Narrabri Coal Operations - taking the load off the loadout facility

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ABSTRACT

The Narrabri Coal Mine, one of the four mines operated by Whitehaven Coal in the Gunnedah basin of NSW in Australia, has been operating successfully since 2012 and is Whitehaven's only underground operation. The Coal Handling and Preparation Plant (CHPP) at Narrabri Coal Operation (NCO) produces three product stockpiles which are transferred to the Train Load-Out (TLO) facility for train loading. The TLO has capacity to dispatch up to 8.5 Mt/a of coal.

Over the years because of unplanned events, various interlocks and restrictions were added to the control logic for the TLO which inadvertently limited the system from delivering desired reclaim rates. This led to greater operator intervention during train loading to optimise and maintain control of the system as not to impact production. Furthermore, poor reclaim and bin level control had resulted in significant downtime events and delays to operations of the TLO.

To help debottleneck the system, Whitehaven engaged Mipac to conduct a process review of the existing control philosophy of the TLO and assist with co-developing a revised control strategy to improve functionality and optimisation of the TLO facility. As a part of the review, new logic was commissioned which improved stockpile dozer efficiencies in line with the guideline MDG28: Safety requirements for coal stockpiles and reclaim tunnels (introduced in 2013), which had been updated after the TLO was originally commissioned.

This paper outlines some of the issues identified during the review as well as the implemented control and automation changes which enabled improved functionality, increased reclaim rates, a reduction in stockpile dozer run time, and faster train loadout times which was financially beneficial to the mine with quick return on investment (ROI).

Keywords: Process optimisation, TLO, train loading, automation, process control, reduced variability

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INTRODUCTION

The CHPP at Narrabri Coal Operation (NCO) produces three product stockpiles which are transferred to the TLO facility for train loading where it is railed to the Newcastle port for export internationally. The three product stockpiles produced and exported from NCO are:

- Pulverised coal for injection (PCI) coal;
- washed energy coal; and
- crushed energy coal – referred to as bypass coal.

The PCI stockpile has a capacity of 25 kt, with the combined energy (both washed and bypass) stockpile capacity at 125 kt. Material on the stockpile is transferred via a tunnel reclaim system using drawdown hoppers to the surge bin, where the coal is loaded into train wagons. The TLO facility has the capacity to dispatch up to 8.5 Mt/a of coal.

A schematic of the TLO process flow is illustrated in Figure 1.

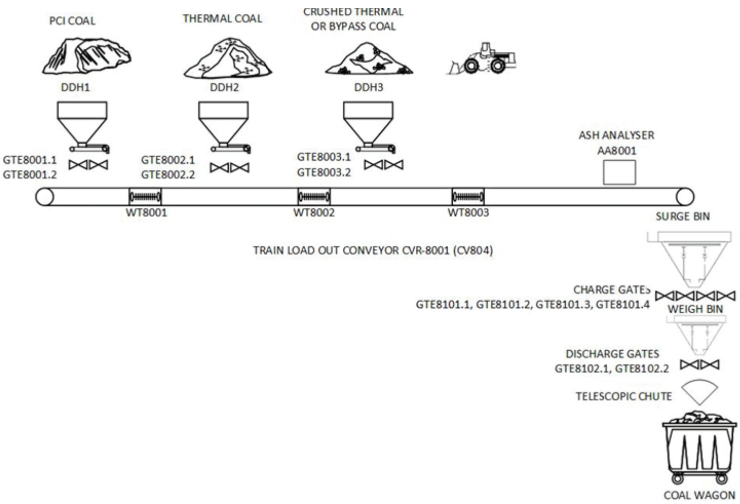

Figure 1: NCO reclaim system and TLO flow diagram

Operator control of train loading

The control system for the TLO consists of Allen Bradley ControlLogix PLCs with operator control and monitoring via a Citect SCADA HMI. The control room operator initiates the load sequence from the local control room and can start and stop wagon loading as well as signal the train operator to enter the TLO facility once the preloaded train details (such as train number, wagon type, required blend, wagon length if applicable) are entered into the SCADA HMI. Train details and schedules are advised by the CHPP supervisors or superintendent from details in Whitehaven Coal's CoalTrak™ system, which manages the transport of goods and logistics.

Once the train loading is initiated, the control system automatically performs the load out and reclaim sequences based on specified train details until loading is complete. There is also provision for the control room operator to manually load the train using a joystick controller in the TLO control room in the event of sequence faults that cannot be rectified in a timely manner.

The challenge

Over the years, because of unplanned events, various interlocks and restrictions were added to the control logic for the TLO which inadvertently limited the system from delivering desired reclaim rates. This led to greater operator intervention and management during train loading to optimise and maintain control of the system so as not to impact production. Furthermore, poor reclaim and bin level control had resulted in significant downtime events and delays to operations of the TLO.

To support improvements to the automation and debottlenecking of the reclaim and loadout system, Whitehaven engaged Mipac to conduct a site visit and process review of the existing control philosophy of the TLO, with the aim to identify any system gaps and process control improvement opportunities at the TLO facility.

FINDINGS FROM THE PROCESS REVIEW

The process review conducted by Mipac identified the following key issues around operation of the reclaim and TLO and were the primary obstacles to optimal TLO performance:

- Reclaim gates have sluggish response to activation commands. Logic sequencing around hydraulic pressure control caused unnecessary delays to gate "open" response.
- Multiple overlay restrictions and duplicate interlocks limited the reclaim gate operation and prevented the system from delivering the desired throughputs. Nominal design was for 5000 t/h with a maximum rating of 5500 t/h.
- Control of weight on reclaim belt and utilising blend ratios was not functioning.
- TLO train wagon detection, speed measurement and fault recovery were poor.

Surrounding these issues was the additional layer of difficulty in troubleshooting and fault tracing. The review identified inconsistencies between SCADA and PLC logic, with poor alarm management and large amounts of redundant code throughout the PLC logic.

Drawdown hopper reclaim gate response

The reclaim system at NCO is a Halley and Mellowes' (HMA) tunnel reclaim system, consisting of three 8' diameter drawdown hoppers (and associated ancillary equipment) providing three reclaim points corresponding to each of the product stockpiles produced from the Narrabri CHPP (PCI, energy, bypass coal).

Coal flow is modulated via hydraulic control of the gates below each drawdown hopper, and each drawdown hopper has a vibratory motor that activates over a predetermined frequency to increase the active reclaim angle to maximise available material for reclaim (HMA Material Handling, 2018).

Observations of the gates while on site during the process review identified a response lag on gate open command, which was evident on all the three drawdown hoppers. It was noted the hydraulic valve activation logic to drive the gates found in the PLC did not reflect the original functional description by the manufacturer (HMA).

As a result of the response lag, operator intervention was frequent during train loading with manual adjustments to the gate opening and gate activation to manage reclaim rates and provide constant supply to the wagons at the desired train loadout speed. This resulted in instances of highly variable reclaim rates and subsequent surge bin levels, which ultimately required greater frequency of the train operators needing to speed up, slow down, or at times stop the train.

Furthermore, with the increased frequency of gate activations to manage reclaim conveyor inventory, there was increased risk of consolidation of the stockpile material which would further inhibit flow. Within the 'as found' PLC logic, there was an interlock where the drawdown hoppers needed to wait four minutes after the last activation before manual activation was allowed. This is believed to be an added protection in response to stockpile consolidation issues in the past.

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Restrictions to desired reclaim rates

The total reclaim conveyor rate is a direct function of the material flow from each drawdown hopper, which is influenced by the active reclaim angles of the stockpile and dozer operations. There is a weightometer below each drawdown hopper to provide feedback on the totalised tonnages of each product on the reclaim conveyor.

Operation of the reclaim system was largely a manually controlled exercise for the control room operator. The control room operator aimed to manage surge bin levels to avoid interlocking the reclaim conveyor due to surge bin level being too full, whilst maintaining loadout at a consistent train speed without triggering low bin level which would require train stoppage. No automatic control action was taken when the required weight on the weightometer was not achieved for each of the drawdown hopper valve controls, and the rate of reclaim was not directly operated or controlled to a target setpoint.

The weight controllers in the logic were configured in a way which made operation difficult to understand in the SCADA. Some logic appeared to have started as traditional proportional-integral-derivative (PID) loops with dynamically calculated control variable limits with proportional responses, but parts of the coding had been altered or disconnected.

Outside of the PID control blocks, additional limits and interlocks were inconsistently applied across each drawdown hopper gate valve to prevent the full range of activation of the gates. The OEM recommended during normal operation the gate valves should operate between 20-60%. From the 'as found' code, some of the gates could not exceed 31% or 35%, and if both gates were operating then a combined value of 54% could not be exceeded but was only applicable to two out of the three drawdown hoppers gate valves. These restrictions are believed to have been introduced following a conveyor bogging event that occurred more than five years prior to Mipac's process review.

Product blending

In addition to managing the total ash content of the train load, product blending also influences the material flow properties. The energy coal produced exhibits the poorest flow relative to the PCI and bypass coal, and NCO has operating guidelines for blending of energy coal to help keep material flowing out the train wagons upon receipt at the port. The better material flow properties of the PCI coal and bypass coal have the added benefit that it could be loaded onto an entire train without requirement for blending (assuming total ash content is within specification).

Product blending via the reclaim system was manually controlled by the control room operator through operating the drawdown hopper gate valves and tracking the totalised tonnages of each respective product. While the required blend proportion would be achieved for the total train load (a total of 82 train wagons), the existing logic was not dynamic or linked to an error in the target blend to initiate corrective action to smooth out the blend variability in each train wagon.

An additional challenge faced with blend management was resourcing availability; when reclaiming from multiple product stockpiles, a minimum of two dozer operators would be required to assist with pushing the material towards the drawdown hopper to ensure consistent flow during loadout. If only a single dozer operator was available, the ability to maintain the blend proportions for each wagon of the train was limited while complying with the safety requirements within the MDG 28 guideline (NSW Trade and Investment, 2013), which was introduced after the NCO TLO facility was originally commissioned.

The guidelines state the requirements for controls around high-risk zones to prevent harm to people and plant. The definition of high-risk zones within the guidelines are "areas on a coal stockpile where there is potential for dozer drivers to lose control of stockpile dozers through ground instability or the development of voids" (NSW Trade and Investment, 2013) i.e. areas surrounding a draw down point. As such, drawing form multiple stockpiles would introduce multiple high-risk zones which could not be safely managed by a single dozer operator.

Train wagon detection, speed detection, and fault recovery

The train detection and batching system utilises an array of photovoltaic cells to determine the train speed, wagon count, and wagon positioning for the batching sequence. A schematic of the light array is shown in the SCADA HMI and presented in Figure 2 for reference.

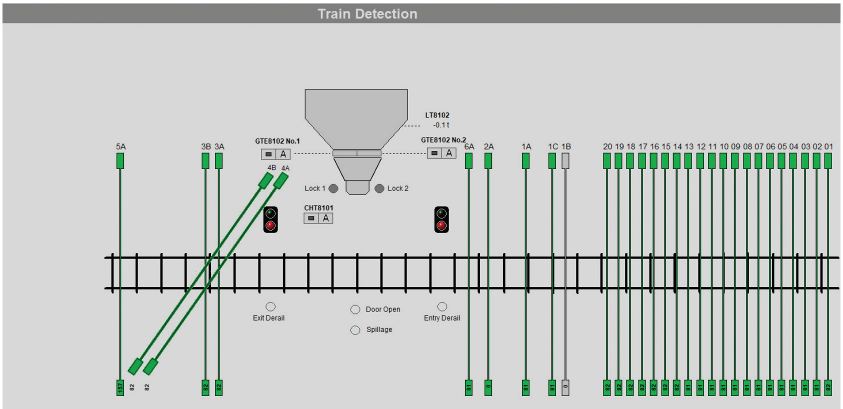

Figure 2: Photovoltaic light array arrangement for TLO

A major operational challenge for NCO occurred when a wagon position was lost due to faults with the light array. In scenarios where the SCADA indicates a "lost" wagon, the control room operator needs to radio the train driver to move forwards or backwards, often multiple times, until the light array detects the leading edge of the correct wagon. This inevitably resulted in significant downtime and delays to TLO. This would also require the control room operator to manually enter the correct details for the current batch weight and wagon number, which introduced another potential issue: if the TLO sequence loses its place, there was risk in entering incorrect data and result in the need to purge records of the entire train from the control system. The control room operator would then need to manually re-enter all the wagon details and batch weights back into the SCADA HMI. During the initial site visit by Mipac, one such event was observed where a clerical error had resulted in a delay of greater than 20 minutes to the TLO operation due to needing to re-upload the train manifest details.

Most wagons were lost due to sudden drops in train speed and bin level control issues, reinforcing the need to revise the reclaim control strategy. Train speed indication is calculated based on seeing a change on the photovoltaic cells (1-20), which do not detect a drop in speed with the current arrangement until a wagon edge passes a cell or the detection times out.

BENEFITS FROM PROCESS IMPROVEMENTS AND CONTROL CHANGES

Based on the findings from the process review, a revised control strategy was co-developed with NCO to improve functionality and optimisation of the TLO facility with the ultimate purpose to achieve the following outcomes for NCO:

- Improve feed rate control to minimise variability and increase average reclaim rates.
- Improve blend control to achieve product specifications and discharge flow properties.
- Improve troubleshooting and communication of TLO sequence faults via the HMI.
- Additional functionality to automate TLO operating limits based on operating conditions (wet weather, improved stockpile dozer efficiency).

The inconsistencies identified between the SCADA HMI and PLC code also highlighted the need to revise and develop an updated functional description to reflect any control strategy changes as part of the automation improvements.

The original SCADA HMI pages for reclaim and TLO did not provide transparency on the controller setpoints or key performance parameters such as reclaim tonnage rates or frequency of drawdown hopper activations. An example of the additional features on the SCADA HMI commissioned for NCO is presented in Figure 3 showing the reclaim page, with changes denoted by the highlighted sections.

The refreshed HMI pages and functionality changes enables improved visualisation of key performance metrics, troubleshooting of interlock conditions and reclaim/loadout sequence status, and improved wagon recovery workflow in the event of a sequence fault.

Additional features to the logic were also discussed and requested by NCO for greater flexibility and functionality of the TLO control system. One of these additions is the ability to supplement reclaim rates with direct CHPP production for more holistic process optimisation and will be discussed further in the following section.

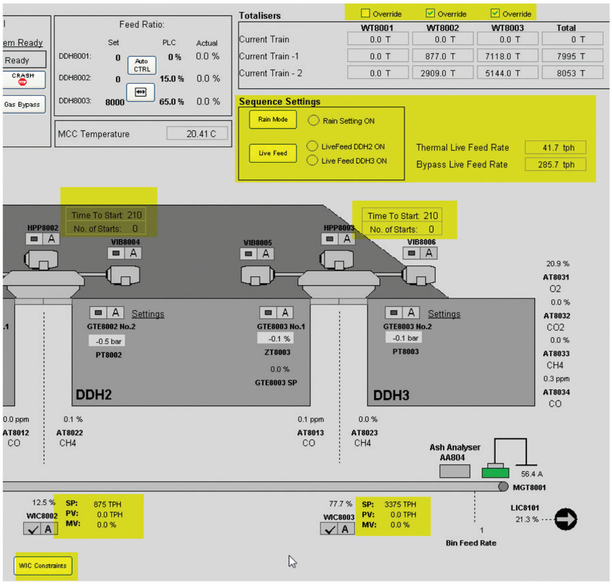

Figure 3: Additional features incorporated into the reclaim page SCADA HMI

Reclaim rate and blend control

A revised control strategy for the reclaim system was implemented which enables the control room operator to input a desired reclaim rate for the TLO. The target reclaim rate, in conjunction with the control room operator preloaded train details outputs a recommended train speed target to maintain the surge bin level within an operating range as not to interlock the reclaim conveyor or require the train to stop due to an empty surge bin.

The target reclaim rate and product blend details feeds into the weight controller (WIC) loop and determines the reclaim rate setpoint of each individual product stockpile. The weightometers under each product stockpile regulates the drawdown hopper modulating flow control gates in PID control to adjust the valve position to minimise the error between process variable and setpoint. The drawdown hopper gate activation frequencies were also reconfigured in line with the original manufacturer manuals to limit frequency of vibrations.

Additional override controls were put in place to ensure the reclaim rate does not exceed the belt design capacity (nominally designed to 5000 t/h with a recommended maximum load rating of 5500 t/h), as well as applying a bias to the control room operator entered reclaim rate to manage surge bin levels (reduces reclaim rates if bin levels approaching the high limit, while increasing if bin level approaching low limit).

The additional surge bin level controller (LIC) loop aims to reduce frequency of overfilling and emptying the surge bin during loadout. Bin running empty and requiring stopping the train during loadout have historically resulted in significant downtime and delays to the operation of the TLO.

A high-level schematic of the reclaim system control is presented in Figure 4.

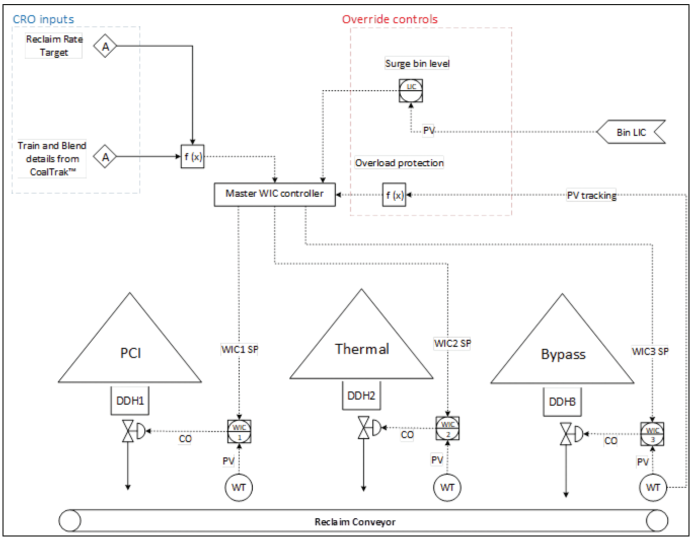

Figure 4: Reclaim control schematic

Prior to implementation of the new logic, the weightometers were not used in the reclaim rate control, with the surge bin level being the primary drawdown hopper gate valve control trigger. As noted, with the additional interlocks applied to the logic in response to unwanted outcomes in the past, there was high variability in the reported reclaim rates during TLO due to the high cognitive load on control room operator's to manually manage and optimise the process. Furthermore, having the reclaim rate respond to a weight controller setpoint enabled more consistent blending on a wagon-by-wagon basis across the entire train.

Presented in Figure 5 is a histogram and box-plot showing the results of the TLO reclaim rates of the previous logic compared to the updated logic. As a basis for comparison, the two data sets have filtered out delay periods (train stoppages) and any reclaim feed rates <500 t/h (treated as initial reclaim ramp up) to broadly represent expected "steady state" operations of the previous and updated control logic. A total of 16 trains have been analysed for under the previous logic conditions, with 9 trains observed for the updated logic based on the period Mipac were on site finalising the commissioning of the proposed control logic changes.

Observing the distribution in the reclaim rates data, there is a notable reduction in the frequency of operating at reclaim rates below 3000 t/h with the updated logic. The implemented changes demonstrated a 12% improvement in median reclaim rates from 3788 t/h to 4227 t/h, and a corresponding 44% reduction in standard deviations from 1317 t/h to 743 t/h for the previous and updated logic respectively.

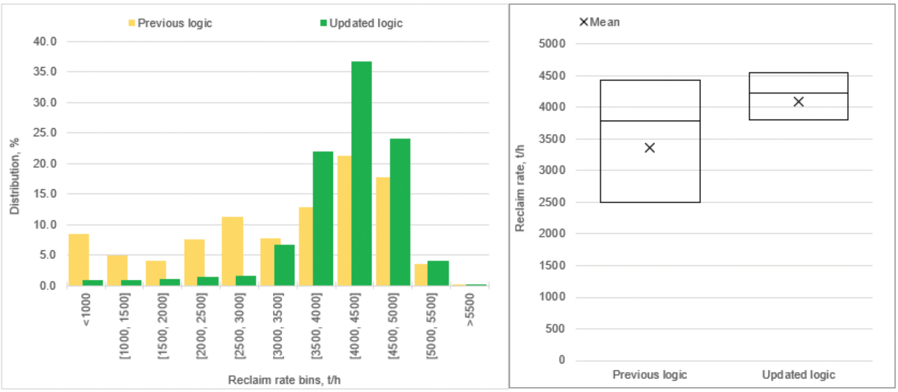

Figure 5: Comparison of reclaim rates

TLO speed target

The reduced variance and increased operating reclaim rates from the implemented controls further enabled NCO to operate the TLO at higher train speeds. Presented in Figure 6 is a histogram and box-plot of the loading speeds for TLO of the previous logic compared to the updated logic. The implemented changes have demonstrated an increase to the median loading speeds at the TLO by ~21% from 0.53 km/h to 0.64 km/h. This translates to a 14-minute (11%) reduction in median TLO times from 2 hours 7 minutes to 1 hour and 53 minutes.

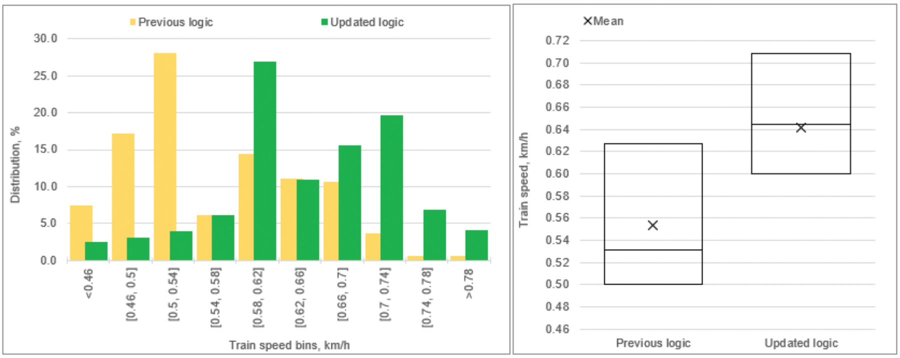

Figure 6: Comparison of loading speeds for TLO

Live feed from CHPP

Additional logic functionality was developed to enable direct feeding of energy product from the CHPP for reclaim during TLO. Integrating the CHPP production into the TLO control logic enabled holistic optimisation of the coal processing chain, though the most significant benefit of implementing this into the TLO control logic was it allowed improved utilisation of dozer resourcing.

Prior to the updated logic, a typical TLO would require at least three CHPP operators (one control room operator and two dozer operators) in line with the site safety management plan to ensure safe management of high-risk zones of the coal stockpile as per the MDG 28 guidelines. Reducing the requirement for two dozer operators by utilising the live feed functionality provided opportunity for operations to free up a resource to focus on other critical plant areas and daily tasks.

Under the live feed scenario when activated by the control room operator, the maximum reclaim from the product stockpile is limited to match the CHPP production rate, thereby limiting the risk of void development at the draw down point and uncontrolled stockpile movements.

To further integrate the stockpile management plan into the control system, additional prompts were incorporated into the SCADA HMI to ensure positive communication between control room operator and dozer operators during TLO and highlight potential material bridging or insufficient coal inventory above the drawdown hopper.

For example, if the weight controller requests an increase in the modulating gate valve opening and reclaim rate was not achieving setpoint after accounting for the process lag in the system (which varies for each drawdown hopper), prior to the next step change a pop-up prompt appears on the SCADA HMI and needs to be acknowledged by the control room operator to check the inventory status above the respective drawdown hopper. An example of the inventory check pop up is shown in Figure 7 below.

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Figure 7: SCADA prompts for control room operator to check for inventory

If communication with dozer operator indicates material is present, and further gate activations do not observe any increase in reclaim tonnages for the corresponding drawdown hoppers weightometer, an additional pop-up will prompt the control room operator to notify the dozer operator of potential material bridging.

CONCLUSIONS

Overall, the revised control strategy and logic commissioned as part of the automation improvements has enabled better operational sequencing and troubleshooting of the NCO TLO facility by integration of:

- Reduced manual operation of process and frequency of downtime events.
- Improvements to control basis for reclaim system for blend compliance target and tracking.
- Improve alarming and troubleshooting of interlock conditions and sequence status.
- Update of sequence to identify interactions with stockpile dozing or direct CHPP production rates.
- Improved stockpile dozer efficiencies.

The implemented changes demonstrated a 12% improvement in median reclaim rates, and a corresponding 44% reduction in standard deviations. This enabled higher loading speeds during TLO operation, reducing overall TLO times by 21%. For NCO, the efficiency gains from the increased train loading speed and halving the required dozer operators during TLO translates to a potential recovery of 2400 operating man-hours per annum (combination of control room operator and dozer operator time).

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