

# REHABILITATION AND CLOSURE PLAN

**Karuah Hard Rock Quarry**

**Prepared for:**

Hunter Quarries Pty Ltd

PO Box 51

Thornton NSW 2322

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## BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Hunter Quarries Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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## DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
V5	31 May 2021	Sam McDonald	Sam McDonald	Sam McDonald
V4	6 February 2020	Sam McDonald	Chris Jones	Chris Jones
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# 1 Introduction

## 1.1 Background

Mountain Industries obtained approval to operate a hard rock quarry at Karuah in 1997, with the site subsequently purchased by Hunter Quarries Pty Ltd (HQPL) in 2002. In October 2004, HQPL applied to the Department of Infrastructure, Planning and Natural Resources (DIPNR) (Now known as the Department of Planning Industry and Environment – DPIE) for approval to expand the quarry into adjoining lands (the Stage 2 area) to allow the extraction of further hard rock resources.

Development Consent was granted by the Minister for Infrastructure, Planning and Natural Resources on 3 June 2005 (ref. DA 265-10-2004), with the approved development including:

- Implementing the remainder of the approved Stage 1 quarry operation;
- Extending the quarry operations into the Stage 2 area;
- Upgrading and using existing infrastructure on site;
- Rehabilitating the site by re-contouring and revegetating exposed surfaces; and
- Producing up to 500,000 tonnes of product a year over the next 22 years.

This *Rehabilitation and Closure Plan* (Plan) has been prepared to satisfy the request of the Department of Planning Industry and Environment (DPIE) and cover the following conditions of the Development Consent:

- *Rehabilitation Management Plan* (Schedule 3 Condition 39 – 41); and
- *Quarry Closure Plan* (Schedule 3 Condition 44).

The Plan contains information regarding the proposed final rehabilitation and closure at Karuah Quarry. As it contains much of the information from the existing *Rehabilitation Management Plan*, the *Rehabilitation Management Plan* will now be superseded – being replaced by this Plan.

The site has Development Consent approval to operate until 3 June 2027, however the current license agreement between HQPL and the owner of Lot 11 expires on 7 May 2024. The Karuah Quarry has entered a closure phase for Lot 11 and some rehabilitation works have commenced on the eastern high wall. Lot 11 rehabilitation works are expected to be completed by 7 November 2021. This will allow 30 months of rehabilitation monitoring to occur prior to the Lot 11 license agreement expiring on 7 May 2024. Lot 21 will continue to be operational until the end of the Development Consent (3 June 2027). A rehabilitation program for Lot 21 will be implemented after this date. For more information regarding rehabilitation schedules refer to **Section 6.4**.

## 1.2 Government Consultation

Key personnel from the Hunter Group met with Colin Phillips and Leah Cook from DPIE on 12 December 2017 to discuss the Quarry Closure Plan requirement of the Development Consent. There was follow up consultation undertaken as part of the development of this Plan with the written consultation outlined in the table below.

HQPL also liaised with the MidCoast Council, with comments relating to this consultation outlined in the table below.

**Table 1 Consultation Summary (DPIE and MidCoast Council)**

Aspect Number	DPIE Aspect	SLR/HQPL Comment										
12 December 2017 – Consultation Email from the DPIE												
1.	A Quarry Closure Plan should satisfy the conditions of consent as set out for Karuah Quarry , see section a) to d) of condition 44;	This Plan meets these requirements. See Section 3.										
2.	<p>The table reproduced below is sourced from the Department’s current standard conditions for Hard Rock Quarries. These objectives are, in effect, quarry closure objectives and are an excellent guide to the material to include in the Karuah QCP.</p> <p><b>Rehabilitation Objectives</b></p> <p><i>The Applicant must rehabilitate the site to the satisfaction of the Secretary. This rehabilitation must be generally consistent with the proposed rehabilitation activities described in the documents listed in conditions 2 and 3 of Schedule 2 and the conceptual rehabilitation plan in Appendix 7 and comply with the objectives in Table 5.</i></p> <p><i>Table 5: Rehabilitation Obligations</i></p> <table><tr><th>Feature</th><th>Objective</th></tr><tr><td>All areas of the site affected by the development</td><td><ul style="list-style-type: none"><li>• Safe</li><li>• Hydraulically and geotechnically stable</li><li>• Non-polluting</li><li>• Fit for the intended post-mining land use/s</li><li>• Final landform integrated with surrounding natural landforms as far as is reasonable, and minimising visual impacts when viewed from surrounding land</li></ul></td></tr><tr><td>Surface Infrastructure</td><td><ul style="list-style-type: none"><li>• Decommissioned and removed, unless otherwise agreed by the Secretary</li></ul></td></tr><tr><td>Quarry benches and pit floor</td><td><ul style="list-style-type: none"><li>• Landscaped and vegetated using native tree and understorey species</li></ul></td></tr><tr><td>Final Void</td><td><ul style="list-style-type: none"><li>• Minimise the size, depth and slope of the batters of the final void</li><li>• Minimise the drainage catchment of the final void</li></ul></td></tr></table>	Feature	Objective	All areas of the site affected by the development	<ul style="list-style-type: none"><li>• Safe</li><li>• Hydraulically and geotechnically stable</li><li>• Non-polluting</li><li>• Fit for the intended post-mining land use/s</li><li>• Final landform integrated with surrounding natural landforms as far as is reasonable, and minimising visual impacts when viewed from surrounding land</li></ul>	Surface Infrastructure	<ul style="list-style-type: none"><li>• Decommissioned and removed, unless otherwise agreed by the Secretary</li></ul>	Quarry benches and pit floor	<ul style="list-style-type: none"><li>• Landscaped and vegetated using native tree and understorey species</li></ul>	Final Void	<ul style="list-style-type: none"><li>• Minimise the size, depth and slope of the batters of the final void</li><li>• Minimise the drainage catchment of the final void</li></ul>	<p><b>Section 2</b> outlines key objectives; <b>Section 5</b> outlines current and proposed land use; and <b>Section 6</b> outlines rehabilitation and closure methodology.</p>
Feature	Objective											
All areas of the site affected by the development	<ul style="list-style-type: none"><li>• Safe</li><li>• Hydraulically and geotechnically stable</li><li>• Non-polluting</li><li>• Fit for the intended post-mining land use/s</li><li>• Final landform integrated with surrounding natural landforms as far as is reasonable, and minimising visual impacts when viewed from surrounding land</li></ul>											
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Aspect Number	DPIE Aspect	SLR/HQPL Comment
3.	The Department has no objection to the QCP being included as a component of the Rehabilitation Management Plan, as these two plans are very much related. However, for the purpose of easily being able to demonstrate that the all the requirements of condition 44 are met, I consider it best of the QCP to be a separate component of the Rehabilitation Management Plan, set out under its own heading. Alternatively, you may choose to submit a stand-alone QCP.	A decision has been made to have one document for the site, being a Plan that meets the relevant Development Consent requirements for a Rehabilitation Management Plan (Schedule 3 Condition 39) and Quarry Closure Plan (Schedule 3 Condition 44). HQPL now propose that the previously approved <i>Rehabilitation Management Plan</i> will become a redundant document.
4.	The Department believes the QCP needs consideration of visual impacts of the final landform (see the Table above and consider the requirements of Condition 29 of Schedule 3). Visual Impact <i>29. The Applicant shall</i> a) <i>implement all practicable measures to minimise the visual impacts of the development;</i> b) <i>retain, re-vegetate and subsequently maintain a visual bund within the Stage 1 works area (in accordance with Figures 13 and 14 of the EIS) to minimise the visual impacts of development;</i> c) <i>include a progress report on the re-vegetation and maintenance of the visual bund in the AEMR, to the satisfaction of the Director General.</i>	See Section 6.3.3 outlines the visual screening.
<b>10 July 2018 – Consultation Email from the DPIE</b>		
1	There are two main areas of concern within the “ <i>Conceptual Rehabilitation and Closure Plan</i> ”: The timing of commencement of quarry closure activities being scheduled three years after the access agreement allowing Hunter Quarries onto Lot 11 DP 1024564 (Lot 11) has expired;	This has been noted and updated in Section 6.4.
2	The lack of any planned revegetation of the benches of the Eastern Highwall of the quarry.	Full revegetation on the Eastern Highwall benches have been deemed too dangerous by the risk assessment completed at site. For a detailed list of findings refer to Appendix A.
3	The Department considers that the timing for the production of a defined (rather than conceptual) Quarry Closure Plan should be brought forward to no later than 2021 (three years prior to the expiry of the access agreement for Lot 11).	This comment is now redundant as further advice indicates the Lot 11 License date ends 7 <sup>th</sup> May 2024, with rehabilitation completed by 7 <sup>th</sup> November 2021.

Aspect Number	DPIE Aspect	SLR/HQPL Comment
4	The Department would need to be provided with an independent risk assessment of safety issues before it would be willing to consider that Hunter Quarries has been demonstrated that some, or all, of the Eastern Highwall benches cannot be safely revegetated. Note that the Risk Assessment of working on, or near, the Eastern Highwall contained in Appendix A of the Conceptual Rehabilitation and Quarry Closure Plan was undertaken by 3 employees of Hunter Quarries.	The Risk Assessment has been completed. For a summary of findings refer to Section 7.7.2. The Risk Assessment is attached as Appendix A.
5	More extensive or detailed review comments follow: Page 6, paragraph 5; Page 25, paragraph 4; Page 26, Table 9 including footnotes; Page 38, last paragraph; – See comment 1 above about the need for the quarry closure phase to be addressed no later than 2021 – not after 2027 as stated in this paragraph.	SLR have updated all sections, paragraphs and comments flagged by the DPIE.
6	Page 15, Section on Benches; Page 32 Section 8.5.1; See Comment 5 above. Most quarries provide for revegetation of the benches of their highwalls. Why is it unsafe to work on the Eastern Highwall benches? Are there some benches, but not others, that could be safely revegetated? Could smaller equipment be safely used (such as Bobcat-sized equipment)? The Department is seeking an independent risk assessment to explore ways and means to revegetate highwall benches, or at least as many as can be safely accessed and worked. Nothing updated yet.	SLR have included the findings from the Risk Assessment within section 7.7.2. The Risk Assessment is attached as Appendix A. The main reasons for why it is unsafe to undertake full rehabilitation on the highwalls are detailed below: <ul style="list-style-type: none"> <li>• Slip trip or fall of person / toppling of plant into pit due to presence of loose debris on benches,</li> <li>• Hit from above or Bench Foundation gives way from Rock Block Slide or Undercut Failures and or Toppling failure of rock columns or wedge failure;</li> <li>• Inadequate access to benches i.e. Too narrow for machinery access, unsafe for personnel to access due to benches being graded towards the pit, or insufficient bench widths; and</li> <li>• Catastrophic bench or Eastern Highwall Face failure.</li> </ul>
7	Page 15, Section on Water Management. Reference to “lease surrender” should be to “consent surrender” or “consent expiry”. There are a few references throughout the document that relate to the operation of a mine rather than a quarry. These should be corrected.	The reference to “lease surrender” in Section 5 – Water Management has been updated to “consent surrender”.



Aspect Number	DPIE Aspect	SLR/HQPL Comment
8	There is also a reference to the provision of safe access for stock. This seems to be an oversight for a site that is planned to be returned, as far as possible, to native vegetation.	The reference to provision of “safe access for stock” has been updated within Section 7.6 to “final void will be to render it safe in terms of access by humans, livestock and wildlife”.
9	Pages 18 and 19, Tables 4 and 5. Please consider and justify the proposed introduction of exotic grasses to the site as part of Hydromulching and Straw Mulching techniques.	The document has been updated to include native vegetation.
10	Page 22, Table 8. Please provide a justification for the proposed tree seed mix. What is it based on? Species list in the EIS? Some one’s recommendation? OEH’s recommendation?	A justification for the seed mix has been added to the text. The seed mix outlined has been extracted from the EIS specialist report from Global Soil Systems (2004). The justification was updated in an earlier version of the Karuah Quarry Closure Plan based on the seed mix that was used for the existing rehabilitation areas at the site.
11	Page 29, first paragraph. I wonder about the term “low acidity”. Maybe this should be “low pH” or “high acidity”. I also wonder if this is relevant for this site? What is the pH the water currently on site? It may be that this area produces naturally alkaline waters?	The terms and content within this section have been taken from a Research Development paper. The pH is typically between 7-8. Data from Sediment Dam 2 (LDP001) reveals an average pH of 7.81 (November 2016 data).
12	Page 30 Section 7.6. There seems to be the word “not” missing from the first dot point “this is not an option as there would not be enough material to fill the void”. As a comment, the Department has recently been in receipt of enquiries about the use of quarry sites as places to emplace VENM and ENM produced by Sydney infrastructure construction activities. The sites involved have included sites in the Hunter and Upper Hunter.	Note, for the Plan, HQPL has had further consultation with DPIE and the landowner and this document has been updated to remove final void options. The final landform of the void is a ‘water storage’.
13	Page 32, Section 8.1. reference to a “mineable seam” seems to be an oversight.	The words “mineable seam” have been replaced by the word “rock” to reflect the operation at site.
14	Page 35, Table 10. Please include “remediation of any hydrocarbon contamination” as a dot point in the list of decommissioning activities.	The dot point has been included within Table 12 (note table numbers have changed)
15	Page 36, Table 10. Please confirm that the reference to Section 73 of the Water Act (1992) is current and relevant.	The reference to Section 73 of the Water Act (1992) in Table 12 has been updated to the current legislation - Water Management Act 2000.

Aspect Number	DPIE Aspect	SLR/HQPL Comment
16	Page 37, Section 10.2. The restriction of post-closure monitoring to 18 months is way too short. Please provide a monitoring period that is commensurate with revegetation activities.	The post closure monitoring is three years for Lot 21 and thirty months for Lot 11 (refer to below meeting record dated 6 May 2021)
17	Page 38, paragraph below Table 11. The Department expects that <i>"the most widely respected current methodology for rehabilitation monitoring"</i> will be identified no later than 2021.	The wording <i>"the most widely respected current methodology for rehabilitation monitoring"</i> 'will be identified no later than 2021' has been added to the text in Section 9.2.
<b>18 February 2019 – Consultation Email from the DPIE</b>		
1	The Department believes that remote means to achieve rehabilitation of these benches must be explored prior to the closure of the quarry. These methods may include the use of helicopters or drones for aerial treatment of the benches to deliver seeds and ameliorates to the surfaces of the benches or whether the opportunity exist for hydromulching of some benches, either from the floor of the quarry or elevated locations adjacent to the highwall. This needs to be considered for Sections 6.1 to 6.3 of the CR&CP.	Addressed in Section 6.3.
2	The lesson to be learned from the Karuah Quarry experience is that rehabilitation of highwall benches needs to be undertaken progressively, while safe access to the quarry benches is available. Most likely this would occur prior to the next lower level of the quarry being "benched".	Noted. The only operational benches at Karuah Quarry are the southern benches. Lessons learnt from Eastern benches will applied to southern benches.
3	The Department, guided by past events, remains concerned about access to the lands of Lot 11 for undertaking rehabilitation activities. On page 6 of the CR&CP, it is stated that rehabilitation of the Lot 11 is planned to commence at the cessation of the lease agreement with the landowner (unless the lease agreement of the Lot 11 landowner is extended) (see also Section 6.4). The risk evident to the Department is that if the lease is not extended, how can Hunter Quarries be assured of access to the lands on lot 11 to undertake rehabilitation activities?  Therefore, unless it is assured by the lease agreement, rehabilitation of the lot 11 lands must commence PRIOR to the expiry of the lease with the Lot 11 landowner. The Department's view of a nominal commencement date for rehabilitation activities for Lot 11 is May 2021 – subject to extension, if the Department is provided evidence that access to the lands of Lot 11 is available after May 2024 for rehabilitation activities.	Karuah Quarry will complete rehabilitation works on Lot 11 by the 7 <sup>th</sup> November 2021 to allow 30 months of monitoring to be completed on Lot 11 prior to expiry of the license.
4	I found Table 1 of the CR&CP to be an excellent summary and a worthwhile inclusion in the Plan. At the start of page 7 my name is mentioned. I believe that the meeting also included Leah Cook from our Compliance Branch.	Leah Cook's name has been added to the key personnel who attended the meeting with the Hunter Group on the 12 December 2017 to discuss the Plan.
5	Section 1.2.2. have you received any response from Council? If so please include this as an appendix to the CR&CP.	This document will be submitted to Council and the DPIE.

Aspect Number	DPIE Aspect	SLR/HQPL Comment
6	Table 9. The table could be improved by inclusion of "Year" after the word "Timing" in these two rows of the table.	Table 9 has been updated to address the DPIE comment 6.
7	Table 10. Land Relinquishment. Rehabilitation Success Criteria. Consideration needs to be given the relevant water quality standards, in particular that the Protection of the Environment Operation Act 1997 requires that there should be no pollution of waters as defined in that Act, unless an Environmental Protection Licence (EPL) allows otherwise, in accordance with the EPL.	The following text has been added to Table 12 under the 'Land Relinquishment' row to address DPIE comment 7: 'Additionally, the quality of water leaving the site will meet the relevant water quality standards, in particular that the Protection of the Environment Operation Act 1997 which requires that there should be no pollution of waters as defined in that Act, unless an Environment Protection Licence (EPL) allows otherwise, in accordance with the EPL'.
8	Table 11. Weed Presence. What action is planned to be undertaken if monitoring identifies weed infestations? Merely noting the infestation is not sufficient.	The sentence referenced in the DPIE comment 8 has been updated to include a commitment to noting and managing weed infestations. The sentence now reads: 'Significant weed infestations will be noted and managed during the next round of weed management. This includes implementing a weed spraying program'.  This is in Table 13.
9	Section 11.3. The Department supports the concept of the current CR&CP being a conceptual plan, with its review every five years, and importantly, three years prior to the cessation of the lease agreement for access to Lot 11. At that time (May 2021), this conceptual plan will be converted to an "Action Plan" for the rehabilitation of, at a minimum, the lands of Lot 11.	Further details of rehabilitation and closure have been added to the December 2019 document.

Aspect Number	DPIE Aspect	SLR/HQPL Comment
10	You are advised to remain up to date with proposed developments on Lot 11 concerned with the proposed Karuah South Quarry, as this development may impact the rehabilitation of the Karuah Quarry.	Karuah Quarry will remain informed of the proposed developments of the proposed Karuah South Quarry on Lot 11 in consultation with the Department and the applicant for the proposed Karuah South Quarry. If necessary (as a result of the Karuah South Quarry proposal), this rehabilitation and closure plan can be amended in the future in response to any changes in the status of the Karuah South Quarry proposal.
<b>27 August 2019 – Consultation Email from Mathew Bell at MidCoast Council</b>		
1	I note that when the Karuah Hard Rock Quarry was approved, the Pacific Highway alignment was through Karuah and the Karuah Bypass had not opened. As such, the visual impact of the quarry from the upgraded Highway is different and greater. I note that visual impact is discussed in s6.3.3. I would ask that rectifying the visual impact of the quarry from the perspective of the Highway be a further and important consideration in the Plan.	Addressed in Section 6.3.5
2	The rehabilitation objectives appear to be relevant and appropriate.	Noted
3	I particularly support the key objectives relating to environmental protection and restoration, including the re-establishment of functional native vegetation over the quarry disturbance areas, the stabilisation of the landform such that adverse environmental effects are reduced or eliminated and the outcomes sought in relation to downstream water quality.	Noted
4	I support the adoption of the final landform domains as identified in s5.2, including the creation of a wetland within the (minimised) final void area,	Note, for the Plan, HQPL has had further consultation with DPIE and the landowner and this document has been updated to remove final void options. The final landform of the void is a 'water storage'.
5	The woodland seed mix proposed for final restoration (Table 8) appears appropriate as it comprises locally native flora species. It might be beneficial to increase shrub species diversity to include genera additional to just Acacia. It would also be beneficial to include one additional favoured foraging tree species for koalas (being <i>Eucalyptus microcorys</i> ). Weed controls, as noted in the Draft Plan, are very important.	The seed mix has been used successfully before in the area. HQPL have however added <i>Eucalyptus microcorys</i> to the seed mix.

Aspect Number	DPIE Aspect	SLR/HQPL Comment
6	In relation to the option of providing for a waste facility for the void area, I would note that this is not an action that has been canvassed, to my knowledge, in Council's strategic planning for waste management in the region. As such, we would be unlikely, at this time, to support any use of the void for waste disposal,	Note, for the Plan, HQPL has had further consultation with DPIE and the landowner and this document has been updated to remove final void options. The final landform of the void is a 'water storage'.
7	Given the recent presence of priority feral pest animal species in the wider locality (feral pigs), I endorse the discussion in the closure plans that regular pest surveillance and control will be undertaken,	Addressed in Section 9.1.
8	I support the monitoring proposal and would espouse the benefits of adaptive management based on monitoring observations and outcomes,	Noted. Rehabilitation maintenance will be based on the results of rehabilitation monitoring and inspections
9	I would ask that the areas of and means for which the conservation offset areas and the restoration areas for this quarry are permanently legally secured (by instrument on title, covenant, agreement, etc) should be clearly identified within the plan.	An update on the conservation offset area has been provided in the Annual Environmental Management Report (AEMR).
<b>23 December 2019 – Consultation Email from the DPIE</b>		
1	The comment for condition 39(c) that "Minimal rehabilitation is proposed within the next five years as the site remains operational" is incorrect for Lot 11. Reference to Table 9 shows that rehabilitation is due to commence in early 2021 and be "completed" by 2024. This is completely within the next five years timeframe. The entry in Table 3 must be corrected to indicate the different timescales for rehabilitation activities for Lot 11 compared to the remainder of the Karuah Quarry.	Update to Table 3 to differentiate the rehabilitation timeframe for Lot 11 and Lot 21.
2	The comment in Table 3 against condition 38 that "There are limited opportunities for progressive rehabilitation" is incorrect as rehabilitation is proposed to commence on Lot 11 early in 2021.	Update to Table 3 to explain the rehabilitation timeframes for Lot 11 and Lot 21.

Aspect Number	DPIE Aspect	SLR/HQPL Comment
<b>8 February 2021 – Meeting with DPIE staff (Matthew Sprott &amp; Mike Young)</b>		
1	The Department approved the Rehabilitation and closure plan in August 2020. How is rehabilitation progressing?	<p>Side casting of suitable topsoil material from the Karuah East site across the common boundary onto the exposed eastern benches of the Karuah Quarry has commenced.</p> <p>Lot 11 is not owned by Hunter Quarries PL. In line with the license agreement, HQPL will be entirely removed from Lot 11 by 7 May 2024. Noting the proposed Karuah South Quarry, there is potential that rehabilitation of Lot 11 could be substantially impacted. Flexibility with the rehabilitation of Lot 11 in relation to the proposed Karuah South quarry is considered essential (in consultation with the Department).</p>
<b>6 May 2021 – Meeting with DPIE staff (Matthew Sprott &amp; James McDonough)</b>		
1	<p>The Department is willing to approve a reduced (30 month) rehabilitation monitoring period for rehabilitation works completed in Lot 11. To support this process, a revised Rehabilitation and Closure Management Plan is required to be submitted to the Department.</p> <p>The reduced monitoring timeframe will allow strategic consideration of key matters relating to rehabilitation works in respect to the proposed Karuah South Quarry and balance of disturbed areas on Lot 11 associated with the Karuah Quarry.</p>	<p>Although DA 265-10-2004 remains active until 3 June 2027, HQPL's access to Lot 11 is governed by a license agreement. The license agreement expires on 7 May 2024 and it is unlikely that access will be permitted following expiry.</p> <p>The approved rehabilitation and closure plan contains a three (3) year monitoring requirement post the completion of rehabilitation works on Lot 11.</p> <p>Rehabilitation works have commenced on the eastern high wall; however other areas of rehabilitation within Lot 11 have not commenced. This is because of the separate Karuah South Quarry proposal (SSD-8795) over Lot 11 and its potential impact on the rehabilitation works to be completed. It is proposed to complete Lot 11 rehabilitation works by 7 November 2021 and then complete 30 months of monitoring prior to the expiry of the Lot 11 license agreement.</p>

## 2 Scope and Objectives

The primary purpose of this Plan is to address feedback from the DPIE (as per **Table 1**) and ensure rehabilitation is undertaken successfully. Although not yet required based on timing until the cessation of quarrying, this management plan has been prepared to satisfy Schedule 3, Condition 39 and conceptually meet the obligations under Schedule 3, Condition 44 of the consent. This document relates to the rehabilitation of land subject to the approval to operate a hard rock quarry at Karuah (ref. DA 265-10-2004). This land includes Lot 21 DP 1024341, Lot 11 DP 1024564 and part of Lot 12 DP 1024564 (offset land). The land is shown in **Figure 1**.

Additional figures outlining the final land use are outlined in **Section 5**.



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The key objectives of this Plan are then to:

- Provide an overall framework for Conceptual Quarry closure – including rehabilitation and decommissioning strategies;
- Reducing or eliminating adverse environmental effects once the site ceases operations;
- Ensuring rehabilitation and closure is completed to the satisfaction of the DPIE;
- Ensuring that the site, and any nominated infrastructure, can be put to a suitable beneficial use post closure;
- Ensuring that the needs of HQPL and the local community are appropriately considered and addressed in the closure planning process, with an emphasis on generating minimal negative impacts;
- Re-establish a similar native forest vegetation cover at final rehabilitation, including native shrubs and ground cover, to that which currently exists over most of the Stage 2 area;
- Rehabilitation of the final void as per **Section 7**;
- Establish stable drainage lines on the rehabilitated areas and implement appropriate erosion controls to ensure the potential for erosion is limited, particularly during the establishment of vegetation;
- Ensure disturbed areas are rehabilitated progressively and as soon as practical after they are disturbed and quarrying operations cease. This is to reduce the potential for erosion, and to ensure vegetation is re-established as soon as possible;
- Creating a stable post-disturbance area for long-term beneficial uses, as well as for native vegetation propagation. Ensuring surface water dams to be retained will be safe, self-sustaining and acceptable for the post-quarrying land uses; and
- Preserving downstream water quality – the quality of surface and ground water that leaves the site will be adequate to maintain, or improve, environmental values and beneficial uses downstream of the Development Consent Area.

In the email from the DPIE dated 19 December 2017, a series of rehabilitation and closure objectives are proposed.

**Table 2 Discussion of the DPIE Rehabilitation Objectives**

Feature	Objective	SLR/HQPL Comment
All areas of the site affected by the development	<ul style="list-style-type: none"> <li>• Safe</li> <li>• Hydraulically and geotechnically stable</li> <li>• Non-polluting</li> <li>• Fit for the intended post-mining land use/s</li> <li>• Final landform integrated with surrounding natural landforms as far as is reasonable, and minimising visual impacts when viewed from surrounding land</li> </ul>	<p>The post closure land use will meet these requirements. As discussed in this document, the benches will however remain at closure.</p> <p>An appropriately qualified Geotechnical Engineer will be consulted on final highwall design to ensure the landform is hydraulically and geotechnically stable.</p>

Feature	Objective	SLR/HQPL Comment
Surface Infrastructure	<ul style="list-style-type: none"> <li>Decommissioned and removed, unless otherwise agreed by the Secretary</li> </ul>	All surface infrastructure will be removed at closure (unless otherwise agreed with the DPIE).
Quarry benches and pit floor	<ul style="list-style-type: none"> <li>Landscaped and vegetated using native tree and understorey species</li> </ul>	See Section 7.7 for details on the rehabilitation of benches.
Final Void	<ul style="list-style-type: none"> <li>Minimise the size, depth and slope of the batters of the final void</li> <li>Minimise the drainage catchment of the final void</li> </ul>	There is no further disturbance proposed at Karuah Quarry. Dam 2 will remain at closure.

### 3 Statutory Requirements

The relevant conditions of Development Consent and the section(s) in this document where they are addressed are contained in **Table 3**.

**Table 3 Relevant Conditions of Development Consent relating to rehabilitation and closure**

Condition Number	Condition Requirement	Section/Comment
<b>Rehabilitation Management Plan Condition</b>		
Schedule 3 Condition 39	<i>Within 6 months of the date of this consent, the Applicant shall prepare, and subsequently implement, a Rehabilitation Management Plan for the site, which integrates rehabilitation works for both Stage 1 and Stage 2 areas, to the satisfaction of the Director-General. This Plan must:</i>	
	<i>(a) identify the disturbed area at the site (both Stage 1 and Stage 2);</i>	Figure 2
	<i>(b) describe in general the short, medium, and long term measures that would be implemented to rehabilitate the site;</i>	Section 6
	<i>(c) describe in detail the measures that would be implemented over the next 5 years to rehabilitate the site; and</i>	Section 6 Lot 11: Rehabilitation will be completed prior to the 7 <sup>th</sup> November 2021. With thirty months of rehabilitation monitoring undertaken until the expiry of the license agreement with the landowner on 7 May 2024. Lot 21: Minimal rehabilitation is proposed within the next five years as the site remains operational.
	<i>(d) describe in detail how rehabilitation measures will be integrated with:</i>	Section 5
	<ul style="list-style-type: none"> <li><i>erosion and sediment control works on the site;</i></li> </ul>	Section 6.3.2 See Water Management Plan
	<ul style="list-style-type: none"> <li><i>remnant vegetation and habitat enhancement and conservation works; and</i></li> </ul>	Section 6
	<ul style="list-style-type: none"> <li><i>visual screening works;</i></li> </ul>	Section 6.3.5
	<i>(e) describe how the performance of these measures would be monitored over time.</i>	Section 9

Condition Number	Condition Requirement	Section/Comment
Schedule 3 Condition 40	<i>Within 5 years of providing the Rehabilitation Management Plan to the Director-General, and every 5 years thereafter, the Applicant shall review and update the plan to the satisfaction of the Director-General.</i>	Section 9.3
Schedule 3 Condition 41	<i>The Applicant shall include a progress report on the Rehabilitation Plan in the AEMR</i>	Section 9.3
<b>Quarry Closure Plan Condition</b>		
Schedule 3 Condition 44	<i>At least 3 years prior to the cessation of quarrying, the Applicant shall prepare a Quarry Closure Plan for the development, in consultation with the Council, and to the satisfaction of the Director-General. The plan must:</i>	Plan to be sent to the DPIE and Council
	a) <i>define the objectives and criteria for quarry closure;</i>	Section 2
	b) <i>investigate options for the future use of the site, including any final void(s);</i>	Section 7 now outlines the final land use of the void.
	c) <i>describe the measures that would be implemented to minimise or manage the ongoing environmental effects of the development; and</i>	Section 6
	d) <i>describe how the performance of these measures would be monitored over time.</i>	Section 9
<b>General Rehabilitation and Closure Conditions</b>		
Schedule 3 Condition 38	<i>The applicant shall progressively rehabilitate the site to the satisfaction of the Director-General.</i>	Section 6 Lot 11: Rehabilitation will be completed prior to 7 <sup>th</sup> November 2021. With thirty months of rehabilitation monitoring undertaken until the expiry of the license agreement with the landowner on 7 May 2024. Lot 21: There are limited opportunities for progressive rehabilitation.

## 4 Key Rehabilitation and Closure Processes

Rehabilitation of disturbed areas is an integral component of the quarry operation, and as such will be undertaken as soon as possible after disturbance occurs. Due to the area required for quarrying (Stage 2) and processing (Stage 1), there are few opportunities to complete any progressive rehabilitation until closure.

The proposed progressive rehabilitation techniques for vegetative stabilisation on the site will include, but are not limited to, the following:

1. Major and minor landform shaping;
2. Re-spreading of available topsoil and subsoil in rehabilitation areas (Note - all disturbance has been completed and there is little material available at Karuah Quarry. Some subsoil material is proposed to be transported from Karuah East as per **Section 6.3.4**);
3. Reshaping of post-quarry land surface to ensure suitable drainage and surface stability;
4. Scarification of the surface;
5. Use of direct seeding using a woodland seed mix; and
6. Targeted tubestock planting to increase diversity and address any gaps as necessary.

## 5 Site Domains

### 5.1 Current Domains (Primary Domains)

The current site domains (see **Figure 2**) have been identified for the purposes of rehabilitation and closure management. Primary domains are defined land management units within the site with unique operational and functional purpose and similar geophysical characteristics. Primary domains summarise the current status of the site.

Primary domains are summarised below:

**Buildings and Infrastructure (Predominately within Lot 21)** - This includes:

- Main workshop;
- Portable administrative building;
- Screener and crusher;
- Fuel storage; and
- Quarrying equipment – loaders, trucks (mobile fleet not included in rehabilitation cost estimate as these will be removed at closure).

Most of this infrastructure is currently located in Stage 1 – stockpiling and processing area.

**Haul Roads** – There are a series of roads that connect the different areas of the Karuah Quarry.

**Dam** – includes the main sediment dam (Sediment Dam 2 located in Lot 21) and drainage to the dam.

**Stage 1 Area** – the Stage 1 area is used for the stockpiling and processing of rock from the Karuah Quarry. Infrastructure such as the screener and crusher are located within this domain.

**Stage 2 Area** – The current Stage 2 of the quarry. Rehabilitation in this area will commence in 2021.

**Karuah Red Area** – Area of the quarry (near the main sediment dam) where the Karuah Red product is quarried.

**Highwall /Benches** – The benches represent the current location of quarrying at the Karuah Quarry.

**Existing Rehabilitation Areas** – these are marked up on the figure.

### 5.2 Final Landform Domains (Secondary Domains)

Secondary domains are defined as land management units characterised by a similar post quarrying land use objective (final land use). For the final landform it is proposed that there will be the following domains (see **Figure 3**) remaining:

**Woodland Rehabilitation** – woodland rehabilitation will be completed in the following areas:

- Haul roads (The main haul road will remain to allow inspections post closure. Non - essential roads to be removed);

- Buildings and infrastructure;
- Stage 1 Area;
- Karuah Red Area; and
- Stage 2 Area (Excluding Final Void).

**Benches** – See **Section 7.7** for details on the rehabilitation of benches.

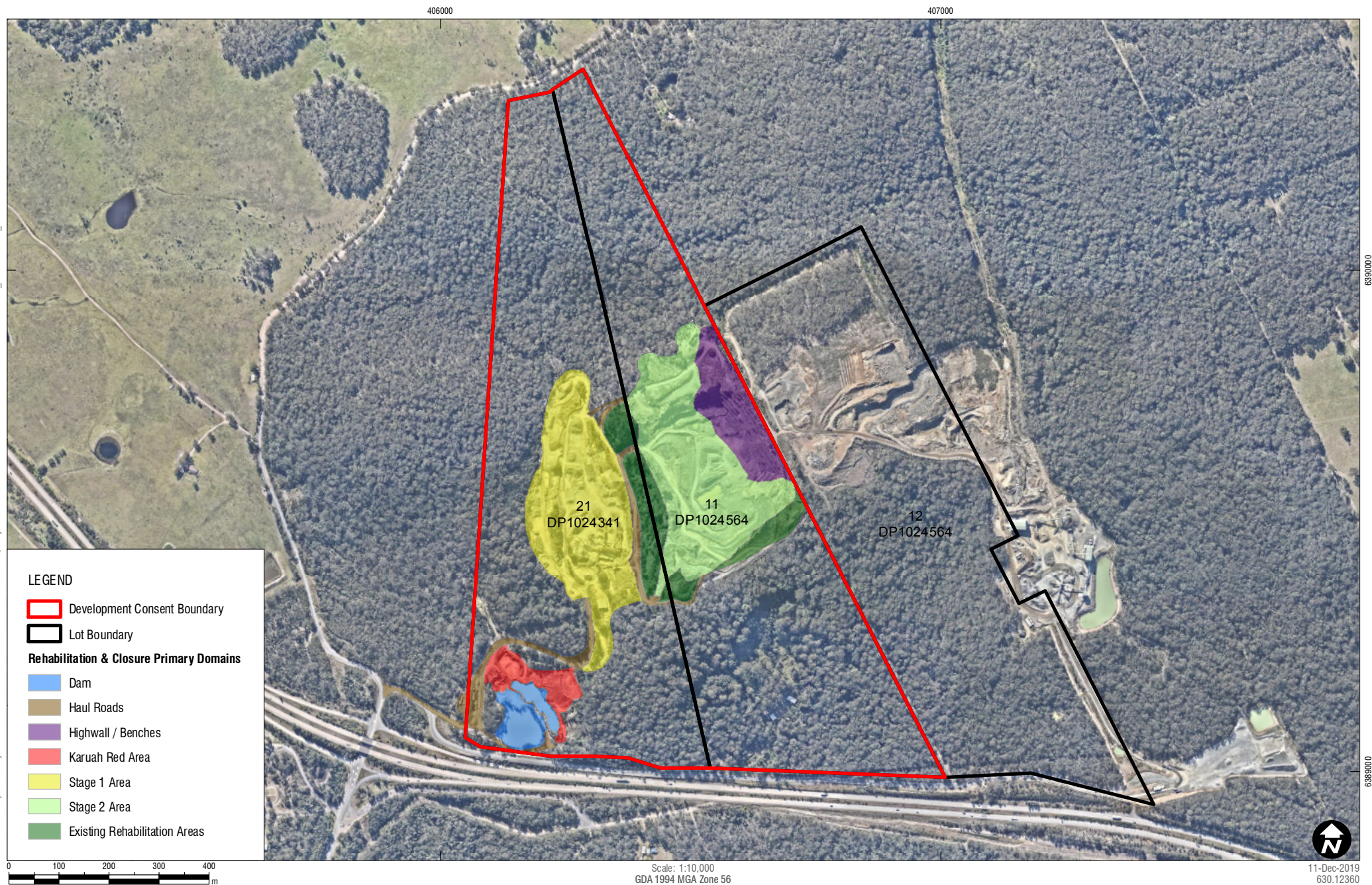
**Final Void** – the final land use of the void will be a water storage.

**Haul Roads** – major haul roads to remain for firefighting access.

**Dam** – Sediment Dams that are to remain after consent surrender will be reviewed and if necessary reshaped prior to quarry decommissioning to provide safe access for native fauna and to satisfy public safety requirements. Two will remain at closure.



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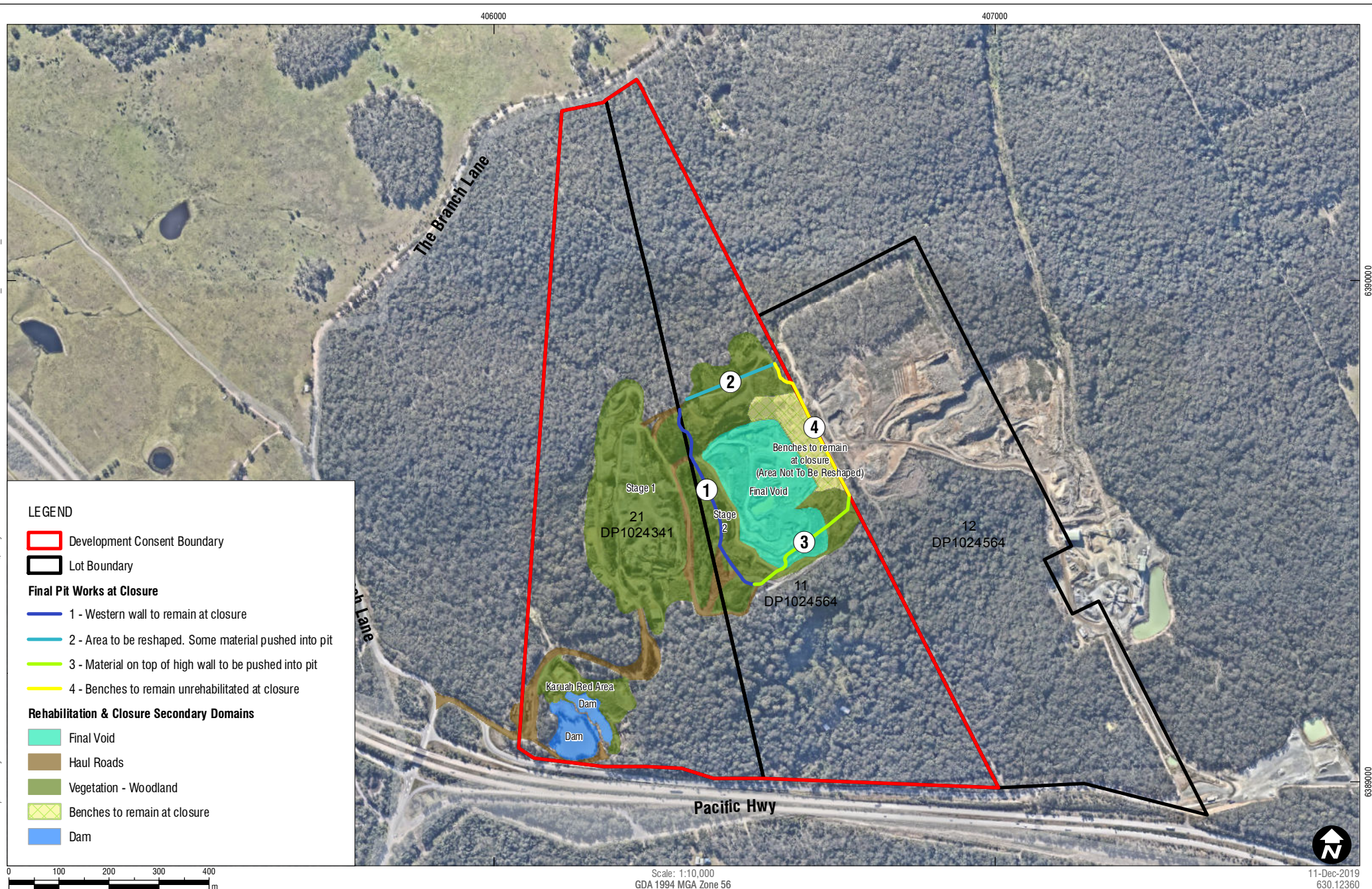


Current Site Domains

FIGURE 2



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## 6 Mitigation and Management Measures

In accordance with the relevant Development Consent conditions, the following sections describe the proposed rehabilitation of the site.

Where revegetation works have been progressively undertaken, these areas will be reviewed on a regular basis to determine the success of the progressive rehabilitation program. All rehabilitation findings will be included as part of the progress report on the Plan in the AEMR.

### 6.1 Short Term Rehabilitation

Short term rehabilitation techniques can be used to temporarily stabilise areas, including benches or steep batters and bunds prior to final closure.

#### 6.1.1 Hydromulching

Hydromulching is a one-step process where seed, fertiliser, mulch and a binder/tackifier are combined together in water. The resulting slurry is sprayed onto the soil surface providing a wood fibre interlocking mat that retains moisture for seed germination.

Almost any seed including native species, trees and shrubs can be used when hydromulching. The seed mix will include native grass seeds. The mulch is dyed green with a non-toxic chemical to help identify areas requiring ongoing treatment.

Application rates vary between contractors and depending upon site conditions (see **Section 4**). A general rule for the application of hydromulch is summarised in **Table 4** below.

**Table 4 Hydromulching Application Rates**

Product	Application Rate
Seed	100 kg/ ha of pasture mix made up of annual crops. Must include at least 20kg/ha of cover crop.
Fertiliser	200 kg/ha (Granulock 15)
Mulch	3500- 5000kg/ha (dry weight)
Binder and emulsion	Anionic Bitumen Emulsion 50/50 bitumen/ water =1500 - 3500 L/ha Polymer binder maximum 350L/ha

It is likely that hydromulching will be used for seeding of areas of the benches which have had the side casting shaping treatment. See Section **6.3.4**

### 6.1.2 Straw Mulching

Straw mulching is the process of blowing a stream of straw to areas covered with seed at a depth of 20mm to 30mm. The cost of straw mulching can be higher than other hydroseeding methods, but will assist with temporary stabilisation.

Straw mulching involves the following steps:

- Seed and fertiliser are applied to an area through a hydroseeding machine. Lime or Gypsum is sometimes required depending on soil conditions. For less steep slopes, seed can be applied by broadcasting or hand sowing.
- Straw shall be applied through a straw mulching machine. There are two approaches:
  - Both the Straw and Bitumen Emulsion can be applied at the same time through the straw mulching machine.
  - Straw can be applied as a separate operation followed by an overspray of bitumen emulsion.

Application rates vary between contractors and depending upon site conditions. A general rule for the application of straw mulch is summarised in **Table 5** below.

**Table 5 Straw Mulching Application Rates**

Product	Application Rate
Seed	100 kg/ha (pasture mix)
Fertiliser	200 kg/ha (Granulock 15)
Straw	Average bale = 20kg x 250 bales per ha (minimum). = 5000 kg/ha
Binder and emulsion	Anionic Bitumen Emulsion 50/50 bitumen/ water =1500 - 3500 L/ha Polymer binder maximum 350L/ha

## 6.2 Stages of Medium to Long-term Rehabilitation

On cessation of all quarrying activities the disturbance areas will be fully rehabilitated to create stable and self-sustaining landform for the nominated end land uses of woodland. Key steps in the rehabilitation and closure phases are outlined in **Table 6** below, with these defined within the Resources Regulator guideline for Mining Operations Plans (MOPs).

**Table 6 Rehabilitation and Closure Phases**

Phase	Description
<b>1</b> Decommissioning	The process of removing plant, equipment, buildings and other structures.
<b>2</b> Landform Establishment	The process of shaping unformed rock or other sub-stratum material into a desired land surface profile including final landform drainage features.
<b>3</b> Growth Medium Development	The process of establishing and enhancing the physical structure, chemical properties and biological properties of a soil stratum suitable for plant growth. This includes placing and spreading soil and applying ameliorants.

Phase		Description
4	Ecosystem and Land-use Establishment	The process of seeding, planting and transplanting native plant species. Incorporates management actions such as weed and feral pest control to achieve species establishment and growth to juvenile communities and habitat augmentation.
5	Ecosystem and Land-use Development	The process of applying management techniques to encourage an ecosystem to grow and develop towards a desired and sustainable post quarrying land use outcome. Incorporates features including species reproduction, nutrient recycling and community structure.
6	Land Relinquishment	Demonstrated ultimate success of rehabilitation process. This may be biophysical or physical. Return or partial return of rehabilitation and closure bond.

Current rehabilitation is in the ecosystem and land-use establishment phase.

## 6.3 Medium to Long-term Rehabilitation

### 6.3.1 Material Shaping and Handling

Bulk earthworks will be required to achieve the proposed final landform for the site. The bulk shaping requirements will differ across the two lots, with the Lot 11 shaping being completed as per **Section 7.7**. For Lot 21 the shaping will be undertaken to minimise steep slopes prior to final trim and rehabilitation.

### 6.3.2 Water Storage Structures and Erosion and Sediment Control

All erosion and sediment control measures will be maintained in a functioning condition until individual areas have been deemed “successfully” rehabilitated. Structural soil conservation works will be inspected after high intensity rainfall so that de-silting and prompt repairs and/or replacement of damaged works can be initiated as required. Erosion and sediment will be managed in accordance with the *Water Management Plan*.

Any excess flows would likely leave the void via a spillway to be constructed in the north western corner of the site. Further details of water management within the final void are outlined in **Section 7.4**.

Sediment Dam 2 will remain after the cessation of quarrying and if required will be reshaped prior to quarry decommissioning to provide safe access for native fauna and to satisfy public safety requirements. This water can be used by the Rural Fire Service for firefighting. Key drainage lines will remain in place following closure, with surface water from Lot 21 reporting to Sediment Dam 2.

Further erosion and sediment control works will be required post closure, with these to be completed in accordance with the Blue Book. A final water management drawing will be prepared prior to closure.

### 6.3.3 Haul Road and Associated Infrastructure Areas

This section relates specifically to the rehabilitation associated with the haul roads and infrastructure areas. During the final rehabilitation phase the main road and smaller access roads will remain for ongoing land management purposes. These remaining roads may also provide beneficial access for the Rural Fire Service in the event of bushfires occurring in the surrounding bushland.

All surface infrastructure will be removed at closure unless otherwise agreed with the DPIE.

Remnant stockpiles and crushing plant will be removed at cessation of quarrying unless other specific agreements with the DPIE and/or development consents are in place. Key infrastructure is located on Lot 21 (owned by HQPL), with the plan to remove this infrastructure by the end of the Development Consent date (3 June 2027).

### 6.3.4 Conservation and Re-spreading of Soil and Overburden

There is limited available topsoil at Karuah Quarry for final rehabilitation. Other ameliorants and bio-solids will be used in rehabilitation at Karuah Quarry. Overburden and soil material will be imported from the Karuah East Quarry, with this to assist in landform shaping of the highwall area. Calculations of material and soil at Karuah East Quarry have demonstrated there will be adequate volumes to rehabilitate Karuah East Quarry and also provide material and soil to Karuah Quarry for rehabilitation (refer to **Table 7** and **8**). The material will be transported via truck through the top gate using internal roads and side casted from the top of the Karuah Quarry onto the benches below. By using internal roads to move material from Karuah East Quarry to Karuah Quarry, Hunter Quarries will ensure public roads are not impacted by additional traffic.

#### 6.3.4.1 Topsoil – Amount calculated from Karuah East Quarry Environmental Assessment 2013

**Table 7** details the quantity of topsoil available at Karuah East Quarry which incorporates all disturbed areas within the project area. Note calculations included in **Table 7** were made during the Karuah East Quarry Environmental Assessment 2013 and actual values may vary. Estimated available topsoil volumes detail the surplus available at Karuah East Quarry.

**Table 7 Estimated Topsoil Balance**

Topsoil	Volume (m <sup>3</sup> )
Amount of topsoil available to be stripped	25,800
Amount of topsoil required for rehabilitation at closure	19,650

#### 6.3.4.2 Subsoil - Amount calculated from Karuah East Quarry Environmental Assessment 2013

**Table 8** details the quantity of subsoil available (as an intermediate layer for rehabilitation) at Karuah East Quarry which incorporates all disturbed areas within the project area. Note calculations included in **Table 8** were made during the Karuah East Quarry Environmental Assessment 2013 and actual values may vary. Estimated available subsoil volumes detail the surplus available at Karuah East Quarry.

**Table 8 Estimated Subsoil Balance**

Subsoil	Volume (m <sup>3</sup> )
Amount of subsoil available to be stripped	131,400
Amount of subsoil required for rehabilitation works at closure	39,300

### 6.3.5 Visual Screening

Areas of visual screening have been planted on the lower point of the Stage 2 Area. Due to the locality of the site in relation to the Pacific Highway, HQPL regularly assess the visual amenity of the site. Where additional screening is possible, the land will be shaped and a woodland seed mix will be used.

Schedule 3 Condition 29 of the Development Consent outlines conditions relating to visual screening. A discussion on where the conditions have been met is outlined within **Table 9**.

**Table 9 Visual Screening Conditions**

Condition	Comment
<i>The Applicant shall</i>	
a) implement all practicable measures to minimise the visual impacts of the development	The area between Stage 1 and 2 has been rehabilitated. Rehabilitation in the future will be undertaken to reduce the visual impact.
b) retain, re-vegetate and subsequently maintain a visual bund within the Stage 1 works area (in accordance with Figures 13 and 14 of the EIS) to minimise the visual impacts of development	The area between Stage 1 and 2 is an established rehabilitation area. Weed management is ongoing in this area.
c) include a progress report on the re-vegetation and maintenance of the visual bund in the AEMR,	Rehabilitation and visual amenity are included in the AEMR.

### 6.3.6 Surface Preparation in Lot 21

Once the appropriate landform is achieved, thorough site preparation will be undertaken to ensure rapid establishment and growth of seedlings. It is proposed that seeding areas will be ripped to an indicative depth of 400 – 500 mm with care being taken not to pull subsoil materials through the spread topsoil, subsoil and ameliorants.

Targeted gypsum and/or lime may be applied to the final surface using broadcasting machinery immediately prior to sowing if it is determined to be necessary to achieve the best rehabilitation outcome. The ameliorants will be incorporated to a nominal depth of 300 mm.

In order to optimise seedbed condition during final rehabilitation, scarification will be conducted when the soil is moist to produce a loose and friable seed bed which is essential for good plant establishment from seed. All proposed seeding areas will be deep ripped where safe and practical.

Cultivating on the contour will be conducted to assist in delaying runoff, increasing infiltration and controlling erosion of the seed bed until an effective vegetative cover is established. As a minimum treatment, steep batters (>2:1) will be scarified using a tined bucket on an excavator to achieve surface roughness prior to sowing.

Where available, topsoil will be spread along the contour of re-graded spoil to minimise erosion by dumping at the top of slopes and grading downwards and across the contour. Once topsoil is spread, vehicle traffic will be prevented from entering the area. Re-spread topsoil/ameliorants will be levelled to achieve an even surface, avoiding a compacted or over-smooth finish. As previously stated there is limited supply of topsoil and subsoil at site, hence ameliorants will be required for rehabilitation.

### 6.3.7 Direct Seeding

Native forest vegetation previously covered most of the Stage 1 and 2 quarry site and it is proposed to re-establish a similar cover to the majority of the post-quarrying landform.

Direct seeding is preferred over tube stock as it enables a far greater success rate, limits the need for ongoing maintenance (e.g. watering) and is a more economical method in achieving a successful rehabilitation outcome.

A mixture of native trees and shrubs will be sown onto the majority of the reshaped and benched pit area following topdressing and site preparation. Tree seeding will complement natural regeneration from seed contained within the soil seed bank. The mix will include many of the major tree and shrub species shown in **Table 10**.

The seed mix outlined in the EIS specialist report from Global Soil Systems (2004) was updated in an earlier version of the Karuah Quarry Closure Plan, based on the seed mix that was used for the existing rehabilitation areas at the site.

**Table 10 Recommend Tree Species Mix**

Recommended Tree Species Mix		
Genus	Species	Rate (kg/ha)
<i>Acacia</i>	<i>falcata</i>	0.4
	<i>longifolia</i>	0.6
	<i>terminalis</i>	0.4
	<i>irrorata</i>	0.3
	<i>decurrens</i>	0.4
<i>Eucalyptus</i>	<i>globoidea</i>	0.4
	<i>resinifera</i>	0.2
	<i>paniculata</i>	0.4
	<i>tereticornis</i>	0.6
	<i>punctata/propinqua</i>	0.5
	<i>moluccana</i>	0.5
	<i>crebra</i>	0.3
	<i>microcorys</i>	0.3
<i>Angophora</i>	<i>costata</i>	0.1
<i>Allocasuria</i>	<i>torulosa</i>	0.1
<i>Corymbia</i>	<i>maculata</i>	0.8
	<i>gummifera</i>	0.3

Supplementary native pasture seeding will be undertaken where specific species combinations are required. Native pasture species including, but not limited to, *Imperata cylindrica* (Blady Grass) and *Themeda australis* (Kangaroo Grass) will be encouraged.

Seed will be appropriately pre-treated in order to break dormancy restrictions. Subject to sufficient follow up rain, high initial tree densities can be expected. These high densities will quickly help stabilise and screen the site and will result in healthy mature tree stands over time. It is intended to create, over time, a mosaic of variable species and plant densities representative of that currently occurring in the area. Growth rates of greater than 1 metre per year (*Acacia* species) can be initially expected for many of the more dominant trees and shrubs. *Eucalyptus* growth rates will be considerably slower than *Acacias*.

The native tree and shrub seed mix will be sown at a total combined rate of approximately 6.6kg/ha. Seed will be mixed with fertiliser at 100 kg/ha. Tree seed and fertiliser will be broadcast evenly onto top-dressed areas. It will not be buried. Where practical, seeding will be conducted in late spring and early autumn giving superior results due to higher ground temperatures. Seeding is generally completed by hand for the site.

HQPL are investigating the potential use of aerial revegetation methods for the eastern benches. Helicopters and drones are market available application methods for revegetation and stabilising hard to reach and inaccessible areas. The effectiveness of these methods for this particular site will be assessed by researching case studies and correspondence with service professionals.

### 6.3.8 Management Maintenance

#### 6.3.8.1 Weed Control

Weeds present one of the most significant problems to the creation of woodland ecosystems. Weeds have been introduced into this area along corridors such as roads. Effective control of introduced species within rehabilitated areas is critical to maintain biodiversity across rehabilitation areas. Weed control will be undertaken on a quarterly basis for the first year of rehabilitation and then biannually in Years 2 and 3. The weed management will mostly focus on the edge of rehabilitation areas and roadways.

#### 6.3.8.2 Maintenance

No maintenance fertiliser will be required for tree areas. Effective control of weed species within rehabilitated areas will be a critical and essential component of the proposed revegetation plan. Weed and noxious animal control will be undertaken on all rehabilitation areas according to relevant state and local government legislation and policy.

Erosion and sediment control relating to rehabilitation is outlined within **Section 6.5.3**.



## 6.4 Proposed Rehabilitation Schedule

### Scheduling of Works

As outlined earlier, minimal rehabilitation can be completed at the quarry until the operation ceases, as the current disturbed areas are required for safe and efficient operation. Although the production rate at the site will likely decrease after 2019; the site will still remain operational for campaign based extraction. **Table 9** and **Table 10** outlines the proposed rehabilitation schedule. The site has Development Consent approval to operate until 3 June 2027, however the current license agreement between HQPL and the owner of Lot 11 expires on 7 May 2024. The Karuah Quarry has entered a closure phase for Lot 11 and some rehabilitation works have commenced on the eastern highwall. Lot 11 rehabilitation works are expected to be commenced by 7 November 2021. This will allow 30 months of rehabilitation monitoring to occur prior to the Lot 11 License agreement expiring on 7 May 2024. Lot 21 will continue to be operational until the end of the Development Consent (3 June 2027). A rehabilitation program for Lot 21 will be implemented after this date.

A summary of rehabilitation activities proposed within Lot 11 and 21 are outlined in **Table 10** and **Table 11**.

**Table 11 Estimated Rehabilitation Schedule Lot 11**

Timing (Year)	2020	2021	2022	2023	2024
<b>Closure Activities</b>					
Decommissioning					
Landform establishment					
Growth media establishment					
Ecosystem and land use establishment					
Ecosystem land use development					
<b>Post Closure Activities</b>					
Maintenance of rehabilitated areas					
Annual rehabilitation inspection and rehabilitation monitoring					
Relinquish lands					
Landowner license agreement ceases					

**Note: Rehabilitation monitoring in Lot 11 is proposed for a 30 month period.**

**Table 12 Estimated Rehabilitation Schedule Lot 21**

Timing (Year)	2024	2025	2026	2027	2028	2029	2030	2031	2032
Development of a more detailed Closure Plan	Already completed for Lot 21, however this will be reviewed prior to closure in this Lot.								
Closure Activities									
Consent Expires									
Decommissioning									
Landform establishment									
Growth media establishment									
Ecosystem and land use establishment									
Ecosystem land use development									
Post Closure Activities									
Maintenance of rehabilitated areas									
Annual rehabilitation inspection and rehabilitation monitoring									
Relinquish lands									

**Rehabilitation Monitoring on Lot 21 is proposed for a three year period.**

## 7 Final Void Landuse

This section of the plan outlines the final void land use for the Karuah Quarry void. The final void will be a water storage.

### 7.1 Reasons for Final Void as a Water Storage

The benefits associated with using the final void as water storage include:

- The use of final voids as water storage post mining/quarrying has been utilised extensively as a post mining/quarrying use for voids in Australia and overseas;
- With the void being filled with water, the public will not be able to access highwalls and benches from within the pit; and
- The area is bushfire prone and could potentially be a water source for bushfire management post closure.

The decision to leave the void as a water storage has been made in consultation with the DPIE and landowner, with this Plan updated to remove potential void management options.

### 7.2 Water Quality

HQPL undertake regular monitoring of water quality on site in line with *Development Consent* (DA 265-10-2004) and *Site Water Management Plan* (March 2016).

As seen in **Table 13**, water pH is consistently neutral from water quality testing in Sediment Dam 2.

**Table 13 Summary of key water quality parameters (*Site Water Management Plan, March 2016*)**

Sample Site	Highest Sample Value			Lowest Sample Value			Mean Sample Value		
	pH	EC ( $\mu S/cm$ )	Turbidity (NTU)	pH	EC ( $\mu S/cm$ )	Turbidity (NTU)	pH	EC ( $\mu S/cm$ )	Turbidity (NTU)
Sediment Dam 2	7.26	451	53	6.83	417	38	7.09	430	43

### 7.3 Highwall/Benches Design

For the purposes of this management plan the highwall is assumed to be composed of undisturbed, solid material generally occurring above the economically lowest limits of the rock in the final void.

A stability assessment will be undertaken on the benched highwall section when quarrying ceases.

The following should be considered for the highwall/benches at closure:

- Geotechnical stabilisation techniques;
- Review of stability of benches;
- Screening to minimise visual impacts;
- Long term groundwater levels;
- Long term final void water levels;

- Height and inclination of slope and number and spacing of intermediate benches;
- Shear strength of the highwall soils and rocks;
- Density and orientation of fractures, faults, bedding planes, and any other discontinuities, and the strength along them; and
- The effects of the external factors such as surface runoff.

To ensure the safety of the final void, the surrounding final slopes should be left in a condition where the risk of slope failure is minimised. The proposed works at closure for the final void and highwall/benches is outlined within **Section 7.7**.

## 7.4 Final Void Water Management

SLR has examined the water balance for the Karuah Quarry final void, to allow an approximation of the equilibrium water level and the amount of water that will discharge to the downstream. Further details are provided in **Appendix B**.

The water balance analysis indicates that water will accumulate in the void until it reaches the spillway level. The present analysis assumed that the spillway is 11m above the floor of the quarry. With a storage depth of 11m (RL76 - RL65) the storage will take approximately 55 years to fill, at an average annual filling rate of 13.5ML/year.

The average rate of water storage filling reduces as the water level gets higher, since the water surface area increases and losses from evaporation also increase.

Once filled, water will spill to the downstream environment. This would occur intermittently but typically only during rainfall events with a substantial depth of rainfall. In between discharge events, the water level would gradually reduce below the spillway level through evaporation. On average the water storage would discharge approximately once per year, and the estimated average annual overflow volume would be 5.85ML.

Once the spillway level is reached, water levels will fluctuate depending on rainfall. Fluctuation is likely to be less than 0.5m on average rainfall years, but could be up to 1.2m during very dry years.

Selection of a final spillway level will be subject to detailed design. The level at which the spillway is placed will dictate the time taken for the quarry void to fill up.

It may be practical to locate the spillway level along the north-western edge of the void so that water will overflow to an existing watercourse and avoid directing discharge into existing operational areas to the west. This would require filling of the existing quarry road entry which is below RL76.

Peak discharges to the downstream environment may be attenuated by use of a low flow weir that discharges water slowly and maintains a water level which is about 0.3m below the spillway level. This maintains some 'air space' to store runoff during heavy rainfall, and then release it slowly to the downstream environment.

It should also be noted that since the average filling rate of the water storage is low, the filling outcome is very sensitive to groundwater leakage. The average filling rate of 13.5ML/year is in the order of 0.4L/s. This means that if the water storage leaks water at an average rate greater than 0.4L/s then it may never fully fill to spillway level.

## 7.5 Groundwater Management

There is a requirement to monitor groundwater quality and quantity as part of the Karuah East Project (adjacent quarry to Karuah Quarry). This will continue following the closure of Karuah Quarry as the Karuah East Quarry has approval to operate until 31 December 2034.

## 7.6 Safety Management

At Quarry closure, one of the main priorities for the final void will be to render it safe in terms of access by humans, livestock and wildlife. In order to achieve this, the following key activities will be considered:

- Instability of the highwall can also induce failures and mass movement. To ensure the stability of the highwalls that are to be retained post closure, an appropriately qualified Geotechnical Engineer will be consulted on final highwall design prior to ceasing operations;
- A physical barrier will be constructed at a safe distance from the perimeter of the void to prevent human access. There is proposed to be a fence constructed along the top of the eastern highwall. The highwall area will be secured by the construction of a trench and a safety berm at the top of the highwall. The trench and berm is to be constructed in such a way that it will physically stop most vehicles. Based on a risk assessment further safety controls may be required. This is to provide an engineered barrier between the pit and the surrounding area;
- Suitable signs, clearly stating the risk to public safety and prohibiting public access will be erected at suitable intervals; and
- Surface water runoff from land surrounding the void will be diverted so as to prevent any potential development of instability of the void walls.

## 7.7 Final Land Use – Highwalls and Benches

### 7.7.1 Landform Design

Some sections of the final void/pit will not be reshaped at closure. A summary of the works proposed within the pit at closure is outlined below and shown visually in **Figure 3** and **Figure 4**:

**Area 1 (Western Boundary of the Pit)** – This comprises a section of overburden has already been mostly rehabilitated and has been pushed up against the western wall of the Quarry Pit. There is no proposed change to the face of the highwall. The area that is currently rehabilitated (top of the western highwall) will remain at closure in its current form with this acting as a partial visual bund for those travelling along the Pacific Highway.

**Area 2 (North West Corner of the Pit)** – There is a small section (approximately 150m in length) within the north western corner of the pit that will be reshaped at closure. This section is located between the existing rehabilitation area and the benches. There will be a spillway added at the top of the north western boundary of the void, with this to be the longterm spillway once the void fills with water.

**Area 3 (Southern Section of the Pit)** – this section will be reshaped and rehabilitated at closure.

**Area 4 (Benches)** – All possible means will be made to rehabilitate this area, however due to unsafe access the level of success may vary. HQPL will investigate the potential use of aerial seeding on these benches.

HQPL have liaised with the landowner and DPIE regarding hauling overburden/soil material from the adjacent Karuah East Quarry into the Karuah Quarry to assist with landform shaping and soil conditioning in the final landform. This would involve hauling the material from Karuah East Quarry to Karuah Quarry, with the material transported via truck through the top gate using internal roads and side casted from the top. This would be mostly in Area 4 of the final void.

### 7.7.2 Risk Management

A risk assessment was completed on the 28th September 2018 to assess potential risks associated with rehabilitation of the benches and highwalls at closure. The risk assessment is attached as Appendix A. The risk assessment for the site focussed on both risk to life and risk to property. The assessment was undertaken in accordance with the Australian Geomechanics Society (AGS) Landslide Taskforce “Practice Note Guidelines for Landslide Risk Management” March 2007.

The process followed during the assessment included:

- Desktop review of the existing geotechnical report;
- A visual assessment of the existing surface of the site and surrounding area; and
- An on-site Senior Geotechnical Engineers Risk Assessment.

The findings of the assessment indicated potential:

- Slip trip or fall of person / toppling of plant into pit due to presence of loose debris on benches;
- Hit from above or Bench Foundation gives way from Rock Block Slide or Undercut Failures and or Toppling failure of rock columns or wedge failure;
- Inadequate access to benches i.e. Too narrow for machinery access, unsafe for personnel to access due to benches being graded towards the pit, or insufficient bench widths; and
- Catastrophic bench or Eastern Highwall Face failure.

In summary the assessment found high and very high risks for major hazards associated with risk to life and property from traditional rehabilitation techniques (shaping and seeding from the bottom of the void). Therefore, rehabilitation methods as proposed in **Section 7.7.1** will be used.





# LEGEND

## Final Pit Works at Closure

- 1 - Western wall to remain at closure
- 2 - Area to be reshaped. Some material pushed into pit
- 3 - Material on top of high wall to be pushed into pit
- 4 - Benches to remain unrehabilitated at closure
- X Proposed location of spillway

0 50 100 150 200  
m

Scale: 1:3,000  
GDA 1994 MGA Zone 56



02/05/2018  
630.12360

## 8 Closure Criteria

The rehabilitation and closure criteria for Karuah Quarry are outlined in **Table 14**.

**Table 14 Rehabilitation and Closure Success Criteria**

Rehabilitation Element	Rehabilitation Success Criteria
Decommissioning	<ul style="list-style-type: none"> <li>• Remediation of hydrocarbon contamination;</li> <li>• Remove all nominated infrastructure;</li> <li>• Make safe any remaining footings;</li> <li>• Remove all remaining rubbish and debris;</li> <li>• Removal of all mobile machinery from the site;</li> <li>• Removal of all petroleum, chemicals and explosive products from the site; and</li> <li>• Access to members of the public is restricted.</li> </ul>
Landform Establishment	<ul style="list-style-type: none"> <li>• Create a stable land form;</li> <li>• Final landform is consistent with surrounding landforms;</li> <li>• Establish drainage systems as part of batter formation to ensure stability.</li> </ul>
Growth Medium Development	<ul style="list-style-type: none"> <li>• Areas designated for woodland rehabilitation will be deep ripped and then direct seeded with a mix of native tree and shrub species which is blended with an appropriate application of fertiliser or other ameliorant as determined by soil testing; and</li> <li>• Undertake follow-up soil testing as considered necessary.</li> </ul>
Ecosystem and Land Use Establishment	<ul style="list-style-type: none"> <li>• The introduction and spread of weeds and pests should be prevented and an active program in place to minimise their presence;</li> <li>• Undertake vegetation monitoring as required to determine target community structure and floristics; and</li> <li>• Sow initial coloniser species with follow-up sowing and/or tubestock planting as required.</li> </ul>

Rehabilitation Element	Rehabilitation Success Criteria
Ecosystem and Land Use Development	<ul style="list-style-type: none"> <li>• Evidence of active use of habitat provided during rehabilitation such as logs and signs of natural generation of shelter sources including leaf litter;</li> <li>• Presence of representatives of a broad range of functional indicator groups involved in different ecological processes;</li> <li>• Typical food and water sources required by the majority of vertebrate and invertebrate inhabitants of that ecosystem type are present;</li> <li>• Water quality of the receiving waters is not affected by surface water runoff from the site and discharge water meets the contaminant limits (EC, pH, TSS and oil and grease) of the EPL conditions;</li> <li>• Nutrient cycling and recycling processes are occurring as evidenced by the presence of a litter layer, mycorrhizae and/or other micro-symbionts;</li> <li>• Representation of a range of species characteristic from each fauna assemblage (e.g. reptiles, birds, mammals) based on analogue rehabilitation monitoring reference sites;</li> <li>• Continue monitoring until self-sustaining levels are confirmed; and</li> <li>• Undertake maintenance work as required – including soil treatment, erosion control, weed spraying and re-sowing.</li> </ul>
Land Relinquishment	<ul style="list-style-type: none"> <li>• Meets the criteria in the 'Ecosystem and Land Use Development' rehabilitation phase.</li> <li>• Establishment of a self-sustaining vegetation community compatible with the chosen land use.</li> <li>• The quality of water leaving the site should be such as not to cause significant deterioration of water quality to the downstream beneficial use(s) or water quality objectives of the receiving waters declared under the Water Management Act 2000.</li> <li>• Additionally, the quality of water leaving the site will meet the relevant water quality standards, in particular that the Protection of the Environment Operation Act 1997 which requires that there should be no pollution of waters as defined in that Act, unless an Environment Protection Licence (EPL) allows otherwise, in accordance with the EPL.</li> </ul>



## 9 Monitoring

### 9.1 Annual Rehabilitation Inspection

Rehabilitation areas will be reviewed as part of the Annual Rehabilitation Inspection.

The rehabilitation inspection is completed for Karuah Quarry. The inspection form includes reviewing key features such as:

- Ground cover;
- Erosion;
- Overstorey, mid storey and lower storey;
- Leaf litter;
- Presence of mortality or die back; and
- Presence of weeds and feral animals.

Based on the results of rehabilitation monitoring, changes to maintenance may be required including weed and feral animal management.

### 9.2 Monitoring Post Closure

With minimal final rehabilitation to be completed until closure of the operation, no formal rehabilitation monitoring is proposed until post closure. This rehabilitation monitoring will be completed once rehabilitation has reached the ecosystem establishment phase. Analogue rehabilitation sites will be chosen to determine suitable final rehabilitation quality for the area.

When rehabilitation monitoring commences at the site it will include:

- Revegetated and landscaped areas on Lot 11 to be monitored for a 30month period;
- Revegetated and landscaped areas on Lot 21 to be monitored for a 3 year period; and
- All rehabilitation works (i.e. fencing, weed control, erosion & sediment control) for the quarry's disturbed areas will be monitored as part of the site's monthly internal environmental inspections.

The rehabilitation monitoring transect will be established as a 100m x 5m (total 500 sq. m) straight-line approximately along the contour (across the slope), attempting to avoid edge effects where possible. The transect may have to be shorter if the total rehabilitation area doesn't allow for full 100m. Each end will be marked with steel picket and permanent tags. The monitoring program will include the following parameters outlined in **Table 15** below.

**Table 15 Rehabilitation Monitoring Parameters**

Rehabilitation Monitoring Program Parameters and their Descriptions	
Surface Erosion	<p>General surface erosion observations made over entire transect. Evidence of rill, gully or sheet erosion, areas of sedimentation/deposition, surface flow paths, and exposed surface soil texture (sandy, rocky, etc.) recorded.</p> <p>If rill or gully erosion observed, representative erosion pins will be established along the gully and re-measured each monitoring visit to indicate erosion activity.</p>
Groundcover	<p>Depending on vegetation community type and accessibility, either stratified observations of groundcover percentage/type over 20 1m x 1m quadrats, or 200 Point Intercept Observations, or both.</p> <p>Calculations will be made for proportion cover of native groundcover, weed groundcover, litter, deadfall, rock and exposed soil (per hectare).</p>
Vegetation (tree & shrub)	<p>Tree and shrub presence recorded for 100m x 5m transect (2.5m either side of transect tape). Tree/shrub species, height and location recorded.</p> <p>Calculations made for native species stems per hectare and species richness. Mortality and premature senescence rates will be recorded in subsequent years.</p> <p>Observations will be noted on the development of community structure (canopy, understory, groundcover, etc.) will be observed as rehabilitation matures.</p>
Weed presence	<p>Significant weed infestations will be noted and managed during the next round of weed management. This includes implementing a weed spraying program.</p> <p>Significant weed infestation includes:</p> <ul style="list-style-type: none"> <li>the presence of any declared weeds or weeds of national significance (WONS);</li> <li>infestations that appear to be interfering with the development of rehabilitated vegetation; or</li> <li>weeds established near creeks or drainage lines that run offsite.</li> </ul>
Feral animals	Noting the presence of feral animals at site.
Comparisons with analogue site	Observations and trends noted for rehabilitation monitoring transect will be compared to information supplied from native vegetation monitoring.

The preferred rehabilitation monitoring consultant will use the most widely respected current methodology for rehabilitation monitoring. Therefore, there could potentially be changes to the methodology outlined within this section. We understand the DPIE has requested that the most widely respected current methodology for rehabilitation monitoring is to be identified no later than two years prior to final closure.

### 9.3 Reporting and Reviewing

A progress report on the *Rehabilitation and Quarry Closure Plan* will be included in the AEMR to be submitted to the DPIE, MidCoast Council and EPA annually, in accordance with Schedule 3 Condition 41 of the Development Consent. All monitoring results will be included as part of the information presented in the progress report.



The Plan will be revised to increase its effectiveness where any changes are recommended based on feedback from the DPIE.

## 10 Responsibilities

The Quarry Manager (or their nominated representative/s) is responsible for the implementation of this Plan.

The **Quarry Manager** will allocate responsibility for specific tasks where necessary, these include:

- Ensure all relevant personnel are aware of rehabilitation procedures;
- Ensure all rehabilitation procedures are followed;
- Ensure sufficient resources are available to meet rehabilitation criteria and schedule;
- Co-ordinate rehabilitation activities;
- Ensure rehabilitation is completed in accordance with this Plan; and
- Engage specialists to assist with rehabilitation monitoring, inspections and closure planning.

The Equipment Operators shall:

- Ensure activities are undertaken in accordance with the Plan.

## 11 References

- Department of Housing, Managing Urban Stormwater: Soils and Construction' – Volume 1, 4<sup>th</sup> Edition (2004) manual.
- Department of Resources and Geosciences, Mining Operations Plan Guidelines (2013).
- Former NSW Department of Land and Water Conservation (DLWC), Guidelines for Designing Stable Drainage Lines on Rehabilitated Mine Sites (1999).
- GSS Environmental, Karuah East Soil Survey and Land Resource Assessment (2011).
- SLR Consulting, Flora and Fauna Management Plan for Karuah Quarry (Reviewed 2014).
- SLR Consulting, Water Management, Erosion and Sediment Control Plan, (Reviewed 2014).
- SLR Consulting, Environmental Management Strategy for the Karuah Quarry, (Reviewed 2014).

# APPENDIX A

## Rehabilitation and Closure Risk Assessment



# Eastern Highwall Risk Assessment

## Karuah Quarry, Karuah NSW



**Ref: P1602-R-001-Rev2**

Written by: Nathan Roberts (Geotechnical Engineering Manager)

Reviewed by: Matthew Lay (Senior Geotechnical Engineer)

Approved by: Karl Dawes (General Manager)

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Client: Hunter Quarries





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**Project Details**

<b>Site Address:</b>	Karuah Quarry, Karuah NSW	
<b>Project Type:</b>	Risk Assessment	
<b>Project No.</b>	<b>Report Type</b>	<b>Report No.</b>
P1602	R	001

**Report Register**

<b>Revision Number</b>	<b>Reported By</b>	<b>Reviewed By</b>	<b>Date</b>
Rev0	Nathan Roberts	Matthew Lay	31/10/2018
Rev1	Nathan Roberts	Matthew Lay	31/10/2018
Rev2	Nathan Roberts	Matthew Lay	2/11/2018


We confirm that the following report has been produced for Hunter Quarries, based on the described methods and conditions within.

For and on behalf of **Valley Civilab Pty Ltd**,



**Nathan Roberts**

Geotechnical Engineering Manager



**Karl Dawes**

General Manager

## Executive Summary

The following report details the geotechnical risk assessment undertaken by Valley Civilab Pty Ltd under the request of Hunter Quarries. A preliminary site visit was undertaken on the 16<sup>th</sup> of August 2018 and follow up site risk assessment on the 28<sup>th</sup> of September 2018 and consisted of a Senior Geotechnical Engineers Site Risk Assessment of the Eastern Highwall Face. It was understood that the Risk Assessment was required for the proposed rehabilitation of the Eastern Highwall Face which is to form part of the Karuah Quarry Closure Management Plan.

A detailed geotechnical risk assessment was undertaken at the site to determine the risk to life and plant for the proposed rehabilitation. The risk assessment methodology was derived from the principles outlined in the Australian Geomechanics Society Landslide Taskforce "Practice Note Guidelines for Landslide Risk Management" March 2007.

Based on the Risk Assessment undertaken it is expected that the proposed rehabilitation of the Eastern Highwall Face will pose:

- a maximum risk to life of  $4.0 \times 10^{-4}$ ;
- a maximum HIGH RISK to plant.

It is therefore Valley Civilab's opinion that both the risk to life and plant are deemed unacceptable for the proposed rehabilitation of the Eastern Highwall Face in its current condition.

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### Annex List:

**Annex A** – Geotechnical Assessment of Risk to Plant and Risk to Life

**Annex B** – Australian Geomechanics Society Landslide Taskforce “Practice Note Guidelines for Landslide Risk Management 2007” Ref: AGS (2007c)

## **1 Introduction**

At the request of Hunter Quarries, Valley Civilab Pty Ltd (VC) have undertaken a Geotechnical Risk Assessment at Karuah Quarry, Karuah NSW. It was understood that the Risk Assessment was required for the Rehabilitation of the Eastern Highwall Face which is to form part of the Karuah Quarry Closure Management Plan.

The purpose of the Risk Assessment was to provide recommendations on the risk to life and plant for the proposed Eastern Highwalls Rehabilitation. The assessment methodology was derived from the principles outlined in the Australian Geomechanics Society Landslide Taskforce "Practice Note Guidelines for Landslide Risk Management" March 2007.

The following report provides details of the Risk Assessment. The report should be read in conjunction with a previous assessment undertaken by Valley Civilab at the site, 'Geotechnical Assessment of Karuah Quarry, Karuah NSW' (report reference P1345 – R – 001 – Rev0, dated 8<sup>th</sup> December 2017).

## **2 General Site Description - Eastern Highwall Face**

The eastern highwall face is benched, each bench noted to be approx. 8m to 10m in rise height and run widths generally 6m or less. Up to 7 benches were noted, the total face was up to 60m in height (approx.). This face was noted to have some consistency and drainage to promote water away from the face.

## **3 Assessment Methodology**

The Risk Assessment of the Eastern Highwall Face was undertaken on the 28<sup>th</sup> of September 2018 and consisted of:

- Desktop review of the existing geotechnical report (VC report reference P1345 – R – 001 – Rev0, dated 8<sup>th</sup> December 2018);
- a visual assessment of the existing surface of the site and surrounding area;
- an on-site Senior Geotechnical Engineers Risk Assessment.

## 4 Risk Assessment

Valley Civilab Pty Ltd have undertaken a risk assessment for the site for both a risk to life and a risk to property. This assessment has been undertaken in accordance with the Australian Geomechanics Society (AGS) Landslide Taskforce "Practice Note Guidelines for Landslide Risk Management" March 2007.

### 4.1 Major Hazard Identification - Potential Failure Mechanisms

The following major hazards (i.e. potential failure mechanisms) were identified on the Eastern Highwall Face exposed rock strata:

#### Hazards on working benches:

1. Slip trip or fall of person / toppling of plant into pit due to presence of loose debris on benches, benches being graded towards the pit, or insufficient bench widths;

#### Hazards above working benches:

2. Person or Plant hit from above from rockfall or loose overhanging debris;

#### Hazards above and on working benches:

3. Hit from above or Bench Foundation gives way from Rock Block Slide or Undercut Failures;
4. Hit from above or Bench Foundation gives way from Toppling failure of Rock Columns;
5. Hit by or Bench Foundation gives way from Wedge Failure due to jointing and discontinuities in rock;
6. Potential for Catastrophic bench or Eastern Highwall Face failure.

### 4.2 Risk Assessment

Valley Civilab Pty Ltd have undertaken a Geotechnical Risk Assessment for the Eastern Highwalls proposed rehabilitation on the hazards noted above.

Both a qualitative risk assessment to determine risk to plant and a quantitative risk assessment to determine risk to life have been undertaken on the hazards noted above as per the principles outlined in the AGS guidelines.

The AGS "Practice Note Guidelines" indicates tolerable risk levels for loss of life. The following table and notes is an extract from the Australian Geomechanics Society (AGS) Landslide Taskforce "Practice Note Guidelines for Landslide Risk Management" March 2007.

**Table 1 – Australian Geomechanics Society tolerable risks for loss of life**

Situation	Suggested tolerable loss of life risk for the person most at risk
New development <sup>4</sup>	10 <sup>-5</sup> / annum

Notes: (4) "New Development" includes any new structure or change to an existing slope or structure. Where changes to an existing structure or slope result in any cut or fill of less than 1.0m vertical height from



the toe to the crest and this change does not increase the risk, then the Existing Slope / Existing Structure criterion may be adopted. Where changes to an existing structure do not increase the building footprint or do not result in an overall change in footing loads, then the Existing Development criterion may be adopted

The result of the risk assessments have been summarised in **Table 4.1** below.

**Table 4.1 – Summary of Risk Assessment for risk to property and risk to life**

Hazard	Risk to plant	Risk to life
1	VERY HIGH	$4.0 \times 10^{-4}$
2	MODERATE	$3.5 \times 10^{-4}$
3	HIGH	$4.0 \times 10^{-5}$
4	HIGH	$4.0 \times 10^{-5}$
5	HIGH	$4.0 \times 10^{-5}$
6	MODERATE	$5 \times 10^{-6}$

A detailed assessment of the site hazards can be found in **Annex A**.

A copy of the Australian Geomechanics Society (AGS) Landslide Taskforce “Practice Note Guidelines for Landslide Risk Management” March 2007 can be found in **Annex B**.

### 4.3 Discussion

The assessment of risk to plant indicated both HIGH and VERY HIGH risks from the major hazards that were identified in **Section 4.1** above. In reference to AGS Guidelines Table 1 Risk to Property:

- a HIGH risk is considered *‘Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property’*;
- a VERY HIGH risk is considered *‘Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of property’*.

The assessment of risk to life indicated risks of  $4.0 \times 10^{-4}$  or lower. The acceptable risk level for new development is  $1 \times 10^{-5}$ , therefore the risk to life for the major risk hazards identified in **Section 4.1** are not considered acceptable for the proposed Rehabilitation of the site in its current state.

**It is therefore Valley Civilab’s opinion that the proposed Remediation of the Eastern Highwall in its current condition will pose unacceptable levels of risk to both life and plant.**

## 5 Report Limitations

The geotechnical data and recommendations within the above report are subjected to the specific inspection that was undertaken at the time of the current investigation. It should be noted that the underlying geology and natural fault lines can vary significantly across a site and the environment can change overtime. If conditions encountered during construction are different to those contained in this report Valley Civilab Pty Ltd should be contacted immediately for site reassessment.

If you have any further questions about this report, please contact the undersigned.

For and on behalf of

Valley Civilab Pty Ltd

Reported by:



**Nathan Roberts**

Geotechnical Engineering Manager  
Bachelor of Engineering (Civil)

Reviewed by:



**Matthew Lay**

Senior Geotechnical Engineer  
Bachelor of Engineering (Civil)

# Annex A



## Risk to Plant Assessment

The following is a qualitative risk to property assessment post construction undertaken in accordance with the Australian Geomechanics Society (AGS) Landslide Taskforce "Practice Note Guidelines for Landslide Risk Management" March 2007

**Client:** Hunter Quarries

**Site Address:** Karuah Quarry, Karuah NSW

**Job No:** P1602

**Fieldwork Date:** 28/09/2018

**Fieldwork By:** Nathan Roberts

Hazard		Likelihood	Consequence	Risk
	Detail			
1	Toppling of plant into pit due to presence of loose debris on benches, benches being graded towards the pit, or insufficient bench widths	POSSIBLE	CATASTROPHIC	VERY HIGH
2	Plant hit from rockfall of loose or overhanging debris from above	POSSIBLE	MEDIUM	MODERATE
3	Hit from above or Bench Foundation gives way from Rock Block Slide or Undercut Failures	UNLIKELY	CATASTROPHIC	HIGH
4	Hit from above or Bench Foundation gives way Toppling failure of Rock Columns	UNLIKELY	CATASTROPHIC	HIGH
5	Hit by or Bench Foundation gives way from Wedge Failure due to jointing and discontinuities in rock	UNLIKELY	CATASTROPHIC	HIGH
6	Potential for Catastrophic bench or Eastern Highwall Face failure	RARE	CATASTROPHIC	MODERATE

The qualitative assessment has been undertaken in accordance with the risk analysis matrix in Appendix C of the Australian Geomechanics Society (AGS) Landslide Taskforce "Practice Note Guidelines for Landslide Risk Management" March 2007

Undertaken by: Nathan Roberts

Date: 30/10/2018

Checked by: Matthew Lay

Date: 30/10/2018



## Risk to Life Assessment

The following is a quantitative risk to life assessment post construction undertaken in accordance with the Australian Geomechanics Society (AGS) Landslide Taskforce "Practice Note Guidelines for Landslide Risk Management" March 2007

Client: Hunter Quarries  
 Site Address: Karuah Quarry, Karuah NSW  
 Job No: P1602  
 Fieldwork Date: 28/09/2018  
 Fieldwork By: Nathan Roberts

Hazard		$P_{(H)}$	$P_{(S:H)}$	$P_{(T:S)}$	$V_{(D:T)}$	Risk
	Description					$R_{(LOL)}$
1	Slip trip or fall of person due to presence of loose debris on benches, benches being graded towards the pit, or insufficient bench widths	1.E-03	1.00	0.50	0.80	4.0E-04
2	Person hit from rockfall of loose or overhanging debris from above	1.E-03	1.00	0.50	0.70	3.5E-04
3	Hit from above or Bench Foundation gives way from Rock Block Slide or Undercut Failures	1.E-04	1.00	0.50	0.80	4.0E-05
4	Hit from above or Bench Foundation gives way Toppling failure of Rock Columns	1.E-04	1.00	0.50	0.80	4.0E-05
5	Hit by or Bench Foundation gives way from Wedge Failure due to jointing and discontinuities in rock	1.E-04	1.00	0.50	0.80	4.0E-05
6	Potential for Catastrophic bench or Eastern Highwall Face failure	1.E-05	1.00	0.50	1.00	5.0E-06

Risk  $R_{(LOL)}$  has been calculated using the following formula:

$$R_{(LOL)} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(D:T)}$$

Where

$R_{(LOL)}$  is the risk (annual probability of loss of life)

$P_{(H)}$  is the annual probability of the hazard

$P_{(S:H)}$  is the probability of spatial impact of the hazard

$P_{(T:S)}$  is the temporal spatial probability (i.e. location being occupied by the individual)

$V_{(D:T)}$  is the vulnerability of the individual (if hit or falls)

Undertaken by: Nathan Roberts

Date: 30/10/2018

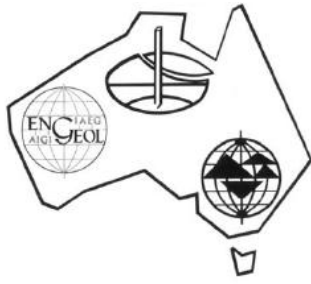
Checked by:

Date: 30/10/2018

Matthew Lay



# Annex B



**Australian  
Geomechanics  
Society**

**Extract from**

# Australian Geomechanics

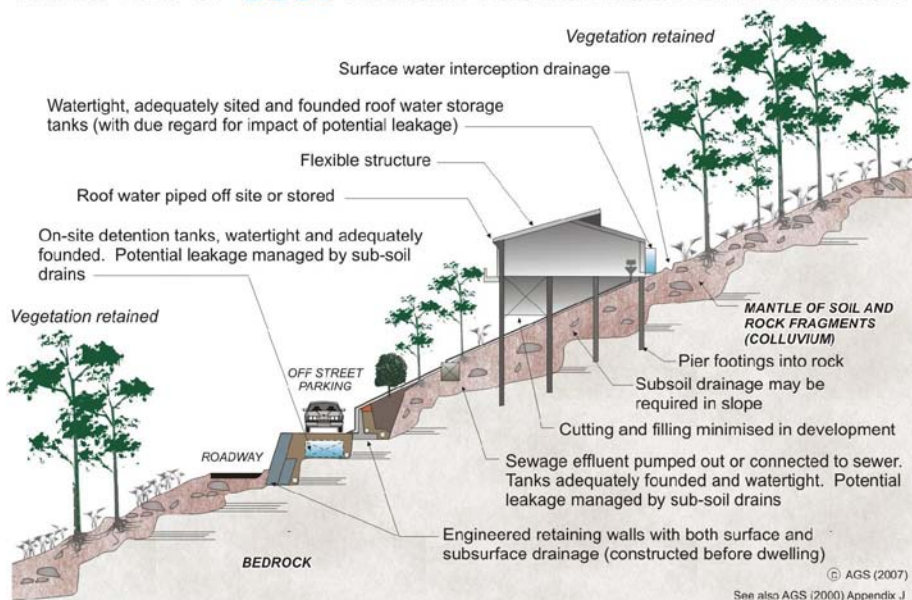
Journal and News of the Australian Geomechanics Society  
Volume 42 No 1 March 2007

**Extract containing:**

“Practice Note Guidelines for Landslide Risk Management 2007”

Ref: AGS (2007c)

## EXAMPLES OF **GOOD** HILLSIDE CONSTRUCTION PRACTICE



## Landslide Risk Management



**ENGINEERS  
AUSTRALIA**



ISSN 0818-9110

# **PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007**

**Australian Geomechanics Society Landslide Taskforce,  
Landslide Practice Note Working Group**

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## PART A: BACKGROUND

### 1 INTRODUCTION

#### 1.1 PREAMBLE

Slope instability occurs in many parts of urban and rural Australia and often impacts on housing, roads, railways and other development. This has been recognised by many local government authorities, and others, and has led to the requirement by many local government councils for stability assessments prior to allowing building development.

In 2000, the Australian Geomechanics Society (AGS) published “Landslide Risk Management Concepts and Guidelines” (AGS 2000). Since then there have been many published papers and discussion which have progressed Landslide Risk Management (LRM) in particular and risk management in general. As a consequence, AGS considered it appropriate to develop more comprehensive guidelines for practitioners and regulators involved in LRM.

This Practice Note Guidelines for Landslide Risk Management (the Practice Note) and its Commentary (AGS 2007d) are one part of a series of three guidelines related to LRM that have been prepared by AGS with funding under the National Disaster Mitigation Programme (NDMP). That programme has been introduced by the Australian Government to fund disaster mitigation, addressing hazards such as flooding, bushfires and landslides.

The associated guidelines which should be read in conjunction with the Practice Note are:-

- AGS (2007a) “*Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning*”.
- AGS (2007e) “*Australian GeoGuides for Slope Management and Maintenance*”.

#### 1.2 PURPOSE

The purpose of this Practice Note is to:

1. Review the Australian Geomechanics Society (AGS) Landslide Risk Management Concepts and Guidelines (AGS 2000) in the light of usage since publication and update accordingly and in addition, to take the opportunity to establish a formal revision process/documentation. Accordingly, a Revision Table is included in the Practice Note.
2. Provide guidance and recommendations on tolerable risk criteria, minimum reporting standards and assessment criteria/options to Local Government and Government bodies who as the regulator, receive Landslide Risk Management (LRM) reports and decide on levels of Tolerable Risk.
3. Provide guidance of a technical nature in relation to the processes and tasks undertaken by geotechnical practitioners who prepare LRM reports including appropriate methods and techniques. The Practice Note is a statement of what constitutes good practice by a competent practitioner for LRM, including defensible and up to date methodologies.
4. Provide guidance on the quality of assessment and reporting, including the outcomes to be achieved and how they are to be achieved. It sets out the functions and responsibilities of the professional carrying out the assessment.
5. Be a reference document for legislative purposes, which has been subject to nation-wide peer review.

#### 1.3 SCOPE

This Practice Note supersedes AGS (2000) as the guideline for good practice and is accompanied by a Commentary (AGS 2007d) which discusses various aspects and gives appropriate references, and which should be read in conjunction with this Practice Note.

AGS (2000) contains much useful and relevant commentary which can (and should) be read in conjunction with the Practice Note. It is not the intention of the Practice Note to supersede this valuable commentary, rather to complement it. AGS (2000) should be regarded as “companion literature”. Unless specifically discussed or revised in the Practice Note, the Working Group considers the commentary, examples and references provided in AGS (2000) to constitute appropriate background for the use of the Practice Note.

The emphasis of the Practice Note is on residential subdivision and development, particularly when considering the requirements for assessment on a lot-by-lot basis for either existing or proposed development.

The recommendations are however applicable to all classes of urban and rural building development or the environment.

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The risk analysis principles could be adopted for short term risks associated with trenches or excavations during construction projects and for quarries and open cut mines. For such cases, risk tolerance criteria are controlled by occupational health and safety requirements and are not covered here.

The Practice Note can be applied to roads and railways. However, special consideration has to be given to the number of users, their temporal spatial probability and the summation of the risk along the route. This is discussed further in the Commentary.

## 1.4 CONVENTIONS USED

The Practice Note includes imperative verbs, such as ‘establish’, ‘use’, ‘identify’ and so on. These are to be understood as meaning; “*AGS recommends that you establish...*”, or “*...that you use....*” or “*...that you identify.....*” and so on as the case may be. This form of expression has been used to avoid unnecessary repetition of wording in the sense of ‘plain English’.

Paragraphs presented in **bold type** constitute the guideline statement and subsequent sub paragraphs provide discussion of the guideline topic. Further discussion is provided in the Commentary.

In the following, use of the word ‘landslide’ implies both existing (or known landslides) and potential landslides which a practitioner might reasonably predict based on the relevant geology, geometry and slope forming processes. Such potential landslides may be of varying likelihood of occurrence. ‘Landslide’ also includes ‘landslip’ (as used in Victorian legislation), ‘slump’ and the various landslide forms (see Appendix B).

## 1.5 STAKEHOLDERS

The various stakeholders who may be affected by landslide risk include:-

- The **landowner** who will frequently be the client in terms of a commission to prepare a LRM report for a site or a development proposal.
- The **occupier** who would most often also be the land owner.
- The **financier** who would often be a financial institution having an interest in the land and any development thereon.
- The **regulator** (Appendix A) who would have responsibility for setting risk acceptance criteria, administering planning controls and approving development proposals as being within the requirements of planning controls, or a policy.
- The **practitioner** (Appendix A) who would have the required expertise for and responsibility of preparing a LRM report and recommending suitable risk control measures, when needed, to achieve the risk acceptance criteria.
- The **design professional** (such as architect or structural engineer) who would be one of the advisors to the client with responsibility for integration of risk control measures recommended by the practitioner into the development scheme, where possible, within the design brief from the client.
- The **insurer** where appropriate may have an interest in providing insurance cover against nominated insurable risks.

Although there is no section in the Practice Note dealing with the Client, clearly the Client is an essential stakeholder in relation to the practitioner. The Client will be relying on unbiased, sound technical advice from the practitioner as to the risk that a development proposal poses to the client and /or his interests. It will be the responsibility of the client to accept the risks involved, subject to the approvals of the regulator.

## 2 RISK TERMINOLOGY

**The framework for the LRM process, as shown in Figure 1 in a simplified flow chart form, should be adopted.**

**Adopt the recommended terminology for ease of communication and clarity as defined in Appendix A.**

As with most areas of expertise, there is a technical jargon associated with LRM. Specialist terminology is used to convey succinct ideas or facts. This cannot be avoided and by necessity is of a technical nature. The relevant terminology is defined in Appendix A. The lay reader is also referred to the Commentary for further discussion and to the GeoGuides (AGS 2007e).

This Practice Note, and the companion AGS guidelines (AGS 2007a, 2007e), use the term ‘landslide’ rather than ‘landslip’ or ‘slump’ or similar, to cover a wide range of failure mechanisms in soil, rock (as discussed in Appendix B) and man made structures such as retaining walls, as implied by the definition in Appendix A.

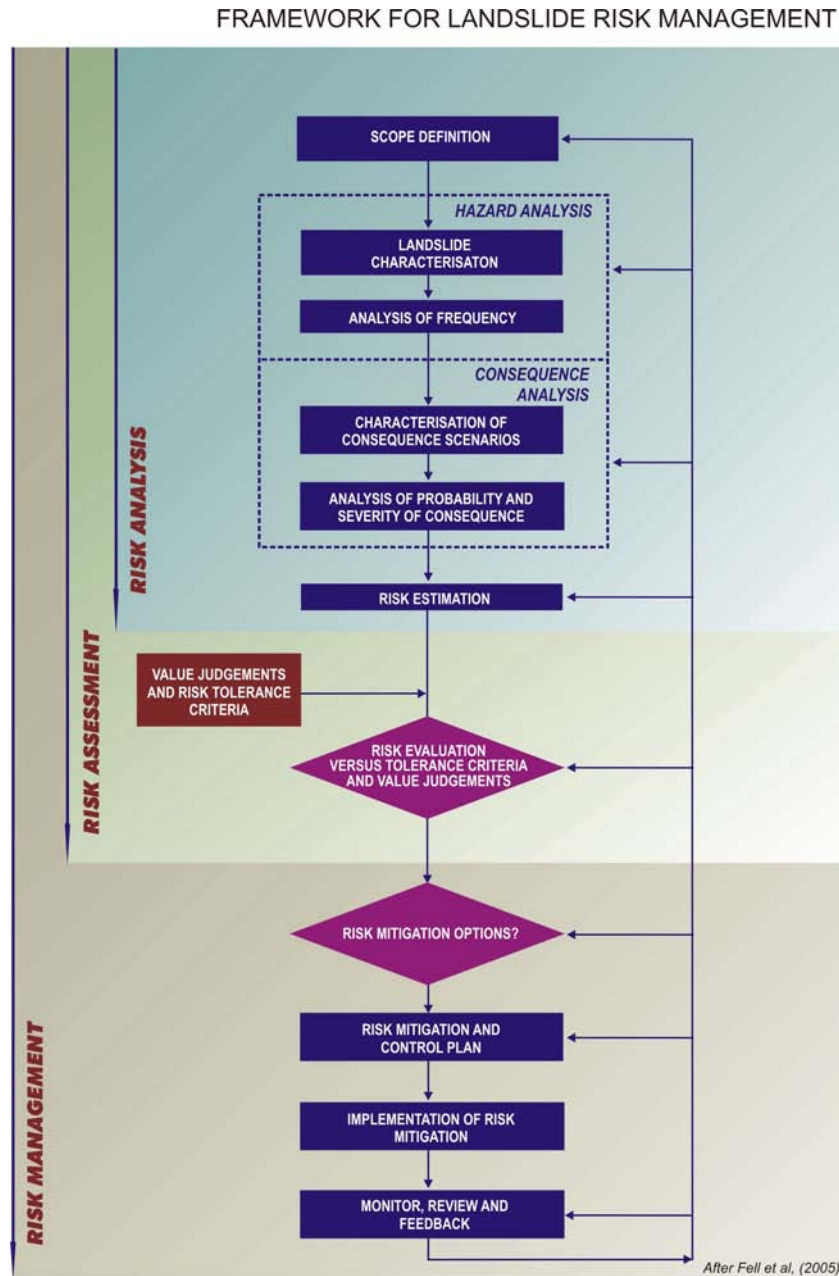


Figure 1.

The Framework for LRM presented in Figure 1 is similar to the flow chart in AGS (2000). However, it has been simplified in presentation and has been amended slightly from AGS (2000) to reflect the inclusion of Frequency Analysis as part of Hazard Analysis (in accordance with the abovementioned definition of hazard and as defined in AGS 2000).

Definitions for associated terminology have also been included in Appendix A together with an explanation of Landslide Risk as presented in AGS Australian GeoGuide LR7.

## PART B GUIDELINES FOR REGULATORS

### 3 GUIDELINES FOR REGULATORS

#### 3.1 BACKGROUND

The term landslide denotes *“the movement of a mass of rock, debris or earth down a slope”*. The phenomena described as landslides are not limited to either “land” or to “sliding” and usage of the word has implied a much more extensive meaning than its component parts suggest. The rates of movement cover the full range from very rapid to extremely



## PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

slow. The size, similarly, can vary enormously. The combination of type of landslide, size and rate of movement can determine the destructive power, and hence potential consequences of the landslide in terms of damage to property, loss of life, economic costs and impact on the environment. Subsidence, as a mechanism, is excluded from consideration, though it may be similar in consequence and appear to be of a similar form. Appendix B presents a summary of the terminology used to classify and describe landslides.

Landslides can impact on human development and activity as well as natural areas / features. It is the potential impact on human development which becomes of concern to the planners, regulators and disaster management authorities. Landslides can be just one of a number of threats which have to be considered, others being for example flooding, bush fires, and seismicity.

Examples of where landsliding is potentially an issue include:-

- a) Where there is a history of landsliding.
- b) Where there is no history of sliding but the topography dictates sliding may occur.
- c) When there is no history of landslides but geological and geo-morphological conditions are such that sliding is possible.
- d) Where there are constructed features which, if they fail, may travel rapidly.
- e) Forestry works and agricultural land clearing which can lead to landslides causing damage to the environment.

Specific examples of the above are given in the AGS Guidelines for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning (AGS 2007a). AGS (2007a) also provides detailed guidance to the regulator in relation to landslide zoning for planning purposes.

### 3.2 RELEVANCE TO APPROVALS PROCESS

Details of the approvals process may vary in detail from state to state. It is understood that in all States and Territories of Australia, the regulator has a statutory responsibility to consider the impact of a number of hazards, including landslides, on potential development of land as a 'duty of care' exercise. The regulator is usually the local government, but may be a State Government department or body. The actual mechanism and regulatory context for dealing with planning controls, building controls and approval process varies from state to state. However, the outcome should be that areas having a landslide risk are properly considered in relation to land use and development proposals.

In order to develop planning controls and building regulations, local government (or other regulators) must ensure that it has the statutory means to:

- a) Through a planning scheme and using the principles in AGS (2007a), identify the areas that are susceptible to or at risk from landslides.
- b) Require planning and/or building approvals for all land use and development within the areas zoned as susceptible to landslides.
- c) Ensure there is a proper process for assessment in relation to existing and proposed development, including the requirement for completion of LRM reports in accordance with this Practice Note.
- d) Provide appropriate risk tolerance criteria for loss of life and property so that there is a means to determine whether it is appropriate for development to occur or the required land use to proceed.
- e) Apply, if necessary, consent conditions on the land use and/or development approval, including conditions requiring maintenance that will appropriately manage the landslide risk for that use and/or development.

It can be seen from the above that zoning in accordance with AGS (2007a) becomes the 'initiator' under the planning scheme and building approvals process to determine whether LRM controls are required and whether more detailed LRM consideration is required.

### 3.3 POLICY REQUIREMENTS

**The regulator should have a specific policy which sets out the requirements for LRM assessments as part of the development application documentation and process.**

The need for such a policy should be determined by zoning studies in accordance with AGS (2007a). Essential components of such a policy will include:

- 3.3.1 When a LRM assessment is required.** This may be related to a Susceptibility or Hazard Zoning Study or some other plan or criteria defining areas or types of development included or excluded.
- 3.3.2 The necessary competencies of practitioners undertaking LRM assessments. Such practitioners should be required to have LRM as a core competency.** A method of demonstrating core competency in LRM is being addressed by the Australian Geomechanics Society and Engineers Australia as a specific area of practice within the National Professional Engineers Register (NPER). Some regulators may choose to define another method of demonstrating competency.
- 3.3.3 The basic requirements of LRM reports** which should be based on compliance with the requirements of this Practice Note.

## PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

- 3.3.4 Require assessment of risk to life as part of a LRM report** which, as discussed below, should be completed in a quantitative basis.
- 3.3.5 Suggest adoption of the preferred qualitative terminology given in Appendix C of this Practice Note for risk to property** so that the regulator can become accustomed to the terminology adopted and implications arising there from. If alternative terminology is to be adopted for LRM, the regulator should only accept non standard schemes where the terms have been clearly defined, the terms have been explained in relation to the preferred terminology and it can be reasonably demonstrated by the practitioner that the alternative is better suited to the particular circumstances of the assessment.
- 3.3.6 Provide the required forms** to control the submissions and approvals process.
- 3.3.7 Specify the criteria under which a decision will be made for both the scope/nature of developments and the appropriate tolerable risk criteria being adopted.**

### **3.4 PROCESSING REQUIREMENTS**

- 3.4.1 The regulator should use a number of forms to provide appropriate QA process control and documentation records of the submitted LRM assessment and subsequent compliance with the approval conditions.**

The forms need to be appropriate to each stage of the development application, approval, detailed design, construction and maintenance of the development. Essential contents will include:

1. Name and qualification of the practitioner responsible for the LRM assessment.
2. A list of supporting documents including the architectural, civil design and structural engineering design drawings, as appropriate, to fully define the extent and scope of the proposed development.
3. A statement of compliance with the requirements of this Practice Note. In some cases the statements will be required to include details of how compliance is achieved.
4. Document reference details (date, reference number, report title) for the relevant LRM assessment submission.

A suite of example forms is given in Appendix D for modification by each regulator to be consistent with their policy. The aim of the forms is to provide appropriate documentary control of the stages required through to completion of a development.

Processing of the application by the regulator should include, amongst other aspects, confirmation that the submission is in accordance with policy requirements, and that the nature of the development complies with the requirements of the LRM assessment.

Where the regulator has specific concerns in relation to the adequacy of a submission, or the conclusions reached, or if required by a Hazard Zoning study, the submission may be subject to peer review or independent specialist advice to the regulator as an audit process or as part of mediation for an agreement. The reviewer should independently review the LRM assessment report in terms of adequacy of compliance with this Practice Note and the reasonableness of the assessment conclusions and risk control measures specified. The review should also consider the specific development proposals as defined by the design drawings.

- 3.4.2 Where the recommendations of this Practice Note have not been followed, then the regulator should either reject the application or require provision of further information before approval is given.**

It is anticipated that the forms in Appendix D will, in part, constitute a checking template for the regulator. Further discussion is given in the Commentary.

- 3.4.3 Where construction is completed but all aspects of the Approval Conditions have not been completed with appropriate documentation or justification, then the final approval by the regulator should not be given until sufficient information is provided to demonstrate compliance.**

It is anticipated that completion of Forms F and G with suitable annotation would help identify where non compliance exists. If the regulator does not have a strong procedure for enforcement of, or auditing of, compliance with consent conditions, then there may be subsequent liability issues for the regulator if non-compliance becomes an issue at a later date.

### **3.5 ESTABLISHMENT OF TOLERABLE RISK CRITERIA**

**The regulator is responsible for setting the Tolerable Risk Criteria for loss of life and property loss. Discussion of the considerations and world practice are given in the Commentary together with the AGS recommendation for consideration by the regulator.**

### **3.6 LANDSLIDE INVENTORY**

**The local Council, or other regulator, should maintain an inventory of past landslide events as discussed in AGS (2007a) and make this information available to all practitioners.**

# PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

## 3.7 ROLE AND RESPONSIBILITY OF THE PRACTITIONER

**The practitioner has the role of providing technical input in relation to the specialized aspect of LRM.** Such input will be subject to the specific requirements of any policy instituted by the regulator. The regulator may require specific levels of qualification and competence of practitioners providing the regulator with advice in relation to compliance with the risk acceptance criteria.

The qualifications and experience of suitable practitioners are as discussed in Paragraph 3.3.2.

It is the responsibility of the practitioner to carry out LRM assessments in accordance with this Practice Note and within the requirements of his/her professional Code of Ethics. The practitioner must provide advice to the client and regulator in an unbiased manner.

## PART C GUIDELINES FOR PRACTITIONERS

### 4 SCOPE DEFINITION

**Establish the purpose and scope of the risk assessment study.**

The practitioner needs to take into account the initial brief from the client and the requirements of the regulator. Usually these will be sufficient for the practitioner to decide on the appropriate scope and level of the study which should then be advised to the client as a “reverse brief”. In the LRM process, the practitioner will have a role to advise the client as to how the landslide risk can be reduced, avoided or otherwise controlled including options or alternatives.

### 5 HAZARD ANALYSIS

#### 5.1 DATA GATHERING / DESK STUDY

**Assemble relevant data and record their sources.**

Often there is a body of local experience which becomes invaluable for the assessment process. Such experience includes published papers, geological maps, aerial photographs and general studies such as Hazard Zoning studies completed for the regulator. Local experience can include previous assessments and knowledge of problematic areas which should be available from the regulator’s landslide inventory. Practitioners new to an area should discuss with locals their knowledge and experience.

Preferred data for the assessment will include site specific data, such as survey plan showing existing features, spot heights, contours and location and nature of services. Initial design proposals are required so that the risk assessment may be completed and appropriate risk control measures specified. (It is a necessary requirement in the performance of a risk assessment for there to be an element at risk, hence the need for a preliminary design or for an assumed development which should be defined in the LRM report).

#### 5.2 FIELD INVESTIGATION REQUIREMENTS

##### 5.2.1 Complete investigations sufficient to establish a geotechnical model, identify geomorphic processes and associated process rates.

The investigation may involve a number of methods and may be completed in stages, with each stage sufficiently detailed to provide a model appropriate to the level of study being undertaken. Further discussion is given in the Commentary.

##### 5.2.2 Inspect the site and surrounds including field mapping of the geomorphic features.

This must be completed by the practitioner for every assessment. The field mapping is to document the observations and to enable formulation of the geotechnical model.

Mapping should be completed to scale on an available survey plan and must include the surrounds (above, below and adjacent) to the site as appropriate to define the landslides and the geotechnical model.

Where a survey plan is not available, then simple survey using hand held tape and clinometer methods should be used to draw up a plan, to scale, using standard mapping symbols and terminology to represent the geological and geomorphic features. (Examples of geological and geomorphic mapping symbols are presented in Appendix E.)

##### 5.2.3 Determine the subsurface profile from exposures or subsurface investigation such as by boreholes and/or test pits.

This is necessary as part of the geotechnical model. Often exposures or knowledge from a nearby site may be sufficient.

Where such data is not available or not appropriate, subsurface investigation is required to enable formulation of the model and must include determination of the depth to rock or to below the depth of potential failure surfaces if this is greater.

## PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

Where pre-existing landslides are expected or suspected, then where practical, use should be made of either test pits (to enable sufficient sample/material to be seen for identification of shear planes or other relevant structure) or boreholes (with appropriate sampling and installation of inclinometers for monitoring for evidence of movements).

### **5.2.4 Assess likely groundwater levels and responses to trigger rainfall events.**

Consideration of the likely ground water response will enable assessment of response to rainfall trigger events. Use may be made of experience in the area, as observation of site specific data will frequently require prolonged periods of monitoring to enable formulation of a groundwater response model taking into account the statistical significance of rainfall events during the monitoring period. For relatively straightforward projects with low to moderate risks, a basic qualitative estimate of groundwater levels and responses may be appropriate when there is a lack of data. However, other more complicated projects, or where risk levels are higher, will require a greater level of understanding of groundwater levels and responses.

For more detailed analysis, particularly of possible stabilisation measures by subsurface drainage, observation of groundwater levels and their response to significant rainfall events is advisable to enable subsequent assessment of the effectiveness of subsurface drainage measures. Careful consideration must be given to the location of piezometers and their construction details.

### **5.2.5 Prepare a cross section drawing (to scale) through selected parts of the site to demonstrate the geotechnical model of site conditions and on which landslides may be identified.**

The resulting geotechnical model should integrate all the data obtained from the mapping and investigations.

The section should demonstrate the likely variation in subsurface conditions on the section including groundwater levels. On large or complex sites, more than one section may be required. All sections are to be drawn to natural scale. If exaggerated vertical scale is required for clarity, then a summary section at natural scale should also be included.

Adequate investigation has been completed when the geotechnical model is sufficiently defined to understand the slope forming processes relevant to the site and surrounds, the form and extent of landslides, likely triggers for the landslides and process rates associated with the landslides. The report should include explanation of uncertainties associated with the model.

### **5.2.6 Take into account slope forming process rates associated with the geotechnical model and landslides.**

An understanding of the slope forming process relevant to the landslides and associated process rate is fundamental for evaluation of likelihood.

### **5.2.7 Identify landslides types/locations appropriate to the geotechnical model based on local experience and general experience in similar circumstances.**

The types of landslides will be dependent on the geotechnical model and to some extent on the nature of existing and/or proposed development. The expected characteristics of the landslides (such as the size, type of material involved, rate of failure and travel distance) need to be assessed. The range of landslide sizes can vary from the very large landslides, which may encompass a whole hillside or region, to a small site specific landslide. The model should include assessment of the fundamental cause as well as likely trigger events. The report must document the hazard assessment which will include the estimated likelihood for each landslide type.

The hazard assessment must address areas upslope from the site, downslope from the site and across the slope adjacent to the site where these may affect the site.

### **5.2.8 If required, further detailed investigations should be completed to better define the model, the landslides, the triggers, the frequency (likelihood) or design of stabilisation measures to control the risk.**

Such additional investigation is most likely to be required on sites where the risk is judged to be intolerable and/or where further input is required to resolve uncertainties.

## **5.3 LANDSLIDE CHARACTERISATION**

**Characterise the landslides based on the desk study and field investigations. Use Appendix B for terminology to describe the landslides.**

The characterization should include the classification, volume, location and potential travel distance of all landslides which may occur on the site or travel on to or regress into the site.

## **5.4 FREQUENCY ANALYSIS**

### **5.4.1 Techniques for Frequency Analysis**

#### **a) Adopt a frequency analysis technique appropriate to the level of study and complexity of the geotechnical model and slope forming process.**

The appropriate technique may change with different levels of study, or for different stages of a project, or with the project brief and available budget. For example, techniques and level of detail may be different for:

## PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

- Subdivision stage LRM
- Residential dwellings LRM
- Infrastructure and utilities LRM
- Natural resource and environmental LRM

It is essential that the assessment be based on the best estimates available and that expert judgment be applied to answers so derived.

It is essential to understand the slope forming process before moving on to the frequency assessment.

The assessment must document the reasoning in a transparent manner.

**b) Gather local and historical knowledge of slope performance and landslide characteristics and occurrence. The resulting inventory enables assessment of frequency.**

This technique is a basic starting point and essential for all studies. However, a common shortcoming is that “local knowledge” is often poorly documented and difficult to collate and assess. Local Council records and experience should be accessed via a landslide inventory made available to practitioners. Analysis of aerial photographs and possibly maps may provide additional data.

Documentation of events by local newspapers may also be a useful source, depending on the quality of reporting and what events are judged at the time to be of local interest.

**c) Empirical methods based on slope instability ranking systems.**

These methods are often devised by expert groups to assist with prioritisation of treatment measures.

The methods are usually based on subjective judgment of the relative importance of contributory factors. The results obtained may be difficult to calibrate or it may be difficult to obtain consistent results and hence may be inaccurate. The methods do not usually allow assessment of frequencies.

**d) Relationship to geomorphology and geology.**

This method is based on the principle put forward by Varnes (1984) that the past and present are guides to the future. Hence, this leads to the assumptions that:

1. it is likely that landsliding will occur where it has occurred in the past and
2. landslides are likely to occur in similar geological, geomorphologic and hydrological conditions as they have in the past.

The use of historic records and landslide inventories of past performance are likely to be required to enable frequency values to be assessed. However, it should be noted that landslide frequency, size and intensity may differ from past performance where altered trigger events are introduced, e.g. due to man made changes or climate change. In addition, other factors (such as periodic or seasonal wetting and drying cycles resulting in soil creep, cyclic degradation and strength loss) can also result in failures after relatively “normal” rainfall events.

The use of other slope attribute factors (such as slope angle, slope drainage, slope age, presence of groundwater, slope orientation) may assist with assessment of particular slopes relative to the broad geomorphic model.

**e) Prepare a statistical evaluation of rainfall and relate to history of landsliding and population of slopes within area of similar slope type.**

Rainfall, and the consequent effect on groundwater levels, is widely recognized as a main trigger event for landsliding. Therefore, indicative frequency values may be related to the frequency of rainfall provided there is sufficient historical data to enable the relationship between rainfall frequency, antecedent rainfall and landslide events to be correlated.

A similar approach may be adopted for other forms of triggering events such as earthquakes.

**f) Consider use of simulation models and Monte Carlo sampling analyses to derive a frequency of failure.**

These methods (including simulation modelling of groundwater response to rainfall, evapotranspiration, and ground water flows) can be difficult to carry out reliably. Picarelli *et al.* (2005) outline some of the difficulties with these methods. Simulation modelling is most likely to be applicable only to medium to large, deep seated landslides where extensive monitoring data is available to enable calibration over a range of rainfall and piezometric responses.

Experience shows that full probabilistic analysis is difficult and time consuming (Robin Fell personal comm.). Therefore this method should only be carried out for special cases where sufficient data is available to enable the results to be meaningful.

**g) Use knowledge based expert judgment or ‘degree of belief’ method which combines experience, expertise and general principles.**

For most assessments this may be the only suitable option to estimate frequency due to the lack of objective data. The assessment relies to a large degree on subjective assessment of available data where other more rigorous methods are not available or viable. The method still requires some degree of research to obtain relevant data and an understanding

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of the geological model to qualify the judgment of likelihood. Nonetheless, the approach requires the proposition of various possible scenarios followed by the systematic testing and elimination of options as a result of investigation, discussion and judgment to develop an estimate of frequency (Lee and Jones 2004).

The result is conditioned by the 'degree of belief' of the practitioner. Typically, the resulting accuracy for a frequency assessment and, perhaps, a consequence assessment could vary from half an order of magnitude at best, to one order of magnitude or perhaps two orders of magnitude. As a result, the risk assessment should clearly display its sensitivity to the input parameters and, unless justified by further investigations, a conservative outcome should be adopted.

- h) Where appropriate, use event trees to provide a structured and auditable approach for the use of expert judgment and subjective probability assessment.**
- i)**

An event tree analysis uses a graphical construct to show the logical sequence of events or considerations that can be used to analyse the system leading to a particular outcome. It can be used for evaluation of probability of failure of a landslide, or consequence of failure, or risk. The logical sequence within the system is mapped as a branching network with conditional probabilities assigned to each branch of a node. The frequency of achieving a certain outcome is the product of the conditional probabilities leading to that outcome times the frequency of the initiating "trigger" such as rainfall.

**i) Other methods.**

The above may not be an exhaustive list but covers the principal methods/approaches. Specific circumstances of a particular area or project may enable other approaches or combinations of approaches to be used. Field techniques may develop to offer alternatives, for example remote sensing by satellite.

Further comment is given in the Commentary together with some guidance on different site investigation methods.

### **5.4.2 Estimation of Annual Probability (Frequency) ( $P_{(H)}$ ) of Each Landslide**

**a) Use 'best estimates' for frequency but consider range / uncertainty / sensitivity.**

Suitable methods are outlined in Section 5.2.

It is important not to infer greater accuracy than is reasonably possible. Evaluation of the sensitivity arising from uncertainty is part of the consideration.

A best estimate is to be derived for each landslide which is then applied to both risk to property and risk to life assessments. The estimate may be related to the size of the landslide and/or the expected amount of movement as part of the hazard assessment. The appropriate qualitative term is chosen from the estimated probability based on the frequency assessment. Note that the reverse, the adoption of a probability value from a qualitative term, should not be undertaken as it has been demonstrated that this results in a range of estimates of frequency several orders of magnitude apart depending on the practitioner.

**b) Estimates of frequency may be derived by partitioning the problem to (Annual probability of trigger event) x (Probability of sliding given the trigger event) over the range of trigger events.**

Landslides of the one 'type', but having varying possible scales (magnitude/travel distance/velocity etc.) need to be assessed separately. Each could well have a different frequency of occurrence. The landslide inventory of performance for an area will provide some basis for the assessment.

A trigger event for a particular locality (e.g. a certain intensity/duration or recurrence interval of rainfall) will not necessarily cause each potential landslide event in that locality to occur. There will be a finite probability (value) that the landslide under consideration may not be set off by the trigger event.

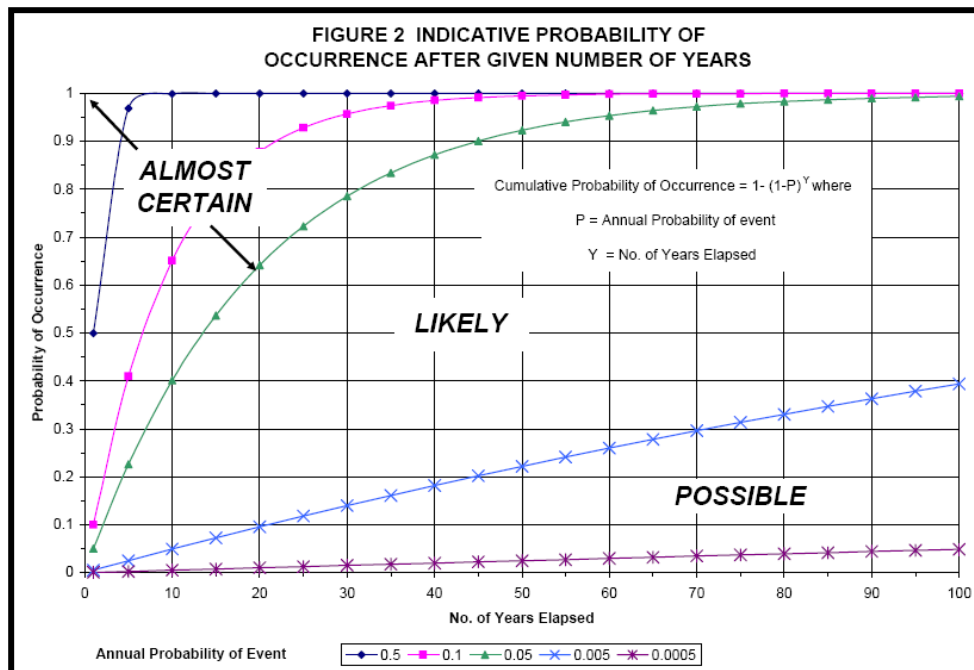
The frequency of landsliding should be assessed over the full range of the triggering events, and the total frequency carried forward in the risk analysis. In practice this process may be simplified to consider only the highest frequency triggering events. An example is presented in the Commentary.

**c) Complete a review of the assessed frequency in relation to the implied cumulative frequency of the event occurring within the design life and known performance within the area.**

This is a 'sanity check' on the result of the assessment. It is important to apply judgment or bias on the final outcome only, not on the input estimates.

Values of the cumulative probability are shown on Figure 2 for different annual probability values as a function of time over usual design life intervals. The resulting cumulative probabilities should be checked to confirm they are reasonable in relation to experience. The implications of the cumulative probability values shown in Figure 2 are discussed further in the Commentary.





#### 5.4.3 Assess the Travel Distance and the Probability of Spatial Impact ( $P_{(S;H)}$ ) of the Elements at Risk

When assessing risk arising from landsliding, it is important to be able to estimate the distance the slide mass will travel and its velocity. These factors determine the extent to which the landslide will affect property and persons downslope and the ability of persons to take evasive action.

The travel distance depends on:

- Slope characteristics
  - Height
  - Slope
  - Nature of material
- Mechanism of failure and type of movement such as
  - Slide, fall, topple etc.
  - Sliding, rolling, bouncing, flow
  - Strain weakening or not
  - Collapse in undrained loading (static liquefaction)
  - Influence of surface water and groundwater
  - Comminution of particles
- Characteristics of the downhill path
  - Gradient and gradient direction
  - Channelisation
  - The potential for depletion/accumulation
  - Vegetation

Information on travel distance from previous events on or near the site may be collected during the site inspection. Predictions of travel distance and travel direction should be based on the assessed mechanism of future events and site characteristics.

For rotational landslides which remain essentially intact, the method proposed by Khalili *et al* (1996) or experience with landslides in similar geological, topographic and climatic conditions can be used to estimate the displacement. Further discussion is given in the Commentary.

For slides which break up, and in some cases become flows, and slides from steep cuts, the travel distance is usually estimated from empirical methods, such as Hunter and Fell (2002) and Corominas (1996). These methods are only approximate, and the wide scatter of data on travel distance angles reflects the range of topographical, geological and climatic environments, different slide mechanisms and limited quality of data from which the methods are derived.

If the empirical methods are to be used for predictions of travel distance and the probability of spatial impact of the elements at risk, much judgement will be required and it is important to try to calibrate the methods with landslide

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behaviour in the study area. It is often useful to allow for a range of travel distances in the calculation and express that range in probabilistic terms as discussed in the Commentary.

The annual probability of the landslide and probability of spatial impact may be considered together in qualitative terms as likelihood of impact on the element at risk being considered.

## 6 CONSEQUENCE ANALYSIS

### 6.1 ELEMENTS AT RISK

The elements at risk will include:

- Property, which may be subdivided into portions relative to the hazard being considered.
- People, who either live, work, or may spend some time in the area affected by landsliding.
- Services, such as water supply or drainage or electricity supply.
- Roads and communication facilities.
- Vehicles on roads, subdivided into categories (cars, trucks, buses).

These should be assessed and listed for each landslide hazard.

For some cases, other risks may also have to be considered. For example:

- Environmental, where the elements at risk are environmental (rather than man made), such as forests or water bodies.
- Social, where the consequences of the landslide may have an impact on social conditions, such as the cost of disruption to traffic where roads are affected.
- Political, where the consequences may not be acceptable in political terms.

### 6.2 TEMPORAL SPATIAL PROBABILITY ( $P_{(T:S)}$ )

When the elements at risk are mobile (e.g. persons on foot, in cars, buses and trains) or where there is varying occupancy of buildings (e.g. between night and day, week days and weekends, summer and winter), it is necessary to make allowance for the probability that persons (or a particular number of persons) will be in the area affected by the landslide. This is called the Temporal Spatial Probability.

For where the elements at risk are mobile it is proportion of a year (between 0 and 1.0) in which a person, car or bus will be below or on the landslide when it occurs. For occupancy of buildings it is a calculation of the proportion of a year (between 0 and 1.0) which the number of persons being considered occupy the building, or the area of the building likely to be impacted.

These calculations should allow for the possibility that the persons may have warning of the impending landslide and may evacuate the area. Each case should be considered by taking account of the details of the situation. Generally persons on a landslide are more likely to observe the initiation of movement and move off the slide, than those who are below a slide which falls or flows onto them unless the rates of movement are slow.

### 6.3 EVALUATION OF CONSEQUENCE TO PROPERTY

#### 6.3.1 Estimate the extent of damage likely to property arising from each of the landslides.

This requires an understanding of the landslide characteristics and experience in assessing the likely impact on property. The consequences are often calculated using the vulnerability ( $V_{(Prop:S)}$ ) of the elements at risk to the landslide.

The factors which most affect vulnerability of property are:

- The volume of the slide in relation to the element at risk.
- The position of the element at risk, e.g. on the slide, or immediately downslope.
- The magnitude of slide displacement, and relative displacements within the slide (for elements sited on the slide).
- The rate of slide movement.

It should be noted that the vulnerability refers to the degree of damage (or damage value in absolute or relative terms) which is judged to be likely if the landslide does occur.

As discussed below, the assessment should be based on a quantitative estimate to enable clarification of the judgment which for a qualitative assessment may be subject to considerable interpretation.

#### 6.3.2 Estimate the indicative cost of the damage.

This requires use of indicative costs of building and remedial works. Frequently, broad brush 'guesstimates' will suffice, but the 'guesstimate values' and basis should be documented. Some guidance is given in the Commentary. It should not be necessary to use a quantity surveyor to establish a more accurate estimate as usually the broad brush guesstimate will suffice for allocation of a consequence term in a qualitative scheme such as in Appendix C.

The indicative cost of damage is to be the Total Cost as this is the most relevant to the owner. Components to be considered comprise:-

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- Direct costs related to reinstatement works for damaged portions of the property (structures and the land).
- Stabilization works required to render the site to an tolerable risk level for the landslide.
- Professional and approvals fees.
- Consequential costs (such as legal fees and alternative temporary accommodation).

It does not include additional stabilisation works to address other landslides which may affect the property.

### 6.3.3 Estimate the market value.

This may be achieved by reference to property sale values within the local area which will reflect the value of the land plus structures. The client is likely to have some knowledge of the local market values. Again, a broad-brush guesstimate should often suffice.

### 6.3.4 Consider the resulting Consequence classification, such as using Appendix C, and implied accuracy of the above estimates.

It is not expected that the assessor will be a quantity surveyor or have similar experience, but that sensible estimates, possibly as a range, can be made and documented. Statement of limits of accuracy or uncertainty are appropriate for sensitivity and appraisal analysis.

## 6.4 EVALUATION OF CONSEQUENCES TO PERSONS

The following factors influence the likelihood of deaths and injuries or vulnerability ( $V_{(D:T)}$ ) of persons who are impacted by a landslide:

- Volume of slide.
- Type of slide, mechanism of slide initiation and velocity of sliding.
- Depth of slide.
- Whether the landslide debris buries the person(s).
- Whether the person(s) are in the open or enclosed in a vehicle or building.
- Whether the vehicle or building collapses when impacted by debris.
- The type of collapse if the vehicle or building collapses.

Persons are very vulnerable in the event of complete or substantial burial by debris, or the collapse of a building. It should be noted that even small slides, and single boulders, can kill people.

Appendix F provides some indicative examples of vulnerability values. The Commentary provides some more detailed discussion.

## 7 RISK ESTIMATION

### 7.1 QUANTITATIVE RISK ESTIMATION

Quantitative risk estimation involves integration of the frequency analysis and the consequences.

For property, the risk can be calculated from:

$$R_{(Prop)} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(Prop:S)} \times E \quad (1)$$

Where

$R_{(Prop)}$  is the risk (annual loss of property value).

$P_{(H)}$  is the annual probability of the landslide.

$P_{(S:H)}$  is the probability of spatial impact by the landslide on the property, taking into account the travel distance and travel direction.

$P_{(T:S)}$  is the temporal spatial probability. For houses and other buildings  $P_{(T:S)} = 1.0$ . For Vehicles and other moving elements at risk  $1.0 > P_{(T:S)} > 0$ .

$V_{(Prop:S)}$  is the vulnerability of the property to the spatial impact (proportion of property value lost).

$E$  is the element at risk (e.g. the value or net present value of the property).

For loss of life, the individual risk can be calculated from:

$$R_{(LoL)} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(D:T)} \quad (2)$$

Where

$R_{(LoL)}$  is the risk (annual probability of loss of life (death) of an individual).

$P_{(H)}$  is the annual probability of the landslide.

$P_{(S:H)}$  is the probability of spatial impact of the landslide impacting a building (location) taking into account the travel distance and travel direction given the event.

$P_{(T:S)}$  is the temporal spatial probability (e.g. of the building or location being occupied by the individual) given the spatial impact and allowing for the possibility of evacuation given there is warning of the landslide occurrence.

$V_{(D:T)}$  is the vulnerability of the individual (probability of loss of life of the individual given the impact).

A full risk analysis involves consideration of all landslide hazards for the site (e.g. large, deep seated landsliding, smaller slides, boulder falls, debris flows) and all the elements at risk.

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For comparison with tolerable risk criteria, the individual risk from all the landslide hazards affecting the person most at risk, or the property, should be summed.

The assessment must clearly state whether it pertains to 'as existing' conditions or following implementation of recommended risk mitigation measures, thereby giving the 'residual risk'.

### 7.2 SEMI-QUANTITATIVE AND QUALITATIVE RISK ESTIMATION FOR RISK TO PROPERTY

When considering the risk to property, it may be useful to use qualitative terms to report the results of the analysis, rather than quantitative values. The risk calculation may be completed quantitatively or by the use of qualitative terms.

A semi quantitative analysis (where the likelihood is linked to an indicative probability) or a qualitative analysis may be used:

- As an initial screening process to identify hazards and risks which require more detailed consideration and analysis.
- When the level of risk does not justify the time and effort required for more detailed analysis.
- Where the possibility of obtaining numerical data is limited such that a quantitative analysis is unlikely to be meaningful or may be misleading.

Section 7.3 describes a suitable and preferred terminology.

### 7.3 RISK MATRIX FOR PROPERTY LOSS

#### a) Adopt a defined qualitative terminology for likelihood, consequence and risk.

Qualitative terminology is presented in Appendix C for property loss. The terminology has been developed from Appendix G in AGS (2000) taking into account the experience and comments as discussed in the Commentary.

For ease of use, the frequency estimate, expressed as an annualized probability and taking into account the probability of spatial impact, is expressed qualitatively as likelihood.

The terminology is aimed primarily at residential development but may also be used for other situations. It is noted that provision of specific numerical values at the Notional Boundaries for the terms adopted does not reduce the uncertainty that may be associated with assessment of appropriate numerical values.

Where sufficient data is available, the risk should be determined from a quantitative analysis. The results can then be objectively compared, especially with quantified allowable risk criteria.

Where there is insufficient data or the study is at a walk over or preliminary design level, then use of qualitative methods or terms may be more appropriate. Use of risk ranking schemes, where component inputs are assigned relative ranks, may be suitable for initial screening. In other cases, it is likely that expression of the likelihood, consequence and risk using qualitative terms is preferable for communication purposes; (for example using terminology as in Appendix C). Selection of the appropriate term should be based on an appropriate evaluation of likelihood or consequence ranges.

Semi-quantitative methods may be a combination of both, for example considering risk to property qualitatively, and risk to life quantitatively based on the appropriate best estimates of likelihood.

#### b) The practitioner should adopt the preferred risk matrix presented in Appendix C.

The terminology presented in Appendix C of this Practice Note has addressed the shortcomings identified with the scheme in Appendix G AGS (2000). Appendix G of AGS (2000) is now superseded and should no longer be used. Adoption of Appendix C as a preferred risk matrix will assist with uniformity of assessment and interpretation. This is discussed further in the Commentary.

The regulator should only accept non standard schemes where the terms have been clearly defined, the terms have been explained in relation to the preferred terminology, and it can be reasonably demonstrated by the practitioner that the alternative is better suited to the particular circumstances of the assessment.

### 7.4 ESTIMATION OF RISK OF LOSS OF LIFE

#### a) Estimate the risk of loss of life quantitatively for the person most at risk.

The annual probability of loss of life for the person most at risk from the landslide(s) should be estimated using the equations in Section 7.1. The person most at risk will often but not always be the person with the greatest spatial temporal probability.

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The individual risk, as determined by summing the risk, for the person most at risk, from all the landslide hazards, is used for comparison with the tolerable risk criteria.

**b) For situations where there is a potential for large numbers of lives to be lost in a single landslide event, estimate the frequency (f) –number (N) of lives lost pairs and total annual risk.**

If the possible loss of large numbers of lives from a landslide incident is high, society will generally expect that the probability that the incident might actually occur should be low. This accounts for society's particular intolerance to incidents that cause many simultaneous casualties and is embodied in the criteria for tolerable societal risk. Societal Risk is discussed further in the Commentary.

In many cases there will be more than one landslide hazard (e.g. rockfall, which may lead to one or two lives lost; medium volume rapid landslide which may lead to several lives lost; and large rapid landslide which may lead to many lives lost). The frequency (annual probability, "f") of the "event" and the number of lives lost (N) should be estimated for each landslide hazard.

The total annual risk =  $\sum (f \times N)$  should also be estimated.

## 8 RISK ASSESSMENT

### 8.1 RISK EVALUATION

**Evaluate the risks against Tolerable Risk Criteria for loss of life and property loss.**

**Accept the risks if tolerable, or seek to reduce risks to tolerable levels by risk mitigation.**

The main objectives of risk evaluation are usually to decide whether to accept or treat the risks and to set priorities. The Tolerable Risk Criteria are usually imposed by the regulator, unless agreed otherwise with the owner/client

Non- technical clients may seek guidance from the practitioner on whether to accept the risk. In these situations, risk comparisons, discussion of treatment options and explanation of the risk management process can help the client make his decision.

It is desirable, if not essential, that the practitioner who prepared the risk assessment be involved in the decision making process because the process is often iterative, requiring assessment of the sensitivity of calculations to assumptions, modification of the development proposed and revision of risk mitigation measures.

Risk evaluation involves making judgements about the significance and tolerability of the estimated risk. Evaluation may involve comparison of the assessed risks with other risks or with risk acceptance criteria related to finance, loss of life or other values. Risk evaluation may include consideration of issues such as environmental effects, public reaction, politics, business or public confidence and fear of litigation.

In a simple situation where the client/owner is the only affected party, risk evaluation may be a simple value judgement. In more complex situations, value judgements on acceptable risk appropriate to the particular situation are still made as part of an acceptable process of risk management.

### 8.2 TOLERABLE RISK CRITERIA

**The regulator is to establish the Tolerable Risk Criteria for loss of life and property loss.**

As discussed in Section 3.5, the regulator is the appropriate authority to set standards for tolerable risk which may relate not only to perceived safety in relation to other risks, but also to government policy. Implementation of a tolerable risk level has implications to the community at large, both in terms of relative risks or safety and in terms of economic impact on the community.

The Commentary provides discussion and gives the AGS recommendations in relation to tolerable risk for loss of life. These are summarized in Table 1

Table 1: AGS Suggested Tolerable loss of life individual risk.

Situation	Suggested Tolerable Loss of Life Risk for the person most at risk
Existing Slope (1) / Existing Development (2)	$10^{-4}$ / annum
New Constructed Slope (3) / New Development (4) / Existing Landslide (5)	$10^{-5}$ / annum

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Notes:

1. “Existing Slopes” in this context are slopes that are not part of a recognizable landslide and have demonstrated non-failure performance over at least several seasons or events of extended adverse weather, usually being a period of at least 10 to 20 years.
2. “Existing Development” includes existing structures, and slopes that have been modified by cut and fill, that are not located on or part of a recognizable landslide and have demonstrated non-failure performance over at least several seasons or events of extended adverse weather, usually being a period of at least 10 to 20 years.
3. “New Constructed Slope” includes any change to existing slopes by cut or fill or changes to existing slopes by new stabilisation works (including replacement of existing retaining walls or replacement of existing stabilisation measures, such as rock bolts or catch fences).
4. “New Development” includes any new structure or change to an existing slope or structure. Where changes to an existing structure or slope result in any cut or fill of less than 1.0m vertical height from the toe to the crest and this change does not increase the risk, then the Existing Slope / Existing Structure criterion may be adopted. Where changes to an existing structure do not increase the building footprint or do not result in an overall change in footing loads, then the Existing Development criterion may be adopted.
5. “Existing Landslides” have been considered likely to require remedial works and hence would become a New Constructed Slope and require the lower risk. Even where remedial works are not required per se, it would be reasonable expectation of the public for a known landslide to be assessed to the lower risk category as a matter of “public safety”.

Acceptable risks are usually considered to be one order of magnitude lower than the Tolerable Risks.

It is important to distinguish between “acceptable risks” and “tolerable risks”.

*Tolerable Risks* are risks within a range that society can live with so as to secure certain benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if practicable.

*Acceptable Risks* are risks which everyone affected is prepared to accept. Action to further reduce such risk is usually not required unless reasonably practicable measures are available at low cost in terms of money, time and effort.

AGS suggests that for most development in existing urban area criteria based on Tolerable Risks levels are applicable because of the trade-off between the risks, the benefits of development and the cost of risk mitigation.

The Commentary discusses Individual and Societal risk to loss of life. Usually Societal risk need not be considered for a risk evaluation in relation to a single dwelling. Societal risk should be evaluated for buildings having high numbers of occupants, such as schools, hospitals, hotels or motels where many lives are at risk. This then addresses society’s aversion to loss of many lives from single landslide events.

The Tolerable Risk Criteria for property loss may be determined by the Importance Level of the development (Appendix A) as discussed in the Commentary.

## 9 RISK MANAGEMENT

### 9.1 RISK MITIGATION PRINCIPLES

#### 9.1.1 Feasible options for risk mitigation for each risk assessment are to be identified and discussed including the reduced risk by adoption of those options.

Alternative methods to be explored include:

- a. **Accept the risk**, which is only an option subject to the criteria set by the regulator. Where the risk is not tolerable then risk mitigation measures are required.
- b. **Avoid the risk**, such as relocation of the site of proposed development, or revise the form of the development, or abandon the development (though this may still require some risks to be controlled due to possible effect on third parties adjacent or nearby).
- c. **Reduce the frequency of landsliding**, by stabilisation measures to control the initiating circumstances, such as by re-profiling the surface geometry where existing slopes are ‘over steep’, by provision of improved surface water drainage measures, by provision of subsurface drainage scheme, by provision of retaining structures such as retaining walls, anchored walls or ground anchors.
- d. **Reduce the consequences**, by provision of defensive stabilisation measures or protective measures such as a boulder catch fence, or amelioration of the behaviour of the landslide, or by relocation of the development to a more favourable location.



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- e. **Manage the risk by establishing monitoring and warning systems**, such as by regular site visits, or by survey, which enable the risks to be managed as an interim measure in the short term or as a permanent measure for the long term by alerting persons potentially affected to a change in the landslide condition. Such systems may be regarded as a method of reducing the consequences provided it is feasible for sufficient time to be available between the alert being raised and appropriate action being implemented.
- f. **Transfer the risk**, such as by requiring another authority to accept the risk (possibly via a court appraisal) or by provision of insurance to cover potential property damage.
- g. **Postpone the decision**, where there is sufficient uncertainty resulting from the available data, provided that additional investigations or monitoring are likely to enable a better risk assessment to be completed. Postponement is only a temporary measure and implies the risks are being temporarily accepted, even though they may not be acceptable or tolerable.

Adoption of particular risk mitigation measures needs to be documented so that the decisions are transparent to future land owners and to the regulator. The documentation will need to make it clear whether there is ongoing maintenance required or not. Responsibility for implementation of the risk mitigation measures (including auditing and reporting) resides with the land owner, particularly where ongoing maintenance is required.

It should be recognized that there may be situations where the risk is such that either no development should occur, or that very strict conditions and/or extensive investigations and implementation of risk control measures will be required. Such risk control measures may render the proposed development unworkable.

### 9.1.2 Wherever possible the recommended options should be engineered to reduce the uncertainties.

It is not possible to remove risk, but it can be reduced.

Risk mitigation options should include robust engineering design to reduce uncertainties and hence the risk.

Guidance on good engineering practice for hillside design and construction is given in Appendix G which has been reproduced from AGS (2000).

It is necessary that the options considered lower the risk to at least tolerable levels. In many cases, the ALARP principle ("As Low As Reasonably Practicable" as discussed in the Commentary) may apply so that reduction to a tolerable level is a pragmatic result since reduction to acceptable levels is not viable in the context of the cost to the individual or community. In other cases, good practice may suggest that risk reduction be applied since it is relatively cheap or cost effective to implement even though risk levels are assessed to already be at acceptable levels. In other words, risk minimization should be a governing feature or tenet of LRM.

Evaluation of mitigation options may take into account relative costs and effectiveness of the measures and inherent uncertainties. Combinations of mitigation measures may be appropriate.

The options should be reassessed if there is a need to reduce uncertainties or if suitable engineering options cannot be adopted.

An issue will be who decides on what level of risk reduction is appropriate. This is dependent on the risk tolerance criteria set by the regulator. The owner is likely to input into selection of the options, subject to approvals by the regulator. For some cases, there may be discussion between the stakeholders to select a suitable scheme of risk mitigation measures.

### 9.1.3 The adopted risk mitigation measures are to be detailed in a mitigation plan to explain and document the implementation of the measures.

The mitigation plan should identify responsibilities for each stakeholder during and after implementation. It may also include cost estimates, programme, required inspection regime, performance measures and expected outcomes. The level of detail will depend on the priority for the option and stage of the evaluation and implementation process.

The mitigation plan may include an emergency plan which should establish from the outset the sequence of events or monitoring results that will activate this plan. The plan may include a number of warning levels and consequent actions. The plan must be carefully reviewed to confirm it is workable and will achieve the desired risk mitigation.

The existence of the mitigation plan needs to be readily known to subsequent land owners. The most readily available method for this is to register the mitigation plan details on the land title.

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### **9.1.4 The risk should be subject to monitoring and review during the assessment of options, during implementation of the risk mitigation measures and during the on going monitoring.**

Further data may come to light during the management process which enables the risks to be reassessed. Such data may be adverse, requiring more stringent risk mitigation measures, or alternatively may be positive by demonstrating satisfactory slope performance under adverse conditions. It is anticipated that the practitioner would have a primary role in the monitoring and review process and particularly to confirm the requirements of the approval conditions had been fulfilled.

### **9.2 SITE SPECIFIC DEVELOPMENT CONDITIONS**

**Identify appropriate site specific development conditions to provide good practice and control the risks to acceptable levels.**

In the context of advice from a technical expert (the practitioner) acting in a consultant capacity, development controls would usually constitute 'recommendations', but as they will be integral with the risk assessment of the final development they may not be optional to the client. The practitioner should provide a statement as to the appropriateness of the development proposals in relation to the risk management requirements.

If 'certification' of the completed development is required (by the planning scheme or regulator's approval conditions), then the development conditions and associated inspections and documentation must be sufficient to enable this to be provided at the later date.

The development conditions should be subdivided into those required at each of the stages of detailed design, construction (including appropriate sequencing and temporary works), and for maintenance. The development conditions must address all the factors relevant to controlling the landslide risk.

### **9.3 DESIGN LIFE**

#### **9.3.1 Design of the risk mitigation measures is to be suitable for the time frame of the life of the structure - the design life. The design life is to be clearly stated on the design drawings.**

Often the design life will be that specified by relevant design codes such as 40 to 60 years for AS3600 Concrete Code, 50 years for AS2870 Residential Slabs and Footings, or for 5 years to 120 years for temporary site works to major public works respectively for AS4678 Earth Retaining Structures.

A design life of at least 50 years would be considered to be reasonable for permanent structures used by people. Some local government policies may require a longer design life as discussed in the Commentary. However, for some structures, such as timber retaining walls, inherent performance of the materials will limit the effective performance life to less than the required design life.

#### **9.3.2 Where the effective performance life is less than the required design life, then the effective life should be extended by a maintenance regime designed to overcome the limitations and to enable the performance to be assessed throughout the required design life. This is likely to require more extensive repair and replacement as determined by regular maintenance inspections.**

For example, experience shows the longevity of timber crib walls is less than for a concrete structure, due to faster degradation of timber with time. Therefore, a more frequent inspection and maintenance / repair / replacement regime will be required for timber crib walls to enable suitable repair and replacement so that a reasonable design life can be achieved. Similar considerations will apply to subsoil drains and stressed anchors.

### **9.4 MAINTENANCE REQUIREMENTS**

#### **9.4.1 The design is to include details of required inspections and maintenance to enable the risk mitigation measures to remain effective for at least the design life of the structure.**

Risk mitigation is not just an exercise in LRM documentation, design of the works and construction of the risk mitigation measures. The owner, including all owners subsequent to those responsible for commissioning the risk mitigation measures, has a responsibility to inspect and maintain the risk mitigation measures.

#### **9.4.2 Refer to the AGS Australian GeoGuide LR111 which provides advice on record keeping.**

The other GeoGuides (AGS, 2007e) also provide advice on the frequency of maintenance tasks.

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- 9.4.3 Implementation of the maintenance plan may require ‘enforcement’ by annotation on the land title so that subsequent purchasers become aware of the requirements and that relevant documents are available for the maintenance plan. Such ‘enforcement’ will be a benefit to subsequent owners as they will be better informed as to their required input responsibilities.**

### 10 REPORTING STANDARDS

- 10.1 The report on the risk assessment is to document the data gathered, the logic applied and conclusion reached in a defensible manner.**

The practitioner will gather relevant data, will assess the relevance of the data and will reach conclusions as to the appropriate geotechnical model and basic assessment of the slope forming processes and rates. Full documentation of these results provides evidence of completion, provides transparency in the light of uncertainty, enables the assessment to be re-examined or extended at a later date and enables the assessment to be defended against critical review. The process often identifies uncertainties or limitations of the assessment which also need to be documented and understood.

- 10.2 The data to be presented includes:**

- a. List of data sources.
- b. Discussion of investigation methods used, and any limitations thereof.
- c. Site plan (to scale) with geomorphic mapping results.
- d. All factual data from investigations, such as borehole and test pit logs, laboratory test results, groundwater level observations, record photographs.
- e. Location of all subsurface investigations and/or outcrops/cuttings.
- f. Location of cross section(s).
- g. Cross section(s) (to scale) with interpreted subsurface model showing investigation locations.
- h. Evidence of past performance.
- i. Local history of instability with assessed trigger events.
- j. Identification of landslides, on plan or section or both, and discussed in terms of the geomorphic model, relevant slope forming process and process rates. Landslides need to be considered above the site, below the site and adjacent to the site.
- k. Assessed likelihood of each landslide with basis thereof.
- l. Assessed consequence to property and life for each landslide with basis thereof.
- m. Resulting risk for each landslide.
- n. Risk assessment in relation to tolerable risk criteria (e.g. regulator’s published criteria where appropriate).
- o. Risk mitigation measures and options, including reassessed risk once these measures are implemented.

Where any of the above is not or cannot be completed, the report should document the missing elements, including an explanation as to why.

The report needs to clearly state whether the risk assessment is based on existing conditions or with risk treatment measures implemented. In some cases, the assessment for both existing and after treatment should be documented to demonstrate the effect of risk control measures on reducing risk.

A report which does not properly document the assessment is of limited value and would appear to have no reasonable basis.

### 11 SPECIAL CHALLENGES

#### 11.1 MINOR WORKS

**Adoption of all the provisions of the Practice Note for minor works may not be appropriate or reasonable. However, the basic principles still need to be considered. Although some policies may make provision for less onerous consideration for minor works, the practitioner will still have a duty of care to advise on all aspects and may have other landslides not connected with the proposed works that will still need to be considered.**

Minor works should be evaluated on a site by site basis but are likely to comprise proposed works of relatively low monetary value (such as may be completed by an owner builder with appropriate approvals and insurances) or those which do not change the existing risk, provided the existing risk has been assessed to be within the tolerable range. In some cases, the risk to life may be much higher than the risk to property and may dictate the need for risk mitigation to achieve tolerable risk levels.

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### **11.2 PART OF THE SITE NOT ACCEPTABLE**

**Existing or proposed development may not involve the full site area. Nonetheless, the practitioner's report must address all risks and advise the client and/or regulator of necessary works to control risks on other parts of the site or adjacent/nearby sites upslope or down slope as appropriate (as a primary duty of care issue).**

Where additional development is proposed, it may be found that risks associated with the proposed development are tolerable but that landslide risks on other parts of the site are not. These other risks still must be addressed.

### **11.3 ADJOINING AREAS NOT UNDER RESPONSIBILITY OF THE SITE OWNER**

In some cases, the risk posed by landslides in areas beyond the control of the land owner may be intolerable.

**The LRM assessment report must identify these landslides and provide a preliminary assessment of appropriate risk mitigation measures, which may require further investigation to better assess the risk.**

**The regulator may then implement appropriate orders (as appropriate to the legal/regulatory framework) to enforce appropriate risk mitigation measures and/or investigations. Alternatively, it may not be appropriate for development to proceed in such cases.**

### **11.4 COASTAL CLIFFS**

**LRM reports on coastal cliffs should include consideration of the existing slope profile, evidence of past instability, geology, defects, ground water, degradation cycles, and degradation rates and possible effects of wave attack, wave run-up and sea spray. The cliff areas should be examined from the face side as well as from the land side.**

Assessment of coastal cliffs is likely to require special expertise to consider the combined effects associated with recession rates, rock mechanics and wave environment. The LRM assessment may require some input from coastal engineers to address possible effects from storm events in terms of wave heights, run-up and frequency. The most frequent hazard is often boulder falls which will have risk determined by the temporal spatial probability.

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## APPENDIX A - DEFINITION OF TERMS AND LANDSLIDE RISK

### RISK TERMINOLOGY

**Acceptable Risk** – A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

**Annual Exceedance Probability (AEP)** – The estimated probability that an event of specified magnitude will be exceeded in any year.

**Consequence** – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.

**Elements at Risk** – The population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.

**Frequency** – A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.

**Hazard** – A condition with the potential for causing an undesirable consequence (the landslide). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.

**Individual Risk to Life** – The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.

**Landslide Activity** – The stage of development of a landslide; pre failure when the slope is strained throughout but is essentially intact; failure characterised by the formation of a continuous surface of rupture; post failure which includes movement from just after failure to when it essentially stops; and reactivation when the slope slides along one or several pre-existing surfaces of rupture. Reactivation may be occasional (eg seasonal) or continuous (in which case the slide is "active").

**Landslide Intensity** – A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, kinetic energy per unit area.

**Landslide Risk** - The AGS Australian GeoGuide LR7 (AGS, 2007e) should be referred to for an explanation of Landslide Risk.

**Landslide Susceptibility** – The classification, and volume (or area) of landslides which exist or potentially may occur in an area or may travel or retrogress onto it. Susceptibility may also include a description of the velocity and intensity of the existing or potential landsliding.

**Likelihood** – Used as a qualitative description of probability or frequency.

**Probability** – A measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty). It is an estimate of the likelihood of the magnitude of the uncertain quantity, or the likelihood of the occurrence of the uncertain future event.

There are two main interpretations:

- (i) Statistical – frequency or fraction – The outcome of a repetitive experiment of some kind like flipping coins. It includes also the idea of population variability. Such a number is called an "objective" or relative frequentist probability because it exists in the real world and is in principle measurable by doing the experiment.
- (ii) Subjective probability (degree of belief) – Quantified measure of belief, judgment, or confidence in the likelihood of an outcome, obtained by considering all available information honestly, fairly, and with a minimum of



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bias. Subjective probability is affected by the state of understanding of a process, judgment regarding an evaluation, or the quality and quantity of information. It may change over time as the state of knowledge changes.

**Qualitative Risk Analysis** – An analysis which uses word form, descriptive or numeric rating scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur.

**Quantitative Risk Analysis** – An analysis based on numerical values of the probability, vulnerability and consequences and resulting in a numerical value of the risk.

**Risk** – A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

**Risk Analysis** – The use of available information to estimate the risk to individual, population, property, or the environment, from hazards. Risk analyses generally contain the following steps: Scope definition, hazard identification and risk estimation.

**Risk Assessment** – The process of risk analysis and risk evaluation.

**Risk Control** or **Risk Treatment** – The process of decision making for managing risk and the implementation or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.

**Risk Estimation** – The process used to produce a measure of the level of health, property or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis and their integration.

**Risk Evaluation** – The stage at which values and judgments enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental and economic consequences, in order to identify a range of alternatives for managing the risks.

**Risk Management** – The complete process of risk assessment and risk control (or risk treatment).

**Societal Risk** – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental and other losses.

**Susceptibility** – see **Landslide Susceptibility**

**Temporal Spatial Probability** – The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.

**Tolerable Risk** – A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.

**Vulnerability** – The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

### ASSOCIATED TERMINOLOGY

**Importance Level** – of a building or structure is directly related to the societal requirements for its use, particularly during or following extreme events. The consequences with respect to life safety of the occupants of buildings are indirectly related to the Importance Level, being a result of the societal requirement for the structure rather than the reason *per se* of the Importance Level.

**Authority** or **Council** having statutory responsibility for community activities, community safety and development approval or management of development within its defined area/region.

The **Regulator** will be the responsible body/authority for setting Acceptable/Tolerable Risk Criteria to be adopted for the community/region/activity, which will be the basis for setting levels for Acceptable and Tolerable Risk in the application of the risk assessment guidelines.

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Importance Level of Structure	Explanation	Examples (Regulatory authorities may designate any structure to any classification type when local conditions make such desirable)
1	Buildings or structures generally presenting a low risk to life and property (including other property).	Farm buildings. Isolated minor storage facilities. Minor temporary facilities. Towers in rural situations.
2	Buildings and structures not covered by Importance Levels 1, 3 or 4.	Low-rise residential construction. Buildings and facilities below the limits set for Importance Level 3.
3	Buildings or structures that as a whole may contain people in crowds, or contents of high value to the community, or that pose hazards to people in crowds.	Buildings and facilities where more than 300 people can congregate in one area. Buildings and facilities with primary school, secondary school or day-care facilities with capacity greater than 250. Buildings and facilities for colleges or adult education facilities with a capacity greater than 500. Health care facilities with a capacity of 50 or more residents but not having surgery or emergency treatment facilities. Jails and detention facilities. Any occupancy with an occupant load greater than 5,000. Power generating facilities, water treatment and waste water treatment facilities, any other public utilities not included in Importance Level 4. Buildings and facilities not included in Importance Level 4 containing hazardous materials capable of causing hazardous conditions that do not extend beyond property boundaries.
4	Buildings or structures that are essential to post-disaster recovery, or with significant post-disaster functions, or that contain hazardous materials.	Buildings and facilities designated as essential facilities. Buildings and facilities with special post-disaster functions. Medical emergency or surgery facilities. Emergency service facilities: fire, rescue, police station and emergency vehicle garages. Utilities required as back-up for buildings and facilities of Importance Level 4. Designated emergency shelters. Designated emergency centres and ancillary facilities. Buildings and facilities containing hazardous (toxic or explosive) materials in sufficient quantities capable of causing hazardous conditions that extend beyond property boundaries.

(from BCA Guidelines)

**Practitioner** – A specialist Geotechnical Engineer or Engineering Geologist who is degree qualified, is a member of a professional institute and who has achieved chartered professional status – being either Chartered Professional Engineer (CPEng) within the Institution of Engineers Australia, Chartered Professional Geologist (CPGeo) within the Australasian Institute of Mining & Metallurgy, or Registered Professional Geoscientist (RPGeo) within the Australian Institute of Geoscientists – specifically with Landslide Risk Management as a core competency.

A Practitioner will include persons qualified under the Institution of Engineers Australia NPER – LRM register.

It would normally be required that the Practitioner can demonstrate an appropriate minimum period of experience in the practice of landslide risk assessment and management in the geographic region, or can demonstrate relevant experience in similar geological settings.

**Regulator** – The regulatory authority [Federal Government/ State Government/ Instrumentality/ Regional/Local.

## APPENDIX B - LANDSLIDE TERMINOLOGY

The following provides a summary of landslide terminology which should (for uniformity of practice) be adopted when classifying and describing a landslide. It has been based on Cruden & Varnes (1996) and the reader is recommended to refer to the original documents for a more detailed discussion, other terminology and further examples of landslide types and processes.

### Landslide

The term **landslide** denotes “the movement of a mass of rock, debris or earth down a slope”. The phenomena described as landslides are not limited to either the “land” or to “sliding”, and usage of the word has implied a much more extensive meaning than its component parts suggest. Ground subsidence and collapse are excluded.

### Classification of Landslides

Landslide classification is based on Varnes (1978) system which has two terms: the first term describes the material type and the second term describes the type of movement.

The material types are **Rock**, **Earth** and **Debris**, being classified as follows:-

The material is either rock or soil.

- Rock:** is “a hard or firm mass that was intact and in its natural place before the initiation of movement.”
- Soil:** is “an aggregate of solid particles, generally of minerals and rocks, that either was transported or was formed by the weathering of rock in place. Gases or liquids filling the pores of the soil form part of the soil.”
- Earth:** “describes material in which 80% or more of the particles are smaller than 2 mm, the upper limit of sand sized particles.”
- Debris:** “contains a significant proportion of coarse material; 20% to 80% of the particles are larger than 2 mm and the remainder are less than 2 mm.”

The terms used should describe the displaced material in the landslide before it was displaced.

The types of movement describe how the landslide movement is distributed through the displaced mass. The five kinematically distinct types of movement are described in the sequence **fall**, **topple**, **slide**, **spread** and **flow**.

The following table shows how the two terms are combined to give the landslide type:

Table B1: Major types of landslides. Abbreviated version of Varnes’ classification of slope movements (Varnes, 1978).

TYPE OF MOVEMENT		TYPE OF MATERIAL	
		BEDROCK	ENGINEERING SOILS
			Predominantly Coarse      Predominantly Fine
FALLS		Rock fall	Debris fall      Earth fall
TOPPLES		Rock topple	Debris topple      Earth topple
SLIDES	ROTATIONAL	Rock slide	Debris slide      Earth slide
	TRANSLATIONAL		
LATERAL SPREADS		Rock spread	Debris spread      Earth spread
FLOWS		Rock flow (Deep creep)	Debris flow      Earth flow (Soil creep)
COMPLEX		Combination of two or more principle types of movement	

Figure B1 gives schematics to illustrate the major types of landslide movement. Further information and photographs of landslides are available on the USGS website at <http://landslides.usgs.gov>.

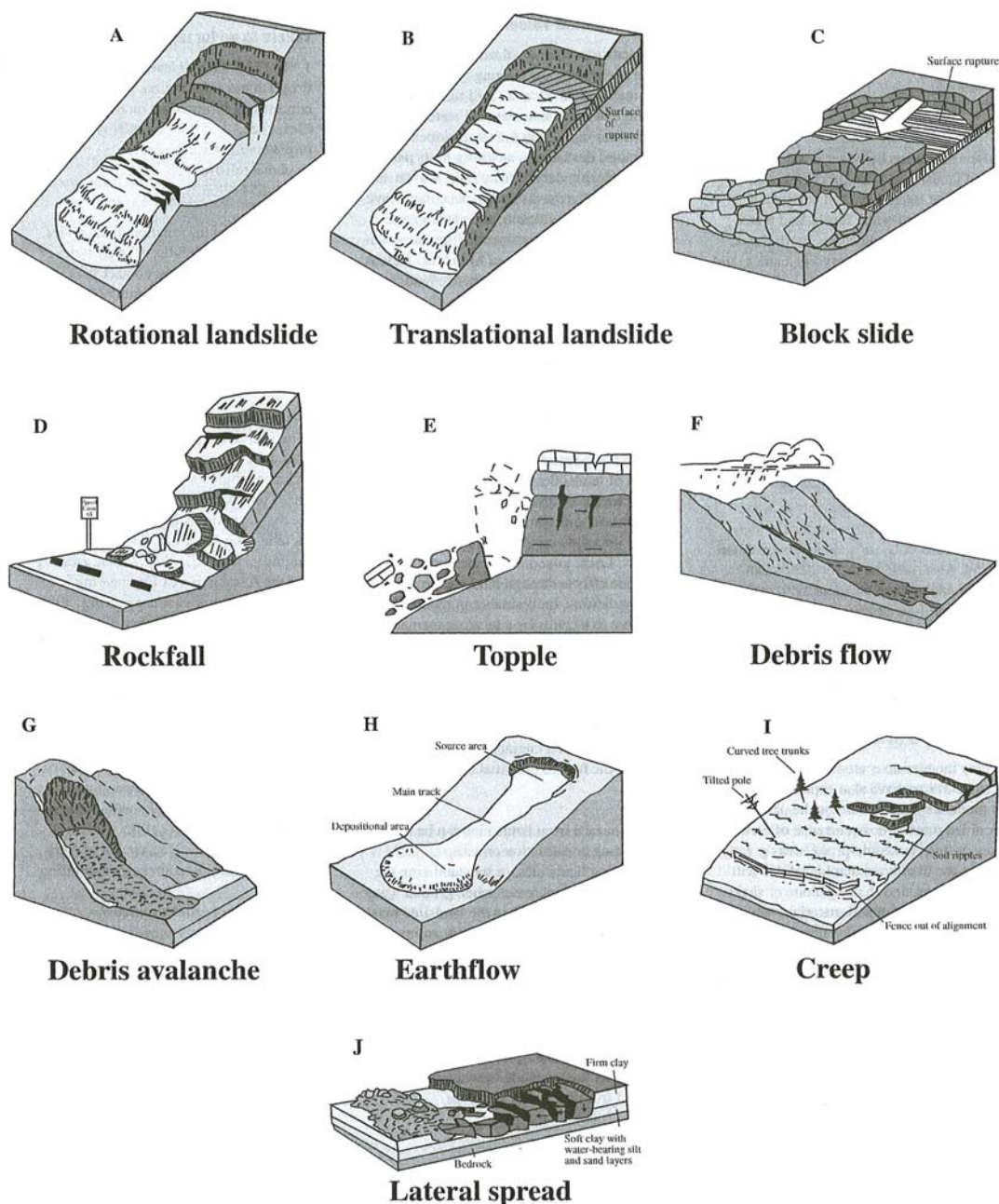


Figure B1: These schematics illustrate the major types of landslide movement.  
(From US Geological Survey Fact Sheet 2004-3072, July 2004, with kind permission for reproduction.)

The nomenclature of a landslide can become more elaborate as more information about the movement becomes available. To build up the complete identification of the movement, descriptors are added in front of the two-term classification using a preferred sequence of terms. The suggested sequence provides a progressive narrowing of the focus of the descriptors, first by time and then by spatial location, beginning with a view of the whole landslide, continuing with parts of the movement and finally defining the materials involved. The recommended sequence, as shown in Table B2, describes activity (including state, distribution and style) followed by descriptions of all movements (including rate, water content, material and type). Definitions of the terms in Table B2 are given in Cruden & Varnes (1996).

Second or subsequent movements in complex or composite landslides can be described by repeating, as many times as necessary, the descriptors used in Table B2. Descriptors that are the same as those for the first movement may then be dropped from the name.

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For example, the very large and rapid slope movement that occurred near the town of Frank, Alberta, Canada, in 1903 was a *complex, extremely rapid, dry rock fall – debris flow*. From the full name of this landslide at Frank, one would know that both the debris flow and the rock fall were extremely rapid and dry because no other descriptors are used for the debris flow.

The full name of the landslide need only be given once; subsequent references should then be to the initial material and type of movement; for the above example, “the rock fall” or “the Frank rock fall” for the landslide at Frank, Alberta.

Table B2: Glossary for forming names of landslides.

<b>Activity</b>			
<b>State</b>	<b>Distribution</b>	<b>Style</b>	
Active	Advancing	Complex	
Reactivated	Retrogressive	Composite	
Suspended	Widening	Multiple	
Inactive	Enlarging	Successive	
Dormant	Confined	Single	
Abandoned	Diminishing		
Stabilised	Moving		
Relict			
<b>Description of First Movement</b>			
<b>Rate</b>	<b>Water Content</b>	<b>Material</b>	<b>Type</b>
Extremely rapid	Dry	Rock	Fall
Very rapid	Moist	Earth	Topple
Rapid	Wet	Debris	Slide
Moderate	Very Wet		Spread
Slow			Flow
Very slow			
Extremely slow			

Note: Subsequent movements may be described by repeating the above descriptors as many times as necessary. These terms are described in more detail in Cruden & Varnes (1996) and examples are given.

### Landslide Features

Varnes (1978, Figure 2.1t) provided an idealised diagram showing the features for a *complex earth slide – earth flow*, which has been reproduced here as Figure B2. Definitions of landslide dimensions are given in Cruden & Varnes (1996).

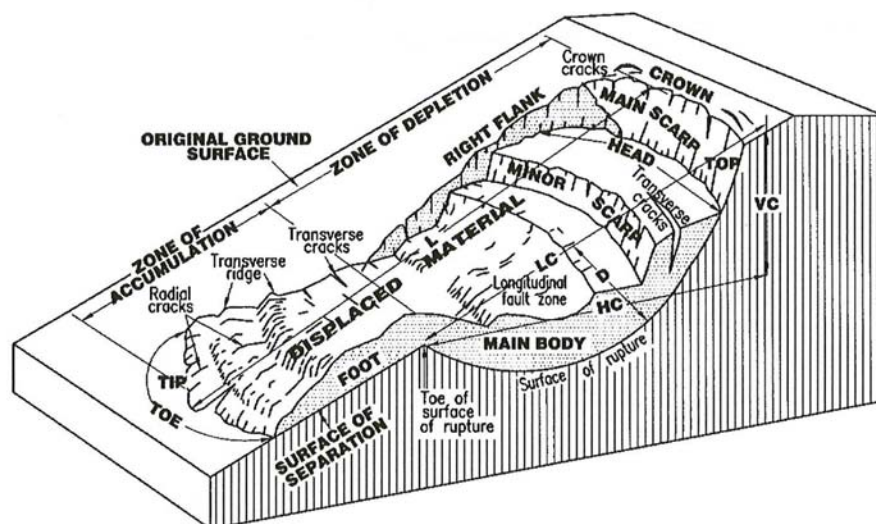


Figure B2: Block of Idealised Complex Earth Slide – Earth Flow

(Varnes, D J (1978), *Slope Movement Types and Processes*. In *Special Report 176: Landslides: Analysis and Control* (R L Schuster & R J Krizek, eds.), TRB, National Research Council, Washington, DC, pp.11-33).

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## Rate of Movement

Figure B3 shows the velocity scale proposed by Cruden & Varnes (1996) which rationalises previous scales. The term “creep” has been omitted due to the many definitions and interpretations in the literature.

Velocity Class	Description	Velocity (mm/sec)	Typical Velocity	Probable Destructive Significance
7	Extremely Rapid			Catastrophe of major violence; buildings destroyed by impact of displaced material; many deaths; escape unlikely
		$5 \times 10^3$	5 m/sec	
6	Very Rapid			Some lives lost; velocity too great to permit all persons to escape
		$5 \times 10^1$	3 m/min	
5	Rapid			Escape evaluation possible; structures, possessions, and equipment destroyed
		$5 \times 10^{-1}$	1.8 m/hr	
4	Moderate			Some temporary and insensitive structures can be temporarily maintained
		$5 \times 10^{-3}$	13 m/month	
3	Slow			Remedial construction can be undertaken during movement; insensitive structures can be maintained with frequent maintenance work if total movement is not large during a particular acceleration phase
		$5 \times 10^{-5}$	1.6 m/year	
2	Very Slow			Some permanent structures undamaged by movement
		$5 \times 10^{-7}$	15 mm/year	
	Extremely SLOW			Imperceptible without instruments; construction POSSIBLE WITH PRECAUTIONS

Figure B3: Proposed Landslide Velocity Scale and Probable Destructive Significance.

## REFERENCES AND ACKNOWLEDGEMENT

- Cruden, D.M., & Varnes, D.J. (1996), “Landslide Types and Processes”, Ch.3 in “Landslides. Investigation and Mitigation”, Eds Turner, A.K. and Schuster, R.L. Special Report 247, Transport Research Board, National Research Council, Washington D.C. Extracts reprinted above by kind permission of the authors and publishers. Copies of the publication can be obtained from “Transport Research Board, National Research Council, 2101 Constitution Avenue, N.W., Washington D.C. 20418, USA.
- IAEG (International Association of Engineering Geology) Commission on Landslides, (1990). Suggested nomenclature for landslides, Bulletin IAEG, No. 41, pp.13-16.
- Varnes, D.J. (1978). Slope Movement Types and Processes. In *Special Report 176: Landslides: Analysis and Control* (R.L. Schuster and R.J. Krizek, eds.), TRB, National Research Council, Washington, D.C., pp.11-33.
- WP/WLI (International Geotechnical Societies’ UNESCO Working Party on World Landslide Inventory) (1990). A suggested method for reporting a landslide. Bulletin IAEG, 41, pp.5-12
- WP/WLI (International Geotechnical Societies’ UNESCO Working Party on World Landslide Inventory) (1993). A suggested method for describing the activity of a landslide. Bulletin International Association of Engineering Geology, 47: 53-57.
- WP/WLI (International Geotechnical Societies’ UNESCO Working Party on World Landslide Inventory) (1994). Multilingual Glossary for Landslides, Bitech Press, Vancouver, in press.



**PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007**  
**APPENDIX C: LANDSLIDE RISK ASSESSMENT**  
**QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY**

***QUALITATIVE MEASURES OF LIKELIHOOD***

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	Notional Boundary					
10 <sup>-1</sup>	5x10 <sup>-2</sup>	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10 <sup>-2</sup>		100 years		The event will probably occur under adverse conditions over the design life.	LIKELY	B
10 <sup>-3</sup>	5x10 <sup>-3</sup>	1000 years	200 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10 <sup>-4</sup>	5x10 <sup>-4</sup>	10,000 years	2000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10 <sup>-5</sup>	5x10 <sup>-5</sup>	100,000 years	20,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10 <sup>-6</sup>	5x10 <sup>-6</sup>	1,000,000 years	200,000 years	The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

**Note:** (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

***QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY***

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	Notional Boundary			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%		Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	40%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	10%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%	1%	Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

- Notes:** (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.
- (3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.
- (4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not *vice versa*

## PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

### APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

#### *QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY*

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	1: CATASTROPHIC 200%	2: MAJOR 60%	3: MEDIUM 20%	4: MINOR 5%	5: INSIGNIFICANT 0.5%
<b>A – ALMOST CERTAIN</b>	10 <sup>-1</sup>	VH	VH	VH	H	M or L (5)
<b>B - LIKELY</b>	10 <sup>-2</sup>	VH	VH	H	M	L
<b>C - POSSIBLE</b>	10 <sup>-3</sup>	VH	H	M	M	VL
<b>D - UNLIKELY</b>	10 <sup>-4</sup>	H	M	L	L	VL
<b>E - RARE</b>	10 <sup>-5</sup>	M	L	L	VL	VL
<b>F - BARELY CREDIBLE</b>	10 <sup>-6</sup>	L	VL	VL	VL	VL

**Notes:** (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

#### *RISK LEVEL IMPLICATIONS*

Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

**Note:** (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

## APPENDIX D -EXAMPLE FORMS

The following example forms have been prepared as templates to provide appropriate documentation for the control of submissions and approval process.

It is envisaged that the regulator would edit the forms to suit local requirements and to use terminology appropriate to regulatory framework of the regulator's LRM policy. Items between '<>' are to be edited as appropriate. The following terms have been used in a generic sense and should be amended by the regulator accordingly:

**<the Regulator>** - the authority responsible for the approval of the development application.

**<Regulator's geotechnical DCP>** - the appropriate LRM policy title/reference, or Development Control Plan (DCP).

**<add reference>** - the section or page of the geotechnical report which addresses the item.

**<PCA>** - the Principal Certifying Authority, or the authority who will be responsible for confirmation of compliance with the development approval conditions.

**<tolerable risk>** - amend to 'acceptable risk' if that is required by the <Regulator's geotechnical DCP> rather than tolerable.

**<Construction Certificate>** - the approval necessary to start construction which documents that design has complied with the conditions of approval for the development application.

**<Occupation Certificate>** - the final approval from the Regulator allowing occupation of the development once all required conditions of consent have been shown to be satisfied.

**<Subdivision Certificate>** - the final approval from the Regulator confirming that subdivision works have been completed in accordance with the conditions of consent such that development on individual lots may proceed.

**<Building Certificate>** - a certificate issued by the Regulator confirming that either existing development is in accordance with the Regulator's requirements, or confirming that the Regulator is not aware of any non-compliance which will require rectification works.

## ACKNOWLEDGEMENT

These example forms have been based on the forms included in the Wollongong City "Geotechnical Development Control Plan - Development of Sites which may be subject to Slope Instability", effective from 12 July 2006 - with their kind permission. Copies of the Word documents may be obtained from AGS by regulators wishing to prepare their own forms.

<b>FORM</b>	<b>A</b>	Page 1 of 2																	
Office Use Only		<h2 style="margin: 0;">Geotechnical Declaration and Verification Development Application</h2>																	
		Regulator: <i>&lt;Add in or change to appropriate name&gt;</i>																	
<p><b>To be submitted with a development application. If this form is not submitted with the geotechnical report the report will be refused.</b></p> <p>This form is essential to verify that the geotechnical report has been prepared in accordance with <i>&lt;Regulator's geotechnical DCP&gt;</i> and that the author of the geotechnical report is a geotechnical engineer or engineering geologist as defined by <i>&lt;Regulator's geotechnical DCP&gt;</i>. Alternatively, where a geotechnical report has been prepared for subdivision or is greater than two years old or by a professional person not recognised by <i>&lt;Regulator's geotechnical DCP&gt;</i>, then this form may be used as technical verification of the geotechnical report if signed by a geotechnical engineer or engineering geologist as defined by <i>&lt;Regulator's geotechnical DCP&gt;</i>.</p>																			
<b>Section 1</b>		<b>Related Application</b>																	
<i>Reference</i>		What is the Council development application number?																	
<i>DA Site Address</i>																			
<i>DA Applicant</i>																			
<b>Section 2</b>		<b>Geotechnical Report</b>																	
<i>Details</i>		Title:																	
		Author's Company/ Organisation Name:	Report Reference No:																
		Author:	Dated:        /        /																
<b>Section 3</b>		<b>Checklist</b>																	
Geotechnical Requirements (Tick as appropriate, either Yes or No)		<p>The following checklist covers the minimum requirements to be addressed in a geotechnical report. This checklist is to accompany the report. Each item is to be cross-referenced to the section or page of the geotechnical report which addresses that item.</p>																	
<table style="width: 100%; border: none;"> <tr> <td style="text-align: center;">Yes</td> <td style="text-align: center;">No</td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> </table>		Yes	No	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<p>A review of readily available history of slope instability in the site or related land as per <i>&lt;Add reference&gt;</i></p> <p>An assessment of the risk posed by all reasonably identifiable geotechnical hazards as per <i>&lt;Add reference&gt;</i></p> <p>Plans and sections of the site and related land as per <i>&lt;Add reference&gt;</i></p> <p>Presentation of a geological model as per <i>&lt;Add reference&gt;</i></p> <p>Photographs and/or drawings of the site as per <i>&lt;Add reference&gt;</i></p> <p>A conclusion as to whether the site is suitable for the development proposed to be carried out either conditionally or unconditionally as per <i>&lt;Add reference&gt;</i></p> <p>If any items above are ticked No, an explanation is to be included in the report to justify why. <i>&lt;Add reference&gt;</i></p>	
Yes	No																		
<input type="checkbox"/>	<input type="checkbox"/>																		
<input type="checkbox"/>	<input type="checkbox"/>																		
<input type="checkbox"/>	<input type="checkbox"/>																		
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<table style="width: 100%; border: none;"> <tr> <td style="text-align: center;">Yes</td> <td style="text-align: center;">No</td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> </table>		Yes	No	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<p>Subject to recommendations and conditions relevant to:</p> <p>selection and construction of footing systems,</p> <p>earthworks,</p> <p>surface and sub surface drainage,</p> <p>recommendations for the selection of structural systems consistent with the geotechnical assessment of the risk,</p> <p>any conditions that may be required for the ongoing mitigation and maintenance of the site and the proposal, from a geotechnical viewpoint,</p> <p>highlighting and detailing the inspection regime to provide the &lt;PCA&gt; and builder with adequate notification for all necessary inspections.</p> <p>State Design life adopted:        Years</p>	
Yes	No																		
<input type="checkbox"/>	<input type="checkbox"/>																		
<input type="checkbox"/>	<input type="checkbox"/>																		
<input type="checkbox"/>	<input type="checkbox"/>																		
<input type="checkbox"/>	<input type="checkbox"/>																		
<input type="checkbox"/>	<input type="checkbox"/>																		
<input type="checkbox"/>	<input type="checkbox"/>																		
<input type="checkbox"/>	<input type="checkbox"/>																		

**Note:** *<Add reference>*: Add in the relevant section or page number of the listed geotechnical report which addresses each item.

<b>FORM</b>	<b>A</b>	Page 2 of 2			
<h2 style="margin: 0;">Geotechnical Declaration and Verification Development Application</h2>					
<b>Section 4</b> <b>List of Drawings referenced in Geotechnical Report</b>					
Design Documents	Description	Plan or Document No.	Revision or Version No.	Date	Author
<b>Section 5</b> <b>Declaration</b>					
Declaration (Tick all that apply) Yes <input type="checkbox"/> No <input type="checkbox"/>  <input type="checkbox"/> N/A <input type="checkbox"/> <input type="checkbox"/> N/A <input type="checkbox"/>  <input type="checkbox"/> No <input type="checkbox"/>  <input type="checkbox"/> No <input type="checkbox"/>  <input type="checkbox"/> No <input type="checkbox"/>	<p>I am a geotechnical engineer or engineering geologist as defined by the <i>&lt;Regulator's geotechnical DCP&gt;</i> and on behalf of the company below, I:</p> <p>am aware that the geotechnical report I have either prepared or am technically verifying (referenced above) is to be submitted in a support of a development application for the proposed development site (referenced above) and its findings will be relied upon by <i>&lt;the Regulator&gt;</i> in determining the development application.</p> <p>prepared the geotechnical report referenced above in accordance with the AGS (2007c) as amended and <i>&lt;Regulator's geotechnical DCP&gt;</i>.</p> <p>am willing to technically verify that the Geotechnical Report referenced above has been prepared in accordance with the AGS (2007c) as amended and <i>&lt;Regulator's geotechnical DCP&gt;</i>.</p> <p>am willing to technically verify that the geotechnical report prepared for the development application for the site confirms the land will achieve the level of <i>&lt;tolerable risk&gt;</i> of slope instability as a result of the considerations described in <i>&lt;add reference to specific section of&gt; &lt;Regulator's geotechnical DCP&gt;</i> taking into account the total development and site disturbances proposed.</p> <p>am willing to technically verify that the geotechnical report prepared for the site and related land being greater than two years old confirms the land will achieve the level of <i>&lt;tolerable risk&gt;</i> of slope instability as a result of the considerations described <i>&lt;add reference to specific section of&gt; of &lt;Regulator's geotechnical DCP&gt;</i> taking into account the total development and site disturbances proposed.</p> <p>have professional indemnity insurance in accordance with <i>&lt;Regulator's geotechnical DCP&gt;</i> of not less than \$.... million, being in force for the year in which the report is dated, with retroactive cover under this insurance policy extending back to the engineer's first submission to <i>&lt;the Regulator&gt;</i>.</p>				
<b>Section 6</b> <b>Geotechnical Engineer or Engineering Geologist Details</b>					
Company/ Organisation Name					
Name (Company Representative)	Surname:		Mr /Mrs /Other:		
	Given Names:				
	Chartered Professional Status:		Registration No:		
Signature			Dated:     /     /		

Reference: AGS (2007c) *"Practice Note Guidelines for Landslide Risk Management"*. Australian Geomechanics Society, Australian Geomechanics, V42, N1, March 2007.

Note: N/A = Not Applicable.

<b>FORM</b>	<b>B</b>	Page 1 of 2				
Office Use Only		<b>Structural/Civil/Geotechnical Engineering</b> <b>Declaration – &lt;Construction Certificate&gt; Application</b>				
		Regulator: <Add in or change to appropriate name>				
<p><b>To be submitted with the structural design forming part of an application for a &lt;construction certificate&gt;.</b></p> <p>This form must be attached with the submission of the structural documentation required for the determination of a &lt;construction certificate&gt; or combined development application and &lt;construction certificate&gt; submission.</p> <p>This form is essential, as it provides evidence to the &lt;PCA&gt; determining the &lt;construction certificate&gt;, that the structural design has been prepared or verified by a structural engineer or civil engineer as defined by &lt;Regulator's geotechnical DCP&gt; and that the structural design has been prepared in accordance with the recommendations given in the geotechnical report for the same development. This form also covers additional design documents required to cover other works not shown on the main structural/civil design drawings. This form is also essential to establish that the recommendations given in the geotechnical report have been interpreted and incorporated into the structural design as originally intended by the geotechnical engineer in preparing the geotechnical report.</p>						
<b>Section 1      Related Application</b>						
Reference		What is the <Regulator's> development application number?				
DA Site Address						
DA Applicant						
<b>Section 2      Structural/Civil Design Documents</b>						
List of Structural/Civil Design Documents (More space on page two if required)		Description	Plan or Document No.	Revision or Version No.	Date	Author
<b>Section 3      Geotechnical Report</b>						
Details		Title:				
		Author:		Dated:        /        /		
		Author's Company/ Organisation Name:		Report Reference No:		
<b>Section 4      Declaration by Structural/Civil Engineer or Designer of Additional Design Documents in Relation to a Geotechnical Report</b>						
Declaration (Tick all that apply) Yes      No <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>		I am a structural or civil engineer as defined by the <Regulator's geotechnical DCP> and on behalf of the company below.				
		I have prepared the structural designs listed in Section 2 above and/or Section 6 below, in accordance with the recommendations given in the above geotechnical report.				
		I am a design engineer and have prepared Additional Design documents listed in Section 7 below in accordance with the recommendations given in the above geotechnical report.				
		I am aware that the <PCA> will rely on this declaration in granting a <construction certificate> for works to which the above structural design documents and geotechnical report relate.				
		I certify that any residential structure designed or erected in accordance with the structural design prepared by the structural engineer or civil engineer achieves the performance requirements of Clause 1.3 of the current version of AS 2870 (this must be ticked when accompanied by minimal impact certification).				
		I have professional indemnity insurance in accordance with <Regulator's geotechnical DCP> of not less than \$.... million, being in force for the year in which the report is dated, with retroactive cover under this insurance policy extending back to the engineer's first submission to <the Regulator>.				

FORM	B	Structural/Civil/Geotechnical Engineering Declaration – <Construction Certificate> Application				
Section 5		Structural/Civil/Design Engineer Details				
Company/ Organisation Name						
Name (Company Representative)		Surname:		Mr /Mrs /Other:		
		Given:				
		Chartered Professional Status:		Registration No:		
Signature					Dated:        /        /	
Section 6		Ancillary Structural/Civil Design Required Prior to Completion of Geotechnical Declaration				
List of Structural Design Documents Required	Description	Company Responsible	Plan or Document No.	Revision or Version No.	Date of Additional Form B *	Author
	eg. Landscaping retaining walls					
	eg. Anchor design					
Section 7		Additional Design Documents Required Prior to Completion of Geotechnical Declaration				
List of Design Documents Required	Description	Company	Plan or Document No.	Revision or Version No.	Date of Additional Form B *	Author
	eg. Surface & subsoil drainage design					
	eg. Infiltration or effluent disposal					
Section 8 and 9 are not to be completed until each relevant ancillary and additional Form B has been completed and forwarded to the geotechnical engineer/engineering geologist						
Section 8		Declaration in Relation to Structural/Civil Designs and Additional Design Drawings				
Declaration (Tick all that apply) Yes        No <input type="checkbox"/> <input type="checkbox"/>  <input type="checkbox"/> <input type="checkbox"/>  <input type="checkbox"/> <input type="checkbox"/>		<p>I am a geotechnical engineer or engineering geologist as defined by the &lt;Regulator's geotechnical DCP&gt; and on behalf of the company below:</p> <p>I prepared and/or technically verified the above geotechnical report and now declare that I have viewed the above listed design documents prepared for the same development.</p> <p>I am satisfied that the recommendations given in the above geotechnical report have been incorporated into the design documents as intended.</p> <p>I consider no additional drawings are required to show all the required works listed in the Geotechnical Report.</p>				
Section 9		Geotechnical Engineer or Engineering Geologist Details				
Company/ Organisation Name						
Name (Company Representative)		Surname:		Mr /Mrs /Other:		
		Given Names:				
		Chartered Professional Status:		Registration No:		
Signature					Dated:        /        /	

Note: \* A separate Form B is required to be completed by the design engineer for those works listed in each of Sections 6 and 7 of this Form B.



FORM	C	Geotechnical Declaration Subdivision <Construction Certificate> Application		Page 1 of 2
		Office Use Only		Regulator: <Add in or change to appropriate name>
<p>To be submitted with an application for an engineering &lt;construction certificate&gt; for subdivision of land. This form must be attached to the application for the &lt;construction certificate&gt;.</p> <p>This form is essential to verify that the geotechnical report has been prepared in accordance with &lt;Regulator's geotechnical DCP&gt; and that the author of the geotechnical report is a geotechnical engineer or engineering geologist as defined by &lt;Regulator's geotechnical DCP&gt;. Alternatively, where a geotechnical report has been prepared by a professional person not recognised by the &lt;Regulator's geotechnical DCP&gt;, then this form may be used as technical verification of the geotechnical report if signed by a geotechnical engineer or engineering geologist as defined by &lt;Regulator's geotechnical DCP&gt;.</p>				
<b>Section 1 Related Application</b>				
Reference		What is the Regulator's Development Application Number?		
DA Site Address				
DA Applicant				
<b>Section 2 Geotechnical Report</b>				
Details		Title:		
		Author:	Dated:        /        /	
		Author's Company/ Organisation Name:	Report Reference No:	
<b>Section 3 Declaration</b>				
Declaration (Tick all that apply) Yes      No <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>		I am a geotechnical engineer or engineering geologist as defined by the <Regulator's geotechnical DCP> and on behalf of the company below:  I prepared the geotechnical report referenced above in accordance with the AGS (2007c) as amended and the <Regulator's geotechnical DCP>.  I am willing to technically verify that the geotechnical report referenced above has been prepared in accordance with the AGS (2007c) as amended and <Regulator's geotechnical DCP>.  I have professional indemnity insurance in accordance with <Regulator's geotechnical DCP> of not less than \$.... million, being in force for the year in which the report is dated, with retroactive cover under this insurance policy extending back to the engineer's first submission to <the Regulator>.  I am aware that the geotechnical report I have either prepared or am technically verifying (referenced above) is to be submitted in support of an engineering <construction certificate> for subdivision of land for the proposed development site (referenced above) and its findings will be relied upon by <the Regulator> determining the engineering <construction certificate>.		

<b>FORM</b>	<b>C</b>	Page 2 of 2	
		<b>Geotechnical Declaration</b> <b>Subdivision &lt;Construction Certificate&gt; Application</b>	
<b>Section 4</b>		<b>Checklist</b>	
Geotechnical Requirements (Tick as appropriate, either Yes or No)		The following checklist covers the minimum requirements to be addressed in a geotechnical report in accordance with <Add reference to specific section of> <Regulator's geotechnical DCP>. This checklist is to accompany the report.	
Yes	No		
<input type="checkbox"/>	<input type="checkbox"/>	The extent and stability of proposed embankments including those acting as retarding basins <Add reference>	
<input type="checkbox"/>	<input type="checkbox"/>	Recommended Geotechnical testing requirements <Add reference>	
<input type="checkbox"/>	<input type="checkbox"/>	Required level of geotechnical supervision for each part of the works as defined under AS3798 – Guidelines on Earthworks for Commercial and Residential Developments <Add reference>	
<input type="checkbox"/>	<input type="checkbox"/>	Compaction specification for all fill within private subdivisions <Add reference>	
<input type="checkbox"/>	<input type="checkbox"/>	The level of risk to existing adjacent dwellings as a result of a construction contractor using vibratory rollers anywhere within the site the subject of these works. In the event that vibratory rollers could affect adjacent dwellings, 'high risk' areas shall be identified on a plan and the engineering plans shall be amended to indicate that no vibratory roller shall be used within that zone <Add reference>	
<input type="checkbox"/>	<input type="checkbox"/>	The impact of the installation of services on overall site stability and recommendations on short term drainage methods, shoring requirements and other remedial measures that may be appropriate during installation <Add reference>	
<input type="checkbox"/>	<input type="checkbox"/>	The preferred treatment of any areas of unacceptable risk within privately owned allotments <Add reference>	
<input type="checkbox"/>	<input type="checkbox"/>	Requirement for subsurface drainage lines <Add reference>	
<input type="checkbox"/>	<input type="checkbox"/>	Overall suitability of the engineering plans for the proposed development <Add reference>	
<input type="checkbox"/>	<input type="checkbox"/>	Risk mitigation plan defined <Add reference>	
<b>Section 5</b>		<b>Geotechnical Engineer or Engineering Geologist Details</b>	
Company/ Organisation Name			
Name (Company Representative)		Surname:	Mr /Mrs /Other:
		Given Names:	
		Chartered Professional Status:	Registration No:
Signature			
		Dated:        /        /	

Reference: AGS (2007c) "Practice Note Guidelines for Landslide Risk Management". Australian Geomechanics Society, Australian Geomechanics, V42, N1, March 2007.

**Note:** <Add reference>: Add in the relevant section or page number of the listed geotechnical report which addresses each item.

# PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

<b>FORM</b>	<b>D</b>	Page 1 of 2				
<b>Geotechnical Declaration Minor Impact</b>						
Office Use Only				Regulator: <i>&lt;Add in or change to appropriate name&gt;</i>		
<p>This form may be used where minor construction works present minimal or no geotechnical impact on the site or related land. A geotechnical engineer or engineering geologist must inspect the site and/or review the proposed development documentation to determine if the proposed development requires a geotechnical report to be prepared to accompany the development application. Where the geotechnical engineer determines that such a report is not required then they must complete this form and attach design recommendations where required. A copy of this form with design recommendation, if required, must be submitted with the development application.</p> <p><b>Note:</b> In all situations, this form will need to be accompanied by Form B where the structural engineer or civil engineer certifies that any residential structure designed or erected in accordance with the plans and specifications prepared by the structural engineer or civil engineer achieve the performance requirements of Clause 1.3 of the current version of AS 2870.</p> <p><b>Note:</b> The use of this form does not preclude the geotechnical consultant from requiring a Geotechnical Report.</p>						
<b>Section 1 Related Application</b>						
<i>Reference</i>		What is the Council Development Application Number?				
<i>DA Site Address</i>						
<i>DA Applicant</i>						
<b>Section 2 Documentation</b>						
<i>List of Documents Reviewed (More space on page two if required)</i>		Description	Plan or Document No.	Revision or Version No.	Date	Author
<b>Section 3 Declaration</b>						
Declaration (Tick all that apply)		I am a geotechnical engineer or engineering geologist as defined by the <i>&lt;Regulator's geotechnical DCP&gt;</i> and I have inspected the site and reviewed the proposed development at the DA Site Address described above. As a result of my consideration of the <i>&lt;Regulator's geotechnical DCP&gt;</i> , of my site inspection and review of the documentation listed above, I have determined and declare that, on behalf of the company below:				
Yes <input type="checkbox"/> No <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>		The current load-bearing capacity of the site will not be exceeded or be adversely impacted on by the proposed development, and  The proposed works are of such a minor nature that the requirement for geotechnical advice in the form of a geotechnical report, prepared in accordance with <i>&lt;Regulator's geotechnical DCP&gt;</i> is considered unnecessary for the adequate and safe design of the structural elements to be incorporated into the new works as there is no change to the current landslide risk on the site in accordance with AGS (2007c), and  In accordance with AS 2870 Residential Slabs and Footings, the site is to be classified as a type: _____  I have attached design recommendations to be incorporated in the structural design in accordance with this site classification.  I have professional indemnity insurance in accordance with <i>&lt;Regulator's geotechnical DCP&gt;</i> of not less than \$.... million, being in force for the year in which the report is dated, with retroactive cover under this insurance policy extending back to the engineer's first submission to <i>&lt;the Regulator&gt;</i> .  I am aware that this declaration shall be used by <i>&lt;The Regulator&gt;</i> as an essential component in granting development consent for a structure to be erected on the site or related land without requiring submission of a geotechnical report complying with the <i>&lt;Regulator's geotechnical DCP&gt;</i> in support of the development application.				

Reference: AGS (2007c) "Practice Note Guidelines for Landslide Risk Management". Australian Geomechanics Society, Australian Geomechanics, V42, N1, March 2007.

FORM	D	Geotechnical Declaration Minor Impact				Page 2 of 2
Section 4 Additional Documentation						
<i>List of Documents Reviewed</i>	Description	Plan or Document No.	Revision or Version No.	Date	Author	
Section 5 Geotechnical Engineer or Engineering Geologist Details						
<i>Company/ Organisation Name</i>						
Name (Company Representative)	Surname:		Mr /Mrs /Other:			
	Given Names:					
	Chartered Professional Status:			Registration No:		
Signature				Dated:       /       /		

# PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

FORM	E	Geotechnical Declaration Remediation		Page 1 of 2
		Office Use Only		Regulator: <i>&lt;Add in or change to appropriate name&gt;</i>
<p>This form must be submitted where development must be staged for geotechnical reasons and remediation of the site to a <i>&lt;tolerable risk&gt;</i> is necessary prior to any further development continuing on the site.</p> <p>This form is essential, as it provides verification at each stage of the development, prior to the next stage commencing, that the remediation of the site to a <i>&lt;tolerable risk&gt;</i> has been carried out in accordance with the requirements of the geotechnical report and <i>&lt;add reference to specific section&gt;</i> of <i>&lt;Regulator's geotechnical DCP&gt;</i> and that no unforeseen ground conditions have been encountered which could impact on the integrity of structures on site or related land or the landslide risk. The geotechnical engineer or engineering geologist who prepared and/or verified the report must carry out site inspections as determined by the report to ensure that the design(s) documented on Form(s) B have been completed prior to signing this form.</p>				
Section 1 Related Application				
Reference		What is the Development Application number?		
DA Site Address		Development Stage (s):		
DA Applicant				
Section 2 Geotechnical Report				
Details		Title:		
		Author:		Dated: / /
		Author's Company/ Organisation Name:		Report Reference No:
Section 3 Declaration				
Declaration (Tick all that apply)		I am a geotechnical engineer or engineering geologist as defined by the <i>&lt;Regulator's geotechnical DCP&gt;</i> and, on behalf of the company below:		
Yes <input type="checkbox"/>	No <input type="checkbox"/>	I inspected and am satisfied that the foundation materials upon which the structural elements of the development have been erected, complied with the requirements and recommendations specified in the geotechnical report for Stage (s) <i>&lt;add&gt;</i> of the development.		
<input type="checkbox"/>	<input type="checkbox"/>	To the best of my knowledge, I am satisfied that Stage(s) <i>&lt;add&gt;</i> of the development referred to above have been carried out in accordance with all the requirements and recommendations of the above geotechnical report, and conditions of development consent relating to geotechnical issues.		
<input type="checkbox"/>	<input type="checkbox"/>	To the best of my knowledge, I am satisfied that where changes to the development occurred during construction, those changes were carried out in accordance with all the requirements and recommendations of the above geotechnical report, conditions of development consent relating to geotechnical issues, and any site instructions or site reports issued by me as listed below.		
<input type="checkbox"/>	<input type="checkbox"/>	I am aware that the <i>&lt;PCA&gt;</i> requires this certificate at the end of stage of the development specified in the development approval and prior to any further development continuing on the site and related land.		
<input type="checkbox"/>	<input type="checkbox"/>	I am willing to technically verify that the site or related land will now achieve the level of <i>&lt;tolerable risk&gt;</i> of slope instability as defined by <i>&lt;Regulator's geotechnical DCP&gt;</i> .		
<input type="checkbox"/>	<input type="checkbox"/>	I have professional indemnity insurance in accordance with <i>&lt;Regulator's geotechnical DCP&gt;</i> of not less than \$.... million, being in force for the year in which the report is dated, with retroactive cover under this insurance policy extending back to the engineer's first submission to <i>&lt;the Regulator&gt;</i> .		

Note: *<add>* relevant stage numbers to be inserted.

FORM	E	Geotechnical Declaration Remediation						Page 2 of 2
Section 4		List of Site Instructions and/or Site Reports Issued						
List of Documents Issued	Description/Title	Reference No.	Date	Author	Associated Design Drawings (tick as appropriate)			
					Yes	No		
Section 5		Geotechnical Engineer or Engineering Geologist Details						
Company/ Organisation Name								
Name (Company Representative)	Surname:		Mr /Mrs /Other:					
	Given Names:							
	Chartered Professional Status:		Registration No:					
Signature		Dated:        /        /						

<b>FORM</b>	<b>F</b>	Page 1 of 2				
Office Use Only		<b>Geotechnical Declaration Final Structural/Civil Certificate</b>		Regulator: <i>&lt;Add in or change to appropriate name&gt;</i>		
<p>This form must be submitted to the <i>&lt;PCA&gt;</i> at the completion of a project and prior to the issue of an <i>&lt;occupation certificate&gt;</i>.</p> <p>This form is essential, as it provides evidence to the <i>&lt;PCA&gt;</i> that the development works have been carried out in accordance with the requirements of the structural design, any site inspections, and that any changes to the development occurring during construction, were carried out in accordance with all the requirements and recommendations of the structural design and geotechnical report, conditions of development consent relating to geotechnical issues, and any site instructions issued.</p>						
<b>Section 1      Related Application</b>						
<i>Reference</i>		What is <i>&lt;the Regulator's&gt;</i> Development Application number?				
<i>DA Site Address</i>						
<i>DA Applicant</i>						
<b>Section 2      Geotechnical Report</b>						
<i>Details</i>		Title:				
		Author:		Dated:        /        /		
		Author's Company/ Organisation Name:		Report Reference No:		
<b>Section 3      Structural Civil Design Documents appropriate to the 'as constructed' development</b>						
<i>List of Structural Civil Design Documents</i> <i>(More space on page two if required)</i>		Description	Plan or Document No.	Revision or Version No.	Date	Author
<b>Section 4      Declaration</b>						
Declaration (Tick all that apply) Yes      No <input type="checkbox"/> <input type="checkbox"/>  <input type="checkbox"/> <input type="checkbox"/>  <input type="checkbox"/> <input type="checkbox"/>  <input type="checkbox"/> <input type="checkbox"/>  <input type="checkbox"/> <input type="checkbox"/>		<p>I am a structural or civil engineer as defined by the <i>&lt;Regulator's geotechnical DCP&gt;</i> and I prepared the above structural designs in accordance with the recommendations given in the geotechnical report described above on behalf of the company below. I:</p> <p>inspected and am satisfied that the structural elements of the above development have been erected, and complied with the requirements and recommendations specified in the structural design and geotechnical report.</p> <p>to the best of my knowledge, am satisfied that the above development has been carried out in accordance with all the requirements and recommendations of the structural design and above geotechnical report, and conditions of development consent relating to geotechnical issues.</p> <p>to the best of my knowledge, am satisfied that where changes to the development occurred during construction, those changes were carried out in accordance with all the requirements and recommendations of the structural design and above geotechnical report, conditions of development consent relating to geotechnical issues, and any site instructions issued by me as listed below.</p> <p>am aware that the <i>&lt;PCA&gt;</i> requires this certificate prior to issuing an <i>&lt;occupation certificate&gt;</i> for the above development and will rely on this certificate as verification that the above development has been erected, and complied with the requirements and recommendations specified in the structural design and geotechnical report as defined by <i>&lt;Regulator's geotechnical DCP&gt;</i> and in determining the <i>&lt;occupation certificate&gt;</i>.</p> <p>have professional indemnity insurance in accordance with <i>&lt;Regulator's geotechnical DCP&gt;</i> of not less than \$... million, being in force for the year in which the report is dated, with retroactive cover under this insurance policy extending back to the engineer's first submission to <i>&lt;the Regulator&gt;</i>.</p>				



FORM F	Geotechnical Declaration Final Structural/Civil Certificate						Page 2 of 2
	Section 5 List of Site Instructions Issued						
List of Documents Issued	Description/Title	Reference No.	Date	Author	Associated Design Drawings		
					Yes	No	
Section 6 Additional Design Documents							
List of Additional Design Documents	Description	Plan or Document No.	Revision or Version No.	Date	Author		
Section 7 Structural Engineer or Civil Engineer Details							
Company/ Organisation Name							
Name (Company Representative)	Surname:		Mr /Mrs /Other:				
	Given Names:						
	Chartered Professional Status:			Registration No:			
Signature				Dated:        /        /			

<b>FORM</b>	<b>G</b>	Page 1 of 2				
Office Use Only		Geotechnical Declaration Final Geotechnical Certificate				
		Regulator: <i>&lt;Add in or change to appropriate name&gt;</i>				
<p>This form must be submitted to the <i>&lt;PCA&gt;</i> at the completion of a project and prior to the issue of an <i>&lt;occupation or subdivision certificate&gt;</i>. This form is essential, as it provides verification that the development works have been carried out in accordance with the requirements of the geotechnical report during construction, and any site inspections, and that no unforeseen ground conditions have been encountered which could have an impact on the integrity of structures on site or related land and any subsequent geotechnical requirements introduced during the construction process.</p>						
Section 1      Related Application						
Reference		What is the Development Application number?				
DA Site Address						
DA Applicant						
Section 2      Geotechnical Report						
Details		Title:				
		Author:		Dated:      /      /		
		Author's Company/ Organisation Name:		Report Reference No:		
Section 3      Work as Executed Drawings & Ongoing Maintenance Plans relevant to Geotechnical Risk Management						
List of Documents (more space on page 2 if required)		Description	Plan or Document No.	Revision or Version No.	Date	Author
Section 4      Declaration						
Declaration (Tick all that apply) Yes      No <input type="checkbox"/> <input type="checkbox"/>  <input type="checkbox"/> <input type="checkbox"/>  <input type="checkbox"/> <input type="checkbox"/>  <input type="checkbox"/> <input type="checkbox"/>		I am a geotechnical engineer or engineering geologist as defined by the <i>&lt;Regulator's geotechnical DCP&gt;</i> and I prepared or verified the geotechnical report as described above on behalf of the company below. I:				
		inspected and am satisfied that the foundation materials upon which the structural elements of the development have been erected, complied with the requirements and recommendations specified in the geotechnical report.				
		to the best of my knowledge, am satisfied that the development referred to above has been carried out in accordance with all the requirements and recommendations of the above geotechnical report, and conditions of development consent relating to geotechnical issues.				
		to the best of my knowledge, am satisfied that where changes to the development occurred during construction, those changes were carried out in accordance with all the requirements and recommendations of the above geotechnical report, conditions of development consent relating to geotechnical issues, and any site instructions or site reports issued by me as listed below.				
		am aware that the <i>&lt;PCA&gt;</i> requires this certificate prior to issuing an occupation or subdivision certificate for the above development and will rely on this certificate as verification that the above development has achieved the necessary level of <i>&lt;tolerable risk&gt;</i> as defined by <i>&lt;Regulator's geotechnical DCP&gt;</i> and in determining the <i>&lt;occupation or subdivision certificate&gt;</i> .				

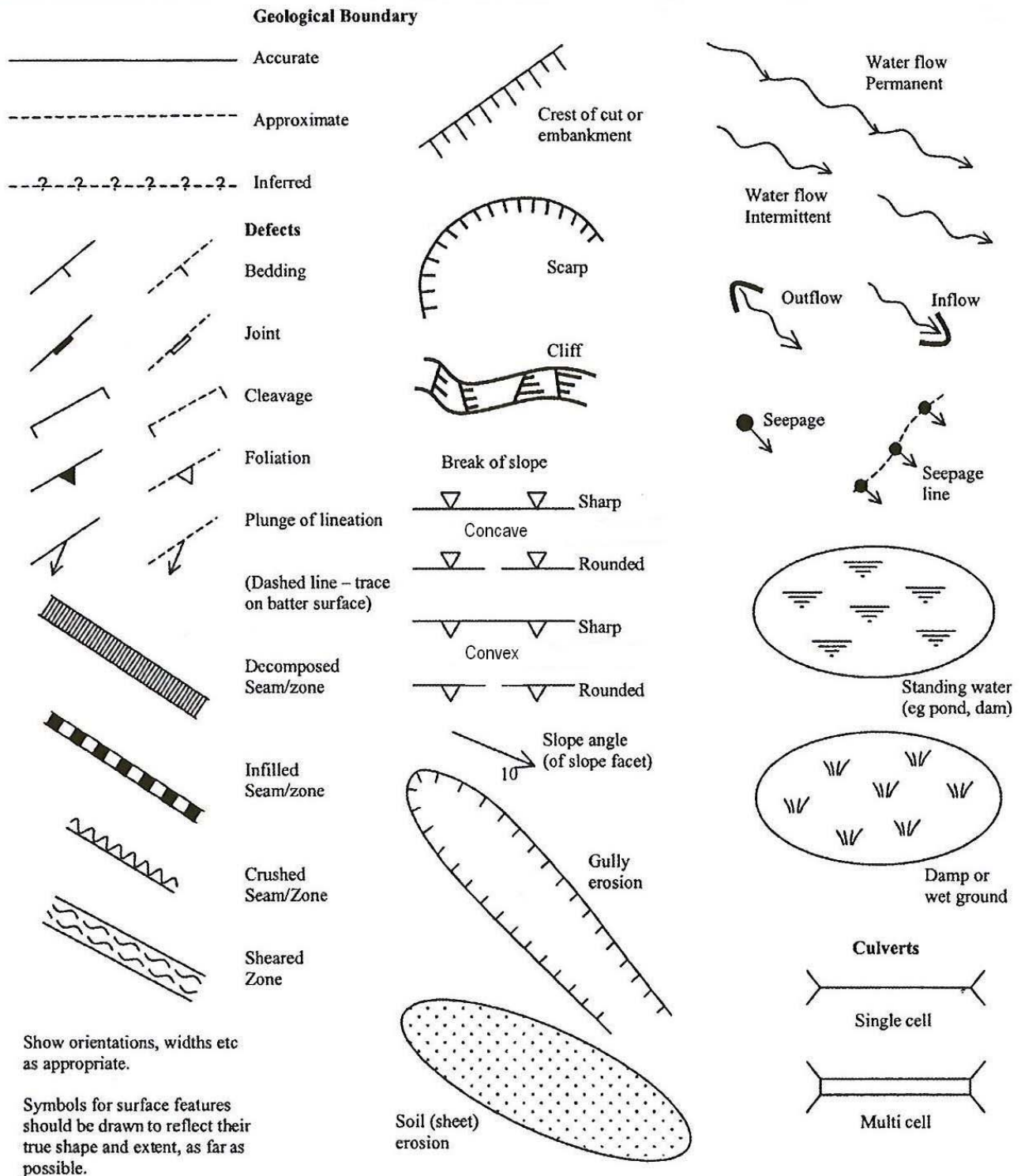
FORM	G	Geotechnical Declaration Final Geotechnical Certificate				
Section 5 List of Site Reports or Site Instructions Issued						
List of Documents Issued	Description/Title	Reference No.	Date	Author	Associated Design Drawings	
					Yes	No
Section 6 Additional Work as Executed Drawings and Ongoing Maintenance Plans relevant to Geotechnical Risk Management						
List of Additional Documents	Description	Plan or Document No.	Revision or Version No.	Date	Author	
Section 7 Geotechnical Engineer or Engineering Geologist Details						
Company/ Organisation Name						
Name (Company Representative)	Surname:		Mr /Mrs /Other:			
	Given Names:					
	Chartered Professional Status:			Registration No:		
Signature				Dated:        /        /		

# PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

FORM	H	Geotechnical Declaration <Building Certificate> or Order		Page 1 of 2
		Office Use Only		Regulator: <Add in or change to appropriate name>
This form is to be submitted with Application for a <Building Certificate> or in response to an order.				
Section 1 Related Application				
Reference		What is the Regulator's DA / BA / Order number?		
Site Address				
Applicant				
Section 2 Geotechnical Report				
Details		Title:		
		Author:	Dated:       /       /	
		Author's Company/ Organisation Name:	Report Reference No:	
Section 3 Declaration				
Declaration (Tick all that apply) Yes      No <input type="checkbox"/> <input type="checkbox"/>  <input type="checkbox"/> <input type="checkbox"/>  <input type="checkbox"/> <input type="checkbox"/>  <input type="checkbox"/> <input type="checkbox"/>  <input type="checkbox"/> <input type="checkbox"/>		<p>I am a geotechnical engineer or engineering geologist as defined by the &lt;Regulator's geotechnical DCP&gt; and I prepared or verified the geotechnical report as described above on behalf of the company below. I:</p> <p>have inspected the site and existing development and am satisfied that both the site and development achieves &lt;tolerable risk&gt; level requirement of the &lt;Regulator's geotechnical DCP&gt;. The attached report provides details of the assessment in accordance with the &lt;Regulator's geotechnical DCP&gt;. The report also contains recommendations as to any reasonable and practical measures that can be undertaken to reduce foreseeable risk.</p> <p>have inspected the site of the existing development. The attached report details the remedial actions required to be undertaken prior to me being prepared to certify that the site and the development achieves the &lt;tolerable risk&gt; criteria required by the &lt;Regulator's geotechnical DCP&gt;.</p> <p>to the best of my knowledge, am satisfied that where changes to the development occurred during construction, those changes were carried out in accordance with all the requirements and recommendations of the above geotechnical report, conditions of development consent relating to geotechnical issues, and any site reports or site instructions issued by me as listed below.</p> <p>am aware that the &lt;PCA&gt; requires this certificate prior to issuing a &lt;Building Certificate&gt; for the above development and will rely on this certificate as verification that the development has achieved the necessary level of &lt;tolerable risk&gt; as defined by &lt;Regulator's geotechnical DCP&gt; and in determining the &lt;occupation or subdivision certificate&gt;.</p> <p>have professional indemnity insurance in accordance with &lt;Regulator's geotechnical DCP&gt; of not less than \$.... million, being in force for the year in which the report is dated, with retroactive cover under this insurance policy extending back to the engineer's first submission to &lt;the Regulator&gt;.</p>		

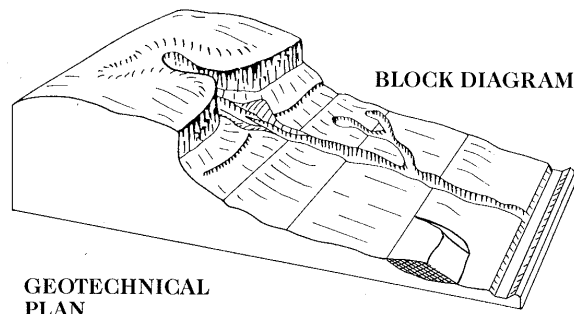
FORM	H	Geotechnical Declaration < <i>Building Certificate</i> > or Order					Page 2 of 2
Section 4 List of Site Reports or Site Instructions Issued							
List of Documents Issued	Description/Title	Reference No.	Date	Author	Associated Design Drawings		
					Yes	No	
Section 5 Geotechnical Engineer or Engineering Geologist Details							
Company/ Organisation Name							
Name (Company Representative)	Surname:			Mr /Mrs /Other:			
	Given Names:						
	Chartered Professional Status:			Registration No:			
Signature				Dated:        /        /			

## APPENDIX E - GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING SYMBOLS AND TERMINOLOGY

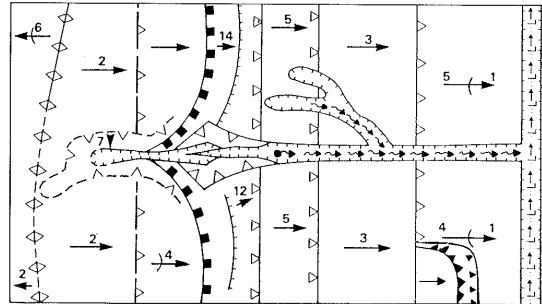


Examples of Mapping Symbols (after Guide to Slope Risk Analysis Version 3.1 November 2001, Roads and Traffic Authority of New South Wales).

# PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007



GEOTECHNICAL  
PLAN



SYMBOL	GROUND PROFILE	
		Convex
		Concave
		Convex
		Concave
		Breaks of slope
		Changes of slope
		Sharp
		Rounded
		Cliff or escarpment or sharp break 40° or more (estimated height in metres)
		Uniform slope
		Concave slope
		Convex slope
		Top
		Bottom
		Hummocky or irregular ground
		Open drain, unlined
		Open drain, lined
		Fenceline
		Property boundary
		Dry stone wall
		Major joint in rock face (opening in millimetres)
		Tension crack (opening in millimetres)

## Example of Mapping Symbols

(after V Gardiner & R V Dackombe (1983). Geomorphological Field Manual. George Allen & Unwin).



# PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

## APPENDIX F- EXAMPLE OF VULNERABILITY VALUES

### SUMMARY OF HONG KONG VULNERABILITY RANGES FOR PERSONS, AND RECOMMENDED VALUES FOR LOSS OF LIFE FOR LANDSLIDING IN SIMILAR SITUATIONS

The following table is adapted from P J Finlay, G R Mostyn & R Fell (1999). *Landslides: Prediction of Travel Distance and Guidelines for Vulnerability of Persons*. Proc 8<sup>th</sup>. Australia New Zealand Conference on Geomechanics, Hobart. Australian Geomechanics Society, ISBN 1 86445 0029, Vol 1, pp.105-113.

Case	Range in Data	Recommended Value	Comments
Person in Open Space			
If struck by a rockfall	0.1 – 0.7	0.5	May be injured but unlikely to cause death
If buried by debris	0.8 – 1.0	1.0	Death by asphyxia almost certain
If not buried	0.1 – 0.5	0.1	High chance of survival
Persons in a Vehicle			
If the vehicle is buried/crushed	0.9 – 1.0	1.0	Death is almost certain
If the vehicle is damaged only	0 – 0.3	0.3	High chance of survival
Person in a Building			
If the building collapses	0.9 – 1.0	1.0	Death is almost certain
If the building is inundated with debris and the person buried	0.8 – 1.0	1.0	Death is highly likely
If the debris strikes the building only	0 – 0.1	0.05	Very high chance of survival

### EXAMPLE OF VULNERABILITY VALUES FOR DESTRUCTION OF PEOPLE, BUILDINGS AND ROADS

The following table is adapted from Marion Michael-Leiba, Fred Baynes, Greg Scott & Ken Granger (2002). *Quantitative Landslide Risk Assessment of Cairns*. Australian Geomechanics, June 2002.

Geomorphic Unit	Vulnerability Values		
	People	Buildings	Roads
Hill slopes	0.05	0.25	0.3
Proximal debris fan	0.5	1.0	1.0
Distal debris fan	0.05	0.1	0.3

### EXAMPLE OF VULNERABILITY VALUES FOR LIFE FOR ROCKFALLS AND DEBRIS FLOWS FOR LAWRENCE HARGRAVE DRIVE PROJECT, COALCLIFF TO CLIFTON AREA, AUSTRALIA

The following table is adapted from R A Wilson, A T Moon, M Hendricks & I E Stewart (2005). *Application of quantitative risk assessment to the Lawrence Hargrave Drive Project, New South Wales, Australia*. Landslide Risk Management - Hungr, Fell, Couture & Eberhardt (eds) 2005. Taylor & Francis Group, London, ISBN 04 1538 043X.

Order of magnitude of landslide crossing road (m <sup>3</sup> )	Rockfalls from Scarborough Cliff		Debris flow from Northern Amphitheatre	
	Landslide hits car	Car hits landslide	Landslide hits car	Car hits landslide
0.03	0.05	0.006	–	–
0.3	0.1	0.002	–	–
3	0.3	0.03	0.001	–
30	0.7	0.03	0.01	0.001
300	1	0.03	0.1	0.003
3,000	1	0.03	1	0.003

**NOTE:** The above data should be applied with common sense, taking into account the circumstances of the landslide being studied. Judgment may indicate values other than the recommended value are appropriate for a particular case.

# PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

## APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

### GOOD ENGINEERING PRACTICE

### POOR ENGINEERING PRACTICE

#### ADVICE

GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
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#### PLANNING

SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
---------------	---	---

#### DESIGN AND CONSTRUCTION

HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.

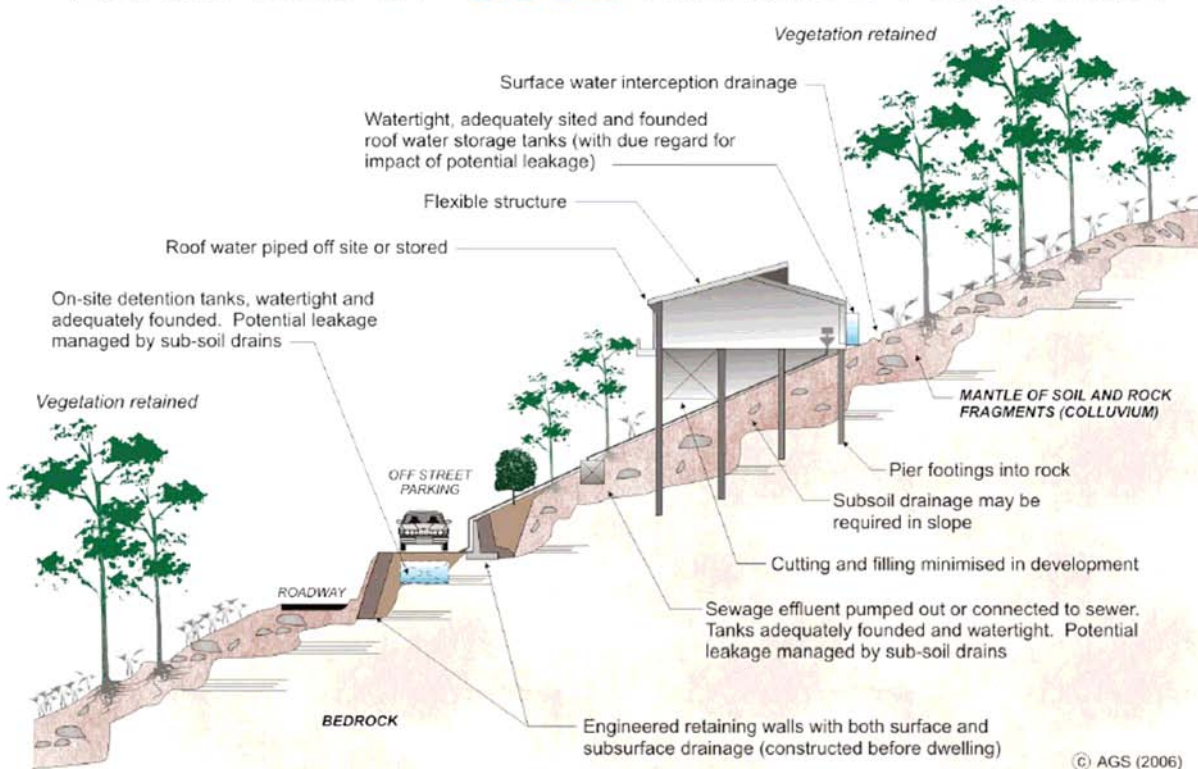
#### DRAWINGS AND SITE VISITS DURING CONSTRUCTION

DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	

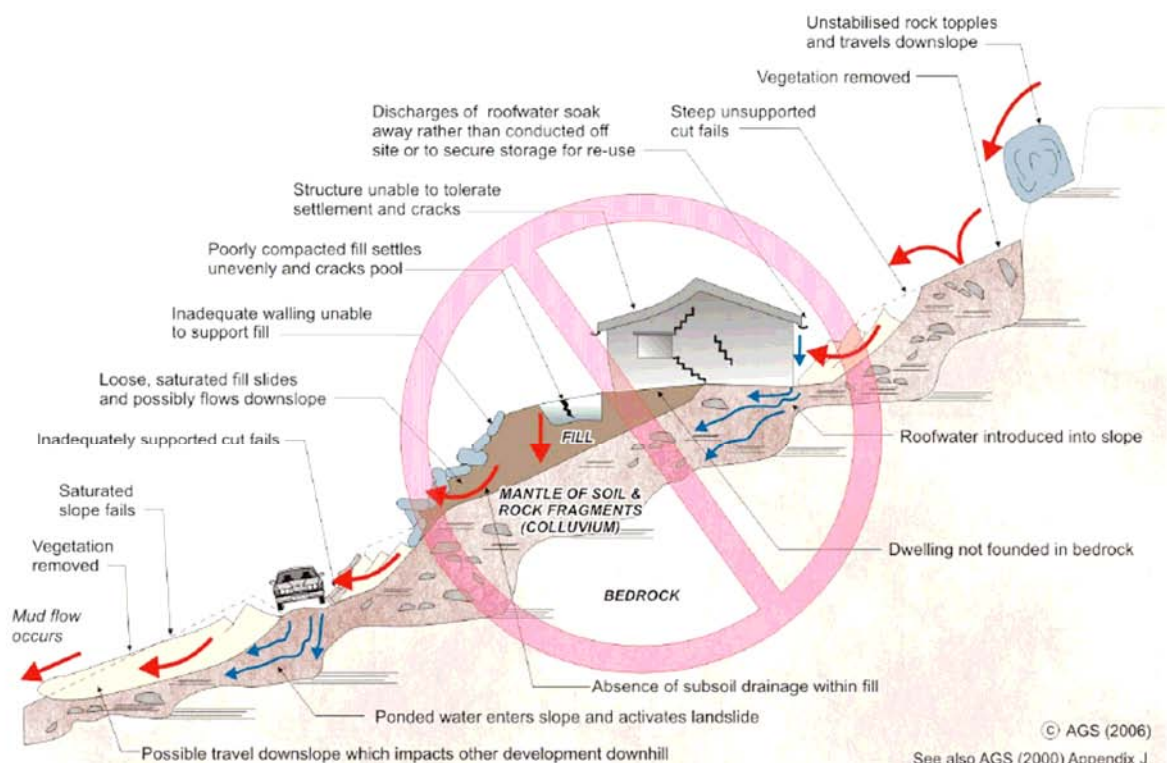
#### INSPECTION AND MAINTENANCE BY OWNER

OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	
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## EXAMPLES OF **GOOD** HILLSIDE PRACTICE



## EXAMPLES OF **POOR** HILLSIDE PRACTICE



# APPENDIX B

## Final Void Water Balance Report

9 December 2019

630.12963-L01-v1.2 Final 20191209.docx

Hunter Quarries Pty Ltd  
Karuah

**Attention: Greg Dressler**

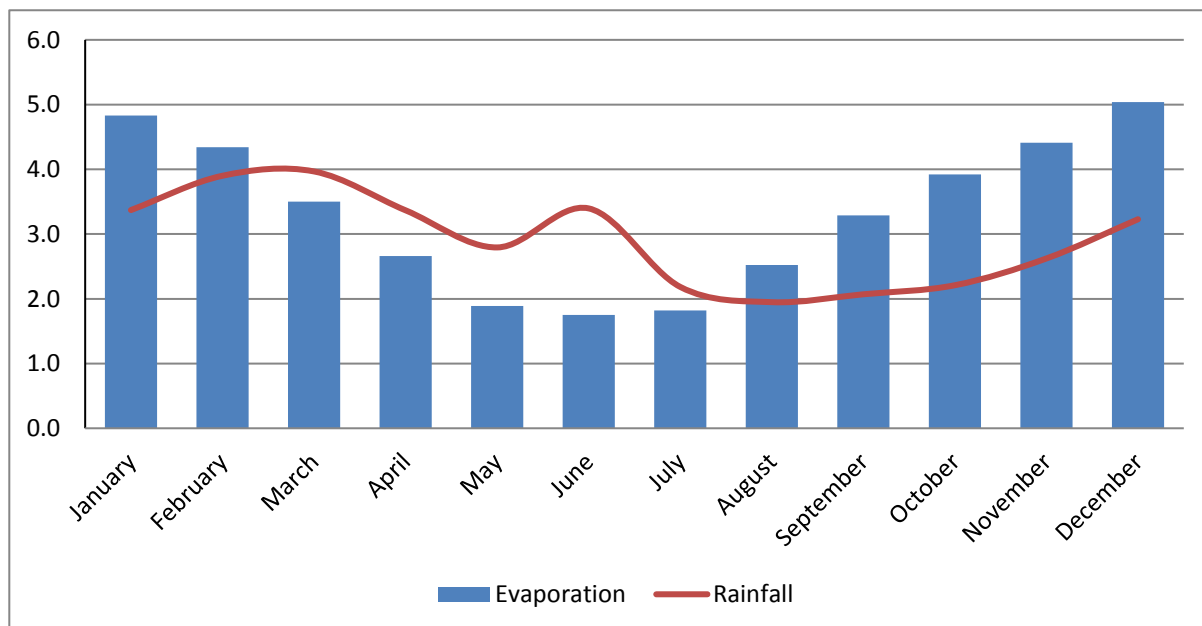
Dear Greg,

## Karuah Quarry Final Void Water Balance

SLR has examined the water balance for the Karuah Quarry final void, to allow an approximation of the equilibrium water level and the amount of water that will discharge to the downstream. We understand that this information will be used to inform final landform designs, rather than be a final determination of precise water levels.

### Climate Data

Monthly climate data at the Clarence Town BOM Weather Station is indicated below:



The average annual rainfall is 1067mm. Average annual evaporation is 1753mm. Using a pan coefficient of 0.7 the annual evaporation is reduced to 1217mm.

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## Water Balance Methodology

Water balance modelling was carried out using the GOLDSIM software, which allows historical daily rainfall depths to be applied to a catchment, and by subtracting evaporation (or other losses), simulate the water storage volumes and levels.

Modelling has been carried out with the following parameters:

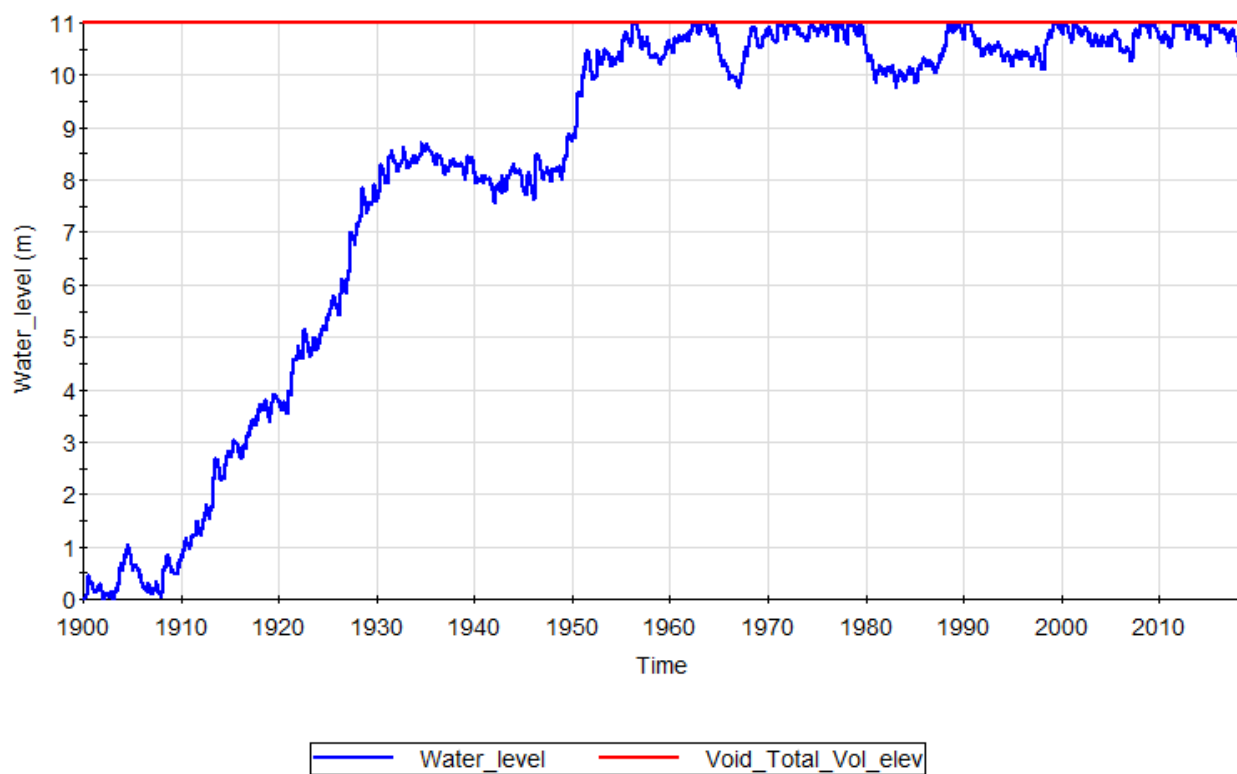
- Historical rainfall records – 118 years of rainfall records from the Bureau of Meteorology station at Prince St, Clarence Town (Station 061010) weather station were applied to the catchment. This station was selected because of its proximity to the site, and length of rainfall records.
- Catchment area has been based on survey data supplied by Hunter Quarries dated 23<sup>rd</sup> of October 2019. The catchment area used was 1.99ha on batters plus a void area of 8.97ha.
- Volumetric runoff coefficient of 1.0 based on hard rock surfaces and subgrades
- Groundwater inflow – Net inflow (water in minus out) was assumed as nil. Whilst on site there was some evidence of seepage into the existing pit. However, when a permanent water body is established, there will also be flows out, which may exceed the flows in. It is also noted that if there is a net leakage then it would be possible to seal the void. In the absence of a quantitative assessment of groundwater the net groundwater inflow was assumed as zero.
- Stage Storage – areas within contours above RL65 were taken from available survey and current contours for the final quarry. Linear interpolation was used to determine areas between available contour data.
- Spillway level – Water balance modelling was carried out with a spillway level at RL76. It is noted that selection of the final spillway level will be subject to detailed design.

## Water Balance Modelling Results

The results of water balance modelling are shown in the graphs below, with the first indicating water depth, and the second indicating storage volume. The level of the spillway is indicated by the horizontal red line.

The x-axis values reflect the period of historical rainfall used in the water balance modelling. Actual rates of water storage filling will of course depend on future rainfall.

**Void\_Water\_Level\_Graph**



**Void\_Volume\_Graph**





**Table 1 - Average Annual Water Balance**

	Description	Average Per year from 1900 to 2018 (ML/year)
<b>Water Source (Inputs)</b>	Catchment runoff	117.7
<b>Water Losses (Outputs)</b>	Evaporation (from water storage)	104.2
<b>Off-site Discharge (once filled)</b>	Void Overflow	5.85

The water balance analysis indicates that water will accumulate in the void until it reaches the spillway level. The present analysis assumed that the spillway is 11m above the floor of the quarry. With a storage depth of 11m (RL76 - RL65) the storage will take approximately 55 years to fill, at an average annual filling rate of 13.5ML/year.

The average rate of water storage filling reduces as the water level gets higher, since the water surface area increases and losses from evaporation also increase.

Once filled, water will spill to the downstream environment. This would occur intermittently but typically only during rainfall events with a substantial depth of rainfall. In between discharge events, the water level would gradually reduce below the spillway level through evaporation. On average the water storage would discharge approximately once per year, and the estimated average annual overflow volume would be 5.85ML.

Once the spillway level is reached, water levels will fluctuate depending on rainfall. Fluctuation is likely to be less than 0.5m on average rainfall years, but could be up to 1.2m during very dry years.

## Discussion

The analysis above assumes a spillway level at RL 76. Selection of a final spillway level will be subject to detailed design. The level at which the spillway is placed will dictate the time taken for the quarry void to fill up.

It may be practical to locate the spillway level along the north-western edge of the void so that water will overflow to an existing watercourse and avoid directing discharge into existing operational areas to the west. This would require filling of the existing quarry road entry which is below RL76.

Peak discharges to the downstream environment may be attenuated by use of a low flow weir that discharges water slowly and maintains a water level which is about 0.3m below the spillway level. This maintains some 'air space' to store runoff during heavy rainfall, and then release it slowly to the downstream environment.

It should also be noted that since the average filling rate of the water storage is low, the filling outcome is very sensitive to groundwater leakage. The average filling rate of 13.5ML/year is in the order of 0.4L/s. This means that if the water storage leaks water at an average rate greater than 0.4L/s then it may never fully fill to spillway level.

In terms of the environmental impact of future water quality of discharges from the water storage to the downstream environment, no present water quality monitoring data is available. It could be expected that water quality will improve markedly once operations cease, the landform is stabilised, and water ponded for long periods.

The information in this letter is intended as an approximation of water storage behaviour intended for use in planning closure activities for this void. Let me know if you require refinement of this modelling during detailed design of the final landform and closure activities.

Yours sincerely,



PAUL DELANEY  
Manager - Civil Discipline

Checked/	PD
Authorised by:	

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