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Tauranga City council Assets - Natural Hazard Risk Assessment

Mount Holiday Park

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Disclaimers and Limitations

This report ('**Report**') has been prepared by WSP exclusively for Tauranga City Council ('**Client**') in relation to conducting a natural hazard assessment for the Mount Manganui Beachside Holiday Park ('**Purpose**') and in accordance with the Short Form Agreement with the Client dated 20 September 2023. The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

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1 Introduction

Tauranga City Council (the 'Client') have engaged WSP New Zealand Limited (WSP) to undertake a Natural Hazards Risk Assessment (NHRA) of the Mount Maunganui Beachside Holiday Park ('the site').

This report presents our interpretation of the natural hazards that are relevant for the site, provides a quantitative assessment of the risk, and discusses how hazards can be mitigated to reduce the overall level of risk. The area assessed comprises the entirety of the site as well as the adjacent eastern flanks of Mauao. The approximate site boundaries and the extent of the adjacent area covered by a site walkover are outlined in Figure 1.

This work has been prepared in accordance with the signed short form agreement signed on 20 September 2023.

Figure 1. Location of the Mount Maunganui Beachside Holiday Park ('the site') within Mount Maunganui, Bay of Plenty.

2 Assessment Approach

A Natural Hazards Risk Assessment (NHRA) has been undertaken to assess the risks posed to the site from natural hazards, and to identify mitigation measures that may limit the effect of these hazards to the built environment, and also to reduce potential harm to users (deemed to be residents/guests of the holiday park, staff working onsite, and members of the public).

For this assessment, we have broadly followed the NHRA approach recommended by the Bay of Planty Regional Council (BoPRC). The operative Regional Policy Statement (RPS) developed by BoPRC sets out natural hazard provisions that have been designed to influence resource consents and the development of regional, city and district plans as they affect natural hazards. The RPS was made operative in 2014, with Change 2 (Natural Hazards) merged into the RPS and made operative from 6 July 2016[1].

The NHRA is a broadly qualitative and probabilistic process that compares the consequence level of a specific hazard for differing magnitudes and return intervals of events. It considers health and safety (e.g., fatalities and injuries); the effects to lifeline utilities and services; and functionality of buildings, with varying degrees of emphasis placed on critical (such as hospitals) or socially/culturally significant buildings (places where large populations gather, marae, places of worship, schools etc.).

It should be noted that this NHRA does not supersede any process or function of the Building Act which also gives provision to natural hazards and regulates building work through the Building Code to protect loss of life and amenity.

The RPS considers eight natural hazards, however, not all the natural hazards listed are considered relevant to the site. The list of natural hazards and their likelihoods for RPS NHRA analysis are set out in Table 6 of the RPS and described further in Section 4 of this report.

2.1 Scope

The following scope of works was undertaken:

1. A desktop study of, but not limited to, the following data:
   - Available geomorphological, geological and hydrological conditions.
   - A review of the Tauranga City Council (TCC) and BOPRC online hazard maps and datasets.
   - Reports and maps pertaining to the natural hazards on the site from publicly available sources e.g., previous technical reports (see References section).
   - An assessment of existing natural hazards risks relevant to the site.
2. A site walkover to gain an understanding of the on-the-ground conditions and to compare these with the digital mapping data, documenting any natural hazards identified, and assessing slopes and historic landslides for signs of instability and/or hazard.
3. A qualitative risk assessment, completed in accordance with Appendix L of the RPS, and undertaken using the information available above.
4. A summary of suggested controls that would help reduce the likely consequential effects of a hazard occurring, where required.

Hazard maps are presented in Appendix A and site walkover photographs are presented in Appendix B.

[1] *https://www.boprc.govt.nz/your-council/plans-and-policies/policies/regional-policy-statement/change-2-natural-hazards*

3 Setting

3.1 Site location and Geomorphology

The site sits at the northwestern end of the Mount Manganui peninsula, at the foot of the mountain Mauao (Figures 1 and 2). The address is listed as 1 Adams Avenue and is legally described as 'APPORTIONMENT OF PT SEC 1 & PT SEC 19 BLK VI TAURANGA S D-REC RES'. The property parcel is shared with the Mount Hot Pools and Surf Life Saving Club. Excluding these areas, the site occupies a land area of approx. 41,400 m^2 (4.14 ha). The site is roughly rectangular in shape (approx. 350 m long and 150 m wide) and orientated north-west to south-east.

The site is bounded to the east by the township of Mount Manganui, to the north by the Bay of Plenty coastline (Main Beach), to the south by the Tauranga Harbour (Pilot Bay) and to the west by Mauao.

The lower areas of the site are located at an elevation of between 3 mRL to 8 mRL (NZVD16), with the lowest-lying areas on southern and northern extremities of the site adjacent to the coastlines. The elevation increases to the west onto Mauao slopes to a maximum elevation of approx. 20 mRL. A triangular shaped raised terrace is situated in the centre of the site and extends eastwards towards Adams Avenue. The terrace sits at an elevation of 10 mRL to 15 mRL, and the banks of the terrace form steep slopes.

The areas to the north and south closest to the coast and harbour, respectively, are low-lying and generally flat. The southern campground area is higher elevation that the northern campgrounds and contains several stepped cut platforms where camping sites are set out. The northern-most campground is very low-lying and is located at an elevation lower than the active beach dunes nearby.

The lower eastern flanks of Mauao (the grassed area above the site) dip at a slope angle of approx. 2H:1V. A number of landslide scarps are present across the lower flanks, some of which have occurred in historic times and have runout deposits that extend into the site.

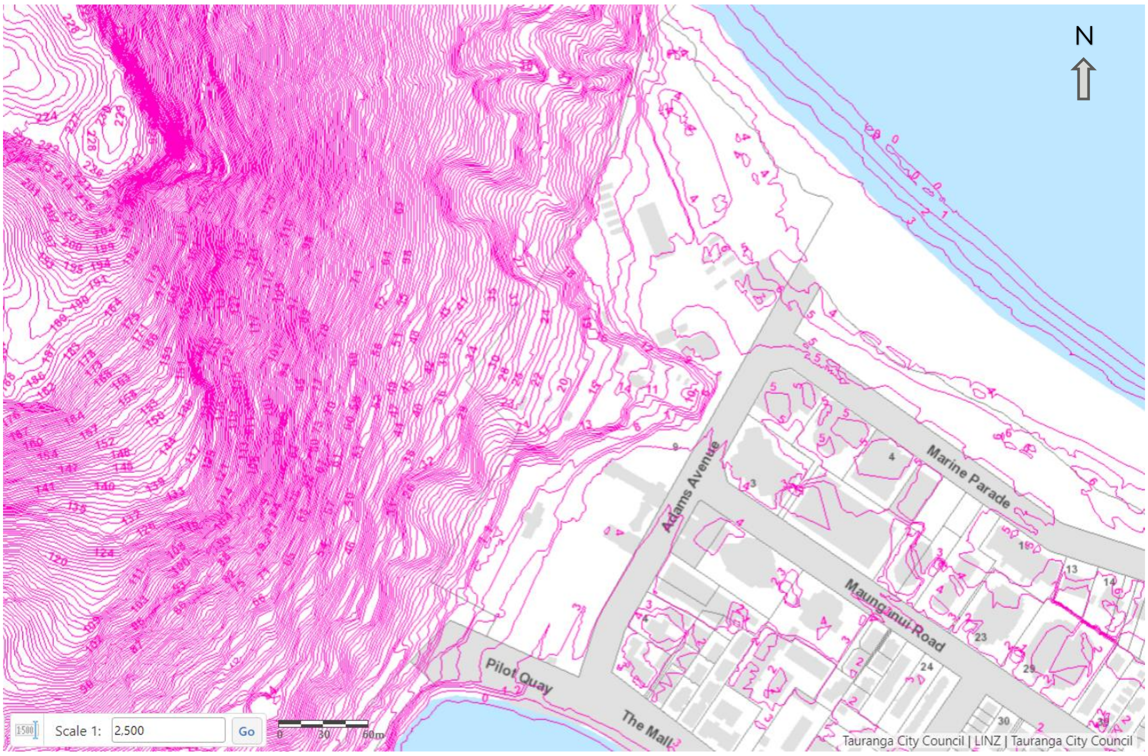

Figure 2. The site with 1 m contours (NZVD16). Source TCC Online maps.

3.2 Geological and Hydrological Setting

3.2.1 Geology

The geology of the Bay of Plenty region is described in the 1:250,000 QMap series of New Zealand (Leonard et al., 2010) and the 1:50,000 scale geological map for the Tauranga area (Briggs et al. 1996) (refer to Figure 3). These published maps describe the site as being comprised of two main geologies:

1. The flanks of Mauao are described as Late Pleistocene-aged, Minden Rhyolite Subgroup (Whitianga Group) volcanics. Mauao is a rhyolitic dome formed by the outpouring of rhyolitic lava approximately 2.3 million years before present. The steep-sided-flat topped dome is made up of three parts; the top, a middle section, and the lower slopes. The top is comprised of steep rhyolitic bluffs, the middle section is less steeply inclined and has been used as pasture for sheep, and the lower slopes are comprised of moderately inclined scalloped slopes comprising thick residual volcaniclastic sediments and soils. These sediments are susceptible to land sliding, especially as they are sensitive, which is commonly associated with the clay mineral Halloysite.

2. The lower elevation beach areas below Mauao are described as Holocene-aged beach deposits consisting of marine gravel, sand and mud. The geology of the coastline (harbour and beach) in this area is dominated by unconsolidated, dune sands which make up the tombolo landform that links Mauao with the mainland.

Regionally, the mapped geology is typically overlain by a thick mantle of Taupo Volcanic Zone tephras comprising (from youngest to oldest) the Younger Ash, Rotoehu Ash and Hamilton Ash beds.

Figure 3. Published geological mapping. Pink indicates Minden Subgroup volcanic deposits, light yellow indicates Holocene beach deposits. Boundaries are poorly constrained at the scale of this mapping (1:250,000) and are only indicative. Much of the Minden Subgroup deposits within the site are likely to be associated with hillslope, coastal/marine sedimentary processes rather than hard rocks such as rhyolite lava. Source: GNS Online Web Map Application.

3.2.2 Seismicity

Tauranga is located within a zone of seismic hazard between the Hauraki Rift (to the west) and the Taupō Volcanic Zone (TVZ, to the south).

A review of the GNS Science active fault database[2] indicates the site is located approximately 35 km of the nearest active fault (Kerepihi Fault) (Figure 4). The Kerepihi Fault is a normal dipping fault with recurrence interval of 2000 to 3500 years. The fault has a low slip rate, and a moderate single event displacement rating.

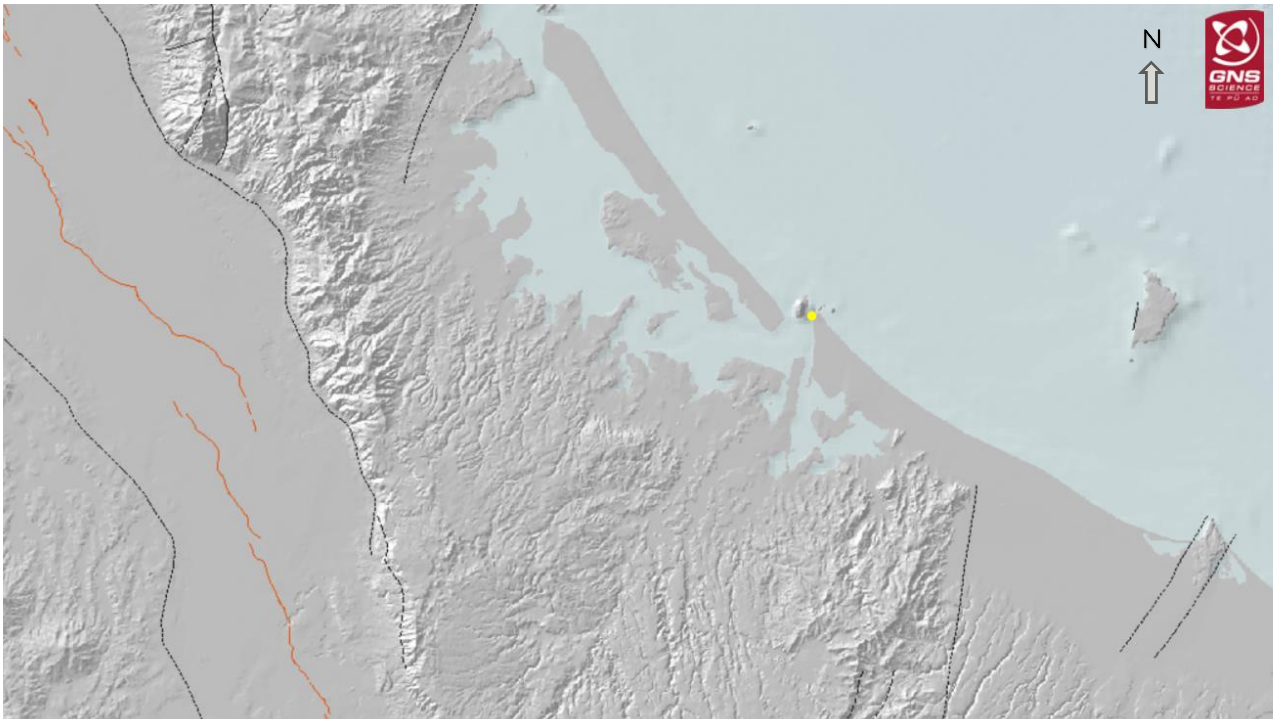

Figure 4. Nearest active faults to the site, from the Active Fault Database. Site is indicated by yellow dot. The Kerepehi Fault can be seen on left of image (red line). Source GNS Science.

3.2.3 Hydrology

TCC online groundwater mapping data from 2019[3] indicate that groundwater levels for the site are between 2.5 to 5 mRL for the lower lying areas, and between 5 mRL to 10 mRL for the raised terrace area (Figure 5). Close to the ocean, groundwater level fluctuations are in response to the daily tidal cycle and by seasonal changes.

Even though the site may have ground elevation above predicted future sea level, these areas may be prone to groundwater flooding as a result of sea level rise.

The flanks of Mauao act as a small catchment, with large amounts of overland and groundwater flow produced during heavy rainfall. A spring (Te Puna Waitapu) exists at the base of Mauao within the southern section of the site that flows into a manmade drain. It is assumed that the water from this spring is sourced from precipitation and water flow through the sediments on the flanks of Mauao. It is assumed that similar groundwater flow is occurring across the eastern flanks of Mauao.

The Mount Hot Pools, adjacent to the site, are fed by deep underground boreholes that tap into a hydrothermal system - a remnant of the volcanic history of the area. It is assumed that the geothermal system is too deep and weak to produce geothermal hazards for the site.

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[2] *https://data.gns.cri.nz/af/index.html*
[3] *https://taurangacc.maps.arcgis.com/apps/webappviewer/index.html?id=4b8325f08aa247379cdc142407519aaf*

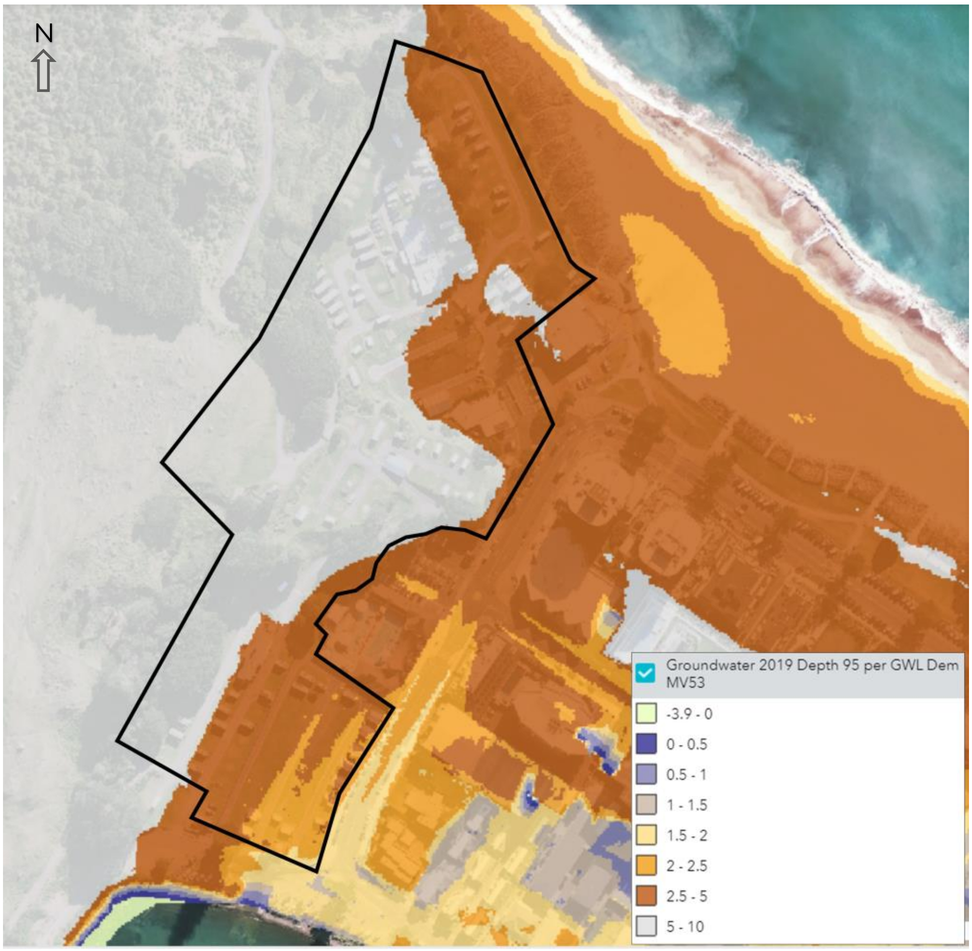

Figure 5. Groundwater levels. Site boundary is indicated by the black line. Source: TCC Online Maps.

3.3 Site Walkover

On 19 October 2023, a WSP Natural Hazard Geologist conducted a site walkover with the following purpose:

- To ground truth the features of the site with the digital mapping data available, and to determine any differences that relate to natural hazard and risk.
- To identify areas that are vulnerable or susceptible to natural hazards, both within the site and outside of the site with the potential to impact the site.
- To inspect the slopes and historic landslide features above the site to gain a preliminary understanding of slope stability, as well as identifying any obvious potential failure features (e.g., tension cracks).

A number of observations were documented; these are annotated on Figure 6 and detailed in Table 1.

Figure 6. Annotated figure showing features identified during the site walkover. Numbers denote identified historic landslides that have runout zones extending into the site grounds.

Table 1. Observation made during the site walkover.

OBSERVATION	DETAILS
Areas vulnerable to flooding and overland flow.	• Low-lying basin-shaped area within the northern campground (Figure 6). • Sections of the south campground area near to Pilot Bay.
Steep slopes, banks and cut faces vulnerable to slope failure	• Many of the steep slopes along the toe of Mauao, with some appearing to be comprised of historic landslide debris (e.g., Landslide 5 in Figure 6). • Steep natural slopes and cut faces along the raised terrace. Slopes are particularly steep on the south of the terrace area. Shallow soil erosion and undercutting of the ground surface is evident in this area (figures 9 to 13 in Appendix B).
Historic Landslides	• Eight landslides were identified via GIS data and inspected during the walkover for signs of instability and/or ongoing movement e.g., tension cracks, slumping, presence of soft ground.

OBSERVATION	DETAILS
	• None of the landslides investigated showed signs of imminent failure or significant movement. Scarps showed signed of "healing" where topography has smoothed over and vegetation is returning. • Landslide 7 shows minor tension cracking within the leaf litter in the centre of the slide scarp (Figure 24 in Appendix B). A previous tension crack formed adjacent to the landslide scarp along an access path has slumped slightly (Figure 22 in Appendix B).
Qualitative inspection of retaining walls	• It was observed that many of the retaining walls have been constructed below historic failures (Figure 6). It is assumed that each was built in response to a landslide event. Some of the retaining structures show degradation: Crib wall: • Located above a recently active series of slope failures that begin above the base track and continue downslope. The scarp above indicates failure was relatively recent (Landslide 3 in Figure 6). The wall shows signs of damage to the concrete and to the soils behind it. Very large void spaces and piping structures are present where water has flowed through the wall, removing sediment. Large masonry retaining wall: • Signs of minor degradation to the masonry (Figure 32 in Appendix B). Very slight forward rotation occurring at the northern end of the wall. Timber retaining wall: • Constructed in response to landslide failures within this area. Historic slips can be seen in the field and within the GIS datasets. Cabins are located very close to the wall and may be vulnerable to future landslide hazards. Gabion rock wall • Appears to have been built in response to the large failures in this area. Some metal wires of the basket structure are rusted away (Figure 31 in Appendix B).
Boulder fields on the grassed slopes of Mauao	• Many scattered boulders that have been transported from upslope and deposited on the lower grassy slopes above the site. Some of the boulders appear only loosely attached to the soils and it is possible that heavy rainfall or seismic shaking will cause them to be remobilised.

4 Natural Hazards

4.1 Introduction

This section presents a summary of available information regarding the selected natural hazards relevant to the site, and discussion of likely effects.

Our present understanding of natural hazards that may affect the site come from sources including city and regional hazard studies, site-specific geotechnical and natural hazard technical reports, the BOP Civil Defence Emergency Management (CDEM) Plan and RPS. A list of referenced material is included in the References section at the end of this report.

The RPS identifies a wide range of natural hazards that affect the region, and these are reproduced in Table 2. The hazards that are relevant to the site and included in the desktop assessment of this NHRA are highlighted.

Table 2. Occurrence of natural hazards in the Bay of Plenty region (after BOPRC RPS, 2016).

NATURAL OCCURRENCE	RESULTING NATURAL HAZARD	DESKTOP ASSESSMENT CONDUCTED IN THIS REPORT?
Volcanic activity	Ashfall Pyroclastic and lava flow Landslip, debris flow and lahar Geothermal hazard Caldera unrest	Yes No (distance too great) No (N/A) No (N/A) No (N/A)
Earthquakes	Fault rupture Liquefaction and lateral spread Ground shaking Landslide and rockfall Tsunami	No (distance too great) Yes Yes Yes Yes
Coastal/marine processes	Harbour inundation Coastal inundation Coastal erosion	Yes Yes Yes
Extreme (prolonged or intense) rainfall	Flooding Landslide Debris flow/flood	Yes Yes No (considered with the above)

This study notes that climate change is expected to exacerbate natural hazards with weather patterns likely to bring more intense rainfall, and result in more frequent and intense flooding. Sea level rise could result in intensified hazards, such as flooding and higher groundwater tables. A higher groundwater table also increases the likelihood of liquefaction-induced ground damage.

- Sea level rise effects have been considered as part of the statutory requirements of the hazard studies – the RPS currently works on the basis of a 1.25 m sea level rise in the next 100 years (sometimes referred to as a 1.05 m rise relative to NZVD16 datum, as opposed to the Moturiki Datum). Other timeframes considered within the district and regional council hazard datasets are Current Day (2030 sea level and meteorological conditions), and Year 2070/2080 (approx. 50 years).

Certain volcanic hazards (pyroclastic flow, lava flow, geothermal unrest, caldera unrest) are excluded due to the distance of the site from these hazard sources and/or low probability of the hazard occurring which extends beyond the scope of the RPS.

4.2 Volcanic Activity

4.2.1 Ashfall

The most widespread volcanic eruption hazard is ashfall, which has the potential to travel many hundreds of kilometres from its source. While ashfall does not often result in fatalities, its widespread dispersal can result in large-scale social and economic impacts. For this reason, volcanic ashfall is typically considered a disruptive rather than destructive hazard.

There are multiple volcanic sources with the potential to impact the Tauranga region. Because of this, Tauranga/Mt Maunganui have experienced numerous ashfall events over recent geological and historic time.

At present, there is limited published ashfall hazard information provided by regional and district councils for the Bay of Plenty. A report prepared for TCC in 2019 presents hazard scenarios corresponding to 500- and 10,000-year recurrence intervals (Table 3). These scenarios are based on a 2010 GNS Science publication outlining a New Zealand ashfall probabilistic volcanic hazard model (PVMH) for the North Island of New Zealand (Hurst and Smith, 2010). Ashfall isopachs of Hurst and Smith (2010) indicate that no ashfall would be expected in the coastal Bay of Plenty region from a 500-year event, while approx. 64 mm would be expected in a 10,000-year event (Figure 7; Table 3). The 500-year volcanic hazard map is dominated by the effects of Taranaki and Ruapehu volcanoes and the Ngauruhoe/Tongariro Volcanic Centre while the 10,000-year event is dominated by Taranaki and volcanoes in the TVZ (Figure 7).

A Waikato Regional Council (WRC) study conducted by GNS estimating the depth of ashfall, using prevailing wind directions, mapped for a 100-year event indicates between 0.1 to 1 mm over the coastal Bay of Plenty could be expected (Figure 8). This is in contrast to the New Zealand ash fall Probabilistic Volcanic Hazard Map (Figure 7) that indicates that no ash fall would be expected in the coastal Bay of Plenty region from a larger, 500-year event.

Any uncertainties in the volcanic history of any of these volcanoes can make a big difference to the final hazard estimates.

Table 3. Probabilistic hazard scenarios. Source; Hurst and Smith, 2010, Waikato Regional Council.

RETURN PERIOD (ARI)	ASHFALL DEPTH (MM)	SOURCE
100-year	0.1 to 1 mm	Waikato Regional Council.
500-year (AEP 0.2%)	Less than 1 mm	Hurst and Smith (2010)
10,000-year (AEP 0.01%)	64 mm	Hurst and Smith (2010)

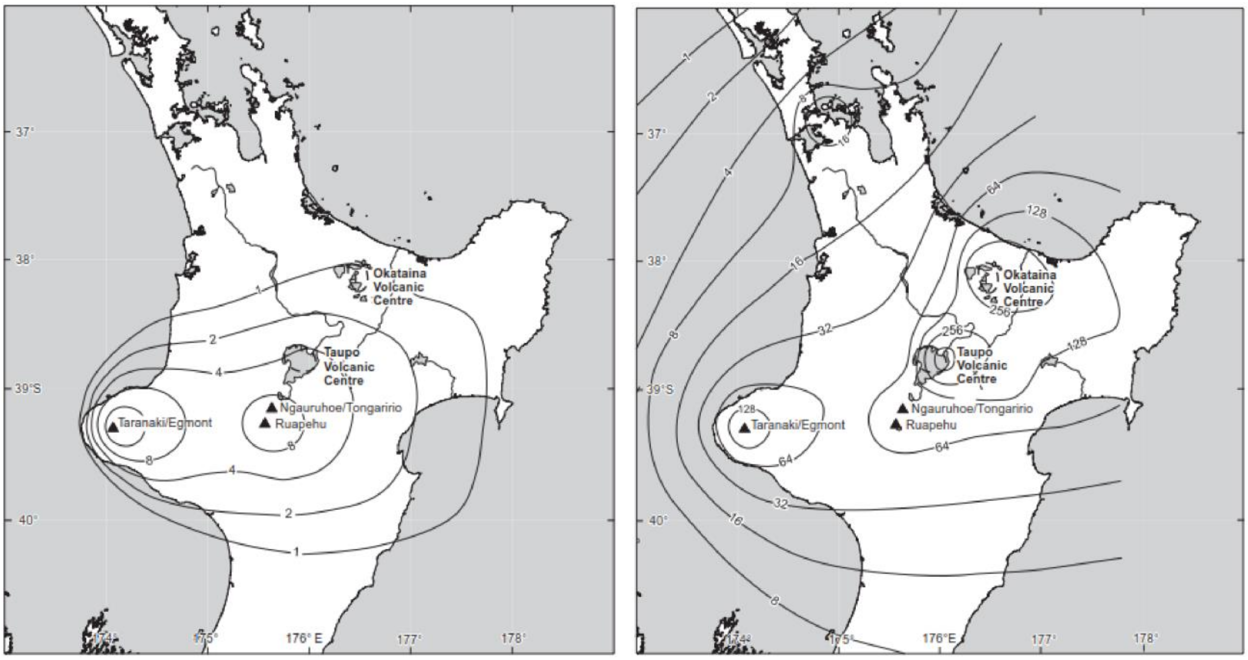

Figure 7. Volcanic ashfall hazard map (contours in mm) for the 500-year return period (left) and 10,000-year return period (right). Source: Hurst and Smith (2010).

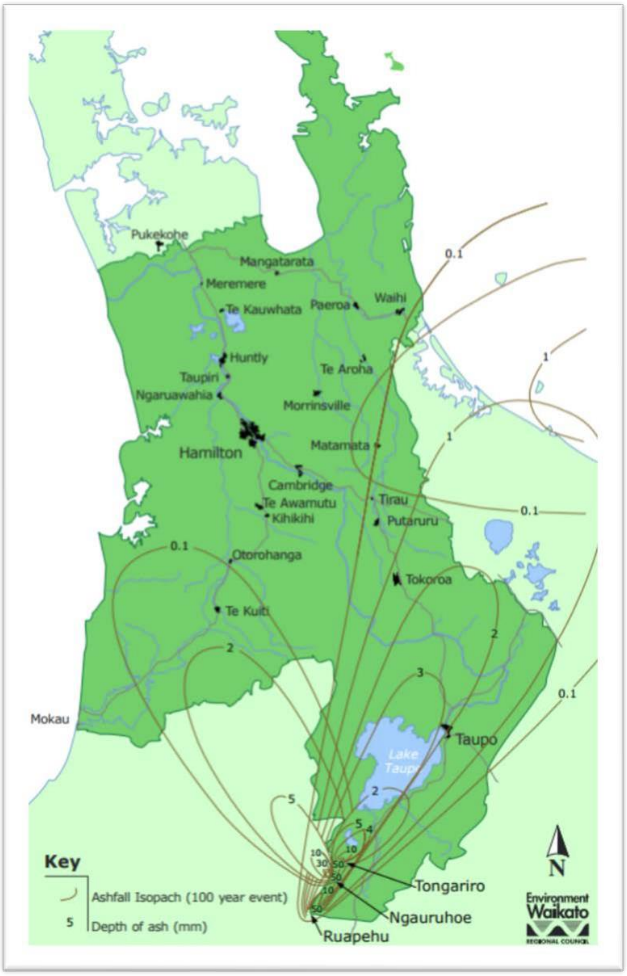

Figure 8. Volcanic ashfall hazard for 100-year event. Source: Waikato Regional Council.

It is important to note that Tauranga has been impacted in the past from large eruptions which resulted in greater ashfall depths than presented in the above maps. For example, the 1314 AD Kaharoa eruption of Tarawera deposited 90-100 mm of ash over the Tauranga area. Tauranga also experienced approx. 5 mm of ashfall as a result of the 1886 AD eruption of Mt Tarawera (this would have been greater if the wind had not transported the ash eastwards). In the most extreme case, the Oruanui eruption from Taupo ~26,000 years ago (one of the largest known New Zealand eruptions) deposited ~400 mm thick deposits of ash in Tauranga.

The consequences of between 0.1 to 5 mm of ash fall are (after Edbrooke, 2005):

- Possible crop damage.
- Minor damage to buildings, vehicles and equipment caused by abrasive ash.
- Water supplies may be cut or limited due to electricity failure.
- Roads may need to be cleared to reduce dust nuisance and prevent storm water systems becoming blocked.

The consequences of between 5 to 100 mm of ash fall are (after Edbrooke, 2005):

- Burial of pasture and low plants; most pasture killed with >50 mm of ash.
- Major ash removal in urban areas.
- Road transport may be halted due to ash build-up.
- Weaker roof structures may collapse in 100 mm ash thickness.
- Roads may need to be cleared to reduce dust nuisance and prevent storm water systems becoming blocked.

The effect of ash fall on buildings and infrastructure is not currently considered in the New Zealand Building Code or other relevant codes.

As the ash fall hazard is not well-defined for the site for all AEP% under the RPS, it will not be considered further by this study.

4.3 Earthquakes/Seismic Activity

4.3.1 Fault Rupture and Ground Shaking

The site is not understood to be intersected by any known faults. A review of the GNS Science active fault database indicates the site is located approximately 35 km of the nearest registered active fault (Kerepihi Fault) (Figure 4). The Kerepihi Fault is a normal dipping fault with a recurrence interval of 5,000 to 10,000 years. The fault has a low slip rate, and a moderate single event displacement rating.

The hazard associated with ground shaking at this site will be realised as liquefaction and/or slope instability (discussed in subsequent sections). The effects of seismic shaking to buildings are managed through structural design processes in accordance with the building code and are not considered further in this report.

4.3.2 Liquefaction and Lateral Spread

Liquefaction can lead to large displacements of foundations and service infrastructure, flow failures of slopes, ground surface settlement, sand boils, and post-earthquake stability failures. Three primary factors contribute to liquefaction potential:

1. Soil grading and density - loose non-plastic soil (typically sands and silts, or in rare cases gravel).
2. The presence of groundwater – having a saturated soil (i.e. below the groundwater table).
3. Earthquake intensity and level of ground shaking – i.e. creating a sufficient ground shaking (a combination of the duration and intensity of shaking).

Liquefaction hazard assessments for Tauranga City are provided in a dedicated online viewing portal[4]. To determine the liquefaction potential, the geomorphology was mapped across the city. The site sits across two geomorphic terrains, the first, *volcanic hills and ranges,* reflecting the Mauao volcanics on the western side of the site, the second, *active and fixed foredunes,* reflecting the lower lying areas in the east of the site (Appendix A, Figure 1a). Tauranga could experience sufficient earthquake intensity and level of ground shaking to induce liquefaction.

As defined by the Ministry of Business, Innovation and Employment (MBIE) guidelines on planning and engineering guidance for potentially liquefaction-prone land (2017), the section of the site that is low-lying and built on the active and fixed dunes is classified as liquefaction is 'Possible', while the area within the volcanic hills is classed as liquefaction is 'Low'. A summary of the likelihood for liquefaction and lateral spread for both zones is presented in Table 4.

Table 4. Mapped terrains and liquefaction details. Source TCC Online Liquefaction Map.

MAPPED TERRAIN	LIQUEFACTION VULNERABILITY	LATERAL SPREAD AREA	DETAILS	UNCERTAINTY
Active Foredunes	Possible	No	Level B	The clean sandy soils that are found in the Active and Fixed Foredunes are typically considered susceptible to liquefaction, this coupled with the relatively shallow depth to groundwater in this area indicates that liquefaction-induced land damage is possible.
Fixed Foredunes	Possible	Yes	Level B	
Volcanic Hills and Ranges	Low	No	Level A	The variable volcanic deposits including rhyolite, welded ignimbrite, andesite, dacite dominant in the upper 10 m of the ground profile are considered not susceptible to liquefaction

In terms of predicted land damage, the site is located within an area mapped as 'None to minor' land damage for any future (incorporates changes to groundwater level) earthquake events, ranging from 1 in 25-year to 1 in 1,000-year (Appendix A, Figure 1b). Note, two small areas within the southwest section of the site are mapped as 'Minor to Moderate' for the 1 in 1,000-year event only (Appendix A, Figure 1c). The area of the site sitting on the central terrace (volcanic hills and ranges) is not mapped as liquefiable and no damage is mapped for any return period.

Lateral spreading occurs predominantly within close distance of a 'free surface' such as a watercourse where liquified soils can become displaced horizontally. Lateral spread is a complex phenomenon, of which the magnitude and extent are not easily predicted. Observations from historic earthquakes indicates that lateral spreading generally only occurs within 200 m of a free face such as a watercourse or exposed slope face.

The dune sands of the Mount Maunganui peninsula near Mauao are generally considered sufficiently dense, and the groundwater table sufficiently low, to resist liquefaction and lateral spreading. The low-sloping beach and harbour margins are not considered a 'free face' and the risk of lateral spreading for the site is considered to be low.

[4] *https://gisapps.tauranga.govt.nz/liquefaction/*

4.3.3 Seismically induced landslides and rock falls

4.3.3.1 Seismically induced landslides

Seismic shaking is a common trigger for mass movements across New Zealand. On Mauao, however, seismically induced mass movements make up only a minor component of the geological and historic record. Rain-induced movements are far more common (e.g., - Martin and Brideau, 2014). This is a consequence of the increased frequency of large storms and cyclones compared to large earthquakes, and the distance from Mauao to a major fault zone, reducing the shaking felt on site. It is possible that large earthquakes (e.g., equivalent to a 1-in-500 or 1-1000-year event) could trigger large failures with long runout distances.

There is currently insufficient available hazard data to differentiate between seismic and rainfall landslides on Mauao, and so we have mainly focussed on rain-induced landslides for this risk assessment. In Section 4.5, we briefly describe possible runout distance for seismically induced landslides.

4.3.3.2 Seismically induced rockfalls

Rockfalls are type of rapid slope movement where rock material is detached from a steep slope and descends by falling, bouncing, rolling or sliding. Rockfalls typically involve the fall of individual or relatively small numbers of blocks of gravel- to large boulder-sized rock masses. There is little interaction between the individual blocks during transport. Rockfalls can be triggered by earthquakes, heavy rain, or long-term weathering of exposed rock faces.

Rockfall hazard has occasionally affected Mauao resulting in closures of the tracks and in some instances removal of hazardous outcrops via blasting before they fail (e.g., 2003[5], 2008[6],2017[7]). However, there is insufficient available hazard data to confidently differentiate between seismic- and rainfall-induced rockfall hazards for risk assessment.

Rockfall sources

Using GIS data and observations during the site walkover, three potential sources of rockfall hazard for the site have been identified (Figure 9).

1. The bluffs below the main summit observation area. Rockfall pathways are predominantly directed towards the northern and central areas of the site.
2. The smaller and less exposed bluffs to the south of the summit area. Rockfall pathways are predominantly directed towards the southern areas of the site.
3. The boulder field within the lower flanks (grassed area) upslope of the site. Boulders of up to 2 m diameter are present and have likely been sourced from the above-mentioned locations by toppling and rolling downslope. Boulders were found across the slope and within the margins of the park. Historic imagery shows boulders scattered across the location of the site. Some of the boulders on the grassed slopes sit precariously, and it is possible they could be remobilised during seismic shaking or heavy rainfall (Appendix B, figures 27 and 28).

Vegetation provides an effective natural barrier to rockfalls. The rock bluffs (sources 1 and 2) lie within the upper vegetated slopes of Mauao and this provides an effective barrier, negating the hazard to some extent (Figure 9). The boundary between the park and Mauao has some tree cover, and this provides some protection from rockfall, however areas of the park where there is no shielding from upslope hazards may be vulnerable to boulders becoming dislodged.

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[5] *https://www.nzherald.co.nz/nz/rockfall-danger-closes-mauao/GO2UV3B3THM2PGCJTMBP7KLVWI/*
[6] *https://www.nzherald.co.nz/nz/blast-moves-dangerous-landmark-overhang/DK3LEKC4PZY3LCVCUSAKAOFNRQ/*
[7] *https://www.nzherald.co.nz/bay-of-plenty-times/news/mauao-track-closed-due-to-rockfall/VOZS4AVKAQG4HQACAFZAKQ64FQ/*

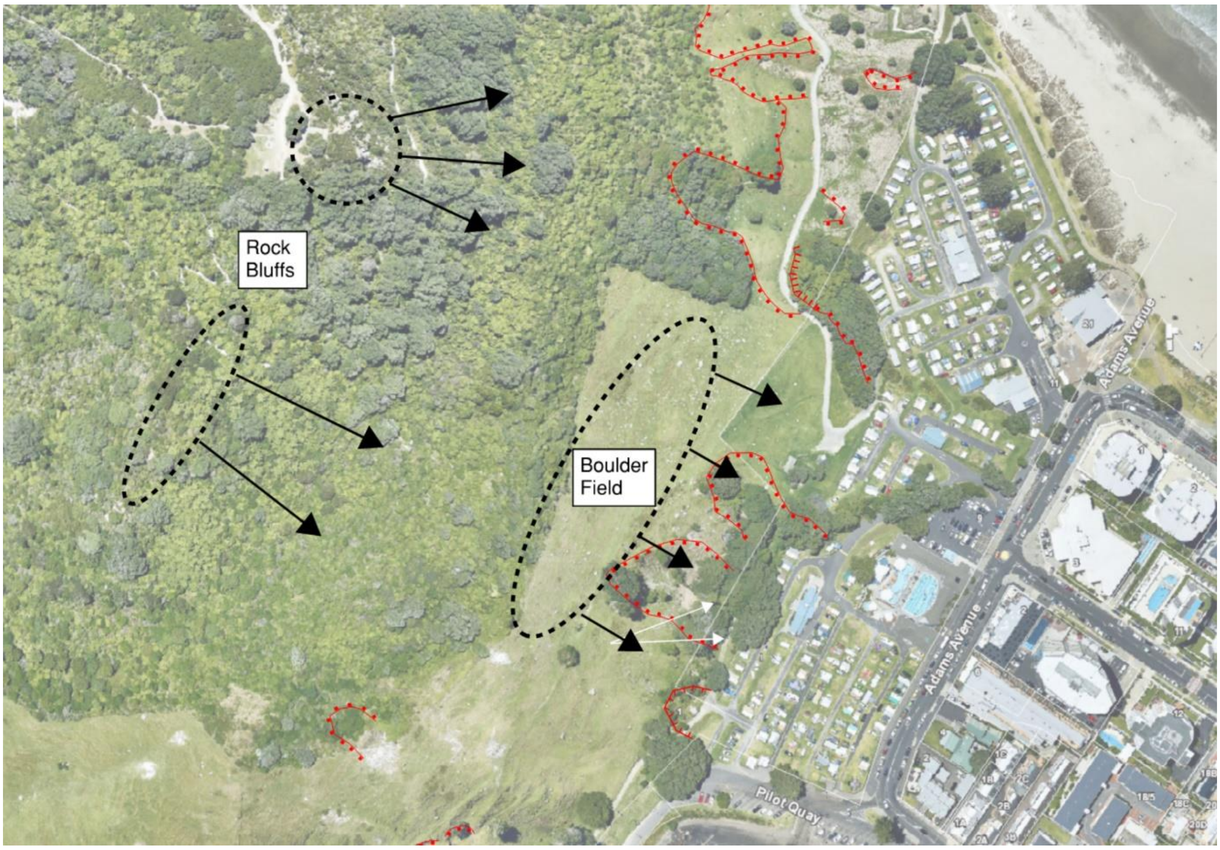

Figure 9. Aerial view of the site with indicated rockfall source areas and travel paths. Vegetation cover between the source and the site is important for providing protection.

4.3.4 Tsunamis

The Bay of Plenty is susceptible to tsunamis from both regional and far-field sources with previous work identifying the Kermadec Trench as the most significant source of large tsunami (Walters et al., 2006).

Initial modelling by NIWA and GNS (Beben et al., 2012) identified a Mw 9.0 fault on the Kermadec Trench as a maximum credible event (MCE) for the BOP coastline. TCC[8] and BOPRC[9] provide tsunami evacuation maps on their websites. In 2023 a change was made to the mapped tsunami evacuation zones where three previous zones based on expected tsunami return periods were replaced with a single evacuation zone.

Online maps show the entire site sits within the evacuation zone - which depicts the area that would be inundated by a Maximum Credible Event (MCE) tsunami. Tsunami modelling provided by TCC indicate that a modelled 9 m MCE wave would produce water depths at the site of up to 2 m or greater assuming the current ground level (Appendix A, Figure 2). The TCC online map, in contrast to the BOPRC map, does not include the elevated terrace within the centre of the site within the evacuation zone.

The nearest tsunami evacuation point for the site is immediately upslope of Mauao to the west. The elevated base tracks to the north and south lie outside of the evacuation zone, and they extend into the park connecting to the site accessways, providing sufficient time to evacuate guests and staff during a tsunami warning.

[8] *https://mapi.tauranga.govt.nz/Html5/index.html?viewer=Mapi*
[9] *https://gis.boprc.govt.nz/Html5/index.html?viewer=bayexplorer*

4.4 Coastal/Marine Processes

4.4.1 Coastal and Harbour Inundation

Inundation is the flooding of low lying coastal/harbour areas by raised sea water. Inundation is mainly caused by severe weather events such as storms where low-pressure weather systems, large waves and strong winds combine to raise water. It is believed that with ongoing climate change, areas that currently experience only minor or occasional inundation are likely to experience much more frequent and severe inundation in the future.

Inundation modelling is used to identify hazard areas and is included in the Tauranga City Plan. Hazard areas may be susceptible to inundation flooding due to their low-lying nature.

Inundation modelling for the Tauranga harbour was carried out in 2009 as part of the City Plan review[10]. In 2019 the National Institute of Water and Atmospheric Research (NIWA) carried out an updated assessment of the potential for inundation of land near the Tauranga harbour (Reeve et al., 2019). In this study NIWA developed a model that incorporates sea levels generated by a range of extreme storm events and the impact of potential sea level rise scenarios out to 2130 (information provided by the Ministry for the Environment). A dedicated online map viewer for harbour inundation scenarios is provided by TCC[11],. The harbour inundation modelling only considered inundation within the harbour and not from the open coast.

For this assessment we have also used a preliminary coastal inundation dataset produced by NIWA that was made available by TCC. This dataset considers inundation from the open coast during storm events, and also models inundation through the harbour entrance with the potential to impact Pilot Bay.

Both the inundation datasets include current and future (years 2070/80 and 2130) hazard timeframes and event likelihoods. This information is presented in Appendix A, figures 3a, 3b and 3c, and the impacts to the site are summarised in Table 5.

Table 5. Harbour Inundation. For various scenarios.

MAPPED SCENARIO	SITE IMPACTS
Current day, 0.2% AEP	Does not affect the site (Appendix A Figure 3a).
2070/80, 0.4 m SLR, 1% AEP	Does not affect the site (Appendix A Figure 3b).
2130, 0.6 m SLR, 1% AEP	0.1 to 0.5 m within a small corner of the southeast margins of the site along Pilot Quay.
2130, 1.05 m SLR, 1% AEP	0.1 to 1.0 within a small corner of the southeast margins of the site along Pilot Quay (Appendix A Figure 3c).
2130 1.4 m SLR, 1% AEP	0.1 to 0.25 m within a significant area of the southern campsite. 0.5 to over 1 m within the southeastern corner of the site.
City Plan 5k-10 Coastal Inundation (TCC Mapi)	0.1 to 0.5 m of inundation within a similar, small area within the south of the site towards Pilot Quay.

4.4.2 Coastal and Harbour Erosion

Coastal and harbour erosion is a natural process by which sediment is removed from beaches and cliffs and transported elsewhere by currents. Erosion occurs through geological and hydrodynamic processes such as king tides, storm surges, wind waves, and swell waves.

[10] *Tonkin & Taylor, 2009. Tauranga Harbour Inundation Assessment Overland Inundation Mapping. Ref: 22288.001*
[11] *https://gisapps.tauranga.govt.nz/harbourinundation/*

TCC provide a dedicated online viewing portal for their coastal erosion mapping datasets[12]. A range of erosion and instability scenarios over various timeframes and sea level rise models are provided. Hazard maps are presented in Appendix A, figures 4a,4b and 4c and a summary of the estimated effects to the site are presented in Table 6.

Table 6. Coastal Erosion for various scenarios and their impacts to the site.

MAPPED SCENARIO	SITE IMPACTS – HARBOUR EROSION	SITE IMPACTS – BEACH/COASTAL EROSION
Current day (Appendix A Figure 4a)	Both Likely and Very Unlikely do not affect the site.	Both Likely and Very Unlikely do not affect the site.
2080, 0.4 m SLR (Appendix A Figure 4b)	Both Likely and Very Unlikely do not affect the site.	Likely: does not affect the site. Very Unlikely: Minor erosion within the north tip of the campsites.
2130, 0.6 m SLR	Likely is the only data. Does not affect the site.	Likely is the only data. Minor erosion within the north tip of the campsites.
2130, 1.05 m SLR (Appendix A Figure 4c)	Likely does not affect the site. Very Unlikely shows a small corner of the southeast margins of the site along Pilot Quay falls within the mapped feature.	Likely: Minor within the north tip of the campsites. Very Unlikely: The entire of the low-lying northern campsite is affected.
2130 1.4 m SLR	Very Unlikely is the only option. A minor section of the southern extent of the site is affected.	Very Unlikely is the only data. Significant impacts. The entirety of the low-lying northern campsite is affected. The campsites on the terrace above are also affected, as is the main roadway into the park next to the reception office.

Note: 'Likely' and 'Very Unlikely' probabilities relate to the likelihood of the mapped 'Potential Coastal Erosion and Instability Hazard Areas' (CEIHA) area regressing landward due to slope instability and the assessed sea level rise. Likely indicates 66% probability of inland exceedance. Very Unlikely indicates 5% probability of inland exceedance.

4.5 Extreme (Prolonged or Intense) Rainfall

4.5.1 Flooding

TCC online mapping flood scenarios currently use a 1% AEP, year 2130 climate change median scenario (RCP 8.5). Flood hazards are modelled for depth as well as the speed and direction of floodwater (its flow path).

4.5.1.1 Overland flow

Overland flow is included within the Year 2130 1% AEP TCC map datasets. Multiple overland flow paths are mapped within the bounds of the site (Appendix A, Figure 5a). The paths typically form on the flanks of Mauao and flow eastwards downslope, entering the site and flowing along the paved surfaces to exit either to the coast or onto Adams Avenue. Table 7 summarises the locations of Minor and Major overland flow hazard. The low-lying northern and southern areas of the park

[12] *https://gisapps.tauranga.govt.nz/coastalerosion/*

are most susceptible, particularly the north where significant flow is estimated for the area where the concrete crib wall is located (Figure 3).

Table 7. Summary of mapped overland flow hazard at the site.

MAPPED OVERLAND FLOW PATH (TCC 1% AEP 2130)	AREA OF SITE AFFECTED (APPENDIX A FIGURE 5A)
Minor Overland Flow	Multiple areas. are typically E-W trending, running off the slopes of Mauao and along sloped accessways of the site
Major Overland Flow	South and north areas of the site along roadways. Adams Avenue. Low-lying northern area is particularly susceptible.

4.5.1.2 Flood Prone Areas

TCC Year 2130 1% AEP modelling is shown in Appendix A, Figure 5a and its projected impact to the site is summarised in Table 8. Previous flooding maps dated before 2020 (now superseded) are still available on the TCC Mapi website and are generally similar to those of the updated maps (Appendix A Figure 5b). Areas of flooding include minor areas at the south of the site, minor areas within the centre of the site near the main reception and facilities building, and heavy flooding across most of the northern campgrounds.

Note, the flood prone area within the centre of the site is the location of the Mount Hot Pools and is not included in this assessment.

Table 8. Summary of mapped flooding hazard at the site.

MAPPED FLOOD PRONE AREA (TCC 1% AEP 2130)	AREAS OF SITE AFFECTED (APPENDIX A FIGURE 5A)	TCC SUPERSEDED PRE-2020 MAPPING DATASET (APPENDIX A FIGURE 5B)
Depth 100 to 300 mm	Low-lying northern campground, small, scattered areas within the northern half of the park. Small areas mapped within the south of park along roadway and within camp sites.	Similar to Year 2130 mapped flooding. This dataset shows an overall larger area of the park susceptible to flooding, including the area around the reception office.
Depth >300 mm	The low-lying north campground is the most susceptible to flooding. Much of the area indicates greater than 300 mm is expected. Other areas less susceptible to flooding include a small area in the centre of the park, and one in the southwest close to the toe of Mauao.	Similar to the current TCC map. Shows the most intense flooding in the low-lying northern campground.

4.5.2 Rain-Induced Landslide

The Tauranga region is prone to slope failures during high intensity rainstorms as a consequence of the highly sensitive, often clay-rich volcanic soils. The slopes of Mauao are particularly prone to landslides due to the steepness of their slopes and the weakly formed colluvial, alluvial and marine sediments that form thick deposits of the lower flanks. An extreme event can cause multiple landslides, for example, in January 2011 when intense rainfall resulted in about 80 mass movements with eight large landslides causing visible displacement of sediment and closing trails (Tonkin and Taylor, 2011).

A study by Martin and Brideau (2014) catalogued mass movements throughout a 68-year period on Mauao and identified four main types; rotational slides, debris flows, debris avalanches and rock falls. The majority of failures were shallow-rotational slides concentrated on the south-western and north-eastern lower flanks (Figure 10). Observations of historic landslides suggest that runout distances are typically less than 100 m.

Similar slope conditions (angle and soil composition) are assumed for the slopes above the site, and small rotational failures with run out distances of less than 100 m are expected. There is also a strong correlation between rainfall-triggered landslides after deforestation. Much of the lower flanks of Mauao have only grass cover.

A WSP report in November 2022 (WSP, 2022) assessed slope risk around the base track of Mauao and described one area to the north of the site (landslides 2 and 3 in this report) as having a risk rating of 'Medium to High' based on a qualitative assessment of the likelihood of slope failure above or below the track.

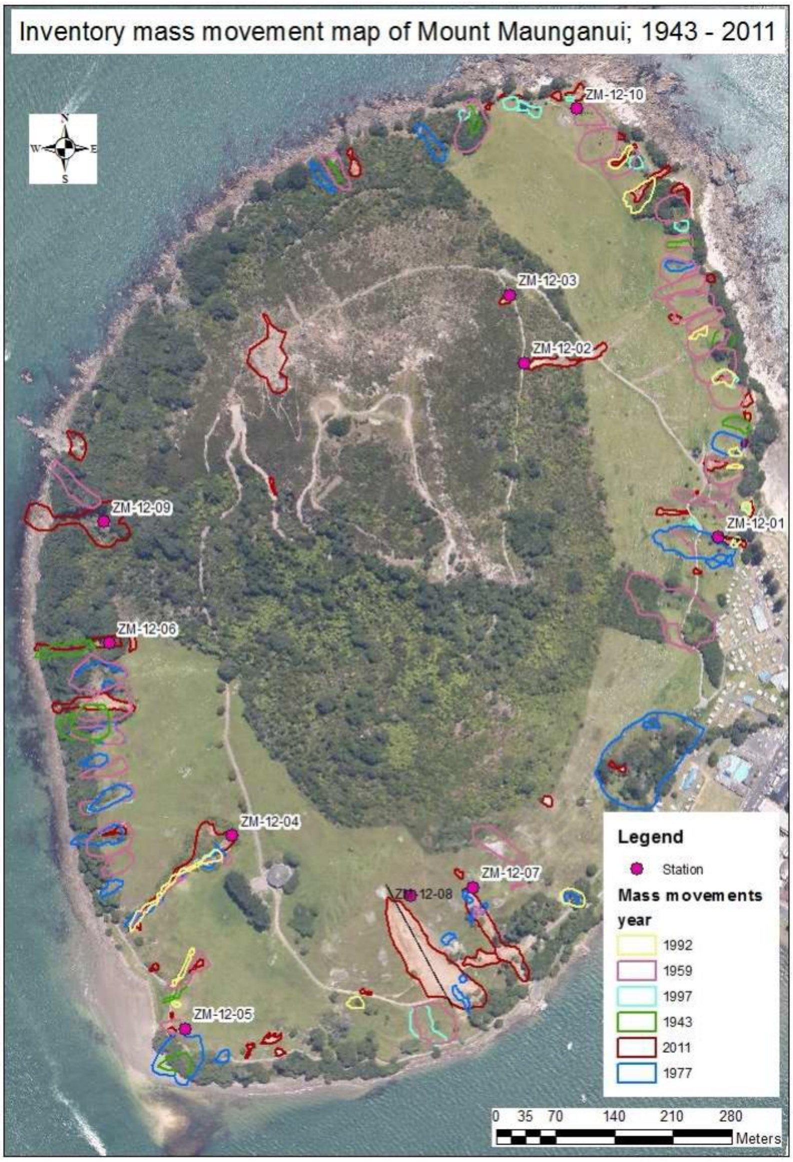

Figure 10. Spatial distribution of landslides on Mount Maunganui between 1943 and 2011. Multiple mapped landslides are present immediately above the site grounds. Source: Martin and Brideau, 2014.

4.5.2.1 Qualitative Slope Failure Assessment

In 2023, TCC updated the city-wide slope maps based on a review of new landslide data, geomorphological mapping and new topographic data. This assessment excluded Mauao, but we understand that it may be included in a future mapping exercise. To provide a qualitative assessment of the potential for slope failure we used a simplified approach based on the TCC methodology.

A slope failure map for Mauao, showing areas that are more susceptible to landslide occurrence and inundation from slope failure, is provided in Appendix A Figure 6. The failure zone, where landslides typically begin (Figure 11) was determined by examining the extent of historic landslides formed on the flanks above the site. Past studies and GIS data indicated that slope failure typically occurs at elevations of approximately 55 mRL and terminating at approximately 10 mRL. Therefore, we have used these elevations to define the upper and lower extents of the failure zone.

Multiple runout zones (land downslope of the failure zone where debris can inundate) were created by projecting slope angles from the crest of the failure zone (as seen in Figure 11). For this analysis we use a 2.5H:1V slope to estimate an approximate *more frequent* scenario (e.g., akin to a 1-in-100-year event) with runout distance similar to those observed over the last 80 years of 100 m that may result from intense rainfall. We also use a 4H: 1V slope to estimate a *less frequent* scenario (e.g., an approximate 1-in-1000-year seismically induced event).

The steep banks around the raised terrace area were also considered, with a failure zone designated between 15 mRL and 5mRL, and runout zones projected based on these elevations.

We have not included a Regression Zone because regression moves upslope and does not pose a hazard to the site.

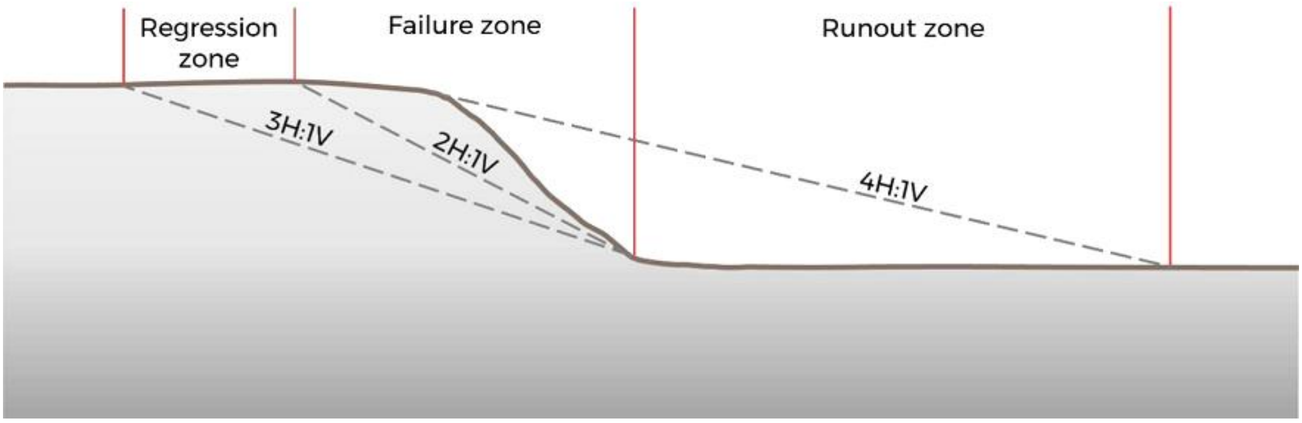

Figure 11. Example of landslide Failure, Regression and Runout zone calculations. Source: TCC website.

Based on our slope failure map, a proportion of the site is within the runout zone. Particularly vulnerable areas include the campsites adjacent to the toe of Mauao. Much of these areas are within the runout areas of historic landslides. Reactivation of these failures is possible during heavy rainfall (e.g., Figure 10 above).

4.6 Summary of Hazards

After consideration of the natural hazards presented in Table 2, and included in Section 2.11 of the RPS, and discussed in the subsections above, the following natural hazards will be assessed using the RPS risk assessment methodology (refer to RPS, Appendix L):

- Liquefaction
- Tsunami
- Inundation
- Coastal Erosion
- Flooding
- Landslides and rockfall

5 Risk Assessment

5.1 Introduction

A NHRA has been undertaken for the site in general accordance with the BOPRC RPS and natural hazard risk management policy framework. This includes identifying the risk and any risk treatment options (if available) and undertaking a risk analysis and evaluation.

A discussion of hazards relative to the site was presented in Section 3. The following hazards are deemed relevant and have been assessed within the RPS NHRA framework:

- Liquefaction
- Tsunami
- Coastal and Harbour Inundation
- Coastal and Harbour Erosion
- Flooding
- Landslides and rockfall

WSP has undertaken a qualitative evaluation as per steps 1 to 4 of Appendix L of the RPS and the results are discussed in Section 5.4.

Step 5 of the methodology for calculating the Annual Individual Fatality Risk (AIFR) has not been conducted for this study. This is due to a number of complicating factors including:

- The variable number and timeframes of the population staying in the site. For example, guests may stay only 1 day to 1 week per year (or only once in their lifetimes), while permanent staff may spend 40+ hours onsite, and other staff may live onsite permanently.
- Seasonal changes to guest numbers, and the unpredictability of where guests may be staying within the site (their location in regard to hazard areas).
- The types of accommodation (e.g., cabins, campers, caravans, tents) that influences the consequences that different hazards (and their intensity) might have.

A more quantitative and in-depth study utilising visitor and staff data from the site is required to determine an AIFR.

5.2 Proposed Risk Treatments

There are currently no specific risk treatments that are proposed for this site.

5.3 Analysis and Evaluation

The following assumptions have been made in undertaking the risk assessment and evaluation:

- For the purposes of this study, we consider cabins, campervans, caravans and tent sites as "Buildings" under Table 21, Appendix L of the RPS.
- The site is not affected by most volcanic hazards or from fault rupture. These natural hazards are therefore excluded from the NHRA.
- Ashfall hazard for the site is poorly defined, but low, and therefore is not considered further. The effect of ashfall on buildings and infrastructure is not considered in the New Zealand Building Code or other relevant codes pertaining to existing structures onsite or any future proposed developments.
- Ground shaking affecting buildings and structures is outside of the requirements of the RPS but covered by the Building Code.
- Liquefaction is only possible within the areas of the site that are underlain by Holocene dune sands.

- The consequences were considered in accordance with the level of consequence described in Table 21 in Appendix L of the RPS. The Tonkin & Taylor (2018) Lifelines Consequence Assessment report was also referenced.
- The overall risk rating has then been determined from the likelihood and consequences using the Risk Screening Matrix from page 374 of Appendix L of the RPS.

A key consequence governing the outcomes of a hazard risk assessment relates to the functionality of buildings following an event. The performance requirement that the RPS considers is the likelihood of relevant buildings or structures being “functionally compromised”. Functionally compromised is defined by the RPS as a condition that “will generally occur when a building cannot continue to be used for its intended use immediately after an event”.

It is difficult to determine the extent to which a caravan, campervan or tent is functionally compromised. It is likely that any natural hazards could result in total loss of functionality (for example, a tent that has been flooded). It is reasonable to assume that in an event, most of these 'buildings' will be heavily damaged and likely unliveable. This is further complicated by these structures being used only as temporary holiday dwellings.

Outside of the RMA framework, the Building Code objective B1.1(b) states that a building is to have a low probability of “loss of amenity” during its life, which is defined as “an attribute of a building which contributes to the health, physical independence and well-being of the building’s user but which is not associated with disease or a specific illness.” “Functionality compromised” is interpreted as being equivalent to the loss of amenity definitions that are set out by MBIE in repairing and rebuilding houses affected by the Canterbury Earthquakes (2012). The term “readily repairable”, is defined by MBIE as a building that can be repaired without relocation of occupants for a period of more than four weeks. Cabins, amenity blocks and reception buildings do fit within the Building Code and can be assessed using these criteria, while caravans, campervans and/or tents do not.

Our risk analyses and evaluations are presented in the following tables:

- Table 9: Liquefaction
- Table 10: Tsunami.
- Table 11: Coastal and Harbour Inundation
- Table 12: Coastal and Harbour Erosion
- Table 13: Flooding
- Table 14: Landslides and rockfall

Table 9. Liquefaction

<table>
<tr><th rowspan="2">Natural Hazard/ Scenario</th><th rowspan="2">Probability (% AEP)[1]</th><th colspan="5">Consequences[2]</th><th rowspan="2">Overall risk rating (AEP vs. consequence)[3]</th><th rowspan="2">Qualitative Consideration</th></tr>
<tr><th>Social / Cultural Buildings</th><th>Buildings</th><th>Buildings Critical</th><th>Lifelines Utilities</th><th>Health and Safety</th></tr>
<tr><td>Liquefaction
-
Current Day</td><td rowspan="2">0.1
(1-in-1000-year earthquake event)</td><td>Insignificant</td><td>Minor</td><td>Insignificant</td><td>Minor</td><td>Minor</td><td>Low Risk</td><td rowspan="2">• Assessments assume a full capacity/occupancy of the site to account for ‘worst case’ consequences (8,000 guests during high peak summer with little to no advanced warning).
• All campsites/locations (cabins, tents, caravans etc) are considered “Buildings” under Table 21 of Appendix L in this assessment.
• It is assumed that the raised central terrace has no liquefaction potential, or estimated damage.
• Land damage across the liquefiable Holocene dune sands mapped ‘None to Minor’ for a 1-in-500-year event during current timeframe.
• For the ‘Future’ conditions (raised GW, 1-in-500-year event), the site is almost entirely (>95%) mapped within the ‘None to Minor’ damage classification.
• For the 1-in-1000 future event approximately 60% of the site is mapped within the ‘Minor to Moderate’ damage classification.
• In the current climate, it is unlikely that liquefaction ground damage will occur at the site causing damage to buildings and associated infrastructure.
• As the soils are liquefiable below the groundwater level, they could damage underground infrastructure while not causing damage at the surface.</td></tr>
<tr><td>Liquefaction
-
Year 2130</td><td>Insignificant</td><td>Moderate</td><td>Insignificant</td><td>Moderate</td><td>Moderate</td><td>Medium Risk</td></tr>
<tr><td colspan="9">Notes/References:
1 Probability (in terms of % AEP) (Refer Appendix L of RPS, Table 20)
2 Consequences (Refer Appendix L of RPS, Table 21)
3 Overall risk rating (Refer to Risk Screening Matrix, page 374 of RPS)
Risk assessment completed in accordance with Appendix L of BOPRC Operative Regional Policy Statement</td></tr>
</table>

Table 10. Tsunami

Natural Hazard	Probability (% AEP)[1]	Consequences[2]					Overall risk rating (AEP vs. consequence)[3]	Qualitative Consideration
		Social / Cultural Buildings	Buildings	Buildings Critical	Lifelines Utilities	Health and Safety		
Tsunami	0.1 (1-in-1000-year tsunami event)	Insignificant	Catastrophic	Insignificant	Moderate	Catastrophic	High Risk	• All campsites/locations (cabins, tents, caravans etc) are considered "Buildings" under Table 21 of Appendix L in this assessment. • Assessments assume a full capacity/occupancy of the site to account for 'worst case' consequences (8,000 guests during high peak summer with little to no advanced warning). • Near complete coverage of the site with >2 m flood depth classification. • Underground infrastructure is unlikely to be damaged, however overland power lines and/or cellphone towers maybe damaged.

Notes/References:
1 Probability (in terms of % AEP) (Refer Appendix L of RPS, Table 20)
2 Consequences (Refer Appendix L of RPS, Table 21)
3 Overall risk rating (Refer to Risk Screening Matrix, page 374 of RPS)
Risk assessment completed in accordance with Appendix L of BOPRC Operative Regional Policy Statement

Table 11. Coastal and Harbour Inundation

Natural Hazard	Probability (% AEP)[1]	Consequences[2]					Overall risk rating (AEP vs. consequence)[3]	Qualitative Consideration
		Social / Cultural Buildings	Buildings	Buildings Critical	Lifelines Utilities	Health and Safety		
Coastal Inundation – Current Day (Year 2030)	1 (1-in-100-year inundation event)	Insignificant	Minor to Moderate	Insignificant	Insignificant	Minor	Low Risk	• All campsites/locations (cabins, tents, caravans etc) are considered "Buildings" under Table 21 of Appendix L in this assessment. • Assessments assume a full capacity/occupancy of the site to account for 'worst case' consequences (8,000 guests during high peak summer with little to no advanced warning, if applicable). • Future scenarios are predictive and may not represent the actual climate, meteorological or oceanographic conditions or their hazards.
Coastal Inundation – Year 2080 0.4 m SLR		Insignificant	Major	Insignificant	Insignificant	Minor to Moderate	Medium Risk	
Coastal Inundation – Year 2130 1.05 m SLR		Insignificant	Major	Insignificant	Insignificant	Minor to Moderate	Medium Risk	

Notes/References:
1 Probability (in terms of % AEP) (Refer Appendix L of RPS, Table 20)
2 Consequences (Refer Appendix L of RPS, Table 21)
3 Overall risk rating (Refer to Risk Screening Matrix, page 374 of RPS)
Risk assessment completed in accordance with Appendix L of BOPRC Operative Regional Policy Statement

Table 12. Coastal and Harbour Erosion

Natural Hazard	Probability (% AEP)[1]	Consequences[2]					Overall risk rating (AEP vs. consequence)[3]	Qualitative Consideration
		Social / Cultural Buildings	Buildings	Buildings Critical	Lifelines Utilities	Health and Safety		
Coastal Erosion – Current Day	1 (1-in-100-year event)	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Low Risk	• All campsites/locations (cabins, tents, caravans etc) are considered "Buildings" under Table 21 of Appendix L in this assessment. • Assessments assume a full capacity/occupancy of the site to account for 'worst case' consequences (8,000 guests during high peak summer with little to no advanced warning, if applicable). • Water, storm water and wastewater underground services are present within the low-lying northern areas. These could be damaged in Year 2080 and 2130 scenarios.
Coastal Erosion – Year 2080 0.4 m SLR		Insignificant	Minor	Insignificant	Minor	Insignificant	Low Risk	
Coastal Erosion – Year 2130 1.05 m SLR		Insignificant	Moderate to Major	Insignificant	Major	Minor	Medium Risk	

Notes/References:
1 Probability (in terms of % AEP) (Refer Appendix L of RPS, Table 20)
2 Consequences (Refer Appendix L of RPS, Table 21)
3 Overall risk rating (Refer to Risk Screening Matrix, page 374 of RPS)
Risk assessment completed in accordance with Appendix L of BOPRC Operative Regional Policy Statement

Table 13. Extreme Rainfall – Flooding and Overland Flow

Natural Hazard/ Scenario	Probability (% AEP)[1]	Consequences[2]					Overall risk rating (AEP vs. consequence)[3]	Qualitative Consideration
		Social / Cultural Buildings	Buildings	Buildings Critical	Lifelines Utilities	Health and Safety		
Flooding and Overland Flow – Year 2130	1 (1-in-100-year flood event)	Insignificant	Major	Insignificant	Insignificant	Minor	Medium Risk	• All campsites/locations (cabins, tents, caravans etc) are considered "Buildings" under Table 21 of Appendix L in this assessment. • Assessments assume a full capacity/occupancy of the site to account for 'worst case' consequences (8,000 guests during high peak summer with little to no advanced warning, if applicable).
Flooding – Pre-2020 TCC (superseded by above)		Insignificant	Moderate	Insignificant	Insignificant	Minor	Medium Risk	

Notes/References:
1 Probability (in terms of % AEP) (Refer Appendix L of RPS, Table 20)
2 Consequences (Refer Appendix L of RPS, Table 21)
3 Overall risk rating (Refer to Risk Screening Matrix, page 374 of RPS)
Risk assessment completed in accordance with Appendix L of BOPRC Operative Regional Policy Statement

Table 14. Landslide and Rockfall

Natural Hazard/ Scenario	Probability (% AEP)[1]	Consequences[2]					Overall risk rating (AEP vs. consequence)[3]	Qualitative Consideration
		Social / Cultural Buildings	Buildings	Buildings Critical	Lifelines Utilities	Health and Safety		
Landslide and Rockfall	1 (assumed 1-in-100) for 2.5H:1V slope runout	Insignificant	Minor	Insignificant	Insignificant	Minor	Low Risk	• All campsites/locations (cabins, tents, caravans etc) are considered "Buildings" under Table 21 of Appendix L in this assessment. • Assessments assume a full capacity/occupancy of the site to account for 'worst case' consequences (8,000 guests during high peak summer with little to no advanced warning, if applicable). • Limited data shows rockfall impact to the site in modern times. • 2.5H:1V slope runout is primarily assigned to rainfall hazard and is given a 1% AEP in accordance with Table 20 of Appendix L. • 4H:1V runout is primarily assigned to seismic triggers however could also be indicative of a large failure caused by very severe weather and/or cyclones. This is given a 0.1% AEP in accordance with Appendix L.
	0.1 (assumed 1-in-1000) for 4H:1V slope runout	Insignificant	Moderate	Insignificant	Minor	Moderate	Medium Risk	

Notes/References:
1 Probability (in terms of % AEP) (Refer Appendix L of RPS, Table 20)
2 Consequences (Refer Appendix L of RPS, Table 21)
3 Overall risk rating (Refer to Risk Screening Matrix, page 374 of RPS)
Risk assessment completed in accordance with Appendix L of BOPRC Operative Regional Policy Statement

5.4 Summary of Risk Assessments

Taking into account risk treatment, analysis and evaluation, the overall natural hazard risk for the site in its current state is presented in Table 15.

Table 15. Risk rating for natural hazards. Where data is available, risk assessments for multiple sea level rise and climate scenarios are included (e.g., Current day, Year 2080, Year 2130).

NATURAL HAZARD (*LIKELIHOODS USED - TABLE 20 IN RPS APPENDIX L*)	OVERALL RISK RATING[1] (AEP[2] VS. CONSEQUENCE[3])		
	Current Day (or 2030)	2070/2080	2130
Liquefaction *('Initial' likelihood AEP used)*	Low Risk	N/A	Medium Risk
Tsunami *('Initial' likelihood AEP used)*	High Risk	N/A	N/A
Coastal and Harbour Inundation *('Initial' likelihood AEP used)*	Low Risk	Medium Risk	Medium Risk
Coastal and Harbour Erosion *('Initial' likelihood AEP used)*	Low Risk	Low Risk	Medium Risk
Flooding *('Initial' likelihood AEP used)*	Medium Risk	N/A	Medium Risk
Landslides and rockfall *('Initial' rainfall-induced likelihood AEP and 'initial' seismic-induced likelihood used)*	Low Risk (*for more frequent, smaller events*) Medium Risk (*for less frequent, larger events*)	N/A	N/A
1 Risk rating (refer to Risk Screening Matrix, page 374 of RPS) *2 Probability (refer to Appendix L of RPS, Table 20)* *3 Consequences (refer to Appendix L of RPS, Table 21,)*			

5.5 Hazard Control Suggestions

Appendix M of the BOPRC RPS contains a list of hazard risk reduction measures[13]. Those that are relevant to the site are included below and may involve:

- Replacement or modification of existing development over time to reduce potential consequences.
- Promoting the use of natural defences against coastal hazards and discouraging hard protection structures.
- Providing only for low intensity activities in specific locations

[13] *https://atlas.boprc.govt.nz/api/v1/edms/document/A4439707/content*

- Restoration, retention or enhancement of natural defences against natural hazards (e.g. dunes) as part of development proposals and promotion of the sustainable functioning of such natural defences to reduce the risk to existing development
- Ensuring that new development anticipates possible hazard event emergencies and provides means to enable effective responses by people and communities including requiring:
  (i) Hazard warning systems; and/or
  (ii) Urban form and transport infrastructure (including for motor vehicles, cycles and pedestrians) that enables rapid and efficient evacuation; and/or
  (iii) Provision for, and safeguarding of, safe and accessible evacuation routes and zones (including, where appropriate, vertical evacuation zones).

A summary of suggested controls that would help reduce the likely consequential effects of a hazard occurring within the site is provided in Table 16 below.

Table 16. Suggested controls for reducing natural hazard risk.

NATURAL HAZARD	SUGGESTED CONTROLS
General Considerations	- Consider in-depth risk assessments for natural hazards where onsite risk to calculated as Medium and High. - Consider undertaking further study to calculate spatiotemporal exposure to natural hazards with the aim of limiting exposure for population groups that spend extended time within the site. E.g., long-term residents, staff and/or permanent staff. - Ensure the site has clear and robust emergency management plan and procedures where warning/alerts, evacuation and exclusion zones are established and clearly communicated to every user of the facilities. - Staff should be well-versed on the hazards and be capable of evacuating users should the need arise. - Consideration should be given to overseas visitors where English is not their first language. - A clear and easy to read (visual) pamphlet (or similar) outlining the dynamic natural environment in which the Park is situated and what to do in an emergency.
Liquefaction	- Determine if buildings onsite are built in accordance with modern standards. If not, then consider updates to bring to code. - Conduct geotechnical testing for site-specific qualitative assessment of the dune sands susceptibility to liquefaction. - Any future developments should consider predicted sea level and associated groundwater rise.
Tsunami	- Little can be done to mitigate the effects of such an extreme event. A robust emergency plan and evacuation procedure is necessary. If not already in place, then this should be established. - Tsunami hazard on the BOPRC maps show the raised terrace as outside of the evacuation zone. This area is included in evacuation zone for the TCC maps and should not be considered safe. - The site should consider conducting an evacuation drill and making sure all signage is clear and easily understood.

NATURAL HAZARD	SUGGESTED CONTROLS
Coastal and Harbour Inundation	- The northern low-lying campground is very prone to flooding and inundation. - Engineering solutions could help to mitigate the effects of inundation (such as improving drainage or constructing barriers). - Alternatively, reconsider the use of this area (e.g., restrict camping in this area during certain times of year of during storm/tide warnings). - When there are warnings of large storm events, consideration should be given to evacuating these low-lying areas until the threat from storm surges has passed.
Coastal and Harbour Erosion	- Hazard maps show that long-term viability of the low-lying north campground could be in question. - An engineering and/or environmental solution to resist erosion could be explored (this would also be tied in with the future of the Main Beach). Future land use of the area would need to be considered in the long-term (e.g., remove campsites and have picnic area).
Flooding	- The northern low-lying campgrounds are the most significant issue. - Consider raising the area or engineering a barrier. - The basin-shaped nature of the area results in poor drainage. - Removing the inundation hazard in this location would drop the risk to Low for 2080 and 2130 scenarios.
Landslides and rockfall	- Consider a site-specific, quantitative assessment of slope hazard and rockfall for the site to obtain accurate data for risk assessment e.g. using the AGS Landslide Risk Assessment or Waka Kotahi's Z/44 Risk Management Practice Guide. - Develop a Trigger Action Response Plan (TARP) for the site, with establishment of slope hazard alert/warning thresholds. Thresholds may be based on the severity of landslide triggers (e.g., forecast rainfall). - Engineering solutions may include passive protection structures (e.g., barriers or catch fences, retaining structures. - Consider land use within the 2.5H:1V runout hazard zone. Campsites and cabins immediately adjacent to the toe of a slope or within the path of a historic landslide could be moved. During heavy rainfall these areas could be evacuated or excluded. - Boulders on the slopes could be examined in detail for those that show stability concerns and be removed. - Regular monitoring of the slopes i.e. once per year should be undertaken to identify any potential slope movement and to build up an inventory for the site. This may allow for proactive management of potential landslides. - Report any changes, such as increased water seepages or water not flowing from the spring, tension cracks, movement or bulges to a geo-professional for further assessment. - Keep retaining walls maintained to ensure adequate protection.

6 Conclusions

WSP was engaged to undertake a NHRA of the Mount Maunganui Beachside Holiday Park located on Adams Avenue at the base of Mauao Maunga, Mt Maunganui. The assessment considers the site in its current state as no proposed developments have been put forth.

A NHRA was undertaken for the site in general accordance with the BOPRC RPS and natural hazard risk management policy framework; including identifying the risk, a qualitative risk analysis and evaluation, and suggested hazard risk reduction control measures.

The natural hazards outlined in the BOPRC RPS were assessed for the site, with the following hazards considered most relevant to the site and evaluated further using a risk methodology framework based on Appendix L of the RPS:

- Liquefaction.
- Tsunami.
- Coastal and Harbour Inundation
- Coastal and Harbour Erosion
- Flooding
- Landslides and rockfall

The risk assessments provided a risk rating for the site for each of the natural hazards:

- High Risk: Tsunami
- Medium Risk: Flooding (for all sea level rise scenarios)
- Low Risk: Landslides and rockfall (Medium Risk for 0.1% AEP event).
- Low Risk: Coastal and harbour inundation (Medium Risk for year 2080 and 2130 scenarios)
- Low Risk: Coastal and harbour erosion (Medium Risk for year 2130 scenario)
- Low Risk: Liquefaction

A summary of suggested controls, which is by no means exhaustive, has been provided in Table 16. It also outlines factors that TCC should consider when future planning at the Holiday Park due to impact of climate change. It should be noted that the risk level may not be able to be reduced from one level to another (i.e. high to medium) but the implementation of controls can minimise the consequences of the hazard.

We recommend that TCC consider implementing some of these controls to ensure the future resilience of the Mount Holiday Park and to minimise the hazard consequences and risk to both Council and the community.

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Appendix A
Hazard Maps

Appendix A - Figure 1a. Liquefaction Vulnerability

Liquefaction Vulnerability

Possible

Low

Holiday Park Boundary

Contour 1m

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		SHEET Mount Maunganui Beachside Holiday Park Natural Hazard Assessment Liquefaction Vulnerability	
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Appendix A. Figure 1b. Liquefaction Ground Damage Current Climate

500-year (Groundwater Current Median) Liquefaction
- None to Minor
- Minor to Moderate

Holiday Park Boundary

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SHEET
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Natural Hazard Assessment
Liquefaction-induced ground damage - 500 year current climate

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Appendix A. Figure 1c. Liquefaction Ground Damage 2130 Climate

500-year (Groundwater Future Climate) Liquefaction
- None to Minor
- Minor to Moderate
- Moderate to Severe

Holiday Park Boundary
Contour 1m

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Appendix A. Figure 2. Tsunami Flood Depth

Max Tsunami Flood Depth at 9m
- Above 2 m
- 1 - 2 m
- 0.5 - 1 m
- 0.25 - 0.5 m
- 0.1 - 0.25 m

Holiday Park Boundary
Contour 1m

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Natural Hazard Assessment
Maximum Tsunami Inundation (MCE)

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Appendix A. Figure 3a. Coastal Inundation Current Climate

Coastal Inundation, Year 2030, 1% AEP
- 0.1 - 0.25 m
- 0.25 - 0.5 m
- 0.5 - 1 m
- Above 1m

Holiday Park Boundary

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Inundation from the open coast - Year 2030, 1% AEP

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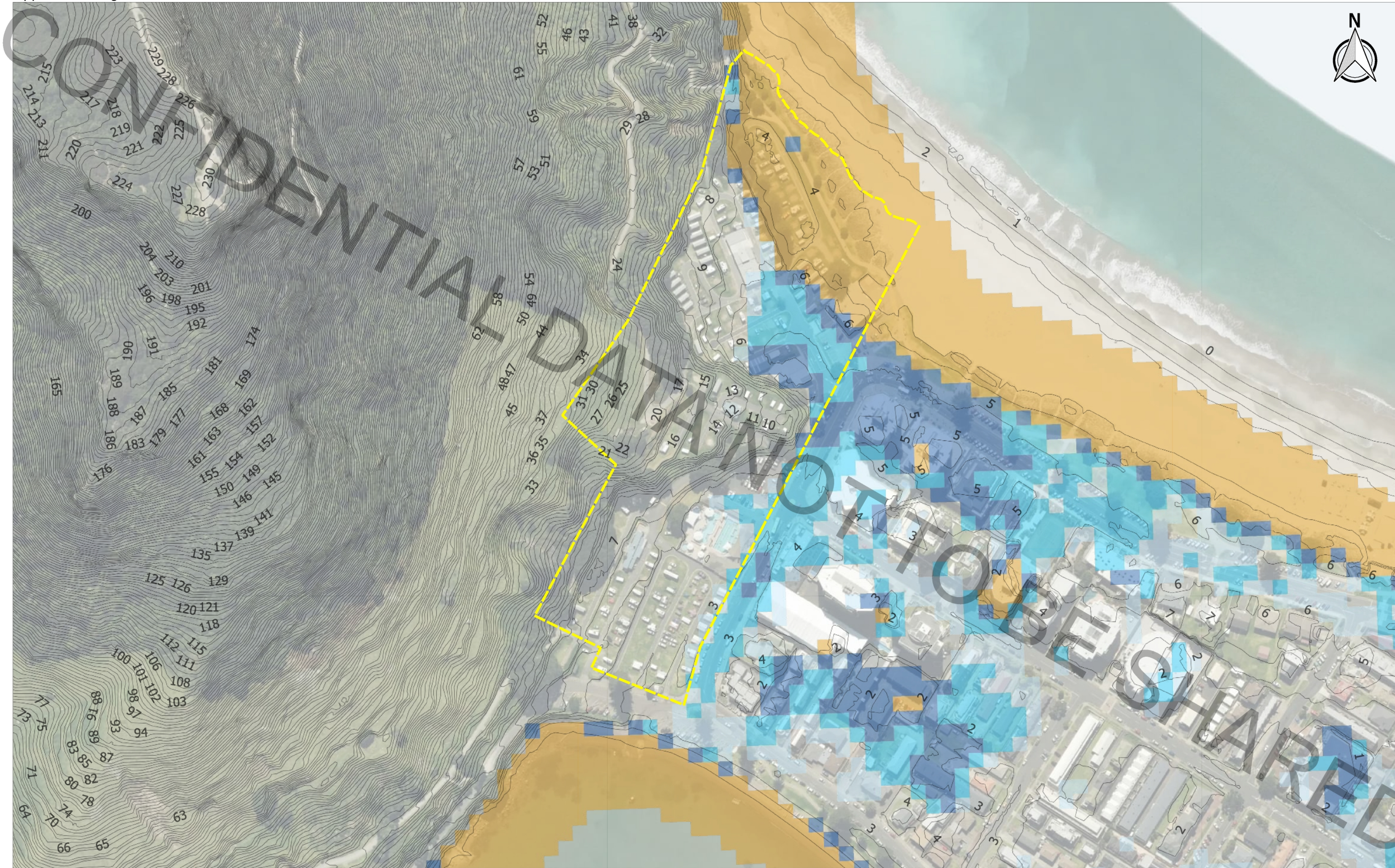
Appendix A. Figure 3b. Coastal Inundation 2080 Climate



Coastal Inundation, Year 2080, Sea Level Rise 0.4m, 1% AEP

- 0.1 - 0.25 m
- 0.25 - 0.5 m
- 0.5 - 1 m
- Above 1m
- Holiday Park Boundary
- Contour 1m

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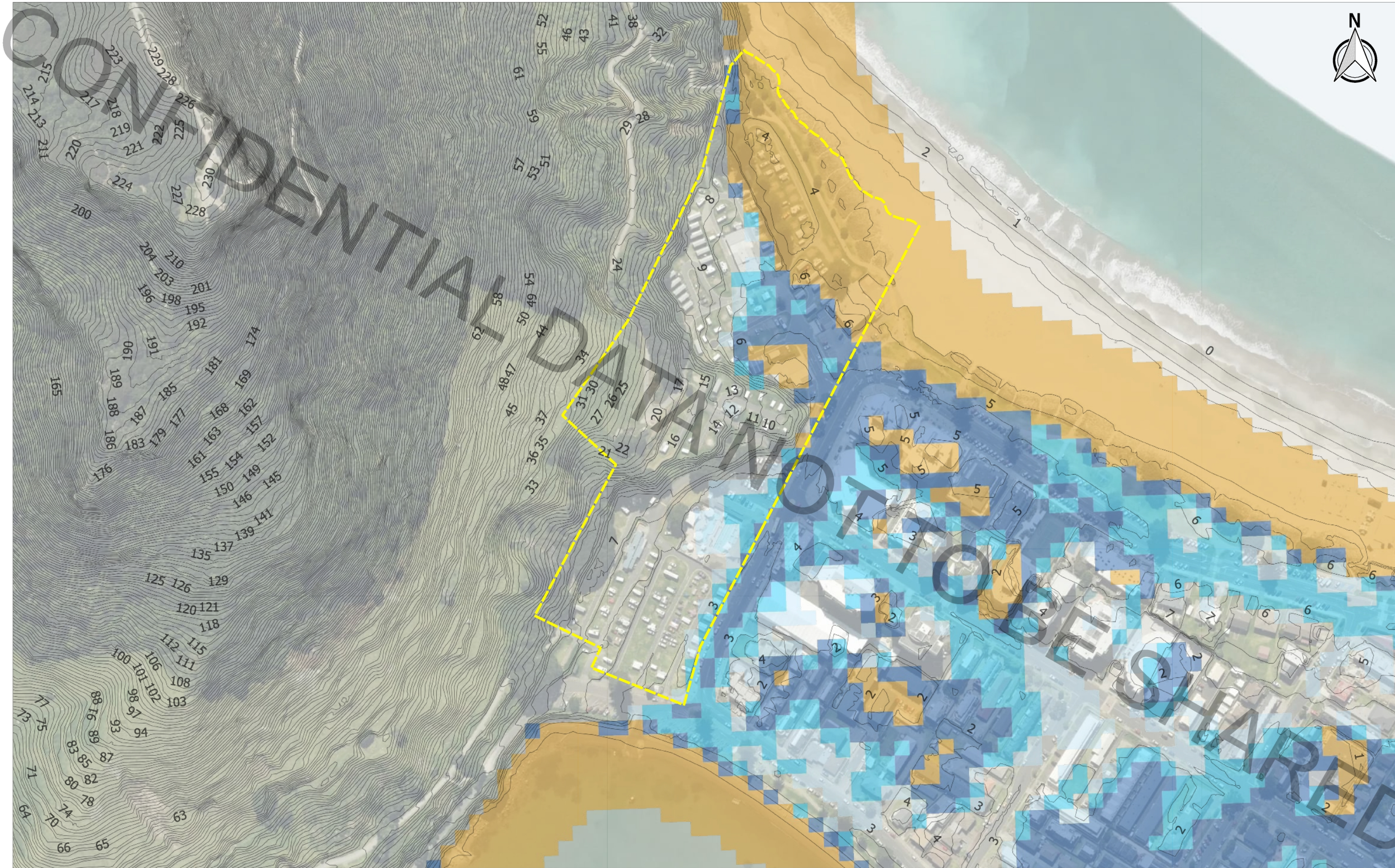
Appendix A. Figure 3c. Coastal Inundation 2130 Climate



Coastal Inundation, Year 2130, Sea Level Rise 1.05m, 1% AEP

- 0.1 - 0.25 m
- 0.25 - 0.5 m
- 0.5 - 1 m
- Above 1m

Holiday Park Boundary

Contour 1m

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Appendix A. Figure 4a. Coastal Erosion Current Climate

Coastal Erosion - Current Day
- 2030 - SLR 0m - extremely unlikely
- 2030 - SLR 0m - likely

Holiday Park Boundary
Contour 1m

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Natural Hazard Assessment
Current Day Coastal Erosion

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Appendix A. Figure 4b. Coastal Erosion 2080 Climate

Coastal Erosion - 2080
2080 - SLR 0.4m - extremely unlikely (RCP 8.5)
2080 - SLR 0.4m - likely (RCP 8.5)
Holiday Park Boundary
Contour 1m

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2080 Coastal Erosion

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Appendix A. Figure 4c. Coastal Erosion 2130 Climate

Coastal Erosion - 2130
2130 - SLR 1.05m - extremely unlikely (RCP 8.5)
Holiday Park Boundary
Contour 1m

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Appendix A. Figure 5a. Flooding from Rainfall 2130 Climate

Overland flow path
- Major
- Minor

Flood prone area
- Depth >300mm
- Depth 100-300mm

Flood plain
- Flood plain

Holiday Park Boundary

Contour 1m

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		SHEET		
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Appendix A. Figure 5b. Flooding from Rainfall (Pre-2020 data)

Flooding from rainfall (1%AEP, pre-2020, Superseded)
- 0.1 to 0.25
- 0.1 to 0.5
- 0.25 to 0.5
- 0.5 to 1.00
- Above 1m

- Holiday Park Boundary
- Contour 1m

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SHEET	Mount Maunganui Beachside Holiday Park Natural Hazard Assessment Flooding from rainfall
PROJECT NUMBER	2-9B577.00
REVISION DATE	29/11/2023
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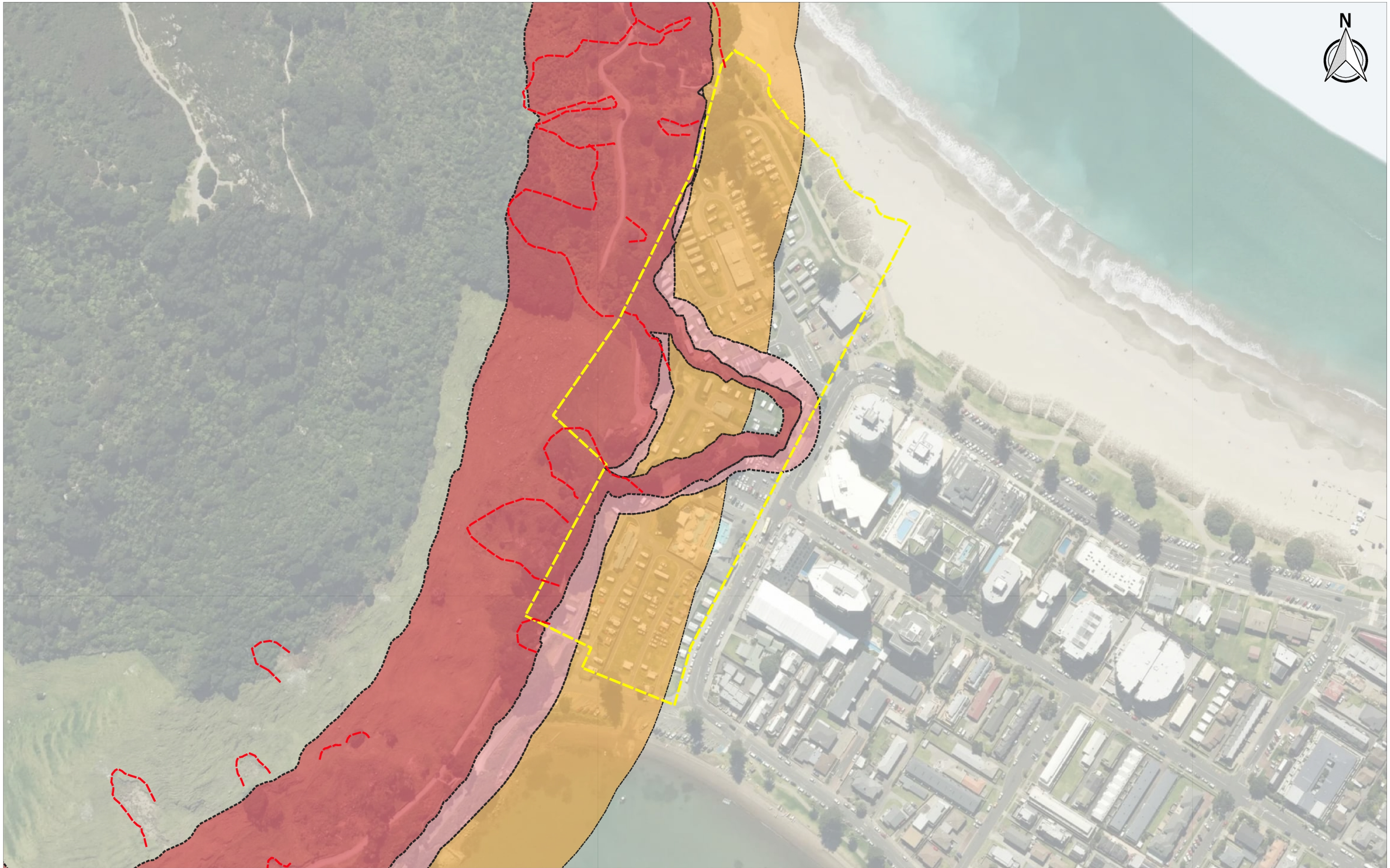
Appendix A. Figure 6. Slope Failure Zones



- Geomorphological Lines
- Area Susceptible to Landslide
- 1:2.5 Slope Runout Zone
- 1:4 Slope Runout Zone
- Holiday Park Boundary

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SCALE: 1:3,000

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Mount Maunganui Holiday Park

SHEET
Mount Maunganui Beachside Holiday Park
Natural Hazard Assessment
Slope Failure Zones

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REVISION DATE: 29/11/2023
REVISION: R0

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Appendix B
Site Photographs

Figure 1. Low-lying north campground.

Figure 2. Low-lying north campground.

Figure 3. Northen campground and raised terrace in background.

Figure 4. View of Northern campground from base track above.

Figure 5. Rock bluffs and slopes above site.

Figure 6. Example of soils exposed in lower Mauao flanks above the site.


Figure 7. Southern campground.


Figure 8. Southern Campground looking towards Pilot Bay.


Figure 9. Steep slopes of raised terrace. View from southern campground.


Figure 10. Eroded, exposed soils in steep banks of raised terrace.


Figure 11. Steep banks of raised terrace.


Figure 12. Steep banks of raised terrace.

Figure 13. Steep banks. View into northern campground below.

Figure 14. Landslide 1 looking upslope from base track stairs.

Figure 15. Landslide 2 looking upslope. Outcrop represents former scarp face.

Figure 16. Landslide 3 head scarp.

Figure 17. Landslide 3 view downslope

Figure 18. landslide 4 toe next to timber retaining wall.

Figure 19. Landslide 4 looking upslope.

Figure 20. Landslide 5 looking downslope from base track. Vegetation hides the very steep slope profile.

Figure 21. Landslide 6 toe from southern campground.

Figure 22. Tension crack formed in January 2023.

Figure 23. Landslide 6 scarp.

Figure 24. Landslide 7. Area within debris pile (above skip location) shows some minor tension cracking.


Figure 25. Landslide 8 (vegetated area). Spring down the centre of axis at toe.


Figure 26. Boulder field. View from central terrace area.


Figure 27. Example of boulder vulnerable to dislodgement.


Figure 28. Example of boulder vulnerable to dislodgement.


Figure 29. Retaining wall at base of Landslide 5.


Figure 30. Gabion wall at base of Landslide 7.

Figure 31. Damage to metal wires in gabion wall.

Figure 32. Damage to masonry wall in northern campground.

Figure 37. Crib wall within northern campground.

Figure 38. Voids and piping structures within crib wall.

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