Jagersfontein Pit Backfill Design Assessment Revision 1

Report Prepared for

Jagerfontein Developments (Pty)Ltd

JAGERSFONTEIN
DEVELOPMENTS

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Jagersfontein Pit Backfill

Design Assessment Revision1

Jagerfontein Developments (Pty)Ltd

1 President Street
Jagersfontein
9974

SRK Consulting (South Africa) (Pty) Ltd
265 Oxford Rd
Illovo 2196
Johannesburg
South Africa

e-mail: johannesburg@srk.co.za
website: www.srk.co.za

Tel: +27 (0) 11 441 1111
Fax: +27 (0) 11 880 8086

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Compiled by:

Dr GC Howell PrEng
Corporate Consultant

Email: ghowell@srk.co.za

Peer Reviewed by:

Mr G Macfarlane PrSciNat
Principal Engineering Geologist/Partner

Authors:

GC Howell PrEng; Xanthe Adams PrEng; MBester PrTechniEng (Mech/Civil)

Executive Summary

Jagersfontein Developments Pty Ltd (JD) operates a process plant to re-treat diamond-bearing waste rock stockpiles at Jagersfontein in the southern Free State. The re-treatment process produces waste, in the form of coarse tailings and fine tailings as a slurry, that is currently discarded into a surface tailings dam that is rapidly nearing the end of its design life. Continued operation of the process plant requires that either a new surface tailings facility be built (which has negative financial and environmental repercussions for the area), or that the waste streams are deposited into the Open Pit. JD is currently seeking authorization from the Authorities for the deposition into the Open Pit.

This report considers the design of the proposed backfilling of the Jagersfontein Open Pit, using coarse and fine tailings from the adjacent stockpile re-treatment operations. The proposed option of filling of the open pit has a long history going back at least 10 years since the JD acquired ownership of the operation from De Beers. The report is a revision (rev1) of the report submitted in July 2019 and contains additional information regarding the practical impermeability of the slurry and the compatibility of the materials to form a basal blanket that is deemed better (less permeable) than a Class C barrier system (ref GHT Appendix I, Section 10).

The re-treatment operations are carried out on the ROM ore that is stockpiled on dumps that surround the plant and pit area. The plant produces waste streams, consisting of coarse tailings (sometimes called ‘grits’) and fines that presents as a pumped slurry containing a high percentage of bonded water that cannot be released due to the very low hydraulic conductivity (permeability) of the material.

Currently, the waste (tailings and fines) is discarded into a fine tailings storage facility (FTSF) to the southeast of the open pit. The area covered by the FTSF is currently about 75ha. This facility is close to full capacity (according to the existing design and permit capacity) with future life of between 9 to 26 months depending on the construction options chosen by JD (refer SRK Report 573772 November 2021: Jagersfontein Fine Tailings Storage Facility (FTSF) Continuation and Future Construction Options Report). Continued waste management of this type would require either ongoing construction of the existing facility to higher elevations or a new FTSF further to the south of the plant. This new facility would further sterilise another approximately 100Ha of surface area to a height of some 33m and, in addition, act as a potential pollution source for the upper aquifer (up to 20m below surface) from which water is currently abstracted in the area.

JD has proposed, therefore, that henceforth, the open pit be used for the deposition of both waste streams (coarse and fine tailings). The remaining ROM stockpiles represent about 36Mt (million tons) of material still to be processed, which will produce approximately 25.6Mm^3 (million cubic metres) of waste. The ‘usable’ volume of air space in the open pit (to elevation 1400mamsl) is 31Mm^3. Accordingly, the remaining waste will only fill to pit to a level some 30m below the rim (1371mamsl). [These volumes represent those applicable in 2019 and since the tailings has since continued to be deposited onto the FTSF, the volumes will have changed in 2021.] From a historical and tourism viewpoint, therefore, the unique geology of the pit will still be observable once re-treatment operations cease. In addition, the current potentially unstable pit slopes will be buttressed by the waste and further break-back (towards the town and surroundings) will be mitigated. Since the waste will only reach to a level below 1371mamsl, which is below the upper aquifer depth, no effect on the regional usable aquifer will result.

Noting that the sidewalls/rockfaces of the pit are near vertical, more than 200m high and potentially unstable, physical access to the pit floor is not possible. Therefore, remote deposition of the waste stream by conveyor (coarse tailings) and pipeline (fine tailings) is the feasible and viable practical solution.

Consequently, JD has requested SRK to consider the design implementation for the immediate commencement for filling of the pit. This report constitutes the design assessment of the backfilling process.

The report considers the design implications of backfilling the Jagersfontein Open Pit. Previous work, studies, publications and reports have been assessed and where applicable, have been included in this document as background information as well as to support the design approach and decisions.

The conclusions reached in the Geochemical Report is that the fine tailings is a Type 3 low risk waste but will be sterile and immobile in this environment. The Geohydrology modeling report shows that the existing plume from the FTSF will attenuate with time, particularly in the scenario where the fines is backfilled in the pit, thus relieving the situation of additional surface loading from a future additional tailings dam. The report shows that it is beneficial to backfill the pit rather than develop additional surface storage facilities. In fact, the procedure of backfilling the pit will, in terms of the geohydrological considerations of plume development, be beneficial to the area since the waste load on the surface will be substantially reduced. These reports, taken together, also show that a physical barrier (such as an HDPE liner, albeit that the installation of such a barrier is practically impossible), is not warranted or necessary since the slurry by virtue of its smectite clay content and very low permeability has the properties of an impermeable membrane over the pit floor and sidewalls and therefore results in a system deemed better than a Class C barrier system (ref GHT Appendix I, Section 10).

The sidewalls and main Mine shaft have been assessed by professional proto-team members who noted that there is no indication of direct piping connections between the pit and the shaft. The base of the pit consists of random fill derived from erosion products from the sidewalls and surrounding areas, overlying block caved debris thus resulting in uncertain conditions with respect to permeability and voids. It has therefore been concluded that the judicious planned strategy of selective tailings deposition, to form a blanket around the southern shaft area, and remote deposition of the fine tailings from the eastern rim, forms the most practical solution to backfilling.

Consequently, the depositional strategy involves the initial deposition of a blanket of coarse tailings for a period of three to four months from the southern rim, followed by fine tailings slurry deposition thereafter. Since the coarse tailings is denser than the fine tailings slurry, co-disposal in separate streams will result in the coarse tailings forming an increasing thickness of blanket with time, while the fine tailings will be displaced and thus constricted towards the northern side of the pit. Evidence of the displacement of fine tailings by coarse tailings can be witnessed in the current construction practices on the FTSF.

Due to the nature of the fine tailings slurry (very low permeability and coefficient of consolidation), it will remain in a fluid state for many decades, save for surface desiccation due to evaporative drying that will cause a thin crust to develop. This in itself is a safety issue, since the visual impression will be created that the material is stable, whereas it will remain fluid below the thin surface crust.

The final level of the tailings backfill once all stockpile (ROM) material has been processed will reach a level some 30m below the lowest rim level (1400mamsl) (to be confirmed once the date of commencement of backfilling is set). This will allow future viewing and (geo-) tourism to continue in the area. Safety of the site, will, however, need to be maintained by the owner.

The depositional strategy is intended to increase the coarse tailings blanket thickness around the main shaft area and side walls commensurate with the disposal rate, therefore minimising the likelihood of ‘piping’ of the fine tailings into the Main Shaft area. However, since the conditions within the pit and sidewalls are not known explicitly, it is recommender that the monitoring program proposed by GHT be implemented prior to pit backfilling and that the water quality be regularly monitored. One possible solution for water supply is to upgrade the North, Loskop and Moon Dams as water storage facilities and to channel surface water away from the rim of the pit.

The implementation of the backfilling method involves the construction of a 750m long overland conveyor system from the process plant to the coarse tailings deposition point to be located on the southern rim, and a 1100m long fine tailings slurry delivery pipeline along the same initial route but extending to the eastern discharge point. The routing of the conveyor and pipeline will be designed on site to suit the site roads and services layout. A concept route is given in the accompanying drawings.

Monitoring protocols are also necessary during and after deposition. Monitoring requirements are included in this report.

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Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (South Africa) (Pty) Ltd (SRK) by Jagersfontein Development Pty Ltd (JD). The opinions in this Report are provided in response to a specific request from JD to do so. SRK has exercised all due care in reviewing the supplied information. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

1 Introduction and Scope of Report

Jagersfontein Developments Pty Ltd (JD) requested SRK Consulting to consider the design of the proposed backfilling of the Jagersfontein Open Pit, using coarse and fine tailings from the adjacent stockpile re-treatment operations. The proposed filling of the open pit has a long history going back at least 10 years since the JD acquired ownership of the operation from De Beers.

The re-treatment operations are carried out on the ore from the stockpiles that surround the area. These stockpiles (ROM – run of mine) form the feed to the re-treatment plant for the purpose of retrieving diamonds from the ROM. The process involves further crushing of the ROM, washing and sorting of the material. The plant produces waste streams consisting of coarse tailings (sometimes called 'grits') and fine tailings (sometimes referred to as slimes) that presents as a pumped slurry containing a high percentage of bonded water.

Currently, the waste (coarse and fine tailings) is discarded into a tailings storage facility (FTSF) located to the south of the open pit. The area covered by the facility is currently about 75ha. This facility is close to full capacity with future life is between 9 and 26 months depending on the constrcution options decide on by JD (refer SRK Report 573772 November 2021: Jagersfontein Fine Tailings Storage Facility (FTSF) Continuation and Future Construction Options Report). Continued waste management of this type would require either the ongoing construction of the existing facility to higher elevations or alternatively the construction of a new TSF further to the south of the plant. This new facility would further sterilise another 100Ha of surface area to a height of some 33m and, in addition, act as a potential pollution source for the upper aquifer (up to 20m below surface) from which water is currently abstracted in the area.

JD have proposed therefore that henceforth, the open pit be used for the deposition of both waste streams (coarse and fine tailings). The remaining ROM stockpiles represent about 36Mt (million tons) of material still to be processed, which will produce approximately 25.6Mm^3 (million cubic metres) of waste. The 'usable' volume of air space in the open pit (to level 1400mamsl) is 31Mm^3 Accordingly, the remaining waste will only fill the pit to a level some 30m below the rim (1371mamsl) (to be confirmed once the date of commencement of backfilling is set). From a historical and tourism viewpoint, therefore, the unique geology of the pit walls will still be observable once operations cease. In addition, the current potentially unstable pit slopes will be buttressed by the waste and further break-back (towards the town and surrounding) will be mitigated. Since the waste will only reach to a level of 1371mamsl, which is below the upper aquifer depth, no effect on the regional usable aquifer will result.

Noting that the sidewalls/rockfaces of the pit are near vertical, more than 200m high and potentially unstable, physical access to the pit floor is not possible. Therefore, remote deposition of the waste by conveyor (coarse tailings) and pipeline (fine tailings) is the only practical solution.

Consequently, JD has requested SRK to consider the design implementation for the immediate commencement for filling of the pit. This report is, therefore, a design assessment of the backfilling process.

2 Current Layout of the Open Pit and Environs

For orientation purposes, Figure 1 shows a recent Google Earth image of the Jagersfontein Pit and the surrounding areas. Jagersfontein town lies to the north and east, while the existing fine tailings storage facility (FTSF) lies to the southeast with the process plant due south of the pit. The ROM stockpiles are located to the southwest and northwest of the pit. The potential site for a future tailings storage facility (if required) is due south of the process plant.

Figure 1: Jagersfontein Pit, Process Plant and current Fine Tailings Storage Facility layout (from Google Earth 5/2/2019)

3 Background and Brief

JD are the owners of the Jagersfontein Open Pit and the nearby diamond reprocessing facility that extracts diamonds from the various dumps around Jagersfontein. As owners, JD are also responsible for the Jagersfontein Open Pit stability and its possible and potential impact on the communities of Jagersfontein, some of which live within 80m to 100m of the current pit rim location.

Since the open pit mining operations ceased in the 1970s, there have been ongoing reports from the community of continuing break back of the very steep/near vertical side slopes of the open pit. The current mine manager, Mr J Combrink, reported on 30 March 2012 during the site visit by SRK that in the previous year (2011) during the periods of heavy rain that there were many reports from the community of Jagersfontein of noise from the open pit when break back of the pit side walls occurred. Similar incidents continue to occur. Regular monitoring in the form of lidar and drone surveys and physical inspections are carried out.

In addition, Jagersfontein Open Pit is the oldest diamond mine open pit in South Africa. From a heritage point of view, some vestige of the history of the area deserves to be maintained for posteriority while providing work opportunities and livelihoods for local inhabitants. The licencing process, for backfilling of the pit, with the statutory authorities is currently underway by others. This report forms the basis for the engineering requirements for the project implementation.

4 Previous Reports

Prior reports, which are applicable to and form the supplementary basis for this report, are as follows:

- "**Review of Jagerfontein Pit Stability and Backfilling Options**" SRK Report Number 445072/2 of May 2012 (included as Appendix A herein).

  This report highlights the stability and likely back break of the steep walls of the pit walls with time, due to erosion, weathering and undermining. The report also describes the setting and the geology of the pit and the surrounding areas and provides a preliminary assessment of the back-filling scenarios. This assessment was done during 2012 and since then (7 years later) a considerable volume of waste has been deposited into the (now rapidly filling) existing tailings storage facility on surface. In 2012, there was sufficient unprocessed material to fill the pit to capacity. This is no longer the case (as is indicated in the Introduction). Nevertheless, the process of filling the pit is still applicable.

- "**Design for the Extension of the Jagersfontein De Beers Tailings Dam**" BRT Report Number BRT-03-2015 of March 2015 (included as Appendix B herein).

  This report concentrates of the requirements for additional 2nd and 3rd phases for the extension of the existing tailings storage facility on site. The proposal makes provision for a further 11 to 15Mt of capacity (6 to 7.4Mm^3 of volume) (of the 36Mt still to be processed). This report concentrates on using the already impacted footprint of the existing dam. The report contains important photographs of the existing facility and, in particular, the behaviour of the fine taililngs behind the coarse tailings perimeter walls. The fine tailings slurry acts as a 'heavy fluid' that is displaced by the deposition of the coarse tailings on the inner face of the embankment wall (constructed with coarse tailings). Consequently, the volume of coarse tailings deposited within the basin as a part of the wall raising activities displaces the fine tailings slurry, resulting in a level increase in the basin. The surface of the slurry is desiccated (due to evaporative drying) to a shallow depth (of about 150mm) while below, the material is still fluid and mobile. This is due to the properties of the slurry that exhibits very low permeabilities (hydraulic conductivity) and very long (in the order of centuries) consolidation characteristics. It is apparent that the same behaviour will be active in the pit back filling process. This report also contains soil laboratory test results that have been used in this report.

- "**Concept Design for the Final Jagersfontein Tailings Dam**" BRT Report Number BRT-06-2016 of June 2016 (included as Appendix C herein).

  This report considers a new surface tailings storage facility for 25Mt (of the 36Mt still to be processed). This proposal covers an area of about 100Ha to the south of the current plant and pit. Considerations for lining the facility with an HDPE liner are highlighted but are rejected due to the substantiated limited impact of the historic dumps over the past 140 years on the groundwater and the environment. The addition of a liner system is considered likely to render the operation uneconomic for the current marginal financial operation, meaning that the operation will be forced to close if the alternative proposal for deposition into the pit is not licenced.

- "**Underground Recce No1 and 2: MRS Shaft: Final Report**" C&A Mining Exploration Consultants dated 25 May 2017 (included as Appendix D herein).

  This report details the investigations by a professional proto-team that attempted to access the underground workings to verify the seals and access points to the pits on levels 154 and 275. The investigation confirmed the unsafe subsurface conditions in the Main Shaft and the *declines. A drone survey concluded that there were no visible concrete plugs or holings into open pit's high walls.*

The implications of this report indicates that no access to the underground is possible (even for experienced miners), but also indicates that there are no visible entry points into the shaft system from within the open pit. This is an important observation and pertains to the practical method of pit filling that is covered below in this report.

- "Surface Water Resources Assessment" EKO Environmental (OJ Gericke), dated June 2013 (included as Appendix E herein).

  This report considers the regional catchment area for the full Jagersfontein site and is particularly focused towards Dam 10 south of the current tailing storage facility. This report has similarities to Section 6.5 of this report where the specific runoff towards the pit is assessed.

- "Storm Water Management Plan (SWMP) by MVD Kalahari (included as Appendix H herein).

  This report considers inter alia the groundwater and groundwater flow, stormwater drainage, infiltration and flood hydrology for the region but focuses on the fine tailings storage facility (FTSF). This report is also germane to the pit backfilling project.

- Specialist Report: Professor Wayne Colliston R2021827/JAGGL.1 (included as Appendix J herein).

  Prof. WP Colliston has submitted a specialist report entitled "GEOLOGICAL INVESTIGATION OF THE AREA AROUND THE PRINCIPAL SLIMES DAM (TSF) AT JAGERSFONTEIN DIAMOND MINE".

  This report considers the geology of the environs around the Pit and concludes that the area is underlain by an exploitable unconfined surface aquifer and a deep confined (non-exploitable) aquifer, separated by a thick very low permeability dolerite sill. The report further confirms that the fine tailings consists of a smectite clay derived from the weathering of the parent kimberlite rock, in slurry form. The smectite layer on the base of the facility has the properties of an impermeable membrane over the sandstone-dolerite sill floor and results in a membrane deemed better than a Class C barrier system. This report is also germane to the pit backfilling project.

5 Proposed Pit Filling Procedure

Since access to the pit, either from surface or from underground, is not possible, the only practical way to fill the pit is from the rim. The proposed filling process of the coarse tailings is from the south rim adjacent to the Main Shaft via conveyor from the plant, while the fine tailings (slurry) will be piped from the plant to a discharge point on the eastern side of the pit.

The main constraint considered in this procedure is the 'protection' of the main shaft area and the floor of the pit using coarse tailings which will be deposited from the south rim for a period of three months prior to commencement of slurry deposition. The following aspects are integral components/constraints for the backfilling procedure:

- The main shaft currently houses water pumps at the 450m level. These pumps provide process water for the plant only. The pumps have been installed (remotely) down the Main Shaft to the extraction level even though physical access is not possible (as confirmed by C&A Mining exploration Consultants).

- The water in the Main shaft is derived mainly from stormwater run-off into the pit from the western and north-western catchment areas together with some minor seepage from the deep aquifer via the (abandoned) underground workings.
- Physical inspection of the pit and the shaft have deduced that there are no open adits or tunnels from the pit walls into the shaft area. It is therefore concluded that seepage of water ingress is through the erosion sediments at the base of the pit and via the block cave material below that level (±275m below surface). The water that is pumped is clean and devoid of sediments, thus indicating that there is no piping or sediment transport into the shaft area.
- In order to protect the base of the pit and the southern (main shaft) wall, coarse tailings will be deposited first in this area to form a “blanket” of a minimum thickness of 10m initially, and increasing in thickness as deposition continues.
- The fine tailings slurry will be introduced by pipeline from the eastern flank of the pit four months after commencement of the coarse tailings deposition.
- Since the fine tailings slurry is less dense than the coarse tailings, the slurry will remain above the coarse tailings (Section 6.2.4). The continued deposition of the coarse tailings from the south rim will displace the slurry laterally and upwards (sink to the bottom as has been the case at DeBeers pit in Kimberley and as observed from the Jagersfontein surface FTSF).
- The tailings will act as blanket material (see the assessment of the characteristics below in Section 6.2.3) and progressively enhance/prevent piping/internal erosion into the main shaft area, thus ensuring the continued availability of water to the pumps.
- Continued deposition of the coarse and fine tailings will progressively buttress the southern flank with coarse tailings and develop a pool of fine tailings slurry towards the north, west and eastern side of the pit. The deposition of the tailings has been assessed (calculated) to remain proud of the slurry surface until late in the backfilling process (at the end of the 6th year of deposition of 6 years).
- Deposition is programmed to take about 6 years (72 months) at the current production levels. Recently a new pan plant has been installed that will increase the ROM production to 700tph (tons per hour) – or 50 4000 tpm (tons per month). Coarse tailings production is 396 000tpm and fine tailings slurry is 153 000m^3/m (cubic metres per month) including makeup water. The total ROM still to be processed is estimated to be 36Mt (million tons). Further assessment of the volumes and rates of rise are contained in Section 7. Once the commencement date of the backfilling is confirmed, these volumes will be reassessed and updated.
- It is proposed that the stormwater entry into the pit (which currently enters at the southern culvert and western depression area) will be re-routed to the west and south to the Dam 10 catchment using a new cut-off trench system as proposed by MVD Kalahari. Rainfall over the pit area will be the only stormwater reporting to the Pit.
- The two main catchment areas (Section 6.5) that report to the Open Pit are from the west and northwest, with a minor catchment for the northeast (town) area. Currently, the western catchment (Loskop Dam) discharges into the pit via the southern culvert. The North Catchment discharges via the North Dam (north of the Fauresmith road) into the north-western area of the pit. It is proposed that consideration be given, during the implementation phase, to upgrade the North, Loskop and Moon Dams for beneficial use and channeling the stormwater overflow toward the west and south towards Dam 10 in order to minimise run-off into the pit.

The sections below consider the technical aspects of the proposed pit filling procedure.

6 Design Aspects

The design aspects covered in this section relate primarily to the design criteria and the characteristics of the coarse and fine tailings. The section also contains an assessment of the hydrology and stormwater run-off expected to report to the open pit during the pit filling period and thereafter.

The information contained has been developed either from first principles or derived from reports and documents that are available from previous work done for the Jagersfontein pit (see Section 4 above).

Recent laboratory testing and experiments on the nature and (lack of) mobility of the slurry are included here as additional information and to confirm the properties of the materials.

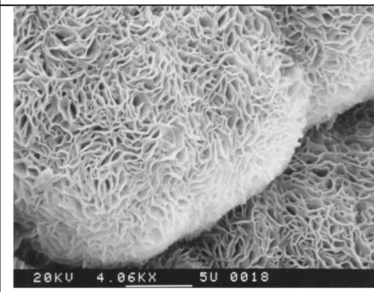
In addition, physical observations on the interaction between the coarse and fine tailings have however been carried out on-site to confirm the relative densities and co-disposal options. This site assessment concluded that co-disposal (prior mixing) would not be successful due to the relative volumes of the coarse and fine tailings produced from the treatment plant which led to rapid segregation of the materials in the tests. Even so, co-disposal, on the other hand, does not assist with the criterion of maintaining a blanket between the slurry and the main shaft area to assist with the beneficiation and monitoring of water. Co-disposal has therefore been rejected in favour of the proposed method described in Section 5, above.

6.1 Design Criteria

Aspect	Description	Notes/Exclusions
Battery Limits	Process Plant to Jagersfontein Pit over Jagerfontein Developments Pty Ltd Property	
Design Criteria		
Purpose	Optimisation of filling the Jagersfontein Pit with tailings and/or Slimes produced by the re-processing plant currently proceeding at the Mine.	
History	Diamonds were discovered in the area in 1868. The Jagersfontein Diamond Mine was proclaimed in 1871. Over the ensuing years of the late nineteenth and early twentieth century, the mine became the largest hand-dug pit in the world. From about 1947, the mine went underground using a sequence of ‘block-caving’ mining methods maintained by the main shaft, sub shaft and declines. The workings reached a depth of 865m, with extensive development at all levels to that level. When the grades reduced, mining was terminated in February 1969 and was finally closed in 1971. The mine has been derelict since that time, save for re-processing of the dumps. Jagersfontein Developments obtained ownership of the land and dumps in 2008 from De Beers and have proceeded with the re-processing.	
The State of the Pit	Geology and jointing of the pit walls has resulted in a near-vertical sided hole where some of the faces are more than 200m in height. The current base of the pit is filled with debris from surface erosion overlying the waste country rock from the block cave mining. The current level of the debris surface is at 268m. The bottom of the pit is currently dry with the water table measured in the shaft at 396m, but	Current open volume = 32.4637Mm^3. This full volume is not available for backfilling which can only take place to the lowest rim level at 1400m level. The volume at 1400m is about 31Mm^3.

Aspect	Description	Notes/Exclusions
	the water level has relatively recently (in the last 15 years) been at a level 90m below surface (before being pumped). The bottom of the pit is clearly permeable since no water retention is observed. The walls of the pit, especially on the northern and north-eastern side are susceptible to open jointing and toppling failures from time to time. The NW/SE trending discontinuity that traverses the pit is also susceptible to erosion in the form of deep gulleys (NW) and block failure. Due to the vertical walls, the pit is inaccessible for normal operations of any kind.	
The Process	The re-processing of the dumps results in the production of tailings (gravel typically in the range +1mm to -8mm) and slimes (typically -1mm to clay) in the form a paste at a density of about 1.4 to 1.6t/m^3. Currently, the tailings is stockpiled as the wall of an on-surface slimes facility into which the slimes paste is discarded. The current design of the slimes facility allows for between 9 and 26 months of deposition, depending on the option selected, whereafter a new slimes facility will be required if the tailings/slimes cannot be disposed of into the Pit.	New slimes facility expensive requires additional surface area.
Current operations in the Pit	None, but water is abstracted by pumps at the 450m level in the main shaft. Water is essential for the operation of the re-processing plant.	The nett annual extraction results in approximately 8m fall in water level. Current water level is 239m which means that there is about 6 years' water supply available (6y*8m/y = 48m)
Characteristics of the CoarseTailings (CT)	The CT tailings is a sandy gravel (USCS – SW) with a grade +1mm to -8mm. The optimum moisture content is of the order of 10 to 11% (according to laboratory tests) The moisture content on release from the plant is wet of optimum and is probably of the order of 15 to 18% (estimated from the mobility of the tailings when deposited on the tailings dam walls). The tailings is dumped and allowed to dry for approximately a day, before being spread with a dozer and/or grader. Compaction by vibratory pad-foot roller takes place about 48hrs after deposition (at a moisture content of close to optimum)	The mobility of the wet tailings on deposition has been used to estimate the free 'angle' of the tailings. For the purposes of beach angle and volume calculations, an angle of 15° has been used.
Characteristics of the Fine Tailings (Slimes slurry)	The slimes slurry is a hydrated smectite/montmorillonite clay with particle size less than 0.8mm to clay sized (<0.075mm). The slimes reports as a paste from the treatment plant at a slurry density of about 1.47 t/m^3. The laboratory tested dry density will be around 1.7 t/m^3 and an optimum moisture content about 18%. The coefficient of consolidation is 0.0032m^2/yr. The estimated t_{50} and t_{90} consolidation times are therefore many centuries (depending on the drainage path length).	Smectite does not release water from the matrix readily and therefore free water will be very slow to be released (if at all). Evaporation causes the surface to become desiccated (to 100 or 200mm), but the bulk remains in a paste state and very difficult to handle. Consolidation will take 10's of years to centuries. Deposition of the smectite clay, in slurry form, at and above the interface with the parent rock or

Aspect	Description	Notes/Exclusions
		CT material, has the properties of an impermeable membrane and results in a membrane deemed better than a Class C barrier system (cf Prof Colliston Appendix J and GHT Appendix I, Section 10)
Volume of Pit	The current total measured volume of the pit is 32.4637Mm^3 (million cubic metres). The usable volume to a level of 1400msL (the lowest level on the perimeter) is 30.991Mm^3 (used in volume calculations)	Surveyor. Volumes at 1400msL are from modelling software.
Surface plan area of pit	196 350m^2 (19.635Ha). Pit walls are sub-vertical (close to vertical) in the upper volume. The horizontal area at level 1400msL is 193.803m^2 (used in volume calculations)	Surveyor. Areas at 1400msL are from modelling software.
Estimate of Dump Tonnage	Estimates of dump tonnages vary considerably between various documents. The best estimate is that the dumps tonnage at the commencement of current operation was between 52.039Mt and 59.275Mt (million tonnes)	Accurate mass balance to be reassessed when the date of commencement of backfilling is confirmed
Estimate of processed material	The current estimate of processed material is 24Mt (May 2019). This is considered fairly accurate since the process is monitored and reported monthly.	Accurate mass balance to be reassessed when the date of commencement of backfilling is confirmed
Estimate of dumps remaining	The estimated mass of material remaining in the dumps (ie to be processed) is 36Mt, (to be reassessed when the date of commencement of the backfilling is confirmed)	Upper limit of ROM tonnage taken for calculation purposes
Estimate of slimes and tailings volumes remaining to be processed (and currently available to be deposited in the pit)	With the assumption that the dry density of the tailings is 1.9t/m^3 and slurry density of the slimes is 1.47t/m^3 (to be confirmed), the current volume of available material that can be deposited is about 25Mm^3. This means that the current deficit volume (ie volume of pit remaining after all the dumps have been processed) is greater than 6Mm^3	For a slurry density of 1400kg.m^3 and an SG of smectitie of 2400kg/m^3, the slime slurry contains about 72% water to 28% solid fraction. Volume assessments include the slurry volume accordingly.
Shortfall in depth within pit	The anticipated final depth of the tailings/slime below the rim of the pit will amount to 29m. This means that if all the processed dump materials are deposited in the pit <u>from now on</u>, then the deposited material will leave a cliff about 30m high at closure. (To be reassessed when the date of commencement of the backfilling is confirmed) This height assessment does not include consolidation of the slime slurry as this will take many decades to occur since the permeability/coefficient of consolidation is very low. Note that continued delays in beginning the pit deposition will mean that the residual cliff heights will increase.	Currently, insufficient material to fill the pit. pit walls will be more than 30m high (given the current tonnages and densities). Residual risk at closure remains for Jagersfontein Developments.
Shortfall in depth per month from delayed deposition	Assuming that the plant processes 360000t per month. At an average density of 1.6t/m^3, this relates to 225 000m^3 (dry volume) or 1.18m/month. Alternatively put, the remaining cliff height will increase by 1.18m per month of	Residual risk quantified.

Aspect	Description	Notes/Exclusions
	delay in beginning the deposition into the pit. This is equivalent to 14m per year. Note that these heights may change when the actual dry and wet densities of the tailings and slimes are determined, but the fact remains that substantial cliff heights will remain.	
Water resource protection: Tailings	Tailings water content is about 12 to 15% (ie well over OMC) – this water is (theoretically) available for release as seepage and/or flow. With the assumption that 80% is lost due to evaporation and other losses approximately 52 litres per m^3 should be available for reuse. On a monthly basis, this amounts to about 5 850m^3 or 5.80 Mega litres)	Calculation: Production = 360000t/mth Tailings production 50% = 180000t/mth = 112500m^3/mth Water = 112500*52 litres/mth = 5,850,000litres/mth
Water resource protection: Slimes	The slimes paste has very little 'free' water that can be released as seepage due to the very low permeability of the material. Whilst the moisture content in the slurry appears high, the nature of the smectite clay is such that the water is entrained/bonded into the fabric of the clay particles (see micrograph of smectite adjacent). "Drying" of the slurry, therefore, requires the addition of energy/heat that can occur from the sun at the surface only. This results in the desiccation of a thin layer of material at the surface with the bulk remaining in a slurry form below. Consolidation (dependent on permeability and drainage path length) is simply not fast enough (order of many decades) to produce significant seepage flow volumes.	
Design Principles		
Site development approach	Maximise the volume of deposition into the pit.	
Liner and drainage system	No access to the open pit is possible. The slimes slurry (that contains water) has very low permeability and coefficient of consolidation, therefore the release of water will be very slow – of the order of decades.	No liner or drainage is contemplated
Depositional system	Tailings transported by conveyor from the plant. Slimes paste pumped.	
Approach to decant of storm events	No special provision. Pit is a natural 'dam'	
Decant facilities	No special provision. Seepage to shaft pump station advantageous via the CT tailings as a drainage medium	
Dust management	Unlikely to be dust since slimes in wet (and will remain wet)	
Closure	The final pit will be filled to about 30m below the rim (level 1371m level using the current production volumes and the immediate deposition (see above). As a result, the pit walls will be available for geological 'tourism' and viewing. (levels will be reassessed when the commencement of backfilling date is confirmed)	(Geo)-Tourism potential remains, but JD will be required to secure the area.
Design standards	SANS10286 where applicable	

6.2 Geotechnical Aspects

Geotechnical characterisation of the Coarse Tailings and Slimes has previously been carried out by a Soils Laboratory and is reported in Appendix B. The following aspects are relevant to the current report:

6.2.1 The Nature of Smectite Clay

The following extracts summarise the nature of smectite clay (note that montmorillonite clay is a member of the smectite group).

CLAY MINERALS

D.G. Schulze, in Encyclopedia of Soils in the Environment, 2005

Smectites

The smectite group consists of minerals with the 2:1 structure already discussed for mica and vermiculite, but with a still lower charge per formula weight, namely 0.6–0.2. As in vermiculite, the interlayer contains exchangeable cations (Figure 5). An idealized formula for a common soil smectite, the mineral beidellite, is: $M^{+}_{0.33}Al_2\ Si_{3.67}Al_{0.33}\ O_{10}OH_2$, where M^+ represents exchangeable cations, typically Ca^{2+} and Mg^{2+}.

The most common smectite minerals range in composition between three end-members: montmorillonite, beidellite, and nontronite. All are dioctahedral, but they differ in the composition of the tetrahedral and octahedral sheets. Smectites do not fix K^+ as readily as do vermiculites because smectites have a lower layer charge, but smectites swell more extensively than vermiculite. This is illustrated in Figure 5 by the larger spacing between the 2:1 layers.

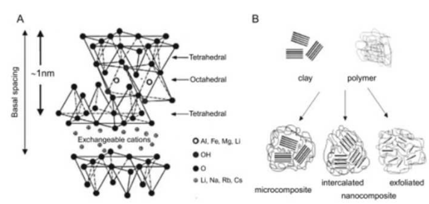
Smectites are important minerals in temperate-region soils. Many plant nutrients are held in an available form on the cation exchange sites of soil smectites. Soils rich in smectite tend to be very effective at attenuating many organic and inorganic pollutants because of the high surface area and adsorptive properties of the smectites. Smectites shrink upon drying and swell upon wetting. This shrink–swell behavior is most pronounced in the Vertisol order and in vertic subgroups of other soil orders. The shrink–swell properties lead to cracking and shifting problems when houses, roads, and other structures are built on smectitic soils.

Food Applications of Nanotechnology

Yining Xia, ... Rafael Auras, in Advances in Food and Nutrition Research, 2019

2.1 Montmorillonite (MMT)

MMT is a naturally-occurring, layered smectite comprised of several tens of stacked nanolayers (tactoids) (~ 1 nm thick and 1 nm interlayer spacing) (Fig. 2A). Each platelet is made up of an aluminum-oxygen-hydroxyl octahedral sheet sandwiched between two silicon-oxygen tetrahedral sheets (Jayaraman & Kumar, 2006). van der Waals interactions, between platelts, make them difficult to separate from each other. The interlayer galleries usually contain sodium cations, which can be exchanged with surfactants, such as long-chain alkyl ammonium ions, to promote the interaction between the gallery faces and polymer chains. The modification of MMT causes swelling of clay galleries, thereby improving polymer chain intercalation and dispersion of the clay in the polymer matrix. The silicate layers of MMT can be delaminated through modification and compounding with a polymer to form a nanocomposite (Fig. 2B, exfoliated structure), resulting in improved tensile properties.



Smectite Group

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Photos of Smectite Group (574)

Saponite	Montmorillonite	Nontronite
Karadag Reserve, Crimea, Russia	Höwenegg Quarry, Immendingen, Tuttlingen, Freiburg Region, Baden-Württemberg, Germany	Iron Monarch open cut, Iron Knob, Middleback Range, Eyre Peninsula, South Australia, Australia

Chemical Properties of Smectite Group Hide

Formula: $A_{0.3}D_{2-3}[T_4O_{10}]Z_2 \cdot nH_2O$

About Smectite Group Hide

Formula: $A_{0.3}D_{2-3}[T_4O_{10}]Z_2 \cdot nH_2O$

Monoclinic clay-like minerals.

Smectite a group name for platy phyllosilicates of 2:1 layer and a layer charge of ~ -0.2 to -0.6 per formula unit. Generally for natural samples, the d(001) spacing is approximately 14.4-15.6 Å, although other spacing may occur depending on H2O retention and interlayer occupancy. The group is further divided into subgroups that are either trioctahedral (according to Bailey, 1980, this subgroup name is "saponite") or dioctahedral (subgroup name of "montmorillonite", according to Bailey, 1980), and these subgroups are further divided into mineral species.
Prior to circa 1975, the smectite group was called the montmorillonite-saponite group.

Smectite minerals have large specific surface areas (10 - 700 m2/g) and exhibit a high expansion (swelling) capability in the presence of H2O. Smectite and vermiculite minerals are often referred to as "swelling" or "expandable" clay minerals. Smectite is commonly a primary constituent of bentonite (see bentonite for respective genesis information) and pelitic sediments (e.g., shales) and occurs in soils.

Positive identification of minerals in the smectite group may need data from dehydration experiments (thermogravimetric analysis, TGA, or differential thermo-analysis, DTA), and X-ray powder patterns before and after treatment by heating and with organic liquids.

The most common members are montmorillonite, nontronite and saponite. A possible V-dominant member is coded as 'UM1979-21-SiO:AlHNaV'.

6.2.2 Gradings

The grading curves for the coarse tailings and slurry are presented in Figure 2 below. The characteristic gradings from the previously work done by SRK for the Kimberley Mines DeBeers Pit backfilling data are also shown for comparison purposes, where it should be noted that the Jagersfontein slimes is, in general, finer than the De Beers slimes although it has slightly more sand-sized particles. The gradings (also called the PSD – particle size distribution) is important since it has a bearing on the permeability/hydraulic conductivity, coefficient of consolidation and on the geotechnical compatibility of the materials in terms of the geotechnical “filter criteria” applicable to piping and stability (Section 6.2.3 below).

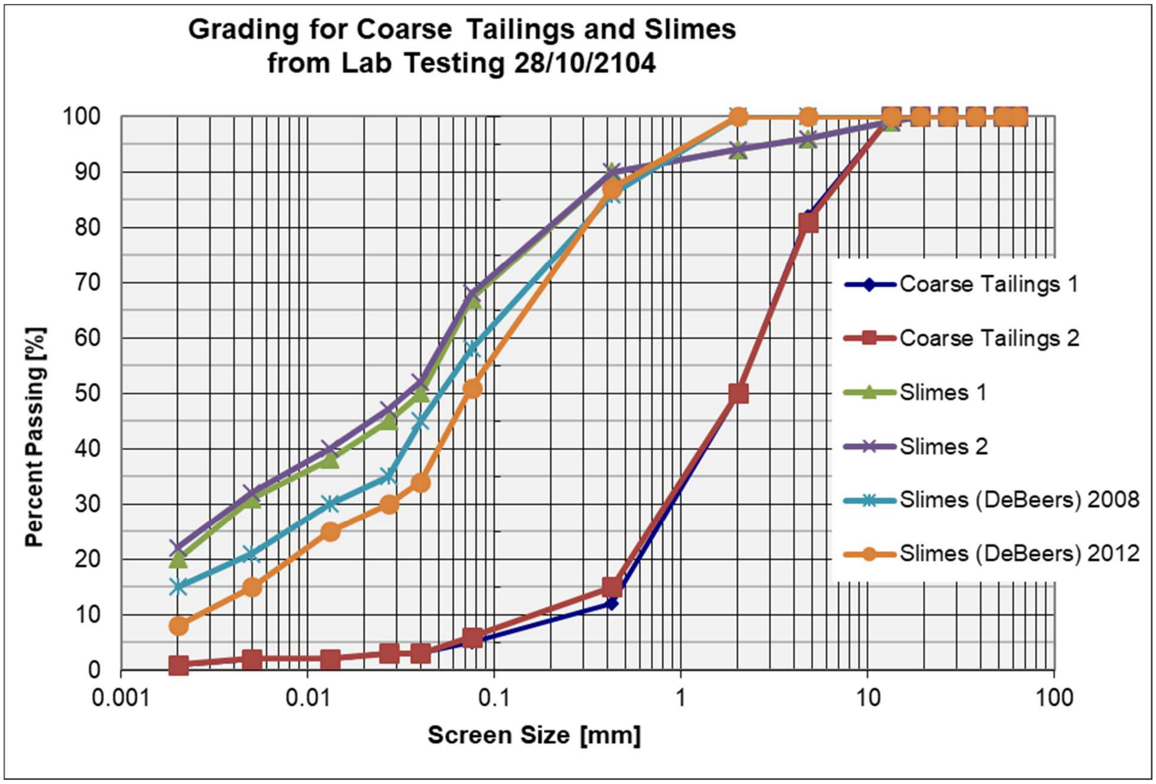


Figure 2: Grading for Coarse Tailings and Slimes (Jagerfontein and De Beers)

6.2.3 Filter Criteria

The grading envelope of the coarse tailings and slimes provides a mechanism for assessing whether the tailings will act effectively as a filter blanket for the slimes. <u>"Filter" in this case is a geotechnical term describing the compatibility criteria between materials in terms of permeability, fines content, internal stability (including piping or internal erosion) and contamination</u>. The criteria are derived from extensive work done by the US Navy, and includes the contribution from Prof Terzarghi; Sherard, Dunnigan and Talbot (1984); and Tan and Weimer et al (1982); resulting in the acknowledged filter criteria as contained in Table 1 below.

Table 1: Filter Criteria for Coarse Tailings retaining Slimes Slurry

Filter Criteria		(r)Retained Material (Slimes)			(f) Filter Material (Coarse Tailings)		
		Fines 1	Fines 2	Ave	Coase T 1	Coase T 2	AVE
D15		0.002	0.002	0.002	0.05	0.05	0.05
D85		0.3	0.3	0.03	5	5	5
D5					0.075	0.075	0.075
D10					0.2	0.2	0.2
D35					1	1	1
D50					2	2	2
D60					2.5	2.5	2.5

Filter Criteria		Formula	Less than	Range		Value	Notes
Terzaghi		$D_{85}(f)$	5			5	OK
Permeability		$D_{15}(f)/D_{15}(r)$		4	20	25	Slightly high but ok
Fines content		$D_5(f)$	0.075			0.075	OK
Internal Stability		$D_{85}(f)/D_{15}(f)$	5			100	
		$D_{50}(f)/D_{35}(f)$	5			2	OK
		$D_{85}(f)/D_{50}(f)$	5			2.5	OK
Cu		$D_{60}(f)/D_{10}(f)$		10	20	12.5	OK
Soil Group	%fines<0.075						
1	85-100%	$D_{15}(f)/D_{85}(r)$	9			1.6666667	OK
2	40-85%	$D_{15}(f)$	0.7			0.05	OK
3	<15%	$D_{15}(f)/D_{85}(r)$	4			1.6666667	OK
4	15 to 40%	$D_{15}(f)$					

The conclusion reached from Table 1 is that the coarse tailings will act as an effective blanket medium for the slurry. This indicates that the slurry will be retained by the coarse tailings. The coarse tailings is, however, free draining. Further comment on the hydraulic conductivity of the material is contained in Section 6.2.5 below.

6.2.4 Densities

The measured densities of the material are tabulated in Table 2.

Table 2: Density Details for Coarse Tailings, Slimes Slurry and ROM

Material		SG	Max Dry Density	OMC%	Insitu Dry Density	Bulk Density	Slurry Density	Source	
			kg/m^3		kN/m^3	kN/m^3	kN/m^3		
			MOD AASHTO		kg/m^3	kg/m^3	kg/m^3		
Coarse Tailings		2.714	2005	10.5	19.0	21.0		Soillab 28/10/2014	
		Assumed			1936.8	2140.7			
Slimes		2.714	1769	17.8			14.7	Site measured	
		Lab					1498.5		
ROM		2.714				17.5		Assumed	
		Assumed				1783.9			

The ROM (Run of Mine) and coarse tailings are quoted in bulk density or dry density respectively since these materials present in tons either entering or leaving the process plant. The in-situ dry density of the tailings is used to calculate the volume of the material that will report to the open pit. The maximum dry density is also quoted and relates to the maximum compacted density that can be achieved under 96% Mod AASHTO compactive effort. This density is used for comparative purposes only, since the material will not be subjected to compactive effort (compaction due to spreading and rolling, as would be the case for road layerworks, for example) but will be deposited by gravity from the conveyor feed, where the in-situ dry density is expected to be less than the maximum.

The fine tailings (slurry) is quoted as a slurry density, meaning that it contains the weight of the water in the assessment of density. In other words, the density is comparable to that of water (10kN/m^3 or 1000kg/m^3). The slurry can, therefore, be considered as “heavy water” and acts as such in-situ.

It is instructive to note that the coarse tailings density (dry) is higher than the slurry density. As a result, the coarse tailings will sink through and displace the slurry, as previously described. This has been observed (in large scale) during the DeBeers Pit filling in Kimberley.

6.2.5 Permeabilities and Coefficient of Consolidation

Table 3 summarises the hydraulic conductivities/permeabilities of the deposited materials.

Table 3: Hydraulic Conductivities and Coefficient of Consolidation

Material	**USCS**	**c_v**	**k**		**Source**
		m^2/year	**m/s**	**m/yr**	
			Hyd Cond/Permeability		
Coarse Tailings	SW-SM		1x10^{-5}	315.36	Grading analysis
Slimes		0.0034	5.56x10^{-13}	1.76x10^{-5}	k:cv relationship
			1x10^{-12}	3.15x10^{-5}	BRT Report
	CL-ML	Soil Lab	1x10^{-9}	3.15x10^{-2}	Grading analysis

The slimes/slurry k (hydraulic conductivity) has been estimated from the grading, from values quoted in the BRT report (Appendix B) and from the relationship between c_v and k. The vast difference in the hydraulic conductivities of the fine tailings/slurry and coarse tailings is illustrated in m/s and m/yr in the table.

The low c_v and k-values for the slimes indicate that the consolidation (or the rate of natural squeezing of water from the slimes) is very slow, of the order to decades and centuries. This illustrates that the interstitial water in the slurry will take a very long time to be removed naturally – considerably longer than the life of mine. Consolidation will be an ongoing process into the future. The result will be that the slimes will remain as a fluid (as is noted in the existing tailings dam) with a thin crust of desiccated material at the surface.

The crust is due to ‘evaporative drying’ of the surface in contact with the air and is also a function of the low permeability of the slimes. The crust will initially tend to be thin (of the order of 100 to 250mm), but with time will desiccate to an increasing depth with time, controlled by the evaporative drying of the material. Below the desiccated crust, however, the slimes will remain fluid. This poses a safety risk to physical entry that the operator needs to be aware of.

6.2.6 Laboratory Testing

Large scale testing commenced in an uncontrolled environment at the home of an SRK engineer, with the purpose of determining the feasibility of conducting a large-scale controlled test in a laboratory environment.

The purpose of the testing is to demonstrate and evaluate the compatibility of the Coarse Tailings (CT) and Fine Tailings (FT) in terms of piping criteria (ie, that the FT is contained by the CT) and that the combined blanket acts as an impermeable membrane deemed better than a Class C barrier system.

Both testing campaigns are ongoing. Nevertheless, interim results obtained to date are presented below.

Uncontrolled large-scale testing

- Start date – 5 September 2021, latest recording date 14 November 2021
- Two columns were set up, fine tailings (618mm high) over coarse tailings (347mm high) (FTE/CTE), and fine tailings (398mm high) only (FTE). Column internal diameter 85mm each
- The columns were placed outdoors, under the cover of a carport (no direct sunlight)
- Readings were taken periodically to record water seepage via the outflow drains installed at the base of the columns
- The fines over coarse (FTE/CTE) column was sealed at the top to prevent evaporation. The fines only column (FTE) was not sealed, but was loosely covered to prevent leaves etc from falling in.
- Water was decanted regularly from the fines over coarse (FTE/CTE) column. It was observed that the level in the outflow pipe rose during the day, dropped overnight, and rose again the following day. [This is postulated to be due to heating and cooling (day/night) resulting in changes of pressure in the column]. When unable to attend to the test (when away from home on site), water spilled from the outflow pipe, despite it being secured vertically on the side of the column, to a height above the contact between the fines and coarse, but not above the level of the fines.
- For the fines only (FTE) column, fines filled the outflow pipe initially, stabilised, and then water started appearing above the fines. The level stabilised at the level of the fines in the column [bleed water].
- Clear water formed at the top surface of both the fines over coarse (FTE/CTE) and fines only (FTE) columns.
- Fresh water was added to the top of the fines only (FTE) column; this appeared to have no impact except for the rise in the level of the outflow pipe.
- Decant readings from the fines over coarse (FTE/CTE) column are tabulated below.

Date	Volume decanted from outflow pipe (ml)
20 September	23
22 September	13
23 September	7
26 September	15
28 September	9
29 September	8
2 October	10
3 October	8
5 October	9
7 October	10
9 October	7
11 October	7
13 October	7

17 October	8
20 October	8
No further readings available due to loss of water from bleed pipe	

- Details of the drop in level of the fines at the top of the columns; 145mm in the fines over coarse (FTE/CTE) with 80mm of clear water formed at the top, and 75mm in the fines only (FTE) column.
- Migration of fine tailings into the coarse tailings over a 2-month period. There was disturbance at the time of pouring the fines into the column, with negligible migration thereafter.

	
16 September 2021	14 November 2021

	
PH3432 – current top of fines. See level of water in outfall bleed pipe. The mark indicates the level of the fines in that pipe	PH3441 – top of fines over coarse. 0mm on tape measure is original top of fines level. Fines consolidated and water formed on the top surface
	

PH3442 – contact between fines over coarse. 0mm is original top of coarse **before** pouring fines into the column	PH3443 – current top of fines. 50mm additional water added to previous top of fines level. Original top of fines at mark at 50mm on tape measure.

<u>Controlled large scale test set-up in a controlled environment in the laboratory (Vietti Slurry Tech)</u>

Samples of coarse and fine tailings were supplied to the Vietti Slurry Tech Laboratory for the construction of a controlled (laboratory monitored) testing similar to that preformed above. The equipment developed for the testing is shown below.

<u>Jagersfontein Large Scale Drainage Tests</u>

<u>Photos</u>

DAY 14 (25 Oct)

Left-hand column – fine tailings over coarse tailings (FTE/CTE). Right-hand column – fine tailings only (FTE).

DAY 35 (15 Nov)

Left-hand column – fine tailings over coarse tailings (FTE/CTE). Right-hand column – fine tailings only (FTE).

Vietti Slurry Tech Laboratory: Draining Tests in progress

Testing is currently ongoing with daily monitoring and measurements. Notes from the laboratory are as follows:

After the initial 14 days of the test (on 25 October 2021), the following was reported:

- Fine tailings overlying the coarse tailings - the fines slowly permeated into the coarse material for the first 7 days of the test but then stopped and have not moved since.
- Seepage water was collected from the bottom of each test column and sent for chemical element analysis. 47ml was collected from the coarse and fine test, 100ml from the fines only test.

A subsequent interim report dated 16 November 2021 reported the following:

EVAPORATION TESTS

SRK-JAG-8936

Sample - "Coarse & Fines"

John Viviers:
Measurements not yet taken

Start Date: - 11 Oktober 2021

Start Time: - 11h00

Valve (Closed/Open)	Settling Time (Days)	Volume Water (Bottom) (g)	Volume Water (Top) (g)	Pictures taken (y/n)	pH (Bottom)	Conductivity (mS/cm)	pH (Top)	Settling Distance (Bed)(mm)	Settling Distance (Fines)(mm)	Water Bottle # 1 - Coarse & Fines (Bottom)
C	0	0	0	y	-	-	-			*10/11/2021 to 10/25/2021 - (Total sample mass 46.81g)*
C	1	0	0	y	-	-	-			
O	2	10.31	0	y	8.25	-	-			
O	3	9.29	0	y	8.23	-	-			
O	4	5.76	0	y	-	-	-			
Weekend										
O	7	4.53	0	y	-	-	-			
O	8	3.73	0	y	8.70	-	-			
O	9	0.19	0	y	8.70	-	-			
O	10	9.13	0	y	8.93	-	-			
O	11	0	0	y	-	-	-			
Weekend										
O	14	8.56	0	y	8.92	-	-			
O	15	1.3	0	y	-	-	-			
O	16	4.2	0	y	-	-	-			
O	17	2.76	0	y	-	-	-			
O	18	2.98	0	y	-	-	-			
Weekend										
O	21	-	-	-	-	-	-	-	-	-
O	22	15.44	21.15	Y	9.01	-	-			
O	23	4.76	0	y	8.86	-	-			
O	24	3.22	0	y	9.03	-	-			
O	25	0.87	0	y	8.93	-	-			
Weekend										
O	28	0.36	6.68	y	9.02	-	8.78			
O	29	9.40	0	y	-	-	-			
O	30	0	0	y	9.02	-	-			
O	31	5.87	0	y	8.93	-	-			
O	32	2.05	0	y	-	-	-			
Weekend										
O	35	2.25	8.9	y	8.98	-	8.86			
O	36					-				
O	37					-				
O	38					-				
O	39					-				
Weekend										
O	42									
O	43									
O	44									
O	45									
O	46									
Weekend										
O	49									
O	50									
O	51									
O	52									
O	53									

EVAPORATION TESTS

SRK-JAG-8936

Sample - "Fines"

Start Date: - 11 Oktober 2021

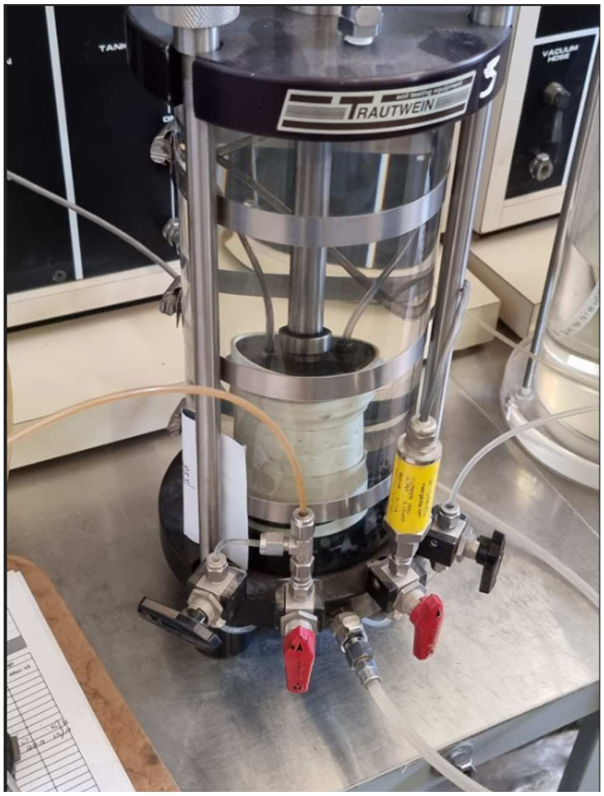
Start Time: - 11h00

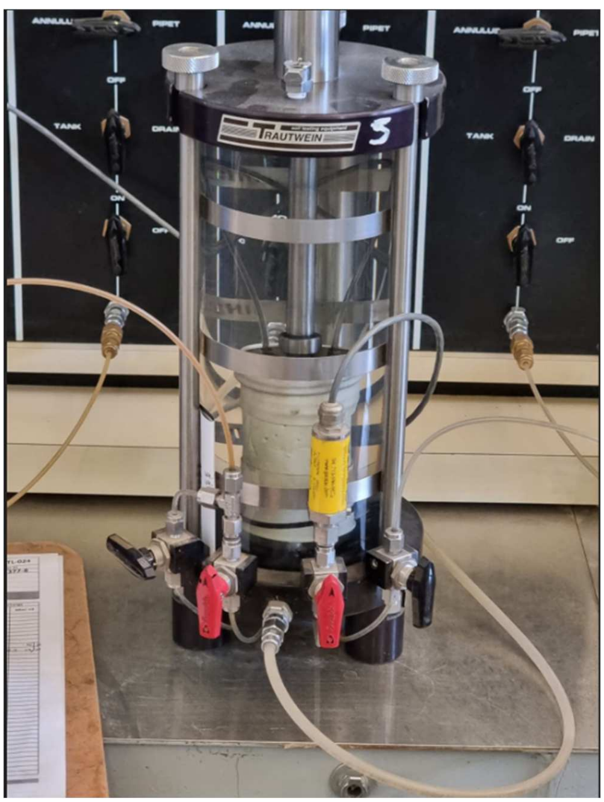
John Viviers:
Measurements not yet taken

Valve (Closed/Open)	Settling Time (Days)	Volume Water (Bottom) (g)	Volume Water (Top) (g)	Pictures taken (y/n)	pH (Bottom)	Conductivity (mS/cm)	pH (Top)	Settling Distance (Bed)(mm)	Settling Distance (Fines)(mm)	Water Bottle # 1 - Fines (Bottom)
C	0	0	0	y	-	-	-			*10/11/2021 to 10/25/2021 - (Total sample mass 100.57g)*
C	1	0	0	y	-	-	-			
O	2	44.19	0	y	8.59	-	-			
O	3	16.32	0	y	8.61	-	-			
O	4	12.23	0	y	8.65	-	-			
Weekend										
O	7	9.23	0	y	-	-	-			
O	8	4.48	0	y	8.96	-	-			
O	9	3.87	0	y	8.83	-	-			
O	10	2.86	0	y	8.86	-	-			
O	11	4.6	0	y	8.73	-	-			
Weekend										
O	14	8.64	0	y	8.79	-	-			
O	15	4.7	0	y	-	-	-			
O	16	5.05	0	y	-	-	-			
O	17	4.05	0	y	-	-	-			
O	18	4.43	0	y	-	-	-			
Weekend										
O	21	-	-	-	-	-	-	-	-	Voting day
O	22	4.49	15.28	Y	9.13	-	-			
O	23	0.95	0	y	9.18	-	-			
O	24	0.98	0	y	9.25	-	-			
O	25	2.36	0	y	9.19	-	-			
Weekend										
O	28	3.21	4.45	y	9.29	-	8.81			
O	29	1.01	0	y	0	-	-			
O	30	1.35	0	y	9.17	-	-			
O	31	1.23	0	y	9.11	-	-			
O	32	1.64	0	y	-	-	-			
Weekend										
O	35	2.14	6.68	y	9.18	-	8.86			
O	36					-				
O	37					-				
O	38					-				
O	39					-				
Weekend										
O	42					-			-	
O	43					-			-	
O	44					-			-	
O	45					-			-	
O	46					-			-	
Weekend										
O	49									
O	50									
O	51									
O	52									
O	53									

Permeability testing (Specialised Testing Laboratory)

A sample of the slurry was sent to Specialised Testing Laboratory to confirm the hydraulic conductivity (permeability) of the fine tailings slurry. For this purpose, a triaxial constant head permeability test is being carried out and is still ongoing (circa 16 November 2021). The equipment used is shown below and the preliminary conclusions are summarised in Section 6.2.7.





Specialised Testing Laboratory: Triaxial Constant Permeability Testing on Slurry in progress

6.2.7 Preliminary Conclusions from Testing

Even though the laboratory testing described above (Section 6.2.6) is still ongoing, the following preliminary conclusions have been reached:

- Specialised Testing Laboratory's hydraulic conductivity (permeability) test on the smectite-rich slurry, has been underway for approximately 6 weeks. To date, the flushing, saturation and 90% of the consolidation cycle has been completed. The best estimate of hydraulic conductivity of the slurry, at this stage, is $<10^{-11}$m/s (<0.000315m/y = <0.315mm/y). The results of the test are only expected by the end of January 2022. The time taken for the test is indicative of the very low permeability of the smectite-rich slurry and the conclusion that the slurry is indeed practically impermeable and better than a Class C barrier or the parent rock and aquifers.

- The observations from the uncontrolled column tests indicate the following:
  - The FT does not pipe into the CT confirming that the two materials are compatible in terms of geotechnical filter criteria. The slurry, therefore, forms a practically impermeable membrane at the CT/FT interface, which remains unchanged with time.
  - A limited volume of water, due to the initial moisture content for the CT leads to some initial drainage. After about 7 days the drainage effectively ceases, with the conclusion that slurry does not allow additional moisture to pass.
  - The addition of water above the slurry (simulating rainfall), appears to have no impact on the drainage, hence confirming the impermeability of the slurry.

- The observations from the laboratory-controlled (Vietti Slurry Tech) column tests, indicate the following:
  - All relevant observations from the uncontrolled columns tests (above) are confirmed.
  - After two weeks the minimal drainage from the FTE/CTE and FTE columns are similar. This indicates that the initial free water (moisture content) of the CT has drained in the first 7 days and little to no water passes through the slurry.
  - The CT/FT interface remains unchanged with time indicating a competent seal/ membrane.

- The overall conclusion reached is that the fine tailings (FT) form a competent and practically impermeable membrane over/against the coarse tailings (CT) blanket (ref Prof Wayne Colliston expert report) that behaves better than a Class C barrier system or the host rock since the characteristics of the FT/CT membrane develops hydraulic conductivities less than $1x\ 10^{-11}$m/s (which is 0.000315m/yr or 0.315mm/yr). This hydraulic conductivity is orders of magnitude less than the jointed parent rock of the pit walls (estimated by GHT Consulting) compared to the upper aquifer ($2x10^{-5}$ m/s), dolerite sill and fractures and the lower aquifer (between $1.157x10^{-9}$ and $1.157x10^{-7}$). This conclusion is the justification that a constructed/manufactured (liner) barrier system is unnecessary for this application (pit backfilling).

6.3 Geochemistry Aspects

Appendix F contains the waste classification of the slime stream from the process plant (note that the report refers to 'tailings' but in this context, it is the fine tailings slurry or 'slimes' that has been evaluated. The conclusions reached in that document are as follows:

- The Norms and Standards assessment of the total metal concentration of Ba, Co, Cu and Ni exceed the TCT0 limit but did not exceed the TCT1 limit. The metals are however relatively immobile under the alkaline conditions of the tailings/slimes and are not mobilised into a leach solution, with all their LC below the LCT0 limit.

- The LC of TDS and SO_4 exceeded the LCT0 limit but did not exceed the LCT1 limit.
- Overall, the fine tailings/slimes is assessed to be Type 3 low risk waste with TC ≤ TCT1 and LCT0 < LC ≤ LCT1
- The fine tailings/slimes therefore theoretically requires a Class C barrier system. However, since the constituents of the fine tailings/slimes are not mobile and the hydraulic conductivity is extremely low (Section 6.2.5) meaning that migration is very slow (if at all), the risk of contribution to a plume is negligible. This is discussed further in Section 6.4: Hydrogeology below. In addition, experience with DeBeers pit backfilling in Kimberley and the practical and physical aspects, restrictions and limitations of the pit mitigates against the use of liners (in the traditional sense) of any kind.

6.4 Geohydrology

The assessment of the geohydrological aspects of the backfilling of the Jagersfontein Pit by GHT Consulting is contained in Appendix I. This document reports on the risk-based approach to assessing the conditions for plume development from the backfilled pit.

The conclusions from this study noted the following:

- A comparison between the simulated groundwater elevations of modelled Scenario1 and Scenario 2 (details can be found in Appendix I) do not indicate decanting of the pit. No additional evaporation due to open-pit conditions has been simulated and it is anticipated that the rise in water table elevations in the pit would, in reality, be even slower due to evaporation. It is therefore not expected ever to reach natural groundwater elevations as the evaporation by far exceeds precipitation combined with groundwater influx (which diminishes with restoring of groundwater gradients as the water level rises).
- The current simulated pollution plume, as well as comparisons between the two scenarios, indicate improvement in the pollution plumes after the end of operation due to natural attenuation. However, earlier improvements are visible in the simulated plumes of scenario 2 due to earlier removal of the pollution sources (transferred to the pit). Simulations indicate limited pollution plume migration from the filled pit due to a few reasons:
    - Filling of the pit would not reach the surface and would thus not reach the base of the exploitable aquifer,
    - Geohydrological properties of the fine tailings/slimes (low permeability and moisture retention).
- If evaporation is considered (not simulated due to complexities and model stability), it is envisaged that the groundwater table in the pit will be even lower whereby groundwater gradients would remain towards the pit and thus further have a localising effect on the pollution plume migration.

This report confirms that special barrier systems are not required and that backfilling of the pit according to the procedures outlined above will not negatively affect the environment. **In fact, the procedure of backfilling the pit will be beneficial to the area since the waste load on the surface will be substantially reduced.**

6.5 Surface Water

Surface water catchment areas are mainly to the west and northwest of the Jagersfontein Pit. To assess the likely flow in the environs of the pit from storm events, a high level hydrological and surface water flow analysis has been carried out. Since the stormwater flow could interact with the coarse and fine tailings deposition process if not controlled, the volume and flow rates under the various likely storm events have been assessed.

This section considers these aspects in some detail but also contains some assumptions that will need to be clarified during the implementation phase, if applicable.

6.5.1 Rainfall data

Rainfall data from the South African Weather Service was obtained from the Kunz (2019). The closest station was Jagersfontein 0229737 which has over 90 complete years of data. The daily data was summed into monthly data and any months with incomplete data removed. An annual average of about 420 mm was estimated from the data, a median annual rainfall of 386 mm and a minimum annual rainfall value of 96 mm. The annual data shows significant variability of the years as shown in Figure 3.

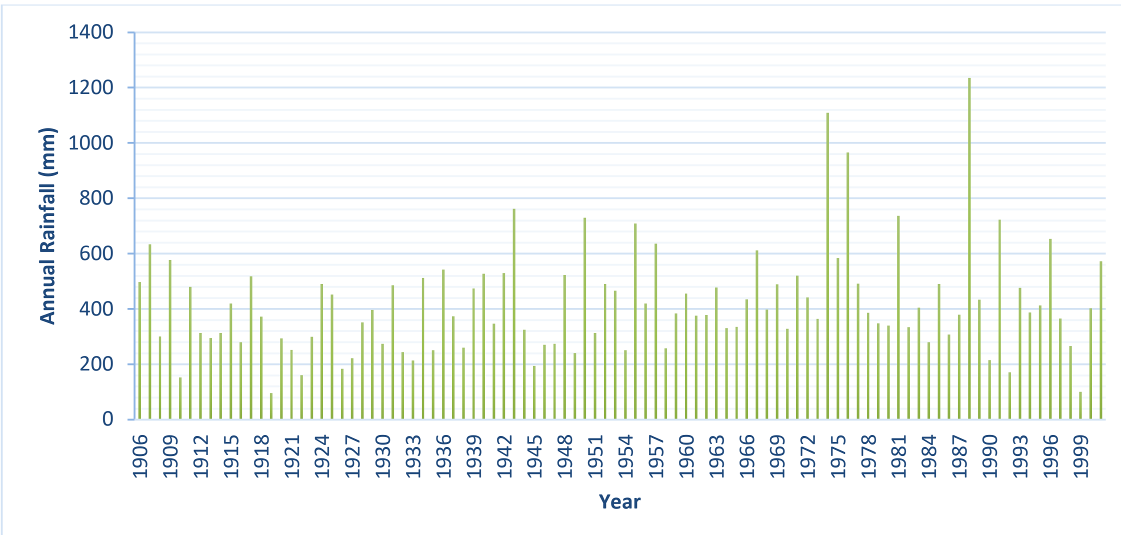
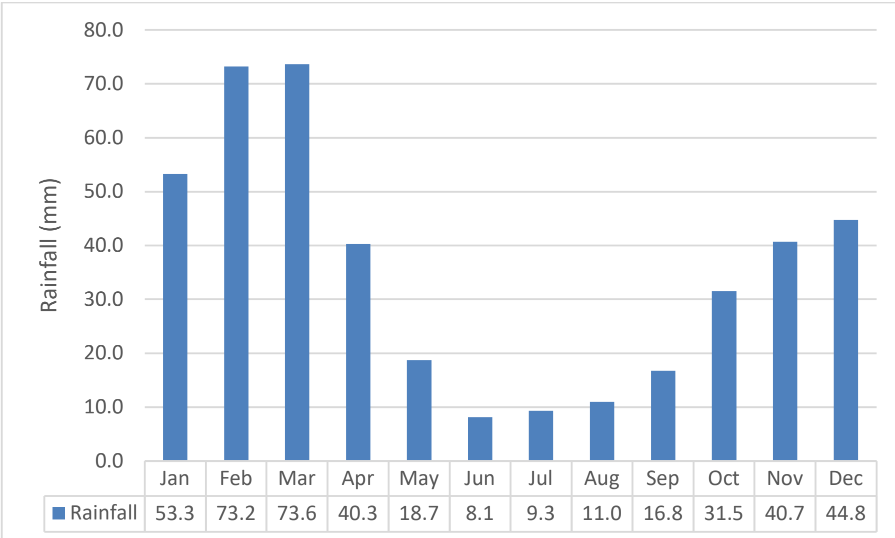


Figure 3: Annual Rainfall Record for Jagersfontein

Monthly averages were then calculated and are shown in Figure 4. Rain falls in all months of the year but peaks in February and March.

Figure 4: Monthly Average Rainfall at Jagersfontein (0229737)



6.5.2 Catchment delineation

Catchments were delineated using 5-metre contours from the South African Topographic series of maps and information from a site visit conducted by SRK engineers (Figure 5). At the site visit, it was observed that 2 culverts convey runoff from the catchments into the pit with the help of small canals. Consequently, the catchments contributing to the pit do not follow the natural catchment boundaries exactly although they are mostly aligned with these. In particular, the S Inlet Remainder catchment (Figure 5) includes a portion to the east of the inlet that would not drain to that inlet if it were not for a small canal directing water in that direction. The exact mechanism of drainage into the eastern side of the pit from the Eastern Catchment is unknown (culverts or overland flow or uncontrolled erosion channels). However, the runoff from this catchment is relatively small and the mechanism of drainage will not materially affect the volume of drainage. The catchments and their surface areas are summarised in Table 4 as well as some information on dams, which is also discussed below.

The exact areas contributing to each inlet to the Pit will be affected by four dams in the upper catchment. One dam, Loskop Dam, was mentioned in an earlier report (EKO Environmental 2013) but all the others are named for ease of reference in this report with names reflecting their general location or shape. Each catchment was divided into sub-catchments based on the dams. It is not known whether the dams are being used for water supply or not or if the walls of the dams are intact. This will need to be verified.

Table 4: Catchments

Catchment	Area (m^2)	Comments
S Inlet Catchment	5 866 585	This catchment contains 2 dams, it is unclear if either is functional. Directly downstream of one dam is a disturbed, very poorly draining area, where water is visibly collecting. It is likely that much of the runoff from this catchment is getting trapped at this location
NW Inlet Catchment	7 464 403	This catchment contains 2 dams, it is unclear if either is functional
E Catchment	258 052	This is the small catchment to the east which drains towards the pit. Exact entry points to the pit are unknown
Pit Area	214 282	

Another area that will affect the catchment of the pit is an area of poor drainage immediately downstream of the Moon Dam. Based on the aerial image, this area appears to be a borrow pit. Both the contours and ponding water, visible on the aerial image, suggest that this area is very poorly draining and prevents some of the runoff from the Moon Dam catchment from reaching the pit, even if water is released from the Moon Dam. During the implementation phase of this project, the site will require further investigation/assessment/ground-truthing to develop a more accurate assessment of surface drainage.

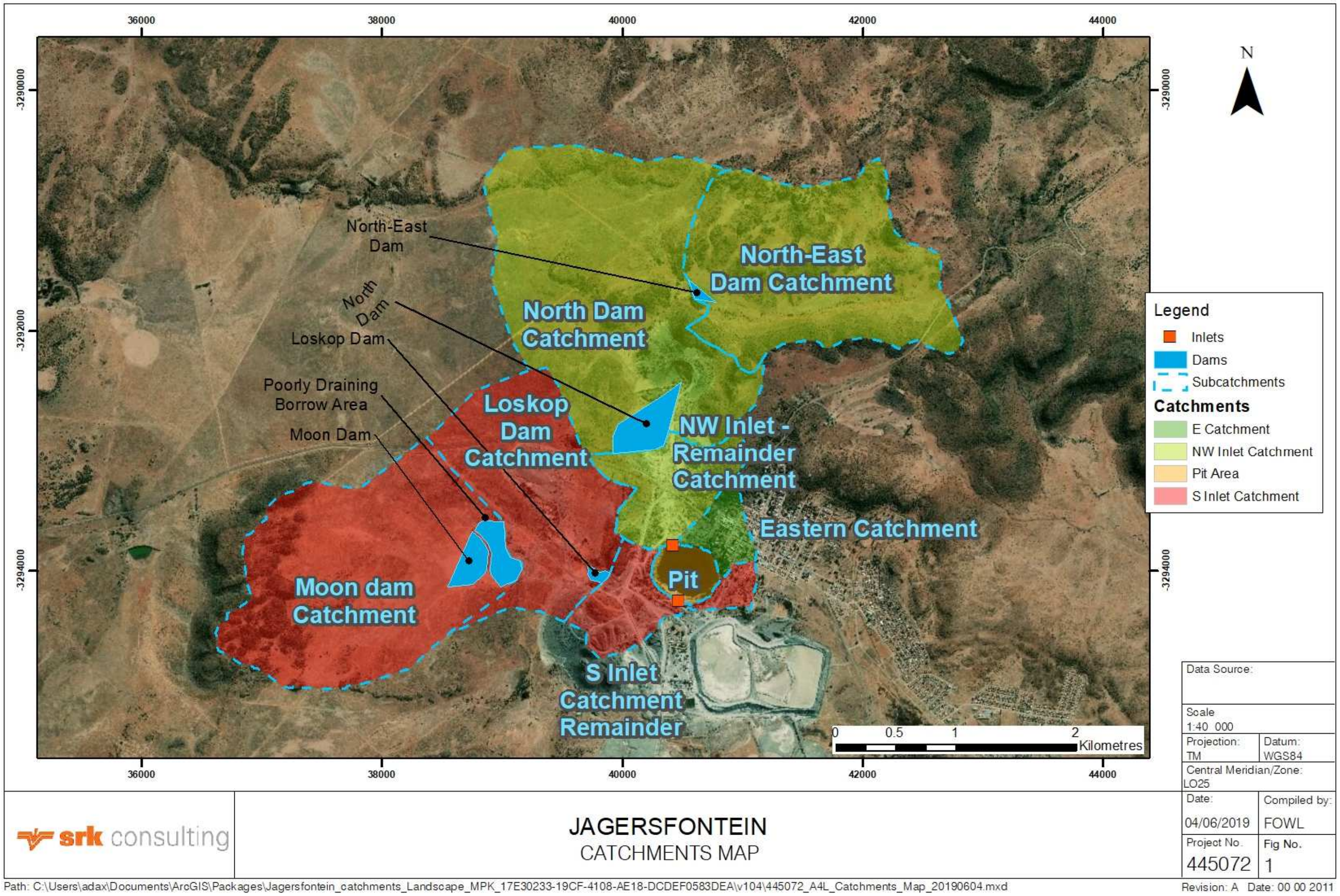


Figure 5: Jagersfontein Catchments Map

6.5.3 Runoff Calculation methods

WR2012 is a national database maintained by funding from the Water Research Commission. It is the culmination of a number of water resource appraisals that have been carried out over the past four decades. SCS or Soil Conservation Service method is a method of estimating catchment runoff based on the soil type and land use in an area. It was developed by the United States Department of Agriculture and can be applied to both small and large rainfall events. These two methods are commonly used in South Africa as estimation methods and are a good first estimation prior to hydrological modelling.

Runoff was calculated using WR2012 data and checked using the SCS method. In general, the methods provide an estimate of the runoff ranging from 5 to 15% of the annual rainfall, depending on the location, soil type and land usage.

6.5.4 Runoff – WR2012 Method

WR2012 provides average annual runoff for each quaternary catchment in South Africa and estimates a runoff of 21.7 mm per year for the Jagersfontein Catchments (21.7/386=5.6%). Using the catchment areas, the runoff to the pit can be estimated as about 300 000 m^3 per annum to the pit (based on the estimate contributing catchment area) if all parts of the catchment contribute. However, if none of the catchments with dams contribute (ie all runoff from these catchments is contained by dams) the number drops to about 40 000 m^3 per annum.

Table 5 Runoff for catchments calculated using WR2012

Name	Area	Full Catchment		Without areas behind dams		
Catchment	**Area (m^2)**	**MAR (mm)**	**MAR (m^3/annum)**	**Area (m^2)**	**MAR (mm)**	**MAR (m^3/annum)**
S Inlet Catchment	5 866 585	21.7	127 305	614 406	21.7	13 333
NW Inlet Catchment	7 464 403	21.7	161 978	723 250	21.7	15 695
E Catchment	258 052	21.7	5 600	258 052	21.7	5 600
Pit Area	214 282	21.7	4 650	214 282	21.7	4 650
Mean Annual Runoff to Pit	**13 803 322**		**299 532**			**39 277**

It is important to note that the pit area receives direct “runoff”. To calculate the amount of rain that reaches the bottom of the pit due to rainfall on the direct area of the pit, the rainfall should be multiplied by the pit area and evaporation subtracted. Using the average rainfall calculated in Section 6.5.1, approximately 90 000 m^3 of rain falls on the pit area each year. The evaporation is more difficult to estimate because evaporative conditions in the Pit will be unique because of the pits’ depth, shadows and wind. Consequently, regional evaporation rates or rates from nearby weather stations will not be representative of the pit. Nonetheless, it can be concluded that direct rainfall on the pit will not increase the average volume of surface water reaching the pit beyond the range of 390 000 m^3 (considering the full catchment areas plus the pit) to 130 000 m^3 (excluding the areas contained by dams plus the pit) per year.

6.5.5 Runoff - SCS Method

The SCS method was used to calculate daily runoff from daily rainfall values. The SCS method assumes that limited runoff occurs during light rainfall with the exact number of millimetres required to generate runoff determined by the land use. If the catchment needs to be modelled in more detail, then the rainfall patterns of the area should also be included.

For this analysis, the land-use was assumed to be sparse veld for most of the area and a combination of disturbed veld and rock dumps for the catchments that did not include dams. The estimate SCS curve numbers for these two land uses were 60 and 65 respectively. The curve numbers were based on recommended SCS curve numbers for South African veld conditions (SANRAL 2006) as well as SRK experience with hydrological investigations on mines.

The calculated mean annual runoff using SCS is shown in Table 6 and compared to the WR2012 method. The methods yielded similar results with the SCS method slightly higher because it considered the disturbed land use and actual rainfall data.

Table 6: Mean Annual Runoff calculated by the SCS method and compared to the WR2012 method

Catchment	MAR (m^3/year) using SCS Method	MAR (m^3/year) WR2012 Method
Full Catchments		
NW Inlet Catchment	191 615	161 978
S Inlet Catchment	150 598	127 305
E Catchment	6 624	5 600
Pit Area*	89 998	4 650
Total	**438 836**	**299 532**
Catchment assuming sub catchments of dams do not contribute		
NW Inlet Partial	24 959	15 695
S Inlet Catchment - Partial	21 203	13 333
E Catchment	6 624	5 600
Pit Area*	89 998	4 650
Total	**142 785**	**39 277**

* SCS method assumes full rainfall volume. In reality this will likely be lower due to evaporation. Evaporation cannot be estimated at this time as evaporative conditions in the pit are not represented by data from nearby weather stations

The SCS method was also used to estimate mean monthly runoff and the results are shown in Table 7. The runoff is high in the summer months and low in the winter months.

Table 7: Mean monthly runoff for the catchments contributing to the two inlets

Month	NW Inlet Catchment	NW Inlet Partial	S Inlet Catchment	S Inlet Catchment - Partial
Jan	24 879	3 245	19 553	2 757
Feb	41 132	5 233	32 327	4 446
Mar	38 884	4 980	30 561	4 230
Apr	15 084	2 019	11 855	1 715
May	6 925	911	5 442	774
Jun	2 251	308	1 769	262
Jul	3 063	415	2 407	353
Aug	3 688	495	2 899	421
Sep	7 489	965	5 886	819
Oct	11 959	1 604	9 399	1 363
Nov	17 269	2 285	13 573	1 941
Dec	18 993	2 499	14 927	2 123

6.5.6 Runoff – Extreme Events

The runoff generated during a 1 in 50 and 1 in 100 year rainfall event was calculated using the SCS method as **380 000 m^3** and **470 000 m^3**respectively The rainfall depths for these events were extracted from the Design Rainfall Program (Smithers et al. 2002) and are shown in Table 8. The catchment area, mean catchment slope (1%), river length (4960m) and climatic zone (2) were used as inputs to the SCS model.

Table 8: Design Storm rainfall values for Jagersfontein

Design Rainfall Data (mm) interpolated from six closest stations							
Mean annual rainfall	414	mm	Latitude	29	degrees	45	minutes
Altitude	1453	mamsl	Longitude	25	degrees	25	minutes
Storm duration	**Return Period (Years)**						
	2	**5**	**10**	**20**	**50**	**100**	**200**
5 minutes	8.8	12	14.2	16.4	19.3	21.5	23.8
15 minutes	15.1	20.5	24.3	28	32.9	36.7	40.7
1 hour	23.5	32	37.8	43.6	51.3	57.3	63.4
1.5 hours	26.7	36.4	43.1	49.7	58.4	65.2	72.2
2 hours	29.3	39.9	47.2	54.4	64.1	71.5	79.1
8 hours	41.3	56.3	66.6	76.8	90.4	100.9	111.6
24 hours	54.3	74	87.5	100.9	118.7	132.5	146.6
5 day	72.6	98.9	117.1	135	158.8	177.2	196.1

6.5.7 Runoff - Summary

In summary, annual surface water flows in the environs of the pit are likely to be 300 000 to 400 000 m^3 if the full catchment contributes or between 40 000 to 130 000 m^3 if the dams block off all flows from the upper catchments. In a 1 in 100-year storm event, and assuming that all catchments contribute, a volume of 470 000 m^3 is possible. This volume will be received in a few days rather than over the entire year.

These volumes must be considered in perspective with the proposed monthly deposition volumes (Section 7.2 below) which amount of a total of between 300 000 and 350 000m^3/month. The water inflows are therefore equivalent to about one month of deposition or 1/12 of the annual deposition volume. This is therefore considered small and thus relatively inconsequential to the backfilling process.

The depositional strategy takes cognisance of the possible contamination of the process water source from the tailings to the main shaft pumps (Section 7.4) and recommends that alternative water sources be investigated. To continuosly assess the water quaitly, the monitoring plan proposed by GHT Consutling must be implemented before backfilling commences.

6.5.8 Canal sizing

It is recommended that a channel bypass system on the western side of the pit be installed to prevent runoff water from entering the pit from the northern and western catchment areas. For this purpose, a conceptual channel sizing has been undertaken to cater for the various storm events. The details for a channel to accommodate the 1:100-year storm event are shown in Appendix F.

6.5.9 Recommendations with respect to surface water

The following recommendations pertaining to surface water management are indicated for the implementation stage:

- The status and/or upgrading plans for the dams in the catchments should be investigated since this greatly affects the inflows required to provide a reasonable estimate of channel flows and concept designs for the by-pass channels required to prevent inflow into the pit.
- The accuracy of the runoff prediction can be improved by modelling with the software PC-SWMM.
- If further accuracy of the runoff is required (to within 25 %) then evaporation should be measured and a water balance completed for the direct rainfall onto the pit.

References

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7 Backfill Design Aspects

7.1 Actual Production Rates

Data received from JD for ROM (Run of Mine), coarse tailings (CT or grits) and fine tailings (FT or slimes) confirm the target and actual production rates from January 2017 to May 2019 – noted as "previous" in the tables below. Table 9 represents the actual (achieved) production rates for the ROM and CT for the period January 2017 to May 2019, and for the FT for January 2018 to April 2019. This information, therefore, gives an accurate assessment of the rates achieved during this period. The table also gives the average monthly production rates achieved over the respective months.

The data is shown graphically in Figure 6 and Figure 7. Figure 6 shows the production in tpm (tons per month) for the ROM and CT with the FT (slimes) in m^3/month. Figure 7 shows the production in m^3/month, assuming a density of 1.6 for the ROM and CT.

Jagersfontein					
Previous Production Rates			**Jan 2017 to May 2019**		
Source:	**JD**		**May-19**		
Month	**Units**	**ROM (t)**	**CT (t)**	**Units**	**Slimes (m^3)**
Jan-17	t	238464	140029	m^3	
Feb-17	t	288880	184910	m^3	
Mar-17	t	339186	204162	m^3	
Apr-17	t	311703	200533	m^3	
May-17	t	336431	207232	m^3	
Jun-17	t	300879	187997	m^3	
Jul-17	t	302295	202438	m^3	
Aug-17	t	306389	205788	m^3	
Sep-17	t	308808	190880	m^3	
Oct-17	t	317062	190465	m^3	
Nov-17	t	301232	180556	m^3	
Dec-17	t	123376	73376	m^3	
Jan-18	t	237226	139028	m^3	69396
Feb-18	t	269285	165817	m^3	130707
Mar-18	t	320693	197063	m^3	163220
Apr-18	t	312881	191489	m^3	108104
May-18	t	303411	182019	m^3	96492
Jun-08	t	290235	187075	m^3	185939
Jul-18	t	302186	203578	m^3	124355
Aug-18	t	303338	218457	m^3	154692
Sep-18	t	293865	215371	m^3	118368
Oct-18	t	312920	219777	m^3	124934
Nov-18	t	296720	216379	m^3	157529
Dec-18	t	118070	80951	m^3	0
Jan-19	t	243258	165459	m^3	156223
Feb-19	t	255632	184786	m^3	127710
Mar-19	t	314012	195649	m^3	189278
Apr-19	t	297397	204790	m^3	190765
May-19	t	153951	99330	m^3	
TOTAL	t	8099785	5235384	m^3	2097712
No of Months	no	29	29		16
Average	tpm	279302.9	180530.5	m^3/m	131107

Table 9: Previous Production Rates for ROM, CT and Slimes (Jan 2017 to May 2019)

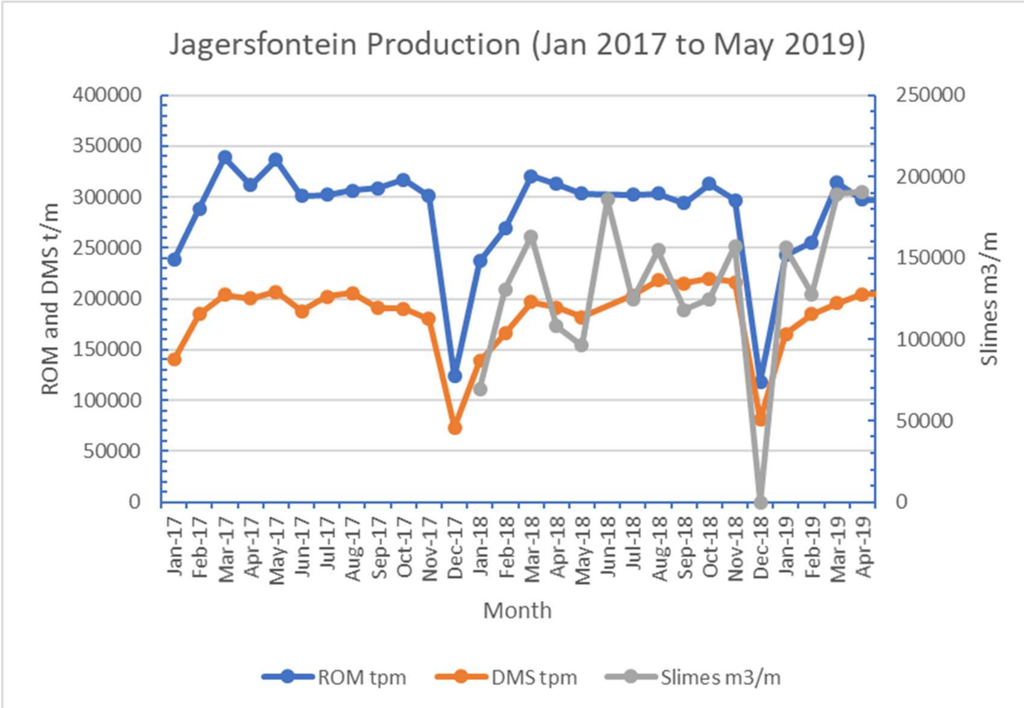

Figure 6: Previous Production Rates for ROM, CT and Slimes (Jan 2017 to May 2019) (units of tpm and m³/m)

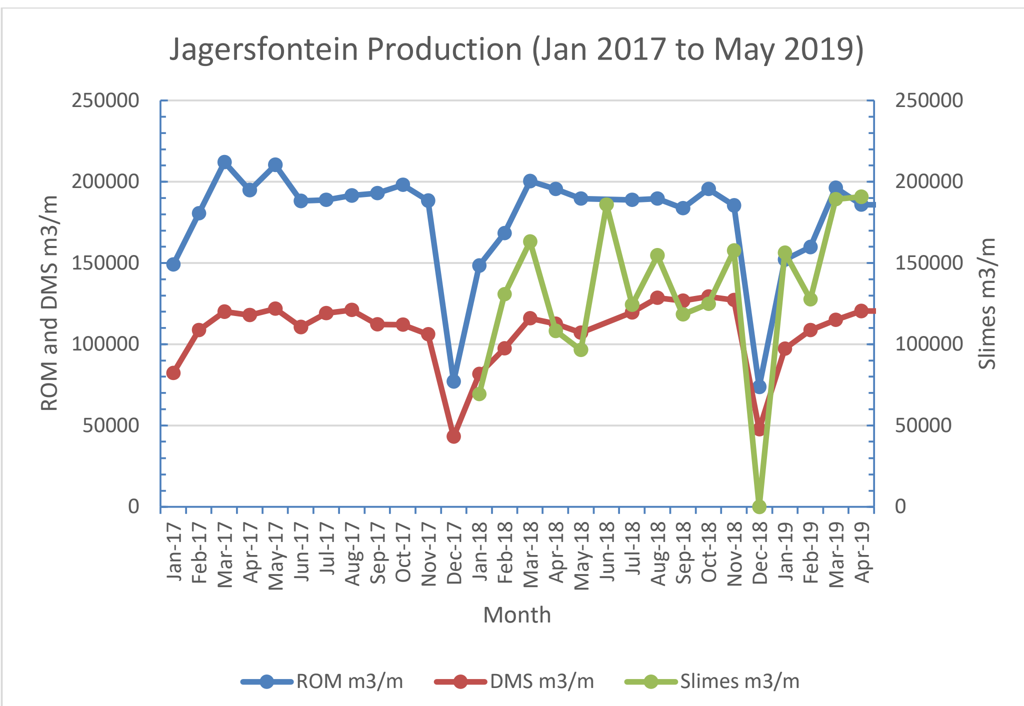

Figure 7: Previous Production Rates for ROM, CT and Slimes (Jan 2017 to May 2019) (units m³/m)

The information from this analysis is used to predict the likely production rates in Section 7.2.

7.2 Planned Production Rates

Recently (May 2019), a new pan plant has been installed that has increased the production rates – these planned production rates are used in Table 10 to predict the life of mine using the information available from the mine and assessed densities (from Section 6.2.4) and the analysis of the actual production rates (from Section 7.1).

Table 10: Production Rates: Planned and Likely

Jagersfontein										
Production Rates Planned and Likely										
Material		**Remaining Stockpile**		**Planned Production**			**Time**	**Total**	**Likely Production**	**Time**
Units	**Statisitics**	**Mt**	**m^3**	**(tph)**	**(tpm)**	**(m^3/m)**	**(mths)**	**(m^3)**	**m^3/m**	**(mths)**
ROM		36	18587368	700	504000	260223	71.43		201892	92.07
Tailings				550	396000	204461		14604361	170886	
				(m^3/h)	**(m^3/m)**	**(m^3/m)**				
Slimes	Min			175	126000	126000		9000000	112377	
	Max			250	180000	180000		12857143	149837	
	Average			212.5	153000	153000		10928571	131107	
							Average	25532932		

Table 10 summaries the planned and likely production rates for the ROM, coarse tailings and fine tailings (slimes) production.

The 'planned' production rate has been provided by JD (ROM = 700tph = 504000tpm; Coarse Tailings = 550tph and Fine Tailings (Slimes) varying between 175 and 250m^3/h). This assessment indicates that the Life of Mine is 71.43 months (≈ 6 years).

The 'likely' production rate has been assessed from the analysis of the actual production rates achieved since January 2017 (Table 9) and prorated for the increase in ROM production from 500tph to 700tph with the addition of the new pan plant. The likely ROM, coarse tailings and fine tailings (slimes) volumes from this analysis are 201892, 170886 and 131107$m^{3/}$month respectively. This assessment indicates that the Life of Mine could extend to 92.07 months (≈ 7.7 years).

The stage capacity curve for the backfilling of the pit is shown graphically in Figure 8.

Recently, the plant recommenced operation in mid-2021 after the installation of 'flat bed' cyclones in the production cycle. Thereafter, measurement of the feed volumes of CT and FT to the FTSF was carried out. Initially, the volumes were measured as:

- CT + Sand: 207 000m^3/month
- FT: 92 405m^3/month

After some optimisation, the latest production volumes are:

- CT + Sand: 155 192m^3/month
- FT: 97 620m^3/month

The volumes will be used in the updating and development of the stage capacity assessment and deposition planning for the pit backfilling operation in due course.

7.3 Construction Aspects

Illustrative drawings consisting of a layout plan, together with yearly production plans and indicative section areas are contained in Appendix K.

The construction aspects are relatively simple and consist of:

- Construction of a feed conveyor for the tailings from the north-eastern side of the current plant to a point on the southern rim of the pit via a point to the east of the Main Shaft. This represents a distance of some 750m. The route requires planning on-site to optimise the interference with roads and services and to locate under- or over-pass culverts for that purpose.

  Consideration has been given to a multiple point discharge along the southern rim of the pit using secondary conveyors. For this purpose, modelling of the deposition fan from three points approximately 100m apart was undertaken. The final discharge fan was, however, little different to that from a single discharge point and therefore, no benefit accrued. The multiple conveyor discharge system was therefore abandoned in favour of a single point discharge initially.

  Depending on the initial development of the CT blanket, during optimisation of the site operations, consideration will be given to extending the conveyor system to the east, west and north to create a more even distribution of coarse tailings around the periphery of the pit that will also provide additional stability to the pit walls.

  The conveyor system proposed for the backfilling will not cause any associated vibration, break backs or incsed pit instability since no heavy machinery will be used. This will be a silent activity with the material being dumped from the conveyor, and being relatively fine material (particle size -8mm with no boulders), impact noise will be insignificant.

- Construction of a slurry pipeline to the slurry discharge point on the eastern side of the pit. It is proposed that the slurry pipeline follows the alignment of the coarse tailings conveyor to its termination point and then diverts eastward to the designated discharge point. Since the slurry will act like a ‘heavy’ fluid, the position of discharge is of lesser importance provided that the slurry enters the pit into the already deposited slimes pool. Given its fluid-like physical behavioural characteristics, a near-horizontal surface will form. This is evident in the FTSF where a single discharge depositional point is used.

7.4 Deposition strategy

Coarse tailings deposition is required to take place for a period of 3 to 4 months before the commencement of slurry deposition. This period will allow the coarse tailings to form a blanket of a minimum thickness of 10m to develop in the basin with a deposition cone from the southern rim. The progress of coarse tailings deposition will need to be monitored during the initial deposition to assess the effective beaching angle (angle of repose or flatter?) and the apparent depth of the coarse tailings blanket before the introduction of the fine tailings slurry. From observations on site, the beaching angle of the coarse tailings is likely to be about 15° to 25˚ initially, but this may change depending on the water content of the tailings, evaporation and gravity compaction.

Fine tailings slurry deposition will form a pool at the lowest point of the pit (it having been already covered by coarse tailings). Thereafter, co-disposal of the coarse tailings from the conveyor discharge point at the south rim and fine tailings slurry discharge from the eastern discharge point will proceed. Since the coarse tailings is denser than the slurry, a conical fan ‘beach’ will develop progressively under the slimes from south to north (as indicated in the drawings in Appendix I, causing the slurry to be displaced and increase/rise in elevation continuously. At this stage, monitoring of the shape and levels of the coarse tailings fan and the level of slurry will be required on a weekly basis. The beach angle of the coarse tailings will likely change (increase) at the contact with the slimes (as the slurry will exhibit some minor shear strength with time) and it will be advantageous to measure this angle so that future predictions over the life of deposition can be made to provide information for possible adaptations to the deposition method if necessary. During deposition and depending on the shape of the coarse tailings blanket, consideration will be given to extending the conveyor system to allow deposition around the periphery of the pit. Realignment of the slurry pipeline will also be required in this situation.

The deposition strategy has been designed to develop a blanket of coarse tailings over the southern side of the pit and over the pit base and to increase the blanket thickness with time during the co-disposal phase, since the permeability and the presence of voids in the pit base and sidewalls are not known (save for the fact the C&A Consultants could not find any entry points to the shaft. As an ongoing monitoring protocol, the quality of the water abstracted from the shaft should be tested and reported weekly to give forewarning of any piping occurring underground according to the monitoring protocols proposed by GHT Consulting.

7.5 Monitoring protocols

The protocols for monitoring are covered in concept in Section 7.4 above and will be developed further during the follow-up implementation stage. Monitoring and monitoring frequency should, as a minimum, include the following, some of which are already recorded:

- Regular weekly measurement and recording of the coarse tailings and slurry densities and water content.
- Weekly production volumes of coarse tailings and slurry
- Monthly monitoring of the water quality vis-à-vis slurry content.
- Weekly measurement and recording of the coarse tailings beach angle and levels.
- Weekly measurement and recording of the slurry levels
- Monthly mass/volume balance between production volumes and levels in the pit.
- Monthly geometric mapping of the coarse tailings and slurry plan areas
- Additional data as may be deemed to be necessary during further assessment/design.

These monitoring protocols are further developed by GHT Consulting referenced in Appendix I.

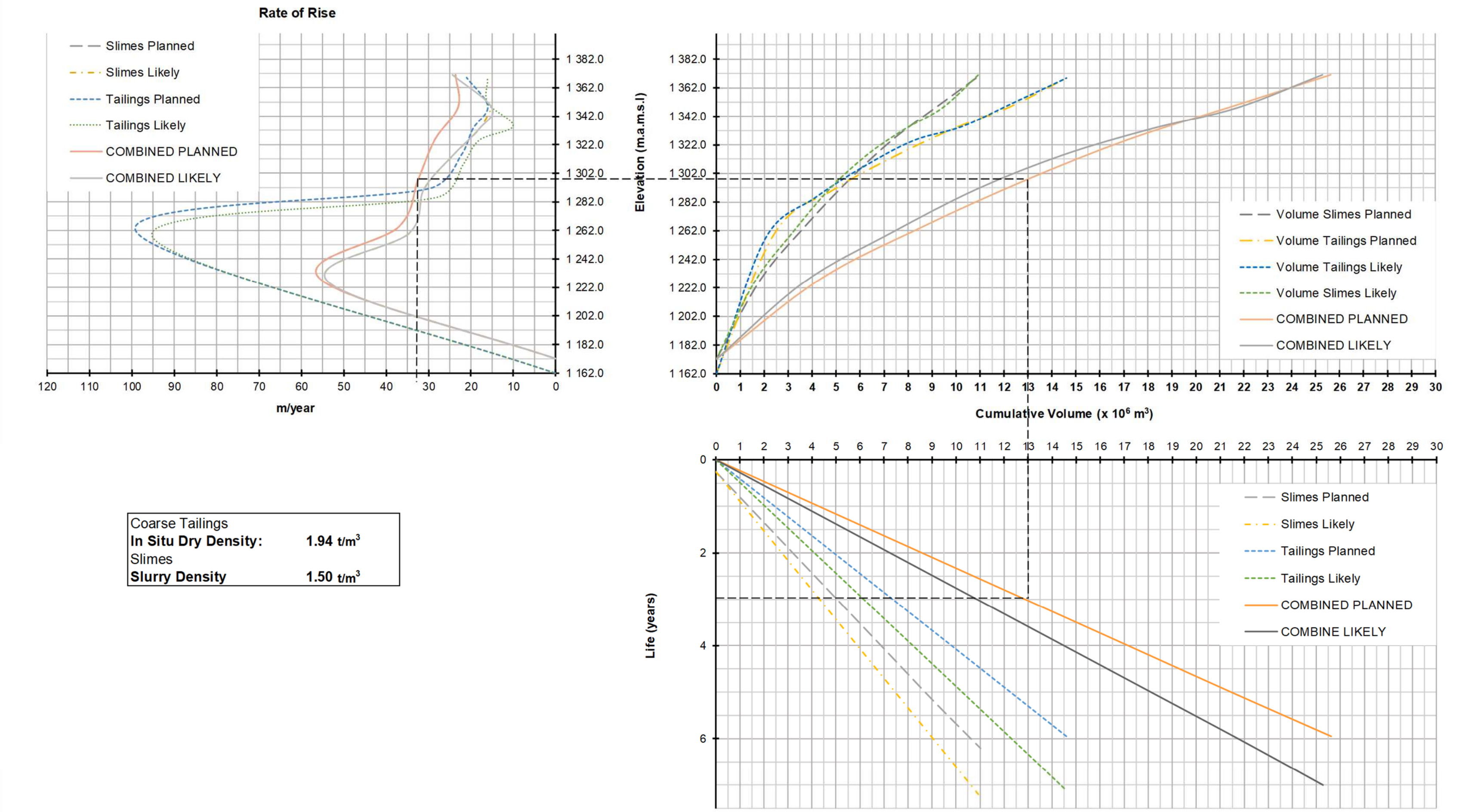

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Figure 8: Stage Capacity curve for Planned and Likely Production Rates

8 Conclusions and Recommendations

This report has considered the design implications of backfilling the Jagersfontein Pit with coarse tailings (or otherwise called grits) and fine tailings slurry (otherwise referred to as slimes). Previous work and reports have been assessed and, where applicable, have been included in this document as background and to support the design decisions.

Of particular importance are the Geochemical characterisation report and the Groundwater modelling report. The conclusions reached in the Geochemical Report is that the fine tailings/slimes is potentially a Type 3 low risk waste but is sterile and immobile in this environment. The Geohydrology modelling report shows that the plume attenuates with time, particularly in the scenario where the fine tailings is backfilled into the pit, thus relieving the situation of additional surface loading from a future additional tailings storage facility. The report, therefore, shows that it is beneficial for the area to backfill the pit rather than develop additional surface tailings storage facilities. These reports, taken together, also show that a physical barrier (such as an HDPE liner), is not warranted or necessary, albeit that the installation of such a barrier is practically impossible.

Since the base of the pit consists of random fill derived from erosion products from the side walls and surrounding areas overlying block caved debris, the actual permeability/voided nature of the material is unknown and cannot be assessed (due to safety reasons). The sidewalls and main shaft have been assessed by professional proto-team members who noted that there is no indication of direct piping connections between the pit and the shaft. It has therefore been concluded that the judicious planned depositional strategy of selective tailings deposition, to form a blanket comprising coarse tailings around the southern shaft area, and remote deposition of the fine tailings slurry from the eastern rim, forms the most practical and environmentally sound solution to backfilling.

Consequently, the depositional strategy involves the initial deposition of a blanket of coarse tailings for a period of three to four months from the southern rim. Thereafter the fine tailings slurry deposition will commence. Since the coarse tailings is denser than the slurry, co-disposal in separate streams will result in the coarse tailings forming an increasing thickness of blanket with time, while the slurry will be displaced and be constricted towards the northern side of the pit. In the final situation, the slurry will cover most of the coarse tailings.

Due to the nature of the fine tailings slurry (very low permeability and coefficient of consolidation), it will remain in a fluid state for many decades, save for surface desiccation due to evaporative drying that will cause a thin crust to develop on the surface. This, in itself, is a safety issue, since the visual impression will be formed that the material is stable, whereas it will remain fluid below the surface crust.

The final level of the coarse tailings/slurry once all stockpile (ROM) material has been processed will reach a level about 30m below the lowest rim level (1400mamsl). This will allow future viewing and (geo-) tourism to continue in the area. Safety of the site will however need to be maintained by the owner.

The depositional strategy is intended to increase the coarse tailings blanket thickness around the main shaft area commensurate with the disposal rate, therefore minimising the likelihood of ‘piping’ of the slurry into the Main Shaft area. It is also recommended that the water quality be regularly monitored accordign to the GHT Consuting protocols

The implementation of the backfilling method involves the construction of a 750m long conveyor from the process plant to the southern rim coarse tailings deposition point and a 1100m long slurry delivery pipe, along the same route, to the eastern discharge point. The routing of the conveyor and pipeline should be designed on site to suit the site roads and services layout. A concept route is given in the accompanying drawings.

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Prepared by

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Dr G C Howell Pr Eng

Corporate Consultant

Reviewed by

____

Mr G Macfarlane Pr Sci Nat

Principal Engineering Geologist/Partner

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.