OPEN PIT MINING THROUGH UNDERGROUND WORKINGS

GUIDELINE

Department of Industry and Resources

MOSHAB

Mines Occupational Safety and Health Advisory Board

FOREWORD

This Mines Occupational Safety and Health Advisory Board (MOSHAB) Guideline offers advice on the issues that should be addressed when open pit mines are excavated through abandoned underground workings, or in close proximity to current underground workings.

Comments on, and suggestions for, improvements to the Guideline are encouraged. This Guideline will be revised as appropriate.

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1.0 INTRODUCTION

A number of open pit mines in Western Australia (WA) are mining orebodies that have previously been mined by underground methods. There are hazards with high risk potential which develop where open pit mines approach and then progressively mine through underground workings.

These hazards in the open pit include:

- sudden and unexpected collapse of the open pit floor and/or open pit walls;
- the loss of people and/or equipment into unfilled or partially filled underground workings;
- loss of explosives from charged blast holes that have broken through into the underground workings;
- overcharging of blastholes where explosives have filled cavities connected to the blasthole;
- risk of ejecta (flyrock, etc) from cavities close to the pit floor and adjacent blast holes, particularly when explosives have entered the cavity from the blasthole during charging and the loss is not detected.

In general, the above hazards are significantly increased when the underground workings have not been backfilled with waste rock, sand fill, etc. As these hazards are not generally evident during normal open pit mining operations it is necessary to take additional measures to better define their nature and extent. Some of these measures are discussed in **section 5**. Once the relevant hazards have been adequately defined the mine operator should put in place a range of controls to mine safely through the underground workings. A number of these controls are discussed in **section 6**.

In addition to the above hazards, when open pit mines approach currently operating underground mines, the potential hazards may include:

- flooding of the underground workings;
- instability of the open pit walls and surrounding surface areas;
- adverse effects on the underground mine ventilation system.

This guideline primarily addresses hazards associated with open pit mining through abandoned underground mine workings. Some of the additional hazards associated with open pit mining through currently operating underground mine workings are summarized in **Appendix A**.

2.0 LEGISLATIVE REQUIREMENTS (WA)

The **Mines Safety and Inspection Regulations 1995** includes a provision (**Regulation 13.8**) relating to surface mining operations where mining is being conducted through or in proximity to underground mine workings.

> Geotechnical considerations
>
> 13.8. (3) Each responsible person at a mine must ensure that appropriate precautions are taken and written safe working procedures are followed if open pits are excavated through abandoned underground workings, or in close proximity to current underground workings.
>
> Penalty: See regulation 17.1.

3.0 HAZARD IDENTIFICATION

Knowledge of the previous mining history of the area to be mined will be of primary importance in determining the likelihood of abandoned underground workings being present below the open pit. A thorough review of previous mine plans is essential prior to any open pit development. The validity of old underground mine plans should be checked diligently, particularly if they are abstracted or copied from originals.

A review of underground workings should be part of the design and planning of the open pit to ensure, as far as reasonably practicable, that:

- all known underground workings are marked clearly on all working mine plans and the plans rechecked;
- there is a recognition that the rock mass surrounding the underground workings may be highly variable in strength and potentially unstable;
- a three dimensional model of underground workings is developed and used in all mine design, planning and scheduling.

It is essential that all plans are updated following all phases of exploration to ensure that the revised outlines of the actual extent and shape of underground workings are recorded.

A further aspect requires a cautious approach. Tributors may have carried out further work in old gold mines, which may not have been recorded on the closure plans lodged by the mine before tribute mining took place.

Where it is likely that underground workings could be of large dimensions and extended in length and depth, or where no previous plans are available, it may be necessary to carry out specific investigations to confirm the location of the workings. Some of the methods that may be used for this purpose are briefly discussed in **section 5**.

4.0 MAKING THE HAZARD VISIBLE

All areas of a working bench or flitch that are likely to be underlain by underground workings must be clearly marked and access to this area must be controlled by a specific set of procedures. These procedures should specify the personnel responsible for monitoring and marking out the hazardous areas. Every bench or flitch should be clearly marked with the projected excavation outline as mining progresses downward through the underground workings.

The marking of areas potentially underlain by underground workings must involve a clear method of identifying the potential hazard. If coloured flagging tape is used, a specific colour – preferably visible in both day and night conditions - should be used solely for this purpose. Steps should be taken to ensure that hazardous areas are adequately marked at all times. Damaged or displaced flagging tape should be immediately replaced. All employees must be informed as to the purpose of the marking or flagging tape.

Care should be exercised in the location of the marked areas. Allowance should be made for the uncertainty in the precise position of the underground workings and any potentially unstable ground surrounding the underground workings. In short, an extra margin of safety should be allowed in the separation of permissible work areas from suspect zones.

5.0 RISK ANALYSIS

5.1 Determining the extent of underground workings

A number of detection methods are available which may be used to confirm the lateral extent and shape of underground workings prior to mining, including:

- probe drilling[1];
- geophysical techniques – including seismic, resistivity, conductivity, and gravity methods;
- ground probing radar;
- laser based electronic distance measurement (EDM) surveying methods;
- closed-circuit TV cameras lowered through probe holes;
- where practicable, actual physical inspection and survey.

Probe drilling is the most widely applied technique to delineate the detailed geometry of underground workings in WA. Remote sensing techniques (ie geophysical techniques and ground probing radar) have been used with varying degrees of success, with individual techniques having limitations depending on the nature of the local geological conditions. Ground probing radar has been used with limited success to detect voids below open pits in WA. Remote sensing techniques are not universally applicable and even when successful, require some level of confirmatory drilling.

5.2 Probe drilling procedures

Site specific written probe drilling procedures are essential. These procedures should specify the following:

- the type of drilling rig to be used and the provision and use of any special safety precautions, eg safety lines, remote controls, communications procedures, refuelling procedures, maintenance;
- the training requirements for persons operating drill rigs used for probe drilling purposes;

[1] Probe drilling should be carried out only on ground determined to be secure. Information obtained from exploration drilling, or grade control and blasthole drilling, may be of assistance when determining the shape and extent of underground workings.

- the procedures to be followed when working or drilling within a marked area that may be underlain by underground workings; the person responsible for approving entry to a marked area should be identified;
- the procedures to be followed when marking out the proposed probe drilling pattern;
- the sequence in which drilling should proceed – drilling operations should proceed from known safe ground towards the anticipated underground workings, see **Figure 1**;
- any equipment, eg tapes, inclinometers, etc required for the drilling activities;
- the capability to drill steeply dipping holes to determine a floor pillar thickness (measured vertically) is generally available; however, it may be necessary to drill shallow dipping holes to determine a rib pillar width (measured horizontally) in the walls of an open pit;
- the requirement for and method of completing any logging sheet to record the result of the drilling operations; eg driller, hole number, void depth, void size, descriptions of the ground conditions encountered, types of material encountered, drilling difficulties;
- the procedures to be followed when:
  - (a) difficulties occur in completing the hole to its planned depth;
  - (b) workings (either open or filled) are intersected during the drilling of a hole;
  - (c) workings are intersected at or less than the minimum stable floor pillar thickness or width (as determined in section 6);
  - (d) other potential hazards are intersected, eg gases, water, etc;
- the minimum and maximum probe hole drilling depth, angle and spacing; these should ensure that workings of hazardous magnitude do not remain undetected, eg ore passes, etc;
- the procedures to be followed when other personnel are working adjacent to any marked area when drilling is in progress, eg surveyors, samplers, maintenance crew, etc;
- special requirements or restrictions on carrying out maintenance work on the drilling equipment within a marked area; (ordinarily no maintenance work should be carried out within a marked area).

6.0 RISK CONTROL

6.1 Introduction

The control measures that are available to eliminate or minimise the risk of unexpected pit floor and/or wall collapse include:

- leaving a pillar of adequate dimensions between the current working bench or flitch and the underground workings;
- placing fill materials into the underground workings;
- restricting work to areas clear of the suspect location, with an adequate margin of safety;
- blasting waste rock in the pit floor into voids, followed by further back filling to stabilize the area.

6.2 Determination of adequate pillar dimensions

In all open pit mines where there is a risk of intersecting underground mine workings, appropriate studies must be carried out to determine the minimum stable pit floor pillar and/or rib pillar dimensions. The minimum pit floor pillar thickness is defined as the minimum rock cover, measured vertically, above the highest point of the underground workings which provides an acceptable factor of safety against floor pillar failure during all mining activities. The minimum rib pillar width is defined as the minimum rock and/ or soil barrier, measured horizontally, between open pit walls and adjacent underground workings which provides an acceptable factor of safety against wall failure.

The overall dimensions of the pillar, ie length, width (measured horizontally) and thickness (measured vertically) should be taken into account in any analysis of stable pillar thickness. Consideration should also be given to the appropriate factor of safety when selecting pillar dimensions. The factor of safety selected should be commensurate with the level of the risk posed by the extent of the underground workings and the nature of the rock mass.

The determination of the stable pit floor pillar thickness and/ or rib pillar width should be the result of a geotechnical engineering assessment in which specific attention is paid to:

- orebody geometry, particularly orebody dip and orebody width;

- the likely modes of failure of the stope crown pillar or floor pillar, whether controlled by, or independent of, geological structure;
- the likely modes of failure for the immediate hangingwall and footwall rocks whether controlled by, or independent of, geological structure;
- the potential accumulation of water in the open pit due to localised ponding via surface runoff from the surrounding catchment area and/or incident rainfall within the open pit perimeter;
- the loads imposed by equipment or stockpiles on the floor pillar;
- rock mass strength and/or general competence of pillar and wall rocks;
- "worst-case" geotechnical conditions with particular emphasis on structural geological features (planes of weakness), groundwater, variations in rock strength and their likely impact on the stability of the pit floor or rib pillars;
- the influence of open pit blasting on the integrity of the pillars;
- the relationship of pillar thickness to the width and strike length of stoped areas.

The adopted stable pillar thickness or stable pillar width will vary both within an individual site and from site to site, to reflect the extent of the hazard, the variation in controls on pillar stability, the range of geotechnical conditions, together with the extent and dimensions of stoping. The planned cut-back of an open pit wall may produce a situation where the stable rib pillar width that previously existed is reduced to unacceptable dimensions.

6.3 Open pit mining issues

Conventional open pit mining methods may need to be modified when mining above or through abandoned underground workings, when:

- mining through floor pillars smaller than the minimum stable thickness (the use of remote control of drilling and explosive charging operations may be required);
- backfilling narrow stopes (experience has shown that narrower stopes are potentially more difficult to backfill due to material "hanging up" or bridging across the stope walls);
- backfilling large stopes (backfill should not be relied upon as the sole means of providing safe working conditions);

- considering the use of mass blasting methods[2];
- mining through pillars and stopes has the potential to destabilise open pit walls[3]. This may have adverse consequences for mine infrastructure within or adjacent to the pit.
- maintaining the minimum safe working width on either side of stoped areas, particularly in the lower sections of narrow pits where mining widths may be restricted;
- controlling access to, and movement on, each bench or flitch, particularly where previous stoping may be continuous along strike.

6.4 Safe working procedures

A flow chart illustrating the key activities that need to be considered when an open pit is mining through abandoned underground workings is shown in **Figure 2**. This chart should be used as a basis for framing site-specific procedures, and the review and updating of all mining plans to ensure that an accurate model of the geometry of underground workings is maintained at all times.

Before commencing any open pit mining near or through abandoned underground workings an appropriate set of safe working procedures should be established that address a range of issues, including:

- probe drilling procedures;
- marking out the extent of the underground workings;
- drilling and blasting;
- plant and equipment movement;
- placement of fill materials in unfilled workings;
- rock stability monitoring;
- daylight and night operations;
- plant and equipment specifications;

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[2] Such use should be reviewed on a case by case basis having regard to the stability of the surrounding rock mass, adjacent open pit walls, the potential hazards associated with charging of blast holes in the vicinity of underground workings and the requirement to monitor explosive quantities loaded into each blast hole.

[3] Experience suggests that stope hangingwall instability may be more extensive with the potential to undercut open pit walls, particularly in large unfilled stopes.

- personnel movement;
- regular communication of information and discussion of issues of concern with all those involved.

These safe working procedures should be progressively reviewed as the open pit depth increases.

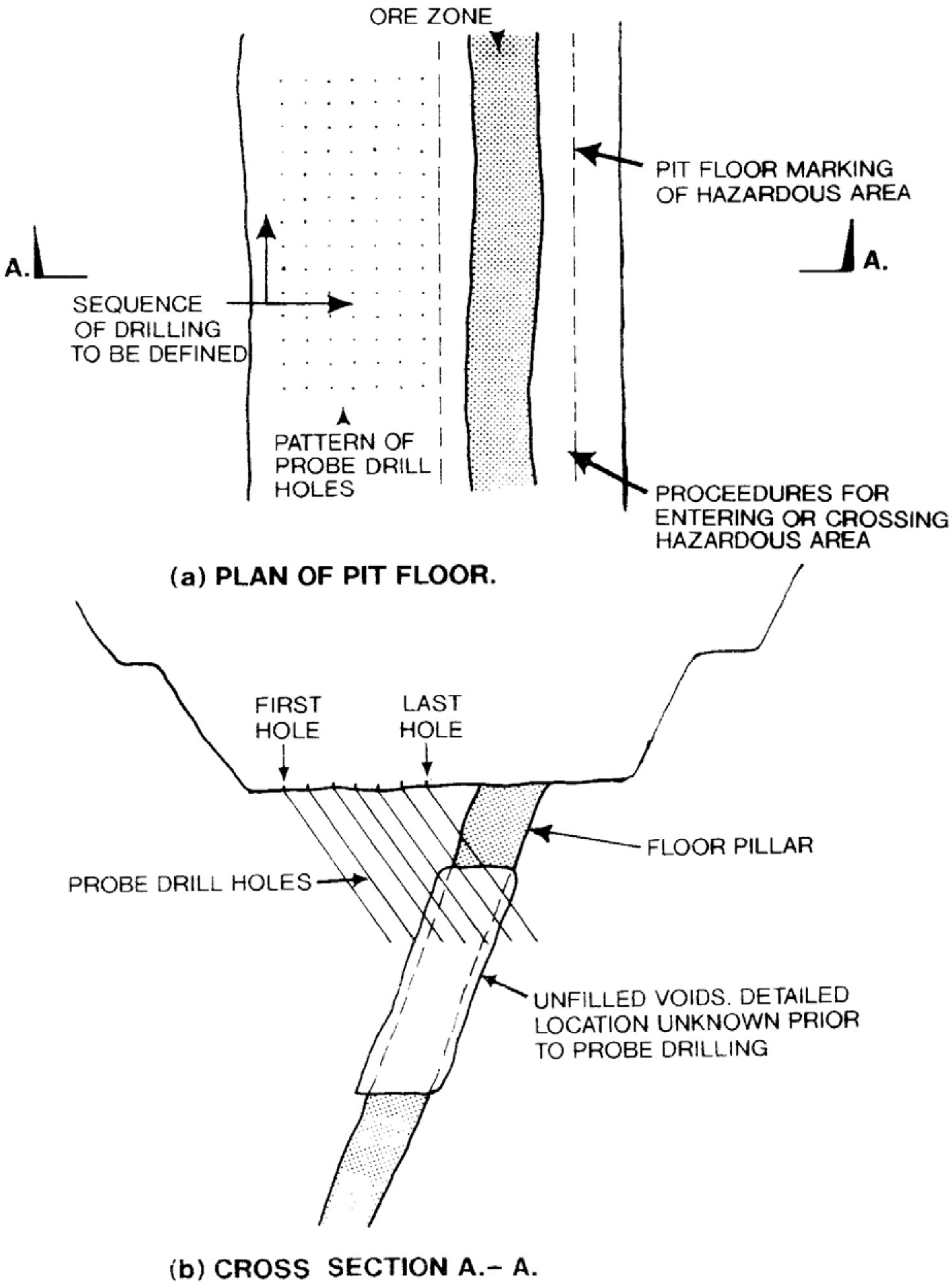

Figure 1. Probe hole drilling to locate underground workings

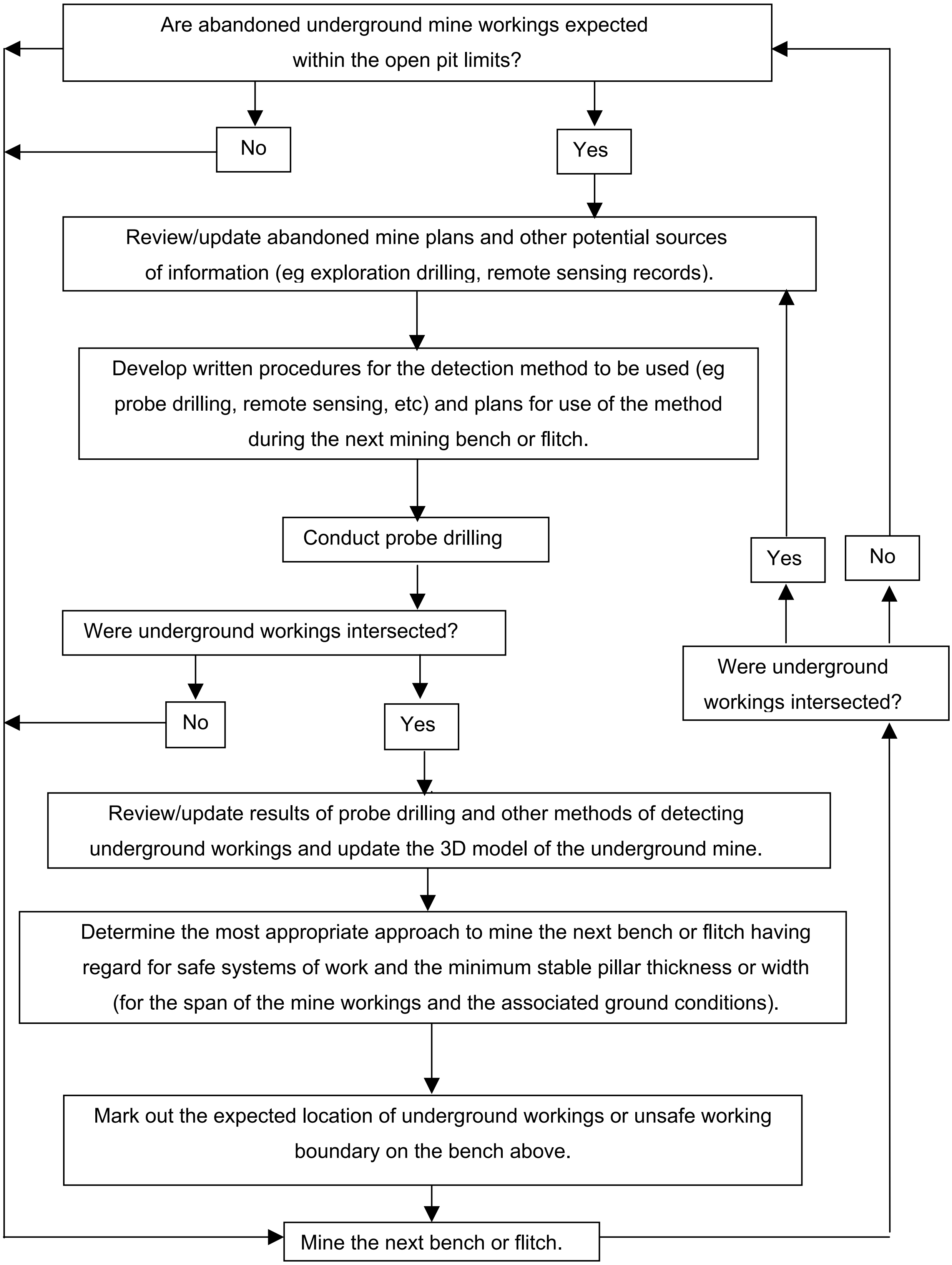

Figure 2. Flow chart for each bench or flitch, as appropriate, showing the key activities in open pit mining through abandoned underground workings

APPENDIX A - HAZARDS ASSOCIATED WITH OPEN PIT MINING THROUGH CURRENT UNDERGROUND WORKINGS

Currently operating underground mines may face a number of potential hazards when open pit mining is conducted through underground workings associated with the underground mine.

The location and extent of the current underground mine workings should be known with a much greater level of confidence than is the case with abandoned underground mine workings. The use of current underground mine surveying methods and equipment should largely eliminate any uncertainty as to the location of current underground mine workings. The presence of large unfilled stope voids may result in large scale collapse of the surrounding rock mass into the stope void. When this occurs the extent and location of the boundaries of the underground workings (eg walls, backs, etc) will obviously change.

The hazards associated with open pit mining through current underground mine workings include:

- flooding of the underground mine workings from large water and/or mud inrushes via the open pit and surrounding catchment areas;
- flooding of filled stopes, by accumulated drainage or by inrush, containing uncemented or inadequately cemented fill materials, that may become saturated, causing bulkheads to fail under hydrostatic pressure, resulting in a fill or mud rush in the mine;
- instability of the open pit walls and the surrounding surface areas, including any mine infrastructure (ventilation fans, shafts, headframes, winders, buildings, mobile equipment, any underground mine excavations in close proximity to the open pit, rising mains, electric cables in bore holes, fill passes, bore holes used for delivery of fill materials, etc);
- adverse effects on the underground mine ventilation system (short circuiting, ingress of open pit blasting fumes and dust, rock falls in large open stope voids creating dust which is drawn into the main intake airways, etc);

- potential for collapse of large unfilled stope voids that may cause a significant change in the underground mine geometry;
- deficiencies in co-ordination, communication and control of mining activities between the open pit and underground mines.

Each of these hazards must be adequately investigated and controlled by appropriate means according to the identified risk.

APPENDIX B - LEGISLATIVE FRAMEWORK

The *Mines Safety and Inspection Act 1994* sets objectives to promote and improve occupational safety and health standards. The Act sets out broad duties and is supported by more detailed requirements in the *Mines Safety and Inspection Regulations 1995*. A range of guidance material, including Guidelines, further supports the legislation. The legislative framework is set out in **Figure 3**.

Guidance material includes explanatory documents that provide more detailed information on the requirements of the legislation and include codes of practice and guidelines.

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

Figure 3: Legislative framework

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

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