PRO FORMA CODE OF PRACTICE TO COMBAT ROCKFALL ACCIDENTS IN SURFACE AND OPEN PIT MINES

INTRODUCTION

This document has been prepared as part of a Safety in Mines Research Advisory Committee (SIMRAC) research project OTH 602 entitled “Best practice rock engineering handbook for other mines including underground and open pit mines and quarries”.

The objective of this document is to assist employers at surface and open pit mines in preparing a code of practice to combat rockfall and rockburst accidents (COP) in accordance with the requirements of the Mine Health and Safety Act (MHSA), 1996 (Act No. 29 of 1996), and in accordance with the Department of Minerals and Energy (DME) Guideline Reference No. 7/4/118-AB4 (Surface and Open Pit Mines). At the time of compiling this pro forma COP, this Guideline for surface and open pit mines had been issued in draft format only. It is recommended that the new Guideline be consulted when it becomes available.

STRUCTURE OF DOCUMENT

This document presents the requirements of a COP as defined in the Guideline as boxed text.

REQUIREMENTS AS BOXED TEXT

The requirements are followed by an example of how the actual COP document may be written to satisfy the requirements. Additional notes on particular issues that require attention are presented in *italics.*

FORMAT AND CONTENT OF COP

TITLE PAGE	
• *Name of mine*	*Y*
• *Heading: Mandatory COP to Combat Rockfall and Rockburst Accidents in Surface and Open Pit Mines*	*Y*
• *Statement: The COP was drawn up in accordance with DME Guideline, Reference No. 7/4/118 AB1 issued by Chief Inspector of Mines on 16 October 1996, and DME Guideline, Reference No. 7/4/118 AB4 (Draft).*	*Y*
• *Mine's reference number*	*Y*
• *Effective date*	*Y*
• *Revision date*	*Y*

OPEN PIT MINE (PTY) LTD

MANDATORY CODE OF PRACTICE TO COMBAT

ROCKFALL AND ROCKBURST ACCIDENTS IN

SURFACE AND OPEN PIT MINES

This code of practice (COP) was drawn up in accordance with DME Guideline, Reference No. 7/4/118 AB1 issued by Chief Inspector of Mines on 16 October 1996, and DME Guideline, Reference No. 7/4/118 AB4 (Draft)

REF. No.	:	OPEN PIT COP1/2001
EFFECTIVE DATE	:	FEBRUARY 2001
REVISION DATE	:	FEBRUARY 2002

CONTENTS OF CODE OF PRACTICE	
Table of contents	*Y*

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

STATUS OF MANDATORY COP	
State that:	
• *The COP has been drawn up in accordance with the relevant guideline issued by the Chief Inspector of Mines.*	***Y***
• *This is a mandatory COP in terms of Section 9(2) of the Mine Health and Safety Act, 1996 (Act 29 of 1996).*	***Y***
• *This COP may be used in accident investigation/inquiry to ascertain compliance and also to establish whether the COP is effective and fit for purpose.*	***Y***
• *This COP supersedes all previous COP's in this regard.*	***Y***
• *All managerial instructions or recommended procedures and standards on the relevant topics must comply with the COP and must be reviewed to ensure compliance.*	***Y***

1 STATUS OF MANDATORY CODE OF PRACTICE (COP)

- The COP has been drawn up in accordance with DME Guideline, Reference No. 7/4/118 AB1 issued by Chief Inspector of Mines on 16 October 1996, and DME Guideline, Reference No. 7/4/118 AB4 (Draft).
- This is a mandatory COP in terms of Section 9(2) of the Mine Health and Safety Act, 1996 (Act 29 of 1996).
- This COP may be used in accident investigation/inquiry to ascertain compliance and also to establish whether the COP is effective and fit for purpose.
- This COP supersedes all previous COP's in this regard.
- All managerial instructions or recommended procedures and standards on the relevant topics must comply with the COP and must be reviewed to ensure compliance.

MEMBERS OF DRAFTING COMMITTEE	
• *Full names*	*Y*
• *Designation*	*Y*
• *Professional qualifications, experience and affiliation*	*Y*
• *Must include a competent RE practitioner*	*Y*

2 MEMBERS OF DRAFTING COMMITTEE

The Manager of Open Pit Mine, after consultation with the Health and Safety Committee (H&SC), appointed a committee for the drafting of this COP to combat rockfall accidents. Combating rockbursts does not form part of this COP, since the likelihood of rockbursts occurring at Open Pit Mine is minimal.

The full names, designation, professional qualifications and/or experience and affiliation of the COP Drafting Committee members are:

Mr BLA Stall (Production Manager)

- National Higher Diploma - Metalliferous Mining (Technikon Witwatersrand)
- National Diploma - Metalliferous Mining (Technikon Witwatersrand)
- Mine Manager's Certificate of Competency
- Mine Overseer's Certificate of Competency
- Associate Member of Mine Managers Association.
- Thirteen years mining experience in various positions in the production environment.

Mr CLE Wirr (Rock Engineering Consultant)

- BSc (University of Pretoria) 1980
- BSc Hons (University of Pretoria) 1982
- Registered Pr. Sci. Nat. 1986

- COM Certificate in Rock Mechanics 1985
- Member of SANIRE
- Member of SAIEG
- Eighteen years mining rock engineering experience.

<u>Mr EX Ploration</u> (Senior Mine Geologist)

- BSc Geology (University of the Witwatersrand) 1986
- BSc Hons (University of the Witwatersrand) 1988
- Twelve years experience in Open Pit mining:
  - Five years Exploration Geologist Mine A
  - Four years Mine Geologists Mine B
  - Three years Senior Mine Geologist Open Pit Mine

<u>Mr STOF Engate</u> (Section Manager Drill and Blast)

- Mine Manager's Certificate of Competency
- Mine Overseer's Certificate of Competency
- Nine years experience in Open Pit mining:
  - Six years Mine Overseer Mine A
  - Three years Section Manager Open Pit Mine

<u>Mr PA Soppa</u> (Safety Officer)

- N.O.S.A
- S.A.M.T.R.E.C.
- Ten years experience in Open Pit mining:
  - Three years Safety Officer Mine A
  - Seven years Safety Officer Open Pit Mine

GENERAL INFORMATION	
Include locality map, indicating: • *location relative to towns* • *existing infrastructure* • *other relevant features, e.g. common boundaries, dams, rivers and other topographical features which could influence the strategies adopted.*	 *Y* *Y* *Y*
Describe geological structures, such as: • *faults* • *dykes* • *stratigraphy (around individual orebodies or seams)*	 *Y* *Y* *Y*
Highlight any dangerous or difficult strata.	*Y*
Include typical section.	*Y*
Include map showing major geological features in relation to mining outlines and shafts.	*Y*
Give general description of orebodies or seams being mined, including relevant information such as: • *average mining depth* • *range of mining depths* • *orebody width* • *dip* • *strike*	 *Y* *Y* *Y* *Y* *Y*
Describe regional hydrology such as the occurrence of any significant groundwater and/or any relevant information.	*Y*
Describe ground control districts based on: • *known geological hazards* • *structures* • *jointing* • *changes in rock type* • *changes in rock strength* • *any other factors which may impact on mining.* *(Include nature of virgin stress field, occurrence of significant pore water and any other local geological features)*	 *Y* *Y* *Y* *Y* *Y* *Y*

Depict location and extent of above information on a plan.	*Y*
Tabulate 5 year history of rock-related: • *casualties* • *non-casualty incidents (where available).* *(Categorise according to rockfalls per 1000 employees at work for both surface and underground operations.)*	 *Y* *Y*
Present above information graphically, depict annual statistics and highlight trends.	*Y*
State who is responsible for: • *completion of accident report forms* • *maintenance and interpretation of mine accident statistics.*	 *Y* *Y*
Use accident report form 13 and ID root causes of fatal and reportable accidents	*Y*
Store above information in mine's data bank	*Y*

3 GENERAL INFORMATION

3.1 Locality

Open Pit Mine is a large open pit mine, which commenced production in 1994. The mine is situated within the Lebowa Manganese Field in the Northern Province of the Republic of South Africa, 350 km north east of Johannesburg, and some 90 km south of Pietersburg (Figure 1 and Figure 2).

The altitude is 1 060m above sea level. The climate is predominantly semi-dry and warm. During summertime temperatures can rise to 42º C whilst wintertime temperatures seldom drop to below freezing point. Rainfall is sporadic and the average annual rainfall of 1500 mm usually falls during the summer months.

Electricity is supplied to Open Pit Mine by ESKOM and water is pumped from boreholes close to the mine.

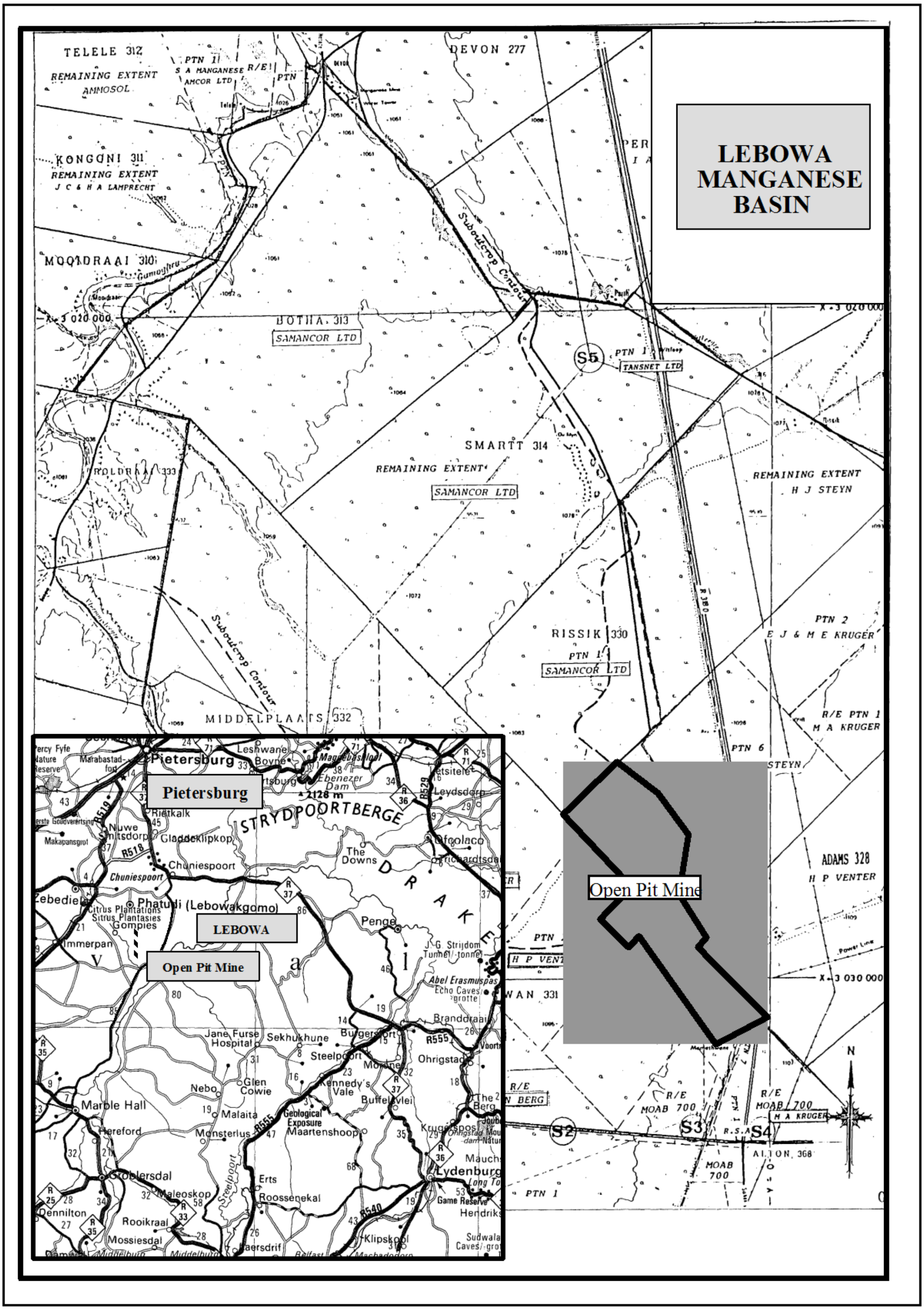


Figure 1 **Locality map**

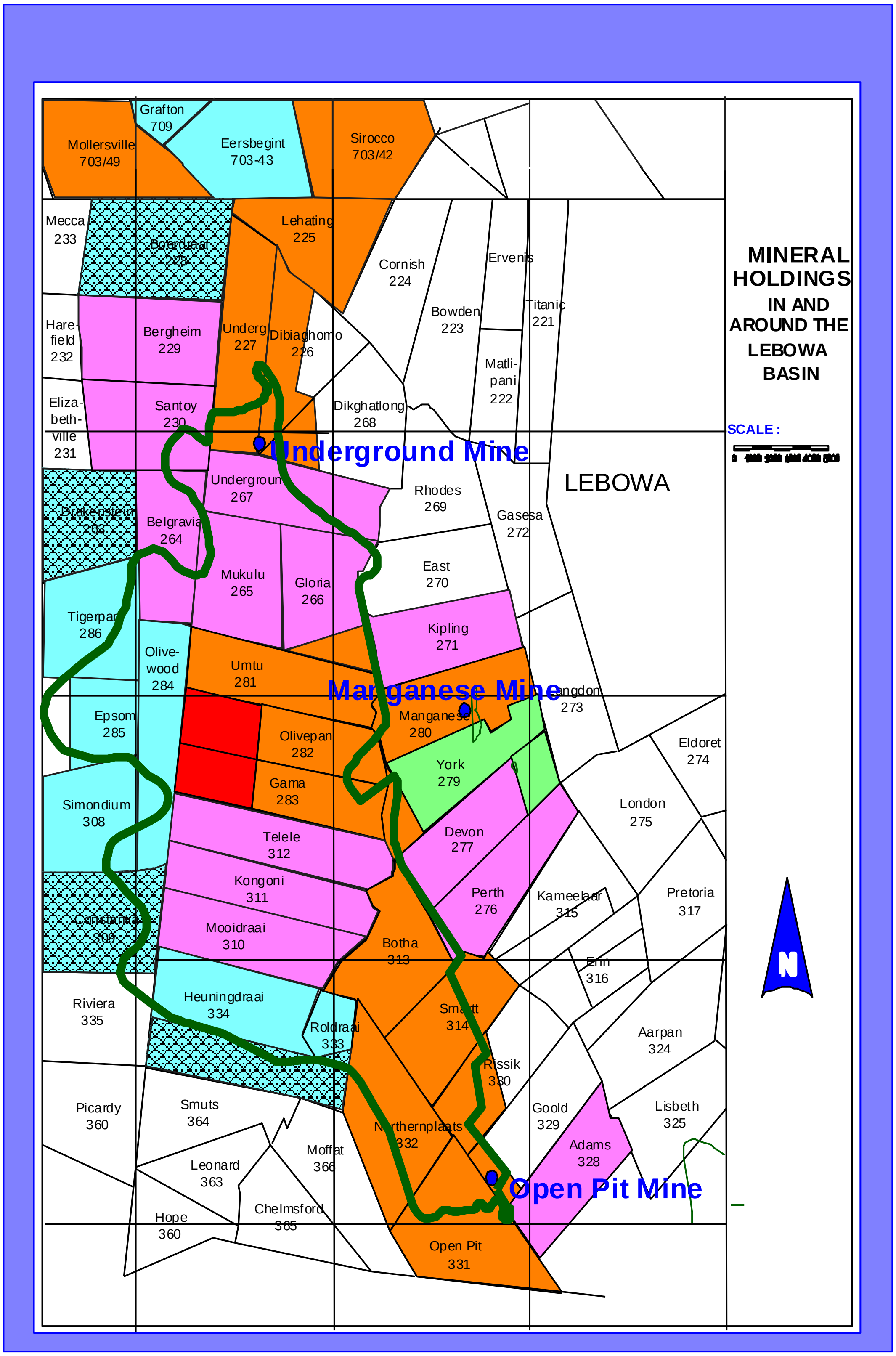


Figure 2 Mineral holdings of the Lebowa Basin

3.2 Geological structure

The Lebowa manganese field consists of five structurally preserved erosional remnants of the Phatudi Formation of the Transvaal Sequence. The main field extends continuously in a north westerly direction from Open Pit Mine for a distance of 34 km to Underground Mine in the north. The width of this field varies from 5 km to 20 km and the area underlain by manganese is some 23 000 hectares in extent.

Three manganese horizons occur within the Phatudi Formation. However in the Open Pit Mine the upper two horizons have been eroded and the Tertiary Lebowa Formation, consisting of aeolian sand, calcrete, gravel and clay, with a total thickness of up to 45m rests unconformably on the lowermost manganese horizon (Figure 3 and Figure 4).

The thickness of the manganese is dependent on the extent of erosion which occurred prior to the deposition of the Lebowa beds and varies from 0 meters to 45 meters. The Phatudi Formation conformably overlies the andesitic Ongeluk Lava (Figure 5).

The ore dips at some 5º to the west and is continuous to the Northern Mine, 5 km away at the south western edge of the manganese field, where the ore is some 400 meters below surface. Faulting with displacements between 0 and 9 meters has occurred and two directions of folding have given rise to gentle basin and dome structures, however these have had very little effect on mining operations.

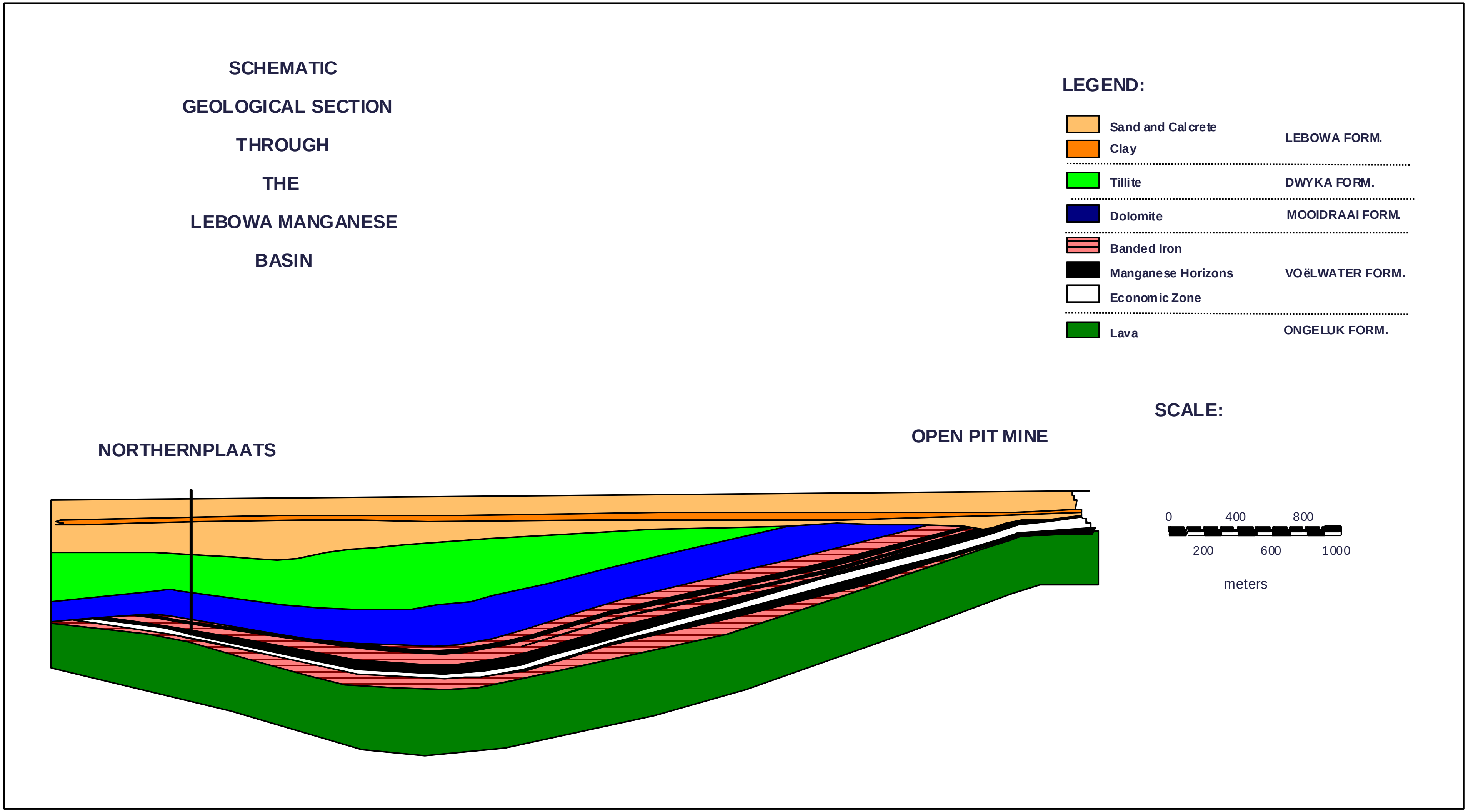


Figure 3 **Schematic geological section through the Lebowa Manganese Basin**

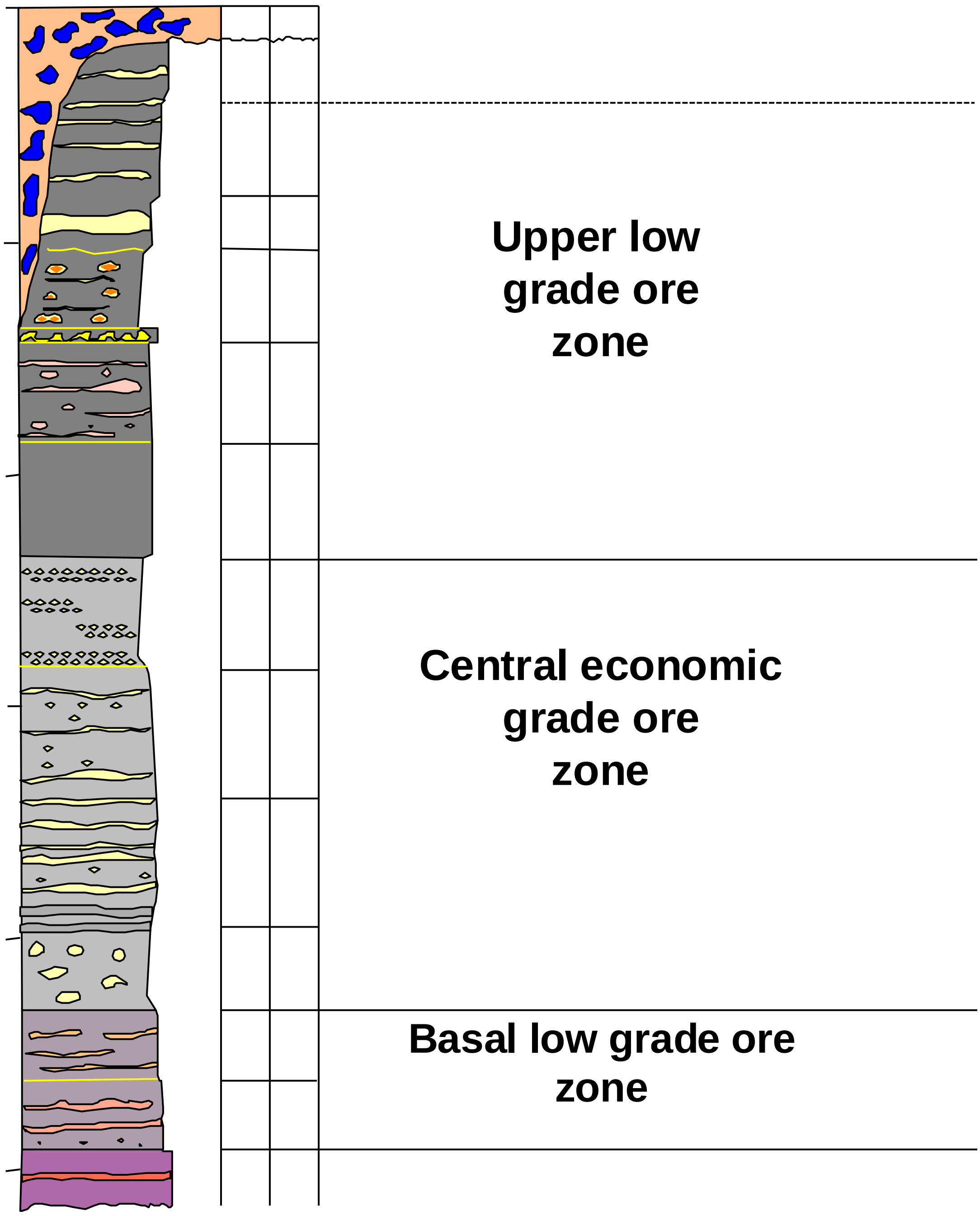


Figure 4 **Stratigraphic profile of the Open Pit Mine manganese horizons**

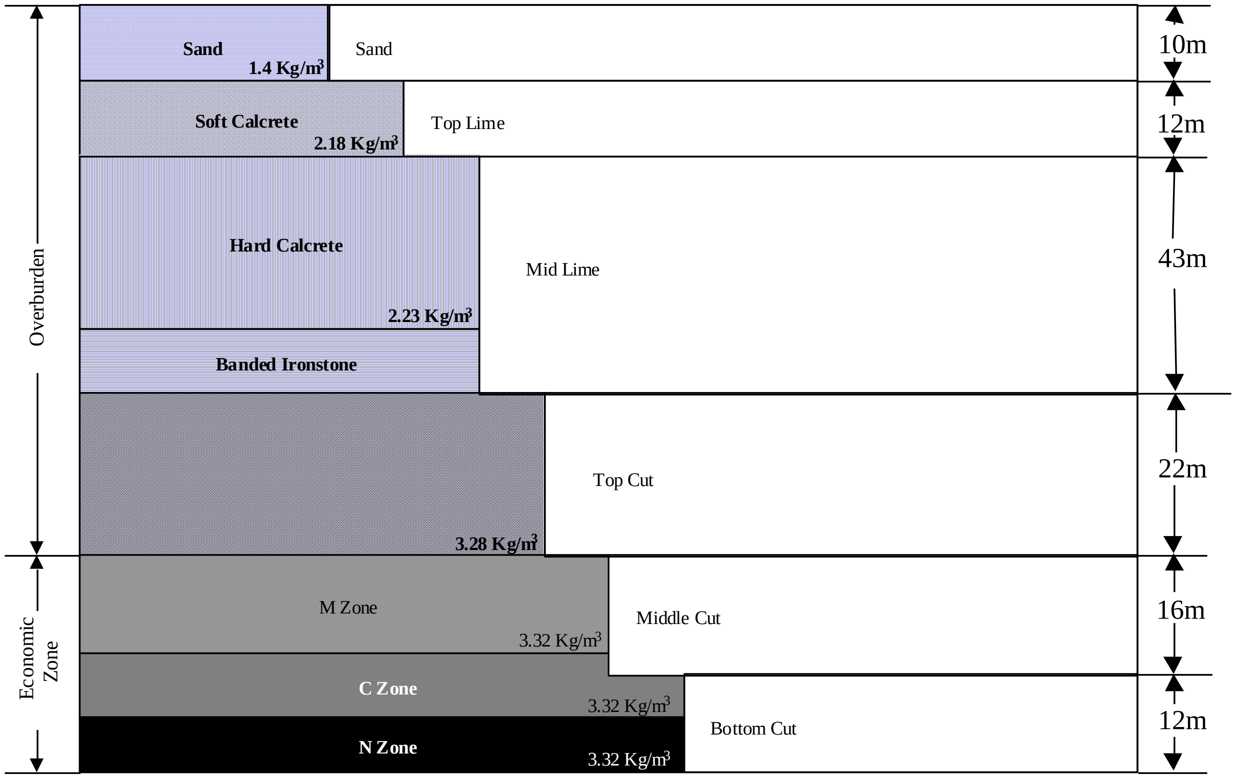


Figure 5 Thickness of overburden and ore horizons

3.3 Orebodies Mined

Average mining depth is 80 m below surface, with depths ranging from surface to 115 m below surface. The orebody dip at 5° to the west.

The Manganese ore can be subdivided into three zones (Figure 5):

- The lower or footwall, is an uneconomic zone, approximately 12m thick with an average manganese content of less than 30%. This zone is not mined and forms the footwall of the open pit mining operation where it is retained in situ.

- The middle or economic zone has an average thickness of 28m, a manganese content of 38% and Mn : Fe ratio of 8 : 1 or better. This is mined in three benches. The upper bench is maintained at a height of approximately 10m and the lower benches are variable in height depending on the overall width of the economic zone.

- The upper zone of lower grade manganese and slightly higher Fe is approximately 22 meters thick and averages over 30% manganese. This is mined as two benches.

Each of the above zones are again subdivided into different layers which have their own chemical and physical character. The lower zone is subdivided into two layers, the economic zone into three and the upper zone into five.

In general the ore is dull in appearance and is well laminated throughout its thickness. Near the base the ore is siliceous and ferruginised with a banded appearance. Higher up the ore has numerous oolites and lenticular remnants of limestone which tend to be concentrated in layers.

The Open Pit Mine ore is a diagenetic to low grade metamorphic carbonate bearing braunite manganolutite ore, consisting of the following minerals:

Braunite, kutnahorite, hausmannite, calcite and hematite
The ore is in places oxidised to cryptomelane, particularly alongside open fissures and along the sub outcrop where the ore is directly overlain by the Lebowa formation.

The relatively high carbonate content makes this ore virtually self fluxing and the comparatively low Fe content (4 - 6%) results in the ore having a Mn/Fe ratio suitable for the production of high manganese alloys.

3.4 Regional hydrology

For the 1998/99 financial year, total water consumption consisted of 150,000 m^3 from the Chuniespoort-Zebediela water contract, which was supplemented with an estimated 600 m^3/day from P19 borehole and 30,000 m^3 pumped from the mine.

Natural ground water levels are well below the current mining depth, generally resulting in a dry mine, but with the only exception being the tendency of the calcrete layers to hold water during the rainy season which could result in slippery road conditions.

3.5 Seismological setting of the mine

Open Pit Mine is a shallow open pit mine with no history of natural of mining induced seismic activities.

3.6 Ground control districts

Refer to Figure 5.

3.6.1 Overburden

The overburden comprise of all non-economical and sub-economical zones i.e. Lebowa Sand, Calcrete, Clay, Banded Ironstone and low grade manganese. A large variation in uniaxial compressive strengths are present within these zone, ranging from < 1 MPa for the sand and clay and < 30 MPa for the calcrete up to 300 MPa for the Banded Ironstone. Rock mass classification results also gave large variations in Mining Rock Mass Rations (*MRMR*) for the different overburden materials, ranging from 1,5 for the sand and 5 for the clay to 35 for the calcrete and 42 for the Banded Ironstone (Table 2).

Overburden is pre-stripped from top to bottom (which is replaced in reverse order by backfilling) resulting in a stripping ratio of 2.5:1. The general thickness of the overburden is 90 meters with a weighted average specific gravity of 2,300 kg/m^3 derived mostly from the heavier Top Cut and Mid Lime Benches.

Due to the characteristics of the named zones the main geological hazards include the natural slope angle and stand up time of the benches after blasting. As a result of the low overall pit slope angles, thorough cleaning of loose material (after the blast) and the wide road width these hazards can however be reduced.

The mine layout is such that geotechnical zones can be handled separately.

The occurrence of structures and jointing in the Lebowa sand and Calcrete zones are such that they represent non-existence. The structures and joints occurring within the harder zones are of such dimensions that the massive mining methods reduce their geotechnical impact.

Through forward exploration and proactive mine planning techniques the occurrence of larger structures can be dealt with when they do occur.

3.6.2 Ore Zone

The ore zone comprise of the M, C and N zones with a total thickness of approximately 28 m after the overburden has been removed. The Economic zone has a SG of 3,6300 kg/m^3 made up evenly over the Middle and Bottom Cuts. The uniaxial compressive strengths vary between 150 MPa and 250 MPa with an average *UCS* of 190 MPa.

The Mining Rock Mass Ration (*MRMR*) varies between 55 and 60 for the ore zone (Table 2).

The minor structures and joints occurring are of such dimensions that the massive mining methods reduce their related geotechnical hazard. Through forward exploration and proactive mine planning techniques the occurrence of larger structures can be dealt with when they do occur. The major discontinuity structures include a fissure zone on the western benches and fracture zone in the north-western corner.

The overall bench layout is carried, in a general, perpendicular to the direction of these discontinuities, reducing the probability of failure.

Other geotechnical zones including red-clay formation and Banded Ironstone formation do exist, but falls outside current mining areas and pose no geotechnical hazard at present.

3.6.3 Geological Discontinuities (in hard rock formations)

Joints and other structural discontinuities are universally present in all rock masses. The shear strength of the rock mass is fundamentally affected by the discontinuities and are of over-riding importance to the stability of rock slopes. Such features have much lower strengths than the intact rock.

Discontinuities are therefore be recorded, firstly with respect to their attitude, geometry and distribution during the routine mapping and exploration exercises of the Mine Geologist.

An assessment of the rock structure reveals that the orebody, mining horizon typically contain one sub-horizontal joint set (bedding) and up to four sub-vertical joint sets.

The orientation of joints within the rock mass results in the formation of relatively stable keyblocks. The following structures reduce the stability of the rock mass:

- horizons of closely spaced jointing
- major features i.e. fissure zones
- inclined blasting fractures

Therefore, the Mine Geologist pays special attention to these zones during mapping exercises.

3.7 Rock Mass Classification

The rock mass characterisation process will be discussed in Section 0 and the different rock mass classification systems in Section iii. Results are, however, included in this section, because of the significance of rock mass classification to geotechnical areas. Table 1 gives the variation in *Q*-values for the Banded Ironstone and Manganese horizons. Table 2 gives the variation in *Q*, *RMR* and *MRMR* values for the different mining horizons.

Table 1 Rock mass classification for individual lithologies

Lithology/ Mining horizon	Sample			*Q*-Classification
	Mean *Q*-Index	SD *Q*-Index	Range *Q*-Index	
Banded Iron Formation	3.0	1.5	2.0 – 4.0	Poor
Manganolutite Top Cut	6.2	2.0	3.0 – 8.0	Fair
Manganolutite Middle Cut	8.5	2.6	5.5 – 13.0	Fair
Manganolutite Bottom Cut	10.0		10.0	Fair to good

SD = Sample standard deviation

Table 2 Mining horizon rock mass classification

MINING HORIZON	*Q* Index	*RMR*	*MRMR*
Lebowa Sand	0.01	15	1.5
Calcrete	13	65 - 70	35
Clay	0.01	15	5
Banded Ironstone	3 - 4	55	42
Top, Middle & Bottom Cuts	4 - 6	60 - 80	55 – 60

3.8 Mine rockfall accident analysis

3.8.1 Rock-related accident statistics

Open Pit Mine is a safe open pit mine where the exposure of workers to hazards including fall of ground and rock burst occurrences is low on a general comparison to other mines. This can be seen in the following statistics. No rock-related personal injuries or incidents were recorded during the previous five years. Only one recorded incident of damage to equipment is represented in Table 3.

Table 3 Accident statistics

Date	Accident Report No.	Job Category	Equipment Damage	Cost Estimate	Accident Description
1997/08/5	1821	Dozer	Dozer Hydr Cylinder	R50 000	Rock break & fall on Ripper Dozer

The safety officer appointed in terms of Regulation 2.17.1 of the Minerals Act (Act 50 of 1991), is responsible for the completion of accident report forms and the maintenance and interpretation of mine accident statistics.

3.8.2 Fall of ground accident records

As required by the Mine Health and Safety Regulation 34.1, accident report Form 13 must be completed for all incidents that result in the loss of 14 or more shifts. This form is formulated in a manner which facilitate identification of the root causes of fatal and reportable accidents.

As mentioned above, information on fall of ground accidents at Open Pit Mine is limited and drawing any meaningful conclusions is therefore difficult. In order to build up a more useful rock-related database, the following data will be recorded for all fall of ground disabling accidents:

- Date;
- Working Place;
- Type of accident (e.g. fatal / reportable / disabling injury)
- Excavation Type;
- Location in Excavation;
- Origin of F.O.G.;
- F.O.G. Dimensions (Thickness, Width and Length);
- Characteristics of geological features at the scene of the accident (joint/fault strike and dip orientation, frequency, etc.);
- Activity being performed at time of accident;
- Support type and density being used at time of accident;
- Distance of accident from support;
- Root causes.

This information will be stored in the mines' data bank to facilitate analyses and identification of root causes.

The responsibilities of safety representatives, supervisors, shift bosses and other officials with regards to accident investigations, completion of accident report forms, maintenance and interpretation of mine accident statistics are as follows:

- Safety Representative responsible for area where accident occurred:
  - He must assist with all FOG accident investigations.
  - He must assist the injured person's immediate supervisor with the completion of the accident report form.

- The injured person's immediate supervisor:
  - He must assist with all FOG accident investigations.
  - He must complete the accident report form.

- The pit foreman in charge of the area where the accident occurred:
    - He must arrange for an in loco investigation of all FOG accidents.
    - He must inform the responsible safety representative, supervisor and safety officer and other officials (if necessary) of the time and place of the accident investigation.
    - He must attend all in loco FOG accident investigations.
    - He must ensure that the accident report form is completed by the injured person's immediate supervisor.
    - He must complete his section of the accident report form.
    - On completion of the accident report form by the responsible mine overseer, the shift boss must forward the accident report form to the safety officer.

- The section manager in charge of the area where the accident occurred:
    - He must attend all in loco investigations for FOG reportable accidents.
    - He must complete his section of the accident report form.

- The safety officer:
    - He must attend all in loco investigations for FOG reportable accidents and all other FOG accidents as far as possible.
    - He must receive all FOG accident report forms and ensure that they have been completed properly.
    - He must analyse the accident and report his findings to the Health and Safety Committee at the monthly meeting.
    - He must keep copies of the accident report forms on file.
    - He must update the FOG accident data base on a monthly basis.
    - He must ensure that Accident Form 13 is completed after each FOG accident.

GLOSSARY OF TERMS AND DEFINITIONS	
Incorporate a glossary of terms and definitions	*Y*

4 GLOSSARY OF TERMS AND DEFINITIONS

A glossary of terms and definitions is included in Appendix A. This appendix forms part of the COP.

ROCK-RELATED RISK MANAGEMENT	
• *Identify and describe rock-related hazards which are likely to arise from the mining of each geotechnical area identified.*	*Y*
• *Assess and prioritise the health and safety risks to which workers will be exposed and record findings.*	*Y*
• *Develop and implement reasonably practicable strategies to reduce and manage these risks, based on above risk assessment and accident analysis.*	*Y*
• *Use Tripartite Risk Assessment Guidelines when dealing with the aspects of hazard ID and risk assessment.*	*Y*

5 ROCK-RELATED RISK MANAGEMENT

A risk assessment, facilitated by a risk assessment consultant, was carried out at Open Pit Mine to identify and describe rock-related hazards. Table 4 summarises the identified hazards according to related risk. A risk rating of 1 denotes the highest (most significant) risk, and a risk rating of 25, the lowest (least significant).

Table 4 Identified hazards

	Identified hazard	**Risk rating**
1	Fissures north – South lead to falls of ground	2
2	Backfilling leads to rolling rock causing fall of ground	3
3	Calcrete overburden leads to fall of ground	3
4	Change in rock type, leads to fall of ground	4
5	Joints leading to fall of ground	5
6	Change of dip leads to fall of ground	5
7	Bedding plane in Ironstone leads to falls of ground	5
8	Red clay leads to fall of ground / slump	5
9	Faults East – West leading to fall of ground	5
10	Blasting leads to an overhang causing fall of ground	5
11	Layout inadequate leads to fall of ground	7
12	Drilling incorrectly leads to fall of ground	8
13	Marking incorrectly leads to fall of ground	8

14	Loading from stacks leads to fall of ground	10
15	Collapse wash away	12
16	Old waste dump unstable leads to fall of ground	12
17	Ground water channels leads to fall of ground	12
18	Weathered sub-outcrop leads to fall of ground	18

Rock-related risk assessment at Open Pit Mine will be carried out in accordance with the relevant requirements of the Mine Health and Safety Act (1996). These requirements are described in Section 11 of the Act, and obligate the manager to:

- identify the hazards;
- to assess the health and safety risks to which workers may be exposed while they are at work;
- record these findings;
- implement reasonably practicable measures to control the risk.

The Guideline for the Compilation of a Mandatory Code of Practice to Combat Rockfall and Rockburst Accidents in Metalliferous Mines and Mines other than Coal[3] (Guideline) requires that, when dealing with the aspect of hazard identification and risk assessment, the Tripartite Risk Assessment Guidelines[2] on the subject should be used. This section of the code of practice (COP) to combat rockfall accidents at Open Pit Mine is based on these and other relevant literature, and summarises the rock-related risk management strategy that will be followed by Open Pit Mine.

5.1 Implementation of Rock-Related Risk Assessment Process

The successful implementation of the rock-related risk assessment process at Open Pit Mine will depend on the successful execution of the underlying aspects by the responsible personnel. Table 5 summarises the responsibilities allocated to the various job categories.

Table 5 Responsibilities of various job categories in terms of the execution of rock-related risk management aspects at Open Pit Mine

DESIGNATION	RESPONSIBILITIES
Mine Manager	• Comply with corporate risk management policy. • Establishment, implementation and maintenance of a rock-related risk management strategy at Open Pit Mine. • Initiate action to prevent or reduce the adverse effects of rock-related risks. • Control further treatment of rock-related risks until the level of risk becomes acceptable. • Appointment of a competent Risk Assessment Co-ordinator or Risk Assessment Consultant. • Arranging external audits of rock-related risk control strategies. • Employ competent personnel for the execution of the rock-related risk control strategies. • Provide personnel responsible for the execution of rock-related risk control strategies with suitably designed and maintained equipment. • Set standards for maximum acceptable rock-related risks.
Risk Assessment Co-ordinator	• Implementation and maintenance of a rock-related risk management system to ensure that all rock-related risks are assessed systematically. • Reports to management on the performance of the rock-related risk management system. • Advises management on the gathering of data relevant to rock-related risk assessments. • Assimilation and analysis of relevant data. • Conversion of data to a useful format. • Selection of risk assessment teams. • Training of the risk assessment team in order to carry out risk assessments. • Conditioning of risk assessment team. • Defining the scope of rock-related risk assessment exercises.

DESIGNATION	RESPONSIBILITIES
	• Facilitation of the rock-related risk assessment process, including: • The review of existing safety measures relevant to the identified rock-related risks; • Development of risk control measures to combat identified rock-related risks; • Defining the roles and responsibilities of people responsible for the execution of risk control strategies. • Analysing and prioritising measured risks. • Reporting and recording of rock-related risk assessment exercises. • Monitoring of rock-related risks. • Review and revision of existing rock-related risk assessments on a regular bases and as required. • Regular auditing of rock-related risk management strategies.
Safety representatives	• Regular feedback on the success/failure of rock-related risk control measures.
Risk Assessment Team	• Systematic identification of rock-related hazards. • Measuring of rock-related risks. • Review of existing safety measures relevant to the identified rock-related risks. • Developing risk control measures to combat identified rock-related risks. • Define roles and responsibilities of people responsible for the execution of risk control strategies.
Open Pit workers	• Perform work safely, using the correct tools and equipment according to the training provided. • Identify rock-related hazards to which they will be exposed to, and to understand the risks associated with those hazards. • Execution of relevant rock-related risk control strategies associated with identified risks.
Training Officer	• Training of front line supervisors to be competent in Critical Task Analysis, Planned Task Observations and workplace inspections.

DESIGNATION	RESPONSIBILITIES
	• Developing training syllabi relevant to the identified rock-related strategies. • Training of identified personnel to be competent in the execution of relevant strategies to combat rock-related risks. • Training of all production personnel, contractors and visitors in rock-related hazards and to be competent in identifying the rock-related hazards to which they will be exposed to. • Training of production personnel, contractors and visitors to be competent in the use of relevant safety devices. • Training of production personnel responsible for strata control to perform their work safely and competently.
Rock mechanics engineer / rock engineering consultant	• Participate in the risk assessment process. • Assist with the development of rock-related risk control strategies. • Design support systems to reduce rock-related risks to acceptable levels. • Assist with the compilation of the mine's code of practice to combat rockfall and rockburst accidents, and relevant mine standards. • Regular audits of risk control strategies.
Front line supervisors	• Implement and supervise the execution of relevant risk control strategies. • Regular auditing of risk control strategies. • Perform Critical Task Analyses, Planned Task Observations and workplace inspections on a regular basis. • Provide subordinates with equipment suitable for the work being performed as regards design, maintenance and reliability.

STRATEGIES TO REDUCE AND MANAGE ROCK-RELATED RISKS	
• *State department or persons responsible for the execution of the particular strategies or portions thereof.* • *Provide time table for preparation and implementation of strategies.* • *Derive mine standards from strategies.*	*Y* *Y*
Mining Method, Sequence and Overall Mine Stability: • *Include measures to avoid failures that may injure employees or damage mine excavations or equipment.* • *Take into account:* - *the geotechnical environment* - *potential major rock related hazards identified in risk assessment* • *Describe:* - *mining method* - *mining sequence to be followed.* • *Describe strategy adopted to manage risk where mining of one orebody can be expected to have an adverse effect on the other.* • *Describe in detail the use of ongoing RE input in mine layout design and performance monitoring.*	*Y* *Y* *Y* *Y* *Y* *Y* *Y*
• *Describe the design methodology and frequency of slope stability investigations. Taking into account the impact of:* - *geology,* - *groundwater,* - *geomechanical properties and* - *discontinuities* • *Describe slope management program to reduce:* - *risk of failures on bench, stack and overall slopes* - *impact on employees and mine equipment* • *Describe detailed strategies for:* - ongoing stability monitoring programme - geotechnical mapping programme - development of pit slope hazard plan • *Describe strategy to reduce backbreaks, e.g. pit limit blasting* • *Describe methods of 'housekeeping', dressing of loose* material	 *Y* *Y* *Y* *Y* *Y* *Y* *Y* *Y* *Y* *Y* *Y*

6 STRATEGIES TO REDUCE AND MANAGE ROCK-RELATED RISKS

Departments and persons responsible for the execution of the different strategies at Open Pit Mine are stated in this section and a time table is provided for the preparation and implementation of strategies not yet in place. Present mine standards at Open Pit Mine are updated and new standards derived from these strategies, where applicable.

6.1 Overall Mine Stability

The strategy for the overall stability of Open Pit Mine include measures to avoid failures that may injure employees or damage mine excavations or equipment. It takes into account the geotechnical environment and potential major rock related hazards identified in the risk assessment process. The mining method and mining sequence to be followed to manage the risk involved are also described as well as the use of ongoing rock engineering input in mine layout design and performance monitoring.

The slope management programme to reduce pit failures at Open Pit Mine, housekeeping and the pit slope hazard plan are discussed. Competency criteria of persons responsible for the execution of strategies are discussed. Present training modules will be updated to comply with this COP and new modules compiled to ensure critical competencies. Strategies are cross referenced with hazards identified above.

6.1.1 Mining Method

Open Pit Mine is an open-pit operation, which started in 1994. The mine operates within the Lebowa Manganese Field of the Northern Province.

Current dimensions of the open pit range in the order of 1 km wide, 1.5 km long and 115m deep (Figure 6). Conventional open pit mining methods are practised in the sense that the overburden is first removed to uncover the manganese ore body. Overburden material is used to backfill the mined out portions of the pit as mining progresses.

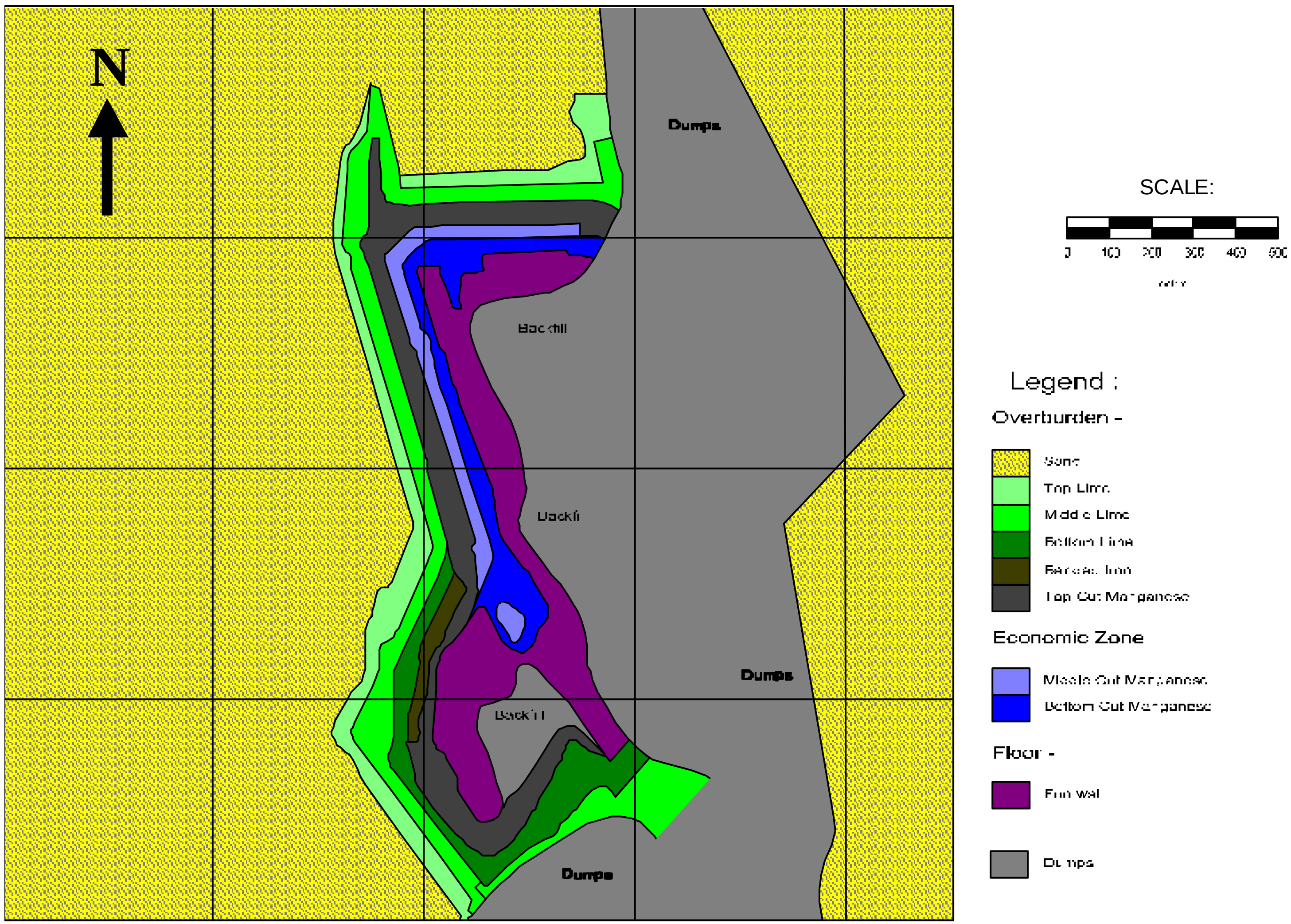


Figure 6 **Open pit geometry**

The mine is primarily divided into two working faces, namely, north and west. These faces are advanced between 30m and 40m per annum over the full active bench length of some 1.5 km. The lengths and rate of advance of the various faces are determined by the grade of the ore and information obtained from prospect boreholes. By blending ore from the various faces a constant quality of ore is guaranteed.

6.1.2 Mining Sequence

Removal of the overburden is done in stages: sand (one cut), limestone (four cuts) and banded ironstone (three cuts). This process produce three types of natural waste material at Open Pit Mine, which are currently replaced (in similar order to its natural occurrence) in the eastern side of the mine.

The dumps comprise:

- stockpiles of Aeolian sand;
- dumps of dolomitic calcrete;
- rock dumps containing low grade manganese bearing ore.

These dumps act as backfilling material for the purpose of rehabilitation as required by legislation.

The stripping ratio at present is 2.5 : 1.0 overburden : manganese ore

The manganese ore body is mined in two cuts and the height of the cuts is determined by the grade cut-off contours, which in turn are determined by sampling of the blastholes. The Middle Cut is the upper bench of the middle zone and the Bottom Cut is the lower bench of the middle zone.

The Top Cut, in the upper zone (M2 grade), contain a lower grade, for which a low demand is currently experienced and therefore its subsequent grouping with the overburden (see Figure 5).

6.1.2.1 Slope Stability Investigations

Unsafe conditions at Open Pit Mine, as seen from a rock engineering point of view, are when rolling rocks from bench faces occur and/or when failure of the overall pit slopes takes place. To ensure that the pit can be excavated safely, mining personnel (who know what excavation they would ideally like to have) need to answer to the following questions:

- Will the planned pit slopes be stable?
- Will it be necessary to change the shape or design, or what support is required to make the pit slope sufficiently stable?

Rock mass characterisation is fundamental to the planning of an open pit mine. It is the basis of the definition of geotechnical areas; for the evaluation of rock mass strength and deformation behaviour; for the identification of most likely modes of potential rock mass failure; for evaluation of stability of the rock mass; and for the evaluation of the requirement for support of the rock mass. The design approach at Open Pit Mine is therefore based on a sound geotechnical database.

The stability evaluation and slope design follows a strait forward path:

The purpose of the pit determines its geometry and size, for example:

- the mining extraction pit geometry is dictated by the orebody shape and the chosen mining method and equipment.
- The practicality and stability of the pit must then be evaluated in relation to the quality of the rock mass in which it is located:
- is it, or will it be, stable?
- what is the mode of identified instability, if any?
- can the instability be overcome by modifying the geometry and location of the pit?
- what support, if any, is necessary to ensure that the desired stability is achieved?

Slope stability investigations at Open Pit Mine therefore centres around the following two aspects:

- Rock mass characterisation; and
- Slope stability design considerations.

These two aspects are documented well in the 'Best Practice Rock Engineering Handbook for 'Other Mines'' and several rock engineering textbooks. Only a short extract will therefore be given in the next two paragraphs to give an overview of the design approach and applicability thereof to Open Pit Mine.

Rock Mass Characterisation

The behaviour of excavations in rock will depend on the structure of the rock mass. Four conditions can be considered:

- massive rock condition;
- major structural influence condition;
- jointed rock mass condition;
- weathered rock and soil.

Rock mass characterisation must be carried out to determine which of these conditions is applicable. It will also determine which method of stability analysis or design is most appropriate. Rock mass characterisation deals with the geotechnical data to be collected, the methods of collection, the recording of the data, the interpretation of the data, and the required outputs. Rock mass characterisation also provides the definition of geotechnical areas, which is an essential requirement in the COP.

The rock mass characterisation process are, for the purpose of the slope stability investigation, subdivided into:

- The collection of geotechnical data;
- Input to rock mass classification; and
- Rock mass classification systems.

One of the main purposes of the rock mass characterisation process is to classify the rock mass according to the Mining Rock Mass Rating system (*MRMR*). Special attention is therefore given to this aspect.

i. Collection of Geotechnical Data

Site investigations

Site investigations is conducted to provide data for the satisfactory planning and mining of safe excavations, information must be obtained on which basis the rock mass will be characterised.

The importance of a thorough understanding of the geological setting, and of the value of the early investigation stages in the site investigation cannot be over emphasised.

Geotechnical logging of borehole core

Exploration logs provide some geotechnical information of value. In particular, these logs will almost certainly define major structural features such as faults, which is critical information for structurally controlled stability situations. Re-log of the core specifically for geotechnical purposes are, however, also necessary and it is important that basic geotechnical data is gathered from borehole core before they are sampled. Additional deflections should be drilled in critical areas to ensure that samples are available for geotechnical purposes.

The following information are recorded during geotechnical core logging:

- Drilling record;
- Recovery;
- Rock Quality Designation (*RQD*);
- Geotechnical interval;
- Rock type;
- Rock competence;
- Weathering;
- Hardness;
- Joint distribution relative to core axis;
- Joint surface condition.

ii. Input to Rock Mass Classification

Data from the geotechnical log can be input directly into rock mass classification systems.

Mapping of exposed rock surfaces

If jointing in the rock mass is judged to be such that excavation behaviour will be dictated significantly by the joint orientations and other joint characteristics, then specific mapping of the joint parameters will be required. If, however, the behaviour will be of a homogeneously jointed rock mass, then rock mass classification mapping will be appropriate.

Joint mapping

A detailed description of methods of joint mapping is not described here, since it is considered that such detailed mapping will always be necessary. To determine the potential for the formation of blocks and wedges (the geometric possibility of occurrence thereof), it is necessary to know the following parameters and their variability for each joint set:

- the orientation (dip and dip direction);
- the joint spacing;
- the joint length.

These parameters have typical statistical distributions which is important to know when doing more advanced probability studies. These distributions are:

- joint dip angle - normal distribution;
- joint dip direction - normal distribution;
- joint spacing - log normal;
- joint length - negative exponential.

Rock mass classification mapping

A less rigorous format than the systematic joint mapping described above, but equally effective for the experienced geomechanics practitioner, is the application of rock mass classification mapping. The important aspect of this approach is to ensure that the required input data for good quality rock mass classification is obtained. Data recorded is comparable to those gathered from borehole core. The recommended way in which this can be achieved is to use a standardised rock mass description sheet, which act both as a check list on the information to be collected as well as a physical data sheet.

Laboratory rock testing

The purpose of rock sample testing is to extend the data available from descriptions and index tests by providing real data on specific properties of the rock.

iii. Rock Mass Classification

A rock mass is generally weaker and more deformable than its constituent rock material as the mass contains structural weakness planes such as joints and faults. The stability of an excavation in a jointed rock mass is influenced by many factors including:

- strength of rock material
- frequency of jointing
- joint strength
- confining stress
- presence of water.

The best practical way in which these weakening/strengthening effects can be taken into account is by applying rock mass classification methods.

Quantitative classification of rock masses has become almost routine, since it provides a rapid means of quantifying the quality of a mass, comparing qualities, and assessing support requirements. Classification applied on a routine basis can have tremendous value in open pit mines.

Two classification methods have stood out, the *Q* System developed by Barton et al (1974) and the Geomechanics Classification System developed by Bieniawski (1989). A system specifically for mining applications, based initially on Bieniawski's method, but now independent, has been developed by Laubscher and Taylor (1976) and refined by Laubscher (1994). The Laubscher (1994) system is being used on Open Pit Mine for slope design purposes.

_Q_ System (Barton)

The Q System classification is based on three aspects:

- rock block size (RQD/J_n)
- joint shear strength (J_r/J_a)
- confining stress (J_w/SRF)

Where: *RQD* is the rock quality designation

J_n is the joint set number

J_r is the joint roughness number

J_a is the joint alteration number

J_w is the joint water reduction factor

SRF is the stress reduction factor.

Geomechanics Classification (Bieniawski)

The Geomechanics Classification System derives a rock mass rating (*RMR*), obtained by summing five parameter values and adjusting this total by taking into account the joint orientations. The parameters included in the system are:

- rock material strength (*UCS*)
- *RQD*
- joint spacing
- joint roughness and separation
- groundwater

A relationship has been found between *RMR* and *Q* as follows (Bieniawski, 1989):

$$RMR = 9 \ln Q + 44$$

Mining Rock Mass Classification (Laubscher)

This system takes into account the same parameters as the Geomechanics system, but combines the groundwater and joint condition, resulting in the four parameters:

- rock material strength (*UCS*)
- *RQD*
- joint spacing
- joint condition and ground water.

Rating values for each of these parameters and adjustments for joint condition and groundwater parameter can be read from tables compiled by Laubscher. The mining rock mass rating *MRMR* value is obtained by summing the four parameter ratings. The range of *MRMR* lies between zero and 100.

Correlation between *MRMR* and *Q* is adequately represented by the equation between *Q* and *RMR* given above.

Table 6 gives typical *Q*-values for individual lithologies at Open Pit Mine.

Table 6 Rock mass classification for individual lithologies

Lithology/ Mining horizon	**Sample**			***Q*-Classification**
	Mean *Q*-Index	**SD *Q*-Index**	**Range *Q*-Index**	
Banded Iron Formation	3.0	1.5	2.0 – 4.0	Poor
Manganolutite Top Cut	6.2	2.0	3.0 – 8.0	Fair
Manganolutite Middle Cut	8.5	2.6	5.5 – 13.0	Fair
Manganolutite Bottom Cut	10.0		10.0	Fair to good

SD = Sample standard deviation

Typical *Q*, *RMR* and *MRMR* values for each of the mining horizons at Open Pit Mine are given in Table 7.

Table 7 Typical Rock Mass Classification Values for the Different Mining Horizons

MINING HORIZON	*Q* Index	*RMR*	*MRMR*
Lebowa Sand	0.01	15	1.5
Calcrete	13	65 - 70	35
Clay	0.01	15	5
Banded Ironstone	3 - 4	55	42
Top, Middle & Bottom Cuts	4 - 6	60 - 80	55 – 60

At Open Pit Mine, rock mass characterisation parameters are to be verified, on an ad hoc basis, by a suitably qualified rock engineering practitioner / consultant, appointed by the mine manager, when ground conditions change visibly.

Slope stability design considerations

Two detailed slope stability design studies have been conducted at Open Pit Mine, one during the feasibility stage and a more recent design study, based on the latest geotechnical data available in the pit. Details of the feasibility study are documented in SRK Report MI 5278/2 'Open Pit Mine, Feasibility Study for Proposed New Open Pit Manganese Mine', February 1994. Details of the design study are given in SRK Report 215 729/1 ' Open Pit Mine, Slope Stability Investigation of the Pit Slope Angles at Open Pit Mine', March 1998. Where applicable, these investigations are updated with new information during routine visits to Open Pit Mine by the rock engineering practitioner / consultant, as discussed in the slope management programme.

6.1.2.2 Slope Management Programme

A slope management programme is required by the Guideline (GME 7/4/118-AB4) to compile a Code of Practice for Surface and Open Pit Mines, which was issued in terms of the Mine Health and Safety Act, 1996. Such a programme is necessary since there are risks of failure of bench, stack and overall slopes in the open pit environment. The slope management programme describes the measures in place to reduce the impact of such failures on employees and mine equipment.

The slope management programme consider the following activities:

- Ongoing rock engineering service;
- Use of artificial support;
- Slope architecture;
- Mine planning considerations;
- Pit slope monitoring;
- Pit limit blasting and
- Groundwater and surface water control.

Rock Engineering Service

An efficient ongoing rock engineering service forms an integral part of the slope management programme. The level of service requires depend on the risk profile of the mine and at Open Pit Mine this is considered to be relatively low. As a result the required service is provided on an ad hoc basis at management's discretion, although management ensure that there is an ongoing relationship to maintain continuity.

The duties of the rock engineering service are to:

- review design and planning of new areas;
- review abnormal ground conditions and make proactive recommendations;
- review designated special areas and advice on requirements;
- participate in regular interdisciplinary mine planning and design meetings;
- initiate and implement monitoring, recording and reporting procedure;
- assist management with training in rock engineering aspects;
- assist management with investigation of serious rock related incidents;
- assist management with risk assessment of rock related issues;
- assist management with compiling and updating of the Code of Practice and
- assist management with the compiling and updating of Mine Standards.

It is appreciated that the service provides maximum benefit if it is proactive and identifies potential hazardous conditions before they occur and create dangerous situations.

Large overall pit slope failures occurred in the past on many open pit mines and such failures are possible on most mines, if not managed properly. Large failures can lead to serious damage to equipment and / or put the safety of people, working at the base of the pit, at risk. These failures and their potential impact can normally be minimised by a proper pit slope design carried out by the rock engineering practitioner / consultant, followed up by routine input into the slope management programme.

Open Pit Mine therefore commissioned Steffen, Robertson and Kirsten (SRK) during the feasibility study to conduct a pit slope stability study. Details of the study are documented in SRK Report MI 5278/2 'Open Pit Mine, Feasibility Study for Proposed New Open Pit Manganese Mine', February 1994.

The feasibility study was followed up by a more detailed pit slope design study, based on detailed geotechnical mapping of pit slope faces and available borehole core, as well as laboratory strength tests conducted at the CSIR on representative samples selected from boreholes drilled within the pit area. This study confirmed in general the overall pit slope angles recommended in the feasibility study. These angles were based on the Laubscher (1990) Mining Rock Mass Rating (MRMR) system and the empirical slope design chart of Haines and Terbrugge (1991) (see Figure 7). However, failures subsequently observed in the pit along the northern highwall adjacent to a fault zone, pose a safety risk. The kinematic analysis (Figure 8), followed up by deterministic and probabilistic analyses, confirmed this. The overall slope angle on the northern side was therefore reduced from 63° to 58°. This has a negative impact on stripping ratio, but management regards this as necessary to maintain the long term stability of the pit. Details of the study are given in SRK Report 215 729/1 ' Open Pit Mine, Slope Stability Investigation of the Pit Slope Angles at Open Pit Mine', March 1998.

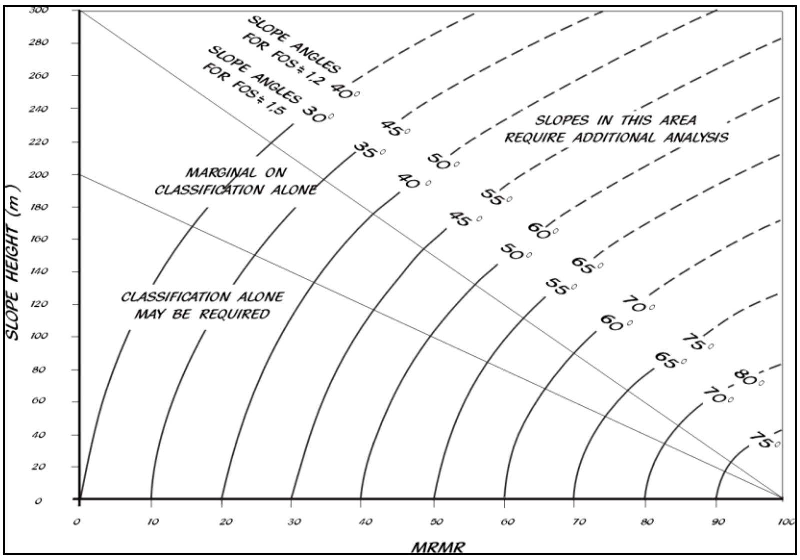


Figure 7 **Empirical slope design chart (after Haines and Terbrugge, 1991)**

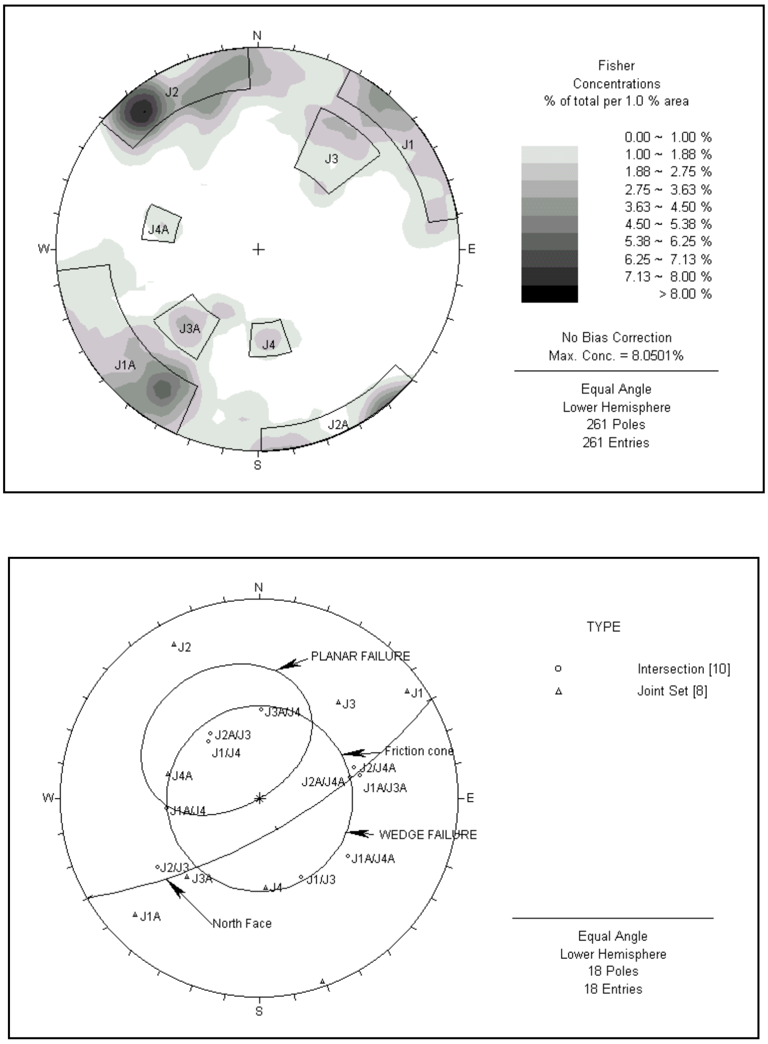


Figure 8 **Stereonet contour plot of the joint orientations and kinematic analysis of the north face**

Inconvenient bench failures also occur from time to time at Open Pit Mine, as is the case on most open pit mines. The risk that such failures could cause serious damage to equipment and / or the safety of people is lower, but the occurrence is much more frequent than the large failures. A bench failure on one of the upper benches can still potentially cause severe damage to equipment and people working underneath in the pit, especially towards the end of the life of the pit when working space becomes limited on the lower levels.

Catchment berms were therefore introduced to handle these failures. Pit limit blasting techniques help to create a more stable overall final pit slope as well as individual benches. All benches and highwalls are regularly inspected for tension cracks and signs of potential failure on a routine basis and monitoring points are inspected and measured. All potential unstable (loose) keyblocks are barred / chained down and failed material blocking catchment berms cleaned where possible. If necessary, further proactive rectifying actions are then put in place and additional monitoring points installed.

At Open Pit Mine, these inspections are conducted on a monthly basis by mine personnel and followed up by a six monthly inspection by the rock engineering practitioner / consultant. The rock engineering practitioner / consultant is also informed of any worrying signs of instability, when observed and more frequent visits are conducted to investigate these signs of instability as well as more frequent, routine visits during heavy rainy periods. Observations and recommendations are documented in short reports after these visits. It was recommended recently that double benches should be considered in a report entitled: SRK Report 275 039 ‘Evaluation of bench stability after abnormal high rain season at Open Pit Mine’, March 2000.

The purpose of double benches is to increase of the relatively small catchment berms Trials will start soon to evaluate effectiveness of single bench pre-split blasting vs double bench pre-split blasting in the relatively difficult ground conditions of Open Pit Mine.

Detailed geological mapping of exposed faces in the pit are conducted by the Mine Geologist of Open Pit Mine. All major geological structures that could have a potential negative impact on slope stability (i.e. faults and dykes) are mapped on a monthly basis, plotted on a plan and reported on in the monthly report. This leads to the early detection of structural deviations and dangerous ground conditions, and proactive actions can be performed if necessary.

Routine geotechnical mapping of exposed faces and geotechnical logging of newly drilled exploration boreholes, are also conducted on a regular basis by the rock engineering practitioner / consultant, when required. This information is also used in the design of pre-splits, trim blasts and production blasts.

Exploration diamond drill holes are drilled on a fixed pattern of 150m x 150m and later filled in on a 40m x 40m pattern. This provides the usual information on quality distributions, but indications and information regarding structural changes can also be collected. If necessary, additional geotechnical information can be gathered from additional diamond drilling from the benches.

Arial mapping of the mining and backfill areas is performed at the end of each financial year when stockpiles are surveyed. A plan representing these areas is compile each year and comparison with previous years indicates deviations.

Artificial Support

Artificial support is commonly used in long term Civil Engineering applications, i.e. stabilising slopes of road cuttings, side walls of foundation excavations for buildings and dams, etc. In open pit mining operations the use of artificial or installed support to stabilise slopes which have become unstable can rarely be justified. The use of cable anchors or shear keys may be required locally for the support of a critically important ramp, for example. However, this would preferably be a temporary situation and the longer term solution would be to relocate the haul road to a more stable area.

An exception to this is the rare case when an open pit operation is specifically designed on the basis of installed support and stability is predominantly ensured by the installation of cables, rockbolts, wire mesh and shotcrete.

Rather than consider stabilisation directly, by installing expensive artificial support, the recommended approach is to adopt a slope management process. In this approach, the configuration of the slope, the mining sequence and the variation in this sequence, and the planning of alternative or dual haul road systems, are all part of the process.

Artificial support is not necessary at Open Pit Mine and will potentially only be considered to ensure stability of the ramp system in the case of unexpected instability. The rock engineering practitioner / consultant will immediately be informed if such potential problem are observed. He will then evaluate the need for artificial support and also investigate alternative options. The slope management programme will be amended if required.

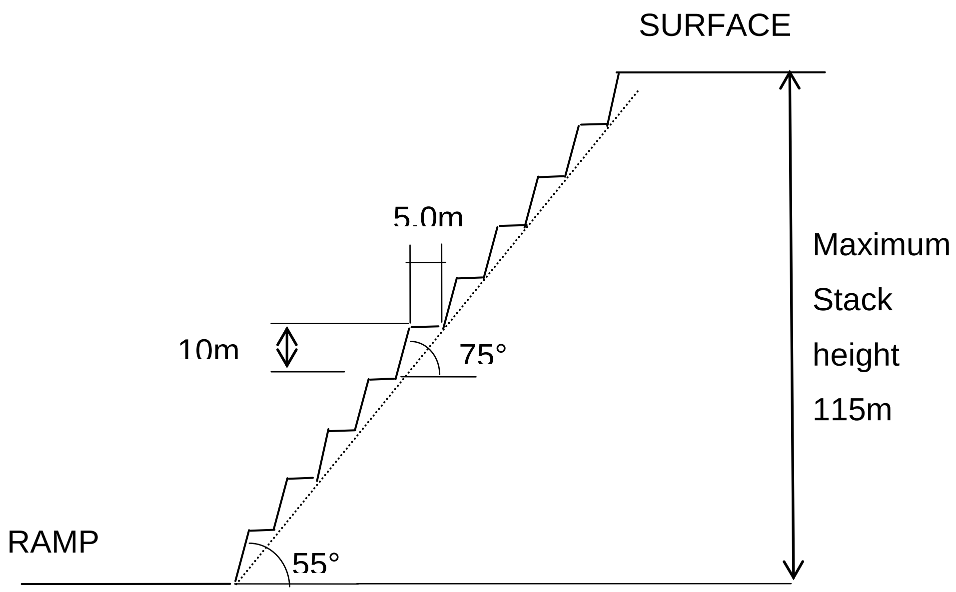
Slope Architecture

The present architecture of the final pit slope angles was recommended by Open Pit Mine's rock engineering consultant, following the design studies conducted in 1994 and 1998, entitled: SRK Report MI 5278/2 'Open Pit Mine, Feasibility Study for Proposed New Open Pit Manganese Mine', February 1994. and SRK Report 215 729/1 ' Open Pit Mine, Slope Stability Investigation of the Pit Slope Angles at Open Pit Mine', March 1998.

Original recommendations of the feasibility study of 1994 was altered during 1998, based on more detail mapping, laboratory tests and analyses conducted during the follow up study, mainly with respect to the stability of the northern highwall. Stability of this highwall will be monitored closely in the future, especially the effectiveness of the relatively narrow catchment berm width of 5.0m. The recommended trial with double benches will increase the berm width and should reduce the risk of bench failures. Double benches will first be tested for a trial period. This is necessary since the close spacing of joints at Open Pit Mine, many low angle joints and the curved nature of some of the joints cause pre-split blasting to be less effective on Open Pit Mine than on most other open pit operations.

The correct application of the slope architecture plays an important role in ensuring highwall stability at Open Pit Mine and special attention is being given to proper survey control and pit limit blasting to achieve the design specifications.

The present slope architecture can be summarised as follows (also see Figure 9):



SLOPE CONFIGURATION NORTHERN SIDEWALL		SLOPE CONFIGURATION OTHER SIDEWALLS	
Bench height	- 10m	Bench height	- 10m
Bench angle	- 75°	Bench angle	- 75°
Berm width	- 5.0m	Berm width	- 6.8m
Stack height	- 115m	Stack height	- 115m
Stack angle	- 55°	Stack angle	- 50°
Ramp width	- 20m	Ramp width	- 20m

Figure 9 Final pit slope configuration

- Limiting overall pit slope angle is measured from toe to crest (Figure 10), including ramps and berms where applicable. A maximum angle of 58° is allowable for the northern face and 53° for the other faces;
- Orientation of final pit slopes are bound by the orebody geometry at Open Pit Mine and limited room exists to improve slope stability by adjusting the orientation of the final slope faces to more favourable orientations, recommended slope angles are based on average slope orientations, although slope geometry (concave vs convex) considerations was also taken into account in the design studies;
- Bench stack angle of 55° is used for the northern face and 50° for the other faces, bench stack angles are measured from toe to toe;
- Maximum bench stack height is 115m;
- Bench face angle is 75° for all bench faces;
- Average bench face height is 10m and fits in well with capabilities of present drilling equipment, lower benches through the economic manganese zone, however, are being adjusted locally to compensate for ore grade variations;
- Present berm widths are 5.0m for the northern highwall and 6.8m for the other highwalls, this will be amended if the trials with double benches are successful;
- Ramp width is 20m and is sufficient for present hauling equipment.

These recommendations should be included in the Mine Standards.

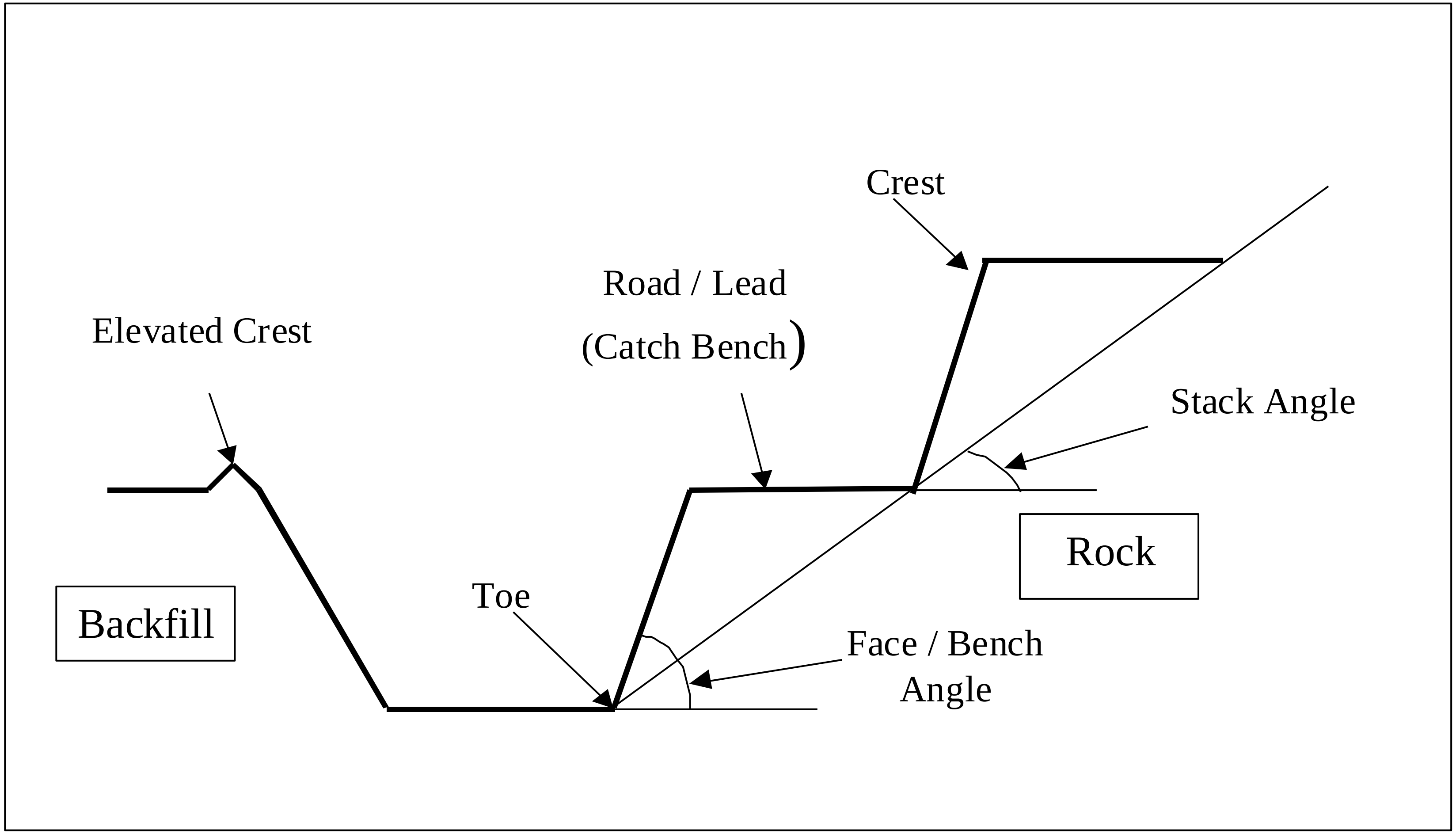


Figure 10 Schematic section through backfill and advancing faces

Mine Planning and Mine Design Considerations

Definitions

Mine planning deals with: production capacity, workforce numbers, equipment selection, budgeting, scheduling and rehabilitation.

Mine design deals with: drilling, blasting, loading, haulage, transportation, electric power, water, dust control, pumping, de-watering, ground support and reinforcement and excavation geometry.

Planning and Design Approach

The importance of a systematic approach to mine planning and design using soundly based geotechnical engineering methods cannot be over-emphasised. Major portions of orebodies are often left behind, because a sound slope management programme was not in place or neglected and the planned overall pit slope angle required to extract the orebody safely, can not be achieved.

This happens because of:

- the sudden increase in operational cost due to the drastic increase in incremental stripping ratio, requirement to increase the final pit slope angles to the originally planned angles;
- time required to do this additional waste stripping, which often comes as a surprise and at an inconvenient time;
- the difficulty to maintain the required production rate, because planned reserved are locked up by the shallower pit slopes that first need to be moved back to their original positions;
- the cost to catch up with the backlog in pit limit blasting, which was neglected and now found to be essential to achieve the required final pit slope angles.

Geotechnical issues should be considered during the whole life of the mining operation, from the pre-feasibility study stage, through the operational life of the mine, to the final closure and abandonment of the mine. Proper design of open pit excavations will prevent hazardous and unexpected failures during the operating life of the pit.

Special attention is therefore given to overall pit slope angles at Open Pit Mine, especially the pit limit practices and survey control to ensure that the planned overall pit slope angles are being achieved. All advancing faces are surveyed on a monthly basis by the Survey Department and plotted on mine plans. Planned slope architecture vs actual architecture are therefore monitored on a monthly basis by the Survey Department. The rock engineering practitioner / consultant also pays special attention to this aspect during routine visits.

All geological structures and dangerous ground conditions, mapped by the Mine Geologist are also taken into account and deviations are reported on in the month end report of the Geology Department. Proactive actions are being put in place when required and the rock engineering practitioner / consultant is also informed of all major deviations. Rectifying actions are being investigated further, if required.

Regular ‘mine planning and design meetings’ is necessary to discuss issues from current operational areas and new areas of the mine. Such meetings should be interdisciplinary involving survey, geology, geotechnical engineering, mining engineering and production.

Regular monthly ‘mine planning and design meetings’ are scheduled at Open Pit Mine. The rock engineering practitioner / consultant attend these meetings on a six monthly basis or more frequently, if required by changes in mine planning, at the discretion of the Mine Manager.

Approval of plans should be confirmed with the signature of members of the interdisciplinary team and a formal mining approval process should be in place. This should include plans, cross-sections and longitudinal projections of the ore blocks, also showing final pit slope positions, plus a written description of proposed mining work and mining issues to be addressed. Mine plans are compiled and updated by the Mine Planning Department and are signed by the members of the interdisciplinary team at Open Pit Mine. Geological plans and sections through the orebody are compiled and updated by the Geology Department, also showing planned vs actual final pit slope positions. Written descriptions of proposed mining and mining issues to be addressed are kept by the Mine Planning and Mine Design (Production) Departments. The Geology and Survey Departments also attend weekly production meetings.

Geotechnical Design Considerations

The original geotechnical design was based on limited information, but this is filled in with more detailed geotechnical investigations, during the economical life of the mine, adjustments are made to the design and slope management programme. With experience with the orebody, it is possible to refine the plan over time to address slope management issues important to the safe operation of the mine.

The original feasibility study at Open Pit Mine (SRK Report MI 5278/2 'Open Pit Mine, Feasibility Study for Proposed New Open Pit Manganese Mine', February 1994), was updated with a more detailed design study (SRK Report 215 729/1 ' Open Pit Mine, Slope Stability Investigation of the Pit Slope Angles at Open Pit Mine', March 1998). Refinements to the design and slope management programme are conducted by the rock engineering practitioner / consultant during routine visits, as new information becomes available.

Early identification of geotechnical issues that plays a role in the safe extraction of the orebody is crucial. Typical issues considered at Open Pit Mine by the rock engineering practitioner / consultant and which is also regularly discussed at the interdisciplinary 'mine planning and design meetings', when deviations / changes takes place, include:

- Depth and life of mining;
- Ground conditions and variability thereof;
- Production rate;
- Size, shape and orientation of the excavation;
- Location of working benches and ramps;
- Potential surface water and groundwater problems;

- Equipment, excavation method and ore / waste handling;
- Presence of nearby surface structures (e.g. roads, railways, pipelines, drainage channels and buildings) and potential access by the general public during and after mining;
- Time dependent characteristics of the rock mass, particularly after abandonment.

Operational Geotechnical Considerations

On-going assessment is required since initial data is often poor and proper data is only becoming available as the open pit operation proceeds. It is therefore necessary to improve on the geotechnical database, to assess the general stability of the mine and the suitability of the original mine design.

The well managed slope management programme at Open Pit Mine include therefore regular discussions of all ground control issues with relevant mine personnel, both during inspections and in formal planning meetings. Special attention is given to:

- Changes in the geological structure and general rock mass conditions and
- The detection and discussion of incipient rock mass failures.

This allows for the early recognition of instability issues. Extraction techniques, mine design, ground support and reinforcement, and monitoring practices are reviewed regularly at Open Pit Mine and modified, before problems become difficult or expensive to control.

The monthly geological mapping by the Geology Department, routine visits by the rock engineering practitioner / consultant and regular interdisciplinary ‘mine planning and design meetings’ at Open Pit Mine compliments the process.

Abandonment

Before open pits can be legally abandoned, the DME requires that all long-term drainage, environmental and public access issues are adequately considered and controlled. Adequate geotechnical data is normally available at mine closure to address all long-term geotechnical concerns regarding the abandonment of the mine.

Although the planned economical life of Open Pit Mine is still 15 years, mining activities are planned in such a manner that they compliment the long-term closure requirements. Special attention is also given to environmental issues.

By making geotechnical engineering input to the mine planning and design process an integral part of the mining operation at Open Pit Mine, improvements are made to mine safety, productivity, economic efficiency as well as closing concerns when abandoning the mine.

Pit Slope Monitoring

Monitoring of slopes is an integral part of the slope management programme and is critically important in open pit mines with a probability of failure of >10%, when continuous monitoring with sophisticated instruments are required to ensure safe mining. (see Table 21).

In smaller operations and operations with a lower probability of failure <10%, this may only be a visual monitoring record. In larger operations and more risky operations, monitoring by survey methods, installed instruments, seismic or micro-seismic systems, or even satellite based global positioning systems are appropriate. It must be emphasised that early knowledge of potential instability, and the consequent ability to implement a plan of action, will be much less hazardous and costly than if a slope failure occurs unexpectedly, subsequently requiring the clearing of the unstable, failed material.

To be successful, monitoring must be carried out regularly and routinely, and the resulting observations and measurements documented and interpreted. Only if this is done will it be possible to identify changes or trends in the pattern of behaviour at the earliest opportunity. This is being achieved through the following, basic monitoring strategy:

The Mine Geologist of Open Pit Mine keep detail records of all observations and measurements, report them on an ongoing basis in month end reports and supply the rock engineering practitioner / consultant with copies of these report. He comments then on the findings and results supplied by the geologist, helps with the interpretation and recommend rectifying actions, if required.

Monitoring at Open Pit Mine is mainly limited to regular (monthly) visual monitoring of tension cracks on surface and individual benches. Visual monitoring alone is acceptable at Open Pit Mine until the pit wall expresses one or more signs of potential instability.

Visual signs indicating incipient failure of pit walls include:

- Formation and widening of tensile cracks;
- Bulging of the slope face or toe;
- Ravelling of rock within the slope;
- Rock noise and ejection;
- Increased water seepage; and
- Bending of reinforcement or rock support elements.

If any signs of incipient pit wall failure are observed visual monitoring will be supplemented with more frequent, accurate, and / or wide spread monitoring, using one or more of the available instrumentation methods. The rock engineering practitioner / consultant will immediately be informed of such observations, since considerable judgement, experience and technical support are required for the selection, location and maintenance of some of the more advanced monitoring equipment.

Signs of incipient pit wall failure observed at Open Pit Mine such far, seems to be limited to bench failures. It was never the less decided by management to be proactive and monitoring pegs and survey beacons, as discussed below has been installed.

A few monitoring pegs installed on both sides of tension cracks on surface and critical benches, where potential instability was observed are also measured once a month. Results of these measurements are plotted on displacement vs time graphs and rate of movement calculated. The rock engineering practitioner / consultant also do inspections on his six monthly visits and report on results of measurements and observations recorded over the past 6 months.

Five survey beacons were also installed on strategic positions on surface to monitor long-term stability of the highwalls. These beacons are linked to a fixed survey beacon, which forms a base station, in a stable area some 200 metres away from the pit. This is to ensure that relative movement of one beacon does not affect the measurements of the other beacons. At Open Pit Mine these beacons are measured on a six monthly basis since no alarming movement has been detected such far. X, Y and Z co-ordinates are measured in order to evaluate any spatial movement. A qualified surveyor conducts these measurements.

The photogrammetric survey of the mining and backfill areas, performed at the end of each financial year when stockpiles are surveyed, also forms part of the monitoring strategy. A plan representing these areas is compile each year and comparison with previous years indicates deviations.

A more detailed monitoring strategy will be developed, if signs of potential large slope failures are detected with the present monitoring programme. The rock engineering practitioner / consultant will be requested to re-evaluate the present monitoring techniques and monitoring strategy and to considered alternative and / or supplementary techniques.

Table 8 Comparative significance of probability of failure

PROBABILITY OF FAILURE (%)	Design Criteria On Basis Of Which Probability Of Failure Is Established		
	Serviceable life	**Minimum surveillance required**	**Frequency of evident slope failure**
50 – 100	Effectively zero	Serves no purpose (excessive probability tantamount to failure)	Slope failures generally evident
20 – 50	Very short term (temporary open-pit mines – untenable risk of failure in temporary civil works)	Continuous intensive monitoring with sophisticated instruments	Significant number of unstable slopes
10 – 20	Very short term (quasi-temporary slopes in open pit mines - undesirable risk of failure in quasi-temporary civil works)	Continuous monitoring with sophisticated instruments	Some unstable slopes evident
5 – 10	Short term (semi temporary slopes in open-pit mines, quarries of civil works)	Continuous monitoring with simple/rudimentary instruments	Occasional unstable slope evident
0 – 5	Medium term (semi-permanent slopes)	Conscious superficial monitoring	No ready evidence of unstable slopes

THE INFLUENCE OF MINING ACTIVITIES ON NEIGHBOURING MINES	
• *Describe method to ensure that, where the possibility exists of one mine's activity influencing the activities of another mine, the mines concerned exchange data concerning:*	
- *mining methods*	*Y*
- *regional support*	*Y*
- *mining sequence*	*Y*
- *common geological features*	*Y*
- *% extraction*	*Y*
- *the location, magnitude and nature of seismic events.*	*Y*
• *Include timing and overall sequencing for the removal of the boundary pillar where applicable.*	*NA*

6.2 The Influence of Mining Activities on Neighbouring Mines

Mining activities on neighbouring mines is remote from Open Pit Mine's boundaries and well outside the zone of influence. Mining on neighbouring mines is therefore not a factor to be considered in this COP. However, this situation shall be reconsidered at least with every review of this COP.

SPECIAL AREAS	
• *Describe strategy to ID and deal with an increased risk of rockfalls which may develop during the course of routine mining operations.*	*Y*
• *Describe responsibility of RE in:*	
- *designing the layout*	*Y*
- *mining sequence*	*Y*
- *support*	*Y*
- *monitoring of special areas*	*Y*
• *Indicate:*	
- *where approved procedure, and any subsequent modifications for individual/specific areas are to be located*	*Y*
- *to whom copies of these instructions are to be distributed.*	*Y*

6.3 Strategies for Special Areas

During the course of routine mining at Open Pit Mine, an increased risk of rockfalls may develop. Such areas will require additional attention and the assistance of a suitably qualified rock engineering practitioner must be considered to advise management on additional support measures, alternative layouts or other rock engineering related issues.

6.3.1 Appointment of Special Area Officer

To ensure the smooth operation of the entire procedure, the mine manager will appoint, in writing, a Special Area Officer. His duties must be specified in the letter of appointment and will include aspects such as:

- convening Special Areas Meetings on a regular basis (at least every three months);
- recording of all proceedings associated with special areas;

- informing all relevant personnel in writing of areas declared as ‘special’ and of any changes to the support, mining layout or other aspects;
- ensuring receipt of written acknowledgement from the above personnel;
- keeping records of all relevant documentation on file.

6.3.2 Special Areas Committee

The Mine Manager will appoint a Special Areas Committee comprising of the Special Area Officer, Mine Manager, Mine Overseer, Shift Boss, Safety Officer and a representative from the Health and Safety Committee. The inclusion of a suitably qualified rock engineering practitioner in this committee will be at the discretion of the Mine Manager.

The function of this committee will be to:

- scrutinise all existing mine layouts and mine planning for the following three months and to identify all potential special areas;
- consider all relevant risks and to declare these areas as □□special□ if necessary;
- review progress with the extraction of previously declared special areas and to reconsider the future classification of these areas;
- co-ordinate general mine policy regarding the extraction of special areas.

This committee must meet at least once every three months.

6.3.3 Special Areas Declaration Procedure

Identification of Special Areas

Mining in the following areas should be considered for declaration as special areas:

- areas in the vicinity of major geological discontinuities such as faults and dykes;

- areas abnormally disturbed by joints or faults with unfavourable density, orientation or quality;
- unexpected presence of water seepage;
- localised areas with severe weathering;
- any other areas as decided by the mine manager.

These areas should be visited by the Special Areas Committee before being declared as a special area.

Notification to Relevant Personnel

All relevant personnel must be informed in writing of the decision to declare an area as ‘special’. They must also be informed of all the necessary safety instructions and changes to existing mine standards.

Acknowledgement of Receipt

All the above personnel must acknowledge receipt of Special Area notifications and relevant instructions in writing.

Work place entry procedure

A copy of the Special Area notification and instructions must be displayed at the applicable waiting places. Workers must be reminded of the relevant safety instructions and standards on a daily basis.

Support Considerations

Alternative pillar spacings, pillar sizes, support types and support spacings must be considered and must reduce the risk of rock fall accidents occurring to a reasonable level.

Documentation

All relevant information regarding the classification, declaration procedure, and monitoring of special areas must be well documented and kept on file by the Special Area Officer.

MONITORING AND CONTROL	
Describe monitoring strategies which will ensure that: • *the orebody is safely exploited* • *early warning of changing conditions is communicated to responsible persons.* *(Monitoring can be done either visually or with the use of instruments)* *Describe procedures and persons responsible (all relevant categories) for:* • *the examination* • *reporting* • *control of the safety of the working area* *Specify appropriate procedures taken:* • *for rendering an area safe* • *to reduce risk.* *For each ID hazard outline the:* • *controls to be followed* • *procedures to be followed* • *the responsible person*	 *Y* *Y* *Y* *Y* *Y* *Y* *Y* *Y* *Y* *Y*
Table content must be site specific.	*Y*
Table must be expanded to include all relevant rock-related: • *hazards* • *controls* • *procedures*	 *Y* *Y* *Y*
Describe monitoring programmes and procedures to ensure that the COP is being properly: • *implemented* • *maintained*	 *Y* *Y*
Describe procedures for defining responsibility and authority for: • *assuring conformance with the COP* • *taking action to mitigate any impact caused by non-conformance* • *implementing corrective actions to ensure conformance.*	 *Y* *Y* *Y*

Describe method to ensure that the general conditions of the rockwalls in ***all*** *working places are reported on a* ***regular*** *basis. For example:* • *record in shift boss's logbook* • *communicate to those specified in COP*	 *Y* *Y*
Specify and describe procedures for analysing the data to ID deteriorating conditions	*Y*
Describe: • *role of RE department/consultant* • *the routine input by RE personnel in the monitoring process.*	 *Y* *Y*
Specify frequency of review of ***every*** *separate working places with different risk classifications by a* ***suitably qualified RE practitioner.***	*Y*
Specify frequency of visits to working places with different risk classifications by suitably trained personnel.	*Y*
Describe influence of mining on adjacent properties.	*Y*

6.4 Monitoring and Control Strategies

This section includes detail strategies for the ongoing slope stability monitoring programme and geotechnical mapping programme and as required the development of a pit slope hazard plan, in order to reduce risks.

6.4.1 Early Detection

Through Geological Mapping, Exploration programs, etc. as performed by the Mine Geologist structural deviations, dangerous ground, etc. can be detected long before a situation arise. As a result evasive action can then be performed.

6.4.2 Geological Mapping

Graphical interpretation of structures, faults, fissures, dykes, etc. are recorded on a monthly frequency by the mine Geologist and is reported in the monthly report.

6.4.3 Exploration

The exploration diamond drill holes are placed on a fixed pattern of 150m x 150m to be filled in later, completing the 40m x 40m pattern. Apart from the usual information on quality distributions, indications and information regarding structural change can also be collected. In the case where not enough Geological/Geotechnical information is available diamond drilling can be performed directly from the benches.

6.4.4 Survey / Aerial Mapping

Aerial mapping of the mining and backfill areas is performed at the end of each financial year when stockpiles are surveyed. A plan representing these areas is compiled. Comparison with previous years can indicate deviations.

6.4.5 Ongoing Rock Engineering

Pit slope angle management

Based on the work and recommendations of the rock engineering practitioner / consultant, constant pit slope management is applied ensuring that all highwalls conform to the criteria. No alterations are planned.

Geomechanical properties and mapping

Under dynamic loading (i.e. blasting), material behaves quite differently than under static loading. The significance of this is that if only static strength properties and the geologic definitions are used from a blast design standpoint, they can be misleading.

Material at the Open Pit Mine is quite varied, complex and challenging in terms of blasting. Section 9.8: Open Pit Mine Schematic Section through benches, illustrates a general schematic cross section of the materials encountered. Rock densities range from a low of 2,180 kg/m^3 to 3,750 kg/m^3, but could be as high as 4,000 kg/m^3 in certain sections. Material strengths range from a low of 10 MPa in calcrete to over 300 MPa in the Top, Middle and Bottom cuts. Spacings of discontinuities range from about 0.75 m. to 1.10 m. *RQD*'s in the main mining areas range from 75 to 100%. Young's Modulus is taken to range from about 17 GPa in the lime to 50 GPa in the manganese and Poisson's ratio varies between 0.24 and 0.22, respectively.

In summary, an overall general estimate of the materials monitored could be classified as a "good" to "very good" rock from a Geomechanics definition.

Stability monitoring

Stability monitoring is not actively performed other than by visual inspection of workings by the Mine Overseer in conjunction with the Mine Surveyor.

It is the responsibility of the Mine Overseer to ensure bench stability is maintained and to change slope angles, or utilise other measures, should ground conditions change. It is furthermore the responsibility of the Mine Geologist to inform the Mine Overseer of any such changes or possible problem areas.

Should the current practice change, or measuring of subsidence of backfilled material become necessary, i.e. at field beacons, results are to be included in later revisions of this Code of Practice. The instruction regarding such measurement will be given by the Mine Manager.

Loose material risk reduction

Reducing the risk of loose material is based on a three pronged approach, firstly the attempt to reduce loose material by means of specified actions i.e. backfilling procedure, cleaning after the blast, etc. The second approach is to reduce risk by means of corrective action if risks prevail. Lastly the area is barricaded off if the risk cannot be removed.

6.4.6 Procedures and Responsible People

Table 9 summarises the strategies in place and responsible person(s) to execute certain strategies to combat identified hazards.

Table 9 Summary of strategies and responsible person(s) to combat hazards

Hazard	Classification	Control	Procedures / rules / standards	Responsible person
Fall of ground	Geology related	Exploration drilling, Geological Mapping	Mine planning policy	Mine Geologist
	Geology related	Geological features indicated on plans	Geological inspections, Monthly report	Mine geologist and Surveyor
	All	Training of all relevant personnel to identify geological features	Training modules, Code of Practice	Mine Manager through appointed personnel
	Sliding or rolling material	Early detection: Rock type, classification, alterations, etc.	Training modules, Geological inspections, etc.	All team members, Geologist
	All	Early shift examination	Code of Practice	Miner
	Loose material, Sliding or rolling material	Backfilling procedure	Code of Practice, 7.2.2	All team members
	Loose material, Sliding or rolling material	Install barricade	Code of Practice, 7.2.2	All team members
	All	Only authorised persons to work in Special Areas	Code of Practice, 7.2.2	All team members
	All	Marking of blastholes to be drilled	Minerals Act, Code of Practice, 7.2.2	Mine Manager, Mine Captain, Miner
	Toppling Over	Highwall angle	Correct mining practice	Mine Manager, Mine Captain, Miner
	Failure due to discontinuity	Bench angle with discontinuity zone	Mine planning, Geological mapping, etc.	Geologist
	All	Blast design	Based on research and experience	Mine Manager, Mine Captain, Miner
	All	Blasting	Code of Practice, 7.2.2	Mine Manager, Mine Captain, Miner
	All	Regular management review	Code of Practice	Rock Engineer, Mine Geologist

6.4.7 Report on risk reduction measures

Mine manager's responsibilities:

- Establish program

It is the responsibility of the Mine Manager to implement a program focussing on the reduction/elimination of rock related risk, at his own discretion, if/when necessary.

- Appointments

It is the responsibility of the Mine Manager (after consultation with the General Manager) to appoint/contract with, any person that he deem necessary, in order to ensure reduced rock related risk. It is furthermore the responsibility of the Mine Manager to adhere to applicable acts, regulations and Minerals and Energy departmental requests dealing with such appointments.

- Regular reporting

It is the responsibility of the Mine Manger to report on any such matter as stipulated in the Minerals Act, and it is his responsibility to ensure that any related incident be brought to his immediate attention.

- Rock Engineering Practitioner

It is the responsibility of the Mine Manager to ensure that the services of a Rock Engineering Practitioner is at all times available (through company relations), or that a consulting Rock Engineering Practitioner is available as alternative.

6.4.8 Training

No formal training programme or module currently exist. A formal training programme is to be compiled and is scheduled to be completed for inclusion into the code at the next review. When included it would satisfy the following criteria:

- All persons who normally work in mining production areas, and all persons who may be required to visit production sections in the normal course of their employment, shall attend and successfully complete an introductory course on rockfall hazards and support, before entering any such production section in the course of their assigned duties.

- The manager shall ensure that an appropriate syllabus is compiled and used for the introductory course on rockfall hazards and shall ensure that all elements of the course are taught in a manner and language comprehensible to the personnel under instruction. The syllabus shall include appropriate material on:

  - The rockfall hazard in general, and at Open Pit Mine in particular
  - Relevant features of the Regulations, the code and mine standards.

- Supervision, with particular reference to the responsibilities and functions of safety representatives, team leaders, miners, and others in relation to the rockfall hazard.
- The need to inspect and make safe
- Personal responsibility in relation to the rockfall hazard
- Action to be taken on becoming aware of dangerous ground conditions
- The manager shall institute, maintain and monitor appropriate systems to ensure that all persons undergo the requisite training course.
- All persons completing the specified courses shall be tested on the respective course contents, and the results recorded on their service records.
- The systems shall ensure that all affected persons returning to work after an absence from work of six weeks or more, whether such absence has been due to leave, injury, sickness or similar cause, shall undergo training before recommencing work.

BLAST DESIGN AND PRACTICE	
• *Describe strategy adopted to minimise blast induced damage. This must include:*	
- *methods to ensure drilling accuracy*	*Y*
- *types of explosives*	*Y*
- *method of initiation*	*Y*

6.5 Blast Design and Practice

Substandard blast results can result in unsafe working conditions, either directly or indirectly from malfunctioning explosives, primers and accessories resulting in misfires and/or inadequate blast results.

Open Pit Mine has some very tough and challenging blasting situations in view of the complex geological structure and grade control requirements imposed on the manganese benches. Overbreak resulting in irregular and unstable highwalls, varying, burdens, the necessity of front row re-drilled holes and loss of fragmentation controls for subsequent blasts.

6.6 Training

Training is regarded as very important at **Open Pit Mine** and proper training material will be compiled in consultation with the Rock Engineering Consultant. Such material should be completed by September 2001.

6.7 The Function of A Rock Engineering Service

According to Open Pit Mine's risk profile, a full time rock engineering service is not required on the mine. The services of a suitably qualified rock engineering practitioner or consultant will be used on an ad hoc basis and at management's discretion. These services will be considered under the following conditions:

- during the design and mine planning for the extraction of new areas;
- when new support systems are considered;
- when abnormally bad ground conditions are experienced;
- when considering any deviations from this COP;
- to review the mine's COP and mine standards on an annual basis;
- to review strategic planning for the mine;
- to review special areas and to advise management on special support requirements;
- to implement monitoring, recording and reporting systems and procedures;

- when designing the layout and support of special service excavations;
- to assist mine management with the training of mine personnel in rock engineering aspects;
- to audit existing mine layouts, planning, support systems and strata control practices;
- to assist mine management with the investigation of serious fall of ground incidents and accidents;
- to do geotechnical mapping and classification of new mining areas;
- to give input on risk assessment matters pertaining to rock related issues;
- when the risk of fall of ground accidents increases.

6.8 Implementation of the Code of Practice

A training and communication programme is required to familiarise the workforce with the strategies and their responsibilities for the implementation of this COP. Training will be structured for the different levels of responsibilities and will include strata control and hazard recognition tuition as well as the strategies of this COP.

The training programme will be controlled to ensure that all the necessary persons have attended and a record of this and each person's assent to having understood their responsibilities shall be maintained. After the period of training required for the initial implementation of the COP, the programme will be continuous and will be presented to all employees on induction and re-induction. Where necessary, employees will also be sent for re-training.

The implementation schedule listed in Table 10 has been compiled to ensure that the COP is implemented within a reasonable time.

Table 10 Implementation schedule

Strategy	Target date for implementation	Responsible person
Mining method	Ongoing	Manager
Mining sequence	Ongoing	Pit Super.
Slope stability investigations • RM Characterisation • Slope stability design considerations	September 2001	Rock Eng. Consultant
Slope management	November 2001	Manager
Influence of mining activities on neighbouring mines	August 2001	Rock Eng. Consultant
Strategies for special areas	Ongoing	Manager
Monitoring and control	October 2001	Manager
Blast design and practice	December 2001	Pit Super.
Training	February 2002	Training Off.

6.9 Conformance to the Code of Practice

The ultimate measure of the proper implementation of and conformance to the COP will be the rock related accident rates. Monitoring and control of strategies and the level of hazard awareness exhibited by workers will also indicate whether conformance is being achieved. However, people with specific responsibilities for assuring conformance with particular sections/strategies of the COP shall be appointed by the Manager.

The implementation of and conformance to this COP will be monitored by the safety officer. In addition, an annual audit will be carried out by a suitably qualified rock engineering practitioner. This will be done prior to the review of the COP.

APPENDIX A

GLOSSARY OF TERMS AND DEFINITIONS

APPENDIX A GLOSSARY OF TERMS AND DEFINITIONS

Adit: A horizontal opening, started from a hillside, to reach an orebody.

Batter slope: The sections of rock mass between catch berms within pit walls - usually excavated to a specific inclination / angle from the horizontal.

Bedding planes: Planes of weakness in the rock that usually occur at the interface of parallel beds or laminae of material within the rock mass

Burden: Distance between an explosive charge and the free surface in the direction of throw.

Buttress: A body of material placed against a section of the pit wall to prevent continued movement or propagation of wall failure.

Cable anchors: One or more steel reinforcing strands placed in a hole drilled in rock, with cement or other grout pumped into the hole over the full length of the cable. A steel faceplate, on contact with the excavation perimeter, would usually be attached to the cable by a barrel and wedge anchor. The cable(s) may be tensioned or untensioned. The steel rope may be plain strand or modified in a way to achieve the appropriate load transfer from the grout and the steel strand to the rock mass.

Catch berm: The width of lateral ground (bench) separating successive batter slopes. The purpose of the catch berm is to both reduce the overall angle of the pit walls, and to catch any loose material or local scale rock mass failures, thus reducing the risk exposed to the workforce at the base of the pit.

Catch fence: A fence constructed either vertically or at an angle to the vertical at the required offset distance from the toe of a slope. The purpose of the catch fence is to catch any loose material falling from overlying blocky ground, thus reducing the risk to the workforce at the base of the pit walls.

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

Competent rock Engineering Consultant: A Professional Engineer or a Professional Natural Scientist specialising in Rock Engineering and practising, or a graduate possessing the Chamber of Mines Certificate in Advanced Rock Engineering shall be a corporate member of the South African National Institute of Rock Engineering (SANIRE) with more than five years practical experience since obtaining the certificate and who is:

(a) employed by a mining company in a group position, or
(b) a contracted person who is not employed by the mining company.

Competent rock Engineering Practitioner: A person who is at least in possession of the Chamber of Mines Certificate in Rock Mechanics (Metalliferous) and has attained the necessary competencies to achieve the outcomes described in the regulations.

Compressive stress: Normal stress tending to shorten the body in the direction in which it acts.

Decoupling: Ratio of the radius of a blasthole to the radius of the charge; this causes a reduction in the amplitude of the strain wave by increasing the space between the charge and the blasthole wall.

Deformation: A change in shape or size of a solid body.

Dilatancy: The property of volume increase under loading.

Dip: Angle at which a stratum or other planar feature is inclined from the horizontal.

Discontinuity Surface: Any surface across which some property of a rock mass is discontinuous (e.g. bedding planes, fractures).

Dowel: An untensioned rod of steel or other material, anchored by full column or point anchor grouting, generally with a face plate in contact with the rock surface.

Drive: A horizontal opening, like a tunnel lying in or near the orebody, parallel to the strike.

Earthquake: Groups of elastic waves propagating within the earth that cause local shaking / trembling of ground. The seismic energy radiated during earthquakes is most commonly caused by sudden fault slip, volcanic activity or other sudden stress changes in the Earth's crust.

Elasticity: Property of a material whereby it returns to its original form or condition after an applied force is removed.

Fault: 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: Waste sand or rock, uncemented or cemented in any way, used either for support, to fill stope voids underground, or to provide a working platform or floor.

Foliation: Alignment of minerals into parallel layers; can form planes of weakness / discontinuities in rocks.

Footwall: Mass of rock beneath a discontinuity surface (in tabular mining, the rock below the reef plane).

Force: An action that tries to move an object from a stationery position, or to change its rate of movement or its direction of movement.

Friction Rock Stabilisers: Steel reinforcing elements, typically C shape, that are forced into holes in the rock and rely on friction between the side of the hole and the element to generate a force to limit rock movement. The anchorage capacity of the device depends on the anchorage length and the frictional resistance achievable against the wall of the hole.

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

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

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

Ground Control Districts: A portion of a mine where similar geological conditions exist which give rise to a unique set of identifiable rock-related hazards for which a common set of strategies can be employed to minimise the risk resulting from mining.

Ground Control District Plan: The plan shall consist of good quality transparent draughting material of a thickness not less than 0,08 mm indicating to a scale of 1 in 2500 all applicable ground control districts of the mine.

Hanging wall: Mass of rock above a discontinuity surface (in tabular mining, the rock above the reef plane).

Hazard: A source of, or exposure to, danger.

High horizontal stress:	Horizontal stress component that is in excess of twice the vertical stress.
Inelastic Deformation:	The portion of deformation under stress that is not annulled by the removal of the stress.
Induced stress:	The stress that is due to the presence of an excavation. The magnitude of the induced stress developed depends on the magnitude and orientation of the in-situ stress and the shape and size of the excavation.
Joint:	A naturally occurring plane of weakness or break in the rock (generally aligned sub-vertical or transverse to bedding), along which there has been no visible movement parallel to the plane.
Kinematic analysis:	Considers the ability or freedom of objects to move under the forces of gravity alone, without reference to the forces involved.
Metalliferous mine:	Includes all mines that are not diamond or coal mines.
Normal force:	Force directed normal (perpendicular) to the surface element across which it acts.
Normal stress:	Component of stress normal to the plane on which it acts.
Ore:	A mineral deposit that can be mined at a profit under current economic conditions taking into consideration all costs associated with mine design and operation.
Ore reserve:	A list of known ore zones that a mine has identified as being suitable for mining at some time in the future.
Overbreak:	The quantity of rock that is removed beyond the planned perimeter of the final excavation.

Permanent Support:	Support that, once installed, is not removed.
Plane of weakness:	A naturally occurring crack or break in the rock mass along which movement can occur.
Plasticity:	State in which material continues to deform indefinitely whilst sustaining a constant stress.
Poisson's ratio:	Ratio of shortening in the transverse direction to elongation in the direction of an applied force in a body under tension below the proportional limit.
Primitive (virgin) stress:	State of stress in a geological formation before it is distributed by man-made operations.
Principal stress (or strain):	Stress (or strain) normal to one of three mutually perpendicular planes on which the shear stress (or strain) at the point in the body is zero.
Ravelling:	The gradual failure of the rock mass by rock blocks falling / sliding from pit or tunnel walls - usually under the action of gravity, blast vibrations or deterioration of rock mass strength. A gradual failure process that may go unnoticed. The term unravelling is also used to mean the same thing.
Reef:	A vein, bed or deposit (other than a surface alluvial deposit) that contains minerals, except in the case of coal or diamondiferous formations.
Regular review:	Assessment of the conditions of an area through discussions, plan critique, planning meetings and/or underground visits.

Reinforcement: The use of tensioned rock bolts/studs 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.

Risk: The likelihood that occupational injury or harm to persons will occur.

Rock: Any naturally formed aggregate of mineral matter occurring in large masses or fragments.

Rock bolt: Used as a generic term for all types of inflexible rock reinforcement units, as well as to the process of rock reinforcement (e.g. roofbolting). Often used specifically for end-anchored bars with bearing plates, spherical seats and tensioning units. (The correct term for such a unit is rockstud, but this is seldom currently used; while a true roofbolt was originally a long bolt with forged head used with a mechanical end anchor).

Rock Engineering: Is the engineering application of rock mechanics.

Rock fall (fall of ground) Fall of a rock fragment or a portion of fractured rock mass without the simultaneous occurrence of a seismic event.

Rock mass: 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 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 instability: A softening within a critical volume of rock indicated by accelerating deformation and a drop in stress.

Rock mechanics: The scientific study of the mechanical behaviour of rock and rock masses under the influence of stress.

Shear: A mode of failure where two pieces of rock tend to slide past each other. The interface of the two surfaces of failed rock may represent a plane of weakness, or a line of fracture through intact rock.

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

Slope: Any continuous face of rock mass within the overall pit wall (without stepping/berms).

Smooth blasting: The use of specialised drill and blast strategies (e.g. low strength explosives, modified production blasting, cushion blasting, pre- and post-splitting) to reduce blast damage and improve wall stability.

Spalling: Longitudinal splitting in uniaxial compression, or the breaking- off of plate-like pieces from a free rock surface.

Special areas: During the course of routine mining an increased risk of rock falls or rock bursts may develop. Such areas requiring additional attention and precautions must be designated special areas.

Spitting: Violent ejection of splinters of rock from the surface of an excavation.

Stiffness: Ratio of force versus displacement.

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

Strength: The maximum stress that a material can resist without failing for any given loading regime.

Stress: Force acting across a surface element divided by the area of the element.

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

Strike: Direction of the azimuth of a horizontal line in the plane of an inclined stratum (or other planar feature) within a rock mass.

Sub-drill: The length of blast hole, which extends beyond the next bench floor level. Sub-drill is included in the blast design to provide adequate broken rock sub-grade for developing working benches.

Subsidence: Downward movement of the overburden (soil and/or rock) lying above an underground excavation or adjoining a surface excavation.

Suitably trained personnel: A person trained in relevant rock engineering / strata control competencies.

Support: A structure or a structural feature built into or around an underground excavation to maintain its stability.

Swelling: Constitutive mineralogical nature of the rock by which water is absorbed, causing a measurable increase in volume; swelling can exert very large time-dependent forces on rock or support systems and reduce the size of excavations.

Tangent modulus: Slope of the tangent to the curve of stress versus strain at a given stress value (generally a stress equal to half the compressive strength).

Tectonic forces: 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.

Temporary support: Support that will be removed.

Tendon (support): Includes the generic "rockbolt", plus flexible forms such as "cable anchors".

Tensile stress: Normal stress tending to lengthen a body along the direction in which it acts.

Thickness: Perpendicular distance between bounding surfaces (e.g. bedding planes)

Wall: A wall can pertain to a section of, or the complete profile of the perimeter of an open pit excavation.

Wedge: A block of rock bounded by joints on three or more sides that can fall or slide out under the action of gravity, unless supported.

Windrow: A continuous mound of loose material, of appropriate height, placed at the toe or crest of a slope as a barricade to falling objects or to prevent personnel/mine equipment from falling inadvertently down pit walls.

Weathering: Process of disintegration and decomposition as a consequence of exposure to the atmosphere, to chemical action, and to the action of frost, water and heat.

Working place: The place where mine workers normally work or travel.

APPENDIX B

ROCK-RELATED RISK MANAGEMENT

APPENDIX B ROCK-RELATED RISK MANAGEMENT

1 BASIC ELEMENTS OF THE ROCK-RELATED RISK MANAGEMENT STRATEGY

The basic elements of the rock-related risk management strategy at Open Pit Mine can be summarised as follows:

1) Rock-related hazards, which are likely to arise from mining, will be identified systematically and will cover all relevant work activities such as barring and drilling of support holes.
2) Rock-related hazards will be described for each geotechnical area.
3) Rock-related hazards will be analysed to facilitate identification of the root causes.
4) The health and safety risks associated with these hazards will be assessed by considering those employees, maintenance staff, visitors and contractors who may be exposed. Those groups and individuals, who may be particularly at risk, such as machine operators or inexperienced workers, will be highlighted.
5) Rock-related risk assessments will address what actually happens in the workplace and not what is perceived to be happening.
6) All rock-related risk assessment exercises will be recorded.
7) Existing rock-related risk control measures, controls and their effectiveness will be considered for each geotechnical area. Where necessary, new strategies will be developed to control the identified risks.
8) Rock-related risk control strategies will be incorporated in the mine's code of practice to combat rockfall accidents.
9) Mine standards, which comply with the mine's code of practice to combat rockfall and rockburst accidents, will be compiled for each geotechnical area.
10) Personnel responsible for the successful execution of rock-related risk control strategies will be identified.
11) Training syllabi, based on the rock-related risk control strategies, will be compiled.

12) Personnel identified for the execution of rock-related risk control strategies will be trained accordingly and to the required level of responsibility and competence.

13) Equipment used to combat rock-related hazards will be suitably designed and maintained.

14) Rock-related risk assessments will be reviewed on a regular basis.

15) Rock-related risk control strategies will be audited internally and externally.

2 FORMS OF RISK ASSESSMENT

The following forms of risk assessment will form part of Open Pit Mines rock-related risk management system:

2.1 Baseline Risk Assessments

Baseline risk assessments will involve the following aspects:

- identification of the major rock-related risks;
- establishing of the priorities of the identified risks;
- establishing of a programme for future risk control;
- periodic review of not less than once every two years to ensure that the baseline risk assessment is still relevant and accurate.

Baseline risk assessments will be comprehensive and may lead to further, separate, or in-depth risk assessment studies.

2.2 Issue Based Risk Assessments

These are separate risk assessments which will be carried out when:

- a new support type is considered for the mine;
- a new support or mining layout is considered;
- an accident or a ‘near-miss’ has occurred;

- new knowledge becomes available and information is received which may influence the level of rock-related risks to employees at the mine.

2.3 Continuous Risk Assessments

This is the most important part of the rock-related risk assessment process, will take place continually, and will form an integral part of the day to day management. It will be conducted by all front-line supervisors. In this type of risk assessment, the emphasis will be on hazard awareness through hazard identification and will include:

- regular audits (e.g. inspections by the shift boss, mine overseer or manager);
- daily pre-work assessments by the ganger and his team from the area of work, in consultation with safety representatives, using checklists (e.g. early morning examination);
- Critical Task Analyses (CTA) and Planned Task Observations (PTO) on an ongoing basis.

Checklists will deal with the critical processes identified by the baseline and issue based risk assessments.

3 HAZARD IDENTIFICATION

Hazard identification is the first and most important stage of the risk assessment process. It also enhances hazard awareness. Hazard identification will be carried out systematically to ensure that all hazards, which are likely to arise because of equipment used, work procedure and actual work practice, are considered.

The following aspects will be considered before and during the hazard identification part of rock-related risk assessments at Open Pit Mine:

- appointment of a risk assessment co-ordinator;
- defining the scope of the risk assessment exercise;
- assimilation and analysis of background information;

- selection of risk assessment team;
- training of the risk assessment team;
- conditioning of risk assessment team;
- identification of hazards.

These aspects are discussed in more detail in the following sub-sections.

3.1 Appointment of a risk assessment co-ordinator

A competent risk assessment co-ordinator, with the necessary risk assessment training and experience, will be appointed by Open Pit Mine. If such a person with the necessary expertise is not available, the services of an external risk assessment consultant will be considered.

The functions of the risk assessment co-ordinator will be:

- to advise management on the gathering of data;
- the selection of risk assessment teams;
- to facilitate the risk assessment process;
- to assist in the development of the code of practice to combat rockfall accidents.

3.2 Defining the scope of the risk assessment exercise

The first task when establishing a risk assessment process will be to define the scope of the risk assessment exercise. Care will be taken to ensure that no areas or activities are missed and that all hazards, which are likely to arise because of equipment used, work procedure and actual work practice, are considered.

Rock-related risk assessments will be scoped in one or more of the following ways:

- **geographically based** such as ramps, box cuts, final slopes, etc.;
- **functional based** such as loading, blasting, hauling, etc.;
- **hazard based** such as highwall and spoil pile slopes.

3.3 Assimilation and analysis of background information

Assimilation and analysis of information from on-mine sources and externally is an essential task before the risk assessment can start. This will be conducted by the risk assessment co-ordinator and will be converted in a useful format so as to prepare the team for the risk assessment exercise.

The following aspects will also be considered:

- The types and major underlying causes of past accidents and incidents will be assessed by using the on-mine databases.
- Accident reports and investigations, together with other records such as log books and audit reports will be reviewed.
- Relevant information from government and industry organisations, publications and databases will be gathered.

Since there are great benefits from extending the cause analysis of accidents to near-misses, a near-miss reporting system will also be considered.

3.4 Selection of risk assessment team

Before a risk assessment exercise can proceed, a team will be selected and prepared for the task ahead. The creation of a team for the risk assessment exercise is essential to ensure ownership of the work and thereby help bring about culture change.

The team will include representatives from all levels of employees, especially those at risk, and their representatives. They will normally be selected from the workplace being reviewed, by taking a vertical slice through the management structure, to the lowest level of the organisation. Where necessary, specialist expertise will also be brought in so that the team carrying out the risk assessment thinks as widely as possible in terms of potential hazards, some of which they may be unfamiliar with.

The risk assessment process will be facilitated by the risk assessment co-ordinator, who will collect all relevant information from the risk assessment team. The risk assessment co-ordinator will also relate this information to basic causes.

Training of the risk assessment team
All members of the risk assessment team will receive the necessary training in order to participate in risk assessments. Front line supervisors will also be trained in Critical Task Analysis, Planned Task Observations and workplace inspections.

3.5 Conditioning of risk assessment team

Once the team has been assembled, they will be conditioned for the work in hand. This will include the following aspects:

- The analysed data will be presented.
- The scope of work will be described.
- Potential hazards the team might encounter will be discussed.
- The team will be encouraged to consider not just the superficial, but also the underlying causes, thereby increasing their hazard awareness.
- Where possible, the workplace will be visited.

3.6 Identification of hazards

A variety of tools, from simple checklists through to sophisticated quantitative techniques, will be considered to assist the team in identifying the hazards. Where more sophisticated tools are considered, special training in the use of the tool will be considered before the team will proceed with the hazard identification exercise.

The following techniques will be considered to ensure that all hazards are identified systematically:

1) Top Down Technique

This technique involves working from a top event downwards to arrive at the underlying causes and also potential other events. Examples of this approach involve checklists, accident analysis, Fault Tree Analysis, task analysis and brain storming.

2) Bottom Up Technique

This approach is one of breaking down the system or problem into small components and then seeing how they or others may fail, building up to a major event. Examples of this type of technique include Hazard and Operability Studies (HAZOP), Workplace Risk Assessment and Control (WRAC), etc.

Whichever method is adopted, the approach will be to seek to identify all possible hazards to those at work or who may be affected by the work activities.

4 RISK MEASUREMENT

Rock-related risks will be measured for the following reasons:

- to prioritise risks;
- to change employee understanding of risks;
- to build hazard awareness; and
- to set direction for management.

Several approaches for the measurement of risk are available. Whatever approach is considered most appropriate, will have the following basic components:

- Explanations and descriptions will be clear so that the risk assessment team can all agree and can use the tool consistently.

- Values will be allocated to the probability of rock-related hazards occurring, the potential consequences (degree of harm) of such hazards should they occur, the probability of people being exposed (how many people, how often and how long?) to the potential consequences of such hazards, and the priority of each risk. Depending on the uncertainty or certainty of events occurring, values will be allocated quantitative (based on statistics) or qualitative (based on judgement).

5 RISK CONTROL MEASURES

Risk control measures will be implemented in order to comply with Section 11(2) of the Act.

Analysis of the three components to risk, the probability of rock-related hazards occurring, the potential consequences should such hazards occur, and the probability of exposure, will be used, not only to provide a means of prioritising risks, but also to develop appropriate risk control strategies such as discussed in the following sub-sections:

5.1 Elimination of risks

If possible, risks will be eliminated. If risks cannot be eliminated, they will be mitigated/controlled or minimised or, if none of these is possible, then personal protection will be provided.

In eliminating risks, the following strategies will be considered:

- removing the hazard from the working environment;
- working in a different area;
- using a different approach, or substance or method of work.

5.2 Mitigation of risks

If risks cannot be eliminated, they will be progressively reduced to acceptable levels. The following aspects will be considered:

- the way the work is organised;
- the working conditions;
- the working environment;
- relevant social factors.

Risk reduction measures taken in isolation are likely to fail. They will therefore be part of an ongoing cycle of risk management that involves performance measurement, goal setting, feedback and analysis.

5.3 Control of Risks at Source

The following aspects will be considered as part of this strategy:

- limiting access to the hazardous area;
- guarding against the hazard;
- operating from a remote distance.

5.4 Minimising of Risks

The following aspects will be considered as part of this strategy:

- implementation of hazard awareness training programmes to ensure that workers keep away from the hazardous areas;
- the use of safety devices.

5.5 Use of Personal Protective Equipment

This approach will be the last resort to risk control. Whatever the protection provided, employees and those affected need to understand what they need to do to make sure the protection works and will therefore be trained accordingly. This will be backed-up by the necessary supervision.

5.6 Monitoring of the risks

High frequency and high consequence hazards will be considered as high priority. Those with a low frequency and low consequence, low priority, and those with either high frequency and low consequence, or high consequence and low frequency, will be considered as medium priority. High consequence, low frequency events, however, will be considered of higher priority than low consequence, high frequency events.

Low priority risks should be accepted and monitored. For other risks, specific strategies will be developed and implemented. The overall performance of the rock-related risk management system will also be monitored, and feedback on the success or failure of certain strategies will be obtained through audits (internal and external), safety representatives and joint health and safety committees.

5.7 Reporting and Recording

Rock-related risk assessment exercises will be recorded according to Section 11(1)(c) of the Act. These records will be accessible to employees, their representatives and to inspectors.

The following aspects will be reported on:

- The major hazards identified. This is, those hazards which pose serious risks to employees or others who may be affected, if they are not properly controlled.
- A review of the existing safety measures and the extent to which they work in controlling the risks.
- Those who may be affected by the major hazards.

6 REVIEW AND REVISION

Section 11(3)(a) of the Act requires managers to review and, if necessary, to modify their risk assessments since they should not be a one-off activity. Risk assessment at Open Pit Mine will therefore be a continuous process. As work changes, the hazards and risks may change and therefore the risk assessment process will also change. Risk assessments will be reviewed or modified when an accident occurs, or if more is learnt about certain hazards in the workplace. Thus, after an accident, the risk assessment co-ordinator will select a risk assessment team and revisit the previous risk assessment to see:

- whether the accident which has occurred was predicted;
- whether it was decided to prevent that accident;
- if so, why the preventative measures did not work;
- if the accident was not predicted, whether it is necessary to revise the risk assessment process or not;
- if the accident was predicted but it was decided to tolerate the risk, whether the decision was valid;
- why the accident occurred, and what should be done to prevent similar accidents occurring, so far as is reasonably practicable.

Rock-related risk assessments at Open Pit Mine will therefore be reviewed at regular intervals. The time between reviews will depend upon the nature of the risks and the degree of change likely to take place in the work activity. Changes in social patterns, which could affect the level of acceptable risk, will also be considered.