REPORT

Tonkin+Taylor

Omokoroa Stage 3 Structure Plan Area

Supplementary Level B Liquefaction Assessment

Prepared for
Bay of Plenty Regional Council

Prepared by
Tonkin & Taylor Ltd

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Executive summary

Liquefaction assessment summary	
This liquefaction assessment has been undertaken in general accordance with the guidance document 'Assessment of Liquefaction-induced Ground Damage to Inform Planning Processes' published by the Ministry of Business, Innovation and Employment in 2017. https://www.building.govt.nz/building-code-compliance/b-stability/b1-structure/planning-engineering-liquefaction-land/	
Client	Bay of Plenty Regional Council (BOPRC)
Assessment undertaken by	Tonkin & Taylor Ltd. PO Box 5271 Wellesley Street Auckland 1141
Extent of the study area	• Total: 280 ha (2.8 km^2), Area of development: 150 ha (1.5 km^2)
Intended RMA planning and consenting purposes	• Information to support land use plan change application
Other intended purposes	• Input to a risk assessment in accordance with the BOPRC Regional Policy Statement
Level of detail within the area of development	• Level B (calibrated desktop assessment)
Notes regarding base information	• This assessment includes consideration of available geotechnical investigations that were within the study area extent and land adjacent to the study area extent on the NZ Geotechnical Database as at 6 May 2019 and additional project specific investigation completed in February 2020. • The mapped depth to groundwater was developed from point measurements of groundwater levels and with engineering judgement. It is intended to be used at a high level to assess suitability of land for land use plan change purposes.
Other notes	• The assessment is not suitable for other purposes (e.g. for appending to Land Information Memorandum reports or detailed design) • The portions of land classified as *liquefaction damage is possible* have been established based on: - Data and information summarised in this report. If more information becomes available, the liquefaction damage category may change for certain areas of land. - The primary indicator of liquefaction vulnerability has been based on the assessment that the Rotoehu Ash is not susceptible to liquefaction and this layer being less than 4 m depth. - The current information indicates that the majority of the proposed development area is likely to have none to minor liquefaction-induced land damage following levels of earthquake shaking up to 500 year ARI.

1 Introduction

Tonkin & Taylor Ltd (T+T) was engaged by Western Bay of Plenty District Council (WBOPDC) and Bay of Plenty Regional Council (BOPRC) to undertake ground investigation and liquefaction risk assessments for the Omokoroa Stage 3 Structure Plan Area in general accordance with the MBIE/MfE Guidelines (2017) in order to inform the suitability of land for the structure plan change. The study area is shown in Figure A1 of Appendix A.

A liquefaction assessment was completed in September 2019 to a Level A (desktop assessment) level of detail. The September 2019 assessment recommended further work to obtain a Level B (calibrated desktop assessment) level of detail suitable for a change in land use and Regional Policy Statement (RPS) risk assessment. To support this increased level of detail, a ground investigation and factual report was completed in February 2020 by T+T.

This report is intended to provide a Level B level of detail with use of the previous Level A assessment of the same study area in Omokoroa (T+T, 2019), and the recent project specific ground investigation data (T+T, 2020). This report is supplementary to the Level A report (T+T, 2019) and therefore should be read in conjunction with that report. The Level A report is included in Appendix C.

This report has been completed for BOPRC in accordance with the scope included in the T+T variation dated March 2020.

2 Objectives from the Level A assessment

The performance criteria for determining the liquefaction vulnerability category from Table 4.4 of the MBIE/MfE Guidelines (2017) was mapped in the Level A study (T+T, 2019). The main outcome of that mapping process was that the land was categorised into two liquefaction vulnerability areas as described below:

- Type A sub area (stream channel and coastal margin areas): *Liquefaction Damage is Possible.*
- Type B sub area (within elevated terraces): *Liquefaction Damage is Unlikely* subject to confirmation that the depth to groundwater is deeper than 4 m and the presence of the Rotoehu Ash layer is confirmed across the area under consideration at a depth of 4 m or less.

The outcomes of the Level A study (T+T, 2019) assisted with targeting the investigation to establish objectives for the investigation. The main objectives were to:

- Assess the depth to groundwater across the study area from standpipe piezometer and other investigation records.
- Assess the presence and depth to the top of the Rotoehu Ash layer (base of the Younger Ash).
- Complete additional CPT investigations for liquefaction analysis.

3 Risk identification

3.1 Target level of detail required for intended purposes

The primary purpose of this assessment is to assess suitability for a land use plan change. T+T understands that the proposed density of dwellings for the study area is likely to be 20 dwellings per hectare. This is consistent with an “urban residential development” as described in the MBIE/MfE Guidelines (2017) (i.e. typically 15 - 60 households per hectare). Table 3.5 of the MBIE/MfE Guidelines (2017) recommends the following minimum level of detail to support a plan change for an “urban residential development”:

- Level A for land categorised as Very Low liquefaction vulnerability category; or
- Level B for land categorised as Low, Medium or High liquefaction vulnerability category.

The previous Level A assessment (T+T, 2019) did not demonstrate a Very Low liquefaction vulnerability, therefore a Level B assessment is targeted to support the proposed land use planning change.

3.2 Base information currently available

3.2.1 Ground surface levels

Additional ground surface level information has not been obtained since the Level A study. The ground level information (2015 LiDAR) is shown in Figure A2 of Appendix A. The resolution is 1.0 m.

3.2.2 Geology and geomorphology

Additional published geological or geomorphological information has not been obtained since the Level A study. However, refinement has been made to the geomorphological mapping as a result of more detailed ground investigation discussed in Section 3.2.3.

The depth and extent of the Rotoehu Ash is a key component of this study because this layer and the underlying soils have been assessed as not susceptible to liquefaction for reasons discussed in Section 4.4. The investigations identified the top of the Rotoehu Ash at depths between 0.9 m and 3.1 m within the terrace areas of the site (Type B sub area). In the stream gullies the Rotoehu Ash was not investigated as stream processes are likely to have eroded this ash material away.

The geomorphology is shown in Figure A3 of Appendix A and the measured depth to the top of the Rotoehu Ash layer is shown in Figure A5 of Appendix A.

3.2.3 Geotechnical investigations

Additional geotechnical information has been obtained from two primary sources since the Level A study:

- Project specific ground investigation as described in the February 2020 geotechnical factual report (T+T, 2020).
- Geotechnical investigation (ten hand augers) for a subdivision at 58 and 70A Francis Road (Aurecon, 2017).

The following table summarises the currently available information within and adjacent to the study area. The ground investigation locations are included in Figure A1 of Appendix A.

Table 3.1: Geotechnical information available within and adjacent to the study area

Source	CPT	HA	SP	BH
Inside the study area				
Project specific geotechnical report (T+T, 2020)	9	10	6	-
New Zealand Geotechnical Database (NZGD)	4	-	-	-
Geotechnical Assessment Report – 58 and 70A Francis Road	-	10	-	-
Preliminary Geotechnical Investigation Report – 452 Omokoroa Road, Omokoroa	-	9	-	-
Sub-total	**13**	**29**	**6**	**-**
Adjacent to the study area				
New Zealand Geotechnical Database (NZGD)	3	-	-	2
Geotechnical Completion Report – Stage 1A Kaimai Views Subdivision, 336, 340 and 344 Omokoroa Road, Omokoroa	18	14	-	-
Geotechnical Completion Report – Stage 1, 423 Omokoroa Road, Omokoroa	-	27	-	-
Geotechnical Completion Report – Stage 1C of the Harbour Ridge Subdivision at 351 Omokoroa Road, Omokoroa	-	15	-	-
Sub-total	**21**	**56**	**-**	**2**
Total	**34**	**85**	**6**	**-**

Notes: CPT = Cone Penetration Test, HA = Hand Auger Borehole, BH = Machine Borehole, SP = Standpipe piezometer

3.2.4 Groundwater

The project specific geotechnical investigations (T+T, 2020) involved installation of six standpipe piezometers within the study area to inform the qualitative assessment of depth to groundwater developed as part of the Level A study. Measurements of the groundwater levels within the standpipes were recorded over four visits. Some of the earlier measurements were variable indicating that the standpipe was equilibrating with the natural groundwater level. The measurements obtained on 18 February 2020 indicate that the water level in the piezometers has stabilised to in-situ groundwater levels.

Figure A4 of Appendix A shows the measured groundwater depths. Within the terraced areas the measurements ranged between 4.41 m (CPT106) and 9.07 m (CPT105) below ground level (m bgl). CPT106 and 107b had relatively shallow measurements, even though they are located at higher elevations. These shallower measurements indicate the potential for locally perched groundwater within the study area, an observation supported by previous geotechnical reports (CMW, 2017; CMW, 2018) and T+T's field experience. Only one standpipe piezometers was located within the stream gully and coastal margin areas, and the depth to groundwater measured at this location was 2.17 m bgl.

3.2.5 Regional seismicity

The adopted ground seismic hazard is documented within the Level A study. The estimated 500 year return period peak ground acceleration (PGA) and effective magnitude utilised for this assessment are 0.26g and 5.9, respectively. This has been calculated in accordance with the NZTA Bridge Manual methodology (2018) assuming subsoil class D.

Since the Level A study was undertaken, Tauranga City Council (TCC) engaged Bradley Seismic Limited (BSL) to undertake a high-level regional seismic hazard assessment (BSL, 2019) for the purposes of informing the seismic hazard component of a regional liquefaction assessment across the Tauranga City area. A comparison of the predicted PGA and Magnitude (M) is provided in Table

4.1. The table shows that BSL predicts PGAs that are 20 to 30% less than the NZTA bridge manual and the magnitudes are slightly higher. If the BSL estimates were utilised to for the Omokoroa liquefaction assessment it is likely that reduced consequences of liquefaction-induced ground damage would be predicted. The Omokoroa Study Area is approximately 7 km northwest of the TCC study area boundary.

Table 3.2: Comparison of seismic parameters between BSL and NZTA Bridge Manual

		BSL Seismic Parameters for Tauranga City		NZTA Bridge Manual Seismic Parameters[(a)]	
		PGA	M	PGA	M
Return period	**25**	0.06	6.1	0.07	5.9
	100	0.11	6.1	0.13	5.9
	250	0.16	6.2	0.20	5.9
	500	0.20	6.2	0.26	5.9
	1000	0.24	6.3	0.35	5.9

Notes: a. Assumed variables: Subsoil class D, Location = Tauranga

3.2.6 Historical observations of liquefaction

Additional historic observations of liquefaction have not been obtained since the Level A study.

3.3 Level of detail supported by currently available information

The currently available information supports a Level B (calibrated desktop) level of detail.

Table 3.3 of MBIE (2017) provides the indicative spatial density for a Level B ground investigation. Table 3.3 provides comparison between the guidance and what is achieved within the study area. The proposed development area is approximately 1.5 km^2 (excluded stream gullies).

Table 3.3: Comparison of investigations completed against MBIE (2017) Guidance

MBIE guidance	Guidance	Achieved
Minimum of 0.5 to 20 deep investigations per km^2	0.75 to 30[(1)]	13
Maximum average deep investigation spacing (m)	220 to 1400	400 to 600
Minimum number of deep investigations for each geological sub-unit[(2)]	3	13

Notes: (1) An area of development of 1.5 km^2 has been determined. (2) The development area is underlain by the same series of ash and sedimentary soil units. The main units being Younger Ash, Rotoehu Ash and Hamilton Ash all underlain by soils within the Matua Subgroup.

Table 3.3 shows that the investigations completed achieve a number and density that is in the middle of the range that would be expected for a Level B assessment.

Based on review of the base information available for this study and consideration of the recommendations provided in Table 3.1 of the MBIE/MfE Guidelines (2017), T+T have assessed the level of detail supported by the currently available information to be as follows for each Geomorphic Zone:

- Stream gullies and coastal margin – Level A
- Terraces – Level B

These geomorphic zones are provided in Figure A3 of Appendix A.

4 MBIE/MfE risk analysis

4.1 Definition of sub-areas

The sub-areas have been defined based on the previous Level A study. However, refinement has been made to the sub-areas based on the new ground investigation information. The sub-areas are as follows:

- Sub-area Type A comprises the stream gullies and coastal margins
- Sub-area Type B comprises the more elevated terrace areas

These are shown on Figure A3 of Appendix A.

4.2 Groundwater depths for analysis

The monitoring period within the study area has not been long enough to assess seasonal fluctuations in groundwater level. To estimate seasonal fluctuations in groundwater level in the study area we have reviewed data from standpipes at Ruamoana Place, Omokoroa (north of the site) where similar soils are present and continuous monitoring has taken place over a number of years.

The location of Ruamoana Place in relation to the site is provided in Figure 4.1.

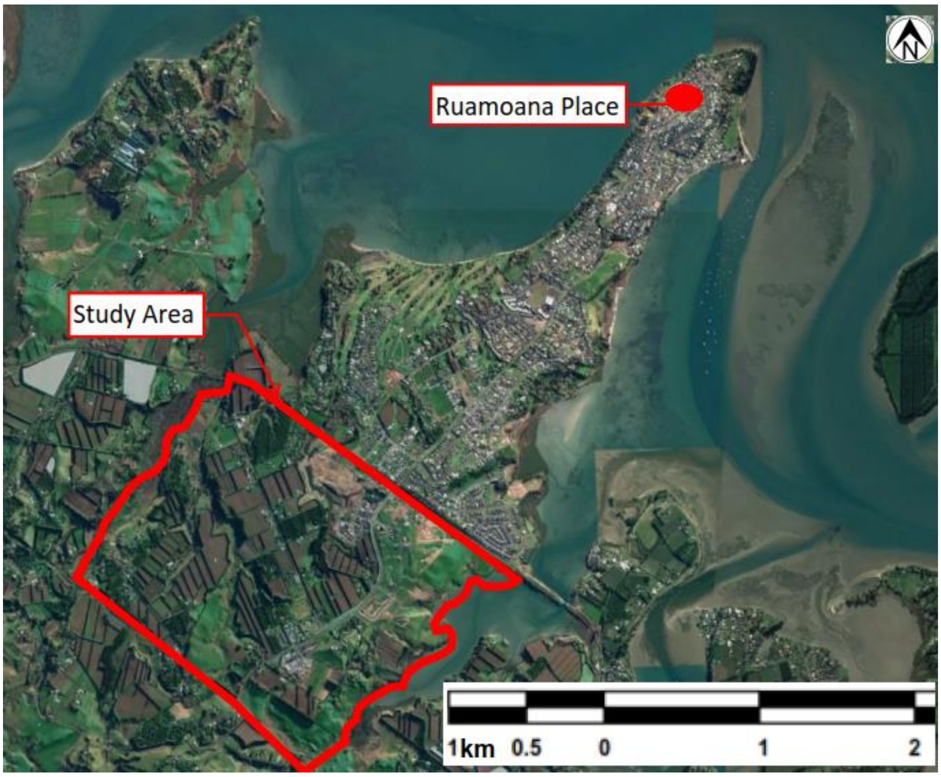

Figure 4.1: Omokoroa Study Area in relation to Ruamoana Place overlain on an Aerial Photograph

Water levels at Ruamoana Place have been recorded in six standpipes, however we have conservatively selected the two records shown in Figure 4.2 as they exhibit the greatest seasonal fluctuations. Based on the records from these two standpipes we have estimated seasonal groundwater level maxima and minima within the study area.

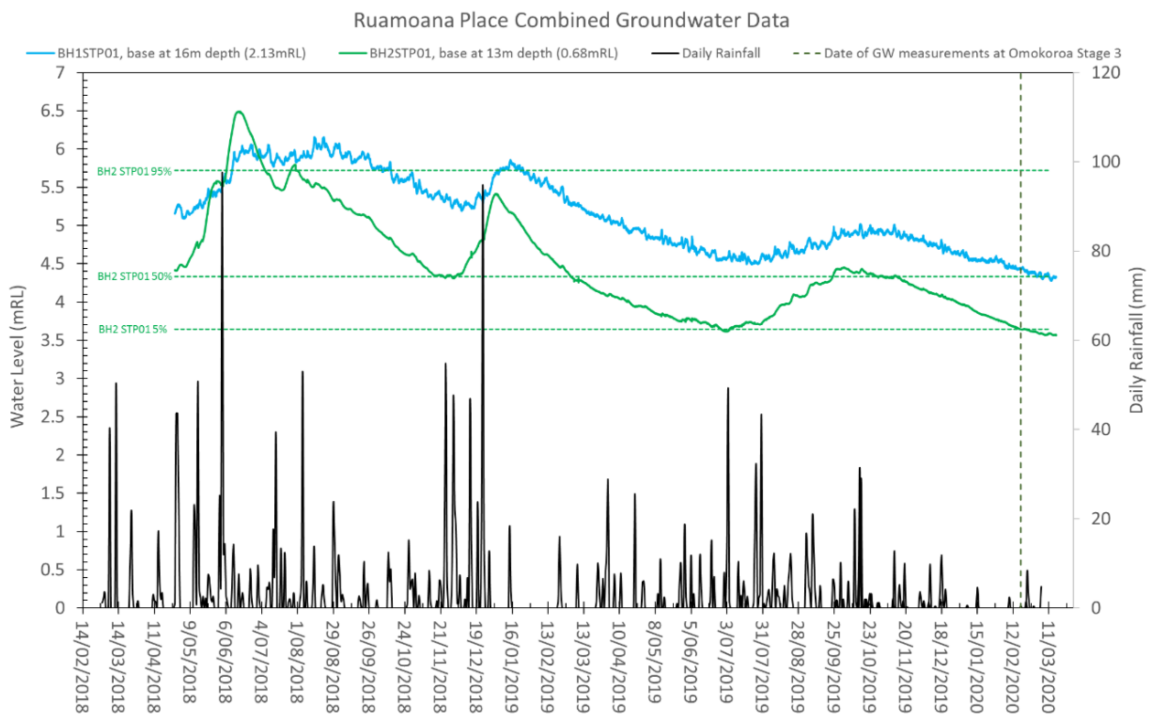

Figure 4.2: Ruamoana Place groundwater monitoring data and rainfall data

Figure 4.2 shows that seasonal fluctuations of between 2.0 and 3.0 m in groundwater level have been observed at Ruamoana Place. We note though that the difference between the 5th percentile and the median is around 0.7 m in these records.

Measurements of groundwater levels within the study area were obtained during summer months, i.e. when the groundwater level was likely to be close to its lowest point (5th percentile). Due to the potential variance between Ruamoana Place and the study area, the median groundwater level has been estimated as 1 m above the measurements obtained from the site on 18 February 2020. This provides median groundwater depth estimates of between 4 and 6 m bgl within the area of proposed development.

We note that there are differences between Ruamoana Place and the study area, such as topography, catchment areas, area of paved surfaces, proximity to the harbour margin, etc. These features influence ground water levels in different ways. However, in the absence of any other local seasonal records, the use of this information is considered appropriate for this study.

Both the measured and estimated median groundwater levels across the site are provided in Figure A4 of Appendix A. The extent of the groundwater depth layer has also been modified since the Level A study based on refinement of the geomorphology and the new groundwater level measurements.

4.3 Earthquake scenarios

This risk analysis has primarily used the ground damage response for a 500 year average recurrence interval using the NZTA Bridge Manual (2018) which results in a PGA of 0.26g and effective magnitude of 5.9. Qualitative considerations have been made regarding the ground damage response for a range of return periods. This is described in the Section 4.4.

The 2019 BSL regional seismic hazard assessment identified that lower PGAs may occur at high return periods within the Tauranga City area, 7 km south east of the Omokoroa study area. These reduced PGAs have not been specifically incorporated into the liquefaction analysis. However, this has supported the overall risk assessment in a qualitative sense, as it provides an indication that the seismic risk is likely to be lower than expected.

4.4 Determination of expected degree of liquefaction-induced ground damage

To determine the expected degree of liquefaction-induced ground damage for each sub area it is necessary to evaluate the liquefaction vulnerability indicators available.

Tables 2 and 3 of Appendix B present the risk analysis based on liquefaction vulnerability indicators. Figure B1 provides a spatial understanding of the expected degree of liquefaction induced ground damage at 500 year levels of earthquake shaking based on the interpreted CPT based liquefaction vulnerability indicators. It is important to note that there is significant residual uncertainty associated with CPT based liquefaction vulnerability indicators and the actual liquefaction induced land damage may differ from that indicated using this analysis.

The primary indicator of liquefaction vulnerability has been the assessment of depth to the Rotoehu Ash layer based on hand auger boreholes. The Rotoehu Ash layer has been assessed as not susceptible to liquefaction for the following reasons:

- The soil is pumiceous with a high apparent cohesion. Vertical cuts of this material have been observed to free stand at near vertical.
- The Rotoehu Ash layer is Pleistocene age airfall deposit (>50,000 years old). The case history of Youd and Perkins (1978) indicates that liquefaction is more common in younger (i.e. Holocene age) soil deposits than older (i.e. Pleistocene age and older) soil deposits. The MBIE/MfE Guidelines (2017) also recognises this differentiation in liquefaction vulnerability based on soil age.

Figure A5 of Appendix A shows spatially the depth of the Rotoehu Ash determined based on the hand auger boreholes. The top of the Rotoehu Ash (or base of Younger Ash) is measured to range in depth between 0.9 m and 3.1 m bgl. In all cases, the depth was measured as less than 4.0 m bgl.

In the CPT based liquefaction analysis in Appendix B, soils within and below the Rotoehu Ash (or below the Younger Ash) have been assumed as not susceptible to liquefaction. The relevant input parameters to the CPT based liquefaction analysis have been included in Appendix B Table 1.

Using the this risk analysis for each sub area, the expected degree of liquefaction induced ground damage by ARI of earthquake shaking for each sub area is summarised in Table 4.1.

Table 4.1: Expected degree of liquefaction induced ground damage by ARI and sub area (refer Figure A3 of Appendix A for each area)

		Expected degree of liquefaction induced ground damage		
		25 year ARI	**100 year ARI**	**500 year ARI**
Sub area	**Type A (stream gullies and coastal margin)**	None-to-minor	None-to-minor	Minor to moderate or moderate to severe
	Type B (terraces)	None-to-minor	None-to-minor	None-to-minor

Because of the proximity of the Rotoehu Ash to the ground surface, the Type B sub area is expected to have 'none-to-minor' liquefaction-induced land damage under earthquake shaking up to at least 500 year ARI levels.

Beyond 500 year ARI levels of earthquake shaking, the expected liquefaction related land damage generally plateaus (i.e. regardless of how much more the shaking intensity increases, the expected liquefaction related land damage is likely to remain the same).

Consideration has also been given to the potential increase in liquefaction vulnerability if the groundwater was shallower than estimated or perched within the Type B sub area. The CPT based liquefaction analysis in Appendix B indicates that groundwater would need to be as shallow as 1 to 2 m bgl for there to be any liquefaction triggering within the soil profile. This is considered unlikely, as the sandy, high permeability Rotoehu Ash is likely to prevent increases in groundwater of this magnitude.

4.5 Liquefaction vulnerability against performance criteria

The methodology described in the MBIE/MfE Guidelines (2017) recommends liquefaction vulnerability categorisation of the land based on the performance criteria described in Figure 4.3 below.

<table>
<tr><td colspan="4">LIQUEFACTION CATEGORY IS UNDETERMINED
A liquefaction vulnerability category has not been assigned at this stage, either because a liquefaction assessment has not been undertaken for this area, or there is not enough information to determine the appropriate category with the required level of confidence.</td></tr>
<tr><td colspan="2">LIQUEFACTION DAMAGE IS UNLIKELY
There is a probability of more than 85 percent that liquefaction-induced ground damage will be None to Minor for 500-year shaking.
At this stage there is not enough information to distinguish between Very Low and Low. More detailed assessment would be required to assign a more specific liquefaction category.</td><td colspan="2">LIQUEFACTION DAMAGE IS POSSIBLE
There is a probability of more than 15 percent that liquefaction-induced ground damage will be Minor to Moderate (or more) for 500-year shaking.
At this stage there is not enough information to distinguish between Medium and High. More detailed assessment would be required to assign a more specific liquefaction category.</td></tr>
<tr><td>Very Low Liquefaction Vulnerability
There is a probability of more than 99 percent that liquefaction-induced ground damage will be None to Minor for 500-year shaking.</td><td>Low Liquefaction Vulnerability
There is a probability of more than 85 percent that liquefaction-induced ground damage will be None to Minor for 500-year shaking.</td><td>Medium Liquefaction Vulnerability
There is a probability of more than 50 percent that liquefaction-induced ground damage will be:
Minor to Moderate (or less) for 500-year shaking; and
None to Minor for 100-year shaking.</td><td>High Liquefaction Vulnerability
There is a probability of more than 50 percent that liquefaction-induced ground damage will be:
Moderate to Severe for 500-year shaking; and/or
Minor to Moderate (or more) for 100-year shaking.</td></tr>
</table>

Figure 4.3: Performance criteria for determining the liquefaction vulnerability category - reproduced from Table 4.4 of the MBIE/MfE Guidelines (2017)

The performance criteria listed in Figure 4.3 relate the liquefaction vulnerability category to the expected liquefaction-induced land damage at a given ARI level of earthquake shaking. The assessment requires the assessor to consider the probability that a particular level of liquefaction-induced land damage will occur for a given level of shaking. In undertaking this assessment it is important to understand the following note attached to the table in the guidance document:

"The probabilities listed in this table are intended to provide a general indication of the level of confidence required to assign a particular category, rather than to be a specific numerical criteria for calculation. Conceptually, these probabilities relate to the total effect of all uncertainties in the assessment…"

In the above statement, the guidance recommends the assessor consider the combined effect of all the uncertainties associated with the available information in the determination of the land damage category.

T+T's assessment of the liquefaction vulnerability category for Omokoroa is presented spatially in Figure B2. Typical cross section schematics of near stream gullies and coastal margins are provided in Figure 4.4 and Figure 4.5 in order to show how sub area boundaries have been classified spatially.

Within the Omokoroa study area, the Type B sup-area (terraces) has been classified as *"liquefaction damage is unlikely".* This is because the Rotoehu Ash is likely to be present at shallow depth. The areas classified as *"liquefaction damage is possible"* comprise locations downslope of the terraces where:

- Rotoehu Ash is unlikely to be present.
- Holocene-aged alluvial soils are likely to be present (increasing in thickness with distance from the terraces.
- Groundwater is likely to be shallower than 4 m bgl.

If further investigation analysis was completed, this boundary may sit closer to the toe of the slopes. However, using the definition based on slope crest creates a buffer zone to account for residual uncertainty associated with:

- The potential for lateral spreading associated with free faces and sloping land within the study area.
- The resolution of the geomorphic mapping which was undertaken largely a desktop exercise.

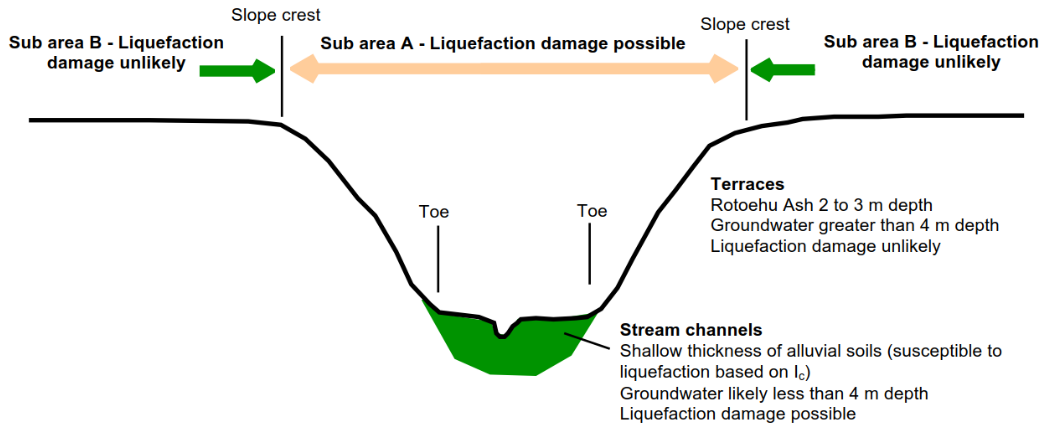

Figure 4.4: Typical cross section showing classification of liquefaction vulnerability near stream channels

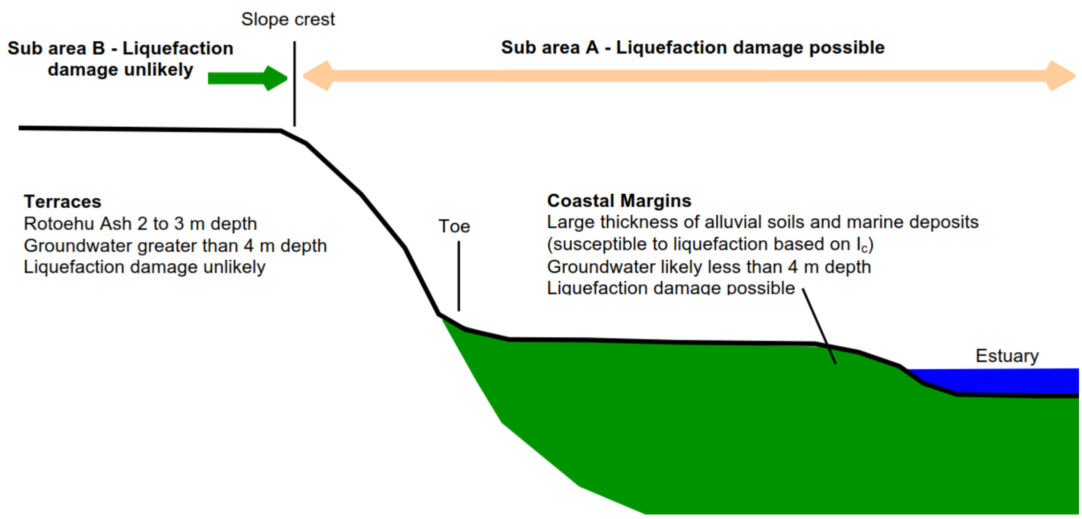

Figure 4.5: Typical cross section showing classification of liquefaction vulnerability near costal margins

It is important to note that the categorisation of land as *Liquefaction Damage Is Possible* does not preclude later assessment of the damage category as either *Low* or *Very Low* liquefaction vulnerability based on additional investigations and analysis. Similarly the categorisation of land as *Liquefaction Damage is Unlikely* does not preclude the modification of the damage category into either *Medium* or *High* liquefaction vulnerability based on additional investigations and analysis – however we note that the way that the performance criteria are assessed makes a shift in this direction less likely.

5 Regional Policy Statement (RPS) risk assessment

The previous RPS risk assessment in the Level A study (T+T, 2019) obtained a low level of liquefaction risk.

The initial process of the RPS risk assessment involves identification of the Hazard Susceptibility Area (HSA). The HSA has been identified as sub area Type A (liquefaction damage is possible) which has substantially reduced since the Level A study. Figure B3 in Appendix B shows the HSA (or sub area Type A) in relation to the structure plan development area. A small portion of the development area is within the HSA (approximately 0.01 km^2 of 1.5 km^2) near to stream gullies. Because the HSA has substantially reduced since the Level A study, and the proposed development has not changed, a low level of liquefaction risk is considered appropriate under the RPS.

For small areas of development located within the HSA, more robust foundation systems may be adopted to reduce the consequence level. However, this would be subject to further investigation and assessment by the geotechnical practitioner and subdivision or building consent stage. Further information on foundation types is provide in Section 5.5.3 of the Level A study (T+T, 2019).

T+T are not aware of any lifelines infrastructure currently planned within the HSA. However, if this is proposed in future, a liquefaction hazard assessment on these lifelines may be required.

6 Conclusions and recommendations

6.1 MBIE/MfE Guidelines (2017)

T+T has undertaken a liquefaction risk assessment in accordance with the MBIE/MfE Guidelines (2017) to a Level B level of detail for the Omokoroa Structure Plan Stage 3 area. The following are the key conclusions from this assessment:

- The currently available base information supports a Level B (calibrated desktop) level of detail assessment within the development area (terraces) and a Level A level of detail within stream channel and coastal margin areas.
- The current information indicates that because the majority of the proposed development area is located on elevated terraces, this land is likely to have none to minor liquefaction-induced land damage following levels of earthquake shaking up to 500 year ARI. Beyond 500 year ARI levels of earthquake shaking, the expected liquefaction related land damage generally plateaus (i.e. regardless of how much more the shaking intensity increases, the expected liquefaction related land damage is likely to remain the same).
- The liquefaction vulnerability mapping process indicates that the land within the Omokoroa study area that is defined as Type A sub area (coastal margin and stream gullies) should be categorised as *Liquefaction Damage is Possible.* These areas are primarily located in stream gullies and coastal margins. The land that is defined as Type B sub area (terrace areas) should be categorised as *Liquefaction Damage is Unlikely.* The Type B sub areas are primarily located in elevated terrace landforms.
- The ground surface elevation information and geomorphological map indicate that there are free-faces and sloping landforms that could enable lateral spreading to occur. These areas are primarily located near stream gullies and coastal margins within areas defined as the Type A sub area where *Liquefaction Damage is Possible.*

We recommend the following geotechnical assessment practices are incorporated as part of future subdivision and building development within the area of proposed development (Figure B3 of Appendix B):

- A geotechnical engineer should consider liquefaction risk based on the results of future geotechnical investigations in accordance with MBIE/Mfe Guidelines (2017). In the development area (Figure B3 of Appendix B) assessment could involve identification of the presence of Rotoehu Ash horizon in the soil profile in relation to groundwater levels. As part of further development, shallow geotechnical investigations (such as Hand Augers) could be sufficient for the purposes for initial screening of liquefaction risk in the development area. This does not preclude the need for deep investigations (such as CPT or boreholes) if the ground conditions differ from those anticipated, for development proposed within the stream gullies and coastal margins, and for assessment of other geotechnical hazards (such as slope instability).
- Assessment of land stability and earthworks design for construction of buildings, roads, and infrastructure in accordance with Section 4.10 (DS10 Natural Hazards and Earthworks) of the WBOPDC Development Code. The geotechnical engineer shall define any development restrictions at resource consent stage and complete certificate 10b (geotechnical suitability of land for development) and 10c (geotechnical suitability of land for building).
- The structure plan has taken account of land stability through identifying land slopes greater than 1V:4H as constrained land (not to be developed). Given the historic observations of slope instability on the Omokoroa Peninsula to the north east of the study area, future geotechnical assessment should take consideration of more detailed slope instability and its effects on land and building development. Building restriction lines near to gully extents may need to be considered.

7 Applicability

This report has been prepared for the exclusive use of our client Bay of Plenty Regional Council, 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.

We understand and agree that this report will be used by Western Bay of Plenty District Council and Bay of Plenty Regional Council in undertaking its regulatory functions in connection with the plan change for the Omokoroa Structure Plan Stage 3 Area.

Recommendations and opinions in this report are based on data from individual CPT and borehole locations. The nature and continuity of subsoil away from these locations are inferred and it must be appreciated that actual conditions could vary from the assumed model.

The susceptibility analyses carried out represent probabilistic analyses of empirical liquefaction databases under various earthquakes. Earthquakes are unique and impose different levels of shaking in different directions on different sites. The results of the liquefaction susceptibility analyses and the estimates of consequences presented within this document are based on regional seismic demand and published analysis methods, but it is important to understand that the actual performance may vary from that calculated.

Tonkin & Taylor Ltd

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Geotechnical Engineer	Project Director
Technical Review by James Russell	

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8 References

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