Government of **Western Australia**
Department of **Mines, Industry Regulation and Safety**
Resources Safety

Geotechnical considerations underground audit – guide

Approved: 10 February 2016

1 Adelaide Terrace, East Perth WA 6004
Postal address: Mineral House, 100 Plain Street, East Perth WA 6004
Telephone: (08) 9358 8002
ResourcesSafety@dmirs.wa.gov.au
www.dmirs.wa.gov.au

Table of contents

Introduction

This document was completely revised and reformatted in November 2015. This was a material change to the content of the guide to closely align this audit with the *Geotechnical considerations open pit audit*.

This guide was originally published in June 2003 under the title *Geotechnical considerations HIF audit*.

Note: The Safety Regulation System (SRS) has replaced the AXTAT system and all reporting is done online through SRS.

The scope of this audit is designed to cover the standards associated with the safe development, operation and closure of underground operations from a geotechnical perspective.

References to interviewing a consultant geotechnical specialist in this audit only apply to those mines that employ the services of such specialists.

Where, in the intent, the word “verify” is used, this means that it is a regulatory requirement, which is mandatory and has to be complied with. Where, in the intent, the word “ensure” is used, it is not a mandatory requirement, but it does set out a recommended safe method which, if followed, should minimise the potential for an adverse incident to take place.

The audit is split up into sections covering mine planning and design, development and maintenance of geotechnical model, operational aspects (including mining control, performance monitoring, rock support and reinforcement, management of unstable rock, drill and blast), design confirmation or back analysis and training.

This audit does not cover open pit operations as these standards are included in the *Geotechnical considerations open pit audit*.

1 Mine planning and design

Mine planning and design

Point	Standard	Guideline
1.1	The design life of the mine and economic limits of the ore body have been determined.	**Intent:** To verify that mine management is capable of developing the optimal life of mine (LOM) design for the full extent of the ore body (e.g. perennial 2 year LOM plan is not considered appropriate). **Personnel:** Registered manager, chief geologist. **Method:** Sight 3D geological model with LOM stoping overlay. Where the LOM orebody is not fully defined, the geological model will need to illustrate potential economic limits of the ore body to target and plan additional exploration. . Refer to MSIR r. 10.28(1).
1.2	Mine management has a documented LOM design.	**Intent:** To verify that mine management is capable of identifying potential future geotechnical problems with current mine plans or designs well in advance of problems occurring. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight LOM design plans or 3D model with estimated scheduling encoded on the LOM design. Refer to MSIR r. 10.28(1)
1.3	Senior mine management has demonstrated a clear understanding and commitment to address the geotechnical issues in underground mining using sound geotechnical engineering practice.	**Intent:** To verify that mine management has sufficient knowledge of potential geotechnical hazards and associated risks and has provided clear commitment to address these issues. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight budgetary commitments. Sight a site-wide geotechnical hazard register and risk assessment for all safety issues related to ground control, and minutes of senior management meetings. Has senior management commissioned geotechnical investigations which consider employee exposure to rock failure hazards and recent rock failure incidents? Refer to MSIR r. 10.28(1).

1.4	A set of development planning and design guidelines have been drawn up to provide general guidance in mine planning and design.	**Intent:** To verify that a consistent approach to development planning and design, particularly during absence of key personnel from site and high personnel turn-over. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight documentation from mine planning and design meetings. Are the meetings minuted or recorded in some way? Sight examples of approved mine plans and accompanying notes or memoranda. Are they stored and accessible for future reference or review. Have mine design standards (e.g. drainage, camber, gradient, subdrill, ground support services) been set and are they documented? Refer to MSIR r. 10.28(1).
1.5	Mine management has established a "geotechnical model of the mine".	**Intent:** To verify that the characteristics of the rock mass within the immediate surrounds of the mine that can have an influence on mine performance have been recognised, quantified and grouped into an effective database (representing the "geotechnical model"). **Personnel:** Geologist, mining engineer, geotechnical engineer. **Method:** Sight geotechnical model/database. For the LOM design note; geological boundaries, geological structure, ranges of mechanical strength properties of all rock mass types, hydrogeology and in-situ stress assessments. Refer to MSIR r. 10.28(1).

1.6	The designed number, types, operating life and dimensions of all openings have been based on a suitable "geotechnical model of the mine".	**Intent:** To determine that mine management has identified the full range of mine openings to be excavated at the mine with respect to LOM design, hydrogeology and ground conditions. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight a database that contains the full range of void geometry and expected rock types within the perimeter of each void with geotechnical verification that each void can be suitably stabilised for the LOM. Applicable two/three dimensional stress analysis techniques are used to determine the interaction, dimensions, and sequencing of mine excavations. These designs have been derived by competent persons and formally documented. Refer to MSIR rr. 10.28(1) and 10.28(2)(c).
1.7	The number, types, design life, dimensions, orientation and spacing of all pillars have been determined by geotechnical methods.	**Intent:** To determine that mine management has identified the full range of mine pillars to be developed at the mine with respect to LOM design and ground stability. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight a database that contains the full range of pillar geometry and expected rock types within each pillar with geotechnical verification (by competent person/s) that each void can be suitably stabilised for the LOM. Refer to MSIR rr. 10.28(1) and 10.28(3)(b).
1.8	Geotechnical domains are used to divide the rock mass into volumes of similar expected ground behaviour.	**Intent:** To ensure that the variation in ground conditions has been recognised and quantified. **Personnel:** Geologist, mining engineer, geotechnical engineer. **Method:** Sight plans, sections, longitudinal projections that show the expected range of ground conditions. Have these been contoured, shaded or otherwise identified? Have the different ground conditions been graded or classed in some way, e.g. A, B, C: class 1, class 2? Is the data represented in three dimensions, using justifiable local design criteria or using one or more of the recognised rock mass classification methods.

1.9	A justifiable design criteria exists for mining beneath / near surface water or water-filled mine workings according to the ground conditions, the mine plan and size of openings and mine access.	**Intent:** To verify that the mine has conducted appropriate geotechnical appraisal of the potential for water inundation into the underground workings (from various sources). **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight relevant investigation/design documentation. (e.g. due consideration has been taken of the potential for caving /stoping on contacting overlying bodies of water, nearby surface water drainage paths flooding into the portal at the base of a box-cut or open pit). If there is no perceived source of water, there should be a formal statement [e.g. within the Ground Control Management Plan (GCMP)] explaining why. Refer to MSIR r. 4.11.
1.10	The mine uses a formalised approach for the design of rock support and reinforcement (RSAR) for all types of mine openings in all geotechnical domains.	**Intent:** To verify that there is a reasoned explanation for the rock support and reinforcement being used in the mine. **Personnel:** Underground manager, mining engineer, geologist, geotechnical engineer, mine planning engineer. **Method:** Interview personnel. Which, if any, of the rock support and reinforcement design methods have been used (see page 18 of the Guidelines Geotechnical Considerations in Underground Mines)? Does the design method specifically refer to the type of support and reinforcement elements proposed (e.g. friction rock stabilisers)? Or has something else been substituted? Does the mine use an estimated maximum dynamic energy event, to design seismic resistant RSAR? The RSAR design takes is based on published or peer review research. Refer: MSIR rr. 10.28(1) and 10.28(3)(e).

1.11	The mine has developed a ground control management plan (GCMP) relevant to the local ground conditions and mining strategies	**Intent:** To verify that there is a formalised "live" document that summarises strategies used for managing all issues relating to ground control at the mine. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight GCMP, is it up to date, does it contain reference to mine history with a description of mining methods and how they were selected, mine planning and design guidelines, mine backfill systems, SWPs, geological environment, hydrogeology, geotechnical qualities, employee responsibilities, RSAR requirements etc. Refer to MSIR r. 10.28(1)
1.12	The mining method, design and positioning of mine infrastructure have taken into consideration the long term stability/viability of nearby tenements and any surface features.	**Intent:** To verify that the mine can be abandoned without impacting on the long-term safety of nearby stakeholders. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight a closure plan that addresses potential long term impacts on the surrounding environment and land owners / stakeholders. The closure plan needs to address issues such as extraction methods used in shallow or weathered rock (subsidence potential), waste dumps, drainage / diversions etc. Refer to MSIR r. 10.28(1).

2 Development and maintenance of geotechnical model

Development and maintenance of geotechnical model

Point	Standard	Guideline
2.1	The range of geological structure (planes of weakness) within the proximity of the mine have been defined, given geotechnical qualification and kept up to date in a suitable structural database.	**Intent:** To verify that there is a good understanding of local planes of weakness in rock within and immediately surrounding the mine, so better decisions can be made with respect to mine design and planning. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight database with known geological structure, describing origin, trends and continuity. Can these be readily presented in 3D across the LOM design. Must be either included within or referred to by the GCMP. Refer to MSIR rr. 10.28(1) and 10.28(3)(a).
2.2	Geotechnical mapping is being carried out on a regular basis in all 'active' and accessible mine voids.	**Intent:** To verify that up to date geotechnical data has been used to quantify and verify the ground conditions and that all records are kept up to date, commensurate with the rate of mining **Personnel:** Geologist, geotechnical engineer. **Method:** Sight geotechnical mapping records. Have geotechnical software packages (e.g. DIPS or other similar program) or manual plotting methods been used to process the data? Have the geotechnical properties of the planes of weakness been determined [e.g. number and orientation (dip and dip direction) of joint sets; persistence (length), spacing and joint surface properties (e.g. roughness, planarity)?] Have these properties been plotted and summarised? Refer to MSIR rr. 10.28(1) and 10.28(3)(a).

2.3	The pre-mining rock stress magnitude and orientation in the mine has been quantified and is updated at suitable intervals commensurate with the rate of mining.	**Intent:** To verify that the mine has sufficient data to quantify the variation in pre-mining stress fields within the rock through all stages of mining. **Personnel:** Underground manager, mining engineer, geotechnical engineer, mine planning engineer. **Method:** Interview personnel. Sight results of rock stress measurement and interpretations of principal stresses in the local rock mass. What method was used to determine the rock stress magnitude and orientation and have the limitations of this method been formalised and taken into account when used for design purposes? Has the mine determined a rock stress relationship with increasing depth, and/or is there localised stress variation dependent on geological structures/environments. Refer to MSIR r. 10.28(1).
2.4	The rock mass strength and deformation characteristics within each geotechnical domain in the mine have been quantified and engineering properties understood.	**Intent:** To verify that the strength and deformation characteristics of the rock mass have been determined. **Personnel:** Underground manager, mining engineer, geotechnical engineer, mine planning engineer. **Method:** Interview personnel. Have the rock strength and deformation properties been determined for the various geotechnical domains? Sight a summary of the estimated rock mass strength and deformation properties (e.g. compressive and tensile strength, Young's modulus, Poisson's ratio) for the various geotechnical domains. Note: This information may have been determined by laboratory testing of rock core samples or from biaxial tests carried out during rock stress measurement, i.e. using intact rock samples. Has the mine determined the extent to which these results need to be adjusted (typically reduced) to take account of jointing and micro fractures etc. in the rock mass. These data may also have been estimated by using stress analysis techniques to "back-analyse" a particular mining geometry. Refer to MSIR rr. 10.28(1), 10.28(2)(a) and 10.28(3)(a).

2.5	Local hydrogeology has been quantified and ongoing measures taken to verify these assumptions.	**Intent:** To verify that hydrogeological data is collected and stored in a database that is readily available for further processing. **Personnel:** Geologist, geotechnical engineer **Method:** Sight hydrogeological database. Does the database have all the required information to allow the interpretation of the extent of aquifers, likely heads of pressure, water quality and potential inflows of water. Refer to MSIR r. 10.28(1).
2.6	Geotechnical diamond drill core logging is used as a tool for ongoing confirmation of mine-wide geological/structural models in conjunction with scan-line and area mapping models.	**Intent:** To ensure that borehole data is used to provide information to help maintain the geotechnical model in advance of mining (relying solely on mapping of areas already exposed may be problematical). **Personnel:** Geologist, geotechnical engineer **Method:** Are exploration holes (in-mine) or specific geotechnical holes being planned and used for advance confirmation of the geotechnical model? Are these holes oriented? The database used could be part of the geological drill hole database. View a sample of the geotechnical database by selecting typical holes chosen at random. Borehole data has more application for predictive work, and should be incorporated in the model verification process to ensure there are no surprises if mining towards a potential geotechnical anomaly. This diamond drill data is regularly entered into an appropriate database that allows easy interrogation of data and trends.
2.7	A comprehensive database is maintained that includes all geotechnical data (e.g. rock mass properties) relevant to the local geological and mining characteristics.	**Intent:** To verify that geotechnical data collected is stored in a single database that is readily available for further processing such as 3D numerical/stress modelling or hazard mapping. **Personnel:** Geologist, geotechnical engineer **Method:** Sight geotechnical database. Reference must be made to this in the GCMP. Does the database have representative data for all parameters (in each domain) required for use in a numerical model appropriate to the mine site. (UCS, E, v, Sig1,2,3, unit weight, fault/defect properties, shear strength and modulus as required etc.) This database must be included within or be referred to in the GCMP. Refer to MSIR rr. 10.28(1), 10.28(2)(a) and 10.28(3)(a).

2.8	A hazard map for existing and future areas of the mine has been developed.	**Intent:** To ensure that hazard mapping is undertaken at the mine to highlight areas of concern in existing areas of the mine and subsequent mining areas and that these are maintained in an appropriate database for future records. **Personnel:** Geologist, geotechnical engineer **Method:** Sight geotechnical hazard map / database. This database must be included within or be referred to in the GCMP.
2.9	A formal numerical modelling ”philosophy” has been developed and numerical model/s exists for the mine, taking into account the nature of the mine, the geotechnical conditions and perceived hazards.	**Intent:** To ensure that all relevant data is being used or can be used at short notice for stress modelling to assess perceived problem areas in the mine or to modify mine planning and design - particularly in deep mines - and that these are maintained in an appropriate database for future records. A prescribed modelling "philosophy" should be formally specified for future reference. **Personnel:** Geologist, geotechnical engineer **Method:** Sight numerical model and modelling philosophy documentation. This documentation must be included within or be referred to in the GCMP.

3 Operations – mining control

Operations – mining control

Point	Standard	Guideline
3.1	A system is in place which ensures that short, medium and long term planning and scheduling are compatible with one another and reviewed concurrently.	**Intent:** To verify that the mine has established a systematic approach whereby short term development and production schedules can deliver required long term plans/schedules. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight long term and short term development and production schedules and notes of meetings and sign-off on each schedule. Refer: MSIR r. 10.28(1).
3.2	Mine design drawings are signed off by the underground manager and all relevant geology, surveying and engineering professionals.	**Intent:** To verify management accountability for the proposed mine plan. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist, mine planning engineer. **Method:** Sight approved mine design drawings and check that signatures and dates are present. The sign-off process must meet with accepted auditing standards and not readily tampered with after the event. Refer: MSIR r. 10.28(1).
3.3	Mine planning and design meetings are held monthly or more frequently.	**Intent:** To verify that mine planning and design is an on-going process and not a series of ad hoc crisis meetings. The mine planning and design process should lead production, not the reverse. **Personnel:** Manager mining, underground manager, chief mining engineer, technical services manager, chief geologist, mine planning engineer, mine geologist, mine surveyor, electrical engineer, mechanical engineer, maintenance engineer (as required). **Method:** Sight minutes of mine planning and design meetings. When was the last meeting held? Refer: MSIR r. 10.28(1).

3.4	Mine planning and design matters are regularly discussed with the underground workforce.	**Intent:** To verify that the underground workforce are made aware of the reasons why mining work is being carried out in various areas of the mine. **Personnel:** Underground workforce. **Method:** Ask the workforce about their understanding of the reasons why certain headings are being developed, why stoping blocks are being mined and what difficulties are expected in say the next 6 months. What do they know about the possible causes of the ground control problems, if any, that the mine has experienced recently (e.g. seismic events, rock bursts, rock falls)? Sight minutes of meetings and/or work plans etc. that inform the workforce of design issues. Refer: MSIR r. 10.28(1).
3.5	For recoverable pillars, an appropriate pillar recovery plan exists and is implemented.	**Intent:** To verify that a suitable process has been developed that takes into account localised stresses, unsupported spans, interaction with other voids and geological structure etc. when extracting pillars. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight pillar recovery strategy document. Refer: MSIR r. 10.28(1)
3.6	The mine has a formalised, clear definition of "unsupported ground" and has derived a formal protocol with respect to persons working near these areas.	**Intent:** To verify that clear definitions of "unsupported ground exist" that are appropriate for all methods and sequences of mining. **Personnel:** Geotechnical engineer, underground manager, underground mining personnel. **Method:** Sight formal definition. Must be included in the GCMP. May have slightly different definitions in different mine areas/mining methods - e.g. airleg mining, raise boring. Must be accompanied by acceptable safe working practices when working near these locations. Refer: MSIR r. 10.28(1)

3.7	The mine has established tolerance limits / trigger points for mine planning/scheduling and trigger-action-response plans relevant to major geotechnical hazards.	**Intent:** To verify that the mine understands various tolerance limits for mine design and scheduling a standard protocol is developed that defines the actions and decision making processes of all relevant personnel when particular trigger points are reached for ground movement and seismic activity. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight registry of geotechnical hazards that influence mine design and scheduling strategies (e.g. extraction sequences to maintain a "chevron" shaped advancing stope face to control mining induced stresses; minimum pillar dimensions when retreat mining to a central pillar, or to limit exposure times in weak rocktypes etc). Sight standardised strategies for cases when certain trigger points have been exceeded or encroached upon. Refer: MSIR r. 10.28(1)
3.8	The mine has formalised procedures for preventing inadvertent access to vertical openings and unsupported ground - as required.	**Intent:** To verify that formal procedures exist to ensure safe, consistent approach to prevent personnel inadvertently accessing these hazards (from below and/or above). **Personnel:** Geotechnical engineer, underground manager, geologists, surveyors, relevant underground personnel (e.g. bogger drivers). **Method:** Sight relevant documents - must be referred to or included directly within the GCMP. Interview mining personnel. Reference must be made to regular checks by nominated persons to ensure these procedures are being consistently and adequately followed. Refer: MSIR r. 10.28(1)
3.9	Appropriate strategies/designs have been developed and implemented to maintain safe working conditions when working near unsupported ground and portal access via open pits - as required	**Intent:** To verify that formal procedures exist to ensure safe, consistent approach by all relevant personnel when working near these hazards (e.g. surveyors, bogger operators etc). **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight relevant documents - must be referred to or included directly within the GCMP. Interview mining personnel. Refer: MSIR r. 10.28(1)

3.10	Waste dumping procedures (surface and underground) have been developed to take into account the full range of materials being dumped and ground/surface water conditions in all areas at both the tip head and toe of the dumping points.	**Intent:** To verify, where relevant, that procedures and geotechnical assessment exists for the dumping of waste rock at the surface or in-mine for the range of foundation and drainage conditions, dump materials, dump geometry, and other local hazards. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight waste dump design and management documents. Refer: MSIR r. 10.28(1)

4 Operations – performance monitoring

Operations – performance monitoring

Point	Standard	Guideline
4.1	The mine has formally established monitoring requirements for all potential geotechnical hazards.	**Intent:** To verify that the mine understands the mechanisms of the propagation of geotechnical hazards and concomitantly understands the appropriate methods required to monitor such hazards before they become problematical. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight register of geotechnical monitoring requirements. Refer: MSIR rr. 10.28(1) and 10.28(3)(a)
4.2	The mine has established tolerance limits / trigger points for all forms of geotechnical performance monitoring and has formalised appropriate trigger-action-response plans.	**Intent:** To verify that the mine understands the tolerance limits for all forms of performance monitoring and that a standard protocol has been developed that defines the actions and decision making processes of all relevant personnel when particular trigger points are reached (e.g. for ground movement, seismic activity, water pressure). **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight documentation prescribing trigger points and concomitant action plans for all forms of monitoring. Does the mine site possess an emergency response plan that describes emergency actions or protocols to be taken by persons working in/near areas where a specific trigger event occurs (e.g. potential high risk ground movement and/or seismic event) and for re-entry into those areas. Refer: MSIR r. 10.28(1)

4.3	There are regular geotechnical inspections of the as-mined conditions of the relevant mine RSAR, openings and their surroundings.	**Intent:** To verify that the geotechnical hazards are continuously assessed at the mine. **Personnel:** Manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight records of geotechnical hazard assessment, mining history and any changes in the observed ground conditions, RSAR status or requirements and perceived potential hazard assessments. This may include the identified geotechnical hazards being ranked according to severity. Who undertakes these inspections? How frequently are they done? Does the mine have its own geotechnical engineer- if not, does the mine have regular visits from a representative of a consulting geotechnical organization? Is a summary produced that is reported to management with recommendations? Refer: MSIR rr. 10.28(1) and 10.28(3)(a)
4.4	An on-going photographic record of important geotechnical events, with written notes of observations, is maintained and regularly updated.	**Intent:** To verify that there is a record of important geotechnical events in the mine. **Personnel:** Underground manager, mining engineer, geologist, geotechnical engineer, mine planning engineer. **Method:** Interview personnel. Sight photographs with notes summarising events. Have these events been interpreted? What are their implications for future mining? Note: Later review of historical data may provide improved insights into what was occurring at the time. This may not be readily apparent, during mining, due to production demands and/or a lack of appreciation of the full magnitude of the event. Refer: MSIR r. 10.28(1)

4.5	Absolute and/or incremental rock stress measurement techniques are used where appropriate.	**Intent:** To verify that the mine can quantify if there has been any change (increase or decrease, orientation) in the rock stress field magnitude as a result of mining. **Personnel:** Mining engineer, geologist, geotechnical engineer, mine planning engineer. **Method:** Interview personnel. Sight results and interpretation of the rock stress measurements (absolute or incremental change). Note: Large changes in the mine geometry, e.g. mass blasting, can cause significant changes in the rock stress field. Generally more applicable in non-entry mining methods, e.g. longhole open stoping, sub-level caving, block caving and vertical retreat mining. Refer: MSIR rr. 10.28(1) and 10.28(3)(a)
4.6	Appropriate surveying techniques are used to monitor as-mined void and pillar geometry.	**Intent:** To verify that the extent of overbreak, underbreak or non-break in all production and development voids can be quantified. **Personnel:** Underground manager, surveyor, mining engineer, geologist, geotechnical engineer, mine planning engineer. **Method:** Interview personnel. Sight results from laser surveying techniques and determination of actual stope profile and overlying or nearby development. Have these results been recorded in a suitable 3D database? Such measurements are useful to help identify potential large scale wall collapse in open stopes, whether active caving is occurring within the stope and whether nearby development or infrastructure is likely to be effected by the caving front. These results will also indicate how well the situation is being managed. Note: The survey data can be useful in calculating wall rock or fill dilution and for confirmation of design criteria (See Section 8 in this audit) Refer: MSIR rr. 10.28(1) and 10.28(3)(a)

4.7	Displacement monitoring instrumentation is used as and where appropriate.	**Intent:** To verify whether movement is occurring in stope walls, on faults, floor settlement, etc. **Personnel:** Underground manager, mining engineer, geologist, surveyor, geotechnical engineer, mine planning engineer. **Method:** Interview personnel. Sight graphical summary of results from extensometers, monitoring pins, convergence monitoring, precise levelling, etc. Sight plans showing monitoring instrument locations, development and stope voids. How often are the monitoring instruments read? How are they read (ie manually or automatically)? Who is responsible for ensuring that they are read? How are these data used? Where access to the underground workings is via a portal in an open pit or deep box-cut, suitable monitoring and preventative actions are taken to limit potential for loose rock to subside onto travelways. Refer: MSIR rr. 10.28(1) and 10.28(3)(a)
4.8	Appropriate seismic monitoring is undertaken where potential exists for rockburst activity to damage mine openings and/or the RSAR systems in the mine.	**Intent:** To verify that a seismic monitoring system is installed in seismically active mines and / or that sufficient information exists that formally explains why/how seismic monitoring systems are not required. **Personnel:** Registered manager, underground manager, mining engineer, geologist, geotechnical engineer, mine planning engineer. **Method:** Refer to GCMP, sight reference to a seismic monitoring strategy or a formal (up-to-date) statement that supports the non-requirement of seismic monitoring. Ascertain from records of mine observations whether seismically induced damage has occurred regularly to mine excavations and the installed ground support? If yes, then a seismic monitoring system should be installed. Interview underground personnel to check the current level of seismic activity in the mine. Does the information from underground personnel compare well with the perceived level of risk and management and monitoring strategies in place at the mine? Refer: MSIR rr. 10.28(1) and 10.28(3)(a)

4.9	The installed seismic monitoring system is capable of detecting, processing and displaying a representative sample of the range of seismic events occurring in real time - including during power outages.	**Intent:** To verify that the installed seismic monitoring system is capable of monitoring a representative sample of the seismic events and rock bursts at the mine. **Personnel:** Registered manager, underground manager, geologist, geotechnical engineer, mine planning engineer. **Method:** Interview personnel. Has the seismic system been supplied by a reputable supplier with experience in the mining industry? Has the supplier conducted test work underground to determine the P and S wave velocities? Has the supplier prepared a report recommending a particular seismic monitoring system, sensor type (ie geophone or accelerometer) and locations of sensors underground? Has this recommendation been accepted in its entirety by the mine? Can the seismic monitoring system carry out the required quantitative seismological processing in real time? Can the system discriminate between blasts and seismic events occurring very soon (i.e. within seconds to minutes) after blasting? Refer: MSIR rr. 10.28(1) and 10.28(3)(a)
4.10	The seismic system is capable of providing coverage to all areas of the mine that persons work for the full range of events used to determine the performance of the mine.	**Intent:** To verify that suitable processes exist that define the areal limitations of existing seismic monitoring in relation to the accuracy and range of seismic data required and strategies and schedules for upgrading or relocating monitoring points. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight design documentation that supports the current configuration of the seismic monitoring system and provides recommended further development of the system with respect to ongoing mine expansion and mining methods. Refer: MSIR rr. 10.28(1) and 10.28(3)(a)

4.11	The results from all forms of monitoring have been used to assess trends of movement or seismic activity.	**Intent:** To verify that systems are in place whereby all forms of monitoring are systematically reviewed and interpretations made of the causes and likely outcomes and potential impacts on mine safety reported within suitable timeframes **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight memorandums / reports that include monitoring results and recommendations of actions to be taken in response to the monitoring data/trends (e.g. Guttenburg / Richter plots for prediction of potential maximum magnitude, or Omori charts used for re-entry restrictions; influence of geologic structure, seismic or failure mechanisms, influence of mine void geometry) Are these recommendations provided in time to prevent exposure to potential hazards in the mine? Refer: MSIR rr. 10.28(1) and 10.28(3)(a)
4.12	ALL forms of monitoring results (underground and where applicable surface) and interpretations are regularly communicated to the workforce.	**Intent:** To verify that management have informed the workforce of monitoring results etc. at suitably frequent intervals or immediately after significant trigger events have occurred. **Personnel:** Underground manager, supervision, mining engineer, geologist, surveyor, geotechnical engineer, mine planning engineer, all underground workforce. **Method:** Interview personnel. Are regular meetings are held with all members of the workforce who work underground? Is ground behaviour information shared with the workforce at these meetings? Are the results of seismic monitoring displayed on plans or longitudinal projections that are readily accessible to the workforce and are explained by cause/effect interpretations? Management should verify that the workforce is informed of potentially adverse ground behaviour that is occurring or may occur in the mine. It is essential to reduce the element of surprise for the workforce. Refer: MSIR rr. 10.28(1) and 10.28(3)(a)

5 Operations – rock support and reinforcement (RSAR)

Operations – rock support and reinforcement (RSAR)

Point	Standard	Guideline
5.1	Load capacity of the individual elements (anchorage, bar or tendon and surface restraint) are appropriately matched to prevent premature failure of any one component for various modes of failure.	**Intent:** To verify that there is no weak link in the support system. For example if the mine uses expansion shell rock bolts, then will the intact rock strength permit the full tensile strength of the bar to be achieved in a load-displacement test; bolts should not be able to pull through plates; mesh should be capable of holding expected loads as well as reinforcement holding the mesh. **Personnel:** Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew. **Method:** Interview personnel. Has load testing been carried out on the support? Sight results of load tests. Does the bar or strand fail before the anchorage method (expansion shell, grout, frictional interference fit)? Does the bar fail before the nut or ring pulls through the plate? What support failures, if any, have been observed? What failed - anchorage method; bar/tube/strand or threaded end/ring/plate/nut/ barrel and wedge anchor? Refer: MSIR rr. 10.28(1), 10.28(2)(e) and 10.28(3)(e)

5.2	The mining cycle has been adapted to the ground conditions to take into account the effect of time dependent behaviour of the rock mass and LOM void design.	**Intent:** To verify that management recognise that ground conditions do not remain the same for ever and that RSAR needs to be installed prior to critical rock movement occurring (e.g. minimising the delay in installing the ground support and sequencing of cable bolt installation in wide spans) and also be capable of withstanding the expected ground movement and stresses over the active life of the mine void. **Personnel:** Underground manager, mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew. **Method:** Interview personnel. Has time dependent deterioration of the ground conditions been experienced at this mine? If so, sight of records kept by the mine, e.g. photographic records, results of simple convergence monitors and regular observations/inspections of suspect areas, preferably noted in a record book. Has the mine carried out any three dimensional stress analyses of each mining stage? This may help to pin point areas of stress decrease/increase and hence possible deterioration of ground conditions. Note: Subtle changes in the rock stress field, particularly stress decreases and stress increases, (as a result of nearby mining) may trigger deterioration in ground conditions. Refer: MSIR rr. 10.28(1), 10.28(2)(f) and 10.28(3)(e)
5.3	A technical specification exists for all the RSAR systems in use, taking into consideration design and performance requirements.	**Intent:** To verify that the mine has its own technical specifications for the various types of rock support and reinforcement in use. **Personnel:** Underground manager, mining engineer, geotechnical engineer, mine planning engineer. **Method:** Interview personnel. Sight a copy of the rock support and reinforcement technical specifications prepared by the mine. The rock support and reinforcement specification states the load capacities (support resistance) and the energy absorption capacities of the various elements in the system. Reference should be made to this in the GCMP. Refer: MSIR rr. 10.28(1) and 10.28(3)(e)

5.4	The mine possesses, and enforces formal standard work procedures for installation of all the various types of RSAR in use at the mine.	**Intent:** To verify that written standard work procedures exist that describe how the rock support and reinforcement is to be installed and that they are enforced. (e.g. Do procedures such as bolt hole diameter tolerance etc. comply with manufacturer's recommendations?. **Personnel:** Underground manager, supervision, mining engineer and operators. **Method:** Interview personnel. Observe installation. Sight copy of standard work procedures. Compare observed work procedures with those in the standard. Are they in agreement? If not, what explanation can be provided? Interview personnel, Have the diameters of holes drilled in the rock for support been measured? Are the re-sharpened drill bits graded according to diameter range? Are the re-sharpened drill bits colour coded to indicate a range of bit diameters? Have support load tests been done using holes drilled with different bit sizes? Has the support load capacity been related to bit size ranges for each geotechnical domain ? Note: This audit point is particularly important with friction rock stabilisers (eg Split Sets) where the load capacity is very sensitive to the correct hole diameter range. Observe holes being drilled. Where appropriate, are the correct hole lengths being drilled (this should not be an issue for spilt sets)? For up-holes, was the drilling water left on after the bit stopped drilling for say a few seconds? Was the return water clean? For down holes, it is much more important to blow the hole out with compressed air (if available) and water to remove all drilling sludge. This is very important for long down holes drilled for cablebolts. Refer: MSIR rr. 10.28(1) and 10.28(2)(e)

5.5	The storage and handling of rock support and reinforcement elements is such that deterioration with time is minimised.	**Intent:** To verify that deterioration of support and reinforcement components is minimised. **Personnel:** Supervision, mining engineer, stores officer. **Method:** Inspect the surface and underground locations where the rock support and reinforcement equipment is stored. Are the components, particularly threaded components, protected from rain, groundwater, contamination during storage and general damage during transport? Are resin cartridges protected from direct sunlight and high temperatures and used before the prescribed expiry date? Are pallets of bagged cement shrink wrapped? Note: Ground support and reinforcement should be stored "like with like" to avoid mis-match of components, eg putting friction rock stabiliser plates on expansion shell rock bolts. Refer: MSIR rr. 10.28(1) and 10.28(2)(e)
5.6	The drill hole orientation is appropriate for the excavation geometry and expected ground/block movement.	**Intent:** To verify that the full effective length of the support is used. **Personnel:** Supervision, mining engineer, rock support and reinforcement crew. **Method:** Observe hole being drilled in the backs and walls, particularly in development headings. Are the holes generally perpendicular to the excavation surface? Note angle of boom to backs and walls. Is it perpendicular to the rock surface? Does the boom length, relative to height or width of the excavation, make it difficult to drill perpendicularly to the rock surface? Note: Very flat holes seriously reduce the "effective" length of the support. Refer: MSIR rr. 10.28(1) and 10.28(2)(e)
5.7	All components to be encapsulated in resin or cement grout are clean and free of deleterious materials.	**Intent:** To verify that the support element is able to development the full bond strength between itself and the grout. **Personnel:** Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew. **Method:** Observe installation procedure. Are the support elements (particularly bar, tube or strand) free of loose flaking rust, oil, grease, paint, fill? Refer: MSIR rr. 10.28(1) and 10.28(2)(e)

5.8	Records are kept that fully grouted elements are actually fully grouted.	**Intent:** To verify that the element is fully encapsulated in grout. **Personnel:** Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew. **Method:** Observe installation of grouted support. Where reinforcement is installed in the hole first and then grouted: is there a grout return at the hole collar? Alternatively, where grout is placed in the hole first and the reinforcement is then pushed through the grout: is some of the grout displaced from the hole collar? This is considered to be the same as a grout return. Refer: MSIR rr. 10.28(1) and 10.28(2)(e)
5.9	Retensioning of relevant anchor rock reinforcement is carried out and/or records are kept to verify that retensioning is not required.	**Intent:** To verify that tension in point anchored and cable bolt reinforcement systems is maintained. **Personnel:** Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew. **Method:** Interview personnel. Does the recommended support installation procedure require that the tension be checked? Is retensioning or torque testing of point anchor reinforcement carried out on a random basis?. Are the reinforcement manufacturer's instructions being followed? Refer: MSIR rr. 10.28(1) and 10.28(2)(e)
5.10	RSAR is protected against corrosion for the design life of the opening.	**Intent:** To verify that the design life of rock support and reinforcement and the openings are matched. Corrosion issues should be addressed and remedied in longer-term openings. **Personnel:** Underground manager, mining engineer, geotechnical engineer. **Method:** Interview personnel. Does the mine have areas where corrosion is likely to be a problem? Is the corrosion in these areas likely to be adverse for the support load capacity? What corrosion protection has been incorporated into the support technical specification? Does the installed support meet the required specification for corrosion protection. Refer: MSIR rr. 10.28(1), 10.28(2)(e) and 10.28(3)(e)

5.11	The mine has formalised procedures to ensure that the quality control of resins and grouts (including shotcrete and fibrecrete) satisfy design requirements at all times.	**Intent:** To verify that management recognise that rock performance is heavily dependent on quality control of all materials used as a fixative or "cementing agent" to rock. **Personnel:** Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew. **Method:** Interview personnel. Sight formalised procedures for assessing installation quality of resins and grouts. Issues to be addressed include: reference to "use by date" of the resin, resin mix and delay time, specification of the water:cement ratio, whether potable (drinking quality) water is to be used to mix the cement grout (e.g. impurities in the water (e.g. chloride salts) may adversely affect the grout compressive strength and corrode the steel in contact with the grout). Sight quality control testing of the "cementing agent" (e.g. slump, UCS tests). Refer: MSIR rr. 10.28(1) and 10.28(2)(e)
5.12	All equipment used for cementitious applications, pressurising swellex-type bolts and tensioning is maintained on a regular basis.	**Intent:** To verify that management recognize that poorly maintained equipment may not correctly inflate Swellex type reinforcement. The anchorage capacity of such reinforcement will be less when not inflated in accordance with the manufacturers recommendations. **Personnel:** Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew. **Method:** Interview personnel.Is equipment maintained in accordance with the manufacturer's instructions? Is the equipment operated at the recommended pressure? The anchorage capacity of such reinforcement will be less when not inflated in accordance with the specification. Sight results of test work conducted by NATA laboratory on mine shotcrete samples. Do the results comply with the shotcrete specification? Refer: MSIR r. 10.28(1)

5.13	Shotcrete/fibrecrete thickness testing is regularly undertaken to ensure that the specified thickness has been applied.	**Intent:** To verify that the shotcrete thickness complies with the technical specification. **Personnel:** Underground manager, mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew, shotcrete contractor. **Method:** Interview personnel. What method is used to determine the shotcrete thickness? How often is testing carried out at each location where shotcrete is applied? Does the shotcrete thickness comply with the technical specification? Does the mine have an action plan to rectify this if the shotcrete thickness specification is not achieved? If the shotcrete is too thin it may fail prematurely. Refer: MSIR rr. 10.28(1) and 10.28(2)(e)
5.14	Regular load versus displacement testing is conducted for all types of rock reinforcement used in the mine.	**Intent:** To verify the installed rock reinforcement load-displacement performance complies with the technical specification for all rock conditions (including seismic) at all times. **Personnel:** Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew. **Method:** Sight results of load-displacement tests conducted during the previous 12 months on the various types of rock reinforcement used in the mine. The test equipment and procedure to be as per the ISRM suggested methods of testing or suitable adaptation thereof. Do the results of the load versus displacement testing comply with the support technical specifications? Note: The load-displacement tests could be incorporated into the rock support and reinforcement supply contract. Reinforcement elements tested shall be installed in the mine by mine workforce using mine equipment and usual work procedures (i.e. not one off specials). The annual minimum number of load-displacement tests should be approximately 1% of the total number installed for each type of support or a minimum of 5, whichever is the larger, for each geotechnical domain. Where load/displacement testing is considered not relevant, supportive comment is to be included in the GCMP. Refer: MSIR rr. 10.28(1) and10.28(2)(e)

5.15	The equipment being used to install the rock support and reinforcement has formal confirmation that it is suitable for that purpose from both installation safety and quality assurance perspectives.	**Intent:** To verify that the equipment used is purpose designed and built for installing rock support and reinforcement. **Personnel:** Underground manager, supervision, mining engineer. **Method:** Interview personnel. Sight the manufacturer's description of the intended use of the equipment. Is this how the equipment is being used? If not, has the mine discussed with the manufacturer the use of the equipment in the manner proposed? How is the equipment maintained and by whom. Is the frequency of maintenance work in line with that specified by the manufacturer? Refer: MSIR r. 10.28(1)

6 Operations – management of unstable rock

Operations – management of unstable rock

Point	Standard	Guideline
6.1	The mine has developed and enforces a scaling policy to be adopted in each area within the mine.	**Intent:** To verify that a formal policy exists that specifies the strategic approach to scaling in all areas of the mine. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight scaling policy documentation. Refer: MSIR rr. 10.28(1) and 10.28(2)(d)
6.2	The mine has developed and enforces a standard work procedure for all forms of scaling used in the mine.	**Intent:** To verify that formal procedures exist that specify the frequency and methods of scaling to be appropriately implemented in all areas of the mine. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight scaling documentation. Refer: MSIR rr. 10.28(1) and 10.28(2)(d)
6.3	The mine conducts on-going regular checks for scaling / rehabilitation requirements of all main access ways.	**Intent:** To verify that all working areas are checked for scaling requirements at regular intervals, commensurate with the rate of rock loosening and perceived magnitude of hazard. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Check scaling scheduling documentation. Interview mining personnel. Observe underground. Refer: MSIR rr. 10.28(1) and 10.28(2)(d)

6.4	Records are kept of all scaling / rehabilitation required and these records are placed into a suitable database for future reference.	**Intent:** To verify that each area requiring scaling has been recorded and signed off as being completed to the required standard and that scheduled scaling intervals are well matched to the frequency and amount of scaling required in particular areas. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight scaling records documentation. Interview personnel. Observe underground. Refer: MSIR rr. 10.28(1) and 10.28(2)(d)
6.5	The mine has a standard specification for scaling bars and other forms of scaling equipment (e.g. mechanised scaling units and work platforms).	**Intent:** To verify that the scaling equipment in use is suited to the purpose, extent, and local ground conditions and do not introduce additional hazards to the job at hand. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight documentation listing specifications for scaling equipment and formal verification that the specifications adequately meet with the requirements for all areas in the mine. Refer: MSIR rr. 10.28(1) and 10.28(2)(d)
6.6	The mine has established trigger points for acceptable limits of issues such as tested load capacity or visual degradation (e.g. "bagging" of mesh, "popped" plates etc) of the installed RSAR system.	**Intent:** To verify that any deficiencies in the load capacity of the installed support systems can and are being identified. **Personnel:** Underground manager, mining engineer, geotechnical engineer, supervision. **Method:** Interview personnel. Sight a copy of the mine's RSAR tolerance limits. E.g. does the mine have a standard definition of how much bagging can be tolerated, and a SWP dealing with "bleeding" of mesh - as required? Similarly, does the mine have a standard definition of how much damage/deformation of reinforcement can be tolerated before remediation actions are undertaken? Refer: MSIR r. 10.28(1)

6.7	The mine has developed and enforces a standard work procedure (SWP) for removal of loose rock (as required) that is considered too hazardous to be scaled or removed by normal methods.	**Intent:** To verify that the mine is capable of safely managing large or dangerously positioned loose rock (e.g. beyond stope brows or potential removal of a "key block" that may cause unravelling above the person scaling or heavily bagged mesh). **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight relevant documentation (e.g. procedure specifies identification, reporting hierarchy, risk assessment, actions taken etc.). Is there a SWP for remediating these areas? Interview underground personnel. Refer: MSIR r. 10.28(1)
6.8	Where appropriate, additional illumination is available and used while the scaling or checking is in progress.	**Intent:** To verify that suitable lighting is available for personnel on foot when checking whether scaling is required in high areas. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Interview personnel. Observe underground workplaces. Refer: MSIR rr. 10.28(1) and 10.28(2)(d)

7 Operations – drill and blast

Operations – drill and blast

Point	Standard	Guideline
7.1	The mine has developed and enforces standard design procedures for drilling and blasting in rises and development.	**Intent:** To verify the achievement of optimum fragmentation and minimum overbreak per excavation blast with the minimum blast damage to the remaining perimeter rock. **Personnel:** Underground manager, mining engineer, supervision. **Method:** Interview personnel. Does the mine have a blast design procedure? Is it largely based on practical experience? Sight examples of use of blast design procedures in use. Have the blast designs been prepared by consultants or in-house expertise? How often are the blast designs reviewed? How do they incorporate changes in the ground conditions? How is back and wall damage minimised? Sight standard work procedure for various blast types. Were they produced using the blast design procedure? Sight reference to preferred powder factors, burden, stemming etc. for each domain. Refer: MSIR rr. 10.28(1) and 10.28(2)(b)
7.2	The mine has developed and enforces standard design procedures for drilling and blasting in stopes.	**Intent:** To verify the mine has taken due consideration of the effect of stope blasts on the stability of stope walls and backs and floor and nearby voids and pillars (low/high stresses, vibrations etc.). **Personnel:** Underground manager, mining engineer, supervision. **Method:** Interview personnel. Does the mine have a blast design procedure? Is it largely based on practical experience? Sight examples of use of blast design procedures in use. Have the blast designs been prepared by consultants or in-house expertise? How often are the blast designs reviewed? How do they incorporate changes in the ground conditions? How is stope wall damage minimised? Sight standard work procedure for various blast types. Sight stope etc. charging sheet. Were they produced using the blast design procedure? Sight reference to preferred powder factors, burden, stemming etc. for each domain. Refer: MSIR rr. 10.28(1) and 10.28(3)(d)

7.3	A standard drilling and blasting pattern exists for all forms of blasting (and is always available to end users) for each geotechnical domain.	**Intent:** To ensure that a design standard is available for "standard" void types and geotechnical domains. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Sight standard patterns, interview personnel, observe underground. Does the GCMP give reference to drill and blast requirements in each geotechnical domain? Refer: MSIR r. 10.28(1)
7.4	The drilling and blasting crew(s) understand the importance of correct drilling and blasting work procedures.	**Intent:** To verify that the drilling and charging/blasting crews understand that correct work procedures are essential for a quality excavation. **Personnel:** Lateral and vertical development mining crews, air-leg miners etc. **Method:** Interview the drilling and charging/blasting personnel, inspect work places. For example, in hard rock conditions, half-hole barrels can be seen in the backs and side walls on a regular basis, particularly in cross-cuts or where prominent planes of weakness are perpendicular to the direction of mining. What problems, if any, have the crew experienced? Refer: MSIR r. 10.28(1)
7.5	All drilling equipment can deliver required hole parallelism at appropriate gradients and operators are capable of achieving this.	**Intent:** To verify that the development rounds are drilled correctly. **Personnel:** Supervision, lateral development crews, maintenance crews. **Method:** Observe drill-hole barrel parallelism back from the face and drilling practises at the face. Refer: MSIR r. 10.28(1)

7.6	The mine implements blast strategies to minimise blast damage to the perimeter of all excavations in all geotechnical domains and ensures that these strategies (e.g. modified perimeter blasting) are followed rigorously underground.	**Intent:** To verify that the explosives, blast initiation strategies and drill patterns used are suitable for minimising blast damage to the rock mass in the walls and backs. **Personnel:** Supervision, lateral development crews, air-leg miners. **Method:** Observe drilling and charging of the face, note explosive used in the perimeter holes. Is this the explosive specified in the standard work procedure? (Note: it is preferable that decoupled cylindrical cartridges are used.) This may also be an issue for the penultimate row of holes. Note: In hard rock conditions, half-hole barrels are generally indicative of "good" mining practice. Refer: MSIR r. 10.28(1)
7.7	Overbreak at the excavation perimeters is monitored.	**Intent:** To verify that measuring of overbreak occurs to maintain quality of excavation. **Personnel:** Underground manager, mining engineer, surveyor, development crews. **Method:** Does the mine have a policy on the maximum percentage or volume of overbreak that is acceptable? Is the amount of overbreak regularly determined? Sight a copy of fortnightly or monthly summary of the overbreak, as calculated by the surveyor, for each heading. Is this information permanently recorded by the mine and contractor? Is the overbreak information regularly given to the development crews? Refer: MSIR rr. 10.28(1) and 10.28(2)(b)
7.8	A system exists to correct mining techniques where excess overbreak is encountered.	**Intent:** To verify that changes in void span due to overbreak variations encountered in the production/stoping or development stage are geotechnically assessed to ensure that the support and / or void design remains within tolerance limits for the prevailing ground conditions. **Personnel:** Underground manager, mine planning engineer, geologist, geotechnical engineer. **Method:** Interview personnel, establish whether rock mass classification, block analysis, stress analysis or other recognised methods been used to determine maximum opening spans that can be mined? Refer: MSIR r. 10.28(1)

7.9	The mine uses appropriate blast monitoring techniques in development, rises and stopes to verify blasting performance on a regular basis.	**Intent:** To verify the stope blast design parameters are monitored (e.g. fragmentation, vibration, general observation and overbreak). **Personnel:** Underground manager, mining engineer. **Method:** Interview personnel. Sight a stope blast monitoring report. Have stope blasts been performing according to design? Refer: MSIR r. 10.28(1)
7.10	Blasting in the immediate vicinity of stopes that contain wet fill is not permitted.	**Intent:** To verify procedures exist that prevent liquefaction of the saturated fill (e.g. uncured paste fill, undrained hydraulic fill and uncured cemented hydraulic fill) by dynamic loading from blasting. **Personnel:** Registered manager, manager mining, underground manager mine planning engineer. **Method:** Interview personnel. Sight records of stope blasts and stope filling (e.g. on a longitudinal section) Estimate the minimum time period between the completion of the filling process and firing of adjacent stopes. What basis is there for the minimum defined time? Has fill liquefaction occurred at the site? How is the potential for fill liquefaction managed? Refer: MSIR r. 10.28(1)

8 Design conformation – back analysis

Design conformation – back analysis

Point	Standard	Guideline
8.1	The mine has conducted back-analyses/comparisons of as-mined void geometry (Section 4) to justify the mine's short term design and planning strategies.	**Intent:** To verify that mine design/planning techniques used remain valid over time and that any discrepancies between observations and design criteria are satisfactorily resolved. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Interview personnel. Observe back analysis documentation, note comparisons made between actual stope and/or pillar dimensions and ground / rock performance monitoring (e.g. falls of ground, seismicity) and predicted/designed mine geometry and behaviour. Refer: MSIR r. 10.28(1)
8.2	The mine has conducted back-analyses/comparisons of as-mined performance monitoring (Section 4) against existing numerical or empirical design criteria to validate existing geotechnical models and justify the mine's short-term design and planning strategies.	**Intent:** To verify that appropriate techniques exist and that any discrepancies between observations (e.g. ground stresses or displacements) and geotechnical modelling are satisfactorily resolved. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Interview personnel. Observe back analysis documentation, note comparisons made between actual stope and/or pillar dimensions and ground / rock performance monitoring (e.g. falls of ground, seismicity) and predicted/designed mine geometry and behaviour. Does the geological / structural model require modification or confer with numerical or empirical techniques? Refer: MSIR r. 10.28(1)

8.3	The mine has conducted back-analyses/comparisons of the as-installed performance of RSAR (Section 4 and 7) against mine site design criteria to validate existing geotechnical models and justify the mine's RSAR short term design strategies.	**Intent:** To verify that appropriate RSAR design confirmation techniques exist and that any discrepancies between observations and design are satisfactorily resolved. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Interview personnel. Observe back analysis documentation. Refer: MSIR r. 10.28(1)
8.4	Methods exist to confirm that existing assumptions for the potential for corrosion/degradation of the RSAR system, cement products and other relevant mine infrastructure can be expected to remain appropriate in all areas of a potentially changing hydrogeological environment.	**Intent:** To verify that design assumptions regarding the expected life and quality of RSAR etc. remain valid for all areas of the mine, for the LOM. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Interview personnel. Is groundwater acidic or highly saline, and is there sufficient knowledge of the distribution of groundwater throughout the mine. Is potable (drinking quality) water used to mix the cement grout? Note: Impurities in the water (e.g. chloride salts) may adversely affect the grout compressive strength and corrode the steel in contact with the grout. Water quality should be stated in the technical specifications. Refer: MSIR r. 10.28(1)

8.5	A procedure exists to ensure that formal records of any changes in the geotechnical model (resulting from back analysis/confirmation processes) are maintained.	**Intent:** To verify that the mine design guideline remains current and that factors contributing to change in mine design / planning (in an ever changing environment) are well understood and that adequate records are kept for future personnel to use for continued safe mine design and planning of the mine. All changes should be given reference in the GCMP. **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist, mine planning engineer. **Method:** Sight notes, memoranda or technical reports accompanying approved mine plans. Have the design decisions been documented. Have the design assumptions, if any, been clearly and unambiguously stated? Have the results of the evaluation of existing geotechnical models and planning / design criteria against performance monitoring been suitably documented for future reference. Refer: MSIR r. 10.28(1)
8.6	Back analysis / design confirmation data is used to verify that the existing geotechnical models and mine design / planning methods can be expected to remain appropriate for LOM designs.	**Intent:** To verify that appropriate techniques exist to allow the mine to determine that RSAR and general mine design strategies and design criteria can be expected to remain adequate for the LOM. (E.g. the ongoing practice of leaving large open stopes or extracting stopes to a central pillar, and issues such as dewatering requirements is regularly justified using performance monitoring and relevant modelling / assessment techniques). **Personnel:** Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist. **Method:** Interview personnel. Observe back analysis / "mine performance" documentation that compares all forms of geotechnical performance monitoring (e.g. rock quality, seismic, absolute stress, convergence, RSAR performance and notes of observations) against expected behaviour at the initial design phase and projects comparisons for LOM performance using current/planned mining strategies. Reference to this document should be contained in the GCMP. Refer: MSIR r. 10.28(1)

9 Training and competency

Training and competency

Point	Standard	Guideline
9.1	The workforce receives on the job training and ongoing competency assessment of issues covering rock fall hazards in the underground workplace.	**Intent:** To verify that the workforce receives on the job training and regular assessment of issues related to the recognition of geotechnical hazards and to understand the importance of geological structure and its influence on rock stability **Personnel:** Manager mining, Training manager. **Method:** Sight training and assessment records. Interview personnel. Refer: MSIR r. 10.28(1)
9.2	The workforce receives on the job training and ongoing competency assessment of issues covering general ground awareness when working near vertical openings, and other areas of unsupported ground.	**Intent:** To verify that the workforce receives on the job training and regular assessment of issues related to general ground awareness when working near drop-offs, ore and waste stockpiles, open stopes and other areas of unsupported ground. **Personnel:** Manager mining, Training manager. **Method:** Sight training and assessment records. Interview personnel. Refer: MSIR r. 10.28(1)
9.3	The workforce receives on the job training and ongoing competency assessment of issues covering the importance of the correct drilling and blasting work procedures.	**Intent:** To verify that the workforce receives on the job training and regular assessment of issues related to the importance of the correct drilling and blasting work procedures. **Personnel:** Manager mining, Training manager. **Method:** Sight training and assessment records. Interview personnel. Refer: MSIR r. 10.28(1)

9.4	The workforce receives on the job training and ongoing competency assessment of issues covering general ground awareness with respect to assessing scaling requirements and safe scaling practices	**Intent:** To verify that the workforce receives on the job training and regular assessment of issues related to general ground awareness with respect to assessing scaling requirements and safe scaling practices. **Personnel:** Manager mining, Training manager. **Method:** Sight training and assessment records. Interview personnel. Refer: MSIR r. 10.28(1)
9.5	The workforce receives on the job training and ongoing competency assessment of issues covering the importance of the correct RSAR installation procedures.	**Intent:** To verify that the workforce receives on the job training and regular assessment of issues related to the importance of the correct RSAR installation procedures. **Personnel:** Manager mining, Training manager. **Method:** Sight training and assessment records. Interview personnel. Refer: MSIR r. 10.28(1)