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

Geotechnical considerations open pit audit – guide

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Introduction

This document was reformatted in November 2015. At this time no material changes were made to the content of the guide, which was originally published in September 2009 under the title *Guide to open pit geotechnical considerations HIF audit 2009*.
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 open pit operations from a geotechnical perspective.

Where site specific circumstances do not warrant an in depth ground control management plan e.g. shallow 2-month life mine with one material type, then the mine should have a formal geotechnical statement that justifies their approach.

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, operation, drill and blast, rock reinforcement, quality control, design confirmation or back analysis and training.

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

1 Mine planning and design

Mine planning and design

Point	Standard	Guideline
1.1	Senior mine management has demonstrated a clear understanding and commitment to address the geotechnical issues in open pit mining using sound geotechnical engineering practice	**Intent:** To verify and establish that the mine is committed to providing adequate geotechnical services to the design and operation of the mine for the full mine life **Personnel:** Registered manager, mining manager, senior mining engineer, mine planning engineer and chief geologist **Method:** Confirm that geotechnical investigation and assessment is budgeted and serviced for the life of the mine. Refer to MSIR 13.8(1)
1.2	The geometry and design life of each open pit excavation and associated waste dumps has been determined and formally documented	**Intent:** To verify and establish that the mine is aware of the effective safe mine-life of all pit walls and waste dumps **Personnel:** Registered manager, mining manager, senior mining engineer, mine planning engineer **Method:** Sight signed documentation. Refer to MSIR 13.8(1)
1.3	The mine has utilized geotechnical input in the mine design process	**Intent:** To verify and establish that the current mine design is based on geotechnical design data **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, and chief geologist **Method:** View documentation with geotechnical data from geotechnical boreholes, use knowledge from nearby pits and waste dumps if the geology can be demonstrated to be adequately similar. Geotechnical data should include planes of weakness, groundwater and surface water rock stress field and rock mass strength from core or undisturbed sample testing. Drilling programs have been used to identify potential areas of contact of the mine with large aquifers/water bearing bodies and have quantified the expected water quality and make over time. Site relevant design documentation. Refer to MSIR 13.8(1)

1.4	The positioning of open pit walls and waste dumps have taken into consideration the tenement boundaries, the locations of major surface facilities and the geotechnical parameters that can affect the integrity of these facilities	**Intent:** To verify and demonstrate that the mine plan and design will not detrimentally impact on minesite and public infrastructure and natural features of significance, and that these features - e.g. creeks and waste dump surcharge, do not impact negatively on the mine **Personnel:** Mining manager, senior mining engineer, mine planning engineer, chief geologist **Method:** Sight Project Management Plan (PMP), any PMP updates/addenda and check current design documentation. Refer to MSIR 13.8(1) and 13.15
1.5	A multi-disciplinary, mine design and planning process exists and is formally implemented	**Intent:** To verify that mine design and planning is an on-going process that is signed off by relevant personnel and not a series of ad hoc crisis meetings. The mine planning and design process should lead production, not the reverse **Personnel:** Mining manager, senior mining engineer, mine planning engineer, chief geologist **Method:** Sight minutes of design and planning meetings. Check that the process is current. Refer to MSIR 13.8(1)
1.6	A set of development planning and design criteria have been drawn up to provide general guidance in mine planning and design for open pits, waste dumps, ROM pads and major haul routes. e.g. stockpiles and waste dumps have been designed to take into account the full range of foundation materials, stockpile/dump materials and ground/surface water conditions	**Intent:** To verify and illustrate that the mine is proactively designing and planning mining activities - not relying solely on "reactionary design" and is aware of the material properties of all waste products, and the influence of the local environment on the performance of these structures **Personnel:** Mining manager, senior mining engineer, mine planning engineer, chief geologist **Method:** Sight guidelines. Refer to MSIR 13.8(1), 13.12 and 13.13

1.7	Geotechnical domains are used to divide the rock mass into volumes of similar expected ground behaviour in three dimensions	**Intent:** To verify and demonstrate that the mine has considered the geotechnical environment as a whole in all areas of the pit and has grouped areas with similar characteristics together as an indication of expected slope performance **Personnel:** Mining manager, senior mining engineer, mine planning engineer, chief geologist **Method:** Sight documentation that presents the inherent variability of the geological structure, rock stress levels, rock mass strength and deformation characteristics. Refer to MSIR 13.8(2)
1.8	The mine has developed a ground control management plan (GCMP) relevant to the local ground conditions and mining strategies	**Intent:** To verify that a formal ground control plan exists, meets required standards and is up to date **Personnel:** Mining manager, senior mining engineer, mine planning engineer, chief geologist **Method:** Review the ground control management plan. Verify if the plan complies reasonably well with the department guidelines. Refer to MSIR 13.8(1)
1.9	The mine has both short and long term production schedules that take into account the likely geotechnical impacts which may have an adverse affect on safety	**Intent:** To verify that the mine design takes into account the excavation exposure time, personnel access, and time dependent performance etc. when considering geotechnical designs **Personnel:** Mining manager, senior mining engineer, mine planning engineer, chief geologist **Method:** Sight long term and short term planning/scheduling documents, check for variation in blasting near temporary walls, workplace inspection, dewatering design and effects, ramp design, reinforcement scheduling, progression of mining working benches and formation of final walls etc.

1.10	An assessment has taken place to determine whether all boreholes need to be fully grouted to prevent contact with water bearing bodies and those requiring grouting are sealed	**Intent:** To verify and demonstrate that the mine has taken the necessary precautions and understands the importance of groundwater inflows and artesian pressures on the slope stability **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, mine surveyor **Method:** Sight plans showing location of boreholes and the current status of these holes. Also requires supportive documentation to verify the decisions made with respect to these boreholes. Refer to MSIR 13.8(2)(c)
1.11	The boundaries of water filled hazards have been accurately determined and a safe working distance specified according to the ground conditions and the mine plan	**Intent:** To verify that the mine has adequately considered the hazard of working near large bodies of ground water where the open pit encroaches onto abandoned and flooded workings **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, mine surveyor **Method:** Sight design criteria. Refer to MSIR 13.8(2)(c) and 13.8(3)
1.12	The interaction of near-by underground mine voids has been taken into consideration for the mine design and excavation sequencing to minimize the potential for adverse stability conditions on pit walls	**Intent:** To verify and demonstrate that 1) the creation of potentially highly stressed pillars is minimised, 2) walls are not significantly undercut by stoping, 3) Crown pillars are designed and scheduled for excavation appropriately **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, mine surveyor **Method:** Sight design criteria/documentation. Refer to MSIR 13.8(3)

1.13	Water diversion and storage structures are designed according to acceptable engineering standards	**Intent:** To verify that water diversion and/or containment structures can perform to the required standards for the full operating life of the mine/structure **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, mine surveyor **Method:** Sight engineering designs and as constructed diagrams and supportive documentation. Refer to MSIR 13.8(2)(c)
1.14	Internal water drainage strategies exist for open pits, waste dumps and haul roads	**Intent:** To verify that the mine has implemented suitable drainage measures that minimise erosion of important structures and pooling of large bodies of water in critical areas (e.g. at the crest of batter slopes or the toe of waste dumps). These drainage control structures need to be applicable for storm events **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologist **Method:** Check pit designs and inspect open pit. Refer to MSIR 13.8(2)(c)
1.15	A justifiable design criteria exists for mining in close proximity to surface water drainage paths and open pit sumps where underground workings exist	**Intent:** To verify that the mine has adequately considered the hazard of working near large bodies of water or fluid material where the open pit encroaches onto surface drainage structures or water/tailing storage structure **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologist **Method:** Sight design criteria. Refer to MSIR 13.8(2)(c)
1.16	The mine has a formalised plan for closure of the open pit	**Intent:** To verify that the mine has in place a strategy for achieving a final practicable and safe result **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologist **Method:** View the site abandonment plan. Refer to MSIR 13.8(1)

1.17	The closure plan considers issues such as drainage, visibility (dusting & road bends), abandonment bunding and erosion materials spreading onto sensitive land	**Intent:** To verify that the mine has considered the issues that will impact on the final safe closure of the pit **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologist **Method:** Sight closure plan details. Determine if the plan specifies a process for closure that covers a strategy for achieving a final practicable and safe result and ensures: 1. All slopes are reassessed in accordance with the Slope Management System 2. The required, actions are undertaken to ensure that slopes are maintained in a safe condition 3. Barriers and signs prevent inadvertent access to areas affected by slopes 4. All reports, plans, logs and records are indexed and preserved for future reference. Refer to MSIR 3.16 & 13.15
1.18	The design of final pit walls takes into account time-dependent effects on rock strength, the degree of inherent uncertainty, and reflects the associated need for conservative slope design criteria	**Intent:** To verify that the final pit wall and dump slope designs will remain safe for the long term and that appropriate design criteria (e.g. department abandonment guidelines) have been used to determine this **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologist **Method:** Sight design criteria and methodology used to derive the long-term geotechnical model. Refer to MSIR 13.8(1)
1.19	The closure plan has been approved by the relevant regulatory bodies and nearby land owners	**Intent:** To verify that the proposed closure plan is acceptable and achievable with respect to site conditions and relevant stakeholders **Personnel:** Registered manager, mining manager **Method:** Sight documents of acceptance by relevant stakeholders. Refer to MSIR 3.16 & 13.15

2 General operational issues

General operational issues

Point	Standard	Guideline
2.1	The mine has implemented the ground control management plan (GCMP) for pit walls, stockpiles and waste dumps	**Intent:** To verify that the GCMP meets required standards, is up to date and is being followed. **Personnel:** Registered manager, mining manager, senior mining engineer, mine planning engineer, chief geologist **Method:** Check current geotechnical design and input. Refer to MSIR 13.8(1), 13.8(2) and 13.12
2.2	The GCMP has a review period and is signed off by relevant management bodies each time a modification is made to that document	**Intent:** To verify that the GCMP is a "living document" and includes input from personnel responsible for key areas of mining that impact on geotechnical performance **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologist **Method:** Check current and earlier versions of the GCMP. Refer to MSIR 13.8(1)
2.3	All relevant personnel understand their roles within this site GCMP	**Intent:** To verify that mine management has in place a working methodology that describes the overall responsibilities of personnel in the mine with respect to geotechnical considerations and lists the systems and design strategies available for each component of geotechnical management and that the relevant workforce possess the basic knowledge required **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist and chief geologist **Method:** Interview relevant personnel in the mine. Refer to MSIR 13.8 (1)

2.4	The mine has a suitably qualified person(s) to oversee geotechnical issues or has appropriate visitation by contracted geotechnical experts with backup from appropriate site personnel	**Intent:** To ensure that sufficient human resources are devoted to geomechanics and that daily issues are addressed. **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist and chief geologist. **Method:** Determine if there is a full time or part time competent person appointed for geomechanics duties. Is this sufficient considering the geomechanics issues at the mine? What are the qualifications of the competent person? Refer to MSIR 13.8 (1)
2.5	The site has formalised procedures for geotechnical mapping commensurate with the rate of mining and the specific site safety risks for those undertaking mapping	**Intent:** To verify that formalised procedures exist for the collection of geotechnical data to enable management to achieve an adequate understanding of ground conditions. **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist and chief geologist **Method:** Sight evidence, databases, plans sections, displaying geotechnical data. Sight geotechnical domains definition, are these current. Refer to MSIR 13.8 (1)
2.6	Geotechnical mapping is being carried out on a regular basis consistent with the rate of mining and areas requiring additional geotechnical information	**Intent:** To verify that geotechnical information is recovered from rock mass exposure, to verify the assumptions made in the design geotechnical model **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist and chief geologist **Method:** Sight the process or work procedure describing which locations are to be mapped geotechnically. Check to make sure relevant, accurate information is being gathered from the mapping process. Refer to MSIR 13.8 (2)(a) and 13.8(2)(b)

2.7	The as-mined pit wall/dump conditions and geotechnical model are used to make risk assessments for each mining area	**Intent:** To verify that the mine is validating the rock domains with observed wall/slope performance and determines the levels of risk for each area of the mine using this information **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist and chief geologist **Method:** Sight current pit wall hazard/risk plans. Refer to MSIR13.8(1)
2.8	Safety/catch berms are maintained such that sufficient catch volume remains to halt the movement of rock down the slope	**Intent:** To verify that the mine understands the importance of catch berms as a safety structure in wall design **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologist **Method:** Observe in pits whether berms have rill piles that do not extend to the berm crest and that suitable access remains in all areas, taking into consideration the site method used for scaling. Refer to MSIR 13.9(2)
2.9	For situations where berms are not in a suitable condition, formalised procedures are in place and implemented to prevent rock from toppling down onto the working areas	**Intent:** To demonstrate that the mine has developed alternative measures (other than the use of berms) to maintain safe working areas for the hazard of falling rock **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, and chief geologist **Method:** Sight formal procedures and inspect mine areas e.g. windrows to restrict access to the toe of the slope. Refer to MSIR 13.9(2)
2.10	The mine has a system for house-keeping loose material after each wall blast and if blocks of loose rock come to rest at the crest of berms	**Intent:** To verify that the mine has a suitable formalised process that minimises loose rock at the batter crests **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologist **Method:** Observe procedures, inspect mine. Refer to MSIR 13.9(2)

2.11	Where underground workings or natural voids exist, the mine has developed formal safe working practices for mining through voids that are formally approved and implemented	**Intent:** To verify that SWP and design criteria for minimal floor thickness exist to minimise exposure to the hazards associated with working on top of open voids **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologist **Method:** Observe SWP and design criteria, inspect mine plan database. Refer to MSIR 13.8(3)
2.12	The mining through voids document complies with the departmental guidelines on open pit mining through underground workings as a minimum standard	**Intent:** To verify that the mine has considered all issues relevant to mining near abandoned underground workings or natural voids **Personnel:** Mining manager, senior mining engineer, mine planning engineer **Method:** Observe SWP and design criteria, inspect mine plan database. Refer to MSIR 13.8(3)
2.13	Appropriate bunding strategies have been developed and implemented to limit access to "drop-offs" from levels above (general traffic ramps and dump tip heads)	**Intent:** To verify that the mine has formal strategies for the design and construction of safety bunds and windrows for the prevention of vehicles falling down slopes **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist. **Method:** View design and construction documentation. Refer to MSIR 13.5(2), 13.7(5), 13.8(1)
2.14	Waste dump procedures have been developed to take into account the full range of excavation materials being dumped and ground/surface water conditions in all areas	**Intent:** To verify that the mine has adequately considered the likely variation in operational performance of waste dumps for the full life of the mine project **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist and chief geologist **Method:** View dump design protocol. Refer to MSIR 13.5(1)

2.15	Waste dump management includes policies for drainage at the top and bottom of dumps, tip head design and management, foundation stability, and dust, where it is an issue	**Intent:** To verify that the mine has considered all factors that can affect the operational status of waste dumps **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist and chief geologist **Method:** Sight operational design criteria. Refer to MSIR 13.5(1)
2.16	Where areas of significant hazard are identified (e.g. undertaking cutbacks, areas with high rates of deformation), suitable safe working practices are developed and implemented to protect personnel that may work below the level of the cut-back	**Intent:** To verify that the mine has in place a strategy to allow mine personnel safe access below areas where inadequate safety berms exist and large scale rill slopes exist **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist and chief geologist **Method:** View generic protocol or specific strategy if such a situation exists at the mine. Refer to MSIR 13.9
2.17	Emergency action plans or protocols exist in the event of a potential high risk ground movement event	**Intent:** To verify that the mine has in place a strategy to warn mine personnel working below areas where monitoring indicates potential large scale ground movements that could overrun containment structures. There are emergency response plans that include: • the safe evacuation of personnel • isolation of an area where a warning of impending slope failure has been generated **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist and open pit operators **Method:** View generic protocol or specific strategy if such a situation exists at the mine. Refer to MSIR 13.8(1)

2.18	The mine conducts regular, on-going, checks of pit walls to determine the need for scaling over time for various types of work (e.g. installation of reinforcement or monitoring installation) and documents any rehabilitation work carried out	**Intent:** To verify that any working area requiring close access to walls by persons "on foot" or driving plant (e.g. rock reinforcement crews, truck operators) is scaled prior to the work being undertaken, and during the process as required **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, and relevant mining personnel **Method:** Interview relevant persons and inspect working areas. Refer to MSIR 13.9(9)
2.19	Records are kept of scaling work undertaken	**Intent:** To verify that the mine design and planning process is providing a safe working environment and to verify that the local conditions are adequate for installation of ground support & reinforcement **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist and chief geologist **Method:** Inspect scaling records. Refer to MSIR 13.9(9)
2.20	The mine has a standard specification for scaling equipment and these specifications can satisfy the full extent of operating conditions	**Intent:** To verify that the mine has developed a scaling policy that can be safely and effectively applied for the full range of operating conditions e.g. reach, timing, and availability **Personnel:** Mining manager, geotechnical specialist, relevant mining personnel **Method:** Check for scaling equipment specifications. Refer to MSIR 13.9(9)
2.21	The mine enforces a standard work procedure for scaling	**Intent:** To verify that the mine has developed a standard protocol for the safe scaling of various features and slope geometries **Personnel:** Mining manager, geotechnical specialist, relevant mining personnel **Method:** View scaling SWP. Refer to MSIR 13.9(9)

3 Drill and blast

Drill and blast

Point	Standard	Guideline
3.1	A standard drilling and blasting pattern exists, and is always used, for each geotechnical domain, and influence of groundwater	**Intent:** To ensure that rational drill and blast design procedures are used, rather than relying entirely on experience as the design tool. The procedure should include: • drill holes parallel and to the correct alignment • careful perimeter blasting practices are implemented to minimise wall damage • detonators and compatible primers used to initiate the main explosive charge • suitable detonators and primers are used when mining below the water table **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, and chief geologist **Method:** Sight the documented standard for each geotechnical domain. Refer to MSIR 13.8(1) and 13.8(2)(f)
3.2	SWP's are available for drilling and blasting operations	**Intent:** To ensure that blasts are conducted as per the design guidelines **Personnel:** Mining manager, mine planning engineer, geotechnical specialist **Method:** Interview personnel. Sight the SWP for production and near wall blasting. Sight a near-slope charging plan to verify that the blast design procedures are routinely followed. Refer to MSIR 13.8(1) and 13.8(2f)
3.3	Suitable subgrade drilling and blasting is undertaken to allow for safe trafficking conditions without damaging batter crests	**Intent:** To ensure that the mine has taken into consideration the potential for batter crest damage by subdrill blasting. The mine uses recognized blast monitoring techniques to verify blasting performance on a regular basis **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist **Method:** Check subgrade drilling procedures and inspect open pit conditions. Refer to MSIR 13.8(1) and 13.8(2)(f)

3.4	All final wall drilling equipment is fitted with automatic hole parallelism and angle controls that are maintained in good working order	**Intent:** To verify that the drilling equipment is capable of accomplishing standard blast designs on a consistent basis **Personnel:** Mining manager, drilling operators **Method:** Interview drill operators. Refer to MSIR 13.8(1) and 13.8(2)(f)
3.5	Overbreak/underbreak at the excavation perimeters is monitored	**Intent:** To establish if the mine has a performance monitoring strategy for standard drill and blast designs. Where repetitive overbreak occurs, the mine should modify the drill and blast design accordingly **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist **Method:** Sight blast performance records and evaluation documents. Refer to MSIR 13.8(1) and 13.8 (2)(f)
3.6	A system exists to correct mining techniques where excess overbreak or burden at the toe is encountered	**Intent:** To demonstrate that the mine has a formal strategy for redesigning drill and blast patterns when significant variation from wall designs are noted after blasting e.g. when berms are lost or significant toe burden exists. There are site procedures for: • reporting blasting and digging damage to crests and toes • assessing the risk and implementing remedial actions **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologi **Method:** Sight relevant documentation. Refer to MSIR 13.8(1) and 13.8(2)(f)

3.7	Where applicable, the impact of blasting on nearby structures e.g. tailings storage facilities or water diversion structures has been adequately assessed and taken into consideration when designing all forms of blast	**Intent:** To ensure that the mine has taken measures to ensure that blasts will not destabilise nearby important or hazardous structures over time **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologist **Method:** Check relevant documentation where such structures exist (e.g. paddock dam, tailing storage facilities (TSF), inside a working open pit). Refer to MSIR13.8(1) and 13.8(2)(f)

4 Rock reinforcement

Rock reinforcement

Point	Standard	Guideline
4.1	The mine has determined ground support strategies for each type of support/reinforcement, geotechnical domain and dimension of excavation	**Intent:** To verify that the mine has developed generic guidelines for assessing the need for ground reinforcement and the types of reinforcement required in each geotechnical domain **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist **Method:** Check formal documentation, may form part of the GCMP. Refer to MSIR 13.8(2)(d)
4.2	A recognised rock support and reinforcement design method has been used to design the required rock support and reinforcement system	**Intent:** To ensure that recognised geotechnical criterion are used for the design of rock support and reinforcement systems. Has the mine used appropriate tools to derive support/reinforcement requirements and that the design capacities assumed for support/reinforcement elements are within acceptable limits. e.g. Catch fences need to take into account the maximum likely size of rill material, and the kinetic energy of falling and bouncing rock; cable bolts are likely to be ineffective in weak/soft rock; if the mine uses expansion shell rock bolts, then the intact rock strength will permit the full tensile strength of the bar to be achieved in a load-displacement test; reinforcement borehole orientation has been established with respect to pit wall geometry and expected direction of ground movement; load capacity of the individual elements (anchorage, bar or tendon and surface restraint) are appropriately matched to prevent premature failure of any one component, e.g. Thickness of all plates and/or straps prevents the nut, barrel and wedge anchor or ring from being pulled through the plate and/or strap at the ultimate tensile strength **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist **Method:** Sight design criteria and calculations. Refer to MSIR 13.8(2)(d)

4.3	A technical specification exists for all the rock support and reinforcement systems in use	**Intent:** To verify that rock support and reinforcement specification have been developed that states the quality of steel, load capacities (support resistance) and the energy absorption capacities of the various elements in the system **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist **Method:** Sight specification documentation. Refer to MSIR 13.8(2)(d)
4.4	The mining cycle has been adapted to the ground conditions to suit any delays in installing the ground support	**Intent:** To verify that the mine has taken into consideration the time and access required to prepare for and install ground reinforcement with respect to mine scheduling **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist **Method:** View review documentation that confirms the suitability of proposed installation strategies with respect to mine scheduling Refer to MSIR 13.8(2)(d)
4.5	Written standard work procedures have been developed for the installation of the various types of rock support and reinforcement 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 these procedures enforced **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, relevant mining personnel **Method:** Interview personnel. Observe installation. Sight copy of SWP. Compare SWP with observed procedure. Refer to MSIR 13.8(2)(d)

4.6	The installation procedures provided by the supplier(s) of the rock support and reinforcement elements are being followed	**Intent:** To ensure that support/reinforcement installation complies with design expectation and specifications. e.g. correct tensioning, clean components, correct storage (e.g. resin), correct filling of hole etc., correct grout mixing etc. are used when reinforcement is being installed. Shotcrete and grout specification states the slump of the mix (for wet mix shotcrete), the uniaxial compressive strength and a measure of the toughness of the product at specified time intervals prior to or following mine application, as appropriate **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist **Method:** Sight supplier installation standards, installation records. Refer to MSIR 13.8(2)(d)
4.7	The storage and handling of rock support and reinforcement elements are such that deterioration with time is minimized	**Intent:** To ensure that reinforcement and support elements are stored according to the supplier's standards and are not allowed to deteriorate to a level below these standards, (e.g. resin grouts are stored at the temperature range recommended by the manufacturer. Resin grouts and additives are consumed before their use by date or within a specified period of time. Non-galvanised materials are kept in a non-corrosive atmosphere, materials needing to be "clean" are kept grease free) **Personnel:** Mining manager, senior mining engineer, geotechnical specialist. **Method:** Sight documentation on recommended storage methods, check storage areas for each element and check for "suitable to use documentation". Refer to MSIR 13.8(2)(d)

5 Quality control and monitoring

Quality control and monitoring

Point	Standard	Guideline
5.1	Regular geotechnical inspections are made on foot by suitably experienced personnel to detect change in ground stability of the walls and berms and to document the performance of pit walls with time	**Intent:** To verify that the mine recognises the importance of visual observations of slope performance in all areas of the mine **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist and chief geologist **Method:** Sight inspection records. Refer to MSIR 13.8(2)(g)
5.2	Strategies for pit wall monitoring are appropriately matched to the mode and scale of potential failures and can provide suitable information with adequate forewarning	**Intent:** To verify that appropriate monitoring methods are used to identify potential wall failures and allow for suitable and timely action to be taken **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist **Method:** Interview personnel. Sight analysis of monitoring results (graph, memoranda, etc.), is there evidence of action plans. Refer to MSIR 13.8(2)(g)
5.3	The mine has established tolerance limits for various modes of failure which are used to determine the appropriate levels of action	**Intent:** To ensure that the mine understands the acceptable rates of movement for various failure mechanisms and rock types and slope geometry and can use this information to plan appropriate safe courses of action according to monitoring results **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist **Method:** View slope movement tolerance criteria. Refer to MSIR 13.8(1)

5.4	Where appropriate, a seismic monitoring system is installed in a mine where seismic activity causes damage to the pit walls and/or the rock support and reinforcement systems in the mine	**Intent:** To demonstrate that the mine has the capability of monitoring seismic events and trends that can be used to plan and design excavation works, and develop safe work procedures for relevant personnel **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist **Method:** Where relevant, observe seismic monitoring records
5.5	Geotechnical hazards and monitoring results are effectively and regularly communicated to the workforce (including management)	**Intent:** To verify that management have informed the workforce of monitoring results and any likely geotechnical hazards **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, and chief geologist **Method:** Interview personnel. Sight minutes of safety meetings or display of monitoring graphs. Refer to MSIR 13.8(1)
5.6	The mine has developed and implemented quality control requirements for each type of rock reinforcement and support element used at the mine	**Intent:** To ensure that the as-installed performance of reinforcement and support elements (e.g. pullout strength, time dependent effects such as corrosion, relaxation). Samples of the mine shotcrete mix are collected at specified intervals, under normal mine operating conditions, and tested in a NATA registered concrete testing laboratory for compliance with the shotcrete specification. Shotcrete thickness is tested regularly during placement to ensure that the specified thickness has been applied.) meet with design criteria **Personnel:** Mining manager, senior mining engineer, geotechnical specialist, relevant mining personnel **Method:** Sight performance monitoring results. Refer to MSIR 13.8(2)(d).

5.7	Groundwater samples are routinely collected and chemically analysed to determine the potential for corrosion of the rock support and reinforcement system	**Intent:** To ensure that the mine understands that the quality of groundwater can vary throughout the mine, and can have a significant impact on the performance of the reinforcement and support elements **Personnel:** Mining manager, senior mining engineer, geotechnical specialist **Method:** Sight water sampling results, check that regular samples are taken and that widespread assessment is made. Refer to MSIR 13.8(2)(d).
5.8	Variations to the recommended installation procedures have been discussed according to the formal design strategy and agreed with the supplier prior to their implementation	**Intent:** To ensure that the modified installation procedures will not result in diminished support and reinforcement performance **Personnel:** Mining manager, senior mining engineer, geotechnical specialist **Method:** Interview design and installation personnel. Sight documentation. Ask about possible variations to the installation procedures. Have these been agreed with the supplier prior to implementation. Refer to MSIR 13.8(2)(d)
5.9	The mine has an action plan that is implemented when it is found that quality control results (e.g. the load capacity of the installed rock support and reinforcement system) do not meet the required standard	**Intent:** To verify that an action plan is developed and implemented when support performance is found to be not according to specification **Personnel:** Mining manager, senior mining engineer, geotechnical specialist **Method:** Sight testing analysis and evidence of action plans. Confirm that ground control operators are instructed, trained and competent enough to stop their current activity if ground control materials and/or equipment are not to specification. Confirm there is a system in place to upgrade ground support where performance is inadequate, or where ground conditions or mining geometries change. Refer to MSIR 13.8(2)(d)

6 Design confirmation/back analysis

Design confirmation/back analysis

Point	Standard	Guideline
6.1	An on-going record of geotechnical monitoring, with written notes of observations, is maintained, regularly updated and current. A procedure exists where changes in the geotechnical model are identified, or change in pit wall performance noted and relevant changes made to the mine design and GCMP(Ground Control Management Plan)	**Intent:** To verify that the mine has established a sound database of pit wall performance that can be used to design future slopes and safe working procedures in certain areas. Observed wall performance and any predictions made by various design methods are compared and any discrepancies are satisfactorily resolved and updated in the GCMP **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologist **Method:** Sight GCMP and history of numerical modelling or mine design changes. Refer to MSIR 13.8(1)
6.2	The pit wall performance documentation is current	**Intent:** To verify that the mine regularly updates the database of pit wall performance that can be used to design future slopes and safe working procedures in certain areas **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist and chief geologist **Method:** Check the last modification date on the document. Refer to MSIR 13.8 (1)
6.3	The as-mined pit wall geometry is known and ratified against initial wall designs	**Intent:** To verify that the as-mined excavation is following the current design **Personnel:** Mining manager, mine planning engineer, mine surveyor **Method:** View confirmation and redesign plans. Refer to MSIR 13.8(1)

6.4	Accurate plans are used to show “as-is” void and pillar geometry of nearby underground mines to confirm design strategies	**Intent:** To verify that the mine adequately checks the as-is status of abandoned underground mine voids, updates the database and confirms that design strategies remain appropriate **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, mine surveyor **Method:** Sight current plan database and assessment documentation. Refer to MSIR 13.8(3)
6.5	The mine has developed a process whereby any slope failures are back analysed to re-evaluate initial designs	**Intent:** To verify that the mine adequately checks the as-is status/performance of open pit walls and waste dumps and uses design failures as a method to improve on the original design and mining strategies **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologist **Method:** Check slope failure documents and back analysis details. Note that it is not always necessary to change the design for each failure. However, the decision must be suitably justified and formally presented. Refer to MSIR 13.8(1)

7 Training and competency

Training and competency

Point	Standard	Guideline
7.1	The workforce receives on the job training and assessment covering the recognition of geotechnical hazards	**Intent:** To verify the workforce possesses the basic knowledge with respect to the geotechnical hazards of open pit mining **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologist **Method:** Check training modules. Refer to MSIR 4.13 and 13.8(1)
7.2	The workforce receives on the job training and assessment covering general ground awareness when working near drop-offs, e.g. pit bench edges, ore stockpiles	**Intent:** To verify that training programs are being implemented throughout the workforce in regard to potential falls of ground below mining personnel when working on foot or in light or heavy vehicles, and to prevent persons from inadvertently falling down drop-offs. **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist and chief geologist **Method:** Review training material for the topics and review attendance lists of the training sessions. Refer to MSIR 4.13, 13.8 (1) and 13.12
7.3	The workforce receives on the job training and assessment covering general ground awareness when working near pit walls	**Intent:** To verify the workforce possess the basic knowledge with respect to working near pit walls in regard to potential falls of ground when working on foot or in light or heavy vehicles **Personnel:** Mining manager, training coordinator **Method:** Observe training documents and course completion database. Refer to MSIR 4.13, 13.7(5) and 13.9(9)

7.4	The workforce receives on the job training and assessment covering general ground awareness when working where underground voids might exist	**Intent:** To verify that the mine has a process to ensure the workforce possess the basic knowledge with respect to the hazards of mining near open voids beneath the pit floor **Personnel:** Mining manager, senior mining engineer **Method:** Check training modules. Refer to MSIR 4.13 and 13.8(3)
7.5	The workforce receives on the job training and assessment covering general ground awareness when working on waste dumps	**Intent:** To verify that the mine has a process to ensure the workforce possess the basic knowledge with respect to the hazards of waste dump operation **Personnel:** Mining manager, senior mining engineer **Method:** Check training modules. Refer to MSIR 4.13 and 13.5
7.6	The workforce receives on the job training and assessment covering the importance of the correct drilling and blasting work procedures	**Intent:** To ensure that the workforce possess the basic knowledge with respect to controlled blasting practices in open pit mines **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, training officer **Method:** Check training records, interview relevant personnel in the mine. Refer to MSIR 4.13, 13.8(1) and 13.8(2)(f)
7.7	The workforce receives on the job training and assessment covering general ground awareness with respect to assessing scaling requirements and safe scaling practices	**Intent:** To verify that the mine has a process to provide the workforce with the basic knowledge with respect to scaling hazards in open pit mining **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, chief geologist, training officer **Method:** Check training modules. Refer to MSIR 4.13, 13.9(2) and 13.9(9)

7.8	The workforce receives on the job training and assessment covering the importance of the correct rock reinforcement installation procedures	**Intent:** To verify that the workforce possess the basic knowledge with respect to installation of ground reinforcement and support in open pit mines **Personnel:** Mining manager, senior mining engineer, mine planning engineer, geotechnical specialist, training officer **Method:** Check training records, interview relevant personnel in the mine. Refer to MSIR 4.13, 13.8(2)(d)
7.9	Mine management have procedures for assessing the ongoing competence and performance of relevant mining personnel in : recognising geotechnical hazards, working near drop-offs, working near pit walls, working where underground voids might exist, working on waste dumps, the correct drilling and blasting work procedures, assessing scaling requirements and safe scaling practices and the correct rock reinforcement installation procedures	**Intent:** To verify that the workforce continues to apply the basic knowledge with respect to safe open pit mining practices **Personnel:** Mining manager, training officer **Method:** Check training records, interview relevant personnel in the mine. Refer to MSIR 4.13 and 13.8(1)