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Namib Lead & Zinc

Hydrological Assessment

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December 2012

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NAMIB LEAD & ZINC HYDROLOGICAL ASSESSMENT

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ACCRONYMS AND ABBREVIATIONS

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

Acronyms / Abbreviations	**Definition**
AMSL	Above Mean Sea Level
ARM	Alternative Rational Method
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
GDEM	Global Digital Elevation Model
MAP	Mean Annual Precipitation
METI	Ministry of Economy, Trade, and Industry of Japan
mm/a	Millimetres per annum
NASA	United States National Aeronautics and Space Administration
RM	Rational Method
RMF	Regional Maximum Flood
RP	Return Period
SANRAL	South African National Road Agency Limited

NAMIB LEAD & ZINC HYDROLOGICAL ASSESSMENT

1 INTRODUCTION

1.1 BACKGROUND

Namib Lead & Zinc Mining (Pty) Ltd (NLZM) intends to develop an underground lead and zinc mining operation. NLZM are currently conducting the pre- feasibility study for the proposed project.

SLR Environmental Consulting (Namibia) (Pty) Ltd was appointed by NLZ to conduct a hydrological assessment as specialist input to the Environmental Impact Assessment planned for the second half of 2012.

The aims of this report were:

- Catchment delineation
- Calculation of flow paths
- Peak flow estimation
- Recommendations for mitigation

1.2 SITE LOCATION

The NLZM project area is located in the Namib Desert at E474667 and N7508827 (WGS_84_33S), within the Erongo Region approximately 30 km north-east of Swakopmund. See Figure 1 for the regional setting of the site.

NAMIB LEAD & ZINC
MINING (PTY) LTD

Figure 1

NLZM Project
Regional Setting

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FIGURE 1: REGIONAL SETTING OF THE NLZM SITE

2 BASELINE INFORMATION

2.1 REGIONAL CLIMATE

The proposed project site falls within the Namib Desert climatic zone. This is an arid region characterised by low and erratic rainfall, high evaporation levels and coastal fog. The regional average temperature is 19°C – 20°C. The regional average maximum temperature varies between 26°C and 28°C during the hottest month (February) and during the coldest month (July) it is approximately 17°C (MENDELSOHN ET AL., 2002).

2.2 RAINFALL AND MOISTURE

The project site is situated in a region where mean annual precipitation (MAP) is less than 50 mm. Rainfall events are erratic, occurring mostly in the summer months in the form of thunderstorms. The average monthly rainfall for the Erongo Region where the NLZM project site is located is shown in Figure 2. The wetter months are January, February, March and April. The drier months are June, July and August. No rainfall data recorded on site was available at the time of this study.

In addition, it must be noted that the project site is within the coastal fog belt. Fog events provide an important source of moisture to the ecosystem functionality. Within the Erongo Region, fog can extend up to 110 km inland. The annual fog precipitation at Swakopmund was estimated to be 35-45 mm in relation to 20 mm that was measured 40 km inland. Fog is expected to occur at the project site in the range between 50 and 75 days per year (MENDELSOHN ET AL., 2002).

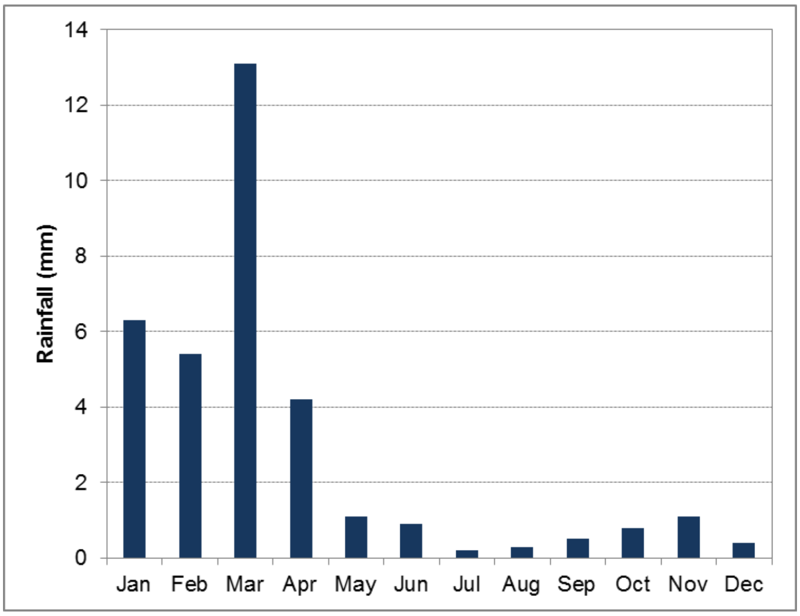

FIGURE 2: AVERAGE MONTHLY RAINFALL FOR THE PART OF THE ERONGO REGION WHERE NLZM IS LOCATED (MENDELSOHN ET AL., 2002)

2.3 DESIGN RAINFALL DEPTHS

Design rainfall depths for various return periods (RP) and storm durations were sourced from the Technical Report 102 “Southern African Storm Rainfall” (ADAMSON, 1981). As no station exists in the direct surrounding of the NLZM project site, data was generated from the Swakopmund station (30 km south-west of the NLZM project site) and the design data from the Arandis surface water study (30 km north-east of the NLZM project site) (SLR, 2012). Design rainfall data for this study was interpolated from these two datasets (Table 1). The resulting MAP is 22 mm.

TABLE 1: DESIGN RAINFALL DATA FOR THE NLZM PROJECT SITE (INTERPOLATED AND SCALED FROM TR102 DATA)

Duration (days)	Minimum annual maximum recorded	Maximum annual maximum recorded	Recurrence interval (years)						
			2	5	10	20	50	100	200
1	4	43	8	16	23	31	45	59	74
2	7	61	9	17	26	38	57	77	103
3	7	64	9	19	29	40	60	80	107
7	9	66	11	21	31	44	66	89	118

2.4 EVAPORATION

Evaporation figures are high, but the values are lower than those observed at desert locations further inland. This is because the Namib Desert is not considered a particularly warm desert with maximum temperatures not exceeding 45˚C. Evaporation rates increase from the coast inland reaching a maximum in the central part of the Erongo Region. The NLZM falls within the 3,000-3,200 mm per year evaporation rate region according to the information contained in the Atlas of Namibia (MENDELSOHN ET AL., 2002). However, it is stated that these values are based on measurements of water loss from standard-sized evaporation ponds, but rates of water loss from open dams, pans and rivers are generally about 30% lower than those from small evaporation ponds. This is because rates of evaporation decrease as the air moving across large expanses of open water picks up moisture. Values used are therefore 30% lower than those recorded at weather stations. Therefore, rates of evaporation for the NLZM project site are between 2,100 and 2,240 mm/a. This indicates that evaporation will significantly exceed rainfall making the area a water-stressed area.

2.5 TOPOGRAPHY

The topography of the NLZM project site and surrounding area is illustrated in Figure 3. The proposed site is located at approximately 280 m AMSL, with a variation in elevation from 183 – 481 m AMSL within the EPL. The larger study area has a rolling to flat topography with mountains bordering the EPL in the east (Rössing Mountains). The proposed site itself has a relative flat topography with a slight fall towards the west. There are smaller “koppies” in the north and north-east of the EPL. As presented in Figure 3, survey elevation data was only available for the site. Consequently, the elevation about the site was sourced from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) with a cell size of 30 m (ASTER is a product of the Ministry of Economy, Trade, and Industry (METI) and the United States National Aeronautics and Space Administration (NASA)). The ASTER GDEM elevations show a vertical variation of approximately 30 m compared to those of the survey.

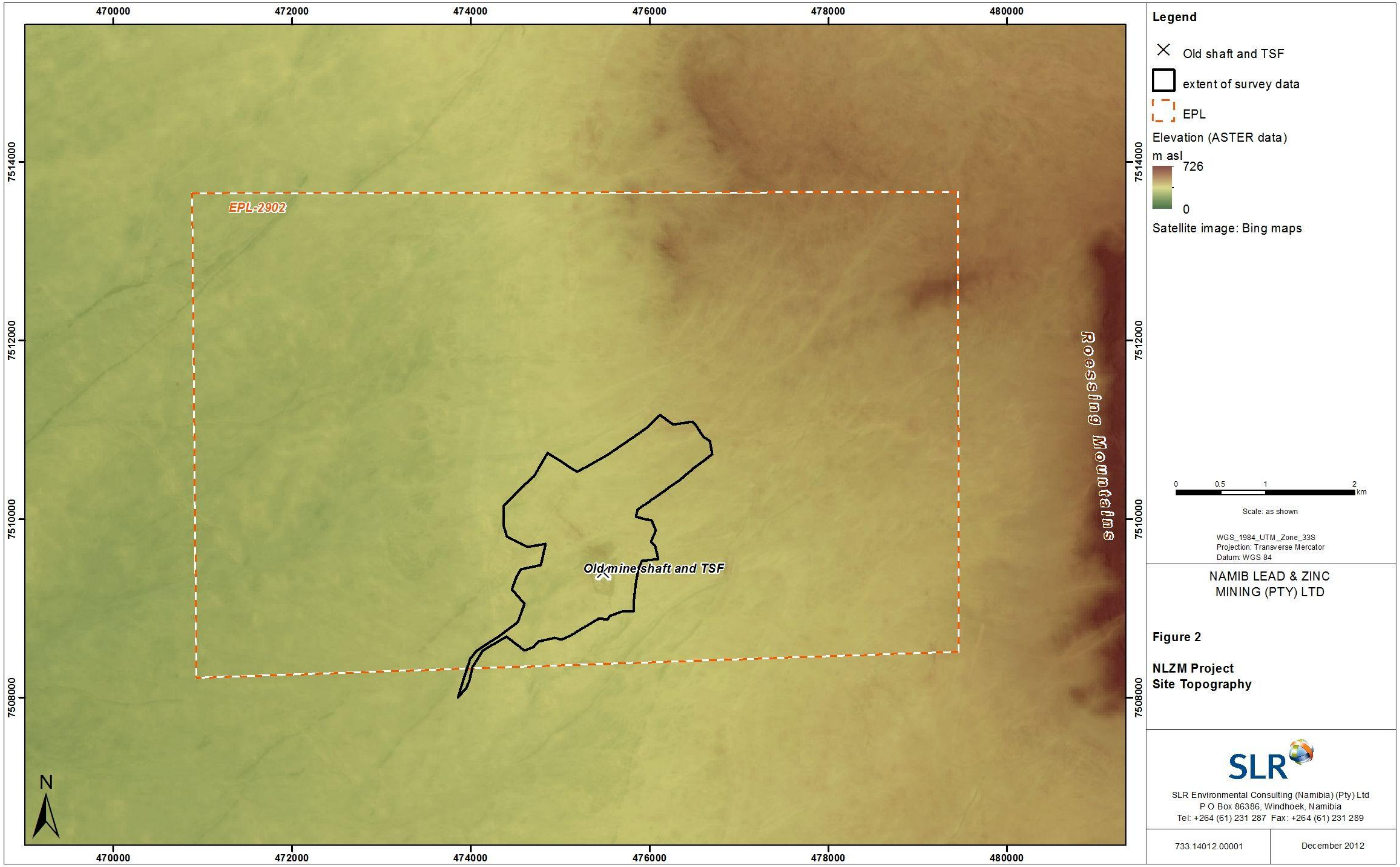

FIGURE 3: SITE TOPOGRAPHY

2.6 VEGETATION AND LAND COVER

The project area is situated in the Namib Desert Biome within the Central Desert vegetation zone. The vegetation within the study area consists of sparse shrubs and grasses. The larger study area is characterised by natural land cover while the area where the old shaft and TSF are located is significantly altered by previous mining operations.

2.7 GEOLOGY AND SOILS

Located in the central zone of the Damara Orogenic Belt the regional geology comprises mainly the Swakop and Nosib Groups of the Damara Sequence. The main rock types prevailing are marbles of the Karibib Formation and schist of the Chuos, Arandis and Kuiseb Formations as well as granites of Namibian and Cambrian Ages.

Soils in the region of the proposed project site are petric gypsisols which are typical for the very dry areas of the central Namib (MENDELSOHN ET AL., 2002). According to COETZEE (2003) these soils have a moderately rapid to rapid infiltration rate and a high internal drainage. However, gypsisols are known to form compact layers or crusts just below the surface promoting surface water runoff.

2.8 SURFACE WATER DRAINAGE AND HYDROLOGICAL REGIME

The proposed project site is located between the Swakop and Omaruru River catchment. These two rivers are ephemeral streams draining westwards into the Atlantic Ocean, whereas the project site is located in a part of the Central Western Plains characterised by dissection from drainage lines and washes generally with east to west orientation. The Swakop River is located approximately 14 km south of the project area. All surface water flow paths in the region are ephemeral and no perennial rivers or permanent water bodies exist. The flow paths in the vicinity of the EPL as well as the watersheds relevant to the project area were determined with the following methods:

- Digitising from topographic map (1:50.000)
- Digitising from satellite image provided by the client
- Calculating from ASTER data

Since no detailed information on the mine plan was available at the time of the study, the hydrological assessment covers the EPL in general rather than particular mining infrastructure, hence two catchments have been investigated for this study, (see Figure 4). The two catchments have a size of 28.5 km^2 (catchment A) and 27.6 km^2 (catchment B) and are draining in a westerly direction. They are sparsely vegetated and the soils are in general freely draining which indicates that minor rainfall events would infiltrate as opposed to generating significant volumes of runoff. After major rainfall events, especially where surface crusts are present, overland flow would form and runoff would flow in the washes.

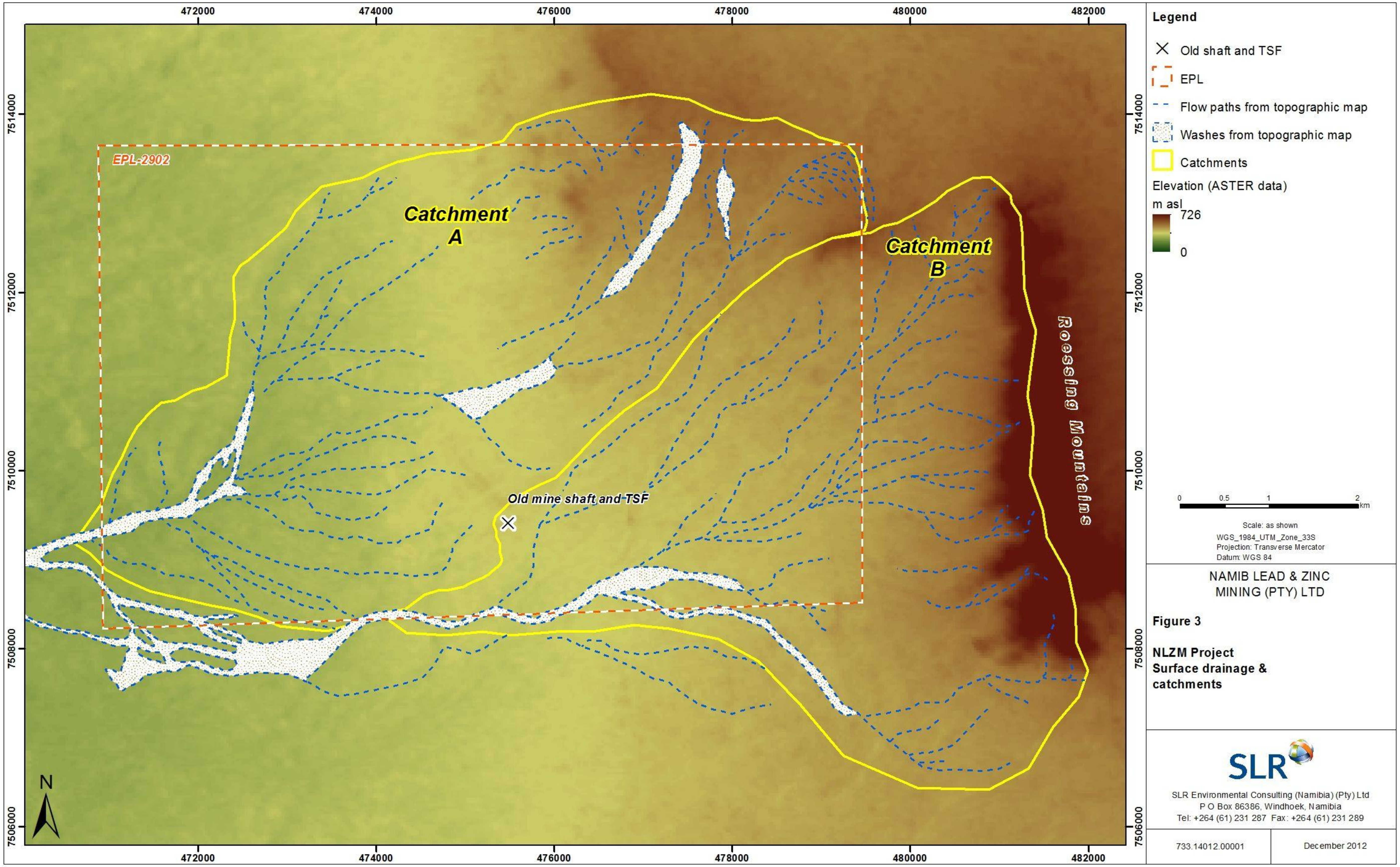

FIGURE 4: SURFACE DRAINAGE AND CATCHMENTS

3 PEAK FLOW ESTIMATION

3.1 METHODOLOGY

Although rainfall is scarce and erratic in the region, significant rainfall events do occur and these events cause temporary surface water flow. The proposed mine infrastructure could have a negative impact on drainage patterns as can drainage have a negative impact on infrastructure. Beyond that, surface water flow can mobilize contaminants from the project site. The extremely arid conditions in the project area make it difficult to establish a flood estimation model and there is no flood data available that can be used for calibration. These limitations must be kept in mind when assessing the flood estimation results.

In order to provide information for the stormwater management plan of the project, peak flows were calculated with the Utility Programs for Drainage (UPD) software (SANRAL, 2006) using the Alternative Rational Method (ARM) and Regional Maximum Flood (RMF) Method. These methods were selected to be most appropriate since they are applicable to the Namibian circumstances and suitable for catchments of that size. The Rational Method (RM) was not applied since this method is only applicable to catchments smaller than 15 km^2.

The ARM is an adaptation of the Rational Method (RM), and both methods are based on a simplified representation of the law of the conservation of mass whereby the peak discharge from a catchment occurs when the total catchment contributes to the flow, i.e. when the time of concentration equals the duration of the rainfall event. The RM uses the depth-duration-return period diagram to determine point precipitation in the catchment. ARM uses the modified recalibrated Hershfield equation for storm durations < 6 hours and the South African Department of Water Affairs' technical report TR102 for durations from 1 to 7 days. For 6 hours < storm duration < 24 hours linear interpolation is used.

Peak flow is calculated as follows (SANRAL, 2006):

$$Q_T = \frac{C_T I_T A}{3.6}$$

where:

Q_T = peak flow rate for T-year return period (m^3/s)
C_T = combined runoff coefficient for T-year return period
I_T = average rainfall intensity over catchment for a specific return period (mm/h)
A = effective area of catchment (km^2)
3.6 = conversion factor

The RMF method is recognised as a reliable method of flood 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, the longest flow paths (river length) as well as the 10-85 height difference (elevations calculated at points 10% and 85% along the main channel, measured from the outlet point) and slopes were calculated based on the ASTER data. A total catchment area of 56.1 km^2 was delineated using a combination of the satellite image, the topographic map and ASTER data (Table 2). The ARM requires “average number of days per year on which thunder was heard” as an input for calculating point rainfall. This parameter was interpolated as 20 days from a map which is only available for South Africa (SANRAL, 2006). As aforementioned, the rainfall input was obtained from scaling and interpolating TR102 data (see section 2.3).

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 NLZM site is located on the border between Kovacs Region < K2 and K2. It was decided to select K2, while area was set to that as indicated in Table 2.

TABLE 2: CATCHMENT CHARACTERISTICS

Description	Catchment	
	A	B
Subcatchment Area (km^2)	28.5	27.6
River Length (km)	12.3	9.4
10-85 height difference (m)	130	107
0-3%	10%	10%
Slope 3-10%	54%	50%
Slope 10-30%	35%	30%
Slope >30%	1%	10%

3.3 PEAK FLOW ESTIMATES

The resulting peak flows are presented in Table 3. The runoff coefficient for both catchments was calculated as 0.45 based on permeability, land cover and slope. The time of concentration was calculated as 2.4 and 1.9 hours for catchment A and B, respectively.

The results obtained from the RMF method are all higher than the ARM results. It is possible that the RMF method overestimated peak flows since the method renders the best results for catchments between 300 km^2 and 20,000 km^2 (KOVÁCS, 1988). Hence, it is recommended to use the average values for further planning.

TABLE 3: PEAK FLOW ESTIMATES FOR RETURN PERIODS OF 50 AND 100 YEARS IN M^3/S

Method	**Catchment**			
	A		**B**	
	1:50	**1:100**	**1:50**	**1:100**
Regional Maximum Flood	66.8	77.6	66.3	77.0
Alternative Rational Method	34.3	41.6	39.5	47.9
Average	**50.6**	**59.6**	**52.9**	**62.5**

4 CONCLUSIONS AND RECOMMENDATIONS

It was found that there are no permanent surface water bodies or major rivers in the project area and rainfall events are very sparse and erratic. Nevertheless, surface water as a key ecological driver in the desert environment must be considered in the environmental management plan with the aim to minimize the project footprint.

Once a detailed plan of the proposed mine infrastructure is available, a second hydrological assessment should be conducted including a conceptual storm water management plan. It is recommended to consider the following actions in the storm water management plan with regard to flood control and pollution prevention:

- No infrastructure should be located within the 1 in 100 year flood line. 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;
- Clean and dirty water systems must be kept separate and must be designed, constructed, maintained and operated such that these systems do not spill into each other;
- Dirty water must be directed to containment dams sized to contain storm water generated during a 1:100 year 24 hour duration rainfall event;
- Priority must be given to re-using dirty water from the containment dams at the site before abstraction of clean water. Dirty water can only be discharged from the site to the environment after treatment and subject to the appropriate permit or license.

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(Project Manager)	**(Project Reviewer)**	**(Author)**

5 REFERENCES

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

ADAMSON, P.T. (1981): *Southern African Storm Rainfall*. Technical Report No. TR 102. Department of Water Affairs, Pretoria, RSA.

ALEXANDER, W. J. R. (2001): *Flood Risk Reduction Measures incorporating Flood Hydrology for Southern Africa.*S.A. National Committee on Large Dams, Pretoria.

COETZEE, M. E, (2003): *Characteristics of Namibian soils in a nutshell*. Spotlight on Agriculture, No 65. Ministry of Agriculture, Water and Rural Development, Windhoek, Namibia.

KOVÁCS, Z. (1988): *Regional Maximum Flood Peaks in Southern Africa*. Technical Report No. TR 137. Department of Water Affairs, Pretoria, RSA.

MENDELSOHN J, JARVIS A, ROBERTS C AND ROBERTSON T. (2002): *Atlas of Namibia: A portrait of the land and its people*. David Philip Publishers, Cape Town, South Africa.

SLR (2012): *Surface Water Study.* SLR Environmental Consulting (Namibia) (Pty) Ltd for Arandis Power (Pty) Ltd, June 2012.

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