Overview of the Methodology Employed During the Feasibility and Trade-Off Studies and Optimum Disposal Strategy

F.J. Marais and B.J. Snyman
Golder Associates Pty Ltd, South Africa
P.F. Lötter, P.D. Newman and J.A. Wates
De Beers Consolidated Mines – Finsch Mine, Golder Associates UK Pty Ltd
Golder Associates Pty Ltd, South Africa

Abstract

Finsch Diamond Mine, owned by the De Beers Group is situated approximately 200 km North West of Kimberley, Northern Cape Province, South Africa. Improved market conditions motivated Finsch Mine to consider increasing their production by 40%. The need to increase production, together with the fact that the existing fine residue deposit facilities, known in the South African diamond industry as Slimes Dams, are nearing the end of their useful lives, initiated a number of feasibility and trade-off studies to develop a new fines disposal strategy.

The scope of the feasibility studies comprised site selection, evaluation of different disposal strategies, optimisation of the slurry transportation system and modifications to the existing process plant. Throughout these studies, social and environmental considerations formed part of the evaluation process. The results of these studies have shown that slimes disposal, as thickened tailings / paste will be optimal in terms of cost, risk and environmental impact.

This paper presents an overview of the methodology employed during the feasibility and trade-off studies to analyse different options relating to paste production, incorporating existing plant and new technology.

1. INTRODUCTION

1.1. Background

Finsch Diamond Mine will increase production and plant throughput by approximately 40% to take advantage of improved market conditions. The increased plant throughput will result in an increased fines residue storage capacity. The existing fines residue deposit facilities are also nearing the end of their useful lives.

1.2. Studies Conducted to Date

The first trade-off study that commenced in June 2003 comprised identification of possible new disposal sites and determination of the optimal deposition strategy. In total seven sites were evaluated and the study found that spigotting would be on site 1. Figure 1 provides a schematic layout of the different sites evaluated.

After the trade-off study, a cost estimate with a level of accuracy of -10%, +15% (class 2) was conducted for the preferred site, including three alternative deposition options, spigotting, impoundment and phased impoundment. The study found that phased impoundment would be the optimal deposition strategy.

After finding a land rights and/or diamond reserve sterilisation flaw on site 1 a feasibility study was initiated for site option 4 which had been identified as the second best option in the trade-off study. This study showed that paste, as deposition strategy at site option 4, would be the optimal deposition strategy.

The feasibility study for site option 4 was followed by a trade-off study, during which alternative ways in which paste could be produced, transported and placed were identified and evaluated.

The methodology employed and results of the trade-off study of paste disposal options at site option 4 are discussed in this paper. The work undertaken on the project to date is summarised in Figure 2.

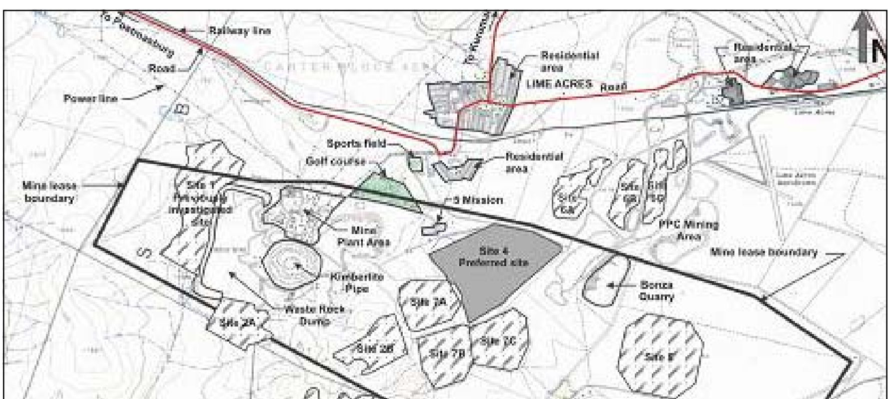

Figure 1: Alternative locations investigated for the new Fines Residue Deposit Facility.

2. Study Objectives and Scope of Work

The feasibility study of the alternative paste production, transport and disposal options included a conceptual design and cost estimate to +/- 25% level of accuracy (class 0). Process flow sheets were prepared for each of the disposal options.

2.1. Required Operational Capacity Statement (ROC)

Finsch Mine issued a ROC in June 2004 to provide a framework within which Golder Associates could undertake the trade-off study. The ROC was applicable to the Finsch Mine Treatment Plant Upgrade (FMTPU) project and the new Finsch Fines Residue Deposit (FRD) project.

The ROC identified the following requirements for the trade-off study:

- A comparison of the disposal options which would confirm the finding of the earlier study, for site option 4, that had shown that paste disposal would be optimal.
- Where uncertainty exists, in terms of the appropriate location of the paste plant, capital and operating expenses, ore variability effects and other such variables should be identified.
- The necessity for establishing a pilot plant to determine metallurgical, rheological and deposition characteristics of the paste could be considered.
- The FRD / paste solution has to integrate with the current main treatment plant (MTP) as well as the planned upgrade of the main treatment plant to increase the diamond recovery efficiency, as well as the rate at which tailings materials can be treated.
- Determine the most viable treatment configuration for Finsch Mine, through effective consideration of the battery limits of the feasibility study and the integration with the current treatment plant.
- The paste disposal system should be designed such that it could be fed by three feed streams including:
    - The current thickener feed, i.e. –0.5 mm material after the plant upgrade;
    - The current thickener underflow with dilution prior to being fed to the paste plant;
    - The current FOS feed, i.e. before separation of grits particles larger than 0.5 mm and less than 1.5 mm.

Variations of the above are also to be considered, i.e. establish a de-grit cut size above 0.5 mm, as well as varying feed densities of the thickener underflow.

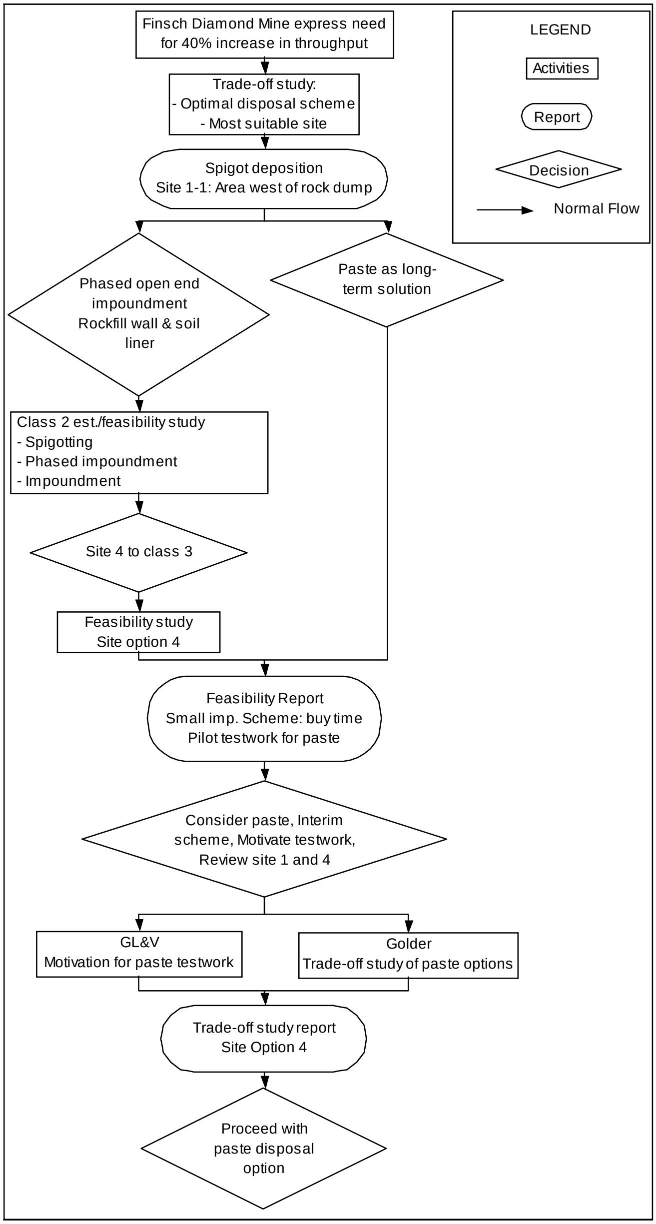

Figure 2: Summary of background work on the project.

2.2. System Input Parameters

The following requirements were considered as important input parameters:

- Feed System
  - Material source
  - Feed rates

- Feed size
- Particle size envelopes
- Slurry feed densities
- Underflow discharge system
  - Discharge density
  - Underflow rheology
  - Discharge distance
  - Life of mine
  - Deposition schedule
- Paste plant
  - Location
  - Thickener type
- Return water system

2.3. System Boundaries and Interfaces

The system boundaries and interfaces were stipulated in the ROC document and are shown in Figure 3.

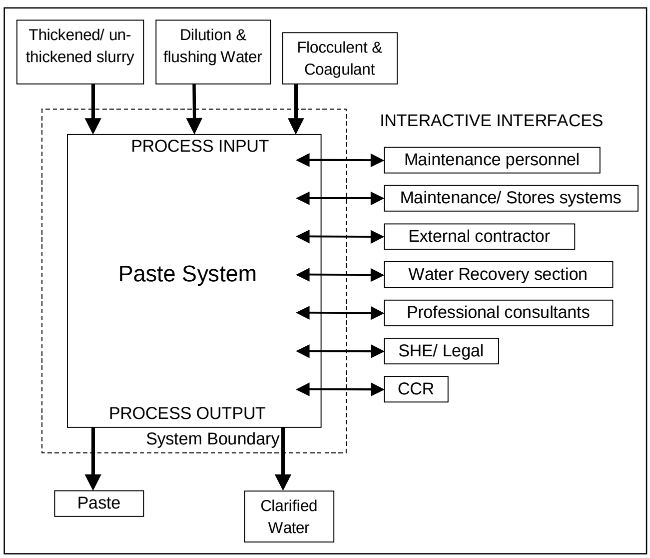

Figure 3: Context Diagram prescribed by Finsch Mine.

3. Existing Disposal Section

3.1. Mechanical Information

The components considered in the "disposal section" of the plant consists of the Fine Ore Separation (FOS) Section, the thickeners, the coarse tailings dump and the Fines Residue Disposal (FRD) facilities.

The FOS section receives –1.5 mm material in slurry form from various parts of the plant. The slurry is separated into a coarser fraction, which is sent directly to the coarse tailings dump, and a finer portion that is sent to the thickeners. The overflow from the thickeners is re-used as process water and the underflow is pumped to the FRDs. Figure 4 provides a schematic layout of the existing Disposal Section.

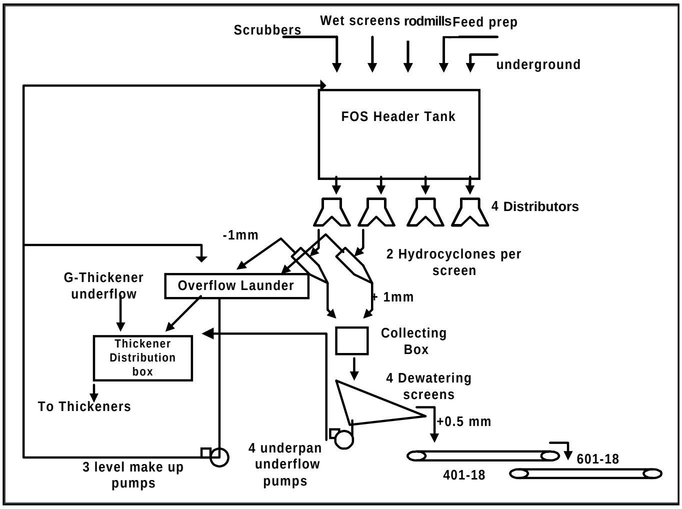

Figure 4: Schematic layout of the existing Disposal Section.

3.2. FOS Section

A 42 m^3 round bottom dirty water header tank is located at the top of the FOS section. Feed to this tank is received from the following sections:

- Rod mill transfer sump.
- Scrubber transfer sump.
- Wet screen transfer sump.
- Feed preparation transfer sump.
- Underground water. Any spillage water from underground is pumped to the dirty water header tank.

The material from the head tank is fed into cyclones via four pipes, with each pipe feeding a two-way distributor. There are a total of 8 cyclones, with 6 operational and 2 on standby at any time.

The cyclone overflow reports to an overflow launder, which feeds the thickener distribution box. A total of four thickeners forms part of the existing disposal circuit, namely the A, B, C and D thickeners. From the distribution box, the feed can either be directed to the A and B thickeners, the C and D thickeners or both. The feed distribution is controlled by manual operated gates.

Also feeding into the thickener distribution box is the underflow from the G-thickener (not part of the disposal section – discussed later), the four underpan pumps from the dewatering screens and three drain pumps.

The underflow from the cyclones reports to collecting boxes. The collecting boxes are joined such that 4 streams flow out of 8 collecting boxes. Each of the four streams feed one of four de-watering screens.

The de-watering screens are three-slope screens with a negative slope on the discharge end. This screen cuts at approximately 0.7 mm. The over size material from these screens reports to a conveyor, conveying all the coarse material to the current tailings dump.

The undersize of the screen falls into screen underpan sumps, each equipped with its own screen underpan sump pump that pumps into the thickener distribution box.

There are three header tank/level makeup pumps. The objective of these pumps is to pump slurry from the overflow lauder into the header tank (this is to maintain header tank level and hence cyclone feed pressure). The pumps can also pump water back in the overflow launder should the level in the header tank be sufficient / excessive.

3.3. Thickeners

From the overflow launder in the FOS section, the material is transported via a launder into the thickener distribution box. This distribution box has two manual gates. One gate leads to C and D thickeners via a launder. The second gate leads to A and B thickeners via a pipe.

3.3.1. C and D thickeners

These are the thickeners that are used during normal operation. The launder feed flows into a feed valve arrangement consisting of two ‘plungers’ that are used to isolate or distribute feed to either C or D thickener feed launder.

Each thickener feed launder splits into two pipes that lead to the centre feed well. There are two flocculant addition points. The slurry feed is mixed with flocculant and diluted by means of an E-duc© system. These thickeners are equipped with variable speed pumps, clarometers and torque sensors.

Each thickener is equipped with two underflow pumps. All thickener underflow pipes pump into the excess sump, which is located at the bottom of the FOS. The underflow density is maintained by continuous monitoring between 1.3 and 1.45 tons/m^3.

The overflow from the thickeners is directed into the thickener clarified tank for re-use in the process.

3.3.2. A and B thickeners

From the splitter box, the dilute slurry is transported via a pipe to the A and B thickener’s splitter box. From here the material splits evenly into the two thickener launders. A manual gate can be used to isolate the feed to either thickener.

These thickeners are smaller than the C and D thickeners and are only used as standby units, should the C and/or D thickeners be offline. The A and B thickeners are not automated and flocculant addition is manually controlled.

Each thickener has two underflow pumps pumping the underflow into the excess sump. The overflow is directed to the thickener clarified tank for re-use in the process.

3.3.3. G thickener

The G-thickener is not strictly part of the disposal circuit. It is used to recover water from the DMS magnetic separator effluent. It does not use flocculant as its feed is very dilute and coarse. The underflow from G-thickener is pumped into the thickener distribution box. All slurry in this distribution box is directed toward the C and D thickeners. The overflow of the thickener is recovered and re-used in the DMS section.

3.4. Excess Sump and Slimes

The excess sump is located on the ground floor of the FOS Section and receives the underflow from the four thickeners.

Material is pumped out of the sump via three pump sets, each with two pumping stages. These pumps deliver slimes directly to a manifold with multiple valves that is used to direct the slimes from any pipe to any one of the FRDs.

4. Identification and Categorisation of Alternative Options

There are three main factors that contribute to produce the alternative options that were considered for the trade-off study, namely thickener configuration, feed type and paste plant location.

The trade-off study identified, considered and evaluated 19 disposal options, based on these three factors, as shown in Figure 5.

4.1. Thickener Configuration

With the existing conventional thickeners operational, it may be beneficial to utilise these thickeners in conjunction with paste thickeners. There are thus three different kinds of thickener configurations, as follows:

- A new paste plant will be constructed consisting only of paste thickeners.
- Paste and existing thickeners. With this configuration the existing conventional thickeners can be used in series with new paste thickeners, with the underflow of the former feeding the latter.
- Existing conventional thickeners only.

The existing thickeners will have to be upgraded to cope with the additional load of the projected future increase in tonnages for the last two options described above. The degree of modifications to the existing conventional thickeners is dependent on the thickener feed.

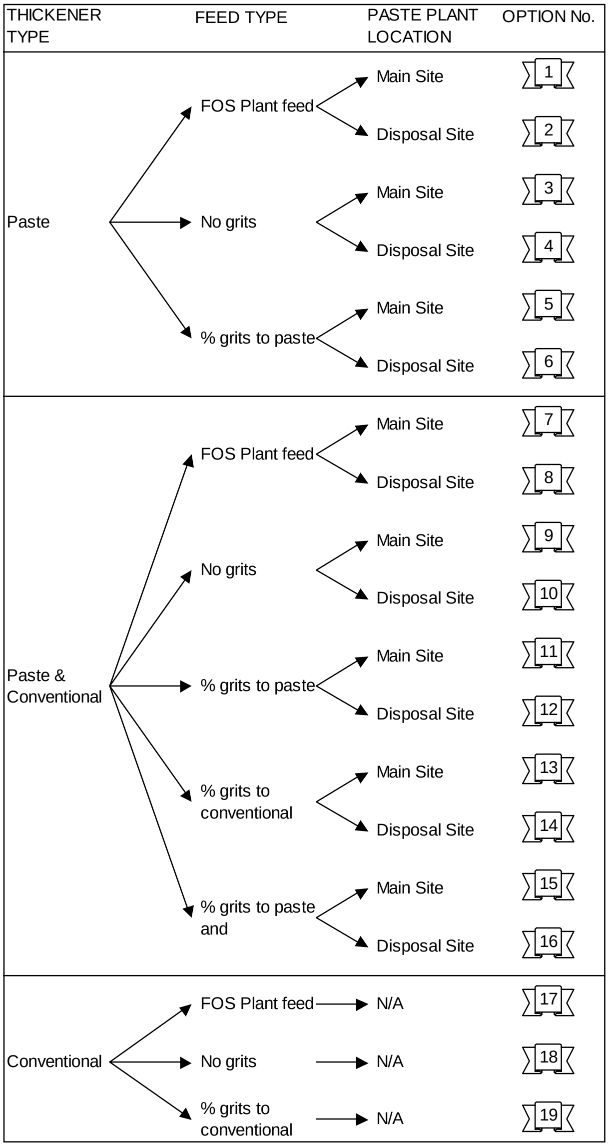

Figure 5: Summary of paste disposal options.

4.2. Thickener Feed

The ROC document stated that the paste disposal system should be designed such that it can be fed with essentially three different feeds steams, namely:

- The current thickener feed.
- The current thickener under flow.
- The current FOS feed.

These three options have been sub-divided to form five different feed streams, being the varying percentage of grits added to the system at various locations. The five different feed streams are:

- FOS feed: This includes all the FOS feed particles with size range of 0 to 1.47 mm.
- Current thickener feed: Also referred to as FOS discharge and includes particles with a size range of 0 to 0.5 mm.
- FOS discharge, but with a percentage of grits added to the paste thickeners. The FOS discharge includes particles with a size range from 0 to 0.5 mm and the 0.5 to 0.8 mm (percentage grits) are added to the paste thickeners.
- FOS discharge, but with a percentage of grits added to the existing conventional thickeners. The FOS discharge includes particles with a size range from 0 to 0.5 mm and the 0.5 to 0.8 mm (percentage grits) are added to the paste thickeners.
- FOS discharge, but with a percentage of grits added to both the existing conventional and paste thickeners. The FOS discharge includes particles with a size range from 0 to 0.5 mm and the 0.5 to 0.8 mm (percentage grits) is added to the paste thickeners.

4.3. Paste Plant

The paste plant, with ancillaries can either be located at the main plant (in the vicinity of the existing thickeners) or at the deposition site.

From an operational point of view the location of the paste thickener at the main plant would be ideal. However from a materials handling point of view, the locality of the paste thickener at the main plant is less favourable as this requires that the thickened slimes will need to be pumped over a long distance.

The ideal locality for the paste thickener at the FRD facility would be on top of the crest of one of the existing slimes dams as schematically indicated in Figure 6.

4.4. FRD Development

The FRD development was evaluated in terms of the following criteria for each option:

- Slimes dam and paste plant area construction (if the paste plant is located at the FRD) which included the following attributes:
  - Pre-deposition earth works, comprising the footprint development, starter walls, toe drains, berms, leachate / seepage interception and dewatering facilities for the excess water and run-off management;
  - The installation of piling to support the paste plant on top of the existing slimes dam No. 1.
- The capital requirements for the FRD development to accommodate the required slimes tonnages were estimated. The cost variances between options are mainly due to:
  - The footprint required for the paste material, which would be larger if grits are included; and

- The development of options 17, 18 and 19 is based on the development for the disposal of conventional slimes material.

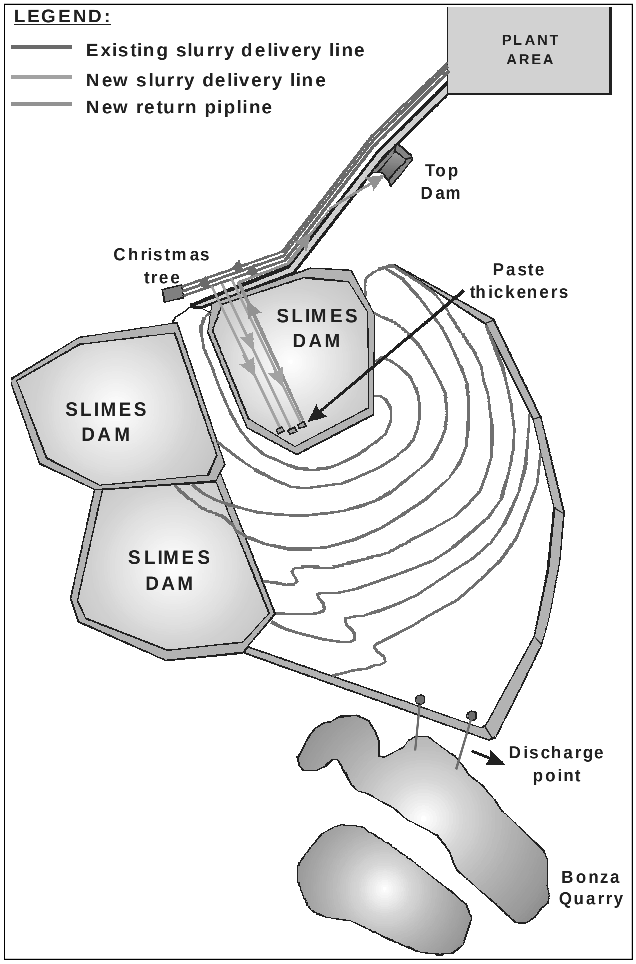

Figure 6: Schematic layout if paste plant is situated at the deposit facility.

The FRD options were also compared in terms of:

- Water consumption.
- Maintenance.
- Number of operators required.
- Construction time.
- Impact on main plant.
- Slimes facility / paste deposition area downtime and plant reliability.

The above items were rated in terms of a qualitative scoring system, while the operating costs for the 19 options were also calculated and included in the evaluation.

4.5. Return Water System

The return water system for each option was evaluated in terms of the following criteria:

- Civil works required.
- Electrical and instrumentation.
- Pumping and piping.
- Power consumption.
- Maintenance.
- Labour requirements.
- Construction time.
- Impact on main plant or vice versa.
- Plant reliability.

The capital requirements are mainly due to additional infrastructure requirements to supplement the existing infrastructure. No major changes are foreseen to the exiting return water system.

5. The "Paste Chain"

5.1. Background

The context diagram, system description and system interfaces listed in the ROC document were used as background information for the study. During the initial discussions, it became apparent that the project team, comprising of the Finsch project team, Golder Associates, Logiproc and GL&V, would need to collaborate closely in the study, to ensure that all elements of what became known as the "paste chain" were covered. A matrix was therefore compiled, which outlined all the key components of the "paste chain", as follows:

- Thickener type (paste or conventional).
- Feed type (process information):
  - FOS feed.
  - FOS discharge.
- Paste plant location (at plant or at deposition site).
- Slimes preparation FOS section.
- Long distance piping and pumping.
- Paste thickening process.
- Slimes deposition piping and pumping.
- The FRD facility (accommodating paste).
- Return water pumping and piping.

The matrix assisted the project team to unpack the attributes for each option within the framework of the matrix. The data assessed included the following:

- The addition of grits (as percentage of the slimes waste stream).
- Process information, i.e. flow rates (m^3/hour), S.G. (t/m^3), particle size (mm) (Figure 7 provides a summary of the process information, illustrating the feed type to the conventional and/or paste thickeners, the underflow and

overflow densities as well as the flow rate for each of the options considered).

- Requirements to either by-pass the existing thickeners and / or to replace with new thickeners or to upgrade the existing equipment.
- Slimes preparation data, i.e. capital and operating costs, construction requirements, plant availability.
- Attributes of the long distance pumping requirements namely civil, electrical and instrumentation, power consumption and maintenance.
- Paste thickening technology, i.e. paste thickening installation/equipment, flocculant requirements, operational requirements etc.
- Slimes deposition pumping and pipeline equipment requirements to place and distribute the material.
- Fine residue facility development information, i.e. civil construction requirements.
- Return water facilities and link-up infrastructure back into the plant.

5.2. Description of the "Paste Chain"

The slimes disposal section of the plant has been defined as stretching from the inlet to the FOS plant header tank to the discharge point of the deposition site return water. To simplify the process of the trade-off study, the slimes disposal section has been divided into manageable areas. Because all the areas are sequential to each other with regards to a slimes direction of flow, they form a chain, which is referred to as the "paste chain", and consists of the following areas:

- Slimes preparation.
- Delivery scheme.
- Paste plant.
- Slimes deposition pumping and piping.
- FRD development.
- Return water.

No of Options	Process Information					
		Feed	Conventional Thickener		Paste Thickener	
		Feed	Under-flow	Over-flow	Under-flow	Over-flow
1	Flow (m^3/hr)	6270,5	N/A	N/A	675,3	5595,3
	S.G. (t/m^3)	1,07	N/A	N/A	1,65	1,00
	Particle Size (mm)	A, B, C, D	N/A	N/A	A, B, C, D	0
2	Flow (m^3/hr)	6270,5	N/A	N/A	675,3	5595,3
	S.G. (t/m^3)	1,07	N/A	N/A	1,65	1,00
	Particle Size (mm)	A, B, C, D	N/A	N/A	A, B, C, D	0
3	Flow (m^3/hr)	6179,4	N/A	N/A	534,7	5644,7
	S.G. (t/m^3)	1,05	N/A	N/A	1,55	1,00
	Particle Size (mm)	A, B	N/A	N/A	A, B	0
4	Flow (m^3/hr)	6179,4	N/A	N/A	534,7	5644,7
	S.G. (t/m^3)	1,05	N/A	N/A	1,55	1,00
	Particle Size (mm)	A, B	N/A	N/A	A, B	0
5	Flow (m^3/hr)	6179,4	N/A	N/A	591,3	5626,3
	S.G. (t/m^3)	1,05	N/A	N/A	1,60	1,00
	Particle Size (mm)	A, B	N/A	N/A	A, B, C	0
6	Flow (m^3/hr)	6179,4	N/A	N/A	591,3	5626,3
	S.G. (t/m^3)	1,05	N/A	N/A	1,60	1,00
	Particle Size (mm)	A, B	N/A	N/A	A, B, C	0
7	Flow (m^3/hr)	6270,5	1097,3	5173,2	675,3	422,1
	S.G. (t/m^3)	1,07	1,40	1,00	1,65	1,00
	Particle Size (mm)	A, B, C, D	A, B, C, D	0	A, B, C, D	0
8	Flow (m^3/hr)	6270,5	1097,3	5173,2	675,3	422,1
	S.G. (t/m^3)	1,07	1,40	1,00	1,65	1,00
	Particle Size (mm)	A, B, C, D	A, B, C, D	0	A, B, C, D	0
9	Flow (m^3/hr)	6179,4	735,2	5444,2	534,7	200,5
	S.G. (t/m^3)	1,05	1,40	1,00	1,55	1,00
	Particle Size (mm)	A, B	A, B	0	A, B	0
10	Flow (m^3/hr)	6179,4	735,2	5444,2	534,7	200,5
	S.G. (t/m^3)	1,05	1,40	1,00	1,55	1,00
	Particle Size (mm)	A, B	A, B	0	A, B	0
11	Flow (m^3/hr)	6179,4	735,2	5444,2	591,3	182,1
	S.G. (t/m^3)	1,05	1,40	1,00	1,60	1,00
	Particle Size (mm)	A, B	A, B	0	A, B, C	0
12	Flow (m^3/hr)	6179,4	735,2	5444,2	591,3	182,1
	S.G. (t/m^3)	1,05	1,40	1,00	1,60	1,00
	Particle Size (mm)	A, B	A, B	0	A, B, C	0
13	Flow (m^3/hr)	6179,4	887,0	5330,6	591,3	295,7
	S.G. (t/m^3)	1,05	1,40	1,00	1,60	1,00
	Particle Size (mm)	A, B	A, B, C	0	A, B, C	0
14	Flow (m^3/hr)	6179,4	887,0	5330,6	591,3	295,7
	S.G. (t/m^3)	1,05	1,40	1,00	1,60	1,00
	Particle Size (mm)	A, B	A, B, C	0	A, B, C	0
15	Flow (m^3/hr)	6179,4	811,1	5387,4	591,3	238,9
	S.G. (t/m^3)	1,05	1,40	1,00	1,60	1,00
	Particle Size (mm)	A, B	A, B, C	0	A, B, C	0
16	Flow (m^3/hr)	6179,4	811,1	5387,4	591,3	238,9
	S.G. (t/m^3)	1,05	1,40	1,00	1,60	1,00
	Particle Size (mm)	A, B	A, B, C	0	A, B, C	0
17	Flow (m^3/hr)	6270,5	1097,3	5173,2	N/A	N/A
	S.G. (t/m^3)	1,07	1,40	1,00	N/A	N/A
	Particle Size (mm)	A, B, C, D	A, B, C, D	0	N/A	N/A
18	Flow (m^3/hr)	6179,4	735,2	5444,2	N/A	N/A
	S.G. (t/m^3)	1,05	1,40	1,00	N/A	N/A
	Particle Size (mm)	A, B	A, B	0	N/A	N/A
19	Flow (m^3/hr)	6179,4	886,98442	5330,64	N/A	N/A
	S.G. (t/m^3)	1,05	1,40	1,00	N/A	N/A
	Particle Size (mm)	A, B	A, B, C	0	N/A	N/A

Legend	Particle Size Reference	
	A	**0 - 0.1 mm**
	B	**0.1 - 0.5 mm**
	C	**0.5 - 0.8 mm**
	D	**0.8 - 1.47 mm**
	0	**0 mm**

Figure 7: Process information for the different options considered and evaluated.

5.3. Slimes Preparation

The battery limits of the slimes preparation area are defined by the inlet at the FOS plant header tank to the:

- Inlet to the paste thickeners, where the paste thickeners are located at the main plant. (see options 1, 3 and 5 on Figure 5).
- Inlet of the holding tank where slimes will be pumped over the long distance to the deposition site where the paste thickeners are located. (Options 2, 4 and 6).
- Inlet of the paste thickeners, located at the main plant, where both the paste and existing conventional thickeners are utilised. (Options 7, 9, 11, 13 and 15).
- Inlet of the excess sump, where both paste and the existing conventional thickeners are utilised and the paste thickeners are located at the deposition site. (Options 8, 10, 12, 14, and 16).
- The inlet of the excess sump, where the existing conventional thickeners are utilised. (Options 17, 18 and 19).

The paste plant and / or existing conventional thickeners overflow water forms part of the slimes preparation area. Where the paste thickeners are located at the deposition site, the overflow of the paste thickeners form part of the return water area. The flocculant system for the existing conventional thickeners form part of the slimes preparation area while the flocculant system for the paste thickeners forms part of the paste thickening area.

5.4. Slimes Deposition Pumping and Piping

This area included the paste thickener underflow pumping and piping. Note that this area only exists if the paste thickeners are located at the deposition site. If the paste thickeners are located at the main plant, the paste thickener underflow pumping and piping forms part of the delivery scheme area. The battery limits stretch from the underflow ports of the paste thickeners to the discharge point/s at the FRD.

6. Evaluation of the Disposal Options

6.1. Evaluation Criteria

A series of overarching criteria were developed for each component of the paste chain. Capital and Operational costs were applied as the key criteria whilst operational criteria such as plant availability, plant downtime and impact on main plant were also included.

A series of environmental criteria were also considered, which included:

- Rehabilitation of the facility after closure.
- Potential impact on the receiving environment.
- Perceived impacts or risks.

6.2. Evaluation Matrix

The key criteria discussed above were combined in an evaluation matrix containing the following components:

- Feed type (FOS feed and discharge).
- Paste plant location.
- Economic criteria (Capital and Operating costs and NPV for each option).
- Slimes preparation.
- Delivery system.
- Paste thickening.
- FRD.
- Return water system.

Figure 8 shows a portion of the matrix, with the first part containing the criteria used to define the different options and the latter part illustrating the evaluation criteria considered for the paste thickening component.

Costs for each option were determined based on civil, mechanical and electrical and instrumentation requirements. Costs for the paste thickeners were supplied by GL&V, based on preliminary capacity requirements. The capital and operating costs were then combined over the planned life of mine to obtain a life cycle cost for each option.

6.3. Comparative Analysis

A rating and ranking system was developed and used to evaluate each key component during a comparative analysis. The scoring system, which included a qualitative rating system, was used to evaluate qualitative criteria. No weightings were applied in the comparative analysis.

Figure 9 contains the results of the comparative analysis in matrix format, illustrating the ranking and rating of the different options.

7. Preferred Option

The comparative assessment detailed above found the following:

- Option 3 (Paste plant at main site, no grits, mothball of existing thickeners and installation of new paste thickeners) resulted in the lowest life cycle cost but scored poorly on some of the key components as shown in Figure 9. Finsch Mine perceived the pumping of paste over a long distance with grits content as a high risk, resulting in a poor score with regard to the delivery system.
- Option 18 (Conventional disposal, no grits) had the second lowest cost, but was ranked as undesirable due to environmental risks.
- Option 10 (Paste, no grits, plant at deposition site) had the third lowest life cycle cost but scored well on all other aspects.

The preferred option from the trade-off study was option 10.

The rating of option 10 was above average, compared to the other options. This was mainly due to the relative low risk of the option because existing equipment would be utilised. Other benefits included:

- Low operational costs.
- Low Capital costs.
- Utilisation of FOS plant.
- Utilisation of existing slimes pipelines.
- No positive displacement pumps required, as the paste thickeners are located at the deposition site.
- Ease of operation due to the lack of grits in the system.

No of Options	OPTION	Thickener Type	Feed Type: FOS Feed	Feed Type: FOS Discharge				Paste Plant Location	Paste Thickening: Capex				Paste Thickening: Opex				Paste Thickening: Construction		Paste Thickening: Other			
		Paste / Conventional Thickener	FOS Plant Feed	No Grits	%Grits to Paste	%Grits to Conventional	%Grits to Paste and Conventional	Main Site / Deposition Site	Paste Thickener Installation (R mil)	Civils (R mil)	Electrical & Instrumentation (R mil)	Flocculant Plant/s (R mil)	Power Consumption (R mil)	Flocculant Consumption (R mil)	Maintenance	No. of Operators Required	Construction Time	Main Plant Downtime During Construction	Impact on Main Plant	Plant Downtime	Availability of Parts	Plant Reliability
1	1 1 1	Paste	Yes					Main Site	4 x 21m PT R55.0	R3.0	R2.0	R0.9	0.1 M.W.hr R0.2	35.7 kg/hr R7.2 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
2	1 1 2	Paste	Yes					Deposition Site	4 x 21m PT R55.0	R3.0	R3.5	R0.9	0.1 M.W.hr R0.2	35.7 kg/hr R7.2 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
3	1 2 1	Paste		Yes				Main Site	2 x 26m PT R42.0	R2.0	R1.5	R0.8	0.1 M.W.hr R0.2	24 kg/hr R4.8 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
4	1 2 2	Paste		Yes				Deposition Site	2 x 26m PT R42.0	R2.0	R3.0	R0.8	0.1 M.W.hr R0.2	24 kg/hr R4.8 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
5	1 3 1	Paste			Yes			Main Site	4 x 20m PT R50.0	R3.0	R2.0	R0.8	0.1 M.W.hr R0.2	29 kg/hr R5.8 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
6	1 3 2	Paste			Yes			Deposition Site	4 x 20m PT R50.0	R3.0	R3.5	R0.8	0.1 M.W.hr R0.2	29 kg/hr R5.8 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
7	2 1 1	Paste and Conventional	Yes					Main Site	4 x 22m PT R60.0	R3.0	R2.0	R0.9	0.1 M.W.hr R0.2	35.7 kg/hr R7.2 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
8	2 1 2	Paste and Conventional	Yes					Deposition Site	4 x 22m PT R60.0	R3.0	R3.5	R0.9	0.1 M.W.hr R0.2	35.7 kg/hr R7.2 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
9	2 2 1	Paste and Conventional		Yes				Main Site	3 x 21m PT R41.0	R2.0	R1.5	R0.8	0.1 M.W.hr R0.2	24 kg/hr R4.8 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
10	2 2 2	Paste and Conventional		Yes				Deposition Site	3 x 21m PT R41.0	R 2.0	R 3.0	R0.8	0.1 M.W.hr R0.2 per annum	24 kg/hr R4.8 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
11	2 3 1	Paste and Conventional			Yes			Main Site	4 x 20m PT R50.0	R3.0	R2.0	R0.8	0.1 M.W.hr R0.2	29 kg/hr R5.8 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
12	2 3 2	Paste and Conventional			Yes			Deposition Site	4 x 20m PT R50.0	R3.0	R3.5	R0.8	0.1 M.W.hr R0.2	29 kg/hr R5.8 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
13	2 4 1	Paste and Conventional				Yes		Main Site	4 x 20m PT R50.0	R3.0	R2.0	R0.8	0.1 M.W.hr R0.2	29 kg/hr R5.8 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
14	2 4 2	Paste and Conventional				Yes		Deposition Site	4 x 20m PT R50.0	R3.0	R2.0	R0.8	0.1 M.W.hr R0.2	29 kg/hr R5.8 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
15	2 5 1	Paste and Conventional					Yes	Main Site	4 x 20m PT R50.0	R3.0	R2.0	R0.8	0.1 M.W.hr R0.2	29 kg/hr R5.8 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
16	2 5 2	Paste and Conventional					Yes	Deposition Site	4 x 20m PT R50.0	R3.0	R3.5	R0.8	0.1 M.W.hr R0.2	29 kg/hr R5.8 per annum	3	1	6 Months	Keep old system - short change over time	2	2	4	4
17	3 1 0	Conventional	Yes					N/A	Not Applicable													
18	3 2 0	Conventional		Yes				N/A	Not Applicable													
19	3 4 0	Conventional				Yes		N/A	Not Applicable													

Legend

Particle Size Reference		Scoring	
A	0 - 0.1 mm	1	Nothing
B	0.1 - 0.5 mm	2	Low
C	0.5 - 0.8 mm	3	Medium
D	0.8 - 1.47 m	4	High
0	0 mm	5	Very High

Figure 8: Portion of Evaluation Matrix.

	No of Options	OPTION	Thickener Type	Feed Type					Paste Plant Location	Economic				Slimes Preparation		Delivery System		Paste Thickening		FRD		Return Water		Total
				FOS Feed	FOS Discharge																			
			Paste / Conventional Thickener	FOS Plant Feed	No Grits	%Grits to Paste	%Grits to Conventional	%Grits to Paste and Conventional	Main Site / Deposition Site	Capex (R mil)	Opex / annum (R mil)	NPV (R mil)	Rank	Technical / Engineering	Operations	Technical / Engineering	Operations	Technical / Engineering	Operations	Technical / Engineering	Operations	Technical / Engineering	Operations	Total Sore
PASTE	1	1 1 1	Paste	Yes					Main Site	R 119.1	R 16.22	R 245.9	13	4	4	4	4	4	4	2	3	2	2	33
PASTE	2	1 1 2	Paste	Yes					Deposition Site	R 117.8	R 14.7	R 232.9	12	4	4	5	5	4	4	2	3	4	5	40
PASTE	3	1 2 1	Paste		Yes				Main Site	R 86.9	R 8.55	R 153.4	1	2	2	4	5	3	3	2	2	2	2	27
PASTE	4	1 2 2	Paste		Yes				Deposition Site	R 99.5	R 11.81	R 191.9	5	2	2	4	5	3	3	2	2	4	5	32
PASTE	5	1 3 1	Paste			Yes			Main Site	R 103.3	R 10.93	R 188.6	4	4	4	5	5	3	3	2	3	2	2	33
PASTE	6	1 3 2	Paste			Yes			Deposition Site	R 109.2	R 12.34	R 205.5	6	3	3	5	5	3	3	2	3	4	5	36
PASTE	7	2 1 1	Paste and Conventional	Yes					Main Site	R 147.4	R 23.4	R 330.6	19	5	5	5	5	4	4	2	3	2	2	37
PASTE	8	2 1 2	Paste and Conventional	Yes					Deposition Site	R 116.9	R 20.4	R 276.6	18	5	5	3	4	4	4	2	3	3	3	36
PASTE	9	2 2 1	Paste and Conventional		Yes				Main Site	R 108.5	R 13.4	R 213.4	16	3	3	2	3	3	3	2	2	2	2	25
PASTE	10	2 2 2	Paste and Conventional		Yes				Deposition Site	R 78.8	R 12.7	R 178.2	3	1	2	1	2	2	3	2	2	3	3	21
PASTE	11	2 3 1	Paste and Conventional			Yes			Main Site	R 105.9	R 15.7	R 228.8	11	1	2	4	5	3	3	2	3	2	2	27
PASTE	12	2 3 2	Paste and Conventional			Yes			Deposition Site	R 96.3	R 14.0	R 205.9	7	1	2	5	5	3	3	2	3	3	3	30
PASTE	13	2 4 1	Paste and Conventional				Yes		Main Site	R 121.0	R 16.7	R 251.7	14	2	3	4	4	3	3	2	3	2	2	28
PASTE	14	2 4 2	Paste and Conventional				Yes		Deposition Site	R 98.4	R 15.44	R 216.9	9	2	3	4	5	3	3	2	3	3	3	31
PASTE	15	2 5 1	Paste and Conventional					Yes	Main Site	R 119.7	R 16.9	R 252.0	15	3	4	4	5	4	4	2	3	2	2	33
PASTE	16	2 5 2	Paste and Conventional					Yes	Deposition Site	R 98.6	R 15.2	R 215.6	8	2	3	5	5	4	4	2	3	3	3	34
CONVENTIONAL	17	3 1 0	Conventional	Yes					N/A	R 183.8	R 12.0	R 277.7	17	4	5	3	4	0	0	5	5	3	4	33
CONVENTIONAL	18	3 2 0	Conventional		Yes				N/A	R 97.6	R 10.0	R 175.9	2	1	2	1	2	0	0	5	5	3	4	23
CONVENTIONAL	19	3 4 0	Conventional				Yes		N/A	R 149.4	R 9.0	R 219.8	10	2	3	3	3	0	0	3	4	3	4	25

Legend

Scoring	
1	Acceptable
2	Above Aver.
3	Average
4	Below Aver.
5	Poor

Figure 9: Matrix illustrating the results obtained from the comparative analysis.

8. Benefits of Methodology Employed

The methodology employed during the trade-off study for paste disposal at site option 4 proved to be a valuable approach. The benefits derived from the matrix approach are summarised below:

- The approach provided the basis for identifing and assessing the different options from a holistic perspective.
- It also provided the means to identify / illustrate the evaluation criteria resulting in a clear, compact and understandable format.
- The approach helped to identify and include all the aspects that influence both capital and operational costs.
- The approach provided the platform to combine quantitative and qualitative evaluation criteria into one system.
- The concept of the "paste chain" was easily explained in conjunction with the matrix, while the constraints posed by one component on another from both a technical and project management perspective was easily illustrated.

The methodology employed during the trade-off study provides an ideal framework for decision making, by incorporating new technology and existing processes into one matrix, consolidating quantitative and qualitative factors.

Acknowledgements

The authors of this paper wish to acknowledge the management of De Beers CHQ and Finsch Diamond Mine for permission to publish this paper.

References

Golder Associates Africa (Pty) Ltd (2003) *Report on Finsch Trade-off Study for a New Fine Residue Disposal Facility* Report No: 5751/5865/1/G, August 2003.

Golder Associates Africa (Pty) Ltd (2004) *Report on Finsch Fine Residue Disposal Design – Report in Support of the Class II Estimate* Report No: 5752/6179/8/S, January 2004.

De Beers, Finsch Diamond Mine (2004) *Required Operational Capacity Statement for the Finsch Paste Trade-off Study,* Document No FMTPU-ROC-FRD-2.01, 2004.

De Beers, Finsch Diamond Mine (2002) *Main Treatment Plant Fines Disposal Capacity,* Document No NFR-TF-J07, 2002, (Compiled by J.J. Rajan).

Golder Associates Africa (Pty) Ltd (2004) *Report on Finsch Mine Residue Disposal Paste Option Trade-off study* Report No: 6439/6480/6/S, August 2004.

This report includes references to all previous work done by others i.e. pilot paste plant work.