
SAFETY BUND WALLS AROUND ABANDONED OPEN PIT MINES

GUIDELINE



Department of
Industry and Resources

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FOREWORD

This Department of Industry and Resources guideline has been issued to assist mining companies with the design of safety bunds required to minimise the potential risk to public safety of inadvertent access to abandoned open pits.

It is emphasised that this guideline is not totally inclusive of all factors concerning the application of geotechnical engineering on the design of abandonment bunds. It may not be totally suited to the specific requirements of every mine.

Comments on and suggestions for improvements to the guidelines are encouraged. The guideline will be revised where appropriate to reflect legislative changes and to accommodate new information, improvements in technology and improvements deriving from operational experience.

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1.0 INTRODUCTION

Under the Mines Safety and Inspection Act 1994 and the Mines Safety and Inspection Regulations 1995 the principal employer at, and the manager of, a mine must ensure that geotechnical aspects relating to the abandonment of open pit operations are adequately considered. These requirements are described in detail in Regulation 13.8; while Regulations 3.14 and 3.16 give specific requirements regarding the notification of suspension of mining operations and the notification of abandonment of mining operations respectively. The relevant regulations are given in full in Section 2.0 of this document.

The method preferred to minimise inadvertent public access to abandoned open pits involves the construction of an abandonment bund wall around the perimeter of the open pit voids, **outside the area designated as being susceptible to wall collapse**. Other barricading methods such as fences of a suitable construction and height may be appropriate in specific cases.

This guideline describes the geotechnical factors with greatest influence on the long-term stability of open pit slopes, and includes simple design criteria for the location and construction of safety bund walls. Whilst it is recognised that the controls on the stability of pit walls will be site specific, the design criteria provided represent a generalised, conservative approach for determining the location of long-term abandonment bunds in all open pits. The design information provided in this document is based on field measurements of failures and tension cracks around pit edges in operating and abandoned open pit gold mines in Western Australia.

In cases where pit wall conditions, during the operating life of a specific mine, have been poor and/or important structures are located near the edge of an open pit, site specific geotechnical studies are required by the State mining engineer to establish abandonment criteria applicable for that particular open pit.

The following points should be noted:

- ◆ This guideline addresses long-term post-mining stability, **not** stability related safety issues in current mining operations.
- ◆ This guideline applies to all open pits that exceed 5 m in depth.

- ◆ In cases where the mine owner wishes to locate the abandonment bund closer to the edge of the open pit than specified by this guideline, it must be demonstrated that the stability of the ground mass between the pit edge and the abandonment bund can be ensured for the very long term.
- ◆ Where **public roads, buildings, pipelines and other significant structures** are sited in close proximity to the edge of the abandoned open pit, the pit owner is required to undertake a detailed site specific geotechnical investigation to demonstrate that there are no geotechnical conditions in the rock mass which may preclude the application of this generic abandonment guideline.
- ◆ For open pits which the State mining engineer does not require specific studies, the location of the abandonment bund, or other effective barrier, should be determined from the procedures given in the following Sections of this document.

2.0 LEGISLATIVE REQUIREMENTS (WESTERN AUSTRALIA)

Details to be included in notification of suspension

3.14. Notification of the suspension of mining operations at a mine must, in addition to the details set out in regulation 3.12, include the following details -

- (d) the measures that have been taken to prevent unauthorised access or entry to the mine;

Details to be included in notification of abandonment

3.16. Notification of the abandonment of mining operations at a mine must, in addition to the details set out in regulation 3.12, include the following details -

- (b) details of precautions taken to prevent inadvertent access to open pit workings;

Geotechnical considerations

13.8 (1) The principal employer at, and the manager of, a mine must ensure that geotechnical aspects are adequately considered in relation to the design, operation and **abandonment** of quarry operations.

Penalty: See regulation 17.1.

(2) Each responsible person at a mine must ensure that the following measures are taken in relation to ground control in the quarry -

- (a) adequate consideration is given to local geological structure and its influence on wall stability;
- (b) adequate consideration is given to shear strength of the rock mass and its geological structure;
- (c) a proper analysis is carried out of rain water inflow, surface drainage pattern, groundwater regime and mine de-watering procedures and their influence on wall stability over time;
- (d) where necessary, appropriate designs of rock reinforcement are applied

- and used, and the quality of installation is verified;
- (e) analysis is carried out of open pit wall stability for the projected geometry of the pit;
 - (f) appropriate drilling and blasting procedures are used to develop final walls; and
 - (g) appropriate methods of open pit wall monitoring are used over a period of time to determine wall stability conditions.

Penalty: See regulation 17.1

General penalty

17.1. The penalty for contravention of a provision of these regulations that refers to this regulation is :

- (a) in the case of an individual, \$5 000; and
- (b) in the case of a corporation, \$25 000.

3.0 STABILITY OF PIT WALLS

In order to establish the location of the safety bund, it is necessary to determine the potential area of ground that can be disturbed by the failure of the open pit walls over the long-term. The long-term stability of the open pit edge is dependent on a number of geotechnical factors, the most important of which are:

- ◆ The presence and orientation of major geological planes of weakness in the rock mass forming the pit walls.
- ◆ The strength of the rock mass within the pit walls.
- ◆ Variation in the strength of the rock mass with time.
- ◆ The geometry of the pit wall.
- ◆ The influence of groundwater and incident rainfall on pit walls.
- ◆ The influence of seismic events.

This guideline provides generic design criteria that allow for the normal variation of all these factors. When alternative abandonment proposals are required, the long term stability of the ground mass between the crest of the pit walls and the abandonment bund will need to be geotechnically justified in relation to all of the above factors.

To assist determining the location of the abandonment bund wall, the area of potential instability of open pit walls has been simplified to represent a single wedge of material extending from the toe of the pit wall, as defined by Figure 1. This wedge of material has been termed the **potentially unstable rock mass**. It follows that for the abandonment bund to be effective over the long-term, the bund must be founded on ground outside the area defined as being potentially unstable rock mass (outside what has been termed the **potentially unstable pit edge zone**). Further definition of the terms of instability “potentially unstable rock mass”, and “potentially unstable pit edge zone” is provided diagrammatically in Figure 1.

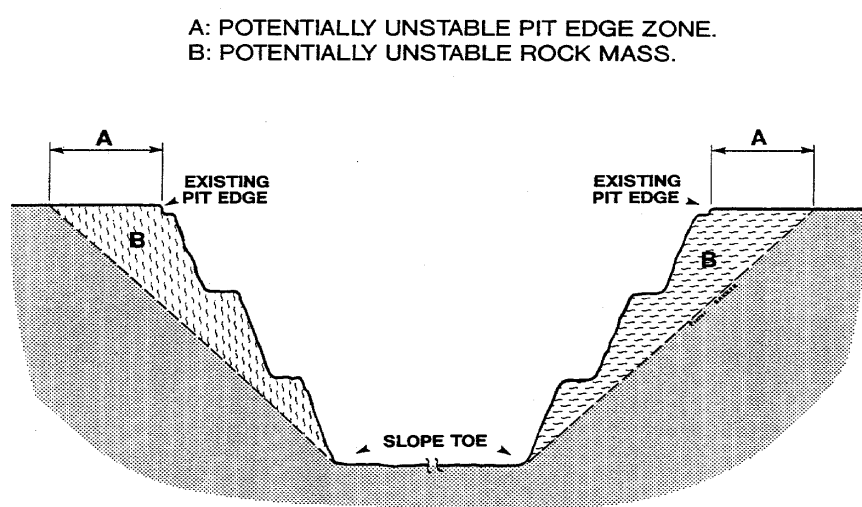


Figure 1
DEFINITION OF TERMS OF INSTABILITY

4.0 DESIGN CRITERIA FOR ABANDONMENT BUNDS

4.1 Bundwall Location

The abandonment bund must be constructed outside the area designated as the *potentially unstable pit edge zone* (defined in Figure 1). Case history data from slope failure and tension crack measurements around open pits in Western Australia suggest that the **overall angle** defining the maximum *potentially unstable rock mass* is primarily dependent on whether the pit wall consists of weathered (oxidised) rock or unweathered (unoxidised) rock. These case data also suggest that the maximum area of *potentially unstable rock mass* for failure through each class of rock can be defined by two separate **design angles**:

- ◆ 25° for weathered rock, and
- ◆ 45° for unweathered rock.

Unweathered/unoxidised rock material shall be taken to include fresh rock - rock that shows no sign of decomposition or staining - and slightly weathered rock - rock that is slightly discoloured but shows little or no change of strength from fresh rock. [Weathering classifications as per Australian Standard AS1726-1993, Geotechnical site investigations Table A9.]

Three general design cases have been recognised:

- CASE 1:** Pit walls excavated entirely in unweathered rock
- CASE 2:** Pit walls excavated entirely in weathered rock
- CASE 3:** Pit walls excavated in both weathered and unweathered rock.

Examples of the design approach to be used in each of these cases are provided in Figures 2, 3 and 4 respectively. **Where the overall angle of a pit wall is less than these design criteria, the bund wall is to be positioned at least 10m away from the final pit wall crest.**

To maximise the long term effectiveness of the abandonment bund, the bund should be constructed at least 10 m outside the area designated as being potentially unstable rock mass, i.e. the pit-side toe of the bund should be positioned a distance not less than the total of the width of the “potentially unstable pit edge zone” plus an additional 10 m away from the existing pit edge.

Note: The use of these design criteria is based on the assumption that no major unfavourably oriented geological features are present within the pit walls, which could induce failure at flatter slope angles.

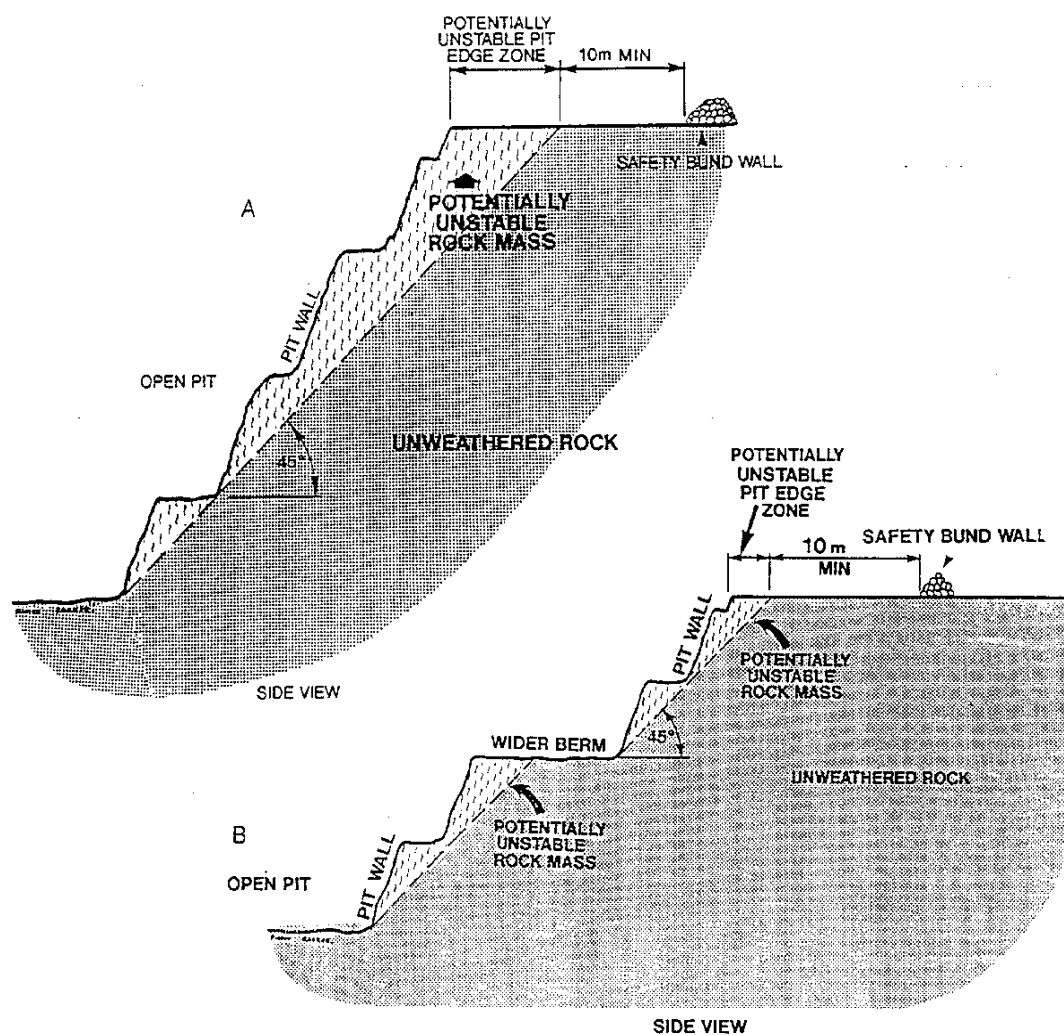


Figure 2
CASE 1: PIT WALL EXCAVATED ENTIRELY IN UNWEATHERED ROCK.

The width of the “potentially unstable pit edge zone” is defined by the distance between the existing pit edge and a point on the ground surface representing the intercept of a 45° plane projected from the slope toe (Figure 2A).

Note: In all three cases, where local variations in wall geometry intersect the projected line of potential instability, (e.g. a wide berm or haulroad) then the width of the potentially unstable pit edge zone is determined as shown in Figure 2B.

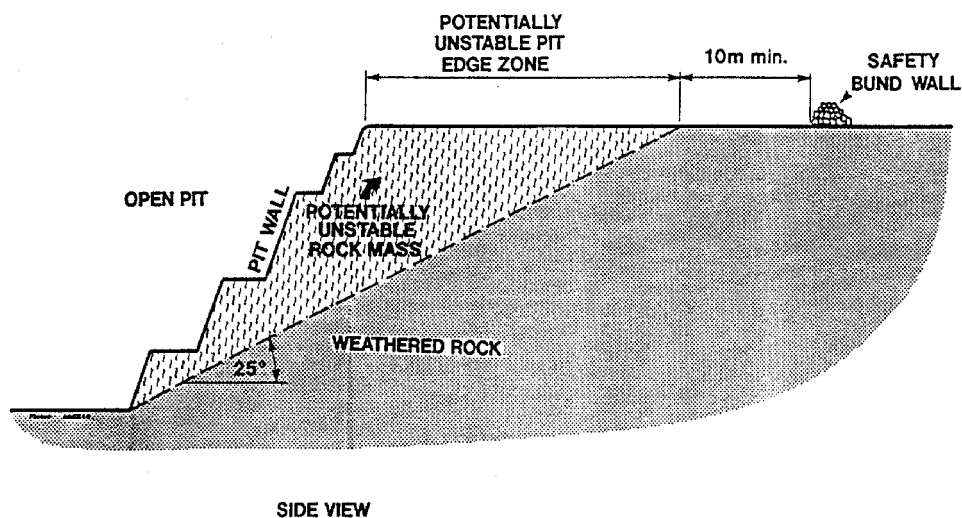


Figure 3
CASE 2: PIT WALL EXCAVATED ENTIRELY IN WEATHERED ROCK.

The width of the “potentially unstable pit edge zone” is defined by the distance between the existing pit edge and the point where a plane drawn at an angle of 25° from the slope toe intersects the ground surface (Figure 3).

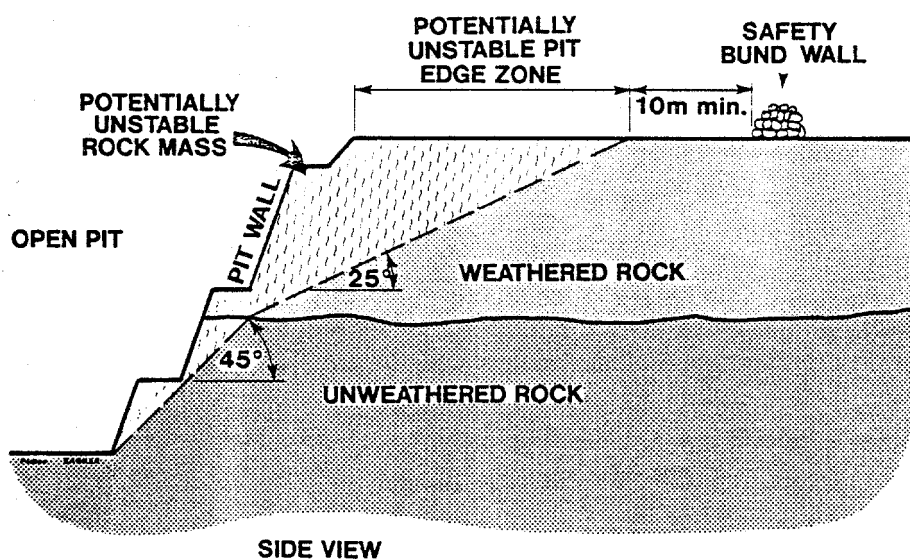


Figure 4
CASE 3: PIT WALL IN WEATHERED AND UNWEATHERED ROCK.

The width of the “potentially unstable pit edge zone” is defined by the distance between the existing pit edge and the point where planes, projected initially from the

pit wall toe, and drawn at an angle of 45° in unweathered rock, changing to 25° in weathered rock, intersect the natural surface (Figure 4).

4.2 Bundwall Construction

Bund walls should be constructed:

- ◆ of the following minimum dimensions: height 2 metres, base width 5 metres.
- ◆ where ever possible, from unweathered, freely draining, end dumped rockfill.

When only oxidised rock is available for construction of the safety bund wall, the least weathered or hardest material should be used. In these cases, the bund wall may need to be supplemented with appropriate surface stabilisation or a properly constructed fence.

Suitable signs, clearly stating the risk to public safety and prohibiting public access, should be erected at appropriate locations around the safety bund wall.

Shrub and/or tree planting at the outside edge of the bund wall should be implemented where practicable, to lessen the visual impact of the wall.

5.0 EXAMPLE OF BUND WALL DESIGN

The following example is an illustration only; specific calculations should be carried out for individual pit slopes.

Problem: Determine the position of a safety bund wall for a portion of a pit with the following geometry and geological conditions:

Total pit depth : 70 m.
Face Heights : 10 m first face, 20 m subsequent faces.
Face Angles : 60° first face, 70° subsequent faces.
Berm widths : 5 m

Weathered (oxidised) rock extends to a depth below ground surface of 35 m.

Solution:

1. Construct a cross section view through the pit wall (Figure 5).
2. Project a line at 45° to the horizontal from the toe of the slope to the weathered /unweathered rock contact at a depth of 35m. From this point, project the line at an angle of 25° to intersect the ground surface.
3. Measure the width of the “Potentially unstable pit edge zone”, 69m for the present example.
4. The pit-side toe of the minimum 2 m high, 5 m wide bund wall should therefore be placed at least 79 m away from the pit edge.

Note: The above graphical design approach can be substituted by geometric analyses.

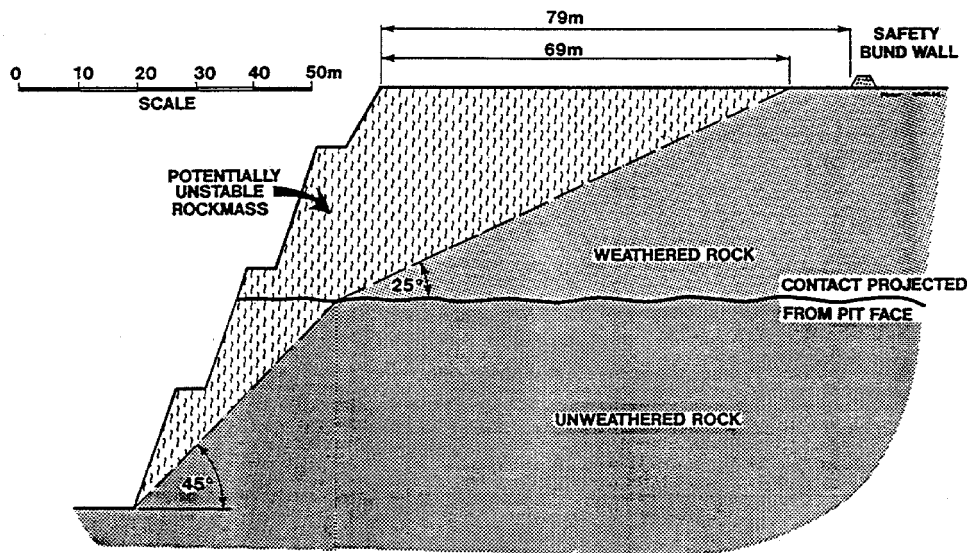


Figure 5
EXAMPLE OF SAFETY BUND WALL LOCATION

APPENDIX

ENQUIRIES AND CONTACT NUMBERS

All enquiries concerning particular sites, or further clarification of these guidelines, should be directed to the appropriate Safety Health and Environment Inspectorates at the following centres and contact numbers:

	Telephone	Facsimile
COLLIE	(08) 9734 1222	(08) 9734 1606
KALGOORLIE	(08) 9021 9411	(08) 9021 3612
KARRATHA	(08) 9186 8243	(08) 9186 8251
PERTH	(08) 9222 3132	(08) 9325 2280