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Coastal Erosion Hazard Assessment:
108-114 Turangi Road Lower,
North Taranaki

A report for LandPro (New Plymouth) as part of a resource consent application to build on this property

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1.0 INTRODUCTION

This erosion hazard assessment (EHA) report was requested by LandPro (New Plymouth). The report is to accompany the Client's resource consent application to build a dwelling at 109-114 Turangi Road Lower (marked in Figure 1). It is proposed to subdivide this property into 3 Lots (marked) with the proposed building to go on Lot 1. However, his hazard assessment applies to the entire property which will also be referred to as "the site".

The site is located on flat ground some 300 m to 500 m landward of a headland and fronted by a 25 to 27 m high cliff, narrow sand-gravel beach an extensive intertidal rock platform and reef system depicted in Figure 1.

The present assessment report was commissioned as the proposed building site is in the NPDC (2019) Proposed District Plan's (PDP) Coastal Environment Overlay Area and also close to the PDP's Coastal Erosion Hazard Overlay Area. In particular, the PDP states:

1) *The Coastal Erosion Hazard Overlay Area, applies to areas considered likely to be at risk of erosion over a 100 year timeframe, based on historic rates of both sea level rise and shoreline change;*
2) *The Coastal Environment Overlay Area, applies to areas where there is a potential risk of erosion over a 100 year timeframe, acknowledging that accelerated sea level rise resulting from worst-case global emission scenarios may occur.*

These two areas were identified from the T&T (2019) District-Wide Erosion Hazard Assessment report where their "Area Susceptible to Coastal Erosion #1 ($ASCE_{1)}$" is used to define the "Coastal Erosion Hazard Area" in the NPDP 2019 PDP. And the T&T (2019) "$ASCE_2$_RCP8.5H^+" is used to define the "Coastal Environment Area" in the PDP. The terms of reference are as follows:

-The EHA is to be based on conditions at, and in the vicinity of, the site, i.e. a site-specific assessment is required;
-The local geomorphology is be assessed as pertains to an EHA;
-A shoreline-change analysis is to be carried out based on historical information;
-A slope stability analysis is to be carried out using current topographic survey data;
-The erosive impact of predicted climate change is to be incorporated;
-The assessment is to be carried out for a 100 year prediction or planning period;
-The investigation is to follow the official guidance and directives contained in NZCPS (2010), IPCC (2014), DOC (2017) and MFE (2008 and 2017), and
-the assessment is to enable comparison with the NPDC Proposed District Plan

Section 2 describes the site in terms of its geomorphology including shoreline change. Section 3 describes the erosion hazard model and derives values for its components. Section 4 presents results for the current (2021) erosion hazard and the 100 year (2121) hazard, and Section 5 sets out conclusions as pertain to the resource consent application.

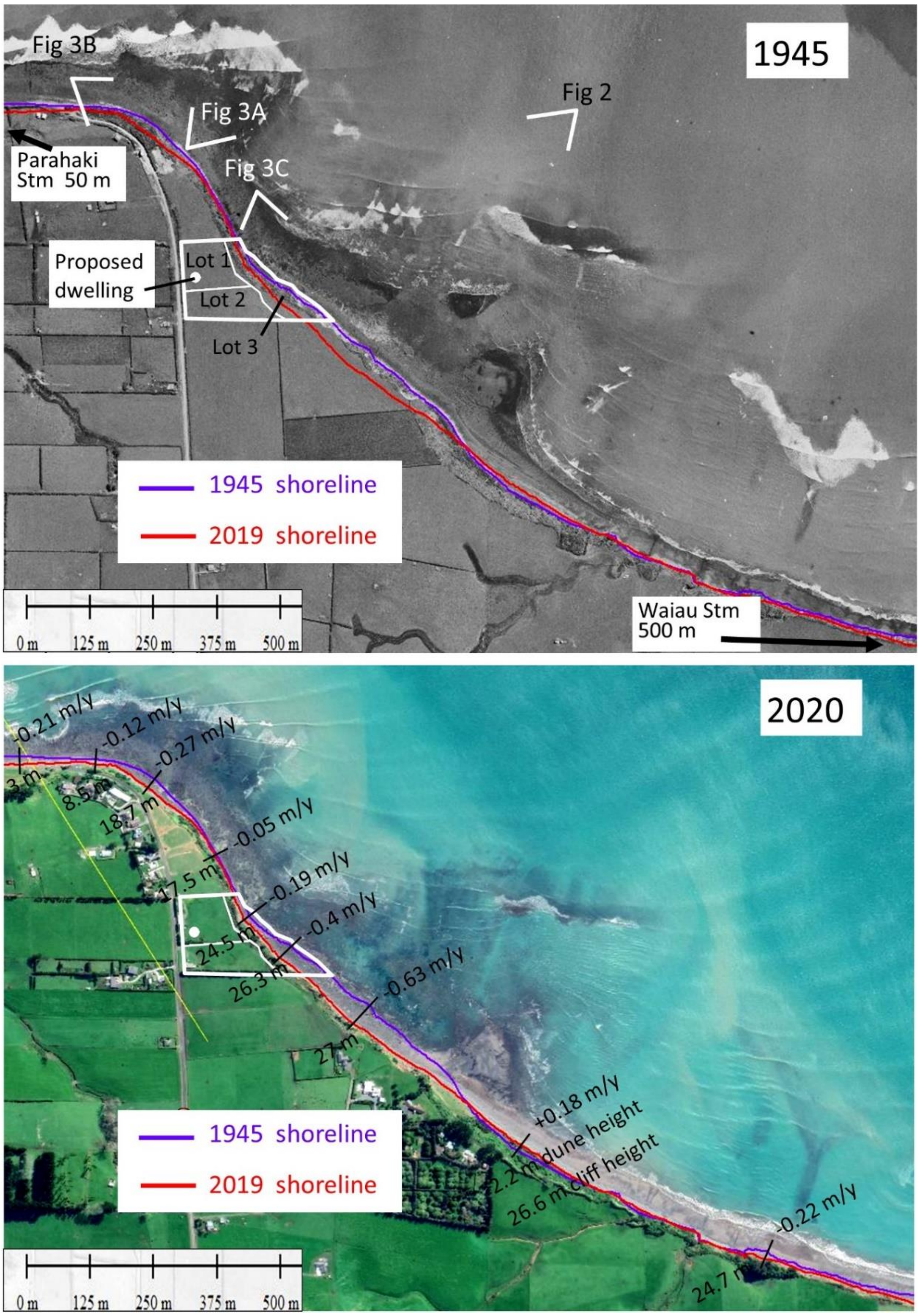

Figure 1 Location of the erosion hazard assessment site (thick white boundary with proposed subdivision lines for 3 separate Lots, and the proposed building (infilled white circle), within the wider environment. The 1945 (upper aerial photo) and 2020 (lower satellite image) show intertidal platform and outer reef locations indicated by dark areas and/or breaking waves. Shorelines (cliff base or dune toe) have been superimposed to illustrate longer-term change with rates (negative = erosion, positive = accretion) and cliff heights (above this shoreline) also marked at relevant locations. Figures 2 and 3 photo locations and orientations have also been marked. Base image sources: 1945 NZAM archive via the LINZ scanning project. and 2020 Google Earth.

2.0 GEOMORPHOLOGICAL ASSESSMENT

This section is based on the following information sources: De Jardine (1992); Duff (1993); Alloway et al. (2005); Miller (2009); T&T (2019); an area-inspection on 26 March 2021; historical survey plans (1885, 1917, 1920); historical aerial photography by NZ Aerial Mapping acquired from LINZ; satellite images from Google Earth and the most recent high resolution aerial photography (2019) from LandPro Ltd. These image sets and their use for detecting and quantifying the shoreline and its behaviour are described further in Section 3.3 on Historical Shoreline Change. Rates of shoreline change were obtained from the 1945 and 2019 data. LIDAR (high resolution 3D aerial data) was also captured during the 2019 aerial survey and is the basis for much of the following quantitative description of the environment.

The site and its setting within the wider environment was depicted in Figure 1 and this enables comparison between the 1945 and 2019 aerial images. About 2 km of coastline is shown in Figure 1, from just east of the Parahaki Stream on the Motunui coast to some 500 m west of the Waiau Stream in the bay, which has also been referred to at times as Buchans Bay.

Of particular significance for the site is its location in the vicinity of the transition between the “laha coast” dominated by volcanic materials and processes, and the “papa coast” to the east - dominated by uplifted marine sediments (mudstone/siltstone). The geological division is the Waiau Stream, so the site lies within the laha Coast.

The area comprises the most recent Taranaki lahas: the Okiawa Formation (105,000 years old) which lies upon the older Motunui Formation (127 to 210,000 years old). Both are debris avalanches (resulting from a catastrophic collapse of the crater side) composed of blocks in a matrix of fine cementing material, and are about 4 m thick. The lower Motunui Formation is unstratified and appears to be more resistant to erosion than the higher Okiawa Formation which has a higher clay content. The Okiawa Formation is overlain by “cover beds” of terrestrial origin such as tephra and ancient dune sand which forms a flat surface at the site with a slight seaward slope.

These laha extend over 5 km seaward and form the reefs and shore platforms within the inter-tidal and subtidal region; these are inferred in Figure 1 by breaking waves or darkened areas. Despite these laha being much less resistant than the older laha about and south of New Plymouth, the boulders and other rock fragments (clasts) are well cemented (Figure 2A) making the platform/reef surface resistant to waves and current action. As waves propagate across the reefs and platforms, energy at the shoreline is reduced and hence their potential for inducing shoreline erosion is also lessened. The observed variation in the width and shape of the platform/reef will therefore influence shoreline behaviour. Shoreline erosion rates and cliff heights are marked in Figure 1.

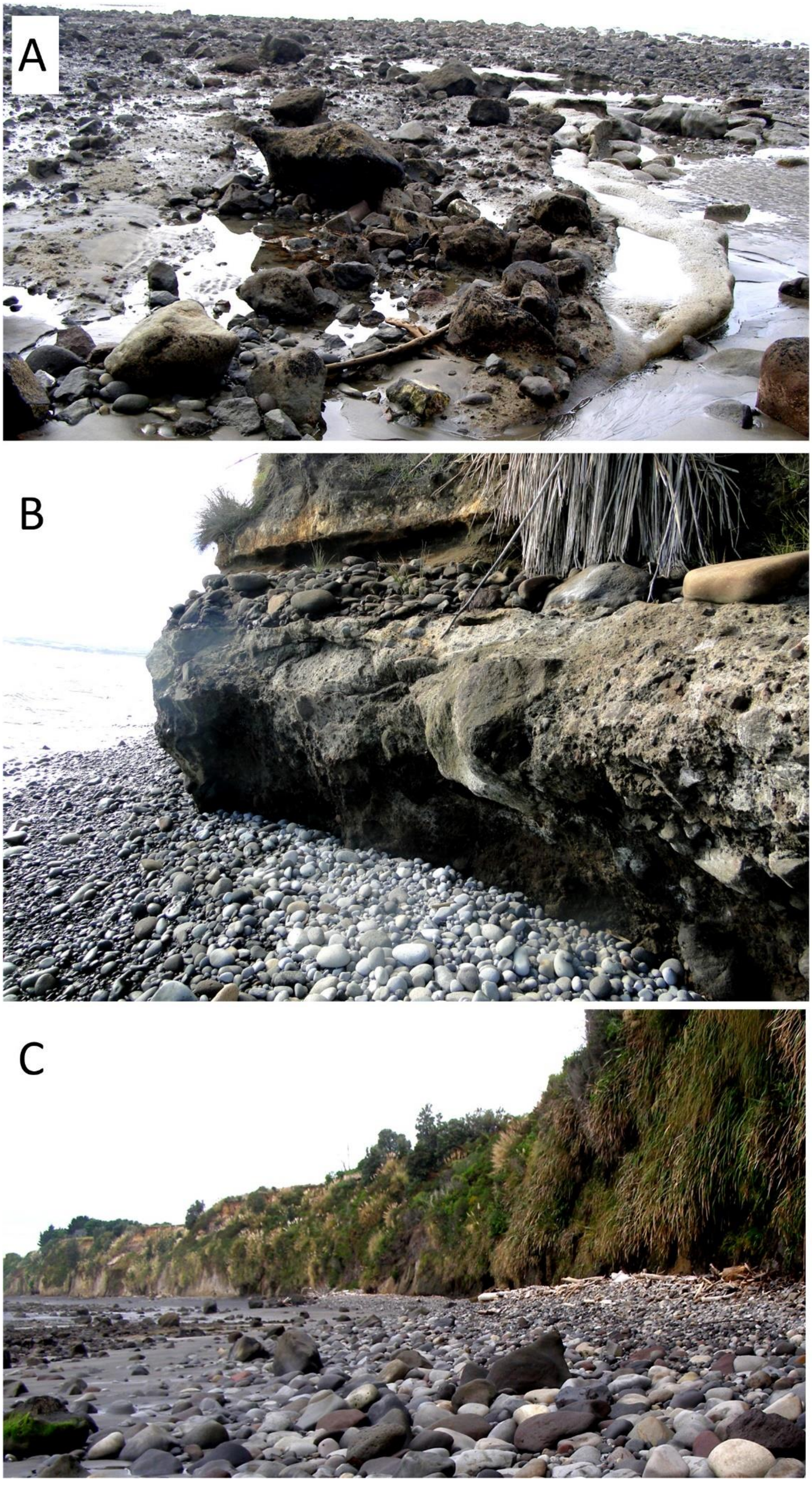

Figure 2 Upper photo (A) shows intertidal platform comprising laharic material—rock clasts embedded within a clay matrix and provides a resistant surface to oceanic forcing. Middle photo (B) shows particularly resistant conglomerate rock within the Motunui Formtion fronting the headland, and the lower photo (C) shows gravels deposited against the cliff base capable of providing local protection against wave and current action. Sand intersects the cliff base in the distance and erosion scars on the adjacent cliff face are evident.

It is evident that there is considerable contrast in cliff topography in the vicinity of the site with lower cliff height and erosion rates (Figure 1) on the headland (8.4 m and -0.12 m/yr) which, in addition to the platform and offshore reef configurations, may relate to a deposit of particularly resistant conglomerate rock (see Figure 2B). Higher cliffs and erosion rate extends some 500 m southeast of the site (27 m and up to -0.63 m/yr) and this corresponds to a gap in the reef system (B in Figure 3) where the predominant wave approach can more easily propagate landward. Lack of vegetation shows this section of cliff is particularly unstable. By comparison, immediately northwest of the site the shoreline is relatively stable at -0.05 m/yr and has near complete vegetation cover (see Figure 3). The cliffs fronting the site are thus is a transition area with height and rates increasing toward the southeast end and decreasing toward the northwest end.

Further contrast occurs 500 m to 1000 m southeast of the site with sand dune replacing cliff and an accretion rate of +0.18 m/yr (Figure 3). From Figures 1 and 3 it can be seen that an extensive platform/reef system fronts this area thus reducing shoreline wave energy and current strength and facilitating deposition and shoreline accretion. Yet further east (in Figure 1 and beyond), cliff erosion again characterizes the shoreline and east of the Waiau Stream the lack of seaward reef fronting the papa coast allows for higher erosion rates. Indeed, the T&T (2019) district-wide erosion hazard assessment adopted a representative conservative erosion rate of 0.44 m/yr for the laha coast compared with 0.65 m/yr for the papa coast to the east.

However, in the shorter term, the erosion pattern may be moderated by variation in littoral drift; i.e. sand and gravel moving west to east under the predominant wave and wind reqime. This drift in the order of 110 and 173 m^3/yr at New Plymouth. Evidence from the Waitara rivermouth suggests eastward littoral sediment transport occurs in discrete “slugs’ generated by river dynamics. Such pulses could moderate the platform/reef effects by enhancing or subduing shoreline erosion potential in the shorter term. Indeed, accumulations of gravels were observed in places on the reef (Figure 3) and also in places against the cliff base (Figure 2C) – both of which could provide for localized and temporary shoreline protection, or enhanced erosion where absent.

This assessment suggests the cliff fronting the central and northwestern end of the site most of the site is undergoing relatively slow erosion resulting from its location relative to the rock platform and reefs. While the cliff toward the southern end of the site has increasing erosion rates, the configuration of the property’s southern boundary means that this has little effect on the hazard rating (see the transect orientation in Figure 5). While shoreline behaviour may vary in the shorter-term in response to littoral sediment input and dynamics, the identified rates are likely to persist in the longer-term.

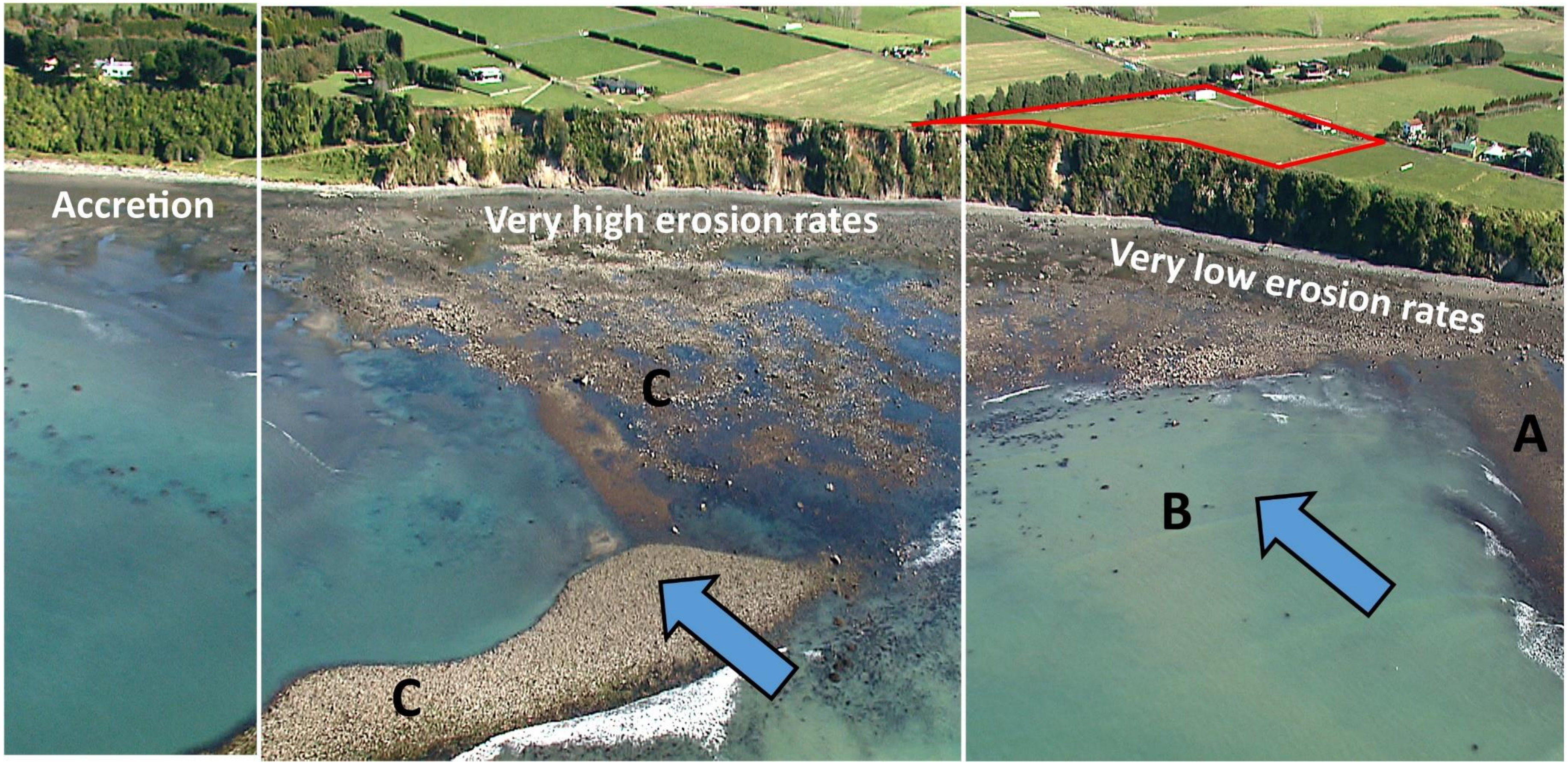

Figure 3 Shoreline variation and behaviour relative to the property (red boundary) and seaward inter-tidal rock platform and reefs. Arrows indicate predominant direction of wave propagation. Platform/reef at (A) protects the marked very low erosion shoreline, lack of reef at (B) exposes the very high erosion rate shoreline, and platform/reef at (C) protects the marked accretionary shoreline.

3.0 EROSION HAZARD ASSESSMENT COMPONENTS

3.1 Background

An erosion hazard assessment involves computing three components: (1) slope stability retreat, (2) long-term historical shoreline retreat, and (3) erosion from projected future sea-level rise. These components are described below and are combined to generate the following erosion hazard distances (EHDs) defined by equations 1 to 3: the current hazard, EHD_Current; the future hazard, EHD_Future1 that includes a continuance of long-term erosion but no additional sea-level rise, and the future hazard, EHD_Future 2 that includes additional effects of sea-level rise (SLR) from predicted climate change – for which there are several scenarios of increasing severity.

$$EHD\_Current = SS \quad \text{eq 1}$$

$$EHD\_Future1 = SS + LT \quad \text{eq 2}$$

$$EHD\_Future2 = SS + LT + RSLR \quad \text{eq 3}$$

Where:
EHD = **E**rosion **H**azard **D**istance inland from the current shoreline (cliff-base in this case);
SS = **S**table **S**lope retreat distance;
LT = **L**ong-**T**erm shoreline erosion distance;
RSLR= **R**etreat caused by **S**ea-**L**evel **R**ise.

The NPDC (2019) PDP Erosion Hazard and Coastal Environment policy is written in terms of the T&T (2019) Areas Susceptible to Coastal Erosion (ASCE), and directly relate to the hazard distances defined above in that they (equations 1 to 3) define the landward margin of these areas. So the landward margin of the T&T (2019) Current_ASCE is as computed using equation 1 above for EHD_Current. And likewise T&T's Future_ASCE1 (NPDC (2019) Proposed District Plan's Coastal Erosion Hazard Area) is as computed using equation 2 for EHD_Future1, and T&Ts Future_ASCE2 (NPDC's Coastal Environment Area) is as computed using equation 3 for EHD_Future2.

LT and RSLR are time-dependent and computed by multiplying the time period of interest by the annual rate of change for each parameter.

NPDC (2019) refers to the Coastal Erosion Hazard Area as an area <u>likely</u> to be at risk of erosion, while the Coastal Environment Area as an area <u>potentially</u> at risk of erosion. Likely is defined in MFE (2008) as having a 66 to 90% probability of occurrence. The term "potential erosion" is interpreted by hazard practitioners as being "very unlikely" (Shand et al., 2015), and this has a probability of occurrence of 5 % (MFE, 2008). Probabilities less than 1% are defined as “exceptionally unlikely” and approaching “worst case” situations.

Where a computation consists of multiple components such as in equations 2 and 3 above, the derivation of a final probability of occurrence is not straightforward. Each component may have its own likelihood range for a section of coast. A “probabilistic” computation routine is required to determine the actual combined probability of the output (EHD) hazard distance and such procedures are described in Shand et al. (2015). However, as the probabilistic approach involves more time and expense, in the first instance, where ranges of values is available for parameters, high-end values are selected thus ensuring the combination exceeds a likely or even a potential likelihood of occurrence. If the proposed development is seaward of this distance, then the parameter values can be refined, or a probabilistic approach used to determine a more exact distance.

Finally it is noted that the T&T (2019) erosion hazard assessment did not record data for Buchans Bay, but rather for Motunui East and Onaero West, so a direct comparison of parameter values is compromised.

3.2 Slope stability retreat distance (SS)

Cliff erosion occurs when storm waves are able to remove material at the base and the unsupported material above collapses leaving an oversteepened cliff. The slope is then reduced by subsequent avalanching and slumping and if the base remains protected by debris, or by a shorter-term influx of sediment, a stable slope is eventually achieved. The rate of adjustment depends on a range of factors such as geological type, weathering profile, local bedding and faulting characteristics, and groundwater. To achieve this stable slope the clifftop has had to retreat landward and the potential retreat distance (SS) is calculated at the base of the cliff as illustrated in Figure 4.

Where a cliff is composed of a single type of material, a single stable angle can be determined to define the cliff-top retreat. However, more complex cliffs, such as at the Turangi Road site are made up of multiple lahar formations as well as terrestrial cover beds. Identification of a stable angle for each layer is difficult and potentially unreliable. A practical field-based approach measures the slope on vegetated cliff-faces as the vegetation can only exist/survive if the cliff-face has attained a basic level of stability. Such an approach requires comprehensive topographic data and the recent (2019) LIDAR provides such information. To ensure a low probability outcome for SS, several measurements were made of well vegetated cliff fronting the property and the lowest angle of 47 degrees (mean = 53, maximum = 61 degrees) was selected to represent the site. The cliff height was then measured at 12 transects approximately 20 m apart as illustrated in Figure 5. The assessment was carried out using multiple transects because Figure 1 indicated significant shoreline change was occurring within the property's cliffed frontage.

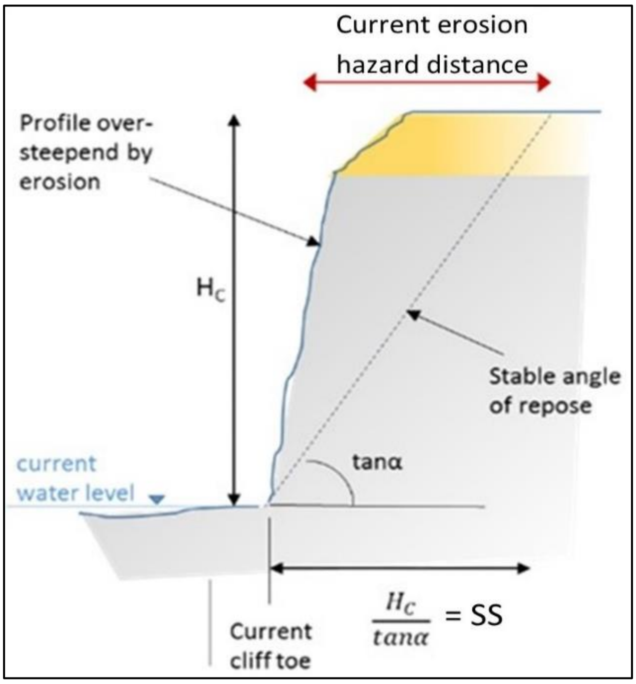

Figure 4 Definition sketch for determining slope stability (SS) in an erosion hazard assessment for a cliffed coast. SS defines the current erosion hazard distance. When time-dependent components are also involved (equations 2 and 3), the slope-stability component is applied last (landwardmost), unless the surface is flat in which case Hc is constant so SS will also be constant. Modified from T&T 2019

The stable slope retreat distance (SS) was calculated for each using equation 4.

$$SS = H_C/tan\alpha \qquad \text{eq 4}$$

Where H_C = height of the cliff in metres and α = 47, the representative stable slope angle in degrees.

The results are listed in Table 1 and ranged between 22.1 m and 24.7 m.

3.3 Historical shoreline change (LT)

The shoreline can be defined using a range of indicators, with that chosen in any particular situation depending upon the nature of the available data. For cliffed coasts the cliff top or the cliff base is typically used as this is identified on early survey plans and often identifiable on historical aerial photography - shadow and vegetation being typical constraints.

Table 1 Erosion hazard distance (EHD) parameter values and modelled EHDs. Terms and value derivations are explained in the text. All distances in meters and rates in metres per year.

Parameters / Transect	SS[1] Current EHD	Shoreline change 1945 to 2019	Shoreline change Rate[2]	LT[3]	LT + SS Future 1 EHD	R_2[4]	RSLR[5]	RSLT + LT + SS Future 2 EHD
1	24	27.4	0.411	41.1	65.1	1.043	63.3	128.3
2	24	29.5	0.439	43.9	67.9	1.116	67.6	135.6
3	24.1	23.6	0.359	35.9	60.0	0.913	55.4	115.4
4	24.7	19.3	0.301	30.1	54.8	0.765	46.4	101.2
5	24.2	13.0	0.216	21.6	45.8	0.549	33.3	79.1
6	23.8	9.8	0.173	17.3	41.1	0.439	26.6	67.7
7	23.4	10.6	0.184	18.4	41.8	0.467	28.3	70.1
8	22.8	13.2	0.219	21.9	44.7	0.556	33.7	78.4
9	22.1	10.6	0.184	18.4	40.5	0.467	28.3	68.8
10	22.6	8.6	0.157	15.7	38.3	0.398	24.1	62.4
11	23.1	4.2	0.097	9.7	32.8	0.247	15.0	47.8
12	22.9	3.0	0.081	8.1	31.0	0.206	12.5	43.5

1. Slope stability (SS) retreat based on a stable angle of 47 deg.
2. Annual average shoreline change over 74 years, with the error term included. R_1 in equation 6.
3. Long-term (LT) erosion over a 100 year period.
4. Total rate of change (historical plus sea-level rise) over a 100 year period (equation 6).
5. Retreat from sea-level rise (RSLR) using the extreme 8.5H+ scenario and over a 100 year period .

Earlier cadastral surveys were obtained from LINZ but unfortunately they only identified the high tide level at the time of the survey which was not constrained enough to allow for a modern comparison. The 1945 vertical aerial photography was thus selected for the early shoreline and compared with 2019 shoreline. The 74 year interval is considered adequate to identify longer-term historical shoreline change, and the cliff base was selected as the representative shoreline as it was clearly identified in both images.

The cliff-base was defined as the change in slope where the face intersected beach sediments. Allowance was made for recent cliff-fall debris. In addition, the present cliff base line was further defined on the 2019 aerial photography by draping the imagery over a (ground surface) digital elevation model derived from the LIDAR to produce a 3D image. This shoreline was compared with the earliest detailed aerial shoreline (1945 SN 375, B6 to B9). It is further noted that both 1945 and 2012 vertical photographs were transformed to "orthophotos" which removes lens and relief distortions and thus makes for more accurate feature analysis. The 1945 imagery was transformed by Skyvue Ltd and the 2019 images by LandPro Ltd.

Dispite the steps taken to ensure accurate feature location, photogrammetric and location errors still occur and a high-end estimate of these errors was assessed and incorporated into the shoreline change data. The 1945 ortho processing errors (include ground point location for georeferencing/ortho photo generation) ranged between ±1.2 and ±2.3 m so the high value was selected. For the 2019 imagery a value of ±1 m is used. Shoreline detection from the 1945 images is estimated at up to ±1.5 m and up to 1 m from the 2019 images

These errors terms are maxima and essentially independent, so the chance of having all high values occurring together (or all low values) is extremely low. Such independent variables are combined using the properties of variance addition (Larson and Karl, 1986) which can be expressed by equation 5.

$$CE = \sqrt{(E_1{}^2 + ... + En^2)} \qquad eq\ 5$$

where CE = combined error (shoreward directed), E_1 = first error term, and En = nth error term. In the present case CE = 2.9 m, so a value of 3.0 m was added to shoreline measurement results in this assessment. This is a high end error value , making the LT values very conservative.

Shoreline change between 1945 and 2019 for the 12 transects spanning the property's cliff are listed in Table 1, along with the annual rate (including the error term) as well as the predicted long-term (LT) change for 100 years. The later ranged between 8.1 m at the northwestern end to over 40 m at the southeastern end.

3.4 Retreat from sea-level rise (RSLR)

Sea-level rise is expected to increase retreat rates of soft to moderate strength cliffed shorelines as more wave energy is able to reach the cliff base increasing hydraulic erosion and the removal of toe-protection debris.

Sea-level rise (SLR) scenarios for the New Zealand coast are provided in MFE (2017). These guidelines define the following four Representative Concentration Pathway (RCP) scenarios of future radiative forcing:

- RCP 2.6 the peak and decline in global emissions occurs soon;
- RPC 4.5 emission peak around 2050;
- RPC 8.5 no effective emissions reduction, and
- RPC 8.5H+ as for RPC 8.5 with faster polar ice sheet melt later in this century.

Each pathway has separate SLR values. The T&T (2019) district-wide erosion hazard assessment computed output using all four RCP/SLR options (ASCE2_RCP26, ASCE2_RCP45, ASCE2_RCP85, ASCE2_RCP85H+). NPDC (2019) then adopted the most extreme scenario, RCP85H+, to define the Coastal Environment. The present assessment will thus only compute the EHD for RCP 8.5H+.

The SLR value for RPC 8.5H+ as provide in MFE (2017) Table 10, is 1.38 m to 2121. However, this must be modified for use in coastal erosion hazard assessments to discount for the 1996 (1986-2005) baseline, and also to account for historical SLR (1.7 mm/y), the effect of which has already been incorporated into the historical shoreline change value. The resulting SLR value for use in the present hazard assessment is 1.10 m to 2121 (for RCP 8.5H+).

Recession rates of sea cliffs are controlled by the geological composition of the cliffs and the configuration of the fronting beach as well as other lesser influences. The computation method currently used for predicting cliff erosion from SLR is explained in Shand et al. (2013) and expressed by equation 6.

$$R_2 = R_1\left(\frac{S_2}{S_1}\right)^m \qquad \textit{eq 6}$$

Where R_2 is the future rate of retreat (incorporating LT and RSLR), R_1 is the current rate of retreat, S_2 is the future rate of sea-level rise, S_1 is the past rate of sea level rise, and m is a negative feedback coefficient determined by the response system.

The T&T (2019) assessment appears to have used a value of 0.25 for m; however, this is considered to be too low for the softer laha cliffs of North Taranaki. A negative feedback of m=0.5 will be used in the present assessment. While this is likely higher than necessary (and hence results in a greater erosion response), this value adds to the conservatism of the present assessment.

Both LT and RSLR are incorporated into equation 5, so the RSLR term on its own is expressed by equation 6

$$RSLR = T^*(R_2 - R_1) \qquad \textit{eq 7}$$

Where
T is the prediction period in years.

Output for 100 years of shoreline retreat (RSLR) under the RCP 8.5H+ scenario are listed in Table 1 for the cliff transects. These retreat values range from 12.5 m at the northwestern end of the property to over 60 m at the southeastern end.

4 EROSION HAZARD RESULTS AND DISCUSSION

Erosion hazard distances (EHD) computed for the three scenarios (EHD_Current, EHD_Future 1, and EHD_Future 2) and measured from the most recently surveyed cliff base for the 12 transects are each listed in Table 1. The resulting lines, together with the cliff-base for both 1945 and 2019, are plotted in Figure 5.

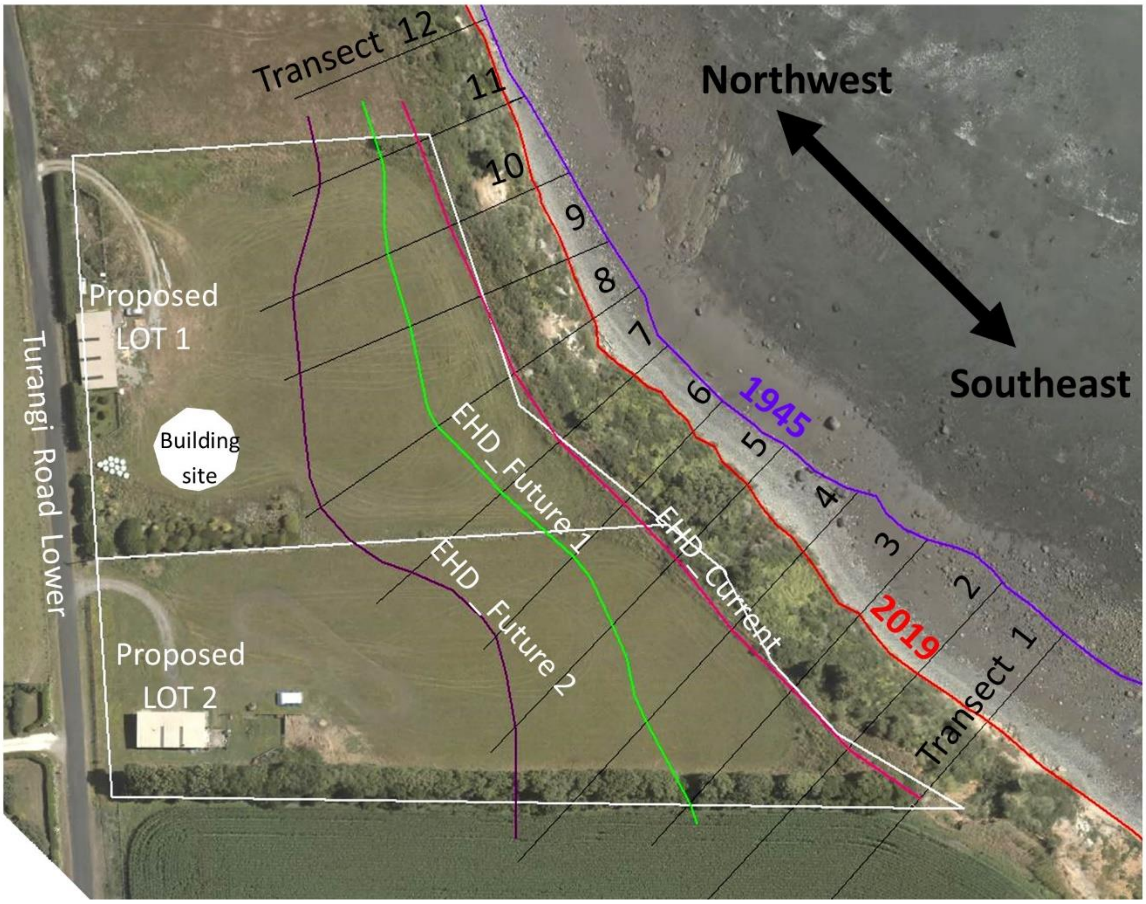

Figure 5 Erosion hazard assessment output for critical scenarios: EHD_Current, EHD_Future 1 (the most liberal future erosion hazard scenario) and EHD_Future 2 (the most conservative future erosion hazard scenario). The proposed building site is marked with white infill, and the proposed subdivision by white lines.

The EHD_Current lines lies very close to the property's seaward boundary. The future (at least 100 years) erosion hazard envelop is that area between the line with the weakest assumptions (EHD_Future 1), and the line with the most restrictive assumptions (EHD_Future 2). The envelop margins lie some 46.5 m seaward of the proposed building site for EHD_Future 1, and 17 m for EHD_Future 2.

It is noted that the non-linear nature of this assessment's erosion hazard lines is related to varying rates of historical shoreline change fronting the property.

The erosion hazard lines modelled for the present site-specific assessment (as shown in Figure 5), together with the equivalent ASCE (T&T, 2019) and PDP (NPDC, 2019) areas are plotted in Figure 6.

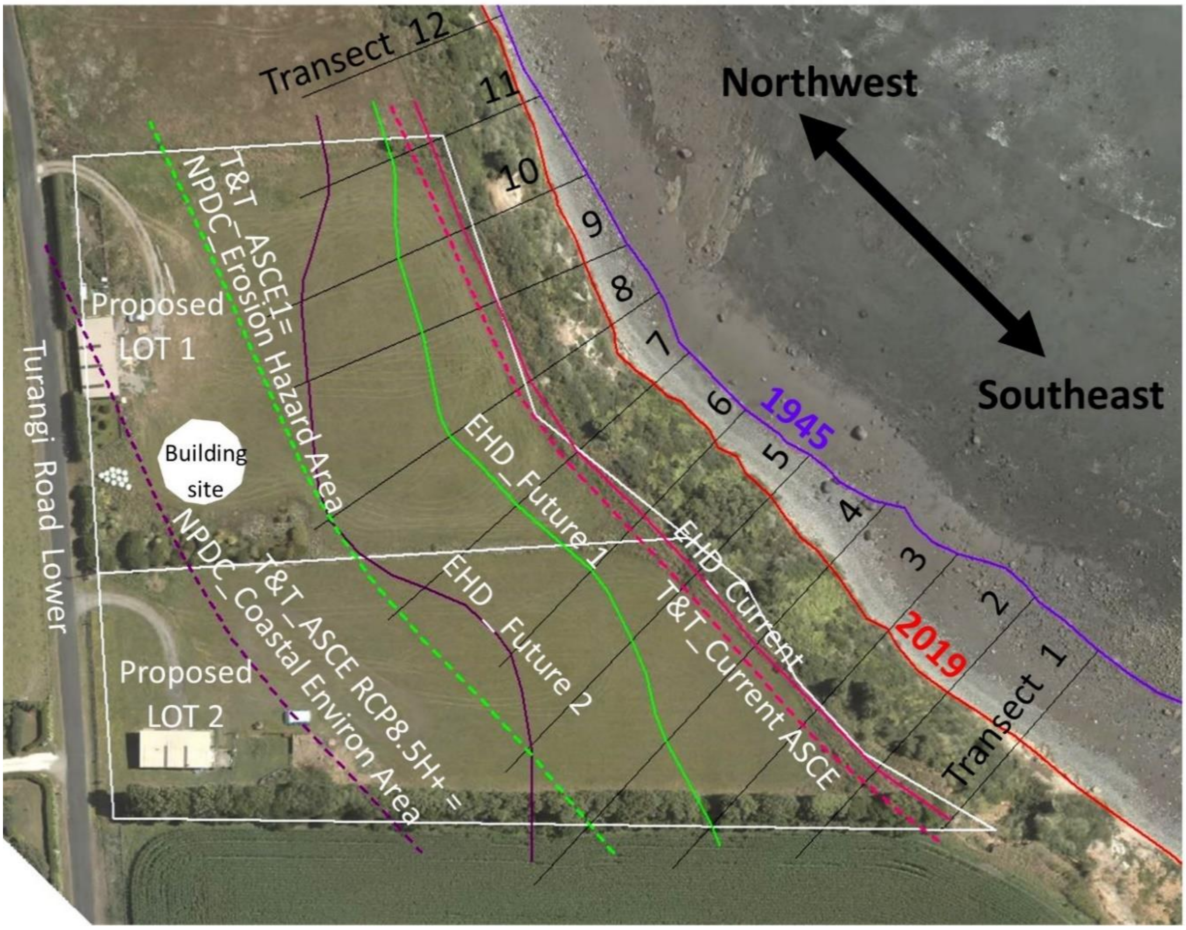

Figure 6 Erosion hazard assessment output for critical scenarios (as in Figure 5) plus dashed lines (with same colour) locating the equivalent T&T district wide assessment and equivalent NPDC PDP areas.

The EHD_Current line is slightly seaward of the T&T (2019) Current_ASCE which had been based on a lower angle of stability (40 deg) c.f. the measured 47 deg. The EHD_Future 1 hazard line (incorporating LT as well as SS), and EHD_Future 2 line (also incorportating the effect of the most extreme SLR scenario) are well seaward of the equivalent T&T (2019)/NPDC (2019) lines. This is because the measured shoreline change rates for transects 3 to 12 were much less than the uniform 0.44 m/yr assumed in the district-wide assessment.

Finally, the matter of how certain can we be that the past shoreline behaviour (and hence both future EHDs) will endure must be addressed. The geomorphological assessment in Section 2 explained the alongshore shoreline variation in terms of the location of inter-tidal and subtidal platforms and reefs. In particular, these features can filter or focus wave and currents to vary their shoreline impact. This effect has been demonstrated by oceanographer Dr Peter McComb's modelling (Alloway et al., 2005). Furthermore, there was surprisingly little variation in the location of platform/reef when comparing the 1945 and 2020 aerial/satellite images indicating platform/reef change operates at a very long (century?) time-scale. Based on this evidence, it is reasosonable to assume past shoreline change should adequately predict future behaviour over the next 100 years at least.

However, even if erosion rates do increase in front of the property, it is still unlikely that the proposed building would be threatened during the 100 year prediction period as

(i) this assessment was carried out using parameter values with a lower likelihood of occurrence than is required, and

(ii) (ii) there is a substantial buffer area between the erosion hazard lines and the proposed building site.

5 CONCLUSIONS

This erosion hazard analysis has been carried out essentially using a worst case scenario and found that the proposed building site was well landward of the modelled erosion hazard lines under the range of possible future scenarios. In particular, it is 47.5 m landward of a future (at least 100 years) erosion scenario based on a continuance of the past erosion trend and no increase in sea-level rise as defined by EHD_Future1, equation 2. And the proposed building site is 17 m landward of a future (at least 100 years) scenario that included the effects of the most extreme sea-level rise scenario as defined by EHD_Future2, equation 3.

In addition, the resulting EHD_Future 1 line ranged between 26 and 46 m seaward of the equivalent to T&T (2019) Future ASCE1 line which was used to define the NPDC Proposed District Plan's Coastal Erosion Hazard Area. And the EHD_Future 2 line ranges between 33 and 65 m seaward of the equivalent to T&T Future ASCE2 which was used to define the NPDC Proposed District Plan's Coastal Environment Area.

As such, further computational refinements to more accurately identify "likely" or "potential" erosion extent, as used in the definitions for Coastal Erosion Hazard Area and Coastal Environment Area, are not required.

Furthermore, this conclusion is further supported by the erosion processes identified in this assessment being likely to continue into the future.

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