OPEN PIT
GEOTECHNICAL
ANALYSIS AND
DESIGN TRAINING
COURSE

26–28 August 2014
Novotel Perth Langley Hotel
Perth, Western Australia

About the training course
This ACG training course is to be presented by industry personnel involved in the geomechanical and hydrogeological aspects of open pit analysis and design. They bring together a wealth of experience to share with course participants.

Who should attend?
This training course is designed for practical operational personnel, mine planners, mining engineers, geologists, and anyone involved in the day-to-day open cut metalliferous and coal mining operations.

Facilitator:
Winthrop Professor Phil Dight
Australian Centre for Geomechanics
The University of Western Australia, Australia

Mine Dewatering and Mine Water Management Short Course

29 August 2014
Novotel Perth Langley Hotel | Perth

www.acg.uwa.edu.au
# Open Pit Geotechnical Analysis and Design Training Course

**26–28 August 2014 | Silver Room | Novotel Perth Langley Hotel**

## Programme*

### DAY 1 | 26 AUGUST 2014

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<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>08:00</td>
<td>REGISTRATION</td>
</tr>
<tr>
<td>08:20</td>
<td>Welcome and introduction Winthrop Professor Phil Dight, Australian Centre for Geomechanics, Australia (PMD)</td>
</tr>
<tr>
<td>08:40</td>
<td>Section 1: Overview (PMD)</td>
</tr>
<tr>
<td>09:00</td>
<td>Section 2: Risk assessment in open pits (PMD)</td>
</tr>
<tr>
<td>10:00</td>
<td>MORNING BREAK</td>
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<tr>
<td>10:30</td>
<td>Section 3: Impact of structural model on geotechnical interpretation (PMD)</td>
</tr>
<tr>
<td>12:30</td>
<td>LUNCH</td>
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<tr>
<td>13:30</td>
<td>Section 4: Pit slope stability in hard rock mines (PMD)</td>
</tr>
<tr>
<td>15:00</td>
<td>AFTERNOON BREAK</td>
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<td>15:30</td>
<td>Section 5: Slope stability in weathered materials (PMD)</td>
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<td>16:15</td>
<td>Section 6: Ground support for open pit mines (PMD)</td>
</tr>
<tr>
<td>17:30</td>
<td>CLOSE DAY ONE</td>
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</tbody>
</table>

### DAY 2 | 27 AUGUST 2014

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Design criteria for open pits in weak rocks: an experience from Vale iron ore mines Téofilo Aquino Vieira da Costa, Vale S.A., Brazil</td>
</tr>
<tr>
<td>10:00</td>
<td>MORNING BREAK</td>
</tr>
<tr>
<td>10:30</td>
<td>Developing hydrogeology inputs to geotechnical models Geoff Beale, Schlumberger</td>
</tr>
<tr>
<td>11:30</td>
<td>Effective slope design communication and implementation Phil de Graaf, Rio Tinto Iron Ore, Australia</td>
</tr>
<tr>
<td>12:30</td>
<td>LUNCH</td>
</tr>
<tr>
<td>13:30</td>
<td>Design of slopes in hard rock – structural control Mark Fowler, Pells Sullivan Meynink, Australia</td>
</tr>
<tr>
<td>15:00</td>
<td>Data confidence in geotechnical analyses and design Michael Dunn, SRK Consulting (Australasia) Pty Ltd, Australia</td>
</tr>
<tr>
<td>16:00</td>
<td>AFTERNOON BREAK</td>
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<tr>
<td>16:30</td>
<td>Discussion</td>
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<td>17:00</td>
<td>CLOSE DAY TWO</td>
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<tr>
<td>19:00</td>
<td>COURSE DINNER</td>
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### DAY 3 | 28 AUGUST 2014

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:30</td>
<td>Open pit slope design with mining rock mass models Dr Clive Seymour, Dempers &amp; Seymour Pty Ltd, Australia</td>
</tr>
<tr>
<td>09:30</td>
<td>MORNING BREAK</td>
</tr>
<tr>
<td>10:00</td>
<td>Elements of rigorous slope design Julian Venter, Rio Tinto Iron Ore, Australia</td>
</tr>
<tr>
<td>11:00</td>
<td>Slope instability monitoring at MMG Century Mine, Qld Michele Salvoni, Australian Centre for Geomechanics, Australia</td>
</tr>
<tr>
<td>12:00</td>
<td>LUNCH</td>
</tr>
<tr>
<td>13:00</td>
<td>Aspects of slope design in the iron ore deposits of the Pilbara Julia Nielsen and Charlie Stoessiger, Coffey International Ltd, Australia</td>
</tr>
<tr>
<td>14:00</td>
<td>Modelling of anisotropic rock mass behaviour in slopes David Sainsbury, Mining One Consultants, Australia</td>
</tr>
<tr>
<td>15:00</td>
<td>AFTERNOON BREAK</td>
</tr>
<tr>
<td>15:30</td>
<td>Numerical modelling for open pit slope stability David Wines, Itasca Australia Pty Ltd, Australia</td>
</tr>
<tr>
<td>16:30</td>
<td>Discussion</td>
</tr>
<tr>
<td>17:00</td>
<td>COURSE CLOSE</td>
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* This programme was correct at time of printing. Course proceedings are not available for purchase. For updates, visit [www.acg.uwa.edu.au/events/current](http://www.acg.uwa.edu.au/events/current).

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**Facilitator:**

Winthrop Professor Phil Dight  
Australian Centre for Geomechanics  
The University of Western Australia

Phil has been involved with the development and design of ground support for mining applications since 1975. Phil has extensive consulting experience in the geotechnical aspects of the mining industry, and has worked on open pit and underground metalliferous mining problems. Much of that early research work has now been formalised in the literature by others. Phil joined the ACG in 2008 and has since been working on stress memory effects in rocks, ground support applications and slope stability problems.

**Dinner sponsor**

Gusti Restaurant  
54 Terrace Road, East Perth

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About the course

This course is aimed at professionals in technical and management positions related to mining hydrogeology, mine dewatering, environmental management and mine water management. The course is based on industry experience and working case studies supported by conceptual hydrogeology and water management theory.

Programme*

29 AUGUST 2014

08:00  Registration
08:30  Welcome and introduction Geoff Beale (GB) and Dr Martin Williams (MW), Schlumberger
09:00  Module I: General principles of mine dewatering (GB)
10:00 MORNING BREAK
10:20 BREAK
10:20 Module 2: Fracture flow hydrogeology (GB)
11:20 BREAK
11:30 Module 3: Dewatering methods (GB)
12:30 LUNCH
13:30 Module 4: Mine water quality: prediction and operational management (MW)
15:00 AFTERNOON BREAK
15:30 Module 5: Pit-slope depressurisation (GB)
17:30 Discussion
17:30 COURSE CLOSE

Presenters:

Geoff Beale
Mining Hydrogeologist
Schlumberger

Geoff is a worldwide expert in mine hydrology and mine water management. He has 37 years' experience in the extractive and mining industries. He graduated from Lancaster University, UK, in 1975 and has since worked on over 250 mining projects in over 50 countries, in all mining commodities, and in all of the world's climatic regions. Geoff was one of the founder members of the Water Management Consultants Group in 1989, and was principal with the company through to the time of its acquisition by Schlumberger in 2007. He has worked for Schlumberger since 2007.

Dr Martin Williams
Geochemist
Schlumberger

Martin's career has spanned more than 25 years, largely dedicated to environmental geochemistry issues in the mining industry with a particular focus on the prediction, mitigation and treatment of acid rock drainage (ARD). Within Schlumberger, Martin's role as a global mining advisor involves coordination of the group's worldwide activities in the field of mining geochemistry. He is responsible for the delivery of ARD, mine closure and related mine water management services to many mining companies. Martin also has extensive experience of minerals sector regulatory compliance.
REGISTRATION FORM

Contact details
Please print. *denotes mandatory fields.
*Title (Mr, Mrs, Miss, Ms, Dr, Prof., Other) ____________________________
*Family Name _______________________________________________________
*First Name _________________________________________________________
Preferred Name _______________________________________________________
*Position ___________________________________________________________
*Organisation _________________________________________________________
*Mine/Dept __________________________________________________________
*Postal Address _____________________________________________________
______________________________________________________________
*Phone _____________________________________________________________
Fax _________________________________________________________________
Mobile ______________________________________________________________
*Email ______________________________________________________________

All attendees will have their name, affiliation, address, telephone, fax and email address printed in the delegate list.

Do not include my details in the event delegate list.

If you require an invitation letter for Visa purposes, please forward a copy of your passport information page. For more information regarding Australian Visas, please visit www.immi.gov.au/visitors/_pdf/general-events.pdf.

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Registration fee includes ACG event proceedings, luncheons and refreshments. Please notify us of any special dietary requirements.
Proceedings will not be available for sale after the event.

DELEGATE CANCELLATIONS
Up to 8 days before event commencement: An administration fee of $150 will be charged. 7 or less days before: no refund.
Non-attendance: no refund. Substitutions will be accepted at any time. The ACG reserves the right to cancel the event if fewer than 16 registrations are received.

† Please visit www.acg.uwa.edu.au/corp_affiliates to view the list of ACG Corporate Affiliates.
^ Students are required to provide proof of full-time enrolment.

Open Pit Geotechnical Analysis and Design Training Course (1409)
26–28 August 2014

Standard Paid after 21 July 2014
Standard $2,200
ACG Affiliate† $1,980
Student^ $880

Mine Dewatering and Mine Water Management Short Course (1426)
29 August 2014

Standard Paid after 21 July 2014
Standard $990
Student^ $330

Events venue
Silver Room, Novotel Perth Langley Hotel
221 Adelaide Terrace, Perth WA 6000
Ph: +61 8 9221 1200
Email: h1764@accor.com

Follow us

How to register:
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+61 8 6488 3300  +61 8 6488 1130  info-acg@uwa.edu.au
Geoff Beale  Schlumberger

**Developing hydrogeology inputs to geotechnical models**

The mining industry has gained an increased understanding of the role of water in the planning, design and management of pit slopes. The introduction of the grouted-in vibrating wire piezometer, and the ability to install piezometers side-by-side with geotechnical instruments, has contributed to a practical understanding of (i) the factors that control the behaviour of water pressure in pit slopes; (ii) the role that water plays in slope stability; and (iii) the link between water pressure and geomechanical behaviour. For the majority of pit slopes, pore pressures are mostly dependent on the wider-scale site hydrogeology. Therefore, it is usually preferable to carry out pore pressure analysis using modelling techniques that have been developed for groundwater studies. The pore pressure profiles can be imported to the geomechanical models in a number of different formats, depending on the type of studies and the importance of water in the slope stability analysis. For intact materials, coupled hydromechanical analysis of pore pressure and rock properties is valuable mostly in low permeability settings. Analysis of transient pore pressure and reduction in shear strength can be important at shallow levels in the slope where confining pressures are low, particularly in wet and/or seasonal climates. The presentation discusses the approach and methods for predicting pore pressures in pit slopes and the techniques that are applied for inputting the pore pressures into geotechnical models.

Téofilo Aquino Vieira da Costa  Senior Geotechnical Geologist and Engineer, Vale S.A., Brazil

**Design criteria for open pits in weak rock: an experience from Vale is soft iron ore**

The presentation covers:

1. Weak rock definitions;
   - a) Glossary
   - b) Characterisation;
   - c) Field and lab tests;
   - d) Classifications;
   - e) Failure mechanism.

2. Open pit designing criteria in weak rock;
   - a) Geological and geomechanical models;
   - b) Slope failure mechanism analyses;
   - c) Operational and final slope designing criteria.

3. Operational approach;
   - a) Final and operational drainage system;
   - b) Final and operational slope implementation;

4. Case studies of Vale in Brazilian iron ore mines;
   - a) Shallow open pits;
   - b) Deep open pits.

Phil De Graaf  Principal Consultant, Rio Tinto Iron Ore

**Effective communication and implementation of slope designs**

Whether the designs are undertaken in-house or by external consultants, there is a fundamental requirement for effective communication of designs to designers, operations and management. This includes key assumptions, design limitations, ore body knowledge status and inherent design risks and opportunities. It is important that this information is available ahead of design implementation to facilitate effective and safe execution of the design. Operational readiness and risk assessment of the likely modes of instability, allow for appropriate controls to be developed and implemented. Understanding the expected or assumed ‘design operational range’ (rock mass and discontinuity strengths, groundwater conditions, etc.) facilitates implementing a slope performance reconciliation approach for early identification of changed conditions, which may trigger design optimisation opportunities or remediation requirements should the found conditions be better or worse than expected. Some case histories will be presented on design communication and implementation.
Michael Dunn  Principal Consultant, SRK Consulting (Australasia) Pty Ltd

Data confidence in geotechnical analyses and design

The reliability and confidence of geotechnical data that is used to develop geotechnical models, and as an input into geotechnical analyses and design is of critical importance. Essentially, the designer wishes to reduce uncertainty in the inputs and provide a reliable and robust design. Data reliability is linked to the quantity of data collected, the spatial distribution of the data collected and the quality of the data collection. In a typical project, there is an opportunity to improve data reliability through the scoping, pre-feasibility, feasibility, and final design and implementation stages.

Geotechnical data and design fall under the Modifying Factors for JORC (2012) which requires that the confidence of the Modifying Factors be considered in the conversion of Mineral Resources to Ore Reserves. It is required that at least a pre-feasibility study should be undertaken to support the conversion of Mineral Resources to Ore Reserves. A feasibility study would have a higher level of confidence than a pre-feasibility and hence confidence in the Modifying Factors would be higher.

Currently very little quantitative guidance exists in the literature on assessing the confidence level of geotechnical studies, although there have been attempts by various authors (Haile, 2004; Haines et al., 2006; Read and Stacey, 2009; Dunn et al, 2011) to qualitatively describe what level of geotechnical data is required. Recently a number of authors have outlined methods that could be applied to assess the reliability of geotechnical data (Read, 2013; Fillion and Hadjigeorgiou, 2013; Thomas, 2013).

These methods will be applied to a number of underground and open pit case studies to assess the reliability and confidence level of geotechnical data at various stages in an attempt to quantify the qualitative confidence levels outlined by Haile (2004) and Read and Stacey (2009) and the impact on design.

Mark Fowler  Principal Engineering Geologist and Director, Pells Sullivan Meynink

Design of slopes in hard rock – structural controls

Slope design of hard slopes is almost always controlled by structure. This presentation covers the background and fundamentals of structural geology and the spectrum of design approaches for structural mechanisms. Topics covered include:

- Over view of failure modes.
- Structural geology and structural domains.
- Design criteria.
- Stereographic projection.
- Kinematics.
- Undercutting methods (McMahon, Morris, etc).
- Qualifications and limitation, and methods.
- Discrete fracture networks.
- Cases studies.

Julia Neilsen and Charlie Stoessiger  Coffey International Ltd

Aspects of slope design in the iron ore deposits of the Pilbara

The anisotropic sediments of the Hamersley Province in the Pilbara, Western Australia, host numerous economic iron ore deposits. These deposits are often hosted within synclinal structures and mined using open pit methods. Traditional geotechnical core logging data along with increasingly available downhole geophysics data is discussed for use in material characterisation. Experience of typical slope performance and instability mechanisms within Hamersley Group material guides the methodology used for slope design. Considerations for classification of raw geotechnical data, domaining of the slope area and appropriate stability modelling methods are presented.

Michele Salvoni  PhD Student, Australian Centre for Geomechanics

Microseismic monitoring project at Century Mine, Qld

Microseismic monitoring allows the recording of the energy released in the form of acoustic waves during the fracturing processes or shearing within the rock. The technique has already been used in several studies of natural rock slopes and underground mine instability to provide information about the rock mass behaviour. However, there are just a few examples, where this technique has been applied in open cut mines.

In November 2013, a microseismic monitoring system was successfully installed at Century Mine, Queensland. Since 2009, the South West corner wall of the pit has been affected by the potential for instability and it is necessary for further investigations to be carried-out. It is of utmost importance to understand the instability mechanisms, the potential volume and the timing of any failure to increase the safety to personnel and equipment and reduce the economic risk to the mine.
The project goal is to determine the contribution of microseismic monitoring to provide a good information source on the rock slope behaviour in open pit mines. The research also involves data analysis using radar and prism monitoring, geology, structural geology and face mapping to reinforce the microseismic results.

The presentation for the “ACG Open Pit Geotechnical Analysis and Design Training Course” will illustrate the main challenges that have been occurring in this project. These are some of the topics that will be discussed:

- Ballistic and calibration blast tests: a possible approach to get better source locations in anisotropic rocks;
- Use of geological/geotechnical information in combination with microseismic data;
- Dealing with shale: anisotropy and weathering processes;
- Possible application of terrestrial radar in monitoring movements during blast operations.

Dr Clive Seymour  Principal, Dampier & Seymour Pty Ltd

Optimising pit slope design with mining rock mass models

The methodology and development of 3d Mining Rock Mass Models (MRMM) will be presented. The MRMM enables a robust geotechnical model comprising block models of various logged or calculated rock mass parameters to be established, viewed and interrogated in 3d. These models are analogous to resource block models in the way that they can be viewed and incorporated into the planning process.

A new approach to assess open pit stability will be presented that estimates the ratio of rock bridge to geological structure and then simultaneously represents the strength characteristics of both rock mass and structure for input into limit equilibrium and numerical models. The method uses data from the MRMM. Fracture frequency, Hoek–Brown and Barton strength parameters for the different rock mass domains identified for the rock mass variability established in the MRMM, with strength parameters being calibrated against laboratory test data. Statistical analyses of shear strength and rock bridge data are then carried out for the rock units within each geotechnical domain. This provides input for slope stability analyses that represent both rock bridge and discontinuity shear strength parameters according to the calculated proportion of rock bridge. This method is more precise and representative than conventional methods that use single or factored failure criteria values.

Julian Venter  Rio Tinto Iron Ore

Elements of rigorous slope design

As the world's stock markets gain more experience at trading mining stocks and mining companies seek to improve margins by decreasing stripping ratios, the amount of scrutiny applied to pit slope designs seem to increase endlessly. This presentation attempts to make the outcome of these changes palatable by providing guidance for auditable, rigorous and robust open pit design. A summary of the Joint Ore Reserves Committee (JORC) requirements for geotechnical design is presented first followed by the geotechnical design principles as defined by Bieniawski. Bieniawski's principles are translated into open pit design terms and the presentation concludes with a checklist for a design report incorporating these elements.

David Wines  Principal Geotechnical Engineer, Itasca Australia Pty Ltd

Numerical analysis for open pit slope stability

Both two-dimensional and three-dimensional numerical modelling is often performed to assess the stability of open pit slopes in soil, soft and hard rock environments. For any analysis, it is important that the person performing the modelling, and those reviewing and using the analysis results, have a good understanding of the modelling process, including the model inputs, results and limitations.

This presentation discusses several key aspects of the modelling process for an open pit slope stability analysis, including:

- The scale of the analyses and the model zone resolution.
- Selection of two-dimensional versus three-dimensional modelling.
- Representation of explicit structures.
- Estimation of rock mass properties, including a discussion on the Hoek-Brown disturbance factor.
- Representation of in situ stresses and groundwater.
- The modelled excavation sequence.
- Back analysis and model calibration.
- Interpretation of the modelling results.

A case study is also presented for a detailed three-dimensional modelling exercise that was performed for an open pit in Australia. Elevated displacements and strains were monitored in the walls during excavation of the lower benches of the final pit, and consideration was given to leaving a buttress at the toe. The modelling formed a key component of the overall risk management approach that was adopted to ensure safe completion of the pit without any alterations to the preferred design.