6. The treatment plant discharges will be measured using TPW1 and TPW2.

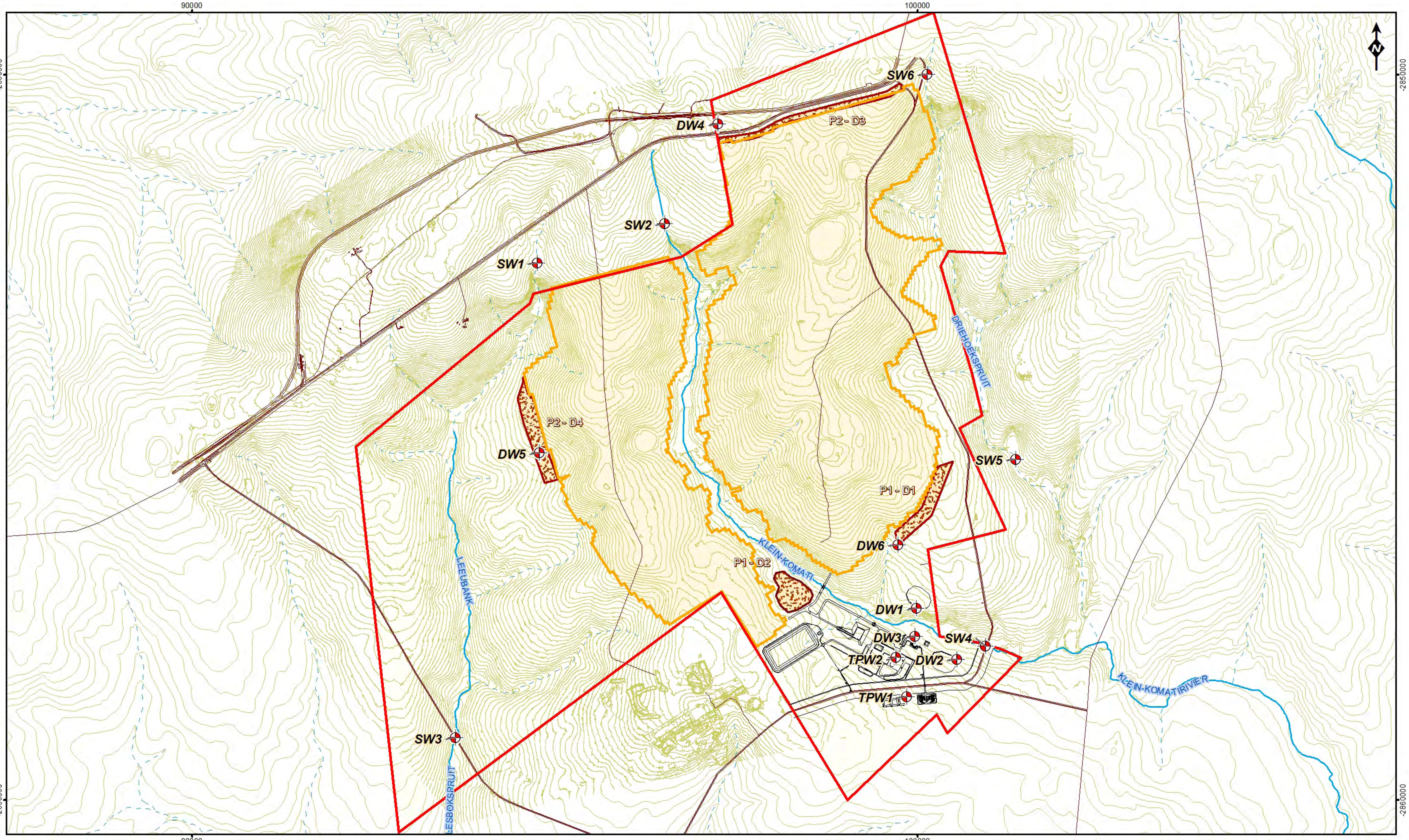
6.8.4 Parameters to be measured

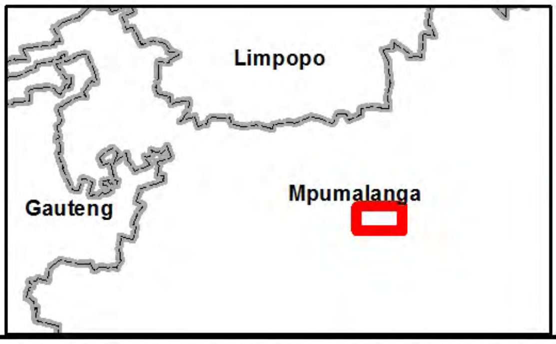
Two sets of key indicators of pollution from a coal mine have been identified and are presented in Table 19.

Table 19: Water Quality variables to be measured

Set A	Set B
pH	pH
EC	TDS
TDS	COD
Ca	NH_4
Na	NO_3
SO_4	PO_4
NH_4	E. coli
NO_3	
Cl	
Mg	
Fe	
F	
B	
Al	
Mn	

The monitoring points with their monitoring details are presented in Table 20.





LEGEND

- Monitoring points
- Plant layout
- Roads
- Rivers
- Rivers - Non-perennial
- 2m & 5m contours
- Mineral rights
- Coal reserve
- Dumps

NOTES

REFERENCE

Projection: LO 29 Cape

PROJECT

SURFACE WATER ASSESSMENT - BELFAST PROJECT

TITLE

SURFACE WATER MONITORING POINTS

Golder Associates
Johannesburg, South Africa

PROJECT No. 12433			SCALE 1:50,000	A3	REV. 1
PHASE: 2		TASK: 0			
GIS	MM	24/02/2011			
CHECK	SC	24/02/2011			
REVIEW	TJC	24/02/2011			

FIGURE 49

Path: G:\GISS\Gis Projects\12433 Surface Water Assessment for Belfast Project\Maps\Feb 2011\12433_Mon_points.mxd

Table 20: Monitoring points with monitoring detail

No	Description	Latitude	Longitude	Water quality measurement	Parameter list	Flow measurement
SW1	Leeubankspruit Upstream (BWQ7)	-25.7802	29.9447	2x/Month	A	2x/Month
SW2	Klein Komati Upstream (BWQ6)	-25.7752	29.9622	2x/Month	A	2x/Month
SW3	Leeubankspruit Downstream (BWQ9)	-25.8394	29.9339	2x/Month	A	2x/Month
SW4	Klein Komati Downstream (BWQ4)	-25.8275	30.0067	2x/Month	A	Continuous
SW5	Driehoek Spruit Downstream	-25.8042	30.0106	2x/Month	A	2x/Month
SW6	Driehoek Spruit Upstream	-25.7564	29.9981	2x/Month	A	2x/Month
DW1	East Storage dam spill	-25.8229	29.9972	No		Continuous
DW2	West Storage dam spill	-25.8292	30.0027	No		Continuous
DW3	Plant Stormwater Dam	-25.8264	29.9970	No		Continuous
DW4	P2-D3 Dump Pollution Control Dam spill	-25.7628	29.9694	No		Continuous
DW5	P2-D4 Dump Pollution Control Dam spill	-25.8039	29.9451	No		Continuous
DW6	P1-D1 Dump Pollution Control Dam spill	-25.8150	29.9945	No		Continuous
TPW1	Desalination discharge	-25.8339	29.9959	1x/Month (*)	A	Continuous
TPW2	Sewage treatment discharge	-25.8290	29.9944	1x/Month (*)	B	Continuous

Note: ** Ec to be monitored on a continuous basis*

7.0 CONCLUSIONS

The following conclusions can be made as a result of the study:

- The proposed development area is located in the Komati River catchment which is a very sensitive catchment due to already high water demands for Eskom, irrigation, afforestation and industry. The economic implications of a deterioration in water quality of the Nooiitgedacht and Vygeboom dams are significant for the power station supply.
- The quality of the stream water is good in the Driehoekspruit. The water quality in the upper reach of the Leeubankspruit and Klein Komati is poor but improves further downstream. This is probably related to agriculture.
- Two small sections of the pits are located within the 1 in 50 year floodline and will need to be modified to be outside of the 1 in 100 year floodline.
- The storage volumes in the backfilled spoils were estimated. The East block pit has almost no storage. The West block pit will start being mined in 2016 and has an estimated 4.2 Mm^3 of water storage which will be fully available in 2030. This storage can be used to store excess recharge during the wet years.
- The simulations show that two storage dams of a 230,000m^3 capacity each will be required. The timing of activation of the second storage dam is likely to be within the 2011 – 2016 period. Excess water is expected to occur until 2016 and will be accommodated by the storage dams. The West block backfilled spoils will be used to store excess water once it is being mined. Once the storage capacity on the mine is being used, a desalination plant will need to be constructed with a capacity of 5,000m^3/d. This is likely to occur between 2026 and 2033.
- Stormwater structures will need to be installed to prevent clean water catchments from being contaminated and keep dirty water within the mine boundaries.
- During the post-closure phase a desalination plant with a capacity of 7,900 m^3/d will be required to prevent water in the pit from decanting into the river.

Water infrastructures were designed to meet regulation 704. The quantitative impact on an individual mine basis showed that the impact at quaternary level, Nooitgedacht Dam level and Vygeboom dam level was low. Water will need to be monitored to ensure that legislation is met.

This report deals with surface water aspects of water management. However the report does not address seepage issues from plant area and the various waste dumps.

8.0 REFERENCES

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APPENDIX A

HEC-RAS Output Results

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
LeeuTrib2	Trib2	1200	1in50	17.5	1731.15	1731.47	1731.47	1731.59	0.020015	1.62	12.39	60.05	1.03
LeeuTrib2	Trib2	1200	1in100	21.9	1731.15	1731.51	1731.53	1731.64	0.020001	1.77	14.75	74.5	1.05
LeeuTrib2	Trib2	820.2067	1in50	17.5	1724.39	1724.62	1724.62	1724.71	0.024773	1.21	12.95	70.4	1.03
LeeuTrib2	Trib2	820.2067	1in100	21.9	1724.39	1724.65	1724.65	1724.76	0.023316	1.31	15.26	74.1	1.03
LeeuTrib2	Trib2	350.4738	1in50	17.5	1714.63	1714.81	1714.81	1714.89	0.022104	1.05	13.8	78.12	0.96
LeeuTrib2	Trib2	350.4738	1in100	21.9	1714.63	1714.84	1714.84	1714.93	0.022059	1.2	16	80.24	0.99
LeeuTrib1	Trib1	1027.456	1in50	7.4	1793.76	1794.21	1794.21	1794.36	0.021128	1.78	4.37	15.13	1.07
LeeuTrib1	Trib1	1027.456	1in100	9.1	1793.76	1794.26	1794.26	1794.42	0.02054	1.88	5.11	16.13	1.07
LeeuTrib1	Trib1	800	1in50	7.4	1774	1774.52	1774.52	1774.73	0.015756	2.09	3.8	9.43	0.99
LeeuTrib1	Trib1	800	1in100	9.1	1774	1774.59	1774.59	1774.82	0.015177	2.22	4.43	9.89	0.99
LeeuTrib1	Trib1	564.881	1in50	7.4	1763.82	1763.95	1764.06	1764.49	0.434214	3.18	2.28	27.87	3.85
LeeuTrib1	Trib1	564.881	1in100	9.1	1763.82	1763.96	1764.08	1764.6	0.461635	3.44	2.57	29.14	4.02
LeeuTrib1	Trib1	349.6991	1in50	7.4	1755.96	1756.4	1756.2	1756.41	0.001676	0.57	13.99	46.3	0.31
LeeuTrib1	Trib1	349.6991	1in100	9.1	1755.96	1756.45	1756.23	1756.47	0.00147	0.59	16.74	48.55	0.3
Leeubank	Up	8400	1in50	10.7	1819.02	1819.19	1819.19	1819.25	0.030004	1.16	9.33	81.83	1.1
Leeubank	Up	8400	1in100	13.2	1819.02	1819.2	1819.21	1819.28	0.029962	1.27	10.65	82.73	1.12
Leeubank	Up	7999.453	1in50	10.7	1795.97	1796.4	1796.64	1797.29	0.121019	4.17	2.57	9.35	2.54
Leeubank	Up	7999.453	1in100	13.2	1795.97	1796.44	1796.71	1797.47	0.12565	4.48	2.95	9.89	2.62
Leeubank	Up	7779.232	1in50	10.7	1786.02	1786.18	1786.18	1786.26	0.02632	1.26	8.72	58.73	1.07
Leeubank	Up	7779.232	1in100	13.2	1786.02	1786.19	1786.21	1786.29	0.0303	1.44	9.49	58.83	1.16
Leeubank	Up	7670.678	1in50	10.7	1781.01	1781.52	1781.3	1781.54	0.001619	0.63	18.36	51.8	0.32
Leeubank	Up	7670.678	1in100	13.2	1781.01	1781.56	1781.33	1781.58	0.001803	0.7	20.37	53.55	0.34
Leeubank	Up	7539.76	1in50	10.7	1781.01	1781.37		1781.37	0.000996	0.34	31.88	140.26	0.22
Leeubank	Up	7539.76	1in100	13.2	1781.01	1781.39		1781.4	0.001044	0.37	35.73	140.65	0.23
Leeubank	Up	7451.04	1in50	10.7	1781	1781.08	1781.08	1781.12	0.029308	0.89	12.36	161.04	1.02
Leeubank	Up	7451.04	1in100	13.2	1781	1781.09	1781.09	1781.14	0.029049	0.96	14.07	161.16	1.04
Leeubank	Up	7397.904	1in50	10.7	1773.13	1773.38	1773.71	1776.32	0.884359	7.59	1.41	9.36	6.25
Leeubank	Up	7397.904	1in100	13.2	1773.13	1773.4	1773.76	1776.62	0.845443	7.95	1.66	9.95	6.21
Leeubank	Up	7200	1in50	23.5	1769.11	1769.53	1769.53	1769.67	0.018087	1.63	14.63	56.02	0.99
Leeubank	Up	7200	1in100	29.5	1769.11	1769.58	1769.58	1769.73	0.017604	1.75	17.17	58.07	1
Leeubank	Up	6800	1in50	23.5	1761.57	1762.05	1762.01	1762.16	0.011632	1.43	16.41	51.8	0.81
Leeubank	Up	6800	1in100	29.5	1761.57	1762.1	1762.05	1762.22	0.012123	1.57	18.84	53.67	0.84

Leeubank	Up	6400	1in50	23.5	1755.65	1756.23	1756.23	1756.36	0.018526	1.59	14.9	61	0.99
Leeubank	Up	6400	1in100	29.5	1755.65	1756.28	1756.28	1756.42	0.017606	1.7	17.63	64.78	0.99
Leeubank	Up	6000	1in50	23.5	1750	1751.38	1750.79	1751.39	0.000328	0.44	57.35	83.49	0.16
Leeubank	Up	6000	1in100	29.5	1750	1751.48	1750.84	1751.49	0.000339	0.49	65.88	86.72	0.16
Leeubank	Middle	5589.479	1in50	59.9	1748.5	1748.86	1748.79	1748.92	0.008428	1.1	54.66	203.3	0.67
Leeubank	Middle	5589.479	1in100	74	1748.5	1748.89	1748.83	1748.97	0.008762	1.21	61.46	204.66	0.7
Leeubank	Middle	5348.799	1in50	59.9	1745.58	1745.87	1745.87	1745.98	0.01911	1.52	40.02	177.72	0.99
Leeubank	Middle	5348.799	1in100	74	1745.58	1745.9	1745.9	1746.04	0.018009	1.63	46.57	181.49	0.99
Leeubank	Middle	5311.328	1in50	59.9	1743.34	1743.59	1743.76	1744.28	0.196184	3.69	16.23	103.12	2.97
Leeubank	Middle	5311.328	1in100	74	1743.34	1743.61	1743.81	1744.41	0.188147	3.94	18.77	104.6	2.97
Leeubank	Middle	5200.913	1in50	59.9	1742.47	1742.93	1742.9	1743.06	0.014274	1.62	36.94	112.78	0.9
Leeubank	Middle	5200.913	1in100	74	1742.47	1742.95	1742.95	1743.13	0.017245	1.86	39.86	114.52	1
Leeubank	Middle	4842.401	1in50	59.9	1739	1740.38	1740.19	1740.45	0.004372	1.17	51.4	107.56	0.53
Leeubank	Middle	4842.401	1in100	74	1739	1740.47	1740.24	1740.54	0.003881	1.22	61.1	113.17	0.52
Leeubank	Middle	4398.637	1in50	89.5	1736	1737.4		1737.65	0.008338	2.19	41.43	58.46	0.8
Leeubank	Middle	4398.637	1in100	113.4	1736	1737.51	1737.42	1737.81	0.00881	2.42	47.91	62.04	0.83
Leeubank	Middle	3933.974	1in50	89.5	1731.5	1733.3	1733.24	1733.57	0.009223	2.38	40.52	62.35	0.84
Leeubank	Middle	3933.974	1in100	113.4	1731.5	1733.43	1733.36	1733.74	0.008722	2.55	48.78	67.55	0.84
Leeubank	Middle	3609.714	1in50	89.5	1729	1730.99	1730.81	1731.2	0.005886	2.03	46.09	64.69	0.68
Leeubank	Middle	3609.714	1in100	113.4	1729	1731.1	1730.94	1731.36	0.006232	2.26	53.46	68.43	0.72
Leeubank	Middle	3234.271	1in50	89.5	1727	1727.92	1727.92	1728.21	0.011412	2.47	40.48	75.04	0.92
Leeubank	Middle	3234.271	1in100	113.4	1727	1728.03	1728.03	1728.35	0.010713	2.63	49.2	81.18	0.92
Leeubank	Middle	2809.154	1in50	89.5	1722.5	1723.27	1723.23	1723.49	0.010868	2.28	45.89	89.27	0.89
Leeubank	Middle	2809.154	1in100	113.4	1722.5	1723.36	1723.33	1723.62	0.010649	2.47	54.52	94.55	0.9
Leeubank	Middle	2400	1in50	89.5	1717	1718.3	1718.3	1718.57	0.013274	2.39	39.79	71	0.97
Leeubank	Middle	2400	1in100	113.4	1717	1718.4	1718.4	1718.7	0.013528	2.54	47.42	77.22	0.99
Leeubank	Middle	2012.944	1in50	89.5	1712.5	1714.24	1713.95	1714.36	0.003569	1.58	59.99	82.25	0.53
Leeubank	Middle	2012.944	1in100	113.4	1712.5	1714.36	1714.06	1714.5	0.003713	1.75	69.72	86.48	0.56
Leeubank	Down	1560.64	1in50	132.7	1707.5	1709.49	1709.14	1709.59	0.003003	1.46	98.34	124.24	0.49
Leeubank	Down	1560.64	1in100	164	1707.5	1709.62	1709.23	1709.73	0.002919	1.54	115.32	130.58	0.49
Leeubank	Down	1200	1in50	132.7	1706	1707.34	1707.32	1707.69	0.011721	2.79	52.63	72.63	0.96
Leeubank	Down	1200	1in100	164	1706	1707.44	1707.44	1707.86	0.011866	3.03	60.47	75.72	0.99
Leeubank	Down	786.2598	1in50	132.7	1702	1703.27	1703.23	1703.52	0.008744	2.55	67.95	112.39	0.84
Leeubank	Down	786.2598	1in100	164	1702	1703.37	1703.33	1703.64	0.008792	2.73	78.82	117.1	0.86

Leeubank	Down	400	1in50	132.7	1699.54	1700.35	1700.18	1700.49	0.006999	1.89	80	123.89	0.72
Leeubank	Down	400	1in100	164	1699.54	1700.44	1700.26	1700.61	0.007	2.05	91.77	127.29	0.73
KleinKomat	Trib1	811.4992	1in50	16.8	1809.98	1810.46	1810.53	1810.76	0.03003	2.57	6.95	19.15	1.34
KleinKomat	Trib1	811.4992	1in100	13.2	1809.98	1810.4	1810.46	1810.66	0.030022	2.38	5.91	18.29	1.31
KleinKomat	Trib1	558.014	1in50	16.8	1804.52	1804.71	1804.7	1804.78	0.023075	1.21	13.82	89.85	1.01
KleinKomat	Trib1	558.014	1in100	13.2	1804.52	1804.68	1804.68	1804.75	0.024295	1.11	11.75	89.59	1
KleinKomat	Trib1	445.8169	1in50	16.8	1798.5	1798.74	1798.86	1799.19	0.160895	2.99	5.62	42.24	2.61
KleinKomat	Trib1	445.8169	1in100	13.2	1798.5	1798.72	1798.82	1799.11	0.169321	2.76	4.78	42.05	2.61
KleinKomat	Trib1	311.2971	1in50	16.8	1794.3	1795.02	1794.79	1795.06	0.002978	0.86	19.47	47.27	0.43
KleinKomat	Trib1	311.2971	1in100	13.2	1794.3	1795.01	1794.74	1795.03	0.001997	0.7	18.89	46.64	0.35
Klein Koma	Up	10638.91	1in50	16.9	1821.74	1822.26	1822.26	1822.44	0.017387	1.89	8.93	25.01	1.01
Klein Koma	Up	10638.91	1in100	20.7	1821.74	1822.31	1822.32	1822.52	0.016858	2	10.35	26.12	1.01
Klein Koma	Up	10400	1in50	16.9	1813	1813.17	1813.25	1813.46	0.138026	2.41	7.19	72.16	2.34
Klein Koma	Up	10400	1in100	20.7	1813	1813.18	1813.28	1813.57	0.17149	2.79	7.63	72.24	2.63
Klein Koma	Up	10219.34	1in50	16.9	1806.56	1807.01	1807.01	1807.16	0.018385	1.72	9.84	33.36	1.01
Klein Koma	Up	10219.34	1in100	20.7	1806.56	1807.05	1807.05	1807.22	0.017961	1.83	11.3	34.14	1.02
Klein Koma	Up	10000	1in50	16.9	1802	1802.87	1802.51	1802.89	0.001187	0.7	24.92	45.25	0.29
Klein Koma	Up	10000	1in100	20.7	1802	1802.93	1802.55	1802.96	0.001301	0.78	27.74	46.74	0.31
Klein Koma	Up	9813.714	1in50	16.9	1802	1802.23	1802.23	1802.29	0.025001	1.1	15.38	131.74	1.01
Klein Koma	Up	9813.714	1in100	20.7	1802	1802.25	1802.25	1802.32	0.023822	1.17	17.7	132.19	1.01
Klein Koma	Up	9600	1in50	16.9	1794.5	1795.63	1795.25	1795.67	0.001875	0.87	19.53	33.31	0.36
Klein Koma	Up	9600	1in100	20.7	1794.5	1795.7	1795.31	1795.75	0.002015	0.94	21.97	34.79	0.38
Klein Koma	Up	9311.242	1in50	16.9	1794	1794.26	1794.26	1794.32	0.025419	1.14	14.81	116.71	1.03
Klein Koma	Up	9311.242	1in100	20.7	1794	1794.28	1794.28	1794.35	0.023435	1.17	17.78	127.88	1
Klein Koma	Up	9215.235	1in50	16.9	1789	1789.96	1789.46	1789.96	0.000467	0.42	40.3	73.99	0.18
Klein Koma	Up	9215.235	1in100	20.7	1789	1790.03	1789.5	1790.04	0.000474	0.45	46.15	77.54	0.18
Klein Koma	Down	8800	1in50	45	1785	1785.64	1785.64	1785.83	0.017235	1.92	23.44	64.01	1.01
Klein Koma	Down	8800	1in100	55.1	1785	1785.7	1785.7	1785.9	0.016586	2.02	27.28	67.03	1.01
Klein Koma	Down	8474.158	1in50	45	1783	1783.76	1783.43	1783.78	0.001123	0.68	70.93	135.05	0.28
Klein Koma	Down	8474.158	1in100	55.1	1783	1783.82	1783.47	1783.85	0.001191	0.74	79.49	137.96	0.29
Klein Koma	Down	8283.945	1in50	45	1783	1783.35		1783.39	0.00497	0.97	49.04	157.38	0.54
Klein Koma	Down	8283.945	1in100	55.1	1783	1783.39		1783.44	0.004925	1.04	55.87	160.16	0.54
Klein Koma	Down	8132.21	1in50	45	1781.5	1781.96	1781.96	1782.1	0.017452	1.71	26.97	93.41	0.99
Klein Koma	Down	8132.21	1in100	55.1	1781.5	1782	1782	1782.17	0.017239	1.85	30.71	94.18	1

Klein Koma	Down	8000	1in50	67.7	1780	1781.06	1780.53	1781.09	0.000948	0.81	96.06	164.32	0.28
Klein Koma	Down	8000	1in100	84.1	1780	1781.15	1780.6	1781.18	0.001	0.88	112.01	175.13	0.29
Klein Koma	Down	7600	1in50	67.7	1779.5	1779.95	1779.95	1780.08	0.017043	1.68	44.86	180.14	0.98
Klein Koma	Down	7600	1in100	84.1	1779.5	1779.99	1779.99	1780.13	0.016482	1.79	52.26	183.94	0.98
Klein Koma	Down	7200	1in50	67.7	1777.5	1778.39	1778	1778.41	0.00092	0.67	105.66	170.91	0.26
Klein Koma	Down	7200	1in100	84.1	1777.5	1778.47	1778.05	1778.5	0.000961	0.74	119.51	172.96	0.27
Klein Koma	Down	6913.517	1in50	67.7	1777.14	1777.57	1777.57	1777.7	0.017968	1.62	42.67	165.01	0.99
Klein Koma	Down	6913.517	1in100	84.1	1777.14	1777.62	1777.62	1777.76	0.01765	1.67	51.55	186.08	0.99
Klein Koma	Down	6797.807	1in50	67.7	1773.5	1774.12	1774.27	1774.62	0.043126	3.12	21.72	57.02	1.61
Klein Koma	Down	6797.807	1in100	84.1	1773.5	1774.19	1774.35	1774.74	0.041119	3.3	25.5	59.37	1.61
Klein Koma	Down	6365.203	1in50	67.7	1770.5	1771.38	1771.13	1771.45	0.003276	1.23	59.11	102.18	0.49
Klein Koma	Down	6365.203	1in100	84.1	1770.5	1771.49	1771.19	1771.57	0.003032	1.31	70.02	107.7	0.48
Klein Koma	Down	6039.622	1in50	67.7	1769.5	1770.74		1770.78	0.001393	0.97	78.7	116.96	0.33
Klein Koma	Down	6039.622	1in100	84.1	1769.5	1770.85		1770.9	0.001453	1.05	92.23	132.45	0.34
Klein Koma	Down	5600	1in50	95.5	1768.5	1769.1		1769.25	0.009772	1.85	57.91	131.77	0.81
Klein Koma	Down	5600	1in100	120.7	1768.5	1769.18		1769.35	0.009013	1.96	69.81	139.34	0.8
Klein Koma	Down	5200	1in50	95.5	1766	1767.45		1767.53	0.002359	1.34	80.45	126.3	0.44
Klein Koma	Down	5200	1in100	120.7	1766	1767.56		1767.66	0.002394	1.46	95.96	137.09	0.45
Klein Koma	Down	4800	1in50	95.5	1764.5	1765.37	1765.37	1765.61	0.014556	2.47	46.43	95.25	1.01
Klein Koma	Down	4800	1in100	120.7	1764.5	1765.45	1765.45	1765.72	0.014393	2.62	54.81	99.52	1.02
Klein Koma	Down	4400	1in50	95.5	1761	1762.6	1762.32	1762.71	0.003519	1.56	68.21	97.07	0.53
Klein Koma	Down	4400	1in100	120.7	1761	1762.71	1762.42	1762.85	0.003607	1.72	79.62	103.03	0.55
Klein Koma	Down	3965.581	1in50	95.5	1758.56	1760.17		1760.37	0.009222	2.08	49.33	81.39	0.82
Klein Koma	Down	3965.581	1in100	120.7	1758.56	1760.29		1760.51	0.008839	2.18	59.33	87.37	0.81
Klein Koma	Down	3574.712	1in50	95.5	1756.5	1758.01	1757.76	1758.12	0.003968	1.71	67.65	97.92	0.57
Klein Koma	Down	3574.712	1in100	120.7	1756.5	1758.12	1757.85	1758.26	0.004113	1.87	78.88	106.48	0.59
Klein Koma	Down	3200	1in50	95.5	1754.5	1755.45	1755.45	1755.65	0.013039	2.17	51.71	129.82	0.94
Klein Koma	Down	3200	1in100	120.7	1754.5	1755.52	1755.52	1755.75	0.012672	2.33	61.66	136.07	0.95
Klein Koma	Down	2805.231	1in50	95.5	1752	1753.24	1753.02	1753.29	0.003286	1.07	102.44	208.19	0.47
Klein Koma	Down	2805.231	1in100	120.7	1752	1753.32	1753.06	1753.37	0.003335	1.17	118.57	213.24	0.48
Klein Koma	Down	2388.111	1in50	95.5	1750	1750.39	1750.39	1750.55	0.019976	1.9	54.87	173.97	1.07
Klein Koma	Down	2388.111	1in100	120.7	1750	1750.44	1750.44	1750.63	0.019423	2.04	64.59	180.12	1.08
Klein Koma	Down	2000	1in50	95.5	1746	1747.65	1747.38	1747.71	0.002968	1.14	87.98	168.73	0.46
Klein Koma	Down	2000	1in100	120.7	1746	1747.75	1747.46	1747.82	0.002779	1.21	106	178.79	0.45

Klein Koma	Down	1600	1in50	95.5	1744	1745.67		1745.84	0.008337	1.8	53.39	97.87	0.76
Klein Koma	Down	1600	1in100	120.7	1744	1745.74		1745.95	0.009313	2.02	60.44	103.5	0.81
Klein Koma	Down	1192.186	1in50	95.5	1742.03	1743.61		1743.69	0.003574	1.31	80.32	153.78	0.51
Klein Koma	Down	1192.186	1in100	120.7	1742.03	1743.72		1743.81	0.003314	1.4	97.23	163.44	0.5
Klein Koma	Down	800	1in50	95.5	1740	1741.21	1741.14	1741.5	0.009845	2.56	42.16	59.57	0.88
Klein Koma	Down	800	1in100	120.7	1740	1741.33	1741.28	1741.67	0.010475	2.79	49.36	65.31	0.92
Klein Koma	Down	400	1in50	95.5	1738	1738.65	1738.47	1738.71	0.005009	1.08	86.73	193.17	0.55
Klein Koma	Down	400	1in100	120.7	1738	1738.72	1738.53	1738.8	0.005004	1.19	101.25	199.79	0.57
DriehoekTr	Trib1	1999.999	1in50	18.9	1831.38	1831.72	1831.76	1831.9	0.030027	1.89	10.03	42.65	1.24
DriehoekTr	Trib1	1999.999	1in100	23.4	1831.38	1831.75	1831.8	1831.96	0.030052	2.03	11.52	43.84	1.26
DriehoekTr	Trib1	1776.891	1in50	18.9	1827	1827.32	1827.32	1827.43	0.020613	1.46	12.92	60.64	1.01
DriehoekTr	Trib1	1776.891	1in100	23.4	1827	1827.35	1827.35	1827.47	0.020067	1.56	15.02	62.92	1.02
DriehoekTr	Trib1	1399.359	1in50	18.9	1822	1822.45	1822.33	1822.5	0.00612	1.06	18.85	58.77	0.59
DriehoekTr	Trib1	1399.359	1in100	23.4	1822	1822.5	1822.37	1822.56	0.006115	1.12	21.95	62.41	0.6
DriehoekTr	Trib1	1200	1in50	18.9	1820.5	1820.79	1820.75	1820.85	0.011643	1.16	17.17	80.16	0.77
DriehoekTr	Trib1	1200	1in100	23.4	1820.5	1820.82	1820.78	1820.89	0.011926	1.26	19.56	81.86	0.79
DriehoekTr	Trib1	799.9999	1in50	18.9	1814.5	1814.85	1814.85	1814.98	0.019015	1.63	11.58	43.39	1.01
DriehoekTr	Trib1	799.9999	1in100	23.4	1814.5	1814.89	1814.89	1815.04	0.018283	1.72	13.58	45.53	1.01
DriehoekTr	Trib1	399.9999	1in50	18.9	1805.99	1806.6	1806.65	1806.91	0.021379	2.45	7.72	17.13	1.16
DriehoekTr	Trib1	399.9999	1in100	23.4	1805.99	1806.67	1806.74	1807.02	0.021998	2.63	8.9	18.13	1.2
Driehoek T	Up	1200	1in50	13.5	1812.5	1813.29	1813.19	1813.42	0.009089	1.59	8.46	18.82	0.76
Driehoek T	Up	1200	1in100	16.7	1812.5	1813.17	1813.26	1813.52	0.029995	2.6	6.43	16.85	1.34
Driehoek T	Up	1082.372	1in50	13.5	1811.5	1811.64	1811.64	1811.71	0.025861	1.23	11.64	84.4	1.06
Driehoek T	Up	1082.372	1in100	16.7	1811.5	1811.66	1811.66	1811.74	0.024556	1.32	13.45	84.73	1.05
Driehoek T	Up	1029.139	1in50	13.5	1807	1807.33	1807.6	1808.58	0.229847	4.95	2.72	12.49	3.39
Driehoek T	Up	1029.139	1in100	16.7	1807	1807.37	1807.68	1808.71	0.20798	5.13	3.26	13.15	3.29
Driehoek T	Up	898.495	1in50	13.5	1807.1	1807.26	1807.26	1807.33	0.020857	0.79	12.55	95.2	0.87
Driehoek T	Up	898.495	1in100	16.7	1807.1	1807.29	1807.29	1807.36	0.019827	0.85	15.01	104.14	0.87
Driehoek T	Up	810.5838	1in50	13.5	1799	1799.28	1799.64	1801.85	0.591955	7.1	1.9	10.34	5.28
Driehoek T	Up	810.5838	1in100	16.7	1799	1799.32	1799.7	1802.12	0.563127	7.41	2.25	11.05	5.24
Driehoek T	Down	400	1in50	32	1786.5	1787.21	1787.21	1787.37	0.015112	1.84	19.05	60.32	0.95
Driehoek T	Down	400	1in100	40	1786.5	1787.27	1787.27	1787.45	0.014863	1.96	22.4	62.96	0.96
Driehoek T	Down	245.3736	1in50	32	1784	1784.89	1784.61	1784.95	0.002564	1.06	31.17	53.5	0.43
Driehoek T	Down	245.3736	1in100	40	1784	1784.97	1784.67	1785.04	0.002643	1.16	35.74	55.04	0.44

Driehoek	Up	8077.431	1in50	24.6	1829.37	1830.01	1830.1	1830.35	0.030008	2.55	9.65	26.06	1.34
Driehoek	Up	8077.431	1in100	30.3	1829.37	1830.07	1830.17	1830.45	0.030028	2.71	11.17	27.52	1.36
Driehoek	Up	7600	1in50	24.6	1815	1816.12	1815.93	1816.28	0.008821	1.77	13.9	25.7	0.77
Driehoek	Up	7600	1in100	30.3	1815	1815.88	1816.08	1816.43	0.028629	3.29	9.2	16.13	1.39
Driehoek	Up	7200	1in50	24.6	1810.95	1811.28	1811.28	1811.38	0.018205	1.16	18.18	83.28	0.91
Driehoek	Up	7200	1in100	30.3	1810.95	1811.36	1811.31	1811.44	0.010741	1.15	24.84	87.53	0.75
Driehoek	Up	6853.984	1in50	24.6	1806.11	1806.52		1806.61	0.010816	1.33	18.54	62.14	0.78
Driehoek	Up	6853.984	1in100	30.3	1806.11	1806.51	1806.51	1806.66	0.018421	1.7	17.86	61.7	1.01
Driehoek	Up	6400	1in50	24.6	1800.5	1801.4	1801.33	1801.54	0.01152	1.67	14.74	36.63	0.84
Driehoek	Up	6400	1in100	30.3	1800.5	1801.47	1801.4	1801.62	0.011159	1.72	17.65	41.04	0.84
Driehoek	Up	6000	1in50	24.6	1795.94	1796.42	1796.39	1796.58	0.013322	1.84	14.23	36.99	0.91
Driehoek	Up	6000	1in100	30.3	1795.94	1796.47	1796.45	1796.66	0.013796	2	16.19	38.33	0.94
Driehoek	Up	5600	1in50	24.6	1789.5	1790.52	1790.52	1790.76	0.015912	2.18	11.26	23.76	1.01
Driehoek	Up	5600	1in100	30.3	1789.5	1790.6	1790.6	1790.86	0.015192	2.28	13.32	25.54	1.01
Driehoek	Up	5200	1in50	24.6	1782.5	1783.27	1782.8	1783.28	0.000497	0.48	52.48	85.69	0.19
Driehoek	Up	5200	1in100	30.3	1782.5	1783.36	1782.84	1783.37	0.000492	0.51	60.4	88.46	0.19
Driehoek	Down	4800	1in50	71	1778.27	1778.76	1778.76	1778.93	0.016029	1.92	40.05	119.84	0.99
Driehoek	Down	4800	1in100	90	1778.27	1778.82	1778.82	1779.02	0.015359	2.07	47.34	122.85	0.99
Driehoek	Down	4320.905	1in50	71	1775.5	1776.58	1775.93	1776.6	0.000546	0.63	113.08	127.34	0.21
Driehoek	Down	4320.905	1in100	90	1775.5	1776.69	1776	1776.72	0.000605	0.71	127.35	130.13	0.23
Driehoek	Down	3920.058	1in50	71	1775.52	1775.84	1775.84	1775.95	0.018621	1.51	48.7	211.82	0.98
Driehoek	Down	3920.058	1in100	90	1775.52	1775.88	1775.88	1776.01	0.018542	1.65	56.46	212.08	1
Driehoek	Down	3815.966	1in50	74	1770.5	1771.33	1771.63	1772.33	0.075368	4.42	16.74	39.53	2.17
Driehoek	Down	3815.966	1in100	93	1770.5	1771.42	1771.73	1772.5	0.071166	4.61	20.18	42.88	2.14
Driehoek	Down	3600	1in50	74	1769.15	1770.22	1770.14	1770.49	0.010027	2.27	32.66	46.28	0.86
Driehoek	Down	3600	1in100	93	1769.15	1770.34	1770.27	1770.64	0.010011	2.43	38.34	49.33	0.87
Driehoek	Down	3270.861	1in50	74	1765	1766.31	1766.31	1766.74	0.012942	2.91	25.45	29.86	1.01
Driehoek	Down	3270.861	1in100	93	1765	1766.47	1766.47	1766.94	0.012626	3.04	30.59	32.95	1.01
Driehoek	Down	3086.272	1in50	74	1762.5	1763.93	1763.72	1763.97	0.00261	0.85	87.87	203.93	0.41
Driehoek	Down	3086.272	1in100	93	1762.5	1764	1763.76	1764.05	0.002531	0.92	102.33	207.39	0.41
Driehoek	Down	2800	1in50	74	1761.5	1762.18	1762.18	1762.45	0.015045	2.31	32.06	60.76	1.01
Driehoek	Down	2800	1in100	93	1761.5	1762.28	1762.28	1762.58	0.014166	2.45	38.11	64.45	1
Driehoek	Down	2366.635	1in50	74	1755	1756.79	1756.56	1756.84	0.002656	1.03	78.07	156.21	0.43
Driehoek	Down	2366.635	1in100	93	1755	1756.87	1756.62	1756.93	0.002639	1.12	90.87	160.57	0.44

Driehoek	Down	2000	1in50	74	1754	1754.66	1754.66	1754.9	0.014796	2.25	35.19	74.78	0.99
Driehoek	Down	2000	1in100	93	1754	1754.74	1754.74	1755.01	0.014368	2.4	41.41	77.69	1
Driehoek	Down	1701.935	1in50	74	1749.76	1751.1	1750.99	1751.37	0.009049	2.3	32.16	41.15	0.83
Driehoek	Down	1701.935	1in100	93	1749.76	1751.23	1751.13	1751.54	0.009291	2.48	37.47	44.39	0.86
Driehoek	Down	1101.831	1in50	74	1743.5	1743.97	1743.97	1744.17	0.016642	2.02	37.94	96.16	1.01
Driehoek	Down	1101.831	1in100	93	1743.5	1744.03	1744.03	1744.27	0.016427	2.2	43.93	99.09	1.03
Driehoek	Down	799.7411	1in50	74	1740.26	1740.88		1741	0.00718	1.56	49.94	105.45	0.69
Driehoek	Down	799.7411	1in100	93	1740.26	1740.95	1740.83	1741.09	0.00722	1.71	57.67	108.29	0.71
Driehoek	Down	413.1479	1in50	74	1737.5	1738.34	1738.2	1738.47	0.006001	1.56	52.02	149.89	0.65
Driehoek	Down	413.1479	1in100	93	1737.5	1738.42	1738.31	1738.55	0.006005	1.67	63.64	159.83	0.66

APPENDIX B

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