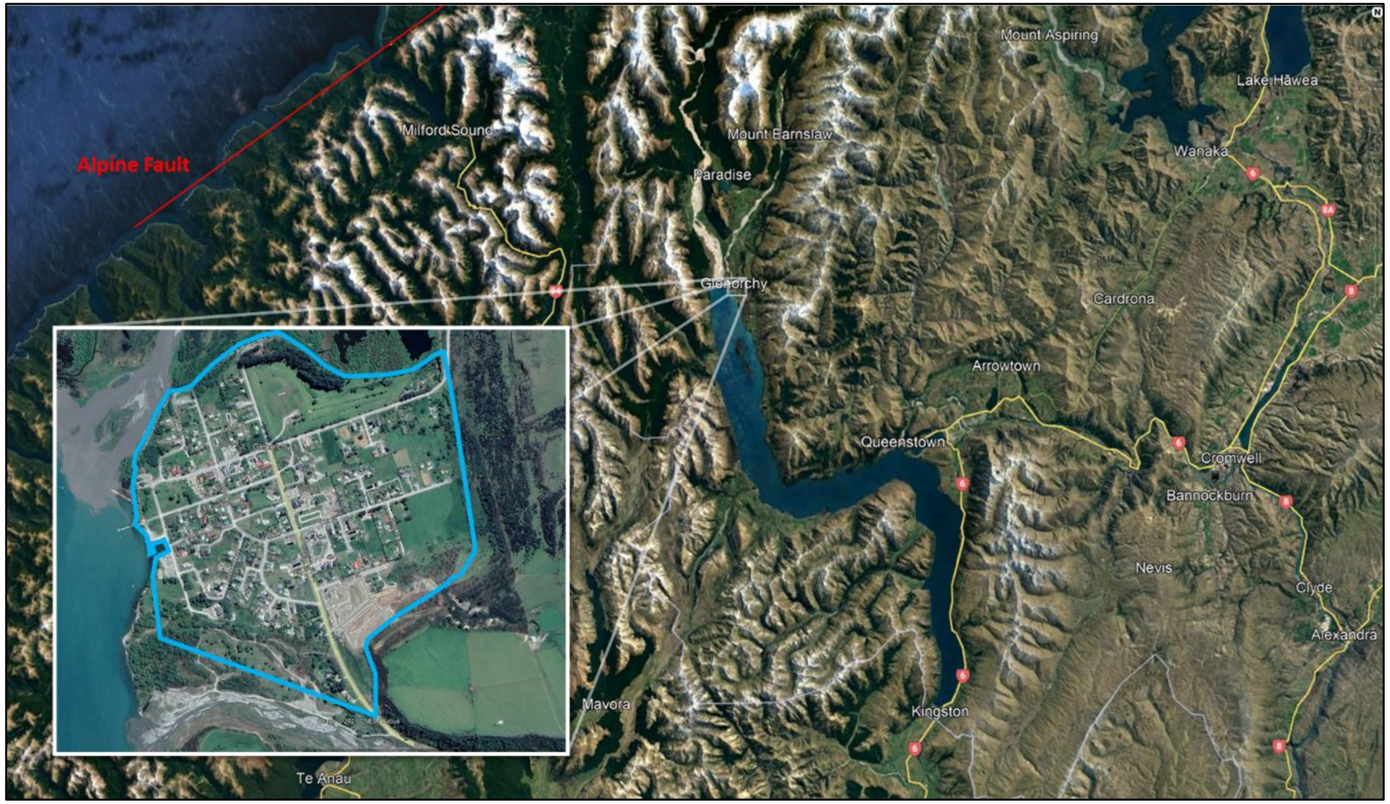
Glenorchy Liquefaction Vulnerability Assessment



By Dr Sjoerd van Ballegooy & Eric Bird & Nathan McDougal

Undertaken for Otago Regional Council

Peer Reviewed by Frederick Wentz

Tonkin+Taylor

Otago Regional Council

WENTZ-PACIFIC GEOTECHNICAL ENGINEERS

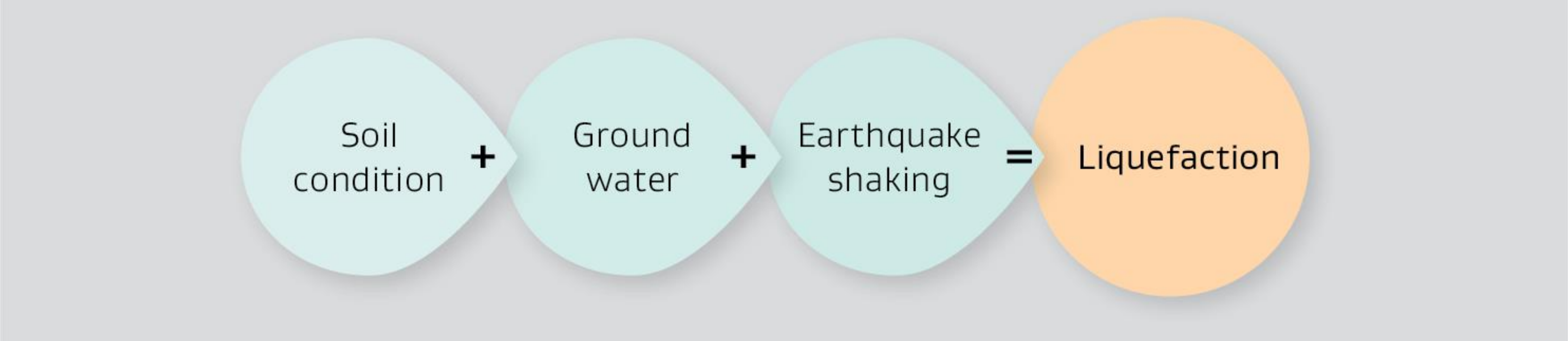
When and How Does Liquefaction Occur?

Three key elements are all required for liquefaction to occur

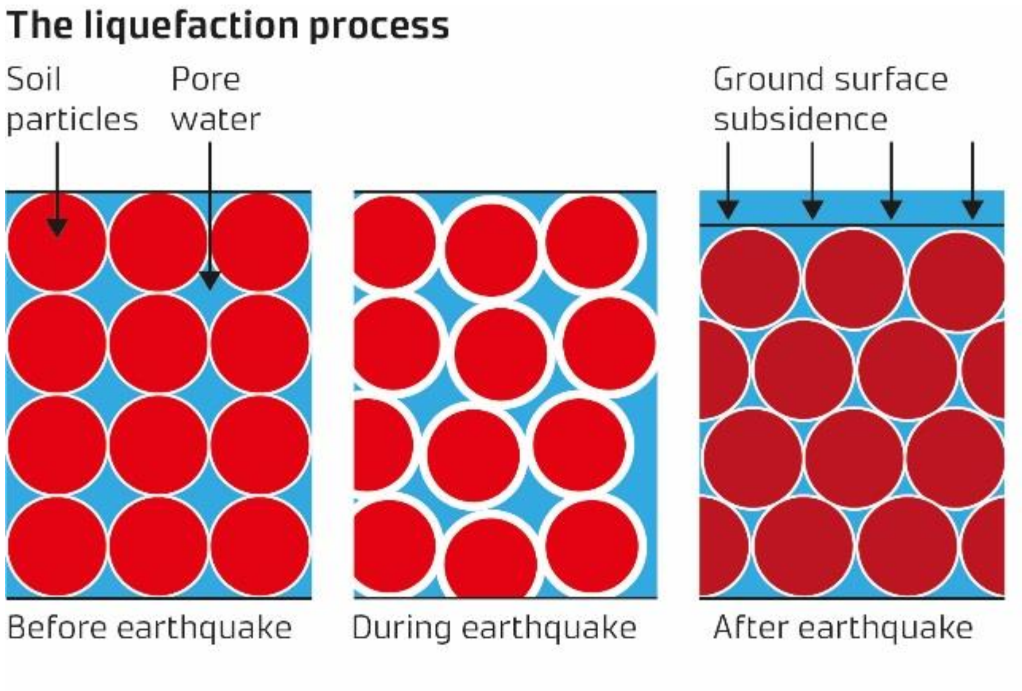
1: Soil condition: Non-plastic, “Loose” *(can include medium-dense)*

2: Saturated *(below groundwater table)*

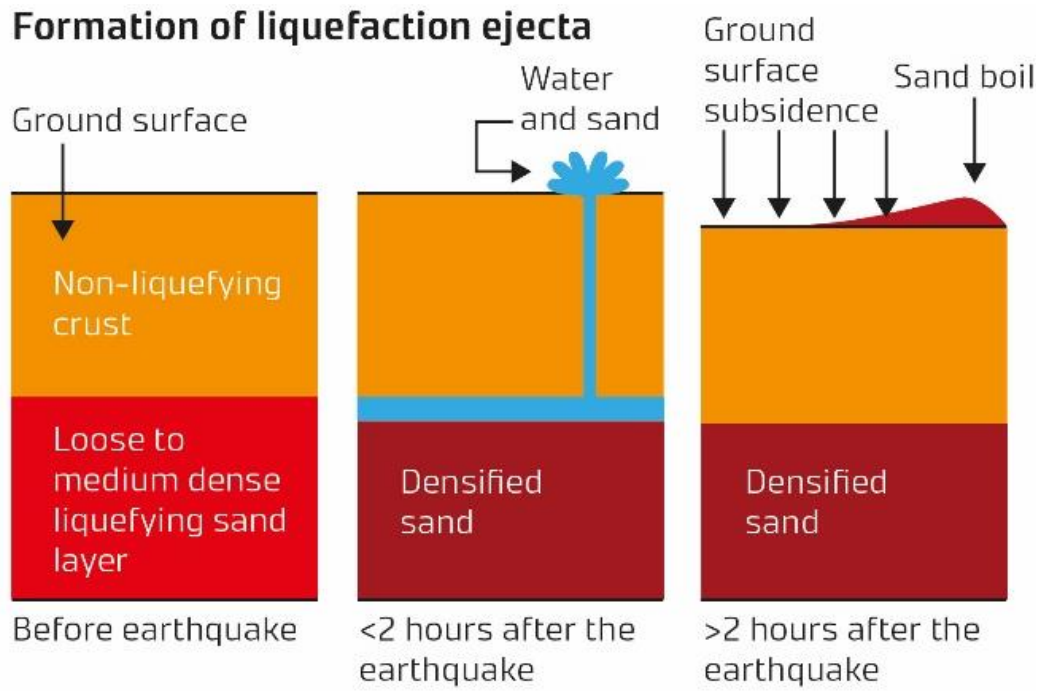
3: Sufficient ground shaking *(combination of duration and intensity)*



What is Liquefaction?



Soil losses strength and stiffness

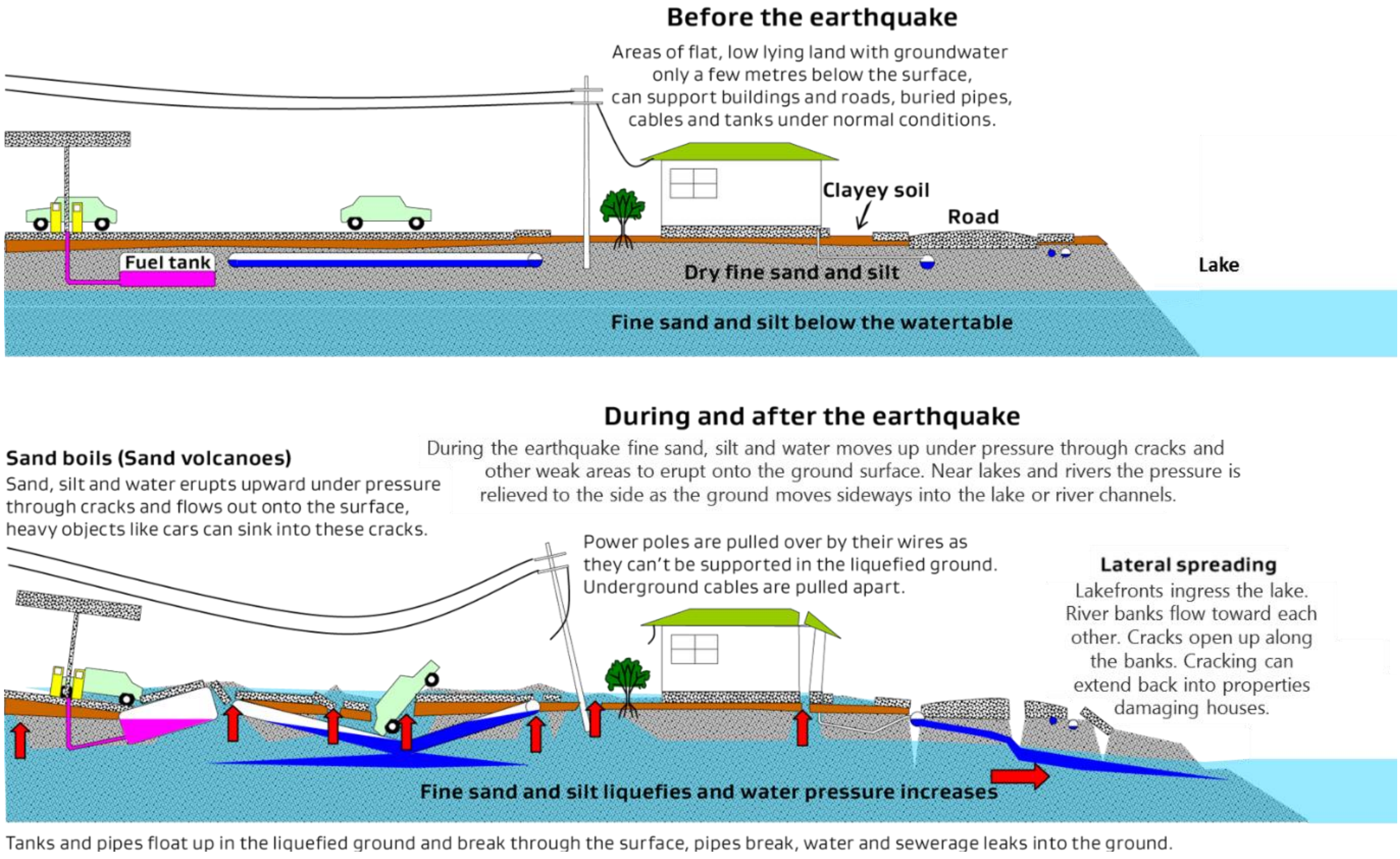


Significant quantities of water and sediment come out of the ground

What is Liquefaction?

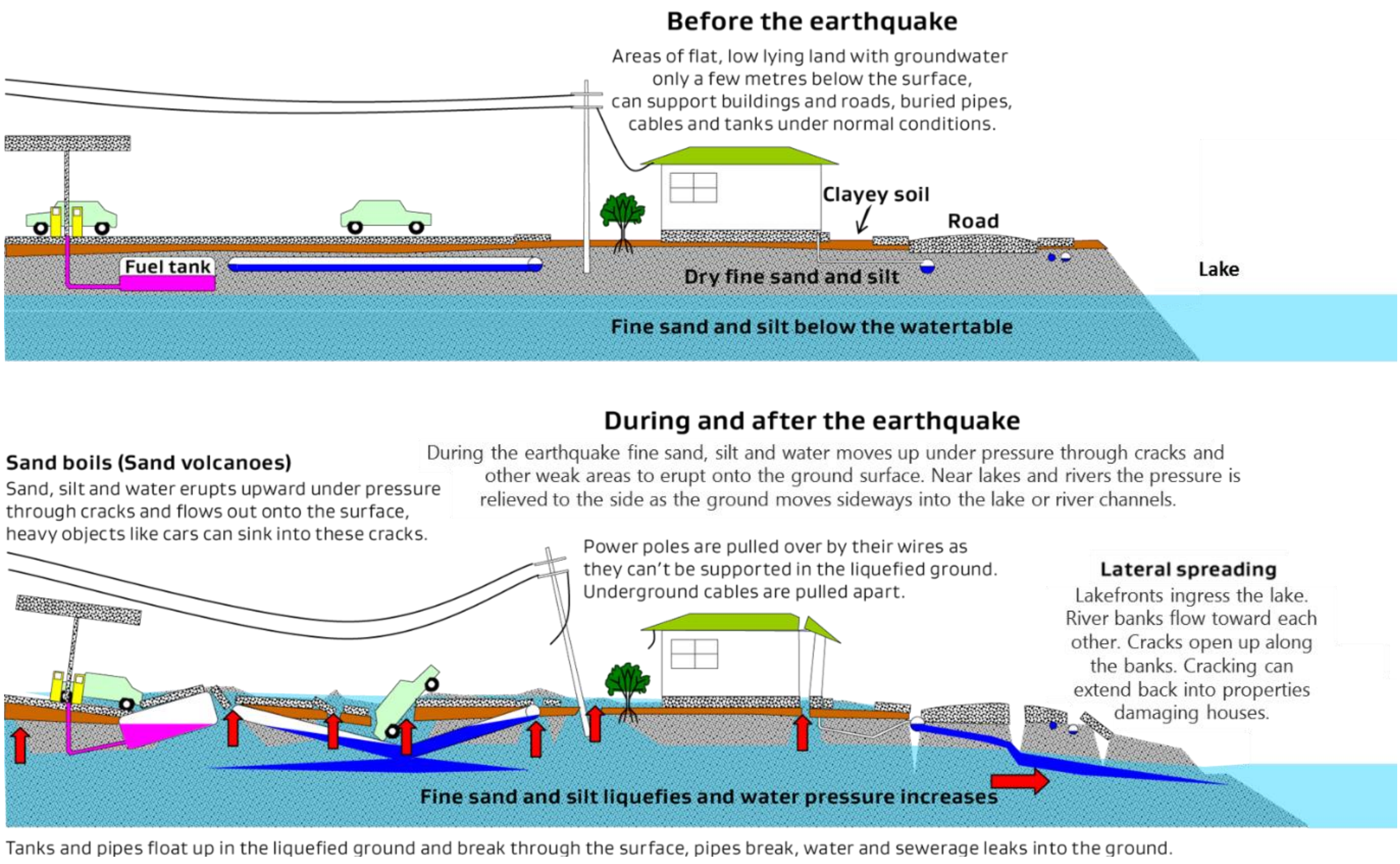
What are the Consequences of Liquefaction?

1. Differential settlement of the ground surface causing damage to buildings, buried pipes and roads



What are the Consequences of Liquefaction?

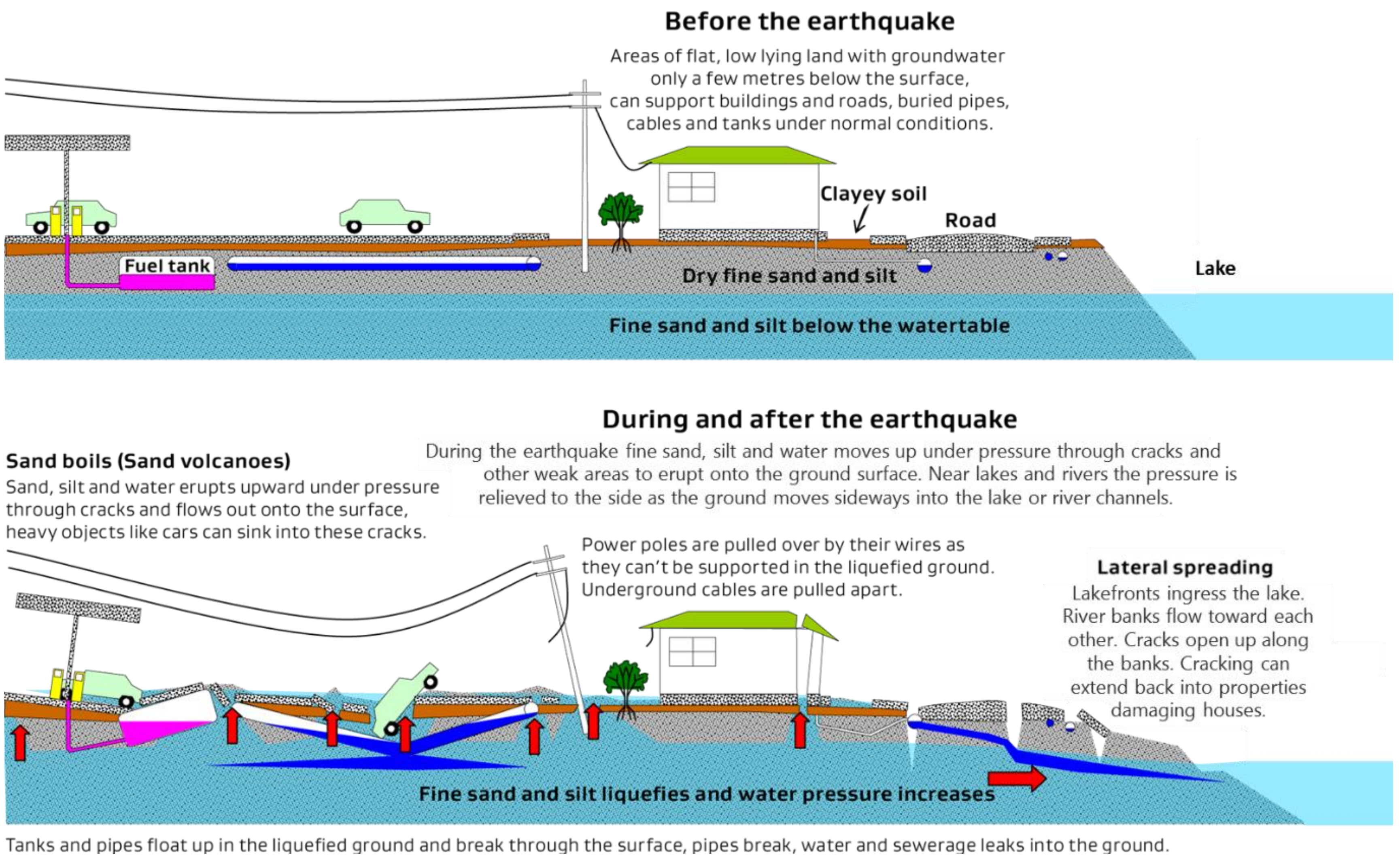
1. Differential settlement of the ground surface causing damage to buildings, buried pipes and roads
2. Heavy objects sink (such as buildings and power transformers)




TOYOTA

What are the Consequences of Liquefaction?

1. Differential settlement of the ground surface causing damage to buildings, buried pipes and roads
2. Heavy objects sink (such as buildings and power transformers)
3. Light objects float (such as manholes and underground fuel tanks)

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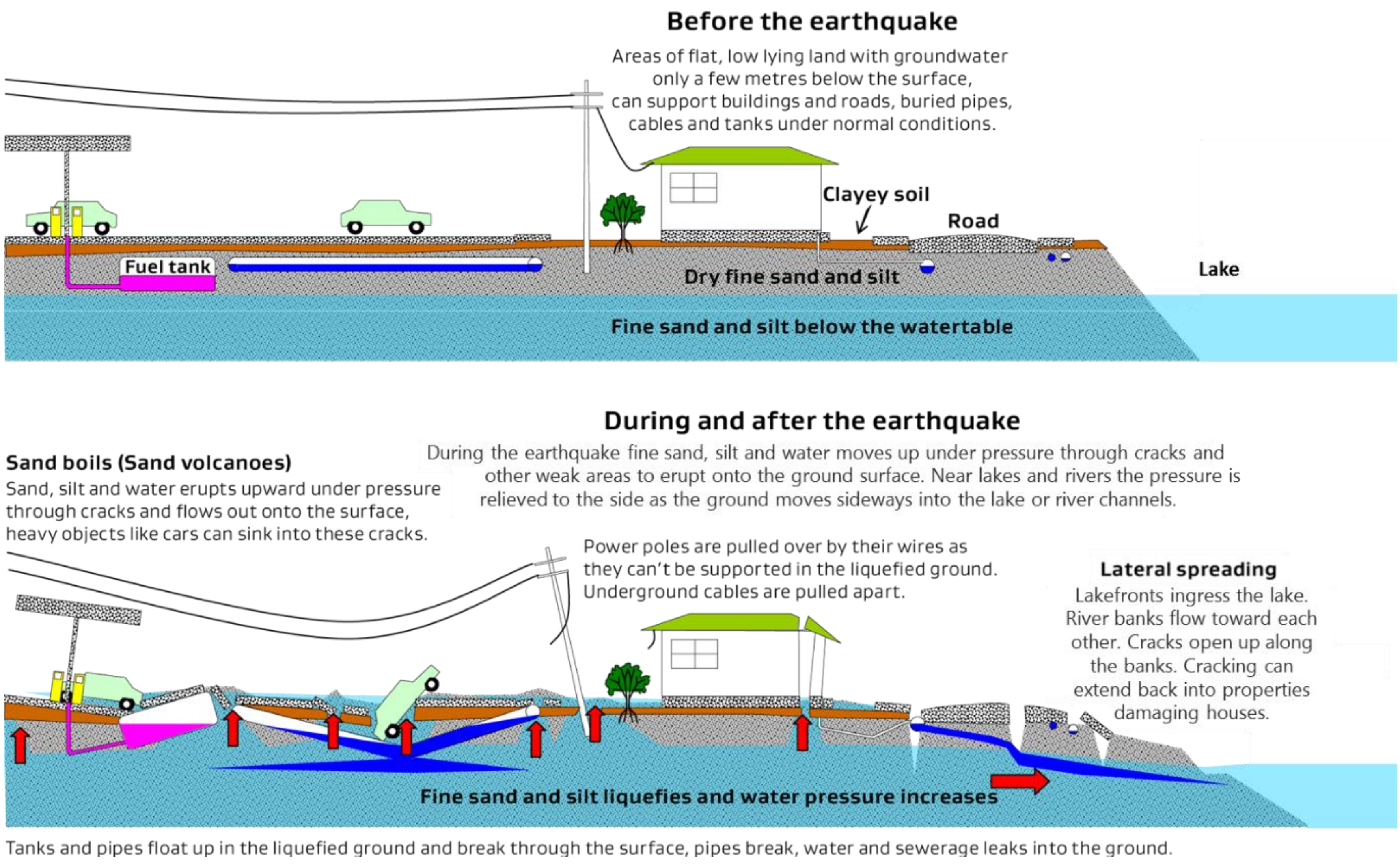

4. Buildings, underground pipes & cables and roads are pulled apart


ROAD
CLOSED




What are the Consequences of Liquefaction?

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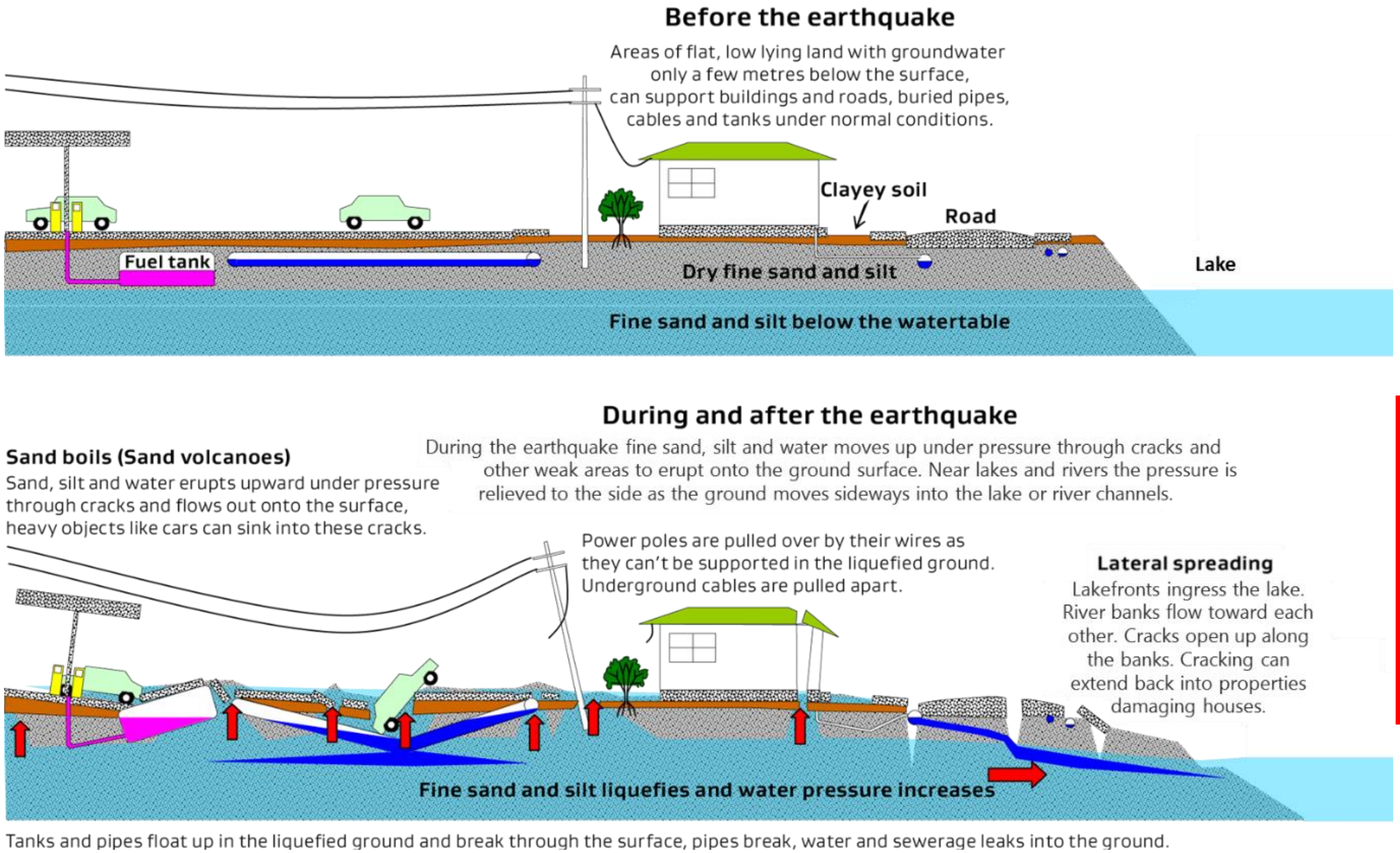
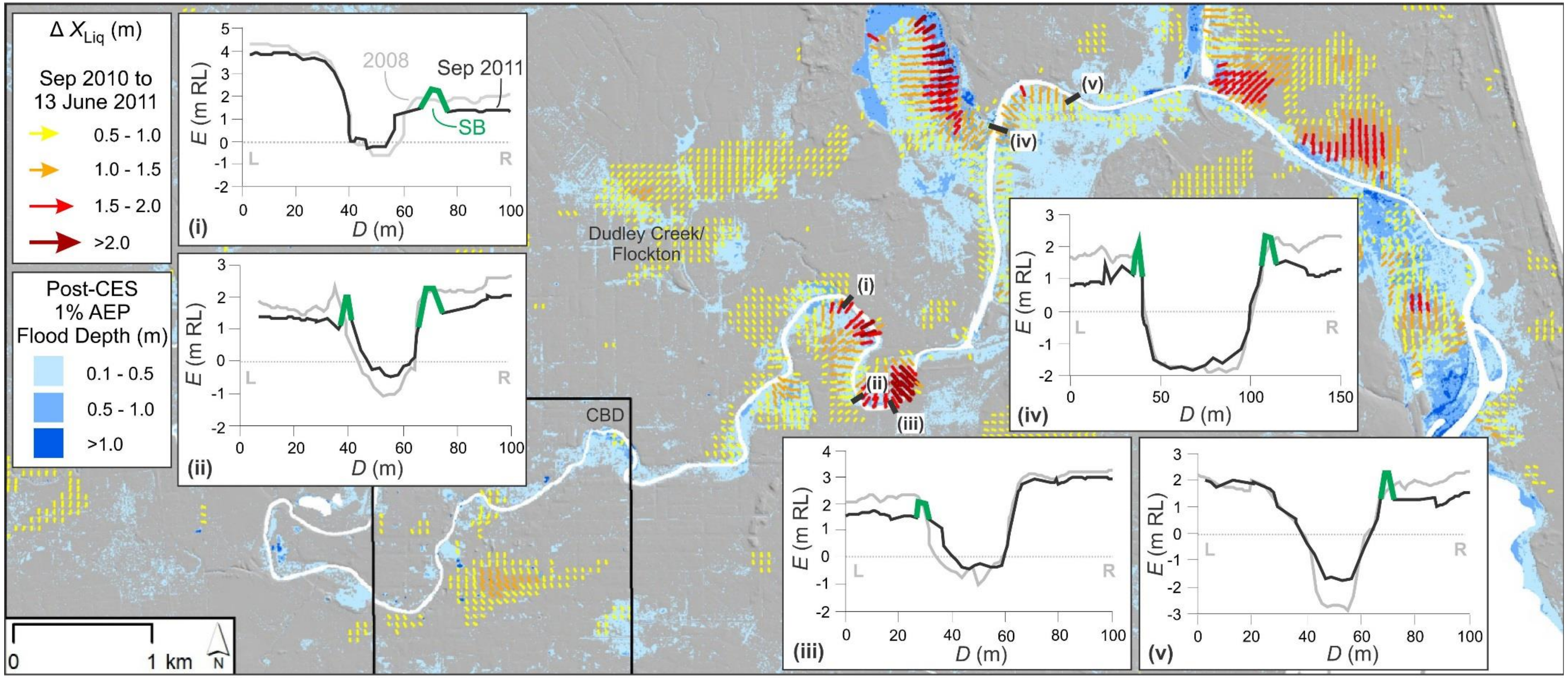
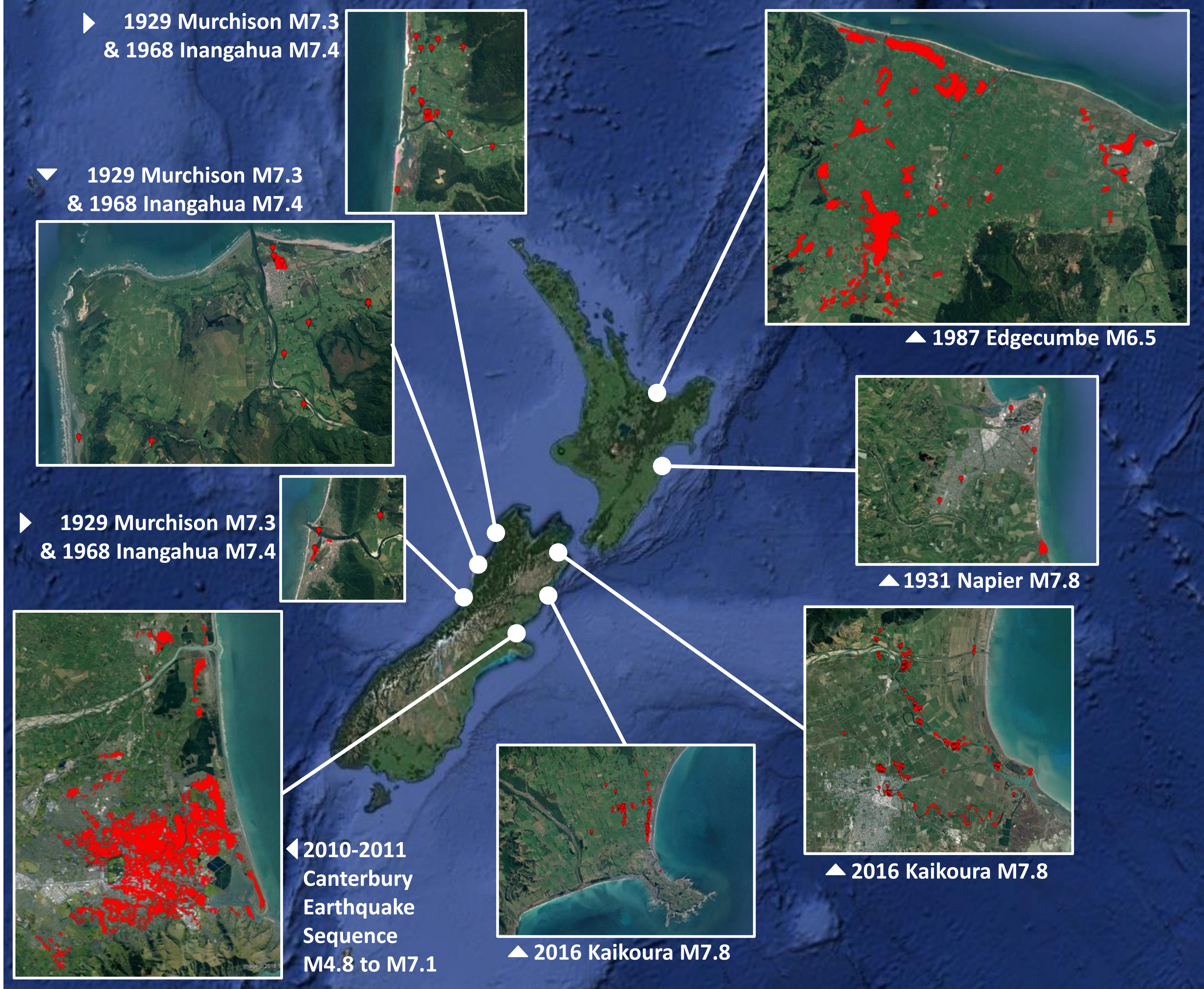


4. Buildings, underground pipes & cables and roads are pulled apart
5. Significant ground surface subsidence (0.5m to 1m) making low lying areas more flood prone

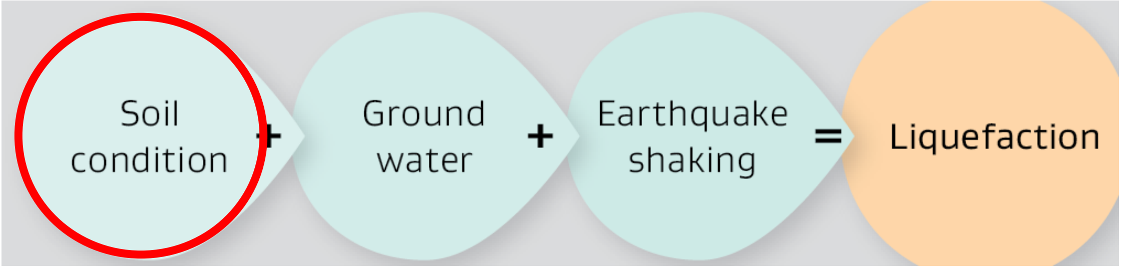
Exacerbated Flooding (Pre Sept 2010 – Post Dec 2011)



Observed Liquefaction from the last 100 years of earthquakes in New Zealand

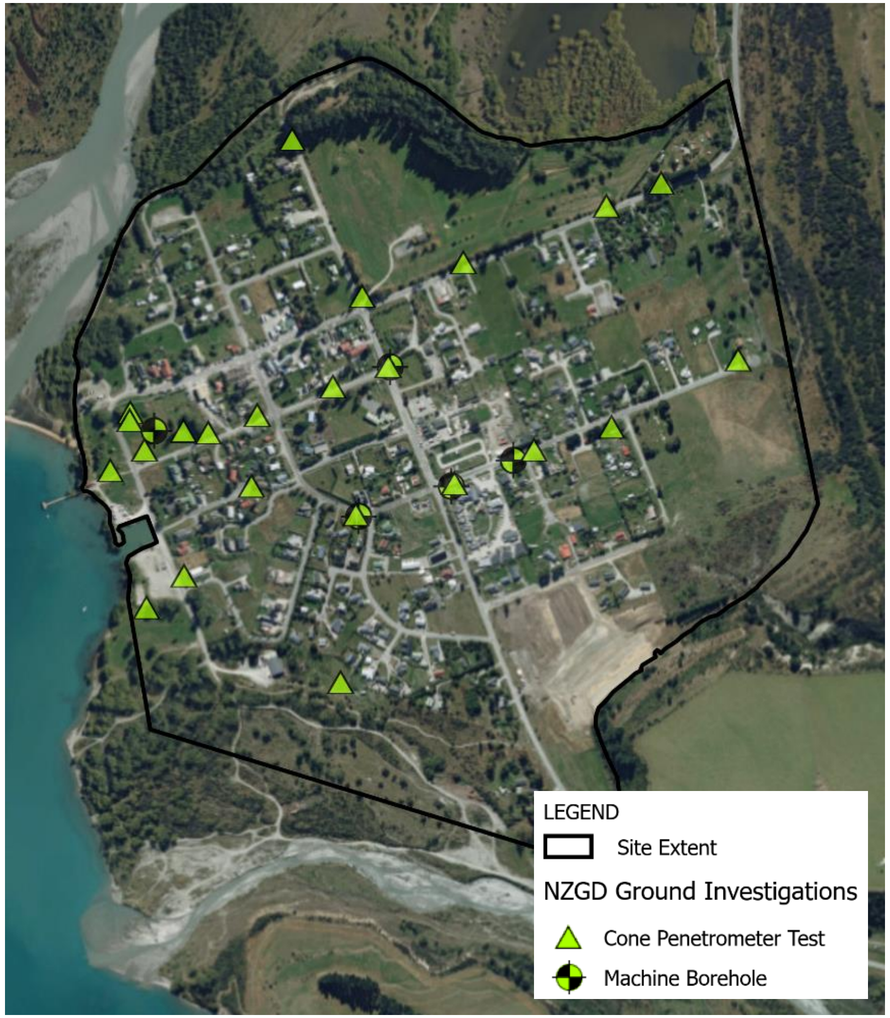


Glenorchy Liquefaction Assessment

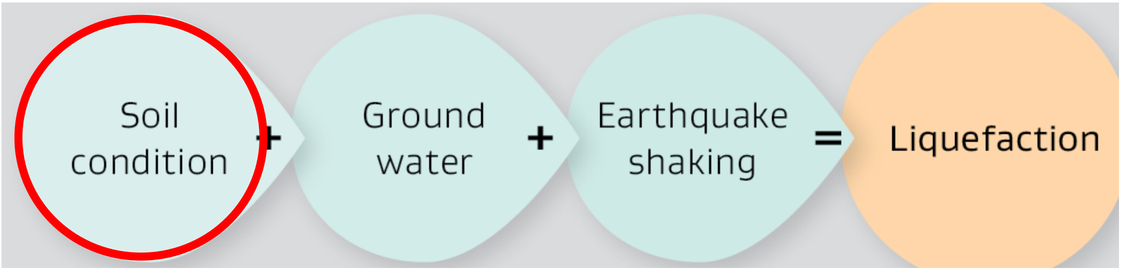


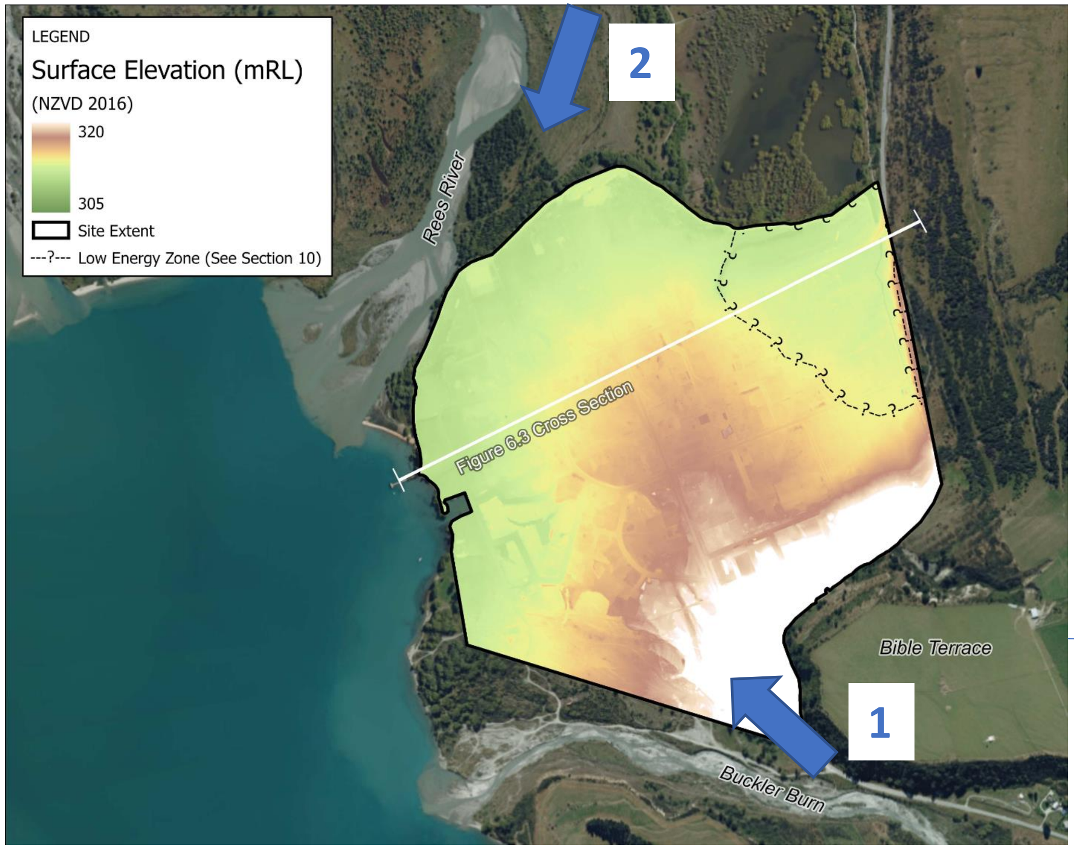
10-16 October 2021

- 19 Cone Penetration Tests (CPT)
- 4 Machine Drilled Boreholes

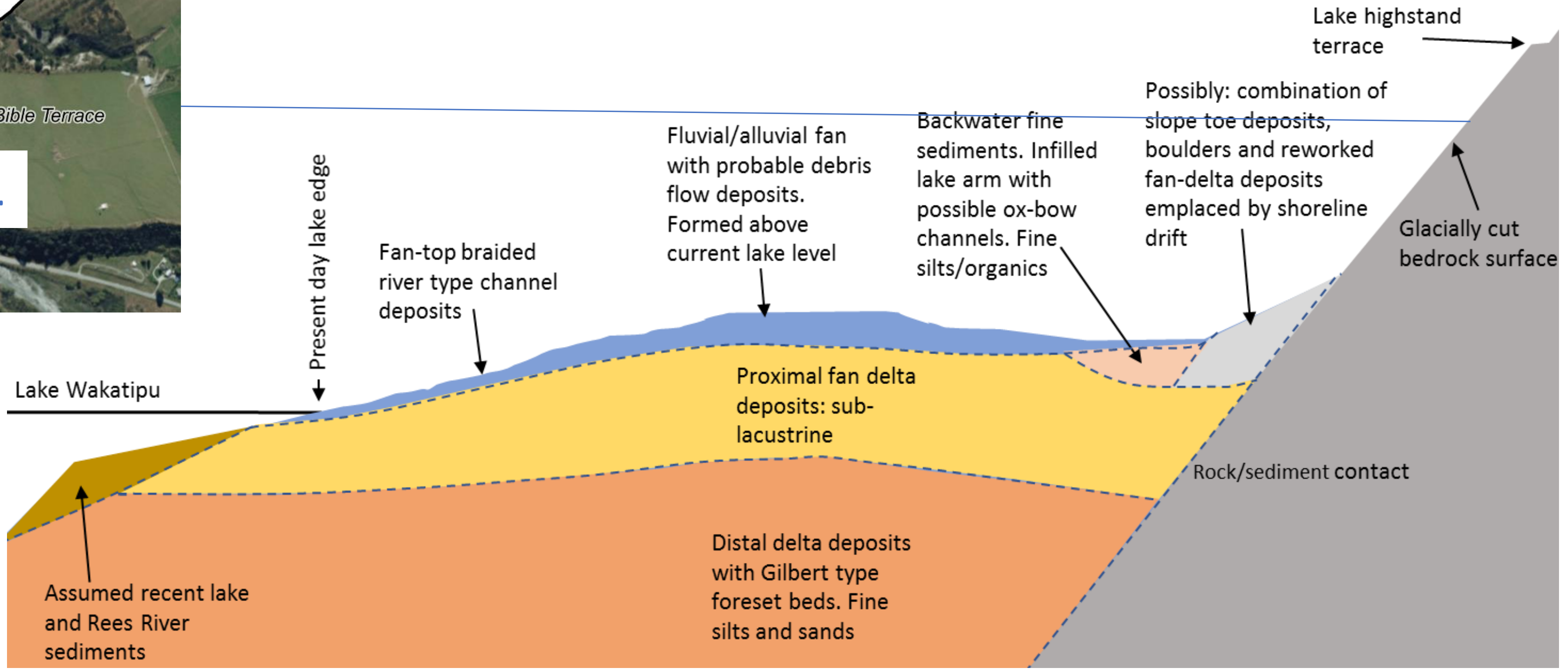


Glenorchy Liquefaction Assessment





- The subsurface soil layers comprise loose to medium dense sands to depths greater than 20m



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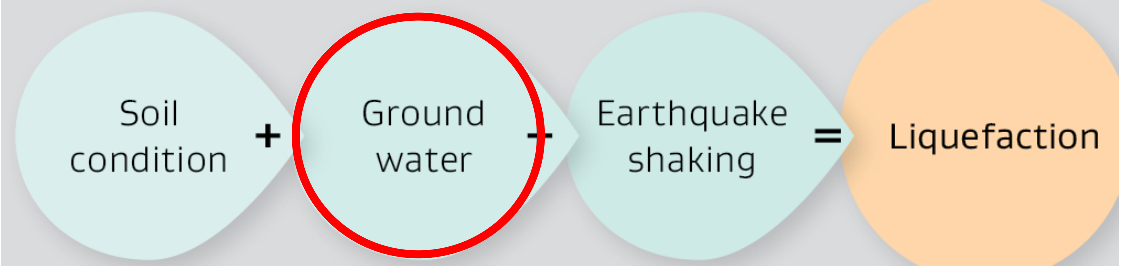
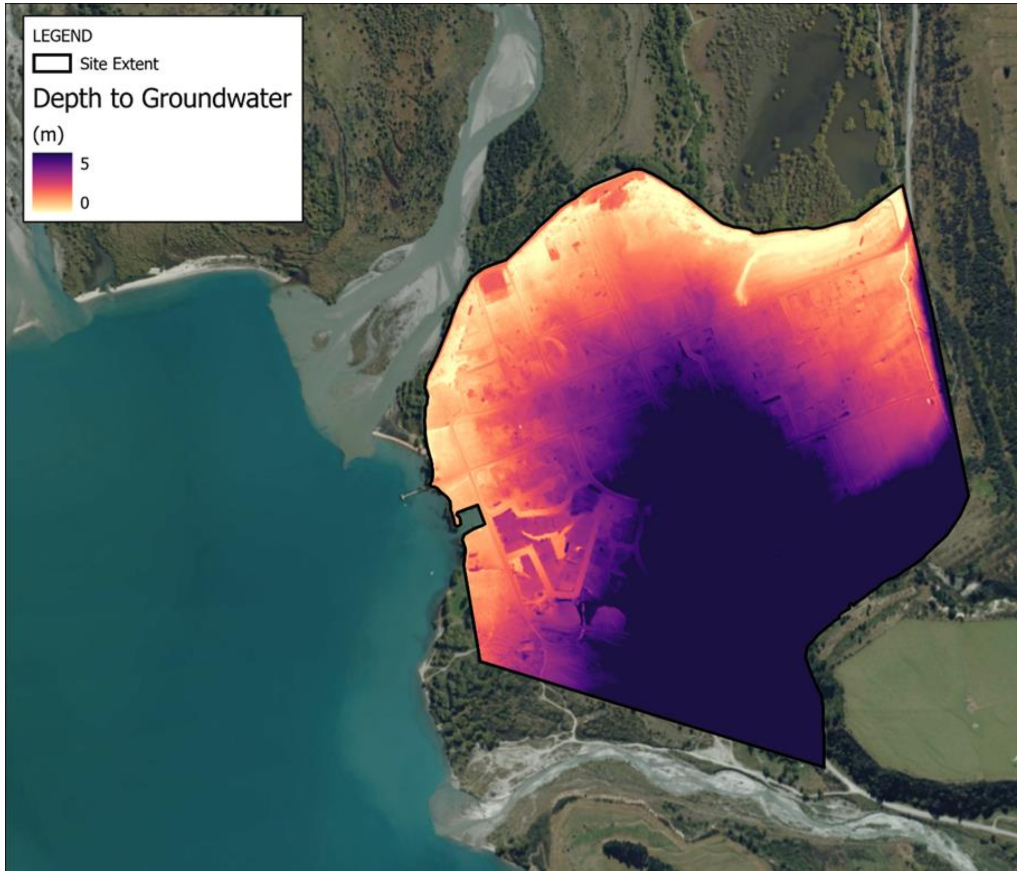


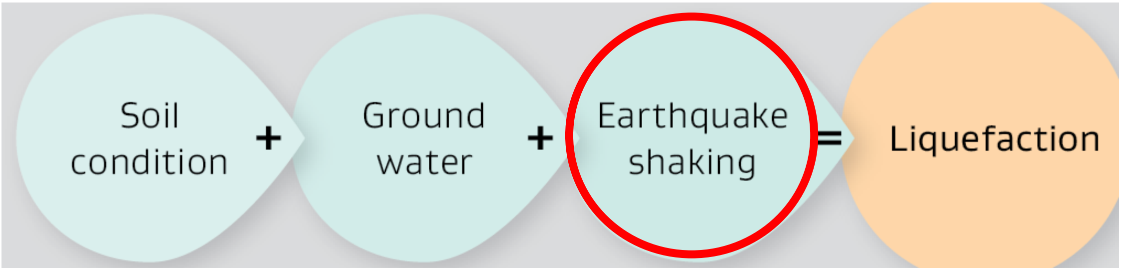
- Groundwater is shallow

▼ Groundwater Levels

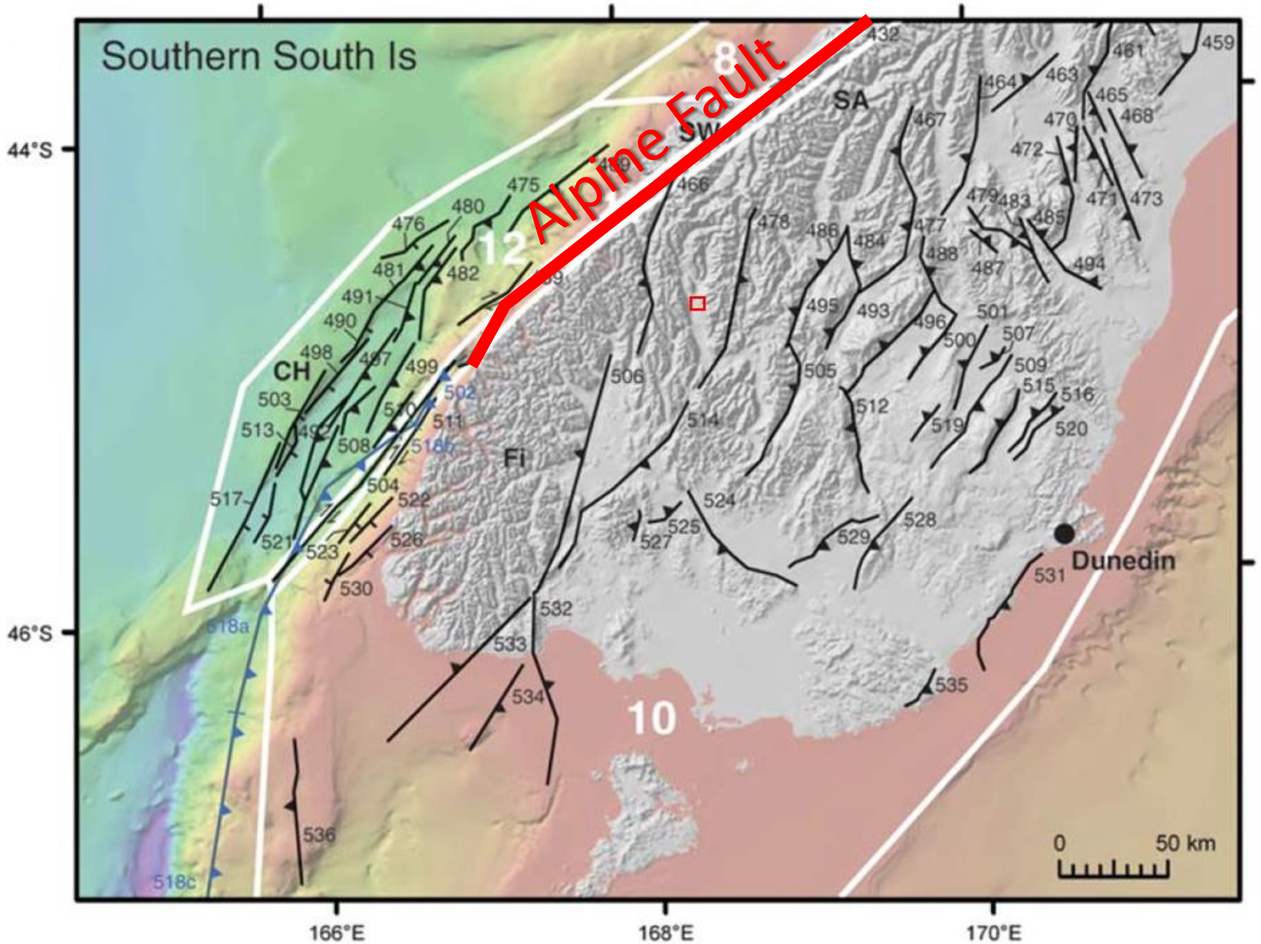


◄ Depth to Groundwater (m)

Glenorchy Liquefaction Assessment

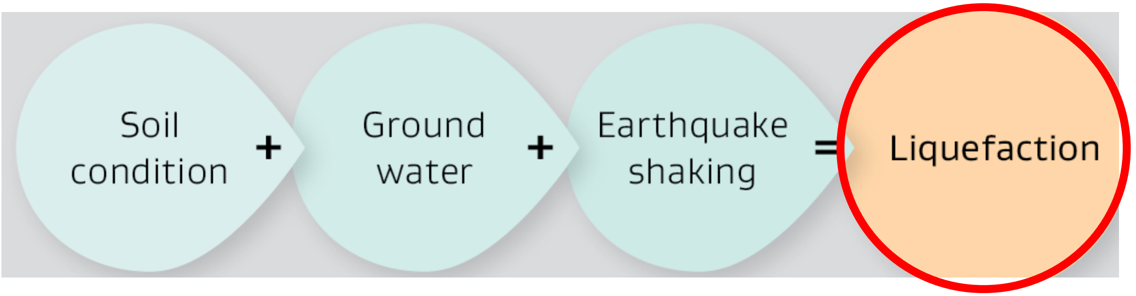


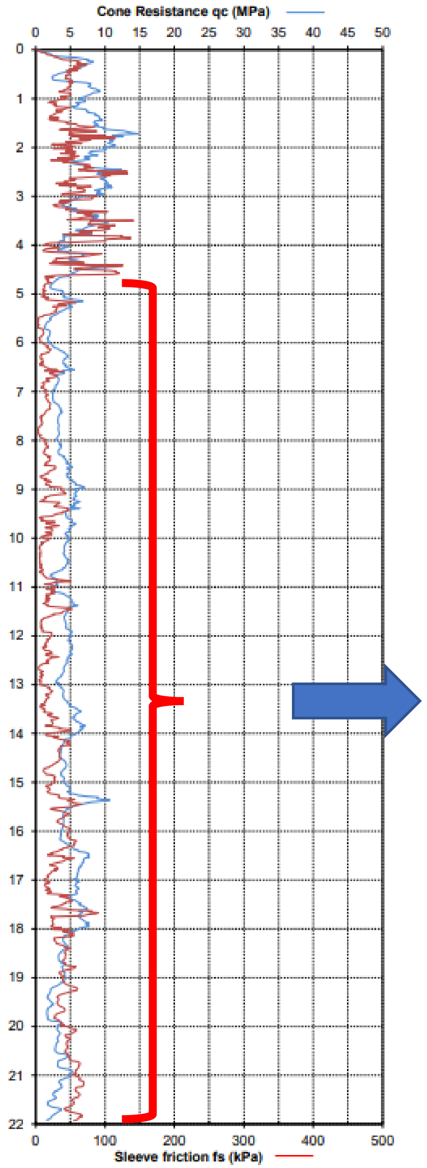
- Seismicity is high for the region and is likely to increase for many parts of New Zealand

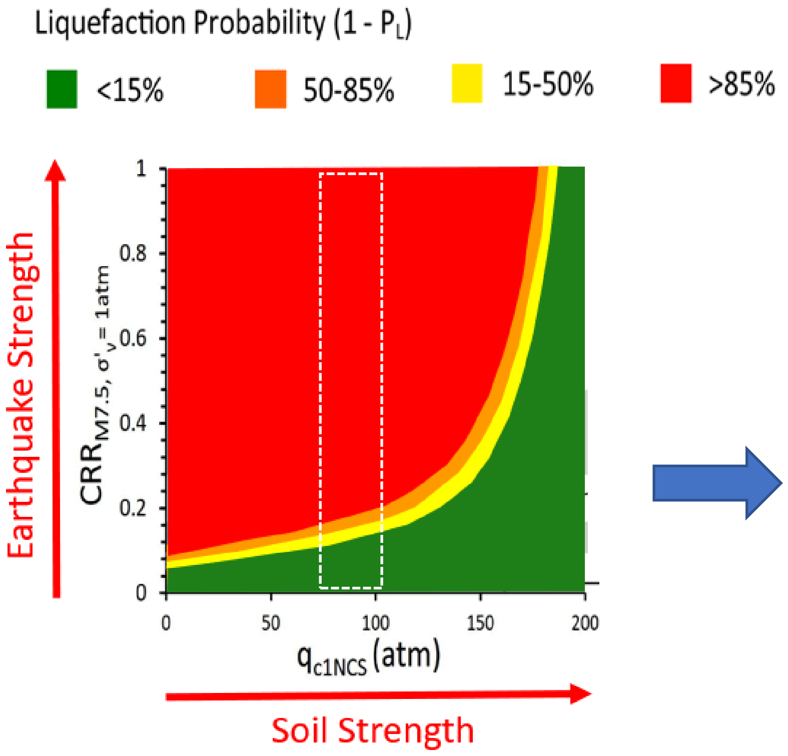


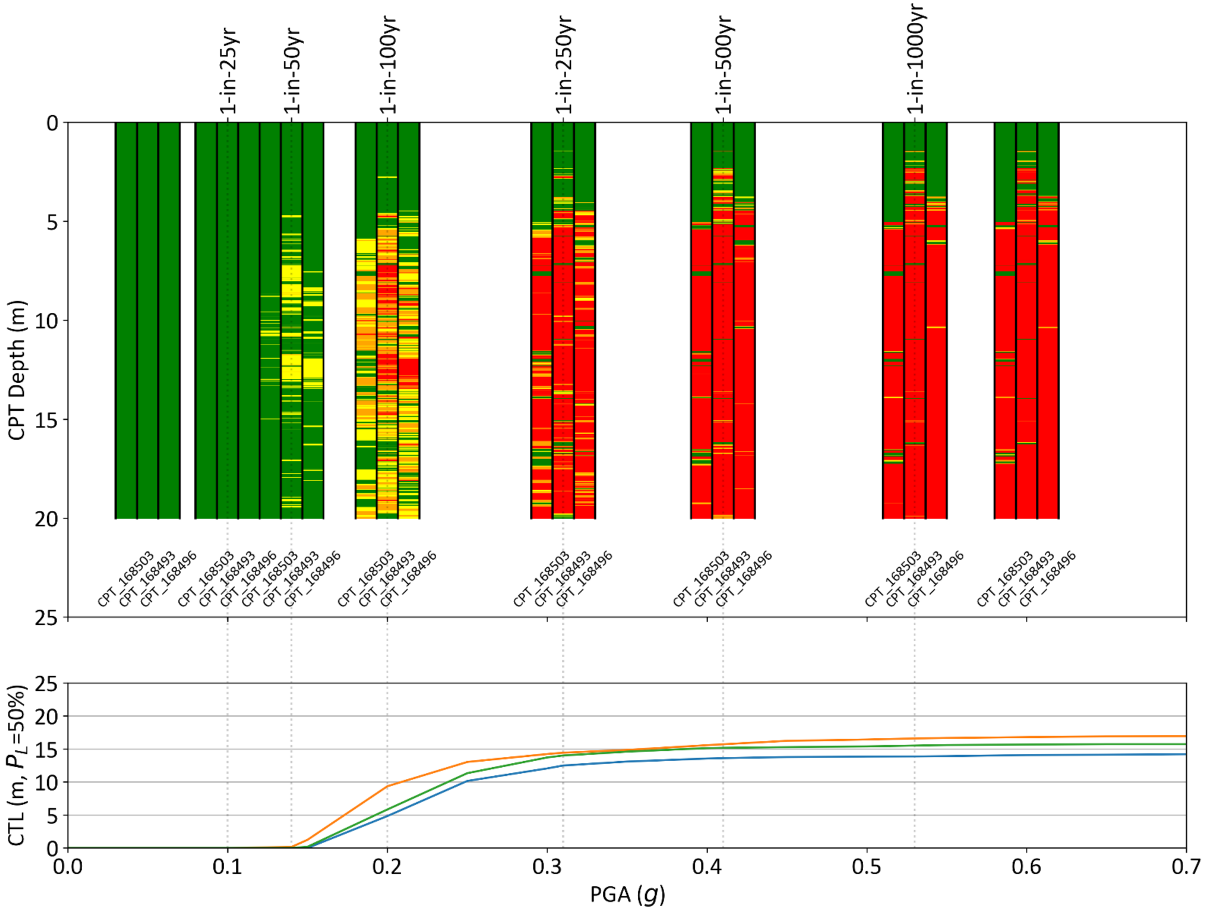
Return Period	25-yr	Alpine Fault Rupture Scenario (approx. 30-yr, conditional)	50-yr	100-yr	250-yr	500-yr	1000-yr	2500-yr
Annual Exceedance Probability	4%	3%	2%	1%	0.4%	0.2%	0.1%	0.04%
PGA (*g*)	0.1 to 0.16	0.11 (16th percentile) 0.19 (50th percentile) 0.32 (84th percentile)	0.14 to 0.22	0.20 to 0.32	0.31 to 0.48	0.41 to 0.63	0.53 to 0.82	0.74 to 1.14
M_w	6.1 to 6.5	8.1	6.1 to 6.5	6.1 to 6.5	6.1 to 6.5	6.5 to 7.1	6.5 to 7.1	6.5 to 7.1
Seismic Source (km)	62 to 17	55	60 to 17	57 to 17	54 to 17	50 to 17	46 to 17	41 to 17

Glenorchy Liquefaction Assessment









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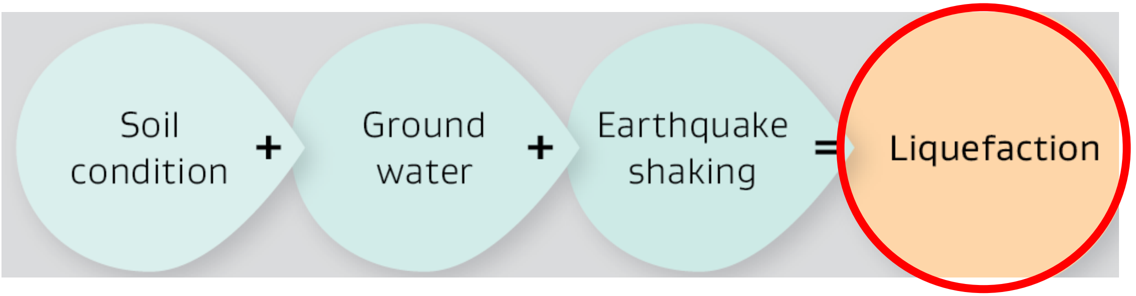
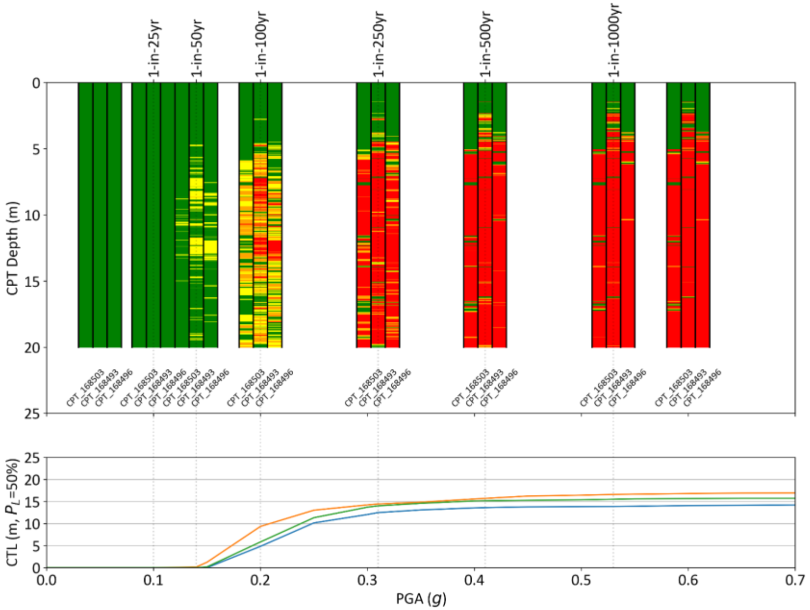
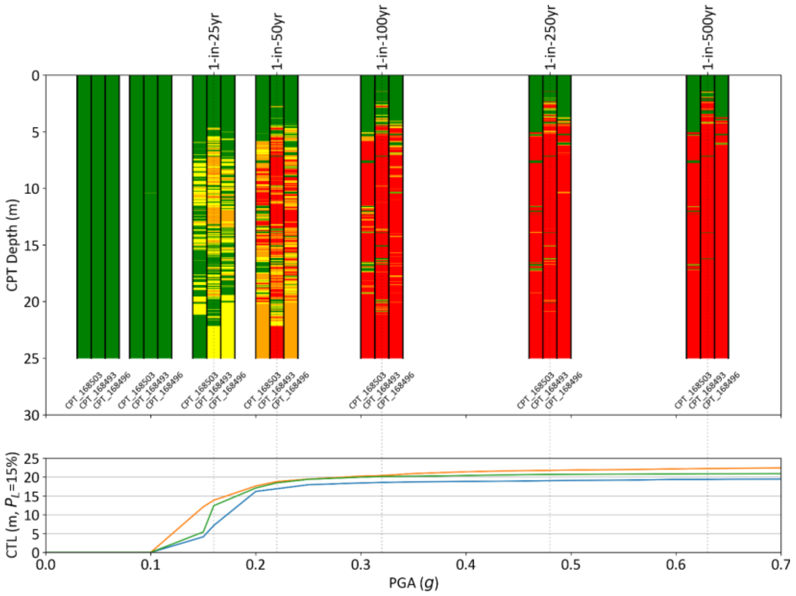


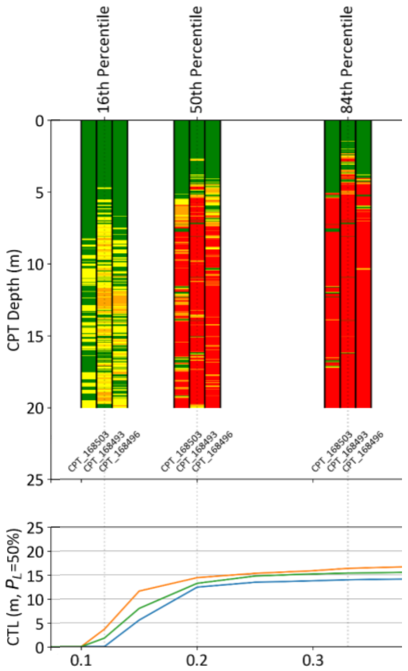
Lower bound



Upper bound



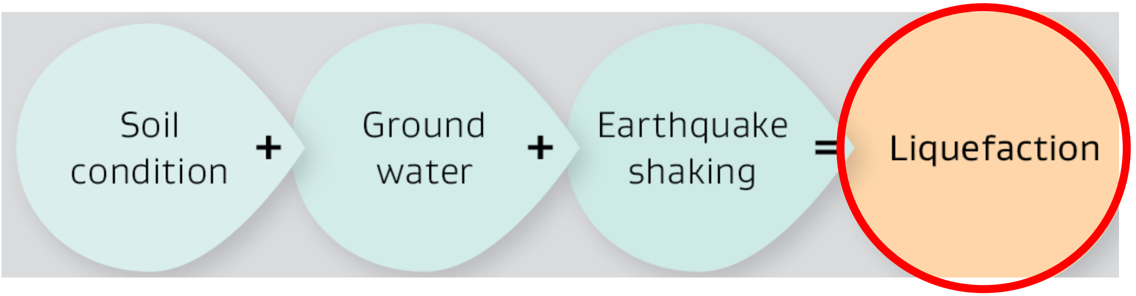
Alpine fault

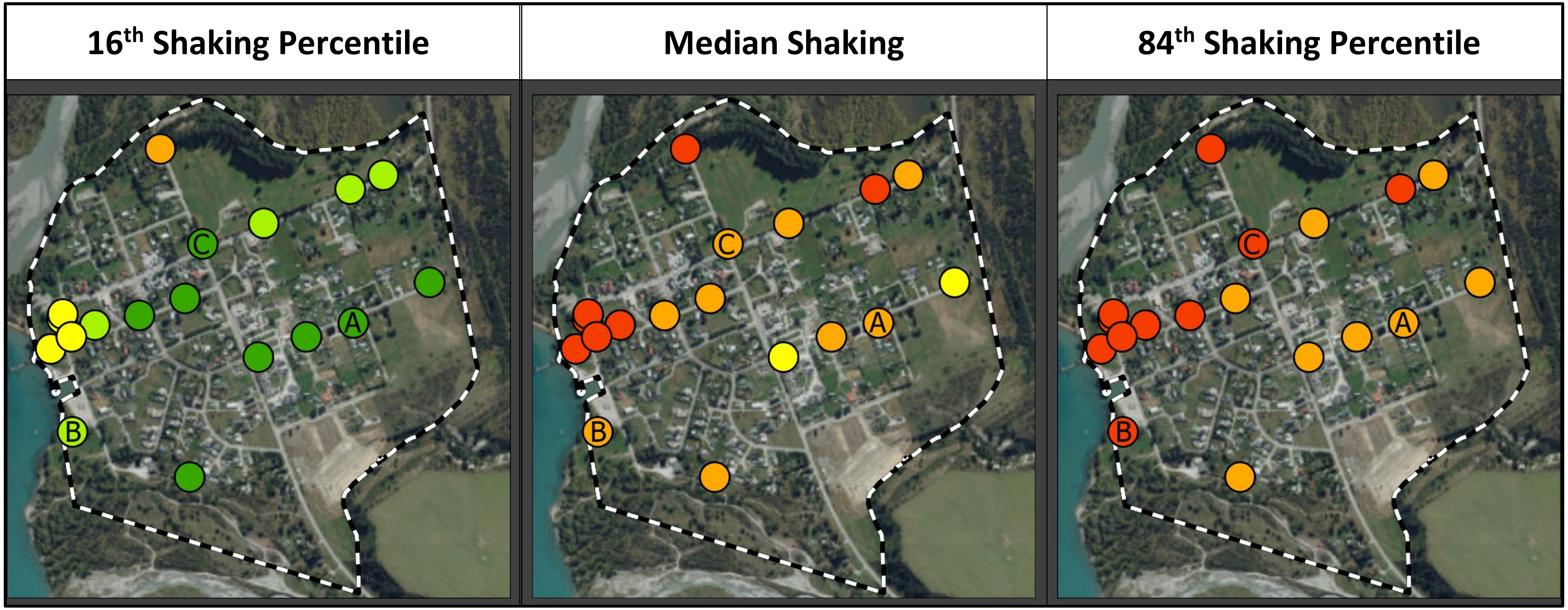


Results

- Liquefaction triggering is predicted to occur at 25 to 100 year period levels of earthquake shaking
- The upper 20 to 25m of the soil is expected to liquefy for most of the Glenorchy township
- An Alpine Fault Rupture Event is likely to trigger widespread liquefaction. This event has a 75% probability of occurrence in the next 50 years

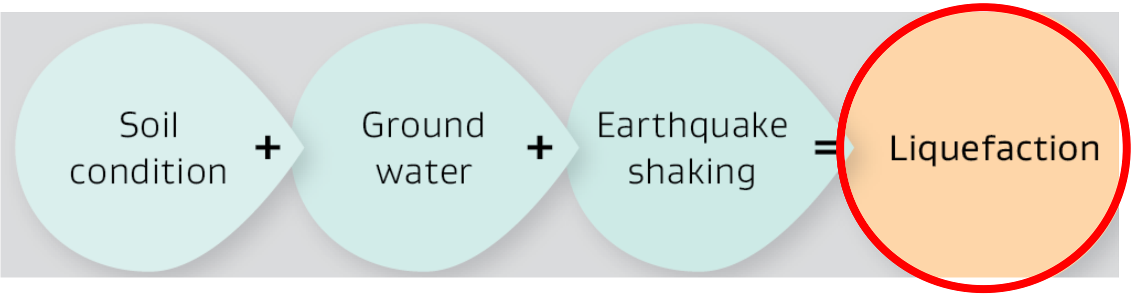
Glenorchy Liquefaction Assessment





Predicted Thickness of Liquefaction
for an Alpine Fault Rupture Event

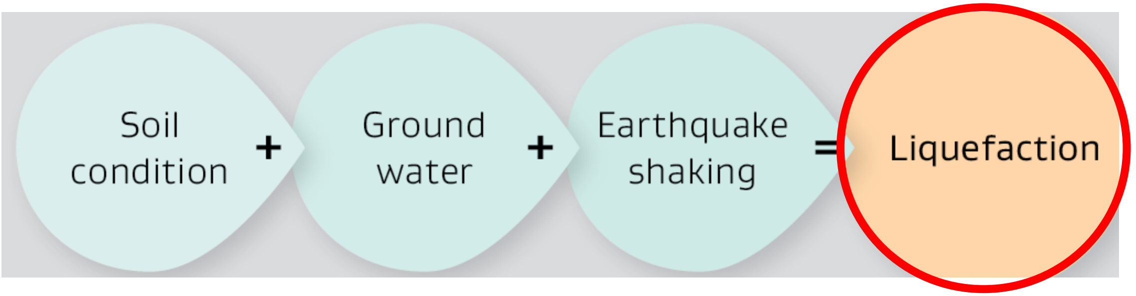
Glenorchy Liquefaction Assessment

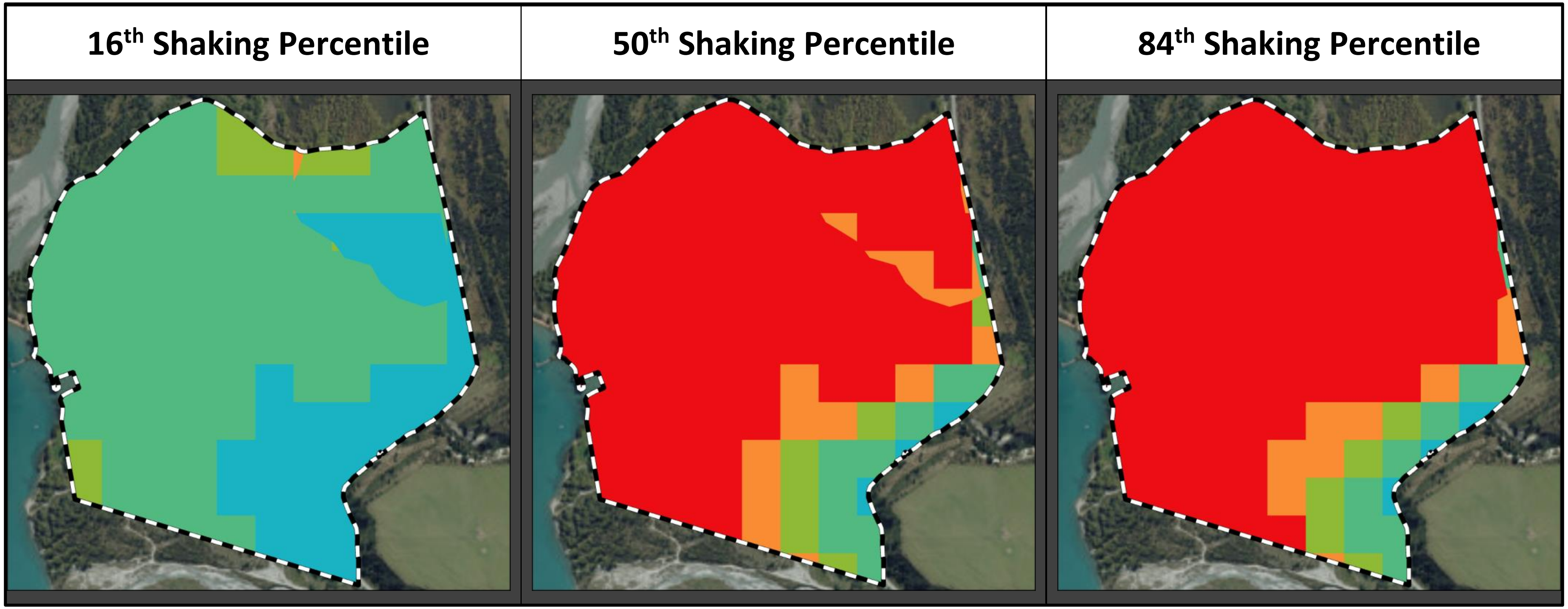


- 0–8 (None to Minor)
- 8–16 (Minor)
- 16–20 (Minor to Moderate)
- 20–25 (Moderate to High)
- 25+ (High to Severe)

Prediction of liquefaction ejecta is undertaken by calculating the Liquefaction Severity Number (LSN)

Glenorchy Liquefaction Assessment



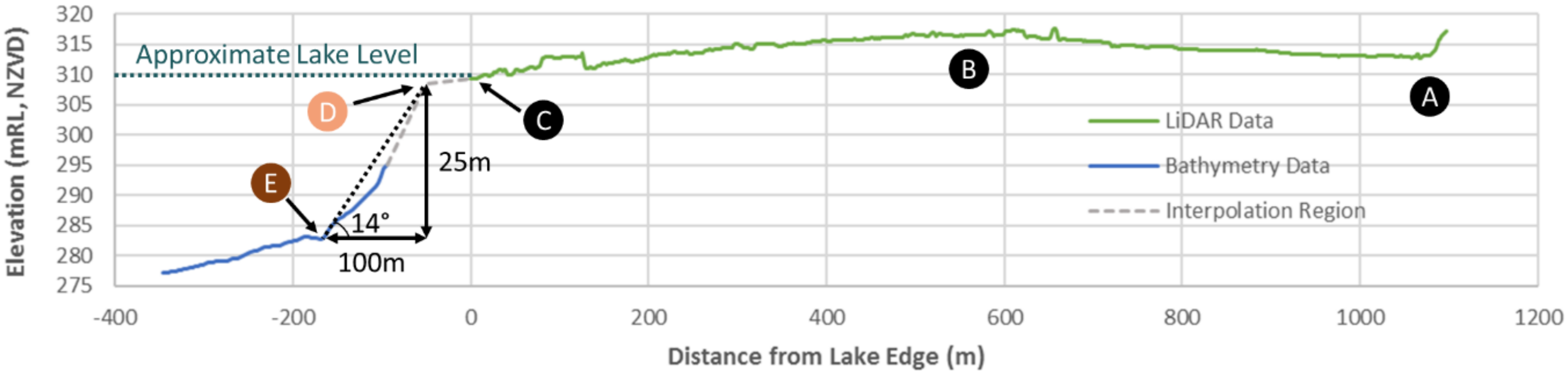


Extensive Moderate to Severe Liquefaction Ejecta is likely to occur across most of Glenorchy for an Alpine Fault Rupture Event

LSN values

- 0–8 (None to Minor)
- 8–16 (Minor)
- 16–20 (Minor to Moderate)
- 20–25 (Moderate to High)
- 25+ (High to Severe)

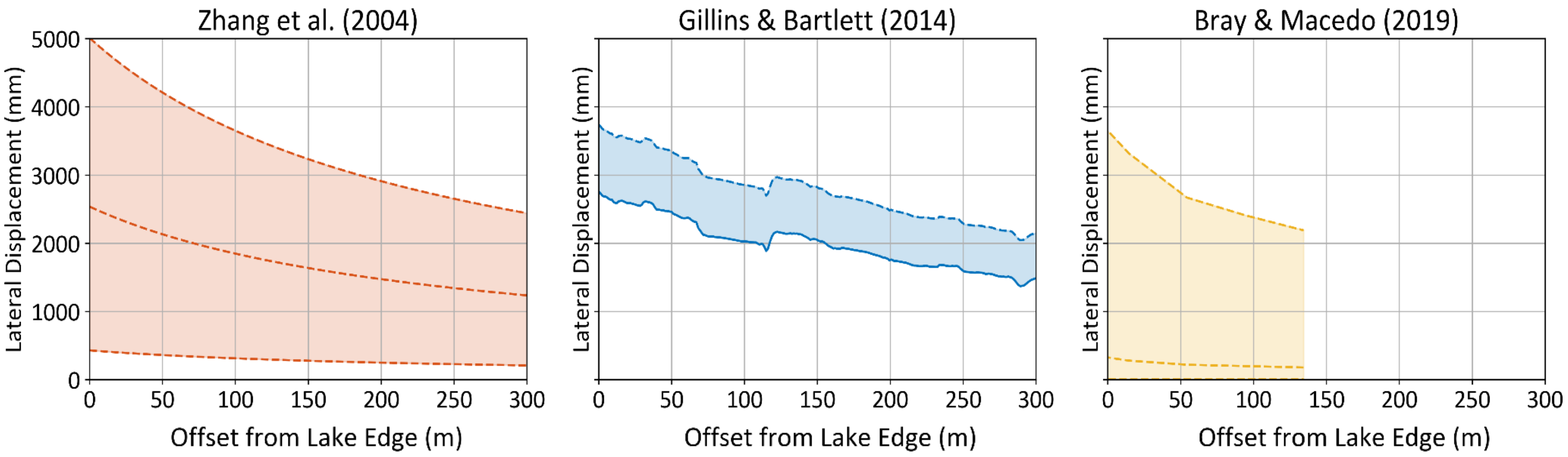
Glenorchy Liquefaction Assessment & Lateral Spreading



- The height of the drop off in Glenorchy is 5x greater than the areas where lateral spreading occurred in Christchurch and Blenheim

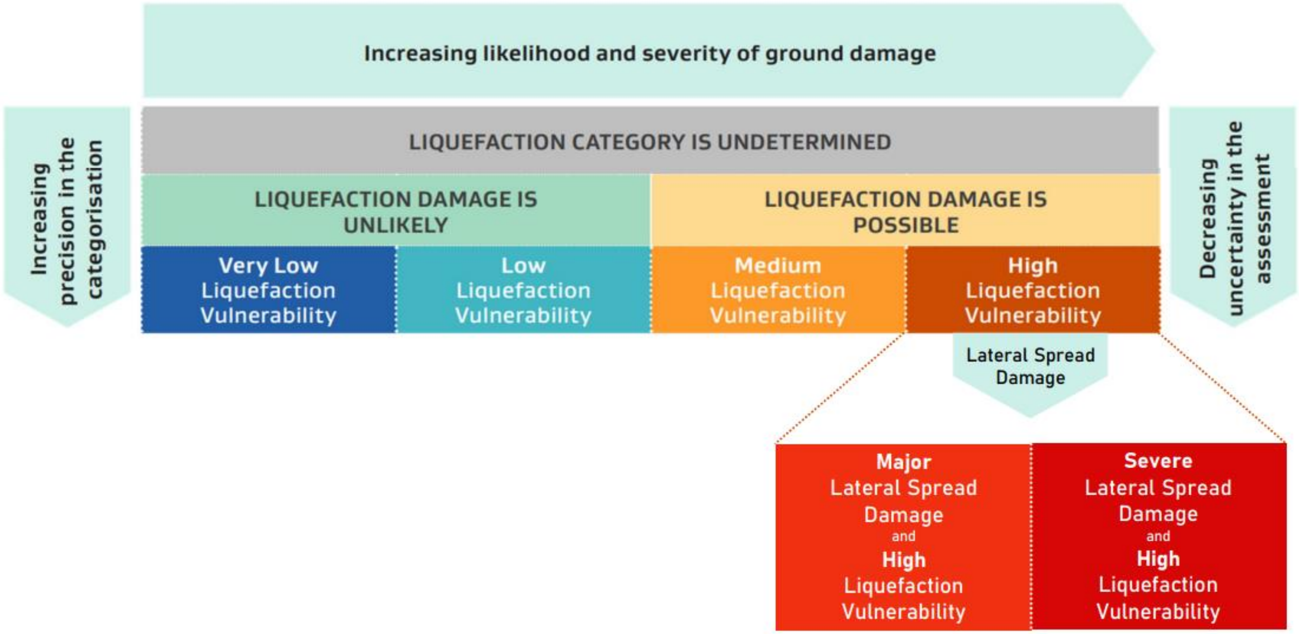
Glenorchy Liquefaction Assessment & Lateral Spreading

- Three methods used to assess lateral spreading
- Generally 3 to 4m of lateral spreading is predicted for an Alpine Fault Rupture Event. This event has a 75% probability of occurrence in the next 50 years
- The lateral spreading decreases with distance back from the lake edge
- The predicted spreading is 2x worse than the lateral spreading that was observed in the Christchurch residential red zone



Glenorchy Liquefaction Assessment – Damage Zones

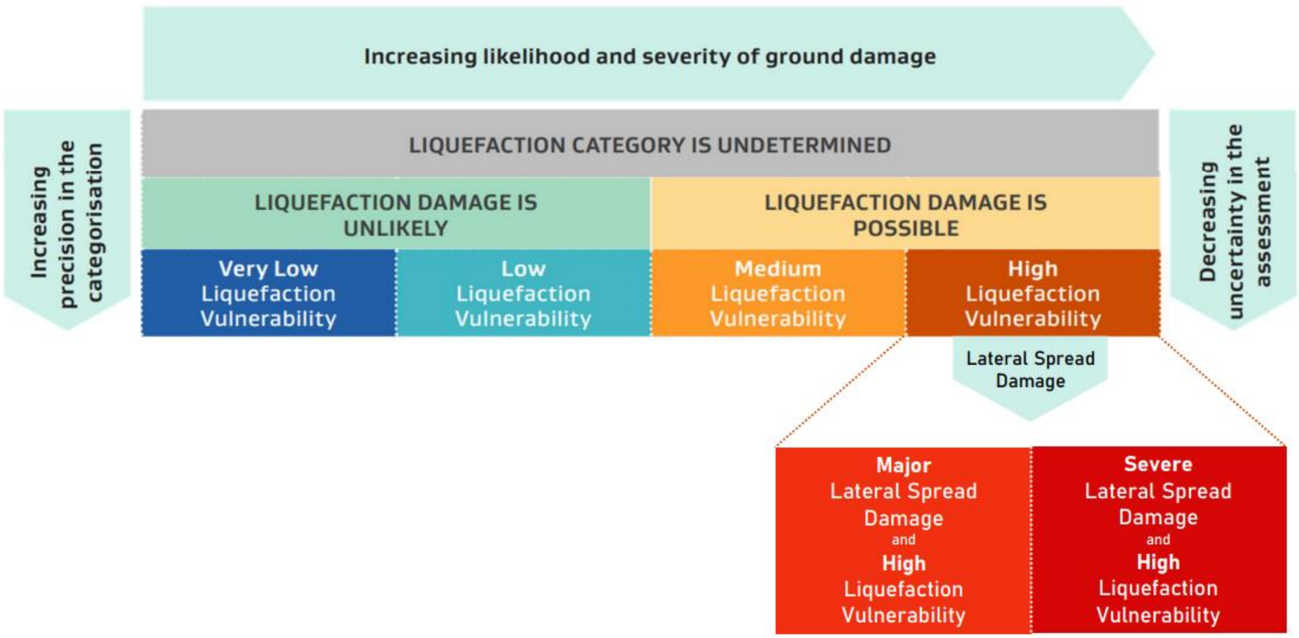
- Based on the MBIE / MFE Guidelines[1]



- The MBIE/MFE Guidelines were developed for the consideration of the liquefaction hazard in the rezoning / development of greenfield land. For greenfield land the guidance recommends:
  - The areas with High Liquefaction Vulnerability be either avoided or area-wide ground improvement be undertaken before building houses on top, or houses be designed with more robust foundation systems to withstand the effects from high liquefaction vulnerability;
  - The areas with Major Lateral Spread Damage be avoided unless the lateral spreading hazard can be mitigated through ground improvement. In the case in Glenorchy, mitigating the lateral spreading is not practical; and
  - The areas with Severe Lateral Spread Damage be completely avoided (i.e. left as a greenfield).
- However, Glenorchy is already an existing town and not a greenfield area. There is no guidance on what to do for the different hazard zones for existing developed areas.

MBIE & MfE. (2017). *Planning and Engineering Guidance for Potentially Liquefaction-prone Land.* Wellington: New Zealand Ministry of Business, Innovation and Employment, Building System Performance Branch.

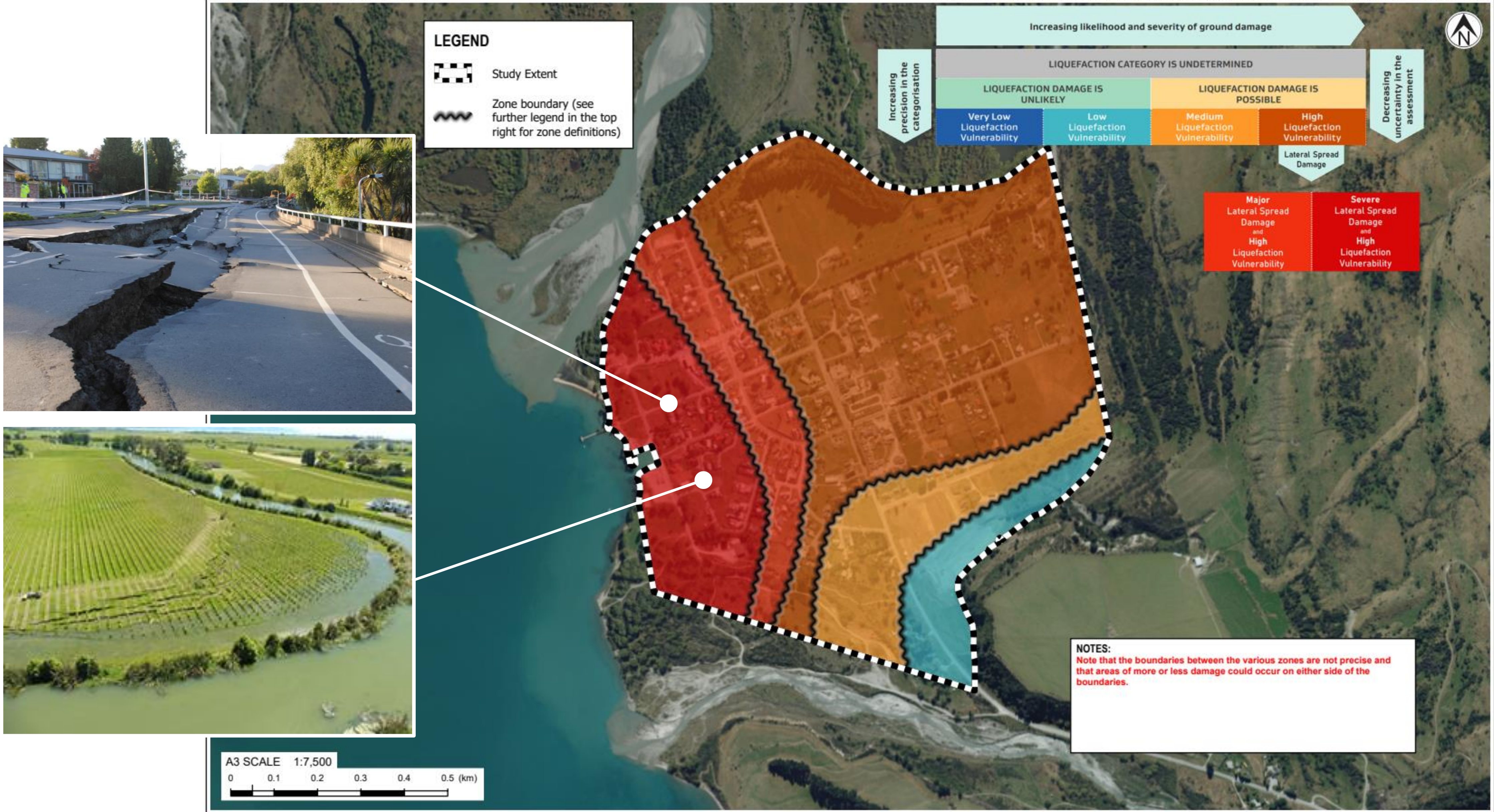
Glenorchy Liquefaction Assessment – Damage Zones



- Given that the Glenorchy area is already developed, Section 12.2.2 of the Canterbury Recovery Residential Guidance (MBIE, 2012) provides guidance for building design for various levels of lateral spread damage vulnerability.
- For the Major Lateral Spread Damage zone only the most heavy duty foundation design options for residential buildings are likely to be suitable (as per the Canterbury Residential Guidance). They are approximately $50 to $100k over and above the cost of a residential house on conventional foundations.
- For the Severe Lateral Spread Damage zone more substantial engineering works are required, which are outside of the scope of the guidance. Without specific engineering design, residential buildings cannot be expected to safely withstand these levels of lateral spread damage.
- Vertical ground surface subsidence in the order of 1m can occur in the Severe Lateral Spread Damage zone, which can significantly increase the flood risks.

MBIE & MfE. (2017). *Planning and Engineering Guidance for Potentially Liquefaction-prone Land.* Wellington: New Zealand Ministry of Business, Innovation and Employment, Building System Performance Branch.

T:\Christchurch\TT Projects\1017916\WorkingMaterial\GIS\Glenorchy_Liquefaction_Figures\Glenorchy_Liquefaction_Figures.aprx Layout: FIG002_LiquefactionVulnerability_MBIE 2022-May-16 11:17 AM Drawn by NAMC



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NOTES:
Basemap NZ - Imagery: Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors. NZ Navigation Map: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.

REV	DESCRIPTION	GIS	CHK	DATE
1	Second version	NAMC	YYYY	16/05/22

LOCATION PLAN

PROJECT No.	1017916.2000	
DESIGNED	NAMC	MAY.22
DRAWN	NAMC	MAY.22
CHECKED		
APPROVED	DATE	

CLIENT OTAGO REGIONAL COUNCIL

PROJECT GLENORCHY LIQUEFACTION STUDY

TITLE LIQUEFACTION VULNERABILITY (MFE/MBIE CLASSIFICATION) AND LATERAL SPREADING DAMAGE ZONES

SCALE (A3) 1:7,500 FIG No. FIGURE A1 REV 1


Questions?