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Northparkes E22 deposit: a strategic re-evaluation of mine design and material handling system

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Abstract

The Northparkes E22 deposit is a localised mineralisation area, separate to and approximately 2 km north of the E26 and E48 underground mines. The E22 orebody commenced using open pit mining methods in 2000 and over the two mining campaigns reached a depth of 230 m. Mining studies over the last 10 years have investigated extracting the remaining ore through numerous methods including further pit cutbacks, sublevel caving and block caving. The basis for the reserves has been a block cave where twin declines are mined from E48, the closest existing underground infrastructure, to form the ventilation and conveyor drives. This 3.7 km of development required to access the E22 orebody has positioned E22 as an investment with five years' upfront capital expenditure before production commences.

In 2021, a pre-feasibility study evaluated in detail underground sublevel caving and block caving methods along with sub options for production rate, net smelter return value, material handling, mine access and ventilation infrastructure. From the viable sub options 13, cases were pursued for financial analysis with four cases put forward for detail design:

- *Sublevel cave conveying ore to the surface secondary screening facility.*
- *Sublevel cave conveying to E48 and hoist ore stream.*
- *Block cave conveying to E48 and hoist ore stream.*
- *Block cave conveying ore to the surface secondary screening facility.*

The evaluation of this work indicated that, for the sublevel cave options, although bringing forward high-grade material, the operating and capital costs were greater than the block caving cases, to recover 40% less tonnes.

The two block cave options differ in their quantity and discharge point of underground ore they deliver to the surface. Options incorporated into the existing material handling hoist system are bottlenecked to the hoist capacity. This means that total Northparkes mill production will rely on surface stockpiles and open pits to supply the additional material not able to be hoisted. Cases that convey directly to surface provide an opportunity to convey up to 8 Mtpa of E22 underground ore, in addition to the hoist capacity. This scenario provides a future opportunity to connect the surface conveyor to the top of bins/base of hoist location via a 1.1 km conveyor. This connection rethinks the Northparkes material handling strategy and allows future mines associated with GRP, E26, and Michael J House (MJH) orebodies to also be conveyed or hoisted to surface.

Keywords: *hoist, conveyor, material handling study*

1 Introduction

Northparkes Mines (Northparkes) is a joint venture between China Molybdenum Co., Ltd (CMOC) (80%) and the Sumitomo Groups (20%). The mine is located 27 km north of Parkes in central New South Wales, Australia, operates block caves and an ore processing plant, producing copper-gold concentrate. The mine has been operating since 1993 from two open pit mines, E22 and E27, one sublevel cave (SLC) E26SLC and four underground block caves E26 Lift 1, E26 Lift 2, E48, E26 Lift 1 North; these last two currently in operation.

2 Background

E22 is a porphyry copper-gold deposit located 2 km northeast of E48 (Figure 1). Mineralisation at E22 is developed as a discrete sub-vertical ore zone around a cluster of pipe-like mineralised monzonite porphyry intrusions. Geological information in the E22 area is derived from previous mining activities and a significant number of surface drill holes completed through exploration, evaluation, grade control and geotechnical drill programs in the past.

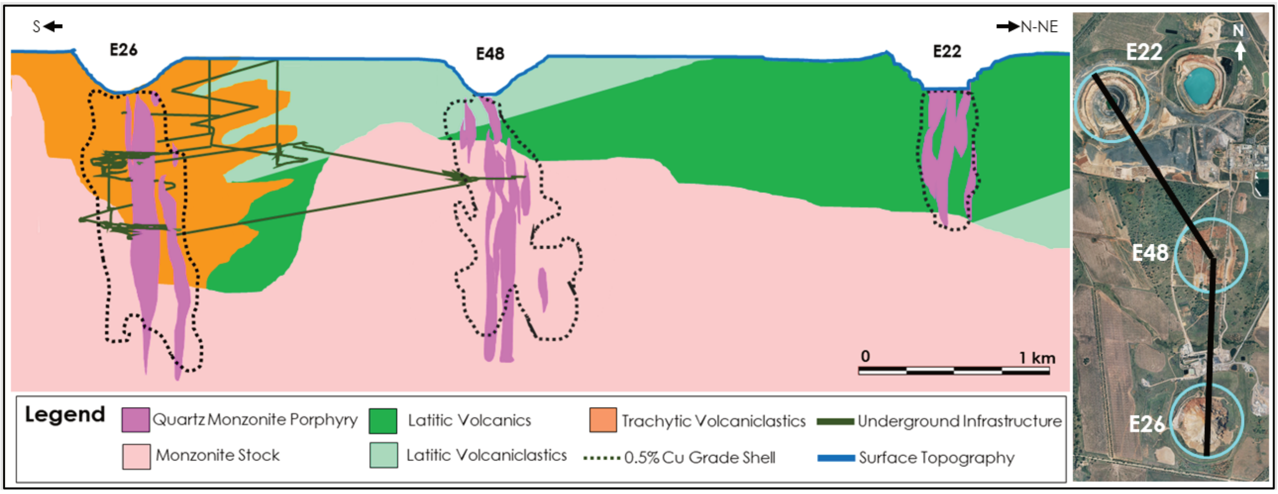


Figure 1 Schematic south to northeast geological section through the E26, E48 and E22 deposits displaying lithological units, current underground infrastructure and 0.5% Cu grade shells (actual section trace outlined in black on the aerial image to the right)

The E22 resource at Northparkes mine has historically been extracted using conventional open pit mining method. The orebody has been mined in three separate campaigns: the most recent being a three-year 25 Mt cutback between November 2007 and October 2010. The existing pit void is approximately 27 Mm^3. It is 600 m in diameter and has been mined to a depth of 230 m (10,055RL).

From 2011–2013, Rio Tinto completed the Step Change Project PFS (Northparkes Mines 2014) evaluating the viability of a Northparkes production rate above 25 Mtpa. The outcome was five open pits and a new block cave operation in the E22 orebody. As part of this study, a trade-off between open pit and underground block caving mining methods for the extraction of the E22 resource was completed in early 2011. A range of economic pit shells and block cave footprints were considered at various operating costs reflecting both the planned Step Change expansion case and processing E22 as a standalone project through the existing concentrator. The trade-off study also considered the potential to utilise the open pit void for tailings deposition, as currently undertaken in the E27 pit. Ultimately the study identified the highest value opportunity for Northparkes, with the existing concentrator, was to mine a small block cave from approximately 550 m below surface or 325 m below the base of the current pit.

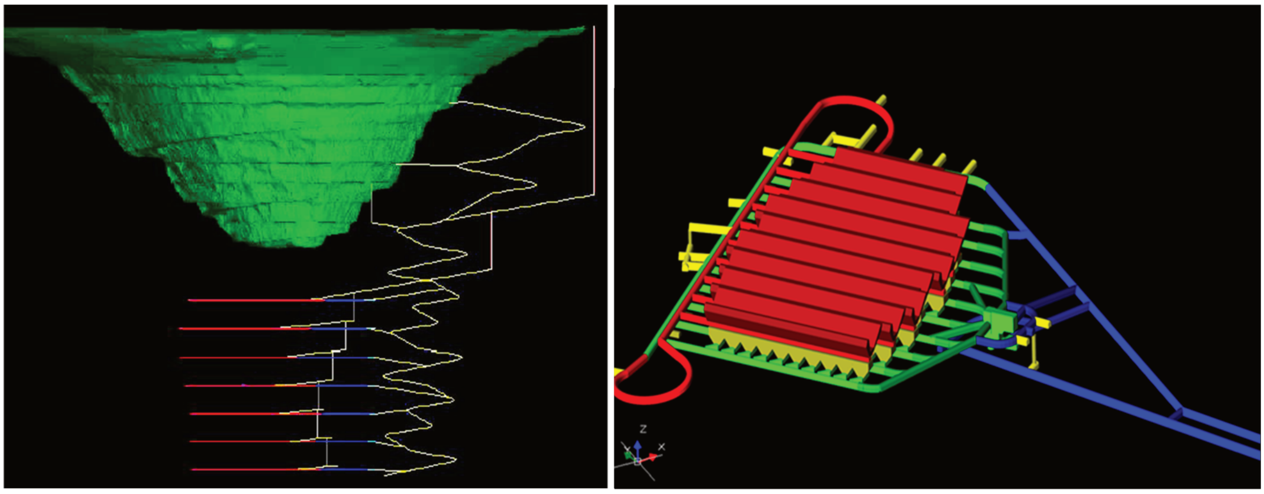
During this study, some preliminary metallurgical test work was also carried out mainly for the comminution and flotation amenability studies. These studies supported the inclusion of E22 in the reserves as 28 Mt.

A concept study on a SLC option, similar to the E26 SLC (Figure 2a), was completed in December 2017. The study indicated that mining seven sublevels over nine years would produce 13 Mt. The concept study showed that a SLC option would add value but had a long payback period. This option was targeted for review in the E22 pre-feasibility study 2021, following completion of the deeper drilling program.

During 2018, the E22 Lift 1 Pre-feasibility Study Update (Northparkes Mines 2018a) identified that a potential of 42 Mt ore can be extracted from E22 Lift 1 (E22L1) block cave (Figure 2b). The E22L1 mine was scheduled to produce up to 5.0 Mtpa.

The key benefits of the E22L1 block cave included:

- Production risk reduction – operation of E22 block cave reduces operational risks through providing an ore source running in conjunction with E26 Lift 1N and Lift 2NN.
- Increase of 14.2 Mt from 2017 declared reserve base.



(a) (b)

Figure 2 Previous E22 mining studies. (a) Sublevel caving concept study – 2017; (b) Pre-feasibility study update – 2018

3 Strategic re-evaluation 2021

Pre-Feasibility Study carried out in 2021 (Northparkes Mines 2021) had the objective to re-evaluate options for mining the E22 orebody. The process started at the mining method selection and progressed through to material handling, net smelter return (NSR) shut-off value, production rate, mine access and ventilation options.

Mining methods focused on bulk mining options as selective methods producing smaller, high-grade tonnages would be insufficient to fill and cover the costs of the Northparkes concentrator, forecasting production at 7.6 Mtpa.

Mining options considered tonnages available at various NSR cut-off or shut-off scenarios. The Northparkes NSR calculation assumes long-term commodity pricing and offsite costs of shipping, freight, transport, treatment, and refining charges.

Two main mining methods were the base of the study, SLC and block cave. SLC options were evaluated from NSR AUD 40 to AUD 80 at AUD 10 increments. The higher NSR evaluations produced lower tonnages where there was insufficient recovery of the reserves and reduced NPV. These more selective options would also bring forward capital in the life-of-mine for constructing the next block cave after E22. SLC rings on levels extending the full height of the orebody were evaluated and resulted in 15 economic sublevels. The best NSR was chosen as this achieved 22 Mt of the total 42 Mt ore in reserves.

Production rates for the SLC were taken from Northparkes experience in the E26SLC. The estimation of the total production ratios for the E22 are shown in Table 1.

Table 1 E22 production rates limits

Level	Extraction ring tonnages per level
1st level	40–60%
2st level	60–80%
3st level	80–90%
4st level	90–100%
5st level +	100% +

The production rates were also limited to the shape of the orebody (funnel shape) shown in Figure 3, and the congestion of equipment in reduced horizontal spaces.

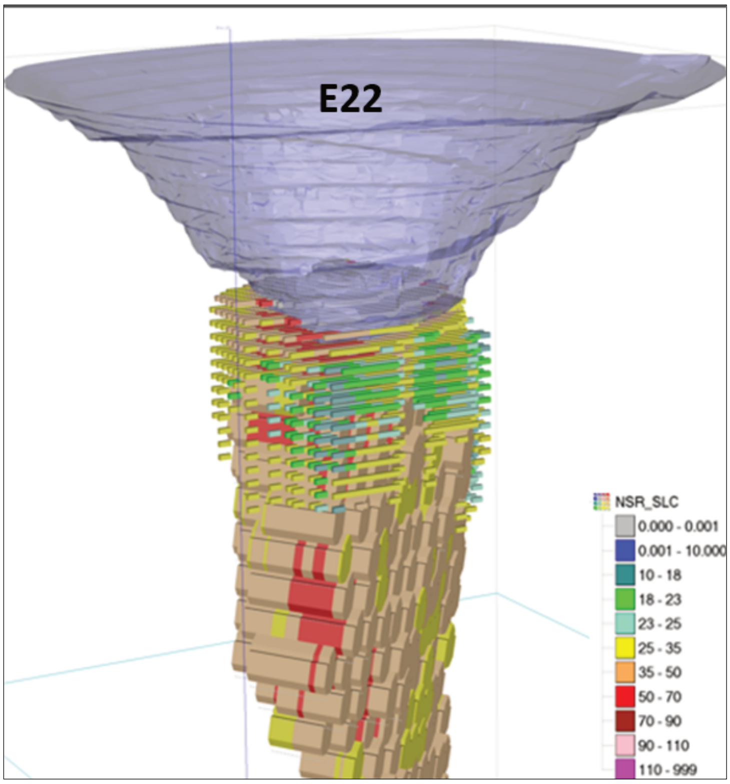


Figure 3 Isometric view of sublevel caving production rings

Shape of the production area and SLC production rates constraints resulted in maximum production tonnes not above 4 Mtpa. Increasing number of production loaders did not provide major improvement; therefore, production increment was not necessarily linked to number of loaders increment. Figure 4 illustrates SLC production schedule versus number of loaders.

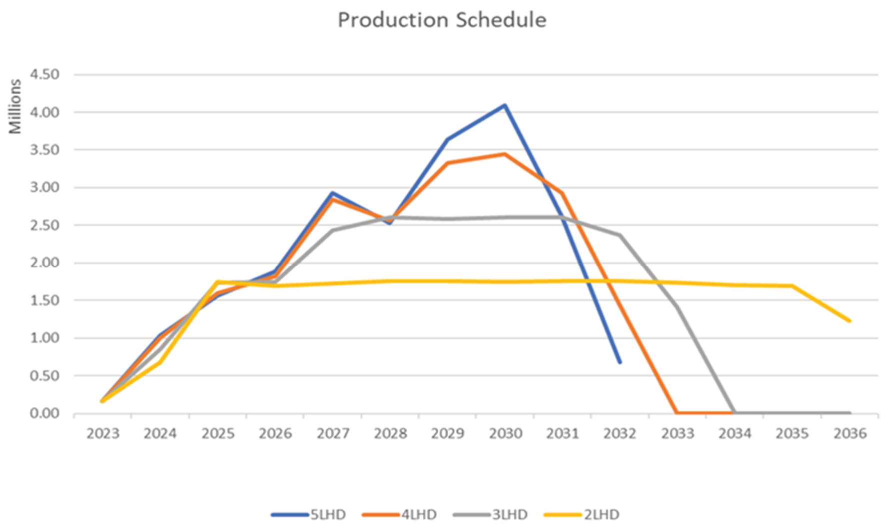


Figure 4 Production tonnes estimation against number of loaders

The block cave footprint finder levels were evaluated at two dollar increments from AUD 18 to AUD 40 and then further refined around the highest value. Drawpoint selection on each NSR is based on the dollar value of every individual drawpoint and must generate an enough revenue to pay for drawpoint construction cost. The mining level of 9730RL was chosen using footprint finder where it maximises the recovery of economic mineralisation, below which, the orebody begins to deplete.

The block cave production rate, for conveying scenarios, is limited by the material handling system and loader congestion at the tipples accessing the crusher. This scenario is proven at Northparkes and the production rates of 4 and 6.5 Mtpa are used for the block cave scenarios. The block cave production scenario was also modelled using Arena simulation software (Simulation Modelling Services 2021) to provide confidence to the production target.

In the life-of-mine, E22 will be running in parallel to E26L1N, which due to caving constrains, is limited at 3.5 Mtpa. E26L1N cave propagation relies on connection with the existing E26L1 cave. This is because its cave propagation occurs due to the existing footprint being extended (Northparkes Mines 2018b). With the mill production rate at 7.6 Mtpa the opportunity for running at E22 higher production rates than 4 Mtpa allows an alternate ore source to E26L1N that can provide near full capacity to the mill. The financial scenarios evaluate E22 with the life-of-mine limited production rate up to 4.1 Mtpa only available for processing E22. This evaluation does not recognise the opportunity for additional value from the block cave in producing at higher rates and aligns it with the constrained sublevel cave production rate.

Production scenarios displayed in Table 2 for both mining methods show that SLC option will require higher production from other sources to achieve the mill plant capacity. The E22 block cave option can achieve 6.4 Mtpa.

Table 2 Production scenarios for the Sublevel Caving and Block Cave options

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11
Mill capacity (Mtpa)	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
Mining options: SLC and block cave											
Sublevel cave	0.9	2.0	2.6	2.5	2.5	2.6	2.7	2.9	2.4	1.4	0.1
Other ore sources	6.7	5.6	5.0	5.1	5.1	5.0	4.9	4.7	5.2	6.2	7.5
Block cave	0.7	2.9	6.0	6.4	6.4	6.4	6.4	3.3	0.0		
Other ore sources	6.9	4.7	1.6	1.2	1.2	1.2	1.2	4.3	7.6		

Mine access for E22 is more capital intensive than previous caves due to it being 1.7 km from the existing E48 infrastructure. The mine access for previous E22 studies is a relatively flat twin decline from E48 north to the E22 extraction level (Figure 5). Alternate mine access options were tested in the locations of a portal from the E22 pit wall, a box cut and portal at the existing surface, primary crusher (east–southeast of E22) and a box cut and portal at the new secondary crushing and screening facility (southeast of E22). The E22 pit and portal are only accessible for the first years of development as the cave growth takes out the lower pit areas. The existing surface crusher was not optimal as conveyor CV025 that connects it to the secondary crusher is limited to 1.7 Mtpa providing a bottleneck to future surface conveyor options. The new secondary crushing and screening facility provided a strategic alternate location to access E22 through tying into the new screening and crushing facility. This option enables an extension of the conveyor to top of bins whereby future underground production rates can be increased and fed directly into the secondary crusher. The last study of E22 is shown in Figure 6.

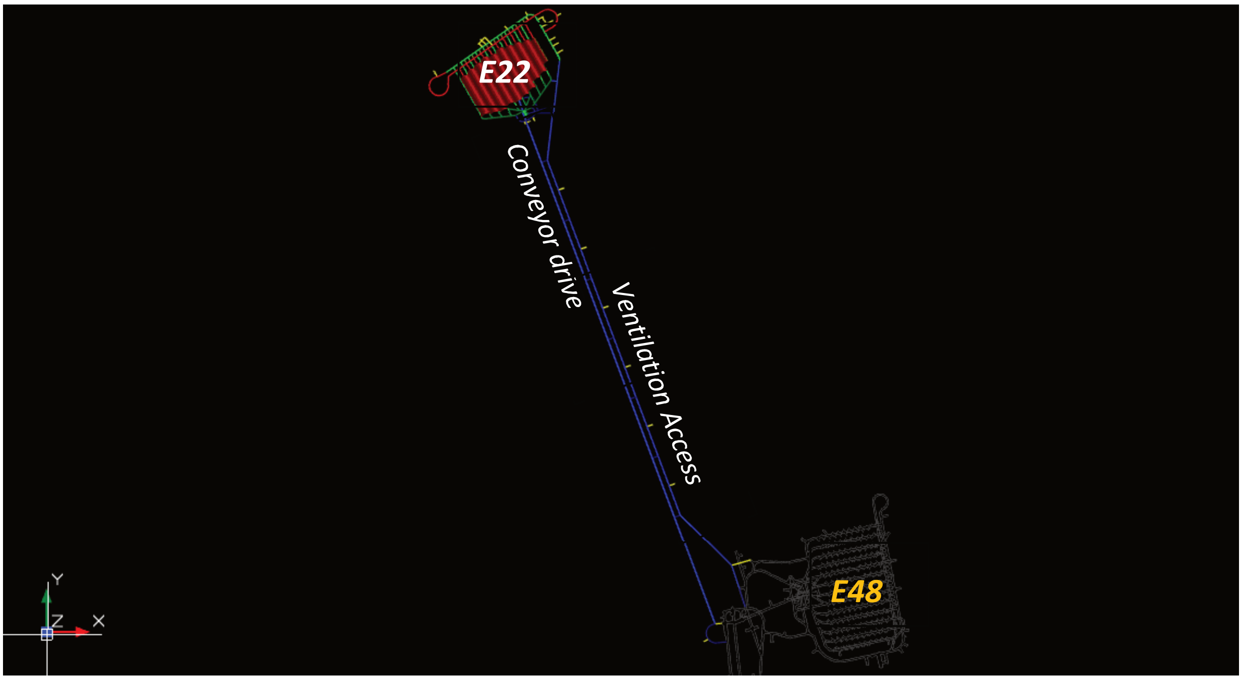


Figure 5 Plan view of previous E22 study showing twin drives for ventilation and material handling system

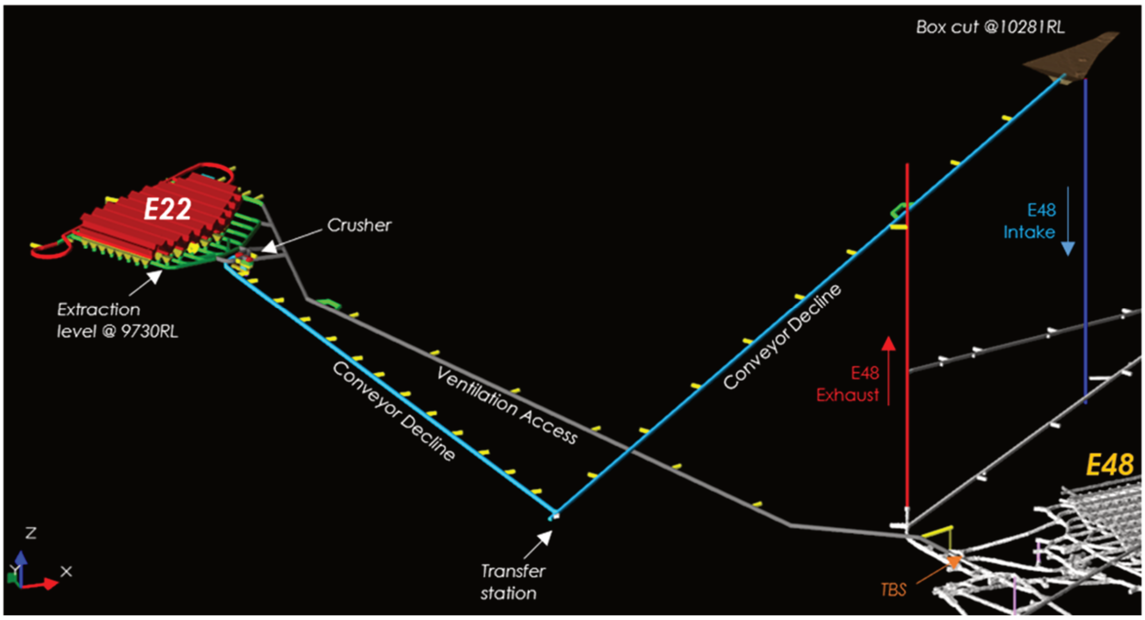


Figure 6 Isometric view of an updated E22 block cave and material handling system

Ventilation in the previous E22 block cave studies was planned to be supplied via the twin decline access from E48. The E48 ventilation circuit includes both a fresh air and exhaust shaft designed to accommodate the E22 project. The option where one decline forms the conveyor to surface aimed to repurpose one of the twin declines development metres. This has ventilation constraints, however, as the ventilation loop could not be established early during development, as in the twin decline options. Various ventilation options were proposed including shafts along the conveyor decline and at the E22 extraction level. Figure 7 shows an approach installing booster fan station along the access drive to E48. Ongoing studies are proposing the inclusion of a vent shaft near the extraction level and at an adequate distance from current pit and the projected E22 subsidence zone.

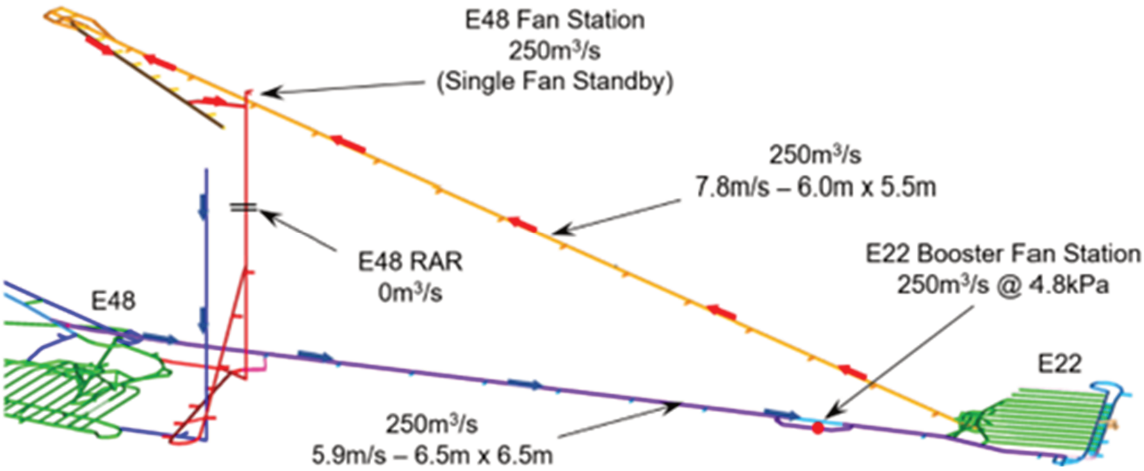


Figure 7 Access drive booster fan station (Bluhm Burton Engineering 2021)

3.1 Mining option selection

Mine designs were completed for the block cave and sublevel cave scenarios, including a hybrid design. Figure 8 compiles the different variations of these methods and the material handling system options.

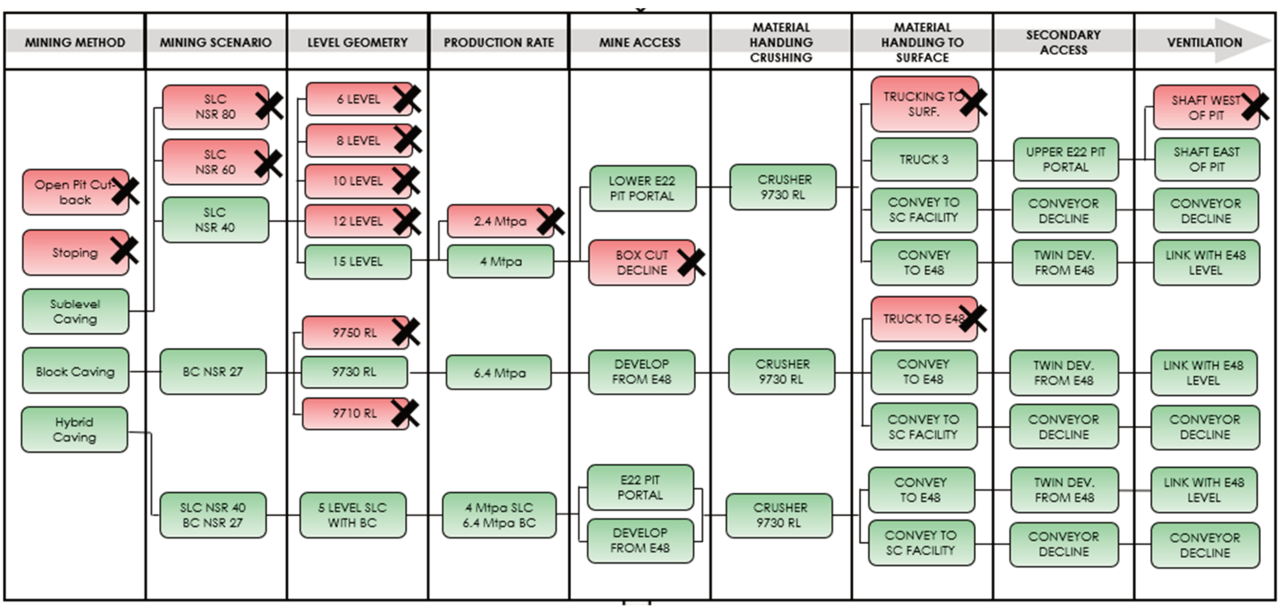


Figure 8 Selection of mining method

An opportunity to test the viability of an undercut-less block cave was also evaluated where the undercut development is eliminated through blasting the drawbell geometry from the extraction level. This innovation is still under trial at Northparkes Mines and, if results are positive, this will have potential to save capital costs and decrease construction time of block caves.

From the viable sub options, along with the hybrid and undercut-less options, 13 cases were pursued for financial analysis as shown in Figure 9. High level mine designs were costed and NSRs calculated based on Northparkes block cave and sublevel cave costings.

This process left four cases remaining:

- Case 3 – sublevel cave conveying ore to the surface secondary screening facility.
- Case 5 – sublevel cave conveying to E48 ore stream.
- Case 6 – block cave conveying to E48 ore stream.
- Case 10 – block cave conveying ore to the surface secondary screening facility.

These four cases have been subject to detailed mine design, development scheduling, production scheduling and costings. The evaluation of this work indicated that for the sublevel cave options, although bringing forward high-grade material, the operating and capital costs were greater than the block caving cases, to recover 40% less tonnes. The difference in NPV from the cases was enough to eliminate sublevel caving as an option to take forward to feasibility study. The comparative operating, capex, and NPV costings at the time of ranking were conducted and on this basis the Case 6 and Case 10 scenarios are presented for consideration with Case 10, block cave conveyor to surface the recommended case.

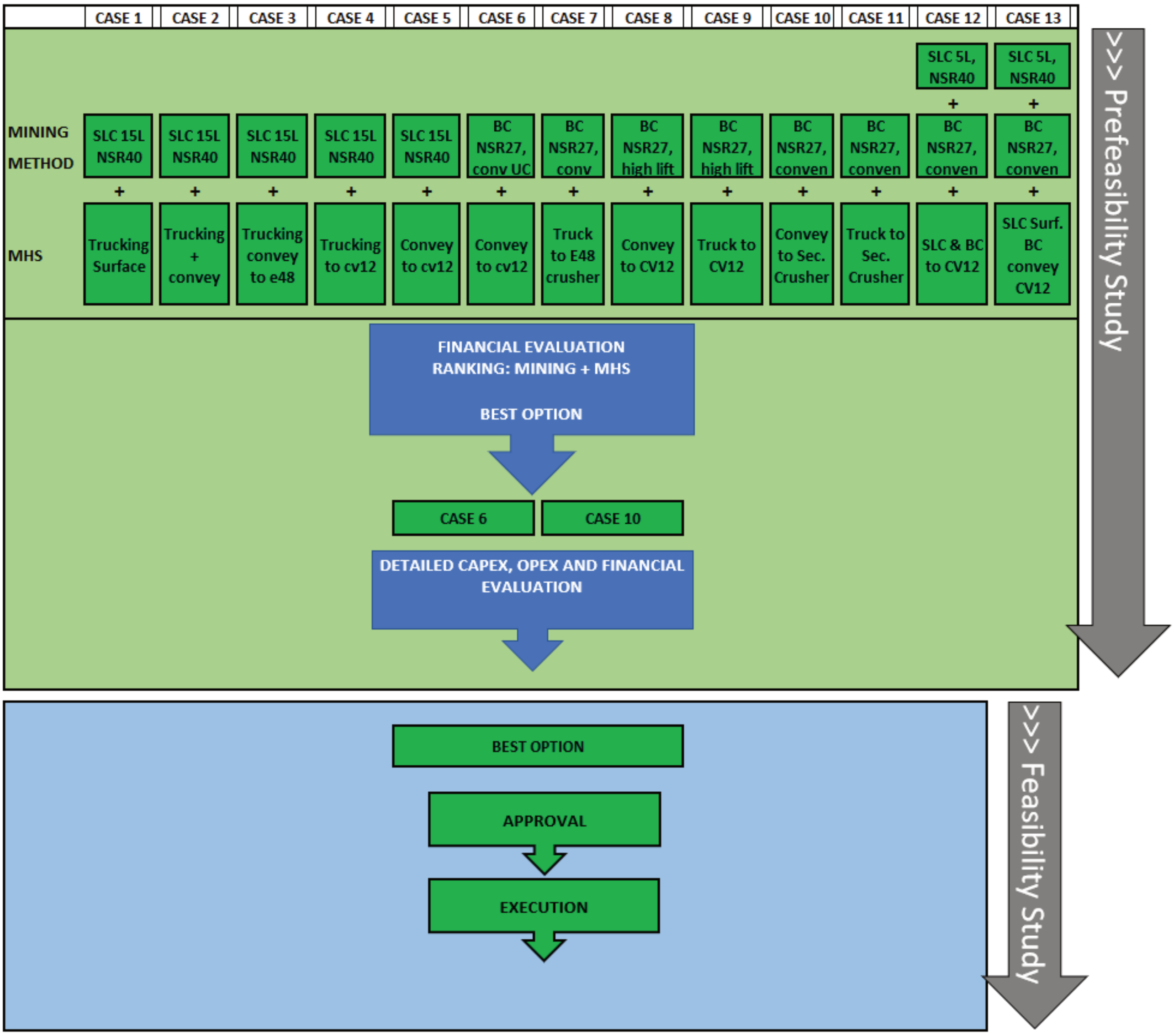


Figure 9 Process evaluation and mining method selection

4 Material handling system

The E22 PFS 2021 explored material handling system (MHS) infrastructure required to support the development and production of the E22 block cave mine. This section describes the best options and main drivers for the MHS selection.

The extraction level of the E22 block cave will be located at a depth of approximately 550 m from surface. The physical location of the E22 mine relative to the E26L2, E48 and E26L1N mines is shown in Figure 10.

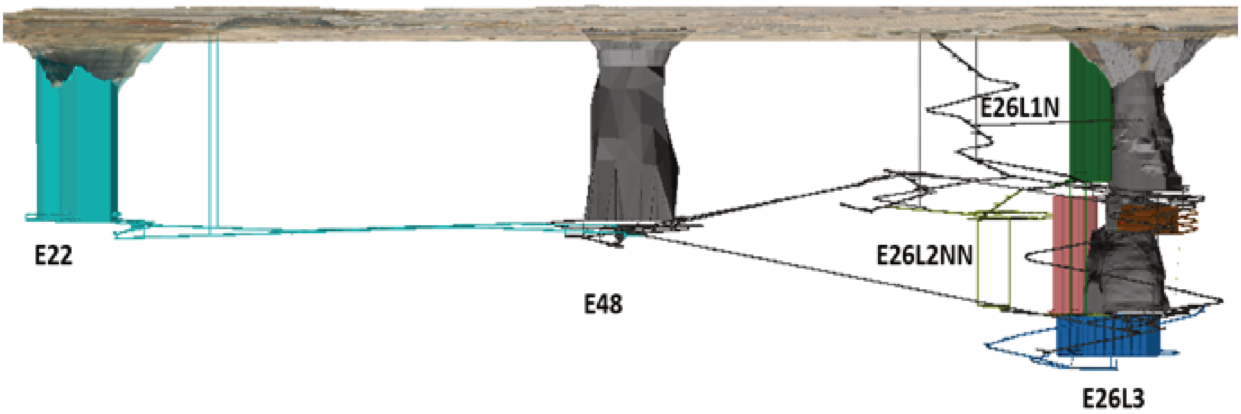


Figure 10 E22 Mine location compared to existing and future orebodies

The E22 block cave was initially planned to produce 4.1 Mtpa. However, the crushing and MHS designed will be capable of handling an average throughput of 6.4 Mtpa with a maximum design rate of 8 Mtpa. Arena simulation modelling was performed to validate the 6.4 Mtpa (Simulation Modelling Services 2021). However, the conveyor system can reach 8 Mtpa. This rate was estimated inhouse by the engineering team of NPM during the E22 pre-feasibility study (NPM 2021), based on the experience of the E48 and E26L1N projects.

The crusher location (Figure 11) has been optimised to balance extraction drifts and drawpoint tonnes per tipple as well as LHS requirements per zone. Load–haul–dump (LHD) options evaluated in previous studies identified as main design constrains:

- Diesel LHDs.
- LHD automation.
- Two tipping points and associated tipping access.

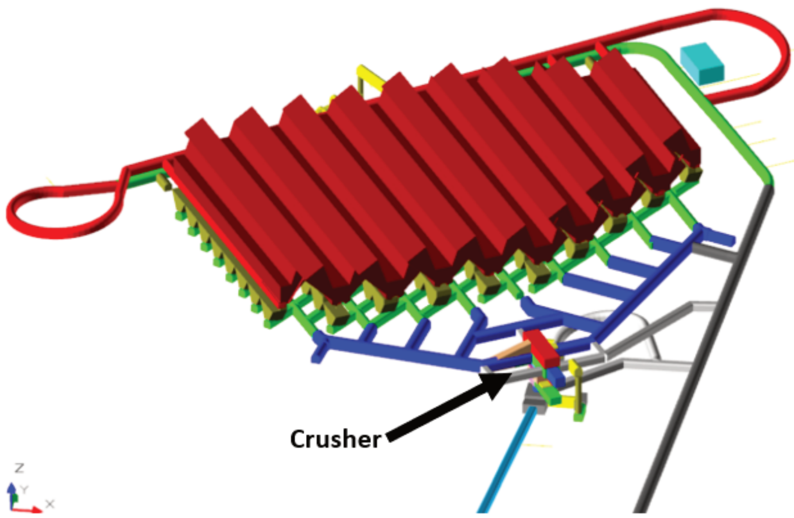


Figure 11 E22 extraction level showing crushing station location

The E22 infrastructure includes a primary crushing station and MHS that includes feeder loading and tramp metal station and conveying system.

4.1 Performance criteria

The general equipment performance criteria is shown in Table 3. The annual production rate shown below is the capacity that the MHS can deliver, considering not only E22 production but also other ore sources coming from GRP or Michael J House MJH projects, after E26L1N production is finished.

Table 3 General equipment performance criteria

Requirement	Value
Mining method	Primarily block cave
Underground haulage method	Belt conveyors
Design life	20 years
Annual production	6.4 Mtpa (nominal); 8 Mtpa (max)
Ore moisture content	3%
Overall system utilisation	80%
Nominal design throughput	900 tph
Maximum design throughput	1,150 tph
Design clay content	10% by volume

4.2 Conveying options

During the pre-feasibility study, 13 different mining options were evaluated. Following these investigations, the mining method selected was for a block cave mine with an underground primary crushing station and underground MHS using conventional underground conveyors to transport the crushed ore to the surface for further processing.

Two preferred conveying options were selected for investigation and are referred as Case 6 and Case 10. The primary crushing stations, feeder loading station and tramp metal removal station are the same for both options.

4.2.1 Case 6: conveying to existing underground conveyor 124CV011

The conveying system for Case 6 ties into the existing underground MHS via an extension to the tail end of existing underground conveyor 124CV011. A plan view of the Case 6 option is shown in Figure 12. Main conveyor 124CV014 runs from the feeder station below the crushed ore bin at the bottom of the crushing station and ties into the existing underground conveying system via an extension to the existing conveyor 124CV011 as shown in Figure 12. Conveyor 124CV014 will run in a dedicated conveyor tunnel that runs parallel to the new main E22 access and ventilation drive that ties into the existing underground ventilation system near E48 (Figure 13). Figure 14 displays an isometric view of E22 Case 6 design.

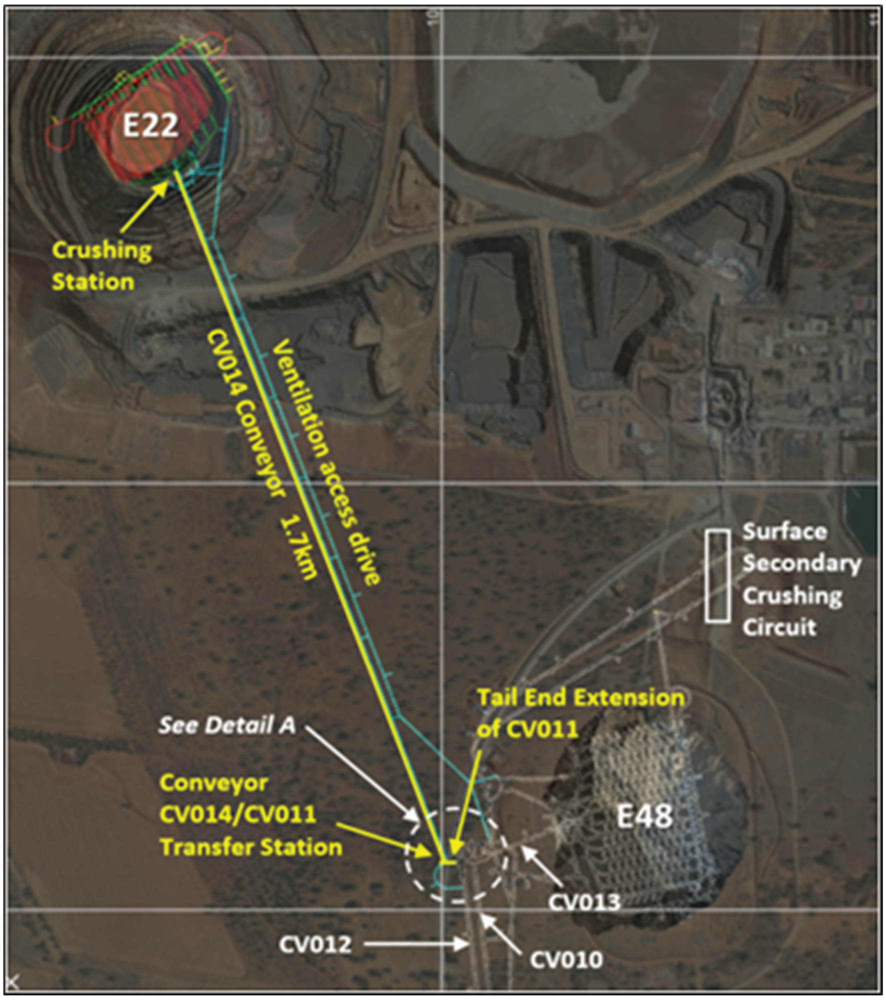


Figure 12 E22 PFS Case 6 layout

Figure 13 Detail A from Figure 12 above showing tail end extension of existing conveyor 124CV011

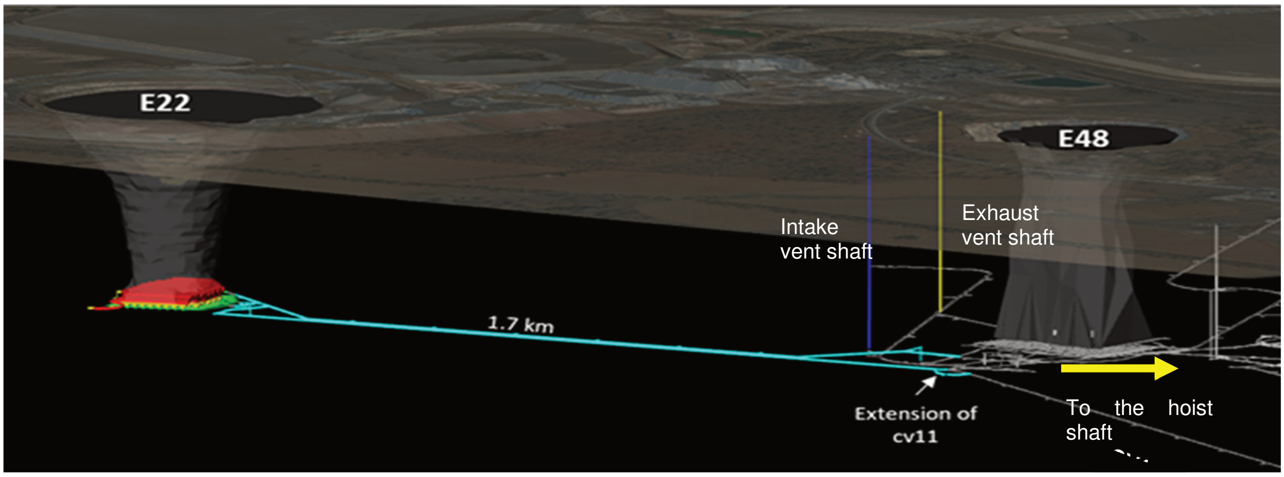


Figure 14 Isometric view of E22 design Case 6

4.2.2 Case 10: conveying directly to surface

The Case 10 proposed design is shown in Figures 15 and 16. This includes a series of new conveyors (124CV014, 124CV015 and 180CV026) that convey the crushed ore from the E22 crushing station directly to surface where it ties into the existing surface secondary crushing circuit near the tail end of the secondary crushing circuit feed conveyor 180CV022.

For this case, a boxcut and portal was planned, and these will be located northwest of the existing overland conveyor 123CV006.

Figure 17 shows the location of the head end section of incline conveyor 124CV015, the conveyor 124CV015 boxcut, transfer station 124CV015/180CV026, conveyor 180CV026 and transfer station 124CV026/180CV022 which transfers the crushed ore onto the existing secondary crushing circuit conveyor 180CV022.

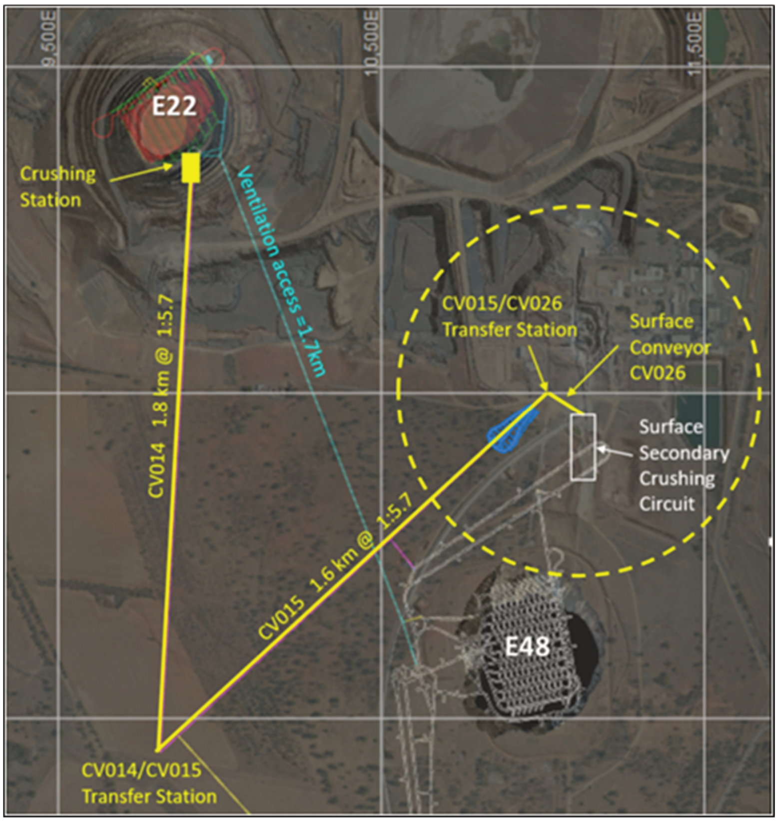


Figure 15 E22 PFS Case 10 layout

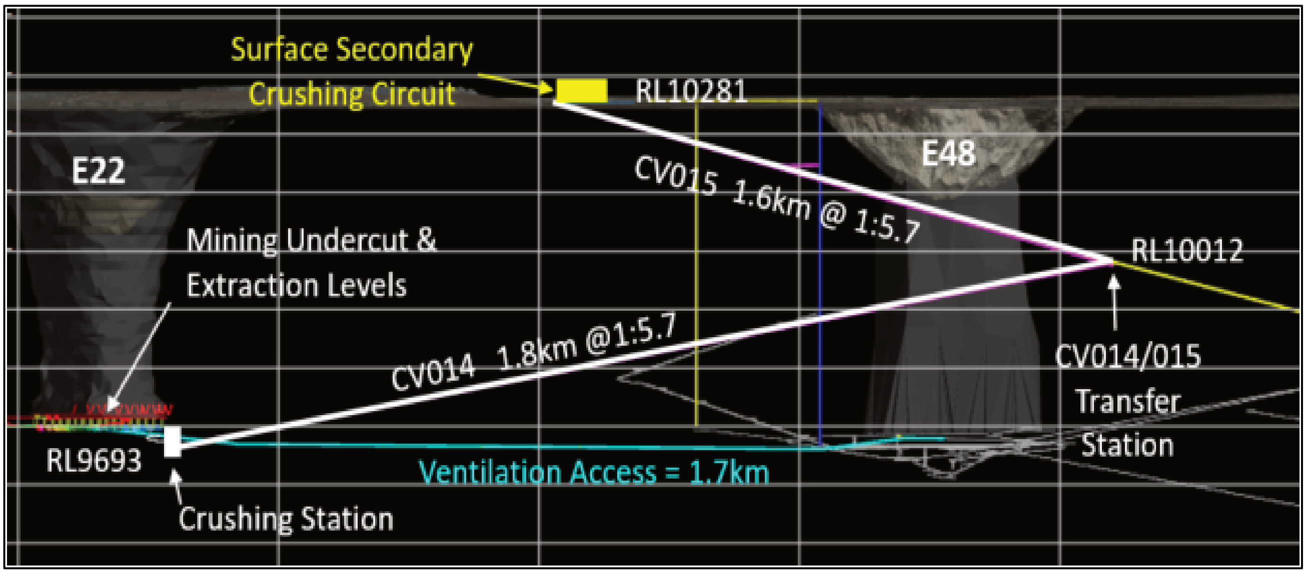


Figure 16 Case 10 underground incline conveyors 124CV014 and 124CV015

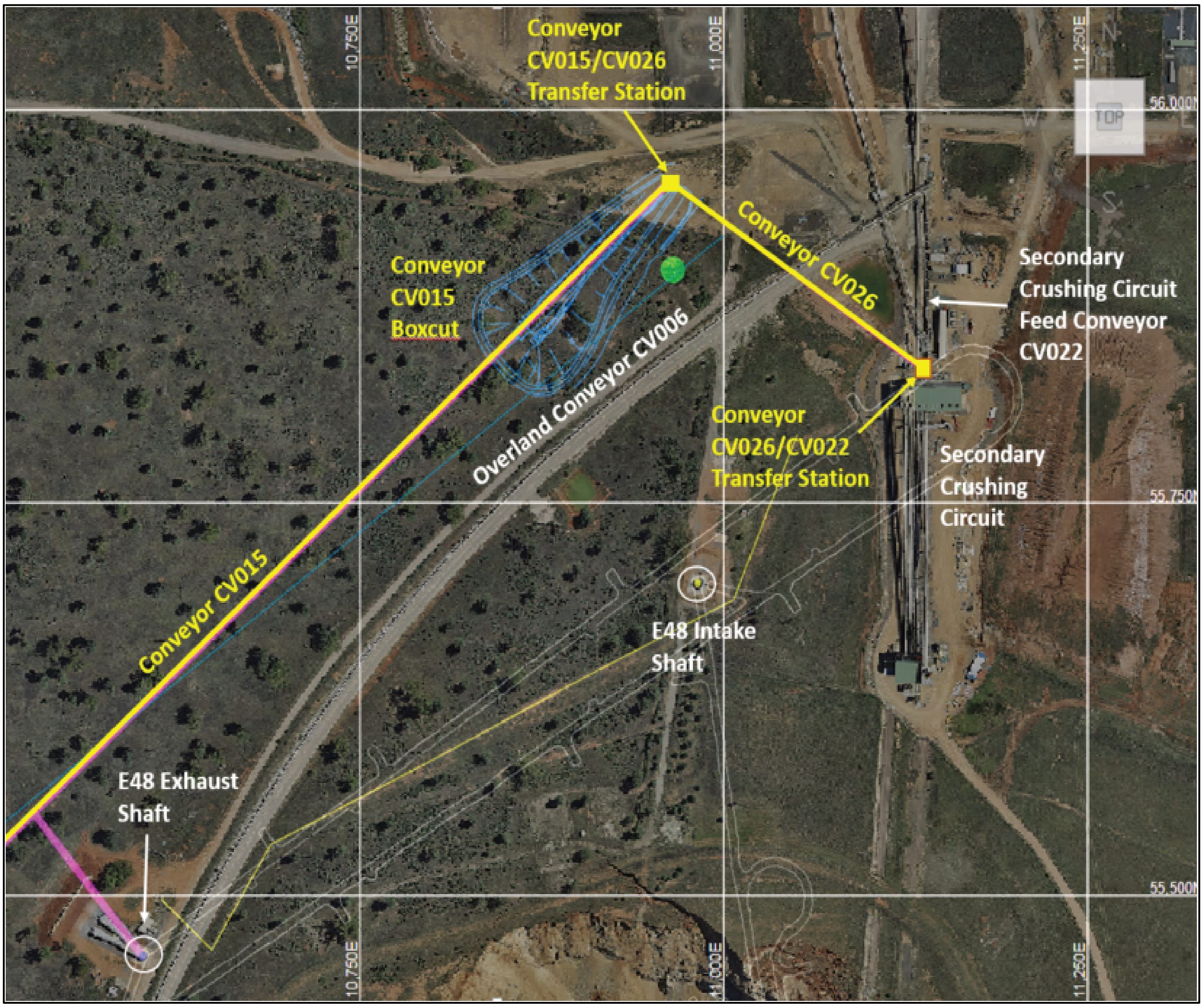


Figure 17 Case 10 head end section of incline conveyor 124CV015 and transfer conveyor 180CV026

4.2.3 *Preferred case selection*

Capital expenditure for these two options, Case 6 and Case 10, were estimated in detail and financially assessed. This analysis showed that the incremental NPV of the Case 10 scenario was similar to Case 6 and the difference between these two block cave cases were considered within the variability of the project estimate.

Some of the main assumptions for this evaluation was the status of the current hoist infrastructure and the future life-of-mine value. Since the Case 6 conveyor system ties into the existing underground conveyor, the E22 production will be constrained by the capacity of the current hoist system at 6.38 Mtpa (7.38 Mtpa after being upgraded). Case 10 provides the opportunity to bypass the hoist since the ore will be conveyed directly to surface and then to the secondary crusher. The current MHS design in Case 10 allows E22 to produce up to 8 Mtpa.

Therefore, the comparison of these two cases showed that Case 10 offers the lowest risk approach due to lower lifecycle cost and is flexible in the way the production rates can be easily increased or decreased at minimal cost whereas Case 6 will be restricted by the hoisting capacity. In addition, Case 6 will rely on equipment that is ageing and will be >15 years old when E22 comes online (the hoisting system will be >20 years old).

Further opportunities and synergies that Case 10 provide over Case 6 are:

- The existing hoist does not need to be upgraded to meet mill production.
- Underground production can increase to accommodate an overall site production increase.
- Operating costs can be reduced for future underground extension options.
- Reduced downtime of underground production (planned/unplanned).
- Safety improvement through establishment of a second decline to underground.
- Additional ventilation capacity through the hoist (intake) and surface conveyor (exhaust).

5 Conclusion

The pre-feasibility study has assessed two mining methods for the E22 deposit; sublevel cave and block cave. This evaluation was performed along with various production rates, NSR value, underground infrastructure and MHS options. Thirteen viable cases were financially evaluated, resulting in four cases to move forward for detail design. Two options considered sublevel cave and two block cave mining method. Each method had a different MHS; one uses a set of conveyors to transport ore from the E22 cave directly to the surface secondary crusher and the second option consisted conveying ore to the existing mine shaft hoisting. Results of this analysis indicated that despite the sublevel cave brings production with high grade earlier than block cave, the capital and operating costs diminished considerably the recoverable tonnes by 40%; therefore, reducing the NPV.

The two remaining options, Case 6 and Case 10, were estimated in detail and re-evaluated. The evaluation showed that incremental NPV for both cases was similar. However, the material handling of the Case 10 conveying system provides the possibility to increase production rates and not being limited by the current underground hoist. Case 6 will have to rely on shaft hoisting having the risk to increase its costs due to its life ageing and will be >15 years old when E22 comes on line. Therefore, this study has selected Case 10 as preferable case since this will bring more opportunities and synergies with future underground ore deposits.

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