

global environmental solutions

Mn48

MN48 MR CONSOLIDATION & EMP AMENDMENT SPECIALIST STUDY: UPDATED LEHATING MINE FLOODING ASSESSMENT -LEHATING MINE

710.12015.00011

Report No. 1

January 2021

Mn48 (Pty) Ltd

Mn48

MN48 MR CONSOLIDATION & EMP AMENDMENT SPECIALIST STUDY: UPDATED LEHATING MINE FLOODING ASSESSMENT -LEHATING MINE

710.12015.00011

Report No. 1

January 2021

Mn48 (Pty) Ltd

DOCUMENT INFORMATION

Title	Mn48 MR Consolidation & EMP Amendment Specialist Study: Updated Lehating Mine Flooding Assessment - Lehating Mine
Project Manager	Natasha Smyth
Project Manager e-mail	nsmyth@slrconsulting.com
Author	Mark Bollaert, Paul Klimczak
Reviewer	Steve Van Niekerk
Client	Mn48 (Pty) Ltd
Project Number	710.12015.00011
Report Number	1
Status	Final
Issue Date	January 2020

MN48 MR CONSOLIDATION & EMP AMENDMENT SPECIALIST STUDY: UPDATED LEHATING MINE FLOODING ASSESSMENT - LEHATING MINE CONTENTS

1	INTRODUCTION	1-1
1.1	BACKGROUND	1-1
1.2	DWAF GOVERNMENT NOTICE 704	1-1
1.3	SITE LOCATION	1-1
2	BASELINE INFORMATION	2-3
2.1	REGIONAL CLIMATE	
2.2	Rainfall	
	2.2.1 RAINFALL DEPTHS	
2.3	EVAPORATION	2-5
2.4	TOPOGRAPHY AND LAND COVER	2-6
2.5	GEOLOGY AND SOILS	2-8
2.6	RIVER SYSTEMS	2-8
2.7	HYDROLOGICAL REGIME	2-8
3	PEAK FLOW ESTIMATION	3-11
3.1	Methodology	
3.2	Model Inputs	
3.3	PEAK FLOW ESTIMATES	
4	HYDRAULIC MODELLING – FLOODING	4-13
4.1	Methodology	
	4.1.1 Choice of Software	
	4.1.2 TOPOGRAPHIC DATA	
4.2	DESCRIPTION OF HYDRAULIC MODEL	4-15
	4.2.1 MODEL EXTENT AND SCHEMATISATION	
	4.2.2 FLOOD PROTECTION	
	4.2.3 ROUGHNESS COEFFICIENTS	
13	4.2.4 INFLOWS AND DOWNSTREAM BOUNDARY CONDITIONS	
4.5 1 1		
4.4		
- - .5		
5		
0		0-23
1		

LIST OF FIGURES

FIGURE 1.1: REGIONAL SETTING	1-2
FIGURE 2.1: SITE TOPOGRAPHY AND HYDROLOGY	2-7
FIGURE 2.2: REGIONAL HYDROLOGY AND WEATHER STATIONS USED	2-10
FIGURE 4.1: SURVEYED CROSS-SECTIONS	4-14
FIGURE 4.2: MODEL EXTENT AND SCHEMATISATION	4-16
FIGURE 4.3: FLOODLINES AND RIVER BUFFER	
FIGURE 5.1: PREFERENTIAL FLOWPATHS	5-22

LIST OF TABLES

TABLE 2.1: MONTHLY RAINFALL FOR WEATHER STATIONS NEAR THE SITE	2-4
TABLE 2.2: RAINFALL DEPTH FOR VARIOUS METHODOLOGIES AND RETURN PERIODS FOR T AND 24-HOUR STORM	HE 1-HOUR
TABLE 2.3: MONTHLY EVAPORATION FOR KURUMAN WEATHER STATION	2-6
TABLE 3.1: CATCHMENT CHARACTERISTICS	3-11
TABLE 3.2: PEAK FLOW ESTIMATES USED IN THE HYDRAULIC MODELLING	3-12
TABLE 4.1: MODELLING ASSUMPTIONS	4-15
TABLE 4.2: RESULTS OF THE HYDRAULIC MODELLING	4-18

ACCRONYMS AND ABBREVIATIONS

Acronyms / Definition Abbreviations Above Mean Sea Level AMSL DDF Depth Duration Frequency DWA Department of Water Affairs MAP Mean Annual Precipitation RLMA&SI Regional L-Moment Algorithm and Scale Invariance RMF **Regional Maximum Flood** RP **Return Period** SANRAL South African National Road Agency Limited SAWS South African Weather Service SDF Standard Design Flood TC Time of Concentration

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

1 INTRODUCTION

1.1 BACKGROUND

Mn 48 (Pty) Ltd (Mn48) (previously known as Lehating Mining (Pty) Ltd (Lehating)) is planning to develop its new underground manganese mining operation located on Portion 1 of the farm Lehating 741, near the town of Black Rock in the Joe Morolong Local Municipality and the John Taolo Gaetsewe District Municipality, Northern Cape Province, South Africa.

The approved Mn48 mining operation comprises an underground mining area accessed via a shaft, a processing plant, waste rock dump (WRD) and support services and infrastructure. No surface infrastructure has been established to date. Initial site preparation has however been undertaken for the development of the access road, erection of fencing and establishment of the Eskom substation, access shaft and ventilation shaft.

Immediately adjacent and to the south of the Mn48 Mining right area, Khwara Manganese (Pty) Ltd (Khwara) holds an EA for the underground mining of manganese on Portion 2 of the farm Wessels 227 and the Remaining Extent and Portions 3 and 4 of the farm Dibiaghomo 226. The EA was issued by the DMR (currently the DMRE) in November 2018. The intention at the time of the application was for the Khwara underground resource to be accessed and mined using Mn48's approved surface infrastructure and as such no surface infrastructure would be established on the relevant portions of the farms Wessels and Dibiaghomo.

Mn48 is proposing to consolidate the Mn48 Mining Right area (and related operations) and the adjacent Khwara Mining Right Application Area (and related underground mining) to support a single contiguous mining operation. In support of this the approved layout of surface infrastructure located on a Portion 1 of the farm Lehating 741 has been optimised based on the outcomes of the Bankable Feasibility Study (BFS) (Worley, 2019). In summary, the changes to the approved operations and surface infrastructure include the following:

- Relocation of the primary crushing facilities from underground to surface;
- Extension of the footprint and capacity of the approved WRD;
- Addition of a second PCD, and relocation of the already approved PCD (note that the previously proposed emergency control dam will no longer be required);
- General re-configuration of approved surface infrastructure;
- Revision of the stormwater management plan to accommodate the changes to the surface infrastructure layout; and
- Establishment of proposed new support infrastructure such as a helicopter pad and weighbridge.

In addition to the above, the approved EMPr for Mn48 specified the need for a TSF. This will no longer be

SLR Africa

required. The project has made a fundamental change to the mineral processing methodology whereby a dry screening process will be used, instead of a wet screening process which would produce tailings.

In order to comply with applicable guidance, namely DWAF Government Notice 704 (GN704) and as input into an Environmental Impact Assessment (EIA), floodlines are required to be modelled. As such, SLR Consulting (Africa) (Pty) Ltd was appointed to undertake a flooding assessment of the main Kuruman River running adjacent the site. The floodstudy included the assessment of preferential drainage flowpaths so as to provide an indication of areas prone to surface water flooding.

The flood study assessment was initially conducted in 2011 and has been updated to be project specific.

1.2 DWAF GOVERNMENT NOTICE 704

GN 704 was established to provide regulations on the use of water for mining and related activities aimed at the protection of water resources. There are important definitions in the regulation which require understanding.

The main principle condition of GN 704 applicable to this study is:

• 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 floodline and 100 year flood line are used for defining suitable locations for mine workings (prospecting, underground mining or excavations) and associated structures respectively. Where the floodline 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.

1.3 SITE LOCATION

The investigated Mn48 project area, portion 1 Farm Legating 741 and portion 2 Farm Wessels 227 is centred at -27.048936° latitude and 22.872371° longitude, within the Northern Cape approximately 265km north-west of Kimberley and approximately 95km south east of the Botswana border. See Figure 1.1 for the regional setting of the site.



2 BASELINE INFORMATION

2.1 REGIONAL CLIMATE

The proposed project site falls within the Northern Steppe climatic zone as defined by the South African Weather Bureau. This is a semi-arid region characterised by erratic rainfall, high evaporation levels, hot temperatures in summer and cold temperatures in winter. The regional average daily maximum temperature varies between 30°C and 33°C in January and in July it is approximately 17°C. The regional average daily minimum temperature is about 15°C in January and in July it is roughly 0°C. Other details of the regional climate pertaining to the hydrology, flood risk and stormwater management of the site include:

- 5 lightning flashes a year (Adamson TR102, lightning flash density per square kilometre)
- 50 thunder days a year (Alexander 2001, average number of thunder days a year)

2.2 RAINFALL

WR2005 (2009) indicates that the mean annual rainfall (MAP) for the site is approximately 320 mm/annum. There are a number of South African Weather Service (SAWS) weather stations within 50km of the site, while the closest Department of Water Affairs (DWA) station is approximately 55km away. Table 2.1 presents the monthly totals of rainfall for the two SAWS gauges near the site; namely Winton and Milner located at 40.5km and 17.5km away respectively, and the DWA station, Kuruman (55km away).

The mean annual rainfall measured at the nearby Winton and Milner weather stations ranges between 330mm and 362mm respectively. Rainfall is typically in the form of thunderstorms during the summer months of October to March. The peak rainy period occurs between the months of January to March. Rainfall is erratic and may vary significantly from year to year. The weather stations presented in Table 2.1 have their positions illustrated in Figure 2.2

	STATIONS				
Station name	Winton	Milner	Kuruman		
Station No.	392148 W	393083 W	D4E004		
Latitude	27º29" S	27º22" S	27º28" S		
Longitude	22º37" E	23º02" E	23º26" E		
Distance to site (km)	55	40	75		
Altitude (m)	1180	1118	1320		
Years of Record	72	67	54		
	R	AINFALL (mr	n)		
January	62.1	66.1	85.6		
February	61.2	61.4	82.9		
March	58.0	66.4	86.5		
April	31.8	35.5	45.1		
Мау	13.9	16.1	21.5		
June	4.2	6.0	7.4		
July	2.5	1.9	2.8		
August	4.9	4.2	9.8		
September	6.2	6.2	7.8		
October	16.2	19.0	26.3		
November	25.7	32.0	45		
December	43.3	46.8	44.9		
Annual	330.1	361.6	465.7		

TABLE 2.1: MONTHLY RAINFALL FOR WEATHER STATIONS NEAR THE SITE

2.2.1 RAINFALL DEPTHS

Design rainfall depths for various return periods (RP) 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 WRC project K5/1060 (Smithers and Schulze, 2002). This method uses a Regional L-Moment Algorithm in conjunction with a Scale Invariance (RLMA&SI) approach to provide site specific estimates of depth-duration-frequency (DDF) rainfall, based on surrounding observed records. This method of DDF rainfall estimation is considered more robust than previous single site methods. The Water Research Commission (WRC) Report No. K5/1060 provides further detail on the verification and validation of the method.

For comparative purposes, HRU (1978) was considered. This method resulted in slightly lower estimates, thereby placing greater confidence in the RLMA&SI estimates with regard to their use in design. Table 2.2 presents the results of the RLMA&SI and HRU estimates for the site.

TABLE 2.2: RAINFALL DEPTH FOR VARIOUS METHODOLOGIES AND RETURN PERIODS	FOR 1	THE 1-
HOUR AND 24-HOUR STORM		

Methodology	Rainfall Depth (mm) for associated Return Periods in relation to a 1-hour rainfall duration						
	2	5	10	20	50	100	200
RLMA&SI (standard)	26.2	37.3	45.1	52.9	63.6	72.1	80.9
HRU 1978	18.86	24.8	30.6	37.6	49.5	61.0	75.1
	Rainfall Depth (mm) for associated Return Periods in relation to a 24-hour rainfall duration						
	Rainfal relation	I Depth (to a 24-	mm) for hour rai	associa nfall dur	ted Retu ation	rn Perio	ds in
	Rainfal relation 2	I Depth (h to a 24- 5	mm) for hour rai	associa nfall dur 20	ted Retu ation 50	rn Perio 100	ds in 200
RLMA&SI (standard)	Rainfal relation 2 58.3	1 Depth (1 to a 24- 5 82.8	hour rai 10 100.3	associa nfall dur 20 117.6	ted Retu ation 50 141.4	rn Perio 100 160.3	ds in 200 179.8

2.3 EVAPORATION

WR2005 (2009) shows a range in annual evaporation for the site of greater than 2600mm (A-Pan estimate). A correction factor of approximately 0.65(based upon the annual average for monthly correction factors) allows for the translation of the A-Pan estimate to the evaporation estimate for a very shallow body of water (Lake), equivalent to 1695mm.

Table 2.3 presents evaporation data sourced from the DWA station (Kuruman) closest to the site.

Month	Mean Monthly A-Pan Evaporation (mm)	Mean Monthly Lake Evaporation (mm)
Jan	259.0	169.7
Feb	208.4	144.9
Mar	161.3	112.1
Apr	122.3	83.9
May	113.2	76.8
Jun	82.5	56.1
Jul	99.1	63.3
Aug	131.2	81.8
Sep	188.5	109.9
Oct	236.3	135.9
Nov	243.6	157.8
Dec	272.7	183.3
Total	2118.1	1375.7

TABLE 2.3: MONTHLY EVAPORATION FOR KURUMAN WEATHER STATION

2.4 TOPOGRAPHY AND LAND COVER

The topography of the mine and surrounding area is illustrated in Figure 2.1. The proposed site is located at approximately 1005m AMSL, with a variation in elevation of approximately 5m. The site and its surroundings are characterised by flat sandy plains with slopes under 10%. As presented in Figure 2.1, survey elevation data was only available for the site. Consequently, the elevation about the site was sourced from the ASTER GDEM with a cell size of 30m (ASTER is a product of METI and NASA). The ASTER GDEM estimates seem to approximate those of the survey, although a -10m vertical variation was evident.

The site is characterised by natural land cover consisting of semi-arid scrub. The vegetation of the site is defined as Gordonia Duneveld, which is a component of Kalahari Duneveld Bioregion.

Both the topography and land cover of the sites are regarded as important considerations in the determination of runoff generated during flood events.





2.5 GEOLOGY AND SOILS

The site is underlain by predominantly Kalahari geology which is a combination of Sand and Limestone lithology.

Soils in the region of the proposed project site are typically Kalahari sediments of gravels, clays, calcrete and aeolian sand. The project area is made up largely of deep Hutton and Clovelly soils (± 90%) with a small percentage of rock outcrops and shallow Mispah soils. The soils are well drained and have a low clay content.

2.6 RIVER SYSTEMS

The site is located in the Orange River Basin, in quaternary catchment D41M. With reference to Figure 2.2, the ephemeral Kuruman River runs to the south of the site from east to west. A large catchment of approximately 13,780km² feeds the Kuruman River, and consequently when the river is in flood, flows can become considerable. The Kuruman River is, however, considered ephemeral as the river only exists during periods of heavy precipitation.

A minor tributary joins the Kuruman River to the south of the site. This river is only defined as having a length of 400m according to the 1:50,000 topographical map for the site. The ASTER data indicates that a catchment area of approximately 58km² drains to this tributary during heavy rainfall events. A secondary elevation SRTM dataset (Shuttle Radar Topography Mission) indicates that this catchment is only 20km². This disparity is due to the coarse topographic data from which the drainage pathways are being derived as well as the flat slopes of the area (which add error into the calculation of drainage pathways). The presence of a second minor tributary 500m upstream of site tributary is the alternate drainage pathway to which a part the 58km² of catchment may flow. To maintain a conservative approach, a 58km² catchment area is assumed. Section 5 provides further detail on the noted SRTM and ASTER difference.

2.7 HYDROLOGICAL REGIME

The catchment is large but sparsely vegetated and features freely draining soils which indicates that minor rainfall events would infiltrate to groundwater as opposed to generating significant volumes of runoff. This understanding is supported by the fact that numerous road crossings and houses are situated within or immediately adjacent to the channel which suggests that the watercourse does not flow on a regular basis. Anecdotal evidence suggests that no flow has been observed within the watercourse in this locality for some years.

The Kuruman River in this locality is meandering and features a low longitudinal gradient (approximately 1V:1050H) indicating that any flows are likely to be relatively deep but slow moving. The Kuruman River and the site tributary are ephemeral in nature only flowing during periods of heavy rainfall. In this regard, the site tributary will only require incident rainfall to fall over its catchment area, whereas the Kuruman River could come into flood due to rainfall occurring somewhere else in its catchment.



3 PEAK FLOW ESTIMATION

3.1 METHODOLOGY

Flood peaks for the catchment draining up to the site were determined using the Standard Design Flood (SDF) and Regional Maximum Flood (RMF) method as implemented in the UPD software (SANRAL, 2006). These methods were selected to be the most appropriate since the size of the main catchment precluded other methods (e.g. Rational and Unit Hydrograph).

The SDF method was developed by Alexander to provide a uniform approach to flood calculations. This method is based on a calibrated discharge coefficient for a return period of 2 to 100 years. Discharge parameters are based on historical data and were determined for 29 homogenous basins in South Africa. The RMF method is recognised as a reliable method of estimation for the purposes of design, due to its use of observed floods within homogenous flood regions as defined by Kovacs (SANRAL, 2006).

3.2 MODEL INPUTS

For the purposes of defining flood risk, only the single main reach of the Kuruman was modelled. A total catchment area of 13,789km² was delineated using a combination of the quaternary catchments dataset and ASTER GDEM.

The SDF method required the input of catchment characteristics as presented in Table 3.1, in addition to the specification of the site as lying within SDF Basin number 13.

The RMF method is even more simplistic in its data requirements, only requiring the input of a catchment area and the selection of a Kovacs Region. The Kovacs Region was set as K2, while area was set to that as indicated in Table 3.1.

For compative purposes, the site tributary was also included in the hydrological modelling.

	Catchment			
Description	Kuruman	Site Tributary		
Subcatchment Area (km ²)	13 789	58		
River Length (km)	194	25		
10-85 height difference (m)	331	70		

TABLE 3.1: CATCHMENT CHARACTERISTICS

3.3 PEAK FLOW ESTIMATES

The resulting peak flows are presented in Table 3.2. These results demonstrate that the majority of flow is attributed to the main river channel as would be expected. It is also noted that the SDF method presents a more conservative estimate and consequently the SDF peak flows were applied to the rest of the project.

TABLE 3.2: PEAK FLOW ESTIMATES USED IN THE HYDRAULIC MODELLING

Methodology	Return Period Flows (m ³ /s)			
Methodology	1:50	1:100		
Kuruman (SDF)	1 411	1 767		
Kuruman (RMF)	1 152	1 457		
Site Tributary (SDF)	36*	45*		

* These estimates assume a catchment area of 58km² vs. the secondary estimate of 20km².

4 HYDRAULIC MODELLING – FLOODING

4.1 METHODOLOGY

The following section details the approach and the methods used in the development of a hydraulic model for the purposes of defining the 1 in 50 year and 1 in 100 year flood extents.

4.1.1 CHOICE OF SOFTWARE

HEC-RAS 4.0 was used for the purposes of modelling the flooding resulting from a 1 in 50 year and 1 in 100 year rainfall event. HEC-RAS is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. The software is used worldwide and has consequently been thoroughly tested through numerous case studies.

4.1.2 TOPOGRAPHIC DATA

Modelling was informed by a total of 13 cross-sections surveyed on 3rd October 2011 at regular intervals through the main channel, with another cross-section through the minor tributary from the north. 0.5m contour data was used to supplement some of the the cross-sections.

Figure 4.1 presents the surveyed cross-section locations.

Some post processing of the cross-sections was required in order to establish a more appropriate section for inclusion into the HEC-RAS model.



4.2 DESCRIPTION OF HYDRAULIC MODEL

4.2.1 MODEL EXTENT AND SCHEMATISATION

A 4870m reach of the watercourse was modelled as shown in Figure 4.2 stretching from 900m upstream to 150m downstream of the study area.

4.2.2 FLOOD PROTECTION

No flood protection infrastructure (berms, channels etc.) were identified or modelled, unless this infrastructure was captured by the contour survey.

4.2.3 ROUGHNESS COEFFICIENTS

Based on observations of the channel and floodplain characteristics from aerial topography a Manning"s "n" value of 0.035 was assigned to the floodplain and a value of 0.03 was assigned for the main channel. Visual review of the cross-sections was used to delineate between the steep sided constrained "channel" and the wider flatter floodplain - in some cross sections raised levees clearly marked the extent of the channel.

4.2.4 INFLOWS AND DOWNSTREAM BOUNDARY CONDITIONS

The calculated (SDF peak flows) were used in the hydraulic model as described in Section 3. A summary of the modelling assumptions and input data sources is presented in Table 4.1

Assumptions	Value	Source
Upstream Boundary Condition	Normal Depth Slope = 0.00095	Topographical survey of channel
Downstream Boundary Condition	Normal Depth Slope = 0.00095	Topographical survey of channel
Flow	1:50 year = 1,411m ³ /s	SDF Method
	1:100 year = 1,767 m ³ /s	

TABLE 4.1: MODELLING ASSUMPTIONS

4.3 MODEL DEVELOPMENT

The surveyed cross-sections were quality checked for ambiguities and supplementary points were taken from the 0.5m contour data. Following initial modelling runs which resulted in a number of warnings relating to the spacing of cross sections, further cross-sections were interpolated within HEC-RAS to ensure that the cross-sections were spaced no more than 100m apart. The addition of interpolated cross-sections facilitated removal of all results warnings except two due to split channel flow. Given the shape of the channel and adjacent floodplain, split channel flow would be expected through certain cross-sections and this warning is not of concern. No errors were reported within the modelling.



4.4 KEY ASSUMPTIONS IN THE HYDRAULIC MODEL

A number of assumptions have been made in undertaking the hydraulic modelling. These assumptions are in the context of the study and are considered appropriate in view of the level of detail required and the existing site conditions. The key assumptions include:

- That the topographic data provided was of a sufficient accuracy and coverage to enable hydraulic modelling at a suitable level of detail. The approach taken in surveying the river was to restrict survey to the limit at which a sufficiently robust hydraulic model could be derived. Consequently, the cross-sections were purposely spaced at a distance 300m to 600m. Due to the very flat nature of the watercourse, a large cross-section spacing is deemed appropirate. It is, however, the case that channel or floodplain anomalies present between cross-sections would not be represented in the hydraulic model.
- Hydraulic structures such as bridges and weirs were not modelled as part of this study. This
 limitation in the model is based on the assumption that only minor structures are likely to be
 present. The size of the peak flows occuring would easily inundate any minor hydraulic structure
 present, effectively "drowing out" their effect.
- The Manning"s "n" values used is considered suitable for use in both the 50 year and 100 year return periods modelled, as well as in representing both the channel and floodplain, for the reasons described in Section 4.2.3.
- Steady state hydraulic modelling was undertaken, which assumes the flow is continuous at the peak rate. This is a conservative approach as is ignores the effect of storage within the system and therefore produces higher flood levels than would be expected to occur in reality. In addition to pure conveyance, in-channel and floodplain flood storage exhibit a large influence on flood levels and floodplain extents within the low gradient watercourses such as the study catchment. As such, the steady state modelling will result in worse case (conservative) estimates of flooding, and resultant flood levels and floodplain extents would decrease significantly if unsteady state modelling were undertaken using an inflow hydrograph as opposed to continuous peak flow.
- A subcritical flow regime was selected for running of the steady state model. This flow regime gave a more conservative estimate than when using a mixed flow regime (which is tailored to both subcritical and supercritical flows).

4.5 DISCUSSION OF RESULTS

Figure 4.3 present the results of the hydraulic modelling. Figure 4.3 also indicates the location of modelled sections. Water surface elevation and velocity at these points is presented in Table 4.2.

			Water Surface	e Elevation (m		
	X-Coord	Y-Coord	AMSL)		Velocity (m/s)
Station	DD	DD	50T	100T	50T	100T
1	22.84747	-27.03753	994.22	994.73	2.51	2.73
2	22.85139	-27.03996	994.72	995.26	2.23	2.42
3	22.85258	-27.04185	994.93	995.48	2.13	2.3
4	22.85456	-27.04364	995.16	995.73	1.88	2.03
5	22.85746	-27.04539	995.32	995.88	2.71	2.89
6	22.85990	-27.04818	995.81	996.35	2.74	2.93
7	22.86116	-27.05117	996.33	996.91	2.19	2.33
8	22.86276	-27.05592	996.79	997.37	1.91	2.02
9	22.86560	-27.05574	997.04	997.63	1.34	1.42
10	22.86971	-27.05086	997.39	997.92	2.9	3.09
11	22.87438	-27.05095	998.17	998.72	2.54	2.71
12	22.87654	-27.05209	998.56	999.12	1.78	1.91
13	22.87658	-27.05732	998.87	999.41	3.11	3.32

TABLE 4.2: RESULTS OF THE HYDRAULIC MODELLING

It should be noted that, for the majority of the watercourse, flood modelling relies on interpolation between discrete surveyed cross-sections which are widely spaced. Given the input data, the flood levels will be more accurate than the horizontal flood-line extents. Therefore, it is recommended that prior to design of any surface infrastructure within the vicinity of the watercourse, further detailed topographical survey be undertaken and cross-referenced against the flood levels presented in Table 4.2 to improve the accuracy of the horizontal delineation of the flood-lines.

The modelling shows that both the 1 in 50 year and 1 in 100 year floodlines approximate the 100m horizontal distance from the watercourse. For the purpose of mine planning (in accordance with GN704), the greater of the two should be used. It should be noted that a 100m horizontal buffer from the river <u>centreline</u> presents a scenario whereby the required buffer will be underestimated according to the guiding principles of GN704. This is due to the 100m buffer from the centreline of wide rivers (greater than 200m) not exceeding the distance of the river banks. In the case of the ephemeral Kuruman River, no flows are normally evident. Consequently, there is no "river" present by which to define the point at which a 100m horizontal distance should be taken (i.e. from the right or left bank). As such, the modelled

SLR Africa

floodlines are particularly important to the planning process due to the uncertainty in using the 100m buffer from the "river".

Consideration was given whether to include the minor tributary in the model. Based on the output from the model it was concluded that flood levels in the main channel were similar to the bed level at the confluence of the tributary and given the steeply sloping nature of this tributary it was concluded that the main channel would not exhibit any backwater effects on the tributary. According to Figure 4.3, the inclusion of a 100m buffer of the tributary (in place of floodlines) is confirmed as conservative. This is due to the results of the modelling of the far larger Kuruman River evidencing a flood extent which approximates the 100m buffer. Consequently, in the case of the site stream, a 100m buffer will exceed the 1 in 50 and 1 in 100 year flood extents due to the smaller flows and steeper channel (both longitudinally and cross-sectionally).

It was noted, however, that the buffered centreline of the site tributary (as defined by the 1:50,000 topographical map, does not correspond with actual channel. As such, the buffered area was extended to include a 100m horizontal distance of the low area which coincides with the site survey.

The results of the modelling show that the Kuruman floodline (either the 1 in 50 or 1 in 100 year) does not exceed the eroded floodplain. The site is therefore not affected, except for the south western perimeter, where the site boundary extends into the floodplain. No works are expected within this area due to the steep topography and proximity to the watercourse.



5 PREFERENTIAL FLOWPATHS

The site was assessed with regards to preferential flowpaths as illustrated in Figure 5.1. Site survey data shows a clear channel running along the eastern side of the site. This channel is a preferential flowpath since surface water will flow along the channel from upslope regions before flowing into the site tributary and on into the Kuruman River (during heavy rainfall events).

Figure 5.1 presents the results of two elevation datasets (ASTER and SRTM). These datasets were used to calculate the likely preferential flowpaths on and into the site. Since both of these datasets have coarse elevation data, there remains a level of uncertainty as to their accuracy. This is highlighted in the case of points A and B. According to the ASTER dataset, approximately 58km² of upstream catchment drains to point A, versus the SRTM which shows this upstream catchment primarily draining to point B.

Given this uncertainty, a conservative approach was previously implemented (see Section 2.6), with a peak flow of approximately 45m³/s being calculated at point A for the 1 in 100 year design rainfall event (see Section 3.3). The remaining ASTER derived flowpaths on site have smaller catchment areas, with a total contributing area of approximately 12.5km² being noted upstream of point C.

A precautionary approach should therefore be adopted on site with regards to the preferential flowpaths, since while these flowpaths are not defined as watercourses, the potential for flooding as a result of concentrated overland flow is still present.

Depression storage may also occur in the aforementioned areas (where depressions exist) as indicated by the site survey data. Cognisance should therefore be taken of the potential for prolonged periods of flooding. This is particularly the case with the depression in the north east of the site, which is also coincident with a preferential flowpath contributing area of approximately 12.5km².

Additional depressions are evident on site, however, without significant contributing areas upslope, these depressions are not expected to have much in the way of surface run-on, runoff or storage.



6 CONCLUSION

The 1 in 50 year and 1 in 100 year flood events were modelled for the main Kuruman River south of the site. In addition to the modelled rivers, two additional minor tributaries were buffered to a horizontal distance of 100m.

The results of the modelling show that the Kuruman floodline (either the 1 in 50 or 1 in 100 year) does not exceed the eroded floodplain. The site is therefore not affected, except for the south western perimeter, where the site boundary extends into the floodplain. No works are expected within this area due to the steep topography and proximity to the watercourse.

The inclusion of a 100m buffer of the site tributary (in place of floodlines) is confirmed as conservative when assessing the results of the modelling, due to the far larger Kuruman River evidencing a flood extent which approximates the 100m buffer. Consequently, in the case of the site stream, a 100m buffer will exceed the 1 in 50 and 1 in 100 year flood extents due to the smaller flows and steeper channel (both longitudinally and cross-sectionally).

Preferential flowpaths on site were assessed, with site survey data showing a drainage channel to the east. This preferential flowpath was confirmed with the use of supplementary ASTER and SRTM datasets. These datasets showed a catchment area of between 20km² and 58km² draining to point A, while approximately 12.5km² of upstream catchment area was noted as draining to point C. A precautionary approach should therefore be adopted on site with regards to the preferential flowpaths, since while these flowpaths are not defined as watercourses, the potential for surface water flooding as a result of concentrated overland flow is still present. Depressions associated with the preferential flowpaths should also be taken into account since prolonged flooding could occur in the event these became filled by surface water run-on.

Mark Bollaert (CSci, CEnv) (Project Manager, Author) Steve Van Niekerk (Pr Eng) (Project Reviewer) Paul Klimczak (CEnv) (Hydraulic Modeller, Author)

7 REFERENCES

Department of Water Affairs and Forestry, 1998. National Water Act, Act 36 of 1998

Department of Water Affairs and Forestry, 1999. *Government Notice 704 (Government Gazette 20118 of June 1999)*

Department of Water Affairs and Forestry, 2006, "*Best Practice Guideline No. G1: Storm Water Management*", DWAF, Pretoria, August 2006

HRU – Hydrologial Research Unit, 1978, *"A Depth-Duration-Frequency Diagram for Point Rainfall in southern Africa"*, Report 2/78, University of Witwatersrand, Johannesburg, South Africa

Middleton, B.J. and Bailey, A.K., 2009, "*Water Resources of South Africa, 2005 Study (WR2005)*, Water Research Commission, WRC Report No. TT 380/08

SANRAL. 2006, "*Drainage Manual-Fifth Edition*", The South African National Roads Agency Limited, Pretoria, 2006

Smithers, J.C. and Schulze, R.E., 2002, "*Design Rainfall and Flood Estimation in South Africa*", WRC Report No. K5/1060, Water Research Commission, Pretoria