Plant Optimisation Approach at the Tropicana Gold Mine

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ABSTRACT

AngloGold Ashanti Ltd's Operational Excellence initiative has seen an ongoing focus on margin improvements through a range of projects to deliver productivity and cost improvements at all of its operations. In processing this meant matching processing plant capability to mining output and maximising plant utilisation and throughput without increasing operating costs. At the Tropicana Gold Mine (AngloGold Ashanti Australia Ltd 70% and manager, Independence Group NL 30%), in Western Australia, considerable emphasis was placed on optimisation of the process circuit using operational data from the processing plant. Traditionally these optimisation exercises had been executed internally by the operations team but in an attempt to improve design and cost outcomes, a collaborative approach was selected, in which external consultants worked closely with the operations team.

The purpose of this paper is to explain the approach that was adopted by the engineering company and the owner to optimise the process circuit and achieve an associated increase in throughput whilst decreasing the operating cost at the Tropicana Gold Mine, namely:

- Optimising the conveyor system to minimise shutdown duration and increase the conveyor design capacity;
- Optimising the design to increase equipment life and reduce scheduled shutdown duration;
- Optimising the leaching circuit;
- Managing the tailing cyanide discharge levels through water management and dilution.

The authors will discuss the various decisions made during the optimisation process and will show that adopting alternate design decisions can have a major positive cost impact. Effective interpretation and understanding of the overarching issues, combined with good collaboration (one joint team including client operational personnel and design consultants), zero base design and effective use of appropriate equipment are some of the factors that can be used to deliver an optimal final outcome. Very good results were achieved at Tropicana, demonstrating the effectiveness of this approach.

INTRODUCTION

AngloGold Ashanti Ltd's (AAGA) Operational Excellence initiative has seen an ongoing focus on margin improvements through a range of projects to deliver productivity and cost improvements at all of its operations. In processing this meant matching processing plant capability to mining output and maximising plant utilisation and throughput without increasing operating costs.

The objectives of the Tropicana Optimisation Project, which commenced towards the end of 2015, were to improve reliability, throughput, recovery and cyanide management in a concerted effort. AngloGold was looking to debottleneck the process plant to achieve an annualised throughput of up to 7.6 Mtpa at 95% availability via a combination of availability improvements and throughput increases from the previous 6.5 Mtpa at 90% availability. It was also understood that this was part of a debottlenecking process and could only be implemented within the constraints of the existing process plant major equipment.

Traditionally these optimisation exercises had been executed internally by the operations team but in an attempt to improve design and cost outcomes, a collaborative approach was selected, in which external consultants worked closely with the operations team.

AngloGold's Tropicana Gold Mine engaged Mintrex to prepare an integrated project plan to coordinate the many identified site projects. The scope included a process review and a capacity constraints review to produce a budget based on the prioritised works.

The project priorities were set as follows:

1. Stay in business projects that address safety and cost issues.
2. Increase utilisation.
3. Increase throughput - constrained by existing major equipment starting with optimising the HPGR.

OPTIMISATION PROCESS

Upgrade Project Identification

Tropicana Gold Mine's operational staff were asked to identify a list of issues encountered while operating the plant based on the first 18 months of operation. This formed the basis for a list of debottlenecking/upgrade sub-projects that could improve safety, environmental aspects, maintenance difficulties, reliability and process control.

A site visit by senior principal engineers from Mintrex enabled direct observation and discussion of these issues helping to reveal the root causes of some problems.

These sub-projects were investigated to establish scopes required to solve the issues and form the basis for estimating and scheduling purposes. During this analysis overlapping of scopes between the sub-projects were identified and the scopes were amended to eliminate duplication. Some sub-projects were identified to address the downstream impacts, instead of the root causes. They were either modified to address the root cause or eliminated if another sub-project would address the root cause. The high level assessment of all the sub-project scopes at once enabled the identification, elimination and/or modification of scopes at an early stage, saving both money and time.

Establishing Project Scopes and Classification

The optimisation process flowsheet developed is depicted in Figure1.

A high level scope of work for each project was identified and established by referencing onsite observations, previous experience, original design documents/drawings, information supplied by external vendors and answers provided by onsite personnel to follow-up questions. The individual scopes of work were used as the basis for estimating costs and schedule.

A workshop was held in collaboration with the client to classify the various sub-projects into the following categories:

1. Health Safety and Environment sub-projects: Sub-Projects affecting Health, Safety and/or Environment were classified together. For instance controlling cyanide emissions improves all three areas.
2. Sub-Projects to be completed under the budget allowed – financial and project management: Sub-projects, which are to be undertaken as top priority with the budget allowed. If overlapping occurs between the classes of sub-projects, any project qualifying for other classes would only be classified here.
3. Throughput increase sub-projects: Any project designed to increase throughput capacity or alleviate issues affecting the current throughput or utilisation. This included issues affecting equipment life and increasing shutdowns for maintenance or those triggering shutdowns.
4. Other sub-projects: Anything that does not fit into the above classifications. These projects are aimed at resolving issues unrelated to the throughput or HSE, which could optimise operating costs, such as resolving clean-up issues.

Estimating process

The established scope for each sub-project was used to estimate the costs using the Pareto Principle (80-20 rule) to estimate the most costly equipment in enough detail to achieve the requested overall budget accuracy of ±25%. Quantities for concrete, structural steelwork and platework were estimated from design drawings where available, and previous experience when not. All relevant supply and install rates were conservatively assumed based on previous experience. Quotes were not sought as no detailed design had been performed and there would only be small impact on overall costs (Pareto Principle). Due to the nature as a series of small projects, rates were assumed to be conservative so modest potential cost savings may be available by seeking tenders for these jobs especially where synergies exists between sub-projects.

EPCM costs and contingency were estimated as a 35% allowance on-top of the overall project supply and install costs, which is a number, based on aggregated experience on various brownfields projects. The EPCM costs and contingency allowance needs to be reported separately, and not against individual sub-projects.

The scope for sub-projects was established at a high level using the available information and experience based assumptions. Any variation in scope, equipment and exact quantities used could have a large impact on the costs and implementation duration for that sub-project. Therefore, ±25% accuracy needs to be considered as an average accuracy for the entire upgrade package. The individual sub-projects may have an accuracy of ±35% for larger sub-projects and ±50% for smaller as more time was spent on establishing the cost of larger projects. Gains made on some projects will offset losses on others.

Once scopes and costs had been established, a workshop was organised between Mintrex and AngloGold to analyse the overall project in order to:

- Identify the overall project budget.
- Establish priorities to determine which sub-projects should proceed as a priority, be undertaken if the budget allows, be delayed or not be undertaken.
- Assign responsibility for management, engineering, procurement and installation for each project between AngloGold operations personnel, maintenance personnel, Mintrex and an external EPCM contractor.
- Estimate implementation durations for design, procurement, pre-shutdown construction and work during shutdowns.

Flow Chart

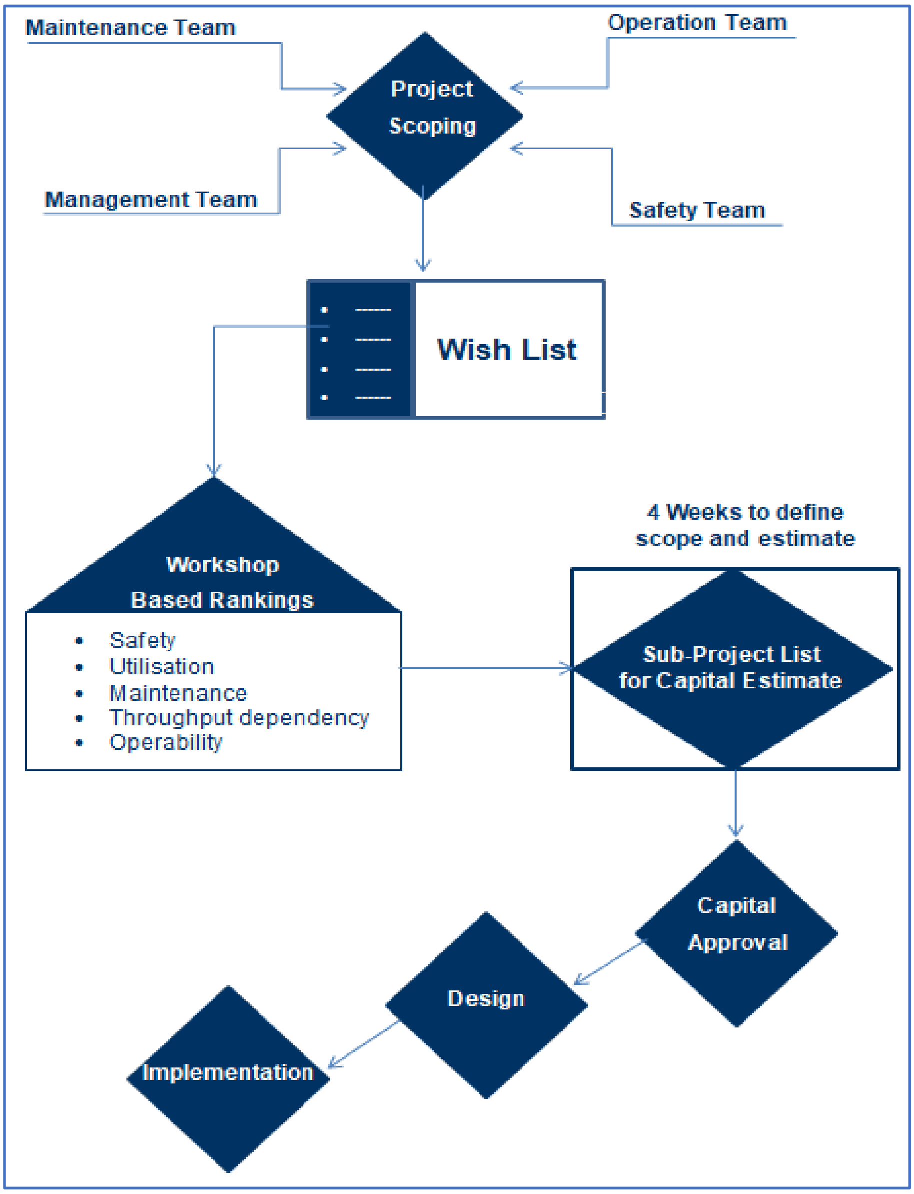


Figure 1 – Optimisation Process Flow Chart

IMPLEMENTATION PLANNING AND EXECUTION

AngloGold's Tropicana Gold Mine engaged Mintrex to prepare a high level project plan to coordinate the implementation of the site projects following the optimisation process, sub-project identification and cost estimating described above. The sub-projects were grouped to allow development of a suitable implementation plan focusing on two groups:

- Engineering and Procurement (EP) sub-projects: these have a range of engineering and procurement activities with majority of construction included in plant shutdown using shutdown labour. These sub-projects were grouped in one 'design' scope to reduce the overheads associated with design management and reporting. Each sub-project formed a task within the 'design' scope with early design and procurement commencement to ensure the sub-projects were scheduled effectively in upcoming plant shutdowns.
- Engineering Construction Management (ECM) sub-projects: these sub-projects had longer construction duration and a higher proportion of the scope of work was completed outside of plant shutdowns. Delivery of these sub-projects was based on a design followed by a lump sum construction contracts with a focus to group the various sub-project disciplines under

fewer contracts to reduce contractors overhead costs. For these sub-projects, an owner managed delivery approach was followed providing interface management, contractor coordination, cost management and reporting.

Integrated team

An integrated team approach (Client and Consultants) was applied to the implementation phase of the optimisation for both the 'Design' and 'Construction Management'. This was a good catalyst for the optimisation success.

Design phase:

During the design phase, all sub-project scopes were bundled up in one project with each sub-project reported as a separate task. The design process did not follow the traditional consulting design approach whereby a design is developed by engineers in isolation and issued for approval then construction, leaving no opportunities for optimisation by the key stakeholders. Instead the design development followed a collaborative approach where the client processing, maintenance and engineering departments formed part of the design team with weekly design review meeting including all various department allowing a quicker concept development and the result achieving the optimum outcomes for all stakeholders and meeting the optimisation targets for utilisation improvement and allowing shutdown duration reduction and frequency increase.

Construction Management phase:

The construction delivery team was based on an owners project managed approach coordinating the various sub-projects with Mintrex providing members in an integrated owners team supporting AGA with the provision of Construction Management (CM) services for the various sub-project for civil, structural, mechanical and piping aspects.

The integrated CM team approach allowed AGA to maintain full control on the project execution and cost management whilst having a robust construction management and technical support providing input into:

- Constructability issues,
- Compliance of the work in accordance with the design, drawings and specifications,
- Speedy turn around for technical queries raised on site resolving engineering queries to the specifications and/or drawings,
- Witnessing of inspections and tests and coordination of pre-commissioning activities,
- Adopt a cost effective and fit for purpose construction methodology in contracting and site management, based on tried and proven philosophies used on previous projects.

Shutdown planning

The integrated team approach provided a shutdown optimisation function reducing the shut duration by identifying and execution of early works over 3 plant shutdowns allowing smoother plant integration and reduced downtime for final sub-project tie-ins.

This optimisation was driven by the integration of the Mintrex design team, owners CM team with the plant operations and maintenance personnel allowing better informed design decisions related to plant isolations and tie-ins management reducing the potential shutdown reliant tie-ins to a minimum hence improving the overall plant integration on commissioning. Coordination and regular communication between the design team and site shutdown planning teams was key to achieving success in this area.

Zero base principal

The integrated delivery teams applied the '*Zero base principal'* described in the paper titled "*Zero base Process Plant Design and Careful Risk Management Deliver Cost Savings*" (Kendall et al., 2015), which aims to minimise capital cost without adversely impacting the operating cost of the plant. This principal was applied at scoping stage of the sub-projects and continued through the design stage. Regular design reviews attended by the integrated team members questioned the design in an attempt to distinguish preference, prejudice and myth from necessity; a risk management approach was adopted to assess the design outcomes and relate it to the project objectives at scoping stages.

Regular design review

Pre-arranged weekly design reviews, organised by the engineering design team, were attended by the clients' processing, maintenance and engineering teams to review the design progress and identify any potential deviation on the project objectives. The review process provided hands on input for all relevant operational departments providing a fit for purpose design meeting acceptance for all operations departments. A further benefit of the design reviews was the refinement of the tie-ins to allow integration of the new designs with the existing plant; these tie-ins were further worked on and updated with the site construction management team by providing a better execution methodology less disruptive to the running operations. Knowledge of the design and equipment selection gained through these reviews provided benefit to the site team and assisted with a smooth transition into operation.

Resource leverage

The implementation strategy adopted, provided resourcing efficiencies amongst the design and CM teams, these efficiencies were achieved through resource leveraging as follows:

Design:

The integration of the design and operations team provided a depth of experience across multiple disciplines and project functions, from design to processing experience, maintenance, shutdown planning and project management.

Construction management:

The construction integrated team provided multiple skills across the team, calling onto project management skills within the client team supported by construction and design expertise integrated from the design consultant, creating a multi-functional team allowing coverage across all construction disciplines with fewer resources due to the access to wider experience personnel through the design consultant.

Packaging cost efficiency

The execution strategy for the site works focused on consolidating multiple sub-projects in a scope of work broken down by discipline to reduce the number of Contractors mobilising to site. Significant cost saving has been achieved due to overheads synergy and a reduction in owners site supervision.

OPTIMISATION ACHIEVEMENTS - EXAMPLES

Optimising conveyor system and increase conveyor design capacity

The calculations prepared by Mintrex indicate that with appropriate control of the feed onto the conveyors, each of the conveyors will comply with the code requirements. Some problems occurring with conveyors at Tropicana are listed below with recommended modifications/upgrades:

- Unexpected material behaviour (such as ore rolling back on conveyor):
    - Replace installed soft starter and fluid coupling with VVVF drive to extend the starting time;
    - Install new gamma scale to monitor and control material sliding; and
    - Reduce take-up counter weight and convert pulley drive to ceramic lagging.

- Ineffective feed control strategy:
    - Review and adjust the equipment settings around the conveyor to reduce recirculation load;
    - If the above recommendation does not provide a satisfying outcome, consider upgrade of conveyor.
- Overloading due to increased throughput:
    - Review and adjust the current control strategy to prevent overloading onto the conveyor.
- Some other problems such as belt tracking and splice failure issues are not related to the mechanical design of conveyors.

Other upgrade recommendations, which can be used for future duty requirements (increase of plant capacity), in addition to the recommendations above are:

- Upgrade the conveyor drive with bigger motor.
- Change conveyor belt to higher speed.
- Change the conveyor drive set up from soft starter / fluid coupling to VVVF. This change only / by itself has helped the improvement of the plant operations significantly. The improvements are as follows:
    - Conveyors are now in a better control, so the start-up is smoother;
    - Before the upgrade, following a crash stop of the conveyor, the conveyor may not be able to be restarted. The conveyor could be restarted at full load torque at a slower speed.

Upgrading of larger conveyors for increased throughput is expensive in most cases. Therefore, careful consideration was given to of which conveyor duties will need to be upgraded in order to only upgrade those necessary. The magnitude of any upgrades needs to be questioned. In all cases, the upgrade recommendations are subjected to detailed engineering design checks of all mechanical and structural components to ensure additional measures are not required to archive safe operation of conveyors.

Wear Liner optimisations

<u>Dry screen bin and HPGR wet screen bin liner optimisation:</u>

Liner change during a shutdown is a time consuming process as access is restricted to winching by a rope or via scaffolding. In addition, the small size of individual liners results in a higher quantity needing replacement.

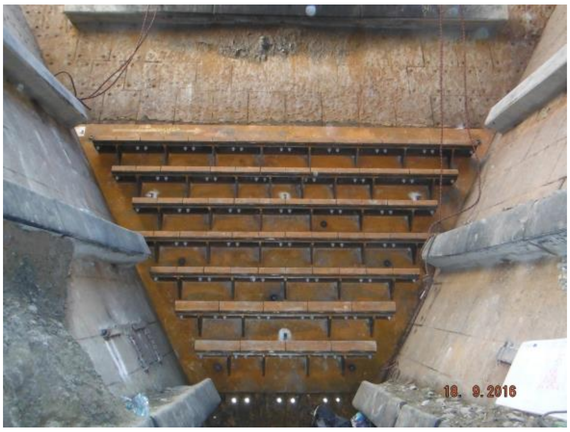
The key objectives for this redesign were:

- Liner design for under 24 hours maintenance time, and
- Liner design for 12 months service between maintenance intervals.

Replacing numerous small liner plates were a tedious task and in many cases were on the critical path for plant shutdowns. In consultation with the plant team, a large modular “one-piece drop-in” design liner was selected, eliminating the need to change multiple small liner plates and thereby reducing servicing durations. The replacements of liners were done utilising a large 90t slewing crane onsite with some modifications to top of bin structure.

Optimisation Result: It took 2 shifts of 12 hours to modify and install the large liners. The upgraded liners have achieved a wear life in excess of 24 months and the liners replacement took less than 24hrs. See figure 2 for the comparison between the two different liner designs.

OLD



NEW

Figure 2 – Comparison of liner designs.

Pulping box optimisation:

The wear rate of the original pulping box was excessive leading to inadequate wear life. Prior to the optimisation process, the maintenance team had to replace the liner at every shut down. This work was labour intensive and required a complete clean out of the bin before any maintenance could be performed (See figure 3). This process normally lasted 48 hours.

The key objectives for the pulping box optimisation were:

- Pulping box design for liner maintenance to be completed in less than 24 hours;
- Pulping box design for 12 months service between maintenance intervals;
- Improving pulping of the material;
- Pulping box redesign so it could be replaced via a rotable unit. i.e. Easy to lift out and disconnect quickly.

Optimisation Result:

The newly designed pulping box has lasted more than 18 months with minimal maintenance requirements during shutdowns. Redesign of the water injection and arrangement of the flow into the box has improved pulping and drastically reduced wear rate of the equipment. A new rotatable unit is in store with a rotatable strategy implemented within the site shutdown strategy and the new rotatable unit took less than 24 hrs to change over.

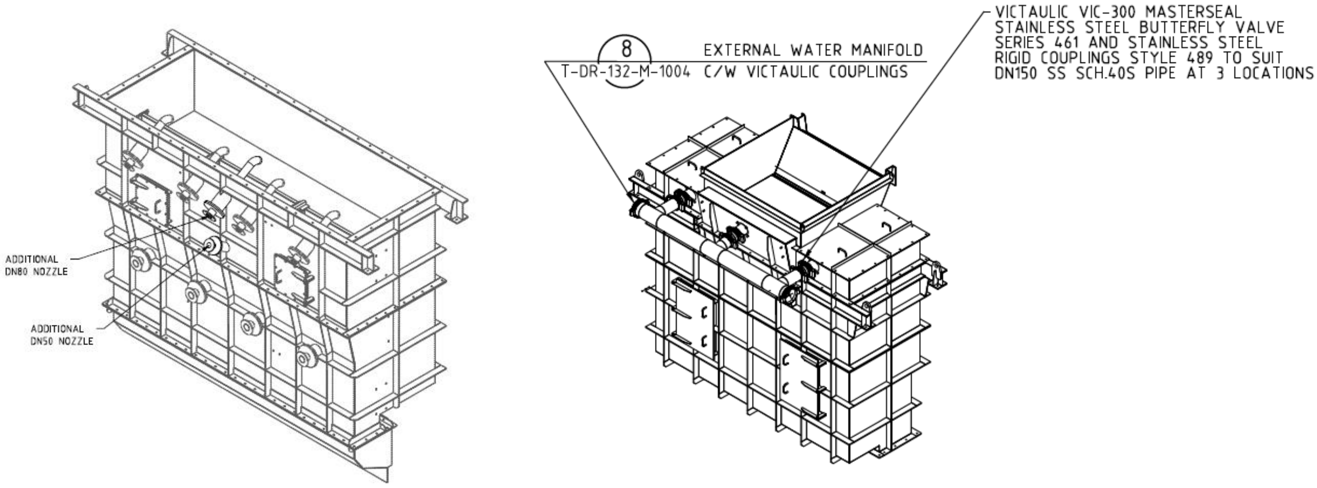
Figure 3 illustrates the wear in the previous box design and the installation of the optimised design.

OLD

NEW

Figure 3 – Comparison of old and new pulping box designs.

See figure 4 for the comparison between the two pulping box designs. Note the change in nozzle positions in the optimised design- All nozzles are near the top of the box. The previous design included nozzles on side of the box, which would cause the wall opposite to wear faster.



OLD NEW

Figure 4 – Comparison of old and new pulping boxes.

HCN gas reduction

The main areas of concern within the process plant, where HCN levels are consistently found to be at unacceptably high levels, are around the:

- HPGR Wet Screens;
- Leach Feed Trash Screens; and
- Tails Tank.

As a consequence, these areas are restricted access areas with gas monitoring in place.

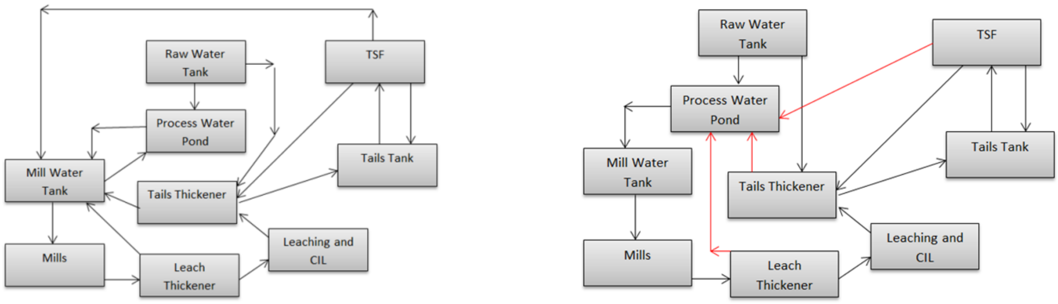
As part of the optimisation project undertaken, elimination or partial elimination of HCN gas generation was identified as a viable option to reduce HCN generation.

The optimum solution was to remove the possible production of HCN gas from the process altogether. The major solution identified was to redirect waters stream containing higher levels of residual cyanide to the comminution circuit without treatment. At the same time, two additional leach tanks were added to optimise the gold recovery, which resulted in lower residual cyanide levels in the tails thickener overflow.

Optimisation Results:

- Mechanical ventilation was used for the leach feed trash screen and carbon safety screen. This installation successfully reduced the HCN levels at the screens.
- The re-neutralisation process was used for the tails tank. This installation was not successful due the residence time required for the gas to react with the hydroxide mist. This was also not needed after the two additional leach tanks were added to increase the leach time to the design value.
- The partial treatment of process water stream was used for the leach feed screens. This modification was a success. The tail thickener overflow bypassed the mill water tank and was treated with Caustic before being discharged into the process water dam. See figure 5 for process water change.

- The treatment of the water sources was excluded due to cost.



OLD NEW

Figure 5 – Schematic of process water flow through process plant.

PROJECT OUTCOMES

The optimisation project delivered multiple benefits to the Tropicana Gold Mine, some of which had immediate results and others with a long term benefit, which was apparent over several months since completion of the process. Those benefits are summarised in the next few paragraphs.

Process benefits

The debottlenecking process of the conveyors, bins and feeder restrictions and addition of two additional leaching tanks allowed immediate benefit by allowing an increase of the plant throughput whilst maintaining expected recovery. The process plant achieved the increase in throughput from 6.5Mtpa to 7.6Mtpa as per the intended design. Additional milling capacity was subsequently added with the throughput increased to 8.1 Mtpa without any further upgrades required on conveyors or bins.

Maintenance/shutdown benefits

The benefits of the optimisation project extended to plant maintenance by allowing time reduction in the replacement timeline for wet screen bin liners from a 48 hrs to 24 hrs due to the redesign of the lining system. This was coupled with a significant wear reduction leading to an extension in liner life from 17 weeks to more than 2 years for the HPGR feed bin driven by the redesign of the bin discharge geometry. The result was a reduction in shutdown duration and an increase in plant utilisation driven by these changes and other equipment optimisation facilitating an improved plant utilisation from 90% to >95%.

Safety benefits

The implementation of safety sub-projects during the optimisation project provided immediate safety improvement for various plant areas by providing safer access to chutes and bins reducing the potential for personnel injury and scaffold requirement for plant maintenance. A great improvement from a safety perspective was the gas reduction providing safer personnel access around specific plant area.

Overall budget

The latest budget forecast as provided by AGAA indicates that the final forecast cost increased by 9.3% over the original approved budget. This increase is well within the 25% estimate accuracy from the cost estimate prepared at scoping stage.

CONCLUSION

The process of optimisation provided measurable benefit to Tropicana Gold Mine using a relentless process of identifying small opportunities for improvements addressing them which, when combined, lead to sizable improvement for the plant operation and maintenance.

The process applied provided a collaboration opportunity amongst various parties each with a different skillset, when combined provided significant quantifiable results meeting the main project objectives. The application of the zero base design principal provided a project governance function to safeguard the project objectives and provide focus in identifying necessary changes versus preference.

The applied collaboration not only provided a wide range of skills for the project, it provided the project owner means to maintain satisfactory project cost tracking and reporting function to all relevant stakeholders.

Resource levelling and effective management was achieved through efficiencies of combining multiple minor construction scopes in a larger well defined scope for the project. This allowed a reduction in construction overheads, leverage on skilled resources from a Contractor perspective (leading to a better quality outcome), and leveraging on resources from the client CM team perspective dealing with one Contractor instead of managing multiple smaller Contractor as well as the additional reporting requirement associated with each sub-project.

Potential improvement was identified which can be applied to future projects by applying a similar process; these can be defined as follows:

- The process could benefit from a refined process for cost control and better separation from other simultaneous work progressing concurrently;
- Albeit limited, some departure from initial design was observed, this could have potentially caused the cost increase of 9.3% from budget. A more refined change control process with clear responsibility will safeguard against future overruns.

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