UPDATE ON GEOTECHNICAL WORK ON THE PORT HILLS

Cliff Collapse and Debris Inundation

Rockfall

Land Movement (Landslides)

Rori Green, Mark Yetton & Don Macfarlane

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"On an international scale this is an enormous project with very challenging technical and social complexities."

Fred Baynes

International Peer Reviewer engaged by CCC

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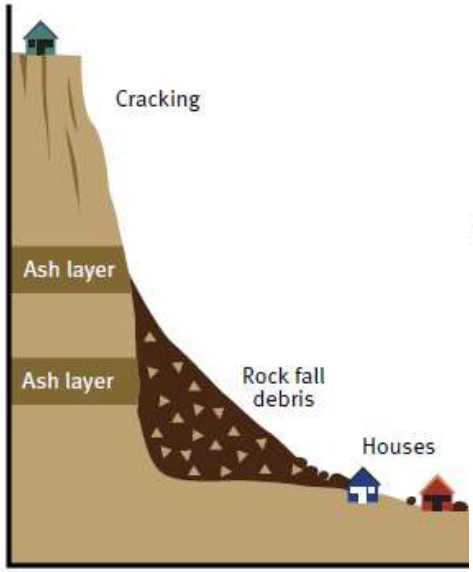
Life-Safety Risk Criteria

- Risk criteria based on Annual Individual Fatality Rate (AIFR)
- International guidelines for tolerable risk for geotechnical hazards: (Australia, Hong Kong)
  - Existing developments , AIFR = 1:10,000 (10^{-4})
  - New developments , AIFR = 1:100,000 (10^{-5})
- CERA zoning decisions based on Year 5 (2016) annual risk of 1 in 10,000 (10^{-4}) [taken as equivalent to Year 1 (2012) annual risk of 1 in 5000]

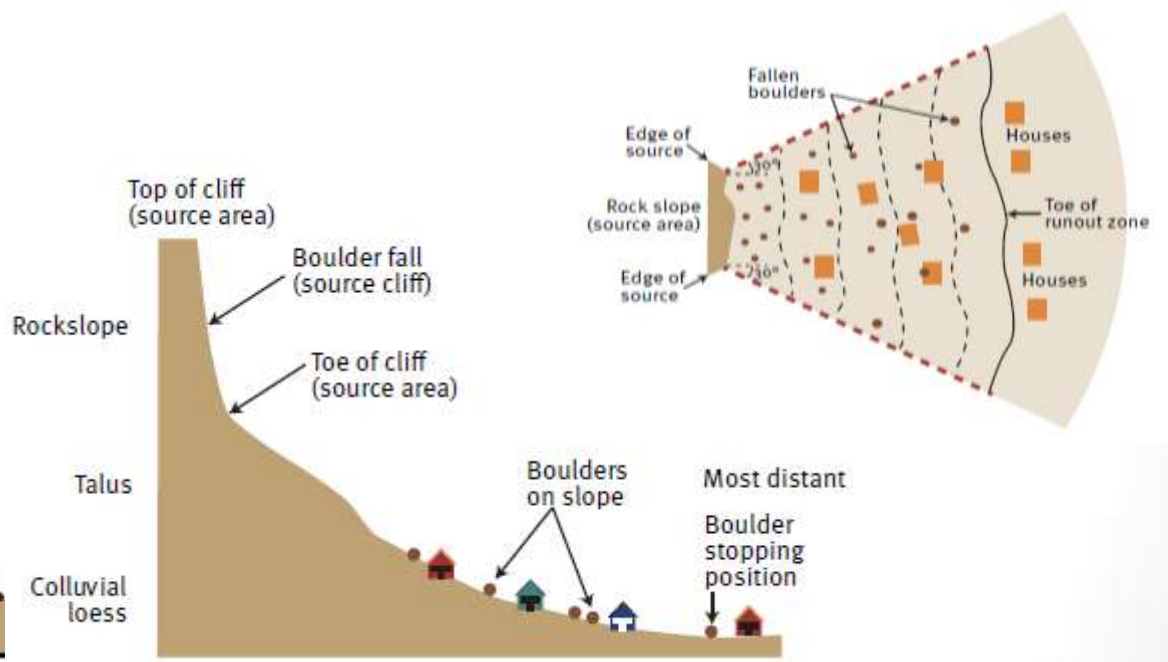
The GNS Risk Models

- Recent presentations by Chris Massey (GNS) available on YouTube

  (www.ccc.govt.nz → Christchurch earthquake → Geotechnical Information Seminars)



Cliff Collapse



Boulder Roll

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Overview of the Process

Boulder Roll

Data (collection and assessment)	• Boulder mapping • Geomorphic mapping • Source characterisation
Risk Model (preliminary risk maps)	• Supported by 2D rockfall modelling (boulder runout limits) *More than 600 2D sections modelled*
Ground truthing	• Individual property visits *Approximately 2000 properties*
Revise risk maps	• Update based on ground truthing

Year 1 (2012) Risk Model C – 100% occupancy, with aftershocks

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GNS Risk Model

Boulder Roll Source Area Characterisation

Continuous Major

Continuous Minor

Discontinuous Minor

Isolated Major

Intermittent

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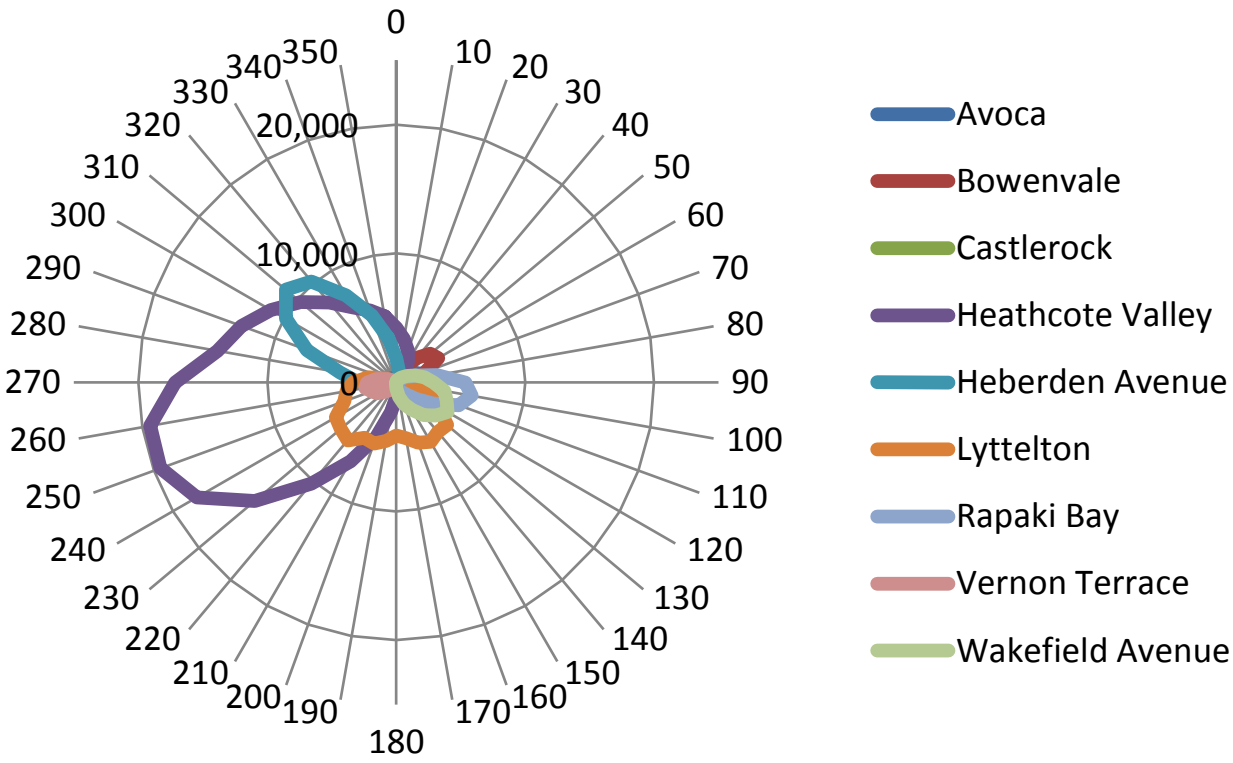
GNS Risk Model

Quantifying the Area of Sources



The surface area (m^2) of the rockfall source areas (slopes > 40 degrees in angle) per suburb within each 10 degree slope aspect bin (0 = North). For example in Heathcote Valley, most of the rockfall source areas have aspects between 240 to 260 degrees (WSW)

Note: there is no link between slope aspect and susceptibility of earthquake triggered rockfalls.

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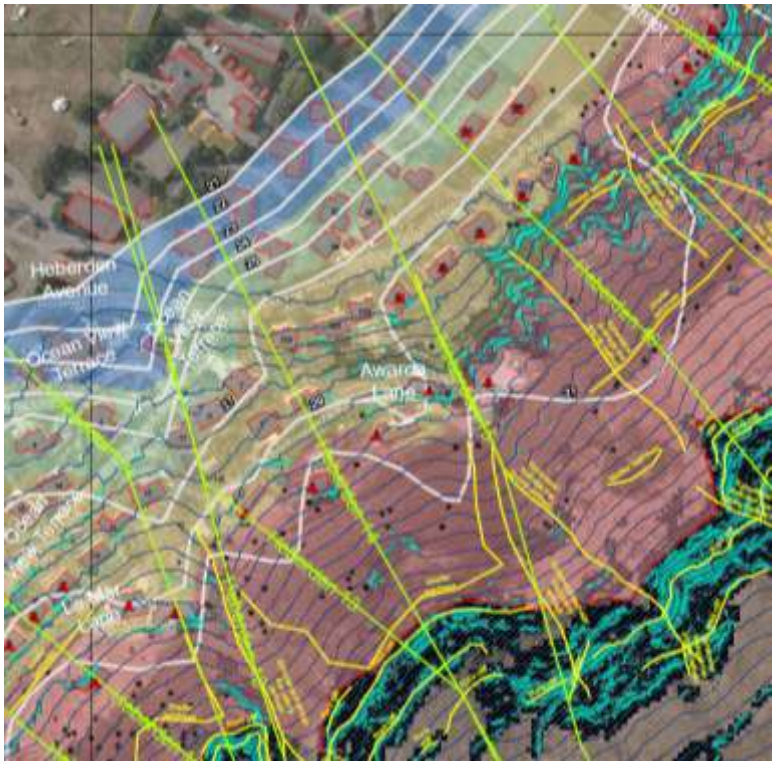
Ground Truthing
Boulder Roll



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Assessment of GNS Model Applicability for Individual Site

Sector: ____ **Address:** _____ **Current S124 Notice?** ☐ *yes* ☐ *no*

GNS $Risk_{LOL}$ at Dwelling*: ☐ *10^{-2} to 10^{-3}* ☐ *10^{-3} to 10^{-4}* ☐ *10^{-4} to 10^{-5}* ☐ *Less than 10^{-5}* (*Risk Model C)

Measured "F" angle at dwelling: _____ or ☐ *Not measurable*

Measured "S" angle at dwelling: _____ or ☐ *Not measurable* GNS Map "S" angle at dwelling: _____

Profile of slope above dwelling: ☐ *sloping run-out* ☐ *localised cliff with flat base* ☐ *slope, flat run-out*

Description of suburb average rockfall source: _____

Did boulder(s) pass or land within 10 m of house
☐ Yes ☐ No
If Yes, ☐ *House hit* ☐ *Landed* ☐ *Passed*
Previously mapped? ☐ Yes ☐ No

Is "F" angle at dwelling less than GNS shadow angle?
☐ Yes ☐ No ☐ Not measurable

Does the rockfall source vary significantly from the suburb average?
☐ Yes ☐ No *If Yes, describe in Comments*
If Yes, how does this affect risk to dwelling?
☐ Increases risk ☐ Decreases risk

Is there a significant topographic feature that influences risk to dwelling?
☐ Yes ☐ No
If Yes, ☐ Ridge ☐ Gully ☐ Flat surface
How does this affect risk to dwelling?
☐ Increases risk ☐ Decreases risk

Are there any other known mass movement issues that could increase risk to dwelling?
☐ Yes ☐ No
☐ Debris flow ☐ Landslide ☐ Cliff collapse

Based on observations of the site, is it possible to assess whether the site risk is same, greater or less than the GNS suburb-scale value?

☐ Yes → **RISK IS** *same / less / greater than* **GNS SUBURB-SCALE VALUE** *(circle as appropriate)*

☐ No → **SITE REQUIRES MORE DETAILED EVALUATION**

Is an S124 Notice Required?
☐ Yes ☐ No
☐ *Cannot make this assessment from available information*

Comments:

Assessed for CCC/Port Hills Geotechnical Group by: _____ Date: _____

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Overview of the Process
Cliff Collapse

Data (collection and assessment)	• Debris/flyrock limits • Ground cracking • Laser scanning (some cliffs)
Risk Model (preliminary risk maps)	• Simulate 3 event lines
Field Check (ground truthing)	• Individual property visits *Approximately 500 properties*

Year 1 (2012) Risk Scenario C – 100% occupancy, with aftershocks

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GNS Risk Model

Cliff Collapse Event Lines

Ground Truthing
Cliff Collapse

Port Hills Geotechnical Group
Assessment of GNS Model Applicability for Cliff Collapse Risk

Sector: ____ **Address:** _____

Pilot Study Area: _____ **Current S124 Notice?** ☐ yes ☐ no

Cliff Type: ☐ *Natural* or ☐ *Man-made* Cliff Height: ☐ >15m or ☐ <15m

In LH column below, complete EITHER grey or yellow boxes, then blue box:

CLIFF BOTTOM PROPERTIES

From existing records, did debris land within 10m of dwelling?

☐ Yes ☐ No

If Yes, ☐ *House hit* ☐ *Not hit* ☐ *Fly rock Passed*

Previously mapped? ☐ Yes ☐ No

Is dwelling within 31 deg "F" angle line?

☐ Yes ☐ No ☐

CLIFF TOP PROPERTIES

Does previously mapped ground cracking pass within 10m of the dwelling?

☐ Yes ☐ No

If Yes, does the cracked area include the dwelling?

☐ Yes ☐ No

Does the recommended risk/setback zone intrude onto the property?

☐ Yes ☐ No

Are there any other known mass movement issues that could increase risk to dwelling?

☐ Yes ☐ No

☐ Debris flow ☐ Landslide

Based on observations of the site, is it possible to determine whether the site risk is consistent with the GNS assessment?

☐ Yes → **RISK IS** *consistent with* **GNS Assessment**

☐ No → **SITE REQUIRES MORE DETAILED EVALUATION**

Is an S124 Notice Required?

☐ Yes ☐ No

☐ *Cannot make this assessment from available information*

Comments:

Assessed for CCC/Port Hills Geotechnical Group by: _____ Date: _____

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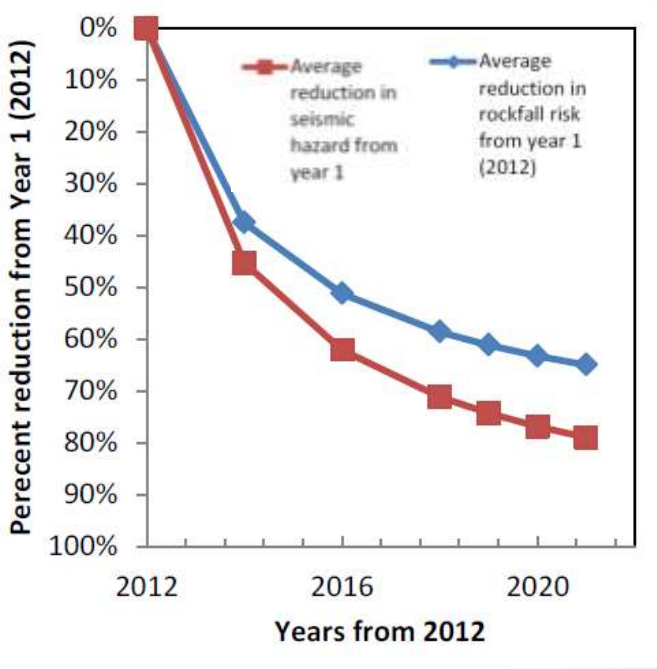
Additional Risk Models

- Commissioned by CERA and CCC
- Sensitivity to parameters most affecting rockfall risk:
  - Time-varying seismic hazard model
  - Occupancy (100% vs 67%)
  - Aftershocks
- Series of models from 2012 (Yr 1) to 2032 (Yr 20)
- Most significant change is due to time-dependant reduction in seismic hazard



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GNS Reports

Cliff Collapse and Boulder Roll

Report No.	Title	Focus
CR 2012/57	Pilot study for assessing life-safety risk from cliff collapse	Cliff collapse in pilot study areas affecting both top and bottom of cliffs *Includes risk maps*
CR 2012/124	Life-safety risk from cliff collapse in the Port Hills	Cliff collapse outside pilot study areas *Includes risk maps*
CR 2011/311	Pilot study for assessing life-safety risk from rockfalls (boulder rolls)	Boulder roll in pilot study areas *Includes risk maps*
CR 2012/123	Life-safety risk from rockfalls (boulder rolls) in the Port Hills	Boulder roll outside pilot study areas *Includes risk maps*

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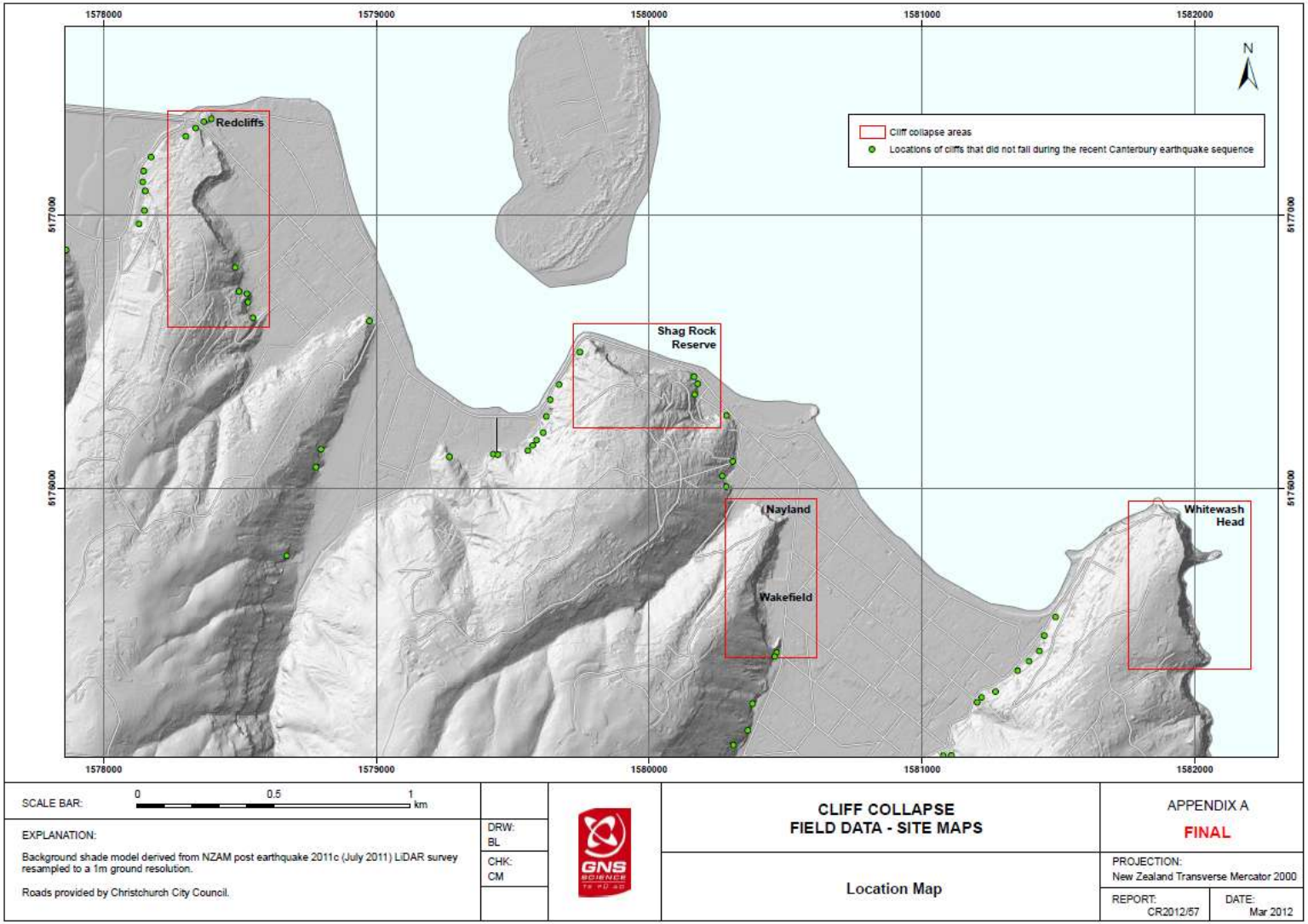
Pilot Study Areas – Cliff Collapse



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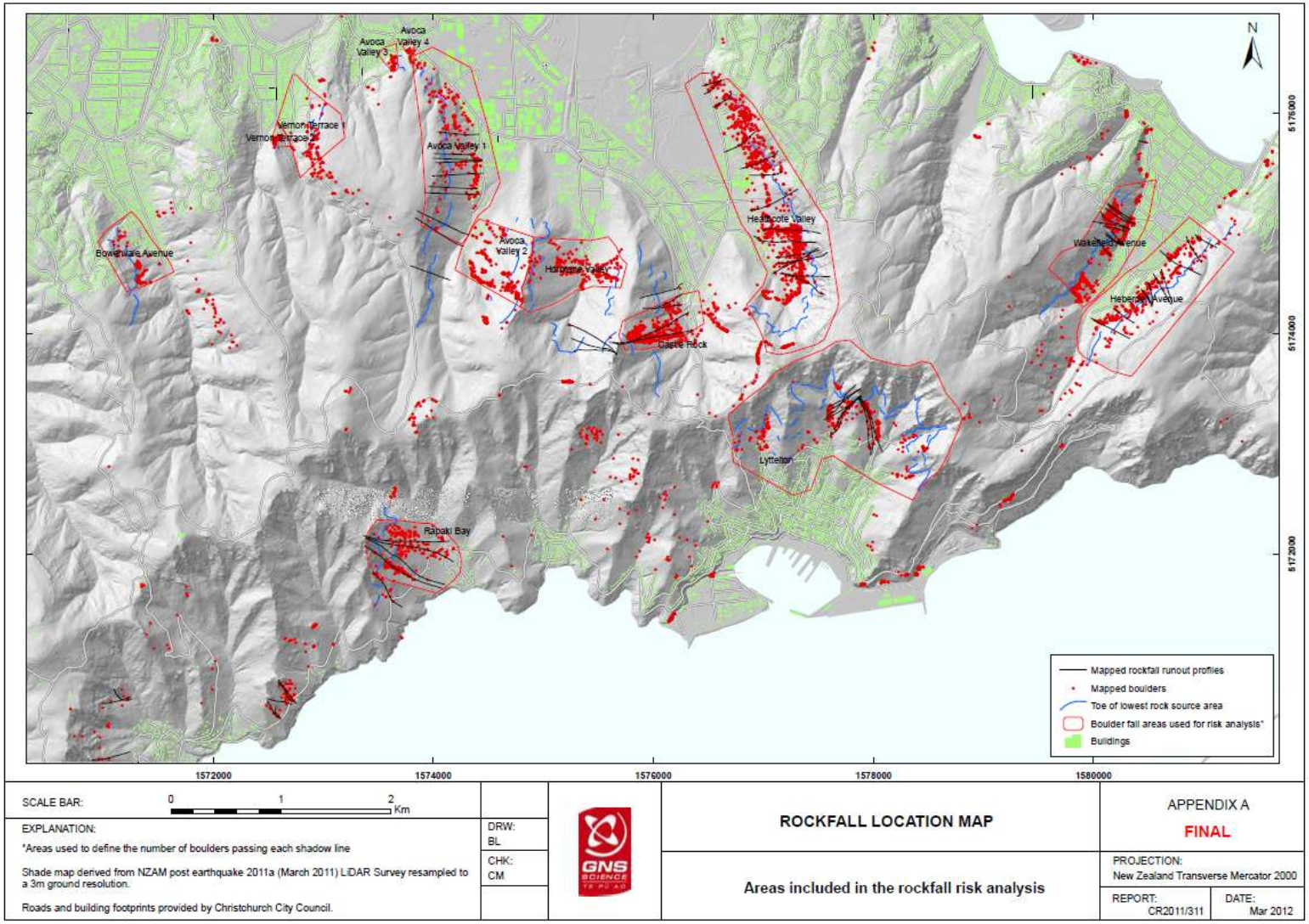
Pilot Study Areas – Boulder Roll



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Additional GNS Reports

Report No.	Title	Focus
CR 2011/319	Principles and Criteria for the Assessment of Risk from Slope Instability in the Port Hills, Christchurch	Evaluation of risk criteria and recommendations on adoption of a tolerable AIFR (i.e. 10^{-3} to 10^{-5})
CR 2012/15	Geomorphology mapping for rockfall risk assessment	Geomorphic maps of Port Hills
CR 2012/214	Additional assessment of the life-safety risk from rockfalls (boulder rolls)	Variation in rockfall risk based on declining seismic hazard (2012 to 2021)

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CERA Rockfall Work

- Commissioned 3D Hy-stone model (Geovert)
- For PHGG work, use has focussed on boulder trail output to help understand 3D topographic effects
- Limitations of 3D model, such as:
  - Runouts, energies & bounce heights have not been calibrated
  - Boulder distributions used in model are not stated
  - Coefficients of restitution used in model are not stated
- Use thoughtfully in light of limitations

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CERA Zoning

- CERA zoning of the Port Hills completed in October 2012
- Zoning Reviews are currently in progress

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Section 124 Notices

- “Dangerous Building” under Section 124 of the Building Act
- Issued and uplifted by CCC (no CERA involvement)
- Residents can request independent review by MBIE
- Not related to CERA zoning (though most S124 Notices are on dwellings within CERA red zone)
- New notices may be issued with demolition of dwellings that provide protection to downslope dwellings

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Work in Progress by CCC

- Changes to the CCC District Plan
  - Revision of geotechnical hazard zones
  - Land use and permitted activities in high risk areas
  - Resource consent requirements for rockfall protection
- Technical Guideline for Rockfall Protection Structures drafted

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Rockfall Protection Structures

- CCC Technical Guideline drafted
  - Site-specific slope assessments
  - Use of existing information (CCC data, GNS reports, 2D & 3D rockfall models)
  - Likely minimum 95% boulder size; boulder flux issues
  - Designer qualifications; Producer Statements
  - Compliance requirements (inspection and maintenance)
- Protective works for residential properties will probably need to demonstrate an AIFR of 10^{-4} or better

Work in Progress by CCC

- Assessment by GNS of 28 mass movement areas in the Port Hills
  - some have lifeline and/or life safety issues
  - majority affect property

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Mass Movement Areas

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Mass Movement Areas

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Questions?

The Port Hills Geotechnical Group

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