Determination 2013/074

Regarding the issuing of a section 124 Building Act Notice (relating to geotechnical hazards) on the property at 7 Finnsarby Place, Christchurch

1. The matter to be determined

1.1 This is a determination under Part 3 of the Building Act 2004[1] ("the Act") made under due authorisation by me, John Gardiner, Manager Determinations and Assurance, Ministry of Business, Innovation and Employment ("the Ministry"), for and on behalf of the Chief Executive of the Ministry.

1.2 The parties to this determination are

- Christchurch City Council, carrying out its duties and functions as a territorial authority ("the authority")
- the owners of the house, A Abakhan and L Belles-Escrig ("the applicants"), who are the applicants for this determination.

1.3 The determination arises from the decision made by the authority to issue a section 124(1)(b) notice ("the notice") in respect of this property because the authority considered that there was a risk that rocks located adjacent to the property could collapse causing death or injury to any person in the house.

1.4 The applicants dispute this finding as they consider that the authority has not adopted a robust methodology nor do they consider that their rock protection system has been sufficiently considered. As a result I received an application for a determination on 2 November 2012.

1.5 Therefore the matter to be determined[2] is the authority's exercise of its powers of decision in issuing a section 124(1)(b) notice. In making this decision I must consider whether the house is dangerous in terms of the Act.[3]

1.6 When considering this matter and arriving at my decision I considered all the information provided to me by the owners and the authority. I also engaged the services of a chartered professional engineer with a specialisation in geotechnical engineering, and a professional engineer with experience in the quantitative modelling of risk. These experts provided advice and analysis in terms of the technical material provided.

[1] The Building Act, Building Code, Compliance Documents, past determinations and guidance documents issued by the Ministry are all available at www.dbh.govt.nz or by contacting the Ministry on ph 0800 242 243
[2] Under sections 177(1)(a), 177(1)(b) and 177(2)(a) of the Act
[3] The relevant section of the Act is section 121(1)(d) as modified by Canterbury Earthquake (Building Act) Order 2011 clause 7

2. Context

2.1 This determination relates to a property located on Canterbury's Port Hills, an area already at risk of rockfall which experienced significant damage as a result of the 22 February 2011 earthquake and subsequent aftershocks. The area is now understood to lie over an earthquake faultline.

2.2 This property is one of a number in the Port Hills with notices applied under the definition of 'dangerous building' that was modified by the Canterbury Earthquake (Building Act) Order 2010[4] ("the 2010 Order"). The 2010 Order was superseded by the Canterbury Earthquake (Building Act) Order 2011 on 17 September 2011 ("the Order") and subsequently by the Canterbury Earthquake (Building Act) Order 2013, which has further extended the application of these notices.

2.3 I have appended a description of the Port Hills and associated rockfall hazards, as well as background to the issue of section 124 notices in the Port Hills including the evolving decision-making process for their issue, as this information provides significant context to the determination.

3. The property

3.1 The site and house

3.1.1 The site slopes to the southeast. The dwelling is located toward the base of the slope. The lower third of the slope is vegetated, and immediately behind the house are a series of small terraces. On one of these terraces is a makeshift rock fence, comprising 150mm to 160mm diameter round timber posts linked with 8 gauge galvanized wire fencing at no specific centres. The alignment of these would lead me to conclude that they are not founded in any form of structural foundation.

3.1.2 The house appears to have been constructed in the mid 1970s, has aluminium joinery and is clad in a fibre-cement weatherboard. The house has been constructed within the scope of NZS 3604[5] and is founded on timber piles and subfloor construction. It has a long run corrugated iron roof in a hip configuration.

3.2 Rock sources

3.2.1 The Port Hills Geotechnical Group (PHGG)[6] reviewed the property on behalf of the authority and identified three potential rock sources (one higher and two lower) above the property. It describes these sources as follows:

> The upper bluff source is 7 to 10m high and is continuous over a distance of about 100m. The lower source is 4 to 6m high and is discontinuous[7].

3.2.2 The rock sources comprise mainly blocky bluffs that are able to generate boulders of 2.0m^3 to 3.0m^3 in size. However, drawing on the GNS Science[8] work on cliff collapse, PHGG has concluded that:

> There was little to no large-scale collapse of cliffs less than 10m high [and] while the rock mass dilated and loosened, no significant rockfall was observed from the bluffs above Finnsarby Place as a result of the recent seismic activity.

[4] Canterbury Earthquake (Building Order) 2010 clause 7
[5] New Zealand Standard NZS 3604: 2011 Timber framed buildings
[6] A consortium of geotechnical engineers contracted to the authority
[7] From PHGG memorandum (supplementary information) of 14 March 2013
[8] A Government-owned research institute that specialises in earth, geosciences and isotope research and consultancy

3.2.3 In its most recent assessment, PHGG said that relatively little earthquake-induced rockfall was observed on the slope above the dwelling and that no recently fallen boulders (i.e. boulders that had fallen in the 2011 aftershocks) were observed within 60m (laterally) on either side of the house.

3.2.4 PHGG had also noted, in its section 124 review dated 15 February 2012, that:

> There is a long run-out zone for boulders travelling from source area high above the property.

4. Assessments of this property

4.1 On 12 July 2011 a notice issued under section 124(1)(b) was affixed to this property by the authority. This notice said it was a dangerous building under section 121 and section 124 of the Act due to risk from rockfall and/or other hazards. I assume that this coincided with the expiration of a Civil Defence-affixed red placard.

4.2 On 8 September 2011, this was replaced by another notice. Both this notice and the earlier notice relied on the definition of dangerous building as modified by the 2010 Order (refer paragraph 2.2).

4.3 On 26 October 2011 a further notice was affixed to this property by the authority. This notice said it was a dangerous building under section 121 and section 124 of the Act and the Order (refer paragraph 2.2) due to risk from rockfall, cliff collapse and/or other hazards.

4.4 On 26 January 2012, PHGG undertook a site assessment at the property. This assessment was part of the suburb-wide field testing of GNS Science's rockfall risk model ("the GNS model").[9] As noted in the Appendix, paragraph A3.4.5, such assessments were carried out at all Port Hill properties and were not section 124 assessments. This assessment concluded:

- The GNS_{LOL} (loss of life) risk at the property was between 10^{-2} and 10^{-3}
- Boulders had not passed within 10m of the house.
- The rockfall source did not vary significantly from the suburb average.
- There were no significant topographic features that influenced the risk to the dwelling.
- There were no known mass movement issues that could increase the risk to the dwelling.

4.5 On 15 February 2012, PHGG completed an assessment of the property using the process that I describe in the Appendix paragraphs A4.3 to A4.3.2. This assessment noted that rocks reached or passed the house but did not hit it and that there was a source of further rockfall from continuous bluffs.

4.6 On 16 April 2012, PHGG carried out a hazard verification report at the site. This concluded:

[9] Reported in GNS Science Consultancy Reports; 2011/311 (March 2012) "Canterbury Earthquakes 2010/11 Port Hills Slope Stability: Pilot study for assessing life-safety risk from rockfalls (boulder rolls)" and 2012/123 (March 2012) "Canterbury Earthquakes 2010/11 Port Hills Slope Stability: Life-safety risk from rockfalls (boulder rolls) in the Port Hills"

> The properties at No. 7 and No. 9 Finnsarby Place, Sumner are at a risk due to a rockfall hazard, which could be triggered by a significant aftershock or other large seismic event
>
> A significant amount of boulder hazards have fallen from the rock outcrops above the properties, subsequent to the February and June 2011 major earthquakes of the Canterbury earthquakes sequence
>
> Boulder hazards have been recorded in proximity to the properties and are identified in the Christchurch City Council/Port Hills Geotechnical Group geographical information system
>
> Potential rockfall source material, comprising rock outcrops and boulder hazards, remains on and above the steep slopes to the northwest of the properties.

4.7 On 4 July 2012, the authority wrote to the applicants to say that as a result of the announcements taken on tolerable life-risk on 29 June 2012 the notice would remain. It said that further geotechnical investigation was needed before a robust decision could be made "for those properties" and completing that work was a high priority for itself and the Canterbury Earthquake Recovery Authority (CERA).

4.8 The authority sent a further letter to the applicants on August 17 2012 to say that, with CERA rezoning this property 'red'[10], the existing notice would remain.

4.9 As a result of this determination application, PHGG carried out a complete reassessment of the notice on this property between 5 February and 8 March 2013 using the process described in the Appendix, paragraphs A4.6 to A4.6.4. The results of this review were provided to the owners and to me by the authority (dated 21 March 2013) and included a summary of site-specific 2D rockfall modelling.

4.10 The review concluded:

> Potentially unstable rocks and rock bluffs were observed upslope of the dwelling
>
> Relatively little earthquake-induced (recent) rockfall was observed on the slope of the dwelling; no recent fallen boulders were observed within 60m (laterally) on either side of the dwelling
>
> There was geomorphic evidence that boulders have landed within 10 to 20m upslope of the dwelling
>
> Two ad hoc rockfall fences are present on the property upslope of the dwelling… Neither fence has been considered as effective protection in our assessment.
>
> The 2D site-specific rockfall models indicate that for a bare slope model, the majority of rocks (75 to 95%) reach the dwelling. The models run incorporating dense vegetation upslope of the house indicate that all of these rocks would be expected to be stopped by the vegetation; the models show that rocks come to rest within 1 to 10m upslope of the dwelling.
>
> The model results are highly dependent on the length of the vegetation upslope of the dwelling and the vegetation parameters used. Because of variations in the type and density of vegetation present on the slope, and uncertainties inherent in the modelling process, the vegetation cannot be guaranteed to stop all rocks from reaching the dwelling.
>
> The risk at the dwelling is judged to be lower than suggested by the GNS model because the rockfall source is judged to be less that the suburb average source. However, because the dwelling is located well within in the greater than 10^{-3} risk band

[10] CERA Red Zone: Port Hills – affected by cliff collapse and there are immediate risks to life, land remediation is not considered viable and infrastructure would be difficult and costly to maintain, or affected by rock roll and the risk to life is considered unacceptable, is unlikely to reach an acceptable level in a reasonable timeframe, and protective works to mitigate the life safety risk are not considered practicable

> (year 1) of the GNS model, it cannot reasonably be concluded that the risk at the dwelling is so much lower that it is within the less than 10^{-4} risk band.

4.11 While a $2.0m^3$ boulder was used as the site-specific 2D model ("using 95^{th} percentile boulder for suburb from CCC database"[11]) the associated report noted that the site specific 95^{th} percentile boulder was estimated to be in the range 1.5 m^3 – 2.0 m^3.

4.12 The summary of the 2D rockfall modelling results indicated that for all three pathways where a vegetated slope was modelled no boulders reached the property. Where a bare slope was modelled boulders including those of 1.0 m^3 in size reached the dwelling with sufficient kinetic energy to exceed the authority's 25 kJ threshold (refer Appendix paragraphs A4.2.2 to A4.2.4).

4.13 The authority's conclusion

4.13.1 In its letter to the owners (dated 21 March 2013), the authority advised the owners that on the basis of this assessment the notice would remain in place.

4.13.2 Whilst the authority's letter does not specifically make reference to constructing a rock protection system, I assume that it accepted the PHGG recommendation, namely:

> That the [section 124 notice] should remain on this dwelling until such time as properly designed, constructed and approved rockfall protection works have been implemented.

5. Section 183 decision for section 124 notice to remain in force

5.1 Pursuant to section 183 of the Act, the authority's decision to issue a notice in respect of this property was suspended when the applicant applied for the determination. However, that provision also gives me the power to direct otherwise.

5.2 On 1 November 2012, the authority requested that I make a direction in respect of this property that the notice should remain. On 6 November 2012 I issued an interim direction that the notice should remain in force until the final determination was made.

5.3 On 3 December 2012, the authority requested that I make a final direction on this matter. The authority noted that the property had been red-zoned by the Minister, although it said it was understood that a final review of the Port Hills zoning decisions was underway. I have made no further direction on this matter.

6. The applicants' views

6.1 The applicants consider that the notice should be removed because:

- There is uncertainty over how much expert evidence has been obtained specific to their home. In particular, they suggest that no authority-employed engineer has inspected their home[12] and they have been unable to verify whether a truly independent peer review was done of the decisions made in relation to their property.
- The flowchart process and brief report seems extraordinarily simplistic (refer Appendix paragraph A4.3).

[11] PHGG S124 (geo) Review Checklist – Boulder Roll Review 15 March 2013
[12] I note that the PHGG engineers have visited the site since the applicants applied for this determination and lodged their submission.

- The GNS Science life risk reports (refer paragraph 4.4) are also simplistic and represent a first attempt at a regional rockfall analysis. Furthermore, they provide a worst case scenario of what could happen in the event that all potential rocks actually fall from the bluffs. The applicants do not believe that the GNS Science modelling has taken into account
  - the actual nature and number of hazardous rocks on the hillside in the vicinity of their home
  - the number, size and likely energy of actual rocks that fell in the vicinity of their home
  - vegetation and local topographical channelling effects
  - existing rock protection barriers, the nature of their home and actual current occupation levels.
- The notice[13] was first issued in March/April 2011 at which time no hazardous rocks had passed within 100m of their home. Since then, the only rockfall to occur was as a result of the June aftershock. In this instance the rocks fell 300m to the south of the property. No further rocks have fallen since then.
- The rockfall protection that the applicants constructed comprises a combination of 100m x 12m steel cable looping through three layers of mesh fencing as well as a 2m retaining wall with wooden poles interlocked for energy dispersal. The applicants contend that this structure will reduce their life risk to 10^{-5}. This assertion is based on an informal review undertaken by an engineer. No rocks have hit the barrier.

6.2 Finally, the applicants submitted that if the authority believes the risk to their property from rocks originating on its land was unacceptable, it might choose to mitigate that risk by installing or reinstating rockfall protection. They say that the advice from internationally experienced rockfall protection companies was that this was feasible and not economically prohibitive.

7. Discussion

7.1 In order to arrive at a view of whether this house is dangerous in terms of the Act and whether the authority correctly exercised its powers in issuing the notice, I need to consider

- the meaning of a dangerous building, and
- whether a risk exists at this property.

7.2 Since issuing the first draft of this determination on 29 May 2013, I have received a significant amount of additional information and analysis from the parties as well as additional expert advice. Given the complexity of this material and to make my considerations in arriving at a view as clear as possible, I have

- outlined the considerations leading to my initial draft decision in paragraphs 8 to 10

[13] I assume this to be a Civil Defence-affixed red placard

- summarised the additional material received and points raised after the issue of a second draft, including at the 23 July 2013 hearing, in paragraphs 11 to 12, and
- outlined my further considerations in paragraph 13.

8. Meaning of dangerous building

8.1 The relevant sections of the Act are:

- section 121 Meaning of dangerous building, and
- section 124 Powers of territorial authorities in respect of dangerous, earthquake-prone or insanitary buildings.

8.2 The relevant clauses of the Order are:

- clause 7 Modification of meaning of dangerous building and extent to which territorial authority can apply modified provision
- clause 9 Modification of powers of territorial authorities in respect of dangerous, earthquake-prone, or insanitary buildings under section 124 of Act.

8.3 The section 124 "rockfall" notice was issued under section 124(1)(b), which provides:

> **124 Powers of territorial authorities in respect of dangerous, earthquake-prone, or insanitary buildings**
>
> (1) If a territorial authority is satisfied that a building is dangerous, earthquake-prone, or insanitary, the territorial authority may– …
>
> (b) attach in a prominent place on, or adjacent to, the building a notice that warns people not to approach the building; …

8.4 The authority issued the notice based on the definition of dangerous building as modified by clause 7 of the Order:

> **121 Meaning of dangerous building**
>
> (1) a building is dangerous for the purposes of this Act if, – …
>
> (d) there is a risk that adjacent, adjoining, or nearby buildings or land could collapse (including collapse by way of rock fall, landslip, cliff collapse, or subsidence) or otherwise cause injury or death to any person in the building

8.5 The expanded definition establishes a very low threshold before a building will be considered dangerous. In respect of the rockfall risk at this property, the only requirement is that 'there is a risk' that adjacent land could collapse by way of rockfall and cause injury or death to any person in the building.

8.6 A 'risk' that something could happen is simply a possibility of that event happening. This is in contrast to the definition of a dangerous building in section 121(a) where a building must be 'likely', in the ordinary course of events, to cause injury or death.

8.7 The modified definition also requires that the risk of injury or death must be 'to any person in the building'. This means that rocks (or other defined hazard) must reach the building itself, not just the property boundary, with sufficient force to injure an occupant. I note further that the term 'building' is defined in section 8 of the Act and includes the house, any decks connected to it, and any outbuildings on the property.

8.8 The extent to which the authority can apply this modified definition is as follows:

7 Modification of meaning of dangerous building and extent to which the authority can apply modified provision

(3) Section 121(1)(d) or (e) of the Act as modified by this clause applies only for the purposes of a territorial authority exercising its powers under section 124(1)(a), (b) or (d) of the Act as modified by clause 9.

9. Whether 'there is a risk'

9.1 In order to arrive at my decision in the first draft of this determination as to whether or not this house is a dangerous building under the Act, I considered whether there was

- a credible risk of a triggering event that would generate a rock fall
- a source of rocks above the property
- a risk that rocks from these sources would reach the building
- a risk that they would do so with sufficient kinetic energy to injure an occupant
- sufficient mitigation that would offset this risk.

9.2 In considering each of these points, I drew on expert advice (as described in paragraph 1.5). My views are summarised below.

9.3 Triggering events that will generate rockfall

9.3.1 A seismic event is in part described by the resulting peak ground acceleration (PGA). This is a measure of earthquake acceleration on the ground and its units are the gravitational constant, *g*.[14]

9.3.2 In order for a seismic event to be likely to generate a hazardous rockfall a minimum PGA is required. The GNS Science pilot study includes frequency data (per annum) at which different PGA values are exceeded. I also note that there are also non-earthquake mechanisms that could release boulders (refer Appendix paragraph A1.3) and this would mean that the exceedance rate for all events is slightly higher than that described in the GNS Science pilot study.

9.3.3 On the basis of this, I accepted that there was a risk that a triggering event could occur that would result in hazardous rockfall.

9.4 Rockfall source

9.4.1 PHGG has identified and described rock sources above the property in the course of its ongoing reviews (refer paragraphs 3.2.1 to 3.2.4, 4.4 to 4.6, and 4.10). These descriptions (and therefore, the associated consequences) vary. However, based on its most recent assessment (refer paragraph 4.10), I concluded that PHGG considered the risk to be less than the suburb-wide risk, which my geotechnical expert agreed with.

9.4.2 In particular, my expert agreed with the following PHGG conclusions:

> …there was little to no large-scale collapse of cliffs less than 10m high [and] while the rock mass dilated and loosened, no significant rockfall was observed from the bluffs above Finnsarby Place as a result of the recent seismic activity.[15]

[14] Peak ground acceleration can be expressed in *g* (the acceleration due to Earth's gravity, equivalent to g-force); for example, a PGA of 2 *g* is acceleration twice that of gravity

and

> There is a long run-out zone for boulders travelling from source area high above the property.[16]

9.4.3 My expert also noted that, while boulders of 2.0m^3 to 3.0m^3 could be generated from these rockfall sources, the largest historic boulder was only 1.2m^3 and this boulder was located 10 to 20m above the dwelling. He also noted that few boulders fell from this rockfall source during the February 2011 and June 2011 seismic events, and none on this property. This was in contrast to the numerous boulders that fell from the bluff above the pony club located to the southwest off Sumnervale Drive.

9.4.4 On the basis of this advice, I concluded that this area provided a source of hazardous boulders and rocks.

9.5 Rockfall pathways and energy calculation

9.5.1 I then considered whether there was sufficient evidence to allow me to conclude that rocks could reach or pass the building with sufficient energy to cause injury to the building's occupants.

9.5.2 My experts reviewed all rockfall modelling that contributed to and underpinned the authority's decision.

9.5.3 Whilst the authority placed some reliance on the 3D Hy-Stone rockfall modelling, I did not as my experts advised me that the model had not been calibrated against actual boulder roll paths and may be unreliable.

9.5.4 I was also provided with results from PHGG's 2D RocFall modelling for three indicative rockfall pathways (Sections 001, 002 and 003, appended to the PHGG memorandum of 14 March 2013). I disregarded section 003 as it did not appear to intercept the dwelling.

9.5.5 2D RocFall model outputs were given for boulder sizes of 1.0m^3, 2.0m^3 and 3.0m^3 and PHGG's conclusion was:

> The 2D site specific rockfall models indicate that for a bare slope model, the majority of rocks (75 to 95%) reach the dwelling. The models run incorporating dense vegetation upslope of the house indicated that all of these rocks would be expected to be stopped by the vegetation; the model shows the rocks come to rest within 1 to 10m upslope of the dwelling.

9.5.6 In my view the results of this modelling (where vegetation is considered) supported PHGG's observations regarding actual rockfall; i.e. that:

> Relatively little earthquake-induced (recent) rockfall was observed on the slope above the dwelling; no recent fallen boulders were observed within 60m (laterally) on either side of the dwelling.

9.5.7 However, PHGG discounted the vegetated slope modelling results, as it concluded[17]:

> The model results are highly dependent on the length of the vegetation upslope of the dwelling and the vegetation parameters used. Because of the variations in the type and density of vegetation present on the slope, and uncertainties inherent in the modelling process, the vegetation cannot be guaranteed to stop all rocks from reaching the dwelling.

---

[15] Supplementary information with PHGG's review of 14 March 2013
[16] PHGG review of 2 February 2012
[17] PHGG review of 14 March 2013

9.5.8 Furthermore, the PHGG memorandum concluded:

> The risk at the dwelling is judged to be lower than suggested by the GNS model because the rockfall source is judged to be less than the suburb average source. However, because the dwelling is located well within in the greater 10^{-3} risk band (year 1) of the GNS model, it cannot reasonably be concluded that the risk at the dwelling is so much lower that it is within the less than 10^{-4} risk band.

9.5.9 I then considered the PHGG conclusions that related to boulder size, vegetation and life safety risk band (AIFR, or Annual Individual Fatality Risk[18]) in the context of the section 124 notice.

9.5.10 Regarding boulder size, I accepted that a $2.0m^3$ boulder might occur but I was uncertain whether the $2.0m^3$ boulder was the appropriate size to use as the 95th percentile boulder when PHGG had concluded that it was more likely to be in the range $1.5m^3$ to $2.0m^3$ (refer paragraph 4.10).

9.5.11 Regarding the vegetation, I did not accept that its existence could be ignored. The test for applying a section 124(1)(b) notice is that a risk exists, which I considered to include taking into account mitigating features. Such mitigating features include neighbouring properties, rock protection systems and vegetation. In this instance, PHGG noted the existence of vegetation and its impact on any fallen rocks. The mitigating effects of the existing vegetation is further demonstrated through the 2D rockfall modelling for a vegetated slope (refer paragraph 4.12).

9.5.12 As well as the presence of any such mitigating features, it was my view that all site-specific factors should be considered. These included

- the frequency of boulders expected from the sources upslope of the dwelling
- the distribution of fallen boulders that resulted from the February 2011 and June 2011 earthquakes and, in particular, whether boulders reached or passed the dwelling
- the energy of the boulders if they reached the rear wall of the dwelling relative to the energy required for a boulder to penetrate the wall.

9.5.13 Despite the authority’s assurance that its section 124 decisions were based on site specific risk, in this instance I was unable to accept this assurance since the decision to retain the notice appeared to be based on the conclusion in the PHGG memorandum I refer to in paragraph 9.5.8.

9.5.14 Regarding the life safety risk, I did not accept that the decision should be made based on the suburb-wide risk band. While the property lies within the 10^{-3} to 10^{-4} risk band for the CERA zoning model, my experts advised that it would not be unreasonable to consider the risk at the dwelling to be within the risk band of less than 10^{-4} given that the rock source was less than the suburb average, as noted in the PHGG memorandum (refer paragraph 9.5.8), and further commented on in that same memorandum:

> The nearly vertical bluffs in the Wakefield suburb model can be regarded as local “cliffs” within the slope. Based on recent GNS work in the Port Hills, GNS observed that there was little to no large-scale collapse of cliffs less than 10 m high. The main bluff source area above 7 Finnsarby Place is a cliff that is about 7 to 10 m

[18] Annual individual fatality risk is used in the GNS work for the authority and CERA to express the probability (likelihood) that a particular person occupying a dwelling will be killed by an event such as rockfall in any one year. This risk is expressed as logarithmic numbers such as 10 (-4) (10 to the power of minus 4) per year.

> high. While the rock mass dilated and loosened, no significant rockfall was observed from the bluffs above Finnsarby Place as a result of the recent seismic activity. This is in contrast to the relatively larger collapses that occurred from higher bluffs present within the Wakefield suburb; these collapses have generated a relatively large number of boulders.

9.5.15 I noted that the PHGG memorandum states:

> The GNS Life Risk models and zoning decisions made by CERA have been considered but do not affect whether or not a dwelling meets the criteria to be classed as a dangerous building under section 121 of the Building Act 2004.

9.5.16 The PHGG memo concluded that with the effects of vegetation modelled no boulders reached or passed the dwelling (refer paragraph 9.5.5). This being so, my experts advise me that it follows that the site specific AIFR in the GNS model would become effectively zero.

9.5.17 I concluded that it appeared the authority had made its decision that a rock could reach or pass the building with sufficient energy to injure an occupant after:

- discounting existing mitigating effects relating to the site-specific rock source and the ad hoc rockfall fences and ignoring the presence of vegetation, and
- discounting actual observed rockfall, and
- relying on this property's location within the suburb-wide risk band, and not factoring in that the 2D RocFall modelling results necessarily changed the risk band.

10. The first draft decision

10.1 Based on my analysis of the authority's decision making process regarding the section 124 notice at this property, I did not accept that the authority had provided sufficient evidence to conclude that there was a risk that rocks could reach or pass the building.

10.2 Accordingly, on 29 May 2013 I issued a draft determination in which I concluded that the authority had yet to establish that the building was dangerous (as defined by the Act and modified by the Order), and the notice should be withdrawn.

11. Responses to the first draft and the hearing

11.1 The authority's views

11.1.1 The authority responded to the first draft of this determination on 14 June 2013, saying it did not agree with my conclusion and requesting a hearing. In particular, it took exception to my view expressed in that draft (refer paragraph 9.5.17) on the basis for its decision to continue the notice.

11.1.2 A hearing was held on 23 July 2013 followed by a site visit.

11.1.3 Before the hearing, the authority provided me with a copy of a report from Geoscience Consulting[19]. This report, which included a geotechnical assessment and concept design for rockfall risk reduction, had been commissioned by the applicants

[19] Geoscience Consulting (NZ) Ltd "Geotechnical Assessment Report, 7 Finnsarby Place, Sumner, Christchurch" 15 April 2013

as required by the authority's Technical Guideline for Rockfall Protection Structures (TGRPS).[20]

11.1.4 On my experts' advice, I have given little weight to this report as

- I do not consider it to be independent of the PHGG analyses or the GNS model as it relies on many of the same source assumptions
- there are two variations from the GNS model that I consider to be errors
    - an assumption of a blanket probability of 99% that a building would be in the way of one or more boulders, with that risk then attributed to a person
    - an assumption that 50% vegetation coverage is 50% effective in stopping boulders. This assumption is not supported by PHGG modelling dated 23 July 2013 which showed that 50% vegetation would stop 96-99% of all boulders from reaching or passing the dwelling.

11.1.5 At the hearing, the authority and PHGG representatives (acting on the authority's behalf) provided further analysis; in particular, relating to the sensitivity of 2D rockfall modelling to mitigating features such as vegetation or rockfall protection structures (RPSs).

11.1.6 The authority's main points in relation to my views on its decision-making process (as noted in paragraph 9.5.17) included the following:

Site specific rock source and boulder size

- As the rock source treatment was incomplete and existing rockfall fences did not appear to be specifically engineered, the authority submitted that neither could be considered effective mitigation.
- The range for the site specific 95th percentile boulder size (1.5 m^3 – 2.0 m^3) was established on the basis of observations at outcrops on the slope above the dwelling and PHGG elected to adopt the conservative end of the estimated range.
- While variations in boulder size influenced its mass and therefore its impact energy, this did not affect the run out distance; i.e. whether or not a rock could reach the dwelling.
- Bare slope Hystone 3D rockfall models (which generally underestimate the runout distances in the Port Hills) also showed rockfall trails that reached and passed the dwelling.

Existing vegetation

- As there are inherent uncertainties in the vegetation input parameters for the 2D rockfall modelling, existing vegetation should not be relied upon to stop falling boulders.
- While the 2D modelling provided on 14 March 2013 suggested that vegetation would stop all boulders upslope of the house, this was relatively close to the dwelling and within the margin of error.

[20] *Technical Guideline for Rockfall Protection Structures*, Christchurch City Council, March 2013

- PHGG tabled further 2D rockfall modelling at the hearing that used another approach to estimate the effect of existing vegetation (which had been described in the Geoscience report – referred to in paragraph 11.1.3 – as 'patchy' with about 50% coverage). The modelling reduced the distance the vegetation began upslope from 35m to 15m. It then alternated vegetated and non-vegetated cover belwo this point. The modelling results indicated that between 0.1% and 0.4% of all boulders could reach or pass the house with greater than 25 kJ kinetic energy.

Consideration of life safety risk

- PHGG considered, but did not quantify, the effect that the 2D rockfall models had on risk. While it accepted that the risk was overestimated at this property, it did not agree that these models necessarily changed its risk band.

11.2 The applicants' views

11.2.1 The applicants provided me with a summary of their key concerns and were accompanied at the hearing by a supporter whose home also had a section 124 notice applied. They expressed concern at the lack of any apparent solutions to allow them to reoccupy their home and expressed their wish for quantitative advice to assist with this.

11.2.2 The applicants and their supporter discussed the specific features of their property and site; in their view the 2D rock fall modelling had not adequately reflected these features. Their concerns also included the

- topographical (mitigation) features of the "Captain Thomas track"
- accuracy of the fallen rock database and therefore the assessment of the site specific 95th percentile boulder
- existing rock fences
- degree of conservatism relating to houses on which these notices had been applied compared with other buildings within the Canterbury region to which the modified definition of dangerous building had been applied.

11.3 Site visit

11.3.1 The hearing concluded with a site visit to review site specific considerations including the extent of vegetation, rock sources and prior rockfall, existing rock fences, and rockfall observed in other locations within the suburb; specifically that associated with 31 Finnsarby Place.

11.3.2 During the site visit my experts confirmed the following:

- No boulders reached either of the rock protection fences as a result of the earthquakes (2010/2011) or aftershocks.
- No fallen boulders were present on the Captain Thomas track above the property and for a distance of approximately 60m to the west and 100m to the east of the property. In contrast, there was evidence of fallen boulders on and below the track further to the east and west.
- A historic (1.8m^3) boulder was located 10m upslope from the house. There were also smaller historic fallen boulders further up the slope.

- The rock bluffs behind the property were between 4m and 10m in height, which might account for the lack of rockfall arising from these bluffs. In contrast, rock bluffs located to the west and east which generated significant rockfall were between 10m and 25m in height.
- Patchy vegetation extended a distance of approximately 30m upslope from the rear wall of the dwelling; i.e. twice the distance shown on the 2D rockfall modelling.
- The slope appeared to comprise mostly loess, which matched the 2D rockfall modelling.

12. The authority's post-hearing submissions

12.1 At the end of the hearing I requested that PHGG undertake further modelling by using a $1.0m^3$ boulder and by reflecting the site's existing vegetation, which had been agreed at the site visit to begin 35m upslope from the dwelling. This information was provided to me in a PHGG memorandum dated 26 July 2013.

12.2 In addition to the information I requested, PHGG also provided 2D rockfall modelling results for $2.0m^3$ and $1.0m^3$ boulder sizes for two sections (Sections 001 and 002) with and without the rock protection fences and using "patchy" vegetation parameters (refer paragraph 11.1.6).

12.3 PHGG accepted that existing vegetation started approximately 35m upslope of the dwelling. However, it did not consider the 2D rockfall modelling results (whereby the rocks stopped approximately 25m upslope) to be realistic.

12.4 As a result, PHGG amended the model in two ways;

- by starting the vegetation 15m to 20m upslope from the dwelling (matching the modelling used and referred to in paragraph 11.1.6), and
- by subdividing the "vegetated band" into sequential bare slope and vegetated segments.

12.5 PHGG stated its views in relation to this property were that:

- A small change in ground surface condition would significantly change the number of rocks predicted to reach or pass the dwelling.
- Increasing the number of rocks modelled by the computer not only changed the number of rocks predicted to reach or pass the dwelling but also increased the calculated maximum and 95^{th} percentile energy values.
- The modelling indicated that the 95^{th} percentile energy was in the order of 50 kJ to 150 kJ depending on boulder size.
- Given the small number of data points it was likely that the energy values would not be statistically meaningful.
- The relatively limited vegetation cover on the slope above the dwelling might stop or slow many boulders, but this could not be modelled accurately.
- The site was "marginal" in terms of rockfall hazard and "engineering judgment" must play a role. Accordingly, PHGG had adopted a cautious,

pragmatic approach and would recommend the installation of rockfall protection if the building were to be used.

12.6 PHGG also advised that site specific geotechnical investigations should be considered in the context of their surroundings and that the large rock that fell and hit 31 Finnsarby Place should be taken into consideration since no apparent triggering event (weather generated or seismic) had occurred.

13. Further discussion

13.1 In order to arrive at a view of whether this house is dangerous in terms of the Act and whether the authority correctly exercised its powers in issuing the notice, my considerations remain those expressed in paragraph 7.1, namely:

- the meaning of dangerous building, and
- whether a risk exists at this property.

13.2 My considerations relating to the meaning of dangerous building are outlined in paragraph 8 and remain unchanged.

13.3 In considering whether a risk exists at this property, I have again considered whether or not there is a

- credible risk of a triggering event that could generate a rock fall
- source of rocks above the property
- risk that rocks from this source would reach the building, and
- risk that they would do so with sufficient energy to penetrate the external envelope.

13.4 Triggering events that will generate rockfall

13.4.1 I previously concluded that there was a risk that a triggering event could occur that could generate rockfall. This conclusion is unchanged.

13.5 Site specific rock source and observed rockfall

13.5.1 In paragraphs 9.4 to 9.4.4 I explained my reasoning for accepting that the terrain above the dwelling could provide a source of rocks.

13.5.2 Notwithstanding this, the source is significantly less than the suburb wide average as confirmed by my expert's site visit (paragraph 11.3.2), during which he noted that the rock bluffs behind this property were only 4m to 10m high compared with the 10m to 25m high bluffs to the west and east which generated significant rockfall.

13.5.3 As discussed further below, I also note that

- no rocks have fallen at or near this property in spite of significant triggering events, and
- the boulder size at this site may have been overstated.

13.5.4 No rocks passed on or near the property as a result of the 2010-2011 Canterbury earthquakes and aftershocks (by 'near the property', I mean along an approximately 160m length of slope above the dwelling between about 17 Finnsarby Place and 34 Summervale Drive). This was in spite of the peak ground acceleration (PGA) meeting or exceeding 1.0 *g* on two occasions (1.3 *g* on 22 February 2011 and 1.0 *g* on 13 June 2011[21]).

13.5.5 With regard to the size of boulders that could be released from the rock source above this property, my expert considers that this may have been overstated. The accuracy of the authority's Port Hills rockfall database has been questioned by the rock engineering consultant who advised the authority regarding rockfall mitigation in the Port Hills. He concluded that boulder size was overestimated in this database[22] and I understand that one reason for this is that small rocks were not mapped.

13.6 Rockfall pathways and energy calculation

13.6.1 PHGG has used 2D RocFall modelling in their analysis of the site specific risk. PHGG has selected a pathway, approximated the ground conditions along the path (vegetation, bare slope, type of rock etc). They then model the runout length and kinetic energy of rocks that may reach or pass the dwelling.

13.6.2 In a previous determination[23] I noted that the veracity of a tool such as RocFall is dependent on calibration and the validity of the size of boulder upon which the energy calculation is made. For that determination I received a report on the calibration and sensitivity analysis from the authority. My experts concurred with the authority's assurance that the RocFall output may be relied upon.

13.6.3 However, since the hearing, my experts have reviewed all the 2D rockfall modelling that PHGG has now provided. In the case of this site, my experts have concluded that the model does not correlate with what the GNS pilot study predicts. In particular they note:

- The bare slope data provided by PHGG indicated that approximately 95% of rocks would reach or pass the dwelling for section 001 and 77% for section 002.
- The suburb scale average as per the GNS pilot study is 6.3% and on that basis the number of rocks reaching or passing the dwelling should be in the vicinity of 5% – 10% rather than 77% – 95%.
- In its memo dated 26 July 2013, PHGG concluded that it is not possible to accurately model run-out distance when taking into account vegetation.

13.6.4 My experts have therefore advised given the poor correlation, that I should place little reliance on the 2D RocFall modelling. I have accepted that advice.

13.7 Qualitative assessments of the site

13.7.1 As detailed earlier, PHGG undertook qualitative assessments of this property in January and February 2012: one in relation to field testing of the GNS model (the January assessment); and the other in respect of the continuation of the section 124 notice. A further qualitative assessment was undertaken on 15 March 2013 as part of the assessment triggered by the determination application. This final assessment also incorporated use of 2D rockfall modelling.

[21] From Table 7 of the GNS Report 2011/311 for the study area "Sumner (Wakefield Ave)"
[22] Dr Laurie Richards' memorandum no. 2 of 18 June 2012
[23] Determination 2013/037: Regarding the issuing of a dangerous building notice under section 124 of the Building Act relating to geotechnical hazards on the property at 4 Awaroa Lane, Sumner

13.7.2 As a result of the assessment (dated 26th January 2012) PHGG arrived at the following conclusions:

- Boulders did not pass or land within 10m of the house.
- The “F” angle is not measurable.
- The rockfall source does not vary significantly from the suburb average.
- There are no significant topographic features that influence the risk to the dwelling.
- There are no known mass movement issues that could increase the risk to the dwelling.
- The site risk is the same as the GNS suburb-scale value.
- Old but not ancient boulders partly litter the colluvial slope.

13.7.3 I note that two of these conclusions were incorrect and should have been as follows:

- the rockfall source **does** vary significantly from the suburb average;
- the site risk is **less** than the GNS suburb-scale value.

13.7.4 The February 2012 assessment concluded that

- rocks fell on this or an adjacent property
- rocks reached or passed the house
- the house was not hit by any rocks
- there is an obvious source for further rockfall
- there is not effective natural or man-made protection (rock fence, houses, bund or trees).

13.7.5 I note that two of these conclusions were incorrect and should have been as follows:

- rocks did **not** fall on this or an adjacent property;
- rocks did **not** reach or pass the house.

13.7.6 Furthermore I now consider the rock source to be less hazardous (as discussed in paragraphs 13.5.3 to 13.5.5), and I do not believe it is appropriate to completely dismiss the natural and man-made protection, given the presence of mitigating features including the Captain Thomas track, patchy vegetation and rock protection fences. These will be at least partially effective in absorbing energy of rolling rocks.

14. The second draft and the authority’s final submission

14.1.1 A second draft, which confirmed the decision of the first draft, was issued to the parties on 27 September 2013.

14.2 The authority’s submission

14.2.1 Following the release of the second draft, the authority provided another submission (dated 14 October 2013). In the following table I note the authority’s continuing concerns, with respect to draft as well as my comments in respect of these concerns.

Authority's view	My comments
A rock source exists above the dwelling, geomorphic evidence indicates that rocks have fallen in the past and have reached or passed the dwelling. In the AIFR model P(H) is an annual probability that rockfall can occur and given past rockfall P(H) cannot be equal to zero	I accept that boulders have fallen in the past, however it is not known how many or over what period. There was an editorial change between the pre and post hearing drafts that has lead to this misunderstanding. The pre-hearing draft correctly referred to boulders that "...reached or passed the dwelling". The post-hearing draft incorrectly referred to boulders that were "...generated from the source". This unintentionally changed the meaning. It has been corrected (paragraph 9.5.16). Paragraph 9.5.16 does not say that the real risk is zero. The observation made is that the GNS Model returns an AIFR of zero if no rocks are predicted to reach or pass the dwelling.
In arriving at their conclusions, Geoscience state that they have undertaken their own site inspection and drawn their own conclusions in respect of rock source, size and risk and have concluded that that the dwelling, under current conditions is exposed to a risk 3.4 times the tolerable limit adopted by CERA and the authority. On that basis weight should be given to this report.	I do not accept the Geoscience report to be independent of the PHGG analyses or the GNS model; it relies on many of the same source assumptions. In paragraph 11.1.4 I also explain errors in the report that led me to place little reliance on the report.
The 2D rockfall model and the GNS suburb-wide risk model are two unrelated pieces of information and to use a comparison of the percentage pass rates as the basis for concluding reliance is simplistic. Each 2D RocFall model represents a single possible path of an individual, specifically sized "design" model capable of being generated by the rock source. This model is then run 2000 times for statistical robustness with the percentage reaching or passing the dwelling merely an indication as to how many of these specific design boulders reach or pass the specified collector point (the dwelling). In contrast the 6.3%, suburb wide average represents the number of observed boulders that passed the 27° shadow angle in the	In relation to the authority's comments I refer to paragraphs 13.5 - 13.6.4. I do not accept that the two pieces of information are unrelated. They are expected to correlate. Furthermore my decision to place little reliance on the model in this instance is not based entirely on the percentage pass rates. It also has been influenced by my view on the 95th percentile rock size. I also note that in other determinations[24], the authority has placed some importance on the comparibility between the results of the 2D modeling and GNS pilot study and I have accepted and relied upon their conclusions. Good matches may have been made for the

[24] Determination 2013/037

GNS suburb-wode model based on a total distribution of boulders across the entire range of sizes from one single event, not 2,000 trials. 2D Rockfall modelling is an internationally recognised method to ascertain the likely run-out of boulders during rockfall events. Where correctly calibrated using back analyses on unimpeded known trails, good matches can be made and appropriate modelling parameters dervied.	66 boulders described in Appendix B of the GNS Pilot Study but these clearly do not extrapolate to the case at 7 Finnsarby Place or the percentage passing would better correlate. This is not a criticism of an internationally recognised model; it is an observation that the input parameters selected in the suburb wide model (table 2 Appendix G) are not necessarily universally applicable across all sites.
The vegetation and ad hoce rock fences have not been completely dismissed. However, it is impossible to quantify the mitigation effect of non-engineered structures and therefore it is inappropriate to rely completely on what are effectively unknowns (i.e. vegetation and the rock fences).	I accept assessing the risk to a dwelling is complicated. I also note that in other areas of the Port Hills reliance has been placed on the mitigation effects of upslope (and deserted) homes, many of which were not specifically engineered. I also refer to the calibration of RocFall parameters prepared by PHGG dated 18 April 2013. Item 3 of this memo discusses the effect of vegetation on the calculated run-out and impact energies and notes that it has been observed that a significant proportion of rocks dislodged by the 2011 earthquakes were captured or slowed by existing vegetation, which is consistent with my expert's observations. The RocFall output for the vegetated slope at this site does indicate that the existing vegetation should have a significant mitigation effect, albeit that there are uncertainties relating to the vegetation parameters. I therefore consider that it is appropriate to conclude that *some* reliance on the mitigation effects of the vegetation and rock fences when taken in the context of this site is justified.
It is inconsistent for the determination decision to conclude that the property is not currently a dangerous building and then recommend that it is prudent for owners to upgrade their existing rockfall protection structure. Given the determination decision a more appropriate response would be to simply recommend maintenance of these structures.	Even though I have concluded that this dwelling is not currently a dangerous building it would be irresponsible of any authority to ignore the opportunity to recommend that existing rock fall mitigation to be updated and improved in light of current knowledge.

14.3 Summary

14.3.1 Despite the concerns of the authority and after taking into account my experts' advice my views have not changed and I summarise them as follows:

- It appears that the rock bluffs are an unlikely source of hazardous rocks.
- The results of the 2D modelling for this site yeild a very poor correlation to the suburb average for percentage of boulders passing the shadow angle and therefore should be given less weight in this situation.

14.3.2 It is my view that the authority has not sufficiently established that there is a risk of rockfall at this property that could cause injury to any person in the building. What is more, the fact remains that no rocks have reached or passed the property despite two seismic events recorded with a PGA greater than 1.0 *g*.

15. Conclusion

15.1 Exercise of powers

15.1.1 In considering whether or not the authority exercised its powers correctly I consider that the authority has yet to establish that the building is dangerous as defined under the Act (as modified by the Order) and have therefore concluded that the building is not dangerous under section 124 of the Act.

15.1.2 Based on my review of the information provided to me and on the advice provided by my experts, I do not accept the authority's view that this property is currently a dangerous building as defined by the Act and that the notice should remain in force.

16. Ongoing rock interception measures

16.1 I understand the applicants are considering upgrading the existing ad hoc rock fences and I consider this to be prudent.

16.2 The applicants may wish to consider obtaining more detailed specialist engineering advice regarding the design of a suitable rockfall protection structure. Another option may be to obtain legal protection for the vegetation so it cannot be removed. Pursuing any such options would obviously be at the applicants' discretion.

17. Decision

17.1 In accordance with section 188 of the Act, I hereby reverse the authority's decision to issue the notice under section 124 of the Act.

Signed for and on behalf of the Chief Executive of the Ministry of Business, Innovation and Employment on 25 November 2013.

John Gardiner
Manager Determinations and Assurance

Appendix A

A1 The Port Hills and associated rockfall hazards

A1.1 The Port Hills are the northern part of the eroded and now extinct Lyttelton basalt volcano, which comprises five overlapping volcanic cones. The hills extend from the southeast edge of Christchurch's main urban area to Lyttelton Harbour and from Godley Head in the east to Governors Bay in the west. They range up to about 500m high and include steep coastal cliffs.

A1.2 The rock forming the hillside slopes and bluffs comprise strong jointed volcanic lava flows. These are composed of basalt and trachyte interbedded with softer breccia (scoria), agglomerate (volcanic gravel), ash and buried soil layers and cut by intruded dykes. The volcanic rocks are generally mantled with loess soils (windblown sand and silt). These are typically about 1m thick but can reach up to 5m thick in places.

A1.3 From time to time, the jointed rock masses release boulders that roll and bounce downhill and then accumulate as talus or scree at the toe of the slopes. Potential triggers for releasing these boulders include earthquake shaking and a variety of non-earthquake mechanisms such as prolonged heavy rainstorms, shrinkage of soil beneath detached boulders during dry periods, and frosts.

A1.4 As well as potentially triggering a boulder release, earthquake shaking can also fracture and loosen the jointed rock masses, making them more susceptible to future rockfalls.

A2 Events relating to the issue of section 124 notices in the Port Hills

A2.1 The magnitude 7.1 earthquake of 4 September 2010 resulted in significant damage to buildings in the Canterbury region. As a result, a Civil Defence emergency was declared. The Canterbury Earthquake (Building Act) Order 2010 ("the 2010 Order") was passed to enable the region's territorial authorities to respond appropriately, and this came into force on 16 September 2010.

A2.2 The 2010 Order expanded the definition of dangerous building to include:

> **7 Modification of meaning of dangerous building and extent to which territorial authority can apply modified provisions**
>
> (1) Section 121(1) of the Act is modified by adding...
>
> (d) there is a risk that other property could collapse or otherwise cause injury or death to any person in the building.

A2.3 On 22 February 2011 the Canterbury region suffered a major aftershock on the Port Hills. As a result of this event, Civil Defence applied red placards to approximately 500 properties including the house that is the subject of this determination. These placards were issued under part 5 of the Civil Defence Emergency Management Act 2002.

A2.4 On 19 April 2011, the Canterbury Earthquake Recovery Act 2011 came into force and provided the power to extend these placards[25] for a further 12 weeks.

[25] Under s85

A2.5 The 2010 Order deemed a red placard to be a notice under section 124(1)(b) of the Act[26]. Therefore, when the red placards expired in July 2011, the authority was required to formally serve section 124 notices.

A2.6 In mid-2011, the authority established the Port Hills Geotechnical Group (PHGG), a consortium of specialist engineers, to assess those properties bearing Civil Defence red placards and to recommend whether (or not) a section 124 notice should be served.

A2.7 The PHGG has continued to review properties on behalf of the authority with regard to issuing, retaining or removing section 124 notices in view of the definition of dangerous building contained in the Canterbury Earthquake (Building Act) Order 2011 ("the Order"). This superseded the 2010 Order referred to in paragraph A2.1 and took effect on 17 September 2011. The 2011 Order further modified the definition of dangerous building:

> **7 Modification of meaning of dangerous building and extent to which territorial authority can apply modified provisions**
>
> (1) Section 121(1) of the Act is modified by adding...
>
> (d) there is a risk that adjacent, adjoining, or nearby buildings or land could collapse (including collapse by way of rock fall, landslip, cliff collapse, or subsidence) or otherwise cause injury or death to any person in the building

A2.8 The Order was superseded on 16 September 2013 by the Canterbury Earthquake (Building Act) Order 2013, which provided for these section 124 notices to remain in force until they are removed by the authority or cease to be in force for any other reason under the Act, or until 18 April 2016 at the latest.

A3 Suburb-wide geotechnical assessments

A3.1 The earthquake and aftershocks of 2010 and 2011 revealed a hitherto unknown earthquake fault in the Port Hills region. This has heightened the awareness of the level of rockfall risk in the area.

A3.2 A considerable amount of geotechnical assessment has been now undertaken to assess that risk. Work has been commissioned by the authority to help with its assessment of risks from rockfall, cliff collapse and related hazards in the area. Work has also been commissioned by the Canterbury Earthquake Recovery Authority (CERA) to inform its land zoning decisions across all affected regions, including the Port Hills.

A3.3 As I consider that this work has influenced some of the decision-making relating to the maintenance of notices issued under section 124 on this and other Port Hills properties, I now describe these assessments

A3.4 Assessments for the authority

A3.4.1 As a result of the February 2011 aftershock, the authority commissioned GNS Science in mid 2011 to undertake a comprehensive assessment of the life-safety risk in the Port Hills from rock fall.

A3.4.2 GNS Science's risk model identified areas of different Annual Individual Fatality Risk (AIFR) within the Port Hills.

[26] cl8(2)

A3.4.3 GNS Science's Port Hills rockfall risk assessments were derived from three independent components:

- the behaviour of people (where and how they lived relative to the Port Hills)
- the nature of the surroundings relative to where people live (where boulders could fall from, the number of boulders available to fall and the paths they could follow), and
- the frequency and magnitude of rockfall triggers such as earthquakes, rain and human disturbance.

A3.4.4 I understand that GNS Science combined the frequencies, probabilities and consequences of these to estimate the different AIFR areas. However, GNS Science noted that this assessment was based on limited data that was subject to uncertainties and therefore had to be generalised as average values.

A3.4.5 This model was further calibrated for GNS Science by PHGG between February and May 2012. PHGG assessed each Port Hills property against the model to calibrate the risk contour maps (it termed this field testing work "ground-truthing"). The finalised model and associated research was made public in September 2012.

A3.5 Assessments for CERA

A3.5.1 At a similar time, the Government recognised that there was land in the Canterbury region that may no longer be able to be built on and wanted to provide options for residents. Accordingly, CERA also commissioned geotechnical and life risk modelling research from GNS Science and others, including 3D rock fall modelling. I understand from the authority that this modelling was not independent but a rerun of the modelling GNS Science had previously carried out for the authority, but with different parameters. This research was used as a basis for CERA's land zoning decisions, in what it deemed to be red zones, since property owners in those zones would become eligible for a Crown purchase offer.

A3.5.2 In late 2012 CERA announced its decisions relating to red zones in the Port Hills. It said red zoned properties were those:

- affected by cliff collapse and with immediate risks to life, or
- where land remediation was not considered viable and infrastructure would be difficult and costly to maintain, or
- affected by rock roll and where the risk to life was considered unacceptable or was unlikely to reach an acceptable level in a reasonable timeframe, or
- where protective works to mitigate the life safety risk were not considered practicable.

A3.6 The section 124 notices and CERA's zoning process

A3.6.1 There is potential for confusion in the understanding of the CERA zoning process and the authority's decisions to issue section 124 notices; both can have significant impact on the living choices of building owners. Both decisions have drawn on similar data and investigative reports, which makes sense given the technical challenges of assessing the increased risk of rockfall and the limited resources of both CERA and the authority. However, it is important to keep in mind that the authority, unlike CERA, must comply with specific statutory requirements before issuing a notice.

A3.6.2 The notices issued by the authority make use of significant powers intended to ensure that a minimum standard of safety is maintained for all buildings and that people's health and safety is not placed at risk by buildings that are dangerous, earthquake-prone or insanitary.

A3.6.3 The powers provided for under section 124 can have a very severe outcome as they can prevent a person from accessing their own home. Accordingly, the authority is required to provide a clear articulation of when these powers will be exercised and appropriate evidence in support of any specific decision to issue a notice.

A3.6.4 While the GNS Science methodology was initially commissioned by the authority, it is a suburb-scale tool which the authority advises me was not applied directly to its decisions to issue or retain section 124 notices relating to rockroll in the Port Hills. The methodology was subsequently applied by CERA, although using a different set of initial assumptions.

A4 The authority's process in respect of section 124 notices in the Port Hills

A4.1 The authority has acknowledged that the decision-making process relating to the application or removal of notices on this and other Port Hills properties has been an evolutionary process. Based on the documentation provided to me in the context of this and similar determinations, I describe this process as I understand it:

- first, by focussing on the authority's decision making criteria (paragraphs A4.2 to A4.2.4), and
- second, by summarising the types of assessment carried out, in chronological order (paragraphs A4.3 to A4.6.7).

A4.2 The authority's decision making criteria

A4.2.1 The authority has applied criteria related to

- whether the building had actually been hit by a boulder or rock
- whether a boulder or rock had landed at or passed the building
- whether there was a rockfall source and how that source compared to the suburb average
- whether any topographic or other mitigation features influenced the risk to the dwelling
- how the site compared with the GNS Science' suburb-scale risk assessment, and
- whether the F angle[27] was less than the GNS shadow angle[28].

A4.2.2 Latterly, additional criteria have been specified. These are as follows:

---

[27] F angle, or Fahrboeschung angle: the angle formed between the horizontal and a line drawn from the actual rockfall source location to the stopping point for a given boulder or to a particular given point on the slope below the source.

[28] S angle, or shadow angle: the angle between the horizontal and a line drawn from the base of the rockfall source to the stopping point for a given boulder or to a particular given point on the slope below the source.

- whether a boulder or rock will pass or reach the building with sufficient energy to damage the building, with sufficient energy now being specified as 'in the region of, or greater than 25 kJ at the dwelling' for an external wall of the type described within NZS 3604, and
- where any interceptors (e.g. a rock protection structure or vegetation) were present, the mitigation effect of those interceptors being limited to 50 kJ unless those interceptors have mitigation effects certified as otherwise.

A4.2.3 The authority has advised me that the energy capacity attributed to a NZS 3604 type external wall (25 kJ) was established as a result of discussion with its engineers and then cross checked by 'basic back calculation' of the energy levels of rocks reaching, impacting or penetrating some of the dwellings directly affected by rocks in Morgans Valley and Sumner.

A4.2.4 The authority advised that it had allocated an energy capacity of 50 kJ to rock protection structures constructed before the 2010/2011 earthquake sequence that had 'typically been installed across the Port Hills, generally comprised of chain-link fence or double-twist mesh' because the performance of these structures was highly dependent on the mode of travel of the boulder, type of construction and quality of workmanship, and that:

> After considering supplier product information, anecdotal evidence, and some limited back analyses, the indication is that these rudimentary structures generally have rockfall stopping capacities no greater than 50kJ.

A4.3 Assessments from mid 2011

A4.3.5 From mid-2011, PHGG assessed all properties for section 124 notices on behalf of the authority. I refer to any house that had a red placard from this time as having a notice. The authority said these notices were placed and reviewed on the basis of site-specific conditions and observations and that PHGG considered topography, vegetation, actual boulder locations in relation to houses, upslope houses and potential rock sources for future boulders. In a letter to me of 26 November 2012, the authority advised that:

> In the expert opinion of the PHGG consultants, where a s124 notice has been issued, the level of risk is very high or extreme.

A4.3.6 This assessment process included a flowchart and considered

- whether rocks fell on this or an adjacent property and, if so, whether they reached or passed the house and whether the house was hit by rocks
- if the slope below the source was steep enough for boulders to roll
- whether there were obvious sources for further rockfall, and
- if there was effective man-made or natural protection such as rock fences, houses, bund or trees.

A4.4 Assessments from mid-2012

A4.4.1 PHGG continued its assessments for the authority from mid 2012 using a revised flow chart that represented its process.

A4.4.2 At this time the process considered

- whether a boulder had passed within 10 m of the house

- if the F angle was less that the GNS shadow angle
- whether the rock fall source varied significantly from the suburb average
- whether topographic features influenced the risk to the dwelling
- whether there were any other known mass movement issues that could increase the risk to the dwelling, and
- whether the risk at the site was the same, less or greater than the GNS suburb-scale value.

A4.4.3 The authority said the GNS Science modelling information was used for context. However, from the documentation, it appears that it used the GNS Science model as a filter as the decision-making process did not allow for an existing notice to be lifted unless the AIFR[29] at the property (as assessed by the model) was less than 1×10^{-6}.

A4.5 Assessments from late 2012

A4.5.1 CERA made several zoning announcements for the Port Hills during 2012, and these triggered further assessments. Properties with existing notices that were zoned red were sent letters by the authority saying that the section 124 notice would continue. I also note that the assessment template changed around that time to reflect CERA's adaptation of the GNS Science life safety risk model. From then on, the decision-making process did not allow for an existing notice to be lifted unless the AIFR at the property was less than 1×10^{-4} as assessed by the GNS Science model for the authority <u>and</u> by CERA's own modelling.

A4.5.2 The authority has recently advised me that it also completed 2D rock fall energy modelling for approximately 130 properties at this time. These properties were those where:

> ...the s124 notice was uplifted following the zoning announcement by CERA in June 2012, but where the [authority] subsequently decided a review was needed to verify the decisions that had been made.

A4.6 Assessments from early 2013

A4.6.1 Where a determination application had been made, a complete reassessment of the rockfall risk for the property was undertaken by PHGG. The review included completion of a two-page checklist, an office review of existing data, further field testing and 2D rockfall modelling.

A4.6.2 I understand that the rockfall model has been calibrated against actual, observed roll/bounce trails of boulders that fell during the Canterbury earthquake sequence. The rockfall model also takes into account the topography, geomorphology, vegetative cover and other barriers along any particular rock-roll path that has been selected.

A4.6.3 I note that in the accompanying memoranda to the authority for all reassessments of this type that I have seen, PHGG says the criteria used to determine whether or not a dwelling was in a location such that it was exposed to a 'clear and present danger' include, but are not limited to, whether (in recent earthquake events)

[29] Annual individual fatality risk, which is used in the GNS work for the authority and CERA to express the probability (likelihood) that a particular person occupying a dwelling will be killed by an event such as rockfall in any one year. This risk is expressed as logarithmic numbers such as 10 (-4) (10 to the power of minus 4) per year.

- rocks fell on this or an adjacent property
- rocks reached or passed the dwelling
- the dwelling was hit by rocks
- the slope above the dwelling was steep enough for rocks to roll down it
- there were obvious sources for further rockfall, and
- the rocks could reach the dwelling with sufficient energy to penetrate the exterior cladding (of the dwelling), and
- there was effective natural or man-made protection for the dwelling.

A4.6.4 In order to undertake the 2D Rock fall modelling and arrive at a calculated potential energy, a 95th percentile boulder size was calculated and the 95th percentile energy value of that boulder at the dwelling was recorded. I understand from PHGG that for many properties the site specific 95th percentile rock was assumed to be the same as the suburb wide 95th percentile boulder size.

A4.6.5 I note further that the review checklist provides for consideration of rockfall mitigation measures, but only if these are approved or consented by the authority:

> Non [authority] approved engineering mitigation works cannot be used to change the risk.

A4.6.6 The checklist also gives PHGG three options for its recommendations to the authority:

- Retain the notice on the property.
- Retain the notice but reassess this once approved rockfall protection measures have been installed.
- Remove the notice.

A4.6.7 The authority has advised that, except for one additional property, this complete reassessment has been limited to:

(a) properties with existing section 124 notices where a determination application had been made; and

(b) properties that are exposed to increased risk of rock fall due to the demolition of an upslope dwelling that currently provides protection and which may need a section 124 notice to be applied.

The reason given for limiting this reassessment was because of the time and cost associated with the reassessment work.