Understanding life-safety risk concepts for rockfall and cliff collapse in the Port Hills

(Summary Series 1/3)

The Christchurch City Council commissioned GNS Science to assess and report on slope-instability risk in the Port Hills following the earthquakes of 22 February 2011. This summary provides an overview of the key risk concepts associated with a risk-based approach for managing slope instability hazards in the Port Hills area of Christchurch. The information provided here should be read in conjunction with Life-safety risk from cliff collapse in the Port Hills (Summary Series 2/3) and Life-safety risk from rockfalls in the Port Hills (Summary Series 3/3).

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What is a risk-based approach?

This approach uses a numerical assessment of probabilities (how likely it is that some event will happen) allowing the regulators and the community to determine an acceptable, tolerable and intolerable level of risk. For a risk to be acceptable, the consequences and likelihood of it occurring are low. A tolerable risk has a slightly higher level of risk than acceptable risk, but the benefits of living with the risk make the risk tolerable. An intolerable level of risk occurs when the level of risk becomes unacceptable.

The risk being assessed in these reports is the probability per year of a particular individual being killed.

How is risk to life expressed?

The cliff collapse (e.g. photo to the right) and rockfall risks discussed in the Summary Series 2/3 and 3/3 are relatively small in terms of the likelihood of a particular individual being killed per year. Therefore the GNS Science reports make extensive use of terminology which expresses risk as probabilities such as 1 in 10,000 per year (one person in every 10,000 at risk of being killed each year). Table 1 shows how these numbers can be expressed in different ways. Figure 1 provides a comparison with other risks New Zealanders face.
To put these numbers in perspective, the odds of a Lotto Division 1 win (correctly picking 6 numbers out of 40) are:

- 1 in 3,838,380 or about $2.6 \times 10^{-7}$ per ticket.

If someone bought one ticket every week for 75 years, their lifetime odds of such a win would be:

- 1 in 984 or about $1.0 \times 10^{-3}$ per lifetime.

**Table 1. Different ways of expressing risk probabilities.**

<table>
<thead>
<tr>
<th>Probability 1 in... (per year)</th>
<th>Is the same as (per year)</th>
<th>Is the same as (per year)</th>
<th>Is the same as</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000</td>
<td>$10^{-3}$</td>
<td>0.001 or 0.1%</td>
<td>8% per lifetime*</td>
</tr>
<tr>
<td>10,000</td>
<td>$10^{-4}$</td>
<td>0.0001 or 0.01%</td>
<td>0.8% per lifetime</td>
</tr>
<tr>
<td>100,000</td>
<td>$10^{-5}$</td>
<td>0.000001 or 0.001%</td>
<td>0.08% per lifetime</td>
</tr>
<tr>
<td>1,000,000</td>
<td>$10^{-6}$</td>
<td>0.0000001 or 0.0001%</td>
<td>0.008% per lifetime</td>
</tr>
</tbody>
</table>

*Based on average New Zealand life expectancy of about 80 years, from 2008 mortality and population data

**Figure 1.** Comparison of other risks in New Zealand and the rockfall and cliff collapse risk in the Port Hills

**Average Individual Fatality Risk, Selected Causes**

NZ resident population in 2008 (source: NZ Ministry of Health mortality statistics)

- All Causes
- Road Accidents
- All Accidents
- Drowning
- Accidental Falls
- Cancer
- Heart Disease

Typical range of risk from rockfalls and cliff collapse in part of the Port Hills.
Living with existing risks in New Zealand

What are the chances of being killed in New Zealand? New Zealanders are living with an approximate annual individual risk of death from earthquakes and landslides in the order of $10^{-6}$ or greater per year (averaged over the whole population). However, earthquakes and landslide hazards do not affect all areas of New Zealand equally, therefore some people may be exposed to levels of risk that are:

- $10^{-5}$ or more per year in low/medium risk areas; and
- $10^{-4}$ or more in high risk areas.

Figure 1 shows the typical range of risk from rockfalls and cliff collapse in parts of the Port Hills compared with other risks in New Zealand.

What is the risk level in the Port Hills?

The summaries Life-safety risk from cliff collapse (Summary Series 2/3) and Life-safety risk from rockfalls (Summary Series 3/3) outline risk levels in the Port Hills. The threshold of acceptable annual individual fatality risk is within a range from $3 \times 10^{-5}$ to $1 \times 10^{-3}$ per year (the shaded area on Figure 1), with an average of $1 \times 10^{-4}$ (1 in 10,000 per year) annual individual risk of death. This is consistent with risk levels currently tolerated in New Zealand and with regulatory practice elsewhere.

A large part of the assessed risk is due to the current increased levels of seismic hazard. As the seismic hazard decreases over time, so too will the risk from earthquake-triggered cliff collapses and rockfalls (see Figure 2). In some locations on the Port Hills there are also properties exposed to risk levels of about $10^{-3}$ from non-earthquake triggered rockfalls and cliff collapses (e.g. those triggered by rainfall and frost). The risk is therefore not just from earthquake-triggered failures.

Figure 2. Rockfall-related risk estimates decrease with time

The risk level (shaded band) is uncertain, but is expected to reduce with time