STORMWATER MANAGEMENT, CENTRAL WATER DAM & ASSOCIATED INFRASTRUCTURE

BASIS OF DESIGN

Beeshoek Plant Optimisation Project – WHIMS Plant

JZADBR4951-CIV-REP-001 Rev A

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REVISION RECORD

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REFERENCES DOCUMENTS

Document Number	Document Description
526742	Beeshoek Lowgrade Ore Beneficiation Definitive Feasibility Study Final Geotechnical Investigation Report
JZADBR4951-CIV-DC-003	Civil, Structural & Infrastructure Design Criteria
JZADBR4951-ME0SPC-001	Site Climatic Conditions
ETBEE-20-5804	Hydrogeological Impact Assessment for Beeshoek Mine” Report No. January 2021.

REFERENCE DRAWINGS

Document Number	Drawing Description
04951-IH-80-P-00322	Infrastructure Site Plan
04951-IH-80-YR-1-00332	WHIMS Plant Stormwater Management General Arrangement
04951-IH-80-YR-1-00346	5000m3 Central Water Dam Layout & Details
04951-IH-80-YR-1-00482	Central Dam Inlet Structure & Spillway Layout & Details
04951-IH-80-BB-4-00487	WHIMS Plant Re-Claim Stockpile Earthworks & Drainage Layout
04951-IH-80-BB-4-00488	WHIMS Plant Re-Claimed Stockpile Earthworks & Drainage Details
04951-IH-80-YR-1-00489	Silt Trap and Dam Inlet Channel – Layout & Details
04951-IH-80-P-00490	WHIMS & JIG Plant Infrastructure & Stormwater Catchment Block Plan

ABBREVIATIONS, TERMS AND DEFINITIONS

Abbreviations/Terms	Definition
DRA	DRA Projects SA (Pty) Ltd
WHIMS	Wet High Intensity Magnetic Separation
DFS	Definitive Feasibility Study
MAP	Mean Annual Precipitation
MAE	Mean Annual Evaporation
LoM	Life of Mine
NGL	Natural Ground Level
TSF	Tailings Storage Facility
CWD	Central Water Dam
GM	Geomembrane
HDPE	High Density Polyethylene
GCL	Geosynthetic Clay Liner
GRI	Geosynthetic Research Institute
NEMWA	National Environmental Management Waste Act
GN704	Regulations on Use of Water for Mining and Related Activities aimed at the Protection of Water Resources (GN 704 GG20119 1999)

SYSTEM OF UNITS

The international metric system of units (SI) will be used throughout the design in all documentation, specifications, drawings, reports and all other documents associated.

TABLE OF CONTENTS

1. INTRODUCTION

Assmang (Pty) Ltd. has embarked on an Environmental Authorisation process to allow for the development of a Low-Grade Ore Beneficiation Facility (LGOBF) at the Beeshoek Iron Ore Mine, located approximately 7km north-west of Postmasburg in the Northern Cape.

This Engineering Report provides the basis of design for the Stormwater Drainage Management, Central Water Dam (CWD), Re-claim Stockpiles and associated infrastructure at the WHIMS Plant, which forms part of the LGOBF. The report is also in support of the application for the Water Use License for the proposed Low Grade Ore Beneficiation Facility.

The proposed WHIMS Plant and associated infrastructure will cover a footprint area of approximately 7.5 hectares, including:

- Stormwater management infrastructure
- Clean water cut off drains upstream of the plant area
- Re-Claim Stockpile pad and associated lining / leak detection system
- CWD and associated lining system / leak detection system, and
- Dam upstream silt trap.

2. DESIGN PARAMETERS

The following design parameters for the present environmental conditions have been obtained from Section 3.1 of Report No. JZADBR4951-ME-SPC-001 Rev.C Site Climatic Conditions (September 2020):

- MAP = 410 mm
- Highest Rainfall Month = January (98 mm)
- Design storm event = 1:50-year 24-hr (112mm)
- MAE = 2,026 mm (A-Pan)

3. WHIMS PLANT

3.1 Stormwater Management

Stormwater runoff upstream of the process plant is considered as clean water and is therefore deflected around and allowed to daylight downstream of the plant. The runoff from within the plant may be polluted due to the processing activities within the plant and therefore deemed as dirty stormwater runoff.

A dirty water drainage system in line with regulation 7 of GN 704, was provided to ensure all dirty water from the plant is controlled and channeled towards the mine's existing polluted water drainage network.

Run-off from the re-claim tailings stockpile was classified as type 3 effluent. The surface run-off from the stockpile terrace is captured along concrete lined drains and discharged into a silt trap where the silt can settle. The overflow from the silt trap will then enter the CWD and circulated back into the process plant.

The peak stormwater runoff was calculated using the Rational Method and the drainage system was sized to accommodate peak runoffs for the 1:50-year storm event from a total catchment area of 7.5Ha. This in compliance with regulation 6 of GN704.

Reference is made to drawings 04951-IH-80-YR-1-00332 & 04951-IH-80-BB-4-00487 for the WHIMS Plant Stormwater Management G.A and WHIMS Plant Re-Claim Stockpile Earthworks & Drainage Layout, respectively. Drawing 04951-IH-80-P-00490 shows the stormwater run-off catchments in relation to the overall Mine Site and Low Grade Plant Optimization Project.

3.2 Silt Trap

The silt trap was sized to individually pass the 1:10-year 24hr storm event. The silt settling design parameters to size the silt trap are as follow:

- Minimum particle size to be settled = 40 microns with an S.G = 2.2
- Silt trap entrance ramp gradient = 1:10 to provide vehicular access for cleaning

The silt trap was designed as a concrete water-retaining structure in accordance with SANS 10100 Part 3. Waterbars shall be provided at all the structure joints to ensure compliance to the above specification.

Mild steel bars, cast into the concrete floor slab and walls, were provided to allow plant to remove accumulated sediment within the silt trap without damaging the concrete floor and walls.

Reference can be made to drawing 04951-IH-80-YR-1-00489 for the silt trap details.

3.3 Central Water Dam

The CWD is sized to contain 5000m3 of process water and the 1 in 50 year 24hr storm water runoff from the re-claim stockpile terrace.

The dam is predominantly in cut with a short wall fill height of less than 2m above natural ground level. The overall depth within the pond is 4.0m and consists of the following:

- 2.7m depth to the operating water level (process water)
- 200mm depth to accommodate the 1 in 50 year 24hr storm event from the re-claim stockpile
- 800mm freeboard to the spillway invert, and
- 300mm spillway top of the dam wall.

The spillway was sized to accommodate overflow if the 100-year flow is exceeded, and any overflow water channeled along a concrete lined drain and discharged into the existing stormwater drainage system downstream.

The dam was designed in accordance with guidelines contained in "Water Affairs and Forestry, 2007;

Best Practice Guidelines A4 - Pollution Control Dams".

The CWD will be located North-West of the proposed WHIMS plant and complies to regulation 4 of GN 704 outlined in the Ground Water Impact Assessment Report, which states that "No facility, including residue deposits, dam, reservoir to be located within the 1:100-year flood line or within 100 m from any watercourse, borehole or well."

The embankment walls of the dam were shaped with internal and external side slopes of 1:3.

A slope stability analysis was excluded for the following reasons:

- From the two test pits carried out in the location of the ponds, it showed that refusal varied from 0,4 – 1,3m below natural ground level, and
- The pond is predominantly in cut with portions of the embankments below refusal.

The CWD layout and associated details are provided on drawing 04951-IH-80-YP-1-00346 Rev B.

3.4 Re-Claim Stockpile

Dry tailings from the existing tailings facility will be hauled to the WHIMS plant area with Cat 777 dump trucks and stockpiled on an engineered terrace. After which, the tailings are loaded onto the plant feed conveyor for re-processing (Re-Claim stockpile). The tailings will be stockpiled to a maximum height of 3,5m with an overall capacity of 6000m3.

The terrace is designed to accommodate the loads imposed by the Cat 777 dump trucks and the maintenance/ loading movements from the Cat 992 Front End Loader.

Leachate from the tailings is considered hazardous (type 3 effluent) as defined in the NEMWA regulations of 2013. In accordance with the Waste Act (No. 59 of 2008), Type 3 waste may be disposed where a Class C barrier system has been provided. The specifications of the barrier system is given in section 4.2 – Barrier Lining System for the Re-Claim Stockpile.

For the Re-Claim Stockpile terrace earthworks and drainage details, refer to drg. 04951-IH-80-BB-4-00488.

4. LINING SYSTEM

4.1 Barrier Lining System for the CWD

The effluent contained within the CWD is classified as Type 3 waste, as defined in the NEMWA regulations of 2013. In accordance with the Waste Act (No. 59 of 2008), Type 3 waste may be disposed where a Class C barrier system has been provided. This has been catered for with the provision of the following composite liner design:

- 1.5mm HDPE geomembrane (GM) double textured,
- A needle punched reinforced Geosynthetic Clay Liner (GCL), 10 mm thick, with a sodium bentonite content of 3,700 g/m^2 total dry weight @ 0% moisture, complying to GRI GCL3 standard specifications, placed on top of
- Underdrainage monitoring system and 150mm base preparation layer which includes 100mm diameter slotted HDPE pipe trenched in stone and wrapped in A4 Bidim.

To ensure that there is an adequate confining stress over the GCL, a 200 mm thick cement stabilized sand (hereafter referred to as soilcrete) will be placed over the GM along the dam floor and along all internal side walls of the dam. To allow placement of the soilcrete on the side slopes, a cellular confinement system, made up of geocells, supported by tendons weaved through the cells, and anchored at the dam crest will be provided. An A6 "Bidim" protection geofabric is placed over the GM prior to the placement of the geocells. Details of the above-mentioned system is provided on the CWD detail drawings. The soilcrete placed over the GM will act as ballast layer and provide a confining stress of approximately 4 kN/m^2, to ensure a good contact interface between the GM and the GCL. In addition, the GCL will have a minimum overlap of 300mm (longitudinal and transverse) between panels. The above is based on the soilcrete mixture having dry density of 2,150 kg/m^3. Since the WCD will be operated at two thirds capacity of the pond depth, the confining stress over the remaining third of the pond will be provided by the ballast layer.

The soilcrete mixture shall be a blend of sand, available on site, with 5% cement and shall consist of approved material, sieved to allow 100% passing of the 4.75 mm sieve. The grading of the material would limit the effects of physical exposure conditions inducing strain within the GM and prevent the total tensile strain exceeding the 3% limit. The exact soilcrete blend would need to be determined through further laboratory testing during the Detail Design phase.

In addition to the ballast layer providing the required confining stress for the GCL as discussed above, it shall prevent panel separation and shrinkage, which may cause loss of overlap and even separation at the roll edge or ends with the bentonite creating cracks and subsequently increasing the GCL's permeability. The ballast layer will also protect and insulate the GM against mechanical and degradation damage adding to the expected life expectancy of the liner, as well as uplift during time of low water level or no water within the dam. Reference shall be made to the CQA document submitted with this report.

Leak detection was provided below the barrier lining system including:

- Tri-Planar Geonet with A4 bidim on both sides, and
- 100mm Subsoil pipes surrounded by 19mm stone wrapped in A4 "Bidim"

Ground water drainage below the dams were omitted based on the following inputs:

- The aquifer in the vicinity of the project is lower than the floor levels of the dam, with the average aquifer depth being greater than 50 mgbl as sourced from the "Hydrogeological Impact Assessment for Beeshoek Mine" Report No. ETBEE-20-5804 January 2021. This is in excess of the 2 m minimum permissible separation between waste and the groundwater as stipulated in the Minimum requirements for Waste Disposal by Landfill (2nd Edition, 1998).
- From the Geotechnical Investigation Report (Reference:526742_Beeshoek Final Interpretive Report), it was noted that "No groundwater seepage was recorded on any of the test pits excavated and/or boreholes drilled at the WHIMS area." From the test pit profile information provided in the vicinity of the dam, there was no indication of material associated with a perched water table.

Further testing of the expected runoff/leachate to be stored in the dams and the subgrade below the GCL would need to be conducted as part of the Detail Design phase to determine the concentration of calcium solutions which may cause ionic exchange within the sodium bentonite in the GCL, rendering the GCL ineffective.

4.2 Barrier Lining System for the Re-Claim Stockpile

Similar to the CWD, the following barrier system was provided below the terrace layerworks:

- Tri-Planar Geonet with A4 bidim on both sides.
- 1.5mm HDPE dual textured geomembrane (GM),
- A needle punched reinforced Geosynthetic Clay Liner (GCL), 10 mm thick, with a sodium bentonite content of 3,700 g/m^2 total dry weight @ 0% moisture, complying to GRI GCL3 standard specifications, placed on top of
- A10 bidim directly below the GCL
- Leak detection monitoring system and 150mm base preparation layer including:
- Slotted HDPE pipe 100mm dia. subsoil Pipe surrounded by washed stone and wrapped in A4 Bidim.

4.3 Estimated Leakage through Liner Barrier System

The estimated leakage through the composite liner specified were based on the equation developed by R. Rowe (Short & Long-Term Leakage through Composite Liners, R. Rowe, 2011) for predicting leakage through a hole in a GM coincident with, or adjacent to, a GM wrinkle.

The formula considers the following factors which are directly linked to the CQA and the frequency of defects anticipated. These include:

- The length and width of the interconnected GM wrinkle forming from either thermal expansion or during construction activities where the GM is covered with a ballast layer, or a combination thereof

- The interface transmissivity between the GM and GCL, which was found through experimental data, controls the leakage through a composite liner, rather than the hydraulic conductivity of the GCL

Conservative assumptions for the above-mentioned inputs were made and are shown as part of the leakage calculation provided in Annexure A of this report. The leakage rates are directional proportionate to the headwater height above the GM. Strict adherence to the CQA shall ensure that leakage is controlled through limiting the defects and ensuring that all the individual products specified, as part of the composite liner, perform optimally.

In addition to the above, electric leakage detection of the covered GM shall be conducted on completion of the liner construction to ensure leakage is eliminated. Testing shall be done in accordance with test methods ASTM D6747 and D8265, where a high voltage is applied to the cover material with a positive electrode and the power source is grounded to the subgrade underneath the GM. Voltage measurements are taken in a grid pattern throughout the survey area using a dipole instrument, with a leak/hole location causing a sine wave pattern in the voltage measurements as the dipole instrument travels across it. Moisture content within the underlying GCL would be kept fairly high due to the moisture content during placement and moisture wick into the GCL from the subgrade which would allow the leakage location survey to be performed.

4.4 Estimated Life Expectancy of Composite Liner

As discussed in Section 4.1, a ballast layer of cement stabilized sand will be provided as a cover layer above the GM liner to not only provide the required confining stress with the GCL, but to protect the liner from mechanical damage and damage caused by the following degradation mechanisms:

- UV radiation
- Oxidation
- Chemical
- Temperature

Since oxidation is the primary degradation mechanism that may limit the service life of the GM, and the oxidation of the polymer is retarded by the presence of antioxidants, considering the depletion rate of antioxidants at various temperatures provides an estimation into the life expectancy of the GM (ref. Barrier Systems for Waste Disposal Facilities, 2nd Edition, 2004).

Sangam and Rowe (2002) provided a summary in their Table 13.6 below, which is based on the GM meeting GRI-GM13 specifications, not being subjected to significant tensile stresses and that it is covered by an adequate protection layer. The table provides a lower bound estimate for the service life, since the samples tested were immersed in either air, water or leachate and thus overestimates the antioxidant depletion for the more realistic case where different conditions exist on both sides of the geomembrane. The leachate strength was also constant during immersion and did not consider leachate concentration decreasing with time. Considering that the above criteria outlined by Sangam and Rowe are being met together with the following site-specific conditions:

- The ponds will operate constantly with water and leachate, and
- The mean monthly maximum temperature (January) is ~26.5°C

The service life for the primary HDPE GM can thereof be estimated at a minimum of 60 years.

Table 13.6 Estimated service life (years) for a primary HDPE geomembrane based on depletion time of antioxidants estimated by Sangam and Rowe (2002), induction time reported by Viebke *et al.* (1994) and an assumed degradation time of 25 years

	Temperature (°C)				
Exposure conditions	*13*	*15*	*20*	*25*	*33*
Leachate and air	270	230	170	130	80
Leachate and water	170	150	110	90	60
Leachate and unsaturated soil	220	190	140	110	70

6. APPENDIX A – LEAKAGE RATE CALCULATION