From: BDC Lgoima
To: [redacted]
Subject: Official Information Request for AON Report – Partial Transfer WCRC Ref: 015/24
Date: Monday, 4 March 2024 4:31:36 pm
Attachments: Buller District Council - Earthquake Loss Estimate - Rev 1.0 .pdf
image002.png

Dear [redacted]

We refer to your official information request transferred to us from WCRC (received by Buller District Council on 2 February 2024).

The information you have requested is attached.

You have the right to seek an investigation and review by the Ombudsman of this decision. Information about how to make a complaint is available at www.ombudsman.parliament.nz or freephone 0800 802 602.

If you wish to discuss this decision with us, please feel free to contact the Buller District Council by return email to lgoima@bdc.govt.nz.

Please note that it is our policy to proactively release our responses to official information requests where possible. Our response to your request will be published shortly at https://bullerdc.govt.nz/district-council/your-council/request-for-official-information/responses-to-lgoima-requests/ with your personal information removed.

Kind regards

Douglas Marshall | Chief Financial Officer (Contractor)
Mobile 027 458 4157 | Email Douglas.Marshall@bdc.govt.nz

Buller District Council | Phone 0800 807 239 | bullerdc.govt.nz
PO Box 21 | Westport 7866

Community Driven | One Team | Future Focused | Integrity | We Care

BULLER
DISTRICT COUNCIL
Te Kaunihera O Kawatiri

WEST COAST
NEW ZEALAND
UNTAMED NATURAL WILDERNESS

From: Toni Morrison
To: BDC Lgoima
Subject: FW: REQ 2024-3009 Information request
Date: Tuesday, 30 January 2024 5:58:34 am
Attachments: image001.png
image002.png
image003.png
image004.png
image005.png
image006.png
image007.png
image008.png

Kia ora [redacted] hope all is well with you.
Re the request below, we don't have a copy of the AON Buller 2017 report – we are thinking we should transfer this part of the request to you? We have the other two reports to provide which are public already.
Unless you have any comments, we will advise the requester of a transfer for that report request to you.
Thanks, have a great day
Toni

Toni Morrison

Policy and Projects Consultant | West Coast Regional Council

toni.morrison@wcrc.govt.nz | +64 3 744 7308 | 0272667633

From: [redacted]
Sent: Friday, January 26, 2024 9:52 AM
To: [redacted]@wcrc.govt.nz>
Subject: Information request

Please email to me copies of:

AON (June 2017) Buller District Council: Earthquake Loss Estimate Analysis for Infrastructure Asset

NIWA (March 2022) Mapping for priority coastal hazard areas in the West Coast Region

Tonkin & Taylor technical review 2023

[redacted]
Principal
[redacted] Parnell, Auckland, 1141

Quantifying Natural Disaster Risk

Buller District Council

Earthquake Loss Estimate Analysis for Infrastructure Assets

June 2017

Tonkin+Taylor

AON
Empower Results®

Confidentiality Notice

This report contains information and analysis which is confidential to **Treasury, Buller District Council, Tonkin + Taylor** and **Aon New Zealand**. This report is provided in confidence and may not be reproduced in any form or communicated to any other person, firm, or company without the prior approval of Aon.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Treasury is evaluating changes in the Crown's risk financing and insurance arrangements. Consequent upon the Canterbury earthquake experience, the understanding and quantification of natural hazard risk for infrastructural assets is now seen as critical.

As part of the ongoing 60/40 infrastructure cost sharing review, Treasury has indicated that natural hazard loss modelling (risk quantification) for earthquake, flood, volcano and tsunami will be a requirement going forward (for those councils exposed to these natural hazards). Treasury has identified a number of councils where they have asked Aon to undertake natural hazard loss modelling, in order to improve their loss estimation understanding. Buller District Council has been identified as one of these councils.

The overall aim of this report is to provide estimates of damage/loss that might be experienced from a significant natural hazard disaster such as an earthquake to infrastructural (water reticulation) assets owned by Buller District Council. As of 2016, Buller District Council declared the total replacement cost of their infrastructure assets to be $114m.

This report focuses on loss from earthquakes. Two uniform earthquake shaking scenarios have been assessed having a target level of shaking in the Buller region of 500 and 1,000 year average recurrence intervals (ARI).

This report will focus on the overall methodology, analysis and outcomes. As part of this process, Tonkin + Taylor Ltd (Tonkin + Taylor, T+T) has been engaged to assess the likelihood of earthquake shaking and vulnerability to earthquake induced-liquefaction damage.

The panel to the right shows the material damage loss estimates for all modelled Buller District Council assets. The loss modelling has incorporated the majority of assets that form the water reticulation systems for Buller District Council.

Mean Loss Expectancy Earthquake
Buller District Council (Modelled Assets)

By ARI:
500yr: $37m
1,000yr: $51m

Whenever analysis of natural catastrophe events are modelled prior to an event actually occurring, assumptions have to be made. Every effort has been taken to include council staff in this process to ensure the outcomes are as robust as possible, based on the information (and understanding) available at the time. There are however, limitations to the analysis and these are outlined in Appendix E.

Portfolio loss modelling assessments give indications of loss potential and should not be used in isolation when making decisions regarding insurance policy loss limits. We would recommend a conservative approach is taken when determining loss limits. It is also worth noting that the loss modelling only considers material damage components of the loss, not other resultant costs incurred (i.e. enablement costs, additional increased cost of working (AICOW), expediting expenses, post loss amplification etc.).

A detailed summary of loss estimates for Buller District Council is provided in Table 3 on page 10.

RISK MANAGEMENT

We are working with Councils across New Zealand to improve Risk Management at a local level.

New Zealand simply cannot afford to fund its inherent natural hazard exposure and has to understand and mitigate its risk exposure and engage international underwriters to provide the required insurance capacity. Robust loss modelling, correct valuation estimates and effective risk transfer are essential considerations, all demanding expert assistance. Aon's role, using its local, global and partnership expertise, is to ensure that risks are identified and quantified and that, as part of a risk management strategy, adequate and sustainable insurance capacity is made available to our clients. In addition to this Aon can provide a valuation service to ensure the loss modelling results reflect realistic replacement values of the three waters infrastructure network.

As illustrated below, the outcomes from this work can also be incorporated into the wider community resilience approach for Buller District Council. Key components of this include a criticality study, an infrastructure and insurance strategy and a disaster response plan.

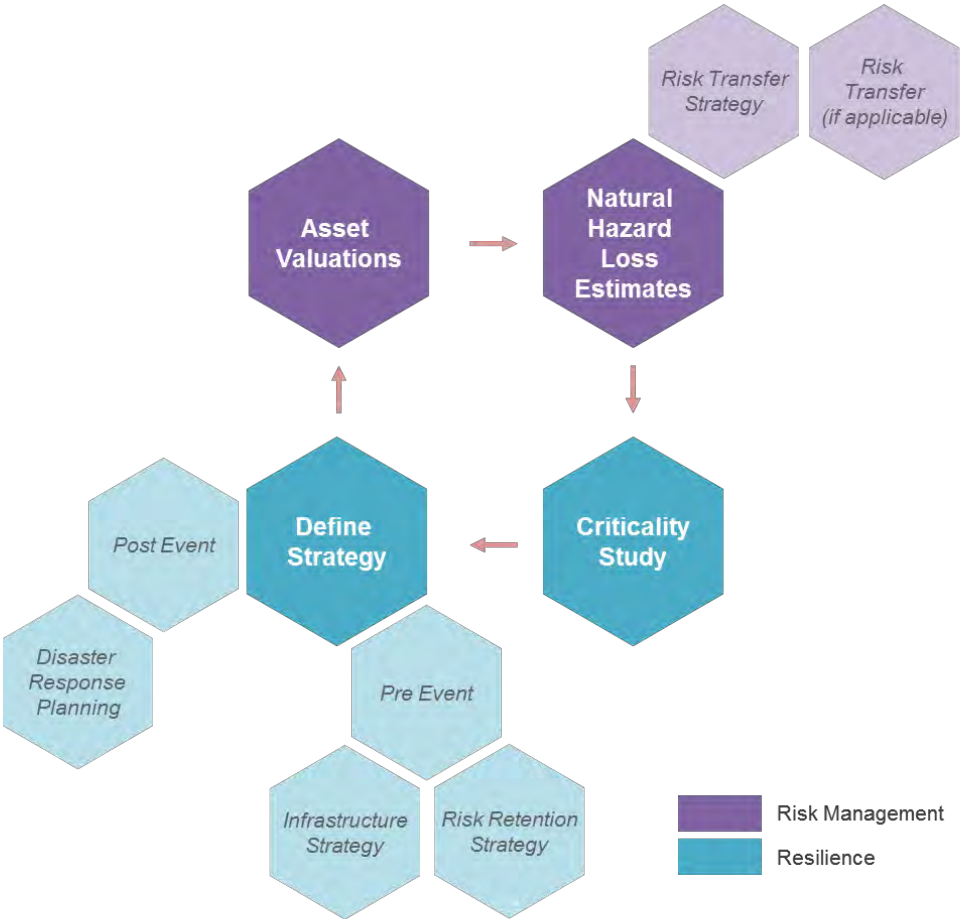

Figure 1 – The steps in improving community resilience

The next steps in the process to develop resilient communities and therefore a resilient New Zealand are discussed in the section titled Next Steps – Resilience.

LOSS MODELLING OVERVIEW

The purpose of the report is to establish the material damage loss estimates (in dollars) for council owned assets following a large natural hazard event such as an earthquake.

The assets included in the analysis comprise both above ground and below ground infrastructural assets. The reviewed infrastructure includes assets such as pump stations, treatment plants, reservoirs and reticulation systems as declared at the last insurance renewal. When it comes to the risk transfer component, some of these assets will be placed on a material damage policy, whereas others will be placed on an infrastructure policy. This report considers the networks in their entirety – the split of assets between policies is a separate consideration.

The analysis contains an assessment of the earthquake hazard and a summary of the corresponding loss estimates. The Buller region is susceptible to a range of possible natural hazards. However, the scope of this assessment focuses on earthquakes with other possible natural hazards, such as flooding and volcanic eruption remaining outside of scope or as part of future additional assessments.

This report has used information provided by Buller District Council along with information available from other sources. Wherever possible, this information has been referenced and credited.

Tonkin + Taylor has provided expertise on liquefaction and earthquake scenarios for the earthquake loss estimate. This includes high level mapping of liquefaction and earthquake shaking with asset overlays. Maps showing liquefaction potential are provided as figures in Appendix F. This report is a joint report provided by both Aon and Tonkin + Taylor.

ASSETS

This assessment covers the three waters pipe network (water supply, wastewater and stormwater) and other requested infrastructure point assets for Buller District Council.

The assets assessed are those provided by the councils in a geospatial database with supporting replacement value information.

To make a spatial assessment of loss, the liquefaction vulnerabilities and earthquake shaking intensities were attributed to the asset in the geospatial database. As this assessment was a simplified assessment asset values were averaged across similar assets with the values taken from the valuation document as of 2016. An indication of the general spread of assets is provided in Appendix F.

The total value of infrastructural and property assets (as declared 2016) for the Buller District Council are broken down in Table 1:

Utility	Type of Assets	Value ($m)	Percentage of total asset values
Water Supply	Infrastructure	45	39%
	Plant	8	7%
	Reservoir	1	1%
Wastewater	Infrastructure	28	24%
	Plant	14	12%
Stormwater	Infrastructure	19	17%
	Plant	0	0%
Total		**114**	

Table 1 – Summary of infrastructural assets and values for Buller District Council.

EARTHQUAKE ASSESSMENT SUMMARY

The Buller District lies predominantly on the west coast of the South Island and extends inland crossing the Alpine Fault in the south eastern extent of the district. The district lies mostly on the Australian tectonic plate, however as eluded to it extends onto the Pacific plate in the southeast of the region. The Alpine Fault is the surface expression of the transform boundary between the Australian and Pacific plates. It is a dextral reverse fault, whereby the Pacific Plate slips along the Australian Plate as they are forced together. Uplift at this boundary from the tectonic activity forms the Southern Alps. There are numerous crustal faults both east and west of the Alpine Fault that are capable of generating earthquakes larger than moment magnitude (Mw) 7.

Figure 2 of Stirling et al (2012), 'National Seismic Hazard model for New Zealand: 2010 update', shows the grouping of the main tectonic zones. The Buller District Council assets are shown as being spread across a region of contractional faulting. Faults in this region are typically 'reverse' and have average recurrence intervals of less than 10,000 years. The typical maximum magnitude for faults in this region is 7.4. We have reviewed the recurrence of ground shaking intensity for the Buller region based on published documentation for the two scenarios to be assessed (500 and 1,000 year ARI's). Table 2 presents the average Modified Mercalli shaking intensities (MM) for each scenario used in the loss estimation process.

MM Shaking Intensity	Average recurrence interval (ARI)
MM9.5	500 years
MM10	1,000 years

Table 2 – MM Shaking intensity recurrence for the loss estimation analysis

For this simplified assessment we have assumed the ground shaking across the region is uniform for each scenario, i.e. each asset is affected by the same level of shaking irrespective of its location.

In an earthquake, infrastructure located in areas of liquefaction can experience greater damage. We have made an assessment estimating the areas of different liquefaction vulnerability and made adjustments in areas susceptible to lateral spreading over the extent of the Buller District Council assets. The areas of liquefaction vulnerability assessed are presented in Figures 29730.8000-01 to 03 in Appendix F.

EARTHQUAKE LOSS ESTIMATES

The following table (Table 3) provides a summary of aggregated damage levels ($) for each asset type for the scenarios modelled.

Damage from an earthquake will be caused by a number of different factors. The majority of damage is expected to be caused by the effects of shaking (cracking/deformation) and liquefaction (especially lateral spread and differential settlement). The potential for damage by large scale differential settlement (i.e. entire land areas raised or lowered) is possible however; this report does not investigate this possibility. Additional notes are provided in Appendix D.

The earthquake loss scenarios considered for this report are severe events but more extreme events can always occur. Considering this the two scenarios modelled have a target ARI of 500 and 1000 years.

Scenario	Utility Class	Asset Type	Damage Estimate ($m)		
			10th Percentile	Mean	90th Percentile
Scenario 1 (500 year ARI)	Water Supply	Pipe Infrastructure	1	2	5
		Plant	2	6	8
		Reservoir	0	1	1
	Wastewater	Pipe Infrastructure	2	10	21
		Plant	7	11	14
	Stormwater	Pipe Infrastructure	1	7	14
		Plant	0	0	0
	Total		**25**	**37**	**53**
Scenario 2 (1,000 year ARI)	Water Supply	Pipe Infrastructure	1	3	7
		Plant	5	7	8
		Reservoir	1	1	1
	Wastewater	Pipe Infrastructure	4	15	30
		Plant	10	13	14
	Stormwater	Pipe Infrastructure	3	11	21
		Plant	0	0	0
	Total		**34**	**51**	**69**

Table 3 – Infrastructural Assets Earthquake Loss Estimates for the Buller District Council

NEXT STEPS – RESILIENCE

The loss modelling has identified areas of high susceptibility and vulnerabilities of the three waters network. Following on from the section titled Risk Management the following provides guidance on the next steps that council may take to increase the resilience of the three waters network and in turn improve community resilience as a whole.

Councils with a detailed understanding of their exposures, vulnerabilities and criticalities of infrastructural assets have the essential components needed to effectively manage risk, ultimately enhancing community resilience. The combination of criticality, combined with a detailed understanding of vulnerability and consequence, enables informed and cost effective strategic decision making around risk mitigation and risk transfer. Aon, with their understanding of the risk and councils' risk management approach are able to present the risk into the insurance markets to ensure the best outcomes are achieved.

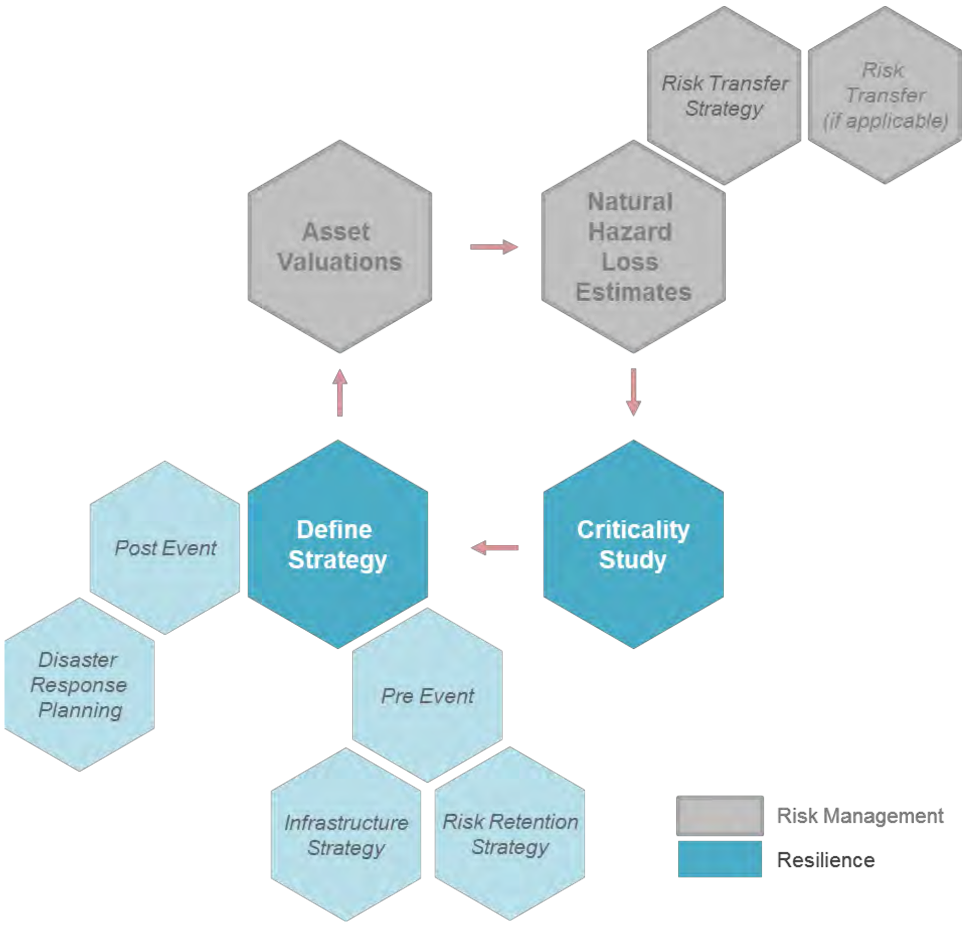

Figure 2 – Steps to improve community resilience

As illustrated above some important steps towards resilience include:

- Producing a Criticality Study – Carrying out a criticality study and relating this back to the loss modelling to enable informed strategy development and decision making regarding where to focus efforts to increase resilience. This may also involve determining the earthquake event sizes that 'trigger' high damage i.e. running scenarios at different return periods.

- Defining Strategy - Defining an insurance, infrastructure and disaster response and recovery strategy which relates to the identified vulnerabilities from natural hazards. Considering criticality and usage requirements Council could determine a more informed strategy on upgrading of the reticulation network, guiding the maintenance and upgrade schedule for plant assets and assisting with other natural hazard risk mitigation measures.

Aon and Tonkin + Taylor would be keen to assist Buller District Council in the extension of the analysis. This would be an additional stage of work beyond that currently undertaken and would require further engagement with Buller District Council. Such work, if undertaken, will also bring cost benefits, i.e. risk mitigation by network hardening may reduce the loss estimate from a natural hazard – reducing the cost or requirement for risk transfer.

SUITABILITY OF DATA FOR FUTURE APPLICATIONS

This report has been produced to assist in the understanding and quantification of natural hazard risk for infrastructural assets of Buller District Council. This data is only intended to be used to assist in establishing an appropriate risk transfer strategy and as such has been modelled to the detail required for this purpose. When used for other purposes, such as civil defence, land use and town planning, it may not be sufficiently robust or detailed. When considering using the data as a starting point for other purposes it is important to ensure the limitations are understood and acknowledged.

CONTACT DETAILS

If you require any further information or have any queries, please contact the following:

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APPENDIX A – REFERENCES

The following is a non-exhaustive list of all the sources of information used for this report:

Earthquake Hazards:

- Atkinson, G. M., & Kaka, S. I. (2006). Relationships between felt intensity and instrumental ground motion for New Madrid ShakeMaps. Department of Earth Sciences, Carleton University.
- Berrill, J. B., Bienvenul, V. C., & Callaghan, M. W. (1988). Liquefaction in the Buller region in the 1929 and 1968 earthquakes. Bulletin of the New Zealand National Society for Earthquake Engineering, 21(3), 174-189.
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- Smith, W. D. (1990). Earthquake hazard in New Zealand: some implications of the Edgecumbe earthquake, March 1987. Bulletin of the New Zealand National Society for Earthquake Engineering, 23(3), 211-219.
- Stirling, M., McVerry, G. H., & Berryman, K. R. (2002). A new seismic hazard model for New Zealand. *Bulletin of Seismological Society of America*, 92, 1878–1903.
- Stirling, M., McVerry, G., Gerstenberger, M., Litchfield, N., Dissen, R. V., Berryman, K., … Jacobs, K. (2012). National Seismic Hazard Model for New Zealand: 2010 Update. *Bulletin of the Seismological Society of America*, 102(4), 1514–1542. http://doi.org/10.1785/0120110170

- Standards New Zealand. (2004). *Structural Design Actions Part 5: Earthquake actions - New Zealand*. Standards New Zealand, Private Bag 2439, Wellington 6020.
- van Ballegooy, S., & Russell, J. (2015). *Canterbury Earthquake Sequence: Increased Liquefaction Vulnerability Assessment Methodology* (No. 52020.140v1.0, October 2015). Tonkin + Taylor. Retrieved from www.tonkintaylor.co.nz

APPENDIX B – EARTHQUAKE ASSESSMENT

EARTHQUAKE HAZARD – REGIONAL

Active faults

The Buller District lies predominantly on the west coast of the South Island and extends inland crossing the Alpine Fault in the south eastern extent of the district. The district lies mostly on the Australian tectonic plate, however as eluded to it extends onto the Pacific plate in the southeast of the region. The Alpine Fault is the surface expression of the transform boundary between the Australian and Pacific plates. It is a dextral reverse fault, whereby the Pacific Plate slips along the Australian Plate as they are forced together. Uplift at this boundary from the tectonic activity forms the Southern Alps. There are numerous crustal faults both east and west of the Alpine Fault that are capable of generating earthquakes larger than moment magnitude (Mw) 7.

Seismicity in New Zealand is estimated in New Zealand using the National Seismic Hazard Model (NSHM) published by Stirling et al. (2012). This defines known fault sources, their characteristic magnitudes and their average recurrence of rupture. Across New Zealand the tectonic setting and the seismicity varies. Figure 2 of Stirling et al (2012), 'National Seismic Hazard model for New Zealand: 2010 update', reproduced as Figure B1 below, shows the grouping of the main tectonic zones, i.e. areas of different structural features of the earth's crust which are associated with earthquakes. The Buller District Council assets all lie on the western side of the Alpine Fault in Zone 8 'Contractional Northwest South Island Faults'.

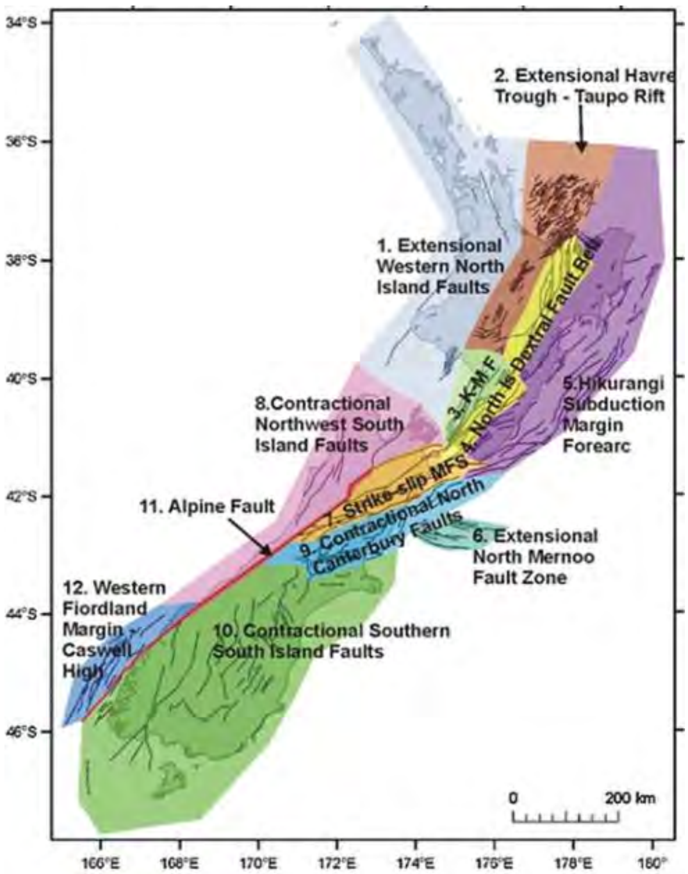

Figure B1 – New Zealand's tectonic zones. The Buller District Council assets are in Zone 8, an area of crustal contraction. Figure from Stirling et al. (2012).

Faulting in this region is typically 'reverse'. Figure 6.3 from the Bridge Manual 3rd Edition (NZTA, 2016), reproduced as Figure B2 below, indicates the typical maximum magnitudes in this region are 7.4 for faults with an average recurrence interval of less than 10,000 years.

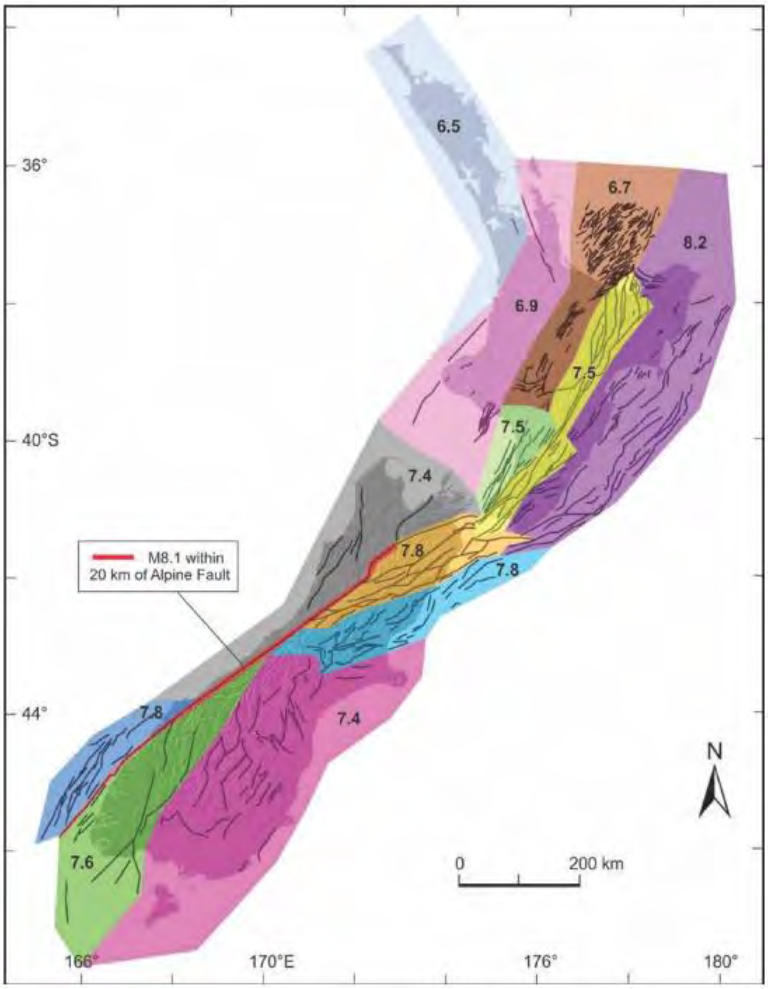

Figure B2 – Maximum magnitudes associated with faults having an ARI of less than 10,000 years as in the Bridge Manual 3rd Edition (NZTA, 2016)

Figure B3 shows the active fault sources represented in the NSHM (Stirling et al., 2012). The magnitude, ARI and distance to selected centres are presented in Table B1.

Further to the known active faults, unknown faulting and other seismogenic (earthquake generating) sources are likely within the region and are represented in the NSHM by a distributed source component extending across the Buller region. Surface expressions of past fault ruptures can be easily hidden by young soil deposits. Earthquakes could be expected to occur at any location and are not limited to known faults as illustrated by the Canterbury Earthquake Sequence which occurred predominantly on unknown faults.

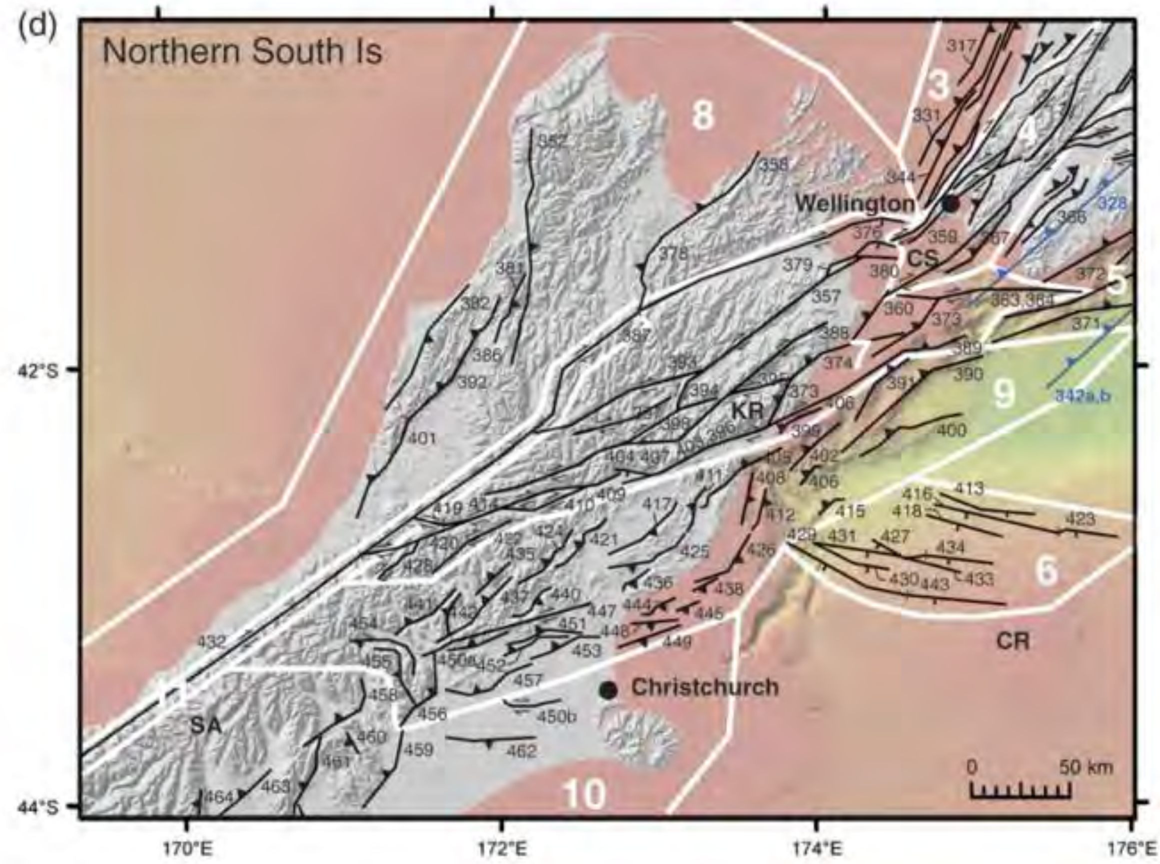

Figure B3- Individual fault sources applied in the Stirling et al. (2012) National Seismic Hazard Model, in and surrounding the Buller region. Unknown faults sources are likely to exist and some consideration is applied in Stirling et al. (2012) as a distributed source model in combination with the fault source model.

Fault Name	Estimated characteristic magnitude	Average recurrence interval	Approximate distance from centres to active fault sources		
			Westport	Reefton	Punakaiki
Paparoa Rangefront (382)	7.5	10,730	10	30	1
Inangahua (386)	7.1	5,290	30	15	40
Maimai (392)	7.1	5,430	35	10	20
Lyell (381)	7.1	13,580	35	25	60
White Creek (352)	7.8	41,790	45	20	65
Brunna Anticline (401)	7.8	10,810	60	35	20
Alpine Fault - Kaniere-Tophouse (387)	7.7	620	75	65	65
Awatere Southwest (393)	7.5	1,180	85	40	80
Clarence Southwest (404)	7.7	1,740	100	55	75
Fowlers (397)	7.2	7,400	100	55	100

Table B1 – Selected active fault sources and indicative distances to the main centres. Based on the NSHM database, Stirling et al. (2012)

Historical earthquake events

Historical observation records of large earthquakes in New Zealand exist back to approximately 1840. Figure B4 shows the earthquakes recorded in the New Zealand Earthquake Catalogue (GeoNet, 2017), a compilation of oral and written history and since 1930 instrumental readings. As smaller earthquakes may have gone unnoticed before the time of ground motion monitoring stations, this record is not complete over this time period and is only intended to be generally indicative.

Table B2 summarises a selection of notable earthquakes in the Buller region over the time of historic records. Shaking intensity is in Modified Mercalli (MM) intensity scale (Dowrick, 1996). The Buller District has been subjected to moderate ground shaking (MM6-MM7) from a number of historic events since records began. Greater than MM8 shaking was experienced in the Buller District from the both 1929 Buller earthquake and 1968 Inangahua earthquake.

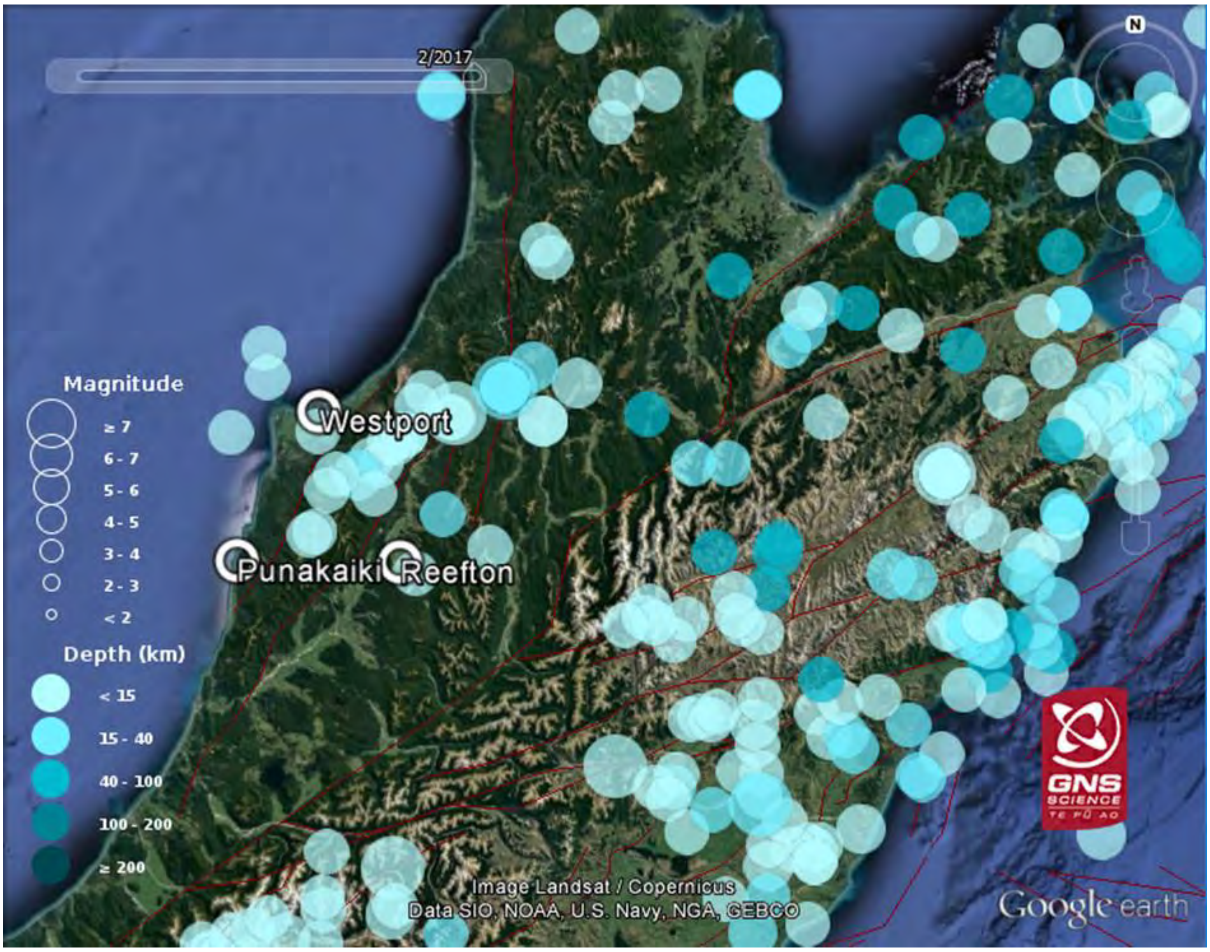

Figure B4- New Zealand Earthquake Catalogue (GeoNet, 2017). Recorded earthquakes greater than magnitude 5 and less than 100km deep in the catalogue.

Earthquake event	Year	Epicentre estimate	Depth	Magnitude estimate	Max MM	MM shaking intensity in urban centres		
						Westport	Reefton	Punakaiki
Marlborough EQ, 15 October	1848	200 km E of Westport	12 km	7.4-7.7	9	6	6	6
Cape Farewell EQ, 19 October	1868	220 km NE of Westport	12 km	7.2	8	6	6	5-6
North Canterbury EQ, 31 August	1888	155 km SE of Westport	12 km	7.0	9	6	6	6
Cape Foulwind EQ, 22 February	1913	5 km S of Westport	12 km	5.3	6	6	6	6
Arthurs Pass EQ, 9 March	1929	120 km SE of Westport	12 km	7	8	5-6	5-6	5-6
Buller EQ, 16 June	1929	50 km E of Westport	20 km	7.3	10	8-9	8-9	8
Buller EQ Aftershock, 22 June	1929	50 km E of Westport	12 km	6.5	7	6-7	6-7	6-7
Buller EQ Aftershock, 15 July	1929	50 km E of Westport	19 km	6.3	6	5-6	5-6	5-6
Westport EQ May, 10	1962	15 km NW of Westport	12 km	5.6	6	6	6	6
Inangahua EQ, 23 May	1968	40 km E of Westport	12 km	7.1	10	8	8-9	7-8
Hawks Crag EQ, 28 January	1991	20 km SE of Westport	17 km	6	6	6	6	6

Table B2 – Recorded historical earthquakes causing notable shaking in the Buller region (GeoNet 2017)

Shaking intensity recurrence

The frequency or recurrence of earthquake shaking at a location is a function of the hazard from all faults and background (distributed) seismic sources, in and surrounding the area of interest. To quantify this a Probabilistic Seismic Hazard Analysis (PSHA) is used. Assessments using PSHA are provided in literature, standards and guidance for the Buller region.

The area encompassed by the Buller District Council is situated across the Greymouth and Nelson QMAP extents. However, the majority of assets lie within the extent of Greymouth QMAP. The Greymouth QMAP provides an assessment of MM shaking recurrence for the Grey District and southern extent of the Buller district, including Westport and Reefton, which is where the majority of the Buller District Council assets lie.

The New Zealand Transport Agency (NZTA) Bridge Manual (BM) 3rd Edition provides PGA and unweighted magnitude recurrence for geotechnical applications like liquefaction assessment. This is also based on Stirling et al. (2002).

For this study PGA, derived from the NZTA BM, has been converted to MM using the relationships in Murashev and Davey (2005) and Atkinson and Kaka (2006). We have assessed the range of MM recurrence intervals calculated by this method, considering the mean and mean plus one standard deviation of the data set, and selected suitable recurrence intervals from within this range.

Murashev and Davey (2005) conversion is derived from matching PGA attenuation relationship from McVerry et al (2000) with MMI attenuation relationship from Dowrick and Rhoades (1999).

Smith (1990) provides a mean recurrence interval for MM intensities for the major centres across New Zealand.

The Average Recurrence Interval (ARI) for shaking intensity (MM) from QMAP, Smith (1990) and inferred from the NZTA BM are presented in Table B3.

Shaking intensity	Greymouth QMAP (Nathan et al., 2002) (years)	Smith (1990) Earthquake hazard in New Zealand, Westport (years)	NZTA (2014) Bridge Manual PGA converted to MM using Atkinson & Kaka (2006), Westport (years)	NZTA (2014) Bridge Manual PGA converted to MM using Murashev & Davey (2005), Westport (years)
MM6	6	8	-	-
MM7	15	26	-	20
MM8	21	91	40	100
MM9	32	330	200	500
MMI10	-	-	1000	2500

Table B3 – Shaking intensity Average Recurrence Interval (ARI) estimates.

GROUND CONDITIONS

General

The three ground condition aspects that are of greatest importance in the assessment of the vulnerability of earthquake damage to infrastructure networks are:

- Subsoil class, which characterises the strength and stiffness of the subsurface materials for the purpose of dynamic response of the ground to shaking;
- Potential for liquefaction, typically in saturated cohesionless soils triggered by earthquake shaking; and
- Potential for slope failure, triggered by earthquake shaking.

Aspects of the ground conditions have been broadly characterised as part of previous studies for the Buller region. This report focuses on the liquefaction vulnerability and the earthquake shaking which can cause damage to pipe networks and point assets.

Slope stability may also occur during earthquake shaking and may affect infrastructure, however an assessment of slope stability issues is beyond the scope of this report.

Surface rupture of faults and tectonic subsidence or uplift are additional earthquake related vulnerabilities to infrastructure. They are likely to occur concurrently with other earthquake related damage and therefore are only important to distinguish when likely to cause a significant additional risk. The occurrence of surface rupture of faults in populated areas in the Buller region is considered to be sufficiently unlikely (significantly greater than an ARI of 1,000 years) to not be considered specifically in this assessment. The aspects of tectonic subsidence or uplift are beyond the scope of this report.

Subsoil class – for infrastructure

For the purposes of this report we have assumed that all soils in the study area are subsoil class C in accordance with NZS1170.5:2004. For this short format report, assessment of shaking amplification associated with changes in subsoil class is beyond the scope of works.

Seismic liquefaction potential

When loose sandy or silty soils are subjected to strong earthquake shaking, there is a tendency for the soil particles to try to compact. If the soil is saturated with groundwater, then the water between the soil particles is unable to escape and becomes pressurised. If the shaking is strong and long enough, and the soil loose enough, then it reaches a point where the water between the particles is now carrying the weight of everything above it, and the soil particles lose contact with each other. At this point the soil behaves more like a fluid, and it temporarily loses much of its strength and stiffness. This phenomenon is called liquefaction. Liquefaction can cause significant damage to land, buildings and infrastructure, such as:

- Ejection of liquefied soil to the ground surface;
- Differential settlement of the ground surface due to ejection and consolidation of soil;
- Horizontal ground movements, either all in one direction where the ground is sloping, or backwards and forwards where the ground is level;
- Settlement of foundations due to loss of strength in the underlying soil; and
- Floatation of buried structures such as pipes and manholes.

Previous studies have looked at past earthquakes causing liquefaction in the Buller region. Berrill et al. (1988) noted 9 sites of observed liquefaction from each of the 1929 Buller and 1968 Inangahua earthquakes. A Buller District Council study (2006) also mapped historic liquefaction sites in Westport from the 1929 Buller, 1968 Inangahua and 1991 Hawks Crag earthquakes.

LIQUEFACTION VULNERABILITY ASSESSMENT

Liquefaction vulnerability areas

Liquefaction vulnerability is the likelihood of damage given the occurrence of earthquake shaking. Earthquake scenarios and shaking are described in the Section ‘Earthquake Scenarios for Loss Estimate Analysis’.

Tonkin + Taylor’s experience in Christchurch is that damage to land depends on the soil profile, groundwater depth and shaking (van Ballegooy, S., & Russell, J., 2015) and we have used this to adapt the past studies and best represent liquefaction vulnerability given the resources and knowledge at this time for this specific assessment.

We have assessed liquefaction vulnerability using the 1:250,000 QMAP surface geology layer. Further modifications were made in the following ways:

1. To account for higher relative vulnerability from lateral spread, zones adjacent to the river channels and tributaries were elevated by one vulnerability grade as follows:
    a. Where originally identified as low this was changed to moderate and identified as a lateral spread area along a 50 m wide strip either side of the river channel;
    b. Where originally identified as moderate this was changed to high and identified as a lateral spread area along a 100 m wide strip either side of the river channel;
    c. Where originally identified as high this was changed to very high and identified as a lateral spread area along a 150 m wide strip either side of the river channel;
    d. Where originally identified as very high a 200 m wide strip either side of the river channel was identified as a lateral spread area.

Maps of liquefaction vulnerability for this loss estimate analysis are presented in Appendix F. We have spatial linked liquefaction vulnerability areas with the assets for loss estimation analysis by Aon. For assets which cross two areas, the higher liquefaction vulnerability was applied.

Pipe damage curves

Assessment of areas of different liquefaction vulnerability is only one part of the assessment. The variation of vulnerability with ground shaking intensity is equally important. Even in areas assessed with very high vulnerability, a moderate level of earthquake shaking (MM6-7) is required for liquefaction damage to start to occur. This damage will become more severe with increasing shaking intensity and then likely level out. At very strong shaking intensities, areas with lower vulnerability for liquefaction could still experience moderate levels of liquefaction damage.

For this loss estimate analysis, to relate the liquefaction vulnerability areas and intensity of shaking to the resulting severity of damage, liquefaction damage factors for pipes shown in B5 are recommended to be applied with those for other earthquake damage types as in Cousins (2013). The shape of these curves was established based on the analysis of an extensive database of geotechnical investigations and liquefaction damage observations undertaken by Tonkin + Taylor for the Earthquake Commission following the Canterbury Earthquakes of 2010-2011 (van Ballegooy, S., & Russell, J., 2015).

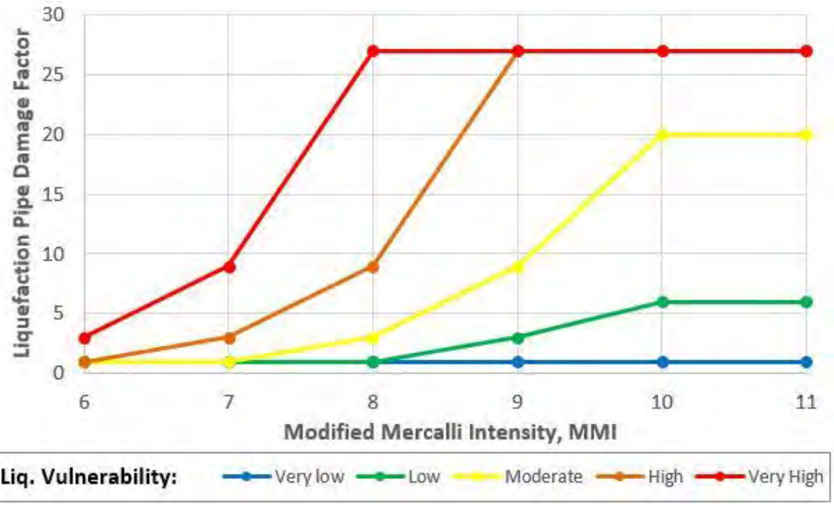

Figure B5 - Curves relating pipe damage factors of Cousins (2013) to the assessed liquefaction vulnerability areas and shaking intensities

Earthquake scenarios for loss estimate analysis

Two earthquake scenarios with uniform ground shaking across the region are used for the purpose of loss estimation. These events have ARI's of 500 and 1,000 years for this assessment.

Based on the estimated ARIs for MM shaking intensity summarised in Table B3, consideration of their currency and magnitude weighting, general regional spread of assets and the potential for uncertainty in the assessment of the seismic hazard, the shaking levels in Table B4 are recommended for use in the loss estimate analysis by Aon for the two Buller District scenarios.

MM Shaking Intensity	Average recurrence interval (ARI, years)
MM9.5	500 years
MM10	1,000 years

Table B4 – MM Shaking intensity recurrence for the loss estimation analysis by Aon

APPENDIX C – MODIFIED MERCALLI SCALE

Level	Description
MM 1	*People* Not felt except by a very few people under exceptionally favourable circumstances.
MM 2	*People* Felt by persons at rest, on upper floors or favourably placed.
MM 3	*People* Felt indoors; hanging objects may swing, vibration similar to passing of light trucks, duration may be estimated, may not be recognised as an earthquake.
MM 4	*People* Generally noticed indoors but not outside. Light sleepers may be awakened. Vibration may be likened to the passing of heavy traffic, or to the jolt of a heavy object falling or striking the building. *Fittings* Doors and windows rattle. Glassware and crockery rattle. Liquids in open vessels may be slightly disturbed. Standing motorcars may rock. *Structures* Walls and frames of buildings, and partitions and suspended ceilings in commercial buildings, may be heard to creak.
MM 5	*People* Generally felt outside, and by almost everyone indoors. Most sleepers awakened. A few people alarmed. *Fittings* Small unstable objects are displaced or upset. Some glassware and crockery may be broken. Hanging pictures knock against the wall. Open doors may swing. Cupboard doors secured by magnetic catches may open. Pendulum clocks stop, start, or change rate. *Structures* Some windows Type I cracked. A few earthenware toilet fixtures cracked.
MM 6	*People* Felt by all. People and animals alarmed. Many run outside. Difficulty experienced in walking steadily. *Fittings* Objects fall from shelves. Pictures fall from walls. Some furniture moved on smooth floors, some unsecured free-standing fireplaces moved. Glassware and crockery broken. Very unstable furniture overturned. Small church and school bells ring. Appliances move on bench or table tops. Filing cabinets or "easy glide" drawers may open (or shut). *Structures*

	Slight damage to Buildings Type I. Some stucco or cement plaster falls. Windows Type I broken. Damage to a few weak domestic chimneys, some may fall. *Environment* Trees and bushes shake, or are heard to rustle. Loose material may be dislodged from sloping ground, e.g. existing slides, talus slopes, shingle slides.
MM 7	*People* General alarm. Difficulty experienced in standing. Noticed by motorcar drivers who may stop. *Fittings* Large bells ring. Furniture moves on smooth floors, may move on carpeted floors. Substantial damage to fragile contents of buildings. *Structures* Unreinforced stone and brick walls cracked. Buildings Type I cracked with some minor masonry falls. A few instances of damage to Buildings Type II. Unbraced parapets, unbraced brick gables, and architectural ornaments fall. Roofing tiles, especially ridge tiles may be dislodged. Many unreinforced domestic chimneys damaged, often falling from roof-line. A few instances of damage to brick veneers and plaster or cement-based linings. *Environment* Water made turbid by stirred up mud. Small slides such as falls of sand and gravel banks, and small rock-falls from steep slopes and cuttings. Instances of settlement of unconsolidated or wet, or weak soils. Some fine cracks appear in sloping ground. A few instances of liquefaction (i.e. small water and sand ejections).
MM 8	*People* Alarm may approach panic. Steering of motorcars greatly affected. *Structures* Buildings Type I heavily damaged, some collapse. Buildings Type II damaged, some with partial collapse. Buildings Type III damaged in some cases. A few instances of damage to Structures Type IV. Monuments and pre-1976 elevated tanks and factory stacks twisted or brought down. Some pre-1965 infill masonry panels damaged. A few post-1980 brick veneers damaged. Decayed timber piles of houses damaged. Houses not secured to foundations may move. Most unreinforced domestic chimneys damaged, some below roof-line, many brought down. *Environment* Cracks appear on steep slopes and in wet ground. Small to moderate slides in roadside cuttings and unsupported excavations. Small water and sand ejections and localised lateral spreading adjacent to streams, canals, lakes, etc.
MM 9	*Structures* Many Buildings Type I destroyed. Buildings Type II heavily damaged, some collapse. Buildings Type III damaged, some with partial collapse. Structures Type IV damaged in some cases, some with flexible frames seriously damaged. Damage or permanent distortion to some Structures Type V.

	Houses not secured to foundations shifted off. Brick veneers fall and expose frames. *Environment* Cracking of ground conspicuous. Landsliding general on steep slopes. Liquefaction effects intensified and more widespread, with large lateral spreading and flow sliding adjacent to streams, canals, lakes, etc.
MM 10	*Structures* Most Buildings Type I destroyed. Many Buildings Type II destroyed. Buildings Type III heavily damaged, some collapse. Structures Type IV damaged, some with partial collapse. Structures Type V moderately damaged, but few partial collapses. A few instances of damage to Structures Type VI. Some well-built timber buildings moderately damaged (excluding damage from falling chimneys). *Environment* Landsliding very widespread in susceptible terrain, with very large rock masses displaced on steep slopes. Landslide dams may be formed. Liquefaction effects widespread and severe.
MM 11	*Structures* Most Buildings Type II destroyed. Many Buildings Type III destroyed. Structures Type IV heavily damaged, some collapse. Structures Type V damaged, some with partial collapse. Structures Type VI suffer minor damage, a few moderately damaged.
MM 12	*Structures* Most Buildings Type III destroyed. Structures Type IV heavily damaged, some collapse. Structures Type V damaged, some with partial collapse. Structures Type VI suffer minor damage, a few moderately damaged.

Table 4 - Modified Mercalli Index from Dowrick (1996)

Construction types

Buildings Type I

Buildings with low standard of workmanship, poor mortar, or constructed of weak materials like mud brick or rammed earth. Soft storey structures (e.g. shops) made of masonry, weak reinforced concrete or composite materials (e.g. some walls timber, some brick) not well tied together. Masonry buildings otherwise conforming to buildings Types I to III, but also having heavy unreinforced masonry towers. (Buildings constructed entirely of timber must be of extremely low quality to be Type I.)

Buildings Type II

Buildings of ordinary workmanship, with mortar of average quality. No extreme weakness, such as inadequate bonding of the corners, but neither designed nor reinforced to resist lateral forces. Such buildings not having heavy unreinforced masonry towers.

Buildings Type III

Reinforced masonry or concrete buildings of good workmanship and with sound mortar, but not formally designed to resist earthquake forces.

Structures Type IV

Buildings and bridges designed and built to resist earthquakes to normal use standards, i.e. no special collapse or damage limiting measures taken (mid-1930s to c. 1970 for concrete and to c. 1980 for other materials).

Structures Type V

Buildings and bridges, designed and built to normal use standards, i.e. no special damage limiting measures *taken, other than code requirements, dating from since c. 1970 for concrete and c. 1980 for other materials.*

Structures Type VI

Structures, dating from c. 1980, with well-defined foundation behaviour, which have been specially designed for minimal damage, e.g. seismically isolated emergency facilities, some structures with dangerous or high contents, or new generation low damage structures.

Other comments

1. "Some" or "a few" indicates that the threshold of a particular effect has just been reached at that intensity.

2. "Many run outside" (MM 6) is variable depending upon mass behaviour, or conditioning by occurrence or absence of previous earthquakes, i.e. may occur at MM 5 or not until MM 7.

3. "Fragile contents of buildings": fragile contents include weak, brittle, unstable, unrestrained objects in any kind of building.

4. "Well-built timber buildings" have: wall openings not too large; robust piles or reinforced concrete strip foundations; superstructure tied to foundation.

5. Buildings Type III to V at MM 10 and greater intensities are more likely to exhibit the damage levels indicated for low-rise buildings on firm or stiff ground and for high-rise buildings on soft ground. By inference lesser damage to low-rise buildings on soft ground and high-rise buildings on firm or stiff ground may indicate the same intensity. These effects are due to attenuation of short period vibrations and amplification of longer period vibrations in soft soils.

APPENDIX D – NOTES ON LOSS ESTIMATES

Earthquake

Notes on loss estimates:

i. *Damage estimates have been calculated as a continuous probability distribution and three values are reported from this to give an understanding of the potential variability of the results for any given scenario. These values are based on the thousands of individual damage simulations for each of the selected scenarios.*
   a. *The 10th percentile represents the value for which 90% of the individual damage simulations might be expected to exceed the $ loss given. It represents a low estimate for the loss potential within the simulation.*
   b. *The 90th percentile represents the value for which 10% of the individual damage simulations might be expected to exceed the $ loss given. It represents a high estimate for the loss potential within the simulation.*
   c. *The mean is the average of all the individual damage simulations for each scenario and is often called the arithmetic mean. It represents a central tendency estimate for the loss potential within the simulation.*
   d. *Given the inclusion of probability in the 10th and 90th percentile values the totals are not simply an addition of the numbers.*
   e. *Note that the damage estimates and values provide include modelled conservatism.*

ii. *Liquefaction effects multiply damage (at increasing levels) from MM6 shaking intensity for areas with very high liquefaction vulnerability and from higher shaking intensities (MM7 to 9) for areas of lesser liquefaction vulnerability (high to low).*

iii. *The estimates take consideration of (among other things) pipe material and diameter. Brittle materials perform poorly particularly on sewage and storm water systems. Large diameter pipes perform better than smaller diameter pipes.*

iv. *Damage ratios based on published curves (Cousins, 2013 and HAZUS) for similar asset types. Indicative material damage loss levels only.*

v. *Damage estimates are based on replacement costs estimates provided by the Council. Aon and Tonkin + Taylor reserves the right but not the obligation to recalculate damage estimates if the information is found to be in error or not suitable to fully replacement the assets in the event of a loss.*

vi. *Consideration of the increase of costs after a large scale disaster, or demand surge, has been made in the damage estimates.*

vii. *Additional detailed assessment (i.e. ground condition checks) is recommended to establish more accurate loss levels.*

viii. *The estimate does not provide for additional damage that could be sustained during large secondary or after-shocks, nor does it factor for a second major earthquake in the region during the same insurance period.*

ix. *For larger point assets, average response conditions have been assumed. Specific localised ground effects or the directional forces of the earthquake may cause specific conditions that exacerbate damage. Initial Evaluation Procedure reports (building assessment compared to current building code) for the majority of buildings has been provided by councils. However, these assessments are arbitrary plus the building standard is meant to protect lives not the building itself. The IEP values provide an indication of potential loss. However, without in-depth structural and geotechnical investigation the actual loss potential cannot be accurately pre-determined. When determining loss limits for insurance purposes, the potential for additional damage to high value point assets, within the portfolio of assets considered, can be improved by undertaking more specific and detailed assessment for that asset.*

x. *Information for all assets modelled has been gained from the schedule of assets provided by the council at the level of detail supplied.*

xi. *The modelled losses presented in this report should be interpreted as follows. The 1000 yea ARI loss means that there is approximately a 1 in 1000 annual probability that a loss of this size will be exceeded in any given year.*

xii. *Catastrophe (cat) models assume high correlation between characteristics of insured infrastructural and point assets and those of the model features (such as vulnerabilities) designed to represent them. Specific individual risks however may have very different attributes to those assumed by the cat models. This means that real-life losses from a single risk or small group of risks concentrated at one or more locations could potentially exceed infrastructure-network/ point assets modelled losses calculated using the natural hazard models.*

xiii. *Aon recommends that the results presented in this report should not be relied upon in isolation when making decisions regarding policy limits.*

APPENDIX E – LIMITATIONS AND DISCLAIMERS

The primary aim of the analysis contained in this report, prepared by Aon and Tonkin + Taylor (we, our) has been to ascertain and determine loss estimates for earthquake events for Buller District Council (the Client). The loss estimates provided are considered pragmatic and at an appropriate level and in line with good practice for loss estimations associated with severe earthquake events.

This analysis has considered a limited number of earthquake scenarios and as natural hazard events are intrinsically unpredictable, there is a margin of uncertainty attaching to the results. The results and findings in this report have been reached through a series of qualitative assessments in combination with various assumptions and limitations. Please note the following in particular:

- Any form of mathematical and/or empirical analysis and modelling (including that used in the preparation of this document) may produce results which differ from actual events or losses.
- The review and calculation of loss estimates was desk-top based and its accuracy is reliant on the information supplied by the Client and/or selected third party sources. We accept no responsibility for the accuracy or completeness of the underlying information provided.
- Unless specified in the original report scope, no assessment of slope stability, ground deformations, ground displacement or landslide implications that may be associated with earthquake shaking has been undertaken as part of this assessment.
- No estimation of the magnitude of settlement associated with liquefaction and its consequences has been undertaken as part of this assessment.
- Damage estimates are based on replacement estimates provided by Council. Aon and T+T reserve the right but not the obligation to recalculate damage estimates if the information is found to be in error or not suitable for full replacement of the assets in the event of a loss.
- We recommend that asset valuations are reviewed on a regular basis and are estimated using an insurance based reinstatement cost, not financial (or depreciation) based valuations (which may not consider all of the various factors associated with a large loss).

The Client acknowledges the assumptions and limitations noted above and agrees:

- Where this report includes a recommendation or an assessment of risk, this is an expression of our opinion only and not a statement of fact. Any decision to rely upon any such recommendation or assessment will be solely at the risk of the Client, for which we accept no liability, and the Client acknowledges that the analysis provided does not replace the need for the Client to make its own assessment.
- We will not be liable, in any event, for any special, indirect or consequential loss or damage of any kind (including but not limited to, loss of profit and business interruption, loss of use, loss of revenue, loss of contracts, increased costs and expenses, wasted expenditure, and all special, indirect and consequential

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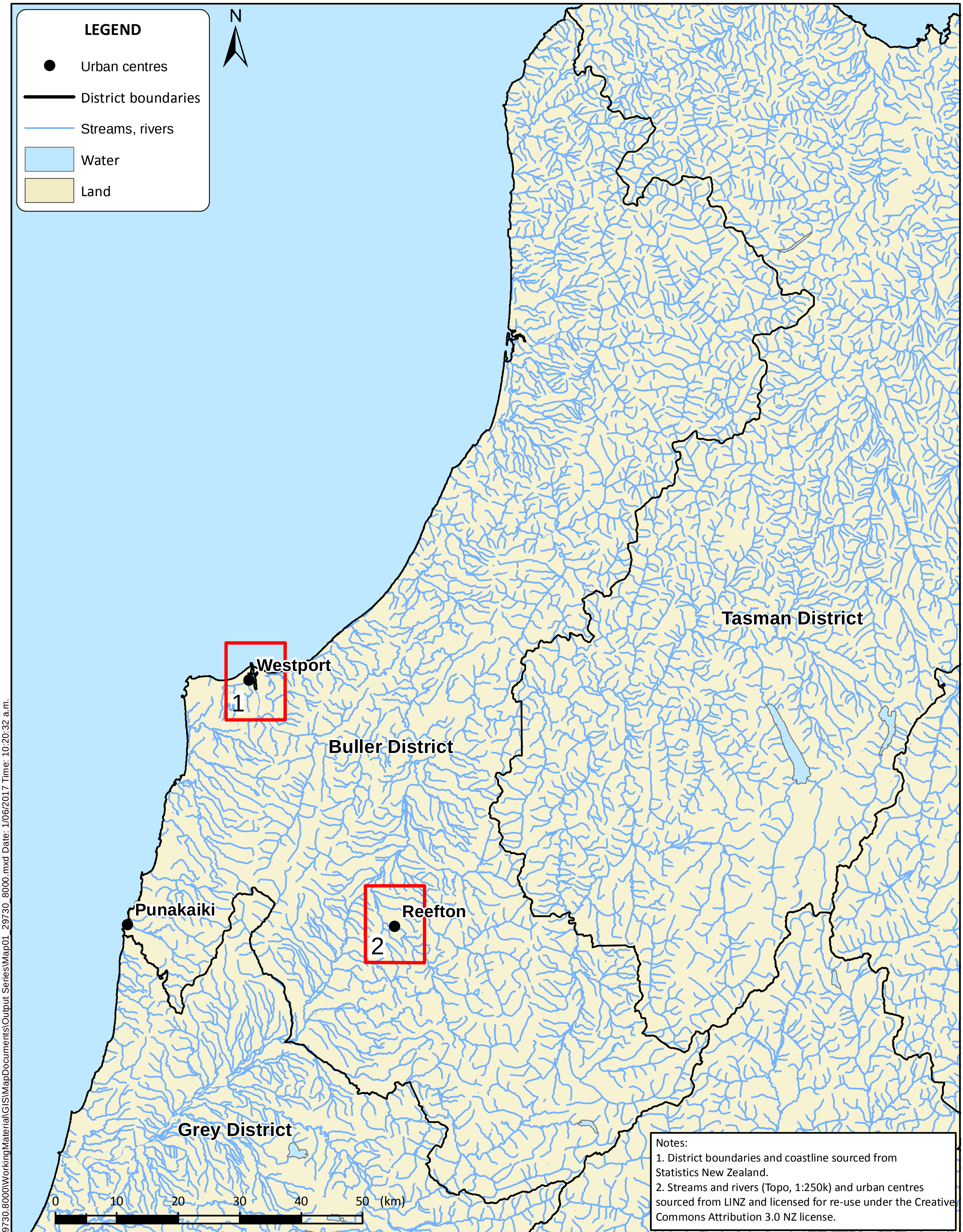
APPENDIX F – OVERVIEW, LIQUEFACTION VULNERABILITY AND EARTHQUAKE SCENARIO FIGURES 29730-8000-01 TO 03



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AON NEW ZEALAND
BULLER DISTRICT COUNCIL INFRASTRUCTURE NATURAL HAZARDS LOSS MODELLING
Overview Plan

FIGURE No. 29730.8000-01

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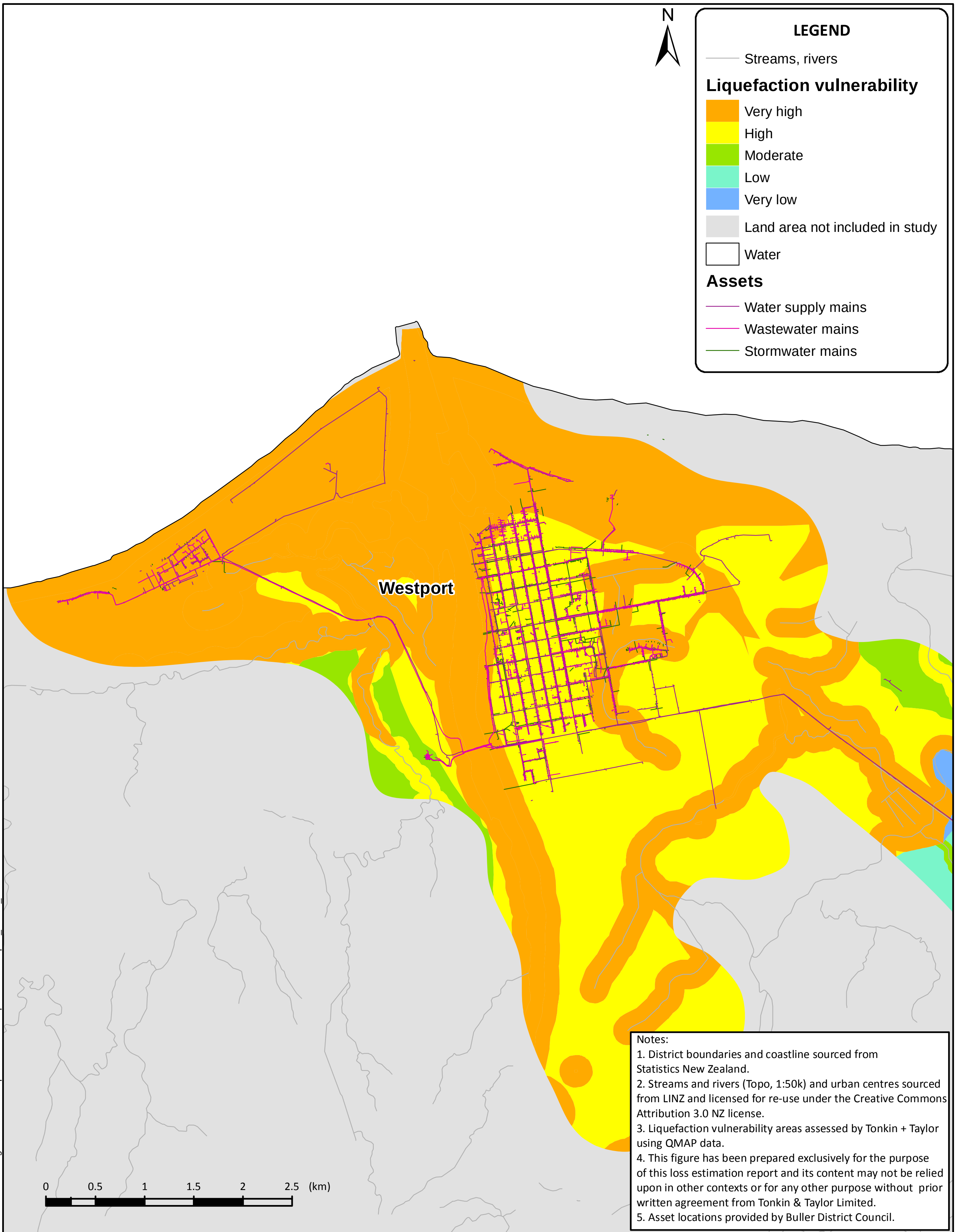

Notes:
1. District boundaries and coastline sourced from Statistics New Zealand.
2. Streams and rivers (Topo, 1:50k) and urban centres sourced from LINZ and licensed for re-use under the Creative Commons Attribution 3.0 NZ license.
3. Liquefaction vulnerability areas assessed by Tonkin + Taylor using QMAP data.
4. This figure has been prepared exclusively for the purpose of this loss estimation report and its content may not be relied upon in other contexts or for any other purpose without prior written agreement from Tonkin & Taylor Limited.
5. Asset locations provided by Buller District Council.

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AON NEW ZEALAND
BULLER DISTRICT COUNCIL INFRASTRUCTURE NATURAL HAZARDS LOSS MODELLING
Liquefaction Vulnerability Areas - Sheet 1

FIGURE No. 29730.8000-02

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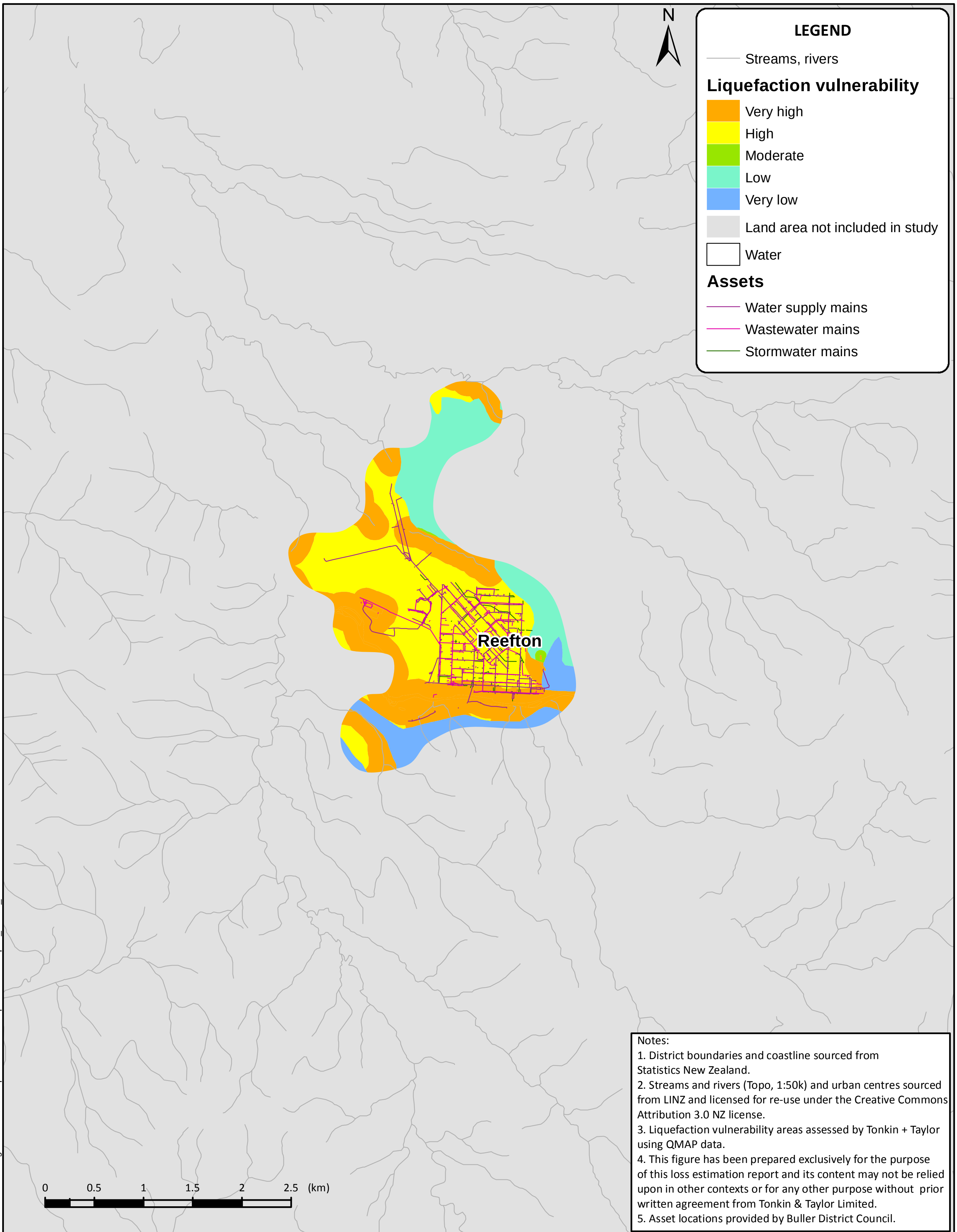

LEGEND

Streams, rivers

Liquefaction vulnerability

- Very high
- High
- Moderate
- Low
- Very low
- Land area not included in study
- Water

Assets

- Water supply mains
- Wastewater mains
- Stormwater mains

Notes:
1. District boundaries and coastline sourced from Statistics New Zealand.
2. Streams and rivers (Topo, 1:50k) and urban centres sourced from LINZ and licensed for re-use under the Creative Commons Attribution 3.0 NZ license.
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BULLER DISTRICT COUNCIL INFRASTRUCTURE
NATURAL HAZARDS LOSS MODELLING
Liquefaction Vulnerability Areas - Sheet 2

FIGURE No. 29730.8000-03

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