APPENDIX F: HYDROLOGY ASSESSMENT

GAMSBERG SMELTER PROJECT SURFACE WATER ASSESSMENT

Gamsberg Smelter Project

Prepared for: Black Mountain Mining (Pty) Ltd

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BASIS OF REPORT

EXPERTISE AND DECLARATION OF INDEPENDENCE

Pfarelo Siebani (Cert.Sci.Nat) **-** Pfarelo is a Hydrologist with over 6 years' work experience specialising in mining/development hydrology, water resources management planning, hydrological modelling, hydraulic modelling, floodlines delineation studies, storm water management planning, soil, land use and land capability assessments. She has been primarily involved in the surface hydrology, soils science fields and water availability assessment projects for mines, municipalities, and agricultural enterprises.

Kevin Bursey (Pr.Sci.Nat) - Kevin is a Principal Hydrologist with over 16 years' international consultancy experience all over Africa and predominantly in South Africa. Kevin specialises in hydrology, flood risk, water resources, drainage and water quality and provides technical specialist input to environmental impact assessments and engineering design studies. Kevin will manage the project and be responsible for coordinating technical specialist input on hydrology, water quality and flood risk management.

EXECUTIVE SUMMARY

Introduction

SLR Consulting (South Africa) (Pty) Ltd (SLR), an independent firm of environmental consultants, has been appointed by Black Mountain Mining (Pty) Ltd (Gamsberg) to develop conceptual designs for the management of the storm water around the proposed Gamsberg Smelter and the Secured Landfill Facility (SLF) for the disposal of Jarosite at the existing Gamsberg Zinc Mine operation. Black Mountain Mining (Pty) Ltd is proposing to construct a new zinc Smelter and associated infrastructure to produce 300 000 tons per annum (tpa) high-grade zinc metal by processing 680 000 tpa of zinc concentrate (Gamsberg Smelter Project). As a by-product 450 000 tpa of 98.5% pure sulphuric acid will be produced both for export and for consumption within South Africa.

The surface water assessment covers the development of a conceptual storm water management plan (SWMP) which is scheduled to be implemented concurrently with the expansion works and when complete must ensure compliance with GN704. Subsequent phases of the project will involve development of the detailed engineering designs, the construction thereof and finally the implementation and monitoring.

The Gamsberg Zinc Mine and associated infrastructure is located in the Namakwa District, between the towns of Aggeneys and Pofadder. It is approximately 120 km east of Springbok and approximately 270 km from Upington along the N14 road in the Northern Cape Province of South Africa.

Baseline Hydrology

The Gamsberg Zinc Mine Mining Right Area (MRA) is influenced by four quaternary catchments D81G, D82A, B82B and B82C. The D81G catchment drains into the Orange River and the D82C catchment is an interior drainage basin that does not drain into the sea. Most of the water courses in the area are transient but the small catchment area on top of the Gamsberg Mine contains a spring and can experience seasonal flows.

A 69-year Daily rainfall record spanning from 1950 to 2019 for rainfall station 0246555_W (Aggeneys Pol), located approximately 13.2 km northwest of the project site, was obtained and used to describe the rainfall expected at the project site. Rainfall data for the gauge was extracted using the Daily Rainfall Utility Program (DRU) - Institute for Commercial Forestry Research (ICFR).

The mean annual precipitation (MAP) at the monitoring station has been determined to be 56.8 mm/annum with a significant variation in annual rainfall at this site. It can be seen that 30% of the years' in the rainfall record experienced less than 53 mm/annum, whilst the driest year experienced only 1 mm/annum of rainfall and the wettest year experienced 233 mm/annum of rainfall.

Evaporation data is based on Symonds Pan (S-Pan) data taken from the WR2012 Database (WRC, 2012) for the quaternary catchment D82C (in which the project site is located). S-Pan evaporation was converted to open water evaporation using evaporation coefficients from WR90 (WRC, 1990).

Baseline Water Quality

An assessment of the water quality at this site was limited as there is no recent sheet flow database of water quality data available for the Gamsberg site due to lack of rain. However, a review of an existing one-year record of water quality data obtained from the SRK Gamsberg Zinc Project Baseline study (SLR Consulting, 2010) was undertaken. The existing baseline water quality analysed in this study was undertaken prior to the start of mining at the Gamsberg Zinc Mine which began operating in 2016.

Three monitoring points had been sampled and analysed. The results were compared to the South African National Standards (SANS) for drinking water quality (SANS241:2006) and the Department of Water Affairs Guidelines for livestock watering (DWAF, 1996) as these are the two most likely water uses for the springs and farm dams in the area.

All parameters were within the limits of the SANS241: 2006. SANS 241 Guidelines only showed exceedances in Barium noted at monitoring points GAMS 1SW and GAMS 3SW.

According to SRK Consulting (2010), it was evident from their observations that the water emerging as springs was fit for domestic use and livestock watering. However, it must be noted that although the average barium values comply with the guidelines over the full monitoring period, there were instances where certain samples did not comply with the WHO guideline concentration level for drinking water.

The results were consistent between consecutive months over the monitoring period, for the majority of parameters monitored, with the most notable exception being nitrate at GAMS 1SW. Nitrate in July and August was ten times greater than that in May and June although still within the SANS for Class I drinking water quality guideline and it is likely that this is related to fertilizer, livestock or sanitation impacts (SRK Consulting, 2010).

Flood line Determination

Sub-catchments were delineated for the determination of flood lines on the Eastern and Western streams that would be influenced by the proposed Gamsberg Smelter Project.

The topographical data forms the foundation for the HEC-RAS model and is used to extract elevation data for the river profiles together with the river cross-sections. The topographical data is also used to determine the positions at which the cross-sections are taken along the river profile, so that the watercourse can be accurately modelled.

The proposed SLF (Alternative 3) will traverse the modelled stream which means that the project will severely impact on the surface watercourses. Either the SLF can be located to ensure that it sits outside of the flood line or a flood protection berm must be developed as recommended and as per the design specifications outlined.

Conceptual Storm water Management Plan

Informed by the baseline hydrology of the site and the surroundings, a review of the proposed surface infrastructure has been undertaken, and a series of design standards for storm water management have been developed to ensure compliance with the requirements of GN704.

In order to meet the design standards conceptual design details for the proposed storm water management measures are recommended for the proposed Smelter and SLF, along with the specific hydraulic design standards, methodologies, assumptions and input parameters for each management measure proposed.

Water management channels were designed and the design features are as follows:

- The channels were sized to accommodate the maximum flow calculated at the downstream end of the contributing catchment.
- The channel sizing is taken as uniform along the entire length of the channel.
- Some cut and fill may be required along the length of the channels to achieve the required gradient to ensure that water flows freely along these channels.
- Clean water will be kept out of the dirty water channels by construction of a bund along the upstream length of the channel with material excavated from the channel.
- A flood protection berm that aims to protect against flooding, by partitioning the slope, is required to prevent the possibilities of flooding around the SLF.

Two storm water dams (SWD) were designed to attenuate storm water around the Smelter complex and the SLF and their design features are as follows:

- Barrier System - Specification to be confirmed during detailed design phase - indicatively the barrier system will comprise of a 1.5 mm HDPE geomembrane (to conform to the latest GRI-GM13 specifications, and installed to SANS 10409), covered by a compacted soil layer of 150 mm thick to protect the liner.
- Emergency Spillway of the SWD will consist of a concrete spillway of 10m width with downstream erosion control along the embankment to ensure controlled discharge during spillage events.
- The capacity of the dam has been determined and will include a freeboard of 0.8m above full supply level.
- Inlet channels - Two concrete lined inlet channels have been specified, the invert levels to be confirmed during detailed engineering phase.
- Basin - To be sloped at 1:300 towards the return water pump/spillway.
- Maximum Depth of SWD - Indicatively 3 m, to be confirmed during detailed engineering phase.

Site Wide Water Balance

A site wide water balance has been developed, to estimate the return water, make up water and discharge requirements based on the proposed infrastructure. The water balance development was undertaken for the wet and dry seasons and the annual averages for the two phases of the mine (e.g. Current and Future Operation herein referred to as Phase 1 and Phase 2, respectively). Current Operation includes all the existing mining activities, TSF and the Concentrator Plant. Future Operation includes all mining activities, the Smelter and the SLF. The project's water circuit has been documented and the collection and water management strategy defined.

Potable water supply into the Horseshoe reservoir for use in the Gamsberg Zinc Mine and Smelter is from the Sedibeng Water Scheme which abstracts water from the Orange River. The water supply volumes are provided in the water balance undertaken by TATA Consulting (2013). The current and future water demand, within the Black Mountain Mine operation, including Aggenneys, Pofadder and Pella towns is a total 43.45 ML/day, the existing intake water pumping system has been designed for 40.8 ML/day.

The water balance indicates that approximately 323 577 m^3 make-up water is required for Potable water use in use in Phase 1 while no make-up water is required for phase 2 as the water supplied meets the water demanded. Approximately 8 552 m^3 per month is required as make-up water for processing during dry season of Phase 2. The Smelter receives exceess water of 66 744 m^3/month in Phase 1 and Phase 2 from the Raw Water Dam; this water can be used to supplement the make-up water required.

There is an opportunity to implement measures to collect, recycle and conserve excess water from the Smelter as more water is treated and recycled between the ETP Plant and RO Plant, which would result in a reduction in other water requirements such as dust suppression, etc.

Impact Assessment

Informed by the site plan layout, baseline hydrology, design specifications for the storm water management system, the flood lines, and the water balance outcomes, the potential impacts of the proposed activities on surface water receptors are presented in this section along with a summary of mitigation measures.

Where possible impacts are assessed cumulatively as they relate directly to the currently impacted environment. However, the impacts of the various (surrounding/neighbouring) activities in the wider region have not been cumulatively assessed in this report.

The impacts of the proposed activities and the related infrastructure have been identified and then assessed based on the impact's magnitude, duration, probability, extent, severity and consequences and the receptor's sensitivity. This analysis then concludes in the determination of the impact significance which indicates the most important impacts and those that therefore require management.

Recommendations

The following recommendations have been made:

- It is recommended that the SLF be relocated and placed outside of the 1:100-year flood line in order to prevent the impact of flooding. It is proposed that the SLF be relocated to an estimated 150 meter distance east of the original SFL location.
- In the event that the SLF is not moved, a flood protection berm that aims to protect against flooding and reduced flow velocity may be used to minimise the impact and should be developed. The design specification of the flood protection berm is presented in Section 5.4.4.
- It is recommended that the hydraulic gradients and channel sizes are confirmed during the detailed design of the storm water channels. The requirement for, and design of, in-channel velocity control measures should be confirmed during the detailed design of the channels. The specification for lining of the channels and the SWDs should also be confirmed during the detailed design of these features.

As part of the detailed design process, the following tasks are recommended:

- Geotechnical Investigation - to assess the structural integrity of the existing embankment, if applicable, as well as to determine the dam footprint for the lining, compaction and storage estimates. Confirm all the levels (base of dam, full capacity, spillway and freeboard). Source clay liner from within the project area while also characterising the available soils for construction materials (road construction, backfill to structures, foundations, etc.).
- SWD Pump Station and Pipeline Design – design and related drawing work including detailed horizontal and vertical routing of the pipelines, hydraulic modelling and surge analysis, pump selection and pump station mechanical, civil, structural, electrical, control and instrumentation engineering tasks.
- Review of Plant Infrastructure Design – to confirm the design constraints on the proposed storm water infrastructure.
- Detailed Engineering Design - including drawings, design report and bill of quantities (if required). This task can be undertaken in discrete packages of design work in accordance with the phasing of the infrastructure development
- Separation of clean and dirty water through the development of storm water structures as detailed in Section 4 of this report. It must be ensured that diverted runoff from disturbed areas is collected in dirty areas and clean water freely discharges to the surrounding clean catchment.
- As discussed above, it is proposed that storm water from dirty catchments is contained and reused for dust suppression. Alternatively, it must be treated and discharged, effectively reducing the catchment area draining to the local watercourses.
- Management of silt by ensuring that the disturbance of soil is minimised, sediment source and erosion control, phasing of earthworks activities, diversion of upslope runoff from entering the earthworks areas and downstream treatment of any collected sediment runoff i.e. use of silt traps.
- Either the SLF must be relocated or a flood protection berm that aims to protect against flooding by partitioning the slope with level and reduced flow velocity is required to prevent the possibilities of flooding around the SLF.

- Water Balance: the site's water circuit has been documented and the collection and water management strategy defined with the reuse of dirty water prioritised. In order to reduce the impacts of the project on the surface water resources,

In addition to the measures presented and discussed throughout this report, the following management measures should be implemented:

- Good housekeeping practices must be implemented and maintained through clean-up of accidental spillages are kept within the defined footprints of the storage areas. In addition, clean-up equipment and material safety data sheets for chemical and hazardous substances should be kept on site for immediate clean-up of accidental spillages of pollutants.

- Regular sessions for the inspection and maintenance of the water management facilities must be scheduled. This must include inspection of drainage structures for any in channel erosion or cracks; de-silting of silt traps/sumps and SWDs; and assurance that any pumps and pipelines are maintained according to manufacturer's specifications.

- Vehicles and plant equipment servicing must be undertaken within suitably equipped facilities. This would include either workshops, or bunded areas, from which any storm water is conveyed to a pollution control dam, after passing through an oil and silt interceptor.

- Pollutant storage – any substances which may potentially pollute surface water must be stored within a suitably sized bunded area and where practicable covered by a roof to prevent contact with rainfall and/or runoff.

- Water conservation and water demand management (WC/WDM) measures should be implemented to ensure that as much water as possible, is collected and reused.

- From operations onwards, grading of the disturbed areas and application of the final layers of growth medium, must be contoured as far as can be achieved in a safe and practical manner; vegetation of the disturbed areas, including seeding, should be performed immediately following application of the growth medium to avoid erosion.

All measures implemented for the mitigation of impacts, should be regularly reviewed in order to conform to best practice and to be compliant with the various licences issued for the site by the authorities. The purpose of the mitigation measures is to ensure that the pre-mining / current water resource status does not deteriorate due to the smelter related activities.

CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
DDF	Depth-Duration-Frequency
DEM	Digital Elevation Model
DMS	Dense Medium Separation
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
ETo	Evapotranspiration
GN704	General Notice 704
HDPE	High-Density Polyethylene
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
mamsl	meters above mean sea level
MRA	Mining Right Area
PCD	Pollution Control Dam
PFD	Process Flow Diagram
RM3	Rational Method Alternative 3
ROM	Run of Mine
RWD	Return Water Dam
SDF	Standard Design Flood
SWD	Storm water Dam
SWMP	Storm Water Management Plan
SWTP	Sewage Waste Treatment Plant
TPM	Tonnes per Month
TSF	Tailings Storage Facility
TSS	Total Suspended Solids
WMA	Water Management Area
WHO	Word Health Organisation
WR2012	South African Water Resources 2012 Study
WUL	Water Use Licence

1. INTRODUCTION

1.1 TERMS OF REFERENCE

SLR Consulting (South Africa) (Pty) Ltd. (SLR), an independent firm of environmental consultants, has been appointed by Black Mountain Mining (Pty) Ltd. to undertake a Surface Water Impact Assessment study to support the Environmental and Social Impact Assessment (ESIA) and integrated authorisation application for the Gamsberg Smelter Project. This report details the surface water impact assessment inputs to the ESIA.

The full scope of the surface water assessment undertaken focused on the proposed Gamsberg Smelter and the Secured Landfill Facility (SLF). However, the water balance assessment that also formed part of the study focused on the current operation of the entire Gamsberg Zinc Mine as well as the currently approved future expansion. The future expansion activity encompasses the construction and operation of the approved Phase 2 of the Concentrator Plant and associated increases in production volumes from the open pit.

The Gamsberg Zinc Mine and the associated infrastructure is located in the Namakwa District in the Northern Cape Province of South Africa, between the towns of Aggeneys and Pofadder. It is approximately 120 km east of Springbok and approximately 270 km west of Upington along the N14 road. The location of the Gamsberg Zinc Mine can be seen in Figure 1-1.

1.2 PROJECT BACKGROUND

Black Mountain Mining (Pty) Ltd, part of Vedanta Zinc International, owns and operates the Gamsberg Zinc Mine. In 2010 Vedanta Resources Limited acquired Black Mountain Mining (Pty) Ltd from Anglo American as part of the acquisition of the zinc base metal mine take over. Following the acquisition of the Black Mountain Mining properties and rights a feasibility and optimisation of technology for the Gamsberg Zinc Mine was undertaken.

An EIA process was completed in 2013 (and approved on 12 August 2013 – Permit 43/2013) and amended on 2 December 2014 (Permit 43/2013 Amendment 2) (Ref: NC/EIA/NAM/KHA/AGG/2012), a Waste Management Licence (Ref: 12/9/11/L955/8), and a Water Use Licence (Ref:14/D82C/ABCGI/2654)) were obtained for the open pit mining activities and the concentrator plant. The Gamsberg Zinc Mine has been in operation since June 2016 and is currently mining up to 4 million tonnes per annum (mtpa) and producing up to 250 000 tonnes per annum (tpa) of zinc concentrate for export.

Mining activities commenced in June 2016 when overburden stripping for the open pit was started. The mining plan for Phase 1 consisted of three smaller open pits within the footprint of the 10 million ton per annum footprint. Development of the open pit mine and the concentrator plant was carried out in phases. The construction of the concentrator plant commenced in 2017 with the official opening in February 2019. Phase 2 will expand the mining capacity to 10 million tonnes per annum (mtpa).

Black Mountain Mining (Pty) Ltd is now proposing to construct a new zinc smelter and associated infrastructure to produce 300 000 tpa special high-grade zinc metal by processing 680 000 tpa of zinc concentrate (Gamsberg Smelter Project). As a by-product of this expansion 450 000 tpa of 98.5% pure sulphuric acid will be produced for both export and for consumption within South Africa.

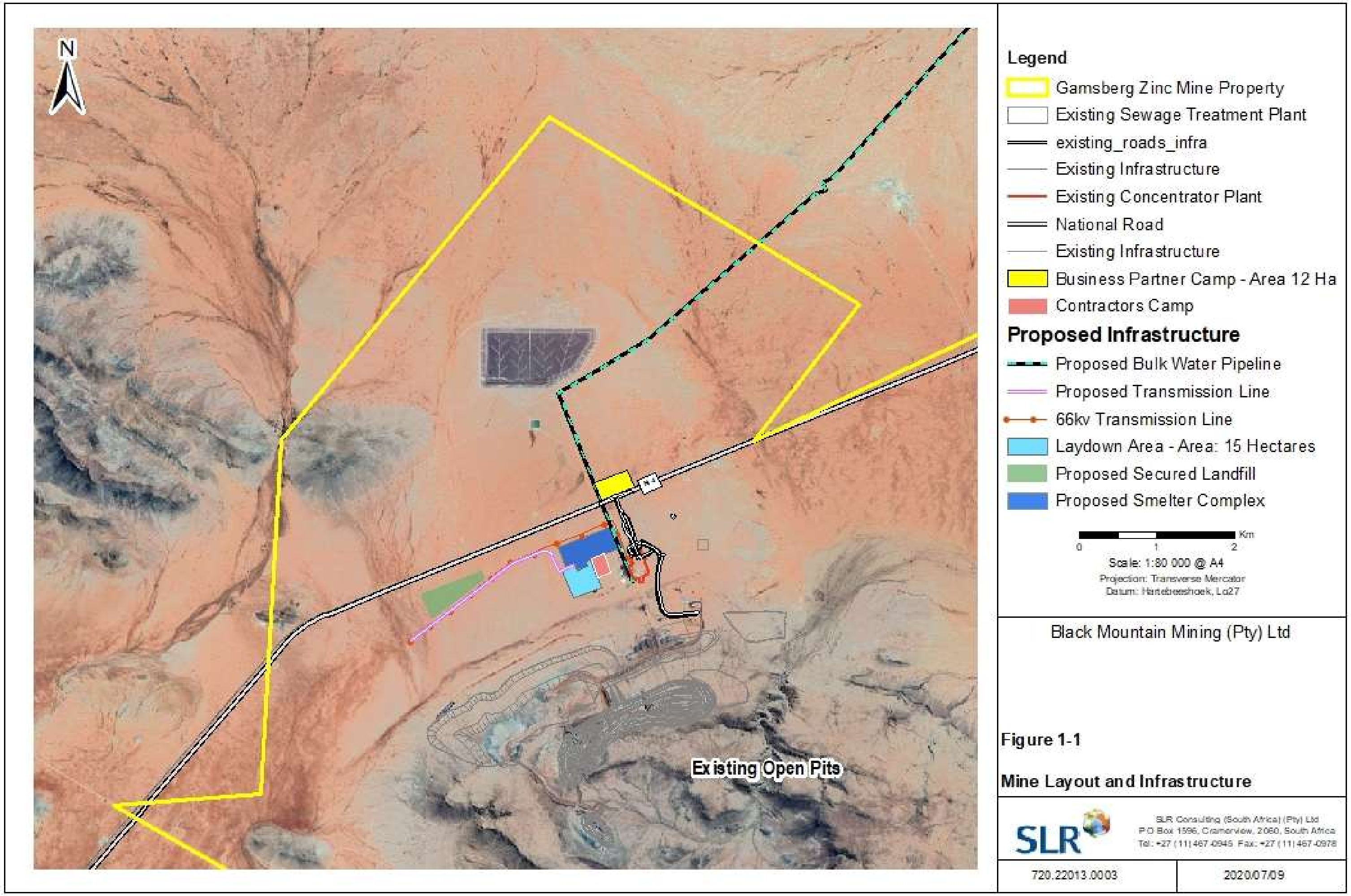

Figure 1-1: Gamsberg Smelter, Secured Landfill Facility and Associated Facilities Layout

1.3 LEGISLATION

The following legislation was taken into account during this assessment:

1.3.1 The National Water Act (Act 36 of 1998)

Water resources management in South Africa is governed by the National Water Act (Act 36 of 1998) (NWA). The Department of Water and Sanitation (DWS) must, as custodians of water, ensure that resources are used, conserved, protected, developed, managed and controlled in a sustainable manner for the benefit of all persons and the environment.

1.3.2 Regulations on the use of Water for Mining and Related Activities

Government Notice 704 (Government Gazette 20119 of June 1999) (hereafter referred to as GN704), was established to provide regulations on the use of water for mining and related activities aimed at the protection of water resources. The three main conditions of GN704 applicable to this project are:

- Condition 4 – indicates that no person in control of a mine or activity may locate or place any residue deposit, dam, reservoir, together with any structure of other facility within the 1:100-year flood line or within a horizontal distance of 100 metre from any watercourse.
- Condition 5 - 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 which may cause pollution of a water resource.
- Condition 6 - describes the capacity requirements of clean and dirty water systems. Clean and dirty water systems must be kept separate and must be designed, constructed, maintained and operated to ensure conveyance of the flow of a 1:50-year recurrence interval storm event. Clean and dirty water systems should therefore not spill into each other more frequently than once in 50 years. Any dirty water dams should also have a minimum freeboard of 0.8m above full supply level.
- Condition 7 - describes the measures which must be taken to protect water resources. All dirty water or substances which may cause pollution should be prevented from entering a clean water resource (by spillage, seepage, erosion etc.) and it should be ensured that water used in any process is recycled as far as practicable.

1.3.3 Best Practice Guidelines

In addition to GN704, the Department of Water and Sanitation (previously Department of Water Affairs and Forestry) has developed several Best Practice Guidelines (BPGs) for the mining industry. These include:

- BPG A4 Pollution Control Dams, Section 5.2.2. In this document it defines the allowable SWDs spillage frequency as being one spill in every 50 years on average. This is equivalent to stating that an RWD or PCD should be designed with an annual spillage probability of 1:50 (2%) or less. In addition to this, BPG A4 recommends that the final design criteria should be determined through the use of a long-term continuous simulation water balance model, modelled at an appropriate time step (preferably daily), where:
    - “The definition of an event is defined as a sequence of continuous spill days occurring during a 30-day window.”
    - “The spillage frequency depends on the size of the dam (capacity) and the abstraction and re-use rate.”
    - “Confirmation of the dam sizing (based on spillage frequency), by means of continuous modelling.”

  - "It is important to consider the loss of storage due to sediment build up in the PCD when sizing the dam."
  - "The PCD water balance will be used to specify a minimum storage level. This ensures that adequate freeboard is maintained so that the storm water inflow can be accommodated, and the spillage frequency met. The management of the PCD should be according to this minimum level. The dam volume should be reduced to this minimum level as soon as possible after storm events."
  - "It is important to consider that, in general, it is not the single events that result in spillage, but rather prolonged wet conditions."
- BPG G1 Storm water Management, Section 4.2, which defines a methodology of planning, designing and implementing storm water management measures to ensure separation of clean and dirty water and provides guidelines to ensure sustainability over the mine's life cycle. It also offers guidelines for the following:
  - Classification of clean and dirty areas.
  - Conceptual designs and review, "The designer has to balance the need to obtain preliminary sizes so that water conveyance systems and retention structures can be provisionally sized, without undertaking a detailed design that may have to be discarded due to inadequacies in the storm water management plan (SWMP), or changes in the conceptual design."
  - Assess the Suitability of the existing infrastructure and define infrastructure changes required.
  - Design of required infrastructure informed by all prior steps.
- BPG G2: Water and Salt Balances, which defines a methodology of planning, designing and implementing water balance objectives to ensure suitable water management strategies and provides guidelines to ensure sustainability over the mine's life cycle.
- South African National Standard (SANS). Drinking Water Standard SANS 241: 2015.
- Targeted Water Quality Range (TWQR) (DWA, 1996).

1.4 SCOPE OF WORK AND REPORTING

The scope of work for this study included the following:

- Baseline Hydrology – Section 2 presents a review and analysis of various sources of rainfall and evaporation data. The section also presents the characterisation of the baseline hydrology of the site and surroundings including topography, watercourse network and catchment delineation;
- Water quality - Section 3 presents a review of available water quality data provided to SLR to classify the baseline water quality;
- Flood lines – Section 4 presents the 1:50-year and 1:100-year flood lines for the streams located near the proposed project as well as the inclusion of a summary of the flood lines historically determined;
- Conceptual Storm water Management – Section 5 presents the recommended storm water management measures including a review of the layout, peak flow estimation (Rational method only), hydraulic sizing of the drainage infrastructure (flood protection berms and channels), and the location and indicative capacity of Storm water Dams (SWD) and silt traps;
- Steady State Water Balance – Section 6 presents the steady state water balance model for the major water components of the mine. This chapter also describes an opportunity to optimize the water management at the mine site as well as determine the amount of make-up water required for the mine;

- Impact Assessment – Section 7 presents a qualitative assessment of the significance of the impact of the project on the baseline surface water environment, a range of mitigation measures to minimise the impacts, and recommendations on the monitoring required; and
- Conclusions and Recommendations – Section 8 presents a summary of the main conclusions of this report and a summary of the recommendations made based on this study.

2. BASELINE RECEIVING ENVIRONMENT

In order to inform the design of storm water management measures, an understanding of site-specific climatic conditions, topography, geotechnical/ ground conditions, and existing storm water infrastructure is required. This section presents a review of the relevant information and the related sources.

2.1 LIST OF AVAILABLE DATA SOURCES

The following sources of data were reviewed, and the data was used for the surface water impact assessment:

- Water Research Commission's database for evaporation and runoff and the South African Weather Service for daily rainfall data.
- Existing Water Use Licence (WUL) for Gamsberg Zinc Mine (DWS, 2016).
- Existing summary of the Gamsberg Tailing Storage Facility (TSF) Water Balance.
- Pre-Feasibility Study Report for a 250 ktpa Zinc Refinery with infrastructure at Gamsberg, South Africa (Tata Consulting Engineers Limited, TATA Consulting, 2019).
- Water quality data from the Gamsberg Zinc Project Interim Baseline Report – Hydrology and Surface Water Quality (SRK Consulting, 2010).
- The GIS and CAD files of the existing and proposed site layouts and infrastructure as provided by the client.

2.2 CLIMATE

The region in which the mine is located is classified as a desert region with very low rainfall and very high evaporation rates. An average rainfall of 92 mm/annum occurs in both summer and winter seasons as the area lies in a transition zone between winter and summer rainfall areas. Summers are hot with mean maximum temperatures in January, the hottest month, ranging between 30.7°C and 35.4°C. During winter, the mean maximum temperatures range from 17.8°C to 20°C with significant temperature reductions at night. The mean annual average temperatures are just below 20°C with very hot summers and cool to mild winters. The Mean Annual Evaporation (MAE) of 2,650 mm/annum was determined using the 1990 WRC publication "Surface Water Resources of South Africa."

2.2.1 Rainfall

Daily rainfall from a South African Weather Service gauge, station 0246555_W (Aggeneys Pol) were obtained and used to describe the rainfall environment around the project site. The Aggeneys Pol rainfall gauge is located approximately 13.2 km northwest of the project site. The available rainfall data, a 69-year record spanning from 1950 to 2019, was obtained. A summary of the data is presented in Table 2-1.

. Rainfall data for the gauge was extracted using the Daily Rainfall Utility Program (DRU) - Institute for Commercial Forestry Research (ICFR). The programme uses a database of observed and patched daily rainfall data developed under the Water Resources Commission (WRC) project (K5/1156). The monthly averages for the record are presented in Table 2-2 while the daily rainfall data is presented in Figure 2-1.

The mean annual precipitation (MAP) from the observed records (unpatched) is 56.8 mm/annum and was checked against the average MAP of 92 mm/annum (patched) derived for the project site (29°15´S; 18°49´E) as per the Design Rainfall Estimation of South Africa database, discussed further in Section 2.3.

Table 2-1: Details of Raingauge Aggeneys Pol (0246555_W)

Parameter	Value
Latitude	-29.15
Longitude	18.49
Record start (year)	January 1950
Record end date (DRU record limit) (year)	December 2019
Years of record	69
Distance to site and direction (km)	11 km E
MAP (mm)	92
Max recorded daily rainfall (mm)	83
Altitude metres above mean sea level (mamsl)	825

Table 2-2: Monthly Average Rainfall for Aggeneys Rainfall Station (as calculated from the daily rainfall record)

Month	Average (mm/month)
January	12.1
February	4.4
March	8.1
April	7.8
May	1.9
June	3.9
July	0.7
August	2.9
September	0.5
October	1.7
November	10.8
December	2.0
Total	**56.8 (mm/annum)**

The MAP at the monitoring station is defined as 56.8 mm/annum (see Table 2-2). Figure 2-2 shows that there is a significant variation in annual rainfall where, 30% of the years' in the rainfall record experienced less than 53 mm. Whilst the driest year, which was 2019, experienced only 1 mm of rainfall and the wettest year, which was 1976, experienced 233 mm of rainfall.

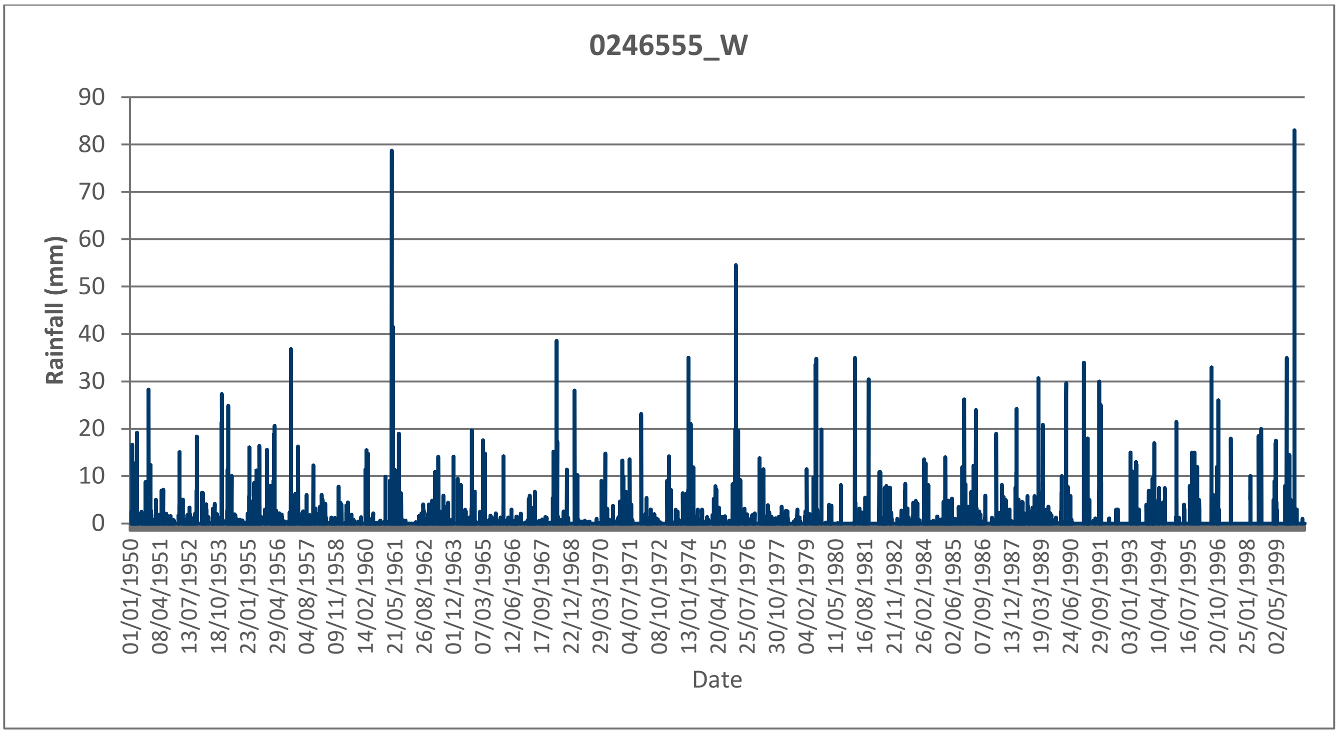

Figure 2-1: Daily Rainfall for the Aggeneys Rain gauge

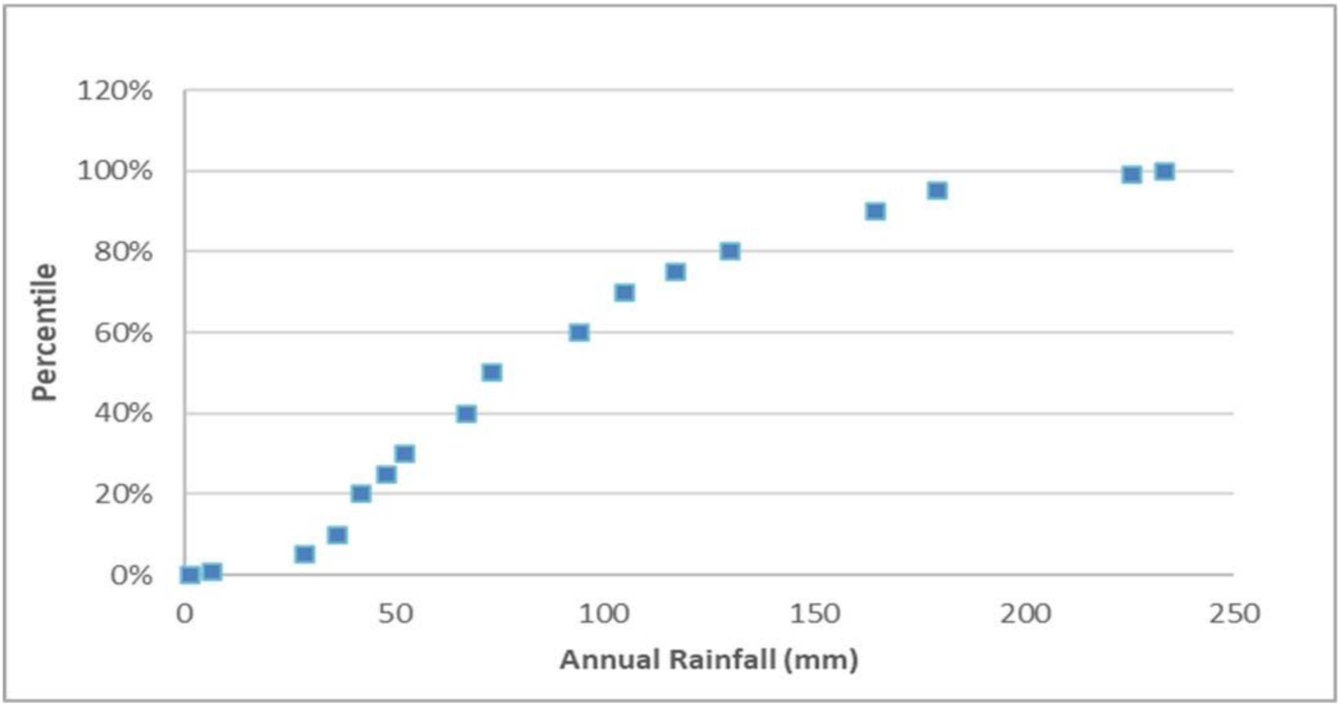

Figure 2-2: Percentile Distribution of Annual Rainfall Totals 1950 -2019 (Aggeneys)

2.2.2 Evaporation

Evaporation data is based on Symonds Pan (S-Pan) data taken from the WR2012 Database (WRC, 2012)[1] for the quaternary catchment D82C (in which the project site is located). S-Pan evaporation was converted to open water evaporation using evaporation coefficients from WR90 (WRC, 1990)[2] as presented in Table 2-3.

Table 2-3: Monthly Average Evaporation

Month	S Pan Evaporation (mm/month)	Pan Coefficient (WR90)	Lake Evaporation (mm/month)
January	346.1	0.84	290.7
February	291.2	0.88	256.3
March	273	0.88	240.2
April	196.1	0.88	172.6
May	131.4	0.87	114.4
June	99.1	0.85	84.2
July	97	0.83	80.5
August	135.7	0.81	109.9
September	191.6	0.81	155.2
October	251.8	0.81	203.9
November	297.3	0.82	243.8
December	339.7	0.83	282
Total	**2650 mm/annum**	**-**	**2233 mm/annum**

2.2.3 Design Rainfall

The design rainfall depths for the centroid of the site were extracted using the Design Rainfall Estimation software for South Africa (Smithers and Schulze, 2002)[3]. Depth Duration Frequency (DDF) rainfall estimates for the site were derived from the Smithers and Schulze method based on analysis of the six nearest rainfall stations (gridded rainfall).

The depths in millimetres for the 1:2-year, 1:5-year, 1:10-year, 1:20-year, 1:50-year, 1:100-year and 1:200-year return periods were determined as indicated in Table 2-4. The adopted storm rainfall depth which will be used in the peak flow calculations, is based on the gridded rainfall depths for the above six stations.

[1] Water Resources of South Africa, 2012 Study (WR2012). http://waterresourceswr2012.co.za/
[2] Water Resources of South Africa 1990 - Volume 1 Appendices. WRC Report 298/1.1/94
[3] Smithers, J.C. and Schulze, R.E., 2002. Design rainfall and flood estimation in South Africa. WRC Project No. K5/1060. Draft final report (Project K5/1060) to Water Research Commission, Pretoria, RSA. 155 pp

Table 2-4: Storm Depth-Duration-Frequency (DDF) Rainfall for the Project Site

Duration	Rainfall Depth (mm)						
	1:2year	1:5year	1:10year	1:20year	1:50year	1:100year	1:200year
5 minutes	4.9	8.3	11.0	14.1	18.8	22.9	27.8
10 minutes	7.1	12.0	16.0	20.4	27.2	33.3	40.3
15 minutes	8.8	14.9	19.8	25.3	33.8	41.4	50.0
30 minutes	10.7	18.1	24.0	30.7	41.0	50.1	60.6
45 minutes	11.9	20.2	26.9	34.3	45.8	56.0	67.8
1 hour	12.9	21.9	29.1	37.2	49.6	60.7	73.4
1.5 hours	14.4	24.5	32.5	41.6	55.5	67.9	82.1
2 hours	15.6	26.5	35.2	45.0	60.1	73.5	88.9
4 hours	17.7	29.9	39.8	50.9	67.9	83.0	100.4
6 hours	19.0	32.1	42.7	54.6	72.9	89.1	107.9
8 hours	19.9	33.8	45.0	57.5	76.7	93.8	113.5
10 hours	20.7	35.2	46.8	59.8	79.8	97.5	118.0
12 hours	21.4	36.3	48.3	61.7	82.4	100.7	121.8
16 hours	22.5	38.2	50.8	64.9	86.6	105.9	128.2
20 hours	23.4	39.7	52.8	67.5	90.1	110.2	133.3
24 hours	24.2	41.0	54.5	69.7	93.0	113.8	137.6
1 day	19.9	33.7	44.9	57.3	76.5	93.5	113.2
2 days	23.3	39.5	52.5	67.1	89.6	109.6	132.5
3 days	25.6	43.3	57.6	73.6	98.3	120.2	145.4
4 days	26.6	45.2	60.1	76.8	102.5	125.3	151.6
5 days	27.5	46.7	62.0	79.3	105.8	129.4	156.5
6 days	28.3	47.9	63.7	81.4	108.6	132.8	160.7
7 days	28.9	49.0	65.1	83.2	111.1	135.8	164.3

2.3 HYDROLOGICAL SETTING

The Gamsberg Zinc Mine Mining Right Area (MRA) is influenced by four quaternary catchments D81G, D82A, B82B and B82C (Figure 2-3). The D81G catchment drains into the Orange River and the D82C catchment is an interior drainage basin that does not drain into the another catchment.

Most of the water courses in the area are transient but the small catchment area on top of the Gamsberg Mine contains a spring and can experience seasonal flows.

The most significant watercourse to be considered for this scope of work is a drainage line running parallel to the N14 at the base of the northern side of the Gamsberg. Quaternary catchment D82C is an endoreic catchment, which implies only that it is an interior drainage basin that does not drain to the sea.. The regional hydrology is presented in Figure 2-3.

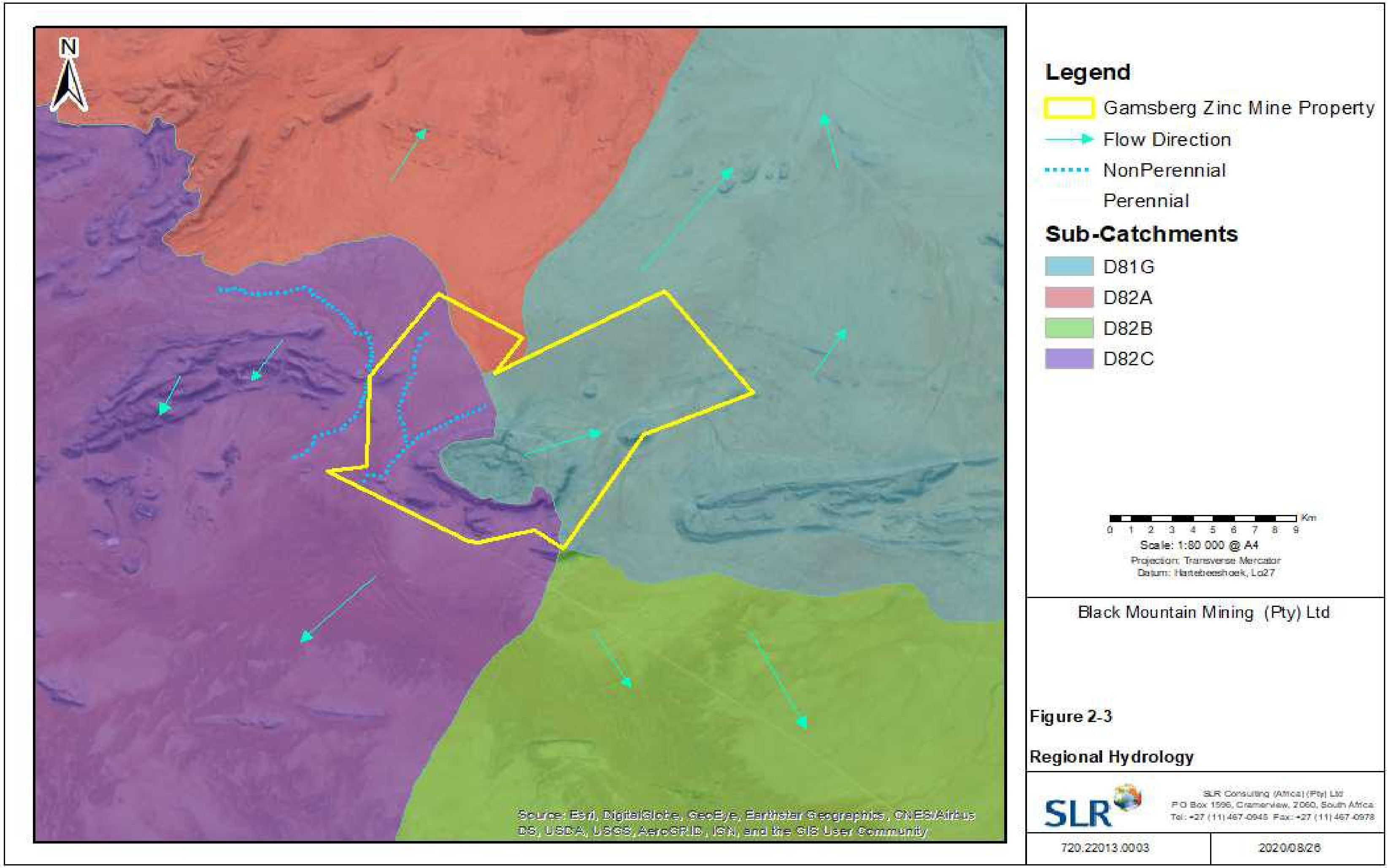

Figure 2-3: Regional Hydrology around the Gamsberg Zinc Mine showing Quaternary catchments

The WRSM2000 hydrological model simulates naturalized runoff for quaternary catchments D81G, D82A, D82B and D82C at a unit runoff of 0.28 mm per annum. The runoff is 0.5% when it is expressed as a percentage of the annual rainfall. The monthly runoff for quaternary catchments D81G, D82A, D82B and D82C is presented in Table 2-5. The low flows from these areas can be attributed to the high evaporation rates within the region.

Table 2-5: Mean Annual Runoff (mm) for Quaternary Catchment D81G, D82A, D82B and D82C

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.02	0.09	0.04	0.02	0.01	0.28

2.4 TOPOGRAPHY

According to ERM (2013) the local topography is characterised with undulating plains, containing low growing shrubby vegetation and grasses. The surrounding plains are approximately 750 – 900 metres above mean sea level (mamsl).

Gamsberg is located on a flat expansive plain with gentle rolling topography protruding above the plain. The soils present in the area are reddish and predominantly shallow and stony. The western and southern portions of the site have deeper red soils.

2.5 WATER SUPPLY

Water is currently supplied to the mine by Sedibeng Water via two existing pipelines from the Orange River. The existing water system has a common intake, low lift pump house and low lift pipeline. The low lift pumping system is feeding two circuits, namely the Black Mountain Mine circuit and the Gamsberg Zinc Mine circuit. Both the circuits consist of a flash mixer, clarifier, dosing system, sludge handling facility, balancing reservoir, high lift pump house, high lift pipelines and Horseshoe Reservoir with associated facilities. The current and future water demand, within the Black Mountain Mine operation, including Aggenneys, Pofadder and Pella towns is 43.45 ML/day, the existing intake water pumping system has been designed for 40.8 ML/day.

The existing bulk water pipeline infrastructure running from the Horseshoe Reservoir to the Gamsberg takeoff covers a distance of approximately 4km and consists of one 400mm diameter underground pipeline and one 400mm aboveground pipeline. A 400mm HDPE diameter aboveground bulk water pipeline runs from the Gamsberg takeoff where the pipeline splits off from the Main Bulk Water Pipeline to the Gamsberg reservoir (25Ml) over a distance of 3km.

2.6 WATER DEMAND

For the Gamsberg Smelter project, water is required for the process plant, drinking, sanitation and other miscellaneous uses like canteen, safety shower, etc. The individual water demands for the various consumers, both existing as well as the proposed plants, are presented in Table 2-6.

Table 2-6: Water Demand in MLD for Existing and Proposed Plant (SLR Consulting, 2020)

Consumers	BMM Operations		Gamsberg Operations		
	1.6 MTPA	2.0 MTPA	Concentrator-1	Concentrator-2	Smelter-1
	(Existing)	(Future)	(Existing)	(Future)	(This Project)
Plant	3	0.5	7	6	8
Mining	3	0.5	2	1.5	

Consumers	BMM Operations		Gamsberg Operations		
	1.6 MTPA	2.0 MTPA	Concentrator-1	Concentrator-2	Smelter-1
	(Existing)	(Future)	(Existing)	(Future)	(This Project)
Aggeneys town	4		0.75	0.6	1.5
Pofadder town	1			0.2	0.5
Pella town	3			0.2	0.2
Total for element	14	1	9.75	8.5	10.2
Total Cumulative	**14**	**15**	**24.75**	**33.25**	**43.45**

3. WATER QUALITY

The water quality assessment for this study was limited as there is no database of water quality data for surface run off for the Gamsberg site. However, a review was undertaken of an existing one-year record of water quality data from the SRK Gamsberg Zinc Project Baseline study (SLR Consulting, 2010). The existing baseline water quality analysed in this study was undertaken prior to the start of mining at Gamsberg Zinc Mine which began operating in 2016.

Ten surface water monitoring points were selected on the site and surveyed, however, only three monitoring points were sampled and analysed due to a lack of rainfall during the monitoring season. The surveyed and monitored points are presented in Table 3-1 and Figure 3-1.

The results have been compared to the South African National Standards (SANS) for drinking water quality (SANS241:2006) and the Department of Water Affairs Guidelines for livestock watering (DWAF, 1996) since these are the two most likely water uses for the springs and farm dams in the area. The relevant standards and guidelines are presented in Table 3-2.

Table 3-1: Description of Surface Water Monitoring Points (SRK Consulting, 2010)

Sample ID	Site Name	Location	Coordinates		Flow/water level measurements
			Latitude	Longitude	
AG1SW	Site 1	Aggeneys farm, Aggeneys tributary intersection with N14, upstream of Site 2. Near Aggeneys turnoff, opposite wildkamp.	-29.28152	18.83941	Level & quality
AG2SW	Site 2	Aggeneys farm, Aggeneys tributary draining to the north, upstream of Site 3. Opposite loop10 road.	-29.23827	18.87533	Quality
AR2SW	Site 4	Aroams farm, Gamsberg road, east of hill.	-29.24631	18.92000	Quality
GAMS1SW	Site 5	Gams farm, spring in drainage line on eastern side of Gamsberg.	-29.25250	19.01539	Quality
GAMS2SW	Site 6	Gams farm, farm dam between Site 9b and Site 5. Stream north of old Gams farmhouse.	-29.22528	19.01778	Level & quality
KL1SW	Site 7	Koups Leegte farm, at junction of kloof tributary and N14, downstream of Site 6.	-29.15444	19.10659	Level & quality
KP1SW	Site 8	Klein Pella farm, at junction of tributary and farm access road. Fannies' Drif.	-29.08389	19.01703	Level & quality
GAMS3SW	Site 9a	Gams Farm Spring in northern kloof, draining Gamsberg.	-29.23260	18.98096	Quality
GAMS4SW	Site 9aW3	Gams Farm Pond located in the northern kloof.	-29.23089	18.98053	Quality
GAMS5SW	Site 9b	Gams farm, access road, runoff east of inselberg.	-29.23997	19.01736	Quality

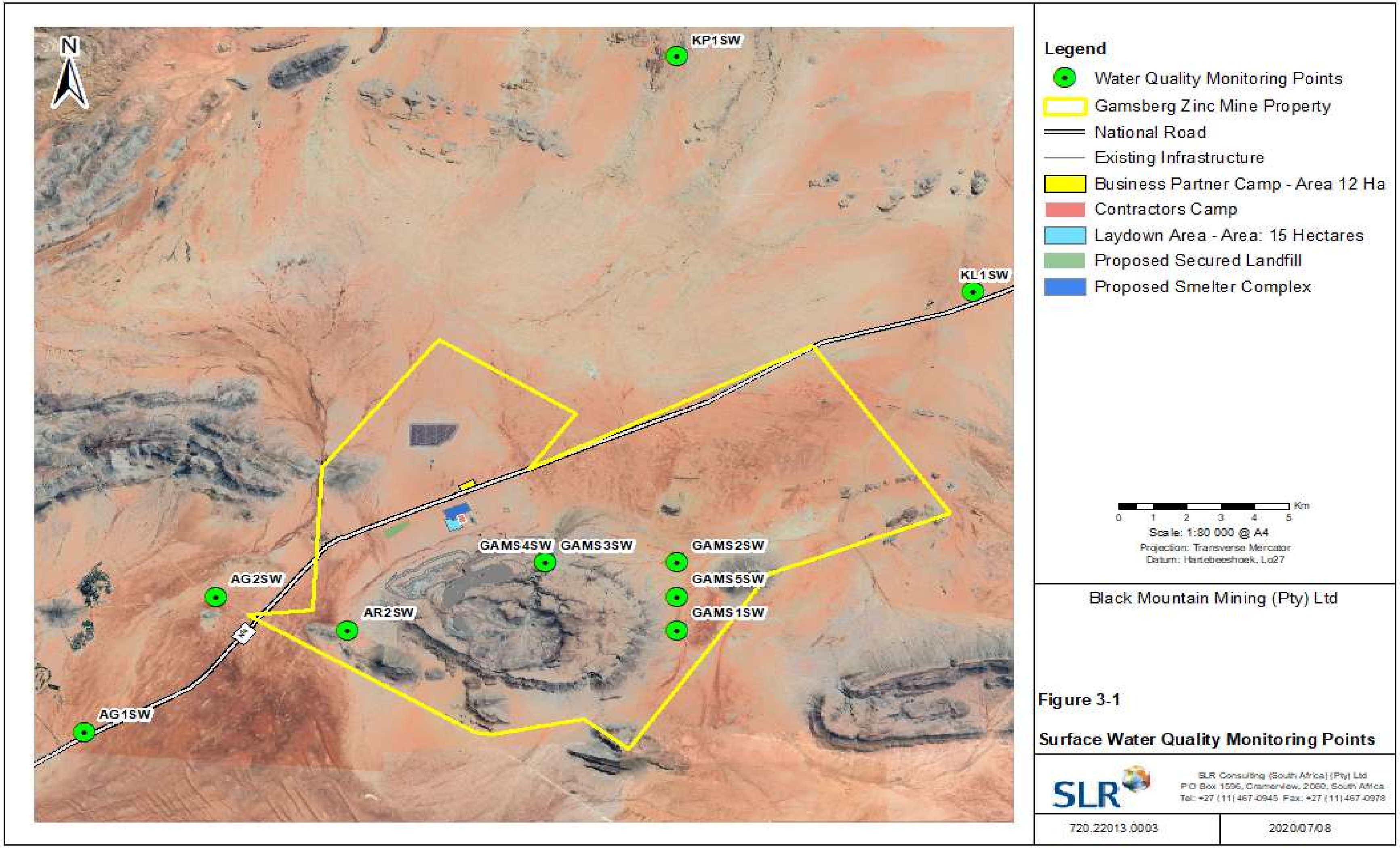

Figure 3-1: Surface Water Quality Monitoring Points

3.1 WATER QUALITY ANALYSIS

All parameters were within the limits of the SANS241: 2006. The SANS241 Guidelines showed exceedances in Barium noted at the monitoring points GAMS 1SW and GAMS 3SW. The excedences in Barium can be attributed to historic barite mining activities undertaken on the north-eastern side of Gamsberg Mine.

According to SRK Consulting (2010), it is evident that the water emerging as springs from the Gamsberg Inselberg was fit for domestic use and livestock watering. However, it must be noted that although the barium values comply on average over the monitoring period there were instances where certain samples did not comply with the WHO guideline concentration level for drinking water (see grey shaded cells in Table 3-2).

The results were consistent between consecutive months over the monitoring period for the majority of parameters monitored with the most notable exception being nitrate in GAMS 1SW. Nitrate in July and August was ten times greater than that in May and June although still within the SANS for Class I drinking water quality. This high concentration in nitrate was considered likely to be related to fertilizer, livestock or sanitation impacts (SRK Consulting, 2010).

Some seasonal variation during the higher rainfall months of February and March may be anticipated with an initial peak in concentrations due to constituents that have built up on surfaces being washed into runoff or infiltrating into the groundwater, followed by dilution effects once these first flush constituents have been removed. These effects are likely to be less evident in the natural springs due to the filtering effects of the soil and the time lag for recharge to groundwater (SRK Consulting, 2010).

Table 3-2: Surface Water Quality Data (SRK Consulting, 2010)

Parameter	Units	South African National Standard for drinking water (SANS241: 2006)		Livestock Watering Guidelines (DWAF, 1996)			09-May	09-Jun	09-Jul	09-Aug	09-May	09-Aug	09-May	09-Jun	09-Jul	09-Aug
		Class I (recommended)	Class II (max allowable)	Target Range	Chronic effects	Acute effects	GAMS 1SW (spring)				GAMS 3SW (spring)		GAMS 1SW (spring)			
pH Value @ 20°C	Unitless	5.0 – 9.5	4.0 – 10.0	-	-	-	6.5	6.6	6.4	6.2	7.9	6.6	7.1	8.2	8.2	8.1
Conductivity mS/m @ 25°C	mS/m	<150	> 150 – 370	-	-	-	23.3	24	23.4	23.3	52.5	16.1	35.1	54.6	58.1	53
Total Dissolved Solids	mg/l	<1000	>1000 – 2400	0 – 2000	2000 – 7000	>7000	214	162	152	156	418	124	294	363	406	374
Calcium, Ca	mg/l	<150	>150 – 300	0 – 1000	1000 – 2000	>2000	10.6	8.7	10.5	6.9	57	6.4	46	48	54	46
Magnesium, Mg	mg/l	<70	>70 – 100	-	-	-	9.1	7.8	7.7	8.1	19.6	6.5	11.9	17.7	17.4	16.2
Sodium, Na	mg/l	<200	>200 – 400	0 – 2000	2000 – 4000	>4000	29	27	25	23	36	15.1	21	35	44	35
Potassium, K	mg/l	<50	>50 – 100	-	-	-	2.6	1.8	2.5	1.9	3.2	3	6.6	4.8	4.3	2.4
Total Alkalinity as CaCO3	Ns	Ns	Ns	Ns	Ns	Ns	28	19	20	21	140	16	120	137	138	124
Bicarbonate, HCO3	Ns	Ns	Ns	Ns	Ns	Ns	34	23	24	26	171	20	146	167	168	151
Carbonate, CO3	Ns	Ns	Ns	Ns	Ns	Ns	Nil	0	0	Nil	Nil	Nil	Nil	0	0	Nil
Chloride, Cl	mg/l	<200	>200 – 600	0 – 3000	3000 – 6000	>6000	47	45	37	37	72	22	37	62	74	69
Sulfate, SO_4	mg/l	<400	>400 – 600	0 – 1000	1000 – 2000	>2000	18.6	25	17.1	18.1	21	30	13.4	22	30	28
Nitrate, NO_3 as N	mg/l	<10	>10 – 20	0 – 200	200 – 400	>400	0.4	0.3	4.5	3.9	0.3	0.2	0.4	0.2	0.1	0.1
Fluoride, F	mg/l	<1.0	>1.0 – 1.5	0 – 6.0	6.0 – 12	>12	0.2	1	0.2	0.2	0.1	<0.1	0.2	0.2	0.1	0.1
Total Suspended Solids	mg/l	Ns	Ns	Ns	Ns	Ns	<1	-	<1	<1	<1	<1	<1	-	<!	<1
Turbidity, NTU	mg/l	<1.0	1.0-5.0	Ns	Ns	Ns	0.6	-	-	0.5	0.54	0.55	0.65	-	-	0.8
Total Phosphate, PO_4	mg/l	Ns	Ns	Ns	Ns	Ns	0.2	-	<0.1	0.8	0.7	0.4	2.1	-	<0.1	0.4
Ortho Phosphate, PO_4	mg/l	Ns	Ns	Ns	Ns	Ns	0.1	-	<0.1	0.4	0.7	0.3	2.1	-	0.2	0.3
Free Ammonia as NH_4	mg/l	<1.0	1.0-2.0	Ns	Ns	Ns	<0.1	-	<0.1	<0.1	<0.1	<0.1	<0.1	-	<0.1	<0.1
Total Nitrogen as PO4	Ns	Ns	Ns	Ns	Ns	Ns	<0.1	-	<0.1	<0.1	<0.1	<0.1	<0.1	-	<0.1	<0.1
Arsenic, As	mg/l	0.01-0.05	>0.05	<1.0	1-1.5	>1.5	0.002	<0.001	<0.02	0.002	0.002	<0.001	0.002	0.001	<0.02	0.01
Aluminium, Al	mg/l	0.3-0.5	>0.5	<5	5.0-10	>10	<0.009	0.008	<0.009	<0.009	<0.009	0.01	0.09	0.008	0.009	0.36
Manganese, Mn	mg/l	0.1-1.0	>1.0	<10	Oct-50	>50	<0.001	<0.001	0.03	0.005	0.005	<0.001	0.15	<0.001	0.03	0.02
Iron, Fe	mg/l	0.2-2.0	>2.0	<10	Oct-50	>50	0.04	0.12	0.05	0.09	0.09	0.06	0.1	0.07	1.1	0.23
Zinc, Zn	mg/l	5.0-10	>10	-	-	-	0.51	0.04	0.82	0.41	0.41	<0.005	0.55	0.07	1.1	0.74
Lead, Pb	mg/l	0.02-0.05	>0.05	<0.1	0.1-1.0	>1.0	<0.001	<0.001	<0.01	0.003	<0.001	<0.001	<0.001	<0.001	<0.01	0.001
Copper, Cu	mg/l	1.0-2.0	>2.0	<0.5	0.5-10	>10	0.005	<0.002	<0.002	0.007	0.005	<0.003	0.003	<0.002	<0.002	0.03
Chromium, Cr (VI)	mg/l	0.1-0.5	>0.5	<1.0	1.0-2.0	>2.0	<0.003	<0.003	<0.003	0.008	<0.003	<0.003	<0.003	<0.003	<0.003	0.007
Cadmium, Cd	mg/l	0.005-0.01	>0.01	<0.01	0.01-0.02	>0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001

Parameter	Units	South African National Standard for drinking water (SANS241: 2006)		Livestock Watering Guidelines (DWAF, 1996)			09-May	09-Jun	09-Jul	09-Aug	09-May	09-Aug	09-May	09-Jun	09-Jul	09-Aug
		Class I (recommended)	Class II (max allowable)	Target Range	Chronic effects	Acute effects	GAMS 1SW (spring)				GAMS 3SW (spring)		GAMS 1SW (spring)			
Uranium, U	mg/l	Ns	Ns	Ns	Ns	Ns	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Barium, Ba	mg/l	<0.7	-	Ns	Ns	Ns	0.08	0.36	0.22	**1.3**	0.1	0.05	0.11	**0.78**	0.04	**1.2**

4. FLOOD LINE DETERMINATION

4.1 METHODOLOGY

The flood line determination and assessment methodology followed here is discussed in the subsections below and summarised in Figure 4-1.

4.1.1 Information Sourcing and Literature Review

A review of various information sources was undertaken to define the baseline climatic and hydrological conditions of the site and surroundings. A hydro-meteorological analysis was carried out using the data obtained from the following sources:

- Water Resources (WRC, 2012) database;
- The Daily Rainfall Extraction Utility programme;
- Design rainfall software (Smithers and Schulze, 2002); and
- The South African Atlas of Climatology and Agro-hydrology (WRC, 2008) which was used to classify general land cover.

4.1.2 Site Visit

The site visit was undertaken by Kevin Bursey (SLR Consulting) on the 6th July 2019. The culverts, hydraulic information and the catchment conditions were documented in the form of photos and field notes.

4.1.3 Topographical Data

The topographical data forms the foundation for the HEC-RAS model and is used to extract elevation data for the river profile together with the river cross-sections. The topographical data is also used to determine placement positions for the cross-sections along the river profile, so that the watercourse can be accurately modelled.

Site topographical information was provided by the client in the form of a contour survey. The contour plan covered the entire site and the contour interval was 0.5m and 1m which were merged into one plan.

4.1.4 Design Flood Peaks

Three methods were used to determine design flood peaks for the delineated catchment (Figure 4-2) at the site. The underlying assumption is that the largest possible peak flow will be observed when the storm rainfall event has a duration equal to the time of concentration of the catchment, i.e. the time required for the entire catchment to contribute runoff at the outlet (SANRAL, 2013). The three methods which were used to evaluate the relevant design flood peaks for the site are as follows:

- Rational Method Alternative 3;
- Standard Design Flood Method; and
- Empirical Method (Midgley and Pitman).

A short description of the above-mentioned methods is provided in the following subsections.

Rational Method Alternative 3

The Rational Method Alternative 3 (RM3) uses storm rainfall and catchment characteristics to generate flood peaks. The Rational Method formula indicates that Q = CiA, where the product of rainfall intensity (i) and catchment area (A) is equal to the inflow rate of the system (iA) and C is the runoff co-efficient. The Rational Method yields a design peak only and the flood response is a function of the catchment slope, land-use, land cover, MAP (i.e. point precipitation) and return interval (RI). The time of concentration (Tc) of the flood peak is a function of the catchment dimensions, specifically the watercourse length and slope. The Rational Method was developed for small catchments (<15km^2) but can be used on large catchments by experienced engineers (SANRAL, 2013).

Standard Design Flood Method

The Standard Design Flood (SDF) method specifically addresses the uncertainty in flood prediction under South African conditions. The runoff coefficient (C) used in the Rational Method is replaced by a calibrated value based on the sub division of the country into 29 regions or Water Management Areas (WMAs) by using the 2-year mean of the annual daily maximum rainfall and average number of days per year on which thunder was heard. The method is generally a more conservative estimate than the Rational Method. The SDF Method can be applied to catchments from 10km^2 to 40 000km^2 in area.

Empirical Method

Empirical Methods (MIPI) are based on the correlation between peak flows and some catchment characteristics. Regional parameters have been mapped for South Africa based on these correlations. These methods are mostly suitable for medium to large catchments (SANRAL, 2013). The MIPI method was employed within this study to determine the design flood peaks and is suitable for obtaining an advance indication of the order of magnitude of peak discharges, thus serving as a rough check on the results of non-statistical methods (SANRAL, 2013).

4.2 FLOOD LINES HYDRAULIC MODELLING

Flood lines for the one identified watercourse were analysed for the 1 in 100-year recurrence interval storm events. The streams included in the analysis were those agreed-upon by SLR and the Client in the proposal phase of this study, augmented by further rivers and streams identified in the DWS database (DWS, 2016).

4.3 CHOICE OF SOFTWARE

HEC-RAS 5.0.3 was used for the purpose of modelling the flood elevation profile for the 1:100-year flood event. HEC-RAS is a hydraulic programme designed to perform one-dimensional hydraulic calculations for a range of applications, from a single watercourse to a full network of natural or constructed channels. The software is used worldwide and has consequently been thoroughly tested through numerous case studies.

In this study the following software were used:

- Arc GIS 10.5 for Geographic Information Systems (GIS) work and mapping (ESRI, 2012);
- HEC-GeoRAS programme (US Army Corps of Engineers, 1995); and
- HEC-RAS hydraulic model (US Army Corps of Engineers, 1995).

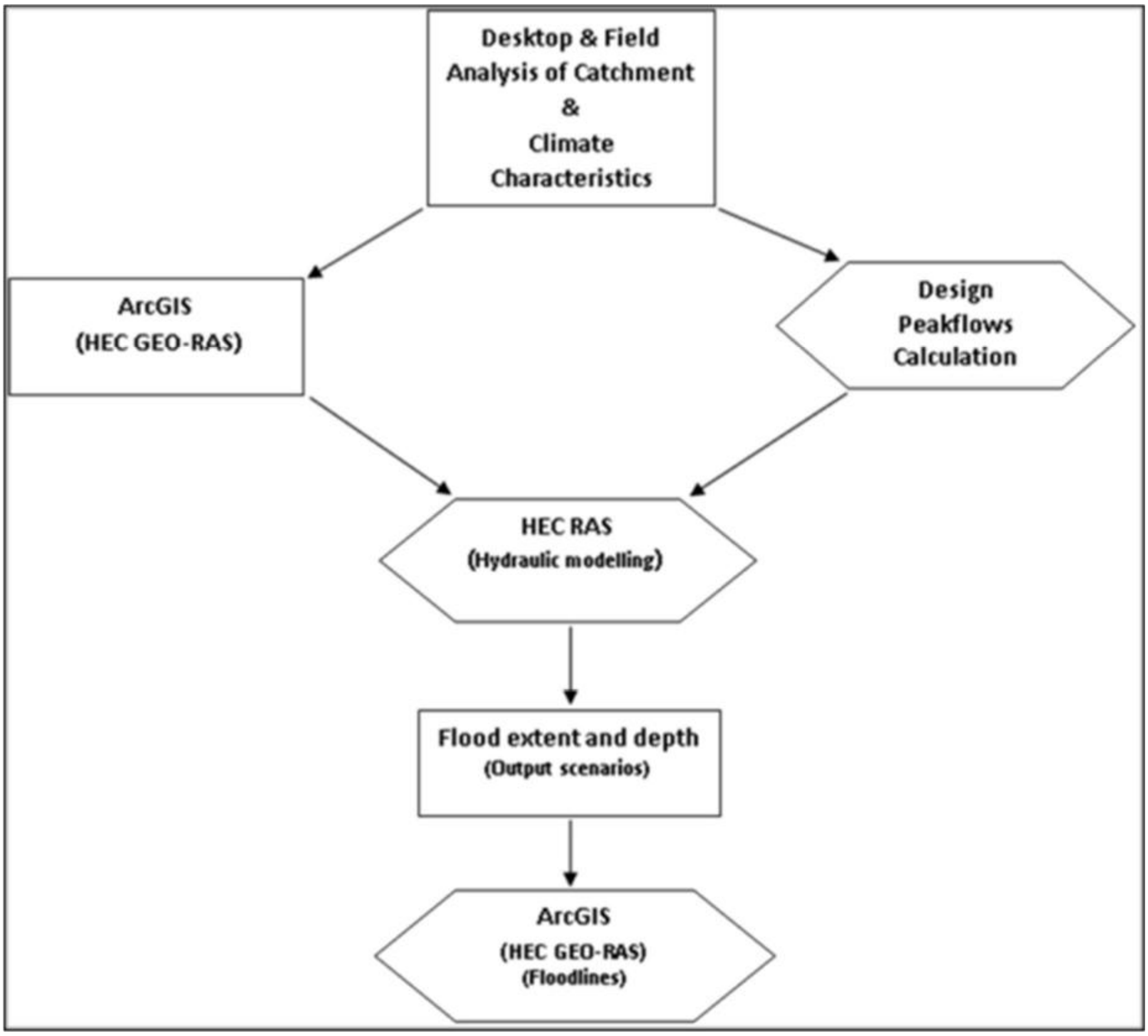

Figure 4-1: Summary of Flood line Methodology

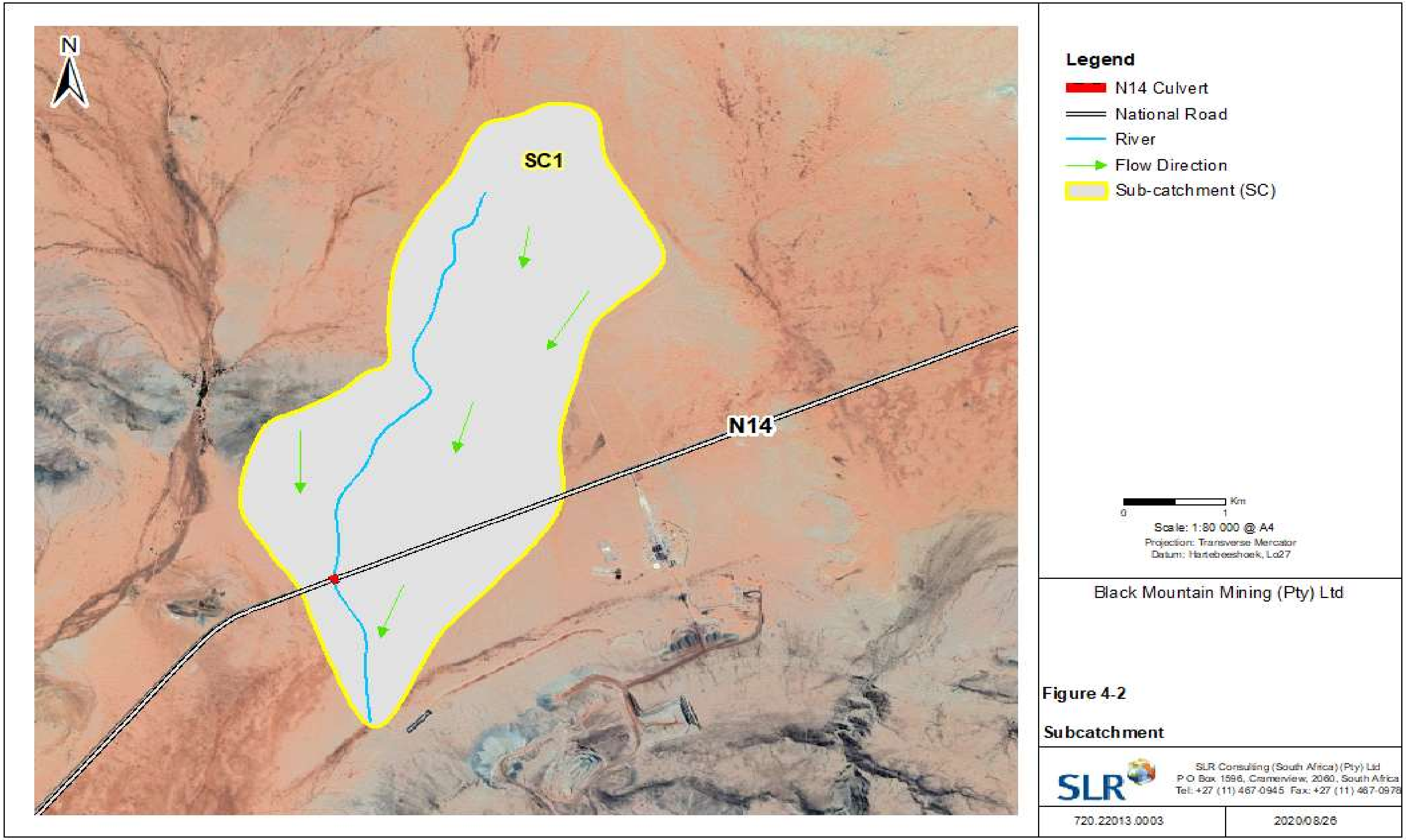

Figure 4-2: Delineated Sub-catchment

4.4 FLOOD HYDROLOGY

4.4.1 Catchment delineation

One sub-catchment was delineated for modelling purposes for the one stream that would be influenced by the proposed Gamsberg Smelter Project. The sub-catchment characteristics are shown in Table 4-1.

Table 4-1: Sub-Catchment Characteristics

Parameter	Value
Area (km^2)	13
Length of longest watercourse (km)	6
Equal area height difference (m)	46
10 – 85 slope height difference (m)	0.0102
Distance to catchment centroid (km)	2.98
Time of concentration (hours)	2.09

4.4.2 Flood peak estimates and boundary conditions

Design peak flows for the 1:100-year recurrence interval storm event was computed for the watercourse in the study site using the RM3, SDF and MIPI methodologies. This was undertaken in order to compare the results obtained by these methods. The comparison of the different flood peaks, using different methodologies, can be seen in Table 4-2.

Table 4-2: Results of the Deterministic Flood Peak Calculations

Method	1:50 Year RP (m^3/s)	1:100 Year RP (m^3/s)
Rational Method using Alternative Algorithms	39.4	55.5
Standard Design Flood Method (SDF)	39.4	49.3
Empirical Method (MIPI)	10.5	13.3

The SDF and RM3 methodology resulted in flood peaks of similar magnitude while MIPI resulted in lower flood peaks. Flood Peaks calculated using Rational Method were adopted because they are conservative and considers a worst case scenario. The selected flood peaks shown in Table 4-3.

Table 4-3: Recommended Flood Peaks to be used in the flood line Determination

Flood Peaks	Stream 1:50 Year (m^3/s)	Stream 1:100 Year (m3/s)
Recommended flood peaks to be used in the flood line determination	39.4	55.5

4.5 HYDRAULIC FLOOD MODELLING

4.5.1 Hydraulic structures

The notable hydraulic structures which would provide controls for the flood flow and which were therefore input into the model were:

- Culvert 1 - Culvert and road crossing on the N14 road in the downstream section of the river reach. The culvert is a single bore concrete pipe, circular in shape, measuring 600 mm in diameter. The road deck was 0.3 m above the top of the pipe.

4.6 ROUGHNESS COEFFICIENTS

The Manning's roughness factor "n" is used to describe the flow resistant characteristics of a specific surface. Based on the site visit undertaken, it was observed that the water channel could be described as: irregular sections with pools, fairly regular sections, unmaintained sections, vegetated and some weedy channels;

- an "n" value of 0.025 was therefore assigned to the channel and banks (floodplains).

4.7 ASSUMPTIONS IN THE HYDRAULIC MODEL

In-line with the development of the flood lines the following assumptions were made:

- The topographic data provided was of a sufficient accuracy and coverage to enable hydraulic modelling at a suitable level of detail;
- Hydraulic structures such as culverts at the site boundary were modelled as part of this study;
- The Manning's 'n' value used is considered suitable for use in all the modelled storm events (1:50 and 1:100 year events), as well as in representing both the channel and the floodplain;
- No alternative abstractions from the river section or discharges into the river section were taken into account during the modelling;
- Levees have been added to confine the modelling to the stream;
- Steady state hydraulic modelling was undertaken, which assumes the flow is continuous at the peak rate; and
- A mixed flow regime which is tailored to both subcritical and supercritical flows was selected for running of the steady state model.

4.8 FLOOD LINE DELINEATION FOR THE CURRENT SCENARIO

Flood lines for the 1:100-year recurrence intervals were determined for the current river network passing through the project site and with the 100m buffer from the watercourses. These flood lines are presented in Figure 4-3.

All the proposed infrastructure associated with the Smelter is located outside of any of the calculated flood lines except for the proposed SLF. Condition 7 of the GN704 indicates that no residue deposit or associated activity may be located or placed within the 1:100-year flood line or within a horizontal distance of 100 metre from any watercourse, whichever is greatest. It is therefore recommended that the SLF be relocated outside the floodlines.

In the event that the SLF cannot be relocated, a flood protection berm has been proposed that partitions the slope from the level space around the SLF. This flood protection berm will need to be 0.8 m high along its full alignment. The river, that the flood protection berm is protecting the SLF from, is diffuse with many smaller rivulets. In a flood event, this will take the form of one stream flowing strongly for a short period of time (due to the catchment size).

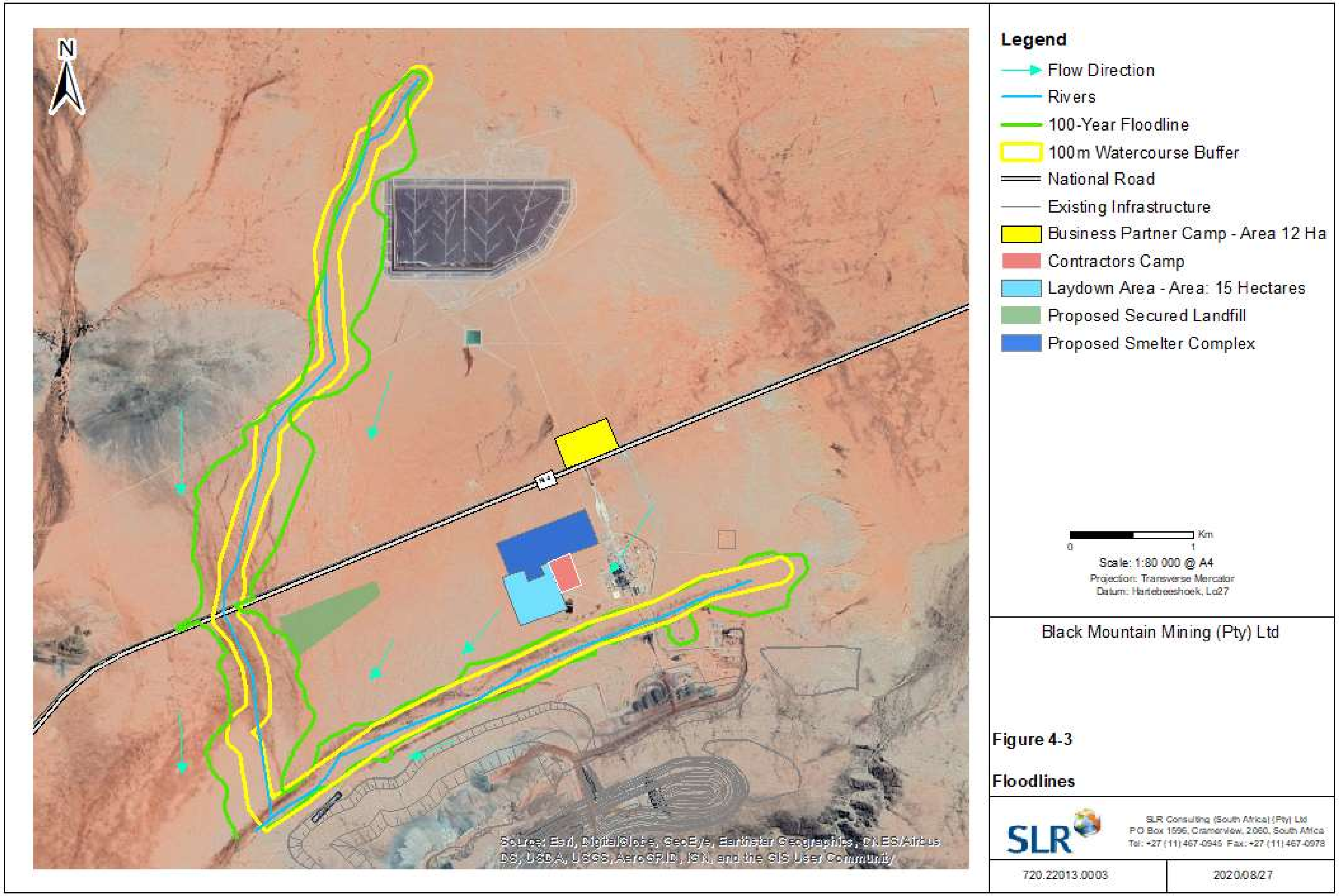

Figure 4-3: 1:100-Year flood lines for the Streams adjacent to the Project Site

5. PROPOSED STORM WATER INFRASTRUCTURE

Informed by the situation appraisal of the site and its surroundings (as presented in Section 2), a series of design principles for storm water management have been developed to ensure compliance with the requirements of GN 704 and the BPGs.

The following terms were used to describe the elements of the Personal Computer Storm water Management Model (PCSWMM) Software used for the development of the SWMP.

Table 5-1: Definition of the SWMP terms

SWMP Element	Description
Catchment (S)	That area determined by topographic features within which falling rain will contribute to runoff to a particular point under consideration.
Conduit (C)	Any artificial or natural duct, either open or closed, intended for the conveyance of fluids.
Weir	An overflow structure across a channel which may be used for controlling the upstream surface level, or for measuring discharge, or for both; usually used in combination with a description of the shape of the notch or the form of the crest.
Channel	A perceptible natural or artificial waterway which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. It has a definite bed and it has banks which confine the water.
Outfall or outlet (O)	The point, location or structure where water or drainage discharges from a stream, river, lake, tidal basin or drainage area; or pipe, channel, sewer, drain, or other conduit.
Flood Protection Berm	A flood protection berm is a level space or raised barrier separating two areas that aims to protect against flooding by partitioning the slope with level and reduced flow velocity.

5.1 DESIGN STANDARDS

As discussed in Section 1.3, GN 704 requires the following:

- Capacity: dirty water systems are to be designed, constructed, maintained and operated so that they are not likely to spill into any clean water system or the environment more frequently than once in 50 years.
- Conveyance: all water systems are to be designed, constructed, maintained and operated so that they convey a 1:50 year flood event.
- Freeboard: as a minimum, any dirty water dams are to be designed, constructed, maintained and operated to have 0.8m freeboard above full supply level.
- Collect and Re-Use: it is required that dirty water be collected and re-used as far as is practicable.
- Diversion: the flow of any surface water or floodwater into operational areas must be minimised.
- Utilising the proposed Smelter and SLF layout provided by the Black Mountain Mining (Pty) Ltd, the clean and dirty water catchment areas were delineated and classified according to the expected quality of the storm water runoff which is expected to be generated from each catchment as presented in Figure 5-1.

The zoomed-in extents for the storm water infrastructure around the Smelter Complex and the SLF are presented in Figure 5-2: Sub-catchments and Proposed Storm water Infrastructure Layout around the Smelter Complex Figure 5-2 and Figure 5-3, where:

- Clean water catchment areas include the areas upstream and to the north east of the Smelter and the SLF including the connecting road; and
- Dirty water catchment areas include the Smelter and the SLF, most of the dirty water catchment within the Smelter areas will be paved.

The proposed conceptual storm water management layout plan, including selected the main channels and the preliminary design dimensions, are presented in Figure 5-2. The key features include:

- Clean storm water will be prevented from entering dirty water catchments by creating perimeter berms around the Smelter and the SLF footprints (channels and berms);
- Storm water generated from the upstream areas will be considered clean and managed by clean water diversion berms or unlined clean water channels, and diverted around dirty areas;
- Dirty water generating areas within the Smelter will be on hardstanding cover and the runoff generated will be collected in the dirty water channels;
- Dirty storm water will be collected by concrete lined open channels and circular culverts and conveyed to the SWDs. Open channels are preferred for ease of maintenance and to minimise the depth of the excavation below ground level to accommodate the infrastructure design capacity, whilst maintaining suitable drainage gradients;
- Some smaller storm water structures are also required in selected places in the form of berms (speed bumps) and small concrete walls to redirect storm water into the desired collection channels;
- Collected storm water in the channels is passed through one silt trap before being conveyed into the storm water dams. The sediment being transported in the storm water (likely to include concentrate) can then be recovered from the silt traps. The silt traps are sized to accommodate runoff generated off the smelter and into the conveyance networks during the 1:5-year, 24-hour duration storm event;
- Some ‘speed bump’ size berms may need to be created to direct water towards the correct channel;
- Ground levels may need to be raised in certain areas, to achieve drainage gradients and remove low spots although this will need to be confirmed through more detailed survey and design work;
- The SWD will be a lined facility and will be equipped with a return water pumping system; and
- A flood protection berm that aims to protect against flooding by partitioning the slope with level and reduced flow velocity is required to prevent the possibilities of flooding around the SLF.

In order to meet the design principles detailed above, conceptual designs for the proposed storm water management measures have been calculated and are presented below, along with the specific hydraulic design standards, methodologies, assumptions and input parameters for each measure proposed.

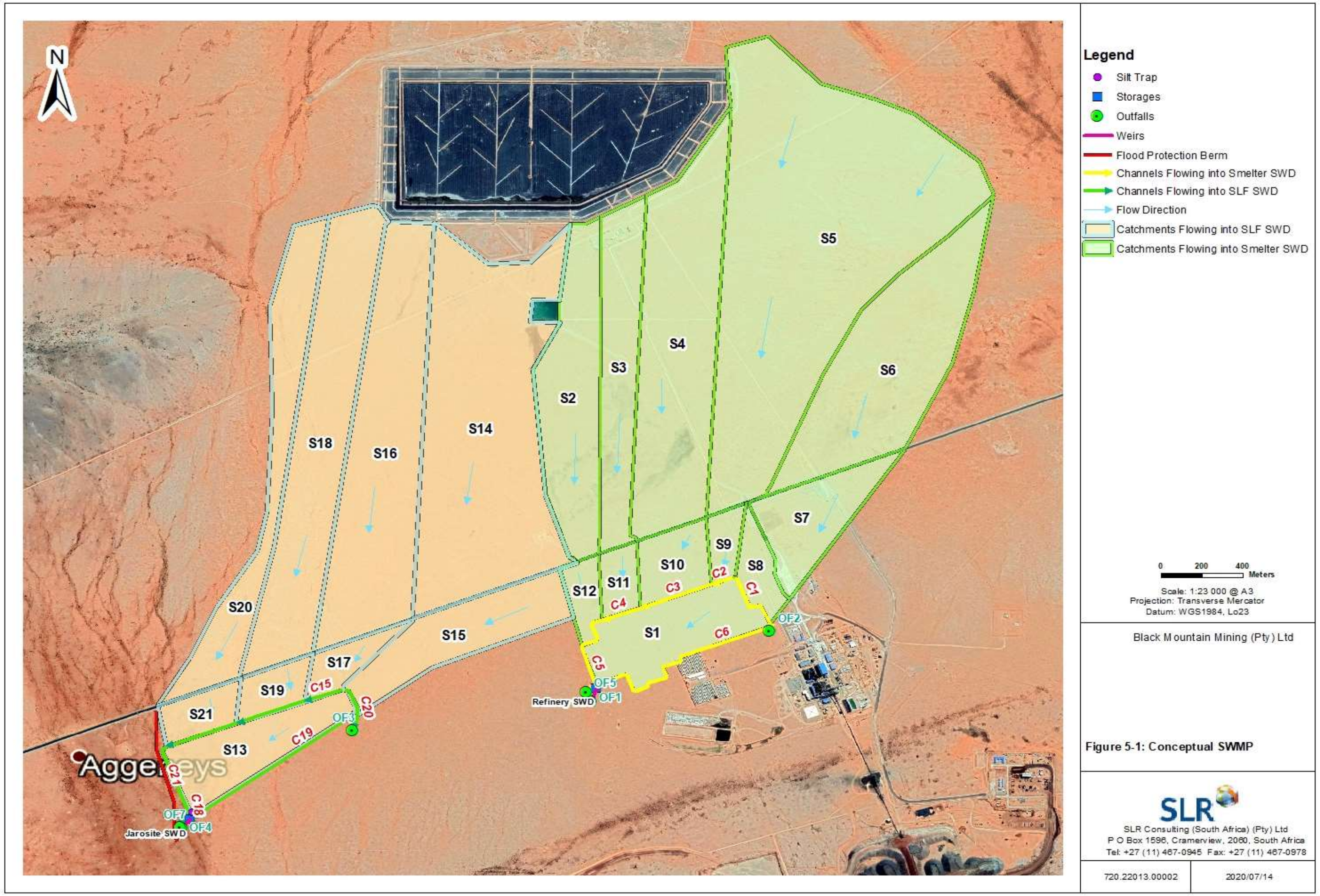

Figure 5-1: Sub-catchments and Proposed Storm water Infrastructure Layout

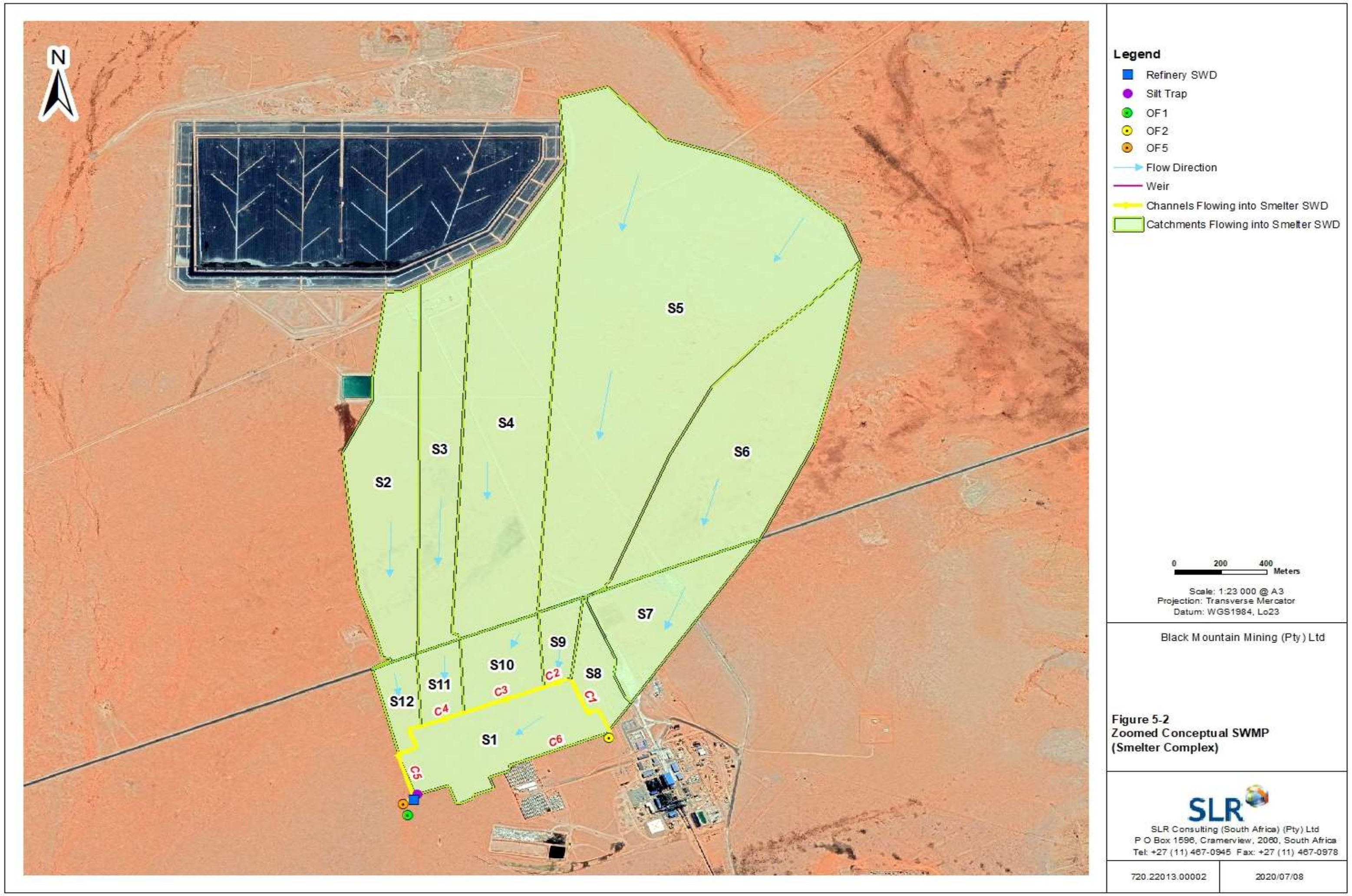

Figure 5-2: Sub-catchments and Proposed Storm water Infrastructure Layout around the Smelter Complex

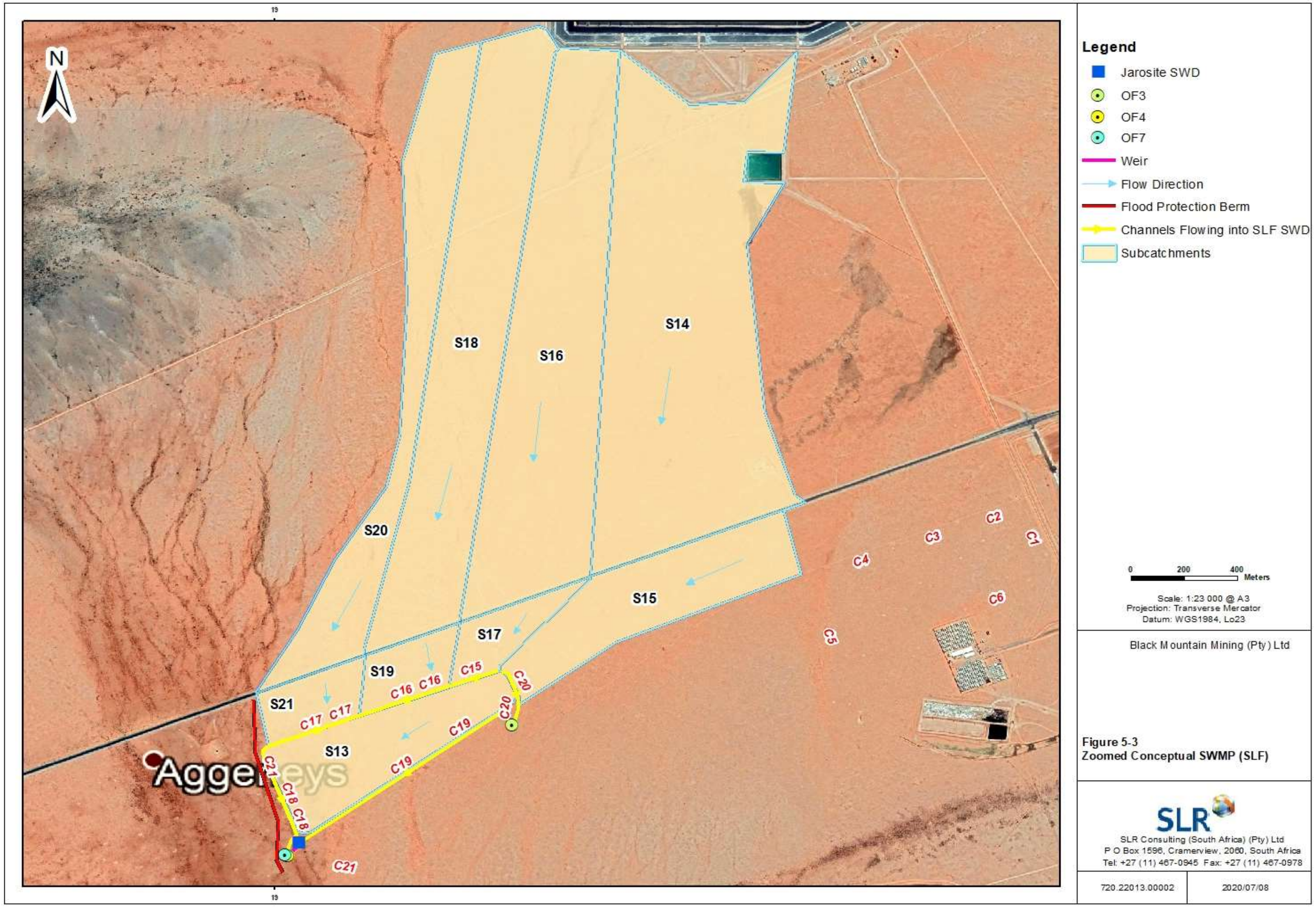

Figure 5-3: Sub-catchments and Proposed Storm water Infrastructure Layout around the SLF

5.2 STORM WATER DAM DESIGN

5.2.1 Design Methodology

A daily time step rainfall-runoff model for the dirty storm water catchments was coupled with a daily time step water balance model for the SWD. The rainfall-runoff model is based on the Soil Conservation Service (SCS) method and is used to estimate the portion of the rainfall which infiltrates or runs off from each catchment, for each day of the simulation. The SWD water balance model considers storm water inflows, the direct rainfall reaching the dam, the evaporation losses and the return water pumping policy and determines the volume of water in the SWD for each day of the simulation.

The key variables and assumptions used in the modelling are as follows:

- The model is run on a daily time step using the 50 years of daily rainfall data available as described in Section 2.1;
- For analysis of results, a "hydrological year" is assumed to run from 1st September of one year to the 31st August in the next year, thereby capturing the entire wet season within one "hydrological year";
- Fixed monthly reference evaporation values were used as defined in Section 2.2.2;
- Storm water runoff from two catchment types were considered:
    - Impermeable surfaces; and
    - Permeable (soil) surfaces
- The return water pumping system will be set up to pump water out of the SWD whenever water is available. Depending on the water quality, water can be re-used in mine for suitable activities i.e dust supression;
- The SWD has been modelled assuming vertical sides for simplicity;
- The runoff from the infrastructure related areas was calculated using the SCS stormflow equation (Schulze et al., 1992) using a curve number of 95 for the Smelter areas (area weighted). The simulated runoff was then entered into the daily time step water balance model to calculate the size of the SWDs and the associated spillage frequency; and
- The volume of water in the dam, the evaporation, the amount abstracted through pumping and the spill volumes were calculated for each day over the full simulation record available. This simulation calculates the required capacity of the dams and the number of spills during the 50-year simulation period taking into account a specified abstraction rate. Table 5-2 indicates the dimensions of the SWDs, the annual spill frequency and the associated abstraction rates.

5.2.2 SWD Modelling Results

The SWD results show three potential dam sizes and related daily abstraction volumes for the Smelter SWD and the SLF SWD. The 18 000 m^3 and 15 000 m^3 dams are respectively recommended due to the acceptable daily abstraction volumes. Table 5-2 shows the three dam volumes and the required daily abstraction amounts, depending on the water quality, water may be recycled in the mine and be used for other mine activities.

Table 5-2: Options for the SWDs – volumes and their required daily abstraction amounts

Smelter SWD					
Option A – 14 100m³ Dam		Option B – 15 600m³ Dam		Option C – 18 000m³ Dam	
Abstraction (m^3/day)	% Annual Spill	Abstraction (m^3/day)	% Annual Spill	Abstraction (m^3/day)	% Annual Spill
1	5.93	1	5.93	1	5.93
1010	3.95	300	3.95	130	3.95
1650	1.98	520	1.98	190	1.98
Jarosite Dump SWD					
Option A – 13 500m³ Dam		Option B – 15 000m³ Dam		Option C – 16 500m³ Dam	
Abstraction (m^3/day)	% Annual Spill	Abstraction (m^3/day)	% Annual Spill	Abstraction (m^3/day)	% Annual Spill
1	5.93	1	5.93	1	5.93
650	3.95	120	3.95	40	3.95
710	1.98	200	1.98	100	1.98

The daily storage volume, the spill volume, the rainfall as well as the maximum dam volume for the selected Storm Water Dam for the Smelter and the SLF are shown below in Figure 5-3 and Figure 5-4.

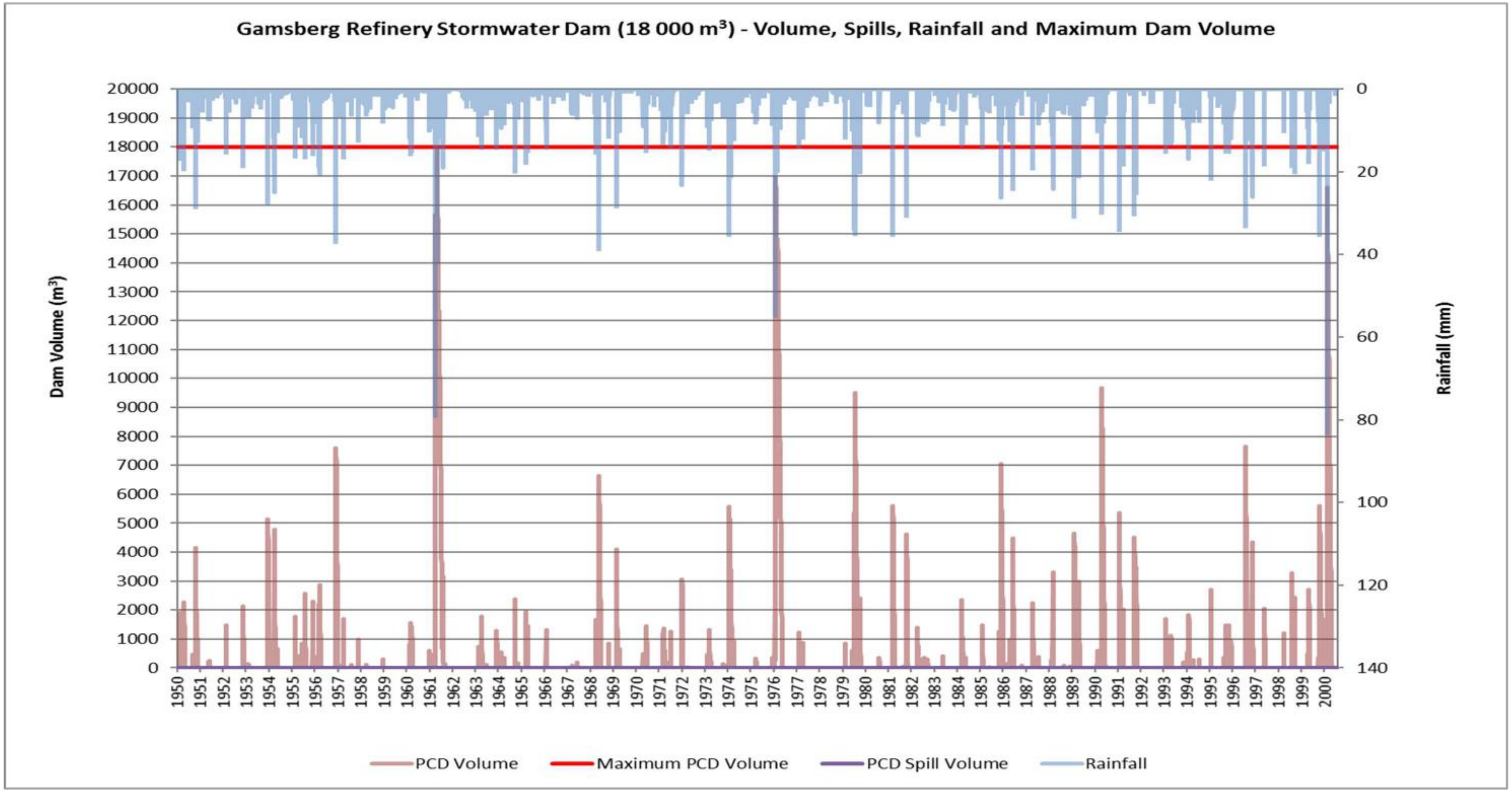

Figure 5 4: Smelter Storm water Dam Daily Volume, Spill Volume, Rainfall and Maximum Volume (Option B)

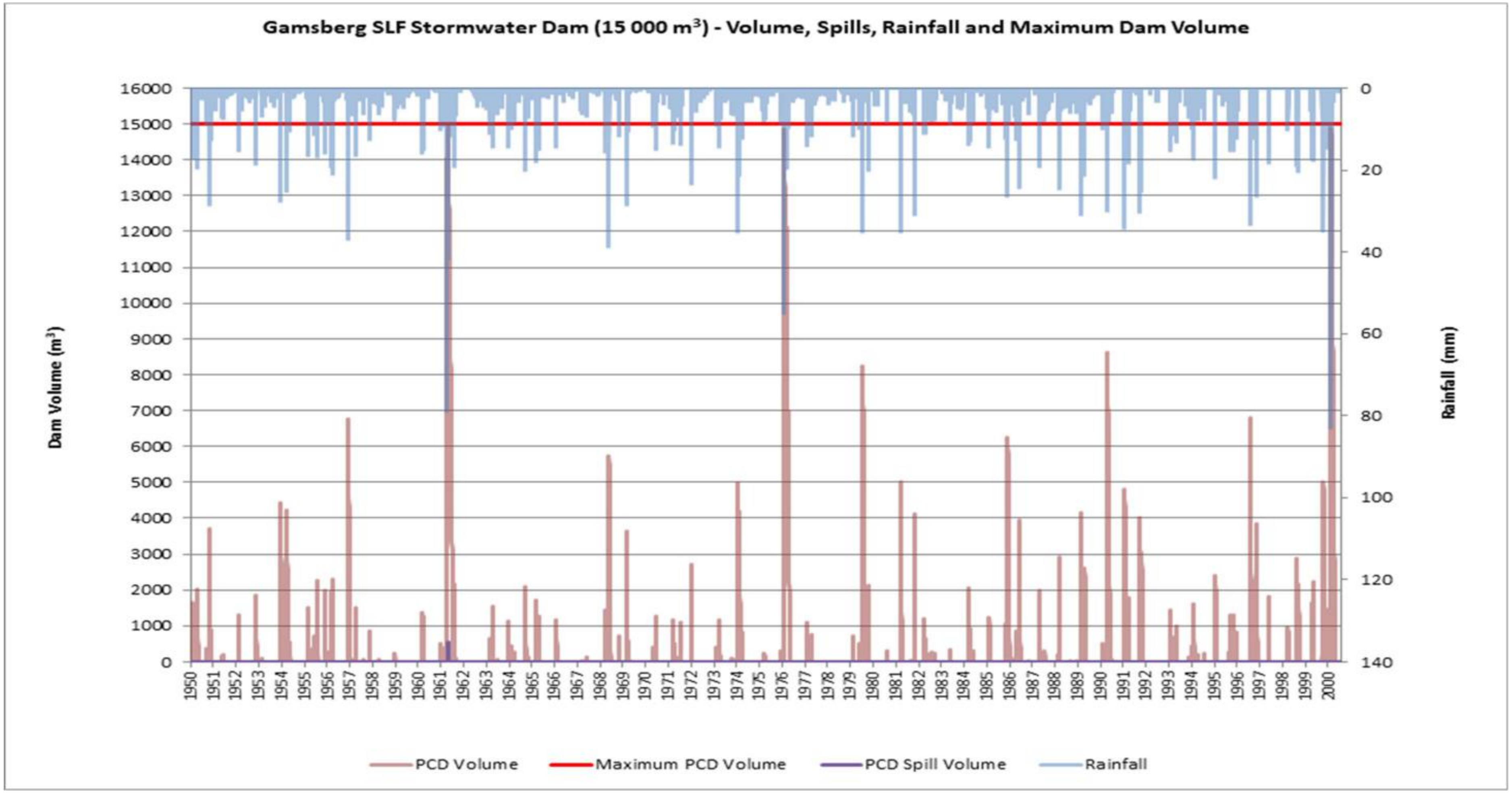

Figure 5-4: SLF Storm water Dam Daily Volume, spill volume, Rainfall and maximum volume (Option B)

5.2.3 Recommended SWD Design Features

The design features of the SWD are presented in Table 5-3 with typical design drawings presented in Appendix C.

Table 5-3: SWD design features

Features	Details
Topsoil Stripping	Topsoil within the SWD footprint will be stripped and stockpiled in accordance with the Envoironmental Management Plan (EMP) specifications.
Barrier System	Specification to be confirmed during detailed design phase - indicatively the barrier system will comprise of a 1.5 mm HDPE geomembrane (to conform to the latest GRI-GM13 specifications, and installed to SANS 10409), covered by a compacted soil layer of 150 mm thick to protect the liner.
Pump station	Water from the Smelter and the SLF SWDs will be pumped out at 190 m^3/day and 230 m^3/day (based on 18 000 m^3 and 15 000 m^3 storage capacity) respectively. The design of the pump station and pipeline to be confirmed during the detailed engineering phase.
Embankment	Existing embankment to be retained and improved where necessary. • All side slopes at 1V : 2.5H • Height above natural ground level <2m
Leakage Detection	The requirement for a leakage detection system will be assessed during the detailed engineering phase.
Access and Access control	Existing road infrastructure to be used. A new road will be built for the SLF and will be paved.
Emergency Spillway	SWD to be provided with a concrete spillway of 10m width with downstream erosion control along the embankment to ensure controlled discharge during spillage events. A freeboard of 0.8m will be provided above full supply level.
Inlet channels	Two concrete lined inlet channels will be specified, the invert levels to be confirmed during detailed engineering phase.
Full supply level capacity	Approximately 18 000 m^3 and 15 000 m^3 for the Smelter and the SLF SWDs respectively
Basin	To be sloped at 1:300 towards the return water pump/spillway
Maximum Depth of SWD	Indicatively 3 m, to be confirmed during detailed engineering phase.

5.3 SILT TRAP DESIGN

The silt trap sizing is based on the sedimentation rate as predicted by Stokes' Law where settling velocity varies with particle sizes.

The channel inlet to the SWDs will need to have its own silt trap and the silt trap will be concrete lined to allow for ease of maintenance, i.e. removal of material and cleaning. The silt trap will have two separate equally sized compartments, an operational and a standby compartment. This will allow one compartment to be cleaned whilst the other is in operation.

The recommended silt trap locations are presented in Figure 5-1, with typical design details presented in Appendix C. The recommended capacity requirements for the silt trap, to ensure adequate retention time for 0.075 mm silt particles are presented in Table 5-4. A smaller silt trap is not recommended as the storm water dams would then not be effective in containing the storm water runoff as required by GN 704.

Table 5-4: Silt Trap Capacity

Facility	1:5-year Peak Discharge (m^3/s)	Depth (m)	Design Capacity (m^3)
Smelter Silt Trap	0.978	2	218
SLF Silt Trap	2.183	2	486

Where site specific constraints limit the size of the silt trap, it can be reduced by designing for a less extreme event (e.g. 1:2-year flow instead of 1:5-year), or by designing for the settlement of coarser material (e.g. designing a sand trap, not a silt trap).

5.4 CONVEYANCE INFRASTRUCTURE DESIGN

The storm water catchments and storm water conveyance infrastructure are presented in Figure 5-1. The estimated design flows and recommended conveyance infrastructure (culverts, kerbing and channels) are presented below.

5.4.1 Design Methodology

Peak flows for design of the storm water conveyance infrastructure were estimated using the SCS Method as applied within the PCSWMM storm water design software package. A Curve Number (CN) of 75 was applied to all catchments that were not part of the Smelter Plant and the SLF. The Smelter Plant and the SLF had a CN of 95. The impermeable area was set at 5%. A Type III storm profile was applied to the 1:50 year, 24-hour rainfall depth (101.4 mm) to estimate peak flows from each catchment (Appendix B).

The channels were sized to take the maximum flow calculated for the downstream end of the contributing catchment and the channel sizing was taken as uniform along the entire length. Some cut and fill may be required along the length of the channels to achieve the required gradient and to ensure that water flows freely along the channels. The dirty water channels have been sized to accommodate the expected 1:50 year peak flow event. The clean water will be kept out of the dirty water channels through the construction of a bund upstream of the channel (see Figure 5-5) using material excavated from the channel.

The freeboard requirements are as follows (already catered for in the sizing):

- The peripheral storm water diversion and dirty water collection channels (or drains) will have a 0.3 m or 0.6 m freeboard height. If the flow is less than 10 m^3/s, then 0.3 m of freeboard is included and if the flow is greater than 10 m^3/s, then 0.6 m of freeboard is included.

Following confirmation of the design flows for each diversion channel, the channels have been sized using the Manning's Equation to ensure that the flow capacity of the channel is sufficient to convey the 1:50 year rainfall event.

The Manning's equation is:

$$Q = A\frac{1}{n}R^{2/3}S^{1/2}$$

Where:

A = Area of Channel (m^2)

R = Hydraulic Radius (area / wetted perimeter) (m);

S = Longitudinal Slope of Channel; and (m/m)

n = Mannings Roughness Coefficient (unitless)

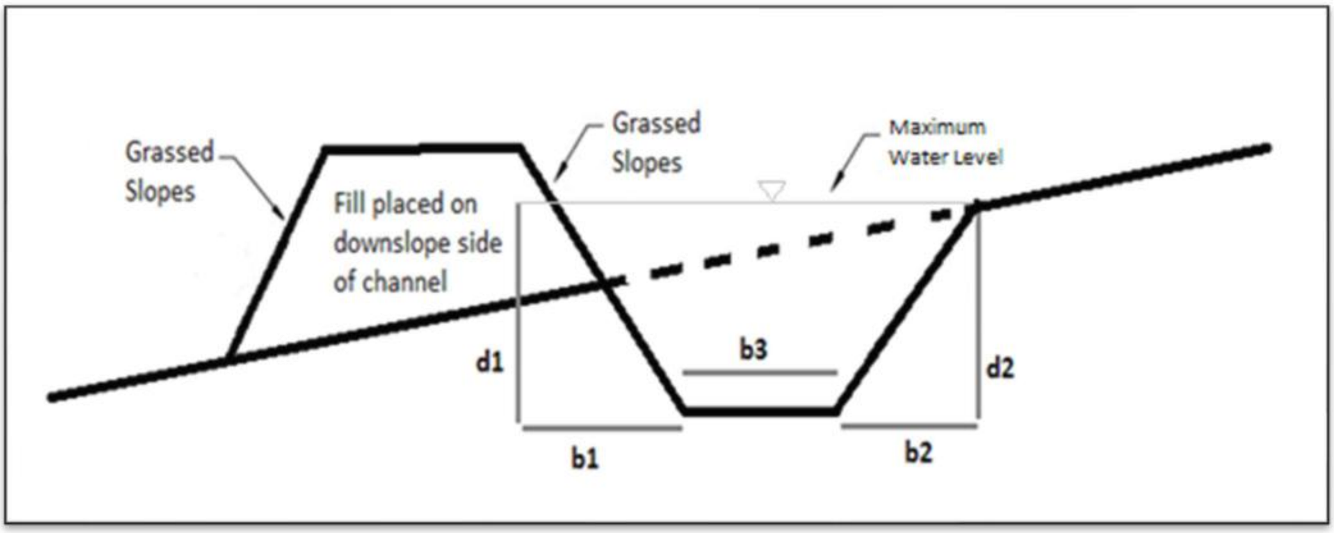

Figure 5-5: Schematic of a cross-sectional view of the channel design

Where:

b = Breadth (m)

d = Depth (m)

5.4.2 Sub-Catchments

The sub-catchments contributing flow into the clean water diversion channels and the dirty water collection channels have been modelled within the PCSWMM software. The salient details of the sub-catchment characteristics are given in Appendix B. The Meanings' n' coefficient for the pervious areas and the impervious areas are 0.13 and 0.015 respectively. The impervious area for each sub-catchment has been chosen to represent the flow responses expected within the different sub-catchments.

5.4.3 Recommended Conveyance Infrastructure Sizes

Figure 5-1 presents the route of the proposed storm water conveyance infrastructure of the main channels. The peak flow estimates for each of the storm water channels, as well as the preliminary channel sizes recommended to accommodate the design flows are presented in Appendix B. Appendix B presents a schematic of the proposed conveyance infrastructure and typical design details. The site will be covered with hardstanding surfaces engineered to slope towards the channels at recommended minimum gradients of 1:200. At certain locations, ground levels will need to be raised to allow the storm water to flow away from these areas and to ensure that the drainage direction is towards the channels.

The dirty water channels will be lined to prevent any seepage of dirty water to the underlying groundwater environment. While from a pollutant point of view, it is not required that the clean water channels be lined, due to intslallation of velocity abatement structures. It is recommended that all of the channels are concreted. The channel velocities are presented in Table 2B. A Manning's 'n' coefficient of 0.014 was used, which is appropriate for concrete lined channels as recommended. This can be reviewed during the detailed design phase in order to better manage costs.

Culverts such as crossing between the road between Smelter and SLF are recommended for conveying flows beneath major road crossings, whilst grated steel covers installed over open channels are recommended for minor road / pedestrian crossings.

Kerbing is recommended on the road edges to influence drainage towards channels.

During the construction of conveyance infrastructure, the location of existing services must be considered, and the drainage channels worked around these where necessary.

5.4.4 Flood Protection Berm at the SLF

The flood protection berm shown in Figure 5-6 will need to be 0.8 m high along its entire alignment. The river, that the flood protection berm is protecting the SLF from, is diffuse with many smaller rivulets. In a flood event, this will take the form of a single river flowing strongly for a short period of time (due to the catchment size).

5.5 LIMITATIONS AND RECOMMENDATIONS

In view of the availability of data, the objectives of this study and the legislation requirements, the following limitations are discussed, and recommendations proposed.

5.5.1 Limitations

The study undertaken is considered adequate for the scope of work – i.e. a conceptual/ pre-feasibility level of design which allows for the identification of potential fatal flaws in the proposed storm water management system. However, the following limitations must be considered:

- Understanding of the proposed infrastructure associated with the Smelter plant expansion is based on a layout plan only, as opposed to full engineering design details, drawings and cross sections. Consequently, it is not clear whether certain infrastructure (such as conveyors) will be above ground or not, which may constrain the chosen route of the water conveyance infrastructure, or facilitate new routes for channels currently not considered;
- No design detail for the existing SWD in the current Gamsberg Mine infrastructure was available and additional construction works may be required for the embankment wall to ensure structural integrity when the dam is full; and

5.5.2 Recommendations

As part of the detailed design process, the following tasks are recommended:

- Geotechnical Investigation –
    - Confirm all the levels (base of dam, full capacity, spillway and freeboard).
- SWD Pump Station and Pipeline Design – design and related drawing work including detailed horizontal and vertical routing of the pipelines, hydraulic modelling and surge analysis, pump selection and pump station mechanical, civil, structural, electrical, control and instrumentation engineering tasks.
- Review of Plant Infrastructure Design – to confirm the design constraints on the proposed storm water infrastructure.

- Detailed Engineering Design - including drawings, design report and bill of quantities (if required). This task can be undertaken in discrete packages of design work in accordance with the phasing of the infrastructure development.

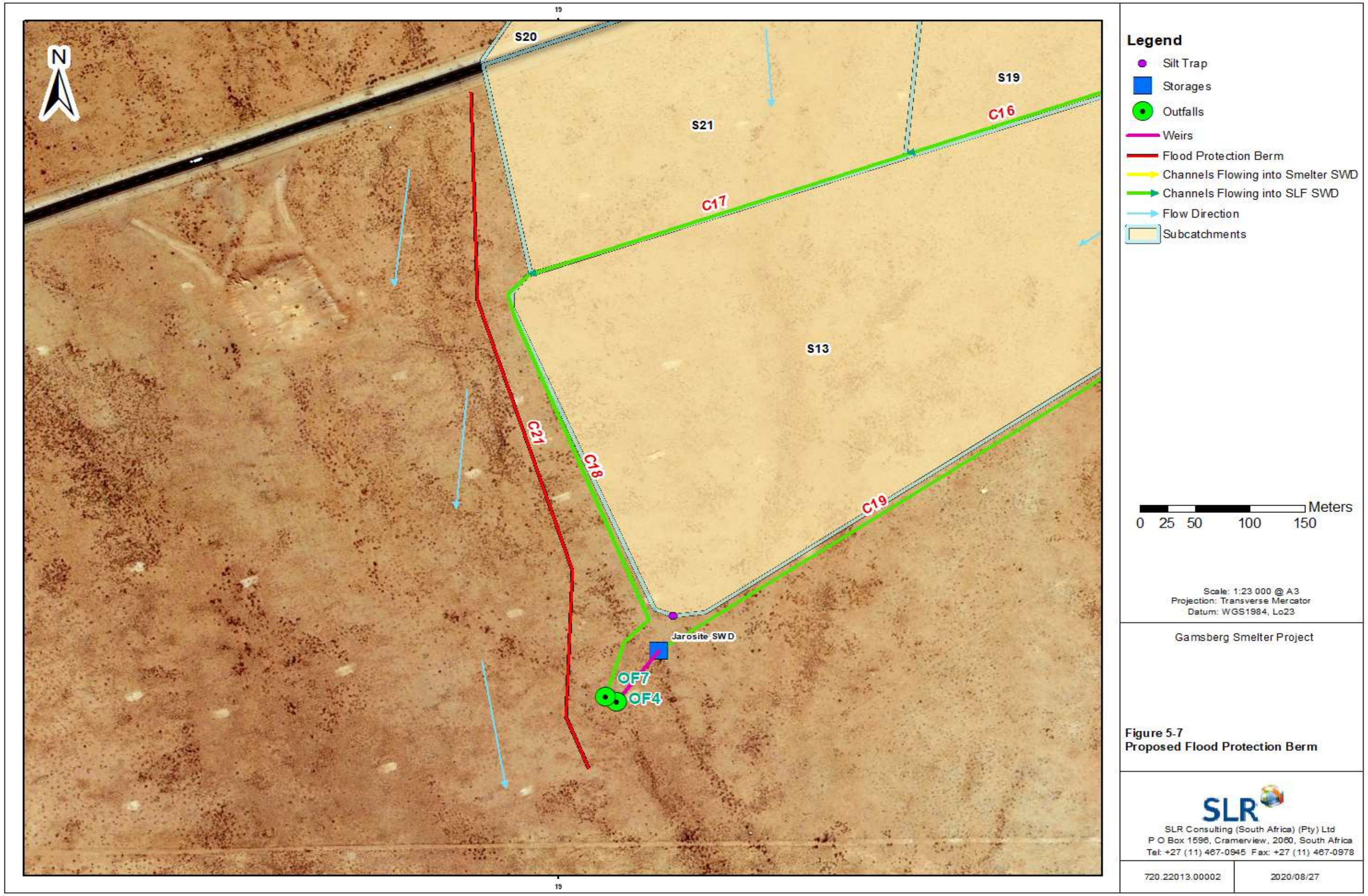

Figure 5-6: Proposed Flood Protection Berm

6. WATER BALANCE ASSESSMENT

6.1 INTRODUCTION

A steady state water balance has been developed for the proposed Smelter and the overall Gamsberg Zinc Mine operation. The Smelter was treated like a black box entity with the internal process flow diagram not being modelled. The inflows and outflows to the Smelter were modelled. The Waste Rock Dumps, Open Pit and the Tailings Storage Facility are included within the water balance.

The water balance will focus predominantly on the interaction between rainfall, evaporation, mine water demands and make up water requirements with the aim of developing a water balance control philosophy for the management of water on the mine.

The water balance development was undertaken for the wet and dry seasons and the annual averages for the two phases of the mine:

- Phase 1: Existing Mine and one full concentrator plant and TSF.
- Phase 2: Future Operation including all mining activities, concentrator one and two, TSF and the Smelter.

6.2 OBJECTIVES OF THE WATER BALANCE

A site wide monthly water balance model was developed for the Gamsberg Zinc Mine operation to establish:

- The average wet, dry season and annual averages of the water balance
- The amount of make-up water required for the processing plant and the Smelter.
- Water re-use opportunities throughout the Gamsberg Mine.

6.3 DESIGN STANDARDS

As discussed in Section 1.3, the water balance, dams and the associated operational infrastructure are to be designed in compliance with the National Water Act (Act No. 36 of 1998), GN704 and DWS BPG which recommends the following:

- The BPG (A4) requires that the determination of the size of the SWD is determined such that it will only spill once in 50 years and requires the application of a continuous model at a daily time step.
- Furthermore, Regulation 6 of GN 704 requires that the capacity requirements of dirty water systems be designed "so that it is not likely to spill into any clean water system more than once in 50 years".

A water balance approach has been adopted which takes into account daily runoff, evaporation and water re-use. The reuse of water is an important component of the SWD dam sizing and is related to the potential pump out rate from the two described SWD (Section 5.2.2) .

6.4 WATER BALANCE ASSUMPTIONS

The following assumptions concerning the water balance apply:

- In order to calculate the potable water demand, to estimate the amount of potable water required for the two phases of the mine, the client estimated that the number of employees who will be available on the mine during the first phase is 913 and 6913 employees (made up of 6000 construction employees and 913 Gamsberg Zinc Mine employees) during Phase 2 throughout the day and each person will require 150 litres per day.
- One hundred and fifty litres per person per day of potable water will be used.

    - It was assumed that based on the water used per person per day 10% is lost and 10% is taken up in use, while 80% is recycled through the STP.

- Information received from the client indicated that open pit mining will not progress below regional groundwater levels around the site.
- The Jarofix when produced is a mixture of Jarosite, Lime slurry and Cement. The moisture in Jarofix is approximately 30% - 40% when produced. It solidifies with time due to the cement addition. The moisture will then be lost due to hydration heat as the concrete sets and evaporates.
- On average the dust suppression at the current mine consumes 25 141.3m^3 of water per month (WUL, 2016). The surface areas of the Smelter and the road to the SLF will be paved and therefore dust suppression over this area will not entail the use of water but rather a vacuum brush.
- The ETP and STP application area is ~ 90 ha equivalent to 900 000 m^2. In order to calculate the rainfall and evaporation within the application area, it was assumed that 50% of the application area is open space that is able to receive natural rain and lose water through evaporation, while the remaining 50% is a closed system.
- Evaporation across all of the open infrastructure was weighted by the area.
- STP is a closed system therefore no natural climate process (i.e rainfall and evaporation) were accouted for.

6.5 PROCESS FLOW DIAGRAM

The insights into how all water flow processes within the Gamsberg Zinc Mine are linked is presented with a Process Flow Diagram (PFD). The mine operational philosophy (obtained from the previous reports), the site visit and the information obtained from the mine personnel were used to develop a PFD and to formulate the assumptions used in the calculation of the mine water balances. All infrastructure footprint and catchment areas used in the water balance calculations are based on the provided infrastructure layout plan. The PFD is provided in Figure 6-1.

6.6 INPUT PARAMETERS

6.6.1 Climate Data

Average Monthly Rainfall

Daily rainfall from the South African Weather Service gauge, station 0246555_W (Aggeneys Pol) were obtained and used to describe the rainfall environment at the project site as presented in Section 2. January to March were regarded as the wet season while May to July were considered the dry season.

Average Evaporation

Evaporation data is based on Symonds Pan (S-Pan) data taken from the WR2012 Database (WRC, 2012)[4] for the quaternary catchment D82C (where the project site is located). S-Pan evaporation was converted to open water evaporation using evaporation coefficients from WR90[5] (WRC, 1990) as presented in Table 2-3.

Potable Water

In order to estimate the amount of potable water required for the two phases of the mine, the client estimated that employees who will be available on the mine during the first phase is 913 and 6913 employees (made up

[4] Water Resources of South Africa, 2012 Study (WR2012). http://waterresourceswr2012.co.za/
[5] Water Resources of South Africa 1990 - Volume 1 Appendices. WRC Report 298/1.1/94

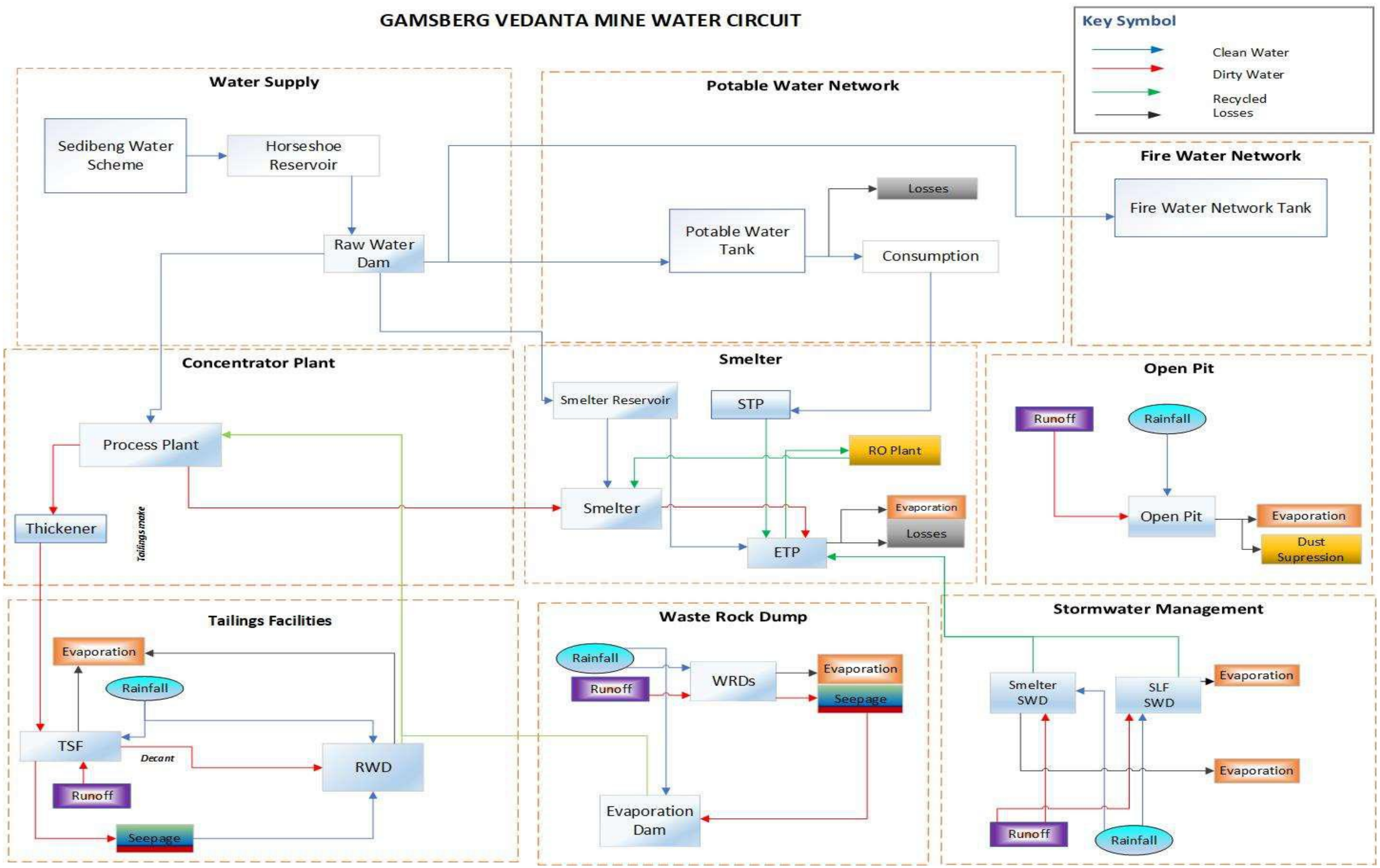

Figure 6-1: Gamsberg Vedanta Mine Water Circuit

of 6000 construction employees and 913 Gamsberg Zinc Mine employees) will be available during Phase 2. These employees will be available throughout the day and each person will require 150 litres per day.

6.6.2 Potable water Supply

Potable water supply into the Horseshoe reservoir for use in the Gamsberg Zinc Mine and Smelter is from the Sedibeng Water Scheme which abstracts water from the Orange River. The quantities of water supply are provided in the water balance undertaken by TATA Consulting (2013) and are presented in Section 0.

6.6.3 Groundwater

There are no Groundwater consumed in the Smelter or the Gamsberg Zinc Mine water balance.

6.6.4 Stormflow

Stormflow volume is defined as the runoff response to a specific rainfall event and the associated surface runoff but excludes base flow (delayed subsurface response). Daily stormflow volumes will be calculated by multiplying daily stormflow depths to contributing catchment areas. Storm water sub-catchments, volumes and pump out rates accounted for are provided in Section 4.

6.6.5 Dust Suppression

Dust suppression volumes were provided by the client.

6.6.6 Mining Water Requirements

Mining water requirements as well as plant process and raw water values required, were provided by the client through a water balance undertaken by TATA Consulting Engineers Limited (TATA Consulting, 2013).

6.6.7 Tailings and Return Water Dam (RWD)

Tailings input into the water balance was obtained from the Tailings Water Balance provided by the client. From the water balance provided by the client the slurry water volume from the plant, decant water and entrapped water were adopted while the climate data used, was as described above.

The TSF water balance provided quantities for the slurry water volume, trapped water, seepage loss as well as decant loss for the wettest and driest season. In order to get the annual average, the two seasons were averaged and multiplied by the number of months in a year. The assumption is that the values for the wet months cover the wetter months of the year (Nov – April) while the dry months cover the drier months of the year (May – Oct).

6.6.8 Make Up Water System

It is envisaged that the makeup water for the concentrator plant will be taken from the Clarified Water Reservoir and necessary arrangements for the same will be provided by the client.

6.7 WATER BALANCE RESULTS

Three water balances per phase were calculated for the Gamsberg Zinc Mine and these are used to provide a general insight into the overall total water demands and uses. These include;

- an average wet season water balance,
- an average dry season water balance, and
- an annual average water balance.

The water balance results are presented in Table 6-1 to Table 6-6.

Table 6-1: Average Wet Season Water Balance Phase 1

Average Wet Season Water Balance for Current Operation					
Facility Name	**Water In**		**Water Out**		
Gamsberg Zinc Mine	**Water Circuit/Stream**	**Quantity (m^3/month)**	**Water Circuit/Stream**	**Quantity (m^3/month)**	**Balance**
Opencast Pit	Rainfall	22 422	Evaporation	35 875	
	Stormwater	13 453	Dust Suppression	0	
	Total	**35 875**		**35 875**	**Balanced**
Potable Water Tank	Raw Water Dam	4 577	Losses	3 154	
	Make-Up Water	26 964	Consumption	28 387	
	Total	**31 541**		**31 541**	Balanced
Raw Water Dam	Horseshoe Reservoir	589 693	Fire Network	18 250	
			Process Water	296 566	
			Smelter Complex	243 336	
			Potable Water Network	31 541	
	Total	**589 693**		**589 693**	**Balanced**
Concentrator Plant	Raw Water Dam	296 566	Tailings Water	321 112	
	Recovery	195 141	Zinc Concentrate	170 594	
	Total	**491 706**		**491 706**	**Balanced**
Smelter Complex	Raw Water	310 080	ETP Cake	331 144	
	Zinc Concentrate	170 594	Losses	82 786	
			Excess	66 744	
	Total	**480 674**		**480 674**	**Balanced**
Effluent Treatment Plant	Raw Water	86 302	Losses	36 987	
	ETP Cake	331 144			
	SLF SWD	6 992	Dust Suppression	18 250	
	Smelter SWD	5 776	Evaporation	59 042	
	STP	28 387	Return Osmosis	344 322	
	Total	**458 600**		**458 600**	**Balanced**
Sewage Treatment Plant	Amenities	28 387	ETP	28 387	
	Total	**28 387**		**28 387**	**Balanced**
TSF	Rainfall	9 304	RWD Decant	197 102	
	Stormwater	15 457	Interstitial Lock	96 334	
	Thickener Inflow	321 112	Evaporation	1 720	
			Seepage Loss	50 717	
	Total	**345 873**		**345 873**	**Balanced**
Return Water Dam	Rainfall	91	Evaporation	2 907	
	TSF Decant	197 102	Returned to Plant	194 286	
	TSF Seepage	50 717			
	Total	**197 193**		**197 193**	**Balanced**
Smelter SWD	Rainfall	49	Evaporation	11 023	
	Runoff	16 750	ETP	5 776	
	Total	**16 799**		**16 799**	**Balanced**
Jarosite SWD	Rainfall	41	Evaporation	6 128	
	Runoff	13 079	ETP	6 992	
	Total	**13 120**		**13 120**	**Balanced**
WRDs	Rainfall	21 335	Seepage	152	
	Runoff	40 180	Evaporation	61 363	
	Total	**61 515**		**61 515**	**Balanced**
Evaporation Ponds	Rainfall	1 558	Evaporation	855	
	Seepage from WRDs	152			
			Plant Return	855	
	Total	**1 710**		**1 710**	**Balanced**
Total Water Balance		**2 752 687**		**2 752 687**	

Table 6-2: Average Dry Season Water Balance Phase 1

Average Dry Season Water Balance for Current Operation					
Facility Name	**Water In**		**Water Out**		
Gamsberg Zinc Mine	**Water Circuit/Stream**	**Quantity (m^3/month)**	**Water Circuit/Stream**	**Quantity (m^3/month)**	**Balance**
Opencast Pit	Rainfall	5 906	Evaporation	9 450	
	Stormwater	3 544	Dust Suppression	0	
	Total	**9 450**		**9 450**	**Balanced**
Potable Water Tank	Raw Water Dam	4 577	Losses	3 154	
	Make-Up Water	26 964	Consumption	28 387	
	Total	**31 541**		**31 541**	Balanced
Raw Water Dam	Horseshoe Reservoir	589 693	Fire Network	18 250	
			Process Water	296 566	
			Smelter Complex	243 336	
			Potable Water Network	31 541	
	Total	**589 693**		**589 693**	**Balanced**
Concentrator Plant	Raw Water Dam	296 566	Tailings Water	299 699	
	Recovery	36 878	Zinc Concentrate	33 745	
	Total	**333 444**		**333 444**	**Balanced**
Smelter Complex	Raw Water	310 080	ETP Cake	221 665	
	Zinc Concentrate	33 745	Losses	55 416	
			Excess	66 744	
	Total	**343 825**		**343 825**	**Balanced**
Effluent Treatment Plant	Raw Water	86 302	Losses	36 987	
	ETP Cake	221 665			
	SLF SWD	3 456	Dust Suppression	18 250	
	Smelter SWD	3 701	Evaporation	20 930	
	STP	28 387	Return Osmosis	267 344	
	Total	**343 510**		**343 510**	**Balanced**
Sewage Treatment Plant	Amenities	28 387	ETP	28 387	
	Total	**28 387**		**28 387**	**Balanced**
TSF	Rainfall	2 451	RWD Decant	37 604	
	Stormwater	4 072	Interstitial Lock	89 913	
			Evaporation	101 885	
	Thickener Inflow	299 699	Seepage Loss	59 183	
			Excess	17 636	
	Total	**306 221**		**306 221**	**Balanced**
Return Water Dam	Rainfall	24	Evaporation	1 031	
	TSF Decant	37 604	Returned to Plant	36 597	
	TSF Seepage	59 183			
	Total	**37 628**		**37 628**	**Balanced**
Smelter SWD	Rainfall	13	Evaporation	724	
	Runoff	4 412	ETP	3 701	
	Total	**4 425**		**4 425**	**Balanced**
Jarosite SWD	Rainfall	11	Evaporation	0	
	Runoff	3 445	ETP	3 456	
	Total	**3 456**		**3 456**	**Balanced**
WRDs	Rainfall	5 620	Seepage	152	
	Runoff	10 584	Evaporation	16 052	
	Total	**16 204**		**16 204**	**Balanced**
Evaporation Ponds	Rainfall	1 558	Evaporation	855	
	Seepage from WRDs	152	Plant Return	855	
	Total	**1 710**		**1 710**	**Balanced**
Total Water Balance		**2 049 495**		**2 049 495**	

Table 6-3: Annual Water Balance Phase 1

Annual Water Balance for Current Operation					
Facility Name	**Water In**		**Water Out**		
Gamsberg Zinc Mine	**Water Circuit/Stream**	**Quantity (m^3/year)**	**Water Circuit/Stream**	**Quantity (m^3/year)**	**Balance**
Opencast Pit	Rainfall	155 350	Evaporation	248 561	
	Stormwater	93 210	Dust Suppression	0	
	Total	**248 561**		**248 561**	**Balanced**
Potable Water Tank	Raw Water Dam	54 919	Losses	37 849	
	Make-Up Water	323 572	Consumption	340 642	
	Total	**378 491**		**378 491**	Balanced
Raw Water Dam	Horseshoe Reservoir	7 076 314	Fire Network	219 002	
			Process Water	3 558 789	
			Smelter Complex	2 920 032	
			Potable Water Network	378 491	
	Total	**7 076 314**		**7 076 314**	**Balanced**
Concentrator Plant	Raw Water Dam	3 558 789	Tailings Water	3 724 866	
	Recovery	1 390 427	Zinc Concentrate	1 224 350	
	Total	**4 949 216**		**4 949 216**	**Balanced**
Smelter Complex	Raw Water	3 720 960	ETP Cake	3 315 506	
	Zinc Concentrate	1 224 350	Losses	828 876	
			Excess	800 928	
	Total	**4 945 310**		**4 945 310**	**Balanced**
Effluent Treatment Plant	Raw Water	1 035 619	Losses	443 845	
	ETP Cake	3 315 506			
	SLF SWD	56 741	Dust Suppression	219 000	
	Smelter SWD	54 363	Evaporation	502 573	
	STP	340 642	Return Osmosis	3 637 452	
	Total	**4 802 870**		**4 802 870**	**Balanced**
Sewage Treatment Plant	Amenities	340 642	ETP	340 642	
	Total	**340 642**		**340 642**	**Balanced**
TSF	Rainfall	64 460	RWD Decant	1 408 237	
	Stormwater	107 093	Interstitial Lock	1 117 478	
			Evaporation	666 357	
	Thickener Inflow	3 724 866	Seepage Loss	651 440	
			Excess	52 908	
	Total	**3 896 419**		**3 896 419**	**Balanced**
Return Water Dam	Rainfall	629	Evaporation	24 749	
	TSF Decant	1 408 237	Returned to Plant	1 384 117	
	TSF Seepage	651 440			
	Total	**1 408 866**		**1 408 866**	**Balanced**
Smelter SWD	Rainfall	341	Evaporation	62 029	
	Runoff	116 051	ETP	54 363	
	Total	**116 392**		**116 392**	**Balanced**
Jarosite SWD	Rainfall	284	Evaporation	34 159	
	Runoff	90 616	ETP	56 741	
	Total	**90 900**		**90 900**	**Balanced**
WRDs	Rainfall	5 620	Seepage	152	
	Runoff	10 584	Evaporation	16 052	
	Total	**16 204**		**16 204**	**Balanced**
Evaporation Ponds	Rainfall	10 795	Evaporation	6 310	
	Seepage from WRDs	1 825	Plant Return	6 310	
	Total	**12 620**		**12 620**	**Balanced**
Total Water Balance		**28 282 805**		**28 282 805**	

Table 6-4: Average Wet Season Water Balance Phase 2

Average Wet Season Water Balance for Future Expansion					
Facility Name	**Water In**		**Water Out**		
Gamsberg Zinc Mine	**Water Circuit/Stream**	**Quantity (m^3/month)**	**Water Circuit/Stream**	**Quantity (m^3/month)**	**Balance**
Opencast Pit	Rainfall	22 422	Evaporation	51 942	
	Stormwater	29 520	Dust Suppression	0	
	Total	**51 942**		**51 942**	**Balanced**
Potable Water Tank	Raw Water Dam	4 577	Losses	913	
	Make-Up Water	0	Consumption	3 664	
	Total	**4 577**		**4 577**	Balanced
Raw Water Dam	Horseshoe Reservoir	591 451	Fire Network	18 250	
			Process Water	258 545	
			Smelter Complex	310 080	
			Potable Water Network	4 577	
	Total	**591 451**		**591 451**	**Balanced**
Concentrator Plant	Raw Water Dam	258 545	Tailings Water	321 112	
	Recovery	195 141	Zinc Concentrate	132 573	
			Excess	0	
	Total	**453 685**		**453 685**	**Balanced**
Smelter Complex	Raw Water	310 080	ETP Cake	791 315	
	Zinc Concentrate	132 573	Losses	87 924	
	RO Plant	777 089	Excess	340 503	
	Total	**1 219 742**		**1 219 742**	**Balanced**
Effluent Treatment Plant	Raw Water	86 302	Losses	36 987	
	ETP Cake	879 239			
	SLF SWD	6 992	Dust Suppression	18 250	
	Smelter SWD	5 776	Evaporation	59 042	
	STP	10 058	Return Osmosis	874 088	
	Total	**988 366**		**988 366**	**Balanced**
Sewage Treatment Plant	Amenities	8 213	ETP	8 213	
	Total	**8 213**		**8 213**	**Balanced**
TSF	Rainfall	9 304	RWD Decant	197 102	
	Stormwater	15 457	Interstitial Lock	96 334	
	Thickener Inflow	321 112	Evaporation	1 720	
			Seepage Loss	50 717	
	Total	**345 873**		**345 873**	**Balanced**
Return Water Dam	Rainfall	91	Evaporation	2 907	
	TSF Decant	197 102	Returned to Plant	194 286	
	TSF Seepage	50 717			
	Total	**197 193**		**197 193**	**Balanced**
Smelter SWD	Rainfall	49	Evaporation	11 023	
	Runoff	16 750	ETP	5 776	
	Total	**16 799**		**16 799**	**Balanced**
Jarosite SWD	Rainfall	41	Evaporation	6 128	
	Runoff	13 079	ETP	6 992	
	Total	**13 120**		**13 120**	**Balanced**
WRDs	Rainfall	21 335	Seepage	152	
	Runoff	40 180	Evaporation	61 363	
	Total	**61 515**		**61 515**	**Balanced**
Evaporation Ponds	Rainfall	1 558	Evaporation	855	
	Seepage from WRDs	152			
			Plant Return	855	
	Total	**1 710**		**1 710**	**Balanced**
Total Water Balance		**3 954 186**		**3 954 186**	

SLR

Table 6-5: Average Dry Season Water Balance Phase 2

Average Wet Season Water Balance for Future Expansion					
Facility Name	**Water In**		**Water Out**		
Gamsberg Zinc Mine	**Water Circuit/Stream**	**Quantity (m^3/month)**	**Water Circuit/Stream**	**Quantity (m^3/month)**	**Balance**
Opencast Pit	Rainfall	5 906	Evaporation	13 682	
	Stormwater	7 776	Dust Suppression	0	
	Total	**13 682**		**13 682**	**Balanced**
Potable Water Tank	Raw Water Dam	4 577	Losses	913	
	Make-Up Water	0	Consumption	3 664	
	Total	**4 577**		**4 577**	Balanced
Raw Water Dam	Horseshoe Reservoir	591 451	Fire Network	18 250	
			Process Water	258 545	
			Smelter Complex	310 080	
			Potable Water Network	4 577	
	Total	**591 451**		**591 451**	**Balanced**
Concentrator Plant	Raw Water Dam	258 545	Tailings Water	299 699	
	Recovery	36 878	Zinc Concentrate	4 276	
	Make-Up Water	8 552			
	Total	**303 974**		**303 974**	**Balanced**
Smelter Complex	Raw Water	310 080	ETP Cake	474 226	
	Zinc Concentrate	4 223	Losses	52 692	
	RO Plant	554 494	Excess	341 880	
	Total	**868 797**		**868 797**	**Balanced**
Effluent Treatment Plant	Raw Water	86 302	Losses	36 987	
	ETP Cake	525 489			
	SLF SWD	3 456	Dust Suppression	18 250	
	Smelter SWD	3 701	Evaporation	20 930	
	STP	8 699	Return Osmosis	551 480	
	Total	**627 646**		**627 646**	**Balanced**
Sewage Treatment Plant	Amenities	8 213	ETP	8 213	
	Total	**8 213**		**8 213**	**Balanced**
TSF	Rainfall	2 451	RWD Decant	37 604	
	Stormwater	4 072	Interstitial Lock	89 913	
	Thickener Inflow	299 699	Evaporation	101 885	
			Seepage Loss	59 183	
			Excesss	17 636	
	Total	**306 221**		**306 221**	**Balanced**
Return Water Dam	Rainfall	24	Evaporation	1 031	
	TSF Decant	37 604	Returned to Plant	36 597	
	TSF Seepage	50 717			
	Total	**37 628**		**37 628**	**Balanced**
Smelter SWD	Rainfall	13	Evaporation	724	
	Runoff	4 412	ETP	3 701	
	Total	**4 425**		**4 425**	**Balanced**
Jarosite SWD	Rainfall	11	Evaporation	0	
	Runoff	3 445	ETP	3 456	
	Total	**3 456**		**3 456**	**Balanced**
WRDs	Rainfall	5 620	Seepage	152	
	Runoff	12 766	Evaporation	18 233	
	Total	**18 385**		**18 385**	**Balanced**
Evaporation Ponds	Rainfall	410	Evaporation	281	
	Seepage from WRDs	152	Plant Return	281	
	Total	**562**		**562**	**Balanced**
Total Water Balance		**2 789 019**		**2 789 019**	

Table 6-6: Annual Average Water Balance Phase 2

Annual Water Balance for Future Expansion					
Facility Name	**Water In**		**Water Out**		
Gamsberg Zinc Mine	**Water Circuit/Stream**	**Quantity (m^3/year)**	**Water Circuit/Stream**	**Quantity (m^3/year)**	**Balance**
Opencast Pit	Rainfall	155 350	Evaporation	359 878	
	Stormwater	204 528	Dust Suppression	0	
	Total	**359 878**		**359 878**	**Balanced**
Potable Water Tank	Raw Water Dam	54 919	Losses	913	
	Make-Up Water	0	Consumption	54 006	
	Total	**54 919**		**54 919**	Balanced
Raw Water Dam	Horseshoe Reservoir	6 296 487	Fire Network	219 002	
			Process Water	3 102 534	
			Smelter Complex	2 920 032	
			Potable Water Network	54 919	
	Total	**6 296 487**		**6 296 487**	**Balanced**
Concentrator Plant	Raw Water Dam	3 102 534	Tailings Water	3 724 866	
	Recovery	1 390 427	Zinc Concentrate	823 905	
	Make-Up Water	55 810			
	Total	**4 548 771**		**4 548 771**	**Balanced**
Smelter Complex	Raw Water	3 720 960	ETP Cake	7 563 975	
	Zinc Concentrate	823 905	Losses	840 442	
	RO Plant	7 647 350	Excess	3 787 798	
	Total	**12 192 215**		**12 192 215**	**Balanced**
Effluent Treatment Plant	Raw Water	86 302	Losses	36 987	
	ETP Cake	525 489			
	SLF SWD	3 456	Dust Suppression	18 250	
	Smelter SWD	3 701	Evaporation	20 930	
	STP	8 699	Return Osmosis	551 480	
	Total	**627 646**		**627 646**	**Balanced**
Sewage Treatment Plant	Amenities	98 551	ETP	98 551	
	Total	**98 551**		**98 551**	**Balanced**
TSF	Rainfall	64 460	RWD Decant	1 408 237	
	Stormwater	107 093	Interstitial Lock	1 117 478	
	Thickener Inflow	3 724 866	Evaporation	666 357	
			Seepage Loss	651 440	
			Excesss	52 908	
	Total	**3 896 419**		**3 896 419**	**Balanced**
Return Water Dam	Rainfall	629	Evaporation	24 749	
	TSF Decant	1 408 237	Returned to Plant	1 384 117	
	TSF Seepage	651 440			
	Total	**1 408 866**		**1 408 866**	**Balanced**
Smelter SWD	Rainfall	341	Evaporation	62 029	
	Runoff	116 051	ETP	54 363	
	Total	**116 392**		**116 392**	**Balanced**
Jarosite SWD	Rainfall	284	Evaporation	34 159	
	Runoff	90 616	ETP	56 741	
	Total	**90 900**		**90 900**	**Balanced**
WRDs	Rainfall	147 817	Seepage	1 825	
	Runoff	335 767	Evaporation	481 759	
	Total	**483 584**		**483 584**	**Balanced**
Evaporation Ponds	Rainfall	10 795	Evaporation	6 310	
	Seepage from WRDs	1 825	Plant Return	6 310	
	Total	**12 620**		**12 620**	**Balanced**
Total Water Balance		**30 187 248**		**30 187 248**	

6.8 WATER BALANCE ANALYSIS

A site wide water balance has been developed, to estimate the return water, make up water and discharge requirements taking into account the proposed infrastructure for the Phase 1 and Phase 2 life of mine. The project's water circuit has been documented in Figure 6-1 and the collection and water management strategy defined. The reuse of process water will be prioritised, thereby ideally reducing the impacts from the project on the surface water resources and storing of water for use in low supply periods.

The water balance indicates that approximately 323 577 m^3 make-up water is required for Potable water use in use in Phase 1 while no make-up water is required for phase 2 as the water supplied meets the water demanded. Approximately 8 552 m^3 per month is required as make-up water for processing during dry season of Phase 2. Total make-up water required for Phase 1 and Phase 2 are presented in Table 6-7. The Smelter receives exceess water of 66 744 m^3/month in Phase 1 and Phase 2 from the Raw Water Dam; this water can be used to supplement the make-up water required.

There is an opportunity to implement measures to collect, recycle and conserve excess water from the Smelter as more water is treated and recycled between the ETP Plant and RO Plant, which would result in a reduction in other water requirements such as dust suppression, etc.

Table 6-7: Make-up Water Requirement

Facility	Phases of the mine					
	Phase 1			Phase 2		
	Wet Season (m^3/mon)	Dry Season (m^3/mon)	Annual (m^3/a)	Wet Season (m^3/mon)	Dry Season (m^3/mon)	Annual (m^3/a)
Potable Water Network	26 964	26 964	323 572	0	0	0
Concentrator Plant	0	0	0	0	8 552	55 810
Total	598 367	598 367	14 355 868	853 818	1 105 632	13 267 588
Total m3	26 964	26 964	323 572	0	8 552	55 810
Total ML	27	27	324	0	9	56
Megalitres per day						
Total MLD	1	1	11	0	0	2

Table 6-8: Recycled Process Water

	Phase 1			Phase 2		
Facility	Wet Season (m^3/mon)	Dry Season (m^3/mon)	Annual (m^3/a)	Wet Season (m^3/mon)	Dry Season (m^3/mon)	Annual (m^3/a)
Smelter	66 744	66 744	800 928	340 503	341 880	3 787 798
TSF	0	0	0	50 717	17 636	52 908
Total m3/mon	66 744	66 744	800 928	340 503	341 880	3 787 798
Total ML/mon	67	67	801	341	342	3 788
Total MLD	2	2	26	11	11	125

7. IMPACT ASSESSMENT, MITIGATION AND MONITORING

Informed by the mine plan layout, baseline hydrology, design specifications for the storm water management measures, and the water balance results, the potential impacts of the proposed activities on surface water receptors as well as the sensitivity of the surface water resources are discussed in this section and presented along with a summary of mitigation measures and monitoring requirements.

Impacts are assessed cumulatively where possible, in that the assessment takes into account the currently impacted environment. The impact assessment undertaken here is for the proposed Gamsberg Smelter Project and its associated infrastructure. The impacts of the proposed Smelter and infrastructure are identified and assessed based on the impact's magnitude as well as the receptor's sensitivity. The impact rating methodology is presented in Appendix D.

The surface water impacts associated with the proposed Gamsberg Smelter Project are assessed according to the three main stages of the project namely the construction phase, the operation phase and the closure phase, as well as the major activities within those phases.

The proposed mining project includes various mitigation measures recommended in the SWMP, flood lines and the water balance model assessments. Theoretically without these measures the impacts on the environment would be much higher, although the mine would almost certainly not be allowed to proceed without achieving compliance with current best practice and relevant industry guidelines presented in this and other reports.

The potential unmitigated impacts (worst-case scenario), and residual impacts of the project after considering the design mitigation measures proposed within this report are qualitatively assessed in this section.

7.1 CONTAMINATION OF SURFACE WATER RESOURCES

7.1.1 Description of impact

There are several contamination sources in all project phases that have the potential to pollute surface water, particularly in the unmitigated scenario. In the construction, decommissioning and closure phases these potential pollution sources are temporary and diffuse in nature. Although these sources may be temporary, the potential pollution may be long term. The operational phase will present the longer-term potential pollution sources.

7.1.2 Impact assessment

Construction and Operational Phases

Potential Impacts

Construction and operational activities that include the use of vehicles and machinery, storage of chemicals, fuels and materials as well as the storage of domestic and industrial waste have the potential to result in washing away the contaminats into watercources. Soluble construction materials also have the potential to dissolve in runoff from the area. This can result in the increase of dissolved solids in downstream waterbodies during periods of rainfall and subsequent flow resulting in a water quality impact. All assessed watercourses are dry for large periods of the year allowing for long periods of time in order to address any spills before natural runoff begins. This impact is likely to be focussed during the construction phase with negligible impacts foreseen beyond the construction period. Table 7-2 presents a summary of contamination impact during construction and operational phases.

Deterioration of water quality during the construction phase can be attributed to the following:

- Clearing of the surface area and site preparation for the new infrastructure would result in exposure of soil surfaces to potential erosion. When a large area of vegetation is cleared and topsoil disturbed, it exposes a large area of loose material which is susceptible to erosion.
- Water contamination could result from poor management of waste from the Smelter complex and SLF during the construction phase if not adequately managed. Typically, the following pollution sources exist at the Smelter: fuel and lubricants, sewage, and erosion of particles from exposed soils in the form of suspended solids.
- Water quality deterioration as a result of discharge of dirty water into the catchment around the Smelter when extreme events do occur, some of the structures may overtop and overflow, causing dirty material to wash into nearby streams.

Table 7-1: : Impact summary – Surface Water Resources Contamination in Construction Phase

Issue: Surface Water Resources Contamination		
Phases: Construction Phase		
Criteria	Without Mitigation	With Mitigation
Intensity	Moderate change or disturbance	Minor change or disturbance
Duration	Medium-term	Short-term
Extent	Beyond Site	Site Boundary
Consequence	Medium	Low
Probability	Probable	Concievable
Significance	Medium	Low
Nature of cumulative impacts	Construction activities that include the use of vehicles and machinery in nearby watercourses, storage of chemicals, fuels and materials as well as the storage of domestic and industrial waste have the potential to result in contamination of the water resource. Soluble construction materials also have the potential to dissolve in runoff from the area. This can result in the increase of dissolved solids in downstream waterbodies during periods of rainfall and subsequent flow resulting in a water quality impact. However, considering the temporary nature of the construction phase, the cumulative impact is assessed to be MEDIUM.	
Degree to which impact can be reversed	All assessed watercourses are dry for large periods of the year allowing for long periods of time to address any spills before flow begins. This impact is likely to occur only during the construction phase with negligible impacts foreseen beyond the construction period.	
Degree to which impact may cause irreplaceable loss of resources	Low as this area receives low rainfall.	
Residual impacts	The residual impact is considered to be LOW with only moderate impacts on the environment.	

Operational Phase Phases

Potential operational phase pollution sources could include:

- Spills from the STP, spill of Jarosite during transportation to the SLF, spillage of operational fuel, lubricants, cement or leaks from vehicles and equipment;

- Contaminated discharges from the dirty water systems including recycled water ponds, dirty water pipelines and STP;
- Residue from the dirty water circuit, chemicals, non-mineralised waste (hazardous, general, radioactive), and concrete wash water, and
- Contaminated runoff and seepage from the SLF.

Table 7-2: Impact summary – Surface Water Resources Contamination in Operational Phase

Issue: Surface Water Resources Contamination		
Phases: Operational Phase		
Criteria	Without Mitigation	With Mitigation
Intensity	Prominent change or disturbance	Moderate change or disturbance
Duration	Long-term	Medium-term
Extent	Whole Site	Beyond Site Boundary
Consequence	Medium	Medium
Probability	Probable	Possible
Significance	High	Medium
Nature of cumulative impacts	Operational activities that include the use of vehicles, storage of chemicals, fuels and materials as well as the storage of domestic and industrial waste have the potential to result in contamination of the water resource. This can result in the increase of dissolved solids in downstream waterbodies during periods of rainfall and subsequent flow resulting in a water quality impact. The cumulative impact is assessed to be HIGH.	
Degree to which impact can be reversed	All assessed watercourses are dry for large periods of the year allowing for long periods of time to address any spills before flow begins.	
Degree to which impact may cause irreplaceable loss of resources	Medium as this area receives low rainfall.	
Residual impacts	The residual impact is considered to be Medium with only moderate impacts on the environment.	

Decommissioning and Closure Phases

Compacted surfaces from moving vehicles and machinery during the decommissioning and closure phase could lead to an increase in runoff into the nearby streams. Surface water resources are receptors of fine materials and contaminants arising from the demolition of infrastructure and from earthworks transported through rainwater and surface runoff. This may be deposited in watercourses causing siltation and contaminating river water with chemical pollutants.

Impacts on Downstream Receptors

At elevated concentrations contaminants can exceed the relevant surface water quality limits imposed by local guidelines. The related unmitigated severity is medium.

In the unmitigated scenario, the contamination of surface water resources could occur for periods longer than the life of the proposed project. With mitigation, pollution can be prevented and/or managed and as such the impacts can be reversed or mitigated within the life of the proposed project. **Error! Reference source not found.** presents a summary of impact during decommissioning and closure phase.

Table 7-3: Impact summary – Surface Water Resources Contamination in Decommissioning and Closure Phases

Issue: Surface Water Resources Contamination		
Phases: Decommissioning and Closure Phases		
Criteria	Without Mitigation	With Mitigation
Intensity	Moderate change or disturbance	Minor change or disturbance
Duration	Medium-term	Short-term
Extent	Whole site	A part of the site
Consequence	Medium	Medium
Probability	Possible	Conceivable
Significance	Medium	Low
Nature of cumulative impacts	Compacted surfaces from moving vehicles and machinery during the decommissioning and closure phase could lead to an increase in runoff into the nearby streams. Surface water resources are receptors of fine materials and contaminants arising from the demolition of infrastructure and from earthworks transported through rainwater and surface runoff. This may be deposited in watercourses causing siltation and contaminating river water with chemical pollutants. However, considering the temporary nature of the decommissioning and closure phase, the cumulative impact is assessed to be MEDIUM.	
Degree to which impact can be reversed	The impact can be fully reversed because once the decommissioning and closure period is completed and area occupied by the SLF is rehabilitated.	
Degree to which impact may cause irreplaceable loss of resources	Low as this area receives low rainfall that can wash away finer material into nearby watercourses	
Residual impacts	The residual impact is considered to be VERY LOW with only minor impacts on surrounding receptors.	

7.1.3 Mitigation

The following mitigation measures per phase are recommended:

Construction Phase

- Minimise the disturbance of vegetation and soils as much as possible by restricting construction activities within demarcated areas.
- Progressive rehabilitation of disturbed land should be carried out to minimize the amount of time that bare soils are exposed to the erosive effects of rain and subsequent runoff.
- Traffic and movement over stabilised areas should be controlled (minimised and kept to certain paths), and damage to stabilised areas should be repaired timeously and maintained.
- Water quality monitoring will be undertaken as per the monitoring programme outlined below.

- Smelter infrastructure will be constructed and operated so as to comply with the NWA guidelines. The design of the storm water infrastructure has been provided in detail in Section 5 and is summarised below:
  - Clean water systems will be separated from dirty water systems.
  - Clean run-off and rainfall water should be diverted around dirty areas and back into the environment.
  - The size of contaminated water generating areas should be minimized, and contaminated water contained in systems that allow for the reuse and/or recycling of this contaminated water.

Operation Phase

- All hazardous chemicals (new and used), mineralized waste and non-mineralised waste must be handled in such a manner that they do not pollute surface water. This will be implemented by means of the following:
  - Pollution prevention through basic infrastructure design such as waste storage containment, hardstanding and bunds.
  - Pollution prevention through maintenance of equipment.
  - Pollution prevention through education and training of workers (permanent and temporary).
  - A Spill clean-up plan to enable containment and remediation of pollution incidents.
- Water quality monitoring will be undertaken as per the monitoring programme outlined below.
- Good housekeeping practices should be implemented and maintained by timeous cleaning-up of accidental spillages, as well as ensuring all dislodged material from the SLF is kept within the confined storage footprints. In addition, spill cleaning kits and material safety data sheets for chemical and hazardous substances should be accessible and available where these are used for immediate clean-up of accidental spillages of pollutants.

Closure and Decomisssioning Phase

- In case of an occurrence of a discharge incident that could result in the pollution of surface water resources, the emergency response procedure should be implemented.
- Phasing / scheduling of earthworks should be implememnted in order to minimise the footprint that is at risk of erosion at any given time, or schedule works according to the season.
- In the case of linear earthworks, phasing of working areas and progressive rehabilitation will be necessary to minimise the footprint of the extent of the disturbance at any given time.
- Water quality monitoring will be undertaken as per the monitoring programme outlined below.
- A post rehabilitation audit should be undertaken during the end of life of mine to ascertain whether the remediation has been successful is recommended and if not, further measures should be recommended and implemented.

7.1.4 Monitoring

- Analytical suites as outlined in Table 7-4 for recommended water quality analysis should be undertaken until a longer-term baseline has been established. Monitoring should additionally be done after storm events.
- The monitoring plan should be reviewed regularly, no more that every three years to ensure appropriateness of sites and sampling frequency during operation.

Table 7-4 : Surface Water Quality Parameters of Concern

Determinant	
pH	Nitrate as N
Electrical conductivity	Ammonia
Total dissolved solids	Potassium
Total suspended solids	Nickel
Aluminium	Manganese
Calcium	Magnesium
Fluoride as F	Iron
Total alkalinity as $CaCO_3$	Copper
Chloride as Cl	Lead
Sulphate as SO_4	Sodium
Uranium	*E.coli*

Reporting

Reporting on the above monitoring should be as follows:

- Internal Reporting – Monthly for:
    - Water Levels in holding dams; and
    - Drainage Inspections.
- External Reporting – Annual for:
    - Water Quality; and
    - Spillages / Emissions.

Accidental spillages and overflows should be reported as and when they occur to the relevant authorities.

7.2 FLOODING

7.2.1 Description of impact

Pre-development natural drainage across the project area is via preferential flow paths. Development can alter the hydrologic response of an area and, ultimately, an entire watershed. The removal of vegetation as well as the compaction of surfaces during construction at the SLF will very likely result in increased runoff. The location of surface infrastructure in relation to surface water bodies is imperative to understanding the impacts of flooding.

7.2.2 Impact assessment

Construction, Operation, Decommissioning and Closure Phases

Potential Impacts

The SLF is presently located within a 1:100-year flood line and as such it is susceptible to flooding. This activity will continue during the construction, operational and decommissioning phase. During heavy rainfall events the secure landfill facility may be flooded by the stream located to the west. The overall high severity rating applies in the unmitigated (all phases) and whilst a medium severity applies in the mitigated scenarios for all phases. The probability of the flooding is definite, but the magnitude of the risk of flooding is medium throughout all the phases of the life of the SLF.

The significance is high in all phases without mitigation. With mitigation this reduces the severity to medium prior to closure and to a low severity thereafter.

The rating provided in Table 7-5 is reliant on the flood protection berm as a mitigation measure.

Table 7-5: Impact summary – Flooding in Construction, Operation, Decommissioning and Closure Phases

Issue: Flooding		
Phases: Construction, Operation, Decommissioning and Closure Phases		
Criteria	Without Mitigation	With Mitigation
Intensity	Severe change or disturbance	Prominent change or disturbance
Duration	Long-term	Medium-term
Extent	Beyond the site boundary	Site Boundary
Consequence	High	Medium
Probability	Definite	Probable
Significance	High	Medium
Nature of impacts	The SLF will be located within a 1:100-year flood line as such it is susceptible to flooding. This activity will continue During the construction, operational and decommissioning phase. During heavy rainfall events the secure landfill facility may be flooded by the stream located to the west, the impact is assessed to be High.	
Degree to which impact can be reversed	In Unmitigated scenario the impact is irreversible because the SLF is a permanent structure.	
Degree to which impact may cause irreplaceable loss of resources	The development of a flood protection berm that aims to protect against flooding and reduced flow velocity may minimise the impact.	
Residual impacts	The residual impact is considered to be Medium with only Moderate impacts on surrounding receptors.	

7.2.3 Mitigation

- It is recommended that the SLF be relocated and placed outside of the 1:100-year flood line in order to prevent the impact of flooding. It is proposed that the SLF be relocated to an estimated 150-meter distance east of the original SFL location.

In the event that the SLF is not moved, a flood protection berm that aims to protect against flooding is recommended. The design specification of the flood protection berm is presented in Section 5.4.4 and in Figure 5-6. The rating provided in Table 7-5 accounts for relocation of the SLF as a mitigation measure.

Table 7-6: Impact summary – Flooding in Construction, Operation, Decommissioning and Closure Phases

Issue: Flooding		
Phases: Construction, Operation, Decommissioning and Closure Phases		
Criteria	Without Mitigation	With Mitigation
Intensity	Prominent change or disturbance	No change or disturbance
Duration	Long-term	Quickly reversible
Extent	Beyond the site boundary	A part of the Site
Consequence	Medium	Very Low
Probability	Probable	Unlikely
Significance	Medium	Insignificant
Nature of impacts	The SLF will be located within a 1:100-year flood line as such it is susceptible to flooding. This activity will continue During the construction, operational and decommissioning phase. During heavy rainfall events the secure landfill facility may be flooded by the stream located to the west, if the SLF is relocated the impact is assessed to be MEDIUM.	
Degree to which impact can be reversed	In mitigated scenario the SLF will be relocated outside of the flood line therefor the impact is prevented.	
Degree to which impact may cause irreplaceable loss of resources	The relocation of the SLF will prevent the flooding impact.	
Residual impacts	There are no residual impacts	

7.2.4 Monitoring

Monitoring and inspection of channels, silt traps, culverts, pipelines, dam walls and dams for signs of erosion, cracking, silting and blockages of inflows, to ensure the performance of the storm water infrastructure is recommended should a flood protection berm be developed as a mitigation measure. Monitoring should be undertaken monthly during wet season and after storm events or as per the site management schedule.

7.3 ALTERATION OF NATURAL DRAINAGE PATTERNS AND FLOW

7.3.1 Description of impact

Natural drainage across the project area is via preferential flow paths (natural drainage line). Development of the SLF can alter the hydrologic response of an area and, potentially, an entire watershed. Development of the SLF can remove beneficial vegetation and replace it with turf grass lawns and impervious roofs, driveways, parking lots, and roads, thereby reducing the site's pre-developed evapotranspiration and infiltration rates. The location of surface infrastructure in relation to surface water bodies is imperative to understanding the impacts of alteration of drainage and natural flow. Construction of the smelter and the road between the Smelter and the SLF will reduce runoff reporting downstream due to stormwater management measures.

7.3.2 Impact assessment

Construction, Operation, Decommissioning and Closure Phases

Potential Impacts

Surface water run-off will be managed utilising engineered infrastructure, which is to be designed and constructed as required by legislation and specified in Section 5.2.2. When the storm water management measures that attenuate surface runoff are constructed on site, clean stormwater will be diverted around the infrastructure and it will alter the drainage flow. Although the region is generally dry, significant rainfall events do occur and these events cause temporary flow of surface water. A summary of the impact is provided in Table 7-7.

The alteration to drainage patterns will continue for the construction, operational and decommissioning phases, until such time as project infrastructure can be removed.

Table 7-7: Impact summary – Alteration of Natural Drainage Patterns and Flow during Construction and Operational Phases

Issue: Alteration of Natural Drainage Patterns and Flow		
Phases: Construction and Operation Phases		
Criteria	Without Mitigation	With Mitigation
Intensity	Minor change or disturbance	No Change or Disturbance
Duration	Medium-term	Ver Low
Extent	Whole site boundary	A part of the boundary
Consequence	Medium	Ver Short
Probability	Probable	Unlikely
Significance	Medium	Very Low
Nature of cumulative impacts	Surface water run-off will be managed in all areas utilising designed water containment infrastructure as required by legislation and specified in Section 5.2.2. When the storm water management measures that attenuate clean surface runoff catchment area for runoff may be reduced. The impact is assessed to be MEDIUM.	
Degree to which impact can be reversed	In the context of the affected quaternary catchments this is considered to be a medium severity because the reduction will not result in a substantial deterioration in the water reserve and downstream water uses.	
Degree to which impact may cause irreplaceable loss of resources	If the SLF is not relocated there will be loss of resources which may not be replaceable.	
Residual impacts	The residual impact is considered to be medium with moderate impacts on surrounding watercourses	

7.3.3 Mitigation

- It is recommended that the SLF be relocated in order to avoid alteration of drainage and flow, or the construction of the protection berm. There are no other mitigation measures to minimize the flow and alteration of drainage paths.
- In order to mimimise the alteration of flow clean water around the smelter and the SLF must be diverted around the infrastructure then allowed to get to preferential flow into the environment.

7.4 ADDITIONAL MONITORING

7.4.1 Water Demand Management

The project's water circuit has been documented and the water management strategy defined. The reuse of process water will be prioritised, thereby ideally reducing the impacts from the project on the surface water resources. The site wide water balance should be refined on an on-going basis with the input of actual flow volumes and then used as a decision-making tool for water management and impact mitigation (**Section 6**).

- Water Conservation and Water Demand Management (WC/WDM) measures are essential and necessary for this project to ensure that water is collected and reused and the abstraction of water from the Sedibeng Water Scheme is minimised.

8. CONCLUSIONS AND RECOMMENDATIONS

This surface water study was undertaken by a suitably qualified, experienced and independent Hydrologist to comply with the NEMA regulations requirements. A summary of the NEMA regulations requirements for technical specialist studies and cross references to the relevant supporting information is presented in Appendix A.

A SWMP has been developed to ensure compliance with the requirements of GN 704. As part of the detailed design process, a geotechnical investigation is necessary to assess the structural integrity of the existing embankment as well as to determine the dam footprint for the lining, compaction, flood protection berm and storage estimates. Confirm all the levels (base of dam, full capacity, spillway and freeboard). Source clay liner from within the project area while also characterising the available soils for construction materials (road construction, backfill to structures, foundations, etc.).

Due to the absence of sufficient rain water leading to flows in the ephemeral streams no recent run off sampling and analysis were conducted. Baseline water quality assessment has been undertaken based on the existing one-year record of water quality data from the SRK Gamsberg Zinc Project Baseline study. The water quality during the year 2009 was acceptable and within the specified guidelines. It is further recommended that monitoring be undertaken whenever possible in accordance with the monitoring plan in 7.1.4. A site wide water balance has been developed, to estimate the return water and make up water requirements with the proposed infrastructure. The project's water circuit has been defined. A collection and water management strategy were also defined where the reuse of process water will be prioritised, thereby ideally reducing the impacts from the project on the surface water resources.

Flood lines for the 1:100-year recurrence intervals were determined for the current ephemeral stream network passing through the project site. The local surface water resources are considered to be of low sensitivity because the area receives low rainfall throughout the year.

Informed by the mine plan layout, baseline hydrology, design specifications for the storm water management measures, the flood lines, and the water balance results, the potential impacts of the proposed activities on surface water receptors, as well as the sensitivity of the surface water resources, along with a summary of mitigation measures.

A monitoring programme is an essential tool to identify any risks of potential impacts as they arise and to assist in impact management plans by assessing if mitigation measures are operating effectively. Monitoring should be implemented throughout the life of the mine.

The outcomes of the baseline assessments, flood lines modelling and storm water management should be implemented in the design of the smelter, secured landfill facility and associated infrastructure. Subject to the implementation of the mitigation measures and the recommendations proposed herein, it is concluded that the activities should be authorised.

All measures implemented for the mitigation of impacts, should be regularly reviewed against best practice guidelines and to achieve compliance with the various licences issued on site by the authorities. The project can continue, if all mitigation and monitoring measures are implemented as recommended.

Pfarelo Siebani
(Report Co-Author)

Kevin Bursey
(Project Manager and Co-Author)

Fred Sutherland
(Reviewer)

9. REFERENCES

DWAF. (2006c). Best Practice Guideline G2: Water and Salt Balances. Pretoria, South Africa: Department of Water Affairs and Forestry.

DWS. (2016). Existing Water Use Licence (WUL) for Gamsberg Zinc Mine (DWS, 2016).

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South Africa. (1998). General Notice 704 of the National Water Act (36 of 1998). Pretoria: Department of Water and Forestry.

SRK Consulting. (2010). Gamsberg Zinc Project Interim Baseline Report – Hydrology and Surface Water Quality

Tata Consulting. (2019). Pre-Feasibility Study Report for a 250 ktpa Zinc Smelter Smelter with infrastructure at Gamsberg, South Africa (Tata Consulting Engineers Limited. WR2012, “Water Resources of South Africa, 2012 Study (WR2012)”, WRC Report No. TT 683/16, Water Research Commission, Pretoria.

APPENDIX A: SUMMARY OF NEMA REGULATION (2017) APPENDIX 6

NEMA Regs (2014) - Appendix 6	Relevant section in report
Details of the specialist who prepared the report	Section 1 and Appendix A
The expertise of that person to compile a specialist report including a curriculum vitae	Appendix A.
A declaration that the person is independent in a form as may be specified by the competent authority	Appendix C.
An indication of the scope of, and the purpose for which, the report was prepared	Section 1.4
An indication of the quality and age of baseline data used for the specialist report	Section 2.2
A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 3 and Section 6
The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment	Section 2
A description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used	Numerous methodologies discussed throughout the report
Details of an assessment of the specific identified sensitivity of the site related to the proposed activity (or activities) and its associated structures and infrastructure inclusive of a site plan considering alternatives	Baseline hydrological conditions are discussed in Section 2
An identification of any areas to be avoided, including buffers	Flood-lines and buffers are discussed in Section 4
A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Figure 4-3
A description of any assumptions made and any uncertainties or gaps in knowledge;	Limitations and further work are discussed in Sections 4.5 and 7.
A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Alternatives are discussed within EIA study
Any mitigation measures for inclusion in the EMPr	Section 4, Section 5, Section 6 and Section 7
Any conditions for inclusion in the environmental authorisation	N/A
Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 7.6
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised and	Section 7
Regarding the acceptability of the proposed activity	Section 7
If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Various recommendations are made throughout the report, most notably Sections 4, 5,6 and 8
A description of any consultation process that was undertaken during the course of carrying out the study	N/A
A summary and copies if any comments that were received during any consultation process	N/A
Any other information requested by the competent authority.	N/A

APPENDIX B: SUBCATCHMENT CHARACTERISTICS AND STORM WATER CONVEYANCE INFRASTRUCTURE ESTIMATED SIZING

Table B1: Sub-catchment Characteristics

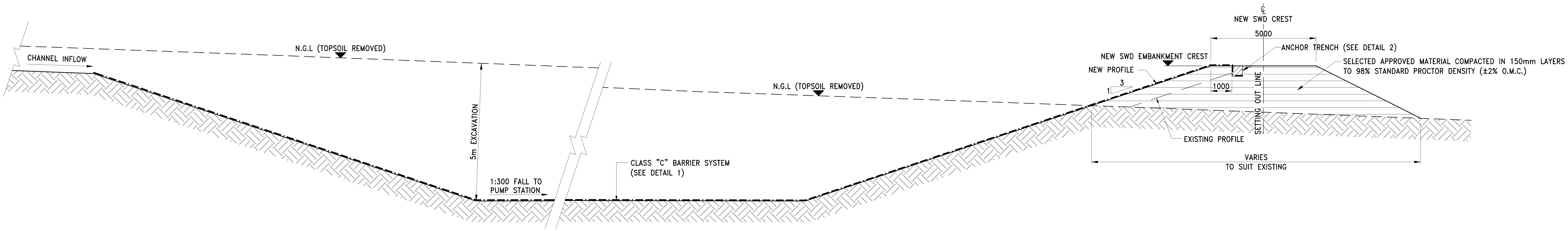
Name	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Runoff Volume (m^3)	Peak Runoff (m^3/s)	Runoff Coefficient
Clean Sub-catchments							
S2	36.2	260	1392.6	1.01	16700	1.38	0.455
S3	28.1	160	1754.6	1.02	12320	1.00	0.433
S4	62.4	330	1891.5	0.95	26650	2.14	0.421
S5	149.7	700	2139.0	0.95	61790	4.92	0.407
S6	55.6	480	1158.4	0.81	26010	2.18	0.461
S7	19.0	350	543.9	0.95	9900	1.03	0.513
S8	7.1	150	471.5	1.15	3740	0.43	0.522
S9	5.0	140	354.8	1.08	2660	0.34	0.529
S10	10.8	315	343.0	0.95	5790	0.73	0.528
S11	5.8	170	340.8	0.85	3090	0.38	0.527
S12	5.5	145	379.7	1.05	2940	0.36	0.527
S14	94.0	505	1861.4	1.15	41270	3.33	0.433
S15	25.3	1050	240.9	1.15	13780	2.28	0.537
S16	65.6	340	1929.4	1.15	28550	2.30	0.429
S17	6.9	310	223.9	2.00	3820	0.78	0.542
S18	57.8	290	1993.3	1.15	24950	2.01	0.426
S19	6.9	310	223.7	2.00	3810	0.77	0.542
S20	34.1	180	1893.8	1.20	14980	1.21	0.433
S21	7.3	320	228.7	2.00	4020	0.81	0.542
Dirty Sub-catchments							
S1	23.3	700	333.1	1.60	20190	3.90	0.854
S13	21.0	750	280.1	2.00	18300	4.11	0.859

Table B2: Drainage Channel Sizing

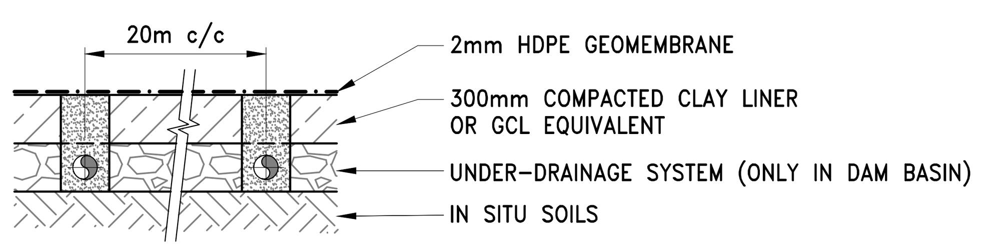
Name	Length (m)	Channel Shape	Depth (m)	Width (m)	Side Slope (H:V)	Slope (m/m)	Max. Flow (m³/s)	Max. Velocity (m/s)	Depth of water in Channel (m)
Clean Channels									
C1	344.5	TRAPEZOIDAL	0.6	0.6	2	1	0.0086	0.42	1.8
C2	98.5	TRAPEZOIDAL	1.4	2.0	2	1	0.0004	5.33	1.7
C3	328.2	TRAPEZOIDAL	1.3	1.0	2	1	0.0044	8.18	3.3
C4	174.6	TRAPEZOIDAL	1.2	1.0	2	1	0.0088	9.61	4.0
C5	465.3	TRAPEZOIDAL	1.2	1.0	2	1	0.0107	11.40	4.6
C15	172.3	TRAPEZOIDAL	1.0	1.0	2	1	0.0088	3.17	3.2
C16	311.1	TRAPEZOIDAL	1.0	2.0	2	1	0.0063	5.93	2.8
C17	323.2	TRAPEZOIDAL	1.0	2.0	2	1	0.0048	8.23	3.5
C18	448.8	TRAPEZOIDAL	1.0	2.0	2	1	0.0100	8.22	4.0
C20	344.7	TRAPEZOIDAL	1.1	1.0	2	1	0.0059	5.62	3.1
C21	1016.8	TRAPEZOIDAL	1.0	1.0	2	1	0.0000	0.00	0.0
Dirty Channels									
C6	976.9	TRAPEZOIDAL	1.0	1.0	2	1	0.0062	0.00	0.0
C19	871.9	TRAPEZOIDAL	1.0	1.0	2	1	0.0101	0.00	0.0

APPENDIX C: TYPICAL DESIGN DRAWINGS FOR STORM WATER INFRASTRUCTURE

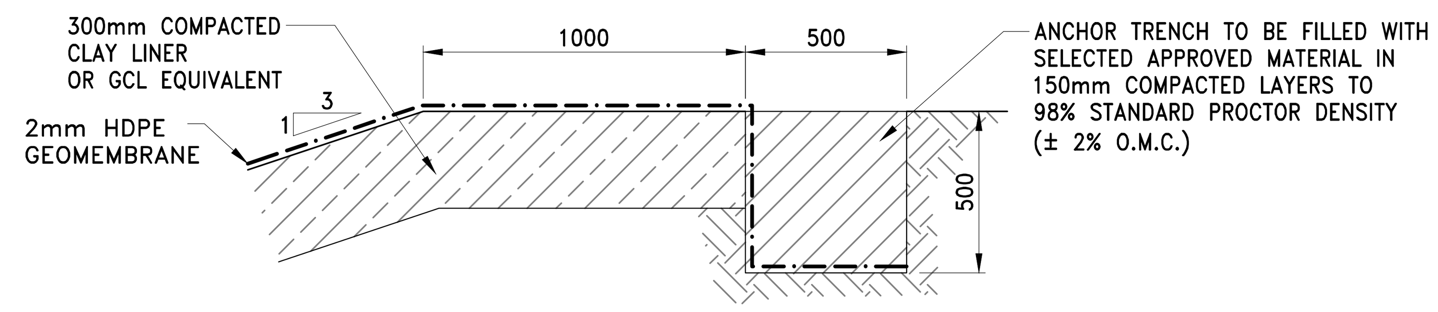
720.22013.00002-001 Typical Design Details for SWD 1 (Smelter Plant)



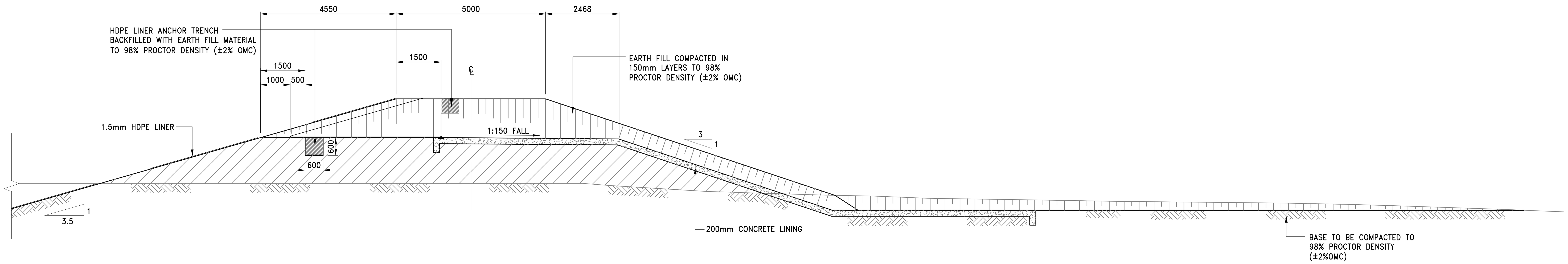
TYPICAL SECTION THROUGH SWD
1:100



DETAIL 1 - SWD BARRIER SYSTEM
N.T.S.



DETAIL 2 - ANCHOR TRENCH
SCALE 1:20



TYPICAL SECTION THROUGH SPILLWAY
1:75

ISSUED FOR INFORMATION ONLY
NOT FOR CONSTRUCTION

DO NOT SCALE - IF IN DOUBT, ASK.

REFERENCE

DRAWING NUMBER	TITLE

REVISIONS

No.	DESCRIPTION	BY	CHKD	DATE
A	ISSUED FOR COMMENT	MM	KB	07.04.20

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APPROVED BY CLIENT

DESIGNATION	DATE	INITIALS	SIGN
1.)			
2.)			

APPROVED BY SLR

DESIGNATION	DATE	INITIALS	SIGN
DRAUGHTSMAN	07.04.20	MM	
DESIGN ENGINEER	07.04.20	KB	
PROJECT DIRECTOR	07.04.20	SvN	
PROFESSIONAL ENGINEER (REG No.)	07.04.20	KB	

GAMSBERG SMELTER PROJECT

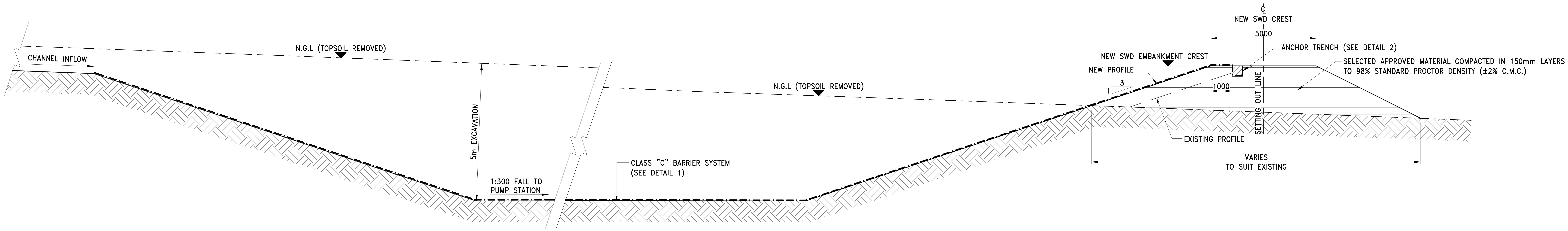
STORM WATER INFRASTRUCTURE
TYPICAL DESIGN DETAILS FOR SWD 1
(REFINERY PLANT)

DRAWING NUMBER : 720.22013.00002-001

SCALE: AS SHOWN
CO-ORD SYSTEM: -
SHEET: 1 OF 1
A1
REV : A

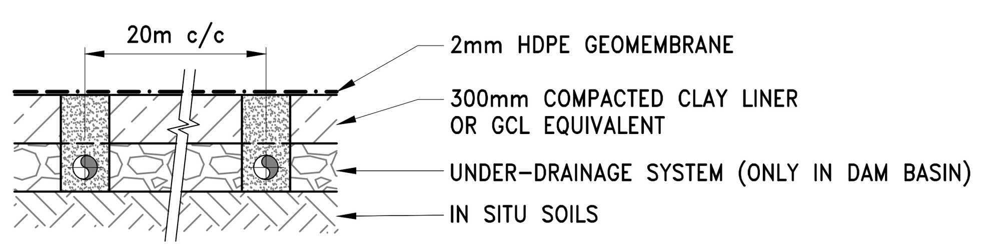
C:\Users\mmariano\Desktop\WORK\Gamsberg\720.22013.00002-001_Typical Design Details For SWD 1_RevA.dwg Apr 07, 2020 - 11:11am

720.22013.00002-002 Typical Design Details for SWD 2 (SLF)



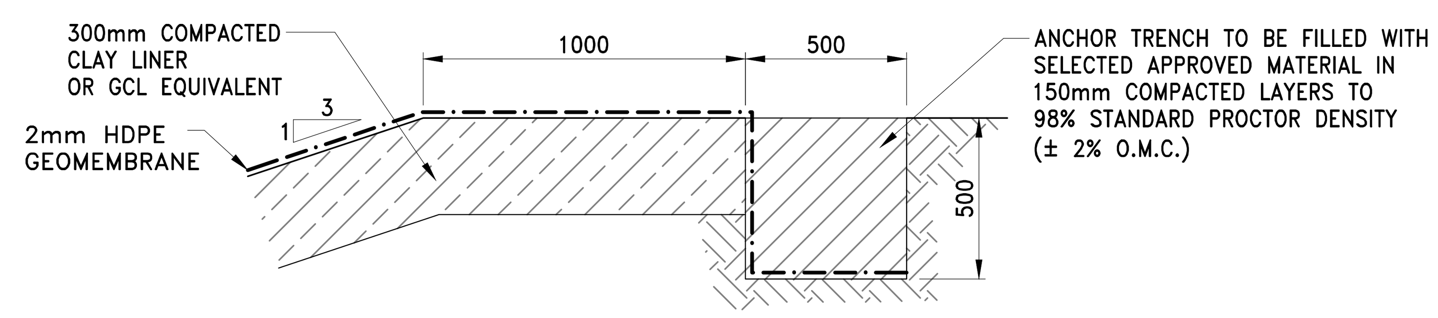
TYPICAL SECTION THROUGH SWD

1:100



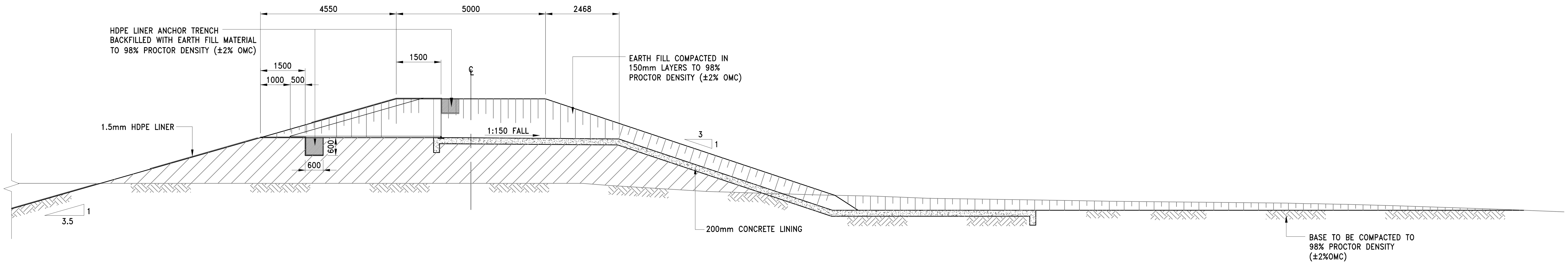
DETAIL 1 - SWD BARRIER SYSTEM

N.T.S.



DETAIL 2 - ANCHOR TRENCH

SCALE 1:20



TYPICAL SECTION THROUGH SPILLWAY

1:75

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PROJECT DIRECTOR	07.04.20	SvN	
PROFESSIONAL ENGINEER (REG No.)	07.04.20	KB	

GAMSBERG SMELTER PROJECT

STORM WATER INFRASTRUCTURE TYPICAL DESIGN DETAILS FOR SWD 2 (JAROSITE DUMP)

DRAWING NUMBER : 720.22013.00002-002

SCALE	AS SHOWN
CO-ORD SYSTEM	-
SHEET	1 OF 1
	A1
REV :	A

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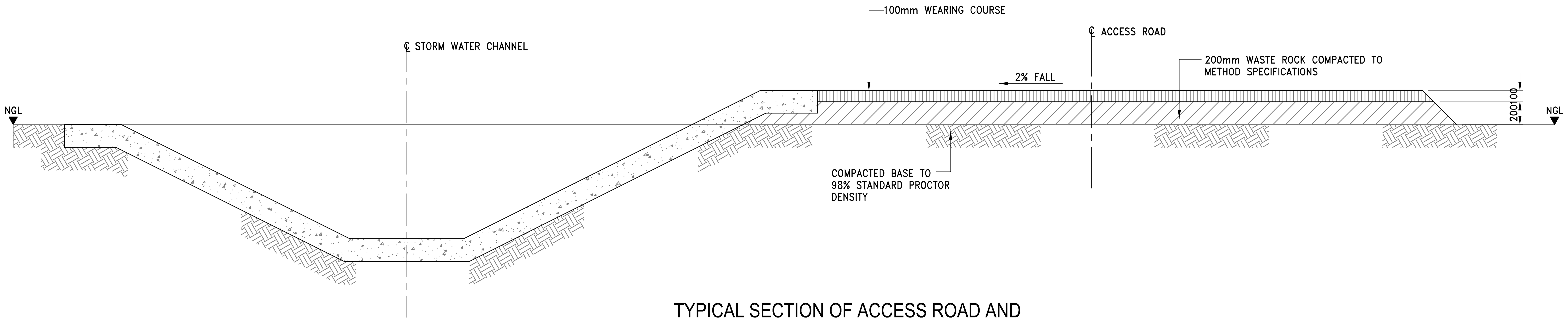
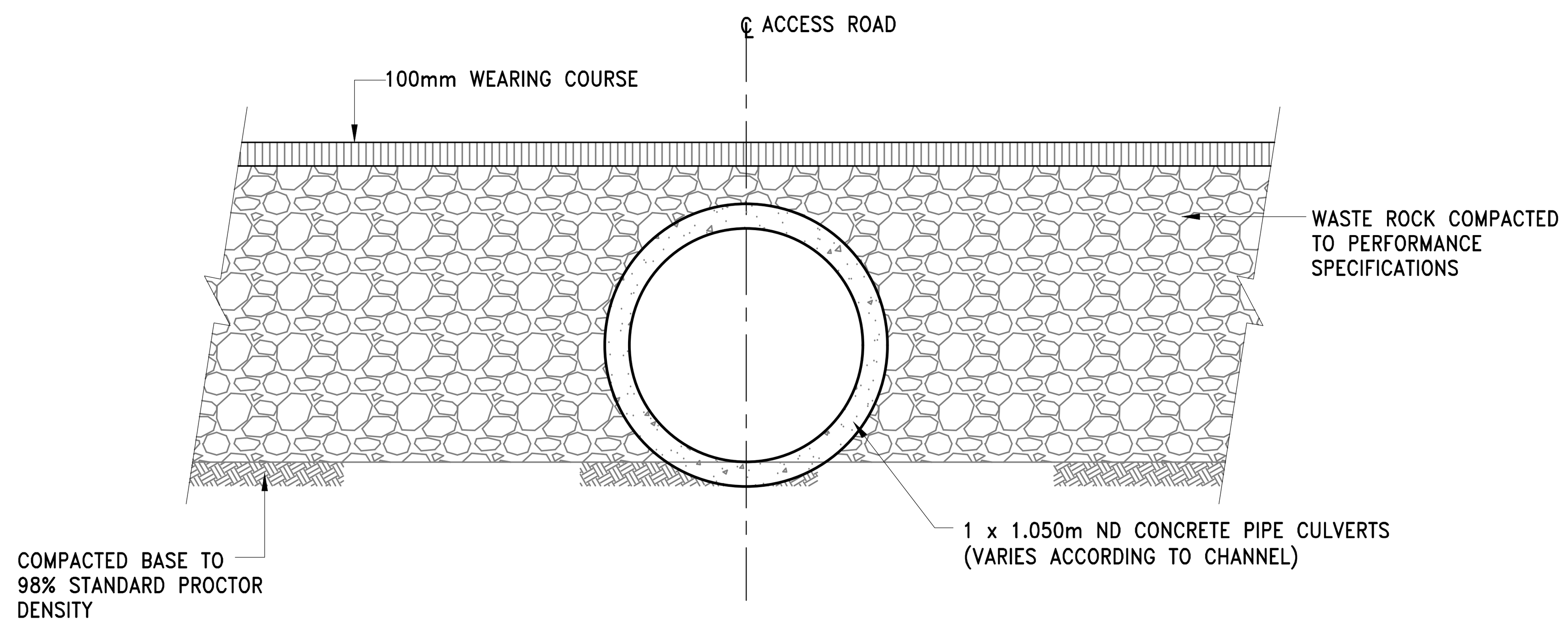
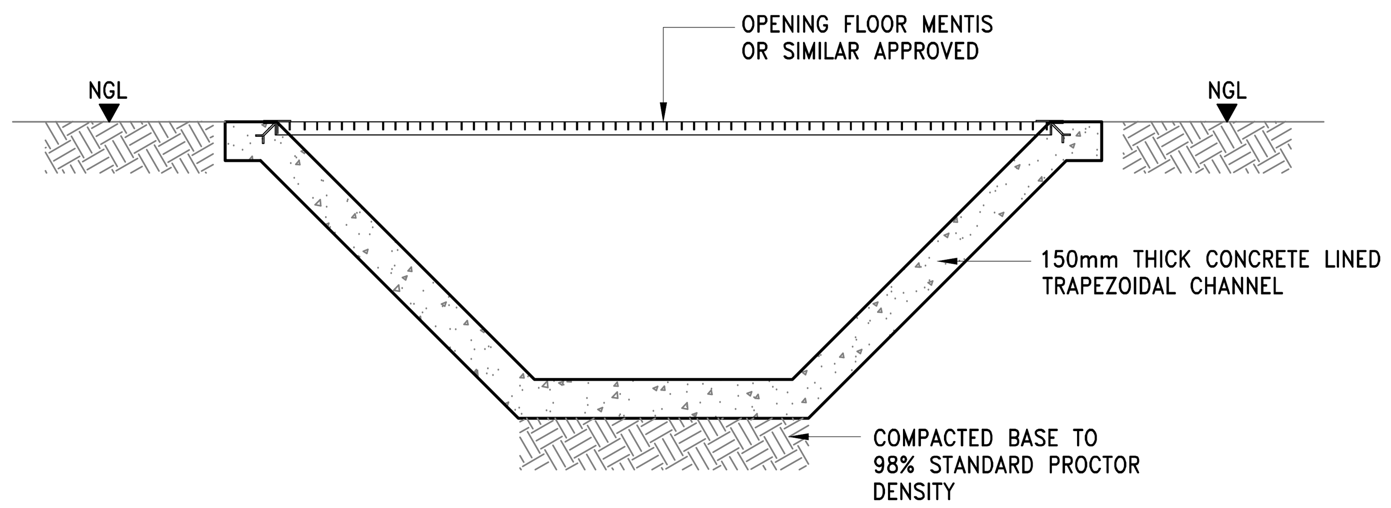
720.22013.00002-003 Typical Design Details for Channels, Culverts and Kerbing



TYPICAL SECTION OF ACCESS ROAD AND
STORM WATER CHANNEL
1:25



TYPICAL SECTION OF PERIMETER ACCESS ROAD
1:25



TYPICAL SECTION OF GRATED
TRAPEZOIDAL CHANNEL
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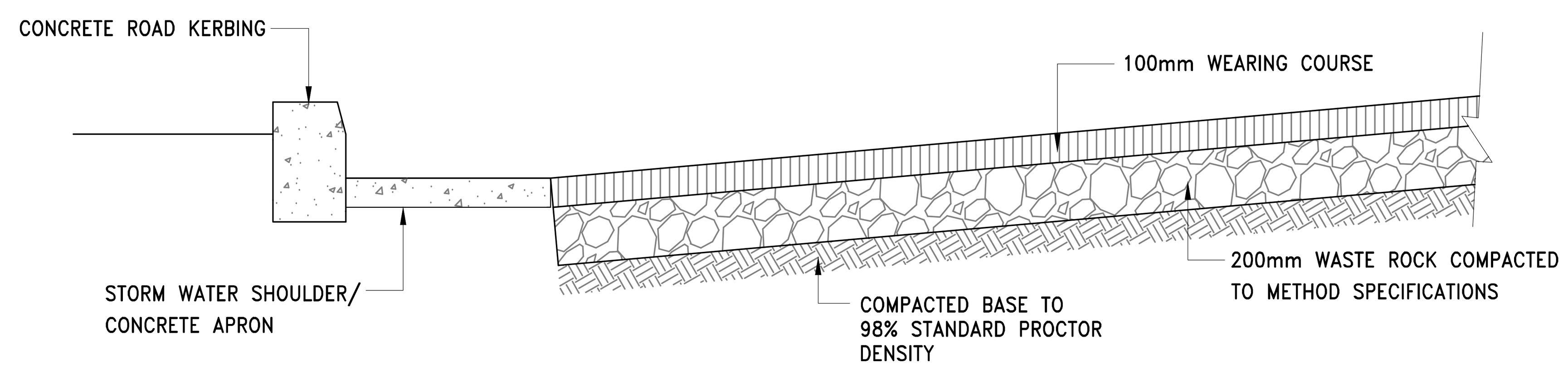

TYPICAL SECTION THROUGH ROAD KERBING
1:10

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GAMSBERG SMELTER PROJECT

STORM WATER INFRASTRUCTURE
TYPICAL DESIGN DETAILS FOR
CHANNELS, CULVERTS AND KERBS

DRAWING NUMBER : 720.22013.00002-003

SCALE: AS SHOWN
CO-ORD SYSTEM: -
SHEET: 1 OF 1
A1
REV : A

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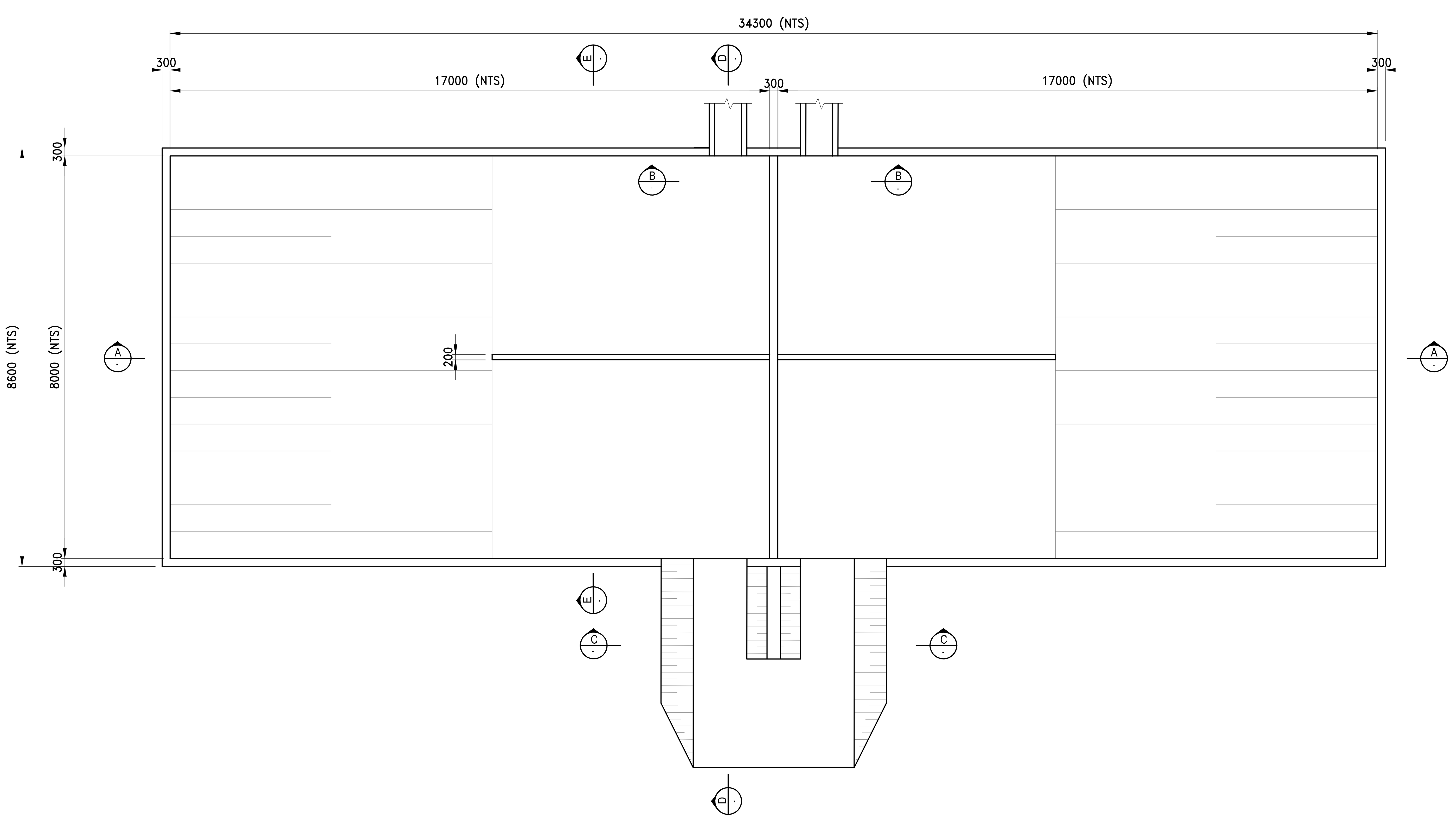
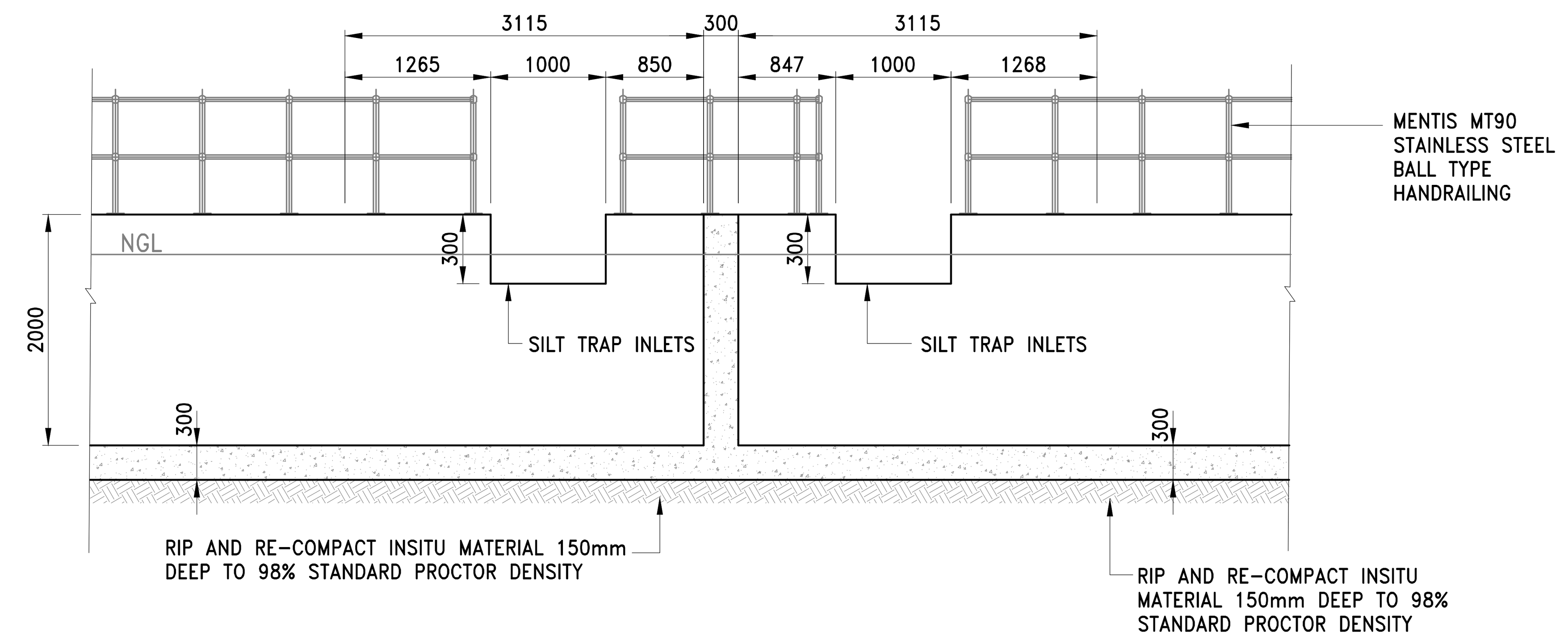
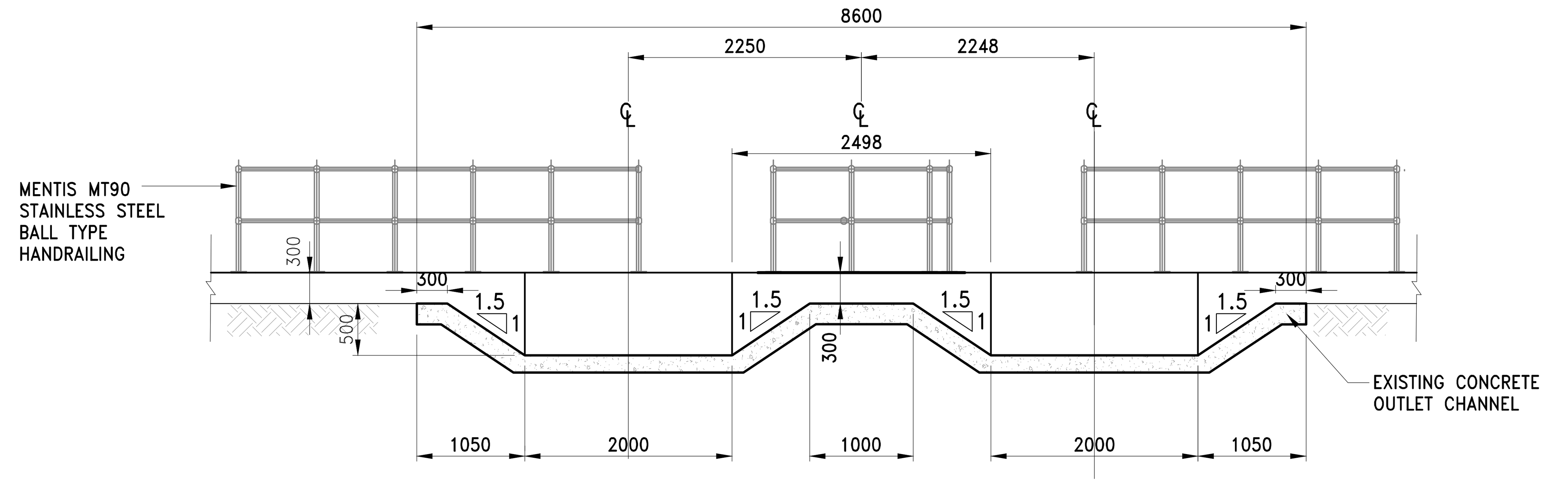
720.22013.00002-004 Typical Design Details for Silt Trap 1 (ST1) (Smelter Plant)



PLAN VIEW OF SILT TRAP
1:125



SECTION B-B
1:50



SECTION C-C
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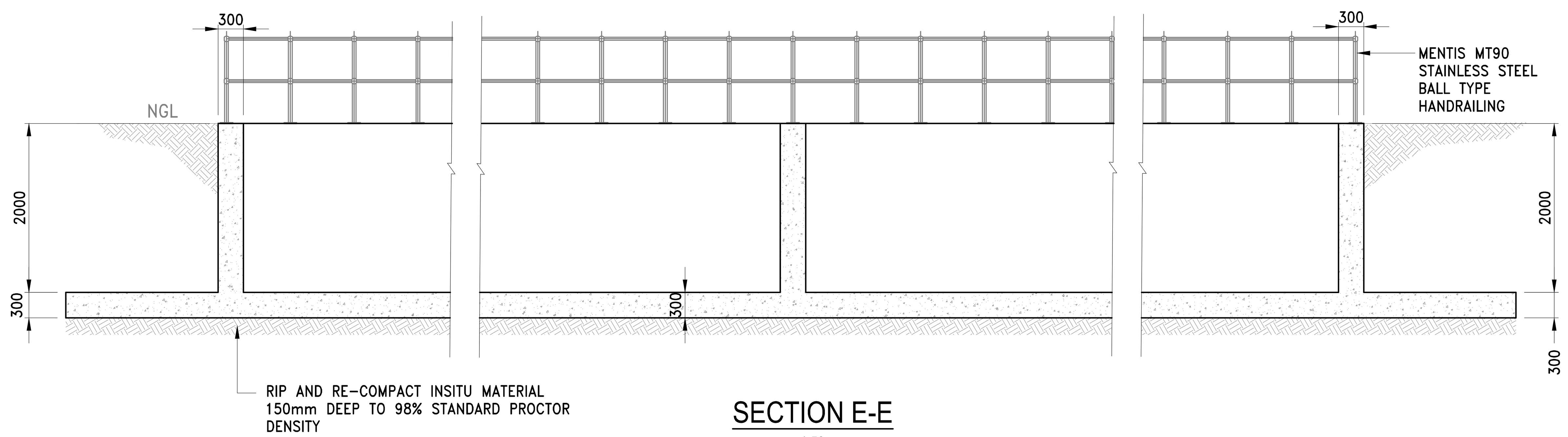

SECTION E-E
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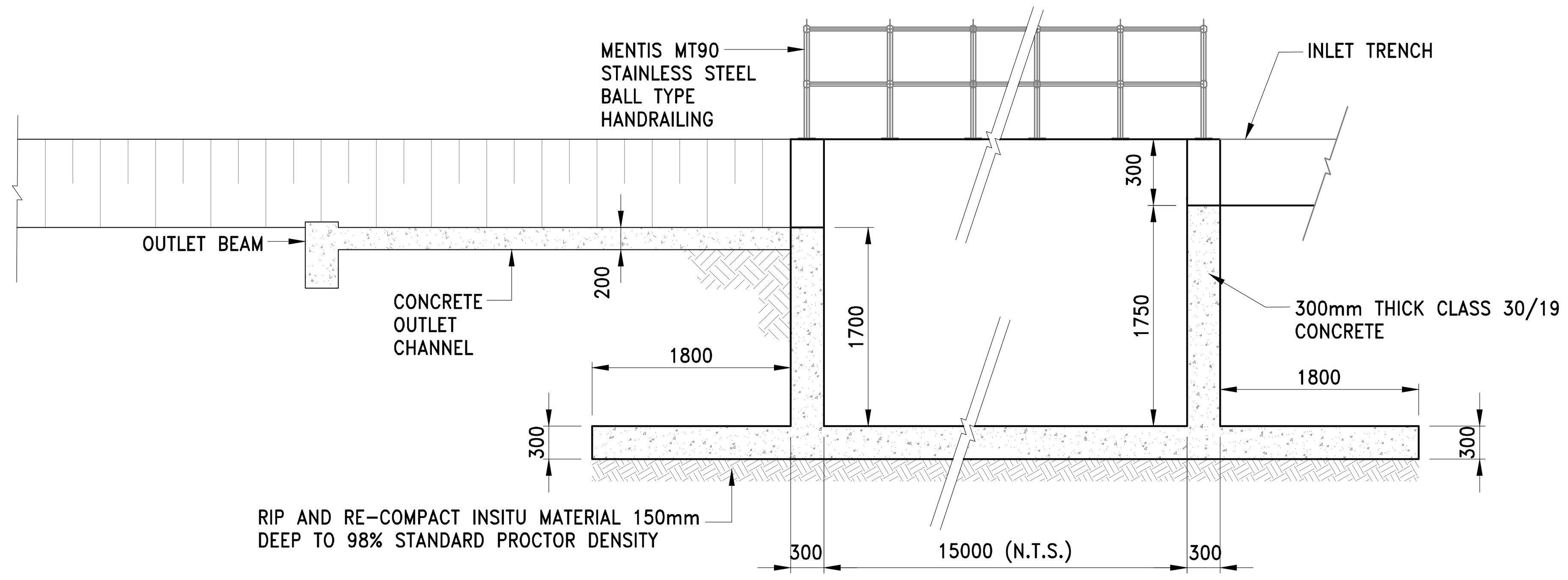

SECTION D-D
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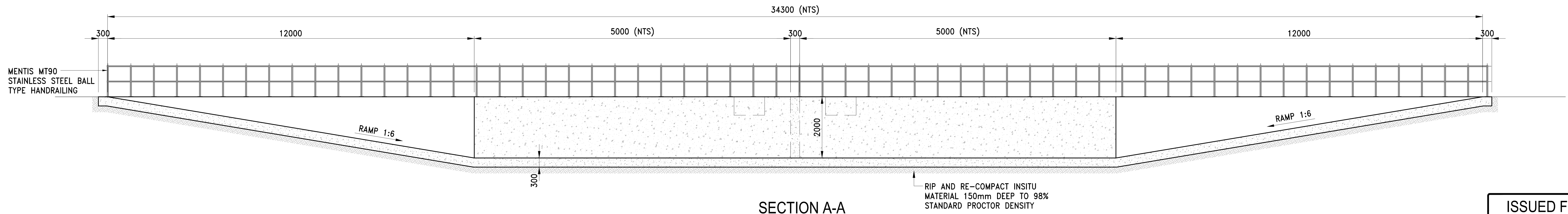

SECTION A-A
1:75

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PROFESSIONAL ENGINEER (REG No.)	07.04.20	KB	

GAMSBERG SMELTER PROJECT

STORM WATER INFRASTRUCTURE
TYPICAL DESIGHN DETAILS FOR SILT TRAP 1
(REFINERY PLANT)

DRAWING NUMBER : 720.22013.00002-004

SCALE: AS SHOWN
CO-ORD SYSTEM: -
SHEET: 1 OF 1
A1
REV : A

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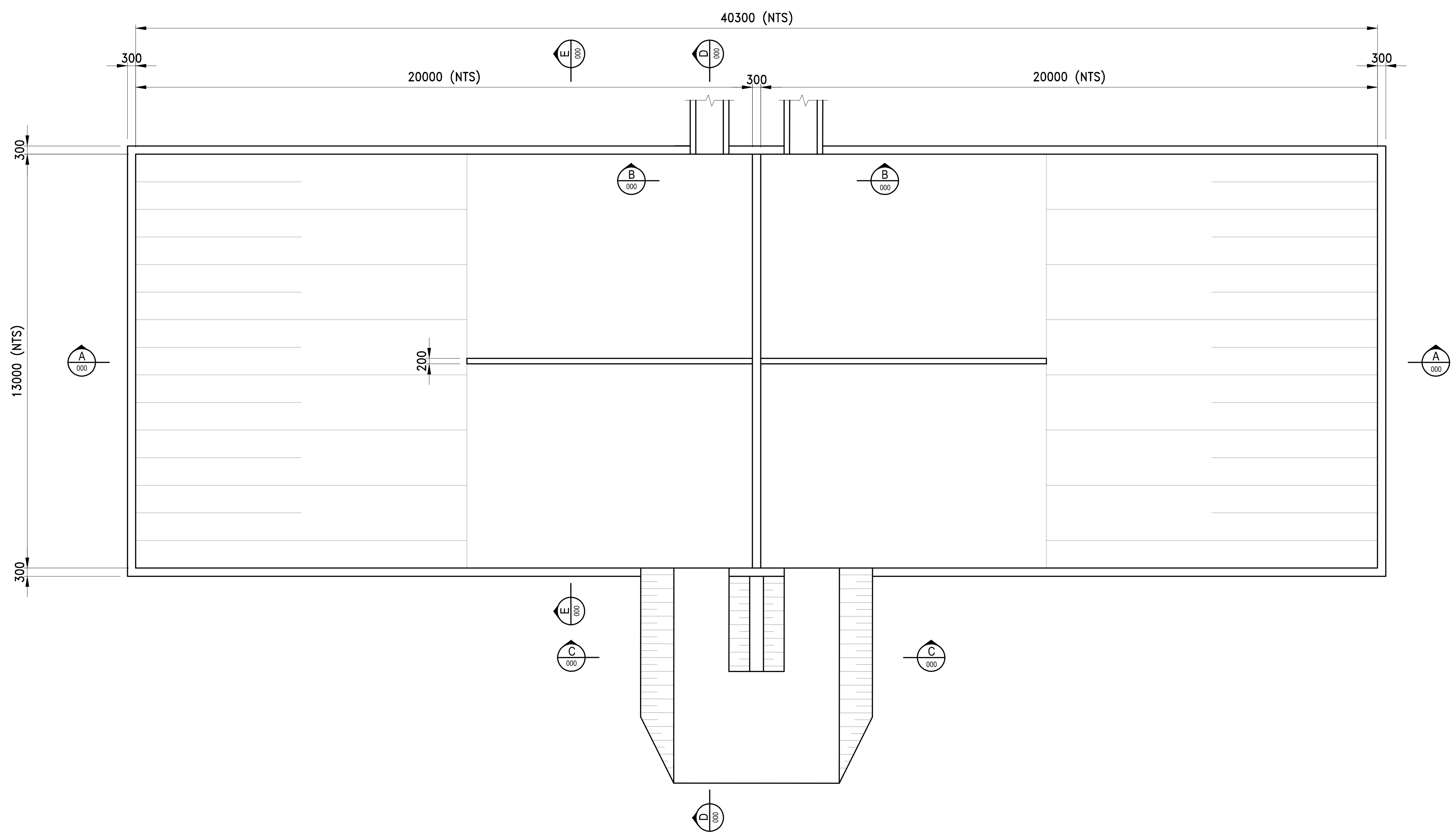
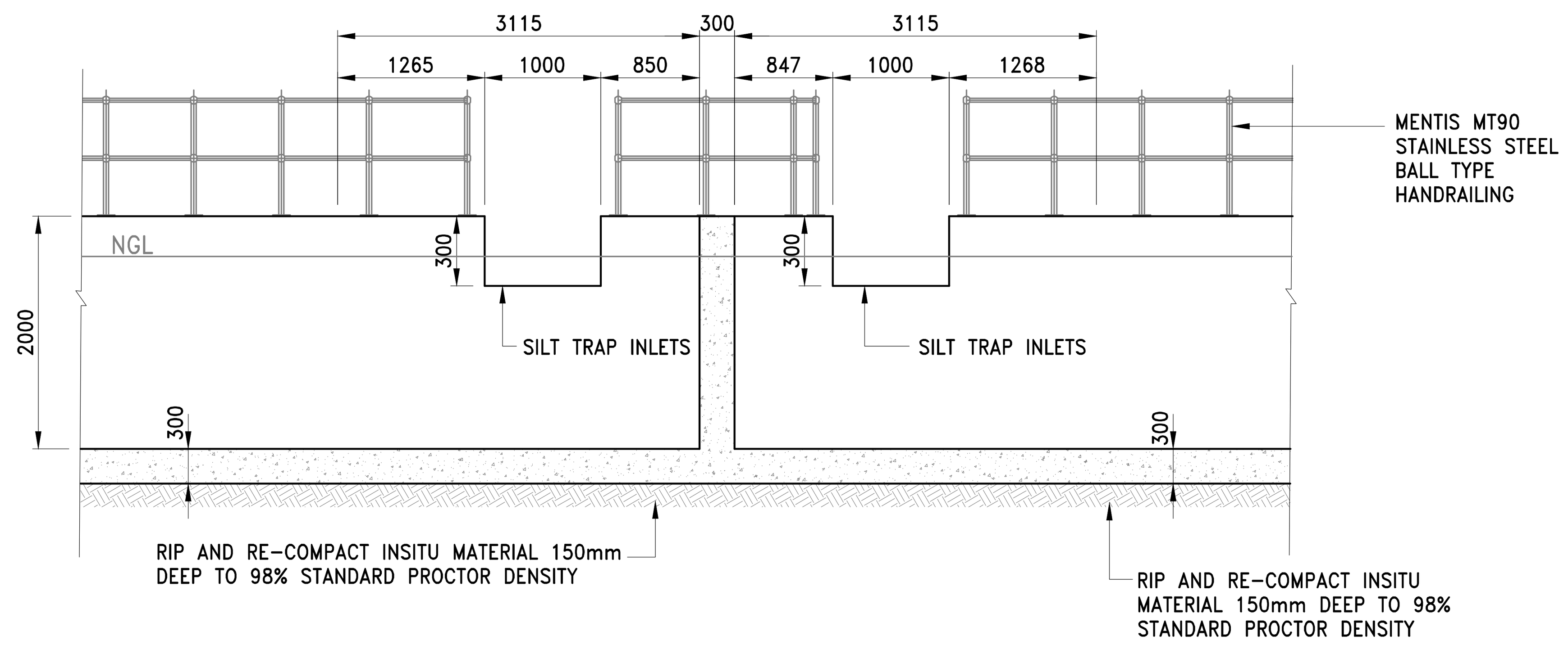
720.22013.00002-005 Typical Design Details for Silt Trap 2 (ST2) (Jarosite Dump)



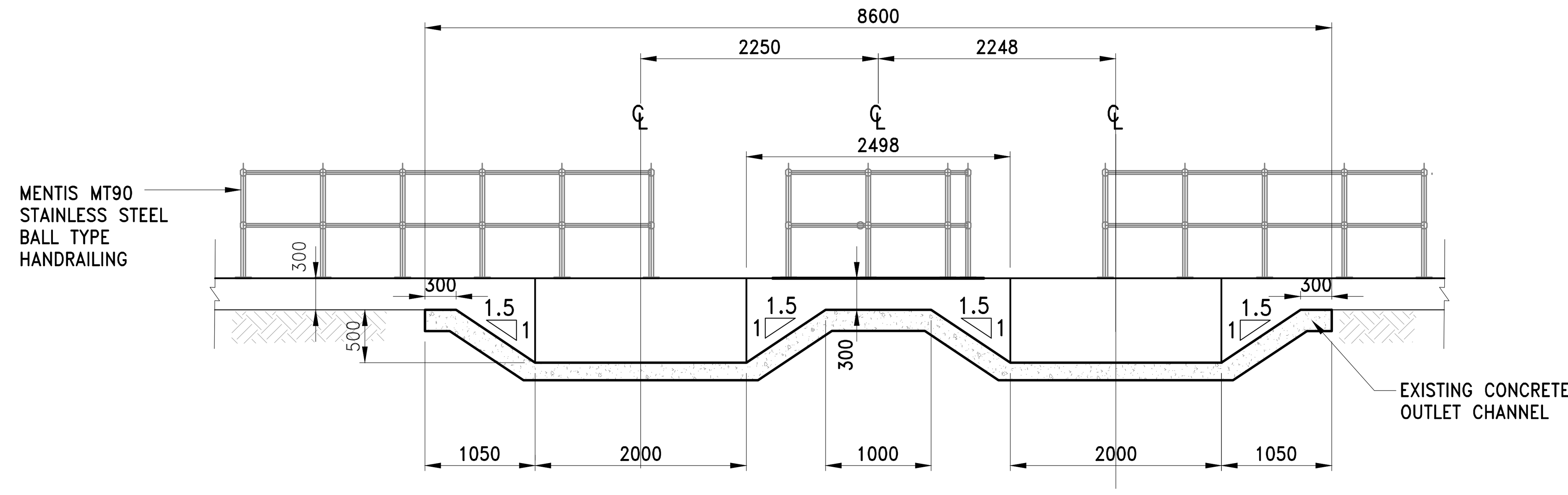
PLAN VIEW OF SILT TRAP

1:125



SECTION B-B

1:50



SECTION C-C

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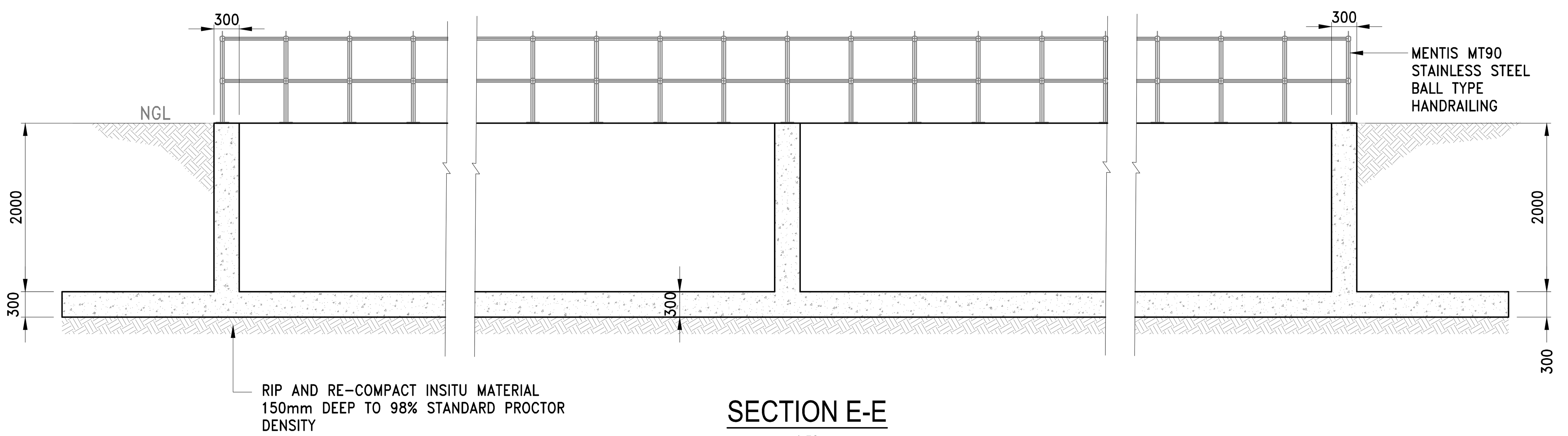

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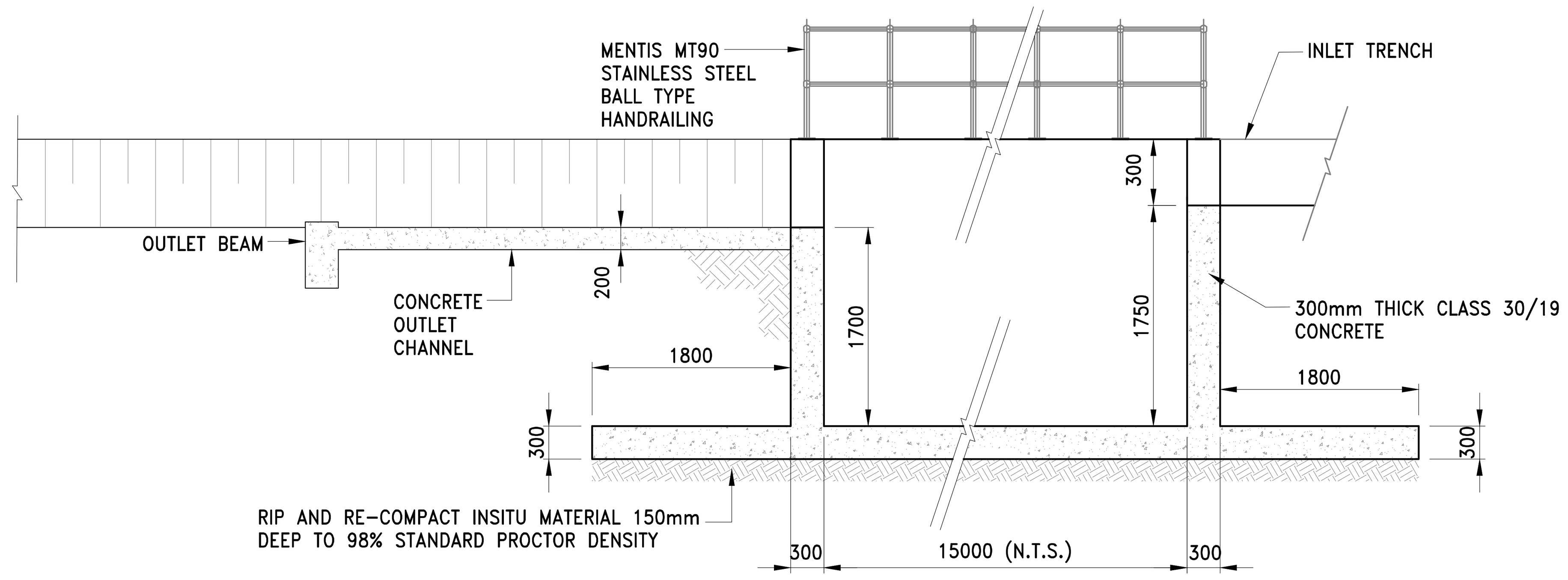

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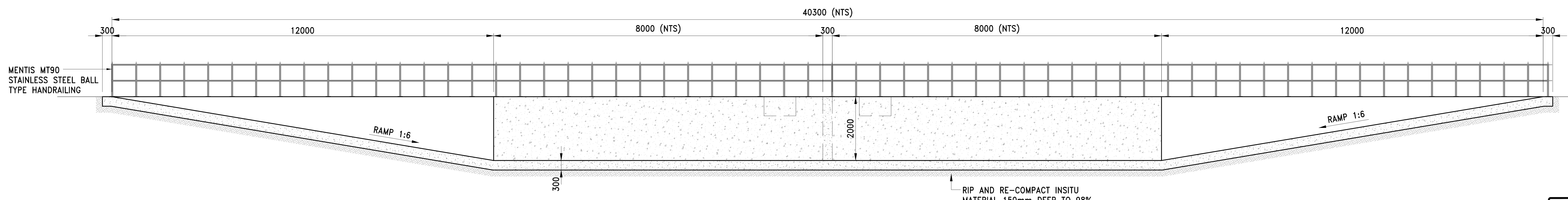

SECTION A-A

1:75

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GAMSBERG SMELTER PROJECT

STORM WATER INFRASTRUCTURE
TYPICAL DESIGHN DETAILS FOR SILT TRAP 2
(JAROSITE DUMP)

DRAWING NUMBER : 720.22013.00002-005

SCALE	AS SHOWN
CO-ORD SYSTEM	-
SHEET	1 OF 1
	A1
REV :	A

APPENDIX D: IMPACT ASSESSMENT METHODOLOGY

Table 9-1: SLR EIA Methodology

PART A: DEFINITIONS AND CRITERIA*		
Definition of SIGNIFICANCE		**Significance = consequence x probability**
Definition of CONSEQUENCE		**Consequence is a function of intensity, spatial extent and duration**
Criteria for ranking of the INTENSITY of environmental impacts	**VH**	Severe change, disturbance or degradation. Associated with severe consequences. May result in severe illness, injury or death. Targets, limits and thresholds of concern continually exceeded. Substantial intervention will be required. Vigorous/widespread community mobilization against project can be expected. May result in legal action if impact occurs.
	H	Prominent change, disturbance or degradation. Associated with real and substantial consequences. May result in illness or injury. Targets, limits and thresholds of concern regularly exceeded. Will definitely require intervention. Threats of community action. Regular complaints can be expected when the impact takes place.
	M	Moderate change, disturbance or discomfort. Associated with real but not substantial consequences. Targets, limits and thresholds of concern may occasionally be exceeded. Likely to require some intervention. Occasional complaints can be expected.
	L	Minor (Slight) change, disturbance or nuisance. Associated with minor consequences or deterioration. Targets, limits and thresholds of concern rarely exceeded. Require only minor interventions or clean-up actions. Sporadic complaints could be expected.
	VL	Negligible change, disturbance or nuisance. Associated with very minor consequences or deterioration. Targets, limits and thresholds of concern never exceeded. No interventions or clean-up actions required. No complaints anticipated.
	VL+	Negligible change or improvement. Almost no benefits. Change not measurable/will remain in the current range.
	L+	Minor change or improvement. Minor benefits. Change not measurable/will remain in the current range. Few people will experience benefits.
	M+	Moderate change or improvement. Real but not substantial benefits. Will be within or marginally better than the current conditions. Small number of people will experience benefits.
	H+	Prominent change or improvement. Real and substantial benefits. Will be better than current conditions. Many people will experience benefits. General community support.
	VH+	Substantial, large-scale change or improvement. Considerable and widespread benefit. Will be much better than the current conditions. Favourable publicity and/or widespread support expected.
Criteria for ranking the DURATION of impacts	**VL**	Very short, always less than a year. Quickly reversible
	L	Short-term, occurs for more than 1 but less than 5 years. Reversible over time.
	M	Medium-term, 5 to 10 years.
	H	Long term, between 10 and 20 years. (Likely to cease at the end of the operational life of the activity)
	VH	Very long, permanent, +20 years (Irreversible. Beyond closure)
Criteria for ranking the EXTENT of impacts	**VL**	A part of the site/property.
	L	Whole site.
	M	Beyond the site boundary, affecting immediate neighbours
	H	Local area, extending far beyond site boundary.
	VH	Regional/National

Table 9-2: Summary of Impacts Significance Ranking Scales

PART B: DETERMINING CONSEQUENCE							
INTENSITY = VL							
DURATION	Very long	**VH**	Low	Low	Medium	Medium	High
	Long term	**H**	Low	Low	Low	Medium	Medium
	Medium term	**M**	Very Low	Low	Low	Low	Medium
	Short term	**L**	Very low	Very Low	Low	Low	Low
	Very short	**VL**	Very low	Very Low	Very Low	Low	Low
INTENSITY = L							
DURATION	Very long	**VH**	Medium	Medium	Medium	High	High
	Long term	**H**	Low	Medium	Medium	Medium	High
	Medium term	**M**	Low	Low	Medium	Medium	Medium
	Short term	**L**	Low	Low	Low	Medium	Medium
	Very short	**VL**	Very low	Low	Low	Low	Medium
INTENSITY = M							
DURATION	Very long	**VH**	Medium	High	High	High	Very High
	Long term	**H**	Medium	Medium	Medium	High	High
	Medium term	**M**	Medium	Medium	Medium	High	High
	Short term	**L**	Low	Medium	Medium	Medium	High
	Very short	**VL**	Low	Low	Low	Medium	Medium
INTENSITY = H							
DURATION	Very long	**VH**	High	High	High	Very High	Very High
	Long term	**H**	Medium	High	High	High	Very High
	Medium term	**M**	Medium	Medium	High	High	High
	Short term	**L**	Medium	Medium	Medium	High	High
	Very short	**VL**	Low	Medium	Medium	Medium	High
INTENSITY = VH							
DURATION	Very long	**VH**	High	High	Very High	Very High	Very High
	Long term	**H**	High	High	High	Very High	Very High
	Medium term	**M**	Medium	High	High	High	Very High
	Short term	**L**	Medium	Medium	High	High	High
	Very short	**VL**	Low	Medium	Medium	High	High
			VL	**L**	**M**	**H**	**VH**
			A part of the site/ property	Whole site	Beyond the site, affecting neighbours	Extending far beyond site but localised	Regional/ National
			EXTENT				

PART C: DETERMINING SIGNIFICANCE							
PROBABILITY (of exposure to impacts)	Definite/ Continuous	**VH**	Very Low	Low	Medium	High	Very High
	Probable	**H**	Very Low	Low	Medium	High	Very High
	Possible/ frequent	**M**	Very Low	Very Low	Low	Medium	High
	Conceivable	**L**	Insignificant	Very Low	Low	Medium	High
	Unlikely/ improbable	**VL**	Insignificant	Insignificant	Very Low	Low	Medium
			VL	**L**	**M**	**H**	**VVH**
			CONSEQUENCE				

PART D: INTERPRETATION OF SIGNIFICANCE	
Significance	**Decision guideline**
Very High	Potential fatal flaw unless mitigated to lower significance.
High	It must have an influence on the decision. Substantial mitigation will be required.
Medium	It should have an influence on the decision. Mitigation will be required.
Low	Unlikely that it will have a real influence on the decision. Limited mitigation is likely required.
Very Low	It will not have an influence on the decision. Does not require any mitigation
Insignificant	Inconsequential, not requiring any consideration.

***VH = very high, H = high, M= medium, L= low and VL= very low and + denotes a positive impact.**

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