REPORT

Tonkin+Taylor

Options for Liquefaction Assessment for Resource and Building Consent

Prepared for
Horowhenua District Council

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1 Objective

This report is intended to assist Horowhenua District Council (HDC) as they develop a framework for assessing liquefaction vulnerability for practitioners and council staff, to promote a consistent approach to liquefaction hazard in Building Consent applications in Horowhenua District.

The objectives of this report are to:

- Provide an overview of the existing national-level and district-level guidance related to resource consent and building consent liquefaction assessments.
- Provide a potential framework or a pragmatic screening approach that Horowhenua District Council could consider for assessing liquefaction vulnerability assessments accompanying resource consent and building consent applications for typical individual building projects in Horowhenua District. This includes a focus on residential-style buildings, to help find an appropriate balance between the costs involved in detailed liquefaction assessment and the level of precision required for a particular situation.

This report is not intended to be a prescriptive document that captures all possible eventualities. The responsibility for specific engineering design and construction review for land development and building works remains with the designers of those works.

2 Background

In 2020 Horowhenua District Council (HDC) engaged Tonkin & Taylor Ltd (T+T) to undertake liquefaction hazard mapping for potential growth areas within the district (T+T, 2020[1]) and further assessment for a development in Foxton Beach[2] in accordance with the MBIE/MfE (2017)[3] guidance. Ten areas were identified as potential growth areas comprising Foxton Beach, Foxton, Tokomaru, Shannon, Waitarere Beach, Mangaore, Levin, Ohau, Waikawa Beach, and Manakau.

Following delivery of the preliminary framework to assist in assessing liquefaction vulnerability across these 10 previously identified growth areas, HDC engaged T+T to undertake a Level A assessment (T+T, 2023[4]) for the remaining Horowhenua District in accordance with the MBIE/MfE Guidance (2017)[3].

The MBIE/MfE guidance defines a tiered system of liquefaction vulnerability categories, as shown in Figure 2.1. Much of the land in the district's western third has been assigned the liquefaction vulnerability category of ***Liquefaction Damage is Possible***, while the alluvial and marine terraces through the central third was assigned ***Liquefaction Damage is Undetermined***, with the exception of southern Levin which along with the Hills and Ranges to the east, which have been assigned a category of ***Liquefaction Damage is Unlikely*** (Figure 2.2). As is typically the case for regional assessments such as this, more precise categorisation (e.g., distinguishing between ***Medium*** and ***High*** liquefaction vulnerability categories) was not possible due to a lack of both subsurface geotechnical investigation and detailed groundwater information.

Recognising that in many cases more detailed assessment of liquefaction will be required to support Building Consent applications, HDC has now engaged T+T to provide technical advice regarding the ways in which Council could assist practitioners and HDC Building Control staff. This report focusses

[1] Tonkin and Taylor, (2020). *HDC Horowhenua District Potential Growth Areas, Liquefaction Assessment* report reference 1009677.v2

[2] Tonkin and Taylor, (2020). *HDC Property, Foxton Beach Liquefaction Assessment* report reference 1009677.0010.v2

[3] MBIE/MfE (2017) Planning and engineering guidance for potentially liquefaction-prone land, Version 0.1, September 2017, Wellington: Ministry of Business Innovation and Employment.

[4] Tonkin and Taylor, (2023), *Horowhenua District Liquefaction Vulnerability Assessment, Level A Assessment* reference 1019568.2000 v1.

on the scope of liquefaction assessment likely to be appropriate for each liquefaction vulnerability category, taking into account the types of development and ground conditions most common across the district and in particular within the areas identified as potential growth areas.

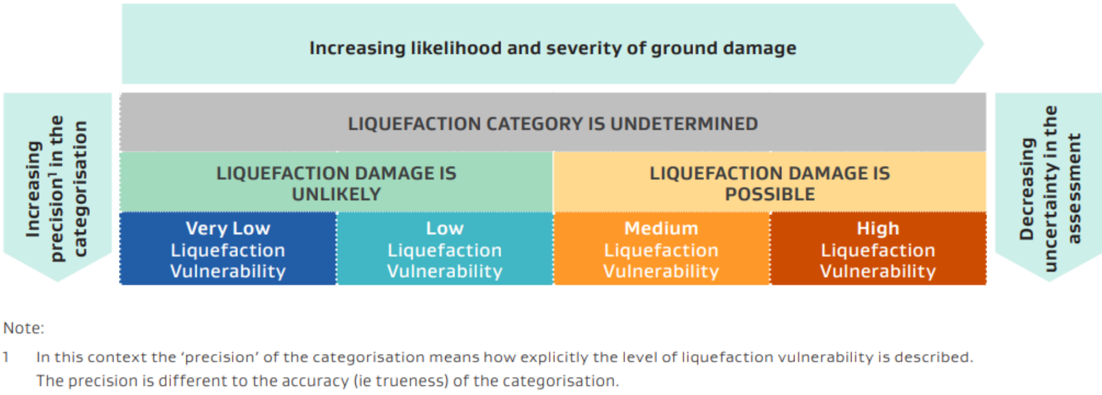

Figure 2.1: Liquefaction classifications from MBIE/MfE (2017)

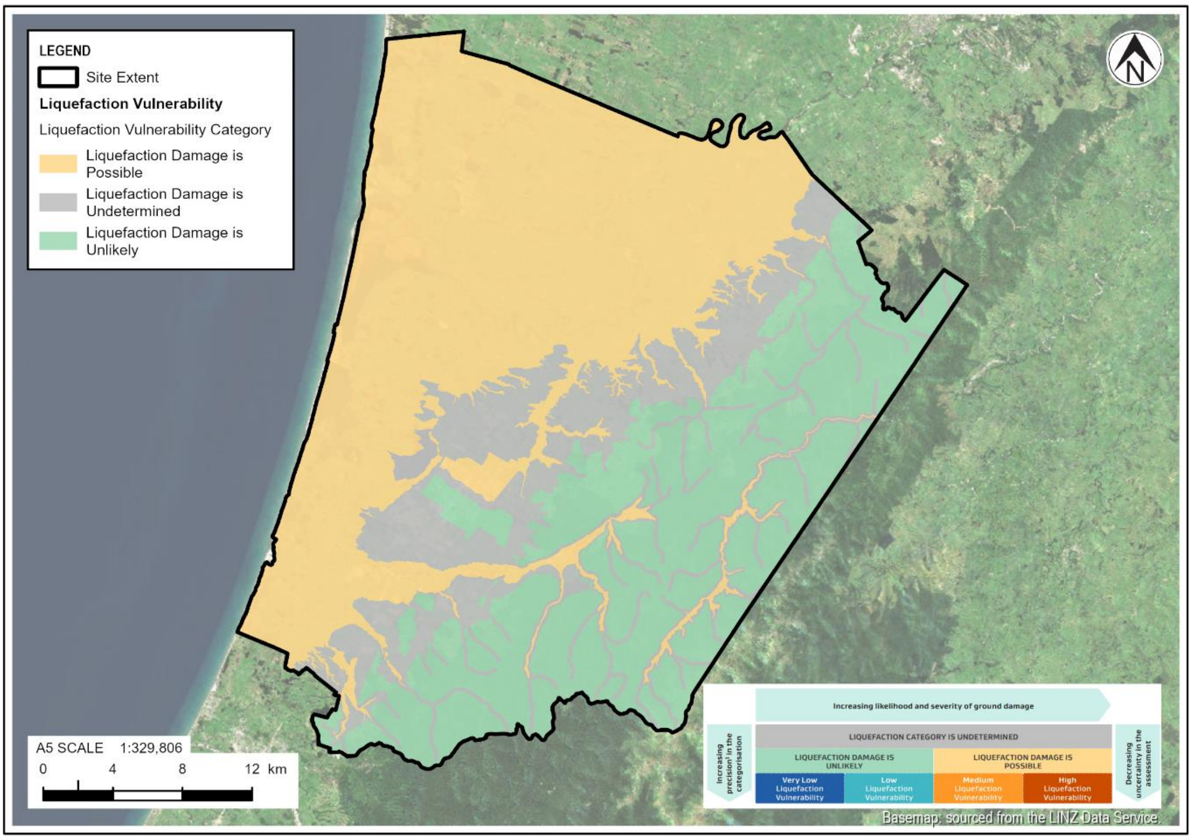

Figure 2.2: HDC liquefaction vulnerability categories assigned by T+T (2023)[4]

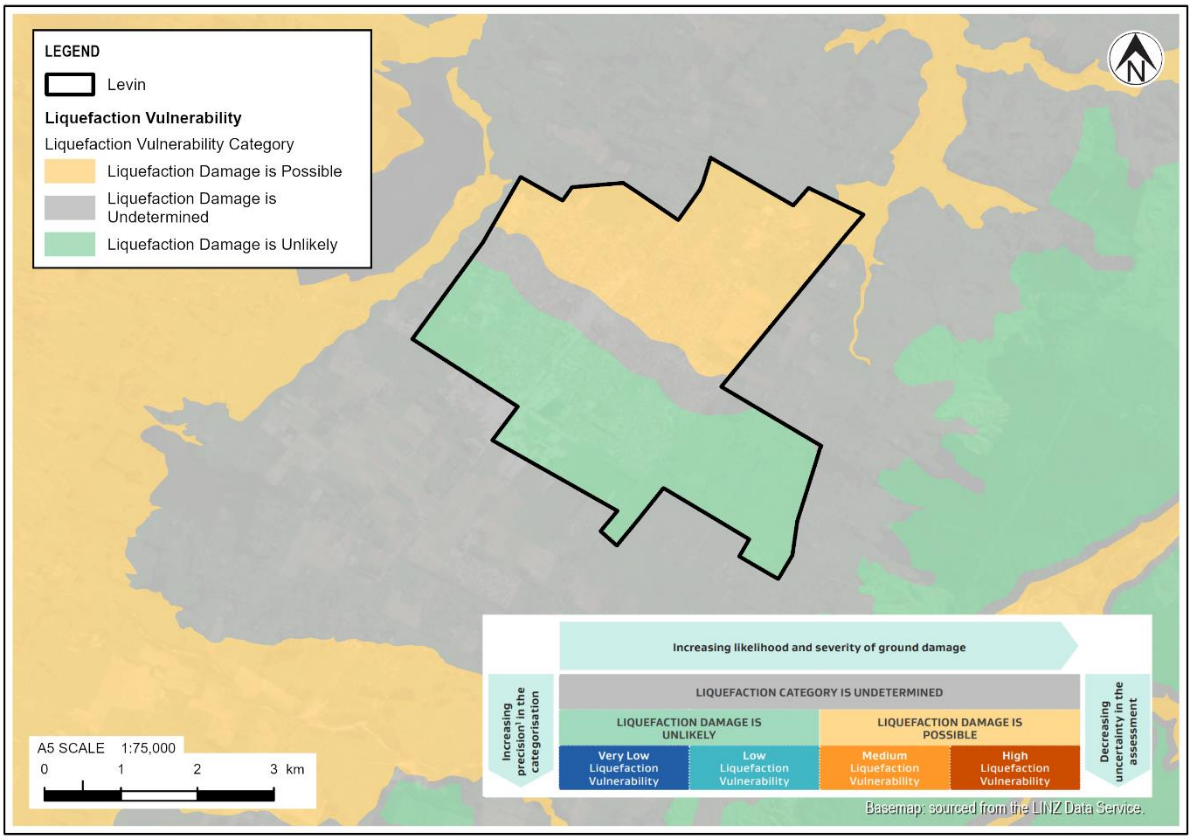

Figure 2.3: Zoomed in level of liquefaction vulnerability classification for Levin township assigned by T+T (2023)[4]

3 Liquefaction guidance, resource and building consent compliance

3.1 National-level guidance

In November 2019, the Ministry of Business, Innovation and Employment (MBIE) made changes to the NZ Building Code which limit the application of the B1 Acceptable Solution B1/AS1 so that it may not be used on ground prone to liquefaction or lateral spreading from 29 November 2021 onward[5]. This was implemented by changing the definition of 'Good Ground' to exclude land with the potential for liquefaction and/or lateral spreading.

Figure 3.1 illustrates the Building Code regulatory framework for New Zealand (MBIE, 2022b). The Building Act and Building Code are mandatory legislation that control three different compliance pathways for buildings in New Zealand. These compliance pathways comprise Alternative Solutions, Verification Methods and Acceptable Solutions.

B1/AS1 is the Acceptable Solution that is the most used means of compliance for residential buildings in New Zealand. For other types of buildings (such as commercial and industrial buildings), other compliance pathways may be more appropriate (such as specific engineering design using the MBIE/New Zealand Geotechnical Society (NZGS) modules in conjunction with B1/VM1) so these are less affected by the change to the definition of 'Good Ground'. The advice in this current report is therefore primarily focussed on residential buildings.

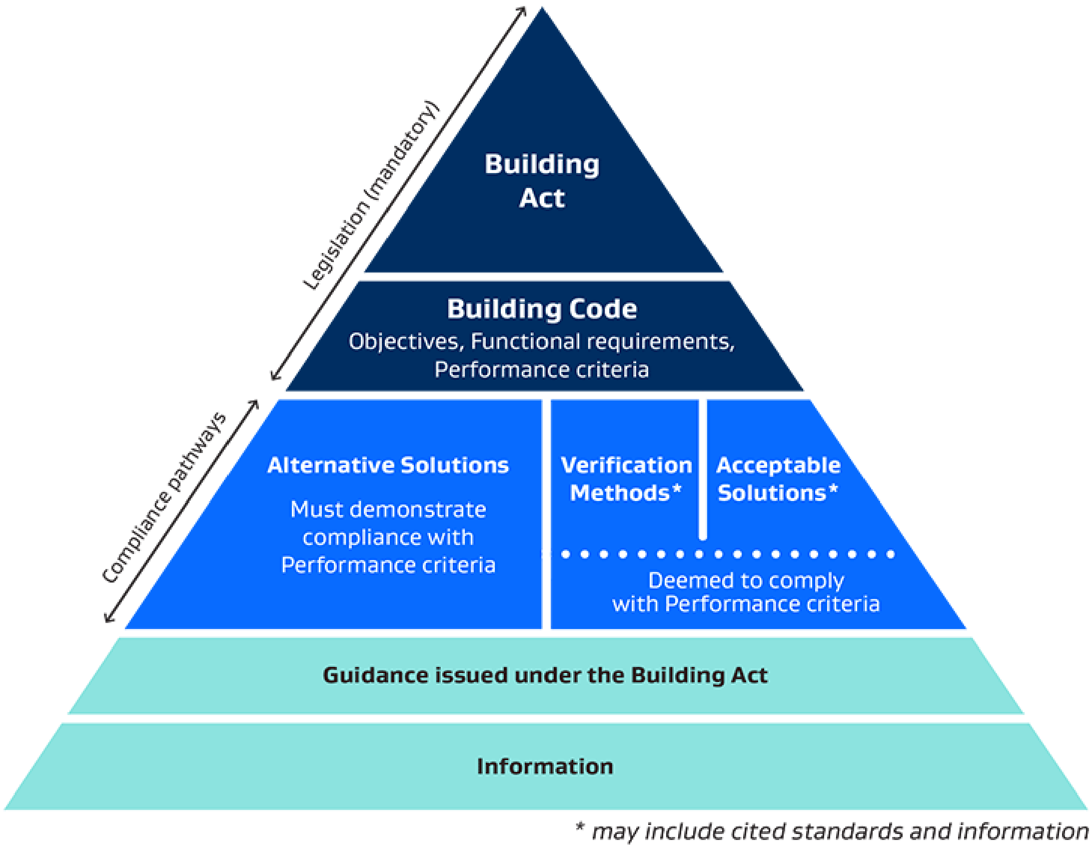

Figure 3.1: Regulation framework figure provided by MBIE – Building Performance (2021)

[5] November 2019 Building Code update | Building Performance, accessed 25 November 2021

MBIE have issued various guidance documents on assessing and addressing liquefaction hazards. The following guidance documents were issued under Section 175 of the Building Act, so while not Acceptable Solutions or Verification Methods, where appropriate they may be used to demonstrate compliance with the Building Code[6] under the Alternative Solution pathway.

- **Ministry of Business, Innovation & Employment – Canterbury Guidance (2018):** The Canterbury Guidance was written to provide a streamlined approach for investigating and selecting foundation solutions for addressing liquefaction prone land in Canterbury to aid in fast-tracking the earthquake recovery. The guidance and processes contained therein are based on the Technical Category (TC) maps, published in 2011 which are only available in Canterbury. While it was initially intended only for use in Canterbury (and this is a stated limitation in the text), at the time of the change to B1/AS1, MBIE added the following note, referring users to the MBIE Canterbury guidance (2018): 'For houses built in areas that have potential for liquefaction, the MBIE guidance document "Repairing and rebuilding houses affected by the Canterbury earthquakes" may be appropriate. This guidance provides a range of potential foundation solutions depending on the expected ground movement and available bearing capacity. These parameters also determine the required degree of involvement of structural and geotechnical engineers and the extent of specific engineering design." MBIE has also published information on their website that relates the TC categories to the liquefaction vulnerability categories in the MBIE/MfE Guidance (2017) (discussed below).
- **Ministry of Business, Innovation & Employment/New Zealand Geotechnical Society Earthquake geotechnical engineering Modules (2021):** MBIE/NZGS module 4 "Earthquake resistant foundation design" discusses compliance and is primarily intended for buildings which typically require specific engineering design. This approach requires defining settlement limits (both total and differential) for buildings to achieve satisfactory performance. Compliance is thereby achieved by defining allowable settlement limits, and specifically designing the foundation and any required earthworks to achieve these limits. This approach is generally not used for routine residential buildings.
- **Ministry of Business, Innovation & Employment/Ministry for the Environment Guidance (2017):** The primary focus of the MBIE/MfE Guidance (2017) is on developing a framework for managing liquefaction hazard by appropriate land use planning under the Resource Management Act, however, Section 3.8 of the document also briefly addresses compliance with the Building Act. It contemplates that most residential houses not requiring specific engineering design would achieve compliance via B1/AS1 but acknowledges that B1/AS1 currently does not address liquefaction.

MBIE also subsequently published information on their website (MBIE, 2022a) on liquefaction in July 2021. This indicates that designers can follow a simplified compliance pathway by considering foundation options outlined in the MBIE Canterbury Guidance (2018). It also provides an indication of how these foundations could relate to the MBIE/MfE Guidance (2017) liquefaction vulnerability categories as shown below (while also noting there is not a direct correlation and other factors and uncertainties should also be considered).

- ***Very Low*** and ***Low*** liquefaction vulnerability = Adopt TC1-type foundations
- ***Medium*** liquefaction vulnerability = Adopt TC2-type foundations
- ***High*** liquefaction vulnerability = Adopt TC3-type foundations

[6] Building Act (2004), Section 19 (2)(b)

3.2 District-level liquefaction guidance

3.2.1 Liquefaction vulnerability categories and 'Good Ground'

T+T (2023)[4] classified land across Horowhenua District into one of three liquefaction vulnerability categories: ***Liquefaction Category is Undetermined***; ***Liquefaction Damage is Unlikely,*** or ***Liquefaction Damage is Possible***. The currently available information does not support further classification of the land into the other (more precise) categories of ***Very Low***, ***Low***, ***Medium*** or ***High*** liquefaction vulnerability. Therefore, translating the currently mapped vulnerability categories to recommendations for TC1/2/3-type foundations is not immediately possible. This outcome is generally expected in a regional-scale study, and it is anticipated that more detailed site-specific assessments to support resource and building consents would follow.

The relevant classifications for the Horowhenua district are explained below:

- Land that has been categorised as ***Liquefaction Damage is Unlikely*** is not considered to be "prone to liquefaction or lateral spreading" so is not excluded from the B1/AS1 definition of 'Good Ground' on this basis (however some locations may still not qualify as 'Good Ground' due to unrelated issues such as such as soft soils).
- Land that has been categorised as ***Liquefaction Damage is Possible*** is considered to be "prone to liquefaction or lateral spreading" and therefore <u>does not meet the definition of 'Good Ground'</u> as outlined in the Building Code amendments.
- For land that has been categorised as ***Liquefaction Category is Undetermined*** there is currently insufficient information to determine whether it is "prone to liquefaction or lateral spreading" within the context of the definition of 'Good Ground' as outlined in the Building Code amendments. If liquefaction vulnerability assessment at a higher level of detail is undertaken in future (e.g., a site-specific assessment) then this may result in reclassification of the land into a different category and whether it meets the definition of 'Good Ground' should be reconsidered based on that new information.
- For land that is ***Unmapped***, no liquefaction assessment has been completed, so this land has not been categorised into one of the three liquefaction vulnerability categories above.

The following sections provide a summary of the assessment for each geomorphic terrain.

3.2.2 Active Coastline and Dunes

The Active Coastline and Dune terrain is likely to comprise thick (>5 m), Holocene-age deposits of sands and silts (which are susceptible to liquefaction) and are unlikely to contain a significant proportion of plastic sediments (which are not susceptible to liquefaction). These sediments are typically deposited in higher energy environments, which means the soils are likely to be denser than those found in lower energy environments. The densest soils are typically found within dune deposits adjacent to the open coast.

Groundwater is also generally shallow (< 4 m) in this terrain because of the close proximity of the coastal margin and the low elevation. The proximity to coastal margins means that the depth to groundwater is likely to become shallower with sea-level rise. For these reasons, these terrains are identified as landforms that are commonly susceptible to liquefaction in Section 2.3 of the MBIE/MfE Guidance (2017).

In this terrain the potential for lateral spreading is consistent with the definition provided in the MBIE/MfE Guidelines (2017), that is in the presence of liquefaction-susceptible soils, lateral spreading is more likely to be possible in areas within 200 m of free faces more than 2 m high or within 100 m of free faces less than 2 m high.

Based on engineering judgement and in accordance with Section 4.5.2 of the MBIE/MfE Guidelines (2017), *"…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*". Therefore, the mapped Active coastline and dunes terrain has been classified as "***Liquefaction Damage is Possible***."

3.2.3 Alluvial Plains and River Flats

Typically, soils found in this terrain are late Pleistocene to Holocene-aged and deposited in low energy environments forming loose and soft layers. The depth to groundwater is also likely to be shallow (< 4 m) within this terrain because it is generally associated with active and historic river systems. The MBIE/MfE Guidance (2017) typically associates these alluvial terrains as being susceptible to liquefaction.

The characteristics of the soils comprising this terrain are highly variable in nature and vary spatially across the landscape. Alluvial sediments typically range from non-plastic sands and silts to plastic clays and silts. These soils typically contain soil layers that are susceptible to liquefaction.

In this terrain the potential for lateral spreading is consistent with the definition provided in the MBIE/MfE Guidelines (2017), that is in the presence of liquefaction-susceptible soils, lateral spreading is more likely to be possible in areas within 200 m of free faces more than 2 m high or within 100 m of free faces less than 2 m high.

Based on engineering judgement and in accordance with Section 4.5.2 of the MBIE/MfE Guidelines (2017), "*…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.*" Therefore, the mapped Alluvial Plains and River Flats terrain have been classified as "***Liquefaction Damage is Possible***".

3.2.4 Relic Dunes

The Relic Dunes terrain is likely to comprise thick (> 10 m), Holocene-age deposits of sands and silts (which are susceptible to liquefaction) and are unlikely to contain a significant proportion of plastic sediments (which are not susceptible to liquefaction). This terrain contains sediments that are typically deposited in higher energy environments, which means the soils are typically denser than those found in lower energy environments.

Groundwater is also generally shallow (< 4 m) in this terrain due to the close proximity to the low-lying alluvial terrains and coastal margin and is likely to become shallower with sea level rise. For these reasons, this terrain is identified as a landform that is commonly susceptible to liquefaction in Section 2.3 of the MBIE/MfE Guidance (2017).

In this terrain, the potential for lateral spreading is consistent with the definition provided in the MBIE/MfE Guidelines (2017), that is in the presence of liquefaction-susceptible soils, lateral spreading is more likely to be possible in areas within 200 m of free-faces more than 2 m high and within 100 m of free-faces less than 2 m high.

Based on engineering judgement and in accordance with Section 4.5.2 of the MBIE/MfE Guidelines (2017), *"…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*". Therefore, the mapped Relic Dunes terrain has been classified as ***Liquefaction Damage is Possible***.

3.2.5 Swamps and Wetlands

The Swamps and Wetlands terrain is likely to comprise thick (> 5 m), Holocene-aged deposits of plastic silts and clays, non-plastic sands and large amounts of organic material. These sediments have typically accumulated in a low energy environment. There is some uncertainty associated with the liquefaction susceptibility of these soils due to the large amounts of organic material that are likely to be present. However, Section 2.3 of the MBIE/MfE Guidelines identify swamp landforms as being commonly susceptible to liquefaction.

Groundwater is also likely to be shallow (< 4 m) in this terrain because of the saturated conditions required for the terrain to develop.

In this terrain the potential for lateral spreading is consistent with the definition provided in the MBIE/MfE Guidelines (2017), that is in the presence of liquefaction-susceptible soils, lateral spreading is more likely to be possible in areas within 200 m of free-faces more than 2 m high and within 100 m of free-faces less than 2 m high. However, as described above, there is currently significant uncertainty as to if/where liquefaction-susceptible soils are present in this terrain.

Due to the uncertainty associated with whether liquefaction-susceptible soils are present, there is currently insufficient information to characterise the expected land performance. Therefore, based on engineering judgement and in accordance with Section 4.5.2 of the MBIE/MfE Guidelines (2017), in this terrain "***Liquefaction Category is Undetermined***" has been assigned at this time.

3.2.6 Alluvial and Marine Terraces

This terrain comprises elevated land that is predominantly early to late Pleistocene in age and includes sediments deposited in both high energy and low energy coastal and alluvial environments, which have both plastic and non-plastic behaviours. The older age of these sediments means that there is the potential for ageing effects to increase the resistance to liquefaction triggering. Furthermore, some younger marginal marine swamp and dune deposits also overlay this terrain in some areas of the district forming surficial swales and hummocks on the older marine and alluvial terraces. As a result, there is significant uncertainty associated with the liquefaction vulnerability of this terrain.

Due to the higher elevation of this terrain, the depth to groundwater is, on average, likely to be deeper (> 4 m) than the groundwater level in the previously described alluvial terrains. However, our analysis of available groundwater data indicates that there are some locations within this terrain where groundwater is shallower (< 4m). These areas of shallow groundwater are most likely associated with gullies and streams. Note that these gullies are small and difficult to differentiate based on the information available and therefore many of the smaller gully features have not been mapped at the target scale for the geomorphic mapping (1:25,000). This also introduces a significant source of uncertainty into the assessment of this terrain.

In this terrain the potential for lateral spreading is consistent with the definition provided in the MBIE/MfE Guidelines (2017), that is in the presence of liquefaction-susceptible soils, lateral spreading is more likely to be possible in areas within 200 m of free faces more than 2 m high and within 100 m of free-faces less than 2 m high. However, as described above, there is currently significant uncertainty about the potential for ageing effects to impact on liquefaction triggering, and the depth to groundwater in the Alluvial and Marine Terraces.

Due to the uncertainty associated with the ground conditions and the depth to groundwater, there is currently insufficient information to characterise the expected land performance over the entire terrain. Therefore, based on engineering judgement and in accordance with Section 4.5.2 of the MBIE/MfE Guidelines (2017), in this terrain "***Liquefaction Category is Undetermined***" has been assigned at this time.

As discussed in Section 3.3.7 of T+T (2023)[4] the nature of the expected ground conditions in this terrain suggest that if more <u>detailed site-specific assessment</u> was undertaken, it is likely that a category of "Low Liquefaction Vulnerability" could be assigned to individual sites. For parts of this terrain, undertaking simple shallow hand auger boreholes to confirm soil properties and/or groundwater depths may be all that is required to determine which liquefaction vulnerability category applies for a specific site[7].

The exception to this generalised categorisation for the Alluvial and Marine Terraces terrain is the southern area of Levin township (as shown in Figure 2.3). Due to more available geotechnical investigation information and previous liquefaction assessments completed (T+T, 2020), the southern area of Levin, as shown in Figure 4.3, has been assessed as "***Liquefaction Category is Unlikely".*** The extent of this category has been mapped based on the 1:250,000 geological map (late Pleistocene river deposit gravels). However, there is significant uncertainty in the mapped extent of this geological unit because there are no distinct features visible at the ground surface to delineate its boundary. To allow for this uncertainty a 500 m wide buffer zone of ***"Liquefaction Category is Undetermined"*** has been assigned along the mapped geological unit boundary. It is also recommended that before the assigned liquefaction vulnerability categories in Levin (both northern and southern areas) are relied upon for individual site assessments, ground truthing should be undertaken to determine whether the site is underlain by this gravel geological unit.

3.2.7 Hills and Ranges

This terrain comprises elevated landforms characterised by highly dissected hills with many gullies and valleys, hills that are more rolling in nature and steep tectonic mountains. These land features ultimately depend on the underlying geological units (which are typically Neogene-aged). The ground conditions vary from exposed rock at the ground surface to thick deposits of residual soils.

Based on the available information, it is likely that the residual soils within this terrain predominantly comprise plastic soils and rock that are not considered to be susceptible to liquefaction. However, although this terrain covers a large portion of the Study Area, there are relatively few geotechnical investigations available to calibrate this assumption. Furthermore, minor valley systems within this terrain may contain alluvial deposits that may not have been captured within the geomorphic map (due to the 1:25,000 target scale of the geomorphic map). This introduces additional uncertainty into the assessment.

The depth to groundwater is highly variable across this geomorphic terrain. As described in Section 4.1 and 4.3 of T+T (2023)[4], it has been categorised as follows:

- In ridge lines and elevated areas the depth to groundwater is assumed to be more than 8 m bgl.
- In sloping land the depth to groundwater is likely to be highly variable.
- In the bottom of valleys and gullies the depth to groundwater is likely to be highly variable depending on antecedent rainfall conditions and the position of the slope, and assumed to be less than 4 m bgl.

In this terrain the potential for lateral spreading is consistent with the definition provided in the MBIE/MfE Guidelines (2017), that is in the presence of liquefaction-susceptible soils, lateral spreading is more likely to be possible in areas within 200 m of free faces more than 2 m high and within 100 m of free-faces less than 2 m high.

A 100 m buffer zone has been applied to the mapped streams within this terrain to capture the incised valley floors where lateral spreading could occur if liquefaction-susceptible soils are present. However, as described above there is currently significant uncertainty to whether liquefaction-susceptible soils are present in the Hills and Ranges terrain.

[7] Note that these comments only apply to site-specific studies undertaken for the purposes of satisfying Resource and Building Consent requirements for individual sites. We are not suggesting that simple shallow hand auger boreholes would enable easy refinement of the liquefaction vulnerability category at a regional level across the entire terrain.

As a result, in the minor valley systems, due to the uncertainty associated with the presence/absence of liquefaction-susceptible soils and the depth to groundwater, there is currently insufficient information to characterise the expected land performance. Therefore, in these locations this terrain has been classified as "***Liquefaction Category Undetermined***" at this time.

In regard to the hilltops, ridges and elevated areas of this terrain, based on engineering judgement and in accordance with Section 4.5.2 of the MBIE/MfE Guidelines (2017), *"…there is a probability of more than 85 percent that liquefaction-induced ground damage will be none to minor for 500-year shaking."* Therefore, these areas are classified as "***Liquefaction Damage is Unlikely***".

4 Assessing and mitigating liquefaction vulnerability in Horowhenua District

For consent applications where liquefaction hazard could be relevant if it were present (e.g., almost all subdivision and building consents) the application will either need to:

- Justify why liquefaction isn't a hazard associated with a subject site or proposed activity.
- Provide mitigation options to appropriately manage the liquefaction hazard.

Consent applications will need to assess soil conditions and ground water conditions on a site-specific basis to assess the liquefaction hazard, particularly for sites that have been categorised as ***Liquefaction Category is Undetermined*** and ***Liquefaction Damage is Possible***.

4.1 Level of detail in resource and building consents

The key difference between resource and building consent applications will lie in the level of detail in the assessment. Resource consent applications are typically lodged when designs are largely conceptual and there are still a number of details to be worked through. The conceptual design may be based on relatively limited investigation information which means that there may be more residual uncertainty about liquefaction vulnerability at the site. As result, there could be a broad number of mitigation options available at this stage. A key focus is demonstrating that there are practical and effective options available to manage hazards, rather than selecting and finalising the details of one single option.

Conversely, at building consent stage the design will be significantly refined as it will have moved through to detailed design stage. If, as part of the resource consent application, liquefaction was identified as a hazard requiring mitigation it may be necessary to collect additional investigation information to further reduce the degree of residual uncertainty. Therefore, a higher level of detail study may be necessary to support the building consent application.

Recognising these differences, the MBIE/MfE Guidance (2017) outlines the minimum level of detail required for liquefaction vulnerability assessments for three different development stages. These development stages relate to resource consents for plan changes, resource consents for subdivision and building consents. For each stage of the development cycle, the guidance relates to five development scenarios which are defined as:

- Sparsely populated rural area (lot > 4 hectares) e.g., a new farm building.
- Rural-residential setting (lot size of 1 to 4 hectares) e.g., a "lifestyle" property.
- Small-scale urban infill (original lot size <2500 m^2) e.g., demolish old house and replace with four townhouses.
- Commercial or industrial development e.g., a warehouse building in an industrial park.
- Urban residential development (typically 15 – 60 households per hectare) e.g., a home in a new subdivision.

The guidance outlines a risk-based approach where the recommended minimum level of detail in the liquefaction assessment varies by both the stage of the development and the type of development scenario. Lower levels of detail are recommended for earlier stages of the development cycle (e.g., resource consent for plan change). Similarly, lower levels of detail are recommended for smaller scale developments (e.g., sparsely populated rural area). For more information about these recommendations refer to Section 3.5 (specifically Tables 3.5, 3.6 and 3.7) of the MBIE/MfE Guidance (2017).

4.2 Options for assessing and mitigating liquefaction vulnerability

We have identified several different options for approaches that Horowhenua District Council could consider when assessing liquefaction vulnerability during resource consent or building consent applications in the Horowhenua District. These options are:

Option 1: No liquefaction assessment / mitigation guidance provided to practitioners

The default approach (in the absence of guidance from MBIE or Council) would be that site-specific geotechnical engineering assessment would be required to support the resource consent or building consent application in all cases where liquefaction hazard could be relevant if it were present (e.g., almost all subdivision and building consents). This approach would use fundamental geotechnical engineering principles to assess liquefaction vulnerability. Typically this would include site-specific deep ground investigations and recommendations for site development works and foundation solutions to mitigate the effects of liquefaction (if required). Unless the assessment demonstrated that the site was not prone to liquefaction, every building would require specific engineering design, typically with reference to the MBIE/NZGS Earthquake engineering modules – there would be no reference to NZS 3604:2011 foundation options or the MBIE Canterbury Guidance (2018) foundation options.

Option 2: HDC endorse adoption of Canterbury guidance

Alternatively, foundation options provided in the MBIE Canterbury Guidance (2018) could be specified to mitigate the potential effects of liquefaction for land and building developments across the district. This approach would still require site-specific geotechnical assessment (and often deep ground investigations) and as such, constitutes a form of specific engineering design. However, the process used by designers to choose appropriate mitigation options would be streamlined with reference to the MBIE Canterbury Guidance (2018). Selection of the foundation options could be further streamlined by undertaking a site-specific liquefaction vulnerability assessment in accordance with the MBIE/MfE Guidance (2017) and correlating the foundation options to the assigned liquefaction vulnerability category as described in Section 3.1.

Option 3: HDC provide Horowhenua-specific guidance

A third approach could remove the need for extensive site-specific geotechnical investigations for some sites and development scenarios. It would aim to provide a balance between cost and accuracy of liquefaction assessments, taking into account the associated risks. A simplified screening assessment could be developed to strike a pragmatic balance between the cost and accuracy of liquefaction assessments for typical individual building projects in the Horowhenua district. This risk-based approach to managing uncertainty is discussed in more detail in Appendix J1 of the MBIE/MfE Guidance (2017), and similar concepts around also feature in recent MBIE regulatory reform discussion documents (MBIE, 2018 & MBIE, 2019).

This approach would allow users to transition from sites previously categorised as ***Liquefaction Category is Undetermined*** to an assumed category of either ***Liquefaction Damage is Unlikely*** or ***Liquefaction Damage is Possible***.

If application of the screening criteria results in recategorisation of the site as ***Liquefaction Damage is Unlikely*** then it is assumed to be not “prone to liquefaction or lateral spreading” and it is not excluded from the B1/AS1 definition of ‘Good Ground’ on this basis. If application of the screening criteria results in recategorization of the site as ***Liquefaction Damage is Possible*** then the site can be assessed against two additional screening criteria to assess the non-liquefiable crust thickness, and the potential for lateral spread. The outcome of the assessment against those two criteria will result in an assumption of ***Medium*** or ***High*** liquefaction vulnerability and specification of TC2-type or TC3-type foundations respectively.

Because of the balance adopted between cost and accuracy of Option 3, there remains greater residual uncertainty in the accuracy of the results, which needs to be accepted as part of using this simplified screening assessment. In particular:

- It is expected that in the majority of cases the screening assessment will determine the correct liquefaction vulnerability category.
- In some cases, the screening assessment will over-predict the liquefaction vulnerability. In these cases it is favouring an approach where money is invested in building a more robust foundation which can handle poorer ground conditions (more than only liquefaction), rather than spending an often-similar amount of money on more detailed liquefaction assessment which might (or might not) show that a less robust foundation system would suffice.
- In a smaller number of cases, the screening assessment will under-predict the liquefaction vulnerability. In these cases, it is favouring an approach where a minor increase in damage in localised areas if/when/where an earthquake occurs in the future is balanced against the high up-front cost of more detailed assessment and more robust foundations across the entire district. We note than in most (but not all) circumstances the consequences of under-predicting liquefaction vulnerability relate primarily to matters of amenity, habitability and repair cost, rather than questions of life-safety.
- To issue a Building Consent, Council needs to be “satisfied on reasonable grounds” that the provisions of the Building Code would be met if the building work were properly completed in accordance with the plans and specifications. Similarly, owners, designers and builders must have reasonable grounds to believe that building work complies with the Building Code. It may be useful to seek legal advice and/or a determination from MBIE to confirm that this option for a risk-based approach is appropriate, and that the residual uncertainty in the liquefaction assessment does not undermine these reasonable grounds for Building Code compliance.

4.3 Possible policy approaches for Horowhenua District Council

Section 4.2 presents three options for assessment and mitigation of liquefaction vulnerability, ranging from providing no guidance to practitioners (Option 1) through to providing district-specific guidance (Option 3). However, there is no need for HDC to select a blanket approach which applies in all cases, and it may be appropriate to adopt different options in different situations. Table 4.1 provides four examples (Policy A through to D) for different combinations of liquefaction assessment/mitigation options that could be adopted in different development scenarios. Each example policy approach is discussed in further detail below.

Deciding on the policy approach that is most appropriate for HDC will involve consideration of a range of factors, such as the need to balance cost and demand for urban development against the risk appetite for accepting a degree of uncertainty in the liquefaction assessment. As noted in Section 5 of the MBIE/MfE Guidance (2017), the risk management process now moves from a technical stage to the beginning of a decision-making stage and so needs to involve the relevant stakeholders and decision-makers.

The level of engineering assessment and mitigation that is optimum for HDC will be strongly influenced by the specific local context, including:

- Availability of existing subsurface geotechnical investigations and groundwater monitoring.
- The spatial extent, density and type of building activity expected in future.
- The skillset of local engineering practitioners.
- The expected range of ground conditions inferred from geomorphic mapping.
- The level of seismic hazard.
- Integration with other council processes for natural hazard management (e.g., District Plan).

Table 4.1: Example of the range of policy approaches that could be considered for liquefaction assessment/mitigation options adopted in different development scenarios

Decreasing detail & cost for engineering assessment
Increasing residual uncertainty

Increasing new capital investment and total exposure / consequence in a single event

Development scenario	Potential HDC policy settings			
	Policy A	**Policy B**	**Policy C**	**Policy D**
Sparsely populated rural area (lot size >4 ha) e.g., a new farm building	Option 1	Option 2	Option 3	Option 3
Rural-residential setting (lot size of 1 to 4 ha) e.g., a "lifestyle" property	Option 1	Option 2	Option 3	Option 3
Small-scale urban infill (original lot size <2500 m^2) e.g., demolish old house and replace with four townhouses	Option 1	Option 2	Option 3	Option 3
Commercial or industrial development e.g., a warehouse building in an industrial park	Option 1	Option 1	Option 1	Option 1
Urban residential development (typically 15-60 households per ha) e.g. home in a new subdivision	Option 1	Option 2	Option 2	Option 3

Notes:

1. ***Option 1:*** No liquefaction assessment /mitigation guidance provided to practitioners.
   Option 2: HDC endorse adoption of Canterbury guidance.
   Option 3: HDC provide Horowhenua-specific guidance.
2. This table shows the highest option number that would be available for practitioners to use in each development scenario for each policy option. In most cases practitioners would also have the option to choose a lower numbered option (e.g., site-specific liquefaction assessment and engineering design would remain an option if practitioners did not wish to follow the available guidance or it was not applicable for the particular circumstances).

Policy A: This involves application of Option 1 (no guidance) in all cases, which would require site-specific liquefaction assessment and specific engineering design to determine suitable mitigation options (if required) for each of the development scenarios and for 'unmapped' areas. This approach would provide practitioners with a high level of flexibility in how they determine suitable mitigation solutions. The detailed assessment required would likely result in lower residual uncertainty about the liquefaction vulnerability, and provide greater confidence in the efficiency and effectiveness of the adopted mitigation solution. However, it would require a high degree of technical competency from both the practitioners developing the solution and the building control officer evaluating the suitability of those solutions. It may also result in higher costs for both investigation requirements, design and approvals being passed on to the applicant as well as longer lead times to develop and evaluate those solutions.

Policy B: Option 1 (no guidance) would apply to all commercial and industrial development scenarios, and all 'unmapped' areas. This is because for these types of development the geotechnical requirements can vary greatly depending on the specific details of the site, the proposed building and foundation type, and the particular functional requirements. This means that specific engineering input is typically required (even if liquefaction is not an issue) and there is little scope to provide guidance for simplified assessment.

Option 2 (Canterbury guidance) would be available for all residential development scenarios. Alternatively, Option 1 could be adopted by the practitioner if they considered it was more appropriate to undertake site-specific assessment and design. This approach provides the same high level of flexibility to practitioners as Policy A, but also with the option of streamlining the selection of standard mitigation solutions from the MBIE Canterbury Guidance (2018). This guidance is intended for use with one- and two-storey timber framed dwellings and therefore for larger and/or more complex residential builds the practitioner may opt for Option 1. When compared to Policy A, this approach enables streamlining of the selection of mitigation solutions for standard residential buildings although the costs may still be significant, in particular on sites where deep investigations are required. At present this approach is being used frequently across New Zealand for liquefaction prone sites.

Policy C: Option 1 (no guidance) would apply to all commercial and industrial development scenarios and 'unmapped' areas, for the reasons discussed above.

Option 2 (Canterbury guidance) would be available for all residential scenarios, with the option for the practitioner to adopt Option 1 if preferred.

Additionally, Option 3 (Horowhenua-specific guidance) would be available for simpler smaller-scale residential applications. This approach further simplifies the process by adding a screening criteria as a tool for practitioners to select a mitigation solution for lower-risk situations. However, as discussed in Section 4.2, the upfront saving this gives in terms of reduced time and cost for engineering assessment is offset against the potentially reduced accuracy. This means that in some cases the adopted foundation may be more robust than required to meet minimum Building Code requirements (incurring higher up-front construction costs), or in some cases the adopted foundation may be less robust than required (with potential for increased damage if/when/where an earthquake occurs in the future).

Policy D: Option 1 (no guidance) would apply to all commercial and industrial development scenarios and 'unmapped' areas, for the reasons discussed above.

Option 3 (Horowhenua-specific guidance) would be available for all residential scenarios, with the option for the practitioner to adopt Option 1 or 2 if preferred. This approach extends the use of the simplified screening criteria to larger residential developments. Therefore, the benefits in terms of upfront savings in time and costs for engineering assessment are extended to a larger number of properties. However, the associated risks relating to adopted foundations being more or less robust than required are also extended to a larger number of properties.

5 HDC preferred approach

Following discussion between HDC and T+T on 16 and 22 March 2022 regarding the options discussed within this report, HDC selected Policy C (refer Section 4.3) as their preferred risk-based approach for liquefaction assessment.

Further guidance regarding a simplified liquefaction screening assessment (Option 3) to assist in Building Consent applications is provided in Appendix A.

As discussed within Sections 4.2 and 4.3, this simplified screening approach results in upfront cost savings by reducing the need for deep ground investigations and specialist geotechnical engineering input. However, this is offset against the potentially reduced accuracy. In some cases the adopted foundation may be more robust than required to meet minimum Building Code requirements (incurring higher up-front construction costs), or in some cases the adopted foundation may be less robust than required (with potential for increased damage if/when/where an earthquake occurs in the future).

6 Future opportunities to reduce uncertainties

The T+T 2023 liquefaction assessment[4] mapped the entire district, and because of limited available geotechnical investigations and groundwater information it was only able to achieve a level of detail of ***Level A (Basic Desktop Assessment)***. This means there is substantial residual uncertainty regarding liquefaction-related risk across the district, which limits the accuracy and applicability of simplified screening criteria.

To help reduce these uncertainties, HDC may wish to consider the following opportunities:

- For the identified future growth areas, targeted ground investigations and groundwater monitoring could be undertaken to help better understand the key uncertainties, enabling a ***Level B (Calibrated Desktop Assessment)***. A potential focus of this work could be to identify areas where liquefaction vulnerability was likely to be no more than ***Medium***, providing greater confidence that a TC2-type foundation could be adopted without the need for additional assessment (simplifying the building consent process for both council and applicants).

7 Document status and limitations

This report is intended to assist parties to comply with their obligations under the Building Act 2004 and the Resource Management Act 1991. It is not mandatory to follow this guidance, but if followed:

- It does not relieve any person of the obligation to consider any matter to which that information relates according to the circumstance of the particular case.
- The consent authority may have regard to the guidance but is not bound to accept the guidance as demonstrating compliance.
- All users should satisfy themselves to the applicability of the content and should not act on the basis of any matter contained in this document without considering, and if necessary, taking appropriate professional advice.

This report has been prepared for the exclusive use of our client Horowhenua District 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 prior written agreement. We understand and agree that this report will inform general guidance about liquefaction assessment provided by Horowhenua District Council to consent applicants and their designers, on the basis that any use or reliance on this guidance is at the party's sole risk.

While T+T has taken care in preparing this document, it is only a guide and professional judgement is required for each site. T+T is not liable for any reliance on this guidance. The responsibility for specific engineering design and construction review for land development and building works remains with the designers of the works.

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EDA

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Appendix A: Liquefaction vulnerability guidance for Horowhenua District

Liquefaction vulnerability screening tool / flow diagrams

For each of the broad liquefaction vulnerability categories mapped across Horowhenua District, the attached flow chart provides a framework for liquefaction assessment to enable hazard screening for Building Consent applications for routine individual building projects (primarily residential-style buildings). It is emphasised that these screening criteria have been developed specifically in relation to the local context, so these screening criteria may not be applicable in other locations. Some factors of particular relevance are summarised in Table A.1, to provide an overview of how these considerations have influenced the development of the screening criteria.

Table A.1: Local context most relevant to development of liquefaction screening criteria for Horowhenua District

Local context	How this has influenced the screening criteria
A lack of subsurface geotechnical investigations and groundwater monitoring across the district.	A focus on confirming soil types and groundwater levels at each individual site.
There is a relatively small amount of new building activity in the district, and much of this is small-scale/in-fill and spread out over a large geographical area.	This means that there is a lower density of capital/social investment and lower total exposure to a single event, so a lower level of risk (refer risk matrices in Tables 3.5 to 3.7 of MBIE/MfE 2017 guidance).
Much of the site investigation and building design in the district is currently undertaken by general civil/structural practitioners, following B1/AS1 and NZS3604:2011.	Use the same types of shallow soil testing that have traditionally been used to confirm "good ground", but with enhancements to also allow simplified liquefaction screening. Structure the screening criteria around factors which can reasonably be assessed by general practitioners without specialist geotechnical expertise. Clearly flag the types of situations where specialist geotechnical engineering input is required.
If a specialist geotechnical engineer or deep geotechnical testing is required, these often need to be brought in from elsewhere around the country – so this poses some logistical and cost challenges. However, the district is relatively easily accessed so this is unlikely to add excessive expense for medium to larger sized projects.	It is not unreasonable to expect specialist geotechnical input for medium to larger projects, where the risk profile is greater and the project budget is better able to accommodate costs by sharing across multiple buildings. For smaller projects, more careful thought may be required to strike a pragmatic balance between cost and benefit of specialist geotechnical input. Where specialised geotechnical testing and assessment is undertaken, this should be collated by council and the factual data made available on the NZ Geotechnical Database to help inform future developments in the area.

Table A.1 (continued):

Local context	How this has influenced the screening criteria
Areas mapped as ***Liquefaction Category is Undetermined***	In these areas there is insufficient information available to determine the liquefaction vulnerability. Some areas within this category have a higher potential for liquefaction-induced ground damage due to the lower ground elevations and therefore closer proximity to the groundwater table and/or loose soils identified in shallow investigations. Furthermore, there are paleo channels throughout the region expected, which results in variable ground conditions over relatively short distances. This means unfavourable ground conditions are more likely in lower elevation areas while more favourable ground conditions are possible in higher elevation areas.
The district is within an area of relatively high seismic hazard (e.g., a 500-year design ground acceleration of 0.55g)*.	Where susceptible soils are present, consequential liquefaction-induced ground damage could occur at relatively frequent levels of design shaking (e.g. as low as 25-to-100-year return period). This means it is especially important for site-specific subsoil and groundwater assessment to identify where significant thickness of liquefiable soils are present at shallow depth.
The next time the District Plan is reviewed this will provide an opportunity to manage liquefaction-related risk proactively through land use planning. In the meantime, the recent Building Code change regarding "good ground" means this risk will be managed predominantly through the Building Consent process.	This guidance note focusses on managing liquefaction-related risk for individual building projects through the Building Consent process. For larger-scale developments (e.g. larger than 4 lots as outlined in Table 3.6 of the MBIE/MfE 2017 guidance) it is likely a Resource Consent will first be required, providing an opportunity to manage risk through that process (refer Section 6.7.2 of MBIE/MfE 2017 guidance).

* MBIE Module 1 November 2021 Update has provided a revised calculation for design ground acceleration that has resulted in higher PGAs than quoted in the HDC liquefaction vulnerability assessments[1,2].

Site assessment for simplified liquefaction screening

To assess the screening criteria outlined in the attached flowchart, various techniques may be utilised. Examples of potential site assessment and ground investigation options are discussed below. Other investigations may be required to assess other aspects of the site (e.g., the presence of compressible/expansive soils, uncontrolled fill or slope instability) and the person assessing the site and specifying the foundation solution will need to undertake their own assessment for these factors.

Lateral spread assessment: This could be undertaken based on a desktop study (including air photos, and ground elevation contours/LiDAR) but should be calibrated by a site visit and visual assessment of the site and its surrounds, noting any channels or free faces present in the vicinity of the site.

Groundwater assessment: This assessment may be undertaken using either direct investigation methods (such as hand augers, machine augers or testpit excavation to 3 to 4 m depth), or by comparison with known, nearby sources of groundwater data such as nearby waterbodies with known water levels, or nearby investigations such as boreholes or excavations where groundwater was recorded. Seasonal groundwater fluctuations should be considered.

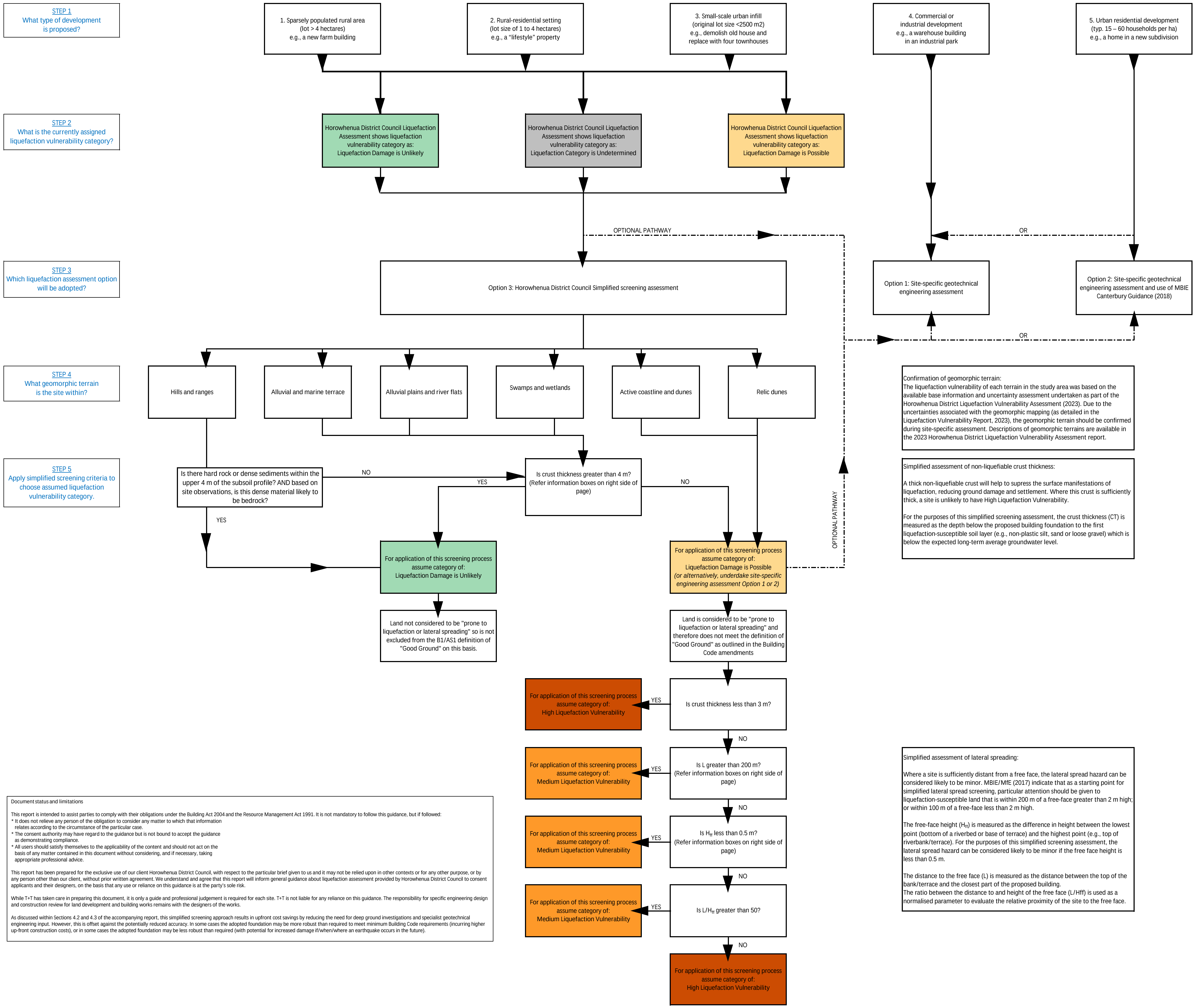
Soil conditions: The investigation of shallow soil conditions should generally follow the procedures outlined in NZS3604:2011 but it is recommended that where practical, hand augers for the examination of soil materials extend to between 3 and 4 m below ground level. Alternatively, test pits, boreholes or Cone Penetration Tests (CPT) may be used to assess soil conditions. Where sufficient nearby data is available to demonstrate ground conditions, this may also be relied upon, in conjunction with investigations on the site in question. Soils should be logged in accordance with the NZGS field guide for description of soil and rock[8].

We note that very little data exists in the New Zealand Geotechnical Database (NZGD) for the Horowhenua District. Advocating the uploading of geotechnical investigations onto the NZGD as part of the process of evaluating resource and building consent applications would progressively increase the amount of geotechnical data available. This would inform future investigations, allow refinement of existing liquefaction hazard mapping and provide valuable information to support future land-use planning and site assessments.

[8] Field description of soil and rock – field sheet – New Zealand Geotechnical Society (nzgs.org) accessed 29 November 2021

Simplified liquefaction vulnerability screening tool for Horowhenua District

This flow chart must be read alongside the June 2023 report "Options for Liquefaction Assessment for Resource and Building Consent" v2 prepared by Tonkin + Taylor for Horowhenua District Council



Confirmation of geomorphic terrain:
The liquefaction vulnerability of each terrain in the study area was based on the available base information and uncertainty assessment undertaken as part of the Horowhenua District Liquefaction Vulnerability Assessment (2023). Due to the uncertainties associated with the geomorphic mapping (as detailed in the Liquefaction Vulnerability Report, 2023), the geomorphic terrain should be confirmed during site-specific assessment. Descriptions of geomorphic terrains are available in the 2023 Horowhenua District Liquefaction Vulnerability Assessment report.

Simplified assessment of non-liquefiable crust thickness:

A thick non-liquefiable crust will help to supress the surface manifestations of liquefaction, reducing ground damage and settlement. Where this crust is sufficiently thick, a site is unlikely to have High Liquefaction Vulnerability.

For the purposes of this simplified screening assessment, the crust thickness (CT) is measured as the depth below the proposed building foundation to the first liquefaction-susceptible soil layer (e.g., non-plastic silt, sand or loose gravel) which is below the expected long-term average groundwater level.

Simplified assessment of lateral spreading:

Where a site is sufficiently distant from a free face, the lateral spread hazard can be considered likely to be minor. MBIE/MfE (2017) indicate that as a starting point for simplified lateral spread screening, particular attention should be given to liquefaction-susceptible land that is within 200 m of a free-face greater than 2 m high; or within 100 m of a free-face less than 2 m high.

The free-face height (H_{ff}) is measured as the difference in height between the lowest point (bottom of a riverbed or base of terrace) and the highest point (e.g., top of riverbank/terrace). For the purposes of this simplified screening assessment, the lateral spread hazard can be considered likely to be minor if the free face height is less than 0.5 m.

The distance to the free face (L) is measured as the distance between the top of the bank/terrace and the closest part of the proposed building.
The ratio between the distance to and height of the free face (L/Hff) is used as a normalised parameter to evaluate the relative proximity of the site to the free face.

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As discussed within Sections 4.2 and 4.3 of the accompanying report, this simplified screening approach results in upfront cost savings by reducing the need for deep ground investigations and specialist geotechnical engineering input. However, this is offset against the potentially reduced accuracy. In some cases the adopted foundation may be more robust than required to meet minimum Building Code requirements (incurring higher up-front construction costs), or in some cases the adopted foundation may be less robust than required (with potential for increased damage if/when/where an earthquake occurs in the future).

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