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Oyu Tolgoi ore handling system truck chute development, raisebore and construction evolution

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Abstract

This paper outlines the development of truck chutes at Oyu Tolgoi Underground (OTUG), which are a key infrastructure component of the material handling system, along with an outline of method improvements associated with their construction. OTUG HNL1 Panel 0 was successfully established without any delays to the ore handling system.

Completion of a truck chute requires several major construction stages: mass excavation chamber development, raiseboring, shotcrete lining and steel can lining, extraction level (EXL) tipple construction, and haulage level (HLL) chute construction. During the initial construction of the early truck chutes, significant challenges were encountered, particularly during raiseboring through geotechnically weak and faulted ground. These issues included raise collapse and difficulties installing the steel can due to ground movement. The construction duration of each truck chute, which was therefore extensive.

Several method improvements were implemented across all stages throughout the development and construction of the Panel 0 truck chutes. Haulage Level chute mass excavation chamber development sequencing was optimised to better align with the overall construction sequence. Raiseboring adopted choke-reaming and shrink-lining methods to minimise the risk of raise collapse in weak ground conditions. Truck chute construction design and constructability were improved, and the capability of the national construction team competency was significantly enhanced, resulting in a notable reduction in construction duration. Collectively, these improvements significantly shortened the overall truck chute completion timeline. This progress provides strong confidence in the team's ability to deliver the remaining truck chutes across multiple panels on schedule, while avoiding with unplanned schedule impacts due to poor ground conditions.

Keywords: *raisebore, poor ground conditions, truck chute construction*

1 Introduction

This paper presents an overview of truck chute development and construction at Oyu Tolgoi Underground (OTUG), with a focus on the evolution of construction sequences, raiseboring methodology, and implemented design improvements. The paper also discusses the operational outcomes achieved and the implications for the delivery of new truck chutes in subsequent panels.

The Oyu Tolgoi block cave design includes 38 truck chutes distributed across multiple panels. Truck chutes are located at the haulage level (HLL) to permit ore transfer from the extraction level (EXL, Figure 1). Each chute requires a complex sequence of underground construction activities, including mass excavation (MassEx) chamber development, raiseboring through variable geotechnical conditions, steel lining (or 'steel can') installation, and construction of associated EXL and HLL infrastructure. Early truck chute construction identified several technical and operational challenges, particularly related to raiseboring through weak and faulted ground, which resulted in instability, construction delays, and increased schedule risk.

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These challenges highlighted the need to review and improve construction methodologies, sequencing logic, and design constructability to improve schedule certainty and reduce exposure to ground-related risks. In parallel, the development of construction capability within the national workforce was identified as a key enabler for sustained delivery performance.

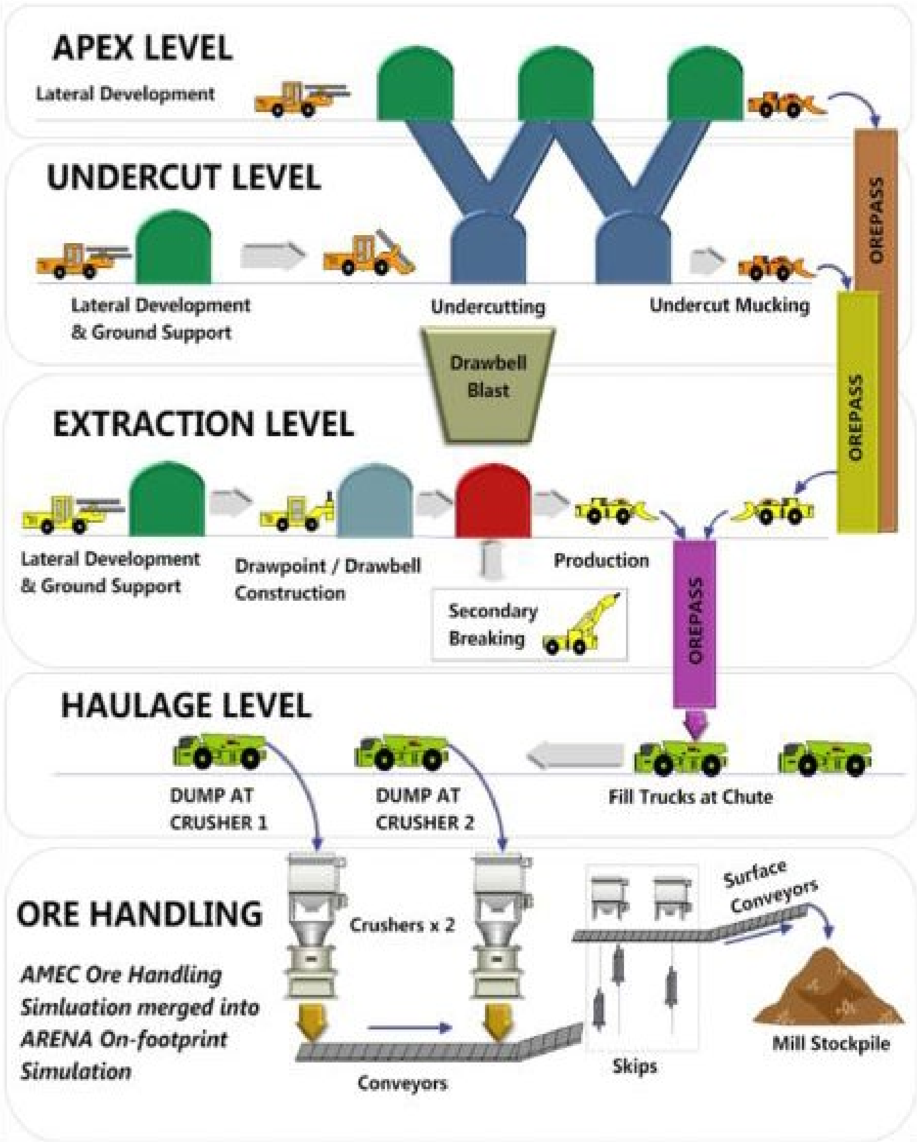


Figure 1 **Oyu Tolgoi material handling system schematic**

2 Truck loading chute system

The ore handling system (OHS) is used primarily to transport run-of-mine (ROM) ore from the EXL to the primary crusher station on the HLL (Figure 1). The OHS includes grizzlies, ore passes, ore bins, and truck loading facilities (Figure 2) that support the movement of ROM ore to the crusher ROM bin. Each truck loading facility is developed with a drive-through layout containing a single truck loading chute, truck loading chute which is fed from a 3 m internal diameter lined ore bin approximately 33–35 m in height. The upper end of the ore bin is located within a chamber on the EXL. Static grizzlies with apertures of 800 × 800 mm are located at the top of each ore bin on the EXL (Figures 2 and 3). Figure 2 graphically presents the truck loading chute layout, with Figure 3 showing completed components of the layout.

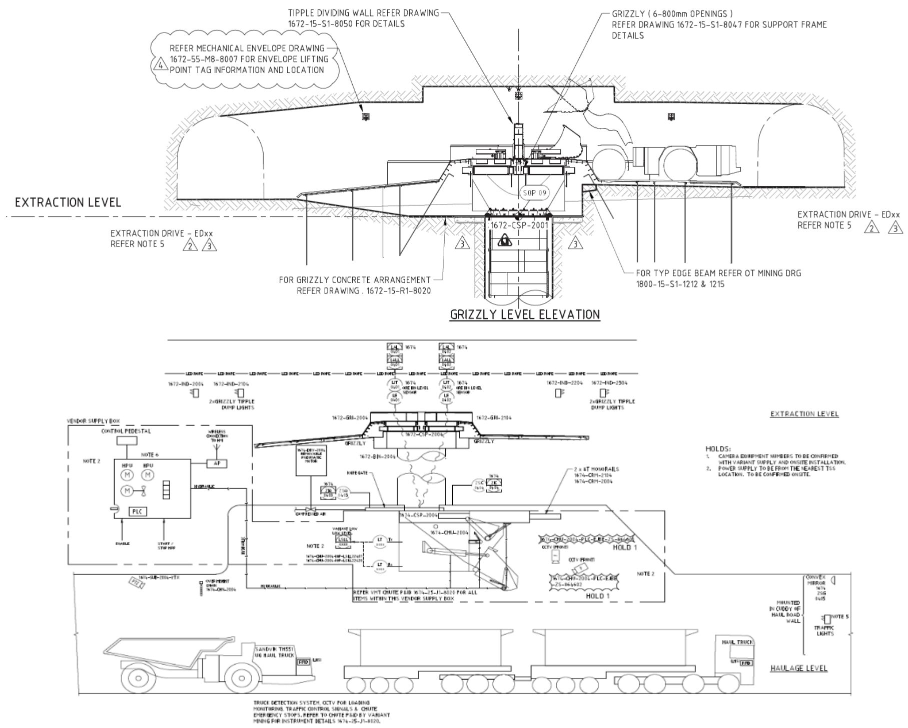


Figure 2 Truck Loading chute system schematic

(a) (b)

Figure 3 (a) Tipple on the extraction level; (b) Truck chute on the haulage level

3 Sequence logic comparison

Each truck chute chamber at the HLL requires development in 2 sections due to the overall chamber dimensions (Figure 4). The original mining sequence required both the top (tipple) and bottom (bench) chambers to be fully developed and supported prior to commencing vertical development. This approach resulted in significant schedule delays, primarily because the bottom chamber footprint was substantially larger than the tipple chamber. In addition, during vertical development, the bottom chamber ramp and bench sections were required to be backfilled to accommodate the raise boring machine's jack reach constraints. This rehandling activity further extended the critical path and reduced schedule flexibility across both levels. Oyu Tolgoi revised the mining sequence to minimise delays at both the top and bottom levels and eliminate unnecessary rework associated with ramp backfilling. The key change involved deferring the bottom chamber benching (Figure 4) until after completion of the vertical development. This revised approach provided greater scheduling flexibility, eliminated idle time on both levels, and reduced the overall duration of truck loading station (TLS) development and construction.

Truck chute mining sequence before:

- tipple-EXL, chute-HLL full lateral development completion
- vertical development (raise spiling + raisebore conventional + steel lining)
- vonstruction activity (civil + structural, mechanical and piping [SMP] + electrical instrumentation [E&I] + commissioning).

Truck chute mining sequence after improvement:

- tipple-EXL, chute-HLL chamber (top) lateral development
- vertical development (raisebore choke-reaming shrink lining + shotcrete lining + steel lining)
- chute-HLL benching (bottom) mining
- construction activity (civil + SMP + E&I + commissioning).

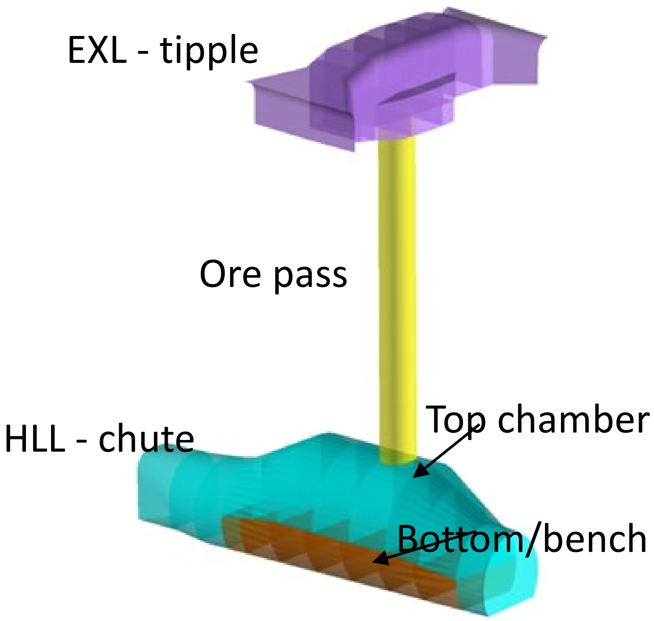


Figure 4 Truck loading chute chamber and orepass schematic (EXL = extraction level; HLL = haulage level)

4 Vertical development evolution

4.1 Geotechnical challenges and rationale for choke-reaming

The Hugo North Lift 1 area is characterised by high in-situ stresses, extensive faulting (Figure 5), and variable rock mass conditions, which present significant challenges for vertical excavations (Ooi et al. 2022). These conditions led to instability during conventional raiseboring, including hole closure and localised collapse, particularly during the unsupported reaming stages. The interaction of high stress and major structural features reduced excavation stand-up time and increased safety and schedule risks. As a result, enhanced raiseboring techniques, including choke-reaming and raise lining, were adopted to improve ground control and maintain excavation integrity in this challenging environment.

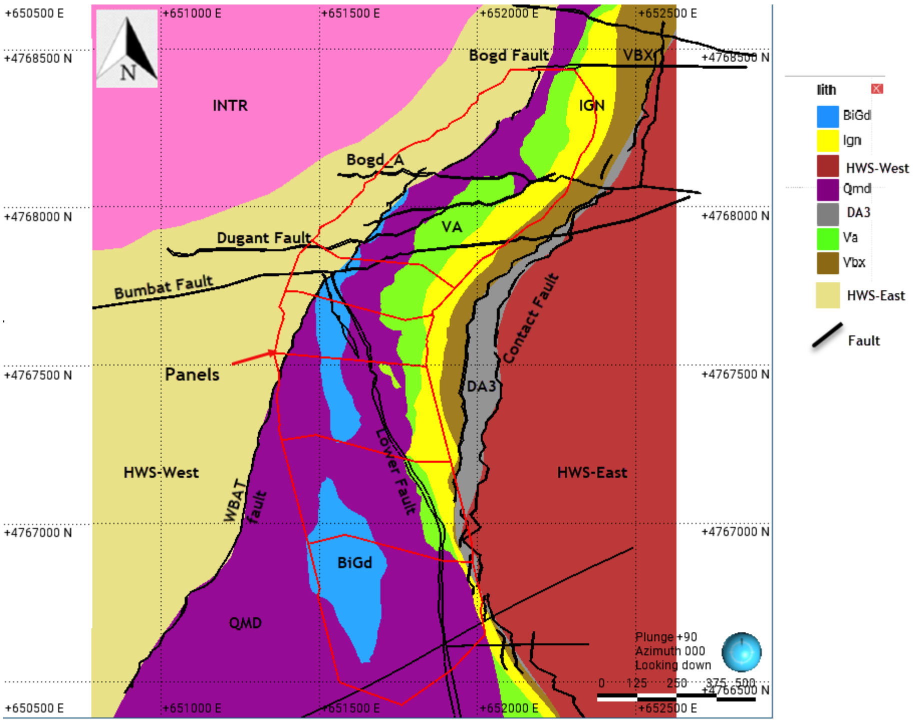
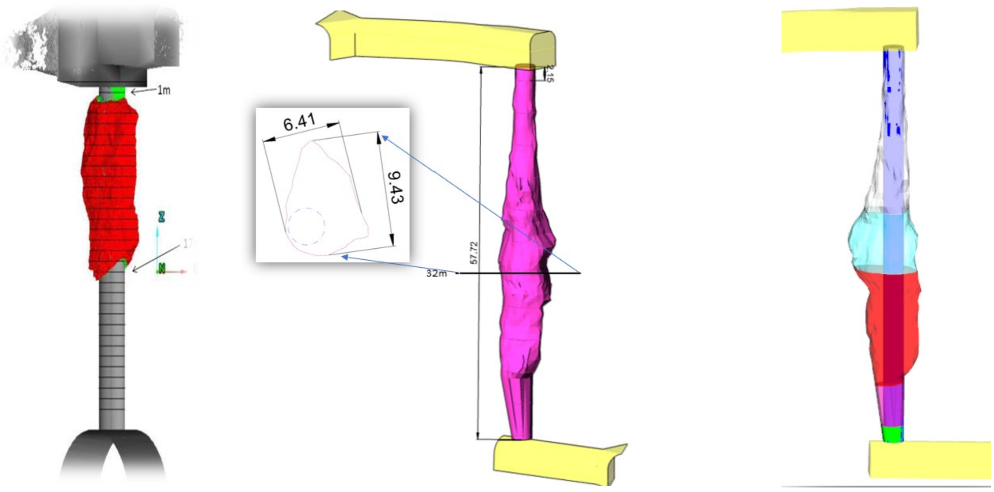


Figure 5 Geological structures in the Oyu Tolgoi orebody

4.2 Raisebore choke-reaming shrink lining: rationale for implementation

Conventional raiseboring proved ineffective under the weak, highly fractured, and stress-affected ground conditions at Oyu Tolgoi Panel 0, resulting in raisebore instability (wall failures) and operational hazards. Figure 6 provides an example of a major raise failure at P0 TX01. In this case, vertical development was delayed for 121 days due to collapse of the raise, followed by the requirement to backfill the failed raise with concrete before re-establishing the pilot and re-reaming through the collapsed raise.

Choke-reaming was therefore adopted as a practical ground control solution, using accumulated cuttings to provide temporary confinement and support to the excavation. This approach improved stability, reduced exposure of unsupported ground, and enabled safer and more reliable development of ore passes and truck chutes critical to underground material handling.



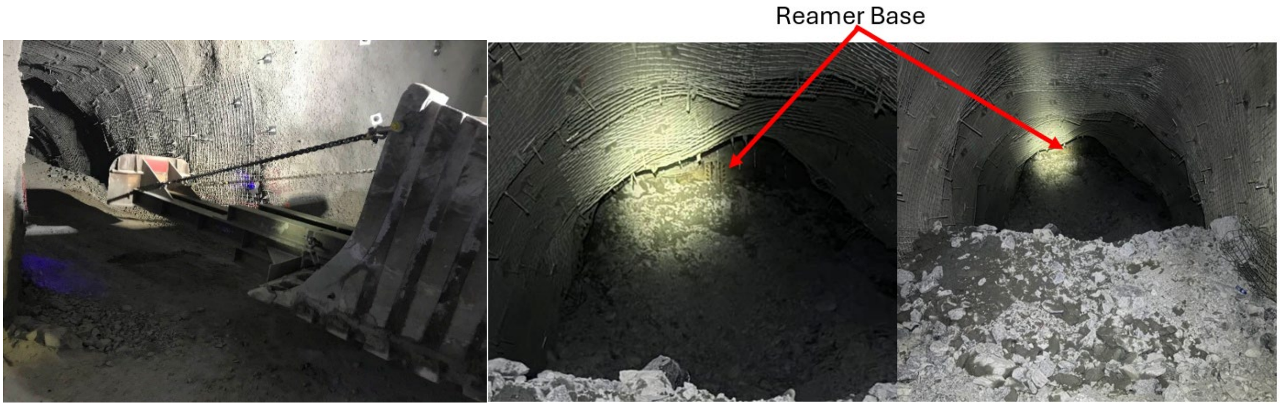
(a) (b) (c)

Figure 6 Raise scans showing (a) truck chute and (b and c) orepass failures

4.3 Steps of choke-reaming shrink lining method

During the raisebore choke-reaming the raisebore reaming process is modified to use cuttings to choke the raise, providing confinement and stability to the hole throughout the excavation up and until the support process. To achieve effective choking of the raise, the bottom of the excavation must be backfilled sufficiently to completely cover the raisebore brow (Figures 7b and 7c).

The maximum reach of the load–haul–dump (LHD) buckets available at Oyu Tolgoi was insufficient to push the muck pile high enough to completely choke off the raisebore brow, hence site an additional attachment was designed and fabricated (a rammer jammer) to enable the muck to be pushed further into the brow area and achieve full choking of the raise (Figure 7a).



(a) (b) (c)

Figure 7 (a) Rammer jammer scoop attachment; (b) Breakthrough; (c) Bottom of raise chamber

Raiseboring reaming (Figure 8) occurs dry without the introduction of water to manage the risk of inrush and inundation on the haulage level from saturated raisebore cuttings and to prevent the consolidation and bridging of the cuttings in the raise.

Monitoring the level of the cuttings is important to ensure the correct amount of swell is removed via LHD on the HLL to keep the reamer clear of the swell whilst ensuring that the raise is provided with maximum confinement and support (Figure 9). The monitoring method chosen was via additional level monitoring drill holes intersecting the raise.

Upon completion of reaming, the raisebore is demobilised and a controlled process of swell removal in 2 m lifts followed by application of 100–150 mm of gunite (dry shotcrete) in 3 layers is built up on the raise walls providing confinement and stability to prevent unravelling failures (Figures 12 to 14).

Following the application of shotcrete to the full length of the raise the orepass is lined with a steel liner of 25 mm Hardox. The liner is installed utilising a hydraulic jacking frame and chairing arrangement that allows for semi mechanised handling of the constructed liner segments in a top-down methodology.

To maintain the clearance between the shotcrete lined raise and steel can outside diameter of 3.3 m, OTUG changed the raisebore reamer dimension from 3.6 to 4.0 m. This provided extra room to accommodate ground convergence in high stress areas for the steel can installations.

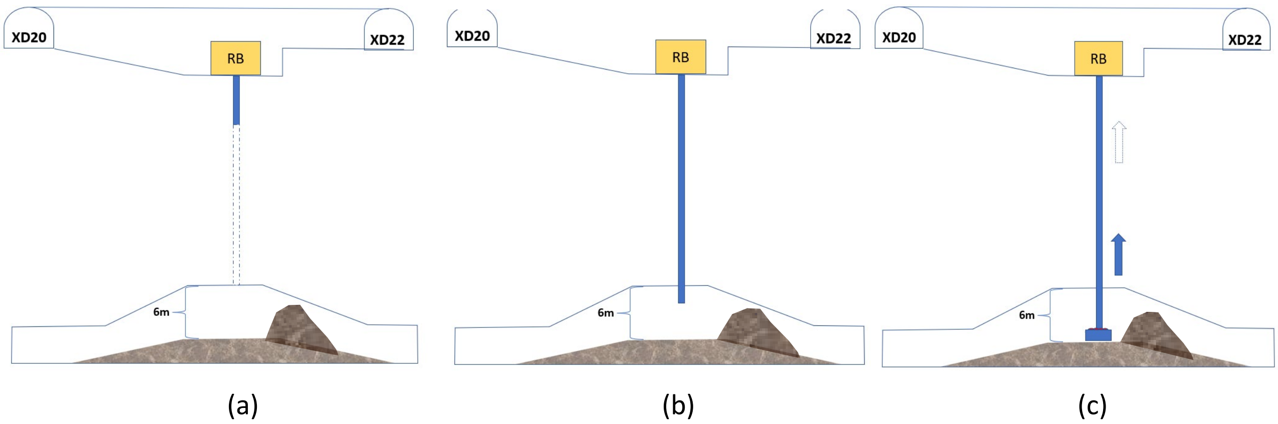


Figure 8 **Schematics showing (a) piloting, (b) breakthrough, and (c) reaming attachment**

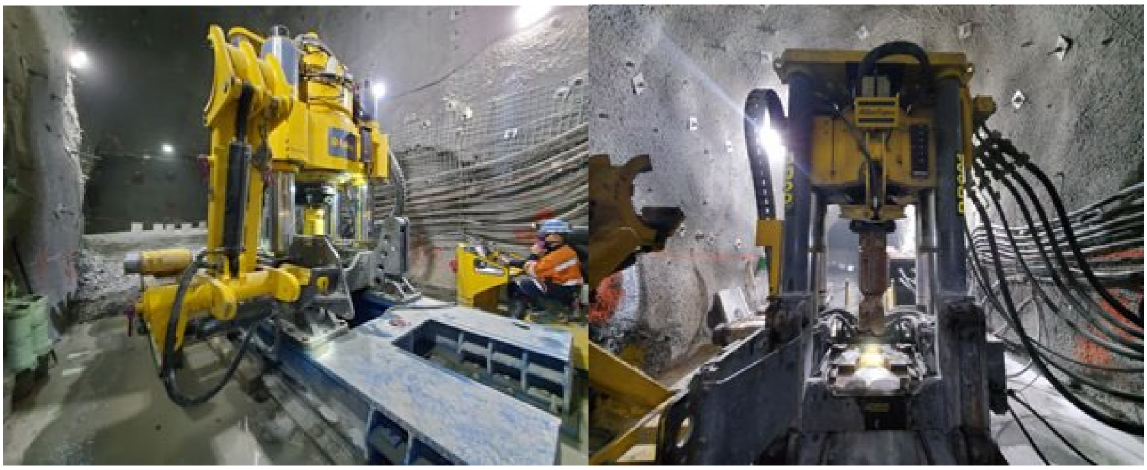


Figure 9 **Raisebore pilot and remaining in progress**

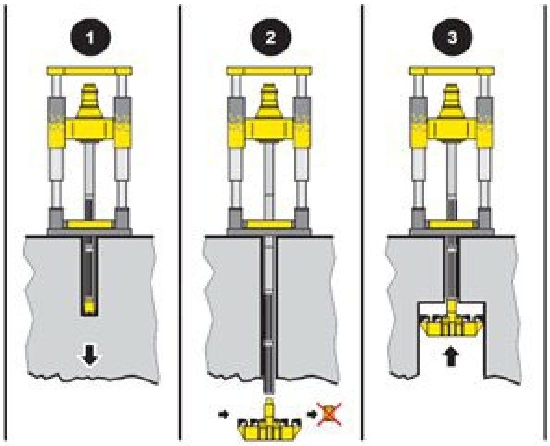


Figure 10 **Schematics showing (1) pilot hole drilling, (2) attach reamer head, (3) and reaming process**

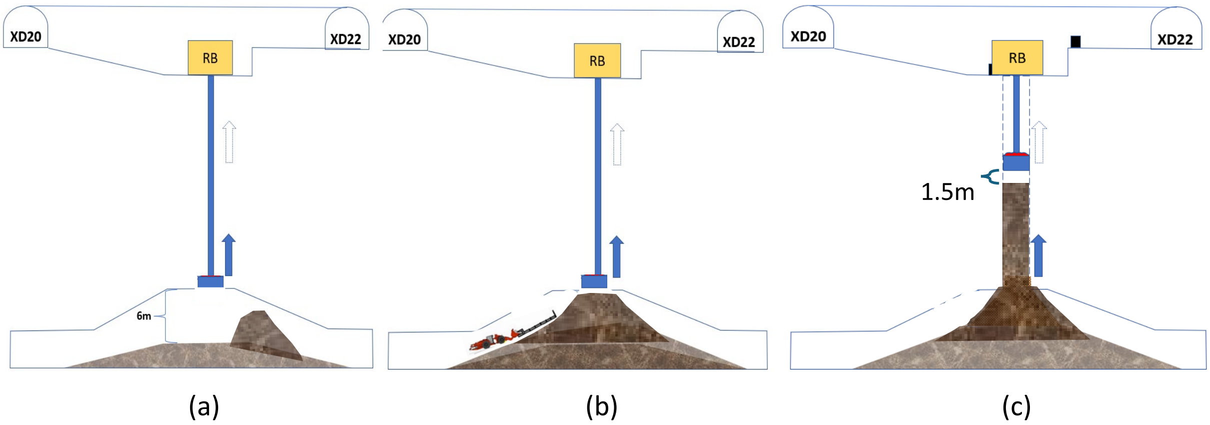


Figure 11 Schematics showing (a) reaming, (b) backfilling, (c) and advance reaming

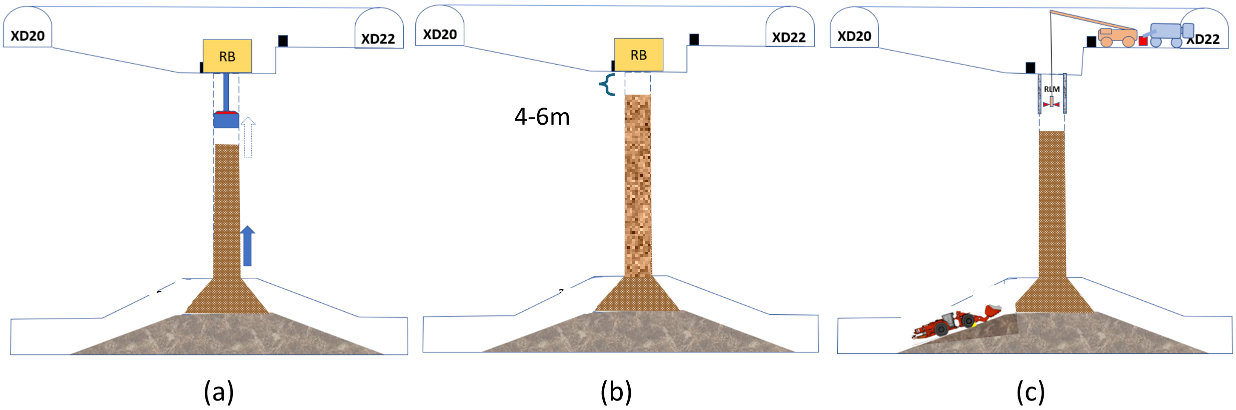


Figure 12 Schematics showing (a) reaming, (b) de-mob raisebore, (c) shotcrete lining remove muck

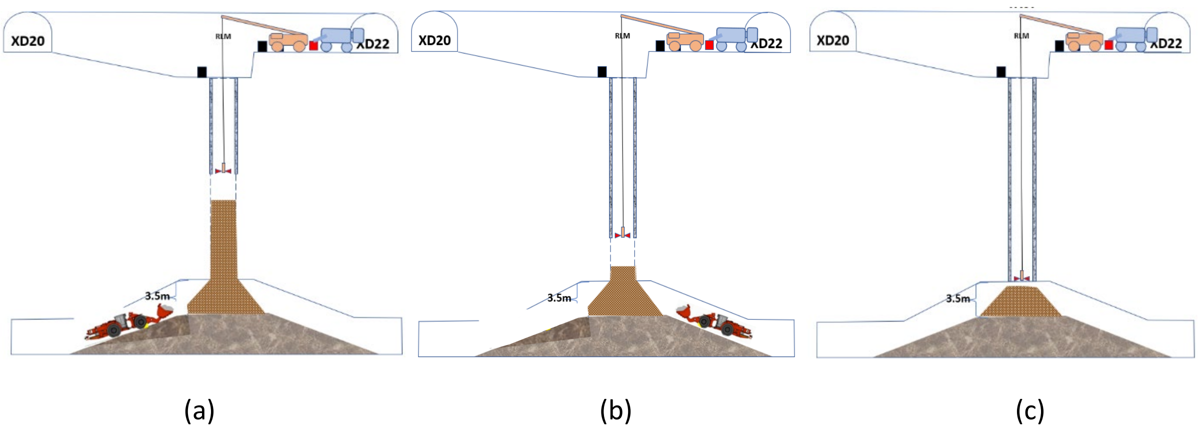


Figure 13 (a) Lining while mucking from bottom; (b and c) Lining finalisation

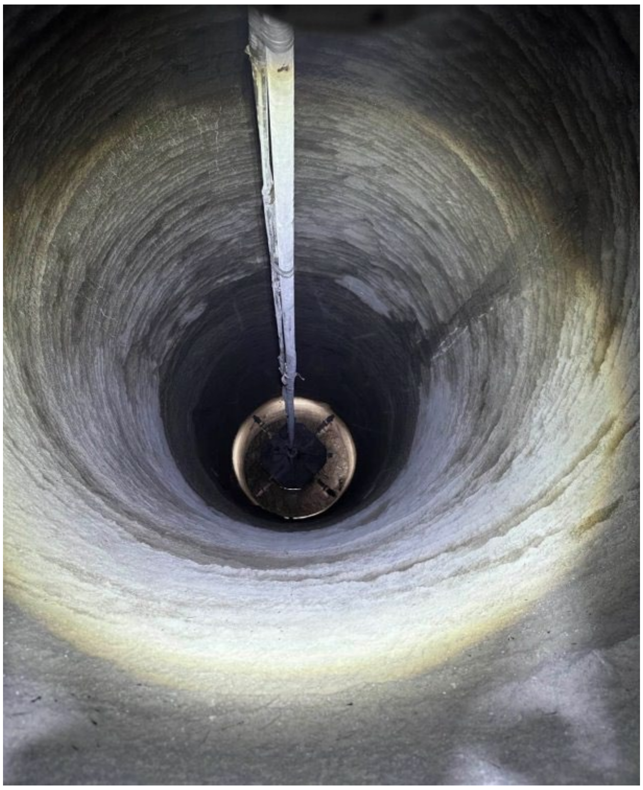


Figure 14 Shotcrete lining of the raise

5 Construction and engineering optimisation

Between 2022 and 2026, the project delivered 11 truck loading stations across different panels. Early stations showed actual construction durations significantly above baseline (as seen in Figure 15) where, for example, TX04 took 398 days compared to 343 baseline days, highlighting the need for a comprehensive re-engineering effort. A structured improvement initiative was launched, using iterative re-engineering implementation to systematically reduce duration, man hours, risk, and schedule variability. This section presents the methodology and the resulting benefits.

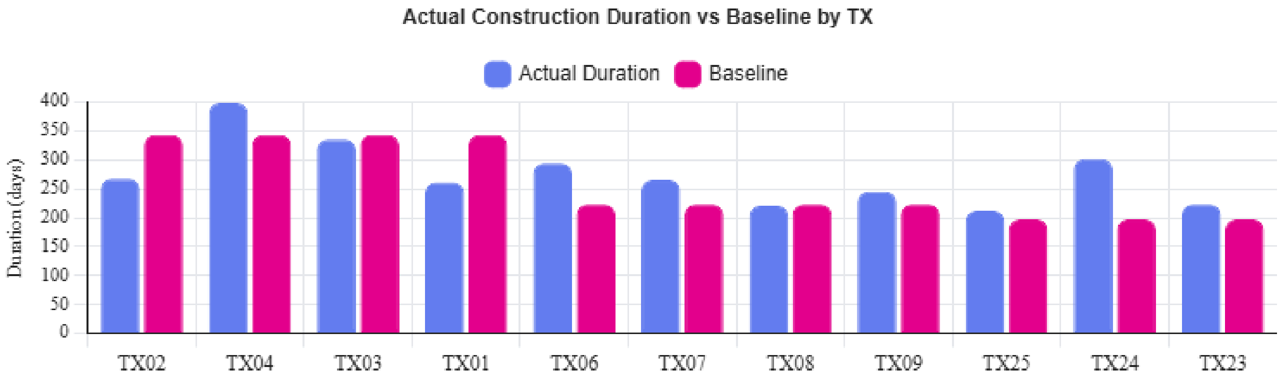


Figure 15 Actual construction duration versus baseline by TX

5.1 Construction complexity

Construction of truck loading stations (Figure 16) requires:

1. civil excavation, foundations, and formworks
2. SMP installation including ore bin cans, chutes, rock box, lip liners, steel structures

3. electrical and instrumentation installation including hydraulic power units, sensors, electrical panels, and control logic, fire alarm system.

These elements must be delivered in a tightly controlled underground environment with simultaneous development and production constraints.

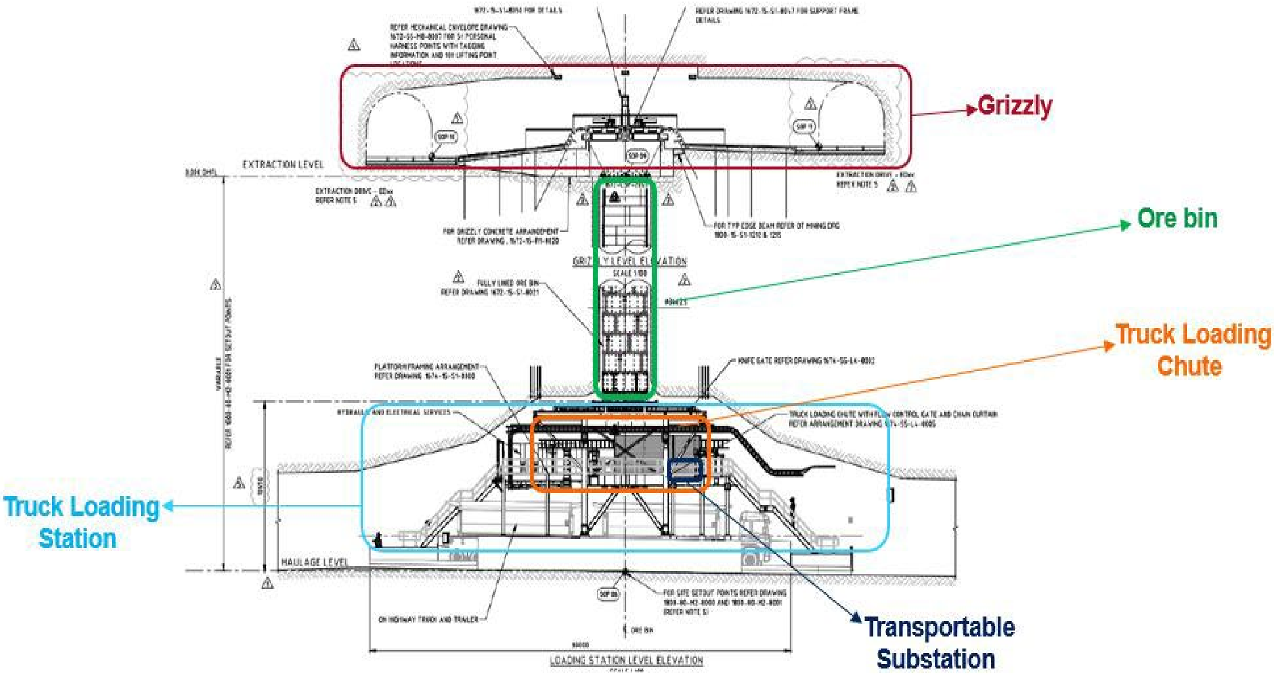


Figure 16 Ore handling system general arrangement

5.2 Engineering improvements

A series of engineering improvements was implemented to enhance constructability, reduce scope, simplify the installation and shorten the duration of critical path activities.

5.2.1 15 tonne strand jack method for lifting

After the installation and backfilling of the ore bin steel cans, the system could remain immobile at the EXL for 3 to 4 months while the HLL chamber advanced. The large footprint of the 70 t strand jack (SJ) frame (Figure 17) constrained the EXL work area, placing EXL and HLL on a dual critical path. To remove this constraint, the lifting strategy was re-designed, resulting in a new 15 t SJ frame engineered for safe lifting directly from the rock box and grizzly (Figure 16). This decoupled the EXL and HLL, enabled parallel progression, early ore bin lining, and uninterrupted tipple construction. The heavy-lift durations were reduced from 18.5 to 8 days, whilst removing 40 days overall from the critical path and eliminating ~130 days of SJ idle time. The change delivered 67,000 man hours saved per station, with projected cumulative savings of 739,200 hours for Panel 2 North (P2N), 403,200 hours for future Panel 1 (P1), and 873,600 hours for future Panel 2 South (P2S). Supported by full structural validation, the 15 t SJ system was a key contributory factor to provide a safer, more flexible, and more efficient installation method, removing the EXL from the critical path.

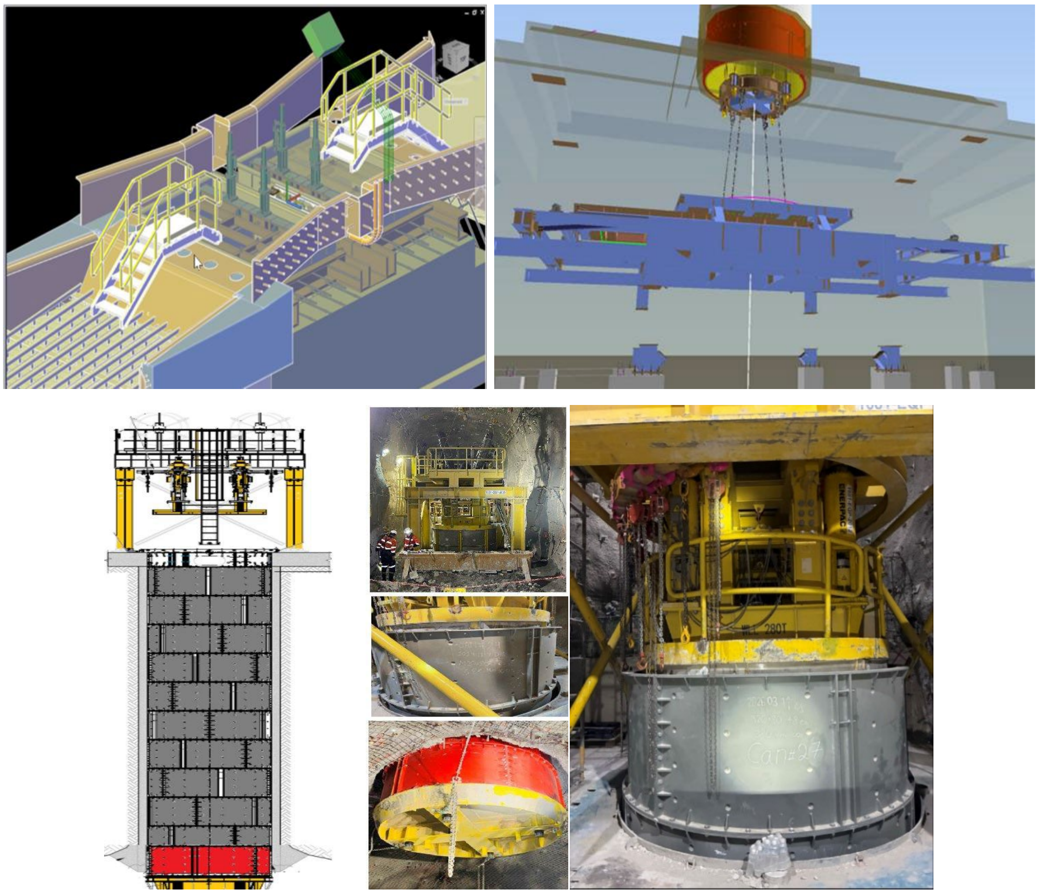


Figure 17 Transition to 15 tonne strand jack method for lifting

5.2.2 Removal of complex structural, mechanical and piping interfaces (knife gate, throat gate)

During routine TLS operations, muck accumulation along the knife gate (or throat gate; Figure 18) knife gate travel path was found to restrict movement and cause delays. A structured analysis confirmed the hypothesis that non-functional elements of the knife gate geometry trapped material and prevented self-cleaning. The assembly was modified by removing these sections and reinforcing the structure with welded gaskets and plates integrated into the subframe. This restored smooth operation, prevented future buildup, reduced downtime, and improved maintainability by aligning the knife gate design with observed material flow behaviour.

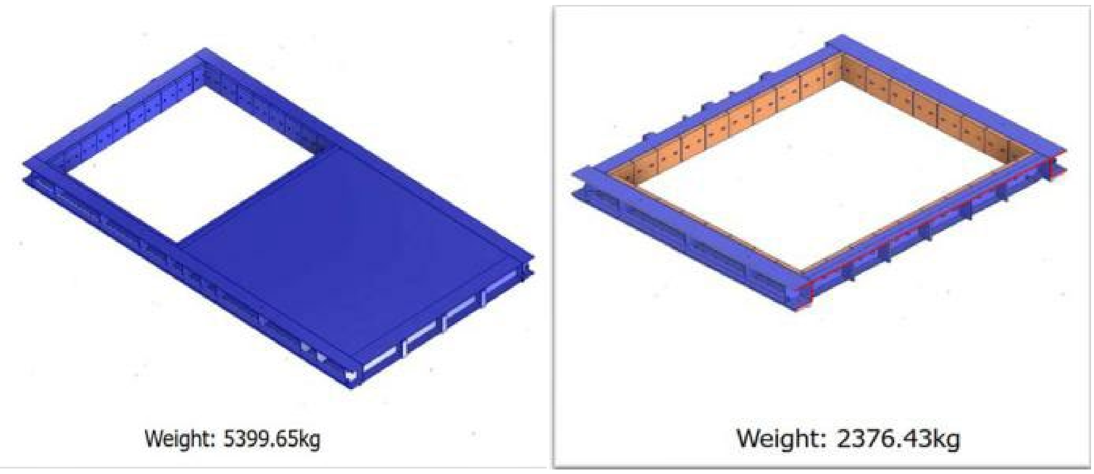


Figure 18 Removal of complex structural, mechanical and piping interfaces (knife gate, throat gate)

5.2.3 *Removal of the 6-tonne monorail out of the truck loading station*

During early OHS development, 6 t and 8 t monorail hoists were installed in the HLL to support chute construction. Subsequent review confirmed that the 6 t monorail tasks could be more efficiently completed using a Franna crane, removing the need for permanent installation in future truck chutes (Figure 19). With each 6-tonne monorail costing ~USD 15,000 and 2–3 chutes delivered annually, this change offers potential savings of ~USD 45,000 per year for Panels 0 and 1. A smaller 1-tonne monorail may be retained where minimal lifting is required. While the Franna crane cannot handle hydraulic power unit lifts without supplementary methods, eliminating the monorail avoids ongoing inspection, certification, and compliance costs, simplifying construction and delivering long-term financial and operational benefits for OTUG.

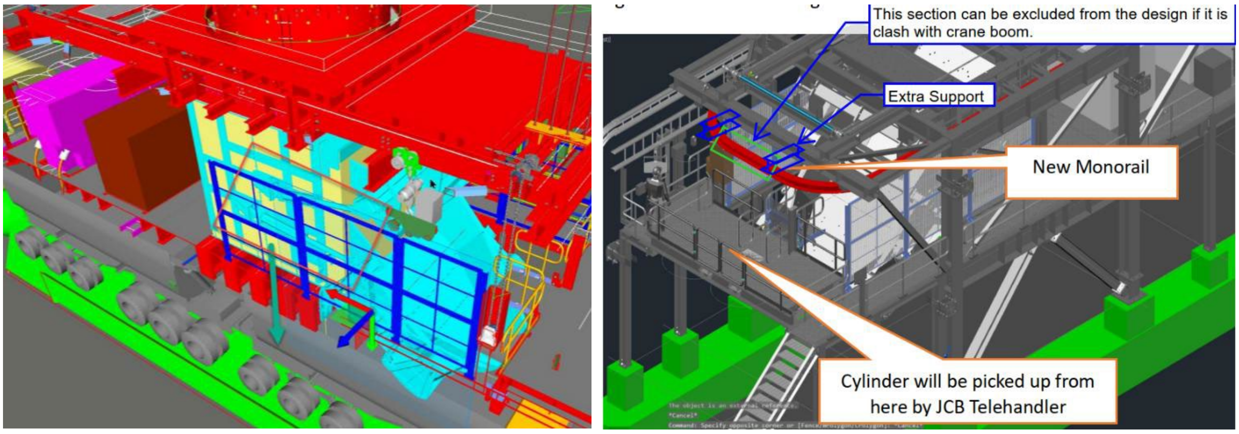


Figure 19 Removal of the 6-tonne monorail

The introduction of railed access, customised formwork and barrier redesign improved the steel can and chute installation efficiency, reducing the effort from 67,000 to 63,500 labour hours and duration from 262 to 210 days.

Between 2024–2025, optimisation of the 70-tonne SJ system (fewer shifts, improved cage utilisation) and custom formwork for the rock box and pedestal, combined with a revised collar angle installation method, further reduced the effort to 36,000–39,000 labour hours and construction duration to 183 days (Figure 20 and 21).

From 2025 to present, productivity gains in cable pulling and ladder installation (driven by more skilled personnel and multi-skilled crew deployment) stabilised execution at approximately 33,500–34,000 man hours, achieving an overall baseline construction duration of 176 days.

This performance now represents the new, repeatable standard construction duration leading to on-time commissioning and operations.

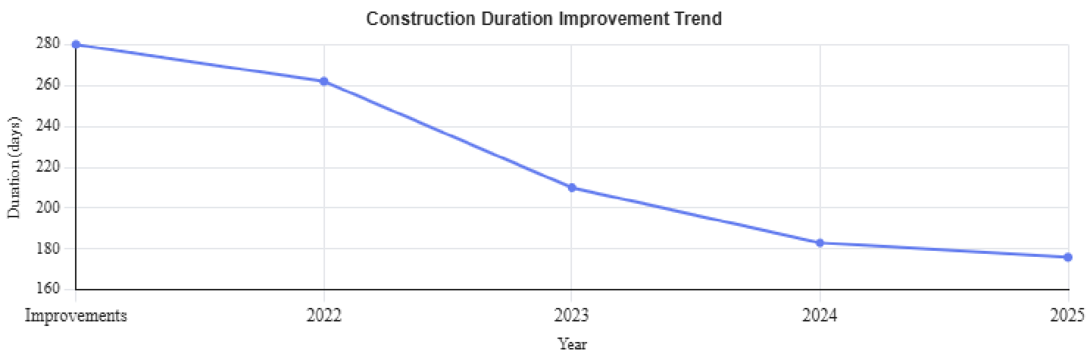


Figure 20 Construction duration as engineering improvement

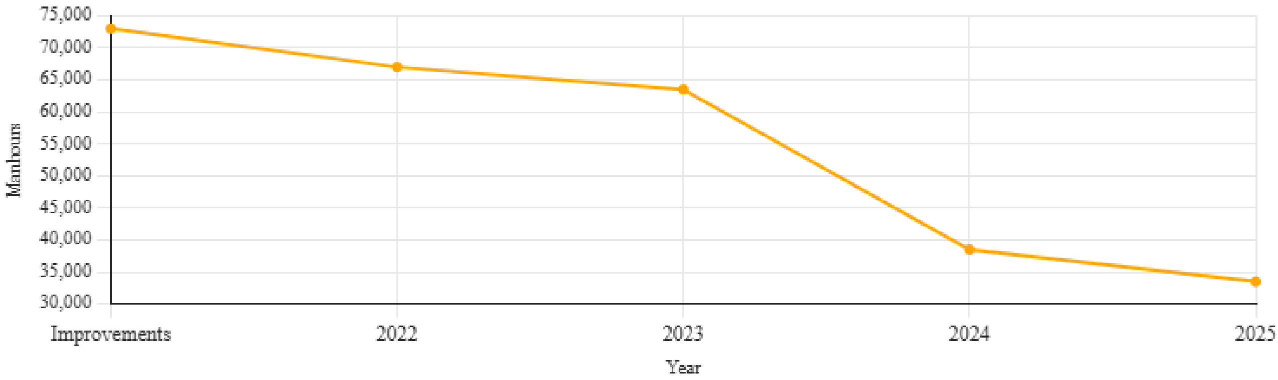


Figure 21 Reduction trend

6 Key learnings

Early sequencing decisions strongly influence overall delivery performance: deferring non-critical excavation and decoupling EXL and HLL activities significantly reduced rework, idle time, and dual critical path constraints.

Ground-responsive vertical development methods are essential in weak, high-stress environments: raisebore choke-reaming and shrink lining provided effective confinement, improved safety, and materially reduced the risk of raise collapse compared with conventional methods.

Constructability-driven design simplification delivers notable benefits: optimised lifting strategies, removal of non-value-adding permanent infrastructure, and simplification of SMP interfaces reduced labour, schedule duration, and operational complexity.

Flexible, right-sized lifting solutions outperform oversized permanent systems: transitioning from a 70 tonnes to a 15 tonnes SJ system enabled parallel work fronts, shortened critical activities, and improved schedule certainty.

Workforce capability and multiskilling are key enablers of repeatability: progressive upskilling and deployment of multi-skilled crews were critical to stabilising productivity and achieving a repeatable baseline duration.

Iterative improvement supported by operational feedback drives sustainable performance gains: embedding learnings from early installations enabled continuous refinement, resulting in a repeatable construction duration of approximately 176 days per truck chute loading station.

(a) (b)

Figure 22 (a) Road train is being loaded; (b) Road train underneath the truck chute loading station.

7 Conclusion

Truck loading chute development at OTUG initially presented significant geotechnical, sequencing and constructability challenges, particularly during vertical development through weak, highly stressed ground and during early construction execution. These challenges resulted in extended construction durations, elevated schedule risk, and reduced delivery certainty for the early truck chutes.

A structured and iterative improvement program was implemented to address these constraints, focusing on construction sequencing, vertical development methodology, design constructability, and workforce capability. A key outcome was the successful adoption of raisebore choke-reaming and shrink lining, which provided effective ground confinement, reduced unsupported exposure, and enabled safe and reliable development through poor ground conditions, where conventional raiseboring had proven unsuccessful. This approach materially reduced the risk of raise collapse and unplanned schedule delays.

In parallel, significant constructability-driven engineering improvements were delivered across the construction phase. Revised sequencing removed unnecessary rework and decoupled EXL and HLL activities. The transition from a 70 t to a 15 t SJ lifting system eliminated dual critical path constraints, reduced heavy-lift durations, and enabled parallel progression of civil and SMP works. Additional simplifications, including removal of non-value adding permanent infrastructure, optimisation of SMP interfaces, customised formwork, railed access, and revised installation methods, further reduced complexity, labour effort, and execution risk.

These engineering and execution changes were supported by progressive development of the national workforce, increased use of multi-skilled crews, and improved task-specific productivity, particularly for E&I activities. Collectively, these measures delivered a step-change improvement in performance, reducing construction durations from early executions exceeding 260 days to a stable, repeatable baseline of approximately 176 days, with labour reduced to approximately 33,500–34,000 man hours per TLS.

The methodologies described in this paper are now standardised as the baseline delivery approach for future panels at Oyu Tolgoi. The outcomes demonstrate that disciplined engineering optimisation, grounded in operational feedback and aligned with geotechnical realities, can significantly improve the safety, predictability, and efficiency of complex underground ore handling infrastructure. The learnings provide a transferable framework for other block cave operations facing similar geotechnical and construction challenges and establish a new benchmark for truck loading chute and orepass construction in cave mining environments.

Acknowledgments

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