REPORT

Tonkin+Taylor

Summary Report: Automated Liquefaction Vulnerability Categories Mapping

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Natural Hazards Commission Toka Tū Ake
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Distribution:

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Table of contents

Executive summary

Liquefaction happens when loose, water-saturated soils temporarily lose their strength during a strong earthquake, which can cause the ground to weaken, crack, or behave like a liquid. This can damage buildings, roads, pipes, and other infrastructure.

The Automated Liquefaction Vulnerability Category (ALVC) map shows, at a national scale, where the ground across New Zealand is more or less likely to be affected by liquefaction during a strong earthquake. The map was produced by Tonkin + Taylor for the Natural Hazards Commission Toka Tū Ake (NHC) using a nationally consistent process (the National Liquefaction Model, version v2025.0). Land is classified into three categories: Liquefaction Damage is Unlikely, Liquefaction Damage is Possible, and Liquefaction Category is Undetermined (where uncertainty is too high to assign another category).

The map provides a national-scale overview intended to support community awareness and to help councils develop local liquefaction vulnerability maps following the 2017 Ministry of Business, Innovation and Employment and Ministry for the Environment's liquefaction guidance (the MBIE/MfE Guidance (2017)). The ALVC map is not suitable for decisions about individual properties, valuations, or insurance.

1 Introduction

1.1 Purpose of this report

This report explains the Automated Liquefaction Vulnerability Category (ALVC) map that is produced as part of the National Liquefaction Model (NLM) project. The map shows, in broad terms, where the ground may be more or less likely to be affected by liquefaction during a strong earthquake. It has been created using a nationally consistent process so that results can be compared across New Zealand and help communities, councils, and other users understand regional patterns of liquefaction risk. This report is intended for a general audience and provides an overview of what the ALVC map is. There is a companion technical report (Tonkin + Taylor, 2026) intended for people who may be using the ALVC mapping outputs to develop regional or district liquefaction vulnerability maps. The outputs described in this report are produced using the NLM model v2025.0. The NLM technical report (Tonkin + Taylor, 2026a) provides details on the NLM model.

1.2 What is liquefaction

Liquefaction happens when loose, water-saturated soils lose their strength during an earthquake. The shaking increases water pressure between soil particles, causing the ground to behave like a liquid for a short time. This can lead to ground settlement, cracking, or sideways movement, which in turn can damage buildings, roads, pipes, and other buried infrastructure. The key elements required for liquefaction to occur are summarised in Figure 1.1.

Liquefaction is more likely to occur in flat, low-lying areas near rivers, lakes or the coast, where sandy or silty soils and shallow groundwater are common. It does not occur everywhere—some materials, such as rock and dense gravel, are not prone to liquefaction.

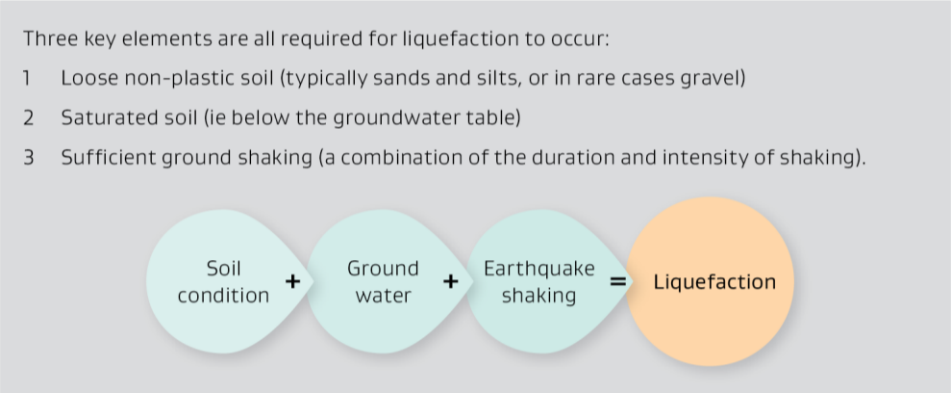

Figure 1.1: The key elements required for liquefaction, from MBIE/MfE Guidance (2017).

2 District- or regional-scale LVC maps

The Resource Management Act 1991 (RMA) requires an assessment of natural hazard risk to support applications for subdivision consent, and therefore there is a need for consenting authorities and applicants to understand whether that land is likely to be affected by liquefaction or not. The MBIE/MfE Guidance (2017) provides a nationally-consistent methodology to carry out liquefaction assessments, with a specific focus on RMA and Building Act 2004 aspects.

The MBIE/MfE Guidance (2017) is important because territorial authorities and regional councils had previously taken varying approaches to this assessment. From collated information to date, mapping has been undertaken for 46 of the 67 territorial authorities across New Zealand using criteria/categories consistent with the guidance. Some of these also have published information

about the interpretation of these maps to support the resource consent and building consent process. Of the remaining 21, 2 have no coverage, 6 only have partial coverage and 13 are produced using criteria/categories that are not consistent with the MBIE/MfE Guidance (2017). Most of these maps are produced at Level A (i.e. the lowest level of detail).

3 What the ALVC map shows

3.1 Liquefaction vulnerability categories

The ALVC map groups land into three broad liquefaction vulnerability categories (LVC) based on the inferred likelihood of liquefaction damage during a major earthquake:

- **Liquefaction Damage is Unlikely** – areas where the model suggests little or no liquefaction-related damage.
- **Liquefaction Damage is Possible** – areas where the model suggests liquefaction could occur, potentially causing some ground deformation.
- **Liquefaction Category is Undetermined** – areas where there is high uncertainty in the assignment of another liquefaction category, or existing district- or regional-scale LVC maps show an expected ground response that differs from the process followed here. Uncertainties considered in this analysis included spatial uncertainty and groundwater uncertainty. The source information and data attributions for each of the district- or regional-scale LVC maps are provided in Appendix A and Appendix B.

These categories follow the same definitions used in Table 1.1 of the MBIE/MfE Guidance (2017). They are intended for **broad planning and awareness**, not for detailed engineering design.

3.2 Example outputs and discussion

Figure 3.1 - Figure 3.3 show example outputs for Christchurch, Hawkes Bay and Wellington. Each region shows the 500-year return period earthquake shaking (Peak Ground Acceleration or PGA), the probability of minor-to-moderate land damage for 500-year return period earthquake shaking with median groundwater depth, and the final ALVC map.

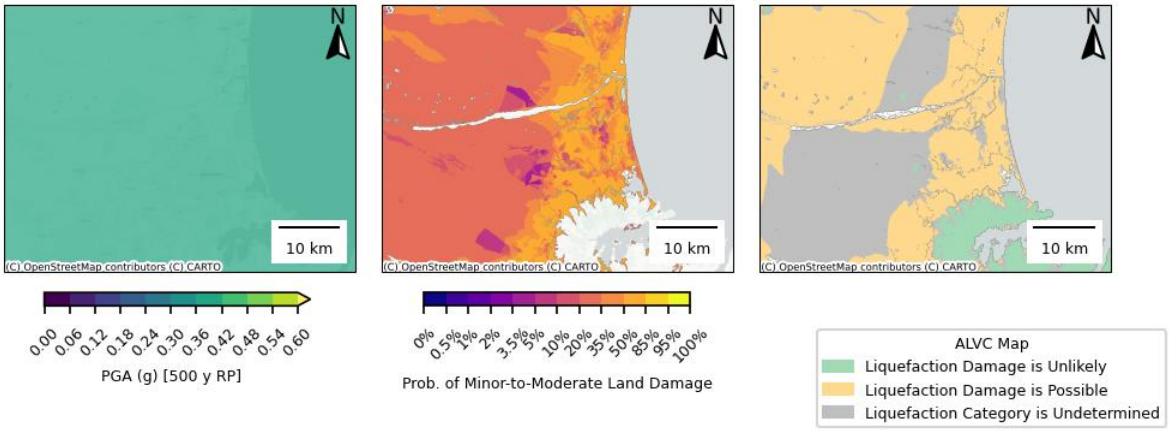

Figure 3.1: Christchurch areas: PGA map (left), Probability of land damage map (centre), ALVC map (right).

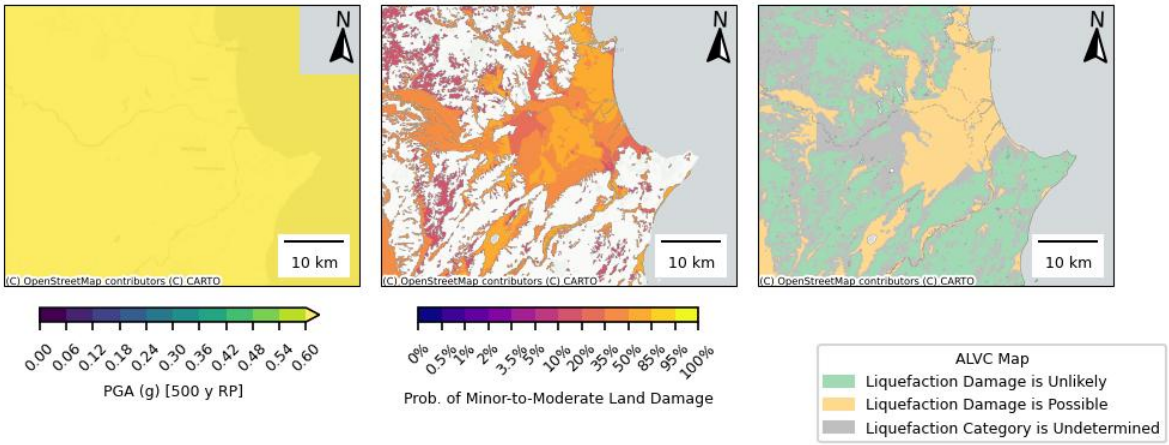

Figure 3.2: Hawkes Bay region: PGA map (left), probability of land damage map (centre), ALVC map (right).

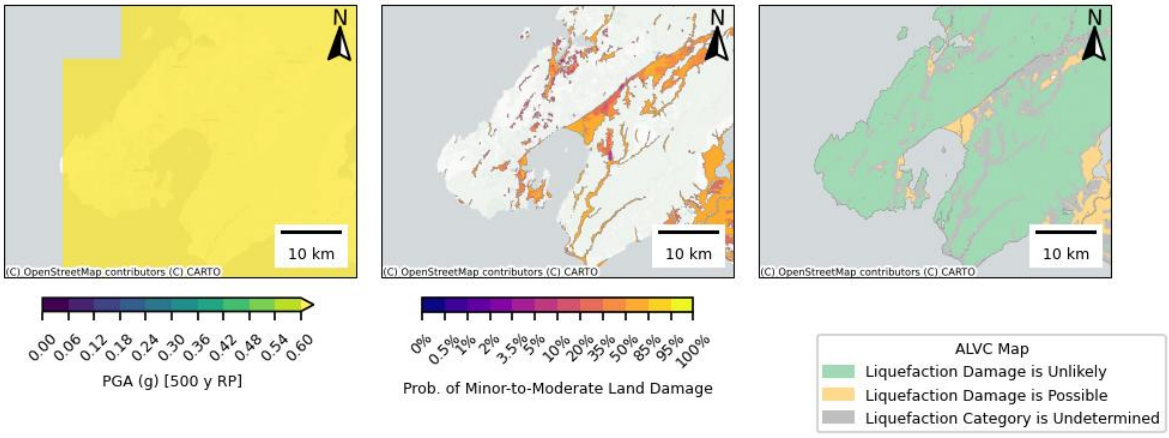

Figure 3.3: Wellington region: PGA map (left), probability of land damage map (centre), ALVC map (right).

The MBIE/MfE Guidance (2017) framework allows for different levels of precision to manage uncertainty, and in particular the assignment of ***Liquefaction Category is Undetermined*** in areas where there is a higher potential for misclassification due to a range of uncertainties.

However, the choice of when to assign ***Liquefaction Category is Undetermined*** within the ALVC map is not simple, primarily because the MBIE/MfE Guidance (2017) is written for regional-level mapping (e.g. recommendations regarding numbers of ground investigations within geomorphology units are

not directly applicable). Additionally, there are both benefits and drawbacks of assigning conclusive categories (e.g. it is informative to assign a category of ***Liquefaction Damage is Possible*** rather than ***Liquefaction Category is Undetermined***, but misclassification can be very unhelpful).

Simple thresholds are adopted within the ALVC mapping process, however, alternative thresholds could also be justified, and those thresholds should be tied into the broader risk management objectives relating to the intended use of the map.

4 Key limitations and recommendations

The following are key limitations and recommendations associated with the ALVC map:

1 The map depends on the NLM liquefaction vulnerability and groundwater models, the land-damage fragility curves, and the scenario-output processes. All limitations outlined in the NLM technical report (Sections 8.9, 9.5, 10.5, and 11.4) also apply. The map is based on a simplified liquefaction assessment that uses binary thresholds to represent uncertainties, which may not reflect the full range of real-world variability. The probability of damage from the NLM does not include liquefaction-induced lateral spreading.

2 The ALVC map is not the same as district- or regional-scale Liquefaction Vulnerability Category (LVC) maps refined by local authorities under the MBIE/MfE Guidance (2017). They may differ especially where additional ground investigation data or expert interpretation has been used. The ALVC mapping process does not include local knowledge, site walkovers, ground-truthing, or stakeholder consultation, which are essential parts of the MBIE/MfE (2017) methodology.

3 The map handles uncertainty through binary classifications, such as whether Liquefaction Category is Undetermined. While this makes the results transparent and easy to interpret, it oversimplifies relationships between inputs and can cause sharp changes in categories from minor variations in data.

4 The map is created at a 100-metre grid spacing. Parameters are sampled at the centre of each raster and extended to fill the cell, meaning locations near the NLM liquefaction vulnerability model polygon boundaries may inherit values from adjacent areas. Spatial uncertainty in the liquefaction vulnerability model can be 2–3 km, particularly in areas with limited ground investigations.

5 The assessment of land-damage probability uses seismic demands from Draft TS 1170.5 (Standards New Zealand, 2024) for a 500-year return period and Site Class V (soft or loose soil). Sensitivity to other return periods or site classes has not been assessed.

6 The scenario outputs may double-count uncertainty in the calculation of the probability of land damage, as described in Section 11.1 of the NLM technical report. This can lead to overestimation of land-damage probabilities at low probability values, particularly in areas with higher uncertainty.

7 The ALVC map does not replace site-specific assessments required for subdivision, building, or engineering design. It is not suitable for property-specific decisions, valuations, or insurance pricing. The map should always be interpreted alongside local hazard information and professional expert advice.

5 Potential future improvements

Potential future opportunities, based on insights from developing the NLM and the ALVC map described in this report, include:

1 **Collate additional remaining district- or regional-scale LVC maps**. Some district- or regional-scale LVC maps are currently under development or could not be easily obtained. Following up with councils to obtain these maps could improve the consideration of local context and knowledge.

2 **Multiple land damage measures.** Obtain the probability of land damage from multiple land damage measures (i.e., not only the liquefaction severity number, LSN). This approach is often applied during development of the existing district- or regional-scale LVC maps as it helps to mitigate some of the limitations of LSN.

3 **Lateral spreading.** Extend the NLM and ALVC map to consider liquefaction-induced lateral spreading.

4 **Regular updates.** Provide regular updates of the ALVC map as the NLM model is updated.

6 References

MBIE/MfE. (2017). *Planning and engineering guidance for potentially liquefaction-prone land: Resource Management Act and Building Act aspects* (Rev 0.1). Ministry of Business, Innovation & Employment. https://www.building.govt.nz/assets/Uploads/building-code-compliance/b-stability/b1-structure/planning-engineering-liquefaction.pdf

Standards New Zealand. (2024). *TS1170.5 Public consultation Draft—Structural design actions Part 5: Earthquake actions—New Zealand* (DZ TS 1170.5:2024). https://consultations.standards.govt.nz/draft-standards/ts1170-5-public-consultation/user_uploads/20240215-ts-1170.5---public-comment-draft_v2.pdf

Tonkin + Taylor. (2026a). *National Liquefaction Model—Final Technical Report* (V5.1; p. 293). https://nzlm.co.nz

Tonkin + Taylor. (2026b). *Technical information about the Automated Liquefaction Vulnerability Categories Mapping* (No. V1). Natural Hazards Commission.

7 Applicability

This report has been prepared for the exclusive use of our client Natural Hazards Commission Toka Tū Ake, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

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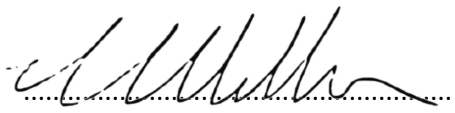

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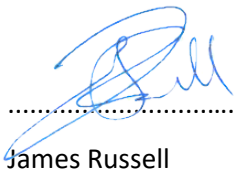

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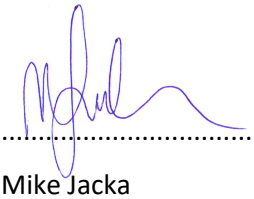

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Expertise Director - Geotechnical

21-May-26
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Appendix A Existing district- or regional-scale LVC maps

Location	Commissioned or produced by	Level	External Link
Far North	Far North District Council (2023)	A	https://experience.arcgis.com/experience/df5f99f47450498f978166472b3500eb/page/Page?views=Hazards
Whangarei	Whangarei District Council (2020)	A	https://www.arcgis.com/apps/mapviewer/index.html?url=https://geo.wdc.govt.nz/server/rest/services/Liquefaction/MapServer&source=sd
Auckland	Auckland Council (2021)	A	https://data-aucklandcouncil.opendata.arcgis.com/datasets/aucklandcouncil::liquefaction-vulnerability-basic-assessment-1/explore
Hamilton	Hamilton City Council (2019)	B	
Waikato	Waikato Regional Council (2021)	A	https://data-waikatolass.opendata.arcgis.com/datasets/waikatoregion::waikato-liquefaction-level-a/explore
New Plymouth	New Plymouth District Council (2021)	A	https://experience.arcgis.com/experience/754cda6a13374346b0afa822519f1cd4
Bay of Plenty	Bay of Plenty Regional Council (2021)	A	https://maps.boprc.govt.nz/datasets/bay-hazards-liquefaction/explore
Mount Maunganui	Tauranga City Council (2020)	B/C	https://gis.tauranga.govt.nz/liquefaction/
Tauranga	Tauranga City Council (2020)	A/B	https://maps.boprc.govt.nz/datasets/bay-hazards-liquefaction/explore?location=-38.228492%2C176.921147%2C9.58
Gisborne	Gisborne District Council (2015)	Different	https://geoportal-gizzy.opendata.arcgis.com/datasets/land-areas-susceptible-to-liquefaction-/explore
Hawkes Bay	Hawke's Bay Regional Council (2017)	Different	https://hbrcopendata-hbrc.opendata.arcgis.com/datasets/8c0b6f4f66fd492fb5b231e57410435a_0/explore
Napier	Hawke's Bay Regional Council (2017)	Different	https://hbrcopendata-hbrc.opendata.arcgis.com/datasets/53a60e8296764f879eed707bee61fd0b_4/about
Horowhenua	Horowhenua District Council (2023)	B	https://www.horowhenua.govt.nz/files/assets/public/v/1/building-consents/hdc-options-for-liquefaction-assessment-in-the-horowhenua-district-june-2023.pdf
Manawatu-Whanganui	Horizons Regional Council (2015)	Different	https://experience.arcgis.com/experience/3f7b4ec2f6f14503af1146ce412de39e/page/Liquefaction
Wairarapa	Greater Wellington Regional Council (2018)	A	

Location	Commissioned or produced by	Level	External Link
Wellington	Greater Wellington Regional Council (2018)	Different	https://opendata.gw.govt.nz/datasets/GWRC::wellington-region-liquefaction-potential/explore
Palmerston North	Palmerston North City Council (2011)	B	
Tararua	Tasman District Council (2021)	A	https://storymaps.arcgis.com/stories/50eb39cb250542388e77329bf2c0c2ae
Nelson	Nelson City Council (2021)	A	https://experience.arcgis.com/experience/4854afe0019e43c9adb51723d78a28db
Tahunanui	Nelson City Council (2013)	B	https://experience.arcgis.com/experience/4854afe0019e43c9adb51723d78a28db
Marlborough	Marlborough District Council (2021)	A/B	https://smartmaps.marlborough.govt.nz/smapviewer/?map=f94aa3aaff0a4d6eb4da7298f412e8f8
Tasman	Tasman District Council (2021)	A	https://tdc.maps.arcgis.com/apps/webappviewer/index.html?id=819fd6f518b9467d88293a732f063ac4%20
Kaikoura	Kaikoura District Council & Environment Canterbury (2019)	A	https://opendata.canterburymaps.govt.nz/maps/23e01f789514469198a0fd937da0a40b
West Coast	West Coast Regional Council (2021)	A	https://www.arcgis.com/home/item.html?id=fcbbe03a9cd34aeba65b6e5b1fcfe1b7
Eastern Canterbury	Environment Canterbury (2012)	A	https://opendata.canterburymaps.govt.nz/datasets/a1d1e268681f4f9896b551b26a6e8bbc_3/
Christchurch	Christchurch City Council (2020)	A/B/C	https://opendata-christchurchcity.hub.arcgis.com/datasets/ChristchurchCity::liquefaction-vulnerability-opendata/explore
Ashburton	Environment Canterbury (2024)	A	https://opendata.canterburymaps.govt.nz/maps/1588bc2547764146ba5cf3ed192862c7
Timaru	Environment Canterbury (2013)	Unsure	https://opendata.canterburymaps.govt.nz/maps/2fcc5cc506214648b86743338fda3489
Mackenzie	Environment Canterbury (2023)	A	https://opendata.canterburymaps.govt.nz/maps/62581b83eef949c485ac7923d6df98e0
Waimate	Waimate District Council (2022)	A	https://opendata.canterburymaps.govt.nz/maps/f22756fbb4f04ec3ac4d370abbf0087d

Location	Commissioned or produced by	Level	External Link
Waitaki	Environment Canterbury (2020)	A	https://www.arcgis.com/apps/mapviewer/index.html?layers=34db4f0f4e294d7289ae1adc2ed9c3ab
Otago	Otago Regional Council (2019)	A	https://www.arcgis.com/apps/mapviewer/index.html?layers=712447df3b3d4489944f5044fd6d7de8
Invercargill	Invercargill City Council (2022)	A	https://www.icc.govt.nz/repository/libraries/id:2swc6cbtp1cxby8vraxn/hierarchy/assets/rates-building-and-property/liquefaction/Appendix_FIGB1.pdf
Glenorchy	Otago Regional Council (2022)	C	
Southland	Southland Regional Council (2012)	A?	https://data-esgis.opendata.arcgis.com/datasets/esgis::southland-liquefaction-risk-2006-2012/explore

Appendix B Third Party Data Attributions

1 Existing local map for Far North was provided by Far North District Council. Licensed under Creative Commons Attribution 4.0 International (CC BY 4.0). Accessed from https://experience.arcgis.com/experience/df5f99f47450498f978166472b3500eb/page/Page?views=Hazards

2 Existing local map for Whangarei was provided by Tonkin + Taylor. Can be accessed from https://www.arcgis.com/apps/mapviewer/index.html?url=https://geo.wdc.govt.nz/server/rest/services/Liquefaction/MapServer&source=sd

3 Existing local map for Auckland was provided by Auckland Council. Licensed under Creative Commons Attribution 4.0 International (CC BY 4.0). Accessed from https://data-aucklandcouncil.opendata.arcgis.com/datasets/aucklandcouncil::liquefaction-vulnerability-basic-assessment-1/explore

4 Existing local map for Hamilton was provided by Tonkin + Taylor.

5 Existing local map for Waikato was accessed from https://data-waikatolass.opendata.arcgis.com/datasets/waikatoregion::waikato-liquefaction-level-a/explore with permission from Waikato Regional Council for use in the ALVC map.

6 Existing local map for New Plymouth was provided by Tonkin + Taylor. Can be accessed from https://experience.arcgis.com/experience/754cda6a13374346b0afa822519f1cd4

7 Existing local map for Bay of Plenty was obtained from the Bay of Plenty Regional Council website. Licensed under Creative Commons Attribution 4.0 International (CC BY 4.0). Can be accessed from https://maps.boprc.govt.nz/datasets/bay-hazards-liquefaction/explore

8 Existing local map for Mount Maunganui was provided by Tonkin + Taylor. Can be accessed from https://gis.tauranga.govt.nz/liquefaction/

9 Existing local map for Tauranga was obtained from the Bay of Plenty Regional Council website. Licensed under Creative Commons Attribution 4.0 International (CC BY 4.0). Can be accessed from https://maps.boprc.govt.nz/datasets/bay-hazards-liquefaction/explore?location=-38.228492%2C176.921147%2C9.58

10 Existing local map for Gisborne was provided by Gisborne District Council. Licensed under Creative Commons Attribution 4.0 International (CC BY 4.0). Accessed from https://geoportal-gizzy.opendata.arcgis.com/datasets/land-areas-susceptible-to-liquefaction-/explore

11 Existing local map for Hawkes Bay was provided by Tonkin + Taylor. Can be accessed from https://hbrcopendata-hbrc.opendata.arcgis.com/datasets/8c0b6f4f66fd492fb5b231e57410435a_0/explore

12 Existing local map for Napier was provided by Tonkin + Taylor. Can be accessed from https://hbrcopendata-hbrc.opendata.arcgis.com/datasets/53a60e8296764f879eed707bee61fd0b_4/about

13 Existing local map for Horowhenua was provided by Tonkin + Taylor. Can be accessed from https://www.horowhenua.govt.nz/files/assets/public/v/1/building-consents/hdc-options-for-liquefaction-assessment-in-the-horowhenua-district-june-2023.pdf

14 Existing local map for Manawatu-Whanganui was obtained from Horizons Regional Council with permission. Accessed from https://experience.arcgis.com/experience/3f7b4ec2f6f14503af1146ce412de39e/page/Liquefaction

15 Existing local map for Wairarapa was provided by Tonkin + Taylor.

16 Existing local map for Wellington was provided by Greater Wellington Regional Council with permission. Accessed from https://opendata.gw.govt.nz/datasets/GWRC::wellington-region-liquefaction-potential/explore

17 Existing local map for Palmerston North was provided by Tonkin + Taylor.

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21 Existing local map for Marlborough was provided by Marlborough District Council. Accessed from https://smartmaps.marlborough.govt.nz/smapviewer/?map=f94aa3aaff0a4d6eb4da7298f412e8f8

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23 Existing local map for Kaikoura was provided by Kaikoura District Council & Environment Canterbury. Accessed from https://opendata.canterburymaps.govt.nz/maps/23e01f789514469198a0fd937da0a40b

24 Existing local map for West Coast was provided by West Coast Regional Council. Accessed from https://www.arcgis.com/home/item.html?id=fcbbe03a9cd34aeba65b6e5b1fcfe1b7

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26 Existing local map for Christchurch was provided by Tonkin + Taylor. Licensed under Creative Commons Attribution 4.0 International (CC BY 4.0). Can be accessed from https://opendata-christchurchcity.hub.arcgis.com/datasets/ChristchurchCity::liquefaction-vulnerability-opendata/explore

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32 Existing local map for Otago was provided by Otago Regional Council. Accessed from https://www.arcgis.com/apps/mapviewer/index.html?layers=712447df3b3d4489944f5044fd6d7de8

33 Existing local map for Invercargill was provided by Tonkin + Taylor. Can be accessed from https://www.icc.govt.nz/repository/libraries/id:2swc6cbtp1cxby8vraxn/hierarchy/assets/rates-building-and-property/liquefaction/Appendix_FIGB1.pdf

34 Existing local map for Glenorchy was provided by Tonkin + Taylor.

35 Existing local map for Southland was provided by Southland Regional Council. Licensed under Creative Commons Attribution 4.0 International (CC BY 4.0). Accessed from https://data-esgis.opendata.arcgis.com/datasets/esgis::southland-liquefaction-risk-2006-2012/explore