Te Tai o Poutini Plan Proposed Plan

Submission form

Have your say! Te Tai o Poutini Plan Proposed Plan

We need your feedback. We want to hear from you on the proposed Te Tai o Poutini Plan. What do you support and what would you like changed? And why? It is just as important to understand what you like in the Proposed Plan as what you don't. Understanding everyone's perspectives is essential for developing a balanced plan.

Your details:

First name: Jackie & Bart Surname: Mathers & Gillman

Are you submitting as an individual, or on behalf of an organisation? [✓] Individual [ ] Organisation

Organisation (if applicable):

Would you gain an advantage in trade competition through this submission? [ ] Yes [✓] No

If you **could** gain an advantage in trade competition through this submission please complete the following:

I am [ ] /am not [ ] directly affected by an effect of the subject matter of the submission that (a) adversely affects the environment; and (b) does not relate to trade competition or the effects of trade competition.

Postal address: 170 Torea Street
Granity

Email: theworxeactrix.co.nz Phone: 03 7828865

Signature: [signatures] Date: 17.10.22

Your submission:

The specific provisions of the proposal that my submission relates to are:

- [ ] Strategic Direction
- [ ] Historical and Cultural Values
- [✓] General District Wide Matters
- [ ] Appendices
- [ ] Energy Infrastructure and Transport
- [✓] Natural Environment Values
- [✓] Zones
- [✓] General feedback
- [✓] Hazards and Risks
- [ ] Subdivision
- [ ] Schedules

All submitters have the opportunity to present their feedback to Commissioners during the hearings process. Hearings are anticipated to be held in the middle of 2023. Please indicate your preferred option below:

[ ] I wish to speak to my submission [✓] I do not wish to speak to my submission

If others make a similar submission, would you consider presenting a joint case with them at a hearing?

[ ] Yes, I would consider presenting a joint case [✓] No, I would not consider presenting a joint case

__Public information__ - all information contained in a submission under the Resource Management Act 1991, including names and addresses for service, becomes public information. The content provided in your submission form will be published to the Te Tai o Poutini Plan website and available to the public. It is your responsibility to ensure that your submission does not include any personal information that you do not want published.

SUBMISSION – B GILLMAN & J MATHERS – 170 & 170A TOREA ST, GRANITY

Our property is in a General Rural Zone opposite a Settlement Zone in Granity, Northern Buller. We have two contiguous titles – one roughly triangular in shape to the north, and a smaller rectangular block to the south encompassing a boundary adjustment we did some years ago. Bordering us are Open Space Zones to the east, a section of unformed road reserve and the Ngakawau-Stillwater railway line to the west along with another privately owned rural block to the north. We also have a section of Special Purpose Zone running through our northern block due to the proximity of the Stockton Coal Mine.

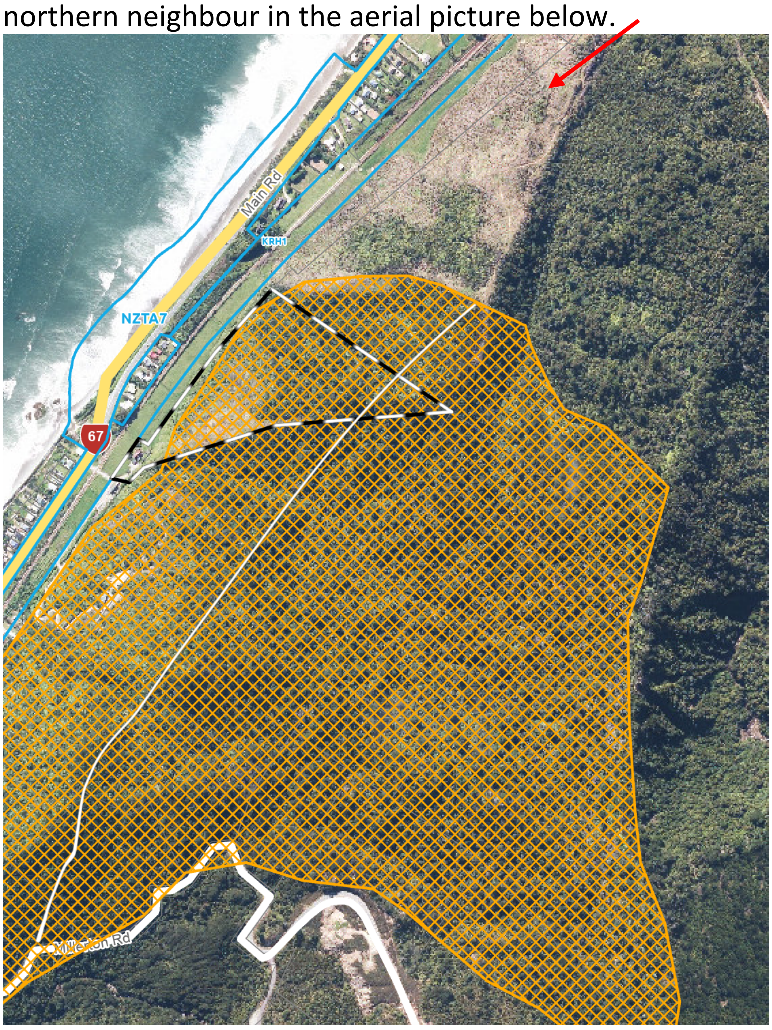
Under the proposed TTPP we will be subject to the following rules.

- NCA54 – High Coastal Natural Character Overlay
- Natural Hazards – Land Instability Overlay
- GRUZ – General Rural Zone

NCA54	Granity - Radcliffe Ridge	A sequence of exposed and steep coastal escarpments covered in windswept coastal forest and scrub. • Natural qualities are clearly evident in the amalgam of landforms, wind swept vegetation cover and their relationship with the Tasman Sea contributing to a very endemic landscape. • Coastal landforms with indigenous vegetation reinforcing topography and exposure to coastal processes. • Natural qualities are clearly evident in the landform, vegetation cover and their relationship with the Tasman Sea contributing to a very endemic landscape. • The prominence of adjoining pasture, farming activities, and development affect the perceived intactness and cohesion of the coastal environment, though they do not overly detract from the highly expressive and natural processes that dominate the landscape.

Our submission on these aspects follows:

1. **High Natural Character Overlay.** We question the proposal that our land meets the definition under Schedule 7 of NCA54 (Granity, Ratcliffe Ridge) as being of a High Coastal Natural Character. Historically all of our land and that of our neighbours has been highly modified and the vegetation is not indigenous or endemic. It has been logged, burnt, fenced and farmed. Our direct northern neighbour (Robert Tyler) questioned this aspect in the exposure draft and had the overlay removed from his property but we did not, and we think that's unfair. In our original submission to the Exposure Draft, we pointed out that we sit on the same ridge as our neighbours however we have chosen to voluntarily retire some of our land from farming and to instead encourage regeneration of vegetation. Whilst this has made the property more attractive from our perspective (and possibly that of those who viewed it for the purpose of defining NCA areas), it should not mean the analysis of our land is any different to that of our neighbours. To us it is clear that the north/west boundary for NCA54 is incorrect. It should be moved further east to encompass the actual "ridge" that not only fits the description of NCA54, but which is undoubtedly an area with higher conservation values than ours. The white line below is where we think the NCA54 boundary north of the Millerton Track should be. If we had sprayed to remove gorse on our land (rather than encourage natural vegetation to deal with it), it would look very similar to that of our northern neighbour in the aerial picture below.



We submit **that an objective analysis and review of the area above should be done prior to any finalisation of NCA54 designated areas** and we would be more than happy to facilitate access to the area for this purpose.

2. **Land Instability Overlay** – this overlay by definition in the proposal, applies to areas where there is a risk from slope instability, landslide, debris flow and rockfall. In our view, this clearly correlates to a very recent BDC risk analysis and report on the area by Kevin England and we support the intent of that report – in particular the drainage basin classifications identified in table 4 of the report (Appendix A - pages 26 and 27).
   We would note that the proposed TTPP Land Instability overlay over Granity, Ngakawau & Hector has not "rolled over from the existing BDC plan" – an incorrect and misleading statement in the information sheets provided with the proposed plan. It has not been part of our world until now. We quote from, and concur, with Kevin England's report on this subject:

   "The Coastal strip north of Hector (between Hector and Miko) has been subject to numerous landslides In the past and is a known land instability area. However, this has been addressed in the recent Te Tai o Poutini Plan Coastal and Land Instability Hazards Draft Document as well as being recognised in the Buller District Plan since 2000, when that area was designated as a "rockfall and rapid debris flow hazard zone".

   Thus debris hazard zones on titles have always been known to be a part of the land north of Hector but this new overlay is news to us. It feels like our communities are being "picked on". Where is land instability overlay on the edge of the Buller River in Westport?, where is a land instability overlay at Cape Foulwind? (essentially a built environment on the edge of an unstable cliff at risk of Tsunami and coastal processes), and where is the land instability overlay on the Coast Road (Maps 26 & 30)? which have more extensive escarpments than we do, and regularly reported rockfall on to the state highway and surrounds. To blanket the entire three communities of Hector, Ngakawau and Granity (and out to sea) with this NH overlay seems unreasonable. By comparison at Punakaiki, more care seems to have been taken to accurately identify known areas of risk (Map 155) as confirmed in the fact sheet for the area where it is stated that the overlay covers much of the residential part of Punakaiki Village with rockfall the major hazard.
   Where in the townships of Hector and Ngakawau has the risk of rockfall ever been an issue? Known areas of slippage due to flooded bush creeks in Granity are apparent but inherent land instability in much of the area is not. TTPP planners should be actively working with BDC to utilise the information provided by Kevin England, disseminated and discussed at local consultation meetings, in order to ensure that landowners are not unjustifiably affected by unreasonable blanket overlays. **We submit that this overlay is incorrectly positioned and should be based on the current known land instability area north of Hector as per the current Buller District Plan.** If the overlay is to be extended, then a more objective, reasoned analysis should be done on the area to ensure it identifies more closely with known areas of risk rather than what appears to be an arbitrary analysis based on very recent occurrences related to rainfall.

3. **General Rural Zone** – Under the current BDC District Plan we are simply zoned Rural. **We agree with the TTPP proposal to allow for three zones underneath the Rural Zone (GRUZ, RLZ and SETZ).** These seem more in line with modern rural lifestyle activities whilst protecting highly productive rural land, and taking in to account potential expansion. **We agree with the statement that places like Granity are now becoming more like commuter towns rather than residential and service towns for the coalfields which were once prevalent in our area.** 50 years ago most, if not all, of our local working population would have been working "up the hill".

4. **Noise R3** – We believe this rule is unworkable and unnecessarily costly for new builds in an area where geography and complex topography means that both the State Highway and Rail Corridors have no option but to locate close to and run through, rural and coastal residential areas. Consequently, a large number of residential sections would lie within 80/40m of the existing SHW carriageway and 40m of existing rail tracks. Our communities are fully aware of this fact and thus aware of the underlying noise and vibration that these existing activities create. Where are the baseline measurements and why should new builds be lumbered with the expense of those?
   Network providers of road and rail are only too happy and financially capable of engaging a project team, providing extensive assessment matrixes and benefit/cost ratios supported by acoustic specialist advice in support of their projects and even hold "noise mitigation" workshops with affected residents where necessary, attended by a swathe of consultants and project staff. However, in this situation, we're talking about individuals and families who in most instances, do not have the financial resources to engage an acoustic or vibration engineer to simply build a single residential dwelling next to an existing rail or road corridor. Recent professional acoustic engineering advice at The Lyric Theatre in Granity cost $3000. The Tasman Sea creates more noise than the road or railway networks here, and it is a constant.

   The NZTA's own guide to assessing road-traffic noise references their "go to" standard NZS 6806, which is used in applications for proposed new or altered roads. It states that the agency considers NZS 6806 "a robust tool to help determine appropriate mitigation of the noise effects of new and altered roads" but the standard is widely quoted in documents the agency appears to now be routinely sending to district and regional council planners where plan reviews are underway.

   From 1 May 2023 new building work in homes must meet new wall, floor and roof insulation performance requirements. These by default will mitigate noise in new buildings with increased glazing standards and extra insulation requirements in floors and ceilings. Homes will be required to reach a minimum R value of 0.37 for all windows and doors from November 2022 and increase this to R0.46 in our part of the country by May 2023. We believe that new dwellings will thus have a higher reduction by default, so why the need to add more complexity in the district plan.

   The effects of noise and vibration from any <u>new</u> proposals for road or rail expansion can very adequately be managed through the RMA consent process for reverse sensitivity issues and thus the inclusion of the words "or expansion" in the overview for this section of the TTPP is unnecessary.

   > Where noise sensitive activities are established near existing noise-generating activities, or areas where higher noise levels are to be expected, reverse sensitivity effects can arise, potentially resulting in the existing noise-generating activities being constrained, in terms of their ongoing operation <u>or expansion.</u> This is a particular concern for important services and community facilities, including Airports and Heliports, Sports Grounds and Stadiums, the State Highway, Railway Corridors and the Ports, which could be constrained if reverse sensitivity effects arise.

There are no acoustic engineering firms on the coast that we are aware of, although we are confident anyone in those industries would need multiple offices coastwide if this rule is held. In addition, the noise level rules proposed must also be achieved at the same time as adequate ventilation, which will usually require windows to be partially open.

Thus, new builds would be subjected to compliance with ventilation requirements of G4 of the Building Code at the same time as having to meet internal noise criteria.

The vibration performance standards proposed are not quantifiable and therefore unworkable. Our concern is that it is a difficult and complex task to predict ground-borne vibration, because it is highly dependent on both the rail and the surrounding ground conditions. As a result, it is normally necessary to undertake measurements of actual vibration at a site as part of any assessment and in our view, the cost of this is not warranted. There are many existing dwellings throughout New Zealand that are within about 12 metres of a rail line, and whilst noise and vibration may exceed accepted guidelines at these locations, we believe that rail vibration is widely tolerated in detached single storey residential dwellings.

Vibration from existing road and railway corridors are generally considered acceptable as they are within recognised guidelines for human comfort applied internationally. At a proposed vibration level of 0.3mm/s (which appears to have come from a British standard concerned with construction related vibrations), that has clearly been recognised in the proposed TTPP. In the standard (BS 5228-2:2009 Annex B) a level of 0.3mm/s is defined as vibration that might be "just perceptible" in a residential environment. But again, **there is no baseline information** available in our district, and the proposed TTPP is making it the responsibility of the homeowner to determine this through qualified engineers, potentially adding thousands of dollars to the cost of a new build.

As there are no relevant NZ standards setting out recommended vibration limits and assessment methodologies, **we submit that no vibration standard be employed for stand-alone single storey residential dwellings.**

We further submit that the proposed Noise R3 rules for new builds only be held if baseline information specific to each area is made freely available to consent seekers and it is provided to them by the noise generating activities as outlined in the overview for this section of the plan. These should include:

- **quantifying the current vibration magnitudes induced by traffic or trains operating on existing SHW network and rail corridors throughout the district; and**
- **establishing how quickly the traffic or train induced vibrations decay with distance for the local soil types; and**
- **derive site-specific soil attenuation coefficients for use in estimating the magnitude of ground vibrations resulting from the noise generating activity.**

The dBL and setback rules under this section of the plan appear to be pandering to Waka Kotahi and KiwiRail, based on unfounded fears of reverse sensitivity issues in relation to our existing rail and road corridors.

A 2021 "Assessment of Plan Provisions to Provide for Human Health and Amenity in accordance with Section 32 of the RMA" was provided by NZTA senior planner Natasha Reid to the Central Hawkes Bay District Council in March 2022. The executive summary of that report states that "Waka Kotahi seeks a gradual reduction in health and amenity effects implemented as new activities are established or existing activities are altered in close proximity to the operational state highway network". It also states that there are "various regulatory methods (within and outside of the RMA) to achieve this outcome. A district plan based method has been assessed as the most implementable method in the current environment".

On viewing the document (Appendix B - attached) we cannot help but suspect this report has formed the basis for the rules being imposed on us in relation to noise and vibration for new builds.
It rather helpfully provides its own version of potential objectives, provisions and rules for council planning purposes and it appears the majority of these have simply been accepted and put into the proposal plan verbatim.

Most of us don't have the time or resources to put together a report like the one produced by Waka Kotahi, but that doesn't mean that because those agencies do, we should simply accept their views.

The assessment also suggests, through an appendix report provided by an acoustic engineering firm, that the cost of building a detached residential home with the dBL rules in place, would be minimal at 0-2% of the overall cost of building. However, the engineers note that "the increase in costs is very dependent on the external noise level" which in turn supports our view that existing external noise levels from the noise generating activities need to be provided by those activities – not the homeowners. By enabling this one request, potential homeowners might find they don't even need upgrades for their builds if external noise levels are very low.

If NZTA and KiwiRail would not jointly support the provision of freely available and area specific data associated with noise and vibration, **we submit in favour of a "no complaints" covenant approach to residential or rurally zoned new build activity within the setback limits provided to address perceived issues of reverse sensitivity.**

Even though Waka Kotahi don't support that approach (refer page 31 of their assessment attached), it is nonetheless a mitigation option that resolves the issues outlined in our submission. We have enclosed a document related to covenants of this nature as produced by the Quality Planning Resource (qualityplanning.org.nz).

5. Request for Rezoning

We seek rezoning of our land and that of our northern neighbours as RLZ. Our reasonings for this are as follows and have taken into account the principles for rezoning as outlined in the TTPP provided information sheet on this topic.

Both our land and that of our northern neighbours (Robert & Lorraine Tyler) is marginal for pastoral activity. Grazing of a small number of dry stock is the only activity undertaken other than typical lifestyle block activities such as the keeping of chooks for domestic purposes. Pukeko and weka are abundant. Grazing can really only be done for 6 months of the year (at best) due to poor soil conditions and limited land availability. We now only graze the rurally zoned railway reserve bordering our property and this is leased from KiwiRail. The Tyler's land and ability to graze is similar, although they allows stock to graze a larger area including the railway reserve. Again, their stock numbers are limited due to the poor quality of the land, which is unable to support anything more intensive than grazing.
Both our land and that of our northern neighbours, encompasses a terrace which sits approx. 50m above the railway corridor, extends northwards and which is not a feature of the almost vertical escarpment topography south of our location.
We have recently located a small 2 bedroom home (built and transported here from Westport) on the lower part of our southern parcel of land (4.5ha) for an elderly family member.

We did this in the knowledge that under the current district plan's Rural Zone we would have been permitted to have two dwellings per site which, whilst preventing the conglomeration of housing on single lots, allowed for those that have workers or relatives on the same site. We have a consented barn situated on the terrace described above, and have been preparing an adjacent site for a new home including a geotechnical report on the proposed house site. By nature, the site is elevated, with expansive views and has good access. We just haven't had the resources to apply for consent to build the house yet. The permitted residential density rules proposed for GRUZ due to the size of the property (albeit discretionary) under the proposed TTPP will not allow us to build a house on that site but the RLZ would, whilst still allowing for primary production (in our case grazing) to occur as per the proposed RLZ description. The same applies to our northern block of 7.2ha which is the location of our current residence, and although we have a positive geotechnical assessment for a second residential unit on that site, we have no existing plans to build there. There are surrounding areas of GRUZ land neighbouring us to the east however these are known to support resource extraction and thus conduct authorised activities under a prospecting or exploration permit. Reverse sensitivity issues are well managed by the provisions within the RLZ through density and building setbacks.

There are no reticulated services available on our properties and they are both self-contained for water supply, wastewater and stormwater. The minimum 1ha residential unit density proposed for the RLZ would enable this to continue as this size density would support independent septic and rainwater tanks. There would be no requirement for any large scale infrastructure extensions by BDC.

We consider that rezoning our land and that of our northern neighbours would have no impact on its current natural character attributes. In reference to natural character, please refer to out submission regarding NCA54 (item 1 above).

We also consider that rezoning our land and that of our northern neighbours would not result in the exacerbation of significant natural hazards or increase these risks to the community. In the risk assessment done by Kevin England our properties are rated as medium risk as related to land within 10m of a watercourse. The remaining land is low risk. We refer to our submission above regarding the Land Instability overlay (item 2 above) and the attached Kevin England risk analysis.

6. **Supplementary notes to request for rezoning:**

Although we have no specific view on this, we think consideration should be given to rezoning the Rail corridor (currently proposed to zone GRUZ) through our area to RLZ on the basis that this land could well provide a suitable zone for coastal retreat once the corridor is no longer required for rail purposes related to the coal industry. As per NH P2 and P5, we would consider the natural hazard risks associated with the railway corridor to be much less than the existing location of the seaward properties in Granity's settlement zone which are subject to the Coastal Severe overlay. This may affect objective RURZ-02 in terms of rural character and amenity but with little choice in local alternatives for coastal retreat, it should perhaps be considered to support settlement viability, particularly when as described above, the surrounding land is not highly productive. The setbacks as proposed for internal boundaries would be problematic due to the narrow corridor of land involved and internal boundary setbacks of 1.5m as per the current district plan for side and rear yards would be more appropriate if possible. A service lane(s) off the State Highway might be a possible solution to the future needs of this area in order to relieve the SHW network setback restrictions along with expansion of the proposed RLZ -R3 item 3 in restricting the size of minor residential units that share a driveway.

Granity Landslides

Preliminary Risk Analysis

The town of Granity

Report prepared by: Kev England, Msc. 16/05/2022	Peer reviewed by: Andrew Palmer BSc(Hons) MSc MIPENZ CPEng IntPE(NZ) of Terra Firma Engineering, Nelson.

Executive summary

A number of damaging landslides occurred in Granity due to a heavy rainfall event in February 2022. As a result of concerns raised by the affected community, Buller District Council is seeking to understand the nature and characteristics of landslides in the Granity area, in particular where those landslides present a risk of harm to people and property.

This preliminary risk analysis identifies two distinct types of landslide that affect the Granity area and it presents corresponding risk zone maps delineating the risks associated with each of these landslide types:

Translational type landslides:

- In the High Risk Zone there are four residential dwellings along with a number of other outbuildings/sheds (with unknown use) as well as a commercial property (the Museum) that are at high risk of impact damage from translational type landslides. For people living in those dwellings there is a calculated risk of loss of life in the order of 8.5×10^{-5} per year[1]. In the 50 year design life of a building, there is a 57% chance of a building in that zone being damaged.
- In the Medium Risk Zone there are approximately twenty residential dwellings and a number of other outbuildings (with unknown use) where the expected risk of loss of life is 2.6×10^{-6} per year[2]. In the 50 year design life of a building there is a 22% chance of being damaged.

The risk to life in both the High and Medium Risk Zones is higher than the risk level for new build homes recommended in the New Zealand Building Code (NZS 1170.5:2004 Structural design actions - Part 5: Earthquake actions).

Debris flow type landslides: There are ten residential dwellings along with a number of other outbuildings/sheds (with unknown use) as well as a commercial property (the Museum) that are at high risk of inundation damage from debris flows. For people living in those dwellings there is a possible risk of harm and it is likely that those buildings will be damaged by debris flows in the future. There are also approximately fifteen residential dwellings and a number of other outbuildings (with unknown use) as well as three commercial properties within the medium risk zone, where property damage may also occur.

It is expected that the risks to life and property will increase over time as climate change progresses.

A range of risk reduction measures are presented and it is expected that these measures be discussed by the affected community and Buller District Council with a view to managing the landslide risk appropriately and cost effectively. That discussion will need to take into account the community's risk tolerance levels and the availability of resources, and will facilitate the development of a landslide risk management plan.

[1] Can be expressed as 0.085% per year, or approximately one death every 10,000 years
[2] Can be expressed as 0.0026% per year, or approximately one death every 400,000 years

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1. Introduction

The coastal strip of residential development at Granity and Ngakawau has been affected by landslides on numerous occasions in the past, some of which have caused property damage. As a result of a damaging heavy rainfall event in February 2022, Buller District Council (BDC) is seeking to understand the nature and characteristics of the landslides, and the ground surrounding these landslides, in particular where those, or similar landslides could present a risk of harm to people and property. This investigation report presents an initial analysis of the landslide hazards in the area and is intended to help the local residents, property owners and BDC make sensible hazard management decisions with respect to the landslide risk.

2. Study area

The study area is defined as the urban area south of the Ngakawau River covering the entire residential settlements of Ngakawau (excluding the commercial coal load out facility) and Granity. State Highway 67 is the western boundary of the study area with all the land to the west of this feature being distant enough from the landslide hazard to be deemed at negligible risk from landslides. Figure 1, below, shows the study area boundary.

Figure 1. The study area outlined in red.

North of the Ngakawau River to the east of the residences in the town of Hector, the slope is moderate and not high enough to generate damaging landslides, so that area has been excluded from this study.

The Coastal strip north of Hector (between Hector and Miko) has been subject to numerous landslides in the past and is a known land instability area. However, this has been addressed in the recent *Te Tai o Poutini Plan Coastal and Land Instability Hazards Draft Document* as well as being recognised in the Buller District Plan since 2000, when that area was designated as a "rockfall and rapid debris flow hazard zone". Since specific planning requirements have been implemented for the properties in that area, it has been excluded from this study. South of the study area the density of residential development is very low, so that area has also been excluded.

3. Methodology

New Zealand does not have its own formal system for assessing landslide risk in residential land. Risk assessment reports generally follow the landslide risk management methodology published by the Australian Geomechanics Society (Fell *et al*, 2007. Guidelines for landslide susceptibility, hazard and risk zoning for land use planning)[3]. This investigation is based on that methodology, which is used extensively throughout New Zealand (and Worldwide) to provide a uniform and standardised approach to landslide hazard management. Modifications to that methodology have been made to better suit the individual requirements and data availability of this study. Figure 1 within that Guideline illustrates the framework for landslide risk management, which shows the entire process from setting the scope of works, through risk analysis, risk assessment and risk management including implementation of risk reduction measures.

This report addresses the first stage of that landslide risk management framework only (risk analysis) and also provides a range of possible risk mitigation options. It presents the zones of varying landslide risk and estimates the risk to life for residents in those zones. This information will form the basis for BDC, the local community and other parties to make informed, data supported decisions on the final two stages, landslide risk assessment and landslide risk management.

Figure 2, below shows the Framework for Landslide Risk Management with the areas covered in this report highlighted with a purple dashed line and the excluded sections highlighted with a blue dashed line.

[3] Available from: https://ro.uow.edu.au/engpapers/2823/

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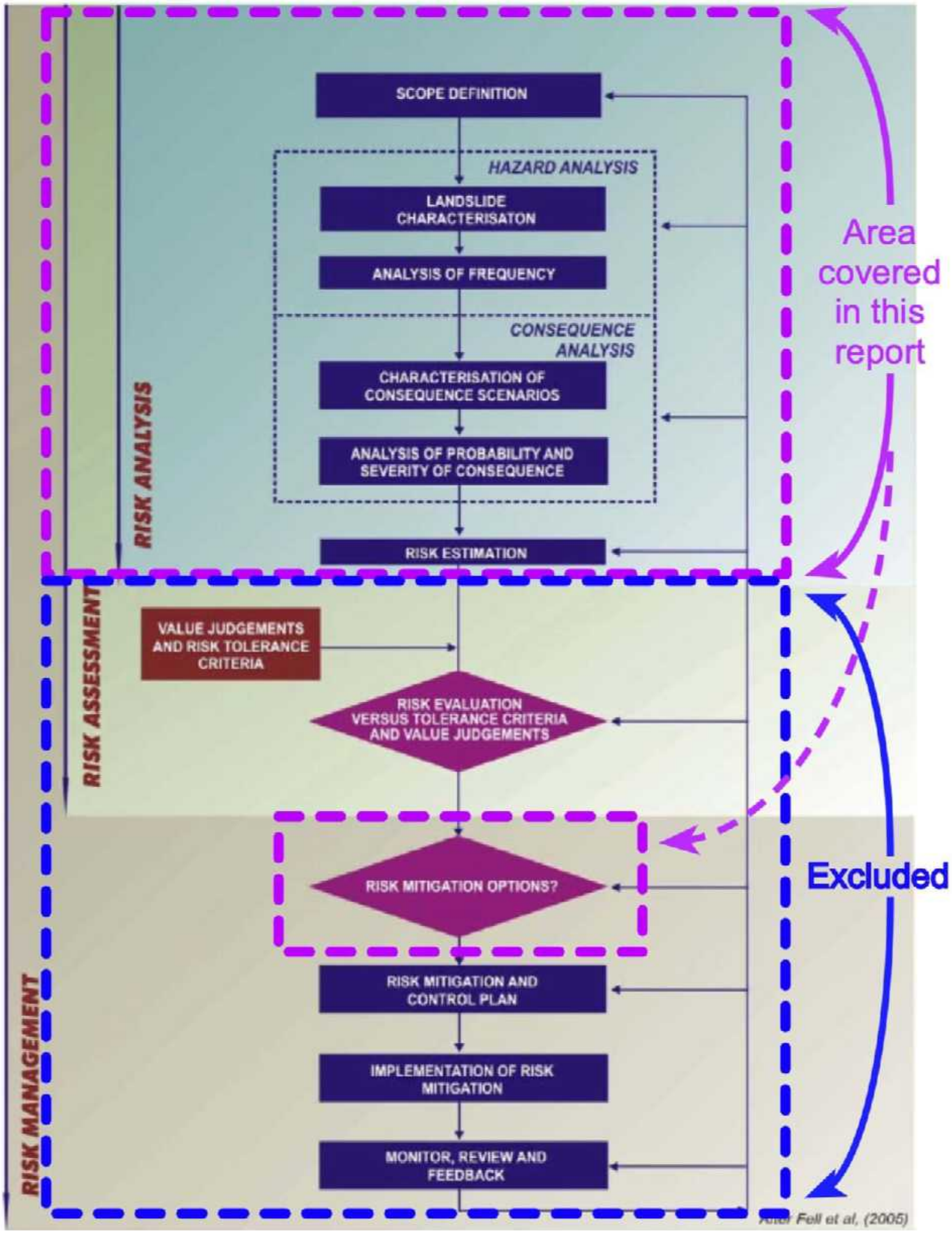

Figure 2. Framework for landslide risk management as defined in the Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning, showing the areas covered in (and excluded from) this report.

This report identifies the past (historic and recent) landslide hazard events in the area based on analysis of:

- Historic aerial photography[4]
- Literature review[5]
- Field mapping of recent landslides
- Aerial imagery provided by BDC (helicopter and drone based)
- Aerial imagery collected by the report author (drone based)

This analysis has created a landslide inventory, which shows all the mapped landslides in the study area. The spatial (mapped land areas) and temporal (events over time) distribution of these landslides has been analysed and compared to other terrain variables (primarily slope angle and geology) within a Geographic Information System[6] to give an estimation of the future likelihood of landslide events within the study area. This information is presented as a **landslide hazard map**, which shows the areas that are more or less likely to experience landslides in the future. The landslide hazard map is then used (along with additional terrain analysis and modelling) to estimate the areas of land that are at risk of being inundated with landslide debris and the level of risk that people and property are exposed to in those areas. That information is presented as a **landslide risk zone map**. So, the hazard map shows where the potential source of harm is located (i.e. where the landslides originate) and the risk zone map shows the areas of lands that may be affected by the hazard (i.e. the runout zones).

There are two distinct types of landslides identified within the study area and these have been analysed separately since they have different mobilisation and runout characteristics; i.e. there are two landslide risk zone maps, one for each distinct landslide type.

The landslide hazards and the consequences to people and property are presented along with a range of potential risk reduction measures.

3. Landslide characterisation

3.1 Landslides overview

The steep range front inland of the Granity area has been uplifted into its current position during a series of earthquakes along the Kongahu Fault Zone[7]. The range front slope is steep (often steeper than 45°) and has a north westerly aspect. The slope is underlain by granitic basement rocks (bedrock) which show varying degrees of fault zone weakening[8]. The weakening of the bedrock has occurred primarily as a result of fracturing and weathering, leaving the exposed rocks susceptible to gravity induced movements. However, in general, the basement rocks are not exposed and are covered by a continuous soil layer. The overlying soils are generally shallow and composed of a 1-2m thick layer of yellowish brown, soft clay with a thin organic soil layer supporting a dense cover of native podocarp forest.

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[4] Available from Land Information New Zealand (LINZ) data service.
[5] Primarily contained within England, K.A. 2011, A GIS approach to landslide hazard Management for the West Coast Region. MSc. Thesis, University of Canterbury.
[6] QGIS is a user-friendly Open Source Geographic Information System (GIS) licensed under the GNU General Public Licence. QGIS is an official project of the Open Source Geospatial Foundation (OSGeo)
[7] Todd, A. 1989. Geology and Coal Resources of the Stockton Sector, Buller Coal Field. Market Information and Analysis Coal Geology Report.
[8] Nathan, S.; Rattenbury, M.S.; Suggate, R.P. (compilers) 2002: Geology of the Nelson area: scale 1:250,000. Lower Hutt: Institute of Geological & Nuclear Sciences. 1:250,000 geological map 9.

During heavy and/or prolonged periods of rainfall (during the heavy rainfall event of February 2022, 166mm of rain fell in 24 hours[9]) the soil layer becomes saturated, which adds additional weight to the soil and at the same time causes a reduction in soil cohesion. This frequently leads to slope instability and landslides occur. Landslides predominantly occur on the steeper (45°+) and higher (upper half) areas of the slope, with the dominant landslide mechanism being **translational type landslide** movements. Often, the debris released in a translational type landslide adds additional weight to the slope below and causes a chain reaction of landsliding, where the debris travels down the slope, adding additional volume as it travels and eventually reaches the base of the slope and accumulates in a debris pile. Sometimes, the debris from a translational landslide can fluidise (usually caused by the addition of excess water either in a creek bed or direct slope runoff in extreme intensity rainfall events) and form a **debris flow**, which can sometimes travel faster and further than the debris from a translational type landslip.

The geological maps of the area show that the geological unit at the base of the slope is a landslide deposit composed of Quaternary age “Earthflow deposits containing poorly sorted clasts up to boulder size in a clay matrix”. This indicates that landsliding is the dominant process contributing to the current landforms in the area and that the base of this slope has been consistently subject to landslide debris deposition for at least the last few thousand years.

3.2 Translational type landslides

3.2.1 Features of translational type landslides

The general layout and features of a typical translational type landslide are shown in figure 3, below:

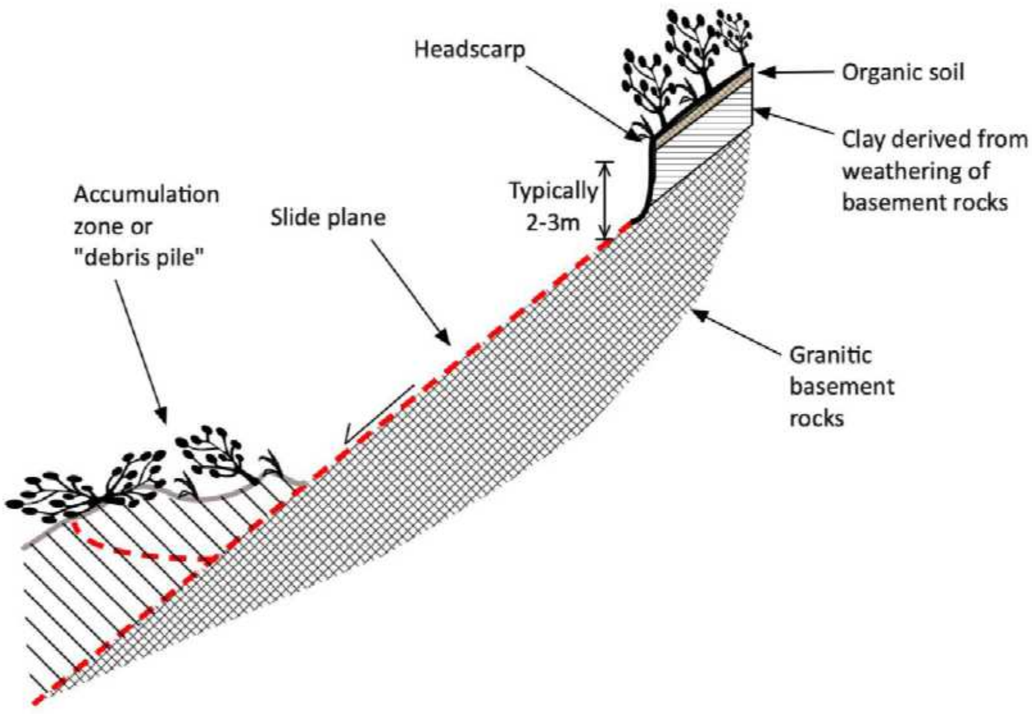

Figure 3. Typical translational type landslide features.

[9] The closest rain gauge is at Mokihinui River at Stoney Creek. Data can be accessed at: https://envirodata.wcrc.govt.nz/dashboards/rainfall/rainfall.php#

From direct and remote observations of the landslides in the Granity area, it can be seen that:

1. The slide plane is generally confined to the overlying clay and organic soils; i.e. the landslides do not appear to have affected the underlying bedrock and ground movement is confined to the superficial soil layer. Occasionally, bedrock is visible within the exposed slide plane, indicating that the slide plane is on the soil/bedrock interface, not within the bedrock (i.e. the bedrock usually remains unaffected during these landslide events). This means that the likelihood of large-scale rockfall sourced from within these rainfall generated landslides is low.
2. The landslides are usually shallow, with the depth of disturbed soil being in the order of 2-3m
3. There is usually a gradual transition across the headscarp areas, with the ground immediately upslope of the headscarp areas (and at the edges of the landslides) being more or less intact, which means that the immediate likelihood of additional landslide debris being released from the headscarp area (headscarp regression) is also low
4. The landslide debris is composed of soft, wet clay with occasional suspended granitic boulders and varying volumes of wood debris derived from trees on the slope
5. The debris usually reaches either the base of a drainage gully on the slope, or the base of the slope
6. The volume of debris in the debris pile is related to the height of the landslip; i.e. where the crest of the slope is higher, the volume of debris will be greater
7. There are very few accumulations of debris within the debris chutes; i.e. the landslide debris generally appears to travel to the base of the slope, leaving the landslide scar more or less free of additional loose material. This means that the presence of a landslide scar does not indicate an elevated likelihood of continued landslide debris deposition at the base of the landslide scar
8. Many of the debris chutes contain flattened or otherwise damaged vegetation. This indicates that revegetation (and subsequent natural ground stabilisation) is likely to be rapid
9. The landslide debris often accumulates in a moderately deep pile (2-3 metres deep) and is usually confined to the immediate vicinity of the break in slope; i.e runout distances are short. The presence of dense native vegetation at the base of the slope appears to very effectively arrest or divert the debris pile motion.
10. Sometimes (particularly where landslide debris reaches a drainage gully), the debris can fluidise and transform into a debris flow and in those cases the debris can travel much further.
11. Rainwater runoff and groundwater seepage can cause a clay rich slurry to flow from the debris pile and cause shallow inundation of land past the toe of the main debris pile, and this may continue for days/weeks after the landslide occurred

Figures 4-9, below, show some of the typical features of the translational type landslides observed in the study area.

Figure 4. The slide plane is shallow and the surrounding ground appears to be unaffected. Flattened vegetation within the debris chute is likely to encourage rapid revegetation.

Figure 5. The headscarp area is more or less intact and the slide plane is shallow. Bands of flattened vegetation are also visible. Photo: BDC.

Figure 6. Exposed granite in the landslide scar indicates that the slip occurred on the bedrock/soil interface. Photo: BDC.

Figure 7. The headscarp of this landslide shows a gradual transition from disturbed to undisturbed ground and there does not appear to be a high likelihood of headscarp regression. Additionally, flattened vegetation within the landslide scar is likely to regrow quickly. Photo: BDC.

Figure 8. Landslide debris composed

Figure 9. The debris has been diverted away from

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predominantly of clay and wood has accumulated in a pile at the base of the slope and is likely to have been slowed by the presence of dense podocarp forest. Seepage has caused minor inundation with clay rich slurry in the paddock.	the building by the dense vegetation, preferentially inundating the cleared land in the left of the picture.

3.2.2 Potential harm caused by translational type landslides in Granity and Ngakawau

The recent landslides caused only minimal property damage. However, there are reports of historic landslide events having caused more severe property damage in the study area, including structural damage to residential buildings[10].

To estimate the predicted potential damage to buildings (and the associated risks to people in the area) that may be impacted by landslide debris it is necessary to first estimate the expected velocity of landslide debris as it is deposited at the base of the slope. From observations made in the field and from other similar sites it is estimated that the velocity of the landslide debris at the point where it meets the moderately inclined (<20° slope) residential land is less than 1m/second; i.e. the debris moves relatively slowly.

When landslide debris composed of clay, boulders and trees (as observed in the study area) impacts upon a typical timber framed building, it is common for the building to deform, causing cracks to windows, internal wall linings and external cladding as well as damage to services. Buildings with a piled foundation system can be pushed off the foundations and the building often moves as a single unit being "shunted" along by the debris. Buildings with concrete slab foundations typically do not get pushed off the foundations, but the debris may cause more severe damage to the wall that is impacted. Where the debris contains large amounts of trees (as observed within the study area) it is common for logs to be pushed through the wall that is impacted.

Typically, buildings that are impacted by this kind of landslide do not break apart and people inside the building at the time of the incident are usually not harmed. However, where trees are pushed through walls there may be an elevated risk of harm, including a risk to life, for the people in that room of the building.

Where clay and other debris rests or pushes against external walls of a building there is often inundation inside the building, which causes damage to carpets, furniture, etc. Figures 10 and 11 below, show typical landslide debris damage from damaged properties that are *outside* the study area.

[10] J. Benn, 2005. Landslide events on the West Coast, South Island, 1867–2002. Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1745-7939.2005.00001.x

Figure 10. Trees pushed through an external wall of a house impacted by landslide debris (example from Marlborough)

Figure 11. Approximately 2m depth of clay-based landslide debris has pushed this house off its foundation (piles) and moved the building as a complete unit (example from Marlborough).

Note: There is the possibility of much larger landslides affecting properties in the study area, which may have the ability to engulf or bury residential dwellings. However, given the shallow depth of soil overlying the bedrock, the volume of landslide debris is likely to be limited to smaller volumes (<1000m^3), which are unlikely to engulf or bury buildings. The effects of climate change will elevate the risk of larger, more catastrophic landslides in the future. This may include the formation of rock block slide type landslides (or other landslide types), which may affect the underlying bedrock as well as the superficial soil layer, thus creating much larger, more damaging debris movement behaviour. Additionally, strong ground shaking during a very large earthquake may also trigger larger landslides to occur, the scale of which may be unprecedented. Further research would be required to better define these risks.

3.3 Debris flows

3.3.1 Features of debris flow type landslides

When a steep mountainous creek or stream becomes swollen, the stream bed and banks can erode and the eroded material is carried downstream by the high energy water flow. This is normal in any stream or river channel. When stream bank erosion becomes excessive, or if large volumes of debris are added to the stream water flow from other landslides, the volume of debris can often exceed the volume of water. In these cases the stream flow is usually termed a debris flow. When the stream enters a less steep or flat land area the water's energy decreases and the suspended debris is then deposited in the "runout zone" , which may be either in the creek bed or on any land that may have been flooded by the creek (if the creek broke its banks).

Repeated instances of debris flow deposition (and normal stream flow deposition) where a creek emerges from the steep range front lead to the build up of an alluvial fan (sometimes called a debris fan). An alluvial fan is a conical shaped sedimentary (sand, gravel and rock) deposit that forms by sporadic, flood related and debris flow related deposition of material over time. Typically, a stream will migrate from side to side over the alluvial fan, depositing debris material more or less uniformly to create the conical shaped landform; i.e. on an alluvial fan where the stream bed is positioned towards the north of the fan, the stream bed will migrate back towards the south as material is deposited in the existing stream bed area.

A debris flow can also originate as a translational type landslide and fluidise with excess water in areas remote from existing stream channels. However, given the fluid nature of the flow, the debris will usually enter a stream channel before reaching the base of the slope.

Note: There is a continuum of flow states within any stream, where increased flow will allow for increased sediment transport. When flow is excessive the term "flood" is often used. During a flood, large volumes of sediment and debris are transported by the water. When sediment and debris transport becomes excessive, the term "debris flow" is then adopted. That continuum extends to the point where water is a minor component of the total volume of the debris flow, yet the debris still acts as a fluid.

The general layout and features of a typical debris flow type landslide are shown in figure 12, below:

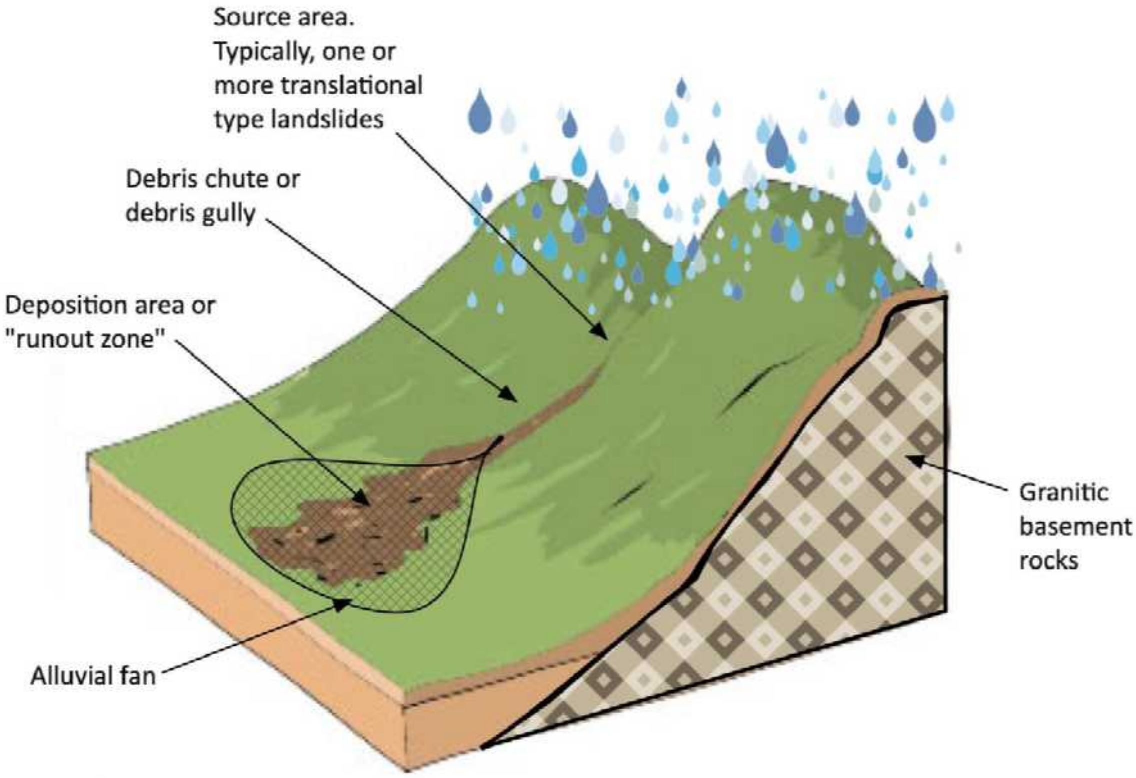

Figure 12. Typical debris flow features

From direct and remote observations within the study area it can be seen that:

1. Debris flows often originate where debris from a translational type landslide (or several) enters a natural drainage gully, which then fluidises with the excess water and travels down the gully
2. In some instances debris flows are formed on the slope, where no drainage gully is present and the debris flow forms a new drainage gully
3. The debris chutes are typically narrow (1-5m wide) and extend all the way to the base of the slope
4. Debris flow velocity is likely to be very rapid (>1m/second) where the slope is steep, but where the slope angle is moderate or flat the velocity and associated energy of the debris is much lower.
5. The debris is deposited on shallowly sloping (or flat) ground at the base of the slope and can inundate large land areas
6. Where debris flows travel down existing stream channels drainage infrastructure can be overwhelmed (culvert blockages) and the debris is then deposited on the surrounding land

7. Debris inundation is generally shallow (less than 0.5m) and is composed primarily of wet, sandy clay, logs and occasional boulders

Figures 13 - 16, below show some of the typical features of the debris flow type landslides observed in the study area.

 Figure 13. Debris flow gully formed as a result of the debris from two small translational type landslides entering a gully.	 Figure 14. Debris flow deposit in a runout zone in residential land in Granity.
 Figure 15. Debris flow deposition around a house in Granity. Approximate depth of inundation is <0.5m. Photo: BDC	 Figure 16. Blocked culverts may have been partly responsible for some of the observed debris inundation in Granity. Photo: BDC.

3.3.2 Potential harm caused by debris flow type landslides in Granity and Ngakawau

Figure 15, above, shows a house in Granity that was inundated with waterborne sand/gravel/clay debris from a debris flow that travelled down an unnamed creek, which was diverted onto the residential property after the downstream culverts became overwhelmed with debris. It appears that the house was not structurally damaged, but that a significant volume of debris was deposited in and around the house. The lack of structural damage to the house and the uniformly flat debris deposit indicates that the flow energy was relatively low. Similarly, Figure 14 shows residential land in Granity that was inundated with debris and caused damage to a plant nursery. In both of these cases the risk of harm to people is low.

The scale of observed debris flow landslides in the study area is limited to low magnitude events, where flooding and associated debris deposition is the most likely outcome. Since the observed debris flows usually occur in existing stream channels, the proximity to these stream channels is the main factor in the level of risk of debris flow inundation at any site. Significantly, the debris flow energy decreases rapidly as the stream gradient decreases, so the further away a site is from steep ground the lower the energy the debris flow will have and thus the less damaging it is likely to be.

Where a building is positioned on an alluvial fan it is likely that it will be affected by debris flows in the future, unless specific mitigation measures are put in place. The nature and scale of these mitigation measures is necessarily location dependent and requires specific engineering design.

Note: There is the possibility of larger, higher energy debris flows affecting properties in the study area, particularly in respect of the effects of climate change. Higher magnitude debris flow events may cause similar damage to the effects of translational type landslides as described above.

4. Landslide inventory

4.1 Data collection

Two aerial photography datasets (one set collected 2009-2011 and the other collected 2015-2016) sourced from Land Information New Zealand (LINZ) were analysed along with a recent drone-based georeferenced aerial photography dataset (collected by the report author in April 2022). Analysis comprised the mapping of landslides present in each of the datasets and has allowed for the presentation of a landslide inventory. The landslide inventory differentiates between landslide type and age and where possible, the deposition area is displayed distinctly from the source area.

The rainfall triggering amounts are not known for the earlier landslides since the exact date of occurrence is unknown. However, for the February 2022 landslides data collected by the West Coast Regional Council[11] shows that at the closest available rain gauge site (Mokihinui River at Stoney Creek) there was 137mm of rainfall in 24hrs on 3 February 2022 and on 10 February 2022 (when these landslides were reported to occur) another 164mm fell in 24hrs. Data presented on the HIRDS[12] database shows that this rainfall amount is currently[13] expected to occur in Granity once every 10 years (Annual Exceedance Probability = 0.1).

[11] https://envirodata.wcrc.govt.nz/dashboards/rainfall/rainfall.php#
[12] NIWA's High Intensity Rainfall Design System (HIRDS) provides a map-based interface to enable rainfall estimates to be provided at any location in New Zealand. It is available at: https://hirds.niwa.co.nz/
[13] The effects of climate change are expected to cause higher intensity and more frequent heavy rainfall events in the future.

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4.2 Landslide inventory map

Figure 17, below, shows the landslide inventory map.

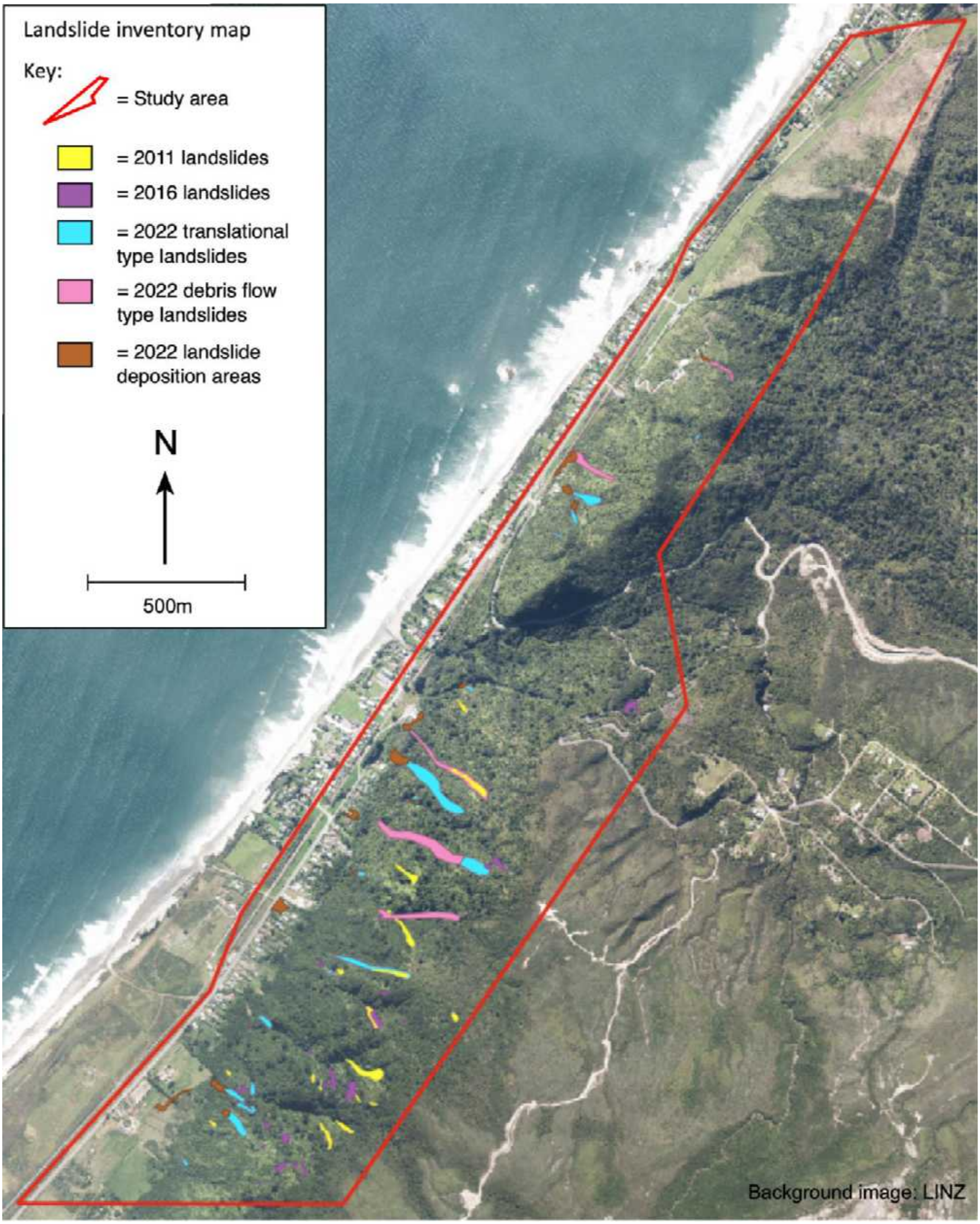

Figure 17. Landslide inventory map

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Table 1, below, shows a breakdown of the landslides displayed in the landslide inventory.

Table 1. Landslide inventory data.

Dataset	Number of landslides	Total area/m^2 (rounded to the nearest $10m^2$)
2009-2011	18	8,710
2015-2016	22	11,030
2022	22 (5 x debris flows and 17 x translational landslides)	42,570 (19,660 due to debris flows and 22,910 due to translational landslides)
Total	62	62,310

In addition to the landslide areas noted in Table 1, there are also 14 mapped areas where landslide debris has been deposited with a total inundated land area of $12{,}250m^2$.

A basic analysis of this data suggests that there is only a slight increase in landslide numbers over time, but that there is a large increase in landslide area over time. However, this may be due in part to some of the limitations listed below (see Section 11. Limitations). The landslide inventory has been used to produce a landslide hazard zone map and two landslide risk zone maps (one representing the risk from translational type landslides and one representing the risk from debris flows).

5. Landslide hazard map

5.1 Method and description

A landslide hazard map identifies areas which are subject to landslides and is measured from low to high hazard. The landslide hazard map takes into account where the landslides occur and what terrain features contribute to their occurrence (in this case slope angle and geology have been considered). The preparation of this landslide hazard map involved generating a slope angle map[14] and overlaying this with a geology map [15] and the landslide inventory. The relationships between the landslide distribution and the terrain variables (slope angle and geology) are interrogated within the GIS and the resultant zones of high, medium and low hazard are then displayed on the landslide hazard map. Landslide frequency (number of landslides per year) has been based on the average observed landslide numbers over the period of time covered by aerial photography datasets. It is acknowledged that the time period covered by the aerial photography datasets is a short time period, so may not accurately reflect the nature of landslide occurrence over time[16].

Table 2, below, shows the terrain variables, landslide distribution statistics and descriptions associated with each of the landslide hazard zones.

[14] Generated from the LINZ West Coast - Westport 1M DEM available from: https://data.linz.govt.nz/layer/105446-west-coast-westport-lidar-1m-dem-2020/webservices/
[15] 1:250,000 scale Geology maps from GNS (QMAPS) available from: https://www.gns.cri.nz/Home/Our-Science/Land-and-Marine-Geoscience/Regional-Geology/Geological-Maps/1-250-000-Geological-Map-of-New-Zealand-QMAP/Digital-Data-and-Downloads
[16] See Section 11. Limitations.

Table 2. Landslide hazard zone descriptors

Landslide hazard zone	Geology	Slope angle	Landslide density		Approximate average number of landslides per year	Description
			Number of landslides per $1km^2$	Percentage of land affected by landslides		
High	Granite and diorite of the Karamea Batholith	> 40°	52.7	4.6%	5	Landslides occur frequently. Debris may travel from this zone into lower hazard zones below
Medium	Mudstone, sandstone and coal of the Kaiata Formation and Brunner Coal Measures	15-40° (with minor areas exceeding 40°)	2.8	0.2%	0.5	Landslides rarely occur and are usually associated with artificial cuts or where debris travels into this zone.
Low	Sand, gravel and silt beach deposits	< 15°	0*	0%**	0	Landslides generally do not occur in this zone. Debris may travel into this zone (particularly from a debris flow).

* There are four areas where landslide debris has been *deposited* in the low hazard zone
** 0.6% of the land area in the low hazard zone has experienced landslide debris *deposition*

The landslide hazard map as shown in Figure 18, below, illustrates where landslides are more or less likely to originate. It does not show which areas are at risk from landslide impact damage or debris inundation. The landslide hazard map has been used to generate a landslide risk zone map (shown in Section 6.2), which shows the land areas that are likely to be impacted by translational type landslides. It has also been used, in combination with additional terrain analysis (including stream channel and drainage basin catchment delineation) to generate another landslide risk zone map that shows the areas of land that are at risk of being impacted, or inundated by debris flow type landslides (shown in Section 7.2).

5.2 Landslide hazard map

The landslide hazard map illustrates where landslides are likely to originate. It is shown in Figure 18, below.

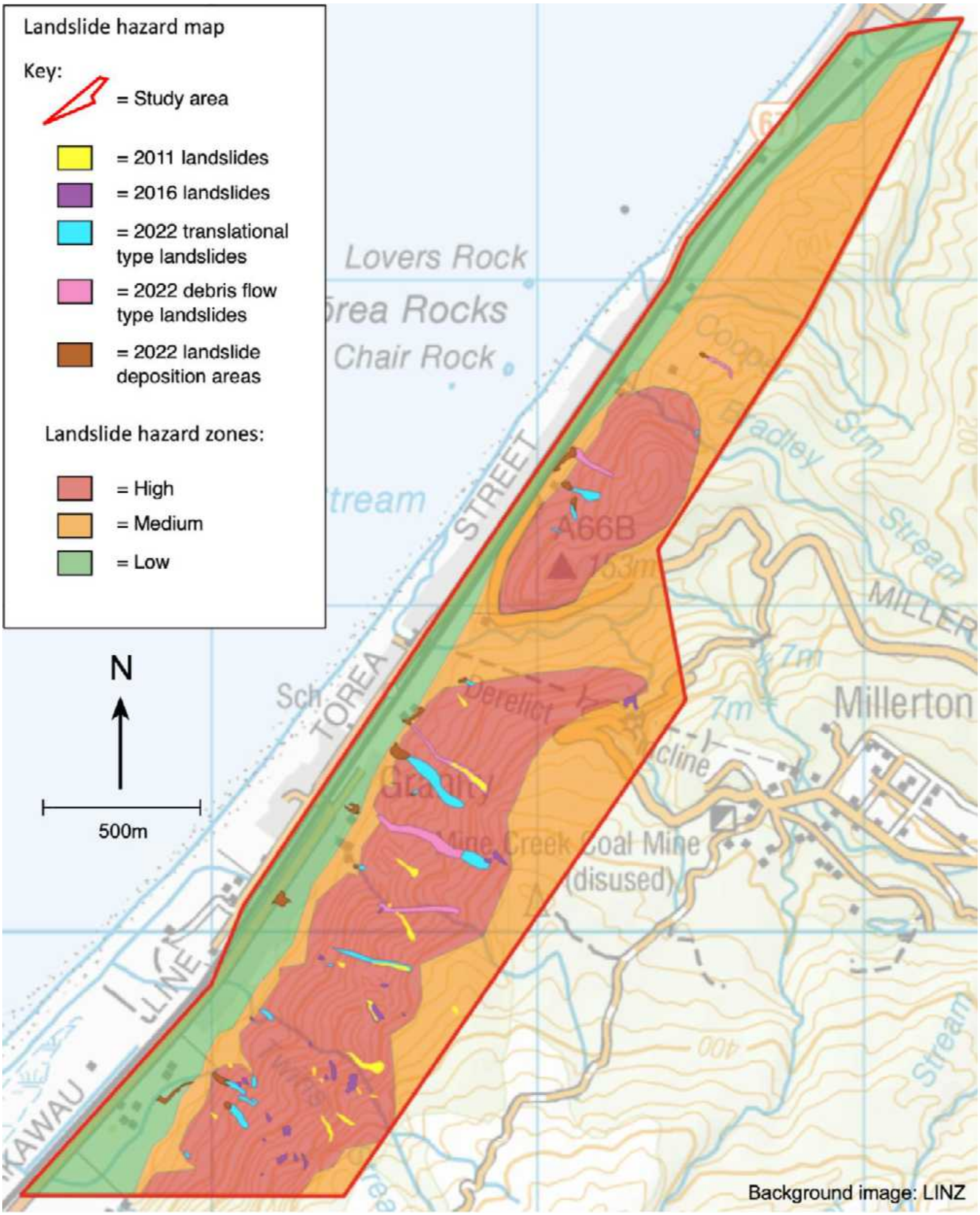

Figure 18. Landslide hazard map. See Table 2 above for descriptors of the three zones.

6. Translational type landslides risk zone map

6.1 Method and description

To classify and delineate the risks to people and property associated with translational type landslides in the study area the frequency of landslides is first established (see Table 2) and then the likely runout zones from those landslides are estimated based on observed landslide debris deposits and GIS based terrain analysis. As previously stated, there are two distinct landslide types that create hazards in the study area and the methods for delineating these hazards and the risks that they present to people and property are different. This section presents the risks associated with translational type landslides and Section 7 presents the risks associated with debris flow type landslides.

The landslide hazard map shown above indicates where landslides are more or less likely to occur. Since the terrain variables are generally uniform throughout each hazard zone. In a high level assessment, it is sensible to assume that the likelihood of landsliding within each zone is also uniform[17]. From observations made of the landslide debris runout distances observed at the base of the slopes it can be seen that the landslide debris derived from translational type landslides generally stops within 20m of the break in slope, where the slope angle changes from steeper than 20° to less than 20°. Therefore, all the land upslope of that point can be expected to be inundated with landslide debris if a translational type landslide occurs upslope of that point. This line has been used to delineate the high risk zone (i.e. all the land upslope of the 20m buffer from the 20° break in slope). Below this line is the medium risk zone, where landslide debris is less likely to inundate the land.

Given that the slope in this area has been created by the deposition of landslide debris over time, it is also sensible to assume that any of the sloping land below the high hazard areas could be inundated with landslide debris, albeit with a much lower likelihood of occurrence. The flat (less than 5°) land at the base of the slope is considered to be at low risk (not zero risk) of inundation and would only be inundated in the event of an extremely large (low likelihood) landslide event. So, the delineation between the Medium Risk Zone and the Low Risk Zone is the 5° break in slope.

To quantitatively calculate the risk to life in each of the zones the following equation[18] has been used:

$$R_{(LOL)} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(D:T)}$$

Where:

$R_{(LOL)}$ is the risk (annual probability of loss of life of an individual).

$P_{(H)}$ is the annual probability of the landslide occurring.

$P_{(S:H)}$ is the probability of a landslide impacting a building (a spatial location) taking into account the travel distance and travel direction given the event.

[17] Site specific investigation work may be able to further identify specific areas within each zone and more accurately delineate the landslide risks. However, that is outside the scope of this report (See Section 11. Limitations)

[18] From Section 7.1, Quantitative Risk Estimation in Fell, *et al*: Practice Note Guidelines for Landslide Risk Management 2007" Journal and News of the Australian Geomechanics Society Volume 42 No 1 March 2007

$P_{(T:S)}$	is the temporal spatial probability (e.g. of the building or location being occupied by the individual at the time of impact) and allowing for the possibility of evacuation if there is warning of the landslide occurrence.
$V_{(D:T)}$	is the vulnerability of the individual (probability of loss of life of the individual given the impact).

Table 3, below, presents an explanation of the input variables to calculate the annual risk to life in each of the landslide risk zones. It also shows the total risk to life ($R_{(LOL)}$) which is calculated as a combination of all the input variables and presents a description of the expected property damage for each zone. Note that the data used for these calculations excludes any projected future effects of climate change.

Table 3. Loss of life risk calculation and risk level descriptors for the three landslide risk zones.

	High Risk Zone	Medium Risk Zone	Low Risk Zone
$P_{(H)}$	Landslides occur at a rate of 5/year so the annual probability of occurrence is **1**	Landslides occur at a rate of 0.5 / year so the annual probability of occurrence is **0.5**	Landslides rarely enter this zone so the probability of occurrence is estimated at **0.1**
$P_{(S:H)}$	The combined length of the two High Risk Zones is 2670m and a 45m length of that was affected by landslides in the Feb 2022 floods. From this it follows that the spatial probability of any point being affected during a landslide event is **0.017**	The length of the Medium Risk Zone is 4345m and a 22m length of that was affected by landslides in the Feb 2022 floods. From this it follows that the spatial probability of any point being affected during a landslide event is **0.0051**	During the Feb 2022 event, there were no landslide debris deposits (from translational type landslides) recorded in the Low Risk Zone. However, it may be sensible to assume that the spatial probability of occurrence is approximately half that of the Medium Risk Zone: **0.0025**
$P_{(T:S)}$	Evacuations are not usually implemented in this area, so the temporal probability of a person being present in a residential dwelling is **1**	Evacuations are not usually implemented in this area, so the temporal probability of a person being present in a residential dwelling is **1**	Evacuations are not usually implemented in this area, so the temporal probability of a person being present in a residential dwelling is **1**
$V_{(D:T)}$	Given that buildings generally do not break apart or drastically deform, but that logs can be pushed through walls, it may be sensible to assume that a person within a building impacted by a landslide would have a 99.5% chance of survival. So, vulnerability is estimated at **0.005**	Given the points mentioned for vulnerability in the High Risk Zone combined with the decreased energy of the landslide debris in the Medium Risk Zone, that a person within a building impacted by a landslide would have a 99.9% chance of survival. So, vulnerability is estimated at **0.001**	Given the points mentioned for vulnerability in the High and Medium Risk Zones combined with the decreased energy of the landslide debris in the Low Risk Zone, that a person within a building impacted by a landslide would have a 99.99% chance of survival. So, vulnerability is estimated at **0.0001**
RISK $R_{(LOL)}$	8.5×10^{-5} (Can be expressed as 0.0085% per year Or one death every 10,000 years)	2.6×10^{-6} (Can be expressed as 0.00026% per year Or one death every 400,000 years)	2.5×10^{-8} (Can be expressed as 0.0000025% per year Or one death every 40 Million years)
Property damage	There is an annual probability of 0.017 of severe damage to a building. I.e. in the 50 year design life there is a 57%[19] chance of being damaged. Damage may require a complete rebuild.	There is an annual probability of 0.0051 of damage to buildings. I.e. in the 50 year design life there is a 22% chance of being damaged. Damage is likely to be moderate and repairable.	There is an annual probability of 0.0025 of damage to buildings. I.e. in the 50 year design life there is a 9% chance of being damaged. Damage is likely to be minor and easily repairable.

Note: Fatalities caused by landslides are not common in New Zealand. Data presented by Te Ara – The Encyclopaedia of New Zealand[20], shows that a total of eighteen fatal landslides have occurred in New Zealand since records began. These eighteen landslides caused a total of eighty eight fatalities in residential land.

[19] Calculated using binomial distribution.
[20] Available from: https://teara.govt.nz/files/d-8801-enz.pdf

6.2 Translational Landslide Risk Zone Map

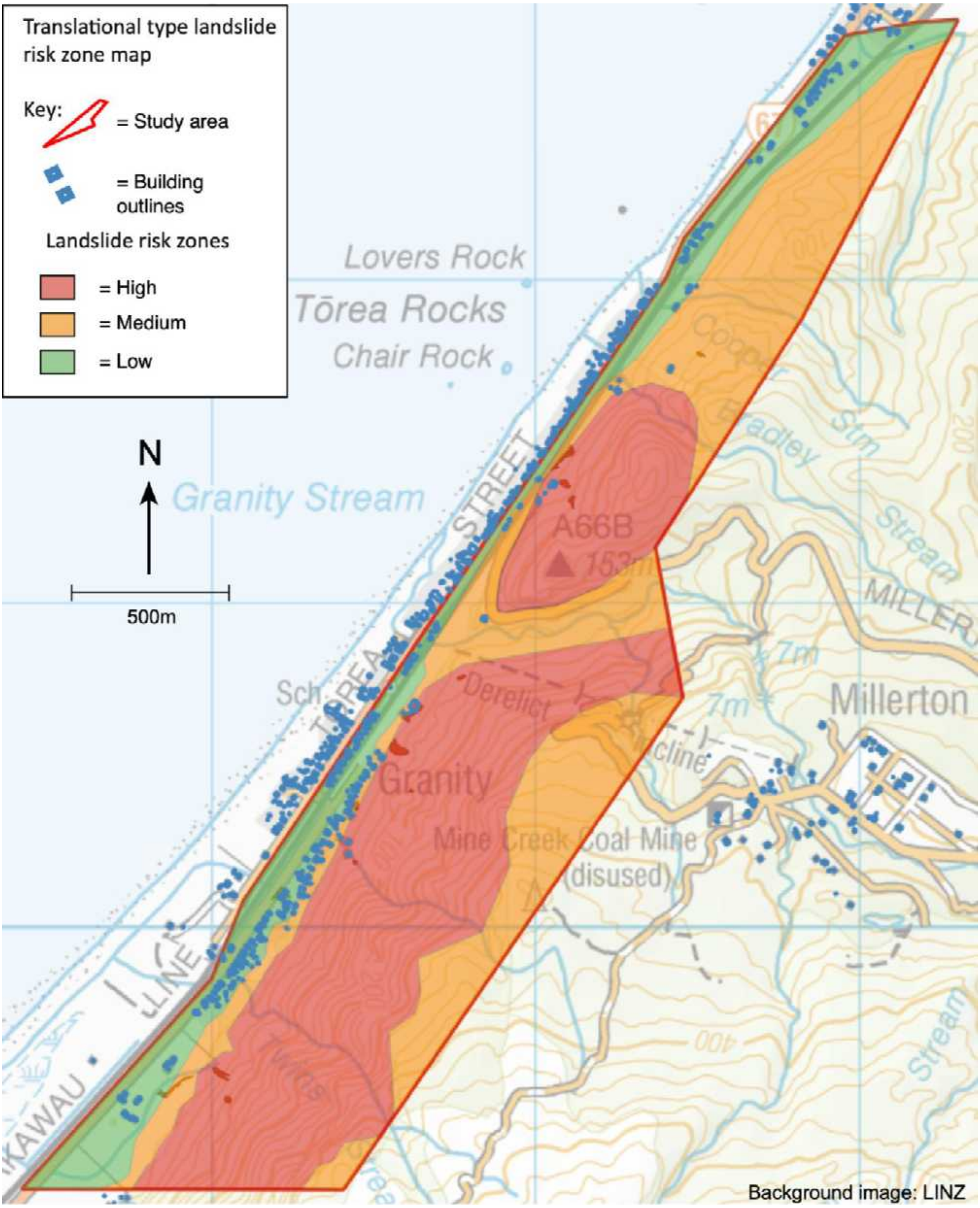

Figure 19. Translational Landslide Risk Zone Map (for descriptions of zones see table 3).

To allow for easier viewing of fine details, smaller scale representations of this map are shown in Appendix A. Additionally, BDC has been provided with vector and raster GIS files for electronic display at any scale.

7. Debris flow type landslides risk zone map

7.1 Method and description

The occurrence, behaviour and consequences of debris flows is not easy to predict. For this reason it has not been possible to produce a quantitative risk assessment (as was done for translational type landslides), so a qualitative method has been adopted. With the following assumptions the debris flow hazards can be classified and the resultant risks to properties can be qualitatively estimated[21].

Assumptions:

- Debris flows usually occur as a result of oversaturation of landslide debris, often derived from translational landslides
- Debris flows can occur in any of the high (or medium) hazard areas and may reach the base of the steep slope
- Debris flows are likely to travel down existing watercourses
- A drainage basin with more landslides is more likely to experience more and larger debris flows than a drainage basin with fewer landslides
- The risk of damage to properties will be related to that property's proximity to the steep, high hazard area and proximity to a watercourse that is likely to experience debris flows
- The energy (and destructive force) carried by a debris flow will be greater where the gradient of the ground is steeper (and energy will be lower in flatter ground). This means that debris flow inundation usually causes minor damage (non-structural) to dwellings, where those dwellings are located on flat ground. More severe damage may occur if a dwelling is positioned on sloping ground closer to a debris flow source area
- Where an alluvial fan is present there is an equal risk of debris flow inundation laterally across the entire alluvial fan (unless specific and well engineered mitigation measures are put in place)
- Where culvert blockages occur this can lead to debris flow diversion over a wide area

To classify and delineate the risks to people and property associated with debris flow type landslides in the study area the following process was used:

1. The zones from the translational type landslide risk zone map have been adopted to also represent the risk zones with respect to debris flows
2. Additional risk areas are added to the risk zone map based on the characteristics of the drainage basins (see Figure 20 and Table 4, below):
    a. Using a GIS, the individual drainage basins on the steep range front were identified and the area of each calculated
    b. The landslide inventory was then overlaid on the drainage basin map and the areas of landslides within each basin were extracted
    c. The proportion of each drainage basin affected by landslides was then calculated
    d. The drainage basins were then classified as High, Medium or Low hazard, based on the % of land within each drainage basin affected by landslides (Below 1% = Low, 1-5% = Medium, over 5% = High)
    e. Evidence for debris flow deposition was correlated between the hazard zones and it was found that all but one of the High hazard drainage basins showed evidence of debris flow

[21] These estimations are based primarily on expert judgement, field observations and limited terrain analysis. Therefore, the level of confidence in these estimations is low. Please see Section 11. Limitations.

deposition, three of the eight Medium hazard drainage basins showed evidence of debris flow deposition and one of the eighteen low hazard basins showed evidence of debris flow deposition. This served to validate the hazard zone classification

f. Three Risk Zones (High, Medium and Low) were established and added to the Risk Zone Map based on the proximity to a watercourse and the terrain in the vicinity of that watercourse (primarily the presence or absence of an alluvial fan). Each drainage basin has been individually analysed and the following rules applied:
   i. For High hazard drainage basins:
      1. The entire alluvial fan (if one is present) and all land within 10m of the watercourse as far as the highway (or railway) has been classed as High risk
      2. All land between 30m and 10m either side of the watercourse has been classed as Medium Risk
      3. Remaining land is low risk
   ii. For Medium hazard drainage basins:
      1. The entire alluvial fan (if one is present) and all land within 10m of the watercourse as far as the highway (or railway) has been classed as Medium risk
      2. Remaining land is low risk
   iii. For Low hazard drainage basins, no additional risk areas have been applied

Figure 20, below, shows the drainage basin areas colour coded to illustrate the debris flow hazard of each basin and Table 4 shows the input data used to classify each of the drainage basins.

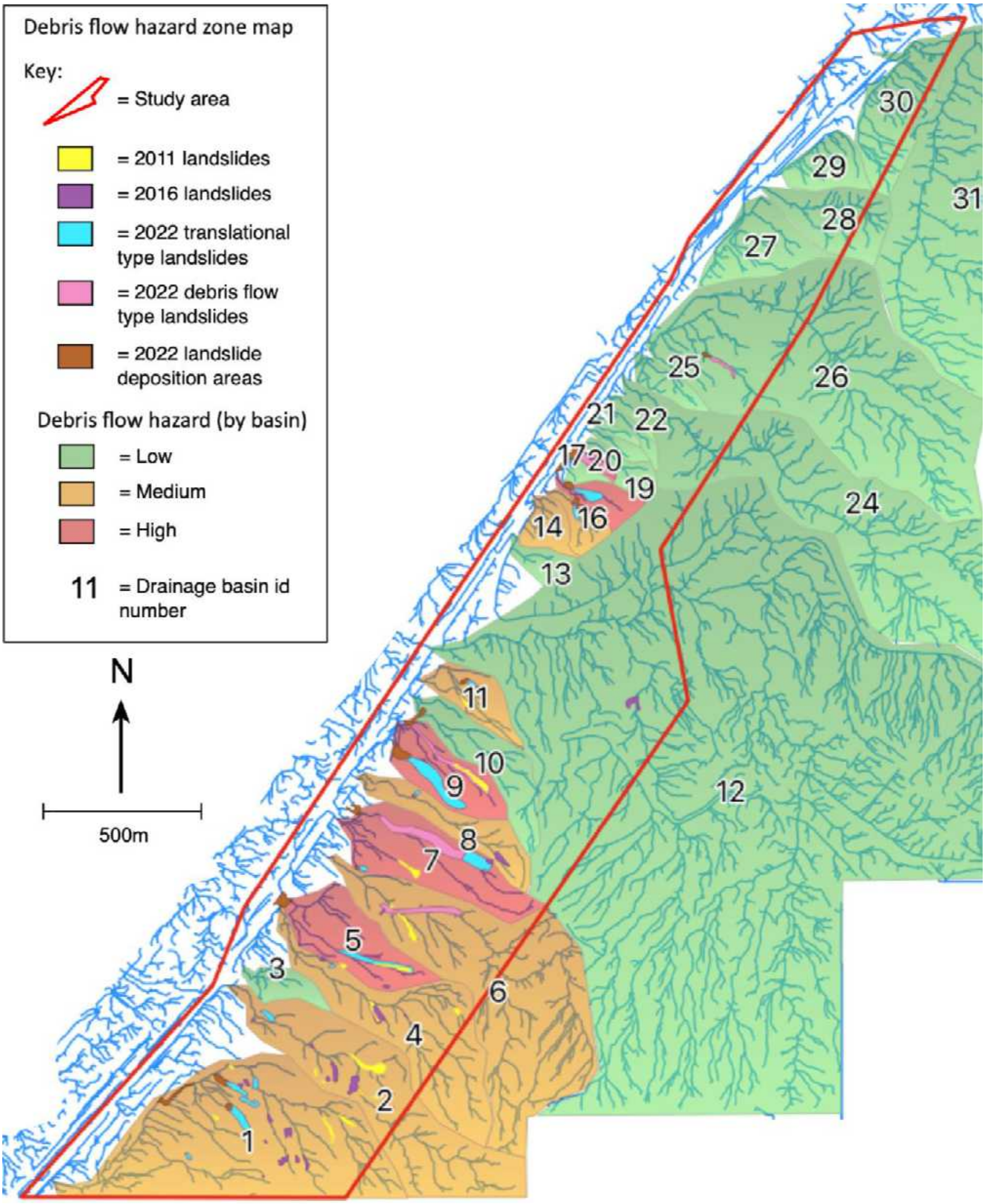

Figure 20. Debris flow hazard zones (watercourses shown as blue lines).

Table 4. Input data used to classify each of the drainage basins.

Drainage basin number	Area / m^2	Total area of landslides within basin / m^2	% of land within basin affected by landslides	Evidence for debris flow deposition	Debris flow hazard	Comment
1	398,520	7,971	2	Yes	Medium	
2	257,398	5,204	2	No	Medium	Twins Stream
3	26,687	0	0	No	Low	
4	200,340	2,677	1	Yes	Medium	
5	9,9902	4,733	5	Yes	High	Debris flow caused dwelling damage in 2022
6	387,868	5,074	1	Yes	Medium	
7	134,722	12,134	9	Yes	High	Debris flow caused dwelling damage in 2022
8	68,393	899	1	No	Medium	
9	76,792	11,848	15	Yes	High	Debris flow caused damage to Museum in 2022
10	83,077	0	0	No	Low	
11	46,790	591	1	No	Medium	
12	2,729,918	904	0	No	Low	Granity Stream
13	19,041	0	0	No	Low	
14	27,089	238	1	No	Medium	
15	22,106	583	3	No	Medium	
16	28,631	1,977	7	No	High	
17	8,386	0	0	Yes*	Low	
18	6,843	2,249	33	Yes	High	Debris flow caused residential land damage in 2022
19	21,733	0	0	No	Low	
20	9,864	0	0	No	Low	
21	6,496	0	0	No	Low	
22	11,704	0	0	No	Low	
23	8,528	0	0	No	Low	Bradley Stream
24	463,664	189	0	No	Low	
25	23,589	0	0	No	Low	
26	586,477	878	0	No	Low	Cooper Stream
27	77,658	0	0	No	Low	
28	78,646	0	0	No	Low	
29	44,434	0	0	No	Low	
30	90,394	0	0	No	Low	
31	529,557	0	0	No	Low	

*Whilst Basin 17 has been classified as Low Hazard (from debris flows) there is evidence of debris flow deposition. This has occurred due to overspill of debris from Basin 18 (a High Hazard basin) due to culvert blockage.

7.2 Debris Flow Risk Zone Map

The debris flow risk zone map was generated using the methodology described above. The risk zone descriptors are shown in the qualitative risk analysis matrix[22] below (Table 5):

Table 5. Risk matrix to be used with the debris flow risk zone map.

	Consequences		
Likelihood	Major. Severe property damage. Injuries to people are possible.	Moderate. Some property damage. People unharmed.	Minor. Inconvenience caused. Debris easily removed.
Highly likely (may occur once every 10 years or more)	High	High	Medium
Possible (may occur once every 100 years)	High	Medium	Low
Rare (may occur once every 1000 years)	Medium	Low	Low

[22] This risk matrix is a simplification of the risk matrix suggested in Fell *et al.* 2008.

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Figure 21, below, shows the debris flow risk zone map.

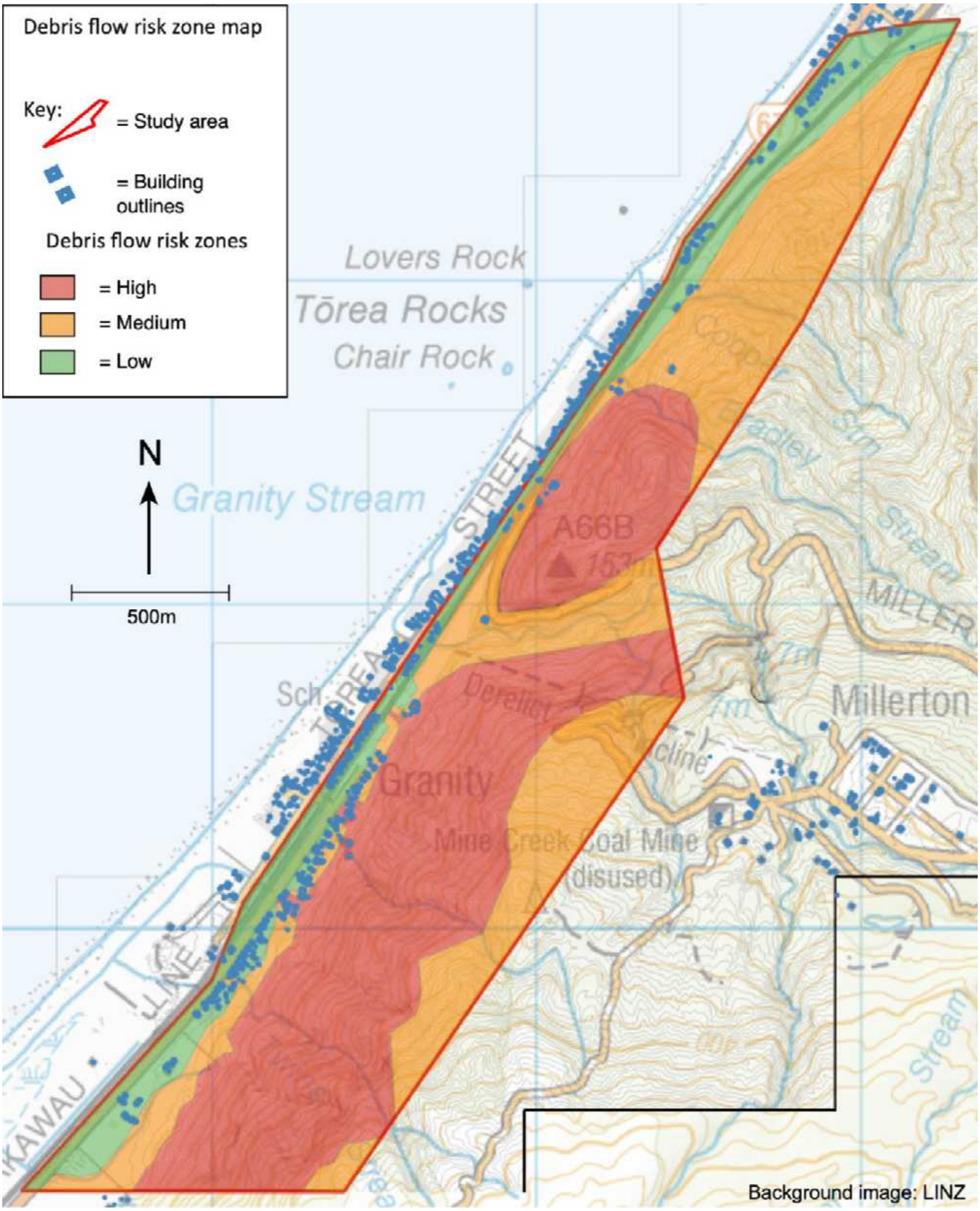

Figure 21. Debris flow risk zone map.

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To allow for easier viewing of fine details, smaller scale representations of this map are shown in Appendix B. Additionally, BDC has been provided with vector and raster GIS files for electronic display at any scale.

8. Other factors affecting landslide risk

This study delineates the risk to people and property as a result of landslides that are triggered by heavy rainfall events. It does not take into account the risk of coseismic landslides (earthquake generated landslides) or the potential for increased landslide risk due to climate change.

8.1 Coseismic landslide risk

An earthquake with a peak ground acceleration (PGA) of 0.2 or above would be expected to cause coseismic landslides to occur within the study area[23]. This precedent behaviour is well established. Previous low frequency seismic events in the Buller area have caused some very large and damaging landslide events with multiple fatalities (i.e. Murchison earthquake in 1929 and Inangahua earthquake in 1968). The National Seismic Hazard Model[24] shows that an earthquake with PGA 0.2 is expected to occur once every 475 years[25]. Therefore, the annual chance of a coseismic landslide at this site is 0.2% per year or a probability of 0.002. However, the scale of this kind of landslide event and the consequences of its occurrence are not known. Further research would be required to meaningfully assess the risk of coseismic landsliding.

8.2 The effects of climate change

Climate change is likely to cause an increase in heavy rainfall event magnitude and frequency. This increase in rainfall is likely to cause a corresponding increase in the magnitude and frequency of landslide events. This means that future landslide events in the Granity area are expected to be more common, bigger and more damaging than the current and past observed landslides.

During the heavy rainfall event of February 2022, 166mm of rain fell in 24 hours. The HIRDS[26] database shows that this is approximately a 1 in 10 year event. Another function of the HIRDS database is to model the potential future rainfall intensity and return intervals with respect to varying climate prediction models. Assuming an RCP2.6 scenario[27], the HIRDS database shows that in the time period 2031-2050 this rainfall intensity is likely to be a 1:5 year event and that a 1:10 year event is likely to be in the order of 187mm of rain in 24 hours (12% more rain). Assuming an RCP8.5 scenario, the HIRDS database shows that in the time period 2031-2050 this rainfall intensity is still likely to be a 1:5 year event and that a 1:10 year event is likely to be in the order of 191mm of rain in 24 hours (13% more rain). From this climate modelling it is expected that landslide events will become more frequent (possibly twice the frequency), and that the magnitude of landslide events may also increase significantly.

The relationship between rainfall intensity and landslide magnitude (size) is not well understood. However, recent observations of a number of very large landslides (40,000m^3+) in close proximity to the study area

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[23] From Table 4.8 in de Vilder SJ, Massey CI, Guidelines for natural hazard risk analysis on public conservation lands and waters – Part 3: Analysing landslide risk to point and linear sites. Lower Hutt (NZ): GNS Science. 52 p. Consultancy Report 2020/52.
[24] Accessed from: https://www.gns.cri.nz/Home/Our-Science/Natural-Hazards-and-Risks/Earthquakes/National-Seismic-Hazard-Model-Programme
[25] https://hazard.openquake.org/gem/models/NZL/
[26] High Intensity Rainfall Design System accessed at: https://hirds.niwa.co.nz/
[27] A Representative Concentration Pathway (RCP) is a greenhouse gas concentration trajectory adopted by the IPCC. Four pathways were used for climate modelling with 2.6 being the best case scenario and 8.5 being the worst case scenario.

(Charming Creek Walkway[28]) suggest that the locally unprecedented scale of those landslides may indicate that larger scale landslides may occur in the Granity area in the future.

Given that rainfall intensity is expected to increase in the order of 12-13% by 2050, it should be expected that landslide magnitude will also increase by at least that amount. This increase in magnitude may have a significant effect on the expected risk to life, particularly for those properties located within the High Risk Zone.

Further research is required to more accurately predict the risks associated with increased magnitude and frequency of landslide events due to climate change. However, the establishment of well planned monitoring systems (including locally installed rain gauges, and post-rain event landslide surveys used to support landslide trend analysis and the establishment of a rainfall intensity landslide triggering threshold) and an appropriate warning system may help to define and manage the climate change related risks as more data becomes available.

[28] England and Company Ltd. Consulting Letter Report to Department of Conservation (Westport Office), dated: 07 December 2021.

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9. Discussion and risk mitigation options

9.1 Review of findings

A brief review of the two risk zone maps shows that:

- **Translational landslides**:
  - **Risk to life in the High Risk Zone.** There are four residential dwellings along with a number of other outbuildings/sheds (with unknown use) as well as a commercial property (the Museum) that are at high risk of impact damage from translational type landslides. For people living in those dwellings there is a calculated risk of loss of life in the order of 8.5 x 10^{-5} per year[29]. As stated in the commentary to NZS 1170.5[30] an accepted basis for building codes is an annual fatality rate of 10^{-6} (this would be an accepted basis for *new builds*, not existing developments). However, other authors (such as Fell *et al*. 2008) have suggested that 10^{-4} is a more suitable risk tolerance threshold for existing developments. An important point to note is that in the High Risk Zone, the risk level is almost two orders of magnitude higher than the accepted level suggested in the commentary to NZS1170.5 for new builds. However, it is within the risk tolerance level suggested by Fell *et al* for existing developments.
  - **Property risk in the High Risk Zone.** In the 50 year design life of a building, there is a 57% chance of being damaged.
  - **Risk to life in the Medium Risk Zone.** There are approximately twenty residential dwellings and a number of other outbuildings (with unknown use) within the medium risk zone where the expected risk of loss of life is 2.6 x 10^{-6} per year[31]. Within the Medium risk zone, the risk to life is approximately double the suggested level (for new builds) in the commentary to NZS 1170.5 (although, given the limitations of the accuracy of these risk level estimations, the actual risk may be within the suggested risk tolerance levels in NZS 1170.5.)[32] However, it is well within the risk tolerance level suggested by Fell *et al* for existing developments.
  - **Property risk in the Medium Risk Zone.** In the 50 year design life of a building there is a 22% chance of being damaged.
- **Debris flow type landslides:** There are ten residential dwellings along with a number of other outbuildings/sheds (with unknown use) as well as a commercial property (the Museum) that are at high risk of inundation damage from debris flows. For people living in those dwellings there is a possible risk of harm and it is likely that those buildings will be damaged by debris flows in the future. There are also approximately fifteen residential dwellings and a number of other outbuildings (with unknown use) as well as three commercial properties within the medium risk zone, where property damage may also occur.

From these findings it is clear that some form of risk reduction work may be appropriate.

[29] Can be expressed as 0.085% per year, or approximately one death every 1,000 years
[30] Structural design actions - Part 5: Earthquake actions - New Zealand Commentary: Amendment 1:2016
[31] Can be expressed as 0.0026% per year, or approximately one death every 40,000 years
[32] See Point 1 in Section 11.2 Limitations of the landslide risk zone maps.

9.2 Risk mitigation options

This report presents a risk analysis of the identified landslide hazards in the study area. The tolerability (or intolerability) of those risks is a matter for discussion within the community (including BDC and commercial stakeholders). That discussion will evaluate the risks against the community's value judgements and existing risk tolerances. Depending on the outcomes of that discussion a range of risk mitigation options can be developed and implemented in a risk control plan (see Figure 2. Framework for landslide risk management).

Broadly, the risk mitigation options are[33]:

1. ***Accept the risk***, which is only an option subject to the criteria set by the regulator (in this case BDC in discussion with the community). Where the risk is not tolerable then risk mitigation measures are required.
2. ***Avoid the risk***, by relocation of the affected high risk buildings and by limiting future development within the High (and possibly Medium) risk zone.
3. ***Reduce the frequency of landsliding***, by stabilisation measures to control the initiating circumstances, such as by re-profiling the surface geometry where existing slopes are 'over steep', by provision of improved surface water drainage measures, by provision of subsurface drainage scheme, by provision of physical works such as retaining walls, anchored walls or ground anchors.
4. ***Reduce the consequences***, by provision of defensive stabilisation measures or protective measures such as debris deflection bunds, or amelioration of the behaviour of the landslide.
5. ***Manage the risk by establishing monitoring and warning systems,*** such as by weather monitoring and alerting residents potentially affected to a change in the landslide risk conditions. Such systems may be regarded as a method of reducing the consequences provided it is feasible for sufficient time to be available between the alert being raised and appropriate action being implemented.
6. ***Transfer the risk,*** such as by requiring another authority to accept the risk or by provision of insurance to cover potential property damage.
7. ***Postpone the decision,*** where there is sufficient uncertainty resulting from the available data, provided that additional investigations or monitoring are likely to enable a better risk assessment to be completed. Postponement is only a temporary measure and implies the risks are being temporarily accepted, even though they may not be acceptable or tolerable.

Assuming that the risk is not simply accepted then the other risk mitigation options should be investigated and suitable solutions agreed upon. Avoiding the risk by relocating buildings (Point 2, above) from the high (and possibly medium) risk zone is by far the most effective risk reduction option. However, forced relocations are usually unpopular, expensive and may not be a suitable option in this instance. Some of the more passive, non-regulatory methods available to local authorities to encourage people to *avoid* the landslide risk include[34]:

- Acquiring or purchasing at-risk land for passive recreational purposes
- Exchanging at-risk land with Council owned land more suitable for the purpose
- Allowing greater development rights on other land if at-risk land is retired or covenanted
- Using structure plans to actively identify and avoid areas with stability concerns

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[33] Modified from Section 9.1, Risk mitigation principles in Fell, *et al*: Practice Note Guidelines for Landslide Risk Management 2007" Journal and News of the Australian Geomechanics Society Volume 42 No 1 March 2007

[34] From Guidelines for assessing planning policy and consent requirements for landslide prone land. Compiled by W. Saunders and P. Glassey GNS Science, GNS Science Miscellaneous Series 7. Available from: http://www.qualityplanning.org.nz/sites/default/files/Guidelines%20for%20assessing%20planning%20policy%20and%20consent%20requirements%20for%20la.pdf

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- Ensuring at-risk land forms part of the reserves contribution as a condition of subdivision consent
- Using financial incentives (for example, rates relief for at-risk land if it is not developed)
- Promoting and helping fund the use of covenants (privately or through the QEII National Trust) for voluntary protection from development of open space on private land
- Education to raise awareness of the risk, and to encourage people to locate buildings away from the hazard

For various reasons (existing use rights, community acceptance, cost, etc.) relocations and land-use changes may not be appropriate for this area. Also, reducing the frequency of landsliding (Point 3, above) by installing stabilisation structures is not a feasible option in this area. That means that the most suitable methods of risk reduction may be to reduce the consequences of landslide events by utilising a suite of defensive measures. Table 6, below, shows a range of potential risk reduction measures that may help to reduce the consequences of future landslide (translational type and debris flow) events. These are presented in no particular order.

Table 6. Risk mitigation options.

Risk reduction measure	Description	Expected risk reduction benefits	Other factors to consider
Debris deflection bunds	Earth bunds can be an effective method of diverting or stopping the downslope motion of landslide debris. These would require Specific Engineering Design (SED) to protect vulnerable properties. Other deflection structures such as concrete tilt panel walls, steel poles and timber pole walls could be considered, but earth bunds are generally accepted to offer the best cost/benefit ratio of these defensive structures.	Very effective within the design parameters. Benefits should be able to be quantified during the SED process	These may be obtrusive and may not be a welcome feature of a residential property. Moderately high cost of installation.
Encourage dense vegetation growth	Healthy, dense tree cover on the ground upslope of a vulnerable building can be an effective means of stopping, slowing or diverting landslide debris. Establishing new growth and limiting the felling of existing trees may be appropriate	Effectiveness may be variable, but is expected to provide some benefits, particularly in respect to the smaller, more frequent events.	Establishing new tree growth takes considerable time.
Debris flow control structures; i.e. debris dams / debris nets	Structures built to detain debris upslope of the elements at risk.	Can be very effective at reducing risks from debris flows	Ongoing maintenance requirements.
Install larger culverts (to reduce the risks from debris flows only)	Some of the observed debris flow inundation damage was likely caused by culvert blockages leading to debris flow diversion onto residential land. Suitably sized culverts may reduce the likelihood of blockage. These would require SED.	Very effective within the design parameters. Benefits should be able to be quantified during the SED process. Would also help to reduce flood risk	High cost. Although some (or all) of the cost may be shared with NZTA and Kiwi Rail.

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Risk reduction measure	Description	Expected risk reduction benefits	Other factors to consider
Maintain upslope waterways (to reduce the risks from debris flows only)	To reduce the risk of debris flow diversion it may be sensible to maintain waterways upslope of a residential dwelling and try to encourage flow away from a vulnerable structure, by construction of channels and bunds. Care needs to be taken with this technique to avoid over sedimentation and alluvial fan aggradation, which can lead to an *elevated* risk if done inappropriately	Can be effective in the short term. Long term, this technique may be counter productive.	Constant work is required to ensure effectiveness of this technique
Monitor and maintain downstream waterways (to reduce the risks from debris flows only)	This will involve ensuring culverts and downstream channels are not blocked so that debris flows are encouraged to stay within the existing waterway channels.	May be effective for small events, but unlikely to be effective for larger events or for prolonged periods of heavy rain, where sedimentation may be constant and overwhelming.	Monitoring can be done cheaply and the results used to cost-effectively allocate resources
Modify residential building usage to favour spending time in lower risk areas of the same building	When landslide debris strikes the side of a building it will cause an elevated risk of harm to people who may be positioned in that side of the building. So, moving a bedroom to the downslope side of a house may help to reduce the amount of time spent in the higher hazard area (reduce hazard exposure time).	Risk to life can be very effectively reduced by this method.	Potentially easy and cheap to implement
Issue landslide warnings based on weather forecasts	A warning can be issued to the entire community (or select high risk individuals) based on forecast rainfall amount. Threshold could be set at 150mm/24hrs, or some other threshold, based on the level of risk tolerance. Actions derived from these warnings may include evacuations, or simply to raise awareness of the temporarily elevated risk	Highly effective risk reduction measure. Evacuations may be unpopular, particularly if these become frequent.	Easy and cheap to implement. May become increasingly important in respect to climate change.
Issue warnings based on locally installed monitoring devices	Rainfall sensors could be installed in various locations along the Granity rangefront, with the intention of providing better, more accurate, site specific information about rainfall amounts. This may become increasingly important as climate change progresses.	If a communication strategy is developed to ensure action is taken on warnings, this could be highly effective	Sensors may require ongoing maintenance. Installation costs should be low. May become increasingly important in respect to climate change.
Apply rules (regulatory) to limit further	Rules can be included in the District plan to discourage further development in high risk areas. These rules may range from a	Depending on the approach taken these rules can be effective	Usually unpopular

Risk reduction measure	Description	Expected risk reduction benefits	Other factors to consider
development in high and medium risk zones	requirement for detailed risk mitigation works for future developments, up to a blanket ban on future development.	at reducing the occupancy rates of the higher risk areas over time and will become increasingly mainstream as insurance becomes harder and more costly to obtain.	
Information provision	Informing the community about the landslide risks[35] will help residents to make their own, informed decisions about landslide risk reduction.	People are able to choose the risk reduction methods most suitable for their own circumstance and risk tolerance levels.	Easy to provide. Required by law.
Monitoring of existing landslides	Geotechnical observations of existing landslides may give pre-warning of imminent debris inundation allowing for immediate evasive action.	Risk reduction benefits may be considerable if monitoring is done effectively with appropriate warning systems in place.	Requires ongoing geotechnical input.
Site specific investigations for high risk sites	For properties that are positioned within the high risk zone, it may be appropriate for these sites to be assessed in more detail to provide a higher degree of confidence in the risk level and to identify the most suitable risk mitigation options that are specific to that site.	Since this would provide site specific advice, this should provide for a high degree of risk reduction benefit.	Costs would likely need to be covered by the individual property owners and may not be seen as beneficial to them.
Insurance provision	Private and Government insurance (EQC) can help to significantly offset the costs associated with natural disaster damage, including landslides. However, property owners should understand the areas and items of insurance coverage (and exclusions) as well as the relevant deductible costs.	Insurance can reduce the costs (to the property owner) associated with landslide damage.	Does not reduce the risks to life or personal safety. Often significant financial shortfalls are experienced upon claim settlement, leaving the insured parties unable to complete the required remediation works.

Note: The inclusion of these options within this report does not constitute advice or a requirement to implement any of these options.

[35] This is also a basic requirement of the RMA, 1991 and the CDEM Act, 2002.

10. Conclusions

10.1 This report

Two landslide risk zone maps have been produced showing the calculated risk to people and property from translational landslides and debris flow landslides. In the case of the translational type landslide risk zone map, four residential dwellings and one commercial property have been identified within the High Risk Zone. The calculated annual risk to life for people resident in those dwellings is in the order of 8.5×10^{-5} (which can be expressed as 0.0085% per year, or one death every 10,000 years). This figure is considerably higher than accepted normal annual risk to life for new builds, but within the suggested acceptable risk tolerance threshold for existing developments. The debris flow risk zone map presents a qualitative risk analysis of the debris flow hazards and highlights additional properties that may experience property damage due to debris inundation. The reported risk levels are expected to increase with time as climate change progresses.

A range of risk mitigation options has been suggested and explained, to help BDC and the local community to effectively manage the landslide risk. Additional work is required to define the landslide risks associated with climate change (and earthquake effects).

10.2 Next steps

Upon receipt of this report, BDC should provide the community with this information, and ensure as far as possible that it is understood by the people who are affected by the landslide risk. This can be done by making this report easily available in electronic and print formats as well as at least one community engagement session, where interested parties can verbally ask questions of the report author and of BDC. Community members should be given an effective forum for community engagement and feedback to help achieve the following:

1. BDC needs to understand the local community's risk acceptance/risk tolerance levels in regards to the landslide risk. This will help BDC to make sensible landslide hazard management decisions that are suited to the community that is affected.
2. People will have the opportunity to ask questions and become more aware of the landslide risk
3. BDC is able to to provide the types of support necessary to help the community reduce their exposure to the landslide risk in ways that are appropriate and accepted by the community (eg. if early warning systems, requiring more rainfall monitoring sites are deemed to be a good method of risk reduction by the community, then resources should be made available to make that happen).
4. A landslide risk management plan should be developed taking into account the advice in this report, the community's risk tolerance levels and any applicable legislative requirements.
5. The landslide risk management plan should be reflected in the District Plan and Regional Policy Statement
6. The effectiveness and efficiency of the final adopted landslide risk management plan will require structured ongoing monitoring and review, particularly to accommodate any changes to the risk profile that occur as a result of climate change

It may also be appropriate to undertake further research to better understand the increased risks due to climate change (and coseismic landslide risk).

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11. Limitations

This report has been produced using the best currently available data and site observations. However, there are various limitations that could affect the accuracy of the results presented. Understanding these limitations will encourage people to make the appropriate decisions based on the information presented in this report

11.1 Limitations of the landslide inventory map

Whilst every care has been taken to produce a landslide inventory that is as accurate as possible, this landslide inventory has the following limitations:

- It is based on three datasets, spanning the past 13 years only. Landslides that occurred prior to 2009 may not be represented. This means that the expected future behaviour and occurrence of landslides in the study area may not be accurately predicted by the behaviours observed over the past 13 years
- The image resolution of the datasets varies (the 2009-2011 dataset has 0.4m pixels, the 2015-2016 has 0.3m pixels and the recent, 2022 dataset has 0.15m pixels). This may mean that landslides are more easily identified in the later datasets
- The LINZ datasets were collected as routine data collection tasks that were not related to landslide occurrence, therefore the landslides shown in these datasets may have occurred a number of months or years prior to the data collection. This may mean that some of the landslides that occurred in that time period (particularly the smaller ones) are not visible in those datasets (either due to resolution or revegetation over time)
- The dataset collected in April 2022 was collected to specifically document the February 2022 landslides (less than 2 months prior to data collection), so the landslides in that dataset are likely to be more visible than the previous two datasets, meaning that comparisons between the three datasets may not be representative of the actual trends over time
- Location accuracy of the LINZ datasets is reported as +/- 2.5m for the 2009-2011 dataset and +/- 0.6m for the 2015-2016 dataset. Location accuracy for the drone imagery collected in April 2022 is estimated to be +/3.5m
- Where dense vegetation covers the ground surface small landslide features, or narrow chutes that may carry debris flows, may not be visible from aerial photography, so these will be omitted from the landslide inventory
- Observations of landslide areas may be affected by areas obscured from view by overhanging vegetation, quality of aerial photography, image resolution and other factors, making the measurement of landslide areas approximate only

11.2 Limitations of the landslide risk zone maps

1. Uncertainty in the input variables may account for an accuracy of the final risk levels being +/- 1 order of magnitude.
2. The methodology used in this report (AGS, 2007) suggests that for residential dwellings a temporal exposure probability of 1 be adopted. A probability of 1 would mean that a person is present in that house 100% of the time. However, in reality a person may only be present in that house for 50% of the time (or some other proportion of time), which would mean that the actual risk is 50% less than reported.
3. The estimation of vulnerability is extremely subjective and this introduces uncertainty into the calculation of the probability of loss of life. I.e. A person's ability to avoid harm during a landslide incident will be dependent on a long list of factors including personal experience, fitness, awareness

and reactiveness as well as the physical characteristics of the building they are in or the terrain on which they are positioned. The overall estimation of risk to life is highly sensitive to this input data and this may also have a large effect on the eventual calculated risk level.

4. Landslide events are most likely to occur during heavy rainfall and it may be that people living within the study area already take certain defensive actions during these rainfall events, which would also affect the calculated risk level.
5. This report does not quantify the expected level of risk reduction benefits from each of the identified risk reduction options. This information can be provided at a later date if required.
6. This report presents the risk to life from rainfall generated landslide hazards only. It does not quantify the risk to life from coseismic landsliding, the expected increased risks due to climate change, or the risks from other natural hazards such as floods and coastal erosion. Some of these other factors may present significant individual and societal risk.
7. The landslide risk zoning has taken a statistical approach to landslide spatial occurrence (i.e. landslides are assumed to be evenly distributed across areas with similar terrain variables). However, more detailed terrain analysis and site specific investigation work may be more accurate in predicting the actual future likelihood of landslide occurrence in specific locations.

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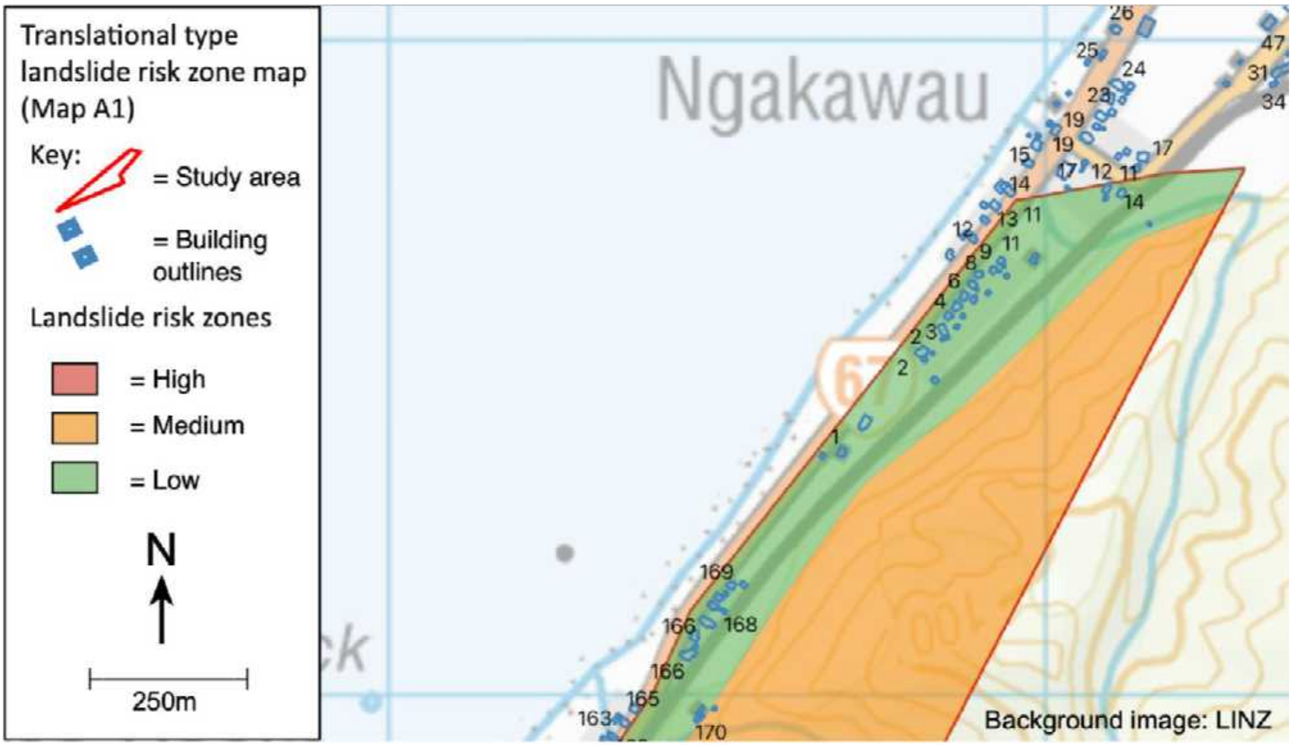
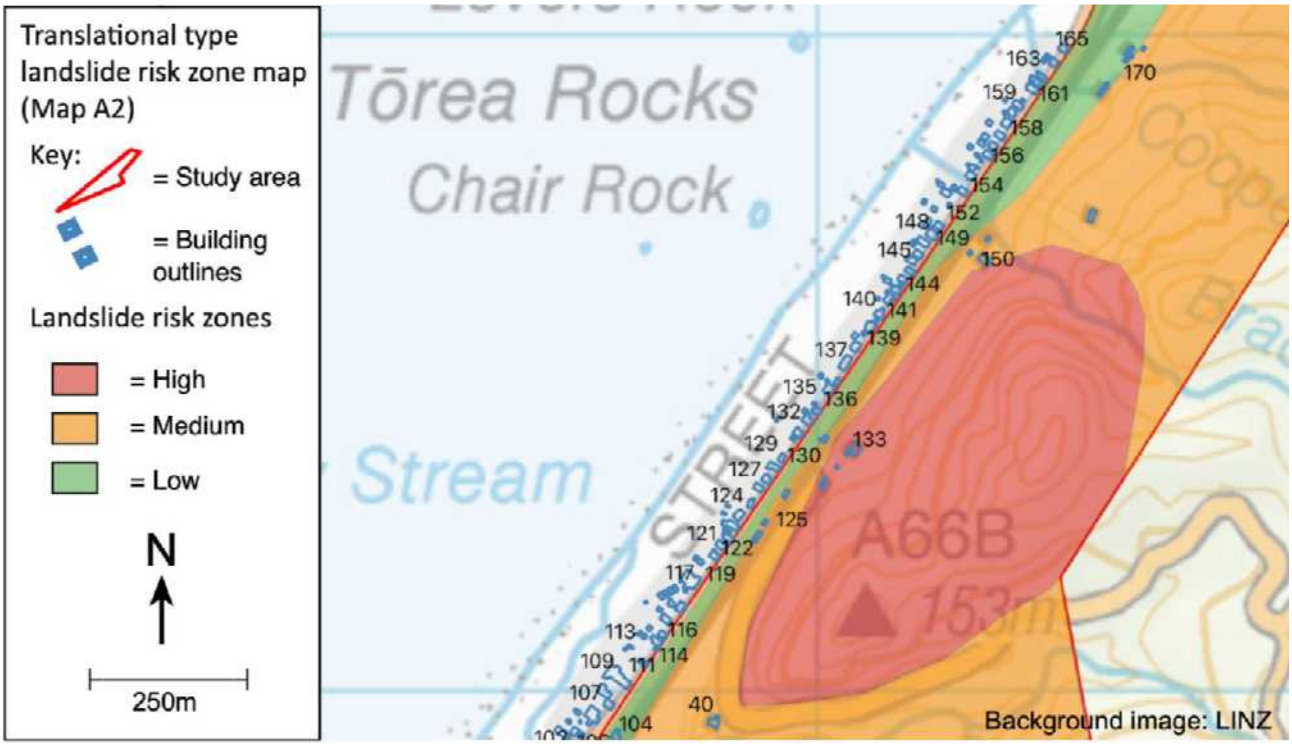
Appendix A

Small scale (approximate scale at A4 1:11,000) translational landslide risk zone maps. Street address numbers are shown next to the building outlines.





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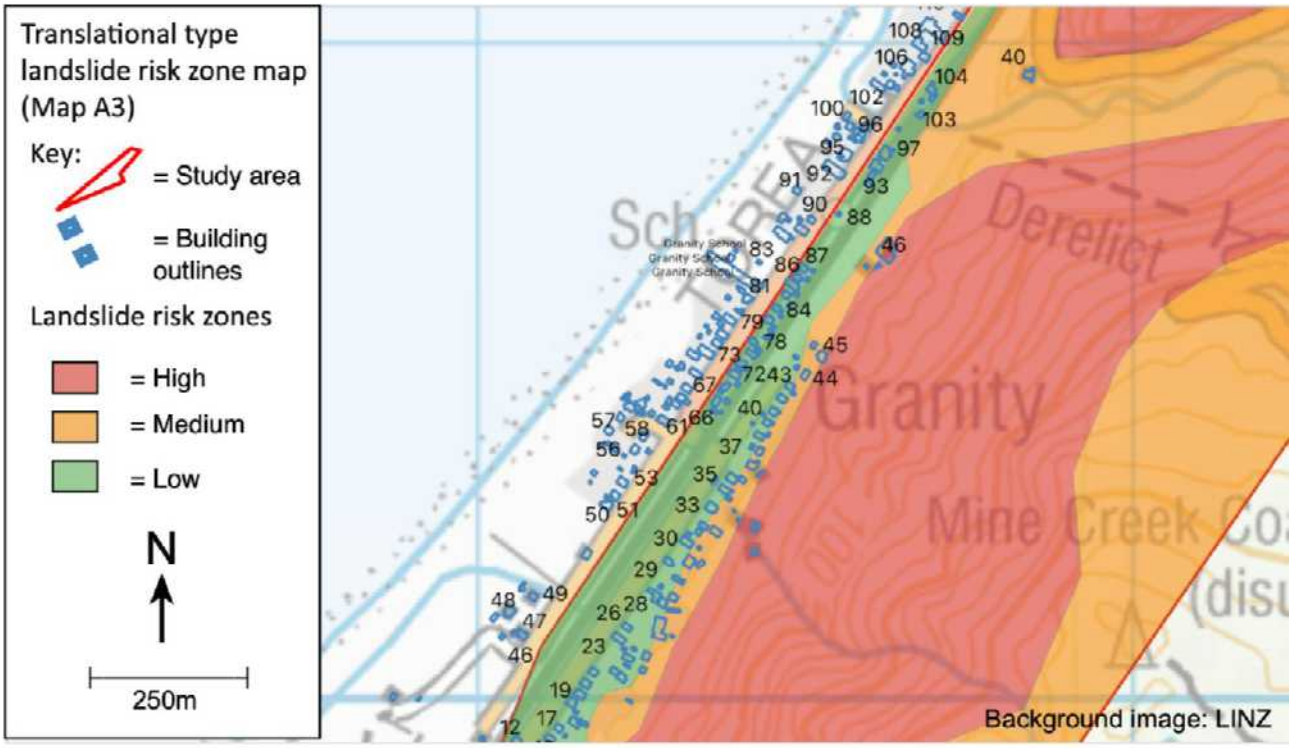

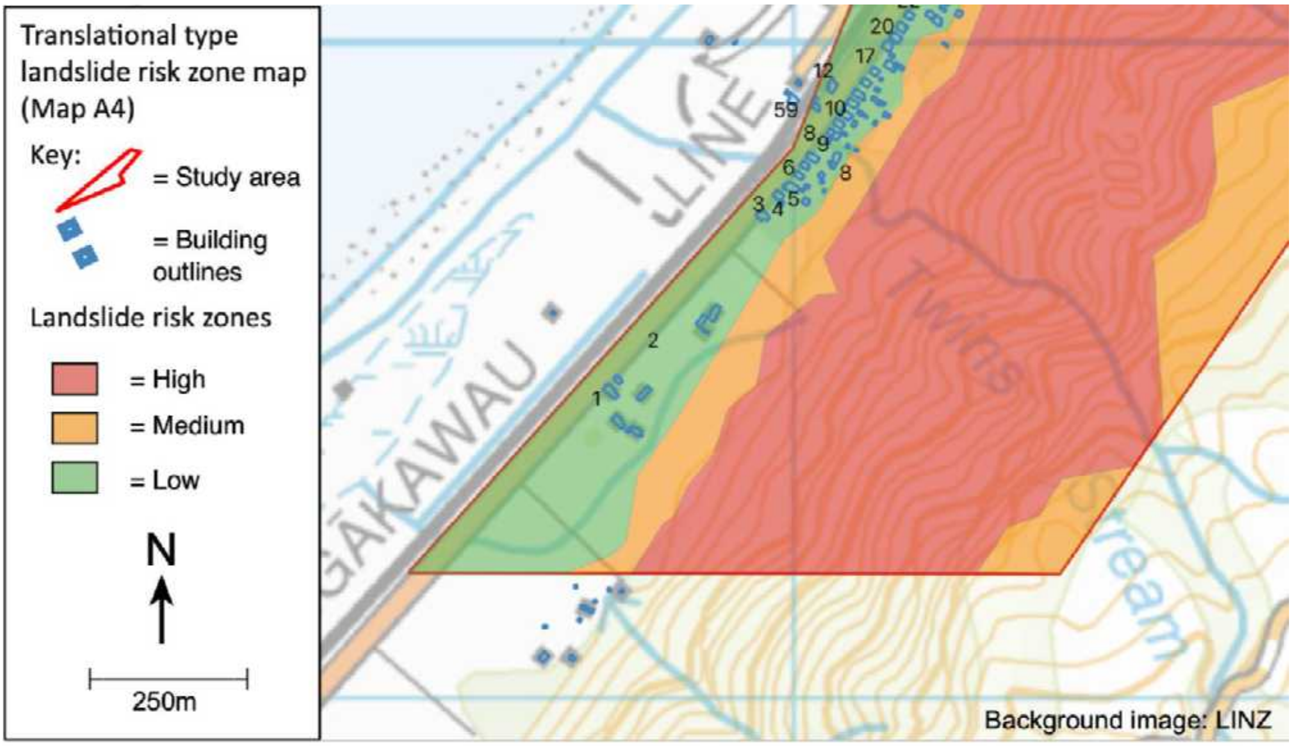

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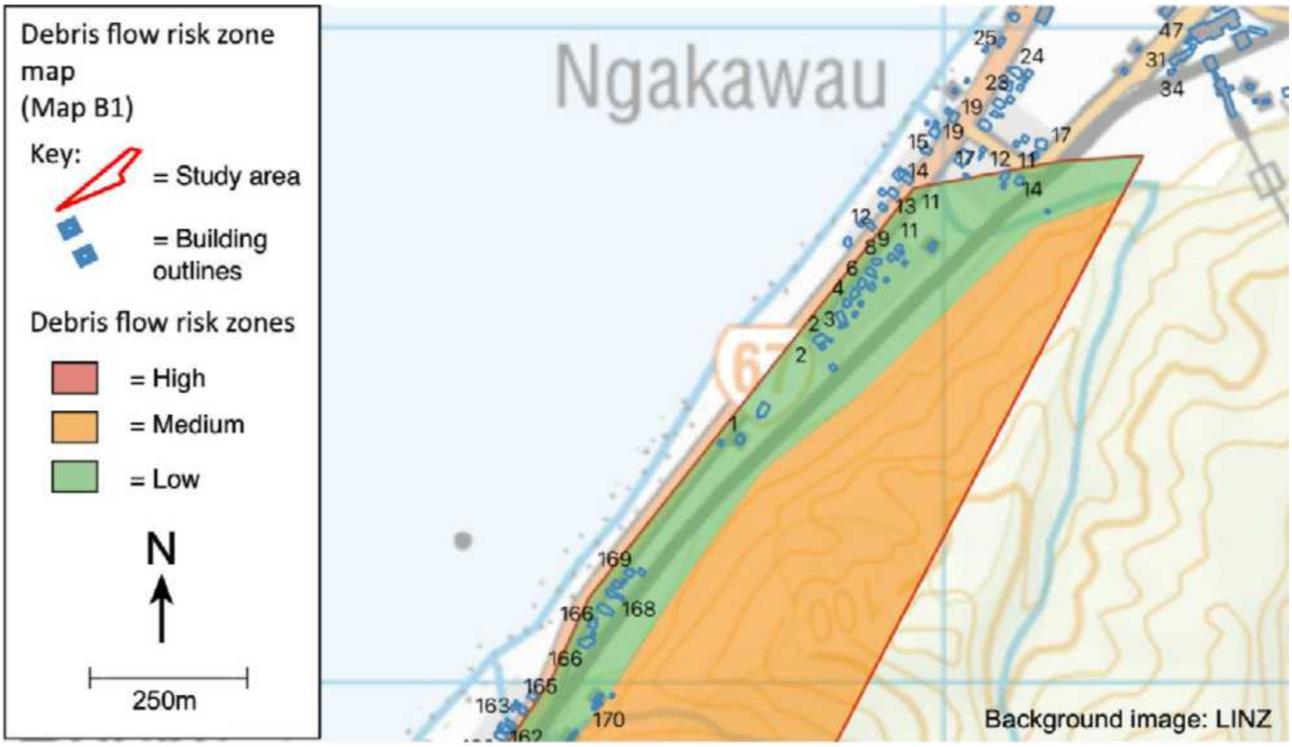
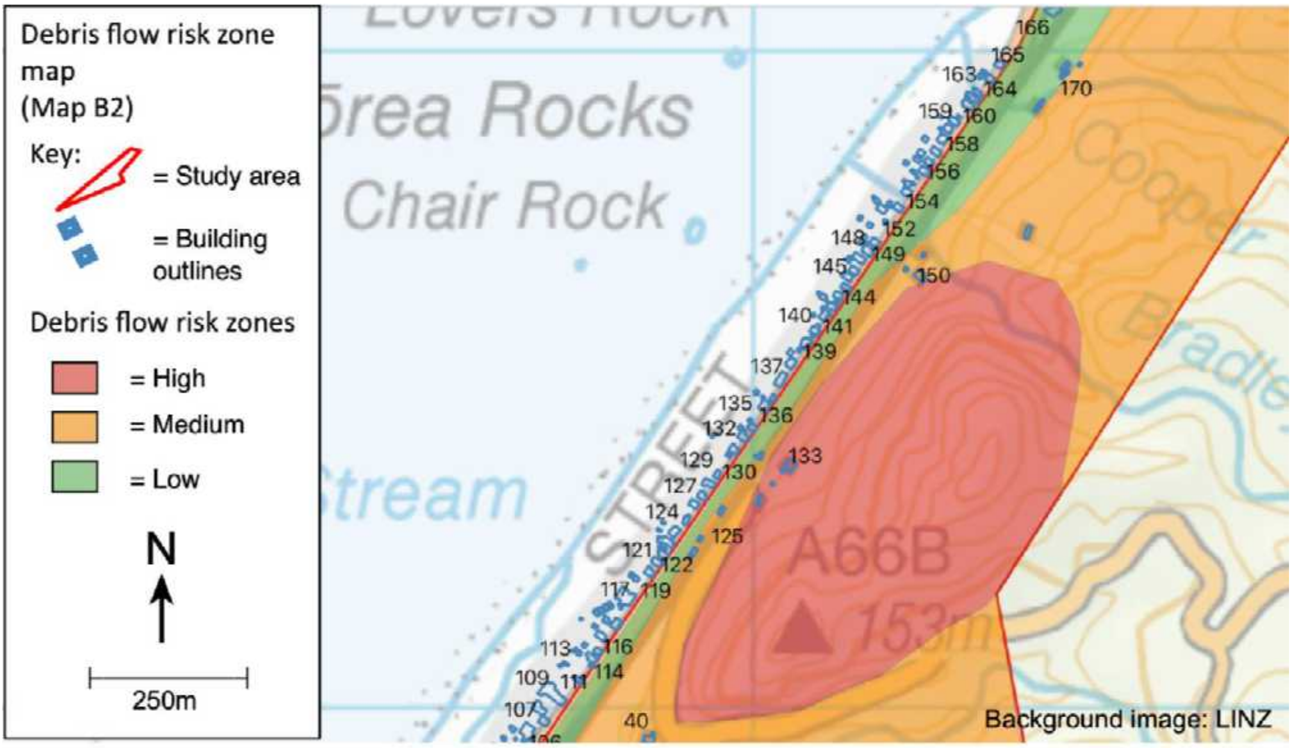
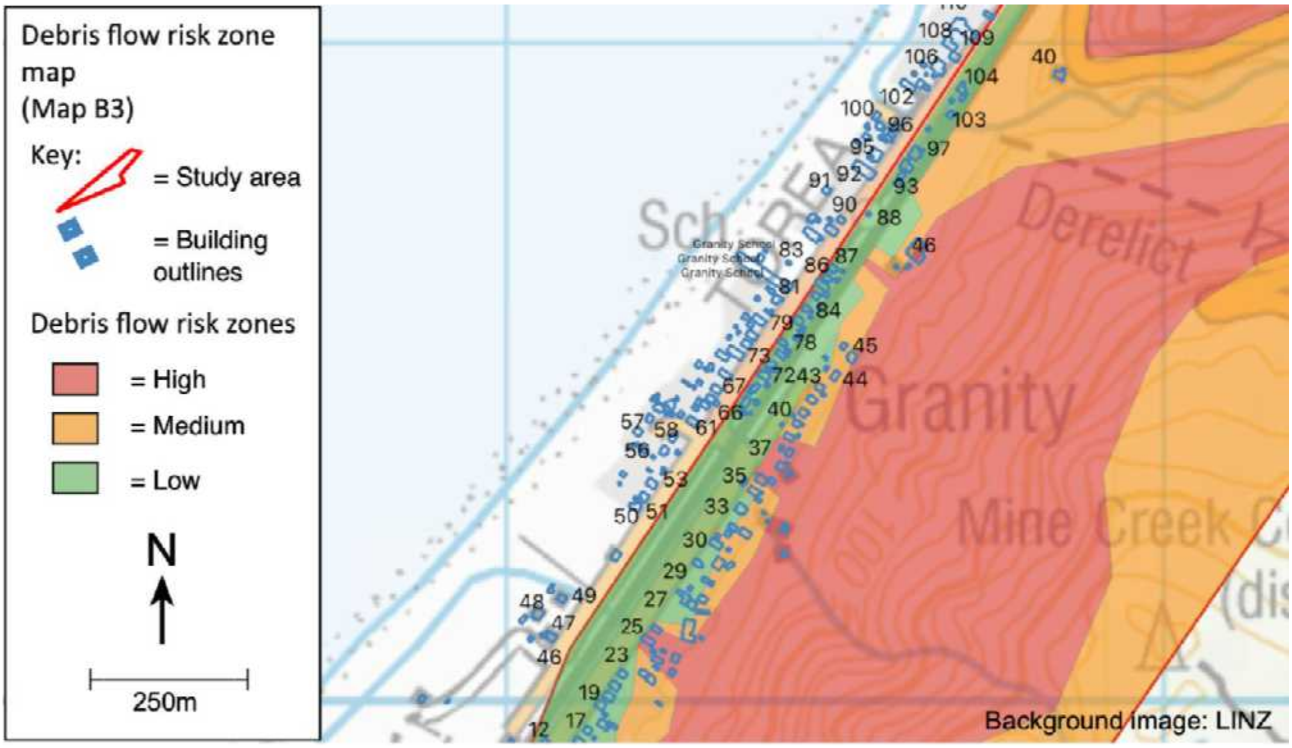
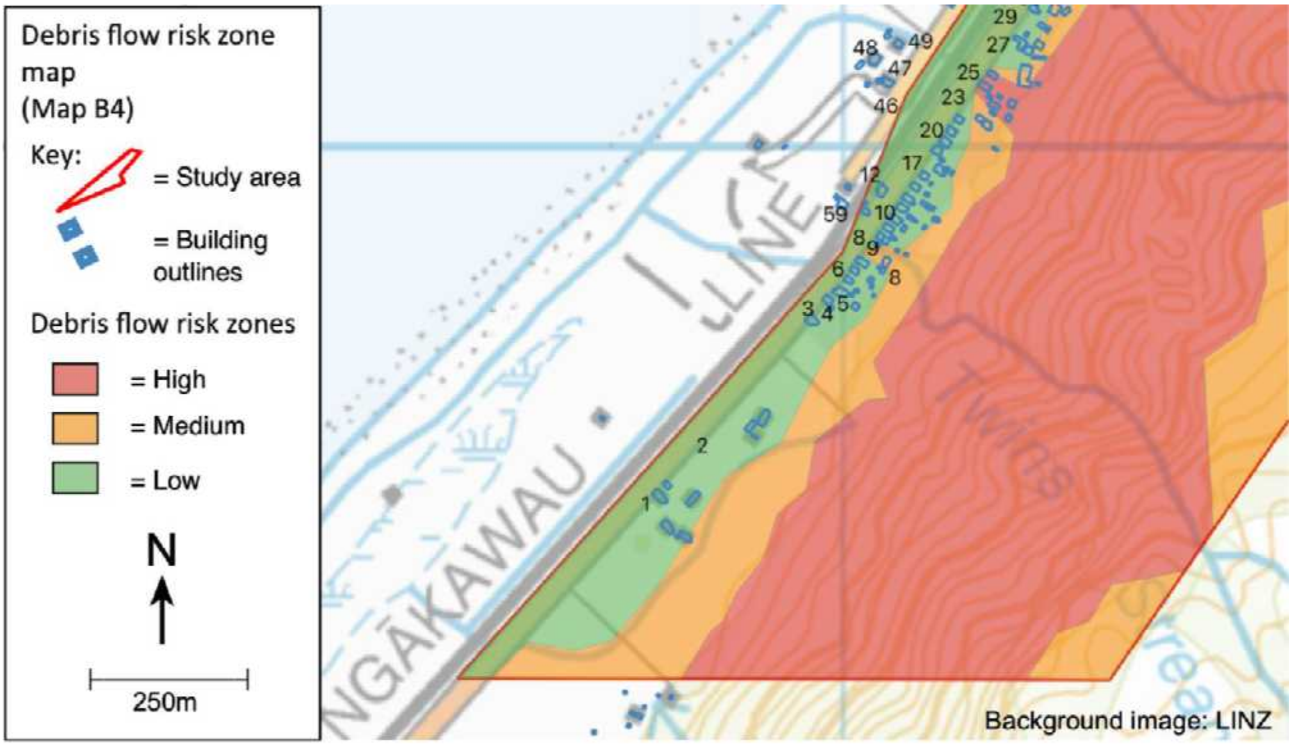
Appendix B

Small scale (approximate scale at A4 1:11,000) debris flow risk zone maps. Street address numbers are shown next to the building outlines.









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From:	Natasha Reid
To:	Jessie Williams
Cc:	Stephen Chiles; andrew.sowersby@wsp.com
Subject:	Costs as requested
Date:	Wednesday, 30 March 2022 4:16:06 pm
Attachments:	image001.png Section 32 Version 8 Oct 2021.pdf

Hi Jessie

Attached is our s32 analysis to support our noise contour modelling. On the final two pages are some costings that may be useful to the panel.

Ngā mihi

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WAKA KOTAHI NZ TRANSPORT AGENCY www.nzta.govt.nz

Assessment of Plan Provisions to Provide for Human Health and Amenity in accordance with section 32 of the Resource Management Act

October 2021

VERSION 8

Table of Contents

Executive Summary

Waka Kotahi seeks a gradual reduction in health and amenity effects implemented as new activities are established or existing activities are altered in close proximity to the operational state highway network. This outcome aligns with *Toitū Te Taiao – Our Sustainability Action Plan*[1] which in turn implements the Government Policy Statement on Land Transport 2018/2019-2027/2028[2] and the enduring Transport Outcomes: *A framework for shaping our transport system: Enabling New Zealanders to flourish Transport outcomes and mode neutrality, Ministry of Transport*, June 2018.

Achieving these outcomes this will assist regulatory authorities achieving Part 2 of the RMA by providing for the use of natural and physical resources in a way which enables people and communities to provide for their health and safety[3] and the maintenance and enhancement of amenity[4].

There are various regulatory methods (within and outside of the RMA) to achieve this outcome. A district plan based method has been assessed as the most implementable method in the current environment. This assessment considers a range of district plan methods as required under section 32 of the RMA.

The assessment concludes that an integrated suite of district plan provisions is the most effective and efficient method to provide reasonable levels of amenity and health protection for sensitive activities. The recommended provisions are based on a (modelled) noise contour line being established with activities 'inside' the contour being subject to specific requirements to provide improved health and amenity outcomes.

The recommended provisions relate to new or altered (increased) sensitive activities located within the modelled noise contour and the usual operation of the transport network, they do not:

a. apply retrospectively to existing buildings or sensitive activities;
b. require land owner to address effects resulting from transport network defects (eg potholes), which are the responsibility of the road controlling authority; or
c. manage amenity effects from transport noise from new or altered roads where these fall within the ambit of NZS 6806:2010 (Acoustics – Road traffic noise – New and altered roads).

[1] https://www.nzta.govt.nz/assets/About-us/docs/sustainability-action-plan-april-2020.pdf
[2] See paragraphs 123-124 and Table 1 Action 25 – Environment.
[3] Section 5(2), RMA.
[4] Section 7(c), RMA.

1. Introduction

The report has been prepared by Waka Kotahi NZ Transport Agency in accordance with Section 32 of the Resource Management Act 1991 (RMA) to assess the inclusion of human health and amenity provisions within District Plans.

Managing health effects from road noise is a shared responsibility between the road controlling authority and adjacent land users. Territorial authorities also have an important role to play in ensuring that planning instruments appropriately acknowledge and address the issue. Waka Kotahi invests significantly in design, construction and ongoing maintenance to minimise the effects of road noise. It is appropriate that those establishing or modifying land uses adjacent to existing State highways also share responsibility for protecting the health of occupants.

Retrospective management of transport noise effects is generally more difficult and expensive to achieve once activities have established adjacent to transport corridors. Management options are also more limited once activities are in place. For example, some design responses (eg. locating outdoor living areas away from noise sources) are not easily implemented or are precluded, retrospective building improvements can be challenging to implement, costly and disruptive, and property constraints may also limit response options (eg. no land available for acoustic barriers or bunding).

This report evaluates opportunities to provide plan provisions in accordance with section 32 of the RMA (s32). Under the RMA, a section 32 evaluation must:

a. Examine whether the proposed objectives are the most appropriate way to achieve the purpose of the RMA (s32(1)(a));

b. Examine whether the proposed provisions are the most appropriate way to achieve the objectives by identifying other reasonably practicable options, assessing their efficiency and effectiveness and summarising the reasons for deciding on provisions (s32(1)(b));

c. Relative to considering the efficiency and effectiveness of the provisions in achieving the objective, include an assessment of the benefits and costs of the effects anticipated from implementing the provisions (s32(2)); and

d. Contain a level of detail that corresponds to the scale and significance of the environmental, economic, social, and cultural effects that are anticipated from implementing the proposal (s32(1)(c)).

e. For plan changes, evaluate the proposal against both the objectives of the proposed plan change and the objectives of the existing plan (s32(3)).

Each of these matters is addressed by examining the key issues pertaining to the human health and amenity, and how a range of responses could operate in order to achieve the desired outcomes. This report is supplemented by an ‘issue identification’ statement (Section 2) which describes the human health effects at issue and assesses the cost of implementing mitigation.

In addition to RMA Part 2 outcomes (including of providing for communities health[5]), Waka Kotahi seeks a gradual reduction in exposure as existing activities are altered or relocated. This outcome aligns with *Toitū Te Taiao – Our Sustainability Action Plan*[6] which in turn implements the Government Policy Statement on Land Transport 2018/2019-2027/2028[7] and the enduring Transport Outcomes: *A framework for shaping our transport system: Enabling New Zealanders to flourish Transport outcomes and mode neutrality, Ministry of Transport*, June 2018.

[5] Resource Management Act, Part 2, Section 5(1).
[6] https://www.nzta.govt.nz/assets/About-us/docs/sustainability-action-plan-april-2020.pdf
[7] See paragraphs 123-124 and Table 1 Action 25 – Environment.

2. Issue identification

It is widely accepted nationally and internationally that noise from transport networks have the potential to cause adverse health and amenity effects on people living nearby. That potential has been documented by authoritative bodies such as the World Health Organisation (WHO)[8] including the publication *Environmental noise guidelines for the European region* in October 2018 (WHO Europe Guidelines).[9] The WHO Europe Guidelines are based on a critical review of academic literature and followed a rigorous protocol to assess the evidence of adverse effects.

With respect to sound from transport networks, the WHO Europe Guidelines note the potential for the following adverse effects:

i. sleep disturbance;
ii. high annoyance;
iii. hypertension; and
iv. ischaemic heart disease.

Based on the strength of the evidence of adverse effects, WHO recommends that policymakers reduce sound exposure from transport networks to below a range of guideline values.

State highways[10] pass through both urban and rural areas and most have sufficient traffic volumes to generate sound above WHO Europe Guideline levels, indicating there will be impacts on human health and amenity where noise-sensitive activities locate nearby.

In New Zealand, Quality Planning's *Managing Land Transport Noise Under the RMA* 2013 Guidance Note[11] recognises that transport noise has potential health effects and identifies district plan responses (eg. managing sensitive activity location, setbacks, zoning (and re-zoning), and structural restrictions). The Guidance Note provides:

> *One of the environmental results expected with the management of noise in plans should be the protection of people and communities from the impacts of land transport noise exposure[12].*

Within the Guidance Note, five alternative (non-RMA) responses[13] are identified (urban design strategy, bylaws, NZ Standards, Building Code and Waka Kotahi guidance). Two of these (the Building Code and Waka Kotahi guidance) are addressed in this assessment.

It is acknowledged that the notified [plan review/plan change] includes provisions which address amenity; however, for the reasons set out below, these are not considered to fully address [the issue].

[8] World Health Organisation, Guidelines for community noise, 1999; World Health Organisation, Night noise guidelines for Europe, 2009; World Health Organisation, Burden of disease from environmental noise, 2011
[9] World Health Organisation, Environmental noise guidelines for the European region, 2018.
[10] May also apply to high traffic volume roads managed by other Road Controlling Authorities.
[11] https://www.qualityplanning.org.nz/node/825
[12] https://www.qualityplanning.org.nz/node/825 *4. Environmental Effects Expected – Optional*, page 12.
[13] https://www.qualityplanning.org.nz/node/825 *Local Approaches – other mechanisms,* page 14.

3. Objectives Assessment

Section 32(1)(a) of the RMA requires an examination of whether a proposed objective is the most appropriate way to achieve the purpose of the RMA. The purpose of the RMA is set out in Part 2, Section 5 of the Act.

5 Purpose
(1) The purpose of this Act is to promote the sustainable management of natural and physical resources.
(2) In this Act, sustainable management means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well-being and for their health and safety while—
(a) sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and
(b) safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and
(c) avoiding, remedying, or mitigating any adverse effects of activities on the environment.

Waka Kotahi has formulated proposed objectives and policies for inclusion in district plans. An assessment of the proposed objective against RMA section 5 is set out in Table 1, below.

Table 1: Assessment of Objective under Section 5	
Proposed Provision	**Reason**
Objective 1 Protect sensitive activities from potential health and amenity effects that may arise from operational state highway noise. Policy 1 Locate and design new and altered buildings containing noise sensitive activities to minimise the potential for adverse effects from the designated state highway network. Policy 2 Manage subdivision which could contain noise sensitive activities through setbacks, physical barriers and design controls to ensure subsequent development can be located, designed and constructed to minimise exposure to noise.	Section 2 of this report describes likely adverse effects on sensitive activities where they are located in close proximity to the transport network. The objective (and supporting policies) will enable communities to provide for their social well-being and health by ensuring that noise sensitive activities located in close proximity to a state highway incorporate appropriate protection so as to ensure improved health outcomes and amenity levels.

The balance of Part 2 of the RMA provides the framework for the sustainable management of natural and physical resources. Section 6 lists matters of national importance that shall be recognised and provided for, section 7 lists other matters that all persons exercising functions and powers under the RMA shall have particular regard to and section 8 addresses matters relating to the principles of the Treaty of Waitangi. No relevant matters in sections 6 or 8 have been identified. The proposed objective has been assessed against the following provisions of section 7 in Table 2.

Table 2: Assessment of Objective under Part 2 Section 7	
RMA Provision	**Objective 1**
s7(b) (the efficient use and development of natural and physical resources)	Objective 1 will provide for the efficient use and development of physical resources (land and the State highway network) by enabling the proximity effects of land use and infrastructure to be managed appropriately.
s7(c) (maintain and enhance amenity values)	Objective 1 will give effect to s7(c) by enhancing amenity by reducing effects of noise on noise-sensitive activities.

It is considered that the proposed objective is consistent with Part 2, section 5 of the Act and will result in the sustainable management of natural and physical resources.

The notified [plan review/plan change] is considered to be a less appropriate or effective way to achieve the purpose of the RMA because …

4. Provisions Assessment

Sections 32(1)(b) and 32(2) require assessment of the proposed plan provisions to be undertaken. These are summarised as:

a. whether the proposed provisions are the most appropriate way to achieve the objectives by identifying other reasonably practicable options, assessing their *efficiency and effectiveness* and summarising the reasons for deciding on provisions; and
b. relative to considering the **efficiency and effectiveness** of the provisions in achieving the objective, include an assessment of the benefits and costs of the effects anticipated from implementing the provisions.

The cost and benefit assessment must identify and assess the costs and benefits associated with environmental, economic, social, and cultural effects including economic growth and employment that are anticipated to be provided or reduced. If practicable, these are to be quantified.

The notified [plan review/plan change] have been included in this assessment.

Section 32(2)(b) also requires an assessment of the risk of acting or not acting if there is uncertain or insufficient information. In this case, there is considered to be sufficient information about the subject to determine the range and nature of effects of the options set out, and so that assessment has not been undertaken.

4.1 Noise

4.1.1 Identifying options

Where the reasonably practical alternative options (assessed in Table 3) include plan provisions, they are framed in the following context:

a. The provisions apply to all new and altered (by increase in floor area) *Noise Sensitive Activities* (defined in **Attachment 1**) which, in addition to residential activities, includes activities such as student or retirement accommodation, educational activity (including in any child care facility), healthcare activity and any congregations within places of worship/marae.

b. Internal noise criteria of between 35 dB $L_{Aeq(24h/1h)}$ and 45 dB $L_{Aeq(24h/1h)}$ have been allocated to the *Noise Sensitive Activities* for the reasons described in **Attachment 2**. Specifications detailing how to achieve internal noise space can be either specified as a *Construction Schedule* included as part of **Attachment 1** or by a design certified by an acoustic consultant.

c. Provisions include ventilation requirements where internal noise criteria are to be met; without ventilation the effectiveness of built acoustic treatment is compromised (ie. windows open for ventilation compromise the performance of building envelope noise mitigation measures). Ventilation requirements are specified in **Attachment 1**.

d. Outdoor living space provisions apply only to areas specifically identified by the district plan as required outdoor living areas.

e. Provisions include a mapped extent to which the provision would apply. This is described as Noise Control Boundary Overlay (NCBO) in accordance with the National Planning Standards Mapping Standard or identified as a ‘yard’.

f. The provisions:
   (i) do not apply retrospectively to existing sensitive activities;
   (ii) are not proposed to require a land owner to address effects resulting from transport network defects (eg potholes), which are the responsibility of the road controlling authority; and
   (iii) do not manage amenity effects from transport noise from a new or altered road; these generally fall within the ambit of NZS 6806:2010 (Acoustics – Road traffic noise – New and altered roads).

The reasonably practical alternative options identified include (a) to (d) above and are identified as:

a. **Do nothing:** No plan provisions to protect sensitive activities from potential health and amenity effects.

b. **Modelled setback:** Require specific response to manage noise based on a (modelled) noise contour line (NCBO) being established. Activities 'inside' the NCBO are a permitted activity (for the purposes of noise) if specific requirements are met. For the reasons set out in **Attachment 2**, the recommended extent of the NCBO is set at 57 dB $L_{Aeq(24h)}$. **Attachment 4** explains the basis of the acoustic model which takes into account environmental factors such as traffic volume, road surface, topography and buildings.

c. **Metric setback:** Require specific response to manage noise where a sensitive activity is located within a specific NCBO based on distance (eg 40m, 80m or 100m) from a state highway. The specific setback distance may be based on speed limit (eg 40m for <70k/hr or 80m or 100m >70k/hr). Activities 'inside' the NCBO are a permitted activity if specific requirements are met.

d. **Yard:** A 'no build' setback from state highways. All noise sensitive activities in the yard area are listed non-complying activities. Yard setback could be set based on road speed limit (eg 40m for <70k/hr or 80m or 100m >70k/hr).

e. **Notified Plan Provisions:** summarise these.

An assessment of the *efficiency and effectiveness* of the options assessed in terms of Sections 32(1)(b) and 32(2) is included in Table 3.

Table 3: Alternative Option Assessment			
Option	Effectiveness and Efficiency	Costs	Benefits
Option A: Do Nothing	Highly efficient but not effective. This option requires no action from the regulatory authority or applicants so is efficient.	An increase in adverse health and amenity impacts (including costs). Poorer health and amenity outcomes fall on wider community and can be difficult to identify or	No additional regulatory cost or costs to land owners in terms of compliance or building cost increases.

Table 3: Alternative Option Assessment			
Option	Effectiveness and Efficiency	Costs	Benefits
	It is considered to be the least effective as it will allow an increase in adverse human health and amenity effects over time.	resolve at an individual level.	
Option B: Modelled Setback	Highly efficient and effective. Utilising a model based on existing environmental conditions to calculate expected noise levels provides a more effective and efficient approach to setting the extent that a noise control should apply compared with Options C and D (both of which are 'standard width' controls regardless of local conditions).	A range of compliance and construction costs will apply when compared with Option A. These range from building and compliance design costs to meet permitted activity standards through to resource consent costs should standards not be complied with. The costs will fall on applicants and compliance confirmation costs will be borne by the regulatory authority and/or the applicant. Costs of mitigation have been independently assessed by Acoustic Engineering Services Limited[14] and indicate typically a 0% to 2% increase in construction cost for new dwellings and additions[15] in new materials. Waka Kotahi will also bear the cost of maintaining up to date modelling data to	Better human health outcomes as there will be less exposure to the causes of negative health and amenity outcomes when compared with Option A. Option B provides a comprehensive regulatory approach which recognises the spatial extent of road traffic noise based on environmental factors (eg traffic volume, topography, road surface, existing building locations). This will result in a more accurate reflection of the extent of likely effects than Options C or D. The provisions do not aim to achieve 'zero' health effects (which is the outcome sought by the WHO Guidelines). Rather, the Modelled Setback/Option B provisions provide for a balance between health and amenity protection, cost and regulatory administration.

[14] **Attachment 3**: Acoustic Engineering Services Limited, Report Reference AC20063 – 01 – R2: Cost of traffic noise mitigation measures, 12 June 2020.

[15] **Attachment 3:** Acoustic Engineering Services Limited, Report Reference AC20063 – 01 – R2: Cost of traffic noise mitigation measures, 12 June 2020.

Table 3: Alternative Option Assessment			
Option	Effectiveness and Efficiency	Costs	Benefits
		support noise contour line establishment.	
Option C: Metric Setback	Moderately efficient and effective. Option provides a reasonable outcome but will 'capture' more sites than is necessary to be highly efficient.	Option C (especially where applied at 80m to 100m) is likely to affect a greater number of sites than Option B. It is a 'blanket' approach which does not reflect individual area conditions. Other costs are the same as for Option B.	Better human health outcomes as there will be reduced exposure to the causes of negative health and amenity outcomes when compared with Option A. Less costly to prepare (set distance rather than modelled) when compared with Option B.
Option D: Yard provision	Highly effective but not efficient. The 'no build' yard will provide a high level of health and amenity protection but does not result in an efficient use of land.	Limits construction on particular areas of a site; high cost borne by land owners as sensitive activity development is limited in these areas.	Good human health outcomes as there will be a reduced number of sensitive activities exposed to the causes of negative health and amenity outcomes.
Option E: Notified Plan Provisions	**This option [is / is not] effective and efficient, because […]**	**[complete assessment if plan includes amenity provisions]**	**[complete assessment if plan includes amenity provisions]**

4.1.2 Assessing reasonably practicable options

Based on the cost benefit analysis presented in Table 3, Table 4 summarises reasonably practicable options.

Table 4: Identifying Reasonably Practicable Options	
Option	Is it reasonably practicable?
Option A: Do nothing This option is currently applied in some District Plans.	✓
Option B: Modelled Setback Options similar to this are currently applied in some District Plans.	✓
Option C: Metric Setback Options similar to this are currently applied in some District Plans.	✓
Option D: Yard requirement Options similar to this are currently applied in some District Plans.	✓

Option E: Notified Plan Provisions Describe if provisions are considered to be a reasonably practicable alternative. Check the Council's s32 report for reasons and address whether you agree or not	**[✗ or ✓]**

4.1.3 Preferred option

Based on the analysis in Table 3 and the reasonably practicable options identified in Table 4, Table 5 rates each of the reasonably practicable options.

Table 5: Preferred Option				
Least Preferred				Most Preferred
Option A: Do Nothing.	Option E: Include notified provisions if applicable.	**Option D:** Yard setback	**Option C:**. Metric Setback	**Option B:** Modelled Setback

For the reasons set out in Tables 3 and 4, the Modelled Setback/Option B is considered to be the most efficient and effective method for addressing the health and amenity effects of transport noise. In accordance with National Planning Standards[16], should they be adopted, the provisions must be located in the district or city wide Noise chapter of the district / unitary plan.

Where there are Council proposed provisions and this is not the conclusion resulting from analysis, consider not utilising the s32 but instead making a submission to change Councils provisions.

5. Conclusion

The Modelled Setback/Option B is identified as the preferred approach to manage the potential health and amenity effects of transport network operations, and to and provide a reasonable and appropriate balance between cost and benefit. The provisions apply only where an existing noise-sensitive activity is extended or a new noise-sensitive activity is proposed adjacent to a designated transport corridor.

The Modelled Setback/Option B have been detailed and compared against a number of alternatives in terms of their costs, benefits, and efficiency and effectiveness in accordance with the relevant clauses of section 32 of the RMA.

The Modelled Setback/Option B are considered to represent the most appropriate means of achieving the proposed objective and of addressing the underlying resource management issues relating to the transport environment, human health and amenity.

[16] The District-wide Matters National Planning Standard requires at 33 that: *If provisions for managing noise are addressed, they must be located in the Noise chapter. These provisions may include: … c.sound insulation requirements for sensitive activities and limits to the location of those activities relative to noise generating activities.*

New or altered State highway transport projects will continue to be assessed under NZS 6806:2010 (Acoustics – Road traffic noise – New and altered roads).

Attachment 1: Provisions (Option B)

Objective 1

Protect sensitive activities from potential adverse health and amenity effects that may arise from designated state highway noise.

Policy 1

Locate and design new and altered buildings containing noise sensitive activities to minimise the potential for adverse effects from the designated state highway network.

Policy 2

Manage subdivision which could contain noise sensitive activities through setbacks, physical barriers and design controls to ensure subsequent development can be located, designed and constructed to minimise exposure to noise.

New Definition

Noise Sensitive Activity(s): Means any residential activity including visitor, student or retirement accommodation, educational activity including in any child care facility, healthcare activity and any congregations within places of worship/marae. Excludes those rooms used solely for the purposes of an entrance, passageway, toilet, bathroom, laundry, garage or storeroom.

1. Permitted Activity Rule Indoor Noise

a. Within the Noise Corridor Boundary Overlay, where:
   (i) a new building that contains a noise sensitive activity; or
   (ii) an alteration to an existing building resulting in an increase in floor area of a noise sensitive activity; or
   (iii) a new noise sensitive activity is located in an existing building;

   is proposed, it is to be:

   (iv) Designed, constructed and maintained to achieve indoor design noise levels not exceeding the maximum values in Table 1; and
   (v) If windows must be closed to achieve the design noise levels in (1)(a)(i), the building is designed, constructed and maintained with a mechanical ventilation system that:
      a. For habitable rooms for a residential activity, achieves the following requirements:
         i. Provides mechanical ventilation to satisfy clause G4 of the New Zealand Building Code; and
         ii. is adjustable by the occupant to control the ventilation rate in increments up to a high air flow setting that provides at least 6 air changes per hour; and
         iii. provides relief for equivalent volumes of spill air; and
         iv. provides cooling and heating that is controllable by the occupant and can maintain the inside temperature between 18^{0}C and 25^{0}C; and
         v. does not generate more than 35 dB $L_{Aeq(30s)}$ when measured 1 metre away from any grille or diffuser.

b. For other spaces, is as determined by a suitably qualified and experienced person.

c. A report is submitted by a suitably qualified and experienced person to the council demonstrating compliance with clauses (1)(a)(i) and (ii) above (as relevant) prior to the construction or alteration of any building containing an activity sensitive to noise.

Table 1

Occupancy/activity	**Maximum road noise level** [Note 1] $L_{Aeq(24h)}$
Building type: Residential	
Sleeping spaces	40 dB
All other habitable rooms	40 dB
Building type: Education	
Lecture rooms/theatres, music studios, assembly halls	35 dB
Teaching areas, conference rooms, drama studios, sleeping areas	40 dB
Libraries	45 dB
Building type: Health	
Overnight medical care, wards	40 dB
Clinics, consulting rooms, theatres, nurses' stations	45 dB
Building type: Cultural	
Places of worship, marae	35 B

Note 1: The design road noise is to be based on measured or predicted external noise levels plus 3 dB.

2. Permitted Activity Rule Outdoor Living Area

a. Where an outdoor living or outdoor activity space required by another rule in the Plan is within the Noise Corridor Boundary Overlay and the outdoor space is required for a noise sensitive activity, the required outdoor living space is to be designed and maintained to achieve noise levels not exceeding the maximum values in Table 2; and

b. A report is submitted by a suitably qualified and experienced person to the council demonstrating compliance with clauses (2)(a) above prior to the construction or alteration of the any building to which the outdoor living space relates.

Table 2

Activity	**Maximum road noise level** Note 1 $L_{Aeq(24h)}$
Required Outdoor Living Space	57 dB

Note 1: The design road noise is to be based on measured or predicted external noise levels plus 3 dB.

3. Restricted Discretionary Activity Rule

Any new or altered noise sensitive activity which does not comply with Permitted Activity (1) or (2).

Restricted Discretionary Activity – Matters of Discretion

Discretion is restricted to:
(a) Location of the building and outdoor living space;
(b) The effects of the non-compliance on the health and amenity of occupants; and
(c) The outcome of any consultation with Waka Kotahi NZ Transport Agency.

Restricted Discretionary Activity – Assessment Criteria

Discretion is restricted to:
(a) Whether the location of the building minimises effects;
(b) Alternative mitigation which manages the effects of the non-compliance on the health and amenity of occupants; and
(c) The outcome of any consultation with Waka Kotahi NZ Transport Agency.

Attachment 2: Technical Basis of Noise Criterion

In preparing the Modelled Setback/Option B, Waka Kotahi has assessed existing research, standards and guidelines to guide selection of appropriate noise criteria.

Two documents are identified as providing national and international guidance and directives for transport noise: the WHO Europe Guidelines and NZS 6806:2010 *Acoustics – Road-traffic noise – New and altered roads* (NZS 6806).

In addition, AS/NZS 2107:2016 *Acoustics – Recommended design sound levels and reverberation times for building interiors* (AS/NZS 2107) is a joint Australia and New Zealand standard which provides compliance measurement methods for background noise and recommends design criteria for occupied spaces.

WHO Europe Guideline

The WHO Europe Guidelines (the Guideline) contains key recommendations in regards to transport noise including:

Road[17]:

- For average noise exposure: recommends reducing noise levels produced by road traffic below 53 dB L_{den}; and
- For night time exposure: recommends reducing noise levels produced by road traffic during night time below 45 dB L_{night}.

The WHO Europe document contains guidelines; it does not set a fixed standard. The Guideline has been prepared as an international research document and its outcomes need to be considered within the New Zealand statutory context before reference or inclusion in planning or policy documents. WHO guidance regarding effects of noise on health (more generally) are reflected in NZS 6806[18].

NZS 6806:2010 Acoustics – Road-traffic noise – New and altered roads

NZS 6806 is the principal national document for management of noise in relation to new and altered roads. The purpose of NZS 6806 is to ensure noise effects on existing sensitive activities (described as Protected Premises and Facilities / PPFs) from new or altered roads are managed. It has been developed with the intention of being suitable to support RMA processes and to set *reasonable noise criteria* for road traffic noise (from new or altered roads) taking into account, among other things, health effects[19].

NZS 6806 is a national standard, has been specifically developed for inclusion within an RMA framework, has been adopted into district plans and utilised in designations for the specific purpose of transport noise management. It is accepted as current good practice in regards to setting requirements which result in *reasonabl*e noise outcomes.

[17] World Health Organisation, Environmental noise guidelines for the European region, 2018. Section 3.1.
[18] NZS 6806 :2010 Section 4.7.1.
[19] NZS 6806:2010 Acoustics – Road-traffic noise – New and altered roads, section 1.1.4.

NZS 6806 includes an external ("Category A") noise criterion[20] for altered roads (64 dB $L_{Aeq\ (24h)}$), and two criteria for new roads depending on design year traffic volumes (64 dB $L_{Aeq\ (24h)}$ for higher volume roads and 57 dB $L_{Aeq\ (24h)}$ for lower volume roads).

Higher volume roads are those which, at design year, are predicted to carry greater than 75,000 AADT (Average Annual Daily Traffic). Lower volume roads are those which, at design year, are predicted to carry between 2,000 and 75,000 AADT.

Internal noise criterion[21] for habitable spaces are set at 40 dB $L_{Aeq\ (24h)}$ for altered and new roads (regardless of AADT).

Analysis of 2018 AADT data[22] shows the majority of existing state highways carry less than 75,000 AADT. It also indicates that only central parts of the Auckland motorway network currently have an AADT greater than 75,000.

While NZS 6806 applies to new and altered roads (ie. the onus is on the road controlling authority to manage effects), it provides strong guidance as to *reasonable* levels and expectations of noise levels in these environs. If these (<75,000 AADT) state highways were constructed (new) or altered in the current statutory environment, the lower level (57 dB $L_{Aeq(24h)}$) of the NZS 6806 external noise limits would be applied.

For road-traffic noise averaged over 24 hours, the internal 40 dB $L_{Aeq(24h)}$ criterion in residential habitable spaces from NZS 6806 represents a reasonable level as at night the level should reduce (as traffic volumes reduce) so as to avoid undue sleep disturbance.

AS/NZS 2107 Acoustics – Recommended design sound levels and reverberation times for building interiors

The scope of AS/NZS 2107 is to recommend criteria for healthy, comfortable and productive environments and it applies to steady-state or quasi-steady-state sounds. The Standard is ambiguous whether it should apply to transportation noise; regardless it provides an indication of reasonable internal levels for different types of sensitive activities. The criteria adopted in the Modelled Setback/Option B are generally consistent with AS/NZS 2107.

Conclusion

For the Modelled Setback/Option B, Waka Kotahi selected the NZS 6806 external level of 57 dB $L_{Aeq(24h)}$ and internal levels of between 35 dB $L_{Aeq(24h/1h)}$ and 45 dB $L_{Aeq(24h/1h)}$. This is because:

a. the majority of state highway AADT fall within the lower AADT band for external noise within NZS 6806 (which requires external noise levels of 57 dB $L_{Aeq(24h)}$ for a new or altered road); and

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[20] NZS 6806:2010 Acoustics – Road-traffic noise – New and altered roads, Table 2 – Noise Criteria, A (primary free-field external noise criterion).

[21] NZS 6806:2010 Acoustics – Road-traffic noise – New and altered roads, Table 2 – Noise Criteria, C (internal noise criterion).

[22] https://www.nzta.govt.nz/resources/state-highway-traffic-volumes/ 2018 data - *State highway volumes by region (in Excel format)*

b. the outdoor noise exposure level of 57 dB and an indoor noise threshold near the top of the design range[23] in AS/NZS 2107:2016 (40 dB) have been selected as these levels are considered to provide a reasonable level of health and amenity protection but are not the most stringent.

[23] *top of the design range* means that the noise limit is at the upper level of range - ie. allows more noise rather than less.

Attachment 3: Building Cost Assessment

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Memorandum

To:	Greg Haldane, Waka Kotahi
From:	Clare Dykes, Acoustic Engineering Services
File Reference:	AC20063 - 01 - R2
Date:	Friday, 12 June 2020
Project:	Cost of traffic noise mitigation measures
Pages:	6

Meeting ☐ Telephone ☐ Memorandum ☑ File Note ☐

Dear Greg,

In March 2020, Waka Kotahi NZ Transport Agency engaged Acoustic Engineering Services (AES) and O'Brien Quantity Surveying to undertake a study relating to the cost of traffic noise insulation measures. The project involved a review of a number of situations where traffic noise mitigation had been installed, including:

- Buildings which required upgrades to reduce traffic noise break-in as a result of their location in proximity to major roads, and;
- New residential neighbourhoods which were constructed near to major roads, where traffic noise barriers were integrated into the overall scheme design so that the upgrading of dwellings was no longer required (or was reduced) and noise in outdoor living areas was reduced.

This memorandum summarises the study, and the general trends visible in the results.

1.0 BUILDING UPGRADES

A common method of ensuring that noise from roads is not intrusive within buildings is to design the building envelope to provide a high level of sound insulation, and to provide a mechanical ventilation system so occupants do not need to open windows for cooling and fresh air.

The Christchurch District Plan contains a rule requiring the design of new noise sensitive buildings to be constructed in higher noise locations to include these sound insulation features. AES have previously completed a study related to the Christchurch District Plan sound insulation rule, which involved a review of the specific circumstances relating to a sample of building projects. The work described in this memo built on aspects of that previous study, and looked to quantify the cost of those building upgrades, to assist Waka Kotahi in understanding the potential financial implications of mandatory traffic noise insulation rules. A number of additional examples from various sources were added to the original sample, to increase the sample size and diversity.

We have also completed a review of the Proposed and Operative District Plans for the 67 New Zealand Districts. Two thirds of the District Plans throughout the country include requirements for sound insulation when dwellings are located in proximity to major roads. Of these, 10 % include a requirement which is very similar to the Waka Kotahi Guidelines[1] centred around an internal noise level requirement of 40 dB $L_{Aeq\ (24\ hour)}$ in bedrooms and other habitable spaces, and the provision of mechanical ventilation. The remaining rules vary, with common variations including requiring different internal noise levels to be met, omitting any mechanical ventilation requirement (or a reduced mechanical ventilation requirement), and specifying a fixed level of sound insulation performance to be achieved by the building façade. As discussed below, all of these rule variations have a different cost impact.

1.1 The sample

A total of 58 buildings were considered for inclusion in the analysis. However, detailed costings were only completed on 23 of these, primarily because:

- A number of the building projects successfully obtained a Resource Consent to legitimise a partial or complete non-compliance with the relevant sound insulation rule, and so these results would not have assisted with understanding the cost of compliance.
- For a number of the building projects there was not sufficient publicly available information to complete an accurate costing.

The final 23 building projects included 11 detached residential dwellings, seven multi-residential units (such as terraced houses and duplexes), and five apartment buildings. These buildings were expected to experience worst-case traffic noise levels ranging from 55 dB $L_{Aeq\ (24\ hours)}$ to 71 dB $L_{Aeq\ (24\ hours)}$.

As discussed above, a variety of sound insulation rules are encountered throughout the country. The building projects in the sample had been assessed against the following rules:

- 12 of the sample has been assessed against a requirement which is similar to that described in the Waka Kotahi Guidelines, including an internal noise level requirement of 40 dB $L_{Aeq\ (24\ hour)}$ in bedrooms and other habitable spaces, and the provision of mechanical ventilation.
- Two of the sample were assessed using a rule which has a different internal noise level requirement with no mechanical ventilation required.
- Eight of the sample were assessed against rule with a façade reduction requirement or a provided set of constructions intended to provide a fixed façade reduction, and no mechanical ventilation required.
- One involved review against an internal noise level requirement of 40 dB $L_{Aeq\ (24\ hours)}$ for some spaces, and a façade reduction requirement for others.

Overall, the sample was relatively small – however a moderate number of examples could be assessed against a rule similar to that preferred by Waka Kotahi. Otherwise the variety within the sample is typical of the variety in sound insulation rules encountered in New Zealand.

Challenges of extending the sample included the lack of a centralised database to use for establishing a list of building projects of potential interest, and then the lack of availability of publicly available information for projects which provides sufficient detail for accurate costings.

1.2 Assumptions

Key assumptions embodied in this part of the study are as follows:

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[1] Waka Kotahi NZ Transport Agency, *Guide to the management of effects on noise sensitive land use near to the state highway network*, Version 1.0, September 2015

- The reported external noise levels are based on the available traffic numbers, road surface, and speed information for the road adjacent to the building project site at the time, and are for the most exposed building façade.
- The upgrades that were recommended by the acoustic engineers involved in each case were installed and alternative systems were not used.
- The systems where not specified were originally 10 mm Standard Gib plasterboard internal linings for walls, and 13 mm Standard Gib plasterboard linings for ceilings, and 4 mm float glass / 12 mm air space / 4 mm float glass for glazing.
- Where 7 mm Ecoply RAB board was specified for external walls it was assumed that this would have been included regardless of the acoustic upgrades, and so was not included in the upgrade costing.
- Where not specified, the mechanical ventilation system was assumed to be of similar or equal design and performance to those projects where this detail was provided.

1.3 Findings

We have summarised a number of key observations from the analysis below.

Table 1.1 outlines the increase in overall building cost associated with any upgrades to the building façade and/or the installation of mechanical ventilation system, to ensure compliance with the various sound insultation rules.

Table 1.1 – Summary of cost of traffic noise mitigation by building type

Building Type	Range of external noise levels (dB $L_{Aeq\,(24\,hours)}$)	Increase in overall cost of building (per residential unit)	Percentage increase in overall cost of building
Detached residential	55 – 68	\$0 – \$16,000	0 – 2 %
Residential units	58 – 69	\$500 – \$15,000	0 – 2 %
Apartment buildings	60 – 71	\$500 – \$16,000	0 – 1 %

These results illustrate that the overall percentage increase in building cost due to compliance with a sound insulation rule was 2 % or less (noting that none of the buildings in the sample were exposed to external traffic noise levels exceeding 71 dB $L_{Aeq(24\,hour)}$).

For the residential units and apartment buildings, the figures in table 1.1 are based on the total cost of upgrades, divided by the total number of residential units in the development. However, some units did not require any upgrades, as they experience lower external noise levels. If the total cost of upgrades is only divided by the number of units in the development which required upgrading, the percentage increase changes to 1 – 4 %.

In table 1.2 the results are presented based on the type of sound insulation rule that the assessment was undertaken against.

Table 1.2 – Summary of cost of traffic noise mitigation by rule type

Rule	Range of external noise levels (dB $L_{Aeq\ (24\ hours)}$)	Increase in overall cost of building per residential unit	Percentage increase in overall cost of building
Internal noise level of 40 dB $L_{Aeq\ (24\ hours)}$ and mechanical ventilation	55 – 71	$0 – $16,000	0 – 2 %
Alternative internal noise level requirement, no mechanical ventilation	64 – 65	$500 – $1,500	0 – 1 %
Façade reduction requirement or defined constructions, and no mechanical ventilation	55 – 69	$0 - $16,000	0 – 2 %

This summary appears to indicate that the costs associated with both the internal noise level and façade reduction rules are similar (noting that the sample size for the 'alternative internal noise level requirement, no mechanical ventilation' rule was very small, and the external levels were moderate). However, we note the following:

- For the methods which used internal noise levels, the increase in costs is very dependent on the external noise level. The developments which resulted in upgrade costs of less than 1 % typically experienced external noise levels below 65 dB $L_{Aeq\ (24\ hours)}$. There are exceptions to this depending on the layout of the units.

- While the 'façade reduction requirement or defined constructions' rules appear to attract a similar cost to the 'internal noise level' rules, those particular rules did not require mechanical ventilation to be installed. Occupants in some situations would therefore have still had to choose between thermal comfort, and noise. Additional cost should have been involved with installing mechanical ventilation in those situations, as was the case for the 'internal noise level of 40 dB $L_{Aeq\ (24\ hours)}$ and mechanical ventilation' examples. To put it another way, the cost may be been similar, but the benefit is likely to have been less in many cases.

- The required construction upgrades (and therefore the costs) of the 'façade reduction requirement or a defined set constructions' rules are not dependent on external noise levels. This means that while the range of cost increases is similar, in some situations the high costs lead to no benefit, as the external noise levels were low. For the 'internal noise level of 40 dB $L_{Aeq\ (24\ hours)}$ and mechanical ventilation' examples where the costs were high, that was at least in response to high external noise levels and so was justified.

For a small number of developments, no upgrades were required as either external traffic noise levels were very low, or the original design included high mass cladding with small window areas on key facades.

2.0 BARRIERS

An alternative method for reducing the levels of road traffic noise experienced by the occupants of new dwellings is for a barrier to be installed to screen a new residential neighbourhood from the road. This means that individual dwellings are less likely to need to be upgraded, and noise levels in outdoor living areas are also reduced. However, the developer of the new neighbourhood is likely to primarily bear the cost of the barrier, compared to the building upgrades discussed in section 1.0 above, which are paid for by the individual building owners.

2.1 The sample

10 new residential neighbourhoods were included in the analysis. All of these adjoined State Highways and were likely to have been designed with some regard to the Waka Kotahi Guidelines. Each of the neighbourhoods had been screened from the State Highway with a traffic noise barrier, including:

- Seven examples with 'acoustic' fences ranging in height from 2 – 3 metres
- Two examples where earth bunds had been constructed – these were 2 – 3 metres in height, and 8 – 9 metres wide
- One example with a combination of acoustic fencing and earth bund

For each example, we determined the number of dwellings which would have experienced traffic noise levels of greater than 57 dB $L_{Aeq\,(24\,hours)}$ without a barrier. These dwellings would have been the most likely to have required upgrading had the barrier not been constructed, in order to satisfy a traffic noise insulation rule of the type discussed in section 1.0 above. We note that it is possible that some dwellings still required upgrading even with the barrier – for example the upper level of two-storey houses. As above, the barrier also reduces the noise levels in outdoor living areas associated with dwellings – which is a benefit compared to the sound insulation rules discussed in section 1.0, which only modifies the environment within a dwelling.

The number of dwellings which would have experienced traffic noise levels of greater than 57 dB $L_{Aeq\,(24\,hours)}$ without a barrier ranged from 1 through to 120. The number of affected lots was dependent on the overall layout of the subdivision relative to the road, as well as the traffic numbers, road surface, and speed.

2.2 Assumptions

Key assumptions were as follows:

- The acoustic fences were constructed of 125 x 75 mm H4 posts, 75 x 50 mm H3 railings, 150 x 25 mm H3 palings with 50 x 25 mm H3 battens over joins and 150 x 50 mm H3 capping.
- In some cases, the effective height of fences was increased, because they were constructed on top of a retaining wall. It was assumed that the retaining walls would have been required for general site levelling and not specifically to enhance the acoustic effectiveness of the barrier. This was therefore not included within the upgrade cost.
- It was assumed that the subdivision layout without the barrier would have been exactly the same. In reality larger setback distances or other rearrangement of the layout may have been included if the traffic noise had not been largely mitigated by the barrier.
- The earth bund was assumed to be constructed with surplus excavated soil from the site, with a layer of imported topsoil 150 mm thick spread on top for grass.

2.3 Findings

We have summarised a number of key observations from the analysis below.

Table 2.1 shows the cost of each barrier, divided by the number of dwellings which would have experienced a noise level of greater than 57 dB $L_{Aeq\,(24\,hours)}$ without a barrier. We have grouped the results together for different barrier types, and have also shown the situations where are large and small number of dwellings benefited from the barrier separately.

Table 2.1 – Summary of cost of traffic noise mitigation by barrier type

Barrier Type	Approximate number of dwellings which benefited from barrier	Cost of barrier per dwelling
Acoustic fence	1 – 10	$15,000 – $30,000
	30	$10,000
	80 – 110	$3,000 - $5,000
Earth bund	10	$60,000
	50	$6,000
Combination	120	$4,000

Overall, this analysis shows that when the number of affected dwellings is low (i.e. the layout results in few lots near the road, or the volume of traffic is low etc.) the overall cost per dwelling is high. When these absolute costs are viewed as a percentage of the likely final value of each of the affected sections, the range is from 2 % (acoustic fence, benefiting a large number of sections) to 30 % (earth bund, benefiting a few sections). As above, in all of these examples for dwellings constructed on these sections, additional costs in the order of those presented in tables 1.1 and 1.2 above would be largely avoided, and traffic noise levels in outdoor living areas would also be reduced.

We note that a key decision in the above analysis is whether the loss of the land under the footprint of any earth bund is included as a 'cost'. In all of the examples the bund fell within an area which was ultimately sold to a homeowner as part of a site, or was within an area close to the State Highway which was unlikely to have been developed for residential use regardless – so the loss of the land under the bund has not been included as a cost. As an example, for the development with approximately 50 affected dwellings, if the cost of the land under the bund was included in the analysis, the total cost as a percentage of the likely final value of each of the affected sections would increase from 3 % to 16 %.

We trust this is of assistance. If you have any queries, please do not hesitate to contact us.

Kind Regards

Clare Dykes
MBSc, MASNZ
Senior Acoustic Engineer
Acoustic Engineering Services Ltd

Attachment 4: Technical Basis of Model and Data Smoothing

Tonkin+Taylor

Memo

To:	**Stephen Chiles**	**Job No:**	**1014982**
From:	**John Carter**	**Date:**	**3 May 2021**
cc:	**Greg Haldane, Jovanna Leonardo**		
Subject:	**GIS advice on smoothing of noise contours around the state highway network**		

I am writing this memo to provide GIS advice on smoothing of noise contours around the state highway network, as you requested in our meeting on the 15th of April.

There are three main smoothing techniques that could be used to assist your work with Waka Kotahi, in refining rules for acoustic treatment of additions to existing houses or new houses being built near existing state highways. The three most relevant techniques are.

1. Buffer;
2. Simplify; and
3. Smooth.

Buffer

Buffering allows you to set the distance and the side of the line you want to create the buffer around. This is demonstrated in Figure 1 below. The buffer distance in metres can easily be modified based and depending on the distance used, the Figure shows how some of the smaller bends in the noise contour line (the dotted black line) are smoothed by the 5 metre (dark blue) and more so by the 10 metre (light blue) buffers.

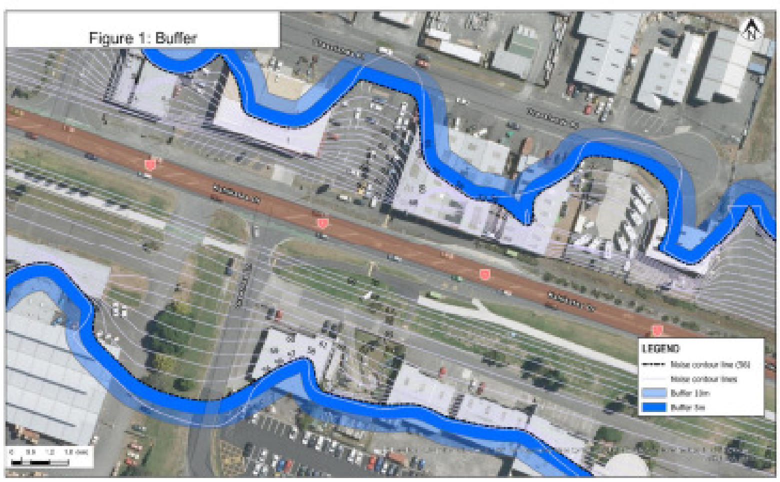


Figure 1: Buffer

Pros:

With buffering you will still keep the general shape of the line and have a consistent distance along the entire contour. This can be easily built into models and automated for the entire country.

Cons:

The negatives of this techniques are you still get some unwanted bends/curves, despite an overall more consistent line. The result of a buffer is an area (polygon), so there are two small steps to convert the polygon into a line, then erase the original line to give one new contour line. The other downside is you push the line out (i.e. needlessly increasing the extent of the contour) in a large proportion of areas where it is already smooth, unlike the smoothing and simplifying methods detailed later in this memo. This can be negated relatively simply by offsetting the line back by buffering the results by the same amount as the original buffer but back towards the original line.

Overall, this is a viable option for your needs, but the main issue would be deciding on the appropriate distance to buffer. Buffering could be used in conjunction with the other methods to provide both a smooth and conservative contour line from the raw modelling results.

As discussed in our meeting, this can be done in ArcGIS, FME and QGIS, but I would only recommend ArcGIS or FME for this task and to allow for integration with automation/existing models. More detail is available from ArcGIS provider ESRI: https://pro.arcgis.com/en/pro-app/latest/tool-reference/analysis/buffer.htm.

Simplify Line

Simplify Line simplifies a line by removing points along the line and therefore unwanted bends/curves, while preserving its shape (depending on the degree of simplification set known as ***the tolerance***).

There are four available methods, when using ArcGIS Pro, the two most viable for this task are 'Wang-Muller' which retains critical bends and 'Zhou-Jones' which retains the weighted-effective areas. I have included the 'Wang-Muller' method on the 56 dB contour in Figure 2 below, with tolerance set at 10 metres and 50 metres.

The Zhou-Jones method needs lower tolerance set in general, as the results of the simplify tool can vary quite a lot from the original line.

Simplify Line with a Barrier

Simplify Line includes an option of having a barrier, which is another layer or feature can be used to prevent the main simplify line touching or crossing the barrier.

Figure 3: Simplify Line with Barrier

Figure 3 shows how this can be used. The Red line is the decibel (dB) 57 contour, it is included in the method as a barrier, to prevent the simplify line from the 56 dB contour line going across the 57 dB contour. The light Blue line has a tolerance of 50 metres and the dark blue line only has 10 metres tolerance. This should prove very useful when it comes to proving a planning line from noise contours.

Pros:

With simplifying you can set a tolerance to keep very true to the original contour line or really simplify it by setting a higher tolerance to cut out unwanted bends. The barrier should enable more sensible results by preventing modelled results of higher noise to be cut off by smoothing. You will keep the general shape of the line and where the line is already smooth or at least simply the line will match the modelled raw output. This can be easily built into models and automated for the entire country.

Cons

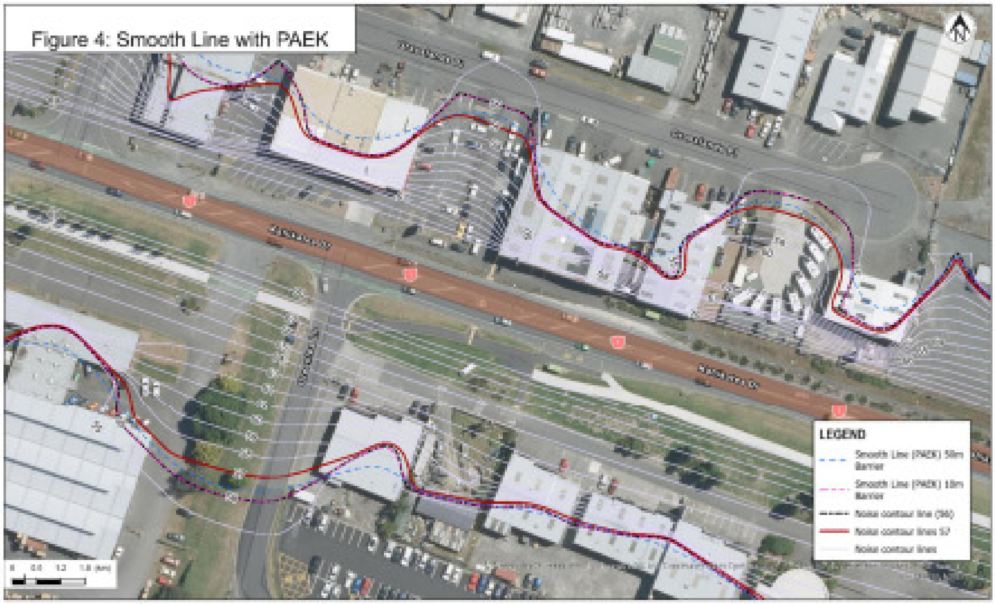
The negatives of this techniques are you still get some unwanted bends, but this can be overcome by adjusting tolerance to suit your wanted outcomes.

Overall, again this is a viable option for your needs, but the main issue would be deciding on the appropriate tolerance distance and barrier location.

More detail is available from ArcGIS provider ESRI: https://pro.arcgis.com/en/pro-app/latest/tool-reference/cartography/simplify-line.htm

Smooth Line

Smoothing lines removes the sharper angles with two main methods or algorithms. The Bezier interpolation method and the Polynomial Approximation with Exponential Kernel (PAEK) method. The Bezier method smooths the lines without using a tolerance, so it is not as viable for this task. The PAEK method, which like the simplify line tool allows you to set the tolerance, although the line may actually be more complicated, or have more points along it, which is something to think about for a national dataset. I have demonstrated the results of the PAEK method in Figure 4 below. The tolerance distance in metres can easily be modified based and barriers are also an option.



The Figure shows how the difference in the two tolerance values of 10 metres and 50 meters can vary greatly, where the 50 metre tolerance varies a lot from the original contour line.

Pros:

With smoothing you can keep use barriers and set tolerance. This can be easily built into models and automated for the entire country.

Cons

The negatives of this techniques are you may find it moves too much from the original contour. The valleys/peaks are removed, so you can get an overall more consistent line. The other downside is you again will have to set a tolerance that suits, and the line will move if that tolerance is pushed out or has higher values.

Overall, this could be a viable option for your needs, but the main issue would be deciding on the appropriate distance of tolerance.

As discussed in our meeting, this can be done in ArcGIS, FME and QGIS, but I would only recommend ArcGIS or FME for this task and to allow for integration with automation/existing models. More detail is available from ArcGIS provider ESRI: https://pro.arcgis.com/en/pro-app/latest/tool-reference/cartography/smooth-line.htm.

3-May-21

Attachment 5: Other Options Considered

For completeness, Waka Kotahi has also considered methods outside of the district plan to manage the issue; these include both regulatory (Building Code; National Environmental Standard) and private covenants ("no complaints" covenants) and built responses:

Regulatory

The **Building Act** (and Code) currently provides specifications to manage inter-tenancy noise (eg noise between residential apartments within the same building with shared tenancy walls). It does not, however, provide requirements for management of noise generated from outside a building (eg transport noise or nightclub noise from a separate building). A change to the Building Code would be needed to address the issue. While proposals for relevant changes to Clause G6 of the Building Code were circulated in 2016 and remain on MBIE's work programme, these are not imminent.

A **National Environmental Standard** (NES) would require promulgation by central government, there is no current plan to promulgate RMA-based national planning direction in relation to health and amenity effects relative to transport.

There are situations where **covenants** are entered into where parties acknowledge and accept particular types of effects in return for locating in an area; commonly referred to as "no complaints" covenants. There are a number of limitations with this approach:

a. it does not remove the actual effects on health and amenity therefore does not address the matters within Part 2 of the RMA;
b. it is reliant on both parties coming to agreement;
c. application of a covenant requires a 'trigger' to commence negotiations (eg. a request from a resource consent applicant to undertake works).

The primary limitation is however that it does not address actual health and amenity impacts.

Changes to the Building Act or promulgation of a NES are not directly within the control of Waka Kotahi; covenants require a 'trigger', agreement between parties and do not actually address the effects generated. None of these options are preferred.

Built Response

Waka Kotahi has undertaken a preliminary assessment of noise improvements across its network. It estimates a cost of at least $150M[24] to retrospectively manage noise exposure for approximately 50% of persons exposed to noise above 64 dB $L_{Aeq(24h)}$.

Responses could include retrofitting acoustic barriers and/or installing low noise road surfaces.

Retrofitting noise barriers by motorways by Waka Kotahi has been found to cost in the range of $4,000 to $10,000 per linear metre of barrier. Construction of noise fences by individuals or land developers generally have lower costs.

Retrofitting acoustic barriers has a number of limitations:

- available land and/or ground conditions;

[24] Not currently funded.

- potential visual dominance and shading;
- ongoing maintenance costs (eg graffiti, landscape maintenance); and
- may not be effective for buildings of more than one storey.

There are also some benefits:

- for barriers close to buildings (or close to the road) and comprehensively blocking the line-of-sight of sensitive land uses to the state highway carriageway, a reduction of 5-10 dB can be achieved;
- where applied to large land areas, cost of protecting multiple sites will aggregate to be less than cost of protecting a low number of sites;
- reduces the need for individuals building houses to have to consider road noise or to keep windows closed;
- can provide visual screening giving a benefit in reducing both perception of noise and actual noise level; and
- can provide improved amenity for outdoor areas.

A porous asphalt surface (low noise road surface) would be in the order of $30+/m^2 (standard two coat chipseal surface would be in the order of $6/m^2 to $10/m^2). It cannot generally be laid directly on existing roads, because low noise (asphaltic) road surfaces require stiff underlying pavements, otherwise they fail prematurely. For much of the existing network, laying new asphaltic surfaces therefore first requires rebuilding of the structural pavement, which would increase the cost to over $100/m^2. Low noise road surfaces can provide in the order of 5 dB reduction in noise generated from the tyre/road interface (although will not materially alter other sounds such as truck engine/air-braking noise). For traffic at highway speeds this is a meaningful improvement, although is often not sufficient to reduce sound to below guideline values.

Overall, while both built options provide some benefits, both options have significant costs and result in the full cost being borne by the road controlling authority in situations where the noise sensitive activity establishes after the state highway.