APPENDIX F: HYDROLOGICAL ASSESSMENT AND GROUNDWATER STUDY

Tharisa Mine

Hydrology Assessment for a Chrome Sand Drying Plant, changes to the Tailings Dam Design and other Operational and Surface Infrastructure changes

SLR Project No.: T014-12

Report No.: 1

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Project Manager	Stella Moeketse
Project Manager e-mail	smoeketse@slrconsulting.com
Author	Paul Klimczak
Reviewer	Steve Van Niekerk
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HYDROLOGY ASSESSMENT

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ACRONYMS AND ABBREVIATIONS

Below a list of acronyms and abbreviations used in this report.

Acronyms / Abbreviations	**Definition**
AMSL	Above Mean Sea Level
DDF	Depth-Duration-Frequency
DWA	Department of Water Affairs
EIA	Environmental Impact Assessment
EMP	Environmental Management Programme
HRU	Hydrological Research Unit
IDF	Intensity Depth Frequency
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
PGMs	Platinum Group Metals
RMF	Regional Maximum Flood
ROM	Run Of Mine
RP	Return Period
SANRAL	South African National Road Agency Limited
SAWS	South African Weather Services
SDF	Standard Design Flood
TC	Time of Concentration
TDS	Total Dissolved Solids
TSF	Tailings Storage Facility
WRC	Water Research Commission
WRD	Waste Rock Dump
WUL	Water Use License

HYDROLOGY ASSESSMENT

1 INTRODUCTION

1.1 BACKGROUND

Tharisa Minerals (Pty) Ltd (Tharisa) produces chrome and platinum group metals (PGM) concentrate at Tharisa Mine (referred to hereafter as “the mine”) near Marikana town within North-West province.

Tharisa has an approved environmental impact assessment (EIA) and environmental management programme (EMP) report (Metago, June 2008) which was supported by a Waste, Surface Water and Closure Cost Report (Metago, May 2008). A Water Use License (WUL) for the mine was issued in July 2012.

There are changes to the mine infrastructure which require an amendment to the EIA/EMP and SLR Consulting (Africa) (Pty) Ltd (SLR), formerly Metago, are commissioned to prepare an EIA/EMP amendment. Full details of the approved infrastructure, project components and closure plan are provided within the EIA/EMP amendment although a summary of the details relevant to this study are presented in Sections 1.2, 1.3 and 1.4.

This report presents a Hydrology Assessment which is prepared in support of the EIA/EMP amendment and includes:

- A review of the baseline hydrology of the site and surrounding areas including the existing stream diversion channel;
- An identification and assessment of potential sources of pollution and related impacts of the project components on surface water resources (quantity, quality and flow characteristics);
- Development of management and mitigation measures including a storm water management plan (SWMP), an updated water balance, a monitoring program and contingency plans.

1.2 APPROVED/EXISTING SURFACE INFRASTRUCTURE

The main components of the approved/existing surface infrastructure include:

- Contractor’s work areas during construction;
- Open pit mining operation;
- Mining contractor’s yard;
- Soil and overburden stockpiles;
- Waste Rock Dumps (WRDs);
- Run of mine (ROM) crushing and stockpiling;
- Internal conveyor and haul roads;

- Mine access road and helipad;
- Concentrator complex for the PGM and chrome plant;
- A tailings storage facility (TSF) complex;
- A sewage treatment plant and associated pipelines;
- Water management infrastructure including boreholes, supply pipelines, dirty storm water control measures, clean storm water control measures, a river diversion, a storm water dam and process water dams;
- Waste management infrastructure: temporary handling and storage of general and hazardous waste and a salvage yard;
- Storage and handling of hazardous substances: fuel, lubricants, various process input chemicals, raw material stockpiles/bunkers, gas, burning oils, explosives;
- Services: power lines and substation, pipelines, telephone lines, communication and lighting masts;
- Security and access control;
- Workshops and wash bays;
- Laboratory, offices, control rooms; and
- First aid clinic.

1.3 NEW/AMENDED SURFACE INFRASTRUCTURE

A brief overview of the new/amended surface infrastructure is presented below:

<u>Chrome Sand Drying Plant</u> - A diesel powered chrome sand drying plant is proposed where wet chrome will be fed into the plant by a front loader and dried chrome will be discharged via a conveyor into a storage bin from where it will be packaged into 1 ton bags, stored in a covered store, ready for dispatch. The plant will have a footprint of 6m x 6m and will be located within the existing concentrator plant area.

<u>Pit Widening and Deepening</u> - Two open pit operations which are located either side of the D1325 Marikana Road, will be deepened beyond their approved depth of 120m to 180m, resulting in an extension of the life of the mine from 12 to 18 years.

<u>Waste Rock Dumps (WRDs)</u> - Two of the four previously approved WRDs will be combined into one, two will be re-shaped and a new WRDs is proposed. A final design report for the Eastern WRD has been prepared by Epoch Resources in July 2013, and draft design reports for the Central and North-Eastern WRDs have been prepared by Epoch Resources in August and September 2013. No design report has yet been undertaken for the Western WRD as yet. The dimensions of the WRDs are presented in Table 1.1.

TABLE 1.1: WASTE ROCK DUMP DIMENSIONS

Approved Waste Rock Dumps				
Dimensions	Western Waste Rock Dump	Western Waste Rock Dump	Eastern Waste Rock Dump	Eastern Waste Rock Dump
Footprint	49ha	22ha	22ha	22ha
Volume	13 330 000m^3	5 890 000m^3	5 890 000m^3	5 890 000m^3
New Waste Rock Dumps				
Dimensions	Western Waste Rock Dump	Central Waste Rock Dump	Eastern Waste Rock Dump	North Eastern Waste Rock Dump
Footprint	49ha	67ha	78ha	94ha
Volume	13 330 000m^3	18 500 000m^3	17 580 000m^3	20 000 000m^3

Tailings Storage Facilities (TSFs) - The increased depth of the pits necessitates an increase in the size of the TSFs, as detailed in Table 1.2.

TABLE 1.2: TAILINGS FACILITIES DIMENSIONS

Dimensions	**Approved TSF1**	**Proposed TSF1**	**Approved TSF2**	**Proposed TSF2**
Footprint	52ha	70ha	100ha	135ha
Maximum Height	33m	40m	31m	40m
Volume	5.4 million m^3	8.1 million m^3	12.8 million m^3	24 million m^3

The construction of the TSFs will no longer include black turf clays underneath the containment walls or low permeability liner along the inside face of the TSF. Instead, toe drains have been incorporated on the inside toe of the TSF containment walls to draw down the phreatic surface of the TSF and a seepage collection trench will intercept seepage.

Truck Parking Area - A 700m long x 8m wide one-way gravel road is required for queuing parking trucks in addition to the main 200m x 50m gravel parking area.

Topsoil Berms - The eastern topsoil berm will be moved closer to the concentrator plant and the height of the berm walls are increased from 10m to 30m to minimise visual and noise impacts.

1.4 MINE CLOSURE

Following closure of the site, the majority of the WRD material will be used to backfill the two pits at the mine although the existing ground levels will not be restored and there will remain a final void and a residual WRD on surface. Sub-soil will be placed over the residual WRDs and the backfilled in pit waste, and the topsoil will be placed over the sub-soil and allowed to re-vegetate naturally.

1.5 POTENTIAL IMPACTS AND MITIGATION BY DESIGN

Without suitably designed mitigation measures the mining operation may have the following impacts upon the baseline hydrology:

- Consumption of water resources during mine activities which will reduce the flows within the surrounding watercourses which in turn may impact upon downstream water users or aquatic ecology;
- Increase in the risk of flooding to life and property by changing the baseline hydrological regime which may increase peak flows, or route surface water to new areas; and
- Introduction of pollutants to the area which may leak into the surrounding watercourses, or earthworks leading to soil erosion increasing suspended solids within the surrounding watercourses both of which may impact upon downstream water users or aquatic ecology.

The above impacts can be significantly reduced or removed entirely by operation of the mine in accordance with current best practices namely:

- Government Notice 704 (Government Gazette 20118 of June 1999) hereafter referred to as GN 704 which was established to provide regulations on the use of water for mining and related activities aimed at the protection of water resources; and
- Department of Water and Forestry's (DWAF) Best Practice Guideline (BPG) – G1: Storm Water Management, which gives guidance on the development and implementation of a SWMP to ensure the impacts of a mining operation on the baseline quantity and quality of water resources and flood risk are minimised.

A conceptual level SWMP has been developed for the mine and is presented in Section 3 of this report, which aims to ensure compliance with the relevant sections of GN 704 and BPG G1 thereby mitigating the potential impacts on the baseline hydrology identified above. A site wide water balance model has been prepared for the average dry and wet seasons, as presented in Section 4, which aims to inform the mining operator's management of water at the site and understand the reduction in baseline flows within the surrounding watercourses. Furthermore, an ongoing water quality monitoring program is outlined which will identify if mining activities are impacting upon the baseline water quality of surrounding watercourses.

2 BASELINE CONDITIONS

The baseline information discussed in this section includes the climate, extreme rainfall data, topography, soils, watercourses, flow regime, flood-lines, river diversion and water quality.

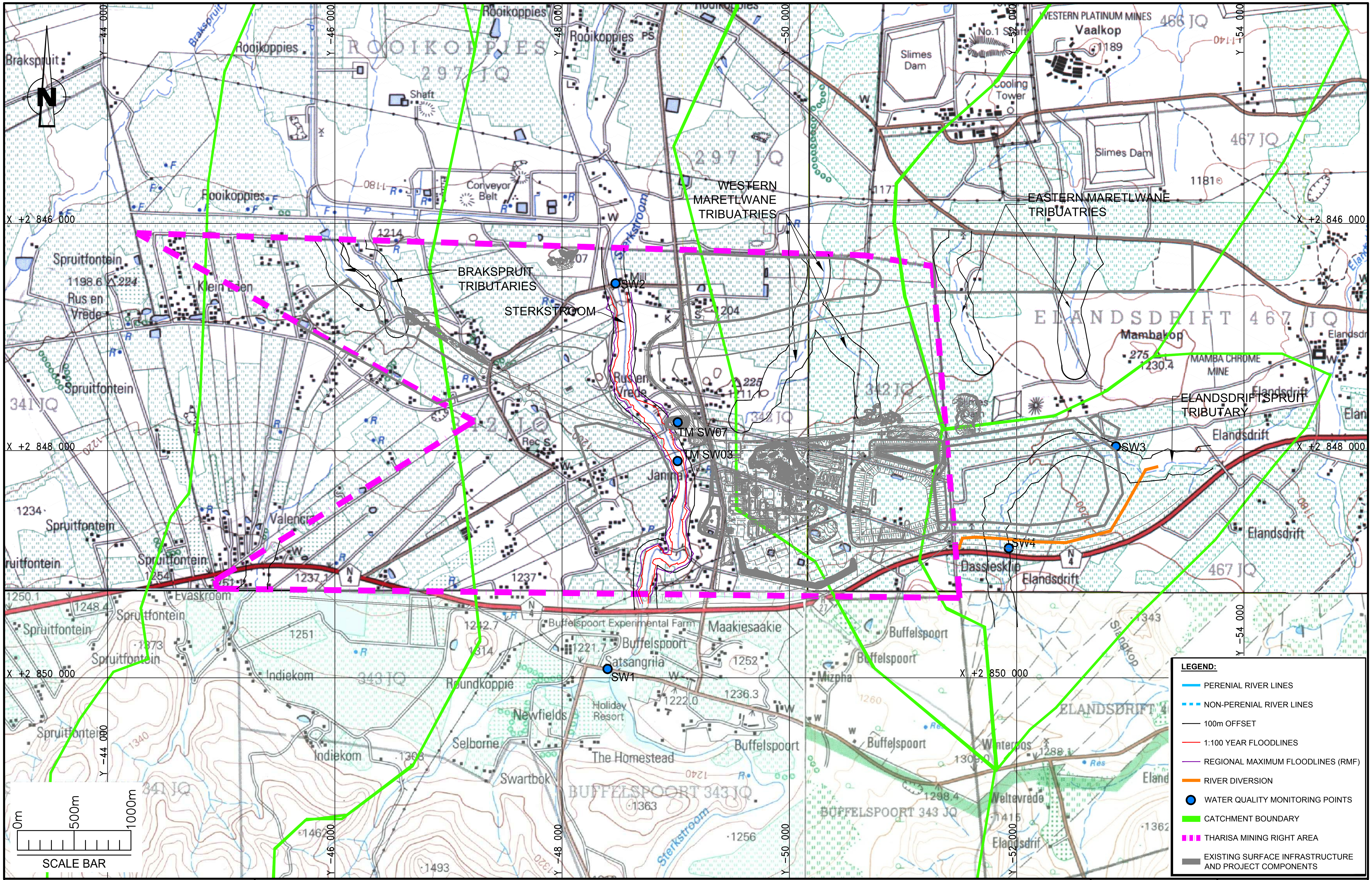
The local hydrology is presented on Figure 2-1 and discussed in further details below.

2.1 CLIMATE

The Tharisa mine site is situated in the Highveld climatic zone (Schulze, 1965). Features of this climatic zone are outlined below:

- Warm, temperate climate;
- Rain generally occurs in summer from October to March;
- Rainfall is generally in the form of thunderstorms. These can be of high intensity with lightening and strong gusty south westerly winds;
- Hail frequency is high tending to occur 4 to 7 times per season mainly depending on the altitude of the mine;
- An average of 75 storms occurs each year;
- In summer average daily temperatures range from 21 to 30°C with the winter average daily temperatures ranging from 1 to 17°C;
- Frosts may occur from May to September for about 120 days per annum.
- Light north to north easterly and south westerly winds prevail. However, strong gusty south westerly winds often accompany thunderstorms; and
- Sunshine duration in summer is about 60% and in winter about 80% of the possible.

The Buffelspoort weather station is the closest station to the Tharisa mine and has therefore been used in hydrological calculations. The monthly average rainfall and evaporation is presented in Table 2.1 and analysis of 24 hour maximum rainfall depths, maximum / minimum monthly rainfall recorded and average number of rain days is presented in Table 2.2.



SLR
Johannesburg Office
METAGO HOUSE
FOURWAYS MANOR OFFICE PARK
CORNER ROOS AND MACBETH STREETS
FOURWAYS
JOHANNESBURG, SOUTH AFRICA
T: +27 (11) 467-0945
F: +27 (11) 467-0978
www.slrconsulting.com

THARISA EMP AMENDMENT

LOCAL HYDROLOGY

Date : JUNE 2014

Scale : AS SHOWN

Project No : T014-12

FIGURE 2-1

TABLE 2.1: AVERAGE MONTHLY RAINFALL AND EVAPORATION ADOPTED FOR THE THARISA MINE

Month	Rainfall Depth* (mm)	Average S-Pan** (mm)	S-Pan to Lake Evap. factor	Lake Evaporation Depth (mm)	Net Gain(+)/ Loss(-)
January	123	195	1	195	-72
February	97	165	1	165	-68
March	85	158	1	158	-73
April	41	125	1	125	-84
May	17	107	1	107	-90
June	8	87	1	87	-79
July	5	97	0.8	78	-73
August	6	128	0.8	102	-96
September	18	168	0.8	134	-116
October	57	193	0.8	154	-97
November	88	189	1	189	-101
December	119	199	1	199	-80
TOTALS	**664**	**1 811**	**-**	**1 693**	**-1 029**

** Supplied by the South African Weather Service based on monthly figures from 1925 to 2007 measured at Buffelspoort II weather station*
*** Supplied by the Department of Water Affairs and Forestry based on monthly figures from 1942 to 2007 measured at Buffelspoort Dam weather station*

TABLE 2.2: RAINFALL DATA FOR SAWS BUFFELSPOORT II AGR USING DATA BETWEEN 1961 AND 1990

Month	24hr Max Rainfall		Total Rainfall per month / year				Average No. of Days with Rainfall >= 0.1mm						
	Depth (mm)	Date (yy/dd)	Max (mm)	Year	Min (mm)	Year	Avg	Max	Min	1mm	5mm	10mm	30mm
January	103	76/05	286	1977	23	1969	12,8	17	7	11,1	7,0	4,3	1,0
February	70	80/16	193	1974	10	1963	10,2	17	4	9,0	5,4	2,9	0,5
March	91	76/19	198	1968	4	1965	9,3	16	2	8,2	4,6	2,7	0,4
April	83	76/02	134	1961	3	1985	6,6	14	1	5,7	2,9	1,5	0,2
May	47	69/20	72	1976	0	1989	2,5	11	0	2,0	1,2	0,4	0,1
June	19	89/03	44	1989	0	1990	1,3	7	0	0,9	0,5	0,3	0,0
July	29	82/26	36	1982	0	1989	0,7	4	0	0,6	0,2	0,0	0,0
August	20	87/26	31	1979	0	1988	1,6	10	0	1,0	0,3	0,1	0,0
September	37	73/29	96	1987	0	1990	2,3	9	0	2,0	1,0	0,6	0,1
October	77	76/02	140	1973	9	1980	7,4	16	3	6,1	3,4	2,1	0,3
November	91	79/25	239	1979	31	1981	11,1	18	5	9,4	5,5	3,2	0,3
December	87	64/12	305	1966	41	1980	11,8	18	6	10,3	5,5	4,0	1,0
YEAR	103	76/05	1062	1976	499	1981	78	94	63	66	38	22	4

2.2 EXTREME RAINFALL DEPTHS

Design storm estimates for various return periods and storm durations were sourced from the Design Rainfall Estimation Software for South Africa, developed by the University of Natal in 2002 as part of a Water Research Commission (WRC) project K5/1060 (Smithers and Schulze, 2002). This method uses a Regional L-Moment Algorithm in conjunction with a Scale Invariance approach to provide site specific estimates of intensity-duration-frequency (IDF) rainfall, based on surrounding observed records.

Table 2.4 presents IDF rainfall estimates that were derived from the Smithers and Schulze method based on data taken from the six nearest rain stations which have similar Mean Annual Precipitations (MAP) and altitudes. A summary of the input stations and interpolated MAPs for the mine is presented in Table 2.3.

TABLE 2.3: SUMMARY OF WEATHER STATIONS USED FOR GENERATING RAINFALL IDF

Station Name	SAWS Number	Distance from Mine (km)	Record Length (years)	Mean Annual Precipitation (mm)	Altitude (mAMSL)
BUFFELSPOORT.	0511855_A	0	67	684	1205
BUFFELSPOORT-2	0511855AW	0	73	684	1253
BUFFELSPOORT-1	0511855_W	0	83	684	1253
BUFFELSFONTEIN	0511858_W	5.4	30	683	1280
MARIKANA	0511851_W	7.2	25	681	1150
NOOITGEDACHT	0512082_W	12.1	27	718	1402
THARISA MINE*	N/A	0	N/A	684	1205

** Data is interpolated from surrounding weather stations*

The Smithers and Schulze method of IDF rainfall estimation is widely accepted to be more robust than previous single site methods. WRC Report No. K5/1060 provides further detail on the verification and validation of the method.

TABLE 2.4: INTENSITY DEPTH FREQUENCY (IDF) ESTIMATES FOR THARISA MINE

Duration (hours)	Rainfall Depth (mm)						
	1:2yr	1:5yr	1:10yr	1:20yr	1:50yr	1:100yr	1:200yr
0.08	10.4	14.2	16.8	19.6	23.4	26.5	29.8
0.167	15.5	21.1	25.1	29.1	34.8	39.4	44.3
0.25	19.6	26.6	31.6	36.8	43.9	49.7	55.9
0.5	24.8	33.6	40	46.5	55.6	63	70.8
0.75	28.5	38.6	46	53.4	63.9	72.3	81.3
1	31.4	42.6	50.7	58.9	70.5	79.8	89.6
1.5	36	48.9	58.2	67.7	80.9	91.6	102.9
2	39.7	54	64.2	74.6	89.2	101	113.5
4	47.3	64.2	76.4	88.9	106.3	120.3	135.2
6	52.4	71.1	84.6	98.4	117.7	133.2	149.7
8	56.3	76.5	91	105.8	126.5	143.2	160.9
10	59.6	80.9	96.3	111.9	133.8	151.5	170.2
12	62.4	84.7	100.8	117.2	140.1	158.6	178.2
16	67.1	91.1	108.3	126	150.6	170.5	191.6
20	71	96.3	114.6	133.3	159.3	180.4	202.7
24	74.3	100.9	120	139.5	166.8	188.9	212.2

2.3 TOPOGRAPHY

The project area is relatively flat with a gentle slope down towards the north. The area has an elevation of approximately 1200 meters above mean sea level (mamsl). The natural topography surrounding the project area has been changed by third-party mining activities to the north, east and west of the project area.

Approximately 2km to the south of the project area lies the Magaliesberg Mountain range. Peaks in this part of the Magaliesberg rise to approximately 1400 mamsl.

2.4 SOILS

A summary of the main soil types is presented below, with a focus on the hydrological properties of the soils.

- Hutton - These soils comprise predominantly fine grained sandy, to silty loams or fine to medium grained sandy clay loams. Clay content varies from 10% to 15% in sandy topsoils to 25% in some instances and to over 65% in the subsoils. The effective rooting depths varies from 200mm to greater than 1100mm.
- Shortlands and Valsrivier - These have a very high clay content and are erosive in nature, have moderately low intake rates, high water holding capabilities, showed evidence of expansive clays and are found with depths of 200m to 1200mm.

- Mispah, Mayo and Milkwood - These soils have moderate to high clay percentages ranging from 20% to 45%, they have low internal drainage, low water holding capacities and are characterised by effective rooting depths of between 100mm and 500mm.
- Sterkspruit and Swartland - These soils are moderately blocky, have low intake rates, moderate water holding capabilities and show evidence of expansive clays, with a fair range in depths, 200mm to 600mm.
- Sepane - These soils are high in transported clay, vary from 200mm to 400mm in depth and are are classified as having a wetland capability.
- Bonheim - These soils are highly sensitive to compaction and erosion and are prone to the formation of hard “clods” when they dry out.

As detailed above, the soils at the mine are typically clay rich with low water intake rates and will generate relatively high volumes of runoff.

2.5 WATERCOURSES

The project area is located within the upper reaches of the A21K quaternary catchment, which falls within the Lower Crocodile Secondary catchment and the Crocodile West and Marico Water Management Area (WMA3).

The local hydrology is presented on Figure 2-1, the following watercourses are noted within the vicinity of the mine:

- Sterkstroom – a perennial watercourse which flows from the Buffelspoort Dam, south of the N4, in a northerly direction through the centre of the project area;
- Unnamed tributaries of the Brakspruit – two non-perennial watercourses which originate in the north-west of the mine, and flow to the north to separate confluences with the Brakspruit;
- Western unnamed tributaries of the Maretlwane – two non-perennial watercourses which originate in the vicinity of the eastern pit, and flow to the north then north-east to a confluence with the Maretlwane;
- Eastern unnamed tributaries of the Maretlwane – two non-perennial watercourses which originate to the north of TSF 2, and flow to the north then north-east to a confluence with the Maretlwane tributaries; and
- Unnamed of the Elandsdriftspruit – a non-perennial tributary which originates just south of the mine and flows north then east through the far eastern part of the mine. The diversion of this was included within the approved EIA/EMP.

Water from the Sterkstroom is used for domestic purposes such as washing and bathing, livestock watering and for agricultural purposes.

An irrigation canal flows from south to north, along the eastern boundary of the TSF. It is understood from discussions with Tharisa Minerals, that there are no users of this irrigation canal north of the TSF.

2.6 FLOW REGIME

The normal dry weather flow for the Elandsdriftspruit, Brakspruit and Maretlwane tributaries is zero. The normal dry weather flow of the Sterkstroom River is dependent on the rate of release from the Buffelspoort Dam situated about 3.25km upstream of the mine site.

Flow measured at the Buffelspoort gauging station in the Sterkstroom River is presented in WRC (1994). The Buffelspoort gauge (gauge no. A2R005; Lat 25°46'16''; Long 27°29'47'') has a catchment area of 119km^2 and is situated downstream of the Buffelspoort Dam and upstream of the mine site. Average flows between 1935 and 2013 indicate a mean annual flow of 7.65 million m^3/year, with average monthly flows varying between 0.29 million m^3/month in July and 1.59 million m^3/month in February.

According to WR2005, quaternary catchment A21K has a catchment area of 865km^2 and an estimated mean annual runoff (MAR) of 22.46 million m^3/year. From the WR2005 data, the MAR in each of the watercourses has been estimated on a pro-rata basis according to catchment area, as presented in Table 2.6. It should be noted that these estimates of MAR based on catchment area should be considered as indicative only, as flow within a catchment is not always directly proportional to the catchment area. For example based on flows recorded at Bufflespoort gauging station, the MAR per km^2 of catchment is 0.064 million m^3/year whereas downstream of this it is estimated to be 0.026 million m^3/year based on the WR2005 data.

TABLE 2.5: MEAN ANNUAL RUNOFF (BASED ON WR2005 DATA)

Catchment	Area (km^2)	Mean Annual Runoff - (MAR) (million m^3/year)
Sterkstroom (downstream of Buffelspoort Dam and upstream of the confluence with Brakspruit)	44.58	1.16
Elandsdriftspruit tributary (upstream of confluence with Elandsdriftspruit)	6.47	0.17
Brakspruit tributaries (upstream of confluence with Brakspruit)	20.75	0.54
Western Maretlwane tributaries (upstream of confluence with Maretlwane)	16.88	0.44
Eastern Maretlwane tributaries (upstream of confluence with Maretlwane)	11.80	0.31
A21K	865.00	22.46

2.7 FLOOD-LINES

As part of the 2008 EIA/EMP flood peaks and volumes for the 1:20, 1:50 and 1:100 year storm events were estimated by Metago for the Sterkstroom and Elandsdriftspruit tributary are presented in Table 2.7. Flows for these watercourses only were estimated, as only these watercourses will involve engineering design in terms of flood-line determination and stream diversion design. Using the peak flows presented below, the 1:50, 1:100 year and Regional Maximum Flood (RMF) flood-lines for the Sterkstroom River were modelled and are presented alongside the 100m offsets on Figure 2.1. The 100m buffers are presented for the other watercourses and considering the relatively small catchments of these other watercourses (Brakspruit Tributaries and Maretlwane Tributaries) which will generate only modest flood flows, the 100m buffers are likely to be significantly wider than the 1:50 or 1:100 year flood-lines, and the 100m buffers will be taken as the developmental constraint in these locations.

TABLE 2.6: PEAK FLOWS AND FLOOD VOLUMES

Catchment	**Area (km^2)**	**Return period**			
		1:20	**1:50**	**1:100**	**RMF**
Peak Flow Rate (m^3/s)					
Sterkstroom	140.3	314	444	544	1185
Elandsdriftspruit tributary	3.3	25	35	43	181
Flood Volume ($x10^6$ m^3)					
Sterkstroom	140.3	7.36	10.39	12.73	-
Elandsdriftspruit tributary	3.3	0.14	0.19	0.24	-

2.8 STREAM DIVERSION

The Elandsdriftspruit tributary flows through the TSF complex and as part of the 2008 EIA/EMP it was proposed that this watercourse be diverted around the tailings dam. The 2008 hydrological assessment included hydraulic sizing of the flow diversion channel. The report recommended that the channel was designed to accommodate the RMF and due to the relatively high flow velocities, it was recommended that the channel be lined with a 300mm thick Reno Mattress underlain by geofabric to prevent erosion whilst suitable vegetation establishes in the channel. Furthermore, an energy dissipating structure and rock armouring were recommended at the confluence to minimise erosion.

2.9 SURFACE WATER QUALITY

The sampling locations are shown on Figure 2-1 and the results are presented in Appendix A. There are sampling points on Elandsdriftspruit tributary and Sterkstroom River, although typically only Sterkstroom River can be sampled as the flow is not sufficient to allow sampling in Elandsdriftspruit. SW1 is an upstream monitoring point which can be used to give background information on the local water quality, SW2 is downstream of the mine and TM SW03 is approximately halfway between SW1 and SW2.

It is noted that downstream of the site, the stream is being used for general domestic purposes by residents of the local township who may be impacted by any polluting activities at the mine.

The water quality has been compared to the following guidelines:

- South African National Standard for Drinking water (SANS 241:2011);

- South African water quality guidelines for livestock;
- South African water quality guidelines for irrigation; and
- South African water quality guidelines for aquatic ecosystems (target values).

2.9.1 BASELINE WATER QUALITY

Tharisa's mining operations commenced after June 2008, the water quality during November 2007 and June 2008 can therefore be considered indicative of baseline conditions prior to the commencing of the current mining.

During both 2007 and 2008 sampling rounds, the following parameters were found in higher concentrations downstream (SW2) of the Tharisa site than upstream (SW1):

- pH;
- total dissolved solids (TDS);
- alkalinity;
- sulphate;
- calcium; and
- magnesium; and
- sodium.

Whereas, concentrations of iron were found in slightly higher concentrations upstream (SW1) of the Tharisa site than downstream (SW2).

The following parameters exceeded one or more of the guidelines values on several occasions: TDS (irrigation), ammonia (aquatic ecosystems target), manganese (irrigation) and mercury (aquatic ecosystems target and irrigation).

The above indicates, that prior to commencement of Tharisa's operations, the water downstream of the mine generally had higher concentrations of major cations, major anions and pH than upstream.

2.9.2 OPERATIONAL WATER QUALITY

Potential pollution sources at a mine site (not necessarily the Tharisa mine site) include an incorrectly designed or constructed stormwater management scheme which allows spillage of polluted water into local watercourses; erosion of un-vegetated soils during earthworks; stockpiles of ores, or tailings outside of appropriately designed and drained facilities; storage of chemicals and hydrocarbons outside of fit for purpose roofed, bunded storage areas; or maintenance of vehicles and plant outside of hardstanding areas which are appropriately drained to a dirty water sump.

The water quality results for 2008 to 2014 show that following parameters are frequently found in higher concentrations downstream (SW2) of the mine than upstream (SW1):

- pH;
- total dissolved solids (TDS);
- alkalinity;
- nitrate;
- chloride;
- sulphate;
- aluminium;
- calcium;
- magnesium;
- sodium;
- sulphur;
- silicon; and
- strontium.

Of the above parameters, all except for nitrate, chloride, aluminium, sulphur, silicon and strontium were identified at higher concentrations downstream of the mine than upstream during the baseline survey rounds indicating that the source of these parameters pre-dates mining operations.

When considering the water quality results at monitoring points SW1 and SW2 over time, there are no identifiable trends showing increasing concentrations of parameters since the mining operation commenced, with the exception of aluminium.

Comparison of the results against the guideline values concludes that: TDS, ammonia, aluminium, iron and manganese are observed in concentrations which exceed the guideline values in both upstream and downstream samples, suggesting that activities or chemical sources upstream of, and therefore unrelated to the mine, is impacting upon the water quality of Sterkstroom.

On several occasions pH and aluminium are observed downstream of the mine, in concentrations which exceed guidelines values, whilst the upstream of the mine are below the guidelines, which indicates that there is a source of pollution between the two sampling points which is possibly the mine.

Comparison of water quality against drinking water standards concludes that, with the exception of aluminium and E. coli, none of the parameters analysed for were identified at concentrations above drinking water standards. Aluminium was found at 2.2 and 1.9 times the drinking water standard downstream of the mine, whilst upstream values were below the guidelines. On two occasions out of two sampling rounds, E. coli (which doesn't form part of the usual analytical suite) was observed at levels exceeding the drinking water standard both upstream and downstream of the mine.

The water quality of Hernic Quarry (TM SW07) typically shows elevated concentrations of TDS, ammonia and nitrate which exceed guideline values.

3 STORMWATER MANAGEMENT STRATEGY

3.1 AIMS AND OBJECTIVES

The objectives of stormwater management and control include (DWAF, 2006):

- Protection of life and property from flood hazards;
- Planning for drought periods in a mining operation;
- Prevention of land and watercourse erosion;
- Protection of water resources from pollution;
- Ensuring continuous operation and production through different hydrological cycles;
- Maintaining the downstream water quality requirements;
- Minimising the impact of mining on downstream users; and
- Preservation of the natural environment.

GN 704 was established to provide regulations on the use of water for mining and related activities aimed at the protection of water resources. Some important definitions from GN 704 appropriate to this project include:

- **Clean water system:** This includes any dam, other form of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of clean unpolluted water;

- **Dam:** This includes any return water dam, settling dam, tailings dam, evaporation dam, catchment or barrier dam and any other form of impoundment used for the storage of unpolluted water or water containing waste (i.e. contain polluted water);

- **Dirty area:** This refers to any area at a mine or activity which causes, has caused or is likely to cause pollution of a water resource (i.e. generate polluted water); and

- **Dirty water system:** This includes any dam, other form of impoundment, canal, works, pipeline, residue deposit and any other structure or facility constructed for the retention or conveyance of water containing waste.

The four main principle conditions of GN 704 applicable to this project are:

- *Condition 4* which defines the area in which mine workings or associated structures may be located with reference to a watercourse and associated flooding. The 50 year flood-line and 100 year flood-line are used for defining suitable locations for mine workings with the 50 year flood-line applicable for prospecting, open cast or underground mining operations and activities and the 100 year flood-line applicable for residue deposits, dams, reservoirs and associated infrastructure. Where the flood-line is less than 100 metres away from the watercourse, then a minimum watercourse buffer distance of 100 metres is required for both mine workings and associated structures.

- *Condition 5,* which indicates that no residue or substance which causes or is likely to cause pollution of a water resource may be used in the construction of any dams, impoundments or embankments or any other infrastructure;

- *Condition 6,* which describes the capacity requirements of clean and dirty water systems. Clean and dirty water systems must be kept separate and must be designed to convey flows up to and including a 1:50 year flood and must be constructed, maintained and operated such that these systems do not spill into each other more than once in 50 years on average; and

- *Condition 7,* which describes the measures, which must be taken to protect water resources. All dirty water or substances, which cause or are likely to cause pollution of a water resource either through natural flow or by seepage, are to be mitigated.

3.2 OVERVIEW OF EXISTING DRAINAGE INFRASTRUCTURE

The mine already features several containment and transfer dams which form part of the operational water management strategy for the mine, a summary of these dams is presented in Table 3-1 and their locations are shown on Figure 3-1. In the absence of further design detail, it is assumed (in accordance with GN 704) that these dams already include a 0.8m freeboard above the maximum water level.

TABLE 3.1: EXISTING CONTAINMENT AND TRANSFER DAM CAPACITIES

Dam	Capacity
Raw Water Dam	44 000m^3
MCC Dam	40 000m^3
Plant Stormwater Dam	30 000m^3
Hernic Quarry	250 000m^3
Process Water Dam	25 000m^3

Stormwater from the plant area currently drains into the plant stormwater dam, which when full is designed to overtop into Hernic Quarry via an open channel. Pit dewatering (stormwater and groundwater) from both the west and east pits is pumped to Hernic Quarry. Water within Hernic Quarry is pumped out to the process water dam for re-use at the processing plant.

3.2.1 HERNIC QUARRY – ENVIRONMENTAL RISKS

It is noted that Hernic Quarry is situated within close proximity of Sterkstroom River and the following environmental risks were identified with using it as a dirty stormwater containment dam:

- Flooding - the quarry falls partially within the flood-lines of the Sterkstroom River and during a flood event the river may overtop into the quarry and mix with dirty water, washing pollutants back out into the river.
- Seepage – the quarry is not a lined storage facility and dirty water within the quarry may leak into groundwater and ultimately flow into the Strekstroom River.
- Spillage – water levels within the quarry may not be maintained at a suitable level to accommodate overflow from the Plant Stormwater Dam and may spill into the Sterkstroom River.

3.2.2 HERNIC QUARRY MITIGATION MEASURES

In order to mitigate the above risks, the following recommendations should be implemented.

Flood Protection Measures – a flood protection bund should be constructed between the river and the quarry, to prevent water within the Sterkstroom from mixing with dirty water within the quarry. From a review of the flood modelling undertaken by Metago in 2008, the modelled flood levels at cross-section XS1602 (approximately 50m upstream of the quarry) and XS1502 (located at the downstream end of the quarry) are presented in Table 3.2 below. Flood levels for the upstream end of the quarry (mid-way between XS1602 and 1502) are interpolated from the modelled levels at the upstream and downstream sections.

TABLE 3.2: MODELLED FLOOD LEVELS IN VICINITY OF HERNIC QUARRY

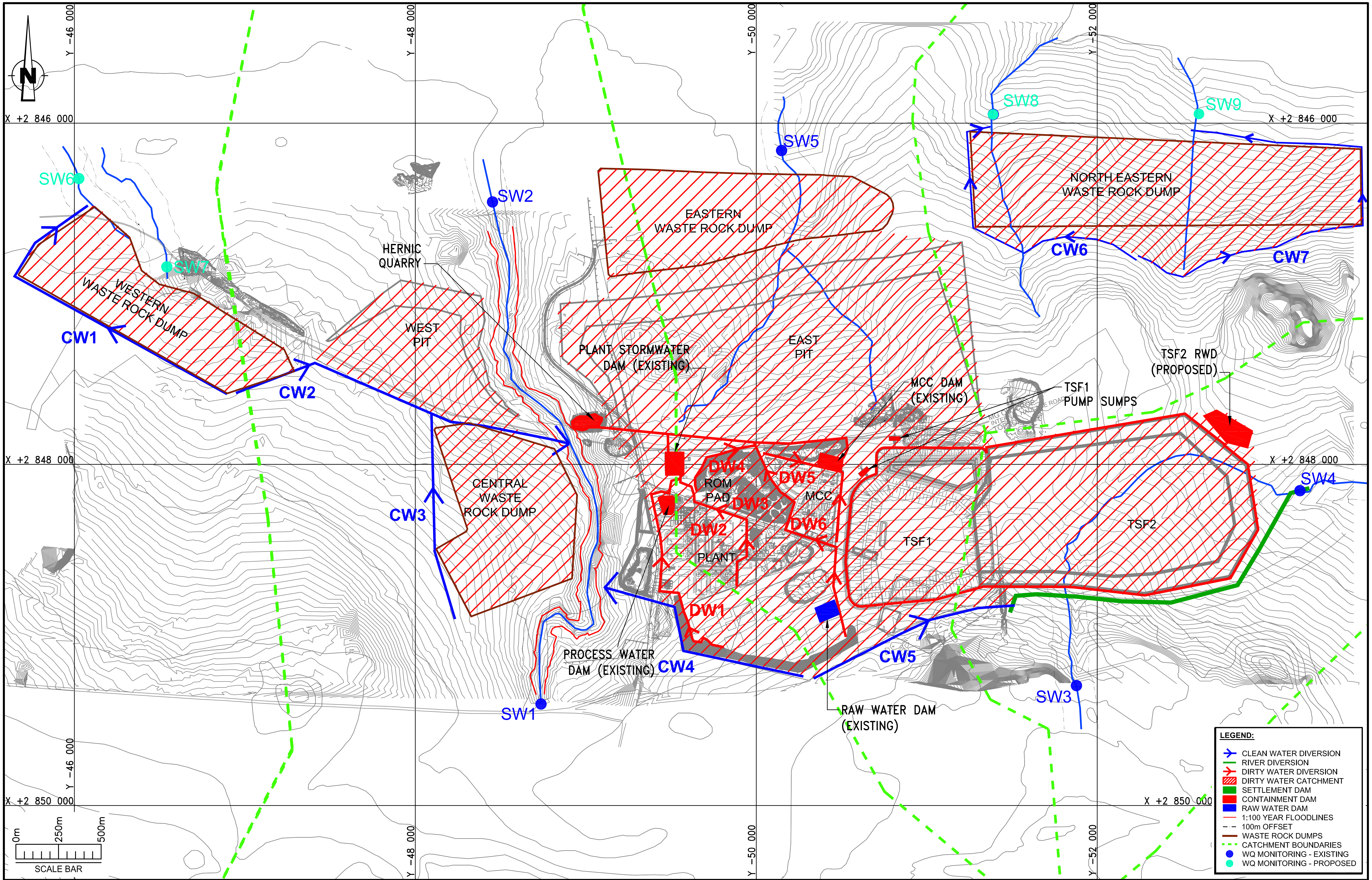
Flood Event	Flood Levels (mAMSL)		
	XS1602	XS1502	Upstream End of Quarry
1:20	1189.10	1188.39	1188.75
1:50	1189.55	1188.76	1189.16
1:100	1189.72	1189.08	1189.40
RMF	1190.95	1190.01	1190.48

It is recommended that the top of the flood bund be situated at or above the 1:50 year flood level and should include a 800mm freeboard to safeguard against modelling inaccuracies and any turbulence in the channel during a flood event. The recommended top of the flood bund should be no lower than 1189.96mAMSL.

It is recommended that the flood bund is designed to ensure that is can withstand the erosion during a flood event, and that it is structurally stable and does not compromise the integrity of the quarry sidewalls.

Water Level Management – in order to prevent seepage from the quarry to the river, water levels within the quarry should be maintained lower than the river, ensuring that any seepage is likely to be from the river into the quarry and not from the quarry into the river (further discussion of this is provided within the Tharisa Groundwater Model Report (SLR, 2014)). In order to achieve this, the following is recommended:

- Monitoring of water levels in the quarry as per recommendations within the Groundwater Model Report;
- A daily timestep water balance model should be developed to assess the capacity of the quarry and inform the inflow and outflow rates, in order to ensure that the water level within the quarry can be maintained below the level of the river whilst ensuring that all stormwater management facilities at the site are operated in compliance with GN 704 and spill no more frequently than once in 50 years.



SLR

Johannesburg Office
METAGO HOUSE
FOURWAYS MANOR OFFICE PARK
CORNER ROOS AND MACBETH STREETS
FOURWAYS
JOHANNESBURG, SOUTH AFRICA
T: +27 (11) 467-0945
F: +27 (11) 467-0978
www.slrconsulting.com

THARISA EMP AMENDMENT

CONCEPTUAL STORMWATER MANAGEMENT PLAN

Date : JUNE 2014	Scale : AS SHOWN
Project No : T014-12	FIGURE 3-1

3.3 DESIGN PRINCIPLES FOR STORMWATER MANAGEMENT PLAN

A conceptual level Stormwater Management Strategy for the mine was developed as part of the approved EIA/EMP and has been updated to cater for changes in mine infrastructure as presented on Figure 3-1, a summary of the key design features is presented below:

- Clean stormwater will be diverted around mine infrastructure and, where possible, routed towards existing watercourse(s) or conveyed into the veld.
- Wherever possible, the footprint of dirty stormwater catchment areas will be minimised by isolating these areas from clean water run off using bunds and/or channels;
- Stormwater from the surface of the TSF facility is pumped to the process water dam for re-use;
- Stormwater from the side slopes of TSF1 will drain towards the eastern pit;
- Stormwater from the side slopes of TSF2 will drain into the return water dam;
- Stormwater from the plant area, will drain via channels to the existing Plant Stormwater Dam, which will overtop via an existing channel taking excess flow to Hernic Quarry;
- Stormwater from the ROM Pad will drain via channels to Hernic Quarry;
- Stormwater from the MCC area will drain to the existing MCC dam, excess flow will be conveyed to Hernic Quarry;
- Stormwater from the plant stormwater dam, MCC dam and Hernic Quarry will be transferred to the process water dam for re-use in the plant;
- Stormwater and groundwater collecting within the pits will be pumped via Hernic Quarry to the process water dam for re-use in the plant;
- The topsoil berms will be allowed to re-vegetated, to reduce erosion and prevent silt from washing into nearby watercourses; and
- Rainfall and runoff from the WRDs will be contained within benches and paddocks and allowed to infiltrate or evaporate (in accordance with Epoch WRD design reports).
- Clean stormwater from the off-site area to the south of the North-Eastern WRD will be managed by one or a combination of options as discussed further in section 3.3.1 below.

3.3.1 CLEAN STORMWATER DIVERSIONS AROUND NORTH EASTERN WRD

The proposed north-eastern WRD is situated across the pathway of two non-perennial watercourses which flow towards the north, and if not mitigated will block these flow pathways and lead to ponding of stormwater (runoff from a 200ha ($2km^2$) catchment) against the side of the WRD and cause flooding of the land to the south of the WRD. Options to manage stormwater in this area should be considered in more detail during the design of this WRD and include:

- Diversion Channels - from a review of the topography in this area, it appears possible that flows can be diverted around the western and eastern ends of the WRD and re-routed back towards the existing channel, as shown on Figure 3-1. A more detailed review of the hydraulic gradients is required and ultimately to maintain a steady gradient the footprint of the WRD may need to be revised (discussed further below). It is likely that runoff from a residual catchment (c. 27ha) will remain below the level of any diversion channels and will not be possible to divert, runoff from this residual catchment will still pond against the WRD.

- Allow Ponding – where no risks associated with ponding of water to the south of the WRD are identified it may be possible to allow runoff to pond and rely on evaporation and infiltration of water after a storm event. It is recommended that the extent of ponding be identified by a water balance model which considers runoff inflows against infiltration and evaporation losses to estimate the maximum likely volume of water, respective water level and lateral extent of ponding in this location.
- Enhanced Infiltration – measures to encourage infiltration of runoff to groundwater could be installed along the southern side of the WRD to prevent ponding in this locality, for example French drains, or a number of boreholes installed into permeable ground.

3.3.2 CONTAINMENT DAM SIZING

Indicative containment dam volumes required to store dirty stormwater generated by the dirty water catchments, are presented in Table 3.2. The containment dams are sized to accommodate runoff from the 1:50 year design rainfall (24 hour) event **and** the highest monthly rainfall (January) falling over the catchment, **less** the corresponding monthly evaporation (January) taking place over the surface area of the proposed containment facility. GN 704 also requires that as a minimum, the 1:50 year design volume and a 0.8m freeboard allowance should always be available.

TABLE 3.3: RECOMMENDED CONTAINMENT DAM VOLUMES

Containment Dam	Area (ha)	1:50yr 24hr Storm		January				Containment Required (m^3)
		Rainfall (mm)	Runoff (m^3)	Rainfall (mm)	Runoff (m^3)	Evap. (mm)	Evap. (m^3)	
Plant Stormwater Dam	47.2	166.8	47 067	123	20 908	195	1 998	65 977
MCC Dam	15.1	166.8	16 776	123	7 452	195	3 900	20 328
Hernic Quarry	58.1	166.8	54 743	123	24 318	195	5 139	73 922
West Pit Sump	60.0	166.8	58 146	123	25 830	195	6 550	77 426
East Pit Sump*	314.8	166.8	291 813	123	129 630	195	32 873	388 570

*****_includes areas external to pit which will drain into the pit (e.g. southern part of WRD and side walls of TSF1)_

Comparison of the existing dam volumes (Table 3-1) with the recommended containment volumes (Table 3-2) illustrates that whilst the MCC dam is of sufficient size, the plant stormwater dam is insufficient to contain the required volumes and the excess 35 977 (i.e. required volume: 65 977 minus existing volume: 30 000), will be allowed to spill into Hernic Quarry which has a capacity of 250 000m^3.

It should be noted that volumes presented in Table 3.2 are indicative only, and as GN 704 requires that dirty water containment facilities are designed, constructed, maintained and operated so that they are not likely to spill into a clean water environment more than once in 50 years, a critical component in sizing the containment pond is the rate at which water is pumped out of dams for re-use at the mine. Therefore, in order to demonstrate compliance with GN 704, it is recommended that, the containment volumes recommended within this report are reviewed using a daily timestep water balance model using rainfall and evaporation data from nearby weather stations in addition to the predicted inflows to, and outflows from each containment facilities.

3.4 STORMWATER DRAINAGE CHANNELS

As detailed in Section 2.8 of this report, the design of the Elandsdriftspruit diversion channel was presented in the 2008 EIA/EMP and remains unchanged.

The location of the recommended cleanwater diversion channels required to minimise cleanwater draining into dirty water areas and prevent risks of flooding to the surface infrastructure are presented in Figure 3-1.

The location of dirty water drainage channels required to convey flows from dirty stormwater catchments to either containment or settlement facilities is present on Figure 3-1.

It is recommended that any clean stormwater channels are designed to prevent cleanwater coming into contact with potential pollution sources (including waste rock and tailings) by lining channels.

In accordance with GN 704, the recommended drainage channels should be designed to convey the flows generated by a 1:50 year rainfall event. Peak flows have been estimated by the Rational Method in accordance with the South African National Road Agency Limited (SANRAL) Drainage Manual. The design flows are presented in Table 3.4. The recommended channel dimensions are presented in Table 3.5 and typical channel design is shown in Figure 3.2.

TABLE 3.4: STORMWATER DESIGN FLOWS (1:50 YEAR)

Catchment	Catchment Area (km^2)	Runoff Coefficient	Time of Concentration (hours)	Rainfall Intensity (mm/hr)	Peak Flow (m^3/s)
CW1	8.90	0.37	1.62	51.7	47.7
CW2	2.89	0.37	1.19	64.1	19.2
CW3	0.48	0.37	1.03	69.5	3.5
CW4	0.49	0.37	0.81	81.8	4.2
CW5	0.87	0.37	0.65	95.4	8.6
CW6	0.90	0.37	0.95	73.5	6.9
CW7	1.13	0.37	1.20	63.8	7.5
Plant Stormwater	0.47	0.66	0.63	91.2	7.9
ROM Pad	0.58	0.56	0.65	89.8	8.2
MCC Area	0.15	0.56	1.05	64.5	1.5

The design of stormwater drainage measures for the TSFs is included as part of the TSF design and is assumed to be fit for purpose and compliant with relevant best practice standards. Stormwater within the pits will naturally move towards the lowest point of the excavation and therefore no formal channels are proposed or sized within either of the pits.

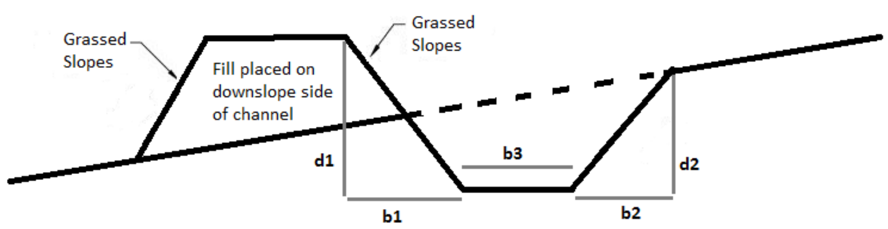


FIGURE 3.2: STORMWATER DIVERSION CHANNEL SIZING

TABLE 3.5: STORMWATER DIVERSION CHANNEL SIZING

Catchment	Design Flow (m^3/s)	b1 (m)	d1 (m)	b2 (m)	d2 (m)	b3 (m)	Slope (m/m)	Manning's n	Velocity (m/s)	Capacity (m^3/s)
CW1	47.7	2.0	2.0	2.0	2.0	4.0	0.008	0.025	4.1	49.3
CW2	19.2	1.8	1.8	1.8	1.8	2.0	0.006	0.025	3.1	21.2
CW3	3.5	1.0	1.0	1.0	1.0	1.0	0.005	0.025	1.8	3.7
CW4	4.2	1.0	1.0	1.0	1.0	1.0	0.010	0.025	2.5	5.1
CW5	8.6	1.2	1.2	1.2	1.2	1.5	0.010	0.025	3.0	9.8
CW6	6.9	1.2	1.2	1.2	1.2	1.5	0.005	0.025	2.1	7.0
CW7	7.5	1.3	1.3	1.3	1.3	1.5	0.005	0.025	2.2	8.1
DW1	5.9	1.0	1.0	1.0	1.0	2.0	0.005	0.025	2.1	6.2
DW2	2.5	0.7	0.7	0.7	0.7	1.5	0.005	0.025	1.6	2.5
DW3	2.5	0.7	0.7	0.7	0.7	1.5	0.005	0.025	1.6	2.5
DW4	6.2	1.0	1.0	1.0	1.0	2.0	0.005	0.025	2.1	6.2
DW5	1.1	0.6	0.6	0.6	0.6	1.0	0.005	0.025	1.4	1.4
DW6	0.5	0.4	0.4	0.4	0.4	1.0	0.005	0.025	1.2	0.6

3.5 IMPACT ON MEAN ANNUAL RUNOFF (MAR)

Stormwater from a total area of 9.3km^2 of the mine including the pits, plant, ROM pad, WRDs and TSF will be diverted away from the watercourses, to containment dams and will be re-used where possible by operations at the mine. The impacts of the mine on the MAR of the surrounding watercourses during the operational phase of the mine has been estimated and is presented in Table 5.1. This table assumes that the MAR is proportional to the catchment area which is not always accurate, as discussed in Section 2.6.

TABLE 3.6: MEAN ANNUAL RUNOFF IMPACT - OPERATIONAL

Catchment	Area (km^2)	MAR (million m^3/year)	Contained Area (km^2)	Reduction in MAR	
				(million m^3/year)	%
Sterkstroom (downstream of Buffelspoort Dam and upstream of the confluence with Brakspruit)	44.58	1.16	2.45	0.064	5.5%
Elandsdriftspruit tributary (upstream of confluence with Elandsdriftspruit)	6.47	0.17	1.54	0.040	23.8%
Brakspruit tributaries (upstream of confluence with Brakspruit)	20.75	0.54	0.61	0.016	2.9%
Western Maretlwane tributaries (upstream of confluence with Maretlwane)	16.88	0.44	4.56	0.118	27.0%
Eastern Maretlwane tributaries (upstream of confluence with Maretlwane)	11.80	0.31	1.41	0.037	11.9%
A21K	865.00	22.46	9.2	0.238	1.1%

Following completion of mining, it is proposed that the pit is partially backfilled, although the pre-mining hydrological regime of the Maretlwane tributary is expected to be permanently impacted as no runoff from the open pits will be expected post closure.

It is recommended that during closure that the residual WRDs at surface are clad with topsoil (excavated from the footprint of the WRD and stockpiled during construction as per Epoch Resources Design reports) and allowed to re-vegetate. Following rehabilitation of the WRDs and once water quality monitoring confirms that runoff from the WRDs is clean and poses no risk to the local water quality, the toe paddocks should be removed along with any build up of salts expected from continued evaporation of any runoff from the WRDs within the toe paddocks, and clean stormwater allowed to runoff to local watercourses thereby reducing the long term impact of the mine on the MAR of these watercourses. Following rehabilitation of the WRDs, the post closure impacts of the mine on the MAR of the surrounding watercourses can be reduced as presented in Table 5.1.

TABLE 3.7: MEAN ANNUAL RUNOFF IMPACT – POST CLOSURE

Catchment	Area (km^2)	MAR (million m^3/year)	Contained Area (km^2)	Reduction in MAR	
				(million m^3/year)	%
Sterkstroom (downstream of Buffelspoort Dam and upstream of the confluence with Brakspruit)	44.58	1.16	1.58	0.041	3.5%
Elandsdriftspruit tributary (upstream of confluence with Elandsdriftspruit)	6.47	0.17	0.00	0.000	0.0%
Brakspruit tributaries (upstream of confluence with Brakspruit)	20.75	0.54	0.00	0.000	0.0%
Western Maretlwane tributaries (upstream of confluence with Maretlwane)	16.88	0.44	3.90	0.101	23.1%
Eastern Maretlwane tributaries (upstream of confluence with Maretlwane)	11.80	0.31	0.27	0.007	2.3%
A21K	865.00	22.46	5.5	0.142	0.6%

4 WATER BALANCE

4.1 BACKGROUND

A site wide water balance model has been prepared for average wet and dry seasons at the mine as presented in Figures 4-1 and 4-2. The water balance model covers the follows aspects of the operation:

- Groundwater seepage into the pits;
- Stormwater runoff from dirty water catchments collected within containment ponds and returned for re-use within the mine;
- Abstraction from the Buffelspoort irrigation canal;
- Abstraction from the well field;
- Process water requirement of the Concentrator Plant;
- Return water from TSF; and
- Treatment and discharge during times of excess water.

4.2 METHODOLOGY

A spreadsheet model was created using information provided on various water inflows, transfers and losses, the input parameters for which are presented in Table 4.1

The inflows were taken as groundwater inflows to the pits, abstraction from the well field and Buffelspoort irrigation canal, and rainfall runoff from the dirty water catchments (identified within the stormwater management section).

Water transfers were taken as the monthly inflows and outflows from each aspect of the mine.

Losses were taken as evaporation from ponds and the surface of the TSF, seepage from the TSF, interstitial lockup, water consumption and any treatment and discharge from the mine.

FIGURE 4.1: WATER BALANCE – AVERAGE DRY SEASON

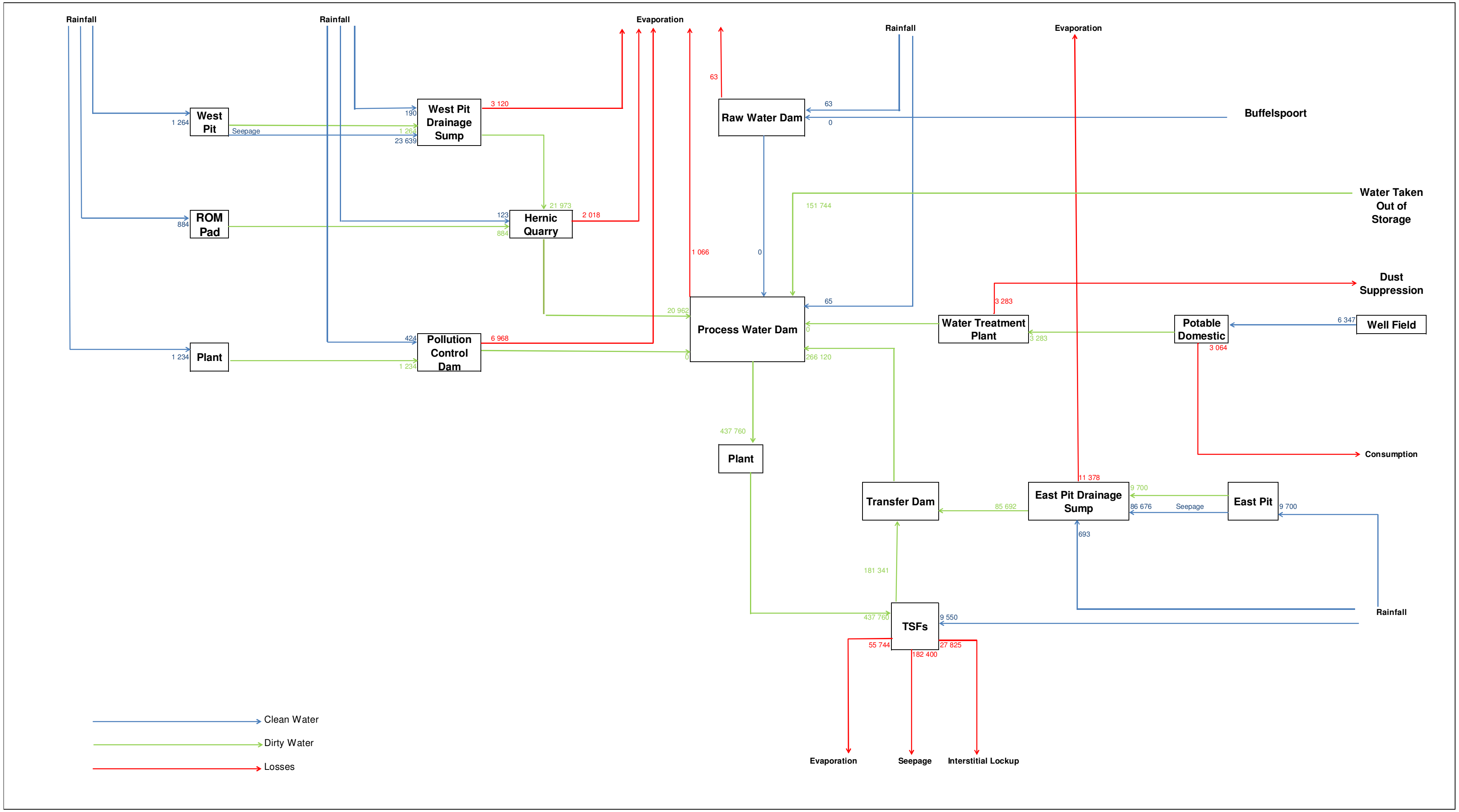


FIGURE 4.2: WATER BALANCE – AVERAGE WET SEASON

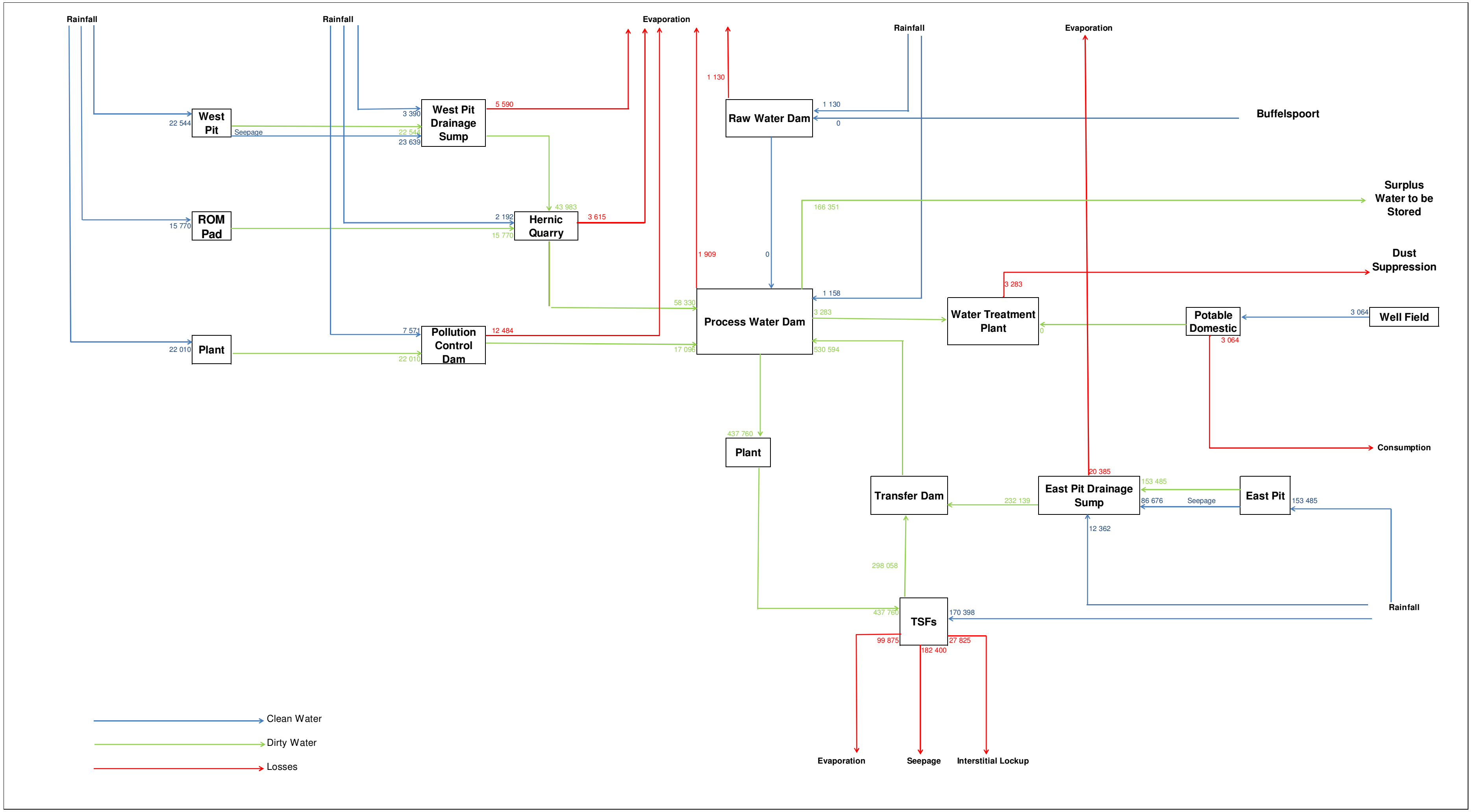


TABLE 4.1: WATER BALANCE INPUT PARAMETERS

Parameter	Value	Source
Tailings Production	437 760 tons/month (600 tons/hr)	Tharisa Minerals – Email 13th August 2012
Water in Tailings	437 760 m^3/month (600 m^3/hr)	Tharisa Minerals – Email 10th September 2012
Interstitial Lockup	27 825 m^3/month (0.18m^3 per 1 tonne of tailings)	Water Balance Analsyis for the Proposed Tharisa Project (Metago, May 2008)
Seepage from TSF	201 m^3/month. Pro-rata'd to total area of TSF1 and TSF2 from 565 m^3/month (TSF1 - 74.4ha).	Seepage Assessment of the TSF for Tharisa Minerals Mine Report 144-001 (Epoch, Sept 2012)
Dust Suppression	10 214 m^3/month (14 m^3/hr)	Tharisa Minerals – Email 10th September 2012
Seepage into West Pit	56 149 m^3/month	Hydrogeology Assessment (SLR Consulting Ltd, October 2012)
Seepage into East Pit	62 411 m^3/month	
Well Field	10 214 m^3/month (14 m^3/hr)	Tharisa Minerals – Email 10th September 2012

4.3 ASSUMPTIONS

The water balance model assumes the following:

- All infrastructure is fully operational and no consideration is given to changes in the operational water management regime during construction and expansion phases e.g. increased inflows to the pits as they deepen or expand in area, or increased catchment area of the TSF as it is expanded;
- There will be no stormwater inflow from the WRDs or topsoil stockpiles;
- Runoff coefficients for each surface were fixed and not influenced by antecedent climatic conditions;
- The seasonal water balance results have been presented as the average values for the three driest and wettest months;
- Any shortfall of water during the dry months is made up by abstraction from the Buffelspoort irrigation canal and/or well field; and
- Any surplus water during the wet months is stored for re-use during the dry season.

4.4 RESULTS

The average monthly flow rates for dry and wet seasons are presented in Figures 4.1 and 4.2.

The results show that during an average wet season, no abstraction from Buffelspoort irrigation canal is required, abstraction from the well field is 3 064 m^3/month and 166 351 m^3/month of surplus water can be stored for re-use during the dry season. During an average dry season, an average of 151 744 m^3/month will be released from storage for re-use within the processing plant and 6 347 m^3/month will be abstracted from the well field, no abstraction from Buffelspoort irrigation canal will be required. It should be noted that surplus water is stored over 5 months of the year and released from storage over 7 months of the year therefore the average wet and dry season (average of the wettest / driest 3 month periods) inflows and outflows from storage are not equal.

It is recommended that a storage facility with capacity of 800 000m^3 should be sufficient to store surplus water from the wet season for re-use during the dry season. Although a more detailed water balance should be undertaken as part of the detailed design of such a facility.

The total water requirement of the mine is 4 358 451 m^3 per year, none of which will be abstracted from Buffelspoort irrigation canal, 86 821 m^3 of which is abstracted from the well field and the remaining amount is sourced from groundwater seepage into the pits (1 323 786 m^3) and runoff from dirty catchment areas (2 539 653 m^3).

It should be noted that the total water requirement of the site should not be compared with the estimated MAR of the surrounding watercourses, for example a consumption of 4 358 451 m^3 per year does not mean an equivalent reduction in the MAR of the catchment, as that would assume that all consumed water would otherwise be discharged directly into the river, without any uptake by vegetation or losses to evaporation or seepage to ground water.

4.5 ABSTRACTION, TRANSFERS AND DISCHARGE MONITORING

In order to review the validity of the water balance and ensure that the containment facilities are suitably sized, it is recommended that monitoring of the flows in the following locations is undertaken:

- Pumping from east and west pits;
- Abstraction from Bufflespoort irrigation canal;
- Abstraction from well field;
- Transfers from MCC Dam, Plant Stormwater Dam and Hernic Quarry to Process Water Dam;
- Return water from TSF; and
- Discharge from the mine.

It is recommended that the water balance be updated on a 2 yearly basis, using the flow monitoring data detailed above.

5 MONITORING AND CONTINGENCY PLANS

5.1 SURFACE WATER QUALITY MONITORING

It is proposed that the current quarterly surface water quality monitoring program is continued to identify any impact that the mining operations may have on surface water quality. The locations to be sampled (subject to flow) are presented on Figure 3.1 and in Table 6.1. All samples will be analysed for the following suite:

- pH
- Conductivity in mS/m @ 25℃
- Total dissolved solids (TDS) @ 180°
- Dissolved oxygen
- Acidity as h
- Alkalinity as CaCO3
- Carbonate as CO3
- Bicarbonate as HCO3
- Nitrate as N
- Chloride as Cl
- Sulphate as SO4
- Fluoride as F
- Sodium as Na
- Potassium as K
- Calcium as Ca
- Magnesium as Mg
- Boron
- Aluminium
- Barium
- Iron
- Manganese
- Chrome(vi)
- Lead
- Zinc
- Cadmium
- Copper
- Selenium
- Arsenic
- Mercury

TABLE 5.1: SURFACE WATER MONITORING LOCATIONS

Reference	Location
SW1	Sterkstroom River upstream of the Mine
SW2	Sterkstroom River downstream of the Mine
SW3	Elandsdriftspruit tributary
SW4	Elandsdriftspruit tributary
SW5	Western Maretlwane tributary downstream of the Mine
SW6	Brakspruit Tributary downstream of the Western WRD
SW7	Brakspruit Tributary downstream of the Western WRD
SW8	Western Maretlwane tributary downstream of the North East WRD
SW9	Western Maretlwane tributary downstream of the North East WRD

In addition to the above, Tharisa will be responsible for biomonitoring of the riverine habitat during and after the mining phase.

5.2 CONTINGENCY PLANS

In order to ensure that the mine's operation continues to minimise any impact upon the baseline hydrology of the area, the following contingency plans are recommended:

- Where monitoring of any surface water downstream of the mine indicates that the operation may be impacting upon the baseline water quality of the local watercourse, then investigative works should be undertaken to investigate how operations can be improved;
- Where water levels within the containment dams do not allow for provision of a 1:50 year 24 hour duration storm event, then the operation of these facilities should be reviewed against the daily timestep water balance (which is recommended to form part of the detailed design of these facilities), and the design and operation should be revised where necessary.

6 SUMMARY AND CONCLUSIONS

This hydrological assessment presents a review of the baseline hydrology of the site and surroundings which includes average monthly rainfall, average monthly evaporation, storm rainfall intensities, topography, soil types, land cover, description of local watercourses, flood-lines, flow regimes and water quality.

The results of pre-mining and post mining water quality within the Sterkstroom River were presented and discussed. It was concluded that there were no identifiable trends of increasing concentrations of any parameters in samples taken downstream of the mine since operations began.

A conceptual stormwater management plan was prepared for the mine, which aims to mitigate the potential impacts of the mining operation on the baseline hydrology in terms of potential reductions in water quality, reduction in baseline flows and increases in flood risk. The impact of the mine on the mean annual runoff for the local watercourses and quaternary catchments was assessed for both the operational and post closure phases.

A water balance was prepared for the site for both average dry and wet seasons, which aims to inform the mining operator's management of water and minimise abstraction of water from off-site sources.

Paul Klimczak (CEnv)
(Project Manager, Author)

Steve Van Niekerk
(Project Reviewer)

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APPENDIX A: WATER QUALITY RESULTS

Analysis (mg/l unless specified)	Target Water Quality Range (TWQR)	South African National Standard for drinking water (SANS 241:2011)	South African Water Quality Guidelines for Livestock	South African Water Quality Guidelines for Irrigation	SW1	SW2	SW1	SW2	SW3	SW1	SW2	SW1	SW2	SW1	SW2	SW4	SW1	SW2	SW1	SW2	SW1	SW2	SW1	SW2
					Nov-07 (Baseline)		Jun-08 (Baseline)			Sep-08		Dec-08		Mar-09			Jun-09		Oct-09		Jan-10		Apr-10	
pH		5.0- 9.7 (O)		6.5 – 8.4	7.1	8	8.24	8.34	8.48	7.92	8.8	7.78	7.73	8	8	8	7.9	8.6	7.2	7.9	7.3	7.8	7.6	7.8
Electrical conductivity in mS/m		<170 (A)		≤ 40	19.9	40.1	7.46	18.8	23.10	22.34	28	5.34	7.92	7	8	12	7	11	18.4	33.1	6	8	6	8
Total dissolved solids		<1 200 (A)	0-1000	≤ 40	140	258	66	106	164	79	179	44	62	41	60	97	58	88	126	200	41	42	48	44
Dissolved oxygen as O_2							6.9	6.5	6.60	6.4	7.6	8	8.1	3.5	4.2	3.4	6.6	6.4	5	5.1	5.2	4.8	5.7	5.9
Acidity as $CaCO_3$							8	8	<5	12	<5	40	8				<5	<5	8	8	32	8	<5	8
Alkalinity as $CaCO_3$					72	156	28	40	84.00	40	80			20	28	48	24	36	72	140	24	28	28	28
Carbonate as CO_3										49	68	39	54	24	34	<5	29	44			29	34	34	34
Ammonia	<0.007	≤ 1.5					0.4	0.4	3.6	1	1								0.2	0.6	0.2	0.2	<0.2	<0.2
Nitrate as N		<11	0-100	≤5.0	0.5	0.7	0.4	0.4	<0.2	1.3	0.9	0.4	0.5	0.4	0.2	0.5	0.2	0.3	0.3	<0.2	0.4	0.5	0.4	0.5
Chloride as Cl		<300	0-1500	<100	13	19	<5	<5	12	10	12	5	5	10	5	6	5	6	11	15	<5	<5	<5	<5
Sulphate as SO4		<500	0-1000		6	29	5	7	16	8	31	5	9	5	19	27	5	6	7	28	<5	<5	<5	<5
Fluoride as F	<0.75	<1.5	0-2	<2.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Hexavalent chrome	<0.007		0 - 1	0 – 0.1			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Faceal coliform per100ml																								
Ecoli per100ml		Detected																						
Silver										1	1						<0.025	<0.025			<0.025	<0.025	<0.025	<0.025
Aluminium	<0.005	<0.3 (O)	0 - 5	0 - 5			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.662	2.91	<0.01	<0.01	<0.01	<0.01	0.183	0.17	<0.1	0.119
Arsenic	<0.01	<0.01	0 - 1	0 – 0.1			<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Barium							0.026	<0.025	<0.025	0.44	0.04	<0.025	<0.025	<0.025	<0.025	0.03	<0.025	<0.025	0.032	<0.025	<0.025	<0.025	<0.025	<0.025
Boron			0 - 5	0 – 0.5			0.026	<0.025		0.44	0.04	<0.025	<0.025	<0.025	<0.025		<0.025	<0.025	0.032	<0.025	<0.025	<0.025	<0.025	<0.025
Beryllium										<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025			<0.025	<0.025	<0.025	<0.025
Bismuth										<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025			<0.025	<0.025	<0.025	<0.025
Calcium			0-1000		9.7	18.1	4	6	20	8	13	6	8	5	6	11	5	7	14	20	4	5	4	5
Cadmium	<0.00015	<0.003	0 – 0.01	0 – 0.01	<0.01	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cobalt		<0.500			<0.01	<0.01				<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025			<0.025	<0.025	<0.025	<0.025
Chromium	<0.012	<0.050			<0.025	<0.025				<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	69.00	<0.025	<0.025			<0.025	<0.025	<0.025	<0.025
Copper	<0.0003	<2	0 – 0.50*	0 – 0.2			<0.025	<0.025	<0.005	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Iron		<2	0 - 10	0 - 5	0.02	<0.01	0.44	0.377	0.12	0.93	<0.38	0.08	0.71	0.805	11.3	2.62	0.558	0.517	2.17	0.06	0.706	0.788	0.548	0.515
Potassium				0 – 100	0.675	0.48	1.1	1.1	2.4	1.1	<1	1.3	1.4	1.6	1.6	3.5	1.3	1.9	1.1	1.1	1.3	1.6	1.4	1.4
Lithium											<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025			<0.025	<0.025	<0.025	<0.025
Magnesium			0 - 500		12.03	32.71	3	6	10	7	17	5	8	4	5	14	4	7	11	27	3	5	4	5
Manganese	<0.18	<0.500	0 - 10	0 – 0.02	<0.01	<0.01	0.04	0.025	0.09	0.13	0.05	0.06	0.07	0.079	0.181	0.65	0.051	0.31	0.361	<0.025	0.06	0.062	0.06	0.054
Molybdenum										<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025			<0.025	<0.025	<0.025	<0.025
Sodium		<200 (A)	0-2000	0 – 70	6.61	12.74	3	4	11	4	7	2	3	2	2	4	<2	3	6	10	2	3	2	3
Nickel		<0.070								<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.06	<0.025	<0.025			<0.025	<0.025	<0.025	<0.025
Phophorus										1	1	<0.025	<0.025	0.035	0.04	0.05	<0.025	0.045			<0.025	<0.025	<0.025	<0.025
Lead	<0.0002	<0.010	0 – 0.1**	0 – 0.2			<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Sulphur										2.98	7.36						1.4	2.1			1.27	1.56	1.25	1.65
Antimony		<0.020								<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.01	<0.01	0.03	0.016
Selenium	<0.002	<0.010	0 - 50	0 – 0.02			<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Silicon										8.15	107	6.4	8.3	4.6	6.5	20	6.3	7.8			4.7	5.8	4.2	4.9
Tin										<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025			<0.025	<0.025	<0.025	<0.025
Strontium										0.11	0.14	0.025	0.04	<0.025	0.029	0.05	<0.025	0.03			<0.025	<0.025	<0.025	0.026
Titanium										<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025			<0.025	<0.025	<0.025	<0.025
Vanadium		<0.200								0.07	0.07	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025			<0.025	<0.025	<0.025	<0.025
Tungsten										<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025			<0.025	<0.025	<0.025	<0.025
Zinc	<0.002	<5 (A)	0 – 20	0 - 1	<0.01	<0.01	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Zirconium										<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025			<0.025	<0.025	<0.025	<0.025
Mercury	<0.00004	≤ 6	0 – 0.001				0.001	0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

< – Values highlighted in red indicates the parameter is below the detection level.

Blank cells indicates the parameter w as not analyzed

Analysis (mg/l unless specified)	Target Water Quality Range	South African National Standard for drinking	South African Water Quality	South African Water Quality	SW1	SW2	SW1	SW2	SW1	SW2	SW1	SW2	SW1	SW2	SW1	SW2	SW1	SW2	SW1	SW2	SW1	SW2	SW1	SW2
					Jul-10		Oct-10		Jan-11		Apr-11		Jul-11		Oct-11		Jan-12		Apr-12		Aug-12		Feb-13	
pH		5.0- 9.7 (O)		6.5 – 8.4	8.1	8.4	7.4	8.5	7.5	7.7	7.6	7.8	8	8.3	7.5	8.3	8.4	8.5	7.5	8	7.7	7.8	7.6	7.9
Electrical conductivity in mS/m		<170 (A)		≤ 40	5	9	18	38	5.9	6.9	5.7	7.5	7	10	14	24	8	11	9	15	12.1	41.1	7.1	8.5
Total disolved solids		<1 200 (A)	0-1000	≤ 40	28	48	88	200	25	37	33	54	42	64	102	180	42	50	41	72	66	242		
Dissolved oxygen as O_2					7.1	7.3	4.8	2.7	4.5	3.3	5.6	5.4	5.5	5.2	8.22	12.89	6.4	6.5	5.6	5.7	5.6	6.7	4.3	4.2
Acidity as $CaCO_3$					<5	<5	16	12	20	16	40	12	<5	<5	8	<5	12	12	12	16	28	<5		
Alkalinity as $CaCO_3$					12	28	64	148	12	20	28	28	20	32	48	88	32	36	32	56	44	132		
Carbonate as CO_3					15	34	78	180	15	24	34	34	24	39	59	107	39	44	39	68				
Ammonia	<0.007	≤ 1.5			<0.2	<0.2	<0.2	<0.2	0.5	0.4	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate as N		<11	0-100	≤5.0	0.4	0.5	0.7	<0.2	0.4	0.3	<0.2	0.2	0.3	0.5	1.5	1.3	0.5	0.6	0.6	0.7	1	7.5	0.2	0.2
Chloride as Cl		<300	0-1500	<100	<5	6	12	17	6	5	5	5	5	6	8	10	6	6	5	6	8	31	<5	<5
Sulphate as SO4		<500	0-1000		5	7	6	30	<5	5	<5	<5	5	8	<5	13	<5	<5	<5	7	6	30	<5	<5
Fluoride as F	<0.75	<1.5	0-2	<2.0	0.3	0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Hexavalent chrome	<0.007		0 - 1	0 – 0.1	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		
Faceal coliform per100ml																	230	220	160	440				
Ecoli per100ml		Detected															220	190	110	340				
Silver					<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Aluminium	<0.005	<0.3 (O)	0 - 5	0 - 5	<0.1	<0.1	<0.1	0.168	0.162	0.577	<0.1	0.125	<0.1	<0.1	<0.1	0.285	<0.1	<0.1	0.107	0.149	0.135	0.135	<0.1	0.151
Arsenic	<0.01	<0.01	0 - 1	0 – 0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Barium					<0.025	<0.025	<0.025	<0.025	0.073	0.047	<0.025	<0.025	<0.025	<0.025	0.025	0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Boron			0 - 5	0 – 0.5	<0.025	<0.025	<0.025	<0.025	0.073	0.047	<0.025	<0.025	<0.025	<0.025	0.025	0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.028	0.028
Beryllium					<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Bismuth					<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Calcium			0-1000		4	5	12	21	3	5	3	4	4	7	9	16	5	7	5	8	9	30	4	5
Cadmium	<0.00015	<0.003	0 – 0.01	0 – 0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cobalt		<0.500			<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Chromium	<0.012	<0.050			<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Copper	<0.0003	<2	0 – 0.50*	0 – 0.2	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Iron		<2	0 - 10	0 - 5	0.439	0.363	2.18	0.626	0.522	1.09	0.547	0.698	0.608	0.617	0.876	0.697	0.682	0.639	0.684	0.55	0.926	0.353	0.544	0.607
Potassium				0 – 100	1.2	1.2	1	1	1.2	2.2	1.2	1.3	1.4	1.3	1.8	1.8	1.3	1.4	1.2	1.6	1.2	<1	1.0	1.0
Lithium					<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Magnesium			0 - 500		3	6	10	30	3	3	3	4	4	7	8	18	4	7	5	10	7	35	4	5
Manganese	<0.18	<0.500	0 - 10	0 – 0.02	0.046	0.03	0.371	0.105	0.043	0.089	0.065	0.064	0.051	0.057	0.252	0.105	0.071	0.052	0.097	0.05	0.104	0.035	0.051	0.045
Molybdenum					<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.092	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Sodium		<200 (A)	0-2000	0 – 70	2	3	5	12	2	3	2	2	3	3	4	7	3	3	3	4	4	9	2	3
Nickel		<0.070			<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Phophorus					<0.025	0.028	0.025	0.211	<0.025	<0.025	<0.025	0.026	0.028	<0.025	0.052	0.04	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Lead	<0.0002	<0.010	0 – 0.1**	0 – 0.2	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Sulphur					1.64	2.35	1.69	9.35	1.18	0.352	0.838	1.27	1.21	2.1							1.56	11	0.423	1.00
Antimony		<0.020			<0.01	<0.01	<0.01	<0.01	0.015	0.011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.015	0.027
Selenium	<0.002	<0.010	0 - 50	0 – 0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Silicon					5.3	6.6	12.2	15.5	4.1	5.7	5.5	6.1	5.6	6.6	5.23	7.69	5.3	6.9	4	4.6	6.1	11.4	2.0	2.4
Tin					<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.031	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.026
Strontium					<0.025	0.025	0.062	0.094	<0.025	<0.025	<0.025	<0.025	<0.025	0.028	0.048	0.075	0.025	0.034	0.032	0.041	0.047	0.125	<0.025	0.025
Titanium					<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Vanadium		<0.200			<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Tungsten					<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Zinc	<0.002	<5 (A)	0 – 20	0 - 1	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Zirconium					<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Mercury	<0.00004	≤ 6	0 – 0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		

< – Values highlighted in red indicates the parameter is below the detection level.

Blank cells indicates the parameter w as not analyzed

Analysis (mg/l unless specified)	Target Water Quality Range (TWQR)	South African National Standard for drinking water (SANS 241:2011)	South African Water Quality Guidelines for	South African Water Quality Guidelines for	SW1	TM SW03	TM SW07	SW1	SW2	TM SW03	TM SW07	SW1	SW2	TM SW03	TM SW07	SW1	SW2	TM SW03	TM SW07	SW1	SW2	TM SW03	TM SW07
					22-Jan-14			26-Feb-14				04-Mar-14				05-Mar-14				06-Mar-14			
pH		5.0- 9.7 (O)		6.5 – 8.4	7.75	8.17	8.37	7.59	7.7	7.71	8.42	7.19	7.31	7.37	8.04	7.55	7.82	7.68	8.22	7.43	7.55	7.46	7.86
Electrical conductivity in mS/m		<170 (A)		≤ 40	13.5	22.4	105	7.52	8.3	8.03	103	9.27	9.31	9.23	97.6	7.56	14	13.3	87.1	6.73	9.3	8.94	74.8
Total disolved solids		<1 200 (A)	0-1000	≤ 40								46	49	51	610	41	71	62	510				
Dissolved oxygen as O_2					1.84	3	2	2.3	3.54	3.98	2.9	1.6	1.64	1.54	1.66	1.14	1.1	1.06	1.3	1.16	1.15	1.04	1.1
Acidity as $CaCO_3$																							
Alkalinity as $CaCO_3$												20.6	24	26.3	173	19.7	39.8	33.7	154				
Carbonate as CO_3																							
Ammonia	<0.007	≤ 1.5			0.101	0.078	0.842	0.065	0.063	0.064	0.436	0.072	0.027	0.033	0.564	0.037	0.062	0.079	0.434	0.102	0.077	0.099	0.264
Nitrate as N		<11	0-100	≤5.0	0.076	0.075	50.3	0.269	0.287	0.264	46.5	0.627	0.617	0.61	44.8	0.369	3.12	1.4	37.1	0.364	1.05	1.18	29.8
Chloride as Cl		<300	0-1500	<100	7.63	9.98	35.2	6.04	4.58	6.13	36.2	7.9	7.38	7.46	36.6	6.29	7.5	6.99	25.7	5.82	6.47	6.47	24
Sulphate as SO4		<500	0-1000		4.73	10.3	108	7.7	4.16	7.2	107	7.52	8.18	7.81	95.6	7.42	4.02	9.22	81.4	2.78	5.64	5.18	79.5
Fluoride as F	<0.75	<1.5	0-2	<2.0	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	0.189	0.191	0.274	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183
Hexavalent chrome	<0.007		0 - 1	0 – 0.1																			
Faceal coliform per100ml																							
E.coli per100ml		Detected																					
Silver																							
Aluminium	<0.005	<0.3 (O)	0 - 5	0 - 5	0.007	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.087	0.025	<0.006	0.095	0.008	0.125	<0.006	<0.006	<0.006	<0.006	<0.006
Arsenic	<0.01	<0.01	0 - 1	0 – 0.1																			
Barium																							
Boron			0 - 5	0 – 0.5																			
Beryllium																							
Bismuth																							
Calcium			0-1000		10.3	16.6	57.6	4.46	5.06	5	50.8	4.59	5.1	5.88	51.7	4.58	7.38	5.71	42	3.28	5.06	4.73	39.1
Cadmium	<0.00015	<0.003	0 – 0.01	0 – 0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt		<0.500																					
Chromium	<0.012	<0.050			<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper	<0.0003	<2	0 – 0.50*	0 – 0.2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron		<2	0 - 10	0 - 5	0.196	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.03	0.041	<0.006	<0.006	<0.006	<0.006	0.02	<0.006				
Potassium				0 – 100	1.29	1.27	7.61	1.72	1.64	1.64	7.86	2.3	2.33	2.37	7.18	1.87	2.33	1.89	5.6	0.753	0.976	0.949	5.03
Lithium																							
Magnesium			0 - 500		8.97	18.8	94.1	4.14	4.9	4.77	76.9	4.48	5.19	5.13	76	3.88	7.79	7.01	62.6	3.22	5.02	4.97	57.7
Manganese	<0.18	<0.500	0 - 10	0 – 0.02	0.036	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum																							
Sodium		<200 (A)	0-2000	0 – 70	4.78	7.72	38.3	2.8	2.93	2.94	50.5	3.73	3.03	3.22	38.2	3.11	4.1	3.83	33.7	2.6	3.18	3.24	34.3
Nickel		<0.070																					
Phophorus																							
Lead	<0.0002	<0.010	0 – 0.1**	0 – 0.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphur																							
Antimony		<0.020																					
Selenium	<0.002	<0.010	0 - 50	0 – 0.02																			
Silicon																							
Tin																							
Strontium																							
Titanium																							
Vanadium		<0.200																					
Tungsten																							
Zinc	<0.002	<5 (A)	0 – 20	0 - 1	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Zirconium																							
Mercury	<0.00004	≤ 6	0 – 0.001																				
Free Chlorine (Cl_2)					0.1	<0.1	0.1	0.1	0.1	0.1	0.1	0.1	<0.1	<0.1	0.1	0.1	0.1	0.2	0.2	<0.1	<0.1	<0.1	0.3
Nitrite (NO_2) as N					0.009	0.034	1.22	0.094	0.094	0.094	1.23	0.076	0.078	0.078	1.25	0.092	0.159	0.173	1.29	0.098	0.106	0.111	1.19
Orthophosphate (PO_4) as P																							

< – Values highlighted in red indicates the parameter is below the detection level.

Blank cells indicates the parameter w as not analyzed

Analysis (mg/l unless specified)	Target Water Quality Range	South African National Standard for drinking	South African Water Quality	South African Water Quality	SW1	SW2	TM SW03	TM SW07	SW1	SW2	TM SW03	TM SW07	SW1	SW2	TM SW03	TM SW07	SW1	SW2	TM SW03	TM SW07	SW1	SW2	TM SW03	TM SW07
					07-Mar-14				10-Mar-14				11-Mar-14				12-Mar-14				13-Mar-14			
pH		5.0- 9.7 (O)		6.5 – 8.4	7.65	7.69	7.69	8.24	7.7	7.85	7.83	8.28	7.63	7.7	7.66	6.9	7.43	7.55	7.57	8.08	7.65	7.71	7.65	8.01
Electrical conductivity in mS/m		<170 (A)		≤ 40	6.77	10.2	9.91	68.9	6.88	14.8	14	69.6	6.79	10.4	9.7	72.7	15	9.43	9.16	70	7.39	11	10.5	68.6
Total disolved solids		<1 200 (A)	0-1000	≤ 40									33	49	45	420	68	43	44	406	39	53	53	402
Dissolved oxygen as O_2					2.24	2.2	2	2.16	2.07	1.45	2.1	2.15	1.63	1.6	1.2	1.32	1.32	1.23	1.4	1.45	1.24	1.6	1.4	1.47
Acidity as $CaCO_3$																								
Alkalinity as $CaCO_3$													17.1	22.1	18.7	122	27.7	17.5	16.6	132	23.6	22.3	23.7	130
Carbonate as CO_3																								
Ammonia	<0.007	≤ 1.5			0.076	0.101	0.115	0.232	0.062	0.111	0.12	0.29	0.038	0.035	0.039	0.311	0.052	0.037	0.044	0.196	0.036	0.056	0.082	0.296
Nitrate as N		<11	0-100	≤5.0	0.216	1.53	1.65	29.1	0.24	4.11	3.96	34	0.356	1.56	1.5	30.1	0.851	1.48	1.48	26.4	0.235	1.84	1.91	26.4
Chloride as Cl		<300	0-1500	<100	6.56	6.89	6.9	22.4	6.68	8.07	7.75	18.2	5.05	5.07	5.91	18.7	15.2	5.17	5.5	19.1	5.22	5.9	5.92	18.6
Sulphate as SO4		<500	0-1000		4.67	6.5	6.34	69.6	3.71	10.9	10	68.5	4.92	7.12	6.46	72.4	8.42	6.45	7.13	70.3	5	7.92	7.34	68.9
Fluoride as F	<0.75	<1.5	0-2	<2.0	<0.183	<0.183	<0.183	0.232	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183
Hexavalent chrome	<0.007		0 - 1	0 – 0.1																				
Faceal coliform per100ml																								
E.coli per100ml		Detected																						
Silver																								
Aluminium	<0.005	<0.3 (O)	0 - 5	0 - 5	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.018	0.03	0.014	<0.006	<0.006	0.026	<0.006	<0.006
Arsenic	<0.01	<0.01	0 - 1	0 – 0.1																				
Barium																								
Boron			0 - 5	0 – 0.5																				
Beryllium																								
Bismuth																								
Calcium			0-1000		3.92	5.94	5.65	36	3.93	8.33	7.87	38	3.63	5.24	4.49	34.1	7.03	4.63	4.58	36	4.7	5.83	5.49	35.1
Cadmium	<0.00015	<0.003	0 – 0.01	0 – 0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt		<0.500																						
Chromium	<0.012	<0.050			<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper	<0.0003	<2	0 – 0.50*	0 – 0.2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron		<2	0 - 10	0 - 5									<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Potassium				0 – 100	1.61	1.68	1.65	5.7	1.55	1.92	1.87	5.81	1.36	1.45	1.29	5.73	2.09	1.39	1.4	5.3	1.23	1.39	1.42	4.98
Lithium																								
Magnesium			0 - 500		3.63	6.11	5.88	51.3	3.62	9.66	9.26	52	3.45	5.92	5.1	50.2	7.19	4.87	4.96	48.3	4.48	6.18	6.17	48.7
Manganese	<0.18	<0.500	0 - 10	0 – 0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum																								
Sodium		<200 (A)	0-2000	0 – 70	2.56	3.26	3.17	32	2.55	4.82	4.64	28.2	2.51	3.55	3.18	30.8	7.47	3.03	3.12	30.1	2.45	3.59	3.58	29.1
Nickel		<0.070																						
Phophorus																								
Lead	<0.0002	<0.010	0 – 0.1**	0 – 0.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphur																								
Antimony		<0.020																						
Selenium	<0.002	<0.010	0 - 50	0 – 0.02																				
Silicon																								
Tin																								
Strontium																								
Titanium																								
Vanadium		<0.200																						
Tungsten																								
Zinc	<0.002	<5 (A)	0 – 20	0 - 1	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Zirconium																								
Mercury	<0.00004	≤ 6	0 – 0.001																					
Free Chlorine (Cl_2)					0.1	0.1	0.1	0.2	0.1	<0.1	<0.1	<0.1	0.1	0.1	0.2	0.1	0.2	<0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nitrite (NO_2) as N					0.052	0.083	0.085	1.15	0.052	0.14	0.136	1.01	0.083	0.103	0.1	1.06	0.087	0.11	0.11	1.07	0.082	0.12	0.122	0.975
Orthphosphate (PO_4) as P																	0.088	-0.025	-0.025	-0.025	-0.025	-0.025	-0.025	-0.025

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Analysis (mg/l unless specified)	Target Water Quality Range	South African National Standard for drinking	South African Water Quality	South African Water Quality	SW1	SW2	TM SW03	TM SW07	SW1	SW2	TM SW03	TM SW07	SW1	SW2	TM SW03	TM SW07	SW1	SW2	TM SW03	TM SW07	SW1	SW2
					18-Mar-14				22-Apr-14				22-May-14				24-Jun-14				24-Jul-14	
pH		5.0- 9.7 (O)		6.5 – 8.4	7.48	7.77	7.65	6.85	7.77	7.87	7.87	8.56	7.5	7.78	7.7	8.29	7.55	7.78	7.72	8.35	7.79	8
Electrical conductivity in mS/m		<170 (A)		≤ 40	7.09	12.8	12.1	74.5	6.93	11.1	10.8	102	6.87	9.26	8.96	99.8	8.07	11.1	10.5	101	6.58	9.71
Total disolved solids		<1 200 (A)	0-1000	≤ 40	36	62	60	442	29	51	43	645	35	51	46	682	38	52	43	630	37	52
Dissolved oxygen as O_2					2.9	2.01	1.77	2.89	1.22	1.13	1.23	1.48	1.37	1.04	1.33	1.45	0.99	0.98	1	1.28	1.39	1.49
Acidity as $CaCO_3$																						
Alkalinity as $CaCO_3$					17.1	28.5	26.1	144	26.8	38.3	28.1	185	21.6	36.4	28.4	235	25.4	36.1	25.1	223	18.3	27.9
Carbonate as CO_3																						
Ammonia	<0.007	≤ 1.5			0.051	0.055	0.07	0.207	0.051	0.034	0.034	0.143	0.073	0.051	0.05	0.079	0.033	0.018	0.02	0.18	0.176	0.266
Nitrate as N		<11	0-100	≤5.0	0.35	2.05	2.09	30.8	0.368	1.39	1.42	52.2	0.482	0.736	0.753	47.3	0.627	0.881	1	42.3	0.498	0.774
Chloride as Cl		<300	0-1500	<100	5.07	5.9	5.96	19.3	<1.408	<1.408	<1.408	29	4.93	5.02	6.02	31.7	4.71	5.88	5.53	31.3	5.66	6.72
Sulphate as SO4		<500	0-1000		6.22	10	9.74	72.3	0.304	3.88	5.33	109	2.96	4.25	3.9	112	1.95	3.13	3.31	108	5.3	6.77
Fluoride as F	<0.75	<1.5	0-2	<2.0	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	<0.183	0.193	<0.183	<0.183	0.184	<0.183	0.189	<0.183	<0.183	<0.183	<0.183
Hexavalent chrome	<0.007		0 - 1	0 – 0.1																		
Faceal coliform per100ml																						
E.coli per100ml		Detected																				
Silver																						
Aluminium	<0.005	<0.3 (O)	0 - 5	0 - 5	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Arsenic	<0.01	<0.01	0 - 1	0 – 0.1	<0.023	<0.023	<0.023	<0.023														
Barium																						
Boron			0 - 5	0 – 0.5																		
Beryllium																						
Bismuth																						
Calcium			0-1000		4.43	6.22	5.17	37.1	3.82	6.02	5.91	54.2	3.96	5.75	5.56	54.9	4.29	5.74	5.34	46.1	4.37	6.29
Cadmium	<0.00015	<0.003	0 – 0.01	0 – 0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt		<0.500																				
Chromium	<0.012	<0.050			<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper	<0.0003	<2	0 – 0.50*	0 – 0.2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron		<2	0 - 10	0 - 5	<0.006	<0.006	<0.006	<0.006	0.026	0.009	<0.006	<0.006	0.078	0.047	0.024	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Potassium				0 – 100	1.43	1.6	1.58	5.57	1.83	1.89	1.89	9.18	1.69	1.43	1.36	7.41	1.94	1.02	1.09	7.07	1.41	1.32
Lithium																						
Magnesium			0 - 500		3.62	7.54	7.46	48.3	2.94	5.65	5.54	66.7	3.4	5.79	5.65	82.7	3.78	6.11	5.63	75.5	3.76	6.31
Manganese	<0.18	<0.500	0 - 10	0 – 0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum																						
Sodium		<200 (A)	0-2000	0 – 70	2.9	4.58	4.63	34.4	2.5	3.96	0.569	32.4	2.22	3	2.95	40.6	2.89	3.7	2.58	37.7	2.68	3.47
Nickel		<0.070																				
Phophorus																						
Lead	<0.0002	<0.010	0 – 0.1**	0 – 0.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphur																						
Antimony		<0.020																				
Selenium	<0.002	<0.010	0 - 50	0 – 0.02	-0.025	-0.025	-0.025	-0.025														
Silicon																						
Tin																						
Strontium																						
Titanium																						
Vanadium		<0.200																				
Tungsten																						
Zinc	<0.002	<5 (A)	0 – 20	0 - 1	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Zirconium																						
Mercury	<0.00004	≤ 6	0 – 0.001		-0.015	-0.015	-0.015	-0.015														
Free Chlorine (Cl_2)					0.2	0.1	0.1	0.1	0.1	0.2	<0.1	0.1	<0.1	0.1	0.1	0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1
Nitrite (NO_2) as N					0.089	0.118	0.116	0.912	0.078	0.07	0.07	0.688	0.086	0.077	0.075	0.634	0.102	0.059	0.061	0.819	0.102	0.099
Orthphosphate (PO_4) as P					-0.025	-0.025	-0.025	-0.025	-0.025	-0.025	-0.025	0.33	-0.025	-0.025	-0.025	-0.025	-0.025	-0.025	-0.025	-0.025	-0.025	-0.025

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