

samrec
South African Code for Reporting of Exploration Results, Mineral Resources and Mineral Reserves

samcode
THE SOUTH AFRICAN MINERAL CODES
SAMREC - South African Code for Reporting of Exploration Results, Mineral Resources and Mineral Reserves
SAMVAL - South African Code for the Reporting of Mineral Asset Valuation

samval
South African Code for the Reporting of Mineral Asset Valuation







THE SAMREC/SAMVAL COMPANION VOLUME CONFERENCE

An Industry Standard for Mining Professionals in South Africa

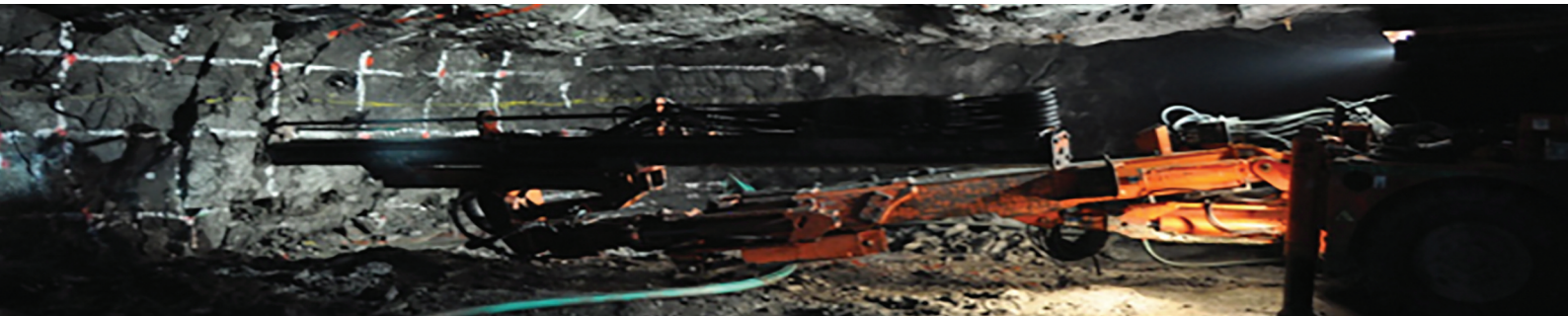




SAIMM
THE SOUTHERN AFRICAN INSTITUTE OF MINING AND METALLURGY
FOUNDED 1894

GSSA
Geological Society of South Africa

17–18 May 2016
Emperors Palace, Johannesburg



THE SOUTHERN AFRICAN INSTITUTE OF MINING AND METALLURGY
JOHANNESBURG 2016

THE SAMREC/SAMVAL COMPANION VOLUME CONFERENCE

An Industry Standard for Mining Professionals in South Africa

17–18 MAY 2016

Emperors Palace, Johannesburg

SAIMM PUBLICATIONS

THE MONOGRAPH SERIES

M1 **Lognormal-De Wijsian Geostatistics for Ore Evaluation**
(2nd ed 1981) D.G. Krige

M2 **An Introduction to Geostatistical Methods of Mineral Evaluation**
(2nd ed 1981) J.-M.M. Rendu

M3 **Principles of Flotation**
(1982) (3rd imp. 1986) Edited by R.P. King

M4 **Increased Underground Extraction of Coal**
(1982) Edited by C.J. Fauconnier and R.W.O. Kersten

M5 **Rock Mechanics in Mining Practice**
(1983) (3rd imp. 1986) Edited by S. Budavari

M6 **Assay and Analytical Practice in the South African Mining Industry**
(1986) W.C. Lenahan and R. de L. Murray-Smith

M7 **The Extractive Metallurgy of Gold in South Africa,**
2 volumes (1987) Edited by G.G Stanley

M8 **Mineral and Metal Extraction — An Overview**
(1994) L.C. Woollacott and R.H. Eric

M9 **Rock Fracture and Rockbursts—an illustrative study**
(1997) Edited by W.D. Ortlepp

THE SPECIAL PUBLICATIONS SERIES

SPI **Proceedings, Underground Transport Symposium**
(1986) Edited by R.C.R. Edgar

SP2 **Backfill in South African Mines** (1988)

SP3 **Treatment and Re-use of Water in the Minerals Industry** (1989)

SP4 **COREX Symposium 1990**
(1990) Edited by H.M.W. Delport and P.J. Holaschke

SP5 **Measurement, Control, and Optimization in Mineral Processing**
(1994) Edited by H.W. Glen

SP6 **Handbook on Hard-rock Strata Control**
(1994) A.J.S. Spearing

SP7 **Rock Engineering for underground coal mining**
(2002) J. Nielen van der Merwe and Bernard J. Madden

SP8 **Second Edition: Rock Engineering for underground coal mining**
(2010) J. Nielen van der Merwe and Bernard J. Madden

SUPPLEMENT TO THE SAIMM *JOURNAL*

The Metals and Minerals Industry in South Africa - Part 1 (1989)
Edited by H.W. Glen

THE SYMPOSIUM SERIES

S1 **Mathematical Statistics and Computer Applications in Ore Valuation** (1966)

S2 **Planning Open Pit Mines** (1970) (4th imp.)
Edited by P.W.J. van Rensburg

S3 **Application of Computer Methods in the Mineral Industry** (APCOM 1973) Edited by M.D.G. Salamon

S4 **Infacon 1974** Edited by H.W. Glen

S5 **Proceedings of the 12th CMMI Congress** 2 volumes (1982) Edited by H.W. Glen

S6 **Rockbursts and Seismicity in Mines** (1984) Edited by N.C. Gay and E.H. Wainwright

S7 **The Planning and Operation of Open Pit and Strip Mines** (1986) Edited by J.P. Deetlefs

S8 **GOLD 100: Proceedings of the International Conference on Gold (1986)**
Volume 1: Gold Mining Technology Edited by H. Wagner and R.P. King
Volume 2: Extractive Metallurgy of Gold Edited by C.E. Fivaz and R.P. King
Volume 3: Industrial Uses of Gold Edited by G. Gafner and R.P. King

S9 **APCOM 87: Proceedings of the Twentieth International Symposium on the Application of Computers and Mathematics in the Mineral Industries (1987)**
Volume 1: Mining Edited by L. Wade, R.W.O. Kersten and J.R. Cutland
Volume 2: Metallurgy Edited by R.P. King and I.J. Barker
Volume 3: Geostatistics Edited by I.C. Lemmer, H. Schaum and F.A.G.M. Camisani-Calzolari

S10 **International Deep Mining Conference (1990)**
Volume 1: Innovations in Metallurgical Plant Edited by G.A. Brown and P. Smith and
Application of Materials Engineering in the Mining Industry Edited by B. Metcalfe
Volume 2: Technical Challenges in Deep Level Mining Edited by D.A.J. Ross-Watt and P.D.K. Robinson

S11 **Infacon 6 (Incorporating Incsac) (1992)**
Edited by H.W. Glen

S12 **Massmin 92** Edited by H.W. Glen (out of print)

S13 **Minefill 93** Edited by H.W. Glen

S14 **XVth CMMI Congress Publications (1994)**
Volume 1: Mining Edited by H.W. Glen– **Volume 2: Metals Technology and Extractive Metallurgy (1994)** Edited by H.W. Glen

S15 **Surface Mining 1996** Edited by H.W. Glen

S16 **Hidden Wealth** (1996) Edited by H.W. Glen

S17 **Heavy Minerals 1997** Edited by R.E. Robinson

S18 **The 8th International Platinum Symposium (1998)**

S19 **Mining in Africa '98**

S20 **Extraction Metallurgy Africa '98**

S21 **Sixth International Symposium for Rock Fragmentation by Blasting (1999)**

S22 **Metallurgy Africa '99**

S23 **Heavy Minerals 1999** Edited by R.G. Stimson

S24 **Tunnels under Pressure** Technical Editor T.R. Stacey

S25 **Mine Hoisting 2000**

S26 **Coal–The Future (2000)**

S27 **The Fifth International Symposium on Rockburst and Seismicity in Mines (RaSim 5) (2001)**

S28 **6th International Symposium on Mine Mechanization and Automation (2001)**

S29 **XIV International Coal Preparation Congress and Exhibition**

S30 **Surface Mining 2002—Modern Developments for the New Millennium**

S31 **IFSA 2002, Industrial Fluidization South Africa**

S31A **APCOM 2003—Application of Computers and Operations Research in the Minerals Industries**

S32 **ISSA/Chamber of Mines Conference—Mines and Quarries: Prevention of Occupational Injury and Disease**

S33 **ISRM—Technology Roadmap for Rock Mechanics**

S34 **Heavy Minerals Conference 2003**

S35 **Safety in Mines Research Institutes (2003)**

S36 **VII International Conference on Molten Slags, Fluxes & Salts (2004)**
Tenth International Ferroalloys Congress INFACONX 2004

S37 **Deep and high stress mining 2004**

S38 **'Platinum adding value' 2004**

S39 **Base Metals—Southern Africa's response to changing global base metals market dynamics 2005**

S40 **Strategic versus Tactical approaches in mining 2005**

S41 **Best practices in rock engineering SARES 2005**

S42 **IFSA 2005, Industrial Fluidization South Africa**

S43 **Southern African Pyrometallurgy 2006 International Conference**

S44 **Stability of rock slopes in open pit mining and civil engineering situations**

S45 **'Platinum Surges Ahead' 2006**

S46 **Hydraulic Transport of Solids - Hydrotransport 17 (2007)**

S47 **Fourth Southern African Base Metals Conference 'Africa's base metals resurgence'**

S48 **Heavy Minerals Conference, 2007**

S49 **Cave Mining Conference, 2007**

S50 **International Symposium on Lead and Zinc processing – Lead & Zinc 2008**

S51 **Surface Mining 2008**

S52 **Platinum in transformation 2008**

S53 **IFSA 2008, Industrial Fluidization South Africa**

S54 **Hydrometallurgy Conference 2009**

S55 **Shotcrete for Africa 2009**

S56 **Base Metals Conference 2009**

S57 **Heavy Minerals Conference, 2009**

S58 **Hard Rock Safe—Safety Conference 2009**

S59 **Sampling and Blending 2009**

S60 **World Gold 2009 Conference**

S61 **Physical Beneficiation Conference 2010**

S62 **Second Hardrock Safe—Safety Conference 2010**

S63 **Platinum in Transition 'Boom or Bust' 2010**

S64 **South African Pyrometallurgy 2011 International Conference**

S65 **Minefill 2011 (10th International Symposium on Mining with Backfill)**

S66 **Base Metals Conference 2011**

S67 **MineSafe 2011 Conference**

S68 **Iron Ore and Manganese Ore Metallurgy 2011**

S69 **Percolation leaching: The status globally and in Southern Africa**

S70 **IFSA 2011, Industrial Fluidization South Africa**

S71 **Southern Hemisphere International Rock Michanics Symposium 2012**

S72 **Platinum Conference 'A catalyst for change' 2012**

S73 **Ferrous 2012—Ferrous and Base Metals Development Network Conference**

S74 **Diamonds - Source to use 2013**

S75 **Sampling and analysis: Best-practice in African mining 2013**

S76 **Base Metals Conference 2013**

S77 **Precious Metals 2013 Conference—The Precious Metals Development Network (PMDN)**

S78 **Physical Beneficiation 2013 Conference**

S79 **21st Century challenges to the southern African coal sector**

S80 **Furnace Tapping Conference 2014**

S81 **Platinum Conference 'Platinum—Metal for the Future' 2014**

S82 **IFSA 2014, Industrial Fluidization South Africa**

S83 **Copper Cobalt Africa 2015**

S84 **The Danie Krige Geostatistical Conference 2015**

S85 **World Gold Conference 2015**

S86 **Slope Stability 2015**

S87 **Nuclear Materials Development Network 2015**

S88 **Diamonds still sparkling Conference 2016**

Published by The Southern African Institute of Mining and Metallurgy
Fifth Floor, Chamber of Mines Building, 5 Hollard Street, Johannesburg, 2107
Republic of South Africa

© The Southern African Institute of Mining and Metallurgy, 2016

ISBN 978-1-920410-81-0

The abstracts in this volume have been for the most part prepared from Word documents supplied by the authors, with additional typesetting and formatting by The Southern African Institute of Mining and Metallurgy.

The Organising Committee expresses its deep appreciation for the voluntary contributions of the technical review panel in assisting to maintain high technical standards for the papers presented at this conference.

M. Austin
A. Birtles
K. Body
H. Bornman
H. Boucher
V. Chamberlain
D. Cowen
D. Dingemans
C. de Jager
L. de Meillon
R. Dixon
S. Duggan
M. de Wit
M. Field
R. Gawthorpe
A. Grills
J. Hancox
P. Hand
R. Ingram
L. Jeffrey
K. Lomberg
B. Ludick
S. Magnus
A. McDonald
B. McKechnie
R. McKinney
K. McMillan
T. Marshall
S. Mathuray
R. Minnitt
A. Moore
J. Nel
S. Nupen
G. Njowa
R. Peattie
G. Rau
K. Redman
A. Rogers
T. Rowlands
S. Rupprecht
C. Smith
J. Sullivan
A. van der Merwe
K. van Deventer
R. Welff
M. Woollam
D. Young

Printed by Camera Press, Johannesburg

Preface

In preparing a Public Report of Exploration Results, Mineral Resources, Mineral Reserves (SAMREC) and their valuations (SAMVAL), the practitioner must satisfy the requirements of SAMREC and SAMVAL Codes. The intention of the Companion Volume is to aid the Competent Person and Competent Mineral Asset Valuator when making these declarations. The objective of this conference and the Companion Volume is to provide a testimony of current industry benchmarks and best practice to be used or referenced when making a declaration. Best practice consistently shows superior results to those achieved with other means or techniques, and as such provides a benchmark for the industry.

It is acknowledged that no single document can cover all accepted industry practices or assist with all possible situations. However, the aim of the Companion Volume is to present the best current knowledge. Expertise is still required when applying best practice as the Competent Person or Competent Mineral Asset Valuator must balance each unique situation with the practices that it has in common with others.

The SAMREC and SAMVAL Codes are guidelines to assist Competent Persons and Competent Mineral Asset Valuators when declaring or valuating Exploration Results, Mineral Resources, or Mineral Reserves. The purpose of the Companion Volume is also to provide information that will be useful to mentor less experienced or inexperienced mineral industry professionals. Despite having these industry practices available, the Competent Person or Competent Mineral Asset Valuators is still required to be prepared to defend themselves to their peers and take responsibly for their work.

The editors and organising committee trust that the reader will find the Companion Volume of great use and guidance in the reporting of Exploration Results, Mineral Resources, or Mineral Reserves and their valuations. Its use will assist practitioners to produce more reliable, and transparent reporting.

K. Lomberg

Chairman, Organising Committee

The Samrec/Samval Companion Volume Conference

Organising Committee

Ken Lomberg – Chairman

Kelly Redman

Craig Smith

Tania Marshall

Jurgens Visser

Steven Rupprecht

Mpho Tlala

Andrew Kinghorn

Godknows Njowa

Andy MacDonald

Jacques Nel

Mark Austin

John Hancox

Lesley Jeffrey

Christina Dohm

Santhoshnie Mathuray

Contents

Page No.

Session 2A: Compliance

Good reporting practices
S.M. Rupprecht 1

Mineral Resource and Mineral Reserve governance and reporting for AngloGold Ashanti
R. Peattie, V. Chamberlain, and T. Flitton 13

Session 3A: Exploration Results

The understanding and importance of sampling in the SAMREC Code
K. Lomberg 21

Mineralisation beyond Inferred Resources
J.R. Dixon 33

Exploration Results, Exploration Targets and Mineralisation
T.R. Marshall 45

Session 4A: Exploration Results

Industry best practice for the collection and validation of exploration data with particular reference to a drilling programme
R. McKinney 55

Best-practice sampling methods, assay techniques, and quality control with reference to platinum group elements (PGEs)
K. Lomberg 67

Session 2B: SAMVAL

The valuation of an exploration project having inferred Resources
S. Rupprecht and G. Njowa 87

The art of reduction: analysing comparable transactions applicable to early stage exploration properties
A.J. van der Merwe 95

Session 3B: SAMVAL

How good are Metal Price Forecasts anyway?
A. McDonald 103

Some common risks to avoid in estimating and applying discount rates
J. Burger and N.J. Odendaal 113

Comparative transactions in project valuation
A. van Zyl 125

Session 4B: SAMVAL

Application of the market approach in the valuation of mineral assets — a practical case study
G. Njowa and C. Musingwini 135

Valuation of alluvial diamond deposits
T.R. Marshall 151

Session 5A: Mineral Resources

Consideration for reporting of tailings
N.C. Steenkamp 163

The new SANS 10320:2016 versus the 2014 Australian guidelines for the estimation and classification of coal resources—what are the implications for southern African coal resource estimators?
J. Hancox and H. Pinheiro 173

Contents *(continued)*

Page No.

Session 6A: Mineral Resources

The Application of Modifying Factors
S.M. Rupprecht 187

Life-of-mine reserves estimation in the dimension stone block extraction industry in South Africa
G. vom Orde, I. Coates, A.L. Forrester, K. Lomberg, and R. Stephens 195

Reporting of geological model confidence level at AngloGold Ashanti's Mponeng mine
G. Flitton 209

Reconciliation of produced grade and tonnage at AngloGold Ashanti
V. Chamberlain, T. Flitton and R. Peattie 217

Session 7A: Mineral Reserves

Towards reliable geoscientific data and improved confidence in reporting through existing guidelines and standards: a case for inclusion in SAMCODES reporting
C. Zermatten 225

The quantification of environmental and social risks as SAMREC modifying factors for decision-making in the business case
C. Zermatten, B. Liber and R. Dixon 239

Practical steps in reporting social and environmental liability in the mining and oil and gas industries
S. Magnus, N.N. Moeketsi, and A. Clay 253

Session 5B: Diamond Resources

A discussion of diamond resource classification
N. Lock 265

Development of a best-practice mineral resource classification system for the De Beers group of companies
S. Duggan, A. Grills, J. Stiefenhofer, and M. Thurston 287

Session 6B: Diamond Resources

Diamond Resource/Reserve estimation of alluvial diamond deposits – a case study of Rockwell Resources Inc.
G.A. Norton 299

Evaluating bedrock-based onshore and offshore marine placer deposits using the new SAMREC/SAMVAL Code
R.J. Jacob, P. Saravanakumar, and J. Jacob 311

Diamond valuation: what can a CP do to ensure it is fit for purpose?
C. Gordon-Coker 325

Diamond Resource reconciliation in a mature block cave
A. Wolmarans, D. du Toit, D. Venter, and A. Rogers 331

Session 7B: Diamond Resources

Application of the SAMREC code to the evaluation of ruby deposits
P.G. Allan 343

Key factors influencing the success of the Orapa Resource Extention Project with reference to SAMREC Table 1
T.V. Rowlands* and B.M. Letsatle 355

APPENDIX

SAMREC Diamond Guidelines

The SAMESG Guidelines

The SAMESG Guidelines 2015 Edition

The organisers of the conference wish to thank the following sponsors for their support

-oOo-

SAMCODES Booklet Sponsors

CCIC COAL
Caracle Creek International Consulting Coal (Pty) Ltd
www.cciconline.com

DMT
DMT Kai Batla (Pty) Ltd

VenmynDeloitte.

XBT
CORPORATE SERVICES

Lanyards Sponsor

coffey

Launch Day Sponsor

JSE

Speaker Gifts Sponsor

SACNASP
South African Council for Natural Scientific Professions

Good reporting practices

S.M. Rupprecht

Senior Lecturer, University of Johannesburg, Republic of South Africa

The SAMREC Code sets out the minimum standard for the Public Reporting of Exploration Results, Mineral Resources and Mineral Reserves. When making a declaration the Competent Person (CP) must disclose relevant information concerning the status and characteristics of a mineral deposit that could materially influence the economic value of the deposit and promptly report any material changes. The Johannesburg Stock Exchange (JSE) Listing enlists Panel Readers to review all CP Reports and annual reports for their compliance with the SAMREC Code and Section 12 of the JSE Listing Requirements.

The JSE Readers Panel assists in achieving reporting compliance. However there are still many Public Reports that are not formally reviewed. Thus, the SAMREC Code is largely reliant on self-regulation. Although Clause 11 of the SAMREC Code makes provision for complaints made in respect of Public Reporting, complaints are rarely made. Yet, noncompliant reporting remains an issue within the southern African mineral industry.

This paper investigates compliance of Public Reports and some of the common compliance issues currently being experienced. The paper also discusses methodologies to improve compliance and Public Reporting, such as self-regulation, coaching and training and other means to promote good reporting compliance.

INTRODUCTION

The South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves (The SAMREC Code) contributes to promoting the minimum requirements of Public Reporting. A declaration in terms of The SAMREC Code requires the Competent Person (CP) to be prepared to defend themselves to their peers. The Code relies on this peer review process and is therefore effectively self-policing. The effectiveness of this self-policing has been debated since the inception of the Code, and although it is sometimes seen as ineffective, self-regulation is the preferred method to monitor Public Reporting.

The Poseidon Nickel bubble of 1970 and the BRE-X scandal of 1997 motivated the creation of international reporting codes, which provide investors, potential investors, and other stakeholders with a sense of confidence in statements made by promoters and owners of mineral projects. Consequently, the aim of the SAMREC Code is to maintaining the trust of investors and other interested parties by promoting high standards of Public Reporting. The SAMREC Code is meant as a minimum reporting standard and advises CPs to report 'too much information rather than too little' (Clause 32 of the SAMREC Code).

Opponents to the monitoring of Public Reporting practices are of the opinion that the Code is presented as a guideline and therefore regulating reporting practices are not necessary. Furthermore, opponents feel that some responsibility must be placed on the investor to be diligent when investing in an exploration or mineral company. The author does not concur with the above opinions, as the mineral industry relies on investments to support project development and, furthermore, the industry historically has a tarnished reputation. Mark Twain in the 1880s famously defined a mine as 'a hole in the ground with a liar on top'. Events such as the 1970s Poseidon Nickel boom-to-bust, Bre-X, and Enron highlight unscrupulous or fraudulent behaviour. In South Africa, recent failures such in coal, platinum, and gold projects and other commodities have eroded investor confidence, for example the delisting of Miranda Coal and closure of Burnside gold mine. In an industry that requires investor capital, often as seed money to fund early exploration or development projects, ensuring investor confidence is paramount.

Public companies listed on the Johannesburg Stock Exchange (JSE) must adhere to the ongoing reporting requirements in terms of Section 12.11 of the JSE Listing Requirements. When a company reports according to the SAMREC Code, the public should have a sense of confidence that the information that has been reported is relevant, factually correct, and provides full disclosure. Fortunately, most companies adhere to the principles and guidelines of the SAMREC Code. In some cases, minor oversights may occur but generally companies observe the underlying values of the Code. Regrettably, there is a minority of companies that do not understand the importance of good ongoing reporting and fail to adhere to industry best practice. In these cases, Exploration Results, Mineral Resources, and Mineral Reserves are reported in an inappropriate manner, leaving the public uninformed as reporting fails to comply with the Code fully, misinterprets data, distorts information, or fails to disclose material information fully. The mineral industry is a difficult enough investment without being encumbered by poor disclosure, non-transparency, and poor quality and /or incompetent reporting.

This paper discusses the issues around compliant Public Reporting and the SAMREC Code. The paper also discusses the governing principles of the Code, self-regulation and complaint procedures, and provides examples of noncompliant reporting. Reference is made to the revised 2016 SAMREC Code and recommendations made going forward regarding Public Reporting, self-regulation, and teaching and mentoring of industry professionals.

GOVERNING PRINCIPLES OF THE CODE

In the course of Public Reporting, CPs sometimes overlook the governing principles of the SAMREC Code, *i.e.* Transparency, Materiality, and Competence (Figure 1).

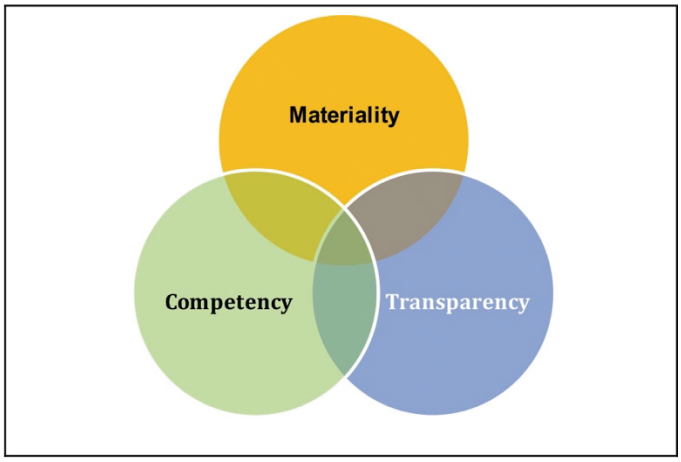


Figure 1. Underlying principles of the SAMREC Code.

Materiality signifies that all relevant information should be made available and that reasoned and balanced reporting should be undertaken. One of the main purposes in developing the Codes was to ensure that various stakeholders, investors, and their professional advisors would be provided with sufficient information for the purpose of making a reasoned and balanced decision. Critical to Public Reporting is the principle that any material aspects for which the presence or absence of comment could affect the public perception or value of the mineral occurrence must be disclosed.

Transparency requires that the CP provide sufficient information, which is clear and unambiguous, and that the CP does not mislead or omit material information. As a rule, it is better for the CP to provide too much information rather than too little. Transparent reporting provides the public with confidence.

Competency requires that all technical work conducted is done by suitably qualified and experienced persons who are subject to an enforceable professional code of ethics and rules of conduct. It is important that the CP is not unduly affected by outside influences and remains able to present a fair and accurate report. Persons undertaking the role of a CP must be capable of defending their professional opinions and not be intimidated by interested parties.

CPs, executives, and other interested parties of publicly listed companies are reminded that the Code sets out the required minimum standards for Public Reporting. CPs, as authors, must insist that they provide written approval (JSE Listing Requirement) of specific documentation that is referred to in a Public Report or statement. The CP must be satisfied as to the form, content, and context in which that documentation is to be included in a Public Report. As a reminder to the reader, the Code (Clause 3) defines Public Reports as follows:

> *Public Reports are all those reports prepared for the purpose of informing investors or potential investors and their advisers and include but are not limited to companies' annual reports, quarterly reports and other reports included in JSE circulars, or as required by the Companies Act. The Code also applies to the following reports if they have been prepared for the purposes described in Clause 3: environmental statements; information memoranda; expert reports; technical papers; website postings; and public presentations. And T8 (A)(ii) Announcements by companies should comply with the SAMREC Code, where applicable, and insofar as they relate or refer to a Competent Person's report they should: (a) Be approved in writing in advance of publication by the relevant Competent Person.*

Unfortunately, Clause 3 is often overlooked by companies. Some Public Reports fail to comply with the above clause and a number of public statements fail to gain approval from the responsible CP prior to the announcement.

In the context of complying with the principles of the Code, the CP is required to comment on the relevant sections of Table 1 of the SAMREC Code. The 2016 SAMREC Code introduces, similar to the 2012 JORC Code, an 'if not, why not' approach to the reporting to Table 1. This necessitates that each item listed in the table be discussed, and if not discussed then the CP must explain why it has been omitted from the documentation. This additional requirement to the Code improves transparency and ensures that the Public Report is clear to the reader (public) and that all items have been considered and have been addressed or resolved.

COMPLIANCE

In terms of Public Reporting, compliance requires reporting in accordance with the principles and guidelines of the SAMREC Code. The importance of compliance is the underlying requirement to provide the public with confidence. Based on discussion held within the SAMREC Working Group, some mining professionals believe that the Codes are becoming overly onerous, while others believe that CP Reports (CPRs) should be made simpler and easier to complete, advocating the use of a 'short

form' CPR. The author rejects the above premise and stresses the need for comprehensive and fully disclosed Public Reporting. CPRs and other Public Reports, including news releases, should not be taken lightly. Noting that Public Reports must ensure that information provided is unambiguous and provide sufficient information for a reasonable person to make an informed decision on the viability of a project and whether to invest or disinvest. A short form report, basically equivalent to an executive summary, is incapable of providing sufficient detail to sufficiently inform an investor.

DECLARATION OF COMPETENCY

One cannot discuss compliance with the SAMREC Code without discussing competency of the CP. The glossary of terms as provided in the SAMREC Code has no definition provided for competency, yet competency is one of the fundamental components of the Code. Competency, as described in Clause 4 of the SAMREC Code, is as follows:

> '*The Public Report is based on work that is the responsibility of suitably qualified and experienced persons who are subject to an enforceable Professional Code of Ethics*'.

Although Clause 9 of the Code does provide clarity on the definition of a CP it relies on the individual to act competently.

> *'A Competent Person is a person who is registered with SACNASP, ECSA or SAGC, IMSSA, or is a Member or Fellow of the SAIMM, the GSSA or a RPO'. 'A Competent Person must have a minimum of five years' experience relevant to the style of mineralisation and type of deposit or class of deposit under consideration and to the activity he or she is undertaking'.*

For a number of years the JSE has been requesting a registration list for CPs. The reasoning behind this drive is to improve the quality of Public Reporting, the objective being that only persons that have demonstrated their 'competency' would be able to provide CPRs to the JSE. To date this registration has not materialized, as many CPs believe that there is sufficient regulation or guidelines in place to ensure competence – the real issue is non-compliance in reporting and the lack of discipline for poor reporting practices. Self-regulation is seen as the preferred method of control, but it requires peers to monitor CPs' work and to report noncompliance.

Some professionals believe that the onus on competency should lie with statutory registration bodies such as SACNASP, SAGC, IMSSA, or ECSA. The issue of competency is sometimes confused with the fact that a CP must be a member of ECSA, SACNASP, SAGC, IMSSA, or member/fellow of the SAIMM, GSSA or a recognized professional organization (RPO), all of which have enforceable disciplinary processes including the power to suspend or expel a member/fellow. This is important in that these professional organizations provide an enforceable Professional Code of Ethics, which is a basic requirement for a CP. Although these organizations have disciplinary powers, they in themselves do not determine whether a person is competent. The responsibility of deeming oneself as competent relies on the individual as the 'Competent Person should be clearly satisfied in their own mind that they could face their peers and demonstrate competence in the commodity, type of deposit and situation under consideration' (SAMREC Code, Clause 10).

It is up to a CP's peers to ensure that indeed authors of technical (Public) reports act in a competent, responsible, and ethical manner. The CP must demonstrate their own competency applying to a Code of Ethics and if in doubt a person should either seek the opinion from appropriately experienced peers or should decline to act as a CP for that specific job.

ROLE OF THE JSE READERS PANEL

The role of the JSE Reader is to ensure that a CPR or annual report is conducted in accordance with the requirements of the SAMREC and SAMVAL Codes, and the JSE Listing Requirements, indicate errors in the text, and indicate whether plans and diagrams accompanying the Public Report support the content of the report. The JSE Reader must be satisfied that the Competent Person or Competent Valuator complies with the professional registration requirements and experience as set out in Clause 7 to 10 of the SAMREC Code and/or Clause 9 and 10 of the SAMVAL Code.

The JSE Reader also must ensure that the Competent Person/Competent Valuator, in terms of a CPR, has correctly referenced the SAMREC and SAMVAL Code (Table 1) or JSE Listing Requirements in the CPR or annual report.

The Reader's job is not to provide sign off on the technical aspects of the work nor validate the conclusions of the CPR. It must be acknowledged that there is an element of peer review in the process of ensuring that technical work makes sense and is fair and reasonable. For example, the JSE Readers guidelines state that '*the Reader should comment on issues which, based on his/her experience appear technically incorrect or inadequately covered*'. However, in the end the CPR remains the responsibility of the author(s).

The JSE Readers Panel review process is viewed by other countries as a good process. However, JSE Readers Panel reviews are only activated in certain situations and not all published CPRs are reviewed, especially those conducted for companies not publicly listed. The reader must understand that many CPRs have not been formally reviewed.

Furthermore, the JSE Readers review process is not without its problems. One of the dilemmas with the Readers review process is that a CPR encapsulates a number of areas that may stretch the capabilities of a single Reader. For example, the Reader may be required to be knowledgeable in mineral resources, geotechnical engineering, mine engineering, ventilation, metallurgical processes, environmental, infrastructural, marketing, governmental and social aspects, as well as the valuation of mineral projects. It may be prudent for the JSE to introduce more than one reader to conduct reviews of CPRs, thereby improving the overall review process. However, it must be recognized that ultimately the responsibility of the CPR remains the responsibility of the CP(s).

As of 2014, the JSE Readers Panel has also begun to review annual reports of mineral and exploration companies to ensure compliance with the ongoing reporting requirements in terms of Section 12.11 of the JSE Listing Requirements. The second year of reviewing annual reports has generally seen an improvement in compliance with the JSE Listing Requirements [SAMREC Code], however, compliance still can improve.

COMPLAINTS PROCEDURE

Professionals when coming across noncompliant Public Reports need to consider if the breach warrants action. The SAMREC Code provides a means to make formal complaints, and Clause 11 states '*complaints in respect of the Public Report of a Competent Person will be subject to the complaints procedures of the [The SAMCODE Standards Committee] SSC.*'

The written complaint will be referred to the Complaints Sub-committee, which will consist of at least three members, and will review the complaint within 21 days of receipt of the complaint. The duty of the Complaints Sub-committee will be to consider all allegations of breaches of the SAMREC, SAMVAL, and SAMOG Codes submitted to the SSC and make a recommendation to the Chairperson of the SSC. If a breach in the Code is established then the Chairperson of the SSC committee shall forward the complaint to the relevant professional or statutory body. The relevant body may be any of the following: SACNASP, ECSA, PLATO (now South African Geomatics Council (SAGC), the Institute

of Mine Surveyors of South Africa (IMSSA), GSSA, SAIMM, or other Recognized Professional Organization (RPO) to which the CP or Competent Valuator is affiliated (Learned Society or Statutory Body).

The difficulty in managing the quality of Public Reports has been the reluctance of mining professionals to regulate their peers and to ensure that Public Reports properly adhere to the Code. The number of noncompliant Public Reports observed by the author indicates that there are members of the mineral industry that are not concerned with compliance. Perhaps this is due the fact that over the past 15 years there have only been a few complaints made to the SSC and therefore there is an attitude that little, if any action is taken for noncompliant reporting. Based on the author's experience, it appears that there are a few CPs, mining executives, and senior managers that project a *laissez faire* attitude toward Public Reporting and that for some there is a resistance to change reporting practices. A general review of exploration and mining company's web sites will support the above statement. Although the author could reference several indiscretions, it is not the intention of this paper to embarrass individuals or companies but rather highlight the issue.

SELF-REGULATION AND COMPLAINTS

The need for self-regulation and action on noncompliant reporting has been an issue and a matter for debate since the inception of the SAMREC Code. There are many reasons for a general lack of discipline in the industry, one being that CPRs are often under confidentiality agreements. Another is the reluctance of practising CPs to make formal complaints against peers – justifying the lack of criticism under the proverb 'persons who live in glass houses shouldn't throw stones'.

Non-compliance in reporting is not limited to South Africa but is a problem for all reporting countries. A general consensus is that more focus should be on coaching and mentoring of CPs. Rather than viewing complaints as a process of taking disciplinary action or sanctions against CPs, there should be a move towards coaching and mentoring. It is proposed that the SSC, through each of the Working Groups, form a subcommittee whose primary objective is to promote short courses through the GSSA and/or SAIMM to improve knowledge of the Code and its reporting requirements.

Similarly, it may be prudent for the learned societies to publish (anonymously) corrective actions taken for noncompliant reporting. The AusIMM successfully does this and the author believes that this approach should be adopted in South Africa. It is interesting to note that if noncompliance is established, the AusIMM may impose a penalty, which may include a reprimand, mediation, and/or counselling. However, suspension of membership to the AusIMM is not imposed by the Complaints Committee.

The Canadian Ontario Securities Commission in 2013 undertook a compliance review of 50 Technical Reports that represented approximately 10% of the NI43-101 Technical Reports submitted over the period 30 June 2011 to 30 June 2012 (Ontario Securities Commission, 2013). The review found that 40% of the CPRs required significant changes and a further 40% were also noncompliant, requiring minor changes. Only 20% of the reports were considered compliant.

It should be noted that professional organizations do not take legal responsibility for a CP or a CPR. Professional membership does not guarantee competency for any specific technical report, nor do qualifications necessarily guarantee competency. The onus of conducting competent technical work remains with the CP. Professional organizations are legally liable for ensuring that a person who applies for and is accepted for membership satisfies the requirements of the organization's constitution and by-laws. In doing so the professional organization affirms that the individual satisfies the requirements for, and has the qualifications required to be, a member and ensures that the member complies with the code of ethics of the organization. These organizations have no liability for the negligent activities of their members. This is one of the reasons for not having a register of CPs, as the holders of the list could be held liable if a CP does not conduct compliant work.

One thing is for certain – if the mineral industry does not self-regulate its reporting then some other agency will and that could lead to non-mineral experts reviewing technical reports; an outcome that will not be good for the mining industry as a whole.

EXAMPLES OF NONCOMPLIANCE

The following section highlights some of the more common or serious mistakes in reporting.

Summary of resources and reserves (MILLION TONS)

SEAM	RESOURCES				RESERVES	
	GTIS	Reconnaissance	Measured	TOTAL	MTIS	ROM
4 Seam	0.06		0.06	0.06	0.06	0.05
2 Seam	0.73		0.69	0.69	0.69	0.60
4 Seam	0.08		0.08	0.08	0.08	0.07
	0.87		0.82	0.82	0.82	0.72
4 Seam	0.19		0.17	0.17	0.17	0.14
2 Seam	1.69		1.53	1.53	1.53	1.27
	1.88		*1.70*	*1.70*	*1.70*	*1.41*
5 Seam	4.67		4.22	4.22	4.22	2.24
4U Seam	2.56		2.31	2.31	2.31	1.22
4L Seam	4.98		4.50	4.50	4.50	2.38
2 Seam	20.36		18.37	18.37	18.37	9.74
1 Seam	4.54		4.09	4.09	4.09	2.17
1L Seam	1.44		1.30	1.30	1.30	0.69
	38.55		*34.79*	*34.79*	*34.79*	*18.44*
2 Seam	40.80	9.79				
4 Seam	61.70	14.81				

Figure 2. Example of a 2013 Coal Resource and Reserve statement.

Figure 2 depicts a public Coal Resource and Reserve statement, which provides an example of a number of common compliance issues observed by the author. Although this statement is dated 2013, the issues highlighted remain relevant. The author has removed the project names as not to embarrass the company or the CP purposely.

Reporting of Reserves

The Coal Reserve is not subdivided in order of increasing confidence into Probable and Proved Coal Reserves. Clauses 32, 33, and 34 of the Code highlight the requirements when reporting reserves. Although not the case in this example, CPs continue to incorrectly us the term 'Proven' instead of 'Proved'. Furthermore, when reporting coal reserves, Mineable Tons In-situ (MTIS), ROM, and Saleable Tonnages must be reported. In the above example the Saleable Tonnage has been left out of the report, and therefore the reader is uninformed of the coal beneficiation efficiency and the planned market for the sale of the washed coal.

Reporting of Coal Quality
Figure 2 highlights another common occurrence in the declaration of Coal Resources and Reserves – the failure to report the quality of the coal. The above example only reports coal tonnages. According to Clause 52 of the Code, appropriate coal qualities must be reported for all Resources and Reserve categories. The selection of the quality parameters is the responsibility of the CP and should include parameters such as ash, volatile matter, sulphur, coking properties, calorific value, *etc*. The coal quality parameters also should include the basis of reporting (air-dry or dry basis, *etc*.), and where applicable Saleable Coal Reserves should be subdivided into the relevant coal product types.

This information is critical and without reporting coal qualities the Coal Reserve is almost useless to an investor. This reporting trend must be stopped immediately; unfortunately, many coal companies observe this trend as being sanctioned. Hopefully, through the JSE Readers Panel's review of annual reports and ongoing training this poor reporting practice will be corrected over the next couple of years.

Reporting Exploration Results
When reporting Exploration or Reconnaissance Results (Clause 20 of the SAMREC Code) the potential quantity, quality, and content should be reported as a range and should include a detailed explanation of the basis for the statement and a proximate statement that the potential quantity, quality and content are conceptual in nature. Failure to report as a range of values and not providing a detailed explanation may be misleading to the investor, as it may appear that there is greater confidence associated with the project than actually exists. Failure to comply with Clause 20, as seen in the provided example, remains a common oversight by some CPs and Public Reports.

Inclusive and Exclusive
When both Mineral Resources and Mineral Reserves are reported the Public Report must include a statement that clearly indicates whether the Mineral Resource is inclusive of, or exclusive to those Mineral Resources that have been modified to estimate a Mineral Reserve (Clause 39). The debate on whether Mineral Resources should be reported inclusive or exclusive of the Mineral Reserve is a decade-long debate that probably will never be resolved. However, whatever the reporting position, a statement is required to avoid confusion and the possibility of the inaccurate valuation of the Mineral Resources. The above example, like many other Resource–Reserve statements, fails to disclose whether the Coal Resources are inclusive or exclusive of the Coal Reserve.

Disclosing Reasonable Prospects
Although Figure 2 is only a summary of the Coal Resource and Coal Reserve, the CP's report also failed to provide commentary on the reasonableness of the projects. For example, on the only operating mine, no comment is provided whether a Life Of Mine (LOM) plan has been completed or any other commentary to support the declaration of a Coal Reserve. For other projects with Coal Reserves, no mention is made if a Feasibility Study or Pre-Feasibiltiy Study (PFS) has been conducted – a requirement in order to declare a Reserve.

The Public Reporting of a Mineral Resource estimate must provide sufficient information on how the projects have a reasonable prospects for economic extraction', assumptions made to estimate economic viability, and the cut-off grade used to estimate the Mineral Resource.

Declaration of Reserves based on Conceptual/Scoping Study
In the above example more than two of the project areas declared a reserve; however the CP declared 'The [deleted] pillar project is still in a planning phase'. In order to declare a Reserve the company should have either conducted a PFS or a LOM Plan. This was not the case at the time of the declaration, and therefore the project should only be classified as a Coal Resource as per Clause 33 and 34 of SAMREC Code read with Clause 47 and 48.

A Mineral Reserve must be based on a minimum assessment of a PFS for a project or a LOM Plan for an operation, and the modifying factors applied must be realistically considered (Clause 32). On

occasion, Mineral Reserves are declared without a PFS being completed, which can have a material effect on the project's valuation. In terms of compliance, this is one of the biggest mistakes a CP can make.

Disclosure
Mineral/exploration companies are required to disclose the full name, address, professional qualifications, and relevant experience of the Lead CP authorizing publication of the information disclosed. Informing the investor of the CP's details and experience is also important to provide the investor with confidence that the CP is competent. For the informed investor, knowledge of the responsible CP may influence the decision to invest or not to invest in a project.

Written Confirmation
It is common for exploration/mineral companies not to include a statement that they have written confirmation from the Lead CP that the information disclosed is in accordance with the SAMREC Code and, where applicable, the JSE Listing Requirements. Again, it is hoped this poor habit will be rectified in the short to medium term.

Inferred Resources
Many Public Reports fail to comment on whether the Inferred Mineral Resource category has been included in Feasibility Studies, and if so, the impact of such inclusion. The use of large portions of Inferred Resources in a PFS is also incorrect, and can falsely elevate the value of a mineral project.

Incorrect use of the term 'Ore'
The terms 'ore' or 'orebody' should be used only when a Mineral Reserve has been completed, and should be associated with Mineral Reserves and not Mineral Resources. For example, the following excerpt from a recent news release is incorrect.

> *The Zone 5 resource (JORC 2012 compliant) now totals an estimated 100.3 million tonnes of measured, indicated, and inferred **ore** grading 1.95% copper and 20 grams per tonne silver.*

Incorrect Use of 'Calculated'
A common reporting mistake is the use of 'calculated' instead of 'estimated' when referring to Mineral Resource and Mineral Reserve statements.

Comparison of Previous Mineral Estimates
The Code requires that a comparison of the Mineral Resource and Mineral Reserve estimates with the previous financial year/period's estimates is provided and an explanation provided of the material differences between the two declarations. This remains a common oversight by CPs.

Statement by Directors and Future Activities
Public Reports often provide no description of future exploration activities, exploration expenditures, exploration results, and feasibility studies undertaken. Directors are required to state (or include an appropriate negative statement) on any legal proceedings or other material conditions that may impact on the company's ability to continue mining or exploration activities. Again, this statement is often overlooked in Public Reporting.

Economic Assumptions
Optimistic assumptions in terms of mining rates, capital expenditure, operating costs, and revenue factors are required. Problems encountered in technical reports include the inadequate disclose of the main components of the capital cost estimate. Also, economic analysis information such as cash flows and or sensitivity analysis is sometimes omitted or lacks detail. Many of the reports do not clearly disclose the assumed metal price or factors related to the mining scenario or mineral processing recovery. Failure to provide this type of information prevents the public from conducting their own techno-economic analysis of the project.

Ongoing Reporting Requirements
When reading an annual report, often one will come across the following or similar statement - 'A resources and reserves summary, which is SAMREC compliant and JSE approved, is carried in full on the [deleted] website.' The annual report must contain the full information, as required by Section 12.11, within the annual report itself. Reference to other documentation providing further detailed information for the public is fine, but should not be used to provide primary information to the public..

General
The identification of risk is mentioned in several areas of the Code, with a dedicated section (T6) in Table 1. Although CPs may comment on risk, seldom is the analysis conducted with the intent of truly identifying risk in the Mineral Resource and Mineral Reserve estimation. A risk assessment should incorporate all technical specialists involved in the Mineral Resource and Mineral Reserve estimation process. For example, Public Reports fail to disclose project-specific risks and uncertainties, such as the availability of infrastructure, government approvals, use of novel mining/mineral processing technology, or the potential impact of regional unrest or civil war, *e.g*. Central Africa. Environmental and social issues have become increasingly important in recent years and remain an area of poor commentary. Based on the guiding principles of the Code, environmental and social issues require appropriate commentary in Public Reports.

TRAINING AND MENTORING

A general consensus is that more focus should be on coaching and mentoring of CPs in order to improve reporting compliance. Coaching and mentoring should be seen as the preferred method, rather than using disciplinary action or sanctions against CPs. Ongoing training for CPs and CVs needs to be actively pursued by professional organizations, with the price of such training kept to a minimum so that costs do not become prohibitive.

Some universities, such as the University of Johannesburg, include tuition in the area of the SAMREC and SAMVAL Code. The Geological Society of South Africa (GSSA) conducts a CPs course twice a year. The JSE also has in the past provided reporting compliance courses and the SAIMM provides *ad hoc* presentations on the varied topics on the codes: recent examples include un update of the 2016 SAMREC and SAMVAL Codes, the application of Modifying Factors, and the Companion Volume to be published to coincide with the launch of the 2016 SAMREC and SAMVAL Codes.

As peers we must play a more active role in regulating our own industry. As a general observation, the mining industry needs to implement a coaching and mentoring approach, thereby uplifting reporting standards. Coaching and mentoring must not be limited to only CPs, but must also extended to exploration and mineral companies who must also abide by the SAMREC Code as well as the JSE Listing Requirements

CONCLUSIONS AND RECOMMENDATIONS

The SAMREC Code already provides guidelines to reporting, as presented in Table 1. The difficulty is that Table 1 is not properly used, as authors of CPRs fail to comply fully with the provided checklist, choosing rather to omit certain clauses of the Code. The updating of the Code should improve compliance with the introduction of the 'if not, why not' approach to reporting.

However, updating of the Code addresses only one aspect of Public Reporting compliance. The implementation of self-regulation and peer review will go a long way towards improving reporting compliance. CPs, as well as the mining industry, must realize that failure to comply with the guiding principles of the SAMREC Code not only damages the reputation of the CP but also the reputation of

the mining profession. The mineral industry must self-regulate, otherwise others will conduct this regulatory process and almost certainly this will not be to the industry's liking or satisfaction.

Along with self-regulation, more teaching and mentoring is required to improve the overall quality of Public Reporting. A number of companies and organizations conduct training courses on a regular basis; some for commercial purposes while other learned societies such the GSSA and SAIMM present courses on a non-profit basis. In the future, courses need to focus on compliance issues, the underlying meaning and intent of the Code, and examples of good and poor reporting practices.

When CPs fail to comply with the Code and a complaint is raised, corrective action must be taken. The process should focus on corrective action rather than punishment. The process should be geared to improve reporting standards, with severe retribution served only to those individuals acting in a fraudulent or incompetent manner. Part of the process must involve educating the mining fraternity on the shortcomings in Public Reporting practices so that deficiencies can be shared and the lessons learned made public.

Any learning outcome must provide a foundation to the intent of the Code. Currently, CPs see the Code as a hurdle to be met in order to complete an assignment. All too often there appears to be a disjoint between creating a report and protecting the interests of investors. Furthermore, CPs must be capable of preserving their professional opinions and not be intimidated by interested parties.

ACKNOWLEDGEMENT

The author would like to acknowledge the assistance and guidance provided by Mr Ken Lomberg of Coffey Mining.

REFERENCES

Ontario Securities Commission. 2013. OSC Staff Notice 43-705 - Report on Staff's Review of Technical Reports by Ontario Mining Issuers. June 2013.

Rupprecht, S.M. 2014. The SAMREC Code 2015 – Some thoughts and concerns. *Proceedings of Surface Mining 2014* . Southern African Institute of Mining and Metallurgy, Johannesburg.

SAMREC. 2009. South African Mineral Resource Committee. The South African Code for the Reporting of Exploration Results, Minerals Resources and Mineral Reserves (the SAMREC Code). 2007 Edition as amended July 2009. Prepared by the South African Mineral Resource Committee (SAMREC) Working Group. http://www.samcode.co.za/downloads/SAMREC2009.pdf

SAMCODE. 2009. The South African Mineral Codes. http://www.samcode.co.za/SAMCODE/SSC/Disciplinaryprocedures [Accessed: 15 April 2015].

Wikipedia. 2014. Regulatory compliance. http//www.en.wikipedia/regulatory compliance. [Accessed 16 April 2015]



Dr. Steven Rupprecht

Senior Lecturer
University of Johannesburg

Steven has 29 years mining experience commencing his career in 1986 with Gold Fields of South Africa where he gained underground production mining experience working at Venterspost Gold Mine, East and West Driefontein Gold Mines, and Leeudoorn Gold Mine. In 1997 Steven was moved to Head Office as Group Mining Engineer and Senior Mining Engineer Coal.
In 1999 He joined CSIR Mining Technology as Research Area Manager and worked extensively on the Deepmine and Futuremine Research Programmes.
In 2003 Steven joined RSG Global as a Principal Mining Engineer until 2007 when joined Keaton Energy as a Technical Director, a position he held until 2009.
In 2010 joined the University of Johannesburg as Senior Lecture and Director of Mining. He also does mining consultancy work for Borrego Sun and Coffey Mining.
Steven is a Fellow of the South African Institute of Mining and Metallurgy (SAIMM), an co-opted member of the SAIMM Council, vice chairman of the SAMREC working group and member of the SAIMM Technical Programme Committee, and the SAIMM Career Guidance and Educational Committee

Mineral Resource and Mineral Reserve governance and reporting for AngloGold Ashanti

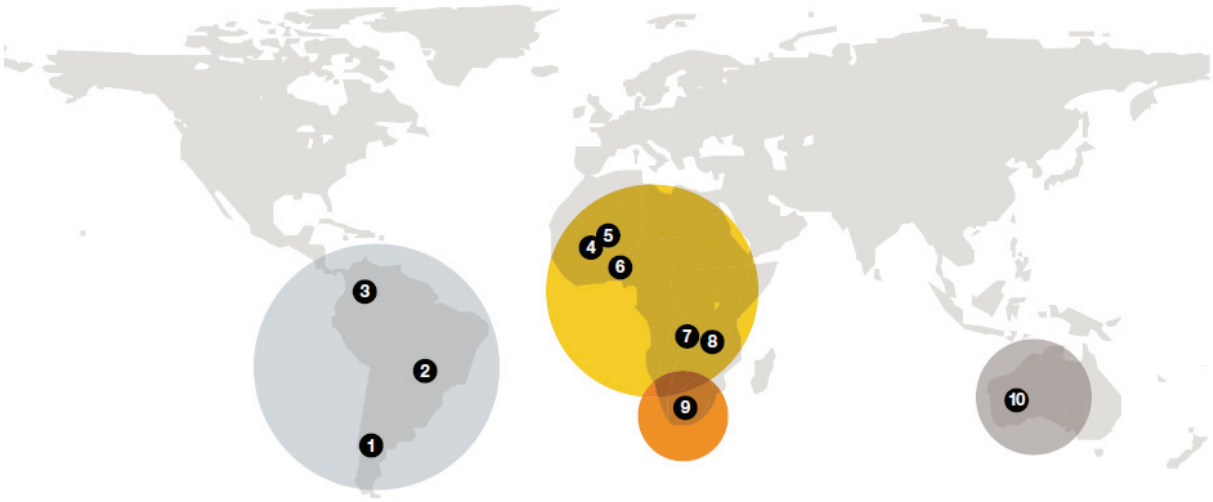
R. Peattie, V. Chamberlain, and T. Flitton

AngloGold Ashanti

Mineral Resource and Mineral Reserve governance is the comprehensive, overarching management process by which the Mineral Resource and Mineral Reserve is estimated, managed, and reported. Mineral Resource and Mineral Reserve governance provides the Board of Directors and investors with assurance on the integrity of the reported Mineral Resource and Mineral Reserve, which is the primary asset of the company and upon which investment decisions are based. The framework for Mineral Resource and Mineral Reserve governance of a company must be compliant with all regulatory codes as well as internal company policies and procedures. It is critical to ensure that reporting is transparent, appropriate, timeous, and reliable. Good Mineral Resource and Mineral Reserve governance should also ensure that all components in the estimation (from exploration to processing) of the Mineral Resource and Mineral Reserve are auditable and defendable. AngloGold Ashanti (AGA) is acutely aware that its primary asset is its Mineral Resource and Mineral Reserve, and has therefore established a formal Mineral Resource and Mineral Reserve governance process that has been structured to ensure that the Executive Committee and the Board has line of sight to the annual Mineral Resource and Mineral Reserve public reporting, as well as the review findings from a stringent internal and external review programme.

INTRODUCTION

AngloGold Ashanti (AGA) has a number of operations across ten countries (Figure 1) and is listed on four stock exchanges, therefore its public reporting must comply with the requirements of a number of different regulatory bodies across multiple jurisdictions.



AMERICAS

1 **Argentina**
Cerro Vanguardia (92.5%)

2 **Brazil**
Serra Grande
AGA Mineração

3 **Colombia**
Gramalote (51%)
La Colosa
Quebradona (92.42%)

CONTINENTAL AFRICA

4 **Guinea**
Siguiri (85%)

5 **Mali**
Morila (40%) [1]
Sadiola (41%)

6 **Ghana**
Iduapriem
Obuasi [3]

7 **DRC**
Kibali (45%) [1]

8 **Tanzania**
Geita

SOUTH AFRICA

9 **South Africa**
Vaal River
Kopanang
Moab Khotsong
West Wits
Mponeng
TauTona
Surface Operations [2]

AUSTRALASIA

10 **Australia**
Sunrise Dam
Tropicana (70%)

Percentages indicate the ownership interest in AngloGold Ashanti, whether held directly or indirectly. All operations are 100%-owned unless otherwise indicated.
[1] Both Morila and Kibali are managed and operated by Randgold Resources Limited.
[2] Surface operations includes First Uranium SA, which owns Mine Waste Solutions (MWS). MWS is managed and operated as a separate cash-generating unit.
[3] Obuasi has been on limited operation since the end of 2014.

Figure 1. Locality of AGA operations and projects.

With the first publication of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves ('the JORC Code') in 1989 and the subsequent publishing of the South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves (the SAMREC Code) in 2007, AGA quickly recognised that the processes in place within the company for the reporting of Mineral Resources and Ore Reserves were inadequate for the evolving regulatory environment. In response, the company embarked on a 10-year journey to develop a far more formalised, structured and standardised approach to reporting.

To simplify this process and provide standardisation, AGA manages its Mineral Resource and Mineral Reserve reporting in terms of the SAMREC Code, supported by internal guidelines. The internal guidelines are set out to ensure the reporting of Exploration Results, Mineral Resources, and Ore Reserves is consistently undertaken in a manner in accordance with AGA's business expectations and also in compliance with internationally accepted codes of practice adopted by AGA. The document outlines the minimum requirement for reporting to ensure that the process is consistent and transparent across AGA.

AGA follows a process-driven approach to the reporting of its Mineral Resource and Mineral Reserve. The lead is taken by the AGA Mineral Resource and Ore Reserve Reporting Committee (RRSC), whose membership and terms of references are mandated under a policy document signed off by the

Chief Executive Officer. Its primary function is as a facilitator of the process, setting the requirements and the standards of quality.

AGA recognises that the reporting of AGA's Mineral Resource and Mineral Reserve is the responsibility of the company acting through its Board of Directors; with access to the Board being through the Board Audit Committee. The final published outcome is based on Mineral Resource and Mineral Reserve reports and supporting documentation prepared by Competent Persons (CPs). To achieve this outcome and ensure regulatory approval, all CPs are members of SACNASP, ECSA, or SAGC, or are a Member or Fellow of the SAIMM, the GSSA, IMSSA, or a Recognised Professional Organisation (RPO). The CPs also need to have a minimum of five years' relevant experience in the style of mineralisation and type of deposit under consideration and in the activities they are undertaking.

Appointment of the individual CPs is by the General Manager, with oversight and ratification by the RRSC. Two CPs are appointed for each operation, one for Mineral Resources and the other for Mineral Reserves.

ANGLOGOLD ASHANTI PROCESS

Mineral Resource and Ore Reserve Steering Committee
The RRSC, which meets at least once a quarter, comprises representatives from the relevant technical disciplines as well as regional representatives. The Senior Vice President: Strategic and Technical chairs the RRSC to ensure the requisite level of authority is assigned to the committee. The RRSC is responsible for setting and overseeing the company's Mineral Resource and Mineral Reserve governance framework and for ensuring that it meets the company's goals and objectives while complying with all relevant regularity codes. Its primary function is corporate assurance and its terms of reference and composition are fixed through a policy document approved by the Chief Executive Officer. They include:

- Providing Group guidelines for the reporting of Mineral Resources and Mineral Reserves
- Compilation of the Group's annual Mineral Resource and Mineral Reserve statement
- Engagement with external regulatory bodies such as JORC, SAMREC, and the SEC to ensure that AGA's interests are protected
- Providing assurance that all Mineral Resource or Mineral Reserve reporting complies with the relevant reporting codes as well as internal Group guidelines
- The ratification of CPs
- Ensuring regular external reviews of Mineral Resources and Mineral Reserves.

The key outputs of the RRSC are the annual Mineral Resource and Mineral Reserve report and the requisite internal Group guidelines for the reporting of Mineral Resources and Mineral Reserves.

Due to the ever-evolving regularity environment, a key aspect of the RRSC is to continuous align itself to the changes and ensure the timeous briefing and training of the CPs.

Guidelines for the Reporting of the Mineral Resource and Mineral Reserves
The Group guidelines for the reporting of the Mineral Resource and Mineral Reserve is an annual document that formalises AGA's interpretation of the various listing requirements, regulatory frameworks, and reporting codes, including the Johannesburg Stock Exchange (JSE) and the Securities and Exchange Commission (SEC), SAMREC, and JORC and provides the necessary company context and detail required for the estimation and reporting of Mineral Resources and Mineral Reserves on an annual basis. It is a live document that is reviewed on an annual basis and whose owner is the RRSC.

To ensure compliance with internationally accepted codes of practice adopted by AGA, the main principles inherent in the language of the document are transparency, materiality, and competence.

To consistently achieve these principles across the company the guidelines provides the standardisation and necessary detail regarding the material assumptions used in the declaration of the Mineral Resource and Mineral Reserve, including:

- Gold price and other critical economic parameters such as exchange rates
- Minimum reporting requirements for a new Mineral Resource and Mineral Reserve
- Detailed definition and work flows for Mineral Resource classification
- Guidelines for reporting reconciliation, cut-off grades, modifying factors, Inferred Mineral Resource in business plan, Mineral Resource and Reserve below infrastructure, Mineral Resource sensitivities
- Guidelines for Competent Persons Reports (CPRs).

Competent Persons

Competency and the competent person (CP) are an integral part of all of the reporting codes. AGA has recognised the importance of selecting the appropriate individuals with the relevant experiences and expertise to become CPs at its operations and projects across the world, and therefore has a formalised approach to the appointment of its CPs. CPs are appointed by the relevant manager of the operation in question and the appointments are ratified by the RRSC. CPs are preferably employed by AGA and are selected based on relevant experience with the style of mineralisation and type of deposit under consideration and with the activity that they are undertaking.

To ensure that the CPs consent to the inclusion of Mineral Resource and Mineral Reserve information in the annual report, they sign a letter of consent once they have reviewed the information in the form and context in which it appears.

A critical aspect of this approval is ensuring that the legal tenure of each operation and project has been verified to the satisfaction of the accountable CP and all Mineral Reserves have been confirmed to be covered by the required mining permits or there is a realistic expectation that these permits will be issued.

Due to the different experience and skills sets required for the estimation and evaluation of Mineral Resources and Mineral Reserves, AGA has separate appointments for Mineral Resources and for Mineral Reserves. This is reinforced by a professional development and support structure to ensure that the CP is fully briefed on the evolving external governance and has the necessary network and training to ensure best practice.

A key aspect of the management of the CPs is the training and succession planning required to ensure the skills and experiences remain in-house to allow the ongoing reporting of the Mineral Resources and Mineral Reserves.

Audit and Review Process

Over more than a decade, AGA has developed and implemented a rigorous system of internal and external reviews aimed at providing assurance in respect of Mineral Resource and Mineral Reserve estimates. External reviews are done on selected operations, in line with AGA's policy that each operation or project will be reviewed by an independent third party on average once every three years. The external reviews focus on the identification of fatal flaws, and through impartiality they provide an independence verification that the reporting is in terms of the requirements of the various codes.

Internal peer reviews are completed on an annual basis before all annual information is captured by the CPs. This review consists of an informal process that involves the relevant CP having to defend their work to their peers, and a formal process where the reviewer will attempt to replicate aspects of the work independently.

The peer review process is seen as an integral aspect of the audit and review process in ensuring consistency, in propagating best practice across the company, and for the personal development of the individuals involved.

In addition, all variation in excess of 10% (net of depletion) in the individual operation or project's Mineral Resource and/or Mineral Reserve statement) requires a formal review by the RRSC.

R³

AGA makes use of a web-based group reporting database called Resource and Reserve Reporting System (R³) for the compilation and authorisation of Mineral Resource and Mineral Reserve reporting. R³ is a fully integrated system for the reporting and reconciliation of Mineral Resources and Mineral Reserves that supports various regulatory reporting requirements, including the SEC and the JSE under SAMREC. AGA uses R³ to ensure that a documented chain of responsibility exists from the CPs at the operations to the company's RRSC.

The web-based reporting system provides a platform that ensures a single version of the truth is captured in a secure, auditable database that is workflow-enabled. The system has a comprehensive set of validation rules that include, but are not limited to, the following:

- The Mineral Resource needs to be captured/imported before the Mineral Reserve can be captured
- Mineral Reserve content cannot be greater than Mineral Resource content per project area
- Inclusive Mineral Resource content must always be greater than or equal to Exclusive Mineral Resource content
- The previous year and all changes in the reconciliation capture must sum up to the current year total for tonnes and grams
- The Inferred Mineral Resource in a business plan content cannot be greater than the Inclusive Inferred Mineral Resource content.

This system is compliant with the guiding principles of the Sarbanes-Oxley Act of 2002 (SOX) and forms the supporting database from which the Mineral Resource and Mineral Reserve report is published on an annual basis. To support the reporting process, the system also contains a database of the various technical specialists and CPs, together with a record of their experience and qualifications. A clear division of responsibilities is assigned within the system that requires a rigid hierarchy of work flow sign-offs; this ensures that the relevant people have access to the information for review and approval before it is made publically available (Figure 2).

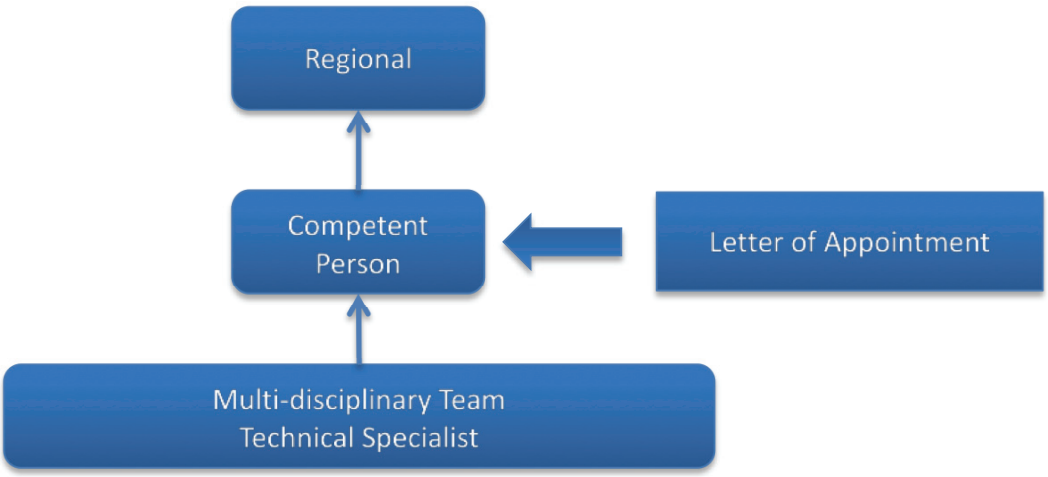


Figure 2. Chain of responsibility.

R^3 assigns individual responsibilities that can be tracked and managed and allows remote access for data upload by the relevant technical specialists and approvals and consent by the CPs. Access, authorisations and work flow sign-off is through a unique secure login that allows a full audit trail.

R^3, first conceptualised in 2003 and rolled out in 2004 as a data capture and company database of the Mineral Resource and Mineral Reserves, immediately proved itself by providing a single source of the truth and minimising human error involved in handling large data-sets. Since then it has evolved into a fully integrated system for the reporting and reconciliation of Mineral Resources and Mineral Reserves that supports reporting to the SEC and the JSE under SAMREC. It achieves this by providing the relevant details, summaries, and reconciliations for end-of-year reporting, together with the necessary consents.

For any particular year of consideration, R^3 provides the following information:

- Mineral Resource (inclusive and exclusive of Mineral Reserve) and the Mineral Reserve statement,
- Inferred Mineral Resource in business plan
- Mineral Resource and Mineral Reserve below infrastructure
- By-product information
- Reconciliations details
- Mineral Reserve modifying factors
- Professional details of all CPs
- Letters of appointment
- Letters of consent for publication
- Tenement information
- CP Reports (CPRs)
- Statement of competence
- Documented chain of responsibility
- JORC Table 1 and the future SAMREC Table 1.

CONCLUSION

The foundation of AGA's Mineral Resource and Mineral Reserve governance and reporting process is to ensure that the right people are doing the right work and that the information that is being made publically available is fully vetted, compliant, and transparent, and therefore meets the guidelines in the SAMREC Code.

To achieve this end, AGA has developed a rigorous Mineral Resource and Mineral Reserve governance and reporting process that is supported by a set of internal Group guidelines, a structure for the management of the process, and an integrated Group reporting database.

This is complemented by a combination of internal and external audits and reviews to ensure independence and impartiality and that the individual operations and projects are estimating and compiling their Mineral Resources and Mineral Reserves in accordance with the company guidelines and external regulatory requirements.

The sum result is a process that ensures that the Executive Committee of AGA and the Board through the Board Audit Committee has line of sight to the annual Mineral Resource and Mineral Reserve public reporting as well as the review findings from a stringent internal and external review programme, and thus the assurance in the integrity of the reported Mineral Resource and Mineral Reserve, which is the primary asset of the company and upon which investment decisions are based.

AGA recognises that both the regulatory framework and the definition of best practice are continuously evolving, and that therefore it is important that the governance framework needs to be sufficiently dynamic to respond to the ever-changing environment. Through the RRSC, AGA has the

structure to both manage the Mineral Resource and Mineral Reserve governance and reporting process and react to these changes in a timely manner. The current process is a work in progress, and while it currently meets the corporate and governance requirement it is continuously being improved to keep pace with the regulatory changes and increases in corporate expectations.

REFERENCES

AngloGold Ashanti. (2014). Mineral Resource and Ore Reserve Report. 192 pp.

AngloGold Ashanti. (2015). Guidelines for the reporting of Mineral Resources and Ore Reserve. Internal Report. 57 pp.

Canadian Securities Commissions (CSA). (2005). National Instrument 43-101. Standards for disclosure for mineral projects.

JORC. 2012. Australasian Joint Ore Reserves Committee. Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves. The Joint Ore Reserves Committee of the Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists, and Minerals Council of Australia. http://www.jorc.org/docs/JORC_code_2012.pdf

SAMREC. 2009. South African Mineral Resource Committee. The South African Code for Reporting of Exploration Results, Mineral Resources and Mineral Reserves (the SAMREC Code). 2007 Edition as amended July 2009. http://www.samcode.co.za/downloads/SAMREC2009.pdf



Richard Peattie

VP Mineral Resource
AngloGold Ashanti

Graduated from the University of the Witwatersrand in 1992 with a BSc (Hons) in Geology and immediately started working career at Western Deep Levels Gold mine. Since then have worked in a number of roles and at a number of mines around the world in countries that included South Africa, Mali and the DRC. In 2007 got a Master of Philosophy in Geostatistics from the University of Queensland in Australia. Currently the VP Mineral Resources for AngloGold Ashanti based in Johannesburg.



Vaughan Chamberlain

Senior Vice President: Strategic Technical Group
AngloGold Ashanti

Started career at AngloGold Ashanti's Tau Tona mine as a mine geologist, moved in Exploration in South Africa and then into Mineral Resource Evaluation with the Ore Evaluation Department of Anglo American. Transferred into AngloGold when it was formed and took up the role of Manager: Mineral Resource. Later move into a more general role managing the technical disciplines.



Tarryn-Marié Flitton

Manager Reporting and Corporate Governance
AngloGold Ashanti Ltd

Graduated from the University of the Witwatersrand in 2000 with a BSc (Hons) in Geology and immediately started working career at Kopanang Gold mine. Tarryn has 14 years' experience on the Witwatersrand goldfields in the field of geoscience, of which more than 10 years are in estimation. Currently the Manager Reporting and Corporate Governance for AngloGold Ashanti based in Johannesburg.

The understanding and importance of sampling in the SAMREC Code

Ken Lomberg

Coffey Mining (SA) Pty Ltd

Samples may consist of rock chips, sludge and/or core from soil samples, heavy mineral concentrates, stream sediment samples, drill core, cut channel samples, bulk samples from trenches, or various samples from mine (underground or open pit) workings. In addition to this variety of sample types, samples can be very different sizes. A sample containing precious metals may be a few hundred grams of rock chips, whereas a bulk sample from a diamond pilot plant can be expected to be several hundred tons. The Competent Person (CP) will need to be fully informed about the sampling protocol in each project that he is working on. Each situation will be different and can be expected to be dealt with in accordance with industry best practice. Experience in this aspect of the process is essential. The SAMREC Code calls for five years of relevant experience.

INTRODUCTION

The value of a mineral asset, whether an exploration target or operating mine, can be related to the declaration of a Mineral Resource or Mineral Reserve. Utilizing an international code as a reporting standard allows the stakeholders to understand the value of the mineral asset and to compare it with other mineral assets. The underlying value is in the Mineral Resource or Mineral Reserve, which is dependent on the underpinning scientific data and its interpretation. This paper will examine what is required by the SAMREC Code (the 'Code') in respect of sampling, analytical techniques, and data management to ensure that the Mineral Resource and Mineral Reserve can be confidently declared.

Sampling is often ranked as an area of relatively low importance, partly because it is a particularly repetitive task generally undertaken by semi-skilled labour. However, it is essential that this activity be performed in a very rigorous way to the strictest standards. All too frequently, the task is delegated to personnel who may not fully appreciate the significance and importance of sampling (Holmes, 2010). Yet correct sampling protocols and practices are critical to the integrity of the data that underlies the declaration of Mineral Resources and Reserves. There is little point in spending considerable time and effort in obtaining the best analytical precision and accuracy if the sample presented for analysis is not representative of the deposit or the management of the data renders the data unreliable.

Introduction to the SAMREC Code

The SAMREC Code (SAMREC, 2009) is an international reporting code for the public reporting of Exploration Results, Mineral Resources, and Mineral Reserves in South Africa. The principles governing the Code are the minimum standard for public reporting. The purpose of the Code is to be able to present information about mineral assets to investors and potential investors and their advisors, as well as to satisfy regulatory requirements.

The Code is a set of standards, recommendations, and guidelines for public reporting in the mineral industry. The Code is in line with the other CRIRSCO (Committee for Mineral Reserves International Reporting Standards) codes such as the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC, 2012), CIM Definition Standards (CIM, 2010), the Pan-European Reserves and Resources Reporting Committee (PERC, 2008) *etc*. The aim of CRIRSCO is 'to contribute to earning and maintaining that trust by promoting high standards of reporting of mineral deposit estimates (Mineral Resources and Mineral Reserves) and of exploration progress (Exploration Results)' (www.crirsco.com).

The main principles governing the operation and application of the SAMREC Code are transparency, materiality and competence.

- 'Materiality' requires that a Public Report contains all the relevant information which investors and their professional advisers would reasonably require, and reasonably expect to find in the report, for the purpose of making a reasoned and balanced judgement regarding the mineralization being reported.

- 'Transparency requires that the reader of a Public Report is provided with sufficient information, the presentation of which is clear and unambiguous, to understand the report and is not misleading.

- 'Competence requires that the Public Report be based on work that is the responsibility of a suitably qualified and experienced person who is subject to an enforceable Professional Code of Ethics.'

PERTINENT ASPECTS OF THE SAMREC CODE

The Code requires that a suitably qualified and experienced professional or Competent Person (CP) declares the technical details of the mineral deposit in terms of the definitions of the Code. The requirements in order to qualify as a CP have been formally defined. The CP must be satisfied in his own mind that he could face his peers and demonstrate competence in the commodity, type of deposit and situation under consideration. The CP is legally accountable for the relevant parts of a Public Report for which he has signed responsibility.

The Code is guideline-based and not a prescriptive set of rules. As a result, the aspects of sampling are not specified in the definitions or made mandatory in any form. However, in order to assist the CP, a table ('*Table 1*') has been provided in the Code (SAMREC, 2009, p. 28) as a high-level checklist in respect of the technical aspects of reporting, including sampling. The checklist is specifically indicated as not being prescriptive, although relevance and materiality are mentioned as the overriding principles that determine what information should be publicly reported. It is the responsibility of the CP to consider all the criteria of '*Table 1*' and determine which criteria should apply to the study of a particular project or operation.

The aspects of '*Table 1*' that may be valuable to examine are presented in Table I of this paper.

The Code has a vast jurisdiction (commodities, mineralization styles, locations *etc*.) in that it is considered relevant to all solid minerals, including coal and diamonds. Being prescriptive would

require the regulators to be up to date with developments in all these fields. A set of guidelines must therefore be considered a sensible approach to the extractive industry.

In this paper, the various aspects of sampling and the Code are discussed. The discussion is not a point-by-point discussion, as many aspects mentioned in '*Table 1*' are mentioned a number of times, *e.g.* QA/QC, audits and reviews *etc.* '*Table 1*' provides a list of the main criteria that should be considered and reported upon, if relevant, when reporting on Exploration Results, Mineral Resources, and Mineral Reserves.

Data integrity is at the core of this discussion. This requires that any sampling is done such that the samples represent the underlying geology in a valid way and that the process of sampling has not been biased or will not lead to an incorrect assessment of the potential deposit.

Table I. Headings of SAMREC Code 'Table 1' indicating the aspects relevant to sampling.

SAMREC TABLE 1							
	Exploration Results	**Mineral Resources**	**Mineral Reserves**		**Exploration Results**	**Mineral Resources**	**Mineral Reserves**
Section 1: Project Outline				**Section 5: Technical Studies**			
1.1	Property Description			5.5	Environmental and Social		
1.2	Location			5.6	Market Studies and Economic criteria		
1.3	Adjacent Properties			5.7	Risk Analysis		
1.4	History			5.8	Economic Analysis		
1.5	Legal Aspects and Permitting			**Section 6: Estimation and Reporting of Mineral Reserves**			
1.6	Royalties			6.1	Estimation and modelling techniques		
1.7	Liabilities			6.2	Classification Criteria		
Section 2: Geological Setting, Deposit, Mineralisation				6.3	Reporting		
Section 3: Exploration and Drilling, Sampling Techniques and Data				**Section 7: Audits and Reviews**			
3.1	Exploration	×		**Section 8: Other Relevant Information**			×
3.2	Drilling Techniques	×		**Section 9: Qualification of Competent Person(s) and other key technical staff. Date and Signature Page**			×
3.3	Sample method, collection, capture and storage	×					
3.4	Sample Preparation and Analysis	×		**Section 10: Reporting of for Coal Resources and**			
3.5	Sampling Governance	×		10.1	Specific Reporting for Coal		
3.6	Quality Control/Quality Assurance	×		10.2	Geological Setting, Deposit, Mineralisation		
3.7	Bulk Density	×		10.3	Drilling Techniques		×
3.8	Bulk-Sampling and/or trial-mining	×		10.4	Reasonable prospects for eventual economic extraction		
Section 4: Estimation and Reporting of Exploration				10.5	Coal Resource Reporting		
4.1	Geological model and interpretation			10.6	Coal Reserve Reporting		
4.2	Estimation and modelling techniques			**Section 11: Reporting of Diamonds and Gemstones**			
4.3	Reasonable prospects for eventual economic extraction			11.1	Geological Setting, Deposit, Mineralisation		
4.4	Classification Criteria			11.2	Sampling of Diamond Projects		
4.5	Reporting			11.3	Bulk-Sampling and/or trial-mining		×
Section 5: Technical Studies				11.4	Estimation and Modelling Techniques		
5.1	Introduction			11.5	Resource/ Reserve Classification Criteria		
5.2	Mining Design			11.6	Audits and Reviews		×
5.3	Metallurgical and Testwork	×		**Section 12: Reporting of Industrial Minerals**			×
5.4	Infrastructure			**Section 13: Reporting using Metal Equivalents**			

THE IMPORTANCE OF SAMPLING IN THE LIFE CYCLE OF A PROJECT

Sampling is of critical importance to each person involved in reporting on mineral assets as well as every person wanting to use the results for decision-making in respect to the project under consideration. Sampling issues are important in all aspects of geological, mining, metallurgical, and environmental studies, including planning, execution (sample acquisition and analysis), interpretation, as well as decision-making. The importance of sampling should be assessed in the context of all the other factors that might affect the conclusions.

Investors, decision-makers, promoters, or board members seldom know enough about sampling to ask or look for supporting evidence that correct and representative sampling took place. They rely on the CP to ensure that the results are reported in accordance with the Code.

Managers of technical studies may not know enough about sampling to be sure that correct and representative sampling took place. They are inclined to leave this responsibility of including 'correct' sampling in every aspect of the data gathering to each subordinate manager. Their attention is often focused on cost and benefit issues, but they should not lose sight of the technical requirements that the results must meet, whether they will assist in attaining the desired goals, result in acceptable risks, or meet legal and policy requirements.

Laboratory and field personnel need to understand sampling issues to ensure that their activities provide results that are appropriate for each study.

The CP needs to ensure the sampling process takes account of all the required statistical and scientific design questions, such as how many samples to take, which location, methodology, and what analytical method is compatible with the type of sample and the required accuracy and precision. The Code assists the CP in making a clear statement of the technical issue(s) that may be part of the sampling process in the form of documentation about the data and a discussion of how it was obtained and how the samples were processed. The results should be reported in the context of the technical question that is being addressed. 'Correct' sampling protocols should be selected that provide 'representative' samples and analytical values that are accurate, precise, and fit for purpose as these practices can influence decisions dramatically.

SAMPLING PROCESS GOVERNANCE

In this paper we will limit our discussion to sampling for geochemical purposes. Exploration that supports Public Reporting includes the systematic measurement of one or more parameters of a deposit *e.g.* bulk density, moisture content, gold concentration, calorific value of coal, soluble copper concentration *etc.* The techniques used would include various forms of drilling, trenching, soil sampling, heavy mineral sampling, and even pilot plants for diamonds.

When reporting to the public, it is a requirement of the Code to disclose the sampling technique(s) used to collect the data, the chain of custody of the samples, as well as database management and control relating to the results of the analyses. The CP should be aware of the whole sampling procedure. He should have an intimate knowledge of all relevant processes, *viz.* data acquisition (capture or transfer), verification of data (QA/QC), data validation, integration with other information/data, data control, and data storage, retrieval, and backup processes.

The Code provides guidelines for the minimum requirements. However it must be noted that one '*gets what one pays for*'. With the right knowledge and a good sampling plan, the effort required can be optimized and potential errors minimized. This requires that the whole team is familiar with what causes the different sampling errors and how to minimize them through correct sampling practices or protocols. Historical data or data from previous exploration programmes should be considered as it

can provide valuable insight into the best protocol for a specific situation.

Sampling, like most scientific studies, involves measurements of a subset of the deposit in order to provide data to allow estimation of the characteristics of the whole deposit and thus allow various stakeholders to make economic decisions in respect of the deposit or project. The process can be represented by the flow sheet in Figure 1

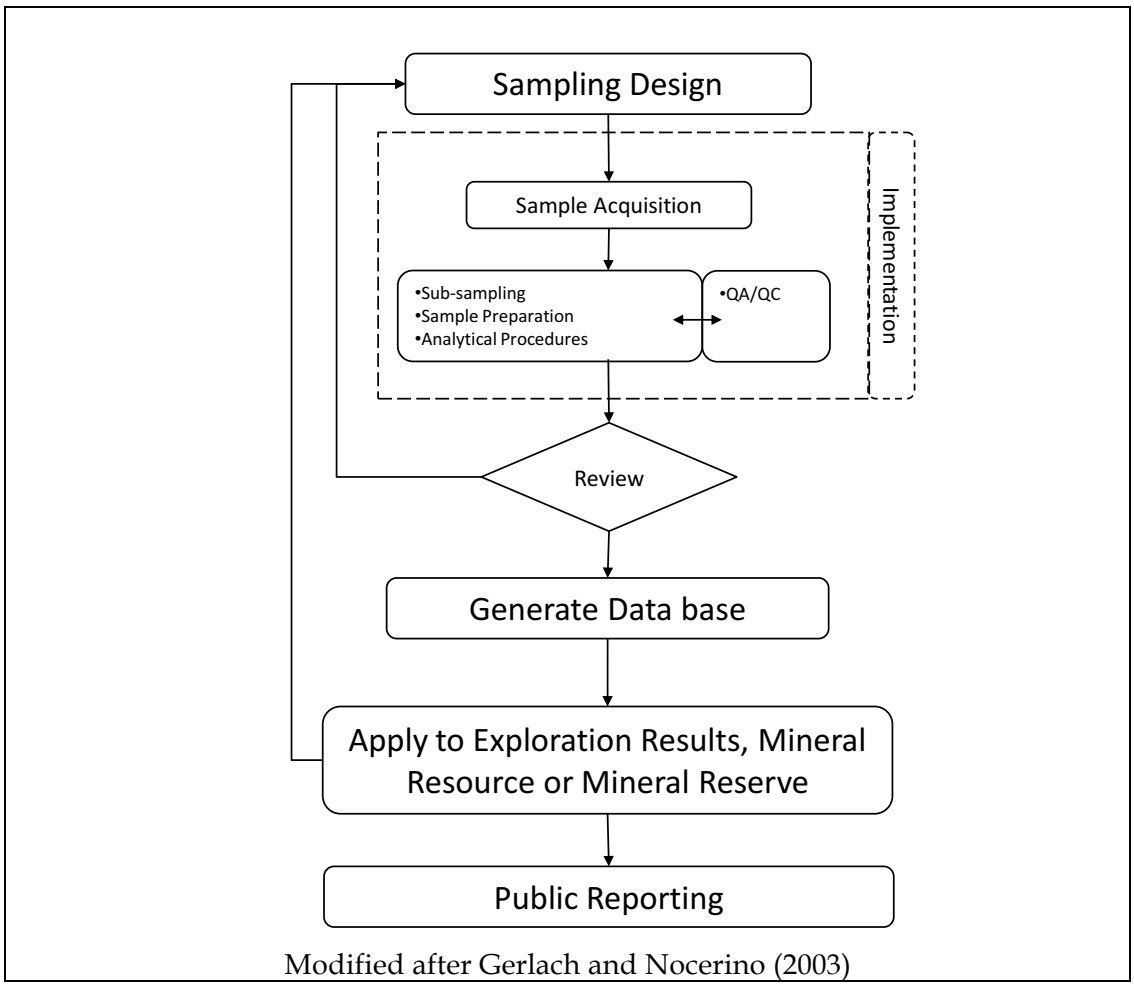


Figure 1. Schematic diagram of the sampling process.

The sampling process should follow only after the appropriate sampling protocol has been designed. That design should describe all of the equipment and practices at each stage of the process, including a sampling strategy, an analytical strategy, and a decision strategy. The strategies developed must be based on industry best practice, theory, and previous sampling campaigns.

The sample acquisition stage may consist of several steps, including sample splitting, sample preparation, and analysis. The analysis usually involves one or more analyses or measurements on each sample. Additional samples are required for quality assurance and quality control purposes (QA/QC). The data should then be reviewed for data validation, completeness, adherence to QA/QC protocols, and the sampling to the required standard under control, and to provide quality data. Once the data passes this stage, it can be accepted into the database, which will form the basis for the public reporting of the Exploration Results, Mineral Resource, or Minerals Reserve estimate.

The sampling protocols and practice according to the Code are required to ensure quality and representivity of samples. These include provisions to prevent poor or variable sample recovery,

possible high-grading by sample selection, selective losses, or contamination, inappropriate core/hole diameter, lack of sufficient internal and external QA/QC *etc*.

SAMPLING PROTOCOLS AND DESIGN

Prior to undertaking the field work, the sampling programme needs to be considered. The basic strategy to the sampling protocol is that if appropriate sampling techniques are implemented, then sampling errors can be minimized and accurate results can be reported publicly. This principle is enshrined in the guidelines of the Code.

The protocol should include consideration of the unique characteristics of the deposit such as the geology, grade, density, quality, diamond breakage, geometallurgical characteristics *etc*. In addition the most appropriate sample type, sample size selection, and collection methods should be decided. The protocol should include aspects of the appropriate metadata, such as unique sample number, sample mass, collection date, spatial location *etc*. All of these aspects relate to the transparency and materiality of the sampling process. The technical aspects of the sampling process need to be fully understood as the potential effect on the result could be significant.

Sample Acquisition

The aim of a sampling programme is to use small samples from a relatively large volume to estimate the actual, but unknown, characteristics of the entire population, noting that any errors or uncertainty in the sample data could influence the results. The confidence in the results are dependent on the characteristics of the mineralization and the quality of the sampling process, including the sample collection, sample preparation, and assaying.

'*Table 1*' in the Code provides some more detail as to the general aspects that should be addressed when considering sample collection. The detail provided is of a general nature and as per the Code is the minimum requirements.

Drilling

Drilling is one of a number of sample acquisition methods that may be used. However, there are a variety of drilling techniques to consider. Consideration of each technique is required, depending on the goal of the drilling programme. In addition to the sampling characteristics, various other aspects such as the depth of the target, the type of sample required, the likely angle of intersection of the mineralization, and the cost should be considered. Although there are a number of available drilling techniques (*e.g*. core, reverse circulation, open-hole hammer, rotary air blast, auger, Bangka, sonic (vibratory), hydraulic-rotary drilling *etc*.), there are only two basic types of drills: drills that produce rock chips, and drills that produce core samples.

The CP needs to be fully aware of the applicable drilling technique. He must consider core diameter, triple or standard tube, depth of diamond tails, face-sampling bit or other type, whether the core is oriented and if so, by what method, *etc*. Each of these parameters needs to be considered as the sample generated may be different or represent a different aspect of the potential deposit. For instance, an inclined diamond borehole may intersect the mineralization at an oblique angle. The size of the core or borehole will result in a larger or smaller volume of sample which may require decisions as to the sample handling and preparation, *i.e*. riffle splitting on site, crushing protocols *etc*. An understanding of the whole process will eliminate any doubt as to the validity of the final sample and assist in demonstrating confidence in the reporting of the results.

Sub-sampling

Once collected, a sample will need to be split or sub-sampled prior to the various analyses undertaken. The quality control procedures adopted for all sub-sampling stages can assist to maximize the representivity of samples and minimize errors.

If the sample is from drill core, the protocol must designate whether the core must be split or sawn and whether quarter, half, or full core is required before being submitted for analysis. If a non-core sample, the protocol must state which method of sub-sampling is required. Independent of the method of collection, it is important to consider whether the sample needs to be crushed or milled before being split and whether the samples should be split when wet or when dry. The sub-sampling or splitting method may be riffling, tube sampling, rotary splitting *etc*. The procedure adopted must ensure that the sample size is appropriate to the grain size of the material being sampled.

The protocol includes the need to ensure that the sub-sampling is representative of the *in-situ* material collected and that errors are not inadvertently introduced in the process.

Sample Preparation
For all types of samples the process of sample preparation needs to be designated, as well as the location of the activity, *i.e*. on site, at a primary/sample preparation laboratory, or at the analytical laboratory. The CP must ensure the quality and appropriateness of the sample preparation technique for the samples, the deposit, and the ultimate requirement of the study. Processes typically undertaken at this stage are crushing, grinding, milling, splitting for size fractions, filtering, diluting *etc*.

This stage is one of the critical stages, as the potential exists for errors. The CP needs to be very vigilant at this stage. The use of blanks to check on contamination is essential.

Analytical Procedures
In the selection of an analytical technique the CP needs to consider numerous factors – anticipated level of concentration, detection limits, anticipated mineralogy, matrix of the rock type, sample size requirements, requirements for partial or total determination, size faction characteristics, requirement for sulphide or oxide analysis, accuracy, precision, laboratory performance (location, accreditation, capability, capacity) . The CP must ensure that the analytical procedure will produce the quality of data required, is appropriate for the characteristic(s) of interests, that the laboratory processes and procedures used are appropriate, and whether the technique is considered partial or total.

Preferences in terms of analytical methods are to apply techniques that are reliable and are well established, or are industry standards or have been recommended or adopted by other projects. In some instances the analytical method should be applicable to a wide range of rock types and matrices rather than those that can only be used for specific rock types. The CP needs to be able to defend his selection or rationale to his peers. Aspects that may be questioned are the method used for sample preparation, sub-sampling and size reduction parameters, and likelihood of inadequate or non-representative samples (*i.e*. improper size reduction, contamination, screen sizes, granulometry, mass balance, *etc*.).

The Code includes reference to indirect methods of measurement (*e.g*. geophysical methods), and suggests that these should be described, with attention being given to the confidence of interpretation. In this situation the CP must have a comprehensive understanding of the technique, potential errors, and be able to demonstrate that the necessary checks are in place to allow him to rely on this data. For instances where geophysical tools such as spectrometers, handheld XRF instruments, *etc*. are used, JORC (2012) provides a little more detail. JORC suggests that the parameters used in determining the analysis including instrument make and model, reading times, calibrations factors applied and their derivation, *etc*. be provided. The CP will need to be cognisant of the anticipated use of the data.

Quality Assurance
The reliability of data can be assessed through the ability to repeat the measurement of the selected parameter (the precision) and the comparison of the results with known examples or standards (the accuracy). The variability in the assay results consists of the inherent variability or nugget effect, sampling errors (sample selection methods, sample collection, sample preparation *etc*.) and analytical errors. To ensure data integrity, protocols need to be in place to monitor the results and minimize

these errors. The design of the quality assurance programme requires a thorough knowledge of the sampling processes and the mineralization. Monitoring or quality control is a continuous and ongoing process conducted when the samples have been submitted for analysis. The Code provides some detail to assist the CP. The Code suggests that the CP 'demonstrates that adequate field sampling process verification techniques (QA/QC) have been applied, *e.g*. the level of duplicates, blanks, reference material standards, process audits, analysis, *etc*.'

Data Storage and Backup
The sampling process should not be considered finished when a sample has been analysed. After the analysis has been completed the data is transcribed, input into databases, and imported into modelling software before being interpreted. Validation of the data is necessary at all these steps.

Sample Storage and Retention
The Code includes a question as to whether the samples have been retained, in what form (*e.g*. core, sample reject, *etc*.), and if there is a specific retention policy. The integrity of the results could be compromised if the policy is to destroy all the material. The reader is referred to the Bre-X scandal, in which the samples were apparently salted with gold and no core was available to check as it was reported to have been destroyed in the initial sampling (www.thecanadianencyclopedia.com/articles/macleans/brex-collapses).

IMPLEMENTATION

The implementation of the protocol must be consistently undertaken with much attention to detail. The design and specification relating to the sampling programme is only the first step in the process. How the programme is implemented could have a significant effect on the final result. The CP needs to be able monitor the progress of the sampling.

Sample Acquisition
In the case of drilling, the CP needs to ensure that the drilling/sample recovery is measured and that the samples used for assay or analysis meet the minimum requirements. Thus the method of recording and assessing core and chip sample recoveries must be known and the results assessed on a continuous basis. This is not always an easy task as the CP cannot be present at every rig all the time. He will have to rely on the management of the drilling programme. However, regular site visits are essential to assess the drilling programme and the recoveries in particular. Where drilling is very difficult, such as close to surface in the weathered zone, it may be necessary to use special drilling techniques or muds to improve the sample recovery. The measures taken to maximize sample recovery and ensure that the samples are representative must be considered so as not to introduce a bias or error into the results. The CP should consider whether the sample recoveries have been properly recorded and the results assessed, as this may bias the analytical results.

Consideration should be given to the consumables used to ensure they do not contain elements of interest or chemicals (*e.g*. Ni, Cr *etc*.) that may react with constituents of the samples *e.g*. sulphur. The CP will need to determine if a relationship exists between sample recovery and grade, and whether sample bias may have occurred due to preferential loss/gain of fine/coarse material.

The chain of custody starts at the point of sample acquisition. The process requires adherence to the protocols set out. Documentation of sampling practices is required.

Analytical Techniques
The analysis has already been shown not to be the only aspect of data integrity that needs to be monitored. However, it may be the easiest aspect of the process to monitor as the results are all numerical, allowing various statistical analyses to be undertaken and the errors quantified.

The whole process of sub-sampling, sample distribution, sample preparation, and analysis needs to be

carefully monitored. This monitoring has become a cornerstone to the resource and reserve estimation process. The development of the techniques as well as the understanding of the process has increased dramatically since the introduction of the various international codes around 2000. Prior to this, very little was done in this regard as the procedure seemed to be too complex and unnecessary.

The CP is now required to fully understand the whole sampling and analytical process as well ensure that it is undertaken to the required specification. It is not a question of 'ticking the boxes' to ensure compliance. Quality control must be an ongoing process with reviews of the data from each batch as the results become available. In this way issues can be resolved quickly and can be prevented from recurring.

One aspect of the analytical data that may arise is the compatibility of one data-set with another. In order to rectify incompatibilities the assay laboratory may have used a factor. The CP must understand why this is necessary and be sure that the approach used is valid. All aspects of the Code should be demonstrated in this process (transparency, materiality, and competence).

Quality Control
The QC programme requires that the CP utilizes the assay data from certified reference materials, standards, blanks, duplicates, or external/referee laboratory checks to determine whether the data meets acceptable levels of precision and accuracy. It should be noted that there may be other aspects of QC that need to be undertaken, depending on the project, *e.g.* visual inspection of the samples and comparison of the grades with the rocks, determining whether a relationship exists between sample recovery and grade, or if there is a sample bias due to preferential loss/gain of fine/coarse material.

All aspects that are noted need to be resolved to ensure the data may be considered reliable. It is important that the specification is known prior to the QC analysis.

Database
Assuming that the data is considered reliable, it is added to the database. The data can then be used in the next step of process without hesitation. Data validation procedures are required to ensure the database is not corrupted by, for example, transcription or keying errors, between its initial collection and its use in later work such as a Mineral Resource estimation. It is recommended that the data be stored in a reliable way, *i.e.* in a relational database and backed up. The data is now a very valuable asset.

It is recommended that documentation of the practice of primary data, data entry procedures, data verification, and data storage (physical and electronic) be compiled. This is useful not only as a protocol, but also for audits or reviews that may be required at a later stage.

Audits and Reviews
The Code also requires the CP to disclose if any audits or reviews of the sampling process (or part thereof) have occurred. Details of audit results and any identified material risks need to be declared. Where significant deficiencies have been found the Code requires that the remedial actions are disclosed.

However, no details of audit or review requirements are provided. The Code essentially looks to the competency of the people requested to undertake audits and reviews. In the sampling and analytical area, it must be noted that there are very few professionals who have sufficient understanding and experience of both the geological and the chemical aspects involved in sampling protocol. Thus the CP may have to rely on relevant opinion from a chemist in these situations.

In some cases it may be necessary to conduct a verification of sampling and assaying of selected samples or intersections. This may include the verification of significant intersections by either independent or alternative company personnel. The use of field duplicates, pulp duplicates, or twin drill-holes may be considered.

OTHER SAMPLING METHODS

Metallurgy

Understanding the metallurgical aspects of a deposit prior to the declaration of a Mineral Resource or Mineral Reserve is important. The Codes require that there is reasonable prospect of eventual profitable extraction. If the product of a mine cannot be sold or has detrimental elements in it that make it difficult to sell, *e.g.* phosphorous in iron ore, the CP should not advise that the deposit can be realistically mined. To demonstrate the technical viability, metallurgical test work may be required. This can assist to confirm that the mineralization under investigation can be processed by current technology, and that the treatment of this material will not result in unacceptable environmental problems.

Metallurgical test work may require additional samples for laboratory- or pilot-scale work. Frequently, the geologist is requested to drill more holes or deflections or use larger diameter drilling equipment to meet the metallurgist's requirement. Alternatively, the metallurgist will request a bulk sample depending on various factors, most notably whether there is reasonable access to the desired material. Representative sampling is critical for metallurgical investigation, as is sample handling to avoid contamination.

The collection of bulk samples should include similar rigour to that required for geological samples in order to minimize sampling errors. The sample taken must represent the ore that would be delivered to the processing facility. This in itself could be a challenge when the cut-off grade and other aspects of the potential ore have not been confirmed or finalized. The distinction between oxide and fresh/sulphide material may be important.

The size of the sample adds an extra dimension to the sampling splitting. The fundamental rule for correct sampling is that all parts of the material being sampled must have an equal probability of being collected and becoming part of the final sample for analysis. If this is not the case, bias (or systematic error) can be introduced and the sample may not be representative. The method of collection used needs to be appropriate and useful to provide the laboratory with a truly representative sample (Loubser, 2006). The CP will need to be assured that this was done correctly.

Bulk Density

The Code requires reporting on the tons of *in-situ* mineralized material. The determination of tonnage requires the use of bulk density in the calculation. The importance of this aspect is represented in the Code by a separate section that needs to be addressed specifically. The minimum requirement is that the densities of the samples collected are representative of the material for which a grade range is reported.

The Code requires that the method of measurement is described, with specific reference to the frequency of measurements and the size, nature, and representativeness of the samples. In addition, the Code specifically indicates that the bulk density must be measured by methods that adequately account for void spaces (vugs, porosity *etc.*), moisture content, and differences between fresh rock and alteration zones within the deposit.

CONCLUSION

The foregoing discussion has focused on the geochemical aspects of the sampling process and has leant towards sampling from an exploration perspective that could be broadened to a mine development project. However, there are a number of other aspects that have not been discussed due to their speciality. These include the sampling processes associated with industrial minerals, diamonds, and coal.

The Code is not prescriptive about how sampling should be undertaken. However, it contains a set of guidelines that need to be carefully reviewed for each situation. They are considered to be the minimum required prior to public reporting of the Exploration Results, a Mineral Resource, or a Mineral Reserve.

The Code requires the CP to assess the key components required for a sampling programme, to ensure it is implemented according to design and thereby confirm that the sampling programme produced quality data that is reliable and can be used for further studies for that particular project.

REFERENCES

CIM. 2010. Definition Standards for Mineral Resources and Mineral Reserves. Prepared by the CIM Standing Committee on Reserve Definitions Adopted by CIM Council on November 27, 2010. http://web.cim.org/UserFiles/File/CIM_DEFINITON_STANDARDS_Nov_2010.pdf

Gerlach, R.W. and Nocerino, J.M. 2003. Guidance for Obtaining Representative Laboratory Analytical Subsamples from Particulate Laboratory Samples. EPA/600/R-03/027. US Environmental Protection Agency.

Holmes 2010. Sampling mineral commodities—the good, the bad, and the ugly. *Journal of the Southern African Institute of Mining and Metallurgy*, 110 (6), 269-276.

JORC. 2012. Australasian Joint Ore Reserves Committee. Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves. The Joint Ore Reserves Committee of the Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists and Minerals Council of Australia. http://www.jorc.org/docs/JORC_code_2012.pdf

Loubser, M. 2006. Raw material and process sampling in analytical challenges in metallurgy. *Proceedings of Analytical Challenges in Metallurgy*, Randburg, South Africa. Southern African Institute of Mining and Metallurgy, Johannesburg. http://www.saimm.co.za/Conferences/AnalyticalChallenges/02-Loubser.pdf.

PERC. 2008. Pan-European Reserves and Resources Reporting Committee. Pan-European Code for Reporting of Exploration Results, Mineral Resources and Reserves. http://www.vmine.net/perc//documents/PERC_REPORTING_CODE_jan2009.pdf

SAMREC. 2009. South African Mineral Resource Committee. The South African Code for Reporting of Mineral Resources and Mineral Reserves (The SAMREC Code). 2007 Edition as amended July 2009. http://www.samcode.co.za/downloads/SAMREC2009.pdf



Ken Lomberg

Senior Principal
Coffey

Ken has some 30 years' experience in the minerals industry (especially platinum and gold). He has been involved in exploration and mine geology and has had the privilege of assisting in bringing a mine to full production. His expertise is especially in project management, mineral reserve and resource estimation.

Ken has undertaken mineral resource and reserve estimations and reviews for platinum, gold, copper, uranium and fluorite projects. He has assisted with the reviews or estimation of diamond and coal projects and assisted or compiled Competent Persons Reports/NI 43-101 for various projects that have been listed on the TSX, JSE and AIM stock exchanges

Ken is also Chairman of the SAMREC Working Group which is responsible for the SAMREC Code and represents SAMREC on the CRIRSCO Executive

Mineralization beyond Inferred Resources

J.R. Dixon

SRK Consulting (Pty) Ltd., Johannesburg, South Africa

CRIRSCO reporting standards are contained in the CRIRSCO International Reporting Template, first published in July 2006 and updated in November 2013, which defines Exploration Results, Mineral Resources – including sub categories of Measured, Indicated, and Inferred Resources, and Mineral Reserves – including sub-categories of Proved and Probable Reserves. The definitions contained in the CRIRSCO Template have been adopted by CRIRSCO members, although due to specific local requirements minor differences may exist among members' reporting codes and standards. These differences are not considered to be material. Public reporting is targeted at investors and potential investors in mineral exploration and mineral companies. Such stakeholders rely on informed statements relating to Exploration Results, Mineral Resources, or Mineral Reserves prepared by Competent Persons as defined in the Template. CRIRSCO acknowledges that mineralization may exist beyond those categories contained in the Template, and also that it is common practice among mineral companies to maintain registers or inventories of such material for their own strategic planning purposes. Such purposes include, for example, the prioritization of exploration targets for future work and maintaining records of mineralized material that currently fails to meet requirements for public reporting but may do so in future (for example, if economic conditions change). This paper is intended to expand on CRIRSCO's views on 'Mineralization beyond Inferred Resources' and to explain the relationship between the CRIRSCO-aligned reporting standards and other classification systems that categorize such material.

INTRODUCTION

The Committee for Mineral Reserves International Reporting Standards (CRIRSCO) is made up of National Reporting Organizations (NROs) who develop, update, and administer Codes[1] and Standards within their own jurisdictions which are aligned with the CRIRSCO International Reporting Template (the Template). Currently there are eight NROs who are members of CRIRSCO and which represent Australasia, Canada, Chile, Mongolia, Russia, South Africa, the United Kingdom and Western Europe, and the United States of America.

The principle objective of CRIRSCO is to promote best practice public reporting of Exploration Results, Mineral Resources, and Mineral Reserves. As a strategic partner of the International Council on Mining and Metals (ICMM), CRIRSCO endorses the aim of that organization to promote transparency and clarity in all reporting carried out by the solid minerals industry.

[1] The term 'Code' is generally used to describe reporting systems where there are formal and legally binding uses defined by regulators. The term 'Standard' is used to describe systems which may be very similar in content to the Codes but which are not the subject of such legal agreements. In this paper the generic term 'standard' is used to denote both Codes and Standards.

The Template includes a number of Mineral Reserve and Mineral Resource categories, based on the extent to which these have been defined by geological and other technical and economic studies. The main stakeholders in public resource and reserve reporting are investors and potential investors in mineral companies, including financial institutions.

CRIRSCO recognizes that situations exist where reporting of potential mineral assets beyond the categories defined by the Template may be required and that different stakeholders, such as governments and international energy agencies, may require reports on these additional categories.

CRIRSCO has engaged and continues to work with organizations developing classifications of material 'beyond Inferred' with the aim of both assisting in such developments and also ensuring that the resulting classification schemes are consistent with the Template.

CRIRSCO continues to monitor developments in other classification systems, but at this stage does not propose to modify the Template to accommodate mineralization beyond Inferred Resources.

BACKGROUND

In November 2013, CRIRSCO updated the International Reporting Template for the public reporting of Exploration Results, Mineral Resources and Mineral Reserves ('the Template')[2], which represents a synthesis of the public reporting standards of CRIRSCO members. CRIRSCO members currently comprise the NROs. The Template and individual member standards are for public reporting for the benefit of investors or potential investors in mineral and exploration companies. Definitions of Mineral (or Ore) Reserves and Mineral Resources are very closely aligned amongst the various NRO reporting standards and are well known and understood in the stakeholder groups that they serve, including not only investors but financial institutions and the media.

CRIRSCO engages with other organizations that categorize, or may consider categorizing, mineralization that is not defined in the Template to ensure that definitions are not contradictory and that such extended systems are complementary to the Template. The organizations include the United Nations Economic Commission for Europe (UNECE), the Society of Petroleum Engineers (SPE), the International Accounting Standards Board (IASB), the International Atomic Energy Agency (IAEA), and various international agencies and governments. Categories of mineralization beyond Inferred Resources are generally not of interest to investors, and are not reported publicly but may be required to be reported to other institutions, for example governments, or may be of use internally by companies developing exploration strategies, prioritizing development options, or for purchase price accounting for exploration prospects. The Template caters to some extent for this by defining Exploration Results, which are points of information, usually derived from drilling and sampling, which may be of interest to investors but which are insufficient to estimate Mineral Resources.

CRIRSCO's engagement with other organizations has helped to develop an understanding of mineral definitions across different industry sectors and for different users. This work has included discussions of the categories of mineralization that exist in other systems that are not primarily intended for public reporting and which are not part of the Template.

THE CRIRSCO TEMPLATE AND OTHER SYSTEMS

The Template was published to provide countries that did not have a minerals classification and reporting standard or that wanted to modify their own standard to become internationally compatible, with a guide to reporting of Exploration Results, Mineral Resources, and Mineral Reserves. Changes to the Template are made with members' agreement and in turn, changes to

individual member standards are openly discussed in CRIRSCO[2] in order to preserve international compatibility. The Template thus represents current international best practice in minerals reporting.

The Template contains standard definitions for Exploration Results, Mineral Resources (including Measured, Indicated, and Inferred Resources) and Mineral Reserves (including Proved and Probable Reserves).

The general relationship between these defined terms is illustrated in Figure 1 and will be familiar to users of the Template. The highest level of confidence is represented by Proved Reserves and the lowest by Exploration Results.

For the purposes of this paper, the conventional representation has been re-oriented in Figure 2 to facilitate comparison with two other systems; the Petroleum Resource Management System (PRMS)[3] sponsored by the Society of Petroleum Engineers and others, and the United Nations Framework Classification (UNFC 2009)[4], which is a product of the United Nations Economic Commission for Europe, both of which contain categories of mineralization not found in the CRIRSCO Template. In a general sense, confidence decreases from top to bottom in this illustration.

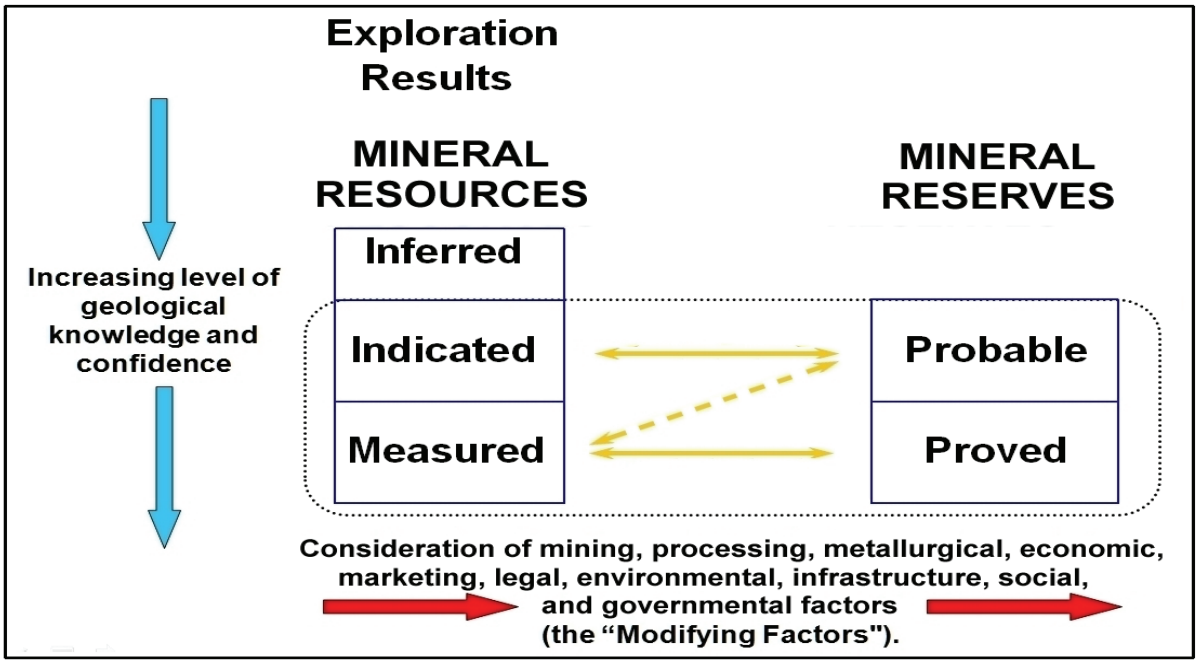


Figure 1. General relationship between Exploration Results, Mineral Resources, and Mineral Reserves as represented in the CRIRSCO Template.

[2] Available at http://www.crirsco .com/template.asp
[3] Available at http://www.spe.org/industry/reserves/prms.php
[4] Available at http://www.unece.org/energy/se/reserves.html

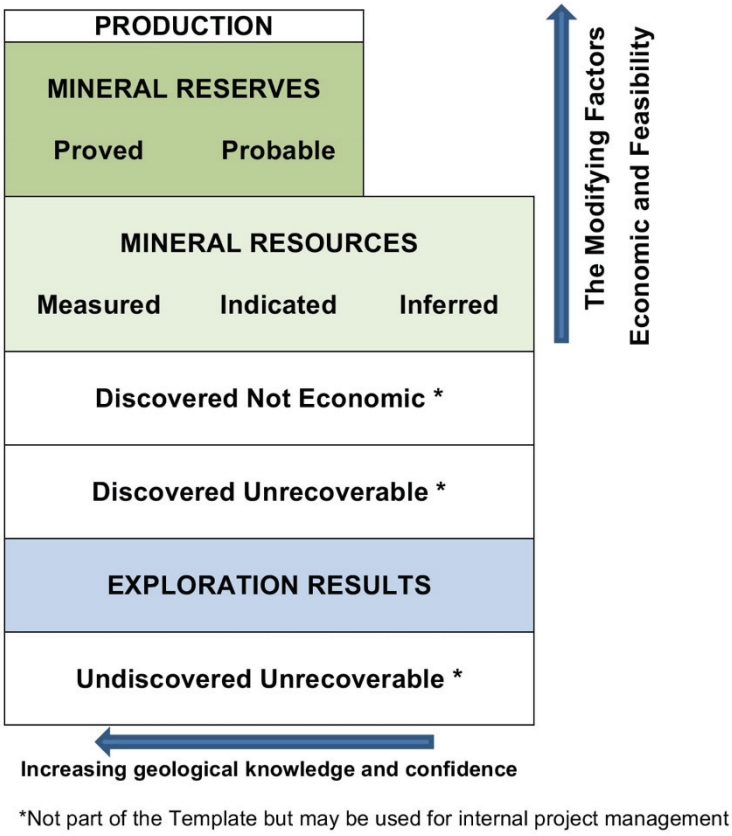


Figure 2. Re-oriented figure showing the CRIRSCO categories (shaded) and additional categories in other systems.

Further details of the mapping exercise conducted between the CRIRSCO system and the PRMS on behalf of the International Accounting Standards Board in 2007 can be found at http://www.ifrs.org/NR/rdonlyres/OE012C2E-EE3E-4E8E-8321-85286B16FEA/0/Extract0803b10bobs.pdf

A report entitled 'Mapping of the United Nations Framework Classification for Fossil Energy and Mineral Resources', which compares the CRIRSCO and PRMS systems to the UNFC, can be obtained from http://www.unece.org/energy/welcome/pub/ense.html#map

EXPANDED CLASSIFICATION SYSTEMS

The most obvious differences between the two versions of the classification scheme in Figure 1 are the additional 'boxes' labelled Production, Discovered Not Economic, Discovered Unrecoverable, and Undiscovered[5]. Essentially, the conventional CRIRSCO system includes only classes that are publicly reported, while the expanded version includes material that may be part of non-public reports to other agencies, such as governments, or simply of use to companies for internal planning purposes.
Taken as a whole, the system in Figure 2 is intended to include all mineralization that has been mined, discovered, or is yet to be discovered within a given area, whether a single deposit, a mineralized province, or a global aggregation of many mineralized areas.

[5] Terms such as 'Discovered Not Economic' are not used in the Template. They are incorporated as a means of simplifying comparison with PRMS.

Figure 3 illustrates the alignment between the Template and the PRMS developed jointly by the SPE and CRIRSCO.

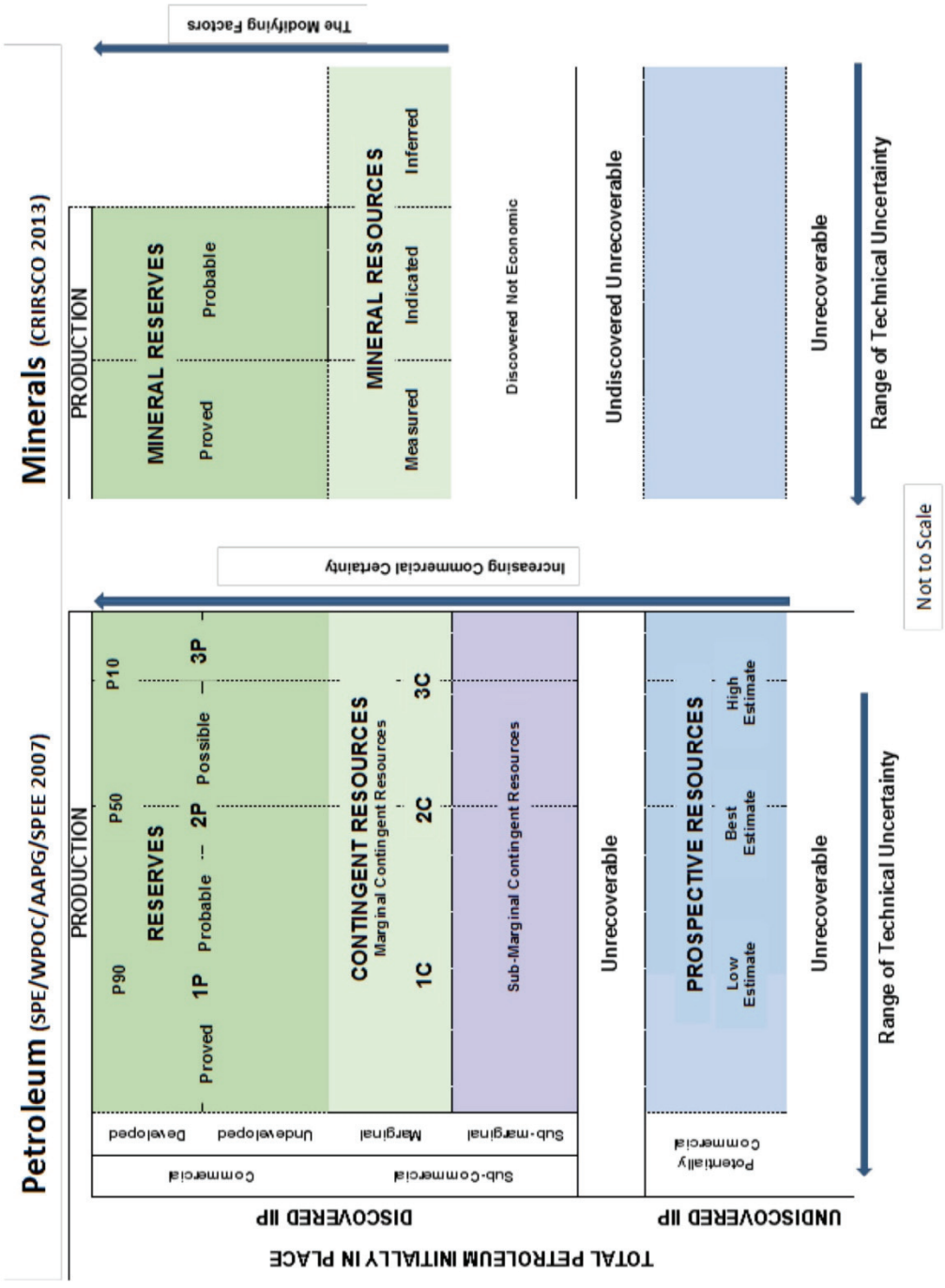


Figure 3. Comparison of the Petroleum Resource Management System (PRMS) and the CRIRSCO Template.

In Petroleum, the whole of the box is termed Total Petroleum Initially in Place. Ignoring production (which is generally reported separately to Resources and Reserves by minerals companies), those boxes shaded on the right have direct or near direct equivalents in the PRMS.

A high-level comparison of UNFC (2009) and the Template, developed as a result of a joint exercise to map the two systems, is shown in Figure 4, with text modified to highlight the Mineral Reserves, Mineral Resources, and Exploration Results areas represented in the Template. As example in the UNFC's numerical codification system a Proved Reserve would be 1,1,1, an Inferred Resource 2,2,3 and Exploration Results 3,3,4. [6-7]

Total commodity initially in place	Production	Sales Production			
		Non – Sales Production			
		Class	Categories		
			E	F	G
	Future recovery by commercial development projects of mining operations	Mineral Reserves	1	1	1,2
	Potential future recovery by contingent development projects or mining operations	Mineral Resources	2	2	1,2,3
		Discovered Not Economic	3	2	1,2,3
	Discovered Unrecoverable		3	4	1,2,3
	Potential future recovery by successful exploration activities	Exploration Results	3	3	4
	Undiscovered Unrecoverable		3	4	4

Figure 4. High-level comparison between UNFC (2009) and the CRIRSCO Template.

THE BOUNDARIES OF CRIRSCO MINERAL RESOURCES

The CRIRSCO Template and NRO standards require that Mineral Resources should have 'reasonable prospects for eventual economic extraction. While the precise meaning of words such as 'reasonable', 'eventual', and 'economic' can be and is continuously debated, the phrase is generally taken to mean that given a set of reasonable assumptions on inputs such as prices, costs, production rates, and mineral recoveries, and a positive economic evaluation, it can be assumed that an eventual mining operation is realistically viable both technically and economically.

[6] Terminology has been changed from UNFC (2009) to align with that used Figure 3. For example 'Discovered Unrecoverable' is described in UNFC (2009) as 'Additional quantities in place associated with known deposits'.

[7] As defined in UNFC (2009), E = Social and economic viability; F= Field project status and feasibility; G=Geological knowledge. Numerical values range 1–4 with 1 being the highest confidence.

Guidance provided in the Template notes that a decision on whether the test of reasonable prospects has been met requires judgment by a Competent Person or Persons, and goes on to say: 'a Mineral Resource is not an inventory of mineralisation drilled or sampled, regardless of cut-off grade, likely mining dimensions, location or continuity. It is a realistic inventory of mineralisation which, under assumed and justifiable technical and economic conditions, may, in whole or in part, become economically extractable' .

This clearly sets a 'lower' boundary to Mineral Resources, which must meet the test of 'reasonable prospects for eventual economic extraction'; that is to say, all classes of Mineral Resource are implicitly economic and technically feasible and may be developed in the future, but without guarantees that such development will eventuate.

The following sections discuss each of the categories 'beyond Inferred' and the CRIRSCO interpretation. Exploration Results will be included as a special case where, despite the fact that they form part of the Template, they are treated differently to their equivalents in PRMS or UNFC.

None of the categories currently meet the test of reasonable prospects for eventual economic extraction for any of a number of reasons. However, the use of the word 'currently' is deliberate as it is to be expected that this 'mineralized inventory'[8] would be dynamic over time and that material would move through the categories, or be removed altogether, depending on the results of continued exploration and technical studies.

Figure 5 illustrates the relationship between categories of mineralization that are 'beyond Inferred' and the standard CRIRSCO categories shown in Figure 1.

Categories that occur 'upwards' from Inferred Resources (including Exploration Results) have a very low level of confidence due to the lack of geological information. Categories that are to the left of Mineral Resources are located on the basis of uncertainties or negative impacts arising from the modifying factors. In simple terms they are not economic and not currently of interest for development.

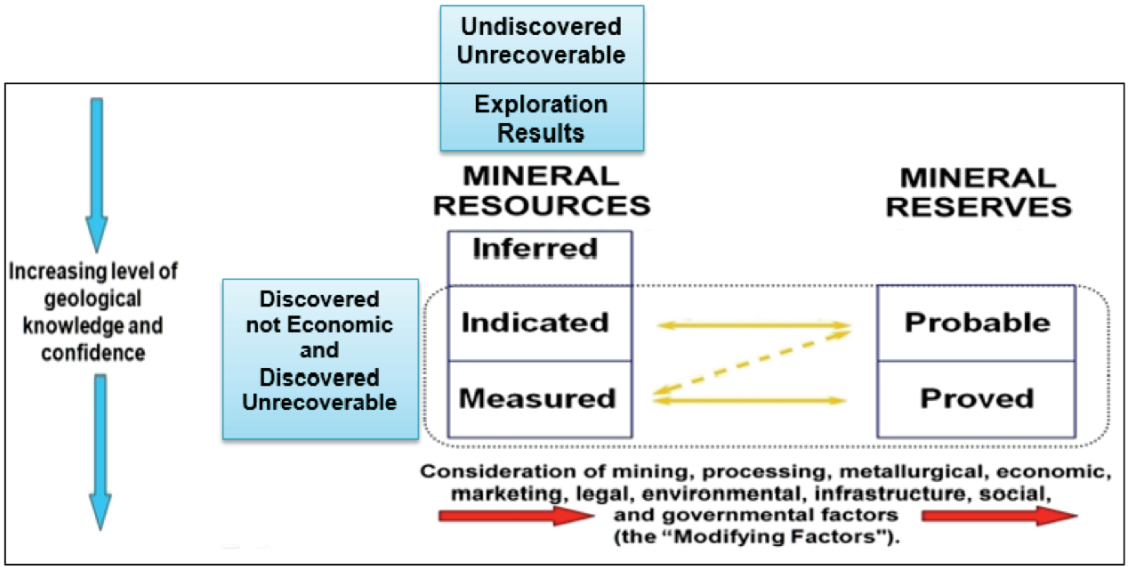


Figure 5. Categories of mineralization 'beyond Inferred'.

[8] The term 'mineralized inventory' is used here to describe material that does not currently qualify as a resource; some companies internally use the term 'potential resources' with essentially the same meaning.

DISCOVERED NOT ECONOMIC

This term provides a direct equivalent to the class of Sub-marginal Contingent[9] Resources in the PRMS.

In terms of geological confidence, there is no difference between categories under Discovered Not Economic and Mineral Resources. The extent to which geological and grade continuity is demonstrated means that Discovered Not Economic categories can be geologically the equivalent of Measured, Indicated, or Inferred, as demonstrated in the UNFC 2009 codification in Figure 4 where they occupy 'boxes' 3.2.1, 3.2.2, and 3.2.3.

The extent to which such mineralization has been studied to determine its technical and economic viability is also likely to be the same as for Mineral Resources. The key difference is that, at the time of estimation, Discovered Not Economic fails the test of reasonable prospects for eventual economic extraction and can therefore not be publicly reported.

Typical reasons for failing the test can include too low a commodity price, or a recovery process that either fails to deliver adequate quantities or quality of product or requires the application of untested or unproven technologies.

As conditions can change with time, companies commonly maintain an inventory of mineralization for which there is a belief that, for example, commodity prices will improve in future or new technologies will be developed to economically recover the minerals, leading to reclassification as a Mineral Resource and potentially a Mineral Reserve.

In larger mineral companies that may adopt a long-term view, often looking several decades ahead, it is quite reasonable to suppose that material that could potentially become Resources and Reserves in the future should be retained 'on file' and incorporated, with appropriate caveats, in long-term strategic planning.

For junior companies, often with only a single significant exploration project, the decision on how to handle discovered but uneconomic mineralization is more difficult. Retaining a property and continuing to explore entails a cost that must be met by the company owners, investors, or financiers. In most cases, the decision will be based on a continuous assessment of whether the deposit has 'reasonable prospects for eventual economic extraction'.

The presence of mineralization, even if currently uneconomic, can provide a junior company with leverage in discussions with potential investors and there is no reason why the results of exploration cannot be discussed for this purpose (see Exploration Results below}. However, when reporting under CRIRSCO-aligned reporting standards, it should always be made clear that the mineralization does not qualify as a Mineral Resource.

DISCOVERED UNRECOVERABLE

Most mining and exploration practitioners will be familiar with the concept that mineralization can be discovered but that it may be unrecoverable for a number of reasons. Examples where recovery may never be possible include locations where mining is not allowed, such as in sites of cultural or environmental significance, *e.g.* national parks, or where parts of the Mineral Reserve have to be left unmined for safety reasons.

[9] The term 'contingent' used in the definition of Petroleum Resources refers to a number of factors, or contingencies, that must be met before the Resources can convert to Reserves. Contingencies are directly equivalent to the 'modifying factors' in the Template.

There are many other examples where the mineralization may be currently unrecoverable but it is not out of the question that recovery might be possible in future, for example where alternative access can be developed, infrastructure moved, or new technologies become available, for example in very deep or very high-temperature environments.

Discovered Unrecoverable mineralization is contained in the 'boxes' 3.4.1, 3.4.2, and 3.4.3 in the UNFC 2009 classification.

EXPLORATION RESULTS

Exploration Results represent a special case where although there are broad similarities with the equivalent Prospective Resources in the PRMS, there are a number of concepts that differ between petroleum and minerals.

All Petroleum Resources, whether discovered or not and recoverable or not, are attributed an estimated recoverable volume. This may be done statistically based on fairly limited data compared to minerals, where confidence in a volume estimate commonly relies on far more drill-holes and samples. In effect, Exploration Results represent an intermediate point on the development curve from an initially identified Exploration Target to a formal discovery when Mineral Resources can be estimated and published.

They typically include points of data, such as outcrop sampling or drill-hole intercepts, without any attempt to link or interpolate these to create volumes.

Exploration Results may be publicly reported but not as estimates of tons and grade due to the inadequate available data. The nearest equivalent to Exploration Results in UNFC 2009, although expressed in tonnage and grade terms, is 3.3.4.

EXPLORATION TARGET

The term Exploration Target, has been defined in the Template of 2013. Exploration Target allows minerals companies to discuss mineral potential that may arise from future exploration. Reporting of exploration targets, which are conceptual in nature, is strictly constrained so that report users will not confuse exploration targets and Mineral Resources.

UNDISCOVERED UNRECOVERABLE

While the concept of mineralization that is both undiscovered and unrecoverable might be alien to practitioners in the minerals industry, it is easier to understand in the context of the probabilistic approach taken in the petroleum sector. At any point in time there will be a statistical probability that extensions may exist to known resources or that regions known to host oil or gas will yield new discoveries.

In the minerals industry it is possible to estimate the probability of making a resource discovery as a guide to developing exploration programmes, and there is likelihood that a proportion of any such discoveries would be unrecoverable. However, recoverability is not likely to be a significant consideration during early stage exploration.

While CRIRSCO recognizes such statistical probabilities, the category is clearly of little interest to investors and would most likely cause considerable confusion if publicly reported. In UNFC 2009, Undiscovered Unrecoverable mineralization is equivalent to 3.4.4.

USES FOR A MINERALIZED INVENTORY

Most companies that report Exploration Results, Mineral Resources, or Mineral Reserves are also likely to maintain some form of additional mineralized inventory, even though this will not be publicly reported. Most commonly such an inventory will simply be a complete record of mineralization, beyond what is publicly reported, contained within property over which the company has exploration and/or development rights.

In some countries it may be necessary to submit information on a mineralized inventory to government agencies for the purposes of long-term strategic mineral planning, but in most cases the inventory will be used by the company for its own purposes. Typical examples would be where mineralization has been discovered and quantities estimated but studies have shown it to be below a break-even cut-off grade or minimum mining thickness and therefore not technically or economically viable.

Where there is a possibility that this situation could change in future, with an increase in commodity price for example, it would be retained 'on file' for further consideration at an appropriate time.

There are no formal rules for what is recorded in a Mineralized Inventory. Early-stage conceptual estimates of potential mineralization may co-exist with areas where mineralization is known to exist as shown by detailed drilling and sampling. Similarly, there is no formal classification of types of mineralization within an inventory. As these do not refer to Mineral Resources, this is generally left to the discretion and business needs of individual companies, although as noted above, there may be instances where governments and international agencies may require information on certain categories of mineralized inventory. An example of this is 'Inventory Coal', a term used in Australia to define all *in-situ* coal before modifying factors have been applied.

High-level strategic studies by governments or international agencies may attempt to consolidate all reserve, resource, and additional inventory mineralization into a form where an assessment of future mineral potential for a country or region can be made. In CRIRSCO's view a simple aggregation of numbers in this way can be misleading in that it adds together material of different confidence levels, for example Resources and Reserves, or attempts to quantify mineralization at a stage of development that is too early for such estimates to be meaningful. For that reason, reporting using the Template requires that all mineral categories are stated separately and, if aggregated, then this is done only on a like-for-like basis, for example Mineral Reserves may be added to Mineral Reserves, but not to Mineral Resources.

CRIRSCO encourages discussion on this topic and continues to engage with other classification systems that categorize mineralization that is not defined in the Template to ensure that definitions are not contradictory and that such systems are complementary to the Template.

REFERENCES

CRIRSCO. 2013. International Reporting Template for the Public Reporting of Exploration Results, Mineral Resources and Mineral Reserves. Committee for Mineral Reserves International Reporting Standards, Council of Mining and Metallurgical Institutions. http://www.crirsco.com/templates/international_reporting_template_november_2013.pdf {Accessed 15 March 2016].

Society of Petroleum Engineers. 2007. Petroleum Resources Management System. http://www.spe.org/industry/reserves/prms.php {Accessed 15 March 2016].

UNECE. (2009). UNFC and Resource Classification. http://www.unece.org/energy/se/reserves.html {Accessed 15 March 2016].

Weatherstone, N. 2010. Mineralisation beyond Inferred Resources – a CRIRSCO position paper. www.crirsco.com/mineralisation_beyond_inferred_r.pdf {Accessed 15 March 2016].



John Roger Dixon

Corporate Consultant
SRK Consulting

Roger Dixon Pr.Eng, BSc (Hons) Mining, Hon Life FSAIMM is a mining engineer with over 44 years' experience in the industry. He spent his early career managing deep level gold mines in the Witwatersrand Basin. He was a founder member and chairperson of the South African Mineral Resource Committee (SAMREC) which developed and published the original SAMREC Code in 2000 and the revised version in 2007. Roger is currently one of two South African representatives on the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) an organization which he chaired in 2009-2010. He is currently a corporate consultant with SRK Consulting SA.

Exploration Results, Exploration Targets and Mineralisation

T R. Marshall

Explorations Unlimited, Johannesburg, South Africa

While the original intent of all of the international reporting codes was to regulate the public reporting of Mineral Resources and Mineral Reserves only, many jurisdictions have seen the need to provide guidance for the reporting of Exploration Targets, which are the lifeblood of junior exploration and mining companies and private operators alike. In harmony with this trend, the SAMREC Code 2016 has greatly expanded the issues surrounding Exploration Results and Exploration Targets and has also introduced the concept of Mineralisation. This document seeks to clarify the concepts and definitions and to assist in clearing misconceptions before they arise. A number of case-study examples are presented in order to illustrate the differences between Exploration Targets that are purely conceptual and those which may be identified as Mineralisation.

INTRODUCTION

The original purpose of the international reporting codes was to regulate the public reporting of Mineral Resources and Mineral Reserves. This is highlighted by the titles of the original codes – for example, the 1999 JORC Code is entitled 'Australasian Code for reporting of Mineral Resources and Ore Reserves' and the 2000 SAMREC Code is 'South African Code for reporting of Mineral Resources and Mineral Reserves'. In both of these codes, issues were confined to reports compiled for the relevant securities exchange. Very little attention was paid to the pre-resource space, with no more than a few lines dealing with the reporting of exploration results, called 'prospecting information' in the 2000 SAMREC Code.

By the mid-2000s, both codes had changed their titles. The 2004 version of JORC had become 'Australasian Code for reporting of *Exploration Results*, Mineral Resources and Ore Reserves' and the 2007 SAMREC Code was entitled 'South African Code for the reporting of *Exploration Results*, Mineral Resources and Mineral Reserves' (italics added). It is noteworthy that, although the emphasis was still on listed company reporting, the definition of 'Public Reports' had been expanded significantly to include all reports that may be of use to investors and potential investors.

This migration appears to be, partially, in recognition of the increasing role played by junior exploration and mining companies and their need to report on strategic exploration targets for continued financial support. In addition to the needs of junior companies, large mining companies need to continuously assess long-term development opportunities in the exploration areas surrounding their operations (Mullins *et al*., (2014). The objectives of these programmes are to develop a thorough understanding of the mineral inventory so that the full mineral endowment potential of an area can be considered under multiple scenarios and long-term investment decisions taken to optimize the development potential of the province. It was argued that such objectives require a consistent approach to evaluating the nature and extents of potentially economic mineralisation. While guidelines such as the JORC Code (and, by extension, the SAMREC Code) adequately address this for public reporting purposes, internal strategic decisions often require a less conservative, but similarly rigorous, approach so that projects and increasingly competitive budgets can be prioritized before all of the information needed for formal resource estimation and classification is available.

Similar to other codes, the 2007/2009 SAMREC Code did not place much emphasis on the definition of Mineral Resources, beyond the statement that there were to be reasonable expectations for eventual economic extraction. Apart from recognizing that it is common practice for a company to comment on and discuss its exploration in terms of target size and type, guidelines for anything in the pre-resource space were even more vague and, consequently, reporting of exploration results, exploration targets, mineralization, and inventory became highly suspect in terms of credibility. The emerging importance of Exploration Results as a defined term was, however, seen in the fact that an entire column in Table 1 of the SAMREC Code ('Exploration Results (A)') was dedicated to the discussion of exploration data and information, where applicable.

'Exploration target' became a sack term for anything that did not meet the requirements of a Mineral Resource and included everything from pure conceptual models to properties where the amount of data and/or the level of confidence in the results fell just short of 'Resource'. Since it is not a Resource, according to the Codes an Exploration Target could not form part of a Mineral Resource statement or tabulation, nor be included in any techno-economic assessment, however preliminary. An unintended consequence of the inclusion of both early and more advanced reconnaissance-stage exploration programmes was that many that of the more advanced reconnaissance-stage properties were shoehorned into the Inferred Resource category because that was the lowest classification that credited the company with having done any exploration on the target property.

The latest versions of the JORC, PERC, and SME codes all define an Exploration Target as 'a statement or estimate of the exploration potential of a mineral deposit in a defined geological setting where the statement or estimate, … relates to mineralisation for which there has been insufficient exploration to estimate Mineral Resources' (*same or similar wording*). Both JORC and PERC note that all disclosures of an Exploration Target should clarify whether the target is based on actual exploration results completed or on proposed exploration programmes yet to commence, implying that Exploration Targets can be both conceptual or advanced. The provisions of SME indicate that only properties where actual exploration results have been obtained can be described as Exploration Targets. Although CIM makes no mention of either of the terms Exploration Results or Exploration Target, the National Instrument 43-101 Companion Policy of 2011 gives limited guidelines on what might constitute such information and how it may be reported publicly in a manner that does not misrepresent the potential prospectivity of the property.

It is in recognition of these matters that the SAMREC Code 2016 has greatly expanded the issues surrounding Exploration Results and Exploration Targets, and has also introduced the concept of Mineralisation (as opposed to mineralisation as a geological term – SAMREC defines mineralisation as 'The process or processes by which a mineral or minerals are introduced into a rock, resulting in a potentially valuable deposit. It is a general term, incorporating various types, *e.g.* fissure filling, impregnation, replacement, *etc.*'). The Code has also seen the migration from reports that deal with purely listed entities to any document that may find its way into the public domain, and even includes statements on social media. In addition to the requirements of the various securities exchanges with respect to public reporting by listed companies of all sizes, *industry best practice strongly recommends that reports compiled for 'private' companies also be compiled in accordance with the SAMREC Code* – the primary argument being that investors in non-listed entities deserve the same level of professionalism in reporting and valuation standards as for listed companies. In recent years there has been an upsurge in the number of Public Reports associated with non-listed companies. The reasons for this are many and varied, but the most common involve the many private companies that are looking to obtain finance for very early-stage exploration projects from financial institutions (such as the Industrial Development Corporation, banks, and/or mining funds), from established (listed) exploration and mining companies, or from high-wealth individuals. In most of these situations, the potential investor requires a Competent Person's Report (CPR) before being willing to commit to commercial terms.

This paper seeks to clarify the thought processes by the Exploration Results subcommittee of the SAMREC Working Group in developing the definitions and concepts integral to the pre-resource space and to assist in clearing misconceptions before they arise.

EXPLORATION RESULTS

The 2016 SAMREC Code (Clause 20) defines Exploration Results as data and information generated by exploration programmes that may be of use to investors, but which do not form part of a declaration of Mineral Resources or Mineral Reserves. The reporting of such information is common in the early stages of exploration when the quantity of data available is generally not sufficient to allow any reasonable estimates of Mineral Resources. What is vitally important in the reporting of such Exploration Results is that they must not be presented in such a manner so as to unreasonably imply that potentially economic mineralisation has been discovered.

Reports of Exploration Results must contain sufficient information to allow for a considered and balanced judgement of their significance and the reporting should be structured to include both positive and negative relevant data and information relating to the mineral property. The overriding emphasis is on balanced reporting, providing *relevant information* relating to prospecting activity that has taken place on the property of interest.

Such Exploration Results may include survey, geological, geophysical, geochemical, sampling, drilling, trenching, analytical testing, assaying, mineralogical, metallurgical, and other data and information, where available. Exploration Results may also include historical data/information as well as data/information from adjacent or nearby properties, if the CP can provide justification for its inclusion. Such justification must include at least some physical evidence of assumed continuity of the mineralisation on the property of interest.

With the rise of the junior exploration company, it has become common practise to comment on and discuss Exploration Results in terms of size and type, even at a very early stage of prospecting, before formal Mineral Resources have been identified. There is a long history of mining projects where the mineral endowment of a district or province is underestimated and careful consideration of the full potential for economic mineralisation in the early stages of assessment could have significantly improved development decisions and long-term profitability (Mullins *et al*., 2014). Likewise, examples of overestimating the potential size of a mineral district have been equally disastrous for shareholder value. Historically, this is where many (listed and private) companies have misused and abused reporting standards, resulting in, at best, the obfuscation of the situation so as to imply better results than actually exist and, at worst, the gross misrepresentation of the potential of projects (probably the most infamous example of this in modern times is the Bre-Ex fiasco in 1995-1997).

Exploration Targets

The term 'exploration target' in the 2007/2009 SAMREC Code (Clause 20) had no formal definition, but was included as a way of reporting Exploration Results that might be of interest to investors. The governing principles of reporting exploration targets was that any statement referring to potential quantity, quality, and content of the target was to be expressed as ranges (to emphasize the lack of confidence in the data) and that they were to be accompanied by various cautionary statements.

The definition of the term 'Exploration Target' in Clauses 21/22 of the 2016 SAMREC Code has retained these essential elements. In harmony with other international codes, Exploration Target is defined as a statement, or estimate, of the exploration potential of a mineral deposit in a defined geological setting where the statement or estimate, quoted as a range of tons and a range of grade or quality, relates to mineralisation for which there has been insufficient exploration to estimate Mineral Resources.

The essence of an Exploration Target is that, at one extreme, it can refer to a concept of mineralisation. It does not necessarily require that any mineralisation be identified or even that the company has identified specific properties for acquisition. A (conceptual) Exploration Target, therefore, need not, imply reasonable prospects for eventual economic extraction (RPEEE). Notwithstanding, there must be a likelihood that this exploration target occurs in an area of geological prospectivity for that commodity and mineralisation type.

For example, a diamond company might target a property located on the Kaapvaal Craton in a region where kimberlite pipes are known to occur. The known kimberlite cluster may or may not include a pipe that is currently being mined, or that was mined in the past. The Exploration Target might be associated with the occurrence of an indicator mineral anomaly or a geophysical anomaly, or perhaps artisanal miners are recovering alluvial diamonds downstream from the property.

At the other extreme, an Exploration Target may refer to a specific area in a property held under licence that has been subject to an advanced reconnaissance exploration programme, but where either the amount of data or the level of confidence in the data is insufficient for classification as a Mineral Resource or where RPEEE have not yet been established for the specific property.

So, the company in the example above might have drilled a number of holes into one of the geophysical anomalies and identified the presence of kimberlite. The systematic drilling was able to identify an initial volume of some 20 Mm^3 of kimberlite down to a depth of 60 m. Each intersection may have been sampled for microdiamonds which indicated potential grades in the order of 30-40 carats per hundred tons (the bulk density was assumed from a regional average average). However, to date, only 25 macrodiamonds have been recovered from the initial bulk sampling programme. While this data will fall short of allowing the project being classified as a Resource, it can be classified as an Exploration Target (with identified Mineralisation).

In terms of Clause 21, anything classified as an Exploration Target must not be expressed so as to be misrepresented or misconstrued as an estimate of a Mineral Resource or Mineral Reserve. Details of the Exploration Target may not form part of a Resource statement or be included in a tabulation of Mineral Resources or Mineral Reserves. Exploration Targets may not be included in a Technical Study (at Scoping, Pre-Feasibility, or Feasibility level) and may not be converted to Mineral Reserves (Clauses 21, 43-46). They may not be included in economic assessments or discounted cash flow (DCF) models, nor be included in valuations based on Income Approaches. Given the levels of uncertainty surrounding the supporting data, the quantity (volume or tonnage) or quality (grade and value) of an Exploration Target may not be reported as a '*headline statement*' in a Public Report (Clause 22).

When discussing Exploration Targets, the CP must clearly describe the rationale for such selection, including the geological model on which it is based. Any statement referring to potential quantity, quality, and content, as appropriate, must be substantiated and include a detailed explanation of the basis for the statement. This must be followed by a proximate statement, with the same prominence, that the potential quantity, quality, and content, as appropriate, are conceptual in nature, that there has been insufficient exploration to define a Mineral Resource and that it is uncertain if further exploration could result in the determination of a Mineral Resource.

'Same prominence' is defined as the same font type and size and 'proximate location' is defined as the cautionary statement being included in the same paragraph as, or immediately following, the reported statement. The cautionary statement may not be by way of a footnote, nor will a general disclaimer elsewhere in the disclosure document satisfy this requirement. This cautionary statement must, further, be made each time the statement of potential quantity, quality, and content is presented.

Any statement referring to quantity and quality must reflect the lack of reliable data. Where the statement includes information relating to ranges of tonnages and grades, these must be represented as approximations. The conceptual nature of the statements must be expressed either through the use of 'order of magnitude', including appropriate descriptive terms (such as 'approximately', 'in the

order of', *etc.*) or as 'ranges', which is defined as the variation between the lowest and highest relevant Exploration Results – the use of ranges in this context has *no statistical relevance*.

Estimates of potential quantity and quality should, preferably, be made in terms of volume (or area) and not mass/tonnage. If, however, target tonnages are reported, then the preliminary estimates, or basis of assumptions, made for bulk density must be stated. The explanatory text must include a description of the process used to determine the grade and tonnage ranges describing the Exploration Target or Mineralisation.

Appropriate rounding should be used to express the level of uncertainty of the estimates. By way of example, 'approximately one to two million tons at a grade of 3-5% Cu' or 'an Exploration Target of more than 100 million tons of coal in excess of 16 MJ/kg for power generation markets' would be acceptable, but not '2 ±0.2 million tons'. When estimates are quoted, statements of both quantity and quality must be provided. It is not permissible to quote one without the other.

In addition, any discussion of Exploration Targets must include the intended exploration work programme to explore for the target, detailing the extent of the proposed exploration activities, the planned timeframe, and the anticipated costs. Public reporting of an Exploration Target shall not be done unless supported by exploration. Without an explicit exploration work programme, public reporting of an Exploration Target must be regarded as being solely speculative (Clause 21). Clause 20, further, notes that, in discussions of Exploration Targets on properties adjacent to, or nearby, properties of known mineralisation, at least some physical evidence of assumed continuity of the mineralisation on the property of interest must be presented by the CP.

Mineralisation

A new term, Mineralisation, (Clause 21/22) has been introduced (as a subset of Exploration Target) to deal with the situation where the Exploration Target is no longer purely conceptual, but where actual data has been obtained on the property and where mineralisation of significance (as opposed to a mineral occurrence) has been identified (see example above). Mineralisation refers to the situations where insufficient data has been acquired to estimate a Mineral Resource, where the existing data is of insufficient confidence to allow the classification of a Mineral Resource, or where RPEEE have not yet been demonstrated. In this respect, the concept of Mineralisation is similar to the term 'deposit' in the previous SAMREC Codes. It can be roughly correlated with the concept of Inventory Coal (SANS 10320, 2nd Edition – note, however, that the term 'Inventory Coal' is not recognized by the SAMREC 2016 Code, nor shall it to be included or presented in Public Reports).

The term Mineralisation has been introduced in deference to the proliferation of both private and junior exploration companies whose continued financial backing depends on the presentation of exploration results in the public domain. It was noted that, unless terminology was introduced and strictly controlled, then the current Resource definitions (especially the Inferred Mineral Resource category) would be adulterated by individuals/companies seeking the highest classification for their projects. It would not be sufficient to simply prohibit the reporting of anything that did not meet the requirements of the 'Resource' definition – the necessity to publicize results would still result in further abuse of the codes.

For an Exploration Target where Mineralisation has been identified based on Exploration Results, a summary of the relevant exploration data/information and the nature of the results should also be presented, including a disclosure of the current drill-hole or sampling spacing and relevant plans or sections. In any subsequent upgraded or modified statements on the Exploration Target, the CP should discuss any material changes to potential scale or quality arising from completed exploration activities.

Typically, the phases of an exploration programme, and the subsequent classification, can be defined by the activities carried out in that phase (Table I). Depending on the mineral commodity and/or style

of mineralisation, the activities undertaken in each exploration phase may differ significantly. The list included in this table is not meant to be exhaustive and is for illustrative purposes only.

Table I. Examples of activities in different exploration phases.

Exploration phase	Examples of activity	Classification
Phase I (Desktop study) Conceptual targets	• Review of historical data or data from adjacent/nearby properties • Regional grades, qualities, values • Satellite/geophysical anomalies • Target volumes/area and grade	*Exploration Target* • Insufficient data and/or confidence levels to estimate a Resource • Need to present all data (volume, area, tonnage, grade and value) as ranges and approximations, with cautionary statements • Cannot be included in Mineral Resource Statements or Tables • Cannot be included in technical studies or economic assessments • Cannot be included in DCF valuations
Phase II (Reconnaissance exploration) Mineralisation	• Reconnaissance drilling and/or /pitting • Reconnaissance sampling • Kimberlitic indicator mineral chemistry • Reconnaissance soil/chip sampling	
Phase III Resource estimation	• Systematic drilling/pitting • Sampling / bulk-sampling	*Mineral Resource* • Reasonable prospects for eventual economic extraction have been demonstrated • Sufficient data and confidence levels to classify the Resource

A number of case studies might be considered, which will help to highlight the differences between conceptual Exploration Targets and Mineralisation. Irrespective of the commodity and/or mineralisation type described in the specific case study, the principles are applicable to all commodity and deposit types.

EXAMPLES

Case Study 1

BHP Billiton, as one of the largest mining companies in the world, is committed to developing large, long-life, low-cost expandable operations. An appreciation of this long-term potential in the earliest stages of development is critical for profitable long-term investment. To estimate this long-term potential, the company has developed a rigorous in-house method to assess the mineral endowment potential of a province that is unconstrained by current markets, technology, and the detailed requirements for Resource classification. Exploration Targets (potential mineralisation) are estimated from a limited set of geological information and are reported as a range to reflect different interpretations and the higher level of geological uncertainty. The geological information can be a combination of geophysical, mapping, and sampling data. Such targets (Mullins *et al*., 2014) capture the essence of '*what we think will be there when the area under consideration is fully explored*' and contribute to the total mineral inventory to consider and prioritize long-term development options for a given orebody or mineral province.

Case Study 2
The Midamines Concession is located along the Kwango River in the Democratic Republic of Congo (DRC). Diamonds have long since been associated with alluvial sediments within this river system both in Angola and the DRC. Historical data (primarily pre 1980s) regarding diamond recoveries covers an area of some 600 km, both up- and down-stream of the project concession; however, no formal Resource statements compatible with any international code were ever issued. Major prospecting/mining activity in this area ceased after independence in 1960, although low-level artisanal activity continued in various locations along the river, and even on the concession itself.

A site visit confirmed that extensive river flats were located on each side of a meandering river as well as the presence of several levels of higher terraces. An interpretation of available satellite data suggested that some 50 km^2 (river channel, floodplain, and terrace) was potentially underlain by gravels. Information gleaned from the artisanals operating on the site indicated that the basal gravels in the present river bed (the primary target) were some 1 m thick. Limited information was also obtained regarding average diamond size and sales value. The only formal mining activity in the Kwango valley was located some 135 km upstream in a different geomorphological setting. A resource statement from this operation was obtained for comparison.

At this stage of knowledge, the first Public Report on the property identified an (early stage, conceptual) Exploration Target of approximately 8–10 Mm^3 in the present river and an additional 35-40 km^2 of abandoned river channel, floodplain, and terrace deposits (De Decker, 2005). Target grades for the Kwango River (and, therefore the project property) are 0.8-1–5 carats per cubic metre (ct/m^3) and average sales values in the region of US$90–140 per carat.

For the sake of the example, if it is assumed that the company proceeded to prospect this property; that a number of bulk sample pits were excavated on the floodplains and terraces and a small dredge was installed on the river itself; also a RC drill-rig was employed to drill on a wide grid spacing (as defined in the exploration programme outlined in the abovementioned geological report). As a result of this programme, 250 ct of diamonds were recovered and valued at US$120 per carat. The next Public Report or news release, if done in accordance with the 2016 SAMREC Code, would indicate that Mineralisation (no longer simply a concept) had been identified on the property in the amount of some 8.5–9.5 Mm^3 of gravel in the present river and approximately 36-38 Mm^3 in the floodplain/terrace environment, at sample grades of 0.8-1 ct/m^3 and an average diamond value of around US$90-140 per carat. The news release would not have the headline '*47.5 Mm^3 of diamondiferous gravel identified on the Midamines Concession*'.

Case Study 3
A number of kimberlite dykes are known to exist on the Bobi concession in Côte d'Ivoire. Volumes were estimated from drilling during 1993-1995 – the exact locations of the holes as well as the original core was destroyed during the civil war of 1999-2011. It is unknown how much material was processed from the different kimberlites over the years or how many diamonds were recovered. Historical documents indicate anecdotal grades of 0.15–0.3 ct/m^3 based on the recovery of an unknown number of carats from an unknown volume of material by artisanals. Diamond values are based on a report by Reuters (in 2014) which indicates that, before the embargo, some 300 000 ct a year were being exported from the Ivorian diamond fields worth around US$25 million (estimated US$83 per carat). Current sales (by small-scale artisanals) to local diamond buyers indicate prices of some US$50-200 per carat

On the same property, a detailed ground geophysical survey (magnetics) was completed during 1974. Seven geophysical targets were identified from this data. No drilling has taken place to confirm whether they represent kimberlite.

Based on this information, this project may be classified as containing identified Mineralisation as well as conceptual Exploration Targets. With respect to the Mineralisation, although some useful information is available from sampling on the property itself, it is totally inadequate to be stated as a

Resource (Marshall, 2014). In addition, RPEEE have not been demonstrated at any scale. In a Public Report, a statement might indicate the identification of Mineralisation of some 300 000–400 000 m^3 of kimberlite to a depth of 60 m at sample grades of 0.15–0.3 ct/m^3 and US$50–200 per carat.

The geophysical anomalies, while occurring on the property, spatially related to the known kimberlites, and having similar (geophysical) characteristics, have not yet been verified as representing kimberlite. These anomalies have geological merit and would be classified as conceptual Exploration Targets. Again, the news release might indicate that the company is pursuing kimberlitic Exploration Targets with a combined volume in excess of 500 000 m^3, where regional grades and values are in the range of 0.15–0.3 ct/m^3 and US$50–200 per carat.

Case Study 4
A company holds rights to a chrome project in the eastern limb of the Bushveld Complex. The project area is covered by recent sediments, with minimal outcrop of the underlying geology. The regional and local geology is well known, with current activity on nearby properties – one is an underground mining operation with identified Mineral Resources and Mineral Reserves; and another project (adjacent to the project property), has been the subject of recent exploration,

No historical mining has been known on the project property and the only documented historical exploration is for adjacent projects including two percussion boreholes that were drilled into the suboutcrop area (LG-6 chromitite unit) near the southern boundary of the farm. An initial exploration programme was initiated by the company, which included an aeromagnetic survey (including 5 m contours for a detailed digital terrain model), as well as the drilling of 10 diamond and reverse circulation drill-holes.

The regional geology of the Bushveld Complex is very well known and it might be tempting on the part of a CP to extrapolate a Mineral Resource based on limited data from the property itself. In this case, the limited exploration borehole information and geophysical data, combined with extensive regional information resulted in the CP declaring an Exploration Target (Clay *et al.*, 2014). The provisions of the 2016 SAMREC Code would add that the Exploration Target could be further described as Mineralisation.

CONCLUSIONS

SAMREC (and other CRIRSCO codes) adequately address the consistent approach required to evaluate and report the nature and extents of potentially economic Mineral Resources. However, limited guidelines exist for the public reporting of material that cannot be described as a Mineral Resource. As a result of these inadequacies, many junior/private exploration companies have misused and abused the Resource classification category (especially the Inferred Mineral Resource category). In an attempt to prevent such abuse and regulate the reporting of the pre-resource space, the 2016 SAMREC Code has greatly expanded on the concept of Exploration Targets – what they may include and how they may be reported in the public domain in a manner that is not misleading, but is useful for potential investors and other stakeholders, is assessing the exploration potential of a specific property of even of an entire mineral province.

The term 'Mineralisation' is introduced as a variety of Exploration Target where the target is no longer purely conceptual, but where actual data has been obtained on the property and where mineralisation has been identified (based on actual Exploration Results). It refers to the situation where insufficient exploration data has been acquired to estimate a Mineral Resource, where the existing data is of insufficient confidence to allow the classification of a Mineral Resource or where RPEEE have not yet been demonstrated.

When discussing Exploration Targets (either conceptual or with identified Mineralisation), the CP must clearly describe the rationale for such selection, including the geological model on which it is

based. Any statement referring to potential quantity, quality, and content, as appropriate, must be substantiated and include a detailed explanation of the basis for the statement. This must be followed by a proximate statement, with the same prominence, that the potential quantity, quality, and content, as appropriate, are conceptual in nature, that there has been insufficient exploration to define a Mineral Resource, and that it is uncertain if further exploration could result in the determination of a Mineral Resource.

Exploration Targets (conceptual or with identified Mineralisation) may not be included in a Technical Study (at Scoping, Pre-Feasibility, or Feasibility level) and may not be converted to Mineral Reserves. They may not be included in economic assessments or discounted cash flow (DCF) models, nor be included in valuations based on Income Approaches. Given the levels of uncertainty surrounding the supporting data, the quantity (volume or tonnage) or quality (grade and value) of an Exploration Target may not be reported as a '*headline statement*' in a Public Report.

It is apparent that, in each of the examples or case studies presented, the Exploration Targets have merit, based on their regional setting, association with known deposits and/or limited prospecting data. However, the paucity of sample data, lack of confidence in the data or lack of demonstrated reasonable prospects for eventual economic extraction means that they cannot be classified as Mineral Resources.

REFERENCES

De Decker, R. H. (2005). *Report on a field visit to the Midamines Concession on the Kwango River, DRC to assess the potential for Diamond Mining.* Noordhoek: De Decker and Associates Consulting Services.

Marshall, T. R. (2014). *Desktop Study of the Bobi Diamond Project, Seguela, Cote d'Ivoire.* Johannesburg: Explorations Unlimited.

CIM Standing Committee on Reserve Definitions. (10 May, 2014). *CIM Definition Standards - For Mineral Resources and Mineral Reserves.*

PERC. (March 2013). *Pan-European standard for reporting of Exploration Results, Mineral Resources and Reserves.* Brussels: PERC.

NI43-101CP. (June 30, 2011). *Companion Policy 43-101CP to National Instrument 43-101 Standards of Disclosure for Mineral Projects.* CIM.

JORC. (December 2012). *Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves.* AusIMM.

Clay, A. N., Orford, T. C., Dyke, S., Myburgh, J. A., & Mphahlele, K. (2014). *Independent Competent Persons' Report on the Moeijelik Chromite Mineral Asset prepared for Bauba Platinum Limited.* Johannesburg: Venmyn Deloitte.

SME: The Resources and Reserves Committee of the Society for Mining , Metallurgy and Exploration, Inc. (June 2014). *The SME Guide for reporting Exploration Results, Mineral Resources and Mineral Reserves.* Englewood, CO: SME.

Mullins, M., Hodkiewicz, P., McCluskey, J., Carey, C., & Terry, J. (2014). Estimating and Reporting Potential Mineralisation at BHP Biliton - the Unconstrained View. (AusIMM, Ed.) *Monograph Series (Australian Institute of Mining and Metallurgy), 30*, pp. 791-798.



Tania Ruth Marshall

Geological Consultant
Explorations Unlimited

Tania R Marshall has been actively, and continuously, involved in the alluvial diamond exploration/mining industry since 1985. She started her career with GFSA, before joining a small private company, prospecting for diamonds and other precious stones up and down Africa.

In 1996 Dr Marshall founded EXPLORATIONS UNLIMITED and has since been involved in consulting and contracting to both South African and international companies involved in the exploration and mining of alluvial diamond deposits. She has worked actively in Africa, South America, Australia and Asia.

In addition to consulting, Dr Marshall continues to write and lecture widely on the subject of alluvial diamond deposition, exploration, evaluation and valuation, in which fields she enjoys an international reputation. She sits on the SAMREC and SAMVAL Committees and is currently the Chair of the SAMCODES Standards Committee (SSC).

Industry best practice for the collection and validation of exploration data with particular reference to a drilling programme

R. McKinney

Coffey Mining (SA) Pty Ltd, Johannesburg, South Africa

The importance of a validated database is often overlooked and it is assumed that if the data runs in a modelling program then the data must be clean. Frequently the data from an exploration programme is not held in a relational database, and there is then an increased risk of it containing errors. A combination of errors can potentially result in some very misleading data that can reduce the confidence in all subsequent work based on the exploration data, lead to incorrect and expensive decisions being made, and ultimately affecting the potential outcomes of the exploration programme. Although errors cannot be eliminated entirely, database validation involves a systematic check of all the aspects of the data collected during the exploration phase so that any remaining errors become irrelevant or the level of risk is made quantifiable by identifying the location and extent of the error. This paper, using a drilling programme as an example, systematically goes through the steps and checks that should be taken when capturing and storing the data, the situations where errors can occur, and the issues that can arise if errors are not discovered, scrutinized, and corrected.

INTRODUCTION

The importance of having a validated database is often overlooked, with the potential effects that incorrect data may have on the outcome of the project not being perceived until it is too late. Taking a project to the next phase, whether that be more exploration work, a feasibility study, or developing a mine, relies on the quality of the resource and reserve estimates as well as assessments of the host rock stability, mining method, and processing requirements. The data collected during the drilling phase is relied upon to provide the technical basis for the resource estimation and interpretation.

A combination of errors can potentially result in some very misleading data that can reduce the confidence in all subsequent work based on the exploration data, lead to incorrect and expensive decisions being made and ultimately affect the outcomes of the exploration programme. Therefore, if the database is not validated and contains inherent issues, then the confidence placed on the resource estimation and all decisions pertaining to it is low. All reporting codes require a certain level of confidence in the data, and therefore in the resource estimation, before a project can progress to the next stage.

Although error cannot be eliminated entirely, database validation involves a systematic check of all the aspects of the data collected during the exploration phase so as to ensure that remaining error becomes irrelevant, or the level of risk is made quantifiable by identifying the location and extent of the error.

Some projects hold the exploration data in a relational database (a database where it is possible to define the domain of values in a data column, add further constraints that may apply to that data value, and relate the data held in multiple tables to one-another). While relational databases can certainly reduce errors as they can check and flag problems such as missing intervals, overlapping intervals, and incorrect codes, they are not infallible. Human error at the initial collection and input phase can introduce errors that a computer program will not pick up, and therefore certain procedures and protocols can and should be undertaken to minimize these errors. In many instances the scale and budget of an exploration project preclude the use of a relational database due to the cost of the program and setting it up to hold the required information. When a relational database is not used, it is even more important to ensure correct capture and storage of the information.

This paper, using a drilling programme as an example, will systematically go through the steps and checks that should be taken when capturing and storing the data, the situations where errors can occur, and the issues that can arise if errors are not discovered, scrutinized, and corrected. The information is based on proprietary procedure manuals as well as the author's personal knowledge.

It should be noted that data from a channel sampling or trenching programme can be treated in essentially the same way. Point data, for example from a soil sampling programme or grab sampling, is much simpler but some of the validation processes can still be applied to check the validity of this type of data.

PROCESS OF DATA CAPTURE

Data capture should begin the moment an exploration project begins. Many companies have their own internal procedures and protocols when it comes to an exploration programme; however, it is nearly always necessary to tailor them to the specific project about to be undertaken. It is the responsibility of the project geologist to ensure that the procedures and protocols are suitable for the specific type of exploration being done, as well as the expected mineral target and orebody type, and to ensure that the logging geologists have been properly trained

.

If codes are to be used for various data then the acceptable codes, together with their meaning, how they are determined, and where they are referenced (*i.e.* the exploration/logging manual) need to be decided in advance and the logging geologists advised. If new codes are subsequently deemed necessary they should be queried and accepted by the project geologist in consultation with the exploration manager before being added to the code lists and used. When this does not happen a database can contain multiple codes describing the same thing or alternatively, codes for which the meaning is unknown.

In many instances the initial logging of core is done on paper log sheets, designed to capture the specific data that is appropriate for the project. If this is the case then it is preferable for the geologist to enter their own data into an electronic format. If, however, a data clerk captures the data on the geologist's behalf it is the responsibility of the geologist to ensure it has been captured correctly, as errors can arise due to poor handwriting or the data clerk not understanding the data and therefore not knowing what may be incorrect. This can lead to typing errors, number transpositions, the use of incorrect codes, and missing essential information, for example. If this is deemed the most efficient and cost-effective method of data capture then providing the data clerk with an electronic data-sheet with embedded codes and some training in what is required is highly recommended. It is also recommended that more rigorous checks and balances should be put in place to ensure correct data capture. Figure 1 shows a generalized flow diagram for data capture.

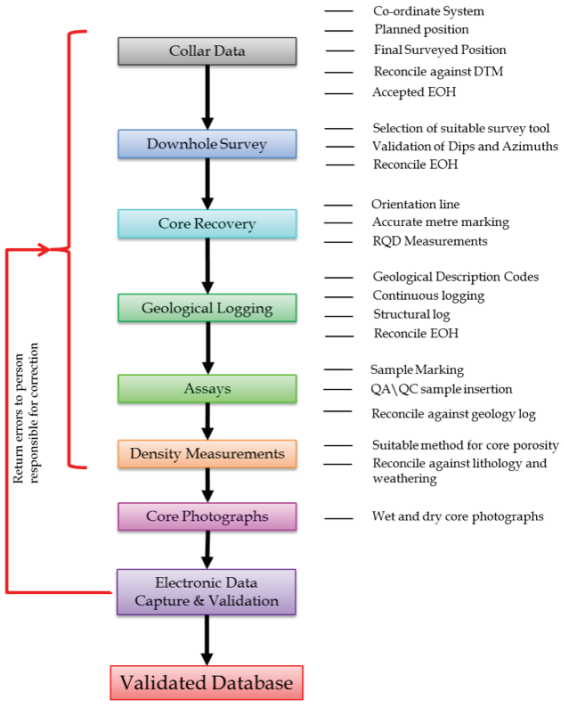


Figure 1. Generalized flow diagram for data capture.

A safer method for data capture is for the geologist to enter the information in an electronic format, whether that be an Excel file or a database program on a tablet, PDA, laptop, or other suitable electronic device. In the case of entering directly into a database program the geologist can run basic validations to ensure correct capture before moving onto the next drill-hole. The database can also be set up to accept only specified codes and often will not allow the entry of incorrect data.

If the data is captured in separate files or worksheets, then there should be a dedicated database manager to ensure that all the data is compiled, validated, and entered into the master database. Access to the master database should be limited to as few staff members as possible and regular validations should be the responsibility of the database manager. Any queries or issues should be reported back to the field staff and rectified timeously within the database as well as in all original paper or electronic files Version control is also the responsibility of the database manager. The frequency of the validation process depends on how the data is initially captured and the quantity of data being produced. On a project with multiple rigs and logging geologists it is recommended that the data be validated on a weekly basis.

Collar Data

The collar positions are determined initially during the programme planning phase. The grid spacing is determined by the expected deposit and mineralization type as well as the required level of resource confidence that the company is aiming for. Initial siting of the boreholes is invariably by means of a handheld GPS, which has limitations depending on the available satellites and vegetation coverage. The elevation reading is particularly inaccurate. Usually, a survey of the collar positions would be undertaken by a qualified surveyor to improve accuracy of the coordinates once the borehole has been completed. It is important that the coordinate system used on the handheld GPS, as well as by the surveyor, be confirmed appropriate for the region, and this should be agreed upon before work commences.

Once the data has been collected the collar positions should be checked to ensure that they plot where expected *i.e.* within the licence boundary, and if available, on a topographical map to confirm they relate to geographical features as they should.

The planned *versus* final surveyed position should be correlated. If a hole has moved significantly from the planned position it should be checked to confirm that there was a viable reason for this *i.e.* access restrictions to the planed site.

A further check, if available, is to confirm that the collar positions correlate to a digital terrain model (DTM). This is particularly useful in picking up errors in the collar elevation.

Confirmation that the coordinates are in the correct geographical and datum system is also important, especially if there are multiple phases of drilling on the project and these have been undertaken by different companies. It is recommended that the coordinate system is stored in the collar table within the database to guarantee that the same coordinate system is used throughout the project life-cycle.

An example of this type of error is from a coal project where the second phase of drilling was managed by a different contactor. This company did not confirm with the client the coordinate system that had been used during Phase 1. When the Phase 2 holes were plotted along with the Phase 1 holes, it was noted that two boreholes fell outside the licence boundary (Figure 2). This was investigated and it was confirmed that the boreholes fell within the licence on the ground. It was finally determined that the contractor had used a UTM system rather than ARC 1950 in the database, resulting in a 300 m variation in the northing.

Finally, the borehole ID names should be checked to ensure that they are identical in all the data tables in the database, for example, BH0101, and not BH101 or BH-101, as a computer program will see these as different holes and will not be able to link the information.

The collar file in a database often holds the end-of-hole (EOH) measurement. This EOH measurement should reflect the end depth of the drilling and therefore should be identical in all tables where the file information extends to the end of the hole, *e.g.* geology, downhole survey, geotechnical, RQD *etc*. If this is not the case, then during validation errors can occur showing missing intervals or intervals beyond the EOH. Some database and modelling software programs do not allow such errors and therefore they need to be corrected.

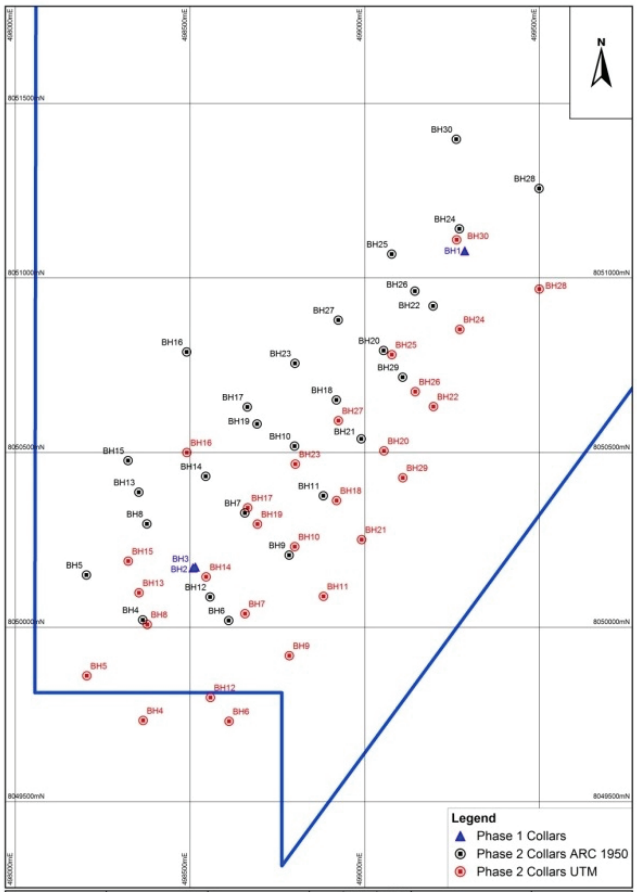


Figure 2. Borehole plan showing variation in co-ordinate systems.

Downhole Survey Data

A downhole survey can be carried out using a number of different tools, and depending on the tool used it can be affected by outside influences. It is therefore very important to check the downhole survey information and flag any entries that fall outside expected ranges.

The most important information in a downhole survey is the dip and azimuth readings. Sudden wild variations in either of these readings should be queried. If the downhole survey included magnetic strength readings these can be correlated against the flagged entries, as variations could indicate that a magnetic stratigraphic layer is affecting the tool. It can also indicate that the instrument was not protruding far enough below the casing and/or drill string when the reading was taken and therefore the steel is interfering with the reading. If an issue is noted a general correction factor can be applied, or alternatively an average from readings either side that have been deemed acceptable. When this has been done it should be noted in the database for audit purposes.

If the stratigraphic units within the borehole are known to be strongly magnetic, then a gyroscope or optical tool should be used as these are not affected by magnetic influences, but they are dependent on correct collar surveys.

In databases that combine surface and underground drilling it must be ensured that the dip has been correctly assigned as a positive or negative value. Generally, the dip of a surface borehole should be negative and that from an underground hole drilled towards the surface should be positive.

In instances where the reason for unexpected variations is not immediately apparent, alternative causes should be investigated. Figure 3 shows an example of drill-holes through a kimberlite pipe

where the host rock was hard magnetic basalt. The initial downhole survey intimated that there had been some deflection of the hole as it passed through the contact from the basalt into the softer kimberlite. It was initially assumed that this, combined with the steeply dipping contacts, caused the decrease in dip of the hole. However, further investigations revealed that the survey tool being used was faulty and produced incorrect dip readings. An EMS tool was used to take a new set of dip readings and the survey file was corrected. If this had not been identified the final model would have been very different, causing erroneous decisions to be made.

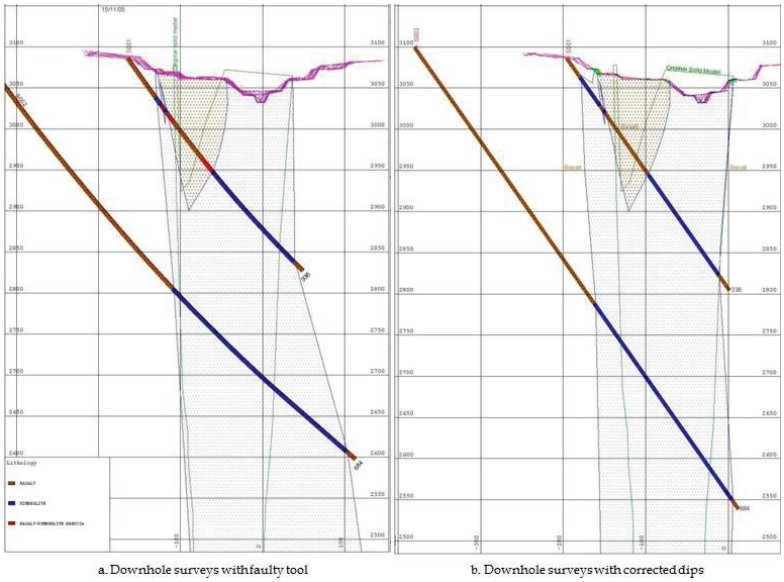


Figure 3. Cross-sections showing incorrect and corrected downhole surveys.

Excessive variations in the dip and azimuth can also be caused by sudden changes in the hardness of the stratigraphic unit or the dip of the strata, and therefore in these instances should not be altered. Figure 4 is an example of drilling through steeply dipping strata. In this instance, when the drill bit encountered a steeply dipping contact at an oblique angle, the propensity is for the bit to deflect towards the normal to the bedding plane. Thus, as in Figure 4, the hole is deflected up and the dip angle becomes shallower as it passes through each stratigraphic layer.

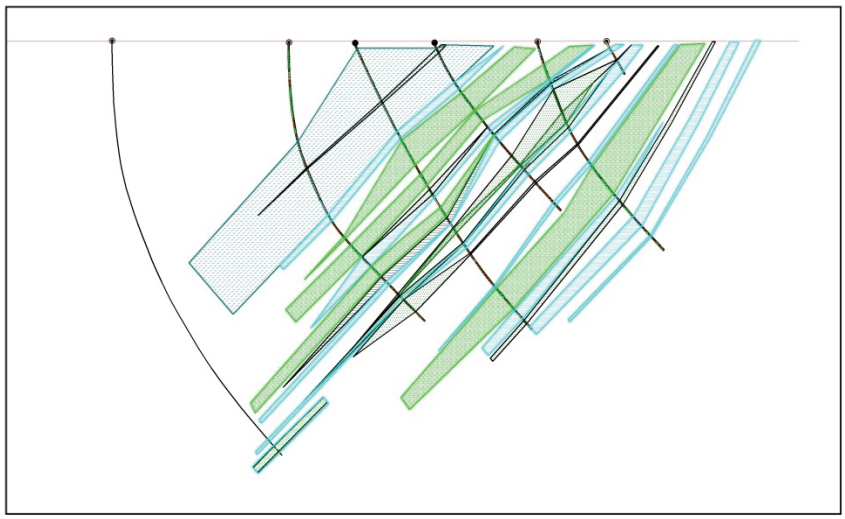


Figure 4. Cross–section showing dip variation due to steeply dipping strata.

Core Recovery
Core recovery measurements should be done before any other logging/sampling of the core is undertaken. The drillers place a block at the end of each run, noting the depth and any core loss or gain within the run. This information is rarely accurate and needs to be verified before the core is logged. Core should be accurately aligned and fitted together with an orientation line drawn on the core.

The data captured usually includes core run intervals, actual length of core recovered as well as the recovery expressed as a percentage, and often the rock quality designation (RQD) which is the combined length of core pieces that are 10 cm or more in length expressed as a percentage of the core run length. Weathering of the core may also be noted.

This log should be a continuous assessment of the core and therefore should not contain any gaps in the intervals recorded. The depths recorded for each core run should be checked to ensure they have been captured correctly. The core recovery and RQD are calculated as percentages and any values that fall above 120% should be queried.

After the core recoveries have been measured and accepted, accurate metre marks should be drawn on the core. It will be these metre marks that determine the accuracy of all subsequent logging and sampling.

Geological Data
The geology table is one of the most important tables in the database and often has the most errors as a result of human input.

A common occurrence is the incorrect entry of the depths associated with each lithology. It is very easy for these numbers to be incorrectly entered into the database and numbers to be transposed. This in turn can cause overlapping entries or gaps between entries. It is generally considered industry best practice that the geological data has consecutive entries without gaps. If there is core loss this should be included in the log.

The geological data is usually codified with codes for the data captured rather than the full name so as to minimize the size of the database. If the codes are not rigorously monitored or restricted then multiple codes meaning the same thing clutter the database. Where data is captured directly into the database during logging the codes can be restricted by the user selecting from an accepted dropdown menu. However, if logging is done on paper and entered into an Excel spreadsheet, for example, codes are not necessarily defined in the sheet and again typing errors can occur. The codes used in a database should be determined, where possible, at the beginning of a drilling programme and regularly monitored throughout the collation of the data. If during a drilling programme a new code is required, then the project manager and database manager must collaborate to ensure a suitable code is chosen before added to the accepted list.

In conjunction with the above, the description of the lithology should be checked against its allocated code to ensure the correct code was selected during input. It is very important to maintain a list of all the codes and what they stand for within the database so that they can be referred to at any time. Frequently when databases are passed between different companies the code descriptions are lost, and if standard codes are not used then it can become impossible to determine what they meant. Where possible, common abbreviations should be adhered to, such as *sh* for shale, *ss* for sandstone, *gn* for gneiss *etc*., as the close similarity to the lithological name makes the abbreviation easier to decipher.

Density Measurements
During a diamond drilling campaign the densities of the rock types are often determined. This can be done using a variety of methods either in the field or by the laboratory when assaying the samples. A common way to deduce the bulk density in the field is by Archimedes' method. Once the core has

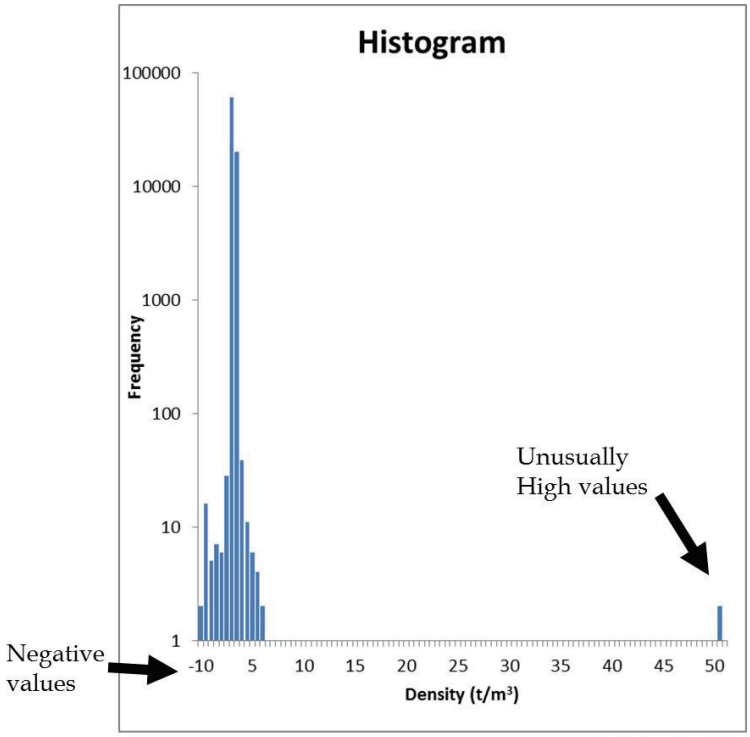
been marked and cut for sampling purposes, each sample is weighed in air (dry weight) and again in water (wet weight), and these measurements are used to calculate the bulk density of the sample. This is usually done by a field assistant and, as with the geological data, is susceptible to human error during data capture either on the hard copy or during entry into the electronic database due to transposition of numbers. When measuring the wet weight of the sample it must be ensured that the sample is fully and properly submerged in the water, otherwise the resulting density will also be incorrect. Poorly measured densities can affect the overall estimated tonnage and therefore the resource estimation.

Once the data has been captured and the density for each sample calculated, then all densities outside reasonable limits for the deposit should be flagged and checked. Generally speaking, most lithologies should fall between 1 and 5 g/cm^3 with a few exceptions. The measurements captured for the flagged samples should be queried with field staff and re-measured to confirm or correct the density.

Once a reasonable data-set for the project area has been obtained, a further check is to sort the densities measured by lithology type and an acceptable range for each lithology can be determined for the project area. All samples falling outside these acceptable ranges can then be queried and re-measured.

It is also important to indicate the amount of weathering the sample has undergone. The more weathered the sample, the lighter it will be, and this will result in an inaccurate dry weight measurement. Also, a weathered sample will be more porous and absorb water when submerged, giving an inaccurate wet weight measurement. A method of sealing the weathered sample, such as using paraffin wax, varnish, or clingwrap, should be considered if the orebody is from close to surface and in the weathered zone in order to obtain more realistic densities, but the weights of these substances must also be taken into consideration in the calculation.

An example of a project where the densities obtained were not sufficiently scrutinized is a Bushveld Complex platinum project. The calculated densities in the database ranged from -5179 to 1823.5, with the majority of the values falling between 2.0 and 3.4 (Figure 5). A number of the outliers were due to only the dry or wet measurement being captured, but the density was still calculated in the database. The other values, falling closer to acceptable limits but still unusual for the lithological types, were mostly due to transposition of numbers during data capture or poor measuring technique. None of the densities had been queried or followed up before a resource estimation was requested.



	Original	Without outliers
Mean	2.89	2.93
Standard Error	0.07	0.00
Median	2.93	2.93
Mode	2.92	2.92
Standard Deviation	19.28	0.12
Sample Variance	371.68	0.01
Kurtosis	65,226.83	22.07
Skewness	- 228.66	- 0.11
Range	7,002.50	4.85
Minimum	- 5,179.00	0.31
Maximum	1,823.50	5.16
Count	81,243	81,210

Figure 5. Histogram plot of density measurements.

Assay Data

This is the most significant data table, alongside geology. The accuracy of the resource estimation and all following decisions made on the project hinges on this information. The information contained in this data file comes from two sources, field data such as depths, lithology, and sample ID and the actual assay results received from the laboratory. As described above for the geology file, most errors are due to data capture mistakes causing overlaps, gaps, or assay intervals that extend beyond the EOH. The difference with this file is that depth interval gaps within the data are acceptable in some instances; the entire hole does not always require sampling and samples should ideally not include core loss. It is therefore more difficult to pick up those errors causing incorrect gaps in the intervals, such as typing errors.

For this reason, sampling protocols initiated at the beginning of an exploration programme that are developed for the specific deposit under investigation become important. By setting out guidelines as to what should be sampled, the minimum and maximum sample length, whether geological

boundaries should be strictly adhered to *etc.*, it is then possible to run validations to check for errors using these protocols.

Apart from using the database program's automatic validation queries to check, another useful method is to create downhole plots of the information, which allows for confirmation that data from a number of the tables correlates correctly. Sample intervals can be matched to the lithology from the geology table to confirm that geological boundaries have not been crossed, that sample intervals do not include core loss, or that samples are not unusually short or long (Figure 6). A combination of both types of validation checks, automatic and visual, ensures that confidence in the data is high.

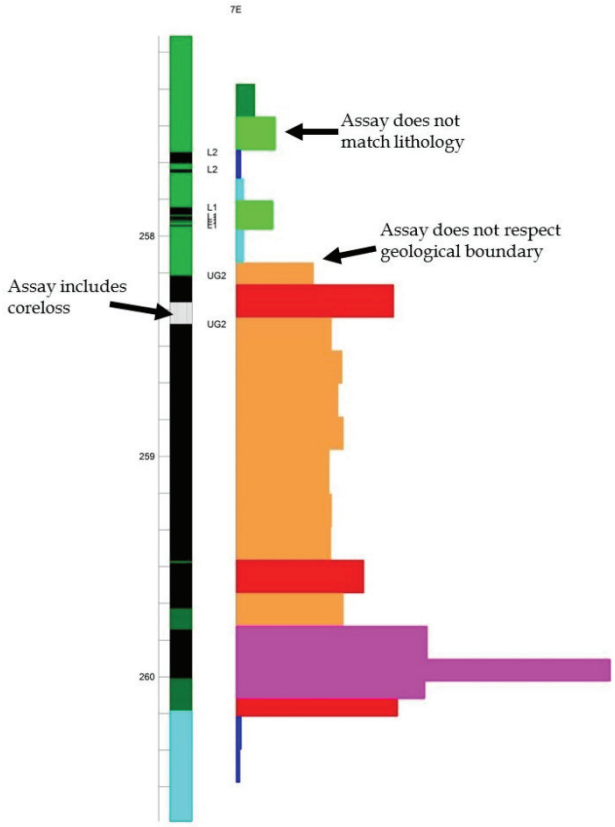


Figure 6. Downhole plot correlating geology and assay data.

As mentioned above, data in this table also comes from the laboratory and will, in most cases, be merged into the database. Care needs to be taken that in every instance the correct result imports into the correct column as well as to the correct sample ID. The assay certificate from the laboratory may not always list the elements assayed in the same order, and may not always capture the sample IDs identically to how they have been captured in the database.

Factors are also sometimes applied to change the unit of measurement of the results from parts per billion (ppb) to parts per million (ppm), or ppm to percent, depending on what the laboratory supplies *versus* what is wanted in the database. Care must be taken that the correct factors are applied to the correct elements.

Finally, there is the treatment of a result being returned below the detection limit of the laboratory method. It is generally deemed industry best practice to replace these results with half the detection value so that calculations can be carried out and results graphed. This cannot be done when the entry in the database consists of a symbol or a default figure such as -99. Care must be taken when undertaking such alterations manually to ensure they are done correctly.

Another useful method of validating the results is to visually check them by adding them to the downhole plots to ensure, for example, that high grade values occur within the correct reef package or lithology.

Any inconsistencies that cannot be attributed to data capture, manual manipulation, or failed merges should be queried immediately with the laboratory, and where necessary re-assaying should be requested as samples can be transposed during the preparation stage of analysis.

Although quality assurance and quality control (QA/QC) analysis is not discussed in detail in this paper, it should be noted that it is an important part of assay data validation. It is a requirement of most reporting codes that QA/QC be undertaken during a programme, but the importance of regular graphing of the QA/QC sample results is often underestimated. The volume and frequency of results being returned should determine how regularly these results are analysed. If issues due to laboratory methods or protocols are not discovered until the end of a project, then they are almost impossible to rectify and confidence in the assay results will be low.

In order to ensure the QA/QC graphs reflect the correct data and are therefore assessed properly, the following issues need to be identified:

- A standard has been transposed with a real sample
- A different standard has been logged into the database or inserted into the sample stream
- Contamination of samples has occurred during the preparation process in the laboratory by the insertion of blanks.

Correcting or highlighting such mistakes timeously in the database will also mitigate a circumstance where the wrong assay values are included in calculating the grade intersection of a hole or the entire deposit.

Other Database Files

Depending on the mineralogy, structure, or deposit type being evaluated there may be other tables in the database, such as geotechnical or mineralization. Generally, the validation methods discussed above can be adapted and applied to fit the specifics of the data held within each table.

CONCLUSIONS

All errors or issues with the database should be recorded and queried with the field staff while they are still on site so that they can be checked and corrected. Hard-copy logs should be corrected as well as working field-data files, and the full database and the different versions of data tracked accurately to ensure the final version is correctly used in the database. Correct storing and archiving of all files, whether hard-copy or electronic, is ultimately the responsibility of the project geologist. Doing these checks during the exploration programme ensures that the data handed over for resource estimations and all that follows is correct and of a high quality and confidence, and adheres to the various reporting codes.

After the project is complete, it is often not possible to regain access to the site or to the core to check and verify data. In some instances the whole core may have been sampled and therefore no longer exists. Guesses would have to be made to fix validation issues so that the data runs in the modelling software, and thus the confidence in the database would be lower and the risk to all subsequent work higher.

REFERENCES

Morel, V. and McKinney, MW. (2006). Coffey Mining Drilling Procedures Manual. Coffey Mining.

Van der Merwe, A. (2002).- RSG Global Compliant Field Procedures. RSG Gobal.



Rachel Louise McKinney

Database Manager
Coffey International

I have 17 years of experience in exploration geology and have worked in various parts of sub Saharan Africa. I have been involved in a number of different projects on various commodities including platinum, iron ore, gold and base metals, from grass roots to feasibility stage. For the last 7 years I have been the database manager at Coffey and have worked on a number of large resource drill outs in southern Africa which has included data compilation, validation, assay and QA\QC analysis as well as assisting with the compilation of code compliant reports.

Best-practice sampling methods, assay techniques, and quality control with reference to platinum group elements (PGEs)

Ken Lomberg

Coffey Mining (SA) Pty Ltd

In this paper the process of sampling and assaying as it relates in particular to the platinum group elements (PGEs) or metals is presented. A discussion of the geology of the deposits is included to provide an understanding of the mineralization that is considered necessary prior to sampling, as this has a direct bearing on the mineral resource estimate and also the selection of an appropriate mining cut. The discussion includes the selection of the sampling technique (drilling or face sampling), the size of the sample relating to the requirements of the laboratory, the potential mining cut, as well as a reference to sampling theory. The selection of an appropriate assay technique that will yield the optimal result based on sample turnaround, precision, accuracy, and cost is discussed. Examples are drawn from work undertaken on the Bushveld Complex (Merensky Reef, UG2 Chromitite Layer, and Platreef) and Great Dyke (Main Sulphide Zone). A discussion of the appropriate QA/QC programme includes the chain of custody, CRM selection, and the QA/QC process.

INTRODUCTION

The exploration and exploitation of platinum group element (PGE) or metals deposits is very challenging due to the very low ore grades, which can be close to the detection limits of the assay techniques, as well as factors such as the significant nugget effect. This emphasizes the need for a good understanding of the geology of the deposits and the reef mineralization in order to choose appropriate exploration technique, and the application of industry-standard sampling and assay techniques when developing these projects.

The foundation of mineral resource estimate is a geological model and valid data. The data that forms the basis of an estimate includes geological logs, borehole collar positions, downhole surveys, and assay data. Where underground data is utilized, face sampling data would be used and would have the same data characteristics as drilling data, *i.e.* position of the cut, the associated geology, and the assay data. The data is interpreted and used to develop a geological model. The raw data is examined, various statistical analysis undertaken to understand it, and possible relationships between the assay and the geology examined before incorporating the data into a mineral resource estimate. This estimate relies on the well-established understanding of the geology and the recognition of the economic horizons, the mineralization continuity, controls on mineralization, and ore genesis.

A mineral resource estimate for a PGE deposit has many aspects in common with those for other deposits, but also has its own unique aspects. Notably the estimate relies on the determination of a mineralization zone or mining cut because the grade is dispersed vertically across a number of horizontally stacked stratigraphic units and lithologies. Thus the determination of the marginal grade cut-off and the optimization of the mining cut must be considered in the light of 'the realistic expectation of eventual economic extraction' (SAMREC, 2009). This is then an integral step towards the mineral resource estimate and is informed by the methodology and protocol of the sampling. Inappropriate sampling could produce a poor mineral resource estimate result.

INTRODUCTION TO THE GEOLOGY OF PGE DEPOSITS OF SOUTHERN AFRICA

PGE-dominated deposits occur in large layered intrusions, such as the Bushveld Complex (South Africa), the Stillwater Complex (USA), and the Great Dyke (Zimbabwe).

Bushveld Complex

The mafic rocks of the Critical Zone of the Bushveld Complex host layers rich in PGEs, chromium, and vanadium, and constitute the world's largest known resource of these metals. The Merensky Reef (Figure 1), which is developed near the top of the Critical Zone, can be traced along strike for 280 km and is estimated to contain 60 000 t of PGEs to a depth of 1 200 m below surface. The pyroxenitic Platreef mineralization north of Mokopane consists of a wide zone of more disseminated-style platinum mineralization, along with higher grades of nickel and copper than occur in the rest of the Bushveld Complex.

The Critical Zone also hosts all the chromitite layers of the Bushveld Complex, up to 14 of which have been identified (Figure 1). The most important of the chromite cycles for PGE mineralization is the upper unit, the UG2 Chromitite Layer, which averages 1 m in thickness.

The Merensky Reef has historically been the most important Au, PGE (Pt, Pd, Rh, Ru, Os, and Ir), and base metal (Cu and Ni) producing layer in the Bushveld Complex. The Merensky Reef varies considerably in its nature, but can be broadly defined as a mineralized zone within, or closely associated with, the ultramafic cumulate at the base of the Merensky cyclic unit.

In addition to the PGE mineralization associated with the Merensky Reef, all the chromitites in the Critical Zone contain elevated concentrations of PGEs. The UG2 is the only chromitite layer that is significantly exploited for PGEs at present.

Merensky Reef

The Merensky Reef is typically a feldspathic pegmatoidal pyroxenite, bounded top and bottom by thin chromitite layers. The chromite layers have variable thicknesses up to some 5 cm, with one being thicker than the other. The thinner may be absent. The pegmatoidal feldspathic pyroxenite (pegmatoid) consists of cumulus bronzite crystals, typically 10–20 mm in diameter, with interstitial plagioclase feldspar, and contains interstitial subhedral pyrrhotite and chalcopyrite blebs. .

The immediate hangingwall is a feldspathic pyroxenite (bronzite) typically 1–2.25 m thick, which grades upwards into a norite. Phenocrysts of diopside (approx 20 mm) are present within the feldspathic pyroxenite. The hangingwall typically contains sulphides (pyrrhotite and chalcopyrite) for some 50 cm from its basal contact with the Merensky Reef. The footwall is variable, consisting of the various noritic, anorthositic, and harzburgitic footwall lithologies.

The grade profile is concentrated around the pegmatoidal feldspathic pyroxenite, with the highest PGE concentration associated with the chromitites (Figure 2). The grade is not restricted to a single lithology or stratigraphic unit but is dispersed over a number of units, although typically centred on the chromitites and pegmatoidal felspathic pyroxenite of the Merensky Reef. The rocks immediately adjacent to the pegmatoidal pyroxenite are mineralized with PGEs. The tenor typically decreases

further from the chromitite stringers and pegmatoidal pyroxenites.

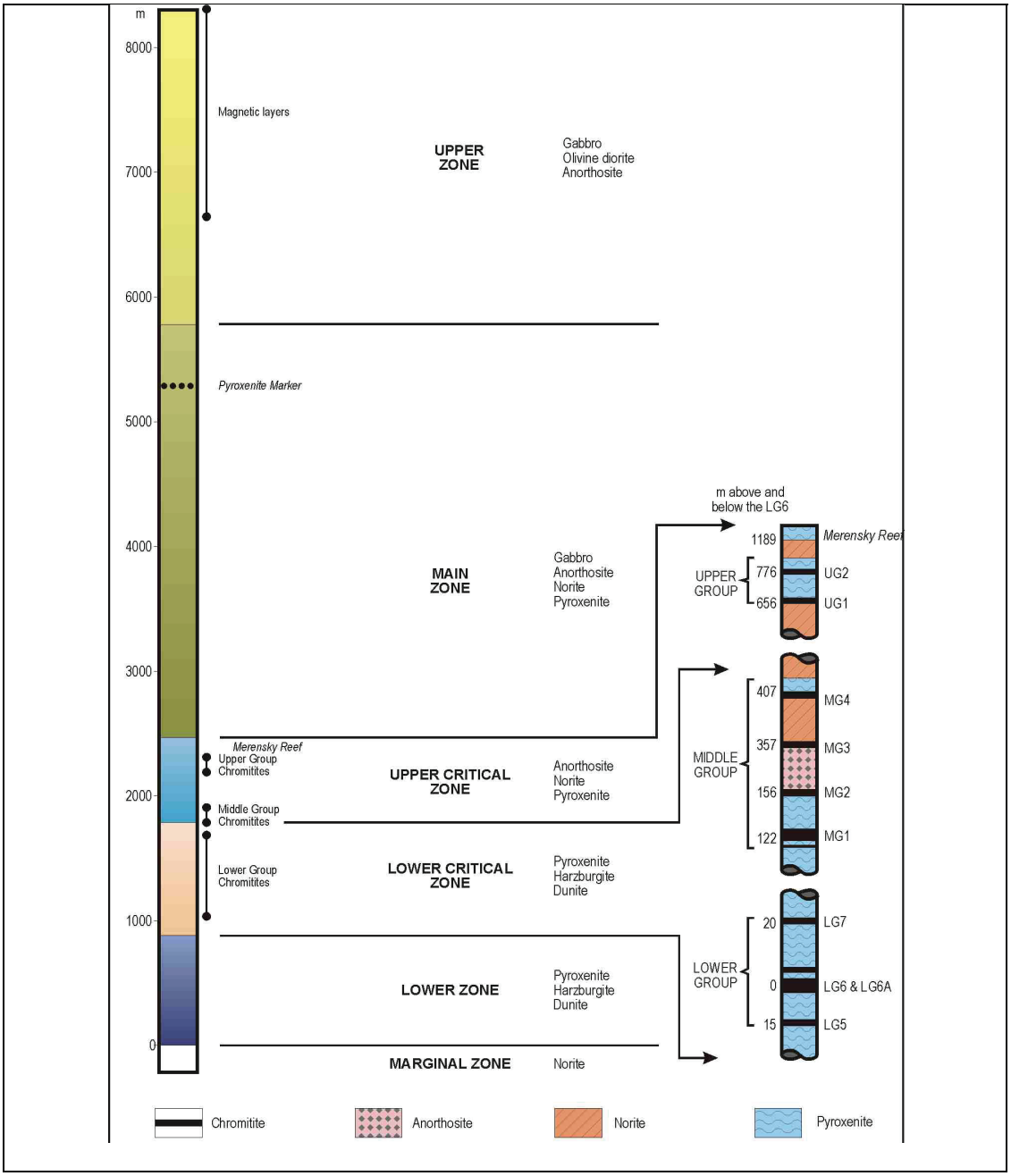


Figure 1. Generalized stratigraphic column of the Rustenburg Layered Suite, Bushveld Complex (after Viljoen and Schürmann, 1998).

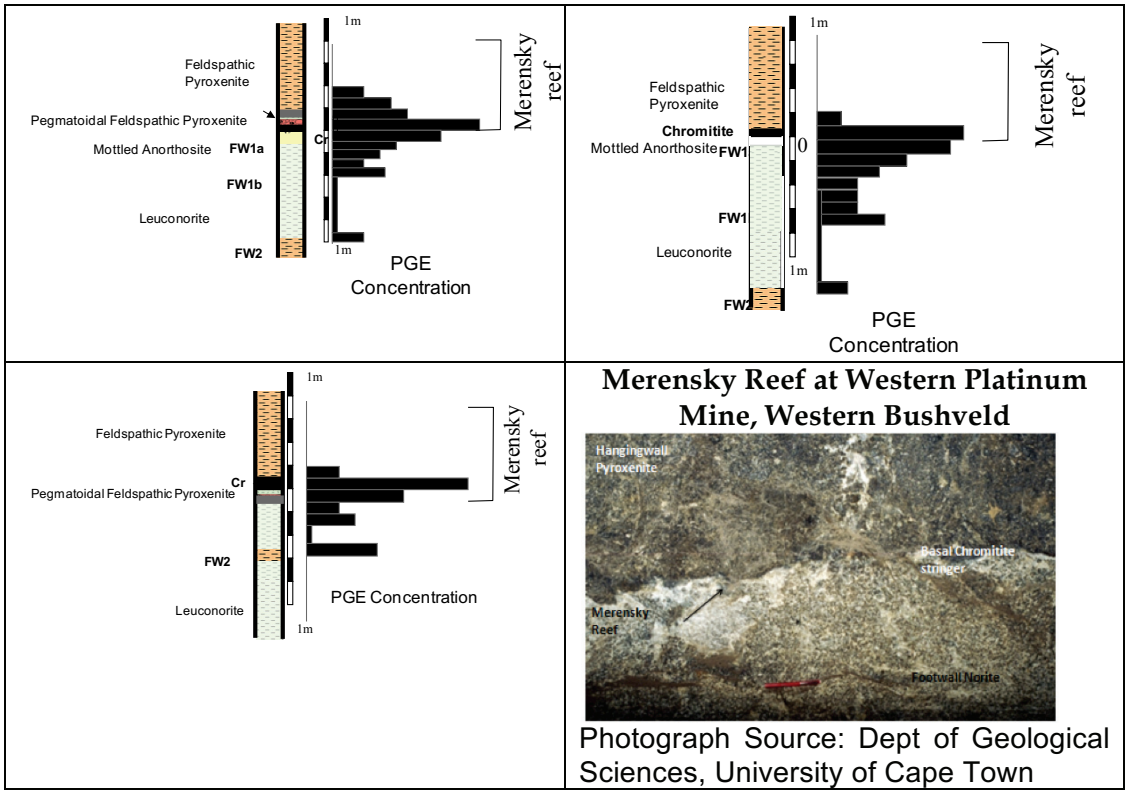


Figure 2. Schematic grade histograms of the Merensky Reef.

Sulphide mineralization extends into both the immediate hangingwall and footwall. In some cases the PGE mineralization characteristics of the Merensky Reef can be correlated with the nature of the footwall. For instance, where the footwall is noritic, the PGE mineralization does not typically extend more than a few centimetres into the footwall, whereas when the footwall is an anorthosite, fine-grained sulphides are frequently present with good PGE mineralization for approximately 40 cm, and more erratically to about a metre below the lower chromite layer. The PGEs encountered in this horizon are predominantly PGE-iron alloys and PGE sulphides. A number of schematic grade profiles are presented in Figure 3.

The importance of the sampling protocol applied is to define the grade profile from which a mining cut can be interpolated.

UG2 Chromitite Layer

The UG2 Chromitite Layer typically consists of a basal pegmatoidal feldspathic pyroxenite (up to 0.5 m thick) which frequently contains chromite stringers and which is overlain by the Main Chromite Layer (30–140 cm thick). A middling pyroxenite from a few centimetres to 6 m in thickness separates the Main Chromite Layer from the alternating chromitite and pyroxenite layers commonly referred to as the 'leaders' or 'triplets'.

The PGEs are associated with sulphides that are interstitial to the chromite grains. The mineralized zone itself is defined by the sharp basal contact with the footwall pyroxenite and the sharp contact at the top of the main chromitite layer. The grade profile typically peaks at the basal and top contacts (Figure 3).

The mineralization is generally associated with the Main Chromitite Layer. However, the mining method generally requires mining of the leaders as the lack of cohesion between the chromitite and pyroxenite typically results in falls of ground, which are dangerous and also dilute the mining cut. A pragmatic approach is to mine the overlying leaders at the same time. The sampling protocol allows

the determination of the grade profile for the mining package and provides important information on which strategic mining decisions are made.

Platreef

In the northern limb, the Platreef occurs proximal to the basal contact of the Bushveld Complex with the country rock, typically as a thicker zone (up to 30 m wide) containing disseminated sulphides and PGE mineralization (Figure 4). The Platreef is developed where the Bushveld Complex is in contact with the floor rocks, which comprise Archaean granite and sediments of the Transvaal Supergroup. The contact between the Rustenburg Layered Suite and footwall rocks in the northern limb is transgressive, with the Platreef in contact with progressively older rocks of different lithologies from south to north.

The Platreef consists of a series of pyroxenites and norites, containing xenoliths/rafts of footwall rocks. It is irregularly mineralized with PGEs, Cu, and Ni. The Platreef *senso stricto* has a strike extent of some 30 km, whereas Platreef-style mineralization occurs over the 110 km strike length of the northern limb (Kinnaird *et al*., 2005). The Platreef varies from 400 m in thickness in the south of the northern limb to <50 m in the north. The overall strike is NW or N, with dips 40–45° to the W at surface, becoming shallower down dip. The overall geometry of the southern Platreef appears to have been controlled by irregular floor topography.

Similar to the Merensky Reef, the importance of the sampling protocol applied is to define the grade profile from which a mining cut can be interpolated (Figure 4).

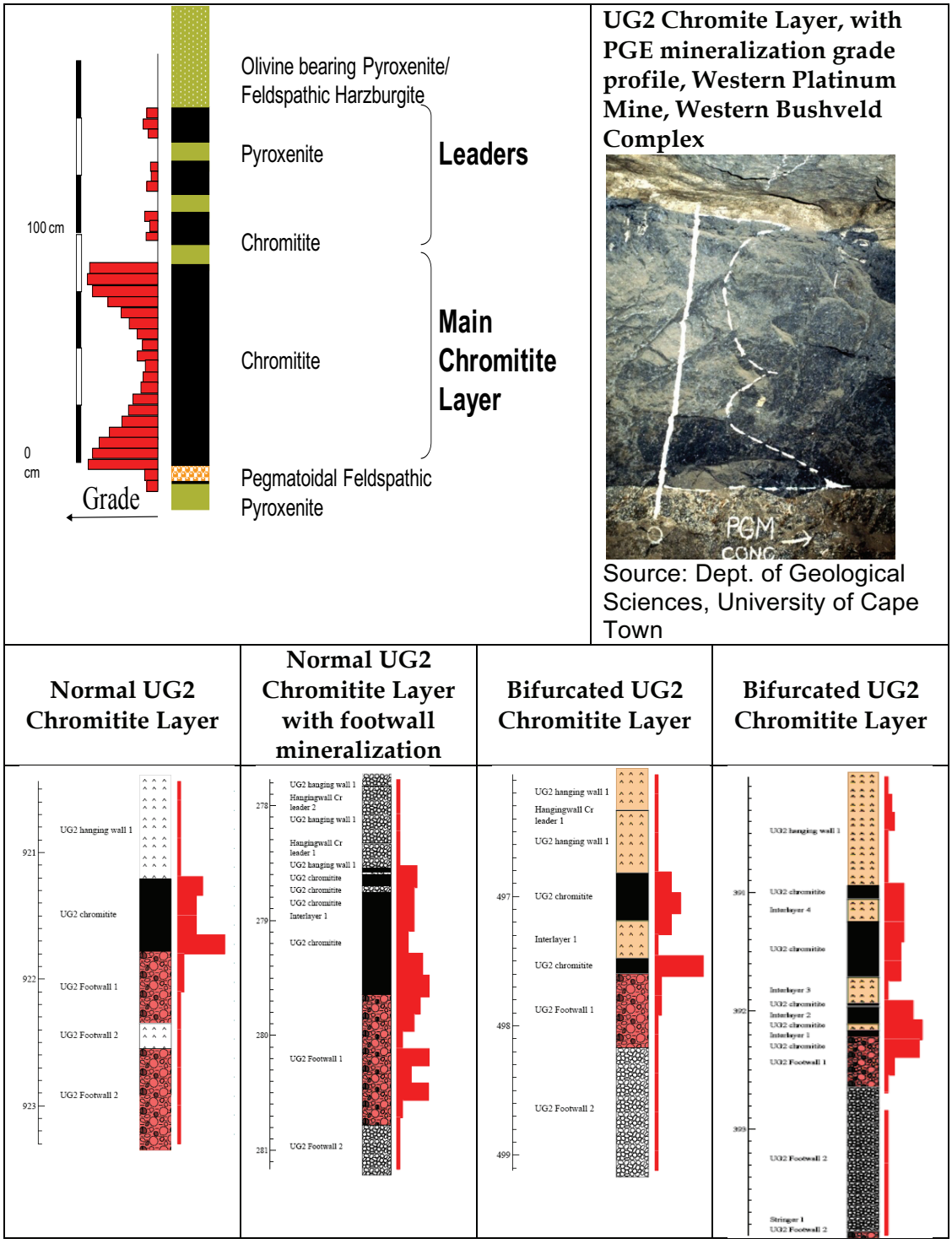
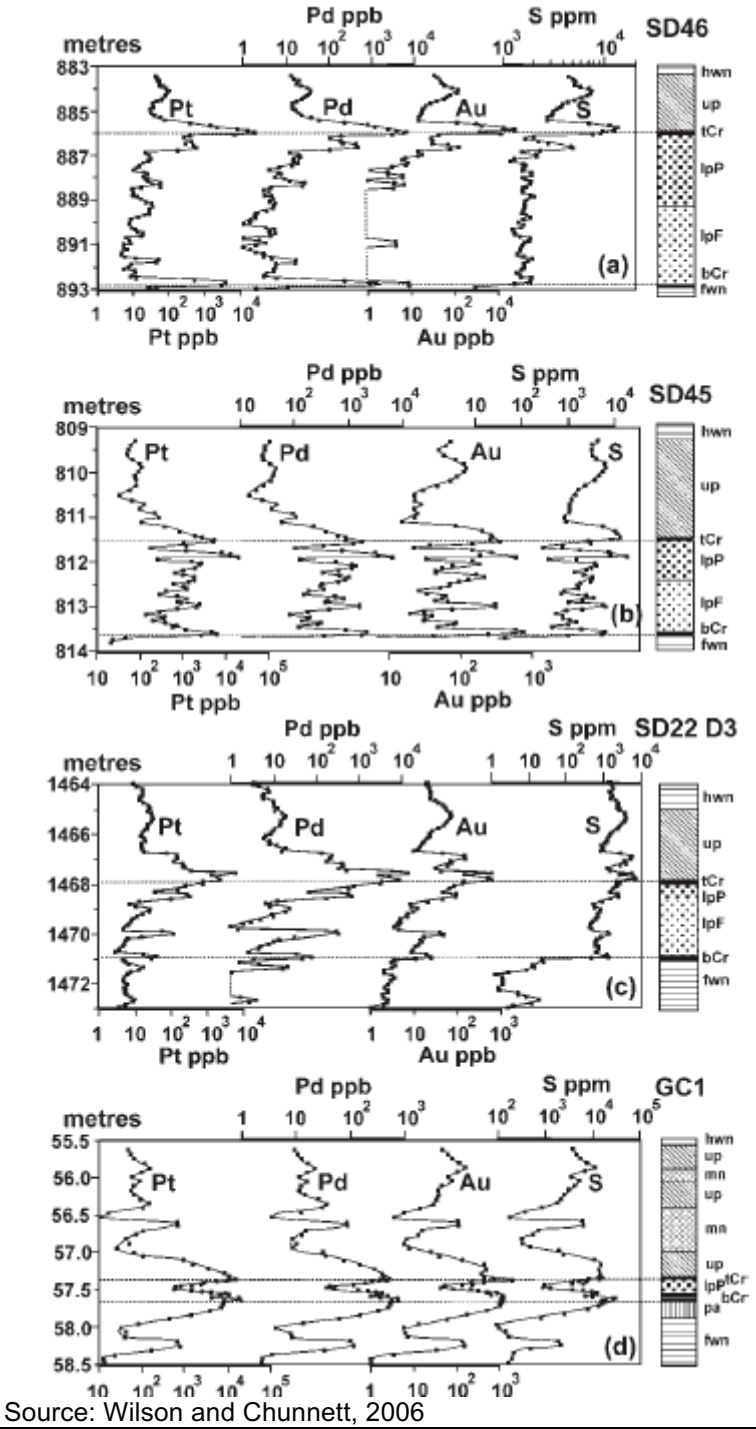


Figure 3. Schematic grade histograms of the UG2 Chromitite Layer (histogram examples courtesy of Anglo Platinum Corporation Limited).



Source: Wilson and Chunnett, 2006

Figure 4. Typical geochemical traces of the Merensky Reef.

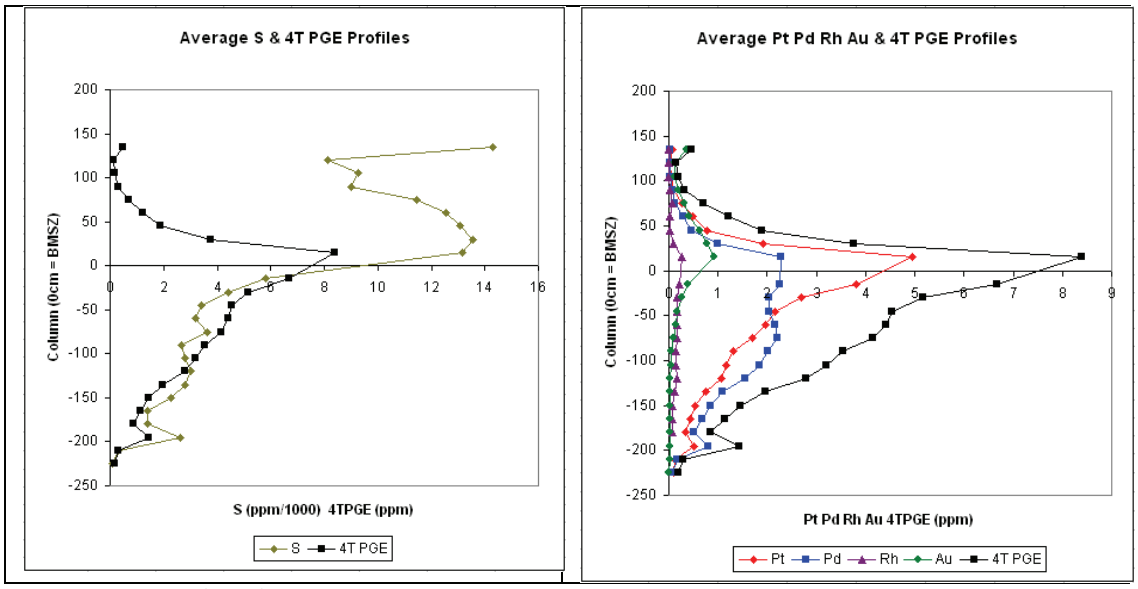
The Great Dyke

The Great Dyke is divided vertically into an ultramafic sequence, dominated from the base upwards by cyclic repetitions of dunite, harzburgite, and pyroxenite, as well as an upper mafic sequence consisting mainly of gabbro and gabbronorite (Wilson and Prendergast, 1989; Prendergast and Wilson, 1989). The P1 pyroxenite is contained within the ultramafic sequence, directly below the mafic-ultramafic contact. The P1 pyroxenite in turn hosts economically exploitable quantities of PGEs

in the Main Sulphide Zone (MSZ), which is generally 10 to 50 m from the top of the ultramafic sequence.

The MSZ is a lithologically continuous layer, typically between 2 m and 3 m thick, that forms an elongated basin. It generally contains iron-nickel-copper sulphides, while elevated PGE concentrations occur towards its base (Figure 5). The peak values for the PGEs and base metals are commonly offset, while the ratio between platinum and palladium also varies vertically. It is often difficult to visually identify mineralization in the MSZ. As a result the delineation of the MSZ is reliant on the geochemical signature and the location of the base of the MSZ (BMSZ). This point can be identified by looking down the sequence for where the sulphide mineralization ceases. The geochemistry reflects this with sudden drops in sulphur and associated base metal mineralization.

The optimally mineralized part of the MSZ is very difficult to identify. Therefore the application of a suitable protocol to the sampling can allow the MSZ to be distinguished and the optimal mining cut interpolated.



Source: Brown (2008)

Figure 1. Schematic geochemical profiles of the MSZ.

History of Sampling and Grade Control

The sampling protocols currently considered as industry-standard are based on the work done by a number of geologists working for the two major mining houses – Anglo Platinum and Impala Platinum Holdings – during the last 50 years. Considering that until the early 1980s the dissemination of information from the companies that predated these companies – respectively JCI and Gencor – was sparse, the methodologies developed were remarkably similar. The current best-practice guidelines are virtually the same, with variations in sample length, numbering, and assay technique being the most significant differences.

The practices have been developed with both mining and exploration in mind. On the operating mines, the mining cut instruction requires that the mining cut for the Merensky Reef be determined. This is based on sampling of the underground excavations. The determination of the mining cut for the UG2 Chromitite Layer is not required as the mining cut is typically defined based on the lithology rather than the grade alone. An additional criterion is the geotechnical analysis of the hangingwall. The final mining cut therefore considers the grade, metal content, and the geotechnical aspects of the chromite layers in the hangingwall. These are sampled as they are grade-bearing, albeit with a lower

grade than the main chromitite layer, and are associated with a weak hangingwall due to the lack of coherence between the pyroxenite and chromite. This generally leads to unsafe conditions, and therefore the leader chromitites are mined together with the main chromitite layer. However, in the project phase the details of the grades of these leaders need to be understood prior to the application of the mining factors.

Mineralogy

Merensky Reef
The PGEs are associated with the base metal sulphides. These sulphides, which constitute about 1–5% of the rock, consist of pyrrhotite (FeS_{1-x}) (40%), pentlandite ($(Fe,Ni)_9S_8$) (30%), and chalcopyrite ($CuFeS_2$) (15%). In addition, trace amounts of millerite (NiS), troilite (FeS), pyrite (FeS2), and cubanite (Cu_5FeS_4) are also present. The major platinum group minerals are cooperite (PtS), braggite ((Pt,Pd)NiS), sperrylite ($PtAs_2$), and PGE alloys, although in some areas minerals such as laurite (RuS_2) can be abundant (Schouwstra *et al*., 2000). Nearly 40% of the total PGEs observed on the Western Bushveld Joint Venture (WBJV) are sulphides and are larger than 1000 µm^2 in size (Muller, 2010)

UG2 Chromitite Layer
The UG2 Chromitite Layer consists predominantly of chromite (60–90% by volume) with lesser silicate minerals (5–30% pyroxene and 1–10% plagioclase) (Schouwstra *et al*., 2000). Other minerals, present in minor concentrations, include phlogopite and biotite, ilmenite, rutile, magnetite, and base metal sulphides. The platinum group minerals (PGMs) present in the UG2 Chromitite Layer are characterized by the presence of abundant PGE sulphides, They consist predominantly of laurite (RuOsIr), cooperite (PtS), braggite (Pt, Pd, NiS), and an unnamed PtRhCuS. The PGMs reach an average size of approximately only 12 µm, with particles larger than 30 µm being extremely rare (Schouwstra *et al*., 2000). They occur in association with the base metal sulphides and silicates. Oonly laurite exhibits a preferred association with the chromite grains.

Platreef
The major PGMs consist of PGE tellurides, platinum arsenides, and platinum sulphides (Schouwstra *et al*., 2000). There appears to be a link between the rock type and the type of PGMs, with serpentinites being characterized by a relative enrichment in sperrylite ($PtAs_2$) and the upper pyroxenites characterized by more abundant PGE sulphides and alloys. PGE alloys generally dominate mineralization closer to the floor rocks (Schouwstra *et al*., 2000). Common base metal sulphides include pyrrhotite, pentlandite, chalcopyrite, and pyrite, and with the PGMs frequently occur enclosed in, or on grain boundaries of, these base metal sulphides (Schouwstra *et al*., 2000).

Main Sulphide Zone
The MSZ contains between 0.5% and 10% sulphides represented mainly by pyrrhotite, pentlandite, and chalcopyrite in about equal proportions, as well as subordinate pyrite. The PGMs are typically included in pyrrhotite or chalcopyrite, sometimes in pentlandite, or they may occur at sulphide/sulphide or sulphide/silicate contacts, or within silicates. PGMs intergrown with pyrite are extremely rare. The suite of PGMs found in the MSZ includes (Pt,Pd)-bismuthotellurides (50.1%), sperrylite (19.0%), cooperite/braggite (8.5%), the PGE-sulpharsenides hollingworthite (RhAsS), platarsite (PtAsS), irarsite (IrAsS), and ruarsite (RuAsS) (11.9%), laurite (RuS_2), (5.0%), Pt-Fe alloy (2.4%), as well as some less common PGMs (Oberthur *et al*., 2012). Grain sizes range from < 5 to 50 µm in general, but may reach up to 480 µm in the longest dimension (Oberthur *et al*., 2012).

SAMPLING METHODOLOGY

Borehole Core

The sampling protocol is determined by the requirement of the sampling. The sample sizes and intervals must be appropriate for the deposit and the grain size of the material being sampled, as well as the intention of the sampling programme. The need to provide standard 'support', in a geostatistical sense, needs to be considered when designing a sampling programme, especially as compositing based on sample length can be expected in the estimation. Equalizing sample length is not the only criterion for standardizing sample support. Factors such as angle of intersection of the sampling to mineralization, sample type, borehole diameter, drilling conditions, recovery, sampling/sub-sampling practices, and laboratory practices all affect the 'support' of the sample. Typically sampling is undertaken to support a mineral resource estimate or to define an optimal mining cut.

Sampling is generally undertaken on half core with a sample size of 15–25 cm in length from BQ (36.4 mm diameter) or NQ (47.63 mm diameter) core. The taking of samples of varying length is unavoidable due the nature of the intersections and the variability of the mineralized stratigraphy or lithology. Sample lengths of up to a metre are generally used to confirm the lack of mineralization or occasionally to sample a complete lithological unit.

The sampling procedure begins with the drilling of the core. Complete core recovery over the sampling zone is required. This is not always possible as a result of the natural fractures in the core. Recovery of over 95% is generally acceptable and should form part of the commercial agreement with the drilling contractor. The core must be transported from the rig site to the core yard. It is imperative that core samples are not unduly damaged during transit. The chain of custody should be properly documented

At the core yard, the core should be checked and marked according to the drill depths. Thereafter the core must be logged according to industry logging standards. The logs should include descriptions of the lithotype, major and minor fractures (including infilling), and the presence of sulphide mineralization (including the prominent sulphide mineral types). The logging detail should be at the level required for this type of mineralization. Once the core is logged, the sampling protocol is applied and the samples marked out.

Samples should be marked so that they are justified to the major lithological contacts with on average an overlap of 2 cm of material being taken in the footwall and hangingwall of economic zones or mining cut. The exact sample size and frequency must take cognisance of suitable geochemical and geological knowledge of the deposit and mineralized horizon. A number of samples are taken into the footwall and hangingwall of the economic zone or mining cut as the grade is distributed into the hangingwall and footwall. Sample breaks are made on the basis of geology, and where possible, natural breaks in the core are used to separate samples if they are approximately perpendicular to the core axis.

The core is then split along its length through the low point of the contact dip by an appropriately trained assistant using a diamond saw, in preparation for bagging. Half core samples are cut to length, and half of the core is then bagged and sealed with sample number tickets both inside the bag and attached to the outside. There is a debate as to whether natural breaks should be used in preference to cut breaks. The debate includes consideration for the loss of material when cut, or the understanding that different samples lengths constitute different support when undertaking a mineral resource estimate. The remaining half core should be suitably marked and kept in the core tray for future reference (
Figure 2). Heavy-duty plastic sample bags must be used, and discarded by the laboratory after sample preparation. Sample bags must not be re-used. Once properly labelled, sealed, and documented the samples can be dispatched to the laboratory.

Once sampling has been completed, it is advisable to photograph the core both in the wet and dry state. This should be mandatory when whole sampling is necessary. Core should be retained to allow comparison of the assay data with the geology, other geological studies (density, magnetic susceptibility, structural *etc.*), for additional sampling (¼ core) and as a record of the drilling. This is invaluable as it allows consideration of aspects of the mineralization that need to be understood and communicated to the mining engineers and process engineers.



Figure 2. Photograph of wet core with samples marked out on core (Source: Kameni Platinum Holdings Ltd).

Sampling of the Merensky Reef

For the Merensky Reef, the potential mining cut as well as the amount of hangingwall or footwall in the cut needs to be determined. Sampling is extended from well above to well below the reef in order to completely close off the mineralization. The smaller the sample length the better definition can be made, as the result is that the effective decision-making is being made at the edge of the mining cut where the grade is lowest and closer to the detection limit.

The Merensky Reef is measured from just above the upper chromitite stringer to just below the lower chromitite stringer. The interval is then divided into even samples of approximately 20 cm in length; although individual sample thickness may range from 15 cm to 25 cm. All chromite associated with the upper and lower chromitite stringers is included in the top and bottom sample of the Merensky Reef. The sample interval is frequently widened further away from the Merensky Reef proper.

Sampling of the UG2 Chromitite Layer

Sampling of the UG2 Chromitite Layer is dependent on the character of the reef encountered. The reef is measured from the top chromitite contact (top of leader) to the base of the main chromitite layer and divided into fairly even sample intervals of approximately 20 cm (again these may range from 15 cm to 25 cm). Where a leader layer is present, it is treated as a separate sample if the leader and pyroxenite parting are of suitable thicknesses – approximately 15 cm each. If the leader and parting are thin, they are included together in a single sample. A parting will therefore either be sampled separately or included with the leader, and is never included with the main chromitite layer. Where additional pyroxenite lenses are developed in the UG2 Chromitite Layer, these are sampled separately if of significant thickness (>15 cm). Finely disseminated chromite grains and chromitite stringers in the immediate footwall to the main chromitite layer should be included with the basal sample (these often carry extremely high grades). Sampling is extended well into the footwall of the UG2 Chromitite Layer.

A comparison undertaken by Platinum Australia (S. Hunns, personal communication) on the UG2 Chromitite Layer showed that there was little variation in the grade over the stratigraphic unit. The advantage of this approach is that it provides the grade directly and the overall cost will be less because fewer assays are required. However, where some optimization or decision-making with respect to the cut is made, the use of smaller sample intervals is best.

Sampling of the Platreef

The grade profile of the Platreef may be difficult to determine (
Figure 3). As a result, sampling tends to be extensive to identify the mineralized horizon and allow for the optimal mining cut.

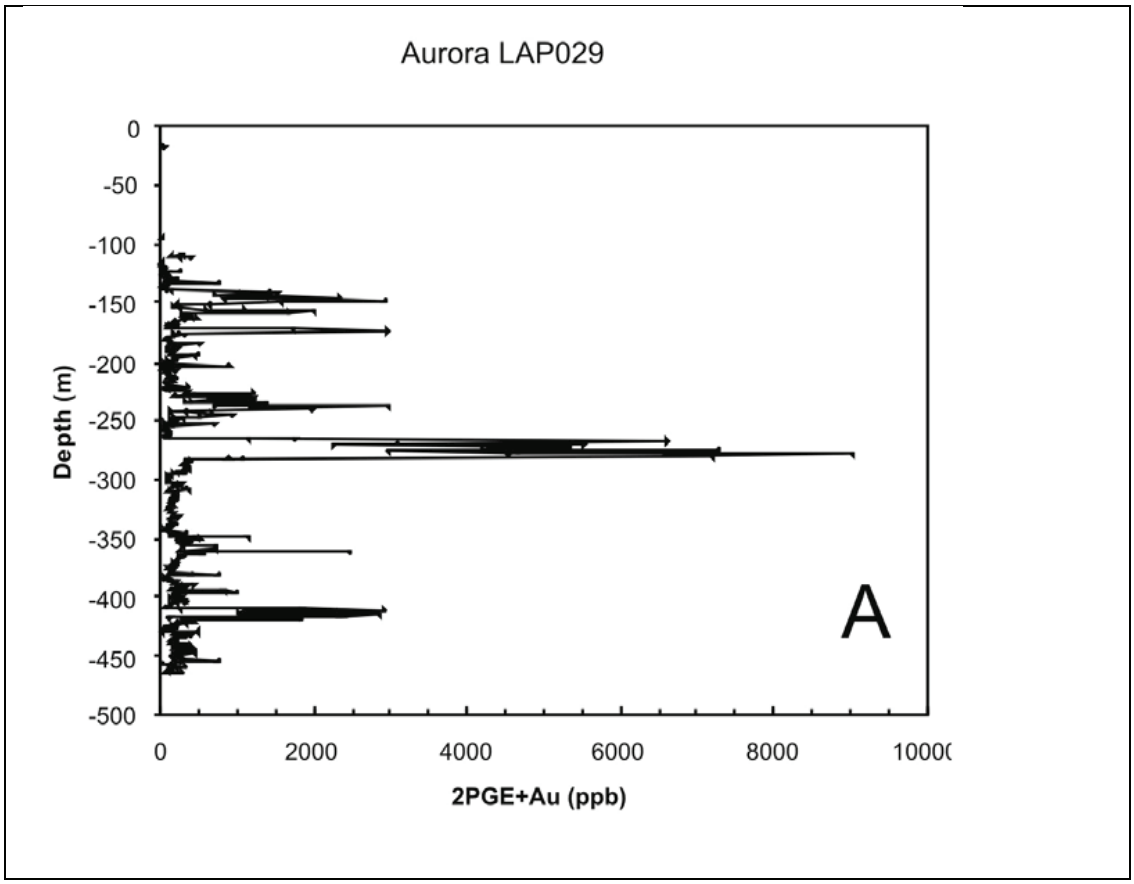


Figure 3. Example of a grade profile of the Platreef (after McDonald and Harmer, 2010).

A common way to keep assay costs down is to use an indicator element. The base metals (Cu or Ni) are frequently used. However, this correlation, although understood academically, needs to be proven or demonstrated before being used (Figure 4).

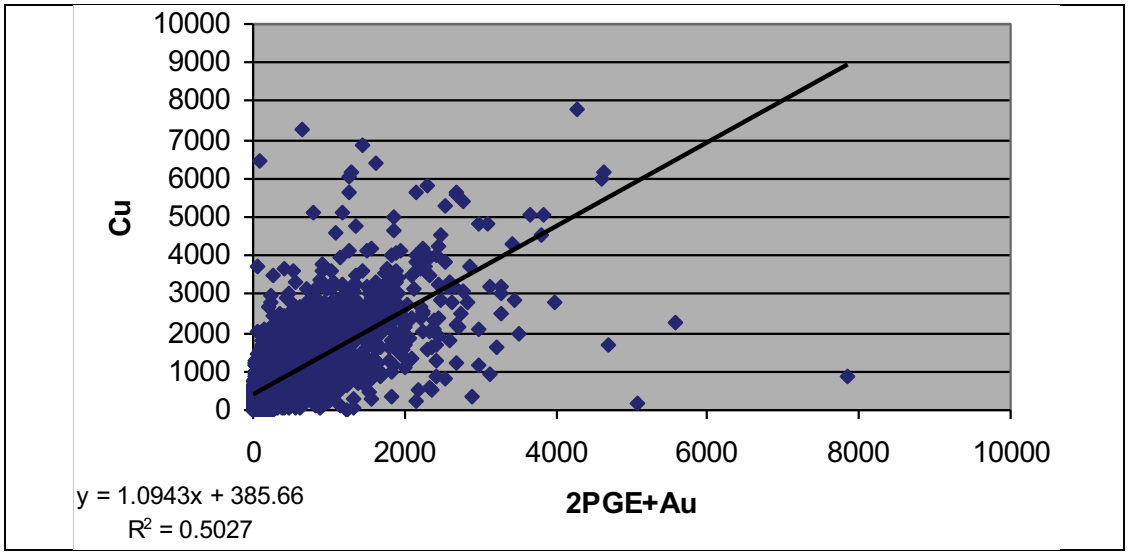


Figure 4. Platreef: Example of the relationship between PGEs and base metals.

Sampling of the MSZ

In the case of the MSZ, the determination of the BMSZ is critical to the determination of the mining cut due to the lack of geological markers. As with other PGE-bearing horizons, a smaller sample size is best for decision-making, but needs to be balanced with the cost and the ability to accurately assay the smaller samples. A sample size of 15–25 cm is considered appropriate and allows for significant accuracy in determining the BMSZ and thus a valid mining cut determination. The sample size is often increased where some understanding of the mineralization exists; however, additional data may be required to confirm that the mineralization does not extend beyond the generally recognized zone.

Underground Sampling

Underground sampling is intended to mimic borehole core. The standard underground sampling protocols are generally similar to those used for core. Differences relate to access to the underground face and the equipment limitations. Traditionally, underground sampling has been undertaken with a hammer and a cold chisel. This method has been recognized as involving inherent sampling errors, and therefore the use of diamond saws has been considered as an industry standard. However, the logistics of getting a pneumatic saw to the face and finding a suitable connection for the compressed air has made it difficult to implement uniformly.

Underground or face sampling is generally undertaken in development ends and in the gullies, advance strike gullies (ASGs), and headings of the stope panels. It is seldom undertaken in the stope faces themselves, as the stope faces generally provide only a limited part of the geology to sample. In addition, stope face sampling may be logistically very difficult as getting equipment into and out of stope faces can be extremely hard work. During trial mining, including development, stope and metallurgical sampling may be required.

A location for ease of sampling, and preferably with no structural discontinuity, is selected and the position determined from the underground survey controls. The sampling method requires the use of a diamond saw to cut the sample channels grooves, which are then chipped out with a chisel. The width of the channels should be 5 cm and the depth 2 cm. The identification of the important lithologies is required to provide the reference from which the sampling is justified. A 2 cm overlap into the hangingwall and footwall lithologies is included with the top and bottom reef samples to ensure consistency with the diamond drill-hole sampling.

Marking continues with samples divisions across the economic unit, according to the requirements of the sampling programme or protocol. Starting from the bottom, grooves are cut at these sample

divisions, with numbering of samples consecutively from the top or bottom as required by the individual protocol.

Prior to sampling, the faces should be cleaned of recent weathered material so that the sample is representative of the actual mineralization. Sampling from the bottom is considered best to reduce contamination. Overbreak into the sample above must be avoided. Samples are put into clean plastic bags of a suitable size. The bag and contents must be properly labelled with reference to the documented location and sample position.

The method of sampling, and the marking and cutting out of the sample channel, must be similar to that used for core sampling.

Blast-hole Sampling
Blast-hole sampling is undertaken in open pit operations such as Mogalakwena platinum mine. The blast-holes are sampled and analysed prior to loading of the blasted material. This is a valuable procedure as it allows determination of grade and therefore indicates to which stockpile the material should be dispatched. The blast-holes are designed and drilled for blasting purposes with 310 mm, 250 mm, and 165 mm size bits.

As a percussion or rotary drill rig is drilling, the chips generated are flushed out of the blast-hole with compressed air. The process is dusty (when the hole is dry) and muddy (when waterlogged). Samples exit in the kerf between the rod and the sidewalls of the hole. Six 2.5 m samples are collected for every 15 m of blast-hole. Samples of 1 kg are submitted for geological (density, PGEs, Cu, Ni) or metallurgical (flotation and hardness parameters) characterization. These results are used to determine the nature of the direct feed and or stockpiling destinations for the blasted muck.

In the past couple of years, Mogalakwena has been replacing blast-hole drilling with reverse circulation (RC) drilling. Beyond 2013, all production sampling at Mogalakwena will be RC drilling. RC drilling involves using a sampling rig to drill for samples independent of blast-holes and thus involves an extra cost.

RC drilling involves blowing chips from the bit face and transporting them through the centre of the rods (in an inner tube) and out to a sampling unit on the side. The sampling unit is a basically a series of cyclones to settle the chips and dust before dropping them down an auto-splitter system. RC drilling samples are always dry as the design allows compressed air to hold back the water even in waterlogged situations.

The quality of samples with the RC drilling method (minimum contamination, minimum human interference, and automatic splitting) justifies the extra drilling cost when compared to blast-hole drilling. RC sampling also goes beyond just one bench (15 m), although the 2.5 m sampling interval is maintained

RC drilling is significantly faster and costs significantly less than diamond drilling. Diamond drilling is still used for exploration drilling only.

Sample Size
The sample mass should be 230–420 g (BQ core) or 410–710 g (NQ core). The weight is important as it relates to the applicability of sampling theory as well as the practical requirements of the laboratory and the specified analytical technique. The recommendation is always to utilize as much sample as possible for fire assay, and hence wherever possible a 50 g aliquot is recommended. Other duplicates are required, as well as back-up pulp samples in case an issue occurs with the assay or as a requirement for duplicate analysis of every sample.

An aspect to be considered is the 'nugget effect'. Geostatistical theory assumes that there should be no difference between a sampled value and a potential repeat sample at the same location (Clark, 2010).

Variations in the grade between contiguous samples are due to aspects of the mineralization, geological features, grain size, *etc.* as well as any 'random' sampling variation that might occur due to the sampling method, the adequacy of the sample size, the assaying process, *etc.* Platinum deposits typically have high nugget effects, *i.e.* two samples taken close to each other have different PGE concentrations, probably due to the very small grain size of the platiniferous minerals, the random distribution of the sulphide mineralization in the host rocks, and the low concentration of the precious metals. The normal approach to understanding the level of the nugget effect is to ensure sufficient sampling. The sampling protocols adopted routinely in the industry have over time been demonstrated not to introduce a bias or influence in relation to the nugget effect.

The sample preparation and communition protocol is very sensitive to the grain size of the precious metals (Lomberg, 2007). The use of a nonogram can show that the size of the mineral grains can significantly influence the liberation of the PGEs during the analytical procedure (Figure 5) (Lomberg, 2007). Au is particularly sensitive due to the much lower concentration.

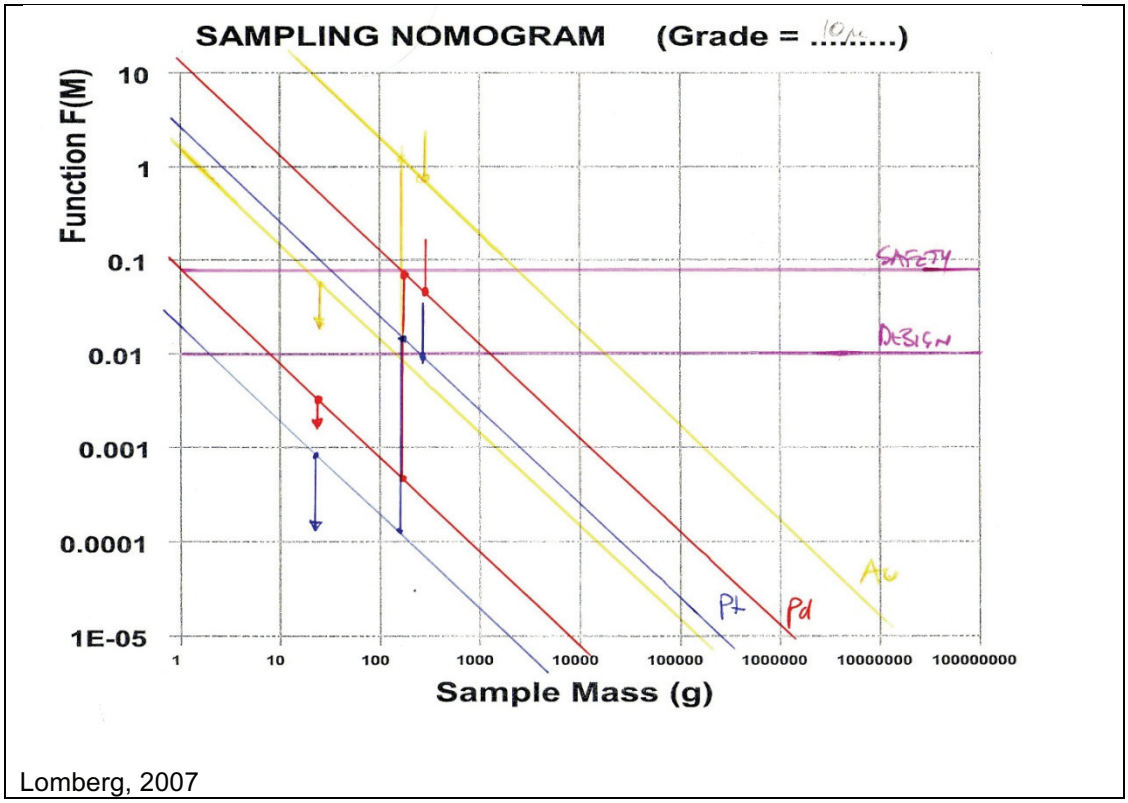


Figure 5. Example of a sampling nanogram for the UG2 Chromitite Layer.

ANALYTICAL TECHNIQUES

PGEs

The chemistry of this special group of elements makes their determination at low concentrations in geological samples difficult. However, the PGE industry and the commercial laboratories have developed methods, procedures, and protocols that allow the determination of these elements, even at these low levels, to be undertaken with a degree of precision and accuracy. This is necessary to support the mining value chain.

The most common form of commercial PGE analysis is fire assay using a number of different collectors to concentrate or capture all of the precious metals. The samples are pulverized to 85% -75 µm. The fire assay method with lead collection involves fusing the sample with a flux mixture at

approximately 1000°C. The resultant melt separates into two immiscible phases, namely a glassy slag (which contains the aluminosilicates and base metals, and is discarded) and a denser phase (including the PGE collector, which sinks to the bottom). The critical aspect is that the PGEs are strongly partitioned into this collector phase, from which they may be subsequently separated for analysis. Thus the selection of the collector is an important decision to be made in the analytical process.

Lead collection is used extensively as it is suitable for the determination of Pt, Pd, Rh, and Au. As these are the major elements of the Merensky Reef and UG2 Chromitite Layer, the use of Pb as a collector is widespread in the industry. The use of Pb as a collector and the reporting of these elements as a sum is common practice, especially on mining operations. The need for more information on the individual elements, or 'prill split', has resulted in the use of other collectors, such as silver as a co-collector, which helps prevent volatile losses during the cupellation stage. The practical limit of detection is 0.1 ppb (Pt) and 0.5 ppb (Pd), although the detection limits used for mine samples are much higher; 0.1–0.5 ppm. The practical reasons are the cost, the volume of analyses required, and the use of the results on a mine where the *in-situ* grades are >3 g/t 3PGE+Au.

The best alternative method until relatively recently was fire assay using a NiS collector. This technique was used more extensively in the metallurgical environment, due to the accuracy required. Geological samples were until the 1990s rarely submitted for NiS fire assay. The method differs from Pb fire assay as all the PGEs are collected in the nickel sulphide. The advantages are that there is complete collection of the entire range of PGEs, and that there is no cupellation step in which some PGEs may be lost. As a result the method is widely considered to provide slightly higher total PGE results. The limits of detection for PGEs provided by commercial laboratories are typically in the range of 0.02 ppm to 0.005 ppm. The analytical detection limit may be 0.1 ppb (Pt) and 0.5ppb (Pd) if required. However, deposits with these grades would not be economic, and so the higher detection limit is a realistic approach given sample volumes and cost.

The fire assay method has the following advantages (Rao and Reddi, 2000):

- Ease of handling large sample masses, which can deal with low analyte concentrations and address non-homogeneity and the nugget effect
- Assurance of quantitative collection of all the PGEs (NiS fire assay) and their complete separation from base metals and other matrix elements.

The few disadvantages of the fire assay procedures are:

- Large reagent blanks due to the presence of PGEs in the chemicals utilized during sample decomposition and solution preparation (*e.g.*, nickel powder is known to contain appreciable amounts of PGEs, and so blank fusions are performed on a regular basis to check for this)
- Selection of suitable flux composition is an important aspect, and the tendency to generalize flux weights often lead to erroneous results
- The experience of the assayer plays a critical role in successful fire assaying, and therefore skilled personnel are required.

Despite this, NiS fire assay is probably the preferred preconcentration method for analysis of PGEs in geological and related materials because of its versatility and broad range. Recently, other alternative collectors have been used, due to the difficulties of NiS fire assay, the cost, and the time required. These collectors have allowed the reporting of precise and accurate results and so are more widely available from some commercial laboratories.

Base Metals
The emphasis of this paper is on the PGEs. However, base metals (Cu, Ni, and Co) are important components of the mineralization. They contribute to the revenue and so need to be assessed in an appropriate manner. For the sake of completeness some discussion is included here. The base metals content that is being considered is an order of magnitude lower than for a primary base metal deposit, therefore the analytical method must have a lower level of detection.

The analytical methods used for the determination of the base metals are listed below. The list is not exhaustive, as the analytical technique should be selected with due consideration of its applicability to the task at hand. The selection criteria should include accuracy and precision, detection limits, expected concentration, and sample matrix.

- Pressed pellet and X-ray fluorescence (XRF)
  XRF is a nondestructive analytical technique used to determine a full range of light to heavy elements by pressed pellet disc. This technique is suitable for large numbers of samples (usually at ppm levels) where the matrix of the material is generally consistent, such as Cu and Ni determination for the Merensky Reef, UG2 Chromitite Layer, and Platreef

- *Aqua regia* leach
  Aqua regia will digest chalcophile elements in particular; however, elements associated with silicates and more refractory minerals may be only partially digested. The concentration may be determined by atomic absorption spectrometry (AAS) or inductively coupled plasma – optical emission spectroscopy (ICP-OES)

- Four-acid digestion
  Four-acid digestion results in total dissolution of most elements, except for a few such as Cr, V, and Ti. The concentration may be determined by ICP-OES or inductively coupled plasma – mass spectroscopy (ICP-MS).

- Sodium peroxide fusion
  Sodium peroxide fusion and an ICP-OES finish provides total analyses of base metals, but at the expense of higher detection limits and lower precision due to the high level of sodium salts in solution. Generally, detection limits are in the region of 20 to 50 ppm

- Wet chemistry consists of titrimetric and gravimetric techniques, and is more suited to concentrates or percentage-level base metals.

It is also important to consider the soluble Cu or Ni sulphides- as well as the total concentration. This is especially true as Ni commonly substitutes into olivines and so is not recoverable. A partial leach (such as acetic acid) that does not mobilize silicate-hosted material reporting sulphide Cu and Ni would be appropriate.

QUALITY ASSURANCE/QUALITY CONTROL

The current investment environment requires the reporting of exploration results against the international reporting codes (SAMREC, JORC *etc.*). Owners, promoters, investors, and other interested stakeholders require exploration results to be reported with confidence. Mineral exploration and mining companies have to de-risk their projects from inception right through to production. Investment risk can be lowered and confidence in the results promoted by the implementation of quality assurance and quality control (QA/QC) programmes (Lomberg, 2013).

QA/QC procedures aim to confirm both the precision and accuracy of assays and ensure that they can be confidently relied upon, thus reducing the risk of a project. The QA/QC programme identifies various aspects of the results that could have adversely influenced the precision or accuracy of the assay data.

In order to do this, control samples are inserted into the sampling stream. The control samples recommended should comprise two different certified reference materials (CRMs), a blank, and a duplicate within every 20 samples submitted. The CRMs are reference samples with a known (stastically) elemental abundance. The CRMs should have a composition (matrix) similar to the range of rock types being analysed to ensure that the QC programme is valid (Méndez, 2011). When choosing which standards to use, the methodology being employed by the laboratory to analyse the samples should be identical to the method used to certify the standard. Finally, one of the CRMs should have concentrations close to the anticipated average concentration of the deposit, and one at (or close to) the marginal or cut-off grade. A blank is a standard with an abundance of the elements of interest below the level of detection of the analytical technique. The duplicate is a second split of a sample taken at a particular stage of the sampling process; *e.g.* field or pulp duplicate. The intended aim is 5% coverage for each of the control sample types. The inserted quality controls should allow the identification and reporting of 'non-conformance' or 'out-of-control' processes during the analytical process (Noppe, 2008). Further control on data integrity is required through submittal of pulps to a referee laboratory at a recommended frequency of one in ten (10%). These check assays are compared with those of the primary laboratory and any bias monitored and eliminated, as well as potential analytical errors at the principal laboratory identified. It is very important that exactly the same assay methodology must be employed by the umpire laboratory to ensure an accurate comparison, and also that standards are submitted between the real samples to ensure the accuracy of the umpire laboratory. The pulp residues submitted should be chosen at random from the data-set and cover the entire grade range being reported. QA/QC samples should be inserted as per the protocols adopted for the sampling programme. The quality control data should be analysed on an ongoing basis and queries addressed to the laboratory.

By using the density of QC samples described above, it is possible to identify samples that have been swapped, missing samples, and incorrect labelling, among other aspects. The value of a good QA/QC programme is that it identifies potential weaknesses in the sampling procedure or sampling errors, and allows the geologist to correct or minimize them before they adversely influence the assay data. These errors may include incorrect sampling, poor sub-sampling methods, errors due to the sampling equipment such as core cutting, invalid splitting methods, *etc.*

CONCLUSION

The use of an appropriate sampling methodology can ensure valid data is collected that allows the estimation of a mineral resource and the selection of a mining cut for a PGE deposit. These methodologies have been established over an extended period and have proven to be practical and pragmatic

The basis for an appropriate sampling regime is a thorough understanding of the deposit and its mineralization. Related to this is the appreciation of the anticipated exploration methods, mining methods, and metallurgical process flow sheet,

ACKNOWLEDGEMENTS

I would like to acknowledge the contributions of Kevin Ferguson and Steve Hunns (Platinum Australia), Barend Meulenbeld (Kameni Holdings), Trust Muzondo (Anglo American Platinum), Kevin Gerber (Setpoint Laboratories), and Thys Botha (Platinum Group Metals Ltd).

REFERENCES

Brown, R.T. 2008. A Brief Summary of the Great Dyke of Zimbabwe. [Unpublished].

Clark, I. 2010. Statistics or geostatistics? Sampling error or nugget effect? *Journal of The Southern African Institute of Mining and Metallurgy*, 110, 307-312

Kinnaird, J.A., White, J.A., and Schurmann, L.W. 2005. Multiphase emplacement of the Platreef, northern Bushveld, South Africa. Abstract: *10th International Platinum Symposium,* Oulu, Finland, 7-9 August 2005. Geological Survey of Finland.

Lomberg, K.G. 2007. Construction and use of a nomogram for the UG2 chromitite layer. Sampling Theory and Methods course assignment, University of the Witwatersrand.

Lomberg, K.G. and McKinney, R.L. 2013. Quality control and quality assurance case studies for the analysis of precious and base metals. *Symposium Series* S75. Southern African Institute of Mining and Metallurgy, Johannesburg. pp. 95-112.

McDonald, I. and Harmer, R.E. 2010. The nature of PGE mineralization in the Aurora Project area, northern Bushveld Complex, South Africa. *Proceedings of the 11th International Platinum Symposium*,21-24 June 2010. Ontario Geological Survey, Miscellaneous Release–Data 269.

Méndez, A.S. 2011. A discussion on current quality-control practices in mineral exploration. *Applications and Experiences of Quality Control*. Ivanov, O. (ed.). InTech, Rijeka, Croatia.

Muller, C.J. 2010. Technical Report on Project 3 Resource Cut Estimation of the Western Bushveld Joint Venture (WBJV) located on the Western Limb of the Bushveld Igneous Complex, South Africa. Western Bushveld Joint Venture. Prepared For Platinum Group Metals Ltd.

Noppe, M. 2008. Notes on data QA/QC requirements. http://www.ebah.com.br/content/ABAAAAHTQAH/quality-assurance-and-control

Oberthür, T., Melcher, F., Buchholz, P., and Locmelis, M. 2012. The oxidized ores of the Main Sulphide Zone, Great Dyke, Zimbabwe: Turning resources into minable reserves – mineralogy is the key. *Proceedings of the 5th International Platinum Conference, 'A Catalyst for Change'. Proceedings of the 5th International Platinum Conference 'A Catalyst for Change'. Symposium Series S72.* Southern African Institute of Mining and Metallurgy, Johannesburg.

Prendergast, M.D. and Wilson, A.H. 1989. The Great Dyke of Zimbabwe - II: mineralization and mineral deposits. *Proceedings of the 5th Magmatic Sulphides Field Conference,* Harare, Zimbabwe. Prendergast, M.D. and Jones, M.J. (eds). Institute of Mining and Metallurgy, London. pp. 21-42.

SAMREC. 2009. South African Mineral Resource Committee. The South African Code for Reporting of Exploration Results, Mineral Resources and Mineral Reserves (the SAMREC Code). 2007 Edition as amended July 2009. http://www.samcode.co.za/downloads/SAMREC2009.pdf

Schouwstra, R.P., Kinloch, E.D., and Lee, C.A. 2000. A short geological review of the Bushveld Complex. *Platinum Metals Review* 44, 33-39.

Viljoen, M.J. and Schürmann, L.W. 1998. Platinum group metals. *The Mineral Resources of South Africa.* Wilson, M.G.C. and Anhaeusser, C.R. eds). *Handbook 16*. Council for Geoscience, Pretoria. pp 532-568.

Wilson. A. and Chunnett, G. 2006. Trace element and platinum group element distributions and the genesis of the Merensky Reef, western Bushveld Complex, South Africa. *Journal of Petrology*, 47, 2369 –2403.

Wilson, A.H. and Prendergast, M.D. 1989. The Great Dyke of Zimbabwe - I: Tectonic setting, stratigraphy, petrology, structure, emplacement and crystallization. *Proceedings of the 5th Magmatic Sulphides Field Conference,* Harare, Zimbabwe. Prendergast, M.D. and Jones, M.J. (eds*).* Institute of Mining and Metallurgy, London. pp. 1-20.



Ken Lomberg

Senior Principal
Coffey

Ken has some 30 years' experience in the minerals industry (especially platinum and gold). He has been involved in exploration and mine geology and has had the privilege of assisting in bringing a mine to full production. His expertise is especially in project management, mineral reserve and resource estimation.

Ken has undertaken mineral resource and reserve estimations and reviews for platinum, gold, copper, uranium and fluorite projects. He has assisted with the reviews or estimation of diamond and coal projects and assisted or compiled Competent Persons Reports/NI 43-101 for various projects that have been listed on the TSX, JSE and AIM stock exchanges

Ken is also Chairman of the SAMREC Working Group which is responsible for the SAMREC Code and represents SAMREC on the CRIRSCO Executive

The valuation of an exploration project having Inferred Resources

S. Rupprecht[1*] and G. Njowa[2]

[1]Senior Lecturer, University of Johannesburg
[2]Venmyn Deloitte (Pty) Limited

Mineral Asset valuation of Mineral Resources and Mineral Reserves as the single fundamental asset for a mining company, according to the SAMVAL Code, CIMVAL Code or the VALMIN code, can be carried out using three valuation approaches, namely; the Cash Flow (Income) Approach, Market Approach, and Cost Approach. Under the 2009 SAMVAL Code the Market and Cost approaches are viewed as the preferred approaches to the valuation of Exploration Properties with mainly only Inferred Mineral Resources, with the Cash Flow Approach 'not generally used'. The updated 2016 SAMVAL Code has split Exploration Properties into two categories; early stage and advanced stage Exploration Properties. For both stages of Exploration Properties the Market and Cost Approach is 'widely used', while the Income Approach is 'not generally used' for early stage Exploration Properties and 'less widely used' for advanced stage Exploration Properties. In both versions of the SAMVAL Code the Income Approach is the least preferred method for valuations of exploration projects, with only Mineral Resources and without any credible studies to assess the technical and economic viability.

Under the 2016 SAMVAL Code, an advanced Exploration Property is defined as a project that has undertaken considerable exploration and a Mineral Resource estimate has been defined and a Scoping Study has been applied to determine whether there are reasonable prospects for eventual economic extraction.

This paper looks at the valuation of early Exploration Properties, especially those with mainly Inferred Mineral Resources, with particular attention on the use of the Income Approach. It will discuss circumstances where Inferred Mineral Resources could be or should not be valued using in the Income Approach-based valuation methodologies.

INTRODUCTION

The fundamental question that we should ask ourselves is whether Inferred Mineral Resources have a value and how they should be valued. It seems obvious that, during the development of a mineral deposit, changes occur along the mine development life cycle as the level of geological confidence in the Mineral Resources increases from Inferred to Measured. The Inferred Mineral Resources in many cases represent the future of the mining operations. This will depend on the level of maturity of the mineral project. Hence this category of Mineral Resources should be assigned a value and should be valued appropriately taking into consideration the low level of geological confidence. To our dismay, the US Securities Exchange Commission (SEC) still does not believe that Mineral Resources have a value. (Lawrence, 2012) The SAMVAL, CIMVAL, and JORC codes are internationally recognized valuation codes that are acceptable to the HKSE Listing Rules [Rule 18.34(1)]. The only exception to these codes that is included in the HKSE Listing Rules is the fact that Inferred Mineral Resources should not be valued or included in the evaluation models. According to rule 18.30 (3) of the HKSE listing rules, Indicated Resources and Measured Resources are included in economic analyses only if the basis on which they are considered to be economically extractable is explained and they are appropriately discounted for the probabilities of their conversion to Mineral Reserves. All assumptions must be clearly disclosed. Valuations for Inferred Resources are not permitted.

The rest of the world might view this differently and there is adequate market evidence that Mineral Resources (even Inferred Resources) have a value, but due care and professional judgement must be exercised in determining that value and how this is disclosed to the stakeholders.

One of the common tenets among the mineral asset valuation reporting codes and the associated securities regulators is that the overarching obligation is to not mislead the investors, and to provide all the information in a transparent and objective manner to enable the investors and their advisors to make professional judgements and investment decisions. (Lawrence, 2012) All the associated risks, uncertainties, and potential should be clearly highlighted in the report in order to enable investors making an investment decision fully aware of the risks and uncertainty associated with assigning value to the lowest level of geological confidence (being Inferred Mineral Resources). Securities regulators aim to strictly regulate Public Reporting in order to inhibit exaggerated claims at the early stages of exploration, especially when only Inferred Mineral Resources are involved

Although the Income Approach is recognized as the least appropriate method to perform mineral asset valuations, some Competent Valuators in recent years have used the Income Approach as a preferred method for valuing Inferred Resources without appropriate technical mine design and application of modifying factors being applied to the Mineral Resources.

VALUATION OF EXPLORATION PROPERTIES

The 2016 SAMVAL Code has identified (as quoted) instances and applications where it is required to conduct a valuation on Inferred Resources, Exploration Properties and/or Exploration Targets. This may be done in circumstances such as the following (but not limited to):

- *The valuation of exploration assets in terms of IFRS 6; [*IFRS 6 is part of the IFRS group of accounting standards and was specifically developed for the extractive industries. The objective of IFRS 6 is limited to specifying the financial reporting of exploration for and evaluation of mineral resources, that is the expenditure spent for exploration and the evaluation of mineral resources before the commercial viability has been demonstrated (IFRS, 2012)];
- *The valuation of Exploration Properties for sale or acquisition, or other valuation purposes;*
- *The valuation of Inferred Resources in the case of a merger or acquisition;*
- *The Valuation of Prospecting or Mining Rights that include Inferred Resources and/or Exploration Targets;*
- *The justification for future (warranted) expenditure on Exploration Targets and properties;*

- *A need to upgrade Inferred Resources to higher confidence levels;*
- *Valuations that are required to justify expenditure to increase the level of confidence in Exploration Targets or Mineral Resources; and*
- *Valuation for estate considerations, taxation, royalties, litigation etc.*

While not included in Mineral Reserve estimation, markets attach value to Inferred Resources during the exploration process. Many operations mine Inferred Resources in practice and these needs should be taken into account in the valuation of going concerns as set out in the respective specific scope.

These aspects may or may not be published in public reports, depending on the nature of the valuation and its purpose.

Furthermore, these aspects may not be reliant on a Mineral Resource statement (in the case of Exploration Targets), particularly where a Market or Cost Approach is applied, as decided by the CV.
Clearly, in such cases, there are material risks associated with the valuation, in terms of the level of accuracy and level of confidence of the estimates, or the approach/method. The CV should therefore qualify any such valuation with the following:

- *A clear statement of the level of confidence, and the risks associated with the valuation;*
- *The reason for the application of the approach and method;*
- *The reasons why the valuation may or may not be based on a SAMREC compliant report;*
- *The application of more than one approach and associated method; and*
- *The modifying factors that have been applied in the assignment.*

It is not considered acceptable to use, in the Income Approach, "potential resources", "hypothetical resources", or any other such categories that do not conform to the definitions of Mineral Resources and Mineral Reserves within SAMREC or the CRIRSCO definitions. Where Inferred Resources are being valued, if, in the opinion of the CV, an Income Approach could be applied, the CV should justify the usage, and indicate the risks associated with the valuation.

From the above excerpt, Inferred Mineral Resources are useable only if included in a mine design, plan, or economic study and only if there exists a mine plan and a statement of Mineral Reserves. The valuating of Inferred Resources requires caution even when applied in a mine plan, let alone when not supported by a mine plan. The valuation of Inferred Mineral Resource should become more stringent so as to prevent investors from being misled. Notably, an Inferred Mineral Resource may does not necessarily mean be converted to a Mineral Reserve, either wholly or in part. A conservative view may be that if owners want to realize the full value of a project its economic viability should be demonstrated, which results in the Mineral Resource being converted to a Mineral Reserve.

Valuation Methods are essentially a subset of the various Valuation Approaches. The choice of the Valuation Method(s) applied is a matter for the judgement of the CV, and the decision to use any particular method (and approach) should be justifiable to the CV's peers.

The results from the Valuation Approaches and Methods employed should be weighted and reconciled into a concluding opinion of value in accordance with Figure 1. The reasons for giving a higher weighting to one method or approach over another should also be stated and justified.

Certain valuation methodologies are more widely used and may be more generally acceptable as industry practice than others, although this could change over time. This is illustrated in Figure 1, which shows how the various approaches are generally applied to different stages of exploration and mining properties. This, however, is for guidance only, and is not prescriptive. Ultimately, the CV should stipulate the quality and level of confidence in the various inputs, in deciding which approach and method to apply.

Use of Inferred Resources in the Cash Flow approach
Clause 26 of the SAMVAL Code provides guidance in using Inferred Mineral Resources in valuating mineral projects:

For Valuation, it is accepted that mine design and mine planning may include a proportion of Inferred Mineral Resources. If this category of Mineral Resource is included in mine design, planning or economic studies for Public Reporting, full disclosure and the effect on the results of the studies must be stated. Inferred Mineral Resources may be included in mine design, mine planning, or economic studies only if there exists a mine plan and a statement of Mineral Reserves making clear that Inferred Mineral Resources have been used. Where a material amount of mining in the mine plan includes Inferred Mineral Resources, a comparison of the results with and without those resources must be shown, and the rationale behind their inclusion must be explained.

Modifying factors and assumptions that were applied to the Indicated and Measured Mineral Resources to determine the Mineral Reserves must be equally applied to the Inferred Mineral Resources.

The above excerpt indicates that Inferred Mineral Resources may be included in a mine design, plan, or economic study only if a mine plan exists and only if a statement is provided that acknowledges the use of Inferred Mineral Resources in the LOM plan. However, the valuation of Inferred Mineral Resource requires caution (see Clause 20 of the SAMREC Code) even when applied in a mine plan, let alone when not supported by a mine plan. The valuation of Inferred Mineral Resources should be conducted with care, and applying modifying factors to Inferred Mineral Resources that are not inclusive of a Pre-Feasibility Study is undesirable and may be misleading to the public. The authors propose that Inferred Mineral Resources should be valued utilising the Cost and Market approaches, as the declaration of an Inferred Mineral Resource does not necessarily mean that all or a portion of the Mineral Resource will be converted to a Mineral Reserve. The risk of utilising discounted cash flow (DCF) to value an Inferred Mineral Resources is that mineralised material may be valued based on modifying factors when there remains a reasonable chance that some, or all, of the Inferred Mineral Resource may not ever be economically viable to mine. The CP/CV must fundamentally understand that an Inferred Resource *is inferred from geological evidence and sampling* and assumed, but not verified geologically or through analysis, to display grade continuity.

In the case of a Scoping Study, it is common to apply modifying factors to the Mineral Resource to indicate viability for technical evaluation purposes or to demonstrate a reasonable expectation for eventual economic extraction. However, the level and detail of work conducted is in no means sufficient to declare a Mineral Reserve. As a guide, the Society for Mining and Metallurgical and Exploration (2014) suggests that Scoping Studies have a capital accuracy of 50%, an operating cost accuracy of 35%, with a contingency of 25% for items not specified in the scope of the study. When conducting or utilising Scoping Studies it is prudent to provide cautionary advice to the reader as to the limitations of the study. The following provides an example of such advice.

The study reports a Run-of-Mine (ROM) head grade and tonnage. The reader is cautioned that the ROM tonnage reported does not constitute a mineral reserve or provide assurance of an economic development case at this stage, as there is insufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit. The work presented is an order of magnitude technical study (Scoping Study) on the potential viability of the Mineral Resources. It includes appropriate assessments of realistic modifying factors together with other relevant mining operational factors that are necessary to demonstrate at the time of reporting that progress to a prefeasibility or feasibility study can be reasonably justified.

Scoping Studies, also commonly referred as Preliminary Economic Assessments (PEAs), are useful in assisting mining professionals and advisors to understand the potential viability of a project and in making decisions regarding project development. Scoping Studies, however, do not prove economic viability and therefore it is advisable not to apply the Cash Flow Approach to valuate mineral projects that have completed a Scoping Study.

It is becoming common practice for CVs to apply modifying factors to resources and thereby generate a DCF, both in cases where a Scoping Study has been conducted and has not been undertaken. The authors regard this as poor practise, especially in the second case. The intention of the SAMVAL Code, through its definition of 'Exploration' and 'Development' properties, is that the Cash Flow Approach should be applied to projects where the economic viability has already been established, and that the Market and Cost Approaches are the preferred valuation methods for projects requiring further work to establish viability (Table I). For ease of reference, the definitions of 'Exploration' and 'Development' properties as provided in the SAMVAL Code (2009) are defined below.

Table I. Relationship between stages of development and Valuation approaches for mineral properties (SAMVAL, 2009).

Technical review approach	Exploration properties	Development properties	Production properties	Dormant properties		Defunct properties
				Economically viable	Not viable	
Cash flow	Not generally used	Widely used	Widely used	Widely used	Not generally used	Not generally used
Sales comparative	Widely used	Less widely used	Quite widely used	Quite widely used	Widely used	Widely used
Cost	Quite widely used	Not generally used	Not generally used		Less widely used	Quite widely used

An Exploration Property is defined as follows:

> *A Mineral Asset that is being actively explored for mineral deposits but for which economic viability has not been demonstrated. Exploration Properties have asset values derived from their potential for the discovery of economically viable mineral deposits. Exploration property interests are bought and sold in the market. Many of these transactions involve partial-interest arrangements, such as farm-in, option or joint venture arrangements.*

A Development Property is defined as follows:

> *A Mineral Asset that is being prepared for mineral production and for which economic viability has been demonstrated by a Feasibility Study or Pre-Feasibility Study and includes a Mineral Asset which may not be financed or under construction.*

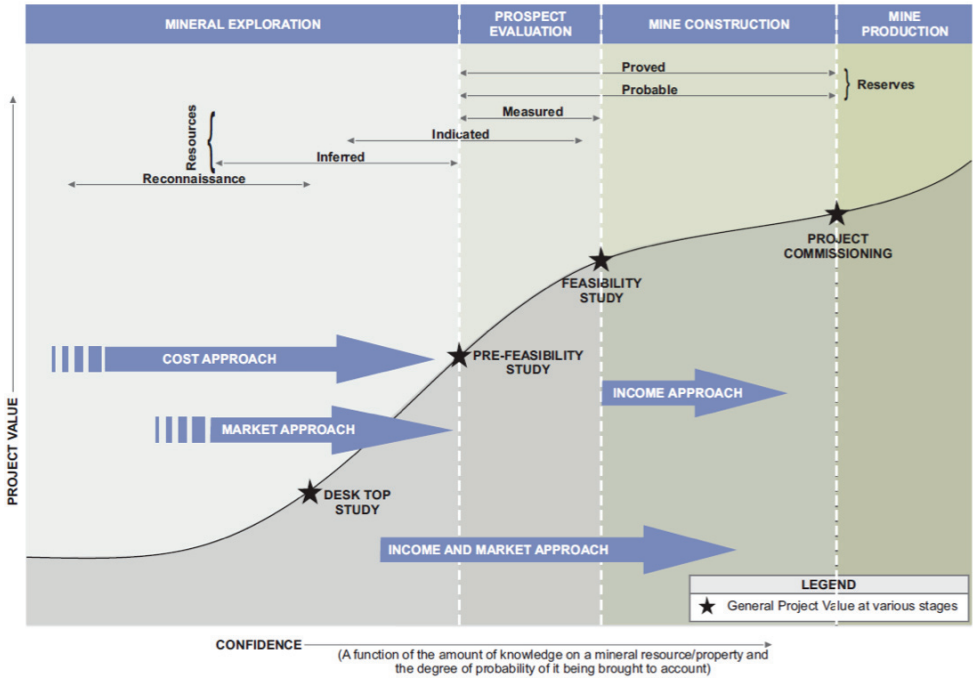


Figure 1.Project lifetime valuation methodology curve (Telfer et. al., 2013).

The project lifetime valuation methodology curve (Figure 1) indicates the preferred valuation techniques during project development. In this example, the Income Approach is advocated before a Pre-Feasibility Study. However, the authors do not agree, and recommend that the Income Approach be used only at a Pre-Feasibility Study level and beyond. The following quote emphasizes the caution that should be applied when valuating Inferred Mineral Resources.

> *Be careful not to confuse "resources" with "reserves". Measured and Indicated resources are reliable as a resource. "Inferred resources" are very speculative mineral inventories, so be careful when "inferred" is used. A resource still has a long way to go to become an economic deposit, as opposed to "reserves" which are deemed to be proven economic and mineable ounces calculated by very strict engineering and government rules* (Kenneth J. Gerbino and Company - 12 Guidelines for Buying Gold Mining Stocks).

The 2016 SAMVAL Code has modified the 2009 relationship between stages of development and valuation approaches introducing 'Early Stage Exploration Property' and 'Advanced Stage Exploration Property' as defined in Table III.

Table II. Relationship between stages of development and valuation approaches for Mineral Properties (SAMVAL 2016).

Valuation Approach	Early Stage Exploration	Advanced Stage Exploration	Development Properties	Production Properties	Dormant Properties		Defunct Properties
					Economically Viable	Economically not Viable	
Income	Not generally used	Less widely used	Widely used	Widely used	Widely used	Not generally used	Not generally used
Market	Widely used	Widely used	Less widely used	Quite widely used	Quite widely used	Widely used	Widely Used
Cost	Widely used	Widely used	Not generally used	Not generally used	Not generally used	Less widely used	Quite widely used

Table III. Definition of early and advanced stage Exploration Property (SAMVAL 2016).

Early Stage Exploration Property	Early stage means tenure holdings where mineralisation may or may not have been identified, and where Mineral Resources have not been defined.
Advanced Stage Exploration Property	Advanced means tenure holdings where considerable exploration has been undertaken and specific targets have been identified that warrant further detailed evaluation, usually by drill testing, trenching or some other form of detailed geological sampling. A Mineral Resource estimate has been defined and a scoping study has been applied to determine whether there are reasonable prospects for eventual economic extraction

Based on the 2016 interpretation, exploration projects still reflect Mineral Resources with Scoping Studies conducted to 'determine whether there are reasonable prospects for eventual economic extraction'. Table II states highlights that the Income Approach is 'not generally used' for early stage exploration and 'less widely used' for advanced stage exploration projects, with the Market and Cost approaches 'widely used' for all stages of exploration. It is only when a project reaches a 'development property or feasibility stage' that the Income Approach is 'widely used". The reader should note that a development property is '*a Mineral Asset that is being prepared for mineral production and for which economic viability has been demonstrated by a Feasibility Study or Pre-Feasibility Study and includes a Mineral Asset which may not be financed or is under construction.*'

CONCLUSION

The SAMVAL Code is intended to provide guidance to the Competent Valuator and is not meant to be prescriptive. The Competent Valuator should be able to defend their decisions to their peers. The authors have presented a case that urges Competent Valuators to be cautious in utilizing the Income Approach to valuate Inferred Mineral Resources. The updated 2016 SAMVAL Code has attempted to better qualify Exploration Properties, but the fact remains that the Market and Cost Approaches represent the more reliable valuation methods for Exploration Properties.

In conclusion, Inferred Mineral Resources should not be used in DCF as the main Mineral Resources category that is being considered in the mineral asset valuation. This approach would lack the engineering input in terms of how the deposit would be extracted, and consideration of mine design and planning, mine ventilation, geotechnical issues, extraction factors, and mine dilution would be ignored. Furthermore, a high level of confidence in the economic assumptions cannot be established because of the lack of technical information, and a conceptual mine plan and design would not suffice.

REFERENCES

IFRS. (2012). Technical Summary: IFRS 6 Exploration for and Evaluation of Mineral Resources. http://www.ifrs.org/IFRSs/Documents/IFRS6en.pdf [Accessed 12 July 2013].

Lawrence, M.J. (2012). Consideration in Valuing Inferred Resources. Valmin Seminar Series. https://www.ausimm.com.au/publications/content/minval_series_2012.pdf [accessed 26 May 2016].

Rupprecht, S.M. (2014). The SAMREC Code 2015 – Some thoughts and concerns. *Surface Mining 2014*. Southern African Institute of Mining and Metallurgy, Johannesburg.

SAMVAL. (2009). South African Mineral Asset Valuation (SAMVAL) Working Group. The South African Code for the Reporting of Mineral Asset Valuation (The SAMVAL Code). 2008 Edition as amended July 2009. http://www.samcode.co.za/downloads/SAMVAL2009.pdf

SAMVAL. (2016). South African Mineral Asset Valuation (SAMVAL) Working Group. The South African Code for the Reporting of Mineral Asset Valuation (The SAMVAL Code). [Draft].

Telfer, C.A., Njowa, G., McKenna, N., Myburgh, JA., Dyke, S., Dikogle, L., and Orford, T.C. (2013). Independent Competent Persons' Report on the Material Mineral Assets of Continental Coal Limited South Africa. 16 September 2013. p. 63.



Godknows Njowa

Snr Manager
Deloitte

Mr Njowa started his mining career as graduate learner mine at AA Mines (Shabanie mine) in Zimbabwe, and moved on to join Rio Tinto Zimbabwe in various capacities in Mine Finance and Project Evaluation. After completing his master's degree at Wits he joined Venmyn Deloitte. His key areas of expertise lie the combination of skills in Mining Engineering Financial Management and Accounting. Currently he leads a team in financial valuation of mineral and mining projects, technical and economic review, due diligences, MRM and mineral resources and mineral reserve estimation.

The art of reduction: analysing comparable transactions applicable to early stage exploration properties

A.J. van der Merwe

The MSA Group, Johannesburg, South Africa

The market approach to valuation of mineral assets is the most direct measurement of market value and is generally one of the preferred approaches. However, often it is difficult to find a reasonable number of arm's length transactions involving a mineral property comparable to the one under valuation, considering the host of variables such as commodity, deposit style, grade, depth below surface, cyclic price fluctuation, and administrative regime. To complicate matters further, exploration properties are rarely traded in pure cash transactions. Typical elements that may form part of a deal include cash, property or asset trade-in, equity, future exploration expenditure, and royalties.

In order to use a comparable transaction to support a valuation, such a transaction has to be reduced to a cash equivalent value. Listed equity can easily be converted to a cash value but future spending and royalties are not so easily quantified in cash terms. Elective portions of the transaction terms can be evaluated according to probability limits assigned to them eventuating. Whenever it is difficult to determine a single cash equivalent value, a probabilistic approach is developed – this sits well with the established best practice of providing a reasonable range of values as opposed to a single number. Finally, in most cases there is some time difference between the date of the comparable transaction and the Valuation Date of the subject assets. An adjustment is required to bring the value of the comparable transaction in line with the Valuation Date.

In this paper these various elements of typical transactions involving mineral exploration properties are unravelled and scrutinized. Techniques for reducing non-cash terms to a cash equivalent are submitted and explained.

INTRODUCTION

Generally, the various approaches and methods that may be used to derive a value for a mineral asset are grouped into three classes, each of which have a particular underlying philosophy:

- The **market approach** (based on the philosophy that something is worth what someone is willing to pay for it)
- The **income approach** (based on the philosophy that the value of something is related to the income that may be derived from it)
- The **cost approach** (based on the philosophy that the value of something is related to the cost of replacing or replicating it).

With each of these approaches, there are several different methodologies that can be applied to derive a value. Table I mentions most of those more generally known.

Table I. Summary of typical valuation approaches and methods (after from CIMVAL, 2003, Table 2, p. 22; Baurens, 2010; Sorentino, 2000).

Approach	Method
Market-based	Comparable sales/transactions Net metal value per unit of metal Value per unit area Market capitalization
Income-based	Cash flow (NPV) Real option Monte Carlo analysis
Cost-based	Appraised value based on expenditures (multiples of expenditure) Geoscience factor Statistical assessment of technical merit and value

Of these, the market approach is the most direct measurement of market value and is generally one of the preferred approaches. The other approaches primarily derive a technical value which is then manipulated to reflect an approximation of market value (Ellis, 2001; Lawrence, 1994).

However, it is often a major challenge to find a reasonable number of arm's length transactions involving a mineral property comparable to the one being valued, considering the host of variables such as commodity, deposit style, size and grade, depth below surface, cyclic price fluctuation, location, and administrative regime. To complicate matters further, exploration properties are rarely traded in a pure cash transaction. Typical elements that may form part of a deal include (Appleyard, 1994; Butler, 2002; Lawrence, 2001, 2002; Sorentino, 2002):

- Cash
- Property/asset trade-in
- Equity
- Future exploration expenditure (which may be compulsory or elective)
- Royalties.

In order to make many potentially comparable transactions really useful for a valuation commission, all the various elements have to be reduced to a cash equivalent amount, since the value opinion is expressed in pure cash terms. These elements are reviewed in the following sections, with the goal of understanding them and how to practically and transparently convert them into a cash equivalent quantum. It must be kept in mind that any value attributed to any of these elements is also time-based, meaning that a cash equivalent value derived would be applicable only for a specific point in time. Such values will require an adjustment to bring them in line with the date of valuation. Ways of treating this are also discussed.

CASH

A cash component is simple: it only has to be converted to the currency base of the Valuation Report. Detailed tables of historical currency exchange rates are readily available on the internet – these can be used to affect the appropriate conversion. It must be noted that the conversion should be effected with the conversion factor(s) prevailing on the date of the transaction. The cash value is added to the cash equivalent values extracted from the other terms of the transaction, and then the total extracted cash equivalent value is adjusted to bring it in line with the Valuation Date (as described in a subsequent section).

PROPERTY OR ASSET TRADE-IN

In the case where an asset is traded as part of the payment side of a transaction, a cash equivalent value for the asset will require a separate valuation of the asset. This valuation would also have to be in accordance with the requirements of the applicable valuation code. It follows therefore that a fair amount of work is required to reduce to cash a transaction that involves trading in a mineral property or asset as part of the payment. The Competent Valuator would have to consider the time and cost required for this effort. However, in a case where there are limited comparable transactions available, it may be necessary to proceed with a 'valuation within a valuation'.

The cash equivalent value of the traded asset is added to the total cash equivalent value of the transaction, which is to be adjusted for the time aspect of value as discussed in a later section.

EQUITY

Should equity be offered as (part) payment upfront, the basis of the value of such an equity portion should be the share price of the equity offered immediately prior to announcement of the transaction, in order to reflect the share price that was considered by the Buyer and the Seller at the time the terms of the transactions were concluded. After a public announcement, the value of the shares may be influenced by the transaction itself.

In the case where future equity is pledged, but at a predetermined price, then the future value should be discounted to the date of the transaction by means of a discounted cash flow model. The discount rate should be chosen to reflect the monetary jurisdiction within which the transaction is taking place. If the future price of the offered shares is not predetermined, then the Competent Valuator has to take a view (and explain why), but it is not unreasonable to simply take the value of the equity at the time of the transaction and discount it from the future to the time of the transaction.

FUTURE EXPENDITURE

It is common for joint venture (JV) terms on an exploration stage project to include some farm-in arrangements, to spread out the effect of cash outflow on the Buyer. The following aspects should be considered when converting such terms into a cash equivalent amount:

- Not all aspects may be cash: non-cash terms (*e.g.* completing a Feasibility Study) have to be assigned a cash value based on the experience of the Competent Valuator or a technical expert
- Committed future expenditure should be discounted to a present-day value (at the date of the transaction)
- Elective future expenditure should, after discounting it to a present day value, be multiplied with a lower and a higher probability of the expenditure actually being completed. The Competent Valuator must assign reasonable probabilities based on an assessment of the technical merit of the relevant asset(s). Note that the probability of a subsequent stage should be multiplied by the probabilities of preceding stages to determine a resultant probability of success.

ROYALTIES

Where a future royalty payable to a private person or company (*i.e.* not royalties owed to a State) is included in the terms of a transaction, such royalty is translated into a cash value by considering the potential value of the royalty, discounted from future time and for the probability that such a royalty will eventually become payable. Experience has shown that, particularly in the Canadian market, royalty agreements often have buy-back clauses which typically value the royalties at between

US$500 000 and US$2 million per percentage. In the absence of any information to the contrary, this range gives a useful guideline when considering the cash value of a potential future royalty. Alternatively, the Competent Valuator will have to assess the scale of potential future production of the transaction property and calculate reasonable future royalties based on such production. Such future royalties should also be subject to discounting for the time value of money and combined with reasonable probabilities assigned to the prospect of the project eventually hosting a successful mine.

TIME-RELATED ASPECTS OF VALUE

Since a stated value of any entity is valid only for a given point in time, the value for a comparable transaction being considered requires adjustment to represent a cash value on the Valuation Date of the Valuation Report being prepared. The value of a mineral asset varies over time due to various other imperatives, some market-related and some not. Hence the value a transaction cannot be adjusted for time elapsed simply on the basis of inflation and currency exchange rates.

Market-related influences are likely to derive from commodity prices, future commodity price outlook, and market sentiment on both the general economy and the specific sector in which the commodity resides. The Competent Valuator may consider all, or any combination of, these impacts when adjusting the value for time. In the author's experience, two useful metrics to guide the Competent Valuator are the commodity price and the performance of the sector on the relevant stock exchange. The former is usually weighted towards technical market considerations such as supply and demand, while the latter is influenced somewhat more strongly by prevailing sentiment (a difficult influence to quantify). One may use just the one or the other metric, but a combination of both may also be preferred.

WORKED EXAMPLE OF REDUCING A JV TRANSACTION TO CASH EQUIVALENT

Perhaps the best way to illustrate the application of the techniques discussed in this article is by means of a practical example. Let us consider a transaction involving a copper project in North America. The original transaction occurred on 1 April 2012. Under the terms of the staged joint venture (JV) agreement, the Buyer is to contribute according to the following schedule to earn a 75% interest:

- Initial payments: issuance of 750 000 Buyer shares to the Seller and a cash payment of US$1.5 million
- First stage (3-year duration): spend US$750 000 on exploration
- Second stage (2-year duration): complete Feasibility Study
- The Seller keeps a 2% Net Smelter Royalty (NSR).

The Competent Valuator considers this transaction to be comparable to a mineral property that is the subject of a Mineral Asset Valuation that the Competent Valuator has been commissioned to complete. Hence the Competent Valuator has to reduce the above transaction to a single cash value (or a range of cash values) that may be deemed valid at the Valuation Date of the Mineral Asset Value assignment. The following sections take the reader through a step-by-step worked example of applying the reducing techniques.

Initial Payments

The value of the cash contribution remains US$1.5 million. The Buyer's shares traded immediately prior to the announcement of the transaction at US$0.57 per share. The deemed value of the equity portion of the payment is therefore US$427 500. The total initial payment thus amounts to US$1 927 500 (in April 2012 money terms).

Subsequent Payments

Considering the prospectivity of the specific project, we assign a lower probability of 0.5 and a higher probability of 1.0 that the first stage of the proposed JV transaction will be completed within a period

of three years. The second stage does not have a specific monetary value assigned to it, but we estimate that completion of a Feasibility Study at the time would cost approximately US$2.5 million. Based on the technical merits of the project, we estimate the probability of the second stage (Feasibility Study) being completed, should the first stage be successful, to range between 0.25 and 0.5. The ultimate probability of the feasibility stage being completed is the product of the probability of the preceding stage(s) and the current stage. Therefore the lower probability of the Feasibility Study being completed successfully is deemed to be 0.5 × 0.25 = 0.125, and in a similar way the higher probability is 0.5.

An electronic spreadsheet can then be used to convert the future elective payments into an upfront cash equivalent value as shown in Table II. Firstly, the cash equivalent future expenditure is discounted back to the transaction date. Then the probabilities are applied to give a range of values of the future expenditure on the date of the transaction.

Table II. Analysis of future expenditure.

	Stage 1	**Stage 2**
Year 1	$ 250 000	-
Year 2	$ 250 000	-
Year 3	$ 250 000	-
Year 4	-	$ 1 250 000
Year 5	-	$ 1 250 000
NPV[#] (8% discount rate)	$ 644 274	$ 1 769 516
Lower probability	0.5	0.125
Higher probability	1.0	0.5
Lower value	$ 322 137	$ 221 190
Higher value	$ 644 274	$ 884 758

[#] NPV at the date of the transaction

Combining the values for stage 1 and stage 2 gives us a range of values: US$543 327 on the lower end and US$1 529 032 on the higher end (in April 2012 money).

Royalties

The Buyer is entitled to purchase half (1%) of the NSR at any time for US$500 000. Based on this, the full (2%) NSR is valued at US$1 million. However, the buying back of the NSR will only occur at some time in the future and the value has to be adjusted for the corroding effect of inflation. It is considered likely that at least 7 years will elapse before any royalties may become payable, so a simple discounted cash flow model returns a present-day value of US$583 490 (8% discount factor). In addition, we consider the probability of the project proceeding to a stage where royalties between 0.05 and 0.5% may be payable. The deemed value for the royalty therefore ranges between US$29 175 and US$291 745 (April 2012 money).

Bringing it Together

The total value for the copper project on the date of the transaction (1 April 2012) can now be calculated as shown in Table III.

Table III. Results of the analysis of transaction components.

Component	**Lower value** (US$)	**Higher value** (US$)
Cash	1 500 000	1 500 000
Equity	427 500	427 500
First stage elective payment	322 137	644 274
Second stage elective payment	221 190	884 758
Royalty	29 175	291 745
Total cash equivalent value (April 2012)	**2 500 002**	**3 748 277**

Adjusting for Market Fluctuation over Time

Our Valuation date is 15 June 2015. Figure 1 shows that the price of copper declined by a factor of 0.7 during the period from April 2012 to June 2015. Similarly, Figure 2 shows that during the same period, the Small Cap Mining Index on Nasdaq declined by a factor of 0.5 (there are other indices that may be used, even a basket of the share prices of relevant mining companies). We select to use the average of these two factors, being 0.6. Note that since the indices are in the money value of the day (nominal money terms), no additional adjustment needs to be made for inflation. Hence the original cash value of our comparable transaction on 1 April 2012 is multiplied by 0.6 to derive the cash equivalent value of the transaction on the Valuation Date (15 June 2015). The resultant values range between US$1 500 001 and US$2 248 966, which is the range of values that can be used to determine a Market Value for the comparable property that the Competent Valuator is valuing.

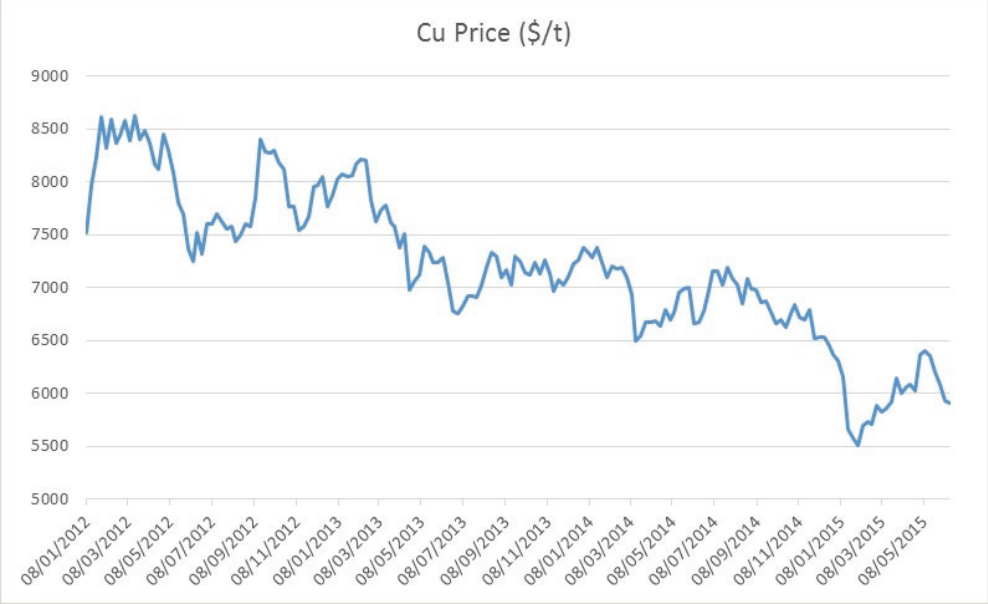


Figure 1. Historical Cu prices (data from Quandl, 2015a).



Figure 2. Historical NASFDAQ Small Cap Mining Index (from Quandl, 2015b).

CONCLUSION

Various value elements can make up a typical transaction involving mineral exploration properties, most of which are not directly expressed in cash terms. Techniques exist for reducing non-cash terms to a cash equivalent, allowing complex transactions to be used as comparable transactions for the purpose of estimating a market value for another mineral asset. These are introduced in a concise manner in this article to enable Competent Valuators to refer to transparent methods for conducting such valuations.

REFERENCES

Appleyard, G.R. (1994). Joint venture terms as a basis for valuation. *VALMIN 1994, Mineral Valuation Methodologies 1994,* Sydney, Australia, 27-28 October 1994. Australasian Institute of Mining and Metallurgy, Melbourne.

Baurens, S. (2010). Valuation of Metals and Mining Companies. [In collaboration with the University of Zürich, Swiss Banking Institute and Prof. Dr. T. Hens]. Basinvest AG, Zurich. http://www.basinvest.ch/upload/pdf/Valuation_of_Metals_and_Mining_Companies.pdf

Butler, R. (2002). Joint venture terms method in mineral property valuation. *AusIMM, Bulletin*, no. 3 (May/June 2002).

CIMVAL. (2003). Standards and Guidelines for Valuation of Mineral Properties. Special Committee of the Canadian Institute of Mining, Metallurgy and Petroleum on Valuation of Mineral Assets (CIMVAL). http://web.cim.org/standards/documents/Block487_Doc69.pdf

Ellis, T.R. (2001). Difference between a value estimate and an appraisal. SME Annual Meeting, Salt Lake City, Utah, 28 February – 1 March 2000. *Preprint no. 00-119.* Society for Mining, Metallurgy and Exploration, Inc., Littleton, CO.

Lawrence, M.J. (1994). An overview of valuation methods for exploration properties. *VALMIN 1994, Mineral Valuation Methodologies 1994,* Sydney, Australia, 27-28 October 1994. Australasian Institute of Mining and Metallurgy, Melbourne.

Lawrence, M.J. (2001). An outline of market-based approaches for mineral asset valuation best practice. *VALMIN 2001, Mineral Asset Valuation Issues for the Next Millennium,* Sydney, Australia, 25-26 October 2001. Australasian Institute of Mining and Metallurgy, Melbourne.

Lawrence, M.J. (2002). Letter to the Editor from R. Appleyard – Response by M.J. Lawrence. *AusIMM Bulletin*, no. 3 (May/June 2002).

Lonergan, W. (2002). Traps In mineral valuations – proceed with care. *AusIMM Bulletin*, no. 3 (May/June 2002).

Sorentino, C. (2000). Valuation Methodology for VALMIN. MICA, The Codes Forum, Sydney.

Sorentino, C. (2002). Joint Venture Terms Method in Mineral Property Valuation - Response from MICA Board. *AusIMM Bulletin*, no. 3 (May/June 2002).

Quandl. (2015a). Historical copper prices. https://www.quandl.com/data/ODA/PCOPP_USD-Copper-Price [Accessed 18 Oct. 2015].

Quandl. (2015b). Nasdaq Small Cap Mining Index. https://www.quandl.com/data/NASDAQOMX/NQUSS1770-NQ-US-Sm-Cap-Mining-Index-NQUSS1770 [Accessed 18 Oct. 2015].



André Johannes van der Merwe

Head of Mining Studies
The MSA Group (Pty) Ltd

André van der Merwe started his career in 1987 with the JCI Ltd as an exploration geophysicist. He expanded his experience by working as a mine geologist in a Witwatersrand gold mine and a rock engineer with the Miningtek division of the CSIR. The late 90s allowed André to increase his knowledge geographically and at executive level. In 1999 André successfully started up a local branch of an Australian consultant (Resource Service Group) which taught some tough lessons on cash-flow management. André next joined SRK Consulting, where he became a Partner.

In 2007 he took on the role of the Operations Manager at a platinum junior (Nkwe Platinum) , where he planned, budgeted and manged a very large project form first drillhole through feasibility stage and initiated the next stage: construction of a world-class mine. The collapse of the minerals market put paid to the dream of building a mine from scratch. Currently André heads up the Mining Studies department at the MSA Group.

André enjoys the challenge of the mining industry for the opportunities they present to achieve something worthwhile working with professional teams and mentoring bright, receptive minds.

How Good are Metal Price Forecasts Anyway?

A. McDonald

SRK Consulting (South Africa) (Pty) Ltd

A key component in any cash flow analysis is the metal price forecast that is used. It is important to use an independent metal price forecast, which is typically provided by economic research divisions of investment banks and financial institutions, market specialists, specialist subscriber-based websites, or consensus market forecasts. The paper will examine metal price forecasts from such sources for a number of different commodities over the past 15 years and compare these to the actual metal prices during this same period. This will highlight the inherent uncertainties in any metal price forecast and emphasize the importance of sensitivity analyses in cash flow outputs. Some important conclusions regarding mineral asset valuation will be presented.

INTRODUCTION

Cash flow models are used at various stages of the project development cycle, from concept stage, to determine whether the project is worth pursuing, to feasibility study to support external financing. The Cash Flow Approach is one of the three generally accepted approaches to Mineral Asset Valuation (SAMVAL, 2009), and requires 'determination of the present value of future cash flows over the useful life of the Mineral Asset'.

The revenue line in such a cash flow model is derived from a number of techno-economic parameters (TEPs), which at minimum include:

- Run-of-mine (RoM) ore mined and fed to the processing plant
- The contained metal in the plant feed, which is derived from the RoM ore tons and grade
- The processing plant recovery
- The forecast metal price and exchange rate (if not reporting in US dollars).

Key components in any financial cash flow evaluation are the macro-economic projections, which include the forecast metal price(s) and exchange rate(s).

The forecast metal prices and exchange rates can be obtained from a number of sources, such as:

- Market specialists or analysts
- Specialist subscriber-based websites
- Economic research companies, *e.g.* CRU Group, Steve Forrest and Associates, Platts (a
- Economic research departments of investment banks and financial institutions
- Company economic/corporate finance departments
- Consensus market forecasts from companies such as Reuters and Bloomberg.

Whenever an independent opinion is required on value or the economic merits of a project or operation, it is essential that the metal price and exchange rate forecasts are obtained from an independent source. This adds credibility to the forecasts used and resultant value derived, and avoids any bias or subjectivity that may arise from in-house derived forecasts.

For certain commodities such as ferroalloys, the number of sources for metal price forecasts is limited. By contrast, for common commodities (such as gold, copper, and platinum), it is possible to obtain forecast prices from as many as 20 separate sources. These forecasts usually show considerable variability – this is where the use of consensus (or average) price forecasts comes in (see the example in Table I).

Table I. Example of variability in forecast copper prices (in US dollars per pound) from a number of investment banks.

Source	2006	2007	2008	2009	2010	2011	2012
Bank 1	1.85	1.40	1.60				
Bank 2	2.30	2.50	2.00	1.80	1.50	1.50	1.50
Bank 3	1.80	1.55	1.20	1.10	0.90	0.90	0.90
Bank 4	3.06	3.25	2.30	2.00			
Bank 5	3.06	2.30	1.62	1.45	1.23	1.11	1.11
Bank 6	2.00	1.75	1.40				
Bank 7	1.95	1.45	1.23				
Bank 8	2.05	1.66	1.38	1.25	1.15		
Bank 9	2.53	2.36	2.00	1.50	1.30	1.30	1.30
Bank 10	3.37	2.04	1.27	1.13			
Consensus/average	2.40	2.03	1.60	1.46	1.22	1.20	1.20

Table I also illustrates that some investment banks are not prepared to provide forecasts beyond three to four years into the future, whereas others will provide forecasts for up to eight years.

This paper examines the metal price forecasts from various sources for a number of different commodities over the past 15 years and compares them to the actual metal prices during the same period. This will highlight the inherent uncertainties in any metal price forecast that may be used today and emphasize the importance of sensitivity analyses in cash flow outputs.

HISTORICAL METAL PRICES

Figures 1 to 4 give historical metal prices for iron ore, gold, platinum, and copper respectively. A common feature in these graphs is a long period of relatively stable prices, followed by a rapid increase in the prices (the global commodity boom), price volatility (after the world financial crisis and market uncertainty) and finally a gradual reduction in prices (market uncertainty and slowing of the Chinese economy).

METAL PRICE FORECASTS

The View in 2000

Consider the perspective of an analyst in 2000 (the blue arrows in Figures 1 to 4). Following many years of stable prices, his forecast metal prices would largely seek to perpetuate the past, as can be seen in Figures 5 to 8. His predictions for the iron ore price were correct in the short term, but after 2004 fell short of the actual prices. If this analysis had been for a greenfield project, production would have started as prices began to increase – the perfect situation all companies hope for but rarely achieve.

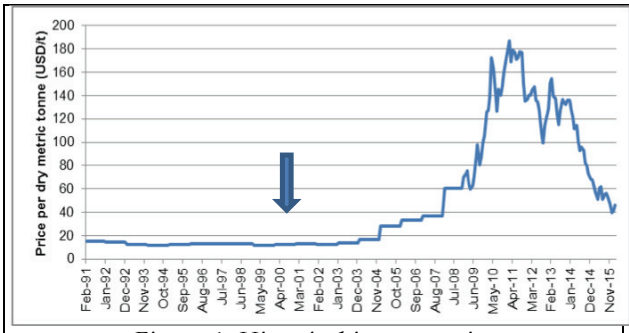


Figure 1. Historical iron ore price (source: www.indexmundi.com).



Figure 2. Historical gold price (source: www.kitco.com).



Figure 3. Historical platinum price (source: www.kitco.com).

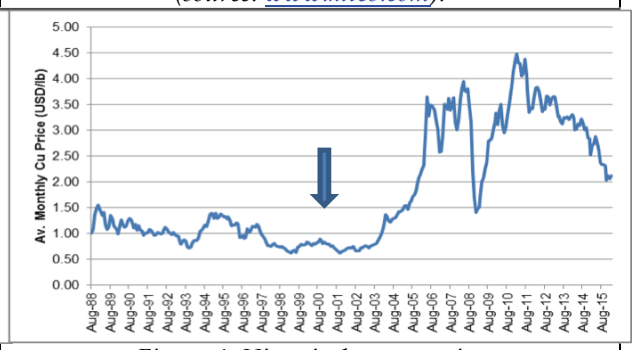


Figure 4. Historical copper price (source: www.investing.com).

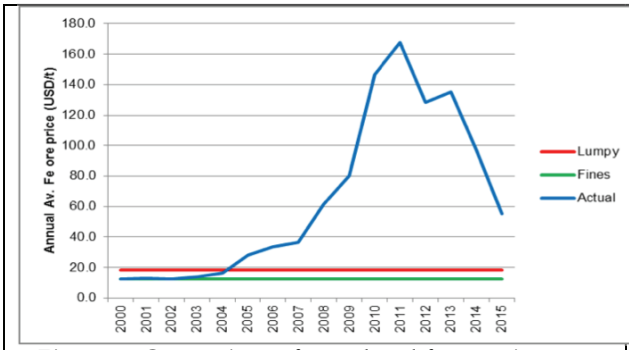


Figure 5. Comparison of actual and forecast iron ore price at 2000.

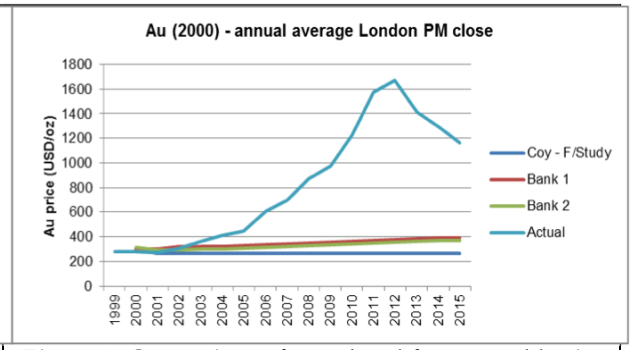


Figure 6. Comparison of actual and forecast gold price at 2000.

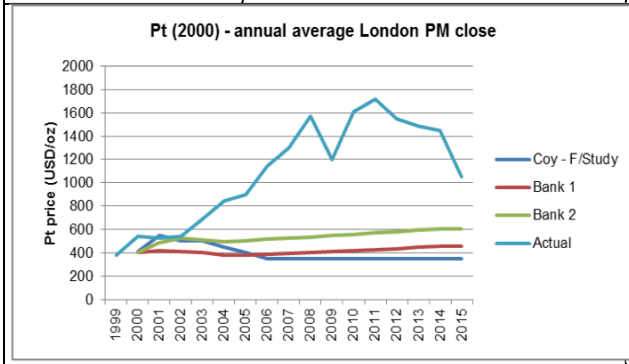


Figure 7. Comparison of actual and forecast platinum price at 2000.

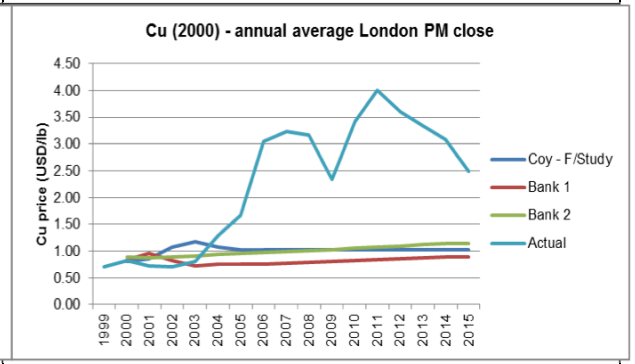


Figure 8. Comparison of actual and forecast copper price at 2000.

The actual and forecast prices in Figures 5 to 8 quickly diverge because the forecasts are based on stable market conditions as per the past, and there was no way of predicting the rapid price increases

that would arise due to the commodity boom. In the examples for the gold, platinum, and copper prices (Figures 6 to 8), the variability in forecasts from different sources can be seen.

The View in 2004

Four years later, no major changes in the long-term trend of metal prices were noticeable and a similar forecasting philosophy was maintained, albeit from a slightly higher base (Figures 9 to 12). The iron ore price projections in Figure 9 were as at 2006 rather than 2004, but still provide the same perspective. The divergence between the actual and forecast prices is as significant as that seen in 2000. The difference in investment bank views of how the prices would perform is again evident.

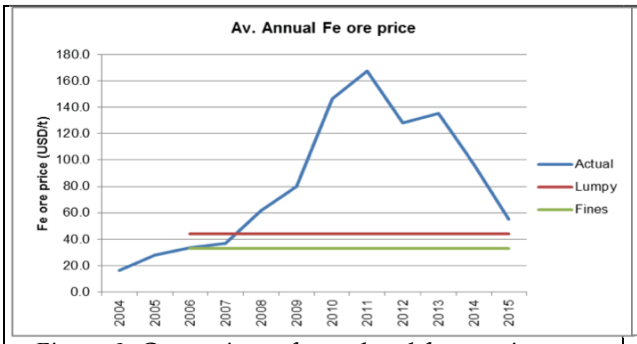


Figure 9. Comparison of actual and forecast iron ore price at 2006.

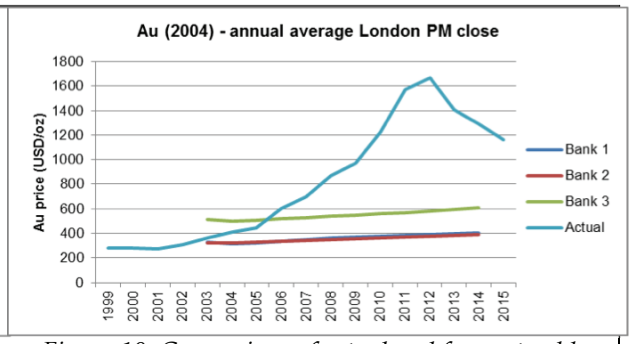


Figure 10. Comparison of actual and forecast gold price at 2004.

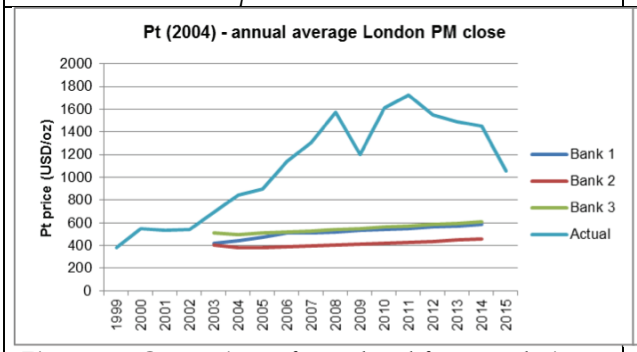


Figure 11. Comparison of actual and forecast platinum price at 2004.

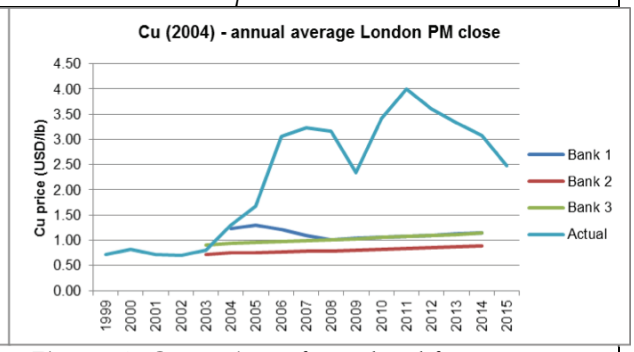


Figure 12. Comparison of actual and forecast copper price at 2004.

The View in 2008

Fast-forward four years to the middle of the global financial crisis in 2008. Markets were in turmoil and the JSE Limited All Share index shed more than 40% of its value in less than six months, dropping from a high of over 32 000 to a low around 18 000.

Three constant price scenarios were used for the evaluation of an iron ore project (Figure 13) – the current price, a long-term price 40% below the current price, and an upside price (20% above the current price). As it turned out, none of these price scenarios was correct.

From the wide scatter of forecast gold, copper, and platinum prices (Figures 14 to 16), there were very divergent opinions regarding how the market was going to react. The general view was a pessimistic one going forward, as shown by the downward trend on the forecast gold, copper, and platinum prices. While the price projections reflected market sentiment, these were very different from what actually happened to the prices.

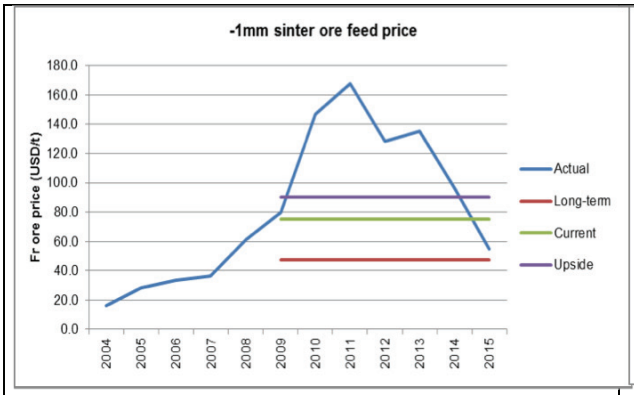


Figure 13. Comparison of actual and forecast iron ore prices at 2008.

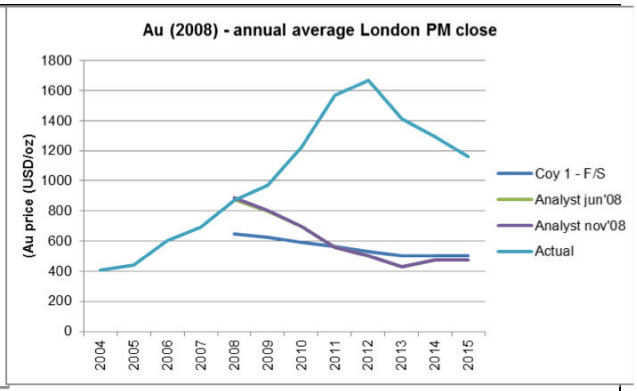


Figure 14. Comparison of actual and forecast gold price at 2008.

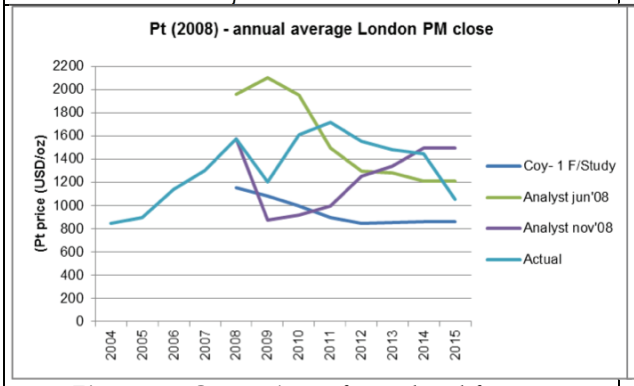


Figure 15. Comparison of actual and forecast platinum price at 2008.

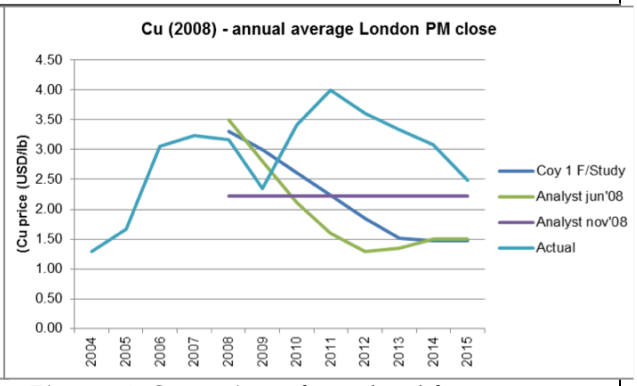


Figure 16. Comparison of actual and forecast copper price at 2008.

The View in 2011

Having survived the global financial crisis and been rescued by massive interventions from the central banks of the USA, Europe, and Asia, the markets and commodity prices recovered quite quickly. There was, however, still a great deal of price volatility as the markets came to grips with conflicting messages. From 2011/2012, the iron ore, gold, platinum, and copper prices commenced a steady decline (see Figures 1 to 4), spurred by concerns over the Chinese economy, the conflict situations linked to the Arab Spring, and recessionary trends.

The forecast for iron ore concentrate and pellets provided for reduced prices over time, but the predictions were optimistic compared with reality (Figure 17). The severity of the pull-back in iron ore prices caught everyone by surprise.

The forecast gold price (in real terms) was initially lower, and then higher, than the actual price (Figure 18).

The forecast platinum price was optimistic (Figure 19). Furthermore, the forecast provided for increasing real prices whereas the prices went the other way.

The forecast copper price showed the correct downward trend, but was much more conservative than the actual scenario (Figure 20).

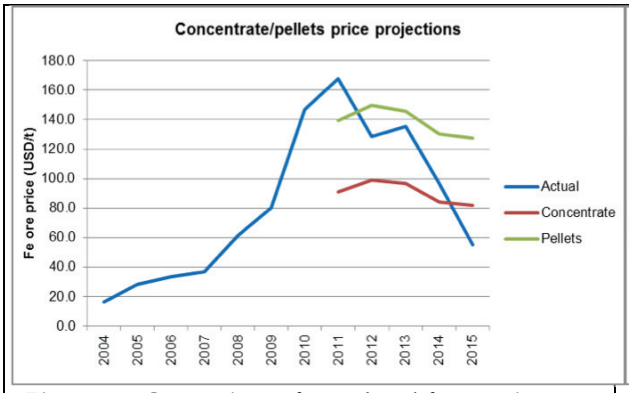


Figure 17. Comparison of actual and forecast iron ore price at 2011.

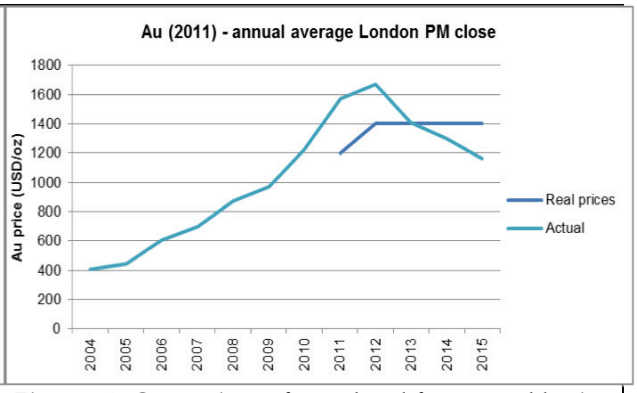


Figure 18. Comparison of actual and forecast gold price at 2011.

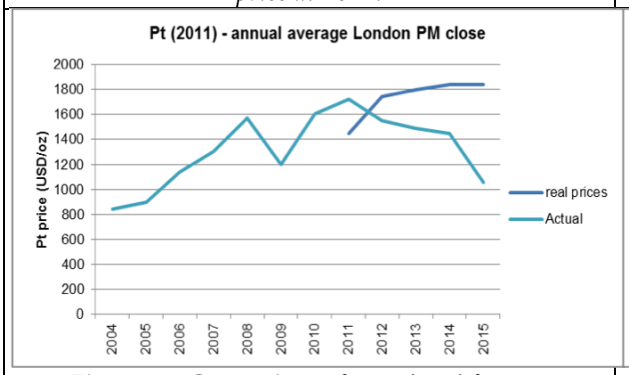


Figure 19. Comparison of actual and forecast platinum price at 2011.

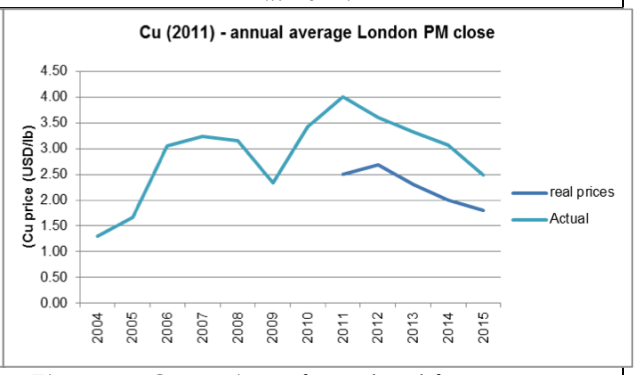


Figure 20. Comparison of actual and forecast copper price at 2011.

So what changed?

What changed so significantly that price forecasts over a decade were so wrong? Until 2002/2003, the market had experienced generally stable commodity prices, and long-term trend lines were generally reasonable for forecast prices.

The iron ore, gold, platinum, and copper prices then deviated significantly from the long-term trends, catching everyone by surprise. Producers had not foreseen the pent-up demand from the East, in particular China, which outstripped supply. The minerals industry had been in the doldrums for most of the 1980s and 1990s, with exploration budgets slashed drastically and new mining projects put on hold indefinitely.

A Structural Shift in the Market?

Around 2011/2012, speculation was rife that there may have been a structural shift in the market (see Figure 21). In other words, the supply-demand dynamics had changed such that future prices could be supported at higher levels. However, the downward movement in commodity prices (see Figures 1 to 4) suggests that these propositions may have been premature.

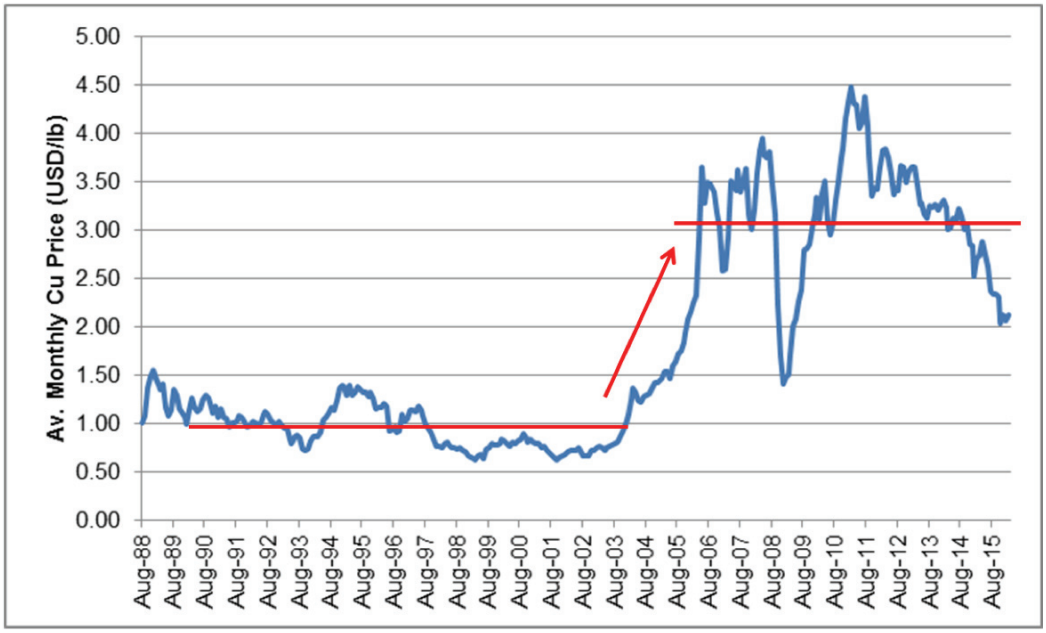


Figure 21. Data illustrating a possible structural shift in the copper price.

OTHER CONSIDERATIONS WITH PRICE FORECASTS

Nominal vs Real

It is necessary when obtaining commodity price forecasts to confirm whether the projections are in real or nominal terms, *i.e.* constant money terms at the date the forecasts are provided, or money terms at some future date. The difference can be seen in Table II.

The real terms forecast will take into account aspects such as operating cost pressures of the primary producers, supply and demand characteristics and other extraneous factors. The nominal terms forecast is based on the real terms forecast, but includes the effect of inflationary pressures on the USA and the US dollar.

Table II. Comparison of nominal and real forecast platinum prices.

Metal price (US$/oz)	2010	2011	2012	2013	2014	2015	2016	2017
Nominal	1217	1340	1419	1427	1415	1467	1522	1560
Real	1202	1291	1334	1309	1266	1281	1296	1296

Link to ZAR:US$ Exchange Rate

With its dominance of supply of a variety of commodities and metals, South African producers can to a certain extent be considered as price shifters, *i.e.* to maintain their margins with rising costs, they can adjust the selling prices into the market and others will follow suit. Examples of such commodities are ferrochrome (FeCr), chrome (Cr), ore and platinum group metals (PGMs).

Under these conditions, any price forecast that does not consider how the South African rand (ZAR) will perform against the US dollar only gives part of the story. It does not help either if price forecasts are obtained from one source and forecast ZAR:USD exchange rates from another – it is very likely that the underlying assumptions and views on market supply/demand conditions will be different, so the two sets of projections will not even be related.

Use of Three-year Trailing Average Price

Based on concerns raised by the British Columbia Securities Commission, American Manganese Inc. agreed to use a three-year trailing average price in the evaluation of the economic feasibility of its Artillery Peak project (Reugh, 2012). Reugh (2012) reported that this was a more conservative price forecast than the expected case provided by the CPM Group.

Inspection of Figure 22 shows that in a rising market, a three-year trailing average understates the price. This illustrates the reason why the price forecast was 'more conservative'.



Figure 22. Three-year trailing average manganese prices.

In contrast, in a falling market, a three-year trailing average will overstate the commodity price. While this method of price forecasting is accepted, it is important to remember its limitations as described above.

Effective Date

Owing to the volatility in commodity prices, it is necessary to state the date at which the price forecasts and exchange rate projections are determined. This Effective Date then prescribes that the cash flow projections, and any opinions on value in a report are valid only at that date.

It is also advisable that all other technical-economic parameters used in a cash flow evaluation are valid at the Effective Date to be consistent with the price forecasts.

DISCUSSION

There were many conflicting views during late 2015 and early 2016 regarding the state of the market and where commodity prices are headed. Mineweb.com, a subsidiary of Moneyweb Holdings Ltd, posted a number of articles regarding views on where the gold price is headed. Levenstein (2015), Holmes (2015), and GFMS (2015) all suggest that there are good prospects for an increase in the gold price in 2016. Gold flows to Hong Kong and China were enormous in 2015, but these flows were not

correctly reflected in the global gold price mechanism (Levenstein, 2015; Bloomberg, 2015). During this time, Russia, Kazakhstan, and Ukraine increased their gold reserves.

Among the gold bears, Lloyd-Smith (2015) and Biesheuvel (2015) were concerned that when the US Federal Reserve raises interest rates this will adversely impact the gold price. This sentiment is echoed by Barnabas Gan of Oversea-Chinese Banking Corp in Singapore, who was quoted as saying 'higher rates drive up the dollar, curbing gold's appeal as an alternative' (Roy and van der Walt, 2015).

Arendse (2015) provided some interesting views on the sophisticated and complex models used by i*nter alia* analysts and investment banks to forecast growth and other market factors. 'Evidence from events such as the dot.com bubble and the 2009 financial crisis show that you would perform just as well if you had simply guessed.' Rowan Williams of Nitrogen Fund Managers was quoted by Arendse (2015) as saying 'there are too many different opinions and it is not clear what the time horizon of the various forecasts is.'

Yaldwyn (2015) provided an interesting view of price forecasting – he recalled someone once writing that he had used a 'cow in a paddock' method to forecast the price of gold. In essence, if you had to predict where a cow would be standing in any paddock in 12 months' time, you would have a better chance of getting it right if you chose the place it was currently standing at. By analogy, today's price is the best prediction of next year's price.

Somerville (2015) recommended that a sensitivity analysis should be done using a range that matches the annual price volatility of the commodity across a number of market cycles.

CONCLUSIONS

Given the uncertainty in forecast prices and exchange rates, it is unlikely that the forecasts satisfy the ±10% confidence requirements of a feasibility study for a mining project. It is therefore critical to evaluate the sensitivity of a project to price and exchange rate fluctuations. The declared Mineral Reserves for a project or mine are also affected by commodity price fluctuations, and the impact of varying prices on the reserves and cut-off grades should be similarly evaluated.

REFERENCES

Arendse, N. (2015). Cut forecasters some slack, but don't bet on accuracy either. http://www.mineweb.com/articles-by-type/analysis/cut-the-forecasters-some-slack-but-dont-bet-on-their-accuracy-either/ 21 October 2015 [Accessed 22 October 2015].

Biesheuvel, T. (2015). Gold volatility near four-week low as prices steady before Fed. http://www.mineweb.com/news-fast-news/gold-volatility-near-four-week-low-as-prices-steady-before-fed/ 21 October 2015 [Accessed 22 October 2015].

Bloomberg News. (2015). China gold imports climb on pre-holiday buying and lower prices. http://www.mineweb.com/news-fast-news/china-gold-imports-climb-on-pre-holiday-buying-and-lower-prices/ 27 October 2015 [Accessed 29 October 2015].

GFMS (ThomsonReuters). (2015). Better prospects for gold on the horizon – GFMS. http://www.mineweb.com/articles-by-type/company-releases/better-prospects-for-gold-on-the-horizon-gfms/ 28 October 2015 [Accessed 29 October 2015].

Holmes, F. (2015). Will gold finish 2015 with a gain? http://www.mineweb.com/articles-by-type/independent-viewpoint/will-gold-finish-2015-with-a-gain/ 20 October 2015 [Accessed 22 October 2015].

Indexmundi. (2015). Historical iron ore prices. http://www.indexmundi.com/commodities/?commodity=iron-ore&months=300 [Accessed 10 March 2016].

Investing.com. (2016). Historical copper prices. http://www.investing.com/commodities/copper-historical-data [Accessed 10 March 2016].

Kitco. (2016a). Historical gold prices. http://www.kitco.com/scripts/hist_charts/yearly_graphs.plx [Accessed 10 March 2016].

Kitco. (2016b). Historical platinum prices. http://www.kitco.com/scripts/hist_charts/yearly_graphs.plx [Accessed 10 March 2016].

Levenstein, D. (Lakeshore Trading). (2015). Gold ready to take its position when QE undoubtedly fails. http://www.mineweb.com/articles-by-type/analysis/gold-ready-to-take-its-position-when-qe-undoubtedly-fails/ 28 October 2015 [Accessed 29 October 2015].

Lloyd-Smith, J. (Bloomberg). (2015). Goldman says Fed raising rates in December will hurt bullion. http://www.mineweb.com/news-fast-news/goldman-says-fed-raising-rates-in-december-will-hurt-bullion/ 22 October 2015 [Accessed 22 October 2015].

Reugh, L. (American Manganese Inc.) (2012). Base case amended to 3 year trailing average after review by BC Securities Commission. http://www.americanmanganeseinc.com/base-case-amended-to-3-year-trailing-average-after-review-by-bc-securities-commission/ 27 August 2012 [Accessed 30 October 2015].

Roy, D. and van der Walt, E. (Bloomberg). (2015). Sorry gold bulls, metal's best forecaster expects more declines. http://www.mineweb.com/news/gold/sorry-gold-bulls-metals-best-forecaster-expects-more-declines/ 1 July 2015 [Accessed 29 October 2015].

SAMVAL. (2009). South African Mineral Asset Valuation (SAMVAL) Working Group. The South African Code for the Reporting of Mineral Asset Valuation (The SAMVAL Code). 2008 Edition as amended July 2009. http://www.samcode.co.za/downloads/SAMVAL2009.pdf

Somerville, K. (2015). Ore Reserve estimates and changes in commodity price – a survival guide. *AusIMM Bulletin*, December 2015. www.ausimmbulletin.com/feature/ore-reserve-estimates-and-changes-in-commodity-price-a-survival-guide [Accessed 26 January 2016].

Yaldwyn, R. (2015). Personal communication.



Andrew John McDonald

Principal Engineer
SRK Consulting (SA) (Pty) Ltd

Has over 40 years of diverse experience in a range of management, technical and financial activities, the past 20 of which have been involved in the fields of engineering studies, statutory reporting for stock exchanges and financial evaluation of mineral projects throughout Africa and other international locations. Has undertaken numerous mineral property and project valuations since 1996.

Some common risks to avoid in estimating and applying discount rates

J. Burger and N.J. Odendaal

Minxcon (Pty) Limited

Discounted cash flow (DCF) analysis is one of the most widely-accepted methods of mineral asset valuation. Operational and corporate decisions based on a discount rate, without due process, could increase the risk in decision-making. One of the most critical issues for an investor to consider in a strategic acquisition is to estimate the worth of the mineral asset. Another example is software that uses net present value (NPV) to determine the optimal pit shell. In both examples the outcome could be significantly different and costly if a project under consideration is either accepted or rejected. A major problem in determining the appropriate discount rate is the subjective approach towards associated risk, rather than a systematic approach. Determining a realistic discount rate for a given project is therefore one of the most difficult and important aspects of cash flow analysis due to the high sensitivity of value to the discount rate. Discount rate should be determined with the full consideration of technical, economic, and political conditions affecting the specific project. It should also allow for changes to the company's capital structure, in order to avoid unrealistically high or low discount rates over the life of an operation.

In this paper we discuss the methods used in calculating a discount rate; and furthermore how to best apply the discount rate to determine value of a mineral asset.

INTRODUCTION

Corporate investment decisions on a mining project are usually made after economic evaluation, which is a standard procedure in every business application. Technical, economic, and political risks are accounted for in the investment decision by applying an appropriate discount rate. There is no doubt that the determination of the discount rate to be implemented for a given project is one of the most difficult aspects of cash flow analysis. In practice, however, the discount rate is still subjective and reliant on corporate or other experience factors.

Mining valuation is similar to valuations in other sectors in the sense that a mine is valuated on the present value of potential cash flow generation, associated with time and certain risks. Mining investments are differentiated from other investments as mining targets are minerals that are hidden beneath the ground. The valuation is dependent on the reserve estimation that approximates the size of the underground orebody and the production capacity based on the suitable mining and processing methods. Therefore, the information on the mineral property needs to be collected and analysed before calculating possible cash flows, and then a certain discounted rate needs to be chosen to calculate the net present value of the mine based on the investor's valuation standard.

There are many purposes for valuating a mine, and manipulation of data may be possible in order to maximize or minimize the value, depending on the preferred outcome of the owner or lending institution. It is therefore important to establish the reliability and correctness of data collected for value determination. The most common purposes of valuations are to sell a property, obtain financing – either from equity or a loan from the bank, assess the capital investment required, and determine the value of the assets.

Careful consideration should be given to the type of cash flow required for a valuation, the risk of the business – high-risk business entities like mining normally go for a large percentage of equity financing at the start-up – and debt *versus* life of mine (LoM) also dictates the application of a specific valuation methodology.

In this paper we outline the procedure of determining a discount rate; and furthermore how to best apply the discount rate to determine value of a mineral asset.

TYPES OF CASH FLOW

Free cash flow (FCF) is a measure of financial performance that represents the cash that a company is able to generate after investing capital to maintain or expand its asset base. A company can access different sources of finance, including common stock, retained earnings, and debt.

Free cash flow to the firm (FCFF) and free cash flow to equity (FCFE) are the most commonly used cash flow methodologies (Figure 1). FCFF is the cash flow available to all the firm's suppliers of capital once the firm pays all operating expenses (including taxes) and expenditures needed to sustain the firm's productive capacity. FCFE is the cash flow available to the firm's common stockholders once operating expenses (including taxes), expenditures needed to sustain the firm's productive capacity, and payments to (and receipts from) debt holders are accounted for.

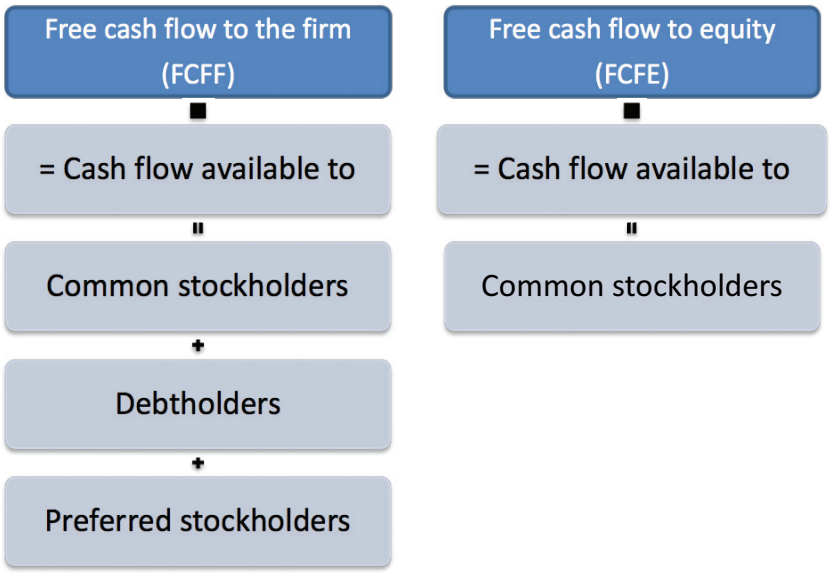


Figure 1. Cash flow examples.

Typically, therefore, the value to shareholders could be shown either in FCFF minus net debt or in FCFE. There are two ways to estimate the equity value using free cash flows:

(1) An entire firm and all its cash flows (FCFF) are discounted, with the relevant discount rate being the weighted average cost of capital (WACC) because this rate reflects the firm's cost of capital and benefits from interest. The value of the firm's debt is then subtracted to calculate the equity value

(2) Only the free cash flows to equity (FCFE) are discounted, with the relevant discount rate being the required return on equity. This provides a more direct way of estimating equity value.

In theory, both approaches should yield the same equity value if the inputs are consistent, as shown in Figure 2.

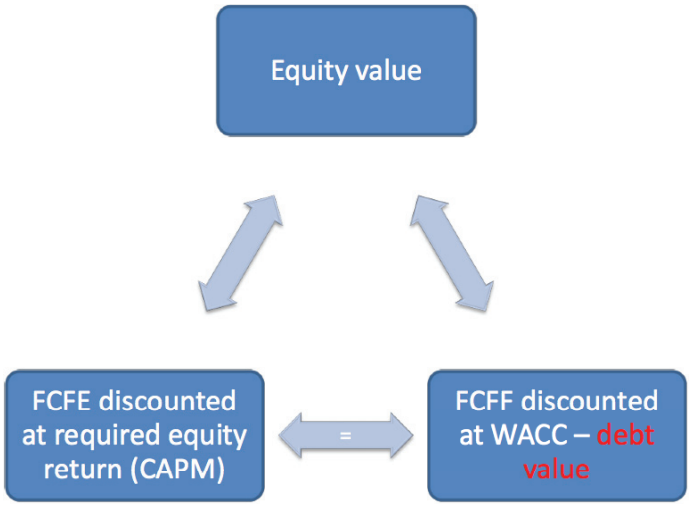


Figure 1. Methods of determining equity value using free cash flows.

EQUITY VERSUS DEBT FINANCING

Debt financing involves borrowing money, typically in the form of a loan from a bank or other financial institution. Equity financing involves investors or partners who provide capital in exchange for a share of ownership of the business. These investors or partners generally invest because they expect to get a specific return (hurdle rate) when the business becomes successful. Unlike a loan, equity capital is risk capital and if the company does not perform there is no obligation to pay back the money. The absence of a monthly principal can free up significant working capital for a mine. Table I summarizes the advantages and disadvantages of equity *versus* debt financing.

Table I. Advantages and disadvantages of equity and debt.

Financing option	Advantages	Disadvantages
Equity financed	▪ Investors take a long-term view (do not expect return immediately) ▪ No fixed loan repayment ▪ More cash on hand for expansion ▪ If the business fails there is no requirement to pay back investment.	▪ Equity finance has ownership (dilution) and voting right ▪ Business relation is ongoing and can be problematic when choosing wrong partner ▪ Equity finance can be more expensive than a loan.
Debt financed	▪ Loan facility has no ownership or vote ▪ Business relation ends when loan is paid back ▪ Interest on loan is tax deductible ▪ Loans can be short or long term ▪ Principal and interest are known and can be budgeted for.	▪ Capital must be paid back within fixed amount of time ▪ In difficult times, the company may find itself in trouble repaying loan ▪ Debt impact growing potential; ▪ Assets of the business can be held as collateral by the lender.

Each type of financing has its own appeal; mines often take advantage of both debt and equity financing, utilizing each to its best advantage.

DISCOUNT RATES

Different discount rates are used when calculating values. FCFF is discounted with the relevant discount rate being the WACC, which reflects all the firm's sources of capital and the tax benefit from interest rates. If there is no debt then the WACC rate is equal to the CAPM rate. The value of the firm's net debt is subtracted to calculate the equity value. FCFE is discounted, with the relevant discount rate being the capital asset pricing model (CAPM). This provides a more direct way of estimating equity value.

The formulae to calculate these two discount rate are displayed in Equations [1] and [2] (Mohendroo, 2014):

$$(CAPM)\ Ke = Rf + (ß \times RPm) + CRP \quad [1]$$

$$WACC = (Ke \times x\ We) + (Kd \times Wd) \quad [2]$$

where Rf is the risk-free rate, RPm the market premium, CRP the country risk premium, Ke the cost of equity, Kd the after-tax cost of debt, and We and Wd the proportions of equity and debt based on market value.

There are various versions of these formulae in practical use. Beta is a measure of the volatility of a stock's returns relative to the equity returns of the overall market, and the slope of that line is the levered equity beta. When ß = 1.00, the returns of the stock are no more or less volatile than returns on the market. When ß > 1.00, the stock's returns are more volatile than the market's returns. The calculation of the discount rates are displayed in Table II.

Table II: Discount rate calculation.

Item	FCFE (CAPM)	Item	FCFF (WACC)
Risk-free rate	8.4%	Cost of equity (nominal terms)	15.5%
Country risk premium	0.0%	Proportion of equity	50%
Market premium	6.0%	Pre-tax cost of debt	9.0%
ß	1.19	After-tax cost of debt	6.7%
Cost of equity (nominal terms)	15.5%	Proportion of debt	50%
Cost of equity (real terms)	**9.0%**	WACC (nominal terms)	11.0%
		WACC (real terms)	**4.7%**

Note: Inflation rate = 6.0
Interest rate is 9.0%
Tax rate is 28%.

Discount Rate Risks – Testing the Theory

In theory, the FCFF and FCFE approaches should yield the same equity value if the inputs are consistent. Testing this theory reveals interesting detail. The following steps were employed:

1. Identical simplified real-term cash flow models (for a 10-year LoM model as well as a 25-year LoM model) were constructed
2. A loan paid back over a period of 10 years (from start of production in year 3) was considered
3. The FCFF using WACC based on a debt/equity ratio of 50:50 was calculated (4.7%)
4. A FCFE with the discount rate based on the CAPM was applied (9.0%).

For FCFE the loan is incorporated into the DCF and the principal and interest payments are paid annually; interest payments are tax-deductible, hence providing a tax advantage. The loan is incurred in year 2 and the first payment is made only in year 3 (1 year's accrued interest). In the FCFF model the principal and interest payments are not included because the tax benefits of interest are already taken care of in the WACC calculation.

The 10-year model yielded almost the same NPV for the two methodologies when value to equity holders was calculated. The results are displayed in Table III and graphically illustrated in Figure 3.

Table III. 10-year LoM valuation results.

Item	FCFE (CAPM)	FCFF (WACC)
Real discount rate	9.0%	4.7%
NPV (R million)	205	250
Debt (R million)	-	-60
Equity value (R million)	205	190
Variance		*-7.3%*

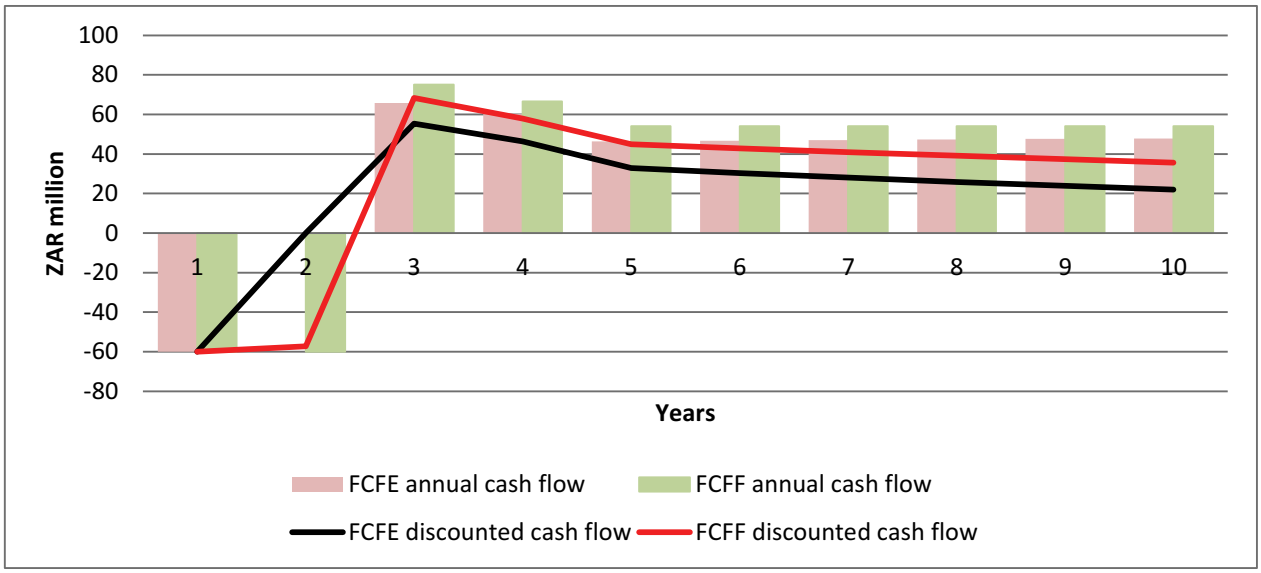


Figure 3. 10-year LoM cash flows.

With the loan still in place for 10 years and the LoM now extended to a 25-year period, the model yields a 41.4% higher NPV for the FCFF. The reason for this is that when WACC is used the same debt-to-equity ratio is assumed to continue over the whole LoM – the longer the LoM the more benefit is generated because of the lower WACC discount rate compared to the FCFE model, where the loan is paid off in 10 years with no further tax advantage for the remaining life. The results are displayed in Table IV.

Table IV. 25-year LoM valuation results.

Item	FCFE (CAPM)	FCFF (WACC)
Real discount rate	9.0%	4.7%
NPV (R million)	401	627
Debt (R million)	-	-60
Equity value (R million)	401	567
Variance		*+41.4%*

The difference in NPVs is substantial and highlights the importance of using the correct assumptions to estimate the value to shareholders when using FCFs. In reality, the FCFE value would be the more realistic in the case of the 25-year plan.

Vélez–Pareja, Tham, and Fernánde (2005) stated that if the capital structure is expected to change significantly over the life of the project, an adjusted WACC could be used as an alternative. The simplest way of incorporating a change in capital structure is to recalculate the WACC using the new capital structure weightings. The DCF of the 25-year LoM plan is displayed in Table V and graphically illustrated in Figure 4.

Table V. 25-year LoM real discounted cash flows.

Free Cash Flow to Equity																													
Years		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Revenue		-	-	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Working Costs		-	-	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Capex		60	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cash Flow Before Tax		-60	-60	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Loan Capital		-	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Principle Repayment				-4	-4	-4	-4	-4	-5	-5	-5	-5	-5	0	0	0	0	0	0	0	0	0	0	0	0	0
Interest		-	-	-5	-5	-5	-4	-4	-3	-2	-2	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cash Flow for Tax income		-60	-60	70	70	70	71	71	72	73	73	74	74	75	75	75	75	75	75	75	75	75	75	75	75	75
Taxable income		-60	-120	-50	19	70	71	71	72	73	73	74	74	75	75	75	75	75	75	75	75	75	75	75	75	75
Tax @	28%	-	-	-	5	20	20	20	20	20	20	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
Cash Flow After Tax		-60	-	66	60	46	47	47	47	48	48	48	49	54	54	54	54	54	54	54	54	54	54	54	54	54
Discounted Cash Flow		-60	-	55	46	33	30	28	26	24	22	20	19	19	18	16	15	14	12	11	11	10	9	8	7	7
CAPM Discount Rate		**9%**																								
IRR		59.6%																								
NPV = Equity Value		**R 401**																								
Free Cash Flow to Firm																										
Years		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Revenue		-	-	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Working Costs		-	-	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Capex		60	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cash Flow Before Tax		-60	-60	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Loan Capital																										
Interest																										
Cash Flow for Tax income		-60	-60	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Taxable income		-60	-120	-45	30	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Tax @	28%	-	-	-	8	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
Cash Flow After Tax		-60	-60	75	67	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54
Discounted Cash Flow		-60	-57	68	58	45	43	41	39	37	36	34	32	31	30	28	27	26	25	24	22	21	20	20	19	18
WACC Discount Rate		**4.7%**																								
IRR		43.2%																								
NPV		R 627																								
Debt		-60																								
Equity Value		**R 567**																								

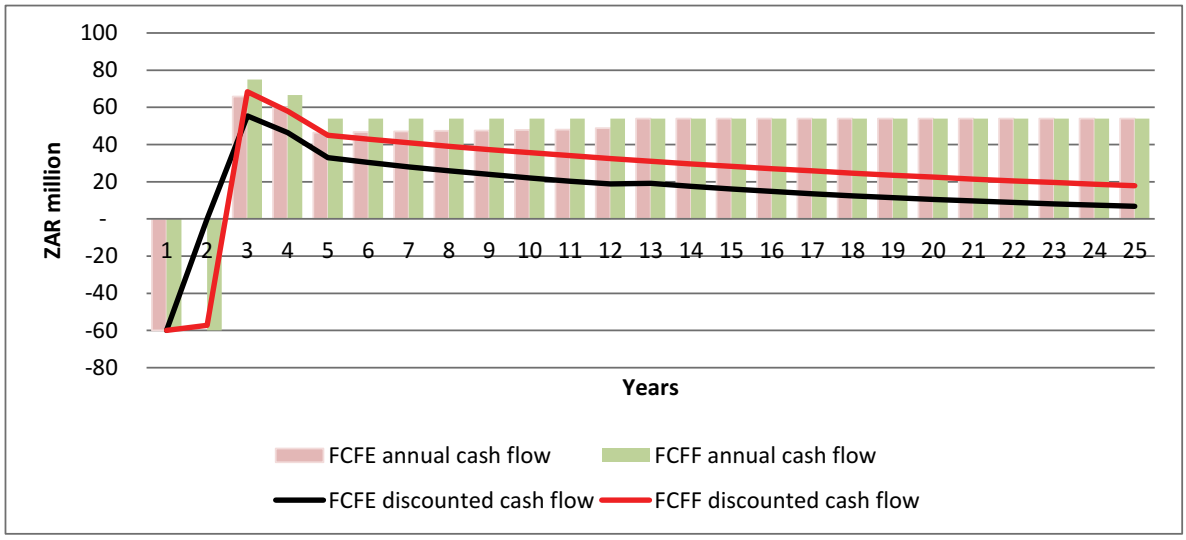


Figure 4. 25-year LoM cash flows.

According to Carnevale (2013), the competent valuator is never 100% certain what the future company earnings will be (although they can make reasonable estimates), and the more uncertain the future earnings, the higher the risk. Thus, companies in very stable industries with consistent cash flows generally make more use of debt than companies in risky industries or companies that are very small and just starting up. New businesses with high uncertainty may have difficulty obtaining debt financing, and therefore finance their operations largely through equity. These considerations also need to be taken into account when choosing a cash flow methodology.

Pit Optimization

It is common practise for companies to select the optimal pit shell, which defines the mineable reserve, without much further consideration. However, companies may consider various strategies to optimize long-term value of the project or to optimize short-term cash flow. Analysis of the entire LoM value estimation process shows that the selection of a discount rate and other parameters should be considered carefully.

According to Breed and Van Heerden (2015), typical pit optimization input parameters include, but are not limited to, the resource model, production rate, cut-off grade, operating and capital cost estimates, the slope angles, treatment capacity, recoveries, and discount rate. Experience shows that pit optimizations usually end by selection of the ultimate pit, although there could be significantly more feasible or better strategically aligned options. Pit optimization only establishes the basis for future analysis and refinement as part of a post-pit optimization process.

Significance of Discount Rate

Pit optimization software models determine the pit shell with the most attractive NPV. One of the factors that have a significant effect on the pit optimization process is the discount rate. Hence, determining a realistic discount rate for a project is one of the most difficult and important aspects of value analysis. The case study identified that operational and corporate decisions on a discount rate, without due process, could lead to the selection of a sub-optimal pit. This could make or break a developing project.

Figure 5 shows the trade-off between increased discount rates and the pits selected (containing fewer ore tons).

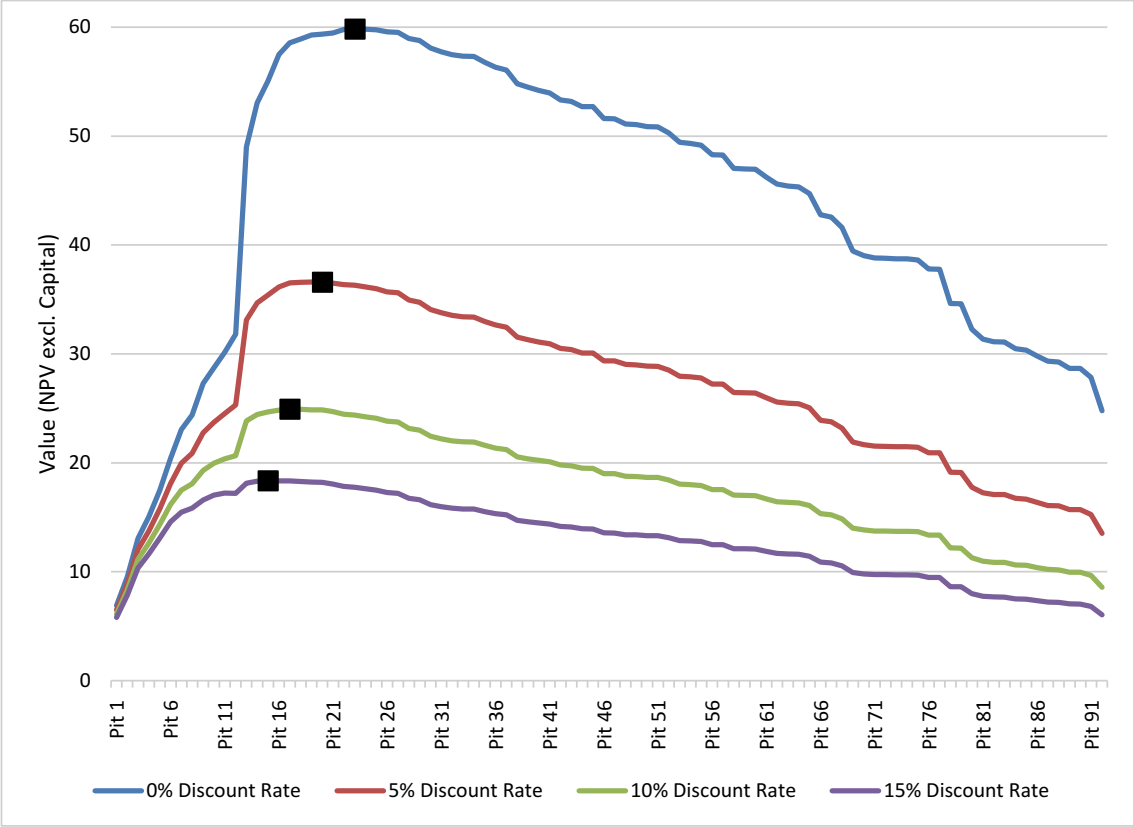


Figure 5. Pit optimization results – varying discount rate.

Further analyses of the optimal pits selected at the varying discount rates are illustrated in Figure 6. This clearly indicates that fewer ore tons are contained in the pits selected at higher discount rates. It is interesting to note that for this specific gold case study, the grade did not decrease as the pit size increased. This was a function of shallow oxide material being mined in the small pits with much lower grades. As the pit size increased the grade increased as more of the deeper higher-grade sulphide material was extracted. This highlights the importance of understanding all the value drivers when evaluating projects and considering the impact of discount rate.

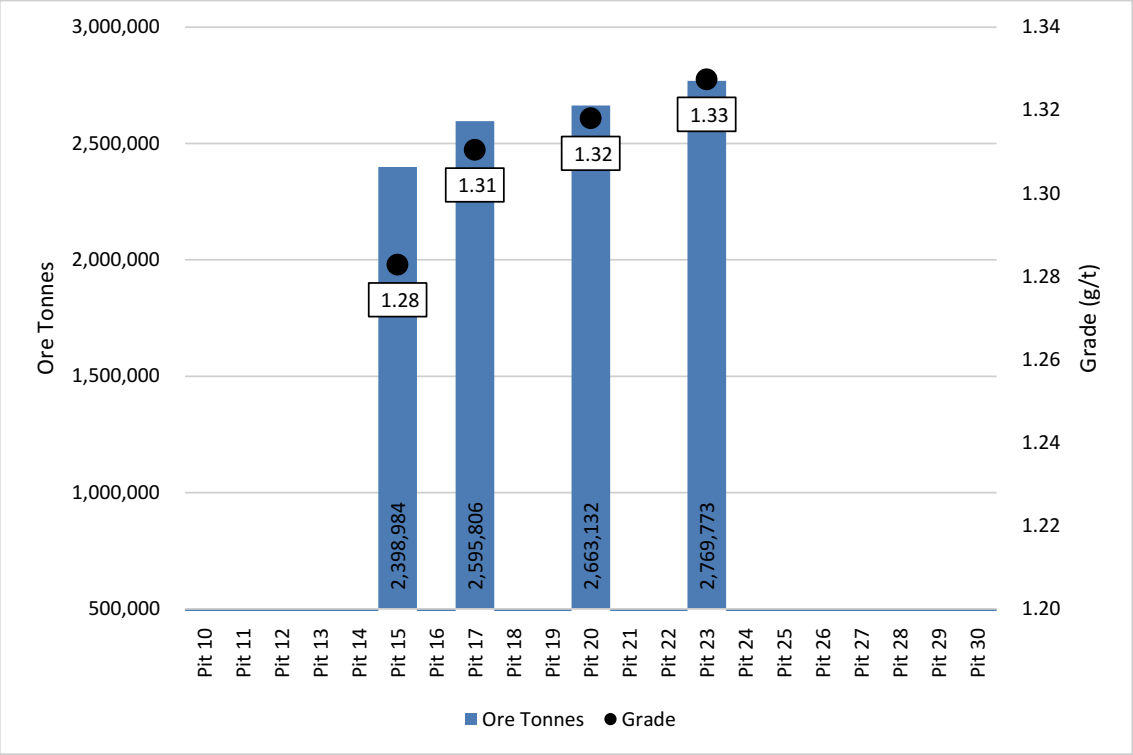


Figure 6. Discount rate analysis.

To further illustrate the sensitivity of discount rate we analysed the four optimal pits generated at 0%, 5%, 10%, and 15% discount rate. We selected each pit size and discounted the cash flow generated at various rates.

Figure 7 illustrates the results and highlights the significance and sensitivity of using discount rate to select an ultimate pit. At zero discount rate the larger Pit 23 has the maximum NPV and at 15% discount rate the smallest Pit 15 has the maximum NPV. It is important to understand that although there is only a maximum of 8% variance in NPV, the size of pit selected could significantly influence the Mineral Reserve. The difference in reserve ounces between Pit 15 and Pit 23 is 16%.

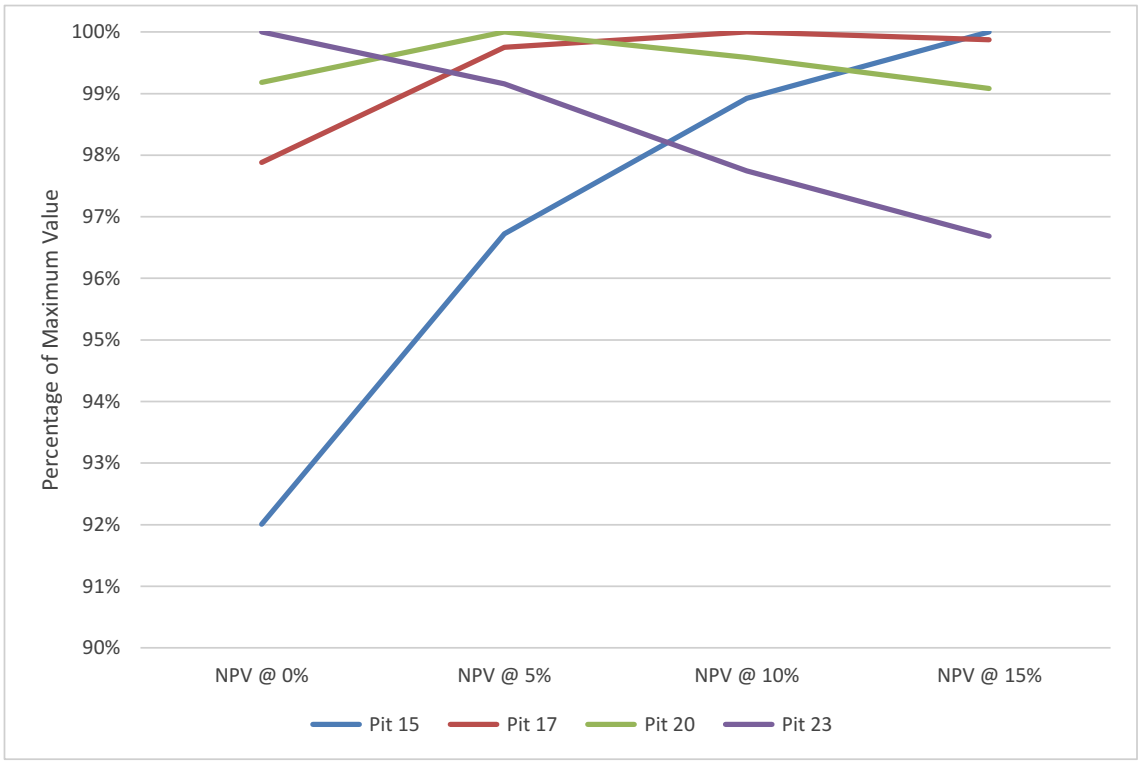


Figure 7. NPV variance with discount rate.

Discount Rate Selection for Pit Optimization

Park and Matunhire (2011) stated that when evaluating mining investment opportunities, the risks associated with the mineral exploration and development should be considered. These risks are classified as technical, economic, and political risks, and are commonly accounted for by changing the discount rate to compensate for the variability of success.

During pit optimization, a discount rate should not be applied to mitigate technical, economic, and political risk. The discount rate applied could be regarded as pure cost of capital. It is the rate of return a company must generate to compensate their investors. A risk-adjusted discount rate should be applied in the subsequent cash flow analysis.

Determining a discount rate for pit optimization remains a difficult decision,. with disastrous consequences if not chosen correctly. However, the decision should be based on the key performance drivers defined in the strategy. Knowledge of the drivers and results obtained at varying discount rates should assist in developing a strategically aligned LoM.

CONCLUSIONS

Valuators and companies often accept the discount rates provided to them from top management without fully understanding the potential impact on the value of the project.

It is important for managers and investors to understand the differences between FCFF and FCFE, as this is dependent on the strategy and objective of the valuation. FCFE is employed from the perspective of buying equity, and FCFF for firm-wide valuation.

The computation of WACC, which is both a sensitive input and surprisingly variable, should be calculated with caution and applied correctly to avoid unrealistically high or low discount rates over the life of an operation.

Discount rates should allow for changes to the company's capital structure in order to avoid impractical discount rates for an operation. The simplest way of incorporating a change in capital structure is to recalculate the WACC using the new capital structure weightings.

REFERENCES

Breed, M. and Van Heerden, D. (2015). Post pit optimisation strategic alignment. *Proceedings of the Mining Business Optimisation Conference.* 16 February 2015. Southern African Institute of Mining and Metallurgy, Johannesburg

Carnevale, C. (2013). What is the correct discount rate to use? Part 2B. http://www.fastgraphs.com/research_articles/2013-09-26-chuck-carnevale-what-is-the-correct-discount-part2b [accessed 14 September 2015].

Mohendroo, M. (2014). Some common mistakes to avoid in estimating and applying discount rates. *Deloitte Middle East Point of View magazine,* Spring 2014. pp. 36-43.

Park, S.J. and Matunhire, I.I. (2011). Investigation of factors influencing the determination of discount rate and the application of quantitative methods for discount rate using risk factors in the minerals industry. *Proceedings of the 6th Southern African Base Metals Conference*, Phalaborwa, South Africa, 18–21 July 2011.. Southern African Institute of Mining and Metallurgy, Johannesburg. pp. 413-428.

Vélez–Pareja, I., Tham, J., and Fernández, V. (2005). Adjustment of the WACC with subsidized debt in the presence of corporate taxes: the N-Period case. *Estudios de Administración* 12 (2), 45-66.

Comparative transactions in project valuation

A. van Zyl

SRK Consulting (Pty) Ltd.

The Market Approach is one of the key valuation methods and is possibly the most regularly used approach given that it is appropriate for both producing properties and exploration projects. However, particularly in a South African context, there are substantial challenges in finding a reasonable number of comparative transactions. It is often the practice for companies to use general market averages in the absence of sufficient comparable transactions that would facilitate a statistically robust conclusion. This paper argues that it is more appropriate for the Competent Valuator to use judgement and experience in interpreting, contextualizing and adjusting the more relevant transactions rather than arbitrarily applying average values.

INTRODUCTION

The SAMVAL Code recommends the methods shown in Table I for the valuation of mineral assets:

Table I. Valuation approaches.

Valuation Approach	Exploration Properties	Development Properties	Production Properties	Dormant Properties		Defunct Properties
				Economically viable	Not viable	
Cash Flow	Not generally used	Widely used	Widely used	Widely used	Not generally used	Not generally used
Market	Widely used	Less widely used	Quite widely used	Quite widely used	Widely used	Widely used
Cost	Quite widely used	Not generally used	Not generally used		Less widely used	Quite widely used

It is clear from Table I that the Market Approach is always at least the second most commonly used approach for all property types. Given the central role that it plays in valuations, any uncertainty around the validity of the conclusions is of concern.

The SAMVAL Code defines the Market Approach as follow: 'The Market Approach relies on the principle of 'willing buyer, willing seller' and requires that the amount obtainable from the sale of the Mineral Asset is determined as if in an arm's-length transaction.'

Roberts (2006) gives the following definition of the Market Approach: 'In market comparable approaches to project valuation, market values for one or more selected comparable mining project(s) are applied to a project of interest to estimate its value.'

Experience suggests that adequate comparable transactions from which statistically robust conclusions can be drawn are seldom available. These comparable transactions should be for properties that are similar in geology, location, mineralization, and other modifying factors. The transactions should ideally be recent and in similar price environments. These restrictions are too onerous in practice if the intention is to mathematically and statistically prove the value determined, and hence the judgement of the Competent Valuator (CV) is implicit in any conclusion drawn.

TRANSACTIONS

Gold transactions in South Africa are selected to facilitate the discussion. South Africa is a globally significant source of gold and the associated mining industry is mature, extensive, and comparatively geologically consistent. In general, the Market Approach to valuation should be as likely to succeed in the gold industry in South Africa as for other minerals in any other jurisdiction.

The past five years have seen significant changes in exchange rate, price, and sentiment in commodities in general and gold in particular. Adjustments can be made to the price paid per ounce in the recorded transactions to make them more comparable.

Adjusting for price does not compensate for changes in sentiment or any strategic benefit that either the purchaser or seller may gain. Changes in sentiment could possibly be included if prevailing consensus price forecasts were considered or through a search of media articles. However, whether the CV would consider the adjustment for the ratio of the forecast prices to carry more weight than the adjustment for the ratio of the spot prices would be a subjective decision.

Furthermore, adjusting for sentiment is not the intended goal of the valuation since the intention is, according to Lawrence (2001), to determine the 'Value-in-Exchange' (or value in the marketplace) not 'Value-in-Use' (or value to the owner).

The prices recorded in readily available databases are those that were actually paid rather than the independent valuations of the CVs involved. These prices would have been affected by sentiment and strategic considerations and would often be thus the Value-in-Use rather than the Value-in-Exchange. Ideally, then, the underlying valuation reports should be considered rather than the prices paid. Further research may be warranted to explore whether there are substantial differences between the opinions of the CVs and the prices paid.

Lawrence (2001) also argues that if the value per ounce that has been paid is based on the NPV over the Resource base then the value per ounce from the transaction is not a Market Approach but rather an alternative Income Approach. In essence, if the price paid by the purchaser was based on the income they expected to receive, then the value per ounce is an arbitrary back-calculation that does not convey any fundamental information. This could be compared to technical trading rather than trading on fundamentals.

The enterprise value per ounce for a company such as Randgold Resources is substantially higher than for Harmony Gold, despite similar annual production rates and Harmony having larger Mineral Reserves and Resources. An argument can be made that the lower value per ounce for Harmony is a result of the lower margin per ounce produced or because the ounces to be extracted in later years are discounted to the point where they are no longer considered valuable. However, both of these rationales would imply that the dollar per ounce valuation is a variation on the Income Approach and not a true alternative valuation methodology.

Company targets for Return on Invested Capital (ROIC) and hurdle rates for investments also imply that projects and transactions would be valued for the associated income rather than the additional production or Reserves. This is not always applied in practice, but if it were accepted as typical then it would further the argument that the value per ounce in transactions was also Income-related.

GOLD TRANSACTIONS

Transactions from 2010 through to a base date of 30 September 2015 were downloaded from SNL©. The transactions shown are for gold assets where at least Resources were included. Transactions where no ounces are listed have been excluded. Table II shows the deal values and details on Mineral Reserves and Resources. Details on the transactions are included in Appendix A.

Table II. Gold transaction values and reserve and resource information.

	Deal value (US$ million)	Primary Reserves acquired (oz)	Primary Reserves acquired (kg)	Primary R&R[1] acquired (oz)	Primary R&R acquired (kg)
1	22.30	2 205 000	1 000 171	31 764 000	14 407 908
2	8.61	453 000	205 477	6 541 000	2 966 947
3	9.10	1 574 000	713 954	1 574 000	713 954
4	182.70	8 064 115	3 657 821	30 629 545	13 893 328
5	3.50	31 700	14 378	2 603 700	1 181 018
6	130.00	521 000	236 321	11 924 300	5 408 771
7	19.00	5 217 337	2 366 544	22 494 114	10 203 158
8	2.50	1 329 780	603 178	30 308 180	13 747 559

[1] R&R refers to Resources inclusive of Reserves

Table III shows the price paid per gold ounce, the gold price at the time of the transaction, the exchange rate at the time of the transaction and the value per ounce when adjusted to reflect changes in the price of gold and the exchange rate subsequent to the transaction. The adjustment is made by multiplying the previous price paid per ounce by the gold price at the time of valuation and dividing by the gold price at the time of transaction.

Table III. Gold base values (US$ per ounce and ZAR per kilogram and adjusted values.

	Price paid in US$oz for Reserves at transaction	Price Paid in US$/oz for R&R[1]	Gold US$/oz at transaction	ZAR/US$ at transaction	Price Paid in ZAR/kg for Reserves	Price paid in ZAR/kg for R&R	Adjusted ZAR/kg for Reserves at base date	Adjusted ZAR/kg for R&R at base date
1	10.11	0.702	1704	6.82	2437	169	3275	227
2	19.01	1.316	1649	7.96	5346	370	6361	440
3	5.78	5.781	1725	7.95	1624	1624	1850	1850
4	22.66	5.97	1552	8.33	6669	1756	8059	2122
5	110.41	1.34	1251	7.24	28 246	344	48 723	593
6	249.52	10.90	1636	7.78	68 596	2997	84 200	3679
7	3.64	0.85	1795	7.92	1019	236	1120	260
8	1.88	0.08	1244	7.63	507	22	835	36
Mean	53	3	1570	7.70	14 306	940	19 303	1151
Median	15	1	1643	7.85	3892	357	4818	517
Std. dev.	87	4	211	0.47	23 752	1068	30 716	1283

[1] R&R refers to Resources inclusive of Reserves

The final three rows of Table III are included to highlight the level of uncertainty associated with the transactions. The median price paid is substantially different from the mean price paid. The lower median is a result of the particularly high prices paid in two of the transactions skewing the distribution. Note that in several instances zero lies within one standard deviation of the mean.

The final two columns show the prices adjusted to the base date. The prices paid per kg of gold for Reserves and per kg for Mineral Reserves and Resources inclusive are adjusted by multiplying the original prices paid per kg with the current gold price in ZAR/kg and then dividing by the gold price in ZAR/kg at the time of the transaction.

ADJUSTMENTS AND ALTERNATIVES

It is possible to adjust for the prevailing commodity price at the time of the transaction relative to the current price. This adjustment does not take sentiment into account (whether the outlook is bullish or bearish at the time) and does not take any other strategic factors into account (a company looking for a base in a new jurisdiction or possibly looking to increase production to over one million ounces per annum, *etc*.).

In addition, some CVs have set up adjustment factors whereby the price paid can be adjusted for depth, grade, deposit size, and other significant factors. This is a rational approach but relies on the underlying price being correct. This is only the case if there are enough transactions to ensure statistical significance or where one or two clearly comparable transactions have been identified.

Adjusting for a combination of margin and the Life-of-Mine (LoM) is also intuitive. However, the

accounting practices followed by mining companies are such that a very detailed evaluation is required in order to determine comparable margins. This is not practical, particularly where the CV is not an accounting specialist.

Furthermore, while a longer life would typically be attractive, the high levels of uncertainty and high discount rates in a jurisdiction such as South Africa make it likely that little value is ascribed to ounces that are not scheduled to be produced within fifteen years. This is further exacerbated by the nature of underground mining, where infrastructure constraints make it impossible to realize value from a sale of Mineral Resources or Reserves that must be extracted through the current shaft infrastructure.

The infrastructure constraints also generally lead to lower productivities and higher costs over time as distances to working places increase. Greater depths also lead to higher energy requirements as increased losses and greater cooling requirements make more distant Reserves and Resources less economic.

However, historical and forecast margins can facilitate contextualizing the transaction information. enterprise value per ounce information from listed stocks can give some guidance as to the likely limits of the transaction values. Some limits are required since the high variances associated with the limited data-points means that negative numbers are often within one standard deviation of the mean, and thus alternate constraints are required.

Ellis (2011) discusses the potential for the Income Approach to produce misleading valuations in isolation and how the development of indirect sales comparisons overcomes some of the difficulties associated with the lack of directly comparable transactions. Indirect comparison involves converting the sales information to a common unit of measure like dollars per Reserve ounce. Further adjustments can be made to reflect the different nature of the assets.

In the same paper, Ellis lists the following adjustment factors that can be considered:

- Minority interest
- Project development status
- Deposit grad
- Deposit/project size
- Property control and security of tenure
- Capital investment requirement
- Operating cost/net operating income
- Production loss/recovery/metallurgical complexity
- Product quality
- Product market stability
- Discovery and expansion potential
- Location and access
- Infrastructure
- Permitting issues
- Reclamation
- Country risk;
- Project risk
- Taxes, royalties, levies.

Expected differences in cost and net operating income are key adjustments. The challenge here is that, as mentioned earlier, the sales approach begins to encroach on the Income Approach and that accurate cost and net operating income information can be difficult to obtain. Cook (2009) conducted a detailed investigation of cost reporting in mining companies and concluded that the only way to determine the actual production costs is from the cash flow model, where the calculated values can be traced to ensure that all relevant costs are included.

Real-terms adjustments to the spot price can be important. In a South African context, mining cost inflation has consistently been higher than official inflation. Initially adjustments were just made for the differences in exchange rate and gold price (in US dollars per ounce). Table IV shows the impact of inflation on the price where a price of R 500 000 per kilogram has been included for illustration for 2015.

Table IV. Effect of inflation on the price.

Inflation	2010	2011	2012	2013	2014	2015
4.5%	401 226	419 281	438 148	457 865	478 469	500 000
6%	373 629	396 047	419 810	444 998	471 698	500 000
8%	340 292	367 515	396 916	428 669	462 963	500 000

If the CV assumes that the price needs to increase in line with the typical cost inflation experienced by South African miners then an equivalent price would probably be from the 8% row. Using the average of the official inflation target range of the Reserve Bank would lead to use of the 4.5% row. This assumption would already introduce substantial variation, and both are reasonable.

If the price per ounce or kilogram at the time of the transaction is adjusted for the ratio between the price then and the current price, the prices paid per ounce do not need to be adjusted for inflation as the price of the commodity would also adjust and the two adjustments would offset each other. However, if the CV is not adjusting for the relative gold prices then the price paid per ounce should be adjusted to reflect the price in real terms at the time of the transaction.

In addition, adjustments to the price based on margin or cost should follow a similar pattern and the CV should make the various adjustments to real terms for the valuation in case the approach does not automatically lead to the effect being incorporated.

The average enterprise value per ounce derived for listed shares is sometimes used instead of transaction values in order to overcome the absence of adequate data. However, this is also not ideal. In the South African gold sector, Sibanye Gold has recently begun to move towards being a diversified miner and Gold One has delisted. Harmony has a significant portion of its possible value associated with a copper asset in Papua New Guinea, and AngloGold Ashanti is predominantly based outside of South Africa.

Roberts (2006) suggests the use of Adjusted Market Capitalization (where the Market Capitalization is adjusted to reflect debt and other relevant variables) per NPV as the market typically adjusts NPV upwards or downwards. This is similar to using enterprise value per ounce, but basing it on NPV generated instead of ounces. Although this is intuitive, there is substantial uncertainty associated with NPV and there would likely be difficult obtaining consistent estimates across several companies where there is no formal requirement to publish NPV.

Roberts highlights the following factors to be taken into account when attempting to determine value:

- Commodity or product
  Commodities like gold tend to have higher enterprise value than is justified by their underlying NPV
- Date of the valuation data
  The premium or discount varies over time over and above that explained by the variation in the underlying price of the commodity
- Location
  Some locations (*e.g.* North America) attract premiums, while others (*e.g.*. South Africa) are typically discounted
- Reserve size

Larger Reserves usually attract a premium (the article does not mention this specifically but this does not apply to South African underground Reserves)

- Deposit type and mining method
  The market has varying preferences for certain types of mines and may, for example, prefer open pit to underground at times
- Processing methods
  The market may show a preference for free-milling over refractory ore
- Cost of production (grade)
  High-grade/low cost per ounce or ton will likely attract a premium
- Capital cost and infrastructure requirements
  Lower capital costs and lower infrastructure requirements will typically attract a premium.

All of the factors mentioned are areas where comparability is desirable in order to ensure that a premium or discount is not being incorrectly applied to the asset under consideration by the CV.

Roberts further lists factors that should be taken into account when considering a corporate transaction:

- Relative project to corporate value
  - Companies that are significantly diversified outside of mining are generally not suitable

- Management strength
  - Companies with strong, experienced and successful management teams may attract a premium

- Balance sheet
  - A strong balance sheet will generally trade at higher multiples as the company is more likely to weather a downturn and will have greater flexibility

- Hedging programme
  - Any hedging programme will have the potential to significantly affect future cash flows and should be carefully considered

- Market capitalization and liquidity
  - Higher market capitalization and greater liquidity will tend to also receive a premium.

It is clear that identifying truly comparable projects is a difficult process and that some adjustment is likely to always be required. In the same way that there are too few transactions to be statistically certain of a true value per ounce, there are also likely to be too few companies to be able to prove that any adjustments made are statistically correct.

These factors are likely to make it difficult to develop opinions on the Market Value of assets that are readily defensible. Taking into account the inaccuracy of metal price and exchange rate forecasts and the uncertainty that this brings to the Cash Flow Approach, the valuation of assets will be heavily dependent on the ability of the CV to create a cogent argument.

CONCLUSIONS

Valuation using comparative transactions is dependent on the existence of adequate transactions from which to draw statistically significant conclusions. In the absence of an adequate transaction volume the interpretation of the prices paid becomes increasingly subjective. It is then necessary to attempt to

identify the most comparable transactions and make suitable adjustments. Cost, operating income, and enterprise value per ounce can provide additional constraints.

A number of techniques are employed by valuators to attempt to adjust the prices paid to reflect the characteristics of the asset being valued. However, these are all premised on the price that is being adjusted being correct. Despite gold and platinum group metals being globally significant for South Africa, there are too few recent transactions to draw statistically meaningful conclusions.

In the absence of a clear price range that can be statistically defined the valuation becomes increasingly subjective. The onus then rests on the CV to make a cogent case for a price range with reference to subjective factors and those transactions that are available and most comparable. There are a range of factors that are outlined to consider when determining comparability. Along with the elimination of transactions that are not comparable, a range of adjustments need to be made and factors considered to arrive at a final range.

Historical and current price forecasts, changes in exchange rates and spot prices, and any relevant enterprise value per ounce information that can be obtained can be used to provide context for the valuation and justification for the selection of a final range. These should preferably be converted to real prices and exchange rates prior to use. Adjustment for other differences between deposits is also appropriate where possible.

Transactions where the price paid reflects strategic value or other value not related to value-in-exchange should be adjusted or removed. Valuations should ideally be based on the price determined by the CV in a transaction rather than the price paid, given that this price would include both sentiment and strategic components. The underlying valuations will not always be readily available.

Ellis (2013) poses the question: 'If this deposit is worth that much, why hasn't it already been mined out?' This and related questions are important sanity checks in a valuation.

There is no substitute for the experience of the CV in developing a coherent argument for a range of prices within the existing constraints. The implicit subjectivity of the process is unavoidable given that arguments cannot be statistically proved. Careful consideration of all of the factors and a detailed and transparent description of the process followed by the CV, and the assumptions made will facilitate the reader of a valuation report drawing their own conclusions and is likely to constitute best practice.

Appendix A – Transactions

Gold Transactions from SNL©

Table V. South African gold transactions from the SNL database.

	Buyer name/ target name	Target	Announce date
1	China African Precious Metals (Pty) Ltd	Armgold/Orkney	5 Aug. 2011
2	Investor Group	East Rand	17 Apr. 2012
3	Investor Group	West Witswatersrand	26 Jan. 2012
4	Pan African Resources Plc	Evander Gold Mines Limited	30 May2012
5	Stonewall Mining (Pty) Ltd	Transvaal Gold Mining Estates	9 Sep. 2010
6	Tannous Investment Group	Tau Lekoa	7 May 2012
7	Village Main Reef Ltd	Blyvooruitzicht	8 Nov. 2011
8	White Water Resources Ltd	ERPM	30 Jun. 2010

REFERENCES

Cook, B. (2009). The terrible truth of gold mining cost reporting. https://www.explorationinsights.com/pebble.asp?relid=3443 [Accessed 10 March 2016].

Ellis, T.R. (2013). If this deposit is worth that much, why hasn't it already been mined out? and other lessons for minerals appraisers. *SME-CMA-AIMA Annual Meeting*, Denver, CO, 24-27 February 2013.

Ellis, T.R. (2011). Sales comparison valuation of development and operating stage mineral properties. *Proceedings of the SME Annual Meeting*, Denver, CO, 28 February--2 March 2011.

Society for Mining, Metallurgy and Exploration, Englewood, CO.

Lawrence, M.J. (2001). An outline of market-based approaches for mineral asset valuation best practice. *Valmin '01, VALMIN Seminar Series 2011-12*. Australasian Institute of Mining and Metallurgy, Melbourne. pp. 115-137.

Roberts, C. (2006). The valuation of advanced mining projects & operating mines: market comparable approaches. http://www.infomine.com/publications/docs/Roberts2006.pdf [Accessed 26 January 2016].



Andrew Tobias van Zyl

Partner and Principal Consultant
SRK Consulting South Africa

Andrew van Zyl, Partner and Principal Consultant at SRK Consulting, holds a B Eng (Chemical) and M Com (Financial Economics) and worked in production and project roles up to 2006, when his focus shifted to strategy, business development and valuation. Andrew has spent several years as technical advisor to government committees overseeing the negotiation of mining conventions and rail and mineral terminal concessions. He has experience in valuing metals and minerals assets, including iron ore, manganese, chrome, copper, coal, gold and the platinum group metals. He has lectured in exchange rate theory and corporate valuation at the University of Johannesburg and has presented

Application of the market approach in the valuation of mineral assets – a platinum case study

G. Njowa[1] and C. Musingwini[2]

[1]Venmyn Deloitte (Pty) Limited
[2]School of Mining Engineering, The University of the Witwatersrand

There are three broad categories of valuation approaches used in valuing mineral assets, namely, the Income (cash flow) Approach, Market (sales comparison) Approach and Historical Cost Approach. The Market Approach is the most common valuation approach that can be used to estimate the value of a mineral property across the full spectrum of the stages of development of a mining project from an early stage exploration project to a defunct operation.

The Market Approach estimates value from an analysis of actual transactions for assets that are comparable to the subject asset. The process is essentially that of a comparison and correlation between the subject asset and recently sold similar assets. The difficulty of the comparison method in the mining industry is that there are few true comparable transactions available to use to arrive at a market value, unlike in the real estate sector, where many comparable transactions exist. The underlying reason is because each mineral asset has many characteristics that are unique. For example, mineral assets have specific criteria with respect to key factors such as location, geology, mineralization, reef type, exploration costs incurred, stage of development, and infrastructure already in place.

In this paper, the authors discuss a step-by-step process of how the Market Approach can be applied in the valuation of mineral assets, with practical examples to illustrate the application of this methodology, taking into account the unique characteristics of each mineral deposit. The paper discusses, the pros and cons of such a methodology in different circumstances. It also highlights the authors' fundamental understanding of the difference between 'value' (intrinsic value) and 'price' (market value) and why these fundamental terms must not be confused. The relationship between these two terms is important when conducting a mineral asset valuation.

INTRODUCTION

The minerals industry is characterized by the cyclical nature of commodity prices. In the case of platinum, prices reached an all-time high of US$2276 per ounce between 2007 and early 2008. Soon after that, the platinum price fell to levels around US$800 per ounce, where it remained for a few weeks before starting to recover, peaking around April 2011 at around US$1800 per ounce. Since that point, platinum prices have been on a downward spiral with little sign of recovery. Historical analysis shows that the commodity supercycles were generally driven by urbanization and industrialization in major economies such as the USA, Europe, Japan, and more recently in China and India (Njowa *et al.*, 2010). These cycles can be characterized as 'boom' or 'bust' periods in the minerals industry. Njowa *et al.* (2010) concluded that during boom periods many mineral projects are brought on stream, and mergers and acquisitions are initiated because of the perception that the boom will last for prolonged periods. Conversely, in 'bust' periods most companies downsize their operations, cut back on expansion capital and exploration costs, and those that fail to contain their costs become possible takeover targets or failures.

Regardless of which period the minerals industry is in, mineral assets require valuation for different purposes, as discussed in detail by Lilford and Minnitt, (2005). In all circumstances Mineral Asset Valuations (MAVs) are required.

For an extractive entity, whether in minerals or oil and gas, Mineral Resources and Mineral Reserves are the most significant components as these are the source of future cash flows (IASB, 2010). This assertion concurs with Ellis (2012, p. 3) who stated that, '*a mineral resource estimate, if one exists, will be an important input in developing a valuation estimate of a mineral property, together with other extensive information such as geographical, environmental, regulatory and permitting, political and social, transport, products and product markets, cost estimates and details from transactions of mineral properties with similar characteristics.*'

The process of valuing mineral assets is complex, as it needs to incorporate uniquely distinguishable factors such as location, geology, mineralization, reef type, stage of development, infrastructure already in place, and exploration costs incurred. The fundamental assets that underpin the value of a mining project or mining company are its Mineral Resources and Mineral Reserves, and a thorough understanding of the Mineral Resources and Mineral Reserves should be the single most important item that drives the value, and how efficient this asset is exploited will drive the financial performance of the company. The global minerals industry has tried hard in the past fifteen years to develop a common set of mineral asset reporting codes to ensure that all mineral assets (Mineral Resources and Mineral Reserves) are reported on a seemingly consistent basis. To this end, the Committee for Mineral Reserves and International Reporting Standards (CRIRSCO), as the global mining standards umbrella body, has worked to align the national reporting standards such as the SAMREC Code, JORC Code, PERC Code, and NI43-101 within the solid minerals space (Njowa *et al.*, 2014). The CRIRSCO family of codes facilitates a foundation or the basis for the estimation of Mineral Resources and Mineral Reserves that form the foundation of mineral asset valuation. This has set a basis for standardized reporting of Mineral Resources and Mineral Reserves providing that reasonable assumptions and acceptable methodologies are utilized in the estimation processes. However, because of the idiosyncrasies of individual mineral assets, some levels of uncertainty continue to exist in the value estimations of mineral assets.

In general, MAVs should be derived using more than one valuation approach or method whenever possible. The South African Code for the Reporting of Mineral Asset Valuation (SAMVAL Code) (SAMVAL, 2009) specifically requires at least two methodologies. The methods applied depend on the nature of the valuation, the development status of the mineral property, and the extent and reliability of available information.

MINERAL ASSET VALUATION AND APPROACHES

The SAMVAL Code (2009) defined 'valuation' in a mining project context in the narrow meaning of 'placing a monetary value on the worth of the mineral asset as a whole'. Valuation, in its simplest form, is the determination of the amount for which the property could transact on a particular date (Njowa *et al.*, 2010). The value can be estimated or determined at any specific point in time, and may be estimated by one of the several methods that are in use, depending on the purpose or nature of the valuation, the stage of development of the mining project, and the extent and reliability of available information.

The Code for the Technical Assessment and Valuation of Mineral and Petroleum Assets and Securities for Independent Expert Reports (VALMIN Code) (VALMIN, 2005) defines valuation as the process of determining the monetary value of a mineral, petroleum, or security asset. The process of attaching a price to a mineral asset is never easy, owing to uncertainties in mineral commodity prices, future production, and other technical and financial factors. The purposes of a mineral asset valuation include, but are not limited to, mergers and acquisitions, capital reductions, fairness and reasonableness reports, income tax assessment, accounting and financial reporting, stamp duty valuations, compensation for compulsory acquisitions, vendors' consideration in a public float, raising debt, equity financing, litigation, estate settlements, corporate valuations, and investment purposes. Given this combination of valuation purposes different development stages of mining, and investor needs, various valuation approaches and methodologies are available and it is the responsibility of the 'valuator' (or 'valuer', depending on jurisdiction) to decide on the valuation methodology or methodologies to use.

There are three broad categories of valuation approaches used in valuing mineral assets, namely, the Income (cash flow) Approach, Market (sales comparison) Approach, and Cost Approach. The Market Approach is the most common valuation approach that can be used to estimate the value of a mineral property across the full spectrum of the stages of development of a mining project from an early-stage exploration project to a defunct operation. Within each approach are several different valuation methodologies as shown in Figure 1, so valuation methods are subsets of valuation approaches.

Certain valuation methods are more widely used and may be more generally acceptable as industry practice than others, although this could change over time. Some methods can be considered to be primary methods for MAVs, while others are secondary methods or rules of thumb, considered suitable only to check MAVs by primary methods, but it is imperative to use at least two methods as required by the valuation codes. Figure 1 illustrated the valuation approaches and the underlying methodologies as stipulated in the SAMVAL Code and CIMVAL Code.

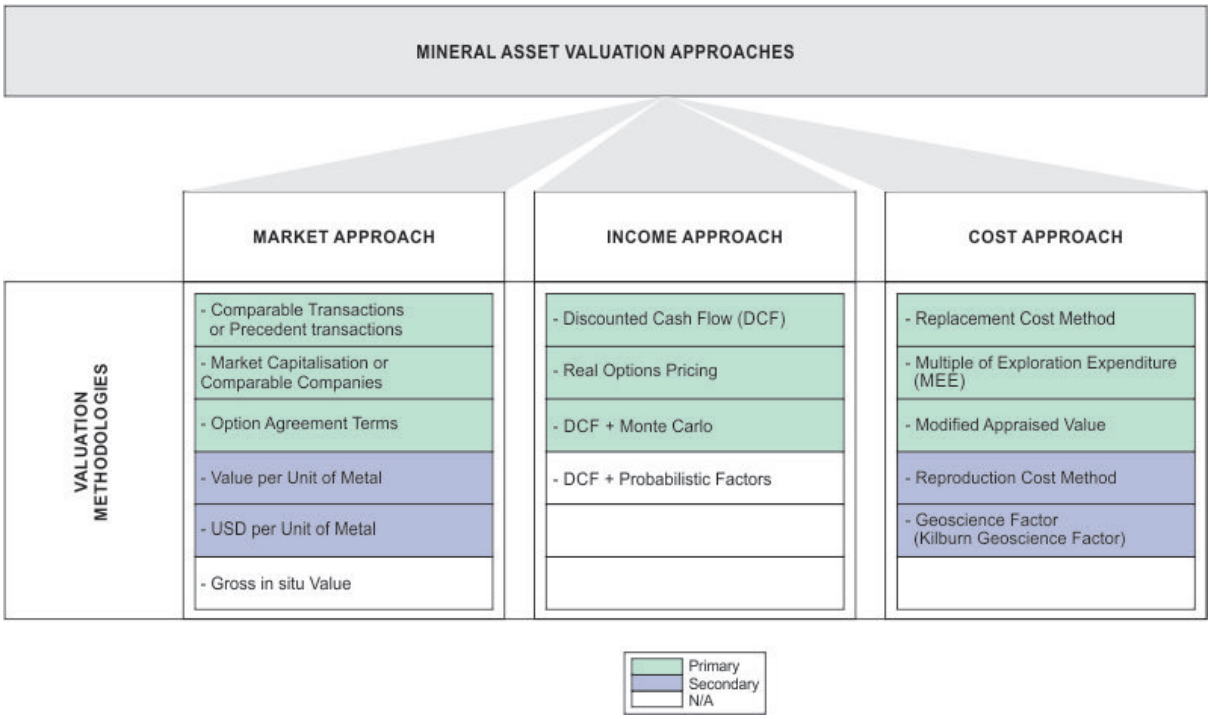


Figure 1. Mineral asset valuation approaches (adapted from Smith, 2013).

The Income Approach is regarded as the most reliable method for estimating the value of a mineral asset in the development and/or operating stage, and primarily uses discounted cash flow (DCF) analysis. In our opinion, this methodology yields the most accurate, fair, and reasonable results by capturing the pertinent aspects of the 'business' investment case at a point in time and based on the information or knowledge at the time. The value derived from this methodology yields the fundamental or intrinsic value of the mineral asset or a mining company (Table I).

Table I. Fundamental or intrinsic and market value of projects and companies

	Fundamental/intrinsic value	Market value
Project value	Net present value (NPV)	Asset transaction price (or multiples) or enterprise value or adjusted market capitalization (AMC)
Corporate value	Net asset value (NAV)	Corporate transaction price (or multiples) or market capitalization

Source: Roberts (2006)

The Cost Approach relies primarily on audited or auditable historical expenditures on exploration and acquisitions, to which can be applied prospectivity enhancement multipliers (PEMs) to arrive at a mineral asset value. This method essentially incorporates the principle of 'successful efforts' and endeavours to capture the change in mineral asset value, mainly for exploration assets, based upon a qualitative assessment of improved or reduced prospectivity. The Market Approach bases the value of a mineral asset on prices and other relevant information on transactions involving similar or comparable mineral assets that have occurred in the market. The comparable transaction method allows the value estimated for a mineral project to be benchmarked against mineral project market values established from recent transactions, based on what the market is currently willing to pay for similar assets (Roberts, 2006). The Market Approach may be considered to be problematic in the minerals industry since it is difficult to find true comparable transactions for comparison with the

mineral assets to be valued because of technical idiosyncrasies that apply to almost every mineral property. To a certain extent this is similar to the real estate sector, but there a high volume of transactions exists to help in providing broadly comparable transactions.

Njowa *et al.* (2010) noted that the grade and quantity of the ultimately recovered Mineral Reserves are always uncertain, since the value is a best estimate of the worth of Mineral Reserves and Mineral Resources at the time. This poses a challenge for valuation, as incomplete knowledge of the quantity of Mineral Reserves means that the useful life of the asset must be estimated with some degree of uncertainty. Njowa *et al.* (2010) concluded that the value of a mineral asset is, therefore, highly dependent on the level of geological confidence ascribed to the Mineral Resource and Mineral Reserve estimation, otherwise termed resource and reserve risk. The mining and petroleum industries individually have their own resource/reserve uncertainty classification systems and they form the basis of any MAV that can be conducted on the asset.

MARKET APPROACH IN MINERAL ASSET VALUATION

Market value is defined in the International Valuation Standards (IVS) 2013 as, *'the estimated amount for which an asset or liability should exchange on the valuation date between a willing buyer and a willing seller in an arm's length transaction, after proper marketing and where the parties had each acted knowledgeably, prudently and without compulsion'* (IVSC, 2013). The CIMVAL Code (2003, p. 8) defined Fair Market Value as *'… the highest price, expressed in terms of money or money's worth, obtained in an open and unrestricted market between knowledgeable, informed and prudent parties, acting at arm's length, neither party being under any compulsion to transact'*. The AusIMM (2005, p. 23) stated that *'**Value** is the **Fair Market Value** of a Mineral or Petroleum Asset or Security. It is the amount of money (or the cash equivalent of some other consideration) determined by the Expert in accordance with the provisions of the VALMIN Code for which the Mineral or Petroleum Asset or Security should change hands on the Valuation Date in an open and unrestricted market between a willing buyer and a willing seller in an "arm's length" transaction, with each party acting knowledgeably, prudently and without compulsion'*. In our view the term Fair Market Value is confusing and only Fair Value or Market Value should be used. In addition, there is no fundamental difference between these definitions.

From these definitions it can be concluded that the following attributes characterize the definition for Market Value as some form of quantifiable amount based on the stated principles:

- The transaction involves a willing seller and a willing buyer
- The transaction must be at arm's length
- Both parties must be informed and knowledgeable
- Neither party must be under any compulsion to transact.

The market approach was defined by the IVSC as *'any approach to value based upon the use of data that reflect market transactions and reasoning that corresponds to the thinking of market participants. A general way of estimating a value indication for an asset using one or more methods that compare the subject to similar assets that have been sold'*

The Market Approach in MAV encompasses all of the methodologies that rely on databases of historical transactions of mineral assets (Lilford and Minnitt, 2005). These databases tabulate the prices at which all previous mineral asset transactions occurred. Such data provides a benchmark against which current mineral asset information and prices can be compared in order to estimate the value of the mineral asset under consideration. The transactions include acquisitions, disposals, and mergers, in addition to market capitalizations per unit of resource/reserve that are used as a sanity check for the transactions. These transactions are considered to have been ideally completed at arm's length with the transacting parties being under no compulsion to transact. This analysis has been adjusted for cash and debt in the calculation of market capitalization per unit of resource/reserve in the form of enterprise value (EV).

The market approach may be considered to be fairly subjective due to professional judgement that has to be applied when comparing the mineral asset to be valued and the pool of mineral assets that have implied value from previous transactions. In the VALMIN and CIMVAL codes, it is a requirement that the Competent Valuer should have a technical understanding of the issues being considered in the MAV. In the VALMIN (2015) Specialists are defined as '*persons whose profession, reputation and relevant industry experience in a technical discipline (such as geology, mine engineering or metallurgy) provides them with the authority to assess or value Mineral Assets, and who prepare and accept responsibility for a Public Report*'. In applying the Market Approach, a Competent Valuer develops an indication of value for the mineral asset that is being valued by comparing similar mineral assets and making adjustments for the differences in the characteristics of mineral assets that have been sold. It is difficult to ensure direct comparisons of different mineral assets because of technical idiosyncrasies that apply to almost every mineral asset.

The most appropriate approach to determine the fundamental value of developmental projects and operating mines would be the Income Approach. However, if there are sufficient mineral asset transactions, these should be analysed and included in the MAV report to establish a reasonable range within which the value of the mineral asset should fall. Both the Income Approach and Market Approach should produce values within a reasonable value range, within the premises of the current market sentiments. Roberts (2006) concurred that the comparable transaction methodologies are a key tool to ensure that the fundamental valuations are congruent with what the market would actually pay. He emphasized that '*if the value estimated for a mining project using a discounted cash flow analysis differs significantly from the value implied using comparable market methods, the valuator may be using metal price or discount rate assumptions that differ significantly from those the market is currently willing to pay for*' (Roberts, 2006, p. 1).

This paper discusses the Market Approach valuation methodology as it would be applied in the platinum industry, with the main focus on mineral asset valuation of development projects and/or production assets, either at project level or at a company level as discussed in the two examples provided.

Comparable Companies Transactions Methodology

Comparable companies analysis is one of the primary methodologies used for valuing a similar minerals company or division. The analysis provides a market benchmark against which a Competent Valuer can establish a valuation for a private mineral company or analyse the value of a public minerals company at a given point in time (Rosenbaum and Pearl, 2009). Comparable analysis has a broad range of applications in the MAV fraternity, most notably in mergers and acquisitions (M&As), initial public offerings (IPOs), company loan restructurings, project finance, and other investment decisions.

The foundation for comparable companies is built upon the premise that similar companies provide relevant reference points for valuing a given target company in the same business due to the fact that they share key business and financial characteristics, performance drivers, operational risks, and challenges (Rosenbaum and Pearl, 2009). Comparable transactions analysis is designed to reflect 'current' valuation based on the prevailing market conditions and sentiment. According to Rosenbaum and Pearl (2009), comparable companies analysis is in many cases more relevant than intrinsic valuation analysis, such as discounted cash flow (DCF) analysis. When conducting a comprehensive valuation, a DCF serves as an important alternative to market-based valuation techniques such as comparable companies and precedent transactions, which can be distorted by a number of factors and sentiments such as the post-subprime credit crunch. As such, a DCF plays an important role as a check on the prevailing market valuation for a publicly traded company. Roberts (2006, p. 1) concluded that '*market comparable and fundamental (e.g. DCF) approaches to mineral project valuation should not be viewed as alternative approaches to estimating project value, but rather can and should be integrated to derive a single value estimate based on both market and fundamental data*'.

The Competent Valuer can establish valuation parameters for the target company by determining its relative positioning among similar peer mining companies, taking into consideration the technical and operational key performance indicators of the individual mineral assets in the portfolio. The peer companies are benchmarked against one another and the target mining company based on various technical, operational, and financial statistics and ratios. At the same time, market trading volume levels may be subject to periods of irrational investor sentiment that skew valuations either high or low.

Furthermore, no two mines or companies are exactly the same, so assigning a valuation based on the trading characteristics of similar companies may fail to accurately capture a given company's true value. The resulting trading comparison should be used in conjunction with the other valuation methodologies. A material disconnect between the derived valuation ranges from the various methodologies might be an indication that key assumptions or calculations need to be revisited.

Precedent Transactions Methodology
Precedent transaction analysis is similar to comparable companies analysis as it employs a multiples-based approach using the historical transactions that have occurred in the industry to derive an implied valuation range for a target mineral asset. This methodology is premised on multiples paid for comparable mineral assets or companies in prior M&A transactions – one of the primary methodologies used for valuing similar minerals companies or divisions. The selection of an appropriate universe of comparable acquisitions is the fundamental basis for performing precedent transactions, with the best transactions typically involving companies similar to the target company on a fundamental level, such as sharing key technical and financial characteristics. Using this methodology, it is often challenging to obtain a robust set of truly comparable mineral assets or transaction.

In general, no orebody is exactly the same as an adjacent orebody in terms of structure, mineralogy, and deposit. As a general rule, the most recent transactions are defined as the transactions that have occurred within the last three to four years and are considered to be the most relevant as they likely took place under similar market conditions to the contemplated transaction.

According to Rosenbaum and Pearl (2009, p. 71):
'under normal market conditions, precedent transactions comparable tend to provide a higher multiple range that the comparable companies for two principle reasons:

- *buyers generally pay a 'control premium' when purchasing another company and the acquirer would receive the right to control decisions regarding the business and its underlying cash flows; and*
- *strategic buyers often have the opportunity to realise synergies, which supports the ability to pay higher purchase prices. Synergies refer to the expected cost savings, growth opportunities and other financial benefits that occur as a result of the combination of two business (sic)'.*

For example, the acquisition of Massmart by Walmart and the acquisition of Aquarius Platinum by Sibanye Gold are two recent transactions where the buyers were considered to be strategic purchasers and a control premium was paid.

The main rationale for the Massmart/Walmart merger was the anticipation of expected cost savings and the streamlining of processes, especially on the global procurement front, through the international chain's ability to source product more cheaply offshore. Massmart already possessed the necessary scale and expertise to import goods into South Africa at competitive prices. Walmart's entry would result in lower consumer pricing, not because it is able to procure goods globally at lower factory-gate prices, but because it has superior logistics capabilities that will allow for greater efficiencies in the supply chain and grow its global footprint.

According to Sibanye (2015a), the Aquarius Platinum transaction had a strong strategic and financial rationale, on a stand-alone basis, but especially when considered in conjunction with the Rustenburg Platinum Mines Limited (RPM) operations it recently agreed to acquire from Anglo American Platinum Limited (AAPL). Sibanye CEO Neal Froneman noted that: '*Significant additional value can be realised from optimising inherent regional and operational synergies between Aquarius' Kroondal mine and the Rustenburg Operations, which are adjacent to it. At higher PGM prices, these assets will substantially increase earnings and value for Sibanye shareholders. The Aquarius operations are efficiently managed, mechanised and low-cost operations that will consolidate Sibanye's position in the South African PGM sector and also provide Sibanye with additional PGM operational experience*' (Sibanye, 2015b). He added that the deal provides an entry point into Zimbabwe through a holding in Mimosa platinum mine. Zimbabwe hosts the second largest platinum reserves in the world and represents significant, low-cost optionality.

Summary Comparable Transactions Methodology

Potential acquirers look closely at the multiples that have been paid for comparable transactions to establish transaction multiples specific to the platinum industry. A summarized methodology for conducting the step-by-step comparable transaction analysis is as follows:

- Step 1 – The selection and identification of a global or set of comparable transactions in the platinum industry within a specified geological environment e.g. Eastern Bushveld or Great Dyke. This can often be challenging and requires a strong understanding of the geological settings, mineralogy, and mineability of these platinum group metal (PGM)-bearing reefs. The first point would be to examine and search through M&A databases and examine the M&A history in the sector for comparable companies (relative to the company or mineral asset to be valued). As part of this process, the Competent Valuer needs to understand as much as possible regarding the specific circumstances and technical and operational characteristics of the orebody and the deal dynamics for each transaction. This would be particularly important for refining the comparable transactions and ultimately honing in on the 'best' comparable transactions, or companies
- Step 2 – Find the necessary deal-related, technical, operational and financial information. The focus here is on sourcing of the deal-related information for M&A transactions involving both public and private companies. Locating information on comparable acquisitions is invariably easier for transactions involving public companies due to the JSE disclosure requirements or for private companies with publicly registered debt securities. The information would normally be contained in annual reports, Competent Persons Reports (CPRs), MAV reports, analysts' reports, fair and reasonableness opinions, company announcements and general media announcements
- Step 3 – Calculate the key statistics, ratios, and transaction multiples. Once all the deal-related information has been gathered, the Competent Valuer calculates the key performance indicators, statistics, ratios, and transaction multiples for each of the transactions. These would typically be the purchase price (either in cash, cash equivalents, or shares), Mineral Resources, Mineral Reserves, production capacities, EBITDA per ounce, and the relative positions on the industry cost curve. This would be used as the basis of comparison
- Step 4 – Benchmark the comparable acquisitions. This level of analysis revolves around an in-depth study of the selected comparable acquisitions so as to identify those considered to be the most relevant for valuing the target mineral asset or company. Each precedent transaction is closely examined as part of the final refining of the universe, with the best comparable transactions identified and obvious outliers eliminated
- Step 5 – Determine the Company Valuation or MAV. Using the precedent transactions, the multiples of the selected comparable acquisitions universe are used to derive an implied valuation range for the target company or mineral asset or project. The Competent Valuer would typically use mean and median multiples from the universe as a guide to establish a preliminary valuation range for the target, with the high and low ends as the reference points. These calculations often serve as the precursor for the deeper level of analysis whereby the Valuer would then use the most relevant transactions to anchor the final valuation ranges and provide a valuation conclusion.

The implied valuation range is then given a sanity check and compared to the output from other valuation methodologies. For example, dividing the resultant MAVs by the metal or mineral content covered in the cash flow provides an equivalent value per unit of Resources or Reserves that can be compared with other equivalent multiples from different methodologies. If these valuation results are not comparable, then the valuer would need to review the calculations and assumptions used in both methodologies. It should be noted that the use of stock as a meaningful portion of the purchase consideration tends to result in a lower valuation (measured by multiples and premiums paid) than for an all-cash transaction (Rosenbaum and Pearl, 2009). Most importantly, the valuation must be consistent with values likely to be assigned in real life.

PRACTICAL EXAMPLE: ACQUISITION OF ANGLO AMERICAN PLATINUM'S RUSTENBURG OPERATIONS BY SIBANYE GOLD

On 8 September 2015, Sibanye Gold entered into an agreement with RPM, a wholly owned subsidiary of Anglo American Platinum Limited (AAPL), to acquire the Bathopele, Siphumelele (including Khomanani), and Thembelani (including Khuseleka) mining operations, two concentrating plants, an on-site chrome recovery plant, and the Western Limb Tailings Retreatment Plant (the Rustenburg Operations). The purchase consideration comprised an upfront payment of R1.5 billion and a deferred payment calculated as being equal to 35% of the distributable free cash flow generated by the Rustenburg Operations over a six-year period, with the minimum payment being R3.0 billion. The deal provides for AAPL to pay Sibanye Gold a maximum of R267 million per annum, should the Rustenburg Operations generate negative cash flows in the period 2016–2018. However, any upside due to price increases in the six-year period will be shared with AAPL. The deal gives Sibanye Gold access to about 800 000 ounces of 4E PGM production and 4E PGM mineral resource, and mineral reserve base of 88.8 million ounces and 9.7 million ounces respectively (Sibanye, 2015).

The Market Approach using comparable transactions is typically an appropriate valuation approach and method to estimate value for production and development properties as described in the above sections. The Market Approach relies on the principle of 'willing buyer and willing seller' and assumes that the amount received is determined on an arm's length basis. The methodology allows the comparison of the asset under consideration to relatively recent asset transactions with similar characteristics. This approach is generally based upon a monetary value per unit of Mineral Resource or Mineral Reserve (if available).

Since Mineral Resources and Mineral Reserves have been classified for RPM, the authors were able to carry out a comparable transaction (Market Approach) valuation on the basis that recent market valuations of a similar nature provide the proxy for value. In order to arrive at a reasonable market value with which to compare the respective projects, appropriate recent and historical transactions were employed as a base stemming from two market valuation observations based on platinum companies' enterprise values and appropriate transactions between 2010 and 2015. It should also be noted that the exchange rate for the companies' enterprise values were based on the spot prices at the date of the analysis.

Applying the above methodologies, following the five steps discussed earlier, both comparable companies and comparable transactions analysis on this transaction yield the results summarized in this section. Since the Mineral Resources and Mineral Reserves are considered to be the single most important asset owned by a mining company, the Resources and Reserves multiples achieved in the precedent transactions in an arm's length transaction should be a reasonable proxy for valuation of the mineral asset. The recent transactions multiples are summarized in Table II, with Table III and Figure 2 showing the technical details of some of the projects.

Table II. PGE recent transaction analysis.

PROJECT	SELLER	BUYER	TRANSACTION DATE	INTEREST ACQUIRED	PROJECT VALUE (US$m)	TOTAL RESOURCE (Moz)	TOTAL RESERVE (Moz)	RESOURCE VALUE (US$/4E oz)	RESERVE VALUE (US$/4E oz)
Aquarius Platinum	Aquarius Platinum	Sibanye Gold	06/10/2015	100%	294.00	47.10	5.50	6.24	53.45
Rustenburg Platinum Mines	Anglo American Platinum	Sibanye Gold	09/09/2015	100%	326.00	88.80	9.70	3.67	33.61
Nkwe Platinum Ltd.	Genorah Resources (Pty) Limited	Zijin Mining Group Co.	20/07/2015	34%	66.11	45.47	-	1.45	-
Everest Platinum Mine	Aquarius Platinum Ltd.	Northam Platinum Limited	26/06/2015	100%	21.29	3.11	1.12	6.84	18.96
Northam Platinum Ltd.	Northam Platinum Ltd.	Zambezi Platinum	10/03/2015	22%	1,736.98	197.51	18.98	8.79	91.51
Eastern Platinum Ltd.	Eastern Platinum Ltd.	Hebei Zhongbo Platinum Co. Limited	07/11/2014	100%	225.00	51.14	0.00	4.40	0.00
Northam Platinum Ltd.	Public Investment Corporation	Zambezi Platinum	22/10/2014	9%	1,886.74	197.51	18.98	9.55	99.40
Nkwe Platinum Ltd.	Nkwe Platinum Ltd.	Zijin Mining Group Co.	05/05/2014	23%	82.11	45.47	-	1.81	-
Kruidfontein	Aquarius Platinum Ltd. (C&L Mining)	Pilanesberg Platinum Mines	30/01/2014	100%	27.00	15.51	-	1.74	-
Boikgantsho/Ga-Phasha	Atlatsa Resources Corporation	Rustenburg Platinum Mines (RPM)	13/12/2013	51%	323.53	101.87	-	3.18	-
Booysendal South	Northam Platinum Ltd.	Aquarius Platinum Ltd	04/05/2011	100%	181.00	31.08	-	5.82	-
Sedibelo West	Bakgatla Ba Kgafela Community	Platmin Ltd	23/03/2011	100%	75.00	6.00	-	12.51	-
Platreef	Ivanplats	Itochu Corp	01/09/2010	2%	500.00	114.25	-	4.38	-

Source : SNL (2016)

Table III. PGE recent transaction analysis – project details.

PROJECT	MINING METHOD	AVERAGE MINING DEPTH (m)	REEFS MINED	TOTAL RESOURCE (Mt)	AVERAGE RESOURCE 4E GRADE (g/t)	TOTAL RESERVE (Mt)	AVERAGE RESERVEE 4E GRADE (g/t)	CASH COST (US$/4E oz)
Aquarius Platinum	Conventional scattered breast mining/ trackless bord and pillar	50-1400	Merensky, UG2, and MSZ	508.5	2.9	61.4	2.8	801
Rustenburg Platinum Mines	Conventional scattered breast mining/ trackless bord and pillar	40-1350	Merensky and UG2	626.3	4.41	95.9	3.15	1030
Everest Platinum Mine	Conventional scattered breast mining	800	UG2	29.03	3.34	12.2	2.86	N/A

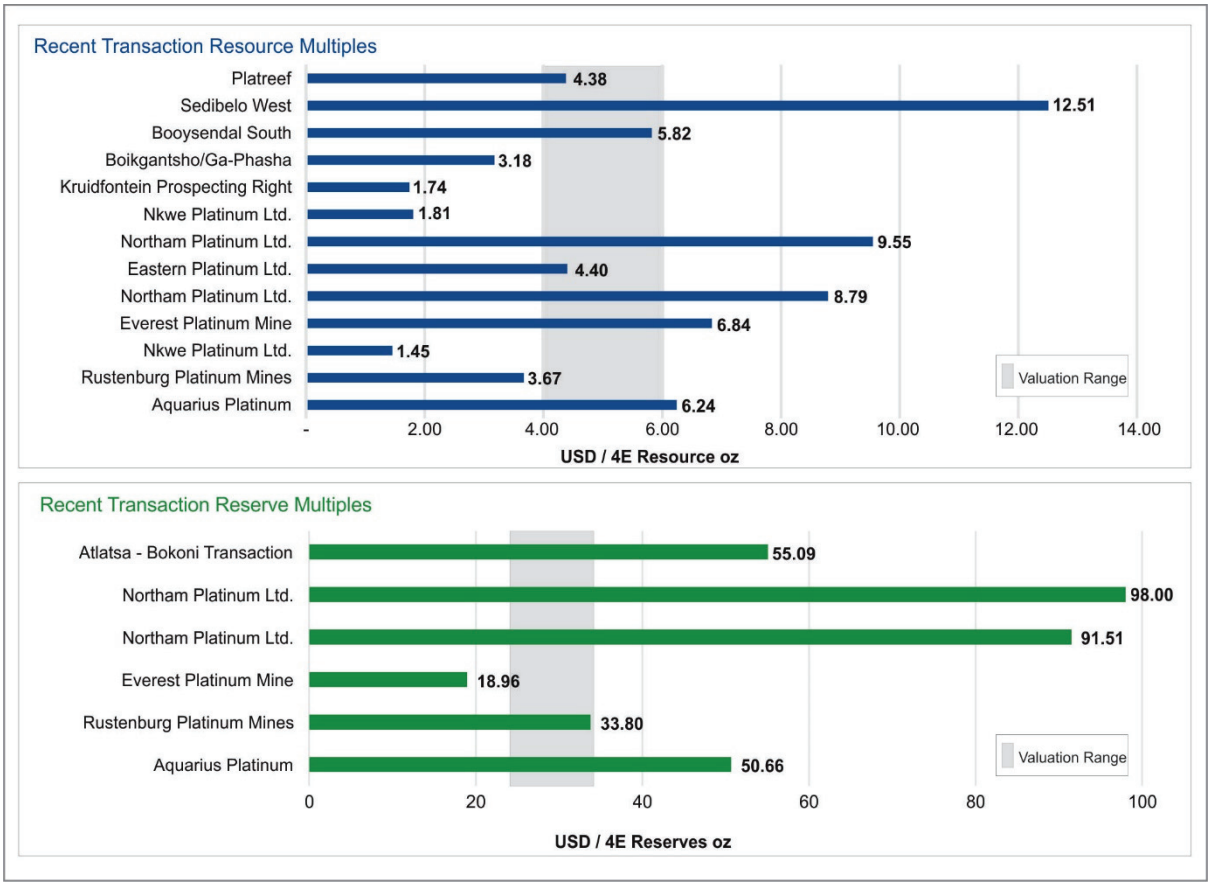


Figure 2. Recent Resource and Reserve transaction multiples.

Comparing all the other recent transactions to the RPM–Sibanye Transaction, it was concluded in terms of geology, Mineral Resource, and Mineral Reserve quantities involved (97 million ounces and 88 million ounces respectively) in the transaction, the Atlatsa–Bokoni transaction is considered comparable to the Sibanye–RPM transaction. Conversely, on the Mineral Reserves side, the Atlatsa–Bokoni Transaction had only 11 million ounces and Sibanye–RPM Transaction had 24 million ounces. The other transactions, especially the one involving Northam Platinum, were not considered comparable as the transactions included related parties and share buy-backs and are thus not considered 'arm's length' transactions. The red boxes in Figure 2 show the average multiples valuation range that would be used for the valuation of the RPM mineral assets, and the actual minimum purchase price is also plotted as a red bar in Figure 2. It should be noted that the minimum purchase price according to the agreements was lower than the market value as determined by the authors. We are of the opinion that this was the case because there is a clause that if the commodity price improve within the next six years, Sibanye would have to share the upside with AAPL, resulting in an increase in the final purchase price.

The minimum purchase price agreed between AAPL and Sibanye is within the ranges of the current resources and reserve enterprise value per ounce as shown in Table IV, which shows the enterprise value per ounce for the major platinum players in South Africa. These values would represent what values the market is prepared to pay for the different platinum mineral assets in the current economic climate and commodity price sentiment.

Table IV. PGE EV values

COMPANY*	TOTAL RESOURCE (4E Moz)	RESOURCE EV/4E oz	TOTAL RESERVE (4E Moz)	RESERVE EV/4E oz
Aquarius Platinum	50.09	5.16	6.93	37.31
Anglo American	896.93	5.64	205.44	24.61
Atlatsa Resources	105.84	1.08	5.47	20.89
Bauba Platinum	10.33	0.94	0.00	0.00
Eastern Platinum	51.14	8.28	0.00	0.00
Impala Platinum	367.61	4.43	44.30	36.73
Lonmin Plc	182.63	4.65	35.52	23.90
Nkwe Platinum	48.23	0.97	0.00	0.00
Northam Platinum	197.51	3.44	18.98	35.84
Royal Bafokeng	47.84	6.37	10.67	28.55
Wesizwe Platinum	15.44	10.83	8.34	20.04
Average		**4.71**		**20.72**
Median		**4.65**		**23.90**

*Based on the company shares prices as at 30 January 2016 and December 2015 balance sheet adjustments

The value ranges determined using the comparable transactions analysis above are within the acceptable ranges, based on the company enterprise value per Reserve ounce ranging from zero to US$37 per ounce as shown in Table III.

The Venmyn Deloitte platinum group element (PGE) valuation curve has been developed and constructed in a way that provides the current market value ranges using the global transactions and adjustment market capitalization as described in Njowa *et al.* (2010), as shown in Figure 3. The main aim of the valuation curve is to confirm reasonableness of mineral asset valuation in the PGE sector. The implied mineral asset valuation ranges for the RPM–Sibanye transaction plots within the envelope of the PGE valuation curve, and plots lower than other similar platinum transactions such as the Atlatsa–Bokoni transaction and Aquarius–Sibanye transaction as show on the valuation curve in Figure 3.

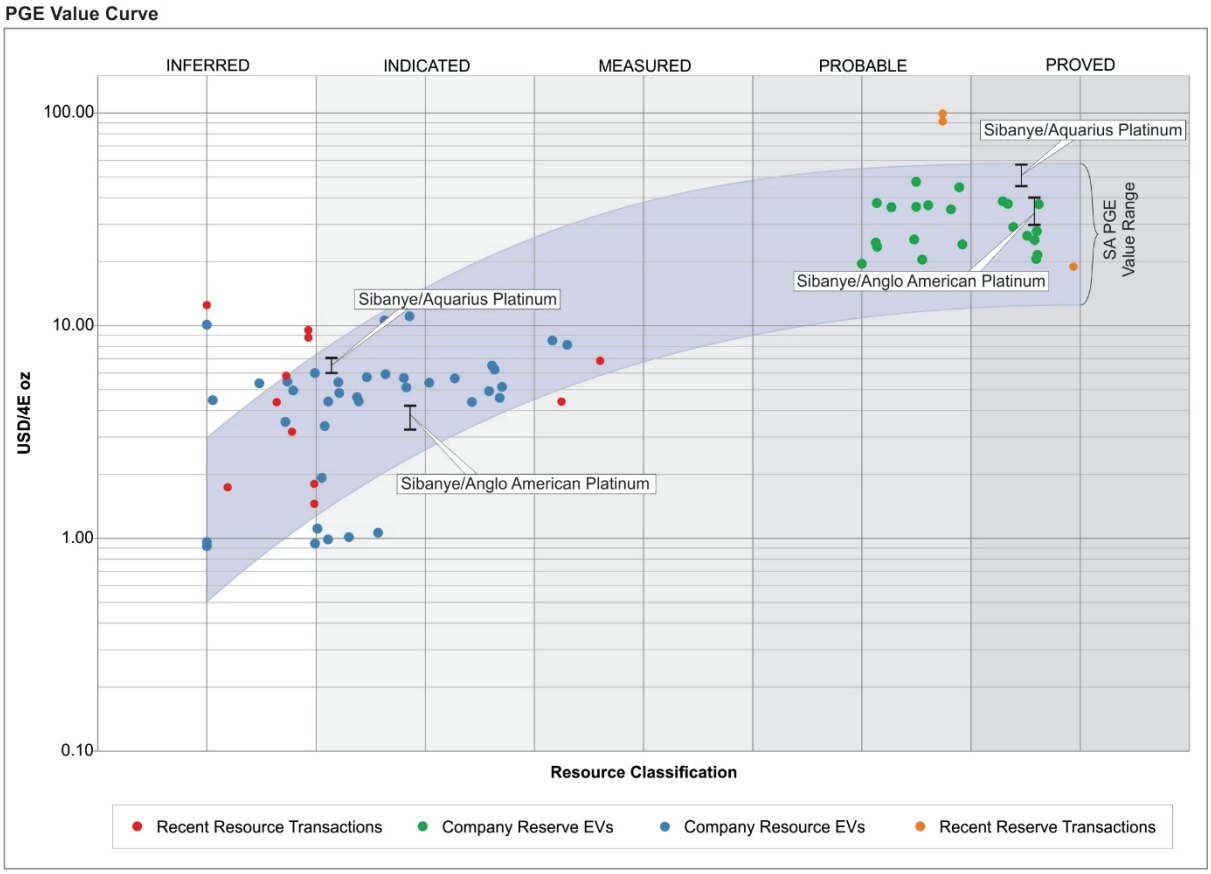


Figure 3. PGE valuation curve (Venmyn Deloitte, 2016).

The Venmyn Deloitte PGE valuation curve provides a high-level cross-reference to other valuation methodologies as these multiples may vary significantly due to different cost structures, technical characteristics of the Resources, stage of development, ratios of Reserves to total Resources, life of mine, access to infrastructure, rationale for the transaction, and access to funding. Njowa *et al*. (2010) noted that cash transactions tends to fall towards the bottom of the valuation curve as they are significantly discounted relative to the market value and the shared based transactions tend to lie towards the top of the valuation curve. The valuation curve can also be used to compare results from other valuation methodologies and assess these values compared to the general platinum market.

CONCLUSIONS

The comparable transactions method is one of the primary market approaches methodologies. This method can provide very useful data on which to base a valuation if a reasonable number of truly comparable transactions can be found. Where this not the case, professional judgements have to be made on the basis of a few (if any) truly comparable transactions and a larger number of only partly comparable transactions. If a reasonable database of values can be compiled, derivative methods such as value per unit of contained metal in Mineral Resources or Mineral Reserves can be applied.

It should be noted that resultant valuation ranges for the Anglo Rustenburg operations have a lower implied market valuation compared to Aquarius Platinum. This is mainly because of the way the transaction was structured. The Aquarius Platinum deal was a cash deal and hence the purchase price is fixed, whereas in the AAPL deal the final purchase price is dependent on future commodity prices and the financial performance of the company in the hands of the new owner. In this case the final value of the transaction may be known only after a certain period of time (6 years).

The difficulty of the comparable method in the mining industry is that there are few truly comparable transactions available to use to arrive at a market value, unlike in the real estate sector where many comparable transactions exist. The underlying reason for this difficulty is because each mineral asset is unique. For example, mineral assets will be uniquely distinguishable with respect to key factors, including but not limited to, location, geology, mineralization, reef type, exploration costs incurred, stage of development, and infrastructure already in place.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Venmyn Deloitte for allowing the use of its proprietary information and methodologies shared in this paper. The authors also wish to specifically acknowledge members of staff at Venmyn Deloitte who supported this work; Andy Clay for sharing ideas and providing constructive comments, Vulani Maseko for conducting the market research required for the PGE valuation curve, and Deborah Spicer for her detailed review and editing of this paper.

REFERENCES

Ellis, T.R. (2012). SME participates in international project for mineral valuation standards. *Mining Engineering*, 64 (11), 42-44. [Re-published in *Newsletter*, American Institute of Minerals Appraisers, 17 (1), January 2013, 5-7.

International Accounting Standards Board (IASB). (2010). Discussion Paper: extractive activities (DP/2010/1). London, UK. 183 pp.

International Valuation Standards Council (IVSC). (2013). IVS Framework. http://standards.ivsonline.org/mod/page/view.php?id=108 [Accessed 4 October 2015].

Lilford, E.V. and Minnitt, R.C.A (2005). A comparable study of valuation methodologies for mineral developments. *Journal of the South African Institute of Mining and Metallurgy*, 115 (1), 29–41.

Njowa, G, Musingwini, C., and Clay, A.N. (2010), Development and implementation of a platinum group elements mineral asset valuation curve at Venmyn. *Proceedings of the Fourth International Platinum Conference, Platinum in Transition 'Boom or Bust'*, Sun City, South Africa, 11–14 October 2010. Johannesburg: Southern African Institute of Mining and Metallurgy. pp. 353- 359.

Njowa, G., Musingwini, C., and Clay, A.N. (2014). A perspective on global harmonisation of major national mineral asset valuation codes. *The Resources Policy*, 39, March 2014, 1-14. http://www.sciencedirect.com/science/article/pii/S0301420713000858 [subscription].

Roberts, C. (2006). The valuation of advanced mining projects and operating mines: market comparable approaches, National Bank Financial. http://www.infomine.com/publications/docs/Roberts2006.pdf [Accessed 17 February 2016].

Rosenbaum, J. and Pearl, J. (2009). *Investment Banking – Valuation, Leveraged Buyouts, Mergers and Acquisitions*. Hoboken, NJ: Wiley.

Sibanye Gold. (2015a) Sibanye announces a recommended cash offer for the entire issued share capital of Aquarius. https://www.sibanyegold.co.za/investors/news/company-announcements/2015/item/188-cash-offer-aquarius-issued-share-capital [Accessed 14 February 2016].

Sibanye Gold. (2015b). Proposed acquisition Rustenburg operations. https://www.sibanyegold.co.za/investors/news/company-announcements/2015/item/175-media-proposed-acquisition-rustenburg-operations-from-aap [Accessed 17 February 2016].

Smith, L.D. (2013). Mineral property Valuation 2 – Approaches and Methods. http://www.edumine.com/courses/online-courses/mineral-property-valuation-2-approaches-and-methods/ [Accessed 17 February 2014].

SAMVAL. (2009). South African Mineral Asset Valuation (SAMVAL) Working Group. The South African Code for the Reporting of Mineral Asset Valuation (The SAMVAL Code). 2008 Edition as amended July 2009. http://www.samcode.co.za/downloads/SAMVAL2009.pdf

CIMVal. (2003). **S**pecial Committee on Valuation of Mineral Properties (CIMVal). Standards and Guidelines for Valuation of Mineral Properties, February 2003.

VALMIN. (2005). Code for the Technical Assessment and Valuation of Mineral and Petroleum Assets and Securities for Independent Expert Reports (The VALMIN Code). 2005 Edition. The VALMIN Committee, a joint committee of The Australasian Institute of Mining and Metallurgy, the Australian Institute of Geoscientists and the Mineral Industry Consultants Association. https://www.ausimm.com.au/content/docs/valmin_2005.pdf

VALMIN. (2015). Code for the Technical Assessment and Valuation of Mineral and Petroleum Assets and Securities for Independent Expert Reports (effective 31 January 2016). The VALMIN Committee of the Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists and Mineral Industry Consultants Association with the participation of the Australian Securities and Investments Commission, Australian Stock Exchange, Minerals Council of Australia, Petroleum Exploration Society of Australia Securities Association of Australia and representatives of the Australian finance sector.



Godknows Njowa

Snr Manager
Deloitte

Mr Njowa started his mining career as graduate learner mine at AA Mines (Shabanie mine) in Zimbabwe, and moved on to join Rio Tinto Zimbabwe in various capacities in Mine Finance and Project Evaluation. After completing his master's degree at Wits he joined Venmyn Deloitte. His key areas of expertise lie the combination of skills in Mining Engineering Financial Management and Accounting. Currently he leads a team in financial valuation of mineral and mining projects, technical and economic review, due diligences, MRM and mineral resources and mineral reserve estimation.

Valuation of alluvial diamond deposits

T.R. Marshall

Explorations Unlimited, Johannesburg, South Africa

Diamond deposits are different from deposits of other commodities, and these differences are sufficiently marked to allow all reporting codes to have a separate section for Diamond Resource estimation. Within the diamond industry, alluvial deposits have certain peculiarities that set them apart from primary, igneous deposits. It is therefore not surprising that the valuation of alluvial deposits should also have distinctive features. The valuation of alluvial diamond deposits follows the same broad outlines as for any other commodity, and there is, certainly, no difference in the acceptable standard of valuation. The three basic approaches to valuation are Cost, Market, and Income, which can be applicable to various stages in the mineral property life-cycle. Valuation of alluvial diamond deposits, however, typically occurs at the early stages of the life-cycle, before Diamond Resources have been identified. This means that Income methods of valuation are used less frequently than other methods. It also means that the Competent Valuer needs to be aware of certain peculiarities of these deposits that may influence the way in which the valuation is completed.

INTRODUCTION

In South Africa, alluvial diamond deposits have, historically, been mined almost exclusively by artisanals and professional diggers – a notable exception being the Trans Hex Group, which has been mining alluvial diamonds successfully since 1965, initially as a private company and since 1981 as a listed company on the JSE (TransHex Group, 2015).

The turn of the 21st century saw an increase in the activities of junior exploration and mining companies. These, mostly foreign listed companies (typically Australian and Canadian) developed an interest in South African alluvial diamond properties and by the mid- to late 2000s a number of these companies were operating on the inland alluvial fields – some more successfully than others. Valuations by such companies were completed according to the listing requirements of the relevant securities exchange (VALMIN, 2005; CIMVAL, 2003; SAMVAL 2008, 2009). At the time, no guidance existed for the specific evaluation and valuation of alluvial diamond deposits – the relevant codes were applied the same as for any other commodity or deposit type. In many cases, the results were less than satisfactory.

In more recent years there has been an explosion in the number of valuation reports for alluvial diamond properties in the non-listed environment. The reasons for this are many and varied:

- Many more private companies and small-to-medium scale operators mining alluvial diamond projects are looking to obtain finance from financial institutions (such as various banks and/or mining funds), from high-wealth individuals, or from diamantaires. Such finance may be in the form of direct loans but, more often, joint ventures and other forms of cooperation are preferred. In most of these situations, the financial partner requires a Competent Person's Report (CPR) with a SAMVAL-compliant valuation before they are willing to commit to commercial terms

- A number of private companies are involved in joint ventures with listed junior exploration and mining companies that require SAMVAL-compliant valuations in terms of their ongoing listing requirements
- In order to comply with the requirements of the Mineral and Petroleum Resources Development Act for BEE partnerships to obtain mining rights, many of these same private companies and small-to-medium-scale operators require valuation of their projects to determine realistic equity inputs.

With respect to valuations completed in the non-listed environment, many (most?) of these have not been based on any reliable standards or the application of systematic principles. All of these situations deserve the same protection in terms of professionalism that is demanded by the JSE and other international securities exchanges in terms of valuation documents. So, while valuation documents for the JSE must be compiled in accordance with the SAMVAL Code, it is suggested that, as best practice, *valuations for non-JSE submissions should also be compiled in a similar manner.*

Diamond deposits are different from deposits of other commodities and these differences are sufficiently marked to allow all reporting codes to either have a separate section for diamonds or refer to specific guideline documents (NAPEGG, 1997; CIM, 2008; JORC, 2012; PERC, 2013; SME, 2013; SAMREC, 2009). The SAMREC Code (2016) notes that the following characteristics of diamond deposits are different from those of typical metalliferous and coal deposits, which emphasizes the need for a diamond-specific Resource Estimation code:

- The widely differing nature of diamondiferous deposits and their associated forms of mineralization and the estimation relevant to these. Diamond deposits can be subdivided into (i) igneous-hosted deposits, (ii) marine and alluvial placers, and (iii) tailings and stockpiles
- The low diamond content of primary and placer diamond deposits and their variability
- The particulate nature of diamonds and individual physical characteristics, which have a significant impact on diamond value. These characteristics are size and assortment, the latter being comprised of model (shape or morphology), quality, and colour
- For diamond exploration programmes, Exploration Targets, Mineralisation, Resources, and Reserves, the term 'quality' cannot be used as a substitute for 'grade'
- The specialized field of diamond valuation
- The relationship between average diamond value and the underlying diamond size distribution.

In contrast, neither SAMVAL nor any of the other international valuation codes have separate sections for diamonds – and rightly so, since the valuation of such deposits must follow the same broad outlines as any other commodity, and there is, certainly, no difference in the acceptable standard of valuation. As with any Mineral Asset Valuation (MAV), acceptable valuation reports on alluvial diamond properties need to be prepared in terms of the SAMVAL Code, on the back of Diamond Resources/Reserves that are compliant with SAMREC (or a related CRIRSCO code).

SAMVAL-compliant documents must be compiled by a registered Competent Valuer (CV) and must apply two different valuation approaches. Different approaches may be more applicable at different stages of the exploration or mining programme (Table I) and it is incumbent on the CV to select the approach and method most applicable to the specific project. None of this is any different from the valuation of any other deposit type or commodity.

The 2016 SAMVAL Code includes the requirement for a site visit to be undertaken by the CV. The potential issues with valuations, described below, make this requirement even more important for alluvial diamond properties. In these situation, non-materiality as a reason for no site visit should be considered questionable, especially if the project is considered an Exploration or Development Property.

Table I. Different valuation approaches (SAMVAL, 2016).

Valuation Approach	Exploration Properties	Development Properties	Production Properties	Dormant Properties		Defunct Properties
				Economically viable	Not viable	
Cash flow	Not generally used	Widely used	Widely used	Widely used	Not generally used	Not generally used
Market	Widely used	Less widely used	Quite widely used	Quite widely used	Widely used	Widely used
Cost	Quite widely used	Not generally used	Not generally used	Not generally used	Less widely used	Quite widely used

ALLUVIAL DIAMOND PROJECTS

Alluvial diamond deposits have certain peculiarities that set them apart from primary, igneous diamond deposits in terms of Resource and Reserve estimation (marine deposits also have specific peculiarities relating to valuation, some of which may be similar to alluvial deposits). It is therefore not surprising that the valuation of these deposits should also have certain distinctive features. Although a diamond-specific valuation code is not required, there are certain peculiarities that may influence the way in which the valuation on such deposits is completed. In contrast with many other situations, most of the transactions (and required valuations) associated with alluvial diamond deposits mentioned in the introduction typically occur at the early stages of the life-cycle, before Diamond Resources have been identified.

Some other complexities involving the valuation of (alluvial) diamond rights include (Lilford and Minnitt, 2002):

- Diamond exploration areas can be very extensive
- While geophysical and remote sensing surveys can be used to identify exploration targets, they cannot determine whether these targets will contain diamonds
- Unlike other commodities, diamonds vary in value (revenue) depending upon a number of factors. The nature of the diamond occurrence cannot be identified in a mineral right, and only once sampling has been conducted can diamond qualities (US dollars per carat) be estimated.

Marine diamond occurrences are even more difficult to value (Lilford and Minnitt, 2002). Here, issues to be recognized include the fact that, due to the specific depositional environment and associated costs, Indicated Diamond Resources may often never be estimated, even after years of exploration, and while mineral rights might cover hundreds of square kilometres, the greater portion of the concession is likely to be non-diamondiferous or sub-economic.

VALUATION METHODOLOGIES

Where Diamond Reserves/Resources have been identified, the preferred method of valuation of alluvial diamond properties is the discounted cash flow (DCF). However, such information is seldom available for privately held projects. This means that Income methods of valuation are used less frequently than other methods.

Cost Approach
This approach is based on the principle of contribution to value. All of the generally accepted methods involve some form of analysis of exploration expenditures with respect to their contribution to the exploration potential of the Mineral Property. In essence, an exploration property can be considered to be worth meaningful past exploration expenditures – some variations also include warranted future costs to test the remaining potential (Smith, 2002).

Relevant exploration expenditure may be subject to premiums or discounts based on previous results. The multiples typically range from 0 to 3 (but may be as high as 5), with zero representing a complete write-off and values greater than unity applying where exploration had successfully upgraded the property (Smith, 2002). These methods are extensively used in early stage (exploration) property valuation. One of the great drawbacks of these methods, however, is that they tend to be subjective, especially in the identification of exploration expenditure that is deemed relevant for the exercise (Thompson, 2002; Lawrence, 2002). These issues are compounded by the fact that exploration properties might be located in very remote areas with limited/minimal infrastructure and where more of the expenditure might be related to access and infrastructure than to direct prospecting. All of these features are common to all projects at a very early stage.

With specific reference to alluvial diamond projects, historical expenditure is often incurred by artisanals or professional diggers (as is often the case in South Africa) and little may be available to substantiate expenditure – many mining costs are often assimilated into farming costs, for example. Prospecting programmes are seldom more than the excavation of prospect pits ahead of the 'mining face'. In addition, these projects are often prospected 'on the cheap' by concession owners lacking in funds. Consequently, Cost Approach methods often undervalue alluvial diamond properties significantly.

Market Approach
Market approaches are based on the premise that similar properties should have similar values. The two most commonly used primary methodologies are Comparable Transactions and Option Agreement Terms.

The Comparable Transaction method is widely used despite the paucity of publicly available information regarding such transactions outside of the listed environment. It has long been noted that there are comparatively few transactions involving diamond properties, resulting in challenges when attempting to compile a valuation matrix since historical acquisition/disposal data is limited (Lilford and Minnitt, 2002). Another complicating issue with this method is that projects associated with public transactions tend to be much larger than those that most private operators deal with (especially in the South African situation), and this difference in scale cannot always easily be applied to small-scale operations.

Furthermore, with respect to alluvial diamond deposits, bedrock and/or depositional environments may vary considerably even between adjacent properties. In addition, both diamond grade and value are known to vary according to the hydraulic constraints of the depositional environment. Consequently, even adjacent properties may have very different grade and value parameters, and 'comparable' properties may not be all that comparable.

A further complicating factor is that most transactions involving alluvial diamond properties include junior exploration companies, artisanals, professional diggers, and/or diamantaires and such transactions seldom involve cash only. Conversion of shares, options, royalties, and cutting/polishing agreements to cash to allow for direct comparison is not always a simple situation (Smith G. L., 2002).

Furthermore, the diamond market is more fickle than the markets for most commodities, since diamonds (especially the gem-quality stones typically associated with alluvial deposits) are a luxury item and demand varies dramatically, with the seasons as well as with international economic

conditions. Consequently, a project valued in December may have a significantly higher value than an equivalent project valued in April.

Of the Market Approaches, the joint venture or option agreement terms method is probably the most useful when valuing a large exploration concession, where there is significant exploration potential, but where little exploration has been carried out. Typically, equity in a property is earned by an incoming participant agreeing to conduct specific exploration activities at their own cost. As a rule, such commitments are firm only for a year or two and only those commitments met or firmly budgeted and approved by a board of directors are included in establishing a minimum value for the property (Lawrence, 2002).

This valuation method applies multiples of early-stage expenditure based on the premise that further project exploration and development costs materially escalate with time, as commonly encountered in base- or precious-metals projects. Application of similar multiples to alluvial diamond projects is prone to significantly overestimate actual project value because early-stage JV/farm-in costs are necessarily inflated by the (equipment and logistical) requirements of extracting and processing on-site large quantities of low-grade alluvial material (Marshall, 2013). In addition, further alluvial diamond project development requires sustaining-level financial commitments that are fractions of early-stage JV/farm-in valuations and may actually decrease with time. As a result, valuations prepared according to the JV terms method, typically, have the propensity to overestimate the value of the alluvial diamond project.

Some of the secondary methods associated with the Market Approach are:

- *Net metal value (or value per unit of metal*): this method wold be inappropriate for alluvial diamond properties (in fact, any diamond property) – due to the wide array of diamond size and assortment characteristics, diamonds do not have a single universal value (revenue figure or price), as is the case with, for example, gold or platinum
- *Value per unit area*: this method can be problematic in that the size of an alluvial diamond property is not always the most significant variable. For example, the value of an alluvial deposit is confined to the river environment and associated terraces, and if this comprises only 10% of the area of the entire exploration property, then the subsequent value per unit area of the project can be skewed. As with any other deposit type where a similar situation could occur, care needs to be taken to identify value per relevant area. Even if this has been taken into account, a situation could occur where the bedrock influence on one stretch of river could be far more conducive to the formation of trapsites (potentially higher grades and higher diamond values) than on the comparison property. So, while the method has merit, it cannot be applied indiscriminately
- *Market capitalization*: this method has been applied quite effectively to the valuation of single-property asset listed companies. However, especially in the context of South African deposits, most alluvial diamond deposits are not owned by listed companies (this is not as applicable to marine diamond deposits).

Income Approach

The Income Approach is based on the principle of anticipation of benefits and includes all methods that are based on the income or cash flow generation potential of the Mineral Property. These methods are the most accurate measures of value, but they also require the most input and, are, by their very nature, most applicable to Development and Production properties.

The principal methods included in the Income Approach are the DCF, Monte Carlo analysis, and option pricing. By far the most widely used and accepted method is the DCF. The most definitive application of the DCF will be the valuation of an existing mining operation with a well-defined Mineral Reserve, no potential for additional discoveries and an established history of consistent production and operating costs (Smith, 2002).

Alluvial diamond projects are almost never fully evaluated before the start of commercial mining. Due to the nature of alluvial diamond deposits, the industry standard is not to complete a one-stage Pre-Feasibility Study (PFS) which converts all of the Indicated Resources to Probable Reserves. Ongoing production (often referred to as 'full production') acts as a continuous trial mining programme for the adjacent Indicated Mineral Resource. As a result, as mining of existing Probable Reserves proceeds and as confidence in the geological and mining parameters is upheld (or increases), then surrounding Indicated Mineral Resources can be upgraded to Probable Mineral Reserves on a continual basis, without the need for a separate PFS. It is only in situations where new processing methodologies are introduced that a new or updated PFS would be necessary.

DCFs based on the net present value (NPV) of a stream of cash flows typically require that a minimum of a PFS has been completed on the project and that Diamond Reserves have been estimated. Preliminary estimates of value, based on Scoping Studies are admissible in public reporting only under very specific circumstances and when suitably discounted. Such assessments consider the potential viability of Diamond Resources (including Inferred Resources) and are extremely useful for in-house planning purposes. However, care must be taken to prevent the creation of unrealistic expectations in the public domain.

Two peculiarities of alluvial diamond deposits that make DCF construction difficult are:

- Most of the capex is spent prior to, or during, the PFS and only minor sustaining capital is, generally, required throughout the life of the mine. This feature results in difficulty in determining a realistic internal rate of return (IRR)
- Although the operation may have multiple years of identified Diamond Resources, the industry standard is to determine only limited amounts of Diamond Reserves ahead of mining. This, typically, results in low NPV and IRR values that might not reflect the true value of the property.

The application of Discount Rates to alluvial diamond properties should be no different from any other commodity. However, special care has to be exercised in the matter of 'Resource Risk'. The basis of the DCF is the Diamond Resource/Reserve statement. A core issue with alluvial diamond projects is the tendency for the Competent Person (CP) to force as much as possible of the volume, grade, and value of the project into the Indicated Resource category. This is done so as to take advantage of the fact that Indicated Resources can be converted to Probable Reserves through a PFS and then valued by DCF. This is, fundamentally, a problem for the CP in the statement of the Resources/Reserves. However, the CV should be aware that this situation is likely to occur in many circumstances (especially those dealing with small-to-medium-scale alluvial diamond operations) and should, therefore, satisfy himself/herself that the Resource/Reserve estimation has been done with due cognisance of the issues peculiar to alluvial diamond deposits. A detailed document entitled '*Policy Document for the Reporting of Diamond Exploration Results, Diamond Resources and Diamond Reserves (and other Gemstones, where relevant)*' has been compiled to assist the CP in compiling estimates and reporting in the public domain – it is recommended that the CV have more than a passing familiarity with this document in the assessing of the Diamond Resource/Reserve statement (in compliance with Table T1.9 of the SAMVAL Code).

In alluvial diamond properties, it has been noted (Marshall, 2013) that the industry standard is typically to identify only a limited amount of Probable Reserves, followed by multiple years of Diamond Resources (both Indicated and Inferred). If such Resources are included in a DCF (subject to the requirements of Clause 4.6 of the 2016 SAMVAL Code), then specific note has to be taken with respect to the application of different discount rates to the different classification of Resources and Reserves. Such discounts might include references to (Lawrence, 2002):

- Potential diminution in Resource volume/tonnage (and changes in grade) for its ultimate conversion to Reserve classification
- Allowances for time and cost of such conversion
- Probability factors for the uncertainty of the expenditure schedule.

However, in the application of such risk, care needs to be taken so as not to 'double discount', especially where diligent risk assessment and mitigation has already been done on key input variables during the resource estimation phase (Macfarlane, 2002).

Monte Carlo analysis is a problem-solving technique used to approximate the probability of certain outcomes by running multiple simulations, using a range of possible values (production variables). Like any forecasting model, the simulation will be only as good as the input estimates. As with the DCF, the CV needs to be aware of the potential issues with Diamond Resource/Reserve estimation as a fundamental input to the Monte Carlo simulation.

Option Pricing: Options are the right, but not the obligation, to buy, sell, or invest at a known price for a specified period of time. Option theory provides a powerful framework for analysing a multitude of business problems, including valuation of investment opportunities, research and development expenditures, capital structure, divestment decisions, timing of investments, and open/closure decisions. Options theory has most direct applicability to the latter end of the valuation spectrum, when there is reasonably good information about resources, capital, and operating costs (McKnight, 2002). With respect to alluvial diamond properties, the application of Option Pricing is subject to the same caveats as all of the Income-based methods.

CASE STUDY

The issues discussed above can best be understood by looking at the case study of an alluvial diamond project (Project Midamines) located on the Kwanza River along the border between Angola and the DRC. The property comprises some 55 km of stream length; the width of the concession varies from 1–5 km, giving an approximate area of some 200 km^2. The project is in the early stage of exploration with a desktop study completed and initial exploration under way to identify a number of exploration targets (De Decker, 2005). No Diamond Resources have yet been identified on the concession. Although diamonds have been recovered from the river and terraces by artisanal operators, no reasonable prospects for eventual economic assessment (RPEEE) have yet been demonstrated by the subject company.

Since no Resources have been identified, income approaches based on DCF are not appropriate. Consequently, the property was valued by Cost and Market approaches (Dimolitsa, Fierens, & Tossens, 2011).

Cost Approach

Limited audited expenditure was approximately US$925 000. The application of a discount or premium was subjective, and pegged at 1.2, resulting in a total estimated value of US$1.1 million. The expenditure details were not available and it is unknown how much of these costs was due to relevant and effective expenditure. It is also likely that the figure was inflated by the logistical costs of operating in a remote environment. Further, since much of the historical prospecting on this concession had been done by artisanals, it was unknown whether the expenses presented even reflected a true indication of the full cost of the exploration.

Market Approach

Market Comparable method

Two CPRs had been compiled for public companies on alluvial diamond properties within 100 km from the target property (Venmyn Rand, 2007; 2010). Fortuitously, both CPR/CV documents had been compiled by the same company, so it could be assumed that similar guiding principles and parameters had been applied in both cases.

The earlier (2007) CPR was completed on a property with no identified Diamond Resources, although both artisanal activity and reconnaissance exploration by the operating company had been carried out.

This property is located adjacent to the Midamines project property. No valuation had been carried out and the property was on the company's books for a nominal value.

Three years later, in 2010, a valuation was compiled for a 110 km^2 alluvial diamond property some 100 km distant from the Midamines property, still in the DRC and in similar geological and geomorphological terrain. Although the operating company had completed no exploration on the property, artisanal and historical results confirmed the existence of diamonds and allowed for the identification of Exploration Targets. The value arrived at, based on the market comparable method (using the nominal value attributed by the 2007 CPR as the base), was some US$1.8 million (US$500 per km^2). Based on this information, the Midamines project property was subsequently valued at some US$100 000 (approximately 200 km^2 at US$500 per km^2).

The lack of comparable properties and some of the questionable logic in the valuation processes led to results that were considered to undervalue the project potential significantly. Consequently, a second Market Comparable method was investigated.

Joint Venture terms method

Under the terms of the JV agreement, the incoming party would be required to fund an initial exploration programme and technical study to determine whether diamonds occur in sufficient quantities to warrant the implementation of a full-scale mining operation. Two budget scenarios indicated that the realistic cost for this exercise would have been in the region of US$10–12 million (Bristow, 2005). The exploration programme to be completed involved sampling using a fully contained dredge, and a 30–50 t/h dense media separation (DMS) plant for the terrace sampling, each with matched earthmoving equipment. The scale of the project was designed to both estimate Resources and initiate a cash flow (a scenario that is typical for alluvial diamond projects). This budget was proposed to cover initial exploration over a two-year programme. In-house techno-financial modelling indicated that the project would require an additional US$4 million to bring it into full production.

Under these conditions, the cost of the exploration programme (US$10–12 million) was significantly higher than the cost of bringing the property into production (US$4 million), which negates the whole premise of the JV terms valuation method. As a result, the US$10–12 million value attributed to the Midamines project (Dimolitsa, Fierens, & Tossens, 2011) in terms of this valuation method is expected to have overvalued the project.

At the end of this exercise, the project was left with a range of valuations from US$1.1–12 million, both extremes of which were deemed unreliable. Recognizing the issues that made these results undependable is fundamental to assisting the CV in applying global valuation principles to deposits with very specific requirements and coming up with results that will be more useful to both listed and private companies.

CONCLUSION

Although most transactions involving alluvial diamond properties occur in the unlisted environment, more and more entities are requiring SAMVAL-compliant valuations. Just as the evaluation (Resource/Reserve estimation) of alluvial diamond deposits have specific peculiarities, so the valuation of these deposits requires that the CV take cognisance of certain unique characteristics.

Cost and Market valuation approaches are generally not good indicators of value of alluvial diamond projects due, in part, to the lack of publicly available data. In addition, the fact that the majority of capital is spent during the early stages of resource estimation (bulk sampling) often overvalues projects based on JV/farm-in methods. Although Income-based valuation approaches are by far the most satisfactory appraisals of value, they are not appropriate for properties without Diamond Resources, and financial valuations of alluvial diamond deposits typically occur at the early stages of

the project life-cycle, when Diamond Resources have not yet been identified. Notwithstanding, the DCF, based on Indicated Diamond Resources converted to Probable Reserves through the application of PFS or Feasibility Studies is the preferred method of valuation for an alluvial diamond project. Even where a DCF can be constructed, however, the inherent complexities of alluvial diamond deposits coupled with an imperfect understanding of the resource estimation procedure may result in the application of incorrect NPV discount rates.

This does not imply that such early stage projects do not have value, and acceptable results have been obtained by inventive combinations of accepted valuation methods. Recognition of the limitations of each of the approaches and the reasons for such inconsistencies will assist the CV in applying the necessary project values.

REFERENCES

Smith, G. L. (2002). Valuation Methods used in Mineral Property Valuation. *Valuation of Mineral Projects and Properties: An African Perspective.* Randburg: SAIMM.

Marshall, T. R. (2013). The Evaluation and Valuation of Alluvial Diamond Deposits. In D. G. Pearson, H. S. Grutter, J. Harris, B. A. Kjarsgaard, H. O'Brien, N. V. Chalapathi Rao, & S. Sparks (Ed.), *Proceedings of the 10th International Kimberlite Conference. 2*, pp. 281-288. New Delhi: Springer.

Macfarlane, A. S. (2002). A Code for the valuationof mineral properties and projects in South Africa. *SAIMM*, 37-48.

McKnight, R. T. (2002). Valuing Mineral Opportunities as Options. *Mining Millennium Valuation 2000. Special Session on Valuation of Mineral Properties*, (p. 7pp). Toronto.

De Decker, R. H. (2005). *Report on a field visit to the Midamines Concession on the Kwango River, DRC to assess the potential for Diamond Mining.* Noordhoek: De Decker and Associates Consulting Services.

Dimolitsa, A., Fierens, J.-P., & Tossens, J.-F. (2011, November 24). *Final award in the arbitration between Midamines SPRL (DRC) and Durnpike Investments (Pty) Ltd.* Brussels: Belgian Centre for Arbitration and Mediation (CEMPANI Case # 22539).

Bristow, J. W. (2005). *Durnpike - Midamines Land and River based alluvial diamond project, Kwango River, DRC.* Johannesburg.

Thompson, I. S. (2002). A Critique of Valuation Methods for Exploration Properties and Undeveloped Mineral Resources. *Mining Millennium Vauation 2000, Special Session on Valuation of Mineral Properties (March 8, 2000)*, (p. 12pp). Toronto.

Lawrence, R. D. (2002). Valuation of Mineral Properties without Mineral Resources: a review of market-based approaches. *Mining Millennium Valuation 2000, Special Session on Valuation of Mineral Properties (March 8, 2000)*, (p. 7pp). Toronto.

NAPEGG. (1997). *Reporting of Diamond Exploration Results, Identified Mineral Resources and Ore Reserves.* Canada: Association of Professional Engineers, Geologists and Geophysicists of the Northwest Territories.

CIM. (4 May 2008). *Estimation of Mineral Resources and Mineral Reserves, Best Practice Guidelines.* CIM.

SME: The Resources and Reserves Committee of the Society for Mining , Metallurgy and Exploration, Inc. (June 2014). *The SME Guide for reporting Exploration Results, Mineal Resources and Mineral Reserves.* Englewood, CO: SME.

SAMREC. (2009). *South African Resource and Reserve Estimation Code.* Johannesburg: GSSA/SAIMM.

PERC. (March 2013). *Pan-European standard for reporting of Exploration Results, Mineral Resources and Reserves.* Brussels: PERC.

Lawrence, M. J. (2002). The Australasian VALMIN Code (1998): Its relevance to South African Valuation Code initiatives. *Valuation of Mineral Projects and Properties: an African Perspective* (p. 11pp). Johannesburg: SAIMM.

Lilford, E. V., & Minnitt, R. C. (2002). Methodologies in the valuation of mineral rights. *SAIMM*, 369-384.

VALMIN. (2005). *Code for the Technical Assessment and Valuation of Mineral and Petroleum Assets and Securities for Independent Expert Reports.* AusIMM.

CIMVAL. (2003). *Standards and Guidelines for Valuation of Mineral Properties.* CIM.

SAMVAL. (2009). *The South African Code for the Reporting of Mineral Asset Valuations.* SAMCODE. The evaluation and valuation of alluvial diamond deposits (PPE-331), 22539 (Belgian Centre for Arbitration and Mediation July 5, 2011).

Venmyn Rand (Pty) Limited. (2007). *National Instrument 43-101 Technical Report on the Kwango, Lubao and Tshikapa Projects of BRC Diamond Corporation.* Johannesburg.

Venmyn Rand (Pty) Ltd. (2010). *Independent Competent Persons Report of the Mineral Assets of Namakwa Diamonds Limited.* Johannesburg.

JORC. (December 2012). *Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves.* AusIMM.

Smith, L. D. (2002). Discounted Cash Flow Analysis Methodology and discount Rates. *Mining Millenium Valuation of Mineral Properties*, (p. 15pp). Toronto.



Tania Ruth Marshall

Geological Consultant
Explorations Unlimited

Tania R Marshall has been actively, and continuously, involved in the alluvial diamond exploration/mining industry since 1985. She started her career with GFSA, before joining a small private company, prospecting for diamonds and other precious stones up and down Africa.

In 1996 Dr Marshall founded EXPLORATIONS UNLIMITED and has since been involved in consulting and contracting to both South African and international companies involved in the exploration and mining of alluvial diamond deposits. She has worked actively in Africa, South America, Australia and Asia.

In addition to consulting, Dr Marshall continues to write and lecture widely on the subject of alluvial diamond deposition, exploration, evaluation and valuation, in which fields she enjoys an international reputation. She sits on the SAMREC and SAMVAL Committees and is currently the Chair of the SAMCODES Standards Committee (SSC).

Considerations for reporting of tailings

N.C. Steenkamp

WorleyParsons RSA, Johannesburg, South Africa

The reporting of tailings has historically posed a conundrum in as far as reporting to the correct level of confidence. Tailings are sometimes over- or underestimated, excluded, or incorrectly reported. Using the correct terminology is important and not just a matter of semantics. Tailings can be defined as a 'mineral' or 'solid material' and as a 'residue stockpile' or 'residue deposit' by current South African mineral reporting codes and law. Tailings need to be included in Public Reports and the company's annual report as either a Resource or a Reserve. According to the 2009 and now the 2016 version of the SAMREC Code, tailings are considered to be a Mineral Resource by default and may be classified as a Reserve after the application of realistically assumed mining, metallurgical, processing, infrastructure, economic, marketing, legal, environmental, social, and governmental Modifying Factors. The following technical aspects need to be understood and considered in order to classify tailings: geochemical and physical characteristics, grain size, homogeneity, level of oxidation, grade(s) or percentage contained, penalty elements, densities (SG) and processable tonnage to be included and non-processable tonnages to be excluded, and volume of the dump. These will determine the 'reasonable prospects for eventual economic extraction' required by the Code. The amount of historical information is also critical, whether or not the tailings were sampled during or prior to deposition and how regularly they were sampled. If no information is available the spacing of the drilling or augering grid, the sampling interval, and number of elements or metals assayed will determine the degree of confidence for classification. Whether or not the tailings are or contain a processable (and by implication saleable) product is also a consideration for inclusion or exclusion. Where historical dumps or current dumps are considered sub-economic, but have potential to be re-worked or reprocessed, the tailings need to be reported. Tailings that are proven unsuitable be utilized furtherthey may be excluded from classification and classified as waste. Material considered as 'waste' becomes subject to the National Environmental Management Waste Act (NEMWA) and has significant cost implication. Legislative considerations, such as the Mineral and Petroleum Resources Development Act (MPRDA), also need to be taken into consideration. It is also crucial to take into account all the minerals, metals, or elements that are contained in the tailing dumps. This can be considered as part of the legal Modifying Factors. If all proven or potential mineral or metals in the tailings have not applied been for, it leaves the potential for external applications to be lodged for the tailings. Therefore, correct and detailed reporting is essential from the start. In terms of the MPRD amendment, all residues produced under the old-order rights and not applied for now vest with the State. Any tailings remaining after closure of a mine will also vest with the State. Historic tailings are considered a heritage site in terms of South African's National Heritage Resources Act.

INTRODUCTION

The reporting of tailings has historically posed a conundrum inasfar as reporting to the correct level of confidence. Tailings are sometimes over- or underestimated, excluded, or incorrectly reported. Tailings are generally only touched upon in a cursory manner in mining and environmental legislation.

BACKGROUND

Tailings and tailings facilities are subject to a number of laws and mineral reporting codes. This article focuses on applicable South African legislation and reporting codes. Reference is made to tailings in the Mineral and Petroleum Resources Development Act (MPRDA), the National Environmental Management Waste Act (NEMWA), and the National Heritage Resources Act (NHRA). An Amendment Bill to the MPRDA has also been promulgated, but was still under review at the time of writing this article, after being sent back to the National Assembly by the President of South Africa.

The review of the MPRDA, resulting in the Amendment Bill, was in part due to a court case in which ownership of old-order tailings was disputed. In the case of De Beers Consolidated Mines Ltd *v.* Ataqua Mining (Pty) Ltd and Others, it became apparent that the original Act did not specify historic dumps or tailings. Tailings were therefore considered to be a movable asset of the permit holder that extracted the material.

Tailings are also defined for classification and mineral reporting purposes in the SAMREC (SAMREC, 2009) and SAMVAL (SAMVAL, 2009) codes.

Tailings management in South Africa is regulated by law in the Guideline for the Compilation of a Mandatory Code of Practice on Mine Residue Deposits issued by the Department of Mineral Resources (DME) in 2000. This guideline makes implementation of a code of practice mandatory for each tailings facility with compulsory adherence to the SANS 10286, Code of Practice for Mine Residue Deposits.

DEFINITIONS

In order to understand the semantics behind classification of previously processed or handled material, the definition of the different types of product needs to be clarified.

The MPRDA definition of 'minerals' included substances that occur naturally in or on the Earth and in any residue stockpile or residue deposit. A residue stockpile was defined as '*any debris, discard, tailings, slimes, screening, slurry, waste rock, foundry sand, beneficiation plant waste, ash or other product derived from or incidental to a mining operation and which is stockpiled, stored or accumulated for potential re-use, or which is disposed of, by the holder of a mining right, mining permit or production right*'.

The definition of 'residue deposit' is similar. It reads: '*Any residue stockpile remaining at the termination, cancellation or expiry of a prospecting right, mining right, mining permit, exploration right or production right.*'

The word 'mine' in the MPRDA, when used as a verb, means any activity for the purposes of winning a 'mineral'. Section 5(4) of the MPRDA states that a person may not mine, *i.e.* win a mineral as defined, without a mining right.

Residue stockpiles or tailings do not occur naturally in or on the Earth. They are created by mining operations. A residue stockpile or deposit therefore falls within the ambit of the MPRDA only if it is created by the holder of a mining right or remains at the termination or expiry of a mining right.

The SAMREC and SAMVAL codes have the same broad definition of a 'mineral' as in the MPRDA, where a 'mineral' is present in tailings. The codes also specify that a '*Mineral Resource covers in-situ mineralization as well as dumps or tailings that have been identified and estimated through exploration or assessment and sampling from which Mineral Reserves may be derived by the application of modifying factors*'.

According to the SAMREC Code, for tailings that are '… *currently sub-economic, but there is a reasonable expectation that it will become economic, then this material may be classified as a Mineral Resource. If technical and economic studies have demonstrated that economic extraction could be reasonably justified under realistically assumed conditions, then the material may be classified as a Mineral Reserve'*. In order to avoid confusion or to make the inclusion or exclusion of tailings from a Resource or Reserve statement easier, tailings may be reported separately with an explanation. Coal and diamond tailings have separate reporting sub-sections in the Code.

As tailings have the potential to be re-processed several times during the life of operations as improved recovery methods are developed, they may need to be reclassified. In the case of a bulk commodity such as chromite or manganese (Figure 1) the entire tailings dump can be reclaimed for sintering. A platinum group element (PGE) or gold tailings dump (Figure 2) can be reprocessed and deposited as a new dump with a lower grade, but still have potential for later reprocessing if recovery methods improve or the material becomes economically viable.



Figure 1. Manganese tailings dump.



Figure 2. Gold tailings dump.

MODIFYING FACTORS

The main technical factors to consider when classifying tailings are the physical properties, which are generally described in terms of geometallurgical characteristics. Other Modifying Factors that can be considered are technical, economic, legal, environmental, social, marketing, governmental, and political factors.

Some operations work on the principle that all tailings have the potential to be reprocessed. Generally, precious metal producers put more effort into recording the properties of the tailings prior to and after deposition. This then provides a body of knowledge that a Competent Person can use in order to classify the tailings.

The following technical factors and geochemical and physical characteristics need to be considered in order to classify the tailings: grain size, homogeneity, level of oxidation, grade(s) or percentage contained, penalty elements, densities or specific gravity (SG), processable tonnage to be included and non-processable tonnages to be excluded, and volume of the dump.

If no or very limited information is available about the tailings dump, the spacing of the drilling or augering grid, sampling interval, and number of elements or metals assayed for will determine the degree of confidence for classification. In the case where the tailings will be reprocessed in bulk, such as chrome or manganese, the grid can be more widely spaced than for tailings where the valuable constituents make up only make up a small percentage of the tailings, such as the platinum group minerals (PGMs). Auger drilling of a tailings dump is depicted in Figure 3 and recovery of auger material in Figure 4.



Figure 3. Auger drilling of a gold tailings dump.



Figure 4. Recovering auger drilled material.

The grain size and habit of the mineralization, *e.g.* refractory *versus* free grain, in the tailings is also a factor that will determine if reprocessing is viable. If ultrafine milling or a re-design of the plant is required, the cost impact can be weighed up against waiting for the introduction of new processing

techniques during the life of mine. The physical and geochemical nature of the tailings also needs to be considered, such as density settling, and mobility of elements over time. The homogeneity of the tailings will also be influenced if the tailings are derived from more than one orebody or multiple seams with different mineralogical characteristics.

A detailed quality assurance and quality control (QA/QC) programme is integral to the classification considerations. This would cover the entirety of the sampling, assay, and reporting process and should be audited by a third party.

A suggested way of modelling tailings dumps is the inverse distance to a power gridding method. As sampling of tailing dumps is inherently difficult, the results tend to be more indicative than absolute. Smoothing is generally required to minimize the 'bullseye' effect. An example of such a contour map of a hypothetical dump is presented in Figure 5.

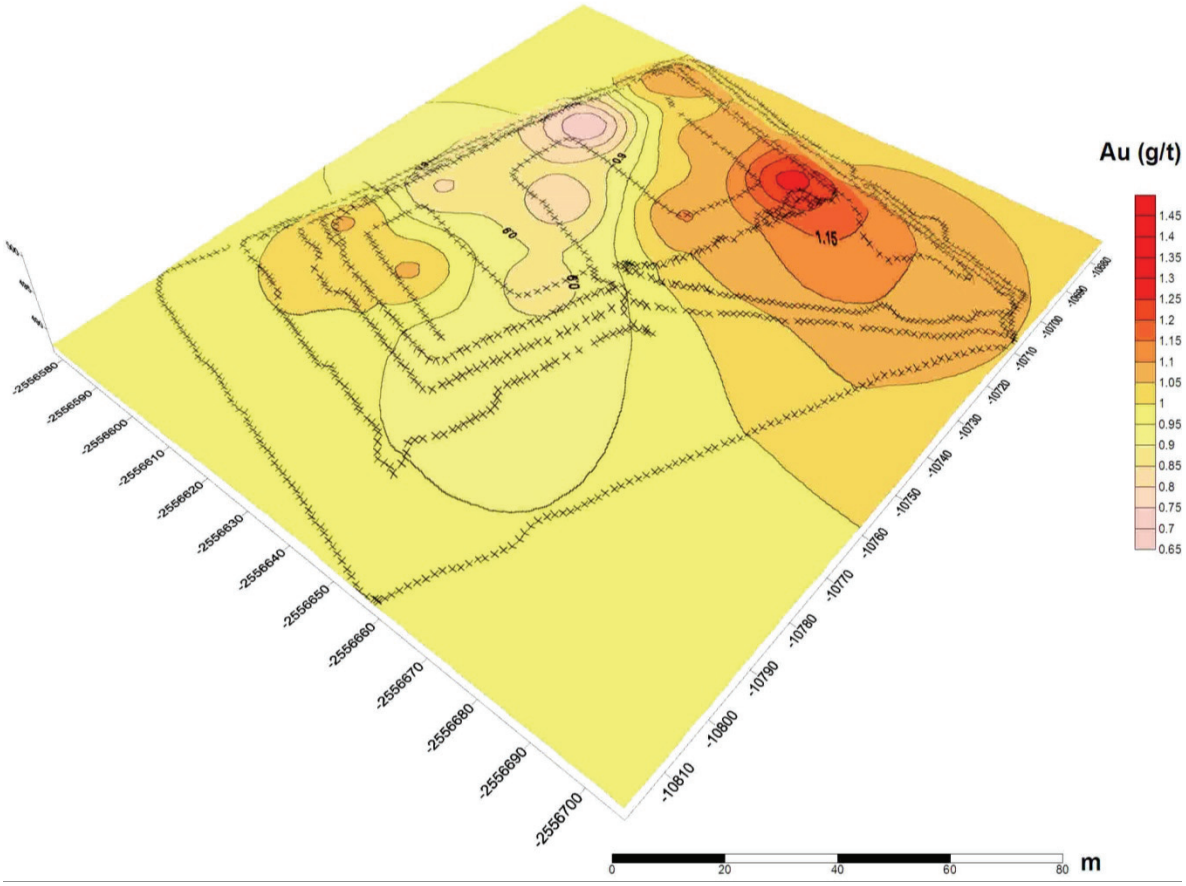


Figure 5. Contour map of a hypothetical dump using the inverse distance to power gridding method.

APPLICATION FOR EXPLORATION AND MINING RIGHTS OVER TAILINGS

When the MPRDA was initially promulgated in 2004 it did not specify tailings, which were therefore legally considered to be a moveable asset of the permit holder that extracted and processed the material. The MPRDA has since been amended, but the amendment remains under review and has not been officially promulgated.

The State holds historical tailings in custody and third parties will be able to apply for prospecting and mining rights for these tailings. The possible consequence of the amendment is that rights to such

tailings will fall under the rights of those parties with prospecting or mining rights to the land physically underlying these tailings.

The MPRD allows the primary holder of a mining right to mine and dispose of associated minerals discovered in the mining process. The MPRD also allows third parties to apply for rights, permits, or permissions over these associated minerals. The only requirement in this regard is that the third party notifies the primary mineral right holder of the application being made.

CLASSIFICATION OF TAILINGS AS WASTE

The SAMREC Code clearly states that: '*Portions of a mineral deposit that do not have reasonable and realistic prospects for eventual economic extraction must not be included in a Mineral Resource*'. These tailings would then not be reported as either a Mineral Resource or a Reserve. The Code goes on to state that: '*a detailed listing of such exclusions and reasons therefore, signed by a relevant Competent Person, should exist*'. The implication is that the tailings would then be classified as 'waste'.

The decision to classify tailings as waste has potential financial impacts. Once the decision has been taken to deposit the tailings as 'waste', the material becomes subject to the relevant environmental legislation. Prior to June 2014, the MPRDA largely regulated mineral waste. Mines did not need a waste licence for their mineral waste – only an approved Environmental Management Plan (EMP) and a water use licence were specified. Mineral waste facilities were designed and operated based on a risk-based approach, which takes into account site-specifics, the nature and the characterization of the waste material, and an environmental specialist consultant's professional judgment.

Mineral waste now falls under the National Environmental Management Waste Act (NEMWA) Amendment Bill, implemented in December 2014. At the same time the 'One Environmental System', which aims to streamline mining, environmental, and water use authorization processes for mining-related operations, was rolled out. The Minister of Mineral Resources is able to issue environmental authorizations and waste management licences in terms of NEMA and NEMWA respectively for mining and related activities. The Minister of Environmental Affairs will be the appeal authority for these authorizations.

The NEMWA Amendment predefines mineral waste as hazardous, and applies the technical requirements of small landfills, for which it was originally intended, to large mine residue deposits. Mines now also need to apply for waste licences for these disposal sites. This poses engineering and cost challenges, including the use of geosynthetic material, which is mostly plastic-based materials and required in landfills, to cover the mineral waste. This would not be viable for dumps that contain material that is prone to spontaneous combustion. Also, the design and type of liner to be used must be of sufficient longevity and integrity so that it will not fail due to the sheer size and weight of the dump. Installation of pollution barrier systems, *i.e.* liners, for certain mineral waste facilities in accordance with the NEMWA Regulations is potentially costly, considering that some of these dumps have been set up for temporary purposes, ranging from ten or twenty years in mining terms, before being reclaimed or used as backfill or for other purposes. Hence, the current dump cannot always be designed as a permanent deposition site. These additional requirements will have an immediate short-term and long-term financial impact on the mining operations, which are not necessarily budgeted for.

OLD-ORDER TAILINGS AND HISTORICAL TAILINGS

The MPRD Amendment Act extended the definition of 'residue deposit' and 'residue stockpile' to include deposits or stockpiles created under old-order mining rights. The effect of the amendment is that ownership of residues held in terms of an unused old-order rights and which have not been converted, now vests in the State.

If, however, the old residues are held in terms of used old-order mining rights which are converted, then the majority opinion is that mining of the residue under the new-order mining rights is permitted. Ownership will then revert to the State after mining ceases.

It was initially unclear whether the provisions contained in the MPRD Amendment Act applied retrospectively effect to stockpiles or deposits created before the MPRD Amendment Act or the MPRDA. In the MPRD Amendment Act, this issue is addressed and it now refers to 'historic mines and dumps created before the implementation of the Act'. Section 42A is the new section, which provides transitional measures dealing with historical residue stockpiles and residue deposits not regulated under the Act. For a period of two years from the date that the MPRD Amendment Bill is promulgated, the rights continue in force and the holder had the right within the two-year period to apply for a reclamation permit. A reclamation permit will be granted if the holder intends conducting mining operations upon the grant of the reclamation permit. Similar provisions to those dealing with the conversion of old-order rights pertain to the conversion of rights in respect of historical residue stockpiles and residue deposits.

Cognisance should also be taken that historic mining site infrastructure older than sixty years is subject to the National Heritage Act. This would include the tailings dumps and associated historic buildings.

CONCLUSION

The Modifying Factors for converting tailings into a Mineral Reserve are influenced by the initial processing method, the manner in which the tailings dump was generated, and the effect of time. The considerations for classification of tailings extend beyond the mineral reporting code requirements and the modifying factors. Legislation ranging from the application to explore and mine tailings to retaining these rights may impact on the considerations. The decision to discard tailings as waste will have a financial impact in terms of the environmental requirements that will have to be met.

The continual advancement of processing methods would suggest that a tailings dump may be re-processed several times during the life of a mine's operations. The physical or geometallurgical characteristics of the tailing are the main considerations when classifying tailings, but classification cannot be considered or done without taking into consideration the legislative and reporting requirements.

REFERENCES

South Africa. (2002). Mineral and Petroleum Resources Development Act 28 of 2002. Government Gazette No. 23922, Notice No. 1273 dated 10 October 2002. Commencement date: 1 May 2004.

South Africa. (2013). Mineral and Petroleum Resources Development Amendment Bill (As introduced in the National Assembly (proposed section 75); explanatory summary of Bill published in Government Gazette No. 36523 of 31 May 2013).

South Africa. (2008). National Environmental Management Waste Act of 2008. Government Gazette No. 32000, Notice No.278 dated 10 March 2009. Commencement date: 1 July 2009.

South Africa. (1999). National Heritage Resources Act 25 of 1999. Government Gazette No.19974 , Notice No. 506 dated 28 April 1999.

SAMREC. (2009). South African Mineral Resource Committee. The South African Code for Reporting of Exploration Results, Mineral Resources and Mineral Reserves (the SAMREC Code). 2007 Edition as amended July 2009. http://www.samcode.co.za/downloads/SAMREC2009.pdf

SAMVAL. (2009). South African Mineral Asset Valuation (SAMVAL) Working Group. The South African Code for the Reporting of Mineral Asset Valuation (The SAMVAL Code) 2008 Edition, as amended July 2009. http://www.samcode.co.za/downloads/SAMVAL2009



Nicolaas Casper Steenkamp

Senior Associate
Advisian (WorleyParsons RSA)

Dr Nicolaas C. Steenkamp works as Geologist and has over 10 years of experience in a broad range of fields. Currently he is involved in contractor management, geological, geotechnical and geometallurgical project work and studies. Dr Steenkamp has a background in the geological field that includes, but is not limited to: Geological- and geotechnical core logging, underground face mapping, regional surface mapping, greenfields- and brownfields exploration. He has also been involved in technical reporting, due diligence and desktop studies. He also has a background in X-ray analytical methods, specifically EMP and XRF. He is involved in a shaft sinking and decline rehabilitation project where a unique set of geological and geotechnical challenges are faced in terms of development through sand and stiff clays. He is the current Geology Stream Lead for Advisian.

The new SANS 10320:2016 versus the 2014 Australian guidelines for the estimation and classification of coal resources – what are the implications for southern African coal resource estimators?

J. Hancox[1] * and H. Pinheiro[2]

[1] CCIC Coal (Pty) Ltd, Johannesburg, South Africa
[2] Ariy Consulting and Advisory, Johannesburg, South Africa

The past three decades have witnessed the publishing of reporting codes for all the main stock exchanges, as well as the evolution of a uniform international standard covering the definition, estimation, and public reporting of Mineral Resources. Many of these reporting codes have commodity-specific reporting sections for coal, and four countries have detailed guidelines for reporting on coal resources. In South Africa (SANS 10320:2016) and Australia (the Australian Guidelines for the Estimation and Classification of Coal Resources, 2014) these companion documents have recently been updated. Unlike their parent codes, which have become increasingly similar, these new guidelines have diverged and are different in a number of significant ways. This in turn will have an impact on coal resource estimators working in the coalfields of south-central Africa, particularly in countries where no commodity-specific guidelines for coal exist.

INTRODUCTION

Due to various reporting irregularities and the need to protect the investing public, the past three decades have witnessed the publication of reporting codes for all the world's main stock exchanges, as well as the release of an international reporting template for the public reporting of Exploration Results, Mineral Resources, and Mineral Reserves by the Combined Reserves International Reporting Standards Committee (CRIRSCO). Many of the codes now have commodity-specific reporting sections for coal. Due to the fact that the governing codes have developed to such an extent, some have questioned the need for coal-specific standards. We would however argue that coal resource estimation does require commodity-specific guidelines, as the processes of coal formation include aspects that are unique and which are fundamentally different from those that apply to most other mineral deposits. In addition, certain coal qualities may be of special interest for specific uses and technological applications, and may require very specific analytical work.

Of the codes that have commodity-specific sections for coal, two are prescriptive (America and Canada) and two are descriptive (South Africa and Australia) and are considered as guidelines. Though termed 'guidelines', most institutions involved in the business of coal resource estimation, evaluation, and ultimately with the goal of raising funding, consider these guidelines as prescriptive, and as a set of standards that must be addressed for a Coal Resource to be considered as being reported in accordance with the required code.

While most of the internationally recognized reporting codes have become very similar, including the South African Code for Reporting Mineral Resources and Mineral Reserves (the SAMREC Code, 2007 as amended 2009; 2016) and that of the Joint Ore Reserves Committee (JORC, 2012), their coal-specific guidelines have recently diverged and differ in a number of significant ways.

ESTIMATION OF COAL RESOURCES IN SOUTH AFRICA

Coal occurs in South Africa in 19 separate coalfields (Figure 1), each of which has unique characteristics relating to coal formation, and the Competent Person should take due consideration of these characteristics when estimating, classifying, and reporting Coal Resources in South Africa.

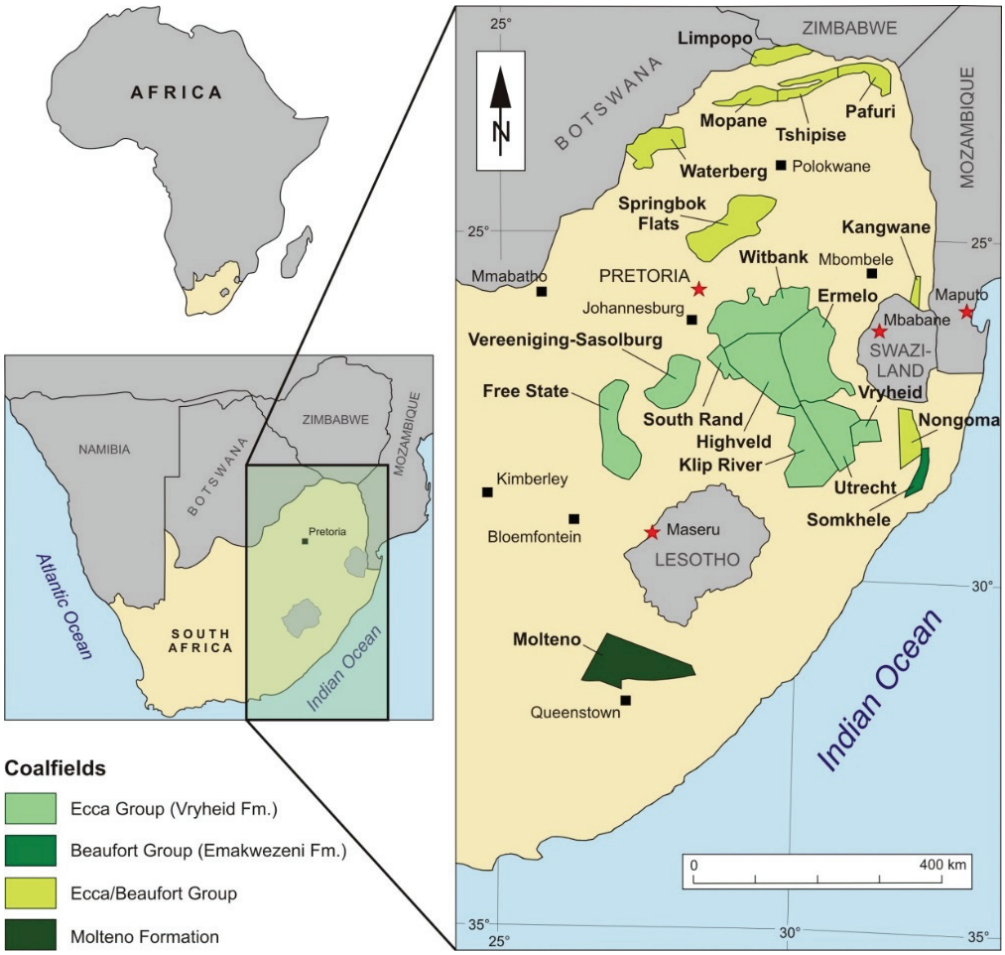


Figure 1. Coalfields of South Africa (Hancox and Götz, 2014).

Currently, Coal Resources in South Africa must be estimated in accordance with the SAMREC Code (2009), with additional guidelines deemed necessary to standardize the reporting of Coal Resources for securities exchange requirements, being supplied by the South African guide to the systematic evaluation of Coal Resources and Coal Reserves (SANS 10320:2004). The standard was originally prepared in conjunction with the SAMREC Code by the SAMREC Coal Commodity Specific Sub-committee. Although not yet published, this guideline has recently been updated as SANS 10320:2016 and has passed the Committee draft stage. Both authors of this paper were involved with this process and were provided with a final draft of the document for use in writing this paper. Once ratified, the new standard will supersede the first edition, and will serve to provide further alignment, clarification, and best practices in terms of the reporting of Coal Deposits, Coal Resources, and Coal

Reserves. Dingemans (2015) and van Deventer (2015) have both provided overviews of what the main changes in the new guidelines will be, and these are documented and discussed below.

One of the most significant aspects of the new SANS 10320:2016 standard is that it applies to all Coal Exploration Results, Inventory Coal, Coal Resources, and Coal Reserves within South Africa, irrespective of the jurisdiction within which the reporting is undertaken. This means that the application of other codes and guidelines to South African coal deposits will no longer be allowed, which will prevent the previous poor practice of using the larger borehole spacing that other codes allow in delineating South African coal deposits.

SANS 10320:2016 will provide the methodologies and definitions of the relevant terms that should be considered when preparing Public Reports on Coal Exploration Results, Coal Resources, and Coal Reserves. In terms of the new standard a Coal Resource is defined as 'coal of economic interest in or on the Earth's crust in such form, quality and quantity that there are reasonable prospects for eventual economic extraction'. Tonnage and coal quality must be reported for all entries in a Public Report, per classification category, in order of increasing confidence in respect of geoscientific evidence, into Inferred, Indicated, and Measured categories. The moisture content for all tonnages and coal qualities must be reported.

The determination of reasonable and realistic prospects for eventual economic extraction is fundamental to the definition of a Coal Resource. Under the new standard, in order to classify a Coal Resource, the Competent Person (CP) shall identify that part of a coal deposit for which there are reasonable and realistic prospects for eventual economic extraction, and that will be economically viable to mine and produce a raw or beneficiated saleable coal product. Consideration must also now, for the first time, be made of Conversion Factors, which are considerations used in a geological study to convert Coal Exploration Results to Coal Resources. These include, but are not restricted to, mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social, and governmental factors. Although these factors are similar to the Modifying Factors used to convert Coal Resources to Coal Reserves, they may be more conceptual in nature.

Under the new standard a Coal Resource risk assessment must be undertaken, and any risks that may affect the potential economic viability of the Coal Resource must be clearly stated. If any key variable or combination of variables of the coal deposit under consideration does not meet a level for which there are reasonable and realistic prospects for eventual economic extraction, then Coal Resources cannot be declared, and must be reported only as Inventory Coal.

While SANS 10320:2004 allowed for a gross tons *in situ* (GTIS) resource to be publicly stated, the new standard will allow such figures for internal calculation purposes only, and not for Public Reporting. Under SANS 10320:2016, for the Public Reporting of Coal Resources, all tonnages and coal qualities must be reported on a Mineable Tonnes *in-situ* (MTIS) basis, with the associated yield, coal quality, and moisture content clearly stated. According to Dingemans (2015) the lowest level of Resource that may be publically reported under the new standard would be an Inferred, MTIS Coal Resource. An MTIS Resource is the tonnage and coal quality, at a specified moisture content, contained in the coal seam, or section of the coal seam, which is proposed to be mined, at the theoretical mining height, adjusted by the geological loss factors and derated for previous mining activities, but excluding contaminant material, with respect to a specific mining method, and after the relevant minimum and maximum mineable thickness cut-offs and relevant coal quality cut-off parameters have been applied.

SANS 10320:2016 will still recognize two different types of South African coal deposits (multiple seam and thick interbedded deposit types) and will still allow for resource category confidence to be assessed based on the density (per 100 hectares) or spacing of cored boreholes with quality data. A difference to the previous SANS 10320:2004 guidelines is that the new guideline specifically mentions that different coal deposit types within the same coalfield must be reported separately. In addition, the new guidelines will allow for a maximum 500 m borehole spacing for the Measured Resource category of thick interbedded coal deposit, as opposed to the 350 m required in SANS 10320:2004 (Figure 2).

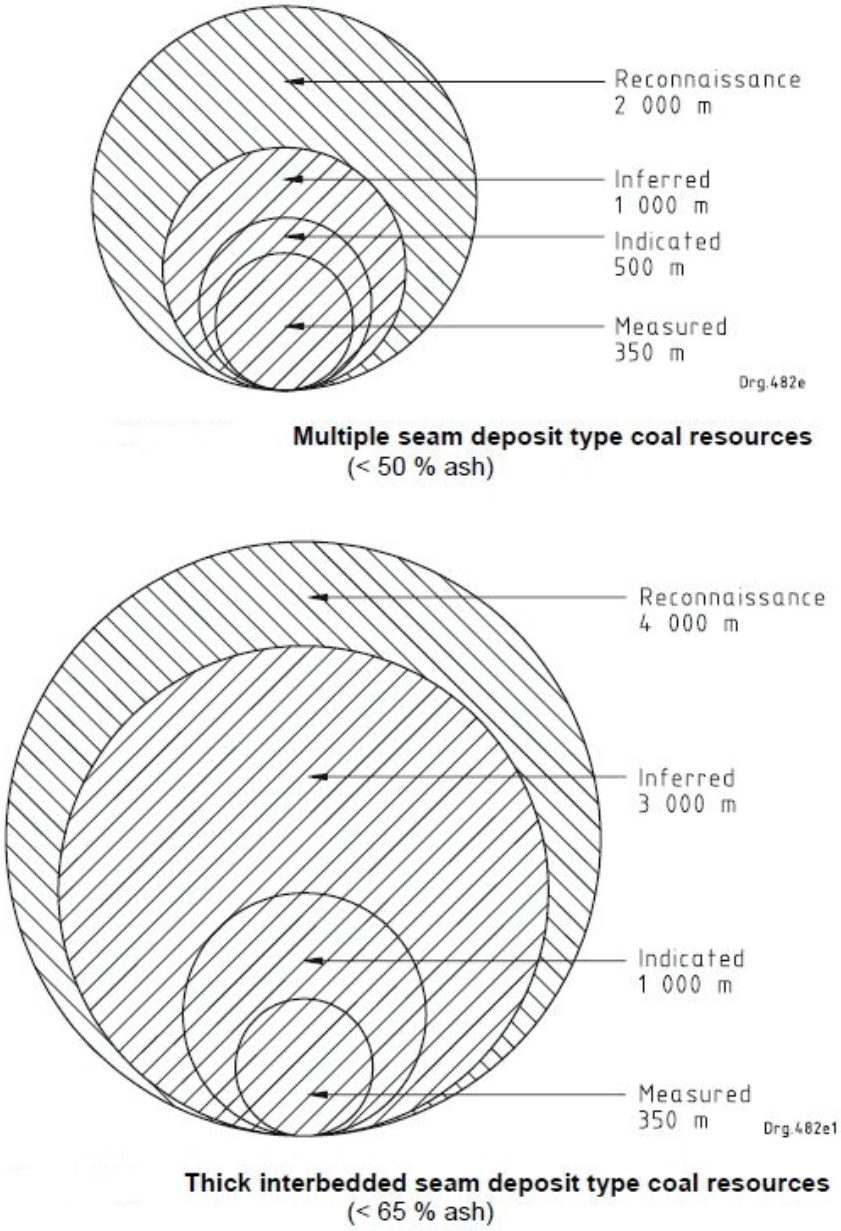


Figure 2. Schematic illustration of the minimum borehole spacing for each Coal Resource classification category for the various South African coal deposit types (the minimum distance between boreholes shown in metres). (SANS 10320:2004).

Typically in South Africa, the Free State, Vereeniging-Sasolburg, South Rand, Witbank, Highveld, Ermelo, Klip River, Utrecht, Vryheid, Springbok Flats, lower Waterberg, Somkhele, and Molteno coalfields are multiple seam deposit types, whereas the upper Waterberg (Grootegeluk Formation), Springbok Flats, Limpopo, Soutpansberg (Mopane, Tshipise, and Pafuri) are thick interbedded seam deposit types. The Nongoma and Kangwane coalfields may be of both coal deposit types (Figure 1). SANS 10320:2016 will supply a list of which coalfields contain which types of coal deposits.

ESTIMATION OF COAL RESOURCES IN AUSTRALIA

The productive coalfields of Australia occur mainly on and around the east coast (Figure 3), predominantly in Queensland and New South Wales, where the coal-bearing sequences show extreme lateral continuity and continuous geometry (Allen and Fielding, 2007).

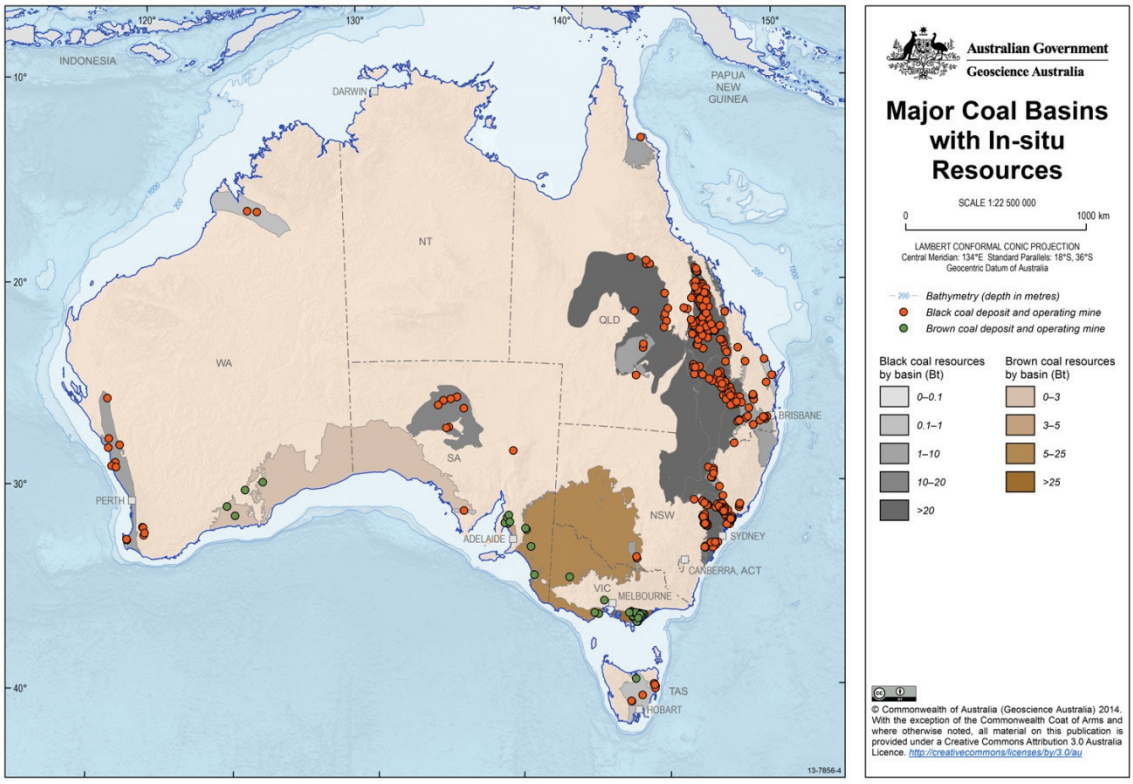


Figure 3. The major coal basins of Australia showing the position of the hard (black) and soft (brown) coal resources. Source: http://www.minerals.org.au/resources/coal/australias_major_coal_regions

Prior to September 1999 the estimation and reporting of Coal Resources in Australia was prescribed by the *Australian Code for Reporting Identified Coal Resources and Reserves* (February 1986). The first direct references to coal are found in clauses 38 to 40 of the 1999 JORC Code. Until October 2014, the JORC (2012) Code required that Coal Resources be reported on the same basis as any other mineral commodity, with cognisance taken of the guidelines contained in the Australian Guidelines for Estimating and Reporting of Inventory Coal, Coal Resources, and Coal Reserves (2003). These guidelines (2003) stated that a Measured Coal Resource may be estimated using data obtained from Points of Observation usually less than 500 m apart, an Indicated Coal Resource from Points of Observation less than 1000 m apart, and an Inferred Coal Resource from Points of Observation less than 4000 m apart. These recommended spacings were based on historically proven continuity of coal seams in the Hunter Valley and the Bowen Basin. Unlike in the SANS 10320:2004 document, only one set of spacings was used no matter what the type of coal deposit.

Subsequent geostatistical work by Bertoli *et al.* (2013) showed that the use of a 'one size fits all' classification scheme (even in the well-documented Bowen Basin) may result in inappropriate resource classification (Table I), and as such the use of fixed drill-hole spacing for resource classification was not good practice.

Table I. Drill hole spacing analysis (DHSA), spacings in metres (m), for various BHP Billiton Mitsubishi Alliance (BMA) coal projects (from Bertoli et al., 2013).

Operation	Measured	Indicated	Inferred
Blackwater	550	1050	2100
Caval Ridge	800	1400	2800
Caval Ridge	500	1000	2450
Crinum M Block	1100	1900	3600
Daunia	650	1250	2800
Goonyella Riverside	650	1250	3150
Gregory Crinum	1100	1900	3600
Lorus North	350	700	1850
Norwich Park	750	1450	3550
Peak Downs	700	1300	2600
Peak Downs	850	1700	4200
Poitrel	400	750	1800
Saraji	750	1400	2500
South Walker Creek	250	500	1000
Coal Guidelines (2003)	**500**	**1000**	**4000**

In October 2014 the new Australian Guidelines for the Estimation and Classification of Coal Resources (Australian Guideline 2014) were ratified. This document represents a significant update and marks a major change in the role of the CP in coal resource estimations in Australia. Probably the most important aspect of this revision is the fact that the concept of defining Resource categories in terms of distance around Points of Observation (which was introduced in 1971 in the first edition of the Code for Calculating and Reporting Coal Reserves by the Geological Survey of New South Wales) has been removed. Instead, the CP must now assess the confidence in the estimate of all significant variables, and the most applicable methods and criteria to demonstrate such confidence should be used to support the classification assigned. Such criteria and methods include statistical and geostatistical analyses, as well as the definition of geological domains, and geological modelling. The estimator must also identify any critical parameters that might affect the eventual economic extraction test or those that may result in contractual penalties. The use of geostatistical methodology, whereby the classification of the resource is driven by the actual *in-situ* variability (or conversely spatial continuity) of the resource, is strongly recommended.

The Australian Guidelines (2014) include a Glossary of terms, which is surprisingly short, and does not include important terms such as 'ply', 'seam', and 'zone'. Yet the concept of ply in particular is vital to the exercise of Australian resource assessment. While the words 'should', 'can', 'may', 'may not', and so on are typical and rather common throughout the guidelines, occasionally 'must' enters the fray. For example, 'seam thickness and location must be unambiguous', in which case it is prescriptive.

For the first time the new Australian Guideline (2014) recommends that the geotechnical conditions of the overburden, interburden, roof and floor strata, the seam gas content and composition, the propensity of the coal for spontaneous heating, the potential of relevant materials for frictional ignition, and any other parameters pertinent to the consideration of reasonable prospects for eventual economic extraction, should be assessed.

Furthermore these guidelines suggest that a CP must assess all relevant aspects of (and risks to) mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social, governmental, and regulatory factors. It notes that while the assessment can in part be qualitative in nature, there generally needs to be at least a basic quantitative evaluation that considers financial indicators and that consideration should be given to whether the tonnage and coal quality are sufficient to ensure satisfactory returns over a reasonable life of mine. These guidelines do not,

however, prescribe: a specific approach to arriving at the key assumptions; the level of detail required; the economic indicators that need to be satisfied; and the level of satisfaction that needs to be achieved for the coal to be said to have reasonable prospects, and hence be classified as a Coal Resource.

COMPARISON OF THE SOUTH AFRICAN AND AUSTRALIAN GUIDELINES FOR COAL REPORTING

There are a number of instances where the two parent codes (JORC and SAMREC) and coal guidelines are now similar, yet different from their previous versions. The most significant of these are that:

- The controlling Code now requires that Table 1 is completed in both instances;
- All reporting must be on an 'if not – why not' basis;
- The basis for quality and tonnage reporting must now be *in-situ* moisture, with the Preston and Sanders (1993) formulae applied for density in tonnage calculations;
- More importance must be placed on the conversion factors in the stating of a Coal Resource; and
- A risk assessment is now required.

The Australian Guidelines (2014) require the CP to assess the likely mining scenario (open cut/cast or underground). For a potential open cut mining scenario, emphasis must be placed on strip ratio, minimum mineable seam thickness, maximum non-separable parting thickness, pit wall stability, and depth of weathering. In an underground mining scenario, aspects such as depth, faulting, igneous intrusions, working section thickness, seam dip, physical properties of roof and floor lithologies, hydrogeology, stress regime, gas content, and lithological composition and permeability should be considered. SANS 10320:2016 will also place more emphasis on geotechnical work, specifically as to how such parameters may influence the potential for eventual economic extraction.

Both documents also now place more emphasis on the role of the CP, often extending outside of such person's normal sphere of expertise, with the Australian Guidelines (2014) going as far as noting that these matters are normally considered in concert with engineers and other specialists, and that it may be necessary to seek expert comment on these factors. The impact of the latter on the cost of exploration cannot be underestimated, and will be significant, especially for junior miners seeking to operate and deliver against such guidelines. Neither guideline however requires the lodging of the CP Report with the controlling exchange, an area which should be addressed.

There are, however, also several differences between the forthcoming SANS 10320:2016 revision and the Australian Guidelines (2014), the main ones being:

- SANS 10320:2016 will still allow the use of maximum distances between Points of Observation for defining resource categories per coal deposit type in South Africa, whereas the concept of defining resource categories on distance around Points of Observation has been removed from the Australian Guidelines (2014), which prefers that the resource classification be founded on the assessment of the confidence in the estimate of all significant variables, based on a series of methods and criteria, such as geostatistical analysis;
- SANS 10320:2016 will still prescribe core recovery in excess of 95% by length within the coal seam intersection of a drill-hole, whereas the Australian Guidelines (2014) state that sample recovery must be considered representative, and that potential loss of material from within a sample may be critical, irrespective of the relative percentage lost; and that downhole geophysical data should be used to confirm the location and nature of any core loss in the coal seam. The use of downhole geophysical data is not prescribed in the new SANS 10320:2016 standard;
- The Australian Guidelines (2014) also note that the analysed sample should be representative of the *in-situ* material within the interval of interest, and as such hints that it is in fact the percentage of material that makes it to the laboratory that is important. SANS 10320:2016 does

not state that the received sample at the laboratory must represent 95% of the recovered material;

- SANS 10320:2016 refers to both Coal Resources and Coal Reserves, whereas the Australian Guidelines (2014) is now only applicable to Coal Resources;
- In SANS 10320:2016 the only level of tonnage reporting is MTIS; the Australian Guidelines (2014) makes no distinction between GTIS, TTIS, and MTIS, and does not mention that geological losses need to be specified;
- SANS 10320:2016 guidelines specifically mention that different coal deposit types within the same coalfield (*e.g.* for the Waterberg Coalfield) must be reported separately, whereas this is not required by the Australian Guidelines (2014), other than as stipulated in section 5.2.2;
- SANS 10320:2016 must be applied to all Coal Exploration Results, Inventory Coal, Coal Resources, and Coal Reserves within South Africa, irrespective of the jurisdiction within which the reporting is undertaken; whereas the Australian Guidelines (2014) are intended for use in Australian coalfields;
- The revised SANS 10320:2016 guidelines for Coal Resource estimation do not require the reporting of tonnages beyond the *in-situ* stage. Where the Coal Resource is deemed suitable to be exploited for a washed coal product, the associated theoretical yield and washed target product shall, however, be stated. In the case of the Australian Guidelines (2014) the application of certain quality and potential utilization factors is required, thereby allowing for reporting of a coal quality that is closer to a saleable product;
- For the Australian Guidelines (2014) a CP must at least undertake a basic quantitative evaluation of financial indicators, whereas this is not a requirement of the SANS 10320:2016 guidelines.

Despite the Australian Guidelines (2014) stating that it is intended for use in Australian coalfields, it also follows with the wording 'but may also provide guidance internationally', thus leaving the door open for its use elsewhere, such as is the case in the coalfields of Mozambique.

ESTIMATION OF COAL RESOURCES IN MOZAMBIQUE: A SOUTHERN AFRICAN EXAMPLE OF THE APPLICATION OF THE TWO DIFFERENT COAL GUIDELINES

The coalfields of the Tete Province of Mozambique occupy an area stretching over 350 km, from Lake Cahora Bassa in the west to the Malawi border in the east (Figure 4). From west to east these are variously termed the Chicôa-Mecúcoè (including the Mucanha-Vuzi sector), Sanângoè-Mefídézi, Moatize (or Moatize-Benga), Muarazi, and Minjova sub-basins, with northwest and southeast extensions Ncondezi (N'condezi) and Mutarara (Vasconcelos, 2012).

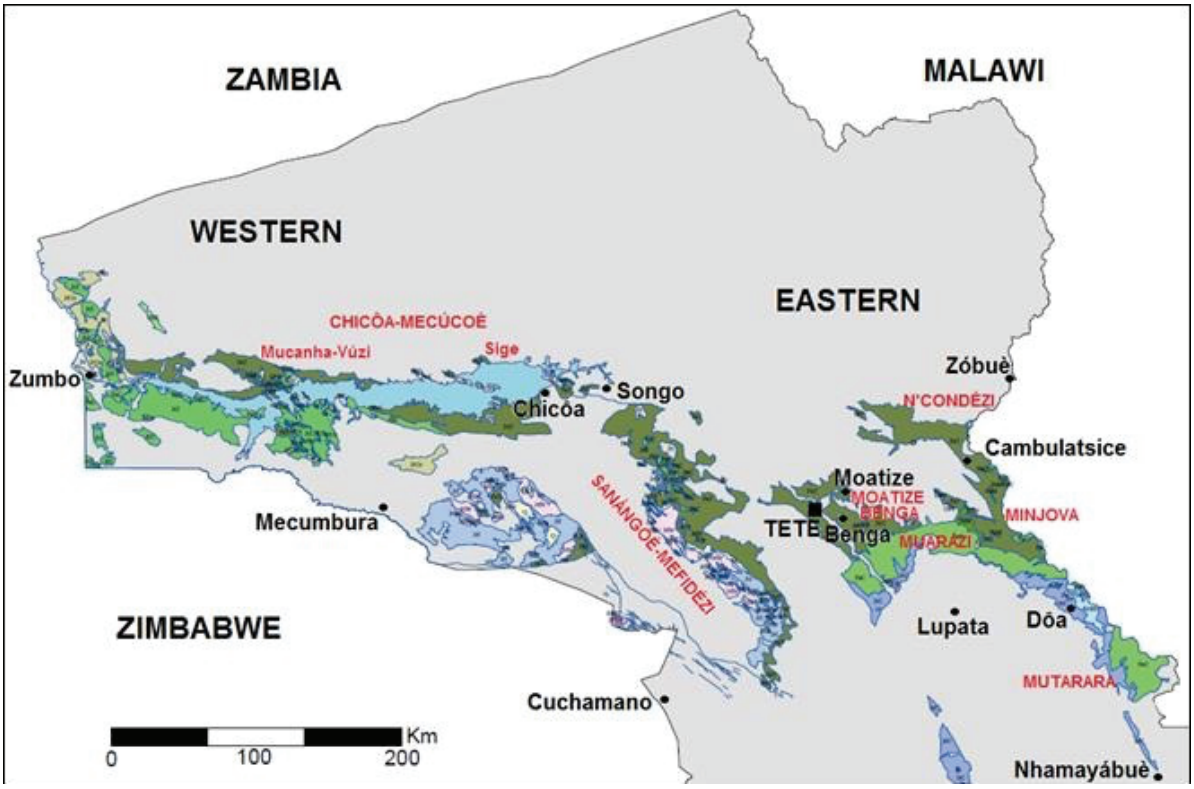


Figure 4. Map showing the sub-basins of the mid-Zambezi Valley (Vasconcelos, 2012).

In the past decade a lot of exploration focus has been placed on the coalfields of Mozambique. However, at present Mozambique does not have its own reporting code or commodity-specific coal reporting guidelines. The JORC Code has mostly been used by companies active in the coalfields, and prior to October 2014 this meant that the more loosely constrained maximum distances between Points of Observation allowed for by the 2003 Australian Coal Guidelines could be used to define coal resources.

As an extreme example of how things stood prior to the new codes and coal guidelines, consider a South African CP utilizing the SAMREC Code (2009) and SANS 10320:2004 to define a coal resource in Mozambique. Based on a drill-hole spacing of 500 m and raw coal quality data, the CP would be able to disclose an Indicated GTIS Coal Resource, with no geological losses required. Even considering the changes proposed in the SANS 10320:2016 update that GTIS may not be reported, a 1.5 billion ton (Gt) open-castable GTIS Resource may drop by only 10–20% (geological losses) if full seam extraction is considered, to give an MTIS Resource of 1.2–1.35 Gt. An Australian geologist considering the same resource and reporting in terms of the JORC (2012) code and 2003 Australian Guidelines (prior to October 2014) would be able to define a similar resource estimate in the Measured Resource category, and would not have to apply any geological loss.

Strict application of the Australian Guidelines (2014) may mean that many publicly stated coal resources in Mozambique may have to be re-defined based on a geostatistical evaluation of the density and variability of their Points of Observation, as well as on all critical variables. Given that coal represents a heterogeneous mixture of constituents there is a large range of coal quality parameters that would have to be considered by the CP, and geostatistical analysis on a ply-by-ply and variable-by-variable basis (as may be required in the Tete Province coalfields of Mozambique) would be extremely onerous and costly. Under the more stringent requirements of the Australian Guidelines (2014) it is also highly likely that several of the resource estimations made public prior to the new guidelines may have to be downgraded in tonnage and resource category, and that some isolated deposits in remote areas may not make it into the resource category at all.

Since many of the coal deposits of Mozambique consist of thick interbedded seams, the application of the new SANS 10320:2016 guidelines would allow a spacing of 500 m for the Measured category (as for the 2003 Australian Coal Guidelines), and we may therefore in future see previously JORC-compliant resources turning to the SAMREC Code (2016) and SANS 10320:2016 guidelines. The new SANS 10320:2016 guidelines, however, specifically mention that different coal deposit types within the same coalfield must be reported separately, and this would impact on the reporting of Mozambique coal resources, where both thick interbedded and multiple seam styles may occur within a coalfield or sub-basin. Additionally, in structurally complex deposits, such as those found in Mozambique, it is structure (and not only coal quality) that can often be the critical resource-limiting determinant. Mozambique should therefore be considered to be a unique setting, with structural complexity far greater than seen in Australia or most of South Africa. As has been shown above, the rigid application of either the SAMREC (2016) or JORC Code (2014) may not be best practice, and Mozambique desperately requires a set of coal reporting guidelines of its own.

DISCUSSION

There is no doubt that the revised Australian Coal Guidelines (2014) and SANS 10320:2016 guidelines are superior to their predecessors. The authors, however, contend that there is still one glaring omission in both the guidelines and controlling codes, and that is the failure to ensure a requirement for the lodging of the CP Report with the controlling exchange (such as is the case for the Toronto Stock Exchange).

While both the Australian Guidelines (2014) and the SANS 10320:2016 revision place more emphasis on the role of the CP, neither address how to gauge (or maintain) the level of competency. Both the proposed SANS 10320:2016 update and the Australian Guidelines (2014) require that a coal resource geologist (whose core skills should be coal geology, modelling, and resource estimation) must also be familiar with conversion (SANS 10320:2016) or modifying factors (Australian Guidelines, 2014). The Australian Guidelines (2014) further require the CP to be conversant with the potential product qualities, potential utilization, product yields and value, and mining horizon/target, which will undoubtedly require at least a mine plan, and more realistically a pit shell for opencast mining. These aspects are more traditionally defined as the Modifying Factors, and fall within the realm of the mining engineer. It is therefore evident that the lines are becoming blurred in both codes, more notably so in the case of the Australian Guidelines (2014).

The SANS 10320:2016 update could also benefit from various considerations found in the new Australian Guidelines (2014), such as the geostatistical analysis of drill-hole data. There are, however, some concerns with a geostatistical approach to resource classification in South Africa, the main one being that the creation of a robust semivariogram requires sufficient data-points, and that one cannot create a robust semivariogram if the data has a mix of different populations. Small coal resource areas, such as are often found in South Africa, would require data-sets with drill-holes numbering far in excess of what is currently required for Coal Resource reporting.

The authors also feel that while the level of recovery through the seam is mandated in the revised SANS 10320:2016 guidelines, the level of that material reporting to the laboratory is not. The authors have come across many a South African example when it is stated that 95% recovery was obtained through the coal seam, yet less than 50% of the mass has been delivered to the laboratory.

One last point of discussion that arises from the new Australian Guidelines (2014) is the death of the spotted dog' (Figure 5) – the poor practice of estimating Measured, Indicated, and Inferred Resources over disconnected circles of influence around individual Points of Observation or along a line of Points of Observation (Stephenson *et al*., 2006).

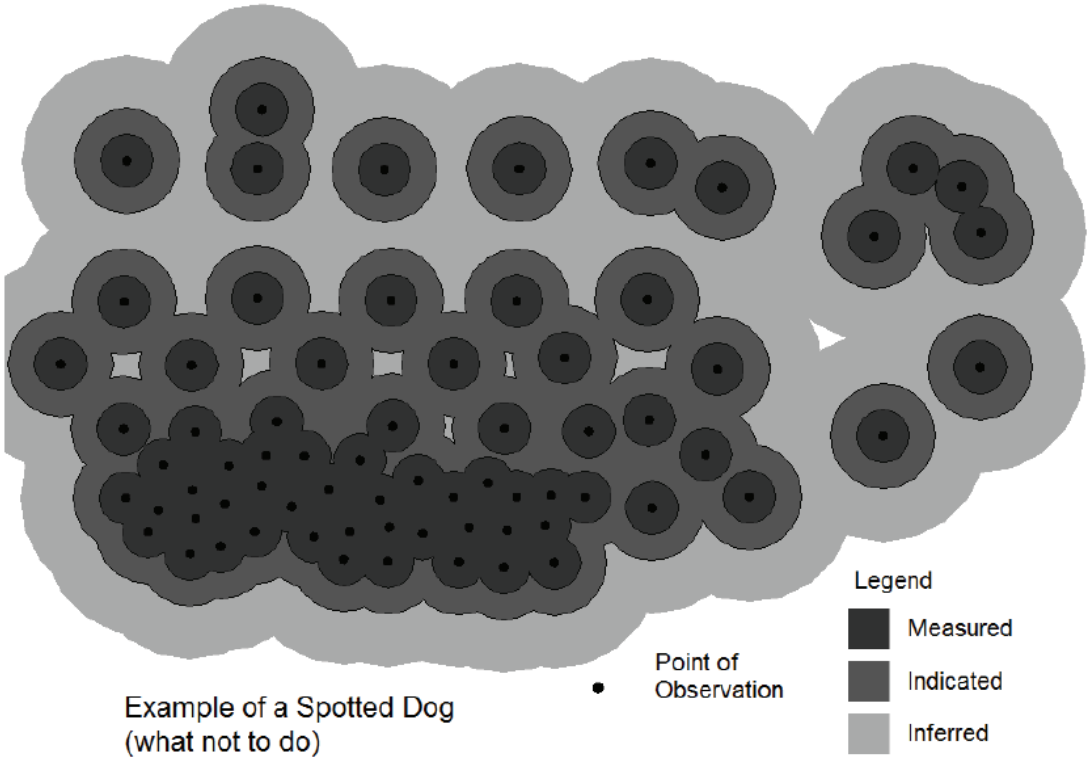


Figure 5. Example of a 'spotted dog' – what not to do (Australian Guidelines (2014), Figure 3).

The exclusion of such practice means that the new Australian Guidelines (2014) directly contradict the USA (USGS Circular 891) and Canadian (GSC Paper 88-21) systems, which are rules-based and prescriptive, and which rely on the use of spotted-dog methodologies.

CONCLUSIONS

This paper has shown that while the parent codes (JORC and SAMREC) are very similar, the coal reporting guidelines for the two are not. In the case of the revised Australian Guidelines (2014) there is a significant increase in certain requirements, which include the application of geostatistical parameters to resource classification criteria, as well as expert knowledge of coal beneficiation, utilization, and mining practices. While this places an increased burden on the Competent Person (and, the authors believe, moves into the territory of reserving), the new codes and guidelines do at least mean that the days of seeing a 1.5 Gt Coal Resource reported with Reserves of only 200 Mt will be a thing of the past.

REFERENCES

Allen, J.P. and Fielding, C.R. 2007. Sequence architecture within a low-accommodation setting: an example from the Permian of the Galilee and Bowen basins, Queensland, Australia. *American Association of Petroleum Geologists Bulletin*, 91 (11), 1503-1539.

Australian Guidelines for Estimating and Reporting of Inventory Coal, Coal Resources and Coal Reserves. 2003 Edition. Coalfields Geology Council of New South Wales and the Queensland Mining Council, 2003. 8 pp.

Australian Guidelines for the Estimation and Classification of Coal Resources. 2014 Edition. Coalfields Geology Council of New South Wales and the Queensland Resources Council. 16 pp.

Bertoli, O., Paul, A., Casley, Z., and Dunn, D. 2013. Geostatistical drillhole spacing analysis for coal resource classification in the Bowen Basin, Queensland. *International Journal of Coal Geology*, 112, 107–113.

Dingemans, D. 2015. The update of the SAMREC & SAMVAL Codes and SANS 10320: Progress and Changes. Presentation at the Witbank Recreation Club, March 2015.

Hancox, P.J. and Götz, A.E. 2014. South Africa's coalfields — a 2014 perspective. *International Journal of Coal Geology*, 132, 170-254.

JORC. 2012. Australasian Joint Ore Reserves Committee. Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (The JORC Code, 2012 Edition). The Joint Ore Reserve Committee of the Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists and Minerals Council of Australia (JORC), (Effective 20 December 2012, mandatory 1 December 2013). 44 pp. http://www.jorc.org/docs/JORC_code_2012.pdf

Preston, K.B. and Sanders R.H. 1993. Estimating the in-situ relative density of coal. *Australian Coal Geology*, 9, 22-26.

SAMREC. 2007. South African Mineral Resource Committee. The South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves (The SAMREC Code). 2007 Edition as Amended July 2009 . 61 pp. http://www.samcode.co.za/downloads/SAMREC2009.pdf

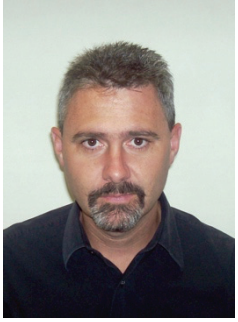
SANS 10320:2004. South African guide to the systematic evaluation of coal resources and coal reserves. Standards South Africa, Pretoria. 140 pp.

SANS 10320:2016. (in press). Systematic evaluation of coal exploration results, inventory coal, coal resources and coal reserves. Standards South Africa, Pretoria.

Stephenson, P.R., Allman, A., Carville, D.P., Stoker, P.T., Mokos, P., Tyrrell, J., and Burrows, T. 2006. Mineral Resource classification – it's time to shoot the 'spotted dog'! *Proceedings of the Sixth International Mining Geology Conference*, Darwin, NT, 21–23 August 2006. Australasian Institute of Mining and Metallurgy; Carlton, Victoria, Australia). pp 91-95.

Van Deventer, K. 2015. Update of the Resource and Reserve Reporting Codes and Guidelines for the Coal Industry with specific focus on the SAMREC and SANS 10320 update. Progress and changes and the practical application thereof. Presentation for the SAMCODE Committee, September 2015.

Vasconcelos L. 2012. Overview of the Mozambique coal deposits. *Proceedings of the 34th International Geological Congress*, Brisbane, QLD, Australia 5–10 August 2012. 25 pp.



Philip John Hancox

Managing Director
Caracle Creek International Consulting Coal (Pty) Limited

Dr Philip John Hancox is a graduate of the University of the Witwatersrand with a B.Sc. (Hons.) Geology/Palaeontology and a Ph.D Geology. From 1193-2005 he was a part-time lecturer, associate lecturer, Lecturer and Senior Lecturer, firstly in the Palaeontology Department, then the Geology Department, and finally in the School of Geosciences at the University of the Witwatersrand. He holds a position of Honorary Research Fellow in the School of Geosciences and also lectures the postgraduate course in coal at Rhodes University.

The Application of Modifying Factors

S.M. Rupprecht

University of Johannesburg, Republic of South Africa

Demonstration of the feasibility of economic extraction is not required before Exploration Results or Mineral Resources are reported. However, the use of Modifying Factors is fundamental in demonstrating feasibility and thus in converting a Mineral Resource to a Mineral Reserves. Understanding the application of theses Modifying Factors is important to ensure the correct declaration of a Mineral Reserve. Failure to properly investigate all relevant Modifying Factors can lead to the incorrect conversion of Mineral Resources to Reserves, adding unnecessary risk to a project or even leading to premature closure of a mine. The importance of correctly applying Modifying Factors to Mineral Resources is discussed and examples provided to demonstrate the negative outcomes when Modifying Factors are incorrectly applied.

Traditionally, mining engineers have looked to the more conventional Modifying Factors; such as mining, metallurgical, legal, and economic factors. However, other factors, for example, governmental, social and labour, environmental, and infrastructure factors, previously thought by some engineers to be less significant, are now recognized as key factors. The paper discusses the application of Modifying Factors and their importance in establishing the feasibility of a mining project.

INTRODUCTION

Establishing a Mineral Reserve demonstrates the financial viability of a mine or project. Having sufficient Proved Reserves to cover the payback period of a project is viewed by most lenders as an essential requirement; one which limits risk to the investor. For the Competent Person (CP) it is important that all Modifying Factors are considered when declaring a Mineral Reserve. Failure to properly investigate all relevant Modifying Factors can lead to the incorrect conversion of Mineral Resources to Mineral Reserves, adding unnecessary risk to a project or even leading to premature closure of a mine. The author has been involved with a number of recent projects that have closed due to project teams failing to fully understand the effect of Modifying Factors.

The SAMREC Code 2016 states that:

> *A Mineral Reserve is the economically mineable part of a Measured and/or Indicated Mineral Resource.*
>
> *It includes diluting materials and allowances for losses, which may occur when the material is mined or extracted and is defined by studies at Pre-Feasibility or Feasibility level as appropriate that include application of Modifying Factors. Such studies demonstrate that, at the time of reporting, extraction could reasonably be justified.*
>
> *The reference point at which Mineral Reserves are defined, usually the point where the ore is delivered to the processing plant, must be stated. It is important that, in all situations where the reference point is different, such as for a saleable product, a clarifying statement is included to ensure that the reader is fully informed as to what is being reported.*

Based on the above statement, it is clear that in order to declare a Mineral Reserve a Pre-Feasibility or Feasibility Study must have been completed and all Modifying Factors included to demonstrate, at the time of reporting, that extraction could be realistically and reasonably justified. In terms of Proved and Probable Mineral Reserves the Code also allows for a life-of-mine (LOM) plan to be suitable for an operating mine. Until 2016, Pre-Feasibility or Feasibility Study were not adequately defined. However, in order to improve transparency the 2016 SAMREC Code now defines Pre-Feasibility and Feasibility Study and LOM Plan.

> *A Pre-Feasibility Study is a comprehensive study of the viability of a range of options for a mineral project that has advanced to a stage at which the preferred mining method in the case of underground mining or the pit configuration in the case of an open pit has been established and an effective method of mineral processing has been determined. It includes a financial analysis based on realistic assumptions of technical, engineering, operating, economic factors and the evaluation of other relevant factors that are sufficient for a Competent Person, acting reasonably, to determine if all or part of the Mineral Resource may be classified as a Mineral Reserve. The overall confidence of the study should be stated. A Prefeasibility Study is at a lower confidence level than a Feasibility Study.*
>
> *A Feasibility Study is a comprehensive design and costing study of the selected option for the development of a mineral project in which appropriate assessments have been made of realistically assumed geological, mining, metallurgical, economic, marketing, legal, environmental, social, governmental, engineering, operational and all other modifying factors, which are considered in sufficient detail to demonstrate at the time of reporting that extraction is reasonably justified (economically mineable) and the factors reasonably serve as the basis for a final decision by a proponent or financial institution to proceed with, or finance, the development of the project. The overall confidence of the study should be stated.*
>
> *A LOM Plan is a design and costing study of an existing operation in which appropriate assessments have been made of realistically assumed geological, mining, metallurgical, economic, marketing, legal, environmental, social, governmental, engineering, operational and all other Modifying Factors, which are considered in sufficient detail to demonstrate at the time of reporting that extraction is reasonably justified. The level of study should at least be equivalent to a Prefeasibility.*

The above sets out the minimum expectations for the various technical studies. Table 2 of the 2016 SAMREC Code also provides recommendations in terms of the confidence levels associated with capital expenditure and operating costs for the types of technical studies. The CP is expected to understand the level of work required to declare a Pre-Feasibility Study or Feasibility Study; however, the Code provides additional guidance in order to improve transparency. In the past, some CPs have

stretched the definition of Scoping Studies to attempt to justify the declaration of a Mineral Reserve when the study is in fact not conducted to a Pre-Feasibility Study level.

When converting a Mineral Resource to a Mineral Reserve the two most significant Modifying Factors are dilution and mining loss. Mining dilution is defined as waste material, either barren material or waste containing some mineral content below the cut-off grade, and which is extracted during the course of mining operations and thereby forms part of the Mineral Reserve. Mining loss is defined as ore left behind in the mining operation due either to practical mining considerations such as the application of a maximum mining cut in deep Witwatersrand gold deposits, designed stability pillars, *etc*. Unplanned ore loss results from ore being left behind due to poor cleaning practices, poor sampling, estimation errors, or misdirected (tipped) trucks or hoppers resulting in ore being tipped into waste passes.

Underestimating dilution can lead to the overstating of the head grade, and the understatement of mining losses can lead to the overstatement of tonnage. An accurate estimation of the head grade is the more critical of the two, and the author has seen a number of new mines fail due to the overestimation of the head grade. The CP must ensure that appropriate factors are applied when converting Mineral Resources to Mineral Reserves. The author has observed a number of mines' head grades negatively affected due to underestimation of mining dilution.

MODIFYING FACTORS

In order to convert a Resource to a Reserve one must consider the application of all the Modifying Factors. It is not uncommon to view reports that inadequately cover some of the Modifying Factors when demonstrating the viability of a project. Key factors identified are:

- Mining
- Metallurgical
- Economic
- Marketing
- Legal
- Environmental
- Infrastructural
- Social and governmental.

Mining

The application of mining losses and dilution is probably one of the more contentious elements of applying Modifying Factors to mineral resources. Project owners tend to be optimistic in estimating mining dilution and mining losses. For operating mines the CP should make use of historical results to benchmark the mining factors. For Mineral Reserves estimated from technical studies the CP must use their experience to select the appropriate factors.

An example of the important role of mining factors in the Reserve estimation process is the following. In 2006 a Feasibility Study was conducted on a platinum project which estimated dilution at 14.5% at a grade of 1.5 g/t (4E). Based on the assumed dilution a run-of-mine (ROM) head grade of 3.16 g/t was used for the project evaluation. At the mine's start-up the actual ROM head grade ranged from 2.1 to 2.4 g/t (4E). During this period the Mineral Reserve grade was reviewed and re-adjusted from 3.16 g/t to 2.65 g/t (4E), based on planned improvements in stoping width and other in-stope dilution controls. In 2012, the project was placed on care and maintenance with the actual ROM grade never consistently achieving the estimated 2.65 g/t. In the author's opinion, the failure to achieve the planned ROM head grade was one of the main reasons why the mine was placed on care and maintenance.

Additional considerations include the mining method, mine plans and production schedules. The CP should provide a description and justification of the mining method(s), as well as discussion of the mining rate, mine equipment selection, grade control measures, geotechnical and geohydrological consideration, human resource requirements, health and safety, dilution, mining losses, and operating costs. For open pit mines additional inputs for pit slopes, slope stability, and strip ratio are required. For underground mining, the mining method, rock engineering considerations, ventilation and cooling, mine drainage, as well as the impact on surface and groundwater require discussion.

Metallurgical or Beneficiation

The metallurgical characterization of any ore is critical in terms of describing or identifying any factors that may have a negative impact on product quality and recovery. Frequently, metallurgical recoveries are based on historical data or test work based on limited sample sites that do not always reflect the natural variability in most orebodies. If the metallurgical inputs are not properly considered, inaccurate recoveries may be used resulting in either lower or higher plant recoveries, thus potentially impacting on the accuracy of the reporting of Mineral Reserves (Pienaar and Freese, 2016).

Metallurgical considerations include the metallurgical process or method, equipment, plant capacity, efficiencies, and personnel requirements. The CP should discuss the nature, scope, and representativeness of metallurgical test work undertaken and the recovery factors used, and comment on the appropriateness of the selected methodology, *e.g.* whether it is well established or new technology. A detailed flow sheet and a mass balance should exist, especially for multi-product operations from which the saleable products are priced according to different chemical and physical characteristics.

The CP should state what assumptions or allowances have been made for deleterious elements, the results of any bulk-sample or pilot-scale test work, and the degree to which such samples are representative of the orebody as a whole. Stated recoveries must be related to full-scale operations, taking into account laboratory scale test results as well as the geological domain in which the ore is sourced. The CP must consider environmental, community, and health and safety issues associated with the metallurgical process, with those sections dealing with hazardous materials or operations incorporating more detail. Issues like acid water drainage and other hazardous seepages into the groundwater from tailings and waste storage facilities should be carefully considered as the cost of lining such facilities is enormous.

Economics Parameters

The financial viability of a project is a critical factor – in order for a Mineral Reserve to be declared, the project must be economically feasible, proving the deposit is mineable The CP should ensure that the commodity prices are relevant to the product quality and volume being sold and related to the market. For example, in the case of Coal Reserves the coal quality must be reported in order to support the proposed market and selling price. Without such details it inappropriate for the CP to declare a Reserve. For projects/mines selling commodities under a current contract the CP should consider whether the full Reserve is covered by the contract or establish the likelihood of the contract being extended, including commentary on future commodity prices and volumes.

When considering economic parameters the CP should provide a description of the product to be sold and the market conditions for the product, its impact on that market, and whether contracts for the sale of the product are in place or expected to be obtained. The CP should state and justify all economic criteria that have been used for the study, such as capital and operating costs, exchange rates, revenue inputs, royalties, and cut-off grades. The method used to estimate the commodity price profiles used for cut-off grade calculation, economic analysis and project valuation, including applicable taxes, inflation indices, and exchange rates should be described. The CP should demonstrate that the product price assumptions are reasonable and supportable, andjustify assumptions concerning production cost and value of the product. Consideration should be given to transportation, treatment, penalties, exchange rates, marketing, and other costs.

A detailed cash flow analysis for the life of the project, including a summary of taxes, royalties, and other government levies must be completed. Sensitivity and risk analyses related to grade, prices, capital costs, operating costs, and any additional significant variables should be conducted. The date of the financial report and the base date of the financial analysis must be stated.

CPs must also ensure that the point of sale is clearly defined and that on- and off-mine costs are accurately accounted to the point of sale. The documentation supporting commodity prices and sales volumes should include a comparison of prices with historical, current, and future price forecasts as well as a consideration of contracts, market conditions, exchange rates, and any other material information. In special cases, commodity prices may be confidential and it may be necessary for the CP to withhold price-sensitive information. In such cases, for transparency the CP needs to justify why such information is not disclosed.

Marketing
The SAMREC Code requires the consideration of the supply, demand, and stock situation for the particular commodity, consumption trends, and factors likely to affect supply and demand into the future. A customer and competitor analysis along with likely market windows for the product should be discussed and a description of the product to be sold, customer specifications, testing, and acceptance requirements included in the analysis. The CP should discuss whether there exists a ready market for the product and whether offtake agreements are in place or are expected to be readily obtained.

A realistic commodity price is important. The market assessment may indicate that minerals are not saleable in the proportions in which they are to be produced, and as a result the Reserves estimates may need to be adjusted.

Legal
A statement in the study is required to the effect that no legal issues exist that could negatively affect the project. Although the CP may not be qualified to conduct a legal due diligence, he/she should conduct basic checks to verify that the prospecting permit or mining right, or other rights, are valid or reasonably expected to be granted. CPs should be careful when actual tenure is not secured, as more than one example can be provided where a client believed that the prospecting or mining right would be granted only to find that the right had already been granted to another party. No tenure means no Mineral Reserve.

Environmental
The CP should provide information on the status of studies of potential environmental impacts of the mining and processing operation, as well as a statement on the status of the approval processes for all necessary permits (tailings and waste). The CP should describe future yearly environmental liabilities, compliance methods and costs, including rehabilitation and closure funding. Reference to the Environmental Impact Study should be recorded and the CP must recognize that environment permitting may change over time, which could impact on the Mineral Reserve estimation. If problems arise or are solved, the Mineral Reserve estimates must be adjusted accordingly.

Some permits cannot be obtained until after a detailed mine study has been conducted, *i.e.* a Mineral Reserve has been declared. The CP should recognize that there may be reasons why obtaining some permits could be postponed. Furthermore, as the regulatory process may be time-consuming it is recognized that material information should be released to the investors in a timely fashion, and therefore it is acceptable that material is disclosed prior to granting of permits, as deemed appropriate by the CP. To reflect the above, the Table 5.5 in the 2016 SAMREC Code has been modified so as to enable a Mineral Reserve to be declared on anticipation of the approval of various environmental permits.

Recent discussions around the updating of the Code have included the introduction of material input to the environmental section of the Code, as well as Table 1. This approach has been largely rejected

since the Working Group was of the opinion that sufficient guidance is already present in the Code. While many environmental issues need to be considered when developing a mineral project, it is not the place for the Code to provide guidance on all of these issues. Sufficient requirements are made in terms of Environmental Impact Assessments, water use, and other aspects. Rather, the Code is there to ensure that the CP has satisfied himself/herself that full environmental compliance has taken place. The declaration of a Mineral Reserve must fully comprehend environmental factors that may impact on the project.

Infrastructure
The CP should report in sufficient detail to demonstrate that the necessary facilities have been allowed for, which may include, but are not limited to, processing plant, tailings dam, leaching facilities, waste dumps, road, rail or port facilities/allocations, power supply, potable water, wastewater treatment, stormwater handling, communications, fuel storage, offices, housing, security, resource sterilization testing *etc*. Detailed maps showing locations of facilities should exist. Project milestones and completion dates should be stated. In South Africa, the availability of power, water, and material handling (off-mine logistics) are critical. The author has reviewed a number of projects where infrastructure requirements have been critically underestimated, in some case to the extent that realistic infrastructure requirements have led to the failure of the project. In South Africa, the cost of self-generated power has a significant impact on the operating costs. Therefore, the delivery date of power sourced from the local grid must be carefully considered. The allocation of water rights and delivery is equally critical.

Social and Governmental
One of the significant changes included in the 2016 SAMREC Code is the relaxation of the clause dealing with obtaining the necessary government approvals. *'A statement* [deleted] *(to) the effect that mandatory social and labour management programmes, if any, have been approved or there is reasonable basis to believe that approval can be obtained. Costs of such programmes should be considered in Techno economic studies*.' This clause has replaced the 2009 clause that '*A statement should be provided to the effect that all necessary permits have been approved*.' The above has brought the SAMREC Code in line with other international codes, as well as account for the fact that investors may require Mineral Reserve status while awaiting the various governmental permits to be approved – a task that often may take over two years to accomplish. The critical aspect of the new clause is the 'reasonable basis', which the CP must consider.

Local environmental laws and processes must be taken into account. To demonstrate reasonable expectation that all permits, ancillary rights, and authorizations can be obtained, the reporting entity must show understanding of the procedures to be followed to obtain such permits, ancillary rights, and authorizations.

Information that materially increases or decreases the risk that the necessary legal rights or permits will be obtained must be publicly disclosed. It is recognized that the legal and permitting environment may change over time and that such changes could have an impact on the Mineral Reserve estimate. If obstacles arise or are eliminated, the Mineral Reserve estimates must be adjusted accordingly.

It is recognized that some permits cannot be obtained until after a Mineral Reserve has been declared. There might be sound business reasons why obtaining some permits should be postponed. It is also recognized that waiting for all permits to be on hand could result in critical information not being released to the investors in a timely fashion, and therefore it is recommended that disclosure of material information occur prior to obtaining permits as appropriate

Documentation should include a brief description of the title, claim, lease, or option under which the reporting entity has the right to hold or operate the property, indicating any conditions that the registrant must meet in order to obtain or retain the property. Royalty terms and clawback rights of former claimholders also must be disclosed. If held by leases or options, the expiration dates of such

leases or options should be stated. If extension of leases or options will be needed to mine the Mineral Reserves, there should be reasonable expectation that such extension will be granted.

A statement should be provided to the effect that mandatory social management programmes (social and labour plan), if any, have been approved. A statement should also be provided to the effect that such governmental requirements have been approved. A number of statutory requirements relevant to project development should be considered. The following lists a few South African government requirements that should be considered by the CP (Rupprecht, 2014):

- Mineral and Petroleum Resources Development Act (MPRDA) (Act 28 of 2002)
- MPRDA Act of 49 of 2008
- MPRDA Amendment Bill 2013
- Broad-based Socio-Economic Charter
- Mineral and Petroleum Resources Royalty Act (Act 28 of 2008)
- National Environmental Management Act (NEMA) (Act 107 of 1998)
- National Environmental Management Air Quality (Act 39 of 2004)
- National Environmental Management Waste Act (Act 59 of 2008)
- National Environmental Management Protected Areas Act (Act 57 of 2003)
- Environmental Conservation Act (Act 73 of 1998)
- National Forests Act (Act 30 of 1998)
- National Water Act (Act 36 of 1998)
- Mine Health and Safety Act (Act 29 of 1996) and amendments (MHSA).

Risk Analysis
Project technical, social, environmental, and economic risk should be highlighted in order to inform the reader of the likelihood of the identified risk, mitigating considerations, and the impact the risk may have on the Mineral Reserve declaration. Depending upon the identified risk, the Mineral Reserve declaration could result in a Measured Resource being converted to Probable Reserves or even removed from the reserve category altogether. Similarly, an Indicated Resource could be found unsuitable for Reserve declaration. The author has observed several Mineral Reserve declarations that are only 'going through the motions'. A risk analysis should be viewed as a powerful tool to help management mitigate potential problems before they become significant.

CONCLUSION

As commonly understood, the application of the Modifying Factors constitutes an integral part of the Mineral Reserve estimation process. It is the responsibility of the Competent Person to ensure that all, not just some, of the Modifying Factors are adequately considered during the estimation and reporting of Mineral Reserves. This paper provided an analysis of the Modifying Factors provided in the 2016 SAMREC Code as a mechanism to improve reporting standards, reporting transparency, and provide assurance that all technical inputs have been considered. The 2016 SAMREC Code provides a comprehensive checklist (Table 1) for the Competent Person to consider and comment.

REFERENCES

Pienaar, D. and Freese, L.B. 2016. The importance of geometallurgical characterization of metalliferous ore bodies. The Southern African Institute of Mining and Metallurgy, SAMREC and SAMVAL Companion Volume. In press

Rupprecht, S.M. 2014. The SAMREC Code and its impacts on mine valuation and the SAMVAL Code. *3rd Mineral Project Valuation School*. Southern African Institute of Mining and Metallurgy, Johannesburg.

SAMREC. 2009. South African Mineral Resource Committee. The South African Code for Reporting of Exploration Results, Minerals Resources and Mineral Reserves (the SAMREC Code). 2007 edition as amended July 2009. Prepared by the South African Mineral Resource Committee (SAMREC) Working Group. http://www.samcode.co.za/downloads/SAMREC2009.pdf



Dr. Steven Rupprecht

Senior Lecturer
University of Johannesburg

Steven has 29 years mining experience commencing his career in 1986 with Gold Fields of South Africa where he gained underground production mining experience working at Venterspost Gold Mine, East and West Driefontein Gold Mines, and Leeudoorn Gold Mine. In 1997 Steven was moved to Head Office as Group Mining Engineer and Senior Mining Engineer Coal.
In 1999 He joined CSIR Mining Technology as Research Area Manager and worked extensively on the Deepmine and Futuremine Research Programmes.
In 2003 Steven joined RSG Global as a Principal Mining Engineer until 2007 when joined Keaton Energy as a Technical Director, a position he held until 2009.
In 2010 joined the University of Johannesburg as Senior Lecture and Director of Mining. He also does mining consultancy work for Borrego Sun and Coffey Mining.
Steven is a Fellow of the South African Institute of Mining and Metallurgy (SAIMM), an co-opted member of the SAIMM Council, vice chairman of the SAMREC working group and member of the SAIMM Technical Programme Committee, and the SAIMM Career Guidance and Educational Committee

Life-of-mine reserves estimation in the dimension stone block extraction industry in South Africa

G. vom Orde,[1]* I. Coates,[2] A.L. Forrester,[3] K. Lomberg,[4] and R. Stephens[5]

[1] Logistics, process simulation, Gottlieb Duttweiler Institute Switzerland
[2] Geologist, Chemist and Ceramics Technology. Stafford University Great Britain
[3] B Sc. Geology Hons. Rhodes University South Africa
[4] B Sc. Geology & Geochemistry, BSc Geology, B Com (Economics & Statistics), M Eng (Mining Engineering), Pr. Sci Nat
[5] B Sc. Hons. Mineral Estate Management. Sheffield Hallam University Australia

A very important aspect of any resource evaluation involves the DIMENSION-STONE quarry geology and a methodology how to calculate the quantities of reserves and resources. Reserves are the terms for a particular proven resource. Part of geology is defined in the nature, extent and quality of the products, the markets they serve, and the product pricing structure.
In order to estimate quarry reserves the qualified person must have a good understanding of the geology as well as the commercial and market issues. Estimating the quantities of so called reserves is a common measure for the extent of the geology, but a commercial assessment needs to consider marketability as well.

Reserves: [A portion of the total estimable resource]

Reserves are usually split into the categories namely Proven, Probable and Possible. Summarised as empirical value from more than 250 similar quarry evaluations in "Classification and risks" categories:

- 1/6 Proven (low risk easily accessed)
- 2/6 Probable (medium risk, accessible)
- 3/6 Possible (high risk not easily accessed and probably only inferred)
- 100% = the Total RESOURCE

Proven Reserves Low-Risk; (probably already accessed and clearly usable & tested).

These reserves indicate a high level of certainty in quality and quantity of a particular resource. If a quarry operation is/was active, then exposed quarry faces clearly indicates the geology of the resource in a given area. Already processed and regularly tested material can proof the consistency for the market. Proved reserves would generally consist of resources at the back of a known quarry face.

Probable Resources Medium Risk (requiring further provenance and testing).

These would involve areas where little geological testing has been done, although the likelihood of the resource existing is still very strong.

Possible (Inferred) Resources High Risk (not easily accessed, excessive overburden etc.).

These are resources outside of a consented area, deposits at greater depths, or those not economically accessible.

For valuation purposes the proven reserves, probable and possible resources are assessed to identify the different levels of risk and uncertainty involved in each category. The risk factor should also be adjusted depending on the lifespan of each category and the mineral output.

The reserves and resources are calculated by identifying the area of land within which the geological deposit occurs and within any planning or other constraints. The various areas are then multiplied by the depths to provide a total volume of the resource. Once a total volume is derived, the life of the total reserves and resources can be calculated by dividing the total reserve or resource by the estimated annual output. Further estimations, dependent on the method(s) of extraction and block trimming will influence extraction-or recovery rate.

OVERVIEW

The following paper focuses on the methodology required to estimate the life of mine for a Dimension Stone block extraction quarry, based on possible history of formation and the background of granite composition. This paper does not additionally speak to the assessment techniques needed in the case of sedimentary deposit´s such as limestone and marble.

MINERALS (Reserves) VERSUS DIMENSION STONE (Reserves):

The methods used to determine the life of mine for a granite dimension stone quarry are very different to that of a conventional mineral mine. This is well reported by; Stephens Valuation and Consultancy Pty. Ltd. (www.quarryvaluations.com). It is worth noting that Roderick Stephens [BSc (Hons) MC MRICS AAPI (CPV)] is a Certified Practicing Competent Person and Chartered Mineral Surveyor with the experience of having analysed 250 quarries in Australia

INTRODUCTION:

The dimension stone industry is not widely known or appreciated within the mainstream mining industry, in South Africa. As a result, the reporting of Mineral Resources and Reserves for dimension stone has not received much attention. Furthermore, the Mineral Resource and Reserve statements are not like those of a base or precious metals operation but are akin to those commonly used for bulk commodities and other industrial minerals, and need to relate to the specifications required for the commodity to be saleable in a market dictated by fashion and cultural preference.

The value of dimension stone stems from its physical properties and appearance.

The success of a dimension stone project depends on the ability to market the natural stone because of its appearance, and the ability to produce rectangular blocks of suitable dimensions that meet

customers' requirements and specifications. A critical aspect of any resource evaluation involves the quarry geology.

The geology also determines the accessibility, nature, extent, and quality of the products, the markets they serve, and the product pricing structure. Therefore, in order to estimate the reserves of a quarry the Competent Person must have a good understanding of the geology, as well as the commercial and market issues.

The saleable product is a primary and fundamental determinant of the Resource and Reserve. Marketability therefore forms a paramount criterion, when assessing reserves and life-of-mine in the Dimension stone environment.

The extent of the deposit (which forms the basis of the estimation of quantity of the Resources and the Reserves), with the yield is a critical determinant of the quantity of saleable product.

This paper summarizes these aspects and presents a case study in support of the discussion. The focus is on the methodology required to estimate the life of mine for a dimension stone block extraction quarry, based on possible history of market acceptance, pricing and long-term sustainability of production ~~and~~ of the granite composition being suited for slab-mining and block extraction and the declaration of the Mineral Resource and Mineral Reserve.

Dimension stone is a collective term for various natural stones used for structural or decorative purposes in construction and monumental applications. The value of dimension stone stems from its physical properties (strength and block size, which relate to the presence or absence of discontinuities) and its appearance (colour, texture).

The principal rock types used for dimension stone are granite, limestone, marble, sandstone, and slate. Commercially, the term 'granite' is often used to denote a range of other types of non-granite dimension stone, including any feldspathic crystalline rocks or other igneous or metamorphic rocks that possess qualities similar to granite's grainy, interlocking texture.

Granite is an intrusive igneous rock consisting of quartz and feldspar (alkali and plagioclase feldspar) and some mafic minerals (*e.g*. biotite, hornblende) and which is widely distributed throughout the Earth's crust at depths up to 50 km (Figure 1). Granite has a characteristic grainy structure and its strength is the result of many individual crystals that form a tightly interlocking structure as the magma slowly cools within the large, deeply buried intrusions.

Igneous (Granite & Metamorphic) stone is the main resource extracted as Dimension Stone in Southern Africa.

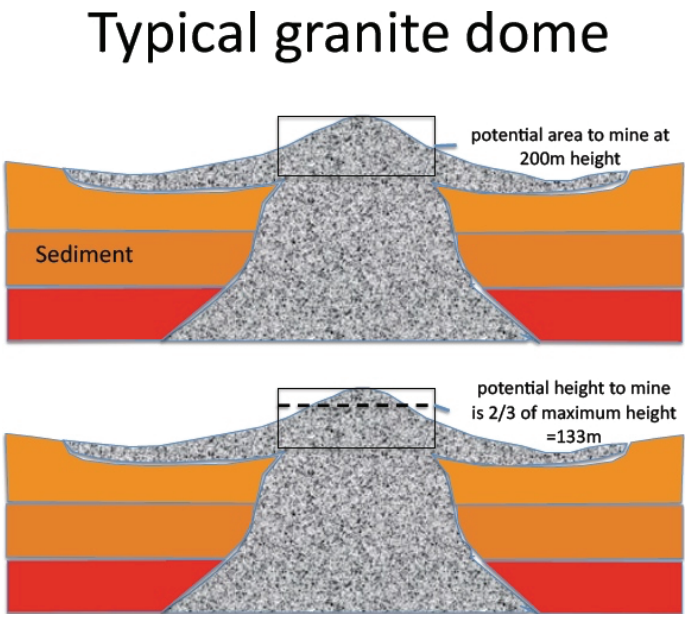


Figure 1. Example of an igneous deposit that may be a source of dimension stone.

Many variations of granite appear on the commercial market with white, grey, pink, and red being the most common colours. Greens and browns are also available, as well as darker greys and black.

GRANITE-COMPOSITION AND PROPERTIES:

Three basic minerals are found in granite; namely as quartz (SiO_2) at least 20%, alkali feldspar between 35% up to 65% by volume, and mica. In addition, other minerals depending on the place of origin are found and will determine the special texture and colour of granite.

The visible grain size of granite varies from fine-to coarse grained with varying smelting temperature between 1215°C und 1260°C and different chemical properties result in high resistance, usually above 200 MPa, against weathering and mechanical influence. The high compactness of granite results in the density of 2,65 to 2,75 g/cm^3 depending on the different kind of granites.

PERC Code:

The Pan-European Code for Reporting of Exploration Results, Mineral Resources and Reserves (PERC Code) has included a section on the reporting of Dimension Stone. PERC defines dimension stone as 'a technical/commercial term that includes all natural stones that can be quarried in blocks of different dimensions and processed by cutting or splitting, and that possess the technical and aesthetic properties required for their use in the building and construction industries' (PERC, 2015).
While other materials derived from natural rocks are almost exclusively used for load-bearing and filling functions, dimension stone materials offer special qualitative features that can perform both structural and decorative architectural functions (PERC Draft, 2015).

The success of a dimension stone operation depends on the ability to market the natural stone because of its appearance, and the ability to produce rectangular blocks of suitable dimensions that meet the customer's requirements and specifications.

A dimension stone block thus has value as a result of its dimensions and appearance, underlain by a set of minimum physical properties, among which are various strength parameters, workability, ability to take a polish, and resistance to physical and chemical weathering (Ashmole and Motloung, 2008).

The aesthetics of a dimension stone is the intrinsic factor on which depends its use as a construction material with decorative functions. Although it may be strongly subjective, aesthetics can be used for the technical evaluation of a dimension stone, because it is the result of the conjoined perception of a set of criteria; namely colour, texture, and the presence or absence of discontinuities. The homogeneity of a dimension stone deposit, in terms of colour, texture and discontinuities, is therefore particularly relevant during geological surveys, as it is the base for establishing the limits of a saleable dimension stone deposit that complies with, or is in demand in, the marketplace (*i.e*. this is not simply a 'geotechnical evaluation').

There has been a significant trend towards the adoption of a more professional approach in exploration for and operation of dimension stone deposits in recent times. Various authors (*e.g*. Ashmole and Motloung, 2008) attest to the mining engineering challenges of dimension stone quarries.

Dimension stone is generally a high-volume low-value commodity. Like other basic construction materials that are easily and commonly available, expensive or sophisticated geotechnical evaluation is not warranted.

The typical exploration sequence for evaluation a granitic dimension stone deposit commences with a desktop study, followed by field (surface) mapping, detailed mapping, resource assessment, test quarrying (not drilling – in the case of granite) and bulk sampling/test processing. Assessment for marketability of colour, texture, and grain "movement" in decorative dimension stone via the presentation of cut and polished sample tiles 150 mm x 150 mm x 6 mm to 10 mm thick and is the standard sample presentation method used worldwide in this industry. Secure off-take contracts will inevitably require presentation of these samples, for verification. Some supply contracts will require ongoing individual blocks to also be supplied with a diamond-wire cut and polished "observation corner" for reference inspection/comparison.

Dimension block marketability is also dependent upon finished, properly-squared block size, to suit the downstream processing industry that requires specific continuous-length slabs, for use in the decorative for work-tops and/or floor and wall-cladding (tiling) work. Hence higher values are placed on blocks of say 3,2 m length than those of less than 2,4 m. Contracts will specify blocks sizes, but will be limited not only by the stone's length or width etc. but also by logistics constrains for the handling and shipment (typically less than 30 tonne per block for example) of the stone.

In general, dimension stone can be quarried in regular and/or unshaped blocks by using different mining methods (drilling and splitting, diamond wire and diamond chainsaw cutting) and processed (cut, polished, and subjected to other surface treatments) to produce semi-finished products (slabs or blocks) and finished products (tiles and cut-to-size products).

The mining methods or quarrying techniques range from relatively simple and low-technology methods to some quite technologically advanced methods. Differences in the particular quarrying techniques used depend on the physical properties of the rock (strength, homogeneity, direction and density of fractures and discontinuities), depth, economics, and operator preference.

Nevertheless, the technical process is relatively simple: locate or create (minimal) breaks in the rock, remove the blocks using heavy machinery, secure the blocks on a vehicle for transport, and/or move the blocks to storage (Figure 2).

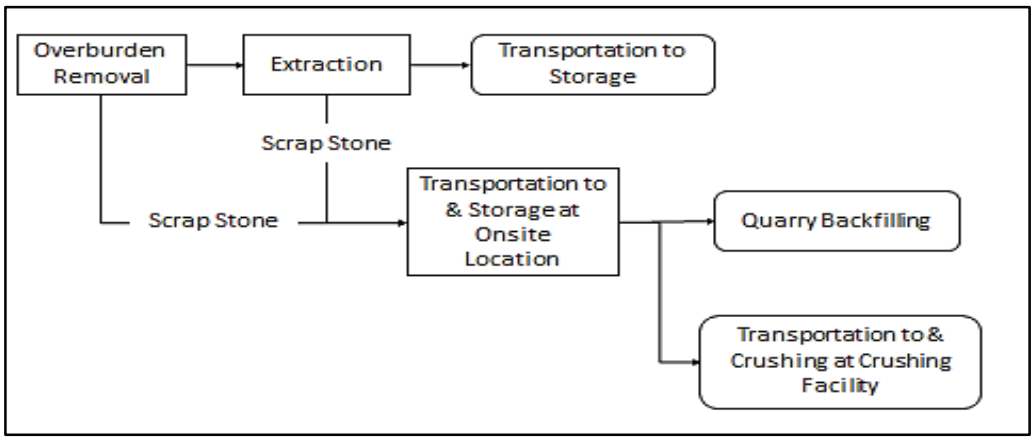


Figure 2. Schematic flow chart of quarrying operation (University of Tennessee. Center for Clean Products, 2008).

It is estimated that 80% of the dimension stone produced is used in the construction sector, with the funerary monumental industry accounting for 15% and various special applications for around 3% (Ashmole and Motloung, 2008).

The demand for dimension stone follows a cyclical pattern in line with the world economy, and the market for individual types of dimension stone is determined by customer fashion trends. Internal demand for dimension stone is reported as 142 Mt per annum, with limestone being the most important at 42% followed by granite at 21% (USGS, 2016). Only granitic rock types are mined in SA as Dimension Stone; there are no surviving Limestone or Marble Dimension Stone operations in SA.

The top five producing countries in 2012 were, in descending order by tonnage, China, Turkey, India, Iran, and Italy and these countries accounted for about 72% of the world's production (USGS, 2013). South Africa at one stage (*circa* 2000), was producing about 1 200 000 t for export but the export volume has declined severely in recent years and a sizeable proportion of production is now taken up by local downstream beneficiating operations.

PROJECT EVALUATION AND RESOURCE ESTIMATION

Significantly, dimension stone is not a high-value commodity that is extensively available. As a result, prospecting and exploration have been undertaken by individuals with little formal geological or mining training, and who seldom conducted formal investigations or evaluations prior to opening quarries. It has, however, become good practice to perform a thorough geological investigation for existing and new quarries.

The nature of the product precludes a large exploration investment or the use of sophisticated geological and exploration techniques.

The important aspects of a quarry are presented in Table I.

Table I. The critical aspects of a dimension stone deposit and quarry (after Ashmole and Motloung, 2008).

Dimensions of the deposit	Homogeneity of the rock	Structural features e.g. fracturing, discontinuities	Geological considerations
• Thickness of productive units • Volume of the deposit • Spatial disposition	• Colour • Texture • Discontinuities	• Preferential directions • Frequency • Density • Intensity • Type and morphology	• Colour variations • Textural characteristics and textural variation • Structural and macro-discontinuities • Micro-discontinuities • Intrusives • Inclusions • Accessory minerals • Contact zones • Alteration

These criteria can be evaluated using geological mapping and structural geological investigation, supported by diamond core drilling, to evaluate the size and homogeneity of the deposit.

The recognized sequence of investigation for dimension stone resource evaluation is:

1. Desktop study
2. Field evaluation
3. Detailed mapping
4. Structural geology and application of geophysics
5. Drilling [This is done in the case of sedimentary rock deposits but not usually in the case of granitic outcrops that are accessible above-surface country rock][2]
6. Bulk sampling
7. Test quarrying.
8. Market assessment and comparative value linked to delivery logistics and extraction costs [2]

(Ashmole and Motloung, 2008).

This paper highlights a few aspects that are important to the declaration of a Mineral Resource or Reserve based on the detailed exposition of Ashmole and Motloung (2008).

The field evaluation identifies the general soundness and appearance of the stone, including the colour, texture and the ability to be cut and polished. The recognized method for testing this is the production of small polished slabs (100 mm × 100 mm). A number of samples across the deposit or quarry would be prepared. Customer feedback and engagement is required to determine the potential market and price for the material.

Geological mapping provides a range of information such as the different outcrops and ages of rocks together with detailed descriptions of the rock types. The mapping also shows known and conjectural fault lines, dip of the strata, previous mines, overthrows, thrusts, synclines and anticlines, and often cross-sections through the strata.

However, geological mapping provides only a broad overview of the geology, and a site-specific investigation can reveal a very different picture. Therefore, the Competent Person needs to keep an open mind until the mapping information is fully supported by all the available information.

Geological mapping is available for the majority of populated areas throughout South Africa and provides a great deal of information. Mapping may not be available for remote areas, but these areas are unlikely to service any sizeable markets and so the Competent Person would have to make judgements based on the products and consideration of the working faces and any testing or investigations that have previously been carried out.

Should initial field evaluation indicate that there is a potential product and that the proposed quarry may be economically viable, detailed geological mapping of the deposit would be conducted. For an existing quarry, mapping beyond the current extent of the quarry would be undertaken. During the detailed field mapping, special attention would be paid to the composition, colour, and structure of the stone, as well as the fracturing and the homogeneity of the rock within the area of study.

The three-dimensional homogeneity of the deposit needs to be established or confirmed before bulk sampling or test quarrying is carried out. In the evaluation, the continuous/discontinuous and homogeneity/varied nature of the geology and structure should be clearly understood. Various techniques are available, including geophysics, to complement the existing geological information as well as provide details of the structure and degree of fracturing. As with any phased approach a successful conclusion of one phase will inform the subsequent phase.

If the outcome of previous phases of field evaluation and the structural geology established through *inter alia* geophysical investigations is positive, the next step should be to consider drilling (in the case of a sedimentary deposit) [2]. Drilling would be able to demarcate the extent of the rock mass that has the necessary physical and aesthetic qualities and provide more definitive information as to the lateral and vertical extent of a potential quarry or extension to an existing quarry.

Diamond core drilling would be preferable, as the core can be evaluated for colour consistency as well as various structural aspects such as joints, veins, and banding that may influence the recovery of marketable blocks. A note of caution is required that if only vertical holes are detailed, some structural elements may not be observed because of their orientation relative to the drilling orientation. (In the SA context and applying to Granite domes and similar outcrops, it is not usual practice to core-drill but rather to extract small sample blocks for polishing/ testing) [2]

Should the results of the previous phases be positive, the next phase would be to conduct bulk sampling to remove several blocks in order to test market acceptance.

The number of blocks required will depend on the marketing strategy and whether access to a cutting facility is available. Depending on the nature of the deposit, whether there is an existing quarry or whether the blocks will be cut on site, between 2 and 10 blocks would be required to evaluate response to the material. This step of bulk sampling should not be confused with the next phase, that of test quarrying. In the case of a new deposit of an established material, it may possible to skip the bulk sampling phase and proceed directly to test quarrying.

If the market feedback regarding bulk samples is positive, or in the case of a material with an established market, the final phase of evaluation and confirming the viability of a deposit or quarry is test quarrying. The aim of test quarrying is to fully evaluate the recovery of saleable blocks in order to determine whether full-scale mining or quarrying is economically viable, as well as to evaluate the implications of extraction methods on the economics of the project.

Test quarrying is required, as the preceding methods can give only an indication of the range of possible recovery, and the actual recovery can be established only by mining and determining the production profile and production costs. It also allows for the optimization of extraction methods in order to determine the most feasible method to be employed.

While recent advances in dimension stone quarry evaluation have shown that there is potential for geostatistical methods to provide reasonable assessments of potential exploitability of a deposit, Ashmole and Motloung (2008) consider that they are not a substitute for test quarrying.

A full-scale quarry has significant cost and environmental implications and is often close to residential areas. A poor evaluation could have severe consequences in terms of the social licence to mine if not fully considered.

BASIS FOR REPORTING OF EXPLORATION RESULTS, MINERAL RESOURCES, AND MINERAL RESERVES FOR DIMENSION STONE

The PERC Draft (2015) includes a number of aspects that are considered important in the Resource/Reserve declaration and the evaluation of the dimension stone deposit:

- The qualitative and aesthetic characteristics e(colour, grain, texture and their regularity in distribution) and/or structural performance (compressive and flexural strength, abrasion resistance, porosity, ability to be polished, radioactivity, *etc*.) that may be more important for the market and applicable and acceptable as the basis of the reporting.
- Any chemical analyses that may be relevant for the material evaluation.
- Where necessary, chemical analysis may be used to verify the possible presence of minerals and related alteration that could result in important quality defects in finished products.
- Chemical/compositional analysis may also identify mineral components and/or assemblages and is used to predict the future technical requirements of the quarrying-processing equipment.
- For dimension stone deposits that are capable of yielding different products (different materials and/or different market grades within the same material), suitable for the production of more than one finished or semi-finished product, and for more than one final application and/or specification, these should be specified as the various products may be sold in the market at different prices.
- The Competent Person should normally report the Resources and Reserves within the framework of an existing mining plan and/or Feasibility Study or established set of products and market assumptions and objectives.
- Inclusion of the final product specifications, proximity to markets, type, structure, and market demand, which may vary from area to area except where the material is well established.
- A professional evaluation of the market quality by the Competent Person is the key to evaluating the final product marketability and is a critical Modifying Factor in the definition of Mineral Reserves for dimension stone.
- The Competent Person should explain in detail in the report the method utilized for the market quality evaluation and the market references cited, together with documents referenced or used.
- The raw block or 'as-mined' product is usually reported in all its forms, shapes, and dimensions. These are also factors that drive the market.
- The Public Report may use either the geological or commercial names of the target dimension stone(s).
  In certain cases, commercial sensitivity may preclude the publication of detailed information and data associated with Mineral Resources and Reserves. In such cases this should be clearly justified in the report (either prepared for an individual site or on an aggregated basis).

CONCEPTUAL EXAMPLE:

The Reserves and Resources are estimated by identifying the area within which the deposit occurs. The various areas are then multiplied by the depths to provide a total volume of the Resource. The depth in this case is the practical, technical, and economically reachable depth of the benched quarry operation (Figure 3), rather than the assumed depth of dimension stone. Based on the total volume of the Resource, the quarry exploration and mining method used will determine the maximum yield of the demarcated area.

Owing to the way in which granite formations are created, the most accurate way of estimating the life of a dimension stone quarry is by dividing the volume by the estimated annual output and industry-standard recovery percentages. These volumes would be classified in terms of Resources (Measured, Indicated, or Inferred) and Reserves (Proved or Probable).

The Measured Resource, which could be converted to a Proved Reserve, indicates a high level of certainty as to the quality and quantity of the deposit. If a quarry operation is active or was recently active, then quarry faces are often exposed, clearly indicating the geology in a given area. In addition, the quarry material would also be processed and regularly tested to establish its consistency for the market.

Proved Reserves would generally consist of Resources at the back of a known quarry face, but also confirmed by boreholes, trial pits, or test bulk extractions, and other geological information, to fully support the consistency of the Resource.

Measured Resources (low risk) can be defined as areas where the granite is visible or exposed, which clearly indicates the geology of an area. Typically, approximately 1/6 of the volume will be considered as a Measured Resource which, after application of Modifying Factors, would be declared as a Proved Reserve, effectively considering the reporting of Resources inclusive of Reserves.

The Indicated Resource, which could be converted to a Probable Reserve, would involve areas where very little geological testing has been taken place, although the extension of the Resource has been demonstrated. As workings progress in the quarry and quarry faces are removed, and as further geology is exposed and the consistency confirmed, the Indicated Resource may be upgraded to a Measured Resource and the Probable Resources to a Proved Reserve.

Indicated Resources (medium risk) can be defined as areas where the presence of the granite has been demonstrated but the volume is not exposed in the quarry faces. Typically, approximately 1/3 of the volume will be considered as an Indicated Resource which, after application of Modifying Factors, would be declared as a Probable Reserve

The Inferred Mineral Resource is typically ½ of the volume determined and is considered to be associated with more risk. The Inferred Resources would either be Resources outside of a consented area, or deposits at greater depths than have been sampled. There are always geological conditions that can occur within a mineral deposit when a quarry operator least expects them.

Faulting can significantly affect the geology in a given area. Fissures and faults can also affect the quality of the Resource in given areas.

For valuation purposes the Measured, Indicated, and Inferred Resources are assessed to identify the different levels of risk and uncertainty involved in each category.

The risk factor should also be adjusted depending on the lifespan of each category and the mineral output. In addition, the specification of the product is required, which may include the specification of a number of products, including aggregates.

The life of the mine or quarry can be determined by dividing the volume of the resource base by the estimated annual output, taking the yield into account. The life of the mine or quarry changes every year as the market changes. This may be a reflection of the market share of the quarry, which is influenced by the presence of competing quarries, changes in construction requirements, location, costing, *etc*.

A typical life of mine/quarry is presented in Table II and a Resource and Reserve summary is presented in Table III:

Table II. A typical life of mine/quarry determination.

Risk	**Estimated volume, m³**	**Total mined, m³/a**	**Life, a**	**Yield for dimension stone, %**	**Volume dimension stone per year, m³**
Low risk, easily accessed	1 000 000	40 000	25	15%	6 000
Medium risk, accessible	2 000 000	50 000	40	10%	5 000
High risk, not easily accessed	3 000 000	60 000	50	6%	3 600
Resource	**6 000 000**	**150 000**	**115**	**9.73%**	**14 600**

Table III. Example of a Resource and Reserve statement

Classification		**Estimated volume, m³**	**Yield for dimension stone, %**	**Volume dimension stone, m³**
Resource	**Reserve**			
Measured	Proved	1 000 000	15%	150 000
Indicated	Probable	2 000 000	10%	200 000
Inferred	Possible	3 000 000	6%	180 000
Total		**6 000 000**	**9.73%**	**530 000**
Specification: Dimension blocks [Granite] to be well "squared" and preferably with wire-cut surfaces with lengths of 2.4m, 2,7m and 3.2m and width ranging from 1.0 to 1,2 and up to 1,8m and height 1,5m to 2,1m with an observation window to be clearly ground and polished on one corner to verify colour and texture. All blocks to be thoroughly washed and for those being shipped by container, phytosanitary certificate to be issued for each container with max 27 tonne per container. Only blocks numbered and registered on a client-approved block list may be dispatched from the quarry				

The Resource and Reserve declaration assumes that it is reasonable that the quality and requirements of a specific market have been demonstrated. The Competent Person will need to determine that this is indeed the case.

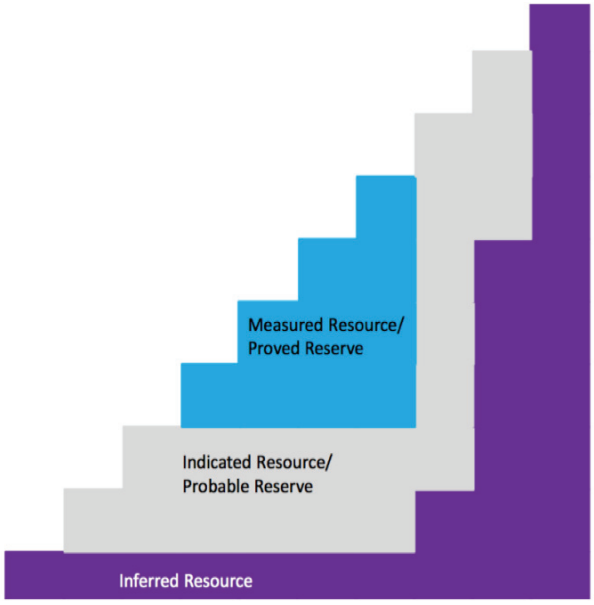


Figure 2. Graphic of simplified Proved Reserve estimation

PRACTICAL ESTIMATION EXAMPLE:

The following example is an estimate of a life of mine calculation. The aim of using graphics is to further simplify the estimation

Measured Resource		
In-situ volume	158 m × 158 m × 40 m deep	= 1 000 000 m^3
Recovered volume	× 0.15 (15% recovery)	= 150 000 m^3
Production	500 m^3/month or 6 000 m^3/a	
Life of mine	150 000 m^3 / 6 000 m^3	= 25 years

It is therefore sufficiently conservative to estimate an area of approximately 274 m × 274 m surrounding the Proved Reserves/Measured Resources to represent the Probable Reserves/Indicated Resources:

Indcated Resource		
In-situ volume	274 m × 274 m × 40 m deep	= 3 000 000 m^3
Minus Measured Resource	–1 000 000 m^3	= 2 000 000 m^3
Recovered volume	× 0.10 (10% recovery)	= 200 000 m^3
Production	417 m^3/month or 5 000 m^3/a	
Life of mine	200 000 m^3 / 5 000 m^3	= 40 years

CONCLUSION

The assessment of Reserves and Resources involves a high degree of specialist knowledge within;

- geology, the quality of the material,
- the intrinsic appearance of suitably trimmed and polished sample tiles,
- the nature of the market in which the quarry operates, as well as an understanding of how these factors relate to valuation principles, and
- the mining methods

Life –of-Mine projections and production of a feasibility report requires that the competent person must consider all of the input factors, not least of which is market acceptance and the proven contractual off-take contract.

In order to estimate the reserves of a quarry the Competent Person must have a good understanding of the geology, as well as the commercial and market issues. Determining the quantities of the resource is limited by the extent of the geology, but determination of a reserve needs a commercial assessment to consider the marketability of the stone. The saleable product is a determinant of the resource and reserve.

Obviously, issues such as proximity to the market, planning, licensing, access, and operating costs are some of the other factors involved, but without a quality Resource, then finally, there may not be a market, therefore market acceptance assessment is in reality the final arbiter

REFERENCES

Ashmole, I. and Motloung, M. (2008). Dimension stone: the latest trends in exploration and production technology. *Proceedings of the International Surface Mining Conference 2008 – 'Challenges, Technology, Systems and Solutions'*, Sandton, South Africa, 5–8 August 2008. Southern African Institute of Mining and Metallurgy, Johannesburg. pp. 35–70.

PERC. (2015). Reporting Standard 2015 (Draft). Pan-European Standard for Reporting of Exploration Results, Mineral Resources and Reserves (The PERC Reporting Standard). The Pan-European Reserves and Resources Reporting Committee.

Stephens, R. (2012). Stephens Valuation & Consultancy. http://www.quarryvaluations.com/index.php?p=1_25 [Accessed 9 Jan. 2016].

University of Tennessee. (2008). Granite Dimensional Stone, Quarrying and Processing: A Life-Cycle Inventory. Report Prepared for: Natural Stone Council Center for Clean Products, University of Tennessee.

Reporting of geological model confidence level at AngloGold Ashanti's Mponeng mine

G. Flitton

Mponeng Mine, AngloGold Ashanti Ltd

Estimation in deep-level Witwatersrand gold mines is based on far more limited information than is available for shallower orebodies. A great deal of interpretation and extrapolation of information is essential, especially for complex orebodies. The application of the SAMREC Code in Mineral Resource classification and reporting requires standardisation of the approach for managing of the many risks inherent in Mineral Resource management. In the geological environment, the risk is a function of uncertainty and possible impact, which is indirectly proportional to the quantity and quality of information available decision-making. The calculated confidence levels of grade estimates within homogeneous populations are categorised in order of increasing confidence into Inferred, Indicated and Measured Mineral Resources.

At the AngloGold Ashanti's South African operations the catergorisations are based on a combination of calculated confidence levels and a final review of information density and what it is inferring in relation to current orebody understanding. The application of these categories is moderated according to the inherent complexity and continuity of the orebodies being classified. This allows for orebody confidence to be effectively managed.

INTRODUCTION

Mineral Resource and Reserve estimations are often based on low levels of geological and evaluation data. Deep-level gold mining is no exception. Owing to the difficulty of gathering the data ahead of and far away from the mining fronts this data is sparse and often hard to come by. The extent of the geological model is based on few scattered sample points, often from boreholes drilled thousands of metres deep from sites that can be located on surface or from existing underground tunnels. This has always been the practice of gathering information regarding areas for possible future mining on deep underground gold mines such as AngloGold Ashanti's Mponeng mine.

Behind the advancing mining front there exists an extensive database of sample points collected through chip sampling across the orebody channel. The boreholes drilled in addition to this data-set complement the understanding and are a good representation of the complex spatial distribution that exists.

Geologists collate all the data and generate a model that can be considered a simplification of this reality, derived from partial and incomplete data coupled with background understanding and knowledge of the mineralisation that is being quantified (Vann *et al*., 2014). Vann *et al*. also note that models are never the truth; they are approximations or predictions and cannot exactly represent the Mineral Resource.

Uncertainty is inherent in each stage of these predictions, which are and therefore prone to errors throughout. The higher the level of uncertainty the greater the Mineral Resource risk (McGill *et al.*, 2006). In the geological environment, uncertainty is inversely proportional to the quantity and quality of information available.

The classification of Resource estimates is critical for the reporting of Mineral Resources and Mineral Reserves. The categories of Mineral Resources are based on the level of geological knowledge and confidence.

CLASSIFICATION OF MINERAL RESOURCE CONFIDENCE

The growth and entrenchment of international reporting codes such as the SAMREC Code has standardized the approach to managing many of the risks inherent in Mineral Resource management. The Mineral Resource and Mineral Reserve classification is the responsibility of the Competent Persons (CPs). The SAMREC Code provides definitions of the Mineral Resource categories as well as guidelines on matters related to the estimation and classification of these Mineral Resources.
The SAMREC Code is not prescriptive in this regard and the judgment and experience of the CP is utilized to best describe the Mineral Resource.

The degree of confidence in the geological interpretation must be taken into account when classifying the Mineral Resources. The density of the geological data is the best indication of this and when utilized to compile the model must be clearly understood (Stephenson, 2001). Borehole targets drilled away from mining area probably represent only a small percentage of the orebody if treated on their own, and the estimates in these areas will have a low confidence level due to the uncertainty. The chip sample data-set is a better representation of the orebody, and owing to the density of the sample spacing should be categorized at the highest confidence level.

First-pass Mineral Resource categorization
At the AngloGold Ashanti's South African operations, the SAMREC Code categories of Measured, Indicated and Inferred are utilized for the Mineral Resource classification. The Indicated category is further subdivided into Indicated 1, Indicated 2 and Indicated 3 in order of reduced confidence (Table I).

The gold grades in the reef blocks are estimated using the chip samples as well as any acceptable drilled samples using geostatistical methodologies. A number of estimation processes are applied to the data, which is usually reasonably extensive in the immediate vicinity of mine excavations but is extremely limited over large parts of the deposit

The calculated confidence levels of various estimation processes applied within a statistically homogenous population, shown in Table II, are used as a base for the classification of Mineral Resources into the various confidence categories. Figure 1 illustrates how the confidence in an estimate decreases as the range increases from the particular data-set and that different calculated confidences can be achieved using different techniques. At AngloGold Ashanti's South African mines, in order to improve the calculated confidence level of an estimate, different estimation processes are applied to maximize the confidence over certain ranges. This constitutes the first pass in the estimation process for determining the percentage confidence in reef blocks based on sample information available for the estimation, and is described below.

The limit of the optimized 30 m × 30 m blocks of the simple kriging exercise determines the "local" extent of the Measured component of the Mineral Resource. The remaining four categories are determined by the lower limit percentage confidence as calculated from the macro co- kriging estimated results.

For every macro block that is estimated a 95% confidence lower and upper value is calculated for the estimate (in Ln space). The ratio of the 95% lower limit value to the estimated value (in real space) is expressed as a percentage of the lower limit percentage confidence.

The 95% lower limit value is used as this represents the risk in the estimated value (the 95% upper limit value represents the opportunity). The lower the ratio of lower to upper limit, the less confidence there is in the estimated value because the difference between the estimated mean and the lower limit becomes greater. Figure 1 shows an example of this.

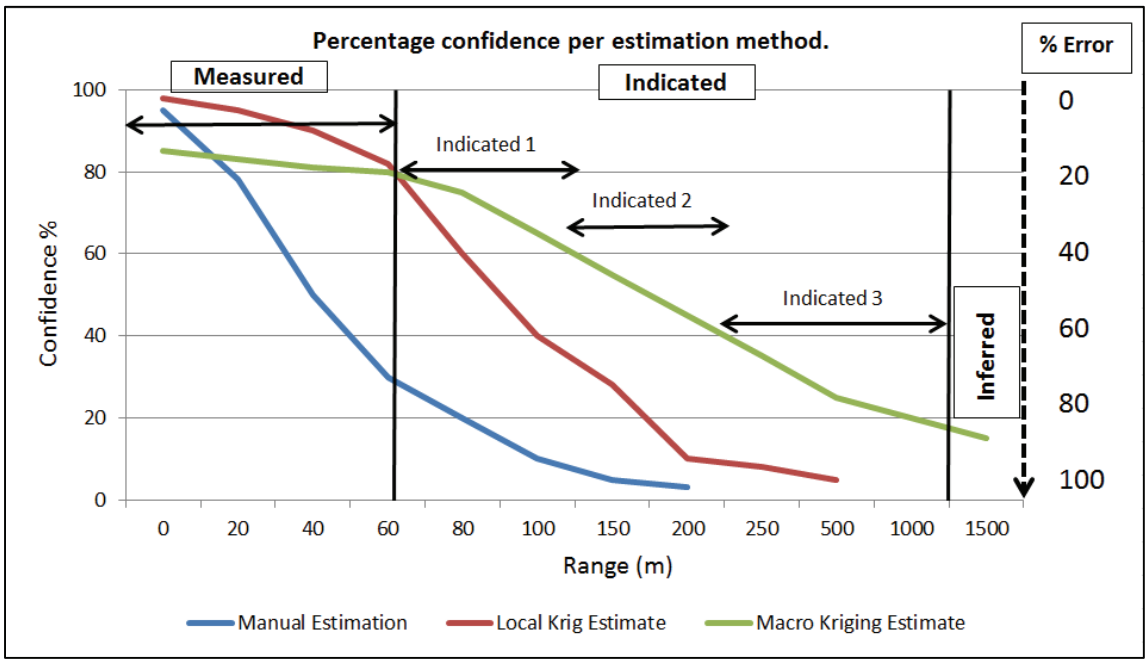


Figure 1. Diagrammatic illustration of relationships between grade estimation process, range, confidence levels and resource categories.

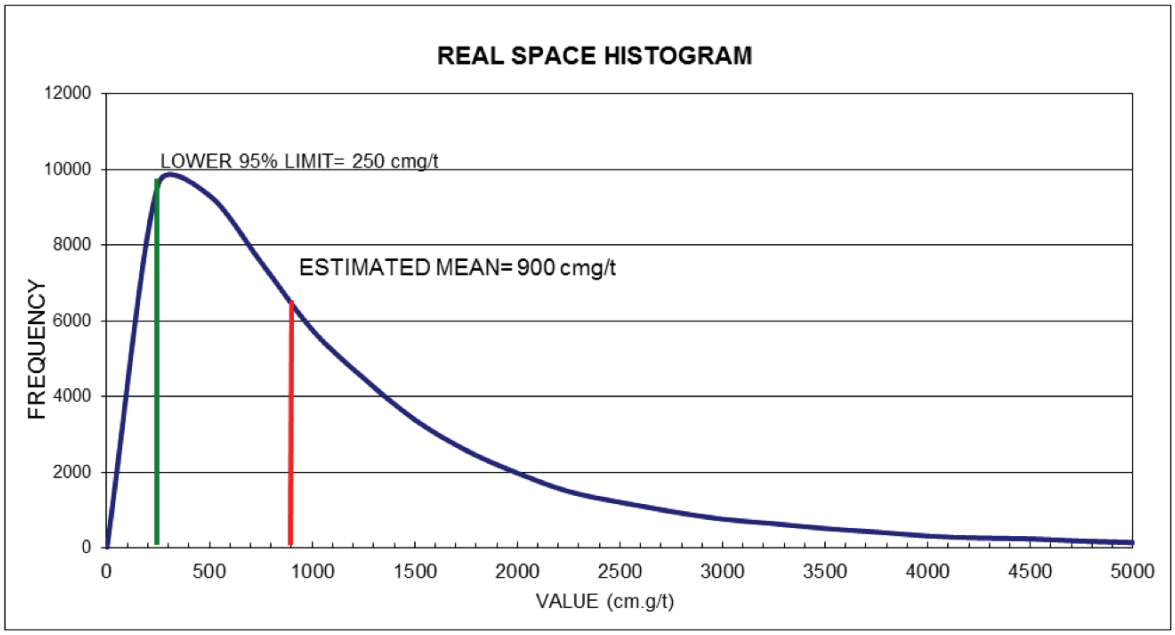


Figure 2. A real-space histogram used for the calculation of lower limit percentage confidence.

The lower limit (LL) percentage confidence for the example in Figure 2 is calculated as follows:

(95%LL)/estimate*100 = Ratio

250/900*100 = 28%

Once these percentages are calculated for each macro block the blocks are categorized according to Table I. The categories decrease in confidence from 100% to zero. Table I shows that by using the calculated ratio from Figure 3 the result of 28% calculated confidence means that the block can be classified as Indicated 3. This calculation is performed for every estimated macro block and is used to determine the calculated confidence.

Table I: Percentage confidence based on the lower limit percentage confidence subdivisions.

Category	Percentage confidence
Measured	Optimized simple Kriging
Indicated 1	Greater than 60%
Indicated 2	60 – 40%
Indicated 3	40 – 20%
Inferred	20 – 0%

Geological Downgrade – the Final Mineral Resource Categorization Process
Where additional geological uncertainty exists, the first-pass SAMREC Code categorization can be downgraded according to an internal AngloGold Ashanti guideline. The guideline's categories are based on the data density and the inherent geological confidence in the reef block being reviewed. In this way specifically the Indicated portion of the Mineral Resource is redefined.

In order to define an Indicated Mineral Resource it is required that the nature, quality, amount and distribution of data is such as to allow the CP to confidently interpret the geological framework and to assume geological continuity of mineralization. The continuity is reviewed in accordance with the amount of data and the nature of the mineralization. Areas where limited measurements and sampling have been completed and where the data is insufficient to allow continuity to be confidently assured are downgraded within the defined guidelines. Calculated confidences can never be upgraded since this would undermine the estimation process, but blocks can be downgraded where the CP deems it necessary.

Geological Continuity
The 'continuity' of a Witwatersrand sedimentary reef depends on the extent of its original deposition, and the burial and tectonism that the orebody has been subjected to over time. The Ventersdorp Contact Reef formed over a far greater area than that of a typical mine. The continuity in this case can be assumed within a certain level of confidence due to the scale of the orebody. When exploration is completed and intersections are found some distance from an advancing mining front, the CP can infer that the orebody extends into that area. This inference, based on the CP's experience and background knowledge of the orebody, is accompanied by a certain degree of confidence and when more information is obtained the understanding of the Mineral Resource improves. The criterion for the geological downgrading process is described in Table II.

Mponeng Mine's Final SAMREC Classification
Figure 3 illustrates the differences between the first-pass Mineral Resource classification and the final published SAMREC Code classification after the CP's review and downgrading process at Mponeng mine.

Table II. Tabulation of geological confidence criteria.

Geological confidence criteria used for the review of Mineral Resource classification downgrades			**SAMREC Code category based on geological data density**
CONFIDENCE	**Confidence in sedimentary facies and mineralization models**	**Confidence in structural model**	**SAMREC Code category**
Very low	Speculative models based on intuition, no data available	Speculative, no data available at resolution better than 1:250 000 scale	**INFERRED**
	Extrapolated from contiguous area, continuity suspected, no confirmatory surface reef intersections available	Major faults extrapolated from contiguous area, cut-offs not defined, no surface reef intersections available	
Low	Confirmed by one or more surface or long inclined borehole reef intersections, continuity not confirmed, but likely	Some of the major faults intersected in one or more surface or long inclined boreholes, cut-offs ill defined. 3D seismic data available and used.	
	Facies and mineralization continuity confirmed by routine GBH* or long inclined boreholes drilling from leading haulages and reef intersections in scattered surface holes	Structural interpretation based on drilling from leading haulages and widely spaced surface drilling. 3D seismics. Major cut-offs defined	**INDICATED**
Medium	Facies and mineralization continuity confirmed by routine GBH or long inclined boreholes drilled from access haulages and crosscuts	Major cut-offs confirmed by routine GBH or long inclined boreholes drilled from access haulages and crosscuts	
High	Confirmed by drilling from crosscut, mapped in boxhole	Structure based on drilling from haulages and crosscuts, most significant cut-offs defined by extrapolation from measured areas	
	Mapped in reef development and/or stoping on one side of Resource	Faults and cut-offs extrapolated from mapping in reef development and/or stoping on one side of Resource	**MEASURED**
Very high	Mapped in raise and stopes flanking Resource	Faults and cut-offs interpolated from mapping in raise and stopes flanking Resource	
	Extensively mapped in detail in surrounding stopes	All faults >1 m and cut-offs interpolated from mapping in surrounding stoping	

*GBH – Geological borehole – short boreholes drilled as part grade control and structure model confirmation.

The Measured category is not affected by the re-classification as it is the best estimation of the Mineral Resource and the majority of the changes to the categorization were made to the Indicated portion of the calculated confidence areas.

In this example for Mponeng mine (Figure 3), borehole intersections marked with blue circles indicate the limit of the currently drilled information on the orebody. Therefore the confidence in the continuity of the orebody up to the lease boundary is downgraded into the medium to low category from the calculated confidence interval, which is determined to be up to 60%.

The Indicated 3 category is that portion of the orebody where the reef is understood to exist based on geological knowledge and understanding of the orebody, but confidence is low with regard to the type of *in-situ* mineralization to expect. More information must be generated through more exploration drilling to improve the density of the data distribution across the area in order for the area to remain at a Medium confidence classification (Table II).

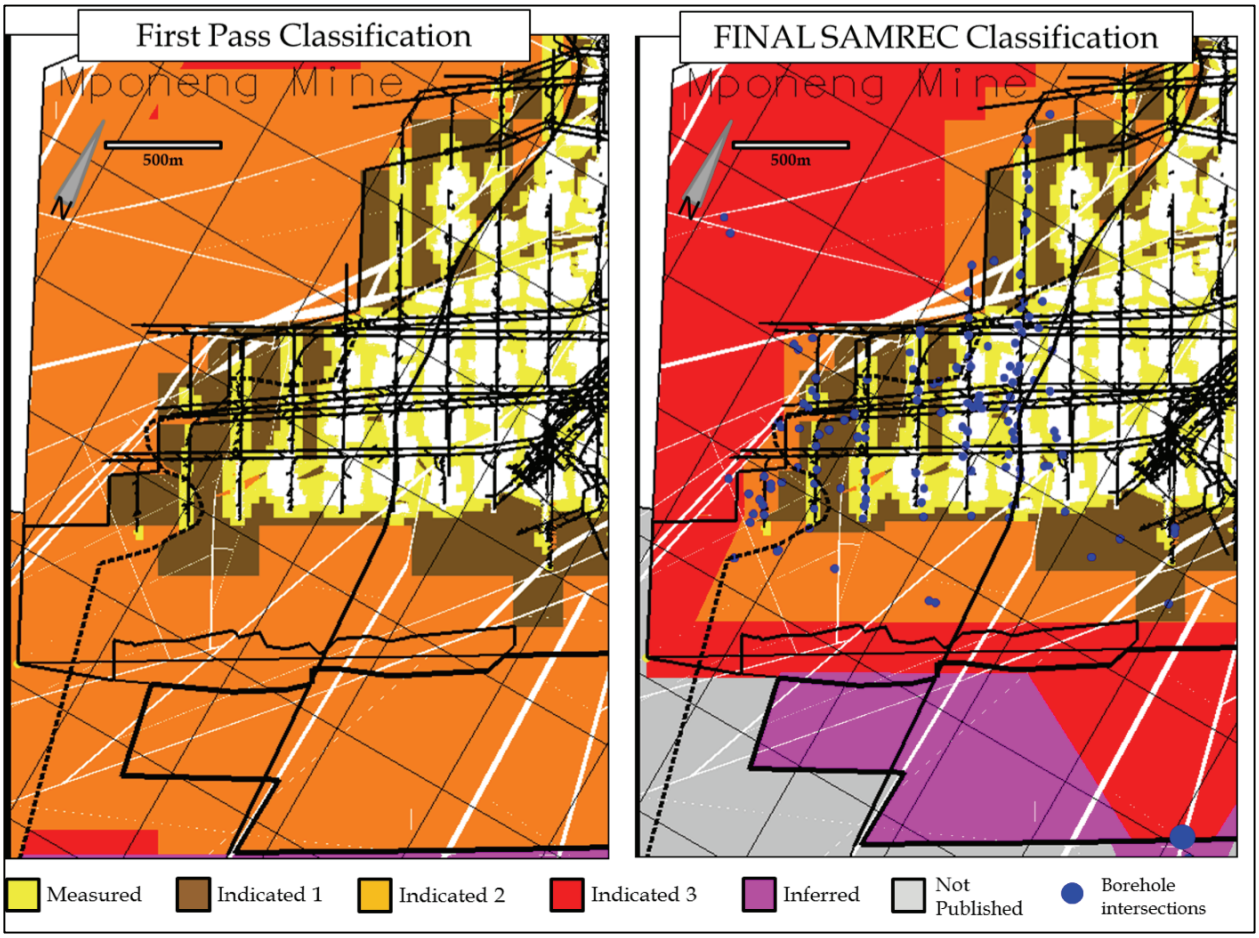


Figure 3. Example of first-pass classification and the final SAMREC classification for the western edge of the Mponeng mine lease area.

It is important to note is that a portion of the orebody, even though it has a calculated confidence of Indicated 2 (40–60% from Table), is downgraded and not published at all due to the lack of information. In this way the CP does not create expectations of the Mineral Resource where the uncertainty is too high.

The criteria per SAMREC Code category that a CP can use as a guideline is summarized as follows:

Inferred (Low confidence):

Confirmed by at least one surface or long inclined borehole with reef intersections. Continuity not confirmed, but likely.

Indicated 3 (Low to Medium confidence):

Facies and mineralization continuity confirmed by routine geological boreholes (if available) or by a number of intersections in long inclined boreholes drilled from leading haulages or other suitable sites, and reef intersections in scattered surface holes.

Indicated 2 (Medium confidence):

Facies and mineralization continuity confirmed by routine geological boreholes or long inclined boreholes drilled from access haulages and crosscuts that are in place or being blasted into the vicinity of the reef block.

Indicated 1 (Medium to High confidence):

Confirmation by drilling from crosscut, where mapping in the immediate footwall to reef confirms that the certainty of the reef is in line with the drilling results.

Measured (High to Very High confidence):

Mapped in reef development and/or stoping along the Mineral Resource. The Mineral Resource is extensively sampled.

CONCLUSION

The Mineral Resource confidence categories form an integral part of Mineral Resource evaluation and reporting. As only Measured and Indicated Mineral Resources can be converted to Mineral Reserves the Competent Person needs to ensure that information that is published has been scrutinized to a reasonable level of confidence (Dohm, 2004).

To achieve this, the AngloGold Ashanti South African operations have developed a rigorous Mineral Resource classification process that is supported by internal guidelines, and which is reviewed annually to ensure impartiality on the part of the Competent Person.

Elements considered to influence the confidence of a Mineral Resource are the size of the orebody, the continuity of the mineralization, and the reliability and spacing of the data use for the final estimation.

The calculated confidence is determined for reef blocks ahead of the face and is controlled through the different estimation processes applied, which vary according to the distance from the data. The more data that is available, the higher the calculated confidence in a block.

Geologists constantly attempt to generate more information ahead of advancing mining fronts to improve their understanding of the orebody and thus cannot rely on a calculated confidence classification method alone. A downgrade of the calculated confidence level is therefore applied according to the clearly defined set of guidelines.

By ensuring the effective management of this process to generate a final confidence classification, AngloGold Ashanti can confidently publish Mineral Resources of the highest quality.

REFERENCES

Dohm, C. (2004). Quantifiable mineral resource classification: a logical approach. *Geostatistics Banff 2004*, vol. 14. The Netherlands: Springer. pp. 333–342.

Flitton, G. and Bischoff, I. (2014). Competent Person Report for Mponeng Mine December 2014. AngloGold Ashanti Ltd South African Region, Report MRS2014-2363 West Wits CPR December 2014.

McGill, J.E. and Theart, H.F.J. (2006). Technical risk assessment techniques and practice in Mineral Resource management with special reference to the junior and small-scale mining sectors. *Journal of the South African Institute of Mining and Metallurgy*, 106, 561–567.

Stephenson, P.R. and Stoker, P.T. (2001). Classification of mineral resources and ore reserves. *Mineral Resource and Ore Reserve Estimation – The AusIMM Guide to Good Practice*. Melbourne: Australasian Institute of Mining and Metallurgy.

SAMREC. (2009). South African Mineral Resource Committee. The South African Code for Reporting of Exploration Results, Mineral Resources and Mineral Reserves (the SAMREC Code). 2007 Edition as amended July 2009. http://www.samcode.co.za/downloads/SAMREC2009.pdf

Vann, J., Stephenson, P.R., Jackson, S., and Pilger, G. (2014). Common sense and good communication. *Mineral Resource and Ore Reserve Estimation – The AusIMM Guide to Good Practice*. 2nd edn. Melbourne: Australasian Institute of Mining and Metallurgy.

Reconciliation of produced grade and tonnage at AngloGold Ashanti

V. Chamberlain, T. Flitton, and R. Peattie

AngloGold Ashanti

In 2009 AngloGold Ashanti (AGA) identified the need to establish a group-wide reconciliation system as the basis for understanding potential opportunities and losses in the mining value chain. A code for the reconciliation of produced grade and tonnage accounts for all stages within the mining chain, including *in-situ* estimation, mining, transporting, processing, and recovery was therefore developed.

Any reconciliation process must measure the differences between each stage of the mining chain so as to provide useful management information regarding the quality of grade and tonnage estimation, dilution, and ore loss in the individual activities as well as across the operation as a whole. The reconciliation chain encompasses mass, density, and volume measurement, material sampling, sample preparation, chemical analysis, Mineral Resource estimation, data processing, as well as data storage and reporting. From a corporate viewpoint, adopting a consistent approach to the reconciliation of produced grade and tonnage allows a standardized framework for reporting that affords management the tools to easily compare between assets. At an operational level, it allows mine management to focus efficiently on the underlying cause of production problems and ensure that estimating, mining, and processing inefficiencies are discovered and can be corrected while improving the possibility of detecting metal theft or fraud. A fully integrated reconciliation process supported by accurate and relevant measurements allow an overall increase in the confidence in all activities across the reconciliation chain, including confidence in the stated Mineral Reserve.

AGA strives to achieve the highest possible accuracy in accounting and reconciliation activities, thereby improving the quality of management decisions across the entire value chain so as to return full value to the shareholder.

INTRODUCTION

AngloGold Ashanti (AGA) is a global company with operations encompassing varied mineralization styles and mining processing methods. Many of these operations were developed by other companies and incorporated into AGA through mergers and acquisitions. As a result, there was a need to implement consistent reconciliation of produced grade and tonnage standards across all operations. This ensures that the reconciliation is accurately reported and comparable with other operations in the Group – thereby supporting analysis and review.

Reconciliation in this context is defined as the process and practice of comparing measures and estimates of grade and tonnage along the full mining value chain in such a way as to identify inefficiencies and highlight opportunities. The stages within the mining chain include *in-situ* estimation, mining, transporting, processing, and recovery. Reconciliation is then the comparison between each of these stages. Over time AGA has developed a standardized approach for dealing with reconciliation for all its operations and has formalized this in a code signed off by the Chief Executive Officer (AngloGold Ashanti, 2009). This code applies to all company-managed mines in AGA and covers the accounting for grade and tonnage at specific stages through the production process, beginning with the Mineral Resource model through to Plant Accounted. The benefits in adopting a consistent approach to the reconciliation of produced grade and tonnage are:

- Ensuring that estimating, mining, and processing inefficiencies are discovered and corrected
- Improving the possibility of detecting precious metal theft or fraud
- Increasing confidence in all activities across the reconciliation chain and hence increasing confidence in the stated Mineral Reserve
- Improving the quality of management decisions across the entire value chain
- Providing a set of standard factors to be applied in mine planning.

ANGLOGOLD ASHANTI PROCESS

Tonnage and Grade Principles

The principles described below are the minimum that AGA operations need to comply with in conducting the reconciliation of production grade and tonnage. The reconciliation process is based on the idealized production reconciliation chain (Figure 1). Grade and tonnage should be measured or modelled at each stage in the reconciliation chain. Where measurement or modelling is not currently possible, site-specific criteria for estimation are developed and approved by the appointed senior reconciliation official. The number of estimations is limited as far as possible and implementation of measurement systems is addressed as a matter of priority. Any measurement has associated errors which include, but are not limited to, sampling errors, precision and accuracy issues, survey errors, grade modelling inaccuracies, incorrect tracking of material movements, and uncalibrated weightometers, densitometers, and flow meters (Riske *et al*., 2010). AGA requires that all sources of error be considered in interpreting the results and minimized wherever possible.

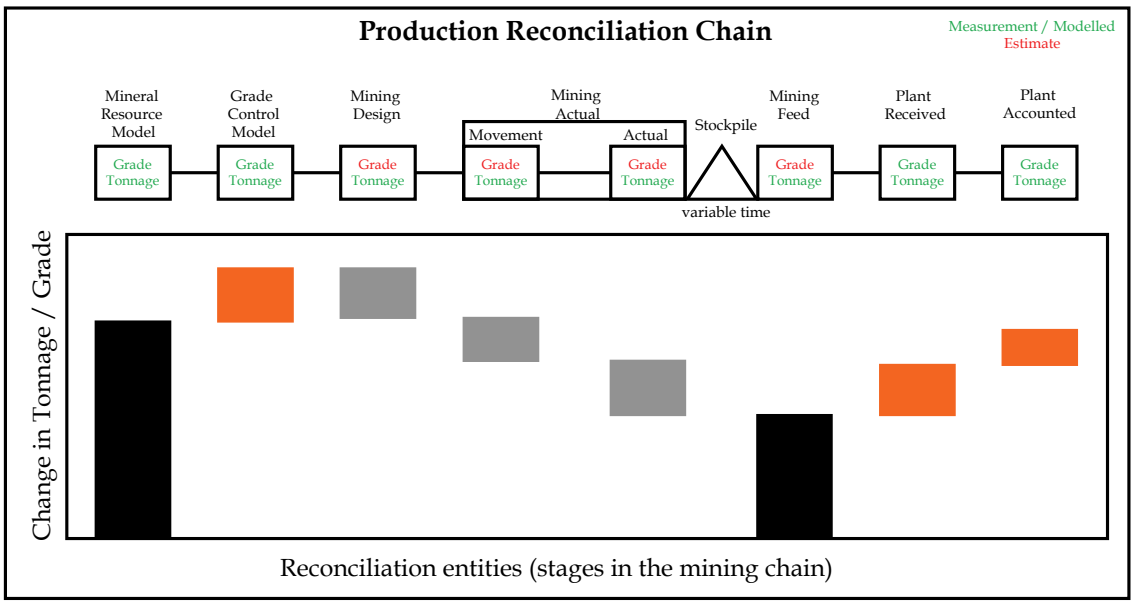


Figure 1. Idealized production grade and tonnage reconciliation chain.

To ensure consistency of reporting across the operations, the reconciliation entities (stages in the mining chain) are defined as follows (Figure 1):

- The Mineral Resource model represents the model on which the long-term planning was based. The grade and tonnage is reported for the monthly planned volume and is quoted at the mining cutoff grade for the selective mining unit (SMU) block size.

- The grade control model represents the final model used to predict grade and tonnage for mining. It must be created on the basis of additional sampling, post-exploration. This sampling must be at a tighter spacing than exploration drilling and may consist of channel sampling, reverse circulation drilling, or diamond drilling. The model must be created at least at the SMU block size. Where a difference exists between theoretical and actual SMU, reasons for this difference must be quantified. The grade and tonnage as reported will be for the SMU size at the mining cut-off and it will be constrained within the monthly planned volume

- The grade and tonnage for the Mining Design entity are estimated by a process of defining the volume to be mined. In the case of an open pit this would be the mining perimeter design, and in an underground case this would be the reef development and the stope design. Inherent in this process is the incorporation of planned dilution and planned ore loss into the grade and tonnage. The grades as estimated in the grade control model are assumed to be correct. Dilution grades must also be estimated from the grade control model

- The 'Mining Actual' may well consist of two measurements, *i.e.* Mining Movements and Mining Actual. If both of these are measured they are both reported. However, as a minimum, the mining actual is reported. The Mining Movements serve as a measure of production and the tonnage measurement comprises of records reflecting trucking, tramming, and/or hoisting. Grade is determined by assuming that the mine design grades hold for each design. Intentional redirection of material during the mining process is included in the estimation of tonnage and grade at this point. This estimate of grade and tonnage for the Mining Actual must consist of actual survey measurement, and the grades are once again derived by assuming the grade control grades are correct

- The Mining Feed entity (also known as 'Delivered to Plant') represents that grade and tonnage of material estimated to have been fed to the plant by the mine. Where large stockpiles are present the estimates of grade are divorced in time from the mining actual grades. This commonly results in grade discrepancies when large tonnages are fed ex-stockpile and results in the mining actual grades being swamped by less certain historic stockpile grades

- The Plant Received entity represents the grade and tonnage of material estimated to have been received by the plant. This consists of the measured head grade based on raw sample data and the head tonnage as measured

- The 'Plant Accounted' is the most accurate gold accounting metric for the operation and is essentially the total of the gold production and the gold in residue. The gold in residue must be calculated by using the average of all the tails sample grades and the processed tonnage. All sample data is also used in this calculation and is not altered/biased in any manner. It is critical that the integrity of the residue sample is not compromised in any way and that the samples are obtained, prepared, and analysed in line with the standards specified in the metal accounting code, a supported code of practice in AGA.

Reconciliation Process

The general manager for each operation appoints a senior official (preferably the most senior employee in the Mineral Resource/Mineral Reserve disciplines) as the official responsible for reconciliation of produced grade and tonnage. The reconciliation process involves the monthly

capturing, by the senior official, of key data per reconciliation entity into a web-based reporting system. The data that is captured is summarized (Figure 2) per month, rolling 3 months, and rolling 12 months.

Reconciliation is undertaken between each stage in the reconciliation chain and the previous stage. Percentage differences in grade and tonnage between each stage are calculated and reported (Figure 2). Benchmarks based on historical performance, and less commonly expected performance, are set between each stage in the mining chain for tonnage, grade, and gold. Significant deviations between the benchmarks and measured percentage differences are investigated and the findings, together with corrective action plans, are reported to management. To ensure that the benchmarks are fair and relevant, the final numbers are signed off and approved between line management and the relevant discipline head.

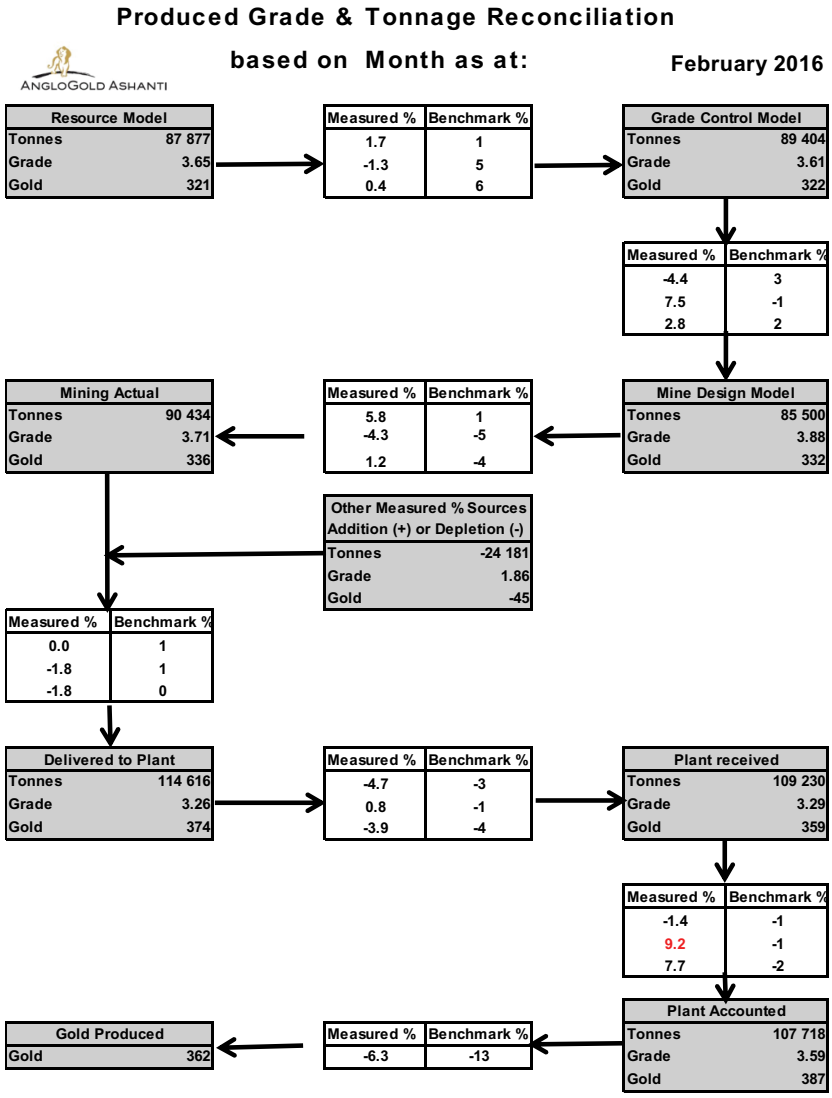


Figure 2. Example of the reconciliation chain showing measured and benchmark percentage difference (gold is reported in kilograms, grade is reported in grams per ton, and the red numbers are outside of the defined limits).

A work flow enabled web-based reporting system was developed in-house and provides a platform that ensures that a single version of the results is captured in a secure, auditable database. Not all the data needs to be captured as some of the key data is extracted from other reporting systems within AGA, thus avoiding duplication in capture as well as preventing multiple versions of key metrics

being made available that might be giving conflicting information. Responsibilities are assigned within the system that require work flow sign-offs and ensuring that the relevant people have access to the information for review and approval before it is reported to senior management. To ensure chain of custody and ownership through the company, regional comments on the operations data and findings are also captured.

Consolidation of the information and comments is then done centrally for all the operations where there is a final review that highlights significant variances requiring action by management.

The main aspects and functionality of the in-house reporting system include;

- Capture of the data electronically, ensuring a single version of the results and avoiding duplication of capture
- Transfer of required data from other databases where possible to avoid duplication of work
- The data is then stored in a single database and this information is made available to relevant individuals across various disciplines at different levels of the operation
- The reporting platform is a user-friendly interface where data and comments are summarized monthly and archived
- Users are assigned work flows and set levels of access. Emails are used as notifications once workflows are complete to inform the next level
- Significant deviations from benchmarks relative to a tolerance set in the system are highlighted and comments requested
- Regional and central staff are able to view the reconciliation chain in its entirety and to focus on the problem areas providing their comments and proposed actions to the operations
- Critical actions for each operation are reported at a Group level for upper management review and follow-up.

As a multidisciplinary system, this ensures that there are no artificial barriers between departments and supports the accountability being taken up at the right place.

The collection of consistent production data over a long period supports deeper analysis, including a further understanding of current mining and metallurgical processes as well as a measure of performance over time. Two of the measures that are routinely used are the long-term factor (LTF) and the short-term factor (STF).

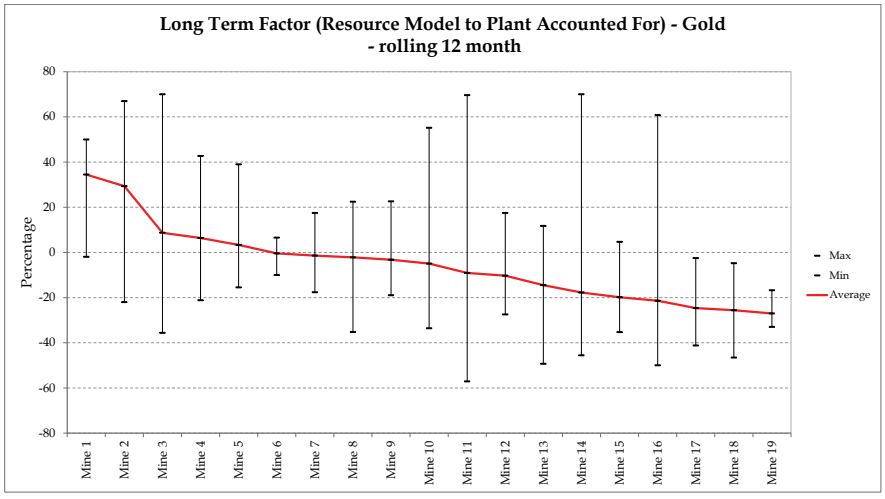


Figure 3. Rolling 12-month LTF for the Group.

The LTF has been developed as a measure of the overall performance of the Mineral Resource model and is defined as the percentage comparison between the Mineral Resource model and plant

accounted. STF is defined as the percentage comparison between the grade control model and plant accounted (often referred to as mine call factor in the South African context). An example of the LTF over a rolling twelve-month period for multiple mines within AGA is shown in Figure 3. Significant variations are highlighted and investigated. Comparative benchmarking between operations of similar estimation methods and mining methods is easily carried out and the process supports early decision-making around interventions that may be required.

Another example of a key measurable that is attained from the reconciliation framework is the Plant Unaccounted loss or gain. This is the percentage comparison between the Plant Received and Plant Accounted. An example of the rolling three-month period Plant Unaccounted loss or gain for multiple operations within AGA is shown in Figure 4. As with the LTF, significant variations are highlighted, leading to accurate interventions within the relevant metallurgical plants.

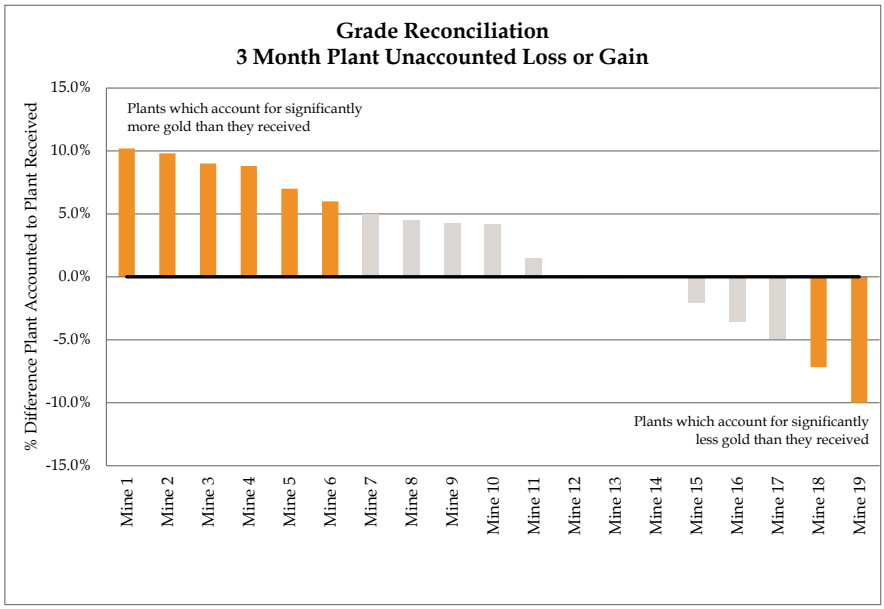


Figure 4. Rolling 3-month Plant Unaccounted loss and gain for the Group.

CONCLUSION

A consistent approach to the reporting of produced grade and tonnage within AGA has afforded the company the ability to quickly focus in on key operational issues and highlight the underlying causes, thus ensuring rapid response to capturing opportunities and reducing losses. Simultaneously, it has provided management with a mechanism to effectively benchmark the various operations across the Group, allowing sensible portfolio discussions to be held as a result of reliable and meaningful data.

The reconciliation of produced grade and tonnage for AGA has been reported for six years and over this time has consistently demonstrated its value add to both the Group and the individual operations within the Group. The collection of consistent production data over longer periods supports deeper analysis and further understanding of current mining and metallurgical processes as well as the measurement of performance over time.

REFERENCES

AngloGold Ashanti. (2009). Code for the reconciliation of produced grade and tonnage. Internal Report. 10pp.

Riske, R., Mark, P.D., and Helm, S. (2010). Mine reconciliation – for better or worse! *Canadian Institute of Mining, Metallurgy and Petroleum*, Vancouver. 8 pp.



Richard Peattie

VP Mineral Resource
AngloGold Ashanti

Graduated from the University of the Witwatersrand in 1992 with a BSc (Hons) in Geology and immediately started working career at Western Deep Levels Gold mine. Since then have worked in a number of roles and at a number of mines around the world in countries that included South Africa, Mali and the DRC. In 2007 got a Master of Philosophy in Geostatistics from the University of Queensland in Australia. Currently the VP Mineral Resources for AngloGold Ashanti based in Johannesburg.

Towards reliable geoscientific data and improved confidence in reporting through existing guidelines and standards: a case for inclusion in SAMCODES reporting

C. Zermatten

SRK Consulting (Pty) Ltd, Johannesburg, South Africa

The geotechnical design of open pit mines utilizes a geotechnical model, which in turn relies heavily on input from a number of other geoscientific disciplines. In collecting geoscientific data for the purpose of building a geotechnical model, a number of standards, guidelines and benchmarks can be utilized to facilitate accurate and relevant data collection. The purpose of a reliable data collection programme in geotechnical engineering is equivalent to that of a reliable ore sampling programme in resource/reserve estimation – that is, sound inputs are needed to produce meaningful results.

Geotechnical design faces additional challenges in that some of the input data is variable – such as changing groundwater conditions due to seasonal changes – and several elements produce range values, not absolute values, with the result that the Competent Person is tasked with applying their mind to selecting a suitable and representative value from the range of results. These elements combine to inform the level of confidence of geoscientific data and the extent of knowledge used when reporting Exploration Results, Mineral Resources, or Mineral Reserves under the South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves (the SAMREC Code). Consistent handling of data/information in **all** aspects of the mineral project is needed in order to facilitate transparent and material reporting.

While the standards, guidelines and benchmarks identified in this paper do not provide for the same clarity of quantity in the distinction of Reconnaissance, Inferred, Indicated, and Measured, as those in the South African National Standard (SANS) 10320, the information does build toward the essential aspects of geoscientific knowledge, consistency, reproducibility and therefore confidence. The paper aims to present information that addresses the standardization of the collection of technical data, for the purpose of conforming to the SAMREC principles of materiality, transparency and competency.

It is proposed that industry-wide discussion be undertaken to debate the merits of establishing and implementing a code for the reporting of geotechnical elements in mining that have been relied on during a Mineral Resource/Reserve classification. The code should reside alongside SAMREC, within the SAMCODE family, and is intended to attest the diligence and relevance applied to the geotechnical design process for the purpose of the design that is relied on during a Mineral Resource/Reserve valuation.

While the standards and benchmarks for geoscientific data used in the design of underground mines are equally relevant, they fall outside the scope of the paper.

INTRODUCTION

The design of open pit slopes relies on a variety of geoscientific data to build the geotechnical model, which ultimately identifies the optimum design configuration of the open pit. Largely, optimization reflects the configuration that is regarded as the steepest slope angle that can be achieved for a given rock mass, while adhering to acceptable safety criteria. This approach serves to maximize ore recovery while minimizing waste stripping throughout the life of the mine, in order to satisfy the economic needs of the owners of the mine. Figure 1 illustrates the potential impacts of slope steepening, namely increased access to ore.

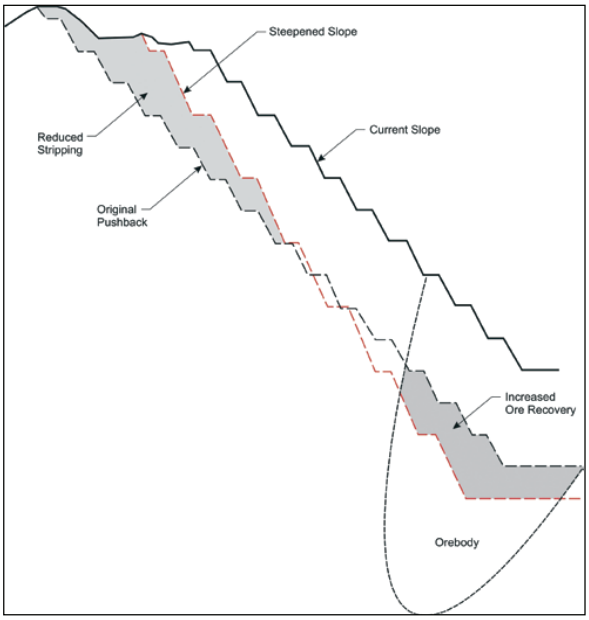


Figure 1. Potential impacts of slope steepening (CSIRO, 2008).

The design configuration is not an expression of will or desire – it is a reflection of the steady-state capacity of the rock mass that can be achieved having applied the rigours of mining.

Geological continuity can be considered to be of a 'fixed' nature, where geological units are fixed in place and unchanging. Sampling and further investigation may increase our knowledge and understanding of the geological units, but the geology itself does not change during sampling or during mining operations.

In contrast, several geoscientific aspects of slope design may be considered to be 'variable'; for example, water levels, which may fluctuate in response to seasonal (or unseasonal) rainfall leading to an increase in pressure behind the slope face. Other aspects that influence the design are the quality of in-pit drilling and blasting. For example, poor drilling and blasting may cause significant fracturing and deterioration of the rock mass behind the mine design line, which in turn may adversely affect the performance of the benches and the capacity of catch berms, leading to more 'clean-up' operations and potentially shallower slope angles. While these aspects may be measured during monitoring programmes, they may very well change as mining continues. Such aspects are relevant because the optimized design is based on a number of inputs, as well as the interplay between the different inputs, and subsequently, failing to reach the optimized slope angles (*i.e.* implementing shallower slope angles than designed) results in increased stripping costs and potentially sterilization of ore – which may not have been suitably accounted for in the initial estimation report in accordance with the South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves (SAMREC Code).

It has been stated that, other than the coal commodity-specific South African National Standard (SANS) 10320, the South African Mineral Codes (SAMCODES) have no recognized guidelines or standards for geoscientific data (Southern African Institute of Mining and Metallurgy (SAIMM), 2015). The current paper takes the opportunity to present recommendations on recognized guidelines, standards and industry benchmarks for the collection of geoscientific data for open pit mines, for the purpose of conforming to the SAMREC principles of materiality, transparency and competency.

It is important that the nature and extent of the geoscientific data be described to provide insight into the confidence in the data for the purpose of interpretation as a modifying factor in SAMREC reporting.

OPEN PIT SLOPE DESIGN

The process of designing a stable open pit slope is illustrated in Figure 2 (CSIRO, 2008), where many aspects are interactive and/or iterative (Zermatten and Terbrugge, 2015). At the start of the process, the geological, structural, rock mass and hydrogeological models are required in order to build the geotechnical model. Each of these models has requirements in itself, and the subsections below will explore existing standards, guidelines and benchmarks available to facilitate reliable data collection for the different aspects of investigations.

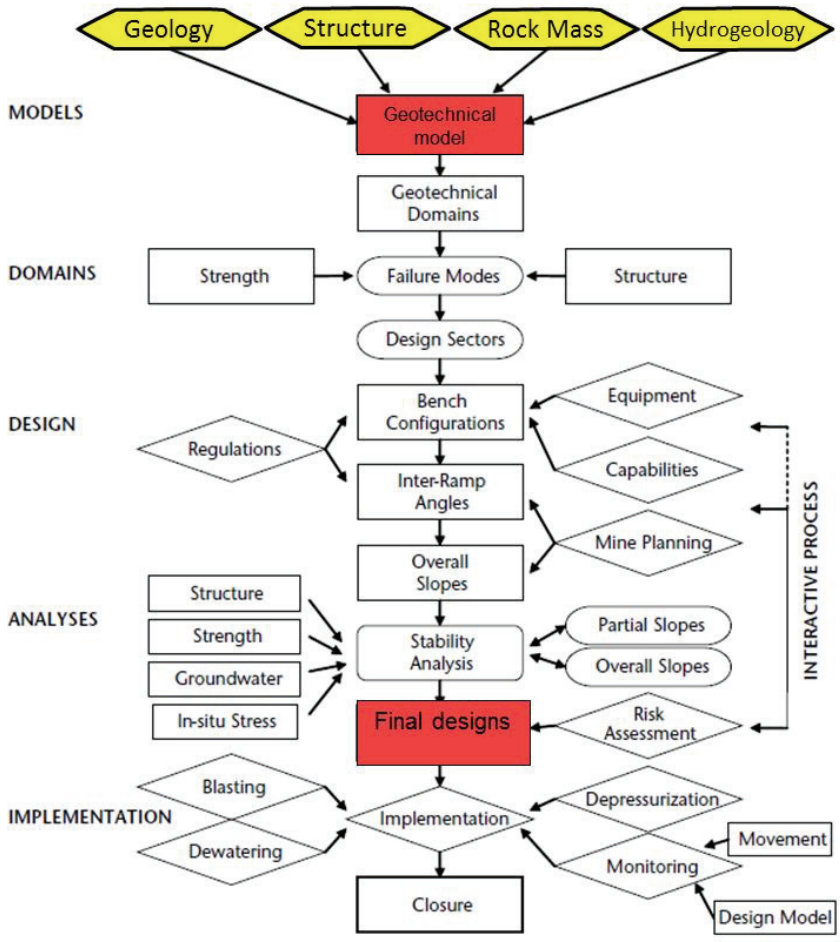


Figure 1. The slope design process (modified from CSIRO, 2008) (author's emphasis using coloured blocks).

INTERRELATEDNESS OF DATA ASPECTS

With regard to data collection and knowledge acquisition for the purpose of geotechnical design, the following aspects are relevant:

- '**Why'** various data should be collected (philosophy of design approach and purpose of data during modelling)
- '**When'** the data needs to be collected (timing with regard to investigations for scoping, prefeasibility and feasibility studies)
- '**What'** type of data should to be collected (for example, reading a piezometric level *versus* acquiring pore pressure data in groundwater investigations, or measuring the orientation of discontinuities *versus* spacing of discontinuities in structural investigations)
- '**How much**' data is needed (*i.e.* quantity of data)
- '**How**' the data is collected within an established scientific framework.

Each aspect deserves discussion; the themes of uncertainty, quality and quantity of data for geotechnical design are very important in informed discussion for the purpose of SAMREC-compliant reporting. In the realm of geotechnical engineering, these themes are very topical and draw increased levels of professional interest and research.

However, for practical reasons only the concept of '**how**' geotechnical data could be reliably collected will be addressed in the current paper. It is envisioned that detailed discussions (and associated publications) will follow the SAMREC/SAMVAL 2016 Companion Volume Conference.

GEOSCIENTIFIC DATA AND KNOWLEDGE

The input data for the geotechnical model is collected for geological, structural, rock mass and hydrogeological models through indirect and direct means. Data is collected remotely using relevant technologies or collected *in situ*, such as identification, measurements and descriptions (qualitative and quantitative) that enable characterization and subsequently classification. Samples are collected and undergo laboratory testing. Rating systems, characterization frameworks, and classification schemes are utilized when processing geotechnical data.

The output is typically a database from which the required parameters can be extracted, and these in turn serve as input into further rigorous computational analysis to determine stable design configurations. The geotechnical engineer applies professional judgement in many regards, and the process as a whole, builds the geoscientific knowledge that forms part of the mine design and ultimately, the SAMREC-reportable concept of confidence.

Sources of data uncertainty

A comprehensive discussion of data uncertainty relevant to open pit mine design is provided in CSIRO (2008). In summary, data uncertainty can be attributed to three sources:

1. Geological uncertainty, which considers the difficulty in correctly identifying and understanding geological components and their relationships
2. Parameter uncertainty, which represents the uncertainties of the values for the parameters used to account for various attributes of the geotechnical model
3. Model uncertainty, which encompasses the selection of suitable computational methods of analysis.

Quality of data

Given the array of elements that will be incorporated in a mine design study, it is important that each element be suitably described and recorded. The quality of the descriptions and measurements (being

relevant, accurate and precise) is facilitated through competency of the person making the descriptions and taking the measurements.

Quantity of data
Unlike SANS 10320 for the evaluation of coal resources and reserves, there as yet are no fixed requirements for other commodities as to the amount of data (or the extent of different types of data) required. Similarly, the quantity of data for the design of slopes in open pit mines is not yet prescribed, although qualitative guidelines are in place (CSIRO, 2008).

The addition of more data points to the database does not necessarily always increase the confidence level associated with the data – for the reason that standard deviation may increase, compelling the geotechnical engineer to make an informed, but subjective, decision on the representative value for a given parameter. This phenomenon can be observed, for example, in joint orientation data. Advances in computational analysis allow for the inclusion of statistical variability, although the input data still needs to be sound and the statistical relationship of the data needs to be meaningful (*i.e.* the raw data-set must be large enough to facilitate useful interpretation).

Competency
The collection of some geoscientific data may be somewhat subjective – for example, the description of the extent of weathering and/or alteration, or the determination of whether a break in the drill core is natural or artificially induced. Therefore, in order to acquire reliable and accurate data, it is vital that the data be collected by suitably trained and experienced personnel. To emphasise the importance of competency, an example of drill core logging is presented, where Figure 2 shows 'discing' in drill core. Discing is a drilling-induced phenomenon (Stacey, 1982) and an inexperienced person carrying out geotechnical core logging may be inclined to count each and every 'break' and record them as natural discontinuities, with the result that the rock mass rating would be downgraded, and in turn, initial slope design angles may be shallower to accommodate what is perceived to be a poor quality rock mass.



Figure 2. ***'Discing'*** *– a drilling-induced phenomenon; pictured using drill core in core tray (Flotmann et al., 2004).*

Confidence in geoscientific knowledge and reporting thereof
Currently, reporting on the confidence in geoscientific data is highly variable and subjective, whereby descriptions of the adequacy/inadequacy of the data, or problems encountered during the open pit slope design process, are described qualitatively in geotechnical reports. The results of these reports are typically summarized for inclusion in financial evaluations of projects without transferring all the 'ifs' and 'buts' identified during the open pit slope design project.

The initiative to identify a reporting framework for geotechnical data – as that for the minerals reporting framework of the SAMCODES – is very topical and draws increased levels of professional interest and research. It is envisioned that detailed discussions (and associated publications) will follow the SAMREC 2016 Companion Volume Conference.

While the SAMREC Code concerns itself with Mineral Resources and Reserves and does consider the role of Modifying Factors (some in turn depend on geoscientific data, *e.g.* geotechnical or geometallurgical data), it would be impractical to include new and detailed codes for all of the data underlying the Modifying Factors – the report would expand into an impractically cumbersome and indigestible document.

However, given that the slope design is essential for facilitating a number of other financial considerations to assess the viability of the project (examples of which are suggested in Table I), it is proposed that industry-wide discussion be undertaken to debate the merits of establishing and implementing a specific code that may be overseen, for example, by a South African Mining Geotechnical Committee (SAMGEOT) with regard to the reporting of geotechnical elements in mining that have been relied on during a Mineral Resource/Reserve classification. The code should reside alongside SAMREC, within the SAMCODE family.

It is proposed that existing principles from the SAMCODE family be carried over to the geotechnical reporting code, in that:

- It should not be prescriptive
- It should not be an exhaustive account of every step of the geotechnical data processing stages; rather, it is intended to provide a ***record of significant model assumptions and methods used***
- It should not be used to repeat literature on the theoretical aspects of sampling, modelling, engineering, computer software programming, and so on
- It should neither conflict nor repeat information that is already contained in any other SAMCODE report
- It should neither conflict with nor attempt to replace SAMCODE ideals, but rather should work synchronously with the elements that have already been identified within the philosophies of the SAMCODE and the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) International Reporting Template (IRT)
- Relevance and materiality should inform the decision on what information is made available to the reader
- It should ultimately *'report all matters that might materially affect a reader's understanding or interpretation of the results'* [in the geotechnical direction].

The information for reporting is intended to attest the diligence and relevance applied to the geotechnical design process for the purpose of the design that is relied on for a Mineral Resource/Reserve valuation.

Table I. Examples of elements linked to changes in design of overall slope angle which may potentially affect viability of project (not exhaustive).

Thematic planning considerations	**Aspect**	**Consider scenario where 'planned' *vs* 'actual' differ**	**Variation occurs**	**May result in**
Financial	Cost of removing a predicted volume of overburden is used to estimate viability of project	Slope angle implemented needs to be shallower than initially expected	More overburden needs to be removed than initially expected, resulting in increased expenditure	Actual profitably of operation lower than forecast profitability
Financial	Income earned from selling a predicted volume of ore is used to estimate viability of project	Slope angle implemented needs to be shallower than initially expected	Less ore is accessible than initially expected, resulting in decreased revenue	Actual profitably of operation lower than forecast profitability
Financial, safety and reputational	The type, quality and/or quantity of data, used in the geotechnical design does not match level of investigation of Mineral Resource/ Reserve classification The assumptions applied during modelling are not well-suited to the environment being modelled	Implemented slope angle is not supported by the data used or models run	The slope (in whole or in part) requires the implementation of additional elements to maintain stable design and safe operations Failure occurs (*e.g.* multi-bench, stack or overall slope failure)	Loss of access to ramp, which subsequently interrupts mining for an indeterminate length of time Injuries – therefore a Section 54 stoppage which subsequently interrupts mining for an indeterminate length of time Tarnished reputation, which in turn may result in withdrawal of investor support or may affect operation in other ways Additional expenditure to install the additional elements, make safe the design, clean up failure Actual profitably of operation differs to forecast profitability *Force majeure*

INDUSTRY BENCHMARKS, GUIDELINES AND STANDARDS

Industry benchmarks provide insight into routine practices, accepted norms, common assumptions and typical outcomes for a given aspect, but they are not necessarily 'optimized'; rather, they represent 'commonly accepted' elements. Nevertheless, industry benchmarks can be very useful when no other formal prescription is available.

Guidelines, such as the 'Guidelines for Open Pit Slope Design' (CSIRO, 2008) and its companion publication 'Guidelines for Evaluating Water in Pit Slope Stability' (CSIRO, 2014), explore and describe fundamental principles that form part of the design of stable slopes in open pit mines. In implementing the principles, the use of international standards further improves the credibility of the undertaking.

The benefits of utilizing guidelines and standards are significant, as they facilitate:

- Consistency of nomenclature
- Predictability of work elements
- A standardized approach that subsequently enables comparisons and evaluations
- Performance assessment and/or auditing of work elements and/or outcomes
- A minimum or optimum (as the case may be) level of work to be conducted
- Tolerance limits for relevant aspects
- The best practice (for the relevant aspect) that has been established over time by experts in a specific field of the professional industry.

The International Organization for Standardization (ISO) is the *'world's largest developer of voluntary international standards'* (ISO, 2015a) and these appear with prefix 'ISO-'. Different countries, as well as regions within a country, may establish their own standardization institutions and formulate standards in response to applicable legal directives (Bach, 2010). In South Africa, the South African Bureau of Standards (SABS) was established as a statutory body in terms of the Standards Act 24 of 1945 (as amended) and continues to operate in terms of the Standards Act 8 of 2008 (as amended) (SABS, 2015). The SABS formulates standards (which are not intended to conflict with ISO-standards) that are prefixed with 'South African National Standard' (SANS).

It is to be noted that every reasonable effort has been made to cite the most recent [updated] version of the guidelines and standards. However, such documents are reviewed and revised by their respective institutions on an ongoing basis and as such it is possible that documents may be revised, replaced, or withdrawn during the period of preparation of the paper and its publishing in the SAMREC Companion Volume.

Because the collection of geoscientific data encompasses many elements, the standards are grouped 'approximately' in the subsections below – but the lists are by no means exhaustive. The objective of the paper is to draw attention to the wide array of work that has already been completed by organizations worldwide to standardize geoscientific methods, techniques and tests with the end purpose of recommending the inclusion of many of the standards into geotechnical investigations for open pit mining projects, with the rationale that:

> *'Greater control, consistency and reproducibility serve to reduce uncertainty, and in turn, increase confidence'.*

The relative increase in confidence in geoscientific data is illustrated simplistically in Figure 4. Eventually, this confidence in geoscientific data can carry forward the spirit of the SAMCODE reporting philosophy.

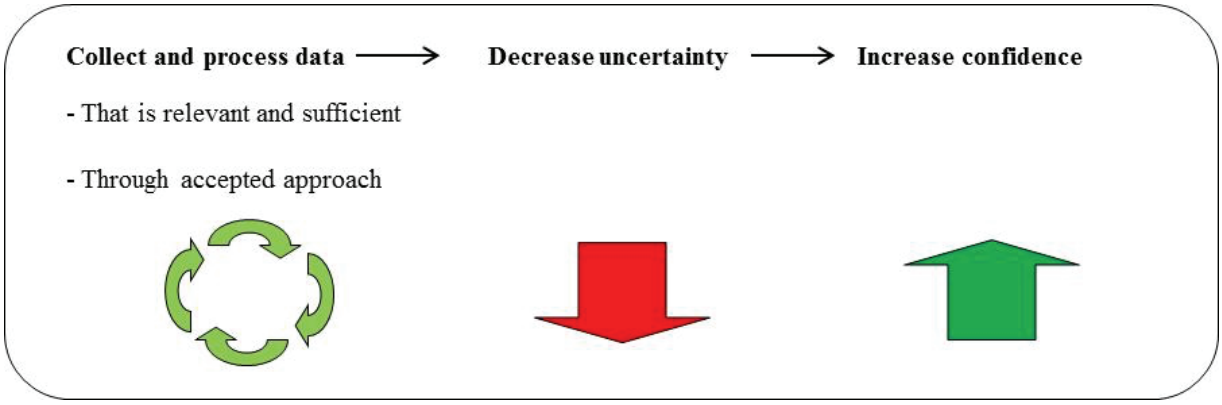


Figure 4. Simple approach to increasing confidence in geoscientific data.

Geotechnical site investigations
The Eurocode 7, *viz*. EN1997-1 (Austrian Standards Institute, 1997) and EN1997-2 (Austrian Standards Institute, 2007), provide an extensive publication with comprehensive explanations on all aspects to be considered during geotechnical site investigations. Although the publications are primarily intended for geotechnical site investigations as part of civil engineering projects, many of the aspects can be translated into site investigations for mining engineering projects – in terms of the breadth, type and manner of collection of geotechnical data.

In addition, general elements to be addressed in geotechnical site investigations are explained in:
- The United States Army Corps (2001), including an overview of surface and subsurface investigations in document EM 1110-1-1804
- The South African Institute of Civil Engineering (SAICE) (2010) code of practice established by the geotechnical division
- British Standard (BS) 5930: 2015 (code of practice for ground investigations) which has replaced BS5930:1999 (code of practice for site investigations) formulated through the British Standards Institution (BSI) (2015a)
- ASTM D653 – 14 (Standard Terminology Relating to Soil, Rock, and Contained Fluids)

Groundwater measurements
The technical principles of sampling groundwater and taking groundwater measurements are dealt with in ISO 22475-1:2006.

Geological mapping
For naming formally approved lithostratigraphic units in South Africa, the South African Committee for Stratigraphy (SACS) catalogue of South African Lithostratigraphic Units (SACS, 1999) applies.

The United States Army Corps (2001) provide an overview, including mapping elements, of regional geologic investigations in document EM 1110-1-1804.

The ISO standard for representing graphical symbols on detailed maps, plans and geological cross-sections has several parts:
- ISO 710-1:1974 (Graphical symbols for use on detailed maps, plans and geological cross-sections - Part 1: General rules of representation)
- ISO 710-2:1974 (Part 2: Representation of sedimentary rocks)
- ISO 710-3:1974 (Part 3: Representation of magmatic rocks)
- ISO 710-4:1982 (Part 4: Representation of metamorphic rocks)
- ISO 710-5:1989 (Part 5: Representation of minerals)

- ISO 710-6:1984 (Part 6: Representation of contact rocks and rocks which have undergone metasomatic, pneumatolytic or hydrothermal transformation or transformation by weathering)
- ISO 710-7:1984 (Part 7: Tectonic symbols).

Identification and description of soil and rock
In recording information during field exercises (*e.g.* using drill-holes, auger holes, excavated pits, and other subsurface exposures such as roadside cuts or stream banks) ASTM D5434–03 presents a standard guide for the field logging of subsurface explorations of soil and rock.

Aspects for the identification and classification of soil appear in ISO standards such as:
- ISO 14688-1:2002 (Geotechnical investigation and testing - Identification and classification of soil - Part 1: Identification and description)
- ISO 14688-2:2004 (Geotechnical investigation and testing - Identification and classification of soil - Part 2: Principles for a classification).

The American Society for Testing and Materials (ASTM) provides for understanding soils through:
- D2487-11 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
- D2488-09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

Similarly, in terms of rock, the ISO standard ISO 14689-1:2003 for geotechnical investigation and testing deals with the identification and classification of rock (*i.e.* Part 1: Identification and description).

The International Society for Rock Mechanics (ISRM) has compiled and published a number of suggested methods for rock characterization, testing, and monitoring (ISRM, 2006). The suggested methods include:
- The Quantitative Description of Discontinuities in Rock Masses
- In Situ Stress Measurement Using the Compact Conical-Ended Borehole Overcoring (CCBO) Technique
- Rock Stress Estimation.

Specific elements of geotechnical drill core
ASTM D2113–14 provides for the standard practice for core drilling and sampling of rock for site exploration, followed by ASTM D5079-08 which describes standard practices for preserving and transporting drill core rock samples.
The ISO Technical Committee (TC) 82 has a number of standards relating to equipment for drilling and mine excavation – including:
- Rock drilling equipment
- Rotary core diamond drilling equipment - System A (metric units) and System B (inch units)
- Wireline core diamond drilling equipment - System A (metric units) and System B (inch units).

Once the drill core has been made available, the standard test method for determining rock quality designation (RQD) of rock drill core is described in ASTM D6032–08.

Index and laboratory testing
ISRM (2006) elaborate on suggested methods for determining, for example, direct tensile strength, the strength of rock materials in triaxial compression and large-scale sampling and triaxial testing of jointed rock.

The ISO 22476 series (ISO, 2015b) covers geotechnical field testing – including electrical cone and piezocone penetration testing, dynamic probing, standard penetration testing, flexible dilatometer testing, and mechanical cone penetration testing.

The ISO 17892 series (ISO, 2004b) covers geotechnical laboratory testing of soil, including the determination of water content, bulk density, particle density, particle size distribution, unconfined compression on fine-grained soils, unconsolidated undrained triaxial testing, consolidated triaxial compression tests on water-saturated soils, direct shear, permeability, and Atterberg limits.

The ISO 22282 series (ISO, 2012) describes the general rules and principles for geohydraulic testing in soil and rock, addressing water permeability, water pressure in rock and pumping and infiltrometer tests.

The Eurocode 7, *viz*. EN1997-1 (Austrian Standards Institute, 1997) and EN1997-2 (Austrian Standards Institute, 2007), provides an extensive list of both (*in-situ*) index testing information and (*ex-situ*) laboratory testing standards relevant to geotechnical investigations. While the author aims to draw attention to the comprehensive nature of the Eurocode 7, for practical reasons the list of standards applicable to laboratory testing is not reproduced here.

CONCLUSION

A number of international guidelines and standards are available for adoption to facilitate the gathering of reliable geoscientific data for the purpose of improved confidence and incorporation into the SAMCODE reporting framework. While the guidelines and standards do not all prescribe the amount of data (or the extent of different types of data) required, such as SANS 10320 provides for the evaluation of coal resources and reserves, they do fulfil a much needed role of providing consistency and enabling reliable, reproducible results. Greater control, consistency and reproducibility serve to reduce uncertainty, and in turn, increase confidence.

Currently, standards are available for a number of aspects during the geotechnical programme - including geotechnical site investigations, groundwater measurements, geological mapping, identification and description of soil and rock, specific elements relating to drill core, as well as index and laboratory testing of soil and rock.

While the SAMREC Code concerns itself with Mineral Resources and Reserves and does consider the role of Modifying Factors, it would be impractical to include new and detailed codes for all of the data underlying the Modifying Factors (some of which may rely on geotechnical data). It is proposed that industry-wide discussion be undertaken to debate the merits of establishing and implementing a specific code with regard to the reporting of geotechnical elements in mining that have been relied on during a Mineral Resource/Reserve classification. The code should reside alongside SAMREC, within the SAMCODE family.

REFERENCES

Bach, C. (2010). Attack of the Clones: Why are there so many versions of some ISO standards? http://standardsforum.com/attack-of-the-clones-why-are-there-so-many-versions-of-some-iso-standards/ [Accessed 29 October 2015].

American Society for Testing and Materials (ASTM). (2003). ASTM 5434 – 03 Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock. West Conshohocken, PA.

American Society for Testing and Materials (ASTM). (2008). ASTM D6032 – 08 Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core. West Conshohocken, PA.

American Society for Testing and Materials (ASTM). (2008). ASTM D5079-08 Standard Practices for Preserving and Transporting Rock Core Samples. West Conshohocken, PA.

American Society for Testing and Materials (ASTM). (2009). D2488-09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). West Conshohocken, PA.
American Society for Testing and Materials (ASTM). (2011). D2487-11 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System). West Conshohocken, PA.
American Society for Testing and Materials (ASTM). (2014). ASTM D653 – 14 Standard Terminology Relating to Soil, Rock, and Contained Fluids. West Conshohocken, PA.
American Society for Testing and Materials (ASTM). (2014). ASTM D2113 – 14 Standard Practice for Rock Core Drilling and Sampling of Rock for Site Exploration. West Conshohocken, PA.
Austrian Standards Institute. (1997). ÖNORM Eurocode 7, Geotechnical design, Part 1: General rules, EN1997-1. Vienna.
Austrian Standards Institute. (2007). ÖNORM Eurocode 7, Geotechnical design, Part 2: Ground investigation and testing, EN1997-2. Vienna.
British Standards Institution (BSI). (2015). BS5930: 2015 Code of practice for ground investigations. London.
British Standards Institution (BSI). (2015a). BS5930:1999. London. http://shop.bsigroup.com/ProductDetail/?pid=000000000030190275 [Accessed 31 October 2015].
Commonwealth Scientific and Industrial Research Organisation (CSIRO). (2008). Guidelines for Open Pit Slope Design. CSIRO Publishing, Clayton, Victoria, Australia.
Commonwealth Scientific and Industrial Research Organisation (CSIRO). (2014). Guidelines for Evaluating Water in Pit Slope Stability. CSIRO Publishing, Clayton, Victoria, Australia.
Flottman, T., Campagna, D.J., Hillis R., and Warner, D. (2004). Horizontal microfractures and core discing in sandstone reservoirs, Cooper Basin, Australia. *Proceedings of Eastern Australasian Basins Symposium II*. Boult, P.J., Johns D.R., and Long S.C. (eds). Petroleum Exploration Society of Australia (PESA). pp. 689-694.
International Organization for Standardization (ISO). (1974). ISO 710-1:1974 (Graphical symbols for use on detailed maps, plans and geological cross-sections -- Part 1: General rules of representation). Geneva.
International Organization for Standardization (ISO). (1974). ISO 710-2:1974 (Part 2: Representation of sedimentary rocks). Geneva.
International Organization for Standardization (ISO). (1974). ISO 710-3:1974 (Part 3: Representation of magmatic rocks). Geneva.
International Organization for Standardization (ISO). (1982). ISO 710-4:1982 (Part 4: Representation of metamorphic rocks). Geneva.
International Organization for Standardization (ISO). (1984). ISO 710-6:1984 (Part 6: Representation of contact rocks and rocks which have undergone metasomatic, pneumatolytic or hydrothermal transformation or transformation by weathering). Geneva.
International Organization for Standardization (ISO). (1984). ISO 710-7:1984 (Part 7: Tectonic symbols). Geneva.
International Organization for Standardization (ISO). (1989). ISO 710-5:1989 (Part 5: Representation of minerals). Geneva.
International Organization for Standardization (ISO). (2002). ISO 14688-1:2002 (Geotechnical investigation and testing -- Identification and classification of soil -- Part 1: Identification and description). Geneva.
International Organization for Standardization (ISO). (2003). ISO 14689-1:2003 (Geotechnical investigation and testing -- Identification and classification of rock -- Part 1: Identification and description). Geneva.
International Organization for Standardization (ISO). (2004a). ISO 14688-2:2004 (Geotechnical investigation and testing -- Identification and classification of soil -- Part 2: Principles for a classification). Geneva.
International Organization for Standardization (ISO). (2004b). ISO/Technical Committee 182/Subcommittee 1: Geotechnical investigation and testing, ISO 17892 (Part 1 to Part 12). Geneva.

International Organization for Standardization (ISO). (2006). ISO 22475-1:2006 (Geotechnical investigation and testing - Sampling methods and groundwater measurements - Part 1: Technical principles for execution). Geneva.
International Organization for Standardization (ISO). (2012). ISO/Technical Committee 182/Subcommittee 1: Geohydraulic testing, ISO 22282 (Part 1 to Part 6). Geneva.
International Organization for Standardization (ISO). (2015a). About ISO. http://www.iso.org/iso/home/about.htm [29 October 2015].
International Organization for Standardization (ISO). (2015b). ISO/Technical Committee 182/Subcommittee 1: Geotechnical investigation and testing, ISO 22476 (Part 1 to Part 15). Geneva.
International Society for Rock Mechanics (ISRM). (2006). The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006. Hudson, J.A. and Ulusay, R. (eds). ISRM Turkish National Group, Ankara, Turkey.
Shen, J. and Karakus, M. (2014). Simplified Method for Estimating the Hoek-Brown Constant for Intact Rocks. *Journal of Geotechnical and Geoenvironmental Engineering*. 140 (6), 8.
South African Bureau of Standards (SABS). (2004). South African National Standard (SANS) 10320:2004. South African Guide to the Systematic Evaluation of Coal Resources and Coal Reserves. Pretoria.
South African Bureau of Standards (SABS). (2015). About SABS. https://www.sabs.co.za/About-SABS/index.asp [29 October 2015].
South African Institute of Civil Engineering (SAICE) Geotechnical Division. (2010). Site Investigation - Code of Practice.
Southern African Institute of Mining and Metallurgy (SAIMM). (2015). The SAMREC/SAMVAL Companion Volume Conference. http://www.saimm.co.za/component/virtuemart/?page=shop.getfile&file_id=772&product_id=101 [Accessed 28 October 2015].
South African Committee for Stratigraphy (SACS). (1999). Catalogue of South African Lithostratigraphic Units. Vol. 6. Council for Geoscience, Pretoria.
South Africa. (2008). Standards Act 8 of 2008 (as amended). Government Gazette, vol. 517, no. 31253, 18 July 2008, as amended.
South Africa. (1945). Standards Act 24 of 1945, (as amended).
Stacey, T.R. (1982). Contribution to the mechanism of core discing. *Journal of the Southern African Institute of Mining and Metallurgy* 82, 269-276.
United States Army Corps of Engineers. (2001). Engineering and Design - Engineer Manual: Geotechnical Investigations EM 1110-1-1804. Washington, DC.
Zermatten, C and Terbrugge, P.J. (2015). Slope instability in the public realm – A motivation for systematic geotechnical data collection and reporting to facilitate sharing of lessons learned. *Proceedings of the International Symposium on Slope Stability in Open Pit Mining and Civil Engineering*, Cape Town. Southern African Institute of Mining and Metallurgy, Johannesburg.



Carrie Zermatten

Engineering Geologist
SRK Consulting (Pty) Ltd

Carrie is an engineering geologist at SRK Consulting and has been involved in mining for 11 years. She specialises in risk assessments (qualitative and quantitative) and project management. Her expertise extends to slope stability investigations including database compilation, analyses (empirical, kinematic and numerical) and interpretation. She has worked in Botswana, Mozambique, Uganda, Japan and extensively throughout South Africa; she has previously conducted techno-economic evaluations for alluvial diamonds, feldspar, tungsten, mica, sandstone, sand, kaolinite and coal deposits amenable to exploitation by small-scale miners.

The quantification of environmental and social risks as SAMREC modifying factors for decision-making in the business case

C. Zermatten, B. Liber, and R. Dixon

SRK Consulting (Pty) Ltd, Johannesburg, South Africa

Diligent consideration and comprehensive assessment of various modifying factors that may affect the relationship between Exploration Results, Mineral Resources and Mineral Reserves are required in order to achieve the aims and intentions of the South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves (SAMREC Code).

Environmental and social risks form part of the modifying factors which are duly considered during the conversion of Resources to Reserves. While the concept of 'social licence to operate' is readily acknowledged regarding mining projects, the quantification of environmental and social risks for the business case will benefit from more attention.

The paper introduces relevant topics to the theme of the quantification of environmental and social risks, risk assessment, as well as risk management and mitigation, which may influence the business case of the conversion of Resources to Reserves. The initiation of the South African Guideline for the Reporting of Environmental, Social and Governance Parameters within the Mining, Oil and Gas Industries (the SAMESG Guideline), which is overseen by the South African Environmental, Social and Governance Committee (SAMESG) Working Group, is introduced.

The paper serves to bridge the paradigms of social licence and the quantification of environmental and social risk for the business case. International and national case examples are mentioned to show the potential of these aspects for significant disruption to mining projects.

INTRODUCTION

Globally, many organizations are voluntarily moving toward greater transparency regarding reporting material governance aspects, with the goal of conforming to ideals of 'good corporate citizenship' and, *inter alia*, communicating the organization's intention to abide by acceptable business practices. Environmental and social responsibility and sustainability are often closely linked to the governance ideals of a forward-thinking organization.

Simultaneously, the need for transparent reporting around mining projects has been recognized by the minerals industry. To address this aspect, international professional bodies were created such as the (now defunct) Council of Mining and Metallurgical Institutes (CMMI), the International Council for Mining and Metals (ICMM), and the Committee for Mineral Reserves and International Reporting Standards (CRIRSCO). ICMM and its members, which consist of mining and metals companies, national and regional mining associations, and global commodity associations, strive to address the core sustainable development challenges faced by industry members (ICMM, 2015). CRIRSCO's affiliated members, the National Reporting Organizations (NROs), are responsible for developing mineral reporting codes, standards, and guidelines in their respective countries.

In developing a mineral reporting code for South Africa, the South African Mineral Resource Committee (SAMREC) Working Group has established the South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves (the SAMREC Code). The Code sets out minimum standards, recommendations, and guidelines. Over time, opportunities for guidance, clarification, and improvement to the Code have been identified, and have been implemented through discussion documents, guidance notes and/or updates. The improvements foster a '*greatly increased sense of understanding and maturity in resource reporting in South Africa*' (SAMCODE News, 2008).

In addition to the launch of the 2016 updates to the SAMCODES, examples of advances in the Codes are shown in:

- The SAMVAL Guidance note (South African Mineral Resource Committee/ South African Mineral Asset Valuation Committee (SSC), 2009), which differentiated between the definitions of 'weighed' and 'weighted' in order to limit the application of subjective weightings to individual value ranges determined by the Cash Flow, Market, and Cost approaches when determining a final value
- The SSC Working Group (2011) circulated an issue paper for comment and discussion, having identified '*important debate concerning the problems relating to consistent and unambiguous presentation of Mineral Resource and Mineral Reserve Statements in the minerals industry*'. The issue dealt with wording which allowed companies to report Resources inclusive or exclusive of Reserves
- The update of the 20090 SAMVAL Code which had been initiated '*as a result of certain inconsistencies in the current Code, but also as a result of a number of external activities and events that have created the need for the update*' (McFarlane, 2012)
- Application and alignment of the principles of the Codes to complementary reporting requirements for mineral-specific sectors such as those presented by Lomberg (2014) at the Regional Workshop on Application of United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources (UNFC) 2009 to uranium resources
- Critical discussion of the Codes such as those presented by Rupprecht (2014).

The role of '*external activities and events*' has also prompted developments with regard to elements *within* the Codes. In the context of SAMREC Modifying Factors, greater consideration of environmental and social risks represents some of the elements prompting development. In this regard, the South African Guideline for the Reporting of Environmental, Social and Governance [ESG] parameters within the mining industry (the SAMESG Guideline) has been

initiated by the South African Environmental, Social and Governance Committee (SAMESG) Working Group.

SAMESG

The SAMESG Guideline has been written in alignment with the existing SAMCODES and is intended to ensure that adequate information is provided on ESG matters and their role in assessing the '*reasonable and realistic prospects for eventual economic extraction in the extractive industries*' (SAMESG Working Group, 2015; South African Mineral Codes, 2015).

The Guideline is divided into

- Part I, which describes the application of the principles
- Part II, which identifies requirements regarding competencies, and responsibility
- Part III , which addresses specific items required to comply with the Guideline
- Part IV, which applies to disclosures made by or on behalf of reporting entities
- Part V, which outlines the reporting criteria for Exploration Results, Resources and Reserves in its respective sub-sections.

Additionally, the SAMESG Guideline makes reference to the International Organization for Standardization (ISO) Standard ISO 26000. ISO 26000:2010 provides guidance through definitions, principles, practices, stakeholder identification, and engagement as well as performance regarding social responsibility (ISO, 2010).

SOCIAL LICENCE TO OPERATE

Social licence to operate is directly relevant in quantifying environmental and social risk. The role of securing and maintaining 'social licence to operate' (SLO) has been widely discussed by authors such as Nelson (2006), the Benchmarks Centre for Corporate Social Responsibility (CSR) (2010), Boutilier and Thompson (2011), Prno and Slocombe (2012), Boutilier *et al.* (2012), the Sustainable Business Council (SBC) (2013), and Moffat and Zhang (2014).

The SBC identifies that the concept of SLO emerged in the mining industry as a means of engaging with local communities, referring to '*widespread publication of the industry's failure to resolve community conflicts*' (SBC, 2013). The concept of SLO does not conform to a single definition (SBC, 2013), rather it addresses a number of relevant concepts such as:

- It does not derived from regulatory compliance but does speak to lowering risk for the organization
- The measure of confidence and trust the community has in an organization to behave in a '*legitimate, transparent, accountable and socially acceptable way*'
- Society demonstrates its tolerance, acceptance, or approval of the organization's activities through an unwritten contract with the organization
- Trust between the parties as well as '*quality of information, accountability, flexibility and transparency from all parties*' is essential in fostering the relationship described in the unwritten contract
- The terms of a SLO are often highly project- or location-specific. '*Local communities are usually the 'key arbiter' of the terms of the SLO due to their proximity to the company's activities and associated effects*', although society as a whole values the concepts encompassed by the SLO (Prno and Slocombe, 2012 in SBC, 2013).

Figure 1 shows levels of social licence to operate and their corresponding indicators. This diagram is useful in transforming qualitative ideas of environmental and social risk, toward quantitative estimates: if community acceptance is understood, response can be gauged, likely displays of action can be surmised, and required responses/mitigation can be approximately estimated (financially –

where positive displays of action are likely to lead to positive, low-cost, voluntary responses and negative actions are likely to lead to higher cost, reactionary responses, and mandatory mitigation).

Perceptions of Trust and Risk

A challenging aspect of navigating the SLO is the perception of trust. Communities' trust may be '*difficult to earn and can be easily revoked*' if society believes that the company is not meeting the implied terms of the contract, therefore continuous reassessment (of the terms of the SLO) is required by the organization to accommodate changes in social expectations (Nelson, 2006 in SBC, 2013). Alongside, this, an additional challenge exists in trying to profile the community's perception of risk. It is evident from social science research combined with societal debate, that personal experience, exposures, belief systems, as well as the group's own risk attitudes and risk behaviour (Rohrmann, 2008 in Rohrmann and Eichner, 2012) greatly influence a community's perception of hazards.

Rohrmann and Eichner (2012) investigate the perception of risk, given the highly interdisciplinary nature of the debate. Risk perception varies among individuals. Dobbie and Brown (2014) provide an in-depth discussion of a nested contextual system of human phenomena which may affect collective and personal influence. Similarly, Rohrmann (1994), Renn (1998), and Renn and Rohrmann (2000) navigate the role of risk perception for risk management, cross-cultural risk perception, and cross-national risk perception.

Given the wide spectrum of possibilities that may be relevant to a single mining operation, tailored risk assessments should be undertaken to consider the array of scenarios applicable to that particular mining operation – generic, broad-sweeping assessments are no longer applicable and no longer add value to the evaluation of the viability of proposed mining projects. By understanding the potential level of SLO in relation to specific mining projects, the corresponding level of risk may be deduced and subsequently quantified.

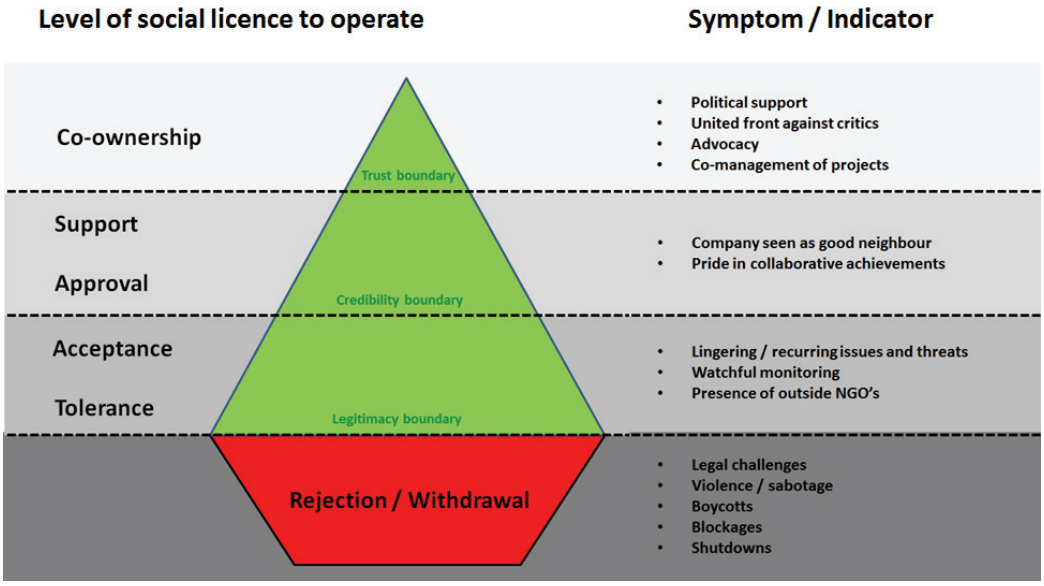


Figure 1. Levels of social licence to operate and their corresponding indicators (modified from SBC (2013), ibid adapted from Boutilier and Thomson (2011)).

RISK

Risk analyses are described under 'T 6. Risk Analysis' in SAMRECs Table 1 (currently SSC, 2009 and following the launch, in SSC, 2016) where any risk assessments carried during the evaluation of mineral resources are reported and detailed risk assessments (which include risk management options for the risks assessed) must be reported in the evaluation of Mineral Reserves (generally, risk analyses are not applied to Exploration Results).

The definitions of 'risk' and concepts related to risk assessment have been debated over time (*e.g.* Kaplan and Garrick, 1981; Kaplan, 1997; Taleb, 2007). A common definition of risk that is typically employed during assessments considers the ***probability*** of an event occurring and the ***consequence/s*** associated with that event. It is against this background, that an overview of the risk assessment process is described.

The risk assessment will typically consider the following elements: the nature and cause of the risk; the consequences that may be expected if the risk materializes; and the actions and controls that can be adopted to reduce and/or mitigate the risk. These actions and controls are identified proactively, although they may be implemented at different times than the risk event (contrasting preventative and corrective controls). The effectiveness of controls is also evaluated. In interpreting the suitability of the risk management plan, the inherent and residual risk profiles are often compared. The risk profile is measured against the risk appetite (tolerance) of the mining organization.

Different methods are available for assessing different forms of risk and include qualitative descriptions, quantitative evaluation, risk matrices, fault trees, event trees, and the evaluation of probability distributions. Given that the risk assessment spans a number of disciplines within the mining operation, it is ideal for knowledgeable representatives from each of the disciplines to participate during the risk assessment and development of the risk management plan.

'Black Swans', 'Perfect Storms', and *Force Majeure*

Paté-Cornell (2012) provides insight into the aleatory uncertainties (randomness) that accompany 'perfect storms' and the ultimate epistemic uncertainty which typifies 'black swans'; providing particular discussion on situations when existing statistics are insufficient for further risk management evaluations. A 'black swan' is a metaphor (Aven, 2015) that forms part of a larger philosophy for understanding and dealing with risk, as described by Taleb (2007), and describes an event (either positive or negative) that is 'highly improbable' owing to the fact that it is 'unpredictable' and the consequences are 'massive'. A 'perfect storm', in this context, refers to a combination of events, however unlikely, resulting in an extreme event or catastrophic situation. Both concepts are relevant in assessing and managing risk, because it is possible that the realization of extremely unlikely, but highly impactful events may eventually result in *force majeure.*

An approach to adaptive risk management (using the oil and gas industry as an example) is elaborated on by Bjera and Aven (2014). The approach considers a wider range of uncertainty within the risks, profiled observations, as well as modification of tools to deal with the outcomes.

Given the increasing understanding and conceptual acceptance of 'black swans' and 'perfect storms' in assessing the overall risk profile of a project, it is becoming more common to consider what events and/or combination of scenarios would need to be realized in order to reach *force majeure.* In the context of quantification of environmental and social risks, one would consider what *extent of environmental disaster* and/or what level of *social upheaval* would need to be encountered in order to reach *force majeure*.

Statistical and Scientific Approaches Available for Modification

Kupiec (1995) determined that the '*formal statistical procedures that would typically be used in performance-based verification tests* [of value at risk estimates] *require large samples to produce a reliable assessment of a*

model's accuracy in predicting the size and likelihood of very low probability events'. This is not particularly helpful as the sample data to predict social phenomena is considerably limited.

Rather, Shan *et al*. (2010) have developed a quantitative method to evaluate social risk using a structural equation model (SEM), though social risk synthesized index systems have been developed over a number of years (McDonald and Ho, 2002). Mathematically speaking, SEM is considered a '*powerful multivariate technique*' which uses a conceptual model, path diagram, and system of linked regression-style equations in order to capture complex and dynamic relationships within a web of observed as well as unobserved variables (Gunzler *et al.*, 2013). The model by Shan *et al*. (2010) is based on an index system using six first-level indexes (*viz.* the current climate of the external social environment, economic power, social security, social control capabilities, distribution of social wealth and lastly, social psychology) and 40 second-level indexes. Based on these indices and the relationships between them, the SEM uses an improved partial least square (PLS) algorithm to determine the best iterative initial value. Although the SEM is directed toward the national context, extrapolation of the concepts may allow for tailored indices to be developed that would suit regional- or community-specific mining operations.

Moffat and Zhang (2014) used survey methods to research community acceptance of mining projects and provide descriptive statistics and bivariate correlations for key variables. Using path analysis, a hypothesized path model as well as an alternative model was generated. The research identified concepts regarding frequency and quality of communications from the mining organization to the community and demonstrated a model of the key elements of a social licence and how these relate to each other. A conceptual model was also proposed; the effect of the impact on social infrastructure, intergroup contact, and procedural fairness are believed to affect the community members' acceptance of a mining development through trust in the operating mining organization.

Mudd (2007) recognizes the links between gold production trends and resource intensity (water, energy, and chemicals consumption and pollutant emission). Using a number of fundamental issues, Mudd '*links data sets on historic gold mining production trends with emerging sustainability reporting to estimate resource intensity*', which demonstrates the sensitivity of ore grade for gold production and sustainability, thereby making valuable strides towards quantifying environmental and resource sustainability.

One example of this is the cyanide consumption required to produce gold, where '*for relatively high-grade mines (>6 g/t Au), the cyanide cost is commonly less than 100 kg CN/kg Au, while for lower grade mines (<2 g/t Au), the cyanide cost increases rapidly as grade declines*'. Mudd (2007) identifies that '*cyanide consumption seems more likely to increase gradually in the medium term, pointing to the need for greater transparency and focus on cyanide management'*. Eisler and Wiemayer (2004) describe the cyanide hazards posed to plants and animals from gold mining (and other water-related issues) which prompt the inference that increased environmental risks *will most likely* accompany increased cyanide consumption – and these environmental risks should be evaluated accordingly.

The approach may potentially be used in a similar fashion to quantify aspects of a wide range of environmental risks (in all mineral sectors) through the determination of costs associated with water, energy, and chemicals consumption; costs associated with increased pollutant emission; costs associated with improved cyanide management; and costs associated with improved environmental management and suitable remediation, to arrive at a risk-informed position during decision-making.

The tools and techniques used by Mudd (2007), Shan *et al*. (2010), and Moffat and Zhang (2014) provide interesting entrance points to the meaningful evaluation and prediction of social acceptance – which in turn allows for specific risks to be identified and constrained, and therefore, quantified.

With regard to environmental elements, remote sensing, satellite imagery, and aerial photogrammetric images are used to identify and map vegetation coverage, for example, or study water cycling elements. This enables the estimation of costs for elements associated with the events

that disrupt or destroy natural environment and that are related to the specific mining operation. Similarly, satellite-based interferometric synthetic aperture radar (InSAR) can be used to analyse data over stockpiles, pits, tailings dams, and leach sites with the goal of identifying and predicting safety scenarios.

PREDICTING ENVIRONMENTAL AND SOCIAL RISK

In considering several prevalent above-the-ground risks in the platinum sector, Lane and Kamp (2013) state that '*local communities seek to limit the disruption that mineral development will cause to their economic, social, and cultural context, and want access to the opportunities presented by mining developments*'.
In contrast, the differing focus areas of mining organizations (*viz.* production output, and profitability) and national governments (which seek tangible economic benefits linked to taxation, royalties, and infrastructure development) often exacerbate aspects of social risk. Lane and Kamp (2013) further note that frustration rises within communities and is followed by social unrest, which in turn is said to lead to heightened demands by those communities on mining companies.

It is difficult to identify each and every environmental and social risk element that may be encountered across the spectrum of commodities and mining operations in a single publication; however, Table I suggests types of costs that may be experienced by mining companies as a result of conflict with communities, irrespective of the cause of conflict. The costs suggested in Table I can be used in relation to the symptoms/indicators identified in Figure 1.

Table I. Types of costs that may be experienced by mining companies as a result of conflict with communities (Franks et al., 2014).

Type of cost	Examples
Security	Payments to state forces or company security contractors Increased operational costs of security: fences, patrols, escorts, transport, alarm/leak monitoring systems, reduced mobility Increased security training and management: staff time, lost production, cost of programmes
Project modification	Design modification costs: application, redesign, legal Additional works
Risk management	Insurance: higher premiums and coverage, risk rating, withdrawal of coverage Legal and conflict expertise: specialist training for staff; additional staff
Material damage	Damage or destruction to private property or infrastructure Damage or destruction to public property or infrastructure
Lost productivity	Operations discontinued: voluntary closure or enforced through injunction Temporary shutdown of operations Lost opportunity for future expansion and/or for new projects Disruption to production: delays, temporary or indefinite, absenteeism Delays in deliveries/supplies Greater regulatory burden/scrutiny
Capital	Loss of value of property: full write-off, other depreciation, sale at a loss, theft Inability to repay debt or default on debt Difficulty raising new capital Share price instability/loss in value (within relevant time period)
Personnel	Staff time spent on risk and conflict management Costs of remediation: mediators, meetings, negotiations Hostage-taking: ransom payments, rescue operations, compensation Arrests of staff Injuries to staff and deaths Low morale and stress-related effects Retention: higher salaries, compensation packages, bonuses Recruitment: advertising positions, screening, interviewing, induction training
Reputation	Higher expenditure on public relations: consultants, dissemination of information Competitive loss/disadvantage: impact on brand, investor confidence
Redress	Compensation (out-of-court payments) Fines Increased social and environmental obligations: health care, education and training, provision of other services, clean-up and remediation costs Costs of administrative proceedings or litigation: costs of proceedings themselves; judgment/settlement costs

COST OF CONFLICT

Environmental Concerns: Water Pollution

Dixon (2014) provides information on the cost of conflict around environmental and social issues. These include the following examples:

- Rosia Montana, a gold and silver project in Romania, was operative in Roman times. An open pit was proposed and approximately US$250 million had been spent on the project. Community protests began in 2013 over the use of cyanide in the metallurgical process and plans to deposit cyanide-rich tailings in the Corna River valley causing significant concerns regarding the expected water pollution
- The Pascua-Lama project high in the Andes on the border of Chile and Argentina was also opposed by local communities due to potential pollution of water supplies. Subsequently, Chile suspended the project licence, preventing development. Barrick Gold is said to have spent upwards of US$2 billion on the US$5–8 billion project
- A major environmental disaster occurred at the Philex copper and gold mine in Benguet, Philippines in the form of a breach of the wall of the tailings storage facility. 20 Mt of tailings found its way into the Agno River of Balog Creek. Philex was ordered to pay a P1 billion fine (P = Philippine peso)

- The development of the Minas Conga gold project in Peru was suspended by Newmont. Opponents to the project went as far as vandalizing the mine site and kidnapping a worker as local communities protested about the threat to their water supply
- Despite an investment of $250 million by Royal Dutch Shell, the Camisea oil project in Peru did not proceed because of significant community opposition (SBC, 2013).

Project Delays result in Losses

Franks *et al.* (2014) provide invaluable insight into the cost of conflict – having collected information from over 50 cases relating to cases of prolonged or escalated company–community conflict around mining organizations. The findings are very interesting:

- Franks *et al.* (2014) found that *environmental* issues were the most common proximate issues that the parties to conflict identified as the central issues in dispute
- It is reported that the most common *underlying* issues (which may not have precipitated conflict but which did contribute to the state of the relationship between the parties) were social and economic issues
- The most frequent costs identified were those arising from lost productivity as a result of delay.

A number of international examples are mentioned which demonstrate the significant costs associated with community-company conflict, quoted directly from Franks *et al.* (2014), these include:

- *A 7-day blockage of an energy project's supply route in a Middle Eastern country cost US$20 000 per day.*
- *A 9-month delay during construction* [at a] *Latin American mine in 2010 resulted in US$750 million in additional project costs (i.e., roughly US$20 million per week).*
- *A major, world-class mining project with capital expenditure of between US$3 and US$5 billion suffering roughly US$20 million per week of delayed production in net present value terms as a result of community conflict.*
- It is recognized that costs can accrue as early as the exploration stage. '*In the case of initial mineral exploration (early reconnaissance work), it was estimated that around US$10,000 is lost for every day of delay in lost wages and the costs of maintaining an exploration camp. For advanced exploration involving drilling and geophysical delineation, up to US$50,000 a day is lost when programs are forced into "stand-by" as a result of company–community conflict*'.
- In some projects, the cost of delay had been integrated into 'construction costs' in the project budget, which (in one such project) '*included a 50% margin to cover delays arising from community conflict*'.
- The prospect of delays in valuations of projects is reported to also be considered by financial services companies: '*Credit Suisse applied a 2.9% discount on its corporate valuation of AGL Energy (Australia) to account for the risk of regulatory approval delays following local community opposition to hydraulic fracturing at their planned Gloucester coal-seam gas project*' (Credit Suisse, 2014 in Franks *et al.*, 2014).

Other Manifestations of Social Risks: Illegal Mining

Seccombe (2014) reports that Harmony Gold stood to lose approximately R112 million as a result of having to close its Kusasalethu mine (Carletonville, South Africa) for two weeks to remove illegal miners (Odendaal, 2014). In addition to the losses that result from disruption and temporary closures, other costs are also relevant. The estimated value of the financial loss suffered by mining organizations as a result of illegal mining is difficult to quantify accurately – Venter (2004) states that gold theft cost South Africa's economy an estimated R2 billion rand during 2004; Seccombe (2014) reports that between 5% and 10% of South Africa's annual gold production were stolen in 2012 (worth R78 billion) through illegal mining and R225 million of platinum group metals were stolen, Kotze (2014) identifies that an estimated R7.5 billion in revenue was lost due to illegal mining, while Ndaba (2015) mentions that illegal mining causes losses to the local economy of more than R5 billion – creating the strong impression that the social factors which eventually lead to illegal mining must indeed have a modifying effect on the value of the projects affected.

Illegal mining has affected a variety of commodities in South Africa:

- **Gold** in the gold fields of the Free State Province (Venter, 2004; Schmidt, 2006; Beresford, 2006)

- **Gold** in the West Rand gold fields of Gauteng Province (Venter, 2004; Beresford, 2006)
- **Gold** in the North West Province (Northwest Newspapers, 2015)
- **Gold** in Gauteng (SAPA, 2015a; Eliseev, 2006; Maylie, 2014; Chadderton, 2014; Gernetsky, 2015)
- **Diamonds** in the Northern Cape Province (Stoddard, 2012)
- **Coal** in the KwaZulu-Natal Province (South Africa, 2014)
- **Sand** (typically extracted directly from main river channels and adjacent sandbanks) in the KwaZulu-Natal and the Eastern Cape provinces (Chevallier, 2014)
- **Aggregates** from coastal regions of South Africa (Mining Weekly, 2014)

CONCLUSION

The assessment of risk extends past the regulatory requirement and includes the social licence to operate. Through the quantification of environmental and social risk, using modifications to existing statistical methods and existing scientific methods for the collection and evaluation of data, the business case stands to benefit from having achieved a more meaningful and in-depth consideration of the potential paths the proposed mining project could take. Advances in risk management methods now address highly unlikely events that may have catastrophic consequences. A number of international and national case examples show the potential of aspects related to environment and social risk, as well as conflict, to cause significant disruption to mining projects. Associated closely with that disruption is the financial impact of lost production. The paper shows that diligent and comprehensive consideration is needed when assessing environmental and social risk for the purpose of determining the viability of a proposed mining project, as well as for managing the associated risk attributes. In this regard, the development of the South African Guideline for the Reporting of Environmental, Social and Governance Parameters within the Mining, Oil and Gas Industries (the SAMESG Guideline) is relevant.

REFERENCES

Aven, T. (2015). Implications of black swans to the foundations and practice of risk assessment and management. *Reliability Engineering and System Safety*, 134, 83–91.

Benchmarks Centre for Corporate Social Responsibility (CSR). (2010). Policy Gap 10, "Floating or sinking", Social Licence to Operate (SLO): Kumba Iron Ore Limited. 71 pp.

Beresford, B. (2006). A mile underground, gold smugglers with home-made bombs battle police. http://www.theguardian.com/world/2006/nov/17/southafrica.davidberesford [sccessed 21 August 2015].

Bjerga, T. and Aven, T. (2014). Adaptive risk management using new risk perspectives – an example from the oil and gas industry. *Reliability Engineering and System Safety*, 134, 75-82.

Boutilier, R G and Thomson, I. (2011). Modelling and measuring the SLO. *The Social License to Operate Seminar,* Centre for Social Responsibility in Mining, University of Queensland, Brisbane, 15 July 2011. http://www.socialicense.com/publications/Modelling%20and%20Measuring%20the%20SLO.pdf [accessed 23 March 2016].

Boutilier, R. G., Black, L., and Thomson, I. (2012). From metaphor to management tool: How the social license to operate can stabilise the socio-political environment for business. *Proceedings of International Mine Management 2012.* Australasian Institute of Mining and Metallurgy, Melbourne. pp. 227-237.

Chevallier, R. (2014). Illegal Sand Mining in South Africa. South African Institute of International Affairs, Governance of Africa's Resources Programme, Policy Briefing, 116. pp. 6.

Chadderton, S. (2014). Hundreds of illegal miners trapped underground after suspected rockfall in Johannesburg, South Africa. http://www.mirror.co.uk/news/world-news/johannesburg-mine-collapse-more-200-3151420 [21 October 2015].

Paté-Cornell, E. (2012). On "Black Swans" and "Perfect Storms": Risk Analysis and Management When Statistics Are Not Enough. *Risk Analysis,* 32 (11), 1823-1833.

Dixon, R. (2014). Environmental and Social Modifying Factors. *Mongolian Institute of Geosciences and Mining (MPIGM) Workshop*, Ulaanbaatar, Mongolia,.18 October 2014.

Dobbie, M.F. and Brown, R.R. (2014). A Framework for understanding risk perception, explored from the perspective of the water practitioner. *Risk Analysis*, 34 (2), 294-308.

Eisler, R. and Wiemayer, S.N. (2004). Cyanide hazards to plants and animals from gold mining and related water issues. *Reviews of Environmental Contamination and Toxicology*, 183, 21-54.

Eliseev, A. (2006). Gold pirates caught in police net. http://www.iol.co.za/news/south-africa/gold-pirates-caught-in-police-net-1.303251 [accessed 21 August 2015].

Floreani, W. 2007. Mitigating security risk in Africa. *Mining Mirror*, July 2007, 24-25.

Franks, D.M., Davis, R., Bebbington, A.J., Alia, S.H., Kempa, D., and Scurrah, M. (2014). Conflict translates environmental and social risk into business costs. *Proceedings of the National Academy of Sciences*. 6 pp.

Gernetzky, K. (2015). Departments need to co-ordinate to stop illegal mining http://www.bdlive.co.za/business/mining/2015/08/21/departments-need-to-co-ordinate-to-stop-illegal-mining [sccessed 21 October 2015].

Gunzler, D., Chen, T., Wu, P., and Zhang, H. (2013). Introduction to mediation analysis with structural equation modelling. *Shanghai Archives of Psychiatry*. 25 (6), 390-394.

International Council for Mining and Metals (ICMM). (2016). Members. http://www.icmm.com/members [accessed 24 March 2016].

International Organization for Standardization (ISO). (2006). ISO 26000:2010 (Guidance on social responsibility). Geneva.

Kaplan ,S. (1997). The words of risk analysis. *Risk Analysis,* 17 (4), 407-417.

Kaplan, S. and Garrick, B.J. (1981). On the quantitative definition of risk. *Risk Analysis,* 1 (1), 11-27.

Kotze, C. (2014). SA lost R7.5bn to illegal mining last year, scourge posing health, safety hazards. http://www.miningweekly.com/article/illegal-mining-costs-sa-billions-a-year---com-2014-04-25 [accessed 28 August 2015].

Kupiec, P.H. (1995). Techniques for verifying the accuracy of risk measurement models. *Journal of Derivatives*. 3 (2), 73-84.

Lane, A. and Kamp, R. (2013). Navigating above-the-ground risk in the platinum sector. *Journal of the Southern African Institute of Mining and Metallurgy*. 113, 163-170.

Lomberg, K. (2014). The SAMREC Code and Uranium. *Regional Workshop on Application of United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources (UNFC)-2009 to Uranium Resources*, Johannesburg, South Africa, 10 -14 November 2014.

Maylie, D. (2014). Dangerous economy thrives in South Africa's abandoned gold mines. http://www.wsj.com/articles/dangerous-economy-thrives-in-south-africas-abandoned-gold-mines-1408933804 [accessed 14 September 2015].

McDonald, R.P. and Ho, M.R. (2012). Principles and practice in reporting structural equation analyses. *Psychological Methods*, 7 (1), 64-82.

McFarlane, A. (2012). The update of the South African Mineral Asset Valuation Code (SAMVAL). http://www.samcode.co.za/samcode--ssc-mainmenu-66/samval-mainmenu-103/122-the-update-of-the-south-african-mineral-asset-valuation-code-samval [accessed 24 March 2016].

Moffat, K. and Zhang, A. (2014). The paths to social licence to operate: An integrative model explaining community acceptance of mining. *Resources Policy*, 39, 61–70.

Mining Weekly. (2014). Illegal sands, aggregate mining a concern. http://www.miningweekly.com/article/illegal-sands-aggregates-mining-a-concern-2014-07-04 [accessed 24 August 2015].

Mudd, G.M. (2007). Global trends in gold mining: Towards quantifying environmental and resource sustainability. *Resources Policy*, 32, 42–56.

Ndaba, B. (2015). ANC and DA differ over zama zamas. http://www.iol.co.za/news/crime-courts/anc-and-da-differ-over-zama-zamas-1.1937117#.VjNdRkZFpx4 [accessed 28 October 2015].

Nelsen, J. (2006). Social licence to operate. *International Journal of Mining, Reclamation and Environment*, 20 (3), 161-162.

Northwest Newspaper. (2015). SAPS face-off against mines, zama zamas 7 August 2015. http://www.northwestnewspapers.co.za/lentswe/home/latest-news/8-home/latest-news [accessed 21 August 2015].

Odendaal, N. (2014). Harmony shuts Kusasalethu after illegal miners cause fire. http://www.miningweekly.com/article/harmony-shuts-kusasalethu-after-illegal-miners-cause-fire-2014-10-31 http://www.miningweekly.com/print-version/harmony-shuts-kusasalethu- [accessed 28 August 2015].

Prno, J., and Slocombe, D.S. (2012). Exploring the origins of 'social licence to operate' in the mining sector: Perspectives from governance and sustainability theories. *Resources Policy*, 37 (3), 346.

Renn, O. (1998). The role of risk perception for risk management. *Reliability Engineering and System Safety*, 59 (1), 49–62.

Renn, O. and Rohrmann, B. (2000). Cross-cultural risk perception: State and challenges. *Cross-Cultural Risk Perception: A Survey of Empirical Studies*. Renn, O. and Rohrmann, B. (eds). Dordrecht: Kluwer Academic Publishers. pp. 213–233.

Rohrmann, B. (1994). Risk perception of different societal groups: Australian findings and cross-national comparisons. *Australian Journal of Psychology*, 46 (3), 150–163.

Rohrmann, B. (2008). Risk perception, risk attitude, risk communication, risk management: A conceptual appraisal. *The International Emergency Management Society. Global Co-operation in Emergency and Disaster Management - 15th International Emergency Management Society (TIEMS) Conference*, Prague.

Rohrmann, B. and Eichner, K. (2012). Perception of hazards for health and safety - social-science perspectives. *Zeitschrift fuer erfahrungswissenschaftliche Sozialforschung*. 19 pp.

Rupprecht, S. (2015). The SAMREC Code 2015 – some thoughts and concerns. *Copper Cobalt Africa, incorporating the 8th Southern African Base Metals Conference*, Livingstone, Zambia, 6–8 July 2015. Southern African Institute of Mining and Metallurgy, Johannesburg. pp. 11-19.

Schmidt, M. (2006). R2bn in SA gold swindled. http://www.iol.co.za/news/south-africa/r2bn-in-sa-gold-swindled-1.276665?ot=inmsa [accessed 21 August 2015].

Seccombe, A. (2014). Harmony takes R112m hit to stop illegal miners. (http://www.bdlive.co.za/business/mining/2014/11/03/harmony-takes-r112m-hit-to-stop-illegal-miners) [accessed 28 October 2015].

Shan, W., Liu, H., Pan, Y., and Tong, H. (2010). Evaluation of social risk using structural equation model. *iBusiness*, 2, 188-192.

South African Mineral Resource Committee (SAMREC)/South African Mineral Asset Valuation Committee (SAMVAL) Committee (SSC) Working Group (2009). Guidance Note: SAMVAL Code: Interpretation of Clause 26. http://www.samcode.co.za/samcode--ssc-mainmenu-66/samval-mainmenu-103 [accessed 24 March 2016].

South African Mineral Resource Committee (SAMREC)/South African Mineral Asset Valuation Committee (SAMVAL) Committee (SSC) Working Group. (2011). Issue Paper for Comment – Reporting Standard and Format of Mineral Resources and Mineral Reserves, May 2011.

South African Mineral Resource Committee (SAMREC)/South African Mineral Asset Valuation Committee (SAMVAL) Committee (SSC). (2009). South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves (the SAMREC Code). 2007 Edition as amended July 2009. 61 pp.

South African Mineral Resource Committee (SAMREC)/South African Mineral Asset Valuation Committee (SAMVAL) Committee (SSC). (2016). South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves (SAMREC Code).

South African Environmental, Social and Governance Committee (SAMESG) Working Group. (2015). The South African Guideline for the Reporting of Environmental, Social and Governance Parameters within the Mining Industry [in preparation]. 12 pp.

South African Mineral Codes News. (2008). SAMCODE News, 1 (1), April 2008. 1.

South African Mineral Codes. (2015). SAMESG. http://www.samcode.co.za/samcode--ssc-mainmenu-66/samesg [accessed 20 April 2016].

South African Press Association (SAPA). (2015). Death toll rises to 18 in mine explosion. http://www.iol.co.za/news/south-africa/death-toll-rises-to-18-in-mine-explosion-1.7835 [accessed 21 August 2015].

South Africa. (2014). Media Statement: Parliament on illegal coal mining. http://www.gov.za/parliament-concerned-about-illegal-coal-mining [accessed 21 October 2015]

Stoddard, E. (2012). Bodies of 10 illegal diamond miners found in South Africa. http://www.reuters.com/article/2012/05/27/us-safrica-mining-dea [accessed 21 October 2015].

Sustainable Business Council (SBC). (2013). Paper on Social Licence to Operate. 25 pp.

Swart, E. (2003). The South African legislative framework for mine closure. *Journal of the South African Institute of Mining and Metallurgy,* 103, 482-493.

Taleb, N.N. (2007). The Black Swan: the impact of the highly improbable. New York: Random House. 366 pp.

Venter, B. (2004). Gold theft costing SA billions. http://www.iol.co.za/news/south-africa/gold-theft-costing-sa-billions-1.223721 [accessed 21 August 2015].



Carrie Zermatten

Engineering Geologist
SRK Consulting (Pty) Ltd

Carrie is an engineering geologist at SRK Consulting and has been involved in mining for 11 years. She specialises in risk assessments (qualitative and quantitative) and project management. Her expertise extends to slope stability investigations including database compilation, analyses (empirical, kinematic and numerical) and interpretation. She has worked in Botswana, Mozambique, Uganda, Japan and extensively throughout South Africa; she has previously conducted techno-economic evaluations for alluvial diamonds, feldspar, tungsten, mica, sandstone, sand, kaolinite and coal deposits amenable to exploitation by small-scale miners.

Practical steps in reporting social and environmental liability in the mining and oil and gas industries

S. Magnus , N.N. Moeketsi , and A. Clay

Venmyn Deloitte (Pty) Ltd, South Africa

There are extensive technical standards available that provide a detailed framework for the determination of social and environmental liabilities in the extractive industries. These frameworks span the various business units in an organization addressing the technical, engineering, management, and financial accounting requirements for operational environmental management, closure, and remediation. Different business units within an organization often operate autonomously, resulting in unforeseen disconnects regarding the accurate determination and communication of environmental liability. International financial reporting and auditing standards are becoming increasingly stringent regarding the accurate disclosure of organizational environmental liability. The ramifications of these requirements have echoed throughout the extractive industry, most notably through greater recognition of environmental liability in the reporting codes. This article will examine how implementing practical steps in reporting socio-environmental liability can further support the accurate disclosure of organizational socio-environmental liabilities.

INTRODUCTION

There are numerous technical standards available that provide a detailed framework for the determination of socio-environmental liabilities in the extractive industries. These frameworks apply to the various business units in an organization that address the technical, engineering, management, and financial accounting requirements for operational socio-environmental management, closure, and remediation.

The accurate reporting of socio-environmental liability has become a key area of focus for the international financial reporting and auditing community. One of the major challenges that have been identified is the tendency of business units within an organization to operate autonomously, resulting in challenges regarding the accurate determination and communication of socio-environmental liability.

This disconnect has become more visible in recent years, and this has been acknowledged in the financial reporting and auditing community through increasingly stringent standards, and the interpretations thereof, when disclosing organizational remediation liability.

The ramifications of the requirement for greater emphasis on accurate reporting of socio-environmental liability have been felt throughout the extractive industry, most recently through greater recognition in the South African Securities Exchange reporting codes.

Key challenges remain in the financial reporting and auditing community when disclosing socio-environmental liability. These can be practically addressed by considering the aspects which are reported on in existing technical socio-environmental reporting standards.

This article examines how aligning the accounting standards with existing technical standards, using Southern Africa as a case study, can further support the accurate disclosure of organizational socio-environmental liability in financial accounting reports.

Closure and Rehabilitation Liability in the Extractive Industries

Closure and rehabilitation planning is acknowledged by global institutions as an intricate process, which in many ways is as complex as the project feasibility process that culminates in construction. The closure planning horizon can vary from months to decades and must consider the social, economic, and environmental parameters, which will almost certainly change over the life of the operation (ICMM, 2008).

In many countries, the regulation of closure and remediation activities for projects in the extractive industries is supported by an extensive international and national legislative framework. Inclusive within the framework are international treaties and protocols, national acts, regulations, standards, and guidelines that address the management and financial accounting requirements for closure and remediation. An in-depth understanding of the various factors that contribute to the requirement for remediation is essential (Figure 1).

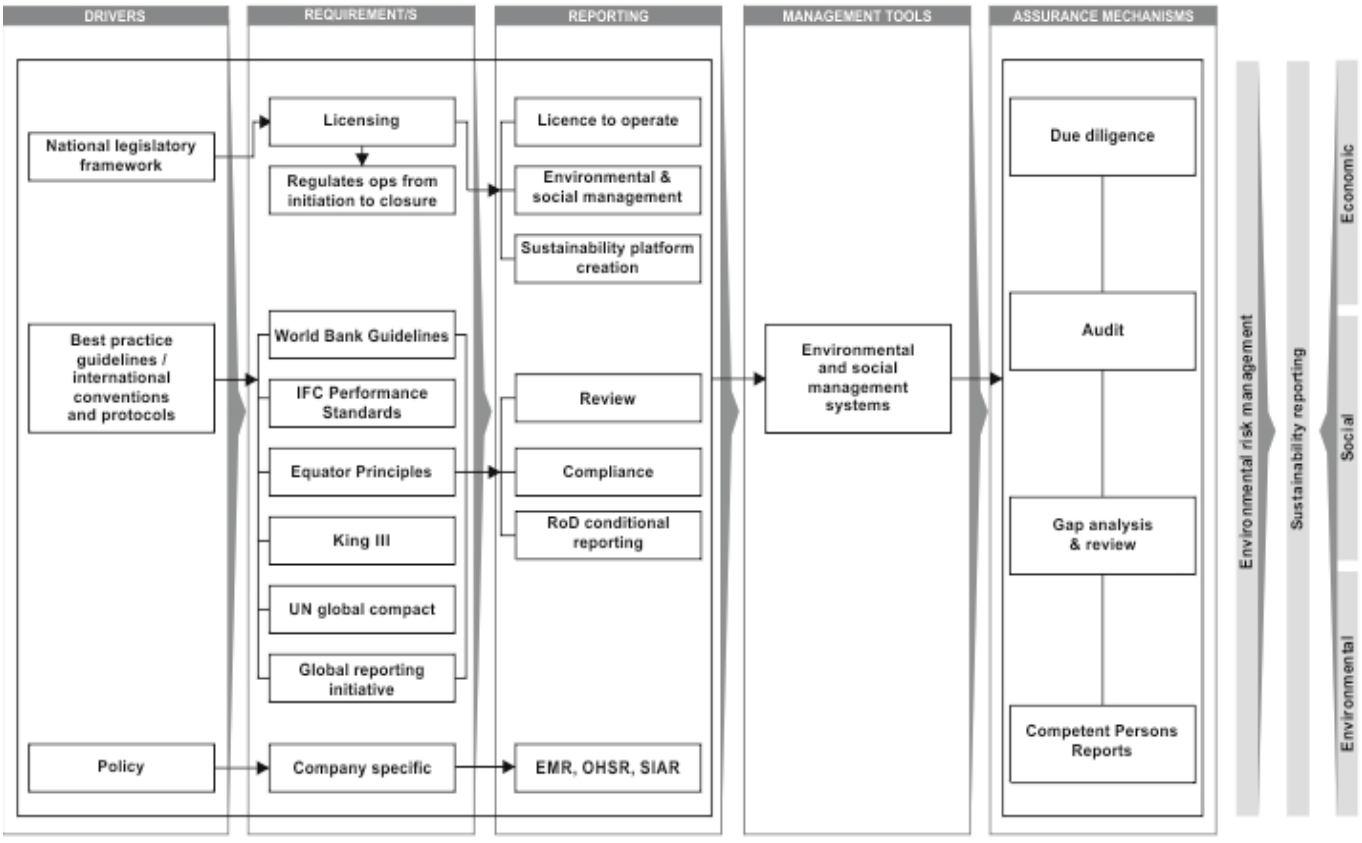


Figure 1. The environmental, social, and associated governence (ESG) value chain, including drivers, requirements, reporting structures, management tools,, and assurance mechanisms for addressing ESG requirements.

Good International Industry Practice (GIIP) publications highlight that good remediation and closure planning should:

- Present a vision for closure, with clearly defined closure outcomes and completion criteria
- Be an integral part of a project life-cycle
- Be undertaken early in the process of mine development, and in consultation with the regulating authority, local communities, and other stakeholders
- Include financial provisions to ensure that there are sufficient funds available to complete the prescribed closure activities
- Be regularly updated and refined to reflect changes in mine development and operational planning, as well as the environmental and social conditions and circumstances
- Include adjustments to closure funding arrangements to reflect any changes in mine closure requirements.

Many licences to operate within the extractive industries require that the activities and costs for operational closure and remediation be considered. Due to the complexity of the processes required when determining remediation requirements, the quantum of closure provision required is often understated, resulting in the accompanying financial provisions being insufficient to meet remediation requirements. This results in various impacts on the business, including the balance sheet (impairments, *etc.*) and potential for continued operation.

One of the main challenges facing industry at present is that, while the short-term success of remediation activities can be easily demonstrated, there is substantial concern regarding the potential emergence of long-term issues, which pose severe and ongoing maintenance requirements. These impacts commonly manifest after closure and remediation activities are complete, with no funding to address the associated costs. Appropriate planning (and the consideration of all contributing aspects) is therefore critical in supporting successful remediation.

The challenges associated with effective historical socio-environmental management within the extractive industries are widely acknowledged. South Africa in particular faces various socio-environmental management issues in the form of acid rock drainage (ARD) and mine abandonment. The consequences are very clear, with the burden of remediation often falling to the State. This process needs to be reconfigured such that the socio-environmental liabilities are understood (and can be effectively managed and accounted for) during the operational lifetime of the project.

Industry Tools that Support Appropriate Environmental Liability and Remediation Reporting in the Extractive Industries In Southern Africa

There are numerous international standards that have been developed and which provide detailed frameworks for remediation in the extractive industries. These frameworks include the International Council for Mining and Metals (ICMM) Closure Toolkit (ICMM, 2008), International Organization for Standardizarion (ISO), the World Bank Group Equator Principles (The Equator Principles Association, 2013), the Principles for Responsible Investment (UN SSE Initiative, 2015), and the International Finance Corporation Sustainability Framework (IFC, 2012).

These standards are intended to feed into broader sustainable frameworks and initiatives, such as:

- The United Nations Global Compact (United Nations Global Compact, 2015), a sustainability initiative for companies to align their strategies and operations in the areas of human rights, labour, environment, and anti-corruption
- Agenda 21 (United Nations, 1992)
- The Global Reporting Initiative (GRI), a widely-used reporting framework that sets out principles and performance indicators for companies to report on ESG performance (GRI, 2015)
- The Carbon Disclosure Project, a reporting system through which companies disclose greenhouse gas emissions, water management and climate change strategies (CDP, 2015).

The South African Guideline for the Reporting of Environmental, Social and Associated Governance within the Mining and Oil and Gas Industries (SAMESG)

The South African Guideline for the Reporting of Environmental, Social and Governance Parameters within the Extractive Industry (the SAMESG Guideline) defines the minimum standards, recommendations, and guidelines for Public Reporting of environmental, social, and governance (ESG) matters in the extractive industries for public companies in South Africa.

SAMESG has been written in alignment with the existing South African Code for the. Reporting of Exploration Results, Mineral Resources and Mineral Reserves (SAMREC Code), the South African Code for the. Reporting of Mineral Asset Valuation (SAMVAL Code), and the South African Code for the. Reporting of Oil and Gas (SAMOG Code) (collectively the SAMcodes), which define the reporting requirements for extractive industry Public Reports on the South African Securities Exchange.

Previously, environmental and social aspects had been classified as modifying factors within the SAMCodes, with limited descriptions required. SAMESG classes ESG components according to the following aspects (SAMESG, 2015):

- Description of organizational structure, systems, policies, procedures and management plans, and governance procedures in place to manage ESG issues
- Key plans, maps and diagrams (enabling a visual representation of key aspects that should be considered)
- Legal aspects (including applicable ESG legal compliance requirements and any mandatory and/or voluntary standards or guidelines to which the project target subscribes, such as permits, authorizations, and licences that have been issued to the project target as well as those permits, authorizations, and licences that have been identified as required but not yet applied for or issued
- Descriptions of any penalties, fines, and damages that are due and payable by the target in response to an order of court, decision by a mediator, or a decision by an arbitrator, whether or not subject to an appeal process, and pending administrative enforcement action
- Environmental parameters
- External social and political parameters, inclusive of the external social and political context within which the project is located, current social and political risks, and social and political issues that may have a material effect on the planned operational programme and which may require remediation
- Internal social parameters
- Conformance and compliance audits, and material findings therein
- ESG risk analysis process
- ESG liability, including closure, social obligations, rehabilitation plan, activities, remaining liability and compliance costs, mechanisms in place to address unplanned closure, and bonding obligations in place to ensure that these liabilities can be funded on a qualitative and quantitative basis.

Financial Reporting of Socio-environmental and Rehabilitation Liability

For financial accounting purposes, socio-environmental liabilities are generally separated into operational environmental and social management (as associated costs therein) and closure and remediation liability.

Operational environmental and social management issues, including concurrent remediation activities, are often recorded as operational costs, with few challenges arising when determining where the appropriate ledger entry should be recognized.

There are many cases that emphasize the challenges associated with the accurate financial reporting for remediation liability. Key challenges include:

- Determining the timeframes within which remediation activities must take place
- Determining an appropriate level of detail for the assessment of costs associated with remediation

- Determining what operational, legislative, political, technological, and social factors contribute to the remediation obligation.

Many international financial institutions and investors, as well as sponsors, borrowers, and regulatory authorities, seek to implement reasonable measures in line with good industry practice to mitigate the risk of non-performance of closure and remediation in the extractive industries. The specific risks contributing to poor closure and remediation include:

- Premature termination of activities during construction of the project
- Material changes to closure requirements and objectives
- Material changes to the project and processes
- The risk of financial failure
- The danger of closure funds being redirected
- The government possibly continuing operating an inherited project.

The International Accounting Standard (IAS) provisions within which the requirements (and associated quantum therein) for closure and socio-environmental liabilities are considered, are:

- IAS37 Provisions, Contingent Liabilities and Contingent Assets, referred to in this paper as 'IAS37' or 'the Standard' (IASB, 2012)
- IFRIC 1 Changes in Existing Decommissioning, Restoration and Similar Liabilities (IASB, 2004)
- IFRIC 5 Rights to Interests Arising from Decommissioning, Restoration and Environmental Rehabilitation Funds (IASB, 2004).

IAS 37 addresses reporting requirements for provisions, contingent liabilities, and contingent assets. The Standard outlines the accounting for provisions, together with contingent assets and contingent liabilities. Provisions should be measured at the best estimate (including risks and uncertainties) of the expenditure required to settle the current obligation, and reflect the present value of expenditures required to settle the obligation where the time value of money is material.

Within the context of IAS37, closure and rehabilitation liabilities fall within the definition of an Asset Retirement Obligation (ARO). IAS 37 defines an ARO as the liability associated with the eventual retirement of a fixed asset. The liability is commonly a legal requirement to return a site to its previous condition as far as practically possible in the context of the operation and associated impacts on the surrounding communities and environment.

The Standard requires that a business should recognize the fair value of an ARO when it incurs the liability and if it can make a reasonable estimate of the fair value of the ARO. If a fair value is not initially obtainable, the ARO must be recognized at a later date, when the fair value becomes available. If a company acquires a fixed asset to which an ARO is attached, must recognize a liability for the ARO as of the fixed asset acquisition date.

Emphasis is placed on the recognition of ARO liability as soon as possible, to enable the readers of a company's financial statements to better grasp the true state of a company's obligations, especially as ARO liabilities in the extractive industries have the potential to be material to the net present value (NPV) of the business.

For each class of provision, IAS 37 requires disclosure of:

- The nature of the obligation
- The factors relevant in determining the timing of the expenditure where there is significant uncertainty
- The amount provided and methods used to determine the amount
- A statement of whether the amount is discounted, where applicable
- Any actual or potential offsets to the liability.

Historically, consideration of the factors that contribute to the closure and rehabilitation liability has been limited to discussions with the management team. Although this approach is not incorrect, the numerous aspects that contribute the closure and rehabilitation liability in the extractive industries are complex. Often, these aspects are influenced by external factors that are not necessarily considered by one department or management team, but rather by various departments. Any disconnect between these departments has the potential to influence the accuracy of the closure and rehabilitation liability disclosed in the financial statements.

The following are trends of challenges experienced when determining closure and rehabilitation liability in accordance with IAS37:

- There is a mismatch between total rehabilitation and closure liability considerations and accounting frameworks. This is evident in the quantifying liabilities or provisions where uncertainties exist
- Indirect legislative requirements are often missed when determining the true rehabilitation liability
- Materiality is an important factor in the context of the presentation of financial statements as it plays an important role in determining which risks are disclosed in the financial statements.

A key issue that exacerbates challenges experienced when determining closure and rehabilitation liability in accordance with IAS37 is the time value of liability – notably, the tendency to escalate the liability quantum in accordance with the remaining operational timeframes, with de-escalation at a higher rate. The result is always a significant underestimation of the quantum of the liability, the outcome of which is often an underfunded rehabilitation account that cannot be adjusted at the time of operational closure due to the magnitude of the liability.

These concerns can be rectified only through an understanding of all of the aspects that contribute to remediation obligation, and appropriate incorporation of these in the financial accounting reports.

METHODOLOGY

When determining an appropriate remediation liability in the extractive industry, the following requirements should be considered:

- IAS 37 financial reporting requirements
- Legal requirements
- Operational design on an ongoing basis
- Finance institutional requirements and associated commitments
- Company policy
- Industry-specific requirements
- Industry standards and guidelines.

Consideration of the contributing aspects should be supported by the following process:

- Assessment of compliance with in-country legislative requirements when determining rehabilitation obligations
- Assessment of the appropriateness of the models used to determine the scope and quantum of the rehabilitation liability informing the ARO
- Assessment of the appropriateness of ARO models used to determine the quantum of the rehabilitation liability in accordance with the requirements of IAS 37 (regarding current disturbance and associated obligation)
- An assessment of the competency of the technical specialists (if any) appointed to determine rehabilitation activities
- A review of the financial allocations made:
  - For rehabilitation liability in the cash flows (concurrent rehabilitation;
  - To address the costs associated with unscheduled closure
  - To address the final rehabilitation liability

- A review of the technical ARO reports (and supporting documentation) to assess whether all material risks or areas of concern have been appropriately considered in the rehabilitation liability assessments
- Consideration of additional factors (if any) that may materially alter the rehabilitation liability quantum.

This process is illustrated in Figure 2.

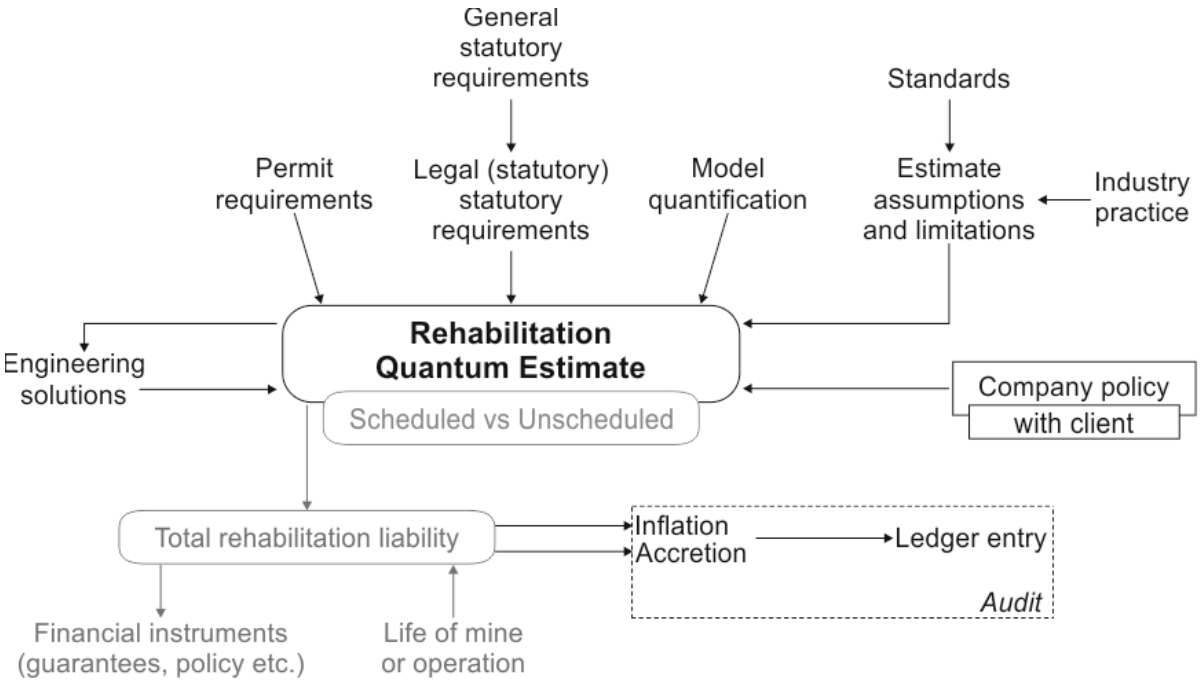


Figure 2. Aspects that should be considered when determining an appropriate remediation liability in accordance with the requirements of IAS37.

Financial provision for remediation is a process that continuously influences the balance sheet and operational parameters. As such, the process of determining an appropriate rehabilitation liability should be iterative, as illustrated in Figure 3.

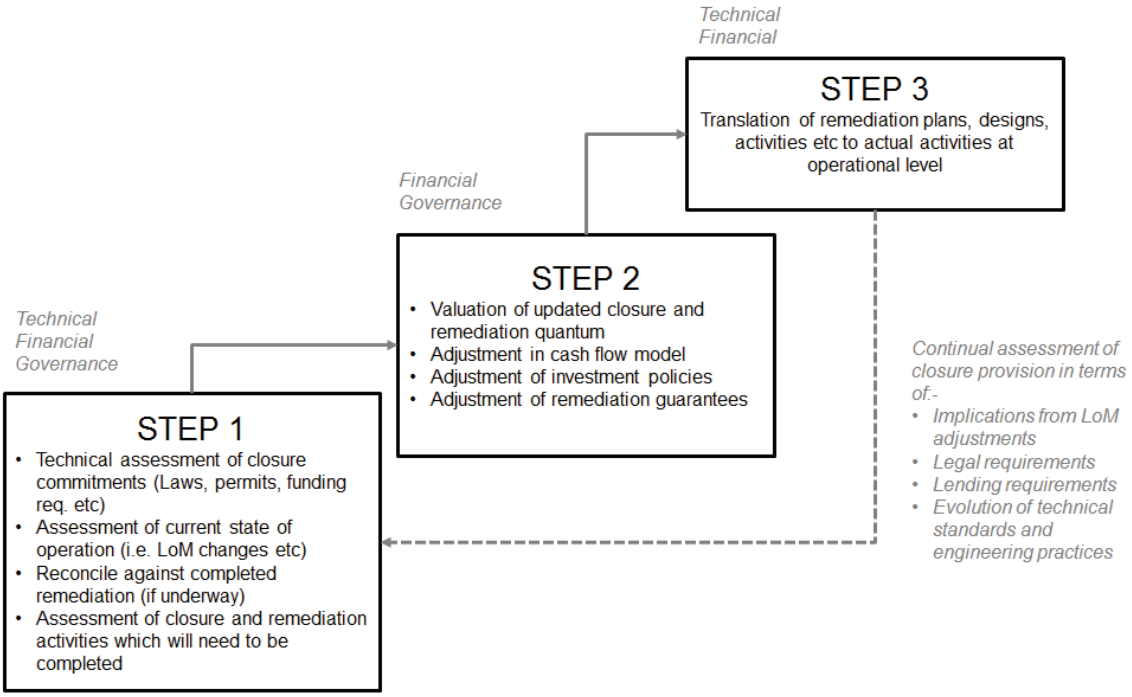


Figure 3. Iterative process for appropriately determining remediation liability.

Steps one and two in Figure 3 are critical for the purposes of appropriate remediation reporting for financial accounting purposes

Step One: Technical Assessment of Closure Commitments

Closure and remediation estimation begins with a technical assessment of requirements:

- What are the legislative requirements?
- What are the company policy requirements?
- What permitting requirements exist?
- What commitments have been made in terms of closure planning?
- What technical methods will be applied?

Multiple cross-sectional elements need to be taken into account to ensure that an appropriate provision is made. Costing contributors include:

- Age of operation (and the associated progression of operational activities and impacts)
- Location
- Type of mine and mineral extracted
- Physical size and infrastructure
- History of environmental and social management
- Volume of waste
- Presence of important geological features (pyrite, dolerite dykes *etc.*)
- Legislative requirements
- Company policy.

Step Two: Model Assessment and Adjustment

Key points for consideration include:

- Determination of the rehabilitation liability estimate through consultation with

organizational business units that contribute to the operational rehabilitation obligation
- Assessment of any operational changes that need to be included in the remediation plans
- Assessment of any legislative and/or industry progressions that may influence remediation obligations.

ASSESSMENT OF REMEDIATION LIABILITY USING THE ITERATIVE PROCESS FOR APPROPRIATELY DETERMINING REMEDIATION LIABILITY: A CASE STUDY

Venmyn Deloitte has performed assessments of various operations within the mining, oil, and gas industries, both within Africa and globally, to assess the potential merit of the application of the iterative approach to operational closure and rehabilitation liability provision. In all instances of application, the iterative process of assessment identified aspects that had not been included within the liability, and yet were materially significant.

Most recently, the assessment of a South African mining organization illustrated areas of key risk exposure.

The exercise included:
- An assessment of operational compliance with South African legislative requirements when determining closure and rehabilitation obligations, notably:
  - Requirements for the determination of closure and rehabilitation liability in accordance with section 41 of the Minerals and Petroleum Resources Development ACT (MPRDA) Act 28 of 2004, and General Notice Regulation (GNR) 547
  - Consideration of potential requirements (if any) for closure and rehabilitation obligations in terms of the National Environmental Management Act (NEMA) Act 107 of 1998
  - Consideration of potential requirements (if any) for closure and rehabilitation obligations in terms of the National Water Act (NWA) Act 36 of 1998
  - Consideration of potential requirements (if any) for closure and rehabilitation obligations in terms of the National Environmental Management: Waste Act (NEM:WA) Act 59 of 2008
- An assessment of the appropriateness of the models used to determine the scope and quantum of the closure and rehabilitation liability informing the ARO in accordance with recognised Good International Industry Practice (GIIP)
- An assessment of the appropriateness of the models used to determine the quantum of the closure and rehabilitation liability in accordance with the requirements of IAS 37 (regarding current disturbance and associated obligation)
- An assessment of the competency of the technical specialists (if any) appointed to determine the closure and rehabilitation
- A review of the financial allocations made:
  - For environmental and closure liability in the cash flows (concurrent rehabilitation)
  - To address the costs associated with unscheduled closure
  - To address the final rehabilitation and closure liability
- A review of the technical ARO reports (and supporting documentation) to assess whether all material risks or areas of concern have been appropriately considered in the closure and rehabilitation liability assessments
- Consideration of additional factors (if any) that may materially alter the closure and rehabilitation liability quantum.

The findings of the review identified numerous aspects that had not necessarily been considered within the rehabilitation liability statement. These included:
- Each operation should be reviewed on an annual basis for the following factors (and the associated socio-environmental and rehabilitation liability adjust accordingly):
  - Assessment of whether any material adjustments of the rates if necessary (e.g. fuels)

    - Assessment of whether any changes to the mining / smelting operations have occurred that may result in amendments to the ARO quantum, for example the addition/removal of infrastructure
    - Change in mining plan (and any consequent amendments of operational environmental permits)
- Assessment of changes in the regulatory environment that may impact upon the determination of the closure and rehabilitation obligation
- Assessment of changes in company policy that may impact upon the determination of the closure and rehabilitation obligation.

The resulting recommendations impacted upon the total socio-environmental and rehabilitation liability by up to 40%, with an agreed-upon timeframe of one year for the operations to assess the extent of the liability and provisions required therein. The results identified key areas of risk exposure, and highlighted areas where increased cross-departmental collaboration would result in a greater understanding of the latent and residual socio-environmental and rehabilitation liabilities.

CONCLUSION

The determination and associated reporting of remediation liability is a complex process.
Closure and remediation planning in the extractive industry is, in many ways, as complex as the project feasibility process that culminates in project construction. The planning horizon is measured in decades, not months or years. Planners must deal with social, economic, and environmental parameters that over a generation are bound to change, adding an additional level of complexity to closure planning and the associated required financial provision.

Key challenges remain within the financial reporting and auditing community when disclosing socio-environmental liability. These can be practically addressed by considering the various aspects that contribute to remediation obligations in the extractive industries.

REFERENCES

CDP. (2015). Global Climate Changer Report 2015. London, UK: Carbon Disclosure Project.

GRI. (2015). Global Reporting Initiative Principles and Standards. Amsterdam, The Netherlands: Global Reporting Initiative.

IASB. (2004). IFRIC 1 Changes in Existing Decommissioning, Restoration and Similar Liabilities. London, UK: International Accounting Standards Board.

IASB. (2004). IFRIC 5 Rights to Interests Arising from Decommissioning, Restoration and Environmental Rehabilitation Funds. London, UK: International Accounting Standards Board.

IASB. (2012). IAS 37 Provisions, Contingent Liabilities and Contingent Assets. London, UK: International Accounting Standards Board.

ICMM. (2008). Planning for Integrated Mine Closure: Toolkit. London, UK: International Council on Mining and Metals.

IFC. (2012). The International Finance Corporation Sustainability Framework. Washington, DC: International Finance Corporation.

SAMESG. (2015). The South African Guideline for the Reporting of Environmental, Social and Governance Parameters within the Mining and Oil and Gas Industries (The SAMESG Guideline). Johannesburg, South Africa: Southern African Institute of Mining and Metallurgy.

The Equator Principles Association. (2013). The Equator Principles. UK: The Equator Principles Association.

UN SSE Initiative. (2015). Model Guidance on Reporting ESG Information to Investors. London, UK: PRI Association.

United Nations. (1992). United Nations Conference on Environment & Development, Rio de Janerio, Brazil, 3–14 June 1992. New York: United Nations.

United Nations Global Compact. (2015). Guide to Corporate Sustainability. New York: United Nations.



Mrs Sarah Magnus

ESG leader
Venmyn Deloitte

Sarah has worked in the field of Environmental Sciences for 8 years and presently leads the Venmyn Deloitte Sustainability Solutions team.
The Sustainability Solutions team provides a diverse range of services, including
governance planning, programme management and implementation, enterprise risk management, impact management and planning, management systems alignment and implementation, performance and assurance, technical reporting, due diligence and assessment of rehabilitation and closure liability. Technical reports include Competent and Qualified Persons' Reports for company listings on various international stock exchanges, as well as other regulatory reporting. Sarah's experience includes working on projects located in Italy, Kazakhstan, Russia, Mali, Namibia, Uganda, Tanzania, Zimbabwe, Madagascar, Mozambique, Botswana, Zambia, DRC, the United Kingdom, and within South Africa. Commodities include gold, platinum, chromite, metals, base metals, diamonds, iron ore, industrial minerals, coal and uranium.
Sarah actively provides audit support and transactional support for Deloitte's Global Audit and Corporate Finance teams, and serves as a member of the Core Mining Team in the UK as well as being recognised as an environmental subject matter expert within the energy and resources sectors for Deloitte globally.
She serves as the first and current Chairman of the South African guideline for the reporting of environmental, social and governance (ESG) parameters within the mining and oil and gas industries (the SAMESG).

A discussion of diamond resource classification

N. Lock

Independent Consultant

Classification of diamond resources is a statement of the risk assessment of the mathematical manipulation of geological data. It is the important flag for the non-technical reader of technical reports. Resource categories are of high, reasonable/moderate, or low confidence for Measured, Indicated, and Inferred diamond resources respectively. High confidence equals low risk, and low confidence equals high risk.

The SAMREC Code requires that the Competent Person (CP) must evaluate the geological data and interpretation when assigning resource categories. A numeric outcome of tons and grade (and in the case of diamonds, value expressed as dollars per carat must satisfy the overriding requirement for 'reasonable prospects for eventual economic extraction'. Technical and economic aspects must be considered and CP experience applied with an explicit statement of the assumptions. Absence of sampling information precludes a resource declaration. Microdiamonds are used in grade estimation only in combination with macrodiamonds.

The Code is not prescriptive regarding classification. Each CP, or company, will devise appropriate procedures for the commodity or project, and report transparently. This presentation concentrates on diamond resources from primary (kimberlite) sources. Different companies will establish internal standards to determine reasonable prospects. As a minimum, the CP must consider aspects significant to project economics for resource declaration; large corporations may require a desk engineering study for this purpose.

The Code outlines minimum standards, recommendations, and guidelines.

Oosterveld[1] observes that 'For most operating mines resources fall short of making the Measured Diamond Resource category.' He further comments that the Code 'implies that on a monthly basis production could be accurately forecasted and actual production would not vary more than say 10-15% from the estimate. For most (diamond) mines the variations are much larger.'

The guidelines of the new SAMREC Code reflect this: 'As a result of the above characteristics, diamond deposits rarely achieve Measured status.'

[1] Oosterveld, M.M. (2001). Diamond Resource Classification. [A note for Mr J. Clarke. President MineGem Inc.]

The 2004 SAMREC Inquisition included presentations on diamond resource estimation and classification. A scorecard method is a favoured approach by several companies and consultants. It is based on the concept that geology, volume, density, grade, and value are the five critical building blocks to resource declaration. The score is the accumulation of points on a scale that is divided, based on experience, into groups to define categories. Examples, including comment on the key assumptions, from the Inquisition and from Public Disclosure documents, will be presented to illustrate the range and variety of procedures adopted by different companies and consultants.

Too often drill-hole spacing and the geostatistical evaluation of geospatial data distribution have become overriding factors. Care must be taken not to allow for 'black-box' classification.

Some helpful pointers to better classification include:

- The geological interpretation may be paramount
- The geologist most familiar with the deposit should be involved in the classification
- Consideration should be given to the possible effect of additional drilling and sampling on the likely outcomes of the estimate
- Any variation from the estimate would not significantly affect potential economic viability
- The impact of mining method (and cut-off grade)
- The relevance of reporting periods to the estimate.

INTRODUCTION

Public disclosure reporting on diamond projects, and in particular the details of diamond resources, continues to be hampered by an industry inclination to secrecy. This is a global feature of diamond projects but with local variability between reporting domains and codes. The first challenge then is to restate the first two principles of the CRIRSCO-style reporting codes (CRIRSCO, 2013), namely Transparency and Materiality.

'Transparency requires that the reader of a Public Report is provided with sufficient information, the presentation of which is clear and unambiguous, so as to understand the report and not to be misled.'
'Materiality requires that a Public Report contains all the relevant information which investors and their professional advisers would reasonably require, and reasonably expect to find in a Public Report, for the purpose of making a reasoned and balanced judgement regarding the Exploration Results, Mineral Resources or Mineral Reserves being reported.' (CRIRSCO, 2013).

Although CRIRSCO is clear that Competent Persons (CPs) must 'respect and safeguard confidential information', this cannot be taken to mean that a fundamental fact such as the diamond price can remain secret. The diamond price is a critical aspect of demonstrating 'reasonable prospects'. Notwithstanding that transparency is a requirement, this duty of care should be interpreted to allow many proprietary modelling and estimation methods to remain confidential, with disclosure limited to a summary, thus protecting the details of intellectual property.

Resource classification is a statement of fundamental confidence in the data quality and estimation methodology. It is based on three simple categories (Inferred, Indicated, and Measured) defined by low, reasonable, and high confidence levels respectively. It is a qualitative definition based on quantified data collection, processing, and outcomes.

This paper will explore aspects of transparency and materiality relevant to resource classification, and numerous case studies that provide more or less transparency into a broad spectrum of diamond projects. Prior to discussing classification, however, a discussion of what a diamond resource is must

be considered. For the purpose of this paper the discussion is limited to primary, and not secondary diamond, deposits (*i.e.* kimberlite and not alluvial or marine deposits).

WHAT IS A DIAMOND RESOURCE?

A diamond resource, as with any other mineral resource, is determined primarily from a consideration of the most important statement in the SAMREC Code – 'A "Mineral Resource" is a concentration or occurrence of material of economic interest in or on the earth's crust in such form, quality and quantity that there are reasonable prospects for eventual economic extraction.' (Italics added for emphasis).

'Reasonable prospects' suggests that data from exploration will be used in the estimation and interpretation of specific geological evidence and knowledge, including sampling data. Specifically, a diamond resource may not be estimated without current sampling data or valuation of a representative diamond parcel. Equally, a diamond resource is not an inventory of mineralization; it is mineralization that meets a minimum requirement of being economically extractable at the report date and under stated technical and economic conditions.

A test of reasonableness is required in this discretionary process. It is not reasonable to declare a Resource if the value of the *in-situ* mineralization is less than the cost of mining and processing the host rock to liberate the mineralization.

'Reasonable prospects 'also suggests that the techno-economic processes will require justification, not in isolation but in the context of the project. Thus for example:

- A diamond project with a typically viable *in*-situ value in southern Africa may be unreasonable in Arctic Canada
- Diamond mineralization in the form of a palaeoplacer deeply buried in a sedimentary basin is also likely to be unreasonable
- Extraction of diamonds through processing of the host rock using total liberation techniques will certainly require comprehensive description to justify as this is a non-standard, and novel process, on an industrial scale.

Therefore the CP is required to assess '… the geological, engineering (including mining and processing parameters), metallurgical, legal, infrastructural, environmental, marketing, socio-political and economic assumptions which, in the opinion of the CP, are likely to influence the prospect of economic extraction.' The Canadian supporting documents (CSA-CIM, 2009) express this as '… project economics should be clearly defined, current, reasonably developed and based on generally accepted industry practice and experience.'

Guidance is provided in Clause 23 of the Code and Section 4.3 of the '*Table 1'* checklist in the SAMREC Code.

It is also pertinent to discuss the use of the word 'eventual' in the phrase 'reasonable prospects of eventual economic extraction.' 'Eventual' implies some comment on a timeline. SAMREC makes it clear that this timeline for bulk commodities such as coal, iron ore, or bauxite may extend into decades, due to development considerations. In contrast, gold projects may have project timelines that are much shorter. In all cases, a judgement is required as to the applicable commodity price over the project life. This judgement may require skills beyond the experience of the typical resource estimator; commodity price prediction and exchange rate fluctuations may be matters for financial experts although application of recognized methods (CSA-CIM, 2008) should be acceptable in most projects. These would include current prices, three-year trailing averages, long-term historical averages, margin over cash cost of production, consensus pricing, and contract pricing.

Unfortunately this guidance does not help with diamonds, where the external expertise is very specific to diamonds. In the case of diamonds, value is deposit-specific. Consequently, the aspect of a

timeline may be further complicated. Although historical rough diamond prices may have shown less fluctuation on a short-term basis than gold, for example, in more recent times rough prices have demonstrated volatility more in line with typical metals deposits. A potential project life-of-mine may provide some guidance on a diamond value for the project. While some comment on upside potential that may transpire from forward price predictions is a valid balance to discuss, it is not recommended that this be built into a base-case price for assessment of reasonable prospects. Similarly, historical valuations may be very unreliable as other economic circumstances may have changed significantly. The SAMREC Code now requires that diamond valuations should be less than six months old relative to the Effective Date of the report.

CIM Definition Standards (2014) does not include the word 'eventual' in their 'reasonable prospects of economic extraction'. This may be a reflection of the lesser importance of bulk commodities in the Canadian minerals industry, or perhaps the CIM's generally firmer wording of many aspects of public disclosure reporting. Canada is alone in not including this simple but important word. But the CP should not interpret 'eventual' as suggesting a lesser standard of classification; this is not a matter for semantics between reporting codes and simply reflects local preference.

If all these factors have been considered by the CP, a body of *in-situ* diamond mineralization will have been established that has demonstrated economic viability. The level of confidence in this body must still be determined and a Resource category classified.

Diamond resources are notoriously difficult to estimate and classify. Figure 1 illustrates this difficulty. This figure has been often displayed by many presenters and authors and is always worth keeping in mind as it graphically illustrates the concept of exploration difficulty. The figure is a simple qualitative view of grade for a variety of mineralization types plotted against homogeneity of the mineralization. For diamonds, what is clear is that the diamond grade for both kimberlites and alluvial diamonds is perhaps two orders of magnitude lower than for any other mineralization type. The consequence of this is an explicit inherent difficulty in the resource estimation process, which should require an even higher degree of care than for other commodities.

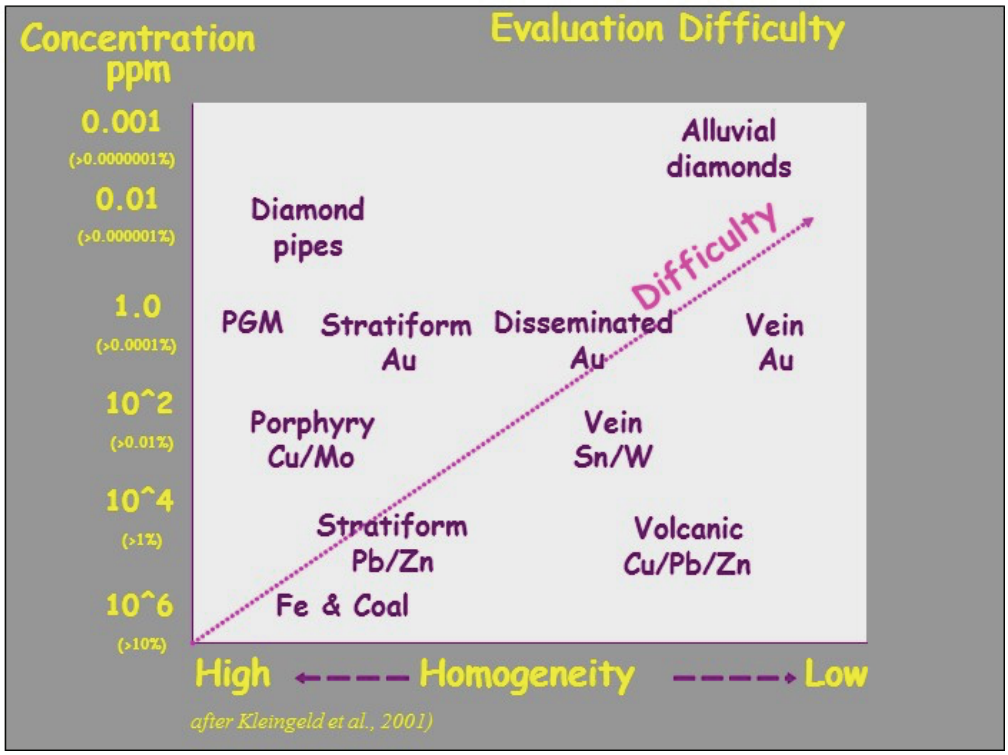


Figure 1. Grade and geological continuity – sampling and estimation difficulty (after Kleingeld et al., 2001).

Tinus Oosterveld was for many years during the 1970s to 1990s the De Beers' Chief Ore Evaluation Consultant. He was the pioneer in the development of modern diamond resource estimation methods, especially the use of microdiamonds. Oosterveld (2001) observes that 'For most operating mines, resources fall short of making the Measured Diamond Resource category.' He further comments that the SAMREC Code 'implies that on a monthly basis production could be accurately forecasted and actual production would not vary more than say 10-15% from the estimate. For most (diamond) mines the variations are much larger.'

The guidelines of the new SAMREC Code reflect this: 'As a result of the above characteristics, diamond deposits rarely achieve Measured status.'

A SCORECARD APPROACH TO CLASSIFICATION

Many consulting companies have taken an approach to classification that tabulates the level of confidence of key categorization criteria. While the list in Table I was never intended to be exhaustive, these criteria illustrate the thought process applied to determine a wide-ranging view of factors and levels of confidence for classification, and are consistent with Clauses 23 and 28 of the Code. The levels of confidence are kept simple as low, moderate, and high in keeping with the three resources categories of Inferred, Indicated, and Measured.

Table I is consistent with the suggestion of Snowden (2001) based on JORC guidelines, and this mainly qualitative approach concludes with the discretion of the CP in aggregating the factor confidence levels into a single statement of confidence for classification. It is neither completely objective, nor subjective. Snowden (2001) comments that 'By stating the criteria used in this way, there is some degree of discipline/rigour introduced into a procedure which can otherwise be very subjective. It is possible for an interested party to review the information tabulated and reach an independent decision if necessary.'

Table I. Key categorization criteria.

Key categorization criteria	Discussion	Confidence High/moderate/low
Drilling/sampling techniques		
Logging		
Drill sample recovery		
Sub-sampling techniques and sample preparation		
Quality of assay data		
Verification of sampling and assaying		
Location of sampling points		
Data density and distribution		
Audits or reviews		
Database integrity		
Geological interpretation		
Rock dry bulk density		
Diamond size frequency distribution		
Estimation and modelling		
Diamond valuation		
Cut-off grades/reasonable assumptions		
Mining factors or assumptions		

In late 2004, the SAIMM and GSSA organized a conference titled 'The SAMREC Inquisition' as a prelude to the two-year process leading to the launch of the revised SAMREC Code in early 2007.

Two presentations at this conference (Telfer, 2004; Balf, 2004) are of particular relevance to the present discussion.

Telfer (2004) gave a presentation entitled 'Diamond Resource Classification Reasoning … Logical or Illogical'. She proposed that we:

- Apply our minds, in a consistent manner
- Apply a consistent set of criteria for the selection of the classification category
- Ask if these criteria be included in SAMREC's diamond code?

The criteria were specifically based on the definitions for Measured, Indicated, and Inferred Mineral Resources and referred to levels of confidence with respect to:

- Tonnage
- Densities
- Shape
- Physical characteristics;
- Grade
- Average diamond value.

Continuity of geology and grade and a sufficiently large parcel of diamonds were also referred to.
It was noted that geologists are reluctant to quantify aspects of their work, and it was proposed that resource classification boundary-specifics be included in the diamond code. It was concluded '… this will ensure the consistent, logical and comparable classification of diamond resources'. While SAMREC did not pursue these ideas, perhaps because of the difficulty in achieving consensus on what the boundaries should be, sharing these ideas certainly gave food for thought, and may facilitate better understanding of reports prepared using this methodology.

Balf (2004) presented the De Beers resource classification methodology, titled 'Mineral Resource Classification'. The logic of the methodology is to establish a consistent and standard De Beers internal policy across the diversity of the Group's properties and projects that also conforms to the various international reporting codes. It was noted that:

- Reporting codes may be open to interpretation
- There are no standard procedures
- Different techniques are used for different projects
- The roles of geology and geostatistics
- The variety of diamond deposit types.

De Beers developed a Mineral Resource Classification Scorecard as an audit tool for this methodology. The scorecard is an attempted quantification of levels of confidence with scores out of 100. Scores in the range 30 to 69 are classified as Inferred; 70 to 89 are classified as Indicated; and scores above 90 are classified Measured.

De Beers labelled scores below 30 as 'Deposits', which provides a valuable management tool for determining the progress of exploration projects for internal consideration of possible economic costs and outcomes.

In more detail the project information is grouped as geology, grade, volume, density, and revenue models, similar to the criteria of Telfer, (2004), and each grouping is investigated in more detail for a comprehensive list of factors that are scored. Each model ultimately achieves an aggregated score and an overall weighted average score is evaluated for classification as illustrated in Figure 2.

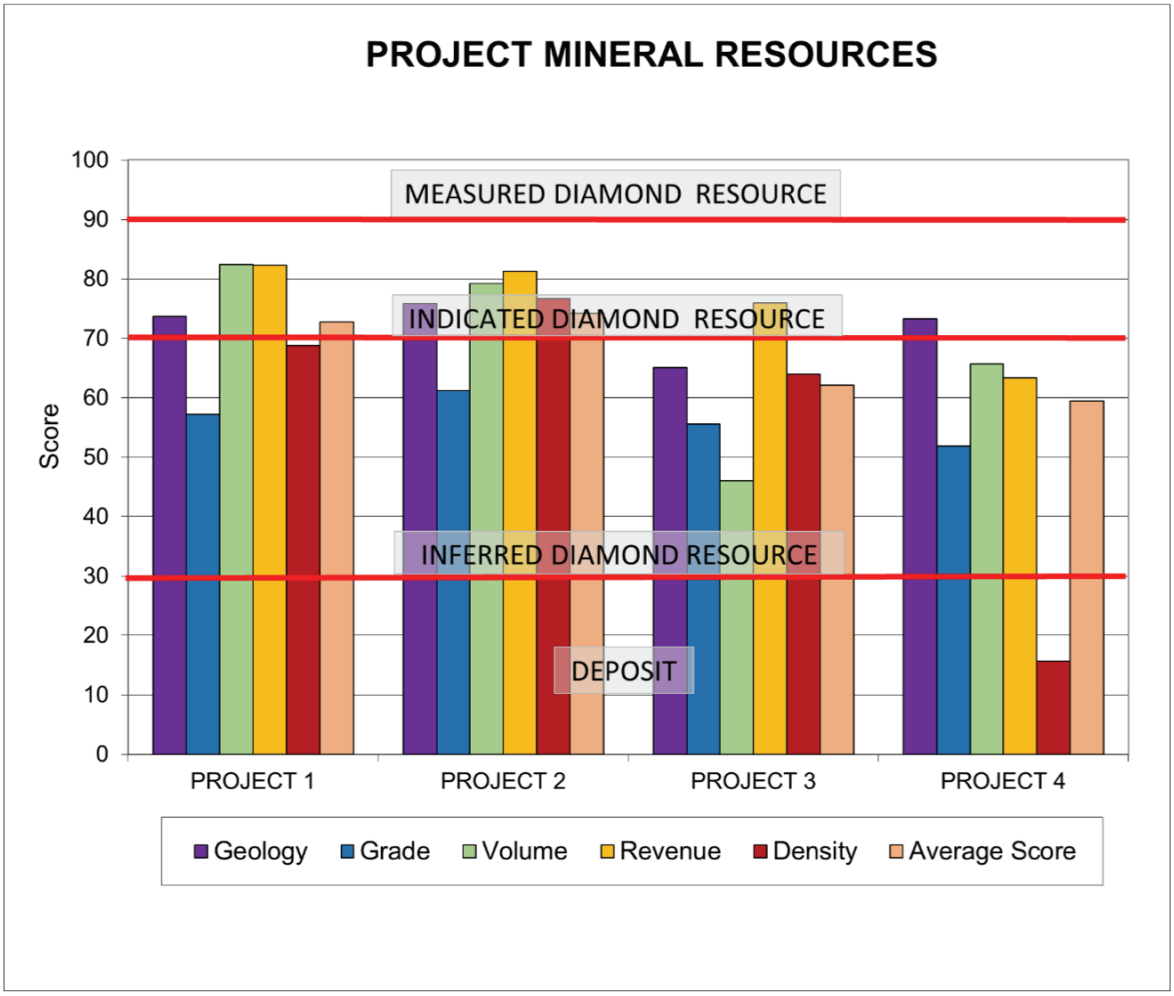


Figure 2. Resource scorecard example.

Note that for Project 4, the overall average score achieves an Inferred category score; however the score for density is well below the threshold for an Inferred Mineral Resource. This situation can be evaluated by the CP in one of two ways; either the overall average is accepted and a qualifying statement highlights the low score for density, or a lowest common denominator approach is adopted and the classification is limited to the 'Deposit' category in this case. A similar observation is appropriate for Projects 1 and 2, where one or more of the model scores does not achieve 70 but the overall score does. If classification is accepted on the overall average score it would be imperative to qualify this with a recommendation for additional work in those areas that score below the class threshold. This is particularly important in the examples given, as the low score is for grade, which is perhaps, together with revenue, the most important model.

De Beers shared the details of their scorecard factors with the SAMREC Diamond Review Group in 2005 and 2006. These are illustrated in Table II in summary form. Readers may adapt the items considered by De Beers to their own needs.

Table II. De Beers scorecard factors and scores.

Factor	Geology	Grade	Volume	Density	Revenue
Exploration techniques	20				
Geological sampling integrity	20				
Sample representivity	20				
Geological model definition	40				
Sample integrity		15		20	20
Sample accuracy		15			
Sampling programme		10		10	10
Estimation methodology		20	40	20	20
Risk analysis		40	30	50	50
Data integrity/compatibility			30		
	100	100	100	100	100

PROJECT EXAMPLES

The Kimberley Process (2014) Annual Global Production Statistics show that the Russian Federation and Alrosa Group of Companies are the world leaders in diamond production by both volume (38.3 million carats) and value (US$3700 million), followed closely by Botswana and Debswana (24.7 million carats and US$3600 million).

For the purpose of this paper these production statistics are less useful than other industry reports that provide data by both source and company. Thus, the De Beers Group of Companies (2014) identified the De Beers Group as the largest producer by value when all the Group production in South Africa, Botswana, and Canada is aggregated; Alrosa is identified in second place by value but is still clearly the largest producer by volume. Rio Tinto, SODIAM (Angola), and Dominion Diamond Corporation follow in this order by carat output. Bain and Company (2014) show similar relative production shares and include Petra Diamonds plc with the other major companies, while not separately identifying SODIAM.

In this paper project examples are grouped as the 'Big Three' (Alrosa, De Beers, and Rio Tinto), the 'Mid-Tier Companies' (Dominion Diamond Corporation, Petra Diamonds plc, Gem Diamonds Ltd., and Lucara Diamond Corporation) and 'The Best of the Rest' (Stornoway Diamond Corporation, Tahera Diamond Corporation, Peregrine Diamonds Inc., Diamondcorp plc, Kopane Diamonds plc, and Shore Gold Inc.).

The Big Three

Alrosa

Bartlett (2013) reported in compliance with the JORC Code on the diamond resources of the Alrosa Group assets. Classification was stated as being based on the quantity, quality, spatial distribution of sampling data, and the level of confidence of the resource tonnage and grade.

While this is not very helpful in understanding the details of the classification process, it may be of assistance to the reader to consider the Russian State Commission for Mineral Reserves (Gosudarstvennaya Komissia po Zapasam – GKZ) methodology, which is very prescriptive in terms of process. However, it is not the purpose of this study to consider this additional complexity.

An important aspect of the JORC classification was the inclusion of production reconciliation into the process. This provides an additional level of knowledge and confidence into the process that extends the results beyond the confidence in a first estimate of resources.

De Beers

In 2001 De Beers Consolidated Mines Limited (Kleingeld *et al*., 2001) prepared a Technical and Financial Report for the diamond business interests of De Beers and its partners, informally referred to as the Delisting Document. This comprehensive statement of De Beers Group Mineral Resources and Reserves was compiled and presented in compliance with the first SAMREC Code. Although this report contains a wealth of important detail of value to the CP new to the diamond industry, a discussion of the process of classification was not included. This report predates the De Beers scorecard discussed in the previous section, but it is reasonable to assume that a rigorous process was even then followed by the global leader in the industry.

Since the acquisition of De Beers by Anglo American, details of the resources are limited and details for the purpose of this review are lacking. However there are exceptions to this in the public disclosure for De Beers Canada operations at Gahcho Kue (Johnson *et al*,. 2014) and De Beers' participation in the Grib Kimberlite Project located in the Arkhangelsk Oblast (Region) of the Russian Federation (Ferreira and Skublak, 2008).

The Gahcho Kue report (Johnson *et al*,. 2014) specifically refers to the scorecard groupings of geological model, volume, grade, density, and average diamond value but does not provide any detail about the actual scoring beyond the outcomes as Indicated or Inferred Resources.

The Grib report (Ferreira and Skublak, 2008) is less clear but states 'De Beers Group Services has a detailed method of mineral resource classification, taking into account data integrity, methodology, adherence to procedures and sampling information', which from the 2008 date must refer to the scorecard. In addition the sampling procedures were reviewed and considered reasonable, and of an appropriate standard and level of quality control for classification under National Instrument 43-101 (NI 43-101, - the Canadian public disclosure standards for mineral projects).

The Snap Lake project was acquired by De Beers from Winspear Diamonds Inc. in 2000. This pre-dates the introduction of NI 43-101 in 2001. The De Beers Delisting document mentioned above includes a summary of resources for this project but no discussion of the classification process. It is possible that Winspear Diamonds filed its feasibility study in 2000 but this cannot be found on www.sedar.com. No doubt under the De Beers ownership, the resources are classified under the scorecard system.

Rio Tinto

The Diavik Diamond Mine in Canada is a 60/40 joint venture between Rio Tinto plc and Dominion Diamond Corporation. Rio Tinto has public disclosure obligations under Australian JORC and US SEC reporting requirements. Dominion Diamond Corporation has public disclosure obligations under NI 43-101 in Canada. Rio Tinto, as the operator, has met all these obligations for many years now and has commented in Yip (2008). Indeed, Rio Tinto has internal global standards and internal review/audit criteria for the estimation and reporting of Mineral Resources that are 'reinforced through a formal global community of practice'. As an example, these internal standards require order-of-magnitude desk studies to support the reasonable expectations for even the minimum Inferred Mineral Resource classification.

Periodic independent external resource audits have provided an additional level of confidence in the estimation over many years, with four audits completed to date since the mine opened in 2003.
The long production history at this mine has also facilitated the application of reconciliation data in the estimation and confidence in resources. Yip (2008) reported consistently more diamonds in production than had been modelled for resources. These positive changes were found in the recovered diamond size/frequency distribution and the amount of external dilution in the feed to the processing plant. Diavik introduced reconciliation factors to adjust for about 10% higher diamond recovery across

the several pipes comprising the mine. Further refinements in estimation procedure were developed and reported by Yip and Thompson (2015) to limit the spatial influence of high-grade pockets observed during sampling. In this way production history has assisted in fine-tuning the estimates and improving confidence.

Notwithstanding the transparency provided for the corporate standards, reviews, and reconciliation applied by the owners, details of the classification process are poorly documented in comparison with De Beers' discussion of its scorecard.

Roscoe and Postle (2005) observed that the key criteria for Diavik resource classification were the '… assessment of geologic continuity, the density of LDC (Large Diameter Core) drill hole and sample spacing both vertically and horizontally, and the visual assessment of stone density and stone size profiles from LDC results.' Analysis of errors in the estimated stone density and conditional simulation of the location of pipe wall contacts contributed to improved confidence assessment in assigning the classifications.

The Mid-Tier Diamond Companies

Dominion Diamond Corporation

Dominion Diamond Corporation acquired the Ekati Diamond Mine in the Northwest Territories of Canada from BHP Billiton Canada Inc. at the end of 2012. As the new owner, Dominion was required as per NI 43-101 to file a current technical report (Heimersson and Carlson, 2013), and this report provides a clear outline description of the resource classification methodology applied by Dominion and its predecessor BHP Billiton.

The initial classification of the multiple kimberlite pipe occurrences was based on drilling spacing thus:

- Measured less than 30 m to nearest sample
- Indicated less than 60 m to nearest sample
- Inferred less than 90 m to nearest sample.

Kriging variance was used to support this initial classification in some cases.

Dominion (and previously BHP Billiton) applied a scorecard rating to extend this simplistic initial classification. This scorecard built on a robust geological model and was based on a '… workshop rating of key model data sets including volume, grade, internal geology and diamond valuation.' It also took account of '… tenure status, processing characteristics and geotechnical and hydrogeological factors …' and may in outcome be similar to the De Beers scorecard. The final score was a weighted average of all the factors considered with class ranges as follows:

- Measured: 3.5–4.0
- Indicated: 2.5–3.5
- Inferred: 2.0–2.5.

Commentary on classification for the various pipes in the mine complex included, but was not limited to, the following:

- Lack of a large separate robust valuation parcel (Koala)
- Small grade sample sizes, uncertainty associated with the kriging parameters, and uncertainty with the internal geological model (xenolith model) (Fox)
- Despite extensive drilling, there is uncertainty with sample grade variability, excessive contamination in some RC holes, and changes in de-grit slot sizes in the sample plant for the various RC campaigns (Misery)
- Uncertainty in pipe contacts (Pigeon)
- Limited diamond parcel size, uncertainty in geology, and sparsity of density data (Sable)
- Limited drilling pierce points, small diamond parcel, and minimal data on internal geology and density (Jay).

This commentary is referenced to illustrate some of the issues that may impact levels of confidence in classification.

Petra Diamonds

Petra Diamonds has a portfolio of hard-rock diamond mines on the African continent, located primarily in South Africa. Petra Diamonds built up its portfolio of producing operations by first acquiring the Sedibeng, Star, and Helam fissure mines in 2005 by merger with ASX-listed Crown Diamonds. Resources and Reserves on these mines were classified in compliance with the JORC Code (1999) using production information (diamond recoveries and detailed spatial records of fissure and stoping widths recorded during mining) to project grade, fissure width, and stoping width down-dip (Retter and Snowden, 2005), taking into account down-dip host rock characteristics to predict sidewall dilution – a major consideration for diamond grade and tonnage in Proved and Probable Reserves.

The Northern Cape (Messina) and Free State (Star) fissure mines presented an interesting challenge for resource estimation and classification, which was addressed by Retter and Snowden (2005) in their valuation report for their acquisition by Majestic Resources NL prior to the later consolidation under Petra Diamonds (included in the Petra Diamonds AIM Admission Document for the acquisition of Crown Diamonds NL). For different reasons, these two fissure kimberlite mines (and indeed the Helam mine, which also passed into Petra Diamonds ownership) faced the challenge of how to extrapolate production data to depth below current mining levels where limited geological data and no sampling data was available to demonstrate continuity of geology and grade.

Retter and Snowden (2005) stated: '*The down-dip projection of diamond grade in the kimberlite fissure therefore relies upon grade information from the deepest mining areas at Messina and through consideration of the mine's historical diamond production performance. In Snowden's opinion it is acceptable and appropriate to rely on this data to project the diamond grade of the fissure down-dip for the next 240 m, albeit with decreasing confidence as the depth increases below 21 Level*.'

Reporting in compliance with JORC (1999), they classified diamond resources with decreasing confidence as follows:

- Measured Resource: one level (40 m) below the base of the current working levels
- Indicated Resource: two levels (80 m) below the base of the Measured Resource
- Inferred Resource: three levels (120 m) below the Indicated Resource.

Any CP considering adopting this approach to classification must provide a comprehensive description of the logic used for the specific project, in the same way that Retter and Snowden (2005) have done for Messina and Star. It should be noted that this approach may be valid only for operating diamond mines, and not for exploration and/or development projects.

In 2006 Petra Diamonds started acquiring non-core assets from De Beers, starting with the Koffiefontein diamond mine in 2007, the Williamson diamond mine in Tanzania and the Cullinan diamond mine in 2008, the Kimberley underground diamond mine in 2010, and the Finsch diamond mine in 2011. Resources and Reserves for all these assets had been classified using the De Beers scorecard system in compliance with the SAMREC codes (2000 and 2007) as described in the section titled *A Scorecard Approach to Classification*. Petra Diamonds has continued to rely on the De Beers scorecard system for Resource and Reserve updates for these operations, with revenue and volume models updated using actual diamond sales data and production depletions respectively (Rogers, personal communication, 2015).

Gem Diamonds

Gem Diamonds plc acquired the Letšeng diamond mine in 2005 and has operated with great success in the ten years since then. Letšeng is a very atypical diamond source in that it is a hard-rock kimberlite pipe mine but with alluvial diamond deposit characteristics of very low grade and very high value. The pipe has provided five of the 20 largest white diamonds ever recovered globally. The

first of these (the 601 carat Lesotho Brown) was found during artisanal mining operations in 1967; this has been followed by stones of 603, 493, 478, and 550 carats in the years since the Gem acquisition.

Despite the excitement and romance of these, and many other, special stone recoveries, resource classification for Letšeng has been problematic since before the first production under De Beers' ownership from 1977 to 1981. RTZ was the first company to apply modern exploration and evaluation methods to the Letšeng pipes, but was unable to achieve an acceptable level of confidence within that company's knowledge and understanding. The property was optioned to De Beers in 1973 and the gamble to open a mine was taken amid muted fanfare. The collapse of the diamond market in 1981 led to the demise of the mine at that time. This production period preceded the era of public disclosure codes and coincided both with the historic high levels of secrecy in the global diamond industry, and perhaps some of the international trading constraints during the *apartheid* era.

Telfer and McKenna (2011) documented the then current status of the geological and economic knowledge for this mine. Their resource classification was '… based upon historical exploration and production results, previous drill holes and recent production and sales information.' Their Table 23, *Resource Classification Logic Table for Letšeng*, followed the logic discussed by Telfer (2004).

It is not the purpose of this paper to challenge the results of any specific published Resource. Readers are encouraged to access the report by Telfer and McKenna (2011) and consider the geological and mining scenario for themselves. It is very clear that the Letšeng Mine has proved extremely successful over the last ten years and that production reconciliation, in this case, is the critical aspect of assessing levels of confidence. Nevertheless, it is patent that a single important check phrase of the SAMREC (2007/9) diamond resource definition is not fulfilled. This phrase is 'the continuity of geology and grade'. The assumption in this case is asymmetric because, although deep geological data may have been acquired through drilling, no sample grade data exists below the current mining levels. SAMREC (2016) is even more prescriptive with regard to estimating diamond resources.

While the 'proof may be in the pudding' and production results continue to support the estimates, the question may be to what depth this production data may reasonably be extrapolated. The valuation report referenced in the Petra Diamonds section here (Retter and Snowden, 2005) provides a template, or example, to resolve this dilemma.

Any CP considering adopting this approach to classification must provide a comprehensive description of the logic used for the specific project, in the way that Telfer and McKenna (2011) have done for Letšeng. Only in this way can readers come to their own decision if this is at variance with the report. It should be noted that the approach may be valid only for operating diamond mines, and not for exploration and/or development projects.

The resource classification in Telfer and McKenna (2011) for the Ellendale Lamproite Diamond Mine in Western Australia and the Gope (now Ghagho) Diamond Mine in Botswana followed the same methodology.

Lucara Diamond Corporation

Lucara Diamond Corporation acquired a majority interest in the AK6 project from De Beers Botswana Prospecting (Pty) Ltd in November 2009. Consolidation of 100% ownership was completed in 2010, in good time for commissioning of the new mine, called Karowe, in 2012.

Much of the technical development work through to feasibility studies was completed by De Beers before that company divested its interest in the project. Although De Beers' technical reports are not publicly available, it is reasonable to assume that resource classification followed their scorecard methodology. However this is not clear from Lynn *et al.* (2014), and this most recent report simply states that classification is based on CIM Definition Standards (CIM, 2014).

The reliability of the geological model was considered moderate to high with a level of confidence appropriate for classification as an Indicated Mineral Resource. This was based on the drilling density and the thorough geological and geochemical logging technique. Deeper parts of the pipe with fewer drill-holes were classified as Inferred Mineral Resources.

The extensive density sample data and the statistical treatment were deemed to be at high confidence and supportive of Indicated Mineral Resource classification in the upper levels of the pipe, but falling away to low confidence with depth.

The spatial distribution of grade samples was likewise considered to be at confidence levels sufficient for Indicated Mineral Resource classification above 400 m depth, but reducing thereafter.
Inclusion of diamond size frequency distribution (SFD) and sales price data from production has considerably improved the diamond revenue model for Karowe in comparison with the previous reported resources (Lynn *et al*., 2014). This is not uncommon with a new mine when SFD and valuation have been based on relatively small parcels and an indication of larger diamonds is apparent but not yet supported by diamond recoveries. Consequently, the level of confidence has improved and fully supports an Indicated Mineral Resource classification even though it is acknowledged there is still uncertainty for the special stones (+10.8 carat).

Lucara Diamond Corp completed a 600 000 t trial mining programme for the Mothae kimberlite, located close to the Letšeng mine in Lesotho, but sold the project to Paragon Diamonds Limited in May 2015. The diamond grade and value for this kimberlite showed some similarity to Letšeng but with higher grade and lower value; the combination of grade and value did not meet Lucara's economic objectives.

Lynn and Ferreira (2013) prepared a resource estimate for the project with classification of Inferred Mineral Resources based on evaluation of the uncertainty of primary components of tonnage (volume and density), grade, and value tabulated in a matrix for the geological domains. The final resource classification was determined from the highest risk component, in contrast with the aggregated outcomes of the De Beers scorecard. This resulted in diamond value being the determining component. Although the geological model was not included in the matrix, considerable work went into developing the domain models, which probably reflect a moderate level of confidence.

Best of the Rest

Stornoway Diamond Corporation
The Renard diamond project is currently being developed by Stornoway Diamond Corporation for mine commissioning in 2016 and full production in 2017. It will be the first diamond mine in the Quebec Province of Canada, with projected production of 1.6 million carats per annum.

Bagnell *et al*. (2013) prepared an updated feasibility study filed as required by NI 43-101. This report provides brief comment on the procedure by which classified mineral resources were constrained using drilling density and sample distribution. Levels of confidence of sampling results and drill-hole intercepts were considered and classification embraced aspects of geology, grade revenue, density, SFD, and continuity. Substantial sampling data supported Indicated Mineral Resources to 600 m depth in Renard 2. More limited sampling data is available for the other pipes, but there is deemed to be sufficient confidence in the geological/lithological/volumetric/density aspects for the same classification as Renard 2. Sufficiently large parcels of diamonds have been recovered to support Indicated Mineral Resources for Renard 2, 3, and 4.

Tahera Diamond Corporation
The Jericho diamond mine is a now dormant operation northeast of Yellowknife, Northwest Territories, Canada that was owned and operated by the Tahera Diamond Corporation between 2006 and 2008. Financial losses due to operational difficulties, the exchange rate, the oil price, and other factors impacted the viability of the mine in 2007 with the advent of the global financial crisis. Shear

Diamonds Limited purchased the property in 2010 but its plans to reopen the mine have not been fulfilled.

Reipas *et al*. (2004) prepared a Preliminary Assessment (now Preliminary Economic Assessment) filed as a NI 43-101 report.; The objective of this study was to provide an opinion on the inclusion of Inferred Mineral Resources in the Jericho open pit production schedule and plant feed as a supplement to the Feasibility Study prepared earlier in 2003.

Classification of the mineral resources considered the geometry of the pipe and the diamond distribution. Reasonable confidence and a commensurate Indicated Mineral Resource classification were determined for the upper portions of the North and Centre lobes, with Inferred Mineral Resources below. Although other factors may have been considered, they are not mentioned in the report.

Peregrine Diamonds
Peregrine Diamonds Ltd is the owner of the Chidliak Project, Canada's most recent exciting diamond discovery, located on Baffin Island in northern Nunavut. Despite some very good diamond sampling grades well in excess of one carat per ton, and the JV involvement of both BHP Billiton and De Beers, the small sizes of the kimberlite pipe take some of the gloss off the early euphoria. Both JV partners have since withdrawn.

The first mineral resource report by Farrow *et al*. (2015) provides a solid foundation for understanding the future viability of the project. An Inferred Mineral Resource of 3.3 Mt at a grade of 2.58 carats per ton (cpt) was declared for CH-6; additional potential tons in the range 3.2 Mt to 4.4 Mt was reported for CH-6, with further ranges of 3.7 Mt to 6.0 Mt for CH-7 and 1.3 Mt to 3.2 Mt for CH-44.
Comparison should be made with the Marsfontein M1 kimberlite pipe in Limpopo Province, South Africa (Kleingeld *et al*., 2001), which was a very small but high-grade diamond mine that operated briefly and very profitably in the late 1990s.

Although Farrow *et al*. (2015) state that 'Classification of resources in diamonds is an inclusive process, examining aspects of geology, drilling, sampling, grade, revenue, density, and diamond size frequency', their description of the actual classification for this project is limited to the observation that there is '… sufficient drilling and sampling …' that '… includes macrodiamond and microdiamond samples from drill core and from a surface trench' for the delineation of an Inferred Mineral Resource.

Peregrine Diamonds Ltd is also the owner of the Lo27 Project in the Northwest Territories, Canada where an Inferred Mineral Resource of 19.5 Mt at a grade of 0.94 carats per ton has been reported by Eggleston and Brisebois (2008).

Classification of the mineral resource in this project has been constrained by a Lerchs-Grossman computer-generated pit shell using certain fixed parameters. Kimberlite material within this pit shell was declared as Indicated Mineral Resources. This purely numeric method differs from all the previous descriptions discussed here; the computation complies with the requirement for 'reasonable prospects' but does not clearly address the level of confidence in the data and estimate.

Diamondcorp plc
The Lace diamond mine is 100%-owned by Lace Diamond Mines (Pty) Ltd, which is 74% held by Diamondcorp plc, a company listed on the AIM in London. The mine had a history of sporadic mining until 1931 and was sold to De Beers in 1939. The property was dormant until 1997, when it was divested and eventually passed to the present ownership.

The most recent resource statement and report was prepared by Zweistra (2012), but only a tabulation of tons and grade are provided on the company website.

Inferred diamond resources were declared for the fresh kimberlite underground below the depth of 345 m to 855 m in the Main pipe and 600 m in the Satellite pipe. The rationale for classification at this low confidence level is not publicly documented. The absence of diamond grade data should have precluded a resource declaration for the Satellite pipe. Additionally, the absence of any statement of diamond value should have precluded a resource declaration; indeed, under the revised SAMREC Code in preparation, this will be prohibited.

Indicated diamond resources were declared for fresh kimberlite underground from 73 m depth to 345 m depth for both the Main and Satellite pipes. The rationale for classification as Indicated Resources is not publicly documented. Diamond value was not stated.

Measured diamond resources were not tabulated, although tailings were previously reported as Proven and Probable Reserves in the CPR supporting the AIM Admission Document (Sobie, 2007).

Kopane Diamond Developments plc

Leroux (2010) prepared a CPR for the AIM Admission Document supporting the merger of Kopane Diamond Developments plc and Firestone Diamonds plc. Although the Admission Document also reported on other properties, this CPR was limited to the Lighobong diamond mine located in Lesotho, and compiled technical reports and studies up to Feasibility level, as well as a new diamond resource estimate, for this mine.

Although Leroux (2010) referred to the common five factors of geology, volume, density, grade, and revenue for resource classification, he surprisingly stated that only the grade component was under consideration in this report.

The grade data from large-diameter drilling (LDD) on a grid of 50 m spacing and 20 m sample lengths was considered 'reasonable'. Variograms showed grade continuity and predictability, and Indicated diamond resources were classified to a depth of 150 m, with Inferred diamond resources to the maximum depth of drilling.

The resources have been updated since this report (Bosma *et al*., 2015) with the classification approach closer to the De Beers scorecard, perhaps reflecting the career experience of the CPs.

Shore Gold

Shore Gold Inc. is the owner of the Star–Orion South diamond project, Fort À La Corne, Saskatchewan, Canada. This property is a potentially large-scale mining project. Development is awaiting an improvement in the mining viability with the recovery of global economic fundamentals. Mineral Resources and Reserves have been estimated by P & E Mining Consultants Inc. of Toronto, Canada, and updates have been undertaken during the waiting period.

Ewert *et al*. (2009) has been selected as the most recent resource estimate filed under NI 43-101; other reports in 2010 and 2011 present the engineering studies with summary resource reporting.

Grade estimation from adjusted LDD sample data was by ordinary kriging. Kriging parameters were developed from variography. A minimum of four and a maximum of six samples from two or more LDDs within the semivariogram range of 170 m were required to estimate and classify Indicated Mineral Resources.

Blocks not populated during the first pass were estimated in a second pass. This estimate required a minimum of three and a maximum of six samples from one or more LDDs within twice the semivariogram range of 340 m and were classified as Inferred Mineral Resources.

Although this estimation and classification methodology would appear to rely entirely on a 'black box' approach, this is not quite true. The estimate was disclosed as a NI 43-101 report with the prescribed report format that includes multiple sections requiring CP/QP opinion on the data quality

for resource estimation. In this way the Canadian disclosure method closes the gap in the oft-repeated components for a diamond resource classification, namely geology, volume, density, grade, and value. However, in this report it is necessary to review multiple previous sections of the report where a common statement is that data or results are '… adequate to support Resource Estimation and mine planning activities.' In all cases this wording precludes the reader making a judgement on confidence levels that are the requirement for deciding on resource category.

Some Helpful Suggestions

The SAMREC Code is not prescriptive with regard to classification and common sense should be applied by the CP. Stephenson and Vann (2001) have observed '… there is nothing in the JORC Code which requires classification to be a complicated process or to be based on a particular procedure …'. They conclude that '… consideration of confidence in continuity of geology and metal values in conjunction with the quality, quantity and distribution of the data … the resulting classification should be in accordance with the JORC Code.' This view holds equally for the SAMREC Code.

The Oxford English Dictionary defines 'common sense' as 'Good sense and sound judgement in practical matters'. It is this meaning that should be applied to all of our estimation and classification work processes, keeping in mind that the data is a combination of quantitative and qualitative information which will always require an element of judgement and discretion in how it is used.

Geological Interpretation

Appleyard (2001) states that the geological interpretation may be paramount. This should not be a surprise to the project and resource geologists involved in any project as it progresses from discovery through evaluation. Indeed it is the foundation for any estimation and is an iterative process that may even take a backward step on occasion.

A robust geological model will also be essential to the effective use of geostatistical estimation methods, and demonstrates how computer-software-driven estimation may go off the rails if not constrained properly.

The role of good geology continues into the mining phase of any project, but this is beyond the scope of the present paper.

Project Geologist

Stephenson and Vann (2001) point out that the geologist most familiar with the deposit should be involved in the classification. This need arises from the fact that independent consultants may often be required for regulatory or other reasons to conduct the estimate. However, these CPs may make only a cursory visit to the property, during which time familiarity with the geology and other matters must embrace a wealth of information. If the resulting estimate and classification is at variance with the project geologist's view of the deposit, there may be doubts and confusion in the minds of the company executives and other readers or end-users of the report, to the detriment of the project.

Effect of Additional Drilling and Sampling

Stephenson (1995) and Stephenson and Stoker (2001) report that consideration should be given to the possible effect of additional drilling and sampling on the likely outcomes of the estimate. The benefit of more drilling may be patent in both a better definition of the kimberlite domain 3D models (and thus tonnage), and in variance in grade estimates from spatially constrained (*e.g.* LDD) sample collection. In the first case, the volume estimate will be improved and the CP should consider the extent of this improvement. In the latter case the grade estimate will certainly benefit from additional samples; however, the CP should consider whether the possible reduced variance could impact the level of confidence for classification. The comment of Oosterveld (2001) referred to in this paper may be helpful in this regard.

Stephenson and Stoker (2001) suggest a simple test whereby any additional drilling may affect the shape and/or distribution of the mineralized zone but not the tonnage-grade estimate, and an Indicated Mineral Resource classification may be appropriate. They go further in suggesting that if the CP has adequate confidence for the estimate to be used in technical and economic studies, then the requirements for an Indicated Mineral Resource have probably been met. Indeed, this aspect in now integral to the definition of an Indicated diamond resource in the SAMREC Code.

Effect of Estimation Variance on Economic Viability

The SAMREC Code guidelines to the definition of a Measured Mineral Resource states that '… any variation from the estimate would not significantly affect potential economic viability.' In line with the comment of Oosterveld (2001), this provides a useful test for classification; a simple check of the grade and value (and their variance limits) in the test for 'reasonable prospects' should confirm that the lower limit of the variance remains within the bounds of viability. If this lower limit does not meet the test, a Measured Mineral Resource cannot be declared; an Indicated or Inferred Mineral Resource may still be acceptable if the mean grade estimate fulfils the 'reasonable prospects' test and all other criteria support such classification.

A very simple test could be to enter the downside variance limits of the grade (carats per hundred tons) and/or value (dollars per carat) into the 'reasonable prospects' test to investigate the impact on the economic outcome.

Impact of Mining Method and Cut-off Grade

The application of cut-off grades to kimberlite diamond deposits may not always be appropriate (CSA-CIM Working Committee, 2008). This question-and-answer feedback stated 'In certain circumstances, the contacts between the rock types define the mining limit, rather than an economic cut-off grade. Examples of this are diamonds in a kimberlite pipe …'. Nevertheless, the impact of the mining method and scale may affect resource definition and classification. A bulk mining operation may tolerate a lower rock value that meets the test of 'reasonable confidence' and may be classified differently from the same numeric outcome where the volume and tonnage are significantly smaller.

Reporting Periods

Oosterveld (2001) has shown the relevance of reporting periods to the estimate, and consequently the classification. It is probable that this view of a potential operation may become apparent only when mine plans are under consideration. Notwithstanding this aspect, the CP who visualizes the possible future mining options as part of the process of assessing classification confidence will be able to factor conceptual operational fluctuations into the classification.

Snowden (2001) shows that grade risk forms the estimation compared with simulated median, maximum, and minimum grades for scheduled production years (Figure 3). Although the simulation displays a smoothing of the grade with time, scheduled production grades in years three, seven, and nine are well outside the simulation envelope, highlighting risk periods that may have relevance for classification.

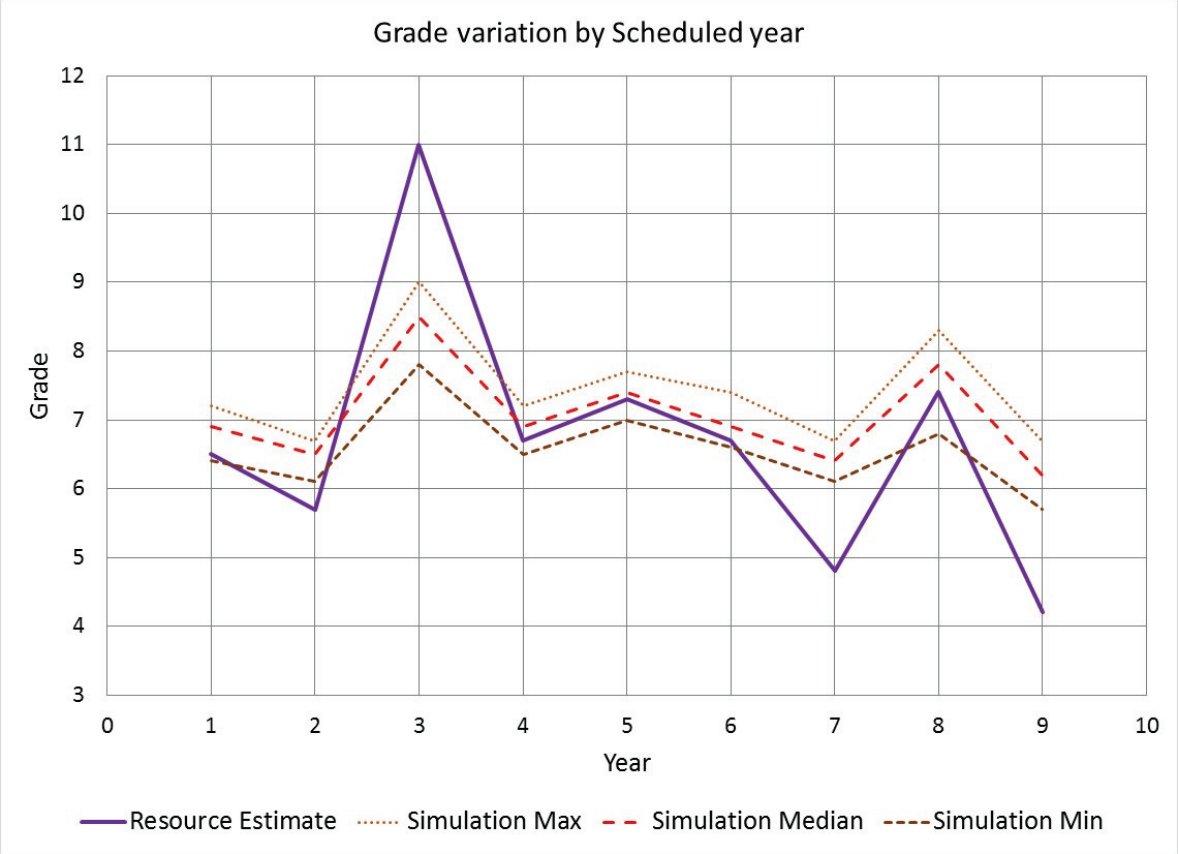


Figure 3. Grade risk illustrated by reporting period (after Snowden, 2001).

CONCLUSIONS

The ultimate test of any diamond resource classification is progress of the project to production, and profitable operations thereafter. Among the project examples listed in this paper there is only one demonstrable 'failure' – the Jericho diamond mine in Canada. In the context of the current discussion it is not entirely clear if that failure was the result of poor classification or the impact of the Global Financial Crisis that started in 2007. Perhaps a more conservative classification would have resulted in additional studies that better identified the various financial and technical risks.

Porter (2007) has discussed, from a project management viewpoint, how a well-defined project may still deliver value, whereas a poorly-defined project, at the early stage, is unlikely to deliver value even if well executed.

Several project examples listed here have completed feasibility studies but not yet achieved financing, mine construction, or production. Until they do, a lingering doubt may persist regarding 'reasonable prospects' and/or classification.

Studies of project failure that may be pertinent to this discussion show that the areas of problem and frequency (McCarthy, 2013) are:

Geology, resource and reserve estimation	17%
Geotechnical analysis	9%
Mine design and scheduling	32%
Mining equipment selection	4%
Metallurgical test work, sampling and scale-up	15%

Process plant equipment design and selection	12%
Cost estimation	7%
Hydrology	4%

While failures due to engineering and other non-resource factors appear more common, this should be no reason for complacency among the resource geology community.

Lucara's Karowe mine may be a project where production results have exceeded expectations. However, minor changes in grade and significant improvement in value may partially be the consequence of the bottom cut-off being used in production. Notwithstanding this factor, there is no doubt that the continuing good-news story of large Type IIA stones and blue diamonds reflects improving knowledge of the impact of the large size 'tail' to the SFD, and the occasional recovery of exceptional blue stones. It would have been challenging to have demonstrated these positive features at the feasibility stage without considerably larger bulk samples to increase the probability of recovering these special stones. The original classification was fully justified, as has been confirmed through production results.

Perhaps the very best good-news story was the discovery, evaluation, and commissioning of the Jwaneng diamond mine in Botswana. This kimberlite pipe, discovered in February 1973 (Lock, 1985), was evaluated using the then-novel 381 mm diameter jumper (churn) drilling (Lock and Barton, 2007). The method involved many sampling and data challenges that could impact resource classification if the work were to be done in the same way with today's compliance requirements. These came to light, in a good way, after the mine went into production in 1982. Diamond recovery exceeded expectations to such an extent that the mining engineers believed they were doing an exceptional job! However, challenging discussion about the veracity of the resource fundamentals led to an extensive re-crush test programme and the commissioning of a re-crush plant that showed grade, value, and rate of return that many mines would be happy to achieve with primary recovery! Such is the profitability of the Jwaneng diamond mine.

The moral of this story is that we may not always get it quite right, in either a negative or positive manner. Our responsibility is to undertake our estimation and classification work to the best of our ability applying industry good practice. Our classification directly relates to the financial risk assessment advice that the project owner needs to progress the project, or not, and is thus of utmost importance.

ACKNOWLEDGEMENTS

I wish to acknowledge and thank Tania Marshall of Explorations Unlimited, and Andrew Rogers of Petra Diamonds; their early reading of a first draft of this paper provided some initial improvements. I would also like to acknowledge and thank the two anonymous reviewers whose helpful comments and edits that have improved the presentation in this paper.

REFERENCES

Appleyard, G.R. (2001). An overview and outline. *Mineral Resource and Ore Reserve Estimation – The AusIMM Guide to Good Practice.* Edwards, A.C. (ed.). Australasian Institute of Mining and Metallurgy, Melbourne. pp. 3–12

Bagnell, W., Bedell, P., Bertrand, V.J, Brummer, R., Farrow, D., Gagnon, C., Gignac, L-P., Gormely, L., Magnan, M., and St-Onge, J-F. (2013). The Renard Diamond Project, Québec, Canada. Feasibility Study Update. NI 43-101 Technical Report for Stornoway Diamond Corporation. www.sedar.com.

Bain and Company, Inc. (2014). The Global Diamond Report 2014. Diamonds: Timeless Gems in a Changing World. http://www.bain.com/publications/articles/global-diamond-report-2014.aspx

Balf, A.J.A. (2004). Mineral Resource Classification. Presentation for the SAMREC Inquisition. [Unpublished]. Southern African Institute of Mining and Metallurgy, Johannesburg. http://www.samcode.co.za/downloads/SAMCODEnews.pdf

Bartlett, S.C. (2013). Independent Expert Report on Reserves and Resources of the Diamond Assets of the Alrosa Group of Companies. Micon International Co. Limited. http://eng.alrosa.ru/investors/reserves-and-resources/

Bosma, P., Lohrentz, C., Bush, D., Hunter, S., Gallagher, M., and Chama, T. (2015). Firestone Diamonds Plc. Liqhobong Mine Expansion Project, Diamond Resource and Reserve Report. [http://www.firestonediamonds.com/operations/reserves-resources].

CIM. (2014). Definition Standards for Mineral Resources and Mineral Reserves. Prepared by the CIM Standing Committee on Reserve Definitions. [http://web.cim.org/standards/MenuPage.cfm?sections=177&menu=178

CRIRSCO. (2013). International Reporting Template for the Public Reporting of Exploration Results, Mineral Resources and Mineral Reserves. Committee for Mineral Reserves International Reporting Standards, Council of Mining and Metallurgical Institutions. http://www.crirsco.com/templates/international_reporting_template_november_2013.pdf

CSA-CIM Working Committee. (2008). Questions resulting from CSA-CIM Committee Meetings (April 14, 2008). CIM, Montreal. [Available on request].

CSA-CIM Working Committee. (2009). Additional Guidance – Reasonable prospects for economic extraction. http://web.cim.org/standards/MenuPage.cfm?sections=177&menu=178

De Beers Group of Companies. (2014). The Diamond Insight Report. 2014. http://insightreport.debeersgroup.com/

Eggleston, T. and Brisebois, K. (2008). Peregrine Diamonds Limited. DO-27 Diamond Project, Northwest Territories, Canada. NI 43-101 Technical Report. Prepared AMEC for Peregrine Diamonds Ltd, Dentonia Resources Ltd, and Kettle River Resources Ltd. http://www.sedar.com

Ewert, W.D., Brown, F.H., Puritch, E.J., and Leroux, D.C. (2009). Technical Report and Resource Estimate Update on the Star Diamond Project, Fort à la Corne Area, Saskatchewan, Canada. Prepared for Shore Gold Inc. by P&E Mining Consultants Inc. http://www.sedar.com

Farrow, D., Pell, J., and Fitzgerald, C. (2015). 2015 Technical Report for the Chidliak Project, Baffin Region, Nunavut. Prepared by GeoStrat Consulting Services Inc. for Peregrine Diamonds Ltd. http://www.sedar.com

Ferreira, J. and Skublak, W. (2008). Technical Report on the Grib Kimberlite Pipe, Verkhotina Licence Area, Arkhangelsk Oblast, Russian Federation. Report for NI 43-101 Prepared for Archangel Diamond Corporation. http://www.sedar.com

Heimersson, M. and Carlson, J.A. (2013). Ekati Diamond Mine, Northwest Territories, Canada. NI 43-101 Technical Report prepared for Dominion Diamond Corporation. http://www.sedar.com

Johnson, D.D. Meikle, K., and Pilotto, D. (2014). Gahcho Kué Project 2014 Feasibility Study Report. NI 43-101 Technical Report. Prepared for Mountain Province Diamonds/De Beers Canada. http://www.sedar.com

Kimberley Process Certification Scheme. (2014). Annual Global Summary: 2014 Production, Imports, Exports and KPC Counts Summary Report. https://kimberleyprocessstatistics.org/public_statistics

Kleingeld, W.J., De Sousa-Oliveira, M.L.S., and Penny, G.P.H. (2001). Technical & Financial Report for the Diamond Business Interests of De Beers and its Partners.

Leroux, D.C. (2010). Competent Persons Report on the Exploration and Mining Assets, Liqhobong Diamond Project, Lesotho. Prepared by ACA Howe International Ltd. for Kopane Diamond

Developments Plc. and included in the Firestone Diamonds Plc AIM Admission Document related to the acquisition of Kopane Diamond Developments Plc.

Lock, N.P. and Barton, E. (2007). A commentary on diamond grade evaluation: from Jwaneng to the present. *Diamonds in Kimberley Symposium*, 23–24 August 2007. Geological Society of South Africa.

Lock, N.P. (1985). Kimberlite exploration in the Kalahari region of southern Botswana with emphasis on the Jwaneng kimberlite province. *Proceedings of Prospecting in Areas of Desert Terrain*, Rabat, Morocco, 14–17 April 1985. Institution of Mining and Metallurgy, London and the Ministry of Energy and Mines, Government of Morocco. pp. 183–190.

Lynn, M. and Ferreira, J. (2013). NI 43-101 Technical Report and Mineral Resource Estimate for the Mothae Diamond Project, Lesotho. Prepared by The MSA Group (Pty) Ltd on behalf of Lucara Diamond Corp. http://www.sedar.com

Lynn, M., Nowicki, T., Valenta, M., Robinson, B., Gallagher, M., Bolton, R., and Sexton, J. 2014. Karowe Diamond Mine, Botswana. NI 43-101 Independent Technical Report (Amended). Prepared on behalf of Lucara Diamond Corp. http://www.sedar.com

McCarthy, P. (2013). Why Feasibility Studies FAIL. Melbourne Branch, Australasian Institute of Mining and Metallurgy. (https://www.ausimm.com.au/content/docs/branch/2013/melbourne_2013_02_presentation.pdf)

Oosterveld, M.M. (2001). Diamond Resource Classification. [A note for Mr J. Clarke. President, MineGem Inc.]

Porter, D.J. (2007). Mining Projects Delivering on their Promise to the Business. http://www.ppmprojects.co.za/documents/Mining_proj_DJ_Porter_PPM_Paper.pdf

Reipas, K.S., Jakubec, J., Scott, C.C., Connolly, B.H. (2008). Tahera Diamond Corporation. Preliminary Assessment of the Economic Potential of the Jericho Diamond Project, Nunavut. Prepared by SRK Consulting (Canada) Inc. http://www.sedar.com

Retter, C. and Snowden, P.A. (2005). Valuation of the Messina and Star Diamond Mines – South Africa. Prepared by Snowden Mining Industry Consultants for Williams de Broë Plc. and included in the Petra Diamonds Limited AIM Admission Document related to the acquisition of Crown Diamonds NL.

Rogers, A. (2015). Personal Communication. Andrew Rogers, Group Geology and Mineral Resource Manager, Petra Diamonds plc.

Roscoe, W.E. and Postle, J.T. (2005). Diavik Diamond Mine Mineral, Reserve and Mineral Resource Audit. Prepared for Aber Diamond Corporation. NI 43-101 Report. Roscoe Postle Associates Inc. http://www.sedar.com

Snowden, D.V. (2001). Practical interpretation of mineral resource and ore reserve classification guidelines. *Mineral Resource and Ore Reserve Estimation – The AusIMM Guide to Good Practice*. Edwards, A.C. (ed.). Australasian Institute of Mining and Metallurgy, Melbourne. pp. 643–652.

Sobie, P. (2007). Competent Person's Report on the Lace Diamond Mine Project, Republic of South Africa. Prepared for Diamondcorp Plc. http://www.diamondcorp.plc.uk/investors-and-media/aim-rule-26

Stephenson, P.R. and Stoker, P.T. (2001). Classification of mineral resources and ore reserves. *Mineral Resource and Ore Reserve Estimation – The AusIMM Guide to Good Practice*. Edwards, A.C. (ed.). Australasian Institute of Mining and Metallurgy, Melbourne. pp. 653–660.

Stephenson, P.R. and Vann, J. (2001). Common sense and good communication in mineral resource and ore reserve estimation. *Mineral Resource and Ore Reserve Estimation – The AusIMM Guide to Good Practice*. Edwards, A.C. (ed.). Australasian Institute of Mining and Metallurgy, Melbourne. pp. 13–20.

Stephenson, P.R. (1995). Reporting using the 'Australasian Code for Reporting of Identified Mineral Resources and Ore Reserves'. *Proceedings of Understanding Resources, Short Course on Resource Estimation Practices*, November 1994. ECS Mining Consultants, Bowral, NSW.

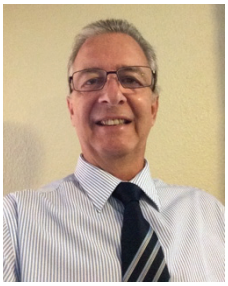
Telfer, C. (2004). Diamond resource classification reasoning … logical or illogical. Presentation for The SAMREC Inquisition. [Unpublished]. Southern African Institute of Mining and Metallurgy, Johannesburg. http://www.samcode.co.za/downloads/SAMCODEnews.pdf

Telfer., C.A. and Mc Kenna., N. (2011). National Instrument NI43-101 Technical Report on the Letšeng Diamond Assets in Lesotho, the Ellendale Diamond Assets in Australia, and the Gope Diamond Assets in Botswana of Gem Diamonds Ltd. Prepared by Venmyn Rand (Pty) Ltd. http://www.gemdiamonds.com/gem/uploads/reports/reports/Gem_IndependentTechnical Report_18May20111.pdf

Yip, C.G. (2008). Mineral Resource and Reserve Update. Diavik Diamond Mine. Northwest Territories, Canada. NI 43-101 Technical Report prepared for Harry Winston Diamond Corporation. http://www.sedar.com

Yip, C.G. and Thompson, K.S. 2015. Diavik Diamond Mine, Northwest Territories, Canada. NI 43-101 Technical Report prepared for Diavik Diamond Mines Inc. (www.sedar.com)

Zweistra, P. 2012. A Resource Review of the Lace Mine, Kroonstad, South Africa. Prepared by VP3 Geoservices (Pty) Ltd for DiamondCorp plc. [Tabulation of resources on company website at http://www.diamondcorp.plc.uk/projects/resource-statement]



Norman Philip Lock
Independent Consultant

Norman began work at Orapa in 1967. He graduated from Leeds University in 1972 and returned to Botswana with De Beers. In early 1973 he drilled the Jwaneng discovery hole. He transferred to the Letseng Mine in Lesotho and completed a PhD on Letseng in 1980. He worked with the Botswana Geological Survey for 10 years before joining Botswana Diamondfields in 1990.

Norman has been a consultant from 2000, with RSG Global and MSA Geoservices. From 2009 with Coffey Mining in Toronto he collaborated with colleagues in South America, Africa and Australia. Since late 2013 he has been a freelance consultant.

He was secretary to the diamond group for the SAMREC Inquisition in 2005/6 and has contributed to numerous technical reports under JORC, SAMREC and NI43-101 as well as compliance issues with regulators in Canada and South Africa.

Development of a best-practice mineral resource classification system for the De Beers group of companies

S. Duggan[1], A. Grills[1], J. Stiefenhofer[2], and M. Thurston[2]

[1]Z Star Mineral Resource Consultants (Pty) Ltd
[2]De Beers Group Services (Pty) Ltd

The De Beers Group of Companies has operating diamond mines and exploration projects in numerous countries including South Africa, Namibia, Botswana, and Canada. Diamond deposits are often geologically complex and typically characterized by significant variability in terms of grade and other variables. In addition, diamond revenue also needs to be estimated. These issues make evaluation sampling difficult and accurate Mineral Resource estimation problematic. De Beers identified the need for sound Mineral Resource classification that highlighted areas of uncertainty in the Mineral Resource. As a result De Beers has invested considerable time in developing a best-practice Mineral Resource Classification System (MRCS). In 2004 De Beers developed a prototype that identified the five key Mineral Resource criteria of geology, grade, volume, revenue, and density. A set of key questions and associated answers were developed for each criterion and a scoring system introduced. The MRCS prototype was tested on a wide range of De Beers diamond deposits. Critically, this extensive database of deposits allowed the questions, scoring, and priorities to be adjusted until representative and consistent classifications were produced. The MRCS has evolved through time and, more recently, significant changes have been made that include the ability to take cognisance of new data obtained during mining and production performance. The process involves the project geologist completing the five scorecards, which are reviewed internally prior to an independent review and final ratification by a Competent Person (CP). De Beers is of the opinion that the system is leading practice and provides a repeatable and constant depiction of the confidence in the Company's mineral resources.

INTRODUCTION

Diamond deposits are often geologically complex and typically characterized by significant variability in terms of diamond content (grade), diamond value, and other estimation parameters. The particulate nature of diamonds, their size distribution in the deposit, shape, quality, and colour also impact on the estimation and classification of diamond resources. This can lead to high levels of uncertainty during evaluation compared to other mineral deposits. Sampling to define grade variability on a local scale is often problematic as diamond deposits generally have very low grades (in terms of parts per million or ppm) when compared to other mineral deposits, as illustrated in Figure 1.

These factors make the accurate estimation of diamond resources challenging and dictate that a significant quantity of optimized sampling is required to minimize risk. It follows that an accurate view on the level of uncertainty in the Mineral Resource estimate is critical in terms of obtaining a representative Mineral Resource classification for diamond deposits. The classification plays a critical role in terms of the status of a diamond deposit in the project delivery pipeline and the associated investment decisions. As a result, De Beers has invested considerable time in devising a best-practice classification methodology and subsequently develop an appropriate software package, the Mineral Resource Classification System (MRCS).

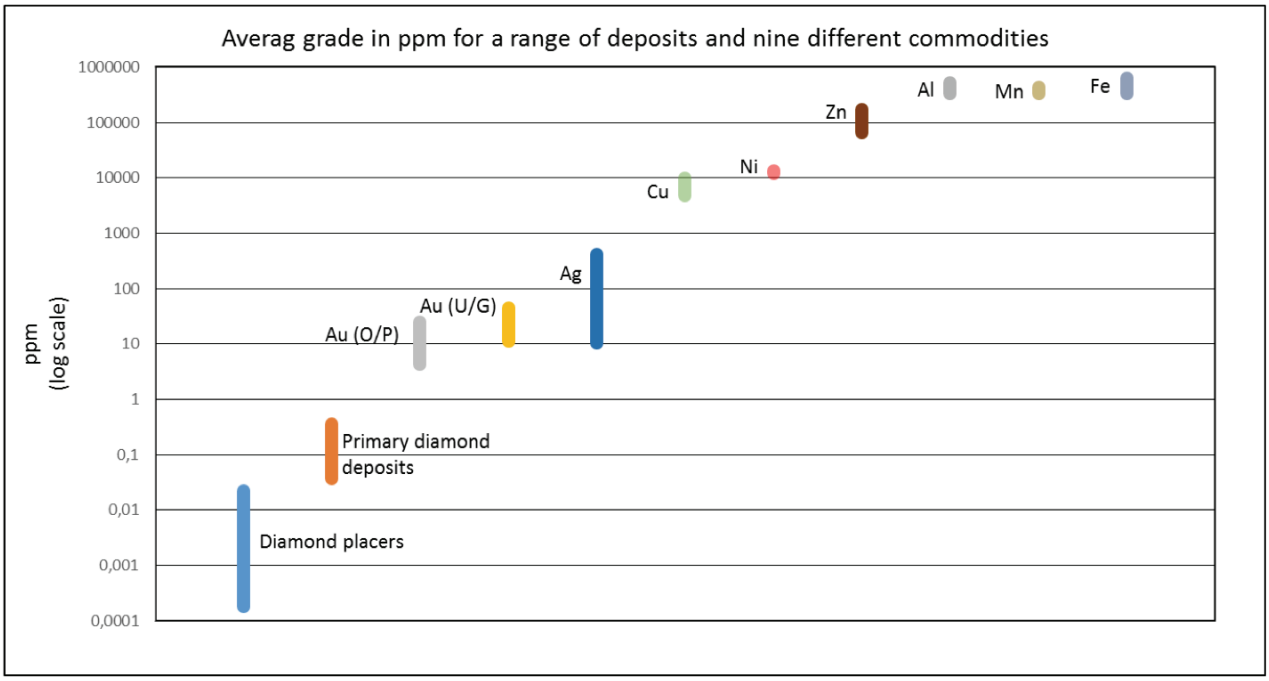


Figure 1. Illustration of grade variation in ppm for different commodities.

CLASSIFICATION OF DIAMOND DEPOSITS

In the authors' experience there are many cases where insufficient diligence is applied to the Mineral Resource classification process relative to the completion of the Mineral Resource estimate. This lack of thoroughness is often related to a poor understanding of the classification categories and/or the ability to interpret the various classification code guidelines. However, the need for an Indicated Mineral Resource in order to conduct a feasibility study determines that the classification process should be thorough and justifiable. As highlighted in the introduction, the classification of a diamond resource is typically more complex than for other mineral resources for a number of reasons:

- *In-situ* diamond grade can be highly variable within a single rock type and can vary significantly between rock types in the same deposit
- In the kimberlite environment the explosive volcanic nature of the pipes often leads to extensive dilution, which adds to the complexity of the grade estimate
- Diamond deposits are particulate and characterized by extremely low grades, typically less than 1 ppm. (Figure 1). This makes representative sampling extremely difficult and expensive. In many cases, due to cost, a move has been made to micro-diamond sampling, *i.e.* the sampling of a particular portion of the size frequency distribution (SFD) to estimate the diamond grade for the entire SFD
- Diamond revenue is typically estimated from a SFD and an assortment. The assortment provides an average US dollar value per carat per size class based on modelling valuation results. This is combined with the SFD to provide an overall average US dollar per carat

estimate. This estimate may be for the entire pipe, or for a particular rock type within the pipe. The accuracy of the assortment, in particular, is often dependent on acquiring a sufficiently representative diamond parcel (*e.g.* >5000 carats)

- Being particulate in nature, diamond resources must be quoted at a defined bottom cut-off, *e.g.* a nominal square mesh cut-off of 1.15 mm. The grade and bottom cut-off are typically determined by economic studies that optimize these parameters for the resource in question. Should the production plant have a different bottom cut-off (*e.g.* 1.40 mm) or treatment process, *e.g.* re-crush to a different particle size, Resource to Reserve modifying factors are required.

In 2004, based on the above reasons, De Beers identified the need to develop an appropriate classification methodology (and associated system) to categorize diamond deposits. The methodology had to accommodate three primary requirements:

- To enable mineral resource managers across the De Beers Group to refer to a standard system of classification across all deposit types (kimberlites, placers, and tailings) and thus ensure compatibility across the Group
- To consistently and accurately assess the diamond resource risk
- To undertake a classification compatible and compliant with generally accepted international reporting codes.

HISTORICAL CLASSIFICATION AT DE BEERS

The methodology devised for classifying De Beers mineral resources involved the development of prototype scorecards for each of the five key mineral resource variables:

- Geology (the thinking behind the emplacement or deposition model)
- Grade (the data integrity, estimation methodology, and process and validity of results)
- Volume (the constructed 2D or 3D representation of the geological thinking)
- Revenue (the data integrity, SFD and assortment modelling, and validity of results)
- Density (the data integrity, estimation methodology and process, and validity of results).

The process started with the development of the prototype scorecard based on a set of key questions and associated range of answers for each variable. The scoring associated with each question ranged from low for a negative outcome through medium for a partial outcome to high for a positive outcome. The questions in each of the variable scorecards were grouped into sets, *e.g.* data integrity or estimation methodology, and a priority assigned to the group of questions. The ability to assign priorities to each of the variables (geology, grade *etc.*) was also introduced as some variables, *e.g.* grade, were deemed to be more important than others, *e.g.* density.

Importantly, the prototype scorecard system was tested on a wide range of De Beers diamond deposits, *i.e.* kimberlites, placers, and tailings mineral resources. Critically, this extensive database of deposits allowed the questions, scoring, and priorities to be adjusted until representative and consistent classifications were being produced.

Once the scorecard methodology had been approved and implemented, the formal classification of all diamond deposits across the De Beers Group of Companies was undertaken by a Mineral Resource Classification Committee (MRCC) in 2004. The committee comprised De Beers specialists representing the mineral resource disciplines of geological modelling, grade and density estimation, and diamond revenue modelling. The committee mechanism assisted in ensuring consistency and compatibility of classification across all operations and deposit types; the chairman of the committee was responsible for the final sign-off of a classification.

The classification scorecard can also be used in a proactive sense to analyse the work undertaken on a deposit and identify the risks (areas outstanding) that require addressing prior to attaining a particular confidence level, *e.g.* Indicated.

KEY ELEMENTS OF THE CURRENT DE BEERS CLASSIFICATION METHODOLOGY

The formal classification at De Beers was initially undertaken by the MRCC. Typically, the project geologist or relevant mineral resource manager would present a preliminary scorecard to the MRCC for review. The scorecards would be interrogated and modified during the meeting, if required. At a later stage the MRCC would meet to ratify the scorecard. This process involved checking the classification database to ensure that question scores were compatible with deposits elsewhere in the Group where a similar amount and quality of work had been undertaken. Once ratification was complete the scorecard was signed off by the chairman of the MRCC.

More recently the emphasis has moved towards ownership on the operations with the relevant Competent Person (CP) approving the final classification. However, the current classification process does require a peer review on the operation and, in addition, an independent external review. To this end there are four key steps in the current De Beers classification process:

- An initial classification by the project geologist, *i.e*. based on the project work undertaken, a series of questions are answered for each of five scorecards and scores assigned
- An on-site peer review by a committee, *i.e*. answers and scores are amended where applicable according to group consensus
- An independent external review (*i.e*. different company and external to the mine) – no changes are implemented, but recommendations are made regarding questions and scores for the CP's consideration
- Finalization by the De Beers-appointed CP (may include the external review's recommended changes if deemed appropriate).

This best-practice approach to mineral resource classification ensures good governance by providing a representative semi-quantitative view on the level of confidence, thus ensuring adherence to the various international reporting guidelines (*e.g*. SAMREC, JORC, and NI 43-101).

The methodology developed comprises four main processes (Figure 2):

- A preparation phase where the deposit to be classified is defined and information required collated
- A set-up phase which requires the user to select the appropriate De Beers company and operation in the MRCS and create a Resource, group, and classification
- A completion phase where a preliminary scorecard is completed, reviewed by the operation, and finally submitted for external review (*i.e*. by a different company)
- A final ratification and sign-off by the CP.

In terms of the MRCS a typical classification will require eight steps as illustrated in Figure 2.

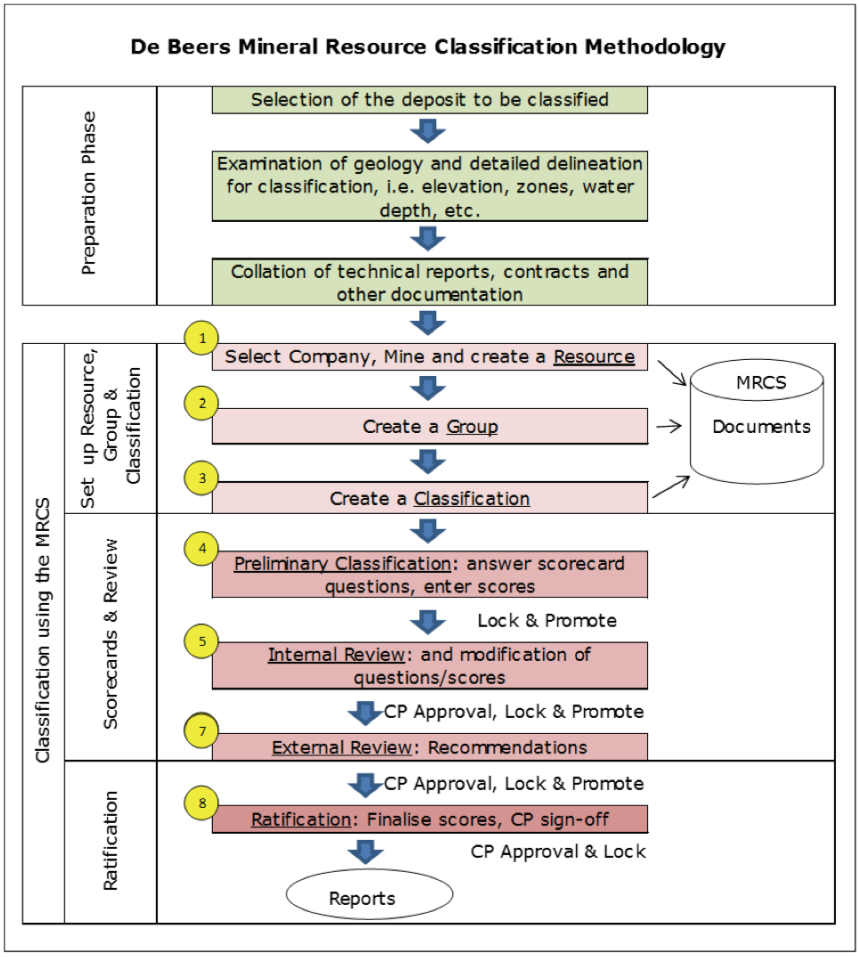


Figure 2. The De Beers mineral resource classification methodology.

Preparing for Classification

One of the most important tasks in the classification process is the subdivision of the deposit prior to completing the scorecards. It is often the case that a portion of the deposit may have a higher sampling density; this may be a higher grade area that was found first or it may simply be the part of the resource that is closer to surface and has been easier to drill. The higher sampling density will typically facilitate a better understanding of the geological model and thus improved definition in the volume model, the interpolation of local block grades and density estimates, and the recovery of more diamonds, resulting in a higher confidence revenue estimate. When an area or volume is delineated for classification it is critical that the entire portion has had a similar level of evaluation work undertaken. If this is not the case, the questions become problematic as there can be more than one answer to each question. In summary, it is very important that, having taken the geological model into consideration, the deposit is carefully subdivided into portions with reasonably equal levels of evaluation work prior to classification.

Method of Scoring

An individual score is assigned to each of the 84 questions in the scorecards. Within each individual scorecard, *e.g.* geology, the assigned scores within each group of questions are averaged. These average scores are then added to provide an overall score for the criteria out of a maximum of 100. The scorecards for the five key criteria are summarized in Table I in terms of the priority assigned to various groups of questions.

Table I. Illustration of the maximum possible score for groups of questions in each scorecard.

Group	Geology	Grade	Volume	Revenue	Density
Knowledge techniques	20				
Sampling/data integrity	20	15	30	20	20
Sample representivity	20				
Sample accuracy		15			
Sampling programme		10		10	10
Estimation methodology		20	30	20	20
Definition of the geological model	40				
Other risk analysis techniques		40	40	50	50
Totals	100	100	100	100	100

In Table I, the knowledge techniques relate to the application of appropriate methods, the sample (and data) integrity is associated with procedures, security issues, logging methods, positioning accuracy, *etc*. The sampling accuracy with respect to the grade scorecard relates to how the sample area and/or sample volume was measured.

The original De Beers classification committee determined that three of the five variables – geology, grade, and revenue – are critical and should be assigned the highest weighting (3). Volume was viewed as being slightly less important as it is a constructed representation of the geology and was assigned a lower weighting (2), and density was assigned the lowest weighting (1). These weightings are applied to the relevant scorecard and a final average classification score calculated.

Classification limits were assigned as follows:

- 0-30 – Deposit (excluded from the resource)
- 30-70 Inferred Mineral Resource
- 70-90 – Indicated Mineral Resource
- 90-100 – Measured Mineral Resource.

External review

The De Beers classification methodology calls for each classification to be independently reviewed prior to final sign-off by the CP. The external reviewer is given access to the MRCS and is required to comment on the answers and the scores but has no permissions to change the original entries. The external reviewer documents appropriate comment and the Microsoft Word™ file is stored in the MRCS.

Competent Person (CP)

De Beers officially appoints a CP for each Anglo American reporting cycle (typically a year), and this person is responsible for mineral resource classification on a specific operation or project. The MRCS has been designed with this structure in mind, and represents a change from historical classifications, where the final responsibility rested with a classification committee.

In keeping with international reporting codes the CP is ultimately accountable for the classification of mineral resources on an operation and must ensure that correct procedures have been followed during the classification process. The company letter of appointment signed by the CP and the mine general manager includes an abridged CV indicating the number of years of relevant experience that the CP has in terms of the type of deposit and style of mineralization. It includes proof of membership of a designated professional organization (*e.g*. SACNASP) and the letter is stored on the MRCS.

THE MINERAL RESOURCE CLASSIFICATION SYSTEM (MRCS)

The methodology has evolved through time, and recently significant changes have been made to the scorecard and the MRCS. For example, the ability to take cognisance of production history has been introduced as an accurate assessment of performance that shows the resource is performing as expected will result in reduced risk and therefore enhance the resource confidence. The software application has a number of attributes that simplify the classification process, namely, a sequel database facility that stores a list of documents and information associated with the particular resource being classified, a help facility to explain the meaning of each question, and a user-friendly 'front end' that streamlines the process.

The MRCS includes a hierarchical structure that enables users to easily select (or create) the company, operation, resource, group, and classification. Permission to create a new company or operation is restricted but most users may create and edit a resource, group, or classification (Figure 3). Each of these operations is briefly explained below:

- A Resource is named by the user and is defined by the geology (*e.g.* kimberlite, dyke, aeolian placer, beach placer, deep-water marine placer, fluvial placer, shallow-water marine placer, tailings mineral resource, stockpile) and the deposit type (*e.g.* primary, secondary, tertiary)
- A Group constitutes a user-defined group of classifications in a particular Resource, named by the user and including a brief description and spatial definition (*e.g.* a 'from-to' elevation in the case of a kimberlite)
- The Classification scorecard status could be preliminary, internally reviewed, externally reviewed, or ratified depending on how far the Mineral Resource has moved along the classification process.

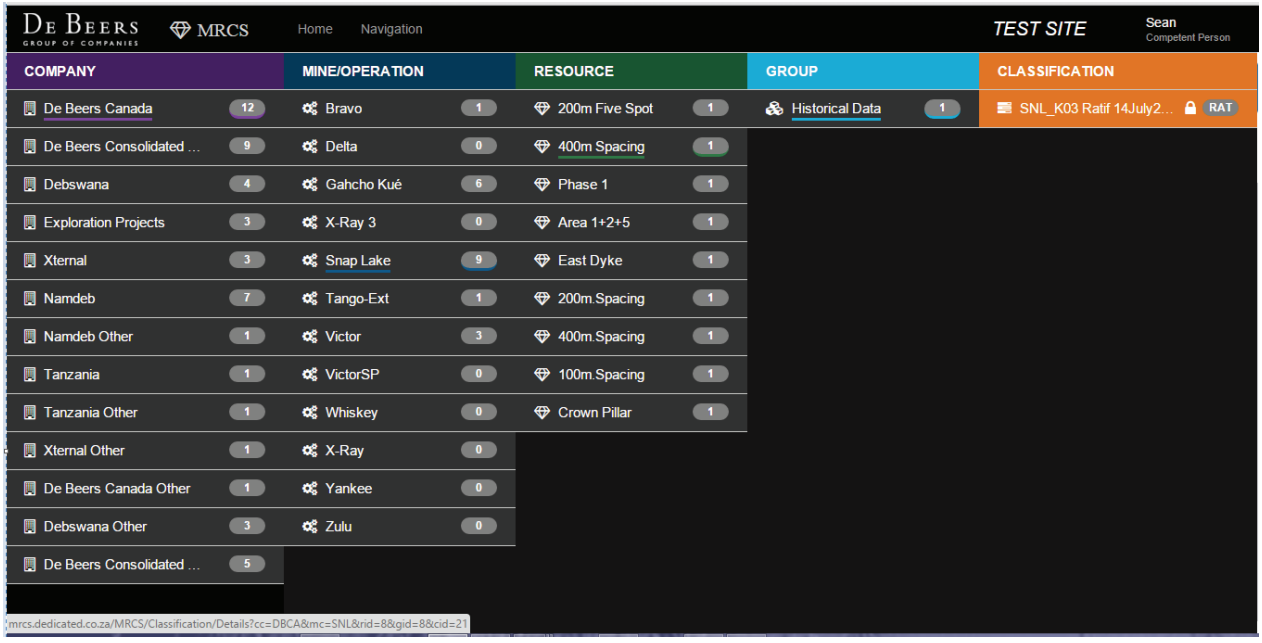


Figure 3. Example of the MRCS hierarchy showing a classification linked to a Group, a Resource, an operation, and a company.

Once the hierarchy has been appropriately defined the classification scorecard is created and the user answers the questions appropriately based on his knowledge of the Mineral Resource (Figure 4). Hints are provided for uninitiated users as a guide to understanding the questions and comparative scoring functionality aids the user in selecting an appropriate score.

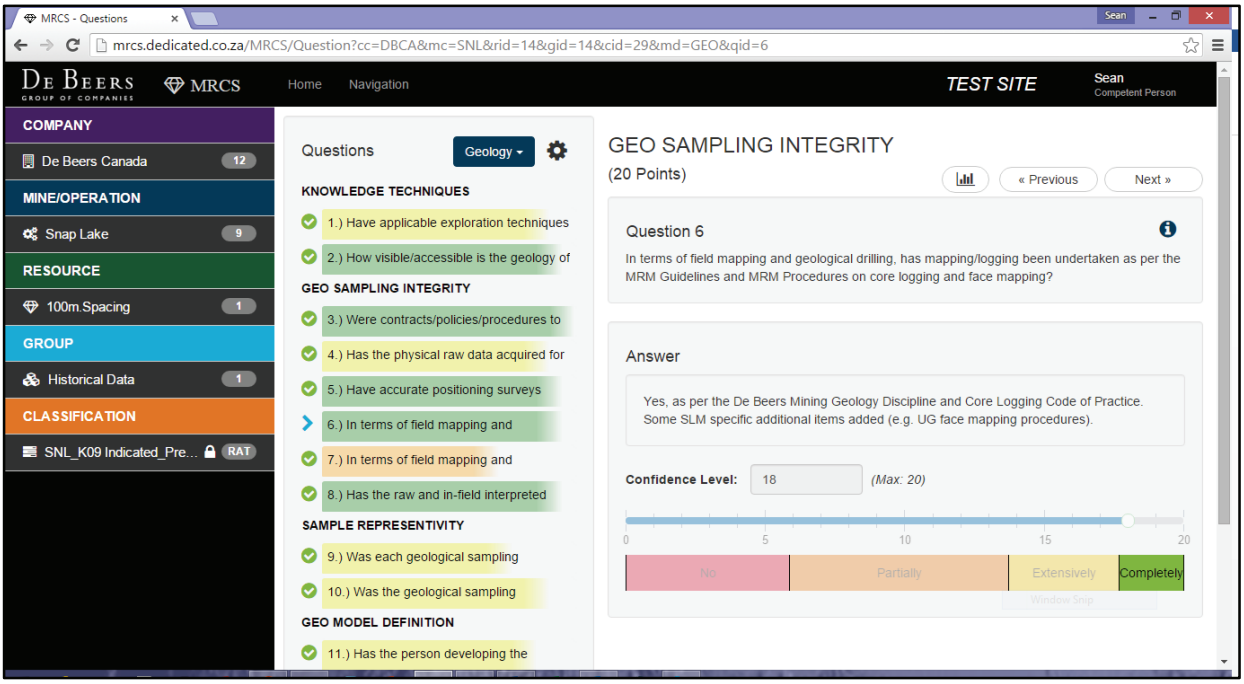


Figure 4. The geology scorecard of the De Beers Mineral Resource Classification System (MRCS).

COMPARATIVE STATISTICS

The De Beers classification method remains a subjective process and therefore it is useful to provide a guideline related to how questions should be interpreted. To this end the MRCS includes functionality that enables the user to compare scores and answers from other classifications across the De Beers group of companies. This is achieved by a selection process that enables the user to compare scores for a specific question, a group of questions on a scorecard, an entire scorecard, or the whole classification. This process is extremely useful as De Beers has a vast array of diamond resources that have been classified and enables new resources to be benchmarked. The comparative statistics module is user-friendly and provides rapid graphic solutions, as illustrated by the example in Figure 5. The upper portion of this figure shows a number of options for selecting classifications for the comparison, which include selection by company, mine, Resource, group, deposit type, and geology type.

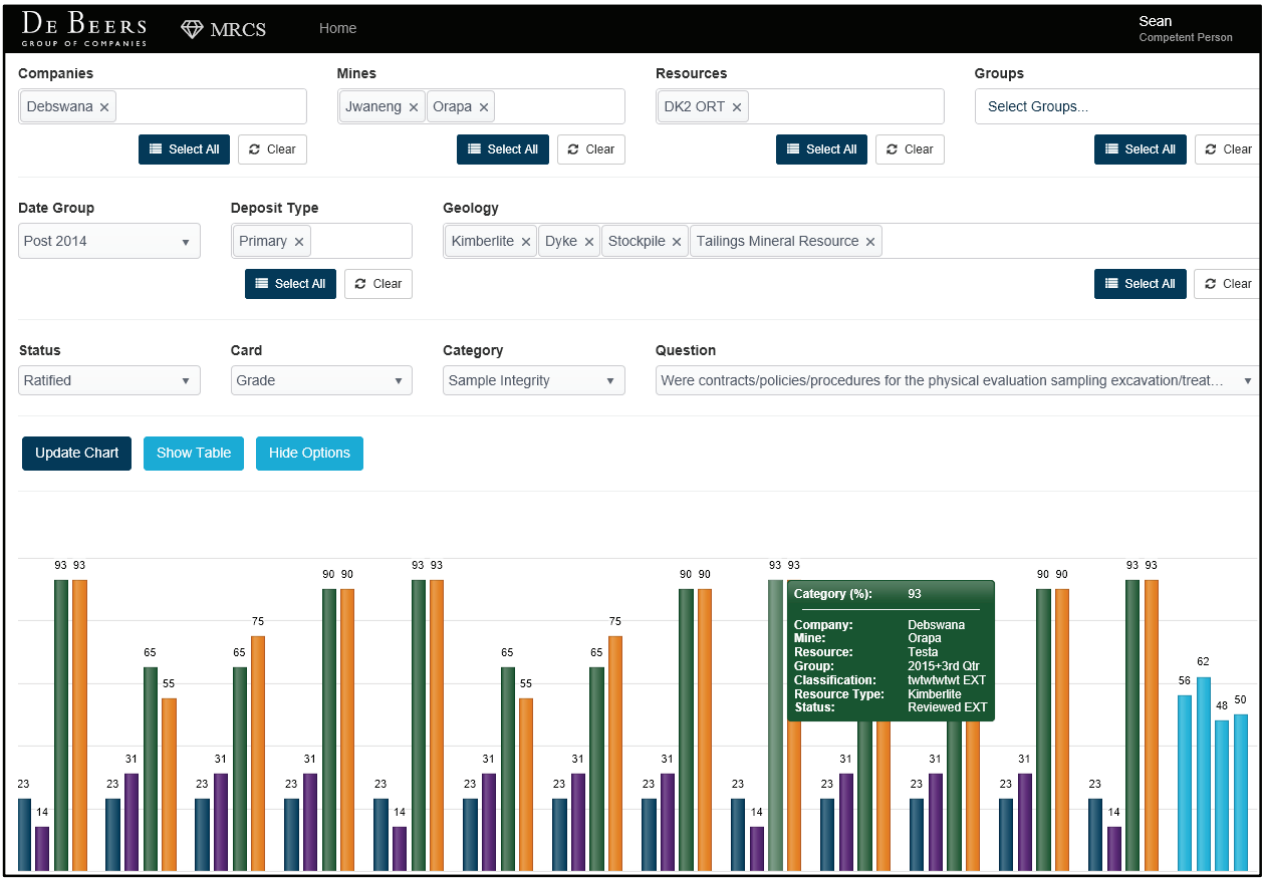


Figure 5. An example of the MRCS comparative statistics functionality.

CLASSIFICATION DOCUMENT MANAGEMENT

The MRCS includes a facility to store and manage documents associated with each classification. By way of example it is important for users to have access to the documented sampling procedures, the geological models, the estimation reports, and review or audit documents. All versions of the classifications are stored and therefore the MRCS document management component provides a record of the estimation process for each Mineral Resource, thereby creating an historical record for future users. Files of any format can be stored in the MRCS, *e.g.* ArcInfo™ files, Word™ documents, Gemcom™. files and Excel™ spreadsheets.

MINING PERFORMANCE

In the latest MRCS, mining performance has been introduced as a method for assessing the level of confidence in a small part of the Resource close to existing production. This approach, documented by Noppé (2014) and others, is intended for a relatively small part of the Resource, for example the next two years of mining. By way of example, for a typical kimberlite Mineral Resource the performance documentation may include a model like the one illustrated schematically in Figure 6. In this example of a kimberlite mine a few benches have been included below the current mining level. The decision as to what is included is documented in the MRCS, *e.g.* three benches falling within the vertical variogram range. Should the business rules be met, the dark green portion shown in Figure 6 would be upgraded to an Indicated category.

In assessing confidence in this local resource the MRCS requires the user to answer a number of questions (all of which should be affirmative), including the following:

- Has face mapping, blast-hole chip sampling, field observations *etc*. been undertaken?
- Is the change in geology insignificant in adjacent mining?
- Is the orebody envelope changing insignificantly?
- Do the density estimates correlate with geology?

Finally, as a measure of grade and value consistency, the following ratios are also considered:

- RsCR: the average Resource carat ratio by year, defined as the carats expected from the Resource divided by the carats recovered
- RvCR: the average Reserve carat ratio by year, defined as the carats expected from the Resource after applying modifying factors divided by the carats recovered
- Rv$R: the average Reserve revenue ratio by year, defined as the value (in US dollars) expected from the Resource carats after applying modifying factors divided by the value of the carats recovered (in US dollars).

For an Indicated Mineral Resource, these ratios should meet the so-called 15% rule (Cañas, 1995; Dohm, 2004; and others), meaning that the standard error of a given ratio measured over a period of one year should be 15% or less (90% confidence limits).

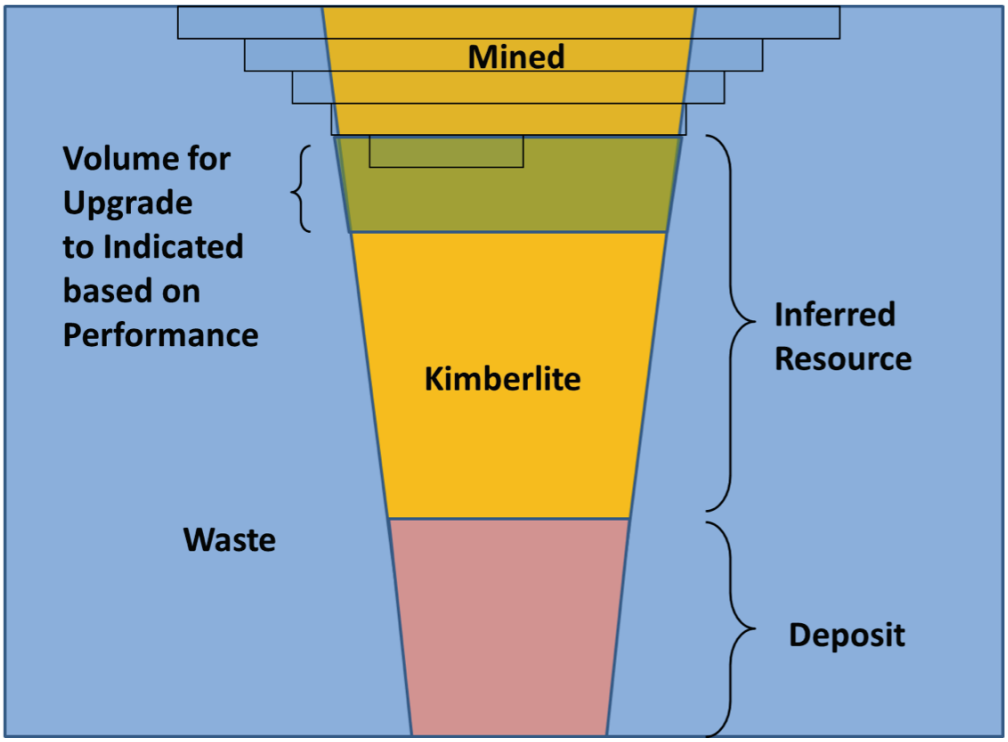


Figure 6. Schematic showing the application of performance assessment .

CONCLUSIONS

The De Beers semi-quantitative approach to classification is robust and satisfies the key components of the international reporting codes, *i.e.* transparency, materiality, and competence. The classification method is not focused on specific estimation variables, such as kriging variance, but rather covers the five key criteria that combine to produce a diamond Mineral Resource estimate, geology, grade, volume, revenue and density. The classification approach is standardized and semi-quantitative and enables CPs on the operations to make informed decisions in terms of confidence. The comparative

statistics is a powerful tool that allows classifications to be benchmarked against a large database of De Beers diamond mineral resources. The introduction of a performance module to incorporate information from mining is an important addition.

The MRCS is a user-friendly and flexible system and ensures that a robust record of the classification process on all De Beers operations is stored electronically. Importantly, the MRCS provides De Beers with a best-practice documented and justifiable classification for all types of deposits: kimberlites, placers, and tailings. Although the MRCS continues to change, the essence of the scorecard approach has been applied to successfully produce several hundred De Beers classifications.

REFERENCES

Cañas, J.D. (1995). Salobo Ore Reserve Model Review. Letter from MRD (Mineral Resources Development Inc.) to Dr Alvaro Tohar (Anglo American Corp.), 30 July 1995.

Dohm, C.E. (2004). Quantifiable mineral resource classification: a logical approach. *Proceedings of Geostatistics Banff 2004*. Springer, Dordecht:. pp. 399-341.

JORC. 2012. Australasian Joint Ore Reserves Committee. Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves. The Joint Ore Reserves Committee of the Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists, and Minerals Council of Australia. http://www.jorc.org/docs/JORC_code_2012.pdf

Noppé, M.A. (2014). Communicating confidence in Mineral Resources and Mineral Reserves. *Journal of the Southern African Institute of Mining and Metallurgy* 114, 213-222.

SAMREC. 2009. South African Mineral Resource Committee. The South African Code for Reporting of Exploration Results, Mineral Resources and Mineral Reserves (the SAMREC Code). 2007 Edition as amended July 2009. http://www.samcode.co.za/downloads/SAMREC2009.pdf



Sean Duggan

Director/Principal Analyst
Z Star Mineral Resource Consultants (Pty) Ltd

Sean's career started with Anglo American in base metal and gold exploration and in 1985 he joined to the De Beers Marine team responsible for developing the first successful deep water diamond mining operation. Sean honed his mineral resource skills at Anglo American Minred and as Evaluation Manager at Namdeb. He has specialist expertise in the development of optimal sampling techniques, the design of sampling programmes and mineral resource estimation. As a Z* Principal Analyst and director Sean continues to work primarily on the estimation of diamond deposits which, in recent years, has extended to the evaluation of a range of other commodities including gold, base metals, uranium and industrial minerals.

Diamond Resource/Reserve estimation of alluvial diamond deposits –a case study of Rockwell Resources Inc.

G.A. Norton

Rockwell Diamonds Inc. Douglas, Northern Cape

The 21st century saw an increase in the number of alluvial diamond deposits prospected and mined by commercial companies listed on various international stock exchanges. As a result, the Resource/Reserve of such deposits had to be evaluated in terms of the applicable reporting codes. Historically, this had caused significant problems for international regulators and investors/analysts alike, as many companies (mostly private), trying to maximize the value of their projects, forced all mineralization into Resource/Reserve categories that the available data could not realistically sustain (Lock, 2003; Marshall, 2005). Very little cognisance was taken of the fact that Diamond Resources are required to have reasonable expectations of eventual economical extraction.

Rockwell Diamonds Inc. (Rockwell or the Company) opened its first alluvial diamond mine in South Africa (the Klipdam/Holpan Mine) in 2006. Since then, the Saxendrift, Niewejaarskraal, Wouterspan, and Tirisano mines have been put into operation successfully, and the Rietputs, Zwemkuil, and Remhoogte exploration projects have been added to the RDI portfolio. Since RDI is listed on the Toronto Stock Exchange (TSX) and the Johannesburg Stock Exchange (JSE), it is subject to rigorous regulatory scrutiny. Consequently, the Company has developed a meticulous approach to the assessment, evaluation, and classification of its alluvial gravel deposits, and has established a highly robust classification scheme that has found favour in all the jurisdictions where its public documents are filed.

The classification and Diamond Resource/Reserve estimation procedure adopted by Rockwell is believed to reflect accurately the nature of the alluvial diamond deposits it evaluates and operates. Further, the volume, grade, diamond value, and related financial parameters so determined are sufficiently robust to be used in the company's financial modelling and forward planning.

INTRODUCTION

This paper documents the procedures adopted by Rockwell in the evaluation (and valuation) of its alluvial diamond deposits. One of the objectives of this exercise is to show that Diamond Resources/Reserves can be estimated effectively for alluvial diamond deposits, and that this can also be done in a practical and cost-efficient manner. Further, several of the challenges that Rockwell has identified in estimating average diamond grades will be discussed, along with the manner in which these have been addressed.

Diamond Resource Characterization and Classification

The Indicated and Inferred Diamond Resource categories used by Rockwell for its alluvial diamond deposits follow, essentially, the Canadian Institute of Mining (CIM) (2003, 2005; NAPEGG, 1997) definitions, since Rockwell's primary listing is in Canada. The resultant estimations, however, are materially similar to those set out under the South African SAMREC Code (SAMREC, 2009). The salient points of the CIM definitions are summarized below for ease of reference.

> *Inferred Mineral Resource classification has a lower level of confidence than that applying to an Indicated Mineral Resource and is intended to cover situations where a mineral concentration or occurrence has been identified and limited measurements and sampling completed, but where the data are insufficient to allow both geological and grade continuity to be confidently interpreted. Due to the uncertainty which may be attached to some Inferred Mineral Resources, it cannot be assumed that all or part of an Inferred Mineral Resource will necessarily be upgraded to an Indicated or Measured Mineral Resource as a result of continued exploration. Further, confidence in the estimate is insufficient to allow the meaningful application of technical and economic parameters or to enable an evaluation of economic viability other than at an early stage of project development in a preliminary economic assessment*
>
> *Indicated Mineral Resource classification covers mineralisation where the nature, quality, quantity and distribution of data are such as to allow confident interpretation of the geological framework and to reasonably assume the continuity of both grade and geology (both CIM and SAMREC agree that the confidence level associated with the Indicated Mineral Resource is sufficient for this information to be applied to global mine design, mine planning; to allow the appropriate application of technical and economic parameters; and to enable an evaluation of economic viability).*
>
> *Measured Mineral Resources cover the situation where the nature, quality, quantity and distribution of data can be estimated with a high level of confidence – sufficient to confirm geological and grade continuity.*
>
> *A Mineral Reserve is the economically mineable part of a Measured or Indicated Mineral Resource demonstrated by, at least, a Preliminary Feasibility Study (PFS). This Study must include adequate information on mining, processing, metallurgical, economic and other relevant factors that demonstrate, at the time of reporting, that economic extraction can be justified. A Mineral Reserve includes diluting materials and allowances for losses that may occur when the material is mined. Mineral Reserves are sub-divided in order of increasing confidence into Probable Mineral Reserves and Proven Mineral Reserves.*

DISCUSSION

Rockwell's Diamond Resource Classification Criteria

Alluvial diamond deposits, by their very nature, are heterogeneous and low grade (Figure 1). Fundamental to their evaluation is an understanding of the geology – sedimentology, stratigraphy, depositional environment, and morphotectonic evolution – of the deposit. Without this understanding, it is impossible to make assumptions regarding continuity, especially with respect to gravel units and, subsequent, grade variation (Marshall, 2003a, 2003b, 2007). As a result, relatively detailed drilling and sampling are of prime importance. Rockwell's Diamond Resource estimation programme relies substantively on the collection of physical data to deliver reliable results. Statistical (and geostatistical) methods are not employed by Rockwell because (a) there are no studies showing their reliability in these deposit types, and (b) in-house studies on Rockwell operations have indicated significant variability within certain deposits that would preclude the use of such methods as a standard operating procedure.

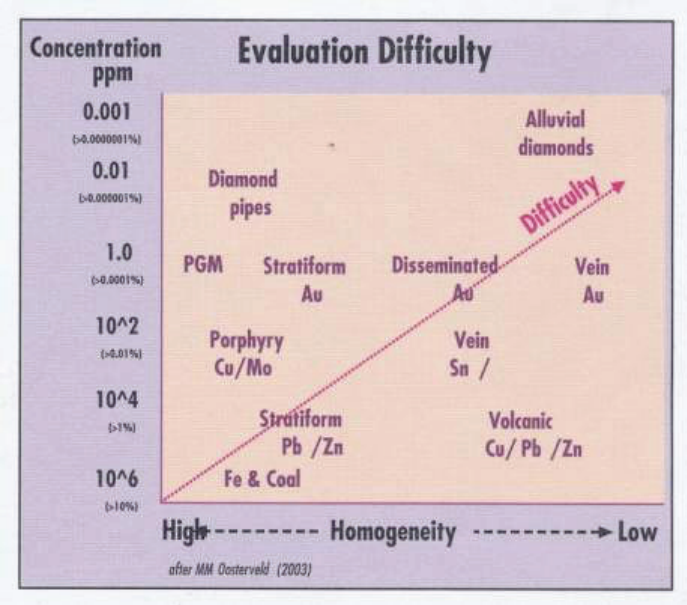


Figure 1. The extremely low concentrations of alluvial diamonds, combined with low homogeneity results in significant difficulties in the evaluation of alluvial diamond deposits (Lock, 2003).

In order to comply with international classifications of Diamond Resource estimation and to establish a standard operating methodology across all of Rockwell's operations, the following criteria have been developed.

Inferred Diamond Resource Classification

- The deposits being classified must lie in a similar broad geological environment. For example, the deposits must lie on the same terrace and be of the same gravel type (no extrapolation from colluvial or eluvial to fluvial-alluvial units)
- A minimum drill grid of 200 × 200 m (given suitable geological continuity)
- A minimum of 500 carats from the property (for value estimation). Extrapolation from an adjacent property may be considered if the geology is similar and some 3000–5000 carats have been recovered from the adjacent property (*i.e.* an Indicated Diamond Resource has been identified)
- A combined bulk sample size of some 0.5% of the anticipated Inferred Diamond Resource (for example, if the drilling points towards an Inferred Diamond Resource of some 5 Mm^3, then the minimum bulk-sample size would be expected to be in the order of 25 000 m^3.

Indicated Diamond Resource Classification

- Of primary importance in the Indicated Diamond Resource classification is the confidence that can be placed on the volume model. Rockwell has implemented a system whereby the volumes of mined-out areas are regularly reconciled with the volumes predicted by the drilling. Where a good correlation is found (within 15% annually) then adjacent areas are considered for Indicated Diamond Resource category based on the diamond recoveries
- An Indicated Diamond Resource has to lie within 250 m of a current bulk sample or trial mining pit where the geological and grade characteristics are well constrained. As a result of the variability of diamond grades (details described below), it has been seen that it is not possible to extrapolate over large distances between areas of known data with any great confidence and, therefore, classify large and extensive volumes as Indicated Diamond Resources without sufficient control sample points
- As for Inferred Diamond Resources, the geological environment is considered – Indicated Diamond Resource gravels need to lie within the same geological environment as the reference bulk sample
- A minimum drilling grid of 50 × 50 m is preferred, except where bulk sampling or trial mining has

identified greater geological and grade variability. In specific (local) instances, where lower variability has been demonstrated, a drilling grid of 100 × 50 m is considered sufficient
- In line with Canadian best-practice guidelines (CIM, 2008), a representative parcel of at least 3000–5000 carats of diamonds is required for valuation (best achieved by realized sales values obtained on an open market)
- A total bulk sample (including trial mining) size of some 3–5% of the anticipated Indicated Diamond Resource would be expected to be processed to provide the confidence that Rockwell requires of this resource category, especially since the associated PFS would be used to convert these Diamond Resources to Probable Diamond Reserves.

Measured Diamond Resources

The inhomogeneous geological nature of the typical alluvial diamond deposit, along with various issues of grade determination (discussed in some detail below) makes it very difficult (if not impossible) to estimate all the required parameters to the 'high level of confidence' required by the definition of a Measured Diamond Resource without over-capitalizing the project. Consequently, Rockwell will deal with Inferred and Indicated Diamond Resources only (with conversions to Probable Diamond Reserves in the case of the economically recoverable portions of the Indicated Diamond Resource). It is noticeable that De Beers does not classify Measured Diamond Resources (and, consequently, Proved Reserves) on any of their mines – even on a kimberlite such as Orapa, where the grade, over many years of production, has run at some 60 carats per hundred tons (cpht), the confidence required of a Measured Diamond Resource is still lacking (Lock, 2003). In contrast, the Namdeb and Namaqualand alluvial diamond operations typically show two years of Probable Diamond Reserves, a similar amount of Indicated Diamond Resources, and slightly more Inferred Diamond Resources.

Grade Determination Issues

Typically, in precious or base metal prospects, assays may be done on small drill-sample core and the sample size may range from kilograms to tons. In the case of alluvial diamond deposits, however, in order to obtain effective and reliable grade results a number of issues need to be addressed.

Low average grades

The grade of a diamond deposit is the estimated number of carats per hundred tons (cpht), carats per ton (cpt), and carats per hundred cubic metres (ct/100 m^3) of material, and is commonly less than 1 cpht or 2 ct/100m^3 (roughly equivalent to 0.001–0.0001ppm) for alluvial deposits (Lock, 2003). Table I identifies the grades (in ct/100 m^3) published by Rockwell for its various mining operations.

Table I. Published grades of Rockwell alluvial diamond operations.

Operation	Average sample grade (recovered) for Indicated Diamond Resource estimates
Saxendrift	1.01 ct/100 m^3 (Marshall and Norton, 2009a)
Wouterspan	0.7 0ct/100 m^3 (Marshall and Norton, 2009b)
Niewejaarskraal	0.84 ct/100 m^3 (Marshall and Norton, 2009c)
Tirisano	2.37 ct/100 m^3 (Marshall, 2009)

Low Homogeneity of Diamond Distribution

Individual diamonds are not evenly or uniformly distributed throughout an alluvial deposit, neither are they randomly distributed. Rather, their distribution has been described as a random distribution of clusters of points, where the clusters are randomly distributed in space and the point density of each cluster is also random (Rombouts, 1987).

Figure 2 represents a typical palaeofluvial-alluvial system, typified by different sequences of gravel deposits (gravel runs) and fine sand. The dark stippled areas represent coarse gravel bars (scale of metres to hundreds of metres) enriched in diamonds and the intervening pale areas represent fine sandy layers with very low or barren diamond content. It can clearly be seen that two directly adjacent

properties (represented by the two hexagons) may have different grade potentials and that small individual samples will have totally different, non-representative results.

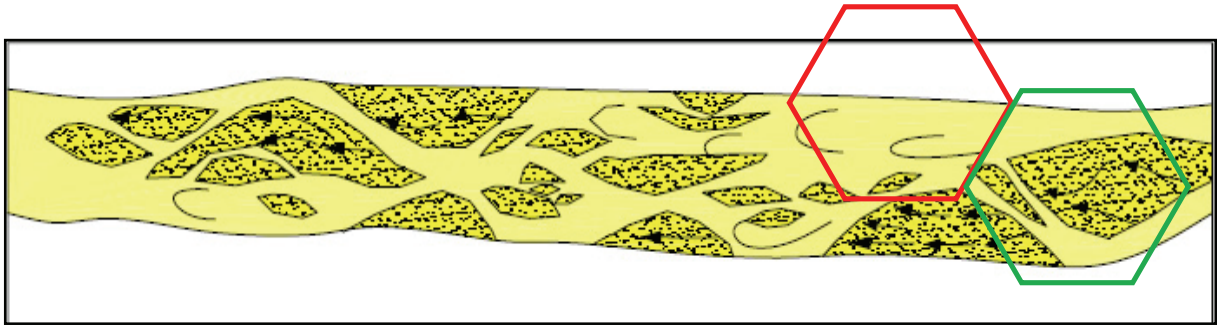


Figure 2. Representation of a palaeofluvial-alluvial channel.

Figure 3 represents the distribution of diamonds in a space (random distribution of points in clusters. The clusters are randomly distributed and so are the points within the clusters). It should be immediately apparent that the grades recovered from each of the small individual samples contained within each block will be significantly different. Consequently, individual samples are not representative, whereas much larger (bulk) samples comprising several of the boxes will provide a better estimate of the overall grade. Moreover, the diamond distribution pattern (grade) of alluvial deposits is such that poor repeatability of sample results is to be expected as the norm. Consequently, grades recovered from one operation cannot necessarily be applied to another property.

Depositional environments

Rivers and streams that create both modern and ancient alluvial deposits are in most cases highly transient environments, (Jacob, 2005). This is particularly so for braided stream segments. The braided channels are unstable through time and gravel bars are formed and destroyed continuously. Shifting bars and channels cause wide variations in local flow conditions, resulting in varied depositional assemblages. Common features in braided stream deposits include irregular bed thicknesses, restricted lateral and vertical variations within the sediments, and abundant evidence of migration, erosion, and re-deposition.

Large individual diamond sizes

Diamonds constitute discrete units of varying size and weight. In all of the inland alluvial deposits in South Africa, average diamond sizes are in the range of 0.5–2.0 carats/stone (which is extremely large when compared with the average size of diamonds recovered from primary deposits) (Figure 4). Consequently, diamonds form discrete particle deposits as opposed to disseminated particle deposits. Often the size and value distribution from stone to stone is variable and it is possible that the majority of the value of a parcel is attributed to a single stone.

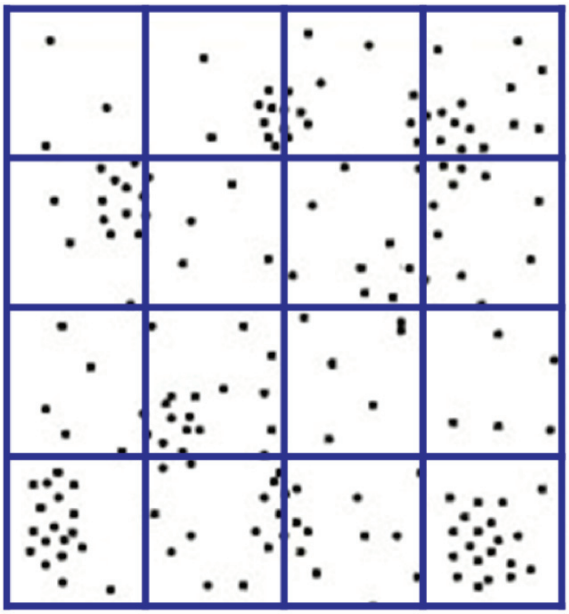


Figure 3. Representation of diamond distribution within a unit of gravel (modified after Rombouts, 1987).

Lack of Associated Heavy minerals or Geochemical Signature

In contrast to kimberlite deposits, alluvial diamond deposits are not characterized by any standard satellite or heavy mineral assemblage (or even microdiamonds) that may occur in higher, more easily measureable, concentrations. Neither do these deposits have any associated geochemical signature that could possibly be used as a means of determining the distribution of different layers or assemblages. Consequently, there are no other minerals or methods that would provide a 'proxy' for diamond grades and distribution.

As a result, taking of smaller samples for these satellite/proxy minerals is not possible – the programme has to sample the gravels to recover macrodiamonds, taking specific cognisance of their size frequency distribution.

On a broad scale (ten to hundreds of metres), most deposits are variable in nature (Figure 5) and comprise multiple units of coarse and fine sedimentary bar features. Locally (one metre to tens of metres), bedrock features play an important role in diamond concentration of the alluvial deposits, with diamonds occurring preferentially in natural traps such as gullies, potholes (Figure 6) and gravel bars and, typically, reworked through one or more post-depositional colluvial or eluvial cycles. However on a macro-scale (typically up to 250 m or greater), the deposits are, generally more repetitive in nature and stratigraphy. Consequently, there is a tendency toward an overall consistency of grade and diamond distribution when averaged over large volumes such as >500 000 m^3.

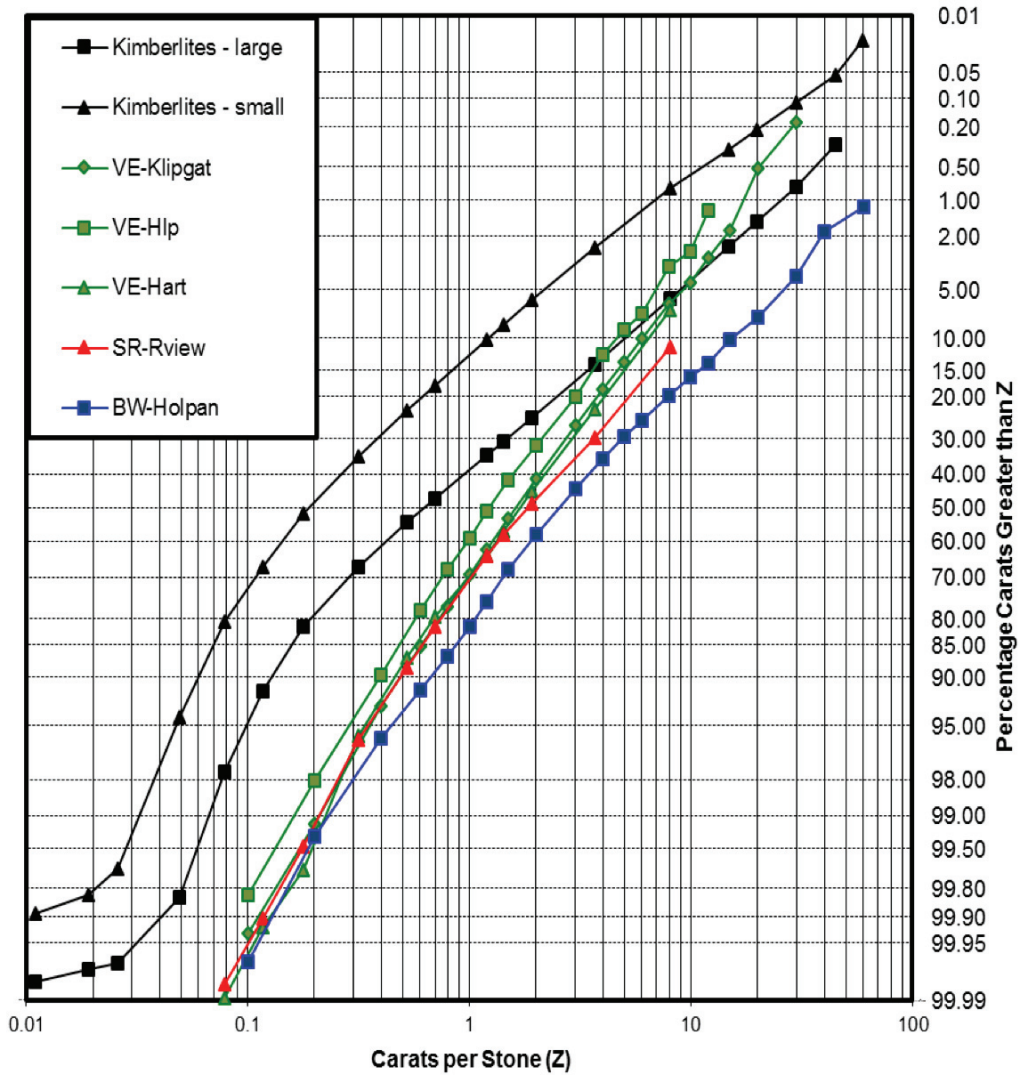


Figure 4. Size-frequency distribution of diamonds from alluvial deposits in the Ventersdorp (VE), Schweizer Reneke (SR), and, Barkly West (BW) areas in comparison with primary kimberlites (after Oosterveld, 2007). 'Kimberlite – large' refers to large stone producers and 'kimberlite – small' refers to small stone producers (no further details are available from the original reference).

Grade Variation

In a single alluvial gravel unit, the diamond grade may vary from uneconomic to over 100 cpht. This is due to any combination of the various features described above, together with the high specific gravity (ρ = 3.53) of diamonds. Figure 7 shows the variation in grade recovered from samples of the same gravel unit on the Saxendrift mine over a two-year period, during which some 99 000–220 000 m^3 of gravels were processed each month. If these quantities represented individual samples, it is apparent that a large quantity of gravels would need to be processed before a representative average value could be determined.

As can be seen from the above discussion, the grade estimated from any individual sample can vary widely – a single sample provides only a limited amount of information and the conclusions drawn are, correspondingly, uncertain. Consequently, individual samples of alluvial gravels need to be much larger than those usually taken in precious/base metal deposits and, for this reason, are referred to as 'bulk samples'. Typically, to be effective as grade indicators, individual bulk samples may be of the order of tens to hundreds of thousand tons. Several of these bulk samples generally need to be taken across the deposit to establish reliable estimates of average grade and grade variation.



Figure 5. An example of multiple sedimentary units indicating the extreme variability that can be present on a broad scale (Marshall, 2009).



Figure 6. Bedrock variability (local scale) can play a fundamental role in gravel (and diamond) distribution (Marshall and Norton, 2009a).

All these issues notwithstanding, the international industry standard for Diamond Resource estimation on alluvial diamond deposits is to estimate slightly more than two years of Measured Diamond Resources at prevailing production rates, two to three years of Indicated Diamond Resources, and multiple years of Inferred Diamond Resources. As the Diamond Resources are consumed (depleted), there is a continuous cycle of resource rollover

.

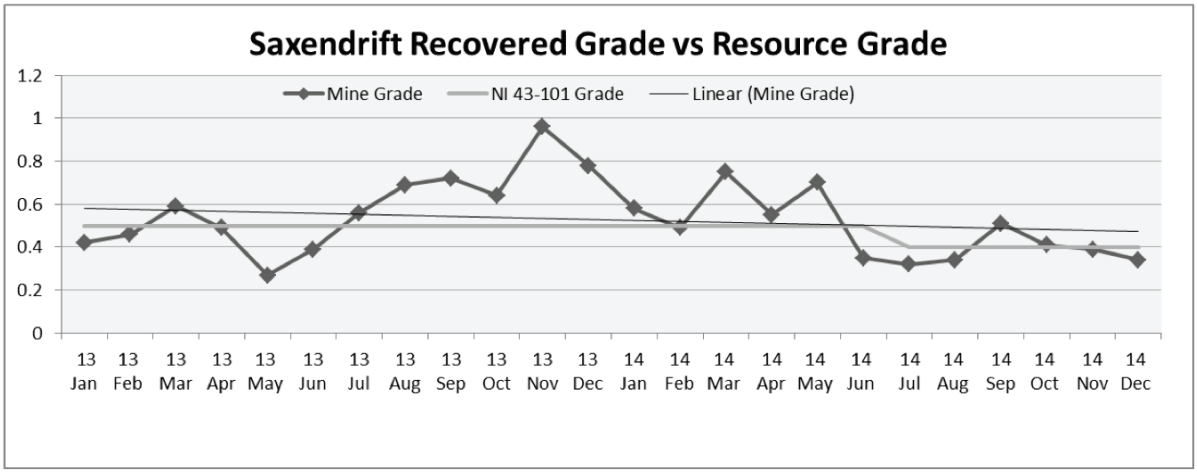


Figure 7. Monthly grade variation within an alluvial deposit (Saxendrift).

The fact that alluvial diamond deposits typically have fairly limited volumes of Indicated Diamond Resources (and, generally, no Measured Diamond Resources) often results in very restricted life-of mine valuations. Consequently, Inferred Diamond Resources are often included in mine planning, design, and economic studies. Under these circumstances, all the Modifying Factors and assumptions that were applied to the Indicated Diamond Resources to determine the Probable Diamond Reserve must be even more strictly applied to the Inferred Diamond Resources (Smith, 2002).

DIAMOND RESERVE ESTIMATION

The conversion of a Diamond Resource to a Diamond Reserve demands that either a PFS or Feasibility Study has been completed on the deposit. Such studies typically determine the extent to which the estimates of Diamond Resources may be mined economically and, further, how the various environmental, legal, financial, socio-economic, and marketing issues (together known as the 'Modifying Factors') materially affect the commercial viability of the deposit. In an attempt to quantify these variables, the following data is, generally, considered:

- Diamond Resource volumes (life-of-mine) and grade
- Mining and production rates
- Revenue
- Operating costs and fees
- Capital costs
- Taxes and royalties
- Depreciation, interest, and residual value.

In alluvial diamond deposits, most, if not all, of these Modifying Factors are considered from the start of exploration and continue to be considered through the bulk-sampling and trial mining phases. As has been mentioned above, Rockwell has not defined Measured Diamond Resources on its operations – consequently, only Probable Diamond Reserves are estimated.

On Rockwell operations, bulk sampling is taken to be the initial period(s) of gravel sampling during which reconnaissance targets are investigated and Inferred Diamond Resources are identified (typically, the first one or two years of prospecting). During this stage, preliminary economic assessments based on Scoping Studies may also be undertaken for management decision purposes. Thereafter, as the programme expands to estimate significant Indicated Diamond Resources, this is defined as the trial mining period. It is during this trial mining, which may extend over a further two to three years, that the relevant Modifying Factors are evaluated that may ultimately lead to the conversion of the Indicated Diamond Resources to Probable Diamond Reserves through a PFS. Due to

the time covered by the trial mining, the ensuing PFS is conducted in-house, by relevant, professional, qualified Rockwell personnel, supervised by both independent and non-independent Competent (qualified) Persons. Since this period of trial mining may cover a number of years, PFSs are hardly ever carried out as additional, independent studies as these can become expensive and time-consuming.

ROCKWELL DIAMOND RESOURCE/RESERVE ESTIMATION PROCEDURES

Rockwell's approach to Diamond Resource and Reserve Estimation criteria is summarized in Table II.

Based on the procedures shown, Rockwell is able to characterize and classify its alluvial diamond deposits in a robust manner and provide estimates of grades and diamond values. Most critically, in the course of its evaluation, development, and mining activities Rockwell continually reconciles recovered grades with estimated Resource/Reserve grades on all of the company's operations. Where Indicated Diamond Resources or Probable Diamond Reserves are estimated, it is expected that the recovered grades/values must be within 15% of the estimated/sample results. Figure 8 shows the reconciliation over a two-year period for Wouterspan (this operation was put on care and maintenance at the start of the economic recession).

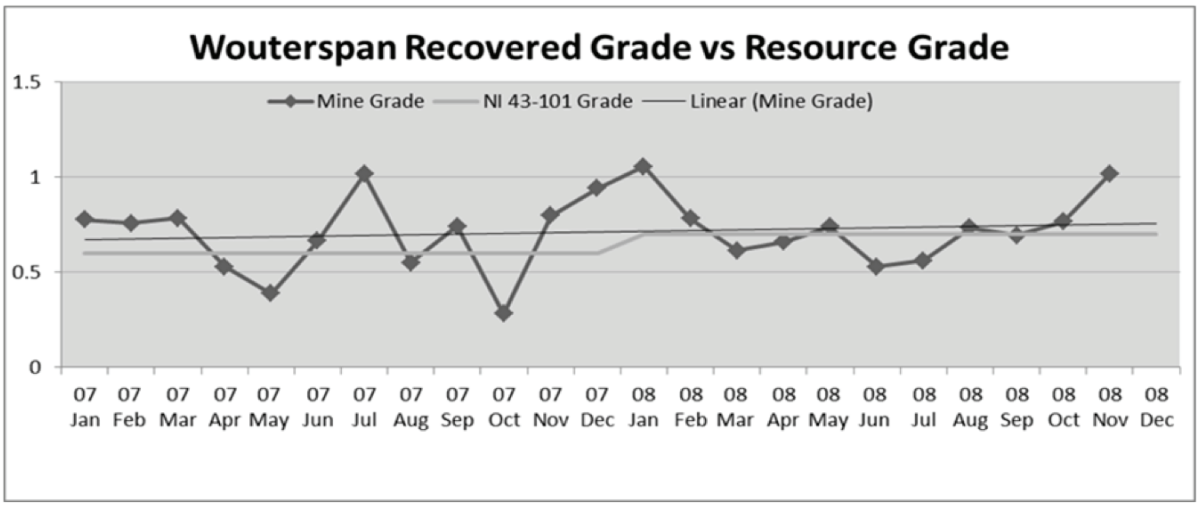


Figure 8. Monthly grade variation within an alluvial deposit (Wouterspan).

The grey line shows the bulk sample as reported in the NI 43-101 technical report (Marshall and Norton, 2009b) grades and the black line the trial mining grade. While the monthly grades (thicker, dark grey line) may vary significantly, the long-term averages for each of these operations show very good correlation with the sample grades.

Table II. Rockwell's Diamond Resource/Reserve classification criteria.

Procedure		**Comments**
Desktop studies	Target selection	Typically the target area is selected in a well-known alluvial diamond area or region with, preferably, a history of past production and diamond sales.
Field studies and identification of exploration targets	Geological mapping, remote sensing studies, and reconnaissance drilling	To increase confidence in geological model and to obtain historical information regarding diamond grade and value.
Inferred Diamond Resource estimation	Detailed drilling on 100×100 m grid	To establish the nature of the geology (stratigraphy, sedimentology, *etc*.) and to estimate gravel volume.
	Bulk sampling some 0.5% of intended declared Resource	To estimate grade.
	Recovery of a minimum of 500 ct	To estimate diamond value and size frequency.
Indicated Diamond Resource estimation	Infill drilling on a close spacing (50×50 m)	To improve geological knowledge, construct detailed 3D resource models, and improve the confidence in the estimate of gravel volume .
	Further bulk sampling and initiation of trial mining	To estimate grade.
	Recovery of 3000–5000 ct*	To estimate diamond value and diamond size frequency.
Probable Diamond Reserve estimation	Continuation of the trialemining of some 3-5% of the declared Diamond Reserve	To complete a PFS to allow conversion to Probable Diamond Reserves.

* CIM requires the recovery and sale of 3000–5000 ct for Indicated Diamond Resource estimation

REFERENCES

CIM. (2005). Canadian Institute of Mining Guidelines for the Reporting of Diamond Exploration Results and the Estimation of Mineral Resources and Mineral Reserves Best Practice Guidelines.

CIM. (2008). Estimation of Mineral Resources and Mineral Reserves Best Practice Guidelines, Canadian Institute of Mining and Metallurgy, May 4, 2008

Jacob, R.J. (2005). The erosional and Cainozoic depositional history of the lower Orange River, south-western Africa. PhD thesis, University of Glasgow. 167 pp.

Lock, N. (2003). Comparing carats to kilograms. *Mining Mirror*, October 2003, 36-38

Marshall, T.R. (2003a). Exploration for, and evaluation of, alluvial diamond deposits. *Alluvial Diamonds in South Africa, SAGS Workshop and Fieldtrip*, Glenhove Conference Centre, Johannesburg, 2-4 April 2004.

Marshall, T.R. (2003b). The prospecting and evaluation of alluvial diamond deposits. *Diamonds - Source to Use* Colloquium, SA National Museum of Military History, Saxonwold, Johannesburg, 29-30 October 2003. Southern African Institute of Mining and Metallurgy, Johannesburg.

Marshall T.R. (2005). Bad practice in reporting of SAMREC Diamond Resources – Part 1 (Diamond Grade). *Diamonds - Source to Use Colloquium*, Mintek Conference Centre, Randburg, 26-27 October 2005. Southern African Institute of Mining and Metallurgy, Johannesburg.

Marshall, T.R. (2007). Evaluation of alluvial diamond deposits. *Diamonds - Source to Use Colloquium*, Mintek Conference Centre, Randburg, 26-27 October 2005. Southern African Institute of Mining and Metallurgy, Johannesburg.

Marshall, T.R. (2009). Technical Report on the BlueGum Alluvial Diamond Project (Nooitgedacht 131, Hartbeestlaagte 146 and Zwartrand 145 properties), Ventersdorp district, Republic of South Africa, (effective date of October, 2009). www.sedar.com

Marshall, T.R. and Norton, G..A (2009a). Technical Report on the Saxendrift Alluvial Diamond Project, (Saxendrift Mine and Kwartelspan Prospect), Hay District, The Republic of South Africa, for Rockwell Diamonds Inc (updated 22 December 2009). www.sedar.com

Marshall, T.R. and Norton, G.A. (2009b). Technical Report on the Wouterspan Alluvial Diamond Project, Herbert District, The Republic of South Africa, for Rockwell Diamonds Inc (updated 22 December 2009). www.sedar.com

Marshall, T.R. and Norton, G.A. (2009c). Technical Report on the Niewejaarskraal alluvial diamond project, Hay District, The Republic of South Africa, for Rockwell Diamonds Inc (updated 22 December 2009). www.sedar.com

Marshall, T.R. and Norton, G.A. (2009d).Technical Report on the Klipdam/Holpan Alluvial Diamond Properties, Barkly West District, The Republic of South Africa, for Rockwell Diamonds Inc (updated 22 December 2009). www.sedar.com

NAPEGG (1997). Reporting of Diamond Exploration Results, Identified Mineral Resources and Ore Reserves. Yellowknife, NT, Canada: Association of Professional Engineers, Geologists and Geophysicists of the Northwest Territories (Canada).

Oosterveld, M.M. (2007). Vaal and Orange river regions - Comparison of the diamond size frequency of alluvial deposits and a comparison with kimberlite deposits. Internal report for Rockwell Ventures Inc. March, 2007.

Rombouts, L. (1987). Evaluation of low grade/high value diamond deposits. *Mining Magazine*, September, 217-220.

SAMREC (2009). South African Mineral Resource Committee. The South African Code for Reporting of Exploration Results, Mineral Resources and Mineral Reserves (the SAMREC Code). 2007 Edition as amended July 2009. http://www.samcode.co.za/downloads/SAMREC2009.pdf

Smith, L. D (2002). Discounted cash flow analysis methodology and discount rates. *Mining Millennium Valuation 2000, Special Session on Valuation of Mineral Properties*, Toronto, Canada, 8 March 2000.

Evaluating bedrock-based onshore and offshore marine placer deposits using the new SAMREC/SAMVAL Code

R.J. Jacob, P. Saravanakumar, and J.Jacob

Namdeb Diamond Corporation (Pty) Limited

Evaluation of a marine placer deposit requires an understanding of the regional geological framework, the diamond emplacement model and associated geological model, and development of the mineralization (grade) model and the associated revenue model. Understanding of the source-conduit-sink pathway and associated geological processes are very important during the whole evaluation process. The regional geological framework is based on the emplacement model for that particular region or area. Once established, the detailed geological model requires definition with geoscientific data. Focused delineation campaigns, comprising geophysical surveys and possibly widely spaced geological drilling campaigns, need to be conducted to establish the broad geometry and geology of the deposit. The resource development framework, which encompasses grade and revenue sampling, consists of resource delineation and definition stages. Ideally, the resource definition stage requires more detailed geophysical surveys, as well as denser sampling, to move from an Inferred to an Indicated level of confidence. In these deposits, a Measured level of confidence is generally not attained due to a combination of high resource variability and the high costs of sampling.

For revenue modelling purposes, 100–300 stones are needed for size frequency modelling and revenue estimation at an Inferred level of confidence, whereas at least 300–600 stones are needed for an Indicated level of confidence. These numbers are applicable only in an area with a well-known stable diamond assortment. In newly discovered areas, larger diamond parcels will be required to establish the assortment model.

During the pre-feasibility and feasibility studies, bulk sampling and test mining should be executed to collect data for establishing the geotechnical, mining, and metallurgical parameters. This data is used to populate resource-to-reserve conversion factors, and is critical to establish due to the high sensitivity of marine mining to mining rate.

INTRODUCTION

The majority of natural diamonds are mined from kimberlitic sources. In Africa, approximately 45 million carats (Mct) are estimated to be produced annually from kimberlitic or lamproitic sources (de Wit *et al.,* in press). Alluvial deposits, although widespread, are generally smaller scale but nevertheless are estimated to produce between 15–20 Mct annually, and have contributed nearly 700 Mct of the total of 3200 Mct or almost a quarter of the estimated amount of diamonds that have come out of Africa (de Wit *et al.,* in press). A total of three categories of placers are recognized, namely retained, transient, and terminal (Bluck *et al*., 2005). Retained placers are those deposits remaining on the craton and not readily available to the dispersal system. Transient placers are those that, during the current cycle of erosion, have been dispersed but have been temporarily stored in or on the margin of the dispersal route, and terminal placers are the final accumulation from the current drainage (Bluck *et al*., 2005) (Figure 1).

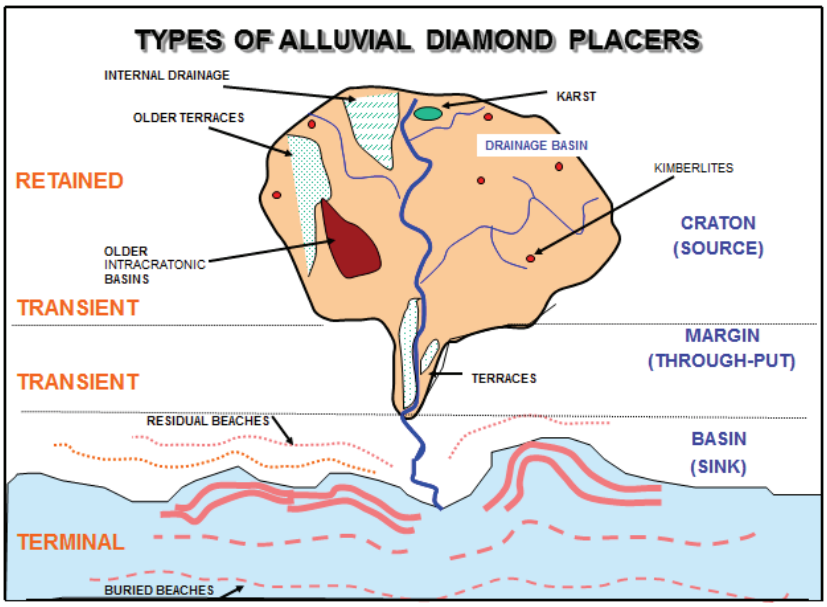


Figure 1. Placer types (after Bluck et al., 2005).

Marine placers are therefore terminal placers – they are rare in comparison with alluvial placers, but should the right conditions prevail, have potential to host large deposits at relatively high grades. The only two known so-called megaplacer deposits as defined by Bluck *et al.* (2005) occur on the southwestern coast of Africa, namely the Namaqualand and Namibian megaplacers. Megaplacers are defined as containing more than 50 million carats at higher than 95% gem quality (Bluck *et al.*, 2005). Since the initial discovery near Lüderitz in 1908, this region, which stretches over 1500 km from the Namaqualand coast of South Africa northwards to the Skeleton Coast of Namibia (Figure 2; Lotz, 1909; Cornell, 1920; Williams, 1932; Hallam, 1964; Rogers, *et al.*, 1990; Schneider and Miller, 1992; Corbett, 1996; de Wit, 1996; Ward *et al.*, 2002; Bluck *et al.*, 2005) has produced at least 156 million carats of gem quality diamonds, the bulk of which were derived from the Namibian deposits along the Sperrgebiet coast. In this regional mineral province, the diamonds are hosted in a variety of world-class placer types that, broadly speaking, encompass alluvial, fluvial, marine, deflation, and aeolian settings with temporal ranges from at least the Cretaceous through the Cainozoic to the modern day. In turn, the majority of carats produced from these spectacular occurrences have been derived from littoral environments, namely raised beaches, and by far the greatest remaining potential is in the offshore submerged beach deposits.

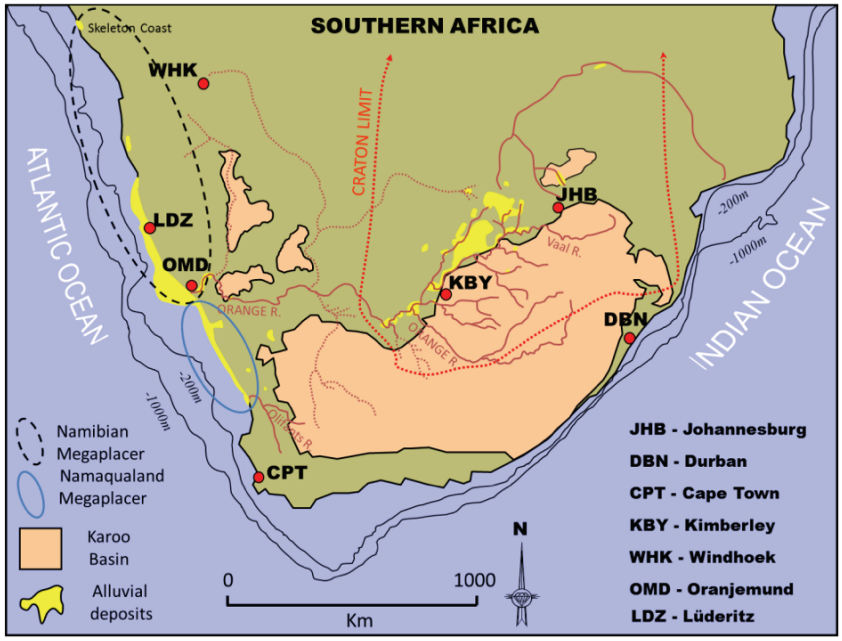


Figure 2. Locality map of the Orange River system and the Namibian and Namaqualand megaplacers.

REGIONAL GEOLOGICAL CONTEXT

Marshall and Baxter-Brown (1995) stress that there are basic principles governing any search for and evaluation of diamondiferous alluvial deposits. Prior to starting with field exploration, comprehensive knowledge of the following is required: regional geomorphology, axes of uplift, tectonic setting, structural controls, palaeotopography, sedimentology, fluvial geomorphology, and any post-depositional modification of the deposit. Similarly, for a coastal area to be prospective, Bluck *et al.* (2005) argue that a number of geological conditions need to be met:

- A prospective source area supplying the coast, and the availability of both primary and secondary deposits to the transport system
- The exit drainage needs to be on a large scale and preferably single, with low volumes of diluting sediment. Multiple drainages at different times may 'rob' the craton of accumulated diamonds. Furthermore, the exit drainage should have a large percentage of its drainage area located on the craton. A total of 35% of the Orange River basin is located on the Kaapvaal Craton, in comparison to the Lena and Congo which have 25% and 10% of their drainage basin areas located on cratons
- Tectonic setting – all diamonds delivered to the coast must be available for re-concentration at the terminal area, thus little or no subsidence of shelf area. This will enable the re-working of sediment during sea level changes, and removal of unwanted diluting sediments. A coast with a high-energy wave regime is important for this winnowing and re-concentration process
- The erosion of the hinterland and delivery of diamonds to the coast needs to coincide with optimum conditions for sediment winnowing and diamond placer concentration processes to operate
- A sediment-starved coastline (such as the desert coastline of Namibia) is important, to prevent undue dilution of the placer deposits
- The timing of this emplacement needs to be recent enough so that diamonds are recovered from unconsolidated sediment, rather than hard rock.

Thus, a good understanding of the source-conduit-sink pathway and associated geological processes is critical during the whole evaluation process. The rarity of marine diamond placers worldwide attests to the fact that the abovementioned conditions are seldom met. However, should all the

conditions be met, and such a discovery be made, more detailed focus on the local geology is required to understand the emplacement model of the potential deposits within the target area. Use can be made of regional geophysical and geological data-sets to obtain a basic understanding of the geometry and general characteristics of the deposits, such as broad stratigraphic relationships and ages. More detailed evaluation invariably requires the collection of more detailed geoscientific data.

RESOURCE EVALUATION

The evaluation of a diamond deposit needs to be based on a geological and statistical model (Rombouts, 1995). The collection of geoscientific data for the development of the detailed geological model differs considerably, depending on whether the target area is onshore or offshore. In both cases, the objective is to delineate the detailed geometry of the deposits to obtain the geological, stratigraphic, and volume models, after which the diamond content of the deposits is investigated to obtain the grade and revenue models.

Onshore Evaluation

If the deposits are exposed, detailed surface mapping using satellite imagery or aerial photographs can be done. Internal mapping of terrace and bedrock levels is based on drilling data. More commonly, areas will be covered by overburden sand, and then geophysical and drilling methods, or pitting and trenching, are needed to delineate the geometry of the underlying deposits. Geophysical methods have generally been unsuccessful in delineating the geometry of onshore deposits. Conventional seismic methods, as well as techniques such as resistivity and ground penetrating radar, have not delivered accurate results, possibly due to the effects of post-depositional cementation or saline groundwater. Due to the accuracy constraints of the geophysical techniques, *in-situ* geological sampling of the deposit is generally needed, and most commonly small-diameter drilling (100–130 mm) is used to delineate the stratigraphy of the deposits. The most effective techniques employed on the Mining Area No. 1 deposits at Namdeb are reverse circulation drilling, and more recently sonic drilling, which delivers high-quality samples. It should be noted that these drilling techniques do not provide any information on diamond content, but only lithological data, which is used to contruct the geological model. In some cases, pitting and trenching together with geological mapping can be used to construct the geological model. However, these techniques are generally considerably more expensive, and are not commonly used.

To obtain the grade and revenue models, *in-situ* sampling for diamond grade is needed. Prior to any sampling, a sample optimization study needs to be undertaken, according to the detailed geological model. About 66% of the diamonds in the beach deposits of Mining Area No. 1 are concentrated in fixed basal trapsites (Jacob and Prins, 2015). Hence a two-dimensional estimation is conducted. A sample support size (areal footprint) of 5 m^2 has proven to be adquate and practical for these deposits. A grid of 200 x 20 m governed by the anisotropy as observed in linear beaches is recommended if the objective is to estimate a resource at an Indicated level of confidence on a 200 x 100 m block support (Figure 3). Spatial continuity is governed by sea-level stands and is more pronounced along the strike of the beach. In many cases it is difficult to obtain a meaningful variogram from sample results, hence a moving average estimate is used instead of kriging. Sampling techniques vary from large-diameter drilling (5 m^2 footprint) to more expensive pitting and trenching campaigns. The Namibian megaplacer onshore raised beach deposits in Mining Area No. 1 were delineated (1930s to 1960s) using continuous trenches 1 m wide, spaced at 500 m apart and oriented perpendicular to the strike of the deposit. Each trench was divided into sections of 5 m length (Oosterveld *et al.*, 1987), resulting in a sample support size of 5 m^2. Nowadays, sampling on this scale is unlikely to be repeated, and a more cost-effective method of large-diameter sampling is used in the form of a Bauer BG36 bucket auger, with a sampled area of 5 m^2 per sample (Figure 4). The hole is stabilized using a combination of attapulgite mud and Viscopol polymer. Sample integrity is assured by drilling 0.5–1.0 m into the bedrock footwall. Subsequent mining in areas previously drilled using the BG36 confirms the penetration into the schist bedrock (Figure 5).

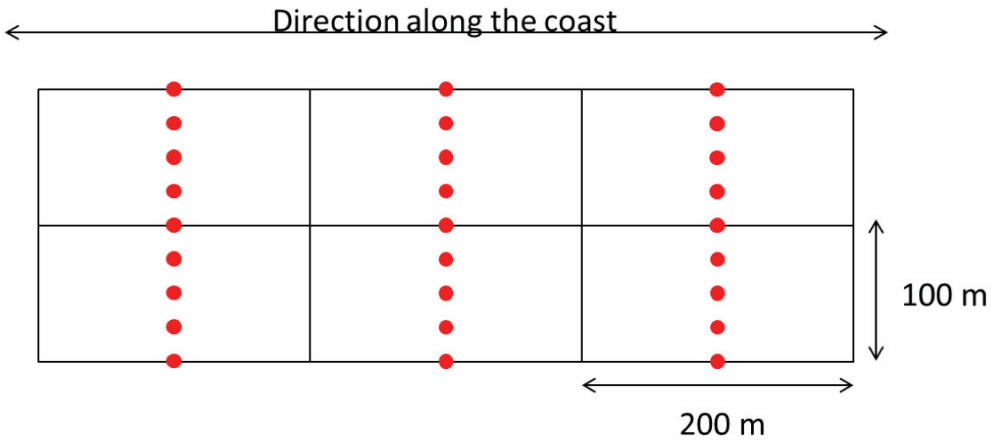


Figure 3. Onshore evaluation sampling configuration (200 x 20 m) for a 100 x 200 m block size.

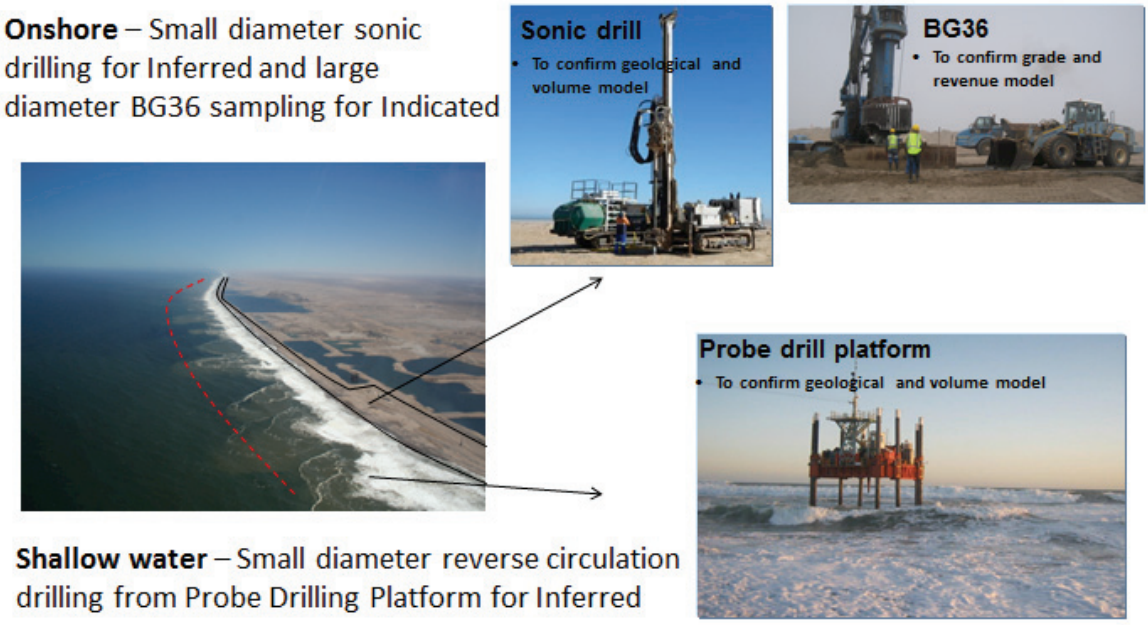


Figure 4. Drilling and sampling techniques for onshore and shallow water littoral deposits.



Figure 5. Two BG36 large-diameter drill holes exposed during mining operations – note the good penetration into the schistose bedrock.

Offshore Evaluation (Midwater Deposits along the Southwestern Coast of Namibia)

The major factors in determining where diamonds are most likely to be concentrated in the present environment are proximity to depositional environments of known diamond concentration (*i.e.* estuaries, palaeochannels, and ancient beach deposits), direction of sediment transport, and the nature of trapsites on exposed basement topography (Figure 6). Trapsites can take the form of large-scale features such as depressions, channels, embayments, or sea cliffs, or small-scale features in the form of gullies, joints, and potholes. The identification of such trapsites is vital when assessing a deposit's mineralization potential.

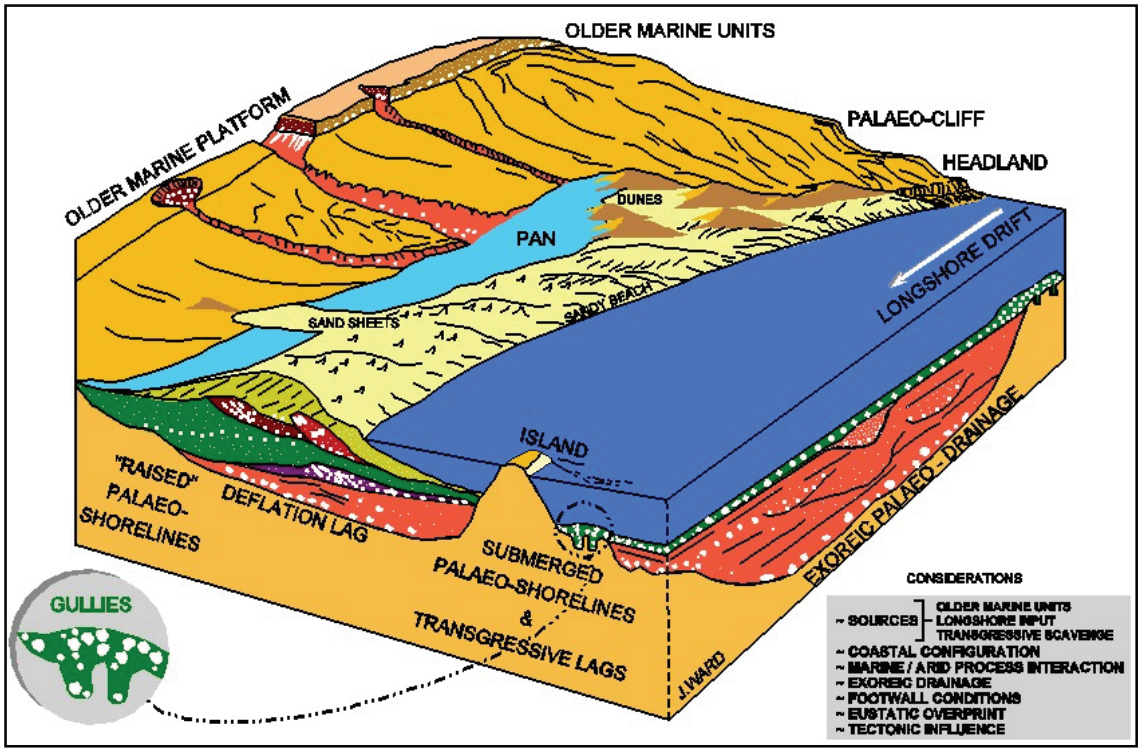


Figure 6. Illustration of the marine and littoral geological model for coastal deposits (Ward, 1998).

In the offshore environment, where no direct mapping can take place, one is completely dependent on geophysical data to develop the geological model. In the last 20 years, great advances have been made in hydrographic surveying techniques. The initial step is measuring the topography of the seabed surface. For this, swath bathymetry is used to obtain a very accurate three-dimensional surface of the seabed. If sufficiently accurate, this surface can be used to map out areas of exposed bedrock, or sediment patches. Generally the large sediment patches are the more prospective targets. Additionally, side-scan sonar data can be collected to complement the bathymetric data-set, by recording the textural differences on the seabed to differentiate sediment and bedrock. In the sediment patches, delineation of the geometry of the deposits and stratigraphic mapping is undertaken using seismic techniques. Often more than one technique is used, employing different frequencies: the lower frequencies deliver greater penetration at lower resolution (to delineate the footwall contact), and higher frequencies deliver greater detail for the mapping of sequences within the sedimentary package. Figure 7 illustrates the use of different geophysical data-sets in the delineation of marine placer deposits. Ground-truthing of seismic data needs to be done, either using a vibrocore, or 5 m^2 drill (also used for grade sampling) deployed in a widely spaced geological drilling campaign primarily to obtain geological, lithological, and geotechnical data. This programme in turn provides the geophysicist with critical lithological data, which is used to calibrate the seismic velocity parameters, vital for the processing, and ultimately a more accurate geological model is produced.

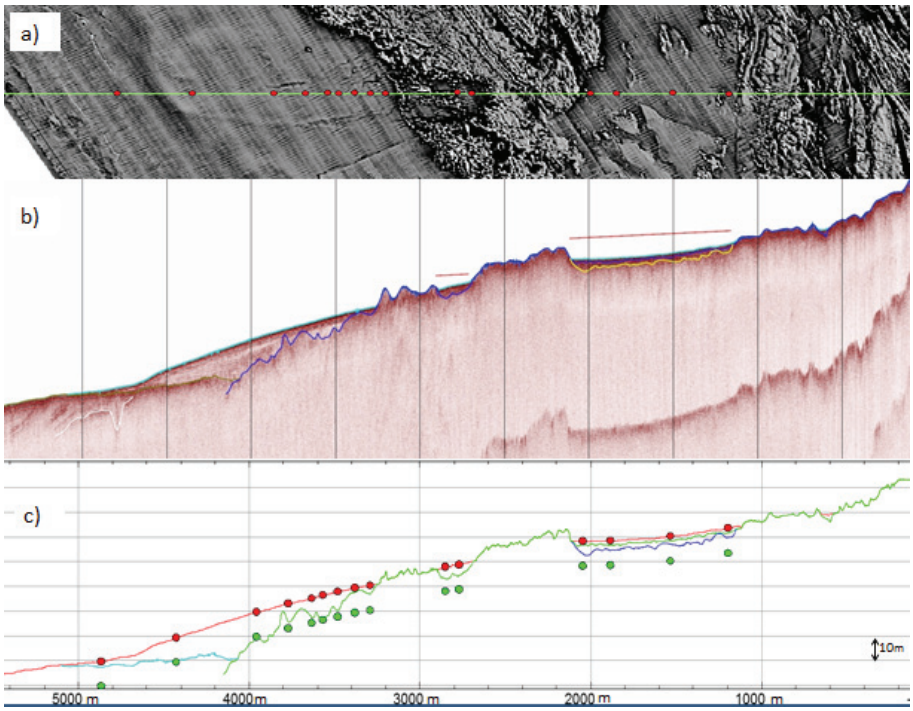


Figure 7. Geophysical methods used in the offshore deposits. (a) Swath bathymetry image showing the clear differences between exposed bedrock and sediment patches. (b) Seismic section along the green line in (a). (c) Interpretation of the surface and bedrock of the seismic section (red and green dots represent the surface and bottom points of 12 m deep hypothetical drill-holes)

From the resulting geological model, geological zones or domains can be defined using footwall elevation, morphology, lithology, gravel occurrence, and overburden texture. As with the onshore deposits, a sample optimization study is done to determine the sampling grid, per geological target. Sample spacing depends on the selectivity needed for mining, mining tool availability, expected mineralization model, and expected anisotrophy. Unlike the onshore linear beaches, the offshore deposits generally display a diffusion-type grade distribution model (a gradual transition from high grade to low grade), due to continuous reworking of the deposits during numerous sea level changes, or aeolian and sheetwash processes, and hence exhibit less anisotropy across strike.

The sample spacing depends on the geometry and shape of the geological zones and grade heterogeneity. Generally, sample spacing at an early stage of exploration is 1600 x 50 m or 800 x 50 m. Due to the high cost of marine exploration, prior to any further infill sampling being executed a preliminary economic assessment of the target is carried out using discounted cash flow models. This preliminary economic assessment assumes that the technology to mine the resources is available and the approximate cost of the mining is known. Higher resolution geophysical data and infill samples are then collected at configurations ranging from 400 x 50 m to 100 x 50 m (see Resource Classification section for permutations) to delineate the deposit more accurately and estimate grade at the required confidence levels.

Diamond grade sampling is done using vessels designed specifically for this purpose, with the processing plant onboard (Figure 8). In the past (1970s–1990s), samples of 1–2.5 m^2 were common, but were ineffective in determining the grades, or even the prospectivity, of an area accurately due to the large number of barren samples returned. Currently, sample sizes of 5 m^2 and 10 m^2 are used in the evaluation of marine deposits. During sampling, extreme care needs to be taken to ensure that sample integrity is maintained, and careful observation of over- or undersampling needs to be undertaken by the onboard geologist(s). Figure 9 illustrates the marine resource evaluation process. There are uncertainities in the geological or estimation domain boundaries and individual sample support size (areal footprint), which results in a different level of confidence in the final resource estimates. The indicated level of confidence is such that the relative error is ±15%, 9 out of 10 times for annual production.



Figure 8. MV Explorer sampling vessel, fully equipped to recover final product.

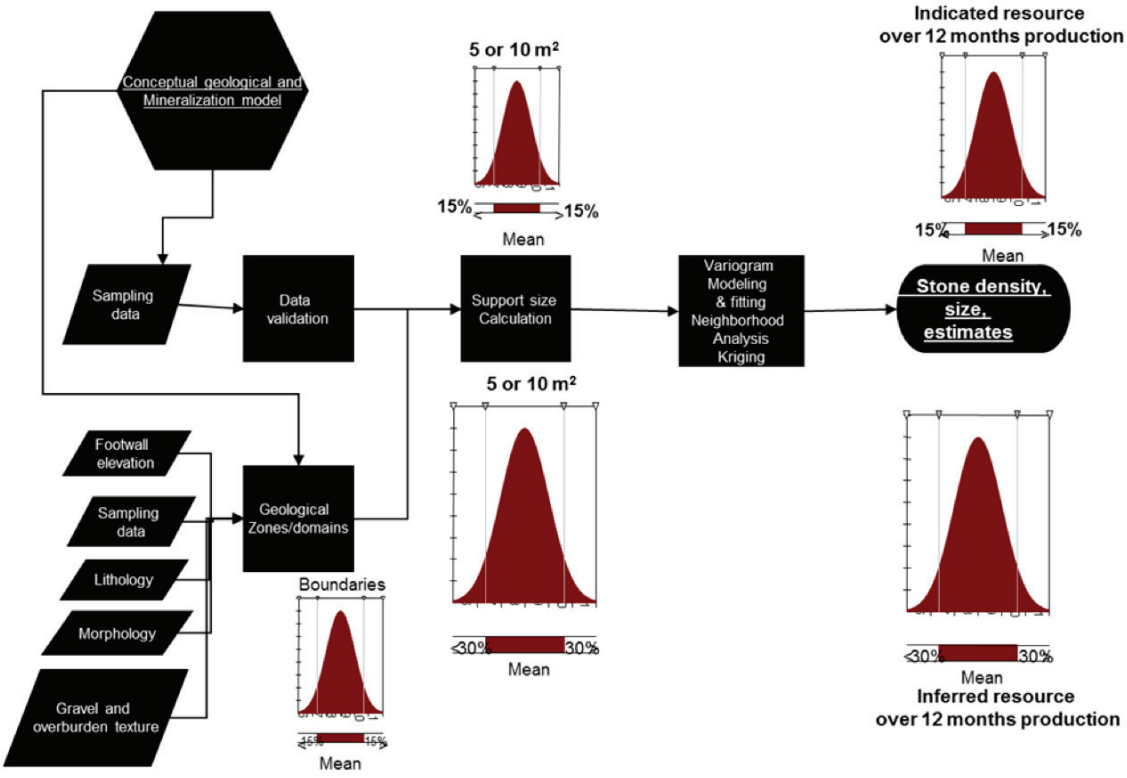


Figure 9. Simplified flow sheet of the marine resource evaluation process in the midwater deposits in southwestern Namibia.

A detailed data validation exercise is carried out prior to the estimation process. Commonly validated parameters are: sample ID and coordinates, stratigraphy, footwall type and depth, simulant and audit sample checks, drill duration, and processing parameters. During estimation, in most cases a robust variogram with 50–70% nugget effect is observed. The variogram range varies from 100 m to 250 m based on the geological terrain sampled. The local block estimates (100 x 50 m, 100 x 100 m, or 200 x 50 m) of stones per square metre are based on ordinary kriging with kriging efficiency varying from 0.5 to 0.8. The local block estimates of the average diamond size are always based on the moving average with a wider neighborhood search radius. As with the onshore beach deposits, the relatively thin offshore deposits are evaluated two-dimensionally. With the discovery of thicker deposits and multiple layers offshore, it will be necessary in future to sample and evaluate these deposits in three dimensions.

RESOURCE CLASSIFICATION

As part of the revision of the SAMREC Code, a process was started in 2013 and several Working Groups were set up. The Diamond (and Other Gemstone) Reporting Work Group focused on the following aspects for the 2016 rewrite of the SAMREC Code (Rupprecht, 2015):

- Stone distribution
- Diamond price
- Geological domains
- Minimum representative parcel or samples for various deposits
- Recovery factors
- Use of kimberlitic indicator mineral chemistry in grade and value estimation
- Valuation of microdiamonds and sampling protocols
- Relationship between the micro- and macrodiamond portions of the total content curve.

Only the first five aspects mentioned above pertain to alluvial/marine diamond deposits.

In addition, the SAMREC Diamond Guidelines (2016) highlights the following issues that require consideration.

Grade and value classification must be based on *in-situ* samples from the geological zone of interest. It cannot be based on production data from an adjacent prospect.

Generally, *in-situ* diamond sampling is needed for Inferred Resources to be declared in alluvial and marine deposits. However, in the Mining Area No. 1 onshore linear beach deposits, Diamond Resources are classified at an Inferred level of confidence using geological information from small-diameter drilling combined with a mature geological model and long-term production history and knowledge. The classification is dependant on geological continuity (marine basal gravel occurrence) being implied. Indicated Resources can only be defined with *in-situ* grade sampling. In unknown onshore beach deposits, such as the Pocket Beach deposits in the northern Sperrgebiet, *in-situ* diamond sampling is needed to declare an Inferred Resource. All Diamond Resources need to be declared at a specific bottom cut-off.

For offshore marine deposits, in the absence of production history and due to the high costs of sampling and mining, detailed sample optimization with cost-benefit analysis should be carried out when increasing the confidence level from Inferred to Indicated resource categories.Geostatistical simulations are a proven method to quantify the uncertainty associated with the estimates (Brown *et al.*, 2004; Burger and Duggan, 2010; Saravanakumar *et al.*, 2014). The example below describes a sample optimization for a typical midwater target.

At least one hundred conditional simulations using the cox process are created for a domain equivalent to the planned annual production area (Brown *et al.*, 2004). These simulations are based on an existing denser sample set. The simulations are validated using statistical, spatial, and graphical methods recommended by Leuangthong *et al.* (2004). The simulations are sampled at four different spacings (100 x 100 m, 100 x 50 m, 50 x 200 m, and 250 x 50 m) and then each sample set is estimated into 100 x 100 m blocks with ordinary kriging. A comparison between the simulation and estimated block results is carried out and the confidence of each sampling pattern determined. The relationship between the distribution of the 100 realizations of the simulation and estimated blocks could then be used to assess the merit of each sampling pattern. The ratio of simulation and estimation for the whole area (equivalent to one year's production) is calculated for the 100 simulations and plotted on a control chart. The sampling pattern that satisfies the 90% confidence limit (less than 10 ratios are outside the 15% confidence limit) is chosen. Figure 10 shows an example of control charts for different sampling patterns. All of the sampling patterns except the 250 x 50 m pass the 90% confidence limit test. Further refinement of these options requires a full cost-benefit analysis.

One of the sampling patterns is used based on the expected selectivity required by the mine plan (less selectivity for dredging and high selectivity for drill-ship-based mining), expected cut-off grade, geological terrain, and expected anisotrophy. For example, a 100 x 100 m sampling pattern is the optimum for terrain that is highly homogenous with respect to geologicy and mineralization, with a high expected percentage of area well above the cut-off and no anisotrophy. On the other hand, in less homogenous terrain with less expected percentage of the area above the cut-off with anisotrophy, a 100 x 50 m sampling pattern is the optimum.

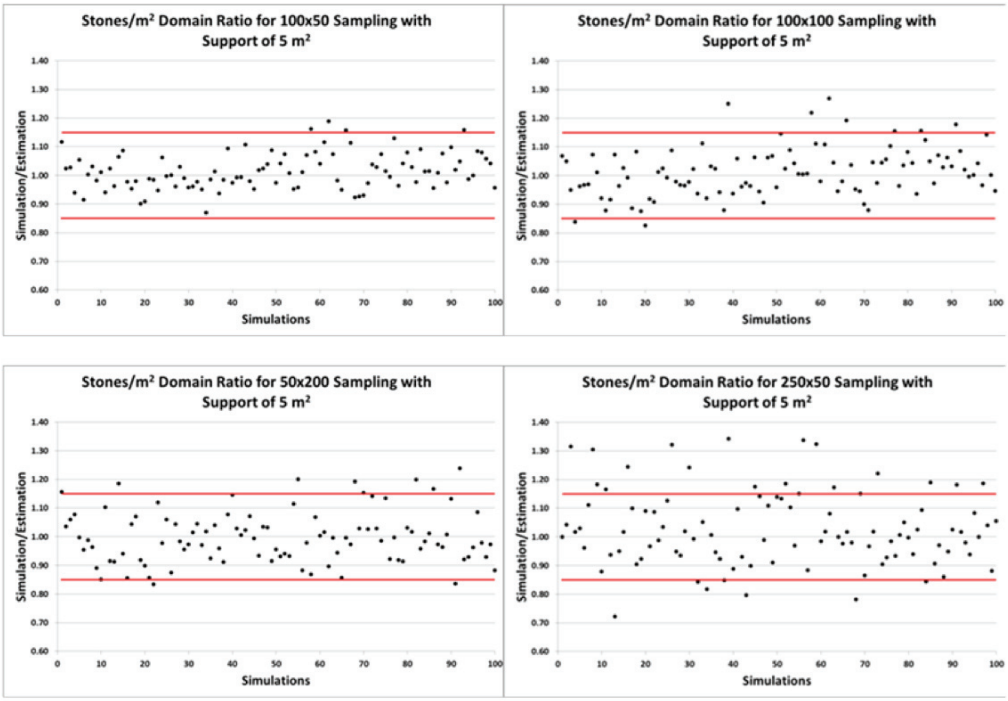


Figure 10. Control charts for differing sample densities in a midwater target.

Figure 11 shows the sampling cost cost relative to total cost as well as percentagerevenue for an Indicated resource for different sampling patterns. At configurations of 100 x 100 m and 50 x 200 m, sampling costs are virtually the same due to the similar areal coverage per sample (10 000 m²). However, 100 x 50 m sampling pattern costs are doubled due to the lesser areal coverage per sample (5 000 m²). The minimum and maximum sampling costs are calculated by varying the sampling rate per day, expected mining rate per day, and revenue per carat. This cost excludes geophysical data acquisition and interpretation. This kind of sample optimization exercise can be carried out only where there are adequate samples available. To validate the sample optimization results, it is advisable to repeat this exercise after 1 or 2 years of production data.

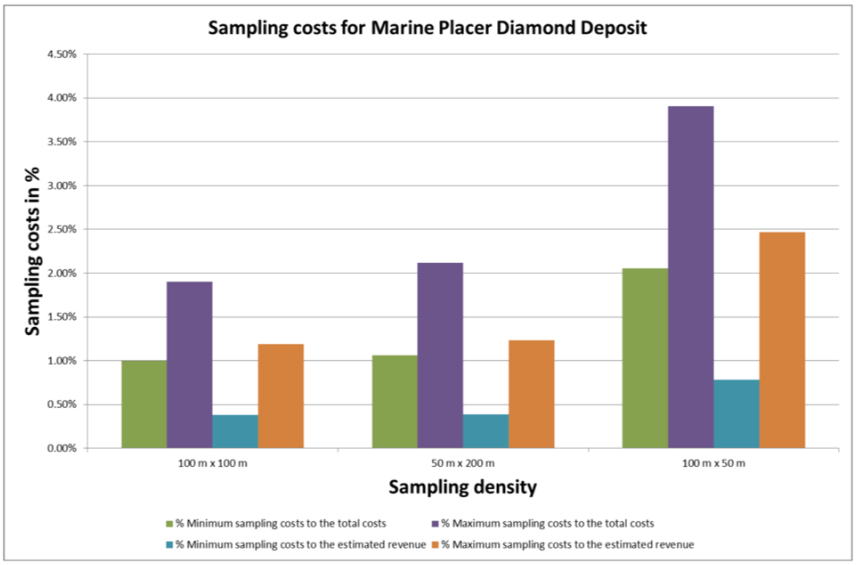


Figure 11. Sampling costs for different sampling densities in a midwater target.

In both onshore and offshore deposits, for revenue modelling purposes, 100–300 stones are needed for size frequency modelling and revenue estimation at the Inferred level of confidence, whereas at least 300–600 stones are needed for an Indicated level of confidence. These numbers are applicable only in an area with a well-known or homogenous diamond assortment. In newly discovered areas, larger diamond parcels (500–1000 stones) are required to establish the assortment model. In onshore deposits, density is measured *in-situ* per facies during a separate density sampling campaign which measures the loose bulk density and bulking factor of the *in-situ* material. Currently, no measures of *in-situ* density are carried out in offshore deposits due to technical constraints.

During prefeasibility and feasibility studies, bulk sampling and trial mining should be conducted to collect data for establishing the geotechnical, mining, and metallurgical parameters for conversion of Resources to Diamond Reserves. In the marine environment, in addition to the accurate estimation of *in-situ* grade, it is critical to establish the mining tool efficiency, mining rate, and vessel availability and utilization as these parameters are fundamental to establishing the economic cut-off grades in any given deposit.

CONCLUSION

Economic marine diamond deposits, although rarer than their alluvial counterparts, can often contain large volumes of high-value and high-quality diamonds at grades well above economic cut-off. The coast of southwestern Africa hosts two diamond megaplacers that have been mined for more than 107 years. Due to the long history of onshore mining, the extensive mining data-set has contributed to the maturity of the geological model, which makes evaluation of the remaining deposits easier. In contrast, most of the remaining potential of these megaplacers is contained in the offshore deposits which are in the early stages of development. Due to the high costs associated with marine exploration and mining, continuous economic assessment of each target needs to be undertaken at every step of the evaluation process to ensure that the limited exploration funding is used to efficiently and accurately delineate the deposits that are most likely to be mined. The relative mobility of the marine mining platforms does afford marine mining projects some flexibility in terms of accuracy of individual resource estimates, in comparison to onshore deposits which have relatively fixed onshore infrastructure which is both time-consuming and expensive to move. Nevertheless, levels of confidence in marine projects should be such that estimations are sufficiently accurate to base financial decision on.

ACKNOWLEDGEMENTS

The authors would like to thank the De Beers and Anglo American Mineral Resource Departments and Namdeb Management for their support, providing access to data, and permission to publish this work. The authors appreciate the comments and helpful suggestions from the reviewers.

REFERENCES

Bluck, B.J., Ward, J.D., and de Wit, M.C.J. (2005). Diamond mega-placers: southern Africa and the Kaapvaal craton in a global context. *Mineral Deposits and Earth Evolution*. McDonald, I., Boyce, A.J., Butler, I.B., Herrington, R.J., and Polya, D.A. (eds). *Special Publication* no. 248. Geological Society, London. pp. 213–245.

Brown, G., Lantuéjoul, C., and Prins, C. (2004). Sample optimisation and confidence assessment of marine deposits using cox simulations. *Proceedings of Geostatistics Banff 2004*, vol. 1. Leuangthong, O. and Deutsch, C. (eds). Springer, Dordrecht. pp. 315-324.

Burger, U. and Duggan, S. (2009). Comparing different methods of sampling to estimate the mineral resource in the Elizabeth Bay aeolian diamond placer. *Proceedings of the Fourth World Conference on Sampling and Blending*, Cape Town. pp. 157-164.

Corbett, I.B. (1996). A review of diamondiferous marine deposits of western southern Africa. *Africa Science Review* 3, 157-174.

Cornell, F.C. (1920). The Glamour of Prospecting. [Reprinted 1992]. Creda Press. 336 pp.

De Wit, M.C.J. (1996). The distribution and stratigraphy of inland alluvial diamond deposits in South Africa. *Africa Science Review* 3, 175-189.

De Wit, M.C.J., Bhebhe, Z.M., Davidson, J.M., Haggerty, S., Hundt, P., Jacobs, J., Lynn, M.D., Marshall, T.R., Skinner, C.P., Smithson, K., Stiefenhofer, J., Roberts, M.A., Revitts, A., Spaggiari, R.I., Ward, J.D., and Jacob, R.J. (2014). Overview of diamond resources in Africa. *IGC Special Publication, In press.*

Jacob, J. and Prins, C.F. (2015). Construction of expert opinion based virtual orebodies for a diamondiferous linear beach deposit. *Proceedings of the Danie Krige Geostatistical Conference*, 19–20 August.. Geostatistical Association of Southern Africa and Southern African Institute of Mining and Metallurgy, Johannesburg. pp. 155-164.

Hallam, C.D. (1964). The geology of the coastal diamond deposits of southern Africa. *The Geology of Some Ore Deposits in Southern Africa*. Haughton, S.H. (ed.). Geological Society of South Africa, Johannesburg. Vol. 2, pp. 671-728.

Leuangthong, O., Mclennan, A.J., and Deutsch, C. (2004). Minimum acceptance criteria for geostatistical realisations. *Natural Resources Research* 13 (3), 131–141.

Lotz, H. (1909). Uber die Lüderitzbuchter Diamantvorkommen. *Zeitschrift fur Praktische Geologie* 17, 142.

Marshall, T.R. and Baxter-Brown, R. (1995). Basic principles of alluvial diamond exploration. *Journal of Geochemical Exploration* 53, 277-292.

Oosterveld, M.M., Campbell, D., and Hazell, K.R. (1987). Geology related to statistical evaluation parameters for a diamondiferous beach deposit. *APCOM 87, Proceedings of the 20th International Symposium on the Application of Computers and Mathematics in the Mineral Industries*. *Vol. 3: Geostatistics*. Southern African Institute of Mining and Metallurgy, Johannesburg, pp. 129-136.

Rogers, J., Pether, J., Molyneux, R., Genis, G., Kilham, J.L.C., Cooper, G., and Corbett, I.B. (1990). Cenozoic geology and mineral deposits along the west coast of South Africa and the Sperrgebiet: Guidebook, Geocongress '90. Geological Society of South Africa, Johannesburg. PR1, 1-111.

Rombouts, L. (1995). Sampling and statistical evaluation of diamond deposits. *Journal of Geochemical Exploration* 53, 351-367.

Rupprecht, S. (2015). The Proposed 2016 SAMREC Code. *Proceedings of Copper-Cobalt Africa (incorporated in the 8th Southern African Base Metals Conference*). Southern African Institute of Mining and Metallurgy, Johannesburg. pp. 11-20.

Saravanakumar, P., Brown, G., and van Eck, G. (2014). Sample support size and spacing determination for resource development of a marine placer gold deposit. *Journal of the Southern African Institute of Mining and Metallurgy* 114 (1), 7-18.

Schneider, G.I. and Miller, R.McG. (1992). Diamonds. *The Mineral Resources of Namibia*. 1st edn. Geological Survey of Namibia, Windhoek. pp. 5.1-1 to 5.1-32.

Ward J.D. (1998). Inshore Marine and Littoral model for northern Sperrgebiet, Namibia. Internal Report, Namdeb Diamond Corporation, Oranjemund.

Ward, J.D., Jacob, R.J., de Wit, M.C.J., Spaggiari, R.I., and Bluck, B.J. (2002). Post-Gondwana Evolution of the Vaal-Orange Drainage System: Economic Implications. Excursion Guide, I, Rand Afrikaans University, South Africa. p. 75.

Williams, A.F. (1932). The genesis of the diamond. Ernest Benn. Vols 1 and 2. 642 pp.



Jurgen Jacob

Head : Mineral Resource and Environment
Namdeb Diamond Corporation (Pty) Limited

Jurgen is a geologist by profession, and holds a Phd from the University of Glasgow, specializing in alluvial diamond deposits and gravel-bed rivers. He is responsible for all aspects of mineral resource and environmental management at Namdeb, including exploration and evaluation of new alluvial diamond deposits, measuring and monitoring resource performance and long term mine planning. Jurgen has held a variety of positions at Namdeb, mainly in the exploration and production environment, and prior to joining Namdeb, was based on a small alluvial diamond mine in the Richtersveld.

Diamond valuation: what can a CP do to ensure it is fit for purpose?

C. Gordon-Coker

Mineral Resource Management, De Beers UK Limited

The valuation of a diamond parcel can often be shrouded in mystery. The combinations of size, model (shape), quality, and colour (the diamond *assortment*) are to some extent subjective and open to considerable interpretation. Furthermore, a diamond is not a commodity and the valuation approach may be subject to proprietary practices with little means of external validation. The particulate nature of diamonds and their extremely low concentration can make it difficult for the Competent Person (CP) to ensure that the sample valuation (and the subsequent revenue model) is both statistically robust and fit for purpose. The 2016 SAMREC/SAMVAL Companion Volume Conference provides an ideal opportunity to share some best-practice insights as to what should be considered when reviewing such a valuation.

INTRODUCTION

Rough, uncut diamonds are not fungible; one stone cannot be readily exchanged for an identical second stone. There is no widely recognized rough diamond trading platform or global pricing standard, and if a company wishes to obtain a valuation for a sample, in the absence of any in-house expertise, they may need to seek the assistance of a qualified diamond valuator. If the sample is small and requires modelling to estimate a run-of-mine average value, then further capability will be required in the form of a revenue estimator to construct a representative size frequency distribution (SFD) and assortment.

The SFD simply represents the number of carats per size class, usually defined by diamond sieves (*e.g.* -9+7 indicating that a stone falls through a '9' sieve but remains on a '7' sieve) or individual mass ranges *e.g.* 4 carat (3.8–4.79 carats). The assortment (combinations of size, model (shape), quality, and colour) meanwhile represents the visual characteristics of the rough stones in terms of how they might eventually be polished. The combination thereof will produce the all-important US dollar per carat ($/ct) revenue estimate.

Although it may have been acceptable in the past simply to accept the diamond revenue components at face value, most diamond-specific regulatory codes now require a far greater understanding of, and responsibility for, the valuation elements. This paper offers the CP some insights as to what to look out for across all stages of the process, from initial valuation to final modelled price.

THE DIAMOND SAMPLE

Sample Size The 2016 SAMREC Code, Clause 62 deals with the size and representivity of the diamond sample. Itself a topic of much debate, the number of carats (and stones), and equally importantly their distribution across the size classes, this is a critical element of the valuation. However, it is a variable that is explicitly quantifiable and can be easily compared with other samples, but remains deposit-specific. It is essential for the CP to ascertain whether the sample size matches the objective stated in the initial sample plan and is sufficient for the level of resource classification intended. Too few carats and the confidence in the estimate may fall short of expectations.

Since the revenue estimate comprises both a modelled SFD and assortment, the sample size must be adequate for both purposes. There may be as much as an order of magnitude difference between the number of carats necessary for the former compared with the latter. The nature of diamonds is such that, given the grade of the deposit, there will be considerably fewer stones recovered in the larger size classes. However, these stones will typically contain a far greater proportion of the overall value and are consequently of significant input to the revenue model. It is therefore incumbent on the CP to consider both aspects of the revenue estimate when reviewing the sample size. If there are indications of very high-value stones occurring with limited frequency then it may not be possible to obtain a representative sample size until trial mining has commenced.

Clause 62 states that industry practice suggests that although as few as 100 carats may be adequate to characterize an SFD in a diamond deposit, a minimum of 500 carats is generally recommended to achieve even a low-confidence valuation (revenue estimation), and classification of an Inferred Diamond Resource. However, the stability of the size distribution and the complexity of the assortment may not be well understood with small samples.

Where early indications do show a stable SFD and diamond assortment, a parcel size in the order of 2000 carats may be sufficient to achieve a reasonable valuation (for Indicated Diamond Resource classification). In deposits with highly variable stone sizes and assortment, or deposits in which a small number of very high-value stones have a large influence on the overall average stone value (such as low-grade alluvial deposits), parcels well in excess of 2000 carats may be required for Indicated Diamond Resource classification. In extreme cases, a confident parcel size may never be obtained during industry-standard evaluation sampling, or even trial mining.

Where geological continuity can be assumed and the sample has been taken to represent the deposit (and valuation data already exists), then as few as 100 carats may be required for size frequency modelling and a minimum of 500 carats for an assortment estimate at an Inferred level of confidence. At least 1000 carats may be needed for a revenue estimate at an Indicated level of confidence.

Spatial Variability
In order to obtain a sample of sufficient size, excavating a trench or some other form of single-point bulk sample may be considered. However, this approach runs the risk of overlooking any spatial variability that may occur across the orebody. To counter this, if the bulk sample is made up of multiple bulk and drill samples on an optimized grid, then the combination of the two data-sets will likely produce an estimate at a much greater level of confidence.

The revenue estimate should not be considered in isolation, and adherence to the geological model is critical. While the assortment is likely to remain broadly consistent across a lithology, the SFD and average stone size may well vary within rock types in the case of placer deposits. In this instance, even greater care must be taken to understand the spatial nature of the deposit.

Sample Valuation
If generating the caratage required for a representative sample is the most important aspect of the project, then ascribing a value to these carats is a close second. At this stage of the revenue estimation process the number of variables remains considerable. Firstly, the choice of a qualified diamond

valuator or valuators is critical, and the CP must take care to review the credentials of the diamantaire who has carried out the valuation.

Experience in the industry and exposure to a wide variety of diamond deposits and diamond characteristics are invaluable. The ability to characterize or classify an individual stone into a specific category is quite different from ascribing a price to that stone. In order to build up a realistic sample valuation the valuator must have experience of, or access to, recent actual rough stone trades and not simply theoretical prices that may not accurately reflect the current market.

The circumstances of the valuation itself must also be understood. Were the stones cleaned before being presented for valuation? If not, how has the valuator compensated for this? Was the sample viewed in ideal conditions? Were daylight lamps available? Were diamond scales used to weigh the parcel; were these tared with recognized reference weights? Additionally, were reference samples available, particularly those useful for colour?

If the answer to any or all of the above is no, what does this mean for the CP? Although it certainly does not render the valuation obsolete, industry standards would most likely lead to a reduction in confidence and therefore suggest a lower level of classification than if these guidelines were more closely adhered to.

The CP should understand the method of valuation. Has any rolling taken place beforehand? (This would involve physically combining samples before the valuation commenced.) Was this rolling by geology, by zone, by depth, or any other grouping? Was this witnessed by the valuator or the CP? Ideally, the samples would have been presented at a layout before the valuation began. This would normally take the form of all the samples being placed on a bench, spatially aligned with the drill-holes (by depth) or trenches and taking into account any geological or lithological information.

If the parcel was large, were all the stones individually classified or was a representative sample taken? If a sub-sample was cut off, how big was this parcel (was it large enough to be statistically representative?) and how was it split from the main sample?

The issue of diamond damage and breakage should also have been considered. Does the valuation report make reference to this, and has the final result been modified in any way to compensate for it? Is this based on the understanding of the sample recovery process compared to what might be expected in the final plant flow sheet? It is important for the report to distinguish between 'natural' damage, or breakage that has incurred during emplacement, and 'fresh' breakage that has occurred during the recovery process. The former will be a characteristic of the orebody, while the latter may be addressed through process modifications
.
Similarly, the presence of diamond fluorescence may have been observed, and if so, was there any adjustment to the value as a result? Finally, were there many 'borderline' stones observed for which, if the classification was marginally altered, the final valuation would significantly change?

Once again, a number of guiding principles are presented that will enhance the quality of, and the confidence in, the valuation and the associated revenue estimate, and once again the CP should be on the lookout for situations where 'best practice' has not been followed. In some circumstances *e.g.* rolling of samples, no remedial action can be taken if this was considered to have been sub-optimal. However, re-visiting the size of the parcels sorted or requesting diamond damage studies may still be possible. This may lead either to the sample valuation being amended and/or the modelled SFD and assortment being adjusted accordingly.

Given the difficulty with which the sample value can be verified, many companies may choose to have the sample valued by multiple diamantaires. How these valuations are combined must also be explained – an averaging process; the elimination of maximum and minimum? It is imperative for the CP to understand whether these values are based on actual, recent sales or simply on a theoretical

price book. The prices themselves, as stated in the 2016 SAMREC Code, Clause 61, should not be more than six months old. This is of particular relevance when the rough diamond sector is going through a period of volatility, as large price swings may be seen in relatively short periods of time.

The form in which the valuation is made available is another element for the CP to review. What level of detail was submitted – dollar per carat per size class or full price point information *i.e.* the mass, classification (description), and price of each individual stone? The security of the value chain (from recovery to valuation to storage of samples and data) should also be checked with a view to understanding the possibility of theft, substitution, and the prevention of any cross-contamination between samples.

THE REVENUE MODEL

It is unlikely that the diamond sample will be of sufficient size, and therefore representivity, for the valuation to be used without any form of modelling. The CP must therefore understand how both elements of the final revenue model (the SFD and diamond assortment) have been created.

SFD Model

This is arguably the easier of the two elements of the revenue estimate to construct. It is not the intention of this paper to debate the various methods of SFD modelling; given the predominantly lognormal distribution of diamond size, the process of compensating for under-represented size classes and extrapolation into the larger sizes is well documented. The CP should of course ensure that any modelling is well supported by the raw data, paying particular attention to the coarser sizes and any modifying factors introduced to compensate for sampling inefficiencies and issues such as breakage and damage mentioned above.

The top and bottom cut-offs (for both the sampling plant and proposed production plant) are critical factors, and the presence of 'incidental' carats (stones recovered below the bottom cut-off) should be recorded. The final result should state whether these are included in the distribution or whether a strict cut-off, with no stones below this point, has been applied. Modification of these cut points can have a dramatic effect not only on the volumes of carats recovered, but on the resultant average price of the diamond parcel.

Assortment Model

No two rough diamonds are identical, and yet the industry approach is to value each stone with a view to the polished product – both its worth and potential saleability. This may be a single polished stone or a number of stones, depending on the characteristics of the original rough. At any point in time, multiple polished options may exist for a single uncut stone, depending on prevailing preferences and the demand for specific cuts and sizes.

In order to classify each rough stone, its size and its model (shape), quality, and colour (the assortment) must be defined. While size is an absolute measure of mass, in carats, (where one carat is defined as one-fifth of a gram (0.2 g)), the remaining attributes are less easily specified. Furthermore, the various permutations of these variables can typically lead to several thousand individual rough price points. The need to obtain a statistically representative sample of these price points is why the parcel size for a given level of resource category is so much larger than that required to model an SFD.

The skills required to perform a diamond valuation are not widely available and the ability to model the resultant valuation, so as to be representative of a run-of-mine production, is rarer still. The CP may therefore find him- or herself confronted with a somewhat arcane process that nonetheless requires verification. Assortment modelling is often based on proprietary processes from the valuation stage right through to the estimation techniques subsequently applied.

With the exception of broad-based mineral deposit evaluation courses, there may be no formal qualifications in diamond revenue estimation for the CP to check. However, experience and the nature of previous valuation exercises will go some way to provide assurance of the accuracy of the estimator's work.

Mathematical and statistical credentials should be evident and involvement in the 'midstream' *i.e.* rough diamond sorting, valuing, and trading, will provide crucial insight into the understanding of the diamond assortment. Knowledge of multiple kimberlite emplacement types and less-common diamond characteristics, such as fancy colours and shapes, and their impact on the overall average price, will all play an important part. The estimator should typically have spent at least five years modelling diamond revenues.

Unlike the SFD, the relationship between price and value is neither normal nor lognormal. Indeed it may be multi-modal and is essentially a man-made construct; changing over time as any correlation between the price of larger gem stones and smaller, cheaper pieces varies over time and with the prevailing trading conditions.

So what should the CP look out for? Although the assortment modelling process may involve confidential information and/or proprietary methods, the extent of any modelling is crucial. Over what size range was the raw sample considered to be statistically robust? How have any under-represented, higher value stones been modelled? If the SFD is particularly coarse, what values are ascribed to the larger size classes? If these are also above average, then the impact on the overall average value will be significant.

Are there multiple SFDs for the resource in question (one per lithology) and is the corresponding assortment model global *i.e.* applicable to the entire deposit? This is a not uncommon situation, but again the CP must ensure that the revenue models are consistent with the geology and that any subdivisions are justified. Equally, if the assortment has not been split across different zones, is this because of the underlying sample size or is there genuinely little difference between the characteristics per lithology or area?

CONFIDENCE LIMITS

Having combined the modelled SFD and the assortment estimate, an overall average value in the form of a dollars-per-carat figure will be generated. This may be further broken down into a dollars-per-carat/size class table and, if the sample is large enough, an estimate of the wider assortment characteristics for the run-of-mine production. But what level of confidence exists in this estimate and how has it been calculated? If the SFD is tabulated by sieve class and the assortment based on the more traditional carater and grainer split (where there are four grainers to every carat), how have they been converted and combined? If lower critical sizes per sieve class are used, are they relevant for the nature of the deposit?

Traditional Monte Carlo techniques may have been applied, but it is important to remember that both the modelled SFD and the assortment estimate will be subject to error, while the skills of the estimator will reduce these variances. The limits are also unlikely to be symmetrical given the positively skewed nature of the value distribution; *i.e.* greater upside would be expected than downside.

With reference to the sample sizes discussed at the beginning of this paper, depending on the complexity of the orebody and the amount of modelling of both the SFD and assortment that was required, upper and lower limits of some 15% of the modelled average price might be expected with a sample size of the order of 3000–5000 carats. Mid- to low-value deposits (particularly with low grades) but with high-value large stone potential will have much wider confidence limits, again with significant upside. These limits are likely to be narrowed only with production-level volumes of carats available for analysis.

CONCLUSION

The diamond sample valuation process is highly complex, and the subsequent revenue estimate even more so. However, while the valuation is a matter of expert opinion, the CP must still take accountability for the estimate. Even if the CP is not a skilled diamantaire, he or she can ensure that the results are fit for purpose. By breaking down the estimate into its constituent elements and asking appropriate questions at each step, a suitable level of assurance can be achieved. The examples given above are by no means an exhaustive list, but they should provoke a level of interrogation that will highlight any material issues in order that a robust explanation of the valuation can be given in the accompanying CP report.



Chris Gordon-Coker

Manager, Mineral Resource Management London
De Beers (UK) Limited

Chris Gordon-Coker joined De Beers in January 1985 at the then named Central Selling Organisation (CSO), subsequently the Diamond Trading Company (DTC). He worked in Management Information Services in the forecasting team looking at global diamond intakes before moving to the Sales Department analysing production, stocks and availabilities for sale to Sightholders.
In 1999, following his post-graduate studies, he moved to Johannesburg to join the Mineral Resource Management (MRM) team at De Beers CHQ as Diamond Revenue Manager. He was responsible for calculating diamond revenues for all the De Beers operations and global exploration projects. Chris returned to London in February 2003 to run the MRM department at De Beers UK. He and his team continue to generate diamond revenue estimates for new projects and detailed price point forecasts and reconciliations for all the De Beers mines whilst promoting a greater understanding of MRM revenue accountabilities across the Group of Companies.

Diamond Resource reconciliation in a mature block cave

A. Wolmarans[1], D. du Toit[2], D. Venter[2], and A. Rogers[1]

[1] Petra Diamonds, Johannesburg, South Africa
[2] Petra Diamonds, Finsch Diamond Mine, South Africa

Since its acquisition of Finsch diamond mine in 2011, Petra Diamonds has been focused on maximizing the potential of the remaining Block 4 Resource and the accelerated development of the deeper Block 5 mining levels. In order to maintain a continuous production profile, the life of Block 4 has been optimized to maintain production levels until the Block 5 sublevel cave is in full production.

In this mature block cave environment, the mine plan is sensitive to the accuracy of the Resource and Reserve determination, which relies on the accurate accounting of the ingress of material from pit sidewall failures. Material from sidewall failures will impact on the life of the block cave, and can be added to the Block 4 Reserves if the distribution of waste and kimberlite within the broken material can be understood, and the mixing of the material accurately modelled as it reports to the drawpoints in the block cave. Volumetric differences between the pit scan surfaces are used to quantify pit failure material in order to account for depletion and the relocation of material. In conjunction, block cave mining simulation software is used to estimate material mixing and dilution in order to effectively manage the remaining Reserve.

These robust workflows allow for the development of mine plans at the required level of confidence and provide an accurate estimate of the remnant material that will eventually report to the future Block 5 cave.

INTRODUCTION

Finsch diamond mine is situated approximately 165 km northwest of Kimberley, South Africa and is located across two farms, namely the Brits farm and a portion of the remainder of the Carter Block farm, in the magisterial district of Hay. The Finsch mining right, which covers an area of 1 568 hectares, was converted to a new order right in October 2008 and is valid for a period of 30 years to 2038.

As at 30 June 2015, Finsch has an Indicated Diamond Resource of 38.8 Mt containing an estimated 26.7 million carats (Mct) at an average grade of 68.9 carats per hundred tons (cpht) at a 1.0 mm plant bottom cut-off in the Block 4 and Block 5 Resource blocks. The underground Inferred Diamond Resource (excluding tailings resources), which is estimated at 35.0 Mt at an average grade of 60.4 cpht, is spread between the depleted upper mining blocks (Block 2 and Block 3), the current Blocks (Block 4 and Block 5) and the deeper future Resource block (Block 6).

Geology

The Finsch kimberlite pipe is a group 2 kimberlite that has been dated at 118 ± 2.8 Ma. It is a complex orebody, consisting of a main diatreme which truncated numerous kimberlite precursor bodies during its emplacement. A total of four major precursor bodies and five kimberlite facies within the main orebody (F1, F2, F4, F7, and F8), are recognized in addition to blocks of intact basalt and mudstone and their brecciated equivalents (Ekkerd *et al*., 2003). The largest of the precursor bodies is the South West Precursor (SWPC), which is also the most economically important with an Inferred Resource in Block 4 of 4.15 Mt containing an estimated 2.23 Mct at an average grade of 53.82 cpht at a 1.0 mm plant bottom cut-off.

Mining Method

Current production is from the mature Block 4 block cave (which is largely mined out) with the extraction levels being 61 level and 63 level, while development and engineering infrastructure is being put in place for future production from the Block 5 sublevel cave (SLC). A schematic diagram illustrating the mining block layout is provided in Figure 1, with the tonnage production profile for the life of mine shown in Figure 2. Production from underground will ramp up from 3.0 Mt in 2016 to 3.5 Mt in 2019. The current mine plan, which includes the main Block 5 block cave below the SLC, extends to 2030.

The mining method allows for the continuous deepening of the open pit without leaving a crown pillar or roof block to prevent the material from pit sidewall failures from mixing with the ore being mined. Remnant material from the upper mining levels will therefore progressively report to the lower mining levels for extraction, mixing as it is drawn down.

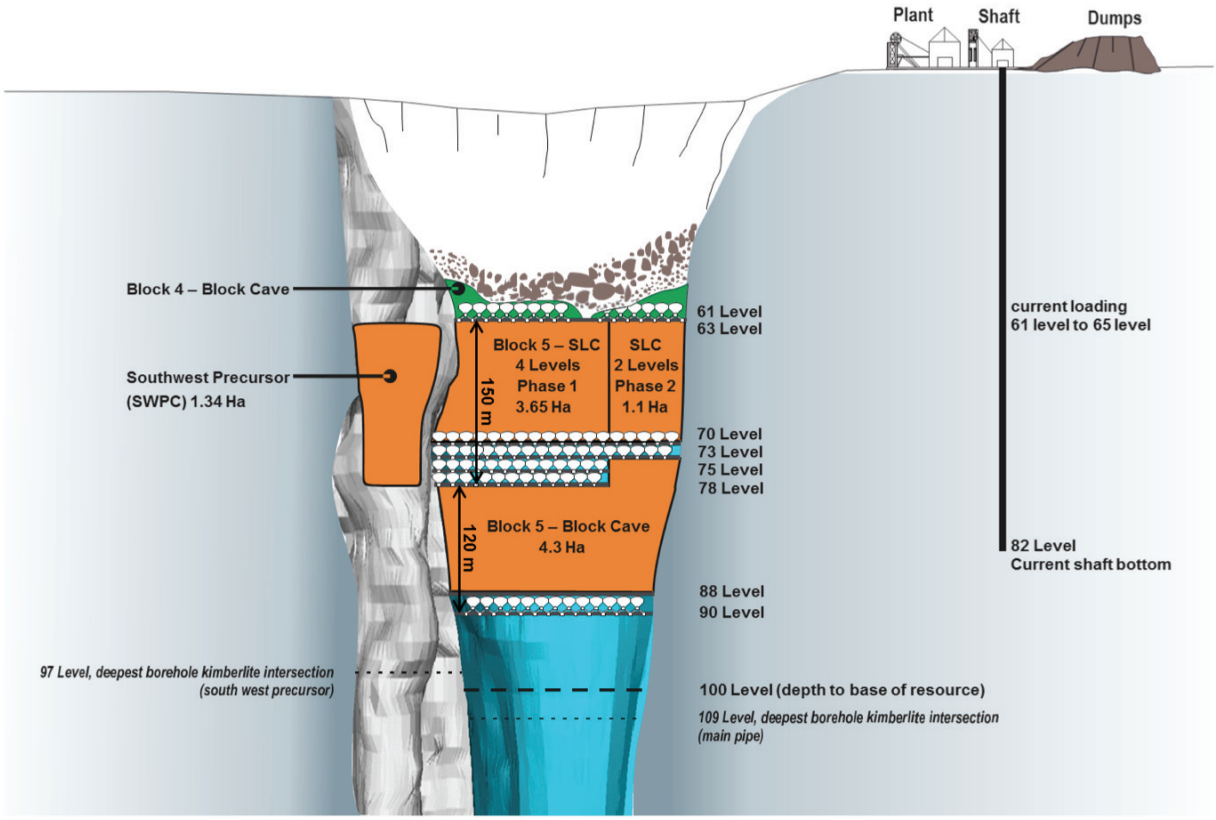


Figure 1. Schematic diagram showing layout of the mining blocks at Finsch mine.

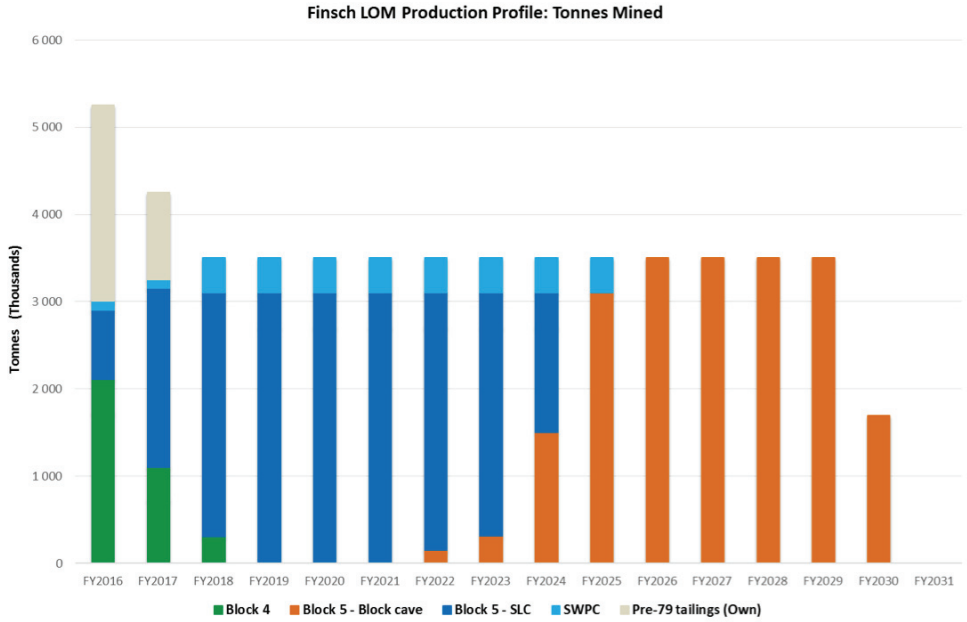


Figure 2. Life-of-mine tonnage production profile for Finsch mine.

This remnant material is typically a mix of kimberlite left behind in the previous mining levels as well as a mixture of waste rock and kimberlite that has collapsed from the unsupported sidewalls of the open pit above the production levels. The nature of the precursor bodies (especially the SWPC) is such that collapses are relatively common, resulting in the inclusion of a significant amount of SWPC kimberlite in the '*broken pot*' mix of ore in the current Block 4 cave.

RECONCILIATION PROCESS

Annual tonnage and carat reconciliations have always been important in monitoring the performance of the Block 4 block cave. However, as the block becomes depleted and approaches the end of its life an accurate estimate of the Block 4 remnant material and its composition (*i.e.* volume, spatial location, and diamond grade of ore types and waste) is even more critical in order to develop reliable short- and long-term mine plans that optimize extraction. This is also important in estimating the remnant material that will report to Block 5 in future.

In order to achieve this, a robust ore accounting process based on accurate survey reconciliation and draw control has been developed.

Survey reconciliation

The reconciliation process begins with remote surveying of the Finsch open pit to detect and quantify any sidewall failures, and to measure movement in the broken material at the base of the pit (which constitutes the top of the material being extracted from the Block 4 block cave). The volumetric differences are calculated between 3D pit scan surfaces from one production period to the next. Prior to 2006, pit scans were not done routinely but only after major failure events. Previously, pit topography measurement technology included digital photogrammetry and a scanning laser mounted on the boom of a crane to obtain a clear, uninterrupted view of the pit bottom. The crane-mounted laser scanning method has become obsolete due to the depth of the pit (approx. 530 m) limiting the view of the pit bottom, and recently airborne unmanned aerial vehicle (UAV) and gyrocopter platforms have been used to perform pit scans.

The gyrocopter is the current preferred method as it is equipped with a Lidar system, providing a point cloud from which the digital terrain model is constructed. Pit scans have been done annually,

but are currently conducted quarterly to keep an accurate tally of the small amount of material remaining in the cave.

Figure 3 shows an example of a significant pit sidewall failure observed between consecutive annual pit scans. The material that collapsed and collected on the pit floor can be seen on the right, where the two surfaces (from Year 1 and Year 2) are shown. The section on the left-hand side of Figure 3 drawn through this area highlights the differences. The pit bottom also lowered during this period due to normal mining extraction from the block cave, as can be seen from the difference between the two surfaces at lowest portion of the pit.

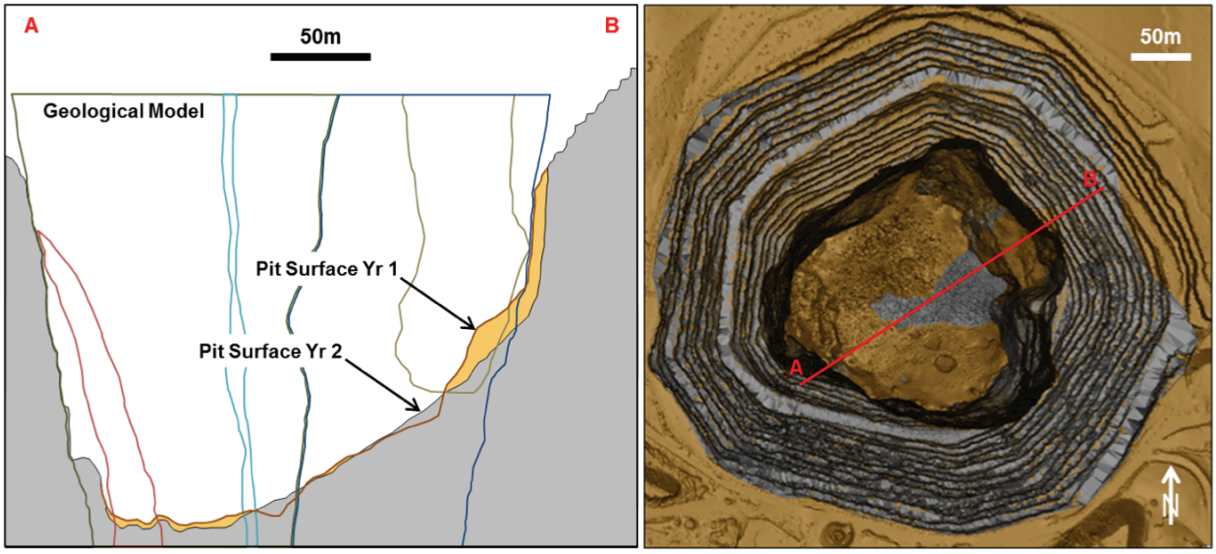


Figure 3. Pit scan surface comparison between two successive periods, illustrating pit sidewall collapse. The outlines of the simplified geological model are shown on the section on the left.

The 3D geological solid model is incorporated in the calculation in order to accurately define the volume difference per geological unit, thereby quantifying the sidewall failures hat report to the pit bottom in terms of ore and waste. This allows the relocation of sidewall collapse material from upper Resource blocks to the Block 4 broken pot on the pit bottom while accounting for the tons and carats relocated per geological facies and Resource unit.

Due to the precursor kimberlite bodies remaining in the sidewall of the pit, the grade of the failure material can vary significantly from one area of the pit bottom to another. In August 2014 the pit bottom was therefore divided into quadrants so that failure material was allocated to the quadrant into which it failed, rather than being incorporated into the block cave simulation as a single homogenous layer above the original block cave ore, as was done previously. This resulted in a significant improvement in the correlation between survey depletion results and the block cave depletion simulation results.

It is important to have this level of detail, as the precursor kimberlites, of which the SWPC is volumetrically dominant, are classified as Inferred Resources. This material, together with the waste failure material, will then mix with ore of the main pipe and report to the drawpoints in the block cave.

Draw control and draw reconciliation

Planning, scheduling, and depletion are managed through an integrated draw control system, the main components of which are the block cave simulation and scheduling package (Geovia PCBC), the draw control management system (Geovia CMS), and the production control system (Sandvik PCS). PCBC applies caving and ore mixing algorithms to the Resource block model to predict ore and waste movement through the cave based on production tonnages from each drawpoint.

The complete draw control and reconciliation process can be summarized as follows. Based on the depletion strategy and model constraints, PCBC produces a monthly production schedule. The schedule is optimized into daily draw orders by CMS and issued to production. The actual production data is recorded by PCS and includes information on any deviations from the schedule, such as drawpoint hangup *etc*. The records are fed back to CMS, which optimizes the draw order for the next day on the basis of the actual results. At month end, the tons mined through the CMS are uploaded to PCBC which depletes and updates the block cave simulation, and forecasts ore make-up (kimberlite facies and waste) and grade for each drawpoint. The integrated draw control system is illustrated in Figure 4.

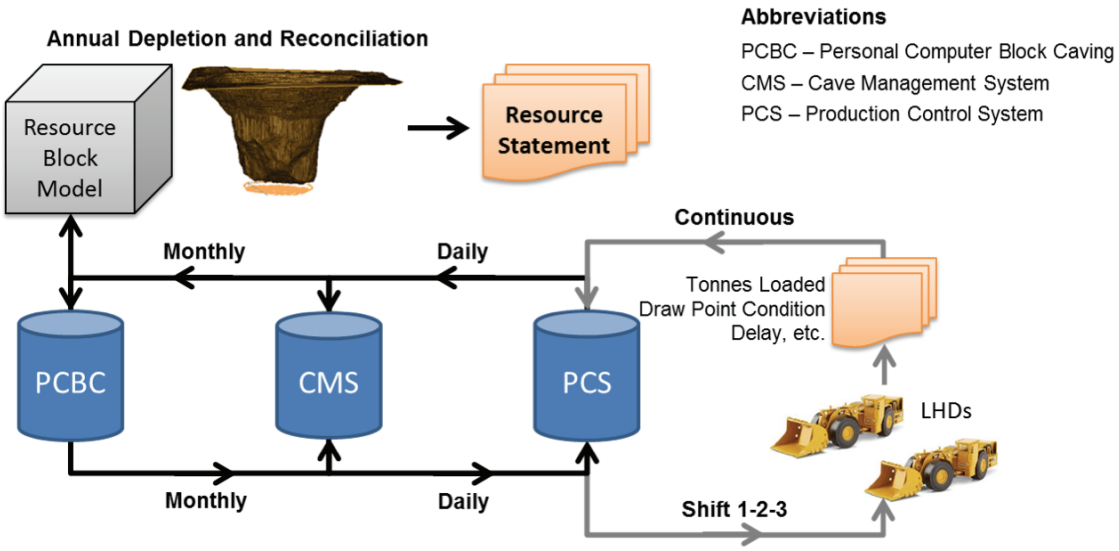


Figure 4. Schematic illustration of the integrated draw control system.

The accuracy of the PCBC block cave simulation model is verified through drawpoint sampling and observation as well as correlation with recovered grade and correlation with the survey volumetric reconciliation. The graph presented in Figure 5 shows a comparison between the dolomite waste ingress predicted by PCBC and the actual waste profile obtained from sampling at the drawpoints over the past three years. The point at which the PCBC model was recalibrated, as discussed in the following section, is also indicated.

Reconciliation of the block cave depletion model

From mid-2013 to mid-2014, a number of deviations from actual observations started to emerge in the PCBC predictions. The actual waste ingress was on average 13% less than predicted by PCBC, and congruently, the PCBC-predicted grade was trending below the recovered grade. The pit scan calculations showed that there was significantly more material remaining in the pit than was estimated by PCBC. In addition, the bottom cut-off size in the treatment plant was reduced from 1.47 mm to 1.03 mm, which required that PCBC be updated with the resource grade model at the same bottom cut-off as the treatment plant. On the basis of the abovementioned issues, the PCBC model was updated and recalibrated.

The dolomite waste profile before and after calibration of the PCBC model is shown in Figure 5, comparing the PCBC estimated waste profile with the observed waste profile obtained from drawpoint sampling.

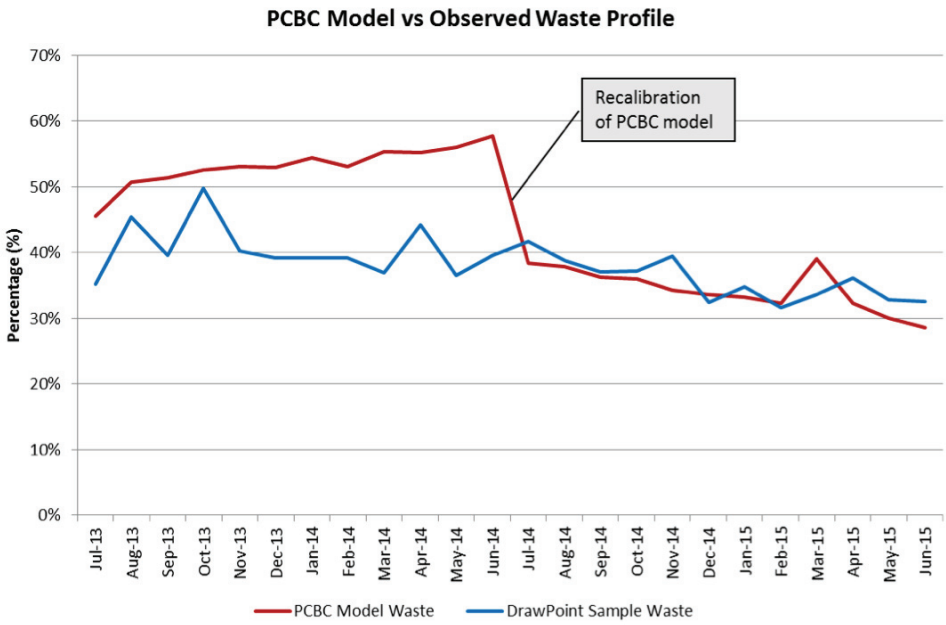


Figure 5. Comparison of the dolomite waste profile estimated by PCBC and the actual waste content from sampling.

Good correlation with the observed waste content and recovered grade was obtained once the quadrants that domained the pit sidewall failure material were implemented in the PCBC model. The post-calibration PCBC schedule matched very well with the tonnage remaining in the pit obtained from the pit scan, with good agreement between the actual and estimated pit surfaces. A comparison between the surfaces obtained from PCBC (post calibration) and the pit scan is shown on the right-hand side of Figure . The Block 4 drawpoints in PCBC are shown in the centre of the figure, coloured by quadrant, with the location of the section shown on the pit scan surface on the left-hand side of Figure 6.

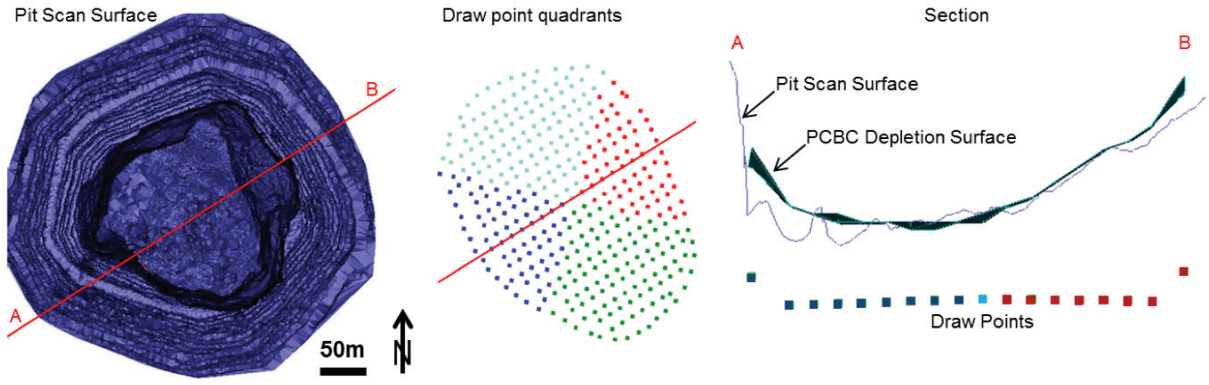


Figure 6. Section (on the right-hand side) showing a comparison of the pit scan surface and the block cave depletion surface from PCBC. The PCBC drawpoint layout, coloured by quadrant, is shown in the centre, with the location of the section indicated on the plan view of the pit scan surface on the left-hand side.

RESOURCE RECONCILIATION

Confidence in the PCBC model having been established, the PCBC schedules are used to report the Block 4 Diamond Reserves once the treatment plant recovery factors have been taken into account. Due to the addition of the pit failure material, which was not part of the original Resource, the Block 4

Reserve contains more carats and significantly more tons than the Resource, but at a lower average grade. Section 37 of the SAMREC Code allows for the Reserve to contain diluting and waste material that was not part of the original Resource.

In the process outlined in the preceding sections, the Reserve is a function of the original underlying Resource model, mining depletion, sidewall collapse additions, and the mixing of the material in the cave as simulated by PCBC. We demonstrated that it was possible to keep account of Resource depletion and relocation of material from one Resource unit to the next while honouring the original Resource classification. We also quantify the dilution material that must be added to the Reserve for accurate mine planning.

As production progresses and the block cave becomes more depleted, the remaining Reserves are progressively influenced more by the block cave simulation and calibration, and less by the original *in-situ* Resource block model. With the block cave nearing the end of its life and with the increased focus on ensuring optimal extraction, inconsistencies in the material mixing and depletion predictions made by PCBC were becoming apparent. Towards the middle of the past production year, the PCBC schedule started to close drawpoints as they were 100% depleted in the simulation model, but from the pit scans and visual observations it was clear that there was still material available in those draw columns.

Having established a procedure to adjust the PCBC topographic surface to the pit scan surface to replace the tons in the PCBC model, the real issue was to determine the grade of the material that would fill the void between the PCBC depleted surface and actual surface. At this point in the life of the cave, the spatial distribution of grade and rock type bears little resemblance to the original Resource model. It was decided that, rather than use the original Resource model, the spatial distribution of grades and rock types in the PCBC depletion model would be used, and spherical interpolation based on nearest neighbours was applied to estimate the grade of the filled material. The approach delivered satisfactory results, but the conundrum was that we have used grade results from a depletion model that was no longer completely representative of the ore movement to estimate grade into the areas of error in the same model.

RESOURCE CLASSIFICATION

The Diamond Resources at Finsch diamond mine are classified on a scorecard-based classification system developed by De Beers. The qualitative system is based on several series of questions designed to provide information on the five essential variables or models of the Resource, namely geology, grade, revenue, volume, and density. The weakness of the system is not only that it allows subjectivity in the scoring of the questions, but that it is almost completely reliant on Resource sampling and estimation information, and that it does not take cognisance of production data. This is a feature common among many of the classification systems used in the industry, as in accordance with the SAMREC Code, production data should not be used to classify a Resource, but rather be used to improve the quality and quantity of geoscientific data collected while mining. This approach to Resource classification is problematic for massive mining methods such as block caving, where the movement of ore through the cave can be predicted, but not tracked accurately.

The Resource classification scorecard for the Finsch mine underground Resources is summarized in Table I. Scores for the Block 1, 2, and 3 Precursor kimberlites are not shown as they were classified as Inferred Resources using a different method. A weighted average score between 50 and 70 results in an Inferred classification and a score of 70 to 90 is required to obtain an Indicated classification. The Finsch Main Pipe Blocks 3, 4, and 5 obtained a score of 76 during the previous production year and these blocks were therefore classified at an Indicated level of confidence.

On the basis of the reduced confidence in the grade continuity of the Block 4 remaining material due to the grade interpolation process discussed in the previous section, the classification of the Block 4

Resource was reduced from Indicated to an Inferred level of confidence in accordance with the SAMREC Guideline (Clause 67). This is due to the fact that grade continuity is implied, but cannot be verified without sampling.

Table I. Finsch Mine underground resource classification.

Finsch UG - 2014	**Score per model**						
Model	**Geology**	**Grade**	**Volume**	**Revenue**	**Density**	**Weighted average**	**Classification**
Weighting	**3**	**3**	**2**	**3**	**1**	**12**	
Block 1, 2, and 3 Precursors	-	-	-	-	-	**N/A**	Inferred
Block 1 and 2 Main Pipe	-	-	-	-	-	**N/A**	Indicated
Blocks 3, 4, and 5 Main Pipe (423–880 m)	79	73	72	91	70	**76**	Indicated
Block 6 Main Pipe (880–960 m)	47	46	47	66	43	**51**	Inferred
Block 4 Precursor	33	39	24	41	38	**35**	Inferred
Block 5 Precursor	61	47	56	41	61	**52**	Inferred
Block 6 Precursor	-	-	-	-	-	**N/A**	Deposit
2015 Revised *Block 4 Main Pipe (423–880 m)*	*79*	***45***	*72*	*91*	***48***	***70***	*Inferred*

Calibration of the PCBC depletion model also brought into question the bulk density of the broken rock in the Block 4 model, as the bulking factor required to calibrate the PCBC remaining tons to the survey remaining tons was on the verge of being unrealistic.

A further complicating factor is that the amount of failure material from the SWPC contained in the pit bottom which is scheduled by PCBC, has steadily increased to more than 15% of the remaining Block 4 tons to be mined. Removing the waste from the total tons mined increases the SWPC component to 30% of the ore tons scheduled by PCBC. The SWPC is classified at an Inferred level of confidence, so the Block 4 broken pot is actually a mixture of Indicated and Inferred Resources. This supported the decision to remove Block 4 from the Diamond Reserve.

The updated scorecard for Block 4 Main Pipe (refer to Table I) shows an overall score of 70, which is the lower limit for the Indicated category. However, the Competent Person took the decision to reduce the overall classification to an Inferred level of confidence based on the fact that the individual scores for two out of the five models (grade and density) are at an Inferred level.

We must highlight the large influence that the revenue model has on the overall score. The revenue model caries a weighting of 3, similar to the geology and grade models, and it obtained a score of 91. The revenue model is, however, based on valuations from production parcels.

Confidence Intervals

Production data can be used to verify the level of confidence in the Resource. Several authors have provided descriptions of expected accuracy and confidence limits for different Resource categories (Noppé, 2014; Parker and Dohm, 2014). Noppé (2014) recommends an accuracy of ±10–15% (at 90% confidence limits) over a production period of three months for Measured Resources. Parker and Dohm (2014) consider the nature of the type of deposit and state that a quarterly or monthly period could be used. Typically, the period of measurement should be at the same resolution as the financial budget.

There is general agreement among authors that the expected accuracy for Indicated Resources should be ±15% with 90% confidence over an annual production period. This implies that the production results for 1 in 20 years are expected to be less than 15% of the estimate, and that 1 in 20 years are expected to be 15% above the estimate.

We use the error in the Resource Carat Ratio to calculate the accuracy and 90% confidence intervals, assuming that the error is normally distributed. The Resource Carat Ratio is defined as the ratio of the actual carats recovered to the carats expected from the Resource. Strictly speaking, we use a modified Resource Carat Ratio, as the Resource carats are modified for extraction, but we do not apply any modifying factors for plant recovery. It would be incorrect to refer to the Reserve Carat Ratio in this case, as Block 4 is no longer in Reserve. The error in the (modified) Resource Carat Ratio is provided by the following equation.

$$RsCRerr = {(Actual\ ct - Resource\ ct)}/{Resource\ ct} \quad [1]$$

The upper and lower limit of the 90% confidence interval is calculated according to the statistical process provided by Parker and Dohm (2014) with the basic statistical parameters of the normal distribution shown in Figure 7.

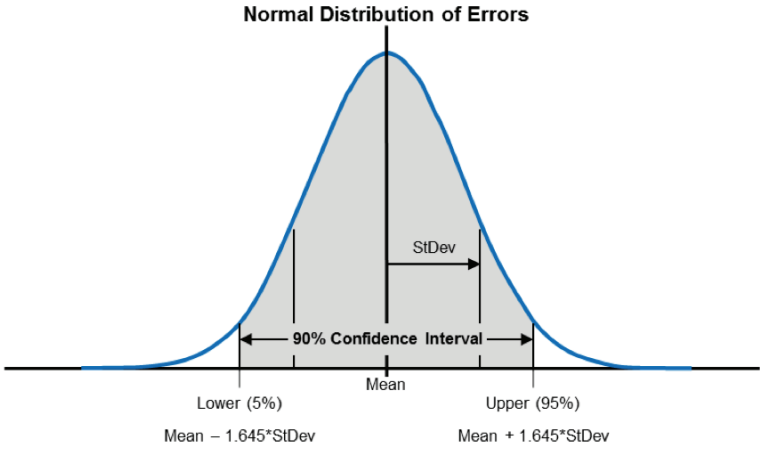


Figure 7. Illustration of the parameters of the 90% confidence interval on a normal distribution.

Figure 8 shows a plot of the calculated annual Resource Carat Ratio error over a period of more than 10 years since the start of Block 4 in 2004 until 2015. The error for the first quarter of the 2016 production year is also included. The 90% confidence interval of the data is displayed on the graph with the lower limit (5%) at -10.74 and the upper limit (95%) at 12.81.

The relative accuracy is within the limits of ±15% over the period of roughly 10 years, with the exception of the 2014 production year which exceeded the estimate by 21%. This was due to the change in bottom cut-off in the treatment plant during that year, which resulted in more carats being recovered at a lower bottom cut-off than what was estimated from the Resource (at a higher cut-off) during the period of the changeover.

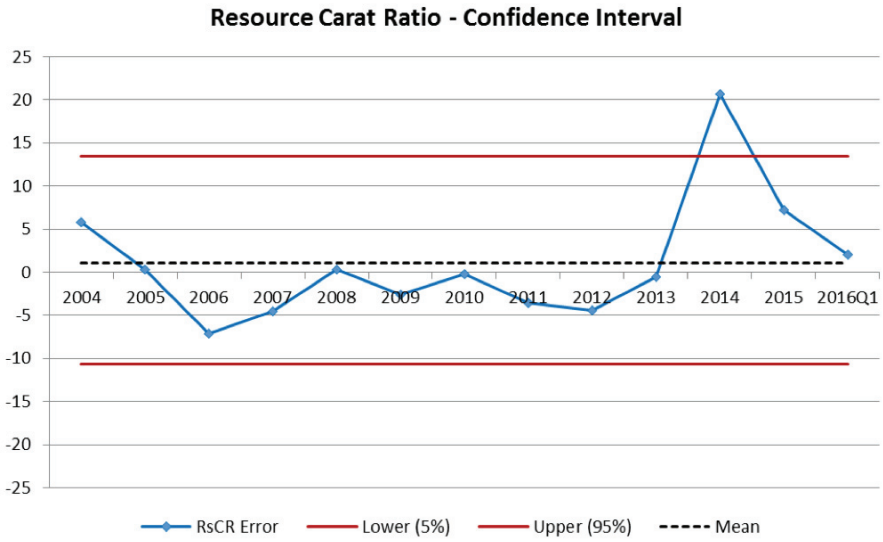


Figure 8. Plot of the annual Resource Carat Ratio error (from 2004 to 2015) with 90% confidence interval.

If we then remove the 2014 data point on the basis of the fact that it is not due to Resource performance but is an artefact of the bottom cut-off parameters, the 90% confidence interval shrinks to -7.18 (5% lower limit) and 6.58% (95% upper limit) as shown in Figure 9, which provides a plot of the corrected Resource Carat Ratio error and calculated 90% confidence interval. The relative accuracy at 90% confidence is located well within the recommended limits of ±15% for an Indicated Resource on annual production data.

The calibration of the PCBC model during 2015 brought the Resource Carat Ratio error closer to zero, implying that although the scorecard classification for the remaining Block 4 Resource has gone down, the accuracy of the predicted production information (Resource Carat Ratio) has increased.

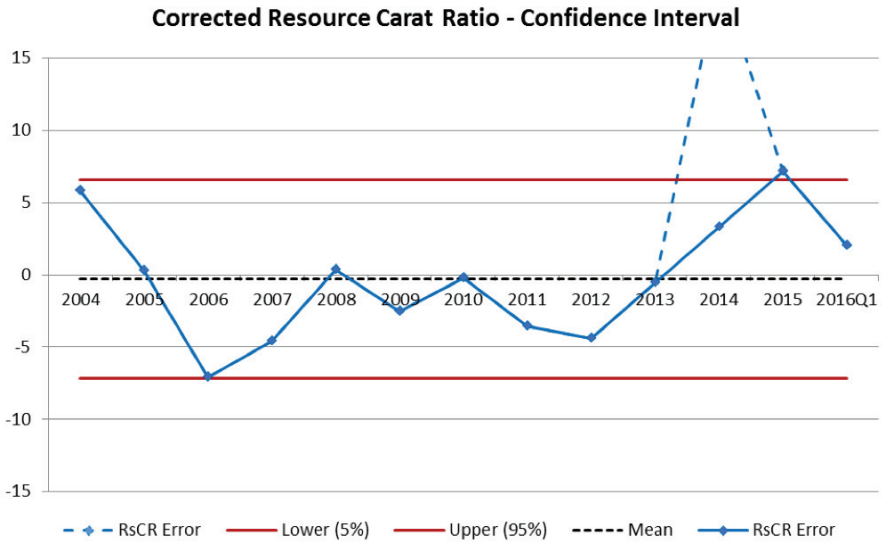


Figure 9. Corrected annual Resource Carat Ratio error (from 2004 to 2015) with 90% confidence interval. The uncorrected Resource Carat Ratio error results are shown by the dashed line.

CONCLUSION

Accurate Resource reconciliation becomes paramount when a block cave approaches the end of its life and production from the block needs to be carefully planned and scheduled to ensure optimum extraction. An accurate estimate of the remnant material in the depleted cave is required as this material will report to the new mining block below.

The scorecard system as currently employed at Finsch is a robust Resource classification system that is heavily weighted to the quality and integrity of the original Resource estimate, and the information used for the estimate. It is apparent that under certain circumstances the mining method employed during production can alter the original Resource to the extent that this scorecard system begins to lose its significance. The Finsch example is a point in question where recalibration of the PCBC depletion model has improved the predicted production grade, but caused a downgrading of the Resource classification due to the classification system applied.

Any Resource classification system should have the provision to take into account production data to verify the levels of confidence in the Resource estimate where appropriate.

REFERENCES

Ekkerd, J., Stiefenhofer, J. Field, M., and Lawless, P. (2003). Geology of Finsch Mine, Northern Cape Province, South Africa. *8th International Kimberlite Conference*, Victoria, BC, Canada, 22–27 June 2003. (Long Abstract).

Isabel, A. (2014). Finsch Diamond Mine Block 4 Calibration. Project Report No. 16602 prepared for Finsch Mine. Midrand, South Africa: Dassault Systemes South Africa.

Langenhoven, J. (2009). Note for the record: Pit Failure Reconciliation 2003 – 2009. Internal report, De Beers Consolidated Mines.

Noppé, M.A. (2014). Communicating confidence in Mineral Resources and Mineral Reserves. *Journal of the Southern African Institute of Mining and Metallurgy,* 114, 213-222.

Parker, H.M. and Dohm, C.E. (2014). Evolution of Mineral Resource classification from 1980 to 2014 and current best practice. *Finex '14 Julius Wernher Memorial Lecture*. London: Minsouth (a society of IOM[3]). www.crirsco.com/docs/H_Parker_Finex.pdf [accessed 23 Oct. 2015].

SAMREC. (2009). South African Mineral Resource Committee. The South African Code for Reporting of Exploration Results, Mineral Resources and Mineral Reserves (the SAMREC Code). 2007 Edition as amended 2009. http://www.samcode.co.za/downloads/SAMREC2009.pdf

SAMREC. (2016). Guidelines for the Reporting of Diamond Exploration Results, Diamond Resources and Diamond Reserves. The South African Mineral Resource Committee. In press.

Walraven, F. (2009). Finsch Mine – GEMS Volumetrics. Report prepared for Finsch Mine. Johannesburg: Gemcom Africa.



Anton Wolmarans

Mineral Resource Manager
Petra Diamonds SA Pty Ltd.

After completing an Honours degree in Exploration Geophysics at the University of Pretoria in 1994, I joined Anglo American and went exploring for gold and base metals in West Africa. I returned to South Africa to join the Geophysics team at the Africa Exploration division of De Beers, looking for kimberlites all over Africa, and a few other continents. With a growing interest in resource evaluation and mining, I focussed on in-mine geophysics with the Mineral Resource Management (MRM) department at De Beers Group Services. My experience broadened in MRM shifting from geophysics into geological modelling and mineral resource development, with a good measure of resource and reserve reporting. When the opportunity came to join one of De Beer's largest operations as the Mineral Resource Manager, I took up the challenge. I finally left De Beers after 16 years to join the Mineral Resource Management team at the vibrant and dynamic Petra Diamonds.

Application of the SAMREC code to the evaluation of ruby deposits

P. G. Allan

Independent Precious Stones Geologist

The recent discovery and successful exploitation of world-class ruby deposits in northern Mozambique, coupled with aggressive marketing of coloured stones, has led to an increased interest in the exploration for ruby deposits and the need for a standardised evaluation approach in line with the SAMREC Code. In particular, there is an extremely large range in ruby values between the different types of mineralisation. These extremes in value are further affected by various types of post-recovery heat treatment and glass filling to improve the colour and clarity of the rubies. This paper summarizes some of the important characteristics of the ruby occurrences of northern Mozambique that have a major influence on their economic viability.

INTRODUCTION

The evaluation of ruby deposits is broadly similar to that of diamond deposits in terms of the extreme ranges in ruby values as well as the occurrence of both primary and secondary (within the alluvial, eluvial, and colluvial environments) sources showing large variations in grade. In addition, the precious stones market has traditionally been subject to an erratic supply of gemstones from small, widely spread producers, which has further increased the fluctuations in the price per carat. However, this situation has changed rapidly over the last few years due to the discovery in 2009 of world-class ruby deposits in Mozambique, their subsequent exploration and exploitation by Montepuez Ruby Mining Lda, and the active marketing campaigns for coloured gemstones, largely conducted by Gemfields Plc.

The success of Gemfields Plc, which has auctioned over US$122 million worth of rubies since June 2014, has resulted in considerable interest in the ruby market and in particular the exploration potential for ruby in Mozambique. This paper reviews the current status of the ruby potential in Mozambique and outlines various factors that need to be addressed to ensure accurate and consistent reporting on the exploration potential and evaluation of ruby deposits in accordance with the SAMREC Code.

GEOLOGY OF THE MOZAMBICAN RUBY OCCURRENCES

Ruby deposits form in a wide variety of geological environments, and include primary igneous or metamorphic deposits and anatectic-related deposits as well as in secondary alluvial or eluvial deposits (Simonet *et al.*, 2008). Historically, most rubies were recovered from marble-hosted deposits (Burma) or secondary basalt-related deposits (Thailand). However, the recently discovered primary amphibolite-hosted deposits within the Mozambican Belt in East and Southern Africa (see Figure 1), together with their related secondary deposits, are now considered to account for the largest portion of the worldwide ruby trade. In particular, the primary amphibolite-hosted and secondary ruby deposits currently being exploited by Montepuez Ruby Mining Lda (MRM) are estimated to account for 40% of the ruby trade.

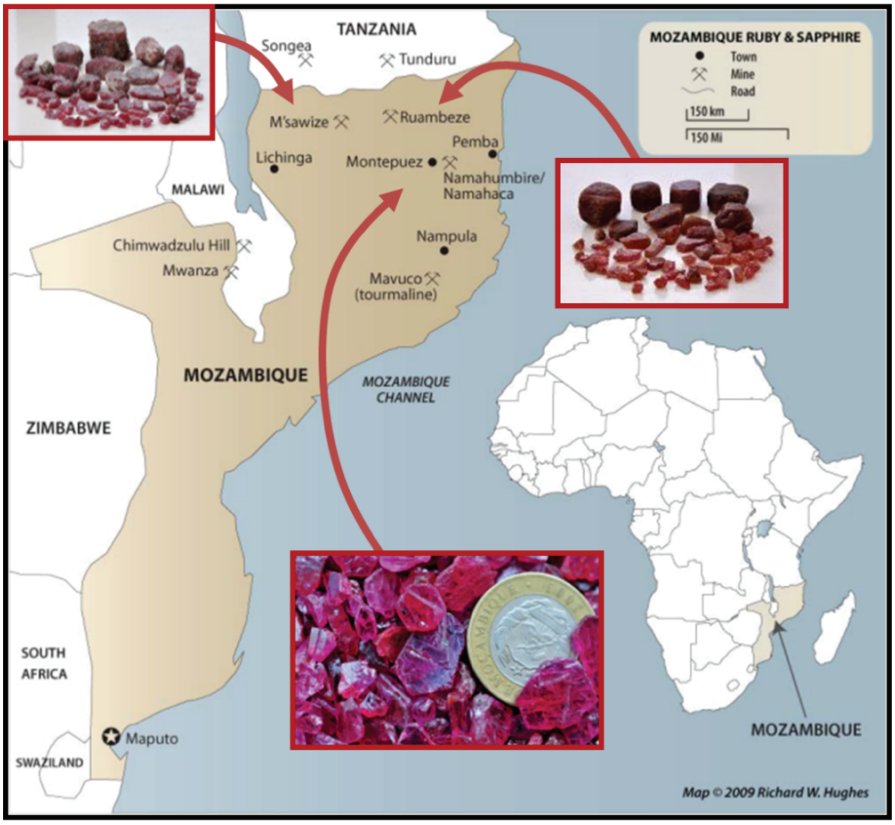


Figure 1. Known ruby occurrences in northern Mozambique (after Pardieu, 2009).

All the primary ruby deposits discovered to date in northern Mozambique are hosted by amphibolite-rich assemblages. These deposits include the following occurrences.

The Ruambeze deposit (Pardieu *et al*., 2009) is reported to be the oldest ruby deposit in Mozambique. Discovered in 1992, it produces orange to brownish dark red-coloured cabochon-grade material that is sometimes suitable for glass filling.

The M'sawize deposit (Pardieu *et al*., 2009) is located in a remote area within the Niassa National Reserve and was discovered in 2008. Both primary ruby mineralisation (associated with an amphibole and white feldspar-bearing gabbroic assemblage), as well as secondary mineralisation within eluvial soil are present.

The Montepuez (MRM) ruby deposits, in the Cabo Delgado province of northern Mozambique near the village of Namanhumbir, were discovered by local inhabitants in 2009. These deposits are located within the Montepuez Complex (see Figure 2), a wedge-shaped, thrust-bounded, terrain of strongly deformed orthogneisses (ranging from granitic to amphibolitic in composition) and paragneisses (comprising quartzites, meta-arkoses, marbles, quartz-feldspar gneisses, and biotite gneisses). The Montepuez Complex, together with surrounding younger geological complexes, comprises the southern extent of the Mozambique Belt. These complexes were juxtaposed along tectonic contacts during the late Neoproterozoic to Cambrian Pan-Africa Orogeny (Boyd *et al*., 2010).

Apart from the known occurrences mined by MRM near the village of Namanhumbir, several other ruby-mineralized localities of a similar nature are known to the southeast near Nacaca and to the northwest near Namahaka.

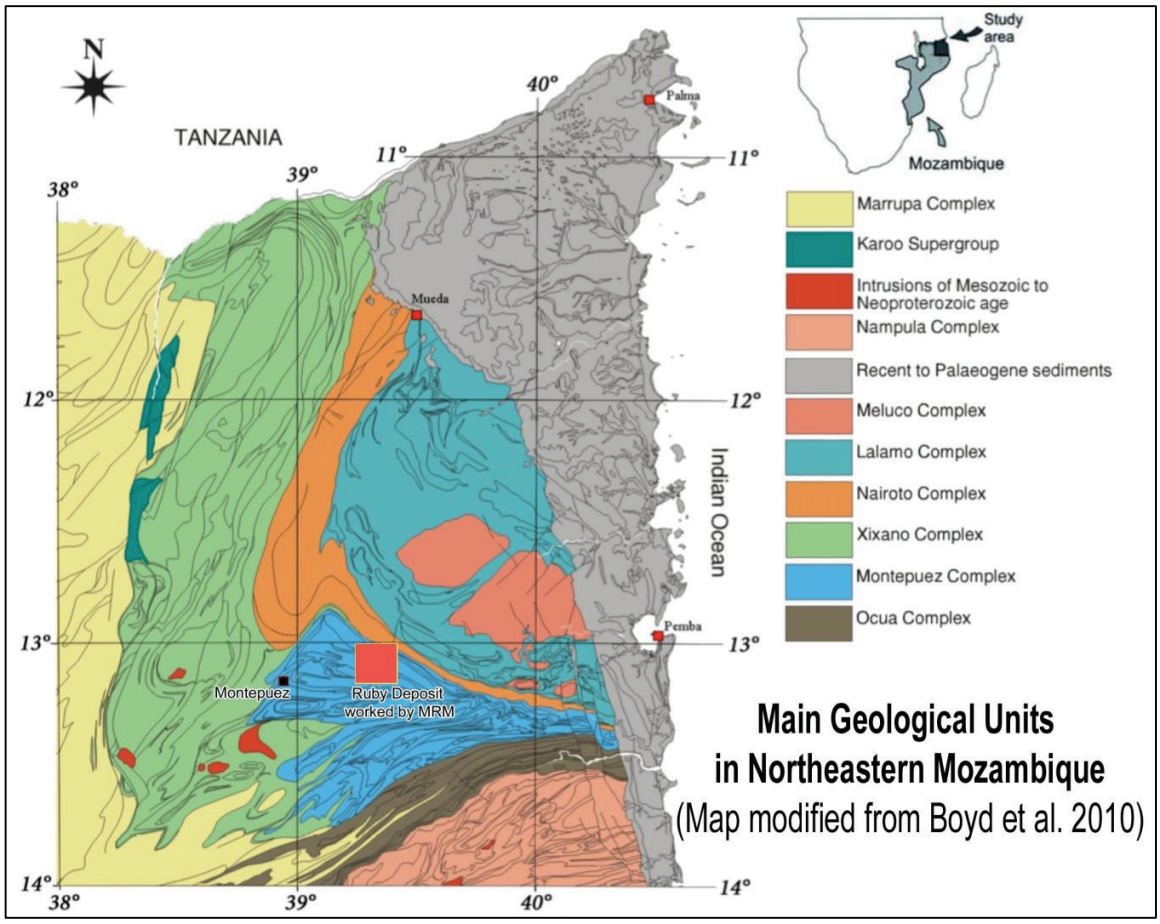


Figure 2. Regional geological map of Northern Mozambique showing the location of the MRM deposits (from Hsu et al., 2014)

Primary Ruby Mineralisation

The primary ruby mineralisation is hosted by an amphibolite unit that has been intruded by a structurally controlled stockwork of intrusive weathered white veins comprised predominantly of anorthite (see Figure 3). Ruby is a gem variety of corundum and is formed as a result of the crystallization of corundum from intrusive aluminium-rich veins in the presence of amphibolite. The amphibolite is the source of the chromium that is responsible for the red ruby colour (see Figure 4). Raman spectroscopy conducted by the GIA in Thailand has confirmed the green amphibole as pargasite and the feldspar as anorthite (Pardieu *et al.*, 2013).

Secondary Ruby Mineralisation

In contrast to the primary mineralisation, the secondary mineralisation is hosted by alluvial and eluvial gravel horizons forming discontinuous lenses (see Figure 6) within the soil overburden and overlying the bedrock. These lenses are generally fairly immature, suggesting a proximal source of the ruby mineralisation. The secondary rubies are far more rounded in comparison to the tabular and euhedral stones recovered from the primary sources identified to date.



Figure 3. Primary ruby mineralisation associated with feldspar-rich veining intruding amphibolite at the MRM Deposit. Photo courtesy of V. Pardieu/GIA.



Figure 4. Close-up showing primary ruby mineralisation within the amphibolite. Photo courtesy of V. Pardieu/GIA.



Figure 5. Example of primary ruby recovered by MRM. Photo courtesy of V. Pardieu.



Figure 6. Example of ruby-mineralized gravel lens. Photo courtesy of A. Lucas/GIA.



Figure 7. Example of rubies derived from MRM's secondary deposit. Photo courtesy of V. Pardieu/GIA

Ruby Chemistry

The chemistry of the Montepuez rubies shows similarities to the amphibolite-hosted rubies from deposits in East Africa and Madagascar, with moderate to high iron contents. They are quite different to those rubies from either marble-type deposits (such as those from Myanmar), which are highly fluorescent with low iron contents, or basalt-related deposits (such as those from Thailand and Cambodia) known for their low fluorescence (Pardieu *et al*., 2013). This large range of iron content (see Figure 8) means that Mozambican ruby is potentially suited to a wide range of different markets (Hsu *et al*., 2014).

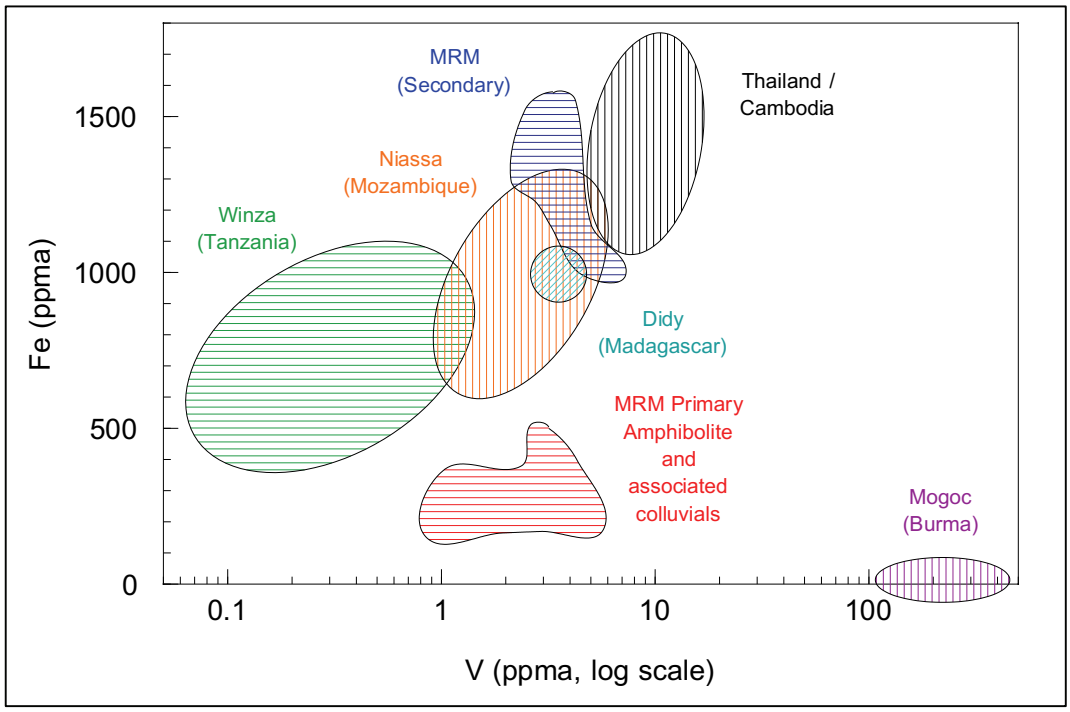


Figure 8. Characterization of rubies from different sources according to Fe and V contents, Data from Pardieu et al., 2013.

It is noteworthy that the rubies from the Montepuez area form two discrete populations – a predominantly primary population with low iron content and a predominantly secondary population with a higher iron content. One possibility is that the populations derive from similar primary sources with the more brittle low-iron/high-chromium stones breaking down preferentially in the secondary environment. The alternative explanation is that the source of much of the recently mined secondary deposits has yet to be discovered. The absence of any continuum in the chemistry between the two populations may make the latter alternative more likely and attests to the high exploration potential of the regional area.

EVALUATION OF RUBY DEPOSITS

The evaluation of ruby deposits is in many respects similar to that of diamond deposits, and as such ruby deposits are unlikely to achieve Measured Resource status. In particular, the particulate nature of gemstones with highly variable and often subjective individual physical characteristics has a significant impact on value. This is reflected in the large price variation of the material that Gemfields has auctioned to date, which ranged from US$4 to US$688 per carat. The consistent grading of ruby is thus of critical importance to any ruby project evaluation. To this end, Gemfields Plc has introduced a grading system similar to that used for emeralds (see Table I).

Table I. Ruby classification derived by Gemfields Plc (SRK, 2015)

Category	Specifications	Level 1 subdivision	Level 2 subdivision	Level 3 subdivision
Premium Ruby	Rough greater than 0.5 g in mass and of desirable shape, clarity, and red colour with no or few inclusions.	10 grades based on clarity and colour.	10 weight grades.	-
Ruby (secondary)	Rough less than 0.5 g in weight with desirable shape, clarity, and colour. Rough greater than 0.5 g in weight but either included or pink in colour.	10 grades based on clarity and colour.	10 weight grades.	-
Ruby (primary)	Rough less than 0.5 g in weight with desirable shape, clarity, and colour. Rough greater than 0.5g in weight but either included or pink in colour.	Three grades based on degree of inclusions.	6 size grades (<5.8 mm, 5.8-8 mm, 8-11 mm, 11-16 mm, 16-22 mm, +22 mm).	Three grades based on shape (flat, normal, thick).
Low Ruby	Gemstones with required pinkish red to red colour, but of translucent clarity with significant inclusions.	Three grades based on colour (red, red-pink, pink-red).	3 size grades (<8 mm, 8-16 mm, +16 mm).	-
Sapphire	Very light to light pink gemstones of variable shape and clarity.	Three grades based on clarity.	3 size grades (<8mm, 8-16 mm, +16 mm).	-
Corundum	Rough of opaque non-gem quality.	Three grades based on colour (red, red-pink, pink-red).	3 size grades (<8 mm, 8-16 mm, +16 mm).	-

The MRM deposit is also characterized by vastly different grades of the primary and secondary sources. The average grade of the primary amphibolite is 115.4 ct/ton while that of the secondary gravels varies from 0.11 to 5.64 ct/ton.

Ruby evaluation is further complicated by possible post-recovery treatments which may enhance the value significantly and are summarized in the SRK CP Report (2015) as follows:

- High-temperature heat treatment in a controlled environment, which drastically improves the red colour by removing any blue or purple hue. In addition, heat treatment may also improve the clarity as small fissures are annealed. High-temperature heat treatment is particularly suitable for gemstones in the mid- to lower priced commercial jewellery category

- Glass filling of fractures, which dramatically improves the appearance of low-quality ruby by infusing it with high-refractive-index lead glass. Glass filling is also used to smooth out the appearance of highly fractured gemstones

- Deep colour diffusion heat treatment, whereby elements such as chromium (for rubies) and titanium (for sapphires) are diffused into the gemstone lattice to enhance the colour.

MRM/Gemfields offered some heat-treated commercial-quality rough (with full disclosure) at its low-quality auction in Jaipur, India (April 2015) which was well received by the market. Any evaluation of ruby deposits thus has to address the potential market and the possibility of associated post-recovery treatment.

In addition to the treatments outlined above, the country of origin also has a profound effect on the value, particularly for smaller stones (less than 3 carats). Heat-treated Mozambican rubies are currently valued at 50% to 75% of that for Burmese heated-ruby (SRK, 2015). This disparity is likely to be reduced with a consistent supply, coupled with significant marketing of Mozambican ruby.

APPLICATION OF THE SAMREC CODE TO RUBY DEPOSIT EVALUATION

Ruby deposits bear similarities to diamond deposits in terms of their value and particulate nature, together with their occurrence in primary as well as secondary environments. Most of the SAMREC Diamond Guidelines document is thus directly applicable to ruby deposit evaluation. Table II outlines parts of the SAMREC code and summarizes their applicability to ruby deposit evaluation. Due to the extreme variation in value between different ruby populations particular attention needs to be paid to the establishment of an accurate average value (dollars per carat) for each population.

Rubies have a high specific gravity of 3.9 to 4.1 and are thus recoverable by traditional heavy-mineral extraction processes. As with diamonds, security plays a major role in every phase of the extraction process and any evaluation should thus review the security procedures applicable to the scale of the operation. These will most probably include entry and exit searches for high-risk areas, the coverage of surveillance cameras and guarding, as well as the use of glove boxes and procedures for the storage and transport of the product.

Table II. Sections of the SAMREC Code and their specific relevance to ruby mineralisation and ruby deposit evaluation.

SAMREC Code/Table	Section	Comments particularly applicable to ruby mineralisation and evaluation
10.1	Specific reporting for diamonds and gemstones	
10.2	Geological setting, deposit, mineralisation	Reporting must clearly distinguish between primary and secondary ruby mineralisation and should describe and identify the potential origin of the ruby mineralisation as far as possible.
10.3	Sampling	Sampling should be appropriate to the type of ruby mineralisation present. In cases where secondary deposits overlie primary deposits, this must be clearly stated and the types of mineralisation should be sampled and evaluated separately. Drilling techniques should be applicable to the target mineralisation. Generally, primary deposits may be delineated by core drilling while secondary deposits require large diameter drilling, auger drilling, or pitting to obtain the relevant information on gravel thicknesses. Bulk sampling is required for any further evaluation of both primary and secondary ruby mineralisation.
10.4	Bulk sampling	The primary and secondary ruby deposits identified thus far in Northern Mozambique contain significantly higher grades than that present in primary and secondary diamond deposits respectively. It must therefore be clearly stated whether grades are in carats or grams. Grade is usually expressed on a per ton basis and should be applied consistently. For evaluating secondary deposits, results may be presented as the number of stones per ton or per cube (as with alluvial diamonds).
10.5	Estimation and modelling techniques	The evaluation is broadly identical to that of diamonds for Exploration Results, Mineral Reserves, and Mineral Resources. However, particular attention should be paid to separate modelling of the grade and tonnage estimates of the various types of ruby mineralisation.
10.6	Resource / Reserve classification criteria	The evaluation is broadly identical to that of diamonds for Exploration Results, Mineral Reserves, and Mineral Resources. However, particular attention should be paid to establishing an accurate dollar per carat value for each ruby populations present. Attention should also be paid to whether or not the ruby value may be significantly affected by heat treatment, glass filling, or element diffusion.

Further attention needs to be paid to possible post-recovery heat treatment and/or glass filling of the gemstones, which may add significant value, particularly for lower quality material. A study of the applicable market for each ruby population present within a deposit is thus essential for the successful economic evaluation of ruby deposits.

The above uncertainties in the dollars per carat value imply that most Mineral Resource estimates for ruby deposits, particularly those of secondary origin, may not progress beyond the Inferred Resource category without extensive bulk sampling combined with product sales and possible further processing of the gemstones. While the grade of the deposit, particularly that of a primary deposit,

may be accurately known the same cannot be said of the dollars per carat value. Given the extreme variation in ruby value it is not easy to specify a total carat recovery from which a reliable dollars per carat value may be estimated. It is thus essential to obtain a realistic estimate of the probable market value of individual ruby populations before upgrading a deposit to an Indicated Mineral Resource.

ACKNOWLEDGEMENTS

Gemfields Plc is thanked for their support in including the ruby classification for rough material which they have pioneered over the last few years and applied most successfully in their ruby auctions, as well as for their review and support of this paper. The valuable contributions of the reviewers of the manuscript are much appreciated.

REFERENCES

Boyd, R., Nordgulen, Ø., Thomas, R.J., Bingen, B., Bjerkgard, T., Grenne, T., Henderson, I., Melezhik, V.A., Often, M., Sandstad, J.S., Solli, A., Tveten, E., Viola, G., Key, R.M., Smith, R.A., Gonzalez, E., Hollick, L.J., Jacobs, J., Jamal, D., Motuza, G., Bauer, W., Daudi, E., Fetio, P., Manhica, V., Moniz, A., and Rosse, D. (2010). The geology and geochemistry of the East African Orogen in North-eastern Mozambique. *South African Journal of Geology,* 113 (1), 87 – 129.

Hsu, T., H., Lucas, A., and Pardieu, V. (2014). Mozambique: a ruby discovery for the 21st century. Gemological Institute of America. http://www.gia.edu/gia-news-research-mozambique-expedition-ruby-discovery-new-millennium

Pardieu, V., Jacquat, S, Senoble, J.B., Bryl, B.P., Hughes, R.W., and Smith, M. (2009). Expedition report to the ruby mining sites in Northern Mozambique (Niassa and Cabo Delgado provinces). Gemological Institute of America. http:// www.giathai.net/pdf/ Fieldtrip_to_Mozambique_December_16_2009.pdf

Pardieu, V., Sangsawong, S., Muyal, J., Chauviré, B., Massi, L., and Sturman, N. (2013). Rubies from the Montepuez area (Mozambique). Gemological Institute of America. http//www.giathai.net/wp-content/uploads/2015/02/GIA_Ruby_Montepuez_Mozambique.pdf

SRK Consulting (UK) Limited. (2015). A competent persons report on the Montepuez Ruby Project, Mozambique. https://xmbl.files.wordpress.com/2015/07/u6362_mrm_cpr_mining_report_final_v3a_clean.pdf



Paul Guthrie Allan

Independent Precious Stones Geologist

Paul Allan (BSc Hons., Dip. Bus. M.) has over 25 years' experience in multi commodity geology, predominantly precious stones exploration and evaluation. Initial experience began with Anglo American Research Laboratory / Debeers in kimberlite mineral chemistry and petrography as well as Wits type Gold Research. Following this Paul contracted to several diamond related ventures throughout Southern Africa (including MPH Botswana) while also lecturing in Geology at the University of Fort Hare. In 2001 Paul again took up employment in the industrial sector with SouthernEra (a Canadian Junior Diamond and platinum company) where he became the Regional Exploration Manager for Southern Africa in 2005.

In 2008 Paul joined Firestone Diamonds Botswana as Project Geologist (Modeling) and as Senior Project Geologist which included responsibility for the geological exploration and evaluation conducted on Firestone Diamonds projects in Botswana and Lesotho. From 2012 to 2014 Paul joined Gemfields as Project Geologist responsible for the geology of their Montepuez Ruby Project in Mozambique. Paul is currently self-employed with various diamond (including Lace Diamond Mining) and precious stone clients (Mozambican Ruby) throughout Southern Africa.

Key factors influencing the success of the Orapa Resource Extension Project with reference to SAMREC Table 1

T.V. Rowlands[1] and B.M. Letsatle[2]

[1]De Beers Group Services (Pty) Ltd, Johannesburg, South Africa
[2]Debswana Diamond Company (Pty) Ltd, Orapa, Botswana

The Orapa Resource Extension Project (OREP) began in 2006, and culminated in the Resource model update that was completed at the end of 2014. The project was informed by conceptual studies for the Cut 3 life extension, ensuring a sound strategic fit with the overall Debswana growth strategy. The development of clear sampling objectives, supported by careful project planning, and the establishment of detailed project governance mechanisms, were critical to the success of the project. The diligence that was applied in these three areas played a key role in the successful execution of the sampling phase. The objective of this paper is to provide readers with insight into these elements of a Resource extension project. Furthermore, the discussion of sampling provides examples of the level of work and measurement that can be carried out to satisfy the requirements of a Competent Person's report, as summarized in SAMREC Table 1, sections 11.2, 11.3, and 11.6. Reference is made to these sections, and their sub-sections, throughout the paper. Drilling and resource estimation are not covered in this paper.

INTRODUCTION

Orapa Mine is located within the Orapa kimberlite cluster in northern-central Botswana, approximately 240 km west of Francistown (Figure 1).

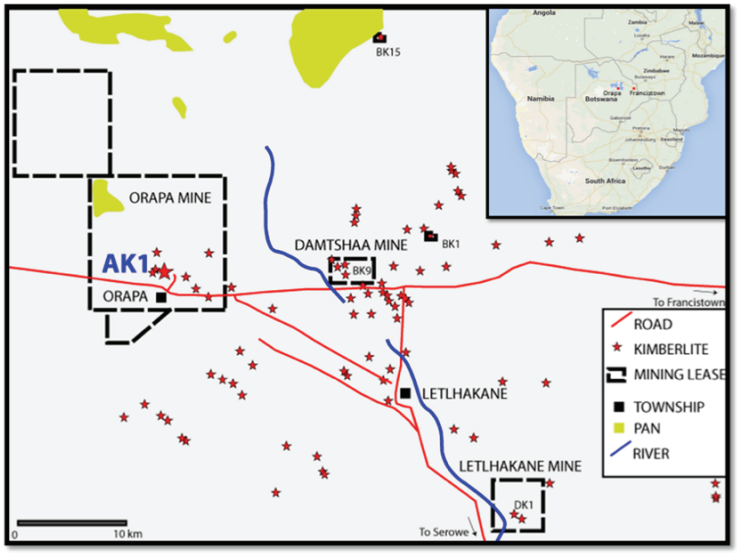


Figure 1. Location of the Orapa kimberlite cluster.

The Orapa AK1 kimberlite, dated at 93 ± 1 Ma, was emplaced into Karoo Supergroup basalts, sandstones, and mudstones that unconformably overlie Archaean amphibolite-bearing granite-gneiss and tonalite. The kimberlite consists of two pipes coalescing at the surface. Each of these pipes represents a discrete batch of kimberlite magma, which has resulted in a variation in the nature of the diamonds found within each pipe. The North Pipe was emplaced first, and is dominated by primary pyroclastic deposits (Field *et al*., 1997). This was followed by emplacement of the South Pipe, which is dominated by a combination of mass flow and primary pyroclastic deposits. Talus cones, alluvial fans, grain flow deposits, and mass debris flow events introduced significant volumes of volcaniclastic and sedimentary material into the crater, creating a complex internal stratigraphy. Isolated pyroclastic episodes occurred late in the life of the South Pipe (Gernon *et al.*, 2009) (Figure 2).

A number of Resource extension projects have been conducted over the life of Orapa Mine. The first major project was conducted from 1967 and 1980 in order to define the volume and internal geology from core drilling to a depth of 125 m below ground level (mbgl). Pitting and trenching also took place during this period, and an Indicated Resource was established to a depth of 30 mbgl. From 1982 to 1993 a cable tool programme was carried out to sample for macrodiamond grade and to extend the Indicated Resource to 265 mbgl. The next programme was a core drilling project aimed at increasing confidence in the volume and internal geology of the Resource to a depth of 600 mbgl. This programme took place between 1993 and 1997, when the first digital three-dimensional geological model was produced.

The Orapa Resource Extension Project (OREP) began in 2006, and culminated in the Resource model update that was completed at the end of 2014. The project was informed by conceptual studies for the Cut 3 life extension, ensuring a sound strategic fit with the overall Debswana growth strategy. Debswana has developed a comprehensive long-term total extraction plan for all of its assets. All projects in Debswana are justified within the context of this plan, and all undergo a techno-economic assessment that ensures a commercially sound, strategic, and risk-based fit for each project. In addition, project management principles and methodologies are strictly adhered to, in order to ensure that maximum value is realized.

Although there are many areas that contributed to the success of OREP, the authors have concentrated on three key factors that, in their opinion, contributed most to the success of the project. These factors, all within an overall project management framework, were the development of clear sampling objectives, careful project planning, and the establishment of a detailed project governance framework. The diligence applied in these three areas played a key role in the successful execution of the sampling phase. In addition, and since sampling is the crux of any Resource extension project, the authors discuss aspects of this sampling to demonstrate the level of work and measurement that can be carried out to satisfy the requirements of SAMREC Table 1, sub-sections 11.2, 11.3, and 11.6, within the diamond section. These sub-sections refer to Sampling, Bulk Sampling and/or Trial Mining, and Audits/Reviews, respectively. Drilling and resource estimation are not covered in this paper.

SAMPLING OBJECTIVES

Resource extension projects are undertaken as a basis on which to enhance geological understanding, in order to ensure that the required levels of confidence to support and de-risk the business case, are achieved. Before any sampling is begun, it is essential that the objectives of the programme be clearly defined.

A Diamond Resource model can be viewed as consisting of five key elements. The objectives of the programme should be aimed at establishing the appropriate level of confidence in the geology, volume, grade, revenue, and density elements of the Resource model, in order to support the business case requirements for the relevant project phases. In establishing the target levels of confidence for each variable, factors such as overall business risk tolerance, likely mining options, and likely sensitivities of the mining solution should be considered. For example, the success of one mining

project may be particularly sensitive to grade, while another may be more sensitive to the volume or geometry of the orebody. Furthermore, the objectives of the programme would usually include assessment of geometallurgical, hydrogeological, and geotechnical variables. It is, therefore, recommended that the objectives of the Resource extension project be agreed in collaboration with techno-economics, mining, ore processing, and other relevant technical disciplines. This approach will optimize the integration and maximize the value of the programme, and will also reduce the probability of costly scope changes and time overruns later in the project.

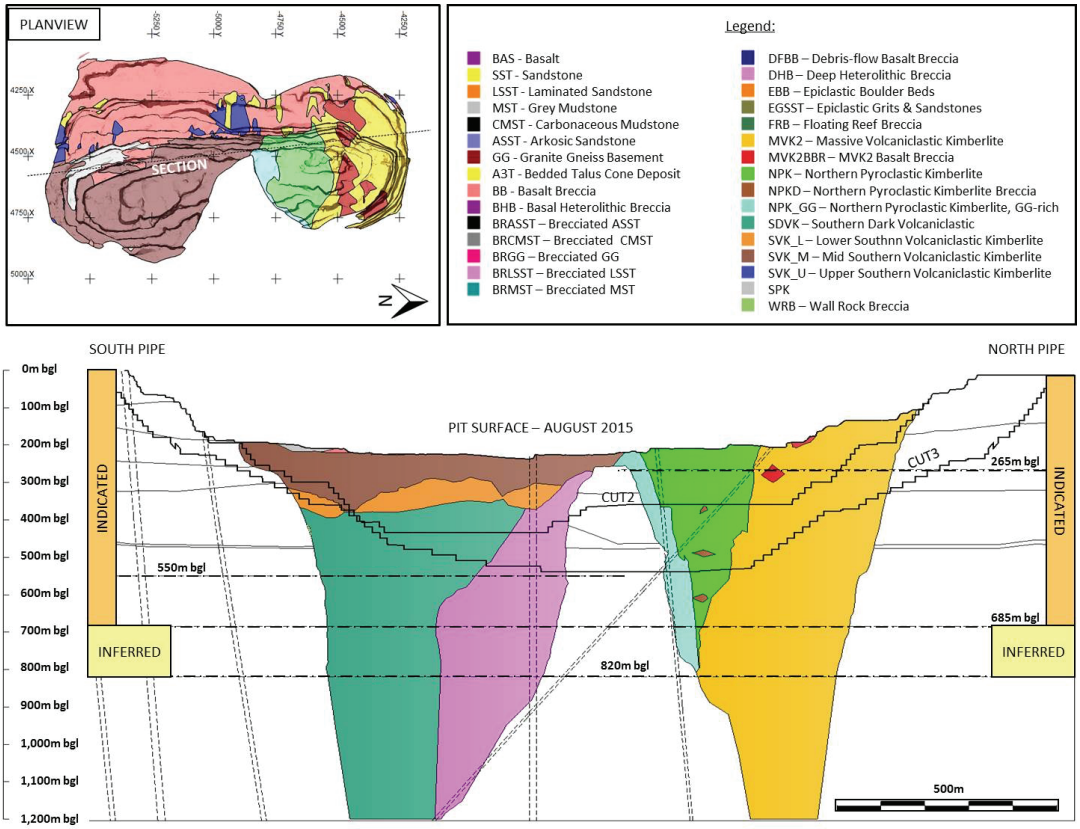


Figure 2. Cross-section through the Orapa AK1 three-dimensional resource model, showing levels of confidence relative to Cuts 2 and 3. The three-dimensional model, in both the cross-section and the plan view, is cut by the August 2015 pit surface. Geological units that are not shown do not occur on the section line and are not exposed by this pit surface.

In the case of OREP, the key objective of the project was to raise the classification of the Resource between 265 mbgl and 685 mbgl from Inferred to Indicated to support the Cut 3 life extension project (Figure 2). The scope included establishing the geometallurgical characteristics of the Resource, as well as the geotechnical characteristics of both the kimberlite and the country rock. The project was divided into two phases. Phase 1 consisted of a core drilling programme aimed at establishing an Indicated level of confidence in the geology, volume, and density components of the Resource model. The objective of Phase 2 was to raise the confidence in the grade and revenue variables to an Indicated level. This was achieved through a combination of core and large-diameter drilling, providing for microdiamond and macrodiamond sampling, respectively. Importantly, the design of Phase 2 sampling was based on the understanding of the geology that was established in Phase 1. This allowed for geostatistical and cost optimization of the Phase 2 programme. Further geometallurgical, country rock, and geotechnical data was added in Phase 2, based on the understanding of these models from the results of the Phase 1 programme.

Following the successful execution of the OREP drilling, sampling, and resource estimation, both the North and South pipes were classified as Indicated to a depth of 685 mbgl early in 2015. Inferred

resources were added between 685 mbgl and 820 mbgl. Changes in the geological model brought about substantial change in the Orapa Resource estimate, emphasizing the importance of basing the sampling and resource estimation on a sound geological model. Geometallurgical, country rock, and geotechnical models were also established to the required level of confidence.

The conceptual Cut 3 pit shell (Figure 2) extends to a depth of approximately 550 mbgl. Thus, Indicated Resources were established well beyond the life of Cut 3. The next phase of drilling and sampling is currently in the early stages of planning, and will be designed to probe the pipe at depth in order to establish the scope of further Resource extension work to support likely post-Cut 3 mining options.

PROJECT PLANNING

Planning of the OREP project was focused on organizing resources and interlinking activities, with a view to defining a clear suite of project management objectives, processes, and performance measures. OREP was supported by a robust Project Charter linked to an expansion project with a positive business case. This Project Charter included a description of the project context, objectives, scope, deliverables, budget, schedule and milestones, governance and organization, communication plan, key factors required for success, risks, and constraints and assumptions. Once the Project Charter was authorized, the project manager was tasked with executing the project. The Project Execution Plan (PEP) was then carefully developed, and served as a logical and detailed extension of the high-level Project Charter into a workable execution framework. The PEP is the physical collection of documents that define how the project will be executed, monitored, controlled, and closed. It is important that the planning of all technical aspects of the project is comprehensively documented in the PEP.

It is critical that relevant disciplines and stakeholders review and provide input to the PEP in order to ensure that it is robust. The diligence applied at this stage of the programme will have an impact throughout the life of the project. Further, all activities should be designed to achieve the requirements of a company standard for the development of mining projects, which will allow for structured review and release of the project studies through the desktop to implementation stage gates. Debswana progresses projects in accordance with the De Beers Asset Development Standard, which has strong links with both Table 1 and Table 2 of the SAMREC Code, and is also consistent with the De Beers Mineral Resource Management guidelines. The target level of confidence in the Resource should be commensurate with the level of technical study that is specified in the standard. SAMREC Table 2 provides a benchmark for the relationship between Mineral Resource and Mineral Reserve confidence and the level of technical study.

The project management processes to be applied should be appropriate to the project life-cycle. For example, the project management processes to be used at Feasibility Study level will differ from those applied at the level of a desktop study. Internal company standards should guide selection and implementation of, for example, cost and time management processes. Each process should be accompanied by a description of the tools and techniques to be applied. Cost control tools, for example, should be the same as those used in the other disciplines within the overall study. For example, the cost templates should be the same for the Resource extension component of the overall study as for the engineering component. This would allow for roll-up and analysis of costs at an overall study level. Other examples would include the risk, change control, and nonconformance management processes. The integrity of project performance baselines, and how they will be used, is another key aspect requiring planning ahead of execution.

PROJECT GOVERNANCE

As part of the overall governance framework within the PEP, it is important that a detailed governance plan for all of the technical activities within the resource extension project be established.

The technical governance component should consist of relevant governance documentation (policies, procedures, standards, checklists, and templates) used to manage execution of technical activities, and a quality assurance programme set up to ensure compliance with procedures and standards. Furthermore, a Steering Committee should be established as defined in the Project Charter. This committee, which should consist of members from different disciplines, provides support and guidance to the owner's team, and serves as the forum in which all major decisions and scope changes are ratified. The owner's team is the core team representing the client organization.

A significant part of the OREP success was due to the implementation of a very sound quality management system. The quality management system for OREP was centred on quality planning, quality assurance and quality control, each of which is described briefly below:

Quality Planning
The purpose of quality planning was to anticipate any circumstances likely to affect the deliverables of the project, and to establish guidelines for dealing with these circumstances. Quality planning was conducted for all activities that were identified as being critical to achieving project deliverables. All of the quality standards that were relevant to the critical tasks in OREP were identified as part of this planning process. For example, the accurate logging of core was identified as being critical to the success of the project. A circumstance that could compromise consistency and accuracy of logging could be the rotation of core loggers, and hence it was important to ensure the proper management of standards and consistency within the core logging team.

Quality Assurance
A quality assurance programme of work was implemented in order to obtain relevant data for determination of conformance or nonconformance with established standards and baselines. This programme of work should include the use of external parties for key processes, as appropriate, in order to provide an independent perspective. The quality assurance programme should be applicable across all aspects of the project.

Quality Control
This refers to the implementation of short-interval monitoring processes designed to ensure that the desired quality was achieved across all aspects of the project requiring control. For example, immediate 'check-logging' was conducted by a different member of the core logging team once each hole was complete. The particle size distribution of the large-diameter drill chips was, for example, continuously monitored as an indicator of drilling performance. Quality control was managed directly by the OREP owner's team. The focus was on early identification of nonconformance and rapid correction of inappropriate practices.

The quality assurance component of OREP consisted of a framework of activities and deliverables associated with both levels of review and time intervals between reviews. The principle in the implementation of the framework was to prevent deviation from the objectives and standards, through the appropriate and timeous execution of audits, combined with the measurement of performance. For example, the quality of core logging was reviewed on a continuous, structured basis by peers working on the project, at least twice per year by a De Beers Group specialist, and at least once per year by an external specialist. The development of the kimberlite emplacement model was regularly reviewed, particularly in the period prior to updating the three-dimensional digital model. Similarly, the development of the three-dimensional geological model and the resource estimate was punctuated by regular interim reviews, so as to ensure the appropriate level of independent expert influence on the final product. All final deliverables, including the data-set (final database and original data), were appropriately assured both internally and externally. It is critical that an element on which another depends is assured before the dependent process commences. Using the example above, assurance on the geological logging must be complete before the kimberlite emplacement model is documented, and assurance of the kimberlite emplacement model must be complete before commencement of the three-dimensional modelling process. Apart from improving the quality of the

final product, this diligence will ensure limited re-work, and hence support adherence to the project schedule and cost.

Quality control measures were applied to all key processes in which data was collected, measured, and analysed, including the monitoring and calibration of measuring devices (*e.g.* dense medium separation unit, point load machine, weighing scales). A nonconformance log was kept for all processes and corrective action managed in a structured way. All changes were managed in accordance with a change control procedure, and a decision log was also maintained.

Section 11.6 of SAMREC Table 1 describes the Audit and Review requirements for a Competent Person's (CP's) report. Sub-sections vii and x stipulate that QA/QC processes and cross-validation be discussed.

OREP EXAMPLES OF SAMPLING PROCESSES

The primary body of work undertaken in any Resource extension project is the collection of data through sampling processes. It is this data that ultimately informs the update of models. A clear understanding of these processes is therefore critical to success. This section aims to provide some insight into the sampling that was carried out as part of the OREP. These descriptions are not intended to be exhaustive, nor to serve as procedures for the collection of samples, but rather to demonstrate the level of work and measurement that can be carried out to satisfy the guidelines set out in SAMREC Table 1, sub-sections 11.2, 11.3, and 11.6.

The OREP Phase 1 and Phase 2 programmes were optimized in order to achieve Indicated status in each element of the Resource model. The Phase 1 core drilling programme was optimized visually to establish an Indicated level of confidence in the volume of the pipe, internal geological boundaries, and the density variable. The Phase 2 core drilling programme was optimized to establish an Indicated level of confidence in the grade variable. This was done using geostatistical simulation where different sampling grids were tested. The LDD programme was designed primarily for estimation of the revenue variable at depth in the major units and to support the modelling of microdiamond data. It was confirmed that the distribution of holes in the two core-drilling programmes would provide suitable spatial coverage for the collection of samples for ore dressing studies and geotechnical parameters. Core photography and detailed geological, geotechnical, and dilution logging was completed and reviewed before the core was sampled.

Sections 11.2 and 11.3 of SAMREC Table 1 stipulate the requirements for description of sampling processes and results in the CP's report.

Core Sampling

Microdiamond Sampling

The OREP microdiamond (MiDa) sampling protocol was developed as part of the optimization study, complemented by internal De Beers MiDa sampling procedures. The Phase 2 core holes were drilled vertically on a 50 × 50 m grid, and 20 kg samples were collected every 30 m down the hole. With 15 m bench heights, this meant that a sample was collected from every second bench per hole, staggered vertically across the pipe. No sampling across geological contacts was undertaken. Dilution was estimated along four scan lines on each core sample before the sample was collected and packaged. Section 11.2 of SAMREC Table 1, sub-sections i and ii require that the sample type, as well as the size, distribution, and representivity of the samples be discussed in the CP's report.

Samples were consigned to the De Beers Kimberley Micro Diamond Laboratory (KMDL) and to the Saskatchewan Research Council (SRC) due to limited KMDL capacity. All data collected prior to sampling, and all results from the laboratories, were captured in a secure SQL database. Both the KMDL and the SRC are accredited laboratories with comprehensive QA/QC processes. Importantly,

QA/QC processes formed part of the contract with the laboratories, and adherence to these processes was reviewed at an appropriate level on-site by the OREP manager. Detailed audit reports and spiking reports were also produced along with a report on the configuration of the master results database, which combined information generated at the KMDL and the SRC. Section 11.2 of SAMREC Table 1, sub-sections iii to vii requires that the sample facility, treatment rate, size reduction, sample processes, and accreditation, among other parameters, be discussed in the CP's report.

Specific Gravity Sampling

There are various methods for the measurement of density. De Beers has standardized on the 'calliper method' for measuring the density of core samples, as this method has tended to be the most accurate. Density is mass divided by volume, and the volume of a cylinder is equal to $\pi r^2 h$, where h is the length of the cylinder and r is its radius. Thus, the mass, length, and diameter of the core required consistent measurement as part of the OREP programme. Both wet (*in-situ*) and dry density were measured. Wet density was measured immediately after cutting the core and dry density was measured after core was dried in an oven at 105°C for a period of 12 hours (overnight). Three samples were collected per bench, at 5 m intervals. Each sample, cut from the core at right angles with a specialized core splitter, was approximately 20 cm in length. Density samples were taken at predetermined intervals, with allowance for the sample to be taken ±50 cm on either side of the interval in the case of damaged core. Three length and three diameter measurements were taken using Vernier callipers, and the mean was calculated automatically within the sampling database. The mass was determined to the nearest 0.1 g, using a measuring balance. Approximately 90% of the samples informed the density estimate, the other 10% having been damaged, thereby compromising sample integrity. Outlier analysis was undertaken on the data-set and basic statistics were used to provide a sanity check.

Grade in kimberlite pipes is typically estimated in carats per cubic metre. The units must then be converted to carats per hundred tons (cpht), which is required for mine planning, and is used for the internal and public reporting of Diamond Resources and Diamond Reserves. For this reason, is it critical that the density estimate that is used in this conversion is estimated at an appropriate level of confidence. The density sampling method should be described as required in Section 11.2 of SAMREC Table 1, sub-sections i and ii. Section 11.4, subsections i, ii, vi, vii, and viii provide guidelines as to how the density data should be treated for resource estimation.

Geotechnical Sampling

Geotechnical sampling was conducted in order to determine rock mass characteristics for the major rock types. The samples for geotechnical analysis were collected by following an internal procedure, and submitted to a specialist laboratory for analysis of the following parameters: uniaxial compressive strength (elastic modulus and Poisson's ratio); triaxial compressive strength test (elastic modulus and Poisson's ratio); base friction angle (based on a direct shear test); Slake durability index test; Brazilian tensile strength. All tests were conducted according to the International Society for Rock Mechanics (ISRM) suggested methods.

Although typically executed as part of a Resource extension project, geotechnical parameters are required for mine design purposes. Thus SAMREC Table 1 Section 11.2, which focuses on the requirements for Resource development, does not require a discussion of geotechnical sampling. However, as part of a CP's report, which includes description of the development of a mine design, mine plan, and Mineral Reserve, the geotechnical considerations will require discussion under Section 5.2, sub-section ii. Section 11.2, sub-section i allows for the introduction of all sample types and sample purposes in the CP's report, and the appropriate descriptions should be carried through the subsequent sections. For example, the size, distribution, and representivity of the geotechnical samples should be discussed under Section 11.2, sub-section ii.

Geochemical Sampling

Representative samples from the kimberlite units were collected for groundmass spinel and whole rock geochemical analysis as well as for heavy mineral analysis. Whole rock geochemistry samples

from the country rock lithologies were also collected in order to understand the impact of these lithologies on the geochemical signatures observed for each kimberlite lithology. Analysis of the chemistry provides insights into the mantle conditions in which the diamonds were formed, and the relationship between the phases of volcanism. The conclusions drawn support the development of the emplacement model, which is a critical precursor to the development of a geologically sound three-dimensional geological (volume) model. The quality of this model is critical as it forms the basis for the resource estimation. Discussion of this sampling in the CP's report falls under Section 11.2 of SAMREC Table 1, sub-sections viii to x.

Ore Dressing Studies
Ore dressing studies were conducted in order to understand the metallurgical characteristics of the ore types. This data was then used in simulations of material flow through both the existing plant and potential future plant flow sheets. Simulation results should be compared with and calibrated against results from actual treatment through the existing plant. Analysis of these results informed future plant design options for Orapa, and provides insight into changes that may need to be made to the existing plant, should it not be replaced by a new facility. The distribution of samples for ore dressing studies was determined on a qualitative basis, ensuring good spatial coverage throughout the pipe for each ore type. The \ test work included comminution, densimetric analysis, slurry/smectite behaviour, luminescence intensity (LI) of both diamonds and gangue, and magnetic susceptibility.

All sample collection, packaging, and consignment processes were cross-checked for conformance with procedures by the external geometallurgical consultant on the project, who also carried out quality checks as the samples were delivered to the laboratories in South Africa. Any deviations were recorded. QA/QC reviews of the external laboratories were undertaken by selected members of the project team, including the geometallurgical consultant.

Large Diameter Drill (LDD) Sampling
The LDD programme was designed for estimation of diamond revenue at depth in each of the major units that were not yet mined, and to support the modelling of microdiamond data. Studies had shown that the micro-macrodiamond relationship could be modeled at Orapa, but highlighted complexity in the diamond distribution within key lithofacies of AK1.

Drilling
The drilling method that was used was reverse-flood air-lift assist (RFALA), using a 24-inch milled tooth tricone bit for the softer lithologies and a tungsten carbide bit for the harder units. A primary objective was to produce coarse chips (preferably using the milled tooth bit) in order to minimize diamond damage. The RFALA method is ineffective at shallow depths, so the first 12–16 m was drilled using conventional mud rotation.

Each LDD hole was centred on a mining block, and a pilot core hole drilled first in the position of the LDD hole in order to provide adequate geological control prior to the collection of samples from the LDD hole. Holes were drilled vertically to a planned depth of 685 mbgl. Since the volume of the LDD holes is critical, and the drilling contractor is responsible for the quality of the holes, it is most appropriate to have this done by an independent party. The OREP project made use of a local geophysical company for this purpose. The caliper was calibrated and then checked a second time prior to each logging run.

Collection of samples, as well as all quality assurance and control on the drilling site, was the responsibility of the rig geologist. All statistics related to time and motion (*e.g.* moving and set-up, client and driller delays, *etc.*), were recorded in a structured manner. The drill bit was photographed and its diameter measured before and after drilling, and a rig geologist report was produced after each hole was drilled. The quality of the chips was reported to the driller if excessive fines, flat bladed chips, or mud balls were observed, and action taken to improve the quality. The screen underflow was also checked regularly for any +1.0 mm material and a log of the results was kept. If +1.0 mm material was recovered in the underflow the drilling was stopped until the cause of the problem was identified

and corrected. The geologist also had a key quality assurance role to play in weighing the collected sample using a crane scale in order to later compare this mass with the treated mass.

Sampling
Sample collection was carried out in accordance with a plan and associated procedure developed as part of the programme. The default was that samples represented the 15 m bench heights, but where geological boundaries interrupted the samples, they were cut off for all but very small lithological intervals. The chips from the first 12–16 m of the hole were bagged and labelled as 'ream samples'. Caving of holes results in material reporting to the bottom of the hole. This material was collected during cleaning of the hole, and also labelled as 'ream samples'. A series of sample numbers was generated by the sampling database prior to the commencement of each hole. The rig geologist ensured that each sample and its sub-samples was correctly labelled.

Particle size distribution (PSD) and granulometry samples and data were collected for every bulk sample for the purpose of diamond liberation analysis. The PSD samples were also used for estimation of internal waste content. For each bulk sample, representative sub samples were collected as geological reference samples at 1 m intervals, and these were used to verify the geological log.

All LDD samples were submitted, in bags weighing a maximum of 1000 kg, to the on-site drill chip sampling plant (DCSP) plant for processing and generation of macrodiamond concentrate. Concentrate was shipped to the Group Exploration Macro Diamond Laboratory (GEMDL) in South Africa for the final recovery of macrodiamonds.

Drill Chip Sampling Plant
The DCSP had a design throughput capacity of 50 t/h. The flow sheet of the DCSP was designed to mimic the main treatment plant as closely as possible.

A comprehensive QA/QC process for the treatment of samples through the DCSP was put in place and routinely executed. Liberation efficiency was monitored primarily through sampling of the crusher product and analyses of the PSD for any indications of crusher gap drift. Screening efficiency was measured on a regular basis by conducting PSD analyses on effluent from the feed preparation and DMS screens, in order to determine the condition of screen panels. DMS efficiency was monitored via tracer tests conducted at the beginning of each shift.

In order to determine the degree of diamond lock-up in the kimberlite, the tailings residue was sampled for granulometry analysis. The PSD data was used as input into an in-house diamond liberation calculator.

An external consultant was contracted to conduct assurance reviews on the treatment process, laboratory sampling and document control. Findings from the reviews were rectified by the DCSP team. Treatment of the LDD samples at the DCSP was carried out under surveillance and in compliance with all Orapa mine security standards and protocols. Access into the plant area was restricted and monitored by security staff. Surveillance cameras were strategically placed in high-risk areas around the plant. The concentrate discharge end of the plant was cage-sealed for control of access.

The concentrate generated by the DCSP was consigned to the GEMDL laboratory in South Africa for final recovery and sorting. Samples were then sent to the Diamond Trading Company – Botswana (DTC-B) for reconciliation prior to consignment to the Central Acidising Centre at Jwaneng Mine, for cleaning. After acidisation the samples were returned to the DTC-B for valuation and long-term storage.

QA/QC processes at the laboratories are well established and documented. Key controls included those associated with the plant processes, the reconciliation and tracking of diamond samples from

one facility to the next, and the exporting and importing of diamonds from and to South Africa. The laboratories were visited by members of the OREP owner's team and the procedures were checked.

Section 11.3 of SAMREC Table 1 specifies the requirements in the CP report for description of bulk sampling and/or trial mining. Discussion of sampling results, whether they be from core, LDD, bulk sampling, or trial mining, fall under this section. The sealing of samples and the chain of custody from source to reporting of results should be discussed under Section 11.6, sub-section i of SAMREC Table 1.

OREP DATA MANGEMENT

The importance of the proper management and storage of data from a Resource extension project cannot be over-emphasized. A robust data-set is the deliverable from the drilling and sampling phase. The integrity of the resource estimate is underpinned by the integrity of the data on which it was based.

Sampling data was captured into SQL relational databases via a series of forms developed as part of a suite of custom-developed interfaces. In many cases, data was captured directly onto the server through the use of tough books in the field. Security and auditability of the SQL databases is robust, with initial validation and final verification processes, followed by locking of records, well established.

All original hard-copy files, including log sheets and reports, were catalogued using Textbase, a web application, by the Mineral Resource Integration section on the operation, and stored in dedicated strongrooms. All core photos were stored on the Orapa Electronic Data Management System (EDMS), and backed up per the group data management policy outlined below.

External laboratory results were checked by the laboratory supervisor and the laboratory manager before being sent to the OREP manager and downloaded directly onto the OREP network folder. An application was designed to enable this data to be uploaded automatically into the relevant tables in the database. Built-in checks ensured that the data was imported correctly. All data was verified by the project team. Original copies of the data were archived on a network folder.

Downhole survey data was provided by the surveying contractor in both electronic and hard copy files. This data was verified internally by the project team and externally by a consultant.

Database security and access was managed through the on-site Mineral Resource Integration department. Levels of authority and control were closely managed. The SQL servers on which the databases are stored are maintained by the on-site Information Management (IM) Department. The server is backed up regularly in accordance with the IM procedure. Backups are done on a daily basis, followed by full backups of the week's data at the end each week. At the end of each month a full backup for the whole month is run, and the tapes stored in a purpose-built off-site facility. This process also applies to all data stored in the EDMS.

Internal database audits were carried out on a structured basis by the project team. Following every sample collection process, reports from the database were printed and the original paper copies checked against the captured data. The team also used various statistical techniques to validate data internally prior to routine external audits.

The core is stored in dedicated core sheds inside the mining area, which were designed for all core logging and sampling activities as well as final storage.

Sections 3.5 and 3.6 of SAMREC Table 1 stipulate the requirements for discussion of governance and QA/QC, respectively, in the SAMREC Code compliant CP report.

RESOURCE CLASSIFICATION

The OREP Resource estimate was classified as Indicated to depth of 685 mbgl from a previous depth of 265 mbgl. De Beers classifies its Diamond Resources in accordance with international reporting codes using a well-established scorecard system. The system assesses geoscientific knowledge across the five key elements of a Resource model, namely geology, volume, grade, revenue, and density. Each scorecard contains a set of questions that allow for the data, process, methods, and (ultimately) the confidence in that element of the Diamond Resource to be assessed. The influence of the three key factors described in this paper was instrumental in determining the integrity of the data-set.

For detailed discussion of Resource Classification in De Beers please refer to Duggan *et al*., 2016.

CONCLUSIONS

The development of clear sampling objectives, supported by careful project planning, and the establishment of detailed project governance mechanisms, was critical to the success of OREP. The authors believe that documenting these three elements of the programme comprehensively before the execution phase will prepare a Resource extension project for success. Furthermore, good quality execution of sampling processes and proper management of data will provide for robust input to the development of models. It is important that all project plans and activities be documented and managed within an overarching and standardized project management framework. Documentation of the Resource extension project in the form of a SAMREC Code-compliant CP report is required for companies listed on the Johannesburg Securities Exchange (JSE). SAMREC Table 1 provides a checklist of requirements for detailed description in the CP report.

REFERENCES

Duggan, S., Grills, A., Stiefenhofer, J., and Thurston, M.L. (2016). Development of a best practice Mineral Resource Classification System for the De Beers group of companies. SAMREC Companion volume 2016 (this volume).

Field, M., Gibson, J.G., Wilkes, T.A., Gababotse, J., and Khutjwe, P. (1997). The geology of the Orapa A/K1 kimberlite Botswana: further insight into the emplacement of kimberlite pipes. *Journal of Russian Geology and Geophysics*, 38 (1), 24-39.

Gernon, T., Fontana, G., Field, M., Sparks, R.S.J., Brown, R.J., and MacNiocaill, C. (2009). Pyroclastic flow deposits from a kimberlite eruption: the Orapa South Crater, Botswana. *Lithos*, 112 (1), 556-578. doi:10.1016/j.lithos.2009.04.016

SAMREC, (2009). South African Mineral Resource Committee. The South African Code for Reporting of Exploration Results, Mineral Resources and Mineral Reserves (the SAMREC Code). 2007 Edition as amended July 2009. http://www.samcode.co.za/downloads/SAMREC2009.pdf



Benjamin Moshi Letsatle

Project Manager
Debswana Diamond Company

Benjamin Moshi Letsatle (Ben) is a Resource Geologist with 22 years of experience in diamond exploration and mining. After obtaining his first degree in Geology from the University of Botswana, Ben gained a BSc Honours degree in Geology from Rhodes University and a Master's degree in Project Management from the University of Southern Queensland, Australia.

Ben is currently a Resource Evaluation Project Manager for Debswana Diamond Company in Botswana. He recently managed and successfully delivered the Orapa Resource Extension Project (OREP). Prior to joining Debswana, Ben worked for De Beers Group Exploration in Botswana and South Africa (Kimberley and Finsch Mines) as a Field Geologist, Senior Project Geologist and Exploration Laboratory Manager.

SAMREC Guideline Document for the Reporting of Diamond Exploration Results, Diamond Resources and Diamond Reserves (and other Gemstones, where Relevant)

("SAMREC Diamond Guidelines")

Table of Contents *Page*

1 INTRODUCTION 1
2 DIAMOND EXPLORATION RESULTS 3
2.1 DIAMOND EXPLORATION TARGETS 3
2.1.1 Kimberlitic Indicator Mineral Chemistry 4
2.1.2 Diamond Mineralisation 4
3 DIAMOND RESOURCE ESTIMATION 5
3.1 DIAMOND RESOURCE ESTIMATION PRINCIPLES 5
3.2 REASONABLE PROSPECTS FOR EVENTUAL ECONOMIC EXTRACTION (RPEEE) 7
3.2.1 Eventual Economic Extraction 8
3.3 DIAMOND RESOURCE CLASSIFICATION 9
3.3.1 Inferred Diamond Resource 10
3.3.2 Indicated Diamond Resource 11
3.3.3 Measured Diamond Resource 11
3.4 DIAMOND VALUE (REVENUE ESTIMATE) 12
3.4.1 Parcel Size and Representivity 13
3.5 MICRODIAMONDS 13
4 TECHNICAL STUDIES 14
4.1 BULK SAMPLING VS TRIAL MINING ON ALLUVIAL DIAMOND DEPOSITS 15
5 DIAMOND RESERVES 16
5.1 PROBABLE DIAMOND RESERVE 16
5.2 PROVED DIAMOND RESERVE 17
6 MISCELLANEOUS 17
Appendix 1: Recommended table of contents for Competent Person's Report (CPR) for diamond deposits

1 INTRODUCTION

This Guideline Document, as presented in the SAMCODE Companion Volume and as updated from time to time, provides the methodologies and definitions of the relevant terms that shall be considered in the preparation of reports on Diamond Exploration Targets, Diamond Resources and/or Diamond Reserves (SAMREC Clause 59). It is to be read in conjunction with the 2016 SAMREC Code where it provides further explanation of Clauses 59–79.

Clauses 1–46 of the Code and the requirements of Table 1 also apply to the reporting of Diamond Exploration Results, Diamond Resources and Diamond Reserves, unless otherwise stated in this document. Where applicable, the term 'Diamond' should replace the term 'Mineral' and 'grade and average diamond value' should replace 'grade and mineral content'. In this document, references to diamonds may equally be applied to other gemstones, unless otherwise stated.

Public Reporting of diamond projects is not restricted to documents compiled by/for listed companies in respect of ongoing Stock Exchange requirements (Refer SAMREC Code Clause 3 for details). Public Reports include any/all documents prepared for the purpose of informing investors, potential investors or other interested parties that may find their way into the public domain. Public Reporting includes Competent Persons' Reports (CPRs) and other geological/technical documents compiled for regulatory authorities, private companies or individuals, *even with respect to alluvial diamond deposits*. It is recognised that situations may arise in which supporting documentation, prepared by a Competent Person (CP) for company or other private use, may not specifically be prepared in terms of the Code – in such situations, the documentation shall include a prominent statement to this effect. It is, however, recommended by the SAMREC Working Group, that the principles and standards in the Code and this Guideline Document should be adopted as a minimum standard for all diamond related documentation.

In this first edition of the Diamond Guideline Document, all references to the SAMREC Code are presented in Arial 10pt typeface. **Definitions from the Code are highlighted in bold Arial 10pt**. Policies, guidelines and explanations to assist in interpreting the Code as per this document are presented in Times New Roman 10pt font (normal and italics).

The word 'shall' is used where a provision is mandatory; 'should' is used where a provision is preferred; and 'may' is used where alternatives are equally acceptable. Any variance from the standards of the Code and Policy Document shall be motivated in a clear and transparent manner on an 'if not, why not' basis.

The following characteristics of diamond deposits are different from those of typical metalliferous and coal deposits, and they emphasise the need for a Diamond-specific Code.

- The widely differing nature of diamondiferous deposits and their associated forms of mineralisation and the estimation relevant to these. Diamond deposits can be subdivided into (i) igneous-hosted deposits, (ii) marine and alluvial placers, (iii) tailings and stockpiles.
- The low diamond content of primary and placer diamond deposits and their variability.
- The particulate nature of diamonds and individual physical characteristics, which have a significant impact on diamond value. These characteristics are size and assortment, the latter being comprised of model (shape or morphology), quality and colour.
- For diamond exploration programmes, Exploration Targets, Mineralisation, Resources and Reserves, the term 'quality' cannot be used as a substitute for 'grade'.
- The specialised field of diamond valuation.
- The relationship between average diamond value and the underlying diamond size distribution.

As a result of the above characteristics, diamond deposits rarely achieve Measured status. This impacts significantly upon the classification of Proved Reserves (see also SAMREC Clauses 69 and 71). The sampling and estimation of marine placer deposits is particularly difficult and expensive and thus even the assignment of Indicated status may prove difficult.

In all Public Reporting of diamonds, please note that:

- A carat (diamond) is defined as one fifth of a gram (0.2 g) – often described as a metric carat (ct). Any deviation from this standard shall be explained in detail.
- Sample grade is used in the context of carats per unit of mass, area or volume above the specified bottom cut-off sieve size.
    - For primary deposits, the sample grade should be reported as carats per dry metric tonne (cpt) and/or carats per 100 dry metric tonnes (cpht).
    - For placer deposits, sample grades quoted in carats per tonne or carats per m^3 (ct/m^3) or carats per 100 m^3 ($ct/100\ m^3$) are equally acceptable, as are stones per unit area, volume or mass[1].
    - In the marine placer environment, diamond sample grades are, typically, reconciled per m^2 (typically referred to as 'planar grades').
- Where carats per unit of mass is used, a discussion of volume to mass conversion shall be provided.

[1] *In the physical sciences, the terms 'mass' and 'weight' are rigidly defined as separate measures in order to enforce clarity and precision. In everyday use, however, given that all masses on Earth have weight and this relationship is usually highly proportional, the term 'weight' often serves to describe both properties, its meaning being dependent upon context. For example, the net weight of diamonds actually refers to mass and is properly expressed in carats; and the weight of kimberlite or gravel refers to its mass and is expressed as kilograms or tonnes.*

- All diamond values shall be reported in US$/ct. If reference is made to local currencies then the prevailing exchange rate shall be noted, as well as the effective date of the exchange rate. The date of valuation shall be reported and should be based on diamond prices less than six months old.

2 DIAMOND EXPLORATION RESULTS

The principles of SAMREC Clause 20 also apply to the reporting of Exploration Results on diamond properties. These are summarised below for ease of reference.

SAMREC Clause 20

Exploration Results include data and information generated by exploration programmes that may be of use to investors but which do not form part of a declaration of Mineral Resources or Mineral Reserves.

Exploration Results include relevant data and information relating to the diamond project/property – both positive and negative, but shall not be presented in a way that is misleading. Exploration data and information may include (but not be limited to) survey, geological, geophysical, geochemical, sampling, drilling, pitting, trenching, analytical testing, mineralogical, and metallurgical information, where available. The actual data/information shall be appropriately described and presented.

Historical data and information may also be included if, in the considered opinion of the CP, such is relevant and reliable, giving reasons for such conclusions.

The data and information may be derived from adjacent or nearby properties if the CP can provide justification of continuity for such an association. At least some physical evidence of assumed continuity of the mineralisation on the property of interest shall be presented by the CP (such evidence may include geophysical and/or remote sensing information).

2.1 Diamond Exploration Targets

SAMREC Clause 65

A 'Diamond Exploration Target' is a statement, or estimate, of the exploration potential of a diamond deposit in a defined geological setting.

It is accepted that companies must continuously assess long-term development opportunities in their exploration programmes. The main objectives of these programmes are to develop a thorough understanding of the mineral inventory so that the full mineral endowment potential can be considered under a variety of scenarios and then to make long-term investment decisions that optimise the development potential of the exploration provinces. These objectives require a consistent approach to evaluating the nature and extent of potentially economic mineralisation (Diamond Exploration Targets) in a rigorous approach.

A Diamond Exploration Target may refer, inter alia, to a kimberlite target, a particular river or stretch of river, a stratigraphically defined sedimentary unit or sequence, or an area of marine deposits, which is considered to have diamond potential. There must be a likelihood that this Exploration Target occurs in an area of geological prospectivity for that style of mineralisation. A Diamond Exploration Target, in its simplest form, need not represent any discovered mineralisation, nor does it imply that reasonable prospects for possible eventual economic extraction (RPEEE) have been demonstrated.

Geophysical and/or remote sensing anomalies may be identified as Diamond Exploration Targets. Estimates of potential grade and/or average diamond value may be based on very limited information and analogies with known deposits of similar geological character may be drawn. However, the reporting of analogous information,

preliminary exploration sampling or geophysical results must not be constructed so as to imply that potentially economic mineralisation has been discovered.

When discussing Diamond Exploration Targets, the CP shall clarify whether the target is based on proposed exploration programmes (conceptual Exploration Target) or on actual Exploration Results (Diamond Mineralisation – see section 3.2 below). In either case, the CP shall describe clearly the rationale for the selection of the target, including the geological model on which it is based, as well as justification for any statements of conceptual quantity, grade and average diamond value, as relevant. In addition, the intended exploration work programme to explore for the target shall be included, detailing the extent of the proposed exploration activities, the planned timeframe and the anticipated costs.

Public Reporting of a Diamond Exploration Target shall not be done unless supported by an exploration programme. Without an explicit concrete exploration work programme on a specific mineral property held by the company, public reporting of a Diamond Exploration Target shall be regarded as being solely speculative.

2.1.1 Kimberlitic Indicator Mineral Chemistry

SAMREC Clause 60

Kimberlitic Indicator mineral chemistry does not provide direct grade or diamond value information, and shall not be used to infer these parameters for Diamond Resource estimation purposes.

Major and trace element mineral chemistry of kimberlitic indicator minerals (in particular, pyrope and eclogitic garnets, ilmenite, chrome spinel and chrome diopside) provide indirect evidence for the potential occurrence of diamonds, and is useful in (early stage) diamond exploration for ranking exploration targets in terms of their diamond-bearing potential.

Reference to relevant peer-reviewed published research articles should be made when reporting the interpretation of mineral chemistry data for diamond exploration projects.

2.1.2 Diamond Mineralisation

SAMREC Clause 65

'Diamond Mineralisation', as used in the Code, is defined as a concentration (or occurrence) of diamonds of possible economic interest, in or on the Earth's crust, for which quantity and quality cannot be estimated with sufficient confidence to be defined as a Diamond Resource. Portions of a Diamond Exploration Target or Diamond Mineralisation that have not demonstrated reasonable prospects for eventual economic extraction shall not be included in a Diamond Resource.

Diamond Mineralisation[2] not classified as a Diamond Resource or Diamond Reserve can only be reported under Exploration Results. The data and information relating to it must be sufficient to allow a considered and balanced judgement of its significance.

Mineralisation refers to in-situ mineralisation of significance. In other words, it is an Exploration Target that is based on actual Exploration Results, but where either the amount of data/information or the level of confidence in the data/information is insufficient to estimate Diamond Resources. It may also include situations where both the amount and level of confidence in the data/information are satisfactory, but where RPEEE have not yet been demonstrated. Note that the occurrence of individual diamonds or microdiamonds in surficial deposits would not, typically, qualify as Diamond Mineralisation.

Where the statement of Mineralisation includes information relating to volumes/tonnages, grades and values, these shall be represented as approximations. The conceptual nature of the statements shall reflect the lack of reliable data and should be expressed either through the use of 'order of magnitude', appropriate descriptive terms (such

[2] *Diamond Mineralisation, in this context (written with a capital 'M'), can be considered as similar to the term 'deposit' as used in Clause 21 of the 2007/2009 SAMREC Code. It is a subset of Exploration Target and not a variety of Inferred Resource.*

as 'approximately', 'in the order of', etc.) or as 'ranges'. The use of the term 'ranges' in this context has no statistical relevance and is defined simply as the variation between the lowest and highest relevant exploration results. The explanatory text shall also include a description of the process used to determine the grade, value and volume/tonnage ranges used to describe the Mineralisation.

Appropriate rounding shall be used to express the level of uncertainty of the estimates. By way of example, 'approximately 10–20 million tonnes at a grade of 15–20 carats per hundred tonnes and an average diamond value of US$100–200/ct' would be acceptable, but not '10±0.2 million tonnes'. When such potential assessments are presented, statements of mass/volume/area, grade and average diamond value should be provided. It is not permissible to discuss one without reference to the other two. Estimates of potential quantity should, preferably, be made in terms of volume (or area) and not tonnage. If, however, target tonnages are reported then the preliminary estimates of, or basis of assumptions made for dry bulk density shall be stated.

Public Reporting of a Diamond Exploration Target with identified Mineralisation shall not be done unless supported by an explicit exploration work programme on a specific mineral property held by the company, detailing the extent of the proposed exploration activities, the planned timeframe and the anticipated costs.

3 DIAMOND RESOURCE ESTIMATION

3.1 Diamond Resource Estimation Principles

The principles of SAMREC Clauses 23–33 also apply to the estimation of Diamond Resources, where relevant.

SAMREC Clause 66 (Diamond Resource)

A 'Diamond Resource' is a concentration or occurrence of diamonds of economic interest in or on the Earth's crust in such form, quantity (volume/tonnage), grade and value that there are reasonable prospects for eventual economic extraction. The location, quantity, grade, value, continuity and other geological characteristics of a Diamond Resource are known, or estimated from specific geological evidence, sampling and knowledge interpreted from an appropriately constrained and portrayed geological model. Diamond Resources are subdivided, and must be so reported, in order of increasing confidence in respect of geoscientific evidence, into Inferred, Indicated or Measured categories.

Any Diamond Mineralisation that has not demonstrated reasonable prospects for eventual economic extraction shall not be included in a Diamond Resource.

The principles of SAMREC Clauses 23–33 also apply to Diamond Resource estimation, where appropriate. It is particularly relevant to note the provisions of Clause 32, that the words 'Ore' and 'Reserves' shall not be used with reference to Diamond Resources. These terms imply a level of technical feasibility and economic viability and are appropriate only when all relevant Modifying Factors have been applied.

Where considered appropriate by the CP, Mineral Resource estimates may include Mineralisation below the selected cut-off grade to ensure that the Mineral Resource consists of bodies of Mineralisation of adequate grade, size and continuity to properly consider the most appropriate approach to mining, including any dilution or contamination resulting from the requirements of any minimum mining width (in addition to cut-off grades, Mineral Resources can also be defined by geological constraints, which may include, but are not limited to, structure, stratigraphic boundaries, or geometallurgical/mineralogical constraints). Documentation of Mineral Resource estimates shall clearly define any such inclusions, and Public Reports shall include commentary on the matter, if considered material.

SAMREC Clause 60 (Declaration of Bottom Cut-off Screen Size)

The average diamond grade and value shall not be reported without specifying the bottom cut-off screen size.

The bottom cut-off screen size should be the same for both grade and value estimations. If they are different, then the CP shall include a full description of the difference and the reasons for such.

SAMREC Clause 23

A Mineral Resource shall not be estimated in the absence of sampling information.

A Diamond Resource shall not be estimated in the absence of sampling information from the project property or geological unit.

- Volume shall not be based on remote sensing data (for example, satellite images and/or aerial photographs) or geophysics alone – corroborating drilling/pitting data must exist. Exceptions to this requirement may include the use of remote sensing (including aerial photography by drones) for surveying and volume estimation of Tailings Mineral Resources (TMR) and stockpiles. Any such concession, however, requires the justification of the specific situation and a description of the process in a clear and transparent manner.
- The extent to which Resource information has been extrapolated from existing data points shall be identified and justified.
- Grade and value, at Resource classification, shall not be based solely on production data from adjacent properties. Kimberlites in the same field, including satellite pipes and dykes, usually do not have the same grade and value. Similarly, alluvial deposits on adjacent properties shall not be assumed to have the same grade/value characteristics unless sufficient geological evidence of deposit continuity is present.
- Resource estimates shall not be based on unverified or unverifiable historical[3] or artisanal results only.

If the project has no surveyed volumes, no recorded production data, or no (Kimberley Process compliant) sales/valuation data, then no Diamond Resource can be estimated.

SAMREC Clause 60

A Diamond Resource estimate must identify separate geological domains where applicable. For each geological domain, a size frequency distribution, grade and diamond value estimate should be established, and a bottom cut-off size must be stated. Reports of diamonds recovered from sampling programmes must describe the nature of the sample, how the sample was taken and the method used to recover diamonds from the sample. The mass of diamonds recovered may be omitted from the report only when the diamonds are considered to be too small to be of commercial significance.

When estimating an Inferred Diamond Resource, it is necessary to identify preliminary geological domains, each of which should have at least an initial indication of area (for planar secondary deposits) or volume, density (for primary deposits), stone size distribution, grade and average diamond value. Such information shall be obtained from bulk samples.

In order to progress to an Indicated Diamond Resource, and from there to a Probable Diamond Reserve, it is likely that much more extensive, representative bulk sampling (and/or trial mining[4]) would be needed to determine fully the stone size distribution and value. Commonly, such bulk samples would be obtained by opencast or underground development designed to obtain sufficient diamonds to enable a confident estimate of price or, in the marine environment, by deploying a vessel equipped for mining the deposit to undertake extended sampling. In the case of a marine placer (or certain alluvial deposits) where the assortment is well understood through mining or sampling and where it can be demonstrated that the average diamond mass is well correlated with average diamond value, knowledge of the average diamond mass may be sufficient to derive an average diamond value.

In complex deposits, however, it may be very difficult to ensure that the bulk samples taken are truly representative of the whole deposit. The CP shall provide an opinion on the representativeness of the bulk sampling and on the validity of the conclusions drawn from this information.

[3] *Historical data, in this context, refers to anything that has not been subject to a SAMREC/CRIRSCO compliant resource estimation exercise.*

[4] *See Section 5.1 for a discussion on bulk sampling vs. trial mining*

The stone size distribution and price of diamonds are critical components of the Resource and Reserve estimates. At an early exploration stage, reconnaissance, sampling and delineation drilling will not usually provide this information, which relies on bulk sampling through pitting, trenching, or large diameter drilling. In the case of Inferred Resources, it is expected that the available data will be limited, but sufficient to imply, but not to verify, geology, grade and value.

SAMREC Clause 64

For diamond exploration programmes, Exploration Targets, Mineralisation, Resources and Reserves, the term 'quality' must not be used as a substitute for 'grade.' The use of 'grade' and 'value' helps avoid confusion with diamond quality, which is only one aspect of the diamond assortment.

All statements/tabulations of Diamond Resources and Diamond Reserves shall include quantity (volume/tonnage/area), grade, carats and diamond value. It is not permissible to report estimated contained carats unless corresponding estimated quantities (volume/tonnage/area) and grades are also reported in the same statement/tabulation. It is acknowledged that, under very specific situations, certain information regarding diamond revenue may be considered confidential. In these circumstances, the CP should outline what the confidentiality issues are and present as much information as possible within the available contractual/legal parameters. Listed companies are referred to the JSE Listing Requirements on how to deal with these situations with respect to their ongoing reporting obligations.

When target ranges/approximations are provided for exploration programmes, Diamond Exploration Targets and Diamond Mineralisation, statements should also include information relating to quantity, grade and average diamond value. However, such statements shall not be included in statements/tabulations of Diamond Resources and Diamond Reserves.

3.2 Reasonable Prospects for Eventual Economic Extraction (RPEEE)

RPEEE shall be demonstrated through the application of an appropriate level of consideration of the potential viability of Diamond Resources. Such a consideration shall include a reasoned assessment of the geological, engineering (including mining and processing parameters), metallurgical, legal, infrastructural, environmental, marketing, socio-political and economic assumptions which, in the opinion of the CP, are likely to influence the prospect of economic extraction. All of the issues listed in Table 1 (Section 4.3 of the SAMREC Code), under 'Reasonable Prospects for Eventual Economic Extraction' shall be discussed *at the level appropriate for the specific investigation*.

For ease of reference, these are:

(i) Discuss and justify the geological parameters. These would include, but not be limited to, grade, volume (and/or tonnage), diamond value, bulk densities, cut-off grades, strip ratios, top and bottom cut-off screen sizes.
(ii) Discuss and justify the engineering parameters. These would include, but might not be limited to, mining method, processing, geotechnical, geo-hydraulic and metallurgical parameters.
(iii) Discuss and justify aspects of infrastructure including, but not limited to, site accessibility, access to labour as well as the availability of power and water.
(iv) Discuss and justify the legal, governmental, permitting and statutory parameters. For diamond projects, this would include compliance with Kimberley Process certification.
(v) Discuss and justify the environmental and social (or community) parameters.
(vi) Discuss and justify the marketing parameters.
(vii) Discuss and justify the major economic assumptions and parameters. For diamond projects, these factors include, but are not limited to, possible capital and operating costs as well as diamond price forecasts, where relevant. It may also include a brief discussion of sensitivities related to the major factors influencing potential profitability.
(viii) Discuss any material risks.
(ix) Discuss the parameters used to support the concept of 'eventual'.

When addressing RPEEE, note that there is no definition of this phrase in the Code. Such assessment is the responsibility of the CP and requires judgement based on the CP's experience. However, both the Code and Table 1 provide guidelines that should be considered by the CP in using judgment for this critical aspect of resource estimation and reporting.

The assessment shall be based on the principle of reasonableness, and shall be justifiable and defendable. The assumptions used to test for RPEEE shall be within known/assumed tolerances or have examples of precedence. They should be applied at an appropriate and practicable scale. The principle of reasonableness shall be applied together with the primary SAMREC Code principles of Materiality, Transparency and Competency.

Where untested practices are applied in the determination of RPEEE, the use of the proposed practices for reporting of the Diamond Resource shall be justified by the CP. Such untested practices refer to methods or practices which are outside of the ordinary, which may be considered novel, innovative, pioneering or which might not be understood by the non-specialist. Transparency with respect to untested practices is patent and should support the reasonableness in determining potential extraction.

In order to demonstrate that a Diamond Resource has RPEEE, some appreciation of the likely stone size distribution and value is necessary, however preliminary this estimate of size distribution and value may be. Spatial data distribution as well as geological and grade continuity must also be considered. It is, furthermore, critical that project economics risk factors shall be clearly defined, current, reasonably developed and based on generally accepted industry practice and experience. As an example, the potential capital cost may be relevant and should always be shown to be recoverable from project revenue.

While it is understood that some practitioners and companies may apply a variety of protocols for an assessment of RPEEE, the SAMREC Code provides for 'minimum standards, recommendations and guidelines' in this matter. Thus, while company A may require 'an order-of-magnitude' engineering study to support RPEEE, minimum standards imply a less rigorous level of care or detail in establishing prospects. For an early stage exploration project, this less rigorous level of care may be acceptable and understandable as long as all the compliance requirements discussed here are fulfilled in a competent, material and transparent manner.

As an example of this aspect, in some public disclosure reporting domains, the application of a Lerchs-Grossman (LG) open pit model may be used to constrain the limits of Diamond Resources. This computational method incorporates the required criteria in mathematical form for the assessment and blocks captured are reported as meeting the requirement of reasonable prospects, with material outside the pit falling short of this threshold. *The use of this software-driven method may be appropriate for advanced projects but is not necessarily applicable to early stage Diamond Resource estimation (especially with respect to placer deposits).*

For early stage Diamond Resource estimation, a simple reference to all of the factors listed under Section 4.3 of Table 1 may suffice. Other approaches may also be valid, depending on the specific circumstances. Irrespective of what approach is used, the methodology and assumptions made by the CP in determining whether the project has RPEEE must be presented explicitly and in sufficient detail so as to be transparent.

3.2.1 Eventual Economic Extraction

Interpretation of the word 'eventual' in this context may vary depending on the commodity, mineral involved or legal tenure. For example, for many occurrences of coal, iron ore, bauxite and other bulk minerals or commodities, it may be reasonable to envisage 'eventual economic extraction' as covering periods of 50 years or more. However, for other deposits, application of the concept may be restricted to much shorter periods. For diamond mineralisation (and especially with respect to alluvial deposits) it should always be understood that the timeline to development is short in comparison with many other commodities. The presence of the word 'eventual' in this context shall not be used to justify applying an unreasonably long timeframe to the assessment of reasonable prospects.

The CP shall discuss the parameters used to support the concept of 'eventual' in the specific instance as it relates to the project at hand and not in terms of global generalisations. In this respect it may also be useful for the CP to consider a timeline for development of the project in discussing the concept of 'eventual economic extraction'.

3.3 Diamond Resource classification

SAMREC Clause 28

For each category of Mineral Resource the basis of classification must be disclosed.

The main section of the SAMREC Code is not prescriptive beyond this brief disclosure requirement. However, the implications are that for each category of Diamond Resource and/or Reserve, the CP shall disclose the classification criteria used. Section 11.5 of Table 1 provides a list of criteria that may be used as a basis for consideration. In addition, the CP is encouraged to research public disclosure documents for further guidance and to develop a wide-ranging list of classification criteria.

Such classification may be by way of a simple tabulation of key criteria and levels of confidence, a more comprehensive scorecard protocol or any other systematic methodology. Irrespective of what technique is selected by the CP, the logic behind the methodology shall be provided in sufficient detail so as to be understandable and transparent. Phrases such as 'the author feels …', 'the author believes …' or 'the author sees no reason why it shouldn't be classified as …' are *not* valid classification criteria.

SAMREC Clause 28

The Competent Person responsible for the Resource estimate must determine the appropriate Mineral Resource category based upon the quantity, distribution and quality of data available and the level of confidence attached to the data with reference to Table 1. The method of determining these confidence levels must be disclosed.

In estimating a Diamond Resource, the drilling grid as well as the number and size of samples will depend on the specific geology of the deposit. Different types of diamond deposits will require different (drilling/sampling) specifications for Resource classification. In all cases, the programme should be optimised appropriately to the geology. In complex deposits, it may be very difficult to ensure that the bulk samples taken are truly representative of the whole deposit. Diamond deposits, especially placer deposits, may require significant amounts of drilling and/or sampling before a meaningful Diamond Resource can be estimated. All of these issues shall be taken into consideration by the CP when deciding on the relevant Resource classification.

Other important issues that need to be considered by the CP when classifying Diamond Resources are:

- The CP should consider a range of relevant risk factors and their confidence levels – as a minimum, the effects of geology, grade, volume, density, average diamond value and the quality/integrity of data should be included. The weighting given to each of these (and other factors, as applicable) may vary, depending on whether the project covers an alluvial, a marine or a primary deposit. The determination of levels of confidence may be partially software-driven or simply experiential. More rigorous determination of levels of confidence may involve semi-quantitative scorecard protocols.
- The CP shall apply experience and discretion in considering the relative weighting to apply to confidence levels for the range of factors taken into account. The differences between average and specific estimates may be instructive for classification if they impact confidence for mine planning (i.e. differentiating between Inferred and Indicated classifications).
- Any relevant assumptions applied or manipulation of data during the estimation and classification process shall be clearly described.
- SAMREC Figure 3 stresses that Diamond Resource classification is dependent on both increasing geological knowledge *and* confidence in the geological data. Therefore, the amount of direct sampling and the uncertainty in demonstrating spatial continuity of size, grade and price relationships should be persuasive in determining the appropriate resource category. It is incumbent on the CP to justify the classification in a transparent and professional manner.

The CP shall also offer commentary on Resource reconciliation. The objective of these observations is to demonstrate how well the Resource has been evaluated. Two areas should be considered; the most obvious is

how the Resource estimate compares with any subsequent production data[5] (i.e. actual recovered vs. expected recovered); the second area of consideration should reconcile Resource data as it progresses through the classification categories – for example, what was the estimate at Inferred classification and how (and why) it has changed as the Resource is upgraded to Indicated and Measured, if applicable. The information obtained through this exercise may assist the CP in refining appropriate Resource classification criteria for such deposits.

3.3.1 Inferred Diamond Resource

The principles of SAMREC Clauses 24–25 also apply to the estimation of Inferred Diamond Resources, where relevant.

SAMREC Clause 67

An 'Inferred Diamond Resource' is that part of a Diamond Resource for which quantity, grade and average diamond value are estimated on the basis of limited geological evidence and sampling. Geological evidence is sufficient to imply, but not verify, geological and grade continuity.

An Inferred Diamond Resource has a lower level of confidence than that applying to an Indicated Diamond Resource and must not be converted to a Diamond Reserve. It is reasonably expected that the majority of Inferred Diamond Resources could be upgraded to Indicated Diamond Resources with continued exploration.

Although the confidence level of an Inferred Diamond Resource is defined as 'low', it does not mean 'no confidence', nor is it a 'guesstimate'. The confidence in the estimate must be higher than that required for Diamond Mineralisation. There is, furthermore, an expectation that the majority of Inferred Diamond Resources will be able to be upgraded to Indicated Resources if additional drilling/sampling were carried out, although this cannot be guaranteed.

The Inferred Diamond Resource category is applicable when data locations may be too widely or inappropriately spaced to verify geological and grade continuity but spaced closely enough for continuity to be implied, *and* where the diamond parcel is only large enough for a low confidence estimate of average diamond value. Although too small to be fully representative, the diamond parcel (for value) must come from the property (and from the deposit being estimated) – it must not be a regional value nor extrapolated from adjacent/nearby operations, nor even from a satellite deposit.

Note that geological evidence of continuity of mineralisation in the form of outcrops, trenches, pits, workings and/or drill-holes is required to estimate a Diamond Resource. Geophysical anomalies, remote sensing data, satellite image and/or aerial photographic evidence alone are insufficient. Estimates of quantity, grade or value based on limited information and analogies with known deposits of similar geological character are inadequate for classification as Inferred Diamond Resources.

Grade and value data that are not SAMREC compliant may not be used to estimate a Diamond Resource – purely historical[6] or anecdotal estimates are insufficient.

An Inferred Diamond Resource can be based on interpolation between widely spaced data where there is reason to expect geological continuity of Mineralisation. Where relevant, the extent of extrapolation outside of the nominal drilling or sampling grid spacing should be justified. The CP shall provide sufficient information to inform the reader of:

- The maximum distance that the Diamond Resource is extrapolated beyond the sample points.
- The proportion of the Diamond Resource that is based on extrapolated data.
- The basis on which the Diamond Resource is extrapolated to these limits.

[5] *Although the most obvious parameters for such reconciliation exercises are grade, average value and quantity (volume/mass), other factors may also be considered.*

[6] *Historical estimates, in this context, refer to anything that has not been subject to a SAMREC/CRIRSCO compliant resource estimation exercise.*

A diagrammatic representation of the Inferred Diamond Resource showing clearly the extrapolated part of the estimated resource should also be provided.

Where the Diamond Resource being reported is predominantly an Inferred Diamond Resource, sufficient supporting information must be provided to enable the reader to evaluate and assess the risk associated with the reported Diamond Resource.

3.3.2 Indicated Diamond Resource

The principles of SAMREC Clause 26 also apply to the estimation of Indicated Diamond Resources, where relevant.

SAMREC Clause 68

An 'Indicated Diamond Resource' is that part of a Diamond Resource for which quantity, grade, value, density, shape and physical characteristics of the deposit are estimated with sufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit.

Geological evidence is derived from adequately detailed and reliable exploration, sampling and testing and is sufficient to assume geological and grade continuity between points of observation. An Indicated Diamond Resource has a lower level of confidence than that applying to a Measured Diamond Resource and may only be converted to a Probable Diamond Reserve.

The Indicated Resource classification is appropriate when sampling and testing locations may be too widely, or inappropriately, spaced to confirm geological and grade continuity but are spaced closely enough for continuity to be assumed, *and* where sufficient diamonds have been recovered to allow a reasonable estimate of average diamond value.

The sampling and estimation of marine placer deposits is particularly difficult and expensive and, thus, even the assignment of Indicated status may prove difficult.

The level of confidence in an Indicated Diamond Resource shall be sufficient to convert to Probable Reserves and determine a Life of Mine Plan, based on a trial mining and/or Pre-Feasibility/Feasibility Study (PFS/FS).

The CP shall refer to SAMREC Clause 62 (Section 3.4.1 below) for guidance on the selection of an appropriate diamond parcel size applicable to the estimation of Indicated Diamond Resource classification.

3.3.3 Measured Diamond Resource

The principles of SAMREC Clause 27 also apply to the estimation of Measured Diamond Resources, where relevant.

SAMREC Clause 69

A 'Measured Diamond Resource' is that part of a Diamond Resource for which quantity, grade or value, density, shape, and physical characteristics of the deposit are estimated with sufficient confidence to allow the application of Modifying Factors to support detailed mine planning and evaluation of the economic viability of the deposit.

Geological evidence is derived from detailed and reliable exploration, sampling and testing and is sufficient to confirm geological and grade continuity between points of observation.

A Measured Diamond Resource has a higher level of confidence than that applying to either an Indicated Diamond Resource or an Inferred Diamond Resource. It may be converted to a Proved Diamond Reserve or to a Probable Diamond Reserve.

The Measured Resource classification is applicable when sampling and testing locations are spaced closely enough to confirm geological and grade continuity *and* where sufficient diamonds have been recovered to allow a confident estimate of average diamond value**.** The CP shall refer to SAMREC Clause 62 (Section 3.4.1 below) for guidance on the selection of an appropriate diamond parcel size.

For most diamond operations, Resources fall short of making the Measured Diamond Resource category and special care has to be taken if Resources are reported in this category (*this provision is especially applicable to alluvial diamond deposits*).

3.4 Diamond Value (Revenue Estimate)

SAMREC Clause 60 (Average Diamond Value as a Component of the Diamond Resource)

A Diamond Resource or Diamond Reserve shall not be stated without an estimate of the average diamond value/revenue, which shall be based on a run-of-mine, or representative bulk sample, parcel of diamonds that has been recovered from the project property.

The average value (or revenue estimate) of a diamond parcel is estimated from a knowledge of the assortment of the parcel and the size frequency distribution (SFD), resulting in US dollars per carat (US$/ct) per sieve class[7] or size. This revenue value (valuation) is limited to the specific parcel under discussion, for which the SFD and assortment[8] may not be representative of the diamond content above the bottom cut-off.

The value of a parcel of diamonds, as defined, in this Code, is a measure of the revenue (US$/ct). The valuation or assessment of a revenue estimate may be based on the sale of a representative diamond parcel on the open market or it may be based on modelling of both diamond size class prices and the diamond SFD above a defined bottom cut-off. A revenue estimate is date-specific, and linked to a value or price that should not be more than six months old.

In defining the value of a diamond parcel, the size of the parcel in carats and in number of stones shall be stated and the CP shall discuss and provide an opinion on the representivity of the parcel (cf. Clauses 61 and 62).

SAMREC Clause 61 (Diamond Valuation Methodology)

Any valuation of a parcel of diamonds shall be based on a sales docket or a report from a demonstrably reputable and qualified expert whose qualifications, credentials, affiliations and independence/non-independence must be presented.

It shall be clearly stated whether the reported value is based on sales, valuation (without sale) or modelled and, in the last case, an outline[9] of how the modelling was carried out and by whom. Reports of diamonds recovered from sampling programmes shall provide material information relating to the basis on which the sample is taken and the method of recovery of the diamonds. The valuer should provide an indication of variability of quality and values within the parcel, and at least a qualitative level of confidence in the average value per carat estimate.

The valuation of diamonds shall state that the average diamond value includes all categories of diamonds recovered above a bottom cut-off (i.e. run-of-mine and not a selected parcel). The bottom cut-off should coincide with that used to disclose diamond grades. The mass in carats and the bottom cut-off size in mm of the contained diamonds shall be stated along with the dates of the valuation, revenue estimate and/or diamond prices. The value

[7] *Refer also to section 1 under 'Miscellaneous' on p. 17.*
[8] *Diamond assortment is defined as the model (shape or morphology), quality and colour.*
[9] *It is acknowledged that this process may involve confidential information, in which case, a high-level discussion is all that is required to fulfil this obligation.*

of the diamonds shall be given in US dollars per carat, along with any foreign exchange information where relevant and should be based on diamond prices that are not more than six months old.

3.4.1 Parcel Size and Representivity

SAMREC Clause 62 and 63

Where the valuation is used in the estimation of Diamond Resources or Diamond Reserves, the valuation shall be based on a parcel representative of the size distribution and assortment of the diamond populations in the deposit. The CP shall explain the rationale behind the parcel size that has been used in the estimation of value for the Diamond Resource or Diamond Reserve and the level of confidence in the estimate.

The minimum representative size of the valuation parcel depends on the characteristic stone distribution and quality of stones in the deposit. For all valuations (irrespective of Resource classification), associated diamond size frequency distributions shall be provided, along with a discussion of the relevant applicable parcel size.

Diamond value is deposit-specific. The parcel size for diamond valuation at each Resource category confidence level is also deposit-specific. The planning of the recovery of diamonds for valuation purposes is an important activity that should attempt to predict the parcel size ahead of sampling in order that the level of confidence in this factor may not fall short of expectations for the stage of project progress. Under certain circumstances, the number of stones/carats required to estimate the diamond value to a low, reasonable or high confidence may need to be significantly different[10] from the numbers and thresholds given below for guidance. The SFD and assortment under study should be the determining factor for the specific numbers and threshold.

In all circumstances, the CP shall state the number of stones/carats selected and discuss the rationale behind the selection as well as the level of confidence that the CP has in the estimate.

Industry practice suggests that, although as few as 100 carats may be adequate to characterise a size frequency distribution in a diamond deposit, a minimum of 500 carats is generally recommended to achieve even a low confidence valuation (revenue estimation), and classification of an Inferred Diamond Resource.

For primary deposits with a low variability of stone sizes and assortment, some 2000 carats may be sufficient to achieve a reasonable valuation (for Indicated Diamond Resource classification).

In all deposits with highly variable stone sizes and assortment, or deposits in which a small number of very high value stones have a large influence on the overall average stone value (such as low grade alluvial deposits), parcels in excess of 2500 carats may be required for Indicated Diamond Resource classification. Under specific circumstances, parcels of more than 5000 carats may be required and in extreme cases a confident parcel size may never be achieved during industry standard evaluation sampling or even trial mining.

In the marine environment, as few as 100 carats may be required for size frequency modelling and a minimum of 500 carats for an assortment estimate at an Inferred level of confidence. At least 1000 carats may be needed for a revenue estimate at an Indicated level of confidence.

3.5 Microdiamonds

For the avoidance of doubt, the use of microdiamonds is not relevant in the placer environment.

A distinction between 'micro' and 'macro' diamond' has been deliberately avoided in this document on the basis that there is no natural boundary in the continuum of diamond sizes present in a diamond bearing host rock. A complete set of sieve data using a standard progression of sieve sizes may provide superior data. The CP shall provide relevant details regarding definitions, specifications and sieve sizes used.

[10] *Generally higher, seldom lower*

SAMREC Clause 62 (Application of Total Liberation Methods)

Diamond valuations should not be reported for samples of diamonds processed using total liberation methods which will be composed mainly of microdiamonds.

Total liberation generally refers to acidisation or caustic fusion of microdiamond samples, which is useful for estimating grade and determining SFD. However, microdiamonds have no commercial value and are not useful for estimating diamond value, other than providing an SFD which represents one component of diamond revenue.

There may be instances where valuation of macrodiamonds recovered from such processes may be useful to the CP and may have been used in the estimation of a modelled average diamond value. If such valuations were to be disclosed then this must be done in the correct context and qualified carefully so as not to be misleading.

SAMREC Clause 63 (Correlation of Micro- and Macro- diamond Size Frequencies)

Where Diamond Resource or Reserve grades are based on correlations between the frequency of occurrence of microdiamonds and of commercial size stones, this shall be stated, and the reliability of the procedure shall be discussed by the Competent Person.

Details of the laboratory facilities used for the processing of samples and the method for recovery of microdiamonds should also be disclosed and the cut-off sieve size for microdiamonds reported. In addition, it should be clearly stated whether selective sampling has removed any diluting material from samples prior to sample submission for processing, since this will have an impact on microdiamond-based grade estimates.

Diamond grade estimation using microdiamonds is not sufficient to declare a Diamond Resource unless sufficient macrodiamonds have also been recovered to enable an estimate of average diamond value.

However, in the case of a producing mine or development property, where Diamond Resources have been declared and sufficient macrodiamonds have been recovered for estimation of average diamond value, it is permissible to extrapolate diamond values if geological homogeneity and continuity can be demonstrated and a preliminary SFD can be modelled. The CP shall take a view on the adequacy of the quantity of recovered macrodiamonds to estimate average diamond value, and the confidence in the assumption or demonstration of geological homogeneity and continuity.

Key issues in the micro-macro diamond modelling approach are the use of appropriate sampling protocols to ensure that dilution in the sample is sufficiently understood. The relationship between the micro- and macro-diamond portions of the total content curve may be critically affected by country rock dilution and diamond liberation.

Other than total dissolution techniques in microdiamond sample processing, sampling of diamond deposits does not provide an assay as with other minerals or commodities. Conventional macrodiamond sample processing will not liberate or recover all the contained diamonds. The relative efficiencies of microdiamond sampling, macrodiamond sampling and full-scale treatment and recovery technologies should consider aspects such as granulometry and mineral dressing studies to derive appropriate Diamond Resource to Reserve Modifying Factors.

4 TECHNICAL STUDIES

SAMREC Clause 43

A mining project typically passes through exploration, resource definition and design phases; each of which involves rapidly escalating levels of investment. Each phase requires an increasing level of economic and technical assessment with increasing levels of confidence for the project design, scheduling, costs and risks to justify progression of the project to the next investment level.

SAMREC Clauses 44–46 and Table 2 provide guidance in terms of the level of Technical Studies. The CP shall consider these issues when considering any techno-economic assessment of a diamond project.

The Code does not require that a full FS has to be undertaken to convert Diamond Resources to Diamond Reserves. It does, however, require that at least a PFS or Life of Mine Plan will have been carried out to determine that the mine plan/production profile is technically achievable and economically viable, and that Modifying Factors have been considered to an appropriate level of confidence.

During early exploration, some level of financial analysis may be carried out by a company on exploration data which might not include Diamond Resource estimates to assess the potential for the project to proceed to the next phase of exploration. These analyses are considered to be a part of the exploration programme planning and are *solely for internal company decision making purposes. They are not for public disclosure.*

Indicated or Measured Diamond Resources may be converted to Diamond Reserves through the application of a PFS/FS. Inferred Diamond Resources shall not be converted to Reserves through the application of any Technical Study. This is not to be confused with the situation where Inferred Diamond Resources may be included in an initial assessment of value in a Scoping Study (the CP is referred to Clause 44 of the SAMREC Code for further guidance on the conditions under which Scoping Studies may be reported).

There are no differences in the *standard* of PFS or FS required for secondary or primary diamond deposits. Both categories of study on all diamond deposits are, typically, based on technical and economic data obtained from trial mining which grows seamlessly out of bulk sampling and need not, necessarily, be a separate exercise.

Since conventional macrodiamond processing techniques (for both primary and secondary diamond deposits) are not designed to liberate or recover all contained diamonds, there is no such thing as an '*in-situ'* grade – it is only a processed or recovered grade, which is dependent on the plant or process employed. Therefore, the relative efficiencies of sampling and subsequent mining technologies shall be addressed. In primary deposits, any recovery factors based on microdiamond estimates should also be described. These recovery factors are given more confidence when the results of tailings and tracer audits for the recovery plant in use are presented and discussed.

Due to the discrete nature of diamond mineralisation and the (relatively) large average size of individual diamonds, many projects suffer from theft. Since such theft usually involves the larger and/or better stones, this can have a devastating effect on the project outcome, especially in very low grade settings. As a result, a discussion on 'risk' should include a high level discussion of general security arrangements in and around the diamond recovery plant and the protocols used in the final recovery section to prevent theft of the diamonds.

4.1 Bulk Sampling vs Trial Mining on Alluvial[11] Diamond Deposits

On alluvial deposits, bulk sampling programmes expand into trial mining, which, typically, moves seamlessly into full production mining once the techno-economic or Modifying Factors of the gravels are determined. In the interests of standardised terminology:

- *Bulk sampling* is taken to be the initial period of sampling during which Exploration Targets are investigated and Diamond Resources are identified.
- *Trial mining* is the period during which the relevant mining, processing and other economic factors (the Modifying Factors) are evaluated that may, ultimately, lead to the conversion of some or all of the Indicated Diamond Resources to Probable Diamond Reserves. Trial mining typically forms the basis of the PFS/FS. In certain circumstances (specifically marine projects), trial mining may not always be justifiable and Modifying Factors are, typically, projected from engineering design specifications and historical performance which are then used to estimate production with appropriate ranges which are imported into the financial and risk assessment models.

[11] *Although this section is specifically written for alluvial diamond deposits, many of the principles are applicable to primary and marine deposits as well. Where relevant, the CP should define the specific requirements of the project at hand.*

The methods of mining and processing used in the bulk sampling, trial mining and production mining phases of alluvial operation may be similar (but not necessarily so), except for the volumes processed. Full production is, typically, initiated once Diamond Reserves have been identified. Due to the nature of alluvial diamond deposits, it is often not possible to complete a single-stage PFS that converts all of the Indicated Resources to Probable Reserves. Ongoing production from Diamond Reserve blocks typically acts as a continuous trial mining (PFS/FS) programme for the adjacent Indicated Diamond Resource. Consequently, as mining of existing Probable Diamond Reserves proceeds and as confidence in the geological and mining parameters is upheld (or increases), then surrounding Indicated Diamond Resources can be upgraded to Probable Diamond Reserves on a continual basis, without the need for a separate Technical Study. It is, generally, only in situations where new processing methodologies are introduced (or where any of the Modifying Factors change materially) that an additional PFS/FS may need to be completed.

5 DIAMOND RESERVES

The principles of SAMREC Clauses 34–42 also apply to the estimation of Diamond Reserves[12], where relevant. Especially important in the estimation of Diamond Reserves is the degree of confidence in the diamond revenue model. Note also the implications of SAMREC Clause 32 – if the Modifying Factors should change materially, then Diamond Reserves must be reclassified as Diamond Resources until technical feasibility and economic viability have been established.

A rider to this statement would also imply that a Diamond Reserve estimated on one processing technology may not be applicable to another plant type. With specific reference to alluvial diamond deposits, a Reserve estimated through the use of dense medium separation (DMS) by company A, for example, does not translate into a Reserve based on a rotary pan plant by company B. Furthermore, the Modifying Factors applicable to company A are likely to be very different from those related to company B, especially where the two companies are of vastly different size or operating capacity. Consequently, Modifying Factors shall be determined with the specific project and operator in mind – Modifying Factors and Diamond Reserves are not simply transferable from one operator to another.

It is accepted that mine design and planning may include a proportion of Inferred Diamond Resources. If this category is considered in mine design, planning or economic studies, the results of which are publicly reported, full disclosure shall be made and the effect on the results of the studies shall be stated. Inferred Diamond Resources may be included in mine design, mine planning and economic studies only if a mine plan exists and a statement of Diamond Reserves that states that Inferred Diamond Resources have been used[13]. Where a material amount of mining in the mine plan includes Inferred Diamond Resources, a comparison of the results with and without these Inferred Diamond Resources shall be shown, and the rationale behind their inclusion shall be explained.

Modifying Factors and assumptions that were applied to the Indicated and Measured Diamond Resources to determine the Diamond Reserves shall be equally applied to the Inferred Diamond Resources, if considered as part of the Life of Mine Plan.

Inferred Diamond Resources cannot be converted to Diamond Reserves and shall not be stated as part of the Diamond Reserve.

5.1 Probable Diamond Reserve

SAMREC Clause 70

[12] *Although the term Mineral Reserve is used throughout the SAMREC Code, it is recognised that the term Ore Reserve is still in general use. For the purposes of reporting on diamond deposits, however, the term Diamond Reserve is preferred.*

[13] *Locally, where Inferred Resources have factors applied and are used in mine planning and design, the term 'Scheduled Inferred Resources' has commonly been used. Note that this term is not SAMREC compliant and shall not be used in a statement or tabulation of Diamond Resources/Reserves.*

A 'Probable Diamond Reserve' is the economically mineable part of an Indicated, and in some circumstances, a Measured Diamond Resource. The confidence in the Modifying Factors applying to a Probable Diamond Reserve is lower than that applying to a Proved Diamond Reserve.

A Probable Diamond Resource requires the application of at least a PFS, based on Indicated Diamond Resources. There shall be a reasonable degree of confidence in the diamond revenue model if a Probable Diamond Reserve is declared.

5.2 Proved Diamond Reserve

SAMREC Clause 71 (Proved Diamond Reserve)

A 'Proved Diamond Reserve' is the economically mineable part of a Measured Diamond Resource. A Proved Diamond Reserve implies a high degree of confidence in the Modifying Factors.

There should be high degree of confidence in the diamond revenue model if a Proved Diamond Reserve is declared.

Since a Measured Diamond Resource is the basis for a Proved Diamond Reserve and, since this status is seldom achieved (cf. Clause 69), it follows that a Proved Diamond Reserve classification will rarely be attained.

6 MISCELLANEOUS

1. When referring to sieve sizes, the CP should define and discuss the sizing definition used – DTC, Rubin/Antwerp, Christensen, grainers, nominal square mesh, Tyler mesh, etc. This has important implications for revenue models that are often dependent on a mixture of size classes for the microdiamond and bulk-sample sample recoveries and the valuations on the same parcels. It can be even more significant where SFDs and total diamond count (TDC) models are being constructed – in these cases, the size class lower critical size and average size may be assumed as a generic average but are in reality deposit-specific, depending on stone shapes.

2. With respect to Resource estimation of tailings (residue stockpiles/deposits), the measurement of bulk density is of critical importance. It is also important to differentiate between bulk density and any other measure used and its implication for grade and volume/tonnage estimation.

3. The principles of reporting of diamond projects are applicable to other gemstones as well. It is realised that certain clauses will have greater or lesser application to these deposits. It is expected that the CP will be able to adapt the specifics of the Code to the particular situation, while still adhering to the basic principles. Various industry-specific recommendations exist outside of this forum for the classification of, *inter alia*, tanzanites, emeralds and rubies/sapphires. CPs are encouraged to familiarise themselves with these and refer to them, where appropriate.

4. Valuation of diamond and other precious stones projects shall only be done in accordance with the provisions of the SAMVAL Code and shall be based on a SAMREC/CRIRSCO compliant Diamond Resource/Reserve estimate. There are no differences in the *standard* of valuations between diamond projects and any other commodities. It is significant, however, that transactions on alluvial diamond properties often occur very early in the life of the mine, typically prior to the estimation of Diamond Resources. This does not mean that they have no value, but rather that such projects shall not be valued by Income Approach methodologies. Rather, Market and Cost Approaches are more applicable in the pre-Resource stages of these operations. It is notable that, for alluvial diamond properties, each of these approaches has specific peculiarities, which the Competent Valuer (CV) needs to be aware of.

- Although Income-based valuation methods are by far the most satisfactory appraisals of value, they are not appropriate for properties without Diamond Resources. They are best applied after the conclusion of Scoping and PFS/FS Studies.
- The application of Discount Rates to alluvial diamond properties should be no different from that applied to other mineral commodities. However, special care has to be exercised in the matter of 'Resource Risk'. The basis of the discounted cash flow (DCF) is the Diamond Resource/Reserve statement. A core issue with many alluvial diamond projects is the tendency for the CP to force as much as possible of the available volume, grade and value of the project into the Indicated Resource category. This is done so as to take advantage of the fact that Indicated Resources can be converted to Probable Reserves through a PFS and then valued by DCF. This is, fundamentally, a problem for the CP in the statement of the Resources/Reserve estimate. However, the CV should be aware that this situation is likely to occur in many circumstances and should, therefore, satisfy himself/herself that the Resource/Reserve estimation has been done with due cognisance of the issues peculiar to alluvial diamond deposits.
- Notwithstanding, the DCF based on Indicated Diamond Resources converted to Probable Reserves through the application of PFS/FS, is the preferred method of valuation for an alluvial diamond project. Even where such can be constructed, however, the inherent complexities of alluvial diamond deposits coupled with an imperfect understanding of the resource estimation procedure could result in the application of incorrect discount rates.
- The peculiarities of alluvial diamond Resource/Reserve estimations can also result in low NPV and IRR values that might not reflect the true value of the project.

5. It is recommended that the CP consider all of the papers presented in the Companion Volume for additional background and guidance – not only those in the Diamond Section.

6. Supplementary industry guidelines on the estimation and reporting of Diamond Exploration Results, Diamond Resources and Diamond Reserves published in other jurisdictions may be useful and the CP is encouraged to consult them for further information. Such guidelines, however, will not, under any circumstances, override the provisions and intentions of the SAMREC Code and this Guideline Document.

7. The CP is also referred to Appendix 1 of the SAMREC Code for guidance in compiling a table of contents for a CPR on a diamond project/property, which must be read in conjunction with the SAMREC Code, Table 1 and this Guideline Document. The headings of the chapters are provided here for guidance only to ensure that all of the requirements of SAMREC Table 1 are incorporated. CPs may select to use their own headings and sub-headings, as relevant.

19 November 2015

APPENDIX 1

RECOMMENDED TABLE OF CONTENTS FOR COMPETENT PERSON'S REPORT (CPR) FOR DIAMOND DEPOSITS

This table of contents is given only as a guide to the compilation of CPRs. It is designed to incorporate all of the requirements of Table 1. It must be read in conjunction with Table 1 and the Code.

Title Page
Include a title page setting out the title of the CPR, the general location of the diamond project, the name and professional designation of each CP, the effective date of the CPR and the date of signature.

Executive Summary
Briefly summarise important information in the CPR, including property description and ownership, geology and mineralisation, the status of exploration, development and operations, Diamond Resource and Diamond Reserve estimates, and the CP's conclusions and recommendations.

Table of Contents
Provide a table of contents listing the contents of the CPR, including figures and tables.

1 Introduction

- Terms of reference and scope of work
- Sources of information (not to be confused with Reference List – see Chapter 13)
- Units and currency
- Site inspection or field involvement of CP(s)
- Limited disclaimers and reliance on other experts or third party information

2 Project Outline

- Property description
- Property location
- Country profile
- Legal aspects and permitting
- Royalties and liabilities

3 Accessibility, Physiography, Climate, Local Resources and Infrastructure

- Topography, elevation and fauna/flora
- Climate and weather
- Access
- Proximity to population centres
- General infrastructure

4 Project History

- Previous ownership
- Previous exploration and/or development
- Previous Diamond Resource Estimates
- Previous Diamond Reserve Estimates
- Previous Production

Compliance or noncompliance with the SAMREC Code or other international reporting code must be included in the discussion on previous Exploration Results, Resource and/or Reserve estimation. This section may also include a discussion of relevant historical estimates.

5 Geological Setting, Mineralisation and Deposit Types

- Geological setting (regional and local)
- Nature of, and controls on, mineralisation
- Deposit type
- Geological models
- Nature of deposits on the property

6 Exploration Data/Information

- Remote sensing data interpretation
- Geophysics
- Mapping
- Structural studies
- Drilling
- Sampling
- Indicator mineral studies
- Bulk sampling
- Trial mining
- Database management
- QA/QC analysis
- Survey data
- Data verification, audits and reviews

7 Diamond Resource Estimates

- Estimation and modelling techniques
- Diamond Resource classification criteria
- Reasonable prospects for eventual economic extraction
- Diamond Resource statement
- Diamond Resource reconciliation

8 Technical Studies

Scoping Studies, Pre-Feasibility Studies, Feasibility Studies (and ongoing life-of-mine studies) analyse and assess the same geological, engineering, and economic factors with increasing detail and precision. Therefore, the same criteria may be used as a framework for reporting the results of all three studies.
Scoping Studies shall not convert Inferred Diamond Resources to Diamond Reserves.
Technical studies shall not include Diamond Exploration Targets or Diamond Mineralisation.

- Geotechnical and geohydrology
- Mine design and schedule
- Metallurgical
- Project infrastructure
- Market studies and contracts
- Environmental studies
- Legal and permitting
- Taxation
- Social or community impact
- Mine closure
- Risk assessment
- Capital and operating costs
- Economic criteria
- Financial analysis

9 Diamond Reserve Estimates

- Estimation and modelling techniques
- Diamond Reserve classification criteria
- Diamond Reserve statement
- Diamond Reserve reconciliation

10 Other Relevant Data and Information

- Adjacent properties
- Risk assessments (including a high level discussion of issues surrounding diamond theft)

11 Interpretation and Conclusions

Summarise the relevant results and interpretations of the information and analysis being reported on. Discuss any significant risks and uncertainties that could reasonably be expected to affect the reliability or confidence in

the Exploration Results, Diamond Resource or Diamond Reserve estimates, or projected economic outcomes. Discuss any reasonably foreseeable impacts of these risks and uncertainties to the project's potential economic viability or continued viability. A CPR concerning exploration information must include the conclusions of the CP.

12 Recommendations

Provide particulars of recommended work programmes and a breakdown of costs for each phase. If successive phases of work are recommended, each phase must culminate in a decision point. The recommendations must not apply to more than two phases of work. The recommendations must state whether advancing to a subsequent phase is contingent on positive results in the previous phase. In some specific cases, the CP may not be in a position to make meaningful recommendations for further work. Generally, these situations will be limited to properties under development or in production where material exploration activities and engineering studies have largely concluded. In such cases, the CP should explain why they are not making further recommendations.

13 References

Include a list of all references cited in the CPR.

14 Appendices

- Relevant supporting information
- Glossary of terms
- Abbreviations
- Compliance statement and certificate of competence
- Consent form (if relevant)

Date and Signature Page

The CPR must have a signature page (at either the beginning or end of the CPR). The effective date of the CPR and date of signing must be on the signature page.

SAMESG

THE SOUTH AFRICAN GUIDELINE FOR THE REPORTING OF ENVIRONMENTAL, SOCIAL AND GOVERNANCE PARAMETERS WITHIN THE MINING AND OIL AND GAS INDUSTRIES

(THE SAMESG GUIDELINE)

2015 EDITION

Prepared by

The South African Environmental, Social and Governance (SAMESG) Committee Working Group

APPENDIX 1

Appendix 1 of the SAMESG Guideline defines all terminology associated with the Guideline and its interpretation.

The definitions provided have been sourced from the various internationally recognised institutions referenced in the SAMESG Guideline. For the purposes of this document, these institutions include:

- Agenda 21
- The Global Reporting Initiative (GRI)
- The United Nations Global Compact (UNGC)
- The Carbon Disclosure Project
- The International Organization for Standardization (ISO)
- The World Bank Group Equator Principles (EP)
- The International Finance Corporation (IFC) Sustainability Framework
- The Principles for Responsible Investment (PRI)
- The International Corporate Governance Network (ICGN).

Appendix 1 of the SAMESG Guideline will be amended from time to time to reflect updated opinions and findings arising from the internationally recognised institutions, to recognise and include additional institutions, where relevant, and to provide clarity on terminology where this is deemed necessary for the accurate compilation of Public Reports.

Agenda 21	Agenda 21 refers to the principles of Sustainable Development adopted as action plans at the 1992 Earth Summit held in Rio de Janeiro in 1992.
Carbon Disclosure Project (CDP)	The Carbon Disclosure Project is an organisation based in the United Kingdom that works with shareholders and corporations to disclose the greenhouse gas emissions of major corporations.
Conformance Audits	Conformance audit is an audit process that assesses the fulfilment of a requirement in respect of an Environmental, Social and Governance (ESG) management system in place at the reporting entity.
Compliance Audits	An ESG compliance audit is an investigation of the legal compliance status of a facility and/or the extent of ESG liability. This process is a systematic, documented evaluation of a project target, focusing on current operating and administrative legal procedures, processes and compliance records. The outcome is an evaluation of compliance against legal requirements.
Competent Person	A Competent Person (CP) is person who is registered with South African Council for Natural Scientific Professions (SACNASP), Engineering Council of South Africa (ECSA) or the South African Council for Professional and Technical

	Surveyors (PLATO), or is a Member or Fellow of the South African Institute of Mining and Metallurgy (SAIMM), the Geological Society of South Africa (GSSA) or a Recognised Overseas Professional Organisation (ROPO).
Competent Person's Report (CPR)	A CPR is a technical report prepared by a Competent Person (CP). The contents are determined by the nature/status of the project/mine being reported.
Environmental, Social and Governance (ESG)	The PRI, GRI, EP, International Finance Corporation Performance Standards (IFC PS) and UNGC note that a definitive list of ESG issues does not exist. The PRI continues by stating that any such list would inevitably be incomplete and would soon be out of date. However, for the purposes of this version of the SAMESG Appendix, ESG has been defined in accordance with the PRI broad classification: i. Environmental (E): Issues relating to the quality and functioning of the natural environment and natural systems. These include: biodiversity loss; greenhouse gas (GHG) emissions; climate change; renewable energy; energy efficiency; air, water or resource depletion or pollution; waste management; stratospheric ozone depletion; changes in land use; ocean acidification; and changes to the nitrogen and phosphorus cycles. ii. Social (S): Issues relating to the rights, well-being and interests of people and communities. These include: human rights; labour standards in the supply chain; child, slave and bonded labour; workplace health and safety; freedom of association and freedom of expression; human capital management and employee relations; diversity; relations with local communities; activities in conflict zones; health and access to medicine; HIV/AIDS; consumer protection; and controversial weapons. iii. Governance (G): Issues relating to the governance of companies and other investee entities. In the listed equity context these include: board structure, size, diversity, skills and independence; executive pay; shareholder rights; stakeholder interaction; disclosure of information; business ethics; bribery and corruption; internal controls and risk management; and, in general, issues dealing with the relationship between a company's management, its board, its shareholders and its other stakeholders. This category may also include matters of business strategy, encompassing both the implications of business strategy for environmental and social issues, and how the strategy is to be implemented. In the unlisted asset classes governance issues also include matters of fund governance, such as the powers of Advisory Committees, valuation issues, fee structures, etc.
Equator Principles	The Equator Principles is a risk management framework adopted by financial institutions for determining, assessing and managing environmental and social risk in projects and is primarily intended to provide a minimum standard for due diligence to support responsible risk decision - making.
Extractive/s Industry	Any processes that involve the extraction of raw materials from the Earth to be used by consumers. The extractive industry consists of any operations that remove metals, mineral and aggregates from the Earth. Examples of extractive processes include oil and gas extraction, mining, dredging and quarrying.
Global Reporting Initiative (GRI)	The Global Reporting Initiative (GRI) is a non-governmental sustainability organisation that promotes the use of sustainability reporting as a way for organisations to become more sustainable and contribute to sustainable development.

International Finance Corporation (IFC) Sustainability Framework	The IFC's Sustainability Framework articulates the Corporation's strategic commitment to sustainable development, and is an integral part of IFC's approach to risk management. The Sustainability Framework comprises the IFC's Policy and Performance Standards on Environmental and Social Sustainability, and IFC's Access to Information Policy
International Organization for Standardization (ISO)	The ISO is an independent, non-governmental membership organisation and the world's largest developer of voluntary international standards.
International Corporate Governance Network (ICGN)	The ICGN is an investor-led organisation of governance professionals that supports the development of policy, connects peers and facilitates cross-border communication, and informs dialogue amongst corporate governance professionals through the publication of policies and principles.
Materiality	Definitions of materiality can centre on valuation-based decisions by shareholders, on broader interests of shareholders, or on the perspectives of a wider set of stakeholders combined with assessments of the company's positive and negative impacts on society. For the purposes of ESG reporting, the following constitutes a material issue: i. On the results of a comprehensive impact assessment, the level of impact within the mine's pre-defined Zone of Influence (ZoI) has been rated as a significant impact. These impacts are those that are still significant *post* mitigation action (should a competent EIA process be undertaken, in which a suitable impact assessment has been performed), or those impacts that cannot be mitigated; ii. Any relocation/resettlement of a community (number of households to be resettled is irrelevant); iii. Any permanent loss of ecosystem functionality (irrespective of area of impact), with specific focus towards sensitive ecosystems in critical biodiversity areas; iv. An issue that contravenes a legal requirement that can or will result in the issuance of directives, penalties, suspension of authorisations and/or prosecution; and v. Any major finding from a conformance audit.
Natural Gas	Natural gas means a naturally occurring mixture of hydrocarbon gases and non-hydrocarbon gases.
Principles for Responsible Investment	The United Nations-supported Principles for Responsible Investment (PRI) Initiative is an international network of investors working together to put the six Principles for Responsible Investment into practice. Its goal is to understand the implications of sustainability for investors and support signatories to incorporate these issues into their investment decision-making and ownership practices
Public Reports	Public Reports are all those reports prepared for the purpose of informing investors or potential investors and their advisers and include, but are not limited to, companies' annual reports, quarterly reports and other reports included in Johannesburg Securities Exchange (JSE) circulars or as required by the Companies Act.

Recognised Claims	Recognised claims are claims that have been lodged against the project target and which are the subject of pending criminal proceedings, civil litigation proceedings, mediation or arbitration proceedings. Recognised claims also include claims that are the subject of settlement negotiations between the target, relevant authorities, persons or entities.
Reporting Entities	Reporting entities are all entities (including economic entities) in respect of which it is reasonable to expect the existence of users dependent on general purpose financial reports for information that will be useful to them for making and evaluating decisions about the allocation of scarce resources.
Reserve	A Reserve is the economically mineable material derived from a Measured or Indicated Resource or both. It includes diluting and contaminating materials and allows for losses that are expected to occur when the material is extracted. Appropriate assessments to a minimum of a Pre-Feasibility Study for a project and a Life of Mine Plan for an operation must have been completed, including consideration of, and modification by, realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors (the Modifying Factors). Such Modifying Factors must be disclosed.
Resource	A Resource is a concentration or occurrence of material of economic interest in or on the Earth's crust in such form, quality and quantity that there are reasonable and realistic prospects for eventual economic extraction.
SAMESG Guideline	The guideline for the reporting of Environmental, Social and Governance parameters within the Mining and Oil and Gas industries.
SAMOG Code	The South African Code for the Reporting of Oil and Gas Resources.
SAMREC Code	The South African Code for Reporting of Exploration Results, Mineral Resources and Mineral Reserves.
SAMVAL Code	The South African Code for the Reporting of Mineral Asset Valuation.
Social	The environment developed by humans as contrasted with the natural environment; society as a whole, especially in its relation to the individual.
Sustainable Development	The Brundtland Commission's report defines sustainable development as "*development which meets the needs of current generations without compromising the ability of future generations to meet their own needs*". The concept supports strong economic and social development, in particular for people with a low standard of living. At the same time it underlines the importance of protecting the natural resource base and the environment. Economic and social wellbeing cannot be improved through measures that destroy the environment. Intergenerational solidarity is also crucial: all development has to take into account its impact on the opportunities for future generations.
Sustainable Development Indicators	The most recent United Nations Corporate Sustainable Development (CSD) indicators contain a core set of 50 indicators. These core indicators are part of a larger set of 96 indicators of sustainable development. The introduction of a core set helps to keep the indicator set manageable, whereas the larger set allows the inclusion of additional indicators that enable countries to do a more comprehensive and differentiated assessment of sustainable development. Core indicators fulfil three criteria. Firstly, they cover issues that are relevant for sustainable development in most countries. Secondly, they provide critical information not available from other core indicators. Thirdly, they can be calculated by most countries with data that is either readily available or could be made available within

	reasonable time and costs. Conversely, indicators that are not part of the core are either relevant only for a smaller set of countries, provide complementary information to core indicators, or are not easily available for most countries. Sustainable Development Indicator Themes recognised by the United Nations as the most updated CSD Themes are: Poverty • Governance • Health • Education • Demographics • Natural hazards • Atmosphere• Land • Oceans, seas and coasts • Fresh water • Biodiversity • Economic development • Global economic partnership • Consumption and production patterns.
Technical Specialist	A Technical Specialist is a person who is registered with SACNASP, ECSA or PLATO, or is a Member or Fellow of the SAIMM, the GSSA or a Recognised Overseas Professional Organisation (ROPO). A complete list of recognised organisations will be promulgated by the SAMREC/SAMVAL Committee (SSC) from time to time. The Competent Person must comply with the provisions of the relevant promulgated Acts. A Technical Specialist must have a minimum of five years' experience relevant to the industry and associated reporting requirements within the SAMESG Guideline. Persons being called upon to sign as a Technical Specialist must, within the context of this definition, be clearly satisfied in their own minds that they are able to face their peers and demonstrate competence.
Transparency	The reader of a Public Report must be provided with sufficient information, the presentation of which is clear and unambiguous, to understand the report and not be misled.
United Nations Global Compact (UNGC)	The UN Global Compact is a strategic policy initiative for businesses that are committed to aligning their operations and strategies with ten universally accepted principles in the areas of human rights, labour, environment and anti-corruption.
Zone of Influence	The area within which the project target has or can have material impacts or can influence impacts due to its activities, products or services. Typically the Zone of Influence is unique to each project, is larger than the actual project footprint, and encompasses: i. The area of direct disturbance. This would include the 'footprints' of areas immediately adjacent to the primary and service infrastructure, such as power lines, pipelines, roads, railway lines, conveyors, borrow pits, disposal areas, construction camps, etc. ii. The area directly affected by the project's material adverse impacts, such as groundwater cones of depression, groundwater pollution plumes, etc. iii. The area affected by secondary, induced or cumulative impacts. (Secondary impacts arise from other impacts that are directly due to the development, e.g. loss of fisheries due to water contamination. Induced impacts are due to unplanned/unintended/secondary activities that are 'catalysed' by the project, e.g. illegal logging along access routes. Cumulative impacts are a result of numerous individual activities, which might not be material on their own but which can interact or combine to cause material impacts). iv. The development's primary labour-sending and money-spending area(s), i.e. the towns and communities that are likely to experience economic benefits from the project. v. Surrounding areas that could potentially benefit from the project, such as sites of high biodiversity, protected areas, etc.

Associated facilities should also be considered when determining the zone of influence. These are facilities that are funded separately by the company or third parties (e.g. government), but whose viability and existence depend (almost) exclusively on the project and whose goods or services are essential for the successful operation of the project.

SAMESG

THE SOUTH AFRICAN GUIDELINE FOR THE REPORTING OF ENVIRONMENTAL, SOCIAL AND GOVERNANCE PARAMETERS WITHIN THE MINING AND OIL AND GAS INDUSTRIES

(THE SAMESG GUIDELINE)

2015 EDITION

Prepared by

The South African Environmental, Social and Governance Committee (SAMESG) Working Group

FOREWORD

The South African Guideline for the reporting of Environmental, Social and Governance (ESG) Parameters within the Mining and Oil and Gas industries (the SAMESG, or the Guideline) defines the minimum standards, recommendations and guidelines for Public Reporting of ESG matters in the extractive industries (inclusive of mining and oil and gas).

The intention of this Guideline is to ensure that reporting entities provide adequate information on ESG matters that relate to their influence on the reasonable and realistic prospects for eventual economic extraction of the specific commodity being reported.

The SAMESG Guideline has been written in alignment with the existing SAMREC, SAMVAL and SAMOG Codes, and considers the appropriate detail of ESG studies required when declaring Resources and Reserves for the mining and oil and gas industries in Southern Africa**.**

The evolution of the SAMESG Guideline follows that of the SAMVAL, SAMREC and SAMOG Codes. Concurrently, the Committee for Mineral Reserves International Reporting Standards (CRIRSCO), initially a Committee of the Council of Mining and Metallurgical Institutions (CMMI), has, since 1994, been working to create a set of standard international definitions for reporting mineral and oil and gas Resources and Reserves.

As a result of the CRIRSCO/CMMI initiative, considerable progress has been made towards widespread adoption of globally consistent reporting standards. These are embodied in similar guidelines and standards published and adopted by the relevant professional bodies around the world.

The SAMESG Guideline has been drafted by the working group of the SAMESG Committee, with input from the SAMREC, SAMVAL and SAMOG (SSC) committees, under the joint auspices of the Southern African Institute of Mining and Metallurgy (SAIMM) and the Geological Society of South Africa (GSSA).

The SSC consists of representatives of the:

- Southern African Institute for Mining and Metallurgy (SAIMM)
- Geological Society of South Africa (GSSA
- South African Council for Natural Scientific Professions (SACNASP)
- Geostatistical Association of South Africa (GASA)
- South African Council for Professional Land Surveyors and Technical Surveyors (PLATO)
- Association of Law Societies of South Africa
- General Council of the Bar of South Africa
- Department of Minerals and Resources (DMR)
- JSE Limited (JSE)
- Council for Geoscience
- South African Council of Banks
- Minerals Bureau
- Chamber of Mines of South Africa (COM)
- South African Institute of Chartered Accountants (SAICA)
- University of the Witwatersrand.

ENVIRONMENTAL, SOCIAL AND GOVERNANCE CONTEXT

Numerous organisations have moved towards greater transparency when disclosing Environmental, Social and Governance (ESG) information in recent years, and have contributed greatly through the development of industry-specific technical standards.

Many internationally recognised institutions have developed extensive guidance frameworks for the adoption of accepted best practice across industry. The movement towards achieving a better standard of practice arises from the Principles and Intentions of Agenda 21.

A key driver for organisations to adopt ESG reporting is that more investors are incorporating ESG criteria into their valuations and investment strategies. Many exchanges are also introducing different measures to encourage or require ESG reporting. Within the context of the South African reporting environment, the JSE Sustainability Reporting Index (SRI) is the recognised exchange body that regulates ESG reporting on the South African Securities Exchange.

Included within the internationally acknowledged ESG standards and frameworks are:

- The Global Reporting Initiative (GRI), a widely-used reporting framework that sets out principles and performance indicators for companies to report on ESG performance.
- The Carbon Disclosure Project, a reporting system through which companies disclose greenhouse gas emissions, water management and climate change strategies.
- The United Nations Global Compact, a sustainability initiative for companies to align their strategies and operations in the areas of human rights, labour, environment and anti-corruption.

Technical standards which this Guideline acknowledges and promotes include the International Organization for Standardization (ISO), the World Bank Group Equator Principles, the Principles for Responsible Investment, and the International Finance Corporation Sustainability Framework. These principles and technical standards include the internationally accepted industry-specific Environmental, Health and Safety Guidelines to which this Guideline refers.

There are also the OECD Guidelines for Multinational Enterprises, which comprise a set of recommendations to multinational enterprises in all the major areas of business ethics. The ISO 26000 Guidance on Social Responsibility addresses seven core subjects of social responsibility and includes proposals for integrated reporting, which link an organisation's strategy, governance and financial performance and the social, environmental and economic context within which it operates.

The Code for Responsible Investing in South Africa (CRISA) provides in Principle 3 that "where appropriate, institutional investors should consider a collaborative approach to promote acceptance and implementation of the principles of this Code and other codes and standards applicable to institutional investors". This correlates with the UN-backed Principles for Responsible Investment (PRI) launched in March 2006. These principles encourage collaborative engagement to improve incorporate environmental, social and governance issues in decision-making and ownership practices. There are similar recommendations for engagement, stakeholder consulting, working jointly, collective action, etc. in the King Report on Governance for South Africa, 2009; and the International Corporate Governance Network (ICGN) – Statement of Principles on Institutional Shareholder Responsibilities.

Under these circumstances, the SAMESG Working Group has prepared a set of rules and guidelines recognising the international standards for best ESG practice and guidelines. These rules inform reports prepared by a *reporting entity* which support the determination of significant ESG aspects in the extractive industries and which have the potential to influence the reasonable and realistic prospects for eventual economic extraction.

PART I

GENERAL APPLICATION

The SAMESG Guideline provides the basis for minimum disclosure of information for Public Reporting of environmental, social and governance parameters when reporting on mining and oil and gas reserves and resources. Such reports must comply with this Guideline and report in the manner prescribed herein.

The definitions contained in Appendix 1 relate to the interpretation and application of this Guideline.

This Guideline recognises the following:

1. The level of detail required for each reporting requirement (or item) increases throughout the project development phases from pre-conceptual through to operational phase and ultimately closure.
2. Project evaluation phases can overlap with the exploration phase, especially when expansion projects take place immediately adjacent to operational mines and oil and gas operations.
3. While the format of the SAMREC and SAMOG codes is adopted to ensure alignment with the Resource classifications applied, some ESG data will overlap all areas of a possible project target and not align exclusively to the Resource classifications as mapped geographically. In other words it is possible to complete detailed ESG baseline assessments over an entire project area even if the level of Resource classification is quite low.
4. Costing information to address a material ESG issue may be considered commercially sensitive. For this reason, high- level costs (for example, those to manage a subset of the ESG mitigation costs) may be included in the report if appropriate.
5. Where a project has progressed to the implementation phase and beyond, then the reporting requirements default to those for Reserves for the entire project area.

PART II

COMPETENCIES AND RESPONSIBILITY

Documentation detailing the material ESG reporting matters described in this Guideline must be prepared by, or under the supervision of, a Technical Specialist and signed by a Competent Person as referred to in the SAMREC Code.

Where any specific documentation is referred to in a Public Report, the written consent of the author must be obtained as to the form, content and context in which that documentation is to be included in the Public Report.

Complaints made in respect of the Public Report of the Technical Specialist will be dealt with under the disciplinary procedures of the SSC or under the relevant ROPO agreement.

PART III

SPECIFIC ITEMS REQUIRED FOR THE SAMESG GUIDELINE

The SAMESG Guideline requires that preparers of mining and oil and gas Public Reports comply with this Guideline.

PART IV

REQUIREMENTS APPLICABLE TO PUBLIC DISCLOSURE

Application of Part IV – this Part applies to disclosures made by or on behalf of a *reporting entity:*

1. To the public; or
2. In other circumstances in which, at the time of making the disclosure, the reporting entity knows, or ought reasonably to know, that the disclosure is or will become available to the public.

PART V

REPORTING CRITERIA IN ACCORDANCE WITH THE EXISTING SAM CODES

The SAMESG Guideline is intended to serve as a supplement to the description of Modifying Factors as defined in the SAMREC and SAMOG Codes.

GENERAL INSTRUCTIONS

1. To the extent that any Item or any component of an Item specified in this Guideline does not apply to a reporting entity and its activities and operations, or is not material, reference must be made as to why that Item or component is not applicable or not material.

2. This Guideline sets out minimum reporting requirements. A reporting entity may provide additional information not required by this Guideline provided that it is not misleading and not inconsistent with the requirements of the Guideline, and provided that material information required to be disclosed is not omitted.

PART 1

GENERAL REPORTING REQUIREMENTS

DATE OF STATEMENT

Item 1.1 Relevant Dates

1. Date of the statement.

2. Disclose the effective date of the information provided.

3. Disclose the preparation date of the information provided.

4. The frequency of reporting for matters arising in this Guideline should reflect the same dates of appraisal as the SAM Codes, include all new listings, and should consider information that, where relevant, is not older than 1 (one) year from the time of reporting. For the purposes of understanding significant and existing trends, information older than 1 (one) year must be included.

INSTRUCTIONS

1. The same effective date applies to each category reported.

2. The preparation date, in respect of written disclosure, means the most recent date to which information relating to the period ending on the effective date was considered in the preparation of the disclosure. The preparation date is a date subsequent to the effective date. This is because it takes time to assemble the report for the reporting period after the finalisation of information required for disclosure as at the effective date.

3. If the reporting entity provides information as at a date more recent than the effective date, in addition to the information required as at the effective date, also disclose the date at which that additional information is provided. The provision of such additional information does not relieve the reporting entity of the obligation to provide information as at the effective date

PART 2

REQUIREMENTS FOR THE DISCLOSURE OF ESG PARAMETERS WHEN REPORTING EXPLORATION RESULTS

Item 2.1 General

1. Provide a description of organisational structure, systems, policies, procedures and management plans, and governance procedures in place to manage ESG issues.

Item 2.2 Key plans, maps and diagrams

1. Provide a map that identifies the locality of sensitive receptors within the prospecting right area and at least the zone of influence of the site. All surface water features to be included on maps.

2. Describe the location of any sensitive areas within and around the project area, including within the prospecting right area and within the zone of influence of the site.

Item 2.3 Legal aspects

1. Outline the applicable ESG legal compliance requirements and any mandatory and/or voluntary standards or guidelines to which the project target subscribes.

2. Identify the ESG permits, authorisations and licences that have been issued to the project target as well as those permits, authorisations and licences that that have been identified as required but not yet applied for or issued. Motivate whether there is a reasonable basis to believe that all ESG permits, authorisations and licences can be obtained.

3. Provide a description of any recognised claims received during the reporting period.

4. Provide a description of any penalties, fines and damages that are due and payable by the project target in response to an order of court, decision by a mediator or a decision by an arbitrator, whether or not subject to an appeal process.

5. Provide a description of any pending administrative enforcement action such as, but not limited to, directives or compliance notices instituted against the project target, including any notice received by the project target of the intention of any authority concerned with the regulation of ESG matters to issue a directive or compliance notice, whether or not such pre-compliance notice or compliance notice has been suspended pending corrective action.

6. Provide a description of any known future financial liabilities that arise by virtue of recognised claims, penalties, fines, damages and administrative enforcement action that will become due and payable in future, including the due date for payment.

Item 2.4 Environmental parameters

1. Provide a high level analysis of the environmental context within which the project is located and give an appropriate analysis of the material aspects and impacts that may need consideration. Include issues that are likely to remain material despite the implementation of proposed mitigation measures.

2. Describe, assess and prioritise the risks associated with any obvious environmental factors that could result in a material modification to the planned exploration programme.

Item 2.5 External social and political parameters

1. Provide a high level analysis of the external social and political context within which the project is located.

2. Describe and prioritise current social and political risks, and potential risks taking into account how exploration activities may exacerbate or mitigate existing risks.

3. Report on any social and political issues that may have a material effect on the planned exploration programme. Include issues that are likely to remain material despite the implementation of proposed mitigation measures.

Item 2.6 Internal social parameters

1. Describe and assess the risks associated with any obvious internal social factors and/or specific contextual details that could have a material effect on the planned exploration programme.

Item 2.7 Conformance and compliance audits

1. Provide a description of legal compliance audits undertaken during the period, including a summary of material findings and management plans to address these findings.

2. Provide a description of ESG management system conformance audits undertaken during the reporting period, including a summary of material findings and management plans to address these findings.

Item 2.8 ESG liability

1. Describe the project target's closure plans and obligations, social obligations, rehabilitation activities, remaining material liability and compliance costs.

2. Provide a description of mechanisms in place to address unplanned closure

Item 2.9 Risk analysis process

1. Provide a description of the risk assessment process that has been undertaken to identify material ESG issues. Describe programmes in place to continuously update and monitor identified material ESG issues.

2. Describe how the risk assessment process is integrated with the overall risk management framework.

PART 3

REQUIREMENTS FOR THE DISCLOSURE OF ESG PARAMETERS WHEN REPORTING ON RESOURCES

Item 3.1 General

1. Provide a description of organisational structure, systems, policies, procedures and management plans, and governance procedures in place to manage ESG issues.

Item 3.2 Key plans, maps and diagrams

1. Provide a map that identifies the locality of sensitive receptors within the prospecting right area and at least the zone of influence of the site. All surface water features to be included on maps.

2. Identify and describe the location of any sensitive areas within and around the project area, including within the prospecting right area and within the zone of influence of the site.

Item 3.3 Legal aspects

1. Outline the applicable ESG legal compliance requirements and any mandatory and/or voluntary standards or guidelines to which the project target subscribes.

2. Identify the ESG permits, authorisations and licences that have been issued to the project target as well as those permits, authorisations and licences that have been identified as required but not yet applied for or issued. Motivate whether there is a reasonable basis to believe that all ESG permits, authorisations and licences can be obtained.

3. Provide a description of any recognised claims received during the reporting period.

4. Provide a description of any penalties, fines and damages that are due and payable by the project target in response to an order of court, decision by a mediator or a decision by an arbitrator, whether or not subject to an appeal process.

5. Provide a description of any pending administrative enforcement action such as, but not limited to, directives or compliance notices instituted against the project target, including any notice received by the project target of the intention of any authority concerned with the regulation of ESG matters to issue a directive or compliance notice, whether or not such pre-compliance notice or compliance notice has been suspended pending corrective action.

6. Provide a description of any known future financial liabilities that arise by virtue of recognised claims, penalties, fines, damages and administrative enforcement action that will become due and payable in future, including the due date for payment.

Item 3.4 Environmental parameters

1. Provide an appropriate analysis of the environmental context within which the project is located. Give an appropriate analysis of the material aspects and impacts that may need consideration, including how existing activities may exacerbate or mitigate existing aspects and impacts.

2. Describe, assess and prioritise the risks associated with any obvious environmental factors that could result in a material modification to the planned resources programme. Focus on issues that are likely to remain significant despite the implementation of proven and economically viable mitigation measures.

Item 3.5 External social and political parameters

1. Provide an appropriate analysis of the external social and political context within which the project is located.

2. Describe and prioritise current social and political risks, and potential risks taking into account how activities may exacerbate or mitigate existing risks.

3. Report on any social and political issues that may have a material effect on the planned resource programme. Include issues that are likely to remain material despite the implementation of proposed mitigation measures.

Item 3.6 Internal social parameters

1. Describe, assess and prioritise the risks associated with any obvious internal social factors and/or specific contextual details that could have a material effect on the planned resources programme.

Item 3.7 Conformance and compliance audits

1. Provide a description of legal compliance audits undertaken during the period, including a summary of material findings and management plans to address these findings.

2. Provide a description of ESG management system conformance audits undertaken during the reporting period, including a summary of material findings and management plans to address these findings.

Item 3.8 ESG liability

1. Describe the closure plans and obligations, social obligations, rehabilitation plan, activities, remaining liability and compliance costs.

2. Provide a description of mechanisms in place to address unplanned closure.

Item 3.9 Risk analysis process

1. Provide a description of the risk assessment process that has been undertaken to identify material ESG issues. Describe programmes in place to continuously update and monitor identified material ESG issues.

2. Describe how the risk assessment process is integrated with the overall risk management framework.

PART 4

REQUIREMENTS FOR THE DISCLOSURE OF ESG PARAMETERS WHEN REPORTING ON RESERVES

Item 4.1 General

1. Provide a description of organisational structure, systems, policies, procedures and management plans, and governance procedures in place to manage ESG issues.

Item 4.2 Key plans, maps and diagrams

1. Provide a map that identifies the locality of sensitive receptors within the prospecting right are and at least the zone of influence of the site. All surface water features to be included on maps.

2. Identify and describe the location of any sensitive areas within and around the project area within the prospecting right and within the zone of influence of the site.

Item 4.3 Legal aspects

1. Outline the applicable ESG legal compliance requirements and any mandatory and/or voluntary standards or guidelines to which the project target subscribes.

2. Identify the ESG permits, authorisations and licences that have been issued to the project target as well as those permits, authorisations and licences that have been identified as required but not yet applied for or issued. Motivate whether there is a reasonable basis to believe that all ESG permits, authorisations and licences can be obtained.

3. Provide a description of any recognised claims received during the reporting period.

4. Provide a description of any penalties, fines and damages that are due and payable by the project target in response to an order of court, decision by a mediator or a decision by an arbitrator whether or not subject to an appeal process.

5. Provide a description of any pending administrative enforcement action such as but not limited to, directives or compliance notices instituted against the project target, including any notice received by the project target of the intention of any authority concerned with the regulation of ESG matters to issue a directive or compliance notice, whether or not such pre-compliance notice or compliance notice has been suspended pending corrective action.

6. Provide a description of any known future financial liabilities that arise by virtue of recognised claims, penalties, fines, damages or administrative enforcement action that will become due and payable in future, including the due date for payment.

Item 4.4 Environmental parameters

1. Provide an appropriate analysis of the environmental context within which the project is located. Give an appropriate analysis of the material aspects and impacts that may need consideration, including how existing activities may exacerbate or mitigate existing aspects and impacts.

2. Describe, assess and prioritise the risks associated with any obvious environmental factors that could result in material modification to the planned resources programme. Focus on issues that are likely to remain significant despite the implementation of proven and economically viable mitigation measures.

Item 4.5 External social and political parameters

1. Provide an appropriate analysis of the external social and political context within which the project is located.

2. Describe and prioritise current social and political risks, and potential risks taking into account how activities may exacerbate or mitigate existing risks.

3. Report on any social and political issues that may have a material effect on the planned reserve programme. Include issues that are likely to remain material despite the implementation of proposed mitigation measures.

Item 4.6 Internal social parameters

1. Describe and assess the risks associated with any obvious internal social factors and/or specific contextual details that could have a material effect on the planned resources programme.

Item 4.7 Conformance and compliance audits

1. Provide a description of legal compliance audits undertaken during the period, including a summary of material findings and management plans to address these findings.

2. Provide a description of ESG management system conformance audits undertaken during the reporting period, including a summary of material findings and management plans to address these findings.

Item 4.8 ESG liability

1. Describe the closure plans and obligations, social obligations, rehabilitation plan, activities, remaining liability and compliance costs.

2. Provide a description of mechanisms in place to address unplanned closure.

3. Describe the bonding obligations in place to ensure that these liabilities can be funded on a qualitative and quantitative basis.

Item 4.9 Risk analysis

1. Provide a description of the risk assessment process that has been undertaken to identify material ESG issues. Describe programmes in place to monitor identified material ESG issues.

2. Describe how the risk assessment process is integrated with the overall risk management framework.