Tasman Regional Liquefaction Assessment

Prepared for Tasman District Council
Prepared by Beca Limited

24 November 2021



Creative people together transforming our world

Revision History

Revision Nº	Prepared By	Description	Date
1	David Dobson/ Sarah Barrett	Draft for client comment	29/10/2021
2	Sarah Barrett	Final	24/11/2021

Document Acceptance

Action	Name	Signed	Date
Prepared by	David Dobson Sarah Barrett		24/11/2021
Reviewed by	Paul Horrey		24/11/2021
Approved by	Paul Horrey		24/11/2021
on behalf of	Beca Limited		

© Beca 2021 (unless Beca has expressly agreed otherwise with the Client in writing).
Cover Image: Google Earth, 2021
This report has been prepared by Beca on the specific instructions of our Client. It is solely for our Client's use for the purpose for which it is intended in accordance with the agreed scope of work. Any use or reliance by any person contrary to the above, to which Beca has not given its prior written consent, is at that person's own risk.

Contents

Executive Summary 1

1 Introduction 3

2 Rationale and Background 3

3 Liquefaction Process 4

4 Geologic and Geomorphic Setting 6

5 Liquefaction Assessment Methodology 6

5.1 Datasets Considered in our Assessment 9

5.2 Steps Taken in our Assessment 12

6 Areas Potentially Susceptible to Liquefaction Damage 15

7 Assumptions and Limitations of our Assessment 15

8 Suggestions for Future Work 16

9 Planning Considerations 16

Appendices

Appendix A – PDF Map Outputs

Appendix B – Summary of Quaternary Geology

Executive Summary

Beca Ltd (Beca) has been commissioned by the Tasman District Council (TDC) to undertake a regional liquefaction assessment in accordance with a 'Level A – Basic Desktop Assessment' as per the joint MBIE/ MfE (2017) '*Planning and engineering guidance for potentially liquefaction-prone land'* guidance. The level of assessment detail was selected by TDC and meets the requirements placed on TDC by the Resource Management Act (1991) and November 2019 updates to the Building Code to identify areas with deposits potentially susceptible to liquefaction.

Liquefaction occurs as strong ground shaking, such as during earthquakes, causes loose and saturated sediments to lose strength and behave as a fluid. Liquefied deposits may be transported downslope and/or towards a free face such as a riverbank, and termed lateral spreading. Surface effects of liquefaction may include the ejection of liquefied material and groundwater, differential settlement of the ground surface, and/ or cracking of the ground-surface associated with lateral-spreading. Structures founded on soils that have liquefied may experience bearing failure, differential settlements, and/or large horizontal displacements while buoyant structures buried in liquefied soils, such as pipes, manholes and tanks, may rise to the surface. Soils considered susceptible to liquefaction are typically geologically young (i.e. <10,000 years), saturated, and non-plastic sands and silts located in relatively flat areas close to waterways and areas of fill.

The Tasman District extends along Tasman Bay coastline from Farewell Spit to Champion Road in Stoke, down the west coast to Kahurangi Point, and down to the Maruia Valley in the south. The landscape is topographically varied ranging from steep mountainous areas, rolling hillslopes, to low-lying alluvial and coastal plains. Liquefaction was observed in Ngatimoti and the Murchison areas following the 1929 Murchison Earthquake and in Murchison following the 1968 Inangahura Earthquake.

The MfE/MBIE (2017) guidance outlines a risk-based approach for regional and territorial/district authorities in managing liquefaction related risk in land use planning and development. The guidance represents current recommended industry practice and was developed in response to recommendations made by the Royal Commission of Inquiry into Building Failure caused by the Canterbury Earthquake relating to the role of regional and district/territorial authorities in managing liquefaction-related risk. A Level A assessment considers basic information on geology, geomorphology, regional seismicity, and where available, groundwater, to classify areas according to the following land damage criteria:

- ***Liquefaction Damage is Unlikely*** - geological units considered not susceptible to liquefaction based on their geologic description and/or depositional setting.
  - Refined to *Very Low Liquefaction Vulnerability* where there is sufficient conclusive geological information that the underlying deposit is not susceptible to liquefaction i.e. shallow rock and fractured rock comprising landslide deposits in mountainous areas.
- ***Liquefaction Damage is Possible*** – Areas where the geologic setting suggests that the underlying geologic unit may be susceptible to liquefaction.
  Liquefaction Category is Undetermined – Areas not considered in the liquefaction assessment or where there is insufficient data to conclusively determine the liquefaction vulnerability of the underlying geologic unit. Our assessment included a detailed review of the following data sources and followed the methodology outlined in Figure 0-1.
- Regional geology
- Ground surface elevations
- Aerial imagery
- Regional seismicity
- Previous liquefaction hazard assessments

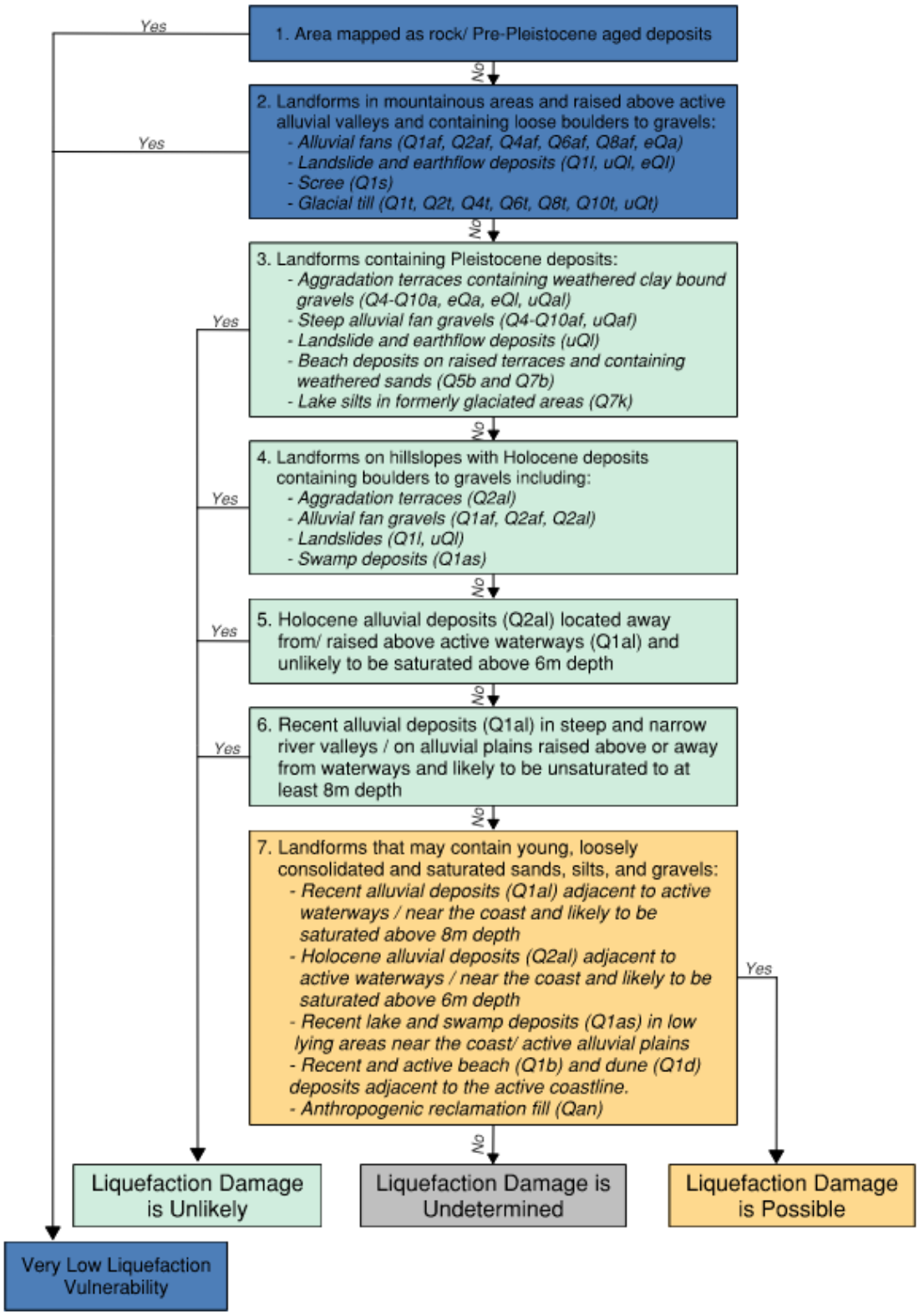


Figure 0-1: Methodology tree outlining the steps taken in our regional liquefaction assessment

The mapping assessment was completed at a scale of 1:25,000 and it is intended that any subsequent use or consideration is completed at a consistent or greater scale. The output is not considered a replacement for site-specific liquefaction assessments and contains residual uncertainties associated with variations in map scales and errors and limitations of the input datasets. TDC may consider a Level B assessment in order to reduce residual uncertainties in the assigned liquefaction category.

1 Introduction

Beca Ltd (Beca) has been commissioned by the Tasman District Council (TDC) to undertake a regional liquefaction assessment in accordance with a 'Level A – Basic Desktop Assessment' as per the joint MBIE/ MfE (2017) '*Planning and engineering guidance for potentially liquefication-prone land'* guidance. The level of assessment detail was specified by TDC and is intended to identify areas containing deposits that are potentially susceptible to liquefaction and which warrant further assessment in land development planning.

This report outlines the methodology and assumptions of our assessment and covers the following aspects as outlined in our proposal dated 16 April 2021:

- Desk study review of readily available information including:
  - Published large-scale regional geological and geomorphological maps and aerial imagery
  - Regional seismicity and groundwater
  - Previous liquefaction assessments
- Assessment of the liquefaction susceptibility of the deposits in the Tasman region in accordance with a 'Level A – Basic Desktop' Assessment'.
- Produce a GIS map overlay outlining the results of the liquefaction assessment at a scale of 1:25,000.

The output of our assessment is a map overlay identifying areas where 'Liquefaction Damage is Possible' and where 'Liquefaction Damage is Unlikely' in accordance with the MBIE/ MfE (2017) guidance. The category has been refined to 'Very Low Liquefaction Susceptibility' where there is sufficient information that the underlying deposit is not susceptible to liquefaction such as presence of shallow rock. Map outputs of our assessment are presented in Appendix A.

2 Rationale and Background

TDC is required under the Resource Management Act (1991) to have specific functions that manage natural hazards, including liquefaction. Management of liquefaction at a regional level should include the identification of potentially susceptible land through regional mapping while specific planning functions may be applied at the district/territorial authority level.

The November 2019 updates to the Building Code mean that standard foundation options (B1 Acceptable Solution B1/AS1) can no longer be applied in areas susceptible to liquefaction and/or lateral spreading. The update places responsibility on councils to complete regional liquefaction mapping in order to identify areas prone to liquefaction.

3 Liquefaction Process

Liquefaction occurs as strong ground shaking, such as during earthquakes, causes loose and saturated sediments to lose strength and behave as a fluid. Liquefied deposits may be transported downslope and/or towards a free face such as a riverbank, termed lateral spreading. The key elements required for liquefaction are shown in Figure 3-1. Surface effects of liquefaction may include the ejection of liquefied material and groundwater, differential settlement of the ground surface, and cracking of the ground-surface associated with lateral-spreading. Structures founded on soils that have liquefied may experience bearing failure, differential settlements, and/or large horizontal displacements while buoyant structures buried in liquefied soils, such as pipes, tanks, and manholes, may rise to the surface.

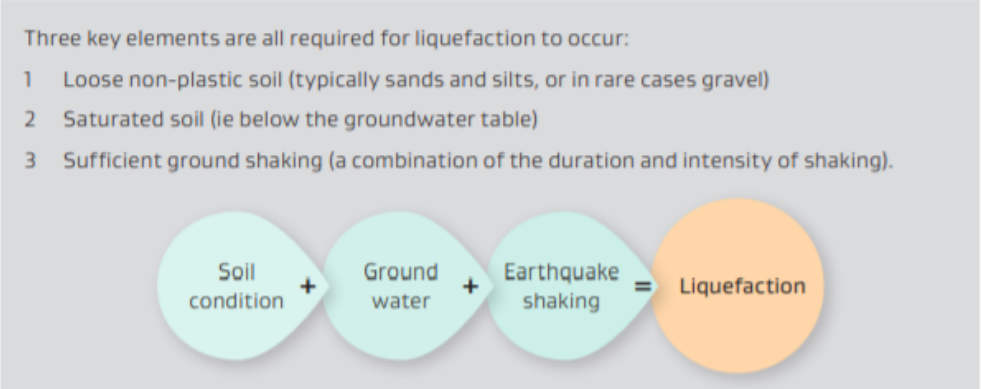


Figure 3-1:Key elements for liquefaction, as outlined by MfE/MBIE (2017).

Soils considered susceptible to liquefaction are typically geologically young (i.e. <10,000 years), saturated, and non-plastic sands and silts, and in some cases loose gravels. These deposits are typically located in relatively flat areas close to active or abandoned waterways including rivers, lakes, swamps, and estuaries, and/or areas of uncompacted or poorly compacted fill. Older sands and silts, dense gravel, rock, and higher plasticity clays are generally considered to have low vulnerabilities to liquefaction. Relationships between the liquefaction susceptibility of sedimentary deposits and their age have been summarised by Youd and Perkins (1978), Kramer (1996), and Idriss and Boulanger (2008). Key relationships between liquefaction susceptibility and the age of sedimentary deposits have been summarised by Youd and Perkins (1978) and are shown in Figure 3-2.

Type of Deposit	General Distribution of Cohesionless Sediments in Deposits	Likelihood that Cohesionless Sediments when Saturated would be Susceptible to Liquefaction (by Age of Deposit)			
		< 500 yr Modern	Holocene < 11 ka	Pleistocene 11 ka - 2Ma	Pre-Pleistocene > 2 Ma
(a) Continental Deposits					
River channel	Locally variable	Very High	High	Low	Very Low
Flood plain	Locally variable	High	Moderate	Low	Very Low
Alluvial fan and plain	Widespread	Moderate	Low	Low	Very Low
Marine terraces and plains	Widespread	---	Low	Very Low	Very Low
Delta and fan-delta	Widespread	High	Moderate	Low	Very Low
Lacustrine and playa	Variable	High	Moderate	Low	Very Low
Colluvium	Variable	High	Moderate	Low	Very Low
Talus	Widespread	Low	Low	Very Low	Very Low
Dunes	Widespread	High	Moderate	Low	Very Low
Loess	Variable	High	High	High	Unknown
Glacial till	Variable	Low	Low	Very Low	Very Low
Tuff	Rare	Low	Low	Very Low	Very Low
Tephra	Widespread	High	High	?	?
Residual soils	Rare	Low	Low	Very Low	Very Low
Sebka	Locally variable	High	Moderate	Low	Very Low
(b) Coastal Zone					
Delta	Widespread	Very High	High	Low	Very Low
Esturine	Locally variable	High	Moderate	Low	Very Low
Beach					
High Wave Energy	Widespread	Moderate	Low	Very Low	Very Low
Low Wave Energy	Widespread	High	Moderate	Low	Very Low
Lagoonal	Locally variable	High	Moderate	Low	Very Low
Fore shore	Locally variable	High	Moderate	Low	Very Low
(c) Artificial					
Uncompacted Fill	Variable	Very High	---	---	---

Figure 3-2: Estimated susceptibility of sedimentary deposits to liquefaction during strong shaking as established by Youd and Perkins (1978).

4 Geologic and Geomorphic Setting

The Tasman District covers an area of 9,786 square kilometres in the north-west corner of the South Island. The region extends from Farewell Spit along Tasman Bay coastline to Champion Road in Stoke and partially covers the west coast to Kahurangi Point. The district extends to the Maruia Valley in the south and is bounded by the Victoria, Brunner, and Spencer Ranges. The landscape is topographically varied ranging from steep mountainous areas in the south and west of the region, to rolling hillslopes and low-lying coastal and alluvial plains near the coast. The morphology of the landscape is closely related to the underlying geology.

The geology of the Tasman region is presented in the 1:250,000 scale geological QMap *Geology of the Nelson Area* by Rattenbury et al. (1998). The map outlines the broad range and types of geologic units in the Tasman area. Quaternary cover deposits are the youngest in the map area at less than 2.6 million years old and are of relevance to the liquefaction assessment (see Figure 3-2). These deposits are further subdivided into Holocene deposits, which are generally accepted to be less than approximately 10,000 years old in New Zealand, and Pleistocene deposits which are greater than 10,000 years old. The type, composition, and geomorphic settings of the Quaternary cover deposits identified in the 1:250,000 geologic map of the Tasman Region are summarised in Table B-1 in Appendix B.

5 Liquefaction Assessment Methodology

The MfE/MBIE (2017) guidance outlines a risk-based approach for regional and territorial/district authorities for managing liquefaction related risk in land use planning and development. It represents current recommended industry practice and was developed in response to recommendations made by the Royal Commission of Inquiry into Building Failure caused by the Canterbury Earthquake.

The guidance outlines four levels of assessment ranging from a ‘Level A’ basic qualitative desk top study to a ‘Level D’ site-specific quantitative liquefaction assessment. The assessments all aim to identify the expected range of ground performance according to the matrix shown in Figure 5-1. A description of the corresponding land damage categories is shown in Figure 5-2.

The key difference between the levels of assessment is the investigation detail and the degree of residual uncertainty in the assigned liquefaction category. Level A and B assessments generally aim to differentiate areas where ‘Liquefaction Damage is Possible’ from areas where ‘Liquefaction Damage is Unlikely’ at a regional scale (see Figure 5-1). Level C and D assessments aim to assess the liquefaction vulnerability of a given area or site and assign the area as ‘Very Low’, Low, Medium, or ‘High’ Liquefaction Vulnerability in accordance with Figure 5-1.

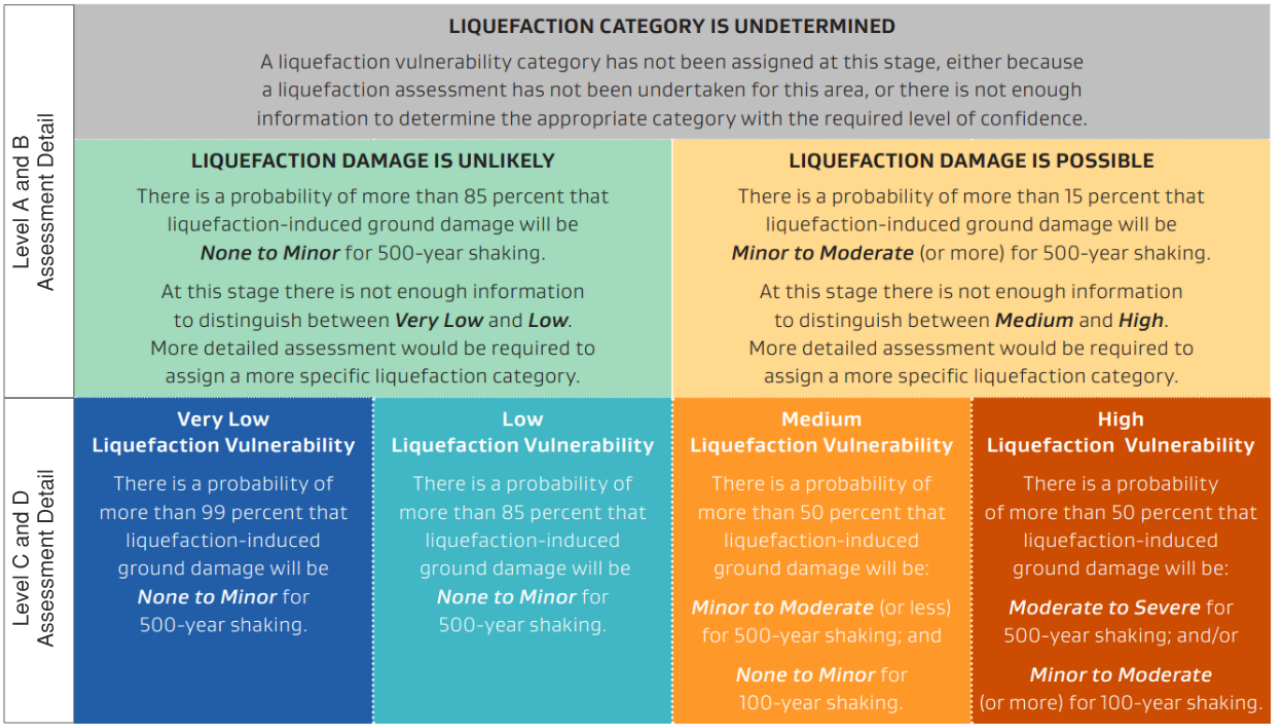


Figure 5-1: Performance criteria for determining the liquefaction vulnerability category from the joint MfE/MBIE guidelines for Level A, B, C, and D assessments.

DEGREE OF LIQUEFACTION-INDUCED GROUND DAMAGE (example photographs)	TYPICAL CONSEQUENCES AT THE GROUND SURFACE These are examples of the type of damage that would be expected, they are not intended to be criteria for calculation
None to Minor 	– ***None to Minor*** no signs of ejected liquefied material at the ground surface[1]. – No more than minor differential settlement of the ground surface (eg undulations less than 25 mm in height). – No apparent lateral spreading ground movement (eg only hairline ground cracks). – Liquefaction causes no or only cosmetic damage to buildings and infrastructure (but damage may still occur due to other earthquake effects).
Minor to Moderate 	– ***Minor to Moderate*** quantities of ejected liquefied material at the ground surface (eg less than 25 percent of a typical residential site covered[2]); and/or – Moderate differential settlement of the ground surface (eg undulations 25–100 mm in height). – No significant lateral spreading ground movement (eg ground cracks less than 50 mm wide may be present, but pattern of cracking suggests the cause is primarily ground oscillation or settlement rather than lateral spreading). – Liquefaction causes moderate but typically repairable damage to buildings and infrastructure. Damage may be substantially less where liquefaction was addressed during design (eg enhanced foundations).
Moderate to Severe 	– Large quantities of ejected liquefied material at the ground surface (eg more than 25 percent of a typical residential site covered[2]); and/or – ***Moderate to Severe*** differential settlement of the ground surface (eg undulations more than 100 mm in height); and/or – Significant lateral spreading ground movement (eg ground cracks greater than 50 mm wide, with pattern of cracking suggesting direction of movement downslope or towards a free-face). – Liquefaction causes substantial damage and disruption to buildings and infrastructure, and repair may be difficult or uneconomic in some cases. Damage may be substantially less, and more likely to be repairable, where liquefaction was addressed during design (eg enhanced foundations and robust infrastructure detailing).

Figure 5-2: Degrees of liquefaction-induced ground damage taken from the MfE/MBIE guidelines and corresponding with the damage described in Figure 5-1.

5.1 Datasets Considered in our Assessment

TDC have requested that the regional liquefaction assessment be completed in general accordance with a 'Level A' assessment as per the MBIE/MfE guidance. The assessment is a desk-based exercise which considers regional datasets and does not include site-specific geotechnical investigations nor quantitative liquefaction triggering assessments. The following datasets have been considered in our assessment:

5.1.1 Regional Geology

The 1:250,000 scale geologic (QMap) of the Nelson Area and accompanying textbook (Rattenbury et al., 1998).

- The map presents the regional geology of the Tasman area including geologic descriptions of the mapped units. It outlines the distribution of Quaternary deposits that have geologic descriptions suggesting that they may be susceptible to liquefaction.
- The scale of mapping means that spatial variations in the geologic units, such as abandoned river channels, are not identified, and that the geologic boundaries do not always precisely align with geomorphic features (i.e. hillslopes and terrace risers).

5.1.2 Local Geology

The following local geological maps cover portions of the Tasman region and were considered in the assessment:

  - 1:25,000 scale geologic map of the Nelson urban area which covers part of Stoke and Richmond (Johnson, 1979)
  - 1:50,000 scale geologic map of Richmond (Johnston, 1981)
  - 1:63,360 scale map of Farewell-Collingwood (Bishop, 1971)
  - 1:63,360 scale map of Takaka (Grindley, 1971)

- These maps present more detail on the geologic units in the specified areas including further subdividing the mapped Quaternary deposits.
- The scale of mapping means that spatial variations within the geologic units are not captured, however the dataset provides more detail in the types of deposits in the map area compared to the 1:250,000 map.
- The mapped geologic boundaries do not always align with geomorphic boundaries observable in aerial imagery and elevation datasets (i.e. hillslopes).

5.1.3 Ground Surface Levels

The topography of the Tasman region was assessed from the World Hillshade model, which has a 20m spatial resolution and is available as a basemap in ArcGIS. The assessment was supplemented with hillshade models with 1m spatial resolutions and created from the Digital Elevation Models (DEM) supplied by TDC.

The elevation datasets outline local topographic variability not captured in the geologic maps and assist with identifying geomorphic features of relevance to the liquefaction assessment. These features include, but are not limited to:

  - Raised terraces separated from active alluvial plains by terrace risers.
  - The steepness and widths of stream channels within alluvial valleys
  - Changes in the topographic profiles along alluvial plains and within alluvial valleys indicating the locations and extents of alluvial fans and landslide deposits.

These geomorphic features enable mapped geologic boundaries to be refined and modified to match the landscape features.

5.1.4 Aerial Imagery

Aerial imagery is available for the Tasman region as a basemap in ArcGIS. The layer consists of stitched aerial and satellite imagery with a minimum resolution of 1m. The dataset assists with identifying geomorphic features of relevance to the liquefaction assessment including:

- Changes in stream profiles such as decreasing channel widths and changes from braided to meandering channels.
- Locations of terrace risers and down-cut stream channels indicating older alluvial surfaces and areas where groundwater is expected to be deeper.
- The position of the active coastline and recent/active alluvial plains surrounding waterways.

5.1.5 Groundwater levels

Groundwater levels in the Tasman Region were assessed from water levels recorded at TDC groundwater monitoring bores and available from the TDC website. The bores provide an indication of the depth to groundwater including seasonal fluctuations in groundwater levels at the 50 monitored sites.

Liquefaction requires the deposits to be saturated, therefore the depth to groundwater can be used to infer the approximate depths to saturated deposits.

5.1.6 Regional Seismicity

The New Zealand Seismic Hazard Model (NZSHM; Stirling et al., 2012) identifies the Tasman region as a zone of contractional faulting associated with continental collision to the northwest of the northern portion of the Alpine Fault. The area is characterised by normal faults that are re-activated as range-bounding reverse faults. The NZSHM assigns the region a 475-year return period shallow soil Peak Ground Acceleration (PGA) of between 0.2 to 0.4g and a 2500-year shallow soil return period PGA of 0.4 to 0.5g.

Saunders and Berryman (2012) report that a PGA of 0.1g or greater is sufficient to trigger damaging liquefaction in highly susceptible soils hosting high-water tables based on recent earthquakes in New Zealand. The region is therefore likely to experience liquefaction under a 475-year return period earthquake.

5.1.7 Historical Records of liquefaction

Areas that have historically experienced liquefaction are likely to contain deposits that are susceptible to liquefaction during future earthquakes. The Tasman region has experienced at least six large earthquakes in the last 170 years including:

- 1848 Marlborough Earthquake
- 1855 Wairarapa Earthquake
- 1868 Cape Farewell Earthquake
- 1929 Murchison Earthquake
- 1968 Inangahua Earthquake
- 2016 Kaikoura Earthquake

Liquefaction was observed in the Ngatimoti and Murchison areas following the 1929 Murchison Earthquake, and liquefaction was reported in Murchison following the 1968 Inangahua earthquake. Collated observations from Carr (2004) suggests that liquefaction was confined to Holocene alluvial deposits close to active rivers and streams.

There are no records of liquefaction in the Tasman District following the 1848 Marlborough, 1855 Wairarapa, 1968 Cape Farewell, nor 2016 Kaikoura earthquakes. These events were not centred in the Tasman region and the shaking intensity (Modified Mercalli Scale; MMI) may not have been high enough to trigger liquefaction. It cannot be discounted that localised liquefaction occurred in the events prior to 2016 and went unreported due the lack of knowledge on liquefaction and the sparser population density.

5.1.8 Previous Liquefaction Hazard Assessments

The liquefaction susceptibility of the deposits in the Tasman region has previously been assessed by Johnston (2013) who considered geologic descriptions, geomorphology, and local experience. The assessment was completed prior to the MBIE/MfE guidance. The study suggested that the distribution of soils considered susceptible to liquefaction are limited to areas adjacent to the coast and in alluvial valleys.

The following specific areas were identified as containing deposits potentially susceptible to liquefaction:

- *Alluvial Valleys* containing Quaternary deposits <10,000 years old and comprised of gravel with some sands that are sufficiently saturated.
- *Waimea Inlet to Riwaka* coastal regions which contain sand and gravel with minor swamp and dune deposits.
- *Abel Tasman* coastal areas (including Kaiteriteri, Marahau and Totaranui) which contain marine sand and estuarine silt and mud.
- *Golden Bay* coastal areas (including Pakawau to Ruataniwha Inlets, Parapara, Pariwhakaoho, Patons Rock, Rangihaeata and Pohara) which contain marine sand and estuarine silt and mud.

5.2 Steps Taken in our Assessment

Our desktop assessment was completed in ArcGIS and included a detailed review of mapped geology and local geomorphology, considering the relationships outlined by Youd and Perkins (1978) and shown in Figure 3-2 and the semi-quantitative screening criteria presented in the MfE/MBIE (2017) guidance and shown in Figure 5-3. The semi-quantitative criteria identifies cases where liquefaction is unlikely based on depth to groundwater and/or 500-year design peak ground acceleration. Our assessment aims to classify the region into the following liquefaction vulnerability categories as per the MfE/MBIE guidelines and shown in Figure 5-1:

- ***Liquefaction Damage is Unlikely*** - geological units considered not susceptible to liquefaction based on their geologic description and/or depositional setting.
  - Refined to *Very Low Liquefaction Vulnerability* where there is sufficient conclusive geological information that the underlying deposit is not susceptible to liquefaction e.g. shallow rock and fractured rock.
- ***Liquefaction Damage is Possible*** – Areas where the geologic setting suggests that the underlying geologic unit may be susceptible to liquefaction.
- ***Liquefaction Category is Undetermined*** – Areas not considered in the liquefaction assessment or where there is insufficient data to conclusively determine the liquefaction vulnerability of the underlying geologic unit.

The boundaries of geologic units were refined from those shown in the geologic maps based on local geomorphology observed in the elevation and aerial imagery datasets and consideration of the depth to groundwater. A methodology tree outlining the steps taken in our assessment is presented in Figure 5-4 and is summarised below. Geologic descriptions of the units listed in the methodology tree are presented in Appendix B.

TYPE OF SOIL DEPOSIT	A LIQUEFACTION VULNERABILITY CATEGORY OF LIQUEFACTION DAMAGE IS UNLIKELY CAN BE ASSIGNED IF EITHER OF THESE CONDITIONS IS MET:	
	DESIGN PEAK GROUND ACCELERATION (PGA) FOR 500-YEAR INTENSITY OF EARTHQUAKE SHAKING[1]	DEPTH TO GROUNDWATER[2]
Late Holocene age Current river channels and their historical floodplains, marshes and estuaries, reclamation fills	Less than 0.1 g[3]	More than 8 m
Holocene age Less than 11,000 years old	Less than 0.2 g	More than 6 m
Latest Pleistocene age Between 11,000 and 15,000 years old	Less than 0.3 g	More than 4 m

Figure 5-3: Semi-quantitative screening criteria presented in MfE/MBIE (2017).

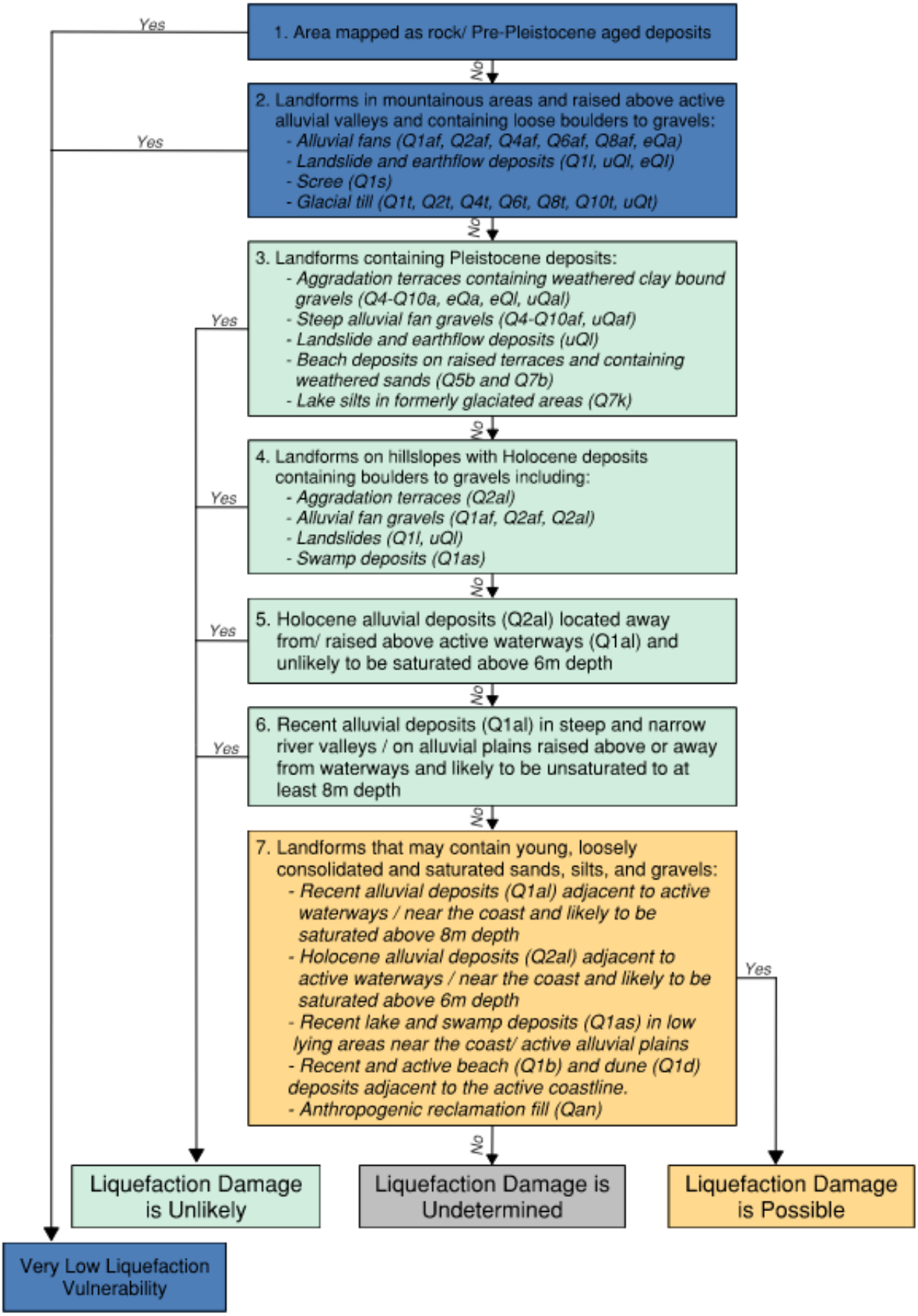


Figure 5-4: Methodology tree outlining the steps taken in our regional liquefaction assessment

Further explanation of the steps included in the methodology tree:

1. Areas underlain by pre-Pleistocene aged deposits (>2.6 million years) including rock and cemented gravels are not considered susceptible to liquefaction due to their composition and are assigned as 'Very Low Liquefaction Vulnerability'.
2. Landforms in mountainous areas that are surrounded by rock and contain boulder to gravel sized rock fragments are unlikely to be sufficiently fine grained and saturated to be susceptible to liquefaction. These deposits were assigned as 'Very Low Liquefaction Vulnerability' and include alluvial fans, landslide, scree, and glacial till deposits.
3. Landforms containing Pleistocene aged deposits are considered to have a low likelihood of liquefaction due to their age, degree of weathering, and precipitation of secondary cements. These deposits are assigned as 'Liquefaction Damage is Unlikely' as the presence of localised landforms containing liquefiable material, such as recent abandoned stream channels, cannot be discounted. Specific deposits include aggradation terraces covered in loess, alluvial fans, landslide deposits, raised beach deposits, and glacial lake silts.
4. Holocene aged deposits that are raised above active alluvial plains and comprised of slightly weathered to very weathered loose to clay-bound gravels are considered to have a low likelihood of liquefaction due to their composition and raised elevations which suggest that the depth to groundwater is likely >4m depth. These deposits are assigned as 'Liquefaction Damage is Unlikely' as the presence of localised landforms with liquefiable material cannot be discounted. Specific landforms include aggradation terraces (Q2a), alluvial fans, landslides, and elevated swamp deposits.
5. Holocene alluvial deposits (Q2al) considered unlikely to contain thick deposits of sufficiently saturated loose sands, silts, and gravels were assigned as 'Liquefaction Damage is Unlikely'. These areas include deposits located away from, or raised above, active waterways and areas inland from the coast where groundwater is expected to be >6m depth.
6. Recent alluvial deposits (Q1al) located in areas where the underlying deposits are considered unlikely to be sufficiently fine grained and/or where groundwater is expected to be greater than 8m depth were assigned as 'Liquefaction Damage is Unlikely'. These areas include:
   - Steep and narrow river valleys in mountainous or hill areas where sediments are close to the source region.
   - Alluvial valleys located inland from the coast where the water table is likely to be sufficiently deep that the near-surface deposits are likely to be unsaturated above 8m depth.
   - Alluvial valleys where the active watercourse is dominated by wide braided channels suggesting the underlying deposits are unlikely to contain thick fine-grained deposits.
7. Landforms that may contain young, loosely consolidated, and saturated sands, silts, and gravels were classified as 'Liquefaction Damage is Possible'. These deposits are generally considered susceptible to liquefaction however there is not enough information to refine the liquefaction vulnerability category. Specific landforms include:
   - Recent alluvial deposits (Q1al) in low-lying flood plains adjacent to active waterways and/or near the active coastline which are likely to be saturated above 8m depth
   - - Holocene alluvial deposits (Q2al) adjacent to active waterways and/or near the active coastline and likely to be saturated above 6m depth
   - Swamp deposits (Q1as) in low-lying areas adjacent to the coast.
   - Recent and active beach (Q1b) and dune (Q1d) deposits near the active coastline.
   - Areas of reclamation fill adjacent to the coast (Q1an)

6 Areas Potentially Susceptible to Liquefaction Damage

Our regional liquefaction assessment identified the following general areas where 'Liquefaction Damage is Possible'. This list is considered a summary of the regional liquefaction assessment and should be considered in conjunction with the maps included in Appendix A.

- Recent beach (Q1b), dune (Q1d) and swamp (Q1as) deposits located adjacent to the active coastline including estuaries, inlets, and alluvial valleys.
- Low-lying recent alluvial deposits (Q1a) forming low-gradient alluvial plains near the mouths of the Waimea, Motueka, Takaka, and Aoerere Rivers which are likely to be saturated above 8m depth. The inland extent of the potentially liquefiable deposits was refined from groundwater monitoring records and elevation contours where available.
- Recent alluvial deposits (Q1al) in recent and active flood-pains in wide alluvial valleys which are likely to be saturated above 8m depth. Specific areas include alluvial valleys near Murchison where liquefaction was reported following the 1929 Murchison and 1968 Inangahua earthquakes and the flood plains of the Waimea, Motueka, Takaka, and Aoerere Rivers and major tributaries. Extents of potentially liquefiable deposits were refined from terrace risers, elevation contours, and where available, groundwater records.

7 Assumptions and Limitations of our Assessment

Regional liquefaction mapping was completed for the Tasman Region at a scale of 1:25,000 in accordance with a Level A assessment as per the MfE/MBIE (2017) guidance. The map is not considered a replacement for site-specific liquefaction assessments and it is intended that any subsequent use is at a consistent or greater scale.

Specific assumptions and limitations of our assessment are outlined below.

- It is assumed that the mapped geology is representative of the underlying deposits. The use of the 1:250,000 QMap and selected 1:50,000 and 1:63,360 local geologic maps adds uncertainty that the mapped geology may not align with geomorphic features nor represents the actual underlying deposits.
- The assessment does not consider site-specific information on the nature of the underlying deposits nor does it consider any development or modifications to the landscape such as ground improvement under existing development.
- The scale of mapping means that localised areas of susceptible soils, such as abandoned channels, are not identified within larger geological units. There is potential for localised areas of liquefaction-induced damage in areas identified as 'Liquefaction Damage is Unlikely'.
- The digital input datasets contain residual uncertainties and accuracy limitations which are not explicitly stated in the datasets nor accompanying metadata.
- The level of assessment detail was selected by TDC.

8 Suggestions for Future Work

- TDC may consider additional work to reduce residual uncertainty in the assigned liquefaction vulnerability categories, and/or refine the extents of areas identified as 'Liquefaction Damage is Possible'.
- A Level B 'Calibrated desktop assessment' may be completed for areas of existing or proposed development and identified as 'Liquefaction Damage is Possible' in the Level A assessment in order to reduce residual uncertainty.
- A Level B assessment involves high-level calibration of mapped geology and geomorphology with deep subsurface investigations with an assessment of given return period earthquake scenarios.
  - The assessment considers a minimum of three investigations per geological sub-unit to assess typical subsurface soil types.
  - The assessment would reduce uncertainty in the assigned liquefaction vulnerability categories and potentially reduce the extent of land classified as 'Liquefaction Damage is Possible'.
- Level C and D assessments involve site-specific assessments and are typically not required for a regional plan. This level of assessment detail may be considered for specific developments and involves quantitative assessments of liquefaction triggering.

9 Planning Considerations

Our regional liquefaction assessment differentiates areas where 'Liquefaction Damage is Possible' from areas where 'Liquefaction Damage is Unlikely', which is further refined to 'Very Low Liquefaction Vulnerability' where there is sufficient information on the underlying deposits. The level of assessment detail is considered sufficient to inform regional policy statements and meets the requirements placed on TDC by the November 2019 updates to the Building Code relating to the identification of areas potentially susceptible to liquefaction.

The MfE/MBIE (2017) guidance presents a detailed overview of how liquefaction should be addressed in regional plans. The guidance recommends that maps outlining land where 'Liquefaction Damage is Possible' be used to support objectives and policies in the regional policy statement and be called 'Regional Policy Statement – Liquefaction Assessment Requirement Maps' and use the legend shown in Figure 9-1. We recommend that TDC refer to the guidance in the development of the 'Aorere ki uta, Aorere ki tai – Tasman Environment Plan'.

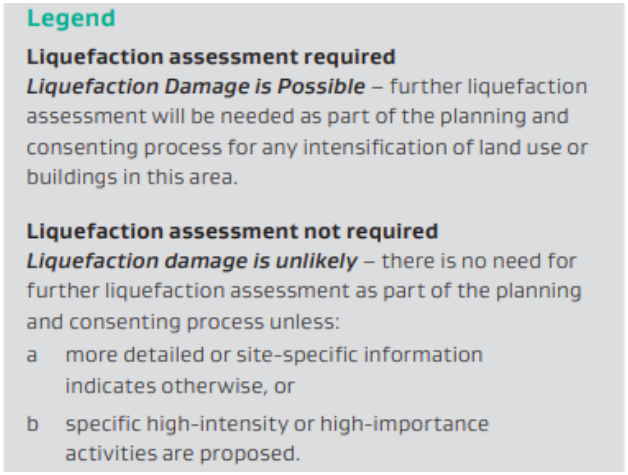


Figure 9-1: Recommended legend for regional policy statement liquefaction assessment maps from MfE/MBIE (2017).

Applicability

This report has been prepared by Beca on the specific instructions of our Client. It is solely for our Client's use for the purpose for which it is intended in accordance with the agreed scope of work. Any use or reliance by any person contrary to the above, to which Beca has not given its prior written consent, is at that person's own risk.

Should you be in any doubt as to the applicability of this report and/or its recommendations for the proposed development as described herein, and/or encounter materials on site that differ from those described herein, it is essential that you discuss these issues with the authors before proceeding with any work based on this document.

References

Beatson, K. and Whelan, H., 1993. *The river flows on: Ngatimoti through flood and fortune*, Nelson, New Zealand, Self-published.

Berrill, J, B. and Dou, Y., 1992. *Pattern Recognition Approach to Evaluation of Liquefaction Potential: Exploration of Buller Sites,* EQC Research Report 92-7, University of Canterbury, Christchurch New Zealand.

Bishop, D.G., 1971. *Sheet S1 and S3 Farewell-Collingwood*. Geological Map of New Zealand 1:63 360. New Zealand Department of Scientific and Industrial Research, Wellington, New Zealand.

Carr, K., 2004. Liquefaction Case Histories from the West Coast of the South Island, New Zealand, *Masters thesis/ EQC Research Report 2004-04,* Christchurch, New Zealand.

Grindley, G.W., 1971. *Sheet S8 Takaka.* Geological Map of New Zealand 1:63 360. New Zealand Department of Scientific and Industrial Research, Wellington, New Zealand.

Idriss, I.M., and Boulanger, R.W. (2008). *Soil Liquefaction During Earthquakes,* Earthquake Engineering Research Institute Monograph MNO12, Earthquake Engineering Research Institute, Oakland.

Johnston, M.R. 1979. Geology of the Nelson urban area. New Zealand Geological Survey urban series map 1. *New Zealand Department of Scientific and Industrial Research*, Wellington. 52 p. + 1 sheet.

Johnston, M. R. 1981: *Sheet N27pt Richmond*. Geological Map of New Zealand 1: 50 000. NZ Department of Scientific and Industrial Research.

Johnston, M., 2013. Revised Preliminary Assessment of the Liquefaction Hazard in Tasman and Tasman, *Report to Tasman District Council and Tasman District Council*, Tasman, New Zealand.

Johnson, M., 2017. An Assessment of Areas of Lower Risk of Potential Settlement due to Seismic-induced Ground Shaking, Tahunanui, Tasman District, *Report to Tasman District Council*, Tasman, New Zealand.

Kramer, S.L. (1996). *Geotechnical Earthquake Engineering*. Prentice Hill Publishers, New Jersey.

MBIE/MfE, 2017. Planning and engineering guidance for potentially liquefaction-prone land Resource Management Act and Building Act aspects; ISBN (online) 978-1-98-851770-4 Rev 0.1 Issue date September 2017, Wellington, New Zealand.

Rattenbury, M.S.; Cooper, R.A.; Johnston, M.R. (compilers) 1998: Geology of the Tasman Area: scale 1:250,000. Lower Hutt: Institute of Geological & Nuclear Sciences Limited. Institute of Geological & Nuclear Sciences 1:250,000 geological map 9. 67 p. + 1 folded map.

Saunders, W.S.A. and Berryman, K.R., 2012. Just add water, when should liquefaction be considered in land use planning? *GNS Miscellaneous Series 47,* 15 p.

Stirling, M., McVerry, G., Gerstenberger, M., Litchfield, N., Van Dissen, R., Berryman, K., Barnes, P., Wallace, L., Villamor, P., Langridge, R., Lamarche, G., Nodder, S., Reyners, M., Bradley, B., Rhoades, D., Smith, W., Nicol, A., Pettinga, J., Clark, K., Jacobs, K. (2012). National Seismic Hazard Model for New Zealand: 2010 Update, *Bulletin of the Seismological Society of America,* 102(4): 1514–1542.

Tasman District Council, 2021. Groundwater Levels. Accessed October 2021 at [https://www.tasman.govt.nz/my-region/environment/environmental-data/groundwater-levels/]

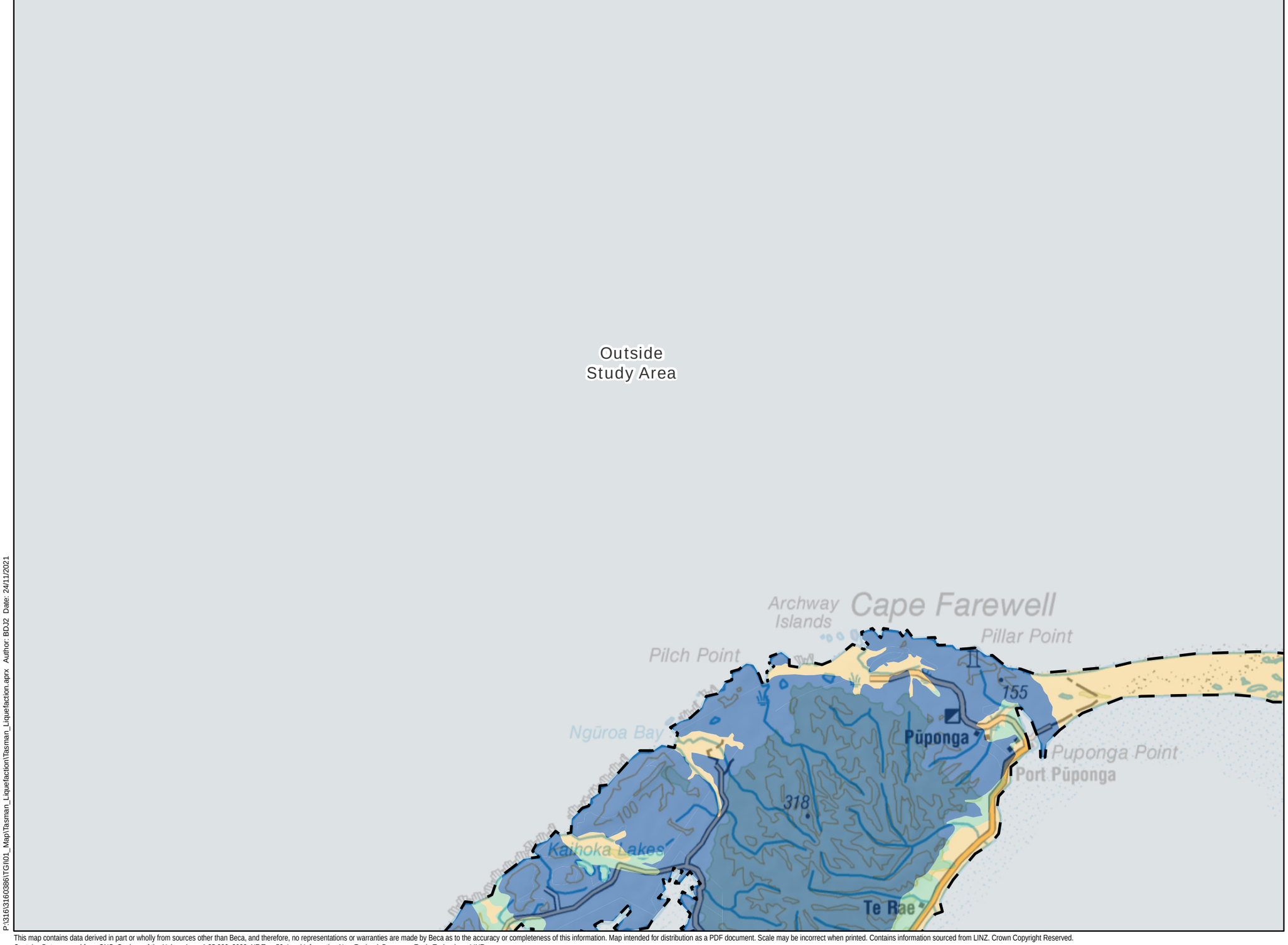
Youd, T.L., and Perkins, D.M. (1978). 'Mapping liquefaction-induced ground failure potential.' *Journal of Geotechnical Engineering, American Society of Civil Engineers*, 104(GT4): 433-446.

A

Appendix A – PDF Map Outputs

GIS@beca.com

Outside
Study Area

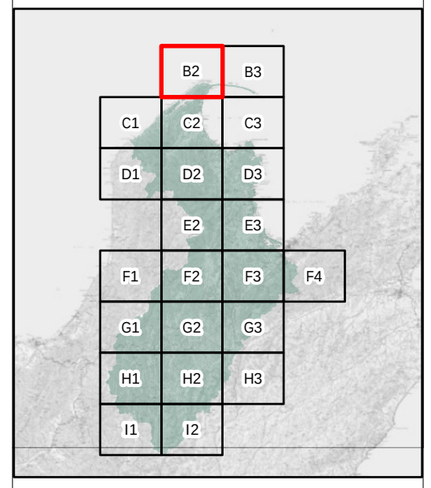


Tasman District Liquefaction Assessment

Map : B2 | Page 1 of 22

Legend

- Water
- Tasman District Study Area
- Liquefaction Damage is Unlikely
  - Very Low Liquefaction Vulnerability
- Liquefaction Damage is Possible



Map Scale @ A3: 1:100,000

0 2,000 4,000
Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

Client: Tasman District

Discipline: GIS

Project: Liquefaction Review and Support

Drawing No: GIS-3160386-01-B2

Beca

P:\3161\3160386\TG\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com

Outside
Study Area

Farewell Spit

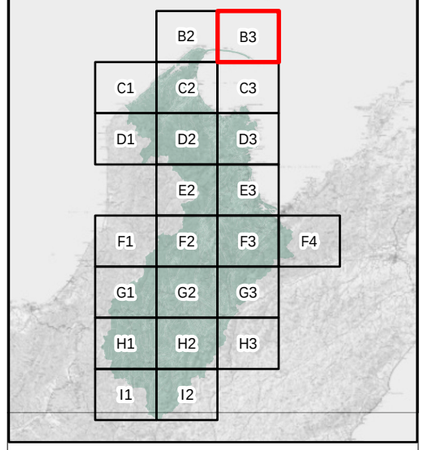
Tasman District
Liquefaction Assessment

Map : B3	Page 2 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-B3

Beca

P:\316\3160386\TG\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com

Outside
Study Area

Kahurangi Point

Otukoroiti Point

Big River

Sandhills

Lake

Webb Stream

Arataki River

Anaweka Creek

Turimawiwi River

271

966

762

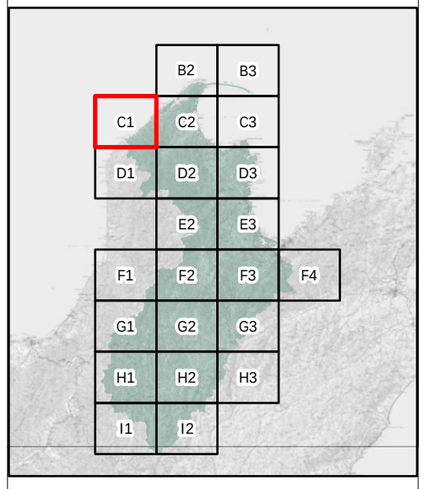
Tasman District
Liquefaction Assessment

Map : C1	Page 3 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-C1

Beca

P:\316\3160386\TG\I01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com

Bar Point
South Head Cone
Inlet
Whanganui
Seaford
Pākawau Inlet
Pākawau
Sharks Head
Waikato
Knuckle Hill
506
Mangarākau
269
Paturau River
BURNETT RANGE
641
Ōpou
678
Outside Study Area
Ferntown
Ruataniwha Inlet
Gibbstown
Collingwood
291
Otuhie River
Mt Haidinger
629
Milnthorpe
Parapara Inlet
Aorere
Kaituna River
151
Parapara
Rockville
230
Ōtere River
916
1037
Bainham
Aorere River
Onekaka
RANGE
Patons Rock
60
Mt Stevens
1208
1213
479
Parapara River
Puramahoi
975

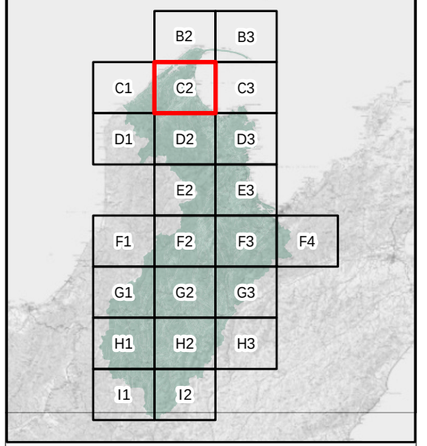
Tasman District
Liquefaction Assessment

Map : C2	Page 4 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

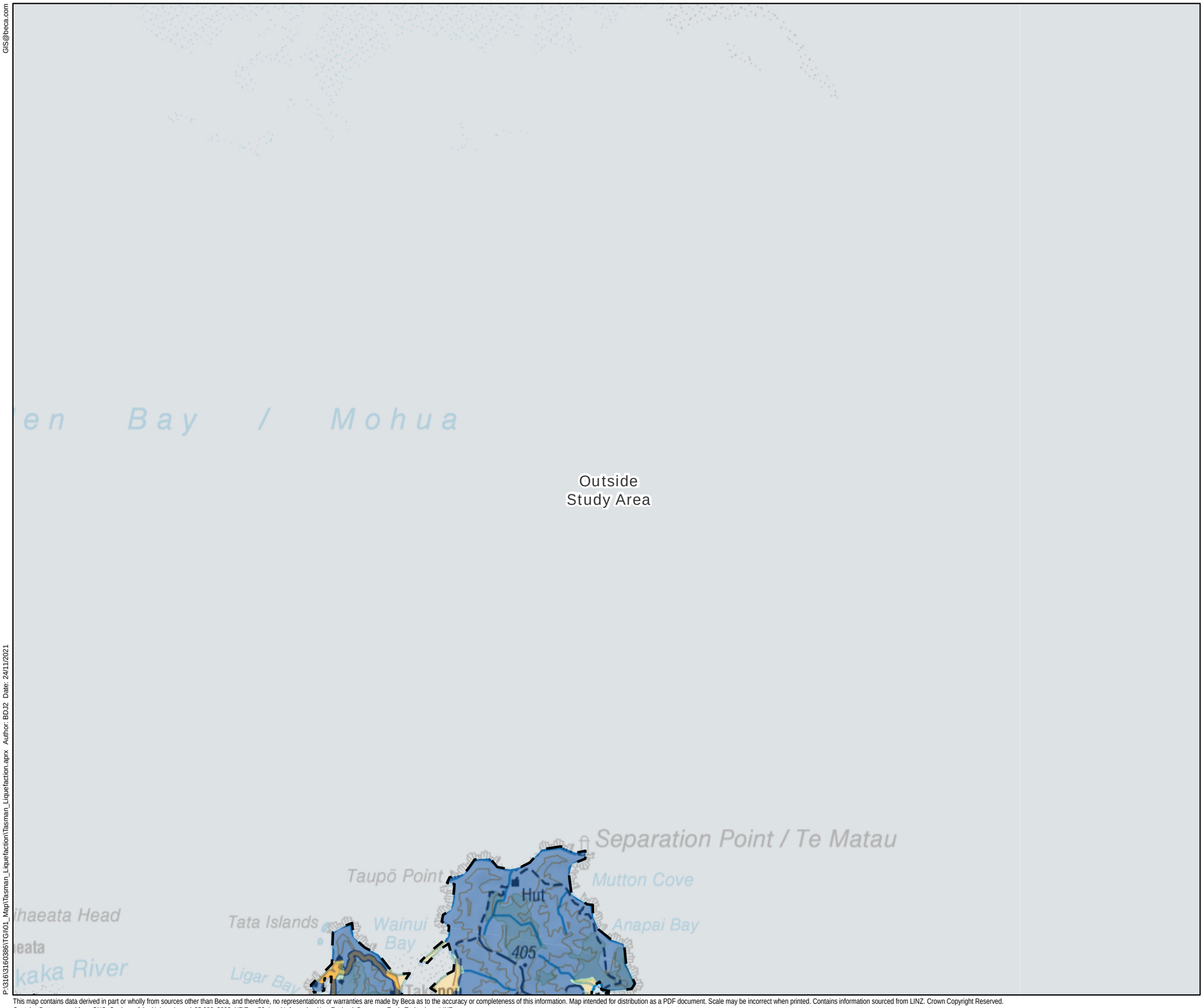
Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-C2

Beca

P:\3161\3160386\TGN01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com



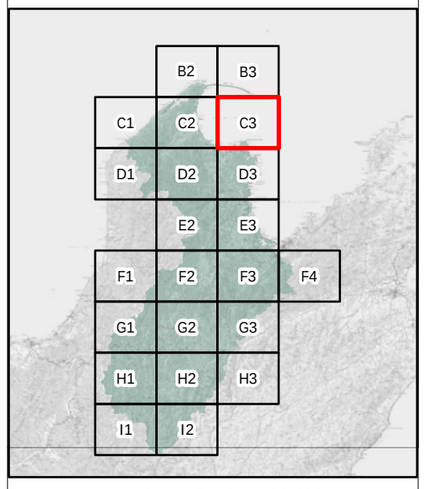
Tasman District Liquefaction Assessment

Map : C3	Page 5 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

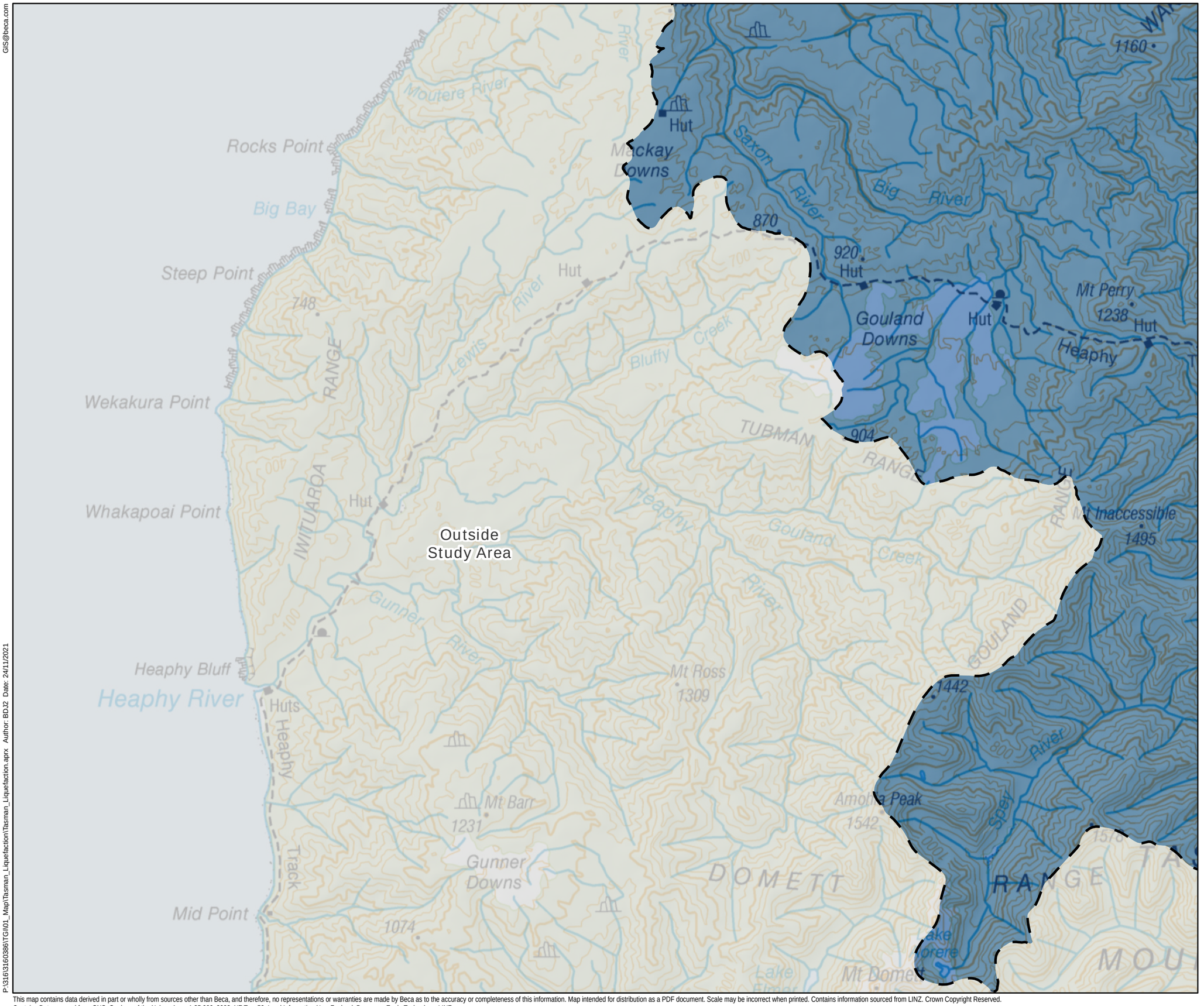
Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-C3

Beca

P:\316\3160386\TG\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com



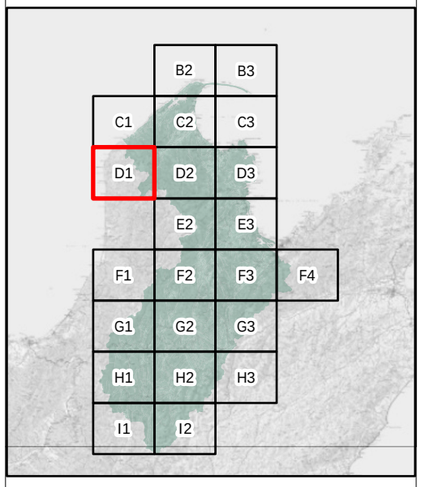
Tasman District Liquefaction Assessment

Map : D1	Page 6 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-D1

Beca

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

P:\3161\3160386\TG\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

GIS@beca.com

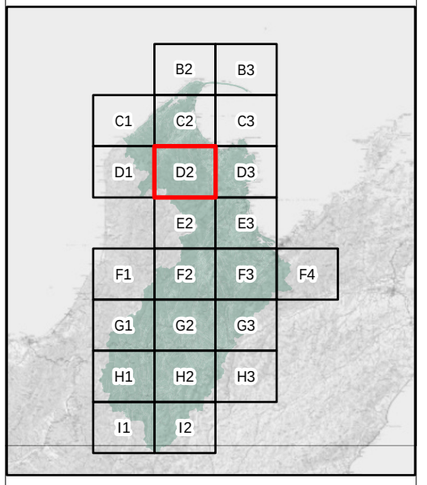
Tasman District Liquefaction Assessment

Map : D2 | Page 7 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-D2

Beca

P:\316\3160386\TG\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

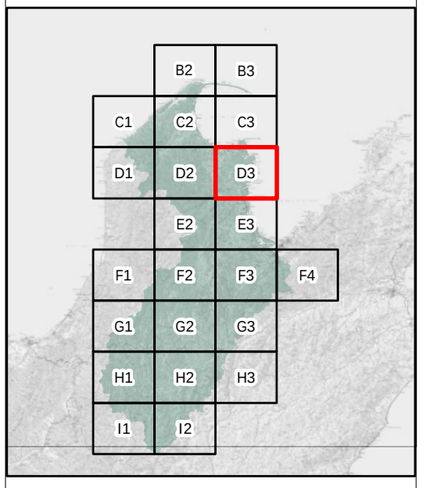
GIS@beca.com

Tasman District Liquefaction Assessment

Map : D3 | Page 8 of 22

Legend

- Water
- Tasman District Study Area
- Liquefaction Damage is Unlikely
  - Very Low Liquefaction Vulnerability
- Liquefaction Damage is Possible



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

Client: Tasman District

Discipline: GIS

Project: Liquefaction Review and Support

Drawing No: GIS-3160386-01-D3

P:\3161\3160386\TG\I\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com

Outside Study Area

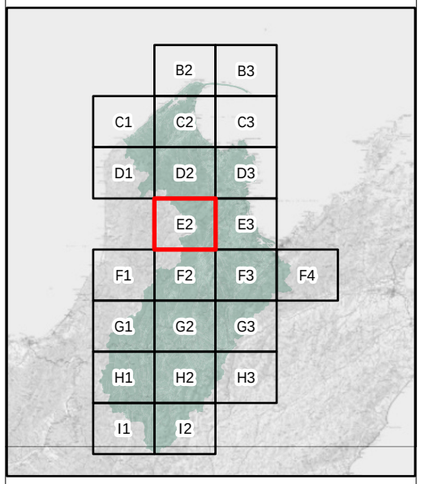
Tasman District Liquefaction Assessment

Map : E2 | Page 9 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-E2

Beca

P:\316\3160386\TG\I\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com

Tasman District Liquefaction Assessment

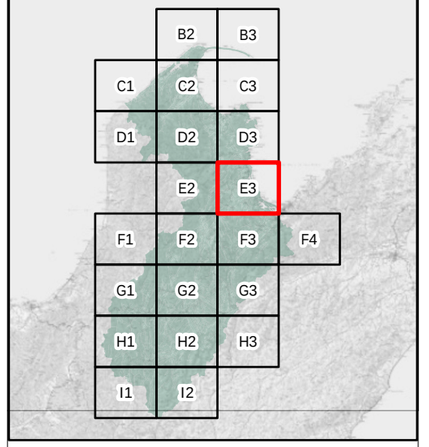
Map : E3	Page 10 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	

Outside Study Area



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-E3

Beca

P:\3161\3160386\TG\I\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com

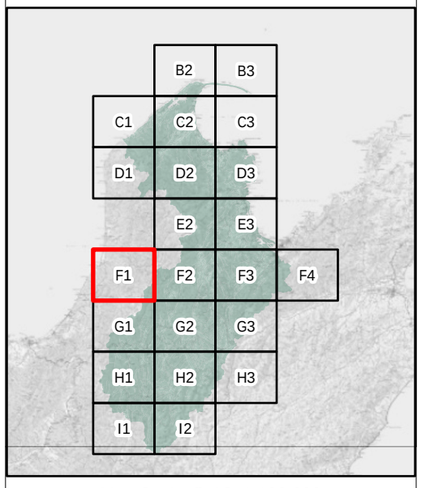
Tasman District Liquefaction Assessment

Map : F1 | Page 11 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

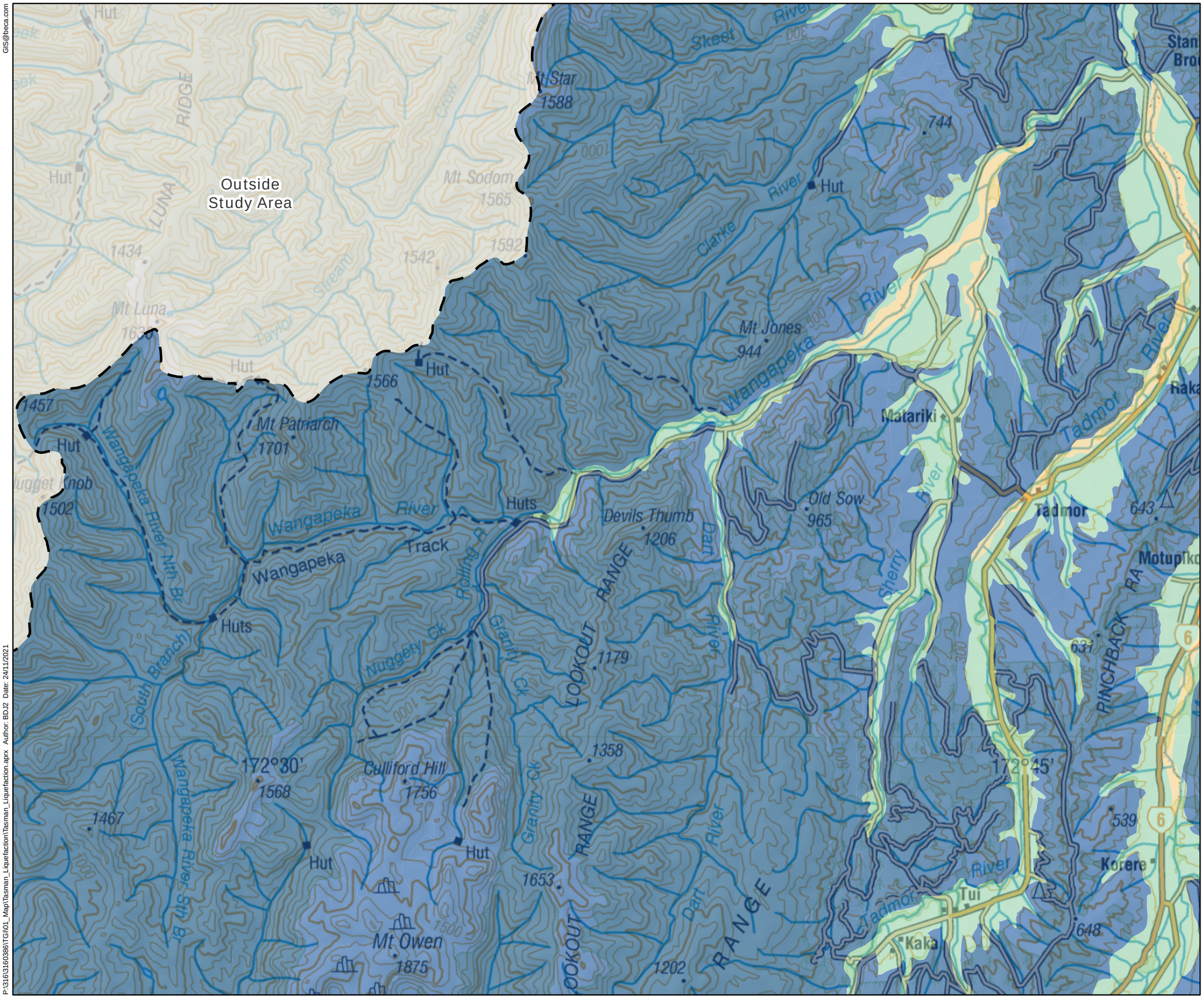
Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-F1

Beca

P:\316\3160386\TG\I01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com



P:\316\316038\6\TG\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

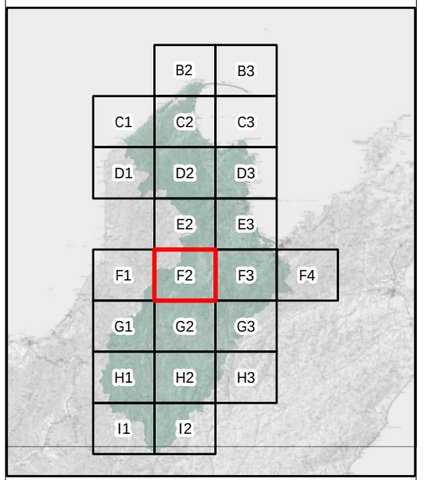
Tasman District Liquefaction Assessment

Map : F2 | Page 12 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-F2

Beca

GIS@beca.com

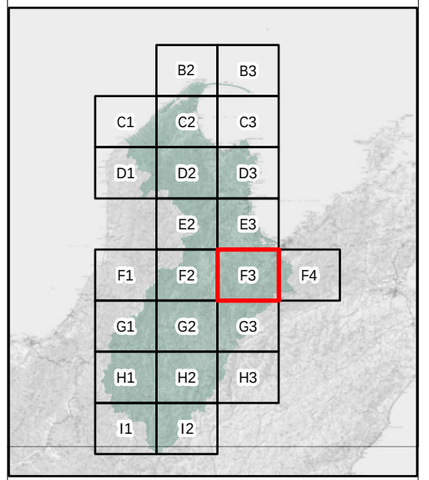
Tasman District Liquefaction Assessment

Map : F3 | Page 13 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

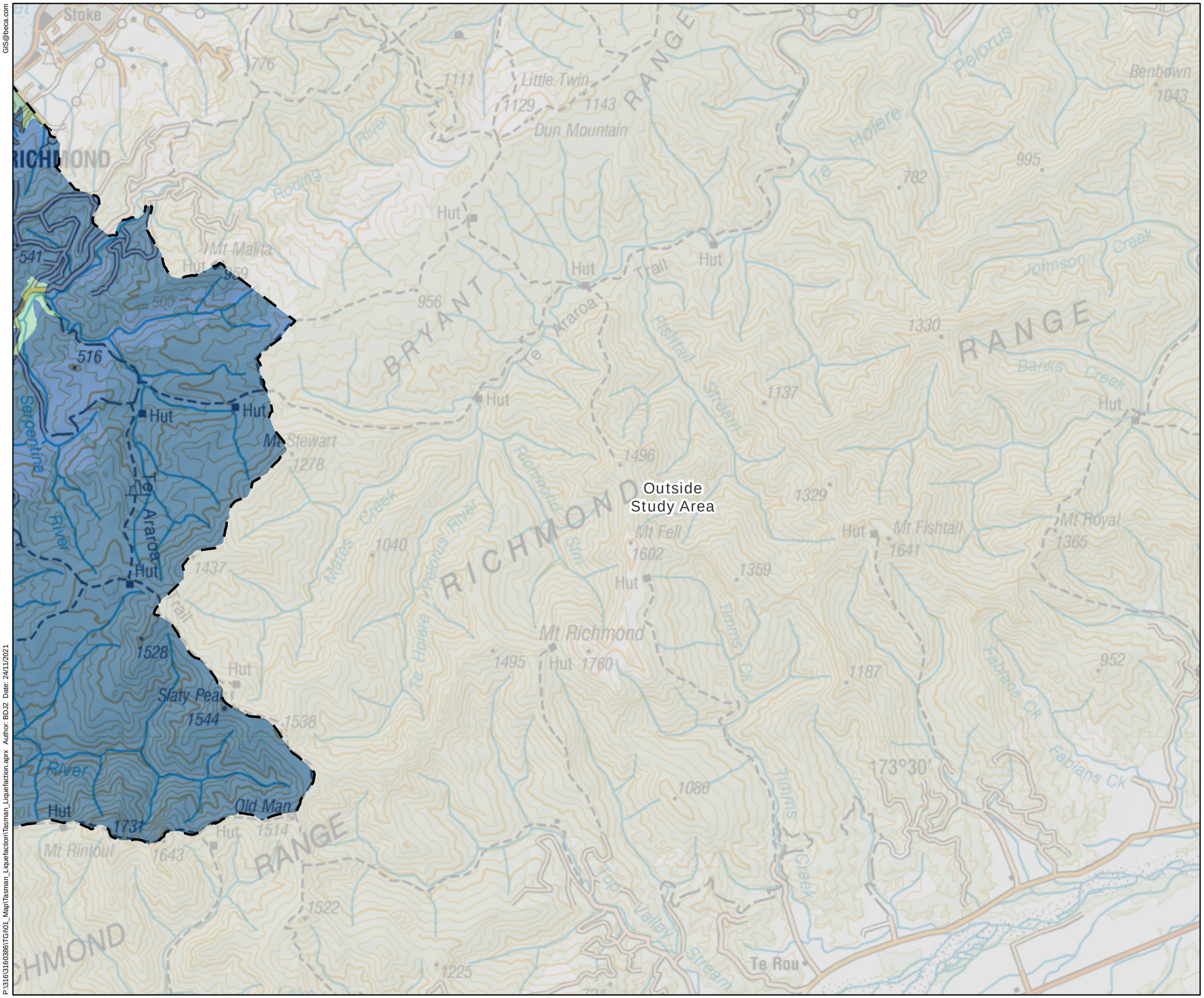
Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-F3

Beca

P:\316\3160386\TGIS\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com



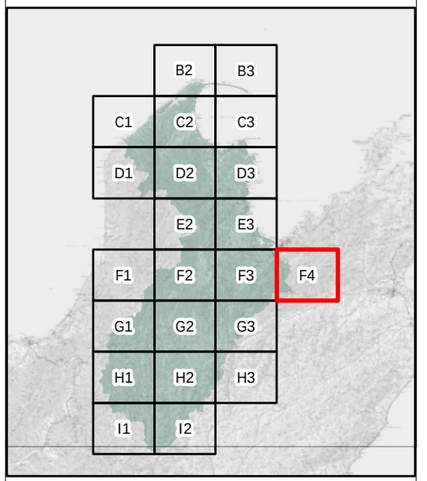
Tasman District Liquefaction Assessment

Map : F4	Page 14 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

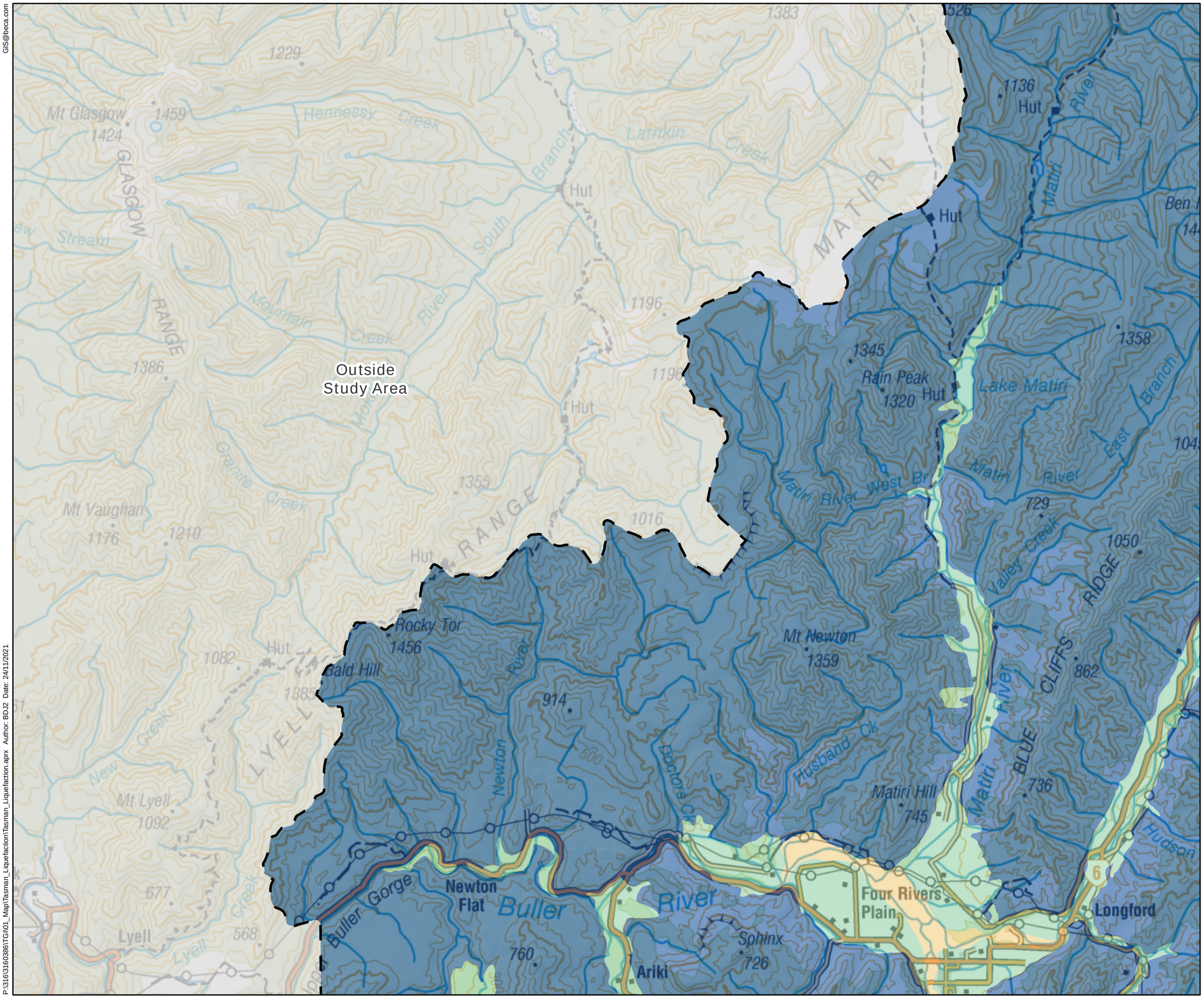
Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

Client:	Discipline:
Tasman District	GIS
Project: Liquefaction Review and Support	**Drawing No:** GIS-3160386-01-F4

P:\316\3160386\TG\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com



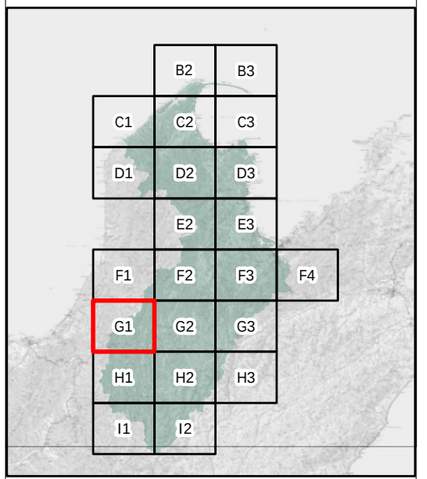
Tasman District
Liquefaction Assessment

Map : G1	Page 15 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-G1

Beca

P:\316\31603866\TGN01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com

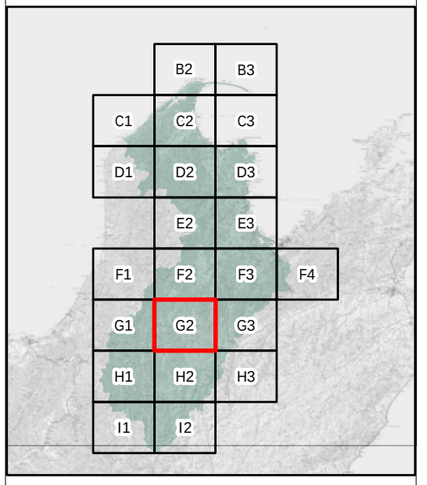
Tasman District Liquefaction Assessment

Map : G2 | Page 16 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-G2

Beca

P:\3161\3160386\TG\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com

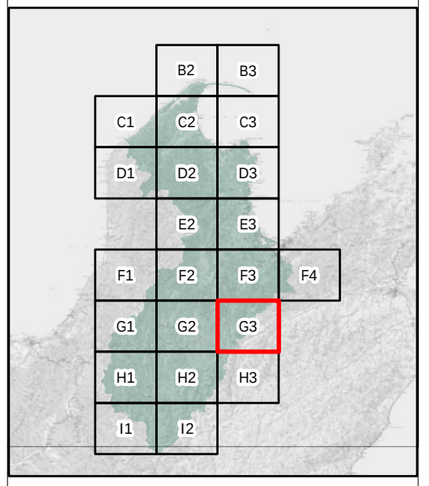
Tasman District Liquefaction Assessment

Map : G3 | Page 17 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-G3

Beca

P:\3161\3160386\TG\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com

Tasman District Liquefaction Assessment

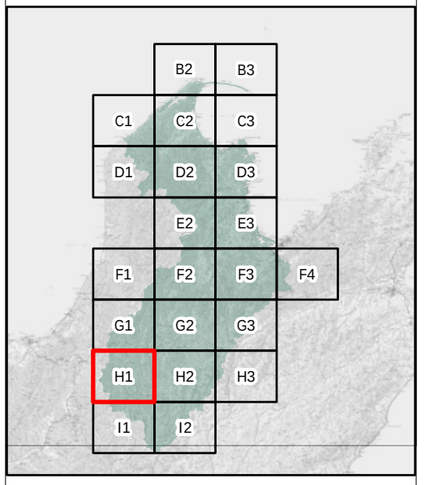
Map : H1 | Page 18 of 22

Outside Study Area

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-H1

Beca

P:\3161\3160386\TG\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com

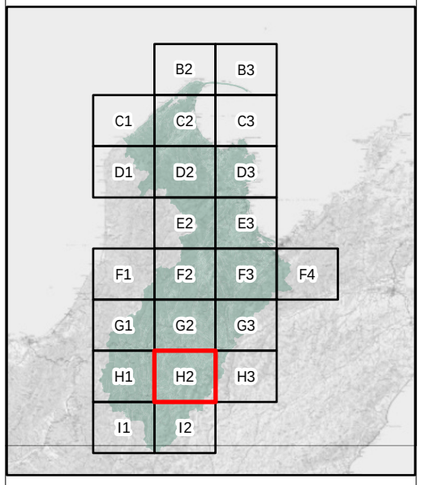
Tasman District Liquefaction Assessment

Map : H2 | Page 19 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-H2

Beca

P:\3161\3160386\TG\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com

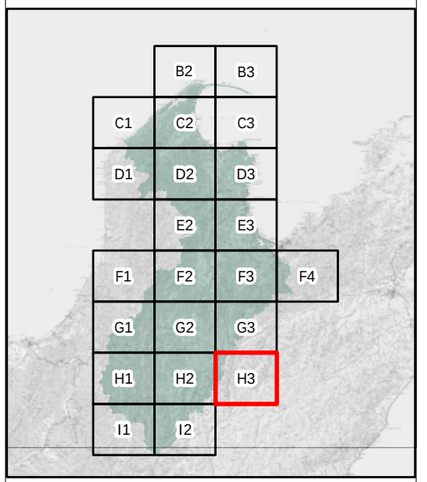
Outside Study Area

Tasman District Liquefaction Assessment

Map : H3 | Page 20 of 22

Legend

- Water
- Tasman District Study Area
- Liquefaction Damage is Unlikely
  - Very Low Liquefaction Vulnerability
- Liquefaction Damage is Possible



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

Client:	Discipline:
Tasman District	GIS
Project:	**Drawing No:**
Liquefaction Review and Support	GIS-3160386-01-H3

Beca

P:\316\3160386\TG\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

GIS@beca.com

Tasman District Liquefaction Assessment

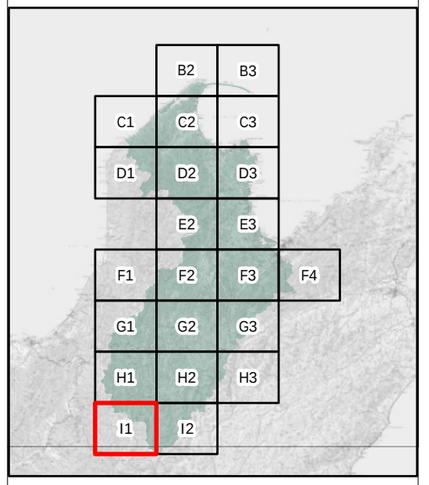
Map : I1 | Page 21 of 22

Outside Study Area

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

Client: Tasman District

Discipline: GIS

Project: Liquefaction Review and Support

Drawing No: GIS-3160386-01-I1

Beca

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

P:\316\3160386\TGI\01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

GIS@beca.com

Tasman District Liquefaction Assessment

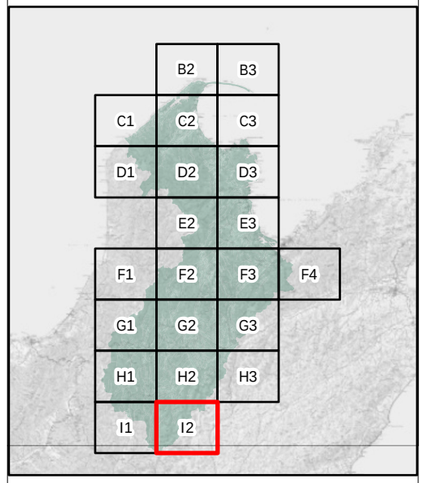
Map : I2 | Page 22 of 22

Legend

- Water
- Tasman District Study Area

Liquefaction Damage is Unlikely	Liquefaction Damage is Possible
Very Low Liquefaction Vulnerability	

Outside Study Area



Map Scale @ A3: 1:100,000

0 2,000 4,000

Metres

Revision	Author	Verified	Approved	Date
2	BDJ2	MM	SB	29/10/2021
1	JS	DRAFT	DRAFT	13/10/2021

N

Client: Tasman District

Discipline: GIS

Project: Liquefaction Review and Support

Drawing No: GIS-3160386-01-I2

Beca

P:\3161\31603861\TG\I01_Map\Tasman_Liquefaction\Tasman_Liquefaction.aprx Author: BDJ2 Date: 24/11/2021

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information. Map intended for distribution as a PDF document. Scale may be incorrect when printed. Contains information sourced from LINZ. Crown Copyright Reserved.
Contains Data sourced from GNS, Geology of the Nelson Area, 1:25,000, 2002. NZ Topo50, Land Information New Zealand. Basemap: Eagle Technology, LINZ

B

Appendix B – Summary of Quaternary Geology

Table B-1: Quaternary cover deposits encountered in the 1:250,000 geological map area

Deposit type	Map Symbol	Composition	Geomorphic Setting
Holocene alluvial deposits	Q1al	Well sorted gravel, sand, and silt	In, and adjacent to active rivers and streams in modern flood plains
Holocene fan and colluvial deposits	Q1af	Poorly sorted gravels	Base of currently active streams and rivers in river valleys and/or on hillslopes
Holocene swamp deposits	Q1as	Poorly consolidated sand, mud, and peat.	Flat low-lying areas adjacent to the coast/ upriver from landslides
Holocene beach deposits	Q1b	Sand, mud, and boulder banks	Boulder bank and preserved beach ridges
Holocene sand dunes	Q1d	Well sorted sands	Adjacent to the active coastline
Holocene landslide and earthflow deposits	Q1l	poorly sorted clasts up to boulder size in a clay matrix	Widespread on hillslopes across the region
Holocene scree deposits	Q1s	Rock fragments of boulder and gravel size in clay matrix	Widespread on hillslopes across the region
Holocene glacial till	Q1t	Unweathered till comprised of gravel, sand, and silt	Margins of most recently glaciated valleys
Pleistocene alluvial deposits	Q2al	Poorly to moderately sorted gravel with minor sand or silt, including clay bound gravels.	Lowest aggradation terraces above major rivers and minor fan deposits
Pleistocene fan and colluvial deposits	Q2af	River gravel and sand; and fan deposits	Base of abandoned streams and/or outside currently active alluvial fans
Pleistocene glacial till	Q2t	Till comprised of gravel, sand, and silt	Margins of formerly glaciated valleys
Pre-Pleistocene fan and colluvial deposits	Q4af, Q6af, Q8af Q10af, UQaf	Slightly to very weathered clay-bound gravels	Margins of formerly glaciated valleys
Pre-Pleistocene alluvial deposits	Q4al, Q6a/ Q6al, Q8a, Qal, uQal, eQa, eQl	Slightly to moderately weathered, poorly to moderately sorted gravels	Intermediate, high, and remnant aggradation terraces covered in loess
Pre-Pleistocene glacial till	Q4t, Q6t, Q8t, uQt	Slightly to moderately weathered till	Margins of formerly glaciated valleys
Pre-Pleistocene beach deposits	Q5b, Q7b	Slightly to moderately weathered sand on	Raised terraces inland from the present coastline
Pre-Pleistocene lake deposits	Q7k	Laminated silts	Glaciated valleys and hillslopes in Murchison area
Undifferentiated earthflow and landslide deposits (Pre-Pleistocene)	uQl	Shattered rock/ poorly sorted clasts up to boulders size in a clay matrix	Widespread on hillslopes across the region
Anthropogenic deposits (<500 years)	Qan	Wood domestic waste sand and boulders	Reclamation fill comprising hard and hydraulic fill