APPENDIX D

Specialist Report: Historical Slimes Rehabilitation - Design Report and DWAS Correspondence

SAMANCOR FERROMETALS

REHABILITATION

OF HISTORIC SLIMES DAMS

DESIGN REPORT

Date: August 2013
Project Number: FM/100/01
File Reference: IPC/100/01

Revision 00

COMPILED BY:

INPROCON CONSULTANTS cc
Consulting Environmental & Civil Engineers

541 Genl Louis Botha
CONSTANTIA PARK
PRETORIA
0181

Tel: +27(12) 993 2423

Inprocon

SAMANCOR FERROMETALS

REHABILITATION

OF

HISTORICAL SLIMES DAMS

DESIGN REPORT

P DU TOIT PrEng
Reg. No. 860635

Date: 26 August 2013

Table of Contents

Page

1. INTRODUCTION

Ferrometals, Business Unit of Samancor Chrome Limited, near Emalahleni (formerly Witbank) produces ferrochrome at its furnaces. In the melting process Off Gasses are captured at the bag house plants and the dust are separated into two size fractions. Coarse dust is fed to the pelletising plant and finer dust is treated, settled and the slurry is pumped to the slimes dams.

Ferrometals operated three historical slimes dams that are decommissioned some time ago. All slimes are currently deposited at the north slimes dam. Inprocon Consultants has been contracted by JMA Consulting, the leading agent, for the rehabilitation design of these historical slimes dams.

2. HISTORICAL SLIMES DAMS

2.1 Site Locations

Ferrometals is situated on the farm Driefontein 297 JS. The historical dams consist of three small slimes tailings dams referred to as the South Slimes Dam, East Slimes Dam and the Stores Slimes Dam.

Figure 2.1: Google Map of Location of Historical Slimes Dams

The historical dams, Stores Dam and South Dam are located on Portion 9 and the East Dam is located on Portion 12. Refer to Figure 2.1 for the position of these dams. At marker 1 is the South Slimes Dam, marker 2 the East Slimes Dam and marker 3 the Stores Slimes Dam near the stores.

The co-ordinates of these sites are also shown in Table 1 below.

Table 2.1: Historical Slimes Dams Co-ordinates

Historical Slimes Dam	**Lat Long Co-ordinate**					
	South			**East**		
	Deg	**Min**	**Sec**	**Deg**	**Min**	**Sec**
South Slimes Dam	25	51	39	29	10	10
East Slimes Dam	25	10	40	29	10	40
Stores Slimes Dam	25	51	14	29	10	15

The south Dam is +- 760m south of the Stores Dam and 850m from the East Dam. The East Dam is +-1,1 km from the stores Dam.

2.2 Spatial Extent

The spatial extent of each historical slimes dam has been determined from local surveys. The volumes were modelled by assuming the perimeter toe of the outside slopes to be the existing original basin surface.

Table 2.2: Historical Slimes Dams Spatial Parameters

Historical Slimes Dam	Footprint ha	Max Height m	Estimated Dam Volume m3
South Slimes Dam	1,48	6,84	45000
East Slimes Dam	2,57	3,60	65700
Stores Slimes Dam	0,23	1,50	5800

The South- and the East Slimes Dams have rectangular shapes and the Stores Slimes Dam a close to circular footprint. The slimes dams have dyke like containment embankments and the Stores Dam seemed to be partly suppressed into the ground with a low perimeter earth berm. The dams have been covered to a varying degree with a soil layer.

2.3 Client furnished information

Ferrometals has no design or operational manuals or technical details of any of the Historical Slimes Dams.

A storm water management upgrade concept plan for Ferrometals has been received. The Historical Slimes Dam sites are not affected or will not be disturbed by the plan. Future clean runoff from the sites may be trapped within the defined dirty demarcated area but the design of the storm water management measures has incorporated it.

The age of the dams could also not be established but more recent aerial images of the site indicate that these dams may have been decommissioned between 1995 and 2005. However some rehabilitation work has been done more recent.

2.4 Existing condition of the historical dams

<u>South Slimes Dam</u>

This dam has dyke like embankment walls and the crest is rather flat. The crest in some areas has been covered with a soil layer and the embankment slopes are vegetated. Some spots on the crest of the South Dam the slimes have not been covered or erosion has stripped the soil layer leaving the slimes exposed.

The current soil cover is rather less than 200mm thick. The crest is not free draining and ponding is visible where reeds are growing.

At the southwest corner of the dam a ramp that is currently been demolished provided access to the top of the embankment and crest. An aerial survey image of the dam is seen in **Figure 2.2**. The natural ground slope dips in a southwest direction with the highest embankment the south wall.

The side slopes of the embankment vary from 1v:1,2h to 1v:2h which is steep based on closure standards.

Eucalyptus globulus (Blue gum) trees have established also at the south end of the dam at the toe and side slope area. The decommissioning of the dam requires upgrading to be compliant with requirements.

Holes were hand augered to determine the cover soil depth and it was observed that the slimes were very moist.

Figure 2.2: Historical South Slimes Dam

East Slimes Dam

This dam has also a dyke like embankment perimeter wall with the crest it seems has been recently levelled with a natural gradient to the south that follows the natural ground slope. The crest has been covered with a marginal soil layer in direct contact with the slimes and vegetation appears to be scattered. Some spots on the crest of the East Dam the slimes have not been covered and erosion has also stripped of the soil layer leaving the slimes exposed.

The current soil cover is rather less than 100mm thick. The crest is free draining with the gradient like mentioned above similar to the ground slope which is +-2%. The runoff from the crest appearing as sheetflow will cause erosion of the cover layer as accumulated runoff flows southwards and discharging at the south toe area.

At the northwest corner of the dam a ramp that is providing access to the crest. An aerial survey image of the dam is seen in **Figure 2.3**. The natural ground slope dips in a southwest direction with the highest embankment the south wall.

The side slopes of the embankment vary from 1v:1,44h to 1v: 2.26h which is steep based on closure standards.

Eucalyptus globulus (Blue gum) tress have established also at the south end of the dam and some number of indigenous trees has also been planted on the crest. The decommissioning of the dam requires upgrading to be compliant with requirements.

Figure 2.3: Historical East Slimes Dam

Pits were excavated by TLB to determine the cover soil depth and it was observed that the slimes at shallow depth were very moist.

<u>Stores Slimes Dam</u>

The Stores Slimes Dam is a small dam with a basin suppression of approximately 1,5m deep sunk into the ground. The dam has been covered with a soil layer varying but approximately 1m thick and in direct contact with the slimes. The walls have been sloped and blends in with the natural ground slope. The crest at the west lowest toe area is less than 1-1,5m high.
The kikuyu grass has established and is flourishing. The site is fenced off and used for an ostrich camp.

Pits were excavated by TLB to determine the cover soil depth and it was observed that the slimes were very moist.

The Stores Slimes Dam is close to the stores and is shown in Figure 2.4.

Figure 2.4: Historical Stores Slimes Dam

2.5 Waste classification

A Waste classification of the slimes at Ferrometals was performed by Geostratum. Leaching was done on samples following the Minimum Requirements. The salt load in the slimes is in general containing Na, K, Mg and Ca with Cl, SO4, F. Cr6+ is fairly soluble and would also be present to some degree in leachate.

In summary it is concluded that the slimes and surrounding soils of the stores and eastern slimes dams show a definite elevated Cr6+ content. While the southern dam slimes sample does not show this elevation, 2 soil samples from around the southern dam does show elevated Cr and/or Cr6+.

Only one sample was taken from each of the historical dam sites. The old dams, as well as the underlying and surrounding soils, should be treated as hazardous material.

Schedule No. R.636 published under the National Environmental Management: Waste Act of 2008, Act No. 59 of 2008, section 7(1)(c) requires hazardous waste to be contained in a Class A Landfill. Therefore the requirement for any new slimes tailings facility to stockpile Ferro Metal slimes would require a Class A Landfill. Thus the containment barrier should comply with the barrier configuration consisting of a double composite lining system with leakage detection system.

At closure the Class A Landfill or tailings facility should be capped with a specified capping configuration as detailed in the Minimum Requirements. It is clearly stated that the final cover or capping works in conjunction with the liner by limiting the long term generation of leachate.

2.6 Groundwater at dam sites

The slimes dam sites are not undermined as this conclusion can be derived from the groundwater level states obtained from the monitoring boreholes sited close by. The shallow boreholes (5m) for the perched water table and the deep boreholes (20-30m) for the weathered zone with water depths measured are indicated respectively in **Figure 2.5** and **Figure 2.6**.

Values indicated were for four sample runs. The values in red represent the measurements taken during February 2012; the values in blue represent the measurements taken during May 2012; values in green represent measurements for August 2012 and values in black represent measurements for the November 2012 sampling run.

The groundwater flow direction at the Ferro Metal site is from east to west. The existing monitoring boreholes are sufficient for monitoring the post closure water quality near the slimes dam sites. However two boreholes sited upstream (east) of the South Slimes Dam and also east of the East Slimes Dam will be necessary to monitor the performance of the rehabilitation of these dams.

Figure 2.5: Ground water level data for 2012 – Shallow Perched monitoring boreholes.
(Courtesy of JMA Consulting (Pty)Ltd)

Figure 2.6: Ground water level data for 2012 – Deep Weathered monitoring boreholes.
(Courtesy of JMA Consulting (Pty) Ltd)

3. PROFILING OF HISTORICAL DAMS

3.1 Introduction

The historical slimes dams after careful consideration do not merit to be merged in a single dam. This mainly due to unavailable space at the existing active facility (North Slimes Dam) that will reach end of life within the next two years. The South- and East Slimes Dams if properly rehabilitated will not extent the already effected footprints and from an economical perspective and stability perspective insitu rehabilitation seems to be the most viable alternative.

The construction, operation and upgrading of the historical slimes dams are covered under Water Use Licence No. 04/B11k/709, dated 02 April 2011 issued by Water Affairs.

During the design it was concluded that the small Stores Slimes Dam should be removed and stockpiled at the South Slimes Dam. The motivation for this decision is based on the following:

- The stores slimes dam is small and clearing would reduce the affected areas at Ferrometals.
- The affected footprint of the South Slimes Dam will not be enlarged by placing the stores dam slimes on top of the crest as fill is required to fill and shape the crest to be free draining.
- On the long term lessor waste sites to manage and monitor.

3.2 Existing Drainage Systems (External & Internal)

The historical slimes dams have not been equipped with any particular barrier designed layer works and no under drains or toe drains could be detected. It appears that only at the South Slimes Dam some form of decant weir and canal could have been used to recycle supernatant water.

No formal surface drainage systems at each and from these dams exist. The stores slimes dam is mostly a sunken dam and groundwater from the perched aquifer could be affected as no formal or definite cut-off trench or impermeable capping will prevent migration of contaminants from the slimes body.

3.3 Minimum Requirements

The historical slimes dams are as the name states existing dams and as observed without any formal base barrier to contain and preventing contaminants from diffusion and entering into the groundwater resource.

The final crest must be shaped at a minimum gradient of 3 % to shed precipitation. The side slopes must be such to allow vegetation to establish and to perform normal maintenance activities.

3.4 Pre-deposition infrastructure

The South historical slimes dam consists only of a perimeter dyke earth embankment. The slimes body is contained within the basin and is fairly moist due to rain water infiltration at the crest. The earth embankment seems to be well constructed and stable.

The East Slimes Dam seems to have been formed with cascading paddocks down slope and was eventually after decommissioning been shaped by bull dozing operation. The existing outside wall slopes from auger tests seems not to be well compacted to any engineering standard.

Hence the perimeter embankment at the South Dam and the berms at the East Dam are the only initial or remaining pre-deposition infrastructure.

3.5 Surface Profiling

The profiling of the historical slimes dams presented in the closure design and detailed in the set of detail drawings considered long term sustainability, maintenance friendly and the curtailment of surface and ground water impacts as of paramount importance.

South Slimes Dam

The design profile of the deposit consists of a crest with a minimum slope of 2% and flattening of the embankment sides to 1 in 5. The crest slopes at the South Slimes Dam is attained by importing of slimes cleared at the Stores Dam and to layer and shape it as presented in the details.

The side slopes are flattened by importing fill material from a borrow site and by layering in well compacted layers next to the existing outside toe of the embankment the 1 in 5 slope is achieved. All vegetation from the crest and embankment slopes must be stripped and cleared before placing of imported slimes and soil material.

The 1 in 5 slope of the sides will be providing a stable slope and maintenance (amelioration, planting and grass cutting) of the slope will have easy access. Erosion will also be minimised by a grass cover that will thrive on the slopes.

The drainage from the capped dam will be towards the four sides as this will prevent a concentration of runoff to cause erosion or scouring. The subtle gradient of the terrain lend it to drain freely in a south to southwest direction.

East Slimes Dam

The East Slimes Dam has not a sufficient integrity side wall as witnessed at the augered test holes. The side slopes are too steep and the crest requires profiling to manage runoff in order to prevent erosion.

The flattening of the side slopes and profiling of the crest surface by extra fill is accomplished by excavating and cutting back the sides to a flatter 1 in 5 slope and placing the cut to profile the crest surface to a 2% slope falling to the four sides. Clean Clayey soil imported from a borrow site will be used to reconstruct the sides to be stable and well compacted.

The 1 in 5 slope of the sides will be providing a stable slope and maintenance (amelioration, planting and grass cutting) of the slope will have easy access.

The drainage from the capped dam will be towards the four sides as this will prevent a concentration of runoff to cause erosion or scouring. The subtle gradient of the terrain lend it to drain freely in a south to southwest direction.

3.6 Slope stability

Methodology

The method of calculating the slope stability of the outer wall is based on Bishop's modified method. With the anticipated capping of the slimes dams based on minimum requirements no water pressures will be developed within the slimes body.

A deterministic and probabilistic analysis was performed using material strength and weight parameter ranges obtained from the geotechnical investigation results. It must be recalled that the slope stability result is not an exact answer but indicates the likelihood of failure. The factor of safety only gives guidance on the actual state of safety of a slope. A factor of safety (FoS) of 1,3 is acceptable if the adopted soil parameters are close to the actual conditions. In any other situation a higher FoS is be propagated.

Material properties adopted

The site is generally overlain with transported soils of various origins. It is regarded as loose to medium dense and varies in thickness. The adopted materials relevant to the slope stability analyses consist of the following from top to bottom:

- Contained Slimes tailing body
- Transported soils used for the slimes dam embankments
- A 3m thickness of transported surface soil cover
- A 2m partially cemented Pedocrete layer
- Shale and sand stone bedrock

The strength parameters used for the stability analysis are summarised in **Table 3.6**.

Table 3.6 Adopted strength Parameters of materials for stability analysis

Material	**Saturated weight (Range) kN/m3**	**Ø° (Range)**	**c (Range) kPa**
Slimes Tailings body	15.7 (14.55-16.82)	30 (28-31)	20 (15-25)
Medium Dense layer	19 (18-20)	29 27-32	10 (5-15)
Partially Cemented layer	20 (19-22)	31 (30-33)	8 (0-10)
Shale Bedrock	21 (20-22)	38 (35-40)	5 (0-10)

The parameters obviously varies and depicts representative values and to allow for variations in a parameter a range has also been adopted for each strength parameter that conservatively makes allowance for any variation.

In the analyses two surface failure mode types were investigated, namely the typical circular failure of the side slope and also a non-circular (or block failure) failure expected along a weak layer. It is expected when a weak layer is involved that the failure surface will follow the weak layer or will be within a weak zone. For both failure modes a deterministic and probabilistic calculation was performed taking into account the expected variation of the parameters.

The **Figure 3.6** is the South Slimes Dam profile at the highest wall height along the perimeter that is at the southwest corner. The actual horizontal and vertical scales are shown. The slope stability analysis was thus performed for the dam after rehabilitated profile and capping.

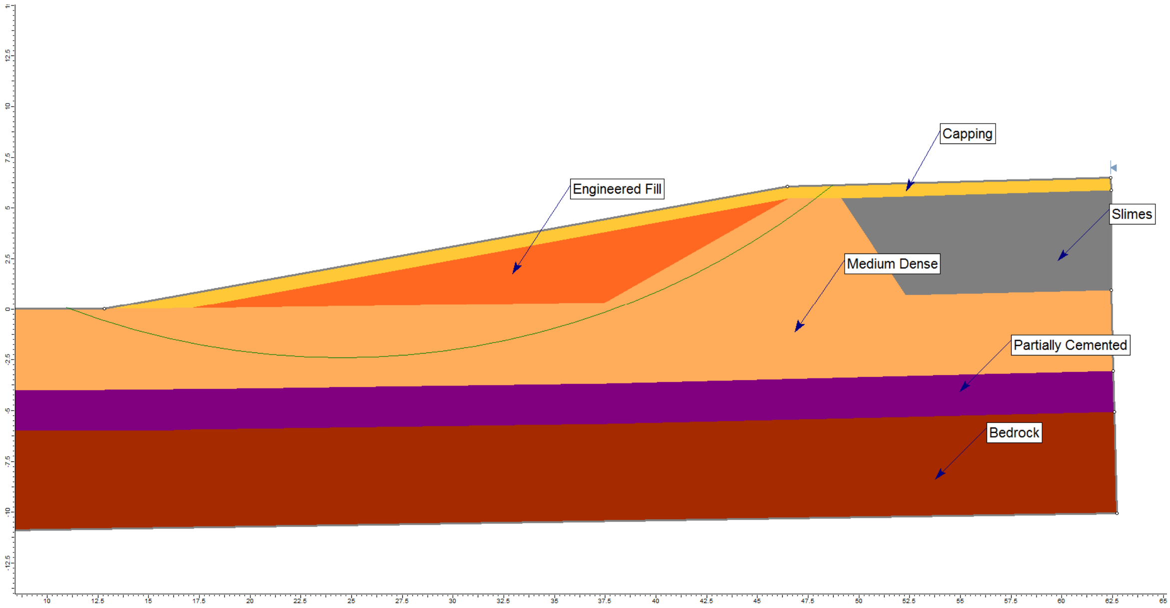


Figure 3.6: Side Slope profile at highest wall

It is clear from the outcome that a flat side slope of 1:5 will be very stable. The fact that the embankment is also not high contributes to a very stable side slope. The cumulative probability plot in Figure 3.7 states that the minimum factor of safety is 3.8 and a 0% probability of failure.

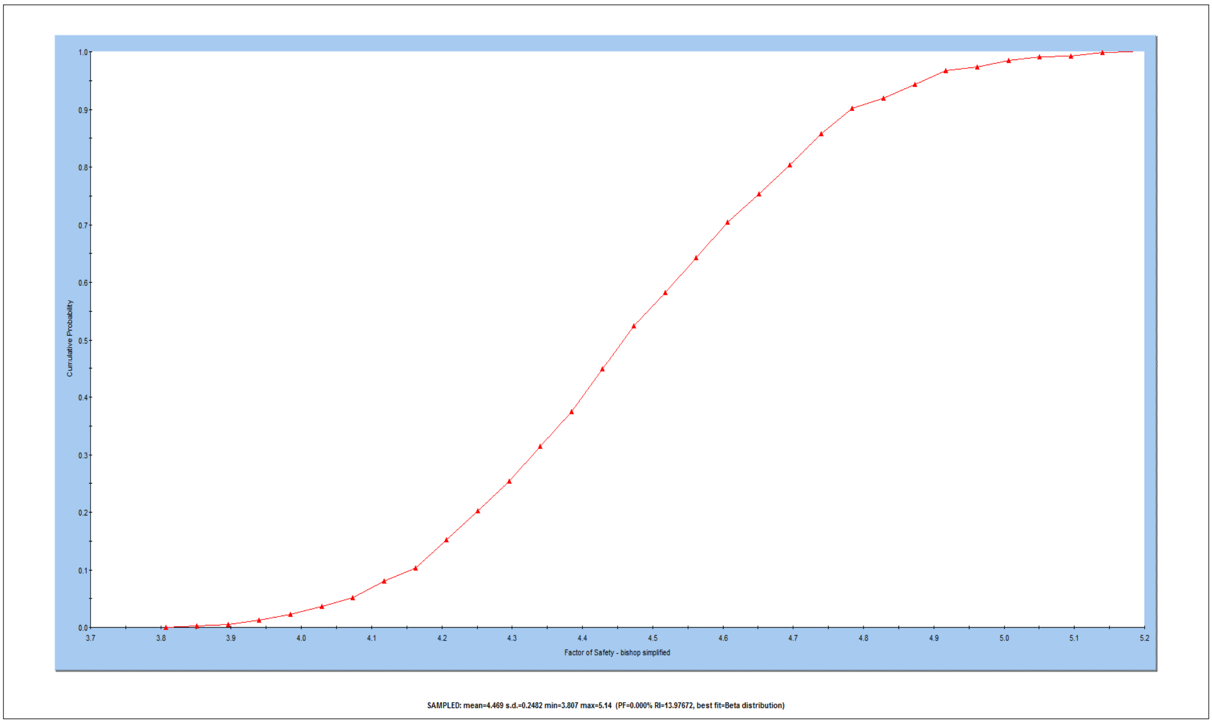


Figure 3.7: Cumulative Probability versus factor of safety (FoS)

The Global Minimum slip surface is indicated in Figure 3.8. This is the slip profile with the smallest FoS. The mean FoS is 4.46 with reliability index >> 3. The Reliability Index is another commonly used measure of slope stability, after a probabilistic analysis. The Reliability Index is an indication of the number of standard deviations which separate the Mean Safety Factor from the critical safety factor (= 1). A Reliability Index of at least 3 is usually recommended, as a minimal assurance of a safe slope design.

It is clear that the stability of the side slopes is more than sufficient as the highest embankment has a minimum FoS above 3.8.

A non-circular or block slip has been evaluated where the slip surface is within the weakest medium dense zone. The slip face is indicated in Figure 3.9. A histogram plot of the FoS for block slip is indicated in Figure 3.10.

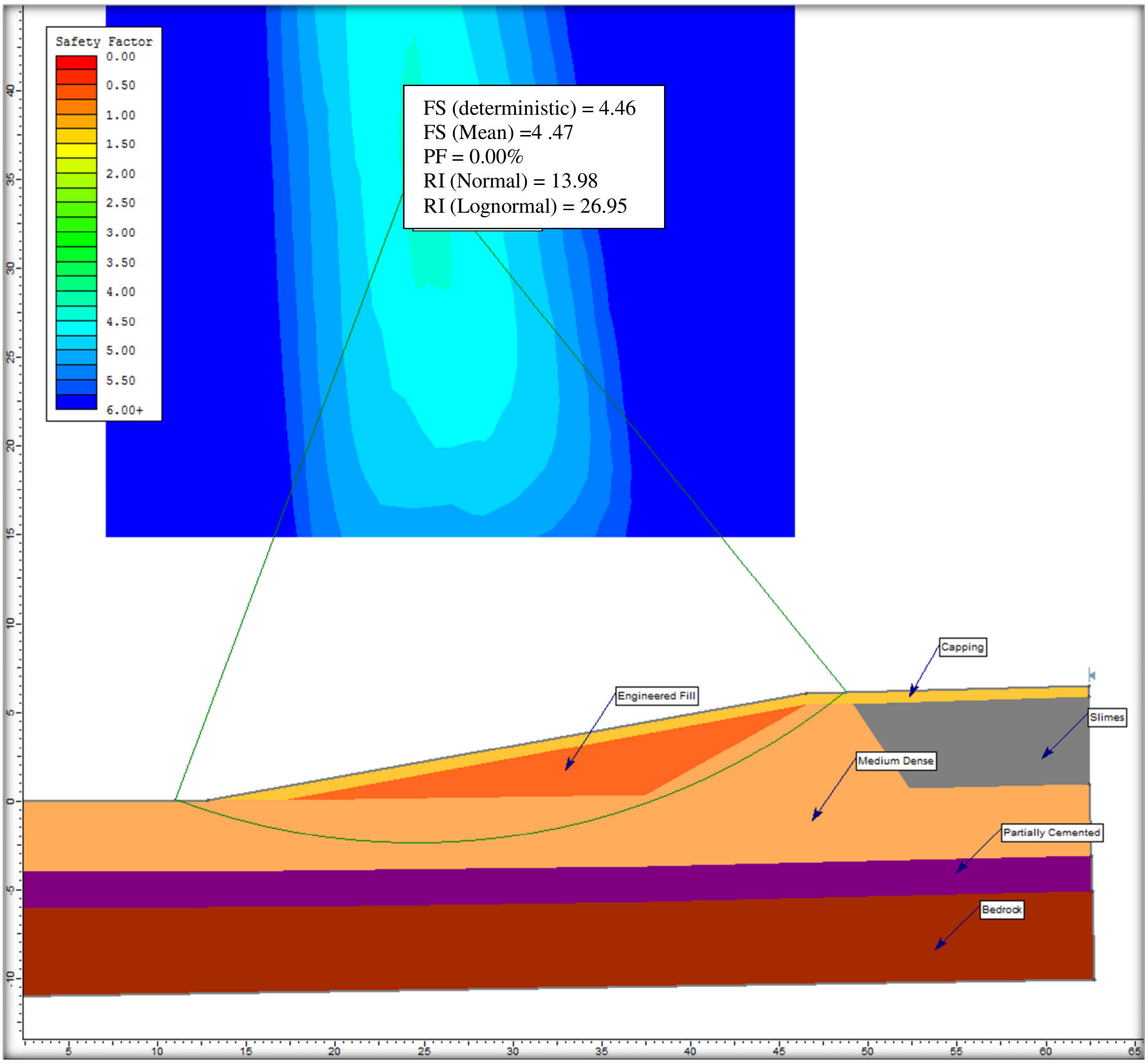


Figure 3.8: Global Minimum Slip Surface FoS- Circular slip

The circular mode failure and non-circular slip modes produces similar results in that the factor of safety well exceeds the 1,3 which is the minimum acceptable norm.

It is therefore clear that the slimes dams when rehabilitated to the proposed profiles it will be stable against slip failure.

The East Slimes Dam has the same proposed rehabilitated profile as the South Slimes Dam except that the crest height of the East Dam is lower than the maximum height of the South Dam. Hence it can be concluded that the safety against deep and global failure of both dams are more than sufficient.

It should be noted that the stability of the final cover requires a separate assessment for stability. This is evaluated in the succeeding section.

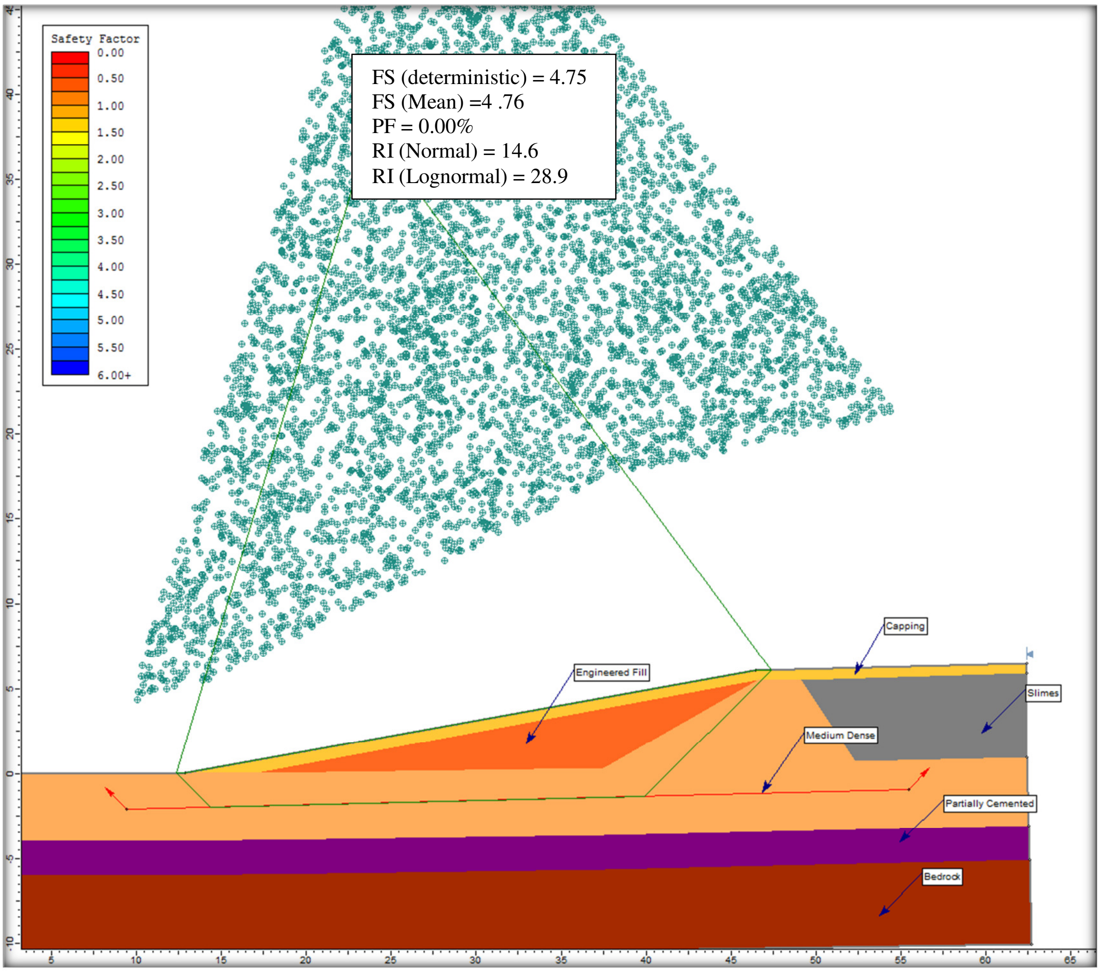


Figure 3.9: Global Minimum Slip Surface FoS- block slip

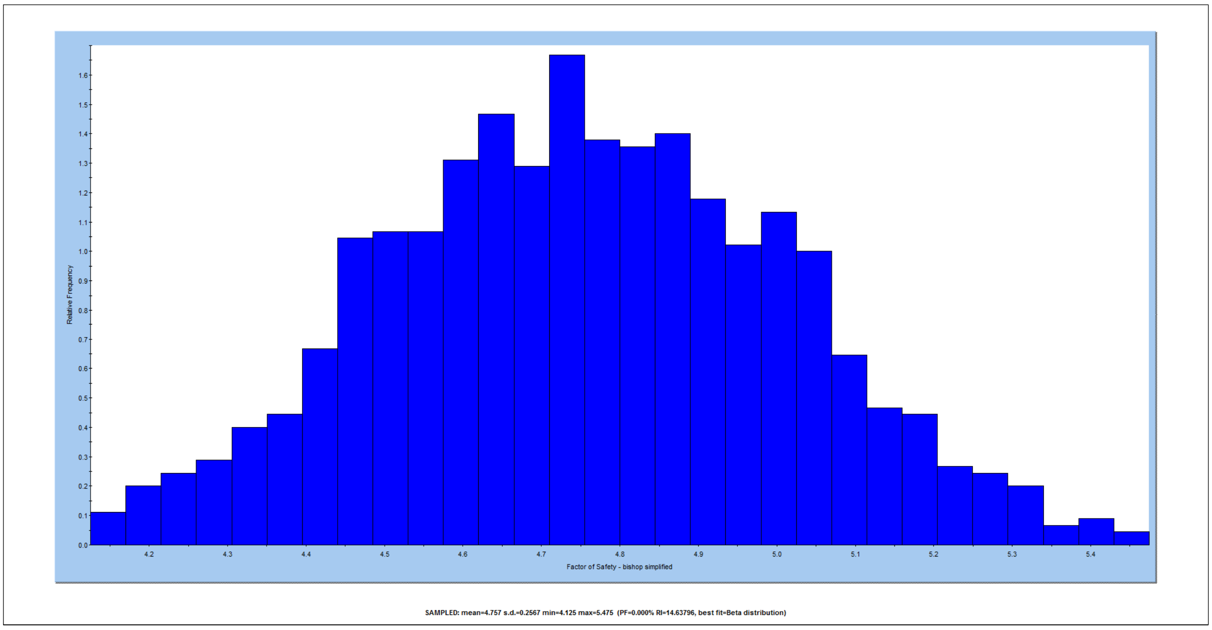


Figure 3.10: Histogram of FoS for Non-circular slip

4. CAPPING DESIGN

The preceding section indicated that the proposed side slope profile of the South- and East Slimes Dam will be stable. The capping of the dams will therefore found onto a stable and steady supporting structure.

The final cover layer comprising of a composite layer along the side slope requires additional checking for cover failure.

4.1 Minimum Requirements

The minimum requirements for waste disposal by landfill states unambiguously states that the containment barrier and final cover or capping works in conjunction with both the liner and final cover limiting the long term generation of leachate.

A hazardous waste landfill or tailings dam requires a double composite liner system with leakage detection system. When a proper barrier or liner is provided, which in the case of the historical slimes dams should have been the double composite liner with leakage detection, the final cover layer would have been from top to bottom consisting of a 200mm topsoil layer, 3x 150mm compacted clayey layers and a 150mm foundation drainage layer. When no bottom containment barrier is present, which is the case at the historical slimes dams, the final cover detail must be extended by providing a flexible membrane below the cover soil with the clayey layers to be 4 x 150mm thick.

It is accepted by DWA that the clayey soil layers may be replaced with a Geosynthetic Clay Layer (GCL) which is +-10mm thick unhydrated.

The capping component of closure is required to be a sustainable solution which prevents rain water infiltration while containing any possible total solute emanating from the deposits which includes seepage and diffusion. Hence a capping system which comprises of a shaping layer followed by a capillary break drainage layer, overlain by a single composite liner (geomembrane and clay component) overlain by an appropriate protection soil layer, would be the acceptable principle.

The soil layer acts as growth medium for a grass cover and serves as protection layer against the long term effects of wind, water erosion, burrowing animals, etc.

4.2 Capping layer

The historical slimes dams do not have a base barrier and the minimum requirements implies that in such case that the capping must ensure that the ingress of precipitation into the waste body to generate leachate must be prevented.

Therefore in the absence of a required base barrier the proposed capping detail consists from top to bottom of:

- 450mm topsoil layer;
- 2mm Flexible membrane (FML);
- Geosynthetic Clay Layer (GCL) and
- 150mm capillary break and drainage layer.

Refer to **Figure 4.2** for the proposed final cover layer system.

The 450mm thick soil acts as protection layer but most importantly as weight to ensure intimate contact between the FML and the GCL.

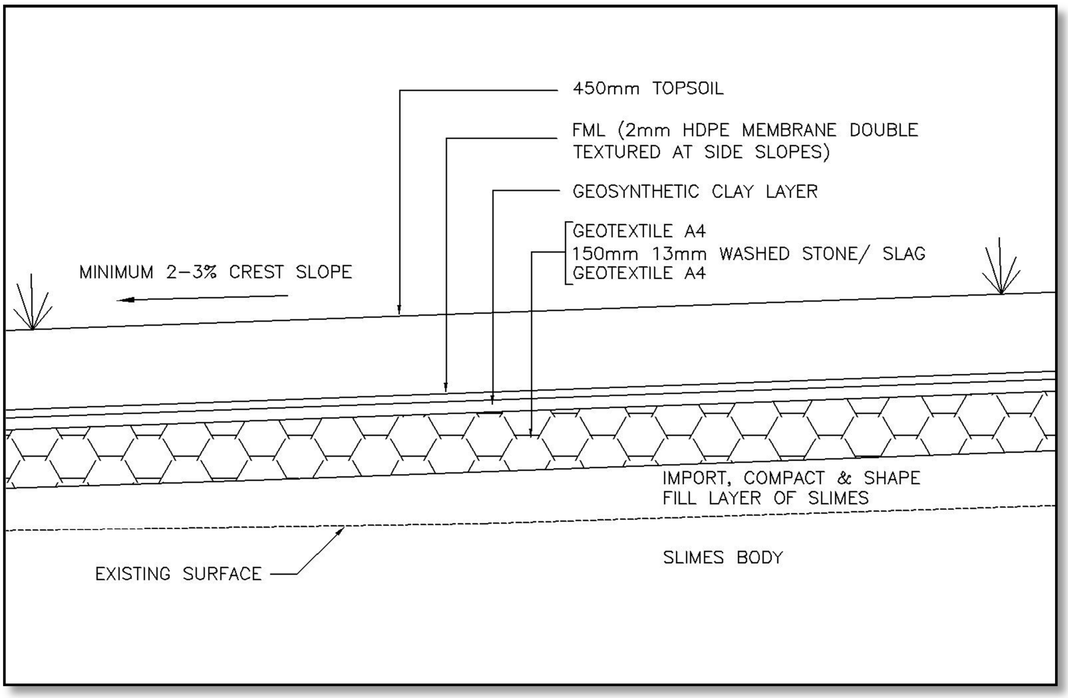


Figure 4.2: Proposed Composite Lining for Capping

The capillary break and drainage layer will prevent negative pressures below the FML and any leakage from the capping will be preventing from escaping to the crest surface. Refer also to the drawings indicating all details.

The incorporation of a GCL just below the 2mm HDPE geo-membrane is predominantly to further improve the performance of the composite liner. This configuration far outperforms compacted clay only layer systems. The reader is referred to "The 2011 Arthur Casagrande Lecture" that deals with the short and long-term leakage through composite liners presented by R. Kerry Rowe from the GeoEngineering Centre at Queen's University, Kingston, Ontario, Canada.

The GCL specified contains natural sodium bentonite powder that is thermal locked and needle-punched. The hydraulic conductivity (k_L) specified is average 2.25 x 10^{-11} m/s with a 97.5% confidence limit. The actual k_L in the field will be different due to final stresses involved, hydrating conditions, hydraulic head and construction aspects. However the latest authoritative literature on composite geo-liners accepts that the interface transmissivity between the geo-membrane and the GCL controls the leakage through a composite liner considering a hole in the membrane that is in direct contact with a GCL.

4.3 Capping performance

Using a formula developed by RK Rowe the leakage through a hole in a geomembrane (GM) coincident with a wrinkle can be predicted.

Table 4.3: Leakage prediction through a hole in geomembrane which is in contact with a composite lining

	hw	ks	kL CCL	kL GCL	kL AL	Theta	2b	HL GCL	HL CCL	HA	D	ha	hd	L	Q	Q	
Composite Liner	m	m/s	m/s	m/s	m/s	m2/s	m	m	m	m	m	m	m	m	m3/s	(lphd)	
1.1 GM+CCL	0.25	1.0E-09	1E-09	5E-11	1.0E-07	1.60E-08	0.2	0	0.6	0	0.6	0	0.85	100	9.1E-07	78	G/C
1.2 GM+CCL	0.25	1.0E-09	1E-09	2E-10	1.0E-07	1.70E-07	0.2	0	0.6	0	0.6	0	0.85	100	2.9E-06	250	P/C
2.1 GM+GCL	0.25	5.0E-11	1E-09	5E-11	1.0E-07	2E-11	0.2	0.01	0	0	0.01	0	0.26	100	4.2E-08	4	G/C
2.2 GM+GCL	0.25	2.0E-10	1E-09	2E-10	1.0E-07	2E-10	0.2	0.01	0	0	0.01	0	0.26	100	2.1E-07	18	P/C
3.1 CCL Only	0.25	1.0E-09	1E-09	5E-11	1.0E-07	2E-11	0.2	0	0.45	0	0.45	0	0.7	100	2.1E-05	1824	
3.2 CCL Only	0.25	1.0E-08	1E-08	2E-10	1.0E-07	2E-10	0.2	0	0.45	0	0.45	0	0.7	100	2.1E-04	18240	

ks= mean conductivity; hw= water head; CCL= compacted clay liner; GM=geo-membrane; AL= attenuation layer; Theta= transmissivity between GM & GCL; HL = clay layer thickness; Ha=attenuation layer thk; ha= head below liner; hd = hw+HL+Ha-ha; L=wrinkle length; D= ΣHL+Ha; 2b= width of wrinkle; G/C= Good Contact; P/C= Poor Contact

Table 4.3 includes three composite capping liner scenarios's . The first scenario is a geomembrane with a 600mm clay layer, the second also a geomembrane with a GCL and the third the Minimum Requirements specification when a base barrier exists when a 450mm compacted total clay layer is required. The leakage detection layer below the CCL or GCL will provide a zero head below the CCL (ha=0).

Assuming typical hydraulic conductivities (low and average) for the GCL and average for clay layers as well as a typical transmissivity (good & poor contact) between the membrane and the GCL or CCL, scenario 2 (i.e design adopted) indicates twenty times (an order) lower leakage expressed as liters per hectare per day (lphd) than scenario 1 and even 100 times lessor than the 450 compacted clay only capping.

The calculations are to demonstrate what is known in the field of geo-composite liners that the GCL with GM has unambiguous performance advantages appose to CCL only systems. The design therefore employs a geomembrane and GCL composite liner with added advantage to cost and long term performance. In the absence of any barrier liner at the base of the historical dams the adopted capping in the design is seen as a minimum requirement. A proper clayey material source is also not available close to the site.

Furthermore the capacity of the leakage detection system has ample redundancy to provide for any worst case scenarios regarding punctures or damage to the geo-membrane GM.

The engineered lining with capillary break and seepage drainage system as indicated in Figure 4.2 will prevent any leachate build up and diffusion.

4.4 Internal Drainage

Refer to detail drawings. The capillary break acting also as drainage layer drains into interceptor crest drains that connects to main collector drains, with manholes at appropriate intervals, on the perimeter of the slimes dams as shown in the detail drawings. Toe drains intercept any seepage from the side slopes and also connect to the manholes.

4.5 Cover stability

The geotechnical aspects of final cover system slope stability follow the same principles used for other geotechnical stability problems. What is unique and important to recognize, relative to final cover systems, is their sensitivity to relatively small changes in loading, slope angle, pore pressures, or shear strengths that make them more susceptible to sliding failures.

The following resisting forces against slippage have relevance:

- Internal shear stability of the soil cover layer itself;
- The shear strength between the soil cover of 450mm on top of the geomembrane;
- The buttressing force at the toe of the slope; and
- If the failure surface is below geosynthetics then there could be a tensile force, from the geosynthetics.

The toe buttressing effect is a significant element of membrane stability. A general rule is that when the vertical height of a slope is more than 25 to 30 times the thickness of the membrane cover soil buttressing becomes to be insignificant. The aim is to provide all of the slope resistance with shear forces and not to put the geosynthetics in tension.

Refer to Annexure B for the calculation of the final cover against down slide. The initial check is to verify that the soil cover will not slide with the shear plane inside the soil cover. When the soil is only saturated the factor against slip (FoS) will be 2 and when a inundated zone of 0,25m within the cover should develop the FoS will be 1.54. Both factors are more than 1.3 that indicated stable conditions also under extreme unlikely inundated conditions.

The follow on stability check consists of verifying that the soil cover will not slide on the flexible membrane layer (FML). Then also to verify that stress in the FML is acceptable.

The FML on the side slopes are 2mm HDPE membrane and is textured on both surfaces to increase slide resistance (or shear angle δ between soil and FML). It should be noted that the friction angles between soil and FML and the FML and LCR (capillary break & drainage) layer must be verified during construction when the soils borrow pit/s have been selected.

With typical parameters assumed for the capping (a sandy soil without cohesion) the slide FoS on the soil- FML contact is 1,8 > 1,3 that is deemed to be OK. It should be further noted from the calculations that a 1:3 side slope will be unstable for the same conditions. Should additional lab tests during construction verify the strength and shear friction parameters the side slope may be adjusted to 1:4.

Normal anchoring of the FML will be required. The maximum tensile force per m width of membrane will be 23,8 kN. The actual force implies 23,8 N/mm compared with the 2mm HDPE strength at yield of 32 N/mm and 66 N/mm at break. This is hence acceptable. The FML must comply with GRI GM13 or the SANS 1526 standard.

5. STORM WATER MANAGEMENT

The South- and East slimes dams are not subjected to large upslope catchments and runoff is directed naturally past the dams.

Ferrometals is in the process of improving their storm water drainage systems also in the vicinity of the historical dams. The rehabilitation of the slimes dams will not impact on the drainage strategy and vice versa.

Runoff from the crest and side slope areas due to the size will be sheet flow that will be intercepted by the existing and future SW management system.

6. GEOTECHNICAL

The slimes properties have been established and sources of capping soil have been identified.

Slimes Properties

The properties of the typical have been extensively investigated by Engeolab. From a closure rehabilitation design perspective obtaining the insitu density and shear strength parameters of the slimes are necessary to perform a slope stability check.

It was found that the slimes vary with depth as can be expected and the generalised engineering characteristics of the slimes are tabulated below.

Table 6.1 General Characteristics of Slimes at Ferrometals

Colour	PI	Dry Density & Bulk Density kg/m3	CBR	Ø°	C kPa	RD
Grey	NP	1328/1550	17	31	16-24	3.2

The specimen were moulded and compacted to 95% Standard Proctor density for performing shear strength. A shear box test on this sample reported cohesion to be 24 kPa and angle of internal friction 31°.

Final Cover Material

Two sources of capping material were inspected, sampled and tested. The sites are 'Jumbo' and 'Rondebult'.

The Jumbo borrow site has clayey sand and the Rondebult borrow site has silty sand respectively classified as G9 and G10 material. Both materials display adequate compaction characteristics for filling. The soil parameters are tabled in Table 6.2. The grading modulus indicates that both material types are closer to fine grained textured. The plasticity index and clay content indicates the material has a low swelling potential thus to be suitable for the side slope fill at the South- and East Slimes Dams.

Table 6.2 Borrow Pit Capping Material Properties

Borrow Pit	Material Type	GM	PI	Mod Aashto Density kg/m3	CBR at 95% Mod	Class	Colour
Rondebult	Silty sand	1.18	6.3	1865	12	G10	Maroon Brown
Jumbo	Clayey Sand	0.92	8.5	2034	15	G9	Ivory brown

General Soil Profile

The general soil profile of the site is transported soils of various origins that are partially cemented Pedocrete with the consistency that ranges from loose to medium dense. This loose transported layer overlays a well cemented Pedocrete layer followed by bedrock (Shale and Sandstone). The loose to medium dense soils varies in thickness but normally up to 4m followed by the 2m partially cemented Pedocrete layer. At the slimes dam sites the top soils are disturbed and for stability purposes the basin base soil profile is assumed to be similar to the general profile.

7. COST ESTIMATE

The estimated cost breakdowns for each of the historical dams are included in the annexure section. The total costs for the rehabilitation of the historical slimes dams are indicated below.

The removal and clearing of the Stores Slimes Dam is included in the costing for the South Slimes Dam.

Historical Dam	Total (R) Excl.
South Slimes Dam	11 405 237
East Slimes Dam	10 870 182

8. CONCLUSION

The Historical Slimes Dams at Ferrometals, Ferrobank near Witbank are classified as Class A (or H:H) landfills. The rehabilitation of such facilities must meet stringent standards and requirements. The shaping and capping proposed in the design meet minimum requirements.

The historical dams have no acceptable barrier system to contain any leachate within the slimes body. Therefore diffusion of solute must be prevented by a suitable and sustainable capping method.

The capping stability is paramount for such facilities and it has been indicated that the proposed configuration of layers are sound and stable.

The affected footprints of the slimes dams will not be enlarged but the side slopes must be flattened for stability and maintenance reasons.

Geotechnical investigations were recently and previously performed on the expected foundation soils, slimes and capping soils.

Local surveys of the slimes dams were conducted and all volumes and areas were derived from 3D rehabilitation models. These models were converted to a set of detail drawings that specifies all work required.

The design further adopts soils and slimes strength parameters obtained from lab testing and of typical values. The stability of the dam is sound provided that the work is done according to details presented. Additional testing on friction angles should be conducted as verification when cover soils are selected.

The estimated cost for rehabilitation totals to R10.8 m (Vat excluding) and R11,4m (Vat excluding) for the East- and South Dam respectively.

REFERENCES

i. Minimum Requirements for Waste Disposal by Landfill, Second Edition 1998, Department of Water Affairs, RSA.

ii. National Norms and Standards for Disposal of Waste to Landfill, Department of environmental Affairs, 23 August 2013.

iii. Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments, by GN Richardson and RM Koerner.

iv. Waste Classification of Ferrometals Slimes Dams Samancor Ferrometals, Report No. 1304001, Final Draft by Geotratum for JMA Consulting (Pty)Ltd, April 2013.

v. Report on the Geotechnical Investigation of the Ferrometals Old and New Slimes Dams, Ferrobank, witbank by Engeolab CC, dated April 2010.

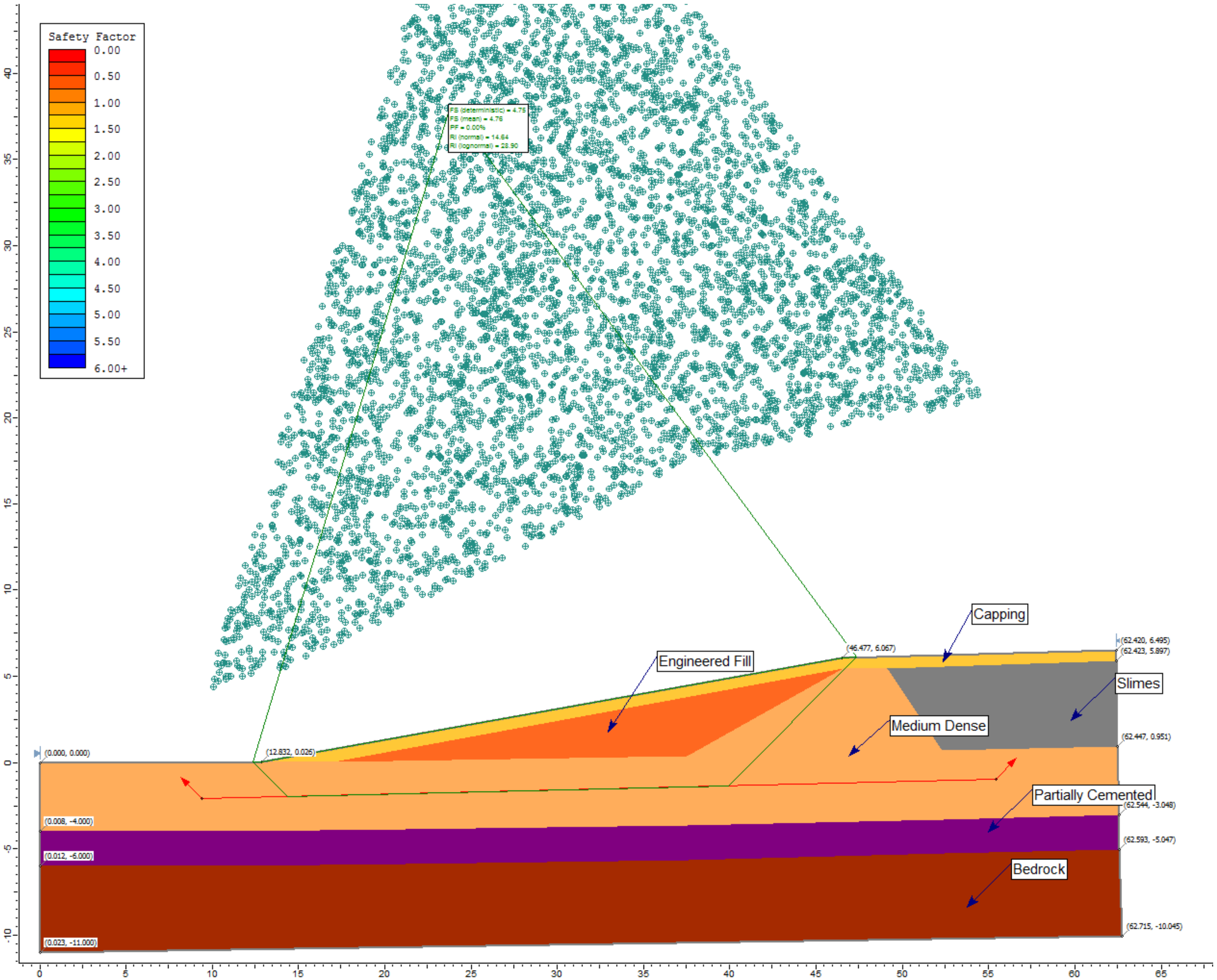
ANNEXURES

ANNEXURE A: COST ESTIMATE

Ferrometals Historical Slimes Dams Rehabilitation for Closure					
Historical South Dam					Rev00
No	**Item**	**uom**	**qty**	**rate**	**Total**
	Site Clearance:				
1	Remove pipe services & other	Sum	1	50000	50000
2	Strip & remove vegetation:				
	a) Crest Surface	ha	1.04	20000	20800
	b) Dam side slopes	ha	0.44	20000	8800
	c) Widened embank base width	ha	0.53	20000	10600
	d) Stores dam surface	ha	0.23	20000	4600
3	Remove & grub all trees complete with stumps within new rehab footprint.	No.	5	2500	12500
4	Remove topsoil to nom. depth 150mm from crest, embank slopes and extended embank base to temp stockpile.	m3	1510	35	52850
5	Remove topsoil to nom. depth 250mm from stores dam surface & stockpile	m3	575	35	20125
	Excavations:				
6	Opening & closing Borrow Pits Provisional	Sum	1	20000	20000
7	Excavate in all materials at stores dam remove, clear and use old slimes to place on crest of south dam in 150mm layers to grade, levels and compaction. Freehaul distance to South Dam.	m3	4600	50	230000
8	Import soil from Borrow Pits and form embankment 1:5 side slopes in 200mm layers keying into existing embankment side 1m cut-backs.	m3	10650	180	1917000
9	Import soil from Borrow Pits & backfill old stores dam to original NGL 300mm layers.	Sum	4600	180	828000
9	Construct access ramp 4m width at 1:7 ramp slope.	Sum	1	10000	10000
10	Excavate trenches for toe drain.	m3	448	50	22400
11	Excavate trenches for anchor/crest drain.	m3	352	50	17600
12	Place topsoil layer all surfaces 450mm depth:				
12.1	Import from temporary stockpile	m3	1510	40	60400
12.2	Import soil from Borrow Pits	m3	7490	180	1348200
12.3	Place topsoil on stores dam surface from temp stockpile	m3	575	40	23000
	Capping & Drainage:				
13	Drainage layer 150mm				
13.1	Slag or washed stone 12-19mm	m3	3038	45	136 688
13.2	Geotextile non-woven A5	m2	42525	35	1 488 375
14	GCL 800 Bentofix	m2	21358	45	961 110
15	2mm Textured HDPE Membrane	m2	21358	60	1 281 480
16	Toe drains complete	m	560	150	84 000
17	Crest drains complete	m	440	140	61 600
18	Slope Discharge	m	106	160	16 960
19	Manholes	No.	7	3500	24 500
20	**Vegetation:**				
20.1	Inorganic fertilizers procured and applied by mechanical equipment	ton	1.10	16638	18 302
20.2	Organic fertilizer procured and applied.	ton	20.00	1264	25 280
20.3	Lime procured and applied.	ton	8.00	998	7 984
20.4	Grass seed mix 45 kg procured and applied.	ha	2	3328	6 656
20.5	Manually re-plant grass sods recovered from existing stores dam surface.	ha	0.23	15000	3450
A	**Sub-total**			R	**8 773 259**
B	Ps & Gs	25.0%			2 193 315
C	Contingency	5.0%		R	438 663
	Total			R	**11 405 237**

Ferrometals Historical Slimes Dams Rehabilitation for Closure					
Historical East Dam					Rev01
No	**Item**	**uom**	**qty**	**rate**	**Total**
	Earthworks:				
1	Earthworks shaping of slimes (side slopes to crest)	m3	3700	85	314 500
2	Import soil to upgrade embankment 1:5 sides	m3	4998	180	899 586
3	150-250 Crest cover layer under	m3	1000	75	75 000
4	Trenches (Toe & Anchor)	m3	637	50	31 860
5	Topsoil 450mm	m3	10380	180	1 868 427
	Capping & Drainage:				
6	Drainage layer 150mm				
6.1	Slag or washed stone 12-19mm	m3	3460	45	155 702
6.2	Geotextile non-woven A5	m2	48634	35	1 702 190
7	GCL 800 Bentofix	m2	23067	45	1 038 015
8	2mm Textured HDPE Membrane	m2	32733	60	1 963 986
9	Toe drains	m	655	150	98 250
10	Crest drains	m	579	140	81 060
11	Slope Discharge	m	168	160	26 880
12	Manholes	no	9	3500	31 500
13	Vegetation:				
13.1	Inorganic fertilizers procured and applied by mecha	ton	1.30	16638	21 629
13.2	Organic fertilizer procured and applied.	ton	26.60	1264	33 622
13.3	Lime procured and applied.	ton	10.64	998	10 619
13.4	Grass seed mix 45 kg procured and applied.	ha	2.66	3328	8852
A	**Sub-total**			R	**8 361 679**
B	Ps & Gs	25.0%			2 090 420
C	Contingency	5.0%		R	418 084
	Total			R	**10 870 182**

ANNEXURE B: SLOPE STABILITY PARAMETERS



Safety Factor
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
6.00+
FS (deterministic) = 4.75
FS (mean) = 4.76
PF = 0.00%
RI (normal) = 14.64
RI (lognormal) = 28.90
Capping
Engineered Fill
Slimes
Medium Dense
Partially Cemented
Bedrock
(0.000, 0.000)
(12.832, 0.026)
(46.477, 6.067)
(62.420, 6.495)
(62.423, 5.897)
(62.447, 0.951)
(62.544, -3.048)
(62.593, -5.047)
(62.715, -10.045)
(0.008, -4.000)
(0.012, -6.000)
(0.023, -11.000)

Slide Analysis Information

Slope Stability of South Slimes Dam

Project Summary

- File Name: South Slimes Dam
- Slide Modeler Version: 6.018
- Project Title: Slope Stability of South Slimes Dam
- Analysis: Slide Program
- Author: P du Toit
- Company: Inprocon Consultants
- Date Created: Jun 2013

General Settings

- Units of Measurement: Metric Units
- Time Units: days
- Permeability Units: meters/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

  - Bishop simplified

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 9.81 kN/m3
- Advanced Groundwater Method: None

Random Numbers

- Pseudo-random Seed: 10116
- Random Number Generation Method: Park and Miller v.3

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 135
- Left Projection Angle (End Angle): 135
- Right Projection Angle (Start Angle): 45
- Right Projection Angle (End Angle): 45
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Bedrock	Partially Cemented	Medium Dense	Capping	Slimes	Engineered Fill
Color						
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [kN/m3]	21	20	19	18	15.7	20
Cohesion [kPa]	5	8	10	10	20	10
Friction Angle [deg]	38	31	29	25	30	35
Water Surface	None	None	None	None	None	None
Ru Value	0	0	0	0	0	0

Probabilistic Analysis Input

General Settings

- Sensitivity Analysis: Off
- Probabilistic Analysis: On
- Sampling Method: Monte-Carlo
- Number of Samples: 1000
- Analysis Type: Global Minimum

Variables

Material	Property	Distribution	Mean	Min	Max	Standard Deviation
Medium Dense	Cohesion	Triangular	10	5	15	
Medium Dense	Phi	Triangular	29	27	32	
Medium Dense	Unit Weight	Triangular	19	18	20	
Slimes	Cohesion	Triangular	20	15	25	
Slimes	Phi	Triangular	30	28	31	
Slimes	Unit Weight	Triangular	15.7	14.5	16.8	
Engineered Fill	Cohesion	Triangular	10	5	15	
Engineered Fill	Phi	Triangular	35	30	38	
Engineered Fill	Unit Weight	Triangular	20	19	22	

Correlation Coefficients

Material	Correlation
Medium Dense	-0.5
Slimes	-0.5
Engineered Fill	-0.5

Global Minimums

Method: bishop simplified

- FS: 4.745220
- Axis Location: 23.780, 38.073
- Left Slip Surface Endpoint: 12.338, 0.025
- Right Slip Surface Endpoint: 47.353, 6.090
- Resisting Moment=74838.8 kN-m
- Driving Moment=15771.4 kN-m
- Total Slice Area=134.684 m2

Global Minimum Coordinates

Method: bishop simplified

X	Y
12.3379	0.0253407
14.3474	-1.98416
39.9212	-1.34141
47.3528	6.09025

Valid / Invalid Surfaces

Method: bishop simplified

- Number of Valid Surfaces: 4860
- Number of Invalid Surfaces: 140

Error Codes:

- Error Code -108 reported for 140 surfaces

Error Codes

The following errors were encountered during the computation:

- -108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).

Slice Data

- **Global Minimum Query (bishop simplified) - Safety Factor: 4.74522**

Slice Number	Width [m]	Weight [kN]	Base Material	Base Cohesion [kPa]	Base Friction Angle [degrees]	Shear Stress [kPa]	Shear Strength [kPa]	Base Normal Stress [kPa]	Pore Pressure [kPa]	Effective Normal Stress [kPa]
1	2.0095	42.1164	Medium Dense	10	29	5.15818	24.4767	26.1167	0	26.1167
2	1.42076	64.0356	Medium Dense	10	29	7.35077	34.881	44.8865	0	44.8865
3	1.42076	69.6147	Medium Dense	10	29	7.80813	37.0513	48.8019	0	48.8019
4	1.42076	75.6117	Medium Dense	10	29	8.29976	39.3842	53.0105	0	53.0105
5	1.42076	81.882	Medium	10	29	8.8138	41.8237	57.411	0	57.4115

		9	Dense			6		5		
6	1.42076	88.154	Medium Dense	10	29	9.32796	44.2632	61.8125	0	61.8125
7	1.42076	94.4252	Medium Dense	10	29	9.84207	46.7028	66.2135	0	66.2135
8	1.42076	100.696	Medium Dense	10	29	10.3562	49.1423	70.6144	0	70.6144
9	1.42076	106.968	Medium Dense	10	29	10.8703	51.5818	75.0155	0	75.0155
10	1.42076	113.239	Medium Dense	10	29	11.3844	54.0213	79.4167	0	79.4167
11	1.42076	119.51	Medium Dense	10	29	11.8985	56.4609	83.8179	0	83.8179
12	1.42076	125.781	Medium Dense	10	29	12.4126	58.9004	88.2184	0	88.2184
13	1.42076	132.052	Medium Dense	10	29	12.9267	61.3399	92.6195	0	92.6195
14	1.42076	138.323	Medium Dense	10	29	13.4408	63.7794	97.0207	0	97.0207
15	1.42076	144.595	Medium Dense	10	29	13.9549	66.219	101.422	0	101.422
16	1.42076	150.866	Medium Dense	10	29	14.469	68.6585	105.823	0	105.823
17	1.42076	157.137	Medium Dense	10	29	14.9831	71.098	110.224	0	110.224
18	1.42076	163.13	Medium Dense	10	29	15.4744	73.4295	114.43	0	114.43
19	1.42076	168.335	Medium Dense	10	29	15.9011	75.454	118.082	0	118.082
20	1.36233	149.066	Medium Dense	10	29	13.3318	63.2624	96.088	0	96.088
21	1.36233	119.43	Medium Dense	10	29	11.0564	52.4652	76.6094	0	76.6094
22	1.36233	89.7934	Medium Dense	10	29	8.78105	41.668	57.1308	0	57.1308
23	1.36233	60.1572	Medium Dense	10	29	6.50568	30.8709	37.652	0	37.652
24	1.36233	30.4345	Medium Dense	10	29	4.22364	20.0421	18.1164	0	18.1164
25	0.619995	3.36659	Capping	10	25	2.40469	11.4108	3.02541	0	3.02541

Interslice Data

- **Global Minimum Query (bishop simplified) - Safety Factor: 4.74522**

Slice Number	X coordinate [m]	Y coordinate - Bottom [m]	Interslice Normal Force [kN]	Interslice Shear Force [kN]	Interslice Force Angle [degrees]

1	12.3379	0.0253407	0	0	0
2	14.3474	-1.98416	62.8465	0	0
3	15.7682	-1.94845	71.6871	0	0
4	17.1889	-1.91274	81.0376	0	0
5	18.6097	-1.87703	90.9364	0	0
6	20.0305	-1.84133	101.408	0	0
7	21.4512	-1.80562	112.454	0	0
8	22.872	-1.76991	124.072	0	0
9	24.2928	-1.7342	136.264	0	0
10	25.7135	-1.69849	149.029	0	0
11	27.1343	-1.66279	162.367	0	0
12	28.5551	-1.62708	176.278	0	0
13	29.9758	-1.59137	190.763	0	0
14	31.3966	-1.55566	205.821	0	0
15	32.8173	-1.51995	221.452	0	0
16	34.2381	-1.48425	237.656	0	0
17	35.6589	-1.44854	254.434	0	0
18	37.0796	-1.41283	271.785	0	0
19	38.5004	-1.37712	289.684	0	0
20	39.9212	-1.34141	308.058	0	0
21	41.2835	0.0209207	195.316	0	0
22	42.6458	1.38325	106.011	0	0
23	44.0082	2.74559	40.1423	0	0
24	45.3705	4.10792	-2.28965	0	0
25	46.7328	5.47025	-21.2164	0	0
26	47.3528	6.09025	0	0	0

Probabilistic Analysis Results (Global Minimum)

- Method: bishop simplified
- Factor of Safety, mean: 4.757349
- Factor of Safety, standard deviation: 0.256685
- Factor of Safety, minimum: 4.125300
- Factor of Safety, maximum: 5.474540
- Probability of Failure: 0.000% (= 0 failed surfaces / 1000 valid surfaces)
- Reliability index: 14.63796 (assuming normal distribution)
- Reliability index: 28.90103 (assuming lognormal distribution)
- * best fit = Beta

List Of Coordinates

Block Search Polyline

X	Y
55.455	-0.951
9.42	-2.108

External Boundary

X	Y
0	0
0.00821554	-3.99999
0.0123233	-5.99999
0.0225927	-11
62.7145	-10.0455
62.5928	-5.04696
62.5441	-3.04755
62.4467	0.951261
62.423	5.89654
62.4202	6.4951
46.4769	6.06671
12.8318	0.0263551

Material Boundary

X	Y
12.8318	0.0263551
16.2043	0.0523286
17.029	0.0586795
37.4976	0.343646
52.3021	0.704186
62.4467	0.951261

Material Boundary

X	Y
0.00821554	-3.99999
12.8513	-3.97361
16.2351	-3.94755
17.0722	-3.94111
37.5768	-3.65564
52.3995	-3.29463
62.5441	-3.04755

Material Boundary

X	Y
0.0123233	-5.99999
12.861	-5.9736
16.2505	-5.94749
17.0938	-5.941
37.6151	-5.6553
52.4482	-5.29403
62.5928	-5.04696

Material Boundary

X	Y
37.4976	0.343646
46.5495	5.47015
49.15	5.47163
52.3021	0.704186

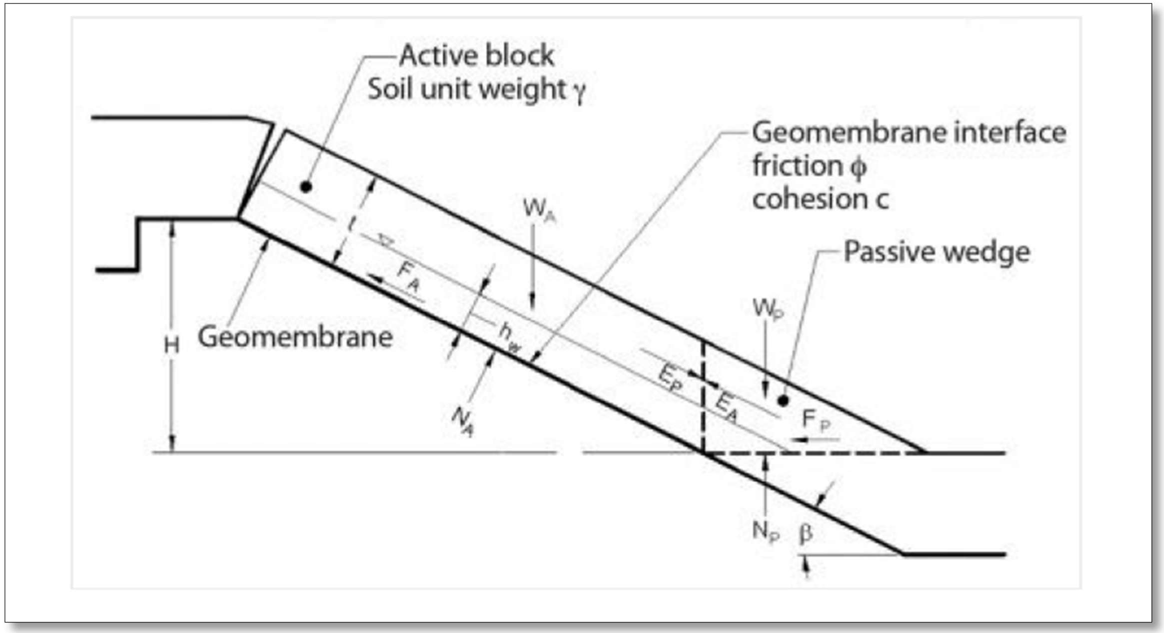
Material Boundary

X	Y
49.15	5.47163
62.423	5.89654

Material Boundary

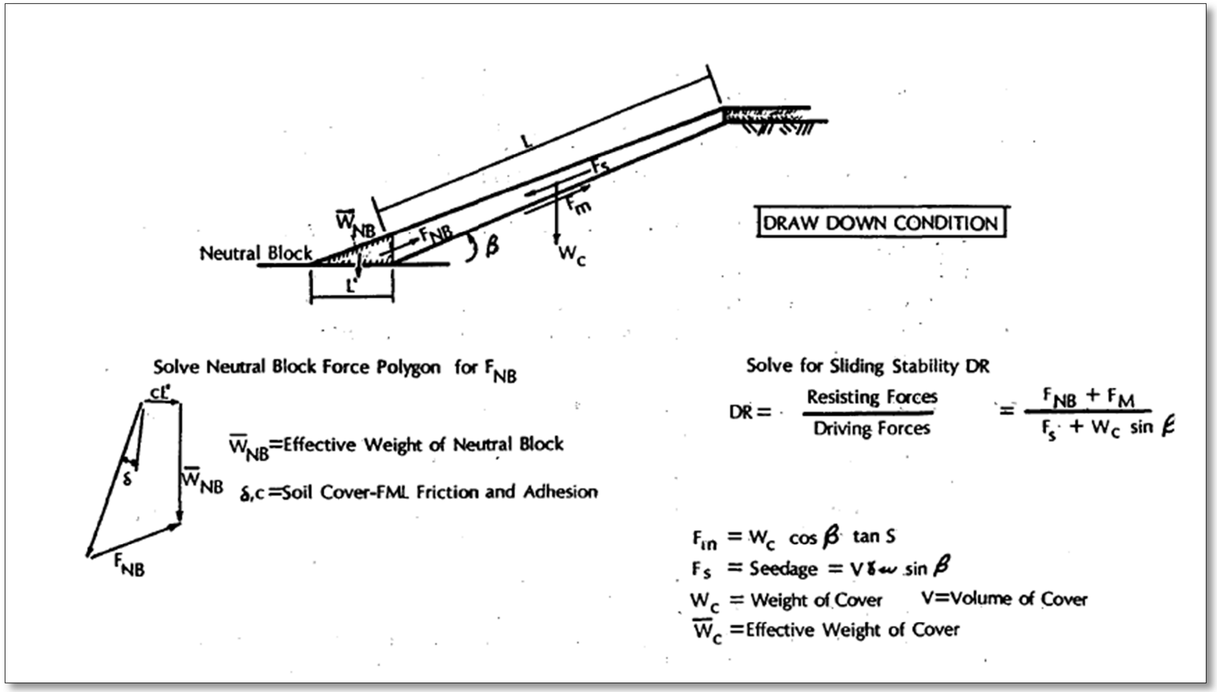
X	Y
17.029	0.0586795
46.5495	5.47015

ANNEXURE C: CAPPING STABILITY



Infinite slope:

t	hw	β (1 / ?)	β Deg	tan β	Ø	tan Ø	FoS Dry	ɣsoils	ɣsat	ɣbouy	FoS wet	FoS bouy
0.45	0.25	0.2	11.31	0.20	30.00	0.58	2.89	18	21	11.19	2.09	1.54

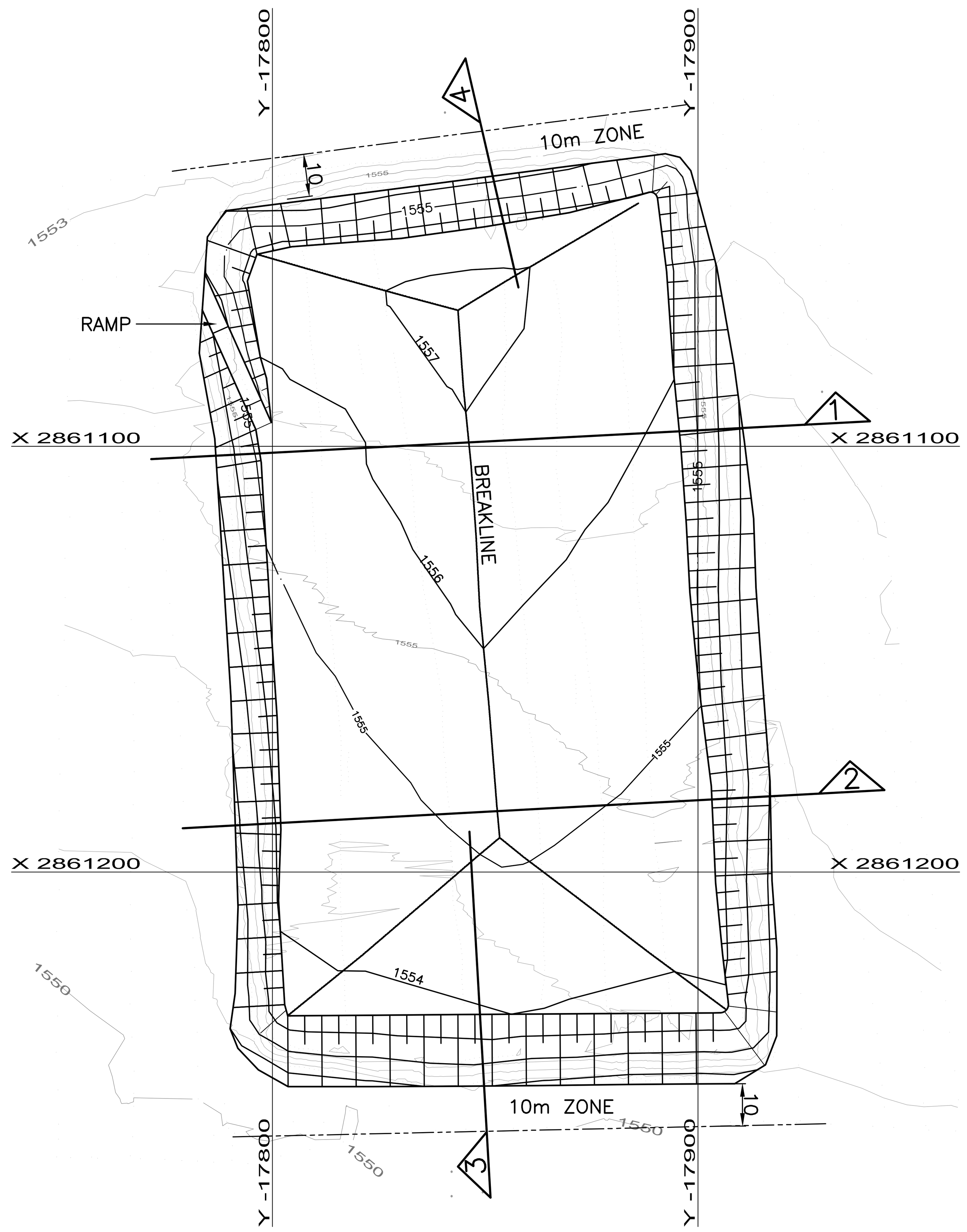


Soil/FML friction δ	FML/LCR friction δ	Slope 1:x	β deg	t	Slope L (m)	ɣsat	ɣbouy	ɣw	cos β	sinβ	tan δ (s/FM)	tan δ (FM/LCR)	Vc m3/m	Effect Wc	Wc (kN/m)	Wc sinβ	Fm kN/m	Fs kN/m	WNB	FNB	Resist F kN/m	Slide F kN/m	FoS (soil on FML)	FL kN/m	T kN/m	
27	30	5	11.31	0.45	27.85	22	12.19	9.81	0.981	0.196	0.510	0.577	12.53	152.77	275.72	54.05	76.33	24.10	6.17	3.15	79.48	78.15	1.02	156.10	-79.76	draw down
29	25	5	11.31	0.45	27.85	22	12.19	9.81	0.981	0.196	0.554	0.466	12.53	152.77	275.72	54.05	83.04	24.10	6.17	3.42	86.46	78.15	1.11	126.07	-43.03	draw down
27	30	5	11.31	0.45	27.85	22	12.19	9.81	0.981	0.196	0.510	0.577	12.53	152.77	275.72	54.05	137.76	24.10	6.17	3.15	140.90	78.15	1.80	156.10	-18.34	expect
29	25	5	11.31	0.45	27.85	22	12.19	9.81	0.981	0.196	0.554	0.466	12.53	152.77	275.72	54.05	149.87	24.10	6.17	3.42	153.29	78.15	1.96	126.07	23.79	expect
27	30	3	18.43	0.45	27.85	22	12.19	9.81	0.949	0.316	0.510	0.577	12.53	152.77	275.72	87.15	133.28	38.86	3.70	1.89	135.17	126.02	1.07	151.02	-17.74	expect
29	25	3	18.43	0.45	27.85	22	12.19	9.81	0.949	0.316	0.554	0.466	12.53	152.77	275.72	87.15	144.99	38.86	3.70	2.05	147.05	126.02	1.17	121.98	23.02	expect

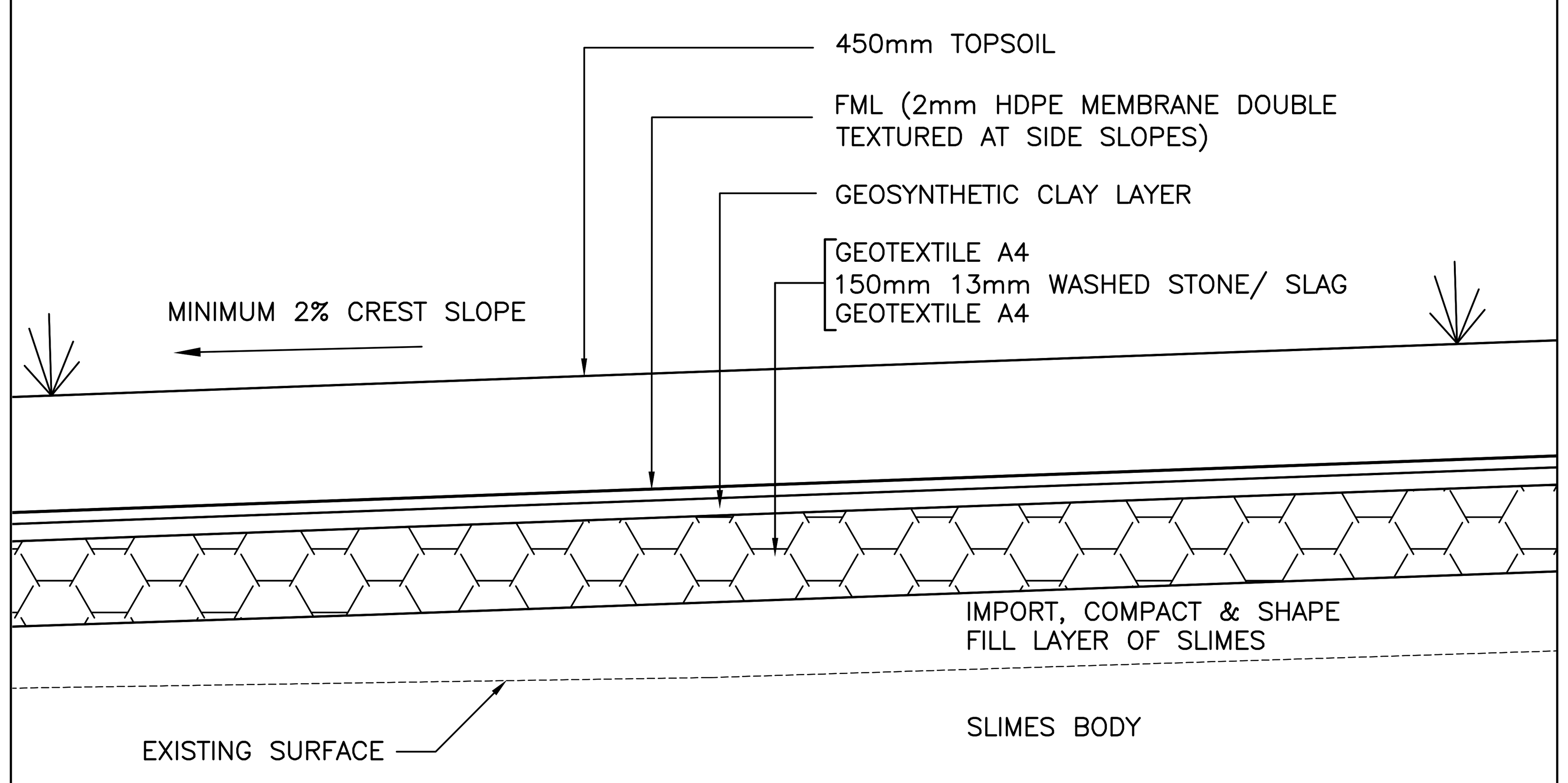
ANNEXURE D: DETAIL DRAWINGS

No.	Drawing Title	Drawing No.
	South Slimes Dam:	
01	Layout & Dam Drainage	IPC/FM/2013/101/01
02	Typical Section & Capping Layer Details	IPC/FM/2013/101/02
03	Typical Profiling Sections	IPC/FM/2013/101/03
	East Slimes Dam	
01	Layout & Capping Layer Details	IPC/FM/2013/100/01
02	Typical Profiling Sections	IPC/FM/2013/100/02
03	Drainage Details	IPC/FM/2013/100/03

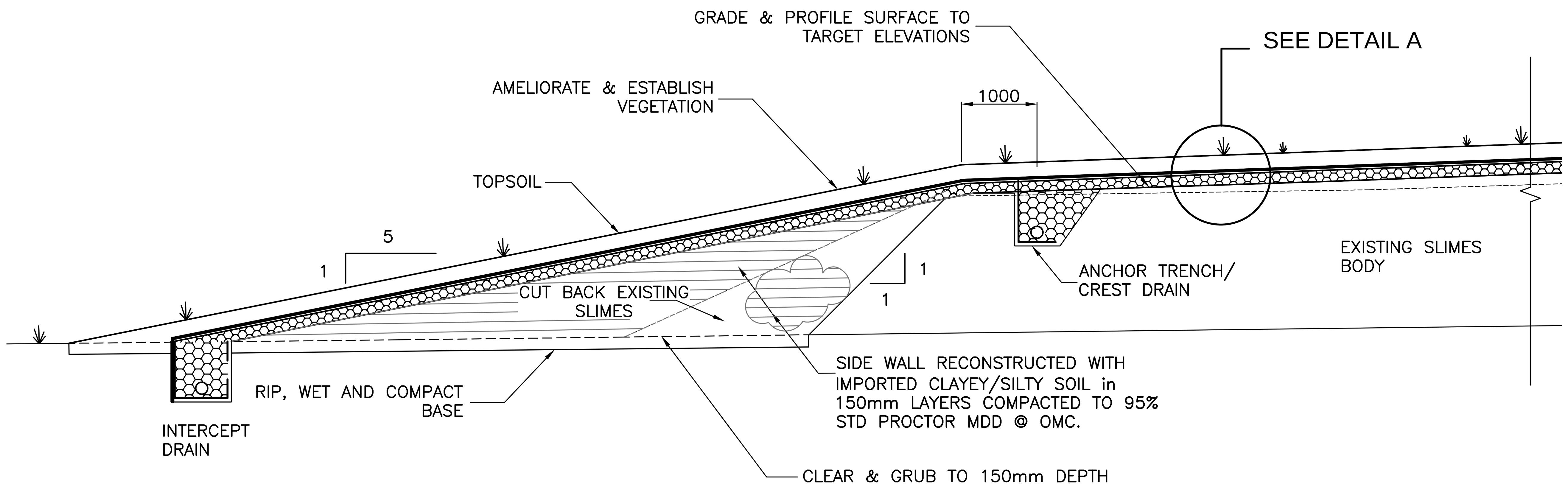
LAYOUT PLAN OF RE-PROFILED SURFACE 1: 1000



LAYOUT PLAN OF RE-PROFILED SURFACE (No back drop) 1: 1000



DETAIL A: CAPPING LAYERS 1: 10



TYPICAL SIDE SLOPE AND CAP DETAILS 1: 25

NOTES:

EARTHWORKS:

1. RE-CONSTRUCT AND UPGRADE SIDE EARTH WALLS BY CUTTING AND IMPORTING SUITABLE SOIL.
2. SHAPE CREST TO INDICATED ELEVATIONS BY FILLING WITH SLIMES AND IMPORTED SOIL.
3. INSTALL CAPPING LAYERS.

DRAINAGE:

1. INSTALL DETECT & COLLECTION TOE DRAINS.
2. INSTALL CREST INTERCEPT DRAINS.
3. INSTALL DRAINAGE CREST LAYER.
4. COLLECTION MANHOLES & DRAIN PIPES.

STATUS: PRELIMINARY

SURVEY CO-ORDINATE SYSTEM : CLARK 1880 LO29 (DEGREES SQUARE 2529)

REFERENCE DRAWINGS	
Drawing name / Tekening naam	No. /Nr.

REVISIONS/WYSIGINGS		
		DEC' 12
Wysiging Revision	Beskrywing/Description	Datum Date

Client: Klient:

SAMANCOR FERROMETALS (PTY)

INPROCON CONSULTANTS cc
ENVIRONMENTAL & CIVIL CONSULTING ENGINEERS

541 GENL LOUIS BOTHA AVE
CONSTANTIA PARK
PRETORIA
0181
TEL 012 993 2423

Project Name: Projek Naam

REHABILITATION OF HISTORICAL EAST SLIMES DAM

Drawing Name: Tekening Naam

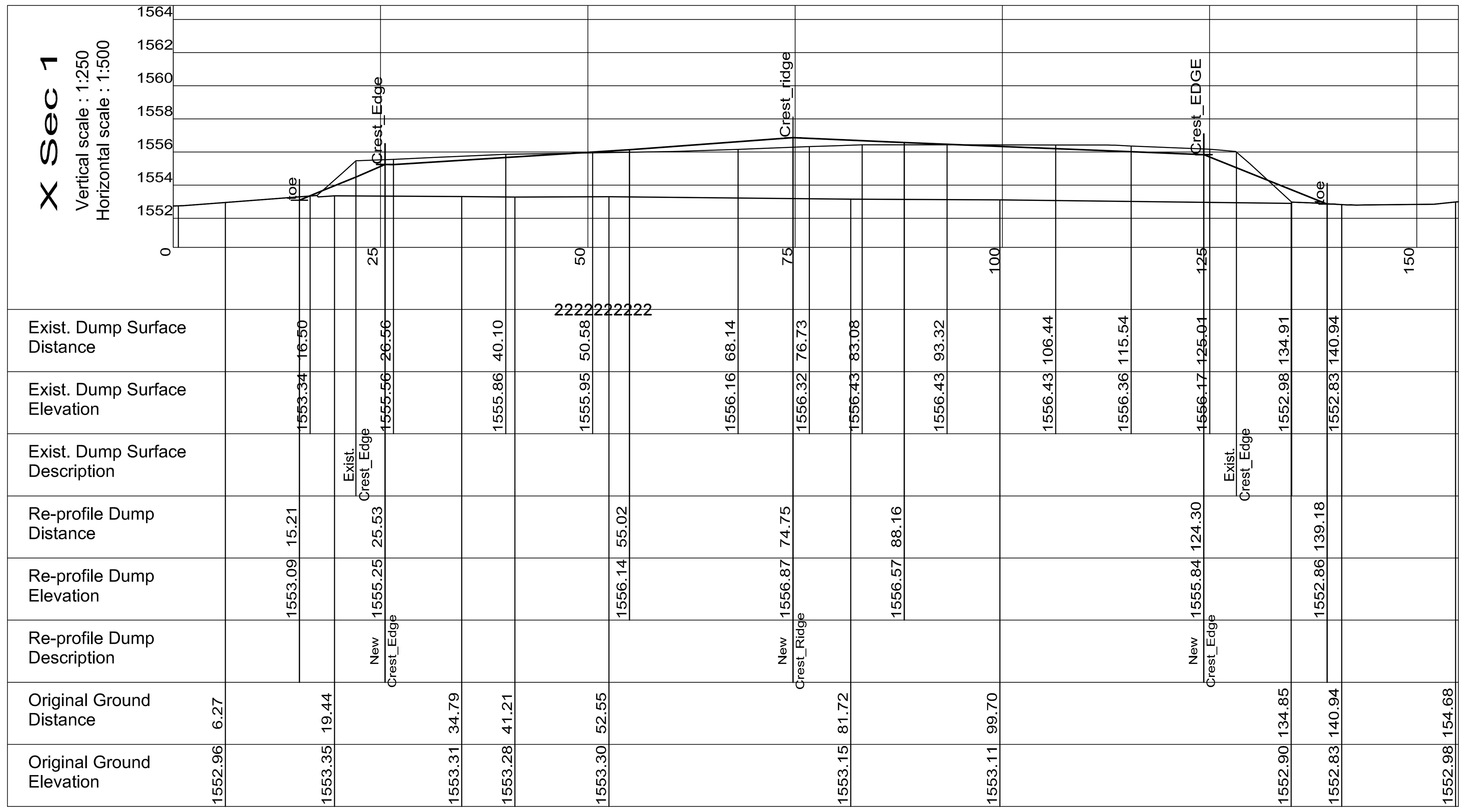
LAYOUT & CAPPING LAYER DETAILS

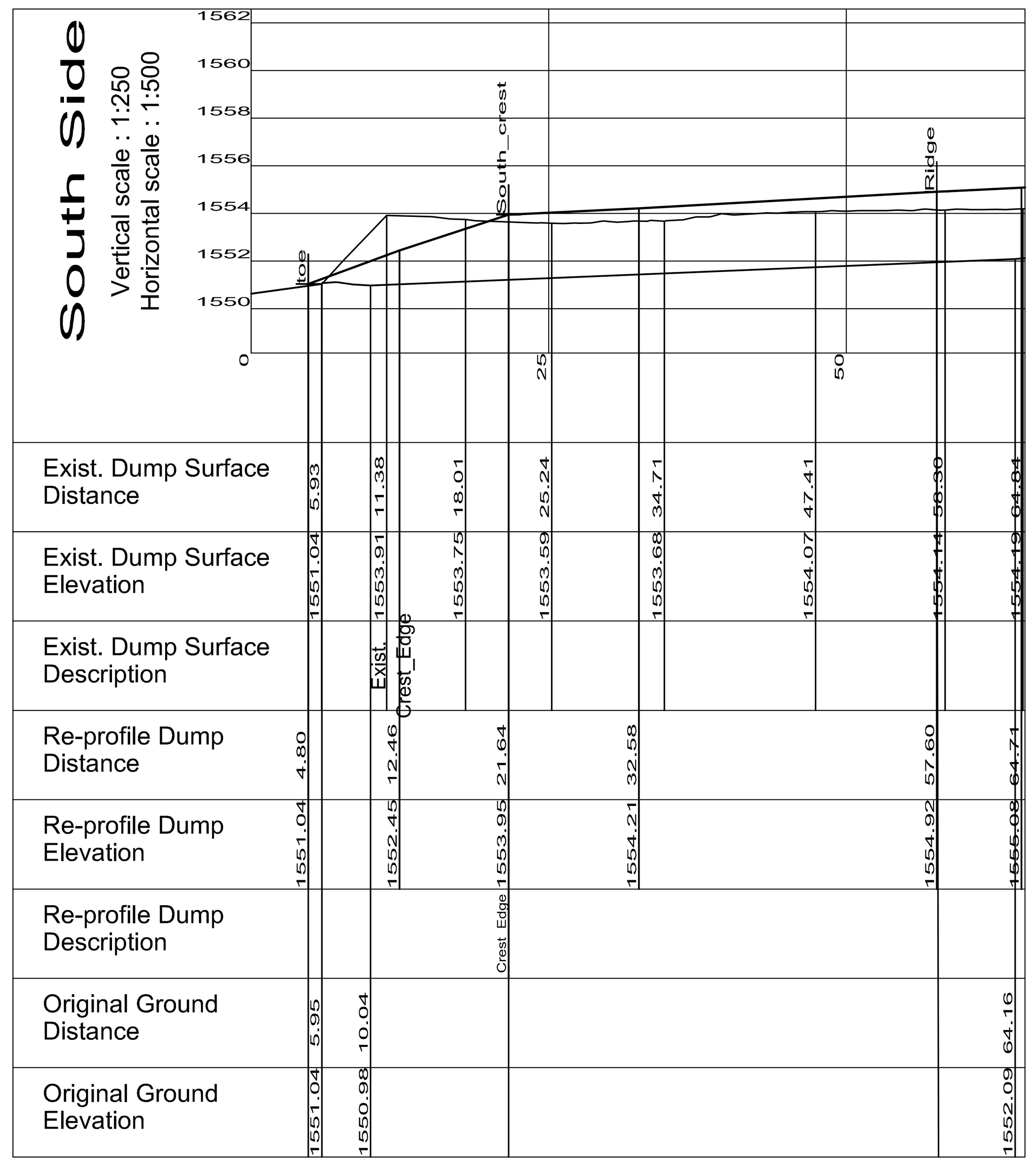
Project No.: Tekening Nr.

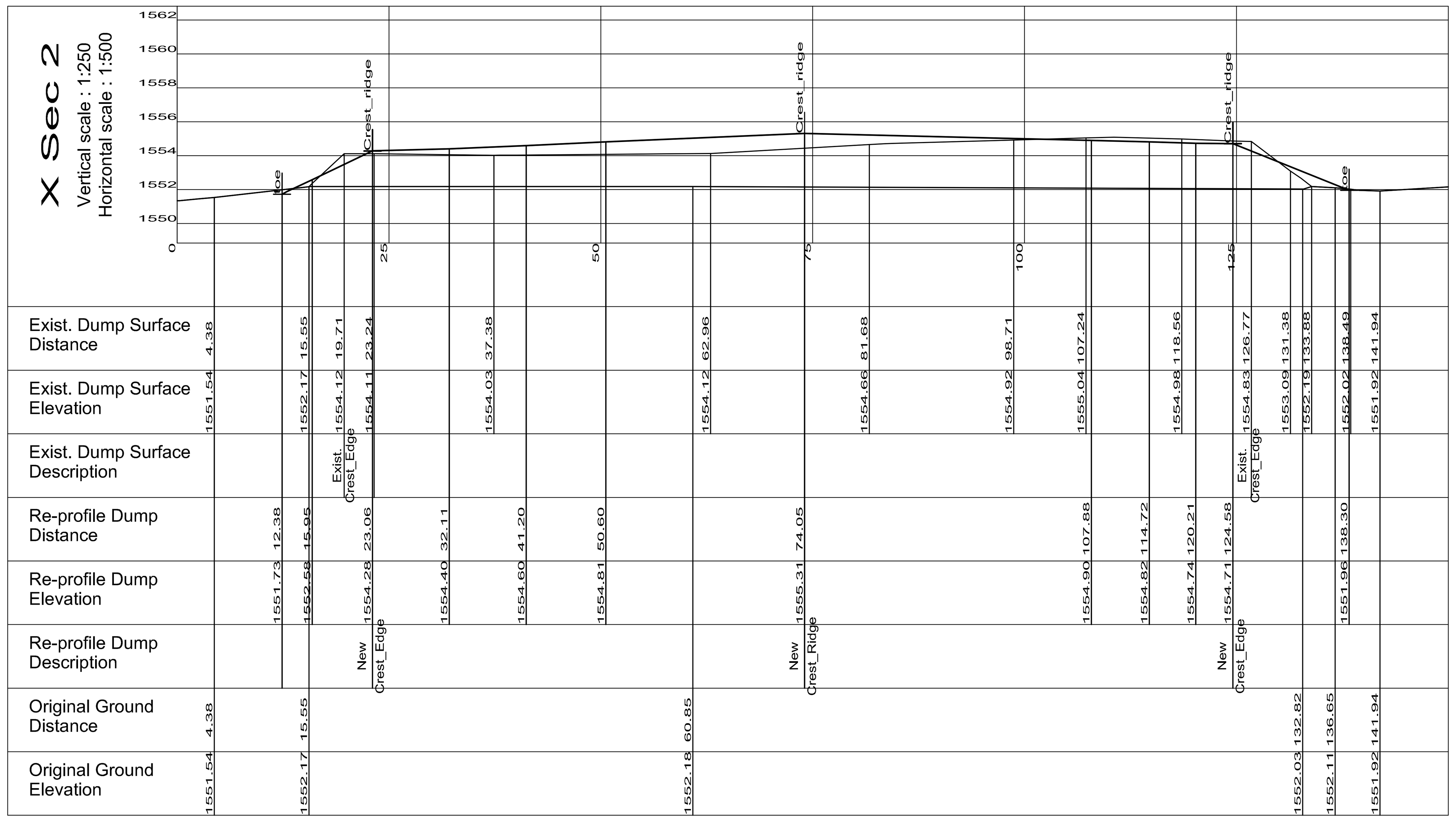
IPC/FM/2013/100/01

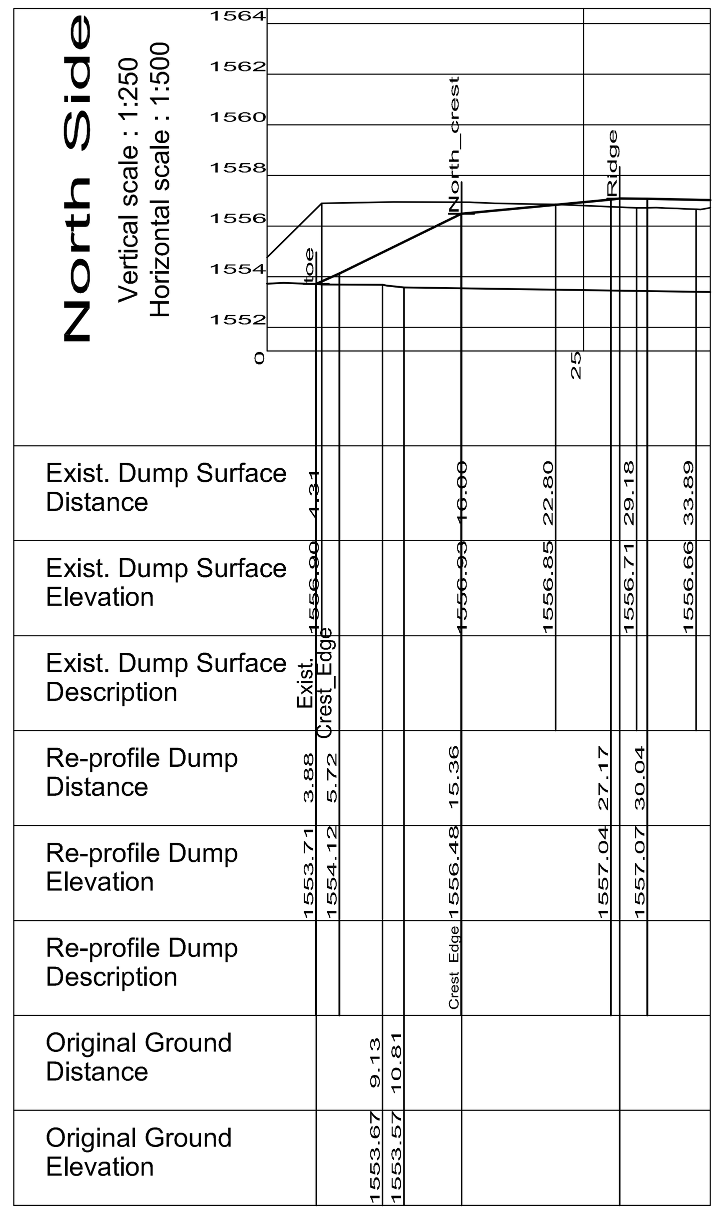
Wysigings Revisions: 0 0

Scale			
As Shown	Designed Ontwerp	P. D. T.	04/2013
	Geteken Drawn	I. P. C.	04/2013
	Nagesien Checked	P. D. T.	04/2013









NOTES:

EARTHWORKS:

1. RE-PROFILE SLIMES SURFACES AND SIDE SLOPES BY CUT TO FILL.
2. PROVIDE 10m FREE DISTANCE AT NORTH AND SOUTH BOUNDARIES.
3. SIDE SLOPES TO BE 1V:5H.
4. CREST SURFACE TO SLOPING 2% MIN.
5. ELEVATIONS INDICATED IN CROSS SECTIONS ARE FINAL RE-PROFILED SLIMES. CAPPING LAYERS TO BE CONSTRUCTED ON TOP OF RE-PROFILED SLIMES.

STATUS: PRELIMINARY

SURVEY CO-ORDINATE SYSTEM : CLARK 1880 LO29 (DEGREES SQUARE 2529)

REFERENCE DRAWINGS

Drawing name / Tekening naam	No. /Nr.

REVISIONS/WYSIGINGS

Wysiging Revision	Beskrywing/Description	Datum Date
		DEC'12

Client: Klient:

SAMANCOR FERROMETALS (PTY)

INPROCON CONSULTANTS cc
ENVIRONMENTAL & CIVIL CONSULTING ENGINEERS

541 GENL LOUIS BOTHA AVE
CONSTANTIA PARK
PRETORIA
0181
TEL 012 993 2423

Project Name: Projek Naam

REHABILITATION OF HISTORICAL EAST SLIMES DAM

Drawing Name: Tekening Naam

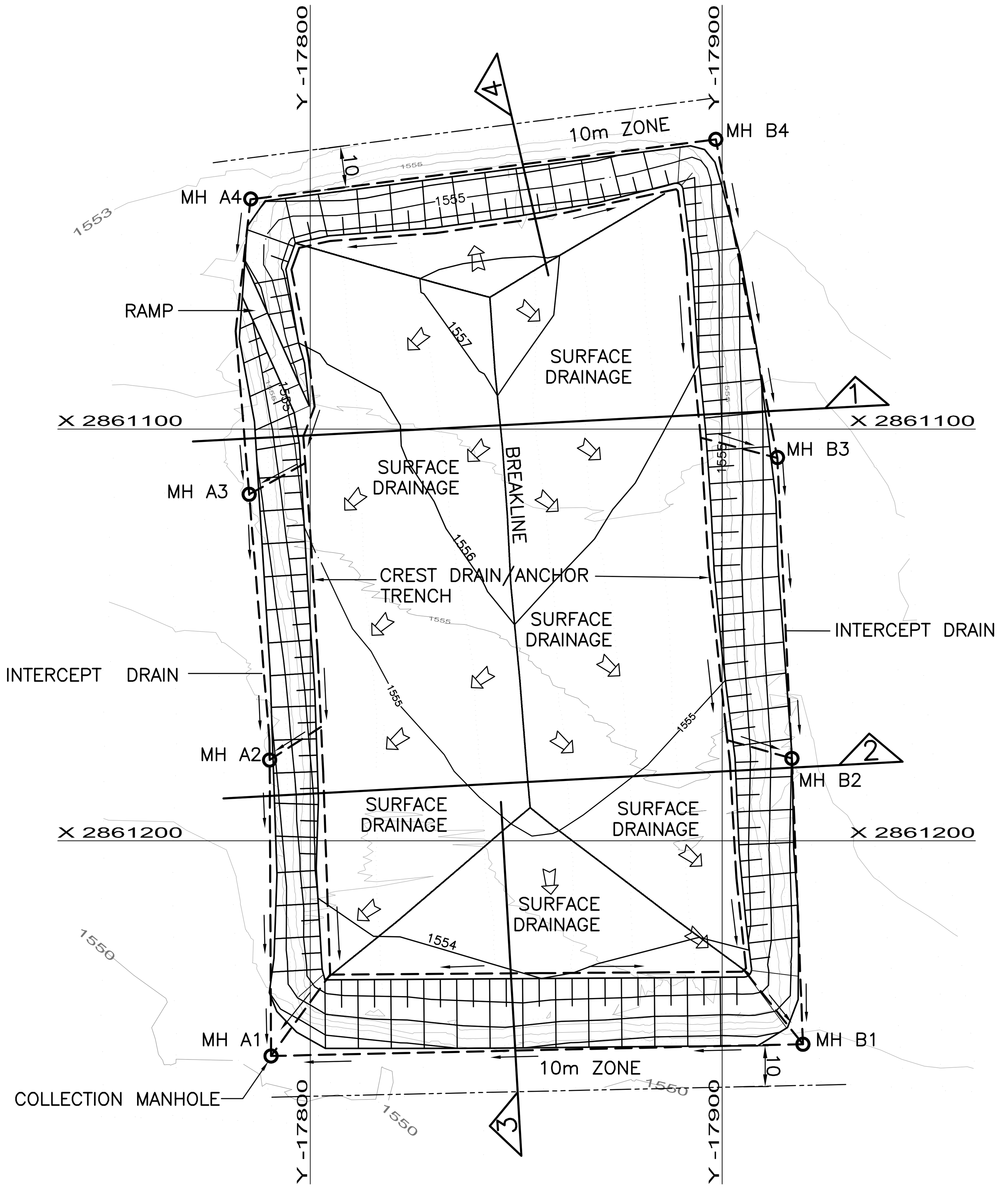
TYPICAL PROFILING SECTIONS

Project No.: Tekening Nr.

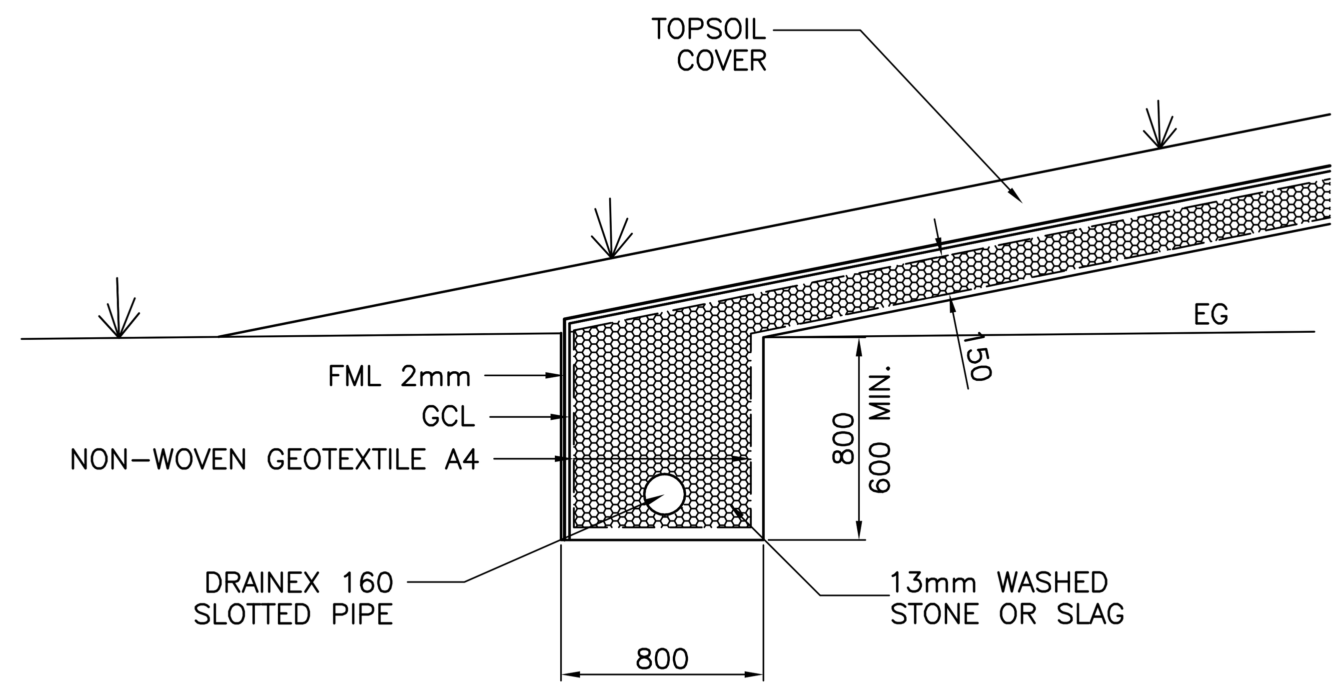
IPC/FM/2013/100/02

Wysigings Revisions: 0 0

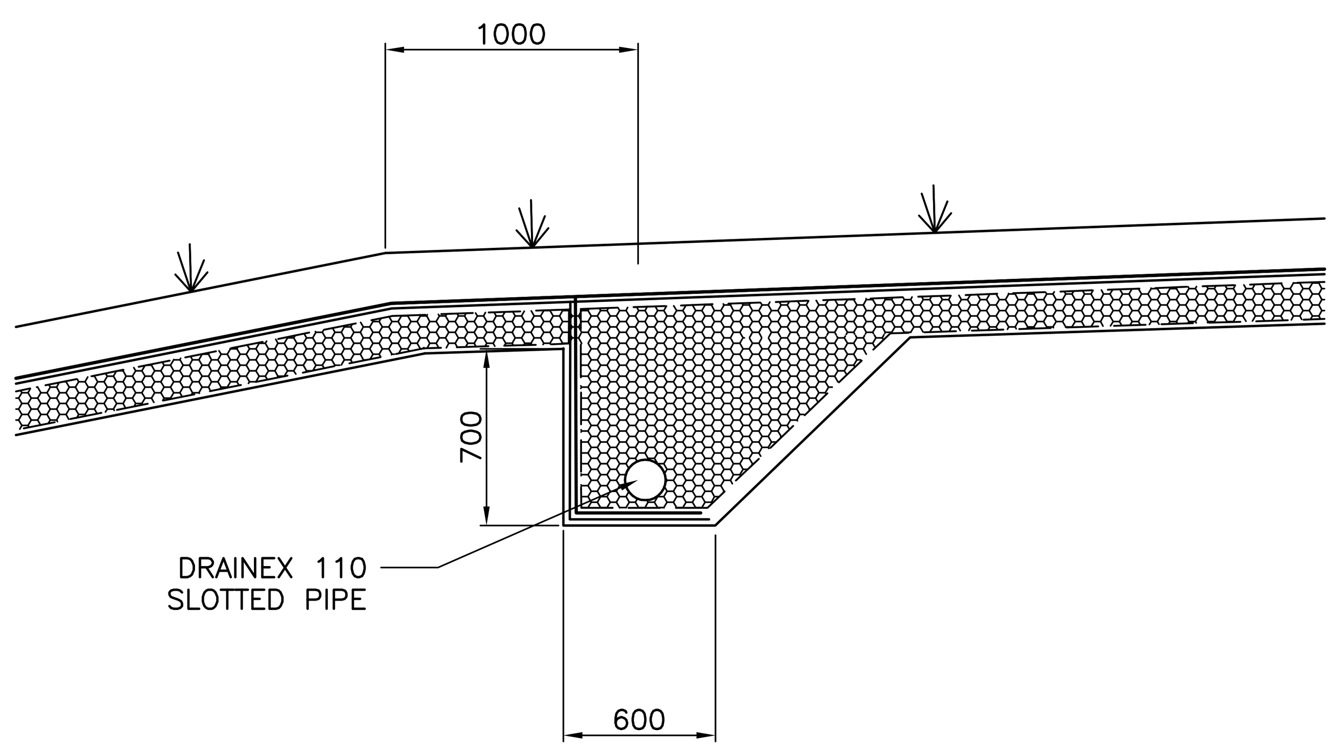
Scale			
As Shown	Designed Ontwerp	P. D. T.	04/2013
	Geteken Drawn	I. P. C.	04/2013
	Nagesien Checked	P. D. T.	04/2013



DRAINAGE PLAN 1: 1000



TYPICAL SECTION TOE INTERCEPT DRAIN 1:25



TYPICAL CREST DRAIN/ ANCHOR TRENCH 1:25

NOTES:

EARTHWORKS:

1. RE-CONSTRUCT AND UPGRADE SIDE EARTH WALLS BY CUTTING AND IMPORTING SUITABLE SOIL.
2. SHAPE CREST TO INDICATED ELEVATIONS BY FILLING WITH SLIMES AND IMPORTED SOIL.
3. INSTALL CAPPING LAYERS.

DRAINAGE:

1. INSTALL COLLECTION TOE DRAINS.
2. INSTALL CREST INTERCEPT DRAINS.
3. INSTALL DRAINAGE CREST LAYER.
4. COLLECTION MANHOLES.

STATUS: PRELIMINARY

SURVEY CO-ORDINATE SYSTEM : CLARK 1880 LO29 (DEGREES SQUARE 2529)

REFERENCE DRAWINGS

Drawing name / Tekening naam | No. /Nr.

REVISIONS/WYSIGINGS

Wysiging Revision	Beskrywing/Description	Datum Date
		DEC'12

Client: Klient:

SAMANCOR FERROMETALS (PTY)

INPROCON CONSULTANTS cc
ENVIRONMENTAL & CIVIL CONSULTING ENGINEERS

541 GENL LOUIS BOTHA AVE
CONSTANTIA PARK
PRETORIA
0181
TEL 012 993 2423

Project Name: Projek Naam

REHABILITATION OF HISTORICAL EAST SLIMES DAM

Drawing Name: Tekening Naam

DRAINAGE DETAILS

Project No.: Tekening Nr.

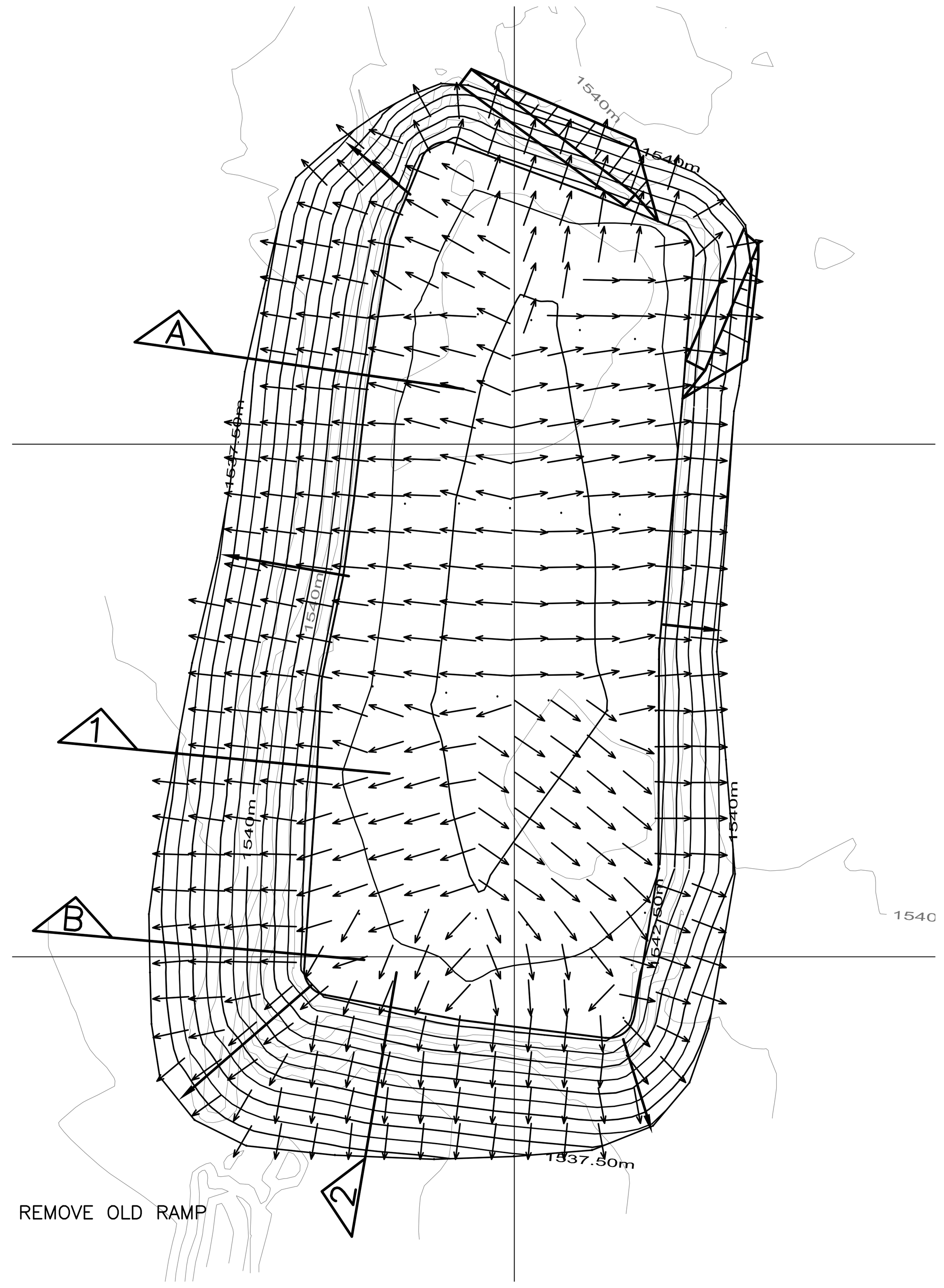
IPC/FM/2013/100/03

Wysigings Revisions: 0 0

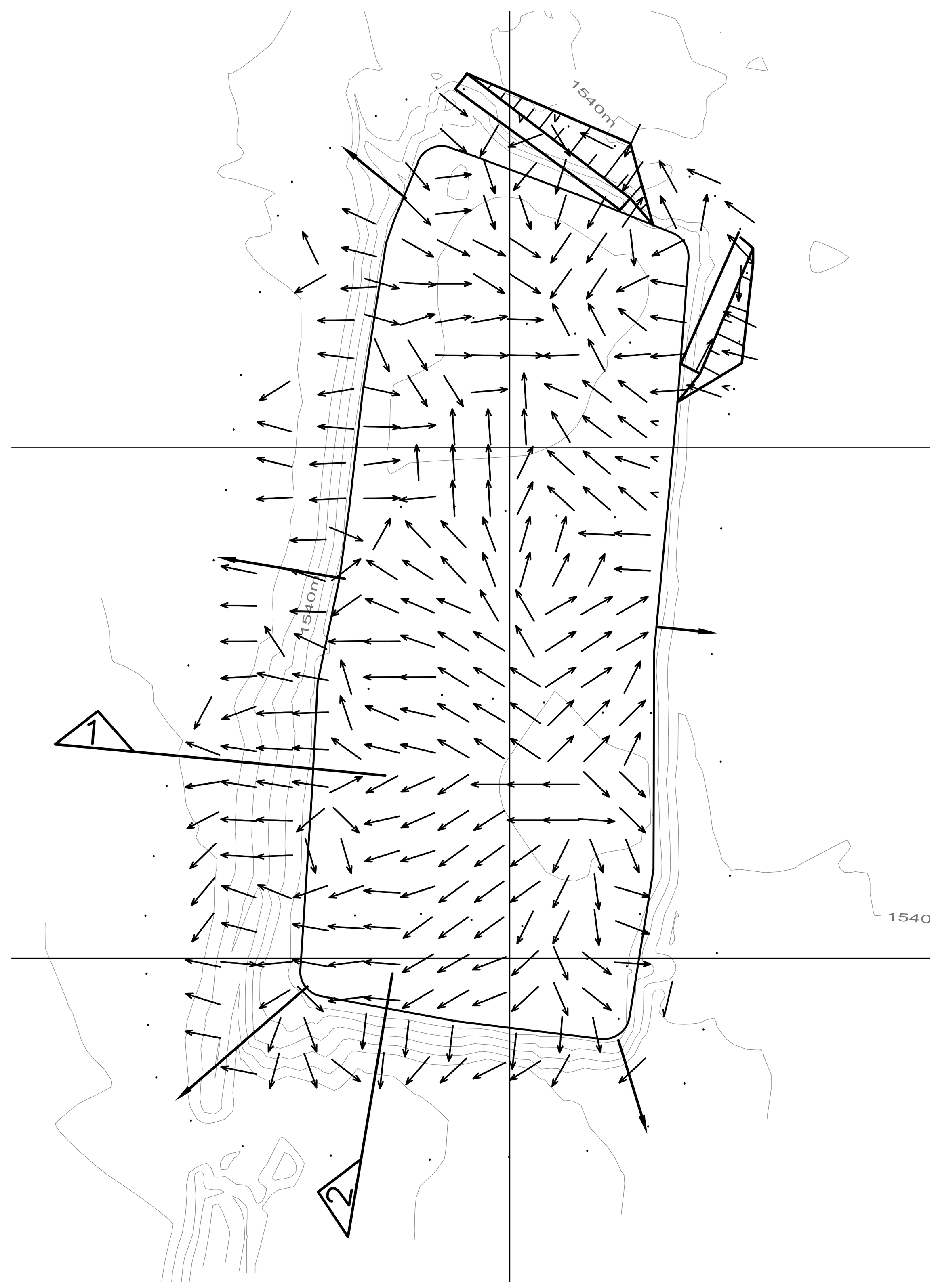
Scale			
As Shown	Designed Ontwerp	P. D. T.	04/2013
	Geteken Drawn	I. P. C.	04/2013
	Nagesien Checked	P. D. T.	04/2013

TOTAL FOOTPRINT OLD DAM AREA (Ha): 1,47
TOTAL FOOTPRINT REHAB DAM AREA (Ha): 2,01
TOTAL OLD DAM VOLUME (m3): 45000
TOTAL REHAB DAM VOLUME (m3): 66900
MAXIMUM EMBANKMENT HEIGHT (m): 5,8

LAYOUT PLAN OF PROPOSED REHABILITATED SURFACE 1: 1000



REHAB PROFILE RUNOFF DRAINAGE 1: 1000



EXISTING RUNOFF DRAINAGE 1: 1000

NOTES:

SERVICES: REMOVE ALL SERVICES INCLUDING PRESSURE PIPE LINE, TELECOMS & ELECTRICAL AND RELOCATE.
DEMOLISH & REMOVE MASONRY AND CONCRETE WORKS OF OLD DECANT INFRASTRUCTURE.

EARTHWORKS:

1. FLATTEN EMBANKMENTS BY IMPORTED FILL.
2. IMPORT SLIMES FROM HISTORICAL STORES DAM AND PLACE IN LAYERS ON CREST.
3. PROFILE CREST TO INDICATED MINIMUM GRADIENTS AND ELEVATIONS.
4. INSTALL CAPPING LAYERS.
5. CAP CREST AND SIDE SLOPES.

DRAINAGE:

1. INSTALL DETECT & COLLECTION TOE DRAINS.
2. INSTALL CREST INTERCEPT DRAINS.
3. INSTALL DRAINAGE CREST LAYER.
4. COLLECTION MANHOLES & DRAIN PIPES.

STATUS: PRELIMINARY

SURVEY CO-ORDINATE SYSTEM : CLARK 1880 LO29 (DEGREES SQUARE 2529)

REFERENCE DRAWINGS

Drawing name / Tekening naam	No. /Nr.

REVISIONS/WYSIGINGS

Wysiging Revision	Beskrywing/Description	Datum Date
		DEC' 12

Client: Klient:

SAMANCOR FERROMETALS (PTY)

INPROCON CONSULTANTS cc
ENVIRONMENTAL & CIVIL CONSULTING ENGINEERS

541 GENL LOUIS BOTHA AVE
CONSTANTIA PARK
PRETORIA
0181
TEL 012 993 2423

Project Name: Projek Naam

REHABILITATION OF HISTORICAL SOUTH SLIMES DAM

Drawing Name: Tekening Naam

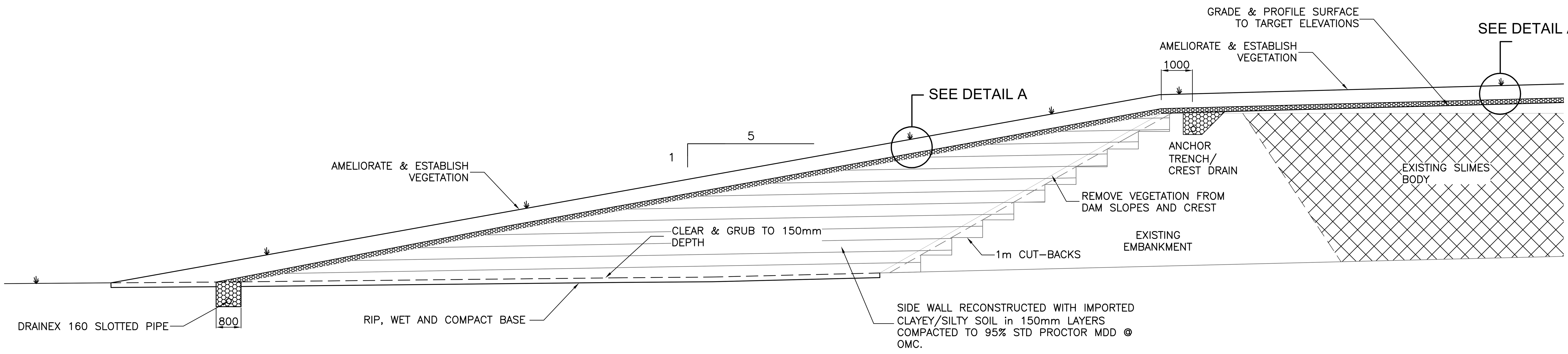
LAYOUT & DAM DRAINAGE

Project No.: Tekening Nr.

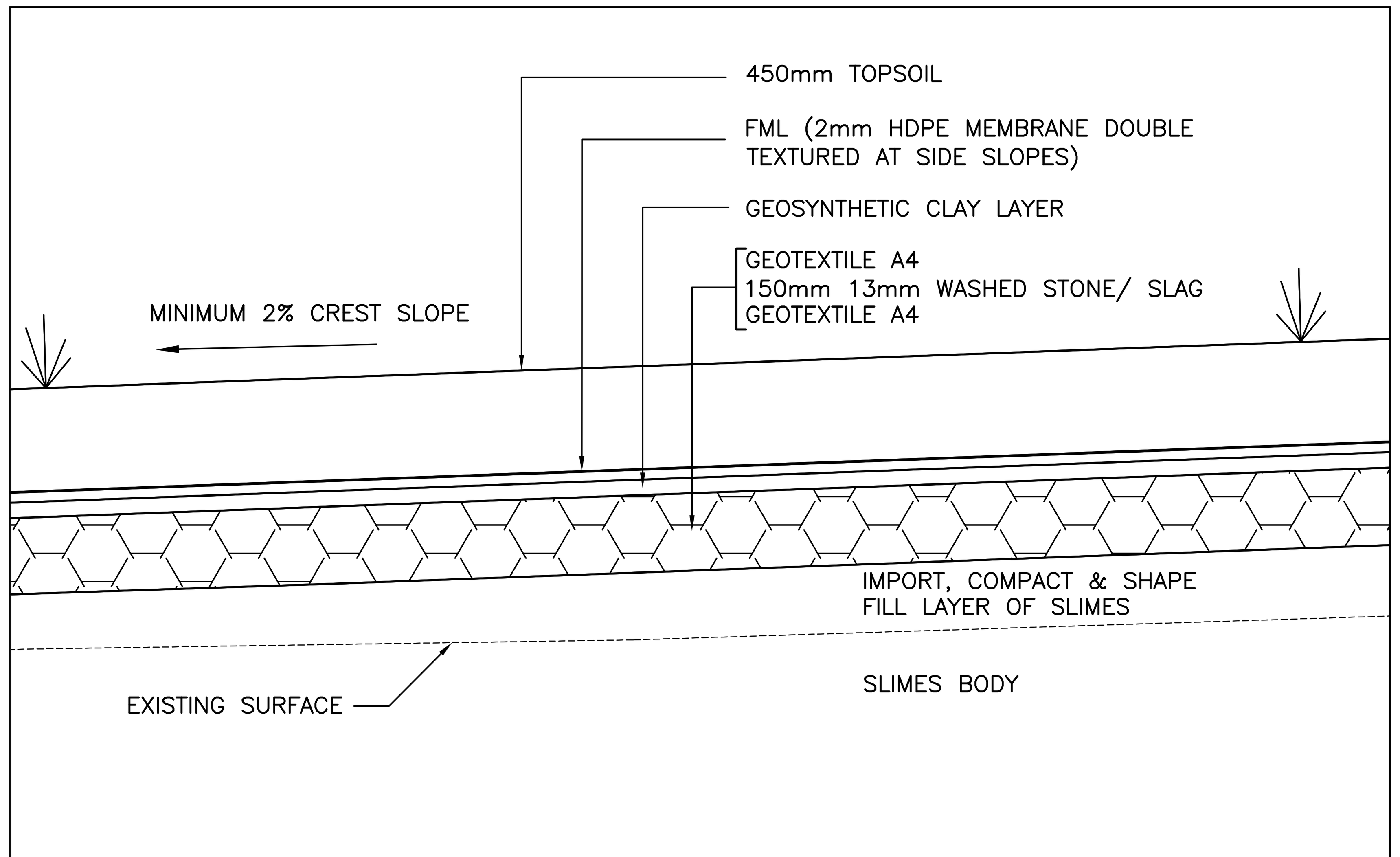
IPC/FM/2013/101/01

Wysigings Revisions: 0 0

Scale			
As Shown	Designed Ontwerp	P. D. T.	04/2013
	Geteken Drawn	I. P. C.	04/2013
	Nagesien Checked	P. D. T.	04/2013



TYPICAL SIDE SLOPE AND CAP DETAILS 1: 25



DETAIL A: CAPPING LAYERS 1: 10

NOTES:

EARTHWORKS:

1. STRIP VEGETATION FROM SIDE SLOPES AND CREST.
2. FLATTEN EMBANKMENTS BY IMPORTED FILL.
3. IMPORT SLIMES FROM STORES HISTORICAL DAM AND PLACE IN LAYERS ON CREST.
4. PROFILE CREST TO INDICATED MINIMUM GRADIENTS AND ELEVATIONS. INSTALL CAPPING LAYERS.
5. CAP CREST AND SIDE SLOPES.

DRAINAGE:

1. INSTALL DETECT & COLLECTION TOE DRAINS.
2. INSTALL CREST INTERCEPT DRAINS.
3. INSTALL DRAINAGE CREST LAYER.
4. COLLECTION MANHOLES & DRAIN PIPES.

STATUS: PRELIMINARY

SURVEY CO-ORDINATE SYSTEM : CLARK 1880 LO29 (DEGREES SQUARE 2529)

REFERENCE DRAWINGS	
Drawing name / Tekening naam	No. /Nr.

REVISIONS/WYSIGINGS		
		DEC'12
Wysiging Revision	Beskrywing/Description	Datum Date

Client: Klient:

SAMANCOR FERROMETALS (PTY)

INPROCON CONSULTANTS cc
ENVIRONMENTAL & CIVIL CONSULTING ENGINEERS

541 GENL LOUIS BOTHA AVE
CONSTANTIA PARK
PRETORIA
0181
TEL 012 993 2423

Project Name: Projek Naam

REHABILITATION OF HISTORICAL SOUTH SLIMES DAM

Drawing Name: Tekening Naam

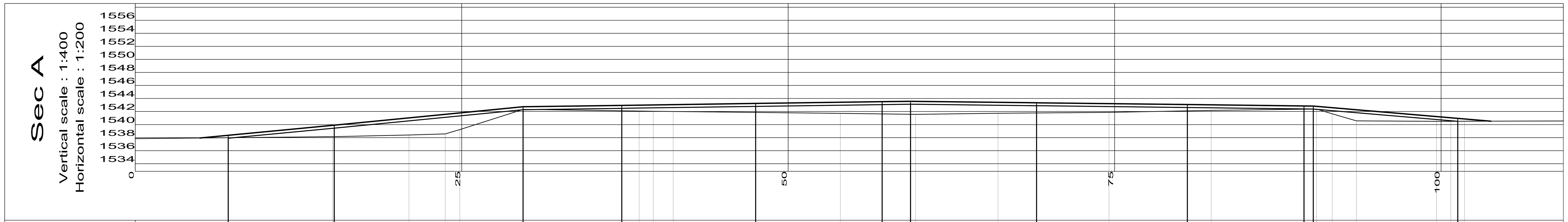
TYPICAL SECTION & CAPPING LAYER DETAILS

Project No.: Tekening Nr.

IPC/FM/2013/101/02

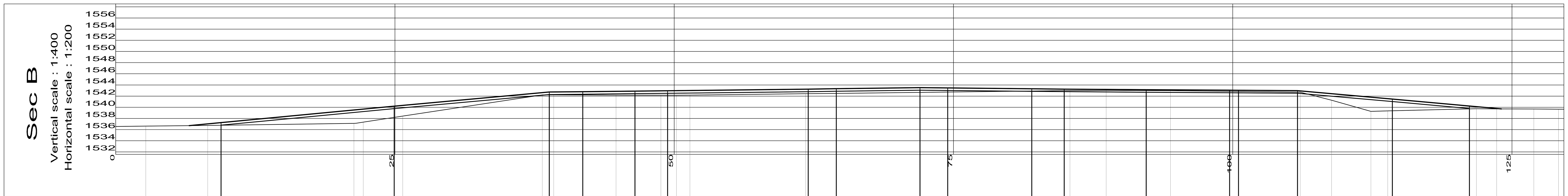
Wysigings Revisions: 0 0

Scale			
As Shown	Designed Ontwerp	P. D. T.	04/2013
	Geteken Drawn	I. P. C.	04/2013
	Nagesien Checked	P. D. T.	04/2013



Distance	Existing Ground Elevation
15.12	1538.15
20.97	1538.40
23.74	1538.56
24.86	1539.23
29.71	1542.33
38.59	1542.08
39.67	1542.05
41.19	1542.01
54.00	1541.71
59.75	1541.56
66.07	1541.74
74.57	1541.88
82.39	1542.18
90.46	1542.39
91.66	1541.66
93.52	1540.57
99.65	1540.49
100.75	1540.50
101.80	1540.51
109.37	1540.54

Distance	Profiled Elevation	Distance	Final Cover Elevation
7.12	1537.90	7.12	1538.35
15.24	1539.46	15.24	1539.91
29.70	1542.28	29.70	1542.73
37.26	1542.49	37.26	1542.94
47.51	1542.79	47.51	1543.24
57.20	1543.06	57.20	1543.51
59.37	1543.12	59.37	1543.57
69.03	1542.89	69.03	1543.34
80.57	1542.62	80.57	1543.07
89.51	1542.40	89.51	1542.85
90.21	1542.39	90.21	1542.84
101.28	1540.50	101.28	1540.95



Distance	Existing Ground Elevation
2.69	1536.62
8.24	1536.74
21.32	1537.12
22.17	1537.33
25.70	1538.43
38.19	1542.22
39.22	1542.24
44.80	1542.18
48.81	1542.16
50.21	1542.16
51.40	1542.17
61.77	1542.44
64.53	1542.48
85.43	1542.99
88.67	1543.02
94.43	1542.98
106.04	1542.70
108.85	1541.26
112.37	1539.27
113.88	1539.36
121.82	1539.74
123.63	1539.71
126.95	1539.69
129.16	1539.65

Distance	Profiled Elevation	Distance	Final Cover Elevation
9.43	1536.80	9.43	1537.25
24.93	1539.76	24.93	1540.21
38.82	1542.29	38.82	1542.74
41.81	1542.34	41.81	1542.79
46.49	1542.45	46.49	1542.90
49.41	1542.51	49.41	1542.96
62.00	1542.79	62.00	1543.24
64.51	1542.88	64.51	1543.33
72.00	1543.06	72.00	1543.51
74.48	1543.01	74.48	1543.46
82.01	1542.86	82.01	1543.31
84.92	1542.81	84.92	1543.26
92.25	1542.70	92.25	1543.15
99.72	1542.60	99.72	1543.05
100.52	1542.60	100.52	1543.05
105.80	1542.52	105.80	1542.97
114.29	1541.02	114.29	1541.47
121.19	1539.77	121.19	1540.22

NOTES:

EARTHWORKS:

1. STRIP VEGETATION FROM SIDE SLOPES AND CREST.
2. FLATTEN EMBANKMENTS BY IMPORTED FILL.
3. IMPORT SLIMES FROM STORES HISTORICAL DAM AND PLACE IN LAYERS ON CREST.
4. PROFILE CREST TO INDICATED MINIMUM GRADIENTS AND ELEVATIONS. INSTALL CAPPING LAYERS.
5. CAP CREST AND SIDE SLOPES.

DRAINAGE:

1. INSTALL DETECT & COLLECTION TOE DRAINS.
2. INSTALL CREST INTERCEPT DRAINS.
3. INSTALL DRAINAGE CREST LAYER.
4. COLLECTION MANHOLES & DRAIN PIPES.

STATUS: CONCEPT

SURVEY CO-ORDINATE SYSTEM : CLARK 1880 LO29 (DEGREES SQUARE 2529)

REFERENCE DRAWINGS	
Drawing name / Tekening naam	No. /Nr.

REVISIONS/WYSIGINGS		
		DEC'12
Wysiging Revision	Beskrywing/Description	Datum Date

Client: Klient:

SAMANCOR FERROMETALS (PTY)

INPROCON CONSULTANTS cc
ENVIRONMENTAL & CIVIL CONSULTING ENGINEERS

541 GENL LOUIS BOTHA AVE
CONSTANTIA PARK
PRETORIA
0181
TEL 012 993 2423

Project Name: Projek Naam:

REHABILITATION OF HISTORICAL SOUTH SLIMES DAM

Drawing Name: Tekening Naam:

TYPICAL PROFILING SECTIONS

Project No.: Tekening Nr.:

IPC/FM/2013/101/03

Wysigings Revisions: 0 0

Scale			
As Shown	Designed Ontwerp	P. D. T.	04/2013
	Geteken Drawn	I. P. C.	04/2013
	Nagesien Checked	P. D. T.	04/2013

DWS Correspondence in terms of The Design Report

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

K. Legge/K Mnisi
Tel: 012 336 8677/8944
Ref: 16/2/7/C231/B18/Y1/1

ACTING CHIEF DIRECTOR: COMPLIANCE MONITORING

For attention Director: Resource Protection and Waste and Ms W Moolman

WASTE LICENCE APPLICATION: ENGINEERING SERVICES COMMENT: FERROMETALS SAMANCOR WITBANK CLOSURE SLIMES DAM AND STORMWATER

1. Presentation

On Thursday 13 November 2014 at 08h00 the project background and detail were presented by JMA Consulting and REDCO under the auspices of Ms W Moolman.

2. Documentation

The following reports, drawings and correspondence were presented for consideration:
a) Samancor Ferrometals Rehabilitation of Historical Slimes Dams Design Report (Concept Designs), includes drawings, having reference IPC/100/01 dated August 2014.
b) Samancor Ferrometals Storm Water Management Plan Detail Designs Technical Report (including drawings) having reference JMA/10427 dated September 2014.
c) Copy of the Power Point presentation by Samancor.
d) Minutes of the meeting e-mailed by JMA Consulting (Pty) Ltd on 14 November 2014.

3. Consideration

The pre application is for the capping closure of 2 existing historic TSFs plus a 3rd partly remediated TSF whose remnants will be transported to the southern TSF for shaping the plateau. Furthermore 5 PCDs are to be considered being numbers 3, 5 and 6 for combinations of process and storm water and 2 and 4 for potentially polluted rain water run-off.

The proposed capping closure for the hazardous historic TSFs comprises a non infiltration composite liner of GM plus GCL, with a capillary break and drainage layer between it and the waste of screened slag protected by an A4 GTon either side, and covered with 450mm soil cap. The side slopes are flattened to 1v:5h for maintainance and erosion resistance.

The polluted water PCDs are double composite liners of 150mm base prep/150mm CCL/2mm GM/A4 GT which may be omitted/cuspated drain/GCL/2mm GM/ballast soil layer which is a marginal amendment of the presented design in which the ballast was above the upper GCL.

The potentially polluted water PCDs 2 and 4 are a single composite liner of 1,5mm GM over a base preparation with GT protection of the GM from foundation protrusions at the discretion of the CQA Engineer. These two facilities provide containment although not equal to Class C but are not required to be.

4. Recommendation

It is recommended that the design is accepted with allowable amendment.

Keith Mnisi
Candidate Scientist: Engineering Geology
Date: 24/11/2014

CHIEF DIRECTOR: ENGINEERING SERVICES
Letter signed by KR Legge
Chief Engineer: Integrated Environmental Engineering
Date 2014/11/24

Attachment: List of Acronyms

DWA ENGINEERING SERVICES REVIEW OF LICENCE APPLICATIONS
Date: 13 November 2014
Time: 08h00

Subject (Project): Ferrometals Witbank Closure
Name of Company:

Name	Company	Telephone	E-mail	Signature
Kelvin Legge	DWA/ES	012 336 8677	leggek@dwa.gov.za	
Claire Fricker	DWA/ES	012 336 6656	frickerc@dwa.gov.za	
Keith Mnisi	DWA/ES	012 336 8944	mnisikk@dwa.gov.za	
Tumi Seake	DWA/ES	012 336 7061	seakeb@dwa.gov.za	
Michelle Parker	DWA/ES	012 336 8252	parkerm@dwa.gov.za	
Wilna Moolman	DWA: RP&W	012 336 7557	Moolman@dwa.gov.za	
Ricen Grobbelaar	JMA	013 6651788	rican@jmaconsult.co.za	
Pierre du Toit	Improcon	012 993 2423	pierre@improcon.co.za	
Prenisha Chetty	Samancor Chrome Ferrometals	013 693 7438	prenisha.chetty@samancorcr.com	
DP v.d. Merwe	REDCO	082 903 1428	dp@redcoservices.co.za	

APPENDIX E

Proof of Submission and delivery of Draft Basic Assessment Report to all State Departments and Organs of State involved in this project

To be included in Final Basic Assessment Report

APPENDIX F

Issues (Comments) and Response Register

To be included in Final Basic Assessment Report

APPENDIX G

Ferrometals Draft Basic Assessment Report (BAR) and

Draft EMP