24-055

Investing in Sustainable Tailings Management: Reduce Risk by Considering Environmental and Utility Costs During Pre-Feasibility

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ABSTRACT

The use of conventional tailings deposition methods has been the standard for decades. With the need to reduce the impact of mining, alternative methods are considered when expanding or upgrading tailings handling systems. Converting an existing tailings management system to a more sustainable deposition method during the operation of a mine may incur considerable operational and financial risk, and when assessed more traditionally, does not provide significant advantages. As a result, most mines choose to continue their current technology and add an additional pumping stage or pumpstation to their tailings line in case of a pipeline extension or Tailings Storage Facility (TSF) expansion. This also often involves raising embankments.

Changing pumping technology is traditionally assessed by comparing the energy efficiency of current and prospective pumping technology. Despite a reduction in absorbed power, this traditional assessment does not include possible savings in water and the carbon footprint. With the consideration of all these three aspects, alternative pump technologies, such as Positive Displacement (PD) technology, become more economically feasible, providing increased sustainability and enable a site to future-proof their operations.

Project feasibility may be affected by the high capital investment required for PD pumps. The benefit of applying PD pumping technology could be enhanced by reducing the volumetric throughput of the pipeline by dewatering the tailings to 65% solids concentration by weight. It was found that despite increasing capital expenditure, the improved reclamation of water will have a positive effect on the direct and indirect cost of fresh water intake to mine operations.

This paper seeks to illustrate that in many applications the long-term benefits of investing in sustainable tailings management are optimized when more efficient PD pumping technology is combined with tailings dewatering when upgrading or expanding the tailings handling system.

INTRODUCTION

The Iron Range in the United States (US) has a long tradition of iron ore mining. Many of the mines in the area have been operational for decades and have significant Life Of Mine (LOM) remaining.

Increasing pressure to reduce emissions, as well as the demand to improve environmental and social stewardship, makes mining companies look at alternative technologies for ore processing and tailings management. Significant investments in the development and implementation of sustainable technology are required to secure profitability of current and future operations. Investing in sustainable solutions may prove to be crucial to secure the license to operate in the coming decades.

Phased Tailings Storage Facilities (TSFs) raises and expansions using conventional deposition methods have been the standard for decades. However, converting an existing tailings management system to a more sustainable deposition method during the operation of a mine may incur considerable operational and financial risk. When considering the feasibility of implementing a more sustainable tailings handling methodology, the common approach is to calculate the break-even period based on reduced, direct, operating costs. In many instances this traditional approach does not provide favorable results. Consequently, most operational mines continue using their conventional tailings management methods. While considering not only power, but also direct and indirect water costs and emissions, alternative pump technologies, such as positive displacement (PD) technology, become more economically feasible.

In this paper, the payback period for the conversion to a high-density tailings handling system is analysed on a holistic basis for an iron ore operation, taking into account the uncertainty in environmental (carbon tax, indirect water costs) and utility costs (power, direct water cost).

METHODOLOGY FOR FEASIBILITY ASSESSMENT

The total cost of ownership (TCO) is assessed, assuming the upgrade of the pumping technology is offset by a reduction in operational costs. Traditionally, in these assessments the main driver in the cost reduction is the assumed cost of energy. An initial conventional assessment of the pumping technology upgrade returned a payback period of approximately nine years, which was not deemed favorable. It was then assessed that the benefit of the upgrade was in future-proofing the operation by mitigating the payment of carbon tax in the near future. With this in mind, the upgrade was assessed as follows:

1. Model the current situation.
2. Model the upgraded pumping scenario(s).
3. Assess the capital cost of the upgrade(s).
4. Assess the difference between the scenarios in:
   – Absorbed power.
   – Water consumption.
5. Assess the reduction of power and water costs.
6. Assess (potential future) carbon tax reduction based on reduced power usage.
7. Assess payback period of the system upgrade.
8. Assess the sensitivity of the payback to variations in:
   – Carbon tax.
   – Power costs.
   – Water costs.

CARBON TAX

In the quest to drive down global emissions, taxation is believed to offer a cost-effective way of reducing greenhouse gas emissions (Ye, 2021). The advantage of an emissions tax over cap-and-trade policies is that it offers a higher level of cost certainty and is therefore favorable for modelling the financial effect on project feasibility of sustainable investments.

Several states in the US have already implemented taxation schemes for carbon emissions. Currently, no federal taxation policy has been implemented in the US, but this may change in the foreseeable future. In January 2021, five federal carbon pricing proposals were introduced, which would establish a carbon tax when implemented. Jason Ye provides a good comparison of the proposed acts (Ye, 2021).

At the start of this study, it was assumed that the carbon tax, when introduced, would be the primary driver behind investing in more efficient pumping technologies. The fact-sheet on the proposed acts shows initial taxes in the range of \$15 to \$59 per ton of CO_2 emitted (Ye, 2021). These values are in line with the required minimum taxation as proposed by the International Monetary Fund (IMF) in 2019 (IMF, 2019).

For this study, it is assumed that a carbon tax of \$30 applies, which according to the customer's estimation may escalate to \$150 per ton of CO_2 emitted when targets are not met within the life of the project.

TRUE COSTS OF WATER

In areas with (seasonal) wet climates, water is commonly considered an almost free commodity. It is common practice to reclaim water from tailings ponds for use as process water. This water may require treatment or dilution before use in ore processing. When the water is readily available, it can be pumped from the tailings pond or nearby lake. The costs associated with the supply of water can be considered direct costs and are made up of, but are not restricted to:

- Pumping and filtration of pond or lake water.
- Water rights.
- Water purchases.

Independent of location, water is lost through seepage. Seepage can have both geotechnical and environmental effects and therefore must be controlled. Seepage control measures range from installing design controls like liners, drains and collection ponds to water treatment systems allowing water disposal to the environment. The costs related to the implementation of these measures are largely dependent on the total volume of seepage. This implies that the cost incurred in seepage treatment can be considered as an indirect cost of freshwater intake. When water is not lost to the environment, it will not require treatment or replenishment. The indirect costs of water intake are therefore:

- Ground water treatment as remediation of seepage-induced contamination of aquifers.
- Seepage control measures like liners, drains and treatment systems.

The collated cost of freshwater intake is the sum of direct and indirect costs. The primary focus should always be on minimising the volume of contaminated water and clean water diversion to minimise the propensity to generate contaminated water (Atkinson et all., 2013).

The direct costs of freshwater intake are driven by flow velocity, pipe diameter, pipeline route, pumping efficiency and water quality. In general, pumping water from a TSF to the process plant costs up to \$0.35 per cubic meter. The indirect costs of water treatment vary based on the type and level of contamination, as well as discharge limitations. For this study, the work of Keir et al. has been used as a reference for indirect costs. Keir indicates that the operational costs of a treatment system are between \$0.90 and \$1.60 per cubic meter (Keir, 2013). Reverse osmosis can require up to 1 kWh/m^3 in energy consumption (Atkinson et al., 2013). Considering the large volumes handled in tailings management, a reduction of this requirement will have a direct effect on both operational costs and emissions.

THE OPERATION

This study considers an iron ore mining operation in the Northern United States that has been operational for several decades. It operates a Tailings Storage Facility (TSF) located 12.5 kilometers from the processing plant. The dilute fine tailings are thickened to 32% solids concentration by weight and pumped to the TSF for disposal using a single pipeline. The pipeline includes two pump stations, each equipped with a centrifugal pump train (three pumps in series for the first pumpstation and four in series for the second pumpstation).

The current pumping layout has reached maximum capacity; hence a review of the pumping strategy was launched. The addition of an extra stage to the second pumpstation would be the conventional approach. The customer's ambition to reduce their emissions led them to consider an alternative tailings handling strategy. Changing to PD pumping technology was considered to reduce emissions by approximately 20% because of its higher efficiency. In this case study the upgrade of the tailings handling system is assessed for feasibility considering the investment is paid for by the savings in energy, water and carbon costs.

The current tailings handling system is presented in Figure 1. The system consists of a single pipeline that is serviced by two pump stations. Pump station 1 is operating at a pressure of approximately 20 bar and pump station 2 between 45 and 50 bar depending on the location of

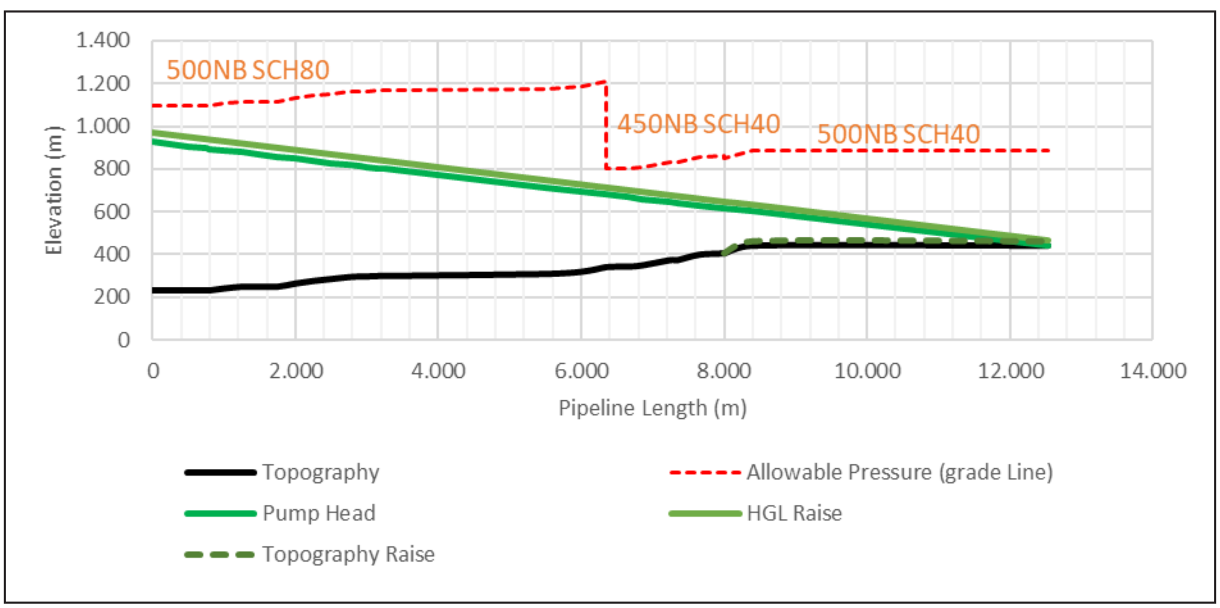

Figure 1. Topography and Hydraulic Grade Line (HGL) of the existing pipeline

spigotting. Additional future raises will be required to accommodate tailings disposal. Within the scope of the assessment two scenarios have been considered:

- Replacing the two centrifugal pumpstations with a single PD pump station.
- Replacing the centrifugal pump stations with a single PD pump station combined with improving tailings dewatering (increase slurry density).

In the first scenario, the only change to the handling system is the exchange of the centrifugal pumps with a single PD pumping station. No changes to the tailings properties or volumes are made. The comparison, therefore, is a trade-off between pumping technologies.

Retrofitting the first pump station with PD pumps makes the second pump station obsolete, which has several operational advantages. The removal of the second pump station eliminates the necessity to deliver the slurry flow at a discharge pressure in excess of the required Net Positive Suction Head (NPSHr). As a result, the total required head for the single pump station is lower than the cumulative head of the two pump stations (see Table 2). The required head is nevertheless too high to allow for re-use of the entire existing pipeline. As a consequence, the bottom section of the pipeline requires an upgrade. The topography and HGL for scenario 1 are given in Figure 2. The volumetric throughput of the pipeline does not change as can be seen from Table 1. The implication of the relatively large flow is that four PD pumps will be required to handle the total flow.

The benefits of applying PD pumping technology can be optimized when the tailings are densified:

1. Reduced volumetric throughput results in the need for fewer pumps.
2. Increased solids concentration might reduce the critical flow velocity, resulting in lower friction losses.

Dewatering

In the second scenario, the dewatering of the tailings is improved. Settling test work indicated thickener performance could be improved to produce a tailings underflow of 65% solids concentration by weight.

In general, the overall tailings water recovery as a percentage of the total water used in processing increases from typically 50% to 60% for tailings disposal as a slurry, 60% to 70% for tailings disposal as a high-density slurry, and about 80% for tailings disposal as a high slump paste (Williams, 2014). The results of settling test work indicated that a consistent solids concentration of 65% by weight is achievable through thickening. Therefore, the lab results are in line with the general theory.

In Table 1, the slurry properties and throughput for the current and two upgrade scenarios are given. Figure 3

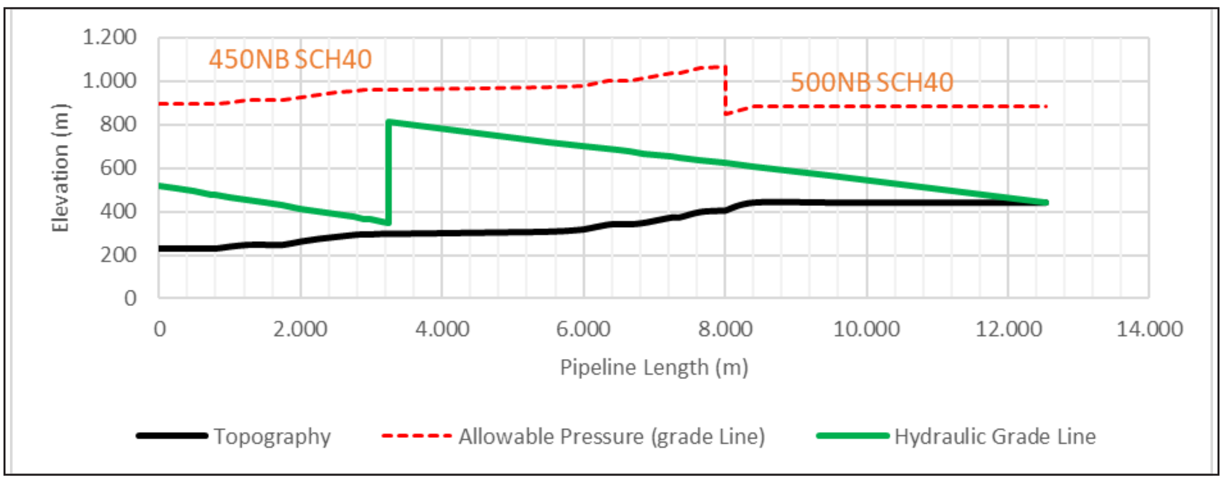

Figure 2. Topography and Hydraulic Grade Line (HGL) of Scenario 1: Single PD pump station, C_w 32%

Table 1. Slurry properties

	Current	PD	PD + Dewatering
Solids throughput	969 t/h	969 t/h	969 t/h
Slurry Density (S_m)	1.270 t/m^3	1.270 t/m^3	1.787 t/m^3
Solids Concentration (C_w)	32%	32%	65%
Volumetric throughput (Q)	2,384 m^3/h	2,384 m^3/h	834 m^3/h

Figure 3. The effect of improved dewatering. Left the current slurry at 32% solids concentration by weight, on the right the slurry at 65% solids concentration by weight

demonstrates the reduced volume of water handled by the pipeline as a result of improved dewatering.

Duty Conditions, Absorbed Power and Water Usage.

The pump duty for the current situation is calculated using the modified Wasp method. The results proved to be in line with field observations. The same method was then used to calculate the pump duty for the scenario in which only the pumping technology was changed. Increasing the solids concentration of the tailings to 65% initiates non settling behavior, hence the tailings can be pumped at a lower flow velocity. Pumping through the current 450NB pipe assures turbulent flow, preventing (laminar) flow settling. On the TSF 500 NB pipe is installed which at low flow velocities might induce settling, but operational risk is minimal due to the relative short pumping distance. In the upgraded scenario the increased duty head requires the use of schedule 80 pipe on the bottom part of the pipeline. Increasing the pipe diameter in conjunction with the higher class pipe results in reduced pressure losses within an acceptable flow velocity interval.

The calculated duties are given in Table 2.

The pump selections for the upgrade scenarios were made following Weir's proprietary pump selection procedures. The absorbed power is known for the current installed base. Power usage for dewatering is based on assumed power usage of 1 kWh/t of dry solids for normal thickening and 1.5 kWh/t for improved thickener operation (Kruyswijk, 2021). The cumulative absorbed power is presented in Table 3.

For this comparison, it has been assumed that the volume of interstitial water is equal for all scenarios. The underlying argumentation is that the tailings are assumed to consolidate to equal in situ bulk densities in each scenario. Site-specific data indicated that approximately 40% of water released at the TSF is lost to the environment through seepage and evaporation. In the current situation, approximately 50% of the water in the tailings is reclaimed from the pond for re-use in the plant. Increasing the solids concentration of the tailings reduces the volume of water pumped out to the TSF by 75%. The result is that the loss of water to the environment through seepage and evaporation is reduced by 89%. The combined effect of the reduced losses and improved thickening is 81% reclamation of water from the tailings stream (see Figure 4).

Burning fossil fuels—whether for electricity generation or diesel-powered equipment—generates CO_2 emissions. Emissions are calculated using an average CO_2 emission of 0.46 kg per kWh absorbed power (Kruyswijk, 2021). In Figure 5, the total annual production for each of the considered scenarios is given. Based on these calculations, it

Table 2. Head requirements

		Pump station		Total pressure /	Raise
Pumping Scenario	C_w	**PS 1**	**PS 2**	**pipeline**	**PS 1**
Centrifugal - Current	32%	21 bar	48 bar	69 bar	NA
PD - 1 PS	32%	60 bar		60 bar	63 bar
PD - 1 PS - dewatered	65%	63 bar		63 bar	67 bar

Table 3. Absorbed Power. (base case without raise)

	Current	PD	PD + Dewatering
Pumping	6,529 kWh	4,829 kWh	1,764 kWh
Thickening	969 kWh	969 kWh	1,454 kWh
Total absorbed power	7,498 kWh	5,798 kWh	3,218 kWh

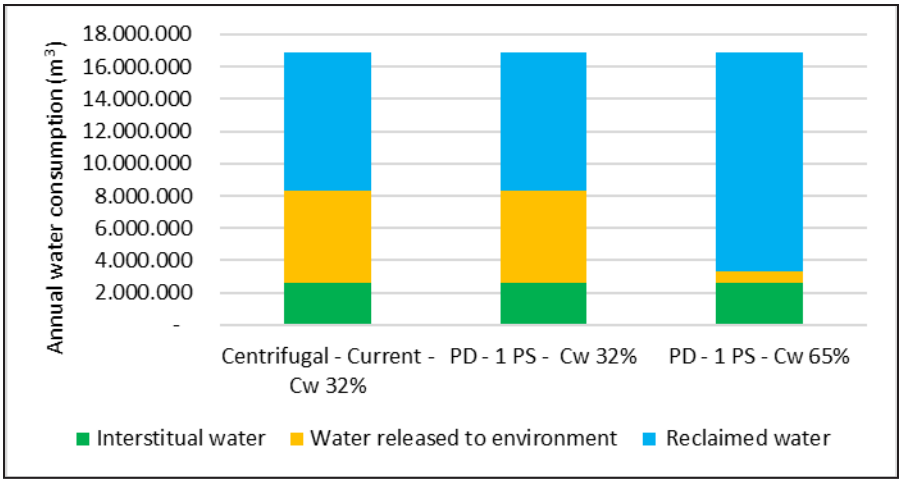

Figure 4. Water balance of tailings

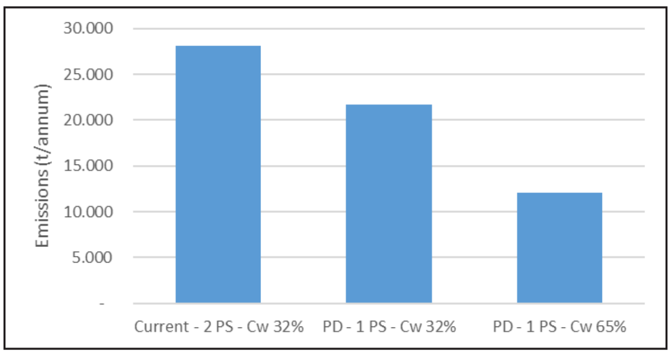

Figure 5. Emissions in tonnes CO_2 per annum for each of the considered scenarios

can be concluded that changing pumping technology combined with dewatering the tailings results in a 57% reduction in emissions. A 23% reduction is achieved when the pumping system is solely upgraded with more efficient PD pumping technology

Operational Costs

The operational costs of the three scenarios have been calculated using the results from the absorbed power and water usage calculations. For the base case the unit costs of power are taken at $0.10 per kWh and water costs are taken at $1.00 per cubic meter. Maintenance costs including spares and maintenance hours are estimated based on pump selection and empirical data of site and identical applications. The emissions related to the absorbed power are included at a tax rate of $30 per tonne CO_2 as a base case. Pumping costs in the current setup is approximately $0.80 per cubic meter. Upgrading the pumping technology reduces operating costs by 13%. This impact is less than might be expected based on the improved efficiency of applying a PD pump. Although the total absorbed power is reduced by the improved pump efficiency, the power required for thickening of the tailings does not change. Thickening makes up approximately 15% of the power consumption; therefore the total reduction in absorbed power is dampened.

When the improved efficiency concurs with a reduction is total pumped volume the reduction in absorbed power is maximised, provided that the thickened tailings / paste can be pumped at lower flow velocity, thus avoiding excessive pressure loss increases. To illustrate this relationship the equation for the calculation of absorbed power is given in equation 1.

$$P = \frac{Q * p}{\eta} \quad (1)$$

In which P is absorbed power in kWh, Q is flow rate in m^3/h, p is pressure in kPa and η is pump efficiency.

Optimizing tailings dewatering by installing high-rate or paste thickeners reduces the total volume of tailings without a major increase in absorbed power for dewatering.

Increasing solids concentration of the tailings reduces the operational costs by 61% compared to the current situation. From Figure 6 it can be concluded that when upgrading only pumping technology, the cost reduction is driven by maintenance costs and absorbed power. Only when increasing slurry density water costs decrease and the reduction in operating costs is optimised.

Capital Costs

The capital costs required for the proposed upgrades includes the replacement of the lower section of the pipeline. Pumpstation 1, located at the processing plant at the start of the pipeline, will be used to fit the new pumps. Upgrading the current thickeners will be required to achieve a higher solids concentration. An investment of approximately $20 million is required to upgrade the tailings handling system to PD pumping technology. Densifying the tailings will have a positive effect on the spent on pumps but will require a major investment in the existing thickeners. An estimated total of $50 million is required for upgrading the system to pump thickened tailings. For the purpose of this paper, no further breakdown of the capital costs is provided.

Economic Evaluation

As demonstrated above, upgrading the tailings handling system reduces operational costs. The capital costs required for such an upgrade are significant. The viability of investing in retrofitting an operational pipeline depends on the monetary return on investment (payback) as well as the operational and competitive advantages of the upgrade. The savviness to invest in upgrades that require more than five years to break even is rare.

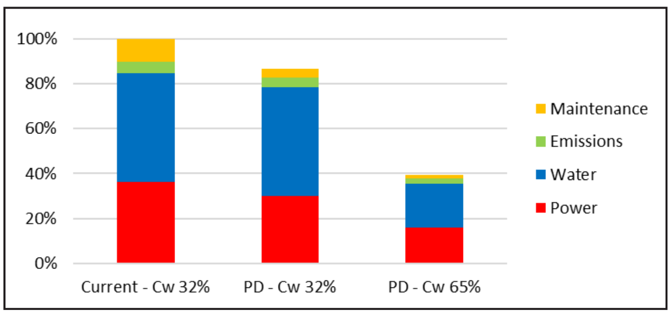

Figure 6. Operating costs. Costs represented as percentage of current operating costs

The payback period for the two upgrade scenarios is calculated assuming the required capital investment is repaid by the difference in operational costs. In other words, the savings in operational costs are considered fictive instalments, offsetting the capital costs. Using this methodology, the break-even period for the PD upgrade is nine years. When the slurry is densified the payback period is reduced to six years.

Sensitivity

The cost breakdown of the operational costs indicates the two major drivers are power and water. Long term changes in these costs affect the viability of the technology upgrade significantly. Figure 7 presents the sensitivity of the payback period as a result of a variation in costs of power, water and carbon tax. As expected, variations in power costs have a significant impact on the break-even period. In the scenario where only the pumping technology has been changed, power costs have the largest impact on the break-even period. In the scenario where the tailings are dewatered prior to pumping, the cost of water has the highest impact on the time required to break even. From these calculations, it can be seen that in this case doubling actual water costs reduces break-even by a third. In contrast with common perception, the taxation of emissions has limited effect on the feasibility of sustainable investments. The positive effect of improved water recovery for breaking even on investment is amplified if water becomes more valuable in the future. Increasing power costs have the second largest

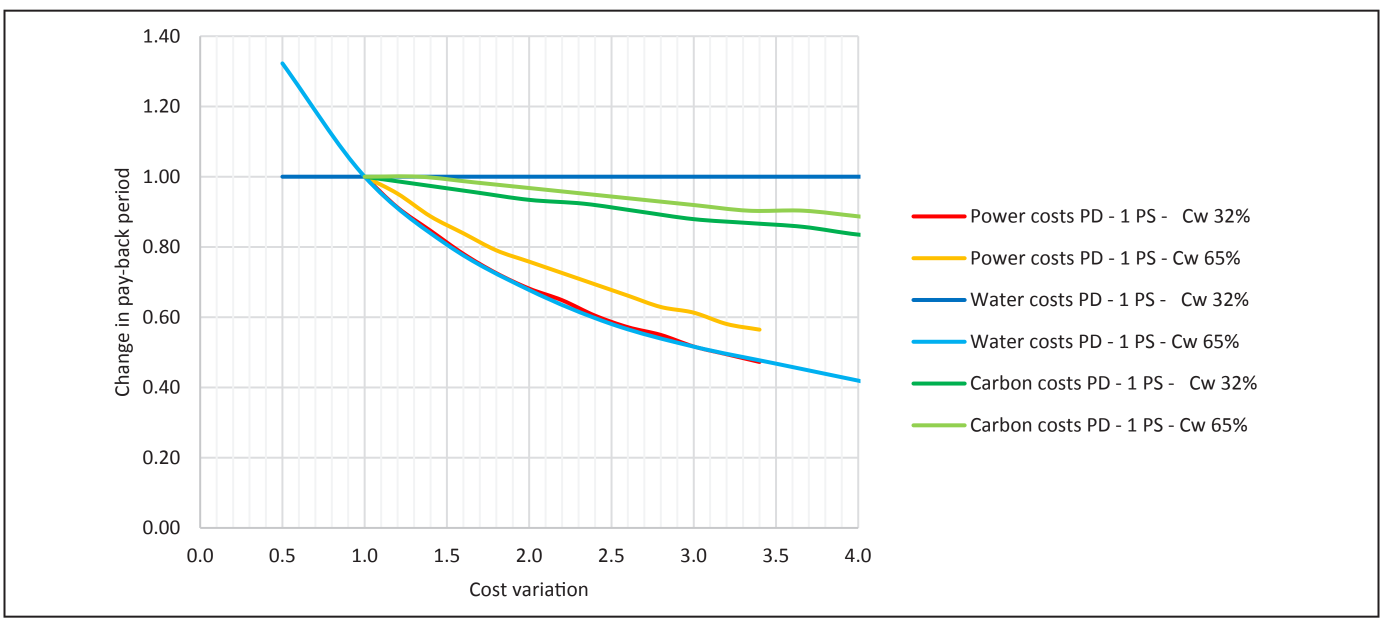

Figure 7. Sensitivity of payback period to variations in power, water and carbon tax costs

effect on achieving break even due to more efficient tailings pumping. This counterintuitive finding is driven by the direct and indirect costs of water intake and discharge. In other words, there is more return on investment when less water is lost to the environment.

CONCLUSION

From this case study, the key drivers behind sustainable development are power and water savings. The benefits of carbon reduction are positive; however, they are significantly less compared to power and water savings. In the comparison between tailings pumping methods without additional tailings dewatering, the pay back is nine years and is considered as a non-viable option. Optimising tailings dewatering has a positive effect on water preservation and results in a significant reduction of the tailings stream. This reduction amplifies the sustainability effects of converting to a more efficient tailings pumping technology to PD pumping. The results indicate that investing in improved tailings dewatering and PD pumping technology reduces payback time to acceptable levels.

In summary, it can be concluded that:

- Upgrading pumping technology reduces absorbed power and carbon emissions.
- Increasing the solids concentration of the tailings maximizes pumping efficiency and decreases absorbed power and emissions even further.
- Conventional tailings deposition is most sensitive to increases in power costs.
- Thickened / paste tailings reduce power costs sensitivity.
- The feasibility of thickened / paste tailings is most sensitive to projected future water costs.
- Taxation of emissions has a very limited effect on project feasibility.

Today's standards are becoming stricter. Considering the environmental and social impact of mining, water usage costs are likely to increase with time. Uncertainty of costs and project feasibility sensitivity to environmental (water), utility costs (electricity), and carbon tax demonstrates the long-term benefits of investing in sustainable tailings management.

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24-056

Kickstarting Culture Change

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ABSTRACT

In the dynamic and challenging modern industry landscape, understanding and unleashing the true role and contribution of technical teams is crucial to business success. The cyclical nature of industries has led to shifts in the technical professional's place within the organization and the technical skills that are desired most. This paper reframes the pivotal role that technical professionals play within complex operating assets to maximize value and realize full potential. This investigation focuses on the Rio Tinto Kennecott Technical group's cultural journey, which is underpinned by an investment in its people. The conflict between legacy industry beliefs and the necessity for cultural change emerges. This is illustrated by a deep dive into the evolving case study of Kennecott's Bingham Canyon Open Pit Mine Technical team. Here, a multi-faceted approach to cultural change is helping to unlock the team's contribution to the life extension of an aging asset. Guided by a vision and strategic roadmap, this approach is part way through a 5-year implementation period and is yielding encouraging business outcomes.

INTRODUCTION

In the struggle for top technical talent, the importance of cultivating company culture cannot be overstated. This foundational aspect is intrinsically linked to productivity and innovation, which drive business performance. Like the metaphorical wilting garden that struggles in changing conditions, organizational culture can be transformed into a landscaped paradise through a clear vision and a nurturing hand. Shaping growth mindsets and fostering effective engagement become easier with a thriving organizational culture. These benefits serve as the catalyst for improving team efficiency and pioneering solutions to complex problems for maximized personal and business outcomes.

Becoming a great workplace with a thriving culture is a transition that is neither quick nor simple. It takes sustained effort and time to cultivate manicured lawns and vibrant gardens. It requires building on the cumulative gains of each year and taking small setbacks in stride. This paper embarks on an insightful exploration of the transformative journey of the Rio Tinto Kennecott Technical group as a common and relatable case study. The seeds are sown for articulating a vision and landscape design for cultural transformation to maturity. A specific case study for the Open Pit Mine Technical team within the Kennecott Technical group demonstrates the systematic yet iterative process of culture change for sustained organizational success.