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BEESHOEK IRON ORE MINE

REPORT ON

CONCEPTUAL DESIGN FOR FINE RESIDUE STORAGE FACILITY

Submitted to:

Beeshoek Mine

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Signed:

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EXECUTIVE SUMMARY

Geo Tail CC was appointed by Beeshoek Mine to carry out the necessary activities and tasks, in accordance with the specified requirements and scope of work, to present a conceptual design for the new fine residue storage facility (FRSF) at Beeshoek Mine.

The purpose of this report is to document the conceptual design in order to utilise it as a baseline reference in the life cycle management of the storage facility.

Design Criteria

The FRSF will accommodate slurry at a deposition rate of approximately 348,000 m^3 per month. The average slurry density is expected to be approximately 1.24.

Design Concept

Impoundment embankments (along the north and west flanks) and existing waste rock dumps (along the south and east flanks) will provide storage capacity for fine residue disposal. Waste material (overburden) from the open pit mining operation will be utilised for embankment construction and the material will be placed mechanically (in horizontal layers) with the mining fleet. The impoundment embankments will be compacted to a nominal specification. The impoundment embankment will have a maximum vertical height of approximately 20 m along the north flank. The vertical height of the impoundment embankment along the west flank is generally less than approximately 5 m.

The slurry delivery pipeline will be placed on the impoundment embankment crest. Fine residue will be discharged at a concentration of approximately 25% solids by mass through open end delivery stations from the impoundment embankments to form a beach that slopes downwards away from the embankments. This will create a top surface geometry that will result in a supernatant pool that is maintained in the immediate vicinity of the decant barge. Steep beach angles are expected at the head of the beach due to segregation and the high specific gravity of the residue. The beach angles will then reduce towards the pool area where the ultra fine residue will accumulate. The performance of the coarse material at the head of the beach (after segregation) is expected to be superior from a drainage, consolidation and strength point of view than is the finer material in the pool area.

Initially, the floating barge will decant from an old quarry located in the northeast corner of the basin. If necessary, the pool will be relocated or the embankment will be lined/sealed in future in order to control the phreatic level in the impoundment embankment adjacent to the pool.

Classification

The classification process concluded that:

- The overall safety hazard rating for the FRSF is "LOW".
- The FRSF has "no potentially significant" impact on the environment.

Planning

The capacity analysis concluded that based on a deposition rate of 110,600 tpm and a place dry density of 2.25 t/m^3:

- At full supply level (1355 mamsl), the total airspace volume is approximately 7.4 million m^3 or 16.7 million tons.
- The final top surface area of the basin is approximately 60 ha.
- The final rate of rise will be approximately 1.0 m/a.
- The design life will be approximately 12.6 years.

The water management plan concluded that:

- A decant rate of 600 m^3/h is required to decant normal operation water and storm water within acceptable periods from the basin of the FRSF.
- The water balance indicates an annual loss of approximately 1.6 million m^3 operation water at the FRSF.
- No spillage is expected from the supernatant pool during the operation phase of the FRSF.

Structural Stability

The stability analysis results indicate that the factor of safety for overall stability will be satisfactory under normal operating conditions. However it assumes that the management of the facility will be adequate and the need to monitor the identified critical parameters are essential.

Closure

The closure plan for the FRSF will be developed during the life of the facility. The principles of the closure plan and the progressive rehabilitation plan is presented in the report.

Recommendations

The report recommends that:

- The deposition plan should be revised on an annual basis during the operation phase of the facility

- A laboratory and field test program should be implemented to assess the geotechnical and geochemical characteristics of the fine residue material and to modify operating procedures, if required.
- The FRSF water balance must be calibrated during the operation phase. In addition, the FRSF water management plan should be integrated into the overall mine water balance.
- A detailed closure plan should be developed during the life of the FRSF.
- A site specific code of practice should be prepared for the FRSF.
- A risk monitoring, surveillance and audit system (including boreholes for environmental monitoring) should be implemented for the life cycle of the FRSF. The critical parameters should be monitored and analysed on a routine basis.

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1.1 General

Geo Tail CC was appointed by Beeshoek Mine to carry out the necessary activities and tasks, in accordance with the specified requirements and scope of work, to present a conceptual design for the new fine residue storage facility (FRSF) at Beeshoek Mine.

The purpose of this report is to document the conceptual design in order to utilise it as a baseline reference in the life cycle management of the storage facility.

1.2 Scope of Work

The scope of work can be summarised as follows:

- Document the design criteria for the project.
- Prepare a safety and environmental classification for the facility.
- Document the design concept.
- Prepare a capacity analysis.
- Prepare a water management plan.
- Undertake a structural stability analysis.
- Undertake conceptual designs for the specific design components.
- Document the closure considerations.
- List the critical parameters to be monitored during the life cycle of the facility.
- Document a conceptual design report, including general layout drawings and typical sections.

1.3 Exclusions

The following work was specifically excluded from the scope of work or will be done by others:

- Client will supply the required survey information in digital format.
- Preparation of legal documents, permits and environmental baselines.
- Hydrogeological investigations, including geochemical modelling.
- Geotechnical investigations.
- Meetings with public or legislative bodies and the preparation or submission of permit applications.

- The electrical and mechanical designs for the slurry pumping system.
- The electrical and mechanical designs for the decant and return water pumping systems.
- Preparation of capital, operating and closure cost estimates.

1.4 Available Information

Prior to the investigation, the following information was available:

Table 1: Available Information

Report no.	Author	Title	Date
5540/6275/4/E	Golder	Beeshoek Iron Ore Mine Environmental Management Programme Report Revision 1	August 2004

2 DESIGN CRITERIA

The design criteria can be summarised as follows:

Table 2: Design Criteria

Item	Criteria	Unit	Design Value	Source
1	Material	type	Iron ore fine residue	Client
2	Process plant utilization (average)	h/mnth	639	Client
3	Deposition rate - average (slurry)	m^3/mnth	347,624	Client
4	Slurry density - average	ratio	1.24	Client
5	Slurry water - average	m^3/mnth	320,656	Client
6	Water : Solids	ratio	2.90	Client
7	Deposition rate - average (dry tons)	ktpm	110,571	Client
8	Particle size distribution (cut size)	µm	< 1,000	Client
9	Specific Gravity	ratio	4.1	Client

Item	Criteria	Unit	Design Value	Source
10	Design storm (1 in 50 year, 24 hour storm)	mm	107	EMPR
11	Climatic data	mm	MAP = 338 MAE = 2,450	EMPR
12	Discharge condition	Comply with Regulation 704 of the National Water Act, 1998. This implies a minimum 50-year spillage frequency, or one spill event every 50 years on average.		Legal requirement
13	Design freeboard	Design storm plus 0.8 m dry freeboard on top of the normal operating level (excluding return).		Legal requirement
14	Topsoil	During stripping operations, topsoil will be separated from trees and brush and stockpiled separately in designated areas for future rehabilitation purposes.		EMPR

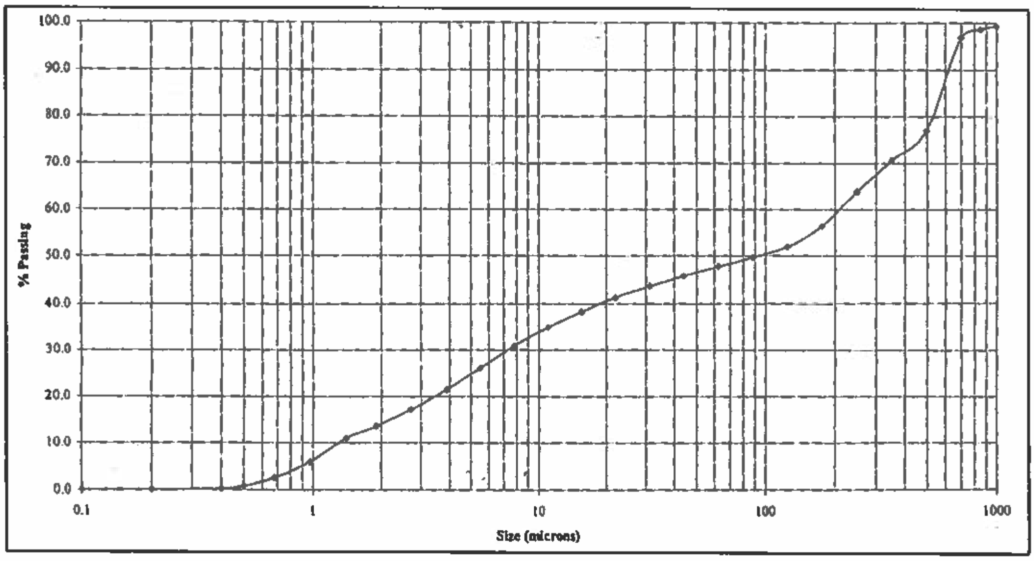
3 SPECIALISED STUDIES

No additional geotechnical or geohydrological investigations were undertaken as part of the conceptual design phase.

4 RESIDUE CHARACTERIZATION

A typical grading curve for the fine residue is presented below:

Figure 1: Typical Grading Curve



5 DESIGN OBJECTIVES

The design objectives are listed below:

- Create a safe and stable structure and minimize risk to human lives, health and property.
- Minimum storage of supernatant on the FRSF.
- The design will be such that it will remain fit for the intended purpose and resist all external environmental influences that are reasonably likely to occur (sustainability).
- Optimal airspace utilisation.
- Comply with the relevant legal requirements.
- Minimize environmental impacts, where potentially possible.
- Maximum water return to the process plant.
- Separation of clean and dirty water.
- Cost effective construction, operation and closure.
- The facility will not be situated such that it sterilises any ore or be in conflict with any mining activity.
- The facility will be located on mine property.

6 DESIGN CONCEPT

The general arrangement and typical sections are included in **Appendix A**. Photographs of typical design components are included in **Appendix D**.

Impoundment embankments (along the north and west flanks) and existing waste rock dumps (along the south and east flanks) will provide storage capacity for fine residue disposal. Waste material (overburden) from the open pit mining operation will be utilised for embankment construction and the material will be placed mechanically (in horizontal layers) with the mining fleet. The impoundment embankments will be compacted to a nominal specification. The impoundment embankment will have a maximum vertical height of approximately 20 m along the north flank. The vertical height of the impoundment embankment along the west flank is generally less than approximately 5 m.

The slurry delivery pipeline will be placed on the impoundment embankment crest. Fine residue will be discharged at a concentration of approximately 25% solids by mass through open end delivery stations from the impoundment embankments to form a beach that slopes downwards away from the embankments. This will create a top surface geometry that will result in a supernatant pool that is maintained in the immediate vicinity of the decant barge. Steep beach angles are expected at the head of the beach due to segregation and the high specific gravity of the residue. The beach angles will then reduce towards the pool area where the ultra fine residue will accumulate. The performance of the coarse material at the head of the beach (after segregation) is expected to be superior from a drainage, consolidation and strength point of view than is the finer material in the pool area.

The consolidation of the fine residue is important in enhancing the structural stability of the facility. It also ensures the best utilisation of the volume capacity by increasing the stored tonnes of fine residue per cubic metre. The expected low permeability of the residue (especially within the pool area) implies that there will be virtually no drainage of entrained water by normal consolidation processes during the life of the facility. The effective operation of the storage facility therefore depends on the consolidation of the residue by drying, which is a very efficient method. All sub-aerial storage facilities utilise the benefit of drying to a lesser or greater extent, and the climate at Beeshoek Mine is conducive to this process. The drying consolidation of the residue can be inhibited by several factors:

- A large supernatant pool.
- Concentrated deposition in one area.
- Low slurry densities.
- High rainfall periods.
- High rates of rise.

It is considered that these problems can be overcome by good operation management practice. The most difficult periods will be during the initial stages, when the rate of rise is high, and during the high rainfall months. It is during these periods that good distribution procedures must be most rigidly adhered to. An optimised tipping cycle will be implemented in order to optimise the drying time. A complete cycle will be achieved when the relevant deposition area has been covered to a slurry depth of approximately 200 mm. At this stage it is assumed that a minimum drying period of 14 days will be required before the next layer is placed. Strict operational control will be required to prevent inconsistent layer development. Layering will reduce the vertical permeability and as a result elevated phreatic surfaces can develop towards the perimeter with a consequent decrease in structural stability and inefficient seepage control. Realistically, it is probable that there will be adequate consolidation at the head of the beach, but that there will be wet zones near the supernatant pool and more significantly in the layers deposited initially near the perimeter.

Supernatant on the top surface will accumulate in a pool at the decant barge, as a result of floor beaching and deposition control. This supernatant, predominantly derived from the process but also from rainfall, will be decanted from the top surface because retained water could:

- Reduce the freeboard and the storm water capacity and so increase the potential for overtopping.
- Increase the potential for slurry flows in the event of a breach.
- Increase the hydraulic gradient of seepage and pore water pressures which could lead to lower factors of safety.

- Inhibit consolidation and so reduce the strength and storage capacity of the facility.
- Increase water losses through evaporation and seepage and so increase the environmental impacts on water consumption and groundwater.

Initially, the floating barge will decant from an old quarry located in the northeast corner of the basin. If necessary, the pool will be relocated or the embankment will be lined/sealed in future in order to control the phreatic level in the impoundment embankment adjacent to the pool.

7 CLASSIFICATION

7.1 Introduction

The dual safety and environmental classification provides the basis for the implementation of differentiated safety and environmental management practices for specified stages of the life cycle of a residue storage facility. The practices prescribed for planning, design, operation and decommissioning may be differentiated on the basis of the safety or environmental classification for each specific storage facility. It therefore allows for the development of a management system that is tailored to suit the needs of the particular facility, rather than imposing a system on all facilities that, of necessity, must cater for the most severe hazards and risks.

7.2 Safety Classification

Great importance is attached to the qualitative safety classification associated with a particular facility. This classification defines the potential consequences of a failure of the storage facility. The results of the safety classification affects the design, operation and monitoring of the facility. It is important to note that a storage facility that may be classified as having a "high" hazard rating may not have an associated "high" risk. The risks (or the likelihood of adverse impacts – that is, probability of occurrence × consequence of occurrence) can be reduced and minimised through the implementation of risk management techniques.

The Code of Practice for Mine Residue (SABS 0286:1998) calls for a safety classification to differentiate between residue deposits of high, medium and low hazard rating on the basis of their potential to cause harm to life or property within the zone of influence. The classification should be based on the anticipated configuration of the storage facility at the end of its design life, and on satisfying any one of the conditions set out in the table below.

Table 3: SABS 0286:1998 Safety Classification

Number of residents in zone of influence	Number of workers in zone of influence[1)]	Value of third party property in zone of influence[2)]	Depth to under-ground mine workings[3)]	Classification
0	<10	0-R2 m	>200 m	Low hazard
1-10	11-100	R2 m – R20 m	50 m – 200m	Medium hazard
>10	>100	>R20 m	<50 m	High hazard

1) Not including workers employed solely for the purposes of operating the deposit.
2) The value of third party property should be the replacement value in 1996 terms
3) The potential for collapse of the residue deposit into the underground workings affectively extends the zone of influence to below ground level.

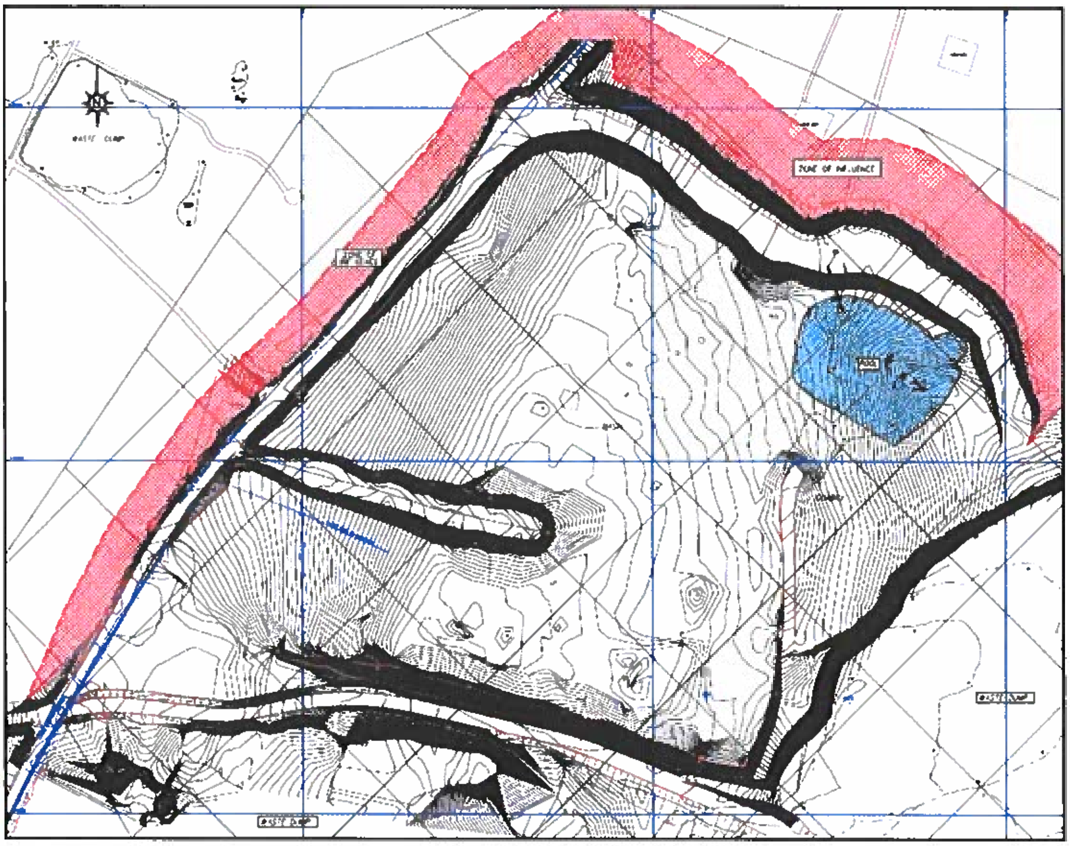
The rating, based on the zone of influence (see **Figure 1** below), can be summarised as follows:

Table 4: Hazard Rating Results

Item	Condition	Zone of Influence - Comments	Hazard Rating
1	Number of residents in zone of influence	None	Low
2	Number of workers in zone of influence	< 10	Low
3	Value of third party property in zone of influence	0	Low
4	Depth to under-ground mine workings	No underground mining within zone of influence.	Low

The above table indicates that an overall "LOW" hazard rating should be assumed for the FRSF.

Figure 2: Zone of Influence



7.3 Environmental Classification

All storage facilities (as a minimum) should be classified into one of the following two environmental categories:

- Storage facilities that have a potentially significant impact on the environment; or
- Storage facilities that have no potentially significant impact on the environment.

The table below has been used as the basis for a preliminary environmental classification of the FRSF.

Table 5: Environmental Classification

Aspect under consideration		Environmental classification		
		Significant	**Possibly significant**	**Not significant**
1	Surface and Groundwater	Deposit has potential to contaminate water that may be consumed by humans (chronic / acute).	Deposit has potential to contaminate water that may be consumed by flora or fauna.	No contamination of water supplies likely.
2	Land	Deposit has potential to permanently render surrounding land unsuitable for its pre-existing potential.	Release of residue from deposit could have a long-term detrimental effect on land.	Release of residue from deposit can be completely remediated.
3	Air	Deposit has potential to degrade air quality to a level that is detrimental to human health (chronic / acute).	Deposit has potential to elevate dust nuisance (only) to an unacceptable level.	Deposit has negligible potential to adversely affect air quality.

The above table indicates that the FRSF has no potentially significant impact on the environment. It is however recommended that operating and monitoring procedures should be implemented to ensure acceptable seepage, runoff and air quality management and control.

8 CAPACITY ANALYSIS

The slurry will be pumped through a 255 mm OD HDPE pipe from the large diameter thickener to the FRSF. The slurry will be distributed through a series of open end delivery stations into the basin of the facility. Initially, deposition will be focussed in the southwest quadrant of the facility. In future, additional delivery stations will be implemented for deposition control.

The estimated average placed dry density (assuming consolidation) can be summarised as follows:

Table 6: Average Dry Density

Moisture content (w) (%)	Specific Gravity (SG) ratio	Void Ratio (e) (w/100*SG)	Dry Density $(\gamma_w*SG)/(1+e)$ t/m^3
20	4.10	0.82	2.25

The storage facility was three-dimensionally modelled for an accurate determination of the relationship between the height, area and capacity. The detail was processed to calculate the rates of rise for average production rates and eventually the design life. The capacity analysis results for the basin are presented graphically below (see **Appendix B** for details).

Figure 3: Capacity & Area vs. Elevation

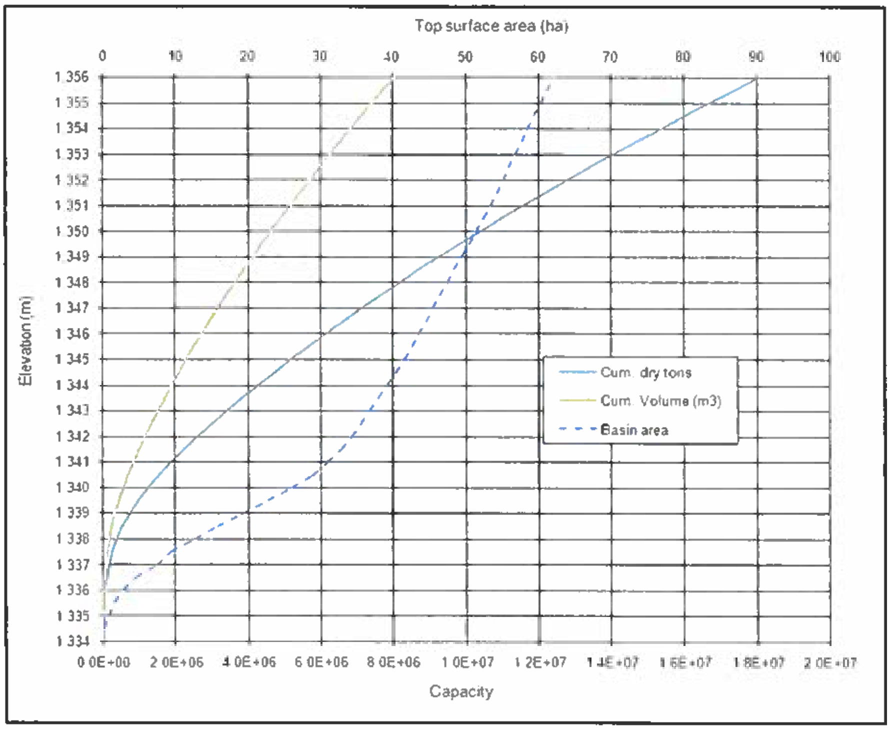
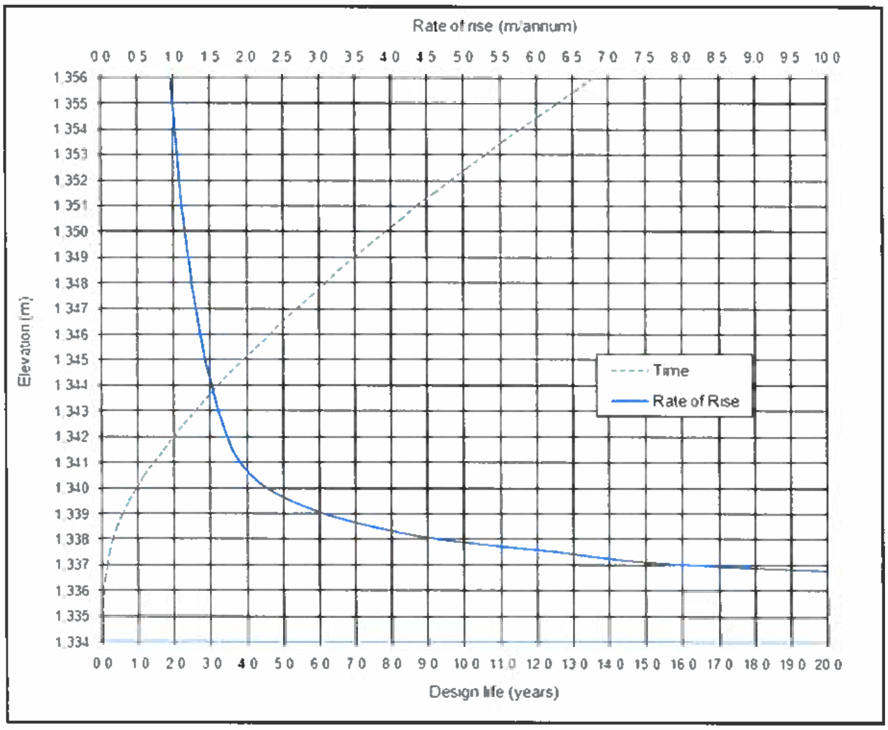


Figure 4: Design Life & Rate of Rise vs. Elevation



In view of the above, it is concluded that based on a deposition rate of 110,600 tpm and a place dry density of 2.25 t/m^3:

- At full supply level (1355 mamsl), the total airspace volume is approximately 7.4 million m^3 or 16.7 million tons.
- The final top surface area of the basin is approximately 60 ha.
- The final rate of rise will be approximately 1.0 m/a.
- The design life will be approximately 12.6 years.

9 WATER MANAGEMENT PLAN

9.1 Introduction

The purpose of the control of water is to:

- Minimise usage,
- Encourage drying and consolidation of the fine residue, and
- Separate clean runoff from potentially contaminated process water.

The principles of the management of water are to:

- Divert clean storm water runoff away from the FRSF,
- Minimise the storage of water on the FRSF, and
- Contain and re-use the water emanating from the FRSF.

9.2 Clean Water Diversion

It is a legal requirement that all clean water runoff arising from an external catchment be prevented from flowing onto the FRSF and consequently becoming contaminated. The only external catchment is the broad valley area upstream of the FRSF. The runoff from this catchment will therefore accumulate against the north impoundment embankment from where it will evaporate or infiltrate into the foundation.

9.3 Runoff Control

Storm water runoff from the impoundment embankment outer slopes will contain some eroded solids. In order to prevent silt and runoff from discharging into the surrounding environment, the side slopes will be dosed down to 1v:3h then covered with approximately 150 mm topsoil and then grassed.

9.4 Seepage Control

No under drainage system is required for structural stability purposes due to the high permeability associated with the foundation material.

9.5 Freeboard

In order to ensure that the freeboard requirement is met and that excess water is not stored on top of the FRSF for any protracted period, supernatant will be pumped from the supernatant pool through a floating barge pump system to the clarify dam, located adjacent to the large diameter thickener at the process plant, for re-use in the process.

It is therefore recommended that decant return from the FRSF should be maximized at all times in order to ensure minimum storage of supernatant on the FRSF. Excess water will therefore only be temporarily stored on the FRSF during high rainfall periods.

9.6 Decant Control

Supernatant on the FRSF compartments will accumulate in a pool at the decant barge, as a result of floor beaching and deposition control. This supernatant (rainfall and supernatant release from the slurry) will be decanted from the top surface of the FRSF to achieve:

- Maximized water return to the plant for re-use in the process.
- Prevention of accumulation and subsequent overtopping (freeboard).
- Drying consolidation of the slurry.
- Reduced infiltration (seepage).
- Prevention of potential rises in the phreatic surface and eventually instability.
- Reduced evaporation losses.

The floating barge will be equipped with a Warman BNP 75 pump. The decant water will be pumped through a 210 mm OD HDPE and 150 mm NB mild steel pipeline to the clarify dam located adjacent to the large diameter thickener at the process plant.

9.7 Water Storage

The clarify dam will be utilised as a temporary water storage facility for return draft from the FRSF to the process plant. No allowance has been made for an additional return water dam and/or storm water dam. The day to day water management is therefore very important at the FRSF.

9.8 Water Balance

A water balance approach was adopted to model the performance of the FRSF under the envisaged normal operation and storm conditions (see **Appendix C** for details). The input parameters and assumptions can be summarised as follows:

- Climatic data:
  - Rainfall - based on historic average rainfall data.
  - Evaporation - based on historic average evaporation data.
- Inflows:
  - Runoff factors are assigned to the beach, pool and external catchment in order to calculate the total inflow from precipitation.
  - The slurry is pumped to the facility, under nominal flow conditions, at a concentration of approximately 25% solids by mass.
- Outflows:
  - Evaporation is computed for a portion of the beach (wet) and the pool surface.
  - Interstitial storage is based on a placed dry density of 1.0 t/m^3.
  - Seepage return is based on the average pool area and an assumed fine residue permeability of 1×10^{-8} m/s.
  - Decant from the pool is computed by assuming that the pool will be operated to remain as small as possible and that storm water will be decanted within acceptable time periods.

The water balance results for normal operation and storm conditions can be summarised as follows:

Table 7: Water Balance Results

Item	Description	Unit	Value
1	Slurry water to FRSF	m^3/annum	3,85 million
2	Decant return	m^3/annum	2,25 million
3	Deficit	m^3/annum	1,60 million
4	Decant rate	m^3/h	600
5	Decant period - normal conditions	hrs/day	9 to 12
6	Decant period - storm conditions	days	5

The above table indicates that no spillage is expected from the supernatant pool during the operation phase of the FRSF.

10 STABILITY ANALYSIS

The stability of the critical final side slope has been assessed using non-circular potential failure surfaces (Bishop simplified method) in the limit equilibrium program SLIDE. This program allows for the analysis of numerous potential failure surfaces, and the identification of the critical surface with the lowest factor of safety against failure.

For the purpose of the stability analysis, a pore pressure parameter r_u has been used to represent the phreatic conditions (where r_u = [pore pressure at a point] / [weight of overburden at that point]). No excess water pressures have been assumed for any of the materials and it is assumed that the project area is in a region of low seismicity.

The shear strength parameters assumed for the stability analysis is summarised in **Table 8** below. The values are based on experience with similar materials. It is recommended that representative samples should be tested during the operation phase.

Table 8: Material Strength Parameters

Material no.	Material Type	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction Angle (degrees)	r_u
1	Upper Foundation	16	0	30	0.1
2	Impoundment embankment	26	0	38	0
3	Fine residue	22	0	30	0.3
4	Lower foundation	18	0	35	0

The factors of safety for overall stability, at the critical section, can be summarised as follows (see **Figures 5 and 6** below):

Table 9: Slope Stability Results

Condition	Factor of Safety for Overall Stability (Bishop Simplified Method)
After construction – angle of repose	1.41
Closure – flattened to 1v:3h	2.20

Figure 5: Slope Stability Analysis – After Construction

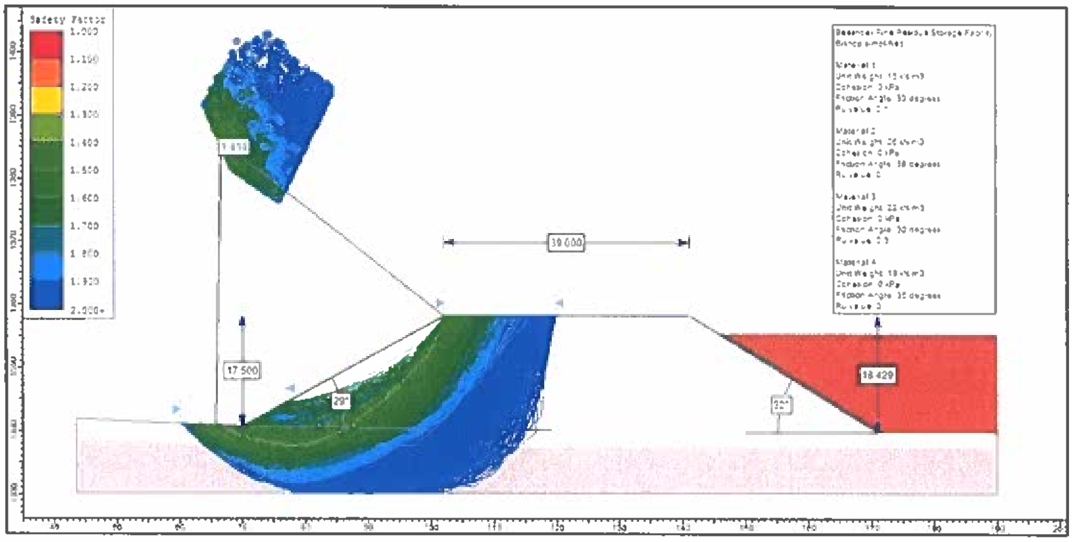
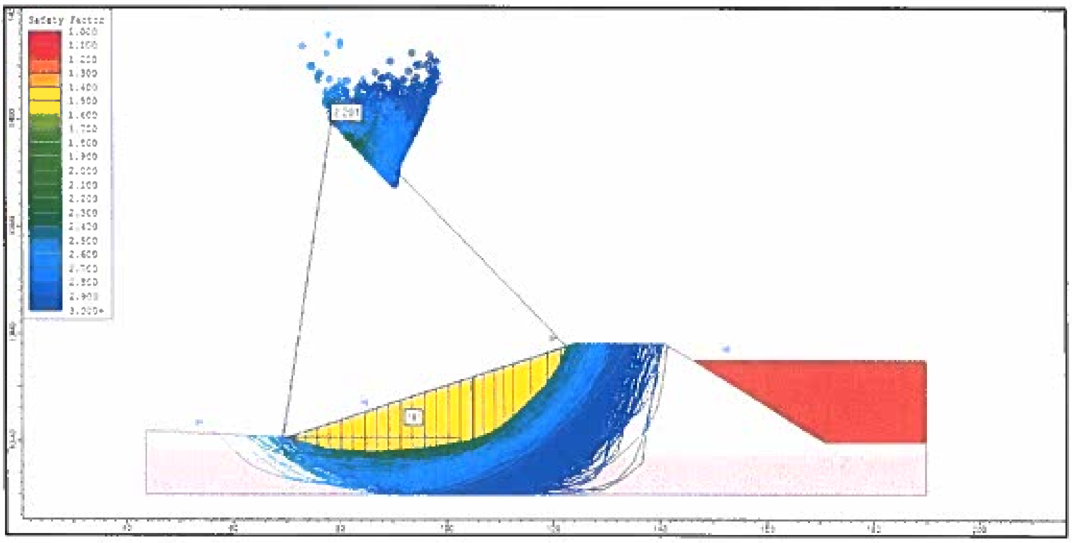


Figure 6: Slope Stability Analysis – Closure



The stability analysis results indicate that the factors of safety for overall stability will be satisfactory under normal operating conditions. However it assumes that the management of the facility will be adequate and the need to monitor phreatic conditions, settlement and slope angles at the outer slopes are critical.

11 CLOSURE

11.1 Introduction

The minimum objectives for the closure and rehabilitation of the FRSF must be to prevent air and water pollution in accordance with the requirements of the relevant regulations and with good international practice. The intended end-use should take into consideration the prior land-use and the location with respect to current and potential future socio-economic development.

The closure plan for the FRSF will be developed during the life of the facility. The purpose of preparing a closure plan is to ensure that the FRSF design, construction and operation procedures are compatible with the achievement of final closure and rehabilitation to acceptable environmental standards and at a reasonable cost. It is anticipated that the closure plan will be updated periodically before the preparation of the final closure plan. The closure plan will be prepared in accordance with "best practice" and the requirements of the environment.

11.2 Closure Considerations

In view of the above, the principles of the FRSF closure plan and the progressive rehabilitation plan can be summarised as follows:

- The fine residue is expected to have a low permeability, especially in the final pool area, with the result that seepage from rain water infiltration will be very limited.
- The required final top surface geometry will be achieved during the operation phase. The top surfaces will either be divided into smaller compartments and/or the water will be allowed to drain in a controlled fashion to the historical pool area.
- The top surface will be rehabilitated with a composite cover of waste rock, topsoil and vegetation. The purpose of the cover is to stabilise the surface (erosion and dust generation) and to minimize the infiltration of water and oxygen.
- An emergency spillway, for draining of the top surface of the FRSF, will be included in the final closure design.
- The outer slopes of the FRSF will be shaped to 1v:3h and progressively rehabilitated with topsoil and natural vegetation.
- Generally all surface structures (i.e. pumps, pipelines, power lines etc) will be removed.

11.3 Aftercare and Monitoring

The following should be provided for in terms of aftercare, maintenance and monitoring:

- Annual inspections by an appropriately experienced person to identify aftercare requirements.
- Repair of major erosion gullies that arise as a result of extreme rainfall events.

- Repair of top soil cover and re-vegetation of damaged areas.
- Continued monitoring of the landscape function indicators to prove progression towards a sustainable self supporting landscape.
- Repair of drainage structures, if and when required.
- General maintenance of the benches and the top surfaces.

12 CRITICAL PARAMETERS

A system of management and monitoring of critical parameters will ensure that the facility is operated safely and efficiently, in accordance with good environmental practice and in a manner compatible with the final closure requirements. Some of the critical parameters to be monitored are listed below:

- Technical (i.e. settlements, phreatic levels, climatic data, side slope geometry, available storage capacity etc.).
- Geotechnical properties of the residue material (i.e. SG, particle size distributions, maximum dry density, optimum moisture content, shear strength, permeability etc.).
- Operational (i.e. run-off volumes, freeboard, in-situ moisture contents, in-situ densities etc.).
- Environmental (i.e. surface and ground water quality, ground water table, environmental properties of residue etc.).

In addition, ongoing maintenance and repairs will be required for all the design components to ensure that the design intent is met at all times.

13 RECOMMENDATIONS

In view of the above, it is recommended that:

- The deposition plan should be revised on an annual basis during the operation phase of the facility
- A laboratory and field test program should be implemented to assess the geotechnical and geochemical characteristics of the fine residue material and to modify operating procedures, if required.
- The FRSF water balance must be calibrated during the operation phase. In addition, the FRSF water management plan should be integrated into the overall mine water balance.
- A detailed closure plan should be developed during the life of the FRSF.
- A site specific code of practice should be prepared for the FRSF.
- A risk monitoring, surveillance and audit system (including boreholes for environmental monitoring) should be implemented for the life cycle of the FRSF. The critical parameters should be monitored and analysed on a routine basis.

14 REFERENCES

1. ISO 14000 series. Code of Practice. Environmental management systems – Specifications. SABS. October 1996.

2. South African Standards: Code of Practice, Mine Residue, SABS 0286: 1998

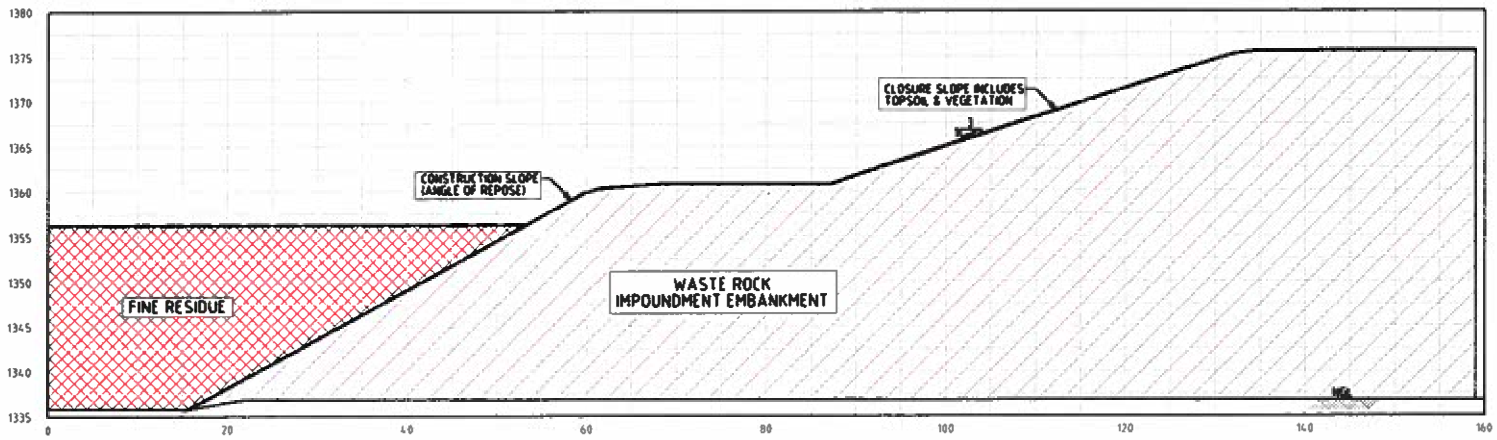
3. Guidelines for Environmental Protection, Volume 1/1979 (Revised 1983 and 1995): The Engineering Design, Operation and Closure of Metalliferous, Diamond and Coal Residue Deposits, Chamber of Mines of South Africa, March 1996, and any Addenda published subsequently.

4. Guidelines on the Safe Design and Operating Standards for Tailings Storage - Department of Minerals and Energy (DME) Western Australia

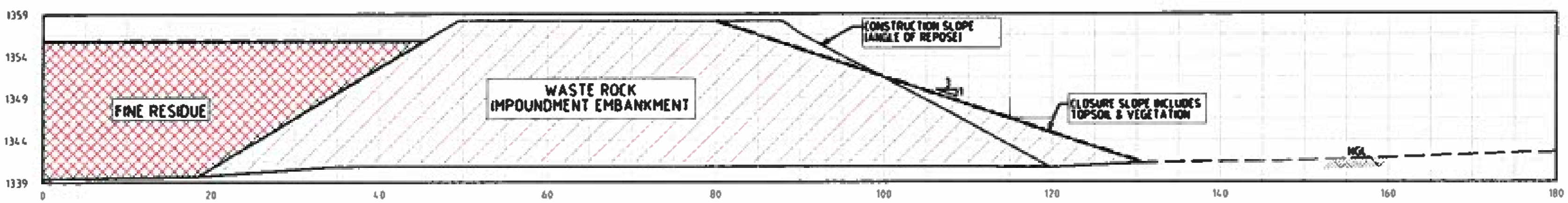
5. A Guide to the Management of Tailings Facilities - The Mining Association of Canada (MAC) - A Guide released in September 1998 by the MAC to encourage mining companies to practise safe and environmentally responsible management of tailings facilities through the development of customized, site-specific management systems.

6. Guidelines for the compilation of a mandatory code of practice on mine residue deposits - Ref. No. DME 16/3/2/5-A1. 30 November 2000, Department of Minerals and Energy, Republic of South Africa.

Appendix A : Drawings



SECTION A -001
1:200



SECTION B -001
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BEESHOEK MINE

FINE RESIDUE STORAGE FACILITY

TYPICAL SECTIONS

GEOTAIL

GT-002

A

Client: BEESHOEK MINE

Project: FINE RESIDUE STORAGE FACILITY

Drawing title: GENERAL ARRANGEMENT

GEOTAIL

Drawing No. GT-001

Revision A

Appendix B : Capacity Analysis

CAPACITY ANALYSIS													
Beeshoek Mine Fine Residue Storage Facility													
Vertical height (m)	Elevation (m)	Area (m^2)	Area (ha)	Volume (m^3)	Acc. volume (m^3)	Deposition rate (tpm)	Dry density (t/m^3)	Acc tonnage (tonnes)	Time (months)	Acc. time (months)	Acc. time (years)	Rate of rise (m/y)	Rate of rise (m/mnth)
0	1,334.0	40	-	-	-	0	2.25	0	0.0	0.0	0.00	0.00	0.00
0.5	1,334.5	296	0.0	84	84	110,600	2.25	189	0.0	0.0	0.00	1992.79	166.07
1.0	1,335.0	6,045	0.6	1,585	1,669	110,600	2.25	3,755	0.0	0.0	0.00	97.58	8.13
1.5	1,335.5	15,827	1.6	5,468	7,137	110,600	2.25	16,058	0.1	0.1	0.01	37.27	3.11
2.0	1,336.0	26,799	2.7	10,657	17,794	110,600	2.25	40,037	0.2	0.4	0.03	22.01	1.83
2.5	1,336.5	43,938	4.4	17,684	35,478	110,600	2.25	79,826	0.4	0.7	0.06	13.42	1.12
3.0	1,337.0	73,530	7.4	29,367	64,845	110,600	2.25	145,901	0.6	1.3	0.11	8.02	0.67
3.5	1,337.5	94,144	9.4	41,918	106,763	110,600	2.25	240,217	0.9	2.2	0.18	6.27	0.52
4.0	1,338.0	126,357	12.6	55,125	161,888	110,600	2.25	364,248	1.1	3.3	0.27	4.67	0.39
4.5	1,338.5	157,651	15.8	71,002	232,890	110,600	2.25	524,003	1.4	4.7	0.39	3.74	0.31
5.0	1,339.0	191,063	19.1	87,178	320,068	110,600	2.25	720,153	1.8	6.5	0.54	3.09	0.26
5.5	1,339.5	226,393	22.6	104,364	424,432	110,600	2.25	954,972	2.1	8.6	0.72	2.61	0.22
6.0	1,340.0	259,592	26.0	121,496	545,928	110,600	2.25	1,228,338	2.5	11.1	0.93	2.27	0.19
6.5	1,340.5	287,796	28.8	136,847	682,775	110,600	2.25	1,536,244	2.8	13.9	1.16	2.05	0.17
7.0	1,341.0	309,158	30.9	149,238	832,013	110,600	2.25	1,872,029	3.0	16.9	1.41	1.91	0.16
7.5	1,341.5	327,326	32.7	159,121	991,134	110,600	2.25	2,230,052	3.2	20.2	1.68	1.80	0.15
8.0	1,342.0	342,138	34.2	167,366	1,158,500	110,600	2.25	2,606,625	3.4	23.6	1.96	1.72	0.14
8.5	1,342.5	354,690	35.5	174,207	1,332,707	110,600	2.25	2,998,591	3.5	27.1	2.26	1.66	0.14
9.0	1,343.0	366,951	36.7	180,410	1,513,117	110,600	2.25	3,404,513	3.7	30.8	2.57	1.61	0.13
9.5	1,343.5	378,977	37.9	186,482	1,699,599	110,600	2.25	3,824,098	3.8	34.6	2.88	1.56	0.13
10.0	1,344.0	391,587	39.2	192,641	1,892,240	110,600	2.25	4,257,540	3.9	38.5	3.21	1.51	0.13
10.5	1,344.5	403,678	40.4	198,816	2,091,056	110,600	2.25	4,704,876	4.0	42.5	3.54	1.46	0.12
11.0	1,345.0	414,993	41.5	204,668	2,295,724	110,600	2.25	5,165,379	4.2	46.7	3.89	1.42	0.12
11.5	1,345.5	425,326	42.5	210,080	2,505,804	110,600	2.25	5,638,059	4.3	51.0	4.25	1.39	0.12
12.0	1,346.0	435,082	43.5	215,102	2,720,906	110,600	2.25	6,122,039	4.4	55.4	4.61	1.36	0.11
12.5	1,346.5	444,679	44.5	219,940	2,940,846	110,600	2.25	6,616,904	4.5	59.8	4.99	1.33	0.11
13.0	1,347.0	454,387	45.4	224,766	3,165,612	110,600	2.25	7,122,627	4.6	64.4	5.37	1.30	0.11
13.5	1,347.5	464,068	46.4	229,614	3,395,226	110,600	2.25	7,639,259	4.7	69.1	5.76	1.27	0.11
14.0	1,348.0	473,626	47.4	234,423	3,629,649	110,600	2.25	8,166,710	4.8	73.8	6.15	1.25	0.10
14.5	1,348.5	483,148	48.3	239,193	3,868,842	110,600	2.25	8,704,895	4.9	78.7	6.56	1.22	0.10
15.0	1,349.0	493,317	49.3	244,116	4,112,958	110,600	2.25	9,254,156	5.0	83.7	6.97	1.20	0.10
15.5	1,349.5	503,444	50.3	249,190	4,362,148	110,600	2.25	9,814,833	5.1	88.7	7.40	1.17	0.10
16.0	1,350.0	513,572	51.4	254,254	4,616,402	110,600	2.25	10,386,905	5.2	93.9	7.83	1.15	0.10
16.5	1,350.5	523,657	52.4	259,307	4,875,709	110,600	2.25	10,970,345	5.3	99.2	8.27	1.13	0.09
17.0	1,351.0	533,130	53.3	264,197	5,139,906	110,600	2.25	11,564,789	5.4	104.6	8.71	1.11	0.09
17.5	1,351.5	542,068	54.2	268,800	5,408,706	110,600	2.25	12,169,589	5.5	110.0	9.17	1.09	0.09
18.0	1,352.0	550,764	55.1	273,208	5,681,914	110,600	2.25	12,784,307	5.6	115.6	9.63	1.07	0.09
18.5	1,352.5	559,068	55.9	277,458	5,959,372	110,600	2.25	13,408,587	5.6	121.2	10.10	1.06	0.09
19.0	1,353.0	567,359	56.7	281,607	6,240,979	110,600	2.25	14,042,203	5.7	127.0	10.58	1.04	0.09
19.5	1,353.5	575,873	57.6	285,808	6,526,787	110,600	2.25	14,685,271	5.8	132.8	11.06	1.02	0.09
20.0	1,354.0	584,592	58.5	290,116	6,816,903	110,600	2.25	15,338,032	5.9	138.7	11.56	1.01	0.08
20.5	1,354.5	593,572	59.4	294,541	7,111,444	110,600	2.25	16,000,749	6.0	144.7	12.06	0.99	0.08
21.0	1,355.0	602,856	60.3	299,107	7,410,551	110,600	2.25	16,673,740	6.1	150.8	12.56	0.98	0.08
21.5	1,355.5	611,541	61.2	303,599	7,714,150	110,600	2.25	17,356,838	6.2	156.9	13.08	0.96	0.08
22.0	1,356.0	620,009	62.0	307,887	8,022,037	110,600	2.25	18,049,583	6.3	163.2	13.60	0.95	0.08

Appendix C : Water Balance

WATER BALANCE - Beeshoek Fine Residue Storage Facility

PROCESS DETAILS			
Specific Gravity	ratio	4.10	
Deposition rate	tpm	110,600	
Ops. time	hrs/mnth	639	
SLURRY CHARACTERISTICS		**Slurry In**	**Slurry Placed**
Moisture content	%	390	75
Void ratio	ratio	11.890	3.075
Slurry density	ratio	1.240	1.761
Dry Density	kg/m3	318	1,006
Water Mass	kg/m3	922	755
Total Mass	kg/m3	1,240	1,761
% Solids	mass	25.6	57.1
% Water	mass	74.4	42.9
Water:Solids	ratio	2.90	0.75
Mass Solids	tph	173	
Mass Water	tph	502	
Mass Total	tph	675	
Vol Solids	m3/h	42	
Vol Water	m3/h	502	
Vol Total	m3/h	544	
Operations water	m3/mnth	320,740	
Interstitial water volume	m3/mnth		82,950
Supernatant release	m3/mnth	237,790	

		Oct to Apr	May to Sept	
Season		**Wet**	**Dry**	**Annual**
Months	mnth	7	5	12
Days	d	213	152	365
Average rainfall	mm	299	39	338
Average evaporation	mm	1,839	611	2,450
INFLOWS				
Supernatant release	m3	1,664,530	1,188,950	2,853,480
Ext. catchment runoff	m3	0	0	0
Beach runoff	m3	25,953	2,974	28,927
Pool runoff	m3	18,538	2,418	20,956
Total runoff	m3	44,491	5,392	49,883
OUTFLOWS				
Beach evaporation	m3	401,343	100,008	501,352
Pool evaporation	m3	100,336	33,336	133,672
Total evaporation	m3	501,679	133,345	635,024
Seepage rate (q=kiA)	m3	11,406	8,147	19,552

Residue area	m2	620,000			
WET SEASON		**Dry beach**	**Wet beach**	**Pool**	**Ext. catchment**
% Split	%	50	40	10	
Area (m2)	m2	310,000	248,000	62,000	0
Runoff factor	%	8	25	n/a	0
DRY SEASON		**Dry beach**	**Wet beach**	**Pool**	**Ext. catchment**
% Split	%	60	30	10	
Area	m2	372,000	186,000	62,000	0
Runoff factor	%	8	25	n/a	0

Evaporation adjustment	0.70*A-pan 0.88*S-pan	0.88
Permeability	m/s	1.00E-07
	m/annum	3.154
Hydraulic gradient	ratio	0.10

RESULTS		Oct to Apr	May to Sept	
		Wet	**Dry**	**Annual**
Decant return	m3	1,195,936	1,052,851	2,248,787
	m3/mnth	170,848	210,570	187,399
	m3/day	5,617	6,923	6,161
	%	53	66	58
Water demand	m3/mnth	320,740	320,740	
	m3/annum	2,245,180	1,603,700	3,848,880
Surplus(+)/Deficit(-)	m3/mnth	-149,892	-110,170	
	m3/annum	-1,049,244	-550,849	-1,600,093
Decant rate	m3/h	600	600	
Decant period	hrs	9.4	11.5	
Return pump rate to Plant	m3/h	600	600	
Pump hours required	hrs	9.4	11.5	
Comments	If <24 = OK	OK	OK	

Description		Basin Storage
1 in 50 year, 24 hour storm	mm	107
Run-off factor	Dry beach	0.3
	Wet beach	0.6
	Pool	1.0
	External	0.0
Total catchment area	m2	620,000
Catchment area (% of total area)	Dry beach	50
	Wet beach	30
	Pool	20
Catchment area (m2)	Dry beach	310,000
	Wet beach	186,000
	Pool	124,000
	External	0
Storm volume	m3	35,160
Decant period	days	5.0
Daily storm decant	m3/day	7,032
Daily operations water	m3/day	10,542
% return	%	53
Daily operations water return	m3/day	5,587
Total daily decant requirement	**m3/day**	**12,619**
Pumping hours per day	hrs	21
Required decant rate to RWD	**m3/h**	**601**

Appendix D : Photographs

Open end Delivery Station

Supernatant Pool in Quarry

Rehabilitated Side Slope

Steep Beach Profile at Head of Beach