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Technical reference guide

Raiseboring operations

(MDG1030)

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Contents

1. Introduction

1.1. Purpose

This technical reference guide (TRG) provides mine operators with guidance on developing and documenting a procedure for raiseboring operations. Mine operators are required to do so in accordance with the Work Health and Safety (Mines and Petroleum Sites) Regulation 2022 (WHS(M&PS) Regulation). This document keeps technical detail in the main body to a minimum and references technical information in footnotes throughout. This document is written to be relevant to underground metalliferous and underground coal mines.

This document replaces MDG 1030 Guideline for raiseboring operations 2013.

This document should be read in conjunction with:

- NSW WHS Acts and Regulations (including for mines and petroleum sites)
- NSW codes of practice:
  - Work health and safety consultation, cooperation, and coordination (August 2019)
  - How to manage work health and safety risks (August 2019)
  - Safety management systems in mines (February 2015)[1]
  - NSW Code of practice: Inundation and inrush hazard management
  - NSW Code of practice: Mechanical engineering control plan
- Australian and International Standards in related fields, for example:
  - AS ISO 31000: 2018 Risk management — Guidelines
  - AS/NZ ISO 45000: 2018 Occupational Health and Safety Management Systems – Requirements with guidance for use
  - AS 4133.3.4 – 1993 Methods for testing rocks for engineering purposes – Rock swelling and slake durability tests – Determination of the slake durability index of rock samples
  - AS 4133.4.1 – 1993 Methods for testing rocks for engineering purposes – Rock strength tests – Determination of point load strength index
  - AS 4133.4.2 – 1993 Methods for testing rocks for engineering purposes – Rock strength tests – Determination of uniaxial compressive tests
  - AS 4240.1 - Remote Control Systems for Mining Equipment Design, construction, testing, installation, and commissioning
  - AS 4240.2 – 2009 - Remote control systems for mining equipment Operation and maintenance for underground metalliferous mining

[1] *Work Health and Safety (Mines and Petroleum Sites) Regulation 2022* (NSW) - The Regulation defines a principal hazard as any activity, process, procedure, plant, structure, substance, situation or other circumstance relating to the carrying out of mining operations that have a reasonable potential to result in multiple deaths in a single incident or a series of recurring incidents.

  - AS 4240.3 – 2013 -Remote control systems for mining equipment Operation and maintenance for underground coal mining

- The technical references and case studies included in the appendices of this guideline.

This TRG seeks to provide clarity around legal requirements of mine operators in managing the risks associated with raiseboring operations. Contractors typically conduct raiseboring operations and mine operators need to ensure that contractors are managed in accordance with sections 19(2)(c)-(f) and 24-26 of the WHS (M&PS) Regulation.

1.2. Scope

This TRG is intended for use by mine operators who undertake raiseboring. It relates to their obligations under the NSW WHS (M&PS) Regulation 2022, Work Health and Safety Regulations , and the *Work Health and Safety Act 2011*. This document identifies the safety-related hazards that workers can be exposed to when raiseboring and how those hazards may be managed. TRGs are guidance. Mine operators are still required to conduct their own risk assessments in compliance with section 14 of the Regulations before commencing any raiseboring activity.

1.3. Application

This guide is designed to assist all mine operators and raiseboring contractors in developing work systems for raise boring operations.

1.4. Consultation

When managing risks, mine operators must consult with workers and other duty holders at the mine in accordance with section 115 of the Regulations. This includes other persons conducting a business or undertaking (PCBUs), such as contractors. The following links provide further guidance on consultation, cooperation, and coordination:

- NSW Resources Regulator Guide – Preparing a principal hazard management plan
- NSW code of practice: Work health and safety consultation, cooperation, and coordination (August 2019), published by SafeWork NSW
- Contractors and other businesses at mines and petroleum sites guide
- Consulting workers fact sheet

1.5. Abbreviations

The following abbreviations are used in this guideline.

AS	Australian Standards
AS/NZ	Australian/ New Zealand Standard
ICMM	International Council on Mining and Metals
LHD	load haul dump machine/loader
M&PS	mining and petroleum sites
PCBU	persons conducting a business or undertaking
PPE	personal protective equipment
RPE	respiratory protective equipment
SMS	safety management system

TRG technical reference guide

WHS work health and safety

2. Complying with the legislative requirements

2.1. Legislative requirements

Sections 14 and 15 of the Regulation require mine operators to have a safe system of work for raiseboring operations. Raiseboring operations also need to consider several other aspects of the regulation, including (but not limited to):

- Section 35 – Notification of high-risk activities – Raiseboring activities for a new mine entry require a HRA submission (Schedule 3, Section 5 or 7)
- Section 19 – Safety management system (SMS) considers contractors, is integrated, and provides for the appropriate monitoring and supervision of raiseboring operations
- Section 21– Duty to maintain a SMS
- Section 23-26 – Duty of contractors
- Section 30 – Duty to prepare a mechanical engineering control plan
- Section 41 – Management of airborne dust, diesel particulate and carbon dioxide
- Section 48 – Management of inrush
- Section 55 – Ground and strata support
- Section 57 to 64 – Management of air quality and ventilation infrastructure
- Section 65 – What needs to be detailed on any mine ventilation plan
- Division 7– Duty to provide information, training, and instruction to workers.

2.2. Reasonably practical

When considering the term 'as far as is reasonably practicable', mine operators must consider clause 36 of the Work Health and Safety Regulation 2017 and the requirement to use the hierarchy of controls when developing hazard management controls.

3. Risk management

Critical controls are those crucial to preventing an event or mitigating the consequences of an event such that its absence or failure would significantly increase the risk of the event despite the existence of the other controls[2]. They are considered important enough to warrant additional monitoring and reporting to ensure they are implemented and maintained to high levels of effectiveness.

The International Council on Mining and Metals (ICMM) recommends the critical control approach to risk management. The mine operator may consider several critical controls in raiseboring operations. This may include isolating workers when changing rods to remove the risk a rotating shaft poses, using remote loading to remove the risk of inundation, or removing raisebore fines at the bottom of a shaft.

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[2] In 2015 the International Council on Mining and Metals (ICMM) released their good practice guide "Health and Safety Critical Control Management" that described how mining and metals industries' risk management outcomes could be improved by focussing on those controls that are most critical for health and safety. Several subsequent ICMM documents have described the CCM framework, including the "Critical Control Management: Implementation Guide" (ICMM, 2015a) and the "Good Practice Guidance on Occupational Health Risk Assessment" (ICMM, 2015b)

3.1. Hazard identification

Further details around potential hazards associated with raiseboring operations are provided in Appendix A.

Before raiseboring, the mine operator should consider:

- unplanned geotechnical failure or harder ground than planned, resulting in a greater number of head and cutter changes
- raiseboring through an aquifer or water course
- unplanned ingress of water or gas, poor ground and / or inadequate provision of services
- cutter/drill string failure due to an incorrect estimation of the drillability or unpredicted failure of the rock mass
- whether equipment is fit for purpose (e.g., selection / matching of raisedrill machine, rods, stabiliser, head size/configuration)
- cutters failing due to adverse hole geometry (diameter, length, direction, and inclination) contributing to increased wear rate or stress
- unplanned project delays (due to operational, technical and / or health and safety issues) that can result in work program delays and potentially unsafe work practices to overcome them
- unexpected air flows that may cause break throughs and non-compliant ventilation conditions
- unexpected breakthroughs into existing workings
- blockages in the raisebore that suspend raisebore cuttings and water to create an inrush hazard at the bottom of the shaft
- worker proximity to the brow when attaching and removing reamer head
- effective isolation for any remote loading of raisebore cuttings
- manual handling – particularly of raisebore rods
- pilot hole breaks through into unplanned location due to excessive hole misalignment, inadequate planning, or excessive deviation
- uncontrolled releases of energy while flushing holes
- loss of circulation of flushing water/medium while pilot drilling
- rock falls or bedding separation on break through (particularly in coal mines)
- damage to installed services at the breakthrough location
- significant inflow of groundwater and/or drilling fluids on the breakthrough
- high pressure fluid injection and its potential to cause injury potential
- dust generation from reaming and drilling

- catastrophic drill rod or reamer stem failure resulting in rods and/or head falling to the bottom of the hole or becoming jammed in the hole in an inaccessible location
- the safe disposal or storage of cuttings removed from the active raisebored hole.

3.2. Risk assessment

Section 14 of the WHS (M&PS) Regulation requires mine operators to conduct risk assessments into all systems of work associated with raisebore operations. The risk assessment must be comprehensive and be carried out by appropriately qualified people with experience and training in raiseboring operations.

3.3. Risk controls

3.3.1. Hierarchy of controls

As discussed in section 2.2, mine operators must implement the hierarchy of controls when selecting controls for hazards. Mine operators should default to implementing highest order controls in the hierarchy unless it is not reasonably practicable to do so.

3.3.2. Preventative controls

Preventative controls available to manage the hazards listed in section 3.1 include:

- remote loading of raisebore cuttings
- rod handling equipment
- geotechnical logging and modelling
- reconciliation of material bogged vs that extracted
- remote reamer change out
- developing and implementing ‘open hole’ fall protection controls and procedures
- the use of laser barricades and clear ways in case of an inrush event when remote bogging raisebore cuttings
- the use of remote sprayheads for fibrecreting completed shafts
- blind sinking sections of poor ground conditions or conditions where there is an inrush risk (e.g., large aquifers) for greater control to reduce the risk of an inrush.

3.3.3. Mitigating controls

Examples of mitigating controls include:

- clearing or limiting workers below the bottom of the raise bore to manage an inrush event
- use of bunds at the bottom of a raisebore for workers that need to enter the area
- PPE including gloves and RPE
- manual handling and lifting/craneage training
- supervision of workers(both the contractor’s supervisors and the mine operator).

3.3.4. Review of control

Section 15 of the WHS (M&PS) requires mine operators to review control measures in response to a relevant event at its operation.

3.4. Effectiveness of controls

3.4.1. Documentation and records management

The records and documentation of the design, planning, contract development (if applicable) and operation of a raiseborer should be integrated into the SMS document control system. Mine operators should keep accurate records of all stages of the raiseboring project, from the design stage to commissioning. Documents and systems that should be considered include:

- risk assessments associated with the mine planning/hole design, geotechnical assessment, groundwater, presence of gas, provision of operational services, site mobilisation, pilot hole drilling, rod handling, reamer assembly/attachment, reamer collaring, cuttings removal, cutter inspections/changes, removal of reamers and demobilisation
- management plans and procedures developed incorporating controls identified in risk assessments
- records of worker training and competency
- design parameters and specifications of equipment
- records of nominated responsibilities
- records of relevant geological mapping, drill logs and any resultant interpretation
- records of any actual water or gas ingress in the planned hole location or area of influence
- testing and maintenance of equipment including mobile equipment, the raiseborer, power packs and compressors, drill strings, raiseborer heads and cutters, lifting gear and ancillary equipment
- reconciliation of cuttings removed and forecast tonnes. If there is a discrepancy this may indicate wall failures within the shaft
- records of workplace inspections/audits
- records of hazard reporting and follow up
- shift supervisor reports.

3.4.2. Information and training

The SMS should include a training and competency plan that ensures all workers are trained and competent to perform the required tasks. Training should include a documented training and assessment program.

Particular attention should be given to ensuring that all people working on raiseboring projects are made aware of the correct use and limitations of all equipment used.

Legislation provides the compliance requirements and SMS options for mine operators and contractors should a contractor(s) be engaged for a raiseboring project.

Mine operators should record all training and competency assessments on workers' personnel files.

Appendix A – Case study: elements of raiseboring

Element: planning and design

The planning and design of a raisebore hole will consider (as a minimum) hole location, length, inclination and diameter, ground conditions, water and gas occurrences, ventilation and drillability.

The objective is to achieve a stable excavation that meets the design purpose for the duration of its planned life. The scheduling of the project should also consider these factors to ensure that activity sequencing and timing does not compromise safety.

Activity	Issues to be considered	Notes and possible controls
Scheduling	• Delayed design and inaccurate scheduling may result in compromising the design resulting in angled holes when vertical hole design may otherwise have been possible. • Angled holes increase stress on drill string and increase the risks associated with reamer collaring and head removal.	• Early identification of the need for raisebored holes in long term and medium term mine planning schedules. These should incorporate all access and associated development for the project. • Integrate hole design with general mine development scheduling to avoid modifications having to be made from a vertical hole to an inclined hole design due to failure to meet development schedule(s). • Schedules should be based on realistic development rates which take into consideration hole location and geological conditions.
Scheduling	• Metalliferous Mines - unplanned significant changes to ventilation airflow.	• Ventilation modelling and simulation during the design phase should ensure that vent control devices are already in place prior to breakthrough. • Prior to breakthrough, procedures should be in place and communication established with supervisors and all workers. • Suggested controls include prior planning and ventilation simulation. • Breakthrough procedures to include anticipated ventilation changes.
Scheduling	• Geotechnical and hydrological assessment and availability of results are made available too late to be incorporated into potential design changes. This may lead to reduced confidence in information by a contractor when preparing the tender bid.	• Allow sufficient time for completing geotechnical and hydrological evaluations within the project plan. • Should the evaluation of information from geotechnical drilling and /or mapping be included in the project design, then allow adequate time for the design to be modified if necessary, and for quality information to be made available to tenderers. This will increase confidence in assessments of ground conditions. This could then prevent last-minute design changes and inadequate preparation that could place the project at risk.

Activity	Issues to be considered	Notes and possible controls
Design	• Planned design may not be practical	• Consider all the design related hazards identified in this document and ensure suggested controls are considered in the design of the raisebored hole and associated development. • • Consideration and, if practical to do so, preference should be given to the removal of the raiseborer head from the top of the hole on completion. The top of hole removal may require specific design and installation of lifting equipment. The size and weight of large reamers may prohibit top of hole removal. • Ensure that the raiseborer chamber is designed to provide adequate space to position equipment and allows pedestrian access for machine operation and maintenance.
Design	• Ventilation design considerations • Coal mines – risk of major changes to ventilation circuits and the potential for methane emissions during pilot hole drilling and reaming. • A particular risk may exist at the completion of reaming. • Methane may be generated from coal seams, coal	• Consideration should be given in the design phase of the project to the provision of controls for changes in the mine ventilation system and potential methane emissions and spontaneous combustion during and after the raiseboring operation. • Many shafts drilled in coal mines are usually intended to be used as future exhaust ventilation shafts and are therefore located in the return airway. Consequently, any dust and gas that may be generated while reaming is drawn out of the mine via the return airways. This also means that the shaft and pilot hole will be downcasting past the drill pipe while reaming. • Consideration should be given to the direction of air flow during pilot hole drilling and reaming and the potential accumulation and measurement of methane at both the top and bottom of the hole. The same consideration applies while the machine is shut down for any reason. Methane is lighter than air. • Upon breakthrough at the completion of reaming, short-circuiting or reversal of the mine's return airway system could occur. Therefore, prior to breakthrough, a ventilation plan must be prepared and be ready to be put in place. This may consist of additional brattices, overpasses, and vent walls, much of which can be constructed prior to breakthrough. However, this construction must be planned, scheduled, and undertaken so that free access to the bottom of the shaft is maintained for mucking and stowage of cuttings and to ensure that an adequate ventilation flow past the bottom of the shaft remains. Access for inspection must also be provided. • Possible controls to avoid disruption to mine operations due to a changed ventilation circuit on reamer breakthrough are: – prepare plans and erect ventilation infrastructure before breakthrough. – consider access to the shaft bottom area and stowage areas while reaming.

<table>
<tr><th>Activity</th><th>Issues to be considered</th><th>Notes and possible controls</th></tr>
<tr><td></td><td>strata and possibly porous sandstone.

• In coal mines, ignition of methane or coal dust through frictional energy from cutter head picks and energy induced into, and retained by, silica particles within the rock mass.</td><td>• There is a potential for methane to accumulate at the cutter head. The hazards of this can be mitigated by considering the following:
– Drilling of the pilot hole will allow drainage of methane from the local strata. During the drilling phase, any such methane can be monitored at the hole collar and the potential for gas accumulation during reaming can be assessed. Consider the use of continuous gas monitor(s)
– While reaming, the mine ventilation pressure difference could ensure a small but significant airflow down past the rods in the pilot hole, resulting in movement of air out of the shaft and into the mine return airways
– This, combined with the air turbulence created by the cutting action of the head and the falling cuttings, should mean that any gas generated at the face will be quickly dispersed into the surrounding air and drawn down the shaft
– This airflow can then be monitored for the presence of methane
– If methane is detected or the hazard is assessed as an unacceptable risk, a sample of the air at the cutter head could be drawn up through the centre of the drill pipes
– In the event of gas accumulation occurring, then compressed air should be forced down through the drill pipe to flush any accumulated methane from the shaft
– Given the above, possible controls for dealing with methane accumulation are:
• Gas monitoring of pilot hole to assess the potential hazard
• Maintain shaft-through ventilation, with as strong a ventilation pressure difference as possible
• Regular gas monitoring at top and bottom during reaming.

• In the event of hazardous levels of gas being detected, then consider:
• Ceasing reaming and flushing the pilot hole with compressed air through the drill pipe and water down the outside of the pipe
• Sampling gas accumulation at the head through the drill pipes.
• Control measures for frictional ignition of methane or coal dust may relate to pick design, water flushing and head rotational speed (aimed at limiting input energies to the rock mass).</td></tr>
<tr><td>Design</td><td>• Geological / geotechnical /</td><td>• Raiseboring operations require accurate and informed knowledge of the conditions of the rock mass and properties</td></tr>
</table>

Activity	Issues to be considered	Notes and possible controls
	hydrological assessment. • Inadequate geological, geotechnical, or hydrological evaluation creating an increase in the risk of falling ground and / or caving during reaming, during cutter inspections, during head removal or during post raiseboring activities.	of the rock before the raiseborer chamber and associated development is mined or a hole is raisebored. • Loss of core from diamond drilling of a pilot hole may result in incorrect interpretation of ground conditions. • Drill core quality and recovery can be enhanced by: – Appointment of drilling contractors and operators with proven competence – Use of triple tube coring in overburden and immediately wrapping core – Paying particular attention to correct handling and orientation of core – Conducting rigorous and frequent checks on the core barrel, wire line attachments etc. • Ground conditions can be assessed during development mapping and diamond drilling. Rock properties and structural features can be determined from a diamond drill core. • The ground conditions throughout the full length of the hole must be suitable for a freestanding unsupported excavation. • Consideration must be given to the provision of suitable controls for rock falls, rock failures, water inflow from the side wall and face during the lifecycle of the raisebore hole. • The most important factors affecting stability are: — structural features (folds, faults, foliation, bedding, discontinuities etc.) — mechanical properties of the discontinuities and of the rock fabric (tensile, compressive and shear strength), — stress (in situ and mining induced) and — ground water quantity and quality. • The assessed risk level of any raisebore project will depend on the confidence that can be placed in the relevant parameters used to determine assessment results.
Design	• Rock quality • Inadequate evaluation of rock quality resulting in unplanned penetration rates, excessive cutter wear or rockfalls. • In soft rock, some materials such as mudstone change	• Penetration rates are a function of rock mechanical properties, namely: strength, abrasivity and hardness. • Strength can be tested and described as tensile (direct method or Brazilian testing), shear (shear box testing) or compressive (uniaxial or point load testing). • Abrasivity can be tested in Los Angeles Machine and hardness can be described as raiseboring index or hardness index. • Quartz content in the rock fabric may give an indication on rate of cutter wear.

Activity	Issues to be considered	Notes and possible controls
	their chemistry when exposed to atmosphere and / or water.	• The physical structure of such materials may change and become ‘putty like’ or disintegrate altogether. This change is usually time dependent.
Design	• Stability Index • Inadequate evaluation and /or use of inappropriate or inaccurate stability index. • The potential for the intersection of zones of ‘running sands’ in sandstone.	• There are several rock mass classification systems that are available to combine geotechnical parameters and excavation stability. • For raiseboring purposes the most used is the ‘Q’ system modified by McCracken and Stacey. This system considers rock block size (rock quality designation and joint set number), discontinuity shear strength (joint roughness and joint alteration) and active stress (water reduction factor and stress reduction factor). • For a raiseboring purpose, the system has been modified by introducing adjustments for orientation of discontinuities, weathering, and wall factor. • A raisebore stability ratio is dependent on the function of the hole and on its planned life. The stability ratio of 1.3 is usually assigned for ventilation raises and 1.6 for ore passes. • If not detected during exploration drilling and effectively managed, uncontrolled inrush of water and sand could occur. A catastrophic hole collapse is likely under these conditions. Control measures can include hole lining or freezing of ground. • The potential for running sand should be detected during exploration drilling. However, this may prove difficult if the density of drilling mud is greater than the liquefied sand.
Design	• Determination and management of water occurrence and flows. • Inadequate evaluation resulting in unplanned water ingress.	• Analyse major structures in the planned path of the hole that may be water bearing. • Raiseboring generally precludes the immediate provision of sealing ground where water bearing strata is intersected. • Analyse data from filled/unfilled stopes adjacent to path of raise – is the fill wet, dry, saturated and / or stabilised? Measures should be taken to ensure circulation is maintained when a pilot hole is drilled through a filled stope or development void. • During drilling a geotechnical drill hole and a pilot hole, ground water conditions should be closely observed, monitored, and recorded. Should water be expected or encountered, water quality should be determined, and pump tests carried out to determine permeability and the rate of water inflow. Rock samples should be tested for permeability. Continuous monitoring of water inflow to the underground excavations should be carried out. • Results from water testing, permeability tests and changes in water inflow should form a basis for analysis of risk and quantity of water inflow during raiseboring.

Activity	Issues to be considered	Notes and possible controls
		• Consider construction of an extended pre-sink if there is unconsolidated water bearing material near the collar of the raise • If a wet hole is anticipated, the mine design should include provision for water to be directed and controlled at the bottom of the raisebored hole. • Consideration should be given to the provision of adequate water storage to protect major infrastructure such as pumps and electrical installations. • Adequate standby pumping capacity should be provided. • Consider pressure grouting.
Design	• Geological structures. • Inadequate evaluation, resulting in potential rockfalls.	• A major factor affecting the stability of a raisebored hole is its diameter. The face stability can be determined in terms of maximum unsupported span that is a function of the raise bore stability index. • During reaming the face is more liable to instability than the sidewall, although during the cutting operation itself the raiseborer head provides a degree of support. The potential for failure wedges should be analyzed in terms of the potential for key block failure, i.e., failure of a particular block that would produce a domino effect and subsequent gravity failures, causing considerable damage to the raise wall. • Different stability criteria may be considered acceptable for the raise face and raise walls. The raise face is temporary, and its failure is likely to affect the raisebore head. The raise walls are permanent, and their failure may lead to progressive and catastrophic failure after completion of raiseboring operations. • Relaxation of ground during lengthy reaming stoppages may represent a hazard resulting in ground failure. It is preferable to achieve continuity of reaming whenever possible to do so. • Failure may be caused by gravity falls or movement of joint determined blocks or wedges, or by displacement by the cutters.
Design	• Drillability. • Avoid cutter changes by selection based on drillability. • Inadequate evaluation resulting in the need for unscheduled cutter inspections / changes.	• Whenever the head is lowered for cutter inspections or changes, the support at the face is withdrawn. It is at this time that failures are most likely. Failures from the edge of the face can subsequently undercut the sidewall. • If cutter changes are anticipated during the reaming phase, if possible, schedule the lowering of the head, inspections and cutter changes when reaming a zone of known good ground conditions. This will reduce the probability of ground failure at the face while the reamer is lowered to the bottom of the hole. • An uneven face can create vibrations and unbalanced drill string loading when re-establishing reaming at the face.

Activity	Issues to be considered	Notes and possible controls
Design	• Raisebore chamber. • Inadequate support design results in ground instability.	• Changes in mining induced stress or long stand-up time can result in loosening of rock in the backs or walls of the chamber. • Raiseboring chambers are often characterised by a high height to width ratio. With such a ratio it may be difficult to notice any changes in geotechnical conditions. It is also difficult to install ground support once the raiseborer and ancillary equipment is installed. It is recommended that, as a minimum standard, all raisebore chambers are fully supported with mine standard bolts and meshed. • In poor or fair ground conditions a competent person should specifically design ground support for each chamber.

Element: pilot hole drilling

A pilot hole should break through on schedule within acceptable tolerance of the planned location without damage to any installed services. There should be no risk to persons from falls of ground at, or adjacent to, the breakthrough position or disruption to the ventilation circuit.

Activity	Issues to be considered	Notes and possible controls
Pilot hole drilling	• Multiple or severe corrections when directional drilling of the pilot hole (or diamond drilled geotechnical hole) may result in adverse stresses on the drill string during the reaming operation. • Enlarging a directionally drilled hole.	• Consideration should be given to determining acceptable deviation tolerances in the pilot hole drilling prior to commencement of the hole. These tolerances should be stated in the contract documentation. Also, planned corrective actions should be established when certain triggers occur. • These trigger levels and predetermined actions should be documented and supported by justifications through relevant data and calculations. • Consideration should be given to the type of drill used to increase the diameter of a directionally drilled hole to full pilot hole size. Should a hammer rig be used with conventional rods, the stiffer raiseborer rods may jam in the hole. • Consideration should be given to preferably utilising directional drilling for deep pilot holes. Tooling is available to drill 16in diameter pilot holes in a single pass.
Pilot hole drilling	• Missing the planned target – particularly when directional drilling is not used. • Locating a pilot hole that has missed a target.	• Surveyor to check alignment of the raisebore rig both before and after collaring pilot hole. • Circumstances and triggers that would/which initiate realignment of the raiseborer, should be decided and included in the contract scope. Consider incorporating contingency plans in the project scope should a target be missed. • Methods employed to locate a pilot hole that has missed a target depend on the following variables: – Length of the hole – longer the hole the lower the level of confidence in predicting actual location – Location, frequency, and orientation of geotechnical features intersected by the pilot hole – Availability and location of adjacent development and development on intermediate levels – Occurrence and flow rates of groundwater intersected by the pilot hole – Quality of groundwater – possibly acidic, radioactive, high in salt content or unusually hot. • Consideration may be given to utilising the following methods when locating pilot holes: – Locating the hole using gyro, radio, sonar, sonic, camera survey or other technique – Developing an access drive from intermediate level development to intersect the hole. This will then

Activity	Issues to be considered	Notes and possible controls
	• Locating a pilot hole that contains water.	facilitate survey pick up and recalculation of the hole coordinates at the breakthrough elevation. • If the pilot hole has the potential to contain water, then controls should be established to minimise the risk of water inrush on breakthrough. These controls may include: – Drilling diamond drill holes to intersect the pilot hole through securely bolted standpipes that are fitted with appropriately pressure rated gate valves – Filling the pilot hole with rock aggregate and mining towards the best-estimated position. • Developing towards the best-estimated position using remote drilling techniques. This should incorporate sidewall water-cover drilling. A risk assessment should be carried out and a Safe Work Procedure developed, documented, and communicated before mining commences.
Pilot hole drilling	• At the top of the pilot hole, hazards associated with sudden releases of energy while flushing the hole may 'throw' cuttings at high velocity significant distances from the collar.	• Attempt to eliminate this risk by engineering the collar configuration such that cuttings are kept clear of the hole. Frequent flushing can also reduce the extent of buildup of cuttings in the hole. • Utilise a correctly engineered and installed Blooie system. *(Ref Atlas Copco Robbins Raise Boring Handbook)* • If manual removal of the cuttings is required, complete a job safety analysis for the task to identify controls to minimise the risks.
Pilot hole drilling	• Potential injury by high pressure fluid injection	• Ensure that all high-pressure hoses and lines are inspected and, if necessary, replaced before and after mobilisation of the equipment to the operational location. • Ensure that operators are aware of hazards associated with injection by high pressure fluids.
Pilot hole drilling	• Potential injury during rod-handling.	• Mine to conduct a risk assessment into manual handling and seek to introduce higher order controls to reduce or remove the requirement for manual handling. • Use the risk assessment to develop a procedure regarding manual handling and then train workers in the procedure. • Consider using a mechanical rod wrench handling system and a wraparound wrench for small diameter rods.
Pilot hole drilling	• Rod rotation / sequencing • Correct rod torque	• Sequencing of the use of rods should be incorporated as part of the operation to minimise rod failure through repetitive exposure to high torque or high stress events. • Establish an effective rod identification and management system to minimise errors. Such management systems could include a computer database of rod history and condition monitoring as well as auditing of on-site compliance to this system. Ensure that rods are torqued to design specifications for all stages of the project.

Activity	Issues to be considered	Notes and possible controls
Pilot hole drilling	• The planned pilot hole breakthrough position may contain reticulated mine services (air, water, electric cables, ventilation ducting) which could be damaged on breakthrough.	• Consider the potential consequences of failing to remove or isolate services prior to breakthrough. Significant safety hazards and disruption to the mine operations may result. • The contract scope should include the identification of installed services and information on isolation procedures.
Pilot hole drilling	• Potential rockfalls / ground movement at, and adjacent to, the pilot hole breakthrough position. • Implement controls prior to breakthrough of the pilot hole. • Inspection of the breakthrough position.	• Site inspection of raisebore site, both top and bottom by survey mine supervisor and geotechnical engineer. • Breakthrough to be treated as an open hole as per the mine's existing controls for open holes. • Controls which may be considered before breakthrough occurs include: – Initial planning to consider local ground conditions and other geotechnical or hydrological considerations. – Real time communications between workers at the top and bottom of raise. – Treat breakthrough area as an open hole and abide by existing site procedures for open holes – The weight on the drill bit should be reduced as breakthrough is approached. • Following breakthrough of the pilot hole, the raisebore should be shut down and isolated and the breakthrough position inspected. The inspection should focus on localised backs (roof) or wall (rib) failure and, in coal mines, for methane or other gases emerging from the hole.
Pilot hole drilling	• On breakthrough significant water flows may enter the breakthrough location.	• Using estimates of water inflow obtained during the planning / design stage of the project, an adequate and effective water management plan should be established prior to pilot hole breakthrough. • Consider the potential effect of additional water flows on the mine drainage and pumping system. • Also, the design and operation of sumps should be reviewed to manage excess water from raiseborer cuttings during removal and disposal.
Pilot hole drilling	• It may be necessary to re-collar the pilot hole bit in the floor of intervening development.	• The optimum design for a raisebored hole sometimes involves the intersection of intermediate development and the re-collaring of the pilot hole in the floor. This is particularly common in raisebored slot raises in large multi-level open stopes in metalliferous mines. • The controls for pilot hole breakthrough described above should be repeated on each occasion intervening development is intersected. • Additional hazards may be identified in this configuration. These include control of drill cuttings and drilling mud after

Activity	Issues to be considered	Notes and possible controls
		re-collaring, isolation of personnel from rotating drill rods in a remote location and control of groundwater from the completed section of the pilot hole. • A safe work procedure should be specifically developed for this operation.
Pilot hole drilling	• Preparation of the reaming chamber (bottom of the hole).	• The design of the reaming chamber should provide adequate space to safely accommodate all planned activities in the area. Planned activities should consider contingencies for cutter inspection or replacement and head recovery operations if a drill string fails and rods and / or a reamer fall to the bottom of the hole. • Additional ground support should be considered before the reamer is in position to support the brow area of the newly cut hole. • Should the pilot hole miss the design breakthrough position, consideration should be given to additional mining and ground support to ensure reamer attachment and detachment operations are not compromised.
Pilot hole drilling	• Review the pilot hole drilling records.	• Review the pilot hole drilling records to identify additional hazards that affect the reaming phase. • Compare the recorded pilot hole drilling records with all other available data used during the hole design phase. • Consider collecting additional data from the pilot hole for final implementation considerations. • Develop controls to minimise future risks throughout the life cycle of the hole.

Element: reaming and cuttings removal

Reaming and cuttings removal activities should be planned and managed systematically so as not to expose personnel to at-risk situations.

Activity	Issues to be considered	Notes and possible controls
Reaming and cuttings removal	• Should the backs (roof) at the breakthrough location not be regularly shaped and / or not perpendicular to the direction of the hole, the rod string and reamer may be subjected to stresses that could result in catastrophic failure.	• Prior to moving the reamer to the breakthrough location to surveying the rock profile at the collaring position. • Should the profile not meet defined tolerances, strip the area until the backs (roof) are flat and perpendicular to the direction of the hole.
Reaming and cuttings removal	• The potential for injury and equipment failure during preparation and assembly of the reamer in the reaming chamber.	• Conduct a risk assessment in accordance with WHS (M&PS) Regulation 2022 section 15 into assembling reamer in reamer chamber. • The risk assessment to consider the size and weight of components, the need to work in confined spaces, poor ventilation, manual handling and working from heights. • From the risk assessment a system of work is to be developed and workers are to be trained in the procedure.
Reaming and cuttings removal	• The following hazardous events have been known to occur during reaming: – Fatigue of operators – Dust contamination of mine ventilating air – Water inrush – Mud / cuttings inrush – Hang up of compacted cuttings – Dropped rods and / or reamer (or parts thereof) – Brow failure – Ground failure of reamed hole face or sidewall – Accumulation of methane – Unplanned power cuts.	• Develop, implement, and monitor an effective fatigue management plan. • As part of the site establishment, provision for effective dust suppression / confinement should be made. This may consist of: — Installation of water sprays — Installation of a curtain adjacent to the brow — Installation of two parallel curtains with water sprays between them — Installation of a ventilation door(s) to isolate the area — Installation of a dedicated ventilation fan & ducting to directly exhaust to a return airway. • If a protective curtain is to be suspended at the brow for use during cutter inspections, complete the installation before collaring the reamer. • Consideration should be given to control measures for hazards associated during the removal (bogging) of cuttings from the bottom of the hole and transportation to the planned disposal / storage area(s). • Controls may include: – Documented inspection procedures to assess the quantity of cuttings present and the status of the brow (open / closed / wet / dry / dusty / clear)

Activity	Issues to be considered	Notes and possible controls
		– Implementing a planned programme of cuttings removal, with appropriate priorities, as an integral part of the mine operations schedule. Include and understand real time reconciliation of planned volume reamed v actual loader buckets v volume bogged – Ensuring regular communication between the raiseborer operator and the person responsible for ensuring that cuttings removal occurs. This communication should include the current rate of reaming and the achieved progress compared to scheduled advance – Scheduling inspections and / or cuttings removal at predetermined 'hold points' as reaming progresses. The 'hold points' should be calculated such that, providing cuttings are removed to a predetermined level, the brow never becomes closed – Ceasing reaming and isolation / lock out of the raise drill during inspections and bogging to eliminate the risk of rod / reamer failure while persons are in the proximity of the bottom of the hole – Ceasing reaming should the brow become closed with cuttings – Should the brow become closed with cuttings, initiate an investigation into the factors causing this situation to occur and to introduce preventative measures – Provision of adequate cuttings storage and disposal sites / strategies – Provision of predrilled drain holes into the brow to intersect water running on the footwall of the raisebored hole – Using a tele-remote loader for cuttings removal – The loss of brow profile may introduce significant additional hazards during cutter inspections or changeouts and during demobilisation. Geotechnical assessments during the planning and mine development stages of the project should focus on the provision of ground support that ensures the brow remains intact during reaming – The loss of brow profile may adversely affect the installation standard of suspended protective barriers – Consideration must be given to establishing procedures which minimise the risk of injury should there be ground failure from within the raisebored hole. These may include the installation of barricades and ceasing reaming during inspections of the bottom of the hole – Inspections utilising remote controlled cameras may help eliminate the risk of injury to persons – Placing a bund in the access to the bottom of the hole at all times when cuttings are not being bogged.

Activity	Issues to be considered	Notes and possible controls
Reaming and cuttings removal	• Catastrophic failure of the drill rods or reamer during reaming. • Does the Safety Management System include controls and procedures to address the hazards arising from these factors?	• Factors which could contribute to catastrophic failure of the reamer or drill rods include: – Reaming large diameter inclined holes – Excessive hole deviations in a directionally drilled pilot hole – Incorrect pressure settings and / or adherence to design advance rates – Poor maintenance of raiseborer and ancillary equipment – Poor management of rod sequencing system – Lack of catch rope on a vertical hole – Inadequate training and competence levels of operators – Inadequate establishment and / or implementation of QA procedures for the drill string and the reamer. These include non-destructive testing and rod rotation – Failure of the reamed hole sidewall or face – Squeezing and distortion of pilot hole through ground movement – Exceeding maximum designed operating hours for in-the-hole equipment – Using an inappropriate or poorly designed reamer head – particularly in large diameter raises. – Using under-specified rods for a particular hole length / diameter or reamer size / design.
Reaming and cuttings removal	• Cutter inspections and changes during reaming. • Cutter condition. • Risk assessment for cutter inspections / changes.	• During the planning / design phase of the project, the selection of cutters should include an assessment of estimated wear rates and condition of previously used cutters. • Worn cutters should only be used if: – there is a high level of confidence that they will not require replacement before the hole is completed, or – replacement before completion of reaming is unavoidable. • The use of new cutters may eliminate the hazards involved in lowering a reamer to the bottom of a partially completed hole for an inspection of cutter(s) condition or cutter replacement. • Should it be necessary to lower the reamer to the bottom of the hole for inspection and / or replacement of cutter(s), a risk assessment of identified hazards should be undertaken, and controls established to eliminate or minimise those hazards. • Controls may include: – Never allowing personnel to position themselves beneath a vertical opening

Activity	Issues to be considered	Notes and possible controls
		– Never allowing personnel to approach the brow beyond a predetermined ‘exclusion zone’ under any circumstances – Erection of barricades and signs to prevent access to high-risk areas or by unauthorised personnel – Provision of effective lighting – Completion of a risk assessment by all personnel involved in working at or in the vicinity of the reamer. • Use of a physical shield or barrier that provides protection to personnel from ricochet rocks while working adjacent to the brow. Such a shield or barrier should not be relied upon to provide protection from direct impact from rocks or material falling under gravity from within the hole.
	• Use of a physical shield or barrier.	• The decision to utilise a particular design / configuration of barrier(s) should include consideration of the design specifications of the barrier, the risk of hole deterioration and the most probable worst case dynamic loading on the barrier.

	• Use of an inflatable barrier positioned in the raisebored hole above the brow to absorb all or part of the kinetic energy from falling rock or material.	• Consider the following:
		– The scope of a risk assessment for the use of an inflatable barrier positioned in the raisebored hole above the brow should include its use in conjunction with other physical shields or barriers to reduce the risk of injury to persons engaged in cutter inspection, cutter changeouts or reamer removal
		– Should a means of access to the raisebored hole be available above the brow elevation, and additional or higher risk hazards are not introduced, consideration may be given to positioning a layer of suitable material on top of the inflatable barrier as protection from sharp impact
		– Inflatable barriers equipped with a top and side high strength ‘protective layer’ (e.g., ‘kevlar’) may exhibit additional protection against abrasive wear and/or puncturing one or more of the bladders.
		– An inflatable barrier should:
		  • Preferably be used in conjunction with a physical shield or barrier
		  • Be inflated prior to transport to the worksite and tested for significant leaks and inspected for structural damage and general condition
		  • Be designed to withstand and absorb the kinetic energy from the maximum potential impact by falling rock(s)
		  • Be constructed to an inflated diameter which is within acceptable tolerances of the actual raisebored hole diameter
		  • Be transported and installed using fit-for-purpose equipment
		  • Be positioned in accordance with safe operating procedures

Activity	Issues to be considered	Notes and possible controls
		• Not be installed until the availability of compressed air to the worksite can be guaranteed • Be maintained at a constant design air pressure using an air pressure regulator and a distribution manifold • Have adequate top and tail rope lengths to ensure personnel can work outside any exclusion zone at all times • Be installed with its suspension cable passing through a 'low friction surfaced' pipe inserted into the inclined borehole into the raise. This will allow easier movement of the suspension cable during insertion into the borehole and reduce the risk of abrasive wear • Have all attachments to the balloon, including the inflation hose, completed before the balloon attachment points are positioned within the exclusion zone.
Reaming and cuttings removal	• Hole completion – rock cap fails due to reaming too far before the reamer is lowered to the bottom of the hole for removal. • Not possible to blast rock cap due to unacceptable risks.	• The rock cap design depth should consider geological and geotechnical conditions. In competent ground a 'rule of thumb' minimum depth of two raise diameters below the machine is often applied. • If the failure of the rock cap is assessed to be an unacceptable risk, then the pre-collar should be constructed and filled with suitably designed concrete. • Consider mounting the rig on an extended reinforced concrete raft. • Consider provision of designed and tested tie-off points to provide anchorage in the event of rig movement or rock cap failure.

Element: demobilisation

Leaving a safe and secure site after safe removal of the reamer and all associated equipment and infrastructure from a completed raisebored hole.

	Issues to be considered	Notes and possible controls
Demobilisation	• Removal of reamer – top of hole. • Removal at the top of the hole is the preferred method, if practicable, as it eliminates risks associated with lowering the reamer to the bottom of a hole and persons working in proximity to a vertical opening.	• Consideration should be given to establishing controls for the following hazards: – Personnel falling into an open hole – Head falling to the bottom of the hole due to inadequate attachment or slinging procedures or standards – Foundations failure leading to machine instability and misalignment – Falling materials, rubbish etc. down the hole creating hazards at the bottom – In coal mines the creation of a hazardous zone if flame or contraband enters the underground workings from surface via a raisebored ventilation shaft. • Controls may include: – Installation of an engineered cover or fencing and appropriate signs around the collar of the hole – Installation of fall protection equipment consistent with 'open hole' Safe Work Procedures – Prior to the reamer breaking through to surface, clearly designating the surface area adjacent to the collar with appropriate signs. Also, education of personnel as to the meaning and implications of the procedure
	• Consideration needs to be given to the weight and dimensions of the reamer head and the risks associated with lifting and maneuvering large and heavy equipment safely.	– Implementation of rigorous housekeeping standards adjacent to, and at, the worksite. • All lifting points, lugs, chains shackles and other lifting equipment and accessories must be designed, tested, and installed to withstand the maximum loading with appropriate safety factors. • The use of a correctly rated crane to lift a reamer head from a completed hole must be considered only after conducting a risk assessment to identify all hazards and establish effective controls. • Consideration must be given to the estimation of the size of the reamer and the maximum lift weight – particularly if there is a risk of the load snagging or being impeded during the lift. • Controls may include:

	Issues to be considered	Notes and possible controls
		– Valid certification of the mechanical condition of the crane – Valid certification of the mechanical condition and weight limitations of all lifting attachments – Valid certification of the crane operator's competency – Valid certification of the rigger and /or dogman's competency – Identification and use of all site-specific permits and authorisations – Restricting access of unauthorised personnel to the worksite – Ensuring adequate lighting / visibility. • In underground situations where access by crane may not be possible, consideration should be given to utilising a LHD to remove the reamer from the bottom of the hole. The risk assessment for this operation may include the following controls: – Documented Risk Assessment which includes the configuration, specifications, and identification of all steps in the process – Consider the use of a remote controlled LHD – Valid certification of the mechanical condition and weight limitations of the LHD, its hydraulic system and all lifting attachments – Valid certification of the loader operator's competency – Valid certification of the rigger and /or dogman's competency. – Identification and correct use of all site-specific permits and authorisations – Restricting access of unauthorised personnel to the worksite – Ensuring adequate lighting / visibility.
Demobilisation	• Removal of reamer (by unscrewing) at the bottom of the hole.	• Consideration should be given to breaking out the reamer remotely to eliminate the high level of risk when working under an open raisebored hole. Ensure that any equipment used for this task is fit for purpose and inspected prior to use. • A decision to remove a reamer at the bottom of a completed hole should be made only after removal at the top of the hole has been determined not to be a practicable option.

	Issues to be considered	Notes and possible controls
Demobilisation	• Removal of reamer (by destructive cutting of a burn out ring or use of a thermal lance) at the bottom of the hole.	• Consideration should be given to identifying all potential hazards associated with this process. In addition to those hazards at the workplace, there may be indirect hazards caused by fumes and resultant variations to normal mine ventilation quantities and quality. • Controls which may be considered include: – Never allowing personnel to position themselves beneath a vertical opening – Clear definition of responsibilities and roles during the work – Fit for purpose and well-maintained equipment – On hand fire-fighting equipment – A fully operational and tested communication system between the top and bottom of the hole – Provision of, and training in, all necessary personal protective equipment. This may include fall protection, respiratory protection, hot work protective clothing – Provision of additional ventilation capacity – Notification to the mine workforce that burning is to take place – Clearing work surfaces of obstructions and trip hazards – Issuing of, and compliance with, all appropriate permits. (Permit to work, hot work permit, site isolation) – In coal mines, compliance with the relevant Codes of Practice – Establishment of a ‘no go’ exclusion zone at the bottom of the hole to minimise or eliminate the risk of injury from ricochet rocks – Provision of a physical barrier to eliminate the risk of injury from ricochet rocks. The decision to utilise a particular design / configuration of barrier should include consideration of the design specifications of the barrier, the risk of hole deterioration and the most probable case dynamic loading on the barrier – Development of techniques and procedures which maximise the length of the lance including the use of remote-controlled equipment. • During the risk assessment of this activity consideration should be given to any potential ‘pendulum swinging’ effect of the drill string once the burn out ring has been cut.

	Issues to be considered	Notes and possible controls
Demobilisation	• The transportation of the raiseborer and associated equipment may involve significant hazards. These include: – Dimensions and weight of components exceed bridge & access limitations – Unplanned movement of equipment – Blocked egress – Failure of slinging and rigging – Failure or damage of high-pressure hydraulic hoses & fittings – Injury through poor manual handling practicesHazards associated with impact by moving equipment and gear.	• Controls for hazards during demobilisation are like those during the site establishment phase. • A review of the site establishment activities should be conducted, and the outcomes incorporated into revisions to any safe work procedures that are applicable to demobilisation activity. • Possible controls are: – To assess the hazards associated with this phase of the project, the principal should ensure that the contract scope clearly describes the means of transporting equipment from the raiseborer site(s). Tenderers should have a good understanding of the hazards involved prior to submitting a tender – Use of fit-for-purpose equipment – Measures to ensure any noise limitations are not exceeded. The use of rubber buffers when handling and stacking rods may be appropriate – For sites on surface, consultation with the community and near neighbours should be considered – Ensuring equipment weights and dimensions are within limitations (bridges, power lines, road conditions) – Using an escort vehicle / person during transportation ensuring the site is secured to prevent unauthorised entry of persons.
Demobilisation	• The project design and scope should include provision for the securing of the top and bottom areas of the open hole.	• Methods for securing the area must take into consideration the full life of the hole. • Provision may be necessary for future access or inspections. These should be designed once a risk assessment of all identified hazards has been completed and the resultant controls incorporated into the design. • For mines near residential areas, the elimination of the risk of children and other members of the community falling down an open hole should be incorporated into the risk assessment outcomes.