

6 Conclusions and Recommendations

- The earthquakes of 4th September, 22nd February, and 13th June caused significant rockfall from the cliffs behind Redcliffs School.
- A rock catch fence erected at the "boundary" between the scree slope and Redcliffs School was installed prior to the seismic event of 4th September. The fence contained most of the rockfall following the seismic events of 4th September, when a limited number of rock fragments and small boulders reached the school.
- Protection works installed following the 4th September event included construction of a confinement rock bund at the base of the scree slope to create a catch area between the cliff base and the bund. The bund is situated behind the school hall to offer further protection.
- The seismic events of 22nd February generated substantially more rock falls behind the school. Observations suggested that the infilling of the storage area behind the bund constructed to protect the school hall makes it more likely that boulders could jump over the existing protection fence. Rock fragments were found as far away as classroom 15 and 16 following the February event.
- A simplified computer model of possible rockfall scenarios was developed to build on observations made following the 22nd February earthquake and to examine the impact the now re-profiled slope may have on rockfall behaviour. The model indicated that boulders could bounce over the existing protection fence and a second line of defense was warranted.
- The protection system implemented following 22nd February included disuse of the school hall, relocation of the classrooms (17, 18 and 19) closest to the cliff, the use of shipping containers to provide a second barrier to boulders should they bounce over the protection fence and bund, and a 4 m high mesh fence to provide additional protection to flying rock fragments. In addition part the western playing fields was removed from use to provide a buffer against any rockfall hazards from the more distant cliffs to the west of the school. These measures were considered temporary and would enable the school to re-open.
- The cliff above Redcliffs School has been progressively degrading since the February 2011 earthquake and the potential exists for larger cliff collapse events to occur in the future. Modelling undertaken by GNS has considered a large scale cliff collapse event and has not found it to be more adverse than their 2012 modelling used as the basis for zoning of residential properties. In particular, the larger volumes that GNS predict could fall in a future event compared to previous events was not found to increase the maximum runout distances for rock that GNS developed in their 2012 modelling.
- While the protection works installed after the February event are thought likely capable of containing even a large scale rockfall event, the degradation of the cliffs and the need to provide a high margin of safety for a school site means that an enhanced protection system is considered necessary.
- The most likely form of long term protection works for the school is considered to be abandonment of approximately 10% of the school closest to the cliffs and construction of an engineered bund protecting the remaining school grounds from the cliffs to the south and the west and broadly following the alignment of the fly rock fence installed after the February 2011 event. The placement of the bund is such that it is at or beyond the limit of rockfall roll distances predicted by GNS, allowing for larger volumes of rock to fall in the future than has occurred in the earthquake sequence to date.
- The revised school boundaries are far enough from the cliffs such that the annual individual fatality risk on the site would be at the 10⁻⁶ background level that all New Zealanders are exposed to. The physical barrier, in the form of an engineered bund, is proposed to provide an additional margin of safety noting the aversion of society to fatalities on sensitive sites such as schools.
- It is anticipated that rock will continue to fall from the cliffs and accumulate behind the bund in the future. Generally it is anticipated that no removal of this rock will be required. Should a large volume fall it would be necessary to reassess the slopes to confirm that the resulting slope configuration does not represent a more adverse situation than that modelled. An operations and maintenance plan will need to be established to define the level of response required after different sized future rockfall events.
- A design concept for the bund is provided in this report. Before being constructed the barrier may require resource consent and will need to go through detailed design so that a building consent can be obtained from the CCC. Work associated with the resource consent, final design and building consent are outside the scope of this engagement.

7 References

- Brown, L.J., Weeber, J.H. 1992. Geology of the Christchurch urban area. Scale 1:25,000. Institute of Geology & Nuclear Sciences geological map 1. 1 sheet. *Institute of Geological & Nuclear Sciences Limited*.
- Christchurch City Council. Technical Guideline for Rockfall Protection Structures, March 2013
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- Geological & Nuclear Sciences (GNS). 2 March 2011. Report on Landslide Reconnaissance Flight on 24 February 2011 following the Mw 6.3 Christchurch Earthquake of 22 February 2011. Job Number: 460W6303.
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- Geological & Nuclear Sciences (GNS). Principles and Criteria for the Assessment of Risk from Slope Instability in the Port Hills, March 2012, Christchurch (GNS Science Consultancy Report 2011/319).
- Geological & Nuclear Sciences (GNS). Life-safety risk from cliff collapse in the Port Hills, May 2012, GNS Science Consultancy Report 2012/124
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- Geological & Nuclear Sciences (GNS). Understanding life-safety risk concepts for rockfall and cliff collapse in the Port Hills. September 2012
- Geological & Nuclear Sciences (GNS). Canterbury Earthquakes 2010/11 Port hills Slope Stability: Stage 1 report on the findings from investigations into areas of significant ground damage (mass movements), GNS Science Consultancy report 2012/317, 1 August 2012.
- Geological & Nuclear Sciences (GNS). Canterbury Earthquakes 2010/11 Port Hills Slope Stability: Risk assessment for Redcliffs, GNS Science Consultancy Report 2014/78, August 2014
- MWH New Zealand Ltd (MWH). 21 March 2011. Redcliffs School, Mitigation of Rockfall Hazard – Emergency Works

8 Limitations

This report has been prepared for Ministry of Education in accordance with the generally accepted practices and standards in use at the time it was prepared. MWH accepts no liability to any third party who relies on this report.

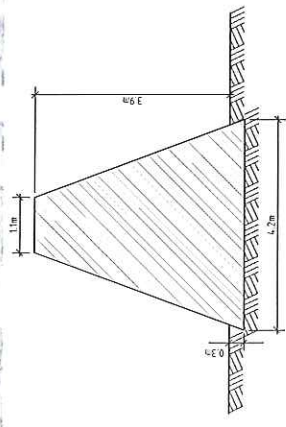
The information contained in this report is accurate to the best of our knowledge at the time of issue. MWH NZ has made no independent verification of this information beyond the agreed scope set out in the report.

Where conditions encountered at the site differ from those inferred in this report MWH NZ should be notified of such changes, and should be given an opportunity to review the report recommendations made in this report in light of any further information. This report does not purport to describe all the site characteristics and properties. Subsurface conditions and testing relevant to construction works must be undertaken and assessed by any contractors as necessary for their own purposes.

Appendix A Drawings





SCALE 1:1000



NOT FOR CONSTRUCTION

Status Stamp	CONCEPTUAL
Date Stamp	11.04.14
Scales	AS SHOWN
Project No	Z1953700
Figure No	C001
Rev	B

REDCLIFFS SCHOOL ROCKFALL PROTECTION	PROPOSED PROTECTION WORKS
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DESIGNED	S. WOODS	01/14	
DRAWN	L. TAITER	01/14	
B. CONCEPTUAL		SW	06/14
A. PRELIMINARY		SW	07/14
REV	REVISIONS	APP	DATE