MWH

BUILDING A BETTER WORLD

5 September 2014

Ministry of Education
39 Princess St
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Attention: David Hobern

Dear David

Relative Risk at Redcliffs School

1 Introduction

All New Zealanders face a level of risk in their day to day lives. Recent earthquake activity in the Canterbury region has highlighted a number of existing risks that many people would not previously have perceived they were exposed to.

One such risk was rockfall from the cliffs and hills that surround the suburbs of Redcliffs and Sumner. Rockfalls during the September 2010, February 2011 and June 2011 earthquakes led to the decision to close Redcliffs School until a mitigation strategy could be put in place to address the rockfall risk.

As part of ongoing work towards a decision on whether to re-open the school, the Ministry of Education have requested a summary of the relative vulnerability to various natural hazards that the Redcliffs School site faces compared to other Christchurch schools, particularly to seismic related hazards. The particular hazards considered are:

- Rockfall
- Tsunami
- Ground Deformation

In order to compare these hazards, recent publically available modelling and mapping work undertaken by a number of organisations has been utilised. The following sections summarise this work for each of the three categories noted above and comment on the vulnerability at Redcliffs compared to other schools in Christchurch.

2 Rockfall Risk

Since the earthquake of 22 February 2011, extensive work has been undertaken by GNS Science (GNS) to quantify the level of risk associated with rockfall hazard. In a number of reports GNS have produced risk contours for people living below the cliffs and slopes of the Port Hills. GNS have elected to express risk in terms of Annual Individual Fatality Risk (AIFR) ie the chance of a fatality for an individual in any given year. In order to provide context to this measure, the following figure (from GNS 2011/319) shows a number of

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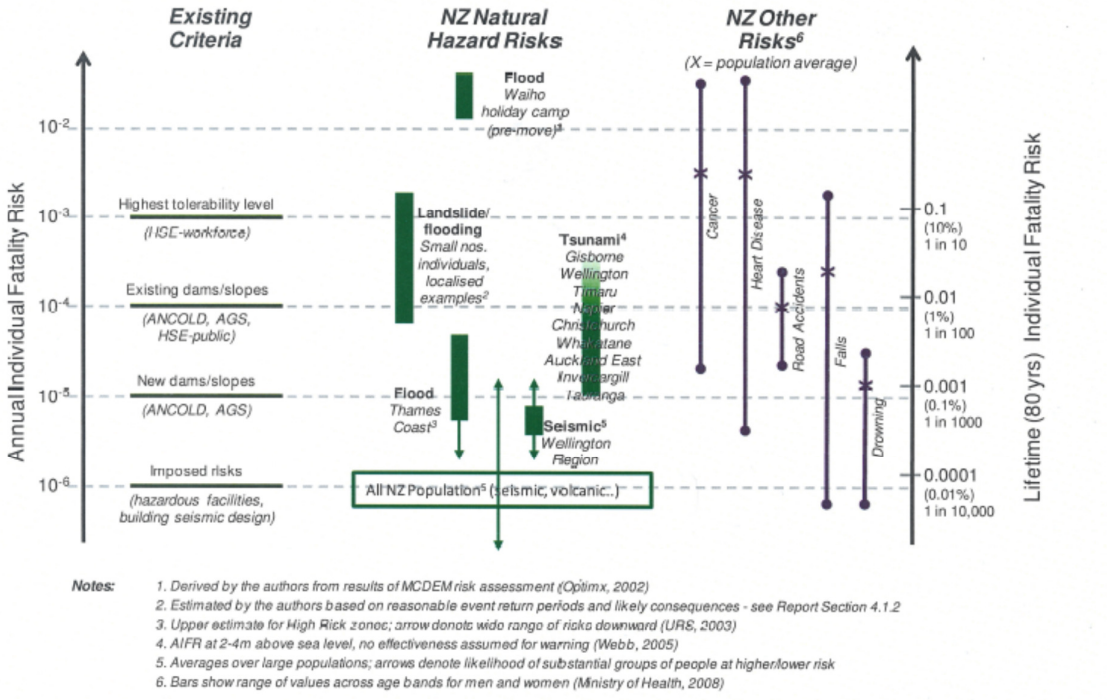
common risks that New Zealanders are exposed to and the typical ranges of AIFR associated with those risks.

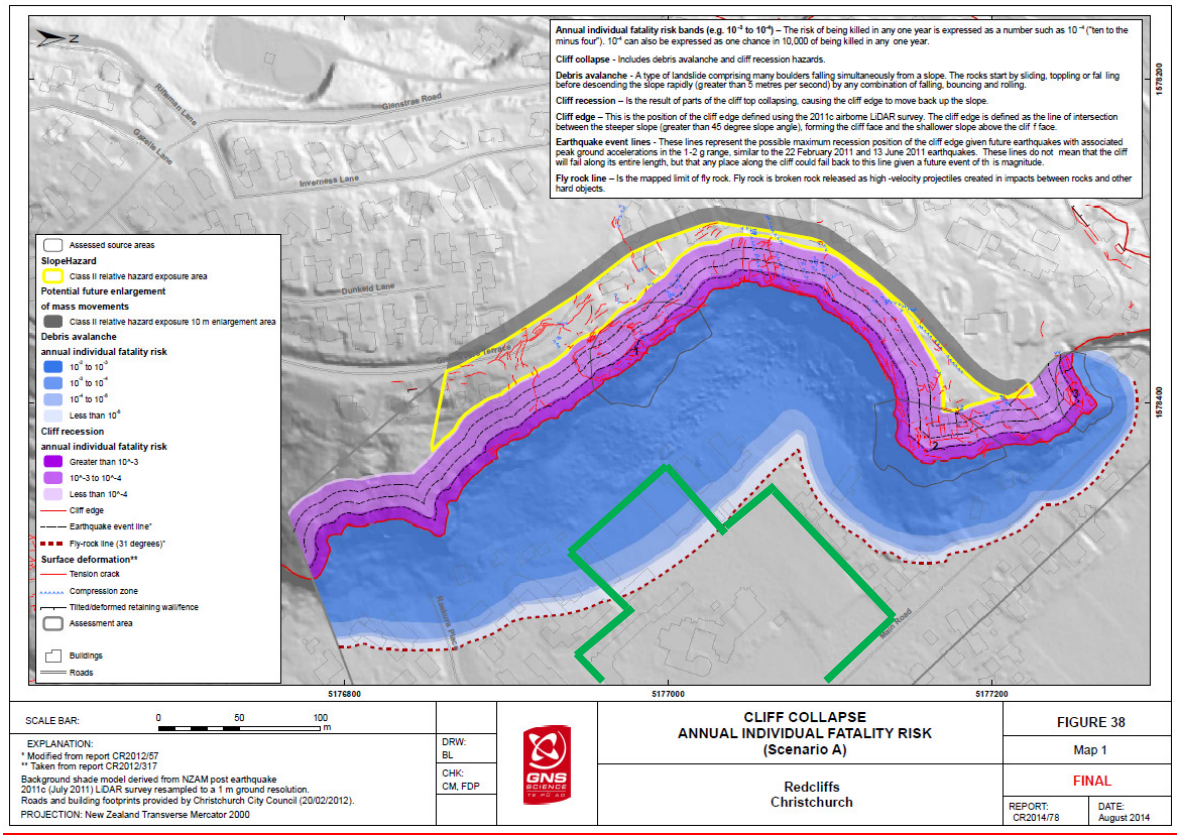
Figure 2-1 – Typical Annual Individual Fatality Risks



In order to make decisions on which parts of the Port Hills would continue to be occupied following the earthquakes a policy decision was required on what level of risk was acceptable We understand that tolerable risk levels for existing dwellings in Christchurch has been set at an average of 10^{-4} annual individual fatality risk (GNS, September 2012) and this risk level has been used as the basis of zoning residential properties, i.e. whether land is acceptable to occupy for residential purposes in the Port Hills. From Figure 2-1 an AIFR of 10^{-4} is comparable to the risk level that New Zealanders face from road accidents or from tsunami if living on the coast in most major population centres.

Once an acceptable risk limit was set, a model was required to determine sufficient distance from rockfall sources before the acceptable level of risk was reached. GNS undertook this assessment and produced risk contours, an example of which is shown in Figure 2-2. This figure shows the area immediately adjacent to Redcliffs School, the current approximate extent of the school grounds shown by the green lines.

Figure 2-2 Rockfall risk contours in the vicinity of Redcliffs School.



The red dashed lines on the figure shows the maximum distance from cliffs that rocks have been found to reach during previous earthquakes or modelled to have reached during future earthquakes. Beyond this line there is considered to be no incremental risk to people from rockfall, although they are still exposed to all of the other risks.

MWH has developed a mitigation strategy for the school (MWH, August 2014) which involves withdrawal from the areas that are shaded blue in Figure 2-2 and erection of a physical barrier on the western and southern (cliff facing) sides of the remaining school. The philosophy of the mitigation measures is that distance from the cliffs is the primary risk mitigation and the barrier provides a second level of defence that addresses residual risk that is beyond the ability of the rockfall model to predict. With the mitigation measures in place, the risk from rockfall is considered to be no higher on the school grounds than on any site remote from the Port Hills. With the mitigation in place the rockfall annual individual fatality risk is considered to be 10^{-6} or less, which with reference to Figure 2-1, is the background level that all New Zealanders face.

We understand that the Van Asch School which also has some vulnerability to rockfall hazard is being assessed separately by others and therefore no comparison of relative hazard is made in this assessment.

An additional consideration around rockfall hazards is the potential vulnerability of people travelling on the Port Hills Road network, including the road network around Redcliffs. The blue and purple shaded areas shown on the following figures (Figures 2-3(a) and Figures 2-3(b)) show areas with exposure to rockfall hazards around the Port Hills. It can be seen that these areas do not extend substantially away from the Port Hills but do extend across many of the local roads. For example in cells A11 and B12 on Figure 2-3(b) the purple cliff collapse risk zones extend onto the main road that links Redcliffs and Sumner.

GNS in their August 2014 report note with respect to the section of Main Road near the school and immediately below the cliffs that "The slope collapse risk on the NEAR (slope) side of the road is very much greater than the motor vehicle crash risk over the same length of road for all road users except motorcyclist, for whom it is comparable" while "The slope collapse risk on the far (seaward, downhill) side of the road is virtually zero".

While no detailed comparison of risk has been undertaken, it is anticipated that similar levels of risk exist in other locations for other stretches of Port Hills Road exposed to rockfall hazard. This hazard is therefore present on many roads in the Port Hills network and is not unique to people travelling to and from the school.

Figure 2-3(a) – Rockfall risk areas throughout the Port Hills

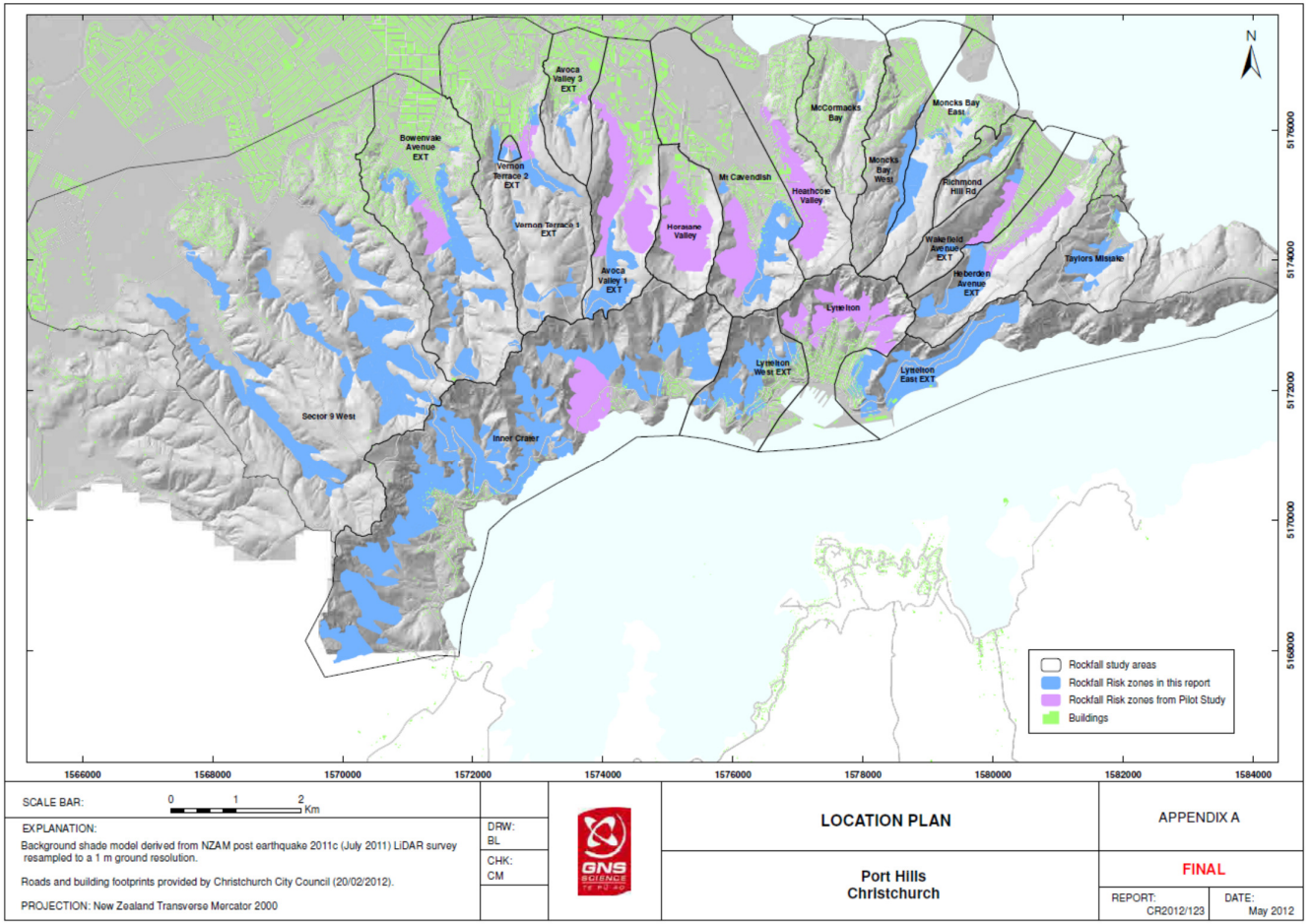


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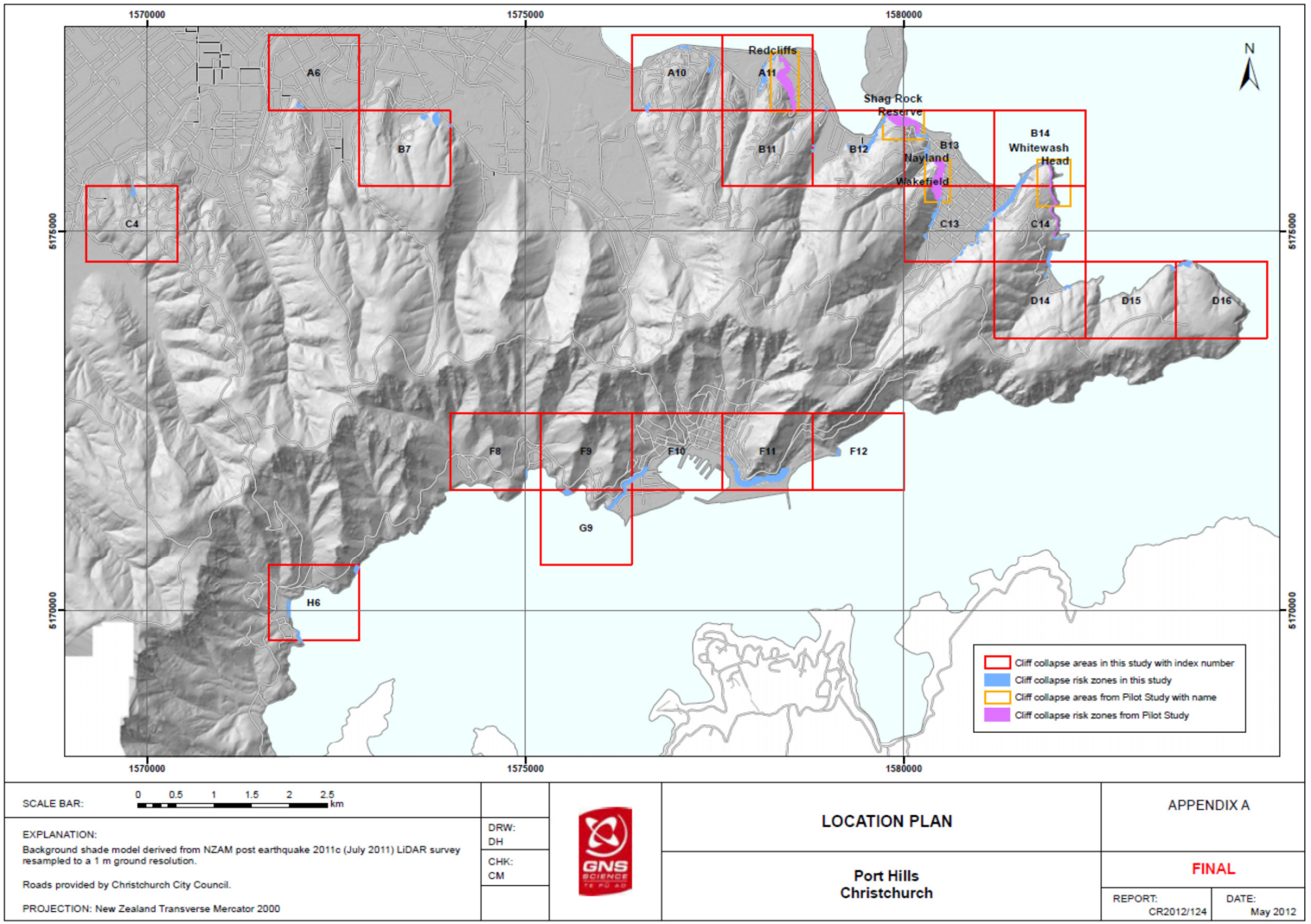
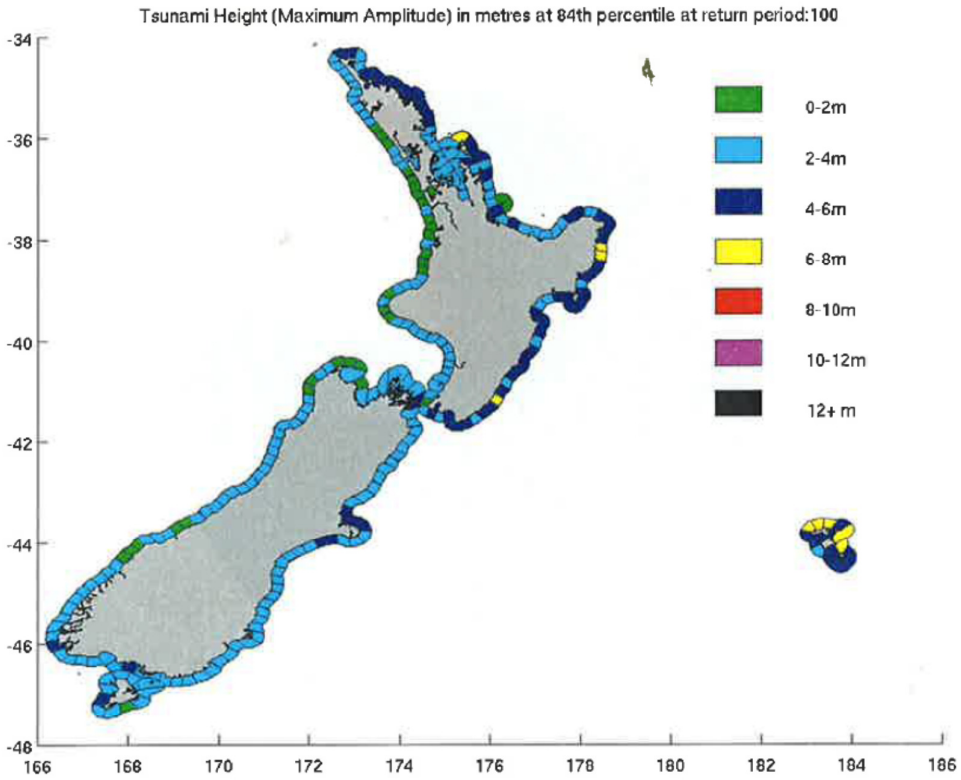
Figure 2-3(b) – Cliff collapse areas throughout the Port Hills



3 Tsunami Hazard

As illustrated in Figure 2-1, tsunami presents an appreciable hazards to New Zealanders living on the coast, compared to many of the common threats that everyone is exposed to. An appreciation of the threats to the Canterbury coast compared to the remainder of New Zealand can be gained from the following figure 3-1 (from GNS, report 2013/131) which shows estimated tsunami generated wave heights at a return period of 100 years (approximately a one in one hundred chance of occurring each year). The largest wave heights, corresponding to the highest level of hazard to people, are located on the Canterbury coast and much of the east coast of the North Island. Therefore schools located near the Canterbury coast would be expected to have a similar level of tsunami hazard to other near coast schools located in similar situations on the east coast of the North Island.

Figure 3-1 Tsunami wave heights on New Zealand coast during 100 year return period event

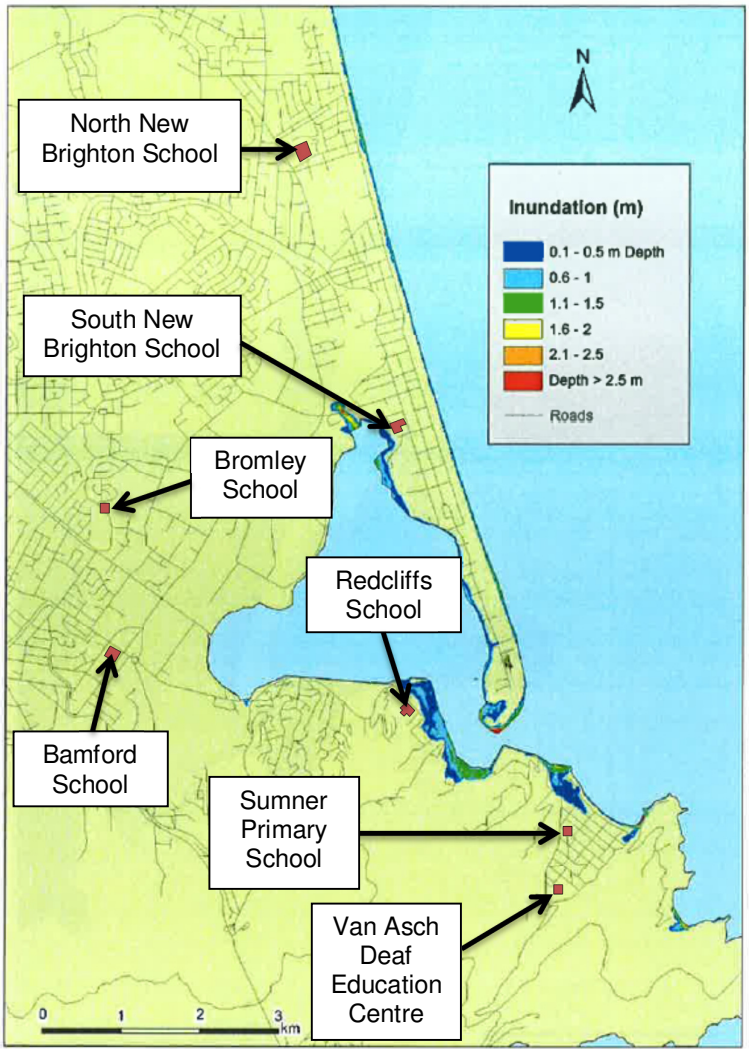


More detailed modelling of the effect of a tsunami striking the Canterbury coast has been undertaken by the National Institute of Water and Atmospheric Research (NIWA). In their 2012 report (R12/38 and CH2012-078) NIWA have modelled the impact of the 1868 South American Tsunami striking the coast under different tidal conditions. This event represents the most destructive event to have hit the Canterbury coast within recorded history, however, does not necessarily represent the worst case event that could occur. We understand that recent work by GNS indicates much larger waves are possible (in the order of twice the

1868 incoming wave height) and work is currently underway to model a revised "worst case" scenario[1]. Nonetheless, the 1868 event modelling allows comparison of the expected inundation at three coastal schools and comparison of their relative vulnerability to tsunami.

The following inundation plots show the expected inundation from the 1868 event, firstly if it was to strike at low tide and secondly if it were to strike at high tide (including an allowance for 50 cm of sea level rise). Redcliffs School along with a number of other coastal schools are shown on the plot in order to illustrate the relative vulnerability of these three coastal schools.

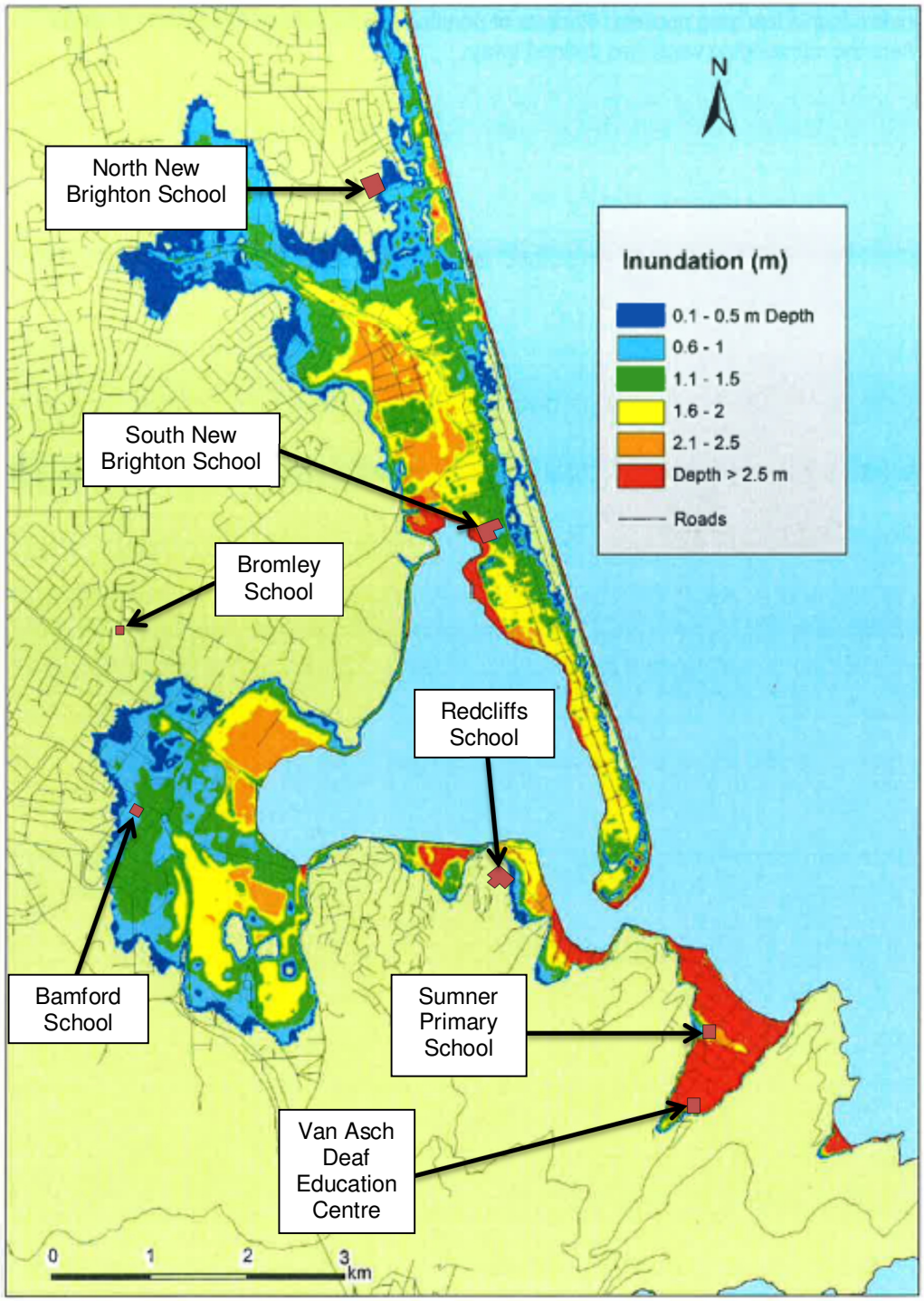
Figure 3.2(a) – Inundation predicted from 1868 tsunami at low tide (NIWA June 2012 Figure 4-10)



The following inundation plot is taken from NIWA CHC2012-078 June 2012 (Figure 4-8).

[1] Pers. Comm. Marion Gadsby, Environment Canterbury

Figure 3.2(b) – Inundation predicted from 1868 tsunami at high tide with 50 cm sea level rise



Under the first of the scenarios (low tide) none of the three sites are subjected to inundation (apart from perhaps minor inundation along the western boundary of South New Brighton School. During the more adverse (high tide) event all of the schools (apart from Bromley) is predicted to receive some degree of inundation. Redcliffs and North New Brighton Schools are similar, each predicted to by inundated by up to 1m of water at one corner of the site but the majority of the site receiving no appreciable (less than 0.1m) inundation. Under this scenario South New Brighton, Bamford, Sumner and Van Asch Schools are subjected to inundation over the full site, with depths of water exceeding 2.5m (red shading on the figures) in places.

The depth of inundation provides a means of judging relative vulnerability to people and infrastructure on each school site. Based on the modelling available it is concluded that:

- Redcliffs and North New Brighton Schools have a similar level of vulnerability associated with tsunami.
- A number of other nearby schools has a higher level of vulnerability associated with tsunami than Redcliffs or North New Brighton Schools.

4 Ground Deformation Hazard

The Canterbury Earthquake Sequence, and in particular the February 22nd 2011 earthquake, illustrated the potential for significant ground deformation as the result of liquefaction and associated lateral spreading. While this ground deformation did not, to our knowledge, result in any fatalities it was found to be very damaging to one and two storey structures typical of residential and school building construction in New Zealand, and damaging to buried services.

Liquefaction is a phenomenon in which saturated and generally sandy soils experience large increases in water pressure in the voids between soil particles and for a brief period behave like a liquid during a seismic event. Typical consequences are settlement of the ground and the ejection of water and soil to the ground surface. Lateral spreading occurs where liquefied soils can flow towards an unrestrained edge, such as a river bank, and generally results in significant ground cracking.

The geological history of Christchurch makes parts of it susceptible to liquefaction during seismic events. To the west of the city are the dense gravel soils of the Canterbury Plains which have high resistance to liquefaction. Moving further east the city was constructed on drained swamp land, and a s a result the conditions of loose sandy soils and high water table exist through much of the city, in particular the eastern suburbs. In the populated valleys of the Port Hills, such as Redcliffs and Sumner, the ground conditions can change over short distances with rock sometimes very close to the ground surface and in other places many metres of soil overlying the rock.

We are not aware of any ground investigation data on the school site, however, nearby data from the Canterbury Geotechnical Database highlights the potential changes in ground conditions over short distances. Near the intersection of Main Rd and Taupata Rd (approximately 150m from the school) the investigation reached a depth of 3m before refusal (which likely was on rock) while 50m away near the intersection of Main Rd and Celia St the investigations reached 20m without striking rock. No definitive comment could therefore be made on ground conditions on the school site without site specific investigations.

One way of visualising the different liquefaction induced ground deformation risks in Christchurch at a high level is by way of the technical categories assigned to the city for residential purposes. While these are intended for residential use only, the general similarity of school building construction in New Zealand to residential construction means that it provides a good understanding of which areas of the city pose the greatest level of risk of ground deformation that could cause damage to school infrastructure.

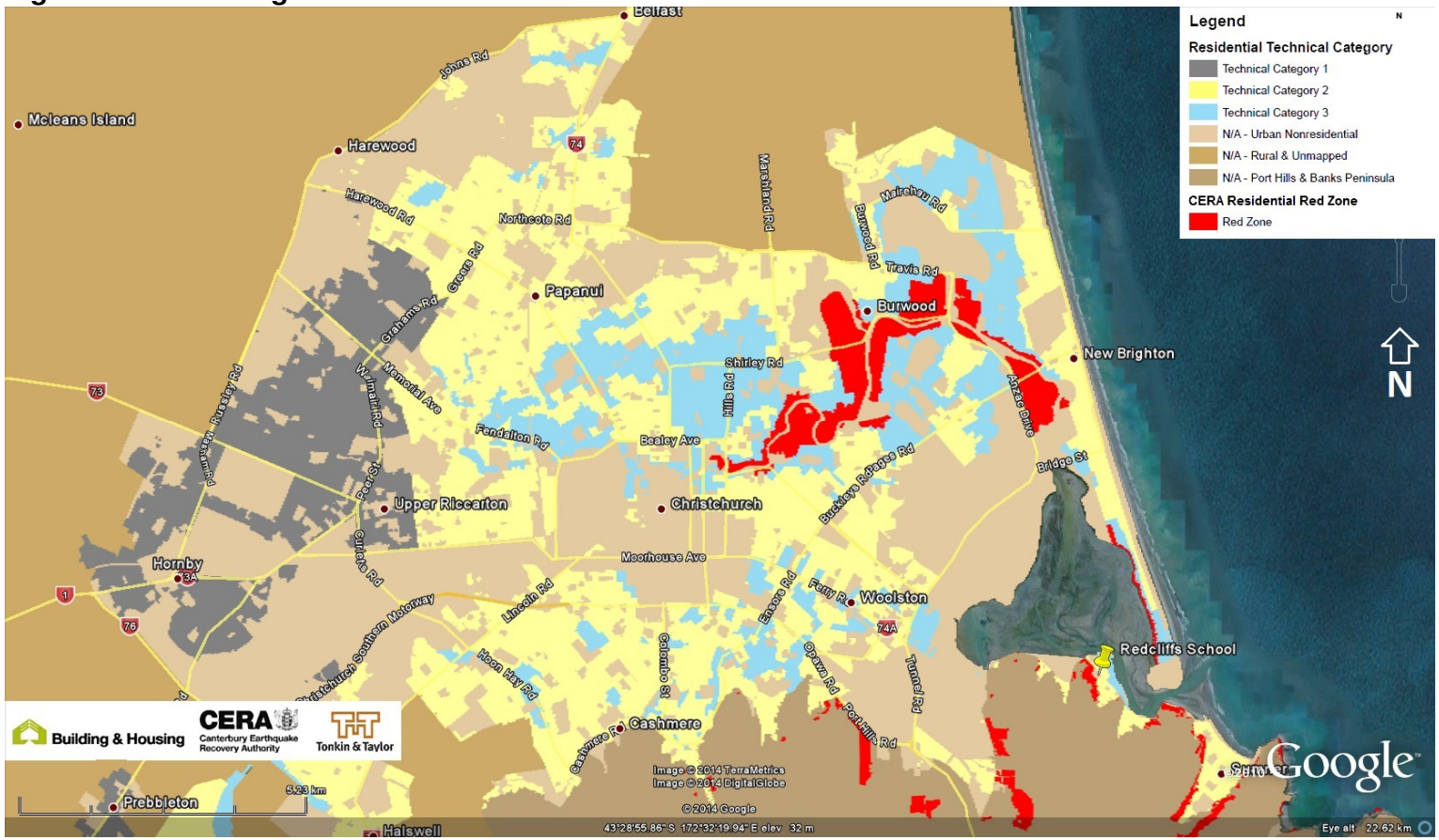
Figure 4-1 shows the technical categories (TC1, TC2, TC3) throughout the city. In general terms:

- TC1 areas are expected to undergo little or no liquefaction deformation.
- TC2 areas are expected to undergo some deformation in a major seismic event but the deformation is expected to be managed with upgraded standard foundations for residential style construction.
- TC3 areas are expected to undergo significant deformation in a major seismic event and special foundations are required for residential style construction in these areas.

In addition, some areas on the flat ground of Christchurch (ie away from the Port Hills) were zoned red on the basis that the potential liquefaction ground deformation was so great that the cost to adequately mitigate it on an area wide basis to allow construction of residential infrastructure and associated services was prohibitive. These areas are generally in areas affected by lateral spreading and often follow a corridor along the Avon and Heathcote Rivers.

Figure 4-1 shows a summary map of technical categories throughout Christchurch. Again it is noted that only residential areas are mapped in this process, however, enough of the city is mapped to give a good overview of the relative ground deformation vulnerability across the city.

Figure 4-1 TC Zoning for Christchurch



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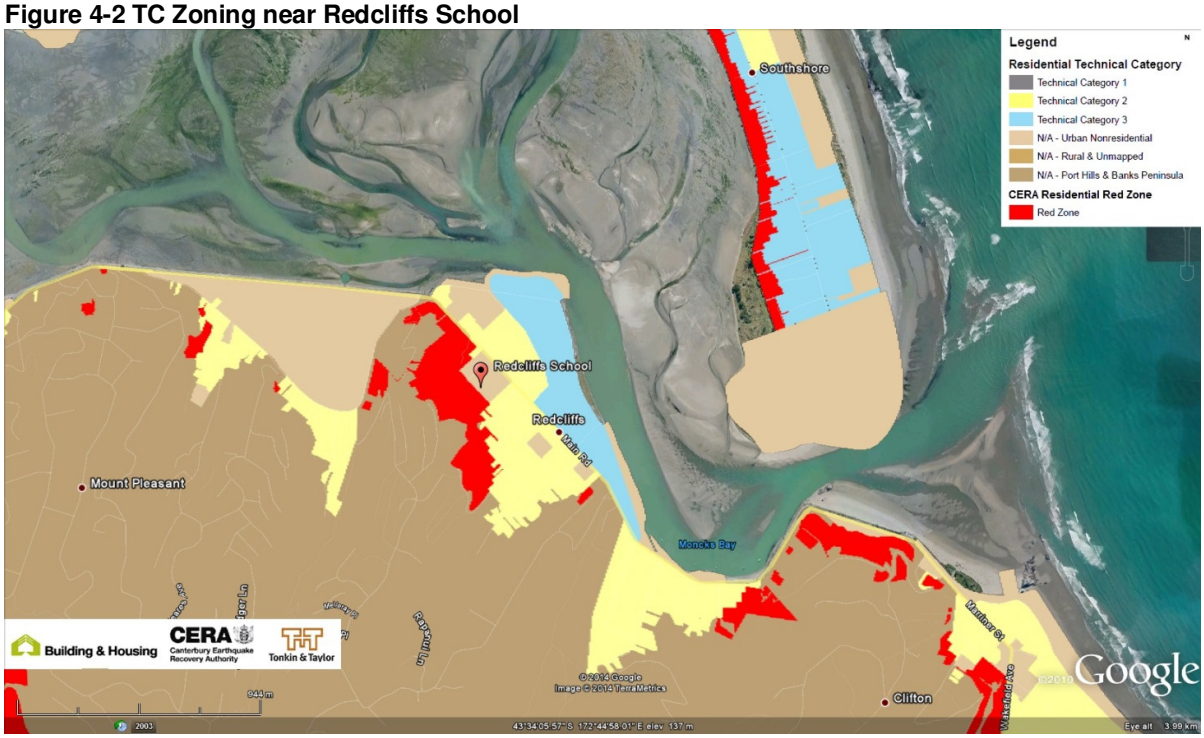
It can be seen that the TC1 areas (shaded grey) generally lie to the west of the city. The areas worst affected by ground deformation (shaded blue and red) are generally along the rivers and to the east of the city. The most common category across the city is the intermediate TC2 zone.

In order to place the city wide zoning in context with Redcliffs School, the following figure shows the TC zoning in the immediate vicinity of the school.

Figure 4-2 TC Zoning near Redcliffs School



The red zoning to the west and south of the school site is due to rockfall issues rather than liquefaction induced ground deformation and the appropriate adjacent zoning for liquefaction induced ground deformation is TC2. It can also be seen that further to the south east (along Main Road) the zoning becomes TC3, signifying a greater amount of ground deformation. This mapping is consistent with the author's observations following the 22 February 2011 earthquake, that there was no observable evidence of liquefaction on the school site but there was further down Main Road, and service connections to the school (presumably running along Main Road) were inoperable for a number of days following the earthquake. Access into the Summer/Redcliffs area was significantly compromised by liquefaction damage to roads and bridges.

From the information available it is concluded that:

- The Redcliffs School site has a similar level of vulnerability concerning ground deformation as much of Christchurch, and therefore many of the schools in Christchurch.

- If rock is found at shallow depths on the Redcliffs School site, as it may be based on nearby investigations, the ground deformation hazard will likely be less than much of Christchurch.

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- Schools constructed on the gravel soils to the west of Christchurch will generally have less ground deformation vulnerability than Redcliffs School.
- Schools constructed near TC3 areas will generally have more vulnerability with respect to ground deformation than Redcliffs School.
- Schools constructed near rivers and other flat-land red zones will generally have the highest vulnerability around ground deformation.
- The largest threat to Redcliffs School concerning seismic ground deformation is likely to be the loss of service connections and compromised road access to the site.

5 Summary

Redcliffs School, like any school in New Zealand, faces risks to people and infrastructure from a number of natural hazards. The following conclusions were drawn around Redcliffs School with respect to a number of seismic hazards investigated

- Once mitigation works, as outlined by MWH in their August 2014 mitigation strategy report, are in place, the Redcliffs School grounds are considered no more than at other schools in Christchurch based on the best available rockfall risk modelling available.

- There is likely to be a residual level of risk of rockfall for people travelling on the road network leading to and from the school. This risk applies to many of the roads in and around the Port Hills.

- In comparison to other coastal Christchurch Schools, Redcliffs School is considered to be at a similar level of vulnerability of tsunami inundation as North New Brighton School and a lower level of vulnerability of tsunami inundation than a number of other nearby schools.

- Based on high level ground deformation mapping of Christchurch, Redcliffs School is considered to be at a similar level of vulnerability of damage to school infrastructure due to ground deformation as the majority of schools in Christchurch. There will be schools, generally to the west of Christchurch with a lower potential for damage and schools, generally in the east of Christchurch and/or near waterways, with a higher level of vulnerability.

- The largest threat to Redcliffs School around seismic liquefaction induced ground deformation is likely to be the loss of service connections and compromised road access to the site, rather than damage to the buildings on the site.

Yours sincerely

Steven Woods
Principal Geotechnical Engineer
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Reviewed By: Charlie Price

6 References

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