Guideline for Inrush Hazard Management

MDG 1024

Produced by Mine Safety Operations Division, New South Wales Department of Primary Industries

April 2007

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

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PUBLISHED APRIL 2007

First Published August 1998

Revision Dates: February 2007

ACKNOWLEDGEMENTS

The constructive evaluation and input provided by the NSW Inrush Working Committee is gratefully acknowledged in the development of this Guideline. The committee consisted of the following members:

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The February 2007 review was conducted by Ian Anderson and other officers of NSW DPI.

FOREWORD

This is a Published Guideline. Further information on the status of a Published Guideline in the range of OH&S instruments is available through the NSW Department of Mineral Resources – Mine Safety, Legislation Update Number 2/2001. The range of instruments includes:

- Acts of Parliament
- Regulations made under the Acts
- Conditions of Exemption or Approval (*Coal Mines*)
- Standards (AS, ISO, IEC)
- Approved Industry Codes of Practice (under the OHS Act, Part 4)
- Applied Codes, Guidelines or Standards (under clause 14 of the Coal Mines (General) Regulation 1999)
- Published Guidelines
- Guidance Notes
- Technical Reference documents
- Safety Alerts

The principles stated in this document are intended as general guidelines only for the assistance of owners and managers in developing an Inrush management Plan. Owners and managers should rely upon their own advice, skills and experience in applying safety standards and systems to be observed in individual workplaces.

The State of New South Wales and its officers or agents including individual authors or editors will not be held liable for any loss or damage whatsoever (including liability for negligence and consequential losses) suffered by any person acting in reliance or purported reliance upon this Guideline.

The Department of Primary Industries – Mine Safety Operations has a review time set for each Guideline that it publishes. This can be brought forward if required. Input and comment from industry representatives will be much appreciated. The Feedback Sheet at the end of this document can be used to provide input and comment.

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Purpose and Scope

The purpose of this guideline is to assist the mine in managing hazards related to inrush. It supports Clause 33 of the NSW Coal Mine Health and Safety Regulation 2006, but should only be seen as one source of assistance, which might be supplemented by other mine initiatives or other sources of information.

This document should not be seen as a technical guide or checklist of actions that a mine should take to prevent major inrush events. It should be used as a resource to help to derive the mines inrush hazard management approach.

Also it is important to note two other points:-

1. This document is intended to address all inrush hazards, including those related to undersea workings.
2. This document is intended to primarily address first workings only, because secondary workings require other processes as per Clause 88 of the NSW Coal Mine Health and Safety Regulation 2006.

The document is written in a risk management process format, beginning with development of a clear and credible image of the nature and magnitude of the relevant hazard(s). This is followed by risk assessment guidance and overviews of some possibly relevant controls for the various inrush hazards. Guidance is also given about systems areas such as documentation, accountabilities, change and auditing.

It is envisaged that these guidelines would be used to develop an Inrush management Plan.

Glossary

Aquifer – An underground geological formation, or group of formations, containing useable amounts of groundwater that can supply wells and springs.

Competent person – a person who has acquired through training, qualification, or experience, or a combination of these, the knowledge and skills qualifying that person to operate the particular equipment to the current industry competency standard.

Dip – The angle at which a bed, stratum, or vein is inclined from the horizontal, measured perpendicular to the strike and in the vertical plane.

Emergency Management System - As referred to in the Coal Mine health and Safety Regulation 2006

Goaf – a. That part of a mine from which the coal has been worked away and the space more or less filled up with caved rock.
b. Workings which are not used and not directly ventilated, considered waste workings.

Groundwater – Water occupying openings, cavities and spaces in rocks. There are two main sources of such water, juvenile water which rises from a deep magnetic source and meteoric water which is due to rainfall having soaked into the underlying rock..

Impoundment Area / Impoundments – Areas containing or confining water or materials that may flow when wet.

Inrush Control Zone – As referred to in the Coal Mine Health and Safety Regulation 2006.

Inrush Management Plan – As referred to in the Coal Mine Health and Safety Regulation 2006.

Risk – the chance of something happening that will have an impact on objectives.

Risk assessment – the overall process of risk identification, risk analysis and risk evaluation.

Risk management – the culture, processes and structures that are directed towards realising potential opportunities whilst managing adverse effects.

Rock Head – The point closest to the surface where solid rock exists.

Seal - a. To secure a borehole or excavation against cave-ins and flowing or escaping gas or liquids by the use of cement or other sealants.
b. To secure a mine opening against flowing or escaping gas, air or liquids by injecting grout, by coating rock surfaces with gunite or by erecting rock, concrete, wood or cloth barriers.
c. A short length of roadway that has been tightly filled with concrete, brickwork, sand or other material to close off an area against fire, gas, or water. In the case of a fire, the seal cuts off the air supply and also prevents noxious fumes given off from reaching other parts of a mine. Also called stopping.

Septum – A partition separating two cavities or two spaces containing less dense material..

Workings – The entire system of openings in a mine. Typical usage restricts the term to the area where the coal, ore or mineral is actually being mined.

References

Legislation

- Coal Mine Health and Safety Act 2002
- Coal Mine Health & Safety Regulation 2006

Australian Standards

- AS/NZS 4360 – Risk Management
- AS/NZS 9000 – Quality Management Systems – Fundamentals and Vocabulary

NSW Department of Primary Industries – Mine Safety Publications

- MDG-1010 Risk Management Handbook for the Mining Industry

General

Accountabilities & Responsibilities

Clearly there is accountability for managing inrush hazards under Duty of Care requirements, as well as the Regulations.

In addition, if there is an inrush hazard, the mine should use the results of the risk assessment and control identification to define roles and accountabilities for relevant persons across the site. Remember that accountabilities should exist in all four (4) control areas, prevention, monitoring, first response and emergency response.

It may also be important to define when the accountabilities apply since hazards may be related to proximity of the operations to the inrush source.

Careful examination of required competency should be included in assignment of responsibilities, including such issues as 24-hour cover.

Documentation Requirements

Best safety practice, as well as the regulations, requires the following information, documentation and distribution.

1. The Inrush Risk Assessment must be documented.

2. If the manager of mining engineering decides that it is not practical to remove or otherwise render harmless a potential source of inrush, the reasons for that opinion must be documented (possibly included in the Risk Assessment controls discussion).

3. The Inrush management Plan must be documented.

4. The Inrush management Plan document must be submitted to the NSW Chief Inspector and an Industry Check Inspector. Any revision of this document must also be sent to those persons.

5. Advice of proposed work within the inrush control zone must be documented, including the reasons for forming the opinion that an inrush will not occur. The advice may include "special systems of working" and, if the inrush hazard is in same seam, a scheme of protective drilling.

The advice of proposed work must be submitted to the Chief Inspector at least one month before commencement of work where the potential inrush source cannot be inspected, otherwise the period is at least one week.

Change Management

Like any critical mining document or plan, changes to the inrush prevention system must be controlled and, if required, systematically addressed. Some changes may be major, such as planning to start secondary workings, or minor, such as a change in a relevant person's accountability.

Typical documentation control mechanisms suggested by the AS 9000 Quality series documents are quite adequate.

Employee representatives must also be consulted regarding revision.

Subsequent to the original inrush risk assessment, the mine may identify a possible requirement to mine inside the inrush control zone.

Audit / Review Requirements

There should be a defined review and audit framework included in an Inrush management Plan.

The following should be considered in that part of the System:

- Review of the Inrush management Plan by an independent expert, before application.
- Full audit of the system after application to check compliance and take required action.
- Investigation of any event causing an inrush or having the potential to cause an inrush using the system to identify weaknesses.
- Regular review of the system to ensure it is still correct / relevant for the hazard.
- Review of the system should drilling or other information indicate that any of the significant assumptions about the inrush hazards were incorrect.

The purpose of reviewing or auditing is basically two-fold, to ensure the System is correct and to ensure the System is in place.

Definitions and Descriptions of Inrush Hazards

An inrush hazard involves the existence of significant quantities of water or other fluid material, any material that flows when wet or flammable or noxious gases, all possibly under pressure, that can swiftly flow or release into or within an underground coal mine.

Note: Outburst hazards are not included in this definition of inrush hazards.

An inrush can arise from four sources.

1. **The seam being mined**
2. **Other seams or strata**
3. **The surface**
4. **Non-mining, man made structures**

Mine plans are key sources of information for many inrush hazards. There are two types of typical plan errors that should be considered, errors in information about other old or current workings and errors in your own workings information.

Following is a description of the potential hazards from the above four (4) listed inrush sources.

1. The seam being mined

There are at least three types of inrush hazards that should be considered in the seam being mined. Hazards from:-

1.A: Abandoned mines
1.B: Workings of adjacent current mines
1.C: Existing workings of your own mine

1.A. Inrush hazards from abandoned mines whether underground or open cut, coal or other, include hazards such as;

- an old adjacent underground mine, not on the current lease,
- an abandoned mine where the barrier has been breached and subsequently plugged,
- a mine on the lease, abandoned before or since acquisition of the current lease,
- an abandoned adjacent surface mine, on or off the lease,
- abandoned single or multiple seam high wall mining operations of an adjacent open cut mine, or
- an adjacent underground mine with incorrect seam correlation.

These hazards can exist in recorded or unrecorded workings.

1.B. Inrush hazards from workings of adjacent current mines, whether underground or open cut, coal or other, including hazards such as;

- goaf or other inaccessible areas of an adjacent mine,
- areas of accumulated water or liquid materials in accessible areas,
- high wall mining operations of an adjacent open cut mine, or
- a discontinued part of an adjacent open cut mine.

These hazards can exist in recorded or unrecorded workings.

1.C. Inrush hazards from existing workings of your own mine, including hazards such as;

- goaf or other inaccessible areas of the mine,
- areas of accumulated water or liquid materials in accessible areas,
- impoundment areas including dams,
- unrecorded roadways or drivages, or
- other openings such as shafts, drift sumps, etc.

2. **Inrush hazards from other seams or strata, either above or below the working seams, including hazards such as;**

- aquifers, buried channels and other natural sources of ground water,
- workings in seams above or below the seam being mined on the same lease, or
- workings in seams above or below the seam being mined in an adjacent mine, including overlapping leases.

These hazards can be affected by faults, geological structures, bore wells or drainage holes, acting as conduits.

3. **Inrush hazards due to surface sources including hazards such as;**

- tidal waters, oceans and connections to the ocean,
- surface creeks, rivers, ponds, lakes,
- surface impoundments or reservoirs, or
- man made or natural unconsolidated material that could flow when wet.

These hazards can be affected by faults, geological structures or active drainage holes, acting as conduits. Percolation should also be considered, as well as the magnitude of hazards affected by rainfall using a 1-in-100 year event as a guide.

4. **Inrush hazards from non-mining, man made structures, including hazards such as;**

- exploration boreholes, water boreholes or gas drainage holes,
- shafts, wells,
- pipelines, tunnels,
- underground repositories, or
- quarries and other earthworks.

Identification of an Inrush Hazard

Identification of inrush hazards from the previous list of potential hazards (see Definitions and Descriptions of Inrush Hazards) involves a process of gathering and analysing information. The following charts and lists of actions are intended to assist in identification of inrush related hazards.

There are three flow charts that illustrate examples of potential steps to be taken for optimal identification of the existence of an inrush hazard. These three charts cover inrush hazards from abandoned mines, current workings of an adjacent mine and existing workings of your mine

Following these three charts there are three lists of actions for the remaining inrush areas, hazards in other seams or strata, from the surface and from non-mining, man-made structures.

Again, these charts and action lists should be seen as helpful guidance to assist the mine in developing their own method to identify any inrush hazards.

The option of drilling to confirm potential inrush hazards is included in some of the following charts where other means of clarifying uncertainty are not adequate. Should the mine decide that drilling is required to confirm position and/or check for unsuspected sources of inrush the following information should be considered.

Scheme of protective drilling

Historically, small diameter limited length boreholes drilled directly from the working face and rib line (either by hand held or small portable drill rigs) have been employed when approaching potential inrush sources. Typically these holes were not drilled through standpipes, and sealing, if it was to occur at all, was by timber plugs.

With the need for continuous advance in development headings and the necessity to drill through standpipes to ensure positive control of any inrush source, it is in general no longer appropriate to employ these traditional drilling concepts. Rather, survey controlled in-seam longhole drilling, through standpipes set in off-face drives, needs to be employed. Such holes, often extending to 1km beyond their start are necessary to prove and protect against potential inrush hazards. Such long holes may be employed to positively locate suspected workings by direct holing or to protect against inadvertent holing through proving ground to be free of unrecorded workings.

The scheme of protective drilling should:

- take into account the actual or possible pressure, volume, toxicity or explosive potential of the fluid material being drilled towards;

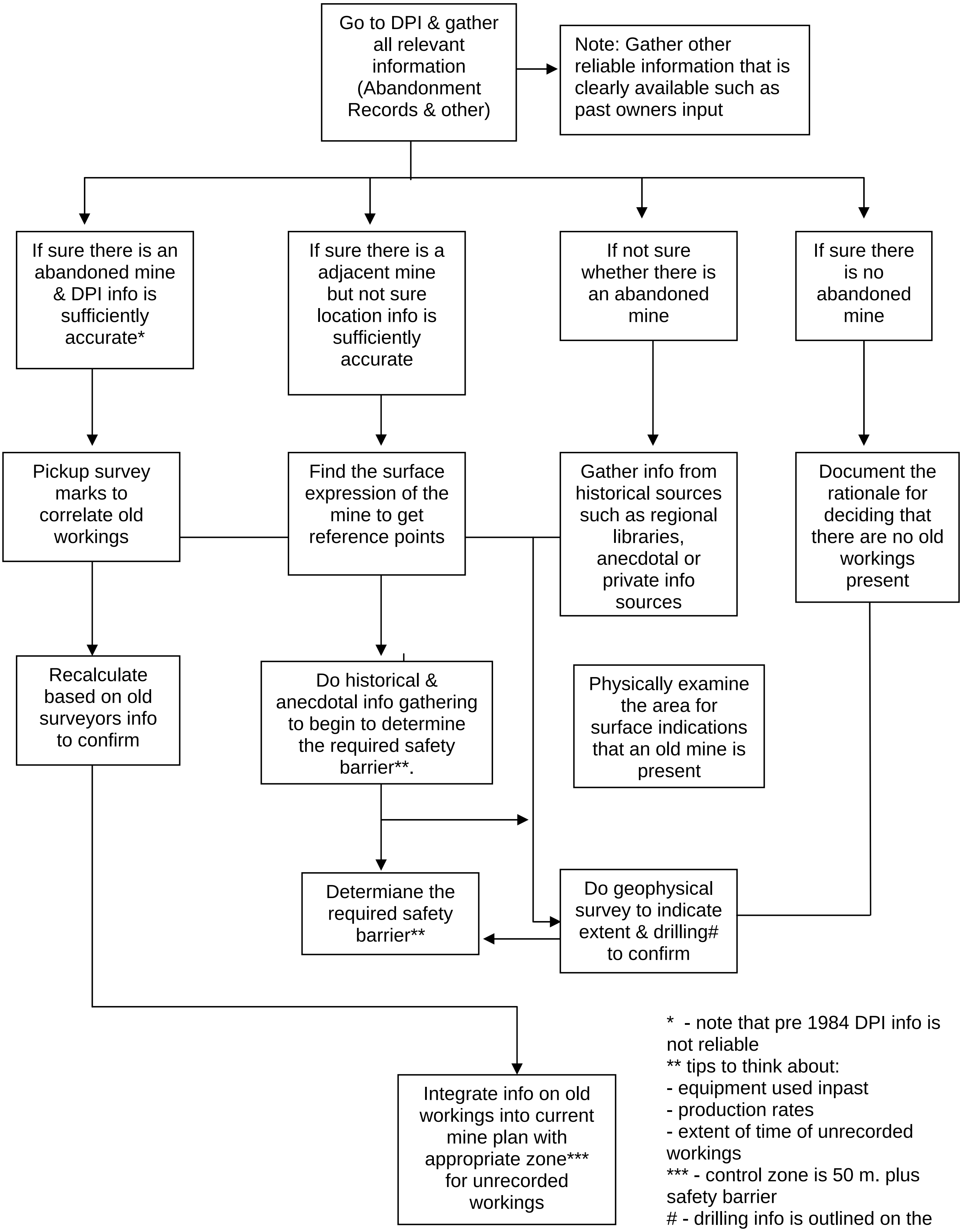
- include protection against the uncontrolled release of water or gas and methods to permanently fill and seal drill holes if the need arises; and

- include adequate training for persons involved in giving effect to the scheme.

Finally, note that an important principle of risk management involves erring on the conservative side when considering major hazards.

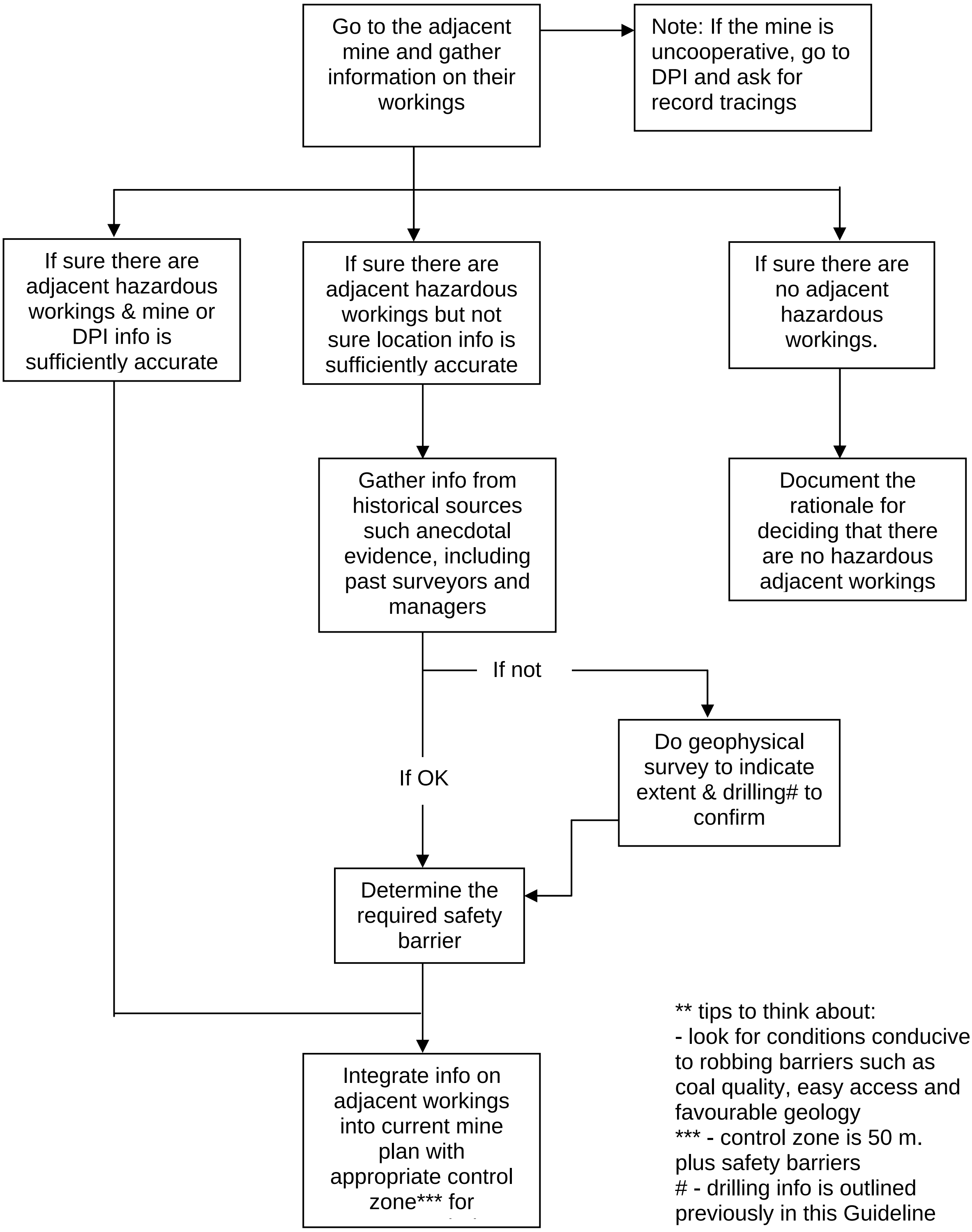
In other words, if the mine is not reasonably certain an inrush hazard does not exist, the mine should manage as if the hazard does exist

Example of how to identify the existence of an Inrush Hazard from abandoned mines

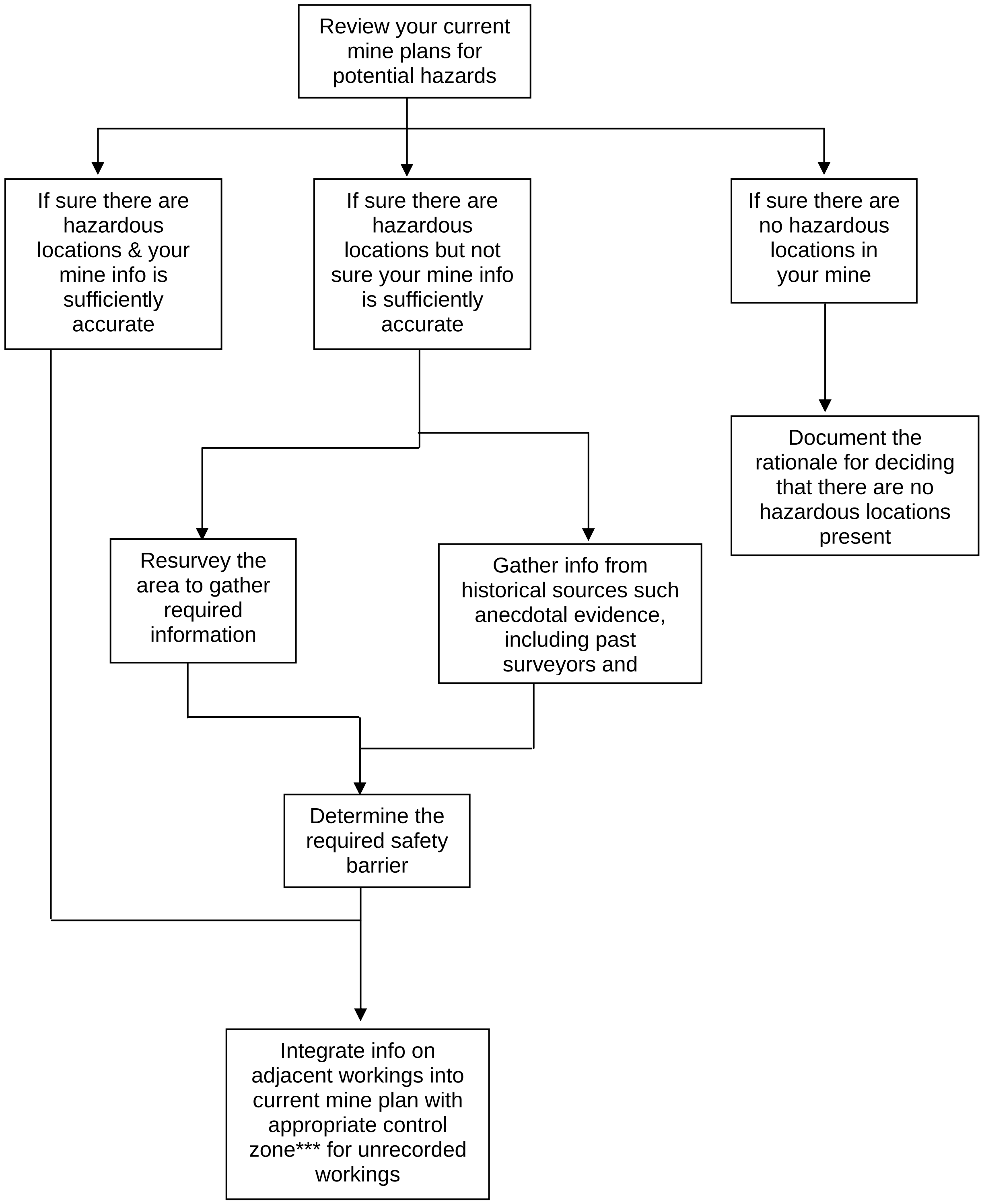


* - note that pre 1984 DPI info is not reliable
** tips to think about:
- equipment used inpast
- production rates
- extent of time of unrecorded workings
*** - control zone is 50 m. plus safety barrier
# - drilling info is outlined on the previous page of this Guideline

Example of how to identify the existence of an inrush hazard from workings in an adjacent current mine



Example of how to identify the existence of an inrush hazard from existing workings in your own mine



Example of how to identify the existence of inrush hazards in other seams or strata

There are several types of sources of inrush hazards from other seams or strata, above or below the working seam:

- For hazards from other seams or strata on an adjacent abandoned lease - see the previous example related to abandoned mines.

- For hazards from other seams or strata on an adjacent operating lease - see the previous example related to current working of existing mines.

- For hazards from other seams or strata in your mine - see the previous example related to existing workings in your own mine.

In order to look for aquifers, buried channels and other sources of natural water;

- check mine history, including mine exploration and development phase,
- check if any hydrology surveys are available for the area, and
- consider known faults, geological structures, boreholes and drainage holes, which may act as conduits.

Remember to consider water sources both above and below the working seam.

If no hazard is identified, document the rationale for deciding that no hazard is present.

If an inrush hazard in seam or strata above or below the working seam has been identified, determine the safety barrier.

Finally, integrate the information into the current mine plan with appropriate control zone.

Example of how to identify the existence of inrush hazards from the surface

There are several types of sources of inrush hazards from the surface (see previous section - Definitions and Descriptions of Inrush Hazards). All of these hazards should be accessible and definable. Remember to consider the 1 in 100 year rainfall or storm event.

Establish the solid rock head between the surface water or materials and evaluate the impact of the mining method to determine the septum.

If no hazard is identified, document the rationale for deciding that no hazard is present.

If an inrush hazard from the surface has been identified, use a risk assessment technique to determine controls and acceptability before proceeding with mining.

Example of how to identify the existence of inrush hazards from non mining, man made structures

There are several types of sources of inrush hazards from non-mining, man made structures (see previous section - Definitions and Descriptions of Inrush Hazards).

In order to look for these types of inrush hazards go to public authorities such as;

- Department of Water Resources,
- Department of Public Works,
- Councils, and
- Public Utilities (water, sewage, electrical supply).

If no hazard is identified, document the rationale for deciding that no hazard is present.

If an inrush hazard from a non-mining, man made structure has been identified, determine the safety barrier.

Finally, integrate the information into the current mine plan with appropriate control zone.

How to Identify the Magnitude of an Inrush Hazard

It is critical that the mine not only identifies the existence of an inrush hazard but also the magnitude. The magnitude of a hazard is the size, nature, energy content and description of the mechanism by which it might manifest.

For example, water-filled old workings might be identified as a relevant inrush hazard. However, before moving on to assessing the risks, the mine must try to understand the amount of water in the workings, the purity / contents of the water, the pressure and the possible pathways that might exist between the water and the mine workings.

If the area is accessible, access the area to identify the nature of the hazard (water, gas and/or materials) and the volume and relative level in relation to the mine operations. Estimate the pressure.

If the area is not accessible either drill into the area (note: apply drilling precautions for pressure release) or assume the worst case. For example, a worst case situation might be flooding to the water table with water and dissolved gases. Estimate the volume and pressure in the worst case condition.

For hazards from the surface or other inrush hazards affected by weather, identify the 1-in-100 year flood event levels.

For hazards from non-mining man made hazards, gather information on the magnitude from the relevant authority;

- Department of Water Resources,
- Department of Public Works,
- Councils, and
- Public Utilities (water, sewage, electrical supply).

Again, like identification of the hazard, establishing the magnitude involves erring on the conservative side. In other words, if **the mine is not reasonably certain of the magnitude, the mine should assume maximum potential.** Maximum potential means the worst case considering maximum volume, impurity, pressure, etc.

The Inrush Risk Assessment Process

Once the existence and magnitude of inrush hazards have been identified and any assumptions defined, the mine can formally assess the relevant risks and establish an effective prevention and control approach.

The Risk Assessment should follow a process as per Australian Standards and MDG 1010 (identify hazards, assess risks, and define required controls).

A Risk Assessment should be done with a team of competent persons, including appropriate employee representation and, possibly, an external expert. Also, the process should include the viewing of any relevant plans, files or other materials held by the Chief Inspector or the NSW Department of Primary Industries.

The requirements of an Inrush Risk Assessment include the following:-

1. Identification of all possible significant inrush hazards

2. Identification of the nature and magnitude of the identified inrush hazard (if not clear the exercise must define assumed hazard, rationale and basis for assumption, including methods/information used to investigate the hazard)

3. Identification of specific loss scenarios for all inrush hazards considering planned or expected mining operations that will be affected or that will affect the hazard

4. Assessment of risks considering conservative probabilities and reasoned worst case position, including single or multi-fatality consequences

Note: Further sections of this document include examples of controls in these four areas.

5. Control identification for unacceptable risks including:

    - Prevention - controls to prevent an inrush event.
    - Monitoring - controls to monitor status of inrush hazard to identify changes.
    - First Response - controls to respond to an inrush event in the early stages.
    - Emergency Response - controls to respond to a major inrush event.

6. Documentation of the above information as per MDG 1010

7. Conversion of the risk assessment results into a useful mine Inrush management Plan.

The inrush risk assessment report is not the mines Inrush management Plan. However, it should be referenced in the system and also possibly put in the appendices of the system.

CONTROLS FOR PREVENTION

Prevention Controls are intended to avoid an inrush event by reducing its likelihood.

The Regulations require that the manager ensure the competency of persons required to perform duties in this or any other part of the plan.

There is an accepted approach to determining the type of prevention control that is most effective for any unacceptable risk. This approach involves five types of controls:

1. Controls that eliminate the hazard by removing the damaging energy (water, materials, etc) .
2. Controls that reduce the magnitude of the hazard (less water, less pressure, etc) .
3. Controls that reduce the likelihood of the event through engineering or "hard" barriers.
4. Controls that reduce the likelihood of the event through procedural or "soft" barriers.
5. Controls that reduce likelihood through warnings.

The effectiveness of these controls decreases from the top to the bottom of this list.

Note: The use of controls four (4) and five (5) alone are not considered to be adequate for major hazards.

Draining or otherwise removing the inrush hazard is clearly the most effect way to prevent inrush. This option is strongly recommended. The Regulations require that a manager of mining engineering who decides that it is not practical to drain or otherwise remove an inrush hazard must document the reasons for forming that opinion. This information should be included in the risk assessment document.

Following are examples of controls, intended to help the mine discuss options and determine effective controls for the specific situation. They are not a required set of controls for inrush.

1. For inrush hazards in the seam being mined such as abandoned mines, workings of adjacent current mines or existing workings of your own mine consider the following.

   - Draining old workings (including ventilating where appropriate) installing dams, seals, plugs, etc.
   - Establishing and maintaining a solid coal barrier of at least 50 metres between the workplace and the assessed worst case position.
   - Designing and justifying any plan to work within the 50 metre solid coal barrier which then becomes the control zone as per the regulations.

2. For hazards in other seams or strata consider the following:

   - Draining off the hazard.
   - Plugging or otherwise isolating shafts, drifts, staples, boreholes and other mining connections.
   - Sealing or otherwise isolating potential geological conduits.
   - Maintaining a septum of at least 50 metres of solid strata between the workplace and the assessed worst case position.
   - Designing and justifying any mine plan to work within the 50 metre solid strata septum which then becomes the control zone as per the Regulations.

3. For hazards from the surface consider the following:

   - Where appropriate, draining or diverting hazards.
   - Isolating surface openings, including subsidence cracks and other types of fissures, from potential water inrush.
   - Sealing or otherwise isolating potential geological conduits.
   - Sealing or otherwise isolating potential man-made conduits such as boreholes.
   - Maintaining adequate thickness of solid strata of at least 50 metres between the workplace and the assessed worst case position.
   - Designing and justifying any mine plan to work within the 50 metre solid strata cover which then becomes the control zone as per the regulations.

4. For hazards from non-mining man made hazards consider the following:

   - Draining where appropriate.
   - Detection and isolation of man-made potential conduits.
   - Sealing or otherwise isolating potential geological conduits.
   - Maintaining a septum / barrier of at least 50 metres of solid strata between the workplace and the assessed worst case position.
   - Designing and justifying any plan to work within the 50 metre solid septum/barrier which then becomes the control zone as per the regulations.

Where relevant in all four (4) of the above, design effective drainage systems taking into account factors such as:

- Volume to be drained.
- Timeframe for drainage with respect to mining scheduling and meeting environmental standards.
- In case of draining water, the potential hazard arising from the release of dissolved gases particularly CO_2.
- The hazard potential of residual water / fluid after the drainage.
- The need for an adequate standpipe design for underground de-watering.
- The need for adequate and appropriately placed sump / water standage for underground de-watering and gas monitoring.
- The need for supplementary ventilation when draining gas or water containing dissolved gases.

Also where relevant for the above four (4) hazards, decide whether a minimum 50 metre barrier is adequate taking into account factors such as:

- Pressure, quantity and nature of hazard.
- Long term stability of the barrier under worst case natural and induced stress regimes.
- Presence of geological weaknesses likely to affect the barrier.
- Nature of the roof and floor contacts.
- Seam and strata permeability.
- Seam grade or dip.

Confirm that the barrier size meets the design width by systematically drilling (see previous section on the Scheme of Protective Drilling), supplemented where appropriate by geophysical and geochemical techniques.

Any drilling strategy or other method for confirming barrier size must also be designed to detect major survey errors in plans of old workings or the presence of unrecorded workings.

The inrush risk assessment may identify a possible requirement to work inside the inrush control zone (at least 50 metres between the workplace and the assessed worst case position). This work must be planned and executed in accordance with the requirements outlined in Clause 33(h) of the Coal Mine Health and Safety Regulation 2006.

This section includes the possibility of developing and applying a "special system of working". If such a system is to be developed, a risk assessment on that system should be used for derivation or draft review. Note that the system must include a Scheme of Protective Drilling (see earlier section) if the potential inrush source is in the same seam.

Mining Under The Sea and Other Large Water Bodies

Mining under the sea and other large water bodies (such as lakes, waters impounded by dams, estuaries, large rivers etc) represents a special risk because;

- the potential inrush source is, for all practical terms, inexhaustible,
- should connection between the mine and the sea or water body be made, then control of the inflow of water into the workings is likely to prove impossible, and
- should connection between the mine and the sea or water body be made, it is highly likely that the entire mine will be lost permanently.

The critical issue to be addressed in under water mining is to establish the minimum thickness of solid strata that must exist between the seam roof and the floor of the water body to ensure no connection can develop.

The minimum thickness of solid strata necessary to prevent connection between the mine and the water body will vary from mine to mine and must be determined in every instance.

Factors such as;

- Mining method,
- Geological anomalies,
- Mining height, and
- Roof strata type

amongst others, will need to be assessed in establishing minimum solid strata thickness.

Mining Method

Any underground excavation may influence the permeability of strata lying over that excavation. In general, the wider the excavation the greater the height of deformation or softening that will occur in the roof rock. Deformation (which results from the overlying strata's tendency to deflect or sag into the excavation), will increase the roof strata's permeability.

In first workings, if roadways are adequately supported, the height of deformation may be measured in metres. However should a fall occur, particularly at an intersection, then the height of deformation is substantially increased.

In second workings, that is where goaf caving may or will occur, the height of roof deformation is extended even further. In this instance it is important to note that the height of deformation extends well beyond goafing height. For this reason considerably greater solid strata is required above second workings when compared to first workings.

Additionally in second workings, the impact of surface and sub-surface subsidence must be considered. Extensive cracking in surface and near surface rocks can be associated with mining induced subsidence. The minimum solid strata designed for must ensure that areas of surface/near surface cracking and the zone of deformation above the seam roof never intersect. To achieve this result in practice, an appropriate safety margin must be included within the designed minimum solid strata thickness. Therefore a substantial zone of impermeable strata will exist between the workings and the rockhead.

Geological Anomalies

Any assessment of the height of deformation above the seam and the depth of cracking below the rockhead can be adversely affected by geological anomalies. Features such as faults, dykes, shear zones, igneous plugs etc can link the zone of deformation above the goaf and zone of surface cracking (in the case of first workings), thus negating the zone of impermeable strata created by the design process. Should such a link occur, water from the sea or other surface water body is likely to enter the mine.

A diligent search for geological features capable of linking the rockhead and the workings is required and if found a conservative estimate of their influence must be made. Where such geological features exist it is likely that mining within the zone of influence of the anomaly may have to be curtailed or even abandoned.

Mining Height

In secondary workings the thickness of extraction will influence both the height of deformation above the seam and also the level of surface subsidence. In general, the greater the extracted height the greater the level of surface subsidence and height of roof deformation. Minimum solid strata thickness must be adjusted accordingly. It must be borne in mind that both pillar strength and stiffness (for a given pillar area), will decrease as the height of the pillar increases. Therefore thick seam pillars are more likely to compress than those in thinner seams. This greater level of compression may adversely influence strata deformation and permeability above thick seam pillars.

Roof Strata Type

Typically, laminated strata is more likely to extend the height of deformation than is a more massive strata. "Chimney" type falls are generally associated with laminated strata and instances of such falls extending at least 20m above the seam have been documented in first workings roadways.

Notes of Caution

1. Once a minimum thickness of solid strata has been selected, it is essential that the exact reduced levels of the rockhead under the waterbody and the roof of the seam be determined to ensure that the minimum design thickness of solid strata does in fact exist. The order of accuracy of any method used to determine the reduced levels must be established and applied conservatively to the value of solid strata measured.

2. **It is foolish in the extreme** to dismiss the erosive capacity of water driven by a permanent and substantial pressure head. The capacity of water to scour joints, cracks, etc, has been long established in dam engineering. Any contemplation that a minor inflow of water directly from the sea or other like water body is acceptable should be dismissed immediately.

3. Caution needs to be exercised when assessing standards for mining under the sea and other large surface water bodies, that have been developed in foreign countries. Such standards (for example the U.K. Code of Practice), are based upon the nature of strata existing in those countries and may not be appropriate for strata conditions prevailing in New South Wales.

Approvals Process for Mining Under the Sea and Large Surface Water Bodies

1. First Workings : In General
   Apart from workings under the impounded waters of a dam, no approvals are required under the provisions of the Coal Mine Health and Safety Act and Regulations.

   However, mining will be conditional upon:-
   - The mine being the holder of a valid lease for the subject area, and
   - Mining being conducted in accordance with lease conditions, the Coal Mine Health and Safety Act and associated regulations (including the appropriate dimensioning of coal pillars).

2. Second Workings: In General
   Under the provisions of Clause 88 of the Coal Mine Health and Safety Regulation 2006 the mine must receive Ministerial approval prior to the extraction of pillars and the commencement of longwall mining. Any approval issued will be subject to conditions deemed necessary by the Minister.

3. First Workings : Under The Impounded Waters of a Dam
   Approval from the New South Wales Dams Safety Committee is required in order to mine within the restricted area under and surrounding impounded waters. Any approval will be subject to conditions deemed necessary by the Dams Safety Committee.

4. Second Workings: Under The Impounded Waters of a Darn
   Approval from the New South Wales Dams Safety Committee is required for any second workings. Approvals will be issued as part of the Clause 88 process and will be subject to conditions deemed necessary by both the Minister and the Dams Safety Committee.

Controls for Monitoring

Monitoring Controls are intended to avoid an inrush event by identifying any indication of potential problems, including changes to the hazard, hazard-related conditions or effectiveness of controls.

There are at least three different ways of monitoring major hazards;

- Monitoring the status of the hazard,
- Monitoring the mechanisms by which the unwanted event occurs, and / or
- Monitoring adherence to key controls.

One or more of these three ways may suit a specific inrush hazard.

An example of the former might use a device to indicate a rise or fall in water level. An example of the latter is deputies' reports and operator awareness / reporting.

Following are examples of monitoring controls for the various types of inrush hazard whether in-seam, other seam / strata, surface or non-mining man made hazards.

- If accessible, monitoring the volume of water for unexpected changes
- Monitoring the volume and quality of water entering the mine in relevant areas
- Checking for unrecorded or incorrectly recorded inrush sources with a scheme of protective drilling (see previous section - Scheme of Protective Drilling)
- Competent operator and deputy monitoring for relevant underground conditions that may indicate unexpected proximity to an inrush hazard or a potential inrush event, including reporting and analysing of the information
- Monitoring status / condition of barriers and other key controls to ensure that their integrity is not compromised and they remain effective

Note: Chemical fingerprinting of hazard water for comparison purposes may help to monitor hazard status, as well as identify the nature of a problem.

Controls for the First Response

First Response Controls are intended to reduce the consequences of an inrush event by controlling the event in its early stages when the immediate impacts are still minor. This section is intended to provide advice in this area of inrush hazard management.

Indications of an early stage of major inrush might include the following:
- Obvious changes in water make-up in the mine workings.
- Abnormal / unusual strata behaviour such as roof problems, face / rib slumps, etc.
- Change in water quality.
- Loss of or damage to inrush barriers.
- Significant unexpected decrease in surface or other hazard water.

First response controls can be "trigger" levels built into the monitoring systems mentioned in the previous section. Following are examples of that approach:
- Pre-set alarm levels for water volume monitors (if the water hazard is accessible)
- Pre-set litres / minute flow rate triggers for evacuation of the area until the event has been investigated and the area deemed safe
- Pre-determined conditions or sets of conditions, including barrier problems, for operator and deputy monitoring that require immediate evacuation of the area

It is important to clearly define the circumstances by which persons should be removed from an area that might be affected by inrush.

Remember that a conservative approach is best, especially if the nature and the magnitude of the hazard is not clear or readily discernible.

An example response to potential inrush warnings might include steps such as:

1. Discontinue coal extraction or extension of workings in the affected area until such time as the hazard has been precisely determined and eliminated or otherwise controlled.

2. Inform personnel and prepare to apply the Emergency Management System.

3. Consider the locations of personnel and the possible inrush event. If necessary move personnel to a safe location.

4. Assess the nature of the inrush warning symptoms, position(s) and direction(s) of any inflow(s) - eg. general seepage through the seam or strata above or below the seam; water / gas issuing from discernible conduits such as boreholes, fissures, faults, etc.

5. Secure, as far as practicable, potential conduits in the affected zone, such as boreholes.

6. Notify the Government Inspector, Industry Check Inspector and the Mines Rescue Station of the situation.

7. Consider further activities to address the situation such as the following (Note: These are not listed in sequential or priority order):
   (a) Acquiring additional expertise to assist with determination and control of the situation
   (b) Determining flow rates of water / gas influx and undertaking chemical analysis where indicated
   (c) Determining or otherwise estimating the worst case scenario regarding source, location, pressure and physical magnitude of the hazard.
   (d) Checking mine plans against the known, suspected or potential hazard.
   (e) Determining practicality of draining the hazard or otherwise rendering it harmless.
   (f) Preparing, where appropriate drainage infrastructure to help control the hazard - sumps, pumps, drainage paths, etc.
   (g) Determining the location for and preparation of, where appropriate foundations for bulkheads and dam walls.
   (h) Other activities to return to safe work conditions.

Controls for an Emergency Response

First Response Controls are intended to reduce the consequence of a major inrush event by removing the people from the hazard or hazardous area, as well as taking other action to minimise the consequences.

This section is intended to provide advice in this area of inrush hazard management.

Every mine with a potential inrush situation should ensure that the Mine Emergency System includes information covering a major inrush. This information should be derived by considering the potential location, magnitude and nature (eg. CO_2, water, materials, etc.) of worst case inrush events. The System might include information such as;

- communication requirements,
- assembling underground to egress,
- egress routes,
- refuge locations should egress be blocked,
- use of transport considering inrush conditions, or
- special equipment to assist in egress or rescue, etc.

Of course, personnel must be competent in the Emergency Management System requirements.

Again, remember that a conservative approach is best, especially if the nature and the magnitude of the worst case event is not clear.

An example response to a major inrush event might include steps such as:

1. Call into effect the Mine Emergency Management System (This might include a sequence of actions, some of which are included below).

2. Evacuate from the mine (or relevant part of the mine) all persons other than those essential for dealing with the emergency, where it is deemed safe to do so.

3. Consider the effect of the inrush event on mine systems such as ventilation.

4. Inform the Government Inspector and the Industry Check Inspector of the event and alert the Mines Rescue Station.

5. Where appropriate activate any drainage system installed at the First Response stage or otherwise seek to contain the extent and effects of the inrush / inundation.

6. Secure any relevant bulkheads or dam walls that may have been installed at the First Response stage.

7. Consider further activities to minimise consequence and move toward recovery such as the following (Note: These are not listed in sequential or priority order):

   (a) Determining the likely timing, progression and extent of the inundation based on the available information and an assumed worst case scenario.

   (b) Installing monitoring apparatus to enable remote recording of the status (progress and nature) of the inrush / inundation.

   (c) Preparing mine plans showing likely development and extent of the inrush / inundation.

   (d) Seeking to dissipate the energy of the hazard away from the active mine workings - eg. relieving the hazard into disused workings that are suitably located and disposed.

   (e) Informing and. seeking cooperation of any neighbouring mine that might be affected by or have potential influence on the event.

   (f) Other activities to minimise consequences of the inrush.

Appendix A: Additional information to be supplied with high-risk activity notification

Working within the Inrush Control Zone

The following plans at a scale of 1 in 4000:

1. The proposed workings layout plan, paying particular attention to the location of barriers to be left against impounded waters (whether they be in-seam, in adjacent seams or on the surface).
2. A seam depth of cover isopach plan.
3. A solid rockhead depth of cover isopach plan (if relevant).
4. A seam thickness isopach plan.
5. A seam grade contour plan.
6. A detailed geological seam structure plan, particularly in strata to be left as a barrier.
7. A plan of relevant borehole logs of the strata above the seam to the surface, below the seam and the seam itself. Fine detail for the seam, strata 50m above and strata 20m below will need to be provided. (This should include the written log for these latter areas). Particular attention should be paid to strata that may degrade and/or change nature under the influence of moisture. Consideration should be given to providing relevant X sections for the area, linking several borelogs on the one plan.
8. A plan showing surface features (if relevant, for example shorelines, the extent of surface impoundments or reservoirs etc).
9. A plan showing other seam workings, including those in the same and adjacent seams.

The proposed workings plan, that is Plan1, should be capable of being overlain on Plans 2, 3, 4, 5, 6, 7, 8 and 9.

The following data:

1. Barrier dimension (rib to rib) in metres. This measurement should be the minimum barrier dimension.
2. Barrier mining height in metres. Dimensions here should be from either side of the barrier if they are not the same.
3. The maximum credible pressure head that acts, or could act, upon the barrier in MPa.
4. A conservative estimation of the volume of water (m^3) held within the impoundment that could enter the mine should the barrier fail in any way.
5. A discussion of the nature of strata forming the barrier for example, heavily sheared or cindered or structure affected.

FEEDBACK SHEET

Your comment on this Guideline for Inrush Hazard Management will be very helpful in reviewing and improving the document.
Please copy and complete the Feedback Sheet and return it to:

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How did you use, or intend to use, this Guideline?

What do you find most useful about the Guideline?

What do you find least useful?

Do you have any suggested changes to the Guideline?

Thank you for completing and returning this Feedback Sheet.