SURFACE WATER SPECIALIST STUDY

FOR

BRAKFONTEIN EIA / EMP

UNIVERSAL COAL PTY LTD

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This document has been prepared by **Digby Wells Environmental**.

Report Title: **Brakfontein EIA/ EMP Surface Water Specialist Report**

Project Number: **UNI1292**

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EXECUTIVE SUMMARY

Digby Wells Environmental (Digby Wells) was appointed, by Universal Coal Plc. as an independent environmental consultant to conduct the Environmental Impact Assessment (EIA)/ Environmental Management plan (EMP) and associated specialist studies in support of a Mining Right Application (MRA). The project entails the mining of coal at the proposed Brakfontein Coal Mine. The project site is located in the Delmas District Municipality, on the western margin of the Witbank coalfield and is one of Universal Coal's three near-term thermal coal production assets in South Africa. This report details the surface water assessment for inclusion into the EIA/ EMP report for the project.

The proposed project site falls over two quaternary catchments namely B20A and B20E of the Olifants Water Management Area (WMA 02). The greater proportion of the project area falls within the B20E covering 1.7% of catchment size while the portion falling over the B20E only covers 0.02% of catchment area.

The flood hydrology assessment was conducted to determine the base flow and the required capacities of the water conveyance and containment facilities associated with the mining activities. The calculated Peak Flood Volume of a 1: 50 yr 24 hr. flood as required to be contained by legislation is 51 000 000 m^3 at a flow rate of 598 m^3/s.

Surface water sampling quality was conducted by collecting 12 samples at strategic areas around the project area including up- and downstream sites from the project area. The surface water quality baseline indicates that the surface water resources are not impacted upon when compared to the SANS 241 (2005) drinking water standards. However when benchmarked against the Wilge River Water Quality Objectives (WQO), the water quality was poor for the following variables of concern Fluoride (F), Chloride (Cl), Alkalinity, Electrical Conductivity (EC), Nitrates (NO3) and Sulphate (SO4). These variables were higher that the WQO by an order of magnitude ranging from 2 to 11 times. These high levels were attributed to upstream mining and agricultural activities.

The Digby Wells developed methodology for impact assessment was used to assess the mining activity impacts on the surface water environment (quality and quantity) and the deterioration of water quality was indicated as the most significant impact that could arise. Mitigation measures were developed for the reduction of the significance of the impacts should they arise. A surface water management plan with action plans for implementation was developed including a surface water quality monitoring programme. Realistic monitoring frequencies were also proposed including the handling of data and reporting.

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1 INTRODUCTION

Digby Wells Environmental (Digby Wells) was appointed, by Universal Coal Plc., as to conduct the Environmental Impact Assessment (EIA)/ Environmental Management Plan (EMP) in support of a Mining Right Application (MRA) for the mining of coal at the proposed Brakfontein Coal Mine. In line with the relevant legislation a surface water specialist study is required as part of the EIA/ EMP. This report details the surface water-related findings of the baseline and impact assessments carried out for the proposed Brakfontein operation.

1.1 Background

The Brakfontein Coal Project is located in the Victor Khanye Local and Nkangala District Municipalities of Mpumalanga Province (Appendix A: Plan 1 - Regional Setting). The area is known as the Delmas District, on the western margin of the Witbank coalfield and is one of Universal Coal's three near-term thermal coal production assets in South Africa.

1.2 Project Description

The proposed mining project (the proposed project) will be carried out in 2 phases. Phase 1 is proposed for 22 years and will entail opencast mining, which will be undertaken during the continued exploration of the underground resources. Phase 2 is proposed for 8 years and will entail underground mining. The project site consists of several seams to be mined using opencast and t underground mining. The coal seams available for mining are No. 5, 4L, 2U for opencast mining and seams 4 and 2 are for underground mining.

Opencast mining will commence with an initial box cut to be established during the construction phase of the project. Topsoil and overburden from the initial box-cut area will be stockpiled at the locations indicated in the mine plan (Appendix A: Plan 2 – Mine Plan). A conventional truck and shovel operation, assisted by roll-over dozing, to allow for continuous backfilling and rehabilitation of the mined out area will be utilised. The expected mining conditions are good, due to the favourable geology and good storm water drainage. The final void will be backfilled with the overburden from the initial box cut. On-going rehabilitation will be implemented for every strip of mined out area.

Underground mining sections will be developed via the high wall of the open pit operations. This will enable a shorter lead time to get the underground sections started, eliminate hoisting requirements, as well as reduce upfront capital costs. As the open pit reserves are mined, the underground mining operation commences, there will be an overlap of underground and open pit mining, allowing for a 1 year ramp-up period.

The mining process will include cutting, drilling charges, blasting, loading and support. Once the coal is mined, it will be transported to Kangala Colliery (another of Universal Coal Inc. operations) for coal beneficiation.

A coal crushing and screening plant will be constructed. The Run of Mine (RoM) feed will be crushed to minus 50 mm, and stockpiled on a plant feed stockpile before being transported to Kangala Coal Mine.

2 TERMS OF REFERENCE

The terms of reference for this surface water assessment area are as follows:

- Site characterisation prior to the commencement of the project by identifying the surface water resources, land and water use activities, base flow and flood volumes in a desktop assessment using available information sources including Water Research Commission (WRC) reports and Geographical Information Systems (GIS);

- A surface water baseline report will be compiled indicating the pre-mining status of the surface water quality as compared to the South African National Standards (SANS) 241 for drinking water (2005) and the relevant catchment Water Quality Objectives (WQO);
- All impacts that may result from the mining activities will be identified and weighted using the Digby Wells method to determine their significance;
- Mitigation measures for the reduction of the significance of impacts will be developed and the significance post mitigation will be determined;
- A surface water management plan will be developed indicating the areas of management and persons responsible for implementation; and
- A surface water monitoring programme will be developed for the LoM phases (construction, operation, decommissioning and post-closure). The areas of monitoring, variables of concern, frequency of monitoring, handling and interpretation of data and reporting will be detailed in the monitoring plan.

3 LEGAL FRAMEWORK

The assessment of environmental impacts is legislated under the National Environmental Management Act (Act 107 of 1998) (NEMA), Mineral and Petroleum Resource Development Act (MPRDA) and includes surface water quality and quantity assessment as part of the specialist investigations. The content of the surface water assessment is also dictated by the NEMA process, the National Water Act (Act 36 of 1998) (NWA) and the amended Government Notice of Regulation (GN R) 704 for use and management of water in mining. The management of water resources and use of water in mining is also guided by the Department of Water Affairs (DWA) Best Practice Guidelines (BPGs) series (DWA, 2008).

4 STUDY AREA

The site is located approximately 16 km north-east of Delmas town, 14 km and 17 km north of Devon and Leandra respectively (Appendix A: Plan 1: Regional Setting). The farm portions covered in the MRA include Portions 6, 8, 9, 10, 20, 26, 30 and the Remaining Extent (RE) of the farm Brakfontein 264 IR (Appendix A: Plan 3 – Land Tenure).

The proposed project area footprint is made up of three distinct project area sections (Appendix A: Plan 2 - Mine Plan). It consists of a large portion on the east and two other small portions to the west. Their details are summarised in Table 1 .

Table 1: Catchment and proposed project area description

Project Area ID	Area (km^2)	Catchment	Catchment Area (km^2)	% Catchment Area Covered by Project
1 (Western sites upper footprint)	0.73	B20E	620	0.12
2 (Western sites the bottom footprint)	0.60			0.10
3 (The main footprint on the eastern side)	9.17			1.48
Sub -Total				**1.7**
1 (Western side upper footprint)	0.14	B20A	574	0.02
Sub - Total				0.02

4.1 Catchment Description

The proposed project site falls within two quaternary catchments (Appendix A: Plan 4- Catchments Boundaries) namely B20A and B20E of the Olifants Water Management Area (WMA 02). The greater proportion of the project area falls within B20E (covering 1.7% of the quaternary catchment) while a smaller portion (about 0.02% of the quaternary catchment) is located in B20A. Based on the location of the percentage occupation of the project site over the quaternary catchments, it is anticipated that the impacts may be small over the catchments.

The project site is drained by several streams draining from the south to the north (Appendix A: Plan 5 – Water Resources). These streams originate from the surrounding municipal areas. A number of the streams have their watershed along the R29, railway line from Devon to Liandra and N17. The stream from southeast originates from Lesedi Local Municipality comprise of two tributaries. The two tributaries are the Wilge River and the Steenkoolspruit. The Wilge River drains through the Delmas Colliery and Ikhwezi Colliery before cutting through the project area. Steenkoolspruit is fed by Holspruit and reaches a confluence with Wilge River close to the Delmas and Ikhwezi Colliery (Appendix A: Plan 6 – Surrounding Mining Activities).

An unnamed stream intersects with the Wilge River and originates in the Govan Mbeki Local Municipality. It begins as two tributaries that confluent at the border of Govan Mbeki and Victor Khanye Local Municipalities, the watershed of these streams is the town area of Leandra.

Another stream drains the proposed project area from the south of southeast originating from two tributaries in the watershed around Leandra. The stream reaches a confluence with Wilge River inside the project area which drains to join with other streams from the South East (Kroomdraaispruit and Dieplaagte Spruit) and one from the west. The stream from the west cuts through the northern parts of the project area. Situated on the streams draining from the south are the JC Dam upstream and Kromdraai Dam downstream on the Kroomdraai Spruit as well as Dieplaagte Dam situated on a stream further downstream. The Wilge River eventually drains to the Olifants River further downstream which will then drain into the Limpopo River through Mozambique and into the Indian Ocean.

Since the area is drained by several streams to be able to further characterise the hydrology of the area, a number of sub-catchments were then delineated (Appendix A: Plan 4 – Catchments Boundary). The delineation process is discussed in Section 6.1.1 of this report.

4.2 Climate

Climate of the project area is described by data obtained from Witbank Weather station (station number 0515320 8) as there are no climate stations in Delmas (South African Weather Bureau, 2012).

The area falls under the Highveld climatic zone characterised by warm and wet summers and cold to frosty winters. Precipitation occurs as showers and thunderstorms falling from October to March with the maximum falls occurring in November, December and January. Rainstorms are often violent (up to 242 mm/day) with severe lightning and strong winds, sometimes accompanied by hail. The winter months are droughty with the combined rainfall in June, July and August making up only 2.3 % of the annual total (661.2 mm).

The average daily maximum temperature in February (the hottest month) is 26.6 °C and in July (the coldest month) is 18.4 °C. The mean daily minimum in February is 15 °C and July 4.2 °C but extremes of 3.3 °C have occurred.

5 EXPERTISE OF THE SPECIALIST

Digby Wells is an independent Environmental Consulting firm providing service to the mining industry. There is a suite of in-house specialists including hydrologists and hydrogeologists. A CV of the specialist is available upon request.

6 METHODOLOGY

The surface water assessment methodology entailed a desktop assessment, site survey and sampling as well as impact assessment. The baseline study was performed in phases to determine both the quantity and quality of the water in the streams around the proposed project site. Sections below detail the methodology employed to achieve the surface water quality and quantity baseline assessment.

6.1 Surface Water Quantity

A description of the surface water environment was conducted based on available information sources and the site survey for the respective delineated catchments. The Mean Annual Runoff (MAR), Mean Annual Precipitation (MAP), Mean Annual Evaporation (MAE) and determination of the Peak Flood Volume were carried out using Water Research Commission (WRC) Report No.: 289/1.1/94 (WRC, 1994). Information on the rainfall and rainfall zones was also obtained from the report.

6.1.1 Catchment Delineation

Catchment delineation was performed for the catchment B20E to cater for the peak flood volumes that each stream could contribute to the project site. The catchments delineation is summarised in Table 2. The characteristics of the sub-catchments were determined and are presented in the results section.

Table 2: Summary of delineated sub-catchments

Quaternary Catchment	Sub-catchment	Comment
B20E	sub1	Catchment to stream originating south of project area passing through Delmas Colliery and Ikhwezi Colliery. It will cater for flood volumes upstream of the proposed project site;
	sub2	Catchment to stream originating from the south flowing directly into the project area. This will cater for the flood volumes from upstream to the proposed project site;
	sub3	Will account for flood volumes directly onto the project site between the confluence of two major southern streams on edge of project area and confluence with Kromdraaispruit and another stream;
	sub4	Catchment for the Kromdraaispruit draining from the south-east;
	sub5	Catchment to the Diepslaagte Dam draining from the East;
	sub6	Catchment to the stream flowing from the west through the northern parts of the project area. Where underground operations will be implemented. Will capture flood volumes that could affect the larger part of project area 1 of proposed project area and the greater part of the proposed project area; and
B20A	sub1	Catchment of stream in which small portion of project area (part of project area 1) will be situated near the underground and informal settlement portions of the Colliery land tenure.

6.1.2 Peak Flood Volumes Estimation

The Peak Flood Volumes for the 1: 50 and 1: 100 return year periods were calculated using the Utilities Programmes for Drainage (UPD) software (Version 1.0.2) (SANRAL, 2007). The calculation took into account parameters determined from the sub-catchment delineation above. The peak flows for the various sub-catchments delineated were assessed utilising a combination of the following Rainfall-Runoff methods (SANRAL, 2007):

- Rational;
- Alternative Rational;
- Standard Design Flood (SDF);
- Empirical; and
- Synthetic Unit Hydrograph.

All the listed methods were utilised. However the standard design flood method (SDF) values would then be used for describing the Peak Flood Volumes in the project area.

The SDF was specifically developed to address the uncertainty in flood prediction under South African conditions. It is based on historical data to adequately describe the flood frequency relationships. The runoff or discharge coefficient (C) is replaced by a calibrated value based on the subdivision of the country into 26 regions on WMAs historical data. This method can work for large catchments without any limitation.

The information used to conduct the model assessment for the two selected methods were specified using various criteria summarised below and detailed in the Drainage Manual (SANRAL, 2007). The percentages of each of these classes were then determined by professional subjective judgement/discretion, and visual inspection on the slope and fraction of the catchment.

The most important parameters were:

- Area distribution – which is estimated based on the catchment area and respective areas covered by the rural, urban and reservoirs;
- Rural area surface slope – which was characterised based on the respective slope (%) classifications to define flat areas from hilly areas and steep area;
- Rural area permeability – which is estimated from the a qualitative guide of soil texture for the classification of the soil permeability as in the Drainage Manual (SANRAL, 2007) and soil maps (1:250 000 interactive map from Agricultural Research Council) and estimation of percentage area by visual inspection;
- Vegetation – which was estimated from site inspections observations and satellite imagery visual classification;
- Urban area parameters – which were based on site observations and inspections;
- The number of days on which thunder was heard – obtained from the WRC Report and the South African Weather Services (SAWS);
- Dolomitic areas – the percentage dolomitic area was determined based on the geology map and using visual inspection and estimation; and
- Overland or defined water course flow – where the average slope of a catchment greater than 5% and catchment larger than 5 km^2 assumes that defined water courses exist.

The model parameters values for each sub-catchment are shown in the model results and the corresponding parameterisation therefore (Appendix B - Flood Volumes).

6.2 Surface Water Quality

6.2.1 Surface Water Sampling

During the scoping phase, 16 sampling sites were identified for surface water quality baseline sampling. The sites were selected at strategic localities where water quality can be monitored optimally. During the site survey and sampling period, 12 out of the possible 16 were sampled since the remaining sites were dry. The detail of sampling points is summarised in the Table 3 and shown on a map (Appendix A; Plan 7 – Water Quality Sampling Points).

Table 3: Surface water quality sample points location and description

Sampling Point	Latitude	Longitude	Description
BRIDGE	26° 11' 3.074" S	28° 51' 56.329" E	Sampled as UCBSW02, bridge within a wetland area. A low flow was observed.
UCBSW01	26° 11' 44.369" S	28° 50' 58.711" E	On stream Northern part of the mine area stream draining from west to east. Water was stagnant and almost dry.
UCBSW02	26° 12' 12.789" S	28° 51' 2.783" E	Not sampled- dry (point name replaced by original Bridge sample)
UCBSW03	26°11' 6.925" S	28° 52' 44.727" E	Downstream of dam which is situated just outside the northern part of proposed project area
UCBSW04	26° 11' 14.331" S	28° 52' 54.599" E	Downstream after confluence of the streams draining south eastern section of project area and the north section. Low flow was observed.
UCBSW05	26° 11' 40.584" S	28° 52' 59.248" E	Downstream on Wilge River with low flow.
UCBSW06	26° 12' 25.312" S	28° 53' 16.379" E	Upstream of an unnamed tributary (with Dieplaagte Dam) before confluence with Kromdraaispruit. Flowing stream was observed.
UCBSW07	26° 12' 30.701" S	28° 53' 15.176" E	On Kromdraaispruit but stagnant water was observed.

Sampling Point	Latitude	Longitude	Description
UCBSW08	26° 12' 33.147" S	28° 52' 45.042" E	Downstream of project area just outside project boundary on Wilge River. This was observed as a cattle watering point with flowing water.
UCBSW09	26° 13' 11.680" S	28° 52' 28.291" E	After confluence of Wilge River and unnamed tributary in project area. Stagnant water.
UCBSW10	26° 13' 33.648" S	28° 52' 1.693" E	On Wilge River upstream of project Area. Stagnant water was observed.
UCBSW11	26° 14' 0.389" S	28° 53' 4.952" E	On unnamed tributary with flowing water joining Wilge River
UCBSW12	26° 13' 31.313" S	28° 50' 13.479" E	Not sampled- ground water pumped to this sampling point for use at nearby chicken farm
UCBSW13	26° 13' 27.333" S	28° 49' 51.019" E	Not sampled- dry
UCBSW14	26° 12' 56.486" S	28° 49' 59.887" E	Not sampled- dry
UCBSW15	26° 12' 24.291" S	28° 50' 35.101" E	Wetland near proposed strip pit mine design, stagnant water was observed.

The collected water samples were submitted for analysis to Clean Stream Scientific Services, a South African National Accreditation System (SANAS) accredited water quality testing laboratory on the 11th June 2012. The following parameters (Table 4) were analysed.

Table 4: Hydrochemical parameters analysed

Total Dissolved Solids (TDS)	Sulphate as SO_4	Sodium as Na	Magnesium as Mg
Nitrate NO_3 as N	Fluoride as F	Calcium as Ca	Potassium as K
Chlorides as Cl	Iron as Fe	Manganese as Mn	Electrical Conductivity (EC*)
Total Alkalinity as $CaCO_3$	pH*-Value at 25° C	Aluminium as Al	Free and Saline Ammonia as N

***All units in mg/l except EC (mS/m) and pH in units of pH.**

6.2.2 Data Analysis

The laboratory data (Appendix C) was captured and interpreted using the Water Interpretation Software for Hydrogeologists (WISH) software to indicate the water quality of the samples collected. The graphical presentation of the data is presented in (Appendix D). The water quality was benchmarked against the South African National Standards (SANS) 241 for drinking water (2005).

6.3 Impact Assessment Methodology

In order to clarify the purpose and limitations of the impact assessment methodology, it is necessary to address the issue of subjectivity in the assessment of the significance of environmental impacts. Even with a number of EIA numerical methodologies available for impact assessment, one has to accept that the process of environmental significance determination is inherently subjective. The weight assigned to the each factor of a potential impact, and also the design of the rating process itself, is based on the values and perception of risk of members of the assessment team, as well as that of the I&AP's and authorities who provide input into the process. Whereas the determination of the spatial scale and the duration of impacts are to some extent amenable to scientific enquiry, the severity value assigned to impacts is highly dependent on the perceptions and values of all involved.

It is for this reason that it is crucial that all EIA's make reference to the environmental and socio-economic context of the proposed activity in order to reach an acceptable rating of the significance of impacts. Similarly, the perception of the probability of an impact occurring is dependent on perceptions, aversion to risk and availability of information.

It has to be stressed that the purpose of the EIA process is not to provide an incontrovertible rating of the significance of various aspects, but rather to provide a structured, traceable and defendable methodology of rating the relative significance of impacts in a specific context. The methodology employed for EIA is divided into two distinct phases, namely, impact identification and impact assessment.

6.3.1 Impact Identification

Impact identification is performed by use of an Input-Output model which serves to guide the assessor in assessing all the potential instances of ecological and socio-economic change, pollution and resource consumption that may be associated with the activities required during the construction, operational, closure and post-closure phases of the project. Outputs may generally be described as any changes to the biophysical and socio-economic environments, both positive and negative in nature, and also include the product and waste produced by the activity. Negative impacts could include gases, effluents, dust, noise, vibration, other pollution and changes to the bio-physical environment such as damage to habitats or reduction in surface water quantity. Positive impacts may include the removal of invasive vegetation, construction of infrastructure, skills transfer or benefits to the socio-economic environment. During the determination of outputs, the effect of outputs on the various components of the environment (e.g. topography, water quality, etc.) is considered.

During consultation with Interested & Affected Parties (I&APs) perceived impacts were identified. These perceived impacts will become part of the impact assessment and significance rating in order to differentiate between probable impacts and perceived impacts.

6.3.2 Impact Rating

The impact rating process is designed to provide a numerical rating of the various environmental impacts identified by use of the Input-Output model. As discussed above, it has to be stressed that the purpose of the EIA process is not to provide an incontrovertible rating of the significance of various aspects, but rather to provide a structured, traceable and defendable methodology of rating the relative significance of impacts in a specific context. This gives the project proponent a greater understanding of the impacts of his project and the issues which need to be addressed by mitigation and also give the regulators information on which to base their decisions. The significance rating process follows the established impact/risk assessment formula:

Significance = Consequence x Probability

Where

Consequence = Severity + Spatial Scale + Duration

And

Probability = Likelihood of an impact occurring

The matrix calculates the rating out of 147, whereby severity, spatial scale, duration and probability are each rated out of seven (Table 5). The weighting is then assigned to the various parameters for positive and negative impacts in the formula. Impacts are rated prior to mitigation and again after consideration of the mitigation measure proposed in the EMP.

Table 5: Impact assessment parameter ratings

Rating	Severity		Spatial scale	Duration	Probability
	Environmental	Social, cultural and heritage			
7	Very significant impact on the environment. Irreparable damage to highly valued species, habitat or eco system. Persistent severe damage.	Irreparable damage to highly valued items of great cultural significance or complete breakdown of social order.	International The effect will occur across international borders	Permanent: No Mitigation No mitigation measures of natural process will reduce the impact after implementation.	Certain/ Definite. The impact will occur regardless of the implementation of any preventative or corrective actions.
6	Significant impact on highly valued species, habitat or ecosystem.	Irreparable damage to highly valued items of cultural significance or breakdown of social order.	National Will affect the entire country	Permanent: Mitigation Mitigation measures of natural process will reduce the impact.	Almost certain/Highly probable It is most likely that the impact will occur.
5	Very serious, long-term environmental impairment of ecosystem function that may take several years to rehabilitate	Very serious widespread social impacts. Irreparable damage to highly valued items	Province/ Region Will affect the entire province or region	Project Life The impact will cease after the operational life span of the project.	Likely The impact may occur.
4	Serious medium term environmental effects. Environmental damage can be	On-going serious social issues. Significant damage to structures / items of	Municipal Area Will affect the whole municipal	Long term 6-15 years	Probable Has occurred here or elsewhere and could

Rating	Severity		Spatial scale	Duration	Probability
	Environmental	Social, cultural and heritage			
	reversed in less than a year	cultural significance	area		therefore occur.
3	Moderate, short-term effects but not affecting ecosystem functions. Rehabilitation requires intervention of external specialists and can be done in less than a month.	On-going social issues. Damage to items of cultural significance.	Local Local extending only as far as the development site area	Medium term 1-5 years	Unlikely Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur.
2	Minor effects on biological or physical environment. Environmental damage can be rehabilitated internally with/ without help of external consultants.	Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Limited Limited to the site and its immediate surroundings	Short term Less than 1 year	Rare/ improbable Conceivable, but only in extreme circumstances and/ or has not happened during lifetime of the project but has happened elsewhere. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures
1	Limited damage to minimal area of low significance, (e.g. ad hoc spills within plant area). Will have no impact on the environment.	Low-level repairable damage to commonplace structures.	Very limited Limited to specific isolated parts of the site.	Immediate Less than 1 month	Highly unlikely/None Expected never to happen.

The significance of an impact is then determined and categorised into one of four categories (Table 6).

Table 6: Probability consequence matrix

Significance										
		Consequence (severity + scale + duration)								
		1	3	5	7	9	11	15	18	21
Probability / Likelihood	1	1	3	5	7	9	11	15	18	21
	2	2	6	10	14	18	22	30	36	42
	3	3	9	15	21	27	33	45	54	63
	4	4	12	20	28	36	44	60	72	84
	5	5	15	25	35	45	55	75	90	105
	6	6	18	30	42	54	66	90	108	126
	7	7	21	35	49	63	77	105	126	147

The significance rating is presented in Table 7. In accordance with Regulation 51 of the MPRDA, management actions will be assigned for all identified impacts.

Table 7: Significance threshold limits

Significance		
High	**108- 147**	
Medium-High	**73 - 107**	
Medium-Low	**36 - 72**	
Low	**0 – 35**	

6.4 Project Activities

The listed project activities are summarised in Table 8.

Table 8: Listed project activities

Phase		Activity
Construction	1	Site Clearing: Removal of topsoil & vegetation
	2	Construction of any surface infrastructure e.g. haul roads, pipes, storm water diversion berms (including transportation of materials & stockpiling)
	3	Blasting and development of initial boxcut for mining (incl. stockpiling from initial cuts).
	4	Temporary storage of hazardous product (fuel, explosives) and waste or sewage.
Operation	5	Removal of overburden and backfilling when possible (including drilling/blasting hard overburden & stockpiling)
	6	Use and maintenance of haul roads (incl. transportation of coal to washing plant)
	7	Removal of coal (mining process) and ROM coal Stockpile
	8	Water use & storage on site (incl. screening & washing, PCD)
	9	Storage, handling and treatment of hazardous products (fuel, explosives, oil) and waste activities (waste, sewage, discard, PCD)

Phase		Activity
	10	Concurrent replacement of overburden, topsoil and vegetation
Decommissioning	11	Demolition & Removal of all infrastructure (incl. transportation off site)
	12	Rehabilitation (spreading of soil, re-vegetation & profiling/contouring)
	13	Installation of post-closure water management infrastructure
	14	Environmental monitoring of decommissioning activities
	15	Storage, handling and treatment of hazardous products (fuel, explosives, oil) and waste activities (waste, sewage, discard)
Post-closure	16	Post-closure monitoring and rehabilitation

7 FINDINGS

7.1 Water Quantity

Catchment characteristics for rainfall and evaporation values were summarised (Table 9) as obtained from the WRC Report no. 298/1.1/94 (WRC, 1994).

Table 9: Catchment Characteristics

Quaternary Catchment	Area (km^2)	MAE (mm)	MAP (mm)	MAR (mm)
B20E	620	1650	661	34
B20A	574	1650	657	38

Characterisation of rainfall was further performed through the estimation of design 24 hour rainfall depths for 50 and 100 year return periods. The weather gauges that were selected were the Strehla and Vlakplaas which were close to the proposed project area. This was calculated using the Design Rainfall Estimation in South Africa software (Smithers and Schulze, 2003). Maximum 24 hour storm event rainfall depths are summarised in Table 10.

Table 10: Maximum 24 Hour Storm Event Rainfall Depth

Return Period (years)	1: 50	1: 100
Station Name (Number)	**24 Hour Rainfall Depth (mm)**	
Vlakplaas (0477494)	153	177
Strehla (0477762)	131	148

7.1.1 Catchment Delineation

A summary of the sub-catchment characteristics is presented in Table 11.

Table 11: Sub-Catchment Characteristics

Quaternary Catchment	Sub-catchment	Area (km^2)	longest stream (km)	Elevation change between 10 and 85% of stream (m)	Distance to catchment centroid (km)
B20E	sub1	146	19.3	70.3	11.4
	sub2	61.4	15.7	57.8	10.5
	sub3	8.25	2.27	17.9	0.85
	sub4	88.9	19.7	78.3	9.43
	sub5	41.0	8.50	38.7	5.89

Quaternary Catchment	Sub-catchment	Area (km^2)	longest stream (km)	Elevation change between 10 and 85% of stream (m)	Distance to catchment centroid (km)
	sub6	22.8	4.86	20.4	3.14
B20A	sub1	36.2	14.3	39.0	7.59

7.2 Flood Volumes

The delineated sub-catchments (Table 11) were utilized to calculate the flood volumes. The Peak Flood Volumes were determined using the Utilities Programmes for Drainage (UPD) software (SANRAL, 2007). Flood volumes calculated are presented in Table 12.

Table 12: Flood Peak Flow volumes calculations (m^3/s)

Quaternary Catchment	Sub-catchment	Rational	Alternative rational	Synthetic Hydrograph	Standard Design Flood	Empirical
		1:50				
B20E	sub 1	252	280	258	312	235
	sub2	115	131	112	186	127
	sub3	66.0	75.7	51.0	100	60.6
	sub4	144	162	160	231	163
	sub5	257	285	193	400	215
	sub6	102	116	58	148	97.1
B20A	sub1	52.3	65.1	64.7	108	78.8
		1:100				
B20E	sub 1	321	339	347	395	297
	sub2	147	159	151	237	160
	sub3	85.0	91.7	70.5	127	76.5
	sub4	184	196	217	294	206
	sub5	356	345	263	510	272
	sub6	130	141	79.4	189	123
B20A	sub1	67.3	78.9	88.7	138	100

In line with the methodology, the expected floods to be considered are the SDF (since the method is calibrated for South African conditions). The results indicate relatively close results in terms of the peak flows however, the SDF method has the highest estimates of flood peak flow. To utilise the results in line with the legislative requirements, the constructed infrastructure for containing dirty water should be able to contain the 1:50 year 24 hr flood volume. The water conveyances and containment systems should be designed to convey/contain a flood volume of 51 000 000 m^3 (51 MCM) as a result of the peak flood flow of 598 m^3/s for 24 hr storm. This is applicable to sub-catchments 1, 2, and 3.

It is also vital for the design of the return water dams from the open pit mining areas in sub-catchments 3 to be able to capture the direct 1:50 year flood peak in sub-catchment 3 of – of 100 m^3/s for 24 hr (8 600 000 m^3).

7.3 Surface Water Quality

The chemical analysis results (Appendix C – Laboratory Results) were evaluated against the SANS 241 (2005) drinking water quality standards (Table 13). The presentation of the results is colour coded to present the Class I and Class II water quality respectively. Values that exceeded Class II are colour coded in red shading.

Table 13: Summary of the surface water quality data benchmarked against the SANS SANS 241 standard

Sample ID		Total Dissolved Solids	Nitrate NO_3 as N	Chlorides as Cl	Total Alkalinity as $CaCO_3$	Sulphate as SO_4	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Iron as Fe	Manganese as Mn	Conductivity at 25° C in mS/m	pH-Value at 25° C	Aluminium as Al	Free and Saline Ammonia as N	Fluoride as F
Class I	(Recommended)	<1000	<10	<200	N/S	<400	<150	<70	<200	<50	<0.2	<0.1	<150	5-9.5	<0.3	<1	<1
Class II	(Max. Allowable)	2400	20	600	N/S	600	300	100	400	100	2	1	370	4-5 or 9.5-10	0.3-0.5	2	1.5
	Duration (years)	7	7	7	N/S	7	7	7	7	7	7	7	7	0	1	0	1
UCBSW 01		96.0	0.18	35.5	23.2	11.1	9.70	7.84	15.3	2.08	0.25	0.00	20.5	7.64	-0.01	0.08	-0.18
Bridge/UCBSW 02		290	0.14	20.6	224	34.7	44.0	27.3	23.7	5.50	-0.01	0.00	53.4	8.11	-0.01	0.03	0.29
UCBSW 03		189	0.12	20.9	157	-0.13	18.5	18.4	23.7	13.7	-0.01	0.07	38.1	7.63	-0.01	0.02	0.50
UCBSW 04		344	1.61	21.8	198	88.0	41.8	32.6	34.6	5.14	-0.01	0.00	59.3	8.69	-0.01	0.59	0.30
UCBSW 05		294	0.31	16.4	172	76.8	35.6	29.2	29.0	2.84	-0.01	0.00	52.1	8.69	-0.01	0.02	0.27
UCBSW 06		299	0.53	40.1	218	22.3	38.3	30.5	33.7	2.75	-0.01	0.08	55.8	8.36	-0.01	0.11	0.19
UCBSW 07		260	0.49	19.4	147	62.6	28.9	23.0	30.9	6.42	-0.01	0.00	46.9	8.18	-0.01	-0.02	0.39
UCBSW 08		578	0.25	24.5	221	242	66.4	51.8	55.5	4.55	-0.01	0.00	86.8	8.30	-0.01	-0.02	0.29
UCBSW 09		505	0.27	23.9	249	172	53.2	46.7	55.9	3.93	-0.01	0.00	81.0	8.40	-0.01	0.09	0.37
UCBSW 10		436	0.36	24.4	250	110	52.0	41.3	53.9	4.52	-0.01	0.04	73.1	8.63	-0.01	0.05	0.34
UCBSW 11		545	0.30	72.6	295	99.7	69.2	56.5	63.5	6.62	-0.01	0.18	93.7	8.60	-0.01	0.03	0.35
UCBSW 15		321	0.25	20.3	76.4	142	37.9	19.1	35.3	20.9	-0.01	0.15	56.4	7.42	-0.01	0.10	0.48

The results (Table 13) indicate an ideal water quality for most the constituents analysed. The exceptions were recorded for samples UCBSW01 (Fe of 0.25 mg/l; Class II), UCBSW11 and UCBSW15 (Mn of 0.18 and 0.15 mg/l respectively; Class II). The slightly elevated Mn and Fe concentration were attributed to upstream mining impacts or historical impacts that have accumulated in the surface water resources. Also, Fe could be associated with the geological characteristic of the site.

The elevated levels of both Mn and Fe in stagnant water of UCBSW01 and UCBSW15 can be associated with the water quality characteristics of pans (where water is filtered through the pan into the ground while there is effect of evapotranspiration which result in the concentration of the elements).

7.3.1 Resource Water Quality Objectives (RWQO)

The DWA performed assessments of water quality and water uses within the stressed Olifants WMA in order to set Water Quality Objectives (WQO). This is aimed at reducing the potential impacts for the most vulnerable water users within the WMA. These WQO were set for the different catchments within the WMA depending on the nature of the most vulnerable water users. In the case of the project site, the Wilge River WQO is relevant. These objectives area more stringent than the SANS 241 (2005) in some cases and where more than one WQO was applicable, the most stringent was used to benchmark the data.

The WQO were also benchmarked against the determined water quality of the various sampling points. Where the water quality exceeded the WQO, the values were colour coded red. Table 14 shows the colour coded classification with respect to the in-stream WQO set for Wilge River Catchment particularly the Upper Wilge River Catchment (http://www.reservoir.co.za : Accessed 27 June 2012).

The results (Table 14) indicated that:

- Parameters of concern with respect to the WQO are the F, Cl, Alkalinity, EC, NO_3 and SO_4 which were higher by an order of magnitude ranging from two to 12 times.

Elevated levels of EC indicate the presence of major ions in these streams mostly as a result of agricultural and mining activities. This is also highlighted in the concentration of Cl ion which is above the WQO. The high levels of NO_3, NH_4 and Na could be attributed to the agricultural activities taking place within the surrounding area. These include livestock watering which can result in the increase of nutrients in the water. Nitrates could be attributed to the use of inorganic nitrate fertilisers as a significant portion of the catchment is under agricultural irrigation use.

Table 14: Summary of the water quality data benchmarked against the in-stream WQO for the Upper Wilge Catchment

Sample ID	Nitrate NO_3 as N	Chlorides as Cl	Total Alkalinity as $CaCO_3$	Sulphate as SO_4	Conductivity at 25° C in mS/m	pH-Value at 25° C	Free and Saline Ammonia as N	Fluoride as F
In stream Water quality objectives: Upper Wilge River Catchment	0.3	15	70	15	35	6.4-8.5	0.2	0.2
UCBSW 01	0.18	35.5	23.2	11.1	20.5	7.64	0.08	-0.18
UCBSW 02	0.14	20.6	224	34.7	53.4	8.11	0.03	0.29
UCBSW 03	0.12	20.9	157	-0.13	38.1	7.63	0.02	0.50
UCBSW 04	1.61	21.8	198	88.0	59.3	8.69	0.59	0.30
UCBSW 05	0.31	16.4	172	76.8	52.1	8.69	0.02	0.27
UCBSW 06	0.53	40.1	218	22.3	55.8	8.36	0.11	0.19
UCBSW 07	0.49	19.4	147	62.6	46.9	8.18	-0.02	0.39
UCBSW 08	0.25	24.5	221	242	86.8	8.30	-0.02	0.29
UCBSW 09	0.27	23.9	249	172	81.0	8.40	0.09	0.37
UCBSW 10	0.36	24.4	250	110	73.1	8.63	0.05	0.34
UCBSW 11	0.30	72.6	295	99.7	93.7	8.60	0.03	0.35
UCBSW 15	0.25	20.3	76.4	142	56.4	7.42	0.10	0.48

7.4 Water Uses

Water uses around the project site is characterised by the activities of agriculture (crop and livestock watering), domestic use, mining and industrial use (thermal power stations). There are also mine areas upstream of the project area, the Ikwezi and Delmas Colliery. These existing mining areas are drained by the Wilge River which also drains into the project area. Downstream of the proposed project area is the Kiaton Mine (Appendix A: Plan 6) which with the impacts of the poposed project can worsen the water quality in the Wilge River.

In the upstream, the watersheds in the south of the proposed project area are the towns of Leandra and Devon.

The dams in the sub-catchments of the study area are the Kroomdraai Dam, JC Dam and the Dieplaagte Dam located to the east of the project area. Portable water will be obtained from drilled boreholes. There are also several wetlands present within the study area and within the catchment.

7.5 Conclusions and Recommendations

The following conclusions can be drawn from the baseline assessment:

- The proposed project could impact on two catchments namely B20E and B20A;
- The surface water quality baseline indicates that the surface water resources are not impacted heavily when compared to the SANS 241 with an exception of three samples which fell within maximum allowable Class II for single parameters; and
- When benchmarked against the WQO the water quality indicate poor water quality particularly for the variables F, Cl, Alkalinity, EC, NO_3 and $SO_{4.}$ The variables of concern exceeded the WQO in magnitude of 2 to 11 times.

The following recommendations are made:

- The design of the conveyances and water holding dams associated with the mining activities should be able to contain peak flood volume of a 1: 50 yr 24 hr flood peak flow volume of 598 m^3/s;
- Design operation and maintenance of the infrastructure should be in line with the legislative requirements of GN R 704 and DWA BPGs;
- Water quality monitoring must be carried out regularly and used as an impact detection tool; and
- Although the area is already impacted upon based on the WQO, it is essential that the management of the project execution ensures that there are minimal impacts to the surface water resources in order to prevent the exacerbation of the quality within the already impacted WMA.

8 IMPACT ASSESSMENT

The impact assessment methodology designed by Digby Wells was utilised for the sixteen listed activities over the construction, operation and decommissioning phases. These are outlined in Section 6.3 and 6.4 respectively.

8.1 Construction Phase

During the construction phase, there will be site clearing, construction of infrastructure, blasting and the temporary storage of hazardous products (explosives) and commencement of the long-term storage of hydrocarbon containing substances such as grease, oil and diesel. The surface water quality impacts that could arise from the construction phase and mitigation measures are discussed below.

8.1.1 Activity 1: Site Clearing and Removal of Topsoil and Vegetation

8.1.1.1 Impact Description: Surface Water Quantity

The clearance of the site results in increased surface runoff which will be prevented from reporting to the catchment as it will be contaminated with silt.

8.1.1.2 Impact Assessment

Parameter	**Impact** **Pre-Mitigation**		**Impact** **Post-Mitigation**	
Duration (7)	Project Life	5	Medium term	3
Scale (7)	Regional	5	Local	3
Severity (7)	Serious Medium	4	Less significant	2
Likelihood (7)	Likely	5	Probable	4
Significance	Medium low	70	Low	32

8.1.1.3 Mitigation Description

There is a requirement to as much as possible limit the cleared area in order to reduce the quantity of contaminated water that cannot report to the catchment. This will be possible with the implementation of roll-over mining where a limited area will be mined at a given time.

8.1.1.4 Impact Description: Surface Water Quality

The clearance of the site results in increased dust generation and potential soil erosion. This could result in silted runoff flowing through the surface to the water resources. The resultant impact could be water increased siltation and water quality deterioration of the already stressed catchment and WMA.

8.1.1.5 Impact Assessment

Parameter	**Impact** **Pre-Mitigation**		**Impact** **Post-Mitigation**	
Duration (7)	Long-term	4	Medium term	3
Scale (7)	Regional	5	Local	3

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Severity (7)	Serious midterm	4	Moderate short term	3
Likelihood (7)	Probable	4	Unlikely	3
Significance	Medium low	56	Low	27

8.1.1.6 Mitigation Description

It is essential to implement clean and dirty water separation and ensure that the dirty area is minimized. Dust suppression measures have to be implemented. The constructed isolation topsoil berms must be vegetated to prevent erosion and the water associated with the dirty area must be contained in Pollution Control Dams (PCDs).

8.1.2 Activity 2: Construction of any Surface Infrastructure e.g. haul roads, pipes, storm water diversion berms (including transportation of materials & stockpiling)

8.1.2.1 Impact Description: Surface Water Quantity

There will be decreased quantity of water reporting to the catchment due to the diversion berms and the isolation of dirty water forming part in catchment runoff.

8.1.2.2 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Project life	5	Medium term	3
Scale (7)	Regional	5	Local	3
Severity (7)	Moderate	4	Moderate	3
Likelihood (7)	Probable	4	Unlikely	3
Significance	Medium low	56	Low	27

8.1.2.3 Mitigation Description

Ensure that clean water is diverted to the catchment with minimal contact with contaminated water. The silt traps could be fitted to ensure that more run-off is diverted to the surface water environment.

8.1.2.4 Impact Description: Surface Water Quality

Surface water quality deterioration could result from spillages of construction material, siltation from dust deposition and soil erosion. Small leaks of hydrocarbon containing material if not detected early could result in major water quality deterioration in the pro-longed LoM.

8.1.2.5 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Permanent: with Mitigation	6	Medium term	3
Scale (7)	Regional	5	Local	3
Severity (7)	Serious medium term	4	Moderate	3
Likelihood (7)	Likely	5	Unlikely	3
Significance	Medium high	75	Low	27

8.1.2.6 Mitigation Description

The separation of clean and dirty water by means of vegetated topsoil berms will reduce the rate of soil erosion and subsequent siltation. The implementation of dust suppression measures will reduce dust deposition of the surface water environment. The establishment of storage areas on compacted hard-park area with bunding will prevent the spread of impacts in cases of spillages. The monitoring of valves must be implemented, where leaks are detecting these should be addressed immediately. On-site and mobile disinfectant and treatment kits must be available in cases of spillages.

8.1.3 Activity 3: Blasting and Development of Initial Box Cut

8.1.3.1 Impact Description: Surface Water Quantity

Blasting could result in fractures in the aquifers bed that would result in altered water flows by reducing the water that could contribute to stream flow. The box cuts result in areas where water could collect and accumulate instead of flowing and reporting to the catchment.

Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Permanent: Mitigation	6	Project life	5
Scale (7)	Regional	5	Municipal area	4
Severity (7)	Very serious	5	Moderate	3
Likelihood (7)	Likely	5	Probable	4
Significance	Medium high	80	Medium Low	48

8.1.3.2 Mitigation Description

It is important to avoid blasting in close proximity to the stream and adhere to the blast pattern so that blasting and detonation is done well and avoid cracks in the aquifer bed in unplanned fashion. Stream flow monitoring is also necessary during this time to ensure that impacts on surface water quantity are detected and mitigation is implemented.

8.1.3.3 Impact Description: Surface Water Quality

Negative impacts could arise from the improper use of explosives, spillages from undetonated explosive material (nitrate and ammonia) and waste left behind after detonation. Heavy vehicle movement could result in elevated dust levels which could result in the siltation of nearby surface water resources. The diesel leakages from the tracks and filling station on site could result in the development of surface water contamination should run-off be allowed to flow off-site.

8.1.3.4 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Permanent –Mitigation	6	Permanent – Mitigation	6
Scale (7)	National	6	Regional	5
Severity (7)	Very significant	7	Very serious	5
Likelihood (7)	Almost certain	6	Unlikely	3
Significance	High	114	Medium low	48

8.1.3.5 Mitigation Description

Ensure water quality monitoring is implemented, dust suppression is implemented and allow only trained and certified personnel to conduct the blasting. This will ensure that adequate quantities of explosives are utilised to minimise excess waste and the remaining rubble is correctly disposed.

8.1.4 Activity 4: Temporary Storage of Hazardous Products (fuel, explosives) or Waste or Sewage

8.1.4.1 Impact Description: Surface Water Quantity

There will be decrease in water quantity reporting to the catchment from runoff where storage facilities areas and sewer storage areas are isolated from the rest of catchment.

8.1.4.2 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Project life	5	Medium	3
Scale (7)	Local	3	Local	3
Severity (7)	Moderate	3	Moderate	3
Likelihood (7)	Probable	4	Unlikely	3
Significance	Medium low	44	Low	27

8.1.4.3 Mitigation Description

It is important to ensure free drainage of as much clean storm water as possible to the catchment and use one designated hazardous substances storage facility to reduce number of highly toxic dirty areas.

8.1.4.4 Impact Description: Surface Water Quality

The water quality impacts could arise from the pro-longed leakages or instant spillages of the hazardous and hydrocarbon containing materials.

8.1.4.5 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Permanent: No Mitigation	7	Long term	4
Scale (7)	National	6	Local	3
Severity (7)	Significant	6	Serious medium term	4
Likelihood (7)	Probable	4	Probable	4
Significance	Medium high	76	Medium Low	44

8.1.4.6 Mitigation Description

The storage and handling of hazardous and hydrocarbon containing material should be in line with GN R 704 regulations. The storage areas have to be located on a hard park area with a bund wall to prevent the spread of materials to the water resources in case of spillages. Only trained and authorized personnel must be granted access the storage facilities. Use of hazardous material must be only by trained and authorized personnel.

8.2 Operational Phase

The operation phase of this project includes the removal of overburden material, initial box cut. The impact of these activities is discussed below.

8.2.1 Activity 5: Removal of Overburden and Backfilling when Possible (Including Drilling/ Blasting Hard Overburden& Stockpiling)

8.2.1.1 Impact Description: Surface Water Quantity

There will be a decrease in water quantity reporting to the catchment as dirty and clean areas are separated. The drilling and blasting could cause aquifer bed fractures and alteration resulting in less (base flow) water flowing to the streams.

8.2.1.2 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Permanent- Mitigation	6	Medium-term	5
Scale (7)	Regional	5	Local	3
Severity (7)	Very serious	5	Serious- medium term	4
Likelihood (7)	Probable	4	Unlikely	3
Significance	Medium low	64	Medium Low	36

8.2.1.3 Mitigation Description

It is important to minimise the disturbed area in order to limit the runoff volume that cannot report to the catchment. It is also essential that the backfilled areas are well graded to closely resemble original contour to minimise erosion and storm water collection points. Grass seeding the area to grow vegetation on rehabilitated area will prevent the increased flow of runoff from the area.

8.2.1.4 Impact Description: Surface Water Quality

Water quality impacts could arise from soil erosion of the stockpiles and the cleared areas which could lead to sedimentation of rivers. The overburden from the mining could resulting in acid Mine Drainage (AMD) when there is pro-longed exposure to air and water depending on the acid generating potential of the overburden.

8.2.1.5 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Permanent: Mitigation	6	Project life	5
Scale (7)	National	6	Local	3
Severity (7)	Very serious	5	Moderate	3
Likelihood (7)	Likely	5	Unlikely	3
Significance	Medium high	85	Low	33

8.2.1.6 Mitigation Description

Reduce the extent of the cleared areas at each particular time and construct berms around the topsoil/ overburden stockpiles. Test and isolate toxic overburden and treat before backfilling. Dust suppression to be implemented, on-going rehabilitation to be implemented and the water quality monitoring to be conducted on a monthly basis where negative water quality impacts are detected, the frequency of monitoring must be increased and the source of pollution must be detected.

8.2.2 Activity 6: Use and Maintenance of Haul Roads (Including Transportation of Coal to Washing Plant)

8.2.2.1 Impact Description: Surface Water Quantity

There will be decrease in water quantity reporting to the catchment as the length of the haul roads increased and the isolation of coal contaminated from the clean catchment.

8.2.2.2 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Project Life	5	Medium-term	3
Scale (7)	Regional	5	Local	3
Severity (7)	Serious medium term	4	Moderate	3
Likelihood (7)	Probable	4	Unlikely	3
Significance	Medium low	56	Low	27

8.2.2.3 Mitigation Description

It is important to minimise the disturbed area in order to limit the runoff volume that cannot report to the catchment. Well-constructed storm water drains are necessary to effectively direct clean water. The dirty water should be treated efficiently and where possible returned to the catchment.

8.2.2.4 Impact Description: Surface Water Quality

Negative Impacts could arise from dust generation and settling on the roads, soil erosion and the coal dust settling on the surface water environment. Pro-longed leaks and spillages could result in water quality deterioration.

8.2.2.5 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Project Life	5	Project life	5
Scale (7)	Regional	5	Local	3
Severity (7)	Very Significant	5	Moderate	3
Likelihood (7)	Almost certain	6	Probable	4
Significance	Medium high	90	Medium low	44

8.2.2.6 Mitigation description

Use dust suppression methods on the roads and regularly maintain haul roads to eliminate erosion. Maintain level of moisture in the coal during transportation. Use the dust covers on truck and oil leak trays. Monthly water quality monitoring is to be conducted on the surface water resources.

8.2.3 Activity 7: Removal of Coal (Mining Process) and ROM Coal Stockpile

8.2.3.1 Impact Description: Surface Water Quantity

There will be decrease in water quantity reporting to the catchment as the pits will capture and contain the rainfall and prevent free flow to the clean catchment. The isolation of coal contaminated areas reduces the clean catchment thus less water quantity reporting to the clean catchment.

8.2.3.2 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Project life	5	Medium-term	3
Scale (7)	Regional	5	Local	3
Severity (7)	Very serious	5	Moderate	3
Likelihood (7)	Almost certain	6	Unlikely	4
Significance	Medium high	90	Medium Low	36

8.2.3.3 Mitigation Description

It is important to once each phase of mining has been completed, backfill the voids and well grad to minimise the water prevented from reporting to the catchment. Pit dewatering should be implemented.

8.2.3.4 Impact Description: Surface Water Quality

Water contamination could result from leaching and toxic drainage of particulates and fines from ROM stockpile and from coal mining areas.

8.2.3.5 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Permanent- Mitigation	6	Project Life	5
Scale (7)	National	6	Local	3
Severity (7)	Very serious	5	Moderate	3
Likelihood (7)	Almost certain	6	Probable	4
Significance	Medium high	102	Medium low	44

8.2.3.6 Mitigation description

The use of bunding around the stockpiles to separate clean and dirty water after rainfall events can minimise impacts. Training of the coal handlers is important to reduce coal breakages that could result in fines that are easily transported to streams and rivers. Monthly water quality monitoring is to be conducted on the surface water resources.

8.2.4 Activity 8: Water Use & Storage on Site (Including Screening and Washing, PCD)

8.2.4.1 Impact Description: Surface Water Quantity

There will be decrease in water quantity reporting to the catchment due to impoundment of water in PCDs. The clean and dirty water separation reduces the clean water flowing to the catchment.

8.2.4.2 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Project Life	5	Project Life	5
Scale (7)	Regional	5	Local	3
Severity (7)	Serious medium term	4	Moderate	3
Likelihood (7)	Likely	5	Probable	4
Significance	Medium low	70	Medium Low	40

8.2.4.3 Mitigation Description

Recycle water used and encourage effective water treatment thus clean water is released to the clean catchment where possible.

8.2.4.4 Impact Description: Surface Water Quality

Seepage of dirty water to the natural streams and accidental spillages from PCDs and flooding of PCDs in extreme rainfall events could result in surface water quality contamination. The impacts of deteriorated water entering the surface water resources will exacerbate the already quality stressed catchment and WMA particularly the most vulnerable water users.

8.2.4.5 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Permanent- Mitigation	6	Project Life	5
Scale (7)	Regional	5	Region	5
Severity (7)	Significant	6	Moderate	3
Likelihood (7)	Likely	5	Unlikely	3
Significance	Medium high	85	Medium low	39

8.2.4.6 Mitigation description

No activities to take place within 100 m from a water resource of inside the 1: 100 yr floodline. There has to be strict adherence to health and safety and the risk assessment has to be conducted regularly. The PCD constructed should be adequately lined to prevent the leaching into the ground and also should have adequate capacity to contain a 1: 50 year 24 hr flood volume based on the peak flows determined.

8.2.5 Activity 9: Storage, Handling and Treatment of Hazardous Products (Fuel, Explosives, Oil) and Waste Activities (Waste, Sewage, Discard, PCD)

8.2.5.1 Impact Description: Surface Water Quantity

There will be increased surface runoff and decreased water quantity reporting to the catchment.

8.2.5.2 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Project Life	5	Medium-term	3
Scale (7)	Regional	5	Local	3
Severity (7)	Moderate	3	Moderate	3
Likelihood (7)	Unlikely	3	Unlikely	3
Significance	Medium low	39	Low	27

8.2.5.3 Mitigation Description

It is important to minimise the storage area by utilising few designated areas and bring in chemicals on site only when they are needed for use.

8.2.5.4 Impact Description: Surface Water Quality

Negative impacts could arise from hazardous substances spillages and leakages from the storage facilities.

8.2.5.5 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Permanent- No Mitigation	7	Medium term	3
Scale (7)	National	6	Local	3
Severity (7)	Significant	6	Moderate	3
Likelihood (7)	Probable	4	Unlikely	3
Significance	Medium high	76	Low	27

8.2.5.6 Mitigation Description

Ensure that storage areas are on hard park areas with bunding to hold spillages, access control to storage areas, allow only trained and authorized personnel to handle hazardous materials, employ on accredited contractors for the removal of hazardous waste, all vehicles to be fitted with oil leak trays, regulated sewer treatment and disposal facilities and on-going monitoring of surface water resources (weekly and monthly during construction and operation respectively).

8.2.6 Activity 10: Concurrent Replacement of Overburden, Topsoil and Re-vegetation

8.2.6.1 Impact Description: Surface Water Quantity

There will be neutral impacts arising from the replacement and re-vegetation of project area as some of the runoff is returned to catchment. Neutral impact because although there are improvements in the state of environment it can never be returned to the original or pre mining state)

8.2.6.2 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Project Life	5	Long-term	4
Scale (7)	Regional	5	Local	3
Severity (7)	Moderate	3	Moderate	3
Likelihood (7)	Likely	5	Unlikely	3
Significance	Medium low	65	Low	30

8.2.6.3 Mitigation Description

Maximise the positive impacts by monitoring the replacement of overburden and the re-vegetation process.

8.2.6.4 Impact Description: Surface Water Quality

Water quality deterioration could result from toxic overburden and from improper handling of the re-vegetation process resulting in siltation and sedimentation from soil erosion.

8.2.6.5 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Permanent- Mitigation	6	Project Life	5
Scale (7)	Regional	5	Local	3
Severity (7)	Significant	6	Serious medium term	4
Likelihood (7)	Likely	5	Unlikely	3
Significance	Medium high	85	Medium low	36

8.2.6.6 Mitigation description

Sediment control should be implemented, and toxic overburden should be segregated and treated before being replaced to the area.

8.3 Decommissioning Phase

Decommissioning of the project entails activities such as demolition of infrastructure including the makeshift site offices and workshops as well as temporary sanitary facilities rehabilitation and monitoring of the environment.

8.3.1 Activity 11: Demolition & Removal of all Infrastructure (incl. Transportation Offsite)

8.3.1.1 Impact Description: Surface Water Quantity

There will be increased surface runoff which will be contaminated prevented from reporting to the catchment.

8.3.1.2 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Medium term	3	Short term	2
Scale (7)	Regional	5	Regional	5
Severity (7)	Minor effects	2	Moderate	3
Likelihood (7)	Unlikely	3	Highly unlikely	1
Significance	Low	30	Low	10

8.3.1.3 Mitigation Description

It is important to minimise the disturbed area in order to limit the runoff volume that cannot report to the catchment. On-going rehabilitation and monitoring of the rehabilitated areas should ensure free drainage to the catchment.

8.3.1.4 Impact Description: Surface Water Quality

Spillage of hazardous substances and hydrocarbon containing material during storage, spillages of material during transportation, dust and erosion form the vehicular movement and the exposed ground respectively could result in water quality deterioration.

8.3.1.5 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Permanent: Mitigation	6	Medium term	3

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Scale (7)	Regional	5	Local	3
Severity (7)	Significant	6	Moderate	3
Likelihood (7)	Likely	5	Probable	3
Significance	Medium high	85	Low	27

8.3.1.6 Mitigation Description

Only accredited contractors should be employed to decommission and dispose of the infrastructure at the correct disposal facilities. Dust suppression to be implemented during the decommissioning phase. Water quality monitoring frequency should be increased to weekly. The decommissioned area should be cleaned up to prevent runoff falling on the site to be contaminated. The cleaned up area must be rehabilitated to prevent soil erosion and siltation of the water resources.

8.3.2 Activity 12: Rehabilitation (Spreading of Soil, Re-Vegetation & Profiling/ Contouring)

8.3.2.1 Impact Description: Surface Water Quantity

The rehabilitation will result in the return of runoff to the catchment and increased runoff. This is a neutral impact since the catchment can never be returned to the pre-project state.

8.3.2.2 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Long-term	4	Medium term	3
Scale (7)	Regional	5	Regional	5
Severity (7)	Moderate	3	Minor effects	2
Likelihood (7)	Rare	2	Rare	2
Significance	Low	24	Low	20

8.3.2.3 Mitigation Description

It should be ensured that there is no damming but that runoff can freely drain to the catchment.

8.3.2.4 Impact Description: Surface Water Quality

There will be a neutral impact on surface water quality since some of the impacts that occurred during the construction and operational phases will have a cumulative impact on the surface water quality.

8.3.2.5 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Long-term	4	Long term	4
Scale (7)	Regional	5	Local	3
Severity (7)	Moderate	3	Moderate	3
Likelihood (7)	Unlikely	3	Rare	2
Significance	Medium low	36	Low	22

8.3.2.6 Mitigation Description

Water quality monitoring and rehabilitation monitoring must be implemented to ensure that there is no soil erosion that could result in the water quality impacts. The rehabilitated areas have to be vegetated to reduce soil erosion. Cumulative impacts have to be monitored through a monitoring programme that will last at least three years after decommissioning.

8.3.3 Activity 13: Installation of Post Closure Water Management Infrastructure

8.3.3.1 Impact Description: Surface Water Quantity

Some runoff can be closed off by post closure water management systems as these should intercept all the water so will most likely store large volumes of water that could otherwise been released to the catchment.

8.3.3.2 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Long-term	4	Medium term	2
Scale (7)	Municipal area	4	Local	3
Severity (7)	Moderate	3	Moderate	3
Likelihood (7)	Unlikely	3	Rare	2
Significance	Low	33	Low	16

8.3.3.3 Mitigation Description

Management should include treatment facilities of the water so that collected water in the post closure can be rechanneled to the catchment when adequately treated to conform to standards.

8.3.3.4 Impact Description: Surface Water Quality

There will be a neutral impact on surface water quality since some of the impacts that occurred during the construction and operational phases will still be present in the surface water resources.

8.3.3.5 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Long-term	4	Long term	4
Scale (7)	Regional	5	Local	3
Severity (7)	Moderate	3	Moderate	3
Likelihood (7)	Unlikely	3	Rare	2
Significance	Medium low	36	Low	22

8.3.3.6 Mitigation Description

Cumulative impacts have to be monitored through a monitoring programme that will last at least three years after decommissioning. Decant studies should be conducted.

8.3.4 Activity 14: Environmental Monitoring and Decommissioning Activities

8.3.4.1 Impact Description: Surface Water Quantity

As much storm water as possible will be allowed to flow back to the catchment. This is a neutral impact since the catchment can never be returned to the pre-project hydrological state.

8.3.4.2 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Medium term	3	Medium term	3
Scale (7)	Regional	5	Regional	5
Severity (7)	Moderate	3	Minor effects	2
Likelihood (7)	Probable	4	Rare	2

Significance	Medium Low	44	Low	20

8.3.4.3 Mitigation Description

It is important to ensure that in rehabilitation, the area is also well vegetated to reduce the dirty surface runoff created. It should also be ensured that there is no damming but that runoff can freely drain to the catchment.

8.3.4.4 Impact Description: Surface Water Quality

There will be a neutral impact on surface water quality since some of the impacts that occurred during the construction and operational phases will still be present in the surface water resources. However monitoring will detect any causes of concern and any water quality issues post mining.

8.3.4.5 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Project life	5	Medium term	3
Scale (7)	Municipal	4	Local	3
Severity (7)	Moderate	3	Moderate	3
Likelihood (7)	Unlikely	3	Rare	2
Significance	Medium low	36	Low	18

8.3.4.6 Mitigation Description

Water quality monitoring and rehabilitation monitoring must be implemented for at least three years after decommissioning.

8.3.5 Activity 15: Storage, Handling and Retreatment of Hazardous Products (Fuel, Explosives, Oil) and Waste Activities (Waste, Sewage, Discard)

8.3.5.1 Impact Description: Surface Water Quantity

There will be increased surface runoff which will be contaminated and decrease in water quantity reporting to the catchment.

8.3.5.2 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Short term	2	Short term	2
Scale (7)	Local	3	Limited	2
Severity (7)	Serious medium term	4	Moderate	3
Likelihood (7)	Probable	4	Unlikely	3
Significance	Medium low	36	Low	21

8.3.5.3 Mitigation Description

It is important to minimise the disturbed area in order to limit the runoff volume that cannot report to the catchment. Ensure the use of few designated areas to reduce the contaminated area that could lead to reduced runoff surface area. On-going rehabilitation and monitoring of the rehabilitated areas could ensure free drainage to the catchment.

8.3.5.4 Impact Description: Surface Water Quality

Water quality deterioration from possible spillages during transportation and including discard could flow into the environment.

8.3.5.5 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Project life	5	Short term	2
Scale (7)	Local	3	Limited	2
Severity (7)	Serious medium term	4	Moderate	3
Likelihood (7)	Probable	4	Rare	2
Significance	Medium high	48	Low	14

8.3.5.6 Mitigation Description

Only accredited contractors should be employed to handle hazardous substances and water quality monitoring frequency should be increased to weekly.

8.4 Post Closure Phase

Post Closure phase of the project entails activities such as rehabilitation and monitoring.

8.4.1 Activity 16: Post-Closure Monitoring and Rehabilitation

8.4.1.1 Impact Description: Surface Water Quantity

As much water as possible will be returned to the catchment and runoff increased when post closure rehabilitation is carried out. This is a neutral impact since the catchment can never be returned to the pre-project state.

8.4.1.2 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Long-term	4	Medium term	3
Scale (7)	Regional	5	Regional	5
Severity (7)	Moderate	3	Minor effects	2
Likelihood (7)	Rare	2	Rare	2
Significance	Low	24	Low	20

8.4.1.3 Mitigation Description

It is important to perform surface water quantity monitoring.

8.4.1.4 Impact Description: Surface Water Quality

Neutral impacts result from the monitoring and it will be possible to pick out post closure impacts such as AMD and impacts from decant.

8.4.1.5 Impact Assessment

Parameter	Impact Pre-Mitigation		Impact Post-Mitigation	
Duration (7)	Project Life	5	Project life	5
Scale (7)	Local	3	Local	3
Severity (7)	Moderate	3	Moderate	3
Likelihood (7)	Probable	4	Unlikely	3
Significance	Medium low	44	Low	33

8.4.1.6 Mitigation Description

Ensure that water quality sampling continues at least 3 years post closure especially for decant.

8.5 Impact Assessment Statement

The water environment in which the project will take place is in a relatively pristine environment based on the SANS 241 standards but is largely impacted when compared to the WQOs. This is as a result of the overall stressed nature of the WMA (in terms of quality and quantity). The execution of the project must ensure that there are no/minimum impacts to the surface water environment particularly in terms of quality. The implementation of monitoring as an early impact detection tool must be enforced.

The on-going rehabilitation will significantly reduce the significance of the impacts on quality and quantity. This has to be implemented in the prescribed manner (particularly with the backfilling with overburden and discard).

The most significant impacts identified relate to surface water quality, thus the execution of the project must be sensitive to the likely potential of these impacts arising. There are already existing cumulative impacts on the surface water resources within the WMA the exacerbation thereof must as much as possible be prevented.

The impact assessment exercise indicates that more impacts will be of surface water quality, thus implementing a surface water quality monitoring programme is paramount to the execution of the project. The quality impacts are likely to be most significant where the hazardous substances are handled, and where overburden is stockpiled. Coal fines would also present a noticeable impact on the water quality. It is also important to ensure that the frequency of monitoring is increased in the construction and decommissioning phases to enable the early detection of negative impacts.

The major surface water risks and findings within the project sub catchments are:

- Contamination of the surface water quality particularly where there is storage and use of hazardous substances and sewer storage;
- The construction of the infrastructure including haul roads, pipeline which include removal of vegetation that can result in major soil erosion that could result in siltation and deterioration of the water quality of the Wilge River;
- The mining process, crushing and screening and handling of the ROM stockpiles could result in water contamination from the generated coal fines;
- Blasting could arise in water quality and quantity problems as the explosives may contain nitrates and could result in water contamination whilst at the same time improper blasting could result in unnecessary cracks in the aquifer bed thus altering the surface water-groundwater interaction reducing stream flows;
- The removal of surface infrastructure could result in major and minor spillages, and procedures for water management and decommissioning if followed carefully could prevent/reduce the significance of any spillages. Good waste handling and appropriate disposal could reduce these impacts;
- The re-vegetation and contouring of mining footprint will result in a neutral impact as it will result in restoring the clean runoff to the catchment once the reclamation and rehabilitation is completed; and
- The only residual impact will be the altered hydrology of the sub catchment which can remain altered even with the construction of closure water management structures.

9 CUMULATIVE IMPLACTS

Coal mining presents negative water quality impacts which emanate from the activities in the form of coal waste and coal slurry. These result in deterioration and alterations of the natural wetlands, prolonged risk to aquatic life, heavy metal bioaccumulation in plants and livestock as well as health risks to humans.

The proposed project area water resources have already been negatively impacted upon and the negative impacts from mining will further deteriorate the environment. In order to reduce the deterioration of the water environment, the execution water management strategies and through the implementation of mitigation measures where the impacts arise should be performed.

The most significant impacts relate to the contamination of surface water in the catchment during the operational activities and reduce stream flows through the alteration of the aquifer bed resulting from blasting activities.

Although there will be alteration of the surface hydrology and volume of runoff reporting to the catchment, the minimization of the dirty area will limit the impacts and subsequent contaminated volume of runoff. The backfilling, grading and contouring of the rehabilitated areas should also be implemented to prevent runoff damming and to ensure that the surface runoff reports to the catchment.

10 MITIGATION MEASURES AND MANAGEMENT PLAN

Mitigation measures and management strategies to address the identified impacts are presented in Table 15.

Table 15: Summary of the Impact Mitigation and Management Strategies

Ranking	Impact	Mitigation/ Management measure	Objectives	Frequency of Mitigation	Legal Requirements	Recommended Action Plans	Timing of implementation	Responsible Person	Significance after mitigation
High risk (108-114)	Water quality deterioration could result from blasting activities, from the spillages of explosives (nitrate and ammonia) and river sedimentation	Ensure water quality monitoring and allow only trained and certified personnel to conduct the blasting in the correct way utilising the correct quantities of explosives Separation of clean and dirty areas and minimization of the dirty area	Prevent water quality deterioration.	Daily monitoring during the operational phase; Water quality monitoring on a monthly basis	GN R 704; DWA BPGs	Adherence to the Spill Prevention/Emergency response plan; Monitoring of the mine's blasting licences and keeping record of them; and On-going waste management strategies for explosives waste.	Construction Phase	Project Engineer; Environmental Control Officer	Medium-low

Ranking	Impact	Mitigation/ Management measure	Objectives	Frequency of Mitigation	Legal Requirements	Recommended Action Plans	Timing of implementation	Responsible Person	Significance after mitigation
Medium High Risk (107-73)	Water quality deterioration as a result of siltation from soil erosion, dust deposition, spillages of hazardous substances and waste and washing off of coal fines into streams.	Implement dust suppression; Vegetate topsoil isolation berms; Prevent dirty water reaching the surface water resources by isolating ROM stockpile; Implement hazardous substances handling procedures and prevent spillages into the environment	Prevent water quality deterioration from siltation, waste and hazardous substances and coal fines.	During construction, operation and decommissioning phases; Daily monitoring of areas that could result in soil erosion	GN R 704; DWA BPGs	Isolate clean and dirty areas with vegetated topsoil berms; Implement dust suppression with water tankers or application of dust suppression chemicals; Training personnel on handling of coal fines on loading to reduce coal breakages into fines; Implement hazardous substances handling procedures	Life of Project	Environmental Control officer; Project Engineer	Medium-Low to Low

Ranking	Impact	Mitigation/ Management measure	Objectives	Frequency of Mitigation	Legal Requirements	Recommended Action Plans	Timing of implementation	Responsible Person	Significance after mitigation
	Water quantity impacts as a result of the increased surface runoff falling on cleared ground and not allowed to report to the catchment as well as the diverted stream flows from aquifer bed fractures and storm water management systems.	Minimise the disturbed area; On-going rehabilitation of the mined out areas; Proper blasting techniques to be followed to minimise fractures; Contouring and vegetation of the rehabilitated areas	To reduce the water quantity that is prevented from reporting to the catchment.	Life of project	GN R 704; DWA BPGs	On-going rehabilitation (minimization of the dirty area) when mining and backfilling and vegetation to ensure that more runoff can report to the catchment; Adhere to the blast patterns and distance from streams to prevent unnecessary cracks and stream diversions.	Life of Project	Site Mine Engineer Environmental Control Officer	Low

Ranking	Impact	Mitigation/ Management measure	Objectives	Frequency of Mitigation	Legal Requirements	Recommended Action Plans	Timing of implementation	Responsible Person	Significance after mitigation
Medium Low(60-39)	Water quality deterioration from dust deposition and spillages of construction material.	Implement dust suppression strategies; Ensure trained personnel operate the infrastructure.	Prevent water quality deterioration from dust deposition and construction material spillages	During construction and decommissioning phases	GN R 704; DWA BPGs	On-going implementation of dust suppression; Monitoring of construction and evaluation of training of machine operators.	Construction and decommissioning	Environmental Control Officer and Site Engineer	Low
	Reduced water quantity reporting to the catchment.	On-going rehabilitation and minimization of dirty areas	Minimize the volume that does not report to the catchment.	During construction with daily monitoring throughout the life of the project	GN R 704; DWA BPGs	On-going backfilling and vegetation of the areas as the pipeline is laid; Monitoring for vegetation growth	Construction and life of project	Environmental Control officer and Project Engineer	Low

11 MONITORING PROGRAMME

A monitoring programme is essential as a management tool to detect negative impacts as they arise and to ensure that the necessary mitigation measures are implemented.

11.1 Surface Water Quality

Various water quality variables will be monitored (Table 4) particularly the Variables of Concern (VoC) identified in the baseline analyses based on the WQO for Wilge River such as Fe, NH_3, SO_4,Cl, NO_3 and EC on a frequency prescribed by the activities (e.g. weekly during construction and decommissioning and monthly during operation). Heavy metals can be monitored on a quarterly basis and from the overburden before it is backfilled since they could result from the overburden as well as coal mining waste. These include Cadmium, Nickel, Selenium, Arsenic, Mercury and Beryllium. Surface water monitoring will be conducted at strategically identified locations.

11.2 Surface Water Quantity

Where possible the water quantity and channels geometry will be monitored in extreme flood events to determine any impact of the mining on river channels and water quantity in general, in the catchment.

11.3 Objectives of Monitoring Programme

The objective of the monitoring plan would be to monitor the impact of the coal mining, coal waste and its subsequent infrastructure through the continuous analyses of water quality and quantity (where possible).

11.4 Monitoring Frequency

The proposed monitoring programme for surface water quality will be implemented at different frequencies over the duration of the project as follows:

Phase	Variables	Frequency
Construction	All	Weekly
Operation	All	Monthly; Where negative impacts are detected (spillage) frequency to be increased to weekly
Decommissioning	All	Weekly

12 CONCULSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are made on the impact assessment of the site.

12.1 Conclusions

The impact assessment conclusions are as follows:

- The most significant impacts could affect the surface water quality particularly since the catchment is already stressed;
- The handling of hazardous substances and waste substances could result in highly significant impacts as a result of huge spillages or pro-longed leakages;
- The potential of siltation of the water resources is likely since there could be soil erosion and dust deposition; and
- Surface water quantity will be impacted upon as the contaminated runoff will not be allowed to report to the catchment.

12.2 Recommendations

It is therefore recommended that the following be taken into considerations:

- Regular monitoring and dust suppression must be carried out;
- The monitoring on the overburden for toxicity must be carried out even before the overburden is backfilled;
- The blasting methods and protocols should be adhered to and monitored;
- The storage and handling of hazardous material must be only by authorized personnel, disposal of the used up material be undertaken by accredited contractors;
- On-going rehabilitation when mining and clearing areas should be carried out to minimise the contamination of surface runoff that is prevented to report to the catchment;
- The process of construction should be carried out in the dry season to prevent the erosion and subsequent siltation of surface water resources;
- The surface water management and monitoring plan be adhered to and the responsible personnel should be trained on the contents in order to execute the project with minimum surface water impacts; and
- The management plan must be reviewed on an on-going basis and adapted accordingly to ensure that it stays relevant.

13 REFERENCES

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Appendix A: Plans

Plan 1: Regional Setting

Plan 2: Mine Plan

Plan 3: Land Tenure

Plan 4: Catchment Boundaries

Plan 5: Water Resources

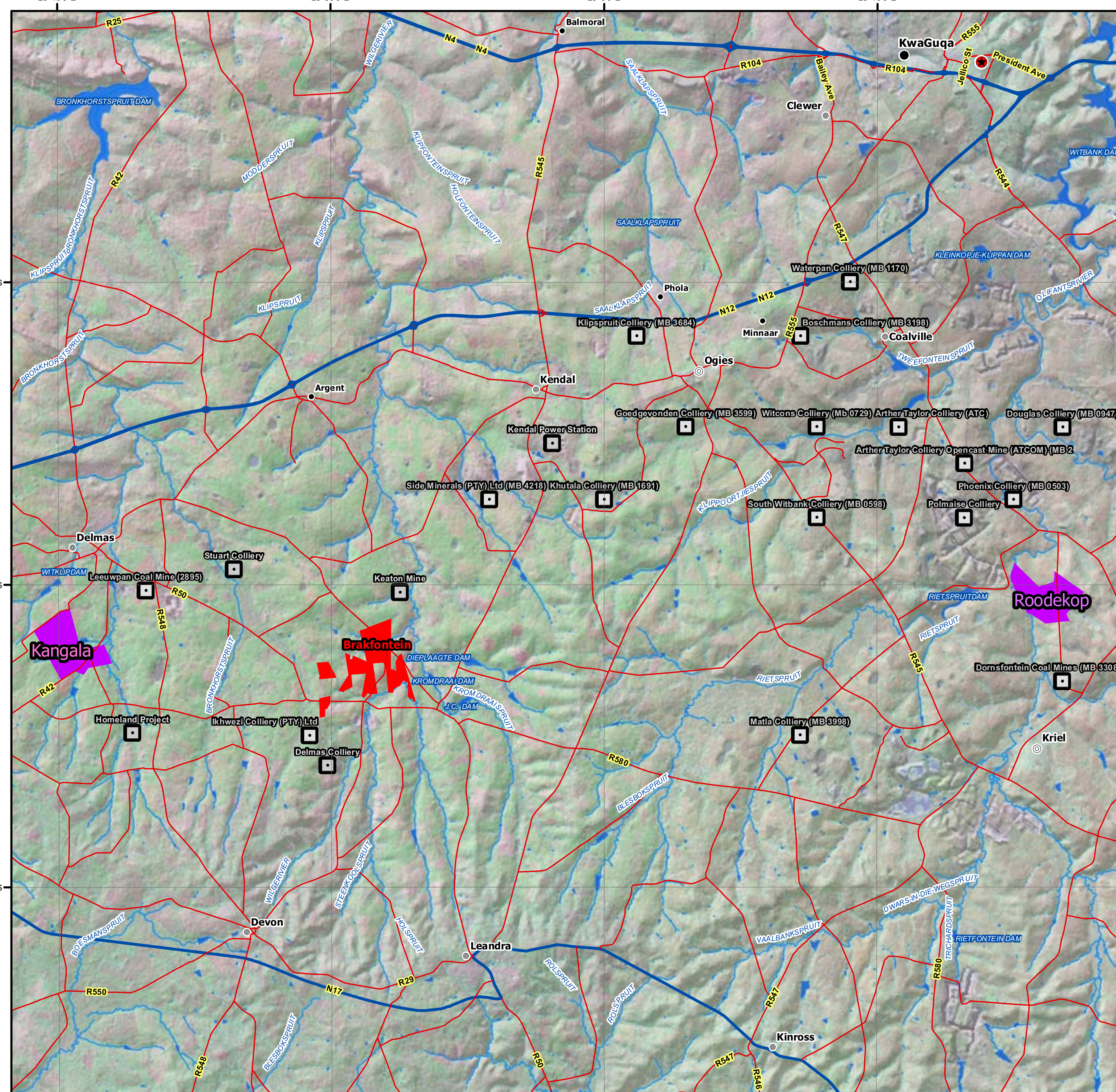
Plan 6: Surrounding Mining Activities

Plan 7: Water Quality Sampling Points

Plan 6

Universal Coal Brakfontein MRA

Surrounding Mining Activities



Legend

- Project Area
- Other Universal Coal Project Areas
- Surrounding Collieries / Mining Related Acitivities
- City
- Major Town
- Secondary Town
- Other Town
- Settlement
- Main Roads
- National Roads
- Non-Perennial Stream
- Perennial Stream
- Inland Water Area

universal coal plc

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Projection: Transverse Mercator
Datum: Hartebeesthoek 1994
Central Meridian: 29°E

Ref #: amc.UNI1292.201208.095
Revision Number: 1
Date: 15/08/2012

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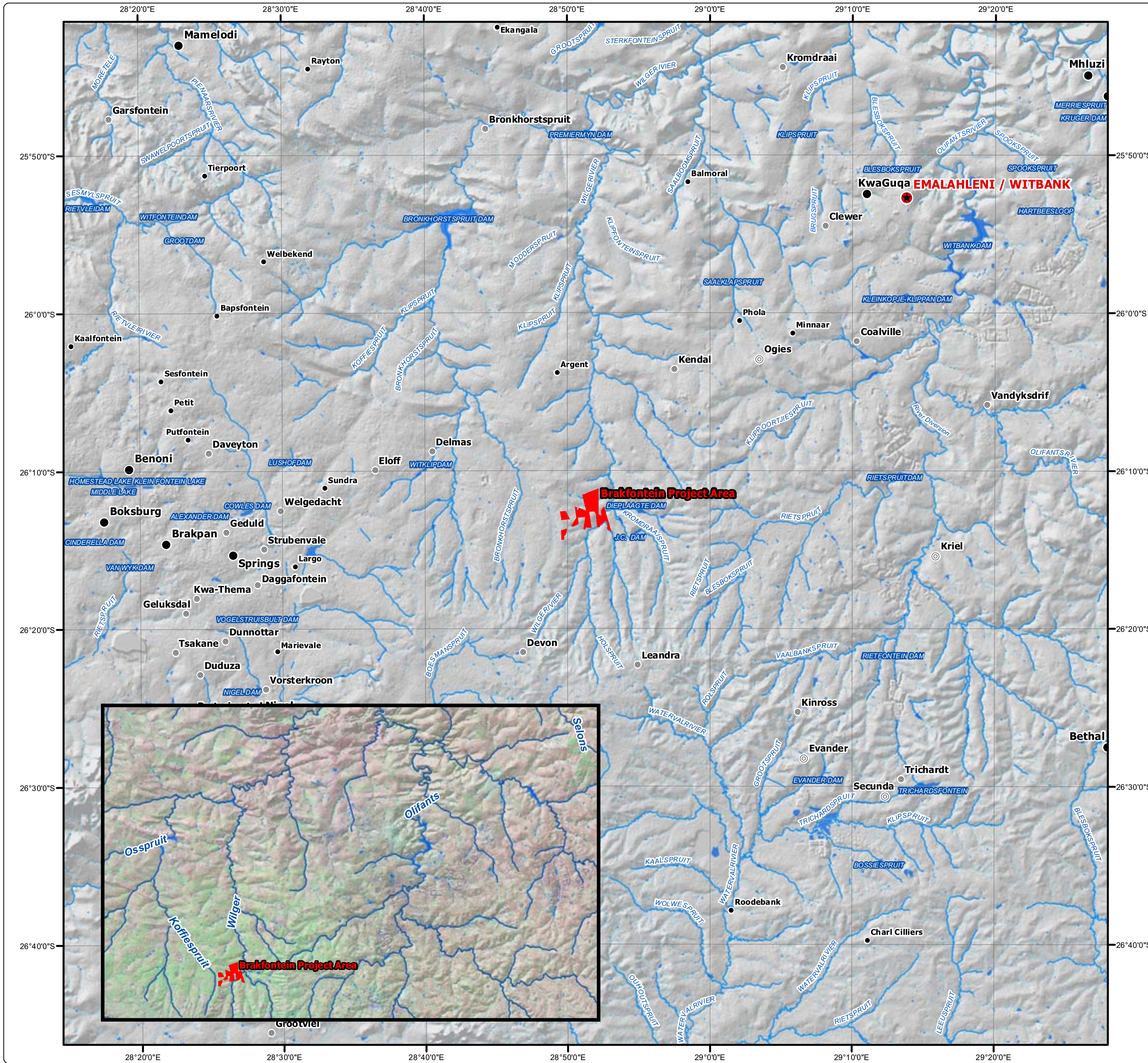
Kilometres
1:250 000

Plan 5

Universal Coal Brakfontein MRA

Water Resources



Legend

- Project Area
- City
- Major Town
- Secondary Town
- Other Town
- Settlement
- Non-Perennial Stream
- Perennial Stream
- Inland Water Area

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Central Meridian: 29°E

Ref #: amc.UNI1292.201208.094
Revision Number: 1
Date: 15/08/2012

N

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Kilometres
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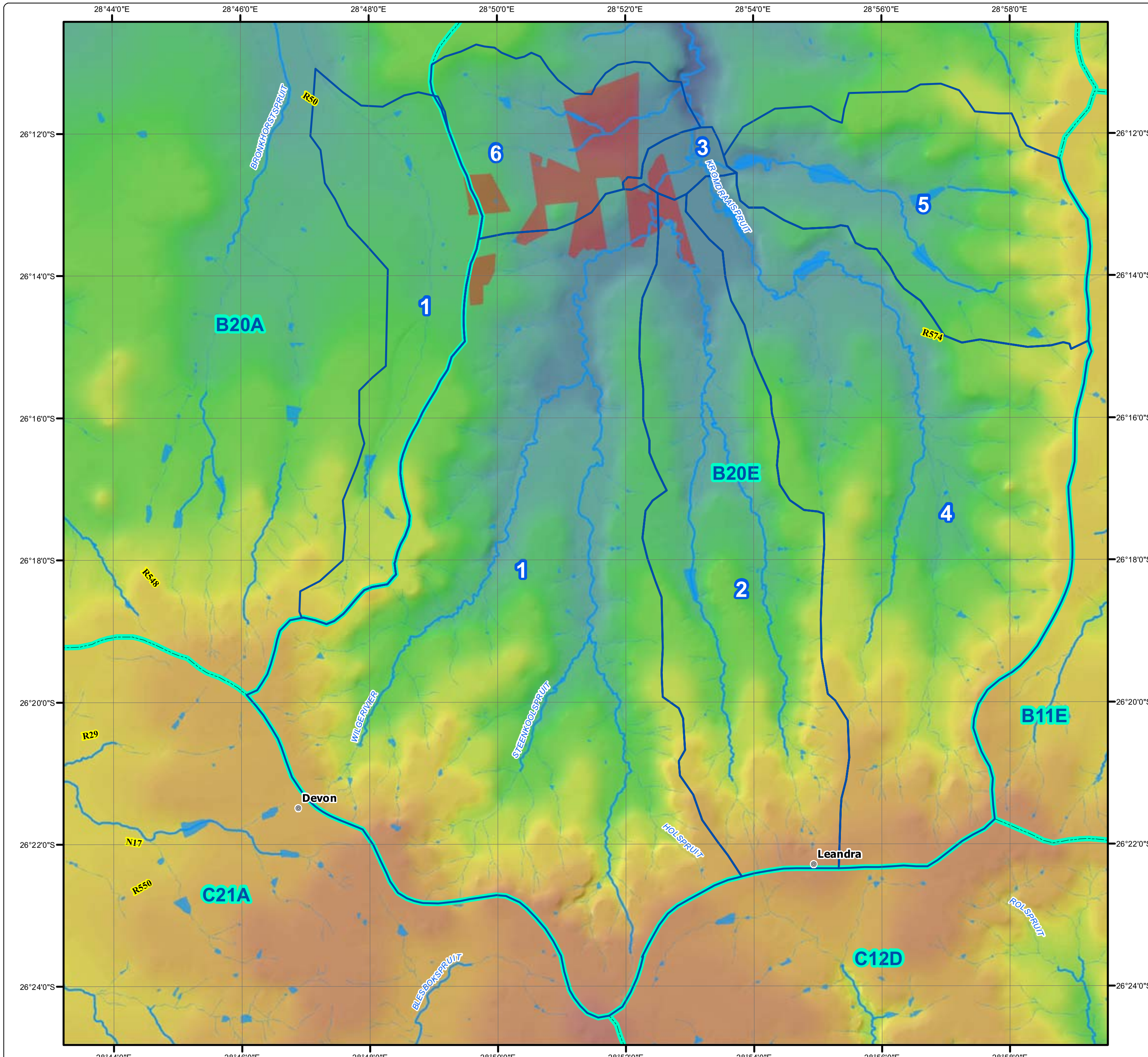
Plan 4

Universal Coal Brakfontein MRA

Catchments Boundaries



Legend

- Project Area
- Town
- Quaternary Catchments
- Sub-Catchments
- Non-Perennial River
- Perennial River

Elevation (m.a.m.s.l)

High : 1701

Low : 1518

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Datum: Hartebeesthoek 1994
Central Meridian: 29°E

Ref #:amc.UNI1292.201207.052
Revision Number: 1
Date: 17/07/2012

N

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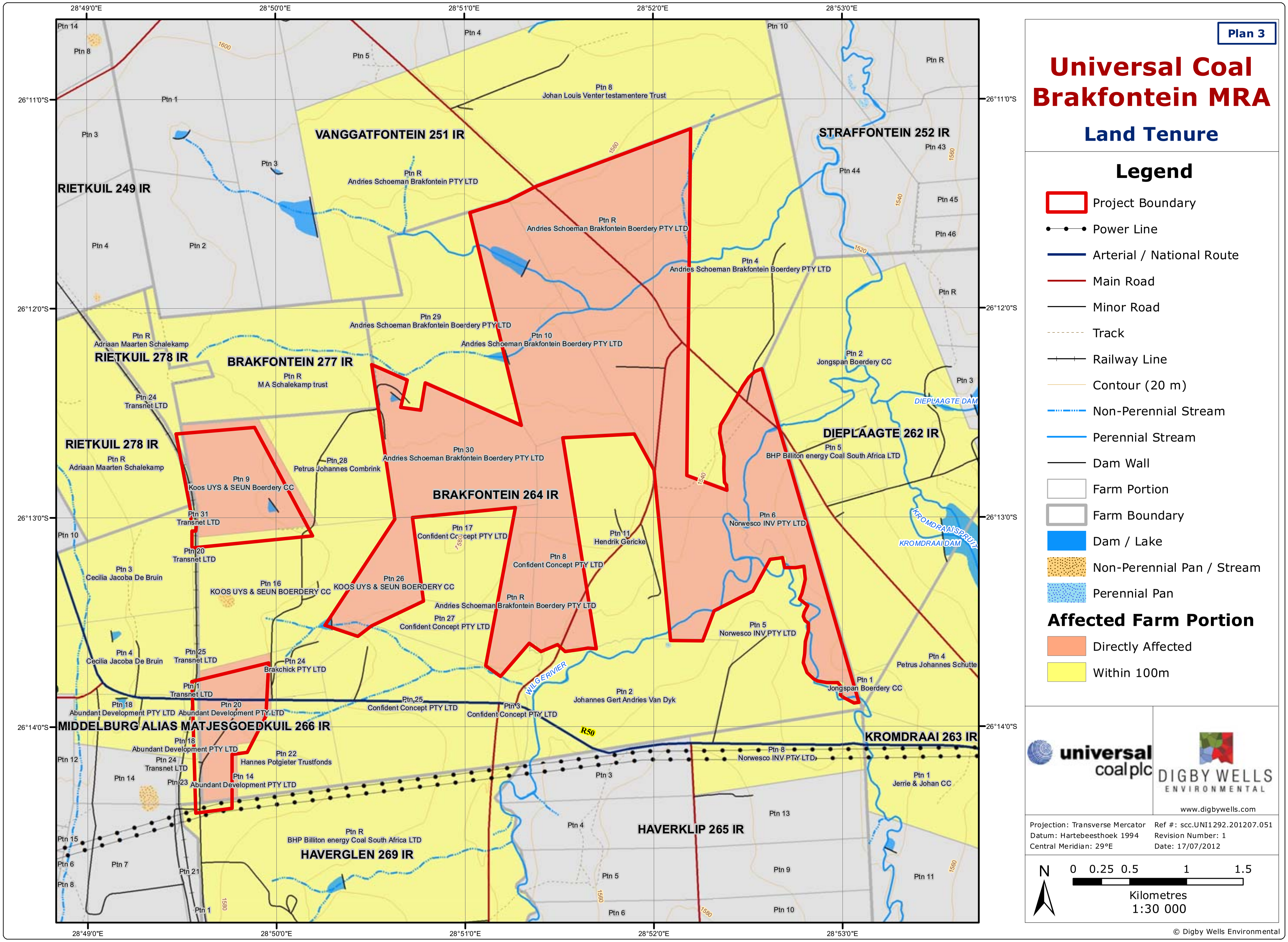
Kilometres

1:100 000



Plan 3
Universal Coal Brakfontein MRA
Land Tenure
Legend
Project Boundary
Power Line
Arterial / National Route
Main Road
Minor Road
Track
Railway Line
Contour (20 m)
Non-Perennial Stream
Perennial Stream
Dam Wall
Farm Portion
Farm Boundary
Dam / Lake
Non-Perennial Pan / Stream
Perennial Pan
Affected Farm Portion
Directly Affected
Within 100m
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Datum: Hartebeesthoek 1994
Central Meridian: 29°E
Ref #: scc.UNI1292.201207.051
Revision Number: 1
Date: 17/07/2012
N
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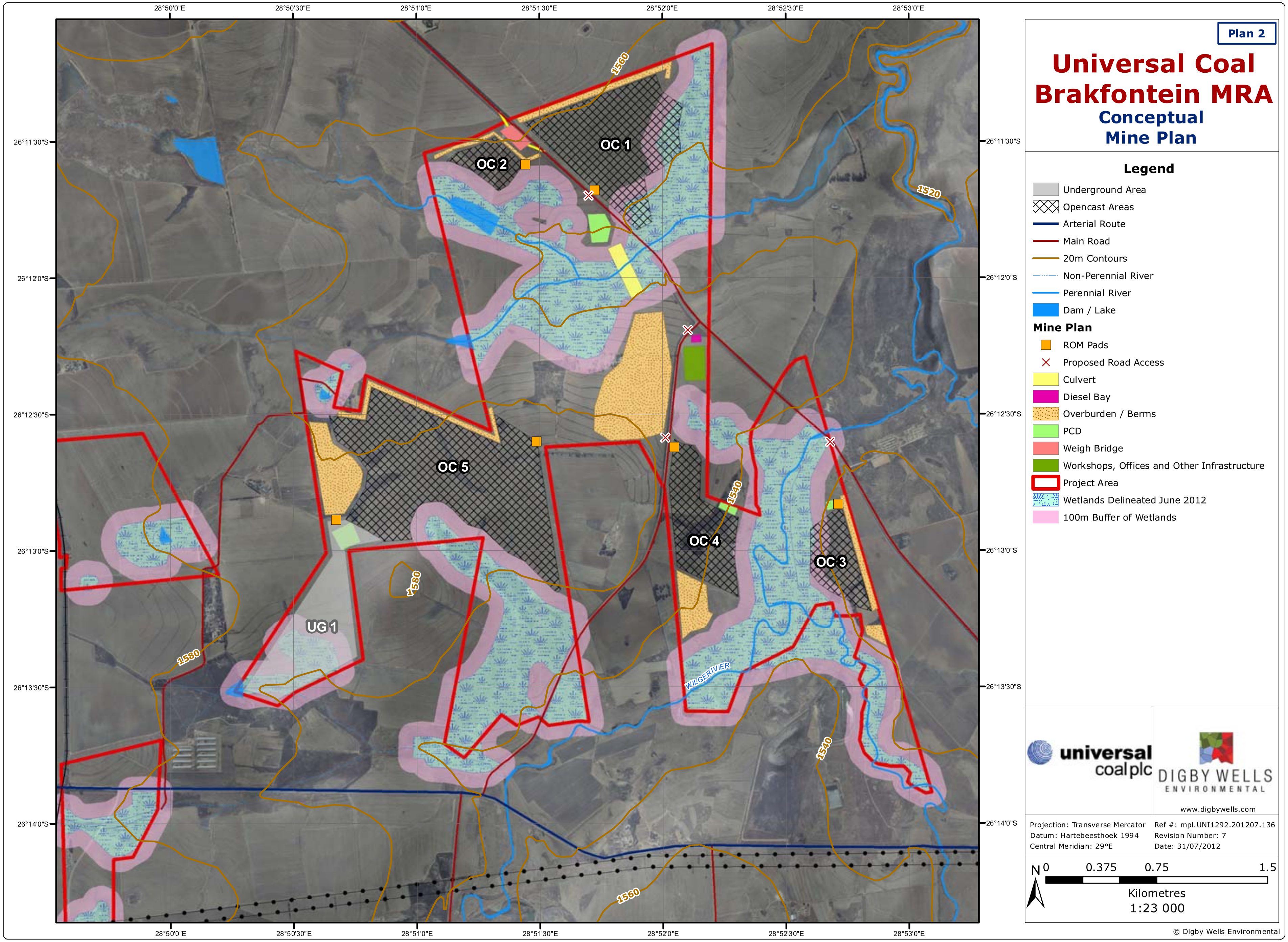
Kilometres
1:30 000
© Digby Wells Environmental
VANGGATFONTEIN 251 IR
STRAFFONTEIN 252 IR
RIETKUIL 249 IR
RIETKUIL 278 IR
BRAKFONTEIN 277 IR
BRAKFONTEIN 264 IR
DIEPLAAGTE 262 IR
KROMDRAAI 263 IR
MIDDELBURG ALIAS MATJESGOEDKUIL 266 IR
HAVERKLIP 265 IR
HAVERGLEN 269 IR
Ptn 8
Johan Louis Venter testamentere Trust
Ptn R
Andries Schoeman Brakfontein PTY LTD
Ptn R
Andries Schoeman Brakfontein Boerdery PTY LTD
Ptn 4
Andries Schoeman Brakfontein Boerdery PTY LTD
Ptn 29
Andries Schoeman Brakfontein Boerdery PTY LTD
Ptn 10
Andries Schoeman Brakfontein Boerdery PTY LTD
Ptn R
MA Schalekamp trust
Ptn R
Adriaan Maarten Schalekamp
Ptn 24
Transnet LTD
Ptn 30
Andries Schoeman Brakfontein Boerdery PTY LTD
Ptn 28
Petrus Johannes Combrink
Ptn 9
Koos UYS & SEUN Boerdery CC
Ptn 31
Transnet LTD
Ptn 20
Transnet LTD
Ptn 3
Cecilia Jacoba De Bruin
Ptn 16
KOOS UYS & SEUN BOERDERY CC
Ptn 26
KOOS UYS & SEUN BOERDERY CC
Ptn 17
Confident Concept PTY LTD
Ptn 8
Confident Concept PTY LTD
Ptn 11
Hendrik Gericke
Ptn R
Andries Schoeman Brakfontein Boerdery PTY LTD
Ptn 27
Confident Concept PTY LTD
Ptn 4
Cecilia Jacoba De Bruin
Ptn 25
Transnet LTD
Ptn 24
Brakchick PTY LTD
Ptn 1
Transnet LTD
Ptn 18
Abundant Development PTY LTD
Ptn 20
Abundant Development PTY LTD
Ptn 25
Confident Concept PTY LTD
Ptn 3
Confident Concept PTY LTD
Ptn 2
Johannes Gert Andries Van Dyk
Ptn 6
Norwesco INV PTY LTD
Ptn 5
Norwesco INV PTY LTD
Ptn 5
BHP Billiton energy Coal South Africa LTD
Ptn 2
Jongspan Boerdery CC
Ptn 1
Jongspan Boerdery CC
Ptn 4
Petrus Johannes Schutte
Ptn 8
Norwesco INV PTY LTD
Ptn 1
Jerrie & Johan CC
Ptn 18
Abundant Development PTY LTD
Ptn 22
Hannes Potgieter Trustfonds
Ptn 24
Transnet LTD
Ptn 14
Abundant Development PTY LTD
Ptn 23
Ptn R
BHP Billiton energy Coal South Africa LTD
DIEPLAAGTE DAM
KROMDRAAISPRUIT
KROMDRAAI DAM
WILGERIVIER
R50



Plan 2
Universal Coal
Brakfontein MRA
Conceptual
Mine Plan
Legend
Underground Area
Opencast Areas
Arterial Route
Main Road
20m Contours
Non-Perennial River
Perennial River
Dam / Lake
Mine Plan
ROM Pads
Proposed Road Access
Culvert
Diesel Bay
Overburden / Berms
PCD
Weigh Bridge
Workshops, Offices and Other Infrastructure
Project Area
Wetlands Delineated June 2012
100m Buffer of Wetlands
OC 1
OC 2
OC 3
OC 4
OC 5
UG 1
WILGERIVIER
1520
1540
1560
1580
28°50'0"E
28°50'30"E
28°51'0"E
28°51'30"E
28°52'0"E
28°52'30"E
28°53'0"E
26°11'30"S
26°12'0"S
26°12'30"S
26°13'0"S
26°13'30"S
26°14'0"S
universal coal plc
DIGBY WELLS ENVIRONMENTAL
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Projection: Transverse Mercator
Datum: Hartebeesthoek 1994
Central Meridian: 29°E
Ref #: mpl.UNI1292.201207.136
Revision Number: 7
Date: 31/07/2012
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Kilometres
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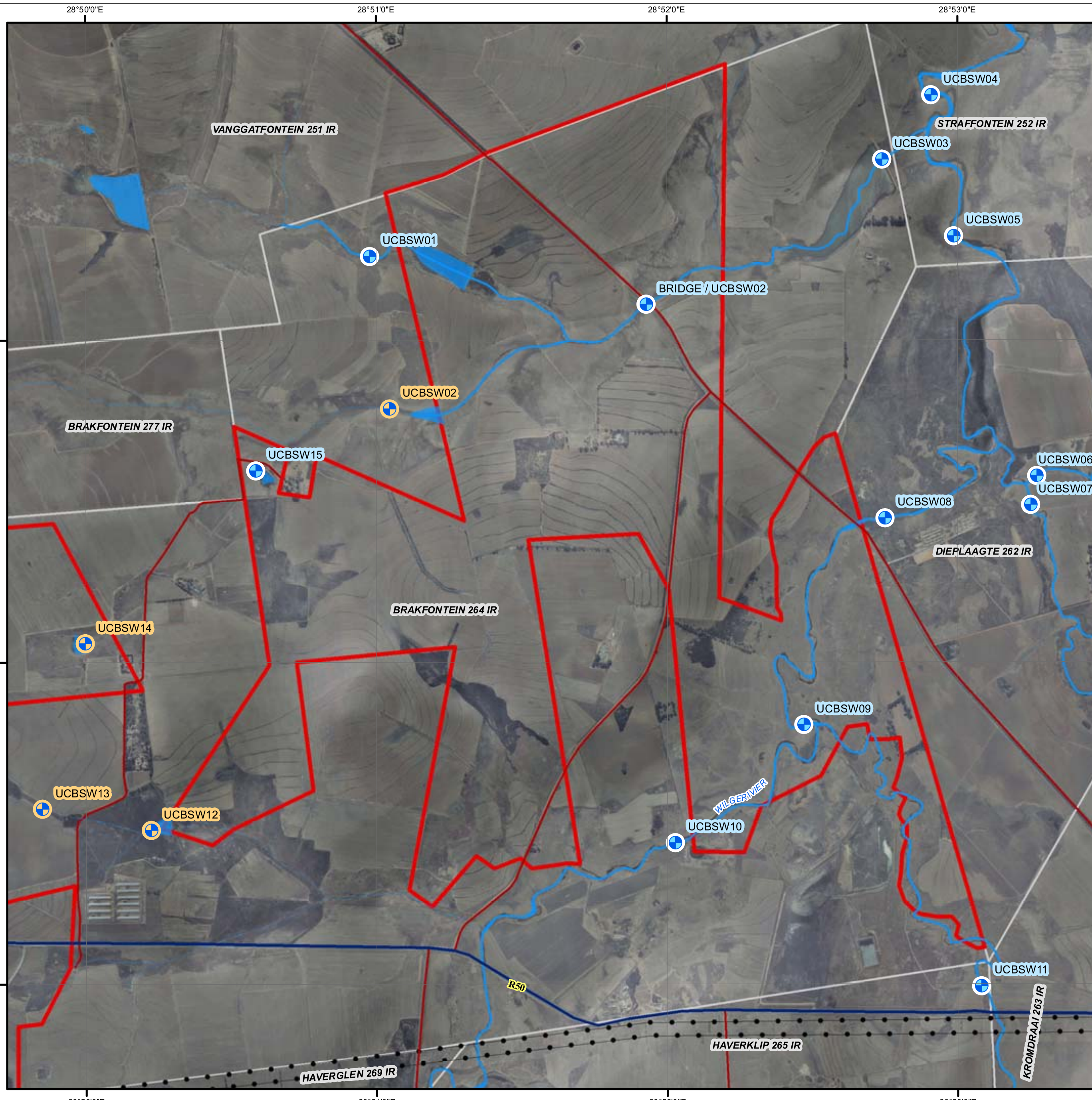
© Digby Wells Environmental



Plan 7

Universal Coal Brakfontein MRA

Water Quality Sampling Points

Legend

Project Area

Water Qualiy Sampling Points

- Not Sampled
- Sampled
- Power Line
- Arterial / National Route
- Main Road
- Railway Line
- Non-Perennial Stream
- Perennial Stream
- Dam / Lake
- Farms

universal coal plc

DIGBY WELLS ENVIRONMENTAL

www.digbywells.com

Projection: Transverse Mercator
Datum: Hartebeesthoek 1994
Central Meridian: 29°E

Ref #: amc.UNI1292.201207.153
Revision Number: 1
Date: 17/07/2012

N 0 0.35 0.7 1.4
Kilometres
1:23 000

Appendix B: Flood Volumes

Flood Frequency Analysis: Rational Method

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed
Description of site = B20E sub 5 upstream of Brakfontein Mine.
Date = 2012/06/12
Area of catchment = 88.85 km²
Dolomitic area = 0.0 %
Mean annual rainfall (MAR) = 620.00 mm
Length of longest watercourse = 8.5 km
Flow of water = Defined water course
Height difference along 10-85 slope = 38.65 m
Rainfall region = Inland
Area distribution = Rural: 98 %, Urban: 0 %, Lakes: 2 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	10	Houses	30	City centre	2
Sandy, steep (>7%)	0	Flats	0	Suburban	0
Heavy soil, flat (<2%)	5	Light industry	2	Streets	51
Heavy soil, steep (>7%)	0	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	15	Very permeable	2	Thick bush & forests	0
Flat area	84	Permeable	90	Light bush & cultivated land	80
Hilly	1	Semi-permeable	8	Grasslands	15
Steep areas	0	Impermeable	0	Bare	5

Average slope = 0.00606 m/m
Time of concentration = 2.46 h
Run-off factor
Rural - C1 = 0.292
Urban - C2 = 0.683
Lakes - C3 = 0.000
Combined - C = 0.287

The HRU, Report 2/78, Depth-Duration-Frequency diagram was used to determine the point rainfall.

Return Period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm)	Factor Ft	Runoff coefficient (%)	Peak flow (m³/s)
1:20	2.46	78.5	93.9	30.0	0.90	25.8	190.80

1:50	2.46	102.1	92.1	38.2	0.95	27.2 256.76
1:100	2.46	125.6	90.3	46.1	1.00	28.7 326.09

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Alternative Rational Method

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed
Description of site = B20E sub 5 upstream of Brakfontein Mine.
Date = 2012/06/12
Area of catchment = 88.85 km²
Dolomitic area = 0.0 %
Length of longest watercourse = 8.5 km
Flow of water = Defined water course
Height difference along 10-85 slope = 38.65 m
Area distribution = Rural: 98 %, Urban: 0 %, Lakes: 2 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	10	Houses	30	City centre	2
Sandy, steep (>7%)	0	Flats	0	Suburban	0
Heavy soil, flat (<2%)	5	Light industry	2	Streets	51
Heavy soil, steep (>7%)	0	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	15	Very permeable	2	Thick bush & forests	0
Flat area	84	Permeable	90	Light bush & cultivated land	80
Hilly	1	Semi-permeable	8	Grasslands	15
Steep areas	0	Impermeable	0	Bare	5

Days on which thunder was heard = 60 days/year
Weather Services station number = 477762
Weather Services station location = STREHLA

Mean annual precipitation (MAP) = 650 mm

Duration	2	5	10	20	50	100	200
1 day	53	72	87	103	126	145	166
2 days	65	87	103	120	144	165	186
3 days	72	96	114	132	158	180	202

7 days 94 127 151 176 211 240 270

The modified recalibrated Hershfield relationship was used to determine point rainfall.

Average slope	= 0.00606 m/m
Time of concentration	= 2.46 h
Run-off factor	
Rural - C1	= 0.292
Urban - C2	= 0.683
Lakes - C3	= 0.000
Combined - C	= 0.287

Return period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm)	Factor Ft	Runoff coefficient (%)	Peak flow (m³/s)
1:20	2.46	90.34	92.2	33.86	0.90	25.8	215.49
1:50	2.46	113.10	92.2	42.39	0.95	27.2	284.78
1:100	2.46	130.32	92.2	48.84	1.00	28.7	345.41

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Unit Hydrograph Method

Project	= Brakfontein MRA
Analysed by	= Chenai
Name of river	= Unnamed
Description of site	= B20E sub 5 upstream of Brakfontein Mine.
Date	= 2012/06/12
Area of catchment	= 88.85 km²
Length of longest watercourse	= 8.5 km
Height difference along equal area slope	= 40.0 m
Distance to catchment centroid	= 5.88 km
Veld type	= Region 4
Duration interval	= 1 hour

Slope of longest stream	=	0.0047 m/m
Catchment index	=	728.6
Catchment lag	=	3.521
Coefficient (Ku)	=	0.386 m^3/s - hours/km^2
Peak discharge of unit hydrograph (Qp)	=	9.740 m^3/s

Return period = 1:20 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	63.5	63.5	88.0	55.8	26.3	14.69
120	75.3	37.6	92.9	69.9	30.1	21.04
180	81.5	27.2	94.8	77.3	31.9	24.69
240	85.7	21.4	95.9	82.2	33.1	27.23
300	88.8	17.8	96.6	85.9	34.0	29.17
360	91.4	15.2	97.1	88.7	34.6	30.74
420	93.5	13.4	97.5	91.1	35.2	32.07
480	95.3	11.9	97.7	93.2	35.7	33.21
540	96.9	10.8	98.0	94.9	36.1	34.22
600	98.3	9.8	98.1	96.5	36.4	35.13
660	99.6	9.1	98.3	97.9	36.7	35.95
720	100.8	8.4	98.4	99.2	37.0	36.70
780	101.9	7.8	98.5	100.4	37.3	37.40
840	102.9	7.3	98.6	101.4	37.5	38.04
900	103.8	6.9	98.7	102.5	37.7	38.64
960	104.7	6.5	98.8	103.4	37.9	39.21
1020	105.5	6.2	98.8	104.3	38.1	39.74
1080	106.3	5.9	98.9	105.1	38.3	40.25
1140	107.0	5.6	98.9	105.9	38.5	

40.73

1200	107.7	5.4	99.0	106.6	38.6	41.19
1260	108.4	5.2	99.0	107.3	38.8	41.62
1320	109.0	5.0	99.1	108.0	38.9	42.04
1380	109.7	4.8	99.1	108.7	39.1	42.45
1440	110.3	4.6	99.1	109.3	39.2	42.83
1500	110.8	4.4	99.2	109.9	39.3	43.20
1560	111.4	4.3	99.2	110.5	39.4	43.56
1620	111.9	4.1	99.2	111.0	39.6	43.91
1680	112.4	4.0	99.2	111.5	39.7	44.24
1740	112.9	3.9	99.3	112.1	39.8	44.57
1800	113.4	3.8	99.3	112.5	39.9	44.88
1860	113.8	3.7	99.3	113.0	40.0	45.19
1920	114.3	3.6	99.3	113.5	40.1	45.49
1980	114.7	3.5	99.3	113.9	40.2	45.78
2040	115.1	3.4	99.4	114.4	40.3	46.06
2100	115.5	3.3	99.4	114.8	40.4	46.33
2160	115.9	3.2	99.4	115.2	40.4	46.60
2220	116.3	3.1	99.4	115.6	40.5	46.86
2280	116.7	3.1	99.4	116.0	40.6	47.12
2340	117.1	3.0	99.4	116.4	40.7	47.37
2400	117.4	2.9	99.4	116.8	40.8	47.61
2460	117.8	2.9	99.5	117.2	40.8	47.85
2520	118.1	2.8	99.5	117.5	40.9	48.08
2580	118.5	2.8	99.5	117.9	41.0	48.31
2640	118.8	2.7	99.5	118.2	41.1	48.54
2700	119.1	2.6	99.5	118.5	41.1	48.76
2760	119.5	2.6	99.5	118.9	41.2	48.97
2820	119.8	2.5	99.5	119.2	41.3	49.18
2880	120.1	2.5	99.5	119.5	41.3	49.39

Return period = 1:50 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	82.5	82.5	84.4	69.6	30.0	20.88
120	97.9	48.9	90.7	88.8	34.7	30.76
180	106.0	35.3	93.3	98.9	36.9	36.51
240	111.4	27.9	94.7	105.5	38.4	40.50
300	115.5	23.1	95.6	110.4	39.4	43.55
360	118.8	19.8	96.2	114.3	40.3	46.02
420	121.5	17.4	96.7	117.5	40.9	48.10
480	123.9	15.5	97.1	120.3	41.5	49.89
540	126.0	14.0	97.3	122.6	42.0	51.47
600	127.8	12.8	97.6	124.7	42.4	52.88
660	129.5	11.8	97.8	126.6	42.8	54.17
720	131.0	10.9	97.9	128.3	43.1	55.34
780	132.4	10.2	98.1	129.9	43.4	56.42
840	133.7	9.6	98.2	131.3	43.7	57.42
900	135.0	9.0	98.3	132.7	44.0	58.36
960	136.1	8.5	98.4	133.9	44.2	59.24
1020	137.2	8.1	98.5	135.1	44.5	60.07
1080	138.2	7.7	98.5	136.2	44.7	60.85
1140	139.1	7.3	98.6	137.2	44.9	61.60
1200	140.1	7.0	98.7	138.2	45.1	62.31
1260	140.9	6.7	98.7	139.1	45.3	62.99
1320	141.8	6.4	98.8	140.0	45.4	63.64
1380	142.6	6.2	98.8	140.9	45.6	64.26
1440	143.3	6.0	98.9	141.7	45.8	64.86
1500	144.1	5.8	98.9	142.5	45.9	65.43
1560	144.8	5.6	98.9	143.2	46.1	65.99
1620	145.5	5.4	99.0	144.0	46.2	

66.53

1680	146.1	5.2	99.0	144.7	46.3	67.04
1740	146.8	5.1	99.0	145.3	46.5	67.55
1800	147.4	4.9	99.1	146.0	46.6	68.03
1860	148.0	4.8	99.1	146.6	46.7	68.51
1920	148.5	4.6	99.1	147.2	46.8	68.97
1980	149.1	4.5	99.1	147.8	47.0	69.41
2040	149.7	4.4	99.2	148.4	47.1	69.85
2100	150.2	4.3	99.2	149.0	47.2	70.27
2160	150.7	4.2	99.2	149.5	47.3	70.69
2220	151.2	4.1	99.2	150.1	47.4	71.09
2280	151.7	4.0	99.2	150.6	47.5	71.48
2340	152.2	3.9	99.3	151.1	47.6	71.87
2400	152.7	3.8	99.3	151.6	47.7	72.25
2460	153.1	3.7	99.3	152.0	47.8	72.61
2520	153.6	3.7	99.3	152.5	47.8	72.97
2580	154.0	3.6	99.3	153.0	47.9	73.33
2640	154.5	3.5	99.3	153.4	48.0	73.67
2700	154.9	3.4	99.3	153.9	48.1	74.01
2760	155.3	3.4	99.4	154.3	48.2	74.34
2820	155.7	3.3	99.4	154.7	48.3	74.67
2880	156.1	3.3	99.4	155.1	48.3	74.99

Return period = 1:100 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	101.5	101.5	80.7	82.0	33.1	27.10
120	120.4	60.2	88.6	106.7	38.6	41.21
180	130.4	43.5	91.8	119.7	41.4	49.49

240	137.1	34.3	93.5	128.2	43.1	55.25
300	142.2	28.4	94.6	134.5	44.4	59.65
360	146.2	24.4	95.4	139.4	45.3	63.21
420	149.6	21.4	95.9	143.5	46.1	66.19
480	152.5	19.1	96.4	147.0	46.8	68.77
540	155.0	17.2	96.7	150.0	47.4	71.04
600	157.3	15.7	97.0	152.6	47.9	73.06
660	159.4	14.5	97.3	155.0	48.3	74.90
720	161.3	13.4	97.5	157.2	48.7	76.57
780	163.0	12.5	97.6	159.1	49.1	78.12
840	164.6	11.8	97.8	160.9	49.4	79.55
900	166.1	11.1	97.9	162.6	49.7	80.89
960	167.5	10.5	98.0	164.2	50.0	82.14
1020	168.8	9.9	98.1	165.6	50.3	83.32
1080	170.1	9.4	98.2	167.0	50.6	84.44
1140	171.3	9.0	98.3	168.3	50.8	85.50
1200	172.4	8.6	98.4	169.6	51.0	86.52
1260	173.5	8.3	98.4	170.7	51.2	87.48
1320	174.5	7.9	98.5	171.9	51.4	88.40
1380	175.5	7.6	98.6	172.9	51.6	89.29
1440	176.4	7.4	98.6	173.9	51.8	90.14
1500	177.3	7.1	98.7	174.9	52.0	90.96
1560	178.2	6.9	98.7	175.9	52.2	91.74
1620	179.0	6.6	98.7	176.8	52.3	92.51
1680	179.8	6.4	98.8	177.6	52.5	93.24
1740	180.6	6.2	98.8	178.5	52.6	93.96
1800	181.4	6.0	98.9	179.3	52.8	94.65
1860	182.1	5.9	98.9	180.1	52.9	95.32
1920	182.8	5.7	98.9	180.8	53.1	95.97
1980	183.5	5.6	98.9	181.6	53.2	96.60
2040	184.2	5.4	99.0	182.3	53.3	97.22
2100	184.9	5.3	99.0	183.0	53.5	

						97.82
2160	185.5	5.2	99.0	183.7	53.6	98.41
2220	186.1	5.0	99.0	184.3	53.7	98.98
2280	186.7	4.9	99.1	185.0	53.8	99.54
2340	187.3	4.8	99.1	185.6	53.9	100.08
2400	187.9	4.7	99.1	186.2	54.0	100.62
2460	188.5	4.6	99.1	186.8	54.1	101.14
2520	189.0	4.5	99.1	187.4	54.2	101.65
2580	189.6	4.4	99.2	188.0	54.3	102.15
2640	190.1	4.3	99.2	188.5	54.4	102.64
2700	190.6	4.2	99.2	189.1	54.5	103.12
2760	191.1	4.2	99.2	189.6	54.6	103.59
2820	191.6	4.1	99.2	190.1	54.7	104.05
2880	192.1	4.0	99.2	190.7	54.8	104.50

S-curve calculations

Dimensionless one-hour unit hydrograph

T/TL	Q/Qp
0.000	0.0000
0.284	0.0829
0.568	0.4759
0.852	0.7564
1.136	0.4034
1.420	0.2634
1.704	0.1710
1.988	0.1097
2.272	0.0654
2.556	0.0385
2.840	0.0214
3.124	0.0100
3.408	0.0018
3.692	0.0000
3.976	0.0000
4.260	0.0000

T/TL	Original S-curve	Mofified S-curve
0.000	0.0000	0.0000
0.284	0.0829	0.0829
0.568	0.5588	0.5588
0.852	1.3153	1.3153
1.136	1.7186	1.7186
1.420	1.9821	1.9821
1.704	2.1530	2.1530
1.988	2.2627	2.2627
2.272	2.3281	2.3281

2.556	2.3666	2.3666
2.840	2.3880	2.3880
3.124	2.3980	2.3980
3.408	2.3999	2.3999
3.692	2.3999	2.3999
3.976	2.3999	2.3999
4.260	2.3999	2.3999

Return period = 1:20 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.756	108.262
120	0.616	126.255
180	0.545	131.118
240	0.475	125.910
300	0.414	117.626
360	0.363	108.783
420	0.323	100.960
480	0.291	94.139
540	0.263	87.652
600	0.239	81.706
660	0.218	76.334
720	0.200	71.491
780	0.185	67.239
840	0.171	63.513
900	0.160	60.218
960	0.150	57.282
1020	0.141	54.647
1080	0.133	52.267
1140	0.126	50.108
1200	0.120	48.137
1260	0.114	46.332
1320	0.109	44.670
1380	0.104	43.137
1440	0.100	41.715
1500	0.096	40.395
1560	0.092	39.164
1620	0.089	38.013
1680	0.086	36.936
1740	0.083	35.924
1800	0.080	34.972
1860	0.077	34.075
1920	0.075	33.227
1980	0.073	32.425
2040	0.071	31.665
2100	0.069	30.944
2160	0.067	30.258
2220	0.065	29.605
2280	0.063	28.983
2340	0.062	28.389
2400	0.060	27.822
2460	0.059	27.279
2520	0.057	26.760
2580	0.056	26.262
2640	0.055	25.784
2700	0.053	25.325

2760	0.052	24.884
2820	0.051	24.460
2880	0.050	24.052

Return period = 1:50 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.756	153.854
120	0.616	184.632
180	0.545	193.868
240	0.475	187.281
300	0.414	175.619
360	0.363	162.843
420	0.323	151.427
480	0.291	141.409
540	0.263	131.824
600	0.239	123.004
660	0.218	115.011
720	0.200	107.791
780	0.185	101.442
840	0.171	95.872
900	0.160	90.941
960	0.150	86.543
1020	0.141	82.593
1080	0.133	79.024
1140	0.126	75.782
1200	0.120	72.823
1260	0.114	70.110
1320	0.109	67.612
1380	0.104	65.305
1440	0.100	63.167
1500	0.096	61.179
1560	0.092	59.325
1620	0.089	57.592
1680	0.086	55.969
1740	0.083	54.444
1800	0.080	53.009
1860	0.077	51.656
1920	0.075	50.377
1980	0.073	49.167
2040	0.071	48.020
2100	0.069	46.932
2160	0.067	45.896
2220	0.065	44.911
2280	0.063	43.971
2340	0.062	43.075
2400	0.060	42.218
2460	0.059	41.398
2520	0.057	40.613
2580	0.056	39.860
2640	0.055	39.138
2700	0.053	38.445
2760	0.052	37.778
2820	0.051	37.137
2880	0.050	36.519

Return period = 1:100 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.756	199.657
120	0.616	247.342
180	0.545	262.816
240	0.475	255.497
300	0.414	240.543
360	0.363	223.659
420	0.323	208.401
480	0.291	194.920
540	0.263	181.935
600	0.239	169.935
660	0.218	159.030
720	0.200	149.154
780	0.185	140.457
840	0.171	132.817
900	0.160	126.048
960	0.150	120.003
1020	0.141	114.570
1080	0.133	109.657
1140	0.126	105.192
1200	0.120	101.113
1260	0.114	97.372
1320	0.109	93.926
1380	0.104	90.742
1440	0.100	87.789
1500	0.096	85.042
1560	0.092	82.481
1620	0.089	80.085
1680	0.086	77.840
1740	0.083	75.731
1800	0.080	73.745
1860	0.077	71.872
1920	0.075	70.102
1980	0.073	68.427
2040	0.071	66.838
2100	0.069	65.330
2160	0.067	63.896
2220	0.065	62.530
2280	0.063	61.228
2340	0.062	59.984
2400	0.060	58.796
2460	0.059	57.659
2520	0.057	56.571
2580	0.056	55.527
2640	0.055	54.525
2700	0.053	53.563
2760	0.052	52.637
2820	0.051	51.747
2880	0.050	50.890

Return period	Storm duration (minutes)	Peak discharge (m^3/s)

1:20 year	180	131.12
1:50 year	180	193.87
1:100 year	180	262.82

Calculated using Utility Programs for Drainage 1.0.2

Flood frequency analysis : Standard Design Flood method

Project name = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed
Description of site = B20E sub 5 upstream of Brakfontein Mine.
Date = 2012/06/12
Catchment characteristics:
Area of catchment = 88.85 km²
Length of longest watercourse = 8.5 km
1085 height difference = 38.65 m
Average slope = 0.0061 m/m
Drainage basin characteristics:
Drainage basin number = 4
Mean annual daily max rain = 58 mm
Days on which thunder was heard = 20 days
Runoff coefficient C2 = 10 %
Runoff coefficient C100 = 50 %
Basin mean annual precipitation = 630 mm
Basin mean annual evaporation = 1600 mm
Basin evaporation index MAE/MAP = 2.54

RAINFALL DATA
The rainfall data in the table below are derived from two sources. The daily rainfall is from the Department of Water Affair's publication TR102 for the representative site.
The modified Hershfield equation is used for durations up to four hours. Linear interpolation is used for values between 4 hours and one day.

Weather Services station ex TR102 = 553351 @ WATERVAL
Point mean annual precipitation = 630 mm

Dur:	RP =2	5	10	20	50	100	200
.25 h	14	24	31	39	48	56	63
.50 h	18	31	41	50	63	73	82
1 h	23	38	50	62	78	89	101
2 h	27	46	60	74	92	106	120
4 h	31	53	69	85	107	123	139
1 day	58	76	89	102	122	138	155
2 days	69	90	106	123	146	165	185

3 days	76	99	115	132	156	175	195
7 days	98	131	154	178	211	238	266

Runoff coefficients C2 = 10 % C100 = 50 %

Return period (years)	Time of concentration (hours)	Point precipitation (mm)	ARF (%)	Catchment precipitation (mm)	Runoff coefficient (%)	Peak flow (m³/s)
1:20	2.46	76.4	92.2	70.4	38.2	269.74
1:50	2.46	95.6	92.2	88.2	45.2	400.00
1:100	2.46	110.2	92.2	101.6	50.0	509.93

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Empirical methods

Project	= Brakfontein MRA
Analysed by	= Chenai
Name of river	= Unnamed
Description of site	= B20E sub 5 upstream of Brakfontein Mine.
Date	= 2012/06/12

Area of catchment	= 88.85 km²
Length of longest watercourse	= 8.5 km
Height difference along equal-area slope	= 40.0 m
Distance to catchment centroid	= 5.88 km
Dolomitic area	= 0.0 %
Mean annual rainfall	= 620.0 mm
Veld type	= 4 & 5A
Kovács region	= K4(K = 4.6)
Catchment parameter with regard to reaction time	= 0.122

Peak discharges by means of an empirical method developed by Midgley and

Pitman

Return period (years)	KT constant	Peak flow (m^3/s)
1:20	0.68	154.05
1:50	0.95	215.22
1:100	1.20	271.86

This RMF calculation includes a transition zone adjustment in the case of small catchments.

Regional maximum flood: 550.2 m^3/s

Q50(RMF): 195.62 m^3/s (based on QT/QRMF relationship for Kovács regions)
Q100(RMF): 257.07 m^3/s (based on QT/QRMF relationship for Kovács regions)

The following equivalent maxima make no transition zone adjustments for small catchments.

Equivalent southern African maximum
K-factor 5.6: 2175 m^3/s

Equivalent world maxima
K-factor 6.0: 3797 m^3/s
K-factor 6.3: 5768 m^3/s

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Alternative Rational Method

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed
Description of site = B20E sub 4 upstream of Brakfontein Mine.
Date = 2012/06/12
Area of catchment = 88.85 km²
Dolomitic area = 0.0 %
Length of longest watercourse = 19.73 km
Flow of water = Defined water course
Height difference along 10-85 slope = 78.263 m
Area distribution = Rural: 95 %, Urban: 0 %, Lakes: 5 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	10	Houses	30	City centre	2
Sandy, steep (>7%)	0	Flats	0	Suburban	0
Heavy soil, flat (<2%)	5	Light industry	2	Streets	51
Heavy soil, steep (>7%)	0	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	19	Very permeable	2	Thick bush & forests	0
Flat area	80	Permeable	90	Light bush & cultivated land	80
Hilly	1	Semi-permeable	8	Grasslands	15
Steep areas	0	Impermeable	0	Bare	5

Days on which thunder was heard = 60 days/year
Weather Services station number = 477762
Weather Services station location = STREHLA

Mean annual precipitation (MAP) = 650 mm

Duration	2	5	10	20	50	100	200
1 day	53	72	87	103	126	145	166
2 days	65	87	103	120	144	165	186
3 days	72	96	114	132	158	180	202
7 days	94	127	151	176	211	240	270

The modified recalibrated Hershfield relationship was used to determine point rainfall.

Average slope = 0.00529 m/m
Time of concentration = 4.96 h
Run-off factor
Rural - C1 = 0.290
Urban - C2 = 0.683
Lakes - C3 = 0.000
Combined - C = 0.276

Return period	Time of concentration	Point rainfall	ARF	Average intensity	Factor Ft	Runoff	Peak

```
coefficient   flow
     (years)     (hours)        (mm)         (%)      (mm)                     (%)
         (m³/s)

-----------------------------------------------------------------------------------------
------------
     1:20        4.96           104.14       95.3     20.00        0.90        24.8
         122.56
     1:50        4.96           130.38       95.3     25.04        0.95        26.2
         161.97
     1:100       4.96           150.23       95.3     28.85        1.00        27.6
         196.45
```

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Unit Hydrograph Method

```
     Project                                     = Brakfontein MRA
     Analysed by                                 = Chenai
     Name of river                               = Unnamed
     Description of site                         = B20E sub 4 upstream of Brakfontein
Mine.
     Date                                        = 2012/06/12
     Area of catchment                           = 88.85 km²
     Length of longest watercourse               = 19.73 km
     Height difference along equal area slope    = 80.0 m
     Distance to catchment centroid              = 9.428 km
     Veld type                                   = Region 4
     Duration interval                           = 1 hour

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     Slope of longest stream                     = 0.0041 m/m
     Catchment index                             = 2921.2
     Catchment lag                               = 5.837
     Coefficient (Ku)                            = 0.386 m³/s - hours/km²
     Peak discharge of unit hydrograph (Qp)      = 5.875 m³/s

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     Return period = 1:20 year

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     Storm           Point      Point        ARF        Average      Runoff
Effective
     duration        rainfall   intensity               rainfall     factor
```

(minutes)	(mm)	(mm/h)	(%)	(mm)	(%)	rain (mm)
60	63.5	63.5	88.0	55.8	26.3	14.69
120	75.3	37.6	92.9	69.9	30.1	21.04
180	81.5	27.2	94.8	77.3	31.9	24.69
240	85.7	21.4	95.9	82.2	33.1	27.23
300	88.8	17.8	96.6	85.9	34.0	29.17
360	91.4	15.2	97.1	88.7	34.6	30.74
420	93.5	13.4	97.5	91.1	35.2	32.07
480	95.3	11.9	97.7	93.2	35.7	33.21
540	96.9	10.8	98.0	94.9	36.1	34.22
600	98.3	9.8	98.1	96.5	36.4	35.13
660	99.6	9.1	98.3	97.9	36.7	35.95
720	100.8	8.4	98.4	99.2	37.0	36.70
780	101.9	7.8	98.5	100.4	37.3	37.40
840	102.9	7.3	98.6	101.4	37.5	38.04
900	103.8	6.9	98.7	102.5	37.7	38.64
960	104.7	6.5	98.8	103.4	37.9	39.21
1020	105.5	6.2	98.8	104.3	38.1	39.74
1080	106.3	5.9	98.9	105.1	38.3	40.25
1140	107.0	5.6	98.9	105.9	38.5	40.73
1200	107.7	5.4	99.0	106.6	38.6	41.19
1260	108.4	5.2	99.0	107.3	38.8	41.62
1320	109.0	5.0	99.1	108.0	38.9	42.04
1380	109.7	4.8	99.1	108.7	39.1	42.45
1440	110.3	4.6	99.1	109.3	39.2	42.83
1500	110.8	4.4	99.2	109.9	39.3	43.20
1560	111.4	4.3	99.2	110.5	39.4	43.56
1620	111.9	4.1	99.2	111.0	39.6	43.91
1680	112.4	4.0	99.2	111.5	39.7	44.24
1740	112.9	3.9	99.3	112.1	39.8	

44.57

1800	113.4	3.8	99.3	112.5	39.9	44.88
1860	113.8	3.7	99.3	113.0	40.0	45.19
1920	114.3	3.6	99.3	113.5	40.1	45.49
1980	114.7	3.5	99.3	113.9	40.2	45.78
2040	115.1	3.4	99.4	114.4	40.3	46.06
2100	115.5	3.3	99.4	114.8	40.4	46.33
2160	115.9	3.2	99.4	115.2	40.4	46.60
2220	116.3	3.1	99.4	115.6	40.5	46.86
2280	116.7	3.1	99.4	116.0	40.6	47.12
2340	117.1	3.0	99.4	116.4	40.7	47.37
2400	117.4	2.9	99.4	116.8	40.8	47.61
2460	117.8	2.9	99.5	117.2	40.8	47.85
2520	118.1	2.8	99.5	117.5	40.9	48.08
2580	118.5	2.8	99.5	117.9	41.0	48.31
2640	118.8	2.7	99.5	118.2	41.1	48.54
2700	119.1	2.6	99.5	118.5	41.1	48.76
2760	119.5	2.6	99.5	118.9	41.2	48.97
2820	119.8	2.5	99.5	119.2	41.3	49.18
2880	120.1	2.5	99.5	119.5	41.3	49.39

Return period = 1:50 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	82.5	82.5	84.4	69.6	30.0	20.88
120	97.9	48.9	90.7	88.8	34.7	30.76
180	106.0	35.3	93.3	98.9	36.9	36.51
240	111.4	27.9	94.7	105.5	38.4	40.50
300	115.5	23.1	95.6	110.4	39.4	43.55

360	118.8	19.8	96.2	114.3	40.3	46.02
420	121.5	17.4	96.7	117.5	40.9	48.10
480	123.9	15.5	97.1	120.3	41.5	49.89
540	126.0	14.0	97.3	122.6	42.0	51.47
600	127.8	12.8	97.6	124.7	42.4	52.88
660	129.5	11.8	97.8	126.6	42.8	54.17
720	131.0	10.9	97.9	128.3	43.1	55.34
780	132.4	10.2	98.1	129.9	43.4	56.42
840	133.7	9.6	98.2	131.3	43.7	57.42
900	135.0	9.0	98.3	132.7	44.0	58.36
960	136.1	8.5	98.4	133.9	44.2	59.24
1020	137.2	8.1	98.5	135.1	44.5	60.07
1080	138.2	7.7	98.5	136.2	44.7	60.85
1140	139.1	7.3	98.6	137.2	44.9	61.60
1200	140.1	7.0	98.7	138.2	45.1	62.31
1260	140.9	6.7	98.7	139.1	45.3	62.99
1320	141.8	6.4	98.8	140.0	45.4	63.64
1380	142.6	6.2	98.8	140.9	45.6	64.26
1440	143.3	6.0	98.9	141.7	45.8	64.86
1500	144.1	5.8	98.9	142.5	45.9	65.43
1560	144.8	5.6	98.9	143.2	46.1	65.99
1620	145.5	5.4	99.0	144.0	46.2	66.53
1680	146.1	5.2	99.0	144.7	46.3	67.04
1740	146.8	5.1	99.0	145.3	46.5	67.55
1800	147.4	4.9	99.1	146.0	46.6	68.03
1860	148.0	4.8	99.1	146.6	46.7	68.51
1920	148.5	4.6	99.1	147.2	46.8	68.97
1980	149.1	4.5	99.1	147.8	47.0	69.41
2040	149.7	4.4	99.2	148.4	47.1	69.85
2100	150.2	4.3	99.2	149.0	47.2	70.27
2160	150.7	4.2	99.2	149.5	47.3	70.69
2220	151.2	4.1	99.2	150.1	47.4	

71.09

2280	151.7	4.0	99.2	150.6	47.5	71.48
2340	152.2	3.9	99.3	151.1	47.6	71.87
2400	152.7	3.8	99.3	151.6	47.7	72.25
2460	153.1	3.7	99.3	152.0	47.8	72.61
2520	153.6	3.7	99.3	152.5	47.8	72.97
2580	154.0	3.6	99.3	153.0	47.9	73.33
2640	154.5	3.5	99.3	153.4	48.0	73.67
2700	154.9	3.4	99.3	153.9	48.1	74.01
2760	155.3	3.4	99.4	154.3	48.2	74.34
2820	155.7	3.3	99.4	154.7	48.3	74.67
2880	156.1	3.3	99.4	155.1	48.3	74.99

Return period = 1:100 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	101.5	101.5	80.7	82.0	33.1	27.10
120	120.4	60.2	88.6	106.7	38.6	41.21
180	130.4	43.5	91.8	119.7	41.4	49.49
240	137.1	34.3	93.5	128.2	43.1	55.25
300	142.2	28.4	94.6	134.5	44.4	59.65
360	146.2	24.4	95.4	139.4	45.3	63.21
420	149.6	21.4	95.9	143.5	46.1	66.19
480	152.5	19.1	96.4	147.0	46.8	68.77
540	155.0	17.2	96.7	150.0	47.4	71.04
600	157.3	15.7	97.0	152.6	47.9	73.06
660	159.4	14.5	97.3	155.0	48.3	74.90
720	161.3	13.4	97.5	157.2	48.7	76.57
780	163.0	12.5	97.6	159.1	49.1	78.12

840	164.6	11.8	97.8	160.9	49.4	79.55
900	166.1	11.1	97.9	162.6	49.7	80.89
960	167.5	10.5	98.0	164.2	50.0	82.14
1020	168.8	9.9	98.1	165.6	50.3	83.32
1080	170.1	9.4	98.2	167.0	50.6	84.44
1140	171.3	9.0	98.3	168.3	50.8	85.50
1200	172.4	8.6	98.4	169.6	51.0	86.52
1260	173.5	8.3	98.4	170.7	51.2	87.48
1320	174.5	7.9	98.5	171.9	51.4	88.40
1380	175.5	7.6	98.6	172.9	51.6	89.29
1440	176.4	7.4	98.6	173.9	51.8	90.14
1500	177.3	7.1	98.7	174.9	52.0	90.96
1560	178.2	6.9	98.7	175.9	52.2	91.74
1620	179.0	6.6	98.7	176.8	52.3	92.51
1680	179.8	6.4	98.8	177.6	52.5	93.24
1740	180.6	6.2	98.8	178.5	52.6	93.96
1800	181.4	6.0	98.9	179.3	52.8	94.65
1860	182.1	5.9	98.9	180.1	52.9	95.32
1920	182.8	5.7	98.9	180.8	53.1	95.97
1980	183.5	5.6	98.9	181.6	53.2	96.60
2040	184.2	5.4	99.0	182.3	53.3	97.22
2100	184.9	5.3	99.0	183.0	53.5	97.82
2160	185.5	5.2	99.0	183.7	53.6	98.41
2220	186.1	5.0	99.0	184.3	53.7	98.98
2280	186.7	4.9	99.1	185.0	53.8	99.54
2340	187.3	4.8	99.1	185.6	53.9	100.08
2400	187.9	4.7	99.1	186.2	54.0	100.62
2460	188.5	4.6	99.1	186.8	54.1	101.14
2520	189.0	4.5	99.1	187.4	54.2	101.65
2580	189.6	4.4	99.2	188.0	54.3	102.15
2640	190.1	4.3	99.2	188.5	54.4	102.64
2700	190.6	4.2	99.2	189.1	54.5	

						103.12
2760	191.1	4.2	99.2	189.6	54.6	103.59
2820	191.6	4.1	99.2	190.1	54.7	104.05
2880	192.1	4.0	99.2	190.7	54.8	104.50

S-curve calculations

Dimensionless one-hour unit hydrograph

T/TL	Q/Qp
0.000	0.0000
0.171	0.0393
0.343	0.1078
0.514	0.2562
0.685	0.9941
0.857	0.7482
1.028	0.4966
1.199	0.3645
1.370	0.2810
1.542	0.2208
1.713	0.1686
1.884	0.1284
2.056	0.0970
2.227	0.0708
2.398	0.0521
2.570	0.0374
2.741	0.0265
2.912	0.0185
3.084	0.0113
3.255	0.0058
3.426	0.0015
3.598	0.0000
3.769	0.0000
3.940	0.0000
4.111	0.0000
4.283	0.0000

T/TL	Original S-curve	Mofified S-curve
0.000	0.0000	0.0000
0.171	0.0393	0.0393
0.343	0.1470	0.1470
0.514	0.4033	0.4033
0.685	1.3974	1.3974
0.857	2.1456	2.1456
1.028	2.6421	2.6421
1.199	3.0066	3.0066
1.370	3.2876	3.2876
1.542	3.5084	3.5084
1.713	3.6770	3.6770
1.884	3.8054	3.8054
2.056	3.9024	3.9024
2.227	3.9732	3.9732
2.398	4.0253	4.0253
2.570	4.0627	4.0627
2.741	4.0893	4.0893
2.912	4.1078	4.1078
3.084	4.1191	4.1191

3.255	4.1249	4.1249
3.426	4.1264	4.1264
3.598	4.1264	4.1264
3.769	4.1264	4.1264
3.940	4.1264	4.1264
4.111	4.1264	4.1264
4.283	4.1264	4.1264

Return period = 1:20 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.994	85.824
120	0.871	107.675
180	0.746	108.256
240	0.651	104.115
300	0.577	98.864
360	0.523	94.544
420	0.480	90.472
480	0.441	86.103
540	0.406	81.734
600	0.377	77.731
660	0.351	74.178
720	0.328	70.690
780	0.307	67.367
840	0.288	64.261
900	0.271	61.494
960	0.256	58.877
1020	0.242	56.423
1080	0.229	54.115
1140	0.217	51.952
1200	0.206	49.927
1260	0.196	48.054
1320	0.188	46.331
1380	0.179	44.740
1440	0.172	43.266
1500	0.165	41.897
1560	0.159	40.620
1620	0.153	39.427
1680	0.147	38.309
1740	0.142	37.260
1800	0.138	36.272
1860	0.133	35.342
1920	0.129	34.462
1980	0.125	33.631
2040	0.121	32.842
2100	0.118	32.094
2160	0.115	31.383
2220	0.112	30.706
2280	0.109	30.061
2340	0.106	29.445
2400	0.103	28.856
2460	0.101	28.294
2520	0.098	27.755
2580	0.096	27.238
2640	0.094	26.743
2700	0.092	26.267

2760	0.090	25.810
2820	0.088	25.370
2880	0.086	24.946

Return period = 1:50 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.994	121.967
120	0.871	157.461
180	0.746	160.066
240	0.651	154.861
300	0.577	147.607
360	0.523	141.528
420	0.480	135.696
480	0.441	129.339
540	0.406	122.924
600	0.377	117.019
660	0.351	111.763
720	0.328	106.583
780	0.307	101.635
840	0.288	97.001
900	0.271	92.868
960	0.256	88.953
1020	0.242	85.278
1080	0.229	81.818
1140	0.217	78.572
1200	0.206	75.530
1260	0.196	72.716
1320	0.188	70.126
1380	0.179	67.733
1440	0.172	65.515
1500	0.165	63.453
1560	0.159	61.531
1620	0.153	59.734
1680	0.147	58.050
1740	0.142	56.468
1800	0.138	54.980
1860	0.133	53.576
1920	0.129	52.250
1980	0.125	50.995
2040	0.121	49.806
2100	0.118	48.676
2160	0.115	47.603
2220	0.112	46.581
2280	0.109	45.606
2340	0.106	44.676
2400	0.103	43.787
2460	0.101	42.937
2520	0.098	42.123
2580	0.096	41.342
2640	0.094	40.593
2700	0.092	39.874
2760	0.090	39.183
2820	0.088	38.517
2880	0.086	37.877

Return period = 1:100 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.994	158.277
120	0.871	210.942
180	0.746	216.992
240	0.651	211.269
300	0.577	202.175
360	0.523	194.383
420	0.480	186.752
480	0.441	178.282
540	0.406	169.652
600	0.377	161.668
660	0.351	154.538
720	0.328	147.483
780	0.307	140.724
840	0.288	134.381
900	0.271	128.717
960	0.256	123.345
1020	0.242	118.294
1080	0.229	113.534
1140	0.217	109.064
1200	0.206	104.872
1260	0.196	100.992
1320	0.188	97.418
1380	0.179	94.115
1440	0.172	91.053
1500	0.165	88.204
1560	0.159	85.547
1620	0.153	83.063
1680	0.147	80.734
1740	0.142	78.546
1800	0.138	76.487
1860	0.133	74.544
1920	0.129	72.709
1980	0.125	70.971
2040	0.121	69.323
2100	0.118	67.759
2160	0.115	66.271
2220	0.112	64.855
2280	0.109	63.504
2340	0.106	62.215
2400	0.103	60.982
2460	0.101	59.803
2520	0.098	58.674
2580	0.096	57.591
2640	0.094	56.552
2700	0.092	55.554
2760	0.090	54.594
2820	0.088	53.671
2880	0.086	52.782

Return period	Storm duration (minutes)	Peak discharge (m^3/s)

1:20 year	180	108.26
1:50 year	180	160.07
1:100 year	180	216.99

Calculated using Utility Programs for Drainage 1.0.2

Flood frequency analysis : Standard Design Flood method

Project name = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed
Description of site = B20E sub 4 upstream of Brakfontein Mine.
Date = 2012/06/12
Catchment characteristics:
Area of catchment = 88.85 km²
Length of longest watercourse = 19.73 km
1085 height difference = 78.263 m
Average slope = 0.0053 m/m
Drainage basin characteristics:
Drainage basin number = 4
Mean annual daily max rain = 58 mm
Days on which thunder was heard = 20 days
Runoff coefficient C2 = 10 %
Runoff coefficient C100 = 50 %
Basin mean annual precipitation = 630 mm
Basin mean annual evaporation = 1600 mm
Basin evaporation index MAE/MAP = 2.54

RAINFALL DATA
The rainfall data in the table below are derived from two sources. The daily rainfall is from the Department of Water Affair's publication TR102 for the representative site.
The modified Hershfield equation is used for durations up to four hours. Linear interpolation is used for values between 4 hours and one day.

Weather Services station ex TR102 = 553351 @ WATERVAL
Point mean annual precipitation = 630 mm

Dur:	RP =2	5	10	20	50	100	200
.25 h	14	24	31	39	48	56	63
.50 h	18	31	41	50	63	73	82
1 h	23	38	50	62	78	89	101
2 h	27	46	60	74	92	106	120
4 h	31	53	69	85	107	123	139

1 day	58	76	89	102	122	138	155
2 days	69	90	106	123	146	165	185
3 days	76	99	115	132	156	175	195
7 days	98	131	154	178	211	238	266

Runoff coefficients C2 = 10 %   C100 = 50 %

Return period (years)	Time of concentration (hours)	Point precipitation (mm)	ARF (%)	Catchment precipitation (mm)	Runoff coefficient (%)	Peak flow (m^3/s)
1:20	4.96	86.1	95.3	82.1	38.2	155.92
1:50	4.96	107.6	95.3	102.5	45.2	230.63
1:100	4.96	123.8	95.3	118.0	50.0	293.71

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Empirical methods

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed
Description of site = B20E sub 4 upstream of Brakfontein Mine.
Date = 2012/06/12

Area of catchment = 88.85 km²
Length of longest watercourse = 19.73 km
Height difference along equal-area slope = 80.0 m
Distance to catchment centroid = 9.428 km
Dolomitic area = 0.0 %
Mean annual rainfall = 620.0 mm
Veld type = 4 & 5A
Kovács region = K4(K = 4.6)
Catchment parameter with regard to reaction time = 0.03

Peak discharges by means of an empirical method developed by Midgley and Pitman

Return period (years)	KT constant	Peak flow (m^3/s)
1:20	0.68	116.70
1:50	0.95	163.03
1:100	1.20	205.93

This RMF calculation includes a transition zone adjustment in the case of small catchments.

Regional maximum flood: 550.2 m^3/s

Q50(RMF): 195.62 m^3/s (based on QT/QRMF relationship for Kovács regions)
Q100(RMF): 257.07 m^3/s (based on QT/QRMF relationship for Kovács regions)

The following equivalent maxima make no transition zone adjustments for small catchments.

Equivalent southern African maximum
K-factor 5.6: 2175 m^3/s

Equivalent world maxima
K-factor 6.0: 3797 m^3/s
K-factor 6.3: 5768 m^3/s

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Rational Method

Project	= Brakfontein MRA
Analysed by	= Chenai
Name of river	= Unnamed
Description of site	= B20E sub 3 on project site
Date	= 2012/06/12
Area of catchment	= 8.25 km²
Dolomitic area	= 0.0 %
Mean annual rainfall (MAR)	= 620.00 mm
Length of longest watercourse	= 2.27 km
Flow of water	= Defined water course
Height difference along 10-85 slope	= 17.88 m
Rainfall region	= Inland
Area distribution	= Rural: 91 %, Urban: 1 %, Lakes: 8 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	10	Houses	44	City centre	1
Sandy, steep (>7%)	0	Flats	0	Suburban	0
Heavy soil, flat (<2%)	5	Light industry	10	Streets	30
Heavy soil, steep (>7%)	0	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	60	Very permeable	0	Thick bush & forests	0
Flat area	40	Permeable	85	Light bush & cultivated land	50
Hilly	0	Semi-permeable	15	Grasslands	20
Steep areas	0	Impermeable	0	Bare	30

Average slope	= 0.0105 m/m
Time of concentration	= 43.2 min
Run-off factor	
Rural - C1	= 0.323
Urban - C2	= 0.611
Lakes - C3	= 0.000
Combined - C	= 0.300

The HRU, Report 2/78, Depth-Duration-Frequency diagram was used to determine the point rainfall.

Return Period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm)	Factor Ft	Runoff coefficient (%)	Peak flow (m³/s)
1:20	0.72	57.3	98.2	78.1	0.90	27.1	48.43
1:50	0.72	74.5	97.7	101.0	0.95	28.5	

```
     66.02
1:100      0.72          91.7        97.2    123.6       1.00       30.0
     84.98
```

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Alternative Rational Method

```
Project                                = Brakfontein MRA
Analysed by                            = Chenai
Name of river                          = Unnamed
Description of site                    = B20E sub 3 on project site
Date                                   = 2012/06/12
Area of catchment                      = 8.25 km²
Dolomitic area                         = 0.0 %
Length of longest watercourse          = 2.27 km
Flow of water                          = Defined water course
Height difference along 10-85 slope    = 17.88 m
Area distribution                      = Rural: 91 %,  Urban: 1 %,  Lakes: 8
%
```

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	10	Houses	44	City centre	1
Sandy, steep (>7%)	0	Flats	0	Suburban	0
Heavy soil, flat (<2%)	5	Light industry	10	Streets	30
Heavy soil, steep (>7%)	0	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	60	Very permeable	0	Thick bush & forests	0
Flat area	40	Permeable	85	Light bush & cultivated land	50
Hilly	0	Semi-permeable	15	Grasslands	20
Steep areas	0	Impermeable	0	Bare	30

```
Days on which thunder was heard        = 62 days/year
Weather Services station number        = 477762
Weather Services station location      = STREHLA

Mean annual precipitation (MAP)        =  650  mm
```

Duration	2	5	10	20	50	100	200
1 day	53	72	87	103	126	145	166
2 days	65	87	103	120	144	165	186
3 days	72	96	114	132	158	180	202
7 days	94	127	151	176	211	240	270

The modified recalibrated Hershfield relationship was used to determine point rainfall.

Average slope	= 0.0105 m/m
Time of concentration	= 43.2 min
Run-off factor	
Rural - C1	= 0.323
Urban - C2	= 0.611
Lakes - C3	= 0.000
Combined - C	= 0.300

Return period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm)	Factor Ft	Runoff coefficient (%)	Peak flow (m³/s)
1:20	0.72	66.59	100.0	92.41	0.90	27.1	57.31
1:50	0.72	83.36	100.0	115.70	0.95	28.5	75.65
1:100	0.72	96.06	100.0	133.31	1.00	30.0	91.66

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Unit Hydrograph Method

Project	= Brakfontein MRA
Analysed by	= Chenai
Name of river	= Unnamed
Description of site	= B20E sub 3 on project site
Date	= 2012/06/12
Area of catchment	= 8.25 km²
Length of longest watercourse	= 2.27 km
Height difference along equal area slope	= 9.0 m
Distance to catchment centroid	= 0.85 km
Veld type	= Region 4
Duration interval	= 1 hour

Slope of longest stream = 0.0040 m/m
Catchment index = 30.6
Catchment lag = 1.111
Coefficient (Ku) = 0.386 m^3/s - hours/km^2
Peak discharge of unit hydrograph (Qp) = 2.866 m^3/s

Return period = 1:20 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	63.5	63.5	98.6	62.6	28.2	17.63
120	75.3	37.6	99.2	74.6	31.3	23.35
180	81.5	27.2	99.4	81.0	32.8	26.60
240	85.7	21.4	99.5	85.3	33.8	28.86
300	88.8	17.8	99.6	88.5	34.6	30.61
360	91.4	15.2	99.7	91.1	35.2	32.04
420	93.5	13.4	99.7	93.2	35.7	33.25
480	95.3	11.9	99.7	95.1	36.1	34.30
540	96.9	10.8	99.8	96.7	36.4	35.23
600	98.3	9.8	99.8	98.1	36.8	36.07
660	99.6	9.1	99.8	99.4	37.1	36.84
720	100.8	8.4	99.8	100.6	37.3	37.54
780	101.9	7.8	99.8	101.7	37.6	38.19
840	102.9	7.3	99.8	102.7	37.8	38.80
900	103.8	6.9	99.8	103.7	38.0	39.37
960	104.7	6.5	99.9	104.5	38.2	39.90
1020	105.5	6.2	99.9	105.4	38.4	40.41
1080	106.3	5.9	99.9	106.2	38.5	40.89
1140	107.0	5.6	99.9	106.9	38.7	41.35
1200	107.7	5.4	99.9	107.6	38.8	

						41.79
1260	108.4	5.2	99.9	108.3	39.0	42.21
1320	109.0	5.0	99.9	108.9	39.1	42.61
1380	109.7	4.8	99.9	109.5	39.2	42.99
1440	110.3	4.6	99.9	110.1	39.4	43.36
1500	110.8	4.4	99.9	110.7	39.5	43.72
1560	111.4	4.3	99.9	111.3	39.6	44.07
1620	111.9	4.1	99.9	111.8	39.7	44.40
1680	112.4	4.0	99.9	112.3	39.8	44.72
1740	112.9	3.9	99.9	112.8	39.9	45.04
1800	113.4	3.8	99.9	113.3	40.0	45.34
1860	113.8	3.7	99.9	113.7	40.1	45.64
1920	114.3	3.6	99.9	114.2	40.2	45.93
1980	114.7	3.5	99.9	114.6	40.3	46.21
2040	115.1	3.4	99.9	115.0	40.4	46.48
2100	115.5	3.3	99.9	115.5	40.5	46.75
2160	115.9	3.2	99.9	115.9	40.6	47.00
2220	116.3	3.1	99.9	116.2	40.7	47.26
2280	116.7	3.1	99.9	116.6	40.7	47.51
2340	117.1	3.0	99.9	117.0	40.8	47.75
2400	117.4	2.9	99.9	117.4	40.9	47.99
2460	117.8	2.9	99.9	117.7	41.0	48.22
2520	118.1	2.8	99.9	118.1	41.0	48.45
2580	118.5	2.8	99.9	118.4	41.1	48.67
2640	118.8	2.7	99.9	118.7	41.2	48.89
2700	119.1	2.6	99.9	119.1	41.2	49.10
2760	119.5	2.6	99.9	119.4	41.3	49.31
2820	119.8	2.5	99.9	119.7	41.4	49.52
2880	120.1	2.5	99.9	120.0	41.4	49.72

Return period = 1:50 year

Storm Point Point ARF Average Runoff

duration (minutes)	rainfall (mm)	intensity (mm/h)	(%)	rainfall (mm)	factor (%)	Effective rain (mm)
60	82.5	82.5	98.2	81.0	32.8	26.58
120	97.9	48.9	98.9	96.8	36.5	35.30
180	106.0	35.3	99.2	105.1	38.3	40.26
240	111.4	27.9	99.4	110.7	39.5	43.72
300	115.5	23.1	99.5	114.9	40.4	46.39
360	118.8	19.8	99.6	118.3	41.1	48.57
420	121.5	17.4	99.6	121.1	41.7	50.42
480	123.9	15.5	99.7	123.5	42.1	52.03
540	126.0	14.0	99.7	125.6	42.6	53.46
600	127.8	12.8	99.7	127.5	43.0	54.75
660	129.5	11.8	99.7	129.2	43.3	55.92
720	131.0	10.9	99.8	130.7	43.6	57.00
780	132.4	10.2	99.8	132.1	43.9	57.99
840	133.7	9.6	99.8	133.5	44.2	58.92
900	135.0	9.0	99.8	134.7	44.4	59.80
960	136.1	8.5	99.8	135.8	44.6	60.62
1020	137.2	8.1	99.8	136.9	44.8	61.39
1080	138.2	7.7	99.8	138.0	45.0	62.13
1140	139.1	7.3	99.8	138.9	45.2	62.83
1200	140.1	7.0	99.8	139.8	45.4	63.50
1260	140.9	6.7	99.9	140.7	45.6	64.14
1320	141.8	6.4	99.9	141.6	45.7	64.75
1380	142.6	6.2	99.9	142.4	45.9	65.34
1440	143.3	6.0	99.9	143.1	46.0	65.91
1500	144.1	5.8	99.9	143.9	46.2	66.46
1560	144.8	5.6	99.9	144.6	46.3	66.99
1620	145.5	5.4	99.9	145.3	46.5	67.50
1680	146.1	5.2	99.9	145.9	46.6	

67.99

1740	146.8	5.1	99.9	146.6	46.7	68.48
1800	147.4	4.9	99.9	147.2	46.8	68.94
1860	148.0	4.8	99.9	147.8	46.9	69.39
1920	148.5	4.6	99.9	148.4	47.1	69.84
1980	149.1	4.5	99.9	149.0	47.2	70.26
2040	149.7	4.4	99.9	149.5	47.3	70.68
2100	150.2	4.3	99.9	150.1	47.4	71.09
2160	150.7	4.2	99.9	150.6	47.5	71.49
2220	151.2	4.1	99.9	151.1	47.6	71.88
2280	151.7	4.0	99.9	151.6	47.7	72.26
2340	152.2	3.9	99.9	152.1	47.8	72.63
2400	152.7	3.8	99.9	152.5	47.9	72.99
2460	153.1	3.7	99.9	153.0	47.9	73.35
2520	153.6	3.7	99.9	153.5	48.0	73.70
2580	154.0	3.6	99.9	153.9	48.1	74.04
2640	154.5	3.5	99.9	154.3	48.2	74.37
2700	154.9	3.4	99.9	154.8	48.3	74.70
2760	155.3	3.4	99.9	155.2	48.3	75.02
2820	155.7	3.3	99.9	155.6	48.4	75.34
2880	156.1	3.3	99.9	156.0	48.5	75.65

Return period = 1:100 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	101.5	101.5	97.7	99.2	37.0	36.72
120	120.4	60.2	98.7	118.8	41.2	48.94
180	130.4	43.5	99.0	129.1	43.3	55.90
240	137.1	34.3	99.2	136.1	44.7	60.77

300	142.2	28.4	99.4	141.3	45.7	64.53
360	146.2	24.4	99.5	145.4	46.5	67.59
420	149.6	21.4	99.5	148.9	47.2	70.19
480	152.5	19.1	99.6	151.8	47.7	72.46
540	155.0	17.2	99.6	154.5	48.2	74.46
600	157.3	15.7	99.6	156.8	48.7	76.27
660	159.4	14.5	99.7	158.9	49.0	77.92
720	161.3	13.4	99.7	160.8	49.4	79.43
780	163.0	12.5	99.7	162.5	49.7	80.83
840	164.6	11.8	99.7	164.2	50.0	82.14
900	166.1	11.1	99.8	165.7	50.3	83.36
960	167.5	10.5	99.8	167.1	50.6	84.52
1020	168.8	9.9	99.8	168.5	50.8	85.61
1080	170.1	9.4	99.8	169.7	51.1	86.64
1140	171.3	9.0	99.8	170.9	51.3	87.63
1200	172.4	8.6	99.8	172.1	51.5	88.57
1260	173.5	8.3	99.8	173.1	51.7	89.47
1320	174.5	7.9	99.8	174.2	51.9	90.33
1380	175.5	7.6	99.8	175.2	52.0	91.16
1440	176.4	7.4	99.8	176.1	52.2	91.95
1500	177.3	7.1	99.8	177.0	52.4	92.72
1560	178.2	6.9	99.8	177.9	52.5	93.47
1620	179.0	6.6	99.9	178.8	52.7	94.19
1680	179.8	6.4	99.9	179.6	52.8	94.88
1740	180.6	6.2	99.9	180.4	53.0	95.56
1800	181.4	6.0	99.9	181.1	53.1	96.21
1860	182.1	5.9	99.9	181.9	53.3	96.85
1920	182.8	5.7	99.9	182.6	53.4	97.47
1980	183.5	5.6	99.9	183.3	53.5	98.07
2040	184.2	5.4	99.9	184.0	53.6	98.66
2100	184.9	5.3	99.9	184.6	53.7	99.23
2160	185.5	5.2	99.9	185.3	53.9	

						99.79
2220	186.1	5.0	99.9	185.9	54.0	100.34
2280	186.7	4.9	99.9	186.5	54.1	100.87
2340	187.3	4.8	99.9	187.1	54.2	101.40
2400	187.9	4.7	99.9	187.7	54.3	101.91
2460	188.5	4.6	99.9	188.3	54.4	102.41
2520	189.0	4.5	99.9	188.8	54.5	102.90
2580	189.6	4.4	99.9	189.4	54.6	103.38
2640	190.1	4.3	99.9	189.9	54.7	103.85
2700	190.6	4.2	99.9	190.4	54.8	104.31
2760	191.1	4.2	99.9	191.0	54.9	104.76
2820	191.6	4.1	99.9	191.5	55.0	105.21
2880	192.1	4.0	99.9	191.9	55.0	105.64

S-curve calculations

Dimensionless one-hour unit hydrograph

T/TL	Q/Qp
0.000	0.0000
0.900	0.6701
1.800	0.1470
2.700	0.0290
3.600	0.0000
4.500	0.0000

T/TL	Original S-curve	Mofified S-curve
0.000	0.0000	0.0000
0.900	0.6701	0.6701
1.800	0.8171	0.8171
2.700	0.8461	0.8461
3.600	0.8461	0.8461
4.500	0.8461	0.8461

Return period = 1:20 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.670	33.849
120	0.409	27.343
180	0.282	21.499
240	0.212	17.497

300	0.169	14.845
360	0.141	12.947
420	0.121	11.516
480	0.106	10.396
540	0.094	9.492
600	0.085	8.747
660	0.077	8.120
720	0.071	7.586
780	0.065	7.124
840	0.060	6.720
900	0.056	6.364
960	0.053	6.048
1020	0.050	5.764
1080	0.047	5.509
1140	0.045	5.277
1200	0.042	5.066
1260	0.040	4.873
1320	0.038	4.696
1380	0.037	4.532
1440	0.035	4.381
1500	0.034	4.241
1560	0.033	4.110
1620	0.031	3.987
1680	0.030	3.873
1740	0.029	3.766
1800	0.028	3.665
1860	0.027	3.570
1920	0.026	3.480
1980	0.026	3.395
2040	0.025	3.315
2100	0.024	3.239
2160	0.024	3.166
2220	0.023	3.097
2280	0.022	3.031
2340	0.022	2.969
2400	0.021	2.909
2460	0.021	2.852
2520	0.020	2.797
2580	0.020	2.745
2640	0.019	2.694
2700	0.019	2.646
2760	0.018	2.600
2820	0.018	2.555
2880	0.018	2.512

Return period = 1:50 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.670	51.034
120	0.409	41.330
180	0.282	32.539
240	0.212	26.504
300	0.169	22.499
360	0.141	19.631
420	0.121	17.467
480	0.106	15.772
540	0.094	14.405

600	0.085	13.276
660	0.077	12.327
720	0.071	11.518
780	0.065	10.818
840	0.060	10.206
900	0.056	9.666
960	0.053	9.187
1020	0.050	8.757
1080	0.047	8.370
1140	0.045	8.019
1200	0.042	7.699
1260	0.040	7.406
1320	0.038	7.137
1380	0.037	6.889
1440	0.035	6.659
1500	0.034	6.446
1560	0.033	6.247
1620	0.031	6.062
1680	0.030	5.888
1740	0.029	5.726
1800	0.028	5.572
1860	0.027	5.428
1920	0.026	5.292
1980	0.026	5.163
2040	0.025	5.041
2100	0.024	4.925
2160	0.024	4.815
2220	0.023	4.711
2280	0.022	4.611
2340	0.022	4.516
2400	0.021	4.425
2460	0.021	4.338
2520	0.020	4.255
2580	0.020	4.175
2640	0.019	4.099
2700	0.019	4.025
2760	0.018	3.955
2820	0.018	3.887
2880	0.018	3.822

Return period = 1:100 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.670	70.514
120	0.409	57.303
180	0.282	45.187
240	0.212	36.841
300	0.169	31.293
360	0.141	27.317
420	0.121	24.315
480	0.106	21.962
540	0.094	20.063
600	0.085	18.495
660	0.077	17.176
720	0.071	16.051
780	0.065	15.077
840	0.060	14.227

900	0.056	13.476
960	0.053	12.809
1020	0.050	12.211
1080	0.047	11.672
1140	0.045	11.183
1200	0.042	10.738
1260	0.040	10.330
1320	0.038	9.956
1380	0.037	9.610
1440	0.035	9.291
1500	0.034	8.994
1560	0.033	8.717
1620	0.031	8.459
1680	0.030	8.217
1740	0.029	7.990
1800	0.028	7.777
1860	0.027	7.576
1920	0.026	7.386
1980	0.026	7.206
2040	0.025	7.036
2100	0.024	6.875
2160	0.024	6.722
2220	0.023	6.576
2280	0.022	6.437
2340	0.022	6.304
2400	0.021	6.178
2460	0.021	6.057
2520	0.020	5.941
2580	0.020	5.830
2640	0.019	5.723
2700	0.019	5.621
2760	0.018	5.522
2820	0.018	5.428
2880	0.018	5.337

Return period	Storm duration (minutes)	Peak discharge (m^3/s)
1:20 year	60	33.85
1:50 year	60	51.03
1:100 year	60	70.51

Calculated using Utility Programs for Drainage 1.0.2

Flood frequency analysis : Standard Design Flood method

Project name	= Brakfontein MRA
Analysed by	= Chenai
Name of river	= Unnamed
Description of site	= B20E sub 3 on project site
Date	= 2012/06/12
Catchment characteristics:	
Area of catchment	= 8.25 km²
Length of longest watercourse	= 2.27 km
1085 height difference	= 17.88 m
Average slope	= 0.0105 m/m
Drainage basin characteristics:	
Drainage basin number	= 4
Mean annual daily max rain	= 58 mm
Days on which thunder was heard	= 20 days
Runoff coefficient C2	= 10 %
Runoff coefficient C100	= 50 %
Basin mean annual precipitation	= 630 mm
Basin mean annual evaporation	= 1600 mm
Basin evaporation index MAE/MAP	= 2.54

RAINFALL DATA

The rainfall data in the table below are derived from two sources. The daily rainfall is from the Department of Water Affair's publication TR102 for the representative site.

The modified Hershfield equation is used for durations up to four hours. Linear interpolation is used for values between 4 hours and one day.

Weather Services station ex TR102 = 553351 @ WATERVAL
Point mean annual precipitation = 630 mm

Dur:	RP =2	5	10	20	50	100	200
.25 h	14	24	31	39	48	56	63
.50 h	18	31	41	50	63	73	82
1 h	23	38	50	62	78	89	101
2 h	27	46	60	74	92	106	120
4 h	31	53	69	85	107	123	139
1 day	58	76	89	102	122	138	155
2 days	69	90	106	123	146	165	185
3 days	76	99	115	132	156	175	195
7 days	98	131	154	178	211	238	266

CAUTION. The time of concentration is less than one hour.
Runoff coefficients C2 = 10 % C100 = 50 %

Return period (years)	Time of concentration (hours)	Point precipitation (mm)	ARF (%)	Catchment precipitation (mm)	Runoff coefficient (%)	Peak flow (m³/s)
1:20	0.72	55.5	100.0	55.5	38.2	67.41
1:50	0.72	69.5	100.0	69.5	45.2	99.96
1:100	0.72	80.1	100.0	80.1	50.0	

127.44

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Empirical methods

Project	= Brakfontein MRA
Analysed by	= Chenai
Name of river	= Unnamed
Description of site	= B20E sub 3 on project site
Date	= 2012/06/12

Area of catchment	= 8.25 km²
Length of longest watercourse	= 2.27 km
Height difference along equal-area slope	= 9.0 m
Distance to catchment centroid	= 0.85 km
Dolomitic area	= 0.0 %
Mean annual rainfall	= 620.0 mm
Veld type	= 4 & 5A
Kovács region	= K4(K = 4.6)
Catchment parameter with regard to reaction time	= 0.269

Peak discharges by means of an empirical method developed by Midgley and Pitman

Return period (years)	KT constant	Peak flow (m³/s)
1:20	0.68	43.36
1:50	0.95	60.58
1:100	1.20	76.53

This RMF calculation includes a transition zone adjustment in the case of small catchments.

Regional maximum flood: 223.0 m³/s

Q50(RMF): 92.76 m³/s (based on QT/QRMF relationship for Kovács regions)
Q100(RMF): 116.84 m³/s (based on QT/QRMF relationship for Kovács regions)

The following equivalent maxima make no transition zone adjustments for small catchments.

```
Equivalent southern African maximum
K-factor 5.6:                    764   m³/s

Equivalent world maxima
K-factor 6.0:                    1468  m³/s
K-factor 6.3:                    2394  m³/s
```

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Alternative Rational Method

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed
Description of site = B20E sub 2 upstream of Brakfontein Mine.
Date = 2012/06/12
Area of catchment = 61.4 km²
Dolomitic area = 0.0 %
Length of longest watercourse = 15.75 km
Flow of water = Defined water course
Height difference along 10-85 slope = 57.8 m
Area distribution = Rural: 94 %, Urban: 1 %, Lakes: 5 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	10	Houses	44	City centre	1
Sandy, steep (>7%)	0	Flats	0	Suburban	0
Heavy soil, flat (<2%)	5	Light industry	0	Streets	40
Heavy soil, steep (>7%)	0	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	15	Very permeable	5	Thick bush & forests	0
Flat area	84	Permeable	90	Light bush & cultivated land	80
Hilly	1	Semi-permeable	5	Grasslands	10
Steep areas	0	Impermeable	0	Bare	10

Days on which thunder was heard = 62 days/year
Weather Services station number = 477762
Weather Services station location = STREHLA

Mean annual precipitation (MAP) = 650 mm

Duration	2	5	10	20	50	100	200
1 day	53	72	87	103	126	145	166
2 days	65	87	103	120	144	165	186
3 days	72	96	114	132	158	180	202
7 days	94	127	151	176	211	240	270

The modified recalibrated Hershfield relationship was used to determine point rainfall.

Average slope = 0.00489 m/m
Time of concentration = 4.30 h
Run-off factor
Rural - C1 = 0.292
Urban - C2 = 0.626
Lakes - C3 = 0.000
Combined - C = 0.281

Return period	Time of concentration	Point rainfall	ARF	Average intensity	Factor Ft	Runoff	Peak

```
coefficient   flow
     (years)     (hours)        (mm)          (%)      (mm)                      (%)
         (m³/s)

-------------------------------------------------------------------------------------
------------
     1:20        4.30           101.98        96.7     22.94         0.90         25.4
         99.21
     1:50        4.30           127.68        96.7     28.72         0.95         26.7
         130.94
     1:100       4.30           147.11        96.7     33.10         1.00         28.1
         158.64
```

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Unit Hydrograph Method

```
     Project                                      = Brakfontein MRA
     Analysed by                                  = Chenai
     Name of river                                = Unnamed
     Description of site                          = B20E sub 2 upstream of Brakfontein
Mine.
     Date                                         = 2012/06/12
     Area of catchment                            = 61.4 km²
     Length of longest watercourse                = 15.75 km
     Height difference along equal area slope     = 78.0 m
     Distance to catchment centroid               = 10.5 km
     Veld type                                    = Region 4
     Duration interval                            = 1 hour

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     Slope of longest stream                      = 0.0050 m/m
     Catchment index                              = 2350.0
     Catchment lag                                = 5.393
     Coefficient (Ku)                             = 0.386 m³/s - hours/km²
     Peak discharge of unit hydrograph (Qp)       = 4.395 m³/s

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     Return period = 1:20 year

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     Storm            Point      Point         ARF         Average      Runoff
Effective
```

duration (minutes)	rainfall (mm)	intensity (mm/h)	(%)	rainfall (mm)	factor (%)	rain (mm)
60	63.5	63.5	89.9	57.0	26.7	15.21
120	75.3	37.6	94.0	70.8	30.3	21.45
180	81.5	27.2	95.7	78.0	32.1	25.03
240	85.7	21.4	96.6	82.8	33.3	27.52
300	88.8	17.8	97.2	86.3	34.1	29.43
360	91.4	15.2	97.6	89.2	34.7	30.98
420	93.5	13.4	97.9	91.5	35.3	32.28
480	95.3	11.9	98.1	93.5	35.7	33.41
540	96.9	10.8	98.3	95.2	36.1	34.41
600	98.3	9.8	98.4	96.8	36.5	35.30
660	99.6	9.1	98.6	98.2	36.8	36.11
720	100.8	8.4	98.7	99.4	37.1	36.85
780	101.9	7.8	98.8	100.6	37.3	37.54
840	102.9	7.3	98.8	101.7	37.5	38.18
900	103.8	6.9	98.9	102.7	37.8	38.77
960	104.7	6.5	99.0	103.6	38.0	39.34
1020	105.5	6.2	99.0	104.5	38.2	39.86
1080	106.3	5.9	99.1	105.3	38.3	40.37
1140	107.0	5.6	99.1	106.1	38.5	40.84
1200	107.7	5.4	99.1	106.8	38.7	41.30
1260	108.4	5.2	99.2	107.5	38.8	41.73
1320	109.0	5.0	99.2	108.2	39.0	42.15
1380	109.7	4.8	99.2	108.8	39.1	42.54
1440	110.3	4.6	99.3	109.4	39.2	42.93
1500	110.8	4.4	99.3	110.0	39.3	43.30
1560	111.4	4.3	99.3	110.6	39.5	43.65
1620	111.9	4.1	99.3	111.1	39.6	44.00
1680	112.4	4.0	99.4	111.7	39.7	44.33

1740	112.9	3.9	99.4	112.2	39.8	44.65
1800	113.4	3.8	99.4	112.7	39.9	44.97
1860	113.8	3.7	99.4	113.2	40.0	45.27
1920	114.3	3.6	99.4	113.6	40.1	45.57
1980	114.7	3.5	99.4	114.1	40.2	45.86
2040	115.1	3.4	99.5	114.5	40.3	46.14
2100	115.5	3.3	99.5	114.9	40.4	46.41
2160	115.9	3.2	99.5	115.3	40.5	46.67
2220	116.3	3.1	99.5	115.7	40.6	46.93
2280	116.7	3.1	99.5	116.1	40.6	47.19
2340	117.1	3.0	99.5	116.5	40.7	47.44
2400	117.4	2.9	99.5	116.9	40.8	47.68
2460	117.8	2.9	99.5	117.3	40.9	47.92
2520	118.1	2.8	99.6	117.6	40.9	48.15
2580	118.5	2.8	99.6	118.0	41.0	48.38
2640	118.8	2.7	99.6	118.3	41.1	48.60
2700	119.1	2.6	99.6	118.6	41.2	48.82
2760	119.5	2.6	99.6	119.0	41.2	49.03
2820	119.8	2.5	99.6	119.3	41.3	49.24
2880	120.1	2.5	99.6	119.6	41.3	49.45

Return period = 1:50 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	82.5	82.5	86.9	71.6	30.5	21.88
120	97.9	48.9	92.2	90.2	35.0	31.57
180	106.0	35.3	94.4	100.0	37.2	37.18
240	111.4	27.9	95.6	106.5	38.6	41.08
300	115.5	23.1	96.3	111.2	39.6	

44.06

360	118.8	19.8	96.8	115.0	40.4	46.48
420	121.5	17.4	97.2	118.2	41.1	48.52
480	123.9	15.5	97.5	120.8	41.6	50.28
540	126.0	14.0	97.8	123.2	42.1	51.83
600	127.8	12.8	98.0	125.2	42.5	53.22
660	129.5	11.8	98.1	127.1	42.9	54.48
720	131.0	10.9	98.3	128.8	43.2	55.64
780	132.4	10.2	98.4	130.3	43.5	56.70
840	133.7	9.6	98.5	131.7	43.8	57.69
900	135.0	9.0	98.6	133.0	44.1	58.62
960	136.1	8.5	98.6	134.3	44.3	59.49
1020	137.2	8.1	98.7	135.4	44.5	60.31
1080	138.2	7.7	98.8	136.5	44.8	61.08
1140	139.1	7.3	98.8	137.5	45.0	61.82
1200	140.1	7.0	98.9	138.5	45.1	62.52
1260	140.9	6.7	98.9	139.4	45.3	63.20
1320	141.8	6.4	99.0	140.3	45.5	63.84
1380	142.6	6.2	99.0	141.2	45.7	64.46
1440	143.3	6.0	99.0	142.0	45.8	65.05
1500	144.1	5.8	99.1	142.7	46.0	65.62
1560	144.8	5.6	99.1	143.5	46.1	66.17
1620	145.5	5.4	99.1	144.2	46.3	66.70
1680	146.1	5.2	99.2	144.9	46.4	67.22
1740	146.8	5.1	99.2	145.6	46.5	67.72
1800	147.4	4.9	99.2	146.2	46.6	68.20
1860	148.0	4.8	99.2	146.8	46.8	68.67
1920	148.5	4.6	99.3	147.5	46.9	69.12
1980	149.1	4.5	99.3	148.0	47.0	69.57
2040	149.7	4.4	99.3	148.6	47.1	70.00
2100	150.2	4.3	99.3	149.2	47.2	70.42
2160	150.7	4.2	99.3	149.7	47.3	70.83

2220	151.2	4.1	99.3	150.2	47.4	71.23
2280	151.7	4.0	99.4	150.8	47.5	71.62
2340	152.2	3.9	99.4	151.3	47.6	72.01
2400	152.7	3.8	99.4	151.7	47.7	72.38
2460	153.1	3.7	99.4	152.2	47.8	72.75
2520	153.6	3.7	99.4	152.7	47.9	73.11
2580	154.0	3.6	99.4	153.1	48.0	73.46
2640	154.5	3.5	99.4	153.6	48.0	73.80
2700	154.9	3.4	99.5	154.0	48.1	74.14
2760	155.3	3.4	99.5	154.5	48.2	74.47
2820	155.7	3.3	99.5	154.9	48.3	74.79
2880	156.1	3.3	99.5	155.3	48.4	75.11

Return period = 1:100 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	101.5	101.5	83.8	85.1	33.8	28.77
120	120.4	60.2	90.4	108.9	39.1	42.58
180	130.4	43.5	93.1	121.4	41.7	50.63
240	137.1	34.3	94.5	129.6	43.4	56.24
300	142.2	28.4	95.5	135.7	44.6	60.53
360	146.2	24.4	96.1	140.5	45.5	64.00
420	149.6	21.4	96.6	144.5	46.3	66.91
480	152.5	19.1	97.0	147.9	47.0	69.43
540	155.0	17.2	97.3	150.8	47.5	71.65
600	157.3	15.7	97.5	153.4	48.0	73.64
660	159.4	14.5	97.7	155.7	48.4	75.44
720	161.3	13.4	97.9	157.8	48.8	77.09
780	163.0	12.5	98.0	159.7	49.2	

78.61

840	164.6	11.8	98.1	161.5	49.5	80.02
900	166.1	11.1	98.2	163.2	49.8	81.34
960	167.5	10.5	98.3	164.7	50.1	82.57
1020	168.8	9.9	98.4	166.2	50.4	83.74
1080	170.1	9.4	98.5	167.5	50.6	84.84
1140	171.3	9.0	98.6	168.8	50.9	85.89
1200	172.4	8.6	98.6	170.0	51.1	86.89
1260	173.5	8.3	98.7	171.2	51.3	87.84
1320	174.5	7.9	98.7	172.3	51.5	88.75
1380	175.5	7.6	98.8	173.3	51.7	89.63
1440	176.4	7.4	98.8	174.3	51.9	90.47
1500	177.3	7.1	98.9	175.3	52.1	91.28
1560	178.2	6.9	98.9	176.2	52.2	92.06
1620	179.0	6.6	98.9	177.1	52.4	92.81
1680	179.8	6.4	99.0	178.0	52.6	93.54
1740	180.6	6.2	99.0	178.8	52.7	94.25
1800	181.4	6.0	99.0	179.6	52.8	94.93
1860	182.1	5.9	99.1	180.4	53.0	95.60
1920	182.8	5.7	99.1	181.2	53.1	96.24
1980	183.5	5.6	99.1	181.9	53.3	96.87
2040	184.2	5.4	99.1	182.6	53.4	97.48
2100	184.9	5.3	99.2	183.3	53.5	98.08
2160	185.5	5.2	99.2	184.0	53.6	98.66
2220	186.1	5.0	99.2	184.6	53.7	99.23
2280	186.7	4.9	99.2	185.3	53.9	99.78
2340	187.3	4.8	99.2	185.9	54.0	100.32
2400	187.9	4.7	99.3	186.5	54.1	100.85
2460	188.5	4.6	99.3	187.1	54.2	101.37
2520	189.0	4.5	99.3	187.7	54.3	101.87
2580	189.6	4.4	99.3	188.2	54.4	102.37
2640	190.1	4.3	99.3	188.8	54.5	102.86

2700	190.6	4.2	99.3	189.3	54.6	103.33
2760	191.1	4.2	99.3	189.9	54.7	103.80
2820	191.6	4.1	99.4	190.4	54.8	104.26
2880	192.1	4.0	99.4	190.9	54.9	104.71

S-curve calculations

Dimensionless one-hour unit hydrograph

T/TL	Q/Qp
0.000	0.0000
0.185	0.0401
0.371	0.1223
0.556	0.3941
0.742	0.9892
0.927	0.6211
1.113	0.4207
1.298	0.3110
1.483	0.2406
1.669	0.1813
1.854	0.1351
2.040	0.1001
2.225	0.0710
2.411	0.0509
2.596	0.0353
2.781	0.0241
2.967	0.0167
3.152	0.0090
3.338	0.0032
3.523	0.0000
3.709	0.0000
3.894	0.0000
4.079	0.0000
4.265	0.0000

T/TL	Original S-curve	Mofified S-curve
0.000	0.0000	0.0000
0.185	0.0401	0.0401
0.371	0.1624	0.1624
0.556	0.5564	0.5564
0.742	1.5456	1.5456
0.927	2.1667	2.1667
1.113	2.5874	2.5874
1.298	2.8984	2.8984
1.483	3.1391	3.1391
1.669	3.3204	3.3204
1.854	3.4554	3.4554
2.040	3.5555	3.5555
2.225	3.6265	3.6265
2.411	3.6774	3.6774
2.596	3.7127	3.7127
2.781	3.7368	3.7368
2.967	3.7535	3.7535
3.152	3.7625	3.7625
3.338	3.7657	3.7657
3.523	3.7657	3.7657

3.709	3.7657	3.7657
3.894	3.7657	3.7657
4.079	3.7657	3.7657
4.265	3.7657	3.7657

Return period = 1:20 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.989	66.133
120	0.805	75.904
180	0.677	74.478
240	0.606	73.330
300	0.547	70.773
360	0.496	67.538
420	0.451	64.001
480	0.412	60.438
540	0.379	57.380
600	0.352	54.536
660	0.326	51.741
720	0.303	49.093
780	0.283	46.669
840	0.265	44.496
900	0.249	42.452
960	0.235	40.555
1020	0.221	38.775
1080	0.209	37.113
1140	0.198	35.575
1200	0.188	34.172
1260	0.179	32.886
1320	0.171	31.704
1380	0.164	30.612
1440	0.157	29.601
1500	0.151	28.662
1560	0.145	27.786
1620	0.139	26.968
1680	0.134	26.202
1740	0.130	25.483
1800	0.126	24.806
1860	0.121	24.169
1920	0.118	23.566
1980	0.114	22.996
2040	0.111	22.456
2100	0.108	21.944
2160	0.105	21.457
2220	0.102	20.993
2280	0.099	20.551
2340	0.097	20.129
2400	0.094	19.727
2460	0.092	19.341
2520	0.090	18.972
2580	0.088	18.619
2640	0.086	18.280
2700	0.084	17.954
2760	0.082	17.641
2820	0.080	17.340
2880	0.078	17.050

Return period = 1:50 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.989	95.113
120	0.805	111.712
180	0.677	110.611
240	0.606	109.445
300	0.547	105.964
360	0.496	101.343
420	0.451	96.194
480	0.412	90.954
540	0.379	86.440
600	0.352	82.224
660	0.326	78.066
720	0.303	74.115
780	0.283	70.493
840	0.265	67.241
900	0.249	64.179
960	0.235	61.332
1020	0.221	58.660
1080	0.209	56.162
1140	0.198	53.849
1200	0.188	51.738
1260	0.179	49.803
1320	0.171	48.023
1380	0.164	46.378
1440	0.157	44.855
1500	0.151	43.438
1560	0.145	42.118
1620	0.139	40.884
1680	0.134	39.729
1740	0.130	38.643
1800	0.126	37.622
1860	0.121	36.659
1920	0.118	35.749
1980	0.114	34.888
2040	0.111	34.073
2100	0.108	33.298
2160	0.105	32.562
2220	0.102	31.861
2280	0.099	31.193
2340	0.097	30.556
2400	0.094	29.947
2460	0.092	29.364
2520	0.090	28.806
2580	0.088	28.271
2640	0.086	27.758
2700	0.084	27.265
2760	0.082	26.792
2820	0.080	26.336
2880	0.078	25.897

Return period = 1:100 year

Storm Unit hydrograph Peak

duration (minutes)	peak (Qe) (m^3/s)	discharge (m^3/s)
60	0.989	125.050
120	0.805	150.666
180	0.677	150.643
240	0.606	149.840
300	0.547	145.557
360	0.496	139.531
420	0.451	132.669
480	0.412	125.609
540	0.379	119.501
600	0.352	113.772
660	0.326	108.097
720	0.303	102.690
780	0.283	97.724
840	0.265	93.259
900	0.249	89.050
960	0.235	85.131
1020	0.221	81.449
1080	0.209	78.004
1140	0.198	74.811
1200	0.188	71.896
1260	0.179	69.224
1320	0.171	66.763
1380	0.164	64.490
1440	0.157	62.382
1500	0.151	60.423
1560	0.145	58.596
1620	0.139	56.888
1680	0.134	55.287
1740	0.130	53.784
1800	0.126	52.369
1860	0.121	51.035
1920	0.118	49.774
1980	0.114	48.581
2040	0.111	47.449
2100	0.108	46.375
2160	0.105	45.354
2220	0.102	44.382
2280	0.099	43.455
2340	0.097	42.571
2400	0.094	41.725
2460	0.092	40.916
2520	0.090	40.142
2580	0.088	39.399
2640	0.086	38.687
2700	0.084	38.002
2760	0.082	37.345
2820	0.080	36.712
2880	0.078	36.102

Return period	Storm duration (minutes)	Peak discharge (m^3/s)
1:20 year	120	75.90

1:50 year	120	111.71
1:100 year	120	150.67

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Unit Hydrograph Method

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed
Description of site = B20E sub 2 upstream of Brakfontein Mine.
Date = 2012/06/12
Area of catchment = 61.4 km²
Length of longest watercourse = 15.75 km
Height difference along equal area slope = 78.0 m
Distance to catchment centroid = 10.5 km
Veld type = Region 4
Duration interval = 1 hour

Slope of longest stream = 0.0050 m/m
Catchment index = 2350.0
Catchment lag = 5.393
Coefficient (Ku) = 0.386 m³/s - hours/km²
Peak discharge of unit hydrograph (Qp) = 4.395 m³/s

Return period = 1:20 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	63.5	63.5	89.9	57.0	26.7	15.21
120	75.3	37.6	94.0	70.8	30.3	21.45

180	81.5	27.2	95.7	78.0	32.1	25.03
240	85.7	21.4	96.6	82.8	33.3	27.52
300	88.8	17.8	97.2	86.3	34.1	29.43
360	91.4	15.2	97.6	89.2	34.7	30.98
420	93.5	13.4	97.9	91.5	35.3	32.28
480	95.3	11.9	98.1	93.5	35.7	33.41
540	96.9	10.8	98.3	95.2	36.1	34.41
600	98.3	9.8	98.4	96.8	36.5	35.30
660	99.6	9.1	98.6	98.2	36.8	36.11
720	100.8	8.4	98.7	99.4	37.1	36.85
780	101.9	7.8	98.8	100.6	37.3	37.54
840	102.9	7.3	98.8	101.7	37.5	38.18
900	103.8	6.9	98.9	102.7	37.8	38.77
960	104.7	6.5	99.0	103.6	38.0	39.34
1020	105.5	6.2	99.0	104.5	38.2	39.86
1080	106.3	5.9	99.1	105.3	38.3	40.37
1140	107.0	5.6	99.1	106.1	38.5	40.84
1200	107.7	5.4	99.1	106.8	38.7	41.30
1260	108.4	5.2	99.2	107.5	38.8	41.73
1320	109.0	5.0	99.2	108.2	39.0	42.15
1380	109.7	4.8	99.2	108.8	39.1	42.54
1440	110.3	4.6	99.3	109.4	39.2	42.93
1500	110.8	4.4	99.3	110.0	39.3	43.30
1560	111.4	4.3	99.3	110.6	39.5	43.65
1620	111.9	4.1	99.3	111.1	39.6	44.00
1680	112.4	4.0	99.4	111.7	39.7	44.33
1740	112.9	3.9	99.4	112.2	39.8	44.65
1800	113.4	3.8	99.4	112.7	39.9	44.97
1860	113.8	3.7	99.4	113.2	40.0	45.27
1920	114.3	3.6	99.4	113.6	40.1	45.57
1980	114.7	3.5	99.4	114.1	40.2	45.86
2040	115.1	3.4	99.5	114.5	40.3	

46.14

2100	115.5	3.3	99.5	114.9	40.4	46.41
2160	115.9	3.2	99.5	115.3	40.5	46.67
2220	116.3	3.1	99.5	115.7	40.6	46.93
2280	116.7	3.1	99.5	116.1	40.6	47.19
2340	117.1	3.0	99.5	116.5	40.7	47.44
2400	117.4	2.9	99.5	116.9	40.8	47.68
2460	117.8	2.9	99.5	117.3	40.9	47.92
2520	118.1	2.8	99.6	117.6	40.9	48.15
2580	118.5	2.8	99.6	118.0	41.0	48.38
2640	118.8	2.7	99.6	118.3	41.1	48.60
2700	119.1	2.6	99.6	118.6	41.2	48.82
2760	119.5	2.6	99.6	119.0	41.2	49.03
2820	119.8	2.5	99.6	119.3	41.3	49.24
2880	120.1	2.5	99.6	119.6	41.3	49.45

Return period = 1:50 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	82.5	82.5	86.9	71.6	30.5	21.88
120	97.9	48.9	92.2	90.2	35.0	31.57
180	106.0	35.3	94.4	100.0	37.2	37.18
240	111.4	27.9	95.6	106.5	38.6	41.08
300	115.5	23.1	96.3	111.2	39.6	44.06
360	118.8	19.8	96.8	115.0	40.4	46.48
420	121.5	17.4	97.2	118.2	41.1	48.52
480	123.9	15.5	97.5	120.8	41.6	50.28
540	126.0	14.0	97.8	123.2	42.1	51.83
600	127.8	12.8	98.0	125.2	42.5	53.22

660	129.5	11.8	98.1	127.1	42.9	54.48
720	131.0	10.9	98.3	128.8	43.2	55.64
780	132.4	10.2	98.4	130.3	43.5	56.70
840	133.7	9.6	98.5	131.7	43.8	57.69
900	135.0	9.0	98.6	133.0	44.1	58.62
960	136.1	8.5	98.6	134.3	44.3	59.49
1020	137.2	8.1	98.7	135.4	44.5	60.31
1080	138.2	7.7	98.8	136.5	44.8	61.08
1140	139.1	7.3	98.8	137.5	45.0	61.82
1200	140.1	7.0	98.9	138.5	45.1	62.52
1260	140.9	6.7	98.9	139.4	45.3	63.20
1320	141.8	6.4	99.0	140.3	45.5	63.84
1380	142.6	6.2	99.0	141.2	45.7	64.46
1440	143.3	6.0	99.0	142.0	45.8	65.05
1500	144.1	5.8	99.1	142.7	46.0	65.62
1560	144.8	5.6	99.1	143.5	46.1	66.17
1620	145.5	5.4	99.1	144.2	46.3	66.70
1680	146.1	5.2	99.2	144.9	46.4	67.22
1740	146.8	5.1	99.2	145.6	46.5	67.72
1800	147.4	4.9	99.2	146.2	46.6	68.20
1860	148.0	4.8	99.2	146.8	46.8	68.67
1920	148.5	4.6	99.3	147.5	46.9	69.12
1980	149.1	4.5	99.3	148.0	47.0	69.57
2040	149.7	4.4	99.3	148.6	47.1	70.00
2100	150.2	4.3	99.3	149.2	47.2	70.42
2160	150.7	4.2	99.3	149.7	47.3	70.83
2220	151.2	4.1	99.3	150.2	47.4	71.23
2280	151.7	4.0	99.4	150.8	47.5	71.62
2340	152.2	3.9	99.4	151.3	47.6	72.01
2400	152.7	3.8	99.4	151.7	47.7	72.38
2460	153.1	3.7	99.4	152.2	47.8	72.75
2520	153.6	3.7	99.4	152.7	47.9	

73.11

2580	154.0	3.6	99.4	153.1	48.0	73.46
2640	154.5	3.5	99.4	153.6	48.0	73.80
2700	154.9	3.4	99.5	154.0	48.1	74.14
2760	155.3	3.4	99.5	154.5	48.2	74.47
2820	155.7	3.3	99.5	154.9	48.3	74.79
2880	156.1	3.3	99.5	155.3	48.4	75.11

Return period = 1:100 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	101.5	101.5	83.8	85.1	33.8	28.77
120	120.4	60.2	90.4	108.9	39.1	42.58
180	130.4	43.5	93.1	121.4	41.7	50.63
240	137.1	34.3	94.5	129.6	43.4	56.24
300	142.2	28.4	95.5	135.7	44.6	60.53
360	146.2	24.4	96.1	140.5	45.5	64.00
420	149.6	21.4	96.6	144.5	46.3	66.91
480	152.5	19.1	97.0	147.9	47.0	69.43
540	155.0	17.2	97.3	150.8	47.5	71.65
600	157.3	15.7	97.5	153.4	48.0	73.64
660	159.4	14.5	97.7	155.7	48.4	75.44
720	161.3	13.4	97.9	157.8	48.8	77.09
780	163.0	12.5	98.0	159.7	49.2	78.61
840	164.6	11.8	98.1	161.5	49.5	80.02
900	166.1	11.1	98.2	163.2	49.8	81.34
960	167.5	10.5	98.3	164.7	50.1	82.57
1020	168.8	9.9	98.4	166.2	50.4	83.74
1080	170.1	9.4	98.5	167.5	50.6	84.84

1140	171.3	9.0	98.6	168.8	50.9	85.89
1200	172.4	8.6	98.6	170.0	51.1	86.89
1260	173.5	8.3	98.7	171.2	51.3	87.84
1320	174.5	7.9	98.7	172.3	51.5	88.75
1380	175.5	7.6	98.8	173.3	51.7	89.63
1440	176.4	7.4	98.8	174.3	51.9	90.47
1500	177.3	7.1	98.9	175.3	52.1	91.28
1560	178.2	6.9	98.9	176.2	52.2	92.06
1620	179.0	6.6	98.9	177.1	52.4	92.81
1680	179.8	6.4	99.0	178.0	52.6	93.54
1740	180.6	6.2	99.0	178.8	52.7	94.25
1800	181.4	6.0	99.0	179.6	52.8	94.93
1860	182.1	5.9	99.1	180.4	53.0	95.60
1920	182.8	5.7	99.1	181.2	53.1	96.24
1980	183.5	5.6	99.1	181.9	53.3	96.87
2040	184.2	5.4	99.1	182.6	53.4	97.48
2100	184.9	5.3	99.2	183.3	53.5	98.08
2160	185.5	5.2	99.2	184.0	53.6	98.66
2220	186.1	5.0	99.2	184.6	53.7	99.23
2280	186.7	4.9	99.2	185.3	53.9	99.78
2340	187.3	4.8	99.2	185.9	54.0	100.32
2400	187.9	4.7	99.3	186.5	54.1	100.85
2460	188.5	4.6	99.3	187.1	54.2	101.37
2520	189.0	4.5	99.3	187.7	54.3	101.87
2580	189.6	4.4	99.3	188.2	54.4	102.37
2640	190.1	4.3	99.3	188.8	54.5	102.86
2700	190.6	4.2	99.3	189.3	54.6	103.33
2760	191.1	4.2	99.3	189.9	54.7	103.80
2820	191.6	4.1	99.4	190.4	54.8	104.26
2880	192.1	4.0	99.4	190.9	54.9	104.71

S-curve calculations

Dimensionless one-hour unit hydrograph

T/TL	Q/Qp
0.000	0.0000
0.185	0.0401
0.371	0.1223
0.556	0.3941
0.742	0.9892
0.927	0.6211
1.113	0.4207
1.298	0.3110
1.483	0.2406
1.669	0.1813
1.854	0.1351
2.040	0.1001
2.225	0.0710
2.411	0.0509
2.596	0.0353
2.781	0.0241
2.967	0.0167
3.152	0.0090
3.338	0.0032
3.523	0.0000
3.709	0.0000
3.894	0.0000
4.079	0.0000
4.265	0.0000

T/TL	Original S-curve	Mofified S-curve
0.000	0.0000	0.0000
0.185	0.0401	0.0401
0.371	0.1624	0.1624
0.556	0.5564	0.5564
0.742	1.5456	1.5456
0.927	2.1667	2.1667
1.113	2.5874	2.5874
1.298	2.8984	2.8984
1.483	3.1391	3.1391
1.669	3.3204	3.3204
1.854	3.4554	3.4554
2.040	3.5555	3.5555
2.225	3.6265	3.6265
2.411	3.6774	3.6774
2.596	3.7127	3.7127
2.781	3.7368	3.7368
2.967	3.7535	3.7535
3.152	3.7625	3.7625
3.338	3.7657	3.7657
3.523	3.7657	3.7657
3.709	3.7657	3.7657
3.894	3.7657	3.7657
4.079	3.7657	3.7657
4.265	3.7657	3.7657

Return period = 1:20 year

Storm duration	Unit hydrograph peak (Qe)	Peak discharge

(minutes)	(m^3/s)	(m^3/s)
60	0.989	66.133
120	0.805	75.904
180	0.677	74.478
240	0.606	73.330
300	0.547	70.773
360	0.496	67.538
420	0.451	64.001
480	0.412	60.438
540	0.379	57.380
600	0.352	54.536
660	0.326	51.741
720	0.303	49.093
780	0.283	46.669
840	0.265	44.496
900	0.249	42.452
960	0.235	40.555
1020	0.221	38.775
1080	0.209	37.113
1140	0.198	35.575
1200	0.188	34.172
1260	0.179	32.886
1320	0.171	31.704
1380	0.164	30.612
1440	0.157	29.601
1500	0.151	28.662
1560	0.145	27.786
1620	0.139	26.968
1680	0.134	26.202
1740	0.130	25.483
1800	0.126	24.806
1860	0.121	24.169
1920	0.118	23.566
1980	0.114	22.996
2040	0.111	22.456
2100	0.108	21.944
2160	0.105	21.457
2220	0.102	20.993
2280	0.099	20.551
2340	0.097	20.129
2400	0.094	19.727
2460	0.092	19.341
2520	0.090	18.972
2580	0.088	18.619
2640	0.086	18.280
2700	0.084	17.954
2760	0.082	17.641
2820	0.080	17.340
2880	0.078	17.050

Return period = 1:50 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.989	95.113

120	0.805	111.712
180	0.677	110.611
240	0.606	109.445
300	0.547	105.964
360	0.496	101.343
420	0.451	96.194
480	0.412	90.954
540	0.379	86.440
600	0.352	82.224
660	0.326	78.066
720	0.303	74.115
780	0.283	70.493
840	0.265	67.241
900	0.249	64.179
960	0.235	61.332
1020	0.221	58.660
1080	0.209	56.162
1140	0.198	53.849
1200	0.188	51.738
1260	0.179	49.803
1320	0.171	48.023
1380	0.164	46.378
1440	0.157	44.855
1500	0.151	43.438
1560	0.145	42.118
1620	0.139	40.884
1680	0.134	39.729
1740	0.130	38.643
1800	0.126	37.622
1860	0.121	36.659
1920	0.118	35.749
1980	0.114	34.888
2040	0.111	34.073
2100	0.108	33.298
2160	0.105	32.562
2220	0.102	31.861
2280	0.099	31.193
2340	0.097	30.556
2400	0.094	29.947
2460	0.092	29.364
2520	0.090	28.806
2580	0.088	28.271
2640	0.086	27.758
2700	0.084	27.265
2760	0.082	26.792
2820	0.080	26.336
2880	0.078	25.897

Return period = 1:100 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.989	125.050
120	0.805	150.666
180	0.677	150.643
240	0.606	149.840
300	0.547	145.557
360	0.496	139.531

420	0.451	132.669
480	0.412	125.609
540	0.379	119.501
600	0.352	113.772
660	0.326	108.097
720	0.303	102.690
780	0.283	97.724
840	0.265	93.259
900	0.249	89.050
960	0.235	85.131
1020	0.221	81.449
1080	0.209	78.004
1140	0.198	74.811
1200	0.188	71.896
1260	0.179	69.224
1320	0.171	66.763
1380	0.164	64.490
1440	0.157	62.382
1500	0.151	60.423
1560	0.145	58.596
1620	0.139	56.888
1680	0.134	55.287
1740	0.130	53.784
1800	0.126	52.369
1860	0.121	51.035
1920	0.118	49.774
1980	0.114	48.581
2040	0.111	47.449
2100	0.108	46.375
2160	0.105	45.354
2220	0.102	44.382
2280	0.099	43.455
2340	0.097	42.571
2400	0.094	41.725
2460	0.092	40.916
2520	0.090	40.142
2580	0.088	39.399
2640	0.086	38.687
2700	0.084	38.002
2760	0.082	37.345
2820	0.080	36.712
2880	0.078	36.102

Return period	Storm duration (minutes)	Peak discharge (m^3/s)
1:20 year	120	75.90
1:50 year	120	111.71
1:100 year	120	150.67

Calculated using Utility Programs for Drainage 1.0.2

The software programs were developed for the convenience of its users. Although every reasonable effort has been made to ensure that the programs are accurate and reliable the program developers, Sinotech CC, accept no liability of any kind for any results, interpretation

Flood Frequency Analysis: Empirical methods

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed
Description of site = B20E sub 2 upstream of Brakfontein Mine.
Date = 2012/06/12

Area of catchment = 61.4 km²
Length of longest watercourse = 15.75 km
Height difference along equal-area slope = 78.0 m
Distance to catchment centroid = 10.5 km
Dolomitic area = 0.0 %
Mean annual rainfall = 620.0 mm
Veld type = 4 & 5A
Kovács region = K4(K = 4.6)
Catchment parameter with regard to
reaction time = 0.026

Peak discharges by means of an empirical method developed by Midgley and Pitman

Return period (years)	KT constant	Peak flow (m³/s)
1:20	0.68	90.69
1:50	0.95	126.70
1:100	1.20	160.04

This RMF calculation includes a transition zone adjustment in the case of small catchments.

Regional maximum flood: 478.1 m³/s

Q50(RMF): 176.56 m³/s (based on QT/QRMF relationship for Kovács regions)
Q100(RMF): 229.57 m³/s (based on QT/QRMF relationship for Kovács regions)

The following equivalent maxima make no transition zone adjustments for small catchments.

Equivalent southern African maximum
K-factor 5.6: 1848 m³/s

Equivalent world maxima
K-factor 6.0: 3275 m^3/s
K-factor 6.3: 5031 m^3/s

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Alternative Rational Method

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed fed by Steenkoolspruit
Description of site = B20E sub 1 upstream of Brakfontein Mine.
Date = 2012/06/12
Area of catchment = 146.08 km²
Dolomitic area = 0.0 %
Length of longest watercourse = 19.3 km
Flow of water = Defined water course
Height difference along 10-85 slope = 70.3 m
Area distribution = Rural: 98 %, Urban: 1 %, Lakes: 1 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	10	Houses	30	City centre	2
Sandy, steep (>7%)	0	Flats	0	Suburban	0
Heavy soil, flat (<2%)	5	Light industry	2	Streets	51
Heavy soil, steep (>7%)	0	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	10	Very permeable	2	Thick bush & forests	0
Flat area	88	Permeable	90	Light bush & cultivated land	80
Hilly	2	Semi-permeable	8	Grasslands	10
Steep areas	0	Impermeable	0	Bare	10

Days on which thunder was heard = 62 days/year
Weather Services station number = 477762
Weather Services station location = STREHLA

Mean annual precipitation (MAP) = 650 mm

Duration	2	5	10	20	50	100	200
1 day	53	72	87	103	126	145	166
2 days	65	87	103	120	144	165	186
3 days	72	96	114	132	158	180	202
7 days	94	127	151	176	211	240	270

The modified recalibrated Hershfield relationship was used to determine point rainfall.

Average slope = 0.00486 m/m
Time of concentration = 5.04 h
Run-off factor
Rural - C1 = 0.299
Urban - C2 = 0.683
Lakes - C3 = 0.000
Combined - C = 0.300

Return period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm)	Factor Ft	Runoff coefficient (%)	Peak flow

(m³/s)

1:2	5.04	38.56	92.5	7.08	0.75	22.7	65.15
1:5	5.04	65.06	92.5	11.95	0.80	24.1	117.01
1:10	5.04	85.10	92.5	15.63	0.85	25.6	162.35
1:20	5.04	105.14	92.5	19.30	0.90	27.1	212.07
1:50	5.04	131.63	92.5	24.17	0.95	28.5	279.89
1:100	5.04	151.67	92.5	27.85	1.00	30.0	339.07
1:200	5.04	171.71	92.5	31.53	1.00	30.0	383.87

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Unit Hydrograph Method

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed fed by Steenkoolspruit
Description of site = B20E sub 1 upstream of Brakfontein Mine.
Date = 2012/06/12
Area of catchment = 146.08 km²
Length of longest watercourse = 19.3 km
Height difference along equal area slope = 80.0 m
Distance to catchment centroid = 11.4 km
Veld type = Region 4
Duration interval = 1 hour

Slope of longest stream = 0.0041 m/m
Catchment index = 3417.4
Catchment lag = 6.180
Coefficient (Ku) = 0.386 m³/s - hours/km²
Peak discharge of unit hydrograph (Qp) = 9.124 m³/s

Return period = 1:20 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	63.5	63.5	85.2	54.0	25.8	13.95
120	75.3	37.6	91.2	68.7	29.8	20.44
180	81.5	27.2	93.6	76.3	31.7	24.20
240	85.7	21.4	95.0	81.4	32.9	26.80
300	88.8	17.8	95.8	85.2	33.8	28.79
360	91.4	15.2	96.4	88.1	34.5	30.41
420	93.5	13.4	96.9	90.6	35.1	31.76
480	95.3	11.9	97.2	92.7	35.5	32.93
540	96.9	10.8	97.5	94.5	35.9	33.96
600	98.3	9.8	97.7	96.1	36.3	34.88
660	99.6	9.1	97.9	97.5	36.6	35.72
720	100.8	8.4	98.0	98.8	36.9	36.48
780	101.9	7.8	98.2	100.0	37.2	37.19
840	102.9	7.3	98.3	101.1	37.4	37.84
900	103.8	6.9	98.4	102.1	37.6	38.45
960	104.7	6.5	98.5	103.1	37.9	39.03
1020	105.5	6.2	98.5	104.0	38.1	39.57
1080	106.3	5.9	98.6	104.8	38.2	40.08
1140	107.0	5.6	98.7	105.6	38.4	40.57
1200	107.7	5.4	98.7	106.4	38.6	41.03
1260	108.4	5.2	98.8	107.1	38.7	41.47
1320	109.0	5.0	98.8	107.8	38.9	41.90
1380	109.7	4.8	98.9	108.4	39.0	42.30
1440	110.3	4.6	98.9	109.1	39.1	42.69
1500	110.8	4.4	99.0	109.7	39.3	43.07
1560	111.4	4.3	99.0	110.2	39.4	

43.43

1620	111.9	4.1	99.0	110.8	39.5	43.78
1680	112.4	4.0	99.1	111.3	39.6	44.12
1740	112.9	3.9	99.1	111.9	39.7	44.45
1800	113.4	3.8	99.1	112.4	39.8	44.76
1860	113.8	3.7	99.1	112.8	39.9	45.07
1920	114.3	3.6	99.2	113.3	40.0	45.37
1980	114.7	3.5	99.2	113.8	40.1	45.66
2040	115.1	3.4	99.2	114.2	40.2	45.95
2100	115.5	3.3	99.2	114.6	40.3	46.23
2160	115.9	3.2	99.2	115.1	40.4	46.50
2220	116.3	3.1	99.3	115.5	40.5	46.76
2280	116.7	3.1	99.3	115.9	40.6	47.02
2340	117.1	3.0	99.3	116.3	40.7	47.27
2400	117.4	2.9	99.3	116.6	40.7	47.51
2460	117.8	2.9	99.3	117.0	40.8	47.75
2520	118.1	2.8	99.3	117.4	40.9	47.99
2580	118.5	2.8	99.4	117.7	41.0	48.22
2640	118.8	2.7	99.4	118.1	41.0	48.44
2700	119.1	2.6	99.4	118.4	41.1	48.66
2760	119.5	2.6	99.4	118.7	41.2	48.88
2820	119.8	2.5	99.4	119.1	41.2	49.09
2880	120.1	2.5	99.4	119.4	41.3	49.30

Return period = 1:50 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	82.5	82.5	80.7	66.6	29.2	19.47
120	97.9	48.9	88.6	86.7	34.2	29.61

180	106.0	35.3	91.7	97.2	36.6	35.54
240	111.4	27.9	93.5	104.1	38.1	39.67
300	115.5	23.1	94.6	109.3	39.2	42.81
360	118.8	19.8	95.4	113.3	40.0	45.36
420	121.5	17.4	95.9	116.6	40.7	47.49
480	123.9	15.5	96.4	119.4	41.3	49.33
540	126.0	14.0	96.7	121.9	41.8	50.95
600	127.8	12.8	97.0	124.0	42.3	52.40
660	129.5	11.8	97.2	125.9	42.6	53.71
720	131.0	10.9	97.4	127.7	43.0	54.90
780	132.4	10.2	97.6	129.3	43.3	56.01
840	133.7	9.6	97.8	130.8	43.6	57.03
900	135.0	9.0	97.9	132.1	43.9	57.98
960	136.1	8.5	98.0	133.4	44.1	58.88
1020	137.2	8.1	98.1	134.6	44.4	59.72
1080	138.2	7.7	98.2	135.7	44.6	60.52
1140	139.1	7.3	98.3	136.8	44.8	61.28
1200	140.1	7.0	98.4	137.8	45.0	62.00
1260	140.9	6.7	98.4	138.7	45.2	62.69
1320	141.8	6.4	98.5	139.6	45.4	63.34
1380	142.6	6.2	98.6	140.5	45.5	63.97
1440	143.3	6.0	98.6	141.3	45.7	64.58
1500	144.1	5.8	98.7	142.1	45.9	65.16
1560	144.8	5.6	98.7	142.9	46.0	65.73
1620	145.5	5.4	98.7	143.6	46.1	66.27
1680	146.1	5.2	98.8	144.3	46.3	66.79
1740	146.8	5.1	98.8	145.0	46.4	67.30
1800	147.4	4.9	98.9	145.7	46.5	67.80
1860	148.0	4.8	98.9	146.3	46.7	68.27
1920	148.5	4.6	98.9	146.9	46.8	68.74
1980	149.1	4.5	98.9	147.5	46.9	69.19
2040	149.7	4.4	99.0	148.1	47.0	

69.63

2100	150.2	4.3	99.0	148.7	47.1	70.06
2160	150.7	4.2	99.0	149.2	47.2	70.48
2220	151.2	4.1	99.0	149.8	47.3	70.88
2280	151.7	4.0	99.1	150.3	47.4	71.28
2340	152.2	3.9	99.1	150.8	47.5	71.67
2400	152.7	3.8	99.1	151.3	47.6	72.05
2460	153.1	3.7	99.1	151.8	47.7	72.42
2520	153.6	3.7	99.1	152.3	47.8	72.78
2580	154.0	3.6	99.2	152.7	47.9	73.14
2640	154.5	3.5	99.2	153.2	48.0	73.49
2700	154.9	3.4	99.2	153.6	48.1	73.83
2760	155.3	3.4	99.2	154.1	48.1	74.17
2820	155.7	3.3	99.2	154.5	48.2	74.50
2880	156.1	3.3	99.2	154.9	48.3	74.82

Return period = 1:100 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	101.5	101.5	76.3	77.4	32.0	24.75
120	120.4	60.2	85.9	103.5	37.9	39.27
180	130.4	43.5	89.8	117.2	40.8	47.85
240	137.1	34.3	92.0	126.1	42.7	53.83
300	142.2	28.4	93.4	132.7	44.0	58.39
360	146.2	24.4	94.3	137.9	45.0	62.07
420	149.6	21.4	95.0	142.1	45.8	65.16
480	152.5	19.1	95.5	145.7	46.5	67.81
540	155.0	17.2	96.0	148.8	47.1	70.14
600	157.3	15.7	96.3	151.5	47.7	72.23

660	159.4	14.5	96.6	154.0	48.1	74.11
720	161.3	13.4	96.9	156.2	48.5	75.83
780	163.0	12.5	97.1	158.2	48.9	77.41
840	164.6	11.8	97.3	160.1	49.3	78.87
900	166.1	11.1	97.4	161.8	49.6	80.24
960	167.5	10.5	97.6	163.4	49.9	81.52
1020	168.8	9.9	97.7	164.9	50.2	82.73
1080	170.1	9.4	97.8	166.3	50.4	83.87
1140	171.3	9.0	97.9	167.7	50.7	84.95
1200	172.4	8.6	98.0	168.9	50.9	85.98
1260	173.5	8.3	98.1	170.1	51.1	86.96
1320	174.5	7.9	98.1	171.2	51.3	87.90
1380	175.5	7.6	98.2	172.3	51.5	88.80
1440	176.4	7.4	98.3	173.4	51.7	89.66
1500	177.3	7.1	98.3	174.4	51.9	90.49
1560	178.2	6.9	98.4	175.3	52.1	91.29
1620	179.0	6.6	98.5	176.2	52.2	92.07
1680	179.8	6.4	98.5	177.1	52.4	92.81
1740	180.6	6.2	98.5	178.0	52.6	93.54
1800	181.4	6.0	98.6	178.8	52.7	94.24
1860	182.1	5.9	98.6	179.6	52.8	94.92
1920	182.8	5.7	98.7	180.4	53.0	95.58
1980	183.5	5.6	98.7	181.1	53.1	96.22
2040	184.2	5.4	98.7	181.9	53.2	96.84
2100	184.9	5.3	98.8	182.6	53.4	97.45
2160	185.5	5.2	98.8	183.3	53.5	98.04
2220	186.1	5.0	98.8	183.9	53.6	98.62
2280	186.7	4.9	98.9	184.6	53.7	99.19
2340	187.3	4.8	98.9	185.2	53.8	99.74
2400	187.9	4.7	98.9	185.8	54.0	100.28
2460	188.5	4.6	98.9	186.4	54.1	100.80
2520	189.0	4.5	98.9	187.0	54.2	

101.32

2580	189.6	4.4	99.0	187.6	54.3	101.82
2640	190.1	4.3	99.0	188.2	54.4	102.32
2700	190.6	4.2	99.0	188.7	54.5	102.80
2760	191.1	4.2	99.0	189.3	54.6	103.28
2820	191.6	4.1	99.0	189.8	54.7	103.75
2880	192.1	4.0	99.1	190.3	54.8	104.20

S-curve calculations

Dimensionless one-hour unit hydrograph

T/TL	Q/Qp
0.000	0.0000
0.162	0.0387
0.324	0.0994
0.485	0.2069
0.647	0.9644
0.809	0.8625
0.971	0.5592
1.133	0.4059
1.294	0.3129
1.456	0.2499
1.618	0.1960
1.780	0.1518
1.942	0.1167
2.103	0.0885
2.265	0.0662
2.427	0.0493
2.589	0.0359
2.751	0.0260
2.912	0.0185
3.074	0.0115
3.236	0.0066
3.398	0.0020
3.560	0.0000
3.721	0.0000
3.883	0.0000
4.045	0.0000
4.207	0.0000
4.369	0.0000

T/TL	Original S-curve	Mofified S-curve
0.000	0.0000	0.0000
0.162	0.0387	0.0387
0.324	0.1381	0.1381
0.485	0.3450	0.3450
0.647	1.3093	1.3093
0.809	2.1718	2.1718
0.971	2.7310	2.7310
1.133	3.1369	3.1369
1.294	3.4498	3.4498
1.456	3.6996	3.6996
1.618	3.8956	3.8956

1.780	4.0474	4.0474
1.942	4.1641	4.1641
2.103	4.2526	4.2526
2.265	4.3187	4.3187
2.427	4.3680	4.3680
2.589	4.4039	4.4039
2.751	4.4299	4.4299
2.912	4.4484	4.4484
3.074	4.4599	4.4599
3.236	4.4665	4.4665
3.398	4.4685	4.4685
3.560	4.4685	4.4685
3.721	4.4685	4.4685
3.883	4.4685	4.4685
4.045	4.4685	4.4685
4.207	4.4685	4.4685
4.369	4.4685	4.4685

Return period = 1:20 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.964	122.782
120	0.913	170.364
180	0.795	175.578
240	0.698	170.683
300	0.621	163.131
360	0.559	155.103
420	0.509	147.430
480	0.470	141.111
540	0.434	134.585
600	0.403	128.130
660	0.375	122.215
720	0.351	116.882
780	0.329	111.702
840	0.309	106.765
900	0.291	102.163
960	0.275	98.006
1020	0.261	94.072
1080	0.247	90.371
1140	0.235	86.878
1200	0.223	83.599
1260	0.213	80.513
1320	0.203	77.638
1380	0.194	74.982
1440	0.186	72.521
1500	0.179	70.233
1560	0.172	68.100
1620	0.166	66.106
1680	0.160	64.238
1740	0.154	62.484
1800	0.149	60.833
1860	0.144	59.277
1920	0.140	57.806
1980	0.135	56.415
2040	0.131	55.096
2100	0.128	53.844

2160	0.124	52.654
2220	0.121	51.521
2280	0.118	50.441
2340	0.115	49.410
2400	0.112	48.425
2460	0.109	47.483
2520	0.106	46.580
2580	0.104	45.715
2640	0.102	44.885
2700	0.099	44.088
2760	0.097	43.322
2820	0.095	42.585
2880	0.093	41.876

Return period = 1:50 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.964	171.302
120	0.913	246.766
180	0.795	257.906
240	0.698	252.597
300	0.621	242.559
360	0.559	231.373
420	0.509	220.456
480	0.470	211.398
540	0.434	201.919
600	0.403	192.466
660	0.375	183.768
720	0.351	175.898
780	0.329	168.229
840	0.309	160.897
900	0.291	154.049
960	0.275	147.856
1020	0.261	141.985
1080	0.247	136.456
1140	0.235	131.230
1200	0.223	126.320
1260	0.213	121.695
1320	0.203	117.383
1380	0.194	113.398
1440	0.186	109.703
1500	0.179	106.266
1560	0.172	103.061
1620	0.166	100.064
1680	0.160	97.255
1740	0.154	94.616
1800	0.149	92.131
1860	0.144	89.788
1920	0.140	87.574
1980	0.135	85.479
2040	0.131	83.492
2100	0.128	81.605
2160	0.124	79.811
2220	0.121	78.103
2280	0.118	76.474
2340	0.115	74.919
2400	0.112	73.433

2460	0.109	72.012
2520	0.106	70.650
2580	0.104	69.345
2640	0.102	68.092
2700	0.099	66.889
2760	0.097	65.732
2820	0.095	64.619
2880	0.093	63.547

Return period = 1:100 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.964	217.790
120	0.913	327.226
180	0.795	347.226
240	0.698	342.800
300	0.621	330.815
360	0.559	316.639
420	0.509	302.456
480	0.470	290.588
540	0.434	277.984
600	0.403	265.301
660	0.375	253.576
720	0.351	242.932
780	0.329	232.516
840	0.309	222.530
900	0.291	213.183
960	0.275	204.719
1020	0.261	196.681
1080	0.247	189.101
1140	0.235	181.928
1200	0.223	175.181
1260	0.213	168.821
1320	0.203	162.886
1380	0.194	157.398
1440	0.186	152.307
1500	0.179	147.570
1560	0.172	143.150
1620	0.166	139.015
1680	0.160	135.138
1740	0.154	131.495
1800	0.149	128.064
1860	0.144	124.827
1920	0.140	121.767
1980	0.135	118.870
2040	0.131	116.123
2100	0.128	113.513
2160	0.124	111.031
2220	0.121	108.668
2280	0.118	106.413
2340	0.115	104.261
2400	0.112	102.204
2460	0.109	100.235
2520	0.106	98.349
2580	0.104	96.541
2640	0.102	94.805
2700	0.099	93.137

2760	0.097	91.534
2820	0.095	89.991
2880	0.093	88.505

Return period	Storm duration (minutes)	Peak discharge (m^3/s)
1:20 year	180	175.58
1:50 year	180	257.91
1:100 year	180	347.23

Calculated using Utility Programs for Drainage 1.0.2

Flood frequency analysis : Standard Design Flood method

Project name = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed fed by Steenkoolspruit
Description of site = B20E sub 1 upstream of Brakfontein Mine.
Date = 2012/06/12
Catchment characteristics:
Area of catchment = 146.08 km²
Length of longest watercourse = 19.3 km
1085 height difference = 70.3 m
Average slope = 0.0049 m/m
Drainage basin characteristics:
Drainage basin number = 1
Mean annual daily max rain = 56 mm
Days on which thunder was heard = 30 days
Runoff coefficient C2 = 10 %
Runoff coefficient C100 = 40 %
Basin mean annual precipitation = 550 mm
Basin mean annual evaporation = 1800 mm
Basin evaporation index MAE/MAP = 3.27

RAINFALL DATA
The rainfall data in the table below are derived from two sources. The daily rainfall is from the Department of Water Affair's publication TR102 for the representative site.
The modified Hershfield equation is used for durations up to four hours. Linear interpolation is used for values between 4 hours and one day.

Weather Services station ex TR102 = 546204 @ STRUAN
Point mean annual precipitation = 550 mm

Dur:	RP =2	5	10	20	50	100	200
.25 h	15	25	33	41	51	59	67
.50 h	20	33	43	53	67	77	87
1 h	24	41	53	66	82	95	107
2 h	29	48	63	78	98	113	127
4 h	33	56	73	90	113	130	148
1 day	56	80	99	119	150	177	206
2 days	71	105	132	161	205	243	286
3 days	80	117	146	177	224	263	308
7 days	102	154	196	242	310	369	435

Runoff coefficients C2 = 10 % C100 = 40 %

Return period (years)	Time of concentration (hours)	Point precipitation (mm)	ARF (%)	Catchment precipitation (mm)	Runoff coefficient (%)	Peak flow (m³/s)
1:20	5.04	91.8	92.5	85.0	31.1	213.06
1:50	5.04	115.0	92.5	106.4	36.4	312.14
1:100	5.04	132.7	92.5	122.8	40.0	395.94

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Empirical methods

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed fed by Steenkoolspruit
Description of site = B20E sub 1 upstream of Brakfontein Mine.
Date = 2012/06/12

Area of catchment = 146.08 km²
Length of longest watercourse = 19.3 km

Height difference along equal-area slope = 80.0 m
Distance to catchment centroid = 11.4 km
Dolomitic area = 0.0 %
Mean annual rainfall = 620.0 mm
Veld type = 4 & 5A
Kovács region = K4(K = 4.6)
Catchment parameter with regard to reaction time = 0.043

Peak discharges by means of an empirical method developed by Midgley and Pitman

Return period (years)	KT constant	Peak flow (m^3/s)
1:20	0.68	168.34
1:50	0.95	235.17
1:100	1.20	297.06

This RMF calculation includes a transition zone adjustment in the case of small catchments.

Regional maximum flood: 706.7 m^3/s

Q50(RMF): 252.38 m^3/s (based on QT/QRMF relationship for Kovács regions)
Q100(RMF): 331.20 m^3/s (based on QT/QRMF relationship for Kovács regions)

The following equivalent maxima make no transition zone adjustments for small catchments.

Equivalent southern African maximum
K-factor 5.6: 2707 m^3/s

Equivalent world maxima
K-factor 6.0: 4633 m^3/s
K-factor 6.3: 6933 m^3/s

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Rational Method

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Bronkhostspruit
Description of site = B20E sub 1 possibly impacted by tiny portion of project area
Date = 2012/06/12
Area of catchment = 36.185 km²
Dolomitic area = 0.0 %
Mean annual rainfall (MAR) = 574.00 mm
Length of longest watercourse = 14.37 km
Flow of water = Defined water course
Height difference along 10-85 slope = 39.028 m
Rainfall region = Inland
Area distribution = Rural: 98 %, Urban: 1 %, Lakes: 0 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	20	Houses	30	City centre	0
Sandy, steep (>7%)	0	Flats	0	Suburban	0
Heavy soil, flat (<2%)	20	Light industry	5	Streets	25
Heavy soil, steep (>7%)	0	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	80	Very permeable	0	Thick bush & forests	0
Flat area	20	Permeable	40	Light bush & cultivated land	50
Hilly	0	Semi-permeable	60	Grasslands	48
Steep areas	0	Impermeable	0	Bare	2

Average slope = 0.00362 m/m
Time of concentration = 4.50 h
Run-off factor
Rural - C1 = 0.238
Urban - C2 = 0.482
Lakes - C3 = 0.000
Combined - C = 0.238

The HRU, Report 2/78, Depth-Duration-Frequency diagram was used to determine the point rainfall.

Return Period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm)	Factor Ft	Runoff coefficient (%)	Peak flow (m³/s)
1:20	4.50	81.9	97.9	17.8	0.90	21.5	38.44

1:50 4.50 106.4 97.3 23.0 0.95 22.6
52.34
1:100 4.50 131.0 96.6 28.2 1.00 23.8
67.30

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Alternative Rational Method

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Bronkhostspruit
Description of site = B20E sub 1 possibly impacted by tiny portion of project area
Date = 2012/06/12
Area of catchment = 36.185 km²
Dolomitic area = 0.0 %
Length of longest watercourse = 14.37 km
Flow of water = Defined water course
Height difference along 10-85 slope = 39.028 m
Area distribution = Rural: 98 %, Urban: 1 %, Lakes: 0 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	20	Houses	30	City centre	0
Sandy, steep (>7%)	0	Flats	0	Suburban	0
Heavy soil, flat (<2%)	20	Light industry	5	Streets	25
Heavy soil, steep (>7%)	0	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	80	Very permeable	0	Thick bush & forests	0
Flat area	20	Permeable	40	Light bush & cultivated land	50
Hilly	0	Semi-permeable	60	Grasslands	48
Steep areas	0	Impermeable	0	Bare	2

Days on which thunder was heard = 63 days/year
Weather Services station number = 477762
Weather Services station location = STREHLA

Mean annual precipitation (MAP) = 650 mm

Duration	2	5	10	20	50	100	200
1 day	53	72	87	103	126	145	166
2 days	65	87	103	120	144	165	186

3 days	72	96	114	132	158	180	202
7 days	94	127	151	176	211	240	270

The modified recalibrated Hershfield relationship was used to determine point rainfall.

Average slope = 0.00362 m/m
Time of concentration = 4.50 h
Run-off factor
Rural - C1 = 0.238
Urban - C2 = 0.482
Lakes - C3 = 0.000
Combined - C = 0.238

Return period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm)	Factor Ft	Runoff coefficient (%)	Peak flow (m³/s)
1:20	4.50	103.21	99.6	22.87	0.90	21.5	49.33
1:50	4.50	129.21	99.6	28.64	0.95	22.6	65.11
1:100	4.50	148.89	99.6	33.00	1.00	23.8	78.89

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Unit Hydrograph Method

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Bronkhostspruit
Description of site = B20E sub 1 possibly impacted by small portion of project area
Date = 2012/06/12
Area of catchment = 36.185 km²
Length of longest watercourse = 14.37 km
Height difference along equal area slope = 40.0 m

Distance to catchment centroid = 7.59 km
Veld type = Region 4
Duration interval = 1 hour

Slope of longest stream = 0.0028 m/m
Catchment index = 2067.3
Catchment lag = 5.147
Coefficient (Ku) = 0.386 m^3/s - hours/km^2
Peak discharge of unit hydrograph (Qp) = 2.714 m^3/s

Return period = 1:20 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	59.5	59.5	93.1	55.4	26.2	14.51
120	70.5	35.3	95.9	67.7	29.5	19.97
180	76.4	25.5	97.1	74.1	31.2	23.10
240	80.3	20.1	97.7	78.4	32.2	25.27
300	83.3	16.7	98.1	81.6	33.0	26.93
360	85.6	14.3	98.4	84.2	33.6	28.29
420	87.6	12.5	98.6	86.3	34.1	29.43
480	89.3	11.2	98.7	88.2	34.5	30.42
540	90.8	10.1	98.8	89.7	34.9	31.30
600	92.1	9.2	98.9	91.2	35.2	32.09
660	93.3	8.5	99.0	92.4	35.5	32.80
720	94.4	7.9	99.1	93.6	35.8	33.46
780	95.5	7.3	99.2	94.7	36.0	34.07
840	96.4	6.9	99.2	95.6	36.2	34.63
900	97.3	6.5	99.3	96.6	36.4	35.16
960	98.1	6.1	99.3	97.4	36.6	35.66
1020	98.9	5.8	99.3	98.2	36.8	36.13

1080	99.6	5.5	99.4	99.0	37.0	36.57
1140	100.3	5.3	99.4	99.7	37.1	36.99
1200	101.0	5.0	99.4	100.4	37.3	37.40
1260	101.6	4.8	99.4	101.0	37.4	37.78
1320	102.2	4.6	99.5	101.6	37.5	38.15
1380	102.8	4.5	99.5	102.2	37.7	38.51
1440	103.3	4.3	99.5	102.8	37.8	38.85
1500	103.8	4.2	99.5	103.3	37.9	39.18
1560	104.3	4.0	99.5	103.9	38.0	39.49
1620	104.8	3.9	99.6	104.4	38.1	39.80
1680	105.3	3.8	99.6	104.9	38.2	40.10
1740	105.8	3.6	99.6	105.3	38.3	40.39
1800	106.2	3.5	99.6	105.8	38.4	40.67
1860	106.7	3.4	99.6	106.2	38.5	40.94
1920	107.1	3.3	99.6	106.7	38.6	41.20
1980	107.5	3.3	99.6	107.1	38.7	41.46
2040	107.9	3.2	99.6	107.5	38.8	41.71
2100	108.3	3.1	99.6	107.9	38.9	41.95
2160	108.6	3.0	99.7	108.3	39.0	42.19
2220	109.0	2.9	99.7	108.6	39.1	42.42
2280	109.4	2.9	99.7	109.0	39.1	42.65
2340	109.7	2.8	99.7	109.3	39.2	42.87
2400	110.0	2.8	99.7	109.7	39.3	43.08
2460	110.4	2.7	99.7	110.0	39.3	43.30
2520	110.7	2.6	99.7	110.4	39.4	43.50
2580	111.0	2.6	99.7	110.7	39.5	43.71
2640	111.3	2.5	99.7	111.0	39.6	43.91
2700	111.6	2.5	99.7	111.3	39.6	44.10
2760	111.9	2.4	99.7	111.6	39.7	44.30
2820	112.2	2.4	99.7	111.9	39.7	44.48
2880	112.5	2.3	99.7	112.2	39.8	44.67

Return period = 1:50 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	77.3	77.3	91.1	70.4	30.2	21.27
120	91.7	45.8	94.7	86.8	34.2	29.70
180	99.3	33.1	96.2	95.5	36.2	34.55
240	104.4	26.1	97.0	101.2	37.5	37.92
300	108.2	21.6	97.5	105.5	38.4	40.50
360	111.3	18.6	97.9	108.9	39.1	42.60
420	113.9	16.3	98.1	111.7	39.7	44.37
480	116.1	14.5	98.3	114.2	40.2	45.91
540	118.0	13.1	98.5	116.3	40.7	47.27
600	119.8	12.0	98.6	118.1	41.0	48.48
660	121.4	11.0	98.7	119.8	41.4	49.59
720	122.8	10.2	98.8	121.3	41.7	50.60
780	124.1	9.5	98.9	122.7	42.0	51.54
840	125.3	9.0	99.0	124.0	42.3	52.41
900	126.5	8.4	99.0	125.2	42.5	53.22
960	127.5	8.0	99.1	126.4	42.7	53.99
1020	128.5	7.6	99.1	127.4	42.9	54.71
1080	129.5	7.2	99.2	128.4	43.1	55.40
1140	130.4	6.9	99.2	129.4	43.3	56.05
1200	131.2	6.6	99.2	130.2	43.5	56.67
1260	132.1	6.3	99.3	131.1	43.7	57.27
1320	132.8	6.0	99.3	131.9	43.8	57.83
1380	133.6	5.8	99.3	132.7	44.0	58.38
1440	134.3	5.6	99.4	133.4	44.1	58.91
1500	135.0	5.4	99.4	134.1	44.3	59.41

1560	135.7	5.2	99.4	134.8	44.4	59.90
1620	136.3	5.0	99.4	135.5	44.6	60.37
1680	136.9	4.9	99.4	136.1	44.7	60.83
1740	137.5	4.7	99.5	136.8	44.8	61.27
1800	138.1	4.6	99.5	137.4	44.9	61.70
1860	138.7	4.5	99.5	137.9	45.0	62.12
1920	139.2	4.3	99.5	138.5	45.1	62.52
1980	139.7	4.2	99.5	139.0	45.3	62.92
2040	140.2	4.1	99.5	139.6	45.4	63.30
2100	140.7	4.0	99.5	140.1	45.5	63.68
2160	141.2	3.9	99.5	140.6	45.6	64.04
2220	141.7	3.8	99.6	141.1	45.6	64.40
2280	142.2	3.7	99.6	141.6	45.7	64.75
2340	142.6	3.7	99.6	142.0	45.8	65.09
2400	143.1	3.6	99.6	142.5	45.9	65.42
2460	143.5	3.5	99.6	142.9	46.0	65.74
2520	143.9	3.4	99.6	143.3	46.1	66.06
2580	144.3	3.4	99.6	143.8	46.2	66.38
2640	144.7	3.3	99.6	144.2	46.2	66.68
2700	145.1	3.2	99.6	144.6	46.3	66.98
2760	145.5	3.2	99.6	145.0	46.4	67.28
2820	145.9	3.1	99.6	145.4	46.5	67.57
2880	146.3	3.0	99.6	145.8	46.6	67.85

Return period = 1:100 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	95.1	95.1	89.0	84.7	33.7	28.53
120	112.9	56.4	93.5	105.5	38.4	

40.49

180	122.2	40.7	95.3	116.4	40.7	47.39
240	128.5	32.1	96.3	123.7	42.2	52.19
300	133.2	26.6	96.9	129.1	43.3	55.88
360	137.0	22.8	97.4	133.4	44.1	58.87
420	140.2	20.0	97.7	136.9	44.8	61.39
480	142.9	17.9	97.9	139.9	45.4	63.57
540	145.3	16.1	98.1	142.6	45.9	65.50
600	147.4	14.7	98.3	144.9	46.4	67.23
660	149.4	13.6	98.4	147.0	46.8	68.79
720	151.1	12.6	98.5	148.9	47.2	70.23
780	152.7	11.7	98.6	150.7	47.5	71.56
840	154.2	11.0	98.7	152.3	47.8	72.79
900	155.6	10.4	98.8	153.8	48.1	73.95
960	157.0	9.8	98.9	155.2	48.3	75.03
1020	158.2	9.3	98.9	156.5	48.6	76.05
1080	159.4	8.9	99.0	157.7	48.8	77.02
1140	160.5	8.4	99.0	158.9	49.0	77.94
1200	161.5	8.1	99.1	160.0	49.3	78.82
1260	162.5	7.7	99.1	161.1	49.5	79.66
1320	163.5	7.4	99.1	162.1	49.6	80.47
1380	164.4	7.1	99.2	163.1	49.8	81.24
1440	165.3	6.9	99.2	164.0	50.0	81.98
1500	166.1	6.6	99.2	164.9	50.2	82.69
1560	167.0	6.4	99.3	165.7	50.3	83.38
1620	167.7	6.2	99.3	166.5	50.5	84.05
1680	168.5	6.0	99.3	167.3	50.6	84.69
1740	169.2	5.8	99.3	168.1	50.8	85.32
1800	170.0	5.7	99.3	168.8	50.9	85.92
1860	170.6	5.5	99.4	169.6	51.0	86.51
1920	171.3	5.4	99.4	170.3	51.1	87.08
1980	172.0	5.2	99.4	170.9	51.3	87.64

2040	172.6	5.1	99.4	171.6	51.4	88.18
2100	173.2	4.9	99.4	172.2	51.5	88.71
2160	173.8	4.8	99.4	172.8	51.6	89.23
2220	174.4	4.7	99.5	173.5	51.7	89.73
2280	175.0	4.6	99.5	174.0	51.8	90.22
2340	175.5	4.5	99.5	174.6	51.9	90.70
2400	176.1	4.4	99.5	175.2	52.0	91.17
2460	176.6	4.3	99.5	175.7	52.1	91.63
2520	177.1	4.2	99.5	176.3	52.2	92.08
2580	177.6	4.1	99.5	176.8	52.3	92.52
2640	178.1	4.0	99.5	177.3	52.4	92.95
2700	178.6	4.0	99.5	177.8	52.5	93.38
2760	179.1	3.9	99.6	178.3	52.6	93.79
2820	179.6	3.8	99.6	178.8	52.7	94.20
2880	180.0	3.8	99.6	179.2	52.8	94.60

S-curve calculations

Dimensionless one-hour unit hydrograph

T/TL	Q/Qp
0.000	0.0000
0.194	0.0407
0.389	0.1318
0.583	0.5800
0.777	0.9316
0.971	0.5586
1.166	0.3839
1.360	0.2846
1.554	0.2165
1.749	0.1594
1.943	0.1164
2.137	0.0831
2.331	0.0582
2.526	0.0409
2.720	0.0278
2.914	0.0184
3.109	0.0107
3.303	0.0039
3.497	0.0001
3.691	0.0000
3.886	0.0000
4.080	0.0000
4.274	0.0000

T/TL   Original S-curve   Mofified S-curve

0.000	0.0000	0.0000
0.194	0.0407	0.0407
0.389	0.1725	0.1725
0.583	0.7525	0.7525
0.777	1.6841	1.6841
0.971	2.2427	2.2427
1.166	2.6266	2.6266
1.360	2.9112	2.9112
1.554	3.1277	3.1277
1.749	3.2871	3.2871
1.943	3.4035	3.4035
2.137	3.4866	3.4866
2.331	3.5448	3.5448
2.526	3.5857	3.5857
2.720	3.6135	3.6135
2.914	3.6320	3.6320
3.109	3.6426	3.6426
3.303	3.6465	3.6465
3.497	3.6466	3.6466
3.691	3.6466	3.6466
3.886	3.6466	3.6466
4.080	3.6466	3.6466
4.274	3.6466	3.6466

Return period = 1:20 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.932	36.679
120	0.756	40.970
180	0.690	43.250
240	0.614	42.067
300	0.548	40.033
360	0.493	37.809
420	0.445	35.537
480	0.406	33.503
540	0.374	31.738
600	0.345	30.006
660	0.319	28.358
720	0.295	26.825
780	0.276	25.499
840	0.258	24.257
900	0.242	23.103
960	0.228	22.029
1020	0.215	21.029
1080	0.203	20.106
1140	0.192	19.268
1200	0.182	18.504
1260	0.174	17.804
1320	0.166	17.161
1380	0.159	16.568
1440	0.152	16.018
1500	0.146	15.508
1560	0.140	15.032
1620	0.135	14.588
1680	0.130	14.172

1740	0.126	13.781
1800	0.122	13.414
1860	0.118	13.068
1920	0.114	12.741
1980	0.111	12.432
2040	0.107	12.139
2100	0.104	11.861
2160	0.101	11.597
2220	0.099	11.345
2280	0.096	11.106
2340	0.094	10.877
2400	0.091	10.659
2460	0.089	10.450
2520	0.087	10.250
2580	0.085	10.059
2640	0.083	9.875
2700	0.081	9.699
2760	0.079	9.529
2820	0.078	9.366
2880	0.076	9.209

Return period = 1:50 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.932	53.774
120	0.756	60.926
180	0.690	64.692
240	0.614	63.127
300	0.548	60.201
360	0.493	56.941
420	0.445	53.578
480	0.406	50.556
540	0.374	47.926
600	0.345	45.337
660	0.319	42.868
720	0.295	40.567
780	0.276	38.577
840	0.258	36.709
900	0.242	34.972
960	0.228	33.356
1020	0.215	31.849
1080	0.203	30.457
1140	0.192	29.193
1200	0.182	28.041
1260	0.174	26.985
1320	0.166	26.014
1380	0.159	25.118
1440	0.152	24.288
1500	0.146	23.517
1560	0.140	22.798
1620	0.135	22.127
1680	0.130	21.498
1740	0.126	20.908
1800	0.122	20.352
1860	0.118	19.829
1920	0.114	19.335
1980	0.111	18.867

2040	0.107	18.424
2100	0.104	18.003
2160	0.101	17.604
2220	0.099	17.223
2280	0.096	16.861
2340	0.094	16.515
2400	0.091	16.184
2460	0.089	15.868
2520	0.087	15.566
2580	0.085	15.276
2640	0.083	14.997
2700	0.081	14.730
2760	0.079	14.473
2820	0.078	14.226
2880	0.076	13.989

Return period = 1:100 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.932	72.135
120	0.756	83.044
180	0.690	88.740
240	0.614	86.898
300	0.548	83.055
360	0.493	78.682
420	0.445	74.122
480	0.406	70.005
540	0.374	66.413
600	0.345	62.864
660	0.319	59.470
720	0.295	56.303
780	0.276	53.562
840	0.258	50.986
900	0.242	48.588
960	0.228	46.354
1020	0.215	44.271
1080	0.203	42.345
1140	0.192	40.596
1200	0.182	39.001
1260	0.174	37.539
1320	0.166	36.194
1380	0.159	34.952
1440	0.152	33.802
1500	0.146	32.732
1560	0.140	31.736
1620	0.135	30.805
1680	0.130	29.932
1740	0.126	29.113
1800	0.122	28.343
1860	0.118	27.616
1920	0.114	26.930
1980	0.111	26.281
2040	0.107	25.666
2100	0.104	25.082
2160	0.101	24.527
2220	0.099	23.998
2280	0.096	23.495

2340	0.094	23.014
2400	0.091	22.555
2460	0.089	22.116
2520	0.087	21.695
2580	0.085	21.292
2640	0.083	20.905
2700	0.081	20.534
2760	0.079	20.177
2820	0.078	19.833
2880	0.076	19.503

Return period	Storm duration (minutes)	Peak discharge (m^3/s)
1:20 year	180	43.25
1:50 year	180	64.69
1:100 year	180	88.74

Calculated using Utility Programs for Drainage 1.0.2

Flood frequency analysis : Standard Design Flood method

Project name = Brakfontein MRA
Analysed by = Chenai
Name of river = Bronkhostspruit
Description of site = B20E sub 1 possibly impacted by tiny portion of project area
Date = 2012/06/12
Catchment characteristics:
Area of catchment = 36.185 km²
Length of longest watercourse = 14.37 km
1085 height difference = 39.028 m
Average slope = 0.0036 m/m
Drainage basin characteristics:
Drainage basin number = 4
Mean annual daily max rain = 58 mm
Days on which thunder was heard = 20 days
Runoff coefficient C2 = 10 %
Runoff coefficient C100 = 50 %
Basin mean annual precipitation = 630 mm
Basin mean annual evaporation = 1600 mm
Basin evaporation index MAE/MAP = 2.54

RAINFALL DATA
The rainfall data in the table below are derived from two sources. The daily

rainfall
is from the Department of Water Affair's publication TR102 for the representative site.
The modified Hershfield equation is used for durations up to four hours. Linear
interpolation is used for values between 4 hours and one day.

Weather Services station ex TR102 = 553351 @ WATERVAL
Point mean annual precipitation = 630 mm

Dur:	RP =2	5	10	20	50	100	200
.25 h	14	24	31	39	48	56	63
.50 h	18	31	41	50	63	73	82
1 h	23	38	50	62	78	89	101
2 h	27	46	60	74	92	106	120
4 h	31	53	69	85	107	123	139
1 day	58	76	89	102	122	138	155
2 days	69	90	106	123	146	165	185
3 days	76	99	115	132	156	175	195
7 days	98	131	154	178	211	238	266

Runoff coefficients C2 = 10 % C100 = 50 %

Return period (years)	Time of concentration (hours)	Point precipitation (mm)	ARF (%)	Catchment precipitation (mm)	Runoff coefficient (%)	Peak flow (m^3/s)
1:20	4.50	85.8	99.6	85.4	38.2	72.95
1:50	4.50	107.2	99.6	106.8	45.2	108.03
1:100	4.50	123.5	99.6	123.0	50.0	137.65

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Empirical methods

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Bronkhostspruit
Description of site = B20E sub 1 possibly impacted by

tiny portion of project area
Date = 2012/06/12

Area of catchment	= 36.185 km²
Length of longest watercourse	= 14.37 km
Height difference along equal-area slope	= 40.0 m
Distance to catchment centroid	= 7.59 km
Dolomitic area	= 0.0 %
Mean annual rainfall	= 574.0 mm
Veld type	= 4 & 5A
Kovács region	= K4(K = 4.6)
Catchment parameter with regard to reaction time	= 0.018

Peak discharges by means of an empirical method developed by Midgley and Pitman

Return period (years)	KT constant	Peak flow (m^3/s)
1:20	0.68	56.43
1:50	0.95	78.84
1:100	1.20	99.58

This RMF calculation includes a transition zone adjustment in the case of small catchments.

Regional maximum flood: 391.1 m^3/s

Q50(RMF): 149.35 m^3/s (based on QT/QRMF relationship for Kovács regions)
Q100(RMF): 192.43 m^3/s (based on QT/QRMF relationship for Kovács regions)

The following equivalent maxima make no transition zone adjustments for small catchments.

Equivalent southern African maximum
K-factor 5.6: 1465 m^3/s

Equivalent world maxima
K-factor 6.0: 2651 m^3/s
K-factor 6.3: 4137 m^3/s

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Rational Method

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed
Description of site = B20E sub 6 cuts from upper north section of mine boundary
Date = 2012/06/12
Area of catchment = 22.76 km²
Dolomitic area = 0.0 %
Mean annual rainfall (MAR) = 620.00 mm
Length of longest watercourse = 4.857 km
Flow of water = Defined water course
Height difference along 10-85 slope = 20.405 m
Rainfall region = Inland
Area distribution = Rural: 95 %, Urban: 1 %, Lakes: 4 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	20	Houses	30	City centre	0
Sandy, steep (>7%)	0	Flats	0	Suburban	0
Heavy soil, flat (<2%)	10	Light industry	5	Streets	35
Heavy soil, steep (>7%)	0	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	60	Very permeable	0	Thick bush & forests	0
Flat area	40	Permeable	50	Light bush & cultivated land	60
Hilly	0	Semi-permeable	50	Grasslands	35
Steep areas	0	Impermeable	0	Bare	5

Average slope = 0.0056 m/m
Time of concentration = 1.65 h
Run-off factor
Rural - C1 = 0.324
Urban - C2 = 0.560
Lakes - C3 = 0.000
Combined - C = 0.313
The HRU, Report 2/78, Depth-Duration-Frequency diagram was used to determine the point rainfall.

Return Period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm)	Factor Ft	Runoff coefficient (%)	Peak flow (m³/s)
1:20	1.65	72.1	96.3	42.1	0.90	28.2	75.15

1:50	1.65	93.8	95.1	54.1	0.95	29.8	101.82
1:100	1.65	115.4	94.0	65.8	1.00	31.3	130.23

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Alternative Rational Method

Project = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed
Description of site = B20E sub 6 cuts from upper north section of mine boundary
Date = 2012/06/12
Area of catchment = 22.76 km²
Dolomitic area = 0.0 %
Length of longest watercourse = 4.857 km
Flow of water = Defined water course
Height difference along 10-85 slope = 20.405 m
Area distribution = Rural: 95 %, Urban: 1 %, Lakes: 4 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	20	Houses	30	City centre	0
Sandy, steep (>7%)	0	Flats	0	Suburban	0
Heavy soil, flat (<2%)	10	Light industry	5	Streets	35
Heavy soil, steep (>7%)	0	Heavy industry	0	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	60	Very permeable	0	Thick bush & forests	0
Flat area	40	Permeable	50	Light bush & cultivated land	60
Hilly	0	Semi-permeable	50	Grasslands	35
Steep areas	0	Impermeable	0	Bare	5

Days on which thunder was heard = 62 days/year
Weather Services station number = 477762
Weather Services station location = STREHLA

Mean annual precipitation (MAP) = 650 mm

Duration	2	5	10	20	50	100	200
1 day	53	72	87	103	126	145	166
2 days	65	87	103	120	144	165	186
3 days	72	96	114	132	158	180	202

7 days 94 127 151 176 211 240 270

The modified recalibrated Hershfield relationship was used to determine point rainfall.

Average slope	= 0.0056 m/m
Time of concentration	= 1.65 h
Run-off factor	
Rural - C1	= 0.324
Urban - C2	= 0.560
Lakes - C3	= 0.000
Combined - C	= 0.313

Return period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm)	Factor Ft	Runoff coefficient (%)	Peak flow (m³/s)
1:20	1.65	82.99	98.0	49.35	0.90	28.2	88.05
1:50	1.65	103.90	98.0	61.79	0.95	29.8	116.23
1:100	1.65	119.72	98.0	71.19	1.00	31.3	140.85

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Unit Hydrograph Method

Project	= Brakfontein MRA
Analysed by	= Chenai
Name of river	= Unnamed
Description of site	= B20E sub 6 cuts from upper north section of mine boundary
Date	= 2012/06/12
Area of catchment	= 22.76 km²
Length of longest watercourse	= 4.857 km
Height difference along equal area slope	= 40.1 m
Distance to catchment centroid	= 3.142 km
Veld type	= Region 4
Duration interval	= 1 hour

Slope of longest stream = 0.0083 m/m
Catchment index = 168.0
Catchment lag = 2.064
Coefficient (Ku) = 0.386 m³/s - hours/km²
Peak discharge of unit hydrograph (Qp) = 4.256 m³/s

Return period = 1:20 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	63.5	63.5	94.6	60.0	27.5	16.50
120	75.3	37.6	96.8	72.9	30.8	22.47
180	81.5	27.2	97.7	79.6	32.5	25.87
240	85.7	21.4	98.2	84.1	33.6	28.24
300	88.8	17.8	98.5	87.5	34.4	30.06
360	91.4	15.2	98.7	90.2	35.0	31.55
420	93.5	13.4	98.9	92.4	35.5	32.80
480	95.3	11.9	99.0	94.3	35.9	33.89
540	96.9	10.8	99.1	96.0	36.3	34.85
600	98.3	9.8	99.2	97.5	36.6	35.72
660	99.6	9.1	99.2	98.8	36.9	36.50
720	100.8	8.4	99.3	100.1	37.2	37.22
780	101.9	7.8	99.3	101.2	37.4	37.89
840	102.9	7.3	99.4	102.2	37.7	38.51
900	103.8	6.9	99.4	103.2	37.9	39.09
960	104.7	6.5	99.4	104.1	38.1	39.64
1020	105.5	6.2	99.5	105.0	38.3	40.16
1080	106.3	5.9	99.5	105.8	38.4	40.65
1140	107.0	5.6	99.5	106.5	38.6	

41.12

1200	107.7	5.4	99.5	107.2	38.8	41.56
1260	108.4	5.2	99.6	107.9	38.9	41.99
1320	109.0	5.0	99.6	108.6	39.0	42.39
1380	109.7	4.8	99.6	109.2	39.2	42.79
1440	110.3	4.6	99.6	109.8	39.3	43.16
1500	110.8	4.4	99.6	110.4	39.4	43.53
1560	111.4	4.3	99.6	111.0	39.5	43.88
1620	111.9	4.1	99.6	111.5	39.7	44.21
1680	112.4	4.0	99.7	112.0	39.8	44.54
1740	112.9	3.9	99.7	112.5	39.9	44.86
1800	113.4	3.8	99.7	113.0	40.0	45.17
1860	113.8	3.7	99.7	113.5	40.1	45.47
1920	114.3	3.6	99.7	113.9	40.2	45.76
1980	114.7	3.5	99.7	114.4	40.3	46.04
2040	115.1	3.4	99.7	114.8	40.4	46.32
2100	115.5	3.3	99.7	115.2	40.4	46.59
2160	115.9	3.2	99.7	115.6	40.5	46.85
2220	116.3	3.1	99.7	116.0	40.6	47.11
2280	116.7	3.1	99.7	116.4	40.7	47.36
2340	117.1	3.0	99.7	116.8	40.8	47.61
2400	117.4	2.9	99.7	117.1	40.8	47.84
2460	117.8	2.9	99.8	117.5	40.9	48.08
2520	118.1	2.8	99.8	117.9	41.0	48.31
2580	118.5	2.8	99.8	118.2	41.1	48.53
2640	118.8	2.7	99.8	118.5	41.1	48.76
2700	119.1	2.6	99.8	118.9	41.2	48.97
2760	119.5	2.6	99.8	119.2	41.3	49.18
2820	119.8	2.5	99.8	119.5	41.3	49.39
2880	120.1	2.5	99.8	119.8	41.4	49.60

Return period = 1:50 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	82.5	82.5	93.0	76.7	31.8	24.37
120	97.9	48.9	95.8	93.8	35.8	33.56
180	106.0	35.3	97.0	102.8	37.8	38.83
240	111.4	27.9	97.6	108.8	39.1	42.50
300	115.5	23.1	98.0	113.2	40.0	45.31
360	118.8	19.8	98.3	116.8	40.8	47.61
420	121.5	17.4	98.5	119.7	41.4	49.54
480	123.9	15.5	98.7	122.3	41.9	51.22
540	126.0	14.0	98.8	124.5	42.3	52.71
600	127.8	12.8	98.9	126.4	42.7	54.04
660	129.5	11.8	99.0	128.2	43.1	55.26
720	131.0	10.9	99.1	129.8	43.4	56.37
780	132.4	10.2	99.1	131.3	43.7	57.40
840	133.7	9.6	99.2	132.7	44.0	58.36
900	135.0	9.0	99.2	133.9	44.2	59.25
960	136.1	8.5	99.3	135.1	44.5	60.10
1020	137.2	8.1	99.3	136.2	44.7	60.89
1080	138.2	7.7	99.3	137.3	44.9	61.65
1140	139.1	7.3	99.4	138.3	45.1	62.37
1200	140.1	7.0	99.4	139.2	45.3	63.05
1260	140.9	6.7	99.4	140.1	45.5	63.70
1320	141.8	6.4	99.4	141.0	45.6	64.33
1380	142.6	6.2	99.5	141.8	45.8	64.93
1440	143.3	6.0	99.5	142.6	45.9	65.51
1500	144.1	5.8	99.5	143.4	46.1	66.07
1560	144.8	5.6	99.5	144.1	46.2	66.61
1620	145.5	5.4	99.5	144.8	46.4	

						67.13
1680	146.1	5.2	99.6	145.5	46.5	67.64
1740	146.8	5.1	99.6	146.1	46.6	68.12
1800	147.4	4.9	99.6	146.8	46.7	68.60
1860	148.0	4.8	99.6	147.4	46.9	69.06
1920	148.5	4.6	99.6	148.0	47.0	69.51
1980	149.1	4.5	99.6	148.5	47.1	69.94
2040	149.7	4.4	99.6	149.1	47.2	70.37
2100	150.2	4.3	99.6	149.6	47.3	70.78
2160	150.7	4.2	99.6	150.2	47.4	71.19
2220	151.2	4.1	99.7	150.7	47.5	71.58
2280	151.7	4.0	99.7	151.2	47.6	71.97
2340	152.2	3.9	99.7	151.7	47.7	72.34
2400	152.7	3.8	99.7	152.2	47.8	72.71
2460	153.1	3.7	99.7	152.6	47.9	73.07
2520	153.6	3.7	99.7	153.1	48.0	73.42
2580	154.0	3.6	99.7	153.6	48.0	73.77
2640	154.5	3.5	99.7	154.0	48.1	74.11
2700	154.9	3.4	99.7	154.4	48.2	74.44
2760	155.3	3.4	99.7	154.8	48.3	74.77
2820	155.7	3.3	99.7	155.3	48.4	75.09
2880	156.1	3.3	99.7	155.7	48.4	75.40

Return period = 1:100 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	101.5	101.5	91.3	92.7	35.6	32.97
120	120.4	60.2	94.9	114.2	40.2	45.97
180	130.4	43.5	96.3	125.6	42.6	53.45

240	137.1	34.3	97.1	133.1	44.1	58.67
300	142.2	28.4	97.6	138.7	45.2	62.67
360	146.2	24.4	97.9	143.2	46.1	65.93
420	149.6	21.4	98.2	146.9	46.8	68.68
480	152.5	19.1	98.4	150.0	47.4	71.06
540	155.0	17.2	98.5	152.8	47.9	73.17
600	157.3	15.7	98.7	155.2	48.4	75.06
660	159.4	14.5	98.8	157.4	48.8	76.77
720	161.3	13.4	98.9	159.4	49.1	78.35
780	163.0	12.5	98.9	161.3	49.5	79.81
840	164.6	11.8	99.0	163.0	49.8	81.16
900	166.1	11.1	99.1	164.5	50.1	82.43
960	167.5	10.5	99.1	166.0	50.4	83.62
1020	168.8	9.9	99.2	167.4	50.6	84.74
1080	170.1	9.4	99.2	168.7	50.9	85.81
1140	171.3	9.0	99.2	169.9	51.1	86.82
1200	172.4	8.6	99.3	171.1	51.3	87.79
1260	173.5	8.3	99.3	172.2	51.5	88.72
1320	174.5	7.9	99.3	173.3	51.7	89.60
1380	175.5	7.6	99.3	174.3	51.9	90.45
1440	176.4	7.4	99.4	175.3	52.1	91.27
1500	177.3	7.1	99.4	176.2	52.2	92.06
1560	178.2	6.9	99.4	177.1	52.4	92.82
1620	179.0	6.6	99.4	178.0	52.6	93.55
1680	179.8	6.4	99.5	178.8	52.7	94.26
1740	180.6	6.2	99.5	179.7	52.9	94.95
1800	181.4	6.0	99.5	180.4	53.0	95.62
1860	182.1	5.9	99.5	181.2	53.1	96.27
1920	182.8	5.7	99.5	181.9	53.3	96.90
1980	183.5	5.6	99.5	182.7	53.4	97.52
2040	184.2	5.4	99.5	183.3	53.5	98.12
2100	184.9	5.3	99.5	184.0	53.6	

						98.70
2160	185.5	5.2	99.6	184.7	53.8	99.27
2220	186.1	5.0	99.6	185.3	53.9	99.83
2280	186.7	4.9	99.6	185.9	54.0	100.37
2340	187.3	4.8	99.6	186.6	54.1	100.90
2400	187.9	4.7	99.6	187.2	54.2	101.42
2460	188.5	4.6	99.6	187.7	54.3	101.93
2520	189.0	4.5	99.6	188.3	54.4	102.42
2580	189.6	4.4	99.6	188.9	54.5	102.91
2640	190.1	4.3	99.6	189.4	54.6	103.39
2700	190.6	4.2	99.6	189.9	54.7	103.86
2760	191.1	4.2	99.6	190.5	54.8	104.32
2820	191.6	4.1	99.7	191.0	54.9	104.77
2880	192.1	4.0	99.7	191.5	55.0	105.21

S-curve calculations

Dimensionless one-hour unit hydrograph

T/TL	Q/Qp
0.000	0.0000
0.484	0.2060
0.969	0.5610
1.453	0.2508
1.938	0.1174
2.422	0.0498
2.907	0.0187
3.391	0.0022
3.876	0.0000
4.360	0.0000

T/TL	Original S-curve	Mofified S-curve
0.000	0.0000	0.0000
0.484	0.2060	0.2060
0.969	0.7671	0.7671
1.453	1.0179	1.0179
1.938	1.1353	1.1353
2.422	1.1851	1.1851
2.907	1.2038	1.2038
3.391	1.2059	1.2059
3.876	1.2059	1.2059
4.360	1.2059	1.2059

Return period = 1:20 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.561	39.401
120	0.406	38.824
180	0.339	37.366
240	0.284	34.120
300	0.237	30.329
360	0.201	26.939
420	0.172	24.052
480	0.151	21.743
540	0.134	19.876
600	0.121	18.333
660	0.110	17.033
720	0.100	15.922
780	0.093	14.961
840	0.086	14.120
900	0.080	13.378
960	0.075	12.718
1020	0.071	12.126
1080	0.067	11.592
1140	0.063	11.108
1200	0.060	10.667
1260	0.057	10.263
1320	0.055	9.891
1380	0.052	9.549
1440	0.050	9.231
1500	0.048	8.937
1560	0.046	8.662
1620	0.045	8.406
1680	0.043	8.166
1740	0.042	7.940
1800	0.040	7.728
1860	0.039	7.529
1920	0.038	7.340
1980	0.037	7.162
2040	0.035	6.993
2100	0.034	6.833
2160	0.033	6.680
2220	0.033	6.535
2280	0.032	6.397
2340	0.031	6.266
2400	0.030	6.140
2460	0.029	6.019
2520	0.029	5.904
2580	0.028	5.794
2640	0.027	5.688
2700	0.027	5.586
2760	0.026	5.488
2820	0.026	5.394
2880	0.025	5.304

Return period = 1:50 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)

60	0.561	58.200
120	0.406	57.991
180	0.339	56.075
240	0.284	51.339
300	0.237	45.713
360	0.201	40.654
420	0.172	36.329
480	0.151	32.866
540	0.134	30.062
600	0.121	27.741
660	0.110	25.785
720	0.100	24.112
780	0.093	22.664
840	0.086	21.396
900	0.080	20.276
960	0.075	19.280
1020	0.071	18.386
1080	0.067	17.580
1140	0.063	16.848
1200	0.060	16.182
1260	0.057	15.571
1320	0.055	15.010
1380	0.052	14.491
1440	0.050	14.012
1500	0.048	13.566
1560	0.046	13.150
1620	0.045	12.762
1680	0.043	12.399
1740	0.042	12.058
1800	0.040	11.737
1860	0.039	11.435
1920	0.038	11.149
1980	0.037	10.879
2040	0.035	10.624
2100	0.034	10.381
2160	0.033	10.150
2220	0.033	9.930
2280	0.032	9.721
2340	0.031	9.521
2400	0.030	9.331
2460	0.029	9.148
2520	0.029	8.974
2580	0.028	8.806
2640	0.027	8.646
2700	0.027	8.491
2760	0.026	8.343
2820	0.026	8.201
2880	0.025	8.063

Return period = 1:100 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.561	78.726
120	0.406	79.429
180	0.339	77.196
240	0.284	70.876

300	0.237	63.225
360	0.201	56.300
420	0.172	50.359
480	0.151	45.593
540	0.134	41.729
600	0.121	38.527
660	0.110	35.826
720	0.100	33.514
780	0.093	31.511
840	0.086	29.757
900	0.080	28.207
960	0.075	26.826
1020	0.071	25.588
1080	0.067	24.470
1140	0.063	23.456
1200	0.060	22.532
1260	0.057	21.685
1320	0.055	20.905
1380	0.052	20.186
1440	0.050	19.520
1500	0.048	18.901
1560	0.046	18.324
1620	0.045	17.785
1680	0.043	17.281
1740	0.042	16.807
1800	0.040	16.361
1860	0.039	15.941
1920	0.038	15.544
1980	0.037	15.169
2040	0.035	14.813
2100	0.034	14.475
2160	0.033	14.154
2220	0.033	13.849
2280	0.032	13.558
2340	0.031	13.280
2400	0.030	13.015
2460	0.029	12.761
2520	0.029	12.518
2580	0.028	12.285
2640	0.027	12.061
2700	0.027	11.847
2760	0.026	11.641
2820	0.026	11.442
2880	0.025	11.251

Return period	Storm duration (minutes)	Peak discharge (m^3/s)
1:20 year	60	39.40
1:50 year	60	58.20
1:100 year	120	79.43

Calculated using Utility Programs for Drainage 1.0.2

The software programs were developed for the convenience of its users. Although every reasonable effort has been made to ensure that the programs are accurate and reliable the

Flood frequency analysis : Standard Design Flood method

Project name = Brakfontein MRA
Analysed by = Chenai
Name of river = Unnamed
Description of site = B20E sub 6 cuts from upper north section of mine boundary
Date = 2012/06/12
Catchment characteristics:
Area of catchment = 22.76 km²
Length of longest watercourse = 4.857 km
1085 height difference = 20.405 m
Average slope = 0.0056 m/m
Drainage basin characteristics:
Drainage basin number = 4
Mean annual daily max rain = 58 mm
Days on which thunder was heard = 20 days
Runoff coefficient C2 = 10 %
Runoff coefficient C100 = 50 %
Basin mean annual precipitation = 630 mm
Basin mean annual evaporation = 1600 mm
Basin evaporation index MAE/MAP = 2.54

RAINFALL DATA
The rainfall data in the table below are derived from two sources. The daily rainfall
is from the Department of Water Affair's publication TR102 for the representative site.
The modified Hershfield equation is used for durations up to four hours. Linear
interpolation is used for values between 4 hours and one day.

Weather Services station ex TR102 = 553351 @ WATERVAL
Point mean annual precipitation = 630 mm

Dur:	RP =2	5	10	20	50	100	200
.25 h	14	24	31	39	48	56	63
.50 h	18	31	41	50	63	73	82
1 h	23	38	50	62	78	89	101
2 h	27	46	60	74	92	106	120
4 h	31	53	69	85	107	123	139
1 day	58	76	89	102	122	138	155
2 days	69	90	106	123	146	165	185
3 days	76	99	115	132	156	175	195
7 days	98	131	154	178	211	238	266

Runoff coefficients C2 = 10 % C100 = 50 %

Return period	Time of concentration	Point precipitation	ARF	Catchment precipitation	Runoff coefficient	Peak flow

(years)	(hours)	(mm)	(%)	(mm)	(%)	(m³/s)
1:20	1.65	69.6	98.0	68.2	38.2	99.90
1:50	1.65	87.1	98.0	85.4	45.2	148.14
1:100	1.65	100.4	98.0	98.4	50.0	188.85

Calculated using Utility Programs for Drainage 1.0.2

Flood Frequency Analysis: Empirical methods

Project	= Brakfontein MRA
Analysed by	= Chenai
Name of river	= Unnamed
Description of site	= B20E sub 6 cuts from upper north section of mine boundary
Date	= 2012/06/12

Area of catchment	= 22.76 km²
Length of longest watercourse	= 4.857 km
Height difference along equal-area slope	= 40.1 m
Distance to catchment centroid	= 3.142 km
Dolomitic area	= 0.0 %
Mean annual rainfall	= 620.0 mm
Veld type	= 4 & 5A
Kovács region	= K4(K = 4.6)
Catchment parameter with regard to reaction time	= 0.136

Peak discharges by means of an empirical method developed by Midgley and Pitman

Return period (years)	KT constant	Peak flow (m³/s)
1:20	0.68	69.49
1:50	0.95	97.09
1:100	1.20	122.64

This RMF calculation includes a transition zone adjustment in the case of small catchments.

Regional maximum flood: 327.9 m³/s

Q50(RMF): 129.92 m³/s (based on QT/QRMF relationship for Kovács regions)

Q100(RMF): 165.75 m³/s (based on QT/QRMF relationship for Kovács regions)

The following equivalent maxima make no transition zone adjustments for small catchments.

Equivalent southern African maximum
K-factor 5.6: 1194 m³/s

Equivalent world maxima
K-factor 6.0: 2202 m³/s
K-factor 6.3: 3485 m³/s

Calculated using Utility Programs for Drainage 1.0.2

Appendix C: Laboratory Data

CLEAN STREAM
Scientific Services (Pty.) Ltd.

489 Jacqueline Drive, Garsfontein, Pretoria, 0042
P.O. Box 905008, Garsfontein, 0042
Tel (012) 348 2813/4, **Fax** 012 348 8575

Specialists in environmental monitoring

Test Report

Client: Digby Wells & Associates
Address: 359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg
Report No: 8473 **Project:** Digby Wells & Associates

Date of certificate: 14 Jun 2012
Date accepted: 12 Jun 2012
Date completed: 14 Jun 2012

Lab no:			90797	90798	90799	90800	90801	90802	90803
Date sampled:			11 Jun 2012	11 Jun 2012	11 Jun 2012	11 Jun 2012	11 Jun 2012	11 Jun 2012	11 Jun 2012
Sample type:			Water	Water	Water	Water	Water	Water	Water
Locality description			UCBSW 01	UCBSW 02	UCBSW 03	UCBSW 04	UCBSW 05	UCBSW 06	UCBSW 07
Analyses:		**Method**							
A	pH	CSM 20	7.64	8.11	7.63	8.69	8.69	8.36	8.18
A	Electrical conductivity (EC) mS/m	CSM 20	20.53	53.40	38.10	59.30	52.10	55.80	46.90
A	Total dissolved solids (TDS) mg/l	CSM 26	96	290	189	344	294	299	260
A	Total alkalinity mg/l	CSM 01	23.2	223.7	156.7	198.0	172.4	217.5	147.2
A	Chloride (Cl) mg/l	CSM 02	35.5	20.6	20.9	21.8	16.4	40.1	19.4
A	Sulphate (SO4) mg/l	CSM 03	11.12	34.72	<0.132	87.99	76.83	22.33	62.59
A	Nitrate (NO3) mg/l as N	CSM 06	0.175	0.142	0.123	1.606	0.308	0.529	0.491
A	Ammonium(NH4) mg/l as N	CSM 05	0.084	0.027	0.019	0.586	0.022	0.111	<0.015
A	Orthophosphate (PO4) mg/l as P	CSM 04	<0.025	<0.025	<0.025	<0.025	0.047	0.045	<0.025
A	Fluoride (F) mg/l	CSM 08	<0.183	0.289	0.499	0.298	0.269	0.188	0.390
A	Calcium (Ca) mg/l	CSM 30	9.701	44.047	18.508	41.752	35.642	38.300	28.940
A	Magnesium (Mg) mg/l	CSM 30	7.843	27.341	18.375	32.604	29.186	30.475	22.954
A	Sodium (Na) mg/l	CSM 30	15.28	23.70	23.67	34.59	29.01	33.67	30.94
A	Potassium (K) mg/l	CSM 30	2.076	5.500	13.687	5.144	2.841	2.747	6.419
A	Aluminium (Al) mg/l	CSM 31	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
A	Iron (Fe) mg/l	CSM 31	0.252	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
A	Manganese (Mn) mg/l	CSM 31	<0.001	<0.001	0.072	<0.001	<0.001	0.081	<0.001
A	Total chromium (Cr) mg/l	CSM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Copper (Cu) mg/l	CSM 31	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
A	Nickel (Ni) mg/l	CSM 31	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
A	Zinc (Zn) mg/l	CSM 31	<0.004	<0.004	0.025	<0.004	<0.004	<0.004	<0.004
A	Cobalt (Co) mg/l	CSM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Cadmium (Cd) mg/l	CSM 31	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
A	Lead (Pb) mg/l	CSM 31	0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
A	Total hardness mg/l	CSM 26	57	223	122	239	209	221	167

A = Accredited (Included in the SANAS Schedule of Accreditation); N = Not accredited (Excluded from the SANAS Schedule of Accreditation)
OSD = Outsourced; S = Sub-contracted; NR = Not requested; RTF = Results to follow; TNTC = To numerous to count; ND = Not detected
NATD = Not able to determine

sanas Testing Laboratory
T0374

Report checked by: H. Holtzhausen (Laboratory Manager)

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Specialists in environmental monitoring

Test Report

Client: Digby Wells & Associates
Address: 359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg
Report No: 8473 **Project:** Digby Wells & Associates

Date of certificate: 14 Jun 2012
Date accepted: 12 Jun 2012
Date completed: 14 Jun 2012

Lab no:			90804	90805	90806	90807	90808
Date sampled:			11 Jun 2012	11 Jun 2012	11 Jun 2012	11 Jun 2012	11 Jun 2012
Sample type:			Water	Water	Water	Water	Water
Locality description			UCBSW 08	UCBSW 09	UCBSW 10	UCBSW 11	UCBSW 15
Analyses:		**Method**					
A	pH	CSM 20	8.30	8.40	8.63	8.60	7.42
A	Electrical conductivity (EC) mS/m	CSM 20	86.80	81.00	73.10	93.70	56.40
A	Total dissolved solids (TDS) mg/l	CSM 26	578	505	436	545	321
A	Total alkalinity mg/l	CSM 01	221.1	249.0	250.1	294.9	76.4
A	Chloride (Cl) mg/l	CSM 02	24.5	23.9	24.4	72.6	20.3
A	Sulphate (SO4) mg/l	CSM 03	242.31	172.06	109.75	99.73	141.82
A	Nitrate (NO3) mg/l as N	CSM 06	0.246	0.267	0.358	0.295	0.252
A	Ammonium(NH4) mg/l as N	CSM 05	<0.015	0.088	0.053	0.025	0.095
A	Orthophosphate (PO4) mg/l as P	CSM 04	0.026	<0.025	<0.025	0.037	<0.025
A	Fluoride (F) mg/l	CSM 08	0.287	0.368	0.336	0.347	0.479
A	Calcium (Ca) mg/l	CSM 30	66.401	53.216	52.008	69.230	37.915
A	Magnesium (Mg) mg/l	CSM 30	51.844	46.729	41.311	56.529	19.137
A	Sodium (Na) mg/l	CSM 30	55.54	55.86	53.91	63.52	35.32
A	Potassium (K) mg/l	CSM 30	4.549	3.928	4.523	6.617	20.875
A	Aluminium (Al) mg/l	CSM 31	<0.006	<0.006	<0.006	<0.006	<0.006
A	Iron (Fe) mg/l	CSM 31	<0.006	<0.006	<0.006	<0.006	<0.006
A	Manganese (Mn) mg/l	CSM 31	<0.001	<0.001	0.037	0.177	0.154
A	Total chromium (Cr) mg/l	CSM 31	<0.002	<0.002	<0.002	<0.002	<0.002
A	Copper (Cu) mg/l	CSM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Nickel (Ni) mg/l	CSM 31	<0.003	<0.003	<0.003	<0.003	<0.003
A	Zinc (Zn) mg/l	CSM 31	<0.004	<0.004	<0.004	<0.004	0.060
A	Cobalt (Co) mg/l	CSM 31	<0.002	<0.002	<0.002	<0.002	<0.002
A	Cadmium (Cd) mg/l	CSM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Lead (Pb) mg/l	CSM 31	<0.001	0.004	<0.001	0.003	0.002
A	Total hardness mg/l	CSM 26	379	325	300	406	173

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OSD = Outsourced; S = Sub-contracted; NR = Not requested; RTF = Results to follow; TNTC = To numerous to count; ND = Not detected
NATD = Not able to determine

Clean Stream Scientific Services does not accept responsibility for any matters arising from the further use of these results. This certificate shall not be reproduced without written approval by the Managing Director. Measurement of uncertainty available on request for all methods included in the SANAS Schedule of Accreditation. This report only relates to the above samples and variables analysed.

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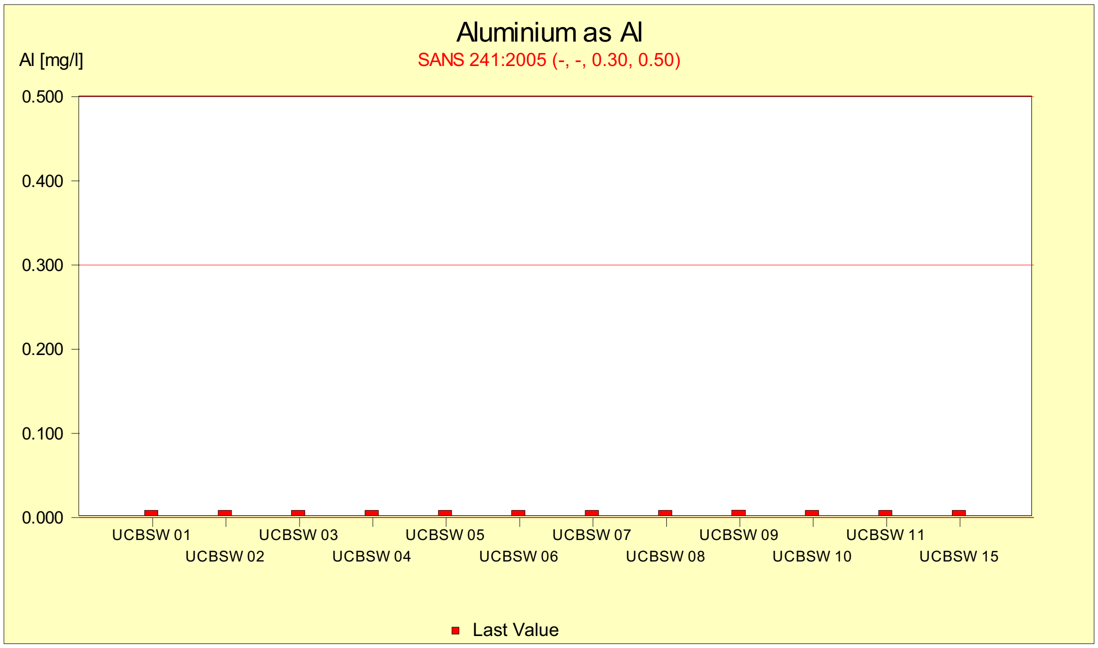
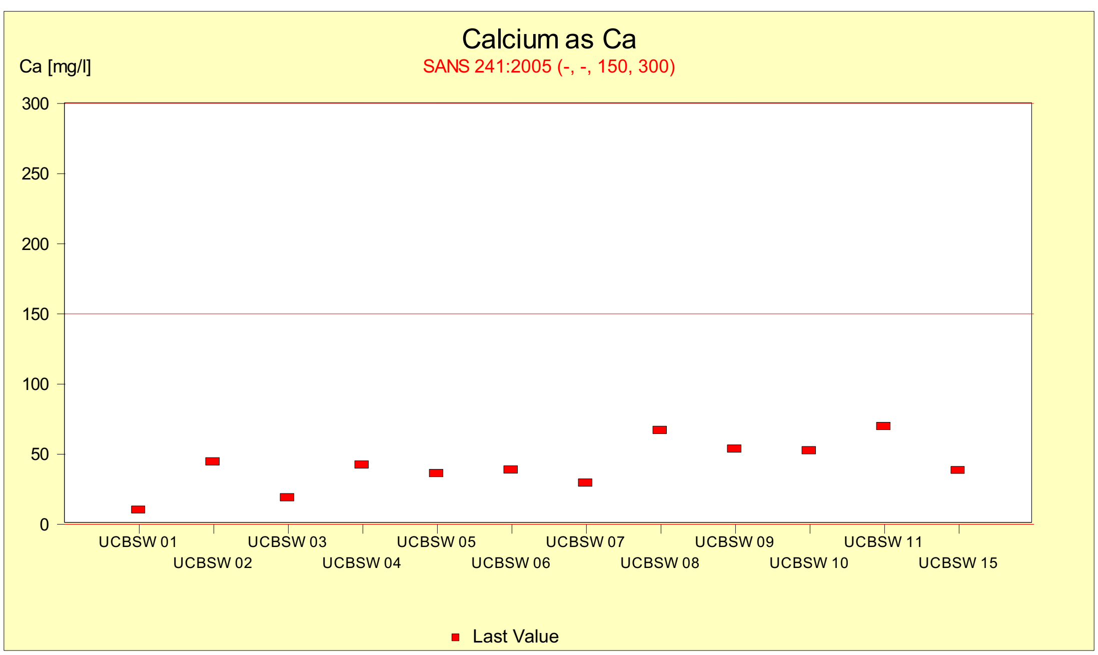
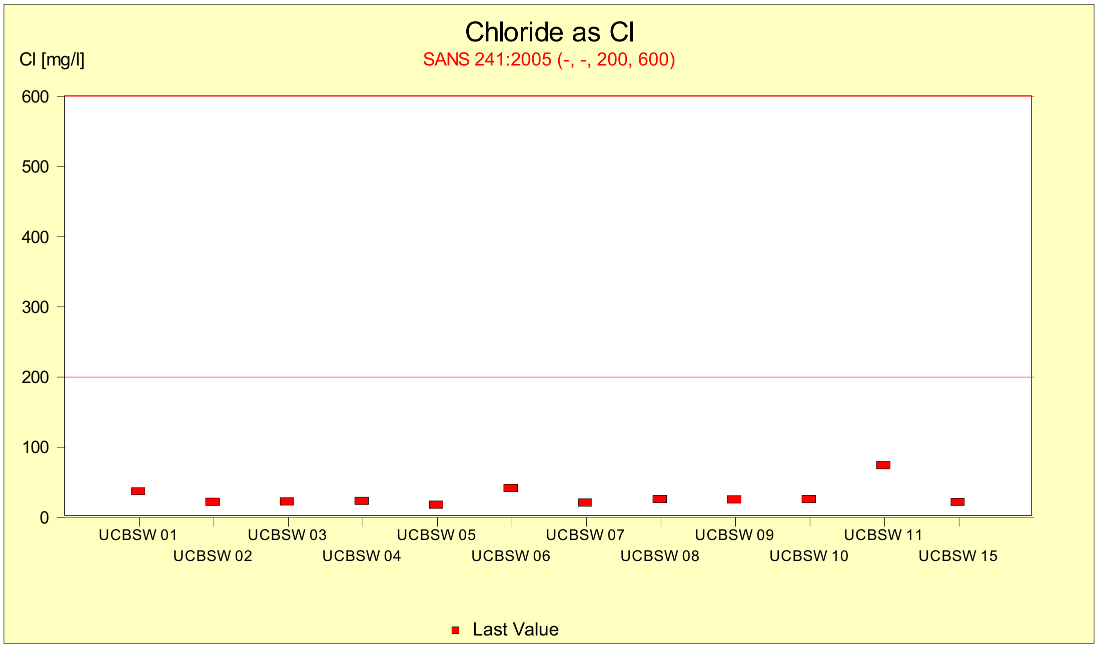
Report checked by: H. Holtzhausen (Laboratory Manager)

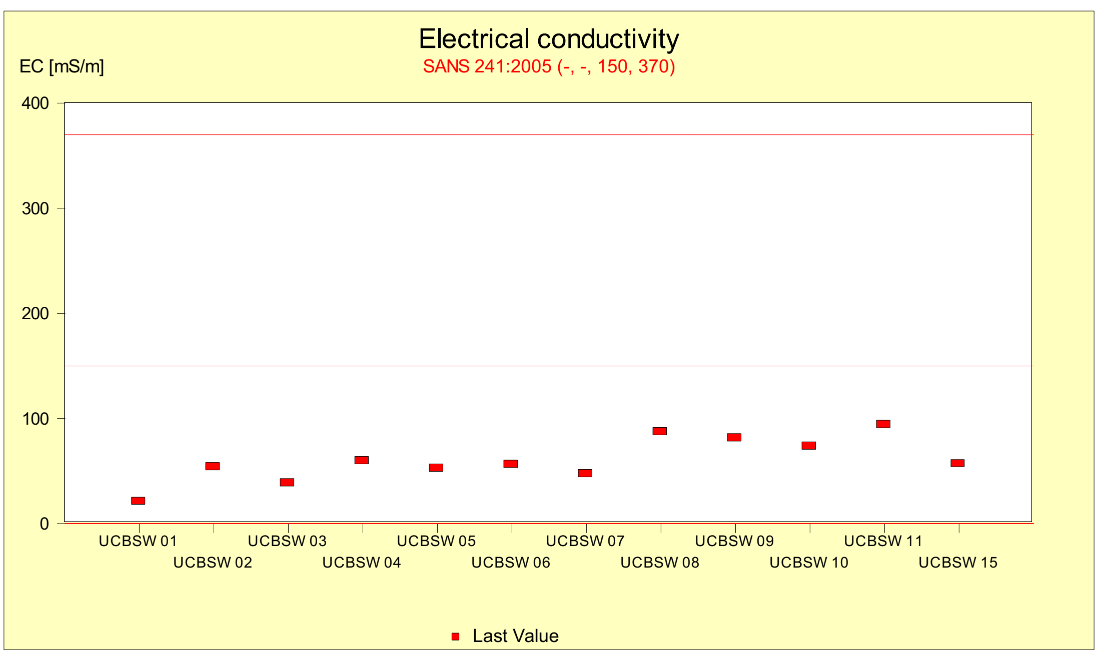
Appendix D: Water Quality Graphs

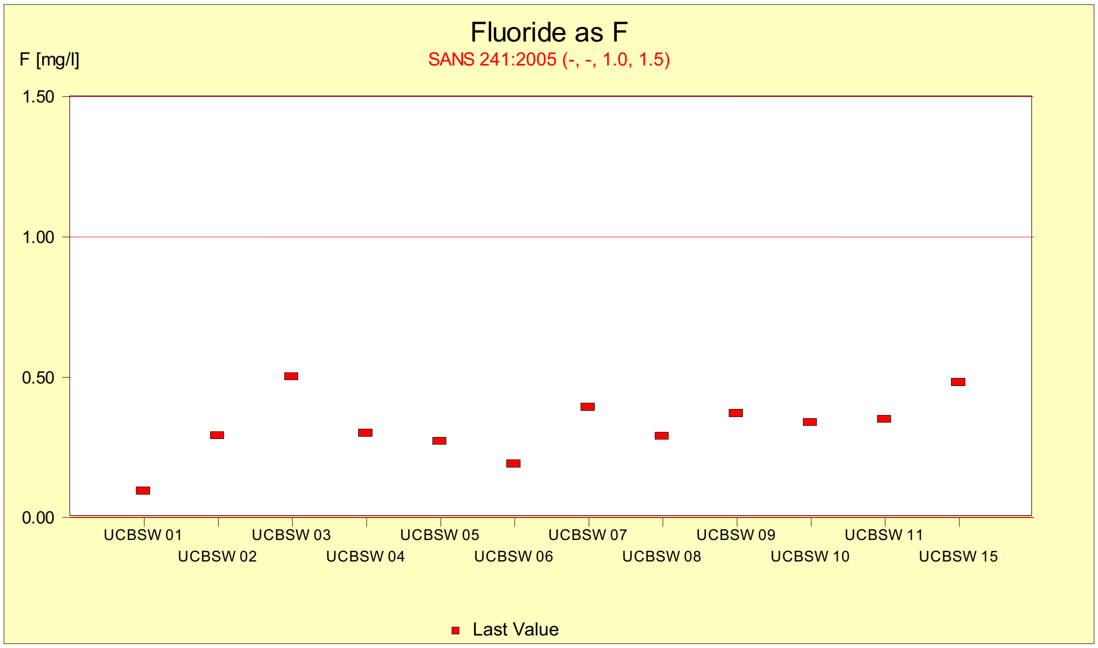
Brakfontein Water Quality WISH graphs

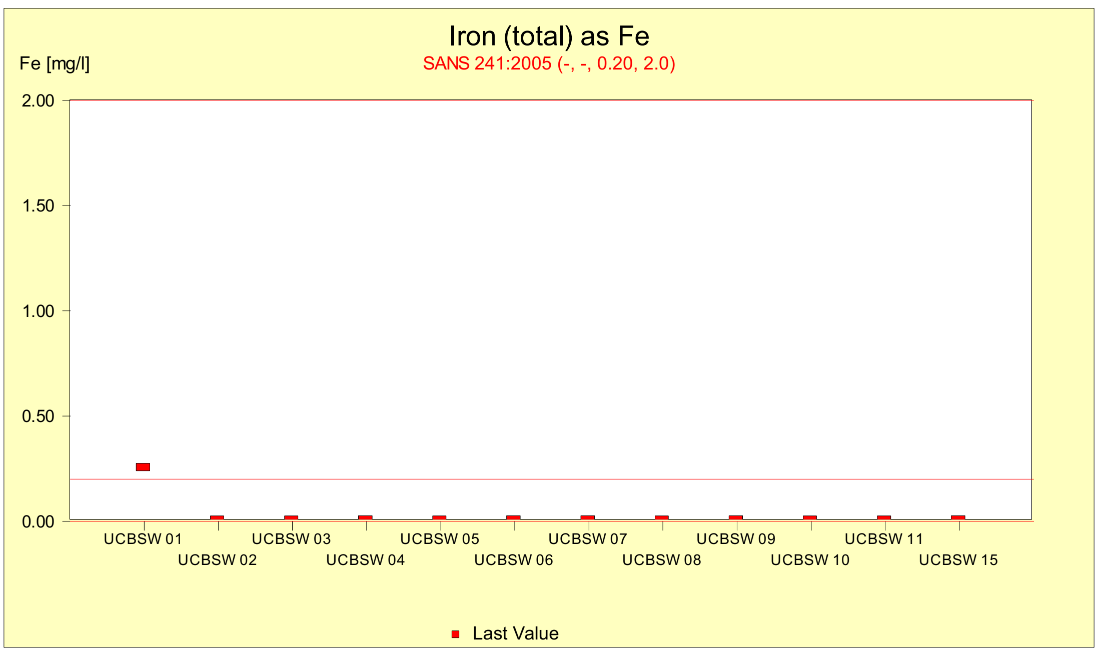


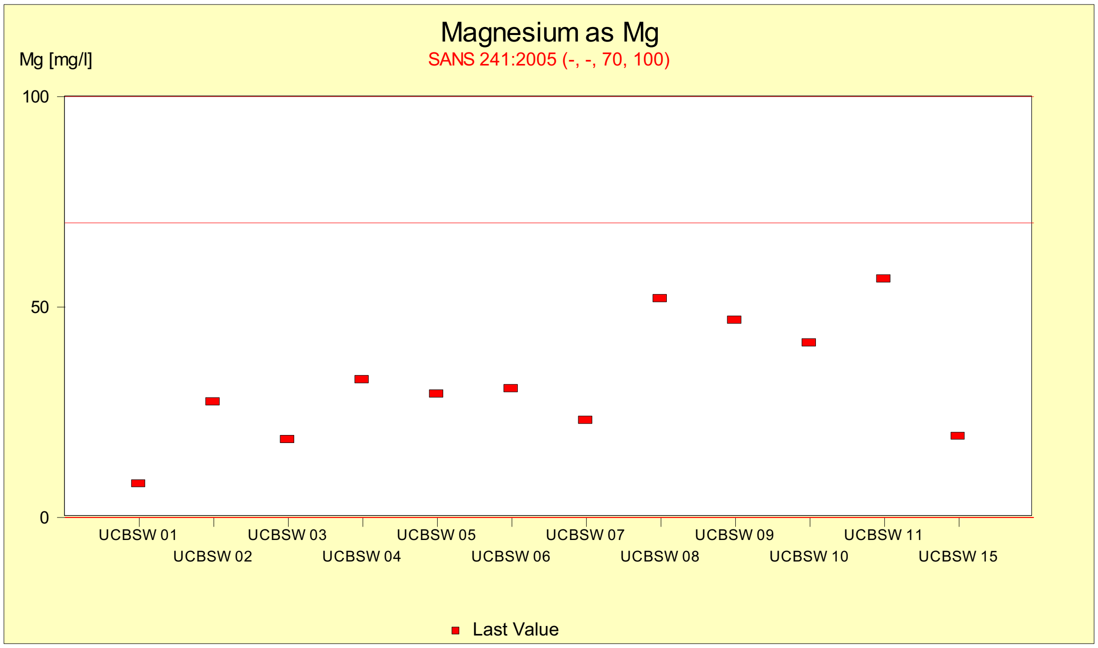


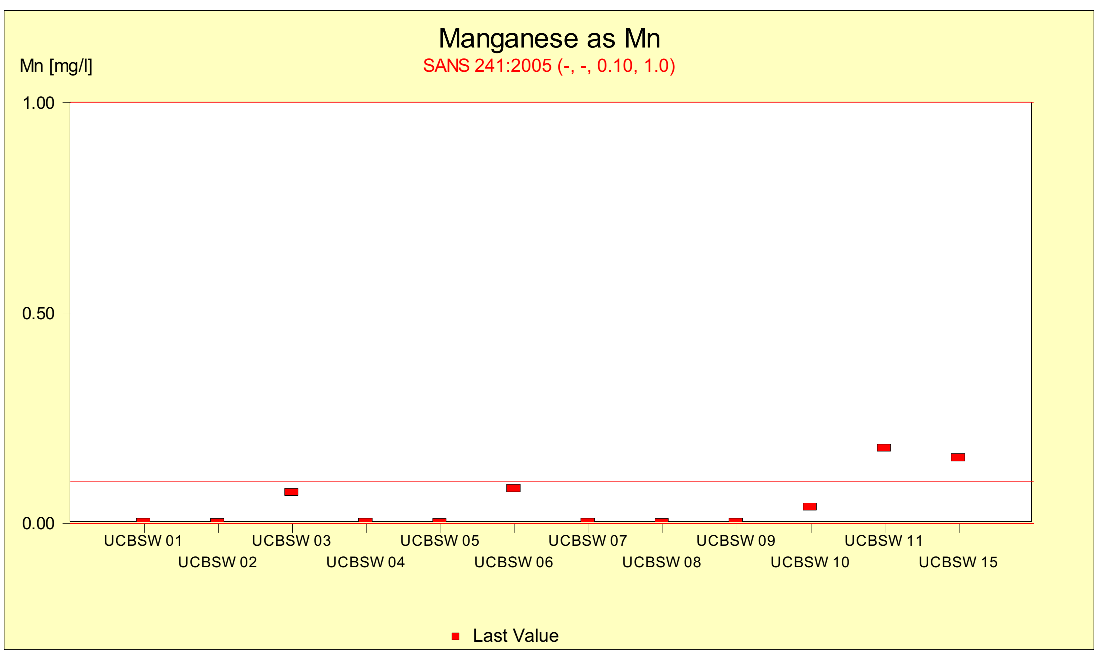

Chloride as Cl
Cl [mg/l]
SANS 241:2005 (-, -, 200, 600)
600
500
400
300
200
100
0
UCBSW 01
UCBSW 02
UCBSW 03
UCBSW 04
UCBSW 05
UCBSW 06
UCBSW 07
UCBSW 08
UCBSW 09
UCBSW 10
UCBSW 11
UCBSW 15
Last Value

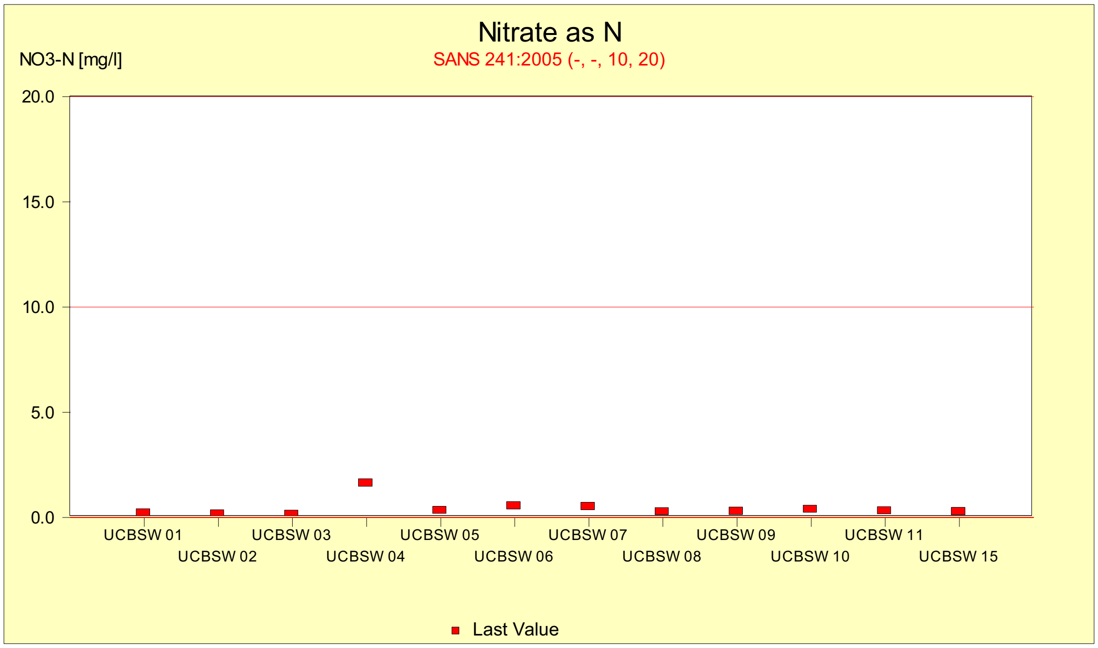

Electrical conductivity
EC [mS/m]
SANS 241:2005 (-, -, 150, 370)
400
300
200
100
0
UCBSW 01
UCBSW 02
UCBSW 03
UCBSW 04
UCBSW 05
UCBSW 06
UCBSW 07
UCBSW 08
UCBSW 09
UCBSW 10
UCBSW 11
UCBSW 15
Last Value

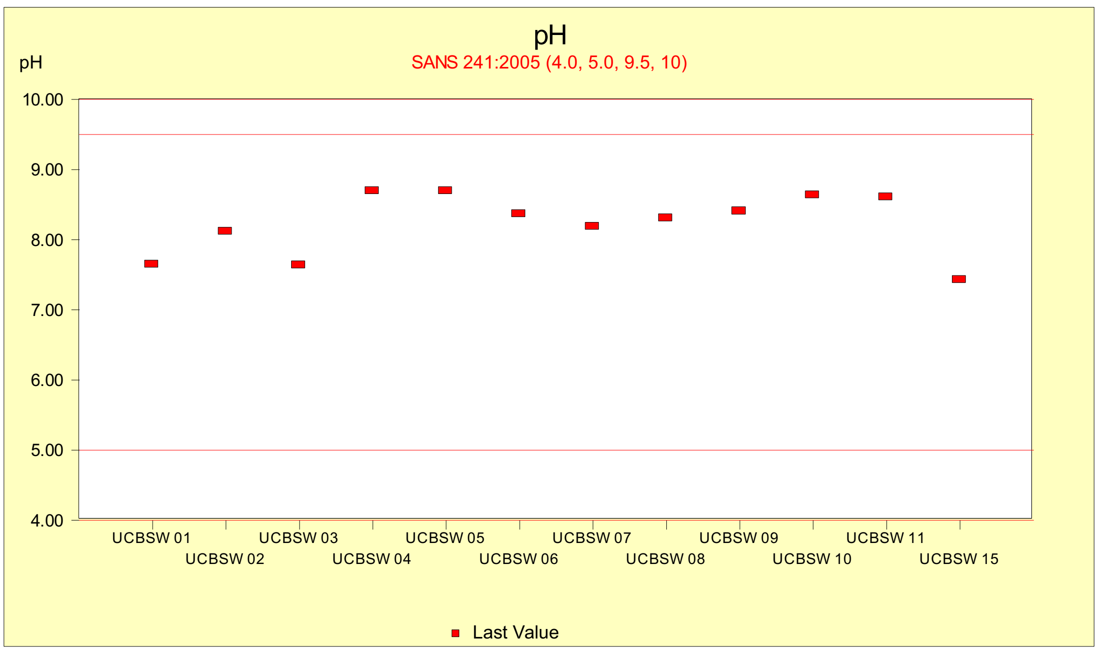

Fluoride as F
F [mg/l]
SANS 241:2005 (-, -, 1.0, 1.5)
1.50
1.00
0.50
0.00
UCBSW 01
UCBSW 02
UCBSW 03
UCBSW 04
UCBSW 05
UCBSW 06
UCBSW 07
UCBSW 08
UCBSW 09
UCBSW 10
UCBSW 11
UCBSW 15
Last Value

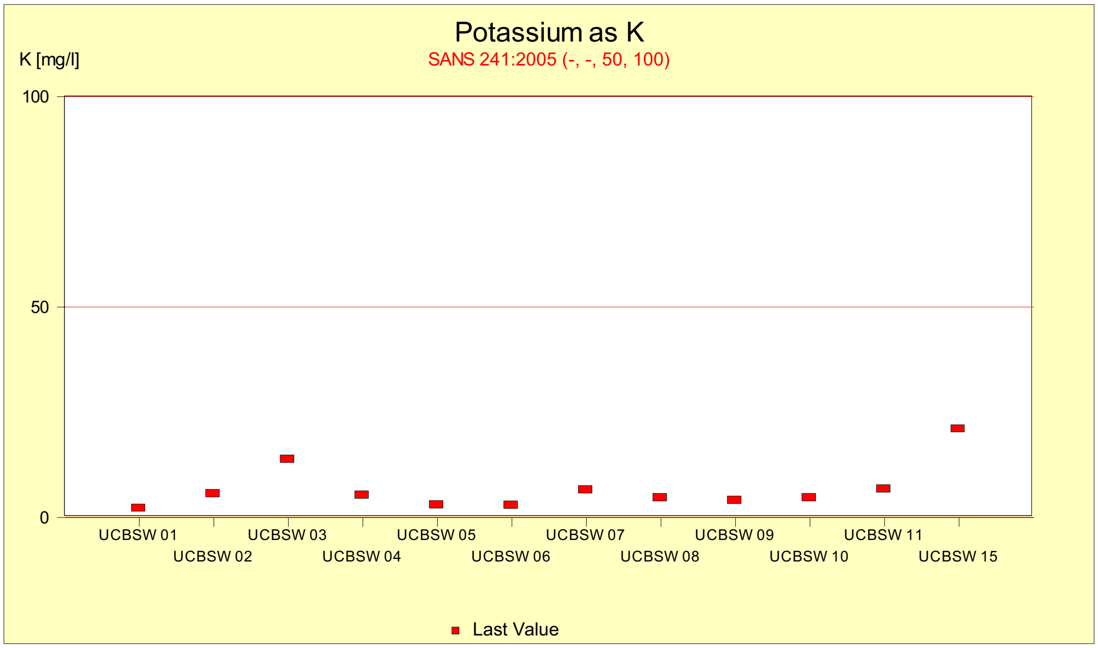

Iron (total) as Fe
Fe [mg/l]
SANS 241:2005 (-, -, 0.20, 2.0)
2.00
1.50
1.00
0.50
0.00
UCBSW 01
UCBSW 02
UCBSW 03
UCBSW 04
UCBSW 05
UCBSW 06
UCBSW 07
UCBSW 08
UCBSW 09
UCBSW 10
UCBSW 11
UCBSW 15
Last Value

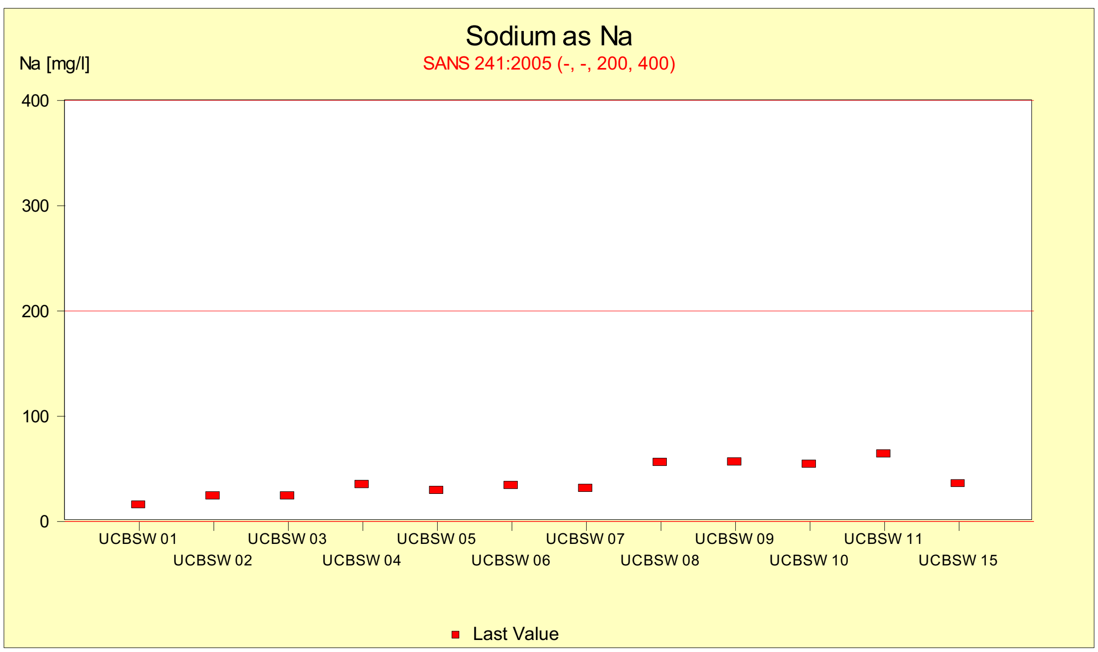

Magnesium as Mg
Mg [mg/l]
SANS 241:2005 (-, -, 70, 100)
100
50
0
UCBSW 01
UCBSW 02
UCBSW 03
UCBSW 04
UCBSW 05
UCBSW 06
UCBSW 07
UCBSW 08
UCBSW 09
UCBSW 10
UCBSW 11
UCBSW 15
Last Value

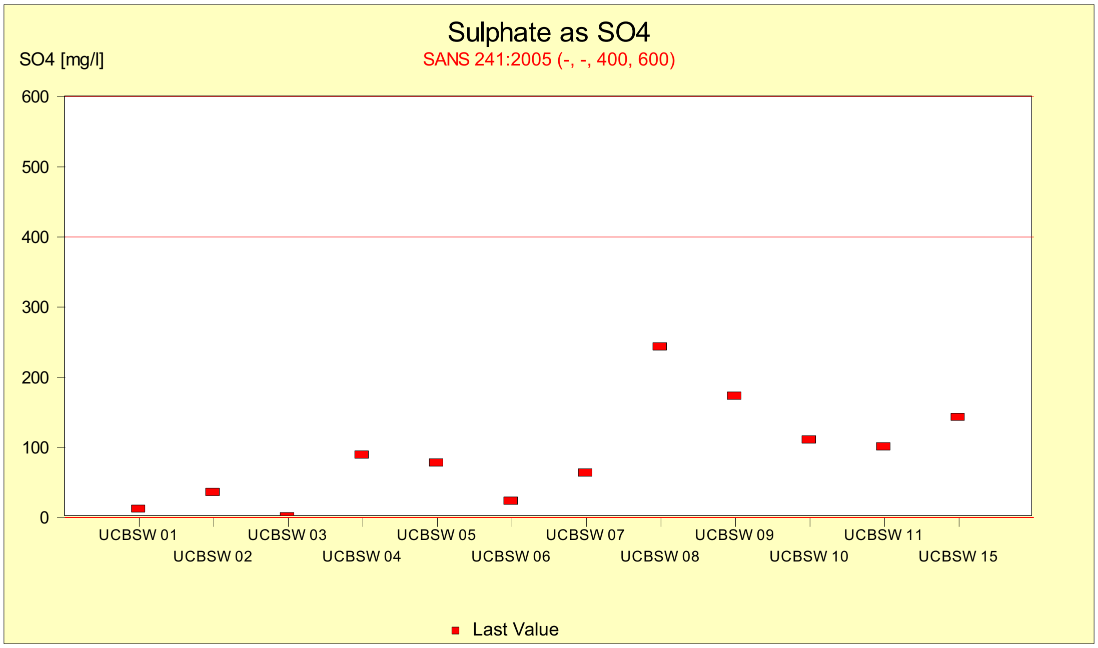

Manganese as Mn
Mn [mg/l]
SANS 241:2005 (-, -, 0.10, 1.0)
1.00
0.50
0.00
UCBSW 01
UCBSW 02
UCBSW 03
UCBSW 04
UCBSW 05
UCBSW 06
UCBSW 07
UCBSW 08
UCBSW 09
UCBSW 10
UCBSW 11
UCBSW 15
Last Value

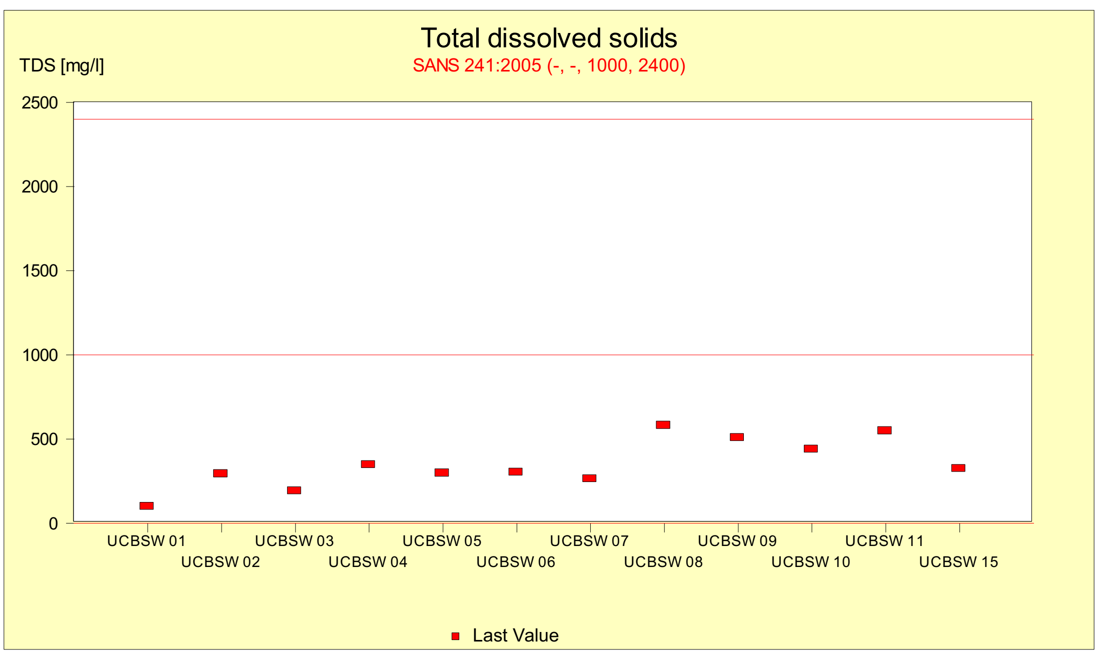

Nitrate as N
NO3-N [mg/l]
SANS 241:2005 (-, -, 10, 20)
20.0
15.0
10.0
5.0
0.0
UCBSW 01
UCBSW 02
UCBSW 03
UCBSW 04
UCBSW 05
UCBSW 06
UCBSW 07
UCBSW 08
UCBSW 09
UCBSW 10
UCBSW 11
UCBSW 15
Last Value


pH
pH
SANS 241:2005 (4.0, 5.0, 9.5, 10)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
UCBSW 01
UCBSW 02
UCBSW 03
UCBSW 04
UCBSW 05
UCBSW 06
UCBSW 07
UCBSW 08
UCBSW 09
UCBSW 10
UCBSW 11
UCBSW 15
Last Value


Potassium as K
K [mg/l]
SANS 241:2005 (-, -, 50, 100)
100
50
0
UCBSW 01
UCBSW 02
UCBSW 03
UCBSW 04
UCBSW 05
UCBSW 06
UCBSW 07
UCBSW 08
UCBSW 09
UCBSW 10
UCBSW 11
UCBSW 15
Last Value


Sodium as Na
Na [mg/l]
SANS 241:2005 (-, -, 200, 400)
400
300
200
100
0
UCBSW 01
UCBSW 02
UCBSW 03
UCBSW 04
UCBSW 05
UCBSW 06
UCBSW 07
UCBSW 08
UCBSW 09
UCBSW 10
UCBSW 11
UCBSW 15
Last Value


Sulphate as SO4
SO4 [mg/l]
SANS 241:2005 (-, -, 400, 600)
600
500
400
300
200
100
0
UCBSW 01
UCBSW 02
UCBSW 03
UCBSW 04
UCBSW 05
UCBSW 06
UCBSW 07
UCBSW 08
UCBSW 09
UCBSW 10
UCBSW 11
UCBSW 15
Last Value


Total dissolved solids
TDS [mg/l]
SANS 241:2005 (-, -, 1000, 2400)
2500
2000
1500
1000
500
0
UCBSW 01
UCBSW 02
UCBSW 03
UCBSW 04
UCBSW 05
UCBSW 06
UCBSW 07
UCBSW 08
UCBSW 09
UCBSW 10
UCBSW 11
UCBSW 15
Last Value