

**Safety in Mines Research Advisory Committee**



**MHSC**

**Final Project Report**

**SIM120201**

**Technology Transfer for “A Risk Based  
Approach to Enhancing Support Design  
in Bushveld Underground Mines”**

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**Research agency : SRK Consulting  
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# **Executive Summary**

The research project “A Risk Based Approach to Enhancing Support design in Bushveld Underground Mines” was completed during 2011 (SIM060201 Track B). A technology transfer program was commissioned in 2012 through the Mine Health and Safety Council (MHSC) to meet the requirements of the Mining Charter (Amendment, 2010). Twenty stakeholder operations were selected in consultation with the Chamber of Mines Rock Engineering Technical Committee (RETC) to adopt the technology.

The project commenced with training sessions that were carried out during the latter part of 2012, following which the operations were tasked to carry out a risk evaluation for support design. SRK commenced with reviews of the risk evaluation in February 2013.

The risk based approach to support design enables the selection of an improved support system by comparing different mining support strategies based on the injury and cost consequences of Falls of Ground (FoG's). On completion of the project, a full risk evaluation for support design had not been carried out on any of the operations, however success was achieved to a large measure in data acquisition, interpretation and rockfall analysis which are essential elements in the process.

## **Data Acquisition and Interpretation**

Data acquisition and interpretation had been carried out with varying success on 80% (16 of 20) of the operations. Key areas of concern common to the operations related to the quality of data acquisition and calculation errors in data interpretation, for which guidance was given by SRK during the reviews. A shortage of tools and equipment inhibited data acquisition on four the operations, while data could not be interpreted on a further two operations. Three of the operations had obtained data through the input of an external consultant.

## **Keyblock Analysis**

The majority of the operations (13 of 20) succeeded in producing at least one or more support scenario analysis which was available for review to check the methodology and provide guidance to correct errors and improve results. A single operation succeeded in interpreting the comparative outputs from which to select an improved support design for the operation (Lonmin4 – Saffy Shaft). At the remaining 7 operations licensed, working copies of the JBlock application had not been acquired and RE users must still become sufficiently proficient in analysing support scenarios for keyblock failures.

Several challenges in constructing and analysing a support scenario were addressed during the reviews with the result that sufficient proficiency in using the JBlock application was demonstrated at the 13 shafts where support scenario analysis had been carried out. Continued improvement is required to ensure that the necessary input data is obtained and correctly applied, however these operations can carry out support scenario analyses using the JBlock application.

## **Risk Evaluation using RiskEval**

A risk evaluation of results from keyblock analysis had not been carried out on any of the stakeholder operations, however an attempt had been made at the XStrata shafts where

some difficulty was encountered in applying suitable strategies for a Bord and Pillar operation. The risk evaluation could not be carried out on 5 of the operations due to IT restrictions against installation of JAVA which is required to run the application.

The most significant obstacles encountered in carrying out a risk evaluation were:

- Absence of injury and costing consequence parameters
- Absence of suitable or sufficient keyblock analysis results to carry out a comparative risk evaluation
- Construction of the correct directory tree from which to run the RiskEval application

## **Recommendations**

The stakeholder operations have been successfully introduced to the risk evaluation process, effectively succeeding in an adoption of the geotechnical data acquisition and interpretation processes followed by block failure analysis. However, complete adoption of the technology has not progressed to include the final stage of risk evaluation for quantifying the rockfall hazard in terms of injury and cost consequences. Some of the operations have not succeeded in using the technology to carry out any of the stages in risk evaluation.

To achieve a successful adoption of the technology in the industry, certain obstacles and shortcomings must be addressed. The guidelines that were compiled by SRK to assist stakeholders in adopting the technology should be utilised.

### **Data Acquisition and Interpretation**

Data acquisition is fundamentally essential for operations to provide technical solutions to ground support problems. Continued data acquisition using the guidelines provided is required on an on-going basis on the operations to ensure that the technology can be suitably well applied. To this end:

- RE practitioners should be suitably equipped in terms of tools, equipment and time to carry out this function on the operations.
- Onerous procurements processes and restrictions in the use of progressive technology in underground workings should be reviewed by industry stakeholders.

### **Rockfall Analysis using JBlock**

Rockfall analysis using JBlock has been successfully adopted at the majority of the stakeholder operations largely attributed to a familiarity by the users with the concept of keyblock analysis. Continued improvement in input data accuracy, hazard zone definition and comparative support scenario analysis is required to provide suitable outputs for the risk evaluation. To this end, similar to requirements for successful data management:

- Licenses for the block failure analysis tool must still be procured on several of the operations.

### **Risk Evaluation using RiskEval**

The concept of quantifying the rockfall risk based on injury and cost consequences appears to be unfamiliar to the users.

- Additional exposure of RE's to the concepts of risk analysis is recommended to encourage adoption of the technology on the operations.
- RiskEval should be enhanced to provide a more suitable risk analysis for Bord and Pillar mining and possibly other methods.
- Additional guidance to users should be given to assist in acquiring the necessary injury and cost consequence data to quantify the rockfall risk. An introduction to mining economics for RE's is recommended to assist in this regard.

### **Recommendations from SIM060201 Track B**

The following recommendations from project SIM060201 Track B are particularly relevant:

- The rockfall model needs to be improved to enable increasing clamping stress with height above the stope to be applied.

- Models need to be developed for other rockfall modes of failure:
  - Rockbursts and seismically induced rockfalls,
  - Pillar failure,
  - Unravelling,
  - Stress damage
  - Time dependant deterioration
- The model needs to be adapted to cover a wider range of mining methods and to development ends.
- The reduction in risk due to monitoring needs to be researched further.
- The software requires ongoing development to ensure that it meets the needs of the rock mechanics practitioners who will use the software.

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## **Disclaimer**

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (South Africa) (Pty) Ltd (SRK) by the Mine Health and Safety Council (MHSC). The opinions in this Report are provided in response to a specific request from the MHSC to do so. SRK has exercised all due care in reviewing the supplied information. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.



## **List of Abbreviations**

MHSC: Mine Health and Safety Council

FoG: Fall of Ground

CoM: Chamber of Mines

RETC: Rock Engineering Technical Committee

RE: Rock Engineer

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# **1 Introduction and Scope of Report**

The research project “A Risk Based Approach to Enhancing Support design in Bushveld Underground Mines” was completed during 2011 (SIM060201 Track B). The risk based approach to support design enables the selection of an improved support system by comparing different mining support strategies based on the injury and cost consequences of Falls of Ground (FoG's).

As a result of the research, a technology transfer program was commissioned through the Mine Health and Safety Council (MHSC) to meet the requirements of the Mining Charter (Amendment, 2010). This report outlines the program that was carried out by SRK in conjunction with industry stakeholders to facilitate adoption of the technology in the industry.

## **2 Program Objectives and Work Program**

### **2.1 Program objectives**

The project is aimed at ensuring that the technology developed during the project “A Risk Based Approach to Enhancing Support Design in Bushveld Underground Mines” is adopted by rock engineering practitioners on Bushveld underground operations. The successful implementation of this technology is expected to lead to improved rockfall-related safety and production performance in Bushveld underground mines.

### **2.2 Work program**

A calendar of the principal stages of the project is presented in Figure 2-1. The project was compartmentalised into seven Milestones which were completed in succession.

The project kicked-off in August 2012 following a meeting between SRK and representatives from the champion mines, viz Impala Platinum (Impala), Anglo American Platinum (AAP), Lonmin Platinum (Lonmin), Northam Platinum (Northam), XStrata Alloys (XStrata), Royal Bafokeng Platinum Mines (RBPM), Aquarius and Africa Rainbow Minerals (ARM). During this meeting the training and review schedule were discussed as well as the format for each planned review, following which the planned schedule and review template were submitted to the Rock Engineering Technical Committee (RETC) for approval. This completed Milestone 1.

Milestone 2 of the project was carried out during September and October of 2012, which comprised training of forty-five rock engineering practitioners in data acquisition and interpretation, analysis of support scenarios and risk evaluation using the technology. Three training sessions of two days each were completed on the operations by SRK in conjunction with Open House Management Solutions (OHMS).

Milestones 3 to 6 comprised the review process during which the resulting support designs on each of the twenty stakeholder shafts were reviewed by an SRK Engineering Geologist. The reviews were carried out during February to June 2013. Each review comprised a three day site visit with an underground visit during which the underground data acquisition, data interpretation, application of the technology and resulting support designs were

checked. Results of the technology transfer were presented in a report for each of the twenty shafts.

The initial review schedule was planned for completion in February 2013, however following the prolonged and disruptive labour action during the latter part of 2012, the project was delayed. Extension from the MHSC was granted during November 2012 to complete the project at the end of June 2013.

Milestone 7 of the project comprises the final report. On completion of each Milestone, a progress report was submitted to the MHSC.

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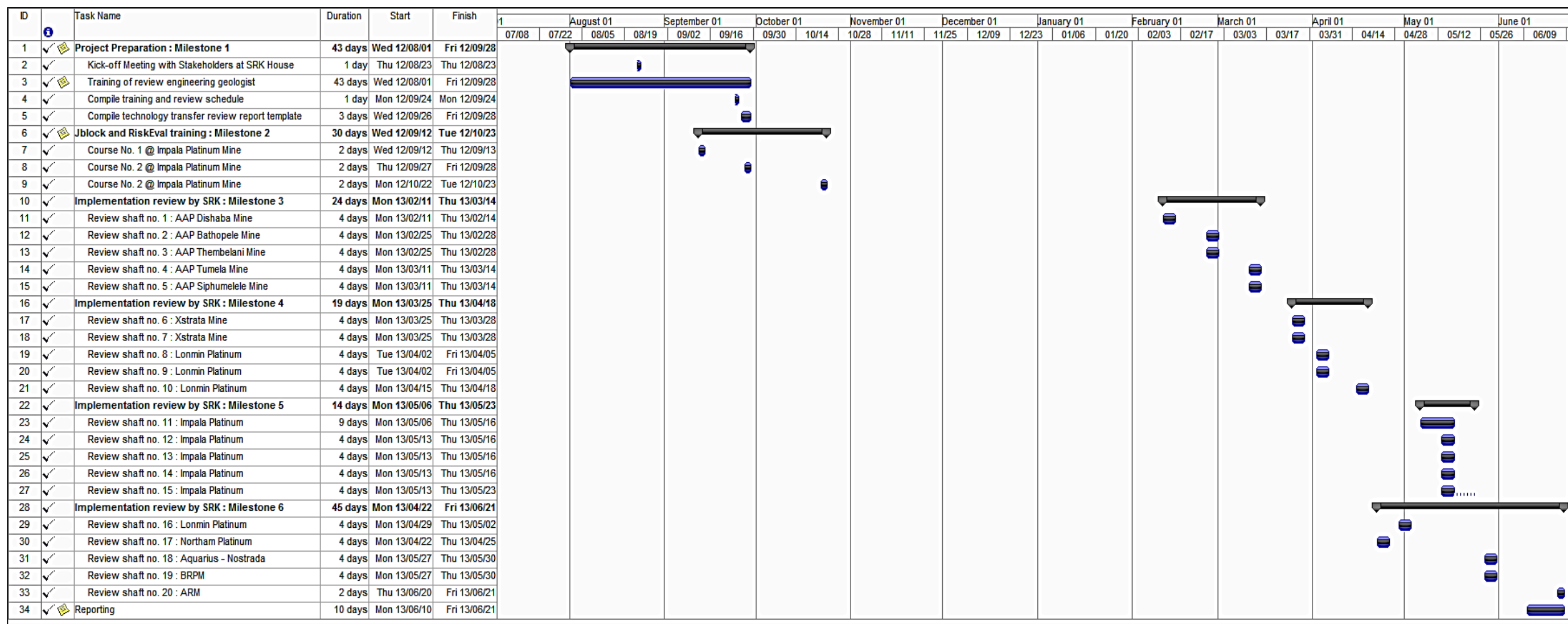


Figure 2-1: Gantt chart representing the actual project implementation and review schedule

## 2.3 Project team

**William Joughin** **Project Leader**  
**Partner and Principal Mining Engineer**

BSc Mining Engineering, MSc Engineering, COMRMC, Advanced COMRMC, Mine Manager's Certificate, Pr Eng

William is a Principal Mining Geotechnical Engineer and Partner of SRK South Africa. He is a SA Professional Engineer with over 20 years of experience in mining and rock engineering. William gained operational experience on deep South African gold mines before joining SRK in 1998. He has subsequently provided consultancy services for mining projects on five continents, with various orebody geometries and rock mass characteristics, exploited with a wide range of mining methods. William specializes in geotechnical investigation, numerical modelling, seismic analysis, rockburst and rockfall risk analysis applied in the design of underground mining excavations. He has over 40 publications in journals and conference proceedings in the field of rock engineering. William is the President of the South African institute of Rock Engineering and a council member of the Southern African Institute of Mining and Metallurgy.

William was the project leader for the research project "A Risk Based Approach to Enhancing Support Design in Bushveld Underground Mines".

**Robert Armstrong** **Supervision of the review of geotechnical**  
**mapping and input parameters**  
**Principal Geologist**

BSc (Hons) Mining and Exploration Geology, Pr Sci Nat

Robert is a Principal Geologist and Professional Natural Scientist with 11 years' experience in rock engineering site investigations and designs. Robert graduated in 2001 and conducted research at the University of the Witwatersrand before joining SRK in 2005. He has consulted on both open pit and underground projects throughout Africa. Recent specifically relevant projects are: Robert led the site investigation team for the Kibali Gold Mine feasibility study (DRC), which included data collection for both mining and underground infrastructure. Robert led the site investigation and open pit design team for the Koidu Kimberlite Open Pit and Underground feasibility study (Sierra Leone), which included data collection for both mining and underground infrastructure. He also trained the team that collected the data for the research project "A Risk Based Approach to Enhancing Support Design in Bushveld Underground Mines". Robert supervised the team of engineering geologists.

**Jeanne Walls** **Review of support designs and risk**  
**analysis**  
**Senior Rock Engineer**

BSc (Hons) Geophysics, COMRMC, Advanced COMRMC, GDE Rock Mechanics, PrSci Nat

Jeanne is a Senior Rock Engineer and Professional Natural Scientist with 12 years' experience in rock engineering and geophysics, having gained operational experience on shallow platinum and deep level gold mining operations as well as offshore exploration projects prior to joining SRK in 2011. Jeanne has been involved in several consulting

projects with SRK, most relevant being a support design review for a shallow underground platinum operation.. She has also carried out geotechnical design reviews of feasibility and prefeasibility studies for shallow underground platinum projects. Jeanne's rock engineering experience in Platinum mines has made her the ideal person to review the support designs and risk analyses. The designs were collected by the engineering geologists and submitted to Jeanne for review.

**Candice Maduray**  
**parameters and collection of data**  
**Engineering Geologist**

**Review of geotechnical mapping, input**

BSc (Hons) Engineering Geology

Candice qualified as an engineering geologist in 2008. She has carried out foundation assessments and rock mass characterisation for open pit designs while working for Jones and Wagner. Since joining SRK in August 2011, Candice has been involved in geotechnical logging and rock mass characterisation for underground and open pit designs. Candice has the necessary geological and geotechnical training and experience to review the geotechnical mapping and input data on site and provided on the job training.

**Denisha Govender**  
**parameters and collection of data**  
**Engineering Geologist**

**Review of geotechnical mapping, input**

BSc (Hons) Engineering Geology

Denisha qualified as an engineering geologist in 2008. She has carried out underground joint mapping and rock mass characterisation for the Ingula pumped storage scheme while working for Eskom. Since joining SRK in June 2012, Denisha has been involved in geotechnical logging and rock mass characterisation for underground and open pit designs. Denisha has the necessary geological and geotechnical training and experience to review the geotechnical mapping and input data on site and provided on the job training.

**Amma Boaduo**  
**parameters and collection of data**  
**Rock Engineer**

**Review of geotechnical mapping, input**

BSc (Hons) Mining Engineering, COMRMC

Amma qualified as a Mining Engineer in 2009. She obtained her Chamber of Mines Rock Mechanics Certificate in 2013. She is a candidate engineer with experience in shallow platinum mining. Her role prior to joining SRK involved underground and open pit joint mapping, rock mass characterisation, monitoring of ground stability and support installation as well as reporting of Falls of Ground. Amma has the necessary mining and geotechnical training and experience to review the geotechnical mapping and input data on site and provided on the job training.

### **3 Technology Transfer: “A Risk Based Approach to Enhancing Support Design in Bushveld Underground Mines”**

#### **3.1 Introduction**

During 2011 the research project SIM060201 Track B titled “A Risk Based Approach to Enhancing Support design in Bushveld Underground Mines”, commissioned through the Mine Health and Safety Council (MHSC), was completed. The project resulted in development of a risk evaluation model to enhance underground support designs by quantifying the consequences of Falls of Ground (FoG's) in terms of injuries and economic losses.

In terms of the Mining Charter (Amendment of the Broad-Based Socio-Economic Empowerment Charter for the South African Mining and Mineral Industry, 2010), the industry is required to adopt results of research which may improve cost effectiveness and safety performance. A technology transfer program was commissioned through the MHSC by which the industry would adopt the research outcomes.

This project is the first technology transfer program carried out in terms of the requirements of the Mining Charter and serves as a case study for future implementation projects. SRK facilitated the adoption on stakeholder operations in the industry with the assistance of Open House Management Solutions (OHMS). This report presents the process that was followed and outcomes of the technology transfer project.

#### **3.2 Risk Evaluation Technology**

The risk evaluation technology developed in the research project SIM060201 Track B, provides a means by which underground support systems can be enhanced by comparing the consequential Fall of Ground (FoG) risk associated with each support system. A full description of the risk evaluation process has been presented in the research report SIM060201 Track B; details of the methodology have not been reproduced in this report. The main stages and key elements to carry out a successful risk evaluation are briefly outlined in Table 3-1.

**Table 3-1: Essential steps to carry out a successful risk evaluation**

Stage	Description
1. Data acquisition	Several sets of data are required for input into the risk evaluation model. <ol style="list-style-type: none"> <li>1. To characterise the ground conditions that create possible Falls of Ground, structural (joint) data is required which entails underground mapping using specific data acquisition tools.</li> <li>2. Additional rock mass property data must be acquired such as rock mass strength and density</li> <li>3. To define a support scenario, excavation geometry, mining practice parameters and support property data is required</li> <li>4. To quantify the rockfall risk, injury and cost data is required</li> </ol>
2. Data processing	Joint data must be processed to obtain inputs for the support scenario analysis
3. Support scenario construction and evaluation of results	Using the application JBlock, the potential Fall of Ground distributions are generated. Different support scenarios must be evaluated and the outcomes compared.
4. Risk Evaluation	Outcomes of the support scenario evaluation are interpreted in terms of the consequential injury and cost risk from Falls of Ground using the application RiskEval.

### 3.3 Process Flow

A three-stage process for the adoption was envisioned, outlined in Table 3-2. Each of the stages comprises part of a project Milestone. The proposed project timeline is included in the table.

**Table 3-2: Planned project process flow**

Stage	Milestone	Proposed Timeline	Planned outcome (deliverable)
Stage 1: Project Preparation	Milestone 1	08/2012 to 09/2012	Together with stakeholder engagement, select and schedule representative shafts to adopt the technology and compile a template to report on the outcomes of adoption on each operation
Stage 2: Risk Evaluation Technology Training	Milestone 2	08/2012 to 09/2012	Training of industry practitioners in the theory and use of risk evaluation technology to enhance underground support design to mitigate against the risk of Falls of Ground
Stage 3: Review of Results	Milestones 3 to 6	10/2012 to 02/2013	Review the outcomes of the implementation on each participating shaft
Final Report	Milestone 7	02/2013	Present findings in a final report

### 3.4 Stakeholders

Key stakeholders of the project are:

- Mine Health and Safety Committee (MHSC)
- Chamber of Mines (CoM)
- Chamber of Mines Rock Engineering Technical Committee (RETC)
- Champion mines representing a total of twenty stakeholder operations on which to implement the technology:
  - Anglo American Platinum (AAP)
  - Impala Platinum Mines (Impala)
  - Lonmin Platinum Mines (Lonmin)



- XStrata Alloys (XStrata)
  - Africa Rainbow Minerals (ARM)
  - Royal Bafokeng Platinum Mines (RBPM)
  - Aquarius
  - Northam Platinum (Northam)
- Rock Engineering (RE) practitioners on the stakeholder operations.

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## 4 Results

### 4.1 Milestone 1: Project Preparation

The first project meeting was held on 23 August 2012 together with members of the Rock Engineering Technical Committee (RETC) representing the Champion Mines. Twenty operations from the Champion Mines were selected to adopt the technology. Key requirements to carry out a successful risk evaluation for selecting a suitable support design were discussed. A review programme was prepared and a technology transfer report template for each shaft review was submitted to the RETC for approval. This completed Milestone 1.

Table 4-1 presents the twenty stakeholder operations selected from the Champion Mines to adopt the technology. It was agreed that forty-five practitioners would be tasked with carrying out a risk evaluation to select a support design using the technology.

**Table 4-1: Stakeholder Operations of the Champion Mines**

Mining House	No of Shafts	Shaft ID	Shaft ID	Shaft ID	Shaft ID	Shaft ID
Anglo American Platinum (AAP)	5	Dishaba (AAP1)	Tumela (AAP2)	Bathopele (AAP3)	Thembelani (AAP4)	Siphumelele (AAP5)
XStrata Alloys (XStrata)	2	Kroondal (XStrata 1)	Waterval (XStrata 2)	-	-	-
Lonmin Platinum (Lonmin)	4	Karee 3 (Lonmin 1)	Karee 4 (Lonmin 2)	Newman (Lonmin 3)	Saffy (Lonmin 4)	-
Impala Platinum (Impala)	5	14# (Impala 1)	20# (Impala 2)	1# (Impala 3)	7# (Impala 4)	Marula (Impala 5)
Northam Platinum (Northam)	1	Northam	-	-	-	-
Africa Rainbow Minerals (ARM)	1	Two Rivers (ARM)	-	-	-	-
Aquarius	1	Kroondal (Aquarius)	-	-	-	-
Royal Platinum Bafokeng Mines (RBPM)	1	North Shaft (RBPM)	-	-	-	-

### Key Requirements

The following was required from the stakeholders to facilitate the implementation process:

- **Training facilities** to present the risk evaluation technology to Rock Engineering practitioners. Venues were made available at Lonmin, Impala and Anglo Platinum.
- **Rock Engineering practitioners** from each of the stakeholder operations, amounting to a total of forty-five practitioners. Stakeholder operations were required to ensure that the practitioners attend the training courses.
- **Tools and Equipment.** Several items of equipment are required to enable the Rock Engineering practitioners to carry out a successful risk evaluation of the support design. Each operation was required to be in possession of:
  - A sufficient length (>30 m) measuring tape
  - Geological compass or suitable tool such as an iPhone to determine joint orientation
  - Logging sheet for data acquisition

- Suitable software such as DIPs (a RocScience application) to evaluate joint sets. This software requires a license which must be procured in advance of implementing the risk evaluation process
- JBlock software license successfully installed
- Successful installation of JAVA technology
- A copy of the RiskEval application (supplied by SRK during the training courses)
- **Adoption of the risk evaluation technology** on each of the stakeholder operations to select a support design based on the outcomes of the analysis.

### **Technology Transfer Report Template**

To prepare for the review of technology implementation at each shaft, a report template was compiled and submitted to the RETC to guide the review process. The report template was accepted with no changes. A copy of the report template is presented in Appendix E.

### **Review Programme**

The initial implementation and review programme was prepared, presented in Table 4-2. Several changes to the schedule were effected during the implementation and review period. The final completion schedule has been presented in Figure 2-1, Section 2.2.

Following the prolonged labour action experienced in the Bushveld Platinum sector during 2012, the Champion Mines suffered some setbacks to implementation of the technology and it was not possible to carry out the shaft reviews in accordance with the initial planned schedule. As a result, SRK requested an extension to the project, which was granted by the MHSC for completion on 30 June 2013.

**Table 4-2: Initial Implementation and Review Schedule**

		2012										2013					
		September		October		November			December			January			February		
Mon	3		1		5	Lonmin		3	Impala					4	Anglo	Lonmin	
Tue	4		2		6			4			1			5			
Wed	5		3		7			5			2			6			
Thu	6		4		8			6			3			7			
Fri	7		5		9			7			4			8			
Mon	10		8		12	Anglo		10	Anglo	Xstrata	7	Aquarius		11	Impala		
Tue	11		9		13			11			8						
Wed	12	Course 1	10		14			12			9			13			
Thu	13	Impala	11		15			13			10			14			
Fri	14		12		16			14			11			15			
Mon	17		15		19	Xstrata	Northam	17			14	ARM	BRPM	18	Anglo		
Tue	18		16		20			18			15						
Wed	19		17		21			19			16			20			
Thu	20		18		22			20			17			21			
Fri	21		19		23			21			18			22			
Mon	24		22	Course 3	26	Lonmin		24			21	Lonmin		25	Impala	Anglo	
Tue	25		23	Anglo	27			25			22						
Wed	26		24		28			26			23			27			
Thu	27	Course 2	25		29			27			24			28			
Fri	28	Lonmin	26		30			28			25						
Mon			29	Impala				31			28	Impala					
Tue			30								29						
Wed			31								30						
Thu											31						

## 4.2 Milestone 2: Training of Rock Engineering Practitioners

Training in the process of risk evaluation for enhanced support design in a given geotechnical environment was carried out during three courses held at facilities provided by the stakeholder operations. A total of forty-five Rock Engineering practitioners received training from Open House Management Solutions (OHMS) together with SRK in data acquisition, data processing and analysis. Each course was carried out over two consecutive days. The first course was presented on 12 and 13 September, three weeks following the kick-off meeting, which was considered to be sufficient time for course attendees to be suitably equipped. The course content covered the background information, theory and use of applications to carry out a risk evaluation for support design as outlined in Table 3-1, Section 3.2.

Each of the Champion Mines was represented by Rock Engineering practitioners from the operations. The course attendees were all in possession of a Chamber of Mines Certificate in either Strata Control or Rock Mechanics (CoMCRM or CoMCSC). A summary of participating numbers from each Champion Mine is presented in Table 4-3.

**Table 4-3: Summary of course attendee numbers from each Champion Mine**

Mine	Lonmin	Impala	Anglo	Xstrata	Northam	ARM	Nostrada	BRPM	Total
Course 1	2	4	3	2	0	0	1	2	14
Course 2	4	3	3	2	1	0	1	1	15
Course 3	3	3	5	2	1	1	0	1	16
Total	9	10	11	6	2	1	2	4	45

### 4.2.1 Day 1: Characterisation of the Geotechnical Domain

The geotechnical domain defines the potential blocks in the rock mass that can result in Falls of Ground (FoG's), i.e. keyblocks. To define the geotechnical domain requires a two-step process of data acquisition followed by data interpretation.

#### Data Acquisition

Practitioners were introduced to typical geotechnical data acquisition parameters and techniques required to characterise a rock mass (Barton, 2002, Barton and Bandis, 1990). A site visit was carried out to collect joint data from a rock mass exposure. The techniques of scanline mapping using a measuring tape, logging sheet and joint orientation tools (compass and iPhone) were demonstrated with an opportunity for practitioners to familiarise themselves with the process. An example logging sheet was provided to the course attendees during the course.

The importance of recording the following parameters was explained and demonstrated:

- scanline orientation and position as well as multi-directional scanline mapping to eliminate effects of joint orientation bias
- joint position relative to a fixed reference point (measuring tape)
- joint condition (joint surface condition)

- rock type and associated characteristics such as tensile strength and rock mass density.

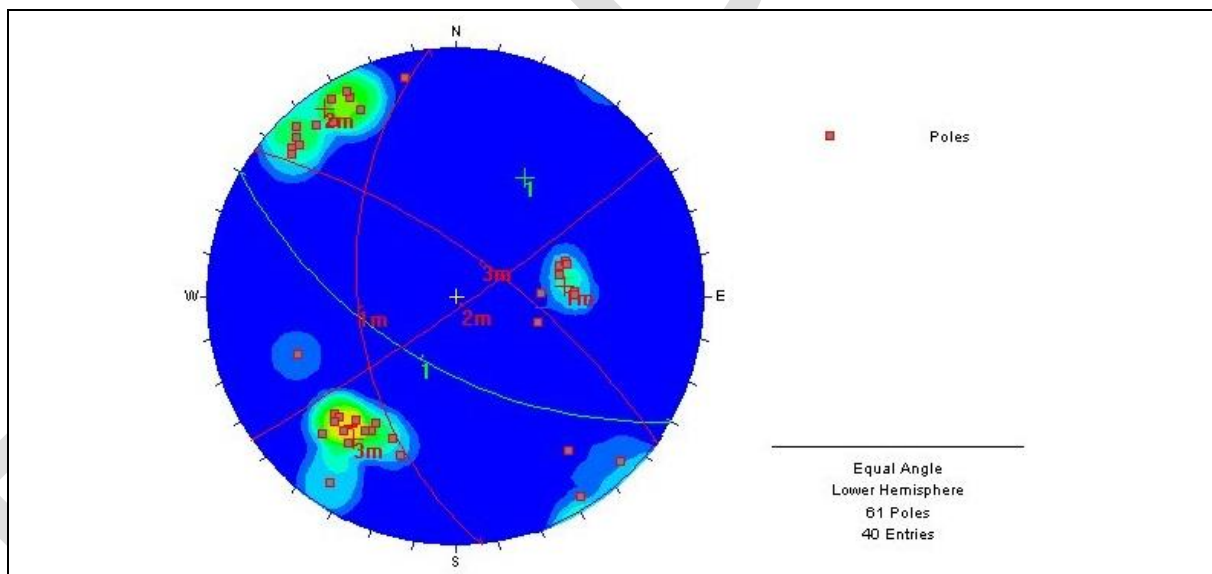
Assistance and guidance was given to the practitioners to ensure that the correct process was followed. During the site visit it was found that several of the attendees were not in possession of the necessary orientation tools (compass or iPhone with suitable orientation application) which required that tools be shared to accomplish the training. Additional equipment was provided by SRK and OHMS for use during the training.

## Data Interpretation

Several steps are required to process joint data for input into the rockfall simulation:

- Joint set determination using a suitable analysis tool such as DIPs (RocScience). An example of a DIPs plot is shown in Figure 4-1.
- Estimation of discontinuity spacing (Priest and Hudson, 1981, Wines and Lilly, 2002)
- Calculation of joint surface condition (Barton, 2002, Barton and Bandis, 1990)
- Estimation of discontinuity persistence (Priest and Hudson, 1981)
- Statistical distributions (mean, maximum, minimum and standard deviations) are required for the parameters

Each of the stages of data interpretation was presented to the course attendees. Most of the practitioners were in possession of the DIPs demo version which does not require a license and enables use of the software for learning purposes, however several attendees were required to share an application.



**Figure 4-1 Example of a DIPs plot for joint set determination**

## 4.2.2 Day 2: Support Scenario Analysis and Risk Evaluation

### JBlock Analysis

The process of constructing and analysing a support scenario using the JBlock application to obtain a block failure hazard for a given mining layout was presented to the course attendants.

Construction of the support scenario analysis requires input of various parameters using a licensed, working copy of JBlock, i.e.:

- Geotechnical domain characterisation, which data is obtained through the process of joint logging and rock mass characterisation presented during the first day of the training course.
- Support properties, i.e. spacing, position and capacity
- Support practices, i.e. installation quality
- Excavation geometry and orientation, which is dependent on the orebody geometry and mining method
- Hazard zone definition, which is a function of practices carried out in the working area.
- Analysis limits such as aspect ratio, volume thresholds and geotechnical parameter thresholds (friction angle and cohesion) to define potential keyblocks in terms of local on-mine experience

The course attendees were provided with training on the importance of obtaining reliable inputs for the JBlock analysis, the process of constructing a support scenario and obtaining a keyblock failure hazard.

Results from a particular scenario analysis comprise:

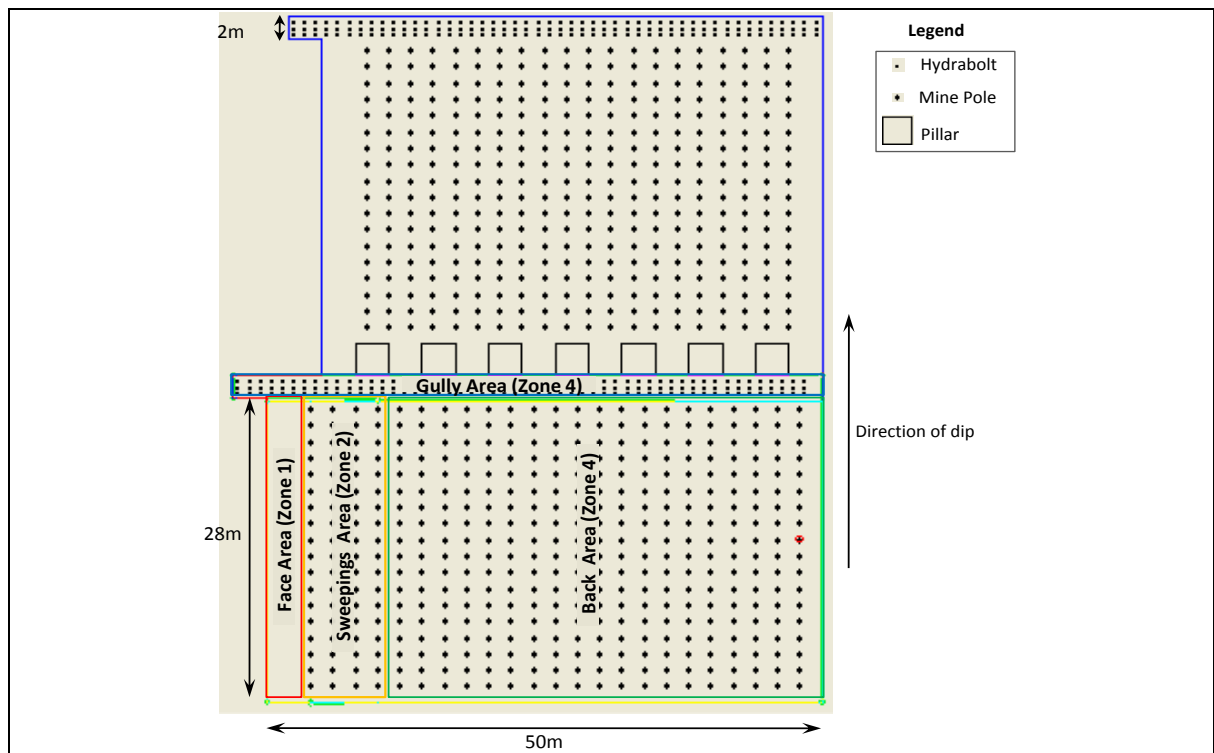
- rockfall distribution images representing block fall location with respect to the excavation
- an output summary of block failure and potential injury distributions
- block size and failure mode histograms
- spreadsheet containing data relating to geometry (e.g. size and volume) and failure mode for each statistically generated keyblock.

On completion of a scenario analysis, the users were guided in interpretation methods to obtain an understanding of the outputs. In particular, the importance of comparing analysis outputs against existing local on-mine FoG data was discussed to assist in checking the fidelity of results against actual conditions. On-mine FoG data is required to quantify the injury distribution hazard as well as the failed block distribution in terms of geometry and location. This completes a single support scenario analysis.

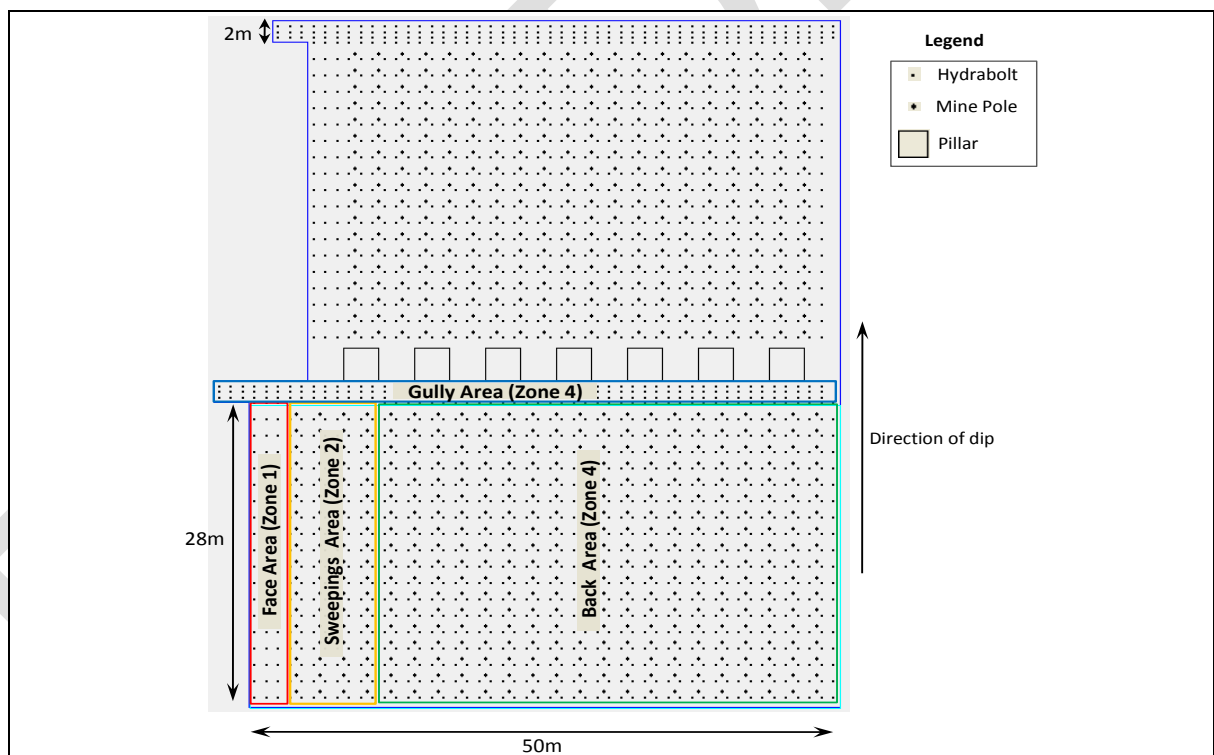
In isolation, a single support scenario analysis quantifies a particular hazard, i.e. a base case. However in order to determine whether the hazard can be reduced and select an improved system, more than one analysis must be carried out by varying certain inputs relating to support and/or excavation parameters and comparing results to the base case. The importance of this component of the risk evaluation process was presented to the course attendees with guidance on how to carry out comparative analyses.

Examples of comparative support scenario analyses are presented in Figure 4-2 and Figure 4-3.

It was found during presentation of the course that most attendees were in possession of a licensed working copy of JBlock, however some users were required to share software with other course attendees which prevented full familiarisation with the software.



**Figure 4-2 Example of base case support scenario**



**Figure 4-3 Example of support scenario with variation of base case**

### **RiskEval Analysis**

The final stage of the risk evaluation process is carried out using the application RiskEval. An installation of JAVA Software is required to run the application. JAVA is a free platform independent programming language that can be obtained from the internet. The RiskEval application requires no license to run and can be utilised when JAVA has been installed.



RiskEval utilises output files from the comparative JBlock hazard analyses to determine the effect of each support scenario on injuries and cost for the operation.

Course attendees were guided through the process of using RiskEval. An explanation was given on the required input parameters, which relate to:

- Mining practice and rehabilitation strategies
- Exposure reduction for workers in terms of activity and duration that an area is occupied by the worker(s)
- Injury consequences, in terms of severity distribution and financial cost
- Production costs and profitability

Guidance was provided with reference to publications (Joughin *et al*, 2012) and software user guides (SIM060201 Track B, Volume II) to assist the users in defining appropriate cost parameters. Results from JBlock analyses that the attendees had obtained during the course were used as inputs into RiskEval to generate results. Presentation of the outputs was explained, with examples.

#### **4.2.3 Adoption of the Technology by Stakeholder Operations**

On completion of the courses, the Rock Engineering practitioners were tasked to implement the risk evaluation process on their respective operations to obtain support designs that might enhance the safety and production performance.

### **4.3 Milestones 3 to 6: Review of Implementation**

The review process was kicked-off during February 2013 with the first shaft review at Anglo American Platinum (AAP). Each review comprised a site visit by an SRK Engineering Geologist who reviewed the risk evaluation results. The reviews comprised an underground visit to check the data acquisition and a desktop review. A report was generated for each of the shaft reviews, and submitted to the MHSC and stakeholder operations. A comprehensive account of findings for each operation is contained in the reports, Appendix F.

#### **4.3.1 Geotechnical Data Acquisition and Interpretation**

A detailed summary of findings for geotechnical data acquisition and interpretation on each of the stakeholder shafts is presented in Table A - 1, Appendix A.

##### **Data Acquisition**

Out of the 20 stakeholder operations, data acquisition had been carried out, with varying success, on 16 of the shafts, of which 13 shafts had carried out their own data acquisition and 3 operations had employed the services of an external consultant to obtain geotechnical information. Different methods were used to collect structural data which included the use of a clinorule, a geological compass, an iPhone with the Geo-ID application or a combination of these tools. The 4 shafts that had not carried out data acquisition were prevented from doing so due to administrative and regulatory restrictions against the use of technology such as iPhones in underground workings, which was their preferred tool for capturing joint data. Data obtained through external consultants was deemed by SRK to be suitably sound for use in the risk evaluation, however this resulted in the operations not incorporating a data acquisition strategy in-house for on-going data management.

During the shaft reviews, it became evident that continued guidance was required to ensure that the data capture and interpretation was carried out correctly. To this end, SRK compiled a spreadsheet containing recommended data acquisition entries and embedded calculations, which spreadsheet was distributed to the operations on completion of the first shaft review at AAP1. A copy of this spreadsheet is presented in Appendix D.

Data was captured sufficiently well on all of the 13 operations that carried out in-house data collection to demonstrate that a working platform for data acquisition had been established. Each of the operations required some guidance to improve the accuracy of data acquisition. Operations at which only single concerns were encountered are AAP3, AAP4, Lonmin1 and ARM which accomplished good data acquisition.

The most recurring problems encountered were:

- Scanline orientation not captured, preventing correction for true joint spacing.
- Joint condition parameters not captured due to incomplete or not using logging sheets.
- Technology such as a compass or iPhone for data acquisition had not been obtained resulting in uncertainty in joint orientations. At 5 operations, the use of an iPhone underground was prohibited, preventing data acquisition.
- Magnetic declination had not been recorded or incorporated into the joint orientation data.

Other significant, yet less critical, concerns include:

- Tensile strength on partings not determined. This was attributed to unavailability of laboratory test data, however available literature contains suitable nominal values for this parameter.
- Data capture at one location on the operation only resulting in localised data acquisition which does not adequately represent a geotechnical domain.
- Data capture along scanlines in one direction only potentially introducing a directional bias in the data acquisition.
- In one instance, strike direction instead of dip direction was used for joint orientation.
- Some improvement on classification of joint condition parameters was required.
- Electronic spreadsheet database management was not established on some of the operations, which was initiated during the review.
- Reliance on another on-mine Department, i.e. Geology, to acquire geotechnical data. This led to an absence of joint condition parameters and uncertainty in joint orientation parameters. Joint spacing is similarly potentially compromised due to selective data mapping by another Department, whereas a RE might select geotechnical data with an understanding of its purpose.
- Data acquisition carried out by the RE only, not transferred to the team as a whole.

### **Data Interpretation**

Data interpretation was carried out, with varying success, on 11 of the stakeholder operations. Of the 13 shafts that had carried out data acquisition, 2 operations could not carry out data interpretation due to a shortage of required tools, i.e. a licensed, working copy of DIPs or similar suitable application to determine the dominant joint sets. These operations, including the 4 operations that had not carried out data acquisition, have endeavoured to acquire the applications, however IT limitations and restrictive procurements processes respectively have inhibited successful acquisition of this application. Data was interpreted through an external consultant for 3 of the operations, the results of which are deemed to be suitably representative for the operation, but could not be reviewed by SRK.

Recurring concerns encountered with the data interpretation process were:

- Calculation of true joint spacing, for which a spreadsheet was compiled by SRK to assist.
- Calculation of joint condition parameters.

Other significant, yet less critical, concerns include:

- Use of the DIPs application wanted for some improvement.

#### 4.3.2 Keyblock analysis using JBlock

A detailed summary of findings for support scenario analysis using the JBlock application on each of the stakeholder shafts is presented in Table A - 2, Appendix B.

Of the 20 stakeholder operations, 10 shafts had obtained licensed, working copies of the JBlock application. Demo versions were used on 4 of the operations to carry out support scenario analyses, however this resulted in limited functionality of the application and only 3 of these operations succeeded in using the application for support design. On the remaining 6 operations, IT restrictions and onerous procurement processes prevented the application from being available for utilisation. Consequently, support scenario analyses were carried out on 13 operations prior to the reviews.

An essential requirement of the keyblock analysis is that several support scenario results are generated for input into the risk evaluation application (RiskEval). Most of the operations (10 of the 13 shafts) succeeded in producing a single support scenario analysis which was reviewed to check the methodology. The remaining 3 operations (Northam, ARM and Lonmin4 – Saffy) produced comparative support scenario analyses by varying selected input parameters. A single operation succeeded in interpreting the comparative outputs from which to select an improved support design for the operation (Lonmin4 – Saffy Shaft).

During the review, challenges that were encountered with carrying out a successful support scenario analysis were addressed and guidance given where required. An outcome of the first review was that SRK compiled a set of guidelines to assist the operations in adopting the technology. The guidelines were distributed to the stakeholders. Appendix D presents a copy of the guidelines.

The most relevant challenges encountered in using the JBlock application and carrying out a support scenario analysis are summarised as follows:

- Setup parameters (aspect ratio and clamping stress) were omitted, resulting in keyblock failures being generated that fall outside the bounds of realistic FoG's. A value of 10 kPa is suggested by the SIM060201 Track B project report.
- Suitable input data limits had not been appropriately selected resulting in an overflow error in the results.
- Incorrect units, i.e. m vs mm and values containing excessive decimal places were used to define input parameters, resulting in a runtime error.
- Excavation size was constructed to simulate a local area without due consideration for the influence of a back area.
- With particular reference to Bord and Pillar mining, guidance was required to correctly construct the excavation and support scenario.
- Definition of hazard zones for Bord and Pillar mining required guidance.
- Hazard zones definition frequently omitted a sweepings area which is required for the RiskEval analysis.
- Quantitative variability data of support installation practices was not available on several operations from which to obtain inputs for comparative analysis of the effects of variable support installation.
- Improvement of input parameters was required to gain confidence in the results (Section 4.3.1).

- Anomalous structural data such as ramp structures had not been included for the operation.
- Output data files had not been utilised for interpretation of the results. This is important to derive comparative analysis between support scenario results.
- On-mine FoG data had not been referenced to check resulting outputs.
- Nuances of the software functionality such as excavation construction and support placement required guidance to overcome display errors.
- The number of statistical simulations carried out exceeded reasonable analysis requirements, causing long run times.
- Software limitations such as retention of input parameters (density, aspect ratio) were highlighted to users to ensure that these parameters are suitably incorporated into the analysis.

On completion of reviews at the 13 shafts at which support scenario analysis had been carried out, sufficient proficiency in using the JBlock application was demonstrated to successfully utilise the application. Continued improvement is required to ensure that the necessary input data is obtained and correctly applied, however these operations can carry out support scenario analyses using the JBlock application.

At the remaining 7 operations (all Impala shafts, AAP5 and Aquarius) licensed, working copies of the JBlock application must still be acquired and RE users must become sufficiently proficient in analysing support scenarios for keyblock failures. During the reviews, SRK provided a license to carry out training for these operations using the data that had been collected. At three of the Lonmin operations licensed applications are still required to adopt the technology, however the RE users demonstrated proficiency in carrying out support scenario analysis using a demo version.

#### 4.3.3 Risk Evaluation (RiskEval)

To complete a risk evaluation of support scenario results, JBlock analysis outputs had to be interpreted using the RiskEval application to quantify the risk in terms of injury and economic consequences. A summary of findings from each of the stakeholder operations is presented in Table A - 3, Appendix C.

A risk evaluation of results from keyblock analysis had not been carried out on any of the stakeholder operations. An attempt had been made at the XStrata shafts, however some difficulty was encountered in applying suitable strategies for a Bord and Pillar operation. The application could not be run on 5 of the operations due to IT restrictions against installation of JAVA which is required to run the application.

The most significant obstacles encountered were:

- Absence of injury and costing consequence parameters
- Absence of suitable or sufficient keyblock analysis results to carry out a comparative risk evaluation
- Construction of the correct directory tree from which to run the RiskEval application

Outcomes of the review are the following:

- RiskEval currently requires some interpretation of the input parameters, in order to apply to Bord and Pillar mining. RiskEval should be enhanced to carry out more reliable risk evaluations for Bord and Pillar mining.
- Additional guidance to users is required to acquire injury and cost consequence data to quantify the rockfall risk. Research results (Joughin et al, 2012, and SIM060201 Track B) contain good guidance on acquiring the necessary parameters, which references were provided to the users. An introduction to mining economics for RE's is recommended to assist in this regard.
- The concept of quantifying the rockfall risk based on injury and cost consequences was introduced during the courses, however this type of analysis appears to be unfamiliar to the users. Additional exposure of RE's to the concepts of risk analysis is recommended to encourage adoption of the technology on the operations.

## 5 Conclusions

Adoption of the risk evaluation technology on Bushveld Platinum operations was facilitated through a process of training and review during which the four main stages of data capture, interpretation, support scenario analysis and risk evaluation were implemented. Completion of a risk evaluation through to the final stage had not been carried out on any of the operations, however success was achieved to a large measure in adopting the first three stages through to support scenario analysis.

Training courses were presented to forty-five practitioners representing twenty stakeholder operations. Sufficient guidance and training material was provided to facilitate successful adoption of the risk evaluation process. However, certain deficiencies in software proficiency, input data requirements and processing of outputs were encountered during the review process. Factors that may have inhibited implementation on the operation are:

- Shortage of tools and equipment, inhibiting practitioners from becoming fully proficient in the process. The shortage has been attributed to:
  - Budget restrictions limiting on-mine procurements exacerbated by the extended labour action during 2012 which resulted in curtailed purchasing options
  - Procurement processes on some operations are onerous which prevented practitioners from being able to obtain tools and software licenses
  - IT restrictions against users from installing software on personal computers
  - The use of certain technology such as iPhones is severely limited on certain operations as a result of regulatory requirements.
- Operational duties and time constraints to inhibit the RE practitioners from carrying out the required technical tasks to provide an engineered solution to FoG management.
- The extended labour action during 2012 resulted in restrictions to underground workings for data acquisition and a delay in the implementation process. When work resumed on the respective operations, RE practitioners were required to carry out operational safety audits for routine start-up procedures which diverted the resources away from the risk evaluation process for support design.
- Training of the Champion Mine RETC members in carrying out a risk evaluation for support design using the technology prior to commencing with the training courses may have assisted in emphasising the importance of ensuring that practitioners were fully equipped to adopt the technology.

Early in the review process, it became evident that continued guidance was required by the RE practitioners to carry out the risk evaluation process correctly. A guideline was compiled by SRK to address shortcomings. Together with the guideline, a spreadsheet was also compiled to assist with the process of data capture and interpretation. The guidelines and data processing spreadsheet were distributed to the stakeholder operations and submitted to the MHSC during the review process.

### **Data Acquisition and Interpretation**

Out of the 20 stakeholder operations 16 shafts had carried out data acquisition of which 3 operations had employed the services of an external consultant to obtain geotechnical information. The 4 shafts that had not carried out data acquisition were inhibited from doing so due to administrative and regulatory restrictions against the use of technology such as iPhones in underground workings.

Data was captured sufficiently well on all of the 13 operations that carried out in-house data collection. Some guidance was required to improve the accuracy of data.

Of the 13 shafts that had carried out data acquisition, 2 operations could not carry out data interpretation due to a shortage of required tools. Data interpretation was carried out on 11 of the stakeholder operations. Data was interpreted through an external consultant for 3 of the operations, the results of which are deemed to be suitably representative for the operation, but could not be reviewed by SRK. The 4 shafts at which data had not been captured, did not interpret results as a consequence. Recurring concerns encountered with the data interpretation process were:

- Calculation of true joint spacing.
- Calculation of joint condition parameters.
- Improvement in the use of the DIPs application.

### **Keyblock Analysis**

Of the 20 stakeholder operations, 10 shafts had obtained licensed, working copies of the JBlock application. Demo versions were used on 4 of the operations to carry out support scenario analyses, however this resulted in limited functionality of the application. On the remaining 6 operations, IT restrictions and onerous procurement processes prevented the application from being available for utilisation. Consequently, support scenario analyses were carried out on 13 operations prior to the reviews.

Most of the operations (10 of the 13 shafts) succeeded in producing a single support scenario analysis which was reviewed to check the methodology. The remaining 3 operations produced comparative support scenario analyses by varying selected input parameters. A single operation succeeded in interpreting the comparative outputs from which to select an improved support design for the operation (Lonmin4 – Saffy Shaft).

Several challenges in constructing and analysing a support scenario were addressed during the reviews with the result that sufficient proficiency in using the JBlock application was demonstrated at the 13 shafts at which support scenario analysis had been carried out. Continued improvement is required to ensure that the necessary input data is obtained and correctly applied, however these operations can carry out support scenario analyses using the JBlock application.

At the remaining 7 operations licensed, working copies of the JBlock application must still be acquired and RE users must become sufficiently proficient in analysing support scenarios for keyblock failures. During the reviews, SRK provided a license to carry out training for these operations using the data that had been collected. At three of the Lonmin operations licensed applications are still required to adopt the technology, however the RE users demonstrated proficiency in carrying out support scenario analysis using a demo version.

### **Risk Evaluation using RiskEval**

A risk evaluation of results from keyblock analysis had not been carried out on any of the stakeholder operations. An attempt had been made at the XStrata shafts, however some difficulty was encountered in applying suitable strategies for a Bord and Pillar operation.



The application could not be run on 5 of the operations due to IT restrictions against installation of JAVA which is required to run the application.

The most significant obstacles encountered in applying the technology were:

- Absence of injury and costing consequence parameters
- Absence of suitable or sufficient keyblock analysis results to carry out a comparative risk evaluation
- Construction of the correct directory tree from which to run the RiskEval application
- Analysis of Bord and Pillar mining layouts

## 6 Recommendations

The stakeholder operations have been successfully introduced to the risk evaluation process, effectively succeeding in an adoption of the geotechnical data acquisition and interpretation processes followed by block failure analysis. However, complete adoption of the technology has not progressed to include the final stage of risk evaluation for quantifying the rockfall hazard in terms of injury and cost consequences. Some of the operations have not succeeded in using the technology to carry out any of the stages in risk evaluation.

To achieve a successful adoption of the technology in the industry, certain obstacles and shortcomings must be addressed. The guidelines that were compiled by SRK to assist stakeholders in adopting the technology should be utilised.

### Data Acquisition and Interpretation

Data acquisition is fundamentally essential for operations to provide technical solutions to ground support problems. Continued data acquisition using the guidelines provided is required on an on-going basis on the operations to ensure that the technology can be suitably well applied. To this end:

- RE practitioners should be suitably equipped in terms of tools, equipment and time to carry out this function on the operations.
- Onerous procurements processes and restrictions in the use of progressive technology in underground workings should be reviewed by industry stakeholders.

### Rockfall Analysis using JBlock

Rockfall analysis using JBlock has been successfully adopted at the majority of the stakeholder operations largely attributed to a familiarity by the users with the concept of keyblock analysis. Continued improvement in input data accuracy, hazard zone definition and comparative support scenario analysis is required to provide suitable outputs for the risk evaluation. To this end, similar to requirements for successful data management:

- Licenses for the block failure analysis tool must still be procured on several of the operations.

### Risk Evaluation using RiskEval

The concept of quantifying the rockfall risk based on injury and cost consequences appears to be unfamiliar to the users.

- Additional exposure of RE's to the concepts of risk analysis is recommended to encourage adoption of the technology on the operations.
- RiskEval should be enhanced to provide a more suitable risk analysis for Bord and Pillar mining and possibly other methods.
- Additional guidance to users should be given to assist in acquiring the necessary injury and cost consequence data to quantify the rockfall risk. An introduction to mining economics for RE's is recommended to assist in this regard.

### Recommendations from SIM060201 Track B

The following recommendations from project SIM060201 Track B are particularly relevant:

- The rockfall model needs to be improved to enable increasing clamping stress with height above the stope to be applied.

- Models need to be developed for other rockfall modes of failure:
  - Rockbursts and seismically induced rockfalls,
  - Pillar failure,
  - Unravelling,
  - Stress damage
  - Time dependant deterioration
- The model needs to be adapted to cover a wider range of mining methods and to development ends.
- The reduction in risk due to monitoring needs to be researched further.
- The software requires ongoing development to ensure that it meets the needs of the rock mechanics practitioners who will use the software.

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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## **Appendices**

## **Appendix A: Geotechnical Data Acquisition and Interpretation**

**Table A - 1: Summary of Findings for Geotechnical Data Acquisition and Interpretation**

Operation	Summarised Findings	Improvement opportunities
AAP1	<p>This operation served for the first review of the project. Good strides were made to adopt the data acquisition process on the operation. Data acquisition and interpretation skills were transferred from the course attendee to the RE team. The necessary software license has been obtained and an electronic database has been initiated. A sound platform has been established to capture and interpret data, acquiring data that can be input into a keyblock failure analysis.</p> <p>This operation has adopted the data acquisition process sufficiently well to continue with the risk evaluation process provided that the improvements recommended are implemented.</p> <p>A key outcome of this first review was that SRK compiled a spreadsheet to assist with the data capture and interpretation. The spreadsheet was distributed to all the stakeholder operations and is presented in Appendix D.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Incorporate scanline orientation, correct for scanline bias and obtain true joint spacing corrections.</li> <li>- Capture and interpret joint condition parameters including tensile strength on partings.</li> <li>- Logging tools such as a compass or electronic application (e.g. Geo-ID for iPhone or iPad) should be used.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- Avoid reliance on data capture from another Department to obtain the correct geotechnical data. Data should be captured by the RE team as a whole.</li> <li>- Data capture should be from multiple locations on the operation.</li> <li>- Maintain the electronic spreadsheet database.</li> </ul>
AAP2	<p>Data acquisition and interpretation skills were transferred from the course attendee to the RE team. The necessary software license has been obtained and an electronic database has been established containing a large volume of data. A sound platform has been established to capture and interpret data, acquiring data that can be input into a keyblock failure analysis.</p> <p>This operation has adopted the data acquisition process sufficiently well to continue with the risk evaluation process provided that the improvements recommended are implemented.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Incorporate scanline orientation, correct for scanline bias and obtain true joint spacing corrections.</li> <li>- Capture and interpret joint condition parameters including tensile strength of partings.</li> <li>- Logging tools such as a compass or electronic application (e.g. Geo-ID for iPhone or iPad) should be used.</li> </ul>
AAP3	<p>Data acquisition and interpretation on the operation has been adopted well.</p> <p>Advanced technology (iPhone) has been used to collect data. Laboratory test results were used for parting property data, which is commendable. An electronic database has been initiated for geotechnical data management. Minor improvements have been recommended, particularly to correct for true joint spacings and obtain an expanded geotechnical database.</p> <p>The platform to carry out a risk evaluation for support design on the operation is sound.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Correct for true joint spacing.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- Data acquisition should be carried out by the RE team as a whole.</li> <li>- Improve classifications of joint conditions.</li> <li>- Data acquisition should be sourced from multiple locations on the operation to represent geotechnical conditions, incorporating a correction for scanline bias.</li> </ul>
AAP4	<p>Data acquisition and interpretation on the operation has been adopted very well.</p> <p>Joint sets and joint spacings are correctly obtained. Minor improvements have been recommended, particularly to calculate joint condition parameters and maintain an electronic spreadsheet database.</p> <p>The platform to carry out a risk evaluation for support design on the operation is sound.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Calculate joint condition parameters correctly from logging data.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- Data acquisition should be carried out by the RE team as a whole.</li> <li>- Tensile strength should be</li> </ul>

Operation	Summarised Findings	Improvement opportunities
		<p>determined correctly.</p> <ul style="list-style-type: none"> <li>- An electronic spreadsheet database should be managed to capture and interpret geotechnical data.</li> </ul>
AAP5	<p>Data acquisition had been carried out on the operation, however several challenges were encountered which must be addressed to obtain suitable data.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- A suitable application such as a licensed, working copy of DIPs must be obtained to interpret joint sets.</li> <li>- Joint spacing, incorporating scanline orientation must be calculated correctly.</li> <li>- Calculate joint condition parameters from correct logging data.</li> <li>- Incorporate magnetic declination to correct for joint orientation.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- Scanline bias must be corrected, collecting data from multiple locations on the operation.</li> </ul>
XStrata1	<p>Data acquisition and interpretation was carried out for the operation through an external consultant. Available data is deemed to be sound, however the RE team has not captured or interpreted geotechnical data for the risk evaluation process.</p> <p>The on-mine RE team was coached during the review by SRK to ensure that data can be captured and interpreted going forward.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- A suitable application such as a licensed, working copy of DIPs must be obtained to interpret joint sets.</li> <li>- Geotechnical data must be captured and interpreted by the RE team to build and maintain a database going forward.</li> </ul>
XStrata2	Findings are the same as for XStrata1 operation.	
Lonmin1	<p>Data acquisition and interpretation on the operation has been adopted well.</p> <p>Improvements and corrections have been recommended, particularly to correct for true joint spacing and obtain an expanded geotechnical database.</p> <p>The platform to carry out a risk evaluation for support design on the operation is sound.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Correct for scanline orientation and true joint spacing.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- Correct for scanline bias by sourcing data from multiple locations in different direction on the operation.</li> <li>- Use dip direction instead of strike direction for joint orientation.</li> </ul>
Lonmin2	<p>Data acquisition and interpretation on the operation has been adopted well.</p> <p>Improvements and corrections have been recommended, particularly to correct for true joint spacing, joint condition and source data from multiple locations on the operation.</p> <p>The platform to carry out a risk evaluation for support design on the operation is sound.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Correct for scanline orientation and true joint spacing.</li> <li>- Interpret joint condition parameters correctly.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- Correct for scanline bias by sourcing data from multiple locations in different direction on the operation.</li> </ul>
Lonmin3	<p>Data acquisition and interpretation on the operation has been adopted well, however improvements and corrections have been recommended.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- A suitable application such as a licensed, working copy of DIPs must be obtained to interpret joint sets.</li> </ul>



Operation	Summarised Findings	Improvement opportunities
		<ul style="list-style-type: none"> <li>- Correct for true joint spacing.</li> <li>- Interpret joint condition parameters correctly.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- Correct for scanline bias by sourcing data from multiple locations in different direction on the operation.</li> </ul>
Lonmin4	<p>Data acquisition and interpretation on the operation has been adopted well.</p> <p>Improvements and corrections have been recommended, particularly in the determination of true joint spacing and cohesion.</p> <p>The platform to carry out a risk evaluation for support design on the operation is sound.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Correct for true joint spacing.</li> <li>- Interpret joint condition parameters correctly.</li> </ul>
RBPM	<p>Data acquisition and interpretation on the operation has been adopted well.</p> <p>Improvements and corrections have been recommended, particularly to determine true joint spacing and orientation.</p> <p>A sound platform of acquiring geotechnical data to carry out a risk evaluation has been established.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Correct for true joint spacing using the scanline orientation.</li> <li>- Correct joint orientation using magnetic declination.</li> </ul>
Aquarius	<p>The RE team has not carried out in-house geotechnical data acquisition or interpretation, however a dataset has been acquired through the input of an external consultant and data from the Geology department. A training session was held by SRK during the review.</p> <p>Full adoption of the risk evaluation technology by the operation will require ongoing in-house database management for which the on-mine team should be equipped.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- A suitable application such as a licensed, working copy of DIPs must be obtained to interpret joint sets.</li> <li>- Suitable joint mapping technology such as a compass or iPhone with Geo-ID application must be obtained.</li> <li>- Geotechnical data must be captured and interpreted by the RE team to build and maintain a database going forward.</li> </ul>
Impala1	<p>Data acquisition has been carried out on the operation, however the data had not been interpreted. Improvements and corrections have been advised, particularly to obtain the required technology to interpret the data.</p> <p>SRK carried assisted the operation to interpret the geotechnical data during the review.</p> <p>Full adoption of the risk evaluation technology by the operation will require ongoing in-house database management for which the on-mine team should be equipped.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- A suitable application such as a licensed, working copy of DIPs must be obtained to interpret joint sets.</li> <li>- Correct for scanline bias by sourcing data from multiple locations in different direction on the operation.</li> <li>- Capture and interpret joint spacing correctly using scanline orientation.</li> <li>- Interpret joint condition correctly.</li> </ul>
Impala2 Impala3 Impala4 Impala5	<p>The RE team has not carried out in-house geotechnical data acquisition or interpretation on these operations, largely due to an administrative restriction on the use of mapping technology (iPhone) in underground workings.</p> <p>Full adoption of the risk evaluation technology by the operation will require ongoing in-house database management for which the on-mine team should be equipped.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- A suitable application such as a licensed, working copy of DIPs must be obtained to interpret joint sets.</li> <li>- Geotechnical data must be captured and interpreted by the RE team to build and maintain a database going forward.</li> <li>- Administrative limitations on the use of progressive technology in</li> </ul>

Operation	Summarised Findings	Improvement opportunities
		underground workings should be investigated and addressed.
ARM	<p>Data acquisition has been carried out to a good standard on the operation. Some minor improvements have been recommended.</p> <p>The operation has a sound basis of geotechnical data acquisition to carry out a risk evaluation for support design.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- None.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- Distinguish joint condition properties per structure.</li> <li>- Transfer data acquisition and interpretation skills from RE to the team.</li> </ul>
Northam	<p>Data acquisition and interpretation on the operation has been adopted well.</p> <p>Improvements and corrections have been recommended, particularly to determine joint condition and eliminate scanline bias.</p> <p>A sound platform of acquiring geotechnical data to carry out a risk evaluation has been established.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Correct for scanline bias by capturing data in multiple directions.</li> <li>- Capture and derive joint condition data.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- Avoid reliance on data capture from another Department to obtain the correct geotechnical data. Data should be captured by the RE team as a whole.</li> </ul>

## **Appendix B: Summary of Results for Adoption of JBlock Analysis**

**Table A - 2: Summary of Findings for Keyblock Analysis using JBlock**

Operation	Summarised Findings	Improvement opportunities
AAP1	<p>The operation had obtained a licensed, working copy of JBlock and carried out keyblock analyses prior to the review. Some guidance was given to the users to address particular challenges. Comparative support scenario results had not been obtained for input into the RiskEval application.</p> <p>Use of the software was suitably well demonstrated, however continued improvement is required for the operation to become suitably proficient to carry out keyblock failure analyses.</p> <p>An outcome of this first review was that SRK compiled a set of guidelines to assist the operations in adopting the technology. The guidelines were distributed to the stakeholders. Appendix D presents a copy of the guidelines.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- A suitable size excavation had not been constructed resulting in an under-estimation of actual keyblock failures.</li> <li>- Suitable setup parameters (aspect ratio and clamping stress) had not been considered.</li> <li>- The number of statistical simulations carried out exceeded reasonable analysis requirements, causing long run times.</li> <li>- Comparative support scenarios had not been analysed for input into the RiskEval application.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- The output data files had not been utilised for interpretation of the results.</li> <li>- Hazard zones had been defined, however some guidance was required to obtain realistic areas for the analysis.</li> <li>- Quantitative variability of support installation properties was not available to represent actual practices.</li> <li>- Suitable input parameters are required to improve confidence in the results (Section 4.3.1).</li> <li>- Anomalous structural data such as ramp structures had not been included for the operation.</li> <li>- On-mine FoG data had not been referenced to check resulting outputs.</li> </ul>
AAP2	<p>The operation had obtained a licensed, working copy of JBlock and carried out keyblock analyses prior to the review, however comparative support scenario results had not been obtained for input into the RiskEval application. Some guidance was given to the user to address particular challenges.</p> <p>Suitable understanding of the JBlock application was demonstrated to carry out keyblock failure analyses going forward.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Suitable setup parameters (aspect ratio and clamping stress) had not been considered.</li> <li>- Suitable data limits had not been selected resulting in an overflow error in the results.</li> <li>- Comparative support scenarios had not been analysed for input into the RiskEval application.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- The output data files had not been utilised for interpretation of the results.</li> <li>- Quantitative variability of support installation properties was not available to represent actual practices.</li> <li>- Suitable input parameters are required to improve confidence in the results (Section 4.3.1), particularly in reference to low-angle joints..</li> <li>- On-mine FoG data had not been referenced to check resulting outputs.</li> </ul>
AAP3	<p>The operation had obtained a licensed, working copy of JBlock and carried out a keyblock analysis prior to the review. Comparative support scenario results had not been obtained for input into the RiskEval</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Suitable setup parameters (aspect ratio and clamping stress) had not been considered.</li> </ul>

Operation	Summarised Findings	Improvement opportunities
	<p>application, however good use of the application was demonstrated. Some guidance was required to assist in overcoming challenges.</p> <p>A good understanding of the JBlock application was demonstrated to carry out keyblock failure analyses going forward.</p>	<ul style="list-style-type: none"> <li>- Comparative support scenarios had not been analysed for input into the RiskEval application.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- Some improvement in input parameters is required (Section 4.3.1), particularly in reference to low-angle joints.</li> <li>- Some guidance was required to correctly define hazard zones.</li> </ul>
AAP4	<p>The operation had obtained a licensed, working copy of JBlock and carried out a keyblock analysis prior to the review. Comparative support scenario results had not been obtained for input into the RiskEval application, however good use of the application was demonstrated. Some guidance was required to assist in overcoming challenges.</p> <p>A good understanding of the JBlock application was demonstrated to carry out keyblock failure analyses going forward.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Suitable setup parameters (aspect ratio and clamping stress) had not been considered.</li> <li>- Comparative support scenarios had not been analysed for input into the RiskEval application.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- The output data files had not been utilised for interpretation of the results.</li> <li>- Some improvement in input parameters is required (Section 4.3.1), particularly in reference to low-angle joints and/or ramp structures.</li> </ul>
AAP5	<p>The operation had not obtained a licensed, working copy of JBlock which was attributed to IT related restrictions. A license was subsequently borrowed to attempt a keyblock analysis for a follow-up review by SRK. Comparative support scenario results had not been obtained for input into the RiskEval application.</p> <p>Guidance was required to address challenges in using the analysis tool. SRK carried out a training review using on-mine data to complete an analysis for the operation.</p> <p>Use of the software was demonstrated, however continued improvement is required for the operation to become suitably proficient to carry out keyblock failure analyses.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Suitable setup parameters (aspect ratio and clamping stress) had not been considered.</li> <li>- Suitable data limits and quantity units had not been selected resulting in an overflow error in the results and a failure to generate keyblocks.</li> <li>- Comparative support scenarios had not been analysed for input into the RiskEval application.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- The output data files had not been utilised for interpretation of the results.</li> <li>- Hazard zones had been defined, however some guidance was required to obtain realistic areas for the analysis.</li> <li>- Suitable input parameters must be acquired to improve confidence in the results (Section 4.3.1).</li> <li>- Anomalous structural data such as ramp structures had not been included for the operation.</li> <li>- On-mine FoG data had not been referenced to check resulting outputs.</li> </ul>
XStrata1	<p>The operation had obtained a licensed, working copy of JBlock and carried out keyblock analyses prior to the review. Comparative support scenario results had not been obtained for input into the RiskEval application, however good use of the application was demonstrated. Some guidance was required to assist in overcoming challenges.</p> <p>The JBlock application was developed based on conventional breast panel mining and the operation was assisted to analyse</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Excavation construction and support simulation for Bord and Pillar mining required guidance.</li> <li>- Definition of hazard zones for Bord and Pillar mining required guidance.</li> <li>- Comparative support scenarios had not been analysed for input into the RiskEval application.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- The output data files had not been</li> </ul>

Operation	Summarised Findings	Improvement opportunities
	Bord and Pillar mining using the technology. A good understanding of the JBlock application was demonstrated to carry out keyblock failure analyses going forward.	utilised for interpretation of the results.
XStrata2	The operation had obtained a licensed, working copy of JBlock and carried out keyblock analyses prior to the review. Comparative support scenario results had not been obtained for input into the RiskEval application, however good use of the application was demonstrated. Some guidance was required to assist in overcoming challenges. Similar assistance to XStrata1 was required to analyse Bord and Pillar mining using the technology. A good understanding of the JBlock application was demonstrated to carry out keyblock failure analyses going forward.	Critical points: <ul style="list-style-type: none"> <li>- Excavation construction and support simulation for Bord and Pillar mining required guidance.</li> <li>- Definition of hazard zones for Bord and Pillar mining required guidance.</li> <li>- Comparative support scenarios had not been analysed for input into the RiskEval application.</li> </ul> Other issues: <ul style="list-style-type: none"> <li>- The output data files had not been utilised for interpretation of the results.</li> </ul>
Lonmin1	The operation had not obtained a licensed copy of JBlock, using instead a demo version, which led to limitations in carrying out a keyblock analysis. Comparative support scenario results had not been obtained for input into the RiskEval application. Guidance was required to address challenges in using the analysis tool. Good use of the software was demonstrated, however a licensed application is required to successfully implement the technology on the operation.	Critical points: <ul style="list-style-type: none"> <li>- Suitable setup parameters (aspect ratio and clamping stress) had not been considered.</li> <li>- Comparative support scenarios had not been analysed for input into the RiskEval application.</li> </ul> Other issues: <ul style="list-style-type: none"> <li>- The output data files had not been utilised for interpretation of the results.</li> <li>- Hazard zones had been defined, however some guidance was required to define suitable areas (sweepings) for the particular down-dip mining geometry.</li> <li>- Suitable input parameters are required to improve confidence in the results (Section 4.3.1).</li> <li>- Anomalous structural data such as ramp structures had not been included for the operation.</li> </ul>
Lonmin2	The operation had not obtained a licensed copy of JBlock, using instead a demo version, which led to limitations in carrying out a keyblock analysis. Comparative support scenario results had not been obtained for input into the RiskEval application. Guidance was required to address challenges in using the analysis tool. Good use of the software was demonstrated, however a licensed application is required to successfully implement the technology on the operation.	Critical points: <ul style="list-style-type: none"> <li>- Suitable setup parameters (aspect ratio and clamping stress) had not been considered.</li> <li>- Input data precision to several decimal places resulted in a software malfunction.</li> <li>- Comparative support scenarios had not been analysed for input into the RiskEval application.</li> </ul> Other issues: <ul style="list-style-type: none"> <li>- The output data files had not been utilised for interpretation of the results.</li> <li>- Hazard zones had been defined, however some guidance was required to define suitable areas (sweepings) for the analysis.</li> <li>- Suitable input parameters are required to improve confidence in the results (Section 4.3.1).</li> <li>- Anomalous structural data such as ramp</li> </ul>

Operation	Summarised Findings	Improvement opportunities
		<p>structures had not been included for the operation.</p> <ul style="list-style-type: none"> <li>- On-mine FoG data had not been referenced to check resulting outputs.</li> </ul>
Lonmin3	<p>The operation had not obtained a licensed copy of JBlock, using instead a demo version, which led to limitations in carrying out a keyblock analysis. Comparative support scenario results had not been obtained for input into the RiskEval application, however good use of the application was demonstrated. Some guidance was required to assist in overcoming challenges.</p> <p>Good use of the software was demonstrated, however a licensed application is required to successfully implement the technology on the operation.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Suitable setup parameters (aspect ratio and clamping stress) had not been considered.</li> <li>- Comparative support scenarios had not been analysed for input into the RiskEval application.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- The output data files had not been utilised for interpretation of the results.</li> <li>- Hazard zones had been defined, however some guidance was required to define suitable areas (sweepings) for the particular down-dip mining geometry.</li> <li>- Suitable input parameters are required to improve confidence in the results (Section 4.3.1).</li> <li>- Anomalous structural data such as ramp structures had not been included for the operation.</li> <li>- On-mine FoG data had not been referenced to check resulting outputs.</li> </ul>
Lonmin4	<p>The operation had carried out a detailed support scenario analysis to improve the support system using JBlock. Several scenarios were evaluated, enabling the a support strategy to be selected based on a comparison of analysis results to improve ground control management on the operation.</p> <p>The operation demonstrated proficiency in using the analysis tool. Some minor considerations to incorporate results into a RiskEval analysis have been recommended.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- None.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- The RiskEval analysis relies on input of a sweepings area which has not been included in the analyses. This must be taken into account during setup of the RiskEval analysis.</li> <li>- Some confirmation of input parameters is required to ensure that data remains relevant for continued analysis (Section 4.3.1).</li> </ul>
RBPM	<p>The operation had obtained a licensed, working copy of JBlock and carried out keyblock analyses prior to the review. Comparative support scenario results had not been obtained for input into the RiskEval application and some guidance was required to assist in overcoming challenges.</p> <p>A suitable understanding of the JBlock application was demonstrated to carry out keyblock failure analyses going forward.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Selection of suitable setup parameters, aspect ratio and clamping stress, required guidance.</li> <li>- Comparative support scenarios had not been analysed for input into the RiskEval application. This was carried out during the review.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- The output data files had not been utilised for interpretation of the results.</li> <li>- Suitable input parameters are required to improve confidence in the results (Section 4.3.1).</li> <li>- Anomalous structural data such as ramp structures had not been included for the operation.</li> <li>- On-mine FoG data had not been referenced to check resulting outputs.</li> </ul>
Aquarius	The operation had not obtained a working,	Critical points:

Operation	Summarised Findings	Improvement opportunities
	<p>licensed copy of JBlock, using instead a demo version, which led to limitations in carrying out a keyblock analysis. SRK carried out a training review session to assist in carrying out a keyblock analysis.</p> <p>Use of the software was demonstrated, however continued improvement using a licensed application is required for the operation to become suitably proficient to carry out keyblock failure analyses.</p>	<ul style="list-style-type: none"> <li>- Support scenario analysis using the JBlock application must be carried out to complete adoption of the technology on the operation.</li> </ul>
Impala1 Impala2 Impala3 Impala4 Impala5	<p>The Impala shafts had not obtained working, licensed copies of the required JBlock application, which was attributed to an onerous procurement process. As a result, no keyblock analysis for the operations was carried out.</p> <p>During the review, SRK carried out a demonstration of keyblock analysis for RE's of the shafts, using the geotechnical data acquired and interpreted for the Impala1 operation.</p>	<ul style="list-style-type: none"> <li>- A licensed copy of the JBlock application must be obtained for the operations to carry out a keyblock analysis.</li> </ul>
ARM	<p>The operation had obtained a licensed, working copy of JBlock and carried out keyblock analyses prior to the review. Comparative support scenarios had been obtained for input into the RiskEval application and to select a suitable support design for the operation. Some guidance was required to assist in overcoming challenges.</p> <p>A good understanding of the JBlock application was demonstrated to carry out keyblock failure analyses going forward.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Selection of suitable setup parameters, aspect ratio and clamping stress, required guidance.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- Anomalous structural data such as ramp structures had not been included for the operation.</li> <li>- Hazard zones had been defined, however some guidance was required to define suitable areas (sweepings) for the analysis.</li> <li>- On-mine FoG data had not been referenced to check resulting outputs.</li> </ul>
Northam	<p>The operation had obtained a licensed, working copy of JBlock and carried out keyblock analyses prior to the review. Comparative support scenarios had been obtained for input into the RiskEval application, however a comparison of JBlock analysis results had not been carried out to select a suitable support system. Some guidance was required to assist in overcoming challenges.</p> <p>A good understanding of the JBlock application was demonstrated to carry out keyblock failure analyses going forward.</p>	<p>Critical points:</p> <ul style="list-style-type: none"> <li>- Selection of suitable setup parameters, aspect ratio and clamping stress, required guidance.</li> </ul> <p>Other issues:</p> <ul style="list-style-type: none"> <li>- Anomalous structural data such as ramp structures had not been included for the operation.</li> <li>- Suitable input parameters are required to improve confidence in the results (Section 4.3.1).</li> <li>- Hazard zones had been defined, however some guidance was required to define suitable areas (sweepings) for the analysis.</li> <li>- The output data files had not been utilised for interpretation of the results.</li> </ul>



## **Appendix C: Summary of Results for Adoption of RiskEval Analysis**

**Table A - 3: Summary of RiskEval Results**

Operation	Summarised Findings
AAP1	RiskEval had not been carried out. Suitable outputs from the keyblock analysis had not been obtained for input into RiskEval. Costing and injury consequence data had not been captured prior to the review. During the review process, an attempt was made to acquire the necessary data, with limited success.
AAP2	RiskEval had not been carried out. A similar want for data as at AAP1 was encountered.
AAP3	RiskEval had not been carried out. Sufficient comparative keyblock analysis results had not been obtained to carry out a risk evaluation, however excellent strides had been made to compile the necessary injury and cost consequence parameters to carry out a RiskEval analysis. Guidance was given by SRK during the review with anticipation that the operation would successfully accomplish a risk evaluation. Failure to implement the technology has been attributed to time constraints and a lack of familiarity with this component of the technology. Good initiative was shown by this operation to attempt the analysis.
AAP4	RiskEval had not been carried out. Similar findings as at AAP3 were encountered. Some effort had gone into compiling an input dataset for the RiskEval analysis, with slightly less success than at AAP3, which is attributed to a lack of familiarity with the risk evaluation component.
AAP5	RiskEval had not been carried out. Suitable outputs from the keyblock analysis had not been obtained for input into RiskEval. Costing and injury consequence data had not been captured prior to the review. During the review process, an attempt was made to acquire the necessary data, with limited success. A demonstration was carried out by SRK during which the requirement to run the application from a specific directory-tree format was affirmed.
XStrata1	RiskEval had been attempted at the operation. Input parameters were obtained, however some uncertainty was raised in the applicability of RiskEval to Bord and Pillar mining. The RiskEval analysis code is uniquely suited to conventional breast panel mining, however available strategies can be incorporated in the application, which were discussed with SRK to simulate Bord and Pillar mining. In particular, the rehabilitation strategies must be adapted in a manner to fit Bord and Pillar mining, which requires some careful evaluation of productivity rates.
XStrata2	RiskEval had been attempted at the operation with similar findings as for XStrata1.
Lonmin1	RiskEval had not been carried out. Sufficient comparative keyblock analysis results had not been obtained to carry out a risk evaluation. Installation of the JAVA platform to run the RiskEval application was inhibited by IT restrictions, preventing use of the application. Costing and injury consequence data had not been captured prior to the review.
Lonmin2	RiskEval had not been carried out. Similar findings as per Lonmin1 were encountered.
Lonmin3	RiskEval had not been carried out. Similar findings as per Lonmin1 were encountered.
Lonmin4	RiskEval had not been carried out. Sufficient keyblock analysis results had been obtained to carry out a comparative risk evaluation, however input data relating to injury and cost consequences were not obtained. Operational time constraints inhibited implementation of the technology.
RBPM	RiskEval had not been carried out. Suitable outputs from the keyblock analysis had not been obtained for input into RiskEval. Costing and injury consequence data had not been captured prior to the review. During the review process, an attempt was made to acquire the necessary data, with limited success.
Aquarius	RiskEval had not been carried out. Suitable outputs from the keyblock analysis had not been obtained for input into RiskEval. Costing and injury consequence data had not been captured prior to the review. Similar uncertainty was raised regarding applicability of RiskEval to Bord and Pillar mining which must be addressed by adapting the rehabilitation strategies accordingly.
Impala1 Impala2 Impala3 Impala4 Impala5	RiskEval had not been carried out. Suitable outputs from the keyblock analysis had not been obtained for input into RiskEval. Costing and injury consequence data had not been captured prior to the review. During the review process, an attempt was made to acquire the necessary data, with limited success. A demonstration was carried out by SRK during which the requirement to run the application from a specific directory-tree format was affirmed.

Operation	Summarised Findings
ARM	RiskEval had not been carried out. Sufficient comparative keyblock analysis results had been obtained to carry out a risk evaluation, however installation of the JAVA platform to run RiskEval was inhibited by IT restrictions, preventing use of the application. Costing and injury consequence data had not been captured prior to the review.
Northam	RiskEval had not been carried out. Sufficient comparative keyblock analysis results had been obtained to carry out a risk evaluation, however the RiskEval application could not be run successfully which was possibly due to IT restrictions (possibly JAVA related), which has not yet been resolved. Costing and injury consequence data had not been captured prior to the review.

Final Draft

## **Appendix D: Guidelines for Risk Evaluation**

## **Appendix E: Technology Transfer Evaluation Report Template**

## **Appendix F: Shaft Review Reports**

## SRK Report Distribution Record

Report No.

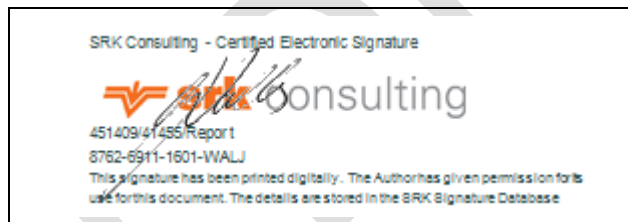
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