Determining the Optimum Location of a High Rate Thickener for a Thickened Tailings System

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ABSTRACT

This paper presents a cost comparison between pumping large volumes of dilute thickener feed to a remote thickener located at the tailings storage facility (TSF), and using high pressure positive displacement pumps pumping thickened tailings from a thickener located at the process plant to the tailings residue facility. The study considers only the pump and pipeline system capital and operating costs, and specifically excludes all costs associated with preparation and placement.

This study shows that for a 2.5 km distance both options have a similar net present cost. As the distance increases to 5 km it is better to locate the thickener at the process plant and pump high density thickened tailings using piston diaphragm pumps. This is mainly due to the differences in annual operating costs over the life of mine as it is not energy efficient to pump large volumes of dilute slurry long distances.

Each site assessment is obviously project specific and this trade-off study shows that it is not immediately obvious as to which pumping solution is the most cost effective.

1. Introduction

There is a great deal of debate over the cost of high pressure positive displacement pumping systems. Many practitioners believe that the high pumping costs are one of the main reasons why this technology is not more widely accepted, and every effort is made to eliminate these pumps from the flow sheet.

It is certainly true that the capital cost of positive displacement pumps and high pressure piping is high, but these costs must be seen in perspective of the total project life cycle. Where it is found that the lifecycle costs are excessive, a more effective solution can often be found by increasing the solids concentrations to the maximum limits of a centrifugal pump.

There are many factors that dictate whether centrifugal or positive displacement pumps are best suited to the application; including tonnage, flow rate, pipe diameter and length, elevation changes, and of course rheology and solids concentration.

This paper presents a trade off study to determine the optimum location of a high rate thickener at a tailings storage facility (TSF). The study considers the following options:

- Positioning the thickener at the TSF, and pumping thickener feed to the thickener, and returning the overflow water to the process plant.
- Locating the thickener at the process plant and pumping the thickener underflow to the TSF.

2. Study Basis

2.1. Scenarios

The study considers the costs of the following systems shown in Figure 1:

- Thickener feed system to a 15 m tall high rate thickener.
- Thickener return water system.
- Thickener underflow system.

Table 1 presents the basic study parameters for the different scenarios.

This study considers *only* the pump and pipeline costs between the thickener and the process plant as it focuses on the transport (pumping) aspects only.

No thickener underflow pumping facilities at the TSF are included as it assumes that the thickener discharges at a single point discharge. No costs associated with placement of the tailings are included, nor are the costs associated with water reclaimed from the TSF, however the cost of returning thickener overflow water is included.

It is assumed that the cost of the thickener facility at the plant is equal to the cost of a remote thickener facility.

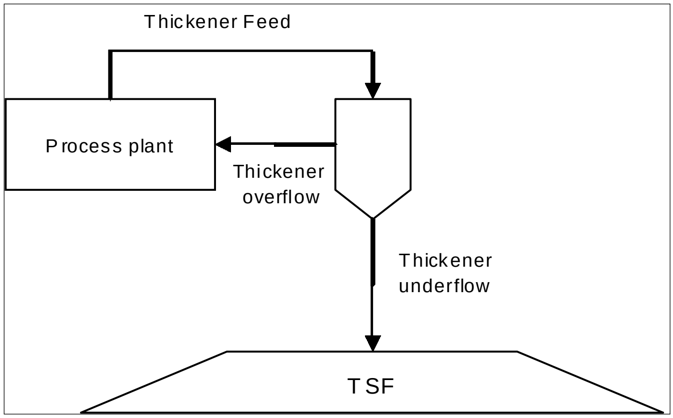

Figure 1: System schematic.

Case	Thickener location	Pumping system	Distance from plant to TSF
1 A	At TSF	Low pressure	2.5 km
1 B	At plant	High pressure	2.5 km
2 A	At TSF	Low pressure	5.0 km
2 B	At plant	High pressure	5.0 km

Table 1: Study Scenarios.

2.2. Process Parameters

The assumed process parameters for the study are shown in Table 2 for a typical co-thickened tailings system transporting a combination of fine and coarse product for co-disposal.

Parameter	Thickener feed	Overflow (from thickener)	Underflow (from thickener)
Mass flow (tonnes/hour)	450	-	450
Slurry density (t/m^3)	1.10	1.00	1.80
Solids %m	14%m	-	70%m
Slurry flow rate (m^3/h)	2,839	-	355
Water flow rate (m^3/h)	2,673	2,485	189
Yield stress (Pa)	n/a	-	100
Plastic viscosity (Pa.s)	(settling slurry)	-	0.150
d_{50} (microns)	500	-	500

Table 2: Process Parameters.

3. Pump and Pipeline System

3.1. Thickener Feed System

The thickener feed behaves as a settling slurry at low densities and will only exhibit non-Newtonian behaviour at higher solids concentrations. High transport velocities are needed to keep the solids in suspension. At the design flow rates it is estimated that a pipeline with an internal diameter of 472 mm is needed to ensure sufficiently high transport velocities for the settling slurry (Wilson et al., 1991).

All metal centrifugal pumps are considered suitable for the flow head requirements. The summarised pump and pipeline requirements for Case 1A and 2A are shown in Table 3.

It is clear that when pumping 5 km to the TSF that higher discharge pressures are needed. The high flow rates and pressures result in a high absorbed power.

Case	1A	2A
Slurry flow rate (m^3/h)	2,839	
Pipeline length (m)	2,500	5,000
Pipeline specification	472 mm internal diameter	
Pump station discharge pressure (kPa)	1,650	3,132
Pump head (m slurry)	153	290
Pump type	All metal centrifugal, each with 630 kW motors	
Number of pumps	4 in series + 4 standby	8 in series + 8 standby
Approximate absorbed total power (kW)	1,825	3,470

Table 3: Thickener feed pumping system.

Notes:

- It is assumed that when the thickener is located at the process plant (Case 1B and 2B) the thickener feed is via a gravity fed launder and no pumps are required. This is standard practice.
- Full centrifugal pump standby is included at the process plant pump station.
- No standby pipeline is allowed for.
- In *all* scenarios a thickener is used to thicken the tailings to 70%m.

3.2. Thickener Return Water System

The thickener overflow at the TSF is assumed to be clear with no suspended solids.

It is assumed that low pressure, large diameter high density polyethylene pipes can be used to gravitate the overflow from the 15 m tall thickener facility to the process plant. No pumping costs are included.

An 800 mm diameter high density polyethylene pipeline is considered suitable for this application. No standby pipeline is included.

3.3. Thickener Underflow System

The thickened underflow with a yield stress of 100 Pa requires the following pump and pipeline combination for Case 1B and 2B.

Case	1B	2B
Slurry flow rate (m^3/h)	355	
Pipeline length (m)	2,500	5,000
Pipeline specification	237 mm internal diameter	
Pump station discharge pressure (kPa)	5,724	11,448
Pump head (m slurry)	324	648
Pump type	Piston diaphragm	
Number of pumps	2 + 1 (400 kW each)	2 + 1 (750 kW each)
Approximate absorbed total power (kW)	675	1,350

Table 4: Thickener underflow pumping system.

Notes:

- High pressure lined steel pipeline is assumed.
- No standby pipeline is allowed for.
- 50% positive displacement pump standby is included at the process plant pump station.

4. Cost Estimate

The following costs are considered in the cost comparison:

- The costs of pumps, motors, switchgear and starters.
- The cost of the pipeline supply and installation.
- Annual maintenance costs for pipelines, pumps and electrical equipment.
- Annual power costs are $34/MW.h.

Capital and operating costs that are considered common to both systems, such as thickening facilities, pump stations, and related infrastructure costs, are excluded from this analysis.

It is likely that a remote thickening facility will incur higher annual operating costs that will increase the further it is away from the process plant. These costs are not included in this comparison.

4.1. Capital and Operating Cost Summary

The summarised capital and operating costs when depositing 2.5 km from the plant are presented in Table 5. The capital cost for pumping to a thickener located at the TSF is 25% less than the cost of a high pressure pumping system from the plant, but the operating costs are estimated to be approximately 22% higher.

Option	**1A**	**1B**
Thickener location	At TSF	At plant
Thickener feed pipelines	$868,644	$0
Thickener feed pumps	$1,334,532	$0
Thickener return pipelines	$1,016,949	$0
Underflow pipelines	$0	$635,593
Underflow pumps	$0	$4,322,034
Total capital costs	*$3,220,125*	*$4,957,627*
Annual maintenance	$137,802	$336,864
Annual power	$496,035	$183,508
Annual operating costs	*$633,837*	*$520,373*

Table 5: Cost summary: TSF 2,500 m from plant.

Table 6 presents the costs for depositing to a TSF 5 km from the plant. In this scenario the capital cost of the pump and pipeline systems is reasonably close, however the annual operating costs are significantly higher when pumping to a remote thickener. In this case the annual operating costs are 80% more than when using a high pressure pumping system.

Option	**2A**	**2B**
Thickener location	At TSF	At plant
Thickener feed pipelines	$1,906,780	$0
Thickener feed pumps	$2,434,487	$0
Thickener return pipelines	$2,033,898	$0
Underflow pipelines	$0	$1,271,186
Underflow pumps	$0	$5,593,220
Total capital costs	*$6,375,165*	*$6,864,407*
Annual maintenance	$261,400	$305,085
Annual power	$943,322	$367,017
Annual operating costs	*$1,204,722*	*$672,102*

Table 6: Cost summary: TSF 5,000 m from plant.

4.2. Net Present Cost Analysis

A net present cost (NPC) analysis using a 15 year life of mine analysis with a 10% discounted cash flow and an 8% interest rate shows that at short distances it is cheaper to install the thickener at the TSF.

As distance increases the NPC of the high pressure pumping system is less than pumping to a remotely located thickener at the TSF. Results are summarised graphically in Figure 2. Assuming an approximately linear relationship for this example only shows the break even point is at about 2.6 km.

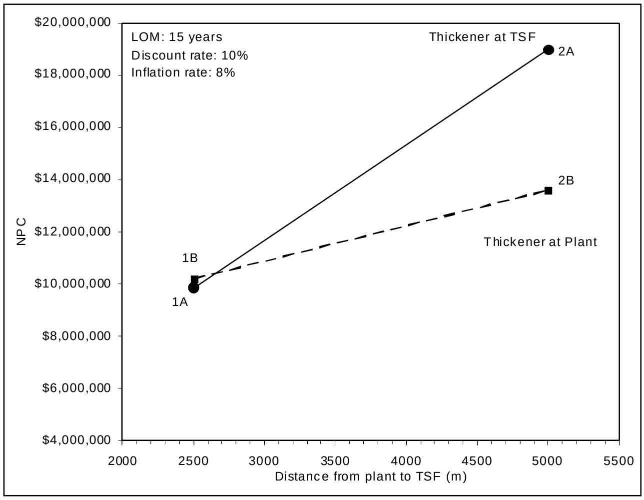

Figure 2: Net present cost analysis.

4.2.1. Affect of life of mine on NPC

Analysis of the affect of life of mine on net cost per tonne is shown in Table 7. It is seen that a high pressure pumping system is always cheaper when pumping longer distances, even for a short operating life.

At short distances, the cost differential increases as life of mine decreases, and a thickener at the TSF is a marginally better short term solution that a high pressure pumping system.

Option	1A	1B	2A	2B
Length	2,500	2,500	5,000	5,000
Thickener	At TSF	At plant	At TSF	At plant
20 LOM	$0.16	$0.16	$0.31	$0.22
15 LOM	$0.18	$0.19	$0.35	$0.25
10 LOM	$0.21	$0.23	$0.41	$0.31

Table 7: Net cost per tonne over life of mine.

5. Conclusions

- The study presents transport (pumping) costs only and excludes the costs of preparation and placement of the thickened tailings.
- The study is intended to highlight the importance of a proper trade-off study on the various pumping options and distances.
- This study is based on South African costs of equipment and power. Currently power in South Africa is relatively cheap compared to elsewhere in the world. As power costs increase, the benefits of energy efficient high pressure pumps will become more apparent.

- When the TSF is approximately 2.5 km from the process plant there is a marginal pumping cost benefit to place the thickener at the TSF and discharge directly to the TSF from the thickener underflow.
- If the TSF is further than 2.5 km from the plant there is an increasing benefit to using high pressure positive displacement pumps located at a thickener at the plant.
- This study assumes a single point discharge of the thickened tailings at the thickener site. A high pressure pipeline from the plant is more flexible than a fixed thickener discharge if more than one discharge location is needed.
- Other costs that may influence this decision include costs for infrastructure to service remote thickener installation and associated increased operating costs.

The study shows that the decision to locate a thickening facility at the process plant or TSF is not straightforward and that the full life cycle pumping system costs need to be carefully considered.

Acknowledgements

The author wishes to acknowledge the input from Graeme Johnson at Paterson & Cooke Consulting Engineers (Pty) Ltd for providing the capital and operating cost estimates.

References

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