Code of Practice

Surface Rock Support for Underground Mines

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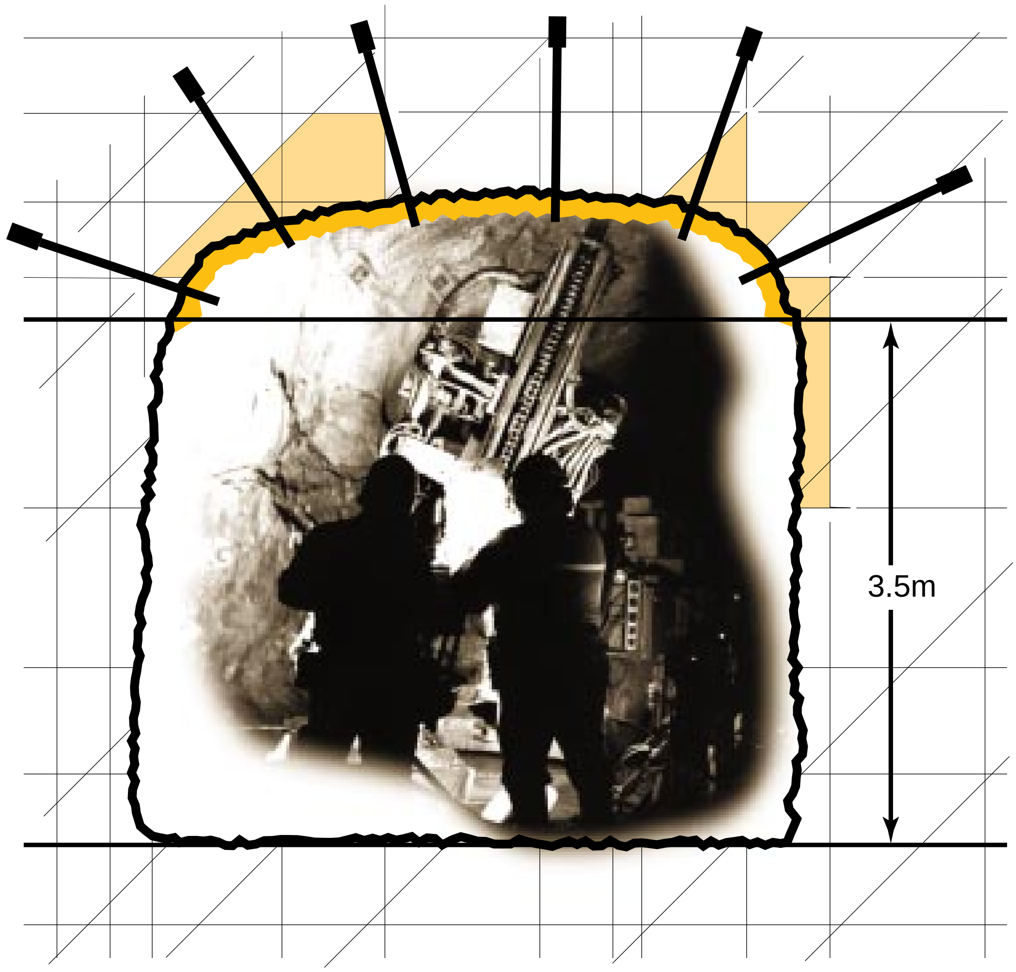

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SURFACE ROCK SUPPORT FOR UNDERGROUND MINES

CODE OF PRACTICE

MINES OCCUPATIONAL SAFETY AND HEALTH ADVISORY BOARD

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SURFACE ROCK SUPPORT FOR UNDERGROUND MINES

CODE OF PRACTICE

FOREWORD

The Surface Rock Support for Underground Mines Code of Practice (hereafter referred to as the Code) applies to all underground excavations in which persons may travel or work and includes development headings and entry-method stopes.

The Code is framed on the assumption that the necessary primary rock reinforcement is in place to ensure the general structural stability of the excavation.

The Code introduces the requirement to install surface rock support in high headings (ie. those greater than or equal to a nominal 3.5m in height) in all Western Australian underground mines unless a documented geotechnical risk assessment justifies otherwise. Where surface rock support is installed, it shall be applied to backs and side walls that are a nominal 3.5m from the floor of the excavation.

The requirements in the Code do not detract from the obligations contained in Regulation 10.28 of the *Mines Safety and Inspection Regulations 1995*.

Installation of surface rock support, such as mesh, shotcrete or other surface treatment, in ***addition*** to existing or primary reinforcement methods may be necessary to control the risk of injury and death that can result from small rock falls from between the installed rock reinforcement elements.

Surface rock support is not intended to replace existing ground reinforcement methods but should be used, where required, in conjunction with these methods, and integrated into the mine's ground control system or strategy.

The Code specifically addresses gravity induced rock falls. Dynamic rock failure mechanisms are not covered by the Code and must be controlled by appropriate means according to the identified risk.

The Code should be read in conjunction with the Department of Minerals and Energy (DME) Guidelines *Geotechnical Considerations for Underground Mines* and *Underground Barring Down and Scaling*.

The Code has been developed through tripartite consultation and has been approved under Section 93(1) of the *Mines Safety and Inspection Act 1994*. The legislative framework which supports the Code is outlined in **Appendix 1**.

The process for achieving compliance with this Code of Practice is outlined In **Appendix 2**.

1.0 INTRODUCTION

Rock falls are an ever-present hazard in underground mining, especially in unsupported ground. They are primarily caused by discontinuities and/or high or low adverse stresses in the rock mass. The intersection of three or more joints or fractures with the back, face or side wall of an excavation may create unstable blocks of rock. These blocks may fall or be ejected into the excavation with little or no prior warning, and pose a serious risk of injury or death.

Ground support is installed to ensure the stability of the excavation and minimise the risk of injury. Ground support must match the ground conditions and the excavation geometry for the life of the excavation and must take into account both inherent and mining-induced stresses.

The presence of ground support however does not necessarily guarantee that there will be no rock falls. While an excavation can be stable in terms of its overall structure it may not necessarily be safe. Localised surface failure can present serious risks.

A combination of one or more of the following may result in unexpected rock falls:

- Deteriorating ground conditions;
- Inappropriate ground support;
- Inadequately installed ground support;
- Ground support that has deteriorated (corroded) over time; and
- Mining-induced or natural seismicity.

Ongoing check-scaling is a critical step in the ground control program to maintain the integrity of the excavation.

In low profile headings, that is, those nominally less than 3.5m high, with adequate and correctly installed ground support, a person can readily visually check for localised surface rock failure and make safe the heading or excavation with the use of a scaling bar.

However, in headings higher than 3.5m it becomes increasingly difficult to check and scale safely without the use of equipment to access the high backs and side walls. In addition, cap lamp illumination is inadequate for high headings.

In high headings where surface rock support is installed the need for regular checking is reduced and the integrity of the excavation is greatly increased.

2.0 GROUND CONTROL METHODS

Some of the methods that are available to limit or control potential rock falls include:

- Controlled drilling and blasting techniques;
- Scaling (manual and mechanised); and
- Ground support (rock reinforcement and surface rock support), including:
  - Meshing;
  - Strapping;
  - Shotcreting; and
  - Other Surface Coatings.

  This list of controls is not necessarily exhaustive, it is likely that new techniques will be developed with time.

Each method is dealt with in detail below.

2.1 Controlled Drilling and Blasting

Substantial and unwarranted damage to the rock at the perimeter of an excavation can result from the use of inappropriate drilling and blasting practices. Controlled drilling and blasting practices are designed to "cut" the rock rather than general demolition of the rock mass.

Rock damage due to drilling and blasting can be minimised by:

- Correct placement and alignment of the holes;
- Selection of appropriate hole diameter, spacing and burden for blast holes, in particular perimeter holes;
- Use of suitable explosives charges (eg. low energy or decoupled) in the perimeter holes;
- Considering the influence that blast holes adjacent to the perimeter holes has on rock damage and, where appropriate, varying the burden, spacing and charge density; and
- Where necessary, seeking the advice of the explosive manufacturer(s) on the appropriate use of various combinations of explosives and initiation system(s).

Where good controlled drilling and blasting practices are consistently achieved there will be a significant decrease in the risk of localised rock fall.

2.2 Scaling

Scaling involves removing loose rock from the walls, face and backs of the excavation. Careful attention should be paid to the following:

- Identifying the ground conditions;
- Manual scaling procedures;
- Mechanised scaling procedures;

- Scaling procedures for large potentially unstable blocks;
- Scaling procedures in ravelling ground;
- Progressive scaling and installation of support;
- Scaling in high headings;
- Scaling in narrow headings; and
- Regular check scaling of main travelways.

Further discussion on scaling is contained in the DME Guideline *Underground Barring Down and Scaling*.

2.3 Ground Support (Rock Reinforcement and Surface Rock Support)

With respect to this Code, the term Ground Support refers to both rock reinforcement and surface rock support.

In general, rock reinforcement is primarily applied internally to the rock mass, such as rock bolts, while surface rock support refers to that which is applied externally to the rock mass, such as mesh, strapping or other surface treatments.

There is a range of rock reinforcement and support methods available that can be used individually or in combination.

Some ground support methods include:

- Rock bolts and cable dowels;
- Friction rock stabilisers;
- Cast concrete lining;
- Shotcrete (plain and fibre reinforced);
- Thin flexible surface coatings;
- Strapping.
- Timber props;
- Timber packs;
- Timber or steel sets;
- Yielding sets;
- Hydraulic props;
- Screw-jack type props;
- Mesh; and
- Backfill (plain and strength enhanced).

Details relating to installation and quality control of ground support methods can be found in the DME Guideline *Geotechnical Considerations in Underground Mines*.

A description of each method is beyond the scope of this Code, however a brief outline of some surface rock support methods is provided below.

2.3.1 Meshing

The installation of mesh on the backs and side walls of an excavation is a technique that can largely eliminate falls of small rocks.

Hoek, Kaiser and Bawden (1995) refer to this approach as a “safety” support system, the purpose of which is to prevent unexpected falls of small rocks.

This type of support system, however, is not designed to support large static or dynamic loads. It can be used in conjunction with other elements to be part of an integrated system for supporting dynamic or static loads.

Providing that the mesh and the reinforcing elements do not become overloaded with loose rock fragments contained in the mesh, this system largely eliminates the need for regular check scaling.

These support systems may also be appropriate, irrespective of heading height, in regular travelways, places where the workforce regularly gather, and permanent installations containing specialised equipment or explosives; eg. shafts, declines, main haulages, workshops, lunchrooms, offices, main pump stations, major electrical sub-stations, crushers, conveyors, main magazines, etc.

There is a variety of mesh available. The three main types are welded wire mesh, chain link mesh and non-metallic mesh. Chain link mesh has greater flexibility than weld mesh, while weld mesh is better suited for use with shotcrete. Where corrosive conditions exist, galvanised or non-metallic mesh is recommended.

2.3.2 Strapping

Strapping is sometimes used to extend the area of coverage of an array of rock bolts. This method may be suitable for restraining relatively large blocks.

Straps are usually installed in a linear or grid pattern along the side walls or the backs and can be installed in conjunction with other surface rock support.

Its use as a control method is limited, as the rock surface between the straps remains largely unsupported and blocks still may fall out.

2.3.3 Shotcreting

There are two types of shotcrete application – wet mix and dry mix. Each method has its particular use in surface rock support.

When designing a shotcrete program the following issues need to taken into consideration:

- Amount of shotcreting required;
- Shotcrete strength;
- Shotcrete thickness;
- Presence of groundwater (eg. quantity, chemistry, pressure);

- Need for drainage of groundwater from behind the shotcrete;
- Water quality (potable);
- Type of shotcrete mix (wet or dry);
- Use of microsilica;
- Admixtures (plasticisers, etc);
- Accelerators (for wet mix);
- Fibre reinforcement;
- Curing (external or internal);
- Testing and monitoring;
- Correct spraying equipment; and
- Correct shotcrete application.

2.3.4 Other Surface Coatings

Recent developments include the use of synthetic rock surface coatings specifically designed for rock stabilisation in underground mines.

Further work to develop these coatings may be required before they can be reliably and effectively used on a routine basis at minesites.

3.0 GEOTECHNICAL RISK ASSESSMENT

The purpose of the Geotechnical Risk Assessment is to identify areas of the mine where the level of ground support needs to be upgraded.

The mine may be divided in areas or regions and categorised according to the relative risk and a documented geotechnical risk assessment shall consider the risk factors listed below.

3.1 Risk Factors

The geotechnical risk assessment shall take into consideration the following risk factors: Ground conditions; Mining method used; and Exposure risk.

3.1.1 Ground conditions

The ground conditions in workplaces, travelways and installations generally shall be assessed to determine the potential for rock falls.

The assessment of ground conditions needs to take into account:

- Geology of the rock mass;
- Geotechnical information on the planes of weakness;
- Mechanical properties of the intact rock, planes of weakness and the rock mass;
- Magnitude and orientation of the three dimensional pre-mining rock stress field;
- Magnitude and orientation of the induced rock stresses caused by the mining process (creation of voids);
- Potential rock failure mechanisms;
- Blast damage to the rock mass;
- Likely scale and nature of the ground movement;
- Possible effects on other working places and installations;
- Previous experience and relevant historical data; and
- Groundwater and exposure to the atmosphere.

The above factors should be considered in relation to any proposed excavation designs and any existing excavations.

Areas of the mine where surface rock support is likely to be needed include:

- Areas where ground conditions are such that loose rock is likely to develop over time;
- Areas which generate loose material and constantly require scaling;
- Areas which are subject to increases or decreases in stress; and
- Areas which are subject to significant blast vibrations.

3.1.2 Mining Method

With entry-method stoping systems the workforce can be exposed to wide stope spans and unsupported ground as each cut is taken.

In these cases, there is a need to re-install the ground support and reinforcement as each stope lift is mined. Consequently, entry-method stoping generally requires a high level of ground control.

Consideration should be given also to areas of large spans, such as intersections.

Non-entry methods of stoping do not permit additional surface rock support within the stope void, however surface rock support is likely to be required in stope access ways and extraction and drill headings.

3.1.3 Exposure Risk

The exposure of employees shall be considered when assessing the risk of each area of the mine.

Facilities and installations where there is regular employee access, eg. crib rooms, workshops etc. should have surface rock support installed.

Areas of “no access” are unlikely to require surface rock support. However, the requirement for remedial work shall be assessed if and when such areas are reopened.

3.2 Risk Assessment

The risk assessment comprises two parts – inspections and risk ranking.

Regular inspections of the mine shall be carried out in a manner consistent with sound geotechnical engineering practice[1]. The mine may be divided into areas prioritised according to the following criteria:

- Where there is no installed rock reinforcement;
- Where existing ground support includes rock reinforcement but no surface rock support; and
- Where existing ground support meets surface rock support treatment requirements.

Particular consideration should be given to areas known to be likely to develop loose rock.

Each area shall be assigned a risk ranking[2] that reflects the risk of localised rock fall. The risk assessment should be documented in a format that will enable an action plan to be developed. An example of the steps to be followed when conducting the geotechnical risk assessment is outlined in **Appendix 3**.

[1] Refer to DME Guideline Geotechnical Considerations for further details.
[2] Refer Draft DME Guideline Risk Management for further details.
A range of commercial available Risk Ranking Tools are useful for the risk assessment step.

4.0 RISK CONTROL

The Code requires that all high headings having a risk of localised rock fall have surface rock support applied, unless the documented ground control management plan has determined that the risk can be managed by regular monitoring and check scaling.

In complying with this Code there are three categories of excavations to be considered:

- *New work which complies with the Code requirements;*

  All new excavations shall comply with the Code. Surface rock support shall be installed where it has been determined necessary in the geotechnical risk assessment. Where no surface rock support is deemed necessary, a documented procedure for monitoring and check scaling shall be implemented.

- *Existing areas which are assessed to comply;*

  Compliance may include surface rock support, or a system of documented monitoring and check scaling.

and

- *Existing areas that are scheduled for upgrade to achieve compliance.*

  In the case of existing excavations, areas of the mine that are identified from the geotechnical risk assessment requiring surface rock support should be prioritised and scheduled accordingly to the risk of exposure.

  Remedial work shall be prioritised and scheduled to ensure the upgrade is completed within a reasonably practicable timeframe.

Where surface rock support is required, then the geotechnical risk assessment should provide the following information:

- To what extent is the surface rock support needed?
- What excavations need to be treated?
- What surface rock support is to be used for each application?
- How will the surface rock support be integrated with the current ground control systems?
- How will the surface rock support be integrated into the current mining cycles and are any changes to procedures required?

A regular inspection and monitoring program shall be established, carried out by competent persons and conducted for all areas identified in the risk assessment. The frequency of inspections should be relative to the risk and must take account of changes in ground and operating conditions.

In the event of a change in conditions, such as a surface rock failure in an area scheduled for surface rock support, the priority of the area must be reassessed. Where such events occur in areas where no surface rock support was considered necessary, the area shall be reassessed taking into consideration the risk factors and the change in conditions.

Any schedule and action plan should be developed in consultation with relevant employees and safety and health representatives.

If the assessment concludes that surface rock support is not required, then the Mine Manager shall show justification in a documented geotechnical risk assessment. The risk assessment should be included in the mine's Ground Control Management Plan[3].

[3] Refer to DME Guideline Geotechnical Considerations for further details.

5.0 FURTHER READING

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APPENDIX 1

LEGISLATIVE FRAMEWORK

The *Mines Safety and Inspection Act 1994* sets objectives to promote and improve occupational safety and health standards. The Act sets out broad duties and is supported by more detailed requirements in the Mines Safety and Inspection Regulations. A range of guidance material, including codes of practice, further supports the legislation. The legislative framework is set out in Figure 1.

Guidance material includes explanatory documents that provide more detailed information on the requirements of the legislation.

Codes of practice contain practical information on how to comply with legislative requirements. They describe safe work practices that can be used to reduce the risk of work-related injury and disease. Codes of practice may also contain explanatory information.

The work practices included in a code of practice may not represent the only acceptable means of achieving the standard to which the code refers. There may be other ways of setting up a safe system of work and, providing the risk of injury or disease is reduced as far as practicable, the alternatives should be acceptable.

FIGURE 1: LEGISLATIVE FRAMEWORK

MINES SAFETY AND INSPECTION ACT	⇦	Major provisions: • The General Duties • Management of Mines • Enforcement of Act and Regulations • Resolution of issues • Safety and Health Representatives • Safety and Health Committees
Supported By		
MINES SAFETY AND INSPECTION REGULATIONS	⇦	The Mines Safety and Inspection Regulations set minimum requirements for specific hazards and work practices, including reference to National Standards, developed by the National Occupational Safety and Health Commission, and Australian Standards developed by Standards Australia.
And		
GUIDANCE MATERIAL	⇦	• Codes of Practice approved for Western Australian mines in accordance with Section 93 of the Act. • Guidelines approved by the Mines Occupational Safety and Health Advisory Board. • National Codes of Practice and National Standards developed by the National Occupational Health and Safety Commission. • Australian Standards developed by Standards Australia.

Further information on the legislative framework can be found in the Chamber of Minerals and Energy's publication "*General Duty of Care in Western Australian Mines*".

The Legal Status of Codes of Practice

The provision for approval of codes of practice is made in Section 93 (1) of the *Mines Safety and Inspection Act 1994*:

> *93. (1) The Minister may approve a code of practice which has been considered by the Mines Occupational Safety and Health Advisory Board, for the purpose of providing practical guidance to employers, self-employed persons and employees and other persons on whom a duty of care is imposed under this Act.*

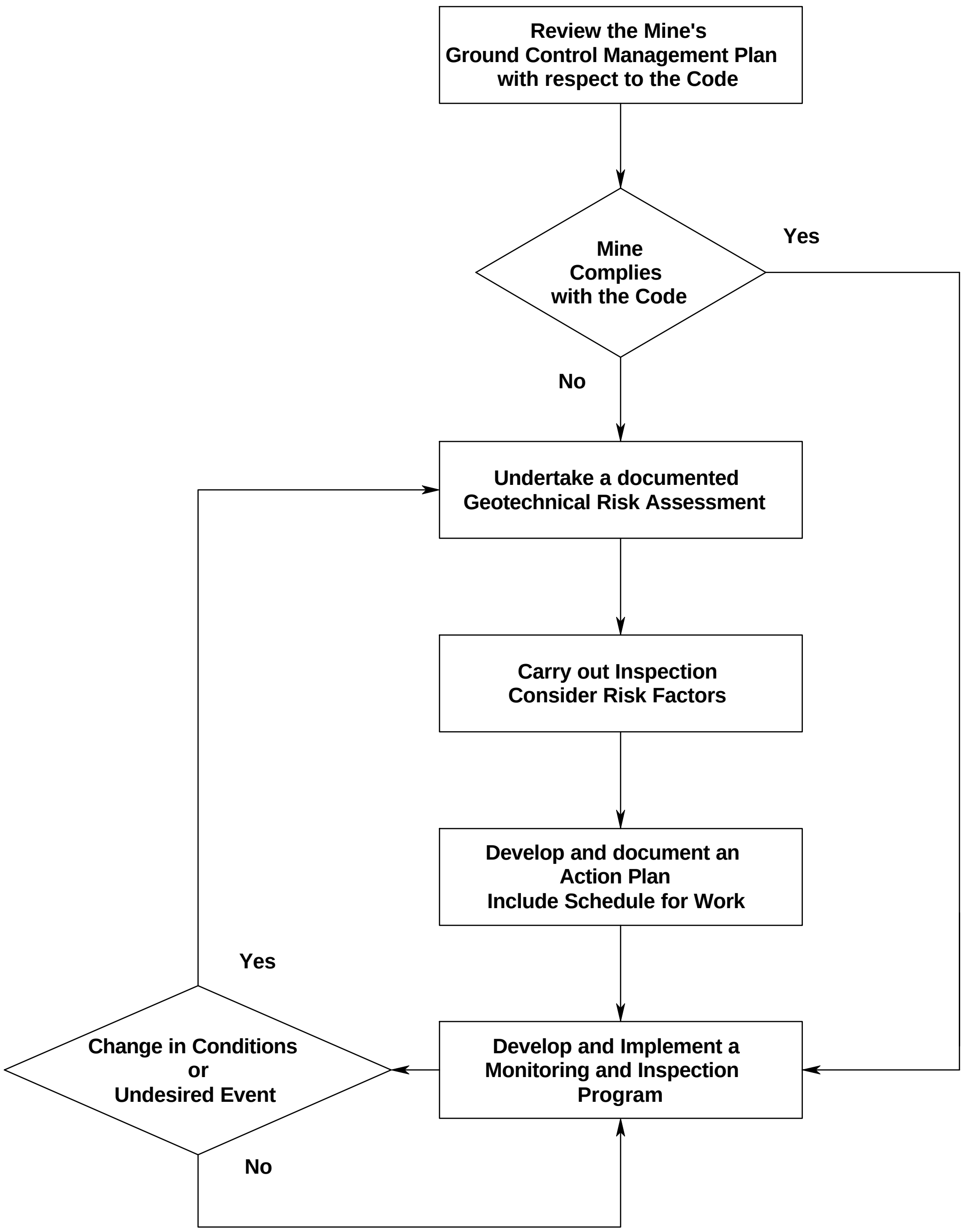
Section 93 sets out the processes associated with the approval and revision of codes of practice, and the status of approved codes of practice in relation to legal proceedings. The following points are included:

- A person is not liable to any civil or criminal proceedings simply because of non-compliance with a code of practice; and
- Where it is alleged that a person has contravened a provision of the Act or Regulations, the information in a code of practice may be used, as evidence to show there is a practicable means of reducing the risk or work-related injury or disease. However, demonstration that the person has complied with the Act or Regulations by some other means would be a satisfactory defence.

Codes of practice may not provide exact solutions to occupational safety and health problems in all workplaces in the industry, but following the practical guidance in this code of practice should help to reduce the risk of serious injury or death from rock falls.

APPENDIX 2

FLOW DIAGRAM
COMPLIANCE WITH THE CODE OF PRACTICE



APPENDIX 3

10 STEP
GEOTECHNICAL RISK ASSESSMENT

DEVELOPMENT HEADINGS AND ENTRY STOPING METHODS

The geotechnical risk assessment should be carried out by competent persons, including geologists, mining engineers, supervisors, safety and health representatives and underground employees exposed to the risk.

Specialist goetechnical advice from appropriately qualified and experienced professionals should be sought when complex, variable and difficult or unusual ground conditions are found.

The frequency and scope of the geotechnical risk assessment shall reflect the level of risk and shall be documented.

The following 10-Step Geotechnical Risk Assessment is provided as an example of the issues that should be taken into consideration when carry out the risk assessment.

STEP 1 **Broadly classify the ground conditions:**
- Soft rock conditions (time dependent behaviour)
- Hard rock conditions
- Seismic rock conditions (dynamic behaviour)

STEP 2 **Quantify the geotechnical properties of the rock mass**

STEP 3 **Establish the geotechnical domains based on geology and rock mass classification methods**

STEP 4 **Identify the potential rock failure mechanisms**

STEP 5 **Review the geotechnical domains having regard for:**
- Underground observations
- Blast damage from large blasts
- Induced stress changes (increase and decrease)
- Water (natural or introduced)
- Deterioration of the rock mass with time

STEP 6 **Draw on mining experience in similar ground conditions (judgement)**

STEP 7 **Review effectiveness of scaling practices**

STEP 8 **Review effectiveness of controlled drilling and blasting practices**

STEP 9 **Consider influence of nearby excavations, pillars and abutments**

STEP 10 **Determine rock support and reinforcement**

Return to STEP 1 and repeat for next section of development or stope

APPENDIX 4

GLOSSARY

Backs. The section of an underground excavation which comprises the overhead rock (in coal mining it is called the "roof").

Controlled blasting. The technique and art of minimising rock damage during blasting. It requires the accurate placement and initiation of minimal explosive charges in the perimeter holes to achieve efficient rock breakage with least damage to the remaining rock around an excavation.

Competent person. Means a person who is appointed or designated by the employer to perform specified duties which the person is qualified to perform by knowledge, training and experience.

Entry-method stoping. Entry-method stoping typically proceeds upward through the orebody with a series of cuts or slices, mining through the previously installed ground support.

Geology. The scientific study of the Earth, the rock of which it is composed and the changes which it has undergone or is undergoing.

Geological structure. A general term that describes the arrangement of rock formations. Also refers to the folds, joints, faults, shears, foliation, schistosity, bedding planes and other planes of weakness in rock.

Ground control. The ability to predict and influence the behaviour of rock in a mining environment, having due regard for the safety of the workforce and the required serviceability and design life of the openings.

Ground Support. In respect to this Code, includes both rock reinforcement and surface rock support.

Hazard. In relation to a person, means anything that may result in injury to the person or harm to the health of the person.

High Heading. Heading with a height exceeding a nominal 3.5m.

Plane of weakness. A naturally occurring crack or break in the rock mass along which movement can occur.

Risk. In relation to any injury or harm, means the probability of that injury or harm occurring.

Rock Reinforcement. The use of rock bolts and cable bolts, placed inside the rock, to apply large stabilising forces to the rock surface or across a joint tending to open. The aim of reinforcement is to develop the inherent strength of the rock and make it self-supporting. Reinforcement is primarily applied internally to the rock mass.

Scaling. The art and function of making the ground safe using a scaling bar to locate and remove loose rock from the walls, face and backs of the workplace. Loose or potentially unstable rock is prised off the rock surface with a scaling bar. Also referred to as barring down.

Shotcrete. Pneumatically applied cement, water, sand and fine aggregate mix that is sprayed at high velocity on the rock surface and is thus compacted dynamically. Tends to inhibit blocks ravelling from the backs, walls and face of an excavation.

Stress. May be thought of as the internal resistance of an object to an applied load. When an external load is applied to an object, a force inside the object resists the external load. The terms stress and pressure refer to the same thing. Stress is calculated by dividing the force acting by the original area over which it acts. Stress has both magnitude and orientation.

Surface Rock Support. The use of mesh, strapping, shotcrete, thin flexible spray-on coatings, steel or timber sets, concrete lining, steel liners, etc that are placed in contact with the rock surface to limit rock movement.