

CMPA

Working Safely with Geotechnical Risk in Quarries



Issue 1

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Author: David McKelvie – DMcK Management Pty Ltd trading as **SAFEMIX**

Consultative Advisory Team

Basil Natoli – Bell Cochrane and Associates, Wayne Deken - Conundrum Holdings,
Rodney Krins – formerly of Full Bore Drill and Blast, Michael Maraspin and Rodger James - Fulton Hogan
Adam Gordon – Orica, Reza Ghaemi – formerly of Orica, Don Miller – Coffey Partners

Disclaimer

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The guidelines here may not apply in all circumstances and should not replace a quarry manager’s considered assessment of a particular situation before them.

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1. Overview

This Guideline “Working Safely with Geotechnical Risk in Quarries” together with the CMPA’s Work Safely Reference Manual aims to support CMPA members in meeting the requirements of the Victorian Occupational Health and Safety Act 2004 by ensuring that:

- Geotechnical hazards associated with quarry ground movement and quarry operations are identified, assessed where required and then controlled in a manner to reduce the risk of personal or vehicle engulfment; and
- Quarry infrastructure is established in a manner so as to prevent vehicles that have lost control, or persons working close to edges from falling to another level.

To achieve the above this Guideline focusses on pit design and water management, the two most critical elements of winning source materials in a safe and economical manner.

2. Purpose

The document outlines established industry practices collectively endorsed by CMPA members that may be used as a guide when:

- Sourcing information for establishing and applying for a Work Plan;
- Planning and establishing quarry infrastructure such as faces, dams, sediment settlement ponds, haul roads, berms, stockpiles, overburden dumps and rehabilitation;
- Conducting drill and blast activities;
- Establishing Safe Work Method Statements (SWMS) and/or Safe Work Procedures (SWP) to guide employees and contractors that are potentially exposed to geotechnical or quarry infrastructure hazards in their working role and working environment;
- Providing resource materials for Registered Training Organisations (RTOs) conducting training in surface extraction operations;
- Providing resource materials to our community who may be seeking information in regards to how CMPA Members and other construction material processors conduct their surface extraction operations.

3. Relevant Regulation and Resource Materials

When controlling geotechnical risk, management must take into account the following legislation:

- Victorian Occupational Health and Safety Act 2004;
- Victorian Occupational Health and Safety Regulations 2007;
- Mineral Resources (Sustainable Development) Act 1990;
- Mineral Resources (Sustainable Development) (Extractive Industries) Regulations 2010.

The CMPA acknowledges the provision of resource materials from within the following guidance materials;

- Guidance Material for the Assessment of Geotechnical Risks in Open Pit Mines and Quarries, Energy and Earth Resources (DEDJTR) Victoria;
- Extractive Industry Work Plan Guideline, Energy and Earth Resources (DEDJTR) Victoria;
- Slope Monitoring: Techniques and Instruments
www.iitbhu.ac.in/faculty/min/.../10%20Slope%20Instrumentation;
- Quarries Working towards a Safe and Healthy Quarrying Industry
- Inspections of Rock Faces 2012;
- HSE (UK) Health and Safety at Quarries, Code of Practice and Guidance 2013;
- Health and Safety at Opencast Mines, Alluvial Mines and Quarries, Worksafe New Zealand, November 2015;
- Geotechnics Face & Stockpile Operations Information Sheet 2 March 2011 Guidance on Excavation and Tip Rules in Quarries. Quarries National Joint Advisory Committee (QNJAC) U.K.;
- Slope Stability Field Book, the Institute of Quarrying Australia 2015;
- “Environmental Guidelines for Management of Small Tailings Storage Facility” (www.energyandresources.vic.gov.au);
- “Your dam, your responsibility” (www.delwp.vic.gov.au);
- CMPA “Blast Management Template in the Construction Materials Industry”, Issue 2 April 2015;
- CMPA “Traffic Management in the Construction Material Industry”, April 2015.

4. Geotechnical Risk Overview

Geotechnical risks at a quarry are defined by the Department of Economic Development, Jobs, Transport and Resources (DEDJTR) - Earth Resources Regulation Branch (ERRB), as those risks associated with ground movements. Ground movements are typically limited to the area of the quarry and to a region around the quarry. Ground movements may be significant (such as subsidence or natural rebound) or catastrophic (such as batter collapse). Irrespective of the type of ground movements, it is possible for persons, infrastructure or the environment to be harmed. It is essential that the risks of harm arising from ground movements are minimised (also known as "Ground Control") during the period of operation of the site, rehabilitation and post-closure. In developing a Work Plan, in the development phase of a quarry, consideration of stability and access (bench width) must be made.

Quarry workers can potentially be at risk when working on, in or the vicinity of:

- **Excavated Slopes** inclusive of hard rock quarry faces developed by drilling and blasting and mechanically excavated hard rock, sand or clay pits developed by excavators, dozers, scrapers, front end loaders, hydraulic sluicing and dredging;
- **Constructed Slopes** inclusive of dam embankments, overburden dumps, berms, stockpiles, slimes or settlement ponds, backfilled ramps and rehabilitated pit faces;
- **Natural Slopes** inclusive of steep natural slopes.

The potential risk associated with working on, in or within the vicinity of a slope is as follows:

- A person, vehicle or mobile equipment falling from the slope to a surface below or into a Water Containment Structure, i.e. dams or silt settlements ponds;
- A person, vehicle or mobile equipment being struck from material falling from the slope;
- A person, vehicle or mobile equipment being engulfed by materials from sliding, collapsing or subsiding slopes;
- A person, vehicle or mobile equipment being inundated with water or silt slurry from a failed embankment of a Water Containment Structure;
- External infrastructure, public safety and environmental receptors may be impacted.



Elevated Slope



Constructed Slope

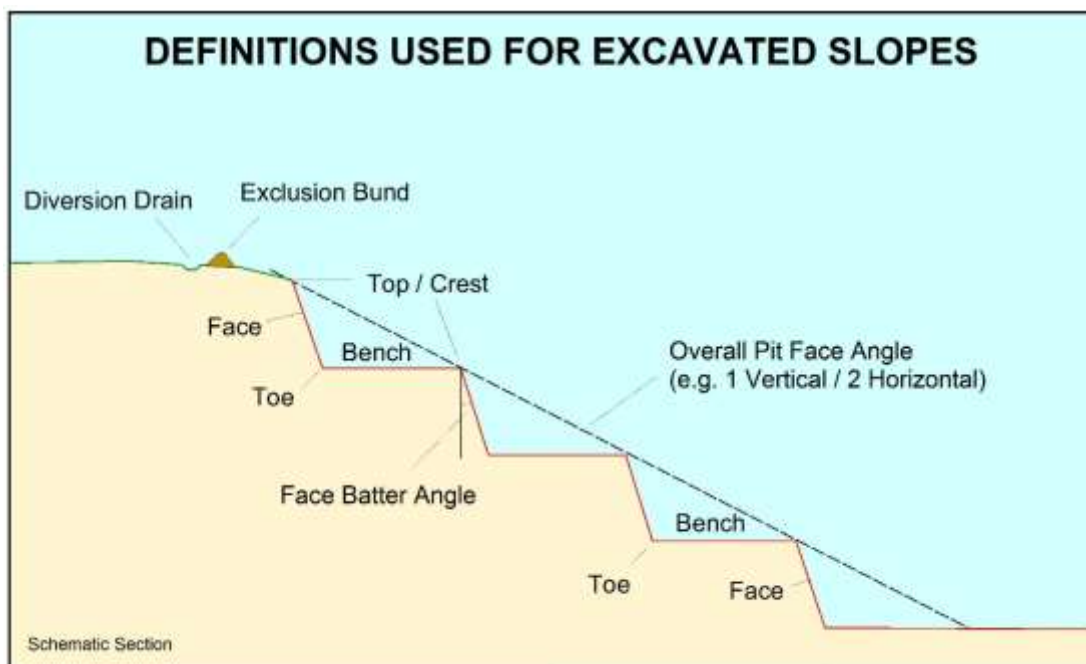


Natural Slope

5. Geotechnical Risk - Excavated Slopes

Slope failure is often due to a number of factors, such as excavation/slope design and excavation techniques, coinciding and generally includes the following hazards and their associated risk:

- Weak geological materials;
- Unstable geological structures;
- Blast vibration, seismic events;
- Changed surface water and groundwater conditions.



Unconsolidated Materials

Weak geological materials include unconsolidated sediments such as gravel, sand, silts and clays but can also include consolidated or hard rocks that have been extremely and highly weathered; weak rocks and rocks with weak structures, for example, mica schists. These materials are generally excavated by mechanical means although some unconsolidated materials such as sands and gravels can be cemented by secondary limonite, calcite and silica and may need to be drilled and blasted. These materials are often referred to as caprock on some deposits.

These unconsolidated materials are generally classified as soils in assessing their engineering properties and their failure mechanism is often referred to as a Slump Circular Failure. This reflects the rotational geometry of the failure surface. Another failure mechanism that can occur is a 2 wedge failure with these unconsolidated materials.

A Slump Circular Failure occurs when a mass of materials moves in a downward direction leaving a circular shaped scour. Its likelihood is increased in weak materials and the ground becomes saturated after heavy rainfall or through poor drainage control.



Overburden Batter Slip



Access Track Batter Slip

Another less common failure method in weak erodible sands and gravels is termed **Piping Failure**. This is generally caused by ground and/or surface water channelling along more permeable and erodible layers within an excavated slope and eventually undermining it and causing its collapse.



Sand and Gravel Piping



Seepage Line and Piping

Unstable Geological Structures

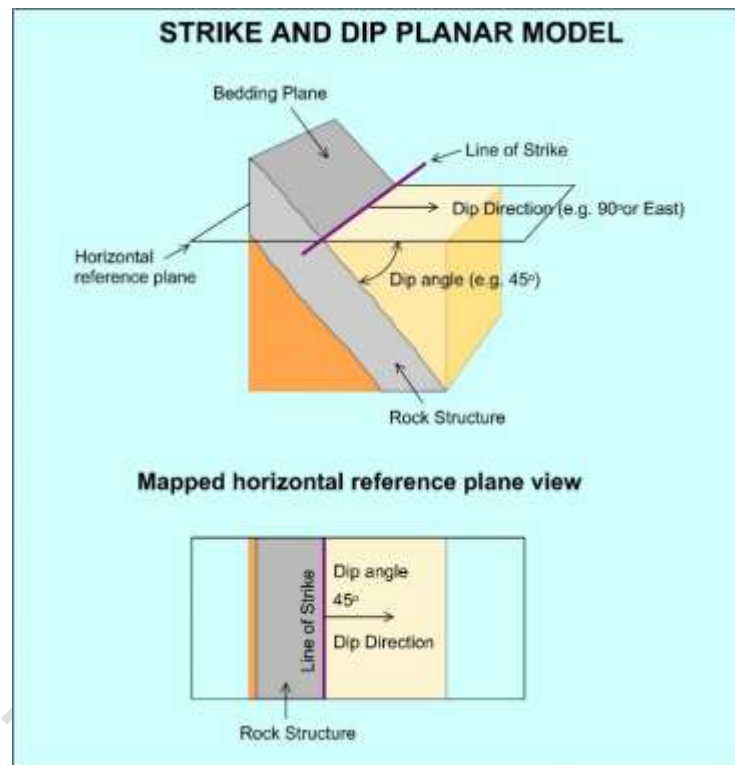
Geological structures are usually evident in consolidated sedimentary and metamorphic rocks, lavas and igneous intrusive rocks. These structures can include:

- Bedding planes;
- Foliation planes;
- Joints, fractures, faults, shear zones;
- Geological contacts/boundaries.

In geotechnical terminology these structures are often called “Defects” or “Discontinuities” in that they are breaks/fractures in the rock mass. The orientation, spacing, frequency and persistence (length) of these or combinations of these structures are important in determining the stability of an excavation. Also important is the nature of the defect surfaces i.e. are they smooth, planar or rough and irregular, clay lined or iron cemented.

Strike and Dip


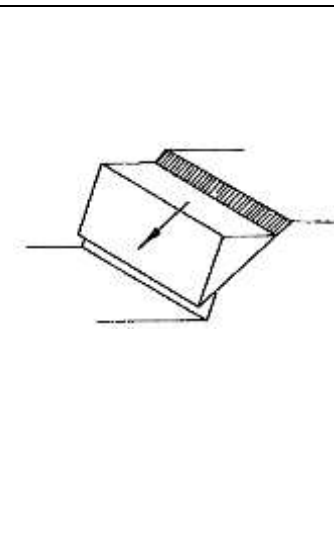
Strike and Dip refer to the orientation of a geologic feature. The strike line of a bed, fault, or other planar feature, is a line representing the intersection of that feature with a horizontal plane. The dip angle or “True Dip” is always measured at right angles to the strike line and is the angle between the horizontal plane and the down slope of the geologic feature. The dip direction is the compass bearing of the “True Dip” down slope line.


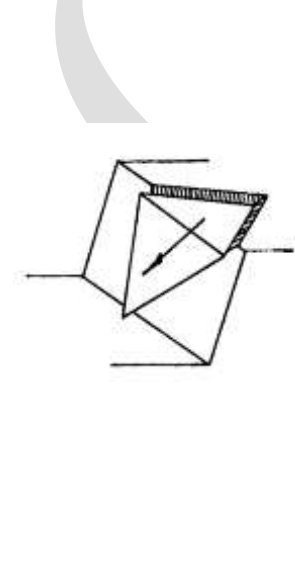


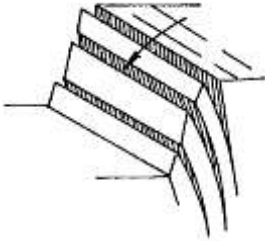

Quarry face showing Strike and Dip



The types of slope failure in consolidated or hard rocks can be described as:-

- Planar Failure;
- Wedge Failure;
- Toppling Failure;
- Slump (circular) Failure.

Planar Failure	
	<p>A planar failure of rock slope occurs when a mass of rock in a slope slides down along a relatively planar failure surface. The failure surfaces are usually structural discontinuities such as bedding planes, faults, joints or the interface between bedrock and an overlying layer of weathered rock.</p>

Wedge Failure	
	<p>Wedge failure can occur in rock mass with two or more sets of discontinuities whose lines of intersection are approximately perpendicular to the strike of the slope and dip towards the plane of the slope.</p>

Toppling Failure	
	
<p>Toppling failures occur when columns of rock, formed by steeply dipping discontinuities in the rock rotates about an essentially fixed point at or near the base of the slope followed by slippage between the layers. The centre of gravity of the column or slab must fall outside the dimension of its base in toppling failure. The removal of overburden and the confining rock, as is the case in quarrying excavations, can result in a partial relief of the constraining stresses within the rock structure, resulting in a toppling failure. Toppling usually needs a basal structure dipping out of the slope.</p>	

Slump Failure	
	
<p>A slump is a form of mass wasting that occurs when a coherent mass of loosely consolidated materials or rock layers moves a short distance down a slope. Movement is characterized by sliding along a concave-upward or planar surface. Causes of slumping include earthquake shocks, thorough wetting, i.e. saturation, freezing and thawing, undercutting, and loading of a slope.</p>	

In very general terms planar structures or wedges that dip at angles between 25 degrees and 70 degrees towards the slope are more prone to sliding into the excavation.

If these structures are continuous on a multi bench quarry then there is potential for several benches to slide into the excavation if they are undercut on the lower levels. This has happened at a Hornfels quarry with several benches sliding.

There are additional complex slope failures that may occur in hard rock quarries such as bi-planar and multi-planar failures, flexural toppling and step-path failures etc.

Basalts with predominantly vertical columnar jointing rarely experience stability issues. The contact between the basalt and the adjoining valley walls can result in planar cooling joints which can be prone to sliding.



Basalt Columns



Edge of Basalt Planar Jointing

Excavated Slope Design

In designing excavations for a Greenfields site there is generally insufficient reliable data on which to base an optimal design. It is prudent to propose a conservative design for initial Work Plan approvals.

Once sufficient exposures are available for reliable measurement of geological structures and material properties then an optimised final pit design can be prepared for approval. Geological structures can change laterally and at depth so the design may need to be periodically updated as the pit develops.

Groundwater is an integral component in the assessment and design of stable excavations. Reliable assessment of groundwater in hard rock aquifers for Greenfields sites is problematical. These assessments are better carried out from a large sump in the excavation once the site has been opened up.

Convex pit perimeters or peninsulas within an excavation can be more prone to instability in that they lack lateral confinement. As a precaution, it often pays to include a backup haul road system in multi-level pit design in case an unexpected failure cuts off access to the pit.

When battering benches, for different batter scales, e.g., individual batter scale, inter-ramp and overall batter scale; different geological structure (small/large scale) and different slope design need to be considered.

Additional factors need to be considered when assessing the risk of slope failure, such as:

- Excavation quality control, scaling and clean-up of excavated pit slopes and berms (benches);
- Surcharge loading from quarry infrastructure (e.g., waste dumps, stockpiles, slimes dams, haul roads); and
- Time dependent deterioration of rock/soil material.



Convex Basalt and Columns

Excavation Techniques

Quarry blast design is essential to ensure safe and predictable blasting outcomes. Poor design can lead to excessive overhang, excessive air blast and ground vibration, unpredictable fly rock, back break and destabilisation of nearby slopes.

Geological structures need to be taken into account in the orientation and blast design of working faces to ensure they remain stable and good fragmentation is achieved.

In some situations where it is difficult to optimise blasting with face orientation, it may be necessary to reduce the face height to avoid block sliding and toe problems with later shots.

Care needs to be taken with some basalts and carbonate rocks as they can contain cavities and rubble zones. Blasting in these can lead to excessive fly rock, air blast and ground vibration. Large fly rock has been projected over 1km in these circumstances.

In mechanically excavated deposits more indurated or cohesive layers of material can sometimes be undercut resulting in large blocks of harder material collapsing suddenly. These can roll down the slope and become a safety hazard.



Sand Pit and Blocky Layer



Sand Dredging

In wet extraction pits with floating dredges and concurrent sluicing extraction, a sudden collapse of the sluiced face into the dredge pond has the potential to generate large waves that may damage equipment and cause personal injury.

Blast Vibration, Seismic Events

Blast vibration can trigger slope failures in situations where they are only marginally stable.

Significant seismic activity is not common in Victoria but there are areas (e.g. south and west Gippsland) where it is more prevalent.

Changed Surface Water and Groundwater Conditions

Increased groundwater content within embankments, surface water saturation, avulsion of rivers/waterways (where a gravel or sand quarry is located on a flood plain), erosion and inundation are common factors in most embankment failures.

Rapid dewatering of excavations can also cause embankment failures if the surrounding ground water levels cannot drop at the same rate as the water in the excavation.

Other factors to be considered:

- The weight of the dump trucks/mobile equipment can start movement on an underlying joint plane;
- Some minerals disintegrate upon exposure to the atmosphere, e.g. zeolite on joint faces, blocks can fall at any time without warning;
- Vegetation - tree clearing in extension areas can make a slope unstable, conversely tree growth on faces can cause rock falls via root jacking.

6. Geotechnical Risk - Constructed Slopes

Slope failure is often due to a number of factors coinciding and generally includes the following hazards and their associated risk:

- Slope design;
- Construction techniques;
- Excavating too close to constructed slopes;
- Blast vibration, seismic events;
- Changed surface water and groundwater conditions;
- Lack of maintenance of surface water drains and overflows structures;
- Over topping of dams.

Constructed Slope Design

A constructed slope needs to be designed to be stable and safe for the duration of its intended purpose. The design has to also take into account:

- The materials it will be constructed with;
- The bearing capacity of the material it is being constructed on;
- Surface drainage;
- Groundwater;
- Construction equipment; methods and control i.e. survey and compaction;
- Maintenance and monitoring.

DEDJTR require an engineering design for embankments/dams constructed over 5m high which will be retaining in excess of 50 mega litres of water or tailings/slimes.

Construction Techniques

The practice of end dumping to achieve stable structures needs to be assessed if it is appropriate for a particular situation. The most stable slopes are usually constructed in layers from the base up.

Construction of a stable slope structure needs to take into account:

- Preparation of base/foundation;
- Keying the structure into the base;
- Groundwater occurrence and potential pit inflow volumes;
- Installation of diversion and sub-surface drainage, filter materials, dewatering;
- Survey and compaction control;
- Finished surface treatment to avoid erosion, scouring.



Laminated Slope



Safe tipping/dumping on a Laminated Slope

Excavating close to Constructed Slopes

Excavating close to constructed slopes has the potential to destabilise the slope.

The ground beneath and immediately around a constructed slope is already surcharged and could fail if disturbed. This is particularly the case for a water or slimes storage containment embankment.

Blast Vibration, Seismic Events

Significant seismic activity is not common in Victoria but there are areas (e.g. south and west Gippsland) where it is more prevalent. Slope failures have resulted following seismic events at some sites.

Blast vibration can also trigger slope failures in situations where they are only marginally stable.

Changed Surface Water and Groundwater Conditions

Large rainfall events can lead to overtopping of embankments and scouring of spillways causing the failure of the embankment.

The subsequent uncontrolled release of contained water or slimes can have very serious safety and environmental consequences.

7. Geotechnical Risk - Natural Slopes

Slope failure is often due to a number of factors coinciding and generally includes the following hazards and their associated risk:

- Steep natural slope already at equilibrium, e.g. borderline unstable;
- Construction of dumps/berms surcharging unstable natural slopes;
- Excavating too close to unstable natural slopes (i.e. near the toe);
- Increased ground vibration due to construction, blasting and seismic events;
- Changed surface water and groundwater conditions;
- Removal of trees, etc.

Existing natural slopes are often taken for granted as being stable, however, there are many areas especially those with steep topography and deep soil or weathering profiles which are prone to landslips.

Steep Natural Slope

Areas prone to landslips often have evidence of old landslips which can be detected by observations of aerial photographs and detailed topographic mapping. These areas are often classified as landslip prone by local authorities who in some cases have plans showing areas of landslip potential and require consideration of this in any development approvals.

Construction of dumps/berms surcharging unstable natural slopes

Construction of large dumps on already unstable ground can trigger failure of the ground beneath the dump and carry the dump with it.

Excavating close to Unstable Natural Slopes

Excavating below unstable natural ground can trigger failure of the slope above the excavation.



Soil Slip

Blast and Construction Vibration, Seismic

Construction vibration, blast vibration and seismic events can all trigger failures in natural slopes which are only marginally stable.

Changed Surface Water and Groundwater Conditions

Changes to surface drainage can lead to saturation and failure of marginally stable slopes. Erosion and scouring of natural slopes can undercut and destabilise them.

Failure of an unstable natural slope into a water or slimes storage can lead to overtopping and failure of the containment structure with downstream safety and environmental consequences.

8. Slope Stability Assessment

A geological and geotechnical stability assessment should be conducted by a qualified geotechnical specialist on all hard and soft rock quarries as part of the initial planning/work plan approval process or an “as needed” basis. The geotechnical specialist should be experienced and competent in the specific resource type and type of extractive operation.

An “as needed basis” may be described as:

- On failure of a slope;
- On identification of previously unidentified fault structures;
- Prior to commencing extraction in areas that have not been assessed previously;
- Prior to constructing slopes.

The objective of conducting a geological and geotechnical stability assessment is to identify and predict geotechnical risk factor problems so as to determine appropriate pit geometry and other suitable controls methods.

The Slope Stability Assessment shall define:

- The maximum vertical height of each working face;
- Bench widths;
- Pit face angles and orientation;
- Haul roads specifications and locations;
- Slope construction history;
- Long term slope configuration for rehabilitation and closure conditions.

The stability assessment should assess and determine the following factors:

- Geotechnical Considerations:
- Topography;
- Rock/Soil type;
- Mechanical properties and orientation of discontinuities;
- Angle of natural repose;
- Presence of caverns and cavities;
- Sources, causes, and drop zones for rock falls;
- Overall steepness of slopes (slope geometries);
- Overall pit height;
- Bench heights and widths.

Hydro-Geological Considerations:

- Ground water and surface water regime as well as ponding;
- Hydraulic connections between bodies of water and the quarry;
- Heavy precipitation and single storm events, the likelihood and consequence of 1/10, 1/50 or 1/100 year events specific to the location;
- Presence or influence of mudflows.

Environmental Considerations:

- Seismic activity of the area;
- Blasting patterns;
- Loading from snow and ice including freeze/thaw cycles;
- Additional loads on slope crests;
- Selection and type of equipment used for exploiting material;
- Quarry planning and design.



Unstable face structure just below stripping level at beginning of pit development

9. Inspection and Monitoring of Slopes

Regular and after seismic events inspections to identify signs of instability or changes that could lead to instability should be undertaken. The inspection should be documented on a checklist as per Attachment (A) and undertaken by the quarry manager or a competent person delegated the responsibility by the Quarry Manager.

Inspection and Warning Signs

Inspection of slopes should occur:

- Daily and/or anytime working close to slopes;
- Prior to and after a shot;
- Prior to and after significant rain;
- After freezing/thawing may have occurred;
- After a seismic event.

Warning signs of instability can include:

- Slope ravelling (small failures often occur before big ones) - rubble on benches;
- Tension cracks increasing in size;
- Faces with water coming out (especially if new occurrence and/or under pressure);
- Overhangs/undercutting;
- Lowering of ground surface;
- Face or toe bulging;
- Trees that are not vertical may indicate creep on soil slopes.

The following should be noted when inspecting slopes:

- Overhanging face crests, unstable wedges, blocks at top of face;
- Water seeping from face, piping cavities, base of dams, dumps;
- Water ponding behind or on top of slopes;
- Cracks, fissures behind crest of slope;
- Cavities, weak or rubble zones within the face;
- Functionality of diversion drains, spillways;
- Freeboard levels of dams and tailings/slimes storages.

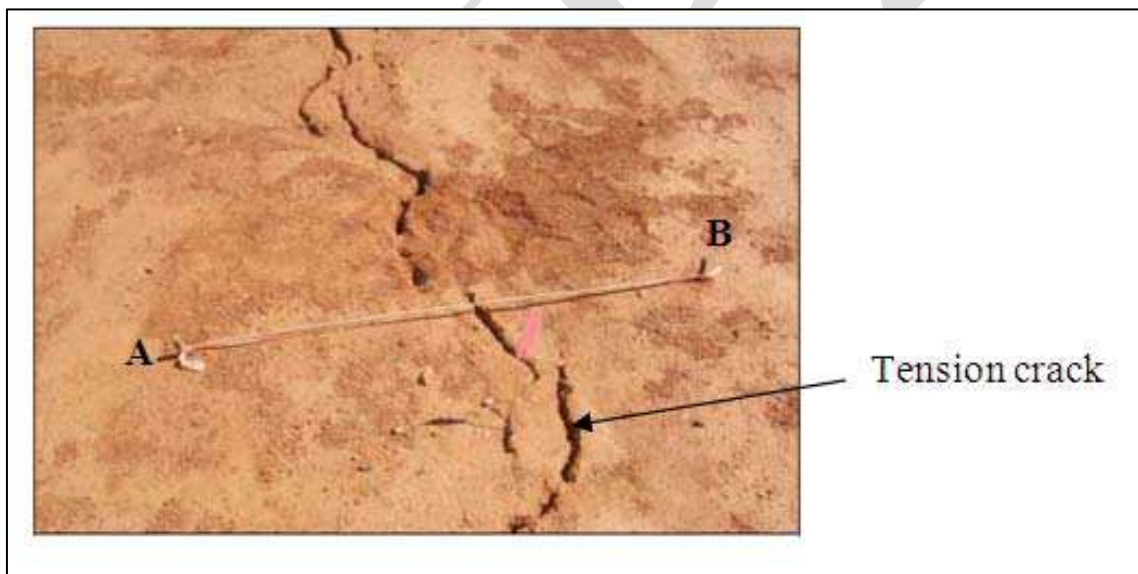
Monitoring Systems

Monitoring systems to measure slope movement, groundwater levels, dam levels and surface water flows may be required at some sites where the consequences of slope failures could be significant. Monitoring systems should be established by a geotechnical specialist.

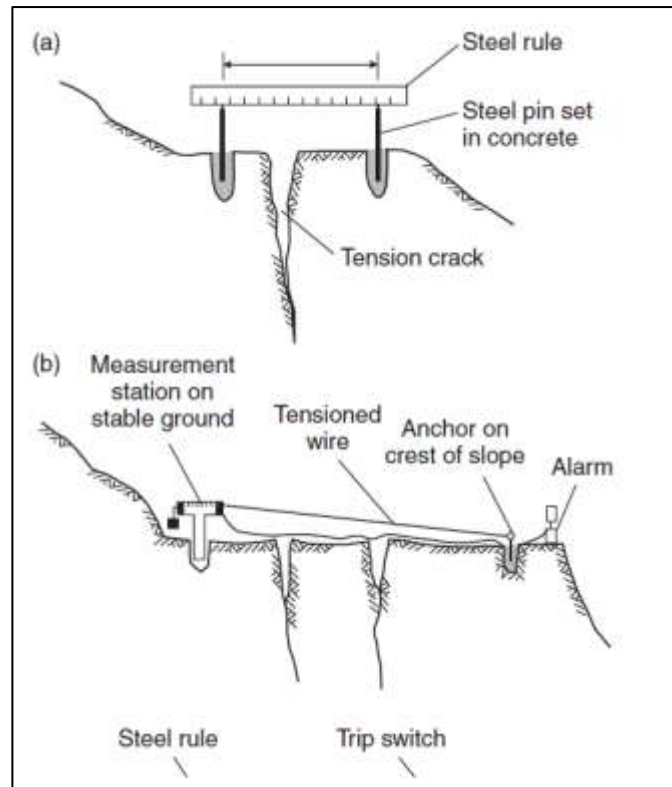
Monitoring can include:

- Survey of monitoring pins/markers attached to the slopes;
- Bore hole extensometers;
- Groundwater levels;
- Nearby river, creek, dam levels;
- Surface water flows from springs, dams;
- Aerial and ground surveys to check compliance with slope designs;
- Photography.

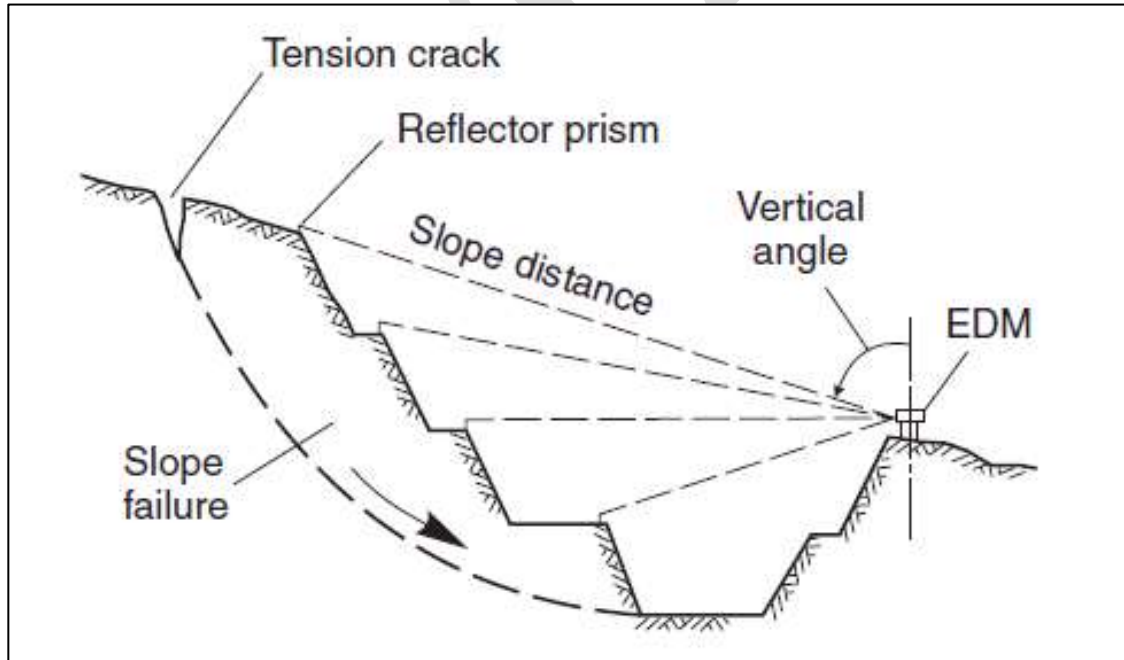
Monitoring and survey systems:



Pin crack meter measuring crack displacement



Method of monitoring tension wire in the cracks in slope



Survey system (EDM – Electronic Distance Meters) to remotely measure slope movement

10. Overview of Controls to Reduce Risk

There are several control methods available to reduce the risk of personal or vehicle engulfment, vehicles that have lost control, persons working close to edges from falling to another level and damage to public infrastructure or the environment. These risks should generally found in the approved work plan.

The following pages will list and detail controls under categories listed below specific to common quarry infrastructure:

- Surface Water and Groundwater Management;
- Berms;
- Haul Roads;
- Drilling and Blasting;
- Stockpiles;
- Faces;
- Sediment Settlement Pits;
- Overburden;
- Rehabilitation.

Where a slope, whether excavated, constructed or natural has been identified as potentially unstable the location must be deemed an Exclusion Zone.

No works or activity should be carried out in an Exclusion Zone without first a risk assessment being conducted, adequate controls implemented and an approval granted by the Quarry Manager. Geotechnical advice may need to be obtained to determine and/or endorse controls arising from the risk assessment.

Exclusion Zones shall be demarcated through the establishment of the following controls:

- Positioning of signage at all access points;
- Installation of physical barriers e.g. barricading, berms and fencing;
- Termination of traffic routes;
- Consultation with and communication to all employees and contractors.

For information on Exclusion Zones under quarry faces refer to section headed Safe Work Practices on Benches.



Suitable Signage for an Exclusion Zone

11. *Surface Water and Groundwater Management*

Significant rainfall events have the potential to cause geotechnical incidents in quarries. Trigger levels for rainfall, groundwater levels and displacement rates can assist in identifying potential slope instability well before failure. These incidents potentially result in the following consequences:

- Slope collapses – both quarry excavations and constructed slopes;
- Inundation of excavations;
- Inundation of fixed and mobile plant;
- Loss of access to plant and stockpiles;
- Loss of ability to operate;
- Public infrastructure and environmental damage;
- Personal injury.

The impact of these rainfall events can be exacerbated after prolonged drought which can cause the ground to dry out and surface shrinkage cracks to form. This allows rainfall to penetrate faster and deeper into slopes contributing to loss of their stability. Also to be considered is perched water in pockets of columns of basalt.

Effective Surface Water and Groundwater Management in quarries (excluding dredging operations) will be detailed in the Work Plan and is achieved by keeping surface water and groundwater away from the operational areas by the planned utilisation, ongoing inspection and maintenance of the following processes:

- Diversion drains;
- Levees in flood plains;
- Perimeter berms;
- Sumps, pumps and retention basins/dams;
- Spillways on dams;
- Drilling reports on water pressure.

Hydrological advice should be sought as to the size, location and construction of drains, sumps and levees to ensure they are effective.



Catchment area upstream from quarry

The risk of incidents and the scale of the incidents will increase the further downstream of the quarry in a given catchment area. Large excavations can fill up in a matter of hours in heavy rainfall events and then take months to pump out. Consideration should also be given to the risk of environmental factors having a detrimental impact on sand or gravel quarry activities such as avulsion from rivers/waterways.

Operators should also be aware of new structures such as stream crossings downstream of their site which could cause surface water to backup into their operations. This would extend to changes to drainage upstream of their sites causing increased runoff and surface flows.

In a floodplain situation, an accurate level of information will be required over a large area for the location and design of levees. This can also lead to expensive hydrological modelling to convince catchment agencies that there will not be an adverse impact on neighbouring properties or infrastructure.



Overburden Dumps need effective surface drainage or battered on an angle to lead water away and not saturate the dump

The structures outlined to keep surface water away from quarry operational areas will only be effective if they are properly designed, constructed, sealed, drained, regularly inspected and maintained.

Additional inspections and maintenance should be carried out before and after large rainfall events.

12. *Edge and Falling Rock Protection Berms*

Berms are generally known as either Edge Protection Berms or Falling Rock Protection Berms:

- Edge Protection Berms are designed to prevent mobile plant, light vehicles and persons from driving, reversing or falling into dangerous areas, e.g. sediments ponds/dams or another level, e.g. the bench below;
- Falling Rock Protection Berms are designed to protect people and property from rock that has the potential to free fall or slide from an unstable face.

Berms are preferable to other less substantial barriers but may hide cracks or signs of instability along the edge of quarry faces. See constructing Edge Protection Berms below.



Edge Protection Berm on Haul Road

Edge Protection Berms - Mobile Plant or Light Vehicles:

Edge Protection Berms to prevent mobile plant or light vehicles from falling should be at least 1.5 times the front axle height of the largest item of mobile plant on site.

Larger Edge protection Berms may be necessary in areas where vehicles have more speed, are travelling around curves or are negotiating steep gradients.

Edge Protection Berms on working haul roads should be constructed out of unweathered, freely draining, materials which can be easily maintained and act as a suitable vehicle barrier and constraint.

Edge Protection Berms – Pedestrians Only

Edge Protection Berms on slopes that can only be accessed by pedestrians and not light vehicle or mobile equipment should be at least 1.0 metres high and constructed from a suitable material to avoid trip hazards.

Note: Light vehicle and mobile equipment access to these areas should be physically restricted by fence or other suitable barriers see CMPA "Traffic Management in the Construction Material Industry", April 2015 for further information on traffic management.

When constructing Edge Protection Berms the following should be considered:

- Berms should be constructed only after inspection of the quarry face or other slope area below or aside. Quarry faces need to be inspected for faults, change in appearance, loose surface, evidence of falling rocks, water seepage, joints and cracks;
- Berms should be firm enough that they are not easily penetrated by tyres;
- Berms constructed of broken rock will normally offer adequate restraint due to the interlocking and frictional resistance of the rock pieces;
- The inside slope of a berm should be steep enough to prevent the tires from easily climbing up and going over the berm;
- The angle of repose of material being used should not undermine the structural integrity of the berm;
- Berms should be constructed a metre or two from the edge where possible so any cracks or deterioration of the slope edge can be seen.

Falling Rock Protection Berms

Falling Rock Protection Berms are also known as Rock Traps and Catch Bunds. They are installed at a suitable distance from the base of the face (the toe) so as to stop and retain rocks free falling or sliding from an unstable face.

Falling Rock Protection Berms must be of sufficient size, in both height and width, to avoid rocks bouncing over or through them.

A rock free falling from the top of a 15 metre face could be travelling, depending on size and weight, at about 60 kilometres per hour when it hits the bench at the bottom. Most rocks will impact the ground within one third of the face height and most rocks will not rollout beyond a distance equal to the face height. This does not apply to rocks that bounce down multiple benches.



Falling Rock Protection Berms made from dust behind shot being prepared

Working within the bounds of a Falling Rock Protection Berm should be prohibited unless for the purpose of removing rocks or drainage maintenance. If such work is required the task should be subject to risk assessment before commencement.

Advice on a suitable distance from the face and the required height to install a Falling Rock Protection Berm should be sought from a qualified geotechnical specialist familiar with the operations and rock source of the particular quarry.

The advice should take into account the number of faces, their height and their incline above the Falling Rock Protection Berm.

13. Haul Roads

The condition of haul roads can be a contributory factor to incidents such as loss of control incidents when they are not constructed or maintained in the correct manner. Surface sheeting, width, road camber, gradients, curvature and drainage are all crucial elements of a well-designed, constructed and maintained haul road.

Road Width

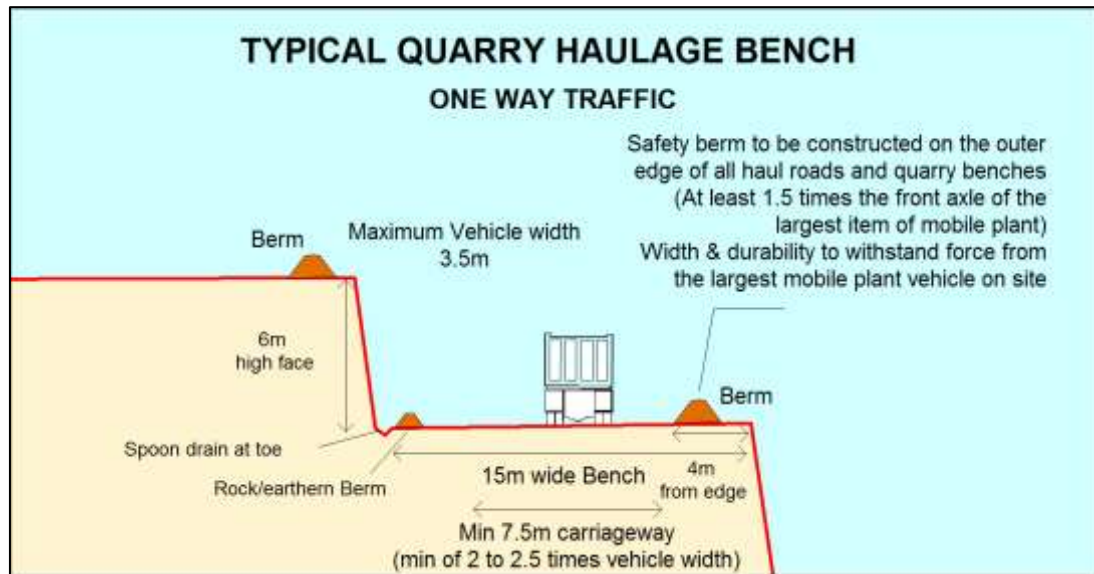
The width of haul roads must be adequate to allow vehicles to manoeuvre and travel safely. Roads that are too narrow can lead to reduced tyre life by forcing trucks operators to run on the Berm when passing another vehicle resulting in both tyre sidewall damage and Berm damage.

Adequate clearance on both sides of the vehicle is equal to one-half of the width of the widest vehicle in use. Where there is a lot of two way traffic a safety berm down the centre of the road is an effective method of separating that traffic

The widths of a road should be based on the size of the largest vehicle in use specific to using that road, i.e. the larger the vehicle the more clearance is required.

One Way Traffic, Straights and Corners

A minimum of 2 to 2.5 times vehicle width.

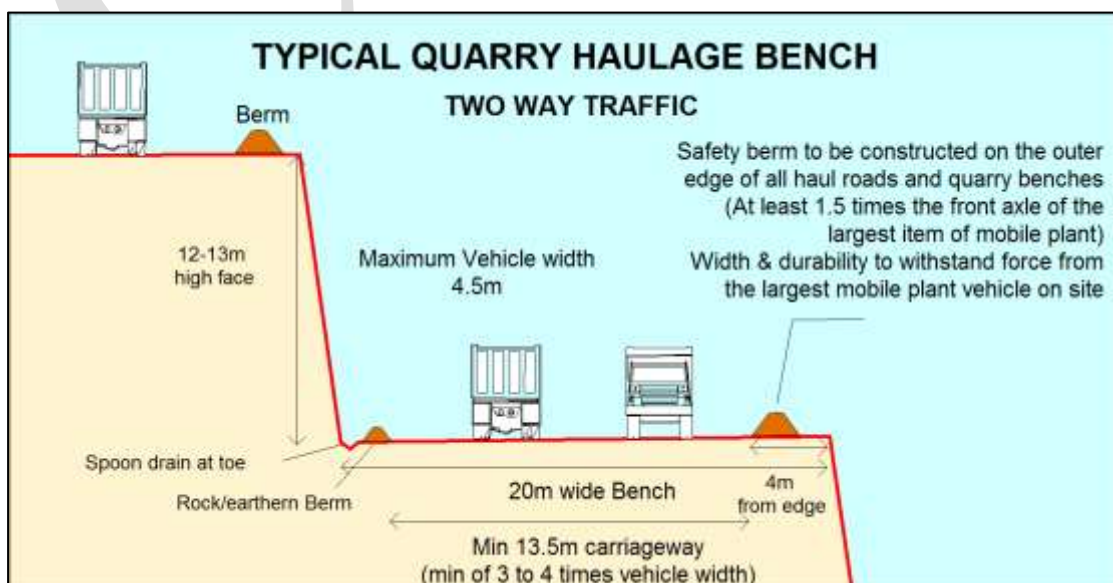


*Assess the stability of bench and face below berm before constructing and placing berm.
4 metres to the inside is a guide only*

Two Way Traffic

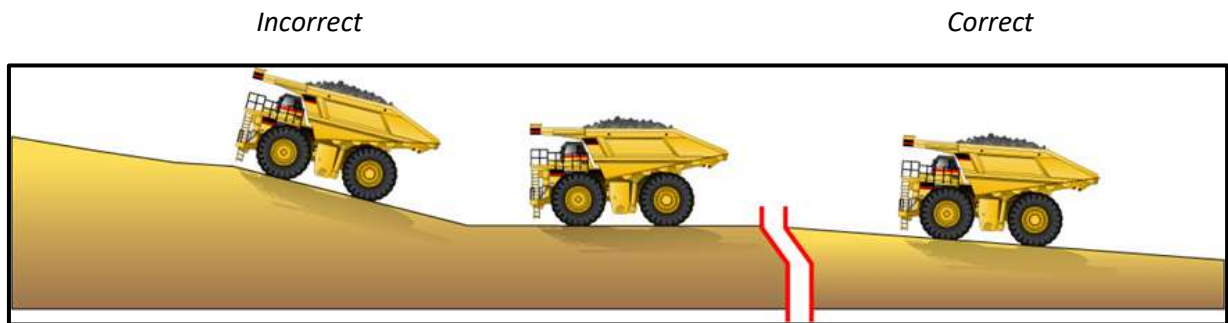
In straights a minimum of 3 to 4 vehicle widths;

In corners a minimum of 3.5 to 4.5 vehicle widths.



Grades and Crossfall

A 2% crossfall to provide drainage from the surface of the haul road is considered optimum for most quarries, depending on local rainfall and drainage ability. Generally, grades should be smooth and constant to minimize transmission shifts and maintain higher average grade speeds. This also allows a more constant braking effort on the return journey, and prevents the retarder from kicking in and out due to an uneven grade. The gradient of the haul road is generally no more than 1/10 but must be within the operating parameters or specifications of the equipment operating on those roads.



Other information to be taken into account is as follows:

- If the design is for a major feeder road, the road width will need to be increased accordingly;
- Right of way should be established and signposted;
- Overtaking bays should be established and signposted;
- Safe distance for vehicles passing should be established, documented and communicated;
- Blindside turns should be eliminated or limited as far as is practicable;
- Bends could be established and utilised to reduce speed;
- Driver line of sight need to be taken into account on bends, corners, rises/crests and areas where sun glare, shadows, wind direction and associated dust movement may affect the line of sight;
- T- Intersections should be at 90 degrees to the through road;
- Where applicable provide delineation of roads using guideposts with reflective tape/markers;
- Utilise speed humps and or bends in roads to reduce speed in critical areas;
- Roads should be designed as free draining to minimise the pooling of water creating potholes;
- The selected road camber should not enhance the potential to slide in wet conditions;
- Drains, culverts and channels should be protected from traffic;
- A dust suppression program for haul roads should be established and implemented.

14. Drilling and Blasting

The activities associated with drilling and blasting, if not effectively controlled, can lead to persons and property being exposed to significant risk that has the potential to result in:

- Engulfment or being struck by rock if the face behind the shot being prepared is not stable and not restrained;
- Engulfment or being struck by rock if blasted and surrounding faces are accessed prior to stability assessment and remediation where required;
- Loss of control of vehicle either driving, rolling or tipping and then falling over edge of face;
- Loss of control or person either walking, tripping, being struck and then falling over edge of face.

Note: This section is not inclusive of general safe work procedures for drill and blast activities and is only focussed on the control of risks as listed above.

Please refer to the CMPA's "Blast Management Plan Template in the Construction Materials Industry" for further and more general information.

For Information regarding:

- The prevention of persons falling from benches, refer to section headed **Safe Work Practices on Benches (page 49)**.
- The prevention of vehicles or mobile equipment falling from benches, refer to section headed **Edge and Falling Rock Protection Berms (page 29)**.

Drill and Blast activities must only be done in accordance with the approved Work Authority and associated Work Plan ensuring that the current blasting activity does not jeopardise the integrity and cost of the ongoing pit development nor make future blasting activity susceptible to unacceptable levels of risk.



Falling Rock Protection Berms capture rock behind drill working perpendicular to the face

The blast design should be continually monitored and amended to suit taking into account the face orientation and the requirement to produce safe faces. Amendment may include:

- Changing blast ratios;
- Altering the spacing of holes and the distance of burden;
- Hole diameters;
- Using specialist blasting techniques.

Prior to the shot being prepared, e.g. surveyed, drilled and loaded, an assessment of the area so as to identify potential hazards and control associated risk is required.

The assessment should be documented using the checklist (Attachment (B) Pre and Post Blast Checklist) and undertaken by the shotfirer and the quarry manager, attached to the Blast Plan and be inclusive of the following practices.

The assessment will take into account all factors involving access of vehicles, mobile equipment, explosives trucks, emergency services and pedestrians to the blast area as well as ensuring that the Drill Rig has the ability to work perpendicular to the face and never trams parallel to the face whilst maintaining a maximum angle of 45 degrees to the face.

On completion of the blast, and once blast area is deemed safe to return, an assessment of the area is required to identify and control any geotechnical hazards that have arisen as a result of the blast. The assessment should be documented on a checklist as per Attachment B and undertaken by the shotfirer and the quarry manager.



Drill working perpendicular to the face behind Edge Rock Protection Berms

15. *Stockpiles*

Stockpiles and the activities associated with unloading on, loading and sampling from can create significant risk such as engulfment and/or loss of vehicle control.

These risks are very much aligned with the following factors:

- Angle of repose of the stockpile;
- Stockpile type and methods utilised to establish and maintain the stockpile;
- The ongoing maintenance of stockpile floor's drainage;
- How well the stockpile surface is sealed and drained;
- Work practices used to unload on, load from and conduct material sampling from the stockpile;
- The interaction of people and vehicles/mobile equipment moving around stockpiles in particular when there is a stock build up and vision is limited.

Stockpiles are generally constructed using either:

- Mobile Equipment to construct Dump Stockpiles, Laminated Stockpiles and Surgepiles; or
- Conveyor/Radial Stacker systems to create Conical Stockpiles or Surgepiles.

The size and type of stockpiles will depend upon the available space and equipment, the flow characteristics of the material, the quantity of required material, i.e., customer demand and the range of products to be made readily available.

A geotechnical assessment performed by a competent person may be required to determine the angle of repose of the material, therefore, the maximum height, width and capacity of the intended stockpile.

Methods to construct stockpiles will vary depending upon the size of the available area, the type of material and type of mobile equipment and/or fixed stockpiles available.

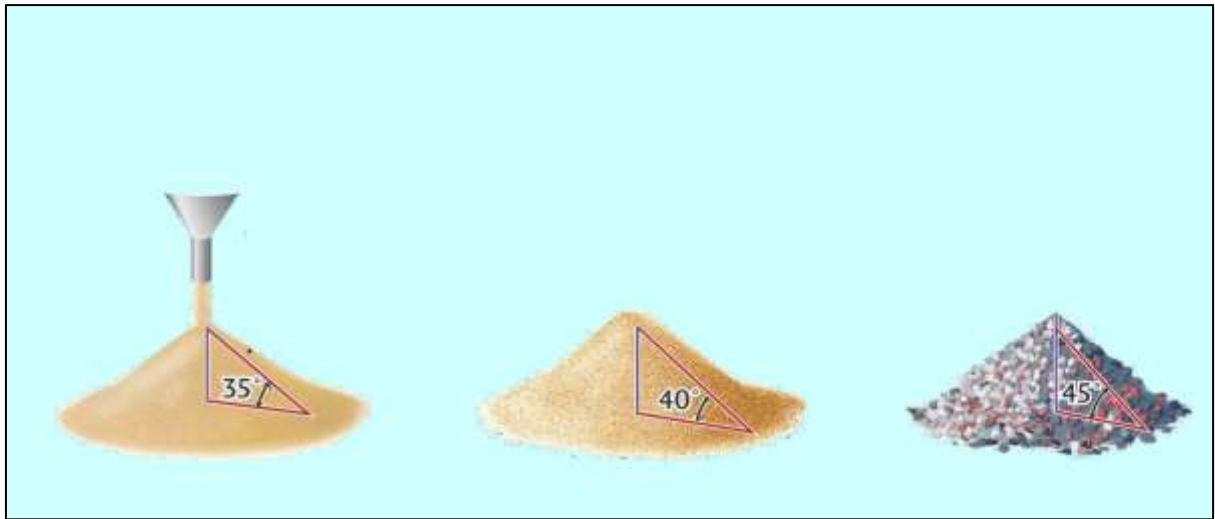
Angle of Repose

The critical angle of repose of a granular material is the steepest angle of descent or dip relative to the horizontal plane to which a material can be piled without slumping.

At this angle, the material on the slope face of the stockpile is on the verge of sliding.

Mass Movement depends on the nature of the materials, water content and slope steepness

Angle of Repose



Fine Sand

Course Sand

Angular Pebbles

The stockpile face can become quickly unstable if materials are piled to the same degree as the critical angle of repose.

The angle of repose depends on several conditions:

- Material consistency, mineralogy;
- Moisture content;
- Degree of compaction;
- Size and shape of the material;
- Flatness and stability of the pile;
- Ice or snow cover on piles.

Typically, the angle of repose is lesser for fine and wet materials such as sand and higher for angular aggregates that bind together. The angle of repose should be established for each material on site being stockpiled. All employees engaged with unloading on, loading and sampling from stockpiles need to be aware of what is a safe angle for the face of that specific stockpile of materials. Safe Working Practices should be documented (and maintained/updated).

Bumper Dump Stockpiling

Dumping a load of material at safe distance back (one truck length) from the crest of the Dump Stockpile;

The load of material is then pushed over the edge by a dozer or a front-end loader using a “bumper” of other material to keep the equipment at a safe distance from the edge.

This method ensures mobile equipment stays away from the edge of the stockpile where the risk of engulfment or loss of control is significant.



Dumping a load of material at safe distance back from the crest

Direct Dump Stockpiling

- Dumping a load directly over the crest of the Dump Stockpile;
- Ensure an adequate Edge Protection Berm is established and maintained
- Ensure that material is not removed from the toe of the stockpile face, whilst dumping is taking place at the top of the pile e.g. restrict access to toe

This method requires constant vigilance by operators in ensuring face stability as the mobile equipment wheels closest to the dump point are directly load bearing on the edge of the stockpile where the risk of engulfment or loss of control is significant. Controls inclusive of physical barriers and Safe Work procedures must be established and implemented to ensure that material is not removed from the toe of the stockpile face, whilst dumping is taking place at the top of the pile

Edge Protection Berms must be established and maintained on all sides of the stockpile inclusive of the drop side of a suitably graded access ramp.



Dumping a load directly over the crest of the Dump Stockpile

Note – Stockpiling by direct dump methods over quarry faces is not recommended due to the inherent risk of this practice.

Laminated Stockpiling

- Loads being tipped along as layers on a multiple level linear stockpile;
- When a single level has the desired amount of material, it is then levelled out and compacted by a dozer, grader or loader;
- The layering continues until the desired height of the multiple level Laminated Stockpile is reached.

Laminated Stockpiles allow the side angle of the stockpile to be maintained less than the angle of repose, resulting in greater slope stability but require a large surface area due to the inclusion of Edge Protection Berms on each layer being laminated.



Preparing a laminated stockpile of overburden



Placing loads of dust for a Laminated Stockpile

Conical Stockpiling

- Materials being fed and falling from either a fixed conveyor or a conveyor feeding a Radial Stacker;
- Radial Stackers can also be configured as a Buffing Radial Stacker meaning the height of the conveyor head drum can be altered to suit the height of the stockpile resulting in less potential for segregation of materials.

Radial stackers are moving equipment, therefore a physical barrier to restrict access must be utilised or a Safe Work Procedure established and communicated to ensure any interaction between the moving stacker and mobile plant or light vehicles is planned and controlled.



Radial Stacker feeding a Conical Stockpile

Surgepile Stockpiling

- Surgepiles are located directly over draw holes feeding material to underground powered feeders or conveyors;
- Surgepiles are fed by overhead conveyors, radial stackers or mobile equipment.

Surgepiles can be particularly hazardous due to unstable material around the draw hole and the possibility of hidden voids under consolidated/bridged material. Inverted cones can form on surge piles drawn by a feeder and bridging can occur over a surge pile feeder creating a cavity particularly as the moisture content of the material increases.



Conveyor fed Surgepile

Stockpile Structures

The following should be taken into account when establishing stockpiles and stockpile layouts and accommodation:

- Well maintained Edge Protection Berms shall be placed along the ramps and edges of Dump and Laminated Stockpiles. **Note:** The presence of an Edge Protection Berm does not signify the crest or face of the stockpile is stable;
- Dump and Laminated Stockpiles must be wide enough to cater for the vehicles load bearing weight to avoid slumping on the side of the stockpile;
- The gradient of the ramp leading to the Dump and Laminated Stockpiles should be no more than 1/10 but must be within the operating parameters or specifications of the equipment operating on the ramp;
- Foundations should be established on solid and level ground that provides drainage to carry rainwater or dust suppression water away from loading or unloading areas on or surrounding all stockpiles. Aggregate bases leading to gravity fed drains provide for this purpose;
- Stockpile layouts must be designed to give consideration to the traffic movements of sales loaders and trucks required to safely load from the stockpile;
- Stockpile layouts must be designed to give consideration to the requirements of reserve material capacity;
- Suitable accommodation requirements must be established at the surge/main boot so as to ensure stored rock and vehicle movements do not contribute to unacceptable risk.

Maintenance of stockpiles is as equally important as the construction of the stockpile.

Laminated and Dump Stockpiles should be sealed and rolled at the end of each shift so as to ensure an effective camber or sloping grade on a solid surface is achieved allowing rainwater to run away and not soak into the body of the stockpile.

General Stockpile Safe Work Practices

All employees engaged in unloading on, loading and sampling from a stockpile should be trained in identifying stockpile hazards.

Safe Work Procedures (SWP) for unloading on and loading from all stockpiles should be established and implemented and all relevant employees trained in its application.

The following general information should be taken into account when establishing SWPs:

- Always check the stockpile before you start, for example for undercutting/undermining, hung up materials, bulging at toe;
- Unloading on and loading from a Dump or Laminated Stockpiles at the same time is a high risk prohibited practice. The practice of loading from a Dump or Laminated Stockpile face or toe must be prohibited if that stockpile is being unloaded on at the crest;
- Access to loading from the stockpile face or toe should be physically restricted whilst unloading activity occurs above at the crest. This may be established through a barrier and signage;

- Stockpiles faces that have been loaded from should be thoroughly assessed for stability and in some cases rehabilitated prior to the re-commencement of unloading at the crest;
- When loading from a Dump or Laminated Stockpile face or toe, the ramp to the stockpile for unloading on at the crest should be physically restricted. A safe approach is to have the front end loader use the first bucket(s) of material to block the ramp going to the top of the stockpile;
- The ramp should remain blocked until the stockpile face has been thoroughly assessed for stability and where applicable, rehabilitated. The stockpile can then be deemed safe to unload on, prior to the re-commencement of unloading at the crest;
- Loaders and excavators should always operate perpendicular (90 degrees) to the crest and toe of the stockpile so as to be able to depart promptly if a stockpile face collapses;
- Stockpiles containing finer materials such as sand or dust should be checked for face stability and correct angle of repose after the application of water for dust suppression or rainfall and prior to the commencement of loading on or loading from;
- Excavation for loading of a Conical Stockpile from a conveyor or radial stacker should proceed progressively around the toe of the pile.
- Safe work practices applicable to working the stockpile face include:
 - ~ The working face shall be sloped at its angle of repose;
 - ~ Do not undercut or leave a concave hollow in the material of the working face beyond the depth of the bucket;
 - ~ Load the bucket by working it up the stockpile face;
 - ~ Do not cut trenches or tunnels into the face or leave overhangs;
 - ~ Do not swing loads over the truck cab;
- When loading trucks the loader should be positioned so that the exit door on the cab faces away from the working face of the stockpile;
- The loader should approach the working face at a right angle and excavate a face allowing the material to run to the toe of the stockpile;
- In cold weather climates, stockpiles can freeze. The face can become vertical and frozen overhangs may risk collapsing unexpectedly. An excavator should be used to pull or push the frozen material down;
- Stop work if visibility is poor due to lack of light, glare, shadow, headwind and dust, fog or rain;
- Ensure floor is level and stable, i.e., no soft spots, pot holes or spillage that may expose the operator to sudden movement and jolting etc.

Dump or Laminated Stockpiles Safe Work Practices

The following information should also be taken into account when establishing SWPs for Dump or Laminated stockpiles:

- Check the stockpile before you start, for example for undercutting/undermining, hung up materials, bulging at toe;
- Check the dump area for unsafe conditions on your approach, staying one truck length back from the edge;
- Stay and dump one truck length back from the edge if:
 - ~ The Edge Protection Berm is inadequate, e.g. the berm is not at least mid-axle height, the berm has been partially undercut;
 - ~ The area below the dump point has been loaded-out and over-steepened;
 - ~ There are tension cracks near the edge of the stockpile;
 - ~ The edge area is soft and the tyres sink in;
 - ~ There are signs of slumping in the side wall or toe of the stockpile;
 - ~ Visibility is poor;
- Back slowly and perpendicular, coming to a gradual stop at the dumping point;
- Use the Edge Protection Berm as a visual guide only. Do not use the berm routinely to help stop the truck;
- Avoid running the rear tyres up on or into the Edge Protection Berm;
- Do not attempt to dump the material if it sticks in the body, especially if it sticks after the body is raised over half of its extension;
- Do not attempt to forward/reverse and jerk or jolt the body to release stuck materials;
- A Spotter may be required to assist in guiding mobile equipment when reversing onto Dump or Laminated Stockpiles;
- When unloading on Dump or Laminated Stockpiles dump trucks/loaders should always park perpendicular (90 degrees) to the crest and on the same wheel tracks prior to dumping so as to remain on a constant and sound footing;
- Excavation for loading from Dump or Laminated stockpiles should proceed along the working face.

Surgepiles Safe Work Practices

The following information should also be taken into account when establishing SWPs for Surgepiles:

- The draw point to the feeder on a Surgepile must be clearly identified. This can be achieved by overhead markers that may also signal the height limit.

- **Prior to pushing in visually check:**
 - ~ The feeder and feed discharge point for cavities;
 - ~ For material flow on the conveyor transfer belt. No material on the belt indicates that a cavity or void is forming above the conveyor feeder.

- **Front End Loader / Dozer working with a surge pile:**
 - ~ Communicate with others in the area including the plant operator;
 - ~ Visually check the surge pile before starting;
 - ~ Always work perpendicular to the edge;
 - ~ Know where the feeder draw points are;
 - ~ Keep the machine facing the draw hole and keep the draw hole nearly full during load out to avoid operating near the edge of a deep draw hole;
 - ~ Never operate directly over or close to the face of a draw hole;
 - ~ Never push material directly into the draw hole. Material should be pushed into place with a bumper or other material in order to keep a safe distance;
 - ~ A chart indicating the safe distance to keep from the centre of the draw hole, relative to the depth of the pile should be visibly displayed in the cabin. The distance should be based on the angle of repose of the material;
 - ~ Work in a position as to be able to view the delivery conveyor or communicate directly with a plant operator who can view the delivery conveyor;
 - ~ If any sign of a void occurs move machine away from draw hole and contact the quarry manager.

Sampling Materials from a Stockpile

All employees engaged in sampling materials from a stockpile should be trained in identifying stockpile hazards so as to assess the risk of sampling and stockpile collapse prior to commencement of the task.

The SWP for materials sampling should be inclusive of a:

- Vehicle exclusion zone being physically established when the sampling activity is being undertaken;
- Limits on the safe height of access to stockpile.

16. Faces

Rockfall is an uncontrolled movement of rock from pit walls and or quarry faces and can lead to persons and property being exposed to significant risk that has the potential to result in:

- Engulfment or being struck by rock if the face behind the working area is not stable and not restrained;
- Loss of control of vehicle driving, rolling or tipping and then falling over edge of face after being struck by rock or forced by a rockslide.

Rockfall is generally caused by unstable rock exposed to:

- Weather and temperature cycles, e.g., heavy rainfall, extreme heat or freeze and thaw;
- Rainfall runoff washing out fine material from between cracks which may be restraining the rock from movement;
- Blasting and seismic activity;
- Vibration due to drilling and heavy vehicle or equipment movements.

When working below faces the selection of appropriate sized mobile equipment is paramount to safety, e.g., the larger the machine the less chance of engulfment and the greater chance of escape in the case of rock fall of face collapse.



Working below a quarry face

Identifying Potential Rockfall

Faces above working places or haul roads must be inspected before work starts to ensure that loose ground or rocks do not create significant risk making it unsafe to work below or above a face. The inspection should take into account the following factors:

- Are there any overhangs, undercuts, loose rock, fractures, wet areas, i.e., any sign of instability leading to potential rock fall, slide or collapse;
- Surface cracking on the bench above;
- Whether maintenance or remediation is required to the face prior to commencing work;
- Whether further advice is required, e.g., from a geotechnical specialist.

An inspection should be conducted after any significant rainfall to gauge ground movement. In situations where the rate of deterioration or the risk is high, inspection will also be required at least once during the shift.



Significant Backbreak

The inspection should be documented on a checklist as per Attachment (C) and undertaken by the quarry manager or a competent person delegated the responsibility by the Quarry Manager

Controlling Rockfall

Once potential rockfall, i.e., unstable rock is identified controls must be established and implemented to reduce the probability of rockfall, and where that is not achievable, to eliminate any consequence to people or property from rockfall.

Reducing the probability of rockfall can involve the following processes:

Scaling – removing loose rock from the face with an excavator, a high risk activity in itself:

- When conducted from the crest on a high elevation face and being positioned behind the Edge Protection Berm the excavator must reach out and below. The excavators reach is limited and this may if pushed jeopardise its balance and stability;
- When conducted from below the face, and loose or overhanging rock is dislodged, the rock's destination is not always predictable;
- The selection of an appropriate sized excavator is paramount to safety.

Falling Rock Protection Berm or catch fence - installed at a suitable distance from the base of the face (the toe) so as to stop and retain rocks free falling or sliding from an unstable face:

- Must be of sufficient size, in both height and width, to avoid rocks bouncing over or through them;
- A rock free falling from the top of a 15 metre face could be travelling, depending on size and weight, at about 60 kilometres per hour when it hits the bench at the bottom;
- Most rocks will impact the ground within one third of the face height and most rocks will not rollout beyond a distance equal to the face height;
- Behind the Falling Rock Protection Berm, i.e., on the toe side should be deemed an exclusion zone with prohibited access.

Drainage – taking surface water well away from crests where there is potential to soak into backbreak cracking or run down faces washing fine bonding materials from rock joints:

- Install spoon drains on the bench side of Edge Protection Berms and the face side of Falling Rock Protection Berms;
- Ensure waste water drainage is maintained and water has the ability to flow so no ponding, therefore, soaking occurs;
- Take into account high rainfall seasons, inspect and clean prior to predicted rainfall and after any heavy rainfall as debris may have collected.

Pre Splitting - comprises of a single continuous row of drill holes which are blasted splitting the material prior to a full blast. Once this process is complete a full drill pattern is drilled in front of the pre-split and blasted allowing the rest of the material to be blasted away from the pre-split line without damaging the wall behind the shot:

- A good prevention measure in areas where face instability is predictable;
- Creates a significant risk of vertical and upward fly rock during blasting due to lack of escape for shot rock;
- Must only be conducted in consultation with a competent blasting engineer and geotechnical expert.

Meshing over faces – may be an option also, however, care must be taken to not introduce additional risk on installation.



Example of pre splitting

Safe Work Practices on Benches

All benches should have both an Edge Protection Berm to prevent loss of control and a Falling Rock Protection Berm to prevent engulfment or being struck by falling rock.

- No work should be conducted on the face side of the Edge Protection Berm;
- The face of the Edge Protection Berm should be at least 2 metres back from the crest, or in the case of an unstable crest, e.g., backbreaks, 2 metres back from the backbreaks.

Where a face has been deemed unstable, the bench or benches below shall be classified as an Exclusion Zone.

An Exclusion Zone is a space below an slope, in this case a face where entry of work is not permitted without first a risk assessment being conducted.

Exclusion Zones shall be demarcated through the establishment of the following controls:

- Positioning of signage at all access points;
- Installation of physical barriers, e.g., barricading, berms and fencing;
- Installation of Rock Nets and Falling Rock Protection Berms, where safe to do so;
- Termination of traffic routes;
- Consultation with and communication to all employees and contractors

No works or activity should be carried out in an Exclusion Zone without first a risk assessment being conducted and adequate controls implemented. Geotechnical advice should be obtained to determine and/or endorse controls arising from the risk assessment.

When establishing an exclusion zone under a face, the following controls should be considered for implementation:

- An Exclusion Zone should be delineated at an acceptable distance from the toe of the face;
- The Exclusion Zone should be demarcated and highlighted as an Exclusion Zone by a barrier asides from the Falling Rock Protection Berm which is a standard fixture under all faces;
- No work should be conducted within the exclusion zone without a geotechnical risk assessment conducted by the quarry manager and a geotechnical expert;
- Personnel are not to stop (if in a vehicle) or be on foot within $\frac{1}{2}$ of the height of an adjacent face;
- Travel within the zone on a main haul road or ramp may be permitted, but only if movement through the zone is unimpeded and no stopping is planned or expected;
- A clear escape path from the Exclusion Zone that caters for both for mobile equipment and pedestrians is mandatory.

Prevention of persons falling over faces

All persons entering a quarry must undergo an induction informing them of all restricted access areas. Persons who are required to work on benches shall only do so under the direction of a SWP.

Wherever possible, quarry management shall consider relocating tasks away from the edge of the quarry face and shall physically restrict access to the edge of the quarry face.

Berms are the most preferable control but Berms may hide cracks or signs of instability along the edge of quarry faces.

If it is not possible to install an Edge Protection Berm that serves people as well as vehicles and mobile equipment, other physical fall prevention barriers such as guard railing should be used.

If the guard railing is installed close to a quarry face, the risk of falls during the erection and dismantling of the guard railing must be identified and controlled.

If it is not reasonably practicable to install a physical fall prevention barrier (e.g., before blasting or due to the set-up of a drill), quarry management shall limit working positions.

This can include using a travel restraint such as a harness connected at a fixed point to prevent workers approaching the edge. Workers must be trained in the appropriate selection and use of harnesses before starting work and guided by a SWP inclusive of a Working at Heights rescue plan.

When considering the use of a travel restraint harness, take into account the following:

- Harnesses do not mitigate the risk of the crest failing and falling beneath the feet;
- The Harness Lanyard must be set so as to restrict persons from approaching the crest;
- The Harness may stop the fall, but rescue will be extremely difficult if not impossible without specific rescue equipment and trained personnel.

Note: Painted Lines, Ropes or Barrier Tapes are not recommended as a suitable means of a fall prevention barrier.

17. Water Containment Structures

Water Containment Structures in Quarries are inclusive of dams for water storage, working ponds for extraction, sediment settling ponds, slimes dams and associated drainage inclusive of channels.

Within this document Water Containment Structures do not include steel, fiberglass, plastic or concrete water tanks and FEL wedge pits.

Water Containment Structures can expose persons and property to significant risk that has the potential to result in:

- Engulfment if working below an embankment that fails and collapses;
- Drowning if a loss of control person or vehicle falls into the water containing structure.

Embankment Stability

Embankment stability is most important in tailings or settling ponds where any breach of the walls could cause inundation downstream or the engulfment of persons working below. Walls should be compacted and either vegetated (not trees or large shrubs) to stop erosion (including from animals) or rock armoured. This prevents inadvertent breaches from occurring but should include controls for overtopping to channel and divert overflow without eroding the pond wall.



Slimes dam with Edge Berm Protection at filling point

Berms and Fencing

All water containing structures that vehicles or mobile equipment can potentially access shall have Edge Protection Berms installed. Where only pedestrian access is achievable a 2metre high chain wire mesh fence may suffice. Refer to Australian Standard AS1725 Chain-Link Fabric Security Fencing and Gates.

Overflows

The control of overflow is critical as uncontrolled overflow over an embankment can result in erosion or embankment saturation, therefore, undermining the structural integrity of the embankment.

Overflows can be decanting pipes, angled pipes, dip in the crest of the dam and rock armoured channels. These should be inspected regularly, particularly when there are periods of high rainfall.

Inspections should include checking for partially blocked intakes of decant or angled pipes with floating vegetation or other debris.

Partially blocked overflow channels should be cleared quickly and safely. Remedial measures to limit the amount of floating vegetation in the ponds should be established. Ensure that armoured channels are not scoured when there is a high water flow as this can erode the dam crest and affect the integrity of the embankment.

Pipes are used through crest embankments of settling ponds to drain settled water to discharge points, or for further settling in a secondary settlement dam. Pipes should be sealed where they pass through the crest of the dam so no leaching can cause the crest to collapse. Routine and regular inspection of the discharge side of the crest for signs of water wicking around the pipe should be undertaken.

Changed Surface Water and Groundwater Conditions

Where there are changed surface water and ground water conditions the water containment structure should have sufficient freeboard (water level below top of embankment) to allow for inflows during significant rainfall events. Changed groundwater conditions such as seepage could indicate altered embankment foundation conditions.

Dewatering Channels

Dewatering channels should be checked for weed growth and side collapses. Safety issues include edge collapse while inspecting, silt build up in the channel and vegetation disguising undermined edges. A safe method of inspecting dewatering channels should be established and implemented. Care should be taken to keep back from the edges when undertaking inspections.

Further information is available from “Environmental Guidelines for Management of Small Tailings Storage Facility” (www.energyandresources.vic.gov.au) and “Your dam, your responsibility” (www.delwp.vic.gov.au).

Working alongside Water Containment Structures

Working alongside water may have the potential to result in drowning due to a slip trip and fall, being struck and knocked, or embankment failure.

All tasks that involve working alongside water should be identified and if not able to be eliminated a SWP should be established and implemented.

The SWP should stipulate the use of controls such as guard railing, life jackets and life buoys and be inclusive of an emergency response process.

Self-inflating life jackets are available that allow a person to work without having a bulky lifejacket getting in the way. They are available in manual and automatic activation and covers can be purchased to protect them from flame and molten metal arising from welding activity.

Life jackets must be labelled and comply with Australian Standard AS 4758 - Lifejackets

All lifebuoys are to be fitted with reflective tape and a rope of a minimum length 10 metres or a greater length appropriate to the potential rescue.

Cleaning out Settlement Ponds

The risks associated with cleaning out a Settlement Pond is created by either undercutting and making the embankment unstable, particularly below water or by a machine driving onto soft ground or the Settlement Pond surface that cannot support the machines weight.

Note: Settlement Ponds can be deceptive, they form a crust which appears stable, but the silt remains soft beneath.

Prior to commencing the clean out of a Settlement Pond, a risk assessment should be conducted and a SWP established and implemented. The SWP should be inclusive of the following processes:

- Inspection of the area shall be carried out by the Quarry Manager or appointed competent person prior to any work commencing;
- The appropriate size excavator with suitable reach must be sourced so as to avoid placing the excavator too close to the edge;
- The operator working the machine shall constantly monitor the crest of the Settlement Ponds for sign of slumping, cracking or instability;
- If any signs of instability are identified, all work shall be suspended; personnel and machinery removed and access prohibited;
- The operator shall inform management and geotechnical advice shall be sought if required;
- Care shall be taken to only remove silt as planned and not excavate the Settlement Ponds retaining structure;
- The edge of the Settlement Pond shall be clearly demarcated at all times by an Edge Protection Berm;
- The excavator shall work from behind the Edge Protection Berm and shall be capable of obtaining the necessary depth of dig from that position;
- The excavator's tracks shall be perpendicular to the Settlement Ponds edge such that a safe and rapid exit from the area can be made if slope instability develops;
- The excavated silt shall be cast as far away from the crest of the Settlement Ponds as possible so as to prevent loading of the crest which could cause failure;
- The placement of silt must not block the safe exit route of the machine;
- The excavated silt must be dried before being placed and blended into an existing stockpile.

Signage

Water Containment Structures should be signposted as follows:



Sediment settling ponds, slimes dams



Water storage dams

Where it is reasonably foreseeable that a person may attempt to swim in a dam then it shall be signposted as follows.



18. Overburden

When planning stripping, i.e., the removal and placement of overburden, the following should be considered:

- The geology of the area to be stripped;
- The quantity and type of overburden;
- Stripping should be kept to the minimal over the life time of the quarry i.e. plan ahead;
- Access roads for mobile equipment, vehicles and pedestrians;
- Any hazards which may affect safety (e.g., overhead power lines);
- Security of the area;
- Preparation of the receiving area;
- Process for tipping off/unloading;
- Settling requirements;
- Drainage and runoff controls;
- Edge Protection Berm requirements;
- Stabilising methods, including inspections;
- Rehabilitation of overburden.

All dump/tip sites should be prepared and able to safely receive the overburden. This includes removal of vegetation and topsoil and keying into the substrata to ensure the stability of the overburden placed above.



Overburden Dump inclusive of Edge Protection Berm and revegetated walls

Subsoil drainage should be addressed to ensure there can be no liquefaction of the overburden placed there. Subsoil drainage can be as simple as placing large rocks to allow moisture to “wick” through or a more sophisticated system using drain coil and piping to capture and transport moisture through the material to a controlled discharge below the work.

There should be no ability for catchment of rainwater on top of overburden dumps and all drainage should lead water well away from the structure of the dump.

When placed, overburden should be stable and battered inclusive of contour drains, covered with soil and revegetated as soon as possible to prevent scouring and water damage through erosion.

Where tree felling is required in preparation for stripping, competent workers should be engaged to undertake the work.

Top soil sourced during stripping and not used for capping dumps should be stored separately from general overburden in preparation for use during rehabilitation.

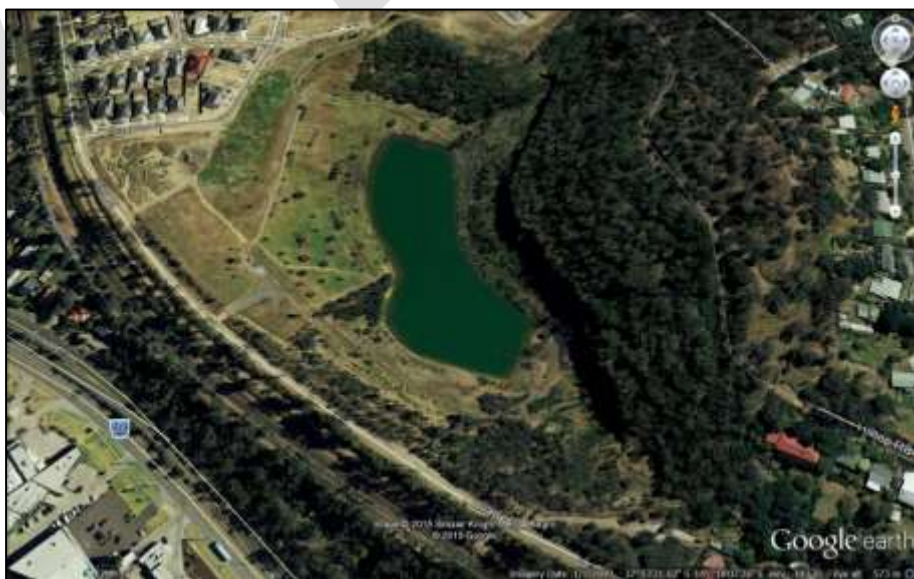
Overburden can be utilised as an earth berm/berm around the perimeter of the quarry.

Any stockpile of overburden must be managed in the same way as any other stockpile or tip: it should have adequate drainage, be on a firm and level foundation and at a safe angle of repose. In addition to top soils and other materials, overburden dumps should be regularly inspected.

19. Rehabilitation

Quarry rehabilitation should be to provide a “safe and stable” slope and is detailed in the Work Plan. It should be carried out in a way that prevents or minimises impacts and risks not only to the environment and public infrastructure but also to health and safety of employees or other persons who may access the site. Rehabilitation plans should detail the processes that will be used to decommission all quarry infrastructures inclusive of all slopes, water storage and drainage facilities.

Rehabilitation should be carried out progressively throughout the life of the quarry, e.g., rehabilitation of overburden tips which have reached capacity, rehabilitation of faces and benches that have been fully extracted. Progressive rehabilitation can generally be conducted in a safer manner than attempting to rehabilitate at the end of the quarry’s life.



Example of best practice quarry rehabilitation

Rehabilitation plans should address management of water runoff, stability of material and erosion control. Stability of material and control of water runoff are the most important as they will be the first indicators of any problems in the total rehabilitation programme.

Stability should be monitored by regular inspection of the:

- Toe area of any overburden or waste material placement to ensure it is well compacted and not bulging or moving out from its original placement;
- Crest or top of the reinstated material to identify cracking or erosion.

When battering benches a safe angle of incline is regarded as:

- 1 in 1.5 to 2 for hard angular rock;
- 1 in 3 to 4 for sand and circular rock.

Battering benches should be done progressively in compacted layers at a depth suitable to the material source so as to enable the desired compaction. Tipping over faces to the bench enhances the risk of segregation of materials, therefore, direct dumping on the bench is the preferred option so as to ensure effective compaction. Direct dumping also reduces the risk of loss of control of vehicle either driving, rolling or tipping and then falling over edge of face.

Edge protection berms should be installed and may be designed to either pond water on the bench for revegetation and or convey excess water to the drainage system.

Surface roughness is an important consideration as roughness tends to trap water and seed and provide better vegetation establishment but in the longer term it may lead to increased erosion and instability.

The final batters should encourage vegetation to grow and stabilize the surface



Example of revegetated benches

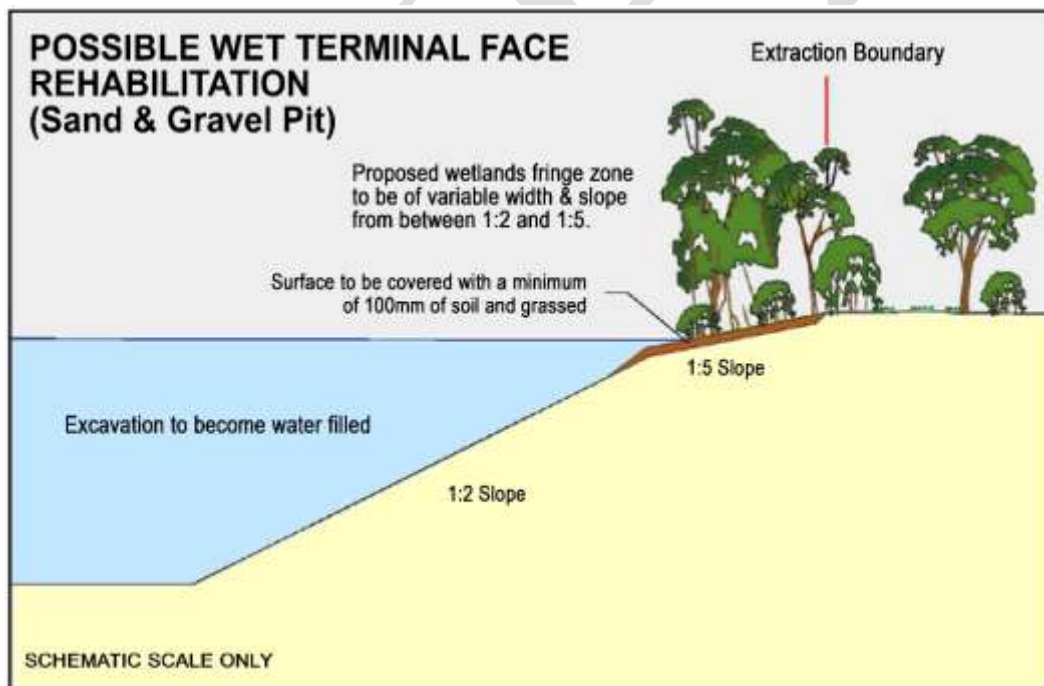
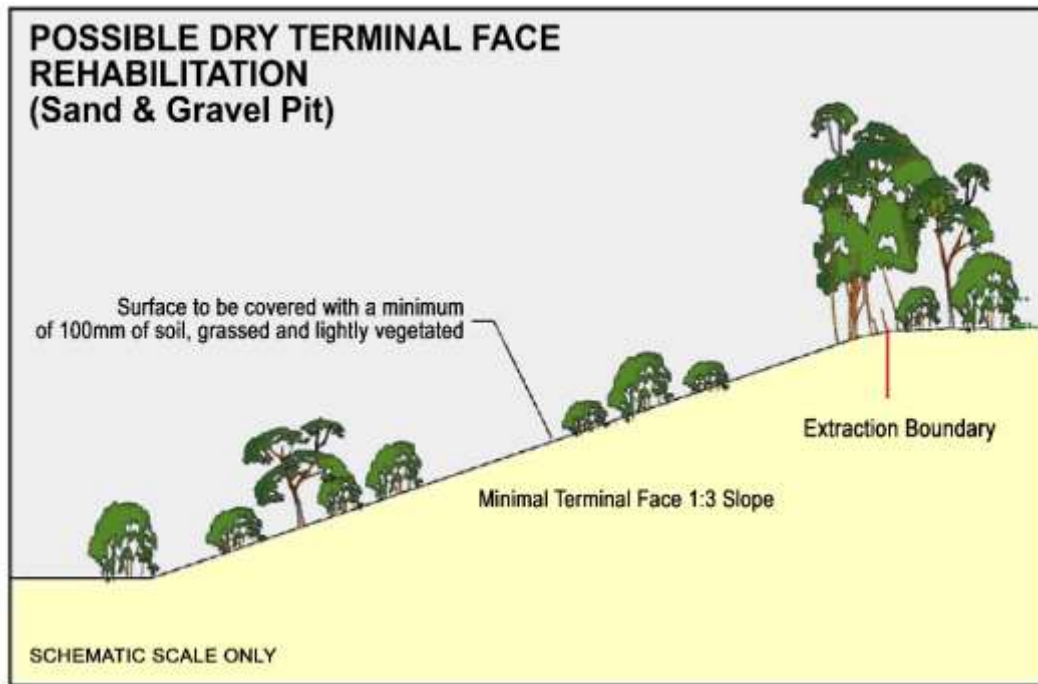


Diagram showing suitable slope for sand and gravel pit rehabilitation

20. *Management of Change*

Any change to excavated or constructed slopes, e.g. method of extracting or placement of material may significantly increase the risk associated with the activity and another geotechnical risk assessment should be undertaken.

This may also be required if fundamental assumptions in the geotechnical assessment are found to be incorrect, for example regarding the geology of the site.

Any new development on land adjacent to excavated or constructed slopes, for example the construction of a school, housing estate or road, could significantly increase the risk. Such changes are likely to be known well in advance and should be planned for.

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ATTACHMENT A - General Slope Stability Check List

Attachment (A) – General Slope Stability Checklist			
Date of Inspection		Inspected by	
Area of Observation			Action Required
Benches, Berms and Haul roads			Yes No
Benches and haul roads stable and without signs of failure			
Wide enough for vehicles and Falling Rock Protection Berm at toe			
Adequate passing areas			
Drainage in place and is adequate/effective			
Roads in good condition, drained and without signs of movement			
Edge Protection Berms in place and in order			
Adverse drainage from access roads			
Stockpiles, Surge Piles and Overburden Dumps			
Installation of Edge Protection Berms to an adequate height where dumping is performed at the top of the stockpile/tip or overburden dump			
Cracking on the surface and crest of the stockpile or ponding			
Evidence of undercutting or undermining of the stockpile			
Washouts from rainfall			
Condition/integrity of physical barriers around previous unstable areas or barriers/fences preventing access (i.e. exclusion zones around undercut stockpiles)			
Where practical, draw point on surge piles identifiable			
Suitable lighting provided for active areas			
Installation of safety berms to an adequate height where dumping is performed			
Dams and Ponds			
Cracking of earthen slope			
Changes in quantity of seepage if seepage exists			
Significant erosion in proximity to spill way/overflow			
Significant shrinkage surrounding any pipe work through slope			
Pit Surrounds			
Drainage away from pit, including storm water			
Any water ponding or normal face water disappearing			
Condition/integrity of physical barriers around previous unstable areas or barriers/fences preventing access			
Surface settlement or subsidence			

Signage		
Exclusion Zones signposted for Unstable Faces or other unstable slopes		
Entrance to Pit Requirements signposted, i.e. 10/20/30 Rule/Radio Contact prior to entry		
Warning signs posted at Sediment Ponds, Water Dams		
Crests		
Lowering of ground surface at or behind the crest of the overall slope/bench		
Water running over the crest of the overall slope/bench		
Water entering cracks behind the crest of the overall slope/bench		
New accumulations of water behind the crest of the overall slope/bench		
Surcharging of ground behind the crest of the overall slope/bench		
Tension cracks increasing in size and/or offsets, sliding of one face of the crack		
Excessive backbreaking		
Edge Protection Berm in place and in order		
Faces		
Bulging of the slope face		
Erosion or mass movement of slope materials down the slope		
Settlement of slope face		
Displacement across joints/bedding planes		
Open structural features inclined > 10 degrees out of the face		
Open structural features inclined steeply > 70 degrees out of the face		
Loose material or overhanging material on the face		
Irregular slope gradient		
Irregularities in plan of the slope face		
Excessive water seepage, surface water disappearance		
Drainage blankets blocked		
Overhanging rock above working faces/roadways, not protected by rock traps		
Signs of active/recent failure of the face including bulging of the face and/or sagging of the face		
Slope deterioration or deformation (batter, bench, floor bulging or toe heave)		
Toe		
Ground movements at or in front of the toe of the overall slope/bench		
Water issuing from or in front of the toe of the overall slope/bench		
New accumulation of water at the toe of the overall slope/bench		
Excavations at or near toe of structure not as per design of quarry/tip		
Falling Rock Protection Berm in place and in order		
Bulging or undercut toe		
Waterlogging at or near slope toe		
Other observations		

ATTACHMENT B - Pre and Post Blast Checklists

Attachment (B) - Pre and Post Blast Checklists	
Pre Blast Checks and Controls	Completed
Assess face behind shot and identify any overhangs, undercuts, loose rock, fractures, wet areas, i.e., any sign of instability leading to potential rock fall, slide or collapse.	
Identify dimensions and layout of Falling Rock Protection Berms required.	
Assess crest of face to be shot, identify any back breaks, fractures, overhang, loose rock, i.e., any sign of instability leading to potential rock fall, slide or collapse.	
Establish dimensions and layout of Edge Protection Berms, taking into account that the Berm must be suffice for both people and mobile plant and the inner side of the berm must be at least 2 metres from the face.	
Establish a method to isolate the working area on the bench above and behind the shot	
Establish a method to isolate the toe of face being profiled, drilled and shot	
Assess condition of the floor of the bench to be shot: is it clean, compacted and level for mobile plant and people to operate on?	
Establish in consultation with driller how the drill rig shall access shot area and its planned means of operation taking into account Falling Rock Protection Berms at rear of shot and Edge Protection Berms at front of shot whilst ensuring the Drill Rig works perpendicular to the face and never trams parallel to the face whilst maintaining a maximum angle of 45 degrees to the face.	
Establish how and where light vehicles shall access shot area and park, e.g. surveyor, shot firer manager.	
Establish how and where heavy vehicles shall access shot area and park, e.g. explosives truck.	
Post Blast Checks and Controls	
Identify any back break fractures and highlight, record on blast management plan for future reference.	
Identify face fractures, over hanging rock, loose rocks in face and remediate.	
Assess all surrounding structures for damage, e.g. Berms, Drainage, Haul Roads, Drop Cuts and Dams. Pay particular attention when blast results in excessive vibration.	
Communicate all findings with Load and Haul team.	
Ensure quarry floor is swept before trucks enter the loading area.	
Other	

NOTE: Additional checks and controls related to blasting can be found in the CMPA "Blast Management Plan Template in the Construction Material Industry".

ATTACHMENT C - Crest, Face and Toe Stability Checklist

Attachment C – Crest, Face and Toe Stability Checklist			
Date of Inspection		Inspected by	
Area of Observation			Action Required
Crests			Yes No
Lowering of ground surface at or behind the crest of the overall slope/bench.			
Water running over the crest of the overall slope/bench.			
Water entering cracks behind the crest of the overall slope/bench.			
New accumulations of water behind the crest of the overall slope/bench.			
Surcharging of ground behind the crest of the overall slope/bench.			
Tension cracks increasing in size and/or offsets, sliding of one face of the crack.			
Excessive backbreaking			
Edge Protection Berm in place and in order			
Faces			
Bulging of the slope face.			
Settlement of slope face.			
Displacement across joints/bedding planes.			
Open structural features inclined > 10 degrees out of the face.			
Open structural features inclined steeply > 70 degrees out of the face.			
Loose material or overhanging material on the face.			
Irregular slope gradient.			
Irregularities in plan of the slope face.			
Excessive water seepage, surface water disappearance.			
Drainage blankets blocked.			
Overhanging rock above working faces/roadways, not protected by rock traps.			
Signs of active/recent failure of the face including bulging of the face and/or sagging of the face.			
Slope deterioration or deformation (batter, bench, floor bulging or toe heave).			
Toe			
Ground movements at or in front of the toe of the overall slope/bench.			
Water issuing from or in front of the toe of the overall slope/bench.			
New accumulation of water at the toe of the overall slope/bench.			
Excavations at or near toe of structure not as per design of quarry/tip.			
Falling Rock Protection Berm in place and in order.			
Bulging or undercut toe.			
Other observations			

ATTACHMENT D - Glossary of Terms

Term	Description
Angle of Repose	The angle of repose or the critical angle of repose, of a granular material is the steepest angle of descent or dip relative to the horizontal plane to which a material can be piled without slumping. At this angle, the material on the slope face is on the verge of sliding.
Avulsion	The sudden separation of land from one property and its attachment to another, especially by flooding or a change in the course of a river.
Batter	The sections of rock mass between catch berms within pit walls – usually excavated to a specific inclination/angle from the horizontal.
Bedding planes	Planes of weakness in the rock that usually occur at the interface of parallel beds or laminae of material within the rockmass.
Bench	A steplike mass of rock behind a face and below a working floor.
Berm	A ridge of overburden, consolidated material, or other material in a lengthened elevation designed to act as a dike or barrier, placed at the toe or crest of a slope as a barricade to falling objects or to prevent personnel/quarry equipment from falling inadvertently down pit walls. Also known as a bund.
Bulging	Mass movement of rock material caused by loading by natural or artificial means of soft rock strata that crop out in faces or valley walls. Such material is squeezed out and deformed; it flows as a plastic, and the disturbance may extend down tens of metres. Folds and small faults may form at the foot of the slope where the rock material is under stress.
Catch fence	A fence constructed either vertically or at an angle to the vertical at the required off-set distance from the toe of a slope. The purpose of the catch fence is to catch any loose material falling from overlying blocky ground, thus reducing the risk to the workforce at the base of the pit walls.
Crest	The highest extremity of a pile. This may be the point of a conical stockpile or the edge of the top surface of a linear or horizontal stockpile.
Dip	The angle a plane or stratum is inclined from the horizontal.
Discontinuity	A plane of weakness in the rock mass (of comparatively low tensile strength) that separates blocks of rock from the general rock mass.
Diversion drain	These are earth structures constructed across a field to intercept and divert surface run-off from the slope above and drain it to a safe outlet.
Draw hole	A ground-level opening through which material is pushed or dumped to supply an underground feeder chute and conveyor.
Edge protection berm	To prevent falls of mobile equipment, vehicles and people over the face of the quarry.
Embankment	A wall or bank of earth to hold back water such as in a dam
Exclusion zone	No go zone.
Face	A rock surface (usually vertical) from which rock is to be excavated.
Falling rock protection berm	Ditch or mound of material at the base of a face to stop or retain falling rocks. Also known as rock traps and catch bunds

Fault	A naturally occurring plane or zone of weakness in the rock along which there has been movement. The amount of movement can vary widely.
Foliation planes	Alignment of minerals into parallel layers; can form planes of weakness/discontinuities in rocks.
Fracture	Any separation in a geologic formation, such as a joint or a fault that divides the rock into two or more pieces. A fracture will sometimes form a deep fissure or crevice in the rock.
Geological structure	A general term that describes the arrangement of rock formations. Also refers to the folds, joints, faults, foliation, schistosity, bedding planes and other planes of weakness in rock.
Geotechnical assessment	The application of soil and rock mechanics principles for the evaluation of slopes, stockpile and surge pile stability.
Geotechnical risk	Those risks associated with ground movements which are typically limited to the area of the quarry and to a region around the quarry. Ground movements may be significant (such as subsidence or natural rebound) or catastrophic (such as batter collapse).
Geotechnical stability	The stability of an excavated slope against mass failure.
Ground control	The ability to predict and influence the behaviour of rock in a quarrying environment, having due regard for the safety of the workforce and the required serviceability and design life of the quarry.
Haul road	A temporary road built to facilitate the movement of people, equipment, and/or materials.
Hydraulic sluicing	Is a form of mining that uses high-pressure jets of water to dislodge rock material or move sediment.
Instability	Condition resulting from failure of the intact rock material or geological structure in the rock mass.
Inundation	To cover with water, especially floodwaters.
Joint	A naturally occurring plane of weakness or break in the rock (generally aligned subvertical or transverse to bedding), along which there has been no visible movement parallel to the plane.
Loose (rock)	Rock that visually has potential to become detached and fall. In critical areas, loose rocks must be scaled to make the workplace safe.
Overburden dump	Is the material that lies above an area that lends itself to economical exploitation (also called waste or spoil) that is removed and dumped to allow for the winning of quarry materials
Overhang	Rock protruding from the face.
Planar failure	A mass of rock in a slope slides down along a relatively planar failure surface.
Pile	The term "pile" used in this advisory means stockpile and surge pile.
Piping failure	Where groundwater and/or surface water channels along more permeable and erodible layers (sands and gravels) within an excavated slope and eventually undermining it and causing it to collapse.
Ravelling	The gradual failure of the rock mass by rock blocks falling/sliding from pit walls -usually under the action of gravity, blast vibrations or deterioration of rock mass strength. A gradual failure process that may go unnoticed. The term unravelling is also used to mean the same thing.

Risk	A probability or threat of damage, injury, liability, loss, or any other negative occurrence that is caused by external or internal vulnerabilities, and that may be avoided through pre-emptive action.
Rock, Igneous	Igneous rocks are formed when magma (molten rock deep within the earth) cools and hardens. Sometimes the magma cools inside the earth, and other times it erupts onto the surface from volcanoes (in this case, it is called lava). When lava cools very quickly, no crystals form and the rock looks shiny and glasslike. Sometimes gas bubbles are trapped in the rock during the cooling process, leaving tiny holes and spaces in the rock. Examples of this rock type include Basalt, Dacite, Diorite, Granite, Pumice, Rhyodacite, Scoria and Tuff.
Rock mass	The sum total of the rock as it exists in place, taking into account the intact rock material, groundwater, as well as joints, faults and other natural planes of weakness that can divide the rock into interlocking blocks of varying sizes and shapes
Rock, metamorphic	Metamorphic rocks are formed under the surface of the earth from the metamorphosis (change) that occurs due to intense heat and pressure (squeezing). The rocks that result from these processes often have ribbon like layers and may have shiny crystals, formed by minerals growing slowly over time, on their surface. Examples of this rock type include Granulite, Greenstone, Gneiss, Hornfels, Marble, Quartzite, Schist and Slate.
Rock, sedimentary	Sedimentary rocks are formed from particles of sand, shells, pebbles, and other fragments of material. Together, all these particles are called sediment. Gradually, the sediment accumulates in layers and over a long period of time hardens into rock. Generally, sedimentary rock is fairly soft and may break apart or crumble easily. You can often see sand, pebbles, or stones in the rock, and it is usually the only type that contains fossils. Examples of this rock type include Argillite, Conglomerate, Greywacke, Limestone, Mudstone, Sandstone and Shale.
Rock trap	See falling rock protection berm
Seismic event	Earthquakes or vibrations caused by sudden failure of rock. Not all seismic events produce damage to the quarry.
Settlement pond	Designed to slowly release runoff, detaining it long enough to allow most of the sediment to settle out.
Shear	A mode of failure where two pieces of rock tend to slide past each other. The interface of the two surfaces of failed rock may represent a plane of weakness, or a line of fracture through intact rock.
Slope	Any continuous face of rock mass within the overall pit wall (without stepping/berms).
Slope, constructed	Can include dam walls (embankments), overburden dumps, berms, stockpiles and slimes or tailings storages.
Slope, excavated	Can be hard rock quarry faces developed by drilling and blasting and mechanically excavated pits developed by excavators, dozers, scrapers, front end loaders, hydraulic sluicing and dredging:
Slope, natural	Can be steep natural slopes that have the potential to become unstable due to nearby extractive activities

Sloughing (or run of material)	An unexpected collapse and flow of material such as crushed stone that occurs on the face or side of a pile when its angle exceeds the material's angle of repose.
Slumping	Sliding material on the slope or face of a pile is evidence that the stockpile side or face cannot support its own weight and is failing. Side refers to the sides of a pile; whereas, face refers to the area of the pile where material is being removed from the toe.
Slump failure	When a coherent mass of loosely consolidated materials or rock layers moves a short distance down a slope.
Stockpile	A constructed pile of loose natural or processed material (i.e. gypsum, aggregate, sand, etc.). Usually built in a conical or linear shape.
Strike	The bearing of a horizontal line in a plane or a joint.
Stripping	The removal and placement of overburden
Subsidence	Is the motion of a surface (usually, the Earth's surface) as it shifts downward relative to a <u>datum</u> such as sea-level.
Surge pile	A constructed pile of loose natural or processed material built directly over a powered feeder or draw hole.
SWP	A Safe Work Procedure identifies each hazard within the steps, and then lists controls alongside.
SWMS	A Safe Work Method Statement lists instruction in conducting an activity safely.
Toe	The lowest edge of a pile at the pile's foundation.
Toppling failure	Occurs when columns of rock, formed by steeply dipping discontinuities in the rock rotates about an essentially fixed point at or near the base of the slope followed by slippage between layers.
Unconsolidated materials	Weak geological materials such as gravel, sand, silt and clays but can also include consolidated or hard rocks that have been extremely or highly weathered; weak rocks and rocks with weak structures such as mica schists.
Undercut	Erosion of material at the base of a steep slope, cliff, or other exposed rock.
Void	A hidden hole, or invisible cavity or opening inside a pile usually occurring under some consolidated bridged material.
Wall	A wall can pertain to a section of, or the complete profile of the perimeter of an open pit excavation.
Wedge	A block of rock bounded by joints on three or more sides that can fall or slide out under the action of gravity, unless supported.
Wedge failure	Occurs in rock mass with two or more sets of discontinuities whose lines of intersection are approximately perpendicular to the strike of the slope and dip towards the plane of the slope.
Working face	The wall remaining after a loader has removed material from a stockpile. The angle of the working face may be greater than the material's angle of repose. Sloughing may occur if the working face breaks loose or is disturbed.