DRAFT

Code of Practice

STRATA CONTROL IN UNDERGROUND COAL MINES

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Draft
CODE OF PRACTICE

STRATA CONTROL IN UNDERGROUND COAL MINES

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FOREWORD

This Code of Practice on strata control in underground coal mines is an approved code of practice under section 274 of the *Work Health and Safety Act* (the WHS Act).

An approved code of practice is a practical guide to achieving the standards of health, safety and welfare required under the WHS Act and the Work Health and Safety Regulations (the WHS Regulations).

A code of practice applies to anyone who has a duty of care in the circumstances described in the code. In most cases, following an approved code of practice would achieve compliance with the health and safety duties in the WHS Act, in relation to the subject matter of the code. Like regulations, codes of practice deal with particular issues and do not cover all hazards or risks which may arise. The health and safety duties require duty holders to consider all risks associated with work, not only those for which regulations and codes of practice exist.

Codes of practice are admissible in court proceedings under the WHS Act and Regulations. Courts may regard a code of practice as evidence of what is known about a hazard, risk or control and may rely on the code in determining what is reasonably practicable in the circumstances to which the code relates.

Compliance with the WHS Act and Regulations may be achieved by following another method, such as a technical or an industry standard, if it provides an equivalent or higher standard of work health and safety than the code.

An inspector may refer to an approved code of practice when issuing an improvement or prohibition notice.

This Code has been developed by Safe Work Australia in conjunction with the National Mine Safety Framework Steering Group as a model code of practice under the Council of Australian Governments' *Inter-Governmental Agreement for Regulatory and Operational Reform in Occupational Health and Safety* for adoption by the Commonwealth, state and territory governments

A draft of this Code of Practice was released for public consultation on [*to be completed*] and was endorsed by the Workplace Relations Ministers Council on [*to be completed*].

SCOPE & APPLICATION

This Code is a practical guide to assist the mine operator to develop and implement a principal hazard management plan for strata instability as required under the WHS Regulations. This Code applies to the underground workings of a coal mine but does not apply to the surface effects of underground mining

Who should use this code?

You should use this Code if you have functions and responsibilities that are contained in the principal hazard management plan for strata instability. This Code can be used by workers and health and safety representatives who need to understand the hazards and risks associated with strata control.

How to use this code of practice

This Code includes references to both mandatory and non-mandatory actions. The references to legal requirements contained in the WHS Act and Regulations (highlighted in text boxes in this Code) are not exhaustive and are included for context only.

The words 'must', 'requires' or 'mandatory' indicate that legal requirements exist, which must be complied with. The word 'should' indicates a recommended course of action, while 'may' indicates an optional course of action.

1. INTRODUCTION

1.1 What is strata control?

Strata refers to rock in all the possible forms that it may take from a high strength material to an extremely weathered, very low strength, essentially soil like material. Strata control refers to the methods applied to manage the risks associated with various forms of strata instability in underground coal mines.

This Code will consider two types of strata controls:

- workplace control – involves factors the workforce has significant control of during their day to day mining activities with some input from mine design and geotechnical staff, and
- mine-wide control – involves factors that affect the stability of the whole mine or large sections of the mine, are usually beyond the capacity of the individual miner or general workforce to deal with and are under the control of mine designers and geotechnical staff.

There are no clear cut boundaries between these strata controls, therefore, some statements made for one particular area of strata control may apply equally to the other.

Effective strata control is a function of three main components:

- strata characteristics
- mine planning and design, and
- strata control measures.

Strata control is applied at all stages of a mine, however, only where it is suited to the particular characteristics of the mine's strata, design and layout of the mine can the risks to health and safety be minimised.

Strata movements relevant to this Code include events such as falls of strata, sagging, swelling, bulking, buckling, heave, and elastic strain.

1.2 Who has duties for strata control in underground coal mines?

Under the WHS Act, all persons who conduct a business or undertaking have a duty of care to ensure, so far as is reasonably practicable, that workers and other persons are not put at risk from work carried out as part of the business or undertaking.

The WHS Regulations identifies strata instability as a principal mining hazard. To effectively control the risks, the mine operator must follow a *risk management process* and prepare and implement a hazard management plan which is included in the work health and safety management system (WHSMS). This Code provides guidance to help the mine operator meet this duty. ***Appendix B*** provides examples of roles and responsibilities when developing a hazard management plan for strata instability.

General guidance on the risk management process is available in the *Code of Practice: How to Manage Work Health and Safety Risks.* Further guidance to develop a WHSMS is available in the *Code of Practice: Work Health and Safety Management System*.

Consultation

When managing risks, the mine operator must consult with workers and other persons at the mine including other persons conducting a business or undertaking. Further guidance on consultation, cooperation and coordination can be found in the *Code of Practice: Work Health and Safety Consultation, Co-operation and Co-ordination.*

2. IDENTIFYING HAZARDS AND ASSESSING THE RISKS

2.1 Identifying hazards

There are a number of ways to identify hazards at the mine. Some of these include:

- consulting with workers as they can provide valuable information about potential hazards
- conducting a visual inspection of the mine focussing on strata control, and
- reviewing available information including incident records and accident reports.

Trends or common problems can be identified from the information collected and may show that locations or areas that are more hazardous. It could indicate a problem with the design and layout of that work area or the way work is a carried out there. These trends may help in deciding which areas to address as a priority.

2.2 Assessing the risks

Regulation 9.2.11 of the WHS Regulations require that when conducting a risk assessment for the purposes of preparing a principal mining hazard management plan, the mine operator must use investigation and analysis methods that are appropriate to the principal hazard being considered. The mine operator must also consider the principal mining hazard individually as well as cumulatively with other hazards at the mine.

The risk assessment must:

- state the likelihood of the principal mining hazard causing or contributing to any harm to the health and safety of any person, and the severity of the harm
- describe the investigation and analysis methods used in the assessment
- describe all control measures considered to control risks associated with the principal mining hazard, and
- state reasons for deciding which risk control measure to implement.

Assessing the risks will help the mine operator take the correct action to eliminate or minimise the associated risks. When undertaking a risk assessment to determine strata control measures, the following factors as outlined in Schedule 9.2 of the WHS Regulations must be considered:

- the geotechnical characteristics of the rocks and soil including the effects of time, oxidation and water on rock support and stability
- the location and loadings from existing or proposed mine infrastructure including waste dumps, tailoring storage haul roads and mine facilities, and
- the proposed and existing mining operations including the nature and number of excavations, the number and size of permanent or temporary voids or openings, backfilling of mined areas and stopes, abutments, periodic weighting and windblast.

When developing the hazard management plan for strata instability, the mine operator should also, so far as is reasonably practicable, make provision for the following matters:

- determine and define the functions and responsibility of person(s) at the mine who will develop and implement the hazard management plan for strata instability
- strata control terminology
- estimation of the geological conditions likely to be encountered
- assessment of the stability of roadways to be developed in those geological

conditions

- recording of geological conditions that may affect roadway stability
- development of support measures that will provide roadway stability in those geological conditions
- calculations (including maximum roadway width and the minimum dimensions of coal pillars) to determine the probability of instability to be assigned to any coal pillar, consistent with the pillar's role or roles over its life
- preparation and distribution of support plans that clearly describe the following:
    - the type of support
    - the dimensions of the support
    - the locations where there are varying types of supports in use
    - the distance between supports
    - the maximum distance roadways can be advanced before support is installed
    - the means of roadway support required to be installed in a manner such that they may be readily understood by those required to install the roadway support
- other information necessary to enable an employee to install support according to the requirements of the hazard management plan
- safe, effective and systematic work methods for the installation and subsequent removal (when required) of the roadway support (including support in connection with the carrying out of roof brushing operations or the recovery of plant)
- availability of adequate plant and resources to effectively install or remove the roadway support
- provision for monitoring, audit, review and change management of the hazard management plan for strata instability including the performance of the design and support to verify its continuing adequacy.
- recording of strata failures that have the potential to cause serious injury to people
- a description of the following features and any special provision made for them:
    - any multi-seam workings
    - any mining that has the potential to cause windblast or rapid stress change
    - any mining at depths of less than 50 metres
    - any coal pillars with a pillar width to pillar height ratio of 4:1 or less
- training of workers in support design principles, support plan interpretation, placement and removal of support, understanding the need for and the importance of the various support systems and recognition of indicators of change that may affect roadway stability
- a prohibition on people entering an underground place at the coal operation that is not supported in accordance with the hazard management plan, unless the person does so for the purpose of erecting support, in which case temporary support should be used
- a prohibition on mining in any place at the coal operation unless there is sufficient support for the place in accordance with the requirements of the hazard management plan, and
- a statement that nothing in the hazard management plan is to be read as preventing the installation of more strata support or support installation at more

frequent intervals than is required by the hazard management plan.

3. CONTROLLING THE RISKS

3.1 Estimation of the geological conditions

The principal hazard management plan for strata instability should make provision for the estimation of the geological environment likely to be encountered.

The collection, modeling and interpretation of data are the primary means of identifying strata related hazards.

Geological information
Geological information can be obtained from the following:

- vertical boreholes – the smaller the distance is between holes increases the confidence level of the information.
- inseam boreholes
- geophysical surveying
- projection of known structures and features to future workings
- mapping, monitoring and observations of excavations and installed support, and
- information from other mines.

Geological Mapping
Geological mapping should clearly show areas where the risk of poor mining conditions is high. For example zones of domain change, major regional faults or dykes, plugs, sills, seam grade changes and associated stress concentrations. These should be marked on all mining plans. Plans should show areas of "normal" conditions and areas of "elevated risk".

Some strata control measures are more appropriate to specific conditions and should be implemented in a proactive way.

Underground geological mapping should be continued during the course of development and any extraction system to delineate and describe any visible threats to mining.

Major features (for example, faults, dykes and shear zones), shall be mapped and presented on a plan as soon as is practically possible after exposure following mining. Significant features should be transferred to the Geological Database.

Someone should be allocated this function in the principal hazard management plan for strata control (usually a geologist). It should also be the function and responsibility of the mining supervisors to record any significant geological features on their shift report.

3.2 Geotechnical data collection

A range of information should be collected to assist in developing the most effective controls. The following information would provide valuable information

Regional assessment of roof and floor lithology
The following information should be sought for up to 5 metres into the floor and 10 metres into the roof:

- rock types
- bed thicknesses
- variability in thicknesses, especially in the immediate roof

- bedding angles
- strength data (selected quantitative data), and
- regional qualitative integrity (logging data).

Coal seam integrity

- Assessment of strength/friability.
- Cleat intensity and direction.
- Existence of planes of weakness.

Local structural features

- Joint sets.
- Slickensides or greasy backs.
- Low angle bedding planes or 'feather' edges intersecting roof horizon.
- Minor faulting.
- Seam, roof or floor rolls.

Regional structural features

- Major faulting, dykes, sills, shear zones.
- Extrapolation of structures from adjacent workings, surface lineaments or other exploration input.

Stress

- Review any available quantitative stress measurement data taking caution regarding its reliability and applicability
- Mapping of any evidence of stress induced features to indicate direction of dominant horizontal stress (for example, preferential guttering).
- Obtain 'depth of cover isopachs and also surface topography contours to establish significant variations in vertical stress and concentrations due to cliff lines and valley effects.

3.3 Mining Geometry

The effects of changes to mining geometry can have major effects on the effectiveness of strata control measures.

Mining geometry should be regarded as a variable which requires management as part of the principal hazard management plan for strata instability.

The management of mining geometry should be considered at each of the following stages.

- Design stage
- Implementation stage (a supervisory or control step)
- Review stage (monitoring actual dimensions)
- Feedback

3.4 Risk Plan

The risk plan maps all the identified risks onto a plan of the mine and can be used as a current picture of the strata risks in the current mine working.

Prior to the commencement of mining in any new section a risk plan should be prepared showing predicted seam, roof and floor conditions along with predicted faults, dykes, structural zones and any other known or potential threat likely to have an impact on mining.

The risk plans should include a plan of the proposed working section to be mined and the location of known and predicted geological threats to mining and indicate their extrapolation across the section. The locations of all surface boreholes likely to be mined should be marked on the plan. The risk plan should be available to workers and updated regularly.

3.5 Section Reviews

Reviews of the principal hazard management plan for strata instability should be made during the course of mining should any of the following conditions arise:

- A significant deviation from the expected conditions.
- Major changes to roadway dimensions or mine layout are to occur.
- New options for support or mining methods are being implemented.
- A major roof failure incident occurs.
- A major rib fall incident occurs.
- Strata failures that have the potential to cause serious injury.

Following the completion of mining in a section of the mine a review should be undertaken. A review can determine if actual hazards aligned with prediction models.

3.6 Strata control of failure model and design of roadway support rules

This section relates to the development of a model of stress and failure patterns around a roadway and the type and density of support necessary to maintain stability.

Failure model
In order to be able to develop an effective strata support system it is necessary to understand what the failure mechanism of the strata could be. For example, will the roof fail due to buckling or will the roof fail in simple bending or will shear failure occur over the rib line.

The model of stress development and strata failure should be developed and be included in the principal hazard management plan for strata instability.

Strata control support design
Once an understanding of the failure mechanism has been established numerous techniques exist to design a specific supports to counteract the predominant failure mechanisms. The mine operator should determine and employ the technique appropriate to the mine.

Roadway and roof reinforcement design should be performed by a person or persons with the appropriate expertise and experience.

Any design techniques employed should be detailed in the principal hazard management plan for strata instability. Any limitations or assumptions in the design should be clearly stated.

Design of roadway support
The initial design of roadways and the strata control measures are of paramount importance. Practical experience during and following development of roadways; will assist the fine-tuning of the strata control measures to ensure safety.

When designing the layout of mine roads, the purpose of the roadway should be considered along with the likely life of that roadway. For example, the life of a longwall gate-road is likely to be considerable shorter than main heading roadways. The design of a roadway for pillar splitting and extraction is likely to be different to the tailgate roadway of a longwall panel.

Whatever strata control strategy is chosen, it should be evaluated to ensure it will be effective. For example is the roadway to be driven on a primary support system only or will additional support be applied at a later period for longwall gateway support.

Strata control support rules

The hazard management plan for strata instability should include the the preparation and distribution of support plans that clearly describe the “rules” that are to apply regarding strata. These rules cover:

- The type of support.
- Dimensions of the support.
- Locations of the varying types of supports in use.
- Distance between supports.
- Maximum distance roadways can be advanced before support is installed.
- Intersection support.
- Breakaway rules.
- Brushing rules.
- Removal of support rules

The rules should be readily understood by those installing the roadway support.
The rules should clearly state that nothing shall prevent the installation of additional support.

Trigger action and response plans

The hazard management plan for strata instability should include actions to be taken when established trigger points are reached. Trigger points could include:

- Changes in the behavior of the strata, for example, overbreaks, opening of joints, excavating outside of defined height and width limits
- Changes in behavior of established roadways, for example, roof buckling, damage to supported roof and ribs, spalling, and
- Reaching pre-determined measurement of monitoring devices.

Installation of strata support

The hazard management plan for strata instability should include provision for safe, effective and systematic work methods for the installation, and removal of the roadway strata support (including strata support in connection with the carrying out of roof brushing operations or the recovery of plant).

The mine operator should provide adequate plant and resources to effectively install or remove the roadway support.

Any material used to instal strata control support should be fit for purpose and available for workers prior to installation. Important considerations are:

- ordering the correct material.
- the product quality, and
- storage and handling that maintains the product quality (especially resins and chemical binders).

Installed strata control support should be inspected in according to the mine’s inspection schedule. The support should also be monitored and audited regularly to ensure that it effectively controls the risks to workers’ health and safety.

Any person installing or removing strata control support should be trained and capable of performing the tasks professionally and safely.

When resin anchored bolts are used, training should include:

- correct hole diameter, length and straightness (oversize hole diameter or excessive length can consume extra resin and reduce the anchorage strength
- cleanliness of the hole (poorly flushed holes can leave a dust or slime residue on the rock surface dramatically reducing bond strength between resin and rock
- resin mixing and nut tightening
- surface reinforcement tight against the rock surface (for example, plates, washers, straps, mesh), and
- location of strata control support in accordance with the plan.

Oversize roadways
With the advent of bigger plant and machinery roadways are often required to be developed considerably higher and/or wider than normal main and gate roads.

Care should be exercised when designing oversized roadways since small increments in width and/or height substantially increase the loading on the roadway.

The principal hazard management plan for strata instability should include provision for oversized roadways, especially the monitoring of these roadways.

Suspending objects from installed roof bolts
When suspending objects from roof bolts, the design of the support system should consider this action and the design modified accordingly. Additional support measures may need to be installed especially for heavy objects such as support beams for heavy equipment lifting.

Longwall take off roadways
Care should be exercised when designing longwall take off roadways since the approaching longwall abutment zone will substantially increase the loading on the roadway.

The principal hazard management plan for strata instability should include provision for longwall take off roadways, especially monitoring of these roadways.

3.7 Longwall strata control

The longwall system of mining can have geotechnical threats not often found in the development of roadways. The threats include abutment loadings, windblast, periodic weighting, collapsed and pinned longwall roof supports along with rock falls (which are also common to roadway).

The removal phase of the longwall roof supports also presents strata control threats.

Abutment loading
The principal hazard management plan for strata instability should include provision (especially in the design phase) for estimating the abutment loading on the face, chain pillars and gate roads along with potential failure and the strata control measures required to mitigate the threats.

Windblast
Windblast can occur in longwall coal mines, especially those where roof strata are competent, and do not cave immediately as the face advances.

This results in the tendency for a large void to be created behind the roof supports in the goaf which collapse when the overlying cantilevered strata can no longer support its own weight.

When the collapse occurs, the air or gas occupying the void is displaced by rock, resulting in a pressure wave and windblast that moves along the roadways of the mine. This may be followed by a "suck back" as the air pressure is equalised with the low pressure created higher up in the goaf.

When designing longwall layouts the mine operator should (unless the roof strata is going to cave easily) consider the possibility of windblast. Where windblast is a potential risk the management of this risk should be included in the principal hazard management plan for strata instability.

Periodic weighting

Periodic weighting is another potential threat to the longwall operation. Periodic weighting of longwall supports occurs during retreat of the face under certain geologic conditions.

Strong strata in the immediate and main roof tend to cantilever over the goaf, weighting the supports periodically. The distance between weighting peaks, as well as the intensity of periodic weighting, is determined by the strength and thickness of roof members, their location relative to the seam, the frequency of jointing, and characteristics of the goaf.

When designing longwall layouts the mine operator should (unless the roof strata is going to cave easily) consider the possibility of periodic weighting.

Where periodic weighting is a potential risk the management of this risk should be included in the hazard management plan for strata instability.

Longwall production

For the safety of longwall personnel the control of the roof and face is of paramount importance. The strata control for longwall mining is primarily a set of longwall hydraulic roof supports.

The mine operator should provide roof supports that are designed for the duty required. The supports should be kept in a fit for purpose state. The operators of the supports should be trained and competent for the task.

Operators working on the face side of the face conveyor

When persons are required to work on the face side of the face conveyor (for example changing shearer picks or for maintenance purposes) there should be provisions for the control of the roof and face.

These provisions should be incorporated into the hazard management plan for strata instability.

When any provision requires reinforcement support of the roof and/or face the persons installing the support should be supplied with support rules for the purpose. These persons should be trained and competent to install such support.

Recovery of longwall hydraulic roof supports

When recovering longwall supports there is the potential threat of falling roof, face spall and goaf flushing.

Provisions should be incorporated into the hazard management plan for strata instability for the measures required to mitigate the risk of these threats.

3.8 Pillar Extraction

The extraction of pillars can have geotechnical threats including abutment loadings, windblast, periodic weighting, and buried continuous miners with roof falls.

Abutment loading
The hazard management plan for strata instability should include provision (especially in the design phase) for estimating the abutment loading on the face, pillars and roadways in the extraction area. The potential failure and the strata control measures required to mitigate the threats should be included.

Windblast
Windblast can occur in extracted areas, especially those where the roof strata are competent, and do not cave readily. This results in the tendency for a large void to be created behind the roof supports in the goaf which collapses when the overlying cantilevered strata can no longer support its own weight. When the collapse occurs, the air or gas occupying the void is displaced by rock, resulting in a pressure wave and windblast that propagates along the roadways of extraction section of the mine. This may be followed by a strong flow reversal as the air pressure is equalised with the low pressure created higher up in the goaf.

When designing pillar extraction layouts the mine operator should, unless the roof strata is going to cave easily, consider the possibility of windblast.

Where windblast is a potential risk the management of this risk should be included in the principal hazard management plan for strata instability.

Periodic weighting
Periodic weighting is another potential threat to the extraction section and the personnel working in that section. Periodic weighting of breaker line supports occurs during extraction under certain geologic conditions. Strong strata in the immediate and main roof tend to cantilever over the goaf, weighting the supports periodically. The distance between weighting peaks, as well as the intensity of periodic weighting, is determined by the strength and thickness of roof members, their location relative to the seam, the frequency of jointing, and characteristics of the goaf.

When designing extraction layouts the mine operator should, unless the roof strata is going to cave easily, consider the possibility of periodic weighting.

Where periodic weighting is a potential risk the management of this risk should be included in the principal hazard management plan for strata instability.

Pillar extraction production
For the safety of pillar extraction personnel the control of the roof and face is of paramount importance. The strata control for pillar extraction is primarily the installed roof and rib support when developing the split or entry and either a set of breaker line supports or passive supports such as wooden props.

Mine operators should provide breaker line supports that are designed for the duty required. The supports should be kept in a fit for purpose state. The operators of the supports should be trained and competent for the task.

When using passive supports such as wooden props the procedure for installation and recovery, if conducted, should be included in the hazard management plan for strata instability.

Recovering a buried continuous miner
When workers are required to recover a buried continuous miner there should be procedures for the recovery. The procedures should include the strata control measures required to maintain control of the roof in the area where recovery work is conducted.

These provisions should be incorporated into the hazard management plan for strata instability.

When any provision requires reinforcement support of the roof or work area the persons installing the support should be supplied with support rules for the purpose. These persons should be trained and competent to install such support.

3.9 Pillar Design

A coal pillar system comprises the pillar itself, the roof and floor strata and the pillar roof and floor contacts.

Pillar systems may collapse gradually and give ample warning, or suddenly to the point of being instantaneous.

In general, pillar system failures initiated by roof or floor failure develop gradually. Sudden collapses are usually associated with pillar system failures involving competent roof and floor strata in which the coal pillar itself fails. Exceptions occur when low strength floor material is suddenly loaded through the pillars by massive roof.

The failures present a great hazard to personnel.

Pillar design process
The process at ***Figure 1*** can assist mine operator's develop a pillar design for the mine. This process is not intended to be absolute and the mine operator could choose a different model.

Design pillar steps
The steps below and at ***Figure 2***, which involve risk assessment and the development of controls, are suggested when designing pillars.

- Decide what a tolerable or acceptable level of risk is. Risk equals probability of failure x consequence of failure. Both components must be carefully considered.
- Determine an appropriate 'DESIGN' Factor of safety (FOS) which reflects this level of risk.
- Select mining dimensions.
- Determine pillar load and strength for selected mining dimensions.
- Calculate the pillar FOS.
- Check stability compliance between the calculated and design value of FOS.
- Check pillar dimensions for mining operational compliance, (for example, wheeling, flit distance, ventilation, spontaneous combustion)

Figure 1: Pillar design process

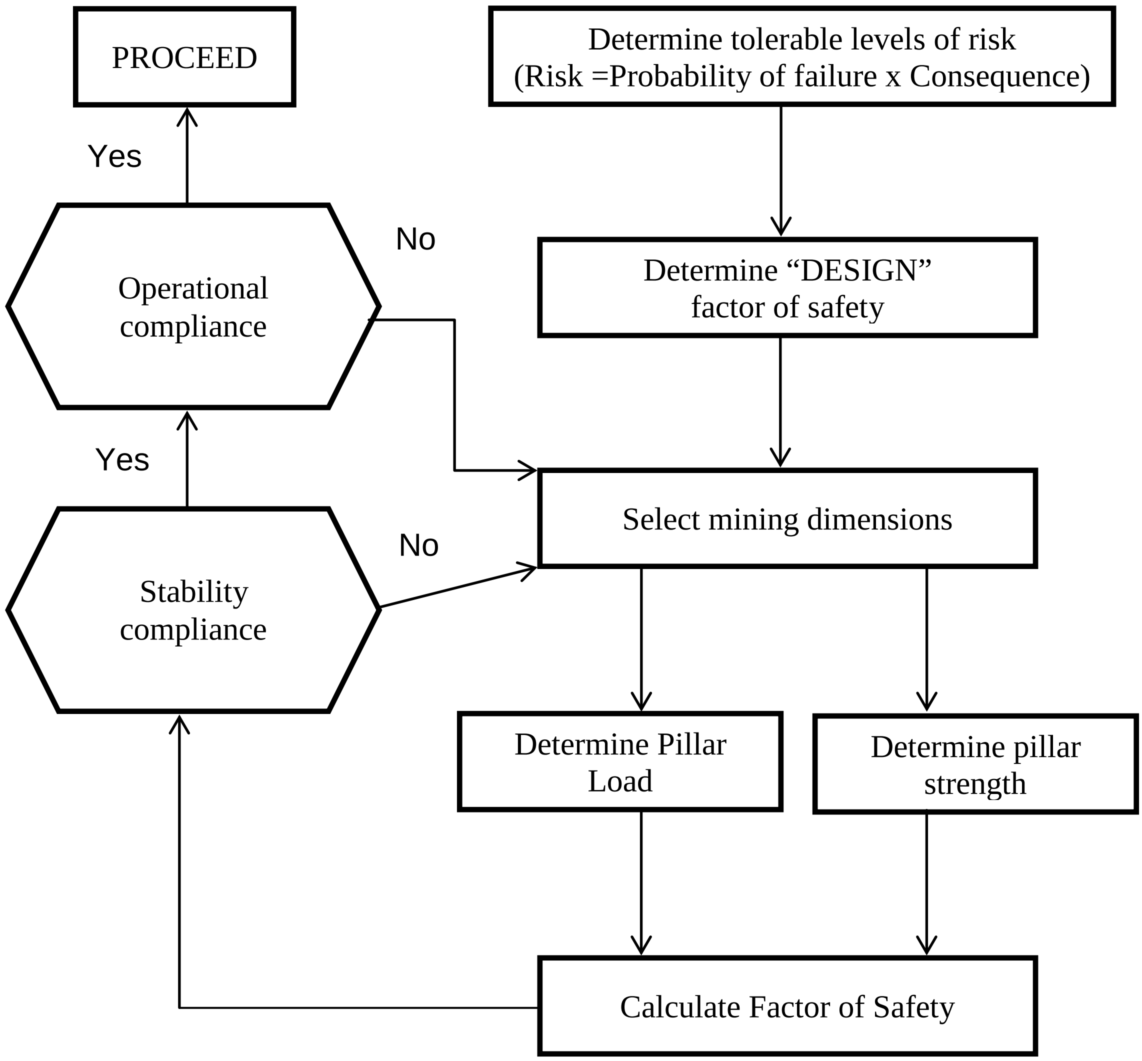
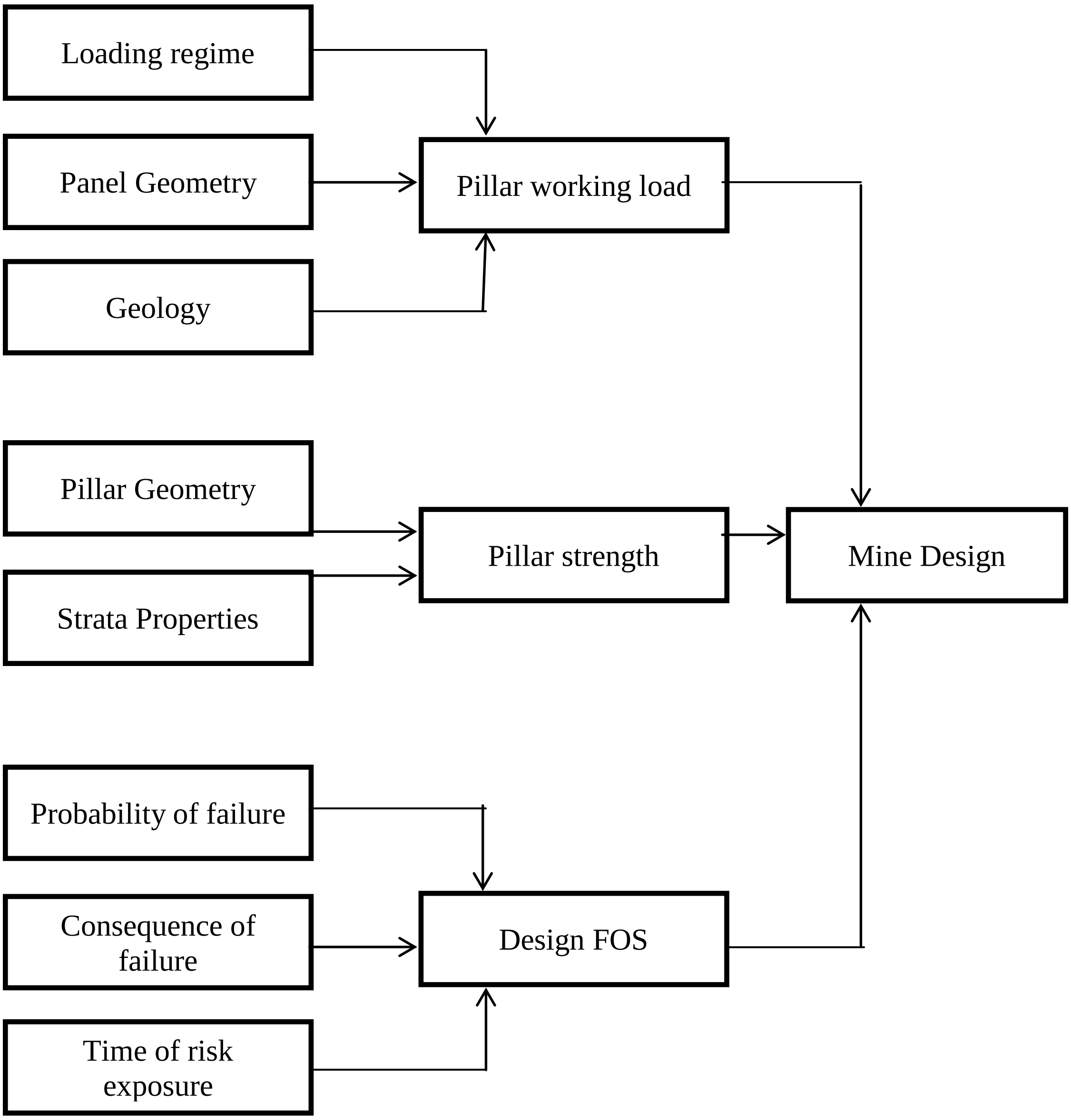


Figure 2: Principal influences on pillar load, strength and FOS

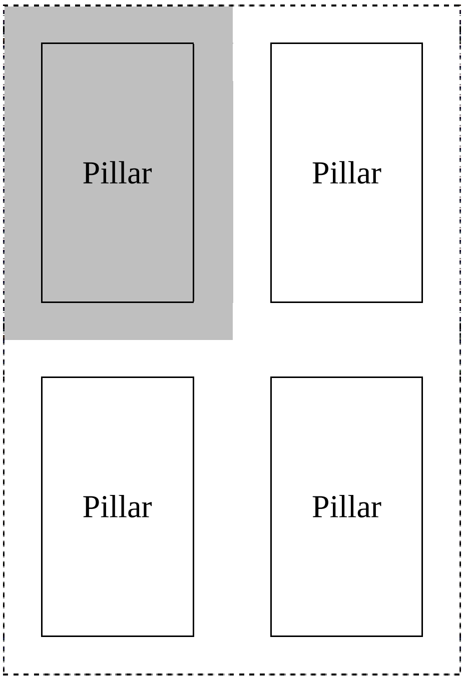


Pillar working load

The pillar working load is the maximum load that the pillar will be subjected to. This is determined by both the stiffness of the surrounding strata and the stiffness of the coal pillar. When a mining section is narrow compared to the depth of cover the roof will remain stiff and it will arch across the section. In this circumstance the total dead weight of the overburden is not transferred to the pillars.

As the section width to depth of cover increases the stiffness of the strata reduces until it is incapable of arching across the section. In this case the full dead weight load of the overburden has to be supported by the pillars.

In an extensive layout comprising pillars of regular size, the pillars are of equal stiffness and therefore share the load equally. The pillar working load is the dead weight of the overburden within the pillars area of influence and the Tributary Area Load as shown below. The tributary area is shown shaded.



In an extensive layout comprising pillars of irregular size, the pillars with the greater width to height ratios are subjected to more load because they are stiffer and therefore provide greater resistance to roof sag.

Note: advanced numerical techniques may be required to calculate the average pillar stress in these layouts. The mine operator should obtain the services of persons competent to conduct such calculations.

Extraction of regular standing pillars

When a panel of regularly sized standing pillars is extracted, the load acting on the pillars adjacent to the goaf is increased. The increase is influenced by the overall span of the goaf, the material properties of the overburden and the sequence and speed of extraction. An extreme situation can occur when the panel width is sub-critical and the super incumbent strata spans across the extracted area resulting in minimal load transfer to the goaf.

Close to the active face line pillar load is constantly changing and is highly dependent on the rate of extraction. Experience suggests that the average pillar loading can be typically 1.3 to 1.5 times tributary area load; a tributary load multiplier of 1.5 is recommended. Where it is known that a row of pillars will remain standing against a goaf edge for a considerable time the load multiplier should be increased to 2.0.

Pillar strength
Strength is defined as the maximum stress a structure can sustain without failing. Calculation of pillar strength is a complex issue due to factors such as rock mass variations, geological imperfections, pillar volume and geometry of the pillar. The mine operator should obtain the services of persons competent to conduct such calculations.

Consideration should also be given to the Australian Coal Association Research Program's Final report on '*Establishing the Strength of Rectangular and Irregular Pillars'* # C5024.

Determination of the Factor of Safety (FOS)
The use of FOS is a means of incorporating acceptable and tolerable levels of risk into engineering designs.

Risk = Probability x Consequence

For this section risk is the instability or failure of a pillar. When the consequences of failure are serious, a reduced probability of failure needs to be adopted in order to achieve an acceptable level of risk.

When mining a panel of pillars, the normal acceptable risk in terms of probability of failure is about 3 in 1000. However this probability of failure would be unacceptable for a serious consequence such as flooding of the workings; in this case a probability of 1 in 100000 should be chosen.

For coal pillars: FOS = Pillar strength/pillar load

The following table provides a comparison with the probability versus FOS; the factors of safety shown are based on firstly the linear formula and secondly the power formula both of which are discussed in the Australian Coal Association Research Program's Final report on *'Establishing the Strength of Rectangular and Irregular Pillars* '# C5024.

Table 1: Correlation between probability of failure and factor of safety

Probability of failure	Factor of safety(Linear)	Factor of safety (Power)
8 in 10	-	0.87
5 in 10	1.00	1.00
1 in 10	1.30	1.22
5 in 100	1.40	1.3
2 in 100	1.54	1.38
1 in 100	1.62	1.44
1 in 1,000	1.9	1.63
1 in 10,000	2.16	1.79
1 in 1000,000	2.42	1.95
1 in 1,000,000	-	2.11

4. MONITORING, AUDIT, REVIEW AND CHANGE MANAGEMENT

Monitoring the response of the strata to mining excavation and subsequent installation of active or passive support is a key part of a hazard management plan for strata instability.

There should be regular and scheduled monitoring, review and audit of principal hazard management plan for strata instability. The mine operator should provide for:

- establishing the type, extent and frequency of monitoring of installed strata support
- monitoring which should include devices such as "tell tales" so that the workers and supervisors can establish that something appears to be changing above the device. The installation and monitoring of devices will require the workers and supervisors to be trained appropriately
- periodic audit and review should be conducted at intervals no greater than 12 months
- investigation of any abnormalities in the plan
- monitoring to ensure there is sufficient inventory of appropriate quality strata control materials, should it they be needed. The conditions of storage should be conducive to maintaining quality of product, and
- communicating any significant changes to the plan to workers

The mine's inspection schedule contributes significantly toward monitoring the effectiveness of strata control support.

Note: The purpose of reviewing or auditing is to check the plan is correct, in place and operating.

Record and report strata failures that have the potential to cause serious injury

The WHS Act requires the notification of dangerous incidents. A strata failure that exposes a worker to serious risk of injury is subject to notification requirements.

It is therefore important that the mine operator gathers quality information regarding such events in order to learn from them and prevent reoccurrence. Photographs and sketches along with any witness statements prove very useful.

The recording and reporting of any failures should be provided for in the hazard management plan

APPENDIX A - GEOTECHNICAL AND MINING TERMS

Abutment means the areas of un-mined rock at the edges of an extracted area that may carry large regional loads. This is generally a zone of strata arching.

Arching means the transfer of rock stress or load from an active mining area, e.g. goaf area back to a more stable area or abutment; this may result in damage to the abutment pillars.

Bedding planes are parallel beds or planes of weakness in the rock formed when there was a change in the deposition of minerals under water.

Cable bolts is one or more steel reinforcing strands placed in a hole drilled in rock, the bolt may be point anchored with resin glue or with cement or other grout pumped into the hole over the full length of the cable. A steel face plate, in contact with the excavation perimeter, is usually attached to the cable by a barrel and wedge anchor. The cable(s) may be tensioned or not. The steel rope strand may be plain strand or modified to improve the load transfer between the grout and the steel strand.

Cleats are natural opening-mode fractures in coal seams. There is generally a primary and secondary cleat direction.

Compressive stress means a stress or pressure that tends to push or clamp objects together. The state of stress found in the rock mass before mining occurs. The stress tends to hold the rock mass together.

De-stressed zone means a zone of rock around the perimeter of an excavation where the rock stress field has exceeded the strength of the rock mass at some time during its mining history. The rock mass is in a post-peak loading condition and it may be capable of carrying significant loads with low levels of lateral confinement being provided by reinforcement.

Dip means the angle a plane makes with the horizontal.

Discontinuity means any significant mechanical break or fracture resulting in negligible tensile strength in a rock.

Dowel means an un-tensioned rock bolt, anchored by full column or point anchor grouting, generally with a face plate in contact with the rock surface.

Dyke means an igneous intrusion into the rock mass

Earthquake is the local shaking, trembling or undulation of the strata surface and the radiated seismic energy caused most commonly by sudden fault slip, volcanic activity or other sudden stress changes in the Earth.

Elastic limit - See yield point.

Elastic means capable of sustaining stress without permanent deformation. Tending to return to its original shape or state when the applied stress is removed.

Fault means a naturally occurring plane or zone of weakness in the rock along which there has been movement. The amount of movement can vary widely.

Fill means a material used either for support or to fill voids.

Friable means easily broken up or crumbled.

Friction rock stabilisers (Rock Bolts) means steel reinforcing elements, typically a "C" shaped shell that is forced into holes drilled in the rock. Frictional forces between the side of the hole and the element to generate forces to limit rock movement. The anchorage capacity of the device depends on the anchorage length above any plane of weakness and the frictional interference between the borehole wall and the outer surface of the shell. Anchorage capacity is dependent on the hole diameter and the effective anchorage length in solid strata.

Goaf means the extracted area associated with a longwall or pillar extraction system

Geological structure is a general term that describes the arrangement of rock formations including folds, joints, faults, bedding planes and other planes of weakness in rock.

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

Geotechnical engineering means the application of engineering geology, hydrogeology, soil mechanics, rock mechanics and mining seismology to the practical solution of strata control challenges.

Strata control terminology

Induced stress is the stress that is due to the presence of an excavation. The induced stress depends on the level of the in-situ stress and the shape and orientation of the excavation.

In-situ stress is the stress or pressure that exists within the rock mass before any mining has altered the stress field.

Instability is a condition resulting from failure of the intact rock material or geological structure in the rock mass.

Joint is a naturally occurring plane of weakness or break in the rock, along which there has been no visible movement parallel to the plane. Joints may show evidence of movement due to stress change.

Over-break is the excess rock broken outside the design perimeter of an underground excavation. Over-break increases the amount of rock to be moved and may reduce mining efficiency. It may also increase the amount of barring down and strata support required.

Pillar is an area of coal left to support the overlying rock. Pillars may be temporary pillars recovered at some time in the future and permanent pillars left in place for the life of the mine.

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

Plastic means capable of deformation at constant stress once the yield point is exceeded. The ability of a material to undergo permanent deformation without returning to its original shape or failing.

Ravelling means the gradual failure of the rock mass by rock blocks falling/sliding from the opening perimeter under the action of gravity, blast vibrations or deterioration of rock strength. A gradual failure process that may go unnoticed. The term unravelling is also used to mean the same thing.

Release of load means excavation of rock during mining removes or releases the load that the rock was carrying. This allows the rock remaining to expand slightly due to the elastic properties of the rock.

Rock bolt is a tensioned bar or hollow cylinder, usually steel, that is inserted into a drill hole in the rock and anchored by an expansion shell anchor at one end and a steel face plate and a nut at the other end. The steel face plate is in contact with the rock surface.

Rock mass strength refers to the overall physical and mechanical properties of a large volume of rock which is controlled by the intact rock material properties, groundwater and any joints or other planes of weakness present. One of the least well understood aspects of geotechnical engineering.

Rock mass is the sum total of the rock as it exists in place, taking into account the intact rock material, groundwater, as well as joints, faults and other natural planes of weakness that can divide the rock into interlocking blocks of varying sizes and shapes.

Rock mechanics is the scientific study of the mechanical behaviour of rock and rock masses under the influence of force fields.

Rock noise sounds emitted by the rock during failure, may be described as cracking, popping, tearing and banging.

Rock Reinforcement is 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.

Rock-burst is the instantaneous failure of rock causing a sudden violent expulsion of rock material at the surface of an excavation. Can be a serious hazard to people and equipment. Coal outbursts are accompanied by the release of substantial quantities of methane and or carbon dioxide.

Scaling is the function of making the strata safe by removing loose rock and coal from the sides, face and roof of the workplace. Also referred to as barring down.

Seismic event is earthquakes or vibrations caused by sudden failure of rock releasing stored strain energy. Not all seismic events produce damage to the mine structure; hence all seismic events are not necessarily rock bursts.

Seismicity is the tendency of strata in a mine to exhibit seismic activity.

Seismology is the scientific study of earthquakes by the analysis of vibrations transmitted through rock and soil materials. The study includes the dynamic analysis of forces, energy, stress, duration, location, orientation, periodicity and other characteristics.

Shear stress is a stress that tends to cause an object to slide.

Shear is a mode of failure where two objects or pieces of rock tend to slide past each other.

Slickenside or greasy back is a surface that is polished and smoothly striated and results from slippage along a fault plane.

Spalling is stress induced failure of the rock mass that results in small, pieces of rock ejected or falling from the ribs of excavations.

Strain is the change in length per unit length of a body resulting from an applied force. Within the elastic limit strain is proportional to stress.

Strata control is the ability to predict and influence the behavior 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.

Strata Support

- **Active support (rock reinforcement)** - Active support is applied to the interior of the rock mass to limit movement of the rock mass, e.g. rock bolts, grouted dowels, cable bolts and friction rock stabilizers. These methods can typically provide active restraining forces to the rock mass soon after installation with little or no movement of the rock.

- **Passive support (surface rock support)** - Strata support is applied to the perimeter of the excavation to limit movement of the rock mass. These methods typically require the rock mass to move on to the support to generate loads in the support. Examples of this kind of support are timber props or cribs.
- **Fill** - A material used either for support or to fill voids.
- **Strata Binder** - A material used to bind broken rock together.
- **Pillar extraction and longwall support** - Pillar extraction and longwall systems often employ the use of moveable hydraulic supports.

Strength is the largest stress that an object can carry without breaking. Common usage is the stress at failure.

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.

Stress field is a descriptive term to indicate the pattern of the rock stress (magnitude and orientation) in a particular area.

Stress shadow is an area of low stress level due to the distribution of stress around a nearby excavation, e.g. a longwall goaf. May result in joints opening up causing damage.

Strike is the bearing of a horizontal line along a plane or a joint.

Tectonic forces are the forces acting in the Earth's crust over very large areas to produce high horizontal stresses which can cause earthquakes. Tectonic forces are associated with the rock deforming processes in the Earth's crust.

Tensile stress is a stress that tends to cause a material to stretch. Can cause joints to open and may release blocks causing rock falls.

Yield point is the maximum stress that a material can sustain without permanent deformation, or rupture. The limit of proportionality between stress and strain. Also known as the elastic limit.

APPENDIX B – EXAMPLES OF FUNCTIONS AND RESPONSIBILITIES

The following are examples only and can be used as a guide; the Mine Operator should establish specific functions and responsibilities to suit the requirement of the plan.

FUNCTION	RESPONSIBILITY
Mine Operator	• Establish the development and implementation of the principal hazard management plan for strata instability. • Specify functions and responsibility and provide training.
Mine Operator or nominated person (for example the underground mine manager)	• Approve the principal hazard management plan for strata instability, its updates and associated standards and procedures • Establish that all individuals with functions and responsibilities under this plan are trained and competent to carry out those responsibilities. • Establish that all personnel are aware of, and understand their responsibilities as stated in the plan, and that these responsibilities are included in their position descriptions. • Establish that training material is developed and provided for all functions of the plan. • Establish that any systems and procedures are developed and implemented in accordance with the requirements of the plan. • Establish the plan is monitored, audited, reviewed at intervals not exceeding 12 months, or if a specific event occurs as defined in the plan. Any changes should be conveyed to the workforce. • Establish that all risk assessment processes are formally documented. Verify that any corrective action undertaken has been conducted. • Compile and Maintain reports of any roof failure with the potential to injure persons. • Co-ordinate remedial action necessary in the event of any emergency occurring underground. • Sign off on the panel reviews as soon as practicable. • Authorise changes to this plan. • Cause copies of the mine support plans to be posted on the surface notice board and underground panel notice boards. • Establish that sufficient resources are allocated. • Comply with any other requirement of the principal hazard management plan for strata instability for this function.
Technical Services Manager or nominated person	• Facilitate the implementation of the principal hazard management plan for strata instability, and ensure it is updated and modified as necessary • Assist the Manager of Mining Engineering in identifying the resources required to meet the

	requirements of this Plan • Ensure that other hazard plans are prepared prior to the commencement of mining in the relevant sections of the mine. • Liaise with the technical experts such as geologists and geotechnical personnel regarding any additional information or investigation that may be warranted for the compilation of the hazard plans • Review the system prior to the mining of any new section of the mine along with a review at the completion of the section. • Oversee intermediate reviews as required. • Oversee compilation of the support plans as detailed in the principal hazard management plan for strata instability • Determine the nature, location and frequency of monitoring. • Organise internal/external reviews. • Comply with any other requirement of the principal hazard management plan for strata instability for this function.
Geologist	• Ensure exploration data is obtained and interpreted to provide an assessment of the geological conditions and threats to mining. • Review and issue a statement confirming the sealing status of all surface boreholes in the hazard plan area. • Maintain the geological database. • Assist management in the preparation of section hazard plans. • Ensure underground geological mapping is conducted and potential structures defined and recorded on the hazard plan. • Ensure exploration boreholes (as necessary) are grouted to a specification upon completion. • Comply with any other requirement of the principal hazard management plan for strata instability for this function.
Mining Surveyor	• Ensure surveying of underground roadways is undertaken. • Check that the roadways are driven to design and in relation to orientation and dimensions. • Ensure surveys are carried out and transferred onto suitable plans for filing and reference purposes and roadways are plotted as constructed. • Ensure all boreholes are shown on section hazard plans. • Comply with any other requirement of the principal hazard management plan for strata instability for this function.

Production Manager (or equivalent)	• Ensure the installation of monitoring stations is in accordance with the principal hazard management plan for strata instability. • Ensure the strata support is installed in accordance with the mine support plans. • Promote the use of trigger action response plans (TARPS). • Establish strata control material stock levels and monitor and rectify if required. • Comply with any other requirement of the principal hazard management plan for strata instability for this function
Senior shift mining supervisors (for example undermanagers)	• Check the installation of monitoring stations is in accordance with the principal hazard management plan for strata instability. • Check the strata support is installed in accordance with the mine support plans. • Ensure corrective action for the above if required. • Respond to alerts from section mining supervisors. • Record details and notify appropriate supervisors of any strata failure with the potential to injure persons or cause significant downtime. • Comply with any other requirement of the principal hazard management plan for strata instability for this function
Mining Supervisors (for example deputies)	• Inspect any areas where new strata is exposed or existing strata is being interfered with. This should be conducted in accordance with the inspection requirements of the mine (as a minimum). • Check the installation of monitoring stations is in accordance with the principal hazard management plan for strata instability. • Check the strata support is installed in accordance with the mine support plans. • Facilitate corrective action for the above if required. • Respond to alerts from section workers. • Record details and notify shift supervisor of any strata failure with the potential to injure persons or cause significant downtime. • Record significant geological features on the shift report. • Check sufficient materials are available and expedite if necessary. • Check that equipment used for strata control is in operating condition. • Direct the installation of additional strata control support if deemed necessary. • Comply with any other requirement of the principal hazard management plan for strata instability for this function

Workers involved with strata control	• Work in accordance the requirements of the principal hazard management plan for strata instability which includes the installation or removal of strata control support or the installation of monitoring devices. • Be aware of and fully understand any TARP that applies to your work. • Check the condition of strata before removing it or supporting it and periodically check during your work. • Install additional strata control support if deemed necessary. • Advise supervisors when abnormal conditions are encountered. • Cease production and withdraw to a safe location in the event of a major fall of strata and immediately notify the supervisor. • Comply with any other requirement of the principal hazard management plan for strata instability for this function
Training Manager	• Ensure training in accordance with the requirement of the principal hazard management plan for strata instability. • Maintain records of training. • Comply with any other requirement of the principal hazard management plan for strata instability for this function

APPENDIX C – OTHER RELEVANT INFORMATION

Codes of Practice

- *Code of Practice: Work Health and Safety Management System, Safe Work Australia*
- *Code of Practice: How to Manage Work Health and Safety Risks, Safe Work Australia*
- *Code of Practice: Work Health and Safety Consultation, Co-operation and Co-ordination*

Other publications

- Australian Coal Association Research Program's –Final Report – Establishing the Strength of Rectangular and Irregular Pillars – C5024
- UNSW Pillar Design Procedure – RR001 research Release No.1 – June 1995
- Work Safe Australia - code of practice for work health and safety consultation.
- Work Safe Australia - code of practice how to manage work health and safety risks
- MDG-1005-Manual-on-pillar-extraction-in-NSW-underground-coal-mines-part-1-of-2
- MDG-1005-Manual-on-pillar-extraction-in-NSW-underground-coal-mines-part-2-of-2
- Roadway and Pillar mechanics Workshop – Stage 2 – Design Principles and Practice UMRC9810/2